B21B-04 0915h

Retrospective mapping of structural and biomass changes in forest ecosystems using photogrammetry and laser altimetry

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The Kyoto Protocol has sharpened the focus on the possible role of forests in contributing to or mitigating climate change. The understanding of carbon dynamics, and the prediction of future carbon stock changes, rely on an analysis of the past forest dynamics. Historical data may often be incomplete, approximate, or strongly generalized. To circumvent this problem, we have recently developed a method for producing precise reconstructions of the forest's three-dimensional structure. A top-of-canopy digital surface model (DSM) is created using stereo matching techniques applied to scanned historical aerial photographs. The DSM is registered to a very accurate below-canopy digital terrain model (DTM) generated using scanning laser altimetry. The elevation difference between the top-of-canopy DSM and the below-canopy DTM corresponds to canopy height, and constitute a canopy height model (CHM). We can thus retrospectively quantify the structural changes, including growth, disturbances, and gaps, for at least the past 60 years, with good accuracy. Recent studies have shown that reliable estimates of forest above ground biomass can be derived from high resolution CHMs. By applying such methods to retrospective CHMs, a detailed analysis of forest biomass and carbon stock changes for a number of ecosystem types of the Canadian forest is currently being performed.

URL: http://www.unites.uqam.ca/dgeo/biocap

B21B-05 0930h

Development and Validation of satellite-based Vegetation Photosynthesis Model

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Gross primary production (GPP) of vegetation is one of the key processes that determine net ecosystem exchange (NEE) of CO2 between the atmosphere and forest ecosystems. CO2 flux measurements at individual CO2 eddy flux sites provide valuable datasets for parameterization and validation of satellite-based diagnostic models. In this paper, we developed and validated the satellite-based Vegetation Photosynthesis Model (VPM) for modeling GPP, and applied it to a temperate deciduous broadleaf forest in the northeastern United States. VPM model estimates GPP of vegetation, using two improved vegetation indices (Enhanced Vegetation Index, Land Surface Water Index), temperature and photosynthetically active radiation (PAR) data. Three sets of simulations of the VPM model were conducted using input data from both the VEGETATION (VGT) and Moderate Resolution Imaging Spectroradiometer (MODIS) sensors. The first simulation used vegetation indices from 10-day composite VGT images and site-specific air temperature and PAR data from 4/1998 to 12/2001. The second simulation used vegetation indices from the 8-day MODIS Surface Reflectance Product, site-specific air temperature and PAR data in 2001. The third simulation used vegetation indices from the 8-day MODIS Surface Reflectance Product, land surface temperature from the 8-day MODIS Land Surface Temperature Product and site-specific PAR data in 2001. Predicted GPP values in the three simulations of VPM model agreed reasonably well with observed GPP of deciduous broadleaf forest in Harvard Forest, Massachusetts. This study highlighted the biophysical performance of improved vegetation indices in the context of GPP and demonstrated the potential of the VPM model for estimating GPP of deciduous broadleaf forests.

B21B-06 0945h

Increase in Carbon Storage for Sahelian Vegetation between 1982-1999

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The Sahel belt of north Africa has been flagged as a hotspot for land cover change. For the period 1982-1999, Eklundh and Olsson (2003) identify large areas of strong, positive trends in NOAA AVHRR-derived NDVI (Normalized Difference Vegetation Index). This discovery implies that the Sahel may play a significant role in the tropical carbon cycle. The NDVI is a quantitative indicator of relative vegetation amount, and has traditionally been used as a surrogate measure of NPP (Net Primary Production), often expressed in terms of carbon content. It cannot, however, quantify absolute NPP amounts. The goal of our work is to estimate the magnitude of the increase in carbon storage in the vegetation of the Sahel for the period 1982-1999 using a light-use efficiency model. A light-use efficiency model encapsulates the essence of the plant growth process at an aggregate level; solar radiation is absorbed by plants to provide energy for photosynthesis, while soil moisture controls the efficiency of light usage. Our model runs at a monthly time-step (the hydrological component has a quasi-daily time-step), and is driven by data from the NOAA AVHRR (Seaquist et al., 2003). The model has undergone sensitivity testing, and various sub-components of the model have been validated. After implementation, monthly NPP surfaces were summed to yield total growing season (May to October) amounts, expressed as carbon content, for the 17-year period. Trends were estimated by fitting linear functions to the data on a pixel-by-pixel basis using ordinary least squares regression. Only those trends that were statistically significant at the 95% confidence interval were mapped. The results show a conspicuous band of moderate to strong increase (25-75%) in NPP across the Sahel belt, especially throughout Mali, Burkina Faso, northern Nigeria, and into Central Chad. The trends become weaker further east, before they intensify through central and southern Sudan. Our calculations show that the average rate of increase in vegetative carbon storage has been 8 gCm-2yr-1 for the Sahel, while certain areas sequestered substantially more, up to 20 gCm-2yr-1. For the Sudano-Sahel region as a whole (from 8 to 20 degrees north latitude) this equals a total increase of approximately 0.06 GtCyr-1. Schimel et al. (2001) point out that for the tropics (30 degrees south latitude to 30 degrees north latitude), terrestrial ecosystems sequester carbon at a rate of about 2.0 GtCyr-1, offsetting the emissions of about 1.6 GtCyr-1 due to tropical deforestation. Our results imply that the Sahel may be part of this sink. Increasing rainfall over the last few years is certainly one reason for the trend, but does not fully explain the change. Other factors, such as land use change and migration may also contribute. Our work takes a significant first step toward contextualizing the role of the Sahel in the tropical carbon budget, but a complete carbon modelling exercise considering below-ground components will be required to support the sink hypothesis. Eklundh, L., and Olsson, L. 2003. Vegetation index trends for the African Sahel 1982-1999. Geophys. Res. Lett. 30(8): 1430, doi:10.1029/2002GL016772. Schimel, D. S., House, J.I., et al. 2001. Recent patterns and mechanisms of carbon exchange by terrestrial ecosystems. Nature 414, 169-172. Seaquist, J.W., Olsson, L., and Ardö, J. 2003. A remote sensing-based primary production model for grassland biomes. Ecol. Mod., 161, 131-155.

B22A CC: 524 A Tuesday 1030h

BOREAS +10: Carbon Cycling and Storage in Canadian Boreal Forest Ecosystems

Presiding: **M Litvak,** University of Texas at Austin**; A McGuire,** University of Alaska, Fairbanks

B22A-01 1030h

The Boreal Ecosystem Research and Monitoring Sites: A Synthesis of Results, 1994-2003

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The Boreal Ecosystem Research and Monitoring Sites (BERMS) program is a multi-year, interdisciplinary study of the carbon, water and energy cycles of the southern Canadian boreal forest in relation to inter-annual climate variability, ecosystem type, and stand age following disturbance by fire and harvest. The three primary BERM sites (Old Aspen, Old Black Spruce, and Old Jack Pine) were established in 1993-4 as part of the Boreal Ecosystem-Atmosphere Study (BOREAS) and have continued since 1997 as part of BERMS. In addition, six satellite sites have been established in young forest stands following disturbance by fire and harvest. The BERM sites are the flagship tower flux sites of the new national Fluxnet-Canada Research Network. The BERMS region has become a "super-site" for collaborative research by others, as the tower network and auxiliary observations provide a research data base suitable for many other environmental studies. We report a synthesis of flux and climate data from 1994-2003. Two climatic features dominate the 1994-2003 time series: the contrasting warm springs of 1998 and 2001 and cool springs of 1996 and 2002, and the extended drought of 2001-2003. The synthesis will include: an evaluation of inter-annual climate variability and its effects on the carbon and water budgets of a boreal aspen forest; a comparison of three contrasting boreal forest ecosystems (aspen, black spruce and jack pine); and a comparison of forest stands of different ages following disturbance by fire and harvest.

B22A-02 1050h

A comparison of methane emissions from the Northern Study Area of BOREAS during two climatically different years

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Methane (CH_4) fluxes were measured at a wide range of wetland and upland sites with a static chamber technique during two years with different climate

patterns as part of the BOReal Ecosystem Atmosphere Study (BOREAS), near Thompson, Manitoba. June-September 1994 and 1996 were both drier and warmer than normal, but summer 1996 received 50 mm more precipitation than 1994 and had a mean daily temperature of $1^{o}C$ greater than in 1994. Seasonal average methane emissions in the wetlands ranged from 30 to 250 mg CH_4 m^{-2} d^{-1} across a diverse mosaic of bogs, fens and permafrost collapse scars (pH 3.9-7.2) and increased an average of 60% during the wetter and warmer 1996 growing season (ranging from 15% to 100% increase depending on initial moisture status). CH_4 fluxes in the uplands (jack pine, black spruce) ranged from a small sink to a small source, and were not significantly different between years. Extrapolating across the Northern Study Area (NSA), based on relative percent cover of different wetland and upland ecosystems, we calculated the percent change in CH_4 fluxes between years. Although wetlands cover less than 10% of the landscape in the NSA, they dominate the increase in CH_4 emission between 1994 and 1996.

B22A-03 1105h

Changing Sources of Soil Respiration in a Boreal Forests With Time Since Fire

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We studied how temperature and moisture affect soil respiration and potential sources (roots and microbial) along a chronosequence of six forest stands ranging from 0 to 150 years following fire. Study sites are located in the BOREAS Northern Study Area in Canada (55N, 98W). The vegetation is dominated by black spruce (Picea mariana) and mosses on clay soils with underlying permafrost. At all sites we measured soil respiration with dynamic chambers and root respiration by field incubations. We determined microbial respiration using laboratory incubations at 0, 73, and 150 years since fire at three temperature and two moisture levels. We determined the radiocarbon ($\Delta^{14}C$) signature of individual respiration sources with AMS. Shortly after fire soil respiration was dominated by root respiration. The fraction of microbial respiration increased with increasing stand age. 15-40 years after fire carbon in the lower organic layer and mineral soil was the source of microbial respiration. In older stands carbon in the upper organic layer was the dominant source. CO_2 respired from black spruce roots was on average 3 to 4 years older than ambient air and thus recent photosynthates. To determine the carbon source of root respiration we measured the $\Delta^{14}C$ values of needle and root soluble carbohydrates and starch. Microbial respiration increased with increasing temperature and moisture, with no significant changes in the $\Delta^{14}C$ values of the respired CO_2. Total fluxes and moisture response of upper organic layers were higher than of lower organic layers.

B22A-04 1120h

Organic Soils of the North: a Mismatch for our Current Climate?

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Soil C reflects long-term net ecosystem production (NEP); therefore, spatial patterns of soil C storage lend insight into broad, lasting variations in NEP. Boreal forests are unique in that many soils retain enough organic matter to develop a chronology of C accumulation, which is related to both fire cycles and permafrost cycles: Accumulation of organic matter in the presence of permafrost or shallow water tables has allowed carbon to become buried into wet, cold environments that were inaccessible to subsequent fire and decomposition. Aggradation of permafrost has allowed repeated fire and regrowth cycles to become buried in accreting peats, particularly peat plateaus. Most uplands, by contrast lost their carbon by efficient decomposition and fire events. Based on large carbon stocks of northern soils, we hypothesized that recent occurrences of wildfires should reflect a similar spatial pattern in which poorly drained soils sustain proportionately less burned area than well drained soils. Surprisingly, we found that in Alaska and western Canada over the past 50 years, burning did not occur preferentially in drier, upland areas. Moreover, in Alaska, wetter areas sustained a disproportionately greater burn area than drier areas relative to the statewide distribution of wetter to drier landscapes. This suggests to us that the long-term patterns of NEP are out of phase with recent decades. Recent measurements of climate and carbon accumulation rates also allude to modern systems being out of phase with long-term averages. For instance, at the northern old black spruce site in Manitoba (NOBS), organic matter has accumulated over the past 6500 years and yet NEP data from the past 10 years indicates that the net accumulation is zero. Furthermore, our NEP reconstructions based on current temperature and decomposition responses over repeated fire and regrowth cycles suggest that either colder temperatures and/or more stable forms of carbon may be responsible for the large C stocks that reside beneath the wetter black spruce/sphagnum systems, which comprise about 50% of the NOBS footprint. Last, in many sites at NOBS, moss and tree indications of recent permafrost have not been supported by the presence of frost in late summer, which appears most sensitive to summer rain than to summer temperature. These systems are sensitive to complex interactions among local temperature, precipitation, and vegetation shifts yet we raise the question as to whether there is converging evidence that boreal forests are undergoing a marked shift in disturbance patterns, reduced NEP, and permafrost degradation that is unprecedented for the millennial timescale in which these northern soils have formed.

B22A-05 1135h

Simulating Fire Disturbance in the Canadian Boreal Forest Using TRIPLEX Model

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Forest fire is a natural part of forest ecosystems and plays an important role in fuel load reduction, tree growth and mortality, and carbon/nitrogen cycling. Over the past century, the changes in land use and land management activities have changed the regime of forest fires. To better understand the effects of forest fires on forests as well as the interactions between human activities and forest fire regime, a fire module has been developed and incorporated into the TRIPLEX forest ecosystem model (TRIPLEX-Fire). TRIPLEX-Fire can be divided into three parts: fire ignition, fire intensity, and fire effects. Fire ignition is simulated as a spatially stochastic process under specific conditions of climate, fuel loadings and fuel moisture. Combustible areas, fireline intensity, and scorch height are major variables for simulating fire intensity. Fire-induced tree mortality, fuel load reduction, carbon emissions to the atmosphere, and soil carbon/nitrogen transformation are simulated and incorporated with post-fire regeneration as a part of fire effects. Observations from two sites in BOREAS study areas were used to calibrate and verify the TRIPLEX-Fire model. Simulations were performed under different scenarios of land use and management to investigate the possible impacts of fire disturbances on the Canadian boreal forest.

B22A-06 1150h

Use of $^{18}O/^{16}O$ in O_2 to Constrain Greenhouse Gas Emissions and Carbon Cycling Processes in Experimental Boreal Reservoirs

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Understanding the biogeochemistry of greenhouse gas (GHG) production in boreal upland reservoirs is one objective of the FLooded Upland Dynamics EXperiment (FLUDEX) at the Experimental Lakes Area (ELA). The decomposition of flooded organic matter produces dissolved inorganic carbon (DIC) and methane (CH_4), and consumes oxygen (O_2). To determine the magnitude of biological processes (community respiration, primary production, CH_4 production, and CH_4 oxidation), isotopic ratio mass budgets of $^{13}C/^{12}C$ in DIC and CH_4, and $^{18}O/^{16}O$ in O_2 were constructed for the 5 years of FLUDEX. Analysis of $^{18}O/^{16}O$ in O_2 by continuous flow is a relatively new technique an can be used to separate O_2 consumed by decomposition from O_2 produced by primary production because each process affects the $^{18}O/^{16}O$ in O_2 at a different magnitude and in opposite direction. Isotopic ratio analyses show that up to 40% of DIC produced by community respiration is removed by primary production and that O_2 evolution by primary producers is an important source of O_2 to keep the water column fully oxygenated for fish survival. O_2 production by benthic primary producers also facilitated increased CH4 oxidation across the sediment-water interface. In addition to the important role O_2 played in GHG biogeochemistry, diurnal and seasonal dynamics of $^{18}O/^{16}O$ in O_2 were used to constrain GHG emissions.

B

B23A CC: 220 C-E Tuesday 1330h

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

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

B23A-01 1330h POSTER

A Dynamic Global Vegetation Model With Biophysics, Biogeochemistry, and Biogeography Suitable for Coupling With Atmospheric GCM's for Decadal to Century Scale Studies

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A dynamic global vegetation model is being developed at the NASA Goddard Institute for Space Studies (GISS) suitable for decadal to century long simulations and for full coupling with atmospheric general circulation models (AGCMs). The model uses computationally efficient, process-based algorithms to predict