shallow water carbonate deposition, atmospheric CO_2 draw-down, and ice-sheet growth, raising the possibility of extreme glaciation. This is consistent with the occurrence of ice ages of near-global extent and multi million-year duration during the Neoproterozoic; climatic events that did not reoccur in the Phanerozoic. We employ a coupled atmosphere-ocean-sediment carbon cycle model to demonstrate the fundamental impact of biomineralization in increased stability of the modern climate system.

B21G-08 1205h

Calcite and Picocyanobacteria in Lakes: Factors Affecting Their Interaction

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Calcites build large deposits which have been observed in the rock record throughout geological time at various localities around the globe. Carbonate deposits have affected atmospheric carbon dioxide concentration. As it has been generally accepted, inorganic precipitation represents a source of carbon dioxide on short geological time scales and a sink of inorganic carbon at long time scales from millions to thousands of millions years. However, recent research indicates that calcite deposits may result from microbial calcification instead of inorganic precipitation. In this case the process may reduce atmospheric carbon dioxide on geologically short time scales. Thus the effect of carbonate sediment deposition on global carbon cycling depends on the origin of carbonate. Thus it is essential to understand the cause and the key parameters affecting calcite precipitation. The role of algae and bacteria in calcite formation in lakes has not been evaluated in detail. Some evidence, however, exists supporting precipitation of calcium carbonate by microbes as the origin of whiting. Several field studies on lakes have also produced puzzling results: The peaks of algal blooms were often not found at the same time as precipitation events of calcite. We suspect that parts of the discrepancies in the interpretation of field observations are due to the activity of autotrophic picoplankton. The unicellular autotrophic picoplankton (APP) is a ubiquitous component of pelagic ecosystems. But it has often been overlooked due to its small cell size of 0.2 - 2 μm in diameter. Coccoid picocyanobacteria of the Synechococcus-type dominate the picoplankton community in most oligotrophic systems. Recently, laboratory experiments and field observations suggested that APP may play an important role in calcite precipitation. The aim of this study was to examine the influence of environmental factors such as saturation state, concentration of different dissolved ions and characteristics of the surface of cells on interaction between calcite and picocyanobacteria under both laboratory and field conditions. Laboratory experiments were performed with a picocyanobacteria strain Synechococcus-type. Using ion selective electrodes we monitored calcite precipitation induced by bacteria in the solutions of a different composition (calcium 0.7 - 48 mM, inorganic carbonate 6 - 35 μM). Electron and atomic force microscopy measurements provided insight into the cell-mineral interface. Furthermore, quantitative investigations of the types and densities of proton binding sites on a bacterial surface will be reported from the acid-base titrations on bacteria. Results of these initial experiments are encouraging and demonstrate by direct measurements the potential of picocyanobacteria to precipitate calcite. The amount of the precipitated calcite varied in experiments with a different ratio of dissolved inorganic carbon and calcium. The microscopic observations provide some evidence that the cell walls of cyanobacteria act as a substrate of nucleation of calcite. Temporal and spatial correlations of cyanobacteria and calcite, as well as images of bacterial shape particles indicated that picoplankton plays an important role in calcite precipitation in Lake Lucerne. This class of phytoplankton has to be considered in studying the biogeochemical cycling of oligotrophic hardwater lakes.

B21H MCC: 3009 Tuesday 1020h

Terrestrial Productivity and Carbon Storage: Research Issues and Tools I

(joint with A, H, OS)

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

B21H-01 1020h INVITED

Controls over the fractional stabilization of GPP: key processes and possible geochemical tracers

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It is often assumed that there is a relationship between biological productivity and carbon storage, but high rates of sequestration can be documented in areas with widely different levels of primary productivity. A number of analyses have shown that estimated global sinks cannot be due only to increases in productivity, because the required increases are too large for known mechanisms. Changes in the rate of storage must also be occurring. Both autotrophic and heterotrophic processes can affect the stabilization of plant material. Likely candidates include high allocation to wood and/or decay resistant organic matter, and increases in residence time of sedimentary organic matter in areas of enhanced erosion. Both of these processes are linked to changes in disturbance regime. In this talk we review mechanisms affecting the fraction of productivity stabilized, the ratio of NBP to GPP, and discuss the utility of this ratio as a tracer. We suggest that because of the chemical and isotopic composition of stable plant material, large-scale geochemical tracers of NBP/GPP may exist.

B21H-02 1035h

The Influence of Stand Development on Annual Carbon Exchange in Ponderosa Pine in Eastern Oregon

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It is commonly assumed that productivity, and therefore total carbon sequestration, is higher in young, actively growing stands than in old-growth stands. We show that ponderosa pine stands in Oregon did not fit this pattern. Carbon and water fluxes were measured continuously by eddy covariance above young-, mature-, and old-aged ponderosa pine (Pinus ponderosa Dougl. Ex P. & C. Laws.) stands located within 10 km of each other in central Oregon. The general study area is on the east side of the Cascade Mountains and is classified as high desert: winters are cool and wet while summers are hot and dry, resulting in seasonal drought stress. The old site is composed of patches of multiple age classes: 27% (by ground area) old trees (> 250 years old), 25% young trees (< 50 years old), and 48% mixed - with both age classes. The forest has a very open canopy with summer maximum LAI of 2.1 (0.1 in understory shrubs). The mature site (approx. 90 yrs. old) is naturally regenerating after clear-cutting and summer maximum LAI is 3.0 (0.1 in understory shrubs). The young site (approx. 16 yrs. old) was previously an old-growth forest that was clearcut in 1978 and allowed to regenerate naturally, and the maximum summer LAI was 1.2 (0.4 in understory shrubs). The mature site had the highest gross ecosystem productivity (GEP) (1350 gC m^{-2} y^{-1}) but also the highest ecosystem respiration (Re) (940 gC m^{-2} y^{-1}). The old site had moderately high GEP (1200 gC m-2 y-1) and lower Re (690 gC m^{-2} y^{-1}). The young site had the lowest GEP (730 gC m^{-2} y^{-1} in 2000-2001 and 790 gC m^{-2} y^{-1} in 2002) and the lowest Re (550 gC m^{-2} y^{-1} in 2000-2001 and 600 gC m^{-2} y^{-1} in 2002). Despite having the highest LAI, the mature site did not have the highest net ecosystem exchange (NEE). The balance of GEP and Re resulted in the highest NEE occurring at the old site (-580 $\pm$75 gC m^{-2} y^{-1}), which experiences the least severe drought stress according to water potential and sapflow data. NEE at the mature site was moderately high (-435 $\pm$60 gC m^{-2} y^{-1}) and was lowest at the young site (-170 $\pm$20 gC m^{-2} y^{-1} in 2000-2001 and -160 $\pm$20 gC m^{-2} y^{-1} in 2002) which experiences the most severe drought stress. The ratio of Re:GEP was 0.6, 0.7, and 0.75 for the old, mature, and young stands, respectively, indicating that as the stands age they respire less per unit carbon fixed. We conclude that more established ponderosa pine stands in this region are likely to sequester more carbon than recently disturbed stands, likely due to a low Re:GEP and a more established rooting system which enables older trees to better withstand drought.

B21H-03 1050h

Interannual Variation in the Relationship Between Aboveground Net Primary Productivity and Net Ecosystem Productivity in a Northern Temperate Grassland

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Measurements of aboveground net primary productivity (ANPP) and net ecosystem carbon dioxide exchange (NEE) have been made in a native Canadian grassland during 6 years (1998-2003) of contrasting weather. The eddy covariance technique was used to measure NEE and these measurements were integrated to calculate net ecosystem productivity (NEP). Variation in summer precipitation input was the major environmental factor influencing ANPP and NEP in this ecosystem. Annual ANPP ranged from 40 to 100 g C/m^2 with a strong positive correlation to the amount of summer (April-August) precipitation (107-412 mm range). However, ANPP varied asymmetrically in response to changes in precipitation, with increases in ANPP during a wet year being much more pronounced than reductions in a drought year. Strong increases in plant water-use efficiency contributed to the resilience of ANPP during times of drought. Annual NEP ranged from a net loss of 18 g C/m^2 to a net gain of 288 g C/m^2. The NEP in a year with normal precipitation was 21 g C/m^2, while years with below normal precipitation had either a net gain of 19 g C/m^2 or a net loss of 18 g C/m^2. Differences in soil respiration were responsible for whether the ecosystem was a carbon sink or source in years of low precipitation. Late summer rain, received after most of the plant canopy had gone dormant, can stimulate soil respiration more than photosynthesis, with a resulting net loss of carbon from the ecosystem. Soil moisture was also observed to have strong control on the temperature sensitivity of ecosystem respiration. ANPP and NEP were closely linked when moisture was abundant. However, in years with normal or lower precipitation, variation in soil respiration strongly influenced NEP and disrupted the correlation with ANPP.

B21H-04 1105h

Ecosystem Productivity and Carbon Exchange in Northern Peatlands

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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