The Seasonal Land Cover Regions (SLCR) version 2.0 dataset was used to identify present-day (1992) vegetation. Each SLCR class was split into estimated area fractions of the 10 PFTs according to knowledge of natural vegetation and cropland composition. Global land cover in 1850 was estimated from a potential natural vegetation map adjusted for cropland area from R&F, combined with natural vegetation observed in the SLCR. Two methods were used to estimate fractional coverage of PFTs. The Linear Interpolation model assumed that natural vegetation area varies in inverse proportion to cropland area. In contrast, the Rule-based model used simple transition rules to represent how natural PFTs are converted to agriculture (e.g., grassland before forest) and how abandoned cropland reverts to natural vegetation. Estimates of land use change for 1992-2100 were based on the IPCC SRES A2 and B2 development scenarios simulated by the IMAGE model for 1970-2100. Differences in the representation of 1992 vegetation cover between SLCR and IMAGE were resolved using a multiple regression approach. The adjusted data were then used to initialize the two models and forecast changes in distribution of natural vegetation and cropland cover. The simulated changes in PFTs for 1850-2100 will be used to represent land-use change effects in the Canadian Terrestrial Ecosystem Model (CTEM), currently being developed for the Canadian Centre for Climate Modelling and Analysis (CCCma) coupled carbon-climate model.

B12A-06 1145h

Importance of ice sheet retreat and vegetation dynamics on the Holocene climate during the past 8 kyr

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Various proxy data reveal that in many regions of the Northern Hemisphere, the middle Holocene (6 kyr BP) was warmer than the early Holocene (8 kyr BP) as well as the later Holocene, up to the end of the pre-industrial period (1800 AD). This warmth is somewhat counterintuitive because the Northern Hemisphere (NH) summer insolation was steadily decreasing since 10 kyr BP. Cooling in the second half of the Holocene (after 6 kyr BP) is hypothesized to be due mainly to the changes in the high-latitude solar insolation driven by slow changes in the orbital parameters. This cooling was also accompanied by significant changes in vegetation cover. The early-to-middle NH Holocene warming, on the other hand, is hypothesized to be due in part to ice-albedo feedback in Norther America, associated with decreases in the Laurentide ice sheet, which completely disappeared by 6 kyr BP. The vegetation-albedo feedback is also hypothesized to have played a role in this early warming event. To test the above hypotheses, the earlier geophysical McGill Paleoclimate Model (MPM) has been coupled to the dynamic global vegetation model known as VECODE (see Wang et al., in preparation), and a number of sensitivity experiments have been performed with the "green" MPM. The model results demonstrate the following: 1) the orbital forcing is most important for the gradually cooling of global SAT from about 6 kyr BP to the end of the pre-industrial period; 2) the disappearance of the Laurentide ice sheet over the period 8 to 6 kyr BP, associated with vegetation-albedo feedback, allows the global SAT to reach its maximum around 6 kyr BP; 3) the northern limit of the boreal forest first moves northward during the period 8-6.3 kyr BP due to the Laurentide ice sheet retreat; 4) during the period 6.3-0 kyr BP, the northern limit of the boreal forest moves southward about 120 km in response to the decreasing solar insolation in the NH; and 5) the desertification of northern African is mainly explained by the weakening of the summer monsoon circulation in tropical and subtropical regions.

B12A-07 1200h

A NEW, REGIONAL-SCALE COUPLED ATMOSPHERE-ECOSYSTEM MODEL: FORMULATION AND RESULTS

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The formulation of self-consistent and computationally efficient atmosphere-ecosystem models requires the bridging of a wide range of spatial and temporal scales. Disturbance events such wind-throw, fire and land-use change give rise to significant sub-grid scale heterogeneity in ecosystem structure and function at a variety scales ranging down to the the size of an individual canopy tree, far below the resolution of both climate and numerical weather prediction models. Moreover, over decadal timescales, the spatial distribution of this heterogeneity is dynamic due to the successional dynamics that follow disturbance events within ecosystems. To address this problem, we have developed the Ecosystem Demography Land Surface Model (ED-LSM), an integrated biosphere model that incorporates plant community dynamics, soil carbon and nitrogen biogeochemistry and land surface biophysics. The fast timescale fluxes of carbon, water and energy between the ecosystem and the atmosphere are captured using the leaf photosynthesis and soil decomposition modules of the Ecosystem Demography (ED) model coupled to a multi-leaf layer, multi-soil layer implementation of the LEAF-2 biophysical scheme. Long term changes in the biophysical, ecological and biogeochemical structure of the ecosystem are captured using the ED model's system of size- and age-structured partial differential equations that track the changes in the vertical and horizontal heterogeneity of above and below ground ecosystem structure that result from ecosystem responses to the atmosphere that play out over years, decades and centuries. The model can be run both offline and coupled to the Regional Atmospheric Modeling System (RAMS), which simulates both atmospheric dynamics and tracer transport of carbon dioxide. We have carried out coupled simulations of the model in temperate, tropical and boreal regions. Comparison of our results with observations from eddy-flux towers and meteorological stations highlights the model's ability to capture the influence of the heterogeneous land surface on the dynamics of the land-surface interaction in these different regions on time scales ranging from the synoptic to the decadal.

B13A CC: 524 A Monday 1330h

Measurement and Modeling of Carbon, Water, and Energy Exchange in Northern Ecosystems I

Presiding: **H Margolis,** Universit Laval**; C Coursolle,** Universit Laval

B13A-01 1330h

Modelling the Response of Energy, Water and CO_2 Fluxes Over Forests to Climate Variability

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Understanding the response of energy, water and CO_2 fluxes of terrestrial ecosystems to climate variability at various temporal scales is of interest to climate change research. To simulate carbon (C) and water dynamics and their interactions at the continental scale with high temporal and spatial resolutions, the remote sensing driven BEPS (Boreal Ecosystem Productivity Simulator) model was updated to couple with the soil model of CENTURY and a newly developed biophysical model. This coupled model separates the whole canopy into two layers. For the top layer, the leaf-level conductance is scaled up to canopy level using a sunlit and shaded leaf separation approach. Fluxes of water, and CO_2 are simulated as the sums of those from sunlit and shaded leaves separately. This new approach allows for close coupling in modeling these fluxes. The whole profile of soil under a seasonal snowpack is split into four layers for estimating soil moisture and temperature. Long-term means of the vegetation productivity and climate are employed to initialize the carbon pools for the computation of heterotrophic respiration. Validated against tower data at four forested sites, this model is able to describe these fluxes and their response to climate variability. The model captures over 55% of year-round half/one hourly variances of these fluxes. The highest agreement of model results with tower data was achieved for CO_2 flux at Southern Old Aspen (SOA) (R^2>0.85 and RMSE<2.37 μ mol C m^{-2} s^{-1}, N=17520). However, the model slightly overestimates the diurnal amplitude of sensible heat flux in winter and sometimes underestimates that of CO_2 flux in the growing season. Model simulations suggest that C uptakes of forests are controlled by climate variability and the response of C cycle to climate depends on forest type. For SOA, the annual NPP (Net Primary Productivity) is more sensitive to temperature than to precipitation. This forest usually has higher NPP in warm years than in cool years. Interannual variability of heterotrophic respiration, however, is strongly related to precipitation. The soil releases more CO_2 in wet years than in dry years. Warm and relatively dry climate enhances the C uptake in this forest stand. Compared with SOA, a temperate deciduous forest in the southern part of the temperate deciduous forest biome in eastern United States responds to climate variability differently. High temperature and low precipitation in the growing season reduces NPP and consequently NEP (Net Ecosystem Productivity). In warm years, the Southern Old Jack Pine forest uptakes less C than in cool years. The modeled heterotrophic respiration and NEP are very sensitive to soil moisture and the empirical equation used to describe the effect of soil moisture on decomposition. This suggests that hydrological modelling is critical in C budget estimation. Next step, this model will be validated against more tower data and used for upscaling from site to region.

B13A-02 1345h

Contribution of Soil CO_2 Efflux to the Carbon Balance of Mature Deciduous and Coniferous Boreal Forests

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The Boreal Ecosystem Research and Monitoring Sites (BERMS) science team (now part of the Fluxnet Canada Research Network) is making long-term measurements of net CO_2 ecosystem exchange (NEE) between the atmosphere and several Canadian boreal forests using the eddy covariance (EC) technique. In order to better understand and constrain the annual carbon budgets obtained with EC, automated soil CO_2 efflux chamber systems were established in three of these stands. This study analyses continuous measurements of soil (R_s) and ecosystem (R_e) respiration (i.e., soil CO_2 efflux and nighttime NEE, respectively) made in 2003 in one deciduous (trembling aspen, SOA) and two coniferous (black spruce, SOBS and jack pine, SOJP) southern boreal forests. These forests are located 80 km apart in central Saskatchewan, Canada, and offer a unique opportunity to compare the response of different forest ecosystems to similar climate forcings. 2003 was characterized by an unprecented drought in western Canada, which significantly reduced the sink strength of these forests. The values of NEE in 2003 were -97, -62 and -29 g C m^{-2} y^{-1} (minus sign means uptake by ecosystem) for the respective sites. Overall, the measurements of R_s and R_e using the two independent approaches agreed well. R_e was largely dominated by R_s at all three sites, the latter accounting for more than 80% of total R_e. Annual estimates of R_s were greater at SOA than at SOBS and SOJP, and likely reflect the higher productivity of the deciduous forest. The approximate values of R_s for the respective sites were 920, 600 and 540 g C m^{-2} y^{-1} in 2003. The spatial variability of R_s was greater at SOBS than at SOA and SOJP and was related to the heterogeneous nature of the moss-dominated forest-floor. The temporal variability of R_s at all sites was strongly controlled by soil temperature. The annual R_{10} and Q_{10} values computed from the relationships of R_s as a function of soil temperature at the 2-cm depth were 4.06, 2.43 and 1.50 (R_{10}), and 2.66, 3.01 and 3.05 (Q_{10}) for SOA, SOBS and SOJP, respectively. R_s was significantly reduced during late summer at SOA and SOBS, when soil volumetric water content was low. These results highlight the increasing evidence that water restriction is likely to have a significant impact on the carbon balance of forest ecosystems, and might counteract the effects of rising temperature in a changing climate.

B13A-03 1400h

Topographic Distribution of Soil Respiration in Northern Hardwood Forests

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Soil respiration is an important source of CO_2 to the atmosphere and fluxes from complex terrains like those found in northern hardwood forests are not well documented. Our initial hypothesis was that the wetlands (swamps) at the bottom of such catchments would exhibit consistently less CO_2 efflux than the upland components. To test this hypothesis we laid out transects along topographic gradients in each of two catchments at the Turkey Lakes Watershed near Sault Ste. Marie Ontario. Soil respiration was determined by the static non-steady state chamber method using an infrared gas analyser in the summer and fall of 2002 and spring to fall of 2003. Measurements of soil temperature, moisture and soil solution DOC concentrations were collected coincidentally with CO_2 efflux measurements. Results indicate that a transition zone exists at the lower portions of the slopes in these high relief catchments that is characterized by higher CO_2 efflux than the wetland or upland sites along the transects. The differences in CO_2 efflux are greatest in mid summer, e.g. August 2003 mean values were 9, 7 and 3 micromoles CO_2 m^{-2} sec^{-1} for the transition, upland and wetland zones respectively. Several topographic features (depressions, shelves, convergent and divergent foot slopes) populate the transition zone but collar placement did not specifically target them. Therefore statistical analysis was done on the three-position model defining the transition zone as simply the lower portion of the slope. On an annual basis the transition zone showed significantly greater effluxes of CO_2 than either of the other two zones ($P < 0.005$). Different topographic positions also exhibited differences in the relationships between CO_2 efflux and soil temperature, soil moisture and soil solution DOC concentrations. This study shows that soil respiration can not be generalized without taking topographic position into consideration. Classification of catchments simply into "wetland" and "upland" components is insufficient to accurately describe CO_2 effluxes in complex terrain. These results point to the necessity of mapping the distribution of topographic features in complex terrain so that their differential contribution to CO_2 efflux can be incorporated into carbon budget models.

B13A-04 1415h

Carbon and water exchange of a younger, drier deciduous forest compared to the long-term study site at Harvard Forest, Massachusetts

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We measured carbon and water exchange by the eddy covariance method at a younger, drier deciduous forest and compared it to the well-known Harvard Forest deciduous site during two growing seasons (2002 and 2003) and an intervening dormant season. Forests at both sites are dominated by red oak (*Quercus rubra*) and red maple (*Acer rubrum*), but the younger forest is situated near a hilltop, as opposed to the long-term Harvard Forest site, which is in a lowland area within 100 m of a stream and about 200 m from a bog. The younger forest had a maximum tree age of about 44 years within 200 m of the eddy flux tower (owing to an intense fire in the autumn of 1957); this compares to maximum tree ages of 65 to 90 years, depending on exact location, near the long-term site. The younger, drier forest stored about 1.7 Mg C/ha from May 2002 through April 2003. We estimate that this was about 30% less than annual storage in the older, moister forest at the long-term site, but as the 12-month periods on which this comparison is based are not completely overlapping for the two sites, this comparison may change slightly. Light-saturated net ecosystem carbon uptake of both sites was about 22 μ mol m^{-2} s^{-1} in June 2002, but by August the value for the drier site was only about 20 μ mol m^{-2} s^{-1} compared to about 24 μ mol m^{-2} s^{-1} for the long-term site, suggesting that water availability may have become a limiting factor for photosynthesis in the drier forest. At the younger site in 2003 compared to 2002, we estimated less C storage in May and June but more C storage in July, August and September, with an overall increase in growing season C storage of about 0.4 Mg/ha. Lower early-growing season in carbon storage in 2003 versus 2002 was associated with slightly lower net ecosystem carbon uptake at all light levels in June 2003 compared to a year earlier. Cloudy and cool weather in May and early June 2003 reduced C uptake directly by reducing light available for photosynthesis, and apparently also caused a delay in leaf maturation and the development of photosynthetic capacity in the trees' foliage.

B13A-05 1430h

Interannual Variability in CO_2 and Water Vapour fluxes from a Recently Harvested Site on the Canadian West Coast

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Forest harvesting and succession have a major impact on the dynamics of carbon and water vapour exchange between forests and the atmosphere. This presentation examines fluxes of CO_2 and water vapour measured using the eddy covariance technique for the first three years after clearcut harvesting and replanting of a coastal Douglas-fir stand on Vancouver Island, BC, Canada. To investigate the impact of changing weather and stand structure on annual and seasonal net ecosystem production (NEP) and evapotranspiration, relationships with biophysical variables such as light, temperature, soil moisture, and leaf area index (LAI) were developed. In all three years, the stand was a large source of atmospheric C (620, 520, and 600 g C m^{-2} y^{-1}). Over the three years, annual gross ecosystem production (GEP) increased from 220 to 640 g C m^{-2} y^{-1} but was exceeded by an increase in annual ecosystem respiration (Re) from 840 to 1240 g C m^{-2} y^{-1}. During this period, the growth of pioneer and understory species resulted in an increase in LAI from about 0.2 to 2.5 m^2 m^{-2}. Seasonal and interannual variations in GEP were well described by variations in photosynthetically active radiation and changes in LAI. Nighttime measurements of NEP (=-Re) exponentially increased with increasing 2-cm soil temperature with an average Q_{10} of 2 and R_{10} that increased from 2.1 to 2.5 to 3.2 μmol m^{-2} s^{-1} in the three years since harvesting. Although the re-establishment of vegetation in this stand had a major impact on both GEP and Re, interannual variations in evapotranspiration (± 20 mm on an average 270 mm y^{-1}) were most affected by variations in weather, particularly in soil moisture. For example, drought late in the summer of the third year significantly reduced evapotranspiration and increased the Bowen ratio. This period of drought also resulted in early senescence of the vegetation and reduced both GEP and Re. As a result, there was less evapotranspiration and more atmospheric C lost from the stand in the third year after harvesting than in the second year.

B13A-06 1505h

Long-term and Seasonal Trends in Dissolved Organic Carbon Mass Balances in the Dorset, Ontario Study Lakes, 1978-1998.

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Mass balances of dissolved organic carbon (DOC) based on stream flows, precipitation inputs and lake outflows were measured for seven unproductive lakes in central Ontario between 1978 and 1998. Fluctuations in annual runoff over the 20 year period were similar in the seven study lakes in response to regional-scale climate variation. Responses of total DOC load (primarily export from catchments) and retained DOC (DOC load not discharged downstream) were also similar. There were similar but less accentuated variations in annual DOC concentrations. There were no clear regional trends evident during the 20 year period towards drier or wetter conditions, less DOC load, clearer lakes, etc. that could be interpreted as signaling a shift towards a different equilibrium state. The seasonal trend in mean monthly runoff was quite pronounced with peak discharge in each lake coinciding with spring melt in April and a much smaller peak in late fall/early winter. There were similar trends in DOC load and storage although the fall peaks in load were almost as large as the spring peaks in spite of much lower runoff, perhaps because of the presence of relatively large amounts of recently fixed, labile organic matter. Monthly DOC fractional retention increased in each of the lakes from lows in January and February to peaks in late summer/early fall. This has implications for the fate of DOC-bound contaminants: contaminants are more likely to be discharged downstream if they reach a lake during December-February. However, if the load contaminant-DOC ratio is constant during the year, than peak contaminant storage in terms of mass will coincide with DOC storage peaks.

B

B14A CC: 524 A Monday 1530h

Measurement and Modeling of Carbon, Water, and Energy Exchange in Northern Ecosystems II

Presiding: **H Margolis,** Universit Laval**; C Coursolle,** Universit Laval

B14A-01 1530h

Net Ecosystem Exchange of Carbon Dioxide in a Temperate Poor Fen: A Comparison of Automated and Manual Chamber Techniques

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We used five techniques to compare Net Ecosystem Exchange (NEE) of carbon dioxide (CO_2) in a poor fen using automated and manual static chambers, and found the methods comparable. Once per week we sampled manually from ten collars with a closed chamber system using a LiCor 6200 portable photosynthesis system, and simulated four photosynthetically active radiation (PAR) levels using shrouds. Ten automated chambers sampled CO_2 flux every three hours with a LiCor 6252 infrared gas analyzer. Results of the five comparisons showed (1) NEE measurements made from May - August, 2001 by the manual and automated chambers had similar ranges: -10.8 to 12.7 μmol CO_2 m^{-2} s^{-1} and -17.2 to 13.1 μmol CO_2 m^{-2} s^{-1} respectively. (2) When sorted into four PAR regimes and adjusted for temperature (respiration was measured under different temperature regimes), mean NEE did not differ significantly between the chambers ($p<0.05$). (3) Chambers were not significantly different in regression of ln(-respiration) on temperature. (4) But differences were found in the PAR vs. NEE relationship with manual chambers providing higher maximum gross photosynthesis estimates (GP_{max}), and slower uptake of CO_2 at low PAR (α) even after temperature adjustment. (5) Due to the high variability in chamber characteristics, we developed an equation to include foliar biomass and water table as well as temperature and PAR, to provide a more direct comparison between automated and manual NEE. Comparing fitted parameters did not identify new differences between the chambers. These complementary chamber techniques offer a