

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 of 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, RHESYS 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, V_{cmax}. 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 V_{cmax} in top leaves (V_{cmax0}) 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.

B54A-04 1615h

Deriving Photosynthetic and Respiratory Fluxes from the CO₂ Mixing Ratio Measured on the Wisconsin Tall Tower

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The variation of the CO₂ mixing ratio in the atmosphere at a given height results from several processes, including photosynthesis and respiration of the underlying ecosystems, the vertical mixing of the atmosphere near the surface and in the planetary boundary layer (PBL), and entrainment of air above PBL. Theoretically, if all atmospheric processes are modeled accurately, we can estimate the magnitude of ecosystem photosynthesis and respiration from the variations in the measured CO₂ mixing ratio. We developed a novel approach of isolating ecosystem metabolism signals from the effects of atmospheric diffusion in the hourly CO₂ record using a 1-d vertical diffusion scheme coupled with an ecosystem model. The approach removes the assumptions of horizontal surface homogeneity and advection-free conditions, but assumes horizontal atmospheric homogeneity. After applying the approach to the hourly CO₂ concentration measured in the entire year of 2001 at three heights (30 m, 122 m, and 396 m) at the Wisconsin tall tower, we demonstrate that daily photosynthetic and respiratory fluxes can be inferred from hourly CO₂ records. These concentration-derived daily photosynthetic fluxes are correlated with those measured by the eddy covariance (EC) method at the tower at the same heights, r^2 being 0.67, 0.51 and 0.51 at 30 m, 122 m, and 396 m, respectively. When averaged for 10-day periods, the corresponding r^2 values are 0.92, 0.85 and 0.84. In 10-day averages, the impact of the model inaccuracy caused by

synoptic variation is greatly reduced. As the CO₂ variations at lower heights have larger diurnal amplitudes, the determination of these fluxes from concentration are more accurate at lower heights. The footprint distance of CO₂ concentration during daytime under the influence of the mixed layer is estimated to be in the range from 10¹-10³ km, which is much larger than the EC measurements. The differences in the footprint area between the EC and CO₂ mixing ratio may partly explain the differences between these two methods. These differences also signify the importance of retrieving flux information from the CO₂ mixing ratio because one of the ultimate goals of our research is to estimate the carbon balance of a region, which often consists of various vegetation types of different densities.

B54A-05 1630h

Estimating Parameters in Inversions for Regional Carbon Fluxes

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In recent years, data on the spatial and temporal pattern of atmospheric CO₂ levels together with inverse forms of atmospheric transport operators have been widely applied to deduce the distribution of carbon fluxes and especially to attempt to locate the "missing" CO₂ sink. This approach however has led to widely differing conclusions, particularly for the longitudinal and land-ocean breakdown of the sink. One contributor to this variability has been the choice of such inversion parameters as the relative weighting of different classes of atmospheric measurements and of other, "prior" information on fluxes, and what uncertainties to assume for data at different locations within each class. A variety of methods of estimating such parameters from the data have been employed in inverse problems in other scientific areas. We explore using generalized cross-validation (GCV), which looks for the parameter values that result in the best prediction of any one measurement from the other data, to choose parameter values for atmospheric CO₂ inversions. As an example we use the TransCom 3 annual mean inversion set-up, which solves for net CO₂

fluxes from 22 regions using 1992-1996 mean CO₂ concentrations at 75 stations. The derived land-ocean and North America-Eurasia distribution of the carbon sink both depend on the extent to which stations are differentially weighted by the station variability and on the relative weighting given to the prior flux estimates. Compared with the published TransCom weighting, optimizing these inversion parameters with GCV results in a similar distribution of solved fluxes in northern regions but in smaller fluxes and greater solution stability in the poorly constrained equatorial and southern regions. We conclude that parameter choice methods such as GCV should be considered as part of the formalism of future inversions.

B54A-06 1645h

Significant Bomb ¹⁴C Enrichment in Deep Soil: a Previously Unrecognized Decadal C Pool

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Globally, soil organic matter contains approximately 1500 Pg C to 1 m soil depth and 2300 Pg C to 3 m depth – more than biomass and atmospheric CO₂ combined. Efforts to account for the effects of land-use or vegetation change on soil organic carbon (SOC) stocks normally limit their focus to the upper 20 or 30 cm of the soil profile, yet 0 - 20 cm SOC stocks are only 42% of 0 - 1 m SOC. Accounting for only the upper 20 to 30 cm of SOC has been justifiable based on the assumption that deeper SOC is unreactive since it displays $\Delta^{14}\text{C}$ -derived mean residence times of hundreds or thousands of years. We report that, at depths of 40 - 100 cm, a well-studied New Zealand soil displays progressive enrichment of over 200‰ across samplings in 1959, 1974 and 2002, indicating incorporation of bomb ¹⁴C during the last 40 years. This pattern of deep ¹⁴C enrichment – previously observed in 2 well-drained California grassland soils – suggests that roots and/or dissolved organic C transport contribute to a Decadally-Reactive Deep Soil C (DRDSC) pool comprising ~10 - 40% of SOC below 30 cm. This SOC pool can react to land use or vegetation change.

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