Hg levels (with respect to common contamination from atmospheric deposition) in soils in western Connecticut are attributed to former hatting factories in the cities of Danbury and Norwalk that were active in the 19th and 20th centuries. Vegetation was sampled that is widespread and sensitive to heavy metal uptake and includes Acer, Spartina, Phragmites and various grass species. Study sites are surveyed using GPS, photography and soil and vegetative cover descriptions. Soil and plant leaves are analyzed for total Hg (THg) concentration with a Milestone Direct Mercury Analyzer and for other metals (Cu, Pb, Cr and Zn) by ICP-MS. Leaf reflectance is measured in situ with an ASD FieldspecFR spectroradiometer with a wavelength range of 350-2500 nm. The THg concentrations range from low ppb values to > 75ppm in soil samples and from 3ppb to 2.7ppm in vegetation samples. The highest concentrations of Hg (40ppb to 2.7ppm) in plant tissue at all sites were from Acer species (when present). Initial results reveal that leaf and soil THg concentrations do not directly correlate, suggesting variations in metal uptake by different species and plant parts. However, there is a positive correlation (R2= 0.67) between soil and leaf THg concentration for a given species such as Acer. The relationship between metal concentration and vegetation spectra is evaluated by correlating spectral vegetative indices (VIs) such as Simple Ratio (SR) and Red Edge Position (REP) with leaf and soil metal concentrations. In Acer species, a shift in the red edge position to shorter wavelengths occurs with increasing leaf THg content (R2= 0 .44). The SR values are negatively correlated with leaf mercury concentration (R2= 0.31). The REP and SR relations for marsh plant species are not significant, most likely the result of the low THg concentration of marsh species leaves (3ppb-14ppb).

B21A-02 0830h POSTER

Mercury in Connecticut and Long Island Sound: Impact of Historic Hatting Industries

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Wetlands in the northeastern region of the U.S.A. are mildly contaminated with Hg as a result of atmospheric deposition, with modern soil concentrations of several 100 ppb Hg. Connecticut was once considered the hat manufacturing capital of the world. A solution of Hg-nitrate was used in the felting process, and old hat factory sites have become point sources of Hg contamination. Surface soils in the former hatting town of Danbury have Hg soil concentration levels that well exceed Connecticut's residential soil remediation standard of 20 ppm. Sediments from the Still River, a small waterway that runs through Danbury and discharges into the Housatonic River, show locally Hg concentrations of several tens of ppm, Cores taken from marsh islands in the Housatonic River show elevated Hg concentrations as well, up to 5 ppm Hg. Sites in Norwalk, another former hatting town, and along the Norwalk River also show values of more than 5 ppm Hg. The old hat factory sites in both towns clearly serve as point sources for Hg contamination downstream. Cores taken from marshes in the Connecticut River, which drains no former hatting towns, had much lower Hg concentrations (up to 500 ppb Hg). The Five Mile River marsh near Darien, CT has lower peak values than found in the sediments of the Housatonic and Norwalk River cores, but still slightly elevated (800 ppb Hg). The Hg from the hat-site point sources is ultimately entering Long Island Sound. High Hg levels are found in western Long Island Sound compared to the eastern section (up to 800 ppb Hg), which is the result of fine-grained sediment transport westwards in the Sound, and the release of Hg-bearing effluent from waste water treatment plants of New York City. The contaminated sediment output from the Housatonic and Norwalk Rivers also contributes to the elevated Hg levels in the western Sound and possibly the Five Mile River marshes. Cores taken from the Housatonic River and western Long Island Sound show also peak Hg concentrations in sediment deposited around 1955, which is attributable to catastrophic flood events that affected the area at that time. The floods led to massive sediment discharge events into the Sound, leading to the deposition of thin Hg-enriched layers in the sediment column. Hatting-derived Hg concentrations in soils and sediments are above common soil standards at a local level in the Norwalk and Danbury areas, are significant in the Housatonic and Norwalk River sediments, and are noticeable in muds from Long Island Sound.

B21A-03 0830h POSTER

Mercury Retention in Wetlands and Potential Long-Term Export to Surface Waters of the Adirondack Region, New York.

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This study quantifies mercury retention in wetlands of the Adirondack Region, New York. Anthropogenic mercury emissions into the atmosphere have increased mercury deposition and subsequently increased contamination of surface waters in remote regions, resulting in toxic rates of mercury bioaccumulation. It is unclear at what rate surface waters might recover and, in the Adirondack Region, it is possible that any effect of declining mercury deposition will be constrained by chronic accumulation and release of mercury from wetlands. Total mercury (Hg_T) and methylmercury (CH_3Hg) retained in peat was determined for 3 headwater and 3 riparian sites. Peat was collected along hydrologic gradients within each wetland and analyzed incrementally by depth. Data indicate that Hg_T accumulated in the top 50 cm of wetland peat was greater in riparian zones than in headwater wetlands. Retention of Hg_T was greatest at the upland interface, and declined along the hydrologic gradient. Total mercury retention was greatest in the zone of water table fluctuation, between 15cm and 35cm, and declined to nearly zero at depths greater than one meter. Dissolved Hg_T concentrations were lower in shallow-peat riparian zones than in deep-peat and stream water. However, Hg_T associated with fine particulate matter was an order of magnitude greater in shallow-peat than in deep-peat and stream water. Quantifying wetland retention of Hg_T and potential export of CH_3Hg will help address possible delays in recovery of mercury contaminated surface waters relative to reductions in mercury deposition in the Adirondack Region, New York.

B21B CC: 524 A Tuesday 0830h

Multitemporal Remote Sensing of Vegetation I

Presiding: **C Song,** University of North Carolina at Chapel Hill**; W B Cohen,** USDA Forest Service

B21B-01 0830h INVITED

Using Multitemporal Remote Sensing to Map Global Land Cover and Vegetation Dynamics

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Data from the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Terra and Aqua spacecraft provides a wealth of information regarding the spatio-temporal dynamics in land surface properties. In this paper, we describe results from efforts to map land surface properties from MODIS, emphasizing land cover and vegetation dynamics. Specifically, we describe algorithms and data sets that are designed to characterize the geographic distribution and phenology of vegetation and land cover types at global scales. Multitemporal data from MODIS is central to these efforts in three regards. First, multitemporal information provides a key source of information that helps to distinguish between vegetation and land cover classes that are otherwise spectrally similar. Second, MODIS data is being used to monitor continental to global scale vegetation phenology, and to identify key intra-annual transition dates such as the onset of greenup and senescence. As part of this effort we are also developing empirical models that characterize and explain the first order sources of spatial variation in these terms (i.e., precipitation and temperature regimes). Third, multitemporal vegetation indices are being used in combination with observations of vegetation phenology to characterize the time-varying fraction of green vegetation at the land surface. This paper will describe how multitemporal data from MODIS is being used to map each of these fields, and in this way, to provide a more realistic representation of time-varying biophysical conditions at the Earth's land surfaces for use in models.

URL: http://geography.bu.edu/landcover/

B21B-02 0845h INVITED

Expressing Vegetation Dynamics Through Transformed MODIS Data

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Land cover is a key parameter in many biogeochemical models. Multispectral imagery is possibly the only efficient, cost-effective way to build a global coverage of land cover information. Land cover attributes must be derived from the spectral properties of vegetation that invariably change over the course of the growing season. Using a data transformation, it is possible to maximize spectral and temporal variation among vegetation types so as to make land cover attributes more readily interpretable from multispectral imagery. Here, we develop a transformation for the Moderate Resolution Imaging Spectroradiometer (MODIS) Nadir BRDF-Adjusted Reflectance (NBAR) product from a global sample and analyze temporal vegetation dynamics in the feature space. A random sample of pixels was drawn from a full year of snow-free, cloud-free data, and only pixels of good quality (based on MODLAND mandatory QA) were subsequently extracted. A principal components analysis was first used to reduce the data into three dimensions. Smaller samples with known land cover attributes were then derived to analyze the resulting PCA space and rotate the axes as needed to maximize the spectral expression of vegetation dynamics.

B21B-03 0900h

Integrating BDRF Into LAI Algorithms For Global LAI Estimation

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Leaf area index (LAI) is one of the most important Earth's surface parameters in modeling ecosystems, climate etc., and regional and global LAI distributions can be estimated from remote sensing measurements. Based on LAI algorithms previously derived from Canada-wide applications, new algorithms are developed to estimate LAI globally as part of a European Space Agency project (GLOBCARBON). The main technical issue is to consider explicitly the bidirectional reflectance distribution function (BDRF) in the LAI algorithms and hence removing the need of doing BRDF corrections to the input images. The core problem of integrating BDRF into LAI algorithms is that semi-empirical BRDF kernels that are required to relate spectral reflectances to LAI are also LAI dependent, i.e., the problem is non-linear. Theoretically the nonlinear problem can be solved through a numerical scheme, but this is no desirable for global applications, which require computation efficiency. We therefore developed a methodology to solve the problem through a simple iteration procedure: (1) a precursor LAI value for a pixel is first estimated from a general cover-type dependent SR-LAI relationship, (2) BRDF kernels are calculated using the precursor LAI value, and (3) final LAI is calculated from the BRDF kernels and SR. A geometrical optical model named 4-Scale is used for modeling the BRDF kernels, and Chebyshev polynomials of the second kind are used to fit simulated relationships between SR and LAI and the coefficients in BRDF kernels as functions of LAI, illumination and observation angles. Example global LAI maps are produced using SPOT VEGETATION images at 1 km resolution.

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