pine, and black spruce stands, are located in central Saskatchewan, and were instrumented as part of the BERMS (Boreal Ecosystem Research and Monitoring Sites) study. Exchanges of energy and water are examined, with a focus on the simulation of the snow pack and snow processes.

B53A CC: 524 A Friday 1330h

Estuarine Ecosystems and Links to Upland Watersheds

Presiding: **D M Peteet,** NASA Goddard Institute for Space Studies**; P Louchouarn,** Lamont-Doherty Earth Observatory

B53A-01 1330h INVITED

The Global Carbon Sink in Tidal Salt Marshes

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For decades researchers have concentrated on proving that C is exported from salt marshes to coastal waters, with limited success. Yet, the C retained in the marsh soils may be equally important. Presumptions that minor amounts of C are stored in salt marsh soils are based upon measurements of low percentages of C in many marshes. Simply measuring the organic matter content of marsh soils provides little indication of the amount or rate of C stored, as this parameter is based upon the percent by mass of the soil. The critical parameter to calculate is C density, derived from percent organic matter and bulk density. (The latter is often neglected in marsh soil studies.) Calculation of C density reveals that minerogenic soils with high bulk densities may have C densities or C storage rates equivalent to more organic soils with low bulk densities. A global average soil C density of 0.055 $\pm$ $0.004 gcm^{-3}$ has been calculated from 107 measurements reported for salt marshes around the world (Gulf of Mexico, NE and NW Atlantic, Mediterranean and NE Pacific). Assuming an average marsh soil depth of 0.5 m and using inventories of marsh area available for Europe, Scandinavia, Africa, Canada and the U.S., the C stored globally in salt marshes is greater than 430 $\pm$ $30 TgC$. The global carbon storage could be twice this as there are no marsh inventories available for Asia or South America. Rates of C storage can be calculated from 96 C density measurements where soil accretion rates also were measured. Globally, marshes sequester an average of $210 gCO_2 m^{-2} yr^{-1}$, an order of magnitude greater than rates reported for peatlands. Salt marsh C storage can have regional importance. At a magnitude of $5 TgCyr^{-1}$, tidal wetlands comprise 1–2 percent of the C sink (300–580 $TgCyr^{-1}$) estimated for the coterminous U.S. In the Bay of Fundy restoration of salt marshes reclaimed for agricultural land could enable sequestration of an additional 240 to 360 $GgCyr^{-1}$, equivalent to 4 to 6 percent of Canada's targeted reduction of 1990-level emissions of CO_2 under the Kyoto Protocol. The C sink in salt marsh soils has advantages over those in freshwater wetlands or terrestrial soils. Presence of abundant sulfate limits release of the potent greenhouse gas, methane, which can be released in substantial quantities from freshwater wetland soils. In salt marshes, turnover of C occurs on time scales of hundreds to thousands of years, whereas the C content of terrestrial soils reaches equilibrium in decades to 100 yr. In many marshes C sequestration will continue or perhaps increase with higher rates of sea level rise accompanying global warming, as soil accretion rates will be greater. However, human impacts on many salt marshes (altering hydrological regimes or displacing sediment supplies), such as those of the Mississippi Delta, limits their sustainability in the face of higher rates of sea level rise and the future of these C sinks is threatened. Future research on C storage in salt marshes must be directed at local controls, for there is as much variability in a single region (e.g., Long Island Sound or the Bay of Fundy) as there is globally. Intensive sampling at multiple elevations in a single marsh reveals C densities to be significantly greater at higher elevations, but rates of C accumulation decline with elevation. Controlling for this variability in elevation reveals that C density decreases with average annual temperature, thus greater understanding of local processes are critical to detect global patterns.

B53A-02 1345h

Marsh Sediment and Species Composition in Hudson River Tidal Marshes: Change over the Last Millennium

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Understanding the signature of the Hudson River watershed to changes in the hydrological cycle is possible using marsh archives downriver. A suite of lower Hudson River tidal marshes is examined to identify changes in organic vs. inorganic content in the context of environmental change. Complex vegetational changes in the various marshes, identified by pollen and macrofossil studies, demonstrate the response to natural climate variability as well as human-induced changes of the last four centuries. While Piermont Marsh shows high inorganic content related to drought during the Medieval Warm Period, the subsequent Little Ice Age that followed shows a drop in this input. However, the nineteenth century of landscape disturbance reveals an increase again in upland watershed inorganics, followed by decline in the twentieth century. Jamaica Bay and Staten Island marshes to date show reduced inorganic input to these wetlands from the watershed up to the twentieth century. Jamaica Bay, NY marsh cores indicate increases in organic content in the twentieth century which may be related to dramatic land use changes in the surrounding New York area. An increase in the sand-sized fraction of organics may be attributed to the changes in local marsh plant production, but multiple hypotheses are being tested. Comparisons with adjacent Hackensack Meadowlands marshes demonstrate that local marsh plant production can dramatically alter the organic content and thus the carbon sequestration in the marshes. Species compositional changes in most of the marshes in the twentieth century resulted in a loss of biodiversity with the invasive increase of Typha (cattail) and Phragmites. This loss is linked to eutrophication of the estuary.

B53A-03 1400h

Subsurface Characterization of the San Jacinto Wetland Research Site

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Investigations of surface/groundwater coupling for contaminant flux were conducted for the San Jacinto Wetland Research Facility (SJWRF). The site is located in a four-hectare wetland on the south bank of the San Jacinto River, near Houston, Texas. This groundwater/surface water interaction study was a component of a multiphase petroleum remediation program. To determine the fate of petroleum contamination, the shallow groundwater of a wetland was characterized. The study area consists of a small, tidally-influenced cove surrounded by an intertidal wetland area. It is usually submerged on a diurnal cycle, barring extreme weather or tidal events. A thin layer (20-30 cm) of low-permeability clayey silt typical of low energy deposition overlays well-graded medium-to-fine-grained sand approximately 2.5-3 m thick. This is underlain by highly impermeable clay. A few dispersed clay lenses were encountered at a depth of 1-1.5 m, but were the exception rather than the rule. The site is equipped with an automated data collection system that records weather and water quality data. It also is used to collect surface and groundwater data from the twelve piezometers surrounding the cove, three 3-D groundwater flow sensors, and two surface water depth sensors. The objective of this research was to characterize the hydraulic flow patterns in the shallow subsurface of the wetland, as the data generated from this characterization can be used to predict the movement of contaminants in the subsurface. By determining water quality parameters for the groundwater at the site, significant physical, chemical, and biological processes can be determined. Hydraulic and physical-chemical characterization of the SJWRF site will allow predictions as to the fate and transport of contaminants in the shallow subsurface. Slug Testing was performed in twelve wells located around the perimeter of the site to determine hydraulic conductivity. They were situated in four groups of three wells, with the individual groups in a triangular formation to allow for horizontal gradient calculation. Values obtained by this method agreed with literature values for similar formations. Horizontal flow patterns were then determined by piezometric analysis and confirmed by In-Situ Permeable Flow Sensors. Piezometer response to changes in river stage indicated that the shallow subsurface water is confined from surface water. The average horizontal flow velocity was found to be 2 x 10^{-7} m/s. The average azimuth of all data from the cove was 210 degrees, trending towards the south-southwest in a direction consistent with river basin direction. Since the shallow subsurface water is confined and flow velocities are small, groundwater interaction with surface processes can be eliminated from consideration in developing remediation strategies.

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B53A-04 1415h INVITED

Chesapeake Bay Sediments: An Archive of Natural and Anthropogenic Environmental Change

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Estuarine sediments contain a unique combination of paleoclimatic and environmental proxies, integrating the pollen record of terrestrial ecosystems with a suite of estuarine organisms. Chesapeake Bay sediments provide a particularly detailed record of Holocene ecosystem variability because of high sedimentation rates (0.2 to 1 cm yr^{-1}) that exceed the temporal resolution available in most lacustrine or marine settings. Pollen assemblages from a suite of cores collected in Chesapeake Bay were used to develop a record of Holocene centennial to millennial-scale variability in the mid-Atlantic vegetation. This record indicates that a series of cool, drier events lasting ~300-500 years occurred every 1,400±300 years. The cool events are indicated by significant decreases in pine pollen abundance, interpreted as representing decreases of between 0.2° and 2° C. The timing of these events is correlated with a series of quasi-periodic cold intervals documented by other proxies in Greenland, North Atlantic, and Alaska and with solar minima interpreted from cosmogenic isotope records. These events may represent changes in circumpolar vortex size and configuration in response to intervals of decreased solar activity, which affects jet stream patterns over eastern North America. Changes in pollen assemblages during the cool, dry events likely represent subtle changes in forest composition as well as altered rates of pollen production. These natural compositional changes are minor compared to forest changes in response to Colonial land clearance, which had unprecedented impacts on forest structure, erosion rates within the watershed, sediment influx to the bay, and estuarine water quality. These records contrast the natural long-term variability of system with specific land-use changes of the past 250 years and provide a useful baseline for restoration goals in both the watershed and estuary.

B53A-05 1430h

The Role of Pulse Dynamics and Watershed-Scale Anthropogenic Impacts on Estuarine Cycling of Terrigenous Organic Matter

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There still exists large uncertainties about the role that terrestrial organic matter (TOM) plays in riverine and estuarine bioproductivity and of the few studies that have addressed its dynamics in estuaries, most have failed to capture the range of hydrologic, seasonal, and land cover variability inherent in these systems. Temporal sampling of particulate fluxes in the water column of the St. Lawrence Estuary for example shows a huge contrast in both the quantity and quality

of TOM that reaches this system over a year's time. Despite the limitations in fully understanding the role of pulse dynamics in carbon cycling, we now acknowledge however that bacterial respiration of terrestrial allochthonous carbon sustains the metabolic activity of many freshwater and estuarine systems. Indeed, it has been suggested that anthropogenic non-point source inputs of TOM (i.e. agricultural land use) may even drive large estuaries towards net heterotrophy. Additionally, large-scale impacts to watersheds such as impoundment of vast reservoirs can significantly alter biogeochemical cycles in river-estuarine systems. Among such impacts, we present a carbon budget from boreal reservoirs that suggest that at a maximum 95% and at a minimum 50% of carbon eroded from flooded soils are unaccounted for in reservoir basins several decades after impoundment. If a significant fraction of this eroded soil organic matter is exported from reservoirs by hydrodynamic forcing, and is redeposited in estuarine/coastal sedimentary basins, then we need to quantify the impact of man-made reservoir generation on translocation inputs to downstream systems. On the other hand, the spiraling of a fraction of that material into receiving streams and, most importantly, estuaries may also contribute to increased CO2 evasion rates and thus need to be taken into account as an indirect emission term of greenhouse gases attributable to reservoirs.

B53A-06 1445h

Seeking a Chemical Signature for Flood Deposits, Neuse River Estuary, North Carolina

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Major flooding in eastern North Carolina during September-November 1999 caused substantial sediment redistribution in the Neuse River estuary. Locations showing both net erosion and net deposition have been identified by comparing profiles of excess 210-Pb and fallout 137-Cs in cores collected before and after the flooding. While these radionuclide tracers are well suited to studies of modern flooding, however, their half-lives and input histories limit their utility to the last 50-100 years. Thus we have sought a chemical signature which might identify flood-derived sediments in older deposits. The 1999 floods did not leave coarse sediments in the thalweg of the Neuse estuary. The only texturally distinctive flood deposits were thin (< 1 cm) and spatially discontinuous shell layers. At one site in the lower estuary, however, the top 6 cm of a core was red in color when collected in November 1999. This gives a minimum of 6 cm flood deposition at this site; 137-Cs maxima before and after flooding suggest net flood deposition of 10-16 cm. Sediment samples from this core, and from a pre-flood (1988) core from the same location have been analyzed for a suite a major, minor, and trace elements. Elemental concentrations in both cores were normalized to aluminum to account for lithologic variations. The post-flood core-top has lower Si/Al, Mg/Al, and Ca/Al than the pre-flood core-top, suggesting that the flood deposits contain less quartz and calcium carbonate than pre-flood sediments. Fe/Al is distinctly higher in the post-flood core-top, but in time diagenesis may erase this signal. For many elements M/Al ratios do not differ systematically between pre-flood and post-flood cores (e.g., M = Cr, Ni, Zr, La, Ce, Th). Cu/Al, Zn/Al and Pb/Al vary between pre-flood and post-flood cores, but because of pollution inputs of Cu, Zn, and Pb these signals probably have little utility in pre-colonial sediments. Given present data the most promising candidates as tracers of flood deposits in the Neuse estuary appear to be Nb/Al and U/Al, both of which are elevated in post-flood core-tops; the U/Al signal may be compromised by estuarine U chemistry in older deposits.

B54A CC: 524 A Friday 1530h

Mathematical Modeling of Greenhouse Gas Exchange Between Terrestrial Ecosystems and the Atmosphere

Presiding: **R F Grant,** University of Alberta**; J Chen,** University of Toronto

B54A-01 1530h

Model Confidence in an Imperfect World: Parameterization and Uncertainty of Grassland Biogeochemical Models

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Ecosystem models incorporating variability of driving variables as an input and addressing uncertainty or functional stability in their predictions are rare, especially outside of forest and cropland applications. It can be complicated to test these models due to the number and range of parameters and inputs; it often becomes impractical to design fully constrained test environments, or to develop single optimized parameterizations. Strategies are needed to intelligently assess our confidence in the predictions. We have been investigating stability and temporal patterns of carbon fixation in a northern mixed grass prairie site using scenarios of varying climate variability and spatio-temporal detail. We present two case studies that illustrate techniques used to improve the parameterizations and evaluate the predictions of two grassland ecosystem models with contrasting levels of spatial and temporal complexity. In the first case, CENTURY (non-spatial, monthly time step) was used to examine long-term responses to climate change scenarios. We propose that stability of vegetation communities may be more important than simply predicting levels of productivity for answering many questions related to the impacts of global change. This is demonstrated using frequencies of consecutive years with low productivity. Moderate increase in precipitation variability without increases to average rainfall can increase productivity and apparently increase stability. Further increases in precipitation variability increase instability. Monte-Carlo simulations were used to examine the effect of temporal aggregation of climate data. Uncertainty in NPP predictions are found to be at the order of 20 g m^{-2} $year^{-1}$, or about 25% of long-term averages, but the uncertainty increases to at least 100% in scenarios with increasing precipitation variability. To incorporate finer temporal and spatial detail, RHESSYs has been modified to incorporate grassland processes. Initial work has demonstrated that the definition of spatial modelling units has a crucial role in our ability to parameterize the model with confidence, and that arbitrary regular tessellations may be the worst choice. Techniques are presented which can be used to evaluate potential tessellations and select appropriate models for further research.

B54A-02 1545h

Evaluating a Coupled Carbon and Nitrogen Cycle Model at a Pacific Northwest Douglas-fir Forest in Canada

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Nitrogen availability could be a key factor to enhance or limit plant photosynthesis under global climate change. This study presents a coupled nitrogen and carbon cycle model incorporated in the Canadian Land Surface Scheme (CLASS) which is used in the Canadian General Circulation Model. The nitrogen cycle model, which follows Dickinson et al., 2002 is coupled to a previously derived carbon model in CLASS. Nitrogen cycling processes taken into account include biological fixation, soil mineralization, immobilization, nitrification, denitrification, volatilization, leaching, root uptake and allocation to various plant components. Root nitrogen uptake depends on soil mineral nitrogen content, ion physical transport, root interface, and also on plant-growth demand for this nutrient. Leaf Rubisco-nitrogen concentration was modeled to determine variations in maximum rate of Rubisco activity,Vcmax. The coupled carbon and nitrogen model was tested at a Douglas-fir forest, growing on Vancouver Island, British Columbia, Canada, using observed eddy covariance flux data from 1998 to 2000. Simulated carbon and nitrogen uptake/loss rates were in broad agreement with observation. The simulated annual soil mineralized nitrogen was 6.3, 5.3, and 6.0 g m-2 in 1998, 1999 and 2000, respectively. The annual nitrogen uptake was 1.78, 1.65, and 1.76 g m-2, respectively. The simulated leaf nitrogen ranged from 1.81 to 1.87 g m-2 leaf area in the growing season, while observed leaf nitrogen values were 1.7 g m-2 in the lower canopy, and 2.56 g m-2 in the upper canopy. Observed Rubisco nitrogen was about 17% of total leaf nitrogen as compared to 16% simulated value. The modeled Vc-max in top leaves (Vcmax0) was as low as 15 mol C m-2 s-1 during the non-growing season, and as high as 80 mol C m-2 s-1 during the full growing season. Comparison of half-hourly observed and simulated gross ecosystem productivity (GEP), ecosystem respiration (R) and net ecosystem productivity (NEP) from 1998 through 2000 gave RMSE of 3.4, 2.2, and 3.5 mol C m-2 s-1, respectively. The simulated annual NEP values for 1998, 1999 and 2000 were 199, 446, and 415 g C m-2, respectively, compared to the observed NEP values of 329, 370, and 394 g C m-2 for the respective years. The low carbon uptake in 1998 was because of high ecosystem respiration - a consequence of warm temperatures during this El Nino year.

B54A-03 1600h

Modelling Temperature Effects on CO2 and Energy Exchange in Temperate and Boreal Coniferous Forests

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The increased frequency of high atmospheric temperatures predicted under current climate change scenarios may adversely impact net ecosystem productivity (NEP) of temperate and boreal conifers. This impact may be caused by stomatal sensitivity to vapour pressure deficit (VPD) arising from low xylem conductance and hence low canopy water potentials (?c) in conifers. The ability to simulate mass and energy exchange under contrasting temperature and VPD is therefore an important attribute in models used to predict climate change impacts on conifer NEP. We compare six ecosystem models differing in their approach to the modeling of atmospheric effects on CO2 and energy exchange by testing them against eddy covariance datasets recorded over a coastal temperate Douglas fir site and a boreal jack pine site. Model performances are discussed in terms of how the parameterizations of their key algorithms affect agreement between modeled vs. measured CO2 and energy fluxes under contrasting VPD at hourly and daily time scales. Annual aggregations of modeled CO2 fluxes are also compared with annual carbon budgets derived from gap-filled eddy covariance measurements and ecophysiological studies at both sites. This model intercomparison was conducted as part of the Fluxnet-Canada research project investigating climate and disturbance effects on the NEP of Canada's forest regions.