

Biogeosciences

B11A CC: 524 A Monday 0830h

Changes in Land Use, Water Use, and Biogeochemical Cycles in Asia

Presiding: X Xiao, University of New Hampshire; J Chen, University of Toronto

B11A-01 0830h

Modeling Impacts of Farming Management Alternatives on Greenhouse Gas Emissions: A Case Study for Rice Agriculture of China

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Since early 1980s, water management for rice agriculture in China has substantially changed, with mid-season drainage gradually replacing the traditional practice, continuous flooding over this 20-year period. This change provided an opportunity for us to estimate how a management alternative could impact greenhouse gas emissions at a large regional scale. To answer this question, we developed a tool by integrating a process-based model, DNDC, with a GIS database. With this tool, we simulated carbon sequestration in and CH₄ and N₂O emissions from all of the rice paddies (about 30 million ha) in China based on 1990 climate and management conditions. Two water management scenarios, continuous flooding and midseason drainage, were applied in the simulations to quantify their effects on emissions of the three greenhouse gases. The modeled results indicated significant impacts of the change in water management on both CH₄ and N₂O emissions although CO₂ fluxes were only slightly altered. Methane emissions were reduced over the 20-year period by about 40 percent, or by 5 Tg/yr, roughly 5-10 percent of total global methane emissions from rice paddies. The mitigating effect of midseason drainage on CH₄ was highly uneven across the country with the highest reduction rates (200-290 kg CH₄-C/ha) for provinces Hainan, Sichuan, Hubei and Guangdong where double- or triple-cropping rice systems dominated with warm weather and high-clay soils, and the lowest reduction rates (less than 25 kg CH₄-C/ha) for Tianjin, Hebei, Ningxia, Liaoning and Gansu where there were only single cropping systems with relatively cool weather and low-clay soils. Shifting water management from continuous flooding to midseason drainage increased N₂O emissions from Chinese rice paddies by 0.15 Tg N per year, which offset a large fraction (65 percent) of the greenhouse gas benefit gained by the decrease in CH₄ emissions. The midseason drainage-induced N₂O fluxes were high (higher than 8.0 kg N/ha) in Jilin, Liaoning, Heilongjiang and Xinjiang where the paddy soils contained relatively high organic matter. In conclusion, the water management alternative (i.e., midseason drainage) has been predicted to have very different effects on mitigation when it is implemented across climatic zones, soil types, or cropping systems. The maximum CH₄ reductions and minimum N₂O increases can be obtained when the alternative management is applied in the rice areas with warm weather, high soil clay content, and low soil organic matter content. The provinces of Sichuan, Hubei, Hunan, Guangdong, Guangxi, Anhui and Jiangsu, which possess 60 percent of the rice paddies in China and produce 65 percent of China's rice harvest, fall into the category.

URL: <http://www.dndc.sr.unh.edu>

B11A-02 0855h

Land Use Change and Soil Organic Carbon Dynamics in China

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The changes of soil organic carbon depend not only on biogeochemical and climatological processes, but also on human activities and their interaction with carbon cycle. A long history of agricultural exploitation, forest management practice, rapid change in land use, forestry policies, and economic growth suggest that Chinese terrestrial ecosystems play an important role in the global carbon cycles. Using the data compiled from China's second national soil survey and an improved method of soil carbon bulk density, we have estimated the changes of soil organic carbon due to land use, and compared the spatial distribution and storage of soil organic carbon (SOC) in cultivated soils and non-cultivated soils in China. The results reveal that 57% of the cultivated soil subgroups (31% of the total soil surface) have experienced a significant carbon loss, ranging from 40% to 10% relative to their non-cultivated counterparts. The most significant carbon loss is observed for the non-irrigated soils (dry farmland) within a semi-arid/semi-humid belt from north-eastern to south-western China, with the maximum loss occurring in northeast China. Our results suggest that total organic carbon storage in soils in China is estimated to be about 70.31 Pg, representing 4.7% of the world storage. The results also indicated that a soil organic carbon loss of 7.1 Pg was primarily due to human activity, in which the loss in organic horizons has contributed to 77%. This total loss of soil organic carbon in China induced by land use represents 9.5% of the world's soil organic carbon decrease.

B11A-03 0910h

Carbon Sequestration in Reforested Areas in China Since 1970

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Since July 2002, a 3-year Canada-China joint project was funded by the Canadian International Development Agency and the Chinese Academy of Sciences to assess the current status of China's forests and the impacts of forestry activities on carbon sequestration. From 1973 to 2001, China's total forested area increased from 122 Mha to 159 Mha, owing to large-scale reforestation for the main purpose of soil erosion control. In this project, four local forest sites in Changbaishan, Heihe, Liping and Xingguo in various regions are chosen for intensive assessments of forest and soil stocks. Ground-based measurements of leaf area index (LAI), net primary productivity (NPP), soil texture,

vegetation and soil carbon stocks are used to calibrate models. High-resolution remote sensing images from ASTER and ETM are used to map LAI and NPP of these sites and for upscaling to the whole China based on MODIS and VEGETATION images. Remote sensing techniques and carbon cycle models (BEPS, INTEC) developed in Canada are being adapted to China's ecosystems. Preliminary results suggest that new reforested areas since 1970 are now actively sequester carbon, making the overall forested area as a carbon sink in the last few decades. Efforts are being made to reduce uncertainties in the estimation through incorporating new nation-wide datasets of forest age, soil texture and organic matter, nitrogen deposition, etc. At Changbaishan, Liping and Heihe, integrated assessments are being conducted to investigate the impacts of reforestation (Grain-to-Green) programs on the social and economic status of farmers as well as the ecological environment and land use options to maximize carbon sequestration.

URL: <http://www.utoronto.ca/cccs2002/index.html>

B11A-04 0925h

Mapping paddy rice agriculture in southern China using multi-temporal MODIS images

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Information on spatial extent and seasonality of inundation and paddy rice fields are needed for water resource management, trace gases emission, and food security. In this study we reported an effort to use images from Moderate Resolution Imaging Spectroradiometer (MODIS) sensor onboard NASA EOS Terra satellite to map inundation and paddy rice fields in southern China. Paddy rice fields are characterized by a period of inundation and open canopy (a mixture of surface water and rice crops). We developed a temporal profile analysis procedure that uses time series data of improved vegetation indices to identify and map inundation and paddy rice fields. The MODIS-based algorithm uses both Enhanced Vegetation Index (EVI) and Land Surface Water Index (LSWI), and excludes those pixels that are covered by cloud and snow from the analysis. Permanent water body mask and digital elevation model were also used in the analysis. Using multi-temporal 8-day composite of MODIS images at 500-m spatial resolution in 2002, we generated a map of inundation and paddy rice fields in southern China. The MODIS-derived paddy rice map was compared with the other datasets of paddy rice agriculture, including the paddy rice map derived from analysis of Landsat ETM+ images in 1999/2000. The results from the comparison have indicated that the MODIS-based algorithm could potentially be applied at large spatial scale for mapping and monitoring of inundation and paddy rice agriculture.

B11A-05 0940h

The Hydrology of a Semiarid Cloud Forest in Dhofar (Oman)

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In this paper we investigate the hydrology of a semi-arid seasonal cloud forest in Dhofar (Oman, Arabian Peninsula). Over the last 30 years the region has lost

vegetation cover, where closed canopy forests have become fragmented, presumably as a result of increased browsing pressure from livestock. In this area the mean annual temperature is 21 degree Celsius and the mean annual precipitation is 250mm, most of which falls during the 3 month long wet season. We use meteorological and hydrological measurements in an intact forest patch to investigate the hydrology of the forest in situ. This investigation will help us study the potential consequences for the removal of vegetation to the hydrology of the region and the potential for re-growth of the removed vegetation cover. Measured through-fall and stem-flow are considerably higher than measured rainfall above the canopy during the wet season. This is a result of additional water gained through interaction between trees and clouds, called horizontal precipitation. At the same time potential evaporation and sap flow are suppressed during the wet season as the permanent cloud cover reduces incoming radiation. As a result, soil moisture increases during the wet season and decreases only when the clouds recede. After the end of the wet season the trees continue to be productive and transpire for another three months, using water stored in the lower soil horizons during the wet season. We conclude that the combination of horizontal precipitation and low net radiation during the cloudy season is a key condition for replenishing deep soil water storage, which promotes net primary productivity of deeper rooted plants beyond the end of the wet season. We speculate that the removal of trees may cause lower amounts of horizontal precipitation, resulting in lower deep soil water storage at the end of the wet season and a shorter period of positive net primary productivity. The shortening of this productive period in turn may inhibit re-vegetation of the degraded areas with perennial plants, such as trees.

B12A CC: 524 A Monday 1030h

Recent Advances in Coupled Terrestrial Carbon Cycle and Climate Modeling I (joint with A, GC)

Presiding: V Arora, Canadian Centre for Climate Modelling and Analysis; **S Cowling**, University of Toronto

B12A-01 1030h INVITED

Impact of Soil Carbon Decomposition Dynamics on Global Climate

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Enhanced release of CO₂ from soils due to increased temperatures may lead to a positive feedback between climate change and the carbon cycle, resulting in much higher CO₂ levels and accelerated global warming. However, the magnitude of this effect is uncertain and critically dependent on the response of soil respiration to changes in climate. Previous studies with the Hadley Centre's coupled climate-carbon cycle GCM (HadCM3LC) have used a simple, single-pool soil carbon model to simulate the response. Here we present results from experiments which use the more sophisticated "RothC" multi-pool soil carbon model driven with the same climate data. The results show strong similarities in the behaviour of the two models, although RothC tends to simulate slightly smaller changes to global soil carbon amounts for the same forcing. We conclude that the projection of a positive feedback between climate and carbon cycle is robust to using these very different representations of soil carbon dynamics but the magnitude of the feedback is dependent on the form of the soil carbon model.

B12A-02 1045h INVITED

The Terrestrial Carbon Cycle and the Role of Historical Land Cover Change in the UVic Earth System Climate Model

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The behaviour of the terrestrial carbon cycle under historical and future climate change is examined using the UVic Earth System Climate Model, which includes a dynamic terrestrial vegetation and global carbon cycle model. When the model is forced by historical emissions of anthropogenic carbon dioxide the UVic ESCM reproduces well the observed increase in atmospheric CO₂. When anthropogenic emissions are separated into those from fossil fuel combustion and those from land cover change, we find that historical land cover change emissions contribute an additional 26 ppmv of atmospheric CO₂ by the year 2000 and result in an increase in simulated twentieth century warming of 0.3 °C. This result is compared to a transient model simulation forced solely by the land-surface changes (such as surface albedo) that have resulted from historical land cover change. This transient simulation results in a global cooling of -0.15 °C from 1850 to 2000, and as a result, we conclude that the net effect of historical land cover change has been to contribute 0.15 °C to anthropogenic climate warming. Carbon cycle and climate simulations are extended into the future, forced by six projections of anthropogenic CO₂ emissions from 2000 to 2100, taken from the Special Report on Emission Scenarios (SRES). Under these future scenarios terrestrial and oceanic carbon sinks continue to take up anthropogenic carbon, though there is evidence that the terrestrial carbon sink weakens somewhat over the 21st century. When plotted as a fraction of anthropogenic emissions, fractional terrestrial uptake declines noticeably after the year 2000, leading to an increase in the fraction of emissions remaining in the atmosphere. Analysis of the feedbacks that operate between the terrestrial biosphere and climate reveals that the dominant effect is a negative feedback that results from increased plant photosynthesis under elevated atmospheric CO₂. A smaller positive feedback to climate results from increased soil respiration in response to climate warming.

B12A-03 1100h

Climate impacts of Australian land cover change

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Australian land cover has been dramatically altered since European settlement primarily for agricultural utilization, with native vegetation widely replaced or modified for cropping and intensive animal production. While there have been numerous investigations into the regional and near surface climate impacts of Australian land cover change, these investigations have not included the climate impacts of larger-scale changes in atmospheric circulation and their associated feedbacks, or the impacts of longer-term soil moisture feedbacks. In this research the CSIRO General Circulation Model (GCM) was used to investigate the climate impacts of Australian land cover change, with larger-scale and longer-term feedbacks. To avoid the common problem of overstating the magnitude and spatial extent of changes in land surface conditions prescribed in land cover change experiments, the current Australian land surface properties were described from finer-scale, satellite derived land cover datasets, with land surface conditions extrapolating from remnant native vegetation to pre-clearing extents to recreate the pre-clearing land surface properties. Aggregation rules were applied to the fine-scale data to generate the land surface parameters of the GCM, ensuring the equivalent sub-grid heterogeneity and land surface biogeophysics were captured in both the current and pre-clearing land surface parameters. The differences in climate simulated in the pre-clearing and current experiments were analyzed for changes in Australian continental and regional climate to assess the modeled climate impacts of Australian land cover change. The changes in modeled climate were compared to observed changes in Australian precipitation over the last 50 and 100 years to assess whether modeled results could be detected in the historical record. The differences in climate simulation also were analyzed at the global scale to assess the impacts of local changes on larger scale circulation and climate at distance from the land cover changes. The Australian continental and regional analyses demonstrated that Australian land cover change did have statistically significant impacts on air temperature and precipitation simulated in the CSIRO GCM. While none of the statistically significant trends in annual precipitation were found to be statistically significant in the climate modelling experiments, the modelled reductions in annual precipitation for south east Queensland and eastern New South Wales corresponded with the strong drying trends in those areas for 1950 - 1999. Larger scale analysis of differences in climate suggested the local changes in surface fluxes had strong impacts

on atmospheric circulation. The largest changes were in austral summer (DJF) circulation where monsoon flow into northern Australia was reduced, corresponding with increased monsoon flow into the South Pacific Convergence Zone and increased south easterly wind flow into eastern Queensland. These changes in circulation influenced DJF moisture flux into northern and eastern Australia, which intensified the direct warming and drying impact caused by the reduced transpiration from land cover change.

B12A-04 1115h

A Protocol for Identifying and Evaluating Key Feedbacks in Coupled Terrestrial Carbon Cycle-Climate Models

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Land and ocean carbon cycling are greatly influenced by climate and atmospheric CO₂. In turn, atmospheric CO₂ is influenced in the short-term and long-term by terrestrial and oceanic carbon cycle processes. Carbon cycle-climate feedbacks play a key role in how fast the Earth warms due to greenhouse gas release. The difficulty of including and evaluating feedback processes in global climate models stems from both climate science and computational science considerations. The scientific challenge for computational climate science is identification and suitable representation of significant carbon cycle feedbacks in the climate system, particularly ones that will change over the next several decades. We outline methods to identify terrestrial carbon cycle and hydrological feedbacks that are large enough to demand increased attention in the continuing development of climate system models. This is accomplished by employing local, site-scale terrestrial carbon and/or hydrologic cycle models that contains process representation of photosynthesis, respiration, decomposition, disturbance, hydrology and vegetation change. These simulations provide insight into mechanisms and complex interactions and secondary effects. A quantitative method involving "off-line" or decoupled global biosphere models is derived to compare the response of each of these processes, at a global scale, to global changes anticipated to occur over the next century. This method can expose unforeseen processes that are significant for carbon cycle-climate simulations. We provide a detailed example of the potential impact of temperature acclimation on heterotrophic respiration and positive climate-carbon feedback at high temperatures. Temperature acclimation itself does not significantly reduce the gain in carbon cycle-climate feedback. However, the response of the specific temperature function in the range of 15 to 35 °C and the readjustment of the relative magnitudes of the various soil carbon pools are significant. Accordingly these are the ecosystem processes that should receive priority consideration in evolving coupled climate-carbon models.

B12A-05 1130h

A Simple Approach to Estimating Temporal Changes in Global Vegetation for Use in a Coupled Terrestrial Ecosystem-Atmosphere Model

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Human-caused conversion of natural ecosystems to agricultural land is thought to have significant impacts on the global carbon cycle and climate. Hence, capturing such effects in global terrestrial ecosystem models is an important requirement when accounting for land-use change effects in coupled carbon-climate models. In this study, changes in area fractions of 10 Plant Functional Types (PFT) were estimated for the period 1850-2100, from changes in global cropland area obtained from the Ramankutty & Foley dataset (R&F).