

unique opportunity to assess the variability and uncertainty in CO₂ flux measurements.

B14A-02 1545h

Surface Water and Heat Exchange Processes at a Swedish Peatland.

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Peatlands cover large areas of the northern boreal biome and have a significant importance in both regional hydrology and global climate context. However, open peatlands are poorly represented in physical descriptions and parameterizations for models of land surface processes, and very few attempts have been made to examine their functions. The main difficulty concerns the Sphagnum mosses which dominate the surface layer. The flux interaction between surface and the scarce canopy as well as the effects of hummock and hollow microtopography are also issues to be examined. A 1-dimensional SVAT model was used to simulate the energy exchange at a Swedish Sphagnum peatland with sparse canopy. Separate parameterizations and simulations were made for hummocks and hollows. The initially used soil parameters, derived from literature values, resulted in too low water contents in most layers. The estimated unsaturated hydraulic conductivity was also far too low to give correct descriptions of soil moisture variation and moss evaporation capacity. In the simulations, differences between wet and dry periods were overestimated and the moss surface had to be simulated as continuously moist and evaporating during both wet and dry periods to avoid overestimation of peat temperature. When the mosses were parameterized to be able to evaporate almost freely, the simulated total atmospheric fluxes agreed fairly well with measured fluxes. The description of hollow heat transport processes was good in saturated conditions but failed when water table dropped, probably because of peat compressibility effects. The results show that current soil property descriptions are not working properly for mosses and fresh peat and there is a call for alternative descriptions. Another dilemma was found in that there were indications that a one-dimensional approach of hummock processes may be improper, because of its three-dimensional appearance.

B14A-03 1600h

Climatic and radiative forcing consequences of peatland response to changing climatic conditions over decadal to millennial timescales

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We explore short- and long-term climatic radiative forcing consequences of CO₂ and CH₄ emissions from peatlands under varying climatic conditions. We couple output from the Peat Accumulation Model with empirical estimates of methane emissions and a first-order atmospheric perturbation model to assess relative impacts of peatland CO₂ and CH₄ emissions dynamics, accounting for differences in atmospheric lifetime and radiative efficiency. This provides a more dynamic and complete view of climatic impacts than a standard global warming potential analysis. We examine the first order effects of changes in moisture conditions in response to changes in the water balance, due to changes in the difference between precipitation and evapotranspiration. We also examine potential second order influences by changing the position of the water table relative to the peat surface, which could be caused by a drop in the peatland surface due to permafrost melting (i.e., collapse scars) and/or the burning of a peatland.

B14A-04 1615h

Photosynthesis Respiration Balance of Lakes

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Growing concern about global climate change necessitates an improved understanding of carbon cycling in aquatic systems. Aquatic ecosystems are net autotrophic and act as sinks for CO₂ if photosynthesis exceeds respiration. When respiration exceeds photosynthesis they are net heterotrophic and act as sources of CO₂ to the atmosphere. The relative importance of net primary productivity over community respiration in both marine and freshwater ecosystems has been a highly debated subject for many years. While some work has shown respiration to exceed photosynthesis in all but the most eutrophic ecosystems, others have found that photosynthesis is greater than respiration in even oligotrophic systems. Independent of these studies is the observation that most lakes are continually supersaturated with respect to CO₂. Previous work has shown stable isotopes of oxygen are an effective means of tracing the photosynthesis respiration balance of aquatic ecosystems. In an attempt to resolve the P:R balance of lakes we have applied this stable isotope technique to twenty-one lakes in Quebec with varying physicochemical properties. The lakes were examined on a monthly basis between May and October 2003 and the metabolic balance determined. Preliminary results indicate the P:R balance of the ice-free period to be near equilibrium, despite near continual supersaturation in CO₂.

B14A-05 1630h

Ebullition of biogenic gas bubbles from samples of near-surface peat.

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There is evidence that peat soils are not water-saturated below the water table (e.g. Rosenberry et al. 2003; Baird and Waldron, 2003), owing to accumulations of biogenic gas bubbles, consisting of poorly-soluble gases such as CH₄. It has been shown that gas bubbles can block pores and reduce rates of water flow in peat soils (Baird and Waldron, 2003). It has also been shown that, beyond certain levels, biogenic gas bubble accumulations become unstable, giving rise to large but episodic ebullition events, and that ebullition may be an important mechanism of CH₄ transfer between peat soils and the atmosphere (e.g. Romanowicz et al., 1995; Rosenberry et al., 2003). However, the studies that have been done on ebullition have looked at relatively deep peat where the bubbles were apparently held below a confining layer of low hydraulic conductivity. Very little is known about the degree to which gas bubbles accumulate in near-surface peat (i.e. the upper 40 cm) and whether they accumulate to such an extent that ebullition and transfer of carbon gases to the atmosphere occur. To address this lack of knowledge we conducted experiments on eight undisturbed samples of near-surface (depths of c. 8 cm to 30 cm) peat taken from two lowland raised bogs, one in SW Scotland and one in W Wales. The samples were c. 10 l in volume and were incubated at 12 deg. C with the water table maintained above the sample surface. Water was allowed to flow through the samples periodically for the measurement of hydraulic conductivity (not reported here). Gas traps were fitted to the tops of the samples and the volume of gas in these was measured c. every 2-3 days. Finally, the samples were fitted with TDR probes and gas permeation samplers to measure gas volume and to take gas samples for the measurement of gas content (CH₄ and CO₂) using a GC. Ebullition was recorded in every sample but only after a build up of biogenic gas bubbles had occurred. We found that ebullition was not episodic and that it appeared to match gas production. The amount of ebullition varied substantially between samples. In two samples from the Scottish bog consisting respectively of *Sphagnum papillosum* and *S. magellanicum* litter, over 400 ml of gas per sample was lost over a 90-day period. At the other extreme, virtually no ebullition occurred from one of the Welsh peat samples, with only 14.5 ml being lost in 125 days. Provisional calculations based on CH₄ concentrations in our gas permeation samplers suggest that CH₄ efflux from the peatland surface via ebullition is potentially as important as that via diffusional transfer. We consider how transportable our data are to field conditions.

B14A-06 1645h

Development and testing of an improved model of the thermal behaviour of peat soils.

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Many biogeochemical processes in peats are temperature-sensitive. Despite this, little work has been done on characterising the thermal behaviour of peats. Most existing studies have looked only at 1-D thermal behaviour using simple models in which the thermal properties are constant with depth, and the temperature variation at the surface is specified from field measurements or is assumed to follow a sine wave. We report on the development and application of a more realistic thermal model of peat soils in which heat transfer is described by a system of capacitors' or nodes and resistors'. Its features include: 1. A realistic surface boundary condition where convective (sensible and latent) and radiative (short- and long-wave) heat transfers are accounted for by nodes representing the air/atmosphere above the peatland surface. 2. The ability to vary thermal properties with depth in order to simulate, for example, the effect of an unsaturated zone above the water table on thermal behaviour. 3. The ability to simulate 3-D patterns of heat transfer in patterned peatlands consisting of hummocks, lawns, hollows, and pools (microforms). In order that the model can be applied to a 3-D system, the standard large-scale parameterisation of the Penman-Monteith equation, used to calculate convective heat fluxes, has been improved. First, aerodynamic resistance has been calculated from newly developed sensitive self-logging atmometers, enabling measurement of potential evaporation at high frequencies and at different positions on and surrounding a microform, either at the ground surface or within the plant canopy. Secondly, dual probe heat pulse sensors (DPHPS) have enabled the measurement of soil thermal properties and volumetric water content of a small volume of soil at regular time intervals. In combination with measured water-table fluctuations, a stack of DPHPS within the unsaturated zone has enabled the accurate measurement of actual evapotranspiration, without the interference and labour requirements of a lysimeter. The model has been applied, in its 1-D form, to a *Sphagnum* hollow and lawn in order to evaluate these new approaches and to test the error that arises when advective heat transfer within the soil profile is ignored. Advective heat transfer has been ignored in the model because of the complex nature of unsaturated water transfer within *Sphagnum* litter and acrotelm peat. The prototype equipment enabled the successful parameterisation and accurate representation of the thermal behaviour of the *Sphagnum* hollow and lawn during dry periods. During wet periods model error increased slightly; however, negative feedback mechanisms at the surface boundary enabled the model to recover quickly. We discuss the future application of this model to a hummock-hollow complex and demonstrate how consideration of points 1, 2, and 3 above can lead to quite different patterns of heat transfer from those predicted in previous simple models.

B21A CC: 220 C-E Tuesday 0830h

Mercury Biogeochemistry at the Terrestrial-Aquatic Interface I Posters

Presiding: B A Branfireun, University of Toronto at Mississauga; M Marvin-DiPasquale, U.S. Geological Survey

B21A-01 0830h POSTER

Effects of Mercury Contamination on Visible and Near Infrared Reflectance Spectra of Vegetation in Connecticut

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Current techniques commonly used to survey metal-contaminated soils are expensive, time consuming and only applicable on a small scale. Remote sensing offers the possibility of a cost-effective method for detecting and mapping the extent of contamination. Although metals cannot be directly detected in vegetation, it may be possible to detect secondary effects of metal stress in plant leaves. The goal of this project is to discern the spectral signature of metals in vegetation in Connecticut. This study encompasses sites that are contaminated from both point and non-point sources of mercury and other trace metals. Elevated

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 ($R^2=0.67$) 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 ($R^2=0.44$). The SR values are negatively correlated with leaf mercury concentration ($R^2=0.31$). 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 MODIS LAND 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 (GLOBECARBON). The main technical issue is to consider explicitly the bidirectional reflectance distribution function (BRDF) in the LAI algorithms and hence removing the need of doing BRDF corrections to the input images. The core problem of integrating BRDF 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 not 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.