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The annual net primary productivity of northern peatlands is relatively small compared to that of many other ecosystems, yet peatlands contain between 200 and 450 Gt C, or 15 to 20% of the world's terrestrial organic carbon. This large carbon store, which is 99% in the form of peat, has resulted from the inhibition of decomposition due to water saturated anoxic conditions. Five years of CO_2 eddy covariance measurements at the Fluxnet-Canada eastern peatland station, Mer Bleue, indicate that the net annual exchange between the peatland and the atmosphere varies between -60 (sink from the atmosphere) and +10 (source to the atmosphere) g C m^{-2} yr^{-1}. Additional carbon losses as methane, DOC and DIC, yield annual changes in the peatland's carbon store of between +50 to -20 g C m^{-2} yr^{-1}. The annual NPP of the Mer Bleue bog is quite small, ranging from 290 to 360 g m^{-2} yr^{-1} (145 to 180 g C m^{-2} yr^{-1}) depending on location within the peatland. The long-term carbon accumulation rate for the last 3,000 years, estimated from age-depth relationships and carbon content and bulk desnity profiles of the peat, varies between -10 and -20 g C m^{-2} yr^{-1}. Analyses of ancillary environmental variables and simulations of the short-term carbon dynamics using the Peatland Carbon Simulator (PCARS) show a combination of factors control the variations in ecosystem productivity. However, the peat winter thermal regime and the summer temperatures and moisture storage appear of be of primary importance. Over the long term (decades to millennia) the feedbacks among peatland wetness, primary productivity, and the partitioning of decomposition between aerobic and anaerobic pathways simulated by the Peat Accumulation Model (PAM) explain a significant portion of the dynamic changes in the carbon storage.

B21H-05 1120h

SpecNet - Linking ecosystem optical and flux sampling for exploring carbon and water vapor fluxes

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SpecNet ("Spectral Network") is a network of terrestrial sites where ecosystem flux measurements are supplemented with scale-appropriate optical measurements for the purpose of understanding carbon dioxide and water vapor fluxes. Results from several SpecNet sites are now leading to new insights into flux controls and offering improved remote sensing methods for detecting fluxes at the scale of the flux tower footprint. This presentation summarizes examples of sampling methods, key results from several SpecNet sites, and future directions for combined optical and flux sampling.

URL: http://vcsars.calstatela.edu/SpecNet/index.html

B21H-06 1135h INVITED

Novel Technique for Remote Estimation of CO2 Flux in Maize and Soybean Canopies

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There is considerable interest in assessing the magnitude of carbon sources and sinks for agricultural lands, grasslands, and forests. Scaling-up from chamber-based measurements of plant/soil gas-exchange has shortcomings, thus other approaches, preferably those that can be implemented remotely, are needed. In this paper, we propose a novel technique to remotely assess CO2 fluxes in row crops (i.e. maize and soybean) using reflectances (r) in two spectral channels either in the red edge near 700 nm or in the green around 550 nm and the NIR (beyond 750 nm). These spectral bands are already available on several operational satellite sensors (i.e. SeaWiFS, MODIS, and MERIS). Differences of reciprocal reflectances [(rRedEdge)-1-(rNIR)-1] and [(rGreen)-1-(rNIR)-1] accounted for more than 80 percent of the variability in mid-day canopy photosynthesis of maize and soybean canopies, in a wide range of CO2 fluxes (from near zero to 2.4 mg/m2/s). The technique was validated by an independent data set; root mean square error in predicting mid-day canopy photosynthesis by [(rRedEdge)-1-(rNIR)-1] was 0.17 mg/m2/s and 0.2 mg/m2/s by [(rGreen)-1-(rNIR)-1] and the slope of the linear relationship between predicted and measured fluxes was 0.926. However, before these previously undocumented relationships between indices [(rRedEdge)-1-(rNIR)-1] and [(rGreen)-1-(rNIR)-1] and canopy photosynthesis can be employed for remote assessment of CO2 fluxes, more work is needed to answer the questions about the accuracy of estimating diurnal CO2 variation as well as the application of the technique in contrasting vegetation types (i.e. grasslands, forests).

B21H-07 1150h INVITED

Mapping Daily Net CO_2 Flux From Grasslands Using Remote Sensing

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The daily net carbon dioxide (CO_2) flux from extensive grassland ecosystems is an important component of the global carbon cycle. In previous studies, instantaneous net CO_2 flux was estimated using a Water Deficit Index (WDI) determined from the relation between surface reflectance and temperature. The mean absolute difference between measured and WDI-derived CO_2 flux was 0.23 over a range of CO_2 flux values from -0.10 to 1.10 (mg m^{-2} s^{-1}). The objective of this study was to determine daily net CO_2 flux from instantaneous estimates for a semiarid grassland site in Southeast Arizona. This objective was reached through two main steps. First, a linear relationship ($R^2 = 0.95$) was found between instantaneous net CO_2 flux and net daytime (6 a.m. to 6 p.m.) flux and used to generate maps of daytime CO_2 flux. Second, a field study was conducted to relate night time flux measurements to daytime measurements. These relations made it possible to map daily (24-hour) net CO_2 flux from a single satellite image and basic meteorological information. A limitation of this approach is the dependence upon empirical relations for deriving daytime and night time estimates from instantaneous measurements. On the other hand, the empirical relations derived at this location were strong and consistent for the six-year study period.

B21H-08 1205h

An Improved Technique for Coupling Remote Sensing With Tower Based Carbon Flux Estimates

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Eddy covariance system provides temporally continuous but spatially limited measurements of carbon flux (C-flux) from terrestrial ecosystems. On the other hand, remotely sensed imagery provides spatially continuous data that are temporally snapshots at best. A third way of estimating C-flux is to use process-based simulation models. This study is aimed at estimating the C-flux of Morgan-Monroe State Forest, a mixed hardwood deciduous forest in South Central Indiana, using multiple techniques in order to couple remotely sensed data with eddy covariance measurements. In addition to tower-based eddy covariance data, photosynthesis data from the Moderate-resolution Imaging Spectroradiometer (MODIS) sensor and outputs from Biome-BGC model simulation, we are collecting time series of hyperspectral data "near-surface" data) from the top of the tower. Also, we are collecting leaf area index (LAI) data using a Ceptometer along two transects radiating 100m northwest and southwest from the tower. An annual series of eight-day composite images from NASA's MODIS sensor are also used to estimate image-based NPP of a 49 km × 49 km area of the forest around the flux tower. The preliminary estimates from last year's (2002) eddy covariance, model result and MODIS imagery showed discrepancies among the outputs. We expect that the addition of "near-surface" spectral data during the current year (2003) will enable us to bridge these discrepancies. Here we present a description of the "near surface" spectral data collection system, its difficulties and rewards, and show some promising results in bridging the gap between "spectral vs. flux" realms using data from this year's growing season.

URL: http://vcsars.calstatela.edu/SpecNet/index.html

B22A MCC: Level 2 Tuesday 1330h

Terrestrial Productivity and Carbon Storage: Research Issues and Tools II Posters *(joint with A, H, OS, GC)*

Presiding: **D Schimel,** National Center for Atmospheric Research**; C Still,** University of California, Santa Barbara**; J A Gamon,** California State University, Los Angeles**; A F Rahman,** Ball State University

B22A-0790 1330h POSTER

Carbon Exchange Along a Vegetation Gradient from Arctic Tundra to Boreal Forest

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Understanding environmental change in arctic and subarctic regions in response to altered climate forcing is of primary interest because of the role these ecosystems play in feedbacks to climate and carbon storage. Shifts in the balance between net carbon gains and losses in high latitude ecosystems could result as the vegetation and soil layers respond differently to changing environmental conditions such as changing moisture and temperature regimes and a lengthening growing season. Vegetation responses such as shrub expansion and northward movement of treeline would be expected to alter carbon cycling in high latitude ecosystems, however, the effect on net carbon storage due to changes in the distribution of plant functional types is incompletely understood. We selected moist low shrub tundra, tall shrub tundra and forest tundra sites near treeline in northwestern Alaska to represent the major structural transitions that would be expected in arctic and subarctic ecosystems in response to warming. In these sites, we measured above ground net primary production (NPPa) and summer net ecosystem exchange (NEE) using tower-based micro-meteorological techniques. We constructed carbon budgets, based on a combination of these direct measurements, literature based estimates and model simulations. All three sites were net sinks for carbon, with the shrub site having nearly twice the sink strength of the tundra and forest tundra site. We compare micro-meteorological and biometric approaches to estimating carbon exchange

and we discuss sources of uncertainty in our estimation techniques.

B22A-0791 1330h POSTER

Soil Trace Gas Flux for Wetland Vegetation Zones in North Dakota Prairie Pothole Basins

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Wetland ecosystems are considered a source for radiatively trace gases [methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O)] but flux data for these greenhouse gases are lacking for depressional wetlands that comprise the Prairie Pothole Region. This region is characterized by thousands of small, closed basins that extend along the Missouri Coteau from north central Iowa to central Alberta. Surrounding each body of water are conspicuous zonation patterns given by specific vegetation life-forms and soil properties that are predominately formed by basin hydrology. Basin vegetation zones include deep marsh, shallow marsh, wet meadow, low prairie, and cropland (Stewart and Kantrud,1971).

Our primary objective was to determine if net greenhouse gas flux for soils in these wetland basins [mg/m^2/day CO_2 equivalent (IPCC, 2000)] vary with vegetative zone for prairie pothole ecosystems. These data may then be used to map estimates for total basin greenhouse gas (GHG) flux. Additionally, we aimed to find the relative contribution of each of the 3 trace gases (CO_2, CH_4 and N_2O) to net GHG flux. We hypothesized that flux would be greatest for marsh areas and lowest for upland areas.

We selected a semi-permenant prairie pothole research site in Max, ND and mapped respective vegetative zones for 3 adjacent basins. Sample points were randomly selected for each basin and zone using aerial imagery. Samples of soil gases were collected using the static chamber method on August 3, 2003, and these were analyzed using gas chromatography for CO_2, CH_4 and N_2O the following day. Soil moisture, clay content, organic matter, and temperature data were also collected.

Net greenhouse gas flux for the cropped zone soils was significantly lower ($p<0.01$) than flux for the deep marsh, shallow marsh and wet meadow zone soils. Average flux measurement by zone (mg CO_2 equivalent/m^2/day) was 283 for cropland, 677 for low prairie, 1067 for wet meadow, 2572 for shallow marsh, and 6686 for deep marsh. Methane, in terms of CO_2 equivalents, contributed most strongly to and was the best predictor of greenhouse gas flux (r^2=0.98). Since most of these basin areas are planted with wheat, average net GHG flux per square meter was 600 to 900 mg CO_2 equivalents per day. Our results indicate that there are flux differences among wetland zones within these closed basin ecosystems and that CH_4 contributes most to net GHG flux for these wetland soils.

URL: http://www.umac.org/gbe/

B22A-0792 1330h POSTER

Estimation of leaf-level contribution to total stand net ecosystem exchange along a boreal forest chronosequence

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Quantifying the role of recovery from fire in stand level carbon dynamics is critical to estimate the current and future contribution of boreal ecosystems to the global carbon cycle. We have been using tower-based eddy covariance to measure net ecosystem exchange (NEE) above 6 black spruce stands that range in age from 5 to 170 years post-burn in central Manitoba since 2001. Here we explore to what extent stand-level patterns in NEE can be explained by changes in leaf-level physiology as community composition and structure vary through succession following wildfire. We combined ecological measures of the dominant plant functional groups in each stand (forbs, deciduous shrubs, deciduous canopy trees, coniferous trees) with leaf-level physiological measurements to calculate the contribution each plant functional group makes to overall stand NEE. From light response curves measured on the dominant canopy and forest floor species in each stand, total leaf area index of each species, above and below canopy PAR, and tower-based eddy covariance measurements we determined the contribution of each functional group to stand NEE in discrete intervals throughout the day. Despite large differences in ecosystem structure, peak summer daytime net CO_2 uptake rates were surprisingly similar across the chronosequence. Above the 5, 13, 20, 73, 160 year old stands peak values for daytime NEE were -16, -13, -18, -15 and -15 μ mol m^{-2} s^{-1}, respectively. As these boreal stands regenerate, high densities of plant functional groups with high photosynthetic capacities (i.e. fireweed: light-saturated photosynthetic rate (A_{max}) = 16.5 μ mol m^{-2} s^{-1}; quantum yield = 0.05) are replaced by plant functional groups with low photosynthetic capacity (black spruce: A_{max} = 4.4 μ mol m^{-2} s^{-1}, quantum yield=0.014). A consequence of this shift in community structure is that the leaf-level contribution to peak daytime NEE remains relatively consistent across the chronosequence.

B22A-0793 1330h POSTER

Aboveground Biomass and C Pools in Pasture Chronosequences Along a Climatic Gradient in Costa Rica

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Although land use / land cover change is an important source of C pool loss, the loss of C over time and the variation in C pool sizes among different climatic zones in primary forest to pasture conversions is little studied. We determined total aboveground biomass (TAGB) and C pools in 31 Costa Rican pastures encompassing 6 chronosequences in 6 life zones along a gradient from tropical dry forest to lower montane rain forest. TAGB varied greatly among sites, ranging from as high as 316 Mg/ha to as low as 3 Mg/ha. The large variation in pasture TAGB, both within chronosequences and across climatic zones was primarily due to remnant trees still standing in the pastures. Younger pastures from the wetter life zones tended to have higher TAGB and C pools than old pastures in the dryer life zones. These results highlight the importance of both land use history and climate in determining the potential for C sequestration in pastures.

B22A-0794 1330h POSTER

Drought-Induced Decrease in Soil Respiration: A Transient Soil Carbon Sink?

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Low rates of soil respiration during droughts have been related to above-average rates of net ecosystem exchange of carbon in forested ecosystems. Lower soil respiration during drought could cause a transitory soil C sink, due to a temporary decline in decomposition, or it could result from reduced root respiration. A throughfall exclusion experiment was established at the Harvard Forest in central Massachusetts to study the effects of experimental drought on soil respiration. Weekly measurements of soil respiration began in the spring of 2001, with 4 manual CO_2 flux chambers installed in each of 6 plots (5 x 5 m). In July 2001, subcanopy roofs with translucent plastic panels were installed in 3 of the plots, while the other 3 control plots were left open. Temperature probes, TDR probes, and gas tubes were buried at 4 depths in each plot. Roofs were removed in autumn 2001 to allow leaf-fall and snowfall, reinstalled in spring 2002, removed again in autumn 2002, and then left off for the entire summer of 2003. The radiocarbon contents of CO_2 emissions and concentrations within the soil were measured periodically. Soil respiration was nearly identical in treatment and control plots (140 and 142 g C m^{-2}, respectively) during the 54-d pre-treatment period. During 85 days in 2001 with roofs in place, 168 mm of throughfall were diverted, and the cumulative soil respiration was 30% lower in exclusion versus control plots (237 and 338 g C m^{-2}, respectively). During 127 days of throughfall exclusion (344 mm diverted) in 2002, cumulative soil respiration was 40% lower in exclusion versus control plots (280 and 490 g C m^{-2}, respectively). Clearly, soil water content is an important factor influencing soil respiration. When natural throughfall was allowed in all plots from September 2002 through August 2003, the cumulative soil respiration was only 6% higher in exclusion versus control plots (702 and 658 g C m^{-2}, respectively), indicating only a modest increase in decomposition after previously dried soils were wetted. The $\Delta^{14}CO_2$ in the soil atmosphere was negatively correlated with CO_2 concentrations, indicating a larger contribution of decomposition of old, radiocarbon-rich substrates in the mineral soil during drought. In dry mineral soil, root respiration produced less CO_2, while gradual decomposition of old, radiocarbon-rich substrates continued at low rates, resulting in low CO_2 concentrations with high $\Delta^{14}C$ values. In contrast, microbial decomposition of old substrates declined more rapidly than did decomposition of young substrates and root respiration in the O horizon, causing the $\Delta^{14}CO_2$ of surfaces fluxes to decline with drought. A depth-dependent differential response of root and microbial respiration to drought is indicated. If decreased root respiration is responsible, it may reflect altered belowground C allocation, but larger treatment plots that include entire trees would be needed to address this question. In any case, a transient soil C sink explains only a small fraction of the drought-induced reduction in soil respiration in this experiment.

URL: http://www.whrc.org/science/neforest/setharvard.htm

B22A-0795 1330h POSTER

Short-term Fate of Carbon in two Woody Species Under Contrasting Resources Availability: Insights From a $^{13}CO_2$ Pulse Labeling Approach

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In response to the environment, plants adjust allocation patterns to maintain a functional balance between the activities of roots and shoots such that belowground resources are acquired in approximate balance with aboveground resources. Changes in allocation driven by changes in environmental conditions may affect the amount of carbon stored in plant tissues, released by the root system, and ultimately sequestered into the soil. The aim of this study was to quantify the allocation belowground of recently fixed carbon in contrasting species and resources availability. We tested the hypothesis that carbon limitation and high nitrogen supply both negatively affect carbon transport to roots, causing a reduction of the carbon flow into the soil rhizosphere. Two woody species, a conifer (*Pinus Ponderosa*) and a deciduous tree (*Acer Rubrum*) were grown in a greenhouse under a factorial of light and nitrogen regimes (full light/shade and limited/excess nitrogen). At the stage of full leaf expansion plants were pulse-labeled by addition of $^{13}CO_2$ and harvested after 0, 7 and 30 days. During the experiment the treatments affected the pattern of plant biomass allocation. Shade negatively influenced belowground growth and Maple showed a more conservative response than Pine. High supply of nitrogen also reduced allocation to roots but only when plants were grown under light. Preliminary results show that the initial amount of recently fixed carbon into the rhizosphere was in general higher under Pine. However, after 7 and 30 days, the new soil carbon pool increased only in the rhizosphere of carbon limited Pine seedlings. These findings suggest that belowground respiration was negatively affected or, alternatively, that the exudates released were less easily decomposable

B22A-0796 1330h POSTER

Can we see the Forest for the Trees? Toward an Ecological/Ecosystem Basis for Remote Sensing of Carbon Exchange.

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Although a top-down approach focusing on the "forest" as a whole would seem to make sense for remote sensing estimates of global vegetation/atmosphere carbon exchange, many current models take a bottom-up, scaling approach that focuses on the "trees". This bias is understandable since most of us, including the authors of this presentation, began our careers studying eco-physiology at the leaf and single plant levels. It may also reflect the scarcity of data relating carbon fluxes to spectral reflectance at sufficiently large scales. This is unfortunate since relationships that are important at small scales are not necessarily the same ones that are most important at larger scales. Although large-scale measurements of carbon flux (from eddy covariance) and reflectance (from satellites) have been available for some time, direct comparisons have been difficult due to mismatches in their temporal and spatial scales. Development of tram systems for measurement of spectral reflectance in the footprints of eddy covariance towers (Specnet) is one approach to providing a better match between these scales. In this presentation we will compare relationships at ecosystem, plant and leaf scales. The degree of correlation between physiological and morphological (canopy structure) characteristics increased with increasing spatial scale. At the leaf and plant level photosynthetic light use efficiency (LUE) is largely independent of vegetation greenness and absorbed photosynthetically active radiation (APAR). However, our measurements at the ecosystem level suggest a strong correlation between LUE and vegetation greenness. Consequently, estimation of LUE as a parameter independent of vegetation greenness may not be as crucial as would be suggested by leaf and individual plant relationships. Although major disturbances temporarily upset the LUE/greenness relationship, we have found that vegetation rapidly re-establishes this equilibrium once the disturbance is removed. Another bias from the plant level is the assumption that greenness is not a useful parameter for estimation of carbon exchange in evergreen dominated ecosystems. However, at the ecosystem level, constant greenness is rare outside the tropics, and even in the tropics, greenness changes in subtle ways with seasonal stresses. Most evergreen coniferous systems include deciduous and annual species that contribute to seasonal variation in greenness of the ecosystem. The controls on respiration also change with spatial scale. Whereas respiration is a function of many factors at small scales, including temperature, moisture and the species of plants and microorganisms, studies at the ecosystem scale are finding respiration to be primarily driven by the input of carbohydrates from photosynthesis. The correlation between temperature and respiration rate largely disappears at larger temporal and spatial scales. At large temporal and spatial scales, acclimation of physiological processes and development of canopy structures that reflect the general availability of resources in the environment result in equilibrium relationships that hold great potential for remote sensing of ecosystem function if we can see the forest for the trees.

URL: http://vcsars.calstatela.edu/SpecNet/index.html

B22A-0797 1330h POSTER

The Effect of Spatial and Spectral Resolution in Determining NDVI

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We explore the impact that varying spatial and spectral resolutions of several sensors (a field portable spectroradiometer, Landsat, MODIS and AVHRR) has in determining the average Normalized Difference Vegetation Index (NDVI) at Imnavait Creek, a small arctic tundra watershed located on the north slope of Alaska. We found that at the field-of-views (FOVs) of less than 20 m^2 that were sampled, the average NDVI value for this watershed is 0.65, compared to 0.77 at FOVs equal to and greater than 20 m^2. In addition, we found that at FOVs less than 20 m^2, the average NDVI value calculated according to each of Landsat, MODIS and AVHRR band definitions (controlled by spectral resolution) was similar. However, at FOVs equal to and greater than 20 m^2, the average NDVI value calculated according to AVHRR's broad-band definitions was significantly and consistently higher than that from both Landsat and MODIS's narrow-band NDVI values. We speculate that these differences in NDVI exist because high leaf-area-index vegetation communities associated with watertracks are commonly spaced between 10 and 20 m apart in arctic tundra landscapes and are often only included when spectral sampling is conducted at FOVs greater than tens of square meters. These results suggest that both spatial resolution alone and its interaction with spectral resolution have to be considered when interpreting commonly used global-scale NDVI datasets. This is because traditionally, the fundamental relationships established between NDVI and ecosystem parameters, such as CO_2 fluxes, aboveground biomass and net primary productivity, have been established at scales less than 20 m^2. Other ecosystems, such as landscapes with isolated tree islands in boreal forest-tundra ecotones, may exhibit similar scaling patterns that need to be considered when interpreting global-scale NDVI datasets.

B22A-0798 1330h POSTER

Scaling Forest Canopy Carbon Flux Measurements From Sites to Landscapes Using Airborne Remote Sensing and Canopy Nitrogen Chemistry

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In order to better understand the factors responsible for differences in canopy carbon uptake across a range of sites, we explore how variation in both foliar nitrogen content and climatic conditions relate to maximum rates of gross carbon exchange (GCE) measured at eddy-covariance flux towers. While climate and canopy structural variables alone explain a portion of the observed GCE variation, studies have shown that foliar nitrogen can also act as an important control on carbon uptake and productivity in the eastern forests of the US. We present model results and remote sensing imagery from four sites which span a north-south vegetation and climatic gradient across these forests. High resolution airborne remote sensing techniques, together with ecosystem modeling, are also presented as an intermediate data source and a way of meeting the challenge of scaling from tower based carbon flux measurements to broad scale remote sensing. Airborne hyperspectral remote sensing is used to drive a model of canopy carbon uptake which, in turn, is used to characterize the spatial variability within the 1 km grid size of most global remote sensing products.

B22A-0799 1330h POSTER

Spatial analysis of growing season length control over NEE

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Using data from a large number of flux measurements, analysis of the annual net ecosystem exchange and the length of the carbon uptake period (CUP, number of days with negative flux) from observations suggest linear correlation between the two. The change in annual carbon uptake per CUP day differs significantly between forests and non-forests. Forest stands in this study are mostly young and regrowing. The ratio between mean daily carbon exchange rates during carbon uptake and release periods is conservative (2.73, with st.dv.1.08) for different vegetation types. It implies that a balance between carbon release and uptake periods exists despite different photosynthetic pathways, life forms, and leaf habits. The mean daily carbon sequestration rate of ecosystem never exceeds the carbon emission rate by more then four times. The growing season length derived from AVHRR NDVI data is closely related to the carbon uptake period and consequently can be used to approximate annual carbon exchange values of the ecosystems. The suggested approach has a potential for extrapolations of NEE over large areas from remotely sensed data, while most currently existing techniques still partially rely on modeling for respiration. Remote detection of growing season length in arid and cloud-covered ecosystem is problematic using data from AVHRR and requires improved, next generation remotely sensed data.

B22A-0800 1330h POSTER

Spatial and temporal variability in carbon flux and its correlation with canopy level vegetation indices

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The temporal variability of carbon and water flux of a sarcocaulescent desert shrub ecosystem from July 2001 to September 2003 as measured using the eddy covariance technique in La Paz, Baja California Sur, Mex are described. Our objective was to link site specific measurements of net ecosystem flux with both canopy and satellite remote sensing measurements. Initially, using daily mid day web cam photos, patterns of phenological development and the rate of carbon uptake or loss were found to be linked with the timing and amount of rainfall. When seasonal rains began earlier than normal (2001), loss of carbon via soil respiration was observed with no development of the photosynthetic canopy. Upon the onset of the historical rainy season for the area, seasonal maximum values of net ecosystem flux (-1.5 vs -0.7 gC m^{-2} day^{-1} in 2001 and 2002 respectively) was strongly correlated with the amount of rainfall in 2001 and 2002 with precipitation in 2001 approximately twice as large as in 2002 (338 mm vs 124 mm). Spatially explicit measurements of soil respiration and canopy level normalized difference vegetation index were initiated in April of 2003. Mid August rains in 2003 resulted in the anticipated response of the vegetation with respect to development of the canopy. Using the spatial patterns of soil respiration and canopy level NDVI coupled with soil moisture and root biomass sampling, root development was shown to make up a large portion of ecosystem respiration upon the onset of the seasonal rains in 2003. These results are compared with 21 years of regional AVHRR and precipitation for the area as well as MODIS remote sensing outputs.

B

B22A-0801 1330h POSTER

Relating Optical Indices to Carbon and Water Fluxes in a Chaparral Ecosystem

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Between 2001 and 2003, spectral reflectance coupled with CO_2 and H_2O flux data were collected at Sky Oaks Biological Field Station, a chaparral-dominated ecosystem in southern California. The reflectance data were collected by walking along a transect (early 2001) and semi-automated 100 meter tram system installed at the site (after mid 2001), while CO_2 and H_2O flux data were gathered with an eddy covariance flux tower. Over the study, which included a normal wet (2001), an extremely dry (2002), and a recovery year (2003), the water band index (WBI) was more closely correlated with ecosystem H_2O flux than CO_2 flux. In the wet year, WBI was closely correlated with both the H_2O and CO_2 fluxes, but when a record drought struck in 2002, the correlation between WBI and CO_2 disappeared as vegetation died off. Also, WBI is dynamic over time, precipitation conditions, and between species in the region. These results suggest that the ecosystem average WBI is an overall more robust estimator of the H_2O flux than CO_2 flux at the ecosystem level and water fluxes can be directly estimated from optical remote sensing.

B22A-0802 1330h POSTER

Relating NDVI and WBI to Carbon Flux and Biomass in a Grassland Ecosystem

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This study explored the relationships between spectral reflectance, CO_2 flux (photosynthesis and respiration), and biomass at Cheseboro Canyon, a grassland dominated ecosystem in the Santa Monica Mountains National Recreation Area, located in Southern California. Field sampling conducted in the winter and spring of 2003 consisted of spectral reflectance measurements, ecosystem CO_2 flux measurement, and biomass estimation. Two optical indices, Normalized Difference Vegetation Index (NDVI) and Water Band Index (WBI), were derived from reflectance and compared to biomass and CO_2 flux data (photosynthesis and respiration rates). There were strong correlations between optical indices, (NDVI and WBI), CO_2 fluxes, and aboveground biomass. Consistently, WBI showed stronger relationships to CO_2 fluxes (especially respiration) than NDVI. The link between carbon flux and this optical index of water content illustrates the strong control on flux by water status in this ecosystem. Respiration had a strong relationship with both NDVI and WBI, suggesting that ecosystem respiration rates are a reflection of recently-fixed carbon. The strong correlations between these optical indices, CO_2 flux, and aboveground biomass suggest that spectral reflectance, especially WBI can be used to estimate carbon flux and productivity in this grassland ecosystem.

B22A-0803 1330h INVITED POSTER

Examining Light Use Efficiency in Multiple Ecosystems

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One approach to modeling the carbon uptake, or gross ecosystem exchange (GEE), is a light use efficiency (LUE) model. LUE models assume a linear relationship between the amount of photosynthetically active radiation (PAR) absorbed by the vegetation canopy and GEE. The slope of that relationship is called the efficiency (e). A key problem in using LUE is the determination of e, and understanding how it may vary both between ecosystems as well as over time. To examine this question, carbon dioxide flux data measured using eddy covariance techniques were combined with ground-based reflectance measurements to determine e on a daily basis over the course of a growing season for a variety of ecosystems, including deciduous forest, conifer forest, wetland, tundra, and prairie. The fraction of PAR absorbed by vegetation was derived from the Normalized Difference Vegetation Index (NDVI). For several sites usable values for NDVI could be calculated from measurements of incident and reflected PAR and shortwave radiation collected from the flux tower. This approach provides an indication of the ways in which remote sensing techniques can be used in conjunction with flux data to aid our understanding of ecosystem function. Daily values of GEE were compared with values for daily absorbed PAR. Values of e were generally consistent for a site throughout the year, allowing an annual value to be determined. Annual values for e were found to range from 1.4 g C/MJ for deciduous forest and grassland to 0.4 g C/MJ for the tundra, with R2 values generally over 0.8. Within the growing season for some sites periods of photosynthetic saturation were observed, examination of these periods assist in identifying sources of stress on the ecosystem.

B22A-0804 1330h POSTER

Measurement uncertainty in spectral indices from field spectroradiometers

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Numerous vegetation indices have been used in remote sensing, all functions of reflectance in a small number of wavebands. Reflectance spectra of a vegetation target exhibit variation due to random and systematic effects. Uncertainty due to these effects is rarely propagated and represented in the calculated values of vegetation indices. We have applied a well-known approximation (referred to in the statistical literature as the "delta method") to the variance of a function of random variables to propagate uncertainty in several recognized spectral indices. Let ρ_1 and ρ_2 denote the measured reflectance in two wavebands and let μ_i and σ_i denote the mean and standard deviation of reflectance measured in the i-th waveband. Also, let σ_{12} denote the covariance of the two reflectance variables. Consider the case in which the index of interest is a function $g(\cdot)$ of ρ_1 and ρ_2. The variance of this function can be approximated using

$$Var[g(\rho_1,\rho_2)] \doteq \sigma_1^2\left(\frac{\partial g}{\partial \rho_1}\right)^2+\sigma_2^2\left(\frac{\partial g}{\partial \rho_2}\right)^2+2\sigma_{12}\left(\frac{\partial g}{\partial \rho_1}\right)\left(\frac{\partial g}{\partial \rho_2}\right) \quad (1)$$

where the partial derivatives of g are evaluated at (μ_1,μ_2). The two-variable case treated here includes some commonly used indices including the simple ratio (SR) and the normalized difference vegetation index (NDVI). With the delta method, we obtain the respective approximations

$$Var(SR) \doteq \frac{1}{\mu_1^2}\left[\sigma_1^2\left(\frac{\mu_2}{\mu_1}\right)^2+\sigma_2^2-2\sigma_{12}\left(\frac{\mu_2}{\mu_1}\right)\right] \quad (2)$$

and

$$Var(NDVI) \doteq \frac{4(\sigma_1^2\mu_2^2+\sigma_2^2\mu_1^2-2\sigma_{12}\mu_1\mu_2)}{(\mu_2+\mu_1)^4} \quad (3)$$

The result can be confirmed by bootstrapping. Estimates of means and variances can be made from experimental measurements. Variance from instrument noise is likely to be smaller than variance due to other exogeneous factors such as changing illumination conditions. These sources of uncertainty need to be understood in order to detect signals from ecophysiological processes in plant spectra.

B22A-0805 1330h POSTER

Characterizing and Filling Data Gaps in ARM Measurements for Carbon Models

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The Atmospheric Radiation Measurement (ARM) data archive includes many of the measurements needed by carbon modelers to predict carbon dynamics in terrestrial ecosystems, but data gaps limit the use of ARM data as input for simulation models. Because the DOE ARM Program records actual measurements, circumstances unavoidably arise when instrument and storage failures create gaps in the temporal stream of measurements. Most temporal gaps are short in duration and affect only one or a few related parameters. However, some rare failures, such as wide-area power outages or ice storms, occasionally affect many measurement streams at one or more ARM facilities simultaneously. We have statistically characterized the frequency of univariate temporal gap lengths in various ARM measurements, and have devised approaches for filling such data gaps in space and time. To make ARM measurements suitable as model input, we identified and eliminated outliers, removed values with known QA problems, aggregated the measurements to an appropriate temporal scale (hours), and filled gaps in the data record using univariate imputation methods across time and space. We have prepared a set of hourly aggregated, gap-filled products from ARM SIRS and SMOS data collected at the SGP site from 1996 through 2001. These products were designed to facilitate the use of ARM measurements as climate drivers for carbon simulations. In cases where no raw data were available, we imputed a replacement value from adjacent hours or sites. ARM measurements differed widely in predictability. Temperature and vapor pressure were easiest to impute, but precipitation was a challenge. Shortwave radiation was more difficult to impute than longwave radiation. Successful imputation created reasonable values and patterns that were indistinguishable from the surrounding measurements. The difficulty of imputation for each measurement could help prioritize instrument repair and operational triage during data collection.

URL: http://www.archive.arm.gov/Carbon

B22A-0806 1330h POSTER

Global and Regional Pools of Arbuscular Mycorrhizal Fungi, a Common Soil Microbe

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Belowground carbon pools in ecosystems have historically been difficult to quantify. Particularly challenging to measure are arbuscular mycorrhizal fungi, a functional group that forms mutualistic symbioses with plants and augments nutrient uptake. These fungi also produce glomalin, a recalcitrant protein that is abundant enough in the soil to constitute a potentially significant carbon sink. We estimated standing stocks of arbuscular mycorrhizal hyphae using "bottom-up" and "top-down" approaches based, respectively, on published values of root colonization by arbuscular mycorrhizal fungi, and a model incorporating net primary productivity derived from remote sensing data. Global

biomass of arbuscular mycorrhizal hyphae was approximated as 43 Tg in bottom-up estimates and 140 Tg in top-down calculations. Thus, hyphal biomass was equivalent to only 0.3 to 1% of standing root biomass. However, the estimated total length of arbuscular mycorrhizal hyphae (18 x 10^{18} to 59 x 10^{18} m) was more than 20 times the length of their associated live fine roots. Temperate grasslands, savannas, and tropical rainforests contained the largest pools of arbuscular mycorrhizal hyphae. These budgets could assist researchers in predicting larger-scale responses of arbuscular mycorrhizal fungi–and ecosystems in general–to global change.

B22A-0807 1330h POSTER

Use of a Microarray to Detect Expression of Genes for Lignin-Degrading Enzymes in Soil Fungi

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Lignin is a complex biopolymer that is degraded by fungi. Several extracellular enzymes have been implicated in degradation and include lignin peroxidases, laccases, manganese peroxidases, and glyoxal oxidases. Versions of these enzymes are produced by multiple species of fungi, and in some cases, multiple versions of a single enzyme may be produced by the same species of fungus. Previous research has indicated changes in fungal activity and diversity along a tallgrass prairie restoration chronosequence (Fermi National Lab, IL). A cDNA microarray was designed to interrogate the expression and microbial source of these lignin degrading enzymes in the chronosequence soils. We hypothesized that less diversity in gene expression would be detected in a farmed soil than in a restored prairie soil. The array had 46 oligonucleotides (15-25mer) that represent each of the enzymes listed above. Messenger RNA was extracted from 32 one-gram subsamples of the target soils then all of the extracts were pooled prior to RNA precipitation and mRNA purification. Aminoallyl modified dUTPs were incorporated during reverse transcription, after which the cDNA was labeled with Alexa-555 dye. The labeled cDNA was hybridized with the microarray for 24 hours and then imaged. Preliminary results support the hypothesis that fewer genes were expressed in the farmed soil than in the restored soil.

B22A-0808 1330h INVITED POSTER

The Short-Wave Aerostat Mounted Imager (SWAMI): a Novel Hyperspectral Remote Sensing Instrument Platform

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The Short-Wave Aerostat Mounted Imager (SWAMI) is a newly designed remote sensing platform attached to the tether line of a 3500 m3 research balloon. We are using the SWAMI to study terrestrial ecosystems by bridging the spatial gap between radiometric measurements collected near the surface and those collected by other aircraft or satellite. Primary instruments of the SWAMI include an Analytical Spectral Devices Dual VNIR spectrometer, video camera, and thermal infrared sensor, which are mounted upon a pointable view hatch with active stabilization. Secondary instruments include a GPS receiver and numerous meteorological sensors. Downloads of sensor data and remote control of the spectrometer occurs via wireless transmission to a ground control station. The balloon can be flown at altitudes up to 2km AGL. Data collected during Summer 2003 over a ponderosa pine forest, a conifer forest/grassland ecotone, and grassland areas are being used to investigate spectral mixture algorithms commonly used in sub-pixel analysis. Portions of the SWAMI platform are planned for use at an Ameriflux tower site in the Black Hills of South Dakota to collect data relevant to SpecNet. Applications of SWAMI technology to the proposed SpecNet network, including wireless spectrometer control and active pointing control mechanisms, will be discussed.

URL: http://www.ias.sdsmt.edu/rsel/

B22A-0809 1330h POSTER

Automated Tram System for Ecosystem Optical Sampling in Flux Tower footprint

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The need for adding non-intrusive remote sensing methods within the flux footprint has led to the development of an automated tram system. The system consists of a cart on a100m track running through the flux tower's footprint. The cart instruments include a dual-detector spectrometer and thermal sensor that collect optical and thermal samples at specified positions repeatedly over time. The two detectors allow correction for changing light conditions (e.g. clouds), and the addition of a programmable micro-controller allows the system to know its position and the time and date the data were collected. The cart also has the capabilities to recharge itself and shut down between sampling intervals, send data to a base station through a wireless link, and ultimately be controlled from a lab station through the internet. Automation of the system eliminates the disturbance that a field investigator would introduce as well as the need of regular field site visits. This system allows spatially and temporally explicit sampling of ecosystem optical and thermal properties within the flux tower footprint, improving our understanding of the controls on ecosystem carbon flux.

B22B MCC: 3014 Tuesday 1340h

Carbon Cycling in Northern Soils and Surface Waters I *(joint with H)*

Presiding: **J J Carrasco,** U.S. Geological Survey**; R G Striegl,** U.S. Geological Survey**; K P Wickland,** U.S. Geological Survey

B22B-01 1345h INVITED

Progress and Challenges in Modeling Soil Carbon Dynamics of High Latitude Ecosystems: Temporal and Spatial Perspectives

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Much progress has been made in modeling the role of soil carbon dynamics in high latitude ecosystems in response to temporal and spatial variation in climate and disturbance. Temporal variation in climate affects soil carbon dynamics at seasonal to millennial temporal scales. At seasonal time scales, progress has been achieved by representing soil thermal dynamics of high latitude ecosystems including the insulating effects of snow in the cold season and the freeze-thaw dynamics of permafrost soils. At inter-annual time scales, some studies indicate that cooling of the Northern Hemisphere after the Pinatubo Eruption affected the atmospheric growth rate of carbon dioxide through the effects of cooling on decomposition. At decadal and longer time scales, responses of decomposition to climate variability largely depend on how fast vs. slow pools are represented in models. Modeling studies and emerging data from field studies of temporal variation in decomposition after disturbance indicate that decomposition is largely controlled by the amount of remaining substrate and inputs to the soil rather than changes in soil environmental conditions after disturbance. Across high latitude ecosystems, both climate and disturbance appear to interact to influence latitudinal patterns of soil carbon storage. Also, glaciation and soil drainage substantially influence soil carbon storage through interactions with permafrost. While there has been much recent progress in representing how soil thermal dynamics influence soil carbon dynamics, the representation of disturbance regimes, glacial history, and soil drainage in a spatial context presents substantial challenges to modeling spatial variation in soil carbon storage. Modeling the lateral transport and processing of carbon in high latitude soils and surface waters has only recently received attention.

B22B-02 1410h

Methane Emissions from the Terrestrial Ecosystems of Northern High Latitudes during the 20th Century: A Retrospective Analysis with a Process-based Biogeochemistry Model

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Terrestrial ecosystems in high latitudes are predicted to experience more dramatic environmental changes from global warming compared with lower latitude ecosystems. The expected changes include lengthening of the growing season and melting of permafrost, both of which have implications for the methane (CH4) exchanges between terrestrial ecosystems and the atmosphere. To date, most models of large-scale methane dynamics have ignored key aspects of the water and soil thermal regimes in high latitudes that control the timing and magnitude of CH4 exchanges between the land and the atmosphere. Extant methane models have not been coupled with well-validated terrestrial ecosystem models, and so the methane models do not simulate the important links among plant productivity, the availability of labile carbon compounds to microorganisms, and CH4 emissions. In this study we have modified our biogeochemistry model, the Terrestrial Ecosystem Model (TEM 5.0), to include the processes of methanogenesis and methanotrophy in areas with and without permafrost. We enhanced TEM's hydrological module to better simulate soil water dynamics including water table fluctuations. We applied our model to the terrestrial ecosystems at northern high latitudes (45oN above) to evaluate the responses of CH4 emissions to the climate change during the 20th century. Our simulations indicated current CH4 emissions to the atmosphere are about 96 Tg yr-1 from natural ecosystems at northern high latitudes, while methane consumption by soil microbes is about 36 Tg yr-1. Therefore, we estimate that this region is a net source of about 60 Tg CH4 yr-1. The simulations showed there is strong interannual variability in CH4 fluxes and a trend of increasing net CH4 emissions with a rate of 0.06 Tg CH4 yr-1 during the 20th Century. If this increase continues, it will create a strong positive feedback to the climate system.

B22B-03 1425h

Changing sources of respired CO2 with time since fire in a boreal forests

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We compared the carbon isotopic composition of soil CO2 fluxes and potential respiration sources (root and microbial) of 6 forest stands along a chronosequence ranging from 0 to 150 years following stand replacing fire. Study sites are located in the BOREAS Northern Study Area near Thompson, Manitoba, Canada (55N, 98W). The vegetation is dominated by black spruce (Picea mariana), the understorey by mosses. The clay soils have underlying permafrost below 50 to 90 cm. Soil CO2 flux and its carbon isotopic composition was measured using dynamic chambers. Heterotrophic and autotrophic respiration were characterized using in situ and laboratory incubations. Results from a preliminary study in 2001 showed an increasing contribution of heterotrophic respiration with time since fire. Drier conditions in 2003 were associated with dramatically lower CO2 fluxes. We will present isotope data collected in the summer of 2003 and contrast it with our earlier

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