-1 Spatial variability of sea surface pCO2 in the Amundsen Sea Polynya, Antarctica

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

The partial pressure of carbon dioxide (pCO2) in surface waters of the Amundsen Sea Polynya (ASP) of Antarctica was measured during the Austral summer from December 2010 to January 2011. Results show that the ASP can be defined as a major sink for atmospheric CO2 with large spatial variability. Surface pCO2 in the central polynya was observed as low as 150 μatm (with a very high average air-sea flux of -4.0 ± 1.4 mol m-2 a-1), contrasting with 450 μatm in the southeast of the ASP near the ice shelf (with flux of +0.78 ± 0.54 mol m-2 a-1). Together with the large pCO2 difference between the atmosphere and surface polynya (delta_pCO2), high wind speeds lead to rapid air-sea flux of CO2. The spatially-averaged CO2 flux for the entire ASP was estimated to be -2.1 ± 1.8 mol m-2 a-1 based on a 90-day annual ice-free period, which compared well with the annual flux in the Ross Sea (-1.5 ± 1.5 mol m-2 a-1). Strong correlation between pCO2 and chlorophyll fluorescence in the polynya surface indicates biological production as an important controlling factor of pCO2 variability; Saturation states of surface CO2 and oxygen indicate the importance of net community production, and provide further insights to other processes affecting surface pCO2, such as changes in annual sea ice coverage, temperature and deeper water upwelling.

-2 Earth System Model FGOALS-s2: Coupling a dynamic global vegetation and terrestrial carbon model with the physical climate system model

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Earth System Model (ESM) is a fundamental tool to understand the climate change and the carbon cycle feedback. The ESM version of FGOALS was recently developed within the IPCC AR5 CMIP5 modeling framework. This paper describes the coupling of the dynamic global vegetation and terrestrial carbon model (VEgetation-Global-Atmosphere-Soil version 2.0, or ‘VEGAS2.0’) and the physical climate system model (PCSM) FGOALS-s2. The performance of the coupled model is evaluated as follows.

In climatology, the simulated global total terrestrial gross primary production (GPP) is 124.4 GtC a-1 and net primary production (NPP) is 50.9 GtC a-1. The entire terrestrial carbon pools have about 2009.9 GtC, comprising 628.2 GtC in the vegetation and 1381.6 GtC in the soil. Spatially, the annual averaged GPP is high in the tropics and low at higher latitudes. In the tropics, seasonal cycle of the NPP and net ecosystem production (NEP) excluding the desert regions exhibits a dipole mode across the equator due to migration of the monsoon rainbelt, while the seasonal evolution of the Leaf Area Index (LAI) is not so significant. In the sub-tropics and temperate zone, especially in the East Asian monsoon region, the seasonal cycle is obvious due to the changes of the temperature and precipitation from the boreal winter to the boreal summer. Vegetation productivity in the northern mid-high latitudes is too low, possibly due to low soil moisture there.

On the interannual timescale, the terrestrial ecosystem shows a strong response to ENSO. The model simulated Nino3.4 index and total terrestrial NEP are both characterized by a broad spectral peak in the range of 2-7 years. The further analysis indicates they’re significantly correlated and the correlation coefficient has reached -0.7 to the maximum when the NEP lags the Nino3.4 index for about 1-2 months.

-3 Inter-annual variability of the global land carbon sinks

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The natural carbon reservoirs – the terrestrial biosphere and the oceans – absorb more than half of the CO2 emitted to the atmosphere by human activities on average, thus slowing down the rate of global warming (Canadell et al., 2007; Le Quéré et al., 2009). However, the strength of this sink is very sensitive to climate conditions (Jones et al., 2001), showing high year-to-year variation (Peylin et al., 2005; Baker et al., 2006; Gurney et al., 2008). This is evident in the dynamics of annual growth rate of atmospheric CO2, which has varied with the amplitude of 5 Pg C yr-1 over the last three decades. Understanding the inter-annual variability of global carbon sink and its driving mechanisms is one of the essential ingredients for predicting future atmospheric CO2 concentration, and future response of the global carbon cycle to climate change (Houghton et al., 2000; Friedlingstein et al., 2006). Here, we use a combination of observations and bottom-up (carbon cycle models) and top-down (atmospheric inversion models) approaches (see Methods) to gain insight into the process underling inter-annual variability of carbon fluxes over the past three decades.

-4 Larval and post-larval stages of Pacific oyster (Crassostrea gigas) are resistant to elevated CO2

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The average pH of surface oceans has decreased by 0.1 unit since industrialization and is expected to decrease by another 0.3-0.7 units before the year 2300 due to the absorption of anthropogenic CO_2. This human-caused pH change, referred to as ocean acidification, is posing serious threats and challenges to the Pacific oyster (Crassostrea gigas), especially to their larval stages. Our knowledge of the effect of reduced pH on C. gigas larvae presently relies presumptively on four short-term (<4 days) survival and growth studies. Using multiple physiological measurements and life stages, the effects of long-term (40 days) exposure to ambient (8.1), near-future (7.7) and extreme (7.4) pH on larval shell growth, metamorphosis, respiration and feeding rates at the time of metamorphosis, along with the juvenile shell growth and structure of the C. gigas, were examined in this study. The mean survival and growth rates were not affected by pH. The metabolic, feeding and metamorphosis rates of pediveliger larvae were similar, between pH 8.1 and 7.7. The pediveligers at pH 7.4 showed depressed weight-specific metabolic and feeding rates, yet were able to sustain a more rapid post-settlement growth rate. However, no evidence suggested that low pH treatments resulted in alterations to the shell ultrastructures (SEM images) or elemental compositions (i.e., Mg/Ca and Sr/Ca ratios). Thus, larval and post-larval forms of the C. gigas in the Yellow Sea are probably resistant to elevated CO_2 and decreased near-future pH scenarios. The pre-adapted ability to resist a wide range of decreased pH may provide C. gigas with the necessary tolerance to withstand rapid pH changes over the coming century.

-5 Towards disentangling natural and anthropogenic GHG emissions by space-based atmospheric concentration imaging - CarbonSat ESA Earth Explorer 8 Candidate Mission

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The objective of the CarbonSat mission is to determine natural and anthropogenic sources and sinks of the two most important greenhouse gases, carbon dioxide and methane. The unique features of the CarbonSat mission concept are that it offers a combination of high spatial resolution (2 x 2 km2) and broad swath (240 km) to provide global imaging of localised strong emission source areas such as large cities (Megacities), landfills, power plants, volcanoes, etc. and to be able to separate anthropogenic from natural fluxes. CarbonSat data will also quantify natural fluxes of CO2 and CH4 (biospheric CO2, wetland CH4 etc.) and their changes, to better understand these important sources and sinks and their sensitivity to a changing climate.

CarbonSat aims to deliver global data sets of dry column mixing ratios of CO2 and CH4 with high precision (goal: CO2 < 1 ppm, CH4 < 9 ppb) and accuracy. Benefiting from its imaging capabilities, CarbonSat will provide an at least one order of magnitude larger number of cloud free measurements than GOSAT and OCO and one order of magnitude better spatial coverage than OCO. The CarbonSat mission concept builds on the heritage and lessons learned from SCIAMACHY (2002-2012), GOSAT (2009-present) and OCO-2 (2014 onwards) to make scientifically important and unique measurements of the amounts and distribution of CO2 and CH4 for biogeochemical and climate change research.

CarbonSat entered industrial system feasibility activities in 2012, which are supported by scientific studies and campaigns. The current status of the mission concept and selected results from the scientific studies and campaigns documenting the expected data quality and characteristics will be presented.

-6 A Terrestrial Carbon Cycle Data Assimilation System based on the VEGAS model: the observing system simulation experiments (OSSE)

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Information on the spatial and temporal pattern of surface carbon flux is critical to understanding the source/sink mechanisms and projecting future atmospheric CO2 concentrations and climate. This study presents the construction and implementation of a terrestrial carbon cycle data assimilation system based on a dynamic vegetation and terrestrial carbon model Vegetation–Global–Atmosphere–Soil (VEGAS, VDAS), in which an advanced assimilation algorithm, the Local Ensemble Transform Kalman Filter (LETKF), is used to assimilate the satellite data or field measurements to improve surface carbon flux estimations. The VDAS was evaluated within an Observing System Simulation Experiments framework through simultaneously assimilating the leaf area index (LAI) and surface carbon flux observations. Results showed that the VDAS has a potential to provide more accurate surface carbon flux estimations compared to model simulations without assimilation. The impacts of the variance inflation methods and ensemble size on the assimilated results were also investigated.

-7 From "ICDC1" in Bern 1981 to ICDC9 in Beijing 2013: a review of global carbon cycle research during the past three decades

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Since the first gathering in Bern in 1981 of 40 scientists, mostly involved in atmospheric measurements of carbon dioxide and its isotopes, global carbon cycle research has expanded into a large, world-wide enterprise. In parallel, the carbon cycle research agenda has shifted gradually from the fundamental question of the global redistribution of the anthropogenic CO2 emissions into ocean and land to the determination of regional carbon budgets and how these change with time under rising CO2, climate change and increasing anthropogenic impacts. Addressing these questions have been fostered by expanded observational networks and by a multitude of new observational windows, such as the reconstruction of past atmospheric CO2 variations from ice cores, large scale carbon inventory surveys in the ocean and recently on land, and the clever use of tracers and other indicators of carbon cycling including stable and radioactive isotopes in CO2, atmospheric oxygen, COS etc. A host of process studies have amassed an impressive amount of knowledge how carbon is exchanged between the different reservoirs and how these exchange fluxes are modified by various drivers. For the integration and extrapolation of the information a modeling hierarchy has been developed from simple box-models in the 1970's to comprehensive process based three-dimensional carbon cycle descriptions in current Earth system models. Despite this impressive development, several of the fundamental questions posed already in the early 1980's still prevail, e.g. the nature of the global terrestrial carbon sink or the reliable quantification of the climate sensitivity of the carbon cycle on different time scales. Ultimately, the ever expanding direct and indirect impacts of a growing world population including food demands and associated land reclamation will substantially impact the fate of atmospheric CO2 in the 21st century. Assessing these impacts in a comprehensive way under various assumptions of future development constitutes an emerging research direction in the portfolio of global carbon cycle research.

-8 Active Sensing of CO2 Emissions over Nights, Days, and Seasons (ASCENDS)

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The Active Sensing of CO2 Emissions over Nights, Days, and Seasons (ASCENDS) mission was recommended by the National Research Council in the report entitled Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond. The ASCENDS mission is considered the scientific and technological next step following Japan’ s Greenhouse gases Observing SATellite (GOSAT) mission and the NASA Orbiting Carbon Observatory (OCO-2) mission.

Using an active laser measurement technique, ASCENDS will extend CO2 remote sensing capability to include all-season coverage of high-latitude regions, nighttime observations with sensitivity in the lower atmosphere, and measurements in partly cloudy conditions. The ASCENDS mission, thereby, expands significantly the sampling of the atmosphere, and it avoids some of the potential biases inherent with the passive systems.

A central issue for any mission is connecting the observations with their uncertainties and biases into information, including uncertainties, regarding the subject of interest—in this case, terrestrial and oceanic surface fluxes of CO2. In this regards, ASCENDS, OCO, and GOSAT are fundamentally different from most space-based missions in which one is observing more directly the subject of interest. In the case of ASCENDS and the other CO2 missions, the purpose of the atmospheric measurement is to determine fluxes at the surface—perhaps distant from where the atmosphere is observed.
This paper presents quantitative information on connecting observations with their uncertainties to estimates of terrestrial and oceanic surface fluxes of CO2, including the associated uncertainties. We will also briefly review the history of ASCENDS and its current status.

-9 Global Greenhouse Gas Observation by GOSAT and Its Contribution to Carbon Flux Estimation

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

More than four years have passed since the Greenhouse gases Observing SATellite (GOSAT) was launched in late January 2009. The primary objective of the GOSAT Project is to observe the global distributions of the two major greenhouse gases, CO2 and CH4, and their temporal variations. The concentration data, retrieved from the GOSAT observational data, were found to effectively fill out gaps in the distribution of CO2 and CH4 data collected in ground-based monitoring networks. The latest version of the Level 2 CO2 and CH4 concentration data products (version 02.**) are now publicly available. Through data validation activities, the uncertainties of both the CO2 and CH4 concentrations were found to be less than 1%, which is smaller than originally targeted. Seasonal variations and annual growth trends were found from the four-year-long data-sets; the data will be further analyzed together with more data to be accumulated.

The second objective of the GOSAT Project is to improve accuracy of carbon fluxes (net sources and sinks) that are estimated on a sub-continental scale. The GOSAT Level 2 CO2 concentration data are utilized for the regional CO2 flux estimation. The result of the estimation for a one-year period between June 2009 and May 2010 was recently released to the public in December 2012 as the GOSAT Level 4A data product. Efforts in improving the quality of these data products are being continued worldwide by several research groups.

I herein summarize the present status and major outcomes of the GOSAT Project.

-10 Uncertainty in estimating the maximum light use efficiency of terrestrial ecosystems based on eddy flux and NPP observations

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Accurate estimation and forecasting of terrestrial ecosystem dynamic carbon cycles and its spatial-temporal pattern are crucial for climate prediction in the context of global change. The maximum light use efficiency is one of key parameters of remote sensing models to estimate primary production in terrestrial ecosystems. Here we applied the Markov Chain Monte Carlo method to inverse the maximum light use efficiency of terrestrial ecosystems in China based on the CASA model using two different datasets: eddy covariance flux observations and net primary production observations. We also compared the difference of estimated maximum light use efficiency driven by both AVHRR NDVI and SPOT VEGETATION NDVI data.

The result showed that the estimated posterior probability distributions of the maximum light use efficiency followed approximately normal distributions. Estimated values of the maximum light use efficiency driven by AVHRR NDVI data were 0.599±0.060 g C MJ-1 in Changbai Mountain temperate mixed forest, 0.809±0.043 g C MJ-1 in Qianyanzhou planted coniferous forest, 0.678±0.025 g C MJ-1 in Dinghushan South Subtropical evergreen broadleaved forest, 0.789±0.030 g C MJ-1 in Xishuangbanna tropical rainforest, 0.203±0.031 g C MJ-1 in Xilingol temperate grassland, 0.199±0.053 g C MJ-1 in Damxung alpine steppe- meadow, 2.201±0.207 g C MJ-1 in Haibei alpine meadow, and 1.429±0.128 g C MJ-1 in Yucheng cropland. The estimates of maximum light use efficiency in above sites driven by SPOT NDVI data were 0.751±0.072, 0.706±0.068, 0.849±0.040, 0.955±0.040, 0.220±0.024, 0.132±0.043, 0.447±0.043, and 1.401±0.125 g C MJ-1, respectively. The maximum light use efficiency values estimated from 549 forest NPP observation data were 0.968±0.062 g C MJ-1 in evergreen broadleaf forest, 0.496± 0.021 g C MJ-1 in deciduous broadleaf forest, 0.416±0.034 g C MJ-1 in mixed forest and 0.435±0.035 g C MJ-1 in deciduous needle leaf forest. The uncertainty in estimated maximum light use efficiency should be pay more attention and quantified in modeling NPP at regional scale.

-11 Cumulative responses, progressive effects and feedbacks in ecosystem responses to rising atmospheric CO2

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Experimentally simulated environmental change can cause instantaneous changes in ecosystems, but those responses can change over time, and they can influence the very pace and direction of continued environmental change. Cumulative responses, initially small but chronic, or highly variable with persistent underlying trends, can manifest as important responses once accumulated over many years. Progressive effects that develop over time involve feedbacks that can amplify, dampen, or even reverse initial responses. Changes in species composition with ecosystem-level impacts, progressive nutrient limitation, and soil carbon and nitrogen accumulation are all examples of responses that may be unimportant or unremarkable initially, but that could progress or accumulate such that, in the long-term, they become important, or even dominant, responses. Microbial processes that alter nutrient availability can shape responses of plant production, and processes involved in the production and consumption of greenhouse gases can feed back directly to the source of environmental change, like the radiation balance of the atmosphere. In this way, these responses could have strong leverage on the long-term responses of ecosystems to experimentally simulated environmental change, challenging the ability to predict long-term responses of natural ecosystems to ongoing chronic changes in the environment. Yet, whether rising CO2 will elicit similar progressive and cumulative responses across multiple ecosystems remains unknown. Here, I discuss results from long-term elevated CO2 experiments that illustrate cumulative and progressive effects and their implications for understanding ecosystem responses to the changing atmosphere.

-12 Surface atmosphere and ocean CO2 dataset obtained by NIES volunteer observation ship program in the Pacific

Sumiko Harasawa *(NIES)*

Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

NIES has been measured CO2 in the atmosphere and in the surface seawater by volunteer observation ships since 1995. Both atmospheric CO2 system and underway pCO2 system are operated on board cargo ships sailing in the Pacific, but some only have atmospheric CO2 system.
The first volunteer observation ship was M/S Skaugran between Vancouver, BC and Japanese ports (38 round trips, Mar. 1995-Sept. 1999). The ocean surface pCO2 observation coverage in the North Pacific has been maintained with succeeding ships, M/S Alligator Hope (16 round trips, Nov. 1999-May 2001) and M/S Pyxis (91 round trips, Nov. 2001-present). These ship routes well covers mid to high latitude areas in the North Pacific. The Western Pacific was covered by M/S MOL Golden Wattle, which was renamed from M/S Alligator Hope, for a short period (6 round trips, Nov. 2001-Apr. 2002), and long term operation has been started from Nov. 2005 by M/S Transfuture 5 (64 round trips) sailing between Japan, Australia and New Zealand.
We are also operating ships only with atmospheric CO2 system for Oceania route (M/S Fujitrans World, 24 round trips, Feb. 2003-Nov. 2005), for high latitude North Pacific route (M/S Skaubryn, 32 round trips, May 2005-Jul. 2010), and for East Asia route (M/S Fujitrans World, 48 round trips, Sept. 2007-present, M/S Transfuture 1, 24 round trips, Nov. 2010-present).
Now NIES established data management scheme to compile quickly after the data recovery from the volunteer observation ships and to make accessible for scientists through various web sites. Currently, the latest data can be available at NIES ship-of-opportunity web site (http://soop.jp). Others are DIAS (Data Integration and Analysis System, http://dias-dss.tkl.iis.u-tokyo.ac.jp/ddc), SOCAT (Surface Ocean CO2 Atlas, http://www.socat.info/) and CDIAC (Carbon Dioxide Information Analysis Center, http://cdiac.ornl.gov/oceans/).
Flask sampler collects atmosphere for laboratory analysis of greenhouse gases. CO2 analytical results are used for quality control of the results from the on board continuous CO2 analyzer. The averaged difference between flask and continuous data is around 0.1 ppm in the atmospheric xCO2. In case the difference exceeds the quality control criterion of 0.2 ppm, we check both on board and many times successfully fixed the problem either in sampling or continuous systems. Our atmospheric CO2 observation well covers distributions over the North and Western Pacific and the Asian air outflow.
Possible quality assurance of ocean surface pCO2 results are cross over check with observational results of National Research Institute of Fisheries Science (courtesy of Dr. Tsuneo Ono) in Japanese coastal zone. These cross over points gave reasonable agreement in the pCO2 results. NIES already submitted ocean pCO2 data upto 2010 to SOCAT version 2 after quality control based on SOCAT criteria.

-13 Atmospheric CO2 and O2 monitoring in connection with subsurface CO2 storage

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

Carbon Capture and Storage (CCS) is considered an important option for the coming decades to combat global climate change. In CCS, the CO2 from fossil fuel burning is captured, transported and stored underground (for example in a depleted gas field). In this way CCS helps to buy time for the necessary energy transition.
CCS is not only a promising technique but it is also controversial. In several countries planned projects were cancelled due to public concerns.
Even though the change for a leak from a CCS location is small, and the change of people suffocating from it is even smaller, it will be necessary to monitor CCS locations. An operator independent alarm system like an atmospheric monitoring program will help public acceptance and is useful for assessing the efficiency of the technique s well. For CCS to be useful in terms of mitigation of climate change, leakage in the total chain must be kept to a very low level.
As the concentration of CO2 in the atmosphere is highly variable, it is difficult to find small leaks from a CCS location by only measuring the CO2 concentration. Several options have been proposed such as the use of chemical tracers. We use a technique that uses oxygen measurements in addition to carbon dioxide (and δ13C) measurements. Most processes in nature that involve carbon dioxide also involve oxygen (e.g. fossil fuel burning, respiration, photosynthesis). This is not the case for a leak from a CCS location, which would only release CO2 without consuming oxygen. Except for a dilution effect, no change in the oxygen concentration would be visible, which makes its measurements a powerful tool to distinguish a CO2 leak from another CO2 source. We present first results, using background measurements and a field experiment with an artificial CO2 source.
Next to this sophisticated technique of concurrently measuring CO2 and oxygen another technique to find leaks is using a set of relatively simple CO2 sensors. This could be beneficial in for example monitoring a pipeline transporting CO2. Although the natural variability of the CO2 concentration can be high, spatial concentration gradients tend to be small. Therefore, a network of sensors should also be able to find leaks. Depending on the wind direction and speed, several or one of the sensors would show a significantly higher CO2 concentration while others still measure the background signal. We present results of a field test simulating a set-up with 300 meter pipeline and an artificial leak.

-14 Coupling of a biogeochemical model with a simultaneous heat and water model and its evaluation at an alpine meadow site

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

In this work, the Biome-BGC and SHAW models were coupled to correctly simulate the carbon, water and energy flux of an alpine meadow site where seasonally frozen soil is widely distributed. The outputs of the coupled model were compared with the observed carbon fluxes (Gross Primary Productivity: GPP, Net Ecosystem Exchange: NEE, Ecosystem Respiration: ER), energy fluxes (Latent heat flux: LE, Sensible heat flux: Hs), water flux (Evapotranspiration: ET), soil moisture and soil temperature. The results indicate that the coupled model can correctly predict the dynamics of an alpine meadow ecosystem.

-15 The pH boundary layer over corals

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Type of presentation: Oral

Key word:

We present net ecosystem productivity (nep) and net ecosystem calcification (nec) in corals using the boundary layer gradient flux technique (CROSS). Coastal anthropogenic inputs and changes in global ocean chemistry in response to rising levels of atmospheric carbon dioxide are of considerable concern. Coral reefs are particularly vulnerable from eroded environmental conditions including ocean acidification and water pollution. CROSS inspects the benthic community and measures productivity/respiration and calcification/dissolution over an area of 10 square meters. Being a boundary layer approach, advection and complex mesoscale flows are not a factor or concern. CROSS is autonomous and can also be used at deep benthic sites. The interrogation area is not enclosed therefore exposed to ambient light, flow, and nutrient levels. Diurnal pH and O2 gradients show the changing acidification, carbon dioxide levels, and potential calcification. These processes will be compared and discussed under different environmental carbon dioxide conditions.

-16 Inverse modeling of the regional CO2 fluxes for GOSAT CO2 Level 4 product

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

We estimate surface CO2 fluxes using atmospheric transport model and GOSAT observations. The NIES-retrieved CO2 column mixing ratio is used together with ground-based observations. The column averaged CO2 mixing ratio (XCO2) and column averaging kernel are provided by GOSAT Level 2 product v.2. Monthly mean CO2 fluxes for 64 regions are estimated together with a global mean offset between GOSAT data and Globalview. Net ecosystem exchange is predicted by the Vegetation Integrative SImulator for Trace gases (VISIT) terrestrial biosphere model optimized to match seasonal cycle of the atmospheric CO2. Monthly ocean-atmosphere CO2 fluxes are produced with an ocean pCO2 data assimilation system. Biomass burning fluxes are provided by the Global Fire Emissions Database (GFED). Fossil fuel CO2 emissions are estimated with ODIAC inventory based on nightlights observations and a large point source database. We use fixed-lag Kalman smoother to infer monthly fluxes for 42 sub-continental terrestrial regions and 22 oceanic basins. When both GOSAT and ground-based data are used together the fluxes change compared to using only ground-based data in the tropical and other remote regions, for those regions flux uncertainties are reduced when compared to ground-based data only case. Analysis of the estimated flux deviations from prior suggest that additional constrains introduced by GOSAT observations reduces flux variance for the regions which are under-constrained when only ground-based data are used. Although the fluxes appear reasonable for many regions and seasons, more scientific results can be expected after improving the retrieval algorithms, data filtering and the inverse modeling method to reduce apparent estimated flux anomalies visible in some areas. In GOSAT Level 4 v.2, product we use aggregation of the GOSAT observations into monthly means over 5x5 degree grids. In the recently developed updates the model-observation misfit is estimated for each observation separately and transport simulation is enhanced by coupling with Lagrangian transport model Flexpart.

-17 Response of ecosystem carbon fluxes to drought events in a poplar plantation in Northern China

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Poplar plantations are widely used for timber production and ecological restoration in northern China, a region that experiences frequent droughts and water scarcity. An open-path eddy-covariance (EC) system was used to continuously measure the carbon, water, and energy fluxes in a poplar plantation during the growing season (i.e., April–October) over the period 2006–2008 in the Daxing District of Beijing, China. We examined the seasonal and inter-annual variability of gross ecosystem productivity (GEP), net ecosystem exchange (NEE), and ecosystem respiration (ER). Although annual total precipitation was the lowest in 2006, natural rainfall was amended by flood irrigation. In contrast, no supplementary water was provided during a severe drought in spring (i.e., April–June), 2007, resulting in a significant reduction in net ecosystem production (NEP = _NEE). This resulted from the combined effects of larger decrease in GEP than that in ER. Despite the drought – induced reduction in NEP, the plantation forest was a strong carbon sink accumulating 591 ± 62, 641 ± 71, and 929 ± 75 g C m_2 year_1 for 2006, 2007, and 2008, respectively. The timing of the drought significantly affected the annual GEP. Severe drought during canopy development induced a lasting reduction in carbon exchange throughout the growing season, while the severe drought at the end of growing season did not significantly reduce carbon uptake. Additionally, irrigation reduced negative drought impacts on carbon sequestration. Overall, this fast growing poplar plantation is a strong carbon sink and is sensitive to the changes in environmental conditions.

-18 Stability of soil organic carbon (SOC) in three typical plantation forests in Beijing area, China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Afforestation of degraded lands may restore some of the original soil carbon stocks and hold potential for ameliorating the rate of increase in atmospheric CO2. However, understanding of the stability of different soil C pools, and the mechanisms of its regulation remain limited. In the current study, we compared metrics of soil organic carbon (SOC) stability by soil type in plantation forest combinations (STPFC-s) in sub-humid area of Beijing, China. We defined SOC stability as the mean in situ turnover time (τ), and evaluated the following relative stability indices (RSI-s) as proxies and (early) indicators of τ: respired carbon from in situ heterotrophic respiration (RR), respired carbon from incubations (RI) or number of incubation days to respired 5% of initial SOC (D), aggregate stability index (ASI), ratio of SOC to total nitrogen (C:N), water soluble carbon (WSC), sand binding carbon (SBC) and microbial biomass carbon (MBC). Among these indices, RI best correlated with RR, and is suggested as an effective and practical index for evaluating the relative stability of different STPFC-s. SOC stock and stability were both relatively lower in fluvo-aquatic soil-poplar plantation (FAP), than in udalfs soil-Chinese pine plantation (UCP) and in cinnamon ustalf soil-East-Liaoning oak plantation (CUEO). The findings suggest that the traditionally non-forested sandy loamy soils may have limited carbon sequestration potential, and would be unlikely to meet the primary goal of the reforestation efforts (i.e. increase soil carbon sequestration across China). We argue that the relative stability indices developed in this study can be used to evaluate the efficacy of the reforestation efforts for carbon sequestration purposes nationwide. Comparison with published incubation results is clearly necessary, but will require a technique for normalizing the disparate sampling and incubation protocols.

-19 Temperature dependence of seawater pH — An experimental study

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

Ocean acidification is driven by the increase of atmospheric CO2. Meanwhile, oceanic pH is also affected by temperature change. In this study, artificial seawater (ASW) with different pH25 (pH value measured at 25 oC) from 7.50 to 10.00, salinity from 20 to 105, and DIC from 1 mM to 5 mM was studied. Experiments were run at continuous temperature change from 0 to 25 oC, in order to investigate how seawater pH is affected by temperature change under different conditions. Data showed that pH decreased linearly with increasing temperature from 0 to 25 oC at all conditions. The pH temperature coefficient (the change of pH per degree temperature change) increased with pH25. DIC and salinity showed no effect on the pH temperature coefficient. This study indicates that the change of pH caused by temperature change can be calculated from pH temperature coefficient without knowing the details of seawater salinity and CO2 system.

-20 Recent Progresses of the Program "Carbon Budget and Relevant Issues in Response to Climate Change" ——A Strategic Priority Research Program of the Chinese Academy of Sciences

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Anthropogenic greenhouse gases (GHG) emission has been identified as the major factor (or at least one of the major factors) in response to global warming in recent decades. Since it is closely related to global sustainable development and international duty of GHG reduction for every country in the world, China, as one of developing countries, is facing double tasks, i.e., to develop national economy and social welfare, and in the meantime, to reduce GHG emission and to increase carbon sink by using green technology. In essence, the relationship between GHGs and climate change is a scientific issue closely related to the Earth's carbon cycle and anthropogenic influence, which is a multi-disciplinary research topic.

Based on the needs of national development and international negotiation for China, a Strategic Priority Research Program called "Carbon Budget and Relevant Issues in Response to Climate Change" of the Chinese Academy of Sciences is established.

According to the above key scientific questions, this program is divided into five projects: GHGs emissions and monitoring technology; carbon sink by different ecosystems and increasing technology; new generation climate system models and the facts and attribution of climate change during the past centuries; climate and ecology changes in the past ten thousand years and human being adaptation; policy suggestion for green development.

The program has started since 2011. During the past two years， significant progresses have been made in all projects, including nation-wide investigation of GHG emissions, in particular, energy utilization efficiency in China, ecological carbon sink investigation and new carbon sink increasing technologies, climate system model development and climate change trend investigation based on instrumental observations and proxy data, new network of aerosol observations in China, past climate and ecology pattern in China, and some preliminary suggestion to the related policies for national carbon reduction.

In this paper, we will present the above progresses.

-21 Status and Analysis of Jiangsu Province’ s Carbon Emission Reduction You Wu

You Wu *(Nanjing University of Information Science & Technology)*

Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Global warming has brought more and more prominent problems. Carbon emissions have become one of the common concern fields in the world. In 2006, China has become the largest emission country of the world in total amount of carbon emissions. As the largest carbon emission country, there is no doubt that China should explore a sustainable development mode with low carbon and energy saving. Jiangsu Province’ s economic development speed is in the top list of China. While Jiangsu’ s economy increased rapidly and continually, coal-dominated energy consumption increased rapidly as well and brought out continual growth of carbon emissions. Some studies showed that the total amount of carbon emissions of Jiangsu’ s had risen from 5613.83 thousand tons in 1995 to 13746.87 thousand tons in 2009, with an increase of 144.88% and an average growth rate of 9.65%, and still continued to grow every year. Jiangsu's economic growth is largely based on the cost of the increase in carbon emissions. This will result in a negligible impact on the sustainable development of Jiangsu. Development of low-carbon economy, promote low-carbon life and the full implementation of carbon emission reduction has become essential. In the period of the “Eleventh Five-Year”, Jiangsu’ s carbon emission reduction has achieved some success. However, the total amount of carbon emissions still continue to increase, regional developments are unbalanced, and high pollution, high energy-intensive industries are still the important driver of Jiangsu's economic growth in view of carbon emissions, regional and industry structure. The situation of carbon emission reduction remains grim in Jiangsu Province. Measuring the total amount of carbon emissions is helpful to analyze the status of carbon emission reduction, to find out shortcomings of carbon emission reduction and to make preparations for the promotion of carbon emission reduction in Jiangsu.

-22 Carbon sequestration via wood harvest and storage: An assessment of its harvest potential

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

A carbon sequestration strategy has recently been proposed in which a forest is actively managed, and a fraction of the wood is selectively harvested and stored to prevent decomposition. The forest serves as a 'carbon scrubber' or 'carbon remover' that provides continuous sequestration (negative emissions). Earlier estimates of the theoretical potential of wood harvest and storage (WHS) based on coarse wood production rates were 10±5 GtC y−1. Starting from this physical limit, here we apply a number of practical constraints: (1) land not available due to agriculture; (2) forest set aside as protected areas, assuming 50% in the tropics and 20 % in temperate and boreal forests; (3) forests difficult to access due to steep terrain; (4) wood use for other purposes such as timber and paper. This 'top-down' approach yields aWHS potential 2.8 GtC y−1. Alternatively, a 'bottom-up' approach, assuming more efficient wood use without increasing harvest, finds 0.1–0.5 GtC y−1 available for carbon sequestration. We suggest a range of 1–3 GtCy−1 carbon sequestration potential if major effort is made to expand managed forests and/or to increase harvest intensity. The implementation of such a scheme at our estimated lower value of 1 GtC y−1 would imply a doubling of the current world wood harvest rate. This can be achieved by harvesting wood at a moderate harvesting intensity of 1.2 tC ha−1 y−1, over a forest area of 8 Mkm2 (800 Mha). To achieve the higher value of 3 GtC y−1, forests need to be managed this way on half of the world's forested land, or on a smaller area but with higher harvest intensity.We recommendWHS be considered part of the portfolio of climate mitigation and adaptation options that needs further research.

-23 Robust Inversion of Carbon dioxide Fluxes over Temperate Asia in 2006-2008

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Carbon dioxide fluxes over the Temperate Asian region have been estimated robustly for the 2006-2008 period using the time-dependent inversion component of the Transcom protocol. Data from 6 CO_2 measuring stations in Temperate Asia including the Indian station at Hanle along with 75 others from different parts of the world were used in the inversion. A careful analysis of a-posteriori errors and model resolution shows that Temperate Asia is a major residual sink of CO_2 with a value of 1.5 Gigatonnes of Carbon (GTC)/yr.

-24 A study of the South Atlantic Ocean: Circulation and Carbon Variability

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Recent analysis supports that the Southern Ocean provides a strong sink, yet low storage, for atmospheric CO2. The South Atlantic Ocean, in particular, facilitates major interbasin exchange through the interaction of the Antarctic Circumpolar Current (ACC), Atlantic Meridional Overturning Circulation (AMOC) and Agulhas Current system. Hydrographic occupations from Drake Passage (WOCE section SR1) in 1990 and 2009, along 30°E from the African continent to Antarctica (WOCE section I6S) in 1996 and 2008 and across 24°S in the Atlantic in 2009 creates a `box' and enables comparison of fluxes and carbon inventories between each box boundary. Calibration factors from GLODAP (Global Ocean Data Analysis Project) and CARINA (Carbon in the North Atlantic) projects were applied for salinity, oxygen and nutrients to 1990 and 1996 occupations.
Distributions of Dissolved Inorganic Carbon (DIC) and anthropogenic carbon (Cant) from each hydrographic occupation support a sectionwide Cant increase of 4.7±0.2 μmol kg-1 per decade at Drake Passage within recently ventilated Subantarctic Mode Water, increasing to 10.4±0.2 μmol kg-1 per decade at 30°E. Seasonal Winter Water ventilates Subantarctic Mode Water and Antarctic Intermediate Water, and further subduction ventilates the ocean interior. Cant increase within Antarctic Bottom Water yields average sectionwide increases of 0.7±0.4/1.4±0.2 μmol kg-1 per decade across both Drake Passage and 30°E, respectively.
Large-scale circulation is estimated by constructing an inverse box model using boundary sections of the South Atlantic Ocean. Interbasin fluxes of volume, temperature and Cant support a southward deep water AMOC of 20.2Sv (1Sv=1m3 s-1) and associated Cant overturning of 0.18Mmol s-1 across 24°S. Net meridional northward Cant transport of 0.70Mmol s-1 confirms the South Atlantic is a present day source of Cant to the North Atlantic Ocean. Further divergence of Cant across 30°E implies significant atmosphere-to-ocean uptake within the South Atlantic. Net Cant fluxes, dominated by higher Cant in the upper ocean are in opposition to the net volume transport across 24°S and across the Agulhas regime. Future increases of Cant within the more voluminous deep ocean are expected to reverse the net Cant flux.

-25 China’s Economic Growth and the Global Carbon Budget

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The carbon emission from the Chinese economic activities has continued to grow at a high rate since China replaced the United States and become the biggest emitter in the world. It is highly expected that within a decade the Chinese emission will exceed the US and EU combined and takes an unprecedented share of the global carbon budget. Therefore, managing China’s economy has major implications for the future of the climate mitigation worldwide. With the inauguration of the new leadership and the shift of political and policy agenda, China seems to be prepared to put ecological progress ahead of economic growth. This presentation reviews the political and socioeconomic background of the current development strategies and policies, and assesses their impacts of the new development agenda on the future greenhouse gas emissions in China, as well as the implications for the global carbon budget. In particular, it will discuss the large-scale, rapid urbanization and industrialization and their expected consequences on China carbon emissions. This presentation will put the China’s economic growth in the context of a global trend of the rise of the emergent economies, and offer an assessment of such a change on climate change its global governance. I will try to explore the forms of global climate governance that fit the current global economic and political structure.

Keywords: China’s economic growth, global carbon budget, climate mitigation, global climate governance

-26 Carbon stocks across a stand age sequence in Pinus radiata plantations in South Australia

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Radiata pine (Pinus radiata) is a common plantation species in Australasia, but information on carbon stocks in response to management factors is limited. This study was to understand how stand age affects the carbon (C) stock of radiata pine plantations in South Australia. Three stand age sequences (13-year-old; 27-year-old; 41-year-old) with varying site quality (from II to VII) were chosen from the Kuitpo radiata pine plantations in the Mount Lofty forest region, South Australia. Carbon concentration and stocks in tree biomass, forest floor and mineral soils were analysed by using site quality as a covariate variable. Aboveground tree C stock was significantly higher in the 27-year-old stand (102.68 Mg C/ha) and 41-year-old stand (85.61 Mg C/ha) than in the 13-year-old stand (58.07 Mg C/ha). The difference in tree C stocks between stand age was attributed to stand basal area (r=0.96). However, forest floor C stock was not significantly affected by the stand age sequences. The soil C stock at 0-30 cm depth declined rapidly with increased stand age sequences (13-year-old: 92.21 Mg C/ha; 27-year-old: 76.83 Mg C/ha; 41-year-old: 35.87 Mg C/ha) because of varying site quality (13-year-old: IV; 27-year-old: III; 41-year-old: VI). The results suggest that C stocks in radiata pine plantations could be improved by forest management practices which enhance overall site productivity.

-27 Soil carbon storage as impacted by stand age and site quality of Pinus radiata plantations in South Australia

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

In Australasia, radiata pine (Pinus radiata) tree is one of the most important coniferous tree planting species; however information on belowground carbon status is limited. This study was carried out to evaluate the effects of stand age and site quality on soil carbon (C) storage of radiata pine plantations in South Australia. Three stand age classes (13-year-old; 27-year-old; 41-year-old) and six site quality classes (Ⅱ, Ⅲ, IV, Ⅴ, VI, Ⅶ) were chosen from the Kuitpo radiata pine plantations in Mount Lofty forest region, South Australia. Soil C concentration and storage were measured at 0-30cm depth. Mean soil C concentration at 0-30 cm depth was significantly higher in the 13-year-old stand (2.85%) and 27-year-old stand (2.22%) than in the 41-year-old stand (0.97%) classes. Total C storage was also significantly higher in the 13-year-old stand (92.26 Mg C/ha) and 27-year-old stand (76.89 Mg C/ha) than in the 41-year-old stand (35.92 Mg C/ha) classes. The C storage at 0-30 cm depth was the lowest in the poor site quality (VI, VII: 27.98-45.56 Mg C/ha), followed by the medium (III, IV, V: 73.93-75.87 Mg C/ha) or good site quality (II: 90.22 Mg C/ha). There were strong positive relationships between mean C concentration (r= 0.94) or total soil C storage (r= 0.91) and site quality classes in radiata pine plantations. The results indicate that soil C storage in radiata pine plantations was attributed to site quality (growth rate) determined by inherent soil property rather than stand-age characteristics.

-28 Global Warming Gains Decomposition of Soil Carbon in Forest

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The global soil respiration (Rs) is the 2nd largest terrestrial carbon flux in terrestrial ecosystem, and was estimated to be 98 ± 12 Gt C in 2008. The increase rate of Rs between 1989 and 2008 was modelled to be about 0.1 Gt C yr-1, and this value equals to about 10% of global terrestrial carbon sink. To date, most of the carbon-climate models imply the exponential functions to predict the future global heterotrophic respiration with a Q10 of 2.0. In their models, global heterotrophic respiration (Rh) increases exponentially with climate warming at an average rate of 6.2% per degree, and resulting that the current carbon sink of terrestrial ecosystem probably convert to a carbon source after 2050. However, this modeling prediction has been very difficult to confirm from measurements because soil respiration is highly spatially and temporally variable, it cannot be measured by large-scale remote sensing, and the soil medium is not easily accessible.

Since 2006, we started to examine the effect of soil warming on Rs by collecting continuous measurement data using a multi-channel automated chamber system and infrared heaters (2.5°C increasing soil temperature at 5 cm depth) in a Japanese red pine forest. In 2012, soil warming enhanced heterotrophic respiration by 13.3 % per degree. The Q10 was 2.72 and 2.45 for control and warming plots, respectively. The lower Q10 for warming treatment was caused by the heating-enhanced summer (July and August) drought.

In our experiment, warming effect on Rs was still significant after 6 year soil warming treatment. Japanese forest contains more amount of soil organic carbon (on average 188 tC ha-1 within 1 m top soil) compared with the world forests. Our results clearly suggest that global warming will gain decomposition of carbon in forest soils, and the warming-induced carbon emission will have significant positive feedback to the regional climate change.

-29 Fossil fuel derived CO2 distribution across different regions of China estimated by radiocarbon (14C) analysis of annual plants

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Previous studies have shown that the 14C level in annual plants can be used as a sensitive tracer for monitoring fossil fuel derived CO2 in the atmosphere. Here we report two cases in our attempt to rapidly trace local fossil fuel derived CO2 emission; one in the Beijing area and the other in wider regions of China, including high mountains in the Tibetan Plateau, grassland in Inner Mongolia, and inland and coastal cities. Corn leave samples were collected during the summers of 2009 and 2010 respectively. The 14C/12C ratio of the samples was measured with the NEC compact AMS system at the Institute of Heavy Ion Physics, Peking University. The fossil fuel derived CO2 was estimated by comparing the measured D14C values of corn leave samples to background atmospheric D14C level. The influences of topography, meteorological conditions and carbon cycling processes on the fossil fuel derived CO2 concentration are considered when interpreting the data. For the samples collected in Beijing area, the D14C value displays a decreasing trend from the outer suburbs to inner suburbs and then to the urban centre. For the sample set from wider areas, our results show an apparent association of the low D14C values with regions where human activities are intensive.

-30 Topsoil CO2 flux in meadow steppe and planted forests with different stand ages estimated by radiocarbon analysis of soil organic carbon

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

How would soil organic carbon pools change after afforestation? Application of radiocarbon (14C) as a tracer at Saihanba Forest Station of Hebei Province, China revealed a decrease in turnover time of soil organic carbon (SOC) after plantation of trees on meadow steppe; the SOC turnover times can be as long as from 70 to 250 years. The decrease is dependent on stand age and true for both bulk samples and aggregate fractions. Such changes in turnover time may increase the CO2 flux, hence possibly reducing the capacity of topsoil to sequestrate organic carbon. Combined stable isotope and 14C analyses on soil aggregate fractions suggest that there are different responses to afforestation of grassland between young and old carbon pools in topsoils. In the young and middle-age planted forests, the proportion of CO2 emission from the older soil carbon pool shows an increasing trend. But in the mature planted forest, its proportion tends to decline, indicating that the stand age may influence the soil carbon sequestration mechanism. The CO2 emission from the topsoils estimated using the 14C method is relatively low compared to those by other methods and may be caused by the partial isolation of the young carbon component from the soil aggregates. For more accurate estimation of CO2 flux, future studies should therefore employ improved methodology for more effective separation of different soil carbon components before isotope analyses.

-31 AIR-SEA CO2 FLUXES AND SATURATION STATES IN THE GULF OF MEXICO

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Until recently, very few surface carbon dioxide measurements had been made in the Gulf of Mexico either spatially or temporally. The unique geographical features of the Gulf make it an important contributor to the total air-sea CO2 flux of the coastal United States. We present the first extensive set of surface ocean carbon measurements in the region, collected on board of Ships of Opportunity and NOAA research vessels. A seasonal climatology of air-sea CO2 fluxes was determined and temporal and spatial variability was analyzed for the Northern Gulf of Mexico (> 24 ˚N). We produced seasonal maps of CO2 fluxes utilizing the optimal interpolated SST product based on remote and in situ SST, salinity from the Real-Time Ocean Forecast System (RTOFS) and remotely sensed winds. Our results suggest that the Gulf of Mexico is a weak sink for CO2 but with significant regional and seasonal differences in magnitude and direction of the air-se CO2 flux. Surface water CO2 levels are a controlling factor for aragonite saturation states and initial seasonal maps of this calculated property will be shown for the Gulf of Mexico.

-32 Change of air-sea CO2 flux in East and South China Sea.

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Based on CCMP data, WRF Assimilation data ,WW3 modeling wave data and the latest in-situ pCO2 observational data, we made an estimation of air-sea CO2 flux of East and South China Sea by using 2 bi-parameter gas transfer velocity formulas and 4 gas transfer velocity formulas parameterized by wind speed. The former result is 30% larger than the latter one. On the whole, bi-parameter formulas strengthen both sink and source of CO2 in the ocean. In addition, East China Sea acts as a sink of CO2. Besides, South China Sea turned into a weak sink from a source due to increasing pCO2 in the air in the past 20 years. The uptake ability of China Seas has also declined.

-33 Atmospheric CO2 and water chemistry changes from the past to the present: planktonic foraminifera in the European Arctic (Fram Strait)

[1]Katarzyna Zamelczyk, [1]Tine L. Rasmussen, [2]Clara Manno, [3]Jelle Bijma, [3]Eduard Bauerfeind *([1]University of Tromsø, Department of Geology, Norway, [2]University of Cambridge, Department of Ecology, UK, [3]Alfred Wegener Institute, Germany)*

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Planktonic foraminifera that live in the upper 200 m of the water column constitute a major group of calcareous species of the marine microplankton in the Fram Strait. Their calcareous shells are highly sensitive to varying sea surface conditions, changes in carbonate chemistry and preservation in sedimentary records. This sensitivity makes them one of the most important objects of investigation of past changes in ocean chemistry, climate and circulation.

The main objective of our study is to reconstruct and to quantify planktonic foraminiferal response to changes in surface ocean chemistry due to shifts in concentration of atmospheric CO2 from the past 30,000 years to the present day in the Fram Strait.

The Fram Strait is the most important oceanographic opening to the central Arctic Ocean where the major water transport takes place. The eastern Fram Strait is occupied by warm and saline Atlantic waters, whereas the western Fram Strait is dominated by cold and fresher Polar water and sea-ice. The two different water masses generate two oceanic fronts, the Polar and the Arctic front, characterized by high primary production and elevated abundances of planktonic foraminifera.

In addition to water column samples taken with plankton net (VP2, 90µm mesh size), surface sediment samples and sediment cores were collected during two cruises along the Atlantic water flow and along a E-W transect at 78N in the central Fram Strait in 2012. The distribution patterns of fossil and living planktonic foraminifera from plankton net and sediment surface samples show strong variability.

A range of new and well established proxies reflecting sea water chemistry will be analyzed on material from all retrieved samples and annually moored sediment trap samples from 2011 and 2012. The analysis will be focused on two species of planktic foraminifera (Neogloboquadrina pachyderma and Turborotalita quinqueloba). Shell weight, degree of fragmentation and measurements of degree of dissolution based on SEM images will be used to establish the state of dissolution. Boron isotopes (a proxy for pH), carbon and oxygen isotopes as well as B/Ca ratios (a proxy for carbonate ion concentration), and Mg/Ca ratios will be measured within the same samples to obtain the profile of chemistry changes in the water column in the study area.

-34 Southern Ocean processes and variability from a 13 year record of in situ atmospheric O2 and CO2 measurements made at Baring Head, New Zealand

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

See attached file.

-35 The value of satellite-based CO2 measurements for constraining carbon source/sink estimates

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Satellite-based CO2 measurements, with their dense spatial and temporal coverage, hold out the promise of allowing surface sources and sinks to be estimated at regional spatial scales and at synoptic and even diurnal timescales. Such estimates should shed light on the key processes driving global CO2 variability and trends. Here we evaluate the CO2 flux constraint provided by measurements from two future satellite platforms, OCO-2 and ASCENDS, against that from the existing GOSAT satellite, the ground-based in situ network (including routine aircraft profiles), and the ground-based column CO2 measurements of the Total Column Carbon Observing Network (TCCON). This is done using simulation experiments with a variational carbon data assimilation system solving for weekly and sub-weekly CO2 fluxes on an ~500 km latitude/longitude grid. The impact of clouds, aerosols, and other interference is quantified using realistic retrieval screens and error estimates from GOSAT. This is projected forward for OCO-2 and ASCENDS by accounting for their greater ability to see through gaps in clouds, given their smaller fields of view.

The results of this study point first to the importance of doing the simulation at regional spatial scales: the flux constraint we obtain, when viewed on the scale of the Transcom3 regions, is several times weaker than that obtained when flux patterns inside each region are fixed in the inversion. This implies that the true difference between the in situ and satellite constraint is even greater than that obtained in this study (as would be seen for simulations done at finer resolutions). GOSAT is found to reduce flux uncertainties by a factor of two over the tropical land regions compared to the existing in situ and TCCON measurements, with less improvement over the oceans and extra-tropical land regions. The OCO-2 and ASCENDS then provide another factor of two improvement broadly over all land regions, and a smaller improvement over the oceans, ending up at uncertainties of 0.1-0.2 PgC/yr at the scale of monthly fluxes across all Transcom regions, land and ocean. Uncertainty reductions on the order of 70-80% are found over land, even at the ~500 km scale.

At these levels of random error, systematic errors in both the measurements and the modeling system come to dominate the problem. We examine the systematic errors in the GOSAT XCO2 retrievals given by NASA's Atmospheric CO2 Observations from Space (ACOS) team and project their impact on the retrieved fluxes. We then discuss our best-guess flux estimate for 2009-2012, derived using both ground-based and GOSAT CO2 measurements, in light of these systematic errors.

-36 Strong Observational Constraints on Seasonal Northern Extratropical CO2 Exchange

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Seasonal CO2 exchange with northern extratropical terrestrial ecosystems is the largest of all influences on atmospheric CO2 distribution. Yet, this quantity is remarkable for how poorly it is known. Quantitative estimates of the amount of CO2 that leaves and enters the Northern Hemisphere extratropical troposphere each year vary by a factor of 4 for state-of-the art prognostic models, and by 50% for global atmospheric inverse models. We present new estimates of this quantity, based on airborne and ground-based CO2 observations, that provide valuable constraints on global terrestrial ecosystem models and carbon budgeting exercises. Prognostic models of terrestrial CO2 exchange have typically been validated by propagation through atmospheric transport models and comparison of the resulting signals to observations from surface stations, making such validations particularly sensitive to the large uncertainties in seasonal vertical mixing in the transport models. Furthermore, global atmospheric CO2 inverse models with incorrect estimates for this seasonal exchange, or incorrect dilution of northern terrestrial signals in different seasons, will by necessity make biased estimates of the much smaller residual annual-mean fluxes, such as tropical or northern terrestrial net ecosystem exchange.

We use high-resolution airborne CO2 observations from the HIAPER Pole-to-Pole Observations (HIPPO) campaigns, spanning the Pacific Basin from 67 S to 87 N and the surface to 14 km and collected at 9 different times of year, to provide direct measurements of seasonal hemispheric-scale CO2 exchange. We use the ACTM atmospheric transport model and output from the TransCom 3 collection of models to show that a slice down 180 W provides a very good approximation of zonal mean concentrations, and to establish that the link between extratropical atmospheric molar abundances and extratropical surface fluxes is largely model-independent. We use observations from surface stations and ongoing aircraft vertical profiles to aid interpolation of the 9 HIPPO missions to the full annual cycle and to place these 2009-2011 campaigns in context of longer-term interannual variations. Finally, we show comparisons of our observations to terrestrial ecosystem fluxes from CMIP5 models and a range of atmospheric inverse results.

-37 Assessing the new generation of Earth System Models with satellite and atmospheric observations: a carbon and oxygen cycle perspective

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Atmospheric Potential Oxygen (APO = O2 + 1.1 * CO2) measurements can provide important information on oceanic processes. Its seasonal cycle, which is mostly driven by the seasonal air-sea gas exchange of O2, is shaped by both physical and biogeochemical oceanic processes and their changes can modify its seasonal dynamics.

Here we combine APO data with data of chlorophyll concentration, primary and export production derived from satellite observations to test robustness of the ecosystem components of the Earth system Models (ESMs) used in the climate model inter-comparison project phase 5 (CMIP5) for present-day climate. These satellite products are closely tied to the part of the O2 cycle that is driven by the upper ocean ecosystem dynamics, so the combination of the satellite products and APO cycles provides a cross cutting test of ocean models.

We examine output of the ESMs participating in the CMIP5 to test the performance of these models at reproducing the seasonal cycles of the biogeochemical variables listed above. For the APO comparison, we rely on atmospheric transport models to relate the air-sea fluxes to the observed APO changes.

The combination of the oceanic and atmospheric observations will help us to constrain the performance of the ESMs that have been used in the latest IPCC assessment for global climate predictions with specific focus on their representation of their carbon and oxygen cycles for present-day climate.

-38 Sensitivity of regional energy, water, and carbon cycles to historical land-cover changes in the Eastern United States since European Settlement

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The impacts of land use and land cover changes on terrestrial carbon, water, and energy cycles, and the resultant feedbacks to atmospheric processes are the core aspects of land-atmosphere interactions. Much of the solar energy that drives the atmosphere first interacts with the land or sea surface. Over land regions this interaction is modulated by surface characteristics such as albedo, aerodynamic roughness length, leaf area index, etc. As these characteristics change, either from anthropogenic or natural land-cover disturbances, the amount of energy reaching the atmosphere from the land surface, and thus weather and climate, is expected to change. This project examines the sensitivity of energy, water, and carbon cycle changes to historical land-cover changes in the eastern United States since the arrival of European settlers. The Regional Atmospheric Modeling System (RAMS) coupled with the Simple Biosphere (SiB) model, SiB-RAMS, will be used to perform a series of one-year ensemble simulations over the eastern United States with the present-day and several past land-cover distributions. The land- cover distributions will be based on the new Reconstructed Historical Land Cover and Biophysical Parameter Dataset developed by Steyaert and Knox (2008). The influence of the land-cover changes on temperature and precipitation, as well as energy, water, and carbon balances will be examined and compared with that expected from CO2-induced climate change (IPCC 2007).

-39 The observed climate change and its future scenarios simulated with ECHAM model at various CO2 emission in China

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

By employing several climate data sets, such as the reanalysis data from ECMWF and NCEP; the CRU interpolation data; and the TRMM remote sensing data, focusing on the variables of temperature and precipitation, we carry out the trend analysis and abrupt change analysis. All these data was first arranged on the grid of 0.25 degree, and the area-weighted average as a whole in the study area was evaluated. The whole regional temperature shows that it increased by 0.66 degC during the 20th century; while the precipitation did not manifest the remarkable change at the same period. Some abrupt changes in the time series of the temperature were significantly detected.
In addition, the climate scenario data simulated with the ECHAM model was used for future climate projection in China. We used two data sets, respectively from AR4 (ECHAM5) and CMIP5 (ECHAM6). At various CO2 emission situation labeled with A1B, A2 and B1 from AR4 and labeled with RCP26, RCP45 and RCP85 from CMIP5, the temperature would increase by from 0.18 to 5.82 degC during the 21th century. The precipitation increases significantly at the strong CO2 emission (A1B, A2, and RCP85). It is expected that the increased precipitation is mainly caused by the extreme rainfall. Therefore, the reduction of CO2 emission into the atmosphere is important for alleviating the climate change in China.

-40 Quantifying the impact of model errors on top-down CO2 flux estimates

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

We now have available space-based observations from a number of satellite instruments, which provide greater observational coverage than the existing surface observational network. Recent inverse modeling studies have shown that integrating the space-based and surface CO2 observations provides greater reduction in the uncertainty of the regional flux estimates than is possible than using either dataset alone. However, the accuracy of the inferred flux estimates is an issue as these inversion analyses are sensitive to systematic model errors. Using the 4-dimensional variational data assimilation system in the GEOS-Chem model, we assess the impact on the flux estimates of discrepancies in simulating mixing processes in the planetary boundary layer and in capturing long-range transport in the model. We focus on the impact of these model errors on regional CO2 flux estimates for North America, Europe, and Asia using space-based observations from the Greenhouse Gases Observing Satellite (GOSAT) and surface measurements from the National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory Carbon Cycle Cooperative Global Air Sampling Network and from Environment Canada. The inversion using the surface data is particularly sensitive to discrepancies in boundary layer mixing, whereas the inversion using the satellite data is more sensitive to long-range transport errors. We quantify the impact of these errors on the inferred fluxes when the GOSAT and surface data are assimilated separately and together.

-41 South Atlantic CO2 and CH4 growth and dynamics observed by continuous high-precision measurement at Ascension Island, East Falkland Island and onboard RRS JC Ross

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

See attached file

-42 Orbiting Carbon Observatory – 2 (OCO-2) Status and Plans

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The OCO-2 spacecraft carries and points a single instrument that incorporates 3, co-bore-sighted high-resolution, imaging, grating spectrometers. The spectrometers are designed to measure the absorption of reflected sunlight within the O2 A-band at 0.764 μm or within the weak and strong CO2 bands centered near 1.61 or 2.06 μm, respectively. Each spectrometer records 3 frames per second in 4 to 8 footprints along its narrow (0.8°) slit. This sampling rate yields > 200 soundings per degree of latitude or > 500,000 soundings over the sunlit hemisphere each day. The instrument has been optimized for sensitivity, with a high signal to noise ratio, large dynamic range, and small sounding footprint (< 3 km2). To further increase the sensitivity to CO2 variations over dark, ocean or ice-covered surfaces, the Observatory can point the instrument' s field of view toward the glint spot at solar zenith angles as high as 85°. With these capabilities, OCO-2 is expected to yield the data needed to retrieve XCO2 with single-sounding random errors < 1 ppm over > 80% of the range of latitudes on the sunlit hemisphere each month.

The OCO-2 instrument and spacecraft bus are now complete, and their pre-launch characterization and calibration tests are ongoing. Preliminary results from the instrument tests indicate that it will meet its radiometric, geometric, and spectroscopic performance requirements. A launch vehicle now has been selected for OCO-2, and the launch is planned for July 2014. This presentation will summarize the results of the OCO-2 instrument characterization tests, and outline the near the plans for observatory integration and launch preparation.

-43 Earth Networks' dense atmospheric GHG observing system

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Long-term continuous atmospheric observations of greenhouse gases (GHG) at regional to local scales are essential for better scientific understanding of interactions between complex natural and anthropogenic factors driving geophysical changes and trends. Reliability and consistency of information provided through such measurements directly relate to effectiveness of policies, either planned or already implemented. To answer the needs of climate scientists, as well as to support various agencies and organizations at national levels worldwide, over the next five years Earth Networks will deploy 100 cavity ring-down spectrometers, which will continuously measure CO2, CH4 and H2O. Work is underway to place instruments at 50 tall towers in the United States, 25 in Europe and 25 around the world. Data from this network will be used for monitoring and verification, and for inverse modeling to estimate natural and anthropogenic sources and sinks of greenhouse gases. Currently, more than 20 instruments have been deployed in the US, and several sites have already accumulated year-long records. A vital part of each instrument is the Earth Networks Calibration System (ENCS), which is the result of collaborative efforts between Earth Networks and Scripps Institution of Oceanography. This system was developed to monitor and calibrate gas analyzers to ensure precise measurement standards. The ENCS is currently used with Picarro gas analyzers with suggested daily calibration frequencies and a standard gas mixture, such as reference gases from NOAA. Time resolution of the instrument is dictated by system flushing and is typically in the 1-minute range. To provide inter-comparison data for other atmospheric GHG observing systems and to expand on variety of measured atmospheric constituents, for example, for attribution studies, the ENCS has been designed to seamlessly interface with PFP (Programmable Flask Package) and other flask packages, that are collected and processed in collaborations with NOAA Earth System Research Laboratory. To simultaneously sample various aspects of local environment for more accurate representation of dynamic GHG sources and sinks, EN also collects surface weather information, provided by more than 10,000 EN's surface weather stations, as well as measurements from lightning system (ENTLN) and boundary layer thermodynamic profilers (ENBLN). These data are used in Earth Networks' GHG monitoring system where various levels of pre-processing include application of data quality and meteorological filters. EN observations are available in real-time from a cloud-based file system.

-44 Development and test of soil respiration parameterization in Noah_MP land surface model

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Global carbon cycle and climate are tightly coupled. Soil respiration has a large effect on the global carbon cycle and is the primary path by which CO2 fixed by land plants returns to the atmosphere. Soil respiration rate controls the soil C flux to the atmosphere and changes the concentration of greenhouse gas, and then affect the climate change. Future global warming would accelerate the soil respiration rate- the soil organic carbon decomposition rate and release more CO2 to the atmosphere and thus enhance the greenhouse effect. Better representing soil respiration processes including microbial respiration and root respiration processes in land surface processes schemes could help improve the climate models' simulation to future climate. In this study, we have developed soil respiration parameterization that can represent the soil CO2 production and transportation processes accurately, and then incorporated it into Noah_MP land surface model. Finally, we tested this model using one-year observational data from the Santa Rita Experimental Range (31.8214°N, 110.8661°W, and elevation 1116 m) outside of Tucson, Arizona, USA in 2007. Comparison of Simulation results and observation has shown that this model can well simulate the diurnal and seasonal variations in soil surface CO2 efflux, and its response to soil temperature and water content.

-45 Atmospheric signatures of air-sea exchanges of CO_2, O_2/N_2, CH_4, CO, and N_2O recorded at the Cape Verde Atmospheric Observatory (CVAO)

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The Cape Verde Atmospheric Observatory (CVAO) located on Sao Vicente island (16°52′ N, 24°52′ W) in the north-eastern subtropical Atlantic was established in 2006. Since 2007 biweekly air flask samples have been taken on a 30m tower and analyzed for concentration and isotopic composition of long-lived trace gases and oxygen at the Max-Planck-Institute for Biogeochemistry in Jena, Germany. In October 2008 a system for quasi-continuous measurements of CO_2, O_2/N_2, CH_4, CO, N_2O and SF_6 has been installed and operated since then, albeit with large data gaps caused by technical difficulties at the remote site. Here we present the observed records from CVAO and analyze the data on synoptic, seasonal and interannual time scales. CVAO is located in the North-Atlantic trade wind system in an area with a very stable marine boundary layer. Seasonal cycles and interannual variability reflect changes in atmospheric transport and sources and sinks of the trace gases in the northern hemisphere. However, sources and sinks closer to CVAO primarily cause synoptic concentration variations. Most air masses arriving at the station have passed over the coastal upwelling areas off the coast of Western Sahara and Mauritania which are supersaturated in CO_2, CH_4, and partly in N_2O, and undersaturated in oxygen. Small shifts in the wind trajectories therefore induce synoptic variations of the atmospheric concentrations depending on the travel time of the air mass over the upwelling region and which can be detected in the observations. Using backtrajectory analyses, we can place bounds on integrated air-sea fluxes in the upwelling area and relate them to in situ surface ocean measurements of biogeochemical gases. Based on the analysis we estimate the potential to detect longer-term changes in air-sea fluxes of biogeochemical gases from long term measurements at the Cape Verde station.

-46 Using atmospheric radiocarbon (14CO2) to constrain fossil and biogenic CO2 fluxes

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The carbon-14:carbon-12 ratio of atmospheric CO2 (expressed as Δ14CO2) is an ideal tracer for identifying atmospheric CO2 gradients resulting from emissions of fossil fuel-derived CO2, since the latter contain no 14C. By difference, Δ14CO2 can also be used to isolate the portion of the gradient resulting from net ecosystem exchange (NEE), without the need of a fossil fuel emissions inventory. Since 2004, more than 3000 high precision measurements of atmospheric Δ14CO2 have been made on air samples collected at surface, tower and aircraft sampling platforms in the United States; most of these have been made since 2009 at an emerging network of 10 sites. Ultimately, our goal is to use Δ14CO2 observations to directly quantify fossil fuel emissions at regional and monthly to annual scales throughout the U.S. Until then, Δ14CO2 observations can be used to adjust regional-scale fossil fuel emissions patterns so as to minimize biases present in inventories. Atmospheric-CO2 inversions assume fossil fuel fluxes are perfectly known, so fossil fuel biases can translate into biases in optimized NEE, via mass balance. Thus, relaxing the assumption of perfectly known fossil fuel by using Δ14CO2 will improve estimates of NEE.

We will first demonstrate the ability of Δ14CO2 observations to partition regional-scale enhancements (or depletions) of total CO2 into fossil and NEE fractions. Our results show substantial contributions of both biological and fossil CO2 throughout the year, with the fossil fuel signal masking the true extent of summer time photosynthetic drawdown. A notable result is that even downwind of major urban areas, such as the US Northeast, wintertime CO2 enhancements are only half fossil, implying that observations of CO2 alone are unlikely to yield reliable estimates of anthropogenic emissions. In order to move towards a fully constrained fossil fuel and NEE CO2 inversion capability, we have constructed a forward model of atmospheric Δ14C within the CarbonTracker/TM5 modeling framework, which contains a full description of both the CO2 and Δ14CO2 atmospheric budgets. We will present analysis of modeled vs. observed Δ14CO2 showing good overall correspondence at North American sites. The forward model does overestimate the fossil fuel contribution in the Northeast U.S planetary boundary layer but performs significantly better when using the VULCAN or ODIAC fossil fuel emission patterns, compared to those from the EDGAR inventory. This result confirms the ability of even the existing set of Δ14CO2 observations to help constrain fossil fuel-CO2 emissions. We will finally discuss how this improved fossil fuel constraint will improve the accuracy of optimized NEE in combined atmospheric CO2 and Δ14CO2 inversions.

-47 Fossil Fuel Energy Resources: An Uncertainty of Climate Change

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Changes in fossil fuel production and climate change are generally studied separately and their relationship has scarcely been researched. When scientists think about the uncertainty of climate change they usually consider variability of climate change impacts generated in model runs driven by increasing CO2 concentrations from now to 2100 obtained from the IPCC Special Report on Emission Scenarios (Nakicenovic et al, 2000). Few consider the resource uncertainties of CO2 emissions. Starting in 1990 the IPCC Assessment Reports developed families of CO2 production scenarios that invoked different projections of population growth, development, and energy resources and reserves of oil, gas and coal. The IPCC SRES Scenarios are still used (especially the Business as Usual Scenario; SRES A2) in many climate change models. The new Assessment Report (AR5) due out in 2013 will use a different approach called Representative Concentration Pathways for modeling the CO2 increase (Moss et al., 2010). These start with four scenarios of future radiation forcings to be reached in 2100 (8.5, 6.0, 4.5, 2.6 W m-2). The pathways to achieve these forcings can be achieved by a diverse range of socioeconomic and technological scenarios (alternative futures). This new approach still requires varying amounts of fossil fuel emissions to reach the specified forcing levels. The IPCC originally built the SRES primarily from two references by energy economists (Rogner, 1997; Gregory and Rogner, 1998) using data (BP, WEC and other sources) from before 1996. The basic economic assumption is that there are vast unconventional energy resources and that technology will evolve to allow their production at affordable cost. Energy economists traditionally have an optimistic view but we now know that vast resources have little to do with production. The SRES also made price assumptions that were much lower than what we see today. The IMF has shown that high prices make new reserves of all types of fossil fuel energy available for production but also reduce production due to demand destruction. In the almost two decades since we have a new view of the prospects for fossil fuel production and the values of the ultimate recoverable resources (URR). One estimate of the total carbon emissions from all fossil fuels sums to 885 GtonC (Tans and Rutledge, in prep). Conventional oil production has already reached a plateau of about 75 mbd (Murray and King, 2012, Nature, 481, 433). Increases in shale gas and tight oil production, touted as "game changers", have been shown to be overhyped as the very rapid first year decline rates are hardly ever mentioned (Hughes, 2013, Nature, 494, 307). This necessitates a treadmill of drilling and higher costs just to stay at constant production. The increase in production of tight oil from the Bakken just offsets the decline in production from Alaska resulting in little net change for the U.S.. Shale gas may be abundant, but the cost of production is well above its current sale price. For production to continue it will have to become much more expensive. So-called proven reserves for coal, are anything but, and remain poorly known but many independent new studies by Rutledge (2011, Int. J. Coal Geology, 85, 23), the Energy Watch Group (2007), Patzek and Croft (2010, Energy, 35, 3109) and Aleklett et al (Hook et al, 2010, Fuel, 89, 3546) show that reserves are not as large as we have been led to believe. Whenever coal reserves are updated the reserve estimates are revised downward (significantly). Major new discoveries are unlikely.

-48 Reconciling global and regional trends in LULUCF fluxes

[1]Joanna House, [2]Richard Houghton, [3]Atul Jain, [4]Kato Etsushi, [5]Kees Klein Goldewijk, [6]Julia Pongratz, [7]Ben Poulter, [8]Corinne Le Quéré, [9]Beni Stocker, [5]Jelle van Minnen *([1]Cabot Institute, Bristol University, [2]Woods Hole Research Centre, USA, [3]Dept of Atmospheric Sciences, Uni. of Illinois, USA, [4]Center for Global Environmental Research, Nat. Inst. for Env. Studies (NIES), Japan, [5]PBL Netherlands Environmental Assessment Agency, [6]Max Plank Inst. For meterology, Hamburg, Germany, [7]Laboratoire des Sciences du Climat et de l' Environnement, CEA-CNRS-UVSQ, France, [8]Tyndall Centre for Climate Change Research, Uni. of East Anglia, UK, [9]Physics Inst., and Oeschger Centre for Climate Change Research, Uni.of Bern, Switzerland)*

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

A variety of data and methods have been applied in calculating LULUCF that include different processes and approaches to calculating emissions. For example, some assume instantaneous emissions of all carbon that will be eventually lost from the system following human action, while others take into account the rate of decomposition, fate of products, and rate of regrowth of replacement vegetation (legacy effects). Some model the dynamic effects of climate and CO2 on biomass and growth/decay rates while others use published inventory data from a fixed point in time. Some account for forms of forest management (e.g. forest harvest and shifting cultivation), few account for peatlands. Some use different definitions e.g. of gross and net fluxes and forest management or degradation. The different data and approaches lead to a large uncertainty in estimating the LULUCF flux and difficulty in interpreting results, highlighting the importance of careful interpretation. Understanding and quantifying the reasons for the differences enables us to reconcile different estimates and reduce uncertainty in future analyses.

Uncertainties become more apparent at regional scales. Regional trends from six modelling studies updated for the latest IPCC Assessment are analysed in detail: the Houghton bookeeping model and land use change data set; and five process-based models (BernCC, IMAGE, ISAM, LPJ-wsl, and VISIT) run using the HYDE data set. The global mean and range across the models is 1.14 (0.88 to 1.5) GtCO2/yr in the 1980s and 0.84 (0.46 to 0.22) GtCO2/yr in the 2000s. All models indicate LULUCF emissions peaked in the 1980s in Asia and Latin America and declined thereafter with levels in 2000 to 2009 of 0.29 (0.19 to 0.38) GtCO2/yr in Asia and 0.27 (0.09 to 0.50) GtCO2/yr in Latin America. This is consistent with a reduced rate of deforestation, and some areas of afforestation most notably in India and China (FAO FRA, 2010). In the Middle East and Africa the picture is more mixed: 0.19 (-0.02 to 0.55) GtCO2/yr in 2000-2009, with Houghton showing a continuing increase in emissions from the 1970s to the 2000s, while the VISIT model indicates a small sink in the 1970s and 2000s. The results for temperature and boreal regions are very mixed ranging from large net sources to small net sinks with a general picture of declining emissions or increasing sinks: OECD 0.05 (-0.08 to 0.33) GtC/yr; and Russia and Eastern Europe 0.04 (-0.07 to 0.35) GtC/yr in 2000 to 2009. These regions include large areas of managed forests, and areas of reforestation (e.g in the USA and Europe). Some differences are due to primary data sources, eg. FAO forest data (Houghton) as opposed to FAOSTAT agricultural data (HYDE), some are also due to how the models interpret land use transitions (resulting in different forest areas), and some due to modelled processes (e.g. including of N cycle in ISAM limits forest regrowth rates due to harvest removal of N).

-49 Reconciling global and regional trends in LULUCF fluxes

[1]Joanna House, [2]Richard Houghton, [3]Atul Jain, [4]Kato Etsushi, [5]Kees Klein Goldewijk, [6]Julia Pongratz, [7]Ben Poulter, [8]Corinne Le Quéré, [9]Beni Stocker, [5]Jelle van Minnen *([1]Cabot Institute, Bristol University, [2]Woods Hole Research Centre, USA, [3]Dept of Atmospheric Sciences, Uni. of Illinois, USA, [4]Center for Global Environmental Research, Nat. Inst. for Env. Studies (NIES), Japan, [5]PBL Netherlands Environmental Assessment Agency, [6]Max Plank Inst. For meterology, Hamburg, Germany, [7]Laboratoire des Sciences du Climat et de l' Environnement, CEA-CNRS-UVSQ, France, [8]Tyndall Centre for Climate Change Research, Uni. of East Anglia, UK, [9]Physics Inst., and Oeschger Centre for Climate Change Research, Uni.of Bern, Switzerland)*

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

A variety of data and methods have been applied in calculating LULUCF that include different processes and approaches to calculating emissions. For example, some assume instantaneous emissions of all carbon that will be eventually lost from the system following human action, while others take into account the rate of decomposition, fate of products, and rate of regrowth of replacement vegetation (legacy effects). Some model the dynamic effects of climate and CO2 on biomass and growth/decay rates while others use published inventory data from a fixed point in time. Some account for forms of forest management (e.g. forest harvest and shifting cultivation), few account for peatlands. Some use different definitions e.g. of gross and net fluxes and forest management or degradation. The different data and approaches lead to a large uncertainty in estimating the LULUCF flux and difficulty in interpreting results, highlighting the importance of careful interpretation. Understanding and quantifying the reasons for the differences enables us to reconcile different estimates and reduce uncertainty in future analyses.

Uncertainties become more apparent at regional scales. Regional trends from six modelling studies updated for the latest IPCC Assessment are analysed in detail: the Houghton bookeeping model and land use change data set; and five process-based models (BernCC, IMAGE, ISAM, LPJ-wsl, and VISIT) run using the HYDE data set. The global mean and range across the models is 1.14 (0.88 to 1.5) GtCO2/yr in the 1980s and 0.84 (0.46 to 0.22) GtCO2/yr in the 2000s. All models indicate LULUCF emissions peaked in the 1980s in Asia and Latin America and declined thereafter with levels in 2000 to 2009 of 0.29 (0.19 to 0.38) GtCO2/yr in Asia and 0.27 (0.09 to 0.50) GtCO2/yr in Latin America. This is consistent with a reduced rate of deforestation, and some areas of afforestation most notably in India and China (FAO FRA, 2010). In the Middle East and Africa the picture is more mixed: 0.19 (-0.02 to 0.55) GtCO2/yr in 2000-2009, with Houghton showing a continuing increase in emissions from the 1970s to the 2000s, while the VISIT model indicates a small sink in the 1970s and 2000s. The results for temperature and boreal regions are very mixed ranging from large net sources to small net sinks with a general picture of declining emissions or increasing sinks: OECD 0.05 (-0.08 to 0.33) GtC/yr; and Russia and Eastern Europe 0.04 (-0.07 to 0.35) GtC/yr in 2000 to 2009. These regions include large areas of managed forests, and areas of reforestation (e.g in the USA and Europe). Some differences are due to primary data sources, eg. FAO forest data (Houghton) as opposed to FAOSTAT agricultural data (HYDE), some are also due to how the models interpret land use transitions (resulting in different forest areas), and some due to modelled processes (e.g. including of N cycle in ISAM limits forest regrowth rates due to harvest removal of N).

-50 Can satellites detect CO2 emissions from thawing permafrost?

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Northern hemisphere permafrost soils hold twice as much carbon as there is currently in the atmosphere. Permafrost thaw and microbial decomposition of soil organic matter to CO2 or CH4 has the potential to release an unknown fraction of this carbon, which could accelerate climate change. Although current satellites can measure atmospheric CO2 or CH4 or measure numerous surface/vegetation parameters, are these observations adequate to detect the release of carbon from thawing permafrost? What would be the ideal set of satellite observations for monitoring permafrost? In this work, we use 3D atmospheric transport model simulations to investigate constraints on permafrost CO2 emissions provided from proposed near-infrared (NIR) observations of column-averaged atmospheric CO2 from a highly elliptical orbit (HEO) satellite mission optimized for the northern latitudes. Supporting measurements of surface/vegetation parameters from the HEO mission and low earth orbit (LEO) missions are discussed in this context.

-51 Predicting wetland extent, distribution and seasonality to estimate biological methane production in the Simple Biosphere Model

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Estimates of wetland extent permit the representation of physical processes relevant to the atmospheric loading of carbon dioxide and methane that have previously been neglected in the Simple Biosphere Model, SiB, and in many other land-surface models. These processes, including organic carbon storage in anoxic soils and the generation of methane therein, are important components of the carbon cycle: and are of particular interest due to their potential for positive feedback to surface warming.

An approach to estimating wetland extent as it varies in space and time has now been developed in SiB. The approach relies on meteorological forcings and modeled soil moistures to inform a parameterization of the topographic wetness index, based on satellite estimates of inundated area. Model estimates of wetland extent over the twelve-year period from 1993-2004 are presented and assessed. At this stage in development, estimates of wetland distribution and seasonality are in line with observational estimates in the tropics, but extra-tropical estimates may reflect model biases and are undergoing revision.

Estimates of wetland extent are used to drive a model of wetland soils, developed within SiB. This model uses a "tiling" approach to diagnose heat, water, carbon dioxide and methane fluxes from the wetland and upland areas in each model grid-cell. Estimates of wetland methane emissions, capable of realistic spatial and temporal variation, should benefit investigation of the atmospheric transport of methane and inverse modeling of methane fluxes, efforts that are underway. The model also affords an opportunity to examine wetlands' contribution to the heat and water budget, which may be important to dynamical processes and precipitation when coupled to an atmospheric model. Longer-term, this coupling could help assess the climatological relevance of wetlands' carbon fluxes.

-52 Growing future north-south difference in atmospheric CO2

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Early coupled carbon-climate models allowed simulated atmospheric CO2 to vary temporally but not spatially. Here with 10 earth system models without this limitation, we have assessed how simulated north-south gradients in atmospheric CO2 in the marine boundary layer change under increased future emissions. Models simulate that relative to the South Pole, north-south gradients in annual-mean CO2 continue to grow. For example, in 2100 under the RCP8.5 scenario, the Mauna Loa – South Pole (MLO-SPO) difference reaches up to 30 ppm. The simulated MLO-SPO gradient in 2100 typically grows by at least three times the present simulated gradient (3-7 ppm), driven by the threefold increase in the emissions rate. Ongoing sensitivity tests are aimed at quantifying how these large spatial differences in atmospheric CO2 will affect future air-sea CO2 fluxes and ocean acidification in the north vs. the south.

Model results were further exploited to test if previous back extrapolations of observed atmospheric CO2 gradients to zero emissions produce an accurate representation of the simulated preindustrial distribution. Models generally simulate a linear response of atmospheric CO2 gradients to prescribed fossil emissions. Over 1850-2100, generally R2 > 0.9 for the northern extratropics relative to the South Pole. But correlations are lower (typically R2 > 0.8) for the observational period (1957-2013) due to large unforced interannual variability, consistent across CMIP5 control runs, historical simulations, and future scenarios. Simulated sensitivities of atmospheric CO2 gradients (relative to the South Pole) to emissions are weak in the southern extratropics (0.0 to 0.2 ppm per Pg C yr-1), increase across the tropics, and level off at higher values in the northern extratropics (0.5 to 1.2 ppm per Pg C yr-1), generally consistent with observational estimates.

Despite these consistencies, models differ greatly in terms of their simulated preindustrial latitudinal distribution of atmosphere CO2 in the marine boundary layer. Nonetheless, their back-extrapolated spatial distribution (intercept term in the linear regression) is typically consistent with their directly modeled preindustrial distribution, but only within the large interannual variations of ±2 ppm. For the first time, some models are found that roughly agree in magnitude with the natural gradient of -1.0 ppm for MLO-SPO deduced from back extrapolation of the observed time series data to zero emissions. Sensitivity tests are underway to test hypotheses for the improved agreement.

-53 Global CO2 flux estimation using GOSAT: An inter-comparison of inversion results

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Since the launch of the Japanese Greenhouse Gas Observing Satellite (GOSAT) more than three years ago, much has been learned about the measurement of greenhouse gases from space. Currently, this information is used by several research groups to work on the main objective of the mission, which is to estimate the global sources and sinks of carbon dioxide and methane. Given the limited possibilities to validate results of atmospheric inverse modelling, the important question is how robust the derived flux estimates are given their sensitivity to subtle spatio-temporally varying systematic errors in the measurements and transport models. It is known from inverse modeling using surface measurements that the robustness of the inversion-estimated fluxes to transport model uncertainties is best analyzed using a multi-model approach. Inversions using satellite data are further complicated by systematic uncertainties in the measurements, which play an important role also. We have organized an inversion inter-comparison experiment to investigate whether, despite these uncertainties, robust signals of sources and sinks can be inferred from the GOSAT data. Each participating group is free to use their preferred inversion set-up, transport model, and measurements, but is asked to report in a common format and for a common time period of one year to allow one-to-one comparison. After a few iterations of the experiment, in which the participants gained experience with the use of GOSAT data, the project has arrived at a final stage. Currently, submissions are available from 9 groups, covering a range of transport models and retrieval data sets. The results show robust features and important differences, which increase towards smaller scales. Independent data from aircraft measurement campaigns allow investigation of the relation between these differences and the corresponding posterior concentrations, which is used to measure inversion performance and gain further mechanistic insight. We will present an overview of the status of the experiment, including a synthesis of the inversion-estimated CO2 fluxes and the performance verification using independent data.

-54 Atmospheric O2 measurements since 1990

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

See upload

-55 Increasing seasonal CO2 exchange in high northern latitudes

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The seasonal amplitude of atmospheric CO2 at the Barrow surface station has been increasing since the start of measurements in 1960 (Keeling et al., 1996). Recent aircraft observations from the HIPPO campaign confirm that this CO2 amplitude trend is representative of the entire troposphere north of 45°N, increasing by approximately 50% since 1960 (Graven et al., submitted). This proves that the trend is not caused by local changes in land surface fluxes in the Barrow area, or by trends in atmospheric circulation. Rather, it implies large structural changes in boreal and arctic ecosystems driven by climate change. We examined monthly land surface fluxes from two time-dependent atmospheric CO2 inversion models (RIGC and Jena) over the period from 1986 through 2006 to see how the seasonality of CO2 exchange in the northern regions has changed. We divided the analysis into two latitude bands, north of 60°N and between 50°N and 60°N. Both models show a CO2 flux amplitude increase of nearly 1% yr-1 north of 60°N, over twice the trend in the 50°N to 60°N fluxes. Increased summer CO2 uptake was observed in both regions, and in the case of north of 60°N, there was also increased autumn release. The autumn release canceled the summer carbon gains in the north of 60°N band, but the zone from 50°N to 60°N showed a trend toward increased annual CO2 uptake, absorbing an extra 231 Tg C yr-1 over the 1986 to 2006 period. These results suggest that despite massive vegetation browning, changes in fire frequency, insect disturbance and land use, that the boreal region is maintaining and likely increasing in CO2 sink strength. Widespread greening in the tundra region seen by satellite is coincident with increasing summer CO2 uptake, perhaps as much as doubling CO2 uptake during the month of July between 1986 and 2006. Recent changes since 2006 will also be explored. The last few years 2009-12 show the largest average seasonal amplitude on record at Barrow. 2012 set the record low for summer sea ice extent and 2011 (National Snow and Ice Data Center) was the third warmest on record for land areas between 64-90°N (NASA GISS). The effects of these recent changes in high northern latitudes on the tundra and boreal ecosystems will be investigated.

References:

C.D. Keeling, J.F.S. Chin and T.P. Whorf, (1996) Increased activity of northern vegetation inferred from atmospheric CO2 measurements, Nature, 382, 146-149.

Graven, H.D., S.C. Piper, P.K. Patra, C. Sweeney, P.P. Tans, L.R. Welp, J.J. Kelley, B.B. Stephens, S.C. Wofsy, and R.F. Keeling (submitted) Enhanced seasonal exchange of CO2 by northern ecosystems since 1960.

-56 Revisiting the Rectifier: Covariance of Mixing & Metabolism Derived from Spaceborne LIDAR

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Covariance between land-surface carbon fluxes and vertical mixing in the atmosphere is among the strongest determinants of the spatial distribution of atmospheric CO2 in the lower troposphere. Differences in the magnitude of this "CO2 rectifier effect" among different tracer transport models has been shown to explain most of the variability in estimates of terrestrial carbon sinks over the northern (vs tropical) continents. We present a new analysis of the magnitude of the CO2 rectifier using a climatology of PBL depth estimated using vertical profiles of LIDAR backscatter from the CALIPSO satellite. More than 1.1 million separate soundings of PBL depth were matched with hourly estimates of photosynthesis and ecosystem respiration from the Simple Biosphere Model (SiB3) at the same locations and times over a period of 6 years. Strong covariance between net carbon flux and atmospheric mixing were observed over the northern continents, especially over Boreal Asia. Negative covariance is observed over monsoon regions, which is especially strong over India. Covariance of net carbon flux with the reciprocal of PBL depth has the units of CO2 tendency (ppm per month), and can be expressed as rectifier forcing. Satellite sampling of this quantity reveals spatially-coherent patterns as strong as +/- 10 ppm per month over Siberia and India.

We computed rectifier forcing with NASA's Modern Era Reanalysis (MERRA) for the same locations and times sampled by CALIPSO from 2006-2011. Comparison of the MERRA and CALIPSO data reveal that the spatial patterns and magnitudes are similar over the northern continents, but much weaker in MERRA than CALIPSO over the tropics. Using MERRA to compute the rectifier effect for SiB fluxes in GEOS-Chem allows us to establish a quantitative relationship between rectifier forcing and response that is evaluated against the CALIPSO boundary layer data.

-57 Interannual Variations in the Seasonal Cycle of Atmospheric CO2 at Mauna Loa, Hawaii

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The seasonal amplitude of atmospheric CO2 at Mauna Loa, Hawaii increased substantially from 1958 until the early 1990s, then decreased afterwards. Surface temperatures, that were earlier suggested to drive the long term trend, however, continued to increase over the entire period. Meanwhile, the phase of the cycle advanced by 6 days over the record. Model simulations with the FRCGC 3-dimensional atmospheric model with reanalyzed wind fields from NCEP2, ERA40, and ERA-Interim for the entire record, using as inputs NPP and respiration fluxes prescribed by the CASA model, predict substantial interannual variations in the seasonal cycle that agree well with observed changes in phase but not in amplitude of the seasonal cycle. This finding suggests that the Mauna Loa record is not simply registering changes in transport but rather serves as a sensitive indicator of changes in terrestrial biospheric fluxes over a large region. Our geographic analyses of surface temperature, Palmer Drought Severity Index (PDSI), and climate indices clearly indicate that the seasonal cycle at Mauna Loa responds strongly to interannual variations in climatic drivers at El Nino to quasi-decadal time scales. A long-term trend driven by temperature, CO2 fertilization and/or additional drivers is superimposed on these shorter-term variations. This interplay appears to be conspicuously different at higher northern latitudes where the observed increase in seasonal amplitude, such as at Barrow, Alaska, has been much larger over time (Graven et al., submitted). As the record of CO2 observations at Mauna Loa grows longer, it continues to reveal new aspects of the interplay of biological, oceanic, and physical processes with the carbon cycle over a large region and a wide range of time scales.

-58 Terrestrial carbon balance in Tropical Asia: Contribution from land use and climatic changes

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Tropical Asia has experienced dramatic cropland expansion and agricultural intensification to meet the increasing food demand and is likely to undergo further rapid development in the near future. Much concern has been raised about how cropland expansion and associated management practices (nitrogen fertilizer use, irrigation, etc.) have affected the terrestrial carbon cycle in this region. In this study, we used a process-based ecosystem model, the Dynamic Land Ecosystem Model (DLEM), to assess the magnitude, spatial and temporal patterns of terrestrial carbon fluxes and pools in Tropical Asia as resulted from cropland expansion and land management practices during 1901–2005. The results indicated that cropland expansion had resulted in a release of 19.12±3.06 Pg C (0.18±0.029 Pg C/yr) into the atmosphere in Tropical Asia over the study period. Of this amount, approximately 22% (4.18±0.66 Pg C) was released from South Asia and 78% (14.94±2.40 Pg C) from Southeast Asia. Larger land area was converted to cropland while less carbon was emitted from South Asia than from Southeast Asia, where forest biomass and soil carbon were significantly higher. Changes in vegetation, soil organic matter, and litter pools caused emissions of 15.58, 2.25, and 1.71 Pg C, respectively, from the entire region. Significant decreases in vegetation carbon occurred across most regions of Southeast Asia due to continuous cropland expansion and shrink of natural forests. When considering land management practices, however, less carbon was released into the atmosphere, especially in South Asia where land management practices contributed to an approximately 10% reduction in carbon emission. This implies that optimizing land management practices could greatly reduce the carbon emissions caused by cropland expansion and might be one of important climate mitigation options in Tropical Asia.

-59 Global land-atmosphere exchanges of CH4 and N2O in the past three decades: Toward a full GHG budget of the terrestrial biosphere

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The importance of Methane (CH_4) and nitrous oxide (N_2O) in influencing global climate has been increasingly recognized. However, as compared with CO_2-related research, less effort has been invested in examining the magnitude of and underlying mechanisms responsible for the net land–atmosphere exchanges of these two gases. In this study, we use multiple approaches (process-based ecosystem model, atmospheric inversion and meta-analysis) to quantify the magnitudes, spatial and temporal patterns of CH_4 and N_2O fluxes in the terrestrial biosphere during 1980-2010, which are further attributed to multiple environmental drivers including: (a) climate variability, (b) changes in land cover and use, (c) changes in the chemistry of precipitation (particularly nitrogen), and (d) changes in the composition of the atmosphere (carbon dioxide, ozone). Our simulated results show substantial inter-annual and spatial variations in terrestrial CH_4 and N_2O fluxes. At the global and regional scales, the climate variability exerted significant effects on the inter-annual variations of the CH_4 and N_2O fluxes; nitrogen input, including nitrogen deposition and nitrogen fertilization, significantly increased emission of CH_4 and N_2O. Rising atmospheric CO_2 concentration enhanced CH_4 emission, yet inhibited N_2O emission from terrestrial ecosystems. Ozone pollution reduced CH_4 emission, but yielded a complicated effect on N_2O fluxes. Of the six major continents (Antarctic excluded), Asia accounted for nearly half of the CH_4 emission because of its large area of rice paddy; Americas and Asia contributed the majority of N_2O emission. The estimation of terrestrial CH_4 and N_2O fluxes derived from the process-based ecosystem model has been compared to results from atmospheric inversion. We use global warming potential (GWP) to indicate the contribution of biogenic CH_4 and N_2O fluxes to global radiative forcing in CO_2 equivalent (CO_2eq). By comparing with the terrestrial CO_2 sink derived from both bottom-up and up-down approaches, we conclude that biogenic CH_4 and N_2O emissions from the terrestrial biosphere largely offset the terrestrial CO_2 uptake. It implies that strategies to mitigate climate change need to take into account non-CO_2 GHG emissions due to their large warming potential.

-60 Regional Distribution and Seasonal Mechanisms of Carbon Uptake in the Global Oceans

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Using the methodology of Schuster et al. (2013) and the RECCAP archive, we evaluate the mean and seasonal cycles of 1990-2009 air-sea CO2 fluxes in 11 regions that cover the global ocean. Best estimates of the mean flux are estimated for each region as the mean of the pCO2 climatology (Takahashi et al. 2009) and the ocean inversion (Gruber et al. 2009). We find that the Arctic, Atlantic, Pacific, Indian and Southern Oceans are responsible for 7%, 29%, 24%, 18% and 21%, respectively, of the 1990-2009 contemporary uptake of 1.7±0.3 PgC/yr. With an estimated river carbon input of 0.45 ±0.2 PgC/yr (Jacobson et al. 2007), our estimate for the global anthropogenic flux is 2.1±0.4 PgC/yr. In each region, estimates are compared to the medians of 11 atmospheric inversions and 7 ocean models. On the whole, these median estimates agree with the best-estimate values within uncertainties. Intra-ensemble agreement is lowest for the ocean models in the Southern Ocean.

Seasonal cycles of air-sea CO2 fluxes in 11 regions agree best in the subtropical gyres, due to temperature dominance of the ocean pCO2 cycles. At the high latitudes, correlations are less strong, but are generally still statistically significant. We assess how well ocean models are able to capture the biologically-driven component of these seasonal cycles. One notable exception to the cross-methodological agreement of seasonal cycles is for the atmospheric inversions in the high latitude Atlantic / Arctic where the ensemble median does not correlate to other methodologies. Cross-methodological correlation of interannual variability is weak and/or insignificant.

-61 On network design for the detection of urban greenhouse gas emissions: Results from the Indianapolis Flux Experiment (INFLUX)

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The Indianapolis Flux Experiment (INFLUX) was designed to develop and evaluate methods for the measurement and modeling of greenhouse gas fluxes from urban environments. Determination of greenhouse gas fluxes and uncertainty bounds is essential for the evaluation of the effectiveness of mitigation strategies. The current INFLUX observation network includes nine in-situ tower-based, continuous measurements of CO2, CO, and CH4 (with an additional three sites to be deployed), flask sampling of 14CO2 and other trace gases, and periodic aircraft sampling of greenhouse gases and meteorological conditions. A total carbon column observing network (TCCON) column remote sensing station was deployed Aug - Dec 2012. The network will soon be enhanced to include an array of eddy covariance and radiative flux measurements, and a scanning Doppler lidar, both to quantify key boundary layer meteorological properties. The data from the towers, TCCON, and aircraft measurements are being used in an inverse-modeling approach to yield estimates of the urban area flux at 1 km2 resolution. Additionally, very high space/time resolution estimates of fossil fuel carbon emissions (Hestia project) offer state-of-the-art "bottom up" emissions estimates for the city and its surroundings. Here we present an overview of the progress from INFLUX, with a focus on tower-based results.

With the unprecedented density of urban tower-based greenhouse gas measurements, we will quantify horizontal and vertical spatial patterns in atmospheric mole fractions of CO2, CO, and CH4 in Indianapolis. The consistency of the observed horizontal gradients with that expected based on differences in land-cover contributions according to footprint analysis will be evaluated. To address the optimal spatial density of tower-based measurements within the city, we will evaluate the spatial coverage of the model footprints. Using observations at several heights on the towers, we will investigate the performance of the forward model, thus addressing the question of the required height for these types of measurements. The ability to correctly model transport and mixing in the atmospheric boundary layer, responsible for carrying greenhouse gases from their source to the point of measurement, is essential. Thus we investigate differences between the modeled and observed sensible heat flux, latent heat flux, air temperature, and wind speed. Finally, we will present initial results of the emissions estimates from the inversion model.

-62 Variation in Soil Respiration Along a Latitudinally Constant Transect

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Radiation is a primary control on ecosystem productivity. Over a suitable time scale, comparable sites along the same latitude will have approximately the same gross productivity and mean annual temperature. However, unquestionably, at any given time, the observable respiration between sites will be different. Measuring along the same latitude, in effect, controls for variations in insolation. For soil respiration, this refers to the quality and quantity of decomposable matter provided via aboveground litter fall. It may therefore be fair to postulate that variations in respiration between sites can be ascribed to inter-site differences due to other primary drivers and co-variables of ecosystem functioning, such as antecedent rainfall patterns, historic logging and other factors that can persist in the ecosystem memory.

We present the findings from such a pilot study that showed a surprisingly strong correlation between distance from the coast and respiration ($r2 = 0.6$, $p = <0.005$). The transect stretches from western France through central Europe at 50oN to eastern Czech Republic and covers fourteen independent forested sites. This study establishes an appropriate transect upon which to build a catalogue of data that will be useful to infer magnitude and direction of ecosystem interference and influence.

-63 The challenge of CO2 simulation with a weather forecast model

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Routine greenhouse gas flux inversions at a national center are desirable for monitoring regional scale fluxes and providing a scientific basis for planning and policy decisions. At the same time, a comprehensive carbon assimilation system can provide the basic tool for carbon cycle science research, including, the assessment of national observing system needs. At Environment Canada, such a system is being developed in the context of operational weather forecasting systems, permitting a sharing of model and assimilation system human and technical resources with air quality and weather forecasting groups. Simulating CO2 with a weather forecasting model has advantages over offline transport models such as the consistency of physical processes (e.g. convection and boundary layer mixing) with the meteorological model as well as the possibility of reduced spurious noise generation due to the intermittent insertion of noisy wind analyses. However, there are major challenges with using a weather forecast model for CO2 transport. Specifically, the use of semi-Lagrangian advection requires ad hoc mass adjustment schemes in order to conserve mass of long-lived species over time scales of seasons to years, and the vertical mixing of surface fluxes appropriate for meteorology or reactive chemistry is not necessarily appropriate for long-lived tracers. Moreover, deficiencies in vertical mixing exacerbate mass conservation issues. In this work, we describe progress in adapting our operational weather forecast model for CO2 simulations focusing on the issues of mass conservation, and improving the parameterization of vertical mixing in the boundary layer.

-64 Can we use δ13C of CO2 to understand the links between the water and carbon cycles and climate?

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The fate of the earth' s climate is intricately linked to that of the global carbon cycle. Much uncertainty remains about those links and the potential responses of both systems to recent and ongoing human perturbations. Different attributes of atmospheric CO2 (e.g. spatial gradients and relative abundances of its isotopologues) provide evidence of the mechanisms that link climate and the carbon cycle. The stable carbon isotope, 13C, is a useful tracer for understanding terrestrial biosphere to atmosphere CO2 exchange (as well as for partitioning land and ocean CO2 fluxes) because photosynthesis discriminates strongly against heavy CO2 (and ocean exchange does not). The degree to which photosynthesis fractionates against 13C depends upon 1) plant functional type distributions, because C3 and C4 plants have very different discrimination, and 2) weather and climate conditions, because stomatal conductance is closely related to C3 plant isotopic discrimination. Ascertaining patterns of C3 and C4 plant response to temperature and precipitation extremes will be key to anticipating which land use policies will best help us adapt our managed lands to accommodate a changing climate. C3 plant stomatal conductance varies in concert with water availability, so that atmospheric δ13C carries information not only about local and upwind drought conditions, but also about the likelihood of ground-to-atmosphere water transfer via transpiration, and the balance of latent and sensible heat fluxes. In the absence of high density or high frequency measurements of transpiration and sensible and latent fluxes, δ13C offers a chance to identify key thresholds and relationships between climate anomalies/change and the modulating climate impacts of plant biosphere response. By unraveling this relationship at local to continental scales, we stand to gain crucial knowledge of how to predict future climate impacts on the carbon cycle and vice versa.

We use a two-step Bayesian inversion model to optimize 1x1 degree and 3-hourly (interpreted at the monthly scale) fields of δ13C of the biosphere over North America for the year 2010. We parse the signal into the effects of C3 stomatal conductance and the relative strength of C3/C4 plant exchange. We further seek to identify correlations between departures of these patterns from the best estimates of late 1980s δ13C of the biosphere (from SiB2) and observed temperature and precipitation anomalies. Influence functions (footprints) are generated with FLEXPART, driven by National Centers for Environmental Prediction Global Forecast System meteorology. Prior information is from CarbonTracker 2011, and background CO2 and δ13C values are from NOAA/ESRL marine boundary layer and aircraft data. Quasi-daily atmospheric observations are from NOAA/ESRL Global Monitoring Division tall towers.

We also examine correlations between atmosphere δ18O of CO2 and climate records. This tracer offers complementary insights into biosphere atmosphere CO2 exchange because of the close relationships between δ18O and relative humidity and precipitation.

-65 Inorganic carbon in Cumberland Sound on Baffin Island, eastern Canadian Arctic

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Rapidly changing conditions in the Arctic can have a significant impact on biogeochemical cycles and these changes can be particularly critical in the coastal areas that are of great importance to local communities and fisheries. This study provides a first look in to the inorganic carbon system in the Cumberland Sound, a major inlet of the Arctic, in the east coast of Baffin Island, Nunavut. Our results show that Cumberland Sound was undersaturated during the ice-free conditions in August 2011 with surface values of water pCO2 between 260 and 300 μatm. DIC and TA values in the upper 40 m ranged between 1779 and 1966 μmol kg-1 and 1922 and 2140 μmol kg-1, respectively. Lowest values were observed at the surface associated with fresh water input. The pH/Aragonite saturation state ranges from 8.16/1.9 in the surface and 8.04/1.4 in the subsurface waters, respectively. Time-series at 60 m show relatively higher values of pCO2 (300-410 μatm), DIC (2512-2180 μ mol kg-1), and TA (2187-2281 μmol kg-1) and lower pH (8.005-8.127) and ΩAR (1.2-1.6). The relationships between TA, δ18O, and salinity suggest high meteoric water input in the surface waters of Cumberland Sound in comparison to the connected Baffin Bay and Labrador Sea.

-66 One year of underway δ13C(CO2) data in the North Atlantic Ocean

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The stable carbon isotope signature of surface ocean carbon dioxide (δ13C(CO2)) holds the potential to improve our understanding of processes such as exchange fluxes between the surface ocean and the atmosphere and biological production.
The combination of a Cavity Ringdown Spectrometer (CRDS, G2131-i, Picarro, USA) with a classical (equilibrator based) GO-pCO2 system (General Oceanics, Miami, USA) and its operation on autonomous platforms such as a VOS (Voluntary Observing Ship) line can help to improve the dataset significantly. The main advance is the increase of both temporal and spatial resolution caused by the possibility of continuous and autonomous measurements directly at sea. This system also shows the capability of accurate and calibration-free measurements of carbon dioxide partial pressure (pCO2) which will be a big advantage compared to common NDIR systems. During a research cruise aboard RV Polarstern we were able to prove the accuracy of the pCO2 measurements by comparing them to NDIR-measurements (LI-7000 CO2/H2O analyzer, LiCOR, USA) (atmospheric measurements: (pCO2) = 0.35 atm, surface ocean measurements: (pCO2) = 2.5 atm). Furthermore, the isotope ratio measurements of CO2 were converted to δ13C(DIC) and compared to Isotope Ratio Mass Spectrometry (IRMS) samples ((δ13C(DIC)) = 0.33 ‰).1 Whereas "calibration-free" pCO2 monitoring is feasible, the measurement of accurate isotope ratios relies on running reference standards on a daily basis.
In spring 2012 we installed the system onboard the container vessel MV Atlantic Companion. Here we were able to measure nearly a full annual cycle of stable carbon isotope data of surface ocean pCO2 in the North Atlantic and to show that the combination of a CRDS analyzer with a GO-pCO2 system is capable to replace the common combination of the GO-pCO2 system with a NDIR analyzer.

Reference:

1.Becker et al., Using Cavity Ringdown Spectroscopy for Continuous Monitoring of δ13C(CO2) and fCO2 in the Surface Ocean, L&O Methods, 2012.

-67 High soil organic carbon losses from peaty croplands

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Drained organic soils are hotspots of anthropogenic CO2 emissions. In the boreal and temperate climate zone, where drained organic soils cover more than 1% of the land surface, these CO2 emissions constitute one of the largest greenhouse gas sources from agriculture, comparable with nitrogen fertilization or animal husbandry.

We synthesize 27 site-years of CO2 and CH4 measurements and modelled annual balances of gross primary production (GPP), ecosystem respiration (RECO), net ecosystem exchange (NEE) and net carbon balance (NEE corrected for harvested carbon export, carbon input by fertilizer, and CH4). The data stem from 14 sites of peaty croplands cultivated with all major crop types (maize, other cereals, vegetables, other crops) representative of agricultural practices on peat soils in the temperate climate zone.

The net carbon balance ranged from about 125 to 1800 g C m-2 yr-1. The mean value and the range tend to be higher than the current IPCC default emission factor of 500 (50-950) g C m-2 yr-1 and suggest that peaty croplands represent larger CO2 sources from soil than previously estimated.

Croplands on organic soils, which are too shallow or too low in carbon to qualify as Histosols were included for the first time in systematic manner. To our surprise, these croplands lose as much carbon as the Histosols, which have been in the focus of previous studies.

The data allow to quantify and factor out the direct human effects of drainage levels, crop type and harvested fraction of crop biomass (grain, straw), organic fertilizer from natural or indirect effects such as soil properties and climate. Drainage level and harvested crop biomass explain most of the variability in net carbon balance. We hypothesize that temperature effects of leaving the peat soil vegetation-free for months contributes significantly to the high net carbon losses.

-68 Estimating CH4 Emissions Across California with Multi-site Observations

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Methane emissions are included in California's commitment (Assembly Bill 32) to reduce total greenhouse gas emissions to 1990 levels by 2020 (a roughly 20% reduction from current levels). We present atmospheric inversion estimates of California's total CH4 emissions for summer 2012, using data from multiple sites (more than 10 sites) covering urban and rural areas of California's South Coast Air Basin, Central Valley, San Francisco Bay Area, and North Coast. We use Bayesian inversions to estimate the CH4 emissions from discrete regions of California by combining the local CH4 measurements, background CH4, two 0.1 degree prior model emission maps (one specific to California and one global), and predicted CH4 signals from an atmospheric transport model (WRF-STILT). We quantify site-specific model-measurement uncertainties due to transport using meteorological data from a network of atmospheric profilers and in-situ sensors, due to background using oceanic and aircraft observations, and prior emissions using the spread results obtained with the two different maps. Bayesian inverse modeling using a network of measurements across California constrains a significant portion of emission regions (>90% of total emissions). Estimated emissions during summer 2012 are consistent with previous work, while posterior uncertainties in emission estimates are reduced.

-69 On the Detection of Trends in Arctic Carbon Emissions

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Vast stores of organic carbon are thought to be frozen in Arctic soils; as much as 1,700 billion tonnes of carbon, several times the amount emitted by fossil fuel use to date and about equal to known coal reserves. If mobilized to the atmosphere, this carbon would have significant impacts on global climate, especially if emitted as CH_4. A recent study suggests that permafrost carbon climate feedbacks may have had profound impacts on past climate, possibly driving the PETM 55 Mya. Model studies project that by the middle of the 21st Century the Arctic will be a net source of carbon to the atmosphere.

NOAA ESRL, Environment Canada, and other agencies have collected observations of greenhouse gases in the Arctic and the rest of the world for at least several decades. Analysis of this data does not currently support increased Arctic emissions of CO_2 or CH_4. However, it is difficult to detect changes in Arctic emissions because of transport from lower latitudes and high inter-annual variability. Arctic surface emissions are also especially difficult to detect from space, and current satellite platforms do not provide useful information about greenhouse gas budgets in the lower Arctic troposphere. Modeling/assimilation systems, such as NOAA's new CarbonTracker-CH4 system can help untangle the Arctic budget and trends of greenhouse gases. CarbonTracker-CH4 has shown success in simulating the inter-annual variability of Arctic fluxes, and it is able to distinguish Siberian fluxes from Boreal North American fluxes. Over the past decade, CarbonTracker (CH_4 and CO_2) does not indicate that emissions have been steadily increasing in the Arctic even though recent bottom-up estimates suggest that, for CH_4, emissions from the Arctic tundra may have doubled between the 1990's and 2000's, and that uptake of CO_2 has increased.

We address the plausibility of monitoring the Arctic greenhouse gas emission trends. How large would Arctic emission trends have to be before they could be identified in network observations? What spatial information could be recovered? How would the spatial density of observations affect our ability to perceive and attribute trends in Arctic emissions? Could emission have already been increasing during the close of the 20th century? Trends in emissions need to be large before they can be discerned in network observations; our calculations show that emissions of methane must increase by at least 5TgCH4/yr to be seen in a 10-year observational record. Long-term surface observations of greenhouse gases are crucial to monitoring the fate of the vast and currently frozen Arctic soil carbon reservoir, and more terrestrial sites are needed with greater participation from all Arctic countries and other interested parties.

-70 Large-scale increase in the seasonal cycle of CO_2 in the Northern Hemisphere since 1960

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

As part of the measurement program of the International Geophysical Year (IGY), airborne observations of CO_2 concentration were conducted over the North Pacific and Arctic Oceans during 1958-61. Samples were collected at 700 and 500 mb (approx. 3 and 6 km altitude) and provide good spatial and seasonal coverage, particularly at 500 mb. With the HIAPER Pole-to-Pole Observations (HIPPO) campaign sampling similar regions of the Northern troposphere during 2009-11, direct comparison of the two datasets provides a measure of the change in the seasonal cycle of CO_2 between the 1950s-60s and the 2000s. We will show that the seasonal amplitude at 500 mb has increased by 40-60% at latitudes north of 45°N, while amplitude changes south of 45°N are smaller than 25%. This pattern is similar to long-term ground-based CO_2 measurements at Barrow and Mauna Loa. The atmospheric observations demonstrate that large-scale changes in the seasonal flux of CO_2 from Northern ecosystems have occurred over the last 50 years. We will investigate the changes in net ecosystem production (NEP) required to produce the observed growth in CO_2 amplitude, discuss mechanisms for the changes in NEP, and examine whether such changes are captured by the terrestrial models participating in the IPCC CMIP5.

-71 Impact of Water on the Terrestrial Gross Primary Productivity

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Water is an essential resource for plant growth and therefore has a strong control on the terrestrial carbon cycle. Water influences not only plant growth but also the decomposition of organic matter in the soil. However, the focus of this study is on its influence on the gross primary productivity (GPP) at the global scale using the BEPS model (Liu et al., 1997, Remote Sensing of Environment; Chen et al., 2012, Global Biogeochemical Cycles). BEPS simulates hourly GPP using a two-leaf approach, i.e. the canopy is separated into sunlit and shaded leaf groups and the total GPP is calculated as the sum of the sunlit and shaded GPP. The soil moisture is calculated using a 6-layer scheme with a root distribution parameter based on the plant functional type. For the purpose of tight coupling between carbon and water cycles, a three-source evapotranspiration (ET) model is developed to separate the total ET into three components: sunlit leaf ET, shaded leaf ET and evaporation from soil and wet leaves. The stomatal conductance is therefore determined separately for representative sunlit and shaded leaves based on the sunlit and shaded GPP using the Ball-Berry equation. The influence of the root zone soil moisture on the stomatal conductance is considered through using a soil water factor as an adjustment to the slope the stomatal conductance and GPP relationship determined by the equation. In this way the mechanistic links between water and carbon cycles are established. The BEPS model is implemented to the global land surface in 1 degree grid for the period from 2000 to 2010. In each grid, the fractions of 6 plant functional types are separately modelled and aggregated. These fractions are determined from a global land cover map (GLC2000) obtained from satellite remote sensing data. In the calculation of sunlit and shaded leaf area index (LAI) for each fraction in each grid, LAI and clumping maps are generated from MODIS data at 1 km resolution using algorithms developed at the University of Toronto. In this presentation, we show spatiotemporal distributions of the soil water factor and its influences on GPP and ET, to demonstrate the level of the impact of water on GPP in different seasons and locations.

-72 Fingerprints of climate variability on atmospheric CO2

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Interannual variability in atmospheric CO2 provide insight into the responses of terrestrial ecosystems to climatic variations. We investigated the signatures that climatic variations and disturbance impart on atmospheric CO2. We developed generalized surface fluxes to represent the potential response of net ecosystem exchange to drought and temperature stress. We developed a set of surface fluxes by assuming a variety of functional forms for the imprint of temperature and precipitation anomalies on net primary production at monthly timescales. We also developed biomass burning emissions estimates by scaling satellite fire counts and burned area. These fluxes were prescribed as boundary conditions in GEOS-Chem, which was run from 1997 to 2010 to simulate atmospheric CO2.
The simulation output was sampled at NOAA ESRL flask sampling sites, and both simulation and observations were aggregated in north-south zones. We examined correlations between the simulations and observations for each of these zones to determine the extent to which simplified fluxes captured the phasing and magnitude of observed variations. We also ran simulations to determine the influence of interannual variability in transport patterns on observed variability.
Our results show that temperature, precipitation, and biomass burning covary in their influence on zonal anomalies in atmospheric CO2 on interannual timescales. The relative importance of these three factors varies regionally, and these patterns of interannual variability may provide insight into future variability in terrestrial carbon fluxes under global climate change. Including fire emissions as basis function in GEOS-Chem significantly improved the simulation of interannual variability in CO2, especially in the tropics and northern hemispheres.
These results elucidate how climatic variations affect CO2 and provide fingerprints that may allow separation of changing natural patterns in carbon cycling from changing human emissions over the coming decades.

-73 On the effect of climate extremes on the carbon cycle from ecosystem to globe

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Climate strongly influences the terrestrial biosphere and hence triggers feedbacks with the carbon cycle. Ongoing environmental change is hypothesized to increase terrestrial carbon sinks, predominantly in the northern hemisphere, via temperature-related increases in growing season length, CO2 fertilization and nitrogen deposition. However, recent studies have demonstrated that climate extremes can lead to strong and lasting decreases of the carbon sink function of ecosystems, or can even cause rapid carbon release from accumulated stocks. Here we review this evidence and give first global quantifications based on carbon monitoring and Earth observation data which indicate that climate extremes have a globally integrated effect on the terrestrial carbon cycle that is of the same magnitude than the current carbon sink. Thus, climatic extremes have the potential to override the sink effects that are currently slowing down global warming and provide a negative feedback in the climate-carbon system. For a projection of future trajectories both climate and carbon cycle models need to achieve higher spatial resolution and resolve related processes more deeply.

-74 Changes in Coupled Water-Carbon Cycles in Contiguous US through the 21st Century

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Climate projections suggest more frequent and severer drought conditions over the US during the 21st century. Such changes in the hydrological cycle will almost certainly have large impacts on the corresponding terrestrial carbon cycle. Here, by using the latest downscaled CMIP5 climate datasets and process-based vegetation models, we examine the predicted climatic impacts on the coupled water-carbon cycles in the contiguous US. Our results highlight a reduction of 75% of the area with springtime (March-April-May) mean temperature lower than 0 oC between 1950 and 2100, significantly altering the amount of snowpack as well as the timing of its melting, in particular over the Northwest US. As higher springtime runoff and lower summer soil moisture anomalies become more common, net ecosystem primary productions are reduced in the semi-arid grasslands and shrub-lands. Over the Pacific Coast Ranges (e.g., Sierra Nevada), the projected climate changes also induce an shift of the dominant forests from boreal tree species to temperate types, which however seems to help alleviate the reduction of GPP/NPP in these regions. The effects of this biome-type shift on carbon storage and net ecosystem exchange need to be further investigated.

-75 Combined CO_2 and O_2 measurements at the High Altitude Research Station Jungfraujoch, Switzerland

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The rising CO2 (carbon dioxide) level in the atmosphere due to fossil fuel burning and land use change will change our climate in the next decades and centuries. Monitoring the ambient CO2 concentration is therefore crucial to improve our knowledge about the sources and sinks. The University of Bern monitors ambient concentrations of CO2 and O2 (oxygen) at the High Altitude Research Station Jungfraujoch (JFJ) by means of flask sampling since 2000 and with a continuous measurement system since 2005. Due to the high altitude the JFJ lies most of the time above the boundary layer and receives therefore background air, which is mainly influenced by exchanging processes of the Atlantic Ocean.

With the combined O2/CO2 measurements one can distinguish between oceanic and terrestrial CO2 fluxes. The CO2 and O2 exchange of terrestrial systems with the atmosphere by photosynthesis and respiration is inversely coupled and has a rather constant stoichiometric ratio of about -1.1 mol O2 / mol CO2. Similarly, the anthropogenic combustion of CO2 requires O2 resulting in an average stoichiometric ratio of about -1.4 mol O2 / mol CO2. In contrast, the air-sea exchange of CO2 and O2 are uncoupled because of a CO2 buffering effect of the oceans. Therefore, one can separate the total CO2 uptake into land and ocean components. The continuous as well as the flask measurements indicate that CO2 is rising with a rate of approximately 1.93 ± 0.01 ppm per year. At the same time the O2 content is decreasing with a rate of about -26.7 ± 0.1 per meg per year. The trend uncertainty does not include uncertainties due to standard value assignments. The annual amplitude of the CO2 and O2 values is 9.4 ppm ± 0.75 ppm and 62 per meg ± 13.5 per meg respectively. This seasonal cycle is mainly caused by biological processes. The lowest CO2 and highest O2 values were measured in late summer, because in spring and summer, the photosynthetic activity dominates respiration and CO2 is assimilated in plants and vice versa in autumn and winter. The increasing CO2 values indicate an on-going fossil fuel combustion. This assumption is affirmed by the decreasing 13C/12C ratio of δ13CO2 because CO2 from fossil fuel combustion is depleted in 13C and therefore lowers the 13C/12C ratio.

-76 Decreasing North Atlantic CO2 uptake: a robust feature of future model simulations

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The North Atlantic Ocean is recognized to be an area of strong in-gassing of CO2 into the ocean, both in the natural (i.e. pre-industrial) cycle and in the anthropogenic perturbation. Recently however observations have indicated that the magnitude of this sink for atmospheric CO2 may be reducing (e.g. Schuster & Watson, Deep-Sea Res. II, 2009). Future simulations run as part of CMIP5 using the Met Office' s coupled climate model HadGEM2-ES show a marked weakening of the North Atlantic sink during the current century. The effect is particularly significant for RCP8.5 which, despite featuring the highest atmospheric pCO2 concentrations, accumulates less net CO2 uptake in that region by the year 2100 than RCP6.0. Similar weakening is seen in parallel simulations undertaken using other models in the CMIP5 database. To explore the causes of this reduction in uptake we have examined the results of a perturbed parameter ensemble (PPE) of future simulations; these runs used a simpler coupled climate model based on the HadCM3 model, but the response of the North Atlantic uptake is clearly traceable to that in HadGEM2-ES. Nearly all the ensemble members show a reduction of uptake by the end of the century, though the timing and magnitude of the maximum uptake vary considerably. These PPE results are then emulated using a box model to discover the factors driving the slow-down. Both physical factors (in particular the Atlantic Meridional Circulation) and chemical factors (the Revelle factor) are implicated. The implications for the time-evolution of the atmospheric CO2 concentration are considered.

-77 The marine carbonate system in a Southern Ocean deep water formation region: accumulation, fluxes and transports from the Weddell Gyre to the global ocean

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

In the Southern Ocean, the Weddell Gyre (WG) is regarded as the primary location for the formation of deep and bottom waters and is potentially a significant area for the sequestration of carbon, nutrients and atmospheric gases. Major quantities of dense, cold waters generated near and on the Antarctic continental shelf spill down the slopes entraining surrounding water masses as they descend. Circulating northwards the waters are subsequently exported into the mid-latitude Southern Ocean, spreading globally at depth as an integral component of the southern closure of the meridional overturning circulation. Measurements of the inorganic carbon system and transient tracers from four cruises that cross and enclose the Weddell Gyre are used to calculate anthropogenic carbon (Canth). Modern carbon and Canth are combined with velocity fields from an inverse model to derive quantitative information on the movements of water masses, and investigate the accumulation, fluxes and transports of carbon into/out of the gyre. The gyre is found to be a sink for both Canth and contemporary carbon dioxide for the summer/fall period under investigation; substantial undersaturation of pCO_2 (up to 80 µatm) of the surface layer down to the depth of the Winter Water temperature minimum is found, possibly related to the recent retreat of sea-ice in the area. Little accumulation of carbon is found to occur in the WG, although elevated concentrations associated with sea-ice production/anthropogenic uptake are observed to be exported through the gaps in the South Scotia Ridge, primarily as transports of Antarctic Bottom Water. These results highlight the role of the region in injecting human-derived carbon into the global abyss.

-78 Atmospheric Inversion of the Surface CO2 Flux with 13CO2 Constraint

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Observations of 13CO2 at 73 sites compiled in the GLOBALVIEW database are used as an additional constraint in a global atmospheric inversion of the surface CO2 flux for the 2002-2005 period for 39 land regions and 11 ocean regions. On the basis of previous inversions involving 13CO2 observations (Enting et al., 1995, Tellus B, 47: 35–52; Rayner et al., 1999, Tellus B, 51: 213– 232; Rayner et al., 2010, Global Biogeochemical Cycles, 22, GB3008, doi:10.1029/2007GB003068), we intend to investigate the influence of the spatial distributions of 13CO2 discrimination and disequilibrium on the inversion of the CO2 flux. A terrestrial ecosystem model (Chen et al., 2012, Global Biogeochemical Cycles, 26, GB1019, 18 PP., doi:10.1029/2010GB003996) and an ocean model (Ciais et al., 1995, J. Geophys. Res., 100(D3), 5051–5070, doi:10.1029/94JD02847) are used to simulate these spatial distributions. These models simulate 13C discrimination rates of terrestrial photosynthesis and respiration and ocean-atmosphere diffusion processes. In both models, the 13C disequilibrium between fluxes to and from the atmosphere is considered due to the historical change in atmospheric 13CO2 concentration. For the 2002-2005 period, the 13C constraint on the inversion increases the total land carbon sink from -3.397 to -3.808 Pg C y-1 (the net land sink is smaller than these due to fire disturbance) and decreases the total oceanic carbon sink from -1.482 to -1.049 Pg C y-1. The largest changes occur in tropical areas: a considerable decrease in the carbon source in the Amazon region, and this decrease is mostly compensated by increases in the ocean region immediately west of the Amazon and the southeast Asian land region. Our further investigation through different inversions with and without the discrimination and disequilibrium spatial distributions suggests that consideration of the differences in the isotopic discrimination and disequilibrium among ocean regions is important in improving the inversion results, while consideration of these differences among land regions only made small differences in the inversion.

-79 Regulatory mechanisms on climate -carbon cycle feedback

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Global warming has fundamentally changed ecosystem carbon cycling. It can increase or decrease C sequestration, with the consequent negative or positive feedback. However our understanding on the underlying mechanisms of climate - carbon cycle feedback is still limited. Although it was proposed that climate-carbon feedback were regulated by complex ecological processes, we lack the fundamental understanding on these regulatory mechanisms.
We conducted a few manipulative warming experiments in temperate steppe and tallgrass prairie to examine how resources availability (water and nitrogen) and biotic factor (plant functional types) regulate ecosystem carbon cycle in response and feedback to climate warming. In temperate steppe in northern China, we simulated climate warming and increased precipitation and their interactions. The results showed that ecosystem had positive feedback to climate warming. The magnitude of this positive feedback was dependent on water condition. Increased precipitation alleviated the negative effects of warming on NEE. The results demonstrate that water availability plays a dominant role in regulating ecosystem C fluxes and their responses to climatic change in the temperate steppe of northern China.
We used long term warming experiment in the tallgrass prairie in US to examine how nitrogen and plant functional types regulate ecosystems response to climate warming. The traditional wisdom is warming will stimulate SOM decomposition and increase N availability, which potentially increase ecosystem C accumulation. But our results showed that the increase of plant C accumulation under warmer environment was not due to the increased N availability, but due to the increase of plant nitrogen use efficiency (NUE). The results suggest that increased NUE via a shift in species composition toward C4 dominance rather than plant N uptake is a key mechanism underlying warming stimulation of plant biomass growth. In order to examine plant functional types in regulating climate-carbon cycle feedback, we compared ecosystems responses to climate warming between a C3-dominated and a C4-dominated grassland. The results showed that there was positive feedback in C4 grassland while negative feedback in C3 grassland. The warming impacts on ecosystem C fluxes were dependent on C4 biomass proportion in the community. These findings demonstrate that C3/C4 plant functional types are important factor in determining ecosystem carbon cycle in response to climate change. These manipulative experiments revealed complex regulatory mechanisms underlying ecosystem feedback to climate warming, which are critical for better understanding global change impacts.

-80 ESTIMATING ECOSYSTEM CARBON STOCK CHANGE IN THE CONTERMINOUS UNITED STATES FROM 1971 TO 2010

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

There is significant geographic variability in U.S. terrestrial ecosystem carbon stocks due to natural and human environmental conditions. Carbon stock changes are primarily driven by climate variability and change, atmospheric chemistry change, natural disturbance, and human land use. In this study, a comprehensive environmental input dataset was developed at 960-m resolution. The original data sources include land cover change information of more than 2,600 sample blocks across the United States (10-km by 10-km in size, 60-m resolution, 1973-2000), wildland fire scar and burn severity information (30-m resolution, 1984-2010), vegetation canopy percentage and biomass level (30-m resolution), spatially heterogeneous atmospheric carbon dioxide and nitrogen deposition (0.5° × 0.5° degree, 2003-2009), and related climate variables (4-km resolution). The process-based Integrated Biosphere Simulator (IBIS) was used to simulate the effects of atmospheric CO2 fertilization, nitrogen deposition, climate change, fire, logging, and deforestation/devegetation on ecosystem carbon source and sink. Simulations were performed at 960-m resolution across the conterminous U.S. Changes of live biomass carbon and soil organic carbon were reported. Net primary productivity (NPP), net ecosystem productivity (NEP), and net biome productivity (NBP), as well as biomass removals from natural and anthropogenic disturbances, were also reported and compared to similar studies. Multiple comparable simulations were implemented to quantify the contributions of key environmental drivers.

Keywords: climate change, land cover change, land use change, fire disturbance, biogeochemical model

-81 Variability of Heterotrophic respiration induced by source diversity and their property at temperate broad-leaved forest soil in Japan

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Heterotrophic respiration (Rh) is significant process for estimating soil carbon efflux and stock in forest. However, estimation of Rh is still controversial, mainly because of the large temporal and spatial variation. The key reason is that Rh source has large "diversity". The decomposing sources such as leaf litter, root litter and CWD, which is supplied on or in forest soil, individually have different physical and chemical properties (e.g., size and DPM/RPM ratio). And, CO¬2 efflux from these substrates differently responds to environmental factors (e.g., temperature and moisture content). Rh of forest soil is sum of these complex processes and totalizing of diverse heterotrophic processes on forest is an important topic of carbon dynamics in forest ecosystem. In this study, to understand such complex and diverse heterotrophic process, we discuss how various properties, such as size and position of substrate and environmental factors, control total Rh at temperate broad-leaved forest, with data on respiration of individual leaf litter, root litter and CWD.
Respiration observations of individual substrate (leaf litter, root litter and CWD) were performed at Yamashiro Experimental Forest (YMS), which is an Asia Flux site, located in southern Kyoto (34o 47' N, 135o 51'). To cross-validate NEP, the eddy-covariance, biometric and chamber methods have been evaluated at this site (Kominami et al., 2008). We have addressed to estimate soil carbon accumulation rate considering Rh source diversity. We analyzed variability of total Rh with respiration, environmental factors, size and position of individual substrate measured at this site.
Maximum Rh among substrates was largely different: Maximum Rh of leaf litter was 12 times larger than that of CWD. Rh range increased with increasing specific surface area, not only among substrates but also within. At warm-temperate forest in Japan, drying and wetting cycles of organic matters itself on soil occur, clearly. Thus, individual Rh has large range from near 0 to potential maximum value. In contrast, organic matter in soil, such as root litter, keeps sustain moisture content and also Rh. Moreover, the variation in moisture content was associated with their size (e.g., diameter) and position (e.g., standing vs. logs, top vs. bottom within A0 layer). These suggested that individual respiration characteristics need to be considered in estimating forest Rh and soil carbon accumulation.

-82 The implications of additional Carbon Cycle processes in the HadGEM2-ES Earth System Model.

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

HadGEM2-ES is the Earth System Model developed by the Met Office Hadley Centre and used for CMIP5. Included within the model is a full Carbon cycle including the TRIFFID interactive vegetation scheme and a decoupled wetland methane emission model. The ESM is therefore able to simulate climate carbon cycle feedbacks on the future evolution of the climate system. Additional processes not included in HadGEM2-ES include the loss of Permafrost Carbon under a warming climate; changing wetland emissions relating to the variation in the areal extent of future wetlands and their associated emission intensity; and the interaction of the Nitrogen Cycle. Nitrogen generally controls vegetation productivity and is tightly coupled with the Carbon Cycle. Nitrogen and its availability are therefore likely to play a role in the magnitude of the land carbon sink.
In this study we investigate the implications of these extra processes and feedbacks on future permissible emissions under the RCP concentration scenarios. To infer the implications of changing atmospheric C burden we employ a simple climate model to derive changes in global mean temperature. Simple offline modeling is used to calculate changes in future permafrost and associated emissions using simulated changes in high latitude hydrology from HadGEM2-ES. Estimates of future N mineralization and availability are used to estimate the excess C stored in vegetation and soil in the future. Methane emissions from wetlands are diagnosed within HadGEM2-ES but are not fully interactive and are included here as additional emissions.

-83 Change of terrestrial carbon storage since the Last Glacial Maximum in China and its effect on atmospheric CO2 concentration

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Ice core measurements reveal that CO2 concentrations of earth' s atmosphere exhibit large variations over glacial-interglacial cycles. Terrestrial carbon cycle, a key component of global carbon cycles, has played an important role in determining atmospheric CO2 concentrations by regulating its storage and fluxes. So the knowledge of potential impacts of climate change on terrestrial carbon storage is crucial for understanding long-term global carbon cycle. To date, the discrepancy in data has long existed between past carbon storage reconstructions since the Last Glacial Maximum (LGM) by ways of pollen, carbon isotopes, and general circulation model (GCM) analysis. This may be due to the fact that these methods do not synthetically take into account significant differences in climate distribution between modern and past conditions as well as the effects of atmospheric CO2 concentrations on terrestrial ecosystem. In this study, a new method (PCM model) for reconstructing past terrestrial carbon storage and an improved China Quaternary Pollen Database were used, PCM was built on a physiological process vegetation model coupled with a process-based biospheric carbon model and the database was developed from China Quaternary Pollen Database by newly collecting the pollen data published from 1997 to 2011. The method was constrained to fit pollen data in an inverse process to obtain realistic estimates of carbon storage. Results showed that terrestrial carbon storage in China was approximately 115 Pg C at the LGM, 136 Pg C at the mid-Holocene, and 122 Pg C at the pre-industrial time. It revealed a significant increase (approximately 25%) of terrestrial carbon storage from the LGM to mid-Holocene, while, a decrease (approximately 14%) from mid-Holocene to pre-industrial time. This change was closely related to the variations of intensity of East Asian Summer Monsoon, which controlled the patterns of terrestrial ecosystems. Our results suggest that the changes of the terrestrial carbon storage in China play an important role in determining atmospheric CO2 concentrations, a sink for CO2 levels from glacial to interglacial period while a source for CO2 since the mid-Holocene, thus natural changes have contributed to the increase in atmospheric CO2 concentration during the Holocene.

Keywords: Palaeocarbon reconstruction, PCM model, pollen biome data, China

-84 Effects of tropical cyclones on the air-sea flux of CO_2

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Tropical cyclones have profound effects on the air-sea flux of CO_2, firstly by the significant increase in wind speed, and secondly by the ‘cold wake’ caused by the increased vertical mixing under the cyclone. Cyclone-induced increases or decreases in the total flux depend on the dominating influence, e.g. increased efflux due to increases wind speed (Perrie et al., 2004) and entrainment of deeper waters with higher carbon content versus decreased efflux due to lower sea surface temperature in the cold wake (Wanninkhof et al., 2007;D'Asaro et al., 2007) and potential phytoplankton blooms due to entrainment of deeper waters with higher nutrient content.

This study will show the flux changes under different scenarios of wind speed and the biogeochemical changes in surface waters affected by tropical cycles. Regional total fluxes will be shown, based on historical records of tropical cyclones.

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-85 Comparison of CarbonTracker-Asia CO2 Flux with AsiaFlux Tower Measurement and CASA Biogeochemical Model Data

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

This study evaluates Net Ecosystem Exchange (NEE) of CO2 in the CarbonTracker (CT)-Asia model using Asia-Flux tower observed data. CT-Asia uses a nested grid to provide enhanced transport resolution over Asia instead of North America (NAM). Its vertical diffusion scheme employs the YSU PBL scheme which has greater vertical mixing, diffusing CO2 in the PBL instead of trapping it in the surface layer. CT-Asia also uses Japan Meteorological Agency's CO2 observations which were not assimilated in CT-NAM. In this evaluation, six tower sites, located from low to high-latitude regions in East Asia, were selected. Simple linear regression analyses were conducted for 30-minute NEE time series, along with bias score and root-mean square error calculations. Diurnal variations were examined for all the sites whereas interannual variation was checked for one site where a long-term dataset was available. Spatial representativeness of the tower sites were also evaluated using the 500-m resolution satellite land-cover dataset. We also performed wavelet analysis to compare the characteristic patterns of the variability in the time series data of both CT-Asia and the flux towers. The CT-Asia showed relatively strong signal in monthly period because it is based on CASA monthly output data. Hence, we compared these results against the CASA monthly outputs to evaluate the effects of optimization procedure. The NEE values from CT-Asia showed very high (>0.9) correlation with the monthly-averaged CASA NEEs but with different magnitudes and patterns. Other interesting results are presented for the comparison results based on different plant functional types.

-86 Responses of forest productivity and carbon storage to climate change in the southern China

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

The data of National Forest Inventories in China (CNFI) indicated the increase in carbon gain rate in the last three decades. Rapid and simultaneous changes in climate and atmospheric CO2 concentration are predicted to occur over the next century. In this paper, we focus on the forest carbon sequestration as metric to investigate the bounds on subtropical forest growth and carbon dynamics that arises due to climate change and CO2-fertilization in Hunan Provinces, southern China. For this purpose, the process-based hybrid model (TRIPLEX1.6) was adapted and validated. The model was parameterized and operated for five forest types that comprise the regionally dominant species, i.e. Cunninghamia lanceolata forests (CLF), Pinus massoniana forests (PMF), other coniferous forests (OCF), broadleaved forests (BLF), and mixed forests (MF). A set of climate data at a monthly-step and a 30-arc second spatial resolution in Hunan Province were used to run the model. The dataset of climate change consist of the data obtained from the past climate observations during the period from 2000 to 2009 and the projections for the period from 2010 to 2099 from 11 CMIP5 general circulation models. The dataset are analyzed for the five forest types in subtropical China for the RCP scenarios 4.5, and 8.5 over the 21th century. We also assumed two extreme scenarios of CO2 concentration that unlimited CO2-fertilization is allowed for the terrestrial vegetation with double CO2 level in one case, and non CO2-fertilization is capped at pre-industrial levels for another simulation. Model output was provided for the future periods of near-term (2010-2039), mid-century (2040-2069), and end-of-century (2070-2099). Overall, our resultes showed that forest carbon sequestration was projected to increase during the period from 2001 to 2009 and century period across all scenarios. The difference between the projections and those of the five forest types, which were not projected to increase significantly, indicated an intensification of subtropical forests in response to both CO2 increases and aerosol changes over the current century. The combined effects of climate change and CO2 fertilization on the increase of NPP were estimated to be 12.5±3.5% on the near-term and 33.5±8.2% at the end-of-century, one of the quarter from the effects of climate change alone scenario. The projected intensification was significantly enhanced by climate change (primarily aerosol) forcing in the first half of the 21st century. However, climate change alone wouldl reduce the soil carbon sequestration, thereafter. Future climate warming would substantially change the vegetation cover types. The simulated effects of CO2 fertilization significantly offset the soil carbon loss due to climate change alone. At the end of the 21st century, the magnitude of these increases showed a positive dependence on projected CO2 forcing.

-87 Trends in anthropogenic carbon in water masses of the Subtropical North Atlantic Ocean along 24.5 degrees North

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

A large proportion of the CO_2 released into the atmosphere by human activities is taken up by the oceans and the North Atlantic is a particularly important sink of this anthropogenic carbon (Cant) due to its role in the formation of deep water masses which transport carbon away from the surface on centennial timescales. Establishing the rate at which oceans accumulate Cant is important in order to better constrain this sink and its variability. Inorganic carbon and tracer measurements from five occupations of the WOCE AO5 section along 24.5 oN (including two previously unpublished datasets) are used to investigate spatial and temporal changes in anthropogenic carbon in the North Atlantic basin between 1992 and 2011. The section is divided into five regions and six density classes and Cant is calculated using three back calculation techniques and the TTD method. The highest concentration of Cant and the greatest rate of change are observed at the surface, both values decreasing with depth. Higher Cant concentrations and greater rates of Cant increase are observed in the western basin where the western boundary current transports recently ventilated deep water southwards. Estimates of the change in anthropogenic carbon based on back-calculation techniques are found to agree well with estimates derived from tracer (CFC-12) measurements.

-88 Modeling of Carbon Dioxide emission from arctic sites

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Northern boreal and arctic permafrost contains a large quantity of climate vulnerable carbon. Peatlands are a common feature of this region. The feedbacks between climate and peatland CO2 emission are complex. The field-measured data in this area are limited due to climate and logistical problems. Process-based computer simulation could scale the limited field measurements up, and may result in better understanding of those feedbacks and projection for future change.

Peatland-VU is a process-based model designed to simulate CO2 and CH4 fluxes from peat soils. It consists of four submodels, a soil physics submodel to calculate temperature and water saturation of the soil layers, a CO2 production submodel, a CH4 submodel and an organic production submodel.

We test this model on two arctic sites, both of which are situated in permafrost zone. The modeled results are validated against data from on-site chamber measurements. The preliminary results show that the magnitude of the simulated CO2 fluxes agree well the measurements, the seasonal pattern of the fluxes are correctly reproduced.

-89 Climate change mitigation as opportunities for low-carbonised and sustainable development, the case study of urban mobility in China

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Climate change has became a global topic and came into international policy arena since two decades, which no countries could have the choice to be excluded from its impacts. Compared with developed countries, developing countries are more vulnerable to the negative influences of climate change due to the fact that they have fewer facilities and less capacity to cope with. Nevertheless, climate change is not the only and foremost problem that many developing and transition countries need to tackle. In these countries which are normally associated with fast urbanisation, the economic growths have frequently related to more and more disparities in income and living standards, as well as environmental deterioration. The situation seems more severe under the adversely impacts of climate change.

This research emphasises on finding synergies between mitigation strategies and sustainable development with a specific focus on urban mobility in China. The author is seeking to explore methods by which low-carbonised development and sustainable development could be achieved simultaneously. The key concept is to integrate policies and projects of mitigation into a broader scenario together with sustainable development. The author then uses China as a case study to demonstrate how to address mitigation with extra social, environmental and economic benefits in a comprehensive process. Lessons could be drawn for the developing and transition countries in need, and also for municipal decision-makers, urban planners who are facing the similar challenges.

-90 North Atlantic variability of oceanic CO2 uptake in response to simulated past, present and future climate change

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

The oceanic carbon uptake is dominated by inorganic carbon uptake at the surface and the carbon transport rate from the surface into the ocean interior. Ocean circulation and temperature are sensitive to climate change and may potentially change the oceans capacity to absorb CO2. In this context, the North Atlantic region is of special interest as it is one of the most important oceanic carbon sinks and incloses the Atlantic Meridional Overturning Circulation, which plays a crucial role in climate change. Quantifying the climate change induced CO2-uptake variability and identifying its main drivers is highly relevant to the prediction of climate developments.

In order to verify and, moreover, quantify the above mentioned relationships, the presented study focuses on two simulations with the Bergen Climate Model (BCM-C). While the first simulation is fully coupled and utilizes varying carbon emissions based on observed records for the period of 1850-1999 as well as the IPCC SRES-A2-emission scenario for the period of 2000-2099, the second simulation is uncoupled. In the latter, the rising CO2 emissions are not "seen" by the radiation code, leading to a simulation with rising atmospheric CO2 but with suppressed climatic change. Hence, the CO2 uptake differences between the two simulations illustrate the climate induced CO2 uptake variability. In the absence of climatic changes, the integrated North Atlantic CO2 uptake increases from 47.27 PgC (years 2000-2049) to 61.27 PgC (years 2050-2099). Changes in the climatic conditions reduce the uptake to 44.79 PgC and 53.80 PgC, respectively. The uptake reduction takes mainly place at North Atlantic downwelling sites (in the Greenland Sea and the Labrador Sea) and in the Subpolar Gyre pointing to the ocean circulation as one of the main drivers of climate change induced CO2 uptake variability. For quantification of the influence of ocean circulation and other oceanic variables, Singular Value Decomposition and Empirical Orthogonal Functions are applied. These methods show that climate change induced CO2 uptake variability in the North Atlantic is in fact attributable to changing physical ocean variables, while changes in the biogeochemical variables alkalinity and dissolved inorganic carbon are of minor importance.

-91 A Global Carbon Assimilation System Based on a Dual Optimization Method

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Ecological models are effective in understanding the distribution of global carbon sources and sinks. However, global-scale models often suffer from substantial uncertainties due to limited local observations. Although the atmospheric CO2 concentration results from the distribution of terrestrial and oceanic carbon sources and sinks and atmospheric transport, the sparse spatial observational sites are not sufficient to estimate the sources and sinks on global dense grids. One way is to combine the observations of the atmospheric CO2 concentration with ecosystem modeling to reduce the error. The BEPS model is used for ecological modeling, and the MOZART model is used for atmospheric transport modeling. We develop a Dual Optimization Method (DOM) similar to the Bayesian synthesis inversion method to inverse the ecological model parameter state and flux state simultaneously. According to the inherent relationship between the parameter state, flux state and the atmospheric CO2 concentration state, we perform an interactive forecast among the three states. Then we present a Global Carbon Assimilation System based on the DOM and the forecast (GCAS-DOM). In GCAS-DOM, the observations of CO2 concentration can be used to inverse the time-dependent parameters, net fluxes, and the historical atmospheric CO2 concentration. We applied the GCAS-DOM to estimate the distribution of carbon sources and sinks on 2.8o×2.8o global grid cells for the period from 2002 to 2006, and this system effectively corrected some flux patterns produced from ecosystem models.

-92 Interannual variability of sea surface pH

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The oceanic uptake of excess, ‘anthropogenic’, atmospheric carbon dioxide chemically reduces the pH of seawater, resulting in potentially significant effects on marine biogeochemical cycles. Major challenges are the effects on marine biota, and the identification of long-term trends and inter-annual variability. Here, the spatial and temporal variability of surface pH will be presented, estimated from regular observations of sea surface pCO2 and related parameters in the North Atlantic (Watson et al., 2009;Schuster et al., 2009). These estimations will be compared with a recent pH climatology (Takahashi and Sutherland, 2013).

Results show variability between the tropical, subtropical, and temperate North Atlantic waters, with the pH decrease being especially significant in more northern latitudes (Fig. 1 b).

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-93 Carry over effects of warming-induced earlier leaf flushing on next year's leaf phenology in two temperate tree species

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

As a result of the recent increase in surface air temperature, strong phenological shifts have been observed in temperate tree species. However, the carry over effect of the current year's phenology on next year's leaf flushing has been little investigated. In this study, we assessed the carry-over impact of advanced leaf flushing due to winter warming on the next year leaf unfolding in two common deciduous temperate tree species: oak (Quercus robur L.) and beech (Fagus sylvatica L.). The results suggest that next year's leaf flushing of both beech and oak was correlated to the current year's leaf flushing date and thus significantly affected by the previous winter's temperature. In other words, physiological changes associated with winter warming and advanced leaf flushing are of such importance that they interfere with the tree's internal clock, affecting the onset of next year's flushing even after one year at ambient conditions. We hypothesize that the advancement of the next year's leaf flushing might be related to an advancement of the eco-dormancy phase (chilling phase) during bud dormancy which was triggered by an (observed) earlier autumnal senescence. Based on these results, we conclude that leaf flushing models driven only by current winter's meteorologically conditions likely fail to capture inter-annual effects of extreme winter warming on leaf flushing of beech and oak.

-94 Constraints on CO2 emissions from burning fossil fuels to 2050

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The largest source of uncertainty in multi-decadal projections of climate change comes from uncertainty in future CO2 emissions. Scenarios of CO2 emissions have been built and used to project climate change under various assumptions of future socio-economic development. Emissions scenarios are generally assumed equally likely, a necessary assumption when projecting far into the future (e.g. 2100). However over shorter time horizon, emissions are constrained by existing economic development, infrastructure lock-in, and social institutions. Here we build a diagnostic model of CO2 emissions at the country level based on observed historical rates of changes in per-capita CO2 emissions. We show that within a wide range of assumptions regarding the rate of future climate mitigation based on historical analogues, cumulative emissions globally between 2011 and 2050 can be constrained to 530±25% PgC, compared to 365 PgC for 1750-2010. CO2 emissions from our central projection would cause warming rates exceeding 0.25°C per decade leading to additional warming of 1.0±0.3°C by 2050 from the 2010 level. This would likely bring global temperature close to two degrees above pre-industrial levels already by 2050.

-95 Potential CO2 efflux of CWD decomposition caused by tree species change under the climate change in Japan

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Global climate change would cause vegetation distribution widely. Especially in case of Japanese forest, various forest types are distributed in comperatively small scale. And this can arouse sensitive change of tree species according with change of environmental conditions. In this study, we estimated CO2 efflux from CWD(dead tree) that occurred by tree species change under the climate change in Japanese forest.
The relationship between most dominant tree species distribution and climatic variables in the Japanese forest was explored using classification tree analysis of species distribution models (SDMs). Potential habitat maps under the current and future climates were estimated at about 1-km spatial resolution. Assuming replacement of dominant species occurs by the difference of current and future habitat (e.g. from deciduous to evergreen species), potential carbon dioxide efflux occurred by decomposition of CWD was estimated using Rothamsted Carbon based model (Roth-C model) modified for evaluation of CWD decomposition processes. For the impact assessment of climate change, we applied a Regional ClimateModel with a spatial resolution of 20×20 km(RCM20; Japan Meteorological Agency 2004) and the Model for Interdisciplinary Research on Climate (MIROC; K-1 Model Developers 2004). Each scenario data for 2081–2100 was spatially interpolated into the Third Mesh cells using the inverse-distanceweighted interpolation method. About at half area of Japanese forest, dominant species potentially change to different species at the environmental conditions of 2081–2100’s scenario Assuming that tree mortality accelerated from 10 to 20 times in the period of tree species replacement by climate change, NEE would change from minus from plus (from up take to efflux) for from 20 to 30 years at most dominant species replace area

-96 Model-Data Synthesis of Terrestrial Carbon Cycles in Asia: From CarboEastAsia Perspective

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Asia, which is characterized by monsoon climate and intense human activities, is one of the prominent understudied regions in terms of terrestrial carbon budgets and mechanisms of carbon exchange. To better understand terrestrial carbon cycle in Asia, we used in-situ observations (CarboEastAsia eddy covariance data), satellite-based observations (AVHRR and MODIS), empirically upscaled estimations (Support Vector Regression), terrestrial biosphere models (e.g. Biome-BGC, BEAMS, VISIT models), and atmospheric inversion analysis (e.g. TransCom). We analyzed the similarity and differences of carbon cycles among each methodology at long-term (30 years; 1982-2011) and decadal (10 years; 2001-2010) scales. The regions of covering Siberia, Far East Asia, East Asia, Southeast Asia and South Asia (60-80oE, 10S-80oN), was analyzed in this study for assessing the magnitudes, interannual variability, and key driving factors of carbon cycles.

During the data intensive period of past 10 years, we find carbon budgets largely differs among methodology, and the terrestrial ecosystem models tend to under/over-estimate uptake than inversion analysis, depending on regions and selection of models. We also confirmed that large anomalies or extreme events in carbon cycle caused by meteorological anomalies (e.g. 2003 summer) are well-captured by each methods, however, its underlain mechanisms are different among models.

In the 30-years analysis, satellite data (AVHRR) were used as observation, and the satellite data analysis based on AVHRR sensor indicated that broad regions (>40%) in Asia have experiences increases in vegetation greenness, especially in Siberia, India, southern China. The long-term changes in vegetation activities inferred by satellite data were tested with multiple terrestrial ecosystem models and atmospheric inversion analyses.

Our attempt of synthesizing multiple sources identified success and failure of each approach. Detailed results and further efforts to reduce uncertainties in estimating carbon budget in Asia will be discussed in the presentation.

-97 Anthropogenic and Climate impacts on the total CO2 increase observed in the South Indian Ocean

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The Southern Ocean has been identified as a key region for the uptake of anthropogenic CO2 through the formation of Subantarctic Mode Waters (SAMW), but its response to climate change and variability remains uncertain. This question can now be addressed directly from observations, thanks to the availability of consistent historical and recent measurements (GLODAP and CARINA synthesis). We used observations collected between 1985 and 2010 to evaluate the change in total CO2 (TCO2) and anthropogenic CO2 (Cant) in the Southern Indian Ocean, a region where SAMW is formed. The accumulation of Cant in SAMW, derived from three different methods, was around 10 μmol/kg/decade, which is close to the theoretical value expected from the increase in atmospheric CO2. The invasion of Cant in the ocean explains most of the increase in TCO2 concentrations observed in SAMW over the 24-years period, but not all. Indeed, the change in TCO2 was lower than the change in Cant over the period 1985-2000, and was associated with an increase in oxygen concentrations. Our results also suggest that the uptake of anthropogenic CO2 by the Southern Ocean did not increase in recent years despite increasing CO2 emissions. We hypothesize that as winds increased over the Southern Ocean in response to a strengthening of the Southern Annular Mode, there was an increase in vertical mixing at mid-latitudes, and possibly more oxygen rich Antarctic waters advected to this region. This would have reduced both the natural and anthropogenic carbon concentrations in SAMW formed during the end of the 1990's, therefore partly compensating for the uptake of anthropogenic CO2 at the air-sea interface.

-98 Ocean and land climate-carbon cycle feedbacks at the regional scale: analysis based on CMIP5 models

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Climate-carbon cycle feedback has been shown to cause faster atmospheric CO2 rise in the 21st century than expected from CO2 emissions alone. But a quantitative estimate of this feedback based on climate-carbon coupled models is still largely uncertain due to the large inter-model spread. This feedback is classically decomposed into a land and an ocean contribution, and for each of them into the response of carbon storage or flux to changes in atmospheric CO2 only (the beta metric), and to changes in climate only (the gamma metric). Here we use the CMIP5 concentration-driven 1% per year CO2 simulations and we apply several feedback decomposition techniques at the regional scale for both the land and the ocean carbon cycle components.

Despite the large inter-model spread seen at the global scale, the 8 climate-carbon coupled models used here show some agreement in the regional distribution of the beta and gamma metrics. Increased CO2 is projected to increase oceanic CO2 sinks almost everywhere, whereas climate warming is projected by the same models to reduce oceanic carbon uptake in most oceanic regions, apart from the Arctic, Antarctic and equatorial regions. Conversely, increased CO2 is projected to increase land CO2 sinks everywhere, whereas climate warming is projected by the CMIP5 models to reduce land CO2 sinks in tropics and mid-latitudes, but to increase land CO2 sinks at higher latitudes.

-99 Quantifying carbon processes of the terrestrial biosphere in a global atmospheric inversion

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Understanding the role of the land biosphere in the global carbon budget is necessary, particularly the response and feedback of carbon fluxes to climatic controls. Atmospheric CO2 measurements have played a key role in assessing source/sink distributions on global scales using atmospheric CO2 inversions (top-down approach). Process-based models (bottom-up approaches) of carbon fluxes are also useful tools for exploring the underlying processes involved in the uptake and release of carbon in the terrestrial biosphere. These methods on their own are unlikely to provide enough information to fully understand the underlying processes driving the uptake and release of atmospheric CO2 (Dargaville et al. 2005). Therefore, we developed a modeling framework that couples bottom-up and top-down approaches and uses different data constraints (atmospheric CO2 concentrations, satellite-driven data, and climate data) in order to quantify the carbon sources and sinks of the terrestrial biosphere. This allows us to better understand the underlying processes by optimizing some internal key parameters of the biosphere model in order to fit the observed CO2 concentrations. In order to assess the impacts of the climate variability on the terrestrial carbon flux for different Spatial and temporal variability, the relationships between the spatial/temporal patterns of the optimized terrestrial carbon flux and the anomalies of the climate variables (e.g. temperature, precipitation, radiation) are analyzed.

-100 Recent changes in the inter-hemispheric CO2 difference in relation with fossil fuel emissions and sinks.

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The inter-hemispheric CO2 gradient (IHG) is a measure of the imbalance between northern and southern fluxes. Over the past 40 years, the IHG defined by the difference in CO2 mixing ratio between Mauna Loa and South Pole has increased proportional to fossil fuel emissions. Yet, during the last 10 years, measurements indicate that the IHG remained below the 'expected' linear relationship. The causes for this abnormal decadal behavior can involve, 1) an increase in northern land and ocean sinks imbalance compared to southern sinks, 2) a shift of fossil fuel emissions towards the equator that paralleled the increasing emissions trends in East Asian countries, which may decrease the Mauna Loa average fossil fuel CO2 difference, 3) an increase in the inter-hemispheric mixing rate, and 4) a shift of sinks within the northern hemisphere from the high latitudes towards the tropics. These hypothesis are investigated using land and ocean process based model results, atmospheric inversions and forward transport model runs, and using atmospheric CO2 long term measurements

-101 Reconciling estimates of regional gross primary productivity among top-down and bottom-up approaches for a tall-tower CO2 concentration footprint area in central Saskatchewan, Canada

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Quantifying regional (~103 – 105 km2) CO2 fluxes is a key to improve our understanding of the terrestrial carbon (C) cycle. Four independent techniques were used to estimate daily regional gross primary productivity (GPP) for a tall-tower CO2 concentration footprint area (~103 – 105 km2) in central Saskatchewan, Canada, which is characterized as a spatially heterogeneous boreal forest-agriculture transition region. These techniques include three bottom-up methods (a processed based ecosystem modeling approach using Dynamic Land Model (DLM), a flux-tower based upscaling approach, a "two-leaf" light use efficiency modeling approach based on remote sensing, and MODIS GPP products (MOD17A3)) and one simply top-down approach based on tall tower equilibrium boundary layer (EBL) budget analysis that allows the estimation of regional GPP at daily time steps from hourly CO2 concentration measurements.

The top-down EBL method was applied to two CO2 concentration towers (the East Trout Lake 106-m tall tower (54°21'N, 104°59'W) with 4-height measurements (95, 55, 33, 22 m) and the Candle Lake 28-m high tower (53°59'N, 105°07'W).The daily concentration footprints were estimated using the authors previously developed footprint model (SAFE-C) based on Eulerian similarity theory. The estimated monthly and annual footprints for each height were similar in orientation and shapes but apparently different in size. The areas of footprints were significantly increased with heights. The 90% accumulative footprint areas for the heights of 22 m to 95 m varied from ~150 – 500 km2 and ~104 – 105 km2 at daily and annual time scales, respectively. The spatial representativeness of the GPP values extracted from CO2 mixing ratio data using the EBL method for each measured heights is theoretically associated with each-level's footprints. These bottom-up estimated GPP values weighted with concentration footprints were highly correlated with tower-based atmospheric top-down estimates for the corresponding measured heights (r2 = 0.80 - 0.85 for 2006-2008). This study shows that atmospheric CO2 concentration data can be used effectively to retrieve regional GPP and flux tower measurements can also be reasonably extrapolated to a region based on remote sensing based ecosystem modeling. Combining and mutually constraining these independent methods to reduce their uncertainties using data assimilation technique is a practical and effective means to derive regional GPP with reasonably high accuracy.

-102 Internal- and intra-model variability in CMIP5 interactive carbon cycle projections of fossil fuel CO2 invasion into the ocean

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The Fifth Coupled Model Intercomparison Project (CMIP5) simulations also include Earth System Model (ESM) experiments with an interactive carbon cycle (ICC) which are driven by CO2 emissions. As a result, carbon exchange between the ocean and land reservoirs and the atmosphere in theses experiments has an impact on the atmospheric CO2 concentration and hence on climate. This allows for investigations of climate-carbon cycle feedback mechanisms within the Earth System. Yet, compared to simulations driven by prescribed atmospheric CO2 concentrations (PAC) which have been widely used in ESMs, such ICC simulations may also introduce new uncertainties to climate projections because the newly included climate-carbon feedbacks may potentially change model climate sensitivity. We investigate the internal- and intra-model variability of the ocean in future climate projections by comparing ICC and PAC simulations provided by 8 ESMs within the CMIP5 framework. The majority of models shows that the ICC simulations produce larger total and interannual variability in gobal integrated CO2 flux. The 'historical' simulations (1850 – 2005) with PAC and ICC show a similar behaviour because atmospheric CO2 concentrations are relatively low and feedback effects are small. Both, PAC and ICC, fairly well reproduce the broad spatial pattern and interannual variability of observed ocean carbon cycle parameters. Differences become apparent when CO2 is increasing under a high CO2 scenario of representative concentration pathway (RCP8.5). The ICC simulations show higher CO2 concentrations in the lower atmosphere especially over the Northern Hemisphere. This is a combined effect of the forcing by emissions with primary sources in the Northern Hemisphere, and climate-carbon cycle feedbacks. The majority of ICC experiments also produce higher surface ocean pCO2 and slightly stronger ocean acidification than their PAC counterparts. By the end of the 21st century, the multi-model mean differences of global mean pCO2 and pH are 80 ppm and 0.03 between ICC and PAC, respectively. Locally, the largest differences appear in the deep water formation region of the North Atlantic, in the subduction region of the North Pacific, and in the Southern Ocean.

-103 Eastern Boundary Upwelling Systems as sources and sinks of atmospheric CO2: Insights from eddy-resolving modeling studies

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The coastal ocean is often not appropriately taken into account in global carbon budget estimates, despite the fact that the associated carbon fluxes are disproportionately large with respect to the small fraction of the global ocean that coastal oceans occupy. Global ocean models tend to be too coarse to resolve important coastal processes and observational data are often limited in space and time. Therefore, coastal air-sea CO2 fluxes are currently still relatively poorly quantified, with considerable regional and global uncertainties. Eastern Boundary Upwelling Systems (EBUS), regions that are particularly dynamic in terms of carbon cycling, experience extreme spatiotemporal variability in carbon fluxes and exhibit an intricate interplay of physical and biological controls on lateral and air-sea CO2 fluxes.

To quantify the air-sea CO2 fluxes and their variability and assess whether these EBUS act as sources or sinks with respect to the atmosphere, we investigated and compared the spatiotemporal variability of the CO2 gas exchange in three EBUS: the California Current System, the Canary Current System and the Humboldt Current System. To this end, we ran a series of eddy-resolving simulations using a coupled physical-ecosystem-biogeochemical oceanic model (ROMS-NPZD) with an integrated carbon module. Our preliminary results demonstrate that on an annual mean, the California and Canary Current Systems act as sources of CO2 to the atmosphere, with corresponding flux densities of 0.42 and 0.36 mol C m-2 yr-1. The Humboldt Current System on the other hand acts as a sink of CO2, taking up 0.20 mol C m-2 yr-1. Further, an examination of subregions within these three EBUS revealed that nearshore upwelling regions tend to experience more extreme CO2 outgassing and uptake fluxes than offshore regions. Generally, the CO2 gas exchange fluxes vary strongly in sign and magnitude between subregions and on a seasonal timescale.

-104 20 years land carbon fluxes and stocks reanalysis from a Carbon Cycle Multi-Data Assimilation System using in-situ FluxNet, satellite NDVI, and atmospheric CO2 observations to optimize a process-based model

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Global land models are used to predict the response of Earth's ecosystems to environmental changes. However, the estimated water and carbon fluxes remain subject to large uncertainties, partly because of unknown or poorly calibrated parameters. Assimilation of in-situ data, remote sensing data, and/or atmospheric trace gas concentrations into these models is a promising approach to optimize key parameters.
So far most of the studies have focused on using one single data stream, either FluxNet (net CO2 flux (NEE) and latent heat flux (LE)) data at specific sites to constrain the hourly to seasonal time-scale processes, remote sensing of the vegetation activity (fAPAR or NDVI) to constrain the phenology of these models, or atmospheric CO2 concentrations (through the use of a transport model) to provide overall large scale constraints. However, the combination of these data streams, possibly with additional measurements such as in-situ forest biomass data should provide a much larger constraint on the different processes controlling the carbon budget of terrestrial ecosystems from daily to inter-annual time scales.

In the context of the EU-funded CARBONES project, we constructed a global Carbon Cycle Multi-Data Assimilation System (CCMDAS) to assimilate MODIS-NDVI observations, in situ NEE and LE fluxes (60 FluxNet sites), and atmospheric CO2 flask measurements. We used a variational data assimilation framework (4D-Var) that allows the optimization of the major parameters of the land surface model, ORCHIDEE. In a preliminary step, we also optimized air-sea CO2 fluxes with observations of partial pressure of CO2 in the ocean surface and a statistical ocean model. The variational optimization was perform over the past 20 years in order i) to provide a coherent global carbon flux and stocks re-analysis over the two decades, ii) to assess the complementarity of each data stream to constraint the parameters of the ORCHIDEE process-based model, iii) and to provide an optimized land ecosystem model to better assess the fate of the carbon cycle.

The estimated land carbon fluxes and stocks from the parameter optimization, using all data streams together, will be analyzed in terms of long-term means, inter-annual variations, and regional flux patterns. They will be compared against independent i) datasets (i.e., Forest biomass products) and ii) approaches (including classical atmospheric inversions or forward simulations of process based models) to highlight the benefit of using a Multi-Data assimilation system. The potential of these data streams to reveal model deficiencies (after optimization) will be discussed through the analysis of the model-data fits and the parameter values. Finally, the impact of the parameter optimization on the simulated land carbon fluxes for the next century will be evaluated with climate forcing from the recent AR5-IPCC exercise.

-105 Predictability of the terrestrial carbon cycle

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Modern civilization is largely driven by fossil fuel energy. Fossil fuel burning releases carbon dioxide (CO2): the main driver of anthropogenic climate change. Given the potential consequences of climate change for human civilization, there has been major research investment to understand and predict how carbon cycles throughout the biosphere, atmosphere and oceans. It is an imperative responsibility of scientists to deliver credible estimates of carbon sequestration in land and oceans.

Terrestrial ecosystems play a crucial role in the global carbon cycle and the regulation of climate change. In the past 50 years, terrestrial ecosystems absorbed nearly 30% of those emissions11. This magnitude of the terrestrial carbon sink has been deduced indirectly: combining analyses of atmospheric carbon dioxide concentrations with ocean observations and working out what the net terrestrial carbon flux must be. When knowledge about the terrestrial carbon cycle itself is integrated into land models, they generate uncertainty that is usually too large to effectively constrain global land carbon sink. Although many research programs are underway to improve understanding of the terrestrial carbon cycle through further observations, experiments, and modeling. They have shown limited success in reducing uncertainty in model predictions. We need to explore alternative approaches to improve our predictive understanding of in the terrestrial carbon cycle.
In this presentation, we explore the issue of predictability of the terrestrial carbon cycle. We asked a question: To what extent is the terrestrial carbon cycle intrinsically predictable? If intrinsic predictability is low, further research should make limited improvements to the accuracy of future projections despite increasing our understanding. However if intrinsic predictability is high, then why do the projections from state of the art models continue to differ so widely? We first examined fundamental properties of the terrestrial carbon cycle, which form a basis upon which its intrinsic predictability can be analyzed. We show that there is abundant empirical and modeling evidence that the terrestrial carbon cycle is actually highly predictable. We discussed the predictability under five types of external forcing, which encompass almost all possible scenarios the terrestrial ecosystems may experience in the Earth system. With the perspective of predictability, we identified major knowledge gaps in carbon cycle research and proposed strategies to improve the predictive ability of the carbon cycle models.

-106 A first in-situ data based annually and seasonally resolved Methane Budget for the Amazon basin

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Tropical land regions have until recently been poorly observed with large-scale integrating in-situ observations. Thus sometimes adventurous claims of very high methane emissions based on poorly verified methods have been publicized. Here we present the first proper atmospheric sampling of the lower troposphere over the Amazon basin to provide solid seasonal and annual CH4 budgets with course spatial resolution. Our aircraft based vertical profile sites are located along the main airstream operating effectively like a conveyor belt for surface sources and sinks. The main air-stream enters the basin from the Atlantic in the latitude band from above the easternmost tip of South America, travels across the basin towards the Andes where it is deflected south and travels back to the Atlantic further south. We will present spatially and seasonally resolved methane flux estimated from our profile using a simple atmospheric back-trajectory approach. From the flux estimates we will calculate basin wide budgets with some differentiation of underlying processes based on carbon monoxide from fires. For the same purpose, and specifically the quantification of wetland emissions, we will also use simulation results of the atmospheric chemistry and transport model TOMCAT. We will then put our estimates in a global context of our current knowledge of status and trend of the methane cycle.

-107 Variability of the northern hemisphere air-sea CO2 flux over the last decade

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Measurements of sea surface pCO2 and related parameters have been done in the North Atlantic and North Pacific for over a decade, using Voluntary Observing Ships, offering the unique opportunity of studying northern hemisphere variability.
Changes in the North Atlantic Oscillation (NAO) are known to induce shifts in the path of the Gulf Stream, leading to changes in sea surface temperature (SST) in the vicinity of such shifts. SST changes can be expected to thermodynamically lead to changes in sea surface pCO2, as seen in the vicinity of 26.6N/62.5W in the Atlantic between 2002 and 2007 (Figure 1a). However, a similar relationship between sea surface pCO2 and the NAO index is not found here. In the North Pacific, the influence of changes in the Pacific Decadal Oscillation (PDO) on sea surface pCO2 are different, and no change in the correlation between sea surface pCO2 and SST is found in the vicinity of 35N/130W between 1998 and 2008 (Figure 1b).
Using Neural network and geostatistical techniques, regional and basin-scale maps of sea surface pCO2 and air-sea CO2 flux are being produced, together with uncertainties being identified. We will present the total northern hemisphere air-sea CO2 flux and its variability over the last decade, and the mechanistic biological, chemical, and physical, and climate mode drivers of identified variability.

-108 Trends and drivers of regional sources and sinks of carbon dioxide over the past two decades

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The land ecosystems absorb over a great proportion of the anthropogenic emissions of carbon dioxide on average every year. These CO2 'sinks' are modulated by climate change and variability, and changes on these drivers have important effects on the global circulation of carbon. While the estimates of the sinks have converged considerably the recent sink rates for the land, and particularly their changes through time remain uncertain.

We use a suite of nine Dynamic Global Vegetation Models (DGVMs) to quantify the global and regional trends in CO2 fluxes over the period 1990-2009, attribute these trends to underlying processes, and quantify the uncertainty and level of model agreement. The models were forced with reconstructed climate fields and observed global atmospheric CO2.

The land simulated land carbon sink was -2.4±1.2 PgC yr-2 with a small significant trend of -0.06 ± 0.03 PgC yr-2. Trends in the land sink were driven by net primary production (NPP) with a significant trend of 0.22 ± 0.08 PgC yr-2 that exceeds a significant trend in heterotrophic respiration of 17 0.16 ± 0.06 PgC yr-2. Most of the DGVM trend in net carbon uptake originates from natural ecosystems in the tropics (-0.04 ± 0.01 PgC yr-2), with almost no trend over the northern land region where recent warming and reduced rainfall offsets the positive impact of elevated atmospheric CO2 on carbon storage.

-109 Net exchange of terrestrial carbon dioxide in Asia during 2000-2009 estimated from atmospheric inverse modeling

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Carbon dioxide (CO2) has been increasing steadily in the atmosphere since the industrial revolution. The terrestrial sink/source information is critically important for understanding and projecting the future atmospheric CO2 level. The global terrestrial ecosystems are estimated to absorb about 1-4 Pg C yr-1, and its magnitude and spatial and temporal distributions remain uncertain. Asia is increasingly becoming a focus area in global carbon research because of its large land area and uncertainty of carbon budget. Asia is characterized by high fossil fuel emissions, a rapid change of land cover by growing population and expansion of agricultural land. In this study, we used a state-of-the-art CO2 data assimilation system called CTDAS (CarbonTracker Data Assimilation Shell) to estimate weekly net ecosystem exchange (NEE) of CO2 in Asia during the period 2000-2009. We applied the CTDAS to Asia with following modeling characteristics: (i) the atmospheric transport model (TM5) was run at 2x3 degree resolution and was nested over Asia to 1x1 degree resolution; (ii) we added 9 more tower sites with CO2 observations in Asia (14 000 CO2 observations), and (iii) we used two different prior fluxes to estimate uncertainties. The inverse results show that the Asian terrestrial biosphere absorbed about 0.92 Pg C yr-1 (10-year average), partly balancing the release (3.80 Pg C yr-1) of fossil fuel emission and cement manufacturing. The ecosystem carbon uptake is attributed to the boreal (0.49 Pg C yr-1), temperate (0.29 Pg C yr-1) and tropical (0.14 Pg C yr-1) areas. The inclusion of the extra observations in CTDAS leads to about 0.2 Pg C yr-1 (22%) extra sinks, which was found mostly in Boreal Asia (0.13 Pg C yr-1, 14%). We also compared our results with other published results using different independent methods and found they are reasonably consistent with about 10-35 % differences.

-110 Regional carbon footprint accounting for China based on a multi-region input-output framework: a consumption based approach

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

We employ the 8 regional input-output tables in China for the year 2007 based on the dataset for energy consumption at sectional level. Results show that: A) Direct and total carbon coefficients in sectors of non-metal manufacture, iron smelt and electric and steam supply are much higher than other sectors in most regions; B) The middle region, the eastern coast region and the northern coast region show high carbon emissions capacity with total carbon footprint each have the value of 671.3, 496.9, 469.2 million tons from consumption-based, while the capital region (including Beijing and Tianjin) possesses first with per capita carbon footprint score 4.5 ton in 2007, which is 3 times of the last region for the southwest part; C) In regions where have high carbon footprint, construction, machine manufacture and food manufacture take relatively high proportion, especially construction, which Accounts for 20%-40% of the total, it may results from huge fixed capital formation in every region; D) Embodied carbon flows take about 35% of the total carbon footprint of the nation, while the eastern coast region, the southern coast region, the middle region and the capital region present to be net importer, with highest value of 160 million tons from the eastern coast region; E) Just like the formation of carbon footprint, construction, machine manufacture and food manufacture hold large part in embodied carbon flows between regions.

-111 Using C* to determine decadal changes in anthropogenic and natural CO2 in the ocean

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Determining the changes in the oceanic inventory of anthropogenic CO2 are one of the major current challenges of carbon cycle research. As homogenized data from the repeat hydrography program have become available, several methods (extended Multiple Linear Regression (eMLR), ΔΔC*, isopycnal ΔCT0, and Transient Time Distribution) have been proposed to calculate this decadal change in the anthropogenic CO2 inventory based on in-situ measurements. However, all methods face the difficulty of a scarce dataset in both space and time, making the use of an appropriate interpolation technique a crucial element of the method. In addition, the existing methods tend to fail to properly separate the total change in carbon into a component driven by the uptake of anthropogenic CO2 (ΔCant) and a component driven by the anomalous air-sea exchange of natural CO2 (ΔCgasex). Here we present a method based on C* , which is a tracer reflecting the total change in dissolved inorganic carbon (DIC) driven by the exchange of CO2 across the air-sea interface. Hence the difference in C* for a certain time interval should give the sum of the changes in anthropogenic CO2 and in natural CO2 attributed to changes in the air-sea gas exchange, i.e., ΔtC* = ΔCant + ΔCgasex. The change in anthropogenic CO2, i.e., ΔCant is separated from ΔCgasex using the eMLR method, which is more robust in this case as the variance that needs to be explained by the MLR is substantially smaller in the case of C* compared to DIC. By applying the eMLR method on isopycnal surfaces across whole ocean basins, and by using independent variables for which gridded climatologies exist, we can then directly estimate ΔCant at each gridpoint, solving the spatial interpolation challenge. This requires first a temporal interpolation of the data, for which we employ the transient steady state assumption, i.e., the assumption that the change in Cant is proportional to Cant. We tested the method using synthetic data from a hindcast simulation with a global ocean biogeochemistry model (NCAR-CCSM with BEC), and will present first results from real observations. We will put our results should into context with the set of different methods working on this dataset and recent surface ocean pCO2 based estimates as well as results from general circulation models.

-112 First measurements of major greenhouse gases in Bangladesh

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

A regular flask sampling programme has been started in collaboration between JAMSTEC, DU and NIES since June 2012. Air samples are collected at weekly intervals in 1.5 litre glass flask at 2 atmospheric pressure from Comilla (23.45 N, 91.20 E), Bangladesh. The site is maintained by the Bangladesh Meteorological Department (BMD) and the air sampling operation is conducted by DU personnel. Four air samples are transported between DU and NIES, via JAMSTEC, at monthly intervals. The NIES ensures that the air samples are analysed for carbon dioxide (CO2), methane (CH4), carbon monoxide (CO), nitrous oxide (N2O), sulphur hexafluoride (SF6) and molecular hydrogen (H2) within about a month from the sampling date. The region of sampling can be categorised as barren land, devoid of dense ecosystem and away from urban environment. Although the site cannot be categorised baseline station, the air inlet is set up at about 20 m above ground for sampling regionally representative air under well mixed planetary boundary layer (around 1500 local time).

The CCSR/NIES/FRCGC AGCM-based chemistry-transport model (ACTM) simulations of CO2, CH4, CO, N2O and SF6 observations are being compared with the measurements data. We find the model simulations are in general agreement with the measurements during the period of analysis June-December 2012. The simulated CH4 concentrations are found to be amongst the highest on the earth surface, depending on the emission database, and these observations are serving as critical checks for model simulations.

Acknowledgements. We thank APN Annual Regional Call for Proposals (ARCP) for funding, co-PI Josep G. Canadell for supporting this measurement programme, H. Sandanbata for analysing air samples. Further co-operations from the international communities are sort for strengthening this observational programme in Bangladesh.

-113 Development of balloon-borne CO2 instruments (CO2 sonde) for the troposphere and comparison with aircraft measurements

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

At present, there is limited number of CO2 monitoring sites, and especially CO2 vertical profile can be obtained by only aircraft measurements. CO2 vertical profile is the key to estimate CO2 sources and sinks in high precision. For example, the commercial aircraft-based observations Comprehensive Observation Network for TRace gases by AIrLiner (CONTRAIL) has reported.
The CO2 sonde developed by our group has three features improved to the present CO2 monitoring methods, portable, low-cost, and all-weather usable. The CO2 sonde can measure CO2 vertical profile up to the altitude of 10 km from the ground. We apply the Non-dispersive infrared (NDIR) absorption spectroscopy technique to estimate the CO2 mixing ratio in the atmosphere. The two wavelengths selected by filters are used for the sensor, 4.3μm for CO2 absorption and 4.0μm as a background. The difference of the two signal intensities represents CO2 net absorption. To determine the absolute value of CO2 mixing ratio in the atmosphere, two different known-density reference gases, 377 and 400 ppm, are measured alternately in real time for in-flight-calibrations. The CO2 data with the information of temperature and humidity is acquired by the GPS sonde every second.
We have conducted the field observations using the CO2 sonde more than 20 times. In this presentation, we will report the precision of CO2 sonde by comparisons with the CO2 vertical profile obtained by CONTRAIL and NIES/JAXA charter aircrafts.

-114 Flux Footprint Estimation for Complex Surfaces

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Footprint modeling is a critical method for estimating the representativeness of surface flux measurements. For complex surfaces (like small lakes, cities) understanding on the impacts of terrain heterogeneity for the exchange processes between atmosphere and surface is crucial. Over a tall forest or building roofs in a city, the measurements are often carried quite close to the canopy top in the roughness sub-layer and the presence of canopy must be taken into account in the footprint estimation. On the contrary, the flux measurements are carried also at the tall towers at the top of the surface layer, where the influence of the above mixing layer must be considered.

We discuss on the recent developments in more advanced footprint modeling based on the stochastic Lagrangian trajectory technique and LES (Large Eddy Simulations) and compare them with the much-used analytical approaches. We discuss on the issues of developing easy-to-use but realistic models, problems of stable atmospheric conditions and issues of parameterizations and look-up tables. The results can be utilized in the better interpretation of the existing data on fluxes and concentrations over complex surfaces as well as in the planning of new measurement sites.

-115 National Carbon Footprint Accounts: Consumption, Displacements and a Decomposition Analysis of Changes between 2004 and 2007

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Recognized as the primary cause of global warming, CO2 emissions from the burning of fuels, especially the fossil fuels, have aroused series of studies focusing on national CO2 emission inventories. Consumption-based National Emission Inventories (NEI) takes into account the emissions embodied in international transportation of goods and services, therefore it can successfully quantify the potential carbon leakage. Footprint is an indicator accounting for the total direct and indirect effects of consumption activity. This study computes the consumption-based NEI, known as national Carbon Footprint (CF), in an input-output framework for the year of both 2004 and 2007 with the latest available data. Significant nations of CO2 emission are identified by both domestic and imported supply. Changes between the year of 2004 and 2007 are studied and are further decomposed into the following four factors – technological effect, economic system efficiency effect, scale effect and structural effect. This structural decomposition analysis (SDA) reveals the vital drivers of those changes for major nations or regions. Finally, policy proposals are suggested according to the spatially characteristic triggers of CF growth.

-116 Retrospective retrieval of long-term consistent global leaf area index since 1981 for carbon cycles research

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The leaf area index (LAI), which is commonly defined as half the total all-sided developed area of green leaves per unit ground surface area, is a critical parameter for modeling vegetation's water, carbon, and energy exchange with the atmosphere. The global long-term LAI is valuable for better understanding the carbon cycle between the vegetation and atmosphere.

The AVHRR sensors have observed the earth continuously since 1981 and the advanced sensor MODIS has provided a higher quality data for LAI mapping. It is valuable to seamlessly fuse the multi-source data to produce a consistent long-term high quality LAI series.

In this presentation, we present an approach for generating a consistent long-term global leaf area index (LAI) product (1981–2012) by quantitative fusion of Moderate Resolution Imaging Spectroradiometer (MODIS) and historical Advanced Very High Resolution Radiometer (AVHRR) data. The LAI derived from AVHRR was intercompared with that from MODIS during the overlapped period. The results show that the LAIs from these two different sensors are good consistency, with LAI differences are within ±0.6 over 99.0% vegetated pixels. The long-term LAI was also compared with field measurements, which has an error of 0.81 LAI on average. Compared with the LAI retrieved directly from the GLOBCARBON algorithm, the LAI derived by our method has a lower temporal noise, which means uncertainties from the low quality of AVHRR measurements can be reduced with the aid of high-quality MODIS data. This product is hosted on the GlobalMapping Web site for free download, which will provide a long-term LAI over 30 years for modeling the global carbon cycles.

-117 Spatial and temporal variability of ocean acidification in the interior western North Pacific

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

Ocean acidification (OA) has been caused by the accumulation of anthropogenic CO2 in the ocean. It is likely that OA negatively affects marine organisms and ecosystems, and is threatening our society that depends heavily on marine resources and services. Information on OA in the upper ocean is essential, but that in the ocean interior is also important to assess the impacts of OA on benthic and abyssal organisms and also to understand the climate feedbacks to OA.

Japan Meteorological Agency has been conducting hydographic/hydrochemical measurements for the past over 40 years along one of its repeat lines at 137°E in the western North Pacific. Spectrophotometric pH measurement using m-cresol purple as an indicator dye has been made since 2003 in the top 2000 m or in the entire water column at every 5 degrees in latitude from 5°N in the tropics to 30°N in the northern sub-tropics together with other physical and chemical components. All discrete data were interpolated into 0.05 sq intervals using Akima method.

The rate of pH change for the last decade was (i.e. seawater has been acidified) in the layers above sq = 27.60 kgm-3 but varied dynamically with the site and layer of the repeat measurements. A higher rate of pH change at -0.004 ± 0.001 yr-1, i.e. more than double that in the surface, has been observed in the North Pacific Subtropical Mode Water at around 25 – 30°N, sq = 25.20 kgm-3 . Apparent oxygen utilization (AOU) was also increasing significantly (+1.1 ± 0.5 mmol kg-1 yr-1) in the NPSTMW. If we assume the DDIC/AOU ratio of = 117/170, nearly half of pH decrease is attributable to the biological degradation in the NPSTMW. These changes would reflect the prolonged time after the water was last in contact with the atmosphere because of the warming in winter in the last a few years in the NPSTMW formation region.

On the other hand, slight increase in pH was detected in the interior at 10°N. This trend differs from that in the surface at 137°E where any increases in pH have not been detected in the last decade.

These results suggest that OA in the ocean interior is attributable to the accumulation of anthropogenic CO2 in the ocean, but changes in the ocean circulation and/or biological activity is also playing an important role.

-118 A Global Carbon Assimilation System Based on an Ensemble Dual Optimization Method

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

A Global Carbon Assimilation System (GCAS) based on a Dual Optimization Method (DOM, which we developed to inverse the ecological model parameter state and flux state simultaneously) assimilates atmospheric CO2 data into a surface flux and atmospheric transport modeling system to optimize both surface flux and ecological modeling parameters. In this system, the error covariance matrix of the modeled flux is an essential input. This matrix is commonly determined based on experiences which are subjective. This causes errors in the final results. To eliminate this subjectivity, we incorporate the idea of ensemble forecast into GCAS-DOM and construct an ensemble version of GCAS (GCAS-EnDOM). By incorporating ensemble forecast, GCAS-EnDOM automatically estimates the error covariance matrix of the carbon flux as the system evolves in time, hence improves the precision of estimation. In deriving this matrix, we assume that the parameter state and the background spatial concentration state vary continuously with time. This made it possible to use identity forecast to approximate the forecasting formula. Simulation studies show that the GCAS-EnDOM has very high precision, with mean squared errors of the flux estimate on the order of 10-3, and is robust against the initial state sample and misspecification of scaling factors in a model. We applied this system to estimate fluxes in 22 global regions over the period from 2004 to 2008, and the initial results show that the terrestrial and oceanic carbon sinks in global ecosystem are about -5.9Pg C/yr on average, which has a good agreement with the results from Carbon Tracker.

-119 On a Dynamic Window Inversion Method

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The Bayesian synthesis inversion method (BSIM) has substantial computational demand when estimating carbon fluxes at high spatiotemporal resolution. The fixed-lag Kalman smoother (FLKS) reduces the computational cost while maintaining the same accuracy as that of BSIM. In order to further improve the computational speed for the inversion, we propose to use observations of CO2 concentration in time-windows to construct a dynamic window inversion method (DWIM) for global carbon sources and sinks. We compared this method with the BSIM and FLKS by means of simulation and case studies. For a time step with length of one month, the simulation shows that the three-step DWIM has the same level of accuracy as the BSIM, slightly better than the FLKS which uses 6 months of transport, while the DWIM inverts more recent carbon fluxes (three months earlier) than the FLKS. The computational expense of the three-step DWIM is 64% of the FLKS. We applied this assimilation system to inverse carbon fluxes in 22 global regions from 2004 to 2008. The results show that, excluding fossil fuel and biomass burning emissions, terrestrial ecosystems and oceans absorb an average of 3.92 and 1.75 Pg C/yr, respectively, which are consistent with the carbon fluxes announced from CarbonTracker in 2011.

-120 The changing marine carbonate system and air-sea flux of the North Atlantic and Arctic Ocean

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

This study investigates the regional changes in the marine carbon system of the Arctic and North Atlantic surface oceans. The aim is to identify changes and main drivers of the marine carbonate system and CO2 fluxes in these two regions over the 21st century. Two analyses were undertaken: an annual analysis of centennial regional air-sea fluxes to enable comparison of the extent and relative variability of CO2 fluxes, and time-lapse comparison of the inter-region variability of CO2 fluxes with associated variability in hydrography and the carbonate system. For the latter the means of the time slices were chosen as 2026-2035 and 2090-2099, which represents short term changes relevant to medium term climate policy and end of the century simulations representing long-term sensitivity of the coupled regions.

We employed one global and one regional model. The chosen global model is the Bergen Climate Model (BCM-C), which we use to simulate the North Atlantic from 0 to 70 For the Arctic we use the SINTEF model (SINMOD) from 70 to 90. The aim of this study is not to do an inter-model comparison between these two models, but to simulate changes in carbonate chemistry and air-sea CO2 fluxes through this century.

In the North Atlantic (0 to 70), the mean annual air-sea flux of CO2 increased in accordance with atmospheric pCO2 concentrations from −0.5 Pg C in the early 2000 to around −0.8 Pg C in 2040, at which time the CO2 uptake stabilized. The seawater pCO2 increased linearly from 380 ppm in 2000 to 700 ppm in 2100 most probably related to the slowdown of Atlantic Meridional Overturning Circulation (AMOC) in and a reduction in the buffering capacity of the surface waters. After 2070, the annual mean CO2 uptake was reduced to between −0.6 and –0.7 Pg C towards the end of the 21st century. This is in accordance with the slow-down in the growth rate of atmospheric pCO2 in the A1B future scenario. The total CO2 uptake in the Arctic Ocean is smaller than for the North Atlantic, due to the large difference in the area. The Arctic Ocean CO2 flux increases from −0.3 to a peak of −0.35 Pg C yr-1 by mid century, but then relaxes back to −0.3 Pg C yr-1 towards the end of the century. The largest present sink of CO2, per unit area, is found in the Barents Sea and the East Greenland Current of around 2 to 4 mol C m-2 yr-1.

There is great heterogeneity in the latitudinal and regional responses of the marine carbonate system that is represented here by a comparison of the contemporary and future fields of pH, Revelle and pCO2. We will discuss the evolution of the marine carbonate system from 2010 to 2030 to 2100 with a breakdown of the dominant hydrographical (including ice cover) and biogeochemical processes. This analysis is crucial if we are to develop better observational strategies for informing ocean management programs.

-121 Application of the ensemble meteorology for CO2 concentration simulations at continuous observation sites

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

In this work we present an approach of carbon dioxide concentration simulation using global coupled Eulerian-Lagrangian model - GELCA (Ganshin et al., 2012) and ensemble meteorology. Ensemble meteorology was created by combining of JCDAS wind fields and ESRL/PSD GEFS Reforecast Version 2 dataset (Hamill et al., 2012). JCDAS data were interpolated from original T106 Gaussian grid to regular 1.25°×1.25° grid, the vertical structure has 40 levels and was used without any modifications. ESRL/PSD GEFS Reforecast 2 includes 10 perturbed forecast members, ensemble mean and one control forecast with 1.0°×1.0° horizontal resolution; the vertical structure is described by 12 pressure levels, 4 hybrid levels near surface and 10m level. To create JCDAS ensemble meteorology ESRL/PSD GEFS Reforecast 2 winds were interpolated to 1.25°×1.25° grid. Flux footprints were simulated with Flexpart LPDM (Lagrangian Particle Dispersion Model) for each of the 10 ensemble members and the CO2 concentrations were simulated using GELCA, footprints and surface carbon dioxide emissions. We have used these 10 different concentrations and applied Kalman filter to obtain the optimal weights of the linear combination for the ensemble members resulting in a best fit to the observations within a fixed size time window of several days. The posterior results obtained with ensemble wind fields and optimized weights show better agreement with observations against the prior ensemble meteorology simulations and model results with original JCDAS dataset.

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-122 Decadal changes in dissolved inorganic carbon in the ocean

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Since the ocean acts as a major sink for anthropogenic CO2, the estimates of CO2 changes in the ocean have been carried out in many previous studies. To evaluate the estimates, it is important to compare them based on various methods.
First, we estimate anthropogenic and natural carbon changes in recent decades using the method based on measured total carbon differences on isopycnal surfaces between high-quality twice observations conducted under WOCE and WOCE revisit projects.
Since the comparison on the isopycnal surfaces is not strongly affected isopycnal surface heaving, small changes can be detected in deeper layers, which show the deeper transport of anthropogenic carbon. From the analysis, we obtained total anthropogenic carbon increases of 0.5-0.8 PgC/yr in the Atlantic, Pacific, and Indian Oceans.
Although the method can detect the exact changes on the isopycnal surfaces, the method can be applied only along the sections occupied twice, and the spatial representativity and the uncertainty of changes in the basins are unclear. Thus, we examine to make the gridded data from the CARINA and PACIFICA data, which are synthesized to keep the data consistency between chemical observations on a basin scale. Since relationships among temperature, salinity, and measured dissolved values are used in making the gridded data, observations of dissolved values as well as temperature and salinity can improve the estimates.

-123 Global Terrestrial Carbon Budget in Recent 30 Years Simulated Using the BEPS Model Driven by MODIS and AVHRR Data

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Carbon sequestration of global terrestrial ecosystems is very important for reducing the buildup of CO2 concentration in the atmosphere. There are still uncertainties in the estimation of the global terrestrial carbon budget. In this study, the process-based Boreal Ecosystem Productivity Simulator (BEPS) model was employed in conjunction with spatially distributed leaf area index (LAI), land cover, soil, and climate data to simulate the carbon budget of global terrestrial ecosystems during 1981 to 2008. The BEPS model was first calibrated and validated using gross primary productivity (GPP), net primary productivity (NPP), and net ecosystem productivity (NEP) measured in different ecosystems across the world. Then, three global simulations were conducted at daily time steps and a spatial resolution of 8 km to quantify the global terrestrial carbon budget and to identify the relative contributions of changes in climate, atmospheric CO2 concentration, and LAI. The LAI data used to drive the model was generated through the quantitative fusion of Moderate Resolution Imaging Spectroradiometer (MODIS) and historical Advanced Very High Resolution Radiometer (AVHRR) data. The meteorological fields were interpolated from the 0.5° global daily meteorological dataset produced by the land surface hydrological research group at Princeton University.

The results show that the BEPS model simulates carbon fluxes in different ecosystems with acceptable accuracy in comparison with existing measurements. Simulated GPP, NPP, and NEP values and their temporal trends exhibited distinguishable spatial patterns. During 1981 to 2008, global terrestrial ecosystems acted as a carbon sink. The averaged global totals of GPP NPP, and NEP were 116.70 Pg C yr-1, 53.89 Pg C yr-1, and 2.76 Pg C yr-1, respectively. The global totals of GPP and NPP increased greatly, at rates of 0.434 Pg C yr-2 (R2=0.728) and 0.262 Pg C yr-2 (R2=0.709), respectively. Global total NEP did not show an apparent increasing trend (R2= 0.036), averaged 2.26 Pg C yr-1, 3.21 Pg C yr-1, and 2.72 Pg C yr-1 for the periods from 1981 to 1989, from 1990 to 1999, and from 2000 to 2008, respectively. The obvious increases in global GPP and NPP were mainly driven by the enhancement of atmospheric CO2 fertilization. The change of LAI played the secondary role. Climate had a small negative impact on global terrestrial carbon sequestration. During 2000 to 2008, terrestrial carbon sinks mainly existed in the northern region of South America, the western region of middle Africa, Southeast Asia, Southeast China, Southeast United States, and some regions of Eurasia.

The effects of atmospheric nitrogen deposition and land cover change on global terrestrial carbon sequestration will be further examined.

Five years of *in situ* atmospheric O_2 and CO_2 data from Weybourne Atmospheric Observatory, Norfolk, United Kingdom

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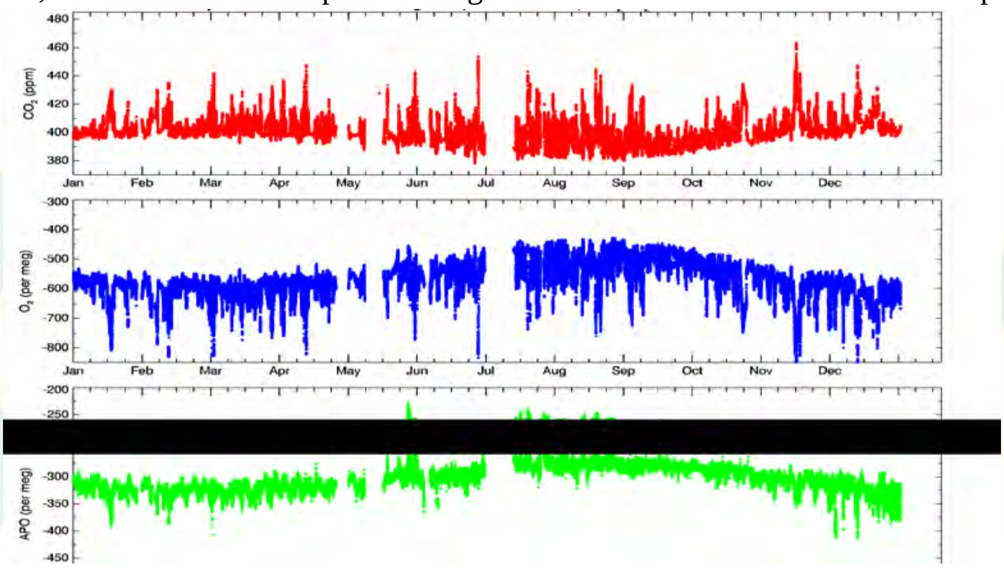
Concurrent atmospheric measurements of oxygen (O_2) and carbon dioxide (CO_2) are a valuable tool to better understand the global carbon cycle. Technological improvements have resulted in near-real-time measurements of both O_2 and CO_2 becoming viable. The increased time resolution of continuous measurements compared to flask samples provides greater insight into atmospheric variations and short-term processes. These measurements will become even more relevant as the research focus shifts from the global to regional scale, e.g. anthropogenic emissions verification.

We present over five years of atmospheric measurements of O_2 and CO_2 collected at Weybourne Atmospheric Observatory (WAO) on the north Norfolk coast (52.95°N, 1.12°E) in the UK, starting from October 2007. O_2 measurements are made utilising an electrolytic reaction on the surface of lead fuel cells in an 'Oxzilla II' analyser from Sable Systems, and CO_2 measurements are made using an 'Ultramat 6E' NDIR analyser from Siemens. A gas handling system similar to that used by Stephens *et al.* [2007] is employed to draw air in from an aspirated inlet at the top of a 10 m a.g.l. tower, dry the air to a dewpoint of -90°C and then control flow rate and pressure before the sample air passes through the two analysers in series. A rigorous calibration methodology similar to that described by Keeling *et al*. [1998] is used to maintain accuracy and precision, and we participate in the 'Cucumber', 'GOLLUM' and WMO round robin intercomparison programmes to ensure the compatibility of our data compared to other global stations. The precision of ambient air measurements is typically ±0.03 ppm for CO_2 and ±2.0 per meg for O_2

We present data for both species and Atmospheric Potential Oxygen (APO), which combines the signals for O_2 and CO_2 so that APO is insensitive to terrestrial processes and thus illustrates mostly only influences due to oceanic processes. Calendar year 2012 data are shown below. Data are examined on interannual, seasonal, synoptic and diurnal timescales. The average amplitude of the WAO seasonal cycle is 14.2 ppm for CO_2, 128 per meg for O_2 and 59 per meg for APO, similar to other stations at similar latitudes. Growth rates over the 5 year period are 2.5 ppm yr^{-1} for CO_2, -26 per meg yr^{-1} for O_2 and -13 per meg yr^{-1} for APO. Short-term analyses reveal clear diurnal cycles in both CO_2 and O_2 that vary seasonally. No diurnal cycle is observed in APO. Short-term events are explored and confirm that WAO experiences both background marine air masses from the Arctic and North Atlantic, as well as fossil fuel pollution signals from the UK and continental Europe.



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-125 Prehistoric land use induced changes of terrestrial carbon storage in Wei valley, northern China

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Quantitative estimation of prehistoric land use during the Holocene is crucial to understand impact of human activity on climate change and abnormal atmospheric CO_2 increase in preindustrial period. Based on pollen and archaeological data, vegetation and human land use from 8 to 4 ka B.P. have been reconstructed in Wei valley, one of agriculture origin centers in northern China, through the spatial interpolation method and PLUM (prehistoric land use model). Then the terrestrial carbon change has been estimated according to the above land cover change areas and their corresponding modern vegetation/soil carbon density. The results reveal that about 0.3-9% of land areas in the valley was used by human activity from 8 to 4 ka B.P., and mainly distributed along the river system. During the period, 0.01, 0.11, 0.19 and 0.11 Pg C has lost from terrestrial ecosystem due to the conversions from forest/grassland to cultivated land by human activity in each 1000-year interval, which would make contribution to the atmospheric CO_2 increase since 8 ka B.P. More accurate evaluation of human impact on global change will be obtained with the scaling up of the study to larger regional and global levels.

-126 The relationship of gas transfer velocity with dissipation rate of turbulent kinetic energy dissipation rate and ocean waves

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The exchange of carbon dioxide across the air-sea interface is an important component of the atmospheric CO2 budget. Understanding how future changes in climate will affect oceanic uptake and releaser CO2 requires accurate estimation of air-sea CO2 flux. This flux is typically expressed as the product of gas transfer velocity, CO2 partial pressure difference in seawater and air, and the CO2 solubility. As the key parameter, gas transfer velocity has long been known to be controlled by the near-surface turbulence in water, which is affected by many factors, such as wind forcing, ocean waves, water-side convection and rainfall. Although the wind forcing is believed as the major factor dominating the near-surface turbulence, many studies have shown that the wind waves and their breaking would greatly enhance turbulence compared with the classical solid wall theory. Gas transfer velocity has been parameterized in terms of wind speed, turbulent kinetic energy dissipation rate, and wave parameters on the basis of observational data or theoretical analysis. However, great discrepancies, as large as one order, exist among these formulas. In this study, we will systematically analyze the differences of gas transfer velocity proposed so far, and discuss the relationships between dissipation rate of turbulent kinetic energy and gas transfer velocity in the presence of ocean waves. A new formula for gas transfer velocity will be given in terms of wind speed and wave parameter.

-127 Flux estimates of CO2 and CH4 over East Asia using a Bayesian inversion with an optimal grid resolution

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

A number of East Asian economies are experiencing rapid economic growth with increased demands for energy and food. This growth is coupled with changes in anthropogenic greenhouse gas fluxes, in particular, CO2, CH4 and N2O. Here, we estimate the fluxes of CO2 (biogenic fluxes only), and CH4 (total flux) over East Asia using a global inversion with an optimized grid resolution. In this approach, the fluxes are discretized onto a grid of multi-scale resolution in which the grid cell varies from a coarse resolution, where there is little atmospheric constraint, to a fine resolution, where there is a strong atmospheric constraint. This has the advantage that a large (or even global) domain can be used while maintaining fine resolution in the regions of interest without dramatically increasing the size of the state vector. Using a global domain (as in this study) also avoids the dependency on boundary conditions and their uncertainties, which if not realistic can bias the results.

For the inversion, we used source-receptor functions calculated from the Lagrangian particle model, FLEXPART. The prior flux estimate of CH4 accounted for fluxes from wetlands (including rice cultivation)(ecosystem model, Orchidee), other (non-rice) anthropogenic sources (EDGAR-4.2), and biomass burning (GFED-3.1). For CO2, the prior flux estimate accounted for biogenic fluxes (CASA), fossil fuel and other anthropogenic emissions (EDGAR-4.2), biomass burning emissions (GFED-3.1), and ocean fluxes (CarbonTracker Ocean). We used surface observations from flask networks and in-situ sites. For CH4, we used a total of 72 sites, including 4 in-situ sites in China from the CAMS network. For CO2, we used the ObsPack dataset. We estimated fluxes of CH4 and CO2 for the year 2009, and present preliminary results for East Asia.

-128 A decadal inversion of carbon dioxide using the Global Eulerian-Lagrangian Coupled Atmospheric model (GELCA

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

A decadal estimation of global CO2 flux distribution for the period of 2001-2010 was conducted using an atmospheric inversion modeling system based on GELCA (Global Eulerian-Lagrangian Coupled Atmospheric model) and a Kalman smoother optimization technique. The use of Lagrangian particle dispersion model (LPDM) to simulate the transport in the vicinity of the observation points enables us to avoid numerical diffusion of Eulerian models, and is suitable to represent observations at high spatial and temporal resolutions. An Eulerian model is run to generate the global background concentrations to be used as the boundary conditions for an LPDM that performs backward simulations from each receptor point (observation location). In the GELCA inversion system, National Institute for Environmental Studies-Transport Model (NIES-TM) version 8.1i was used as an Eulerian global transport model coupled with FLEXPART version 8.0 as a LPDM. Two-day backward transport by FLEXPART was combined with the background CO2 levels 2 days prior to the observations simulated by NIES-TM. The meteorological data for driving both models was taken from JMA Climate Data Assimilation System (JCDAS) with a spatial resolution of 1.25° x1.25° and a temporal resolution of 6 hours. Our prior CO2 ?uxes consist of the following four types: daily terrestrial biospheric fluxes generated by the VISIT model (Vegetation Integrative SImulator for Trace gases); monthly oceanic ?uxes generated by an ocean pCO2 data assimilation system; monthly biomass burning emissions taken from the Global Fire Emissions Database (GFED), version 3.1; and monthly fossil fuel CO2 emissions taken from Open source Data Inventory of Anthropogenic CO2 emission (ODIAC). We employed a Kalman Smoother optimization technique with fixed lag of 3 months, solving for 42 land and 22 ocean regions. Several different setting of observation datasets were used starting by the NOAA flask network ground based observations as a control case.

The performance of the GELCA inversion system was evaluated in various approaches. The global total and large-scale patterns of the optimized emissions agreed overall with those of the inversion with NIES-TM only and other previous studies, whilst the discrepancies appeared in the seasonal variations in regional fluxes. The sensitivity of the inversion to the choice of CO2 observation dataset was discussed using the footprint of each observation dataset.

-129 Integrating Biome-BGC model with assimilated leaf area index to improve the accuracy of water and carbon flux simulations at Harvard Forest .

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Model simulation and in situ observation, which are two often used in water, carbon cycle research of terrestrial ecosystems, have their own advantages and shortcomings. Combination of these two methods could help to reflect the dynamic of ecosystem' s water, carbon flux change information more accurately. Data assimilation provides an effective way for integrating model with in situ observation. In this article, Ensemble Kalman Filter algorithm was used to assimilate field measured LAI and remote sensing LAI and integrate with the Biome-BGC model at Harvard forest Environmental Monitoring Site (EMS) station and to simulate water and carbon fluxes. The results show that field measured LAI in 1998, 1999 and 2006 were assimilated into the improved Biome-BGC model, coefficient of determination R2 between model simulation and flux observation for the net ecosystem exchange (NEE) and evapotranspiration, were increased up to 8.4%, and 10.6%; The sum of absolute error (SAE) and root mean square error (RMSE) for NEE decrease 17.7% and 21.2%, respectively. The SAE and RMSE of the evapotranspiration decreased 26.8% and 28.3% respectively. After MODIS LAI products of 2000-2004 were assimilated into the improved Biome-BGC model, the R2 between simulated and observed results for NEE and evapotranspiration has increased up to 7.8% and, 4.7% respectively. In addition, the SAE and RMSE of NEE have been decreased about 21.9% and 26.3%, and SAE and RMSE of evapotranspiration decreased 24.5% and 25.5% on average. These demonstrate that the simulation accuracy of water and carbon flux can be effectively improved if field measured LAI or remote sensing LAI were integrated into the model.

-130 CO2 fluxes from boreal aquatic ecosystems based on eddy covariance measurements

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Current global estimate of CO2 efflux from lakes, which besides in-lake production process allochthonous carbon, equals to 2 – 5 % of the total average terrestrial net uptake of carbon. In lateral carbon transport from the catchment area to estuaries and finally oceans, rivers and streams are of crucial importance. Lakes as well as rivers and streams are usually supersaturated with CO2 indicating a role as a source of CO2. However, the most common methods for estimating gas exchange are indirect, i.e. sampling is usually discrete and the flux estimates are very seldom based on continuous recordings. Besides, the most commonly applied gas concentration gradient methods rely on simple models between gas transfer coefficient (k600) and environmental parameters. We conducted direct eddy covariance (EC) measurements on CO2 exchange on a small boreal humic lake Valkea-Kotinen surrounded by old growth forest for five years and at the moment we are conducting the corresponding measurements on a larger lake Kuivajärvi surrounded by managed forest. We also had a measuring platform for 30 days in June-July in rapids of a large clear water river Kymijoki. It appeared that all the systems are sources of CO2. On average, the small lake emitted ca. 10% of the terrestrial net ecosystem production of the surrounding forest and the main immediate drivers behind the fluxes were physical rather than biological. The mean annual flux was 6.4 mol $m-2yr-1$. Most of the fluxes took place in late summer and autumn with the mean daily values of 43 to 47 mmol $m-2d-1$, respectively. In the larger lake the summer time daily fluxes vary from 42 up to 173 mmol $m-2d-1$. In the river the daily evasion rate in June-July was 83 mmol m-2d-1. In the river values of k600 derived from the EC measurements were on average 20.8 cm h-1 whereas in Lake Kuivajärvi k600 was 6.9 cm h-1; both of these values are much higher than previously thought. In the river we found only a small effect of wind on k600, whereas friction velocity explained the variation better. In Lake Kuivajärvi heat flux proved to be more important for k600 than wind speed. These results mean that the current estimates for lacustrine and riverine CO2 emissions, based on indirect measurements, are very likely too low. They also emphasize the role of natural inland waters as an integral part of terrestrial carbon cycling. These ecosystems must be taken into account when considering the strength of regional as well as global terrestrial carbon sinks.

-131 Using a coupled regional climate and vegetation model to assess the future of Arctic terrestrial ecosystem carbon exchange

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The Arctic tundra and boreal forests play a pivotal role in regulating carbon exchanged between the atmosphere and biosphere. Continued warming of the Arctic will likely accelerate carbon cycling by increasing both uptake and release of carbon. However, whether pan-Arctic ecosystems will in future act as a sink or a source of carbon is still on a subject of debate, as most previous projections in modeling studies are only based on how vegetation responds to climate forcing rather than interacting dynamically with climate.
In this study, we apply the coupled regional climate and vegetation model RCA-GUESS, over the Arctic. The model is forced with lateral boundary conditions from an EC-Earth CMIP5 climate projection under the RCP 8.5 emission scenario. In RCA-GUESS, the vegetation dynamics model (LPJ-GUESS) simulates phenology, physiology, demography and resource competition of individual-based vegetation, and feeds variations of leaf area index and vegetative cover fraction back to the regional climate model (RCA), thereby adjusting surface properties and surface energy fluxes. We compare simulations with and without vegetation feedback to assess the influence of vegetation-climate feedbacks on net ecosystem exchange in the study domain.
Our preliminary results showed that the land will to act as a carbon sink in both the feedback and non-feedback runs for next three decades, and then be dampened when increased soil respiration outpaces increased net primary productivity in the following decades. The increased vegetation productivity can be attributed to the poleward shift of temperate broadleaved deciduous trees and the expansion of boreal needleaved deciduous trees into tundra land. In general, our results suggest that terrestrial ecosystems in the Arctic will still be a weak carbon sink at the end of this century.
Compared to the non-feedback-run, the extra warming induced by vegetation-climate feedbacks in the feedback-run could further enhance vegetation productivity in pan-Arctic tundra land. The most pronounced warming could take place in spring in tundra land of the Taymyr peninsula and north Canada. However, due to the coupled vegetation feedback, soil respiration in the whole domain would also be raised further, lowering the carbon sink.

-132 Ecosystem Carbon Exchange of Two Subtropical Mangrove Ecosystems in China under Influences of Mariculture, Typhoons and Insect Outbreaks

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Mangrove wetlands are increasing threatened by both climate change and human disturbances. In China, for example, mangrove forests have been severely disturbed and removed widely, mainly by mariculture and land reclamation activities. The total area of mangrove forests in China has reduced by more than 50% over last six decades. Chinese government has made great efforts in restoring mangroves during last 15 years, which successfully reversed the degradation trend. These activities and disturbances should have significant impact on carbon sinks in China's coastal wetlands but data are surprisingly spare on mangrove whole-ecosystem carbon pools and fluxes under these perturbations. In 2008, we established long-term field study sites in two mangrove ecosystems with distinct climate and tidal regimes, one in Yunxiao (23o 55' N, 117o 23' E) of Fujian province with regular semi-diurnal tides and the one in Gaoqiao (21o 34' N, 109o 45' E) of Guangdong province with irregular daily tides. For both stations, we established permanent plots for bio-mass surveys and Eddy covariance towers for continuous monitoring of energy, CO2 and water exchange. We quantified the magnitudes of mariculture operations, typhoon events and insect outbreaks during last few years, and evaluated their possible impact on mangrove carbon cycle processes. Our results showed that the carbon pools and fluxes of these subtropical mangrove ecosystems were adversely affected by human disturbances and typhoon events.

-133 Estimating global fluxes of CO2 for 2009-2010 using measurements from discrete air samples and space-borne (GOSAT) retrievals with empirical orthogonal functions

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Inverse problem of atmospheric transport has been applied to estimate surface fluxes of CO2 for 2009-2010 using weekly surface discrete air samples (NOAA flasks) and space-borne (GOSAT) retrievals. In this work two different XCO2 retrieval products were used for flux inversion (PPDF-S and standard L2 product). Adjustments for each source are represented as a linear combination of main flux components according to surface gas exchange (using empirical orthogonal functions). For atmospheric transport simulation we used a coupled Eulerian-Lagrangian model (GELCA model). This model contains the langrangian transport model FLEXPART and the eulerian taransport model NIES TM. As prior fluxes for different kinds of sources we used Vegetation Integrative SImulator for Trace gases (VISIT) for the biosphere, an ocean transport model with pCO2 data and 4D-var assimilation system for ocean-atmosphere exchange, the Global Fire Emissions Database (GFED) for biomass burning emissions, and the ODIAC database for anthropogenic emissions. Due to the huge number of observations per month (6000-8000) we used a Fixed-Lag Kalman Smoother for solving the inverse problem that allows us to estimate monthly fluxes successively according to assimilation window. Results were presented as 2D fields of monthly surface fluxes for each kind of source with 1 by 1 degree resolution and estimated annual total global fluxes. Model concentrations with optimized CO2 fluxes have been compared with independent station measurements over Siberia. Our calculations show significant uncertainty reduction of fluxes when GOSAT observations are included.

-134 Response and Feedback of Soil Carbon Emission to Global Warming in East Asian Region

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Most of the carbon-climate models imply the exponential functions to predict the future global heterotrophic respiration (Rh) with a Q10 of 2.0, and resulting that the current carbon sink of terrestrial ecosystem probably convert to a carbon source after 2050. However, this has been very difficult to confirm from measurements because Rs is highly spatially variable.
Terrestrial ecosystems in Asia cover large land area and represent various biomes including tundra, boreal, temperate and tropical forests, wetlands, grasslands, crop fields, and the world largest rice paddies extending from the arctic circle to equator. Therefore, knowledge of the carbon budget of the terrestrial ecosystems in Asian region is essential to advance our understanding of global carbon cycle and prediction of the impacts of climate change. Since the mid-1990s, we have been installing multichannel large automated chamber systems in a tundra in the West Siberian lowland, a boreal forest in central Alaska, cool-temperate and temperate forests in Japan, Korea and China (>15 ecosystems), subtropical forests in Japan, Mainland China and Taiwan (5 ecosystems), tropical seasonal forests in China and Thailand, tropical rainforests in China and Malaysia (10 ecosystems), and even arid grassland in Inner-Mongolia and wetland on the Tibetan Plateau, for continuous measurements of forest floor CO2 budget as well as NEP. Among the sites, seven of the systems are using for conducting soil warming experiments. Our ultimate objective is to estimate the carbon budget of Asian terrestrial ecosystems as well as its response and feedback to regional climate change.
Annual soil respiration was about 10-12, 15-20, 25-30, and 50-60 tC ha-1 for cool-temperate and temperate forests, warm-temperate and subtropical forests, tropical forests, and tropical peat swamp forests, respectively. Soil warming enhanced Rh by 8% to 20% per ºC for the humid temperate and cool-temperate mixed forest in northern Japan, about 5% for the summer-drought forests in central Japan, and 10% to 15% for the subtropical forests in Japan and China. The Q10 value was about 3.0 for all of the seven forests. Furthermore, we did not find the acclimation of soil respiration after more than six years warming experiment, probably due to the soil in these forests contains much portion of soil organic matter.
Furthermore, we measured soil organic carbon isotopes (δ13C and Δ14C) profiles at each centimeter to 35 cm depth. Our results suggest beyond doubt that global warming will gain decomposition of decades-old carbon in forest soils and the warming-induced carbon emission will have significant positive feedback to the regional climate change.

-135 Spatial variability of surface pCO2 in the Amundsen Sea polynya, Antarctica

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

The partial pressure of carbon dioxide (pCO2) in surface waters of the Amundsen Sea Polynya (ASP) of Antarctica was measured during the Austral summer from December 2010 to January 2011. Results show that the ASP can be defined as a major sink for atmospheric CO2 with large spatial variability. Surface pCO2 in the central polynya was observed as low as 150 uatm (with a very high average air-sea flux of -4.0 ± 1.4 mol m-2 a-1), contrasting with 450 uatm in the southeast of the ASP near the ice shelf (with flux of +0.78 ± 0.54 mol m-2 a-1). Together with the large pCO2 difference between the atmosphere and surface polynya (delta_pCO2), high wind speeds lead to rapid air-sea flux of CO2. The spatially-averaged CO2 flux for the entire ASP was estimated to be -2.1 ± 1.8 mol m-2 a-1 based on a 90-day ice-free period, which compared well with the annual flux in the Ross Sea (-1.5 ± 1.5 mol m-2 a-1). Strong correlation between pCO2 and chlorophyll fluorescence in the polynya surface indicates biological production as an important controlling factor of pCO2 variability; Saturation states of surface CO2 and oxygen indicate the importance of net community production, and provide further insights into other processes affecting surface pCO2, such as changes in annual sea ice coverage, temperature and deeper water upwelling.

-136 Evaluating drought conditions on the carbon cycle dynamics in contiguous United States on projecting CMIP5 dataset

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Recent years have seen the increase of severity and incidence of climatic extremes, including drought, as a result of climate warming. Such events are linked to inter-annual variations of carbon cycle that affect net ecosystem productivity in North America. Drought-induced biomass senescence caused GPP reduction, which in turn affected the ecosystem respiration. Here we examine the influence of exist summer-droughts during 2000s using data on climate and Ameriflux GPP observation. We first assess the spatial extent, duration and severity of the drought using precipitation data and the Palmer drought severity index (PDSI). Then Biome-BGC is used to simulate evapotranspiration and the carbon stocks under RCP6.0 and RCP4.5 greenhouse gas (GHG) emissions scenarios for the entire 21st century. Despite the inherent difficulty of drought quantification and the uncertainty of drought projections, North America was generally estimated to be a decline of carbon sink to the end of 2100s. Aspects of the water stress, associated changes in the water cycle, are also discussed.

-137 Simultaneous optimisation of process parameters in a terrestrial and marine carbon cycle model using atmospheric CO2 concentrations

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

About half of the anthropogenic CO2 emissions stay in the atmosphere, the remainder is taken up by the land and ocean. However, in the long term the sink capacity of land and oceans may become saturated or even reversed to a source of CO2. Therefore, it is of paramount importance to understand the spatio-temporal distribution of these CO2 sinks, to understand the underlying mechanisms, and to predict its future evolution using process based models. But in many cases the parameters in these process representations are highly uncertain. In order to reduce the uncertainties, parameter estimation methods can be applied, which allow the model to be constrained against observations. The Carbon Cycle Data Assimilation System (CCDAS) has been developed to infer values of the parameters controlling the function of a process model of the terrestrial biosphere from observations of atmospheric CO2 concentrations. In this setup, exchange fluxes between atmosphere and ocean were prescribed.

Here, we present first results from an extension of CCDAS where these oceanic background fluxes have been replaced by a process-based model of the marine carbon cycle. This system is capable of simultaneously optimising the process parameters of both the terrestrial and the marine carbon cycle model using atmospheric CO2 concentrations. The extended CCDAS consists of the terrestrial biosphere model BETHY, the MIT general circulation model (MITgcm) of the ocean, including the DIC marine carbon cycle model and the atmospheric transport model TM2. Altogether some 71 parameters are being optimised: 57 terrestrial and 13 marine process parameters, and one atmospheric initial condition.

-138 The Global Carbon Cycle Simulated by a Climate System Model-BCC_CSM

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The land surface process model with vegetation growth and soil organic carbon decomposition modules, Beijing Climate Center Atmosphere-Vegetation-Interaction Model (BCC_AVIM) was implemented into the coupled global climate-carbon-cycle model, the Beijing Climate Center Climate System Model version 1.1 (BCC_CSM1.1) to simulate the past global terrestrial carbon cycle and projections in the future. BCC_CSM1.1 did a good job in reproducing historical trends of observed atmospheric CO2 and global surface air temperature from 1850 to 2005 under forcing by historical emissions of CO2 from fossil fuels and land-use change. Global land acted as an important carbon sink in the 20th century. The main centers of net carbon sink are located in east America, east China, west Europe, and Oceans in higher latitudes. The net carbon sources are located in the equatorial Pacific and the equatorial Atlantic Ocean. The response of the land carbon cycle to the global warming is much larger than that of the ocean carbon cycle. The potential ability of carbon uptake by land and ocean are obviously enhanced with the increase of atmospheric CO2 concentration. The total CO2 uptake by the earth surface is 3.6 and 4.0 Gt C yr-1 in the 1980s and 1990s, which accounts for 54% and 53% of the anthropogenic carbon emissions for those two decades respectively. The simulated interannual variability of global atmospheric CO2 concentration is closely correlated with the El Nino–Southern Oscillation (ENSO) cycle. The interannual variation of land-to-atmosphere net carbon flux (NEP) is positively correlated with air temperature while negatively correlated with soil moisture for most continental areas, which implies a positive temperature-carbon feedback but a negative soil moisture-carbon feedback at interannual time scale in BCC_CSM1.1. The future projections of global total NPP by BCC_CSM1.1 reaches maximum of 72 Gt C yr-1 around 2040 under scenario RCP2.6 and maximize at 80 Gt C yr-1 around 2075 under scenario RCP4.5, while global NEP peak around 2025 (5 Gt C yr-1), 2045 (7 Gt C yr-1) and 2065 (8.5 Gt C yr-1) in the RCP2.6, RCP4.5 and RCP8.5 projections respectively by using BCC_CSM1.1.

-139 The impact of the Global Financial Crisis on atmospheric CO2

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Using measurement and data selection techniques described in Francey et al. (2013), Southern Hemisphere CO2 growth and inter-hemispheric CO2 difference are examined through the recovery phase of the Global Financial Crisis. A significant step in Mauna Loa minus Cape Grim annual average occurs in 2010 and persists through 2011 and 2012. Smoothed growth rates are more difficult to interpret near the end of a record; however there is emerging evidence for declining growth at Mauna Loa and increasing growth at Cape Grim over the 2010-2012 period. Implications will be briefly discussed.

-140 Sensitivity of speleothem δ13C signals to vegetation viewed from global cave monitoring

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Stalagmite is considered an ideal archive of paleoclimate information because of the precisely U-series chronology controls and the high-resolution. Its oxygen isotope composition (δ18O) in monsoonal zones has been linked to paleomonsoon intensities. Recently, carbon isotope (δ13C) of stalagmite is also used for paleoenvironmental reconstructions, but controversies persist with regards of its environmental significances. Exploration of the links between the δ13C changes in karst systems and surface vegetation changes appears to be a critical step towards revolving this issue.

Based on previously published data from fourteen caves of the world, we compared in this study the δ13C values of vegetation, soil air, soil organic matter and soil water with the δ13C values from the drip water, pool water, and the precipitated calcite (modern stalagmite) within the caves. Partial CO_2 pressures outside and inside the caves, δ13C values of the carbonate bedrocks are also compared. The statistical results show clear seasonal variations in the δ13C values of drip water and precipitated calcite, with lower summer values and higher winter values. The differences are likely attributable to (1) the seasonal changes in photorespiration and microbial decomposition, generally lower in winter and higher in summer, (2) the lower winter precipitation leading to longer residence time of the seepage water from the overlying soils flowing into the caves, and consequently, to the process of prior calcite precipitation (PCP), and (3) the seasonal air pressure differences resulting in isotopic exchanges between the drip water and air.

Detailed analyses of the δ13C values from the vegetation, water and precipitated calcite indicate obvious links between the systems outside and inside the caves. δ13C of the drip water is mainly controlled by the overlying vegetation accounting for a contribution of ~74% while the other ~26% is linked with the contribution from the carbonate bedrocks. Our results, therefore, suggest that the carbon isotope composition of stalagmite would be primarily determined by the vegetation changes. Consequently, δ13C of stalagmites has the potential for documenting the paleo-vegetation changes with high-resolutions.

-141 Emissions of CH_4 from natural gas production in the United States using aircraft-based observations

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

New extraction technologies are making natural gas from shale and tight sand gas reservoirs in the United States (US) more accessible. As a result, the US has become the largest producer of natural gas in the world. This growth in natural gas production may result in increased leakage of methane, a potent greenhouse gas, offsetting the climate benefits of natural gas relative to other fossil fuels. Methane emissions from natural gas production are not well quantified because of the large variety of potential sources, the variability in production and operating practices, the uneven distribution of emitters, and a lack of verification of emission inventories with direct atmospheric measurements. Here we detail two aircraft measurement studies which show methane emissions to be 8.8±2.6% (1) and 4±1.9% (1) of natural gas production in the Uintah County, Utah (UT) and the Denver-Julesburg in Colorado (CO) natural gas field from atmospheric measurements made during a few select aircraft research flights in February and May of 2012. These emissions estimate is significantly higher than inventory-based estimates from these regions and higher than the US EPA nationwide average estimate of leakage from the production and processing of natural gas. Although the emissions for Uintah and Denver-Julesberg may not be representative of other natural gas fields, these studies demonstrate the importance of verifying emissions from natural gas production to enable an accurate assessment of its overall climate impact. The relevance of these emissions to the US and global CH_4 budget will be discussed in the context of recent results from NOAA’ s CarbonTracker CH_4 data assimilation system.

-142 Soil moisture modify temporal response of soil respiration to temperature in a desert shrub ecosystem: hysteresis and sensitivity

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Temporal responses of soil respiration (Rs) to temperature and soil water availability have been well documented in tree stands, but scarcely in desert shrub ecosystem. Continuous soil CO2 efflux in a desert shrub ecosystem was measured with 11 automated chambers using LI-8100A automated soil CO2 flux system in Ningxia in northwest of china from June to October 2012, to quantify the temporal variation in responses of Rs to soil temperature (Ts) and soil water content (VWC). As a result, diurnal variation in Rs was strongly controlled by Ts at 10 cm depth. The diurnal control of Ts over Rs was restrained by low VWC at high temperature in the midday. Seasonally Rs was controlled by both Ts and VWC, being positively correlated to Ts when VWC > 0.08 m3 m-3, and decoupled from Ts below this value. Annual temperature sensitivity of Rs (Q10) was 1.5. Ts was generally around 3 hours lag behind Rs. Observed hysteresis between diurnal Rs and Ts was negatively related to VWC. Hysteresis should be synchronized for soil flux models. Desert ecosystem carbon model should move beyond using an invariant temperature function and a logistic-power model is suggested for simulating seasonal dynamics of Rs. Negative correlation of short-term Q10 with temperature and its positive correlation with VWC indicated a negative feedback of Rs to projected climate change of rising temperature and decreasing soil moisture in desert ecosystem.

-143 Uptake, storage and transport of CO_2 in an ocean biogeochemistry general circulation model

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The natural carbon cycle and the uptake and storage of anthropogenic CO2 in the ocean are simulated with an ocean biogeochemistry general circulation model (OBGCM) that was developed in the Institute of Atmospheric Physics. The OGCM can well reproduce the general features of the ocean circulation and water mass, which was also examined with Natural 14C. The air-sea exchange fluxes of the natural and anthropogenic CO2 in different regions indicate that 0.97 PgC yr-1 of natural CO2 is released to the atmosphere in the global equatorial region within ±15 of the equator. The increase of 20–50 μmol kg-1 for surface dissolved inorganic carbon (DIC) concentrations from the preindustrial era to the 1990s is obtained in the simulation, which is consistent with the data-based estimate. The model generates a total anthropogenic carbon inventory of 105 Pg C as of 1994, which is within the range of estimates by other researchers. Accumulative anthropogenic carbon fluxes minus anthropogenic carbon inventories indicates net outputs that are caused by transport between regions. It is obviously obtained that the Southern Ocean and the high-latitude region of the North Pacific are important export regions, whereas the subtropical regions are the largest acceptance of anthropogenic carbon. The meridional transports of both natural and anthropogenic DIC are estimated from our simulation. The interhemispheric transport of total natural carbon, including DIC and labile dissolved organic carbon, is northward (0.11 PgC yr-1), and the strongest transport of natural carbon is carried by the southward transport of the deep waters in the North Atlantic.

-144 Drought induced carbon export of peatlands in

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Drought induced aqueous (dissolved organic carbon, DOC) and gaseous (CH4, CO2) forms of carbon (C) loss from northern peatlands have been widely investigated. However, there is limit data about peatlands carbon process and loss due to climate-induced drought in Qinghai-Tibet Plateau, which is biggest distribution area of peatland in China and is very sensitive to climate change. Over the pasr 50 years, temperature on the Qinghai-Tibet Plateau have warmed by 0.2 ℃ per decade about twice the observed rate of global temperature increase, how the changes drive of C loss in this region is still poorly quantified. This paper aims to synthesize the main work about peatland carbon dynamics in Qinghai-Tibet Plateau, with focusing on (1): climate history and peatland accumulated in Qinghai-Tibet Plateau; (2): carbon stock in Qinghai-Tibet Plateau (3): drought impact and peatland carbon cycle. The paper concludes with a summary of the main process of the peatland formed, development and changs, which can provide scientifically sound information for decision makers as well as make insightful suggestions for further studies.

-145 Complementary Constraints on Seasonal Carbon Exchange in Southern Amazonia Using GOSAT XCO2 and Fluorescence

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Amazon forests exert a major influence on the global carbon cycle but quantifying the impact is complicated by diverse landscapes and sparse data. We examine seasonal carbon balance in southern Amazonia using measurements of column-averaged dry air mole fraction of CO2 (XCO2) and solar induced chlorophyll fluorescence (SIF) from the Greenhouse gases Observing SATellite (GOSAT) during the period July 2009 – December 2010. XCO2, which is calculated from the NASA Atmospheric CO2 Observations from Space Build 2.9 (ACOS b2.9) algorithm, is used in conjunction with forward simulations of the GEOS-Chem global tracer transport model to estimate seasonal net ecosystem exchange (NEE). SIF, which reflects gross primary production (GPP), is used to disentangle the photosynthetic component of NEE variability. We observe a widespread pattern of low XCO2 during the wet season and high XCO2 in the dry season that is robust to retrieval methodology, including ACOS b2.10, RemoTeC, and NIES, bias correction technique and quality control criteria. The seasonal amplitude exhibits considerable variability across eco-regions, ranging from 4 ppm in transitional tropical forests in southern Amazonia to 2 ppm in cerrado ecosystems to the southeast of Amazonia. XCO2 is inversely correlated with estimates of GPP from SIF ($r = -0.53$, $p < 0.001$), which increases in the wet season and decreases in the dry season, indicating that enhanced XCO2 variability in southern Amazonia is tied to seasonal changes in GPP.

-146 Labile carbon retention in forest soils compensates for CO2 released by priming

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The below-ground C allocation by plants under global warming or elevated CO2 may promote decomposition of soil organic matter by priming effects, strongly affecting C balance. However, the specific effects depend on the amount, duration, and frequency of C inputs. Most priming studies have investigated single C additions, but litterfall and root exudations are relatively continuous in many natural ecosystems. Therefore, we evaluated the effects of organics added to soil at three frequencies: single, repeated, and continuous on C decomposition and budget over 170 days. 13C-labeled glucose was added as 2% of soil organic C (SOC) to tropical (2.8% SOC) and subtropical (13.8% SOC) forest soils and total and 13C labeled CO2 were monitored to analyze priming and net C balances. Cumulative priming induced by the additions ranged over 6.5–7.3 mg C g-1 SOC in subtropical soils, while it ranged from 3.6 to 8.3 mg C g-1 SOC in tropical soils. Single addition induced the most intensive priming compared to repeated and continuous inputs in both soils during the first 3 months. This indicates that single C addition has a short-term effect (a few months) and its extrapolation to longer periods may overestimate priming on SOC decomposition. The amount of added glucose C remaining in the soil after 6 months (subtropical: 14.7–18.2 mg C g-1 SOC; tropical: 16.4–19.0 mg C g-1 SOC) was substantially higher than the C loss due to priming. This clearly shows that increased C input to soils by higher plant productivity increases SOC content even though priming induces faster decomposition of native SOC. This compensation was highest with continuous input and lowest with a single input. Consequently, higher continuous input of C belowground by plants grown under global warming or elevated CO2 will increase soil C despite the acceleration of C cycling.

-147 Interaction of Ocean Acidification and Deoxygenation in the Northeast Pacific Ocean

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The study of ocean acidification has become increasingly urgent as scientists begin to realize the extent of its impact on marine ecosystems. Ocean acidification is caused by more CO2 dissolved into seawater as a result of continuous rising of atmospheric CO2. The acidification process can be potentially enhanced through other anthropogenically introduced change, such as deoxygenation of the ocean. Deoxygenation is believed to be caused by higher water temperature and intensified stratification in water column, followed by more organic matter decomposition at depths. The result of this process is decrease of oxygen, expansion of oxygen minimum zone (OMZ), and decrease of water pH in the ocean. The combined effects of ocean acidification and deoxygenation can potentially acidifying the ocean much faster than either process alone. However, the synergistic effects of the two processes in the ocean have not been fully appreciated and examined. The goal of this study is to investigate the interacting effects of ocean acidification and deoxygenation on seawater pH, calcium carbonate saturation, and other CO2 system parameters in the Northeast Pacific OMZ.

In August-September 2012, we conducted an ocean acidification cruise along the WOCE/CLIVAR P17N transect in the Northeast Pacific oxygen minimum zone. This cruise was part of a comparative project to investigate how the carbonate chemistry in the Atlantic and Pacific Oceans affect the distribution, abundance, shell condition and migratory behavior of pteropods. To assess ocean acidification and deoxygenation effects on carbonate chemistry, we collected discrete samples for analysis of dissolved inorganic carbon (DIC), total alkalinity (TA), pH, and dissolved oxygen (DO), along with other chemical species from depths up to 3000m. These results were contrasted with similar measurements from the 2001 WOCE/CLIVAR P17N cruise to evaluate the acidification rate and shoaling of calcium carbonate saturation as well as the deoxygenation rate and the change in the OMZ. These assessments suggest that ocean acidification and deoxygenation may lower seawater pH and calcium carbonate saturation at similar rates on average in the upper water column (<1000 m), although specific rates may vary with depths greatly. This study suggests that the two different oceanic processes as a result of high CO2 concentration in a warmer world may change ocean chemistry in a synergistic way, such that the effects may be significantly enhanced and felt sooner.

-148 Temperature response of soil CO2 efflux in a Chinese pine plantation: temporal hysteresis and spatial variability

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Although the temperature response of soil respiration (Rs) has been studied for long, its hysteretic characteristics and spatial variability need to be further clarified in ever-expanding plantation forests to reduce uncertainties in carbon modeling. Rs measurements in China' s plantation ecosystems are rare, despite their importance in projecting future global carbon budget. In this study, we monitored soil CO2 efflux with an automated chamber system in a Pinus tabulaeformis plantation near Beijing throughout 2011 to quantify the spatio-temporal aspects of its temperature response. Soil temperature at the 10 cm depth (Ts) was the dominant control over Rs, with the average annual temperature sensitivity (Q10) and basal rate at 10 °C (Rs10) being 2.8 and 1.4 μmol m-2 s-1, respectively. Both Rs and Rs10 showed pronounced seasonal hysteresis with respect to Ts, with the efflux in the second half of the year being larger than that early in the season for a given temperature, indicating the confounding effects of the dynamics of microbial growth and/or litter input. Lags between Rs and Ts were also observed at the diel scale in the early and late growing season, but not in summer. The seasonality in diurnal lags was likely due to the combination of a varying depth of CO2 production over the season and a constant depth of temperature measurements. Daily Q10 decreased with increasing Ts, potentially leading to negative feedbacks under global warming scenarios. Spatial variability in Rs and its temperature response parameters were high in the homogeneous plantation, indicating the need for multi-location measurements in order to accurately project future carbon budgets in plantation forests. Ecosystem carbon modeling should move beyond using a simple, invariant temperature response function, hysteresis and the spatio-temporal dynamics of response parameters should be explicitly considered.

-149 Forty years of baseline CO2 measurements at Baring Head, New Zealand

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The sources of carbon dioxide (CO2) emissions are greater in the northern hemisphere than in the southern hemisphere resulting in inter-hemispheric differences in atmospheric concentration. However the trends in the atmospheric CO2 are comparable between hemispheres due to the fact that the species is long lived and transported to the south. The southern hemisphere geographically is dominated by oceans and these play a significant role in the carbon cycle, several critical questions remain unresolved for the carbon cycle that are linked to southern hemisphere processes (e.g. trends in the Southern Ocean carbon sink, and uptake by southern hemisphere land masses).

Located on a south facing cliff on the southern coast of the North Island (41.4083° S, 174.6944° E), the NIWA operated Baring Head (BHD) monitoring station is ideally situated to observe air masses that have not been in contact with terrestrial sources for thousands of kilometres and multiple days. A site specific filtering process is utilised to ensure that local topography and air flows are considered when selecting what is considered as background or baseline air for atmospheric CO2 measurements, these are representative of mid-latitudes of the southern hemisphere.

We present the 40 year time-series from the site and demonstrate the long-term growth rate of 1.5 ppm yr-1, with a seasonal cycle of 1 ppm. During the last decade (2000-2009) we note a difference between BHD and Mauna Loa of -3.03 ppm primarily as a result of fossil fuel usage in the north hemisphere. A difference between BHD and South Pole over the same period of -0.05 ppm is an indication of the removal processes of the Southern Ocean. The observations at BHD will be compared with model simulations to explore the processes driving seasonal cycles at the station, and with high res lagrangian models, to explore regional transport.

-150 A Carbon Intensity and Production Allowance System for ETS: Bringing Merit Order in Chinese Power Sector

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

Emission Trading System (ETS) in auctioning intrinsically induces cost for every installation regardless of their performances (at least momentary). Besides, ETS based on historical emission leave the room for windfall profit from artificial loss of production. This paper proposes a new sectorial production based Carbon intensity target and analyses its relevance applied to the Power sector. Each year, installations are granted an amount of allowance equal to their year production times the sector carbon intensity target (in tCO_2/MWh). The required amount of allowance to surrender is equal to their year production times the installation own intensity target. Resultant mechanism is technology specific. Low-carbon technology then gets a net positive incentive, without slowing down emerging innovation with unexpected carbon trading costs (Fig.1). Small-scale decentralized renewable energy sources are included. Scheme options for the Japanese emissions trading system consider variations of this principle, but without including small emitters or combining global absolute cap and intensity cap . This work highlights provide way to both to build non-absolute capped trading platform in fast growing economies and manage coal dominated energy mix like in China . This system is applicable to every productive industrial sector besides power sector where production can reliably related to carbon production.

-151 A comparative study of inorganic carbon speciation and fluxes in the Congo and Mackenzie Rivers

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Monthly variations in inorganic carbon chemistry and associated fluxes of the Congo and Mackenzie Rivers were investigated at two time-series stations near the river deltas over a complete annual cycle. The two large river systems occupy opposite ends of the river carbon biogeochemistry spectrum. The Congo, the world's 2nd largest river in terms of discharge, is a large tropical river that is organic carbon rich but inorganic carbon dilute; the Mackenzie, ranking 16th in discharge, is a high-carbonate, Arctic river that is sensitive to permafrost melting as a result of atmospheric CO2 increase and global warming.

For the Congo River, small seasonal variation in dissolved inorganic carbon (DIC) was found in contrast with discharge-correlated changes in pH, total alkalinity (TA), carbonate species, and dissolved organic carbon (DOC). DIC was almost always greater than TA due to the importance of CO2*, the sum of dissolved CO2 and carbonic acid, as a result of low pH. Organic acids in DOC contributed 11 – 61% of TA and had a strong titration effect on water pH and carbonate speciation. Horizontal fluxes and yields of DIC, HCO3-, and TA as well as air-water CO2 fluxes were comprehensively evaluated. The CO2* and bicarbonate fluxes accounted for ~ 57% and 43% of the DIC flux, respectively.

In the Mackenzie River, DIC, TA, pH, and pCO2 showed strong seasonal variations. River discharge had a dilution effect on DIC and TA year-round except near the freshet. DIC and TA increased significantly along the main channel downstream, consistent with the distribution of bedrock geology. Diel changes of the CO2 system parameters suggest significant in-water carbon processing. Annual and daily fluxes of all inorganic carbon species were also evaluated. Speciation of the carbonate system indicates that on average bicarbonate (HCO3-) accounts for ~95% of the DIC flux, while CO2* represents a small but significant (~5%) and previously unaccounted for inorganic carbon species in the total DIC flux.

This study indicates that using TA and pH to evaluate riverine pCO2 and air-water CO2 fluxes may result in large errors, especially for organic-rich and blackwater rivers, due to the contribution of non-carbonate alkalinity, such as organic acid. Even for high-carbonate content rivers, such as the Mackenzie, the pCO2 calculation error by using TA is not always negligible. As such, DIC and pH is a better pair to calculate pCO2 and CO2 fluxes in rivers in cases where direct pCO2 measurements are difficult to make. On the other hand, TA still provides critical information for inorganic carbon speciation in river waters. The large DOC titration effect on the inorganic carbon system observed in the Congo River may also be important on a global scale for regulating carbon fluxes in rivers. In the Mackenzie River, temperature has a significant, positive relationship with the DIC yield in the basin. The first-order estimate suggests that the DIC flux from the Mackenzie River could increase by 20% at the end of century due to warming alone. The warming climate has different implications to carbon biogeochemistry for tropical and Arctic rivers, but both seem to point to the increase of CO2 degassing from rivers.

-152 Mapping greenhouse gas emissions in the Los Angeles basin by remote sensing using a Fourier Transform Spectrometer on Mount Wilson

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Megacities, such as Los Angeles, are significant sources of anthropogenic greenhouse gases (GHGs), therefore it is critical to monitor their emissions. Currently, top-down estimates of GHGs are based on in-situ measurements, at the ground or by aircraft, and satellite data. However, these measurements have certain limitations – in-situ ground measurements are too sensitive to local emissions, aircraft measurements are too expensive for long-term observations and satellite measurements are usually not sensitive to emission variations in the boundary layer, where emissions are located.

Here we present measurements of important greenhouse gases, CO2 and CH4, by ground-based remote sensing from an elevated platform. The California Laboratory of Atmospheric Remote Sensing (CLARS) on Mount Wilson provides temporal and spatial measurements of CO2, CH4 and other chemical species in the Los Angeles basin in the goal of tracking their emissions in the megacity. At CLARS, a Fourier Transform Spectrometer (FTS), located at 1.7 km ASL, points downward at 29 different targets in the basin to measure the slant column abundances of CO2, CH4, N2¬O, CO and O2 using reflected sunlight in the near-infrared regions. This technique allows the spatial coverage of the Los Angeles basin at different times of the day. In addition, the column abundances above Mt. Wilson are measured using a spectralon plate. The basin path-averaged dry-air mixing ratio, XCO2 and XCH4, showed significant diurnal variability due to emissions. Using the Spectralon measurements, which have no diurnal pattern, the contribution above Mt. Wilson is subtracted in order to calculate the basin contribution assigned to anthropogenic emissions. Here we show the spatial variability of the CH4:CO2 ratios in the air mass originating from the Los Angeles basin and comparisons with the ratios calculated from in-situ and total column data.

-153 Decadal trends of CO2 fluxes from a global joint ocean-atmosphere inversion

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Global anthropogenic CO_2 emissions increased at a rate of approximately 1 Pg C yr^{-1} $decade^{-1}$ over the period 1980-2008, yet atmospheric CO_2 growth accelerated by only 0.45 Pg C yr^{-1} $decade^{-1}$. This implies a substantial strengthening of the combined sinks by the ocean and land biosphere by 0.55 Pg C yr^{-1} $decade^{-1}$, so that the relative fraction of the emission staying in the atmosphere remained at roughly 50%, remarkably similar to the value this fraction had over the previous 30 years, when emissions were much lower (Ballantyne et al. , 2012). The regional contributions to this trend in the global carbon sink are important to our understanding of the past and future carbon cycle, yet they remain much less certain, especially in under-observed regions like the tropics.

We present a joint ocean-atmosphere inversion to determine decadal trends in seasonal non-fossil land-atmosphere and ocean-atmosphere carbon fluxes for the 22 Transcom regions for the three periods 1980-89, 1990-99 and 2000-08. In addition to atmospheric CO_2, constraints from ocean interior DIC and surface ocean pCO_2 are included, yet no explicit land prior. The sensitivity of the results to the observational network composition and selected atmospheric transport models is explored.

We find the global oceans to contribute 80% to the change in the overall removal of carbon from the atmosphere, whereas the land biosphere contributes only 20%. Land uptake intensified in the 1990s by 0.4 (±0.3) $PgCyr^{-1}$ compared to the 1980s, but then weakened slightly by 0.2 (±0.4) $PgCyr^{-1}$ in the 2000s. The northern extratropics act as increasing carbon sink throughout the examined period. Boreal regions contribute 86% to the trend in the northern extratropics, induced by enhanced growing season net uptake in boreal America and declining dormant season net release in boreal Asia. Tropical land is estimated to act as an increasing source of carbon, with source magnitude and trend being dominated by intensified CO_2 release in tropical America during the Amazon-mean wet season. Trend estimates for tropical America are robust against the choice of network and the number of applied constraints. By contrast, aggregated tropical regions in Africa and Asia appear as carbon sink with little discernible trend.

Among all constraints, the ocean prior plays a key role in setting decadal trends within latitudinally aggregated bands. At the regional level it has a major impact on carbon exchange for all tropical regions and southern Africa, but also for observationally better constrained regions in North America and temperate Asia. The European trend exhibits an unexpected sensitivity to network composition.

-154 Estimation of CO2 absorbing potential in Korean deciduous forests using KFSC model

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

We estimated CO2 absorbing potential of the deciduous forests in Korea using the Korean Forest Soil Carbon model (KFSC) under the two climate change scenarios (A1B: Intergovernmental Panel on Climate Change (IPCC), 2007; RCP 8.5: IPCC, 2012). Statistical data of forest land area and stocking volume were sorted by administrative district and stand age class. Yield table and allometry equations were used to estimate carbon in above- and belowground biomass while turnover and decay rates were used to estimate carbon in dead organic matter (DOM) and soils. Also periodic harvesting (every 80 years) was applied in the model as a disturbance. CO2 accumulation in the forests increased from 1,072 Mt in 2012 to 1,128 Mt in 2100 under the A1B scenario and increased from 1,073 Mt in 2012 to 1,127 Mt in 2100 under the RCP 8.5 scenario, respectively. CO2 accumulation in above- and belowground biomass and DOM fluctuated depending on harvesting and regeneration while that in soils steadily increased over time because of low decay rate of soil organic matter and slow inflow from stable DOM. The model predicted that approximately 55 Mt CO2 more would be absorbed in the deciduous forests in 2100 compared to that in 2012 under the climate change scenarios. However, only one disturbance was assumed and the influence of temperature was simulated on NPP and decay rate in the current model. Therefore, further studies on model simulation using various disturbances and temperature effects are needed.

-155 Earth and Space-based observations of CO2 and CH4 to quantify and attribute anthropogenic emissions: Megacities and Hotspots

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Anthropogenic emissions of carbon dioxide and methane play a driving role in contemporary climate change. Though these emissions are reasonably well constrained at the global scale, on finer spatial scales large uncertainties arise, confounding studies of natural fluxes while hindering the selection of optimal mitigation strategies and the verification of those efforts. The majority of these finer spatial scale anthropogenic emissions are concentrated in small land areas; prime examples are megacities and fossil-fuel production fields. This concentration of intense emissions leads to large atmospheric signatures, facilitating the use of atmospheric observations to quantify emissions. We will present space-based observations showing signatures of hotspots and megacities, and demonstrate the ability to both quantify and track changes in emissions. We will also present in-situ data being collected in Los Angeles, and demonstrate how multi-tracer observations can be used to fingerprint individual sector contributions to emissions. Finally, we will discuss the potential of earth and space-based networks to monitor and attribute anthropogenic emissions from megacities and emissions hotspots.

-156 Modelling organic carbon stocks in croplands of China under different agricultural management and climate change scenarios

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

We used the Agro-C model to simulate climate and agricultural management scenarios to investigate the combined impacts of climate change and management on future soil organic carbon (SOC) stocks in China' s croplands.

The model was run for croplands on mineral soils in China, which make up a total of 130 M ha of cropland. The model used climate data (years 2011–2050) from the FGOALS and PRECIS climate models based on four Intergovernmental Panel on Climate Change (IPCC) emissions scenarios. Three equidistant agricultural management scenarios were used. S0 was a current scenario, and S2 was an optimal scenario. Under the S2 scenario, crop yields increased annually by 1%, the proportion of crop residue retained in the field reached 90% by 2050, and the area of no-tillage increased to 50% of the cultivated area by 2050.

Across all croplands in China, the results suggest that SOC will increase under all combinations of climate and management and that the effect of climate change is much smaller than the effect of changes in agricultural management. Most croplands in China showed a significant increase in SOC stocks, and only few zones, mainly in northeastern China, showed a decline. Rice paddy soils under the intensive farming management scenario showed higher rates of carbon sequestration than dry-land soils. The maximum carbon sequestration potential of the croplands of China was 2.39 Pg C under S2. Annual increases in SOC stocks could offset a maximum of 2.9% of the CO2 emissions from fossil-fuel combustion in 2009. These results suggest that China' s croplands, especially rice paddies, can play an important role in C sequestration and future climate change mitigation.

-157 Palaeovegetation evolution of the Loess Plateau during warming epochs and its implications for the future

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The trend of vegetation evolution in the warming future has significant effect on terrestrial carbon cycle as well as provides an important reference for agricultural activities. Quantitative palaeovegetation reconstruction obtained from various proxies may not only better understand the driving mechanisms during past climate changes, but also improve knowledge for predicting the future environment evolution. Here, we present a study on the spatial vegetation evolution of the Chinese Loess Plateau during the Last Interglacial and Mid-Holocene periods, characterized with warmer condition to indicate the vegetation changes in northern China in the coming century.

We systematically collected the data of organic carbon isotope composition from Luochuan, Xunyi, Weinan and Lantian loess-paleosol sequences, which is covered the east of Loess Plateau, to quantitatively reconstruct C3/C4 biomass proportion. We added a new Zhouzhuang-Zhangwan section which is on the west of Loess Plateau to better understand the palaeovegetation evolution for the whole Loess Plateau. Results show that the biomass of C4 grass in the east Loess Plateau increased 4-8% and 10-17% during the Last Interglacial period and the Mid-Holocene period, when the global temperatures were as much as 4°C and 2°C higher than present, respectively. However, the biomass of C4 decreased ~12.8 % on the west of the Loess Plateau during the last interglacial period, opposing trends to the changes in the east region, although the biomass of C4 increased both on the west (~8%) and east of the Loess Plateau during the Mid-Holocene period. Results reveal that the abundances of C3/C4 plants differ between the east and the west of the Loess Plateau since the Last Interglacial time with different global warming amplitudes, indicating the complex ecological responses to climate change. Our results suggest the biomass of C4 grasses in the east part of Loess Plateau would increase with global warming in the future, but would first increase and then decrease in the west of the Loess Plateau.

-158 Continuous measurements of CO2 concentration from a tower network (JR-STATION) over Siberia

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Continuous measurements of CO2 concentration have been carried out with a tower network in Siberia (JR-STATION: Japan–Russia Siberian Tall Tower Inland Observation Network) in order to study the spatial and temporal variations of CO2 in the forest, steppe, and wetland regions and estimate the distribution of the flux over this huge area where only few atmospheric investigations were made.

The JR-STATION consists of 9 towers located at Berezorechka (BRZ; 56°09'N, 84°20'E) since 2002, at Karasevoe (KRS; 58°15'N, 82°25'E) and Igrim (IGR; 63°11'N, 64°25'E) since 2004, at Demyanskoe (DEM; 59°47'N, 70°52'E), Noyabrsk (NOY; 63°26'N, 75°47'E) and Yakutsuk (YAK; 62°05'N, 129°21'E) since 2005, at Savvushka (SVV; 51°20'N, 82°08'E) since 2006, at Azovo (AZV; 54°42'N, 73°02'E) since 2007, and at Vaganovo (VGN; 54°30'N, 62°19'E) since 2008. Air samples taken at two heights (5-85 m) on each tower were analyzed with a NDIR (LI-COR, LI-820) for CO2 after passing through the line with a glass water trap, a Nafion membrane drier and a magnesium perchlorate. Measurement precision was ±0.3 ppm. The more detail information of the system was described in Sasakawa et al. [Tellus B, 2010, 2012].

Increasing trends with clear seasonal cycle were observed at all the towers. The stagnation for increase trend in summer minimum from 2008 to 2009 was found in the JR-STATION sites. The stagnation occurred in NOAA coastal sites (Shemya Island, Alaska (SHM), Iceland (ICE), Mace Head, Ireland (MHD)) as well, which suggests that this low CO2 event propagated globally to the same latitudinal zone.

The seasonal minimum at KRS (middle taiga), AZV (steppe region), YAK (eastern Siberia) ranged from the end of July to the early August, which were approximately one month earlier than those at the NOAA coastal sites. This time lag was probably induced by the difference between large CO2 sink regions due to the Siberian taiga and the coastal background sites.

Seasonal CO2 amplitude (the maximum in the winter minus the minimum in the summer) ranged within 26–35 ppm at KRS (2005–2011), 23–30 ppm at AZV (2008–2011), and 21–28 ppm at YAK (2006–2011). These values showed lager variability, particularly at KRS, and much higher than those reported at the NOAA sites whose ranges in 2001–2010 were 13–16, 12–14, and 16–21 ppm at ICE, MHD, and SHM, respectively. Part of this difference was attributed to the low CO2 concentration during the summer due to photosynthesis by the vegetation in taiga. The strong seasonal amplitude observed in the Siberian sites was also attributed to the high CO2 concentration during winter induced by low mixing layer height and the CO2 flux by respiration of the ecosystems in the taiga. We will present the characteristic of CO2 concentration observed at the other Siberian sites as well.

-159 Embodied CO2 Emissions in Beijing’s Domestic and Foreign Trade between 2000 and 2010

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Given its political, economic, and geographical importance, it is critical to understand the embodied CO2 emissions in international trade centered in Beijing. Input-output analysis was applied to evaluate the embodied CO2 emissions in trade from 2000 to 2010 and structured decomposition analysis was further used to analyze the driving forces of the embodied emissions in domestic trade in Beijing. Beijing was a net importer of embodied CO2 emissions during the period 2000–2010, and the city’s embodied CO2 emissions in domestic trade were nearly 4 times that of foreign trade. An increase in trade value and a decrease in CO2 emissions intensity per unit of output were the major factors causing the variations of embodied CO2 emissions in domestic imports for all sectors during the periods of 2000–2005 and 2005–2010. The policy implications of controlling embodied CO2 emissions in Beijing are also discussed.

-160 Sea-air CO2 fluxes in the Southern Ocean: 1990–2009

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The Southern Ocean plays a critical role in the global carbon cycle, yet remains one of the most poorly sampled ocean regions. Different approaches used to estimate sea-air CO2 fluxes in this region include synthesis of surface ocean observations, ocean biogeochemical models, and atmospheric and ocean inversions. As part of the RECCAP (REgional Carbon Cycle Assessment and Processes) project, we combine these different approaches to quantify and assess the magnitude and variability in Southern Ocean sea-air CO2 fluxes south of 44°S, between 1990-2009. A total of twenty-six models and inversions indicate an annual net sea-air CO2 flux of -0.42 ± 0.07 PgC yr^{-1} for the 44° S to 75° S region, consistent with the -0.27 ± 0.13 PgC yr^{-1} calculated using surface observations. Most (90%) of the net annual flux occurs in the 44° S to 58° S (-0.35 ± 0.09 PgC yr^{-1}) circumpolar band compared to the region South of 58°S (-0.04 ± 0.07 PgC yr^{-1}). The median of ocean biogeochemical models captures the observed net sea-air CO2 flux seasonal cycle in the 44°S to 58°S region, while the median of 11 atmospheric inversions shows little seasonal change in net flux. South of 58° S, neither atmospheric inversions nor ocean biogeochemical models reproduce the phase and amplitude of the observed seasonal sea-air CO2 flux. Importantly no individual atmospheric inversion or ocean biogeochemical model is capable of reproducing both the observed annual mean uptake and the observed seasonal cycle, raising concerns about projecting future changes in Southern Ocean CO2 fluxes. The median interannual variability from atmospheric inversions and ocean biogeochemical models is substantial in the Southern Ocean. Trends in the net CO2 flux from the inversions and models are not statistically different from the expected increase due to increasing atmospheric CO2 concentrations. However, resolving long-term trends is difficult due to the large interannual variability and short time frame of this study.

-161 Detecting the anthropogenic influence on recent changes in ocean carbon uptake

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The oceans have, until now, slowed down climate change by taking up roughly one quarter of the anthropogenic emission of CO2, but their efficiency to store CO2 is expected to be weakened by impacts of climate change in the future. While several studies suggest that recent changes can be detected on surface temperature or precipitation, those on ocean carbon uptake remain highly uncertain. Indeed, changes in ocean carbon uptake may already be underway, but have never been attributed to the impact of the radiative forcings of anthropogenic greenhouse gases. Here, we provide a first application of detection and attribution methods to global gridded estimates of ocean carbon uptake. We compare multi-model predictions of the Coupled Model Intercomparison Project phase 5 (CMIP5) with multi-model reanalyses of the Regional Carbon Cycle Assessment and Process (RECCAP) to detect anthropogenic influence on recent changes in decadal variations of CO2 uptake by the oceans between 1960 to 2005. We demonstrate that decadal fluctuations in the global oceanic sink of anthropogenic CO2 are explained by the rise of atmospheric CO2 alone and, therefore, a climate change signal cannot yet be detected. However, latitudinal differentiation unveils that recent changes in the CO2 uptake by the low latitudes oceans are detectable. We attribute these changes to recent climate impacts since the rate at which these oceanic regions take up CO2 cannot be understood without the influence of the radiative forcings of anthropogenic greenhouse gases.

-162 Integrating Prognostic Phenology and Carbon Pools in The Simple Biosphere Model (SiB4) to Estimate Fluxes, Biomass and Stocks

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Since terrestrial carbon fluxes and pools cannot be measured directly on regional and global scales, land surface models are essential tools to improve estimates of carbon sources and sinks and to enhance our knowledge of the processes governing terrestrial fluxes. Land surface models can be evaluated against a variety of data: above and below ground carbon pools from field campaigns; carbon fluxes from chambers and flux towers; and remotely sensed biomass and leaf area index (LAI). In order to utilize these different metrics, we restructured the Simple Biosphere Model (SiB4) to include prognostic phenology and carbon pools in a fully prognostic system.

To create a self-consistent model that uses minimal input data to simulate carbon fluxes and pools, SiB4 includes prognostic phenology for natural plant functional types (PFTs) as well as specific crops (Stöckli et al., 2011 and Lokupitiya et al., 2009); and it calculates terrestrial carbon pools using the strategy from the Simple Biosphere Carnegie-Ames-Stanford Approach (SiB-CASA; Schaefer et al., 2008 and 2009). Photosynthesis is calculated every time step using enzyme kinetics (Farquhar et al., 1980) and stomatal physiology (Collatz et al., 1991 and 1992), while carbon pools and resulting LAI are updated daily. The photosynthesized carbon is allocated into biomass using temperature, moisture and light factors. The leaf allocation factors use the prognostic phenology algorithms, while the root and wood allocation fractions use algorithms from Schaefer et al. (2008). Deciduous PFTs include predictions of LAI, leaf out and senescence timing, and length of growing season. Crops (mid-latitude maize, soybean, and wheat) include predictions of planting date, growth, yield, and harvest. Combining these features creates a fully prognostic model that can be utilized in a wide variety of studies.

This study presents results from SiB4, utilizing field, satellite, and flux tower measurements to analyze SiB4. Preliminary comparisons show that calculating the leaf pool explicitly improves the LAI, particularly in boreal ecosystems, where satellite data overestimate the seasonality, and in mid-latitude croplands, where satellites overestimate the length of the growing season while underestimating the peak magnitude. With improved LAI, SiB4 shows a more realistic seasonal cycle of gross primary productivity (GPP). Rather than using a balanced approach to estimate respiration, using carbon pools to calculate autotrophic and heterotrophic respiration improves carbon fluxes.

-163 Space-based Carbon Monitoring by GOSAT and GOSAT-2: Lessons and Learned from GOSAT in-orbit operation and towards better accuracy of XCO2 observation

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

To observe the global column concentration of carbon dioxide (CO2) and methane (CH4) from space, the Greenhouse gases Observing SATellite (GOSAT) was launched on January 23, 2009, and has started the operational observation. Thermal and Near Infrared Sensor for Carbon Observation – Fourier Transform Spectrometer (TANSO-FTS) has been continuously measuring CO2 and CH4 distributions globally, and the retrieved column CO2 and CH4 data have been distributed to the public. Over four-years operational periods, the useful scientific data sets and interesting articles for carbon source/sink evaluation were produced and published, and these results have been supporting to well understanding of carbon cycle. Currently, the importance of space-based carbon observation has been approved and desired the continuous observation in toward. Through the TANSO-FTS operation with the radiometric, geometric and spectroscopic characterizations, we learned how to improve the accuracy of XCO2 and XCH4 based on short-wavelength FTS. The correction procedures for micro-vibration from companion components, non-linear response of analogue and digitizing circuit are key role on the current on-board operating TANSO-FTS. These procedures were applied on operational level-1 processing algorithm. On instrumental aspects, the robustness and reliability will be required on the future mission to obtain the better spectral quality, and it will be able to lead more accurate XCO2 and XCH4 retrievals. The current retrieval accuracy of XCO2 by GOSAT spectra is around 2 ppm, which is determined by comparing with ground- and aircraft- sampling measured dataset. It suggests that the accuracy of space-based carbon observation is much smaller than 4 ppm of the GOSAT mission target. The improvement of retrieval algorithm for XCO2 and XCH4 is also important both of the accuracy and the processing speed. To elucidate the carbon cycle more precisely, our experiences have to be summarized and applied in the future missions. To continue and improve the space-based carbon monitoring, the conceptual design work of GOSAT-2 has been started. The science and technical highlight of GOSAT and the preliminarily design of GOSAT-2 will be presented with current status.

-164 Monitoring carbon emissions at the regional scale: first of its kind reconciliation of inventory and atmospheric inversion methods

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The terrestrial processes are the primary drivers of seasonal and interannual variability across the globe but yet remains highly uncertain at regional scales. Two methodologies, bottom-up inventories and top-down inversion models, have been used separately to constrain the exchange of carbon over natural and intensively managed ecosystems. Until recently, it has been difficult to reconcile the results from these two methods due to the scarcity of observations as input for the inversion models and the absence of accurate error estimates in both sets of results. The Mid-Continent Intensive (MCI) was a test-bed for comparing top-down and bottom-up methodologies that are used to estimate regional CO2 fluxes. This experiment relies on a unique set of atmospheric measurements that provided high-resolution well-calibrated data over one of the strongest and most localized regions of CO2 drawdown in the world: the US Upper Midwest. At the scale of the entire region, atmospheric inversion CO2 fluxes agreed well with the total inventory budget within the bounds of statistical uncertainty, regardless of whether the inversion was run regionally, continentally, or globally. This research arguably constitutes the most complete, robust, and successful example of a top-down retrieval of CO2 fluxes at a regional scale to date based on comparability with the bottom-up inventory.

We present here multiple sets of mesoscale inversions using independent transport models compared with estimates from the NOAA Carbontracker global inversion system. Correspondingly, a bottom-up inventory of fluxes was compiled from data on forest biomass, harvested woody products, and agricultural soil C from the current US GHG Inventory; high resolution data on fossil and biofuel CO2 emissions from Vulcan; CO2 uptake by agricultural crops, lateral transport in grain harvest, and livestock CO2 emissions using USDA statistics; and CO2 losses from human respiration using US Census data. We demonstrate here the potential of the two methods separately and combined in a single estimate to provide a more precise regional carbon budget and at higher temporal frequency than in the official methodology recommended by current international policies.

-165 Carbon sequestration in conterminous U.S. forests based on climates, disturbances and stand age from AmeriFlux, inventory and remote sensing data

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

U.S. forests, accounting for ~6% of the world forests and ~33% of U.S. landmass, contribute about 10% to the global net terrestrial carbon (C) sink in the late 20th century. Although many studies have explored the effects of non-disturbance factors such as climate and atmospheric composition on the terrestrial carbon cycle, few have systematically considered the impact of disturbances and stand age on the forest carbon cycle at the continental scale. Here we quantify the spatial distribution of forest carbon sources and sinks using a variety of datasets including forest inventories, remotely-sensed, tower flux and climate data through the Integrated Terrestrial Ecosystem Carbon Model (InTEC). The model results are consistent with carbon flux measured at 35 AmeriFlux forest sites (R2=0.83 and root mean square error = 102 g C m-2 yr-1). Our results show that the annual NBP of conterminous U.S. forests increased from 137 Tg C yr-1 in the 1950s, to 222 Tg C yr-1 in the early 21st century with a slight drop in the 1990s (214 Tg C yr-1). The C sink in US forests from 1950 to 2010 was 206 Tg C yr-1 on average with 87% (180 Tg C yr-1) of the sink in living biomass and 13% (26 Tg C yr-1) in soil. If disturbance factors were omitted, the estimated C sink would be reduced by 46%. If non-disturbance factors were omitted, the estimated C sink would be reduced by 24% and estimated soil changes would suggest a small C source (-15 Tg C yr-1). The temporal progression of the forest sink started in the Northern regions then progressed to the Southern and Southeastern regions; the location of the maximum sink shifts gradually from the states of Kentucky and Tennesee to the states of Georgia and Florida after 1990, reflecting impacts of forest regrowth and forest management practices. Over the last 20 years, the disturbance effects dominated the C stock changes in the Southern and Rocky Mountain regions, while these effects are almost equal to the non-disturbance effects in northern regions. In western regions, 60% of the C sink can be attributed to non-disturbance effects.

-166 Evaluating spatial and temporal patterns of MODIS GPP over conterminous USA against flux measurements and a process model

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Using remote sensing and near surface meteorological data, many models have provided annual estimates of Gross primary production (GPP). However, different underlying assumptions and data used in these models sometime generate large uncertainties in GPP estimation. Simple light use efficiency (LUE) models and mechanistic two-leaf Farquhar, von Caemmerer and Berry (FvCB) photosynthetic rate models are used widely. The former uses an intuitive linear relationship between absorbed photosynthetically active radiation and GPP. Conversely the latter are often coupled with a stomatal conductance model to form [A, gs] models based on the principles of biochemical processes in ecosystems. The objectives of this study are to investigate the utility of the two modeling strategies which differ distinctly in their CO2 assimilation processes and address these discrepancies on annual GPP. In this paper, the MODIS GPP algorithm using the LUE approach and the Boreal Ecosystem Productivity Simulator (BEPS) using the two-leaf FvCB model with a soil moisture scalar are applied. Annual simulated GPP by both models are evaluated against tower eddy covariance (EC) measured GPP for a variety of ecosystems at 40 AmeriFlux sites across the continental U.S. during 2000-2005. Although both models simulate the magnitudes of annual GPP with acceptable accuracy, the BEPS performs better than the simpler LUE-based MODIS algorithm. Spatial comparisons at continental scale reveal that annual GPP modeled by the MODIS algorithm exists the analogous systematic biases as suggested by previous studies at shorter scales. The annual GPP tends to be overestimated at poorly productive areas and underestimated at highly productive areas. The largest systematic biases occur in clumped canopies, such as forests, and in canopies with large seasonal variations, such as croplands. For example, annual GPP is underestimated by 34-39% in needleleaf and broadleaf forests by 56% in croplands at higher GPP areas. In contrast, the annual GPP values are 50% higher in croplands at areas with lower annual GPP. Results indicate although the total GPP at the continental scale sounds quite reasonable, the spatial distribution of annual GPP is possible to be distorted. It is not to say the detailed process model is better than the simpler LUE-based model, the truth is that a simple average of canopy LUEs neglecting the influences of leaf attributes e.g., sunlit and shaded and the average canopy LUEs attenuated only by temperature and vapor pressure deficit from maximum LUEs tend to induce biases on LUEs.

-167 Global patterns of ecosystem carbon turnover rates – contrasting data and models

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The turnover rates of carbon in terrestrial ecosystems and their sensitivity to climate are instrumental properties for diagnosing the interannual variability and forecasting trends of biogeochemical processes and carbon-cycle-climate feedbacks. We look at the global spatial distributions of turnover rates of carbon, to explore the association between bioclimatic regimes and the rates at which carbon cycles in terrestrial ecosystems.

Based on data-driven approaches of ecosystem carbon fluxes and data-based estimates of ecosystem carbon stocks, it is possible to build fully observationally-supported diagnostics. These data driven diagnostics support the benchmarking of CMIP5 model outputs (Coupled Model Intercomparison Project Phase 5). The models' performance is addressed by confronting spatial patterns of carbon fluxes and stocks with data, as well as the global and regional sensitivities of turnover rates to climate.

Our results show strong latitudinal gradients globally, mostly controlled by temperature, which are not always paralleled by CMIP5 simulations. The largest difference in temperature sensitivity between models and data occurs in northern, colder, regions. Interestingly, there seem to be two different statistical populations in the data (some with high, others with low, apparent temperature sensitivity of carbon turnover rates), where the different models only seem to describe either one or the other population. Additionally, the comparisons within bioclimatic classes can even show opposite patterns between turnover rates and temperature in water limited regions.

Overall, our analysis emphasizes the role of finding patterns and intrinsic properties, instead of plain magnitudes of fluxes, for diagnosing the sensitivities of terrestrial biogeochemical cycles to climate. Further, our regional analysis suggests a significant gap in addressing the partial influence of water in the ecosystem carbon turnover rates, especially in very cold or water limited regions.

-168 The combined impacts of ocean acidification, upwelling and respiration processes on aragonite saturation state along the Washington-Oregon-California Continental Shelf Margin during the late summer months of 2011 and 2012

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The Washington-Oregon-California continental shelf region is exposed to conditions of low aragonite saturation state during the late spring/early summer upwelling season. However, the extent of its evolution in late summer/early fall has been largely unknown. Along this continental margin, ocean acidification, upwelling, biological productivity, and respiration processes in subsurface waters are major contributors to the variability in dissolved inorganic carbon (DIC), pH, and aragonite saturation state. The persistence of water with aragonite saturation state <1 on the continental shelf off Washington and Oregon has been previously identified and could have profound ecological consequences for benthic and pelagic calcifying organisms such as mussels, oysters, abalone, echinoderms, and pteropods. During the late summer months of 2011 and 2012, we studied the extent of acidification conditions employing shipboard cruises and profiling gliders. We conducted several large-scale chemical and hydrographic surveys of the region in order to better understand the relationships among these natural and human-induced processes and their effects on aragonite saturation. Our results show that in the upwelled waters 14-28% of the overall acidification experienced over the continental shelf during the summer upwelling season is derived from anthropogenic CO_2, 9-20% is derived from local respiration processes, and the remaining 59-74% is derived from the natural process of upwelling itself. These processes combine to maintain corrosive undersaturated waters at depths ranging from 20 to 200 m over most of the continental shelf region during the late summer months.

-169 The oceanic accumulation of anthropogenic CO2 since the mid 1990s

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Model simulations predict that the ocean has taken up about 20 to 30 Pg C of anthropogenic CO2 between the WOCE era (mid-1990) and the mid-2000, bringing the cumulative burden of anthropogenic CO2 in the ocean to about 150 Pg C in 2010. In the last decade, a series of repeat hydrographic cruises have been undertaken with the goal to document and quantify this accumulation. More recently, international synthesis activities have quality controlled and homogenized the data on a basin-scale, opening the opportunity to estimate the anthropogenic CO2 accumulation in the global ocean since the WOCE era with a high-quality data set. We will report on our initial results to estimate this increase on a global-scale, using a range of methods, including the eMLR, ΔΔC*, isopycnal ΔCT0, and TTD methods. This will permit us to assess the uncertainties associated with the separation of the changes in total inorganic carbon from those associated with the uptake of anthropogenic CO2. We will also address the challenges associated with the temporal and spatial interpolation required to arrive at a global integrated number given the relatively spare data sets. The initial results indicate a global uptake at the lower end of the model predicted spectrum, i.e., about 20 Pg C between 1994 and 2006, which amounts to an uptake flux of less than 2 Pg C yr-1 over this period. This flux is currently rather uncertain, but it is of note that it is lower than most estimates for the oceanic sink for anthropogenic CO2, but consistent with the most recent surface ocean pCO2 based estimates (see abstracts by Wanninkhof et al., and Landschützer et al.). If this holds up to further scrutiny, the ocean sink would have slowed down relative to what is expected from the increase in atmospheric CO2.

-170 A joint inversion of CO2 and δ13C in CO2 observations with CarbonTracker

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Over the past years, we have built a new framework to interpret the atmospheric ratio of 13C/12C in CO2. It consists of the CarbonTracker data assimilation system for CO, coupled to the SiBCASA terrestrial biosphere model. We have equipped SiBCASA with additional carbon pools for ^{13}CO, fire emissions following GFED, and isotopic fractionation at all stages of exchange between the atmosphere and chloroplasts. Simulations spanning multiple decades allow us to separately estimate the atmospheric short-term impact (through discrimination during photosynthesis) and longer-term impacts (through disequilibrium) of terrestrial carbon exchange.
A first surprising result is that our best estimates of carbon isotope exchange with SiBCASA does not match the interannual variability constraint imposed by the observed atmospheric growth rate of δ13C. Without invoking large variability in net ocean or net land fluxes, this suggests that other processes, such as for instance changes in the discrimination magnitude, play a large role. This discrimination depends, amongst others, on atmospheric humidity and soil water stress that determine the stomatal conductance, and is considered a measure for water-use efficiency of vegetation.
In our CarbonTracker optimizations, we therefore not only optimize the net carbon fluxes based on atmospheric CO and δ13C, but we additionally allow changes in the isotopic discrimination of vegetation over land. This potentially informs us on the locations and times where drought stress conditions in SiBCASA are not well represented. We will present results from this novel approach and contrast it with the traditional CarbonTracker results, using only CO2 as tracer. Important questions to answer are: Are the estimated sources and sinks by using two tracers still consistent with those using one tracer? What can we learn from the new estimates of discrimination? And when and where do the current treatment of the environmental stress in our terrestrial bottom-up model need to be improved?

-171 Forest Floor Carbon Emissions from the Cloud Forests of Mt. Kinabalu, Malaysia

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Data from temperate studies have established that the temperature sensitivity of montane forest soil organic matter (SOM) decomposition (measured as soil carbon efflux) increases with decreasing temperatures, and that leaf litter decomposition is mainly controlled by abiotic factors (positive correlations with rainfall, leaf N and P content, temperature etc.). While both processes of soil carbon efflux and leaf litter decomposition constitute different stages of organic matter decay, the two have seldom been studied in concert to investigate possible relationships. The tropical montane cloud forests of Mt. Kinabalu, Sabah, Malaysia were used as a model system to study the rates of leaf litter decomposition and soil carbon respiration (SCR). Four study plots (two lower montane and two upper montane) were established along an elevation gradient of approximately 1,800 m a.s.l. (1614 m - 3412 m a.s.l.). In situ SCR measurements using a closed-dynamic chamber system (PP Systems, EGM-4 –SRC-1 system) were made over a period of two months (October – December 2011), with daytime and night readings available for a period of c. 10 days per site to establish baseline CO2 emission levels for each plot. This baseline data is to support our soil transplant incubation studies between plots, which are currently ongoing, both in situ and in controlled lab environments, to investigate the effects of different abiotic parameters on forest SOM temperature sensitivity. These studies are to last approximately 14 days each. Litter bag experiments were set up at each of the same four study plots. Site litter bag treatments include two litter bag mesh sizes (Fine – 1 mm, Coarse – 5 m), three leaf species (1. Macaranga tanarius, a lowland, fast decomposing pioneer species; 2. Syzygium houttuynii, a tough leathery dominant species in one of the study plots [plot 3,106m] and; 3. an unidentified sp 8, which occurs at study plot 1,614m, with intermediate leaf characteristics compared to the other two leaf species). Litter bags were deployed for a 2 year study. Weather stations were set up at four sites corresponding to the four study plots to log abiotic parameters such as hourly precipitation, temperature, humidity, wind velocity, soil temperature and soil moisture. These parameters will be used to help explain differences in the observed rates of litter decomposition and SCR.

Keywords: Soil carbon respiration, leaf litter decomposition, soil organic matter, montane

-172 FENFLUX: The Short-term Climate Response of Carbon Dioxide, Methane and Water Fluxes from different Fens in East Anglia, United Kingdom

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Peatland ecosystems are unique wetland ecosystems in which slow accumulation of peat has occurred due to incomplete decomposition under long-term or seasonal water-saturated conditions. Fen (minerotrophic peatland) is one of the main peatland ecosystem types where water table close to the surface, causing rich in vegetation species and mineral and relatively high pH. Due to the slow peat accumulation, peatlands are frequently carbon dioxide (CO2) sinks and globally represent a major store of soil carbon, storing approximately 30% of global soil carbon stocks. At the same time, they are source of methane (CH4) to the atmosphere because of reduced rates of aerobic decomposition in a perennially waterlogged soil environment. It is recognized that peatlands have a significant role in the global carbon balance and climate regulation. However, peatland ecosystems are also particularly sensitive to climate changes. Changes in climate and land management can subsequently the vegetation cover of the surface. There is a concern that the global warming caused by modern anthropogenic activities and extensive land use changes can drive a huge amount of carbon storage losses in peatlands, a consequence of carbon emissions into the atmosphere. In England, nearly all of the original fens have been drained and cultivated to intensive agricultural land use. Evidence suggested, that it is possible to reduce or even reverse the loss of carbon from peatlands through habitat restoration, and that CH4 emissions are likely to be small in relation to the overall greenhouse gas benefits from protecting the remaining peatland carbon stores and restoring their potential for carbon sequestration. In our study, we have measured CO2, H2O, CH4 and energy fluxes using the micrometeorological and eddy covariance (EC) techniques at our monitoring sites at a regenerating and a semi-natural temperate fen at the Wicken Fen National Nature Reserve, Cambridgeshire, United Kingdom. We present an investigation of the magnitude of the impacts of restoration and their response to climate variability by comparing the two different fen ecosystems. This research will lead to a better quantitative understanding of the relationships between fen peatlands and global climate.

-173 AN HIGH-RESOLUTION REGIONAL CO2 ASSIMILATION SYSTEM FOR ESTIMATING TERRESTRIAL SOURCES AND SINKS IN CENTRAL EUROPE

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

A major challenge in the quest to quantify and understand the sources and sinks of CO2 over the landscape is the large spatiotemporal variability of the driving fluxes, requiring much finer resolution than typically resolved by the large-scale top down approaches. This requires the development of a new class of regional observing and assimilation systems that can resolve the local (<100 km) and regional (order 100-1000 km) scales, permitting to resolve individual emission sources, the response of different vegetation types to climate drivers, and the impact of human interventions (land-use change and land management) on land-atmosphere fluxes. Here we report the development of such a high-resolution greenhouse gas assimilation system to determine and understand the fluxes and balance of CO2 and CH4 in central Europe, mainly in Switzerland. Switzerland is chosen because of its heterogeneous landscape with a complex mixture of agricultural land, forests, pastures, villages and cities, which is representative for many other regions of Europe and the world. This provides a large challenge for atmospheric top-down methods that have avoided so far regions with such complex terrain.

The assimilation system CarbonTracker CH will include the high resolution atmospheric transport model COSMO2 (run at either 7 or 2 km resolutionKM) with meteorological conditions obtained from the Swiss Weather Service, MeteoSwiss, a land surface model (Community Land Model, CLM), and an Ensemble Square Root Kalman filter (EnSRF) as employed in CarbonTracker. This system will be fed with data from a newly developed atmospheric CO2 and CH4 observation network for Switzerland. The atmospheric CO2 concentration is the sum of CO2 from fossil fuel burning, terrestrial biosphere exchange in Switzerland, CO2 from the background signal contained in boundary condition and CO2 from the ocean in our domain. Only terrestrial biosphere will be optimized based on the scaling factors across different ecoregions. In this presentation, synthetic data will be used to assess the performance of the Carbontracker CH system and measurement network.

-174 33 years of CO2 surface fluxes as seen from the atmosphere

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

This paper documents a global Bayesian variational inversion of CO2 surface fluxes during the period 1979–2011, produced as part of the pre-operational Monitoring of Atmospheric Composition and Climate – Interim Implementation service (MACC-II). Weekly fluxes are estimated on a 3.75° × 2.5° (longitude-latitude) grid at once throughout the 33 years. The assimilated observations comprise 136 site records from four large data sets of surface CO2 mole fraction measurements. A Monte Carlo approach rigorously quantifies the theoretical uncertainty of the inverted fluxes at various space and time scales, which is particularly important for proper interpretation of the inverted fluxes. On the basis of observations independent from those used in the inversion, the inversion improves the fluxes compared to a benchmark inversion based on the observed atmospheric growth rate: the atmospheric simulation of CO2 with the Bayesian inversion method is better by about 1 ppm than the benchmark in the free troposphere. We also confront our prior and posterior error models with the mismatch between 4D simulations of CO2 and independent GOSAT retrievals of the total CO2 column. Taking all sources of uncertainties into account, it is shown that both prior and posterior errors are consistent with the actual departures, which shows that the inversion system fairly diagnoses its strengths and weaknesses.

-175 The Amazonian Carbon Observatory Network

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Despite its important role for the global carbon cycle, current understanding of the Amazonian, and more broadly the tropical, carbon cycle is poorly constrained by observations, which result in large uncertainties in predictions of the fate of the Amazonian carbon budget under a warming climate. Since 2012, the Amazon region has been the focus of major UK and Brazilian research projects that aim at improving our knowledge of the Amazonian carbon cycle using detailed, aircraft observations of CO2 and CH4 at four sites. These measurements are a great advance, but they are realized only twice per month. Space-borne measurements have the ability to fill observational gaps and to complement such in-situ datasets and thus to improve the spatial and temporal coverage over regions such as the Amazon. It is essential, however, that such space-based observations are properly tied to the World Meteorological Organization (WMO) reference standard to ensure acceptance of space-based datasets by the carbon cycle community and to prevent misleading results on regional carbon budgets. The central aim of the Amazonian Carbon Observatory Network is to bridge the gap between in-situ and remote sensing observations and communities and to evaluate the feasibility of remote sensing of greenhouse gas (GHG) concentrations for the purpose of GHG flux monitoring over Amazonia to improve our understanding of the Amazonian carbon cycle and to increase our ability for observing tropical carbon fluxes.

-176 Role of GOSAT total column CO2 observations in the estimation of CO2 surface fluxes

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Robust estimates of CO2 sources and sinks are necessary to support carbon management policies, as well as to improve the understanding of carbon-climate feedbacks and thus to improve the predictive ability of earth system models. Hitherto, the ability to accurately obtain global flux estimates at fine spatiotemporal scales has been constrained by the sparse distribution of the in situ CO2 measurement network. With the launch of the Greenhouse gases Observing SATellite "IBUKI" (GOSAT), it is expected that the global coverage provided by GOSAT will improve the scientific understanding of carbon cycle processes and budgets at regional and global scales. Due to its relatively young operational status, however, it is currently unclear the extent to which: (a) the GOSAT XCO2 observations can constrain global fine-scale flux estimates with reasonable precision and accuracy, and (b) the dense but lower precision GOSAT data provide additional information relative to the high precision but sparse observations from the in-situ observations. In this study, XCO2 observations retrieved via the GOSAT-ACOS algorithm and CO2 measurements from surface flask sites are assimilated using a geostatistical ensemble square root filter (GEnSRF; Chatterjee et al., 2012, doi: 10.1029/2012JD018176) to constrain global surface fluxes. GEnSRF is well-suited for conducting the analysis as it has been designed to: (a) handle large observational datasets available from satellites, such as the GOSAT instrument, (b) provide estimates of surface fluxes at high spatial and temporal resolutions (spatial: 1 degree × 1.25 degree; temporal: daily), and (c) estimate data-driven fluxes independently of any a priori flux estimates from flux models and/or inventories. CO2 fluxes are estimated over a period of two consecutive years (June 2009 – May 2011), and demonstrate that the addition of the GOSAT XCO2 observations result in a shift in uptake from the tropical to the temperate lands relative to the flux estimates based only on the surface flask network. In addition, GOSAT observations are found to be particularly valuable for constraining fluxes: (a) during the summer season over the land, and (b) across all seasons over the oceans; in both cases, due to the large number of good-quality retrievals available from GOSAT relative to the limited data available from the surface network. The value of the GOSAT observations is further assessed via a diagnostic metric based on information theory, which within the GEnSRF framework allows for an unbiased quantification of the observational influence on the posterior flux estimates. The metric reveals that beyond the specific cases outlined above, GOSAT observations have a limited influence on the analysis in comparison to the ground-based network. This is attributed to both the limited sensitivity of the GOSAT observations to the surface fluxes and the challenge associated with representing the link between variations in column-averaged CO2 concentrations and surface fluxes in current atmospheric transport models. Nonetheless, overall results underscore that as the errors associated with the GOSAT retrievals decrease, the XCO2 observations have the ability to provide robust fine scale flux estimates. Finally, as part of this study, we provide updated global and regional carbon budgets using both the GOSAT and the surface flask observations, which is a critical step towards attributing the variability and trends of the CO2 surface fluxes to the underlying drivers.

-177 Global Carbon Budget and its Anthropogenic Perturbation in the Land-Ocean Aquatic Continuum

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

A substantial amount of atmospheric carbon taken up on land through photosynthesis and chemical weathering is transported laterally along the aquatic continuum from upland terrestrial ecosystems into the ocean. So far, global carbon budget estimates implicitly assumed that the lateral transport and the myriad of transformation processes along this aquatic continuum have remained unchanged since pre-industrial times. We show here that the anthropogenic perturbations to the land-ocean aquatic continuum may have increased the flux of carbon to inland waters by as much as 1 Pg C yr-1 since preindustrial times, mainly by enhanced carbon exports from soils. Most of this input to upstream rivers is either lost back to the atmosphere by CO2 outgassing (~0.4 PgC yr-1) or sequestered in sediments (~0.5 PgC yr-1) along the freshwater-estuarine-coastal waters continuum, leaving only a perturbation carbon input of ~0.1 PgC yr-1 to the open ocean. Our revised estimate also results in 0.9 PgC yr-1 carbon storage in terrestrial ecosystems in agreement with recent forest inventories. The anthropogenic perturbations to the land-ocean aquatic continuum carbon fluxes are thus significant and need to be taken into consideration in global anthropogenic CO2 budgets.

-178 First net annual carbon balances of the Amazon basin from in-situ vertical profile sampling

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Tropical land is a very poorly constrained component of the carbon cycle, although it is potentially very important because it hosts a very large fast releasable carbon pool in forests and soils potentially amenable to feedbacks with climate. The tropics are a poorly constrained component because until recently there have been very few lower troposphere greenhouse gas measurements that are regionally representative. Amongst the tropical land regions the Amazon is by far the largest and also hosting the largest carbon pools (~200 PgC). Here we report the results from a recently established pan Amazon lower troposphere biweekly to monthly atmospheric sampling program for the years 2010 and 2011. 153 vertical aircraft profiles were performed over 4 sites distributed to represent entire Amazon Basin during this period. 2010 was anomalously dry while 2011 was a wet year thus providing an interesting contrast, particularly given the intensification of the hydrological cycle over the last few decades with an increase in severe droughts and extreme flooding events. Our data permit us not only to estimate net carbon fluxes but using carbon monoxide also carbon release via fires and thus the net carbon balance of the unburned land vegetation. We will discuss the annual and seasonal carbon balances for these two years derived from the atmospheric data using a simple but powerful back-trajectory based atmospheric transport inversion approach, will relate them to controls of land vegetation functioning and independent diagnostics like fire counts and precipitation and will finally put the results into a global perspective.

-179 Quantifying the air-sea CO2 exchange of continental shelf seas at the global scale: a regionalized data driven approach

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Continental shelf seas represent 30 106 km2 and account for 8% of the world's oceanic surface. With a continental shelf CO2 sink recently estimated at 0.25±0.25 Pg C yr-1 (Laruelle et al., 2010, Cai, 2011), they contribute significantly to the reported global oceanic uptake of atmospheric CO2 of 2.0±0.7 Pg C yr-1 (Takahashi et al., 2009). However, these estimates are based on extrapolations from limited datasets of local flux measurements.

Here, we propose to evaluate the CO2 air-sea exchange using the global database of marine pCO2 measurements SOCAT v1.5 and additional public data, together with global wind speed and atmospheric forcings as well as selected observational atmospheric pCO2 data compiled in GlobalVIEW. Although the data coverage is highly heterogeneous in the SOCAT database, it contains hundreds of thousands of coastal measurements and allows constraining robust regional carbon budgets for several regions of the world. Our analysis uses a global segmentation of the shelf in 45 large units and 145 sub-units. Within each of these units, the data density determines the spatial resolution used to calculate the air-sea CO2 fluxes, from a 0.5 degrees resolution in the best surveyed areas (e.g. East coast of the US, Baltic Sea) to a whole unit resolution in the least surveyed. Our results provide new quantitative estimates for well-known CO2 sources (California Current) and CO2 sinks (North Sea, Arctic shelves) on the shelves and allow constructing a regionalized budget for the global air-sea CO2 exchange of the coastal ocean.

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-180 Joint inverse modeling of surface CO2 fluxes using satellite and surface observations of CO2 mixing ratio

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Accurate and precise estimates of regional sources and sinks of carbon dioxide (CO2) are necessary for developing effective carbon management strategies and reliable projection of future atmospheric abundances of CO2. Surface flask observations of atmospheric CO2 have been used in estimating global and regional carbon sinks and sources via various kinds of atmospheric inversion analyses. Though agreement has been made in capturing hemispheric-scale fluxes, large uncertainties still remain in regional flux estimates in different inversions. Space-based observations of CO2 provide greater observational coverage than the surface observational network, and offer complementary constraints on estimates of regional sources and sinks of CO2. Using the 4-dimensional variational data assimilation system in the GEOS-Chem model, we present a joint inversion analysis to estimate surface fluxes of CO2 using satellite observations from the Greenhouse Gases Observing Satellite (GOSAT) and flask measurements from the National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory Carbon Cycle Cooperative Global Air Sampling Network and Environment Canada. We examine here the additional constraints on regional estimates of the CO2 fluxes provided by integrating the GOSAT data with the flask data, and discuss uncertainty reduction obtained by the introduction of the satellite measurements as well as the uncertainty reduction with the surface data.

-181 Spatial and seasonal variability of CO2 evasion from rivers

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The land-ocean transfer of carbon (C) via rivers is an important part of the global C cycle. Recently, growing attention has been paid to the CO2 evasion from rivers to the atmosphere and global estimates in the range 0.3-1 PgC yr-1 have been proposed (Cole et al. 2007; Richey 2004). The robustness of these global CO2 evasion estimates critically depends on the amount and spatial coverage of observational data. For large areas of the world, including potential hot-spots of biological carbon-turnover and CO2 emissions, data density is low and the available data only cover specific fluvial systems and only some periods of the seasonal cycle. In order to fill these data gaps and obtain representative global estimates of CO2 evasion, advanced interpolation/extrapolation techniques are required.

It has been shown that spatial patterns in river water pCO2 can, to a certain degree, be predicted at continental scale (Lauerwald et al., 2013). This approach has recently been used in a regional scale study to produce spatially and seasonally resolved estimates of CO2 evasion from the fluvial network along the North East coast of North America, revealing significant seasonal patterns in river CO2 evasion for this area (Regnier et al, submitted). In the framework of the EU project GEOCARBON, we extend our approach to the global scale. Using the extensive hydrochemical data base GloRiCh, we calculate pCO2 values for > 6,900 river water locations. Next, based on these data, we explore the relationships between river water pCO2 and environmental variables that can be used as predictors of pCO2 in regions not covered by field measurements. Existing empirical approaches are then used to calculate spatially explicit estimates of the river surface area and the gas exchange velocities at the air-water interface. The combination of all these estimates allows us to quantify the CO2 evasion at 0.5 degree resolution for the global river network.

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-182 Diurnal and Synoptic Variability of Carbon Dioxide and Related Tracers in the Namib Desert

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

We present the first results from a new atmospheric station in southern Africa, the Namib Desert Atmospheric Observatory (NDAO). Continuous measurements of carbon dioxide are made at a height of 21 m, approximately 50 km inland at the northernmost border of the Namib Sand Sea (23°34′ 0″ S; 15°03′ 0″ E). Observations of methane, nitrous oxide, carbon monoxide, atmospheric oxygen and basic meteorology are also made at the station. Results for austral spring and summer show background levels typical for the Southern Hemisphere. As the site is located on a gravel plain with little vegetation, local fluxes appear to be low to negligible during the station′ s operational time (October 2012 – present). This is evident in the inverted diurnal cycle of carbon dioxide, with the daily peak usually occurring during the afternoon and minimum values at night. Variability at the site is dominated by the local wind system, which alternates between a sea breeze (southwesterly) and the coastal "plain-mountain wind" (northwesterly). The competing influence of these two flows also creates a strong diurnal cycle in atmospheric oxygen and a small but pronounced diurnal cycle in methane. Accurate modeling of atmospheric transport in the central Namib Desert is complicated by the local wind system. Finally, several synoptic events reveal the influence of biomass burning on terrestrial air masses from the interior of southern Africa.

-183 The seasonal cycle of the δ13CDIC in the North Atlantic Subpolar Gyre

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The isotopic composition (δ13CDIC) of dissolved inorganic carbon (DIC) in the ocean is a useful semi-conservative tracer for various oceanic analysis (e.g. water masses, paleo-circulation) and global carbon studies (constraint for global carbon budget, interpreting anthropogenic carbon). The mean annual large scale distribution of this tracer is now relatively well documented in surface and at depth, but the temporal variability (seasonal to decadal) still needs to be completed.

The seasonal cycle of the δ13CDIC has been well described in the subtropical area (e.g. BATS and HOT) but not yet composed in the subpolar regions. This study introduces for the first time the δ13CDIC seasonality in the North Atlantic Subpolar Gyre (NASPG) using δ13CDIC data obtained between 2005 and 2012 sampling from merchant vessels Skogafoss and Reykjafoss (13 cruises) along with DIC and nutrients observations. On the seasonal scale, the NASPG is characterized by higher δ13CDIC values during summer than during winter, clearly opposed to DIC and nutrients. The seasonal amplitude for δ13CDIC (~0.77‰) and DIC (~70 µmol kg-1) are very large compared to subtropical regions. The seasonality in surface waters is attributed to biological activity in summer and to winter entrainment of deeper waters with strong remineralization. During all seasons, we observed a strong linear relationship between δ13CDIC and DIC. The data also revealed a negative anomaly for δ13CDIC, DIC and nutrients in August 2010 that could be explained by an enhanced biological activity associated to a warming up to +2°C in 2010. In addition, winter data shows a large decrease in δ13CDIC associated to an increase in DIC between 2006 and 2011-2012. The observed time rates (-0.04‰ yr-1and +1.7µmol kg-1 yr-1) are much larger than the expected anthropogenic CO2 signal and Suess effect. This highlight the need to maintain observing system of both tracers to separate natural and anthropogenic signals, as well as to better constrain atmospheric inversions and validate ocean carbon models.

-184 Carbon 13, an additional constraint to reveal anthropogenic carbon uptake in the Southern Indian Ocean

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Anthropogenic carbon dioxide (CO_2) resulting from fossil fuel burning and land use change is depleted in 13C relatively to 12C. In response to the increase in anthropogenic CO_2 emissions, the carbon isotopic composition (δ13C) of atmospheric CO_2 decreases in average by 0.02 ‰ yr^{-1}; consequently, the δ13C values of dissolved inorganic carbon (δ13CDIC) in sea water also decreases; the so-called oceanic 13C Suess Effect provides additional information to understand the anthropogenic CO_2 change.

The Southern Indian Ocean is a well-known region that stores a substantial part of the total oceanic Cant inventory. Ocean CO_2 observations conducted in this region since 1978 have shown large changes in DIC concentrations in intermediate and mode waters, which were attributed to both anthropogenic CO_2 uptake and natural variability in ocean carbon cycle. In this context, we describe new δ13CDIC observations obtained in the South-Western Indian Ocean (25°-60°S) during seven OISO cruises (1998-2012), which complete the historical data set (GEOSECS 1978). This study reveals strong and water-dependent relationships between the δ13CDIC and the other parameters (DIC, oxygen, nutrients) as well as a large change in the carbon isotopic composition in the first 1000m north of the frontal zone. To isolate the anthropogenic signal from the other natural processes, we used an extented MultiLinear Regression (eMLR) between 1978, 1999 and 2012 (100-1200m). These results suggest a large increase over the 34-years period in mode waters (STMW-SAMW) in anthropogenic CO_2 storage (close to 30µmol kg^{-1}) as well as in the amplitude of the oceanic 13C Suess Effect (close to -0.6‰, either -0.018‰ yr^{-1}) with a non-steady Cant storage rate. In addition, the positive values of oceanic 13C Suess Effect observed south of 40°S in deep waters would suggest a balance between the anthropogenic signal and the natural variability of the processes, highlighting amongst others the interest to couple DIC and δ13CDIC observations to better understand the anthropogenic carbon change.

-185 Total Alkalinity Measurements in the Northern Arabian Gulf: Signals of Acidification

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

The ecosystem of the Arabian Gulf is facing serious challenges in terms of climate change issues. The rapid economic growth of the oil-rich Arab states bordering the Gulf increases the energy/water demand and eventually increases the emission of the greenhouse gasses (GHGs); mainly carbon dioxide; as a result of the larger consumption of fossil fuels. The aridity nature of the region contributed in removing the elevated carbon dioxide into the Gulf's water. Once the carbon dioxide dissolves in the water, all its inorganic forms will operate as a natural buffer to the addition of hydrogen ions. But with more carbon dioxide in the seawater system, the carbonates will decrease and the overall buffering capacity will reduce then ultimately acidity will increase. The pH, dissolved inorganic carbon and the total alkalinity are equally important to understand the carbon dioxide system and acidification process in any aquatic environment. Therefore, this study reports the fortnightly measurements of total alkalinity in the surface water of the Northern Arabian Gulf (NAG) during the period between May 2011 and February 2013. The water samples were collected at approximately 1 m depth below the water surface. The total alkalinity was measured using a visocolor HE alkalinity AL7 titration test kit. In-situ measurements of pH, salinity, temperature and dissolved oxygen were conducted using YSI 556 MPS instrument, equipped with a glass sensor with a resolution of 0.01 and accuracy of±0.2 pH units. The sensor was calibrated using three NIST standard solutions between measurements. The concentration of total alkalinity varies between 2320-3800μmol/kg with an average of 2975.09μmol/kg. The minimum of measured total alkalinity is four times higher than those minimum values reported in the Indian Ocean. The higher total alkalinity ranges in the surface water could be a possible quick response to acidifying the North Arabian Gulf waters. In fact, the drop of ~80μmol/kg is also observed in the surface sea water measurements. On the other hand, the pH, salinity, temperature and dissolved oxygen measurements show a very clear seasonal variation without any significant correlation with the measured total alkalinity. Remarkably, the pH measurements show an increasing trend and the salinity does not follow the measured total alkalinity behavior. These observations could not be justified now. Though, the pH in the Arabian Gulf is in decline whereas the temperature is increasing, according to a recent study by (S. Uddin, 2012). The pH and other hydrographic parameters measurements along with the total alkalinity are being continued, considering several chemical, physical and biological factors that could affect the alkalinity/acidity processes. The signals of acidification are existed in the Northern Arabian gulf and keen monitoring and interpretation is needed in order to predict the future trends of acidification in the whole Gulf.

-186 Large changes in seasonality of the surface ocean carbon cycle under anthropogenic climate change

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

There is growing concern that the ocean uptake of anthropogenic carbon may be slowing under the impact of anthropogenic climate change, relative to what one would expect for an unperturbed ocean state. Here we make combined use of observations, theoretical considerations, and CMIP5 coupled climate simulations to show that the seasonal cycle in sea surface pCO2 and air-sea CO2 fluxes will increase significantly over the 21st century, and that this finds maximum expression in subtropical mode water formation (subtropical convergence zones). This increase in the seasonal cycle is shown to be due to non-linearities in the buffering capacity of seawater under increasing ocean carbon concentrations. It is shown that summer-biased measurements lead to significant underestimates of carbon uptake by the end of the 21st century that can be as large as 3 PgC/year.

Additionally, using the CMIP5 models, we evaluate whether these same non-linearities in the buffering capacity of seawater contribute to 21st century carbon-climate feedbacks. The CMIP5 models reveal that the largest reduction in uptake via air-sea fluxes due to physical state perturbations over the 21st century occurs during summer. This indicates that chemical saturation is at least as important as perturbations to water mass transformations and subduction rates in inhibiting ocean uptake of CO2. A quantitative assessment of this effect is presented for the CMIP5 models.

-187 Capability of the Error Covariance Models in CO2 Inverse Problems in Simultaneously Estimating Fossil Fuel Emissions and Biospheric Fluxes

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The accurate temporal and spatial quantification of sources of fossil fuel emissions constitutes a considerable scientific challenge. Amospheric inverse models have the capability to overcome this challenge and provide country level estimates of fossil fuel emissions. However, presently due to sparsity of measurements and computational bottlenecks they are primarily used for providing a combined estimate of "biospheric fluxes and fossil-fuel" emissions of carbon dioxide (CO2) at coarse spatial and temporal resolution. Even in these coarse resolution inverse models disaggregation of a strong signal of biospheric fluxes and a weak signal of fossil-fuel emissions has proven to be difficult but has been accomplished through tracers like 14CO2.

In this study, an attempt is made to disaggregate biospheric fluxes and fossil-fuel emissions on the basis of error covariance models rather than through tracer based CO2 inversions. The goal is to more accurately define the underlying structure of the two processes. Thus, a stationary exponential covariance model in conjunction with a semi-stationary covariance model derived from night lights is used for estimating biospheric fluxes and fossil fuel emissions in an inverse modeling framework that excludes prior knowledge of both these fluxes. Non-negativity constraint on fossil-fuel emissions is imposed by using Lagrange multiplier constrained optimization method. The study is performed within a pseudo and Real data framework for the year 2008 by using the ground based CO2 measurement network over North America. The quality of disaggregation is examined with and without measurement error by comparing the spatial distribution of fluxes and monthly sources and sinks of fossil-fuel emissions and biospheric fluxes. In addition to disaggregation of fluxes, the ability of the covariance models derived from night-lights and/or population density in explaining the fossil-fuel emissions over North America is also examined. The advantage of the simple covariance models proposed in this study can aid in improved estimation and disaggregation of fossil-fuel emissions from biospheric fluxes, especially, in the tracer based inverse models.

-188 Satellite Observations of Greenhouse Gases using Thermal Infrared Sounders

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Hyperspectral sounders like Atmospheric InfraRed Sounder (AIRS, since August, 2002), the Infrared Atmospheric Sounding Interferometer (IASI, since 2008) and the Cross-track Infrared Sounder (CrIS, since 2012) on the NPP provides us the opportunity to measure atmospheric greenhouse gases, like CO2, CH4 and N2O. Although their vertical sensitivities to these GHG gases are mainly in the mid-upper troposphere and less in the troposphere, these measurements have provided valuable information on their distribution and transport in the atmosphere. Some of these data have been used in inverse modeling to improve the quantification of the sources of CO2 and N2O. This paper introduces the measurements of CO2, CH4 and N2O from NOAA and NASA with a focus on the measurements of CH4. Some recent development and results using these data will be presented.

-189 Comparison of continuous in-situ CO2 observations at Jungfraujoch, Switzerland using two different measurement techniques

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

A three year (January 2010 to December 2012) comparison of continuous in-situ CO2 concentration observations has been performed at Jungfraujoch, Switzerland using two different measurement techniques run by the University of Bern (UBern) and the Federal Laboratories for Material Science and Technology (Empa). Empa uses the wavelength-scanned cavity ring down technique (Picarro G1301 from January 2010 to July 2011 and Picarro G2401 from September 2011 onwards) coupled to a custom-built calibration/drying unit. Along with CO2, the instruments are also capable to measure CH4, CO (with the newer instrument) and H2O. Thus, the CO2 data can be corrected for interferences of remaining water traces. Measurements with and without the drying unit were performed during the whole period in order to test the water correction routine.

The UBern system is a combined system for atmospheric oxygen and CO2 measurements. The cryogenically dried air is analyzed for CO2 with a Maihak analyzer based on the broad-band infrared absorption technique. The measurement frequency is every second. The final reported data are averages per 6 minute periods.

At the conference we will present the 2 observational records for the 3 year period. The results shows that the two systems agree well and are mostly matching the WMO compatibility target of 0.1 ppm. Offsets between both systems ranged from -0.16 ppm to +0.31 ppm for the inter-comparison period from January 2010 to December 2012. The linear fit of the data, excluding obvious outliers, leads to a slope of 1.02+-0.02 ppm/ppm. This slope is in good agreement with the slope obtained when comparing 9 standard cylinders in the range of 360 to 450 ppm CO2 resulting in a slope of 1.0014+-0.0024 ppm/ppm.

-190 Temporal monitoring of the air-water CO2 exchange in a Mediterranean Wetland

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Inland and transitional aquatic systems are among the most important ecosystems on Earth because of their role in regulating global carbon cycling. Wetlands and floodplains probably account for the majority of these systems, yet their carbon dynamics are poorly constrained in terms of in-situ data. Due to this need, our study is centered in examining the carbon system in Doñana wetlands, a natural area located in the south-western coast of Spain, characterized by containing a great diversity of biotopes, such as lagoons, marsh-lands, fixed and mobile dunes, scrub woodland and maquis. Those territories included in Doñana area have different degree of environmental protection covering over 100 000 ha: Biosphere Reserve created in 1964, RAMSAR site in 1982 and World Heritage site by UNESCO in 1995. This work presents the results of a monitoring program that was aimed at analyzing the spatio-temporal variability of dissolved pCO2 and air-water CO2 exchange in some of the most representative aquatic systems of Doñana.

Data were obtained from continuous measurements taken by pCO2 autonomous sensors (SAMI pCO2) and from discrete derived calculations using monthly alkalinity and pH records obtained in situ. Sensors were deployed in the shallow semi-permanent pond of Santa Olalla and in the riverine source of La Rocina Stream (El Rocio, Huelva). Salinity, temperature, dissolved oxygen and fluorescence were also measured in the pond with a Seabird CTD 16 plus whereas a Yellow Spring Instruments probe was used in the stream. Additionally samples were taken for laboratory analysis, including suspended material and dissolved organic carbon determinations. Data were collected from November 2011 until February 2013.

Drastic temporal variations of pCO2 in water were observed in both aquatic systems, ranging from 50 to 16000 ppm approximately. Seasonal variability could be linked to the presence of autotrophic or heterotrophic conditions brought about by changes in the water supply and the temperature annual cycle. This pattern clearly conditioned the behavior of the systems as a source or sink of atmospheric CO2.

-191 Carbon monitoring in the Strait of Gibraltar: tracking the Mediterranean CO2 content.

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The Strait of Gibraltar represents the only connection between the Mediterranean Sea and the Atlantic Ocean. Water circulation in the Strait is characterized by an eastward surface inflow of Atlantic waters (AI) that is compensated by a deep outflow of Mediterranean waters (MOW) that abandons the basin towards the North Atlantic trough the Gulf of Cadiz. The pattern of water exchange through the Strait is characterized by large fluctuations at different time scales, from seasonal and subinertial modulated by the change of atmospheric pressure in the Mediterranean basin to tidal variability. The MOW and AI are the mixture of different water bodies originated in the Atlantic and Mediterranean that appear either intermittently or mixed in changing proportions throughout the year creating considerable spatial and temporal variations in the position and intensity of both water flows. The exchange of water masses with distinct thermohaline properties and carrying compounds at a different concentration influences the biogeochemical inventories of the Mediterranean and Atlantic basins. In particular, carbon transport through the Strait of Gibraltar is a complex process that markedly governs carbon balance in the two neighbor basins. The export of alkalinity and inorganic carbon from the Mediterranean to the Atlantic has been reported whereas the import of anthropogenic carbon and dissolved organic carbon towards the Mediterranean takes place (Huertas et al., 2009, Flecha et al., 2012). Carbon transport through the channel is being monitored through the periodic sampling of the Gibraltar Fixed Time Series (GIFT).In order to examine the temporal variability of the carbon content in the MOW, a mooring line containing autonomous sensors (SAMI devices) for simultaneously recording of pH and pCO2 was installed in the GIFT in August 2011. The equipment also includes a CT for salinity and temperature measurements along with ADCP for water transport records. Results presented in this work show the first data base that has been generated in the area from November 2011 to November 2012 and the statistical analysis performed to identify the frequency of variability. During this period, the MOW was characterized by pCO2 values ranging from 400 to 445 ppm whereas the pH of the Mediterranean water oscillated 0.05 pH units, starting at 7.87. A spectral (Fourier) and harmonic analysis of the time series indicated that the short frequency variations observed in both parameters are not related to the tidal regime. In contrast, TS diagrams of the data reveal that oscillations may be well correlated with the changing proportion of the different water bodies that integrate the MOW throughout the year.

-192 Isotope- and tracer- based measurements of fossil fuel and biospheric carbon dioxide in Paris during winter 2010

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The Paris agglomeration is the third biggest megacity in Europe (12 million inhabitants) and according to national emission inventories, the agglomeration is responsible for 13 % of the French anthropogenic CO2 emissions. They are mainly originating from road transport, residential and industrial energy consumption. The objective of our feasibility study was to design an efficient monitoring strategy in order to quantify future trends in anthropogenic CO2 emission in the Paris area. During the winter campaign of the European MEGAPOLI and the French CO2-MEGAPARIS projects, we performed high temporal resolution measurements of CO2 and related trace gases (CO and NOx) from January to February 2010 in the thirteenth arrondissement of Paris (south). We also sampled air in more than fifty flasks covering four full days at the same place for radiocarbon (14CO2) and 13CO2 analysis. In parallel with the Paris measurements, in-situ CO2, CO and other trace gases were monitored at Gif-sur-Yvette, a semi urban station 20 km south west of Paris. Similar synoptic variations of CO2 and CO mixing ratios were found in both sites with maximum mixing ratio up to 495 ppm CO2 and 1000 ppb CO downtown Paris. The mean diurnal variation during this winter period shows peak to peak amplitude of 15 ppm CO2 and 150 ppb CO at Paris and 10 ppm CO2 and 40 CO ppb at Gif-sur-Yvette.

We propose to present the results from the isotopic measurements performed in Paris. Radiocarbon measurements in Paris were used to identify the relative contributions of 77 % CO2 from fossil fuel consumption (CO2ff from liquid and gas combustion) and 23 % from biospheric emission (CO2bio from biofuels and from human and plant respiration). The 13CO2 analysis indicated that gas and liquid fuel contributed 70 % and 30 %, respectively, of the CO2 emission from fossil fuel use. Continuous measurements of CO and NOx and the ratios CO/CO2ff and NOx/CO2ff derived from radiocarbon measurements make it possible to estimate the fossil fuel CO2 contribution over the entire campaign. The ratios CO/CO2ff and NOx/CO2ff are function of the air mass origin and exhibited daily ranges of 7.9 to 14.5 ppb ppm-1 and 1.1 to 4.3 ppb ppm-1. These ratios have been compared with emission inventories from EDGAR 4.2 (global inventories), IER (European inventory) and the national ones from CITEPA and AirParif. The comparisons are sufficiently consistent with the different emission inventories given the uncertainties of the different approaches.

-193 Trends of long-term changes of CO2 and other related gases concentrations in the atmosphere at Hateruma and Ochi-ishi stations in Japan - influence of Asian emissions -

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

We have been continuously observing CO2 and other related gases in the atmosphere at Hateruma Island since 1993 and at Cape Ochi-ishi since 1995. Hateruma island is located in southern most part of Japan (subtropical area) and Cape Ochi-ishi is located in northern part of Japan. Because Hateruma Island is very small (about 5km dia.) and little inversion layer is developed at night, regional background CO2 concentration in the western Pacific can be clearly observed. Therefore, long record of the concentration should be reflected from eastern Asian regional emissions change for CO2 and other gases. On the other hand, northern site must have characteristics of high latitudinal atmosphere, which is influenced by Siberia region.

CO2 level in Hateruma was similar to that of Mauna Loa in Hawaii in summer but the winter CO2 concentration was slightly higher than that in MLO. It is related to air motion such as SE and NW monsoon in each season in this area. CO2 concentration in Cape Ochi-ishi was higher than that in Hateruma in winter but lower in summer, which is similar tendency to the site in high latitude. Long-term trend showed continuous increasing with the average rate of about 1.9ppm/y for twenty years for both sites. However CO2 growth rate was changed with time and highly correlated with annual global temperature anomaly. This relation was quite similar to that of MLO. The most different characteristics in Hateruma from other site were seen in the drastic increase of spring and winters peak events and their strength from 2002 to 2010. Until then we just recorded only small peak events at those season, but after 2002 the observed events became larger than before, the peak height increased from a few ppm up to 15ppm during 5-6years. This drastic increase was not seen in northern site (Cape Ochi-ishi). Hateruma was more influenced by Asian outflow than Cape Ochi-ishi, because the site was much closer to the Asian continent.

Other gaseous constituents were also studied and discussed in terms of Asian emissions. Especially NOx and Halocarbons winter peaks were often observed associated with CO2 peak. Such relationship will be discussed in this presentation.

Results from modeling works on CO2 variability in Hateruma suggest the Asian CO2 emission increase is a reason behind the drastic increase of background averaged CO2 concentration level during winter and spring in this region from 2002 to 2010.

-194 Exploring the small-scale interactions and feedbacks between croplands and the atmosphere for carbon, water and energy

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

During the growing season of agricultural crops, the surface exchanges of carbon, water and energy with the atmosphere are important drivers of the atmospheric temperature and humidity. Recently, Vilà et al. (2012, Nature Geoscience) showed the possible impact of daily exchange processes on cloud formation under future warm and dry conditions. At the same time, the atmospheric temperature, humidity and cloudiness strongly influence the developmental rate and final yield of crops.
To further investigate these interactions, we coupled a detailed crop model used in agricultural yield forecasts (GECROS) with a simple and robust model for the convective boundary layer (MXL). We compared, for a maize crop, the performance of this dynamic system to an alternative coupling of the MXL model with a simpler surface scheme based on a widely used assimilation-conductance relationship (A-gs). We find that the two coupled surface schemes slightly disagree on their daily gross assimilation rates, with the MXL-A-gs midday flux being ~10% higher. However, huge differences exist in terms of their internal CO2 concentration and surface CO2 conductance. The dynamic coupling with boundary layer variables in MXL-GECROS has a minor influence on CO2 assimilation, but produces an energy budget that is different from the one obtained with stand-alone GECROS driven by fixed meteorological conditions. This emphasizes the importance of the feedback between the surface and the atmosphere. We verified our coupled system with available observations over a growing maize field and tested the sensitivity of our results to the variation in leaf area index, nitrogen nutrition level, soil moisture, cloud cover and others. We will present our findings with implications for the use of a dynamic coupling of crop models in weather and climate models to simulate the carbon, water, and energy budgets of croplands.

-195 Investigating the urban CO2 excess of the Greater Toronto Area using two sister sites

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

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Investigating the urban CO2 excess of the Greater Toronto Area using two sister sites

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The addition of Greenhouse Gases (GHG) to the atmosphere has significant impact on the Earth' s biogeochemical cycles and can strongly influence atmospheric chemistry and in particular the global radiation balance [1]. Cities are said to be responsible for approximately 75% of anthropogenic GHG emissions while comprising only two percent of the land area [2]. GHG monitoring sites close to highly populated regions thus offer the unique potential to closely track human emissions of relevant trace gases and derive observation-based source apportionments. The choice of a proper background site does, however, pose a number of challenges, e.g. it is important to distinguish the local/regional from the large-scale contributions to the observed local concentration offsets [3]. The presented study investigates the regional offset of two "sister sites" in Ontario, Canada. Our CO2, CO, ^{222}Rn, 14CO2 and 13CO2 data sets are part of Environment Canada' s continuous monitoring program. Our site in Egbert, Ontario in a rural environment is located approximately 60 km north of the urban site in Toronto, Ontario. Continuous ^{222}Rn observations can reveal situations when both sites show similar diurnal boundary layer height variations and synoptic transport patterns, or they help us to identify situations when the sites encounter significantly differing air masses. During these latter situations Egbert is not an appropriate background for the Toronto station. Selecting situations where the sites show similar patterns allows us to assess the influence of the localized emissions of the Greater Toronto Area. Using 14CO2 and CO measurements as a proxy we can derive an estimate of the local contribution of fossil fuel burning to the CO2 enhancement (DFFCO2). During winter time we find situations where the local offset of CO2 (DCO2) can be fully attributed to fossil fuel CO2 emissions. When using a (generic) Northern Hemispheric background as reference the local CO2 offset, on the other hand, always comprises a significant biogenic CO2 component. Finally, the results of a lagrangian dispersion model help us to define the area of influence (footprints) affecting our two sites. Analyses such as those presented here rely on highly accurate long-term GHG observations programs integrated with a high-resolution modeling capacity.

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-196 Analysis of Asian regional characteristics on greenhouse gaseous concentrations obtained by NIES flask sampling network

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

We Analyzed Greenhouse gaseous (GHG; CO2, CH4, CO, H2, N2O and SF6) concentrations and isotope ratios (δ13C and δ18O) in the air collected by flasks at approximately weekly interval at seven Asian ground-base sites in the NIES flask sampling network. These network includes Ochi-ishi (43.09N, 145.30E: 40m), Hateruma (24.05N, 123.80E, 80m), Guiyang (26.34N, 106.43E, 1598m), Nainital (29.22N, 79.40E, 1958m), Maunaloa (19.54N, 155.58W, 3397m), Danum Valley (4.97N, 117.83E, 526m), Comilla (23.26N, 91.11E, 30m). Ochi-ishi (COI) is located at eastern Hokkaido, Japan. Hateruma (HAT) is a remote southern island located about 500km SW from Okinawa island, Japan. Guiyang (GUI) is located at the interior of southern China. Nainital (NAI) is located at the foot of Himalayas in India. Maunaloa is located on the Hawaii island in the north Central Pacific. Danum Valley (DMV) is located at tropical forest in northen Borneo island. Comilla (CLA) is located about 70km southeastern from Dhaka, Bangladesh.
CO2, N2O and SF6 concentrations in all sites have increased continuously in the observation period. In particular, GUI showed the highest average concentrations these and the increased rates of these gases have been accelerated since 2008.
Annual average CH4 concentrations among all sites didn’t elevate until 2007, but started to increase after that. Again GUI showed the highest concentrations among all sites. The sites expect NAI indicated the lowest concentrations in summer (Jul. to Aug.), and the highest in winter (Dem. to Jan.). On the other hand, NAI indicated the highest concentrations in summer to autumn (Aug. to Nov.), which suggested that methane emitted from paddy fields nearby the site.
In CO concentrations of GUI and HAT showed the highest concentrations in winter (Dec. to Jan.), but other sites showed in spring (Mar. to Apr.), which suggested that anthropogenic sources in China were large. GUI indicated the highest concentrations among all sites.
Thus, differences in the increased rates and the seasonal variation of GHGs concentrations among all sites were clearly found.

-197 Impact of two typhoon cases on meteorological elements and CO2 concentration over East Asia region by the regional model WRF-CO2

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Significant ability of regional CO2 transport models in simulating spatial variation of CO2 concentration over environmentally sharply changing locations is already noted (Ballav et al., 2012 Journal of Meteorological Society of Japan, 90, 959-976). In spite of that, it is important to examine the behaviour of the model when a highly time varying system like typhoon affects a station. In the present study, the regional model is WRF-CO2 (Ballav et al. 2012 ibid). Our domain covers the islands of Japan in the central part along with large part of China, part of Taiwan, part of Korea and Pacific Ocean. It is well known that any CO2 transport model has 3 independent components, namely (i) oceanic, (ii) fossil fuel emission and (iii) biospheric absorption or emission. For giving input flux for biospheric component, there are 2 sources i. e. Simple Biosphere Model (SiB3) with hourly (SH) and monthly (SM) averaging, and Carnegie-Ames-Stanford Approach (CASA) with 3-hourly (CH) and monthly (CM) averaging.

We are considering here 2 cases, each with passage of typhoon over the domain in two different periods of 2002. Impact of the 2 systems was studied at 7 stations i.e. YON (24.47°N, 123.02°E, 30m), HAT (24.05°N, 123.8°E, 10m), RYO (24.47°N, 123.02°E, 30m), COI (43.15°N, 145.50°E, 45m), MKW (34.85°N, 137.43°E, 50m), KIS (36.08°N,

139.6°E, 13 m) and DDR (36.13°N, 139.18°E, 40). Study has been made for CO2 concentration and the meteorological parameters like wind speed, air temperature and relative humidity. In both the cases, the observed track of the system has been recreated by the model nicely. Incidentally, the impact varies largely in 7 stations. But the model makes some consistent result: if the impact is strong, the concentration drops significantly as the system comes closest. When the system goes away, the concentration rises again. Detailed time series of CO2 concentration and meteorological parameter magnitudes is made both in observation and model for some days around the date of impact..

We have presented the Pearson Correlation Coefficient (CC) and Normalized Standard Deviation (NSD) between observed and model concentration. In the first case, CC is poor only at YON and it varies between 0.52 and 0.71 for other 6 stations, if SH is taken as biological flux. Then NSD is in general reasonable (between 0.51 and 0.88) barring 2 stations. Regarding meteorological parameters CC in general, is good barring only 1 case. Standard Deviation for observed and model data is in general close by, except in 1 or 2 instances.

For the second case, CC for CO2 concentration is poor to less significant only at KIS, DDR and YON. Otherwise it varies from 0.61 to 0.76 for SH combination. NSD is more consistent at all the stations. For the meteorological parameters, CC is in general good and the Standard Deviation for observed and model parameters is quite consistent.

One may conclude that the model simulation by WRF-CO2 for a highly time-varying system is reasonably well, though it may not be excellent.

-198 An approach to assessing benefits of advanced global carbon observation system

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Development and maintaining of a global carbon observation system consisting of satellites, towers for measurements of greenhouse gas concentrations and fluxes, a network of field studies, laboratories providing data analysis and modeling etc is very expensive. However, how can we estimate the corresponding benefits that such a system (or subsystem) returns to the society? In this paper we present an approach for assessing some of the benefits of an advanced carbon observation system.

The idea is that not being able to monitor the emissions from deforestation makes REDD a mitigation option that is potentially very costly. We aim to estimate the value of having better carbon flux measurements by evaluating the cost savings that these would imply. There are two (costly) uncertainties, which can be avoided through more exact carbon monitoring: 1) overcompliance - if we try to achieve a reduction in emissions from deforestation, but cannot be sure whether we will achieve the right reduction level, we have to reduce more than the expected value in order to reduce the risk of not achieving the target. 2) under-compliance - if we cannot monitor the decrease in carbon fluxes from reduced deforestation precisely, there will be an incentive to under-comply (=over-report), as it will not be detected. Over-compliance involves spending additional costs but is justified if we do not want to cross (unknown) thresholds triggering irreversible damages. Under-compliance, in turn, produces waste of costs (because only a part of deforestation is reduced) and forces policymakers to spend money for additional emission reduction in other – more costly - activities where monitoring is more exact (e.g. by installing carbon capture in the energy sector).

We use the Global Forest Model (G4M) to calculate deforestation emissions and costs for deforestation reduction, and expert knowledge for an estimate of the reduction of uncertainties in deforested areas, impacted biomass stocks, emissions from soil carbon consecutive to deforestation, re-growth and NPP of secondary ecosystems.

Preliminary results. An advanced carbon observation system may result in reduction of uncertainty in estimates of net emissions from deforestation approximately by half (to 30%, 1-sigma uncertainty) by 2025. 60% accumulated emission reductions in 2026-2050 (19,000 mtCO2) can be obtained at approximately 6$/tCO2 for which the countries must pay 6$/t CO2 x 19,000 Mt CO2= 114,000 million $. However, after the reduction in uncertainty due to more precise carbon flux measurements, we only need to achieve 30% (9,500 Mt CO2) emission reductions by avoiding deforestation (at a carbon price of 3.25 $/t CO2), i.e. 3.25 x 9,500 = 30,875 million $. We can thus save 83,125 million $.

Acknowledgements. The research leading to these results has received funding from the European Union's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 283080, project GEOCARBON

-199 Using Earth Observation (EO) data to constrain leaf phenology of the terrestrial biosphere model ORCHIDEE

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Vegetation phenology plays a direct role in controlling the amount of carbon (C) that is assimilated and released during photosynthesis and respiration. The length of the growing season also affects the surface energy balance and hydrology through changing albedo, surface roughness and evapotranspiration, with important feedbacks to the climate. A recent study (Richardson et al., 2012) showed that there is bias in growing season length and uncertainty in inter-annual variability predicted by most Terrestrial Biosphere Models (TBMs), some of which are used in IPCC predictions. However, prior to parameter optimization it is unclear whether the misfit between modeled and observed LAI/fAPAR is the result of inaccurate parameter values or model structural error. This is a crucial issue to resolve in order to improve predictions of the impact of future changes in land use and climate on the global C cycle.

In this study, satellite-derived NDVI and EVI data are used to constrain the parameters relating to the timing of the leaf phenology (onset and senescence) in the ORCHIDEE TBM. A 4D – variational data assimilation system is used to optimize the parameters of all natural deciduous Plant Functional Types (PFTs) covering the boreal, temperate and tropical biomes, by tuning the simulated fAPAR to the observed NDVI/EVI time series (normalized values). Independent NDVI/EVI data, both satellite-derived and ground-based (where available), are used to validate the resulting LAI/fAPAR simulations. In addition, the ability of the satellite data to improve the seasonal C fluxes is evaluated with atmospheric CO2 data by transporting the modeled net CO2 fluxes with the atmospheric general circulation model LMDz.

For the boreal and temperate PFTs, the optimizations generally result in a decrease in the growing season length, with corresponding reduction in annual Net Ecosystem Exchange (NEE). Validation with independent satellite NDVI data shows an increased correlation in corresponding regions. However, the posterior value for some parameters and PFTs is at the edge of the prior range, suggesting that some processes in the model may still be missing or inaccurate.

For tropical PFTs the picture is less clear. For regions with a simple annual cycle in both the observations and the model, the satellite data are able to constrain the phenology-related parameters in much the same way as for the boreal and temperate regions. However, in many places the annual cycle is more complex, with two or more periods of growth and senescence, and higher inter-annual variability. In these regions the optimizations do not result in an improvement in the misfit between the observations and the model, possibly indicating that the current threshold-based phenology models, and/or the formulations for moisture stress, may be insufficient at predicting higher frequency changes in leaf phenology in response to light and moisture drivers. The inclusion of the soil depth parameter in the optimizations can potentially improve the results for some tropical regions, however, by allowing access to soil water at depth.

The misfit between observations and posterior fluxes provides valuable insights into how the modeling of phenology in TBMs can be improved. Preliminary investigations in this direction will be discussed, including potentially the use of a more generic, PFT-independent phenology model (Jolly et al., 2005) that can respond, to varying degrees in space and time, to one or more environmental drivers (light, temperature, moisture).

-200 Evaluating inter-annual variation and global pattern of methane emissions from natural wetlands using dynamic global vegetation model

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Methane (CH4), as an important greenhouse gas, has much stronger radiative forcing by approximate magnitude about twenty times than carbon dioxide (CO2) on a molecular basis. Atmospheric CH4 originates from biogenic sources account for more than 70% of the global total and the natural wetlands are the largest individual CH4 source. It' s important to increase knowledge concerning CH4 emissions from wetland for better understand the global CH4 budget. In this study, a dynamic global vegetation model coupled with three major processes including methane production, methane transport (ebullition, diffusion, and plant mediated transport) and methane oxidation was used to simulate methane emission from natural wetland at global scale. Model test was conducted over nearly twenty sites with wide geographic distribution throughout global. The model always caught the patterns of temporal variations well and it can be applied to different wetlands under various conditions and to global scale. Then, the spatial and temporal patterns of methane emissions from natural wetland were investigated based on the simulations results from 1901 to 2010. High correlation was found between methane emission rate and atmospheric methane column concentration which was derived from SCIAMACHY observed data.

-201 Role of mode and intermediate waters in future ocean acidification: analysis of CMIP5 models

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Consistently with the past decades observations, CMIP5 Earth System Models project highest acidification rates in subsurface waters. Using 7 ESMs, we find that remarkably high acidification rates in Mode and Intermediate Waters (MIW) on centennial timescales (-0.0008±4x10-5.yr-1 to -0.0023±0.0001.yr-1 depending on the scenario) are predominantly explained by the geochemical effect of increasing atmospheric CO2, whereas physical and biological climate change feedbacks explain less than 10% of the simulated changes.
Mode and Intermediate Waters combine 1) a larger outcrop surface than Deep and Bottom waters leading to 5 to 10 times larger carbon uptake and 2) geochemical properties resulting in a pH sensitivity to increasing carbon concentration 50% larger than in surface waters (ΔpH of -0.003 for every mmol.m-3 of dissolved carbon in MIW vs. -0.002 in surface waters). We show that low pH transported by Mode and Intermediate Waters are likely to influence surface pH in upwelling regions decades after their isolation from the atmosphere.

-202 Response of soil organic matter decomposition to experimental warming in a cultivated Andisol in Japan

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

Decomposition of soil organic matter (SOM) has significant impact on land-atmosphere C exchange directly via microbial heterotrophic respiration (Rh) and indirectly by regulating nutrient availability for primary production. How different soil C pools (labile or stable) respond to warming (temperature) is a key uncertainty for predicting the size of potential soil C responses to climate change. We established the warming experiment on a cultivated Andisol that contains high proportion of recalcitrant C-pools due to long-term management on less fresh-C (residue) input. We investigated the effects of warming on SOM decomposition and how soil moisture modify the warming effects by taking advantage of (1) directly measuring Rh (trenched CO2 efflux) using automatic chambers, and (2) using the 14C signature in soil CO2 profile to access how different fresh (labile) and old (stable) C-pools response to warming.
Six plots, each 2×2 m2 with three as heated plots and the other as non-heated control plots, were established in the Andisol for wheat-soybean double cropping in the winter of 2007. The soil warming started at the end of July in 2008 through the cropping seasons till the end of October in 2010 (no warming during fallow seasons). For each heated plot we used two infrared lamps to warm the soil from 150-cm above the ground, and established a feedback ON/OFF control system to keep the soil temperature at 5 cm depth in the heated plots 2ºC higher than the non-heated control plot. Each plot set up two chambers for the soil CO2 efflux measurement using a newly-developed automatic opening and closing chamber system (AOCC) based on open flow method. The trenching method was adapted to directly measure CO2 emission as Rh, by inserting four PVC boards (45 × 25 cm) into the soil around the chamber to prevent root extending to the chamber. A vacuum line was specially prepared to sample air in soils from 5, 10, 20 and 30 cm depths for measuring Δ14C.
Raising the soil temperature at 5 cm by 2ºC increased SOM decomposition (Rh) during the cool seasons (i.e. Dec to May) by 2-13% through its effect on active soil volumes. In contrast, reduced the Rh in warm seasons (i.e. Jul. to Oct.) by 10-18% that most likely through its effect on soil moisture regime. As a result, soil warming resulted in a lower annual Rh compared to the non-warming control treatment (i.e. 835 and 782 g CO2-C m-2 for heated and control plots through the whole investigated period of 2008-2010). Our results highlight the importance of accounting for warming on temperature vs. moisture interaction in the models when predicting soil carbon dynamics under climate warming. The 14C signature suggests that warming had a greater effect on the decomposition of fresh C compared to old C pools. Further works required such as increasing fresh C input (labile C, e.g. residue or straw compost) to assess soil warming effects in our study site. More attention should be given to standardized protocols for experimental design and measurements, not only for biomass production and soil C fluxes, but especially for water availability/stress, as well as for nutrient availability.

-203 Significance of metrology in global ecological monitoring

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

Large amounts of greenhouse gases have been released since the industrial revolution. Ecological issues arouse widespread concern from the international community. Cooperation in ecological monitoring among the international organizations has been strengthened. In recent decades, several global or region ecological observation networks including ILTER, GEMS, GAW, WIGOS, GLEON and CERN have been established. Due to the limitation of measurement uncertainty in ecological remote sensing caused by harsh and challenging environment of space, the internationally accepted and traceable measurement standards with low uncertainties and precisely monitored and well-controlled stability to accurately measure small changes in status of ecosystem are highly required.

Metrology provides technical support and quality assurance for the global ecological monitoring. The task of the BIPM is to ensure world-wide uniformity of measurements and their traceability to the International System of Units (SI).Under the CIPM MRA all participating NMIs recognize the validity of each other' s calibration and measurement certificates for the quantities, ranges and measurement uncertainties. At the end of February 2013, the total CMCs for carbon dioxide is 184, total CMCs for CCQM in category of "gases" 2054, and total for CCQM 5360.

In China, a complete metrological traceability system has been established. The working measuring instruments used for ecological and environmental monitoring are exercised compulsory verification, which ensures accuracy and reliability of ecological monitoring data. Main areas in ecological monitoring which need support of metrology are Earth observation and remote sensing from space and in-situ sensing platforms, reference standards and calibration methods of greenhouse gas (GHG), trace gases and long-term and stable trend monitoring of atmospheric composition.

Scientists proposed four themes within which metrology will develop in next two decades, which are new quantum SI, measurement at the frontiers in extreme and harsh environments, smart and interconnected measurement by means of global information network, and embedded and ubiquitous measurement. In order to meet the metrological requirements of ecological monitoring, more attention should be given to the trend of measurement technologies in ecology, measurement process and corresponding QA principles.

-204 Terrestrial Ecosystem Carbon Flux as Inferred with New Ground CO2 Observations in China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Atmospheric inverse modeling is an effective means to infer the terrestrial ecosystem carbon flux from CO2 concentration measurements. Most inversion approaches use CO2 concentration observation from the GLOBALVIEW dataset. However, observations from the GLOBALVIEW dataset are not evenly distributed spatially. Especially, there is only one station in China included in the GLOBALVIEW dataset. This station, Waliguan, which locates upwind of most terrestrial ecosystems in China, provides a weak constraint on the inversion of the terrestrial ecosystem carbon flux in China. The newly released ground CO2 concentration observations since 2006 at Shangdianzi, Longfengshan and Linan from the Chinese Academy of Meteorological Sciences, provide an opportunity to better constrain the inversion of the terrestrial ecosystem carbon flux in China for the first time. In this study, a nested inversion system with a focus on China based on the Bayesian synthesis technique, is implemented with CO2 concentration observations from both GLOBALVIEW and these three stations in China. The inverted monthly terrestrial ecosystem carbon flux at 39 regions globally from 2006 to 2009 is presented. The impact of the addition of those three stations on the inversion result in China will be analyzed

-205 Observed interannual variability in latitudinal distribution of annual mean atmospheric potential oxygen (APO) in the Western Pacific

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

We have been observing the atmospheric CO2 and O2 concentrations from flask samples collected onboard commercial cargo ships sailing between Japan and US/Canada and Australia/New Zealand since December 2001. Combining the CO2 and O2 measurements, we obtain a dataset of atmospheric potential oxygen (APO), which is defined as APO=O2+1.1×CO2 (Stephens et al., 1998). Since APO is invariant with respect to the land biotic exchange (1.1 in the definition represents the molar land biotic –O2:C exchange ratio), its variations mainly reflect the variations in the air-to-sea gas exchange. In our previous studies based on the observed APO from the flask samples, we revealed that 7-year average of the latitudinal distribution of the annual-mean APO in the Western Pacific (between about 40°S to 50°N) show a maximum near the equator and a deep trough at latitudes 20-40°N (Tohjima et al, 2012). The latitudinal distribution of the annual-mean APO mainly reflect annual net air-sea O2 and CO2 exchange: ingassing fluxes in the mid and high latitude and outgassing fluxes around the equator, which are related to the large-scale ocean circulation. In addition, from the analysis based on a atmospheric transport model driven by climatological oceanic O2 and CO2 flux fields suggested that seasonal covariation between air-sea flux and atmospheric transport (rectification effect) substantially contribute the APO latitudinal gradient. Accordingly, the distribution of the annual-mean APO has a potential to constrain the air-sea gas exchanges, ocean circulation, the atmospheric transport, and so on.

In this study, we examine the interannual variations in the latitudinal distribution of the annual-mean APO in the Western Pacific during the recent decadal period. We also adopt a dataset of APO from in-situ observations onboard the cargo ship sailing between Japan and Australia/New Zealand (Yamagishi et al., 2012) to improve the spatiotemporal resolution. Instead of substantial seasonal variability, the latitudinal distributions of the annual-mean APO in the Western Pacific show similar equatorial bulge from year to year. However, the equatorial bulge disappeared during the period from July 2009 to June 2010. Because the most recent El Niño event occurred during the same period, the suppression of the Eastern Pacific upwelling might reduce O2 and/or CO2 outgassing around the equatorial ocean. In addition, the annual-mean strength of the Atlantic meridional overturning circulation (MOC) at 26°N showed substantial decline during April 2009-March 2010 (McCarthy et al., 2012). The MOC decline might reduce meridional APO transport from subtropical to tropical regions as well as the meridional ocean heat transport. The contribution of the atmospheric transport to the anomalous APO distribution in 09/10 will also be discussed in the presentation.

-206 Ecosystem light use efficiency and water use efficiency along an Australian precipitation transect

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Light use efficiency (LUE) and water use efficiency (WUE) have been applied to characterize the links between terrestrial carbon, water and energy cycling. Though many studies have been conducted across biomes with different climatic conditions, variability of LUE and WUE of ecosystems within a precipitation gradient are rarely discussed. Thus, we applied eddy covariance and meteorological observations in seven OzFlux sites across an Australian precipitation transect (mean annual precipitation ranging from 306 to 1750 mm) to estimate LUE and WUE at the hourly to annual scales. The Marginal Distribution Sampling method was used to fill small gaps and partition measured net carbon fluxes while large gaps were filled by repeating. Abnormal data were also removed by calculating quantiles. The core of this research is to address two questions: (i) how do LUE and WUE vary at different temporal scales in this transect? And (ii) what are the roles that biotic and abiotic environmental variables play on variations of LUE and WUE?

-207 A revised atmospheric d13C-CO2 record covering the last 1000 years from Law Dome and South Pole, Antarctica

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

We present new measurements of d13C of CO2 extracted from high resolution ice cores from Law Dome (East Antarctica), together with firn measurements performed at Law Dome and South Pole, covering the last 150 years. Our analysis is motivated by the need to better understand the role and feedback of the carbon (C) cycle in climate change, by advances in measurement methods, and by apparent anomalies when comparing ice core and firn air d13C records from Law Dome and South Pole. We demonstrate improved consistency between Law Dome ice, South Pole firn and the Cape Grim (Tasmania) atmospheric d13C data, providing evidence that our new record reliably extends direct atmospheric measurements back in time. We also show a revised version of early d13C measurements covering the last 1000 years, with a mean Pre-Industrial level of -6.50 ‰. Finally we use a Kalman Filter Double Deconvolution to infer net natural CO2 fluxes between atmosphere, ocean and land, which cause small, but significant d13C deviations from the predominant anthropogenically induced d13C decrease. The main features found in the previous d13C record are confirmed, including the ocean as the dominant cause for the 1940s AD CO2 flattening. Our new record provides a solid basis for future investigation of the causes of decadal to centennial variations of the pre-industrial atmospheric CO2 concentration. Those causes are of potential significance for predicting future CO2 levels and when attempting atmospheric verification of recent and future global carbon emission mitigation measures through Coupled Climate Carbon Cycle Models.

-208 Publicly available data sets of d13C of atmospheric CO2

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

With modeling studies now incorporating observations of CO2 and d13C of CO2 to elucidate the magnitude and variability of sources and sinks of the global carbon cycle (eg Rayner et al, this volume), it will become increasingly important to be able to collate and merge publicly available d13C of CO2 data. The two main repositories for this data are the World Data Centre for Greenhouse Gases (WDCGG), maintained by the World Meteorological Organization's (WMO) Global Atmospheric Watch (GAW) Programme, and the United States of America Department of Energy's Carbon Dioxide Information Analysis Center (CDIAC). The 3 major contributors of the d13C data are NOAA/ESRL, CSIRO, and SIO. For more than 20 years these 3 laboratories have been measuring the d13C of atmospheric CO2 and in that time have investigated various aspects of their sample collection and analysis programs with the aim of producing high-quality, internationally traceable data sets. However, differences that remain in the data sets need to be understood if the data is to be used by the international community. We will discuss these differences, highlighting those aspects that are important when using the data sets in global studies.

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-209 Priming Effects on Forest-Carbon Storage

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Increased atmospheric CO2 has been shown to increase plant-litter production and root-carbon exudation. Both of these processes can cause priming, the accelerated decomposition of stabile forms of carbon caused by increasing resource supplies to microbes. Whether priming can increase or decrease system storage of carbon has rarely been assessed. We incubated substrates containing plant-derived carbon with labile carbon (glucose) as well as dissolved nitrogen and phosphorus to supply the most important microbial resources. We measured CO2 release from these incubations with a non-dispersive infrared analyzer. We added glucose with a high 13C/12C isotopic ratio, alkali trapped CO2, measured it by mass spectrometry, and used an isotopic-mixing model to separate CO2 release from added glucose or from these substrates' carbon. The substrates selected were mineral soil, surface humus, dead wood and mixed-species leaf litter; all from a subtropical forest preserve in southwestern China with relatively large carbon storage. For mineral soil and humus, some resource additions doubled the net CO2 loss from substrates (priming), but other combinations showed the same CO2 losses as from water-only treatments. For wood and leaf litter, resource additions caused only small changes in CO2 losses compared to water-only treatments. To complete the carbon balances, we also measured the amount of glucose carbon released as CO2 or retained. For wood and leaf litter, essentially all added glucose was released as CO2, so it had little or no effect on carbon balances. Added microbial resources simply altered the decomposition rates of those substrates. However, both mineral soil and humus retained large fractions of glucose carbon, and that retention was controlled by carbon:nitrogen ratios of the added resources. This means that net effects of priming in mineral soil and humus could lead to either decreases or increases in carbon storage by those substrates. The balance depended on the carbon:nitrogen ratios of resources available to microbial decomposers. Carbon storage under increased CO2 will depend on the amounts of available nitrogen in forests, as well as on carbon fertilization/priming. This research was supported by NNSFC grant 30970535.

-210 Variation Characteristics and Sources of Greenhouse Gases in Urban Atmosphere

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Abstract: The international advanced Picarro greenhouse gas analyzer was used to continuously online monitor the atmospheric CO2 and CH4 concentration in Wuhan City, a metropolis in central China, from June to December, 2012. During the study period, the monthly averaged CO2 concentration at the observation urban station is lowest in July and highest in December, while that of CH4 is lowest in December and highest in June. For seasonal variation, CO2 concentration in summer is lower than that in autumn with a difference of about 10 ppm, while CH4 in summer in higher than that in autumn with a difference of about 60 ppb. For diurnal change, the high values of CO2 and CH4 occur during 05~08 a.m. and low values occur during 13~16 p.m. As indicated in the greenhouse gases concentration wind rose map, high concentrations of CO2 occur in the northwest and northeast while those of CH4 mainly occur in the northwest and southwest. HYSPLIT trajectory model was adopted to calculate the backward trajectory of air mass during the observation period. By the method of clustering associated with greenhouse gas concentration, the spatial distribution, seasonal variation and the corresponding CO2 and CH4 concentration of various trajectory types was analyzed. The results indicate that this urban station can be used to study the emission impact of different air mass sources from South Central China, Pearl River Delta, northern region and so on. Among them, the trajectories from Jianghan Plain in southeast direction as well as from South Central China take up 49% of all trajectories and occur in three seasons. This type of air mass has the shortest transportation distance and the most significant contribution to CH4 level which probably due to numerous wetland in source area, while CO2 level has the greatest variation, reflecting the impact characteristics of small and medium scale transportation and local emission sources. The trajectories from northwest are about 35% of all trajectories and occur after August. This type of air mass is mainly from Loess Plateau and North China Plain in the north. The corresponding greenhouse gases concentration change greatly, especially CH4, which is influenced by agriculture and animal husbandry. The type of trajectories from the north is of 8% occurrence and likely present in autumn. It has the farthest transportation distance and the most significant contribution to CO2 level. All of the trajectories transported long distance from the southern coastal areas occurs in summer, especially in July, taking up about 8% of all trajectories. It has cleaning effect on local pollutants, which result in the lowest corresponding CO2 concentration.

Keywords: CO2, CH4, urban station, backward trajectory

-211 Aerosol Corruption Effect on Satellite-Based Estimation of Gross Primary Production during Drought Period

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

Droughts, forest fires, freezing, insect outbreaks, floods and other extreme events have the potential to strongly alter carbon exchange between vegetation and atmosphere. To monitor and assess these effects, a variety of means including field observations, forest inventories, numerical modeling have been developed. Remote sensing, with the advantage of timely, large spatial span, and low cost, has been more widely applied in this field. Remotely sensed gross primary production (GPP) anomaly during drought period could be attributed to the following aspect. a) Direct water shortage induced vegetation photosynthesis decrease. b) Drought induced fire and insect outbreak disturbance caused tree mortality. c) Aerosol caused decreasing sunlight radiation. d) Aerosol corruption on remote sensing accuracy. During drought period, increased aerosol optical depth (AOD) caused by prevalent biomass burning and other reasons will contaminate the satellite observed data. Because of remotely sensed LAI played an important role in the development of GPP algorithm, aerosol corrupted data could decrease the LAI reliability, therefore will affect GPP estimation. This may be the main reason that many recent studies focused on drought effect on carbon cycle have eventually lead to unexpected result, especially for studies on 2005 Amazon drought and 2010 drought in southwestern China. In this paper, we will present main results as well as future challenges from these two case studies.

-212 Research on the Calculation Method of CO_2 Air - sea Flux Based on Seawater CO_2 Solubility

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The rate of CO_2 exchange between the ocean and atmosphere is related to the issue of global warming. In this paper, on the basis of the analysis and calculation of various parameters of the carbon dioxide system in sea water, the effect of wind speed, temperature and the air-sea partial pressure difference of CO_2 on the CO_2 transfer flux is explored. With the situ experiment monitoring and historical research data, 24-hour CO_2 air - sea flux of Bohai Bay seawater on June 4, 2012 is respectively estimated by three global common methods, of which the results are further compared and analysed.

This study shows the rationality of comprehensive consideration of ocean chemistry data, hydrological data and meteorological data to estimate CO_2 air - sea flux when it occurs to the research on the storage and exchange of oceanic carbon dioxide.

-213 Developing adjoint of the coupled Eulerian-Lagrangian transport model for CO2 inverse modeling

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

During the last decades an observational network of increasing density is being established, measurements on board of ships and airplanes as well as space-borne observations are also becoming available to monitor the greenhouse gases in the atmosphere. Hence such observations provide a possibility to estimate their sources and sinks in more regions. In order to link the surface fluxes to the atmospheric concentration observations, an accurate model of the atmospheric transport and inverse modeling technique are needed. A number of studies have addressed improvements to the inverse methods of the atmospheric transport. The challenging task is using the information from a spatially sparse observational network in an optimal way to derive regional flux estimates together with an estimated range of confidence.

Here we present a development of an inverse modeling system employing an adjoint of National Institute for Environmental Studies (NIES) three-dimensional transport model (TM) coupled with a Lagrangian plume diffusion model. The adjoint has been constructed automatically in the "reverse mode" of automatic differentiation by means of the Transformation of Algorithms in Fortran (TAF) software (http://www.FastOpt.com).

NIES TM is a three-dimensional atmospheric transport model, which solves the continuity equation for a number of atmospheric tracers on a grid spanning the entire globe. Spatial discretization is based on a reduced latitude-longitude grid and a hybrid sigma-isentropic coordinate in the vertical. NIES TM uses a horizontal resolution of 2.5°×2.5°. However, to resolve synoptic-scale tracer distributions and to have the ability to optimize fluxes at resolutions of 0.5° and higher we coupled NIES TM with the Lagrangian model FLEXPART. The Lagrangian component of the forward and adjoint models uses precalculated responses of the observed concentration to the surface fluxes and 3-D concentrations field simulated with the FLEXPART model.

NIES TM and FLEXPART are driven by JRA-25/JCDAS reanalysis dataset, with PBL heights provided by ERA interim reanalysis.

-214 Increased precipitation modifies plant and ecosystem responses to warming in the High Arctic

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The strong warming observed in the Arctic is likely to be accompanied by an increase in growing season precipitation, but the effects of these combined drivers on ecosystem carbon cycling remain largely unknown. The responses of plant functional and structural traits and soil biogeochemistry will feedback on ecosystem properties and the climate system. For example, increased soil carbon losses are expected due to enhanced respiration and melting permafrost, but greater plant productivity and carbon uptake has the potential to offset these losses. We investigated changes in ecosystem fluxes and leaf traits in response to warming and wetting at a long-term climate change experiment in the High Arctic of NW Greenland. Within the range of potential future Arctic climates, we studied two extremes: warming only vs warming combined with 50% increase in growing season precipitation.

At the leaf level, we found the strongest enhancement of photosynthetic capacity for the warming only case. Light saturated electron transport rates were higher in the warmed plants but lower with wetting. Gross photosynthesis and electron transport rates were well correlated, but photochemical energy was partitioned differently between treatments. Wetting resulted in a greater efficiency of the use of electron transport. The differences in photosynthetic capacity between treatments were correlated with leaf N content. There were also changes in specific leaf area: thinner leaves with warming only, and thicker leaves with wetting.

The pattern was very different at the ecosystem scale. Despite the higher photosynthetic capacity of warming only plants, NEE in the warmed plots was decreased by 22% compared to control plots. Although photosynthetic uptake was increased, the concurrent increase in ecosystem respiration was even stronger. In contrast, warming and wetting enhanced NEE by a factor of 6.5-8.7 due to a strong increase in leaf area, and because the more than 3-fold increase in photosynthetic uptake far exceeded the concurrent increase in ecosystem respiration.
Extrapolating to the area of polar semi-deserts, we estimate the current sink strength of this region as 6.3-8.5 Tg C over the growing season. In a warmer and wetter future, polar semi-deserts would take up an additional 68-104 Tg C, whereas warming only would reduce the growing-season C sink by 2.4 Tg C. Our results indicate that precipitation changes may limit or even reverse carbon cycle feedbacks in response to rising temperatures in the High Arctic.

-215 Potential atmospheric CO2 reservoir from the ancient forests buried in Pearl River Delta, South China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Ancient forests buried in Pearl River Delta, South China contain a great amount of old organic carbon (OC) formed in a wetland environment during mid-late Holocene. Take the ancient forests buried in Sihui (23°22′22″ N, 112°42′30″ E) for example, the area of the ancient forests is evaluated to be 400 square kilometers. The forests are usually buried 1 meter to 2 meter under the earth surface, and have formed about 5 meter humic layers in thickness on average. The bulk density of the sediments from the ancients forests are close to 0.8 g/cm3, and the OC contents range between 33.4% and 49.0%. The OC δ13C values vary between -29.0‰ and -29.9‰ which suggesting that almost organic matter remains undecomposed. According to these data, the SOC density of the forests ranges from 1340 T• ha-1 to 1960 T• ha-1. The total OC content thus up to 53.6 Pg C to 78.4 Pg C in the ancient forests, approximately half of the amount of carbon in atmosphere of Pearl River Delta (~ 120 Pg C). The OC are old ones with the 14C ages range from 4218 ± 80 cal BP to 3291 ± 81 cal BP. The forests would be a great atmospheric carbon sink during their development. However, they now turn to be potential atmospheric carbon source due to the large scale mining by local residents. The action would lead to a great amount of CO2 with significantly passive δ13C and Δ14C ranging from -280‰ to -430‰ flux into atmosphere and change the carbon isotopic composition of the local atmosphere. Assuming that the forests are mined at a rate of 0.05 per year in Sihui, the contribution of CO2 derived from the old OC decomposition would be 2.68 Pg C to 3.92 Pg C, and if the forests from other places in Pearl River Delta are considered, the contribution would be obviously greater. Therefore, protecting the ancient forests from mining would be an effective approach to reducing carbon emissions in Pearl River Delta.

-216 ontribution of the soil 14CO2 to the atmosphere from the subtropical forest in South China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Soil 14CO2 as a source of CO2 from the biosphere to the atmosphere is very important to pay attention when the contribution of fossil fuel derived CO2 to the atmosphere is evaluated. In order to investigate the impact of Δ14C value from soil 14CO2 to that from biosphere in South China, soil CO2 from two forest profiles (DHLS with rare plant coverage, and DHS with thick plant coverage) in Dinghushan Biosphere Reservoir (DBR) was collected, and the carbon isotopic composition (δ13C and Δ14C) were measured. Results show that the content of soil CO2 varies between 6120 and 18718 ppm, obviously higher than the background concentration of 390 ppm of the present atmospheric CO2. The Δ14C value of soil CO2 ranges from 100.0‰ to 107.2‰ in DHLS (sample depth of 90 cm), and 102.5‰ to112.1‰ in DHS (sample depth of 105 cm), respectively, higher by 60‰ to 67‰ than the background Δ14C value of 40‰ of present atmospheric CO2. Similar to Δ14C, the CO2 δ13C also enriches. It varies from -24.71¬‰ to -24.03‰ in DHLS profile and from -25.19¬‰ to -22.82¬‰ in DHS profile, respectively, clearly more positive than the ones of SOC and roots in each profile. Given the atmospheric CO2 concentration and Δ14C value are 390 ppm and 40‰, respectively, and the soil respiration contributes about 10% CO2 in the atmosphere, the impact from soil 14CO2 would improve the Δ14C value of CO2 from biosphere by 6‰ to 6.7‰ comparing with the method which is just simply assuming Δ14Cbio≈Δ14Cbac. When the atmospheric fossil fuel derived CO2 concentration is calculated, it would lead to an increase of the fossil fuel derived CO2 concentration by 2.0 ppm to 2.5 ppm in South China.

-217 Fossil fuel-derived co2 contribution to the urban atmosphere in guangzhou, south china by 14co2 observation, 2010 - 2011

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

During October 2010 to November 2011, the urban atmospheric CO_2 concentration in Guangzhou ranged from 550 ppm to 460 ppm, with the mean monthly concentrations fluctuating between 530 ppm and 470 ppm. A lower concentration was observed in summer and autumn, while a higher concentration appeared in spring and winter. The urban atmospheric CO_2 $\delta^{13}C$ values varied between -9.00‰ and -13.10‰, with the mean monthly values fluctuating between -9.60‰ and -11.80‰. There was no significant relationship between CO_2 concentration and $\delta^{13}C$ values, reflecting the influence from the fossil fuel derived CO_2 on the urban atmospheric CO_2. The urban atmospheric CO_2 $\Delta^{14}C$ values fluctuated dramatically from 29.1 ‰ ± 2.5 ‰ to -85.2 ‰ ± 3.1 ‰, with a mean annual value about -16.4 ‰ ± 3.0‰. A similar seasonal variation of the $\Delta^{14}C$ values with the concentrations was observed that the higher $\Delta^{14}C$ values mainly appeared in summer and autumn (July to September), with the mean value about -5.2 ‰ ± 2.9 ‰, while the lower $\Delta^{14}C$ values was mainly observed in spring and winter (December to April next year), with the average value about -27.1‰ ± 3.2 ‰. Base on the $\Delta^{14}C$ values, fossil fuel derived CO_2 concentration are calculated to range between 1 ppm to 58 ppm, with a mean annual concentration about 24 ppm. Similarly, the lower fossil fuel-derived CO_2 concentration appeared in summer and autumn (July to September) with a mean value about 17 ppm, while the higher fossil fuel-derived CO_2 concentration was observed in spring and winter (December to April next year) with an average value about 29 ppm. As indicated from the fossil fuel derived CO_2 concentration during and after the Guangzhou Asian Games in 2010 and the Spring Festival of 2011, controlling the human activities can greatly decreased the fossil fuel derived CO_2 emissions to the urban atmosphere in Guangzhou.

-218 A multimodel evaluation of the seasonal marine carbon cycle and its drivers in CMIP5 and C4MIP Earth system models

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Identifying the physical and biogeochemical processes that cause the most significant errors in pCO2 seasonality should help guide model development and lead to improved confidence in projected oceanic CO2 uptake. We evaluate the seasonality of oceanic pCO2 and its drivers—sea surface temperature and salinity (SST & SSS), dissolved inorganic carbon (DIC) and alkalinity (ALK)—in the two latest generations of coupled carbon-climate earth system models (C4MIP and CMIP5). We use monthly DIC and ALK fields reconstructed from observed pCO2, SSS and SST for the evaluation. The most significant errors in the simulated pCO2 seasonality are driven by the poor representation of DIC in the high latitudes—the same regions where the trends in the future uptake of atmospheric CO2 are strongest and most uncertain. Here, the seasonal cycle in salinity tends to be too vigorous: too fresh in the summer and too salty in the winter. This causes the seasonality in DIC associated with the freshwater fluxes to be overestimated. Consequently, there is a tendency to underestimate the seasonal amplitude in DIC driven by ocean biogeochemical processes (biological production in the spring/summer and upwelling in the autumn/winter). Encouragingly, the representation of the SSS seasonal cycle in the high-latitudes, and, thus, the pCO2 seasonality driven by the freshwater flux, has improved in the latest generation of CMIP5 models.

-219 Climate carbon-cycle feedbacks over Southern Ocean Water masses: a CMIP5 multimodel diagnosis

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Climate-carbon cycle feedbacks are expected to reduce the efficiency of atmospheric CO2 storage by both the terrestrial biosphere and the ocean. Such feedbacks would cause atmospheric CO2 to rise faster than expected from anthropogenic CO2 emissions alone. The Southern Ocean is one of the regions where the marine climate-carbon-cycle feedbacks can be largest and, also, where they differ most between the models. We apply a new automated procedure to track the change in the density and the surface outcrop area of the Southern Ocean water masses in an ensemble of CMIP5 future climate change simulations—the 1% atmospheric CO2 increase scenarios (fully-coupled and radiatively-uncoupled). We demonstrate that analysing climate-carbon cycle feedbacks over watermass outcrops improves both the quantification and diagnosis of the processes driving changes in future CO2 uptake over the Southern Ocean. Over each Southern Ocean water mass, we isolate two geochemically-driven components: one due to the increase in air-sea pCO2 disequilibrium and one due to local geochemical saturation. We also isolate two climate-driven components: one due to large-scale changes in the watermass outcrop areas and one due to the local impacts of climate-change. The net effect of these processes is to reduce the CO2 uptake by Southern Ocean uptake by 30 ± 6 % with the maximum reductions in subantarctic mode and Antarctic intermediate waters. The process dominating the reduction in CO2 uptake is watermass-dependent: geochemical saturation in subtropical and subantarctic mode waters, localized climate change in the Antarctic intermediate waters and the reduction in outcrop areas in both the circumpolar deepwaters and Antarctic bottom waters.

Investigation of the Biosphere with the Aid of Global Spatial Carbon Dioxide Cycle Model Taking into Account Seasonal Regime

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The results of global carbon dioxide cycle modeling with the basic attention to the spatial seasonal dynamics in the "Atmosphere - Terrestrial Plants - Soil" system are presented. A simple carbon cycle model in the "Atmosphere - Ocean" system is added for full description the cycle.

In the model all the land territory is divided to into cells of the size 4°×5° of geographic grid. It is supposed that in each cell there is a given type vegetation according to the world classification. The model is described by system of ordinary nonlinear differential equations. Block of the productive process characterizes the carbon and water dynamics in ecosystems. The model includes the following phase variables: (1) carbon concentrations of land area separately for the biomass of leaves, trunks, and roots, assimilates, and organic matter in soil; (2) moisture in the upper soil layer. The equations are described photosynthesis, respiration of plants, distribution of assimilates in organs, decay of dead organs, and decomposition of soil organic matter.

Climatic data for the modeling were taken from the GCM model of Computing Center of the Russian Academy of Sciences.

Modeling confirmed that photosynthetic activity of terrestrial plants are responsible for seasonal fluctuation of CO_2 concentrations. Moreover, the movement of air masses results in ”sucking out” CO_2 from areas with lower photosynthesis located hundreds of kilometers away. Similar to data obtained by CO_2 monitoring, the model shows that maximal annual decrease of CO_2 concentrations in August-September in moderate and high latitudes of the Northern Hemisphere. These variations are observable up to the equator and even in the Southern Hemisphere. In the Southern Hemisphere (up to the South Pole), the minimum of CO_2 concentrations corresponds to January-February and have lower CO_2 variations. Near the North and South poles, the trend of variations of CO_2 concentrations corresponds to that at lower latitudes (with substantially lower amplitude variations).

Calculations reveal six points of local minimum: at zone of temperate forests and taiga in Siberia and North America, at zone of tropical forests in South America, in Africa, between India and Indochina and in Australia. Their existence and positions are explained by the seasonal dynamics of plant photosynthetic activity.

Simulating experiments also reveal two previously unknown domains. One starts in the minimum of the South America and goes to South part of this continent, neighboring areas of the Atlantic and Pacific oceans, and the greater part of Antarctica. The boundary of this domain is marked by the sharp change in the onset time of CO_2 minimum development accompanied by the substantially lower amplitudes of variations in its concentrations. The

-221 Nonlinearity of ocean carbon feedbacks in CMIP5 models

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

Uptake of carbon by the ocean is increasing with rising anthropogenic CO2 emissions to the atmosphere. Further, climate change causes modifications in ocean circulation, seawater hydrography (temperature, salinity), and marine biogeochemistry, which in turn can alter the marine inorganic carbon system with implications for CO2 uptake. These CO2 and climate driven effects are referred to as carbon-concentration and carbon-climate feedback. Both feedbacks are often assumed to operate independently, that is, the total ocean carbon uptake can be expressed as a linear combination of two fluxes being functions of atmospheric CO2 concentration and climate change alone.
A set of model experiments designed to better understand carbon feedback processes has been run for the Coupled Model Intercomparison Project Phase 5 (CMIP5). A fully coupled simulation with a prescribed 1% increase of atmospheric CO2 per year serves as a baseline, while in two additional simulations the increase in CO2 is "seen" by the radiation code of the model or the biogeochemistry modules only. The latter two experiments are designed to permit carbon fluxes associated exclusively with the carbon-climate feedback or the carbon-concentration feedback, respectively. In this study we analyse this set of simulations using seven CMIP5 earth system models with fully coupled carbon cycle modules. Results show that the total ocean uptake from the "rising CO2 but no warming" and the "warming under constant CO2" experiments do not add up linearly to the CO2 uptake of the fully coupled run. The difference, which amounts to 19 to 54 Pg carbon over the 140 year simulation period, is of the same order of magnitude as the carbon-climate feedback itself. We find that there are two opposing contributions to this non-linear behavior: Changes in carbon chemistry play a minor role only, while the dominant contribution comes from changes in circulation and mixing and associated changes in deep ocean carbon storage.

-222 A Global Carbon Assimilation System Based on a Dual Optimization Method

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Ecological models are effective in understanding the distribution of global carbon sources and sinks. However, global-scale models often suffer from substantial uncertainties due to limited local observations. Although the atmospheric CO2 concentration results from the distribution of terrestrial and oceanic carbon sources and sinks and atmospheric transport, the sparse spatial observational sites are not sufficient to estimate the sources and sinks on global dense grids. One way is to combine the observations of the atmospheric CO2 concentration with ecosystem modeling to reduce the error. The BEPS model is used for ecological modeling, and the MOZART model is used for atmospheric transport modeling. We develop a Dual Optimization Method (DOM) similar to the Bayesian synthesis inversion method to inverse the ecological model parameter state and flux state simultaneously. According to the inherent relationship between the parameter state, flux state and the atmospheric CO2 concentration state, we perform an interactive forecast among the three states. Then we present a Global Carbon Assimilation System based on the DOM and the forecast (GCAS-DOM). In GCAS-DOM, the observations of CO2 concentration can be used to inverse the time-dependent parameters, net fluxes, and the historical atmospheric CO2 concentration. We applied the GCAS-DOM to estimate the distribution of carbon sources and sinks on 2.8 o×2.8 o global grid cells for the period from 2002 to 2006, and this system effectively corrected some flux patterns produced from ecosystem models.

-223 Variability of carbon fluxes in managed ecosystems of Europe- Does management override climate?

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The terrestrial biosphere, encompassing both soil and vegetation, contains about four times as much carbon as the atmosphere. Human activity and climate change contribute strongly to the interaction of biosphere and atmosphere. The European continent is densely populated and has a long history of land management. To develop climate change mitigation strategies for land management it is important to understand to what extent and how the carbon and greenhouse gas balance of different ecosystems can be managed under a changing climate.

In this study we question whether management has a larger influence than climate on gross primary productivity (GPP), ecosystem respiration (Reco), net ecosystem production (NEP) and net biome productivity (NBP). We analysed the interannual variability in climate, management and carbon fluxes for eddy covariance time series in croplands, grasslands and forests (73 sites, 469 site-years). On croplands, the most intensively managed ecosystems, we found the effect of human interventions such as nitrogen input and the time of active vegetation driven by the crop type on GPP and Reco to exceed the effect of annual climatic variability in global radiation, temperature, precipitation and length of the growing season. In grasslands, NEP was significantly correlated with the size of the harvested fraction. Overall the climate effect on carbon exchange increased with decreasing degree of disturbance. However, when harvest as a carbon flux was included into the carbon balance (NBP), management overrode the climate effect in all ecosystems. We conclude that the carbon sink or source strength of a particular ecosystem is more determined by management intensity than by climate. This implies that next to reduction of fossil fuel emissions, land management constitutes an important option to mitigate climate change.

Radon flux map of Europe using terrestrial gamma radiation derived from soil radionuclides--a surrogate approach

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Naturally occurring radioactive noble gas, radon (^{222}Rn) is a valuable tracer to study complex atmospheric processes and to validate global chemical transport models. However, the use of radon as a proxy in atmospheric and climate research is limited by the uncertainties in the magnitude and distribution of the radon flux density over the Earth's surface. Terrestrial gamma radiation is a useful proxy for generating radon flux maps. A previously reported radon flux map of Europe used terrestrial gamma radiation extracted from automated radiation monitoring networks. This approach failed to account for the influence of local artificial radiation sources around the detector, leading to under/over estimation of the reported radon flux values at different locations. We present an alternative approach based on soil radionuclides, which enables us to generate accurate radon flux maps with good confidence. Using our approach we developed a regional scale radon flux map of Europe and validated it with the direct flux measurements at different sites across Europe. On the European scale, we find that the observed radon flux values are higher than our modelled values and we introduce a moisture correction factor to account for this difference. Our approach discussed in this paper enables us to develop reliable and accurate radon flux density maps in countries with little or no information on radon flux values.

-225 A new real-time global atmospheric CO2 forecast product: evaluation and sensitivity to model resolution

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Global atmospheric CO2 concentrations are currently forecasted with a five-day lead time as a part of the pre-operational Monitoring of Atmospheric Composition and Climate - Interim Implementation service (MACC-II). The forecast uses the infrastructure of the European Centre for Medium Range Weather Forecast (ECMWF) Integrated Forecasting System (IFS). It provides very high resolution CO2 fields (~16 km in the horizontal everywhere on the globe, 91 vertical levels) every 3 hours with a lead time that could reach 10 days. The transport model uses fields of CO2 fluxes that are prescribed from inventories and from off-line statistical and physical models. The terrestrial biogenic fluxes are modelled online within the IFS.

The aim of this presentation is to demonstrate the capability of the forecast to simulate the variability of CO2 on different temporal and spatial scales. The impact of using high horizontal resolution is also shown by sensitivity experiments. The CO2 forecast errors are documented by comparing the CO2 simulation to different observations from the past ten years.

The presentation will also present the current and potential use of the CO2 forecast fields. These can indeed serve as prior concentration fields to assimilate measurements from space or in situ; they can also be used as boundary conditions for regional modeling, as well as providing prior information for satellite retrievals and planning the sampling in the current observing system of CO2.

-226 Carbon dioxide (CO_2) distribution and air-sea flux in the Mississippi River dominated continental shelf, northern Gulf of Mexico

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

River-dominated continental shelf environments are active sites of air-sea CO2 exchange and represent an important component of global carbon cycle. We conducted multiple cruises on the Louisiana (LA) shelf, a region strongly influenced by fresh water and nutrients delivered from the Mississippi and Atchafalaya River system. Sea surface partial pressure of carbon dioxide (pCO2) was measured, and air-sea CO2 flux was calculated. The results showed a distinct seasonality indicating that the LA shelf was a net sink of atmospheric CO2 during spring and early summer, and was neutral or a weak source to the atmosphere during middle summer, fall, and winter with an annual net CO2 uptake of 0.963 mol C m-2 yr-1. In addition, CO2 exchange followed distinct patterns along the salinity gradient or across the shelf, being a source of CO2 to the atmosphere in low salinity zones (S<17) in nearhsore areas, a strong sink in the middle-high salinity zones (S=17-33) in the inner shelf, near neutral in the high salinity areas (S>33-35) in the middle to outer shelf, and finally a weak source in open ocean GOM. Furthermore, air-sea CO2 fluxes on the LA Bight were highly correlated to the nitrogen flux from the Mississippi River one month earlier, implying a strong influence of riverine anthropogenic nitrogen export on regional carbon cycle and fluxes. However, the correlation was weakened when the river plume was redistributed by unusual regional wind forcing or currents. These results have significant implications on the attribution of biological production and the associated air-sea CO2 exchanges to anthropogenic river nitrogen export.

-227 Study on the Characteristics of CO2 flux of Alpine Meadow Ecosystem in Tanggula Region of Qinghai-Tibetan Plateau

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The CO2 flux and water-heat dynamics of active layer of the alpine meadow ecosystem in the Tanggula region of the Qinghai-Tibetan were continuously observed using eddy correlation method in 2007.The observed and analyzed results show that the daily variations of CO2 flux in each month all formed an unimodal curve. The daily flux peak generally occurred at noon. The largest emission peak occurred in May, with -0.29 gm-2h-1, and the largest absorption peak occurred in August, with -0.25 gm-2h-1. In most months, the daily variation of CO2 flux exhibited an emission character, while in July and August it exhibited an absorption character. The peak value of the daily variation of CO2 flux in the Tanggula region was significantly smaller than that of the surrounding areas of the continuous permafrost region of the Qinghai-Tibetan Plateau. The seasonal variations of CO2 flux of the alpine meadow ecosystem in the Tanggula region exhibited a bimodal character. It showed strong emission in both spring and autumn, weak absorption in summer and weak emission in winter. May was the largest emission moth of a year, with an emission rate of 132.4 gm-2, while August was the largest absorption month of a year, with an absorption rate of -37.7 gm-2. The CO2 fluxes in spring and autumn showed a significant positive correlation with unfrozen soil moisture content and soil temperature at 5 cm depth; but a significant negative correlation with soil temperature at 5 cm depth in summer. However, the CO2 flux basically showed no response to the photosynthetic active radiation.

-228 Impact of rapid sea-ice reduction in the Arctic Ocean on the rate of ocean acidification

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The largest pH decline and widespread undersaturation with respect to aragonite in this century due to uptake of anthropogenic carbon dioxide in the Arctic Ocean have been projected. The reductions in pH and aragonite saturation state in the Arctic Ocean have been caused by the melting of sea ice as well as by an increase in the concentration of atmospheric carbon dioxide. Therefore, future projections of pH and aragonite saturation in the Arctic Ocean will be affected by how rapidly the reduction in sea ice occurs. The observed recent Arctic sea-ice loss has been more rapid than projected by many of the climate models that contributed to the Intergovernmental Panel on Climate Change Fourth Assessment Report. In this study, the impact of sea-ice reduction rate on projected pH and aragonite saturation state in the Arctic surface waters was investigated. Reductions in pH and aragonite saturation were calculated from the outputs of two versions of an Earth system model with different sea-ice reduction rates under similar CO2 emission scenarios. The newer model version projects that Arctic summer ice-free condition will be achieved by the year 2040, and the older version predicts ice-free condition by 2090. The Arctic surface water was projected to be undersaturated with respect to aragonite in the annual mean when atmospheric CO2 concentration reaches 513 (606) ppm in year 2046 (2056) in new (old) version. At an atmospheric CO2 concentration of 520 ppm, the maximum differences in pH and aragonite saturation state between the two versions were 0.1 and 0.21 respectively. The analysis showed that the decreases in pH and aragonite saturation state due to rapid sea-ice reduction were caused by increases in both CO2 uptake and freshwater input. Thus, the reductions in pH and aragonite saturation state in the Arctic surface waters are significantly affected by the difference in future projections for sea-ice reduction rate. Our results suggest that the future reductions in pH and aragonite saturation state could be significantly faster than previously projected if the sea-ice reduction in the Arctic Ocean keeps its present pace.

-229 Role of large trees in sequestering carbon

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Forests containing large trees play an important role in the global carbon cycle (1). Concern has been raised that large, old trees can be declining in the world (2). In general, it has been reported that the carbon stocks of forests are increasing (3,4), and increasing carbon density has been identified as a dominant driver of biomass expansion (5). Carbon density of tree populations can increase in two ways: the number of individual trees per hectare can increase over time; or the average size of trees in the population can increase over time. Here we report published observations of large trees from forest science literature in the US and Finland and test the following hypotheses: 1) The carbon stock embodied in large trees has increased since the mid 20th century; and 2) the relative share of forest carbon embodied in large trees has increased over time since the mid 20th century. The results of testing these hypotheses are mixed depending of country and region, and depending on the time of observation.

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-230 Global Stream and River CO2 Evasion

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Streams and rivers are increasingly seen as active components of the global carbon cycle. The transfer of carbon dioxide from streams and rivers to the atmosphere has been demonstrated to be a significant pathway within regional carbon cycles. However, global estimates of this transfer have been hampered by a lack of a framework for estimating the surface area and gas transfer velocity of streams and rivers and the absence of a global stream CO2 database. Although regional fluxes as high as 0.6Pg C yr-1 have been reported for streams and rivers of the Amazon and 0.5Pg C yr-1 for the temperate regions of the northern hemisphere 3 global estimates place stream and river efflux at ~1Pg C yr-1. Here we report the regional variation in global stream and river surface area, dissolved CO2 concentration and gas transfer velocity. We report a global stream and river CO2 evasion rate of 2.4Pg C yr-1 with a range of 2.0-2.8 (5th and 95th confidence intervals). This analysis also predicts global hot spots for stream and river evasion with ~80% of the flux occurring over just 20% of the land surface of the globe. The source of this CO2 is still not known with certainty and new studies are needed to research the mechanisms controlling CO2 evasion globally.

-231 Amplified global warming induced by ocean acidification? New climate aspects of the marine sulfur cycle

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The continuous oceanic uptake of anthropogenic CO2 changes the chemical composition of the marine realm resulting in a lowering of pH (ocean acidification). One consequence of ocean acidification might be a reduced production of dimethylsulfide (DMS), a biogenic sulfur compound, in surface waters as indicated by mesocosm studies. Marine DMS emissions are the largest natural source for atmospheric sulfur and changes in its strength have the potential to alter the Earth' s radiation budget.
We investigated the range of potential climate responses to a change in the marine sulfur cycle induced by ocean acidification. Using observational-based relationships between DMS concentrations and pH-changes we performed a set of simulations with a comprehensive Earth system model. Depending on the applied pH-sensitivity we find a reduction of 12 % to 24 % in DMS emissions by the end of the 21st century in a moderate CO2 emission scenario. This causes an additional positive impact on global mean radiative forcing (RF) of 0.1 to 0.64 W/m2 only due the ocean acidification induced changes in the marine sulfur cycle. These changes in RF would be tantamount to an equilibrium temperature response of 0.1 to 0.76 K.
The magnitude of the RF change and the estimated temperature response emphasize that this potential climate impact mechanism of ocean acidification should be in focus of future research and should also be considered in projections of future climate change.

-232 Fluxes and Controls of CO_2 in the Coastal Ocean: River Dominated Margins vs Ocean Dominated Margins?

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The contemporary coastal ocean is generally seen as a significant CO_2 sink at the global scale. Compilation of the available data sets along with different lines of physical-biogeochemical provinces and/or domains have converged to conclude that the coastal ocean is an atmospheric sink of ~0.2-~0.4 Pg C yr-1. Using the most up-to-date flux data, this CO_2 flux in the global coastal ocean is further updated to 0.36 Pg C yr-1. However, mechanistic understanding of the coastal ocean carbon cycle remains limited, leading to the un-answered question of why some coastal systems are sources while others are sinks of atmospheric CO_2. In this context, we proposed a new hypothesis: in addition to the processes identical to those in the open ocean such as thermodynamic and biological pump controls, both land input and exchange with the open ocean are significant determinants of the CO_2 fluxes in the coastal ocean. There are at least two distinct settings: river-dominated ocean margins (RiOMar) and ocean-dominated margins (OceMar). In a simplified scheme, RiOMar, as recognized previously, is featured by concurrent inputs of autotrophic (nutrients) and hetero-trophic (organic matter) loadings, while OceMar is characterized by concurrent off-site inputs, typically from depth, of nutrients and dissolved inorganic carbon (DIC). Using the basin areas of the largest marginal seas of the Pacific and the Atlantic, the South China Sea and the Caribbean Sea as examples of OceMars, we demonstrated that such external CO_2 sources controlled the CO_2 fluxes.

-233 Global cropland monthly gross primary productivity in the year of 2000

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Cropland has unique characteristics as compared with natural ecosystems, and is mainly influenced by human activities. However, large disagreements still exist over current estimations of global cropland gross primary productivities (GPP). In this paper, we present a prior study to estimation global cropland GPP by separating cropland into 26 crop species in a light use efficiency (LUE) based vegetation model. The maximum light use efficiency (ε*(GPP)), a key parameter in LUE approach, varies across crops in our model. ε*(GPP) values for these 26 crop species were generated by combing direct estimations and literature survey, range from 1.2 gCMJ-1 to 2.84 gCMJ-1. In particular, ε*(GPP) of 8 crop species were directly estimated from eddy covariance flux tower measurements with a range of 1.5-2.84 gCMJ-1, and these species cover 55% of global harvested areas. Global cropland GPP was estimated at 11.05 PgCyr-1, just locating in the middle of the values reported previously. Maize contributes higher GPP (1.545 PgCyr-1) than other crops. Asian has 38.9% of global GPP which is the most among continents. In continental United States, annual cropland GPP (1.28 PgCyr-1) is very close to the value reported previously (1.24 PgCyr-1) although ε*(GPP) values we used are much higher than that used in previous study. Our results suggest that more accurate description of cropland distribution (species and growing periods) and sophisticated parameterization will help to solve the problem that field based ε*(GPP) could not be applied directly in vegetation models. These two improvements also could be the potential developing directions of models in the future.

-234 Impact of high resolution meteorological fields on simulation of high frequency variability of CO2 concentration using FLEXPART with 1km flux maps

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

This study aims at generation and application of global high resolution meteorological fields to facilitate resolving high frequency variability of CO2 concentrations using Lagrangian particle dispersion model FLEXPART using high resolution (1km) flux fields. The surface CO2 flux datasets include the three major individual components of terrestrial, oceanic and fossil fuel fluxes. The background concentrations of CO2 are provided by an off-line global atmospheric tracer transport model (NIES-TM). High resolution meteorological fields are generated by the Non-hydrostatic Icosahedral Atmospheric Model (NICAM) at 28km spatial resolution using nudging to NCEP Final Analyses data. The coarse resolution simulation is carried out with 1.25 degree JCDAS meteorological data for the same period and compared with observed concentrations.

-235 Soil abiotic CO2 exchange over alkaline areas

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Although most studies suggest that soil CO2 flux dues to an organic process (i.e., soil respiration), but some scientists had assumed inorganic process may influence and cannot be ignored because of significant evidence. It has been confirmed that, in arid area of saline-alkali soils, an inorganic carbon process has the contribution to soil CO2 flux, equaling organic processes. However, for the separation of the organic and inorganic processes, so far there is still no reliable method. The carbon source/sink size caused by inorganic processes remains a mystery. This manuscript is designed to provide a first approximation for the organic-inorganic separation on large scales. The story of the carbon assignment accompanied with inorganic processes is also illustrated. The mysterious inorganic sink size is finally reconciled.

-236 From crops to boundary layer and back: the ARM/LBNL Carbon Project in the Southern Great Plains

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

One of the challenges in carbon cycle research is the vast range of scales, from plants to continents, which must be bridged by measurements and models. A second major challenge is coupling carbon, water and energy fluxes, for both natural and agricultural systems. The ARM/LBNL Carbon project is making a coordinated suite of carbon concentration, isotope, and flux measurements to support a range of scaling and integration exercises, including those proposed for the North American Carbon Project. The Southern Great Plains testbed, a GCM-grid sized area centered in Northern Oklahoma, has been the locus of these efforts for the past ten years under Atmospheric Radiation Measurement program (ARM) support. Precise CO2 and CH4 concentrations from the central tower and flask sampling from the central tower and from bi-weekly plane flights, both linked to the NOAA-ESRL network, tie the ARM region into the global atmospheric measurement networks. CO2 and CH4 concentrations are higher than global average for the latitude, reflecting continental sources. We compare the NOAA-ESRL flask data, which are collected weekly at 60m, with more finely resolved precise CO2 and CH4 and 13CO2 data collected diurnally at 4 heights. We are measuring carbon, water, and energy fluxes at nested scales, from the 60 m tower and from portable eddy flux systems deployed in crop fields of different management in the ARM region. These efforts provide data to drive and constrain land-surface modeling at the plot and regional scales. Regional-scale estimates of carbon and isotopic fluxes based on "bottom up" (distributed modeling tested at eddy flux sites) and "top-down" (atmospheric profiling of CO2 and water vapor concentrations) approaches are in progress. ARM Data are available from the ARM data archive at www.arm.gov.

-237 A Multi-Year Record of Airborne CO2 Observations in the US Southern Great Plains

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

We report on 10 years of airborne measurements of atmospheric CO2 concentrations from continuous and flask systems, collected between 2002 and 2012 over the Atmospheric Radiation Measurement Program Climate Research Facility in the US Southern Great Plains (SGP). These observations were designed to quantify trends and variability in atmospheric concentrations of CO2 and other greenhouse gases with the precision and accuracy needed to evaluate ground-based and satellite-based column CO2 estimates, test forward and inverse models, and help with the interpretation of ground-based CO2 concentration measurements. During flights, we measured CO2 and meteorological data continuously and collected flasks for a rich suite of additional gases: CO2, CO, CH4, N2O, 13CO2, carbonyl sulfide (COS), and trace hydrocarbon species. These measurements were collected approximately twice per week by small aircraft (Cessna 172 first, then Cessna 206) on a series of horizontal legs ranging in altitude from 460 m to 5,500 m (AMSL). Since the beginning of the program, more than 400 continuous CO2 vertical profiles have been collected (2007-2012), along with about 330 profiles from NOAA/ESRL 12-flask (2006-2012) and 284 from NOAA/ESRL 2-flask (2002-2006) packages for carbon cycle gases and isotopes. Averaged over the entire record, there were no systematic differences between the continuous and flask CO2 observations when they were sampling the same air, i.e., over the one-minute flask-sampling time. Using multiple technologies (a flask sampler and two continuous analyzers), we documented a mean difference of ~0.1 ppm between instruments. However, flask data were not equivalent in all regards; horizontal variability in CO2 concentrations within the 5-10 minute legs sometimes resulted in significant differences between flask and continuous measurement values for those legs, and the information contained in fine-scale variability about atmospheric transport was not captured by flask-based observations. The CO2 concentration trend at 3000 m (AMSL) was 1.91 ppm y-1 between 2008 and 2010, very close to the concurrent trend at Mauna Loa of 1.95 ppm y-1. The seasonal amplitude of CO2 concentration in the free troposphere (FT) was half that in the planetary boundary layer (PBL) (~15 ppm vs. ~30 ppm) and twice that at Mauna Loa (approximately 8 ppm). The CO2 horizontal variability was up to 10 ppm in the PBL and less than 1 ppm at the top of the vertical profiles in the FT.

-238 Do single-species and mixed forests differ in the maximum tree biomass they can support?

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Forests have been proposed as a tool in mitigating global warming by converting atmospheric CO2 to organic biomass in the forest soil and wood stocks. The upper limit of forest biomass stocks can be determined by self-thinning theory based on diameter-density relationship derived from empirical data such as national forest inventory data. A dataset of the diameter-density relationship was used to test whether multi-species forests carry more biomass, as could be expected from niche complementarity among different species. The objectives of this paper are therefore: 1) To obtain the exponent of self-thinning model when assuming the relationship DBH=k* 〖Density〗^(-16/9), where Density is number of individual trees per hectare and DBH is diameter at breast height. Parameter k is a fitted parameter that varies among species and eco-regions;
2) To compare the self-thinning lines among species and between single-species forests and mixed forests, and to show the variation among different stand structure. National Forest Inventory data of DBH and stand density from France and Spain are used to fit the self-thinning model for pure stands as well as mixed stands for the 10 most abundant tree species in Europe. The European eco-region map is used to stratify the data-set into separate eco-regions, allowing more robust inter-comparisons.
Results confirm that there are indeed significant differences in the wood carrying capacity among tree species and show significant differences among pure and mixed stands. In most cases, within the same eco-region, mixed forests exhibit a higher maximum wood biomass than pure forests. In contrast, in mixed stands composed of two pine species, self-thinning occurs at lower standing biomass, indicating increased competition resulting in reduced standing biomass. This research indicates that it is possible for forest managers to increase wood biomass stocks by selecting complementary species combinations.
Key words: forest management, biomass, self-thinning, eco-region, monocultures,
mixed stands

-239 Meta-analysis reveals profound responses of plant traits to glacial CO2 levels

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

Since the start of the Industrial Revolution CO2 levels have risen from 280 ppm to 390 ppm today, levels not experienced by plants for over 25 Ma (Royer 2006), and are expected to increase even further; common model estimates go up to 700 ppm by 2100 (IPCC 2007). The atmosphere today and as predicted for the end of the century will be increasingly different from that experienced by plants during a large part of the recent past.

In contrast to the many studies on plant responses to elevated CO2, considerably less research has focused on the response of plants to sub-ambient CO2. Several individual experiments reveal low CO2 effects at multiple scales from leaf to plant (Gerhart & Ward 2010). Recent research has shown CO2 uptake and water use are highly consistent across CO2 levels, from sub-ambient to elevated (Franks et al. 2013) Thus, there is clearly a need to integrate the knowledge available so far on low CO2 responses to determine if more traits follow a predictable pattern.

A general understanding of the links between atmospheric CO2 concentration and the functioning of the terrestrial biosphere requires an understanding of legacy effects of past low CO2 on plant trait responses to future higher CO2 . An interesting question is whether plant response from current to higher CO2 can be thought of as a continuation of the trajectory of low to current CO2 levels. To investigate this, we performed a meta-analysis of low CO2 growth experiments on 30 studies with 43 species (Temme et al. submitted). We quantified how plant traits vary at reduced CO2 levels and whether C3 versus C4 and woody versus herbaceous plant species respond differently. At low CO2, plant functioning changed drastically: on average across all species, a 50% reduction of current atmospheric CO2 reduced net photosynthesis by 33%; increased stomatal conductance by 60% and decreased intrinsic water use efficiency by 52%. Total plant dry biomass decreased by 51%, while specific leaf area (SLA) increased by 17%. Plant types responded similarly: the only significant differences being no increase in SLA for C4 species and a 16% smaller decrease in biomass for woody C3 species at glacial CO2. Quantitative comparison of low CO2 effect sizes to those from high CO2 studies showed that the magnitude of response of net photosynthesis, water use efficiency and SLA to increased CO2 can be thought of as continued shifts along the same line. However, for stomatal conductance and dry weight responses to low CO2 were greater in magnitude than to high CO2. Understanding the causes for this discrepancy can lead to a more general understanding of the links between atmospheric CO2 and plant responses.

-240 Meta-analysis reveals profound responses of plant traits to glacial CO_2 levels

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

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Since the start of the Industrial Revolution CO_2 levels have risen from 280 ppm to 390 ppm today, levels not experienced by plants for over 25 Ma (Royer 2006), and are expected to increase even further; common model estimates go up to 700 ppm by 2100 (IPCC 2007). The atmosphere today and as predicted for the end of the century will be increasingly different from that experienced by plants during a large part of the recent past.

In contrast to the many studies on plant responses to elevated CO_2, considerably less research has focused on the response of plants to sub-ambient CO_2. Several individual experiments reveal low CO_2 effects at multiple scales from leaf to plant (Gerhart & Ward 2010). Recent research has shown CO_2 uptake and water use are highly consistent across CO_2 levels, from sub-ambient to elevated (Franks et al. 2013) Thus, there is clearly a need to integrate the knowledge available so far on low CO_2 responses to determine if more traits follow a predictable pattern.

A general understanding of the links between atmospheric CO_2 concentration and the functioning of the terrestrial biosphere requires an understanding of legacy effects of past low CO_2 on plant trait responses to future higher CO_2 . An interesting question is whether plant response from current to higher CO_2 can be thought of as a continuation of the trajectory of low to current CO_2 levels. To investigate this, we performed a meta-analysis of low CO_2 growth experiments on 30 studies with 43 species (Temme et al. submitted). We quantified how plant traits vary at reduced CO_2 levels and whether C3 versus C4 and woody versus herbaceous plant species respond differently. At low CO_2, plant functioning changed drastically: on average across all species, a 50% reduction of current atmospheric CO_2 reduced net photosynthesis by 33%; increased stomatal conductance by 60% and decreased intrinsic water use efficiency by 52%. Total plant dry biomass decreased by 51%, while specific leaf area (SLA) increased by 17%. Plant types responded similarly: the only significant differences being no increase in SLA for C4 species and a 16% smaller decrease in biomass for woody C3 species at glacial CO_2. Quantitative comparison of low CO_2 effect sizes to those from high CO_2 studies showed that the magnitude of response of net photosynthesis, water use efficiency and SLA to increased CO_2 can be thought of as continued shifts along the same line. However, for stomatal conductance and dry weight responses to low CO_2 were greater in magnitude than to high CO_2. Understanding the causes for this discrepancy can lead to a more general understanding of the links between atmospheric CO_2 and plant responses.

-241 Unraveling the role of volcanic eruptions and interdecadal modulation of El Niño-Southern Oscillation amplitudes in recent changes of the global carbon cycle

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Tropical explosive volcanisms and El Niño-Southern Oscillation (ENSO) are the most important natural factors that significantly impact the climate system and the carbon cycle on annual to multi-decadal time scales. The three volcanic eruptions in the last 50 years – Agung, El Chichón, and Pinatubo - occurred in spring/summer in conjunction with El Niño events and left distinctive negative signals in the observational temperature and CO2 records. However, confounding factors such as seasonal variability and ENSO may obscure the true forcing-response relationship.

We determine for the first time the extent to which initial conditions, i.e., season and phase of the ENSO, and internal variability influence the coupled climate carbon cycle response to volcanic forcing and how this affects estimates of the terrestrial and oceanic carbon sinks. Ensemble simulations of a fully coupled carbon cycle-climate model predict that atmospheric CO2 response is 60% larger when a volcanic eruption occurs during El Niño and in winter than during La Niña conditions. Our simulations suggest that the Pinatubo eruption contributed 11±6% to the 25 Pg terrestrial carbon sink inferred over the decade 1990-1999 and -2±1% to the 22 Pg oceanic carbon sink. In contrast to recent claims, we show that trends in the airborne fraction of anthropogenic carbon are within the noise level when accounting for the decadal-scale influence of explosive volcanisms and related uncertainties.

Additionally, we evaluate whether recent decadal modulation of ENSO amplitudes play an important role in driving decadal variations in the global carbon cycle. Model simulations reveal that the carbon cycle may have an asymmetric response to the warm equatorial phase (El Niño) and cold equatorial phase (La Niña) component of ENSO variability. This indicates that averaged over times of large ENSO variability there is an anomalous land to atmospheric carbon flux. The implications for the detection and attribution of current trends in the global carbon cycle will be discussed.

-242 The impacts of change in freezing-thawing dynamics on carbon release from foliar litter along an altitudinal gratitude in the alpine/subalpine forests in Eastern Qinghai-Tibet Plateau, China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Carbon (C) release from foliar litter is one of the primary components in C exchange between atmosphere and terrestrial ecosystems. Both freezing and thawing, which are sensitive to ongoing climate change, could play an essential role in controlling C release from litter in cold regions, but very little information is available on this study. In order to examine whether climate warming can promote C release from litter, and which factors dominate C release at different decomposition stages in alpine/subalpine region, a 2-years field litter decomposition experiment was conducted along an altitudinal gradient (from around 2700m, 3000m, 3300m to 3600m) in Eastern Qinghai-Tibet Plateau, China. C release from fresh foliar litter of spruce (Picea asperata), fir (Abies faxoniana) and birch (Betula albosinensis) was investigated at ten stages (5 stages each decomposition year) with different freezing-thawing characteristics as decomposition proceeded: the onset of frozen stage with frequent soil temperature fluctuations around 0°C), deep frozen stage with temperature constantly below 0°C, and thawing stage with temperature around 0°C as the temperature increased, early stage of growing season with temperature continuously increased and later stage of growing season with temperature continuously decreased. Based on decomposition coefficient (k) from Olson model, relative rapid C release from litter of three species was detected at higher altitudes rather than lower altitudes. Regardless of altitude and species, the first early stage of growing season did the highest contribution (occupied 29.9-44.8%) to C release rate in 2-years decomposition, followed by the onset of frozen stage and deep frozen stage in the first decomposition year. Only deep frozen stage showed obvious C release in the second decomposition year. After examined the relationships between carbon release rate and 29 indicators at different stages by step-wise analysis, we found negative degree-days played the dominant role in C release in winter. Compared with initial substrate chemistry, instant chemistry after the former decomposition contributed more to C release from litter at each decomposition stage. Instant lignin concentration and C/P had much closer relationships with C release rates than other examined chemistry indicators. In addition, microbial biomass C showed weak relationships with C release rates at deep frozen stage and thawing period, but strongly related to C release at onset of frozen stage and early stage of growing season together with instant chemistry. Therefore, the results presented here imply that frozen temperature can modify C release from litter directly by physically effects and indirectly by altering substrate decomposability. In the short term, annual temperature increase could delay C release in fresh litter due to the changes of freezing-thawing in this cold region under future climate change scenarios.

-243 Simulation of CO2 concentration distributions in East Asia with RAMS-CMAQ

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The regional air quality modeling system RAMS-CMAQ was developed by incorporating a vegetation photosynthesis and respiration module (VPRM) and applied to East Asia to simulate temporal-spatial variations in atmospheric CO2 concentrations with prescribed surface CO2 flux (i.e. fossil fuel combustion, biomass burning, sea-air CO2 exchange, and terrestrial biosphere CO2 flux). Comparison of model results with eight ground-level in-situ measurements shows that the model was able to capture most observed temporal-spatial features of CO2 levels over East Asia. Simulated CO2 concentrations were generally in good agreement with the observed ones, and the model was able to reproduce the horizontal distribution patterns reasonably well. Besides, the accumulated impacts of anthropogenic emissions contributed more to the increase of CO2 concentrations in urban regions rather than the remote regions. In addition, analysis indicates that CO2 concentrations in East Asia were strongly influenced by terrestrial ecosystem.

-244 A Chinese Joint-Assimilation System (Tan-Tracker) to Simultaneously Estimate Surface CO2 fluxes and 3-D Atmospheric CO2 Concentrations from Observations：Formulation and OSSEs for Insitu-Observations

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

A joint –assimilation system (referred to as Tan-Tracker) to simultaneously estimate surface CO2 fluxes and 3-D atmospheric CO2 Concentrations from observations is developed in this paper. The system is based on the POD-based ensemble four-dimensional variational assimilation method (PODEn4DVar) and a dual-pass optimization framework. The system was developed to overcome computational limitations encountered when a large number of observations are used to estimate a large number of unknown surface fluxes. In the PODEn4DVar, the POD transformation is first applied to the OP space and then this transformation is transferred to the MP space in terms of the linear assumption between the MPs and the OPs. Accordingly, the weighted mean of the OP orthogonal base vectors can fit the 4-D innovation data in the observation space directly, which has the potential to improve the analysis accuracy. We assess the performance of this new system in a pseudodata experiment that resembles the real problem we will apply this system to and conclude that the system is able to provide satisfactory flux estimates for the relatively large scales resolved by our current observing network.

-245 The Macquarie Island in situ CO2 record: Instrumentation, calibration, baseline selection and climatology

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The Southern Ocean (south of 44° S) is a major sink of atmospheric CO2, however our ability to constrain the mean Southern Ocean carbon flux, seasonality and interannual variability, has been limited by the small number of Southern Ocean pCO2 measurements, especially in winter (Lenton et al. 2013). As an additional data stream this paper introduces the in situ CO2 atmospheric record collected since early 2005 at Macquarie Island (54? 38′ S, 148? 52′ E).
Macquarie Island is arguably the most isolated and remote of all the southern ocean measurement stations, lying more than 1500 km from the closest continental land mass. Access to the island is limited to an annual resupply voyage, making on-going maintenance of the instrument challenging and increasing flask storage times.
The instrumentation, a continuous "LoFlo" CO2 analyser, will be presented, along with an assessment of its performance and calibration strategy. This instrument and co-located flask measurements were linked to the WMO x2007 scale. A 10 month preliminary Radon dataset was available for qualitative comparison.
A baseline selection criteria (wind speeds > 5 m/s) was assessed using the Radon record, an earlier Radon study and statistical analysis. There was no clear relationship between wind direction and baseline deviation. Using this criteria the in situ record agreed well with the co-located flask record, with a mean difference (0.1 ppm) of the order of the flask matched pair difference (x¯ = 0.15 ppm).
The general climatology of the record was investigated with a combination of back trajectories and other statistical methods. Back trajectories were used to identify the origin of air masses for the 22 significant long range transport events identified. Of these events only 9 (< 3 % of the total data set) appeared to have been influenced by continental sources demonstrating the dominance of oceanic sources and sinks in the Macquarie Island record.
Lenton, A., B. Tilbrook, et al. (2013). "Sea-air CO2 fluxes in the Southern Ocean for the period 1990–2009." Biogeosciences Discuss. 10(1): 285-333.

-246 Explaining recent anomolies in the growth of atmospheric CO2

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

In recent years the growthrate of CO2 in the atmosphere has failed to keep pace with the apparent rise in anthropogenic emissions. This suggests an increase in one of the sinks for atmospheric CO2. The atmospheric observing network is now approaching a density where we can hope to isolate this anomalous sink. At the same time, terrestrial carbon cycle models produce a good fit to the global interannual variability in CO2 sources. Thus we can use such a model to probe the processes responsible for the anomalous sink.

We perform an atmospheric inversion study of the last decade using the CSIRO Cubic Conformal Atmospheric Model. We combine observations of CO2 and delta-13 CO2 taking advantage of the recent improvements of calibration of this isotopic tracer. We suggest that much of the anomalous sink can be explained by an increase in the northern hemisphere terrestrial growing season net flux (defined as the sum of all net ecosystem exchange towards the biosphere) with an anomaly focused on northern midlatitudes. Experiments with the LPJ terrestrial biosphere model show the same behaviour. The study concludes with an analysis of the processes responsible for the model's increased uptake.

-247 Global inversions of atmospheric CO2 and CH4: Fluxes for the Asia Regions

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

We use the CCSR/NIES/FRCGC Atmospheric General Circulation Model (AGCM)-based Chemistry Transport Model (ACTM) for simulating concentration of species, relating to the carbon cycle science, global warming, and ozone depletion. The forward transport in ACTM is validated for inter-hemispheric and convective transports using sulphur hexafluoride (SF6) and 222radon, respectively, as a part of the TransCom-CH4 model intercomparison. The photochemical lifetimes due to hydroxyl radicals in the troposphere and photolysis in the stratosphere compares well with independent calculations, e.g., the WMO Scientific Assessment of Ozone Depletion. A 64-region matrix-based inverse model and a grid-based inversion system using ensemble Kalman smoother have been developed for estimating fluxes of CO2 from atmospheric measurements. A 53-region land only inversion system has also been developed recently for optimising CH4 emissions. All these inverse modeling systems use ACTM forward chemistry-transport simulations for the corresponding gases. Presently, these inversion systems can ingest data from GLOBALVIEW monthly mean products, flask and in situ observations at surface stations or along the aircraft flight tracks, and remote sensing observations.

For this presentation, we will specifically use the aircraft measurements carried out by the Tohoku University between Sendai and Fukuoka airports during the period of the 1980s to present, in addition to the other available datasets, and show the impact of the former dataset on estimating surface fluxes. Our preliminary analysis shows the aircraft measurements over Japan are key to constrain both the net amount and trends of CO2 and CH4 fluxes for the continental Asia regions.

Detailed results will be presented at the conference.

-248 Long-term variability of sea-air CO_2 flux distribution over the global ocean analyzed by JMA

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

We developed an empirical method for estimating monthly fields of partial pressure of oceanic CO_2 (pCO_2) over the global ocean, with a diagnostic model using relationships between observed pCO_2 and other parameters such as sea surface temperature (SST), sea surface salinity (SSS) and chlorophyll-a concentration (Chl-a) as an additional biochemical parameter. We divided the global ocean into 40 regions and then made optimal equations to estimate pCO_2 by multiple regressions. Monthly pCO_2 fields, obtained from SST (Merged satellite and in situ data Global Daily Sea Surface Temperature (MGDSST)) analyzed by JMA, SSS of ocean data assimilation system (Multivariate Ocean Variational Estimation System / Meteorological Research Institute Community Ocean Model (MOVE/MRI.COM-G)) developed by MRI/JMA and Chl-a from SeaWiFS and MODIS/Aqua ocean color observations, are qualitatively in good agreement with the climatology by Takahashi et al. (2009) and those from other empirical methods. The global average of root mean squares between observed and estimated pCO_2 is about 19 μatm, with meridional variability, 25 to 30 μatm in the high latitudes, 10 to 15 μatm in the subtropics and 20 to 25 μatm in the equatorial regions. Biases are significantly reduced by the use of Chl-a in the high latitudes where net biological uptake of inorganic carbon is very high during the blooming seasons.

The monthly fields of CO_2 flux with a resolution of 1° × 1° from 1985 through 2010 were calculated from the estimated pCO_2 and wind speed datasets. The 26-year mean annual net CO_2 flux (total flux, including natural effluxes) was estimated to be -2.0 ± 0.4 PgC yr^{-1} (a negative value indicates uptake by the ocean). This value is indistinguishable from the climatology of -1.6 PgC yr^{-1} determined by Takahashi et al. (2009) and in the range of -1.4 to -2.6 PgC yr^{-1} assessed by Wanninkhof et al. (2012), taking natural effluxes into consideration. The long-term trend of annual net CO_2 flux is not significant due to its interannual variability. In basin scales, interannual variability of the estimated CO_2 flux is associated with large scale climate variability such as ENSO. In the 1997/1998 El Niño period, the equatorial Pacific released 30% less CO_2 than the average due to the reduced upwelling whereas 20% more CO_2 in the 1999/2000 La Niña period. These changes significantly affected variability of the global annual net CO_2 flux.

-249 Investigating an abrupt change in the land uptake of carbon in 1989

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

A recent study of the net land carbon sink suggests that the net land carbon uptake abruptly increased of about 1 Pg C/yr after 1988/1989. This study used an estimate of the net land carbon uptake as a balance between the atmospheric growth rate of CO2 at Mauna Loa and South Pole, fossil fuel emissions, and ocean uptake obtained from a suite of ocean models. Here we present additional evidence for a shift in the net land uptake of carbon. We detect a shift of a similar size in global net primary production obtained with the data-constrained carbon model CASA-GFED3, showing an especially strong signature in high latitudes and in the tropics. In addition, global gross primary production fluxes obtained through upscaling of local carbon flux observations (based on the global FLUXNET tower network) also compare to our previous analysis and show a sustained increase after the late 1980’s.

-250 The process attribution and model predictability of North American biospheric CO2 flux as informed by atmospheric measurements

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

There are increasing demands for carbon cycle scientists to provide support in predicting future changes in biogeochemical carbon cycling, by examining the feedback between carbon and climate. This need is predicated on understanding biospheric CO2 fluxes on a process level. A successful process-level understanding of biospheric CO2 flux should address two problems: (1) "attribution": what are the major environmental processes controlling terrestrial CO2 flux variability, and (2) "prediction": do current terrestrial biosphere models (TBMs) reflect the "true" processes, and thus can predict CO2 flux under changing climate and land use? These issues need to be resolved at least at monthly and biome scales to examine the underlying biogeochemical processes at regional scales.

Geostatistical inverse modeling (GIM) uses atmospheric observations to estimate CO2 fluxes with varying level of complexity through parameterizing a flux covariate matrix, and this approach can therefore serve as a tool to help identify significant flux drivers. To tackle the two above problems, we use atmospheric CO2 measurements in North America and GIM along with two different sets of auxiliary variables to help explain biospheric CO2 fluxes. The two sets of auxiliary variables are environmental driver datasets and CO2 flux estimates from various TBMs (including CASA GFEDv2, ORCHIDEE, SiB3.0 and VEGAS2) participating in the North American Carbon Program regional and continental interim synthesis activities.

In terms of CO2 flux "attribution," precipitation, specific humidity, and snow cover are identified as significant environmental drivers over Temperate Coniferous Forest (TCoF), Temperate Broadleaf and Mixed Forests (TBMF), Boreal Forests/Taiga (Bore) and Temperate Grasslands, Savannas & Shrublands (TGSS) in January. In July, environmental processes from one additional biome – Dessert & Xeric Shrublands (DeXS) are identified as significant. Evapotranspiration and short-wave radiation are identified as additional significant explanatory variables in July over TBMF, Bore and TGSS. In terms of CO2 flux "prediction," ORCHIDEE over TBMF in both January and July, and ORCHIDEE over Bore and SiB3 over TGSS in July are identified as helping to explain atmospheric signals, indicating that their simulated environmental processes over these biomes are consistent with that "seen" by measurements. However, no TBMs are selected over TCoF, Bore, and TGSS in January and over TCoF and DeXS in July (despite the fact that environmental variables are identified). This suggests that TBM simulations for those biomes/months are likely not within the constraints of atmospheric measurements. We conclude that: (1) for TCoF, TBMF, Bore and TGSS, water availability is a significant driver of CO2 fluxes while Evapotranspiration and radiation provide additional explanatory power in July; 2) while the examined TBMs appear to provide reasonable explanatory power over TBMF, they are less consistent with the atmospheric record over TCoF, Bore, TGSS and DeXS; 3) atmospheric measurement availability may be insufficient to constrain environmental processes in the tropic & subtropic ecosystems (Trop) and Tundra (Tund).

-251 Temporal variations of concentration and isotope ratios of atmospheric methane observed at Ny-Ålesund, Svalbard

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Atmospheric methane (CH4) is one of the most important greenhouse gases, however, contributions of each CH4 source to the atmospheric CH4 variations are still unclear. To elucidate present CH4 budget in the Arctic region, we have maintained systematic observations of CH4 concentration and carbon and hydrogen isotope ratios of CH4 (δ13C-CH4 and δD-CH4) using weekly air samples collected at Ny-Ålesund, Svalbard (78°55′ N, 11°56′ E) since 1991, 1996 and 2005, respectively. The CH4 concentration, δ13C-CH4 and δD-CH4 show clear seasonal cycles with long-term trends. We applied a simple budget analysis on the CH4 seasonal cycles using prescribed OH concentrations, observed CH4 concentrations and the isotope ratios. As a result, we found that the CH4 seasonal cycles were mainly driven by the CH4 release from wetlands from July to September as well as by CH4 destruction by OH in summer. The secular increase of the CH4 concentration had been stagnated from 1999 to around the end of 2005, and then restored at an average rate of 6.6 ppbv/yr between 2006 and 2010. It was shown that the CH4 increase after 2006 could be mainly attributable to strengthening of CH4 release from wetlands by analyzing differences of the increase rates of the concentration and the isotope ratios before and after 2006.

-252 Carbon Dioxide Emission and Carbon Sequestration under Different Tillage and Rice Straw Management in Soil

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Carbon inputs and tillage intensity affect organic matter degradation and thereby CO2 emission, which further negatively affects agriculture and the environment. Information on carbon cycling in rice based cropping system is lacking, therefore, the research was conducted to quantify the effect of rice straw and tillage operation in rice field on CO2 emission and carbon sequestration during August 2010 to May 2012 in four consecutive rice seasons having two tillage operations (minimum and traditional) and three levels of rice straw management (control, rice straw surface mulch and rice straw incorporation) in a factorial RCBD with four replications. Rice straw was applied at the rate of 5 t ha-1. In most of the cases the peak values of CO2 emission reached after 3-4 weeks of rice straw application to soil irrespective of tillage practices. Rice straw application significantly increased CO2 emission in all four rice growing seasons over the control. The CO2 emission under the minimum tillage were about 26, 34, 59 and 34 kg ha-1 day-1in T. Aman 2010, Boro 2011, T. Aman 2011 and Boro 2012, respectively, while under the traditional tillage these values were 25, 33, 96 and 65 kg ha-1 day-1. Minimum tillage sequestered more C in soil, which was attributed by lower rates of C emission and rice straw degradation. Under the minimum tillage C degradation rate constant, k and C sequestration were 0.000300 (day-1) and 3814 kg ha-1, respectively, while under the traditional tillage these values were 0.000394 (day-1) and 1980 kg ha-1, respectively.

-253 Carbon balance of China constrained by CONTRAIL aircraft CO2 measurements and an updated CO2 emission inventory of China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

In order to cope with global warming, it is important and urgent to quantify the fluxes of carbon dioxide (CO2) between the atmosphere and terrestrial ecosystems for different regions in the world. While much is known for Europe and North America, the estimates of the terrestrial CO2 flux over China's landmass are beset with considerable uncertainties since very few measurements of atmospheric CO2 are available in China. To improve these estimates, nested atmospheric CO2 inversion during 2006 - 2009 was performed in this study using passenger aircraft based measurements over Eurasia of the Comprehensive Observation Network for Trace gases by Airliner (CONTRAIL) project in addition to the surface measurement data set of GLOBALVIEW–CO2 and an updated CO2 emissions inventory of China (CNCEI). The emissions inventory includes two sectors, i.e., energy consumption and industrial processes and is compiled at the provincial level. In the compilation, much more data are used to reconstruct the spatial and temporal (monthly) distributions of the emissions than previous inventories. The inversion system includes 43 regions with a focus on China using the Bayesian synthesis approach and the TM5 transport model. The terrestrial ecosystem flux modeled by the BEPS model and the ocean flux simulated by the OPA-PISCES-T model are considered as the prior fluxes. The global fossil fuel emissions inventory from CDIAC and the fire emissions inventory from GFEDv3 are also used. Considering different observations (GLOBALVIEW–CO2 only or GLOBALVIEW–CO2 and CONTRAIL CO2) and different anthropogenic CO2 emissions inventories (CDIAC only or CDIAC and CNCEI), four inversion experiments are conducted. The impacts of CONTRAIL CO2 and CNCEI on inverted China terrestrial carbon fluxes are quantified, and the improvement of the inverted fluxes after adding CONTRAIL CO2 and CNCEI are rationed against climate factors. Results show that the inverted China carbon sinks increased and the posterior flux errors are reduced when constrained by CONTRAIL CO2 and CNCEI. Moreover, the optimized terrestrial carbon fluxes are evaluated against ChinaFlux eddy-covariance observations and by comparing the simulated atmospheric CO2 concentrations with some independent aircraft measurements of GLOBALVIEW–CO2.

-254 Coupled Terrestrial-Coastal Ocean Modeling of Carbon-Cycle Processes in the Mississippi-Atchafalaya Basin and Northern Gulf of Mexico

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Margins that receive input from large rivers represent the extremes of continental shelf systems in carbon cycling and fluxes, and therefore should be a high priority in efforts to quantify regional carbon budgets. Our recent findings in the vicinity of the Mississippi River plume have demonstrated the highly variable nature of carbon fluxes in this system, and the need for both greater spatial and temporal coverage as well as an assessment of the underlying community metabolism driving patterns in surface CO2. Changing climate and land use practices have the potential to dramatically alter coupled hydrologic-biogeochemical processes and associated movement of water, carbon and nutrients through various terrestrial reservoirs into rivers, estuaries, and coastal ocean waters. Here, we describe a NASA Interdisciplinary Science project and complementary Carbon Monitoring System project that employ an integrated suite of models in conjunction with remotely sensed as well as targeted in situ observations with the objectives of describing processes controlling carbon fluxes on land and their coupling to riverine, estuarine and ocean ecosystems. The objectives of these efforts are to 1) assemble and evaluate long term datasets for the assessment of impacts of climate variability, extreme weather events, and land use practices on transport of water, carbon and nitrogen within terrestrial systems and the delivery of materials to waterways and rivers; 2) using the Mississippi River as a testbed, develop and evaluate an integrated suite of models to describe linkages between terrestrial and riverine systems, transport of carbon and nutrients in the Mississippi and Atchafalaya rivers and tributaries, and associated cycling of carbon and nutrients in coastal ocean waters; 3) evaluate uncertainty in model products and parameters and identify areas where improved model performance is needed through model refinement and data assimilation; and 4) establish and populate geospatial portals for sharing and analysis of carbon datasets and products. This research will provide information that will contribute to determining an overall carbon balance in North America.

-255 Change of Soil Organic Carbon Stocks in Typical Regions of China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Multi-purpose regional geochemical survey (MPRGS), using a grid-sampling scheme with the density of 1 sampler/1km2, affords a suitable data base for detecting the change of soil organic carbon stock in typical regions of China. Soil organic carbon density (SOCD) calculated from MPRGS obtained from 2000s was compared with that from the second soil survey from 1980s, and then change of soil organic carbon stock was obtained for the typical regions of China. It was shown that there is a significant soil organic carbon loss in the Northeast Plain of China, However, the SOCD for the traditional farming area, e.g. the North China, East China, and Southwest China. There is little variation of soil carbon stocks for the farming land of South China. The soil carbon loss of Northeast China was attributed both to the Climate Change and Landuse Change in the recent decades. And the increasing carbon stocks in the traditional farming land were caused by the improving agriculture management.

-256 Long-term CO2 fluxes in urban areas – Results from Helsinki and an application for regional carbon budgets

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Cities are a large source for atmospheric carbon dioxide, originating mainly from fossil fuel combustion. The exchange of CO2 between the urban surface and the atmosphere can be directly measured by the eddy-covariance (EC) method that gives the net turbulent transport of CO2. The measurements can be used to derive annual CO2 budgets for a region of few hectares around the measurement tower. The number of long-term CO2 exchange studies is however limited and lot of uncertainty exists in the annual budgets of CO2 and in the controlling factors.

In this study we analyse five years of CO2 flux measurements from Helsinki, Finland. The purpose is to examine seasonal and annual variations of CO2 exchange, and to identify different factors controlling the measured exchange. The measured flux is highly dependent on the wind direction with the highest CO2 emissions downwind from a large road and the lowest emission from the direction of an area of high vegetation cover fraction. In the road area, deviations between seasons are small and were more related to the reduced trafc rates during the holiday rather than vegetation activity. In the more-vegetated area, the seasonal variations are stronger and the effect of vegetation uptake was clear in summer daytime. The measurement site is a net source with an annual average emission of 1760 g C m–2. The annual value varies 16% between the different years and the main factor was the dominant wind direction. Annually, the area of the road emitted 3500 g C m-2, whereas the area of high fraction of vegetation cover emitted only 870 g C m-2.

We also perform a meta-analysis of annual CO2 budget estimates from 14 cities using the EC method to examine the drivers behind the annual CO2 balances. We show that the fraction of natural land area can explain 84% of the intercity variation in CO2 budgets. This dependency is used as a proxy for predicting regional CO2 budgets across the world using a method with satellite-derived land-cover data as the primary source. This up-scaling procedure is verified by extracting 56 case-study cities from the mapping and then comparing the official inventory-based estimates to our land-cover-based estimates. The correspondence is high (r2 = 0.72) which thus corroborates the fraction of natural area as a useful proxy for CO2 budgets of cities.

-257 The Spatio-temporal Variation of Phytoplankton Community Structure and Its Coupling to Particles Organic Carbon Export in the Northern South China Sea

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The technology of high performance liquid chromatography combined with CHEMTAX software to define the phytoplankton community structure was applied in 4 cruises study carrying out during July, 2009~June, 2011 in the northern South China Sea (nSCS). The TChl a biomass was significantly higher in fall or winter than in spring or summer, in which the higher biomass seasons dominated by Diatoms comparing to Prochlorococcus and Synechococcus in warmer seasons. Haptophytes_8 in spring and Prasinophytes in fall were two intermediate populations. Diatoms- Haptophytes_8- Prochlorococcus and Synechococcus succession was remarkable from coast to offshore basin. The temperature, N and P nutrients were the major factors influenced the distribution patterns and biomass.

Positive correlation was constructed between TChl a and integrated primary production, especially with higer IPP under the 30%~50% Nano-fractional phytoplankton biomass. POC Flux/IPP (ThE) was below 10% at most of the status, but increased to 20%~50% somehow in summer or fall. The ThE was higher in fall than the 40%~50% in summer or winter. The predominance of Haptophytes_8 in winter might play the leading role in high f-ratio but low POC Fluxes, as its low settling effciency.

The evidence of Pico- and Nano- phytoplankton’ s sinking to the 300 m and 500 m was obtained using the size-fractional in situ pumps. It was the results of the repackaged effect or aggregated. However, 30%~50% Micro-size phytoplankton in the 1~10 μm samples in the deep water indicated that the broking down of the larger particles existing and also the lateral transmission from the continiental shelf under the dynamic downwelling in winter.

-258 The impact of photosynthesis, calcification and water circulation on carbon chemistry variability above a coral reef: a modelling study.

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Diurnal fluctuations in seawater carbon chemistry occur inside coral reef systems are due to water circulation, air-sea exchange and metabolic processes. Daily changes in carbon ion speciation and pH on reefs can be larger than the century-scale trends predicted for open ocean waters under climate change scenarios. Understanding the drivers of this variability is necessary to assess the potential impact of ocean acidification on coral reef ecosystems. Using detail maps of benthic habitat, we implement a high resolution hydrodynamic model of a coral reef (Heron Island reef, southern Great Barrier Reef, Australia) and couple it to a carbon chemistry model and a calcification/photosynthesis parameterisation developed for Heron Island reef. This coupled model is able to reproduce the observed variability in the water temperature and carbon chemistry at a number of locations within the reef, demonstrating an ability of the model to capture both the circulation and rates of carbon chemistry transformation. A simulation shows that the dominant processes driving the variability in carbonate chemistry at a location on the reef are the location of the different benthic communities and the path the water has taken to arrive at that site. The residence time of the water on the reef varied between 16-60 hours dependant on the wind speed and direction. The longer transit times over the reef reduced the aragonite saturation state Ω in the overlaying water to as low as 2. On average the reef ecosystem reduces Ω at the rate of 0.03 per hour. A scenario in which we remove the benthic non-calcifying microalgae from the reef shows a reduction in the Ω in some regions from 5 to 2.5, and an average reduction of the coral calcification by 25 %. This interaction between
photosynthesis and calcification shows that climate change impacts due to ocean acidification on corals need to consider processes such as eutrophication that can alter the impacts of global ocean acidification at the reef scale.

-259 Three-dimensional behaviors of atmospheric CO2 revealed by the CONTRAIL project and their significance in inverse flux estimates

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Frequent measurements of atmospheric CO2 using Continuous CO2 Measuring Equipment (CME) as well as other greenhouse gases by Automatic Air Sampling Equipment (ASE) onboard the commercial airliners under the CONTRAIL project brought us huge numbers of CO2 data in upper air and revealed latitudinal, longitudinal and vertical difference in CO2 variation worldwide. The CONTRAIL project has been conducted since 2005 using 6 aircraft operated by Japan Airlines. Until 2012, more than 7,000 of CME flights were made between Japan and Europe, South Asia, Southeast Asia, East Asia, Australia, Hawaii and North America, and 13,000 vertical profiles have been obtained over there.
In the Northern Hemisphere, large seasonal changes of CO2 in the upper troposphere are found from spring through summer at northern mid-to-high latitudes with significant longitudinal differences; seasonally low CO2 mixing ratios are vertically transported from the surface over the Eurasian continent and then transported eastward to the North Pacific. In the Southern Hemisphere, the CO2 in the upper troposphere increases rapidly from April to June, indicating clearly the inter-hemispheric transport of high CO2 from the Northern Hemisphere winter. The rapid increase in the upper southern lower latitudes is equivalent to about 0.2 Pg increase in carbon. This three-dimensional field of observed CO2 should be adequately represented in general circulation models for source/sink estimates by inverse methods.
Then, an inversion analysis was performed using the CONTRAIL-CME with the NICAM based transport model, which was found to have sufficient transport performance even in the upper-air. The inversion result shows that the CONTRAIL data have significantly large impacts on estimates of tropical terrestrial fluxes. Comparing inversion with surface data alone, posterior errors were reduced by up to 64 % in the Asian tropics. The inversion with the CONTRAIL data yields the global carbon sequestration rates of 2.22±0.28 Pg C yr-1 for the terrestrial biosphere and 2.24±0.27 Pg C yr-1 for the oceans. This is the first attempt to extensively use the wide-ranging aircraft data set in CO2 inversion and has demonstrated its great utility for constraining tropical flux estimates. The data are also used to validate CO2 measurements from space.

-260 Detecting Power Plant Emissions Signatures from Space

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

CO2 emissions from the combustion of fossil fuels are a major input to the global carbon cycle over decadal time scales. Global total CO2 emissions are still increasing at a pessimistic rate, and international efforts to curb man-made emissions are required in order to mitigate global climate change. Emissions from nations are often estimated based on collections of statistical data which are then reported, to help monitor their compliance with emission reduction targets. We however lack an objective method that allows us to monitor emissions changes directly and/or verify the reported emissions. Future carbon-observing space missions are expected to establish an independent tool for directly measuring these emissions. Since 2009, we have implemented dedicated satellite observations specifically made over intense large point sources (LPS) to detect emissions' signature, using the Japanese Greenhouse Gases Observing SATelllite (GOSAT). Our target LPS sites comprise large fossil-fueled power plants and megacities, throughout the world (N > 300). Those sites have been occasionally included in the observation pattern of GOSAT, and the measurements are made using the target observation mode. We have analyzed GOSAT XCO2 retrievals available from four research groups (five products total): National Institute for Environmental Studies (NIES) (both the NIES standard Level 2 and NIES-PPDF products), the NASA Atmospheric CO2 from Space (ACOS) team (ACOS Level 2 product), the Netherlands Institute for Space Research (SRON)/Karlsruhe Institute of Technology, Germany (RemoTeC), and the University of Leicester, UK (Full-Physics CO2 retrieval dataset). Likely due to geophysical difficulties in the retrievals, we have obtained fewer retrieved soundings relative to our original requests (approximately 0.4-16% depending on products). However, we have obtained statistically significant enhancements at some LPS sites where weather conditions were ideal for viewing. We have also implemented simulations of enhanced XCO2 using the Global Eulerian-Lagrangian Coupled atmospheric transport model (GELCA) and the high-resolution fossil fuel emissions dataset (Odiac). Odiac includes both the emission and location information of the power plants, as requested in our target observations. Our model simulations tend to underestimate the enhancements, but show a good correlation with observed enhancements.

-261 Atmospheric Carbon Dioxide in Korea, 2012

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

To select the background concentration of carbon dioxide we compared its concentrations in three sites located in western, southern, and eastern part of Korean Peninsula. When long range transported air-mass moved into Korea, western and southern sites showed higher value of CO2 than eastern site, while CO2 concentration in western site was only increased under the stagnated condition. However, the CO2 in three of sites had similar value when strong westerly wind flowed. Hourly and daily variation in the concentration of CO2 due to local source and sink are described in each site. We also applied the digital filtering method on raw data and selected data by meteorology and analyzed the differences between both of data.

-262 Detecting the Fossil Fuel Emissions Signal from Atmospheric CO2 Measurements Using Inverse Methods

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

As anthropogenic carbon dioxide (CO2) emissions continue to grow and as efforts to curtail fossil fuel (FF) based CO2 emissions increase, the importance of accurately quantifying and attributing FF CO2 emissions has become substantial. Methods to observationally verify FF CO2 emissions have become a particular focus as countries and states begin to enact policies to reduce their FF CO2 emissions. Inverse modeling, using atmospheric measurements of CO2 concentrations coupled with an atmospheric transport model to trace sources and sinks to upwind locations, has been proposed as a tool to perform the FF CO2 estimation task. However, the complexities and challenges pertaining to FF CO2 estimation using atmospheric data have not been fully explored. The atmosphere integrates all processes, both natural and anthropogenic, rendering the process of disentangling these components at relevant spatial and temporal scales a considerable undertaking. The focus of this study is to explore the feasibility of using an inverse modeling approach for FF CO2 estimation by specifically answering the following questions : (1) Do the atmospheric measurements currently provide sufficient information to detect FF CO2 emissions at monthly and regional scales? (2) What factors limit the degree to which the FF signal is detected?

Detection of the FF CO2 signal in this study is determined through a variable selection procedure that uses the Bayesian Information Criterion to determine the best subset of explanatory variables that help inform the spatial and temporal distribution of CO2 fluxes. If the FF CO2 inventory data of a specific region and month is selected as a significant explanatory variable for inferring CO2 fluxes, the conclusion is that available atmospheric observations and the current representation of atmospheric transport fulfill the necessary, but not sufficient, criterion of detecting the spatiotemporal signature of the FF signal. Analyses using both real and synthetic data cases were carried out using a CO2 monitoring network of 35 continuous measurement towers over North America (representative of 2008). We find that FF CO2 is hardly detectable in the summer months, due to the compounding effects of seasonal transport patterns and biospheric processes. FF CO2 is detected slightly more in the spring and fall, with winter having the most detection overall. This work highlights the need for methodological advancements in inversion studies as well as improved data coverage by in-situ or remote sensing observations if the goal of independent FF emissions verification is to be achieved.

-263 Long-term change of the CO_2 latitudinal gradient in the upper troposphere

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The commercial airliner observation with Japan Airlines (JAL) started in 1993 on the Japan-Australia flight route, and was succeeded since 2005 by the post JAL project of Comprehensive Observation Network for Trace gases by AIrLiner (CONTRAIL) to collect high-precision CO_2 measurements at about 10 km altitude for 20 years. Using this long record, we examined the temporal variations of the latitudinal distributions of the CO_2 annual means in the upper troposphere over the western Pacific between 30N and 30S. The observed CO_2 latitudinal gradients showed a large interannual variation, especially in the tropical regions, that is well associated with the ENSO cycle. This is clearly characterized by the difference of the latitudinal distribution pattern between the El-Niño and La-Niña years. We also found long-term changes of the CO_2 gradients have increasing trends in the most northern latitudes as anthropogenic emissions. Linear regressions of the CO_2 gradients versus global fossil-fuel (FF) emissions give significant positive slopes in the Northern Hemisphere, but small negative slopes around the southern tropics. Back extrapolations of these linear trends to zero FF emissions revealed a negative north-south gradient with the Northern Hemisphere lower than the Southern Hemisphere, as well as a regional CO_2 increase in the tropical regions. This extrapolated distribution to zero FF emissions is remarkably different from that currently observed. The changes of the north-south gradients could offer a unique opportunity to better understand the evolution of anthropogenic and natural CO_2 fluxes.

-264 Evaluation of the IRGASON Integrated CO2/H2O Gas Analyzer and Sonic Anemometer

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

We discuss a laboratory and field evaluation of the Campbell Scientific, Inc. IRGAson. It uses a unique sensor array that collocates an optical path used to measure carbon dioxide and water vapor concentrations with three acoustic paths used to measure the total wind vector and virtual temperature. This design does not require the so-called spatial separation correction in the eddy-covariance calculation of fluxes, however it would be expected to have increased distortion of the wind field. This sensor is under consideration to be used by NCAR/EOL as part of our new CentNet facility to measure (among other quantities) carbon dioxide and water vapor fluxes at up to 100 locations. It is particularly attractive for this application since its total power consumption is about 4W, reducing the amount of power infrastructure that would have to be deployed.

This poster describes tests of both the concentration measurements and distortion of the airflow from this instrument. CO2 concentrations were tested in the laboratory in a controlled temperature chamber against gas cylinders. In the field, mean CO2 concentration values were compared to a Picarro, Inc. CRDS H2O/CO2/CH4 analyzer and a well-calibrated Li7000 and H2O values with a solid-state humidity sensor. Fluctuations and fluxes of CO2 and H2O were compared to those from a Li7500 and Krypton hygrometer, both of which were deployed along with a CSAT3 sonic anemometer. Flow distortion was evaluated by deployment in the field along-side several other sonic anemometers, including several CSAT3s.

-265 Reanalysis of trends in the northern hemisphere land biospheric carbon uptake period

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

See attached document

-266 On the use of Carbonyl Sulfide (COS) as a tracer for estimates of Gross Primary Production (GPP)

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Understanding the responses of gross primary production (GPP) to climate change is essential for improving our prediction of climate change. To this end, it is important to accurately partition net ecosystem exchange of carbon into GPP and respiration. However, quantifying GPP has been difficult because there are no direct measurements at scales larger than the leaf level. Recent studies suggest that carbonyl sulfide (COS) is a useful tracer to provide a constraint on GPP. Similar to the uptake of CO2 during photosynthesis, leaves assimilate COS and irreversibly convert it to H2S. This one-way uptake flux follows nearly the same path as the gross uptake of CO2, but without the confounding return flux through respiration.

We evaluate the use of COS as a tracer for estimates of GPP based on model simulations of atmospheric measurements of COS and CO2 from NOAA/ESRL tall tower and aircraft sampling networks in a receptor-oriented framework. The newly upgraded Hybrid Single Particle Lagrangian Integrated Trajectory Model (HYSPLIT) has been employed to compute the influence functions, i.e. footprints, to link the surface fluxes to the concentration changes at the receptor observations. The HYSPLIT is driven by the 3-hourly archived NAM 12km meteorological data from NOAA NCEP. North American GPP estimates from the Simple Biosphere (SiB) model, the Carnegie-Ames-Stanford Approach (CASA) model, and the MPI-BGC model are employed to simulate the plant uptake of COS. The background concentrations are calculated using empirical curtains along the west coast of North America that have been created by interpolating in time and space the observations at the NOAA/ESRL marine boundary layer stations and from aircraft vertical profiles. The soil uptake and anthropogenic emissions are from Kettle et al. 2002. In addition, we have developed a new soil flux map of COS based on observations of molecular hydrogen (H2), which shares a common soil uptake term but lacks a vegetative sink. We will also improve the GPP estimates by assimilating atmospheric observations of COS in the receptor oriented framework, and then present the assessment of the improved GPP estimates against variations of climate variables such as temperature and precipitation.

-267 Seasonal variation and its controlling mechanism of sea surface partial pressure of CO2 in Jiaozhou Bay

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

We discussed the seasonal variation of sea surface partial pressure of CO_2 (pCO_2) in Jiaozhou Bay, coupling with other biochemical parameters based on four cruises conducted between 2007 and 2010 (Nov, 2007, Feb, 2008, Aug, 2008 and May, 2010). Annual pCO_2 ranged from 148 to 1018 μatm, with an average of 425 μatm. The highest and the lowest value both appeared in the northeastern part of the bay, which is near the urban area of the Qingdao City. Terrestrial input of DIC is dominant in spring, summer and autumn, while input from the seawater outside the bay dominated in winter. Terrestrial source of DOC is significant around the whole year and sewage input and the aquaculture region in the nearshore area are two possible contributors. Despite the annual fluctuation of temperature, the double peak structure of the annual phytoplankton distribution, terrestrial input of both organic matter and large amount of nutrients had led to a large variation of primary production and respiration process in Jiaozhou Bay, especially in the nearshore area. Primary production was mainly controlled by the phytoplankton abundance with peak values appeared in summer and winter. Based on our in-situ incubations in spring, summer and autumn, respiration rate was high in summer (with the highest of 158 mmol m^{-3} d^{-1}) and low in autumn (with the lowest of 6.9 mmol m^{-3} d^{-1}). In addition, the all year long vertical mixing of organic matter from aquaculture region in the nearshore area also intensified the respiration process. In winter, the second peak of phytoplankton abundance and a temperature inhibited respiration kept pCO_2 in a low level (145-315 μatm). Above all, Jiaozhou bay acts as a source of CO_2 to the atmosphere in spring, summer and autumn and a carbon sink in winter. The annual air-sea CO_2 flux in Jiaozhou Bay was 2.32 mmol m^{-2} d^{-1}.

-268 A global analysis of soil microbial biomass carbon, nitrogen and phosphorus in terrestrial ecosystems

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

To estimate the concentrations, stoichiometry, and storage of soil microbial biomass carbon (C), nitrogen (N), and phosphorus (P) at biome and global scales, we collected 3422 data points to summarize the concentrations and stoichiometry of C, N, and P in soils, soil microbial biomass at global- and biome-levels, and to estimate the global storage of soil microbial biomass C and N. The results show that concentrations of C, N, and P in soils and soil microbial biomass vary substantially across biomes; the fractions of soil elements C, N, and P in soil microbial biomass are 1.2%, 2.6%, and 8.0%, respectively. The best estimates of C:N:P stoichiometry for soil elements and soil microbial biomass are 287:17:1, and 42:6:1, respectively, at global scale, and they vary in a wide range among biomes. The vertical distribution of soil microbial biomass follows the distribution of roots up to 1 m depth. The global storage of soil microbial biomass C and N were estimated to be 16.7 Pg C and 2.6 Pg N in the 0-30 cm soil profiles, and 23.2 Pg C and 3.7 Pg N in the 0-100 cm soil profiles. The spatial patterns of soil microbial biomass C and N were consistent with those of soil organic C and total N, i.e. high density in northern high latitude, and low density in low latitudes and southern hemisphere. The globally first available dataset for soil microbial biomass carbon, nitrogen, and phosphorus will be used for incorporating soil microbial mechanisms into earth system model and evaluating microbial contributions and feedbacks to the climate system.

-269 Seasonal to interannual variability of the global ocean carbon sink (1998-2007)

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The global ocean sink for atmospheric carbon dioxide (CO2) is known to vary on seasonal to interannual time-scales, but these variations are not well constrained by oceanic observations. Here we present a new observation-based estimate of the oceanic CO2 sink and its temporal variations from 1998 through 2007. This sink estimate is based on a novel analysis and extrapolation of the surface ocean partial pressure of CO2 (pCO2) observations, benefitting from a continuous strengthening of the observation network and the large collection of underway observations of the pCO2, i.e., the Surface Ocean CO2 Atlas (SOCAT) v1.5 database. We use a new combination of neural network methods to interpolate the observations on a global scale, on a monthly basis, and at a resolution of 1° latitude x 1° longitude. The resulting sea surface pCO2 is then used to compute the air-sea flux of CO2, using a standard gas transfer formulation and high-resolution wind speeds. The evaluation with independent time series data in the different ocean basins shows that our estimates reconstruct the pCO2 reasonably well. For the global ocean excluding the Arctic Ocean and coastal regions we estimate a mean CO2 uptake flux of 1.32 ± 0.52 PgC/yr over the analysis period, which is close to the most recent estimate based on the Takahashi et al. (2009) climatology. Adding recently derived estimates of 0.45 ± 0.18 PgC/yr to account for the outgassing of riverine derived carbon and 0.12 ± 0.06 PgC/yr for the Arctic Ocean sink, our estimate implies a mean anthropogenic CO2 uptake of 1.89 ± 0.55 PgC/yr from 1998-2007. Our data indicate strong seasonal to interannual variability of these fluxes, especially in the Equatorial Pacific, mainly driven by the El Nino Southern Oscillation (ENSO) climate mode, and in the Southern Ocean. Within the period from1998-2007 the global air-sea flux of CO2 ranges from a minimum ocean uptake in 2001 of 0.75 ± 0.35 PgC/yr up to a maximum uptake in 2006 of 1.9 ± 0.72 PgC/yr.

-270 Soil organic carbon sequestration potential on fertilized cropland: calculations from long-term experiments across China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Recent studies present that mineral soils of ecosystems have a limit in C sequestration capacity. Most current results indicated that soil C storage is linearly related to C input and that equilibrium soil C level could increase continuously and without limit as steady-state C input level increase. However, multiple C input treatments that produce little or no increase in SOC stocks at equilibrium show that soils have become saturated with respect to C inputs. SOC storage of added C input is a function of how far a soil is from saturation level (saturation deficit) as well as C input level. Therefore, we calculated soil C saturation deficit on China's cropland based on 25 Long-term experiments (LTEs) that have been established more than 20 years. We determined soil physical fractions from topsoil (-20cm) and chose four common fertilization treatments: unfertilized CK, mineral NPK, NPK fertilizer plus manure (NPKM), and NPK fertilizer plus straw (NPKS). Results showed that average soil C saturation deficit in unfertilized treatments is 0.58±0.08 in China. The lowest saturation deficit was found in north China (0.45) and the greatest in south China (0.68). Soil C saturation deficit in manure applied treatment in north China is 0.13. This means soil storage in north China slightly increase in response to varying C input level and close to saturation capacity. By contrary, soil C saturation deficit manure or straw added treatments in south China is 0.55±0.01 which means the soils in south China with larger C saturation deficit may have a greater SOC sequestrate potential. Thus, we concluded that soils in south China (subtropical monsoon climate) with low C contents may have a greater potential and efficiency to store new added C than soils in north China with temperate semi-humid climate do.

-271 Grassland carbon cycling: relationships between C source/sink strength, net primary productivity and grazing

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Identifying the factors that determine the carbon source/sink strength of ecosystems is important for reducing uncertainty in the global carbon cycle. However, few studies come from grassland ecosystems, especially from pastures. Using Biome-BGC model, we modeled carbon dynamics in Xinjiang over grasslands that varied in grazing intensity. In general, the regional simulation estimated that the grassland ecosystems in Xinjiang acted as a net carbon source, with a value of 8.98Tg C year-1 for the period 1979-2007. There were noticeable effects of grazing on carbon dynamics. Over-compensatory effect in net primary productivity (NPP) and vegetation C was observed when grazing intensity less than 0.40. Top 1m soil C increased significantly (17% percent) after long term grazing, however, with the increase of grazing intensity, soil carbon stock drop dramatically. These findings have implications for grassland ecosystem management related to carbon sequestration and climate change mitigation, e.g., herbivore removal should be considered in strategies that aim to increase terrestrial carbon stocks at local and regional scales. One of the greatest limitations in quantifying the effects of herbivores on carbon cycling is identifying the grazing system and intensity within a given region. We hope our study emphasizes and motivates the need for large-scale assessments of how grazing impact carbon cycling.

-272 Sixteen Years of Carbon Flux Measurements Above a Mixed Forest at Borden Ontario Canada

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The Borden Forest Research Station, in Southern Ontario Canada (44° 19' N, 79° 56' W), has been used to conduct research on forest-atmosphere interactions since 1985. This mixed, predominantly deciduous forest, located in the Great Lakes / St. Lawrence transition zone between temperate deciduous and boreal forest biomes, is a natural regrowth from farmland abandoned in the early 20th century.

Since 1995, eddy covariance flux measurements of forest-atmosphere exchanges of carbon dioxide, water vapor, energy, and momentum have been made at Borden almost continuously, along with numerous auxiliary meteorological parameters. The length of this data record, one of the longest of its type in the world, allows exploration of the influence of interannual climate variability on the carbon dioxide budget at this forest. The data show the forest to be a low to moderate sink of carbon dioxide. There are multiple climatic influences on net ecosystem productivity, including temperature, photosynthetically active radiation, and precipitation, as well as onset of the growing season. The analysis will identify the important climatic drivers of interannual variability in the carbon dioxide budget, and explore the possibility that the carbon dioxide sink has increased over time.

-273 Terrestrial Ecosystems Full Carbon Account as a Fuzzy System: an Attempt to Understand Uncertainties

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Terrestrial Ecosystems Full Carbon Account (FCA) for large territories (e.g., at national or continental scale) is a typical underspecified (fuzzy) system (full complexity or wicked problem). Uncertainties of the results obtained by any of existing methods of carbon cycle study (i.e., landscape-ecosystem approach, LEA, as a systems aggregation of "inventory-based" semi-empirical assessments; eddy covariance; process-based models of different types; inverse modeling), if those are applied individually, are able to present only "uncertainties within an approach" and could have a little common with "real uncertainty" which is understood as an aggregation of insufficiencies of output of the studied system, regardless of those insufficiencies result from a lack of knowledge, the intricacies of the system, or other causes. Formal verification of the past and current FCA is usually not provided due to evident labor and resource limitations.

In our study of the ecosystems carbon cycling for territories of Russia, we applied a systems methodology aiming at a full and verified FCA for the country in a spatially and temporally explicit manner. The methodology is based on integration of different approaches with following harmonizing and mutual constraints of the independent results within and between approaches and their uncertainties. The LEA is used as a systemic design of the account. The information background of the LEA is presented in form of an Integrated Land Information System which includes the hybrid land cover at resolution of 1 km2 (combination of remote sensing multi-concept and relevant ground information) and corresponding numerous attributive databases. Carbon fluxes which are based on long-term measurements are corrected using seasonal climatic indicators. Uncertainties of intermediate and final results are calculated by sequential algorithms.

Based on the LEA, terrestrial vegetation of Russia served as a net carbon sink at range of 500-700 Tg C yr-1 during the decade 2000-2010, mostly at the expense of forests, with interannual variation of around 10-15% at the country's scale. The variation for large regions was significantly higher that depends on seasonal weather and accompanying regimes of natural disturbances. Uncertainties of major carbon stocks of the country are estimated at about ±3% for live biomass (confidence probability 0.9) to ±5% for dead biomass to ±10% for soil organic carbon. Uncertainties of yearly carbon fluxes for most presented land classes were estimated at ±5-7% for Net Primary Production, ±7-12% for Heterotrophic Respiration, ±23-30% for disturbances. Finally, an average uncertainty of the annual Net Ecosystem Carbon Balance was between ±25-32% and ±8-10% for the decade average assuming that the accounting system has no unrecognized biases. We included in the analysis the results and reported uncertainties obtained for Russia by other methods. The role of eddy covariance in the country's FCA is limited by a small amount of measurement sites and lack of reliable gradients for upscaling. DGVMs (applied to the Russian territory) are rather consistent with the LEA in assessing NPP but underestimate the NBP at ~50%. Several independent applications of inverse modeling gave the results surprisingly closed to the LEA. The overall constrained uncertainty of the FCA is defined at ~20-25% at the annual basis and ~7-9% for the decade average. These results contain a number of expert assumptions and systems constraints of impacts which cannot be assessed by formal methods.

-274 Ocean margins as an increasing sink for the atmospheric CO2 – a case study in the US east coast

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

CO2 level in surface waters of open ocean basins appears to follow the atmospheric CO2 increase. We report here that in the continental shelf and upper slope waters, such as those on the U.S. eastern margins, surface water pCO2 had not increased as much as that in the atmosphere between mid-1990s and mid-2000s. Using a combined model of mixed-layer inorganic carbon budget and air-sea CO2 exchange, we show that the short water residence time (1-4 months) in ocean margin waters due to a rapid exchange of water with the deep ocean is the reason that prevents the accumulation of anthropogenic CO2, a process that requires a characteristic time of more than four months. Thus as the capacity of CO2 uptake from the atmosphere likely will decrease in the open ocean, the likelihood of an increase in coastal ocean CO2 uptake could have important ramifications.

-275 Atmospheric 14CO2 at Point Barrow, Alaska, from 2003 to 2013

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Radiocarbon (14C) is a useful tracer for studying the carbon cycle, especially for discriminating between fossil and biosphere carbon emissions. Availability of high quality background 14CO2 records at remote sites is a necessity for such application. However observations of 14C variation in atmospheric CO2 exist for only a few locations. We report here a continuous, high precision and high temporal resolution Δ14CO2 record obtained at the Point Barrow Observatory, Alaska (71°N, 157°W) since July 2003 to present. Sample collection was through the NOAA/ESRL flask sampling network program, which enables us to compare radiocarbon data with other trace gases and isotopes, including CO, CO2 mixing ratios and δ13C and δ18O of CO2. During the collection period, Δ14CO2 decreased by ~5‰/year. We find distinct seasonal cycles for Δ14CO2, with a broad minimum around Mar-Apr and a maximum in Sep-Oct with an amplitude of ~10‰. This seasonal pattern is variable from year to year. Increasing 14C values may reflect injection of stratospheric air in April and May, and higher soil respiration with enriched 14CO2 between May to Aug; rapid declines may be due to reduction in soil respiration and changes in the poleward advection of fossil fuel burned in the winter months. 14CO2 seasonal cycle lags those of CO and CO2 by ~ one month and half month respectively. Our record adds to the a few available records worldwide to provide observational constraints for the roles of 14C isotope disequilibirum among different reservoirs, and hopefully can enhance our understanding of the patterns of atmospheric 14CO2 distribution and its seasonal variation.

-276 Vertical Distributions of Greenhouse Gases in the Stratosphere over the Eastern Equatorial Pacific

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

In order to elucidate temporal and spatial variations of stratospheric greenhouse gases, we have collected air samples over Japan, Kiruna, Sweden and Syowa Station, Antarctica since 1985, using a balloon-borne cryogenic sampler with liquid Helium as a coolant. At the same time, we have devoted ourselves to developing an innovative cryogenic air sampler that does not require liquid Helium. The new sampler is compact so that we can launch it from any place without large facilities for ballooning. By using the newly developed sampler, we conducted stratospheric air sampling in the eastern equatorial Pacific. Four samplers were launched from the Research Vessel Hakuho-maru on Feb. 4, 5, 7 and 8, 2012, and successfully collected air samples of 5-8 LSTP at the respectively assigned altitudes between 20 and 30 kmASL. Air sampling procedures were automatically performed in accordance with commands from an on-board control system. Position and operational status of the sampler were monitored aboard the vessel using a telemeter system. After air sampling, the sampler was detached from the balloon, landed on the sea using a parachute, and then recovered by the vessel. Air temperature, humidity, wind direction and wind speed were simultaneously measured by a rawinsonde mounted on the sampler. Vertical profiles of tropospheric CO2 concentration were also measured up to 10 km by using a newly developed CO2 sonde. Furthermore, air sampling with glass flask was made on the vessel. The air samples collected in the stratosphere and on the surface were precisely analyzed for concentrations of CO2, CH4, N2O and SF6, as well as for their isotopic ratios and isotopomers at Tohoku University and Tokyo Institute of Technology.

Vertical profiles of CO2 concentration measured using the CO2 sonde are similar to each other, showing no clear vertical gradient. These observed profile indicate that CO2 is vertically well mixed in the tropical troposphere, due to strong cumulus convection. On the other hand, the CO2 concentration decreases gradually with increasing altitude in the stratosphere. Since there are no sinks and chemical losses of CO2 in the stratosphere, the observed vertical CO2 gradient would be attributable to slow upward transport of the tropospheric air intruded into the stratosphere in the tropics, resulting in older air with low CO2 concentrations at higher altitudes. By comparing our stratospheric CO2 concentrations with the annual mean values at Mauna Loa by NOAA/ESRL, mean ages of the air at 20.5, 24.5, 28.3 and 28.5 km are estimated to be 1.5, 2.0, 2.4 and 3.5 years, respectively. During the period of Feb. 4 to Feb. 8, 2012, the observed vertical profiles of air temperature are close to each other, with an almost stationary tropopause height of 17-18 km. Analytical results of other constituents and isotopes will be presented at the conference.

-277 Modeling Interactions Between Carbon and Water in the Context of Climate Change in a Central Asian Arid Ecosystem: a Case Study in Xinjiang, China from 1981-2007

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Arid and semiarid ecosystems are particularly sensitive to environmental stresses. Despite their importance to the global carbon (C) cycle, responses of the Central Asian arid and semiarid land to the rapid climate change in recent decades are still unclear. Using AEM, a newly developed, spatially explicit process model for arid ecosystems, a case study was conducted in Xinjiang, a 1.66 M km2 arid and semiarid land in eastern Central Asia. The goal was to assess the impacts of environmental changes (climate change and elevated CO2) on the regional C dynamics from 1981-2007. The results indicated that over the last three decades, Xinjiang acted as a C sink of 0.13 Pg (1 P = 1015), 78.5% of which was contributed by increased vegetation C (VEGC). Ecosystems in northern Xinjiang had a higher C sequestration rate (7.6 m-2 a-1) than in the south (1.9 m-2 a-1) in response to environmental changes. The C dynamic overall was dominated by the CO2 fertilization effect, which resulted in 195.9 Tg C (1 Tg = 1012 g) sequestration from 1981-2007; whereas climate change resulted in a 13.2 Tg C loss in southern Xinjiang and 23.4 Tg C sequestration in the north. Among climate factors, changes in temperature and precipitation caused VEGC to increase by 64.3 Tg and 43.3 Tg, respectively, but reduced soil organic C (SOC) storage by 39.6 Tg and 21.8 Tg, respectively. Interactions between CO2 and climate change resulted in a C loss. This study also revealed complex climate change spatial patterns and their impacts on the C dynamics of an arid and semiarid ecosystem in Central Asia.

-278 The hotspots of high CH_4 and their relations with CO_2 in the surface seawater in the western Arctic Ocean

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Measurements of the partial pressure of CO_2 (pCO_2) and CH_4 (pCH_4) in surface seawater and overlying air were made continuously in the western Arctic Ocean during the cruise of the R/V Mirai (JAMSTEC) in September-October 2012 as a part of GRENE Arctic Climate Change Research Project. The underway measurements were carried out with the system consisting of a WS-CRDS analyzer (Picarro Model G2301) combined with a shower-head-type equilibrator. Temperature, salinity, dissolved oxygen, fluorescence and dissolved inorganic carbon (DIC) were also measured simultaneously.

Throughout the cruise track, CH_4 in near-surface water has been supersaturated with respect to the CH_4 in the atmosphere. However, spatial distributions of CH_4 and CO_2 and their correlation were controlled differently by the biological activity and the topographical feature between coastal and off shore zones. In the coastal zone in the Barrow Canyon where primary production is high due to local upwelling, high pCH_4 hotspots (up to 6.08 µatm) were found in the shelf water. The spatial variation of pCH_4 positively correlated with that of pCO_2 in this region. This correlation suggests that the surface seawater was largely affected by the seawater upwelled from near-seafloor that would contain high level of CH_4 discharged from sediment as well as high level of CO_2 due to remineralization. The positive correlations between pCH_4 and pCO_2 were also found in the shallow Chukchi Sea and the Bering Strait. In contrast, the negative correlation was found in offshore deep sea region. This negative correlation is explained by the large biological activity; active primary production causes drawdown of CO_2 through photosynthesis while it provides productive environments for CH_4 such as organic particles or guts of zooplankton. There, it is likely that the surface water had not been affected by the shelf water that contains high level of CH_4.

-279 Oxygen Decrease with Bidecadal Oscillations in the Northwestern Pacific

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Long-term trend of dissolved oxygen (DO) was comprehensively analyzed over the subtropical through subarctic zones in the western North Pacific at 165°E since 1987 and in the Oyashio (western boundary current of the western subarctic) region off of northern Japan since 1954. We used time-series data acquired by Japan Meteorological Agency and some other data sets including those of WOCE P13. Data quality control was made on these datasets to exclude outliers and to correct offsets among cruises. The rates of DO change were analyzed on densities at 0.1σθ intervals.

In the subtropical region between 25°N and 30°N at 165°E, long-term trends of DO decrease are significantly detected on the density classes between 25.0σθ below the winter mixed layer and 27.3σθ in the oxygen-minimum zone. Bi-decadal oscillations are also clearly seen in the upper layers between 26.7σθ and 27.0σθ. On around 25.5σθ in the lower layer of the North Pacific Subtropical Mode Water, the changing rate of DO was -0.38 ± 0.09 μmol kg-1 yr-1, and was mainly attributed to deepening of the isopycnal surfaces and the reduction of oxygen solubility due to warming. In contrast, in the core of the North Pacific Intermediate Water (NPIW) at 26.8σθ, the changing rate of DO (-0.47 ± 0.08 μmol kg–1 yr-1) was attributed to intrinsic change of apparent oxygen utilization. This trend is consistent with the trend found in the Oyashio region. The phases of periodicity in the NPIW at 165°E are about two years behind those found in the Oyashio region. These results suggest that the long-term decreases as well as bi-decadal oscillations of DO at 165°E in this region have a close connection with those in the Oyashio region.

The long-term decrease of DO in the Oyashio region and in the northern section at 165°E would be attributed to the reduction of ventilation due to warming. In addition, we presume that it is also ascribed to the change in the ocean circulation by the enhanced wind stress toward the increase in the contribution from the subsurface water of the Western Subarctic Gyre.

-280 Air-sea CO2 flux interannual variability correlated with climate indices

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

We quantify the magnitude and extent of the response of surface ocean pCO2 partial pressure to interannual climate variability from 1990-2008. From our analyses, described below, we find a strong correlation between pCO2 and the El Niño Southern Oscillation (ENSO) index in the Equatorial Pacific (15°S-15°N; r = -0.47), where pCO2 levels changed by -6.6 ± 1.0 μatm per index unit (μatm iu-1). This equates to a change in air-sea CO2 flux of 0.118 ± 0.018 Pg C yr-1 iu-1, or 0.21 ± 0.03 Pg C yr-1 for the 1992-4 ENSO event and 0.40 ± 0.06 Pg C yr-1 for the 1997-8 event (positive values indicate a greater flux into the atmosphere or a smaller flux into the ocean). These estimates are twice as large as those based on fits based on relationships with SST and other external variables, suggesting that not all processes are captured by proxy data. Our estimates are smaller, however, than those based on simple extrapolations of the pCO2 data. The Pacific Decadal Oscillation (PDO) has the strongest effect on pCO2 levels in the North Pacific (North of 15°N; r = -0.25). However, the pCO2 response is weak: the largest changes in the PDO index yield an air-sea flux change of 0.13 ± 0.07 Pg C yr-1. We do not find a statistically significant correlation between the North Atlantic Oscillation and pCO2 levels in the North Atlantic (North of 15°N), although the spatial pattern of correlations across the basin compares well with previous studies. The PDO shows a statistically significant correlation with pCO2 levels in the North Atlantic, albeit with a weak pCO2 response, and a corresponding change in air-sea flux of 0.057 ± 0.024 Pg C yr-1 iu-1 across the region.

Our analyses are based on a newly developed interpolation technique adapted to the specific coverage and properties of surface ocean pCO2 observations [Jones et al., 2012]. We have produced a complete data set of pCO2 values from 1990-2008 on a 2.5° x 2.5° global grid based on the SOCAT (Surface Ocean CO2 Atlas) v1.5 database [Pfeil et al. 2012]. The interpolation combines spatial techniques based on a 'radius of influence' to detect nearby related observations with harmonic and cubic spline fitting to determine trends, seasonal cycles, and interannual variability. Tests of reconstructing sub-sampled model output showed that it performs as well as or better than previous regional interpolations. Unlike previous interpolations, our approach does not rely on relationships to external variables such as SST, chlorophyll and mixed layer depth.

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-281 Could global carbon cycle models explain the seasonal cycle of the atmospheric carbon storage?

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The global mean monthly atmospheric concentrations of carbon dioxide provided by NOOA/ESRL [1] show that the carbon storage of the atmosphere undergoes regular seasonal changes. Removing the trend, we can see the seasonal cycle: the de-trended atmospheric carbon storage peaks in April and dips in September. The average amplitude is as wide as 9.6 GtC (average for the period from 2000 to 2010).

The amplitude of seasonal variations in the atmospheric carbon storage put certain constraints on the choice of parameters in the models of global carbon cycle and the joint carbon-climate models. An adequate global carbon cycle model should reproduce the seasonal course of the atmospheric carbon storage. Hence, it would be reasonable to evaluate the models by comparing simulated and observed seasonal variations in the atmospheric carbon storage.
It is surprising that the models are not evaluated in this way. One may find a lot of papers demonstrating that carbon cycle models coupled with atmospheric transport models could reproduce seasonal cycle of CO2 concentrations at some locations [2-4]. However, it is difficult to find an article comparing simulated and observed seasonal variations in the atmospheric carbon storage. The few articles reporting the results of such comparison bring bad news: the observed amplitude of seasonal variations in the atmospheric carbon storage is wider than simulated [5].

This presentation is to reveal the problems that one would face trying to reproduce the observed seasonal course of the atmospheric carbon storage with a carbon cycle model. The most important of them seem to be as follows: (1) the net primary production of the biosphere should be higher than it is commonly assumed and (2) more sensitive to seasonal changes in climate conditions; besides, (3) it should peak earlier than heterotrophic respiration.

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-282 Antarctic sea ice CO2 system and controls

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

In austral summer, from December 2008 to January 2009, we investigated the sea-ice carbon dioxide (CO2) system and CO2 controls in the Amundsen and Ross Seas, Antarctica. We sampled seawater, brine and sea ice for the measurements of total alkalinity (AT), total inorganic carbon (DIC), pH, inorganic nutrients, particulate organic carbon (POC) and nitrogen (PON), chlorophyll a, pigments, salinity and temperature. Large variability in all measured parameters was observed in time and space due to the complex sea-ice dynamics. We discuss the controls of the sea-ice CO2 system, such as brine rejection, biological processes, calcium carbonate (CaCO3) precipitation/dissolution and CO2 exchange. Most (80 to 90%) of the DIC loss was due to brine rejection, which suggests that the sea ice acted as an efficient DIC sink from 0.8 and 2.6 mol m^{-2} yr^{-1} (9.6–31 g C m^{-2} yr^{-1}). The remaining change in DIC was to a large extent explained by net biological production. The AT:DIC ratio in the sea ice was higher than in the under-ice water (UIW), with ratios reaching 1.7, which indicated CaCO3 precipitation and concomitant DIC loss in the sea ice. Elevated AT:DIC ratios and carbonate concentrations were also observed in the UIW, which reflect the solid CaCO3 rejected from the ice during melt. The potential for uptake of atmospheric CO2 in the mixed layer increased by approximately 56 µatm due to the combined effect of CaCO3 precipitation during ice formation, and ice melt in summer.

-283 Consistency between top-down and bottom-up estimates of the CO2 budget of Europe

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Huge uncertainty is still remaining in terrestrial biosphere modeling of carbon budgets over Europe despite a number of model simulations. Major terrestrial component, net ecosystem exchange (NEE), is compared to find the similarity in interannual and spatial variations among nineteen models from three approaches: seven atmospheric inversion models (AIs) and ten prognostic/two diagnostic terrestrial biosphere models (TBMs), over Europe during 15 years: 1996-2010. Summer mean NEE shows relatively high correlation coefficients in interannual variation among the models between AIs and three approaches, and within Diagnostic TBMs in Central Europe. Prognostic TBMs do not reveal apparent correlationships with themselves and with other approaches in interannual variation. Cluster analysis on spatial variations show that annual mean NEE distribution forms two clusters of two diagnostic TBMs and the 8 prognostic TBMs, suggesting that the simulation approach is a key determinant of the spatial distribution of NEE across Europe.

Interannual variation of modeled NEE indicates the consistent sensitivity to biological and climatic indices among the approaches. In Central Europe, all three approaches show strong negative, positive and negative responses to increasing Normalized Difference Vegetation Index (NDVI), air temperature, and precipitation, respectively. Strong positive correlations of the North Atlantic Oscillation (NAO) index appears to annual mean NEE for AIs, and to summer mean NEE for Diagnostic TBMs, respectively, in both Total and Central Europe.

-284 On the seasonal variation of air-sea CO2 fluxes in continental shelves in temperate zone: a case study in the North Yellow Sea

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

A better understanding of temporal and spatial variations is fundamental before air-sea CO_2 fluxes can be accurately evaluated in a continental margin. So far most researchers resolve the seasonal variation of air-sea CO_2 fluxes based on several snap-shot like surveys. This is insufficient since air-sea CO_2 fluxes in continental shelves are subject to tremendous heterogeneities in both space and time. In this study, we investigated the monthly variation of air-sea CO_2 fluxes in a semi-enclosed western north Pacific continental margin, the North Yellow Sea (NYS), based on underway measurements of 26 cruises conducted from 2009 to 2012. In winter, monthly mean surface pCO_2 decreased from 417 μatm in early winter (December) to 388 μatm in January to 355 μatm in late winter (February). In spring months (March, April, and May), the first pCO_2 valley of 305-339 μatm was observed. In summer, the monthly mean surface pCO_2 jumped to 384-403 μatm in June and July. In August, monthly mean surface pCO_2 declined again to 382 μatm, and the second (autumn) pCO_2 valley of 379-391 μatm was revealed in September and October. In November, however, the highest monthly mean value of 437 μatm was observed. As compared to the amplitude of monthly variations, spatial variations of sea surface pCO_2 were minor.

Combined with the monthly atmospheric pCO_2 dataset, the NYS served as a moderate sink of the atmospheric CO_2 in spring and a week source in summer, while it was seasonal-synthetically in equilibrium with the atmospheric CO_2 in autumn and in winter. Annually, the NYS acted as a net sink of the atmospheric CO_2, with a sea-air CO_2 flux of -0.55 mol C m^{-2} yr^{-1}, as estimated based on in situ atmosphere pCO_2, in situ wind speed, and the Wanninkhof (1992) gas transfer velocity equation.

This pattern of monthly variation of air-sea CO_2 fluxes exactly mirrored the climatologically monthly cycle of the remote-sensing-based chlorophyll a in the NYS. A similar seasonal/intra-seasonal variation pattern has also been reported in the outer Changjiang Estuary, northwest East China Sea. Therefore, the dataset presented in this study may reflect a typical time series pattern of air-sea CO_2 fluxes in the NYS.

According to a classic textbook on biological oceanography, the seasonal cycle of marine phytoplankton production in temperate zone is characterized by spring and autumn blooms, while the autumn blooms are generally weaker than the spring blooms. On the other hand, the late autumn collapse of water stratification induces a release of bottom oversaturated CO_2 from shallow waters. Therefore, both time series observation and mechanism-based researches are needed so as to better constrain seasonal/intra-seasonal variations of air-sea CO_2 fluxes in a continental margin.

-285 Continental sources and sinks intensify the steep seasonal and latitudinal gradient of atmospheric carbon dioxide over East Asia

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Here we demonstrate a sharp contrast to the seasonal and latitudinal gradient of atmospheric CO2 over East Asia, where there are relatively few ground-based observations. The Greenhouse gases Observing SATellite (GOSAT) column-averaged dry air CO2 mole fraction (xCO2) retrieved by NASA’ s Atmospheric CO2 Observations from Space (ACOS) (2009-2011) program and GEOS-Chem nested-grid CO2 results are used. The strong anthropogenic emissions mainly from China and intensive vegetation uptake from northeastern Asia lead to a clear seasonal change of the xCO2 between spring maximum and summer minimum (>10 ppm). In particular, the steep latitudinal gradient of summer time CO2 (-0.5 ppm/degree) in the vicinity of the Korean Peninsula (32°N-44°N) is likely attributed to the large difference in CO2 exchanges between northeastern forest and the northwest Pacific region. This study represents the current progress to understand sub-continental scale atmospheric CO2 variabilities with recent satellite retrievals and nested-grid modeling.

-286 Estimation of Satellite-based Growth Primary Production and Validation of Flux tower and ground measurement over South Korea

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

NASA/EOS (Earth Observing System) satellite remote sensing produces a regular global vegetation productivity data for estimating Gross Primary Production (GPP). Terrestrial plants fix the amount of carbon assimilated through photosynthesis and terrestrial ecosystems act as an important sink in the greenhouse gas balance of the atmosphere. Flux tower used eddy covariance technique provides source of carbon, water and energy exchange. Satellite-derived GPP has been estimated through site-specific flux tower in many areas. To estimate ecosystem carbon flux over South Korea, the Moderate Resolution Imaging Spectroradiometer (MODIS) GPP product has been evaluated in Gwangneung (2006-2008 year), Haenam (2004-2008 year) and Cheongju (2010-2011 year). We used GPP product which was restored from the University of Montana in the United States to restore the MOD17 algorithm. The discrepancy of GPP between the satellite and eddy flux tower is about 494.667 g•C/m2/yr over Gwangneung (GDK), and 169.833 g•C/m2/yr over Haenam (HFK), respectively. Also the discrepancy of GPP between the satellite and species of trees is about 481.8 g•c/m2/yr in Pinusdensiflora, 25.7 g•c/m2/yr in Larix leptolepis, and 29.8 g•c/m2/yr in Quercusmongolica, respectively The difference in the estimation methodology and model schemes during the retrieval can make a significant difference in the satellite products, the range of GPP from MODIS and ground measurement were estimated to be 760~1465 g•C/m2/yr.

-287 A multi-data-source estimate of carbon storage in vegetation of Guizhou Province, southwestern China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

In mountainous area of southwestern China, especially Guizhou Province, karst landscapes (a special geomorphology mainly consisting of limestone and dolomite) are continuously, broadly distributed with harsh and fragile habitats. The dissolutional landforms, caves, and aquifers on soluble rocks create the most beautiful landscapes and tourist resorts. They also result in many environmental disasters, such as water pollution, drought, and rocky desertification, thereby creating many severe social problems. Research indicates that forests and shrublands located in karst terrains have low aboveground biomass, but high belowground biomass. However the harsh habitats with many rock outcrops make the biomass observation difficult. The commonly used forest inventory data cannot fully account for the carbon storage in such habitats.

A full account of vegetation carbon storage in Guizhou using data from multi-source is present in this study. Five methods are combined. The simple way is to calculate carbon storage using carbon density directly measured from field vegetation samplings plus vegetation area information derived from its atlas. The second method of estimate is to consider temperature-dependent carbon turnover and net primary production of different vegetation types. The third is using time series forest inventory data and regional volume-biomass transfer functions. Simulations of carbon storage using remote sensing driven ecosystem model (e.g. CASA), and climate driven equilibrium and dynamic vegetation models (e.g. BIOME4 and LPJ) are the fourth and fifth selections, respectively. Karst and non-karst vegetation located in morphologically different terrains are carefully, separately treated. Altitudinal effect of vegetation distribution on carbon storage is considered. Root carbon is considered too. A preliminary result shows that vegetation stores 176 to 554 Tg C with large uncertainty in Guizhou Province. Carbon storage of karst vegetation is significantly lower than that of non-karst vegetation, due to the commonly accepted reason that karst habitats are not suitable to plant growth. This research provides a basic understanding of carbon storage at a regional scale for further fully counting the carbon budget in karst mountainous area of southwestern China.

-288 Ocean Acidification in the Tropical Pacific from Below

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The tropical Pacific Ocean in its western zone includes the "Coral Triangle", a region well known for its extensive coral reef habitat and maximum marine biodiversity. It accommodates more than 75% of the world's coral species, more than 3000 species of fish, and many of the 150 million people that live in the coastal regions of the Coral Triangle depend heavily on fishing and other marine resources and services. One of the emerging issues that chronically threaten coral reef ecosystems over the tropical and subtropical oceans is the ocean acidification being caused by the anthropogenic CO2 emission.

Here we demonstrate the occurrence of ocean acidification in the warm western equatorial zone of the Pacific, with some 25 years of CO2 system measurements taken from the SOCATv1.5 database for CO2 fugacity in surface water (fCO2) (Pfeil et al., 2012) and PACIFICA database for ocean interior CO2 and chemistry in the Pacific (http://pacifica.pices.jp/). In surface water, fCO2 has increased at a mean rate of +1.31 ±0.14 µatm/yr, while no significant trend of change was determined for salinity-normalized total alkalinity. The results are indicative of the increase in salinity-normalized dissolved inorganic carbon (nDIC) at +0.77 ±0.14 µmol/kg/yr, a lowering of pH at -0.0013±0.0001 yr-1 and a reduction of the saturation indices of the carbonate minerals aragonite (Ωarag) and calcite (Ωcalc) at -0.008±0.001/yr and -0.012±0.001/yr, respectively. An increasing trend in remineralization-corrected nDIC [= (DIC – 117/170*AOU)*S/35; +0.41 ±0.15 to +0.62 ±0.29 µmol/kg/yr] was also observed at density classes of 24.0 - 25.5σθ in the Equatorial Undercurrent, which delivers waters to the upwelling in the equatorial divergence zone and subsequently to the surface in the warm western equatorial zone.

Several widely used ocean carbon cycle models are used to argue that the shallow overturning of the Subtropical Cells (STCs) is central to the acidification in the tropical Pacific including Coral Triangle. The implicated pathway is as follows: Water rich in anthropogenic CO2 is detrained from the mixed layer in the subtropical mode water formation regions of both hemispheres, and undergoes equatorward intergyre exchange within the lower branch of the STCs. Upon upwelling in the equatorial divergence zone, an important portion of this water rich in anthropogenic CO2 carbon is advected westward in the South Equatorial Current, undergoing substantial water mass transformations (lightening) during its transit to the west. Models indicate that this circulation pathway is more important than local air-sea uptake of anthropogenic carbon over the tropical Pacific band 15°N - 15°S itself.

-290 Quantification of urban fossil fuel CO2 emissions from the Indianapolis Flux Project (INFLUX)

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Quantification of the magnitude of fossil fuel CO2 (CO2ff) emissions is vital to improving our understanding of the global and regional carbon cycle, and independent evaluation of reported emissions is essential to the success of any emission reduction efforts. The urban scale is of particular interest, because ~75% CO2ff is emitted from urban regions, and cities are leading the way in attempts to reduce emissions. Measurements of 14CO2 can be used to partition CO2ff from total CO2 in flask samples, but it is difficult to obtain sufficient 14CO2 measurements to infer the urban emission flux.
In the Indianapolis Flux Project (INFLUX), we make flask measurements of 14CO2 and ~50 trace gases from a network of towers and from light aircraft. Tower samples are collected as hourly averaged samples to remove short-term atmospheric variability and the background signal is measured immediately upwind of the urban area. CO2ff and other anthropogenic trace gases are consistently enhanced at tower sites downwind of the city and in the urban plume sampled from the aircraft.
Previous studies have shown a strong and consistent relationship between CO2ff and carbon monoxide (CO), thus allowing in situ measurements of CO to be used to quantify CO2ff. We find only weak and variable correlations between CO2ff and CO from aircraft and tower flask samples, likely due to mix of CO2ff sources in Indianapolis, but find that total CO2 is consistently enhanced in the downwind samples, even in summer.
In winter, total CO2 enhancement is slightly higher than the fossil fuel CO2 enhancement, in agreement with Indiana's requirement for 10% bioethanol use in gasoline. This result implies that the enhancement in total CO2 can be used to infer CO2ff emissions for Indianapolis during winter. The choice of background is critical in isolating the urban CO2ff component from biospheric CO2, and we examine this in detail.
We find that it is possible to use the high resolution in situ total CO2 measurements from the aircraft in a simple mass balance model to estimate the urban CO2ff emissions. An initial comparison shows a ~20% difference between the top-down and bottom-up methods from aircraft samples.

-291 Seasonal changes of CO_2, CH_4 and N_2O in the upper troposphere/lower stratosphere over the Eurasian continent observed by commercial airliner

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

North polar region plays an important role for global budgets of greenhouse gases as well as their exchanges between the upper troposphere and lower stratosphere. To understand the temporal and spatial variations of atmospheric greenhouse gases cycles in this region, our group started flask sampling observation over the Siberia under Arctic Climate Change Research Project in the framework of the Green Network of Excellence (GRENE). Automatic air Sampling Equipment (ASE) has been used to collect air samples using the airliner flights of Japan Airlines (JAL) between Europe and Tokyo, Japan at about 10 km altitude once a month since April 2012. After the flight, the sampled air are analyzed for mixing ratios for CO_2, CH_4, CO, H_2, N_2O and SF_6 at the National Institute for Environmental Studies and for isotope ratios for CO_2 and CH_4 at the National Institute of Polar Research and Tohoku University.
Mixing ratios of CO_2, CH_4 and N_2O near the tropopause over the Siberian region largely varied, so that they were classified into two groups of upper troposphere and lower stratosphere by using potential vorticity calculations. CO_2 in the upper troposphere shows the large seasonal cycles with minimum in July, while small and different seasonal changes are found in the lower stratosphere with maximum in summer. On the other hand, CH_4 and N_2O mixing ratios show larger seasonal cycles in the lower stratosphere than those in the upper troposphere. Rapid increase in mixing ratios from July to September suggests the intrusion of air mass from the troposphere into the stratosphere in summer. In the upper troposphere, several events with higher CH_4 and lower CO_2 have been observed, suggesting larger impact of increased wetland emissions and active photosynthesis in this region. Isotope ratios of CO_2 and CH_4 will help the detailed analysis for sources and sinks categorizations.

-292 Variability of CO_2 mixing ratios observed in the upper troposphere revealed by frequent continuous observations by commercial airliner

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

A large number of CO2 data have been obtained by Continuous CO2 Measuring Equipment (CME) onboard the aircraft of Japan Airlines in the Comprehensive Observation Network for TRace gases by AIrLiner (CONTRAIL) project since 2005. CME records 1-min averaged data equivalent to about 15 km horizontal resolutions during cruising flights at about 10 km and 10-sec data for ascending or descending flights corresponding to about 80 m resolutions in vertical near the airport. Now we have obtained more than three million CO2 data from more than 6000 flights in the past 7 years. In this study, we analyze the variability of CO2 mixing ratios in the upper troposphere by utilizing data set with high resolution and frequency.
To assess the representativeness of observed data, we calculate the differences in CO2 mixing ratios observed at any two points during each flight as function of distances between two observational points i and j:
dCO2ij(r) = |CO2i – CO2j|, r=distance between position i and j
For example: 500 sampled data in a flight, 500C2=500x499/2=124750 dCO2ij can be calculated. In this analysis, we could estimate the probability of CO2 distributions around one single measurement depending the area, season and sampling intervals.
The results show the seasonal changes of variability in CO2 mixing ratios. For the data in the upper troposphere between Europe and Japan, 75% or more of dCO2ij are small enough to be less than 0.6 ppm or 1.0 ppm within 200 or 400 km from October to May. From June to September, in contrast, the probability of dCO2ij with less than 1.0 ppm needs observation with higher resolutions of 50 km, because CO2 in summer shows 2 or 3 times larger variations than winter season. Similar analysis for the western North Pacific suggests smaller dispersions of about 1.0 ppm within 800 km throughout a year. Our results suggest that the representativeness of observed CO2 data largely depends on the sampling area and season: higher regional representativeness for the oceanic region over the western Pacific, but much larger fluctuations of mixing ratios in summer over the Eurasian continent. Thus, dependency of the fluctuation intensity should be considered when we validate numerical simulations or satellite observations.

-293 Air-sea re-equilibration based upper ocean sink for anthropogenic CO2

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

On a decadal scale, air-sea re-equilibration accounts for 10% or more of present oceanic uptake rate of anthropogenic CO2. From 1960s to 2000s, this oceanic sink has increased by 100%, since the yearly increasing rate of atmospheric CO2 increased by 150%. In the second half of this century, however, the air-sea re-equilibration induced upper ocean sink for anthropogenic CO2 will inevitably decline, due to exhaustion of chemical buffering capacity in the open ocean surface.

-294 pH Sensor Drift Characteristic Analysis in Ocean Acidification monitoring

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

pH is a most valuable parameter in the coastal ecosystems. It reflects the thermodynamics state in the acid ecosystems. Especially in Oceanography chemical study, pH value is the level of the Ocean Acidification. In view of the importance of pH in Marine monitoring, it is necessary to carry on the long-term pH monitoring, In result, pH sensor must have several important characteristics which are high precision, low drift, long-term continuous in-site monitoring and so on. Hence, pH could use to analyze and understand the natural phenomena of the Ocean chemical and biological.

In this paper, We describe the experiment methods and results which are pH in-situ sensor drift characteristic because it is the most directly effective method in the Marine monitoring. We analyze the relationship of the sensor itself and other factors which are sensor probe drift characteristics, sensor signal output, the dynamic response characteristics on environmental parameters and transfer function identification etc. So we can get the method of the sensor accuracy calibration, the causes of the errors in the practical application. As result, We would improve the precision of the measurement and the reduction of the drift in-situ monitoring. To realize the sensor probe stability is the most important role in long-term in situ Marine on-line monitoring. The stability of the probe is potential time drift degree. The kind of the stability includes the glass probe membrane and the stability of the internal electrode. Chose composite electrode lithium, It has glass electrode and Ag - AgCl reference electrode. In the constant temperature, humidity condition, and known pH value of solution, We would finish pH electrode the long-term continuous drift characteristic test. We could print the pH electrode drift characteristic curve and set the mathematical model on the probe drift. Drift characteristic parameters are put in the high precision pH sensor measurement basis formula. So it could adapt to the measurement requirements, and finally get an optimal measurement results. So as to, We will achieve the long-term in situ on-line monitoring using pH sensor with Self calibration technology.

-295 Analysis of the Climate Change Mitigation Potential of Canada's Forest Sector

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The climate change mitigation potential of forests and the forest sector is widely recognized, but challenging to quantify at the national scale. Forests and their carbon (C) sequestration potential are affected by management practices, where wood harvesting transfers C out the forest into products and bioenergy feedstock and subsequent growth rejuvenates forests to allow further C sequestration. Here we determine the mitigation potential for the 230 million hectares of managed forests and the forest sector of Canada using a national-scale application of the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3), a new harvested wood products model, and an account of emission substitution benefits from the use of wood products and bioenergy. We estimate changes in the carbon stocks of Canada' s managed forests (2010 – 2050) under a base-case scenario (including natural disturbances) and compare it to various possible mitigation scenarios. We estimate the release of C from harvested wood products according to their half-life decay times, rather than the simpler but misleading assumption of instantaneous emissions. We also estimate the actual emissions from bioenergy use rather than assuming carbon neutrality of bioenergy, and we consider emissions displacement due to wood product and bioenergy uses. We examine several mitigation scenarios with different assumptions about forest management activity levels, including conservation strategies, and harvested wood product uses. Results demonstrate large differences among alternative scenarios, and we identify potential mitigation scenarios with increasing benefits to the atmosphere for many decades into the future, as well as scenarios with no net benefit over many decades. We demonstrate the use of mitigation portfolios that combine activities with both short and long-term benefits to the atmosphere and conclude that national-scale forest sector mitigation options need to be assessed rigorously to avoid the development of policies that deliver no net benefits to the atmosphere.

-296 Observations of atmospheric radiocarbon in carbon dioxide at Hateruma Island and Cape Ochi-ishi, Japan: Trends, Interannual variability and seasonal cycle from 2004 to 2012

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

We have been conducted monthly air samplings for measurements of atmospheric radiocarbon in carbon dioxide (14CO2) at two ground-based monitoring stations, Hateruma Island (HAT, 24.05°N, 123.80°E, 47 m above sea level) and Cape Ochi-ishi (COI, 43.15°N, 145.50°E, 100 m above sea level), Japan, since July 2004. We collected whole air samples using 2.0L glass flasks pressurized to 3 atm, and 5L air was used for radiocarbon analysis. The values of Δ14C were measured using compact Carbon Accelerator Mass Spectrometry (CAMS, NEC 1.5SDH). Uncertainty in Δ14C measured by CAMS is less than 2‰, which is based on the number of 14C counts and the scatter of 14C/12C ratios during measurements. The reproducibility of CAMS measurements is ±1.8‰ (standard deviation of Δ14C values in a reference air cylinder).
In this study, we show the Δ14C values of background air observed at HAT and COI from 2004 to 2012. Decreasing linear trends in Δ14C were approximately -4 ‰/year at both stations, however, large interannual variability (IAV) was observed: higher growth rates (less decreasing trends) of -2 ‰/year in 2008-2009 at HAT and in 2009-2010 at COI. The amplitude of the averaged seasonal cycle of Δ14C was 8‰ at both stations. The phase of the seasonal cycle was different between HAT and COI: minimum in January-April and maximum in July-August at HAT, and minimum in May-June and maximum in August-September at COI. The contribution of the fossil fuel emissions and atmospheric transport to the IAV and seasonal cycle of Δ14C at HAT and COI will be discussed in the presentation.

-297 Global scale model inter-comparison with GOSAT L4A and empirical upscaling based estimates of terrestrial biospheric variables

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Due to a lack of reliable spatial data of terrestrial biospheric variables, there have been substantial uncertainties in the global simulation of the future carbon balance. Nowadays, better global products of terrestrial carbon fluxes are available to the community, and these data improve the model reproducibility of carbon budget. One includes Greenhouse gases Observing SATellite (GOSAT), which is the 1st operational satellite promised to deliver the net land-atmosphere carbon budget (net ecosystem productivity; NEP) to the terrestrial biosphere research community. The other is global gross primary productivity (GPP) provided by observation-based empirical upscaling with machine learning algorithms in conjunction with global satellite remote sensing and meteorological data sets. Direct estimation of ecosystem respiration (RE) is difficult because of limited availability of carbon pool data. To overcome this limitation, a combination of two potential most reliable global estimates, GPP estimated by empirical upscaling and NEP from GOSAT L4A, would produce a more reliable budget of global RE.
The objective of this study is to compare a set of observation-based global carbon flux products, NEP from GOSAT L4A, GPP from empirical upscaling (support vector regression based on FLUXNET data), and RE from a combination of them, with three ecosystem models: Biome-BGC, CASA, and LPJ. Comparison was conducted with the standardized format based on GOSAT L4A: 42 sub-continental tiles and temporal coverage from June 2009 to May 2010. Similarities and dissimilarities in (1) seasonal variations, (2) annual averages, (3) variability with climate were evaluated among prepared products.
From the comparison, we found that seasonality of fluxes generally agreed in the high-middle latitude regions and substantially vary in the low latitude regions. Compared to model estimates of NEP, overall variations in amplitude was especially notable in GOSAT L4A. Model-based global annual averages of GPP and RE were lower than observation-based estimates, except LPJ. LPJ exhibited higher carbon fluxes (both GPP and RE) in the high latitude regions compared to the model average. This was the primary attribution to the highest global annual average. While Biome-BGC and CASA showed a similar pattern of weak spatial variability, the observation-based GPP and RE showed relatively strong latitudinal gradient to climate variables (especially, temperature). Overall, we found that dissimilarities among the estimates rather stood out than similarities.

-298 The flux of carbon from land-use over 1979-2011 in Central Asia

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Land use and land-use change (LULUC) contributes to the current terrestrial carbon sink in most regions of a northern mid-latitudes but are poorly documented for dryland systems, e.g. Central Asia. Central Asia is located in the center of the Eurasian continent, where livestock grazing, clearing lands for croplands and abandonment of croplands are the three dominant human activities in the past 60 years. However how these activities affect the regional ecosystem carbon dynamics in central Asia is poor understood.

A process-based model Biome BGC grazing was used to simulate the effect of grazing on a grassland ecosystem in central Asia based on new and more spatially detailed data at a spatial resolution of 40km. The distribution of grassland was derived from the dataset of FAO. The grazing intensity data were obtained from FAO’ s Animal Production and Health Division. Regional daily weather conditions from 1979 to 2011 were derived from the reanalysis data by the CFSR. The soil data were downloaded from Harmonized World Soil Database. According to our analysis, grazing in grasslands released about 0.046 Pg C to atmosphere over the period 1979-2010, which indicates that grasslands have been experiencing a degradation due to continuing overgrazing.

We used a bookkeeping model to calculate the flux of carbon from clearing lands for agriculture and farmland abandonments. Our approach is based on two types of information: rates of the conversion of natural ecosystem to croplands and croplands to other ecosystem, and changes per hectare in carbon that follow a change in cropland use. The results show that clearing lands for croplands led to a carbon gain of about 0.031Pg C over the period 1979-2011, which is attributed to the generally higher carbon stocks per hectare in croplands than in the converted natural ecosystem in central Asia. Abandonment of croplands also resulted in an accumulation carbon gain of 0.01Pg C over the same period, which is largely attributable to the abandonment of rain-fed croplands and the conversion of irrigated croplands to economical forests for a high economic return .

The accumulative flux from the three major land-use types is only 0.004 Pg C, which indicate that the emission of carbon from the major land use is small over the period. The accumulative flux of carbon at first increased and reached about a release of 0.09 Pg C between 1979-1984, then remained relative stable between 1984-1992, finally decreased after the collapse of the former Soviet Union in 1991 and was close to zero (a release of 0.004 Pg C to atmosphere).

-299 Inverse Modeling of CO2 Fluxes Using GOSAT Data and Multi-year Ground-based Observations

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

1. Introduction

The Thermal and Near-infrared Sensor for Carbon Observation-Fourier Transform Spectrometer (TANSO-FTS) onboard the Greenhouse gases Observing SATellite (GOSAT) has been providing the global distribution of column-averaged dry air mole fractions of CO2 (XCO2) from short-wavelength infrared (SWIR) spectra since April 2009. The wide spatial coverage of XCO2, repeated every three days, is expected to improve accuracy of our knowledge of Earth' s carbon budget and reduce uncertainties of estimated fluxes. Here we conduct a multi-year inversion with ground-based CO2 data and a one-year inversion with ground-based data plus GOSAT XCO2 data, and compare their results to assess the GOSAT-derived estimated fluxes using the inter-annual variability (IAV) of fluxes estimated from decadal ground-based data, and assess the utility of GOSAT data to carbon budget analysis.

2. Data and method

We used the NIES GOSAT SWIR XCO2 Level 2 product (version 2.00 and 2.10) for Jun. 2009 to Oct. 2010. Surface measurements of CO2 from discrete air samples from the Global Cooperative Air Sampling Network coordinated by NOAA/ESRL/GMD [Conway et al., 2011; ftp://ftp.cmdl.noaa.gov/ccg/co2/flask/event/] were used from 1999 to 2010. We used a fixed-lag Kalman smoother optimization technique and the NIES off-line transport model to estimate monthly fluxes for 64 sub-continental regions (42 land and 22 ocean regions) for 1999 to 2010. We used single-shot GOSAT data and individual NOAA flask data for the inversions. A priori fluxes used to predict background CO2 mixing ratios were from four datasets, (i) monthly fossil fuel emissions from ODIAC [Oda and Maksyutov, 2011], (ii) daily net ecosystem exchange (NEE) from a process-based model, VISIT [Ito, 2010; Saito et al., 2011], (iii) monthly biomass burning CO2 emissions by GFED [van der Werf et al., 2010] and (iv) monthly air-sea CO2 fluxes produced by an ocean pCO2 data assimilation system using OTTM [Valsala and Maksyutov, 2010].

3. Results

Our results show differences in estimated fluxes between the NOAA data inversion and the NOAA plus GOSAT data inversion, especially in Northern Eurasia and in Equatorial Africa and America where the ground-based observational sites were sparse. Uncertainty reduction rates of 40%–70% were achieved by inclusion of GOSAT data, compared to the case using just the NOAA data. The inclusion of GOSAT data in the inversion resulted in larger summer sinks in northwest Boreal Eurasia and a smaller summer sink in southeast Boreal Eurasia, with a clear uncertainty reduction in both regions. Adding GOSAT data also led to increases in Tropical African fluxes in boreal winter beyond interannual variability from NOAA data inversions.

Acknowledgements

The GOSAT Project is a joint undertaking of three organizations: the Japan Aerospace Exploration Agency, the National Institute for Environmental Studies, and the Japanese Ministry of the Environment.

-300 Chemical weathering and CO2 consumption in the Yellow River basin, emphasizing the origin of high HCO3-

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Chemical data was collected in the summer of 2007 and 2009, and then the forward model was applied to study the chemical weathering in the whole Yellow River basin. It showed that the contribution of carbonate rock to cations in the Yellow River decreased along the mainstream (from 71% to 23%) while that of the silicate rock kept at a stable level (9% to 6%). HCO3- originated mainly from the carbonate rock weathering in the Yellow River basin (80%). According to lithological distributions, the whole Yellow River basin can be divided into the upper Qinghai-Tibet Plateau sub-basin (I) (above the Lanzhou station), the middle Loess Plateau sub-basin (II) (between the Lanzhou station and the Huayuankou station) and the lower sub-basin (III) (below the Huayuankou station). Weathering rates of both carbonate rock and silicate rock were following the sequence of I>II>III. Although the area of sub-basin I is only about half of that of the sub-basin II (30% vs 67% of the whole basin), its chemical weathering CO2 flux is about twice larger (64% vs 35%). Due to our research, HCO3- in the Yellow River originated mainly from the Qinghai-Tibet Plateau, which is different from the most accept viewpoint that the high HCO3- concentration in the Yellow River is coming from the Loess Plateau. In addition, human disturbance on chemical weathering in the Qinghai-Tibet Plateau is not noticeable, but global warming intensifies the weathering process here. Therefore, HCO3- concentration in rivers, originating from the Qinghai-Tibet Plateau, may keep increase in the future.

-301 Underestimation of chemical weathering in river basins, without considering human water consumption

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Increasing agriculture-dominated water consumption not only reduces river discharges but also cation fluxes to downstream reaches or to oceans. Thus, chemical weathering results concluded with actual discharge will be underestimated. With data from references, this paper re-estimated CO2 consumption by chemical weathering in the Yellow River, Yangtze River and Xijiang River basins, considering human water consumption. It showed that, without considering human water consumption, CO2 fluxes by chemical weathering in these three basins were 139%, 12% and 9% underestimated, respectively. In addition, the underestimation percentage of chemical weathering result equals to the ratio of water consumption to actual discharge. According to this, global chemical weathering result is about 10% underestimated. Furthermore, we also raised some critical issues (return water, groundwater irrigation, CO2 release during irrgigation) which should be taken seriously, in order to fullly understand basin carbon cycles. For basins with complex lithologies, we suggest that they should be divided into several sub-basins with similar rock types. Quantification of chemical weathering in these sub-basins can not only plays a meaningful role in revealing impacts of geology and human disturbances on chemical weathering, but also provides more accurate basic data for the regional and global carbon budget.

-302 Sources and sinks of carbon from forest land use change in the last 30 years in Xinjiang province, China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Changes in forest land use contribute to a carbon source in most tropical regions due to a large scale deforestation but are poorly documented for arid forest ecosystem. According to " Guidelines for land use, land-use change and forestry " wrote by IPCC, we estimated sources and sinks of carbon from forest land use change between 1975 and 2005 in Xinjiang province, China. We got some results as follow: (1) the carbon pool of forest ecosystem in Xinjiang is 720.02 Tg, where the vegetation carbon pool is 191.20 Tg, and soil carbon pool is 528.82 Tg; (2)the effect of carbon from forest land use change in Xinjiang performed as a carbon sink overall, with total carbon sequestration 52.78 Tg, and a growth rate of 7.33%. The accelerated afforesting led to a strong carbon sequestration(58.96 Tg) with a high growth rate of 8.20%,while the deforestation showed a main carbon source, releasing 5.52 Tg. The woodland transferring performed a weak carbon source, releasing 0.66 Tg; (3) We recommend that take favorable measures on the quality and quantity of forest resources in the future to increase the forestry carbon sequestration in Xinjiang , and thus can offset the carbon loss from its industrial activities some extent so as to provide sufficient space for the sustained and healthy development of the economy of Xinjiang.

-303 The effect of agricultural ecosystems on the regional carbon flux of the five countries in Central Asia in the past 25 years

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The carbon stock of agricultural ecosystems has a non-negligible contribution to the balance of the global carbon cycle. Based on the statistical data and literature material, combined with the geographical spatial data, we estimated the carbon sequestration and Net biomes productivity of agricultural ecosystems of five countries in Central Asian in the past 25 years by using empirical model. The results indicate that the carbon sequestration and net biomes productivity of agricultural ecosystems of five countries in Central Asian is increased fluctuation trend, and the amount of CO2 uptake of agricultural ecosystems is greater than the amount of CO2 emission in the past 25 years, and agricultural ecosystems in this area is carbon sink. The management of the straw of cropland which pay an important role in carbon sequestration of agricultural ecosystems, to some extent, decides the size of the CO2 exchange between agricultural ecosystems and the atmosphere.

-304 Regional footprints and transport regimes for CO2 measurement sites in New Zealand from backward Lagrangian dispersion modelling

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Since 1990, New Zealand's CO2 equivalent greenhouse gas emissions increased by about 20%, yet it is estimated that its net greenhouse gas budget remained at 1990 levels due to a compensating increase in carbon uptake by forests. This terrestrial uptake plays a key role in the contemporary and future carbon cycle of the country, but remains poorly quantified. Global studies suggest that natural carbon sinks are sensitive to changes in climate and could already have become less efficient, with strong impacts on net carbon release. We use the UK Met Office's Lagrangian dispersion model NAME III to link CO2 observations at stations directly to atmospheric transport and potential source regions at the surface. By running the model in backward mode, we identify the degree to which potential regional sources of CO2 contribute to observed mixing ratios, i.e. the footprint of the station. Footprints are computed over the period 2011-2012 for the three stations Baring Head, Lauder and Rainbow Mountain. NAME III uses hourly meteorological input from the regional forecast model NZLAM-12 over a domain covering New Zealand and the Tasman Sea at a horizontal resolution of 12 km. In addition, we use the large body of back trajectories to identify the predominant transport pathways for each station and to cluster the CO2 observations into a discrete set of transport regimes. We present preliminary results of the footprint and cluster analyses and outline how the results will be used to estimate terrestrial sources and sinks of CO2 at a regional scale.

-305 Quantifying CO2 emissions from Canada’ s oil sands developments – results from a multi-tracer atmospheric observational/modeling approach

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Development of the oil sands in Canada has greatly expanded over the past decades and is projected to continue growing into the near future. While stimulating economic activity and wealth creation, oil sands development results in significant emissions of greenhouse gases (GHGs), as reported from bottom-up inventories. Such inventories, however, remain highly uncertain. In order for decision makers to devise policies that properly account for tradeoffs between the economic benefits of oil sand development and the costs of GHG emissions, a system for quantifying and monitoring such emissions becomes critically important.
We present a quantification/monitoring system that combines atmospheric measurements of GHG mixing ratios, their stable isotopes, and combustion-related species with a model of atmospheric transport. The atmospheric model (STILT) links the observations with their upwind source regions. This framework yields a unique regional scale constraint that can be used to relate the measured changes of tracer concentrations to processes in their upwind source regions. The understanding gained through the combined approach can also be used to verify reported emissions as part of regulatory regimes. Results show the signature of oil sands emissions on the atmosphere and the constraint provided by the framework. Sources of uncertainties in the monitoring system are also discussed.

-306 Progress status of the GOSAT SWIR XCO2 and XCH4

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The column-averaged dry air mole fractions of carbon dioxide and methane (XCO2 and XCH4) have been retrieved globally from the Short-Wavelength InfraRed (SWIR) spectral data observed with the Thermal And Near-infrared Sensor for carbon Observation Fourier Transform Spectrometer (TANSO-FTS) onboard Greenhouse gases Observing SATellite (GOSAT). The retrieval results have been released as the GOSAT TANSO-FTS SWIR L2 product, and its bias and standard deviation are evaluated by comparing with the XCO2 and XCH4 obtained by ground-based high-resolution FTS at several Total Carbon Column Observing Network (TCCON) sites. The SWIR L2 V02.xx XCO2 and XCH4 show smaller biases and standard deviations than those of the previous versions, but there still remain temporal and spatial dependencies in biases. To suppress these unfavorable dependencies, we will take two approaches; (i) an empirical correction by using the simultaneously retrieved auxiliary parameters, and (ii) further improvement of the retrieval algorithm. Our preliminary analysis shows that the retrieved aerosol optical depth, surface albedo, difference between the retrieved and a priori surface pressure, and airmass show relatively large correlations with the differences between the retrieved and TCCON XCO2 and XCH4. Precise analysis of the corrected XCO2 and XCH4 as well as the progress status of the improvement of the retrieval algorithm will be shown in the presentation.

Acknowledgement:
The authors wish to thank NIES GOSAT Project member for their useful comments. TCCON data used in this study are provided by TCCON partners.

-307 Atmospheric inversion with CONTRAIL exposing CO2 dynamics in the Asian tropics

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Because very few measurements of atmospheric carbon dioxide (CO2) are available in the tropics, estimates of surface CO2 fluxes in tropical regions are beset with considerable uncertainties. To improve estimates of tropical terrestrial fluxes, atmospheric CO2 inversion was performed using passenger aircraft based measurements of the Comprehensive Observation Network for Trace gases by Airliner (CONTRAIL) project in addition to the surface measurement dataset of GLOBALVIEW–CO2. Regional monthly fluxes at the earth's surface were estimated using the Bayesian synthesis approach focusing on the period 2006–2008 using the Nonhydrostatic ICosahedral Atmospheric Model-based Transport Model (NICAM-TM). By adding the aircraft to the surface data, the posterior flux errors were greatly reduced; specifically, error reductions of up to 64 % were found for tropical Asia regions. This strong impact is closely related to efficient vertical transport in the tropics. The optimized surface fluxes using the CONTRAIL data were evaluated by comparing the simulated atmospheric CO2 distributions with independent aircraft measurements of the Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container (CARIBIC) project. For the first time, the CONTRAIL CO2 measurements were used in an inversion system to identify the areas of greatest impact in terms of reducing flux uncertainties.

For further study on longer-term variations of atmospheric concentrations and surface fluxes of CO2, the inversion calculation is extended for the longer period of 2006–2011 with the up-to-date datasets of GLOBALVIEW and CONTRAIL. By analyzing the 6-year inversion results, discussion will be made focusing on the Asian tropics, where CO2 budget has a significant interannual variation induced by climate variability.

-308 Interannual Variability in the Northern Hemispheric Seasonal Cycle of CO2 as Observed by GOSAT

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The summer uptake of CO2 over the northern extra-tropical latitudes is the largest component of the net land uptake of CO2. It is also highly variable, being influenced by climatic anomalies such as droughts and singular events such as forest fires. Quantifying these variations is an important goal of current carbon cycle research. Until recently, the only top-down approach for quantifying those variations was to derive large scale CO2 fluxes from observed atmospheric gradients of CO2 at the surface. However, many areas with high flux variations – such as Boreal Eurasia – are poorly sampled by the surface measurement network. To fill this data gap, the Greenhouse Gases Observing SATellite (GOSAT) was launched in 2009, with the explicit goal of ultimately deriving global flux patterns for CO2 and CH4.

In this work, we analyze the first two years' data from GOSAT, and show a marked difference in the northern extra-tropical summer CO2 uptake between 2009 and 2010. Focusing on Eurasia, we attribute the reduced CO2 uptake in 2010 to a heat wave, which influenced biospheric fluxes and fire emissions during the biomass burning season. By correlating the observed CO2 variability with CO emission estimates for the 2010 Russian fires, we show that a significant part of the CO2 variability could have come from those fires. This work illustrates how GOSAT data can provide constraints on estimates of large scale CO2 fluxes.

-309 Extending Arctic CO2 column measurements to cover the complete seasonal cycle using lunar FTIR spectroscopy during Polar Night

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The Arctic is an important region in the global carbon cycle. At our site in Ny Alesund, Spitsbergen (at 79°N) we perform measurements of column abundances of various trace gases within the Total Carbon Column Observing Network (TCCON) and the Network for Detection of Atmospheric Composition Change (NDACC) using solar absorption Fourier Transform Infrared (FTIR) spectrometry. Within TCCON, CO2 and CH4 measurements are precise enough that they are suitable for satellite and model validation and have given deeper insight into carbon cycle science.
At high latitude sites, however, there are few measurements of column abundance during polar night (even from satellites), and therefore we cannot validate model simulations. Due to the lack of sunlight in winter the usual setup is not applicable. After the sun, the moon is the next best source of NIR radiation (reflected sunlight) and we present the results from a new FTIR setup employing a customised, cooled InGaAs detector for the near infrared measuring CO2 and CH4 from the same spectral bands as those used with TCCON.
We were able to extend the retrievable time series to take measurements on up to 7 days around each full moon in the last winter.
Here we present the results of this trace gas retrieval and compare the complete CO2 and CH4 seasonal cycle from combined solar and lunar time series with in-situ and model data.

-310 Mesoscale modeling of atmospheric CO2 over Denmark including exchange with coastal waters

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

As part of the Danish project ECOCLIM (Ecosystems Surface Exchange of Greenhouse Gases in an Environment of Changing Anthropogenic and Climate forcing) a mesoscale model system is under development. Numerical models are an important tool for studies of the processes related to atmospheric CO2 and have been used for decades. More recently mesoscale models have been exploited to simulate the exchange of CO2 between terrestrial ecosystems and the atmosphere at a high spatio-temporal scale. The fine resolution of mesoscale models help capture the heterogeneity of terrestrial ecosystems and its corresponding exchange of CO2 with the atmosphere.

Not many mesoscale studies have included the exchange of CO2 between marine ecosystems and the atmosphere in coastal regions. However, global measurements have indicated that open shelves at high latitudes act as sinks for atmospheric CO2, while inner estuaries and near-shore coastal areas act as sources of atmospheric CO2.

For the area of Denmark it is of greatest importance to include the marine exchange as Denmark is surrounded by estuaries and coastal shelves. In this study a modeling framework of high spatio-temporal resolution is developed for the area of Denmark and its surroundings with the aim of determining the exchange processes between the atmosphere and terrestrial and marine ecosystems, and the resulting concentration of CO2 in the atmosphere. The model system is based on the atmospheric model DEHM (The Danish Eulerian Hemispheric Model) using a nest over Denmark with a spatial resolution of 5.6 x 5.6 km. Meteorology is obtained from MM5 (Penn State University/NCAR mesoscale model). Anthropogenic emissions are taken from the national emission inventory of Denmark aggregated onto an hourly 1x1 km grid according to source regions and CRF sectors. The terrestrial CO2 exchange is facilitated by the Biosphere Energy Transfer Hydrology model (BETHY/DLR) operated at the German Aerospace Center. BETHY/DLR is a vegetation model driven by time series of the Leaf Area Index, meteorology and static maps as land cover, soil type and elevation. The marine component is based on the COHERENCE ocean model that uses meteorological inputs to simulate the surface pCO2 values, which together with the gas transfer velocity and the atmospheric CO2 concentration determine the flux between the atmosphere and marine ecosystems. Validation of the simulated atmospheric CO2 will be enabled by real time measurements from a new Danish tall mast positioned at Risoe. As compared to previous studies the present study offers a unique opportunity to assess the impact of coastal waters on the atmospheric CO2 concentration.

-311 Ocean dynamical and biological controls of variability in the latitudinal gradient of CO2 and O2/N2 across the Pacific Ocean

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The Pacific Ocean plays a key role in global carbon uptake and inter-annual and decadal variability of air-sea fluxes of CO2 through the El Niño Southern Oscillation and the Pacific Decadal Oscillation. Atmospheric observations of CO2 have been widely used to infer regional fluxes and their variability. However the interpretation of these observations in terms of ocean fluxes can be difficult due to the strong influence of terrestrial fluxes, which typically have much larger temporal variability, on the observed atmospheric CO2 mixing ratios.

Since CO2 and O2 are absorbed and released by the terrestrial biosphere with a known stoichiometric ratio, atmospheric observations of O2/N2 ratios and CO2 can be combined to create Atmospheric Potential Oxygen (APO), a tracer that is conserved with respect to the terrestrial biosphere and primarily reflects ocean fluxes of these species. Previous studies have demonstrated that latitudinal gradients of APO have a distinct structure, and that this structure is not stationary with respect to time, but limited work has been done to understand the ocean processes that are controlling these changes.

We present a series of atmosphere and ocean model simulations designed to explore the variability in APO across the Pacific Ocean, the processes controlling it, and the implications for the global carbon cycle. Two versions of the NEMO-PISCES ocean biogeochemistry model are used to provide air-sea boundary conditions for the TM3 atmospheric transport model: a standard control version and a second version that includes a new parameterization of wind stirring that increases summer mixed layer depth. Tagged tracer simulations are used to determine the relative roles of air-sea fluxes from the Subpolar Gyre, North Pacific Gyre, Tropics, South Pacific Gyre, and the Southern Ocean in controlling seasonal and inter-annual variability in the latitudinal gradient of APO.

Preliminary results suggest that accurate representation of the summer mixed layer depth and the timing of stratification and destratification are critical to correctly representing ocean oxygen uptake in the Northwest Pacific in ocean models. Other studies have shown that parameterizations of these processes can have implications for trends in ocean carbon uptake that are comparable to or greater than those that have been suggested due to increasing winds over the Southern Ocean.

-312 The ocean biogeochemistry at the onset of the Paleocene-Eocene Thermal Maximum – an Earth System Model study

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Present day climate change and ocean acidification are strongly connected to atmospheric CO2 increase. To better understand today's and future variations in Earth's climate, it is beneficial to study analogous events in Earth's history. During the Paleocene-Eocene Thermal Maximum (PETM; 55 million years ago) the climate underwent changes similar to today. This event was characterized by a massive carbon release, indicated by a negative δ13C-carbon isotope excursion and carbonate dissolution in the ocean, and associated intense global warming. Especially the rather short timescale (~10 ky), compared to other geological events, in which the global temperature increase occurred qualifies the PETM for further investigations and increases its potential for comparison to today. Based on the ambiguous amount and time scale of the carbon release, the dimensions of change in ocean carbon cycle during the PETM are still uncertain. We use the fully coupled Earth System Model of the Max Planck Institute for Meteorology (MPI-ESM) which includes ocean and atmospheric general circulation models (MPI-OM & ECHAM respectively) and models of ocean biogeochemistry (HAMOCC) and land vegetation (JSBACH). Such a modeling system enables us to simulate the closed carbon cycle in the oceanic, land and atmospheric compartments. Moreover, by using a three-dimensional ESM we get a more detailed representation of the ocean biogeochemistry and the underlying physical processes in contrast to former PETM biogeochemistry model studies, carried out by simpler models. We run different carbon release scenarios for the PETM, starting from a Late Paleocene (pre-PETM) steady-state. We choose a background climate with a fixed 2x pre-industrial atmospheric CO2 concentrations of 560 ppmv at the onset of the PETM. Our PETM simulations comprise a period of several thousand years, in which we prescribe a carbon release of up to 1.5 Gt a-1. First results on how ocean biogeochemistry is affected by the carbon release in a warmer climate, as well as possible interactions within the Earth system will be presented.

-313 Ocean Acidification and CO2 Fluxes in the Pacific-Arctic Region

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Rising carbon dioxide (CO2) concentrations in the atmosphere and ocean have lead to an anthropogenically induced acidification phenomenon in high-latitude seas, which are projected to become persistently undersaturated with respect to important carbonate minerals as early as mid-century. However, seasonal undersaturations have already been observed in surface and shallow subsurface waters in the continental shelf seas of the Pacific-Arctic region, where multiple biogeochemical influences impact pH and carbonate mineral saturation states. Some calcifying marine organisms, including pteropods, foraminifers, and mollusks that could be susceptible to reduced calcification rates under increasing ocean acidity are keystone species in this area. Here, we present new data from recent ship-based observations and moored platforms in the northern Gulf of Alaska, the Bering Sea, and the Western Arctic Ocean that show the extent and controls on ocean acidification in each region. These unique findings show that the intrusion of anthropogenic CO2 is only one of several factors that include riverine and glacial runoff, the biological pump, and sea ice processes that drive seasonal carbonate mineral suppression and undersaturation in the Pacific-Arctic region.

-314 Estimation of European Methane emissions using a regional-scale atmospheric inversion system

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Methane (CH4) is the second most important contribution to the European greenhouse gas budget and is, in the greater part of Europe, clearly dominated by anthropogenic emission sources. Although the anthropogenic emissions are regularly reported to the United Nations Framework Convention on Climate Change (UNFCCC) by almost all European countries, considerable uncertainties still exist in the bottom-up CH4 emission inventories. Inverse modelling can provide complementary top-down emission estimates based on atmospheric concentration measurements and can - in the ideal case - serve as a verification tool for the emission inventories.
The regional-scale inversion system TM3-STILT is applied to estimate European CH4 emissions for 2006-2007 with a nominal spatial resolution of 0.25° x 0.25°. In this inversion system, the high-resolution regional Stochastic Time-Inverted Lagrangian Transport model STILT is coupled to the global 3-dimensional transport model TM3 in order to account for small-scale variability as well as large-scale patterns in fluxes and transport. The inversions are based on hourly atmospheric concentration measurements at 10 European continental sites and flask/hourly measurements at a large number of global sites in combination with a-priori flux estimates obtained from global emission inventories.
A series of sensitivity studies covering a range of inversion set-up parameters is performed to investigate the robustness of the emission estimates and to assess their uncertainties. They confirm that the available observational data mainly constrain the emission estimates for the western and central part of Europe. The overall patterns of the emission estimates for this region are relatively robust, even without the use of detailed a-priori emission information.

Review of GHGs emission characteristic of wetland under human management

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Climate change is now firmly established as a scientific reality, with a variety of emergent challenges for societies in the coming decades. The increased atmospheric greenhouse gas (GHGs) caused by human intervention on the climate are clearly addressed. Wetlands such as mangroves, marshes and peatlands are the largest carbon stocks of the terrestrial biosphere with mineral soils and organic soils which play important role in sustaining Earth's carbon balance. Great concerns were focused on wetland carbon cycle due to its large carbon stock. Carbon balance and GHGs emission are affected mainly by human's wetland utilization. This paper aimed to review the GHGs emission characteristic from wetland under human management practices, and estimate the role of wetland in the global carbon cycle.

This study reviewed researches on wetland carbon cycle, including the impact factors on wetland GHGs emission, wetland carbon source or sink assessment, and the impacts of anthropogenic activity on wetland carbon cycles. The authors analyzed different actual magnitude of human-influenced emissions and removals from wetlands. Results showed that numerous variables, containing management policies, wetland category, wetland area, water level, temperature, precipitation, vegetation composition, soil type, and growing season length determine the actual GHGs emissions from wetland and the removals by wetlands. However, further studies on the interaction of these factors were needed to be conducted. More researches should be conducted in areas where no data is available. This research is for better understanding carbon sink and source function of various wetland types, and for reducing uncertainty in global carbon budget assessment as well.

Keywords: Greenhouse gas emission; Wetland; Characteristics

-316 Multi decadal trend in oceanic surface pCO2 from observation and models

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

We combined observational data sets from SOCAT and other biogeochemistry data products to compute the recent multi-decadal surface pCO2 trend in the world oceans. The data shows that, for the 1990-2011 period, the surface pCO2 trend in the low latitude regions is generally lower than the atmospheric CO2 growth rate, of approximately 2.0 ppm/year, by as much as 1.5 ppm/year. On contrary, high latitude regions such as the subpolar North Atlantic gives pCO2 growth rate as high as 2.5 ppm/year. We use five state-of-the-art Earth system models to understand these regional patterns. On average, most models consistently simulate pCO2 trends between 1.5-2.0 ppm/year throughout most ocean regions. However, the simulated meridional gradients in pCO2 trends are less pronounced than the observation. All models simulate large differences in the high latitude pCO2 trend depending on which season is considered. For example, in the North Atlantic, model pCO2 data from boreal summer period alone would yield a higher pCO2 trend than the respective winter or spring values. Thus, this uncertainty needs to be taken into account when implying regional oceanic pCO2 and carbon uptake trend based on data biased toward certain seasonal period.

-317 Global Ocean Carbon Uptake: Magnitude, Variability and Trends

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The anthropogenic global-integrated sea-air carbon dioxide (CO2) flux from 1990 to 2009 are determined from models and data-based approaches as part of the Regional Carbon Cycle Assessment Project (RECCAP). Numerical methods include ocean inverse models, atmospheric inverse models, and ocean general circulation models with parameterized biogeochemistry (OBGCMs). The median value of different approaches shows good agreement in average uptake. The best estimate of anthropogenic CO¬2 uptake for the time period based on a compilation of approaches is -2.0 Pg C yr-1. The interannual variability in the sea-air flux is largely driven by large-scale climate re-organizations and is estimated at 0.2 Pg C yr-1 for the two decades with some systematic differences between approaches. The largest differences between approaches are seen in the trends. The trends range from -0.13 (Pg C yr-1) decade-1 to -0.50 (Pg C yr-1) decade-1 for the two decades. The OBGCMs and the data-based sea-air CO2 flux estimates show appreciably smaller decadal trends than estimates based on changes in carbon inventory suggesting that methods capable of resolving shorter timescales are showing a slowing of the rate of ocean CO2 uptake. RECCAP model output for five decades shows similar differences in trends between approaches.

-318 Carbon dioxide emission from disturbed peat-land in Kalimantan, Indonesia

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The CO2 emission from disturbed peat-land in Indonesia is reported to be very huge (57Tg/yr from fire in 1994, Indonesian inventry report submitted to UNFCC), but both the amount and mechanism of emission are not well understood. The Mega-rice Project started in the 1980' s has converted the forest/peat-land to rice field by constructing drainage system. This project causes frequent forest/peat-land fires. The fire clearing of agriculture farm acts as the ignition of wild fire that burns bush, fern and dried peat soil. It is very severe when no rain days continue long in El Nino year.

Besides wildfire, aerobic microbial decomposition of peat is the other source of CO2 especially when the water level is low. The amount of this decomposition is not well evaluated. Conventional methods are Stock-change method and Flux method: In the former method, the sink of soil surface is measured comparing with stick heights inserted until mineral soil. In the latte one, chamber/eddy methods are applied. Hirano et al1) have reported a clear correlation between CO2 flux and underground water level, that is, flux increases with decreasing water level. This is a strong evidence to construct water dams along the drainages, which keep the water levels high enough to prevent both wildfire and aerobic decomposition. However, this approach is not approved as the carbon emission reduction activity under UNFCC framework, because the methodology to evaluate the carbon emission reduction is not established (MRV problem). Three different automated measurements have been conducted; CO2 flux, ground level change relative to mineral soil layer and water level since September, 2012 at seriously disturbed peatland near Palangka Raya Kalimantan, Indonesia. This area is located at the summit of peat-dome between Kahayan and Sebangau Rivers. All the original trees were burned and peat fires occred several times. Land is covered by fern and very sparse trees now.

Based on our results, the CO2 flux was proportional to the underground water depth and showed a weak dependence when the depth is below 30 cm. These results suggest that the CO2 flux is less when the surface is very dry. The land surface moves up/down as the ground water level change by the amount of 1 %. It is probably due to the swelling/squeeze of peat by water content increase/decrease. This physical process must be taken into account when the land level is monitored to evaluate the carbon stock change.

1. Hirano, T., Segah, H., Harada, T. Limin, S., June, T., Hirata, R., and Osaki, M., (2007). Carbon dioxide balance of a tropical peat swamp forest in Kalimantan, Indonesia. Global Change Biology 13 (2), 412-425

-319 The GHG balance of a country with substantial land management, the Netherlands

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

We determine the net Greenhouse Gas balance of the Netherlands by using top down regional inversion models and bottom up estimates of the fluxes of the main land use types, grassland, crops and forest. We also provide an estimate of the lateral transport of GH' s and emissions from open water. In the Netherlands land use management is a very strong component of the total balance. We use a biogeochemical model, CASA at very high resolution (1 km) to provide insight into both the management effects and the variability of the fluxes. Farm gate budgets complement the net emissions found from the bottom up flux estimates.

By combining with the atmospheric budget through regional inversions at grid length 10 km, we are able to define both the absolute value of the budget and its uncertainty. This budget can be compared to that submitted to the UNFFCC as independent verification of a (small) country' s GHG budget.

-320 CO2 profiles retrieved from GOSAT/TANSO-FTS thermal infrared spectra using an improved algorithm

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Greenhouse gases Observing Satellite (GOSAT) is a sun-synchronous orbital satellite that was developed by the National Institute for Environmental Studies (NIES), the Ministry of the Environment (MOE), and the Japan Aerospace Exploration Agency (JAXA) for global observations of greenhouse gases. GOSAT has been observing CO2 and CH4 continuously for about four years since its launch on January 23, 2009. The Thermal And Near infrared Sensor for carbon Observation (TANSO)-FTS of the GOSAT can measure both CO2 and CH4 column amounts (XCO2 and XCH4) and CO2 and CH4 profiles simultaneously from the shortwave infrared band (SWIR) and the thermal infrared band (TIR), respectively. The combined use of the SWIR and TIR data has a possibility to estimate the amounts of CO2 in the boundary layer accurately, which could provide a useful dataset for the study of CO2 sources and sinks. TIR Level 2 (L2) CO2 product has been released as V00.01, which was processed using a previous version of Level 1B data (V100.100). The V100.100 L1B spectral data include a relatively large bias especially at around CO2 14-15 micron band. Mainly for this reason, the V00.01 L2 CO2 data have a clear high bias in low latitudes and in mid-troposphere.

We have been developing a new L2 algorithm for retrieving CO2 profiles from the latest TIR L1B spectral data (V150.150). The latest version of the L1B spectral data is improved compared to the previous versions, but still has a bias judging from comparisons with other coincident satellite spectral data. In our new L2 CO2 retrieval algorithm, we adopt a non-linear Maximum a Posteriori (MAP) method with linear mapping and simultaneously retrieve temperature, water vapor, ozone, surface temperature, and surface emissivity at 14-15 micron band other than CO2. We assume that the magnitude of the bias in the TIR L1B spectra correlates with its radiance and utilize the correlation for the bias correction. In our algorithm, we treat surface temperature and surface emissivity as spectral bias correction parameters. The data quality of TIR L2 CO2 profiles retrieved applying our new algorithm is improved compared to the current released L2 CO2 product. The large bias in mid troposphere seen in the V00.01 L2 CO2 product is reduced when applying our simultaneous retrieval algorithm.

-321 A stochastic model for scale interactions in high-latitude peatlands

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Sub-grid and small scale processes occur in various ecosystems and landscapes (e.g., periglacial ecosystems, peatlands and drylands). These local heterogeneities are often important or even fundamental to better understand general and large scale properties of the system, but they are either ignored or poorly parameterized in regional and global models. This is of particular interest in the northern peatlands, because of the huge amount of carbon stored in these regions. Methane, carbon dioxide and water vapor fluxes vary largely within the environment, as an effect of the small scale processes that characterize the landscape. It is then essential to consider the local heterogeneous behavior of the system components, such as the water table level and the microtopographic relieves.

Applications of statistical physics methods could be useful tools to upscale local features of the landscape, relating them to large-scale properties. By partitioning the space in smaller subunits and then analyzing the statistical properties of the tiling, we propose a method to fill the scaling gap from local mechanistic models and large scale mean field approximations.

We developed a stochastic model for northern peatlands, which are able to upscale statistical ecosystem scale properties (1 km or more) of the system taking into account the main processes at a microtopography scale (1 m).

We apply a first tessellation of the space, in order to resolve hydrological and ecological differences (i.e., we can distinguish between bogs and fens). A second stochastic tessellation, using Poisson-Voronoi diagrams, can then consistently represent the surface microtopography. We then compare the results with available recent field studies and demonstrate that the model captures the main statistical characteristics of the landscape and it describes their dynamical behavior under climatic forcings (e.g., precipitation and evapotranspiration). In particular, we model and analyze water table dynamics, and microtopography evolution and dynamics. Both features directly influence greenhouse gas emissions and changes in the system.

-322 The climate change in Central Asia from 1979-2011 based on multiple datasets

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

The arid and semiarid region in Central Asia is sensitive and vulnerable to the climate change. However, the sparse and highly unevenly distributed meteorological stations in the area provided limited data and information for understanding of the region's climate variations. Therefore, in this study, the climate change in Central Asia from 1979-2011 was examined by multiple datasets which included the observations from 31 meteorological stations and three newly developed reanalysis datasets: CFSR, ERA-Interim and MERRA, and the Climate Research Unit (CRU) dataset for the near surface air temperature change; besides the above datasets, the Asian Precipitation-Highly Resolved Observation Data Integration Towards Evaluation of Water Resources (APHRO) dataset and the Global Preciptiation Climatology Centre (GPCC) datasets for the precipitation change. For the air temperature, the results indicate that the three reanalysis datasets match well with most of the local temperature records, especially in the low-lying plain areas; the consensus of the multiple datasets showed significant regional surface air temperature increase at 0.42-0.53℃ per decade during 1979-2011; The rate is larger in the recent years than in the early years in the study period; further, unlike in many regions in the world, the temperature in winter season showed no increase in Central Asia in the last three decades. For the precipitation in Central Asia during 1979-2011, major results suggested that all datasets have annual precipitation change at different ratios: -5.3mm per year for CFSR, -0.27 per year for ERA-Interim, -1.9 per year for MERRA, -0.27mm per year for GPCC, -0.77mm per year for APHRO and 0.05 per year for CRU. Most areas of Central Asia show the decrease in the precipitation. The increase in temperature and decrease in precipitation in this region will have great impact on the ecosystems.

-323 The carbon sequestration of Chinese cement consumption and cement kiln dust (CKD) treatment in past 110 years

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The amount of atmospheric carbon dioxide absorbed in China cement consumption and cement kiln dust (CKD) over 110 year period has been calculated. The carbon sequestration occurs gradually in 35 years initial service life and 64 year of post-demolition period, while occurs quickly in one year demolishing, crushing, and exposure period. The processing of demolition and crush concrete to recycled concrete aggregates as new concrete aggregates, road base, landfill, and stacking increase carbon sequestration rate. The cement kiln dust (CKD) carbonated fast for its large exposure area. The carbonization process of cement and concrete in buildings and cement kiln dust (CKD) resulted in 864.37 million ton carbon sink during 1900-2010, the annual carbon sink is more than 1 million ton C/a since 1973 and reached 86.67 million ton C/a in 2010. Greenhouse gas inventory methodology of cement and other alkaline materials industrial process should be reconstructed to reduce current overestimation.

-324 The direct effects of increasing CO2 concentration in seawater on net primary production of charophytes in the shallow coastal brackish water ecosystem

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The number of studies dealing with the effect of acidification on the brackish Baltic Sea biota is very limited and the topic itself so far poorly understood, but recently more studies have been initiated and data is becoming available. The main aim of current study is to indicate how acidification induced by elevated atmospheric carbon dioxide affects the photosynthetic net production of different charophytes species in the brackish Baltic Sea. The second objective examines the short-term variability of p(CO2), pH, alkalinity, and oxygen saturation in shallow-water macroalgal habitats. The mesocosm experiments were conducted in Kõiguste Bay (northern part of Gulf of Riga, the Baltic Sea) during the field season of 2012. Separate mesocosms were operated in each set with different CO2 concentrations. The experiments were carried out with three different soft bottom species of charophytes: Chara aspera, Chara tomentosa and Chara horrida. The photosynthetic activity response of the plants was measured by the oxygen method. Our results indicated that increased CO2 levels in seawater had species specific response. Results of the experiments showed that in shallow coastal conditions the daily pH is characterized by large amplitude of natural variability. Daily pH changes in shallow water with high macrophyte densities may be of a larger magnitude than those predicted due to ocean acidification over the next 100 years.

-325 An Update on the Total Carbon Column Observing Network

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The Total Carbon Column Observing Network (TCCON) is an expanding network, currently consisting of 17 sites globally. The TCCON utilizes a ground-based remote sensing technique to measure total columns of CO2, CH4 and other gases via solar Fourier Transform spectrometry. TCCON uses measured columns of O2 as an internal standard for the dry-air column, and ratioing retrieved columns of other gases to the O2 allows for high-precision determination of the column-averaged dry-air mole fractions (e.g. XCO2).

To be comparable to in situ measurements that are calibrated to WMO-reference scales, TCCON must in turn be calibrated. This is done by comparison to integrated aircraft profiles performed above the TCCON sites. This calibration indicates good inter-site consistency, and yields XCO2 values that are provided on the same reference scale as in situ measurements, and can therefore be used together in studies with these measurements.

TCCON measurements provide information about regional to hemispheric-scale fluxes, and together with their relative insensitivity to vertical-mixing, provide information that is complementary to in situ measurements. E.g. TCCON column measurements highlight that model simulations have a tendency to underestimate the magnitude of the seasonal cycle in the northern hemisphere, even when these simulations are based on fluxes optimized using in situ measurements. Interannual variability in TCCON measurements is also not completely captured by models, due also to biosphere-driven and dynamical processes.

In addition, TCCON is extensively used for calibration and validation of many satellite missions that aim to provide global coverage of greenhouse gas measurements, e.g. the Greenhouse Gases Observing Satellite, SCIAMACHY, and the forthcoming OCO-2 and CarbonSat missions. Algorithms retrieving dry-air mole fractions from these satellites are rapidly developing, placing increasing demand on TCCON as a validation tool. Here, we also discuss recent progress within the TCCON to improve the network-wide precision and accuracy, particularly for use in validation exercises.

-326 Background and Regional CO_2 Measurements from Three Sites within the Cape Peninsula, South Africa

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Long-term CO_2 measurements in addition to other trace gases have been made at the South African Global Atmosphere Watch (GAW) station Cape Point (34 °S, 18 °E) since 1993. Starting in February 2012, CO_2 and CH_4 are also being monitored at two neighbouring sites within the Cape Peninsula, i.e. at Cape Hangklip and Robben Island. This latter project is a collaborative venture between the Council of Scientific and Industrial Research (CSIR) and the SA Weather Service aimed at providing verification for future bottom-up modeling initiatives of carbon fluxes for the greater Cape Town area.
At all three localities, which fall within a 62-km radius, CO_2 is being measured via cavity-ring-down spectroscopy technique. Measurements at the three sites have been related to a common calibration scale by means of a travelling standard (5-liter aluminium tank) that is traceable to the latest WMO CO_2 calibration scale.
The Cape Point CO_2 time series (1993-2012) as derived from data filtered with respect to background conditions is presented. It largely parallels the observational results at comparable sites. Relatively strong smoothing (circa 5 years) of the interannual variations was applied to the trend curve. This is reflected by the growth rates, which represent the derivative of the trend curve. For 2012 the growth rate amounted to 2.2 ppm yr^{-1}. A linear fit visualizes the general overall increase of the rates. Cape Point CO_2 half-hourly mole fractions (all data) have been analysed in terms of annual frequency distributions. These display either unimodal or bimodal behaviour for specific years. Possible explanations for the inter-annual changes in data distribution are being investigated.
A preliminary evaluation of the 2012 data for all three CO_2 measuring sites shows excellent agreement between the data sets when two or three of theses sites are concurrently exposed to background marine air. Furthermore, wind regimes provide information for an estimate of local emissions when one or two of the sites receive air via the Cape Town metropolitan region, while another one measures only background levels of CO_2.

-327 Inverse modeling of the ice age carbon cycle through a combination of simulated and real sediment cores worldwide

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The explanation of the glacial CO2 drawdown through a combination of different drivers remains a challenging attribution problem. We estimate the simultaneous glacial-interglacial changes of the following governing carbon cycle parameters in a maximum likelihood sense: 1. Sea surface temperature. 2. CO2 release from land. 3. Temperature dependent degradation of biogenic particles. 4. Export production rain ratio. 5. Ocean circulation. 6. Stimulation of biological production through dust input. 7. Stoichiometry of carbon vs. nutrients in biogenic matter (carbon underconsumption). We employ the annually averaged global biogeochemical ocean general circulation model (BOGCM) "HAMOCC" and a comprehensive data base of sediment core data including CaCO3-wt%, BSi-wt%, δ13Cplanktonic, and δ13Cbenthic plus atmospheric ice core CO2 data. The model simulates the marine cycles of carbon, silicon, oxygen, as well as phosphorus. The model includes an atmosphere reservoir and an early diagenesis module. The sediment module predicts time dependent sediment accumulation rates for the different sediment species including individual ages. The simulation follows several steps: 1. A control run with the BOGCM is performed. 2. Forward model integrations with the BOGCM over the past climate cycle (130-0 kyrBP) for variations in single parameters are carried out. 3. The results from the 3-D model are projected onto a linear response model which couples the time dependent variations in governing carbon cycle parameters with the simulated paleo-climate sediment archive (i.e. at each position where sediment core data from geological analysis is available, we "drill" into the model sediment and "recover" a simulated sediment core record for comparison with the real world). 4. The linear response model is fitted to the observational data base of sediment core data resulting in optimal estimates for synchronous glacial-interglacial variations in the seven governing parameters listed above. The results from the fitting procedure still depend on the weighting of the different parameter changes and sediment core records. An advantage of the method is that it provides a consistency check through a comparison between the simulated and observationally derived sediment accumulation rates. The method opens the perspective for systematically including the paleo-climatic sediment core record in data assimilation procedures for calibrating process representations in global Earth system models used also for future climate projections.

-328 Exchange ratios of -O2:CO2 observed in a cool temperate deciduous forest ecosystem of central Japan

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Estimation of oceanic and terrestrial biospheric CO_2 uptake based on the atmospheric O_2/N_2 ratio has been conducted by several research groups since the early 1990s. In order to apply this method, the global average terrestrial biospheric $-O_2:CO_2$ molar exchange ratio is needed and the value of 1.10±0.05 reported by Severinghaus (1995) has been used in recent studies. In order to contribute to a better understanding of the terrestrial biospheric $-O_2:CO_2$ exchange ratio, we conducted soil chamber and branch bag measurements for the O_2/N_2 ratio and CO_2 concentration at Takayama deciduous broadleaf forest site in central Japan (36º09'N, 137º25'E, 1420 m.a.s.l.; TKY as a AsiaFlux site code). We also made continuous measurements of the atmospheric O_2/N_2 ratio and CO_2 concentration in the canopy at the site in summer. The exchange ratios for soil respiration and net assimilation of plant were found to be 1.11±0.01 and 1.02±0.03 from the soil chamber and the branch bag measurements, respectively. The continuously observed atmospheric O_2/N_2 ratio and CO_2 concentration indicated that the average exchange ratio was lower in the daytime (0.90±0.09) than in the nighttime (1.04±0.12), with the daily mean value of 0.94±0.01. The average daytime and nighttime exchange ratios agree with the corresponding values derived for net turbulent O_2 and CO_2 fluxes between the atmosphere and the forest ecosystem using a 1-box canopy O_2/CO_2 budget model. The results of this study also suggest that the daily mean exchange ratio for net turbulent O_2 and CO_2 fluxes depends on the forest ecosystem.

-329 Gravitational separation of major atmospheric components in the stratosphere and its application as an indicator of atmospheric circulation

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

To detect the gravitational separation in the stratosphere, the stratospheric air samples collected over Japan were analyzed for delta15N of N2, delta18O of O2, delta(O2/N2), delta(Ar/N2) and delta40Ar. The vertical profiles of delta18O/2, delta(Ar/N2)/12, delta40Ar/4 and delta15N on June 4, 2007 showed a gradual decrease with height, their average difference between the lowermost part of the stratosphere and 32 km being about 45 per meg. The relationships of delta18O, delta(Ar/N2) and delta40Ar with delta15N were 2.1±0.2, 11.9±1.4 and 4.2±0.6 per meg per meg-1, respectively. These ratios are consistent with the corresponding values of 2, 12 and 4 per meg per meg-1 expected from the gravitational separation, but are clearly different from 1.55±0.02, 16.2±0.1 and 2.75±0.05 per meg per meg-1 determined experimentally for a possible thermal diffusion effect at the air intake of the cryogenic air sampler. This fact indicates that the gravitational separation of the major atmospheric components is clearly observable even in the stratosphere. By using a parameter " Delta" defined as an average of delta15N, delta18O/2, delta(Ar/N2)/12 and d40Ar/4 for each collected air sample, we corrected the values of delta(O2/N2) observed in the middle stratosphere for the gravitational separation. The delta(O2/N2) values, thus corrected, were found to show secular decrease similar to temporal change in the troposphere, and the mean age of the middle stratospheric air calculated from the corrected delta(O2/N2) is consistent with the CO2 age. To examine how the CO2 age and the Delta value are influenced by changes in the stratospheric circulation, we made numerical simulations using the SOCRATES 2-dimensinal model. It was found from the simulations that the CO2 age and the Delta value respond differently to changes in the stratospheric transport. The simulation results also indicate that the gravitational separation for the air with the same age is strengthened if the Brewer-Dobson circulation is enhanced due to global warming, which is just the opposite of our observational result for the period 1995-2010. In the presentation, we will also discuss the latitudinal differences of the Delta values observed in the stratosphere over Kiruna, Sweden, Syowa, Antarctica and the Equatorial Pacific off Peru.

-330 Surface water fCO2 algorithms for the high-latitude Pacific sector of the Southern Ocean

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The feasibility of using remotely sensed data jointly with shipboard measurements to estimate the carbon dioxide fugacity in the surface water (fCO2sw) of the Pacific sector of the Southern Polar Ocean (S> 60 S) is evaluated using a data set obtained during austral summer 2006. A comparison between remotely sensed chlorophyll a (chl a) and sea-surface temperature (SST) with in-situ measurements, reveals the largest bias in areas with rapid and large concentration changes such as at the ice edge, the polar front and in the Ross Sea Polynya. The correlation between fCO2sw and SST, chl a, biological productivity estimates and mixed layer depth (MLD) are evaluated, and single and multiple regression methods are used to develop fCO2sw algorithms. Single regressions between the study parameters and fCO2sw show that most of the fCO2sw variability is explained by chl a. The Multi-Parameter Linear regressions were used to create fCO2sw algorithms derived from field measurements, and using solely remote-sensing products. Based on the best fits from the two data sets fCO2sw estimates have a root means square deviation of ±14 µatm and coefficient of determination of 0.82. The addition of satellite derived estimates of biological productivity in the algorithm does not significantly improve the fit. We use the algorithm with remotely sensed chl a and SST data to produce an fCO2sw map for the entire high-latitude Southern Ocean south of 55 S. We analyze and discuss the seasonal and spatial robustness of the algorithm based on the remotely sensed data and compare with climatologic fCO2sw data.

-331 The impact of biogeochemical processes on the calcium carbonate saturation state in a Circumpolar Flaw Lead in the western Arctic

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

We investigate the annual cycle of carbonate saturation in the polar mixed layer (PML) of the circumpolar flaw lead in the Amundsen Gulf, Arctic Ocean. During 11-months we sampled and measured total alkalinity, and total dissolved inorganic carbon, and calculated the carbonate ion concentration ([CO32-]), and the aragonite saturation state (Ar). Based on the empirical relationships between ([CO32-] and Ar, with nitrate, salinity and temperature, we found that biological processes (photosynthesis and respiration) accounted for about 50% of the monthly variations in both [CO32-] and Ar. Vertical mixing and salinity changes had equal impacts over the annual cycle. The impact of sea-ice melt water resulted in decreasing values in summer, but most of this change was offset by the increase as a result of CO2 drawdown during biological photosynthesis. The seasonal variability of Ar is discussed in a context of the life cycle of aragonitic organisms, such as Limacina Helicina. Our observation that the annual biological cycle has a strong influence on CaCO3 saturation states emphasizes the importance of full annual data coverage of the oceanic carbonate system if we are to ultimately understand the impact of ocean acidification in the Polar Ocean.

-332 Temporal variation on soil carbon storage following thinning treatments in red pine stands

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

This study was carried out to evaluate temporal variation on soil carbon (C) storage between one (2010) and four years (2012) from thinning treatments (2009) in red pine (Pinus densiflora) stands. We measured soil C concentration and storage from two thinning (heavy and moderate) and control treatments of matured natural red pine stands in southern Korea. Carbon concentration in the surface soil depth (0-10cm) was significantly lower in the heavy thinned than in the moderately thinned or control stands. Also, C concentration in the heavy thinned stands was significantly reduced after four years compared with one year from thinning treatments, while that in the moderately thinned stands was not changed between one and four years. Carbon storage at the 30 cm of soil depth was lower in thinned (heavy: 28.75 Mg C/ha; moderate: 33.75 Mg C/ha) than in the control (35.29 Mg C/ha) stands, but the C storage between one and four years was not changed by the thinning treatments. The results suggest that C storage in soil layers could be little affected for four years following thinning in red pine stands.

-333 Ocean surface CO2 mapping and air-sea CO2 flux estimate in the Pacific Ocean based on in-situ observations and neural statistics

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

In order to evaluate temporal and spatial variation of air-sea CO2 flux in the Pacific Ocean, National Institute for Environmental Studies (NIES) has operated comprehensive surface ocean CO2 measurement in the North Pacific and in the western North/South Pacific utilizing volunteer observing ships since 1995. This study produces maps of the partial fugacity of oceanic CO2 (fCO2sea) in the Pacific Ocean for the last decade. The fCO2sea values are estimated by using a self-organizing map neural network technique to explain the non-linear relationships between observed fCO2sea data and four oceanic parameters: sea surface temperature (SST), mixed layer depth, chlorophyll-a concentration, and sea surface salinity (SSS). The observed fCO2sea data is obtained from NIES CO2 dataset as well as Surface Ocean CO2 Atlas (SOCAT) database. The calculated monthly fCO2sea distributions are similar to Lamont-Doherty Earth Observatory pCO2sea climatology and more precisely reflected oceanic conditions. In the North Pacific, the distributions of fCO2sea anomalies during the winter clearly showed regional contrasts between El Niño and La Niña years related to changes of SST and vertical mixing. On the contrary, temporal and spatial fCO2sea variation related to ENSO is apparent not only in the eastern equatorial region off the coast of Peru, but also in the western equatorial region off the coast of Sumatra.

-334 Development of Global Carbon Dioxide Distribution with On-line Tracer Transport Model in JMA

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The Japan Meteorological Agency (JMA) has analyzed the global distribution of carbon dioxide concentration covering recent decades, since February 2009 and it is updated every year. The distribution maps of monthly mean concentration are available on JMA website (http://ds.data.jma.go.jp/ghg/kanshi/info_kanshi_e.html). This analysis is based on the TransCom 3 interannual inversion with observational monthly mean concentration and transport model results.
JMA plans to update the transport model used for the analysis from off-line tracer transport model: JMA Carbon Dioxide Transport Model to a new on-line tracer transport model. Transport process in the new on-line model is directly coupled with a low-resolution version of JMA's operational global numerical weather prediction model.
We compared a transport simulation with the two models. The representation of CO2 distribution and transport process were improved near the surface and in the stratosphere by the new on-line model. In lower troposphere over winter continents, the on-line model simulates moderately high concentration while the off-line model often does very high concentration. Around the tropopause, the on-line model expresses concentration gradient more sharply than the off-line model does. Other several improvements will be presented.

-335 Monitoring and quantifying emissions of greenhouse gases in East Asia through in-situ measurements at Gosan station, Jeju Island, Korea

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Understanding and quantifying the fluxes of greenhouse gases (GHGs) are essential to comprehending the climate change that threatens the natural balance in the earth environments. In this respect, East Asia is important where significant GHG emissions are expected, due to recently accelerated industrial activities, but poorly understood.

To understand regional baseline levels of atmospheric CO2, we have performed weekly flask sampling for CO2 and C-isotope measurements at Gosan station (126°9.9'E, 33°17.4'N, 72m asl), located on the south-western tip of Jeju Island, Korea, since 1990. Continuous, high-frequency measurements of CO2 (LOFLO CO2 analyzer) have been made along with the flask analysis for further understanding of CO2 pollution and draw-down events that occur for hour to day time periods.

In addition, the Medusa GC-MS system was also added in Nov. 2007 to measure halogenated GHGs such as CFCs, HCFCs, HFCs, PFCs, and SF6.Tracer-tracer correlation methods and inverse modeling techniques have been used to estimate halogenated GHG emissions in the East Asian region, and the emission estimates show significant contributions of East Asian to global totals, Also, we applied multi-variation factor analysis to figure out emission source profiles and their quantitative contributions for halogenated compounds in this region.

Future efforts will focus on distinguishing pollution events of CO2 from its natural variability in the high-frequency time series observations and identifying the anthropogenic sources, in combination with halogenated compounds measurements. Also, we are working to ensure compatibility of the GHG measurements at Gosan to international networks such as WMO and AGAGE, and possibly to regional networks as well in the near future.

-336 CARBON BALANCE OF PEATLANDS AT SOUTH TAIGA OF WEST SIBERIA

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The regional assessment of carbon balance for peatland ecosystems in South Taiga of West Siberia is discussed. The study area is located between Iksa and Bakchar rivers (56o58`N 82o36`E) at the Bakcharskoe bog in Tomsk region (Russia). The total bog area is 1400 km2.
Carbon balance was calculated from emission of CO2 and CH4 from peaty soils, vegetation net primary production (NPP), and carbon leaching with bog waters. The basic types of oligotrophic and eutrophic ecosystems were studied. Intensity of CO2 emission at eutrophic mire is 1.2 times higher than at oligotrophic bog. Study of NPP has shown that oligotrophic ecosystems have close values of NPP. NPP at eutrophic mire is 1.5 times higher than at oligotrophic bog. The analysis of results has shown that the carbon balance of ecosystems is positive.
The study of vegetation productivity and greenhouse gas emission from the surface of oligotrophic and eutrophic mires was conducted from 1999 to 2012. The result showed a high interannual variability in the carbon balance. During the period of research decrease in the average air temperature of the growing season and increased precipitation in summer was observed. Significant changes in the carbon balance (NEP) have not been identified. That testifies to the stability of the studied peatland to changing of the environmental parameters.
The analysis of space images and ground data were used for vegetation classification and an estimation of the areas occupied by different ecosystems. Vegetation mapping allows estimate carbon balance for the key area and construct maps of NPP, CO2 emission and carbon balance for studied peatlands. The area of peatlands in South Taiga zone of West Siberia makes 3.4% from the area of mires of the world. Carbon accumulation in the studied area is 11.3% from carbon accumulation by peatlands of the world and 0.27% from carbon accumulation by terrestrial ecosystems. The rate of carbon accumulation in studied peatlands is 3-4 times higher than global estimations of peatland carbon accumulation.

-337 Observation and modeling of annual course of soil respiration at urban area

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Soil respiration is an important component of the global carbon cycle and is highly responsive to changes in soil temperature and moisture. Accurate prediction of soil respiration and its changes under future climatic conditions requires a clear understanding of the processes involved.
The measurements were made at the IMCES observation point in Tomsk city, Russia during 2011-2012. CO2 fluxes were measured weekly using an infrared gas analyzer (OPTOGAZ 500.4, Optec, Russia) with attached static chamber. Respiration from the aboveground plants was excluded by removing living plants inside the collars once a week and the dead plant material was removed from the collars. Soil and air temperature, incoming solar radiation, atmospheric pressure was measured hourly using automatic weather system AMIS (IMCES SB RAS).
Over the growing season, day time soil respiration averaged 244 mgCO2/m2/hr, and in the middle of summer respiration reaches 445 mgCO2/m2/hr. During winter time, when soil covered by 20-80 cm of snow, soil respiration rate reduced to values 0.6-30 mgCO2/m2/hr. Seasonal variations in the soil respiration rate closely followed those of temperature.
Detailed study of diurnal course of CO2 fluxes was made during May, July and October 2012. Transparent automatic chamber was installed at non disturbed vegetation cover and total CO2 flux was measured. Daytime fluxes (CO2 assimilation) in May reach 1166 mgCO2/m2/hr, in July 2183 mgCO2/m2/hr. Maximal nightime fluxes (soil respiration plus plant dark respiration plus decomposition of plant remains at the surface) was estimated as 811, 1354 and 692 mgCO2/m2/hr at May, June and October.
Simple bulk-flux model were suggested for description of the observed CO2 fluxes. The main controlling factor, in this study was soil temperature and incoming solar radiation. Temperature exerted dominant control during most of the year. However, during the most active period of the year, incoming solar radiation and wetting conditions exerted a stronger control over CO2 fluxes. Seasonality of fresh litter inputs played an important role during the last part of the year, probably by enhancing microbial activity. Model was calibrated for three experimental periods. Using the component model, we were able to estimate the relative proportions of heterotrophic and autotrophic respiration in total soil respiration for each of the study period.

-338 Removal of dissolved inorganic carbon and its mechanism in the Yellow River Estuary (YRE)

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

While estuaries are the regions of active land-ocean interactions and play a great role on global carbon cycle, it is really challenging to figure out estuarine biogeochemical processes controlling dissolved inorganic carbon (DIC) distribution, as well as to quantify net DIC flux and its variations in estuaries. The Yellow River basin is located mainly in a semi-arid region, and its water has an exceptually high carbonate content. The biogeochemical processes of DIC were investigated based on four cruises from spring to early fall (September 2005, April 2006, May and September 2009) in the Yellow River Estuary (YRE), together with a one-year monthly investigation at a lower river hydrological station and field incubations in May and September 2009. The results showed that DIC removal process occurs in the low salinity areas (S<18) while that in the Mississippi River plume exists mainly in the salinity about 30. There were about 4-11% of the Yellow River DIC was removed in the estuarine mixing zone and thus was not transported to the sea. DIC concentrations in spring were higher than those in fall cruises. In addition, DIC removal degree was much higher and it occurred at a higher salinity range in spring than in fall. Our analysis suggested that biological activities and calcium carbonate (CaCO3) precipitation were mainly responsible, but each played a variable role for the DIC removal processes. However, their contributions to the DIC removal ranged from approximately equal with each other (September 2005) to biological activities being the dominant factor (May and September 2009). Our study also revealed that the higher Chl a concentration and calcite saturation state (SICalcite) would lead to a higher DIC removal degree. Besides, the longer freshwater-seawater mixing distance (and time) and higher DIC concentrations in the freshwater member also increased the influences of biological activities and CaCO3 precipitation on DIC removal processes.

-339 CO2 concentration-carbon feedback of terrestrial ecosystems in CMIP ESMs

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

Concentration-carbon feedback, which is one of the carbon cycle feedbacks, could have large impact on projected climate but the strength of the feedback is still uncertain. This research focuses on the concentration-carbon feedback in terrestrial ecosystems and analyzes in detail the mechanism and strength of the feedback reproduced in the Earth system models (ESMs) that participate in Coupled Model Intercomparison Project Phase 5 (CMIP5). ESMs driven by a common scenario with biogeochemically coupled settings show a large spread of concentration-carbon feedbacks among models and it is found that this spread can be well explained by the strength of plant productivity reproduced in each model. Simulations conducted under several scenarios with different rate of CO_2 increase show effective carbon accumulation in slower scenarios because of the existence of delayed response of carbon pools. This inter-scenario spread of concentration-carbon feedback is found by numerical and analytical method to be comparable size with the spreads arisen from model difference, strongly depending on the sensitivity of plant productivity and the rate of scenario.

-340 Atmospheric CO2 exchange in urban neighborhoods measured by eddy covariance

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Effective mitigation of greenhouse gases must be based on a good understanding of all emission sources and sinks. Emission inventories at the city scale usually only consider CO2 emitted from combustion sources. These emissions are typically quantified by a bottom-up aggregation process that accounts for emission factors and fuel consumption data on long (annual) time scales. Depending on data availability and representativeness of emission factors, this methodology can be fairly accurate. However, it neither considers the known diurnal variations in activity levels and spatial distribution of emission sources nor does it account for fluxes associated with vegetation, soil and human respiration, even though they can be important sources or sinks. Direct measurements of CO2 fluxes that include all anthropogenic and natural sources and sinks from a specific region can be used to evaluate emission inventories. Such direct flux measurements are now increasingly performed in cities using the eddy covariance (EC) method and fast-response analytical sensors.

This presentation reviews the basic principles and requirements of the EC method, discusses its application in the urban context, and summarizes observations from over 30 EC systems. Using as reference two recent long-term sets of CO2 flux data from two residential neighborhoods of Singapore and Mexico City, the application of the EC method for evaluating emission inventories is demonstrated. The role of urban vegetation in the carbon exchange at neighborhood scale is investigated using the measured fluxes from Singapore together with accurate estimations of anthropogenic emissions, soil respiration and human breathing, and estimations of the annual CO2 sequestration by trees using allometric equations and an alternative model of the metabolic theory of ecology for tropical forests. The Mexico City flux data is also used to show the usefulness of the EC method to evaluate the effectiveness of traffic regulations to mitigate carbon emissions. Finally, the need of transferring the EC methodology to local monitoring networks is highlighted.

-341 Energy, water vapor and CO2 fluxes observed in two desert ecosystems with alkaline soil in Kazakhstan

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Eddy covariance (EC) technique, as a widespread instrument, was used to monitor the energy, water vapor and CO_2 fluxes between the terrestrial ecosystem and atmosphere. Although more than 1000 site years of EC data has been collected in the international network of FLUXNET and the size of EC data is still climbing year by year, data from Central Asian are still unavailable. Absence of data in such a large area results in great uncertainties in the carbon sequestration capacity of Central Asian desert ecosystems and in the assessment of feedbacks between ecosystem and climate change. Further, some of latest research reported considerable abiotic CO_2 absorption by alkaline soil, but the rate of CO_2 absorption has been questioned by peer communities. We have measured the surface energy, water vapor and CO_2 fluxes using EC instrument at two alkaline sites during growing season in Kazakhstan. The objectives are to quantify the energy components and carbon sequestration capacity and associated controlling factors in two alkaline desert ecosystems in Central Asia.

-342 An atmospheric baseline station for monitoring geological storage of carbon dioxide (CCS): Sensitivity of detection for simulated CO2 leaks

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

In July 2010, Geoscience Australia and CSIRO Marine & Atmospheric Research jointly commissioned a new atmospheric composition monitoring station, named Arcturus, in sub-tropical Queensland, Australia. The facility is designed as a proto-type remotely operated 'baseline monitoring station' that could be deployed in areas that are likely targets for commercial scale geological storage of carbon dioxide.

The installed station comprises an air conditioned modified shipping container equipped with gas monitoring instruments and meteorological sensors with a 10 m mast. Two Picarro Wavelength Scanned Cavity Ring Down Spectroscopy (WS-CRDS) gas analysers are deployed to continuously monitor greenhouse gases and CO2 isotopes. One unit measures water vapour and isotopic ratios of carbon in CO2 (12C and 13C) while the other measures the concentrations of CH4, CO2 and water vapour. An automated weather station was installed to measure wind speed, wind direction, temperature, humidity and rainfall. A solar powered eddy covariance flux tower was also installed at the site, some 250 m south of the main station. The 5.5 m high flux tower comprises two LI-COR open-path eddy covariance gas instruments: the LI-7500A measures atmospheric CO2 and H2O, and the LI-7700 measures atmospheric CH4. Wind speed and direction are measured using a 3D CSAT3 sonic anemometer. A wireless network connects the flux tower to the main station and the station can be accessed remotely over the internet.

The Arcturus site and environs are representative of the activities and ecology of Queensland's Central Highlands and the greenhouse gas signals are likely to be influenced by cropping, pasture, cattle production, and gas and coal activities. A key question, given the ecosystem and anthropogenic sources of CO2 in the region, and the absence of a "clean-wind" sector baseline, is how large would a CO2 leak have to be from a geological storage site before it can be detected above the background CO2 signal? To address this, CO2 leak simulation modelling was performed for 1-year period using the coupled prognostic meteorological and air pollution model TAPM at various locations, emission rates and distances (1-10 km) from the station. The results of the simulations were compared to a 2.5-year baseline for different hours of the day. The results indicate that, even at 1 km distance and in the optimum wind sector, the magnitude of the simulated CO2 leak has to be greater than 20 tonne CO2 per day before the perturbation is statistically significant above a background signal. Nevertheless, the study suggests that remotely based atmospheric monitoring can be used for detection of CO2 leaks at geological storage sites and it is particularly suited to sites that have limited accessibility.

-343 Near-surface detection of CO2 leakage using eddy covariance techniques at the Ginninderra CO2 controlled release facility

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

Geoscience Australia and the CO2CRC have constructed a greenhouse gas controlled release facility at an experimental agricultural station maintained by CSIRO Plant Industry at Ginninderra, Canberra. The facility is designed to simulate surface emissions of CO2 from the soil into the atmosphere and is modelled on the ZERT controlled release facility in Montana. Injection of CO2 into the soil is via a 120 m long slotted HDPE pipe installed horizontally 2 m underground.

An eddy covariance (EC) system was installed at Ginninderra during the first sub-surface release (March – June 2012). The EC system, which generated 15 minute averages using a 10 Hz sampling frequency, measured net radiation (as a function of upwelling and downwelling, solar and longwave radiation); wind speed and direction in 3 dimensions; CO2 and H2O concentration; and temperature and pressure. The EC system was installed to provide baseline atmospheric measurements and assess methods for quantifying CO2 leakages. The daily CO2 release rate was 100 kg/d.

Here we report on the application of the CO2 emissions quantification method developed by Pan et al. (2010) for detecting and quantifying CO2 leakages using EC techniques. The approach seeks to isolate the CO2 leakage signal from the natural variation inherent in flux data, using a time-window splitting scheme, median filtering and scaling techniques. Results from application of the EC method at the Ginninderra site will be presented and modifications to the method and its limitations discussed.

Pan, L.; Lewicki, J.L.; Oldenburg C.M.; and Fischer M.L., (2010). Time-window based filtering method for near-surface detection of leakage from geological carbon sequestration sites, Environmental Earth Sciences, 60, pp 359-369.

-344 Predicting the effect of elevated CO2 on NPP using a global coupled C, N and P model

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

A recent modelling-based study suggests that the results from free-air CO2 enrichment (FACE) experiments in temperate climates are well representative of temperate forests, but not applicable to boreal and tropical forests and enrichment effects in tropical forests is more than twice than that in boreal forests. Boreal and tropical forests, however, may be significantly limited by the supply of nitrogen (N) and phosphorus (P), respectively, which is not considered in the previous models. This research will use a coupled C, N and P model (CABLE) to be tested with ORNL FACE dataset and applied to global scale. The objective is to investigate the effect of elevated CO2 on global NPP associated with combined constraints of C, N and P.

-345 The U.S. Carbon Cycle Science Program: Overview and Highlights

[1]Zhiliang Zhu, [2]James Whetstone, [3]Diane Wickland, [4]Gyami Shrestha, [5]Carolyn Olson, [6]Siân Mooney, [7]Kenneth Mooney, [8]Michael Kuperberg, [7]Monika Kopacz, [9]Carol Jones, [10]Randy Johnson, [6]Henry Gholz, [11]Nancy Cavallaro, [7]James Butler, [3]Paula Bontempi *([1]U.S. Geological Survey, [2]National Institute of Standards and Technology, [3]National Aeronautics and Space Administration, [4]U.S. Carbon Cycle Science Program Office, [5] U.S. Department of Agriculture Natural Resource Conservation Service, [6]National Science Foundation, [7] National Oceanic and Atmospheric Administration, [8]Department of Energy, [9]U.S. Department of Agriculture Economic Research Service, [10]U.S. Department of Agriculture Forest Service, [11]US Department of Agriculture National Institute of Food and Agriculture)*

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The U.S. Carbon Cycle Science Program is a key component of the U.S. Global Change Research Program, and is responsible for setting priorities and coordinating government actions for carbon cycle research in the United States. The mission of the national program is to better understand past changes and current trends in atmospheric carbon dioxide and methane, deliver credible predictions of future atmospheric carbon dioxide and methane levels, and strengthen the scientific foundation for management decisions in numerous areas of public interest related to carbon and climate change. The national program is supported and coordinated by eleven U.S. federal agencies and departments in a Carbon Cycle Interagency Working Group (CCIWG). The CCIWG will provide an overview of the Program, its history and achievements as an interagency partnership and its plans and priorities for the next decade. Recent findings from research funded through the interagency process will also be highlighted.

-346 Integrating greenhouse gas emission processes into a dynamic global vegetation model of TRIPLEX-GHG

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Methane (CH_4) and nitrous oxide (N_2O) are two potent greenhouse gases (GHG), which account for almost 20% of anticipated annual global warming. However, very few dynamic global vegetation models have integrated methane (CH_4) and nitrous oxide (N_2O) into the model simulations for climate change studies. In this study, we have developed new modules to simulate greenhouse gas (CO_2, CH_4, N_2O) emission processes over terrestrial ecosystems and integrated them into a dynamic global vegetation model of TRIPLEX-GHG. The model sensitivity analysis indicated that the release ratio of CH_4 to CO_2 and the Q_{10} in methane production are two major factors controlling the methane emission. Meanwhile, the values of these two parameters are spatial heterogeneous. Model testing was conducted over twenty wetland sites across different geographic regions in the globe. Although the model simulation sometimes missed the daily details or the emission pulse, the model always capture the patterns of temporal variations of CH_4 well. Our model simulations results suggest that the TRIPLEX-GHG can be used to simulate greenhouse gas emission under a changing environmental conditions for different global wetlands.

-347 Impacts of Drought-Induced Forest Mortality on Global Forest Carbon Sinks: Recent Progress and Future Challenges

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

One of the greatest uncertainties in global climate change is forecasting changes in feedbacks between the biosphere and the atmosphere. Terrestrial ecosystems and, in
particular, forests exert strong controls on the global carbon cycle and influence regional hydrology and climatology directly through water and surface energy budgets. Recent studies indicated that forest mortality caused by rising temperature and drought from around the world have unexpectedly increased in the past decade and they collectively illustrate the vulnerability of many forested ecosystems to rapid increases in tree mortality due to warmer temperatures and more severe drought. Persistent changes in tree mortality rates can alter forest structure, composition, and ecosystem services (such as albedo and carbon sequestration). Quantifying potential impacts of tree mortality on ecosystem processes requires research into mortality effects on carbon, energy, and water budgets at both site and regional levels. Despite recent progress, the uncertainty around mortality responses still limits our ability to predict the likelihood and anticipate the impacts of tree die-off. Studies are needed that explore tree death physiology for a wide variety of functional types, connect patterns of mortality with climate events, and quantify the impacts on carbon, energy, and water flux. In this presentation, I will highlight recent research progress, and identify key research needs and future challenges to predict the consequence and impacts of drought-induced large-scale forest mortality on carbon sinks. I will focus on three main forest ecosystems (tropic rainforest in Amazon, temperate forest in Western USA, and boreal forest in Canada) as detailed case studies.

-348 Modelling the Carbon Cycle in the Australian Climate and Earth System Simulator

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

The Australian Climate and Earth System Simulator, ACCESS, has been developed over recent years for numerical weather prediction and for climate simulations. Its atmospheric component is the UK Met Office Unified Model, except that the land surface component has been replaced with the Community Atmosphere Biosphere Land Exchange (CABLE) model. The ocean component of ACCESS is a version of the GFDL Modular Ocean Model (MOM). While ACCESS contributed simulations to the Coupled Model Intercomparison Project (CMIP5), those simulations did not include the carbon cycle.

ACCESS has now been further developed to include a land biogeochemical model, including nitrogen and phosphorus cycles, and an ocean carbon model, WOMBAT (World Ocean Model of Biogeochemistry And Trophic-dynamics). WOMBAT includes a two-component plankton model (phytoplankton and zooplankton) where the phytoplankton growth is controlled by phosphate and iron concentrations, light and temperature. Atmosphere-only and ocean-only simulations have been performed to test the land and ocean carbon models independently. Initial tests of the fully coupled system will begin shortly. Following these tests, simulations using prescribed atmospheric CO2, as specified for CMIP5, will be undertaken. The simulated land and ocean carbon uptake over the last four decades, gross primary production, plant and soil carbon pools and atmospheric CO2 will be compared with independent estimates.

-349 Inter-annual variations and long-term trends in the carbon budget and atmospheric CO2 in a cool-temperate deciduous forest ecosystem of central Japan

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The magnitude of climate change impact on the activities of some of the regional terrestrial ecosystems has been demonstrated in some recent studies. In East Asia strongly influenced by Asian Monsoon, the carbon budget is influenced significantly by changes in temperature, precipitation amount and the length of the rainy season. The fact that these changes in abiotic variables could be due to climate change requires a long measurement program in carbon fluxes and atmospheric CO2 concentration, in order to obtain a better understanding of the processes by which the terrestrial ecosystem responds to climate change.

We have been carrying out long-term systematic measurements of the atmosphere-ecosystem CO2 flux, along with atmospheric CO2 concentration and the related parameters, in a cool-temperate deciduous forest at Takayama (36o08’N, 137o25’E, 1420 m a.s.l.), Japan since 1993. Using these data, we have examined their inter-annual variations, long-term trends and environmental factors governing these variations. The results obtained from the analyses are as follows:

(1) Annual net ecosystem production (NEP) and the gross primary production (GPP) vary significantly from year by year, while inter-annual variation in the annual ecosystem respiration (ER) is relatively small. The inter-annual variation in the annual NEP depends strongly on the annual GPP.

(2) Annual NEP shows a statistically significant positive correlation with the monthly NEP in June and July. Higher insolation during the summertime tends to produce higher amount of the annual NEP.

(3) In the warm-spring years, the leaf flushing, beginning of the daily positive NEP and the spring downward zero crossing of tend to occur early. Warm spring can expand the growing season and lead to an enhanced annual NEP. On the other hand, the annual NEP does not show a significant correlation with the leaf-fall, end of the daily positive NEP and the autumn upward zero crossing of atmospheric CO2.

(4) Significant long-term trends in the delayed occurrences in the leaf-fall, end of the daily positive NEP and the autumn upward zero crossing of atmospheric CO2 are found. These are related to the long-term increasing trend of CO2 uptake in the forest ecosystem in autumn.

(5) A significant increasing trend is found in the winter seasonal concentration of atmospheric CO2.

-350 Changes in Carbon Sources and Sinks and Greenhouse Gas Emission Characteristics of Megacity: A case study in China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Analyses of carbon sources and carbon sinks are ways to understand the dynamic factors of climate change [1]. Changes in the carbon sources and sinks have a significant influence on atmospheric CO2 levels [2]. Efforts to control climate change require the stabilization of atmospheric CO2 concentrations. As one of China's developed cities, Tianjin is the center for the Bohai Economic Rim, an emerging economic development region and one of China's largest industrial areas. Tianjin is one of the China's largest emitters of greenhouse gases, and the reduction of CO2 emissions in Tianjin is important for the country's goal of emission reduction [3]. CO2 emissions from the burning of fossil fuels are the primary cause of global warming [4].Using carbon emission calculation methodology recommended by IPCC [5], the amount of carbon emissions and carbon absorptions in Tianjin were calculated from 1987 to 2009. This study analyzed the carbon emission by calculating greenhouse gas emission of energy, human respiration, land use changes (farmland, grassland and forest land) and cement production. The results showed that the carbon emission in energy consumption accounts for 79.67%. The annual CO2 emission increased with 47.16 million ton during the 23 years. The primary and the secondary carbon sinks in Tianjin are soil and vegetation. We analyzed the natural and anthropogenic drivers of the carbon dynamic changes, and also explained the pressure of CO2 emission caused by energy consumption on the environment from the aspect of carbon footprint of energy utilization.
Keywords: Greenhouse gas emission; Carbon footprint; Carbon source; Carbon sink; Tianjin
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-351 Estimation of Surface Fluxes of Carbon from Atmospheric Data Assimilation

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

We succeeded in estimating surface CO2 fluxes at the model grid-scale resolution by assimilating meteorological variables and CO2 simultaneously every 6 hours with the Local Ensemble Transform Kalman Filter (LETKF). This was done as an observing system simulation experiment (OSSE) using the SPEEDY AGCM coupled with the LETKF. The (unmeasured) surface fluxes are estimated with the state vector augmentation method, as if they were evolving model parameters. The simultaneous ensemble Kalman filter data assimilation allows considering the transport errors on atmospheric CO2 forecast since it provides the time-evolving error covariance between wind and atmospheric CO2 fields at every analysis step. Taking a short window (6hr) rather than the very long windows (months) normally used in inversion methods avoids blurring the impact of the surface fluxes on the near surface CO2 and improves the estimation of both the surface fluxes and the atmospheric CO2.

This methodology, including several advanced techniques that were developed for this purpose (Kang et al., JGR 2011, JGR 2012) will be discussed. We are also exploring the possibility of estimating surface fluxes of heat, moisture and momentum, and OSSE experiments are also encouraging. Based on these results, we are implementing our advanced data assimilation system on the NCAR CAM 3.5 model coupled with the LETKF and plan to perform experiments with real observations.

-352 Frequency Response of Sensors for CO2 Flux Measurements

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Frequency Response of Sensors for CO2 Flux Measurements

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The average of atmospheric turbulent fluctuations is zero, but if the concentration of a gas varies with space, turbulent fluctuations can generate a net gas flux. The flux of CO2 can be estimated by pairing its instantaneous local concentrations to wind velocity measurements. We developed a stand-alone probe to measure the instantaneous absolute velocity of the wind and monitor concentrations of gases like CO2, while mounted on unmanned aerial vehicles. Flying through atmospheric disturbances, the frequency of the quantities to be measured increases, and this requires that sensors have a high frequency response. The objective of this work was to measure the temporal response of CO2 sensors in conditions mimicking an aircraft probe setup.

We evaluated the performance of two small-scale optical sensors (Vista-Photonics’ OA2-NF-AC and CO2Meter’s K-30-FR) individually and in comparison with a full-scale CO2 analyzer (LI-7000, LI-COR). To simulate an aircraft probe situation, we modified a calibration wind tunnel by connecting a mixing tube to the beginning of its test section, and adding mixing grids downstream to generate a uniform gas stream. We made step changes in CO2 concentration by injecting CO2 (99.9% purity) to the mixing tube using a mass flow controller (Cole Parmer, accuracy ±0.8 % of reading). Different CO2 flow rates were injected to cause a step change in concentration of 20 ppm, 50 ppm, 70 ppm, and 120 ppm. We placed the CO2 sensors and the LI-COR's intake line inside the wind tunnel test section. We set the wind tunnel at three different wind speeds: 10 m/s, 20 m/s, and 35 m/s, which resulted in flow rates of 2095 l/min, 4190 l/min, and 7332 l/min, respectively. The mixing tube was set to a constant flow rate of 103 l/min. The resulting air velocities at the sensors were 8.1 m/s, 15.8 m/s, and 27.3 m/s. We directed the tunnel outflow outside the building to avoid CO2 accumulation, which would result in increasing background concentrations. The LI-COR has its own data collection software, which collects a time stamp from the computer storing the data. The Vista Photonics sensor stores its data inside a memory card and collects time stamps via GPS signal. The CO2Meter sensor does not have its own data collection software, so we developed a program to store data with a time stamp from the computer running it.

The two CO2 sensors performed very differently to step changes in concentration. The OA2-NF-AC’s 5 Hz measurements tightly overlapped the LI-COR's 20 Hz measurements while the K-30-FR had specific issues in terms of noise, time responsiveness and peak concentration measurements. Results from this work will aid in developing aircraft setups for environmental measurements of atmospheric CO2 fluxes and can be used as a protocol for further sensor testing.

-353 Continuous measurements of the atmospheric O2/N2 ratio at suburban and coastal sites in the northeastern part of Japan

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

To contribute to a better understanding of the global carbon cycle, systematic and continuous observations of the atmospheric O2/N2 ratio, together with the CO2 concentration, were initiated at Aobayama in the suburbs of Sendai, Japan in February 2007 and on Enoshima Island, Japan in October 2008.
At Aobayama site (AOB), the O2/N2 ratio showed a clear seasonal cycle with the minimum value in late March to early April and the maximum value in late July to early August, superimposed on a secular decrease. The CO2 concentration increased secularly and varied seasonally in opposite phase with the O2/N2 ratio. Short-term variations on time scales of several hours to several days were also clearly observed. In winter, it was often seen that the O2/N2 ratio sharply declined in a short time, accompanied by an increase in the CO2 concentration, and the low values last for several hours to a few days. The −O2:CO2 exchange ratio was found to be 1.39–1.38 ppm/ppm for such wintertime short-term variations. Since these ratios are in good agreement with a mean value of the −O2:CO2 exchange ratio calculated for fossil fuel consumption in Japan, the observed decline in O2/N2 ratio is ascribed to the transport of urban air influenced by human activities. In summer, a clear diurnal cycle was observable for both the atmospheric O2/N2 ratio and CO2 concentration, due mainly to terrestrial biological activities near the site. The average −O2:CO2 exchange ratio over the summer periods of 2007–2012 was found to be −1.08±0.10 ppm/ppm for the daytime and −1.08±0.10 ppm/ppm for the nighttime, which are in excellent agreement with −1.10±0.05 ppm/ppm reported by previous studies.
At Enoshima site (ENS), the O2/N2 ratio and CO2 concentration varied seasonally, the respective temporal patterns being similar to those at AOB. However, the seasonal peak-to-peak amplitude of Atmospheric Potential Oxygen (APO; O2−1.1×CO2), which varies mainly by the air-sea O2 exchange, is twice larger at ENS than at AOB. This implies that the seasonal cycle of O2/N2 ratio at ENS is much more strongly affected by the air-sea O2 exchange, compared to that at AOB. In addition to the clear seasonal cycle, irregular short-term fluctuations of APO were observed especially in spring and summer. By comparing the backward trajectories with the distributions of marine biotic net primary production around Japan, it was suggested that the short-term APO fluctuations are closely related to O2 emissions due to marine biological production.

-354 Atmospheric tomography as a tool for quantification of CO2 emissions from potential surface leaks

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Monitoring is a critical component in verifying the integrity of the geological storage of CO2. Most techniques focus on identifying CO2 leaks but accurate quantification is particularly important for regulators, and for supporting carbon pricing mechanisms.
It is therefore crucial to develop accurate, cost effective and reliable techniques to identify and quantify CO2 surface leaks should they occur.

Here we report on the application of a new CO2 quantification and localization technique, called atmospheric tomography. This technique uses an array of sampling points and a Bayesian inversion method to simultaneously solve for the location and magnitude of a CO2 leak. Knowledge of a normalized three-dimensional dispersion plume is required in order to accurately model the leak. A previous study using a high precision Fourier Transform Infrared found that the emission rate was determined to within 3% of the actual release rate and the localisation within 1 m of the correct position. Sampling points were 20 m from the CO2 release chamber.

A trial of the technique was undertaken during 2011 at the CO2CRC Otway Project Stage 2B residual saturation and dissolution test. A byproduct of the field test was the controlled release of CO2 from a well during the water lift and venting activities. The equivalent of approximately 3 tonnes of CO2 was released per day episodically over a three month period. On occasions, the equivalent emitted CO2 flow rate was 9-15 tonnes/day but only for short durations. A network of eight independent CO2 sensors (Vaisala GMP343 CO2 probes) were positioned at distances ranging from 154 to 473 m from the well. A 3D sonic anemometer within the measurement area collected wind turbulence data.

The results of the study indicate that, through careful data processing, measurements from the comparatively inexpensive but lower accuracy and lower precision CO2 sensor array can provide useful data. Results from the application of the tomography technique will be presented and limitations of the technique discussed.

-355 High-precision continuous measurements of the atmospheric O2/N2 ratio initiated at Ny-Ålesund, Svalbard

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

To study temporal variations of the atmospheric O_2/N_2 ratio in the Arctic region in detail, as well as to contribute to a better understanding of the global carbon cycle, we have developed a new high-precision continuous measurement system with a precision of better than ±4.0 per meg, using a fuel-cell O_2 analyzer. Considering its intended use at a very remote site, the measurement system was designed to incorporate some convenient and indispensable functions: (1) the system can be controlled remotely from Japan via the Internet; (2) all of the data output from the system can be monitored and collected in Japan via the Internet; (3) a specially designed water trap based on a Stirling cooler is employed to automate the removal of water vapor from the sample air; (4) the CO_2 concentration can also be measured with a precision of ±0.05 ppm; and (5) it is possible to operate the system for one year without having to manually replace the high-pressure cylinders of standard gases and reference air.
Using this measurement system, systematic and continuous observations of the atmospheric O_2/N_2 ratio were initiated at Ny-Ålesund (78°55′N, 11°56′E), Svalbard on November 8, 2012, which is the first continuous observation project in the Arctic region. By analyzing the observational results of the atmospheric O_2/N_2 ratio and CO_2 concentration obtained so far, the effectiveness of the measurement system was verified. Characteristic temporal variations in the observed atmospheric O_2/N_2 ratio were also examined. For example, two characteristic events related to changes in atmospheric O_2/N_2 ratio were observed on November 11–12 and 22–23, 2012. By considering the relationship between the measured values of the O_2/N_2 ratio and CO_2 concentration, we found that the former event is attributable to air–sea O_2 exchange, while fossil fuel burning is responsible for the latter event.

-356 Greenhouse Gas Network Design for Australia

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Monitoring major greenhouse gases (GHGs) such as carbon dioxide (CO2) is important, not only for the continuous observation of atmospheric concentrations in order to detect global trends, but also for deriving GHG fluxes and their uncertainties on a regional scale. The flux uncertainties are dependent on the network of atmospheric GHG measurements. Here, we aim to assess how the current network of GHG ground based measurement stations in Australia can be extended to reduce the uncertainties on Australian GHG flux estimates, extending an earlier study by Law et al. (2004). This is done by optimising the location of proposed stations for CO2 while also considering logistic constraints such as availability of supporting infrastructure and accessibility and maintenance of the site.

The Lagrangian Particle Dispersion Model (LPDM) is used for the inversion of atmospheric transport and a genetic algorithm is applied for the optimisation of the network. Driving fields are provided using the high resolution (12km) operational version of the Australian Community Climate and Earth System Simulator for the Australian region (ACCESS-R). Prior estimates of CO2 fluxes for the Australian biosphere are obtained from high resolution model simulations (Haverd et al., 2012). Various scenarios are taken into account for the optimisation of the network, starting from existing stations. The locations of the Australian Bureau of Meteorology weather watch radar stations are then added to the network as potential CO2 measurement stations and the benefits of adding or removing individual stations will be assessed.

-357 CO2 Emissions from Land use Change Affected More by Nitrogen Cycle, than by the Choice of Land Cover Data

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The high uncertainty in land-based fluxes of CO2 is thought to be mainly driven by uncertainty in historical change between forests, croplands and grassland. In this study, for the first time, we use three distinct historical reconstructions of land-use and land-use change (LULUC), derived from three common data sets HYDE, RF, and Houghton to drive a process based land-surface model with interactive carbon and nitrogen (N) dynamics to quantify uncertainties in LULUC emissions. The modeled global average emissions for the 1980’s, 1990’s and 2000 to 2005 were 1.8±0.2, 1.7±0.2, and 1.4±0.2 GtC/yr respectively (mean and range across LULUC data sets). The tropical emissions were 0.8±0.2, 0.8±0.2 and 0.7±0.3GtC/yr, and the non-tropics were 1.1±0.5, 0.9±0.2 and 0.7±0.1 GtC/yr. The HYDE data set led to a decrease in emissions in the tropics (30%) and non-tropics (50%); RF showed little change in the tropics and a 34% decline in the non-tropics; Houghton showed little change in either region. Compared to previous studies that did not include N dynamics, modeled net LULUC emissions from the non-tropics were higher in all three data sets. Furthermore emissions from the non-tropics were higher than those from the tropics based on HYDE and RF data. In the model, N limitation reduces regrowth of vegetation in temperate areas resulting in higher net emissions. Our results indicate that exclusion of N dynamics led to an underestimation of LULUC emissions by around 70% in the non-tropics, 10% in the tropics and 40% globally in the 1990’s. The differences due to inclusion/exclusion of the N cycle of 0.1 GtC/yr in the tropics, 0.6 GtC/yr in the non-tropics and 0.7 GtC/yr globally (mean across land cover data sets in the 1990’s) were greater than differences due to the land cover data in the non-tropics and globally. While land cover information is improving with satellite and inventory data, this study indicates the importance of reducing uncertainty due to modeling different processes, in particular the N cycle.

-358 New constraint on the contemporary air-sea CO2 flux using bottle carbon data

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

We develop a new observationally-derived monthly surface ocean climatology for the partial pressure of CO2 (pCO2) that allows an independent data-based constraint on contemporary air-sea CO2 fluxes. Our approach uses a neural network, trained on 23,000 in-situ bottle-derived measurements of pCO2, to diagnose monthly pCO2 levels from standard ocean hydrographic data. Although the pattern of contemporary air-sea CO2 flux is generally consistent with the independent underway pCO2 data network, we find a strong shift in the magnitude of oceanic sources and sinks of CO2. In particular, we find a contemporary Southern Hemisphere ocean CO2 uptake of 0.93 PgC/yr, driven by a prominent CO2 sink in the sub-polar region (25°-60°S), that is five times the magnitude of the Northern Hemisphere ocean (0.18 PgC/yr). Globally, our results suggest a net oceanic CO2 sink of 1.55±0.32 PgC/yr for the year 2000.

-359 Peatland Carbon Dynamics in Warm Climates: Past and Future

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Peatlands in the circum-Arctic region have accumulated a large belowground carbon pool of ~500 GtC. However, the fate of this large carbon pool under a future warm climate is still uncertain and debated. In this presentation I will use the records of past peatland carbon accumulation as natural experiments to learn about the sensitivity of peatland carbon dynamics to climate change, especially past warm climates. Our results from Alaska as well as from global-scale data synthesis show distinct temporal patterns of peatland carbon sequestration, allowing us to discuss their climate controls and their implications for the global carbon cycle during the Holocene (the last 12,000 years). In particular, peatlands in many regions show rapid peatland expansion and carbon accumulation in response to the Holocene thermal maximum (THM) in the early Holocene, the warmest climate period in the present interglacial. For example, several sites on the Kenai Peninsula show peak carbon accumulation during the HTM around 10,000 years ago, about four fold higher than the rest of the Holocene. A compilation of 33 sites from across northern peatlands shows a similar accumulation peak at about 10,000 years ago, at the time of maximum summer insolation (sunlight) in the northern hemisphere, despite variable timings of the HTM across the circum-Arctic region. This observation suggests that the increase in photosynthesis and plant productivity under both high sunlight and warm climate conditions more than compensate the elevated peat decomposition under a warm climate. Also, the peak vertical peat accumulation corresponds with the maximum peatland initiation and lateral expansion in Alaska and across the circum-Arctic region as a whole. At several sites in Alaska, cool and moist climate since 8000 years ago after the HTM caused flooding that significantly reduce carbon sequestration in these peatlands, suggesting that a wet climate is not necessarily good for peatlands and an intermediate moisture condition would maximize peatland carbon sequestration. Furthermore, rapid carbon accumulation has been documented, especially for some wet peatlands, during the Medieval Warm Period about 900 years ago as well as during the last 50 years of ongoing climate warming. In summary, our results show that northern peatlands tend to increase carbon sequestration in warm climates, potentially providing a negative feedback to global warming, but the responses will clearly depend on the moisture conditions as determined by the climatic and hydrological settings of individual peatlands.

-360 Atmospheric verification of point source fossil fuel CO2 emissions

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Large point sources (electricity generation and large-scale industry) make up roughly one third of all fossil fuel CO2 emissions. Currently, these emissions are determined from self-reported inventory data, and sometimes from smokestack emissions monitoring, and the uncertainty in emissions from individual power plants is about 20%. There is a need for independent, objective measurements of these emissions both to improve the accuracy of the reported emissions, and for verification as we move towards a regulatory environment.
We use the Kapuni Gas Treatment Plant to examine methodologies for atmospheric monitoring of point source fossil fuel CO2 emissions. The Kapuni plant, located in rural New Zealand, removes CO2 from locally extracted natural gas and vents that CO2 to the atmosphere, at a rate of ~0.1 Tg carbon per year. The plant is located in a rural dairy farming area, with no other significant fossil fuel CO2 sources nearby, but large, diurnally varying, biospheric CO2 fluxes from the surrounding highly productive agricultural grassland.
We made flask measurements of CO2 and 14CO2 (from which we derive the fossil fuel CO2 component) and in situ measurements of CO2 downwind of the Kapuni plant, using a heli-kite to sample transects across the emission plume from the surface up to 100 m above ground level. We also determined the surface fossil fuel CO2 content averaged over several weeks from 14C in grass samples collected from the surrounding area.
We use the Windtrax plume dispersion model to compare the atmospheric observations with the emissions reported by the Kapuni plant, and to determine how well atmospheric measurements can constrain the emissions. The magnitude of emissions are comparable between the observations and model when examined over an appropriate time interval, but the model has difficulty accurately capturing the fluctuations and short-term variability seen in the flask and in situ measurements. Initial results show good agreement between the observed fossil fuel CO2 derived from the grass samples and the model result averaged over the same period, suggesting that this passive integrated-sampling method has the potential to monitor long-term emissions.

-361 The Non-Steady-State Oceanic CO2 Signal: its importance, magnitude and a novel way to detect it

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The ocean' s role has been pivotal in modulating rising atmospheric CO2 levels since the industrial revolution, sequestering over a quarter of all fossil-fuel derived CO2 emissions. Net oceanic uptake of CO2 has roughly doubled between the 1960' s (~1PgC/yr) and 2000' s (~2PgC/yr), with expectations it will continue to absorb even more CO2 with rising future atmospheric CO2 levels. However, recent CO2 observational analyses along with numerous model predictions suggest the rate of oceanic CO2 uptake is already slowing, largely as a result of a natural decadal-scale outgassing signal. This recent CO2 outgassing signal represents a significant shift in our understanding of the oceans role in modulating atmospheric CO2. Current tracer-based estimates for the ocean storage of anthropogenic CO2 assume the ocean circulation and biology is in steady state, thereby missing the new and potentially important 'non-steady-state' CO2 outgassing signal. By combining data-based techniques that assume the ocean is in steady-state, with techniques that constrain the net oceanic CO2 uptake signal, we show how to extract the non-steady-state CO2 signal from observations. Over the entire industrial era, the non-steady-state CO2 outgassing signal (~13±10 PgC) is estimated to represent about 9% of the total net CO2 inventory change (~142 PgC). However between 1989 and 2007, the non-steady-state CO2 outgassing signal (~6.3 PgC) has likely increased to be ~18% of net oceanic CO2 storage over that period (~36 PgC). The present uncertainty of our data-based techniques for oceanic CO2 uptake limit our capacity to quantify the non-steady-state CO2 signal, however with more data and better certainty estimates across a range of diverse methods, this important and growing CO2 signal could be better constrained in the future.

-362 Constraining Estimates of Global Photosynthesis with Observations of Chlorophyll Fluorescence

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Radiative forcing under changing climate is strongly dependent upon CO2 concentration in the atmosphere. At present, almost half of anthropogenic emissions do not remain in the atmosphere, but are taken up by 'sinks' in the ocean and terrestrial biosphere in approximately equal proportion. The terrestrial component of this sink is the residual between large fluxes of uptake (Gross Primary Productivity; GPP) and efflux (Ecosystem Respiration: Re). The spatiotemporal variability of the terrestrial sink is large, and predictions of its future behavior are dependent upon our ability to quantify the large terms that determine it.

However, global simulations of terrestrial GPP vary by a factor of two or more. Understanding the processes that control GPP and its spatiotemporal variability are crucial to constraining this discrepancy. Large-scale observational datasets of GPP do not exist, and satellite proxies (such as NDVI, or MODIS LAI/fPAR products) are commonly used as model inputs.

The Greenhouse gases Observing SATellite (GOSAT) provides retrievals of column-averaged CO2 concentration, and also has the ability to observe chlorophyll fluorescence. To date, remote observations of fluorescence have been compared to light use efficiency models of Gross Primary Productivity (GPP), and a close correspondence between fluorescence and GPP has been found. Here, we 'go the other way' and calculate fluorescence from first principles using an enzyme kinetic photosynthesis model (the Simple Biosphere Model; SiB). Simulated fluorescence can then be directly evaluated against spectral retrievals.

We find that SiB reproduces the basic behavior seen in fluorescence observations over multiple vegetation types and climatic regimes. However, we've found that in some regions differences arise: in many grassland/savanna areas there is a rapid response to precipitation events in the fluorescence observations that is not reproduced by SiB. In the tropics, observed fluorescence provides insight into the distribution of light- and water-limited regimes that differ slightly from simulations. We have modified both prognostic phenology and soil processes in the model, and find that we improve the correspondence when evaluated against observations.

We will continue model evaluation across vegetative and climatological regimes. Increased temporal length of record (and additional data following the launch of OCO-2) will provide detailed observation of seasonal cycles of biophysical behavior as well as response to variability in forcing. Satellite retrievals of fluorescence will provide insight into photosynthetic process and constrain simulations of the carbon cycle across multiple spatiotemporal scales.

-363 Environmental controls of terrestrial carbon fluxes over Europe based on CMIP5 model estimates

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The productivity of terrestrial ecosystems is governed, among other factors, by water availability and ambient temperature, but the role of these governing factors under a changing future climate remains not well understood. Analyses of the response of terrestrial ecosystems to past climate variations offer a window to assess this sensitivity. But most of the terrestrial carbon flux measurements are available only at a limited number of eddy covariance flux tower sites and these measurements typically cover only the last two decades. An alternative is the analysis of results from different Land Surface Models (LSMs) as they extend over a much longer period, but their sensitivity to different environmental factors is possibly just a result of the particular parameterization chosen by the model developer. Recognizing this limitation, we follow this second strategy and aim to compare model estimates of seasonal terrestrial carbon fluxes over Europe and to infer the sensitivity of these fluxes to different environmental factors such as soil moisture, temperature and evapotranspitation. We analyzed estimates of terrestrial carbon fluxes for the 20th century (1901-2005) based on results from coupled carbon-climate models used in the framework of the CMIP5 project (Coupled Model Intercomparison Project-phase 5). Specifically, we analyze the response of Gross Primary Production (GPP), Respiration (the sum of autotrophic and heterotrophic) and Net Biome Production (NBP) to a series of environmental factors. Land-use-associated carbon emissions were simulated by most of the considered models, but not further analyzed here. Overall, during the peak of the growing season GPP, Respiration and NBP are highly correlated ($r>0.7$) with soil moisture in Central Europe and in Mediterranean regions, while in Northern Europe these fluxes are highly correlated with temperature. The analyzed carbon fluxes are also correlated with evapotranspiration but this correlation is more pronounced in the Mediterranean regions. Our results suggest region and season-specific thresholds in temperature, soil moisture and evapotranspiration which determine whether NBP is positive or negative. Summer NBP in Mediterranean regions becomes positive (CO_2 source) when soil moisture deficits reach more than 1.4 standard deviation and evapotranspiration is less than 1mm/day, while spring NBP becomes positive in Northern Europe when temperature is less than 2oC. The identified relationships are evaluated using new observations-based estimates of moisture and carbon fluxes at the surface (LandFlux-EVAL synthesis dataset, Mueller et al. 2013, and MPI FLUXNET-based upscaled products, Jung et al. 2010).

-364 Accounting the Carbon Budgets in Agriculture and Forests: Current Model Framework and Challenges

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Vegetation growth and land management practices are two important factors influencing terrestrial carbon sequestration and greenhouse gas emissions to the atmosphere. The carbon cycle is a dynamic biogeochemical system and tracking and accounting the changes of carbon budgets under the effects of biotic/abiotic disturbances is a major challenge. The development of a variety of process-based models has helped to improve our understanding of the factors affecting carbon exchanges and has increased our ability to estimate and forecast carbon budgets, which may improve the accuracy of carbon accounting reports for the United Nations Framework Convention on Climate Change (UNFCCC). Comprehensive model validation based on long-term field measurements and comparison of multiple modeling approaches is necessary in order to advance the field and establish confidence and limits on model application.

This study is targeted to evaluate two process-based models (DayCENT and CN-CLASS) and a dynamic vegetation model (Can-IBIS) using the site measurements of eddy covariance flux towers and biomass observations in Canada. The results indicate that our ability to reliably model carbon dynamics requires the model to parameterize accurately, vegetation phenology, the intensity of land management and soil climatic factors. The major challenge of improving the current model framework relies on a higher spatial resolution of model inputs, including soil properties, weather forcing, disturbance history and land management practices. A practical solution might be to initiate a collaborative program for obtaining model inputs through site-level weather station networks and working with local communities.

-365 Patterns and Controls on Soil Respiration in a Deciduous Mixed Forest near Borden, Ontario

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

In order to evaluate the influence of climate on forest ecosystems and to incorporate their response to changing environmental conditions into climate change scenarios, it is necessary to develop models that include realistic representations of the processes controlling carbon exchange. The rate of turn-over of organic matter in the soil can have a large influence on the long-term status of a forest ecosystem as a carbon source or sink. By examining the rate of release of carbon dioxide from the soil (soil respiration), and its response to environmental variables, we can better understand the controlling factors, and can develop algorithms for use in climate models.

Soil respiration was measured over six growing seasons at the Borden Forest Research Station, a deciduous mixedwood forest in southern Ontario (44°19′ N, 79°56′ W). An automated single-chamber system (LI-COR Inc., model LI-8100) was employed in a primarily deciduous area, with occasional manual spatial measurements in deciduous and coniferous areas of the forest.

The behaviour of soil respiration was evaluated with respect to soil temperature and soil moisture on daily and half-hourly time scales at various depths. Relationships with temperature were in the range of those reported for other temperate and boreal forest sites; Q10 ranged from 1.3 – 4.5, the latter under non-moisture stressed conditions at 20 cm depth. Interannual variability was strongly controlled by precipitation patterns through changes in soil moisture. Drying of the soil resulted in reductions in the observed CO_2 fluxes from the soil. The relationship between respiration and soil moisture was more stable when respiration values were normalized with respect to temperature and a significant moisture control was evident as soil moisture decreased below 10% by volume.

The parameterizations employed for modeling soil respiration in CN-CLASS (Carbon and Nitrogen version of the Canadian Land Surface Scheme), and CTEM (The Canadian Terrestrial Ecosystem Model) are also examined.

-366 First tall tower installation in Switzerland for greenhouse gas concentration monitoring within CarboCount-CH

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Within a Swiss collaborative effort named CarboCount CH, the Beromünster tower, a former broadcasting tower, has been equipped with meteorology stations (Gill "MetPak II") as well as with inlet systems for ambient trace gas concentration monitoring. A Picarro G2401 instrument monitors carbon dioxide (CO2), methane (CH4), and carbon monoxide as well as water vapour at five heights (12, 45, 72, 132, 212 masl). Each level is measured for three minutes which allows for 3 measurements per hour and height. The uppermost and the lowest levels are equipped with two intake lines for collecting flask samples of air for auxiliary analyses of carbon isotopes in the laboratory without any interference with the continuous in-situ measurements. Additionally, a Gill "WindMaster" 1590-PK-020 is installed at the top level to monitor and record vertical air movement. This tower installation is part of the CarboCount CH network with which we investigate human-related emissions and natural exchange between the atmosphere and the biosphere of the two most important anthropogenic greenhouse gases CO2 and CH4. The main aim is to develop a prototype modelling and observing system at the regional scale to quantify and understand CO2 and CH4 fluxes and their sensitivity to climate variability. The site as well as the device installations will be presented along with the measured parameters from the first six months.

-367 Elemental carbon emissions in Northern China: results from top-down constraints

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Black carbon has recently been recognized as the second largest agent of anthropogenic climate forcing at the global scale, behind only carbon dioxide. Additionally, elevated black carbon concentrations cause adverse health effects. Elevated atmospheric concentrations of black carbon have been shown to increase rates of cardiovascular and all-cause mortality and cardiopulmonary hospital admissions. Due to its importance, understanding the emissions of black carbon is of critical importance, particularly in a densely populated, rapidly developing region like northern China.

In this study, we combine atmospheric measurements of carbonaceous aerosols in Beijing with a time-reversed Lagrangian particle dispersion model to impose top-down constraints on emissions in northern China. More specifically, "elemental carbon" (referred to as black carbon mass) in fine airborne particulate matters (PM2.5) was measured on weekly-integrated filter samples collected at Tsinghua University in Beijing from January 2006 through December 2008, and used as top down constraints on a bottom-up emissions inventory with a Bayesian inversion technique. Model predicted elemental carbon concentrations were calculated using a spatially resolved emission inventory, air parcel trajectories from the Stochastic Time-Inverted Lagrangian Transport Model (STILT), and background concentrations from the Goddard Earth Observing System Chemical Transport Model (GEOS-Chem). Scaling factors which adjust emissions upwards or downwards were derived by comparing measured versus simulated concentrations. An uncertainty analysis was performed to provide a quantitative measure of the uncertainty in the adjusted emissions estimates. Results show that emissions of elemental carbon in Northern China are likely under-estimated by the bottom-up inventory. The magnitude of the under-prediction increases during the winter months, coinciding with the increased use of coal for residential heating. An apparent contribution by forest fire emissions outside of the domain results in high uncertainties for springtime emissions.

-368 A new look at the uncertainty associated with CDIAC estimates of global carbon dioxide emissions from fossil fuel consumption

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Renewed efforts at examining the uncertainty associated with carbon dioxide emissions from fossil fuel consumption are yielding new results. Since the classical approach of making independent laboratory measurements of the quantity and then comparing that determination to what is actually measured, or in this case, reported from calculation results is not available, the renewed effort focuses on examining the extensive database used to make the calculations. Three approaches are being taken.

The first approach focuses on the approach originally taken by Marland and Rotty (1984, Tellus 36B: 232-261), but updated with currently used values. This approach examines the basic equation used to calculate emissions: emissions are equal to the product of three terms (i.e., fuel consumed, fraction oxidized, and carbon content). Their 6-10% range (90% confidence interval, 1.64 σ) was bounded by whether the terms are dependent or independent of each other and were time-independent. This approach gives an uncertainty estimate for the global total only.

The second approach is based on quantifying the qualitative national error classes shown in Andres et al. (1996, GBC 10:419-429). Uncertainty in the global total is then bounded by assuming that the energy data for each nation are independent of or dependent on other nation's data. This approach gives uncertainty estimates for national and global totals and is time dependent.

The third approach examines how a given national total for a given year changes with subsequent releases of the Carbon Dioxide Information Analysis Center (CDIAC) data set and updating of national data. This approach gives uncertainty estimates for national and global totals and is time dependent.

These three approaches examine uncertainty from different angles. None of the approaches fully evaluates the entire fossil-fuel-carbon-dioxide data set with all of its subcomponents. However, each estimate focuses on one or more subcomponents. Combined, the three uncertainty estimates give a range within which the true uncertainty on the data set should reside.

-369 Contrasting Decadal Variability in Sea Surface pCO2 Between the Equatorial Pacific and Atlantic

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The tropical Pacific and Atlantic Oceans play a significant role in the global carbon cycle and climate system because of their vast expanse, and significant ocean-atmosphere exchanges of heat, water, energy and CO_2. There has been evidence of the abrupt and coherent changes in the climatological conditions at the decadal time scale, the Pacific Decadal Oscillation (PDO), that is well known to affect large areas of the Pacific basin whereas the Atlantic experiences decadal variability associated with the Inter Tropical Convergence zone (ITCZ) and the North Atlantic Oscillation. The most recent PDO shift has led to the rebound of the equatorial ocean circulation in the Pacific since 1998, with clear signatures in oceanic biogeochemistry. The Atlantic has not received as much attention but is known to experience its own regime shifts associated with the Pacific and manifest as zonal and meridional modes of variability in the ITCZ. Here, we report a basin-scale comparative study of decadal variations of the carbon cycle in the equatorial Pacific and Atlantic Oceans and the role of the dynamic and thermodynamic coupling in the two oceans on the biological and solubility pumps at these time-scales.

Our modeling analyses demonstrate colder sea surface temperatures (SST) and higher dissolved inorganic carbon (DIC) post 1998 in the upwelling regions of both basins. However, modeled sea surface pCO_2 is higher in the equatorial Pacific but lower in the equatorial Atlantic, implying that the former is a DIC dominated system but the latter is dominated by SST. While sea surface DIC is similar in the upwelling regions, SST is much higher in the eastern equatorial Atlantic (>25°C) than in the Pacific (<25°C). Our results raise these questions: Will low-frequency warming transition the equatorial Pacific into an SST-driven system similar to the Atlantic? If the answer is yes, what are the implications for the global ocean-atmosphere CO_2 fluxes, given that the equatorial Pacific plays a key role in the global carbon cycle? What is the role of the differences in dynamic-thermodynamic coupling or the Bjerknes feedback on the resulting contrasts in the DIC dynamics in the two oceans and how have the two systems been responding to the ocean warming in the past few decades? Further studies are needed to evaluate the responses of various processes to changes in climate conditions, and the interactions of the biological pump and solubility pump at regional to global scales. We will present the first such contrast between these two important players in the global carbon cycle and climate variability.

-370 Uncertainty analysis of Eddy Covariance CO2 flux measurements for a grassland site in North Rhine Westphalia, Germany

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Eddy Covariance measurements of the net CO2 exchange between terrestrial ecosystems and the atmosphere (NEE) allow evaluating and improving land surface model simulations and can be used in data assimilation approaches to improve model parameterization. Hence, NEE data is essential for investigating the interactions and feedbacks between ecosystem processes and environmental change. Against this background, it is crucial to analyze and quantify the uncertainty of CO2 flux measurements. One of the most common methods to do this is the two-tower approach (Hollinger et al., 2004; Richardson and Hollinger, 2007). The two-tower approach calculates the random error as function of the standard deviation of the difference between simultaneous NEE measurements of two EC towers, assuming nearly identical environmental conditions and a non-overlapping footprint. However, for most EC tower sites in Europe and elsewhere, such an idealized two-tower setup is not given. In this context the following questions arise: What is the critical EC tower distance for an appropriate application of the two-tower approach and what does it depend on? Is it possible to estimate the uncertainty of NEE with a two-tower based approach in a reasonable manner, even though the environmental conditions are not identical? A unique EC tower setup at the experimental grassland site in Rollesbroich (Germany) allowed for an extended analysis of these questions. The Rollesbroich site has one permanent EC tower at a fixed location and an additional roving station was installed at distances of 8 m, 95 m, 173 m and 20.6 km from the permanent station. This roving station measured at each of these locations between 2 and 8 months. For the uncertainty analysis, different environmental conditions and site management at the two EC tower locations were taken into account. Moreover, the energy balance deficit was analyzed for the two EC towers with the attempt to separate the systematic part of the EC flux error, based on Kessomkiat et al. (2013). The apparent uncertainty increased with increasing EC tower distance. However, this increase was less strong than expected. In particular, the 8 m distance which implies overlapping footprints did not yield a considerably smaller uncertainty estimate than the larger distances.

-371 Estimating continuous regional fossil fuel CO2 concentrations in a densely populated area using CO2, 13CO2 and CO measurements

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

In order to dampen the effect of global temperature rise due to anthropogenic greenhouse gases in the atmosphere, significant restriction for their emissions are needed and intended in many countries world-wide. To control these restrictions and the emissions reported to the United Nations Framework Convention of Climatic Change (UNFCCC), an independent verification through atmospheric measurements and models is desirable. In the case of carbon dioxide, the regional fossil fuel CO2 (FFCO2) share can be determined and separated univocally from the regional biogenic CO2 component using 14CO2 observations; however, large costs and analytical restrictions prohibit a high temporal resolution of these measurements. A number of different proxies for FFCO2 have thus been suggested to replace 14CO2 measurements, such as continuous carbon monoxide (CO) or other anthropogenic tracers associated with FFCO2 combustion. Here we present a new method based on continuous CO2, 13CO2, and CO observations, which can be applied to estimate high-resolution FFCO2. The CO-based method recently used in a number of applications (e.g. Vogel et al., 2013) utilizes CO as a tracer for fossil fuel emissions. But since only traffic emissions are highly correlated to CO emissions it is necessary to calibrate the CO/FFCO2 ratio with frequent 14CO2 measurements to account for varying source mixes. The recently available precise continuous 13CO2 measurements offer additional independent information for CO2 source apportionment. Here we use 13CO2 measurements in Heidelberg, a polluted area in south-west Germany, as a tracer to estimate the contribution from very depleted or very enriched CO2 sources. This allows separating industrial CO2 contributions as well as CO2 contributions from domestic heating, as isotopically depleted natural gas is a major fuel component of both emission groups. The traffic-induced CO2 component which has a 13C/12C ratio close to the mean CO2 source mix, on the other hand, is marked by co-emitted CO. The novel 13CO2-CO based method for calculating regional FFCO2 is tested over the course of one year and compared to the FFCO2 contributions from two weekly 14C-based estimates as well as to bottom-up model results, based on EDGAR V4.2 emissions and biogenic CO2 fluxes calculated with Vegetation Photosynthesis and Respiration Model (VPRM). The comparison reveals that the suggested 13CO2-CO based method estimates regional FFCO2 offsets with an uncertainty of about 3 ppm and a temporal resolution of 15 minutes, if initially calibrated with 14CO2 measurements.

-372 GLODAPv2 – a global and quality controlled ocean biogeochemical data product

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

GLODAPv2 will be a quality controlled data product of discrete water column measurements made over the past four decades (up to 2011). This product will allow us to better quantify changes in oceanic inorganic chemistry and to investigate oceanic decadal change in general. As a part of the EU project CarboChange and the NRC project DECApH, an international collaboration of scientists, has been working for the past year and a half to reassess the adjustments that were applied to the original GLODAP data product, to merge this revised product with CARINA (http://cdiac.ornl.gov/oceans/CARINA/) and PACIFICA (http://pacifica.pices.jp/data.html), and to additionally include approximately 80 other cruises that have recently be assembled and calibrated. GLODAPv2 is scheduled for release this year. In this presentation we will explain the work that has been done so far: tools and methods; results from the consistency analysis; applied adjustments; as well as future routines and what remains to be done before the GLODAPv2 data set can be released. GLODAPv2 will also be released as a gridded data product. We expect the gridded version of GLODAPv2 to be particularly valuable to the modeling community.

Estimates of Sources and Sinks of Carbon Dioxide for South Africa through Inverse Modelling of Atmospheric Measurements

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Regional monitoring of CO_2 and other greenhouse gases has been identified as a priority by international agencies, such as the Intergovernmental Panel on Climate Change and the United Nations. On the 1st of June 2006, 189 nations, including South Africa, adopted the United Nations Framework Convention on Climate Change, which has the objective of “stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system”. Monitoring of these gases is essential to achieving this goal.

Solving for regional sources and sinks requires a network of extremely well calibrated, precise sensors, located optimally around the edges of each region. To begin the implementation of this network in South Africa, two additional sensors have been placed on the borders of the City of Cape Town, taking advantage of the existing measurements at the Cape Point GAW station. The purpose of this exercise is to obtain estimates of CO_2 emissions from the City of Cape Town and surrounding areas through inverse modelling of atmospheric measurements of CO_2 and atmospheric transport models.

This presentation details the initial results from a year long measurement campaign around the City of Cape Town, as well as the results from an inverse modelling exercise to determine the most appropriate places for future CO_2 measurement sites in South Africa.

-374 14C evidence of enhanced permafrost carbon export in response to Arctic climate variations

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Arctic permafrost, storing approximately half of the global reservoir of soil organic carbon (OC), is a highly sensitive carbon reservoir during climate variations. As an important process of carbon dispersal in the Arctic, fluvial transport of Arctic permafrost carbon is expected to increase with warming-induced thawing and potentially provides a positive feedback to climate change. However, this impact is challenging to assess due to the diverse processes controlling the release of various carbon pools from heterogeneous landscapes in the Arctic. Here, we present novel radiocarbon evidence for the enhanced export of ancient permafrost carbon in response to temperature variations across the Eurasian Arctic. By radiocarbon dating various terrestrial OC components in river-integrated estuarine sediments, we first uncouple the transfer of younger surface versus old deep permafrost carbon in six Arctic and sub-Arctic rivers (Kolyma, Yenisey, Indigirka, Lena, Ob and Kalix) and then demonstrate different hydrogeographic controls on the mobilization of various carbon pools. As such, delivery of young carbon from surface sources is dominantly controlled by river runoff, whereas highly aged OC from deep permafrost is increasingly mobilized via hydrological conduits in discontinuous permafrost regions. After constraining the main hydrogeographic influences, the age of permafrost- and peat-derived OC increased significantly with extreme summer temperature anomaly within the sediment deposition time, suggesting enhanced transfer of ancient carbon with extreme warming events. As river runoff has significantly increased across Eurasian Arctic in the past few decades [1], increased permafrost carbon release may have been masked by synoptically increased transport of young surface OC in the Arctic. Because permafrost carbon is considered to be vulnerable to degradation during fluvial transport [2], increased fluvial mobilization of ancient carbon deposits may represent a significant and under-investigated positive feedback to climate changes.

[1] Peterson BJ, et al. (2002) Increasing river discharge to the Arctic Ocean. Science 298:2171-2173. [2] Vonk JE, et al. (2012) Activation of old carbon by erosion of coastal and subsea permafrost in Arctic Siberia. Nature 489:137-140.

-375 Seasonal variations of CO_2, CH_4, N_2O and CO in the mid-troposphere over the western North Pacific observed by a cargo aircraft C-130H

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Seasonal natures of carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO) and nitrous oxide (N_2O) variations at about 6 km in the mid-troposphere (MT) over the western North Pacific are presented by using C-130H aircraft measurements conducted by Japan Meteorological Agency. The aircraft flies from Atsugi Base (35.45°N, 139.45°E), located in Kanagawa Prefecture close to Tokyo, to Minamitorishima (MNM; 24.28°N, 153.98°E) frequently collecting air samples with about 24 flasks. This measurement program has started since July 2010 and conducted once a month. In the MT, clear increasing trends of CO_2 and N_2O were observed, while large variability of CH_4 and CO was persistently observed by the aircraft. Over MNM, higher concentrations of CH_4 and CO were found at higher altitude during summer season, while CO_2 seasonal cycles have almost same timings of seasonal maximum and minimum at any altitude. Remarkably high concentrations of CH_4 were observed both for the winter–spring and summer-fall seasons. The average ratios of $\Delta CH_4/\Delta CO$ are 0.47 and 1.2 ppb/ppb for the winter–spring and summer–fall seasons, respectively. In winter–spring, the high CH_4 concentrations likely originated from fossil fuel combustion. Meanwhile, in summer–fall, the high CH_4 concentrations are also attributable to increased biogenic source in Asia. Because the summer–fall high concentrations of CH_4 are hardly observed at the surface station of MNM, the aircraft measurements could be powerful constraints on CH_4 emission estimates.

-376 Long-term variation of the stratospheric CO2 over Japan

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Systematic collections of stratospheric air samples have been carried out over Japan since 1985, using a balloon-borne cryogenic sampler. The stratospheric air samples have been collected almost once a year or two years at 11 assigned heights, ranging from the tropopause to 30 - 35 km. The air samples were analyzed for various gas concentrations, such as CO2, CH4, N2O, and SF6, and their isotopes. Increasing trend of the CO2 concentration was clearly found at heights above 20-25 km, where the CO2 concentration becomes almost constant vertically. To clarify the difference of the secular CO2 increases between the mid-stratosphere and the troposphere, the average values of the CO2 concentration, calculated from the balloon data obtained at heights above 20-25 km, were compared with annual mean CO2 concentrations at Mauna Loa (MLO) observed by NOAA/ESRL. The average increase rate of the CO2 concentration in the mid-stratosphere, calculated by using a least-squares method, was 1.55±0.03 ppmv/year. This value is significantly smaller than 1.73±0.03 ppmv/year calculated for the same period for MLO data. Considering that the mid-stratospheric CO2 concentration corresponds to the tropospheric values earlier by 4-5 years, the CO2 increase rate in the stratosphere should be compared with the tropospheric values shifted by the same years. The average increase rate, thus calculated for the period 1981-2005, was 1.62±0.03 for MLO data. This value is slightly smaller than those described above, due to interannual variations of CO2 increase rate in the troposphere, but still larger than the stratospheric value. These facts imply that the concentration difference between the troposphere and mid-stratosphere gradually increased during the last 25 years. The interannual CO2 variation in the mid-stratosphere was first discovered by our balloon measurements. The secular CO2 increase in the mid-stratosphere is not monotonous, probably due to the propagation of interannual variations in tropospheric CO2, being accompanied by time delay. The CO2 anomalies in the mid-stratosphere, calculated as deviations from the second order polynomial trend and then shifted by -4.5 years, are fairly correlated with those in the troposphere. Such a correlation is found especially in CO2 anomalies observed in the troposphere for a few years after 1991. Measurements of the stratospheric CO2 concentration are one of the most promising methods to detect possible changes in the stratospheric circulation. The CO2-age of mid-stratospheric air varies between 4.3 and 6.0 years, especially being larger in the last 15 years. The average change rate of the mean age in the mid-stratosphere was 0.04±0.01 years/year. Our result shows no decreasing trend of the CO2-age in the mid-stratosphere for the last 25 years.

-377 CarbonTracker South America: a first comparison of model results with independent CO2 observations

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

One of the regions with the largest uncertainties in the net carbon fluxes within the global carbon cycle are the tropics, specifically South America and the Amazon region. This region is important in the carbon cycle as the Amazon Basin contains a large carbon pool stored within the forests and soils which can be released fast (e.g. Gloor et al. 2012).
The CarbonTracker-Europe (Peters et al. 2010) data assimilation system (CTDAS*) is the basis for our new regional scale CTDAS adapted to South America. We use the TM5 zoom grid with 1x1 degrees resolution over South America. We will include unique observations over South America, particularly those from NOAA ESRL's air sampling network and the novel, widespread observations from aircraft sampling since 2010 by IPEN, Brazil, as part of the UK NERC AMAZONICA project in close collaboration with NOAA ESRL.
Within the European project GEOCARBON we will use our regional scale CTDAS and these observations to come up with improved estimates of the carbon sources and sinks of South America. At the conference we will present first results of our model's performance in comparison to independent atmospheric CO2 observations (i.e. observations that are not used in the assimilation), for example vertical CO2 profiles from aircraft sampling.

References:
Gloor et al., The carbon balance of South America: a review of the status, decadal trends and main determinants, Biogeosciences, 9, 5407–5430, 2012.
Peters et al., Seven years of recent European net terrestrial carbon dioxide exchange constrained by atmospheric observations, Global Change Biology, 16, 1317–1337, 2010.
*Documentation: http://www.carbontracker.eu/ctdas/

-378 Annual and monthly Gross Primary Productivity time series (2000 – 2012) for Europe on a 1km² resolution

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

In this study we present monthly and annual gross primary productivity (GPP) time series (2000 to 2012), computed for Europe with the Biosphere Energy Transfer Hydrology (BETHY/DLR) model. BETHY/DLR is designed for regional and continental applications (here Europe) and operated at the German Aerospace Center (DLR). It was adapted from the BETHY scheme to be driven by remote sensing data and meteorology. Time series of the Leaf Area Index (LAI) are used to control the development of vegetation, which are obtained from the geoland2 database. Meteorological time series are used to regulate meteorological seasonality. These comprise daily information on temperature, precipitation, wind-speed and radiation and are taken from the European Centre for Medium Range Weather Forecast (ECMWF). In addition static information of the land cover land use, elevation and soil type are needed. In this study we used the GLC2000 land cover, the SRTM on 1km² resolution and the Harmonized World Soil Database (HWSD).

BETHY/DLR has a particular focus on a detailed parameterization of photosynthesis, and tracks the plant-mediated transformation of atmospheric carbon dioxide into energy-storing hydrocarbons. We take into account environmental conditions that affect photosynthesis. As example reduced water availability, light or temperature excess might limit plant growth. The model separately treats the light and dark reactions of photosynthesis at leaf level, making it possible to mechanistically limiting photosynthesis by either light availability or by the abundance of the carboxylation enzyme Rubisco. GPP, Net Primary Productivity, Net Ecosystem Productivity, Evapotranspiration and the soil water budget are calculated on a daily basis.

To validate our model results we used eddy covariance measurements from the FLUXNET network of 74 towers across Europe. For forest sites we found that our model predicts higher GPP sums (between 20 % and 40 %). In contrast, for cropland sites BETHY/DLR results show about 18 % less GPP than eddy covariance measurements. For grassland sites, GPP calculated with BETHY/DLR show highest correlations (between + 10 % and - 16 %). A mean total carbon uptake of 2.5 Pg C a-1 (± 0.17 Pg) was found for Europe. Monthly and annual data is made available after request at http://www.wdc.dlr.de/data_products/SURFACE/npp.php.

-379 Observation of increasing surface partial pressure of CO_2 in the Southeast Equatorial Indian Ocean, a region of CO_2 source

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Recently, a trend of increase in surface CO2 and decrease in pH was found in lots of regions, where CO2 was taken up from the atmosphere. However, little attention was paid to the change of seawater CO2 in the regions, which released CO2 to the atmosphere. Here, we examined the interannual variability of surface partial pressure of CO2 in the Southeast Equatorial Indian Ocean (5°N-5°S, 90-95°E), a CO2 source region, using data collected during May 2012 and the historical data integrated by Takahashi et al. (2009) (April 1963, May 1999 and April 2007). We found sea surface pCO2 at in-situ temperature in this region increased from ~308 μatm in April 1963, through ~367 μatm in May 1999 and ~386 μatm in April 2007, to ~395 μatm in May 2012. From 1963 to 2012 during the spring intermonsoon period, sea surface pCO2 had a mean increase rate of 1.7~1.8 μatm yr-1, higher than the increase rate of atmospheric CO2 (1.4 μatm yr-1). Thus, sea surface pH in this area may decrease and more CO2 will be emitted to the atmosphere due to the increase of sea surface pCO2. In addition, temperature-normalized pCO2 showed a mean increase rate of 1.6~1.8 μatm yr-1 during this period, indicating temperature was not the factor causing sea surface pCO2 increase. While the interannual variability in biological activity may partially contribute to the pCO2 variation, oceanic circulation may to a large extent account for it by mixing between the CO2 sink region and source region on a basin scale. Thus, we may conclude that increase in surface pCO2 and decrease in pH will not only occur in the region of CO2 sink, but may also in the CO2 source region.

-380 The Effect of Traffic Load on Urban CO_2 Concentration

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

A CO2 concentration monitoring network was built up to understand the effect of traffic load on urban CO2 concentration in Taipei, Taiwan. This network consists of three CO2 monitoring stations: one on the highest building in Taiwan, the Taipei 101 building, another on a grass land on National Taiwan University campus, and the other on a building roof on National Taiwan University campus, too. The measurement heights for these three stations are 354, 1.2, and 26 m, respectively. It was found that the CO2 concentration difference between weekday (high traffic load) and weekend (low traffic load) measurements was around 5 ppm. We also found that the urban grass land was able to reduce the CO2 concentration for about 10 - 15 ppm. Our data showed that the CO2 concentration in Taipei varied between 370 - 525 ppm, and had a diurnal cycle with high concentration in night time and low concentration during day time. This diurnal cycle was strongly related to the development of the atmospheric boundary layer, traffic load, and photosynthesis/respiration of vegetation.

-381 Uptake of anthropogenic CO2 in the Australian sector of the Southern Ocean

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Currently, the oceans are estimated to take up more than 25% of anthropogenic CO2 (Cant) emissions. As observed earlier, the partial pressure of CO2 in surface seawater (pCO2sw) has been increasing at a rate nearly equal to that of atmospheric pCO2, which suggests the pre-equilibrium between sea surface and overlying air. The rate-determining step for ocean sequestration of Cant is the vertical transfer of carbon from the surface to the ocean interior. In order to predict the future increase of atmospheric CO2, it is necessary to understand the vertical transfer of Cant between the ventilated surface mixed layer and the ocean interior. The Southern Ocean has been reportedly to be a particularly important region for the uptake and storage of Cant. In this work, we have estimated Cant by comparing dissolved inorganic carbon (DIC) data between 1995 (WOCE data) and 2010 in the Australian sector of the Southern Ocean. Measurements of DIC were made aboard the TS Umitaka-maru over the period from December 2010 to January 2011 along 110°E. Increases of Cant were estimated by the method reported earlier (Gruber et al., 1996; Sabine et al., 2002a, 2002b; Murata et al., 2007). Along 110°E, the region from 45°S to 50°S is strongest sink of Cant (1.4-1.5 mol m-2 yr-1) and latitudes around 64°S (0.2 mol m-2 yr-1) is weakest. The increase of Cant by the Southern Ocean is a result of the vigorous overturning circulation in regions where water masses are formed and subducted into the ocean interior. Sub-Antarctic Mode Water and Antarctic Intermediate Water formed on the northern flank of the Antarctic Circumpolar Current (ACC) lead to the larger increases of Cant by the Southern Ocean.

-382 Basin-scale Distribution and Seasonal to Inter-annual Variation of Dissolved Inorganic Carbon over the North Pacific

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Monthly distribution maps of surface dissolved inorganic carbon (DIC) were produced over the North Pacific from 2002 to 2008. The estimated DIC agrees well with the observational DIC at research vessel based time-series stations with a root mean square error of 10.2 μmol/kg. Spatial distribution of DIC mean state corresponds with sea surface salinity distribution and ocean circulation. DIC seasonal variation is characterized by 10 areal clusters, and DIC decrease from the end of winter to summer was captured; more than 120 μmol/kg in the northwestern part, while less than 30 μmol/kg in the subtropics. The DIC decreases from March to July subtracting effects of air-sea CO2 flux and salinity change can be considered as net community production (NCP); more than 15 mmolC/m2/day in the boundary region between the subtropics and the subarctic to the west of the date-line, more than 8 mmolC/m2/day in the coastal region of the subarctic, and 4~10 mmolC/m2/day in the offshore region of the subarctic. The NCP spatial distribution corresponds well to 20~30% of the satellite derived net primary production. Inter-annual variation of DIC in the subarctic is caused by changes of salinity, vertical mixing, and biological production. Whereas, DIC variation in the mid-latitudes and the subtropics is caused by changes of salinity and air-sea flux. The Pacific Decadal Oscillation induces the dominant inter-annual variation of the North Pacific carbon cycle via changes of the ocean-atmospheric condition.

-383 The impact of satellite data bias correction in carbon cycle data assimilation

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Recently, a number of satellite observation data have become available for use in carbon cycle analysis (GOSAT, AIRS and so on), and more satellite instruments (OCO-2, Carbonsat, Tansat and so on) are planned for launch in the next few years. The merits of satellite data in carbon cycle analysis include their large spatial coverage and relatively large space representativeness comparing with in-situ observations. However, there are non-trivial points that need to be reconsidered in satellite data. An important issue is bias, which may change with time and space. Many efforts have been made to estimate the bias, but most previous attempts used only a limited number of observations and did not consider spatial and temporal variations of the bias. In this research, we estimate satellite data bias from an independent analysis of CO2 concentrations (JMA CO2 distributions (Maki et al., 2010)) which provides global coverage on a monthly basis. The accuracy of the CO2 concentrations is almost 1.0 ppm in the southern hemisphere and free troposphere. The annual global mean bias of GOSAT SWIR Level 2 (Ver. 2.X) relative to the JMA CO2 analysis is approximately -1.4 ppm and shows some seasonal and latitudinal variations. Our estimates of annual-mean bias are consistent with previous studies (ex. Inoue et al., 2013). We examined several bias correction settings in our carbon cycle data assimilation system. The data assimilation scheme is a local ensemble transformed Kalman filter (LETKF) with a transport model (MJ98-CDTM) at a T42L30 resolution. The ensemble size is fixed at 24, and horizontal localization scale parameter is chosen to be 1,000 km. Our results show that the bias correction plays a crucial role in carbon cycle data assimilation, and that considering the spatial and temporal variations of the bias is also important to reproduce robust CO2 flux and concentrations.

-384 Estimating Carbon Sequestration Capacities in Biologic and Geologic Reservoirs in the United States

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Two separate national assessments are being conducted to estimate the capacities of carbon sequestration in either biologic or geologic reservoirs in the United States. The biologic assessment covers aboveground, surface, and belowground carbon pools of all major terrestrial and aquatic ecosystems, and is based on an integrated use of resource inventory data, land use, climate, soils, and statistical or simulation models. The geologic assessment concerns the capacity of storing carbon dioxide in liquid form in porous subsurface formations, and relies on a probability-based assessment methodology. Both assessments study the natural or anthropogenic processes controlling the size and distribution of the capacities. To date, the two assessments have yielded regional-scale, and spatially explicit results that suggest opportunities, vulnerabilities and challenges of the sequestration capacities. For example, the biologic assessment showed an estimated mean annual rate of sequestration at 151 (34-262) TgC/yr by all major ecosystems in the western half of the continental United States (approximately 4.83 million km2), which is based on consideration of major controlling processes such as land use and wildfire. Over a 50-year performance period, this translates to a biologic capacity of 7.6 (1.7-13.1) PgC. On the other hand, geologic carbon dioxide capacity could be much larger, ranging from hundreds to thousands of PgC in geologic formations in the United States. In this paper, we will present methods used for the two national assessments, and discuss the most current results, and highlight future research directions.

-385 SST phases in the open-ocean and margins of the tropical Pacific: implication on tropical climate dynamics and greenhouse emission

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

The tropical Pacific exerts a major effect on the global climate system and might have driven large extra-tropical climate change. We present a 320-kyr high resolution Uk’37-sea surface temperature (SST) record from core MD052928 (11°17.26’S, 148°51.60’E, water depth 2,250 m) located off southeastern Papua New Guinea (PNG), in the western tropical Pacific. The age model of the core is based on AMS 14C dating of planktonic foraminifers and correlation of benthic to the LR04 stack. The Uk’37-SST ranges from 26.5 to 29°C, showing glacial-interglacial and millennial variations. We assess the phase of the MD052928 Uk’37-SST as part of a synthesis of five other SST records from the tropical Pacific at the precession, obliquity, and eccentricity bands. The SST records can be separated into 2 groups when considering SST phase relative to changes in orbital forcing, ice volume and greenhouse gases (GHGs). SST maxima at open-ocean sites within primary equatorial current systems occur between obliquity maxima and methane (CH4) maxima but early relative to ice volume minima and CO2 maxima at the obliquity and eccentricity bands. In contrast, SST maxima at continental margin sites change are in phase with ice minima and CO2 maxima, likely influenced by the slow response of continental ice sheets and GHGs. At the precession band, the early group located on the Warm Pool area indicates a direct influenced by the local insolation, and with the similar phase progress as the obliquity band. These results indicate that the decreased high-low latitudes insolation gradient and increasing low latitude local insolation resulting in higher tropical Pacific SST. Higher SST would supply more moisture resulting in increased CH4 in the tropical wetlands. This promotes increasing CO2 and deglaciation leading to increase continental and continental margin surface temperatures.

-386 CO2 exchange rates from tundra lichen, moss, and tussock, Council, Alaska

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

CO_2 flux-measurement in dominant tundra vegetation on the Seward Peninsula of Alaska was examined for spatial representativeness, using a manual chamber system. In order to assess the representativeness of CO_2 flux, a 40 m × 40 m (5-m interval; 81 total points) plot was used in June, August, and September of 2011. Average CO_2 fluxes in lichen, moss, and tussock tundra were 3.4 ± 2.7, 4.5 ± 2.9, and 7.2 ± 5.7 $mgCO_2/m^2/m$ during growing season, respectively, suggesting that tussock tundra is a significant CO_2 source, especially considering the wide distribution of tussock tundra in the circumpolar region. Further, soil temperature, rather than soil moisture, held the key role in regulating CO_2 flux at the study site: CO_2 flux from tussock increased linearly as soil temperature increased, while the flux from lichen and moss followed soil temperature nearly exponentially, reflecting differences in surface area covered by the chamber system. Regarding sample size, the 81 total sampling points over June, August, and September satisfy an experimental average that falls within ±10% of full sample average, with a 95% confidence level. However, the number of sampling points for each variety of vegetation during each month must provide at least ±20%, with an 80% confidence level. In order to overcome the logistical constraints, we were required to identify the site's characteristics with a manual chamber system over a 40 m × 40 m plot and to subsequently employ an automated chamber for spatiotemporal representativeness.

-387 CO2 exchange rates in Black Spruce Forest, Interior Alaska

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

CO_2 exchange rate was carried out to estimate the continuous monitoring of soil respiration using automatic chamber system that was equipped with a control system, a compressor, and seven chambers (50 cm diameter, 30 cm high) in sphagnum moss, feather moss, lichen, and tussock in black spruce forest soils, interior Alaska during growing seasons. The average daily soil respiration rates were 0.050±0.012 (standard deviation, CV 23%), 0.022±0.020 (91%), 0.082±0.035 (43%), and 0.027±0.010 mgCO2/m2/s (37%) in lichens, sphagnum moss, tussock and feather moss on black spruce forest soils. The accumulative daily soil respiration was 5.2, 9.5, 2.3, and 2.8 mgCO2/m2/s in lichen, tussock, sphagnum moss, and feather moss of black spruce forest ground during the growing periods. Therefore, averaged regional soil respiration rate is 0.19±0.18 and 0.12±0.08 kgC/m2/(growing season) of 2007 and 2008 in black spruce forest soils, interior Alaska. The winter soil respiration was 0.049±0.013 gC/m2/(winter season), corresponding from 21±7% to 29±13% of the annual CO_2 emitted from black spruce forest soils, interior Alaska, suggesting similar values estimated in same research site. We will discuss on GPP, NEE and Re through the conference.

-388 Intra- and Inter-annual Variation of Stem Respiration of Black Spruce (Picea mariana), Interior Alaska

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

This stem respiration, that is equipped with a control system that consists of data-logger (CR10X), NDIR CO_2 analyzer, and pump, a compressor, and seven stem chambers, was conducted in parallel with the flux-measurement of soil respiration in different-sized black spruce of 4.3 cm to 13.5 cm in DBH (diameter at breast height), interior Alaska during the growing season of 2007 to 2009. The average stem respirations were 0.011±0.005 mgCO2/m3/s (range 0.005±0.002 to 0.015±0.008 mgCO2/m3/s, CV 45%) in black spruce forests, which the DBH (Diameter at Breast Height) of black spruce ranges from 4.3 to 13.5 cm. The stem respiration in different-sized black spruce forest soils has temporally varied during the growing season of 2007-9. This suggests that the young black spruce has 3-fold higher metabolism than the old. Temperature is one of critical roles in determining stem respiration rate. Q10 values on air temperature and average stem respiration rates are 2.02 in 2007, 2.00 in 2008, and 2.37 in 2009 during the growing season, respectively. However, during the dormant season, measurement of stem respiration was failed and especially the diaphragm pump was damaged by input of the extremely cold air of 35 °C below the zero. Interestingly, the lagging effect of stem respiration on temperature and PAR (photosynthetically active radiation) was found during the clear sky, indicating lagging time of 1-2 hours on temperature and of 4-5 hours on PAR, respectively. Based on the Q10 equation on air temperature, annual variation of stem respiration rate was estimated, suggesting that the relationship between measured and simulated daily stem respiration was a good linear for the better understanding of interannual variation of stem respiration rates during 2007-9. The contribution of simulated monthly stem respiration to the ecosystem respiration (Re) by the eddy covariance method was 4.2±2.1 % in 2007, 2.5±0.9 % in 2008, and 5.7±4.3 % in 2009, respectively. The suggests that the higher contribution during 2009 may be due to much higher temperature in late winter and early spring.

-389 The emissions of greenhouse gases from permafrost at the climate change

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The risk of catastrophic release GHG from high latitudes at degradation permafrost is discussed in the literature [Yakushev & Chuvilin 2000, Walter et al. 2008, Shakhova et al. 2010]. As a consequence the Arctic is considered now as a territory of potential importance in extreme increasing GHG concentration in the atmosphere at the climate warming. Hypothetically the permafrost melting may accelerate involving the organic matter pool of permafrost itself in biotic cycle and additional emission of GHG to the atmosphere is possible. The hypothesis is based on the considerable stores of organic matter in tundra ecosystems and permafrost pools.

To study the state of permafrost and, particularly, seasonally thaw depths in dependence on the climate change, in 1990 the Program of Circumpolar Active layer Monitoring (CALM) was set up. This system is a part of Global Terrestrial Observing System (GTOS) and Global Climate Observing System (GCOS) working under WMO. There are a few CALM stations on the Russian territory. The obtained data show different trends of changes of seasonal thaw depths of permafrost. Trends vary between <0 and up to >2 cm per 10 years. In European part of tundra the trend of increase of seasonal melting is higher than in North Eastern tundra [O. A. Anisimov et al., 2012]. Rather big variability of thaw depth from year to year is observed. The warmest years of the last decade were 2007 and 2010. In the most cases the thaw depth in these years was maximal. Hence, the permafrost is warming in response to global climate change, potentially leading to widespread thaw and a larger seasonally thawed soil active layer.

However there is a lack of reliable information on acceleration of emission fluxes of GHG in high latitudes ecosystems during previous decades connected with increasing of global temperature.

The correlation between thaw depth and climatic indices is rather complicated. Snow depth, vegetation class, soil organic horizon thickness, soil texture, water content, macro- and meso-topography are the very important factors in thaw depth variability. Examples of the dynamic of season thaw depth is shown for several points in North East tundra (Kolyma lowlands). Accordingly our study the increase of melting horizons from 0.6-0.7 m (at present) to 2.0 m by the end of 21st century may additionally release about 1.1 kg CH4-C/ha. The methane emission at present days on Kolyma lowlands approaches 140 kg CH4-C/ha.

The experimental data and modeling on carbon fluxes in Russian tundra [Karelin, Zamolodchikov, 2008] showed that carbon balance in tundra ecosystems of Russia is characterized now as a slight sink (2-2.5% of Gross Primary Production - GPP) or a near zero. Modeling show that increase of average temperature by 4-50C during vegetation period at the end of 21st century will practically not change state of tundra ecosystem carbon balance. At the climate warm the process of adaptation of tundra ecosystems to the new temperature conditions possibly will proceed during decades and will be accompanied by acceleration not only GHG emissions but an increasing of net primary production (NPP) as well. Modeling of the dependence of carbon balance on temperature shows that the increase of yearly mean temperature by 40C will make tundra ecosystems as a weak source of CO2.

One more source of GHG in Arctic is destruction of shore line due to melting of permafrost.

The current average rate of shore erosion of Arctic cost varies in range of 2-4 m a year [Anisimov et al., 2012]. The distance of Arctic cost line of Russia is about 5000 km and an average height of the shore is about 25 m. Calculations of emissions rate of GHG showed the CO2- C emissions is about 0.2 Mt and CH4-C is 0.075 Mt per year. These values are negligible in comparison with total emission of GHG (~ 90 Mt C a year) from tundra. Doubled shore erosion rate at the warming will not too much add to emission of GHG as a whole at coastal Tundra.

-390 Stable isotope ratio (13C/12C) mass spectrometry to evaluate carbon sources and sinks: changes and trends during the decomposition of vegetal debris

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Vegetal debris is known to participate in key soil processes such as the formation of soil organic matter (SOM), also being a potential source of greenhouse gases to the atmosphere. However, its contribution to the isotopic composition of both the SOM and the atmospheric carbon dioxide is not clear yet. Hence, the main objective of the present research is to understand the isotopic 13C changes and trends that take place during the successive biodegradative stages of decomposing soil organic inputs. Shifts in the 13C natural abundances of both the solid residues and the CO2 releases were investigated by incubating bulk plant tissues for several months under laboratory controlled conditions. Significant isotopic variations with time were observed, probably due to the isotopically heterogeneous composition of these complex substrates in conjunction with the initial selective consumption of more easily degradable 13C-differentiated compounds during the first stages of the biodegradation, while less available or recalcitrant litter components were decomposed at later stages of biodegradation, generating products that have their own specific isotopic signatures. These results suggest that caution must be exercised when interpreting carbon isotope studies (at natural abundance levels) since perturbations associated with the quality or chemical composition of the organic debris from different terrestrial ecosystems can have an important effect on the carbon stable isotope dynamics. Thus, microbial fractionation of 13C during detritus decomposition can not be neglected when attempting to evaluate the isotopic aspects of the carbon-cycle comprehension and the quantification of 13C discrimination have to be taken into consideration in order to obtain more reliable estimates of the contribution of decaying vegetal debris to SOM buildup in each specific ecological context as well as to avoid errors in appraising the influence of this important source of carbon on the air isotopic fingerprint.

-391 Numerical modeling of regional carbon cycle based on RegAEMS

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Carbonaceous gases such as CO_2, CO, CH_4, and VOC not only have impact on the climate change or photochemical smog, but also can interact with each other. In this study, the regional atmospheric environmental modeling system (RegAEMS) was modified to include CO_2/CH_4 source and sink, VOC biogenic emission, CO_2 and CH_4 transport, CO/CH_4/VOC chemical conversion. The initial and boundary conditions of RegAEMS were driven by GEOS-CHEM. The model was applied to investigate characteristics and mechanism of regional carbon cycle over China in 2009, with various emission inventories of CO_2, VOC and CH_4. Simulation results were verified by observational data from sites and satellites. The high CO_2, CO, and CH_4 concentrations were centered mainly in northern, eastern, and southwestern China. The regional budget of carbon over China was estimated. Annual carbon emissions from CO_2, CO, and CH_4 are 1218Tg, 42Tg, and 49Tg, respectively. The chemical conversion rates from CH_4 to CO_2 and from CO to CO_2 are $0.00113h^{-1}$ and $0.00148h^{-1}$, respectively. The annual amounts from CH_4 to CO_2 and from CO to CO_2 are 0.16Tg and 0.66Tg, respectively. Deposition flux from CO_2, CO, and CH_4 are 657Tg, 10Tg, and 12Tg, respectively.

-392 A new method to evaluate regional-scale forest carbon sinks utilising traditional observation data

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Forest ecosystems have been identified as a large and persistent carbon sink and play a significant role in the mitigation of climate change; however, their magnitude, spatial patterns, and trends are still not well quantified. Various methods such as flux tower observation, forest inventory, and process-based modelling have been used to estimate regional carbon sinks, but each has pros and cons. Main uncertainties are related to the observational sample size and its spatial representativeness or rationality of process-based modelling on parameters and initial values. Due to the absence of spatial-explicit data for initial carbon pools, all regional and global models must first be modified to a hypothetical steady-state and then indirectly simulate the carbon sink at a non-steady-state, which potentially increases the uncertainties of the estimation. In this study, we report a new method, a hierarchical data-model fusion scheme, to directly estimate the regional mean carbon sink for China’ s forests from the abundant sample datasets of traditional ecological measured observations (i.e., net primary production, biomass, litter carbon, and soil organic carbon). Our results show that the vegetation and soil carbon sink in China’ s forests is 89.7 and 14.1 gCm-2a-1, respectively, which are comparable with the estimations from detailed forest inventories and complex process-based regional models. The results demonstrate that the soil carbon sink could be better estimated because our method requires no preliminary modification process and avoids the error transmission that originates from the estimation of the initial carbon pool. As traditional ecological observations are much cheaper and easier to conduct, this method has high potential to evaluate and compare the ecosystem carbon sink for different regions.

-393 Vulnerability of ecosystem productivity over Europe under past and future climate extremes

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Frequency and intensity of climate extremes, e.g. drought, heat and cold waves, have the potential to get stronger in future, and that would evoke the importance to know how terrestrial ecosystems will respond to those climate extremes, and how their feedbacks to climate will change. CarboExtreme project in Europe is pursuing the measure to evaluate the vulnerability and risk on ecosystem productivity.

ORCHIDEE is used to estimate the potential influence by climate extremes under retrospective and future climate projections, composed of ERA40, WATCH, and REMO climate forcings (supplied by Dr. C. Beer, MPI) from 1901 to 2100. Vulnerability is here defined as a difference in expectation of ecosystem productivity, e.g. GPP, NPP, and NEP, under non-hazardous condition and hazardous condition, e.g. 10% percentile and 90% percentile of temperature, rainfall and radiation. We will show the results on those vulnerability estimations according to Dr. O. Marcel (CEH)' s proposal in conjunction with ecological productivity indices by our own definition. Estimation of vulnerability could be potentially extended to other model' s simulations contributed by other research institutes.

-394 GPP estimates in a rotating crop using in situ and MODIS data

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

In order to assess crop ability to act as a CO_2 sink and to describe GPP dynamic evolution, in 2008 we installed an eddy correlation station in an agricultural plot on the Spanish plateau. Continuous measurements of 30-min NEE fluxes and other common variables have been measured until the present time. Agricultural practices at the selected plot applied from 2008 to 2012 consisted of annual rotation of non-irrigated rapeseed, barley, peas, rye, and sunflower crops. This paper presents and compares the accumulated GPP measured values for each type of crop as well as the results of the GPP 8-d estimated values using a Light Use Efficiency Model, LUE. Input data for the LUE model were the FPAR 8-d products supplied by MODIS, PAR in situ measurements, and a scalar f, varying between 0 and 1, to take into account the reduction in maximum PAR conversion efficiency, ε_0, under limiting environmental conditions. The f values were assumed to be dependent on air temperature and evaporative fraction, EF, which was considered a proxy of soil moisture. ε_0, a key parameter, which depends on biome types, was derived through the results of a linear regression fit between the GPP 8-d eddy covariance composites observed and the LUE concurrent 8-d model estimates. Missing values recorded outside of the period of maximum interest (from October 2007 to February 2008 and from August to September, 2011) were filled using the linear fits between GPP 8-d observed and LAI 8-d.

Over the five years of study, the annual accumulated values of GPP 8-d observed exhibited great variability ranging from 1684 to 632 gC m^{-2} s^{-1} for rapeseed and sunflower crops, respectively. The LUE model generally fitted observed GPP 8-d satisfactorily (R^2 ranged from 79.1 to 90.9%). The ε_0 values obtained proved quite contrasting, ranging from 3.605 to 2.227 gC MJ^{-1} for sunflowers and peas, respectively, revealing the major influence of crop type as well as the prevailing general meteorological conditions.

-395 Land-ocean contrast of surface atmospheric CO2 as revealed by observations from Bay of Bengal

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Ship based observations of atmospheric carbon dioxide (CO2) concentration over the Bay of Bangal (region covers lat=11°:21°N,lon=79E:90°E) between 17-July-2009 to 17-Aug-2009 offered an excellent opportunity to evaluate the land-ocean contrast of surface CO2 and facilitated its comparison with a model simulated CO2 concentrations. Elevated values of CO2 with large variability near the coastal region and relatively low values with correspondingly lower variability over the open ocean suggest that this observed CO2 variability over the ocean essentially captures the differences in terrestrial and oceanic CO2 fluxes. Although the region under investigation is well known for its atmospheric intraseasonal oscillations during July and August, the limited duration of observations performed from a moving ship in a research cruise is not able to capture any high-frequency variability of atmospheric CO2 concentrations. But band passed SST and wind anomalies do indicate strong intraseasonal variability over the study region during the observational period. The synoptic data, albeit quite short in duration, thus offer a clear benchmark for abrupt variability of CO2 concentration between land and ocean.

-396 Variations in atmospheric Carbon Dioxide and its association with rainfall and vegetation over India

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

In this paper we have studied variability and growth rate of surface observed atmospheric Carbon Dioxide (CO2) concentrations over Cape Rama, west coast of India and its association with rainfall and vegetation over this region. Cape Rama is a maritime site experiences a seasonal reversal wind pattern receiving air masses having marine (continental) signatures during summer (winter) monsoon season. This study reveals that summer monsoon (JJAS) precipitation and monthly values of atmospheric CO2 concentration during the season are well correlated. Negative correlations are seen with CO2 concentrations of concurrent months of the season as well as subsequent months. However the magnitudes of correlation coefficients are decreased till hot pre-monsoon season (MAM). Annual cycle and interannual variability show negative relationship between CO2 concentration and vegetation over the region. CO2 concentration show increasing trend and NDVI show decreasing trend. However, the magnitude of increasing trend of CO2 concentration is higher. Amplitude of decreasing phase of vegetation is higher than the amplitude of increasing phase. Though the results show certain link between CO2 and climate variability, further examination with dense and longer data may be needed to confirm the result.

-397 Global patterns of net primary production: a model-based analysis

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Persistent divergences among the predictions of complex carbon cycle models include differences in the sign of the response of global terrestrial net primary production (NPP) to global warming, as well as the magnitude of the response of NPP to increasing [CO2]. This and other problems with current models, including those based on remote sensing, indicate a need to re-assess the principles underlying the environmental controls of primary production on land. We explored the global pattern of monthly and annual terrestrial NPP using a modification of the Simple Diagnostic Biosphere Model (SDBM). The SDBM is based on the concept of light use efficiency (LUE), and is driven by incident photosynthetically active radiation (PAR) and remotely sensed green vegetation cover, while taking into account drought effects on photosynthesis. Our modification derives LUE from ecophysiological principles, and accounts for the first-order effect of high temperatures in increasing photorespiratory carbon losses in C3 plants. Tropical moist forests present the highest annual NPP, but higher monthly NPP is predicted to occur during summer in forests of northern mid- to high-latitudes. This finding is consistent with a reported pattern in NPP measurements and provides a simple biophysical explanation for this pattern, based on the seasonal and latitudinal distribution of PAR combined with the physiology of photosynthesis. The model makes a number of ancillary predictions which should be testable using a combination of remotely sensed data, flux measurements and CO2 concentrations.

-398 Application of Carbon Tracking System based on ensemble Kalman filter for estimating the impact of nesting domain on carbon flux analysis in Asia

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Estimation of surface carbon fluxes is important to understand the mechanism of surface carbon source and sink. In Asia, a lot of anthropogenic CO2 emissions are occurred from large industrial area. There are also large uptake regions such as forests in boreal and temperate regions. However, inverse modeling studies focusing on Asia using advanced data assimilation systems are relatively rare. In this study, to investigate the effect of nesting domain on carbon flux analysis, two experiments with different nesting domain are conducted using the CarbonTracker developed by NOAA. The CarbonTracker is an inverse modeling system that estimates surface carbon fluxes using an ensemble Kalman filter with atmospheric CO2 measurements as a constraint. One experiment has a nesting domain centered in Asia (ASI experiment), and the other in North America (NAM experiment). Both experiments are conducted from January 2000 to December 2006.
In general, the results show that setting a nesting domain centered in Asia region enables detailed estimations of surface carbon fluxes in Asia. The annual averages and seasonal patterns of optimized biosphere fluxes of two experiments are similar, but the magnitude of optimized biosphere fluxes of two experiments is different. The magnitude of seasonal averaged optimized biosphere flux of ASI experiment is larger than that of NAM experiment. Weekly aggregated optimized fluxes over the Asia nesting domain in ASI experiment show more diverse patterns than that in NAM experiment, which implies that more detailed analysis of optimized surface carbon flux is available over Asia in ASI experiment. Compared with observations, the proper prior ensemble spreads are simulated in both experiments. Model CO2 concentration calculated by the optimized flux of ASI experiment is more consistent with observed CO2 concentrations in Asia. Finally, calculated background atmospheric CO2 concentration in Asia is more consistent with observed CO2 concentration in ASI experiment than that in NAM experiment.

-399 Belowground carbon status in vegetation restoration areas following landslide

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

This study was conducted to examine carbon (C) status following vegetation restoration in the landslide areas of UooMyeon (Mt.) in Seoul, Korea. The landslide occurred on July 27, 2011 and was one of the worst natural disasters in Korea. Eighteen restored and adjacent undamaged plots were chosen and carbon storage was measured. Carbon concentration and storage were significantly different between the undamaged and restored plots. Soil C concentration was significantly lower in the restored (2.13%) than in the undamaged (4.08%) plots. However, C storage at 15 cm of soil depth was not significantly different between the restored (16.3 Mg C/ha) and the undamaged (13.2 Mg C/ha) plots due to the difference of soil bulk density (restored: 1.14 g/cm3; undamaged: 0.87 g/cm3). The results indicated that soil C concentration following landslide could be declined in vegetation restored areas because of washing away of surface soil layer.

-400 Belowground carbon stocks of restored, unrestored and unburned forests in a fire-damaged landscape

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

This study was conducted to examine belowground carbon (C) status in restored plots by tree planting, un-restored plots, and unburned plots following forest fires of BongDae (Mt.) in Ulsan, Korea. This mountain was one of the frequent forest fire areas in Korea. Carbon concentration of soil and forest floor were the lowest in the unrestored (soil: 1.41%; forest floor: 38.1%), follow by restored (soil: 2.74%; forest floor: 40.3%) and the unburned (soil : 2.78%; forest floor: 48.9%) plots. Carbon storage at 15 cm of soil depth was not significantly different among the treatments (4.7-10.8 Mg C/ha). However, belowground C storage (forest floor and soil) was significantly higher in the unburned (20.2 Mg C/ha) than in the unrestored (8.7 Mg C/ha) plots due to the difference of C storage in forest floor (unburned: 9.3 Mg C /ha; restored: 3.69 Mg C/ha; unrestored: 2.89 Mg C/ha). The results indicate that belowground C reduction following forest fires was due to decreased C storage of forest floor.

-401 Carbon and nitrogen responses of foliage and litter fall following fertilizer application in a red pine stand

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

This study was to examine carbon (C) and nitrogen (N) responses of foliage and litter fall following fertilizer application in a red pine stand. Two types of fertilizer (N:P:K=113:150:37 kg/ha; P:K=150:37 kg/ha) were applied on late April 2011. Carbon and N responses of foliage and litter fall were monitored 3 times (July, September, November) after fertilizer application. Carbon concentration of foliage was little affected by fertilizer application compared with sampling month or needle age, while the NPK fertilizer produced high N concentration of foliage. Carbon and N concentrations of needle, branch and bark litter were not significantly different between the fertilized and the unfertilized plots during the three sampling times. However, the average N concentration of miscellaneous litter was significantly higher in the NPK fertilized (1.16%) than the PK fertilized (0.76%) or unfertilized (0.67%) plots. The results indicate that the C status in foliage and litter fall could be little affected, while N status was significantly changed following fertilizer application in a red pine stand.

-402 Evaluations of the spatial and temporal variations of biomass burning emissions in Southeast Asia during 2001-2010

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Carbon emissions from fire induced biomass burning contribute much of the interannual variability in global atmospheric carbon dioxide concentrations. Biomass burning in Southeast Asia (SEA) is a dominant contributor to the emissions due to the effects of El Nino induced drought and human deforestation. Yet our understanding of the spatial and temporal pattern and variability in fire carbon emissions of SEA is limited. In this study, the fire carbon emissions from biomass burning in SEA were analyzed from 2001 to 2010 with finer spatial resolution of 5 km, taking advantage of recently released satellite product and a physically process-based biosphere model (BEAMS) with fire carbon emissions process embedded. Three series of burned area data from MCD64A1, MCE45A1-Peat and GFED3 were employed to quantify fire carbon emissions. In general, the three different burned data displayed consistent temporal variations for 10 years with peak in 2004. And the average annual burned areas of MCD64A1, MCD45A1-Peat and GFED3 in SEA were 68,104 and 50,933 and 61,263 km2yr-1, respectively. Burned areas were predominantly concentrated in Myanmar, North Thailand, East Cambodia, North Laos in the northern SEA, while large differences also existed in the eastern SEA where peatland extensively distributed. MCD64A1 product and GFED3 burned area showed significantly much extensive burning in Sumatra and Kalimantan of Indonesia, where MCD45A1 missed a large number of forest fires probably due to the persistent cloud cover and smoke. By using peatland map, aerosol and land surface temperature, we improved burned area of MCD45A1 through integrating burned peatland in Indonesia (MCD45A1-Peat). Fire carbon emissions from the three simulations of BEAMS-MCD64A1, BEAMS-MCD45A1-Peat and BEAMS-GFED showed that they presented similar spatial patterns with burned area even though the magnitude of carbon emissions varied greatly greatly with average annual fire carbon emissions of 232.6, 214.1 and 228.8 TgC, comparable with GFED3 210.7 TgC. Compared with interannual variability in AOD, fire carbon emissions presented consistent temporal trend. During dry years of 2002, 2004, 2006 and 2009, we observed substantially higher value of AOD and they showed good consistency with fire carbon emissions and also the MEI (Multivariate ENSO index) during 2001 to 2010. It was attributable to the deep peat soil burning under the influence of El Niño phenomenon and Indian Ocean Dipole pattern in combination with human activities of deforestation for palm oil plantation production.

-403 Widespread of soil organic carbon accumulation on fertilized cropland: evidence from long-term experiments across China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Soil organic carbon (SOC) plays an important role in sustainable agriculture and climate mitigation. We studied SOC dynamics on China's cropland based on 25 Long-term experiments (LTEs) that were established 20-30 years ago. We analyzed SOC change rates in the top 20cm under three common fertilization treatments: mineral NPK, NPK fertilizer plus manure (NPKM), and NPK fertilizer plus straw (NPKS). On average, SOC increased by 0.13±0.13, 0.34±0.15 and 0.57±0.11 Mg C/ha/yr for NPK, NPKS and NPKM, respectively. The greatest increase for each treatment was found in north China for NPK (0.33 Mg C/ha/yr), Yangtze River basin for NPKS (0.49 Mg C /ha/yr), and north and northwest China for NPKM (0.69 Mg C/ha/yr). The smallest SOC increase occurs in northeast China for all the treatments (0.00, 0.19, 0.44 Mg C/ha/yr for NPK, NPKS and NPKM, respectively). Assuming that 50% of China's cropland, i.e., ~65 M ha, has been accumulating SOC at a rate similar to that under the NPK fertilization, total carbon sequestration as SOC on China's cropland would be 8.6 Tg C/yr over the past 2-3 decades. On the other hand, if NPKS fertilization is applied to 100% of China's cropland, total carbon sequestration may reach 44.5 Tg C/yr, which is about 1.7% of the global land carbon sink.

-404 A Process-Based Dryland Ecosystem Model for Central Asia

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The effect of the rapid climate change observed in recent decades on the carbon (C) dynamics of the Central Asian dryland remains unclear. The special root structure of desert plants, the non-uniform canopy structure of the dryland ecosystem, and the intensive root-water interaction in the groundwater-soil-plant continuum are important characteristics of dryland ecosystems that could affect the C and water processes in Central Asia. However, these characteristics of dryland ecosystems have not been adequately addressed by the current ecosystem models. In this study, a process-based Dryland Ecosystem Model (DEM) was developed to model plant and canopy structures and their effects on the coupled C and water processes in dryland ecosystems. In comparison to other models, the DEM includes an improved vertical root distribution submodel, a detailed mechanistic submodel for the root water uptake, a photodegradation submodel, and a plant form submodel that dynamically updates a plant' s aboveground structure and canopy coverage daily. The DEM was parameterized for the major plant functional types (PFTs) in Central Asia, and its performance was evaluated by conducting sensitivity analyses and model validations against field observations. The model accurately predicted the water and C pulses in response to abrupt precipitation events. The numerical experiments indicated that (1) Central Asian dryland ecosystems could respond promptly to changes in climate and groundwater fluctuation, and (2) different PFTs have different sensitivities to environmental changes because of their different plant structures and physiologies. This study showed that a process-based model, such as the DEM, can be useful in studying the complex interactions between plants and their water-stressed environment in the context of the rapid climate change in Central Asia.

-405 Estimation of methane emission from rice paddy soils in Japan by using the biosphere model, BEAMS-C

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

A rice paddy field has submerged unique processes under anaerobic condition, and emits not only carbon dioxide but also methane for irrigation period. Although the methane emission from paddy fields is small amounts comparing with carbon dioxide, many existing studies focused spatial and temporal changes in the methane emission. The reason is an impact of methane on global warming, namely the high radioactive forcing is about 21 times as much as CO2. In this study, we introduced the methane process into the existing biosphere model to more accurately figure out mechanisms of carbon cycle in rice paddies. The model used is the Biosphere model integrating Eco-physiological And Mechanistic approaches using Satellite data for regional Cropland (BEAMS-C) (Sasai et al., 2012).
We introduced three carbon processes: (1) methane production in the anaerobic soil by methanogens; (2) methane oxidation by the methanotrophs; and (3) the three pathways for methane emission. In order to confirm an accuracy of the improved BEAMS, I validated the model estimation at the Mase paddy flux site (MSE) (36°03'14.3"N, 140°01'36.9"E, 15m a.s.l.). Estimated methane emission, biomass, GPP, and NEP had good agreements with the measurements at MSE.
I estimated annual mean carbon exchange (=CO2+CH4), methane emission, NEP, and harvested biomass. The improved BEAMS operated with 1 km by 1 km resolution from January 2001 to December 2010. We used as model inputs satellite dataset (e.g., MODIS, ASTER, SRTM, and ALOS products). The spatial resolution is 1 km grid and the time step is daily. Total amount of the methane emission was 265.7 GgC/year, and the estimation was within reasonable range comparing with results of the previous studies. The methane emission depends on irrigation area in spring, because a methane gas is largely generated under anaerobic condition, and irrigated area is gradually increasing during June to July. In summer and autumn, the emission depended on the total amount of methane substrates generated from litter fall. Since artificially removing carbon biomass as harvest, rice paddies played a role of carbon sink for 10 years. The improved BEAMS-C could accurately estimate the methane emission by introducing paddy filed unique crop calendar and plant growth processes. As future work, we suggested a need to more accurately generate spatial distribution in crop calendar to apply my approach into rice paddy fields at global scale.

-406 Temporal variations in atmospheric CO_2 on Rishiri Island in 2006-2012

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Surface observations of atmospheric CO2 document the natural fluctuation of the carbon cycle. Rishiri Island (RIO, 45.10°N, 141.20°E) is the northernmost Japanese site measuring atmospheric compositions. Because Rishiri Island is located in the boundary region between the Eurasia continent and the west North Pacific, it is a site being co-influenced by both continental and maritime fetches. In comparison with remote sites, Rishiri Island is advantageous in catching regional atmospheric CO2 level in East Asia. Since 2006, in situ observation of atmospheric CO2 was commenced at this site. In association with the result of the simultaneous observation of radon-222 (222Rn) since 2009, we analyzed the six-years CO2 records for the temporal variations from diurnal to interannual scales. The factors that contribute to the variations were investigated.
It was found that there was an obvious diurnal cycle in summer months affected by local vegetation and meteorology. After removing local influences through data selection, the time series analysis of CO2 record was conducted to extract the seasonal cycle and long-term trend. The peak-to-trough amplitude was investigated with a focus on the interannual variation. For the obtained amplitude, it showed a typical mean magnitude of 19.9 ppm, with the seasonal maximum appeared around the beginning of April and minimum around the beginning of August. The amplitude increased from 2006 to 2009 and decreased thereafter until 2012. This variation was affected by temperature in a region around 40–60°N, 90–150°E in East Asia through affecting the seasonal maximum with a time lag of 1–2 years. Interannual variations of 222Rn indicated that the circulation changes were also likely contributing to decreasing amplitude in 2009–2012.
These findings on the interannual variation of CO2 amplitude imply the changes of carbon sources and sinks in East Asia. Although further investigations on the interactions among climate, ecosystem and atmosphere are needed, the study provided robust information for regional carbon budget estimation when we will compare with other approaches such as inversions and flux network observations.

-407 A new data assimilation approach for estimating surface carbon flux distribution

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

We proposed an approach of assimilating CO2 atmospheric abundance data into an ecosystem model (Boreal Ecosystem Productivity Simulator, BEPS) for estimating surface carbon flux distribution. This assimilation approach is still based on ensemble transform Kalman filter, but with several new modifications, including using analysis states to construct ensemble forecast error, a maximum likelihood estimation of inflation factor of the ensemble forecast error, and an ensemble-based estimation of observation error covariance matrix, etc.

The proposed assimilation approach is then applied to estimate terrestrial ecosystem carbon flux distribution for time period of 2002 to 2008. The results showed that this assimilation approach can effectively reduce bias and uncertainties of carbon fluxes modeled by ecosystem model.

-408 CO2 dynamics of seawater in the seasonal ice zone

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The oceanic observations for the partial pressure of CO2 (pCO2) in the surface water and the vertical profile of the carbonate systems were performed in the Indian sector of the Southern Ocean (64–67oS, 33–56oE) in January 2006 to understand spatial and temporal CO2 dynamics of seawater in the seasonal ice zone (SIZ). The pCO2 in the surface water were from 275 to 400 µatm, and there were longitudinal variations dominated by the change of the water temperature and the dilution by sea ice melt water in the area of 33–40oE and by the biological productivity in the area of 40–56oE. Based on the data from the vertical profiles of the carbonate system parameter in the temperature minimum layer, the winter to summer evolution of the pCO2 in the surface water was examined. Results indicated that the seasonal increase of the pCO2 in the surface water was mainly demonstrated by the increase in the water temperature during the winter to summer period while the subsequent biological productivity likely led to decrease the pCO2 in the surface water in SIZ.

-409 Climate Change Scenarios over Bangladesh using a high resolution AGCM

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Rainfall and mean surface air temperature were simulated using Meteorological Research Institute (MRI) global 20-km mesh Atmospheric General Circulation Model (AGCM), called MRI-AGCM. Through calibration and validation the MRI-AGCM was adapted for Bangladesh for generating rainfall and temperature scenarios. The model generated rainfall was calibrated with ground-based observed data in Bangladesh during the period of 1979-2006. The Climate Research Unit (CRU) data is also used for understanding of the model performance. Better performance of MRI-AGCM obtained through validation process made confidence in utilizing it in the future rainfall projection for Bangladesh. Rainfall and mean surface air temperature projection for Bangladesh is experimentally obtained for the period of 2075-2099. This work finds that the MRI-AGCM simulated rainfall and temperature are not directly useful in application purpose. However, after validation and calibration, acceptable performance is obtained in estimating annual rainfall and mean surface air temperature in Bangladesh. Change of rainfall is projected about 0.64 % in Monsoon season (JJAS), 1.90 % in Post-monsoon season (ON) and 13.46 % in winter season (DJF) during the period of 2075-2099. Similarly, change of mean surface air temperature is projected about 2.5 degrees Celsius for the same period.

Key words: Rainfall, temperature, forecast, climate change, simulation.

-410 Refined Estimate of China's CO2 Emissions: Provincial Inventory and Spatiotemporal Distributions

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Recent studies revealed that potential large uncertainty associated with estimates of the world's largest Chinese national emission, which need to be accurately estimated for analyses of carbon balance, future climate projection and carbon management. Here we calculated China's provincial CO2 emissions from fossil fuel use and industrial processes on monthly basis and then mapped those emissions at 0.25o resolution. Emissions from large point sources were independently calculated and allocated to grids using accurate geographical locations. Monthly temporal variations of emissions from various sectors for each province were also estimated. Our Chinese national total CO2 emission from fossil fuel and industrial process was 8.6 billion tones in 2009, which is 2.4 times that in 2000. China's CO2 emissions were estimated to increase in most geographical cells from 2000 to 2009 and great differences between our emissions inventory and other studies' in the spatial distributions were found and analyzed. The grids with higher emission intensities and more rapidly increasing emissions are mostly located in the eastern area, where there have already existed higher GDP densities, higher emissions or more large point sources. Summer usually contributes over 25% of annual CO2 emissions from electricity generation for most provinces in China; however, the situations reverse in some provinces with larger proportions of hydropower.

-411 Determination of aboveground biomass in a Brazilian subtropical forest

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Aboveground forest biomass determination is a key parameter in current carbon sink and dynamics studies. Several models based on empirical and radiative transfer models are highlighted in the literature. However, the absolute determination of forest biomass with field inspection is central in the calibration and validation stage. In this work we aimed to quantify the aboveground biomass in a subtropical forest located at near the confluence of the Rivers Uruguay and Várzea (centered at coordinates of S 27°13’ 35”; W 53°18’ 59”), in South of Brazil. Four field plots with 12 x 12 m were installed and all the vegetation was weighed according a vertical stratification, as follows: Stratum one (E1) comprising all living plants up to 1.3 m in height; Stratum two (E2) all plants with more than 1.3 m in height and diameter at breast height (DBH) up to 5 cm; Stratum three (E3) plants with DBH between 5 and 10 cm, and; Stratum four (E4) all plants (trees) with DBH greater than 10 cm. In the E4 the biomass was classified in: trunk, thick branches, twigs, bark, leaves and miscellanea (lianas, bromeliads, lichens, etc. over de tree) weight. The E3 and E2 were classified in wood and leaves. All the material was thoroughly weighed in field. The samples were dried at 60° until constant weight. Results showed that in the E4 were founded 33 trees encompassing 16 species. For E2 were found 25 trees and bushes from 11 species, and in E3 were quantified 62 plants from 29 species. The total aboveground biomass of all stratum was 497.6 Mg.ha-1, allocated as follows: E1=1.2; E2=11.2; E3=35.5 and E4=431.7 Mg.ha-1, respectively. Trees with the DBH greater than 10 cm were the most important biomass and, consequently, the major carbon reservoir in this kind of forest. Moreover, the miscellanea (all living plants over de tree) is almost six times de leaves weight, and almost equal to the twigs weight. Models based in biophysical parameters such as leaf area index (LAI) should to consider influence of miscellanea as a major change source of this kind of forest. Another important point relies on the absence of trunk holes simulation in several carbon estimation models. With this work we intended to help to supply the lag of validation data to regional and global carbon estimation models.

-412 A compact instrument for measuring atmospheric CO2 column densities at surface monitoring sites

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

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A fiber etalon spectrometer for optical column measurement of atmospheric carbon dioxide (FES-C) monitoring the CO2 absorption in the near infrared region has been examined for its applicability in the field measurement. This commercially available FES-C instrument employed here costs low and is compact, portable and easy to use.
Wilson et al. (2007) have reported that a Fabry-Perot interferometer made of a quartz plate has a high enough spectral resolution for resolving the rotational photoabsorption lines centred at 1575 nm to measure the CO2 column density. A prototype instrument presented by them was composed of a solid etalon. Our fiber Fabry-Perot interferometer (fFPi) has the same optical features with the solid one. The fFPi instrument assembled by fiber optics that have been developed for use in telecommunication industry is essentially optical alignment-free, compact, easy to set up and strong against shock. (Kobayashi et al., 2010) Since the fFPi has a small heat capacity, its transmission wavelength or spectral shift quickly responds to its temperature change, and hence the time interval for measurement is less than 40 s. Bailey (2013) reported recently another type of a Fabry-Perot interferometer for the CO2 column measurement.
A small fiber collimator for our FES-C is installed on a sun tracker. The sunlight collimated onto a single-mode optical fiber is filtered by a combination of a long-pass and a narrow-band filters, which was transmitted into the FES-C analyser, in which photoabsorption intensity by the fFPi and solar reference signal intensity are measured by near infrared detectors.
In the present paper, we will report the results of field performance tests at Tsukuba, Tokushima and Isezaki in Japan, Wollongong in Australia, Xilinhoto in Inner Mongolia of China, and Kalimantan provinces of the Borneo Island in Indonesia.
We thank Profs. Osaki and Hirano of Hokkaido Univ., and JST and JICA programs for partial financial support.
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-413 Remote sensing of carbon dioxide to evaluate the carbon dioxide emission from forest/peat-land fires

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

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The evaluation of CO2 emission especially from peat-land is one of key issues of the MRV (Measurement, Reporting and Verification) activity. In MRV, however, since the surface temperature of peat-land fire is not high enough, peat-land fire is frequently discounted in fire hot-spot data. The amount of carbon loss or CO2 emission is difficult to estimate from the carbon stock change because it is accompanied by in-homogeneous and small subsidence. In addition, the loss of peat-land area occurs underground in some cases. In solving this problem, the loss estimation from the flux observation has an advantage over the stock-change measurement.

The flux observation over forest is usually conducted by flux tower measurement (Eddy covariance method) for carbon budget of ecosystem that includes tree and soil processes. However, this measurement is limited only to the homogeneous process, which is not the case to tropical peat-land fire.

The CO2 flux from fire can be measured by observing CO2 concentration increment and wind speed surrounding the area of interest. The remote measurement of CO2 column density (integrated CO2 amount from surface to the space) can be done either from space by a satellite or from ground by a monitoring site that observes the direct solar spectrum. The authors have developed a fully automated optical fiber system to observe CO2 emission continuously.1,2 Two instruments were separately installed at Banjar Baru and Palangka Raya of Kalimantan provinces of Indonesia in Aug.-Oct., 2011 to measure the CO2 concentration difference between the south/north sites and its diurnal variability by fires. Details of the results will be discussed.

Observation of CO could a useful tool to identify surface fire from underground fire. Preliminary campaing was successfully done at Palangka Raya during the large-scale forest/peat-land fire season.

A part of these results have been reported in SPIE NEWSroom (2013) and "Climate Exchange", (WMO, Tudor Rose Publication, 2012).

We thank financial supports from JST and GRENE-ei.

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1. N. Kobayashi et al., Remotely operable compact instruments for measuring atmospheric CO2 column densities at surface monitoring sites, Atm. Measure. Tech., 3, p. 1103, 2010, doi:10.5194/amt-4-1103-2010
2. A portable instrument is commercially available as model FES-C from Meisei Electronic Co. Ltd., Isesaki 372-8585, Japan

-414 Observed trends of carbon storage, acidification and calcium carbonate saturation along the OVIDE section

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Poster

Key word:

The biannual occupations of the Greenland-Portugal OVIDE section (2002-2012) offer a unique opportunity to quantify the acidification rates and verify its impacts into the calcium carbonate saturation and alkalinity. Ocean acidification due to the uptake of a large fraction of the carbon dioxide (CO2) that is released to the atmosphere by mankind was predicted by models, which have also shown that this acidification is likely to impact calcification rates and predict trends of increase in total alkalinity (AT).
In this work, the period of time of the Pérez et al. (2010) study of the anthropogenic CO2 (CANT) storage rates in the North Atlantic is extended until 2012. The study area is divided in 3 basins: Irminger, Iceland and Eastern North Atlantic (ENA). To evaluate how the acidification affect the alkalinity and aragonite saturation trends in the main water masses, water column was divided into 5 layers delimited by density for each region. To determine those boundaries we follow the limits suggested in several works.
During the first half of the 1990s, when a high North Atlantic Oscillation (NAO) phase was dominant, the CANT storage rates in the North Atlantic subpolar gyre were ~48% higher than during the 1997-2006 low NAO phase that followed. The observed CANT storages are increasing during the OVIDE period (2002-2012), reaching similar rates that those observed during early 90' s.
Taking into account the acidification rates, this study suggests a general decrease of them from Irminger to ENA basin. For instance, the upper ENA basin layer also shows medium acidification rates, while they are non-significant for the deeper layers. The data set shows a positive trend in AT for subsurface North Atlantic waters of 0.27±0.11 μmol·kg-1·y-1 between 1981 and 2012. Models predict that the signal of the increase of alkalinity due to impact of anthropogenic CO2 on the CaCO3 pump would be detectable by 2040 in tropical and subtropical regions.
In addition, the saturation estate of CaCO3 in term of aragonite (ΩArag) shows significant negative trends in all water mass except in deep water masses. Typical negative trends of -1.5 to -3·10-3 y-1 are observed in intermediated waters which correspond with an upward migration of 5-12 m y-1 in the saturation horizons.

-415 Eco-restoration and development of silvopastoral systems: the potential land use options for carbon sequestration

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Atmospheric CO_2 concentrations have increased considerably since 18th century (280 ppm to 391 ppm) mostly due to fossil fuel combustion, industry, deforestation, land clearing and agriculture. Out of the total CO_2 emission almost half of it accumulates in the atmosphere and rest is absorbed by sinks in the ocean and in the terrestrial ecosystems. Developing the low cost methods to sequester carbon is emerging as major areas in the context of global climate change. Improving the processes that accumulate and store carbon should be cost-effective to reduce atmospheric CO_2. Fixation of CO_2 and its accumulation in the terrestrial biosphere can be one of the options to compensate CO_2 emissions. There is sufficient evidence to suggest that land use systems such as agroforestry, intercropping, multi-cropping, lay farming, mixed croping, perennial pasture crops and mulching promote carbon accumulation and sequestration in the vegetative biomass and soil. It has been estimated that the rates of C sequestration is very high through development of silvopasture in the carbon depleted soils because of diverse plant composition and growth forms, enhancing productivity and ability to accumulate and retain carbon stocks in the soil and in vegetation. It has also been estimated that carbon in the subsoil is more stable than in the top soil. Estimation of soil carbon pool and its changes is very important to assess the carbon foot print and the carbon efflux and influx and its sequestration and stabilization in the soils. In hot arid region, organic carbon up to 60 cm deep soil profile was estimated to be about 33.4 Mg C/ha in long term average rainfall of 598 mm/yr. It decreased to 7.4 Mg C/ha in areas having much low rainfalls (average rainfall of 157 mm/yr), indicate long term rainfall is the major influencing factor for carbon stabilization under arid environment.

In different silvopastoral systems under degraded soils in semi-arid tropics of India (average rainfall of >700 mm), the total carbon stock was in the range of 33.77 Mg C/ha to 45.27 Mg C/ha at the age of ten years growth. In one of such study the organic carbon stock of soil increased in the range of 3.39 Mg C/ha to 5.40 Mg C/ha and the carbon sequestration in vegetation has been recorded as 10.23 Mg C/ha to 41.00 Mg C/ha under different pasture and tree-crop combinations in four years. The total carbon sequestration in vegetation+soil under different trees+pasture grasses+legume ranged from 13.49 t CO_2e/ha/yr to 42.25 t CO_2e/ha/yr. Under improved perennial pasture systems, the intercropping of Cenchrus ciliaris+Stylosanthes hamata and Panicum maximum+S. hamata carbon sequestration was 17.27 t CO_2e/ha/yr and 25.10 t CO_2e/ha/yr in above ground vegetative and below ground biomass/soil, respectively. These combinations were evaluted under elevated CO_2 (600±50ppm) in OTC and sequestered 41.67 t CO_2e/ha/yr and 46.47 t CO_2e/ha/yr, respectively exibited their potential to fix the atmospheric CO_2. The findings suggest that integration of grasses and legumes with trees is a potentially viable land use option for mitigation of elevated atmospheric CO_2 and maximization of carbon sequestration. Therefore, restoring of carbon should be the priority in rangelands/wastelands development through promoting appropriate silvopasture systems.

-416 The impact of nitrogen and phosphorous limitation on the estimated terrestrial carbon balance and warming of land use change over the last 150 years

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

We examine the impact of land use and land cover change over the period from 1850 to 2005 using an Earth System Model that incorporates nitrogen and phosphorous limitation on the terrestrial carbon cycle. We compared the estimated CO2 emission and warming from land use change over the period 1850 to 2005 in a carbon only version of the model with those from the simulation including nitrogen and phosphorous limitation. If we omit nutrients, our results suggest LULCC cools on the global average by about 0.1oC. Including nutrients reduces this cooling to ~0.05oC. In terms of the impact of LULCC on the terrestrial carbon balance, our results suggest LULCC has a major impact on total land carbon over the period 1850-2005. In carbon only simulations, the inclusion of LULCC decreases the total land carbon stored in 2005 from around 210 Pg C to 80 Pg C. However, including nutrient limitation significantly decreases the scale of the terrestrial carbon sink to ~80 Pg C. Adding LULCC on top of the nutrient limited simulations changes the sign of the terrestrial carbon flux from a sink (80 Pg C) to a source (~10 Pg C). We suggest that this has important implications for examining the impact of LULCC on the historical period; simulations of LULCC in a non-nutrient limited system will be dominated by the CO2-fertilization effect and excess uptake of CO2 by the biosphere. Including nutrients reduces the efficiency of CO2 fertilization allowing the effects of LULCC to be more accurately determined.

-417 Atmospheric inversion of the European CO2 ecosystem fluxes: evaluation of the uncertainty estimates

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

We study the Bayesian estimate of the uncertainties in the statistical inversion of the Net Ecosystem Exchange (NEE) of CO2 in Europe. This inversion is based on the assimilation of in situ CO2 atmospheric concentration measurements in a regional atmospheric transport model. Comparisons between the prior knowledge about the fluxes from an ecosystem model (respectively the inverted NEE) and the monthly averages of independent eddy covariance measurements give confidence in the theoretical estimates of prior (respectively posterior) uncertainties from the inversion at monthly/European scale. The uncertainties at the monthly scale are significantly smaller than the seasonal variations, which leads to a robust assessment on the seasonal cycle of the NEE. However, the inversion has difficulties to retrieve robust information on the inter-annual variations since these variations are smaller than the posterior uncertainties. Theoretical estimates of uncertainties are also derived for different future configurations of the extension of in situ networks and with different assumptions on the atmospheric transport errors and prior uncertainties in order to study the sensitivity to future improvements in the models and observation networks.

-418 Interdecadal carbon uptake variability in the southern subtropical Indian Ocean

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

Atmospheric CO2 sinks in the southern Indian Ocean was examined for their seasonal, interannual and inter-decadal variability. Two distinct zones of CO2 uptake are identified; located in the 150S–350S band is the northern box where CO2 uptake is dominated by the solubility pump and in the latitudinal range of 350S–500S is the southern box where both the solubility and biological pump are equal players. The anthropogenic CO2 inventories appear to be a result of deepening subduction of CO2 and subsequent invasion into the northern domain. The seasonal and interannual variability of CO2 sinks to the north are rather surface trapped, while the deep CO2 variability is found to be coherent with the atmospheric forcing, consistent with decadal wind stress curl anomalies. This is a step towards separating the secular trends of deep ocean CO2 from its natural variability in the analysis region. The details of the results can be found in Valsala et al., Geophysical Research Letters, 39, L17605, doi:10.1029/2012GL052857.

-419 Intraseasonal variability of terrestrial biospheric CO2 fluxes over India during summer monsoons.

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

The intraseasonal oscillations (ISO) in terrestrial biospheric fluxes of carbon dioxide (CO2) over the Indian subcontinent were investigated for the summer monsoon season from June to September. We utilized two optimized datasets of Net Ecosystem Exchange (NEE) fluxes of CO2 at a spatial resolution of 10x10 grids and at daily time-scale for the years 2000 to 2009. Seasonally, over the whole of Indian subcontinent, terrestrial biospheric CO2 fluxes were found to be a net source (sink) during June and July (August and September). Intraseasonal variability of CO2 fluxes for the two distinct time-scales, 30-60 days and 10-20 days, was extracted with a spectral harmonic filter. The dominant ISO mode in the CO2 flux over India is at a period of 60-days or longer during weak monsoons years but at 10-30 days for strong monsoon years. The ISOs of CO2 flux show coherent structures along with corresponding rainfall ISOs at a 2-3 day lag (CO2 lags rainfall) and nearly 3-4 day lag with ISOs in surface air-temperature (CO2 lags air-temperature). The ranges of these lags are consistent in the two data products examined here. The apparent lags between CO2 flux and rainfall ISOs are found to be induced by the temperature effects on net primary production (NPP) and ecosystem respiration (RE). The terrestrial biospheric fluxes over the subcontinent are coherent with the northward propagating summer monsoon ISOs albeit as a combination of rainfall, available radiation and air-temperature. The study offers a mechanistic understanding of variability of terrestrial biospheric sources and sinks of CO2 over the Indian subcontinent, in tandem with the intraseasonal variability of the summer monsoon rainfall. Details of the results can be found in Valsala et al., 2013, Journal of Geophysical Research-Biogeosciences, DOI: 10.1002/jgrg.20037

-420 GLOBAL TRENDS IN SURFACE OCEAN pCO2 FROM IN-SITU DATA

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

To understand how the ocean carbon sink has responded to climate variability and climate change in recent decades, trends in globally observed surface ocean partial pressure of CO2 (pCO2s.ocean) are evaluated over sixteen gyre-scale biomes that cover 96% of the total ocean area. Trends across a range of decadal to multi-decadal timescales between 1981-2010 are considered. Previous studies [e.g. Metzl et al., 2010; Schuster et al., 2009; Le Quéré et al., 2009] have interpreted pCO2s.ocean trends steeper than pCO2atm trends as indicative of a reduction in the ocean carbon sink. However, this interpretation has not accounted for the fact that pCO2s.ocean not only drives the CO2 sink (via ΔpCO2), but that it also responds to the air-sea CO2 flux. Further, both warming and carbon uptake can drive change in pCO2s.ocean. We use an empirical decomposition of biogeochemical and temperature influences on pCO2s.ocean to evaluate change in the CO2 sink.

In the Southern Ocean, the influence of a positive SAM has waned and the carbon sink has strengthened since the early 2000s. In the North Atlantic subtropical and equatorial biomes, warming has become a significant and persistent contributor to the observed increase in pCO2s.ocean since the mid-2000s. These influences are consistent with model-based analysis of the response of the ocean carbon cycle to observed warming in recent decades [Le Quéré et al., 2010], earlier idealized predictions [Sarmiento & Le Quéré, 1996], and projections with coupled carbon-climate models [Roy et al., 2011]. This long-term warming is beginning to reduce ocean carbon uptake. In other biomes on decadal timescales, pCO2s.ocean trends have been of variable magnitude in comparison to trends in pCO2atm and quite sensitive to the selection of start and end years.

In only a few regions of the ocean are data sufficient to clearly reveal the ocean's long-term response to anthropogenic CO2 loading in the atmosphere. Future work with the extended SOCAT dataset should improve this situation. From the data currently available, evidence for substantial interannual to multi-decadal timescale variability is ample, with pCO2s.ocean trends shallower, parallel and steeper than atmospheric trends all appearing. This is consistent with shorter-term variability in physics and biogeochemistry. However, for the longest timescale trends are considered, we find only pCO2s.ocean trends parallel to or shallower than pCO2atm trends, which is consistent with a long-term response to the growth in pCO2atm that is, in some regions, damped by ventilation of low-anthropogenic carbon waters from the abyss.

-421 Changes in carbon sequestration and soil organic matter stability induced by cropland withdrawal in Russia after 1990

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The land use system in Russia changed considerably after Soviet Union dissolution in the end of XX century: more than 45 million ha of arable lands (or 23% of the agricultural area) were spontaneously withdrawn owing to collective farming system collapse. In this study, we firstly assess the shift of total soil organic carbon (SOC) pool according to these radical land use changes (LUC). For that, we compiled the available literature data reporting the organic C build-up in Russian soils after conversion of cropland to natural vegetation and carried out our own investigations in different regions of European Russia, where representative soil types exposed to the natural post-agrogenic evolution. Using different methodological approaches (approximation and soil-GIS), we calculated the total C sequestration due to the LUC in Russian soils after 1990. The second aim was to quantify the changes in quality of soil organic matter (SOM) sequestered after croplands withdrawal depending on the bio-climatic regions and period after LUC. For this, three representative chronosequences in southern taiga (Albeluvisols), deciduous forest (Luvic Phaeozems), and steppe (Haplic Chernozems) areas were selected. Each chronosequence included arable soil and post-agrogenic soils after different period of LUC. Soil organic matter (SOM) quality was characterized by 13C CP-MAS NMR spectroscopy, differential scanning calorimetry, thermogravimetric, and bio-kinetic methods.
We found an average C accumulation rate of 1.05 ± 0.10 Mg C ha-1 yr-1 in the upper 20 cm of soils for the first 20 years and 0.17 Mg C ha-1 yr-1 during the next 30 years of post-agrogenic evolution. The C accumulation rate, however, significantly differed between soil groups: it was the highest in Chernozems (1.50±0.29 Mg C ha-1 yr-1) and the lowest in Albeluvisols (0.57 ± 0.14 Mg C ha-1 yr-1). The abandoned soils in the Russian Federation provided an additional, previously underestimated, C sequestration at a rate of 47±3 Tg C yr-1 in the upper 20 cm of mineral soils over the period 1990-2009 and about 7.7 Tg C yr-1 after 2010. This sequestered soil C forms net biome production and contributes significantly to climate change mitigation.
Although all SOM compounds increased in abundance after the LUC, the resulting SOM (in the end stage of chronosequences) was more stable (higher aromaticity, increased C/N, higher T50, and lower C labile) than the original arable soil. This implied longer turnover times for the SOM, which contributed to the long-term C sequestration after conversion of arable areas to natural vegetation in main bio-climatic regions of Russia.
This study was supported of RFBR, NSch-6620.2012.4, and Program of Presidium RAS #4.

-422 Vulnerability of carbon cycle in various ecosystems of Central Russia to heat waves and droughts

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

The likelihood of heat waves, droughts, and flooding events increases according to predictions based on global warming for the 21st century. Under some scenarios, regional climate projections show the amplification of drier conditions over most of European Russia and South Europe, Asian and Northern American countries. The repeatability of soil droughts in these regions will increase due to the air temperature rise and the decline in soil moisture during spring and summer. This study was aimed to assess the effect of current climatic changes on carbon cycle in various ecosystems of Central Russia over the seasonal and annual time scales.

Based on observations provided by the Russian meteorological network, we carried out the analysis of medium (28-yr; 1973-2010) and short (14-yr; 1998-2012) climatic trends and estimated weather anomalies for Central Federal district of Russia and for Moscow region (54o20-55'N, 37o34-37'E) where the plots for carbon balance observation were located. The long-term soil CO2 emission (Esoil) monitoring was conducted weekly through the period 1998-2012 in 5 ecosystems which were differed in land use (forest, grassland, and cropland) and soil type (sandy Albeluvisols and loamy Phaeozems). The normalized difference vegetation index (NDVI) was used as net primary production (NPP) predictor for the same period (weekly resolution).

Our calculations showed more significant increase of aridity during the last 14 yrs in comparison to the 28-yr period both for Central Russia and for area studied. Through the period 1998-2012, every fourth year was found to be extremely dry. The summer 2010 heat wave in Central Russia was the warmest and the longest for the last 3 decades. The enhancement of aridity in the studied area evoked the negative trends of Esoil which were more significant in sandy soils in comparison with loamy ones and in agroecosystems versus natural cenosis. The mean summer NDVI value in natural ecosystems also demonstrated the negative tendency for the same time period. The coupled summer heat waves and strong deficit of precipitation induced the negative anomalies of Esoil and mean summer NDVI. Over the seasonal and annual time scales, the Esoil anomalies were higher than negative NDVI (NPP) anomalies.

The analysis fulfilled allows us to conclude that the observed enhancement of climate aridity in Central Russia may lead to the increase of C sink in ecosystems due to the decline in Esoil being more significant than the decrease in NPP values. The soil texture and the land use are the main underlying drivers governing the vulnerability of carbon cycle in temperate ecosystems to the current climate changes.

This study was supported of RFBR, NSch-6620.2012.4, and Program of Presidium RAS #4.

-423 The Causes and Implications of Persistent Atmospheric Carbon Dioxide Biases in Earth System Models

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Increasing atmospheric carbon dioxide (CO2) concentrations, resulting from anthropogenic perturbation of the global carbon cycle, are altering the Earth's climate. The strength of feedbacks between a changing climate and future CO2 concentrations are highly uncertain and difficult to predict using Earth System Models (ESMs). To reduce the range of uncertainty in climate predictions, model representation of feedbacks must be improved through comparisons with contemporary observations. In this study, the historical and future emissions-driven simulation results produced by 12 ESMs for the fifth phase of the Coupled Model Intercomparison Project (CMIP5) were analyzed. This analysis focused on simulations from fully coupled ESMs with interactive terrestrial and marine biogeochemistry models for the historical period and future period change based on the RCP 8.5 scenario. These simulations were forced with CO2 emissions, with global atmospheric CO2 mole fractions computed prognostically from atmospheric transport of these emissions, and interactions with ocean and land processes. The ability of models to accurately reproduce the observed atmospheric CO2 mole fraction trajectory over the historical period provides a broad indication of model fidelity, a necessary but not sufficient condition for credible ESM performance. Comparison of ESM prognostic atmospheric CO2 over the historical period with observations indicates that ESMs, on average, had a high bias in their predictions of contemporary atmospheric CO2. A key driver of this persistent bias was weak ocean carbon uptake exhibited by the majority of ESMs, based on comparisons with observationally-based estimates of ocean carbon inventories from Sabine et al. (2004) and Khatiwala et al. (2009, 2012). The high atmospheric CO2 bias for the multi-model mean produced radiative forcing that was too large and, therefore, unrealistically high temperature increases during the historical period. A significant linear relationship was found between the magnitude of the contemporary atmospheric CO2 biases and future CO2 levels for the multi-model ensemble. This relationship was exploited to create a contemporary CO2 tuned model (CCTM) estimate of the atmospheric CO2 trajectory for the 21st century. This approach reduced the spread of future atmospheric CO2 projections for the RCP 8.5 scenario and yielded radiative forcing and temperature increases during the middle of the 21st century that were lower than the multi-model mean. Our approach and results suggest that because many of the processes that contribute to contemporary carbon cycle biases persist over decadal timescales, uncertainties in future climate scenarios can be significantly reduced by tuning models to the long-term time series of CO2 obtained from Mauna Loa and other atmospheric monitoring stations.

-424 Management effects on GHG exchanges in a boreal forest

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Silvicultural measures are expected to have substantial impact on the exchange of greenhouse gases between forest and atmosphere. In the boreal region, harvest by clear-cutting is the most commonly used method. In Sweden for example, about 200 000 ha is cleared every year. The clear-cut harvest means that the forest is transformed from a closed canopy with a leaf area index of about 5-6 to an area without any photo-synthesizing and transpiring leaves at all, and this will naturally have a dramatic impact on the exchanges of matter and energy. In this study we measured the fluxes of CO2, CH4, N2O, H2O and energy from a recently harvested mature mixed pine and spruce forest located in central Sweden. Fluxes were measured from four sub-plots pairwise dry/wet and one pair with the normal soil scarification and one pair with stump harvest and soil scarification. The first year after clear-cutting showed large emissions of CO2 and CH4 and also small emissions of N2O. There was a clear difference between wet and dry areas with the wet areas showing less CO2 emissions than the dry ones while it was the opposite for CH4. For N2O there was no consistent difference between dry and wet areas although all areas emitted N2O. One explanation for the CH4 emissions is that the evaporation from the clear-cut is much smaller as compared to the standing forest meaning that the ground water table raises and this promotes CH4 emissions. Calculating the CO2 equivalent emissions based on 25-year GWP, show that the first year emissions were in the order of 25-30 t CO2 ha-1yr-1. Based on a previous study that showed that the emissions decreased to about zero after 10-15 years, it was calculated that the emissions from Swedish clear-cuts was in the order of 15-25 Mt CO2 yr-1 which corresponds to 25-40% of Sweden's total emissions. In spite of this, Sweden's forests in total constitute a large sink of CO2 but our results show that there might be room for improvement of the sink capacity provided the emissions from the clear-cuts can be reduced by other silvicultural measures.

-425 Global Hourly Simulation of Atmosphere-Land CO2 Exchange with a Process-based Model, VISIT

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Terrestrial ecosystems exert strong influences on the atmospheric CO2 concentration spatially at leaf- to global-scale and temporally at instantaneous to geological time periods. Current global simulations with terrestrial carbon cycle models are performed typically with half-degree mesh and daily or monthly time step, making it difficult to capture fine variations in the terrestrial CO2 exchange. Temporally, few studies have attempted to conduct global simulations at sub-daily time-step: e.g., CASA and SiB3 for the TransCom. Apparently, there were limitations of the availability of forcing meteorological data and computational ability to conduct huge simulations. Now, these limitations have been gradually reduced, such that more and more powerful computers and data storage are available. While the previous studies used interpolated meteorological data and satellite-derived vegetation parameters, we are able to access hourly-analyzed data and to conduct direct simulations with terrestrial biosphere models.

We conduct global simulations with a terrestrial ecosystem model, VISIT (Vegetation Integrative SImulator for Trace gases), driven by an hourly surface meteorological fields of the Climate Forecast System Reanalysis (CFSR) by the NOAA and NCEP. The data covers the period 1979–2010 with T382 Gaussian grid. The VISIT is a process-based model of terrestrial carbon and nitrogen biogeochemical cycles, and has been applied to point- to global-scale simulations. Because of compromise between accuracy and computational cost, sub-daily simulations have been conducted only at the point-scale (i.e., at FluxNet sites). In this study, we attempt to run the model at an hourly time-step with the CFSR data, enabling us to capture fine variations in photosynthetic assimilation, respiratory emission, and net exchange of CO2 at the land surface. Vegetation distribution and soil properties were obtained from the MODIS land-cover map and Harmonized World Soil Database, respectively.

In the simulated land–atmosphere CO2 exchange field, we see fine spatial and temporal variations caused by orbital solar radiation change, cloud cover, and surface temperature and moisture conditions. At selected point where in situ flux measurement data are available, we make comparison between the simulated and observed CO2 exchange, paying attention to scale-gap between the global model and tower-based micrometeorological observation. Furthermore, the simulated terrestrial CO2 fluxes have the highest resolution to date in the context of combined spatial and temporal fineness, and would be used by atmospheric transport models for forward and inversion estimations.

-426 Carbon transfers between ocean surface and interior: physical pathways

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The physical processes which induce carbon fluxes across the mixed-layer, i.e. carbon subduction and obduction, have received much less attention than biological processes although they are key components of the surface ocean carbon budget. We examine and quantify the different processes leading to carbon transfers (advection, eddy mixing, vertical mixing) and compare them to other forms of carbon transfers across the ocean surface boundary such as air-sea CO2 flux and sedimentation of biogenic material. This is done from a joint data/model analysis of the pre-industrial ocean.
We find that physical carbon transfers vary significantly over the globe.
Physical transfers of organic carbon represent between 20 and 40% of total organic carbon export from the surface.
We also emphasize that physical transfers of inorganic carbon are one order larger in magnitude; at temperate latitude, DIC subduction dominates over sinking of particles in maintaining the waters undersaturated; in the tropical band and Southern ocean, DIC is obducted back to the surface.
At the global scale, we evaluate that, of the 11 PgC of organic material lost from the surface every year, 2.1 PgC are lost through subduction of organic carbon.
This export is balanced by large counter-balancing fluxes of DIC: a supply by obduction of +275.5 Pg and removal by subduction of -264.5 PgC.
Our results suggest that carbon sequestration into the ocean interior depends on physical properties such as mixed-layer depth, ocean currents, wind and eddies which are sensitive to climate variability and change.

-427 First Detection of Volcanic CO2 Signals from Space

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Volcanoes are highly variable but continuous high altitude carbon dioxide (CO2) emitters, distributed globally. Newer estimates show that the bulk of CO2 emissions from volcanoes occur not during explosive eruptions but continuously. In this project, we investigate the feasibility of space-borne detection of volcanic CO2 anomalies. Our motivation is focused on: (a) improving the global volcanic CO2 emissions inventory, (b) developing new volcano monitoring techniques, and (c) use volcanic CO2 emissions for high altitude, strong point source dispersion studies.
Detection of strong volcanic point sources CO2 anomalies from space faces several obstacles: orographic clouds, unknown dispersion behavior, high tropospheric CO2 background, and sparse data coverage from ground-based sensors. These obstacles can be overcome by a small field of view, enhanced spectral resolving power, by employing repeat target mode observation strategies, and by comparison to continuous ground based sensor network data
The Japanese GOSAT sensors aboard the IBUKI satellite include a Fourier-Transform Spectrometer (TANSO-FTS) and an Cloud & Aerosol Imager (CAI) have been producing data since January 2009, measuring CO2 total column concentrations in polar orbit with a repeat cycle of 3 days at an altitude of 666km amsl. With a field of view of ~10km, GOSAT has the potential to provide spatially integrated data for entire volcanic edifices within one point of measurement. In 3-point mode, none of the hundreds of active volcanic emission points on Earth fall within a 10km radius of any standard observation point. Since summer 2010 we have therefore conducted repeated target mode observations of almost 30 persistently active global volcanoes including Etna (Italy), Erta Ale (Ethiopia), and Ambrym (Vanuatu), using L2 GOSAT FTS SWIR data. In this presentation we will summarize results from up to two years of measurements.

-428 What Do We Need to Know about Monitoring the Atmosphere-Ecosystem Carbon Dioxide Exchange---From a Micrometeorologit's perspective

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Monitoring atmosphere-ecosystem carbon dioxide/water vapor exchange using tower networks has been expanded rapidly worldwide. As any material exchange across the atmosphere-ecosystem interface is influenced by atmospheric dynamic processes, various confusing issues related to these processes especially turbulent processes have surfaced, such as how to capture CO2 turbulent transport and advection, tilt correction, effects of random submeso motions on CO2 turbulent transport, etc. I will discuss these issues and challenges for accurately capturing the CO2 exchange between the atmosphere and ecosystem.

-429 The Surface Ocean CO2 Atlas (SOCAT): "automating" community-wide data synthesis

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The Surface Ocean CO2 Atlas (SOCAT) project is an international effort providing global surface ocean CO2 data sets on a routine basis. SOCAT brings together all publicly available fCO2 data for the surface in a common format. (The fugacity of carbon dioxide, fCO2, is the partial pressure of CO2 (pCO2) corrected for non-ideal behaviour of the gas.) The first version of the SOCAT data set, which includes standardized data formats and metadata content with uniform quality-control applied, was made available to the public September 2011 at http://www.socat.info/. The data set will be periodically updated in order to accommodate more recent observations. SOCAT version 2 will be released to the public at the ICDC9 conference in Beijing, June 2013.

The SOCAT data set is expected to serve a wide range of user communities and become a significant resource for several climate services. Two distinct data products are made available with each public release: i) a 2nd level quality controlled global surface ocean fCO2 data set, following agreed procedures and quality control review by regional teams, and ii) minimalist gridded SOCAT products of monthly surface water fCO2 means consisting of a 1° x 1° global grid with no temporal or spatial interpolation, and a similar 1/4x1/4 degree grid representing the continental margins.

In this poster we describe the lessons learned thus far in pursuing an aggressive 2nd level quality control effort that is distributed over a far-flung, international community. One of those lessons is that the process for incorporating new cruise data, uniformly assessing quality, and releasing new versions of the collection must be streamlined to the maximum degree feasible, if the process of continual updates is to be sustainable. We describe the software system and community policies that are under development to support subsequent versions of SOCAT. The forthcoming system is designed to minimize the efforts required of PIs who contribute data and SOCAT team members who perform QC, as well as the database administrators, who manage the data collection. The system will assist individual PIs, who contribute new cruises, by providing automated "sanity checks" of their data and metadata, and by providing data visualizations that include the ability to see the new observations in the context of historical observations from the same region and season.

-430 CARBOCHANGE – Changes in Carbon Uptake and Emissions by Oceans in a Changing Climate

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

CARBOCHANGE - Changes in carbon uptake and emissions by oceans in a changing climate - is a large-scale integrating collaborative research project of 7 million Euros funded by the EU’ s 7th Framework Programme in the period 2011-2015.

CARBOCHANGE aims at quantifying the ocean’ s role in the uptake of human-produced carbon dioxide, and at investigating how large this uptake rate has been in the past, how it is changing at present, and how it will evolve in the future. Carbon dioxide in the surface ocean has to pass through the bottleneck of oceanic mixing on its way to the deep ocean. Climate change feedbacks and biogeochemical processes further modify the oceanic absorption of carbon dioxide. CARBOCHANGE employs cutting-edge measurement and modelling techniques to observe the ongoing carbon dioxide uptake by the oceans, to understand the underlying processes, and to predict future changes in uptake. The project places special emphasis on a systematic combination of ocean carbon observations and ocean models through advanced model performance assessments and data assimilation methods.

CARBOCHANGE results contribute to international assessments such as the Global Carbon Budget 2011 and 2012, and the IPPC 5th Assessment Report. CARBOCHANGE thus provides science-based guardrails for political decisions on mitigation actions in order to control and alleviate the impact of carbon dioxide emissions and climate change.

This poster summarizes the current status of the project.

-431 Extensive Spread of Large Carbonate Accumulation in Arid Region of China

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Pedogenic carbonate (PIC) is an important element for carbon sequestration. However, field data necessary to quantify carbon sequestration as carbonate have been lacking. Here, we report recent studies of carbonate accumulation in soils and sediment in the arid and semi-arid regions of China. First study was carried out in southern Xinjiang, the Yanqi Basin, where more than 100 soil samples were collected from desert land, shrub land and cropland. This study showed that soil inorganic carbon (SIC) stock was significantly higher on the cropland than on the desert land and shrub land. Our analyses suggested that cropping might have led to large PIC accumulation (24-116 g C m-2 year-1) in the Yanqi Basin. Second study was to evaluate carbon sequestration on cropland using archived soil samples from three long-term experiment (LTE) sites: Urumqi, Yangling and Zhengzhou. We found that fertilization resulted in PIC accumulation, ranging from 36 to ~200 g C m-2 year-1, with the greatest found under high rates of combined chemical fertilizers and manure application. In the third study, we collected a 23-cm long sediment core from the Bosten Lake, and measured carbonate content and determined age of the sediments at 0.5 cm intervals. Our preliminary analyses suggested that on average, carbonate accumulation in the sediment was ~100 g C m-2 year-1 over the past 60 years. Our studies provide evidence of large accumulation of carbonate in the arid and semi-arid regions, and point the potential of arid lands for carbon storage and climate mitigation.

-432 Assessing the Impact of Urban Form on Residential CO2 Emission on a Neighborhood Scale in the Atlanta Metropolitan Area, USA

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

Carbon dioxide (CO_2) is the greatest concerned greenhouse gas since it is increasing most rapidly due to human activities and intimately tied to our energy production and consumption. Urban form, described by urban density, connectivity, and land use pattern, might have great impact on CO_2 emission. A good understanding of the impact of urban form on CO_2 emission is important for controlling its emission and for mitigating global warming. In this study, the impact of urban form on residential CO_2 emission on a census-tract scale in the Atlanta Metropolitan Area is assessed by integrating Geographic Information System (GIS), and spatial and statistical analyses. Residential CO_2 emissions from three sectors (vehicle usage, household heating, and household electricity) are estimated based on individual and/or neighborhood socio-economic factors and housing characteristics using spatial and statistical analyses. Urban form characteristics are described using land use and population variables. The relationships between residential CO_2 emission and urban form are analyzed and compared by Ordinary Least Squares (OLS) regression and Geographically Weighted Regression (GWR). The results show that the relationships between residential CO_2 emission and land use and population variables vary over space in response to the changing urban form along the urbanization gradient. Urban form has a significant impact on residential CO_2 emission. This study can provide useful information to government and policy makers for practical applications in land use planning and climate change mitigation.

Evolution of the net land sink during the period 1960-2011 in the context of REDD+

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According with Le Quéré et al. (2012) the Global Carbon Budget (GCB) for 2011 was:

Sources:

9.5 PgC (from fossi fuel combustion, EFF) + 0.9 PgC (from land use change activities, ELUC).

Sinks:

3.6 PgC (atmospheric sink or atmospheric CO2 grow, GATM) + 2.6 PgC (ocean CO2 sink, SOCEAN) + 4.1 PgC (terrestrial CO2 sink, SLAND).

In other words:

EFF + ELUC = GATM + SOCEAN + SLAND

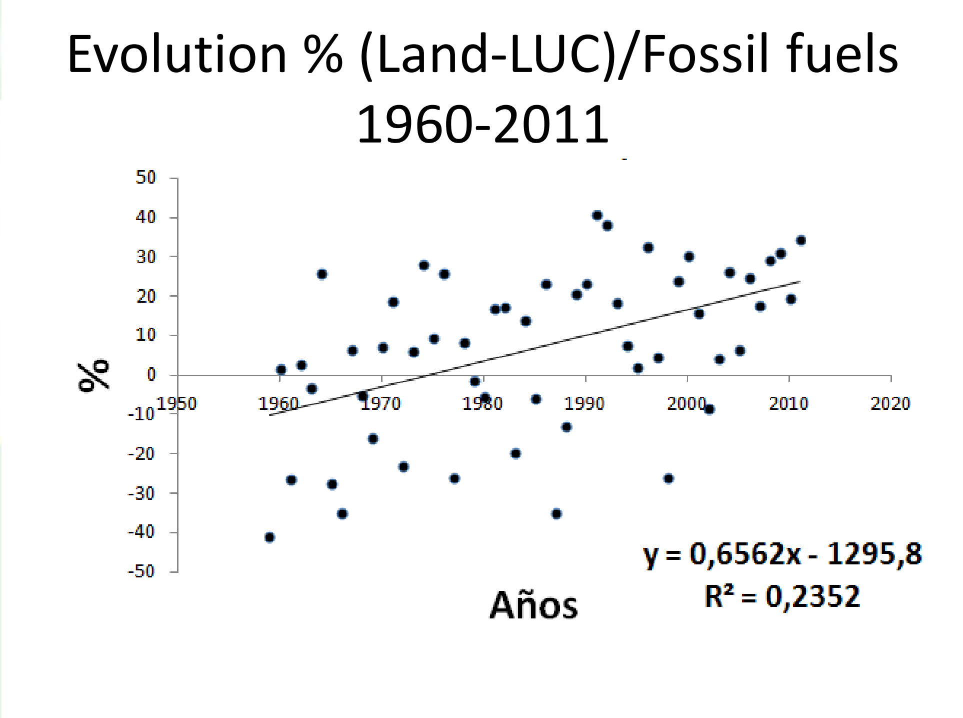
The net terrestrial sink SLANDNET was :

SLANDNET= SLAND – ELUC = EFF – GATM – SOCEAN

During 2011 SLANDNET was 3.2 PgC , that represents the 33.68 % of EFF.

An important question that can be asked is, what has been the evolution of terrestrial net sink SLANDNET over time?

To try to answer this cuuestión, we analyzed the evolution of the variable SLANDNET / EFF over the period 1960-2011, which will have the corresponding GCB.



As shown in the figure, the trend of SLANDNET / EFF is clearly positive in a fairly significant way.

From this evolution can be concluded that the net land sink SLANDNET, is playing an increasingly important role in the absorption of CO2 emitted by burning fossil fuels in the world.

-434 Global sea-air CO2 flux variability from an ocean mixed-layer scheme driven by SOCAT pCO2 observations

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Session: Past and present changes and variabilities

Type of presentation: Oral

Key word:

A temporally and spatially resolved estimate of the global surface-ocean CO2 partial pressure field and the sea-air CO2 flux is presented, obtained by fitting a simple data-driven diagnostic model of ocean mixed-layer biogeochemistry to surface-ocean CO2 partial pressure data from the SOCAT data base.
The estimated seasonality is well-constrained from the data in most regions, and compares well to the widely used monthly climatology by Takahashi et al. (2009). Comparison to independent data tentatively supports the slightly higher seasonal variations in our estimates in some areas. From a comparison with an independent seasonal climatology of surface-ocean PO4 concentration, the diagnostic model is shown to capture relevant surface-ocean biogeochemical processes reasonably well.
The estimated interannual variations are largest in the Tropical Pacific and tight to ENSO. The interannual signals from SOCAT data are compatible with signals from atmospheric oxygen data in the Tropics and the Southern hemisphere.
The global ocean CO2 flux is estimated to be (-1.2 ± 0.25) PgC/yr (1990-2009 average, negative for uptake), in line with earlier pCO2-based estimates. Individual years range between -1.88 PgC/yr (1992) and -0.45 PgC/yr (2001).
The SOCAT-based sea-air CO2 flux estimates (which include seasonal, interannual, and daily variations) are available to other groups as a gridded product in digital form.

-435 The Ocean Carbon & Biogeochemistry (OCB) Program

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

The Ocean Carbon and Biogeochemistry (OCB) Program and its Scientific Steering Committee (SSC) were created by NSF, NASA, and NOAA in 2006 to promote, plan, and coordinate collaborative, multidisciplinary research opportunities on marine biogeochemical cycling and ecosystem processes within the U.S. and with international partners. OCB focuses on the ocean' s role as a component of the global Earth system, bringing together research in biology, chemistry, and physics to advance our understanding of marine ecosystems and biogeochemical cycling. The OCB Project Office, which is based at the Woods Hole Oceanographic Institution (WHOI), provides an important service to the scientific community by organizing timely and strategic community workshops and activities; developing and communicating OCB and OCB-relevant products and activities; interfacing with and providing direct input to national and international carbon cycle science programs and activities; and developing education and outreach activities and products with the goal of promoting ocean carbon science to broader audiences. Here we will provide an overview of OCB, including its scientific scope, recent activities, and programmatic functions.

-436 Atmospheric Emissions of Greenhouse Gases from Different Nitrogen Sources

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Nitrogen fertilizers that produce low greenhouse gas (GHG) emissions from soil are needed to reduce the impacts of agricultural practices on global warming potential (GWP). We quantified and compared growing season fluxes of N2O, CH4, and CO2 resulting from applications of different N fertilizer sources, urea, urea-ammonium nitrate (UAN), ammonium nitrate (NH4NO3), poultry litter, and commercially available enhanced-efficiency N fertilizers as follow: polymer-coated urea (ESN®), SuperU®, UAN + AgrotainPlus®, and poultry litter + AgrotainPlus in a no-till corn (Zea mays L.) production system. Greenhouse gas fluxes were measured during two growing seasons using static, vented chambers. ESN delayed the N2O flux peak by 3 to 4 weeks compared to other N sources. No significant differences were observed in N2O emissions among the enhanced-efficiency and the traditional inorganic N sources except for ESN in 2009. Cumulative growing season N2O emission from poultry litter was significantly greater than from inorganic N sources. The N2O loss (2yr average) as a percentage of N applied ranged from 0.69% for SuperU to 4.5% for poultry litter. The CH4-C and CO2-C emissions were impacted by environmental factors such as temperature and moisture more than the N source. There was no significant difference in corn yield among all N sources in both years. Site specifics and climate conditions may be responsible for the differences between the results of this study and some of the previously published studies. Our results demonstrate that N fertilizer source and climate conditions need consideration when selecting N sources to reduce GHG emissions.

-437 Impact of the agricultural Green Revolution on the global carbon cycle during 1960-2010

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Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Over the last 50 years, global food production has more than doubled while total cropland area remained nearly constant, largely as a result of the Green Revolution. This is largely a result of high yield cultivars, fertilizer and pesticide use, irrigation, and other management improvements. The productivity increase may have had a significant yet poorly known impact on the global carbon cycle. Using the VEGAS terrestrial carbon model in the framework of the NACP MsTMIP and the international TRENDY multi-model intercomparison projects, and a suite of observationally based datasets as well as agricultural statistics, we explored the impact of the Green Revolution and wood harvest on the global carbon cycle. During 1960-2010, the land use contribution changed from a carbon source to a carbon sink of about 0.5 GtC/y. Additional factorial simulations show that the land use effect is comparable to the CO2 fertilization effect. Cropland also has a major impact on the CO2 seasonal cycle: it increases the CO2 seasonal amplitude by 20-30% compared to natural vegetation. Interestingly, the productivity increase led to a long-term increase in the CO2 seasonal amplitude, and may be responsible for a significant fraction of a similar change observed in the Mauna Loa CO2 record. This effect is complicated by the fact that the harvest index (fraction of grain as total above-ground biomass) contributed partially to the productivity increase, and is therefore partially responsible for the total carbon cycle response.

-438 Using Land Surface Temperature and Normalized Difference Index products for desertification monitoring in Bulgan, Mongolia

Hangnan Yu *(Korea University)*

Session: Past and present changes and variabilities

Type of presentation: Poster

Key word:

Desertification monitoring as a main portion for studying desertification process have been conducted by many scientists, however, the stage of research still in the comparison of past and current situation. In other words, monitoring need to concern methods how to take precautions against desertification. In this study, an approach is named vegetation temperature condition index (VTCI), which derived from normalized difference vegetation index (NDVI) and Land surface Temperature (LST) was utilized to observe distribution change of vegetation. The index can be used to monitor drought occurrences at a regional level for a special period of a year, and can be also used to study the spatial distribution of drought within the region. Techniques of remote sensing and geographic information system (GIS) were combined to detect the distribution change of vegetation with VTCI. As a result, we found that the distribution of vegetation in Bulgan, Mongolia could be predicted in a certain degree, using VTCI. Although desertification is a complicated process and many factors could affect the result. However, this study is helpful for provide a strategic guidance to fighting desertification and adjusts the use of the labour force.

-439 Investigating the atmospheric relationship between Carbonyl Sulfide and Carbon Dioxide using solar FTIR spectroscopy and a Chemical Transport Model

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Poster

Key word:

Atmospheric inversions based on CO2 concentration measurements alone can only determine net biosphere fluxes, but not differentiate between photosynthesis (uptake) and respiration (production). Carbonyl sulfide is also taken up by plants during photosynthesis but not emitted during respiration, and therefore is a potential means to differentiate between these processes. Solar absorption Fourier Transform InfraRed (FTIR) spectra contain information about the absorption of both gases in the atmosphere. Here, we investigate simultaneous measurements of OCS and CO2 measured at 3 sites via FTIR spectrometers. These northern-hemispheric sites span a wide range of latitudes and all have multiple year time-series. The sites include Ny-Alesund (79°N), Bremen (53°N) and Paramaribo (6°N). Retrieval using SFIT4 allows both total columns and profiles of OCS to be obtained. We compare these measurements to simulations of OCS and CO2 using the GEOS-Chem model.

-440 Ocean Carbon Sequestration: Controlling Mechanisms and Responses to Global Changes

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: Oral

Key word:

The ocean is the largest carbon sink on this planet. The known mechanisms for carbon sequestration in the ocean include physical pump /solubility pump (SP), biological pump (BP) etc. The SP is dependent on pCO2 and transportation of water mass from surface to depths, which is naturally occurring and beyond human control for management. The BP is driven by primary production initially in the surface water and then dependent on particulate organic matter (POM) sinking process in the water column. Contrasting to the SP, the BP can be enhanced by manipulation in certain marine regions (such as iron fertilization in high-nutrient-low-chlorophyll areas). However, the POM reaches to the sea floor is only a tiny fraction of the total primary production in the euphotic zone. Where is the rest of the organic carbon gone? In addition to the respired major portion (CO2), the majority of the organic carbon in the ocean is actually in the form of dissolved organic matter (DOM) which is equivalent to the total inventory of atmospheric CO2. In fact, the majority of the marine DOM is recalcitrant, with an average age of ~5000 years, constituting a sequestration of carbon in the ocean. However, the mechanisms controlling the generation and removal of the recalcitrant DOM (RDOM) are largely unknown. A recently proposed concept, the microbial carbon pump (MCP) offers a formalized and mechanistic focus on the significance of microbial processes in carbon storage in the RDOM reservoir, and a framework for testing the sources and sinks of DOM and the underlying mechanisms. Understanding of the functioning and efficiency of the MCP is an urgent need since ocean warming may change carbon flux partitioning among different pathways and thus potentially enhance the role of the MCP in carbon storage. A working group joined by 26 scientists from 12 countries has been formed under the International Scientific Committee on Oceanic Research (SCOR) (http://mme.xmu.edu.cn/mcp/; or http:// www.scor-int.org /WorkingGroups /wg134. htm) to address this multi-faceted biogeochemical issue related to ocean carbon cycling and global climate change. Obviously, an integrative consideration of the BP and the MCP could help identify responses of marine carbon sinks to climate changes as well as practices conducive to enhanced carbon sequestration in the ocean. This talk will deliver essential background and emerging knowledge in this regard.

-441 Spatial and Temporal Evolution of Carbon Storage in Terrestrial Ecosystems in the United States from 2000 to 2050

Shuguang Liu *(U.S. Geological Survey)*

Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: null

Key word:

Carbon storage changes constantly under the impacts of land cover and land use change (LCLUC), disturbances, and climate change. Information on the dynamics of carbon storage in terrestrial ecosystems at regional to global scales is essential for formulating carbon management and sequestration policies and strategies. As a component of the USGS effort in assessing potentials of carbon sequestration and greenhouse gas emissions reduction in ecosystems across the country, we quantified and mapped the dynamics of carbon storage in the conterminous U.S. from 2000 to 2050. The major driving forces of carbon change at regional scale were analyzed. Historical land cover and land use change (LCLUC) was reconstructed using satellite-derived maps and the FOREcasting SCEnario of land-use change (FORE-SCE) model. Future LCLUC scenarios were projected according to the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) and downscaled to 250-m resolution. Historic wildfires and their emissions were derived from the Monitoring Trends in Burn Severity database and also used to parameterize models to simulate future wildfires under the SRES scenarios. Carbon dynamics in the U.S. were simulated using the USGS General Ensemble Biogeochemical Modeling System (GEMS) framework with the LCLUC data, projected wildland fire, and future climate change projections from three General Circulation Models (GCMs). Results show large scenario-dependent carbon change patterns in the United States with strong regional variations in magnitude and mechanisms.

-442 Perturbation of sea-to-air DMS flux in Polar Regions and the impact on contemporary climate

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: null

Key word:

The sea-to-air flux of the dimethylsulphide (DMS) constitutes an important radiative impact on climate in remote marine areas. Modelling analyses simulate medium to large changes in the sea-to-air flux in polar regions under warming scenarios. Here we investigate the polar radiative impact change in DMS flux using an atmospheric general circulation model. We use a low-resolution atmospheric GCM with incorporated sulphur cycle to estimate the climatic response to a prescribed meridionally-variable change in zonal DMS flux. Baseline sulphur emissions is compared with contemporary anthropogenic S and a perturbed DMS flux Our results indicate that the global mean DMS vertically integrated concentration increases by about 41%. The relative increase in DMS annual emission is around 17% in 70-80N, although the most significant increase is in 50-70S, up to 70%. However, concentrations of atmospheric and only increase by about 8%. The oxidation of DMS by OH increases by about 20%. Oxidation of SO2 to SO4 by H2O2 increases 7%. The oxidation of by increases around 6.2%. Overall, sulphur emissions increase globally by around 4.6%. Generally, the perturbation on DMS flux leads to higher concentration of DMS and related sulphur compounds in the SH, leading to a mean surface temperature decrease in the SH of around 0.8°K, compared with a decrease of 0.4°K in the NH.

-443 CO2 Activation and Conversion Catalysed by FeS Nano-Catalyst

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Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: null

Key word:

Iron sulfides are abundant minerals with a wide range of applications owing to their interesting physical and chemical properties. This makes them strong candidate materials in technological applications such as solar cells, solid-state batteries and as catalyst materials. For example Wächtershäuser, Russell, Hall and others have hypothesized that many prebiotic chemical reactions were catalysed by mineral surfaces at hydrothermal vents on the ocean floor during the Hadean and early Archean eras. This early environment included minerals replete with transition metals and sulfur, including the iron sulfide group (pyrite, mackinawite, greigite) and violarite (similar to greigite, but containing nickel and iron). The structure of some of these minerals can be considered as being built up from smaller units that have analogues in extant Fe-S protein cofactors. Iron sulfide mineral greigite (Fe3S4) and its pre-cursor mackinawite (FeS) are structurally similar to the (Ni, Fe)S catalytic centres found in modern-day carbon monoxide dehydrogenase (CODH) enzyme which is able to catalyse the reversible conversion between carbon dioxide (CO2) and carbon-monoxide (CO) into a range of organic molecules.

The present study employed a state-of-the-art computational technique based on Density Functional Theory to design and develop of a new class of sulphide catalysts, tailored specifically towards the reduction and conversion of CO2 into chemical feedstock molecules. We show from our calculations that iron sulfide mackinawite is able to spontaneously activate CO2 on both the (011) and (100) surfaces. The CO2 molecule gained significant charges from these FeS surfaces on activation (i.e. forming a negatively charged bent CO2-δ species). We have explored various hydrogenation reaction of the activated CO2 on the FeS surfaces and have identified carbon monoxide (CO), formic acid (HCOOH), formaldehyde (CH2O) and methanol (CH3OH) as the main products. Calculated activation barriers for the hydrogenation steps connecting each minimum have been determined and they all suggest that these reaction products are attainable under moderate conditions.

-444 Carbon flux phenology at Harvard Forest from 1992-2010

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Session: Past and present changes and variabilities

Type of presentation: null

Key word:

Phenology is one of the most important factors that can affect ecosystem net carbon (C) sequestration, or the net ecosystem productivity (NEP). Using the world longest (1992-2010) continuing flux data at Harvard Forest, here we have analyzed the phenology from flux measurements, termed as carbon flux phenology, and its drivers and implications for NEP. A negative exponential model, using polynomial regression and weights computed from the Gaussian density function, was adopted to derive smoothed curves for daily net ecosystem exchange (NEE) and gross primary productivity (GPP) observations. The respective start and end days with negative NEE can then be determined, hereafter referred to as the CUstart and CUend, respectively. The GSstart and GSend were determined as the days when the smoothed daily GPP reached 10% of the annual maximum smoothed daily GPP. Meteorological variables, including air temperature, soil temperature, water vapor pressure (VPD), precipitation and shortwave radiation, were used to explain these phenological variations.

The start of net C uptake has been advanced at the speed of 0.9 d/y ($R2=0.47$, $p=0.001$) during 1992-2010 while the end of C uptake was delayed at a speed of 0.8 d/y ($R2=0.34$, $p=0.009$). These resulted the overall carbon uptake period increased by 1.7 d/y ($R2=0.59$, $p<0.001$). The variations in phenological transitions of GPP were small and we only found a significant delay of the end of GPP ($R2=0.23$, $p=0.04$). Either spring (March to May) air or soil temperature can not explain variations in CUstart, which was in fact controlled by spring VPD ($R2=0.61$, $p<0.001$) and shortwave radiation ($R2=0.64$, $p<0.001$). The CUend, on the other hand, was found to be correlated with autumn (Sep.-Nov.) soil temperature ($R2=0.43$, $p=0.001$) and shortwave radiation ($R2=0.40$, $p=0.003$). The GPPstart was only significantly correlated with air temperature ($R2=0.53$, $p<0.001$) while none of these meteorological variables can explain the end of GPP.

No correlation was found between annual NEP and CUstart but CUend can explain 68% of interannual NEP variability. Although GPP transitions did not have significant effects on annual NEP, the autumn lag between GPPend and CUend was found to be the best indicator of annual NEP ($R2=0.80$, $p<0.001$). These results suggest an important way of combining both carbon uptake and photosynthesis phenology in explaining interannual variability of NEP.

-445 An inverse system of monthly CO2 surface fluxes from regional characteristics of CO2 observations

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Session: Carbon sources and sinks, their changes and trends

Type of presentation: null

Key word:

Spatial and temporal variations of CO2 concentration patterns in the atmosphere reflect the geographical distribution of CO2 sources and sinks. Observations for stations are usually used in inverse systems of CO2 fluxes and used to evaluate the inverse results. Previous research found that CO2 observations for stations in one region have consistent seasonal cycle; the globe can be divided into several regions according to the respectively different patterns in each region. The averaged value of CO2 concentrations for all stations in one region represents the regional pattern of this region. These regional characteristics are used as supplementary observation information in our inverse system of monthly CO2 fluxes and as another criterion to evaluate the regional fluxes. The regional information provides more powerful observational constraints in the inverse system. Inverse system with these additional constraints provides more satisfactory CO2 surface fluxes in pseudodata experiments that resemble the real estimates of global CO2 fluxes we will apply this system to.

-446 Solving CO2 by planting forests in Australia

Arthur Hughes *(CO2 Capture Corporation)*

Session: Future of the carbon cycle: drivers, vulnerabilities, feedbacks and management options

Type of presentation: Oral

Key word:

Climate concern today is based on accelerated burning of coal, oil and natural gas. Many believe that the resulting CO2 will warm the earth leading to serious and possibly disastrous consequences. Many attempts have been made to measure the amount of CO2, and the resulting warmth of the earth, without universal acceptance of the results. Many nations are working jointly to keep people from activities (such as using more electricity) that are based on burning fossil fuels. Despite several years of international attempts, there is, as yet, no workable solution. People do not want to give up their current lifestyle to achieve an uncertain goal – knowing that many other peoples will not similarly cooperate. There is another alternative: capture atmospheric carbon dioxide and store it in a form unlikely to have undesirable consequences. This paper is an exploration of such a solution. Other storage solutions involve massive expenditures of public funds. The solution proposed in this paper does not require any long term public expenditure – in fact it returns a massive profit. It also benefits the earth by converting useless deserts into healthy livable forests.

The solution explored in this paper is the planting of fast growing trees in desert areas in Australia. Australia has 1.31 million square miles of desert – hot, dry and uninhabited land. It has long been known that by planting trees, desert can be converted into forests. The problem is sufficient water. This project involves nuclear power plants coupled with large desalination plants on the shore of the ocean near Perth, Australia. A proposed demonstration project involves 125 square miles in the Great Sandy Desert about 25 miles from the ocean. The goal of the demonstration project is to reduce CO2 in the atmosphere by 880,000 tons per year by converting it into marketable hardwood with an annual profit of more than $400 million per year. Extension of this demonstration to 80% of the entire Australian Desert area could reduce CO2 in the world atmosphere by 7.4 billion tons annually – enough to make a serious dent in the worldwide carbon dioxide problem. At the same time, this solution would not only be self- supporting, but could yield revenue for Australia of more than $2.4 trillion per year – a doubling of the current Australian GDP.

The project starts with a survey by the Australian government, identifying approximately 1,000 tracts of 800 acres in the uninhabited desert which would be leased in the pilot area to major tree planting private companies. The demonstration assumes, as one example, the planting of Paulownia trees – the fastest growing trees in the world today. It is estimated that for each acre of Paulownia trees planted an average yield of 30,000 board feet of lumber can be expected every 7-10 years. With an average price of $3.00 per board foot, the estimated return on 1 acre of Paulownia trees is $90,000 every 7-10 years or about $10,000 per year. http://www.primevalgardens.com/Environment.html

How much water would be needed? A single acre of forest land during the course of a growing season can add 4 tons of biomass (lumber) but uses 960,000 gallons of water to do so. (http://forestry.about.com/od/treephysiology/p/tree_water.htm). The average annual rainfall in Western Australia is 300 mm which translates into about 10 inches per acre or 271,510 gallons per year. This means that to convert the deserts of Western Australia into forests, we need to add 689,000 gallons of fresh water per acre per year. Desalinized sea water costs $0.002 per gallon in Israel and Saudi Arabia. At that cost, tree planting companies need to spend about $1,378 per acre per year on water to maintain Western Australia as forest. Add another $2,500 per year for planting, fertilizer, maintenance, pipelines, pumping, harvesting and the average tree planter could get a net profit of about $6,000 per acre per year – averaged over nine years.

By how much would CO2 in the atmosphere be reduced due to conversion of the Australian Desert? An acre of forest will absorb an average of 11 tons of CO2 per year. If 80% of the desert is converted into forest it would reduce the CO2 in the atmosphere by 7.4 billion tons per year. This reduction is world wide – not just in Australia. How big is 7.4 billion tons in relation to the world problem? The Princeton University Carbon Mitigation Initiative (http://cmi.princeton.edu/wedges/intro.php) reports that keeping emissions flat for 50 years will require trimming projected carbon output by roughly 8 billion tons per year by 2060. That is almost exactly what can be accomplished by converting the Western Australian Deserts to forest. And we do not need to wait to 2063. If we start today, we can have Western Australia making that contribution to the global crisis within 15- 40 years. Assuming the pilot project is a success, there will have to be a period of time to build the desalination plants, pipelines, to do surveys and assign ownership of the land, and several years for the forestry companies to plant and begin harvesting the trees.

-447 Effects of drought on forest ecosystems carbon cycle in China during 2001-2010

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Session: Past and present changes and variabilities

Type of presentation: null

Key word:

Drought, which is expected to increase in frequency, extent and severity with climate change, affecting the structure, function, process of forest ecosystems. The interaction between extreme climate events and forest ecosystem help us to better understand the biodiversity and vulnerability of ecosystems. However, there is still wide concern about how forest ecosystems respond to extreme drought under climate change. In this study, we used drought index (standard precipitation index, SPI) and a process-based model (Boreal Ecosystems Productivity Simulator, BEPS) to characterize the spatial-temporal pattern of drought conditions in China and explore the impacts on forest ecosystem carbon cycle over the last decade. At the national scale, there was no significant change in drought conditions for entire China during 2001-2010. However, the southwestern area showed increased drought intensity, resulting in significant decreases in NPP. In northern China, particularly in the northeast of China, the area behaved NPP increased consistently with its drought intensity declines. Furthermore, the responses of NPP to drought for different forest types have been also considered. Extreme climate events like drought should be considered in estimating the carbon balance of forest ecosystem.

-448 Simulated soil organic carbon with CENTURY model in the past 50 years in Inner Mongolia grassland

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Session: Past and present changes and variabilities

Type of presentation: null

Key word:

Grassland soils play a curial important role in regulating the CO2 (carbon dioxide) content of the atmosphere, and can behave either as carbon sources or sinks. Models are widely used to assess the impacts of management and environmental variables on soil organic matter dynamics which help to study on ecosystem sustainability and carbon cycling under global change. In this study, six long term grassland experiments soil organic carbon (SOC), soil organic nitrogen (SON) and net primary productivity (NPP) were simulated by CENTURY model and estimated on measured and simulated results of meadow grassland, typical grassland and desert grassland in Inner Mongolia of northern China. The results showed that CENTURY model is successfully applied to Inner Mongolia grassland that measured and simulated results had a good consistency, R2 was 0.962, 0.775 and 0.818 on SOC, TN and aboveground live C. NPP of HLBE, WLHT, NMG_L and NMG_S sites had increased from 1961 to 2010 and NPP of NMD and EDS sites was decreased in totally. However, NPP was decreased when enclosed was built some times that NMG_L, NMG_S and WLHT sites was obviously because of long time enclosed. SOC was increased quickly when grassland was enclosed, but increasing ratio was decreased with the enclosed time change. SON was decreased before enclosed but not obviously change after enclosed. Therefore, enclosed is a good measured for enhancing NPP and SOC but not effect on SON.

Research about carbon stocks in secondary forest and gallery forest in Congo

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Abstract

The aim of this research was to compare the soil carbon stock capacity of two different forest types in Teke trays (Republic of Congo), one is gallery forest (GF) and other one is secondary forest (SF). To realize the bad impacts of continuous rising of CO_2 in the atmosphere, this research was conducted in this context, moreover, can play a major role to reduce the poverty level in these areas. In this case, at present, the Teke trays are categorized as a positive forest dynamics. The main objectives of this study are: (i) to understand the responsible factors those may raise the soil carbon stocks capacity in the savannah zone, and (ii) to estimate and compare the total carbon capacity of these two types of forests. Results showed that carbon stocks capacity in these forest types comparatively higher than the old savannah forests. The total carbon stock was found 6400 gC.m^{-2} whereas 6190 gC.m^{-2} in GF and 4592 gC.m^{-2} in FS forests. The average carbon stocks in coarse woody debris was obtained 10993 and 14172 gC.m^{-2} in the GF and SF forests respectively, which was statistically insignificant (P = 0.78). The inter-annual average carbon flow in both these forest types was 1776 and 545 gC.m^{-2} yr^{-1} in the GF and SF respectively, which was also insignificant (P = 0.10). Moreover, carbon stocks in small woody debris were 965 and 83 gC.m$^{-2.}$ yr^{-1} in the GF and SF respectively, whereas it was significantly different (P = 0.0013). In addition, the inter-annual average carbon flow in the small woody debris was found 310 and 51 gC.m$^{-2.}$yr^{-1} in the GF and SF respectively. In 2007, litter fall carbon was found in these forest types as 652 gC.m^{-2} yr^{-1} in the GF and 706 gC.m$^{-2.}$yr^{-1} in the SF, which was insignificant (P = 0.54). The following year, it was 601 and 559 gm$^{-2.}$yr^{-1} in the GF and SF forests. In 2008, total carbon stock was found 1178 and 1032 gC.m^{-2} in the GF and SF forests, that were insignificant (P = 0.415). Between the two forest types, in 0-20 cm soil depth, soil carbon was 772 and 303 gC.m^{-2} in the GF and SF, which showed significant difference between them (P = 0.0149). Next layers of 20-40 cm, less carbon stock was found 173 and 123 $gC.m^{-2}$ in the GF and SF forests (P = 0.2372). Potential of carbon stock capacity in different forest types may help the developing African nations to earn carbon credits, reduce deforestation, eliminate poverty and in long run to ensure the sustainable forest management.

Keywords: Forest types, carbon stock, Teke trays, Congo, Gallery forest, Secondary forest.

Transformational pathways toward mitigating anthropogenic climate change and the future of the carbon cycle: From decarbonization to “negative” emissions

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ICDC9, 4 June 2013

Climate change is a central aspect of adverse impacts of human activities on the planetary scale. The main future challenge is to improve human well being while simultaneously mitigating anthropogenic climate change. The role of technology and associate institutional arrangements in achieving this double challenge is unique. Technology is one of the main driving forces of increasing greenhouse gas (GHG) emissions. It is also an important part of the possible solution in mitigating global warming through reductions of GHG emissions, in helping adapt to its impacts and offseting some of the adverse impacts. The main technology measures for reducing GHG emissions are efficiency improvements, decarbonization of fossil energy, improved land management, afforstation, carbon capture and storage, a shift toward less carbon-intensive and zero-carbon energy sources and processes and possibly also deployment of technologies with “negative” emissions. One such possibility is the sustanabile use of biomass in conjunction with carbon capture and storage.

Generally, cost reductions and improvements will be required to assure timely replacement of carbon-intensive systems by new and advanced technologies with lower, zero or even negative emissions. The nature of technological change requires innovations to be adopted as early as possible in order to lead to lower costs and wider diffusion in the following decades. The longer we wait to introduce these advanced technologies, the higher the required emissions reduction will be. At the same time, we may miss the opportunity window for achieving substantial cost buy-downs with ever higher atomospheric GHG concentrations.

Development pathways will be shown from the ever-growing literature of scenarios that indicate how to respond to the challenge of achieving further imporvement of wellbeing while at the same time mitigating anthorpogenic climate change. By investing significantly in new technologies and decarbonization, multiple co-benefits can be achieved – from providing affordable access to modern energy and creation of new business and economic opportunities to addressing the threat of climate change. Examples will include the recent transformational pathways toward sustainable future developed in the Global Energy Assissment as well as the Representative Concentration Pathways developmed for the IPCC as a joint effort of different modeling “communities” from integrated-assessment models to earth-systems and climate models. The emphais will on comparison the main drivers behind these development pathways especially those concerning the future of the carbon cycle and the range of possible management options.

The oceanic accumulation of anthropogenic CO_2 since the mid 1990s

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Model simulations predict that the ocean has taken up about 20 to 30 Pg C of anthropogenic CO_2 between the WOCE era (mid-1990) and the mid-2000, bringing the cumulative burden of anthropogenic CO_2 in the ocean to about 150 Pg C in 2010. In the last decade, a series of repeat hydrographic cruises have been undertaken with the goal to document and quantify this accumulation. More recently, international synthesis activities have quality controlled and homogenized the data on a basin-scale, opening the opportunity to estimate the anthropogenic CO_2 accumulation in the global ocean since the WOCE era with a high-quality data set. We will report on our initial results to estimate this increase on a global-scale, using a range of methods, including the eMLR, $\Delta\Delta C^*$, isopycnal ΔCT^0, and TTD methods. This will permit us to assess the uncertainties associated with the separation of the changes in total inorganic carbon from those associated with the uptake of anthropogenic CO_2. We will also address the challenges associated with the temporal and spatial interpolation required to arrive at a global integrated number given the relatively spare data sets. The initial results indicate a global uptake at the lower end of the model predicted spectrum, i.e., about 20 Pg C between 1994 and 2006, which amounts to an uptake flux of less than 2 Pg C yr^{-1} over this period. This flux is currently rather uncertain, but it is of note that it is lower than most estimates for the oceanic sink for anthropogenic CO_2, but consistent with the most recent surface ocean pCO_2 based estimates (see abstracts by Wanninkhof et al., and Landschützer et al.). If this holds up to further scrutiny, the ocean sink would have slowed down relative to what is expected from the increase in atmospheric CO_2.

Carbon balance of a winter wheat-summer maize double cropping system in the North China Plain

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Abstract

Crop land may play important roles in the terrestrial carbon (C) cycle, but the net C balance is not well-known, in part because of the many interactive factors, in part also because most studies have focused on natural ecosystems and not crop land. Here, we report on the C balance of a winter wheat-summer maize double crop rotation ecosystem in the North China Plain, using a combination of eddy covariance measurements, crop measurements and soil respiration measurements in 2007 to 2008.

The gross primary productivity (GPP), total ecosystem respiration (TER) and net ecosystem exchange (NEE) were -1.84, 1.41 and -0.43 kg C m^{-2}, respectively. Net primary productivity (NPP), assessed on the basis of crop sampling and analyses, was -1.03 kg C m^{-2}. Using LI-COR 8100 measurements, soil respiration was 0.97 kg C m^{-2}. The net ecosystem assimilation was larger than the exported C in harvest grains during the wheat season (-0.07 kg C m^{-2}), whereas, the opposite was true for the maize growing season (0.13 kg C m^{-2}). Hence, the ecosystem acted as a net CO_2-C source (0.06 kg C m^{-2}).

Key words: Carbon balance, eddy covariance, GPP, NEE and TER, Soil respiration, a winter wheat-summer maize rotation ecosystem, North China Plain

An update to the Surface Ocean CO_2 Atlas (SOCAT)

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Abstract. The Surface Ocean CO_2 Atlas (SOCAT, www.socat.info) is a major synthesis effort by the international marine carbon research community. It aims to improve access to surface water fugacity of carbon dioxide (fCO_2, similar to partial pressure) by regular releases of quality controlled and fully documented synthesis and gridded fCO_2 products. SOCAT version 2 will be released in a lunch time side event at ICDC9. Version 2 extends the SOCAT version 1 data set by 4 years until 2011, while providing many additional data for the years 2006 and 2007. It has 10.1 million surface water fCO_2 data from 2660 cruises between 1968 and 2011 for the global oceans and coastal seas. The procedures for creating version 2 are similar to those for version 1. The SOCAT website (www.socat.info) provides access to the individual cruise data files, as well as synthesis and gridded data products. Interactive online tools allow users to visually explore and interpret the data. Scientific users can also access the data as downloadable files or via Ocean Data View. Version 2 enables global carbon scientists to extend their process, budget and modelling studies by 4 years until 2011.

Highlights and reflections on the Global Carbon Budget

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Accurate assessment of global CO_2 emissions and their redistribution among the atmosphere, ocean, and terrestrial biosphere is important to better understand the global carbon cycle, support the climate policy process, and project future climate change. An effort to annually update the 'global carbon budget' was initiated in 2005, coordinated by the Global Carbon Project and engaging a large part of the global carbon cycle science community (many present at this conference!). This presentation will review the highlights of the seven carbon budgets published so far. It will show the key research results and how they have evolved through time, and discuss how to reduce the uncertainties and expand the research output in the future. This presentation will also show how the global carbon budget effort can help increase the visibility of carbon cycle science worldwide, strengthen interdisciplinary and international collaborations, and support the climate policy process. The continued publication of global carbon budgets could play a critical role in the ramp up to COP21 in 2015, where the successor of the Kyoto Protocol should be defined.

Soil greenhouse gas fluxes from different forest types on Taihang Mountain, North China

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The objectives of this study were to investigate seasonal and spatial variation of greenhouse gas fluxes from soils on sites dominated by *Robinia pseudoacacia*, *Vitex negundo* var. *heterophylla*, *Leptodermis oblonga*, *Punica granatum*, *Ziziphus jujube*, and *Bothriochloa ischcemum*, and to identify how environmental parameters (soil temperature and soil moisture), litter exclusion, and differences in forest type explained the temporal and spatial variance in soil respiration. Fluxes of greenhouse gases were measured using static chamber and gas chromatography techniques. Six static chambers were randomly installed in each forest type. Three chambers were randomly designated to measure the impacts of surface litter exclusion, and the remaining three were used as a control. Field measurements were conducted biweekly from May 2010 through April 2012. Soil CO_2 emissions from all forest types were significantly affected by soil temperature and soil moisture. Driven by the seasonality of temperature and precipitation, soil CO_2 emissions demonstrated a clear seasonal pattern, with fluxes significantly higher during the rainy season than during the dry season. Soil CH_4 and N_2O fluxes were not significantly correlated with soil temperature and soil moisture, and no significant seasonal differences were detected. Removal of surface litter resulted in significant decreases in CO_2 emissions, but had no significant influence on CH_4 and N_2O fluxes. Overall, forest type had a significant effect on CO_2 and N_2O fluxes but not on CH_4 uptake.

Southern Ocean processes and variability from a 13 year record of *in situ* atmospheric O_2 and CO_2 measurements made at Baring Head, New Zealand

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Baring Head, New Zealand (41.41°S, 174.87°E) is home to the world's longest ongoing *in situ* atmospheric O_2 time series and second longest *in situ* atmospheric CO_2 time series. The site experiences southerly winds with high wind speeds approximately 30% of the time, where the arriving air masses have travelled over the Southern Ocean without influence from terrestrial sources or sinks. We have collected concurrent *in situ* O_2 and CO_2 measurements over the 13-year period from 1999-2012 using a modified paramagnetic O_2 analyser and non-dispersive infrared CO_2 analyser. We analyse the measurements using seasonal-trend decomposition by Loess (STL) to decompose the time series into seasonal, trend and remainder components.

From these results, we quantify long-term trends and seasonal cycle amplitudes, including for the derived tracer, atmospheric potential oxygen (APO), which is conservative with respect to the terrestrial biosphere and thus is sensitive mostly only to ocean processes. We examine and speculate upon the Southern Ocean drivers for interannual variability observed in the Baring Head APO seasonal amplitude, as well as interannual variability in the long-term trend. We compare interannual variability observed at Baring Head with climate indices, namely the El Niño Southern Oscillation (ENSO) and the Southern Annular Mode (SAM), to provide insight into Southern Ocean air-sea flux variability.

We also examine the frequency and magnitude of synoptic-scale processes such as ocean ventilation events and marine productivity blooms as observed in the APO data, correlating these with satellite or Argo float-derived data of ocean chlorophyll, sea surface temperature, and mixed layer depth. Finally, we compare our Baring Head observations with output from several ocean biogeochemical models coupled to the TM3 atmospheric transport model. From these model-observation comparisons we can elucidate which processes dominate the observed atmospheric variability. For example, atmospheric transport dominates interannual variability in the atmospheric CO_2 seasonal amplitude, but Southern Ocean air-sea fluxes are expected to dominate interannual variability in the APO seasonal amplitude.

Investigation of the Biosphere with the Aid of Global Spatial Carbon Dioxide Cycle Model Taking into Account Seasonal Regime

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The results of global carbon dioxide cycle modeling with the basic attention to the spatial seasonal dynamics in the "Atmosphere - Terrestrial Plants - Soil" system are presented. A simple carbon cycle model in the "Atmosphere - Ocean" system is added for full description the cycle.

In the model all the land territory is divided to into cells of the size 4°×5° of geographic grid. It is supposed that in each cell there is a given type vegetation according to the world classification. The model is described by system of ordinary nonlinear differential equations. Block of the productive process characterizes the carbon and water dynamics in ecosystems. The model includes the following phase variables: (1) carbon concentrations of land area separately for the biomass of leaves, trunks, and roots, assimilates, and organic matter in soil; (2) moisture in the upper soil layer. The equations are described photosynthesis, respiration of plants, distribution of assimilates in organs, decay of dead organs, and decomposition of soil organic matter.

Climatic data for the modeling were taken from the GCM model of Computing Center of the Russian Academy of Sciences.

Modeling confirmed that photosynthetic activity of terrestrial plants are responsible for seasonal fluctuation of CO_2 concentrations. Moreover, the movement of air masses results in ”sucking out” CO_2 from areas with lower photosynthesis located hundreds of kilometers away. Similar to data obtained by CO_2 monitoring, the model shows that maximal annual decrease of CO_2 concentrations in August-September in moderate and high latitudes of the Northern Hemisphere. These variations are observable up to the equator and even in the Southern Hemisphere. In the Southern Hemisphere (up to the South Pole), the minimum of CO_2 concentrations corresponds to January-February and have lower CO_2 variations. Near the North and South poles, the trend of variations of CO_2 concentrations corresponds to that at lower latitudes (with substantially lower amplitude variations).

Calculations reveal six points of local minimum: at zone of temperate forests and taiga in Siberia and North America, at zone of tropical forests in South America, in Africa, between India and Indochina and in Australia. Their existence and positions are explained by the seasonal dynamics of plant photosynthetic activity.

Simulating experiments also reveal two previously unknown domains. One starts in the minimum of the South America and goes to South part of this continent, neighboring areas of the Atlantic and Pacific oceans, and the greater part of Antarctica. The boundary of this domain is marked by the sharp change in the onset time of CO_2 minimum development accompanied by the substantially lower amplitudes of variations in its concentrations. The second domain starts in the minimum of Siberia and has similar properties but goes to the North up to the North Pole.

Five years of *in situ* atmospheric O_2 and CO_2 data from Weybourne Atmospheric Observatory, Norfolk, United Kingdom

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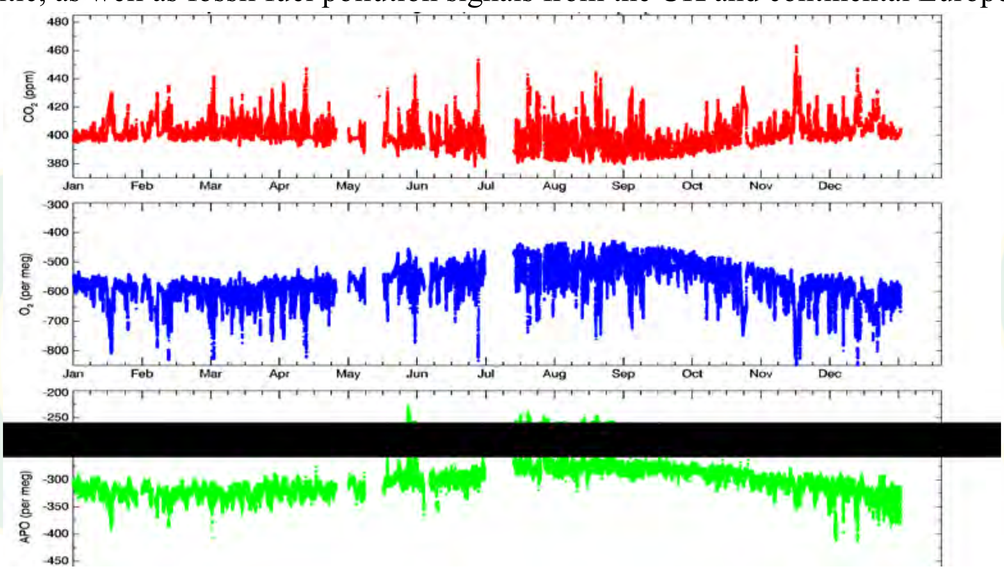
Concurrent atmospheric measurements of oxygen (O_2) and carbon dioxide (CO_2) are a valuable tool to better understand the global carbon cycle. Technological improvements have resulted in near-real-time measurements of both O_2 and CO_2 becoming viable. The increased time resolution of continuous measurements compared to flask samples provides greater insight into atmospheric variations and short-term processes. These measurements will become even more relevant as the research focus shifts from the global to regional scale, e.g. anthropogenic emissions verification.

We present over five years of atmospheric measurements of O_2 and CO_2 collected at Weybourne Atmospheric Observatory (WAO) on the north Norfolk coast (52.95°N, 1.12°E) in the UK, starting from October 2007. O_2 measurements are made utilising an electrolytic reaction on the surface of lead fuel cells in an 'Oxzilla II' analyser from Sable Systems, and CO_2 measurements are made using an 'Ultramat 6E' NDIR analyser from Siemens. A gas handling system similar to that used by Stephens *et al.* [2007] is employed to draw air in from an aspirated inlet at the top of a 10 m a.g.l. tower, dry the air to a dewpoint of -90°C and then control flow rate and pressure before the sample air passes through the two analysers in series. A rigorous calibration methodology similar to that described by Keeling *et al.* [1998] is used to maintain accuracy and precision, and we participate in the 'Cucumber', 'GOLLUM' and WMO round robin intercomparison programmes to ensure the compatibility of our data compared to other global stations. The precision of ambient air measurements is typically ±0.03 ppm for CO_2 and ±2.0 per meg for O_2

We present data for both species and Atmospheric Potential Oxygen (APO), which combines the signals for O_2 and CO_2 so that APO is insensitive to terrestrial processes and thus illustrates mostly only influences due to oceanic processes. Calendar year 2012 data are shown below. Data are examined on interannual, seasonal, synoptic and diurnal timescales. The average amplitude of the WAO seasonal cycle is 14.2 ppm for CO_2, 128 per meg for O_2 and 59 per meg for APO, similar to other stations at similar latitudes. Growth rates over the 5 year period are 2.5 ppm yr^{-1} for CO_2, -26 per meg yr^{-1} for O_2 and -13 per meg yr^{-1} for APO. Short-term analyses reveal clear diurnal cycles in both CO_2 and O_2 that vary seasonally. No diurnal cycle is observed in APO. Short-term events are explored and confirm that WAO experiences both background marine air masses from the Arctic and North Atlantic, as well as fossil fuel pollution signals from the UK and continental Europe.



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Glacial burial and decomposition of ancient organic carbon at King George Island, Antarctica

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An expedition to King George Island (KGI), Antarctica was conducted during January, 2010. The main goal was to search for ancient organic carbon buried under ice and to understand the role of such organic carbon in glacial-interglacial CO_2 and climate changes. Three trips were taken to study the periglacial environment of the Collins Glacier (Bellingshausen Dome) on the southern edge of the KGI icecap. A glacial moraine was found to contain a large quantity of organic carbon. An outcrop was found to contain several clearly distinguishable layers: rubble, soil, moss, soil, shell, moss, muddy soil, and ice. The surrounding area and the glacial outwash downstream contain large amounts of organic material. CO_2 fluxes were measured at two locations using a LICOR-8100 soil CO_2 analyzer, with soil CO_2 fluxes ranging 15-20 ppm/30min (0.15 mmol m^{-2} sec^{-1}). Because there was no observable new vegetation growth on the site, and because the chamber where the flux was measured was dark (preventing photosynthesis), it appears that the CO_2 was the result of the decomposition of the organic carbon that was once buried under ice. Our findings support the hypothesis that organic carbon, including both vegetation and soil carbon, can be buried under ice, and later released back into the atmosphere, thus contributing to climate change through the emission of CO_2, a greenhouse gas. The age of the ancient carbon and the processes and circumstances under which they were buried are yet to be determined.

The expedition was part of a summer school organized in conjunction with the International Polar Year (IPY) 2007-2010. The IPY is a international effort to foster collaborative research in the polar regions of the Earth. The first IPY was from 1882-1883, the second from 1932-1933. This research comes at the tail end of the third IPY, the goal of which was to increase our knowledge of the poles, how they are changing, and to better understand the influence of the poles on the global climate system and vice-versa. The third IPY marks the largest international collaborative science effort since the International Geophysical Year 50 years prior.