

patterns as part of the BOREal Ecosystem Atmosphere Study (BOREAS), near Thompson, Manitoba. June-September 1994 and 1996 were both drier and warmer than normal, but summer 1996 received 50 mm more precipitation than 1994 and had a mean daily temperature of 1°C greater than in 1994. Seasonal average methane emissions in the wetlands ranged from 30 to 250 mg CH₄ m⁻² d⁻¹ across a diverse mosaic of bogs, fens and permafrost collapse scars (pH 3.9-7.2) and increased an average of 60% during the wetter and warmer 1996 growing season (ranging from 15% to 100% increase depending on initial moisture status). CH₄ fluxes in the uplands (jack pine, black spruce) ranged from a small sink to a small source, and were not significantly different between years. Extrapolating across the Northern Study Area (NSA), based on relative percent cover of different wetland and upland ecosystems, we calculated the percent change in CH₄ fluxes between years. Although wetlands cover less than 10% of the landscape in the NSA, they dominate the increase in CH₄ emission between 1994 and 1996.

B22A-03 1105h

Changing Sources of Soil Respiration in a Boreal Forests With Time Since Fire

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We studied how temperature and moisture affect soil respiration and potential sources (roots and microbial) along a chronosequence of six forest stands ranging from 0 to 150 years following fire. Study sites are located in the BOREAS Northern Study Area in Canada (55N, 98W). The vegetation is dominated by black spruce (*Picea mariana*) and mosses on clay soils with underlying permafrost. At all sites we measured soil respiration with dynamic chambers and root respiration by field incubations. We determined microbial respiration using laboratory incubations at 0, 73, and 150 years since fire at three temperature and two moisture levels. We determined the radiocarbon ($\Delta^{14}\text{C}$) signature of individual respiration sources with AMS. Shortly after fire soil respiration was dominated by root respiration. The fraction of microbial respiration increased with increasing stand age. 15-40 years after fire carbon in the lower organic layer and mineral soil was the source of microbial respiration. In older stands carbon in the upper organic layer was the dominant source. CO₂ respired from black spruce roots was on average 3 to 4 years older than ambient air and thus recent photosynthates. To determine the carbon source of root respiration we measured the $\Delta^{14}\text{C}$ values of needle and root soluble carbohydrates and starch. Microbial respiration increased with increasing temperature and moisture, with no significant changes in the $\Delta^{14}\text{C}$ values of the respired CO₂. Total fluxes and moisture response of upper organic layers were higher than of lower organic layers.

B22A-04 1120h

Organic Soils of the North: a Mismatch for our Current Climate?

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Soil C reflects long-term net ecosystem production (NEP); therefore, spatial patterns of soil C storage lend insight into broad, lasting variations in NEP. Boreal forests are unique in that many soils retain enough organic matter to develop a chronology of C accumulation, which is related to both fire cycles and permafrost cycles: Accumulation of organic matter in the presence of permafrost or shallow water tables has allowed carbon to become buried into wet, cold environments

that were inaccessible to subsequent fire and decomposition. Aggradation of permafrost has allowed repeated fire and regrowth cycles to become buried in accreting peats, particularly peat plateaus. Most uplands, by contrast lost their carbon by efficient decomposition and fire events. Based on large carbon stocks of northern soils, we hypothesized that recent occurrences of wildfires should reflect a similar spatial pattern in which poorly drained soils sustain proportionately less burned area than well drained soils. Surprisingly, we found that in Alaska and western Canada over the past 50 years, burning did not occur preferentially in drier, upland areas. Moreover, in Alaska, wetter areas sustained a disproportionately greater burn area than drier areas relative to the statewide distribution of wetter to drier landscapes. This suggests to us that the long-term patterns of NEP are out of phase with recent decades. Recent measurements of climate and carbon accumulation rates also allude to modern systems being out of phase with long-term averages. For instance, at the northern old black spruce site in Manitoba (NOBS), organic matter has accumulated over the past 6500 years and yet NEP data from the past 10 years indicates that the net accumulation is zero. Furthermore, our NEP reconstructions based on current temperature and decomposition responses over repeated fire and regrowth cycles suggest that either colder temperatures and/or more stable forms of carbon may be responsible for the large C stocks that reside beneath the wetter black spruce/sphagnum systems, which comprise about 50% of the NOBS footprint. Last, in many sites at NOBS, moss and tree indications of recent permafrost have not been supported by the presence of frost in late summer, which appears most sensitive to summer rain than to summer temperature. These systems are sensitive to complex interactions among local temperature, precipitation, and vegetation shifts yet we raise the question as to whether there is converging evidence that boreal forests are undergoing a marked shift in disturbance patterns, reduced NEP, and permafrost degradation that is unprecedented for the millennial timescale in which these northern soils have formed.

B22A-05 1135h

Simulating Fire Disturbance in the Canadian Boreal Forest Using TRIPLEX Model

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Forest fire is a natural part of forest ecosystems and plays an important role in fuel load reduction, tree growth and mortality, and carbon/nitrogen cycling. Over the past century, the changes in land use and land management activities have changed the regime of forest fires. To better understand the effects of forest fires on forests as well as the interactions between human activities and forest fire regime, a fire module has been developed and incorporated into the TRIPLEX forest ecosystem model (TRIPLEX-Fire). TRIPLEX-Fire can be divided into three parts: fire ignition, fire intensity, and fire effects. Fire ignition is simulated as a spatially stochastic process under specific conditions of climate, fuel loadings and fuel moisture. Combustible areas, fireline intensity, and scorch height are major variables for simulating fire intensity. Fire-induced tree mortality, fuel load reduction, carbon emissions to the atmosphere, and soil carbon/nitrogen transformation are simulated and incorporated with post-fire regeneration as a part of fire effects. Observations from two sites in BOREAS study areas were used to calibrate and verify the TRIPLEX-Fire model. Simulations were performed under different scenarios of land use and management to investigate the possible impacts of fire disturbances on the Canadian boreal forest.

B22A-06 1150h

Use of ¹⁸O/¹⁶O in O₂ to Constrain Greenhouse Gas Emissions and Carbon Cycling Processes in Experimental Boreal Reservoirs

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Understanding the biogeochemistry of greenhouse gas (GHG) production in boreal upland reservoirs is one objective of the FLOODED Upland Dynamics Experiment (FLUDEX) at the Experimental Lakes Area (ELA). The decomposition of flooded organic matter produces dissolved inorganic carbon (DIC) and methane (CH₄), and consumes oxygen (O₂). To determine the magnitude of biological processes (community respiration, primary production, CH₄ production, and CH₄ oxidation), isotopic ratio mass budgets of ¹³C/¹²C in DIC and CH₄, and ¹⁸O/¹⁶O in O₂ were constructed for the 5 years of FLUDEX. Analysis of ¹⁸O/¹⁶O in O₂ by continuous flow is a relatively new technique an can be used to separate O₂ consumed by decomposition from O₂ produced by primary production because each process affects the ¹⁸O/¹⁶O in O₂ at a different magnitude and in opposite direction. Isotopic ratio analyses show that up to 40% of DIC produced by community respiration is removed by primary production and that O₂ evolution by primary producers is an important source of O₂ to keep the water column fully oxygenated for fish survival. O₂ production by benthic primary producers also facilitated increased CH₄ oxidation across the sediment-water interface. In addition to the important role O₂ played in GHG biogeochemistry, diurnal and seasonal dynamics of ¹⁸O/¹⁶O in O₂ were used to constrain GHG emissions.

B23A CC: 220 C-E Tuesday 1330h

Recent Advances in Coupled Terrestrial Carbon Cycle and Climate Modeling II Posters (joint with A, GC)

Presiding: V Arora, Canadian Centre for Climate Modelling and Analysis; S Cowling, University of Toronto

B23A-01 1330h POSTER

A Dynamic Global Vegetation Model With Biophysics, Biogeochemistry, and Biogeography Suitable for Coupling With Atmospheric GCM's for Decadal to Century Scale Studies

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A dynamic global vegetation model is being developed at the NASA Goddard Institute for Space Studies (GISS) suitable for decadal to century long simulations and for full coupling with atmospheric general circulation models (AGCMs). The model uses computationally efficient, process-based algorithms to predict

carbon and nitrogen cycling and the responses of vegetation physiology, structure, and distribution to climate, atmospheric CO₂, nitrogen deposition, and land use change on time scales of minutes to centuries. All processes are unified through a consistent conceptual structure: the vertical attenuation of light through the plant canopy. This attenuation is responsible for the biophysics of spatial variation in photosynthesis and stomatal conductance, the land surface albedo, the biochemical partitioning of nitrogen to photosynthetic and non-photosynthetic pools, and the long-term biogeographical dynamics of competition between plants for light and soil resources. The new biophysical model of photosynthesis and plant canopy gas conductance uses simple parameterizations derived from a ground-based network of water, carbon, and energy flux measurements, and incorporates realistic responses by vegetation type to atmospheric humidity, light (consistent with photosynthetic nitrogen), and temperature. Results include: significant improvement in the GISS GCM's calculation of surface temperatures; realistic annual global gross primary productivity of 116 Gt-C for the current climate; response to doubled atmospheric CO₂ concentrations increasing CO₂ uptake by 48%, and surface temperatures in some regions by up to 2 °C due to stomatal closure. The model of individual plant growth includes a mechanistic treatment of carbon and nitrogen allocation, morphological changes with development and environment, and process-based foliage dynamics. The model has been tested off-line and is being implemented within the GISS GCM. Prognostic albedos will be obtained from a fast, analytical calculation that can account for different levels of clumping of foliage and plants. Disturbance and vegetation competition will be handled through a theoretically sound approach that overcomes computational challenges by solving for these individual-based phenomena as plant size- and gap age-structured ensemble behaviors. The above improvements advance the science of coupled global vegetation-climate modeling through the novel use of data, introduction of recent theories in plant dynamics, and development of computationally efficient algorithms for parallelized computing in GCMs.

B23A-02 1330h POSTER

Modelling environmental controls on leaf phenology

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The exchanges of energy and CO₂ fluxes between the biosphere and the atmosphere, via the biophysical and biogeochemical pathways, respectively, are strongly influenced by the phenology (timing of onset and offset) of the leaves. Leaf phenology regularly alters land-surface boundary conditions by changing surface albedo, roughness, and the dynamics of the surface water and energy fluxes. Yet, phenology remains one of the most difficult processes to parameterize because our understanding of physical processes that are involved in initiating leaf onset and senescence is incomplete. A lack of understanding of processes that control leaf phenology has led to development of various empirical formulations that have been used with varying degree of success in terrestrial ecosystem models for both extra-tropical and tropical biomes. Of these formulations, the use of growing degree days (GDDs) to initiate leaf onset has received fair recognition and this formulation is used in a number of models. GDD-based and other empirical formulations suffer from a number of limitations when used at the global scale and in transient climate change simulations. A phenology scheme built for the Canadian Terrestrial Ecosystem Model (CTEM) that is currently being developed for inclusion in Canadian Centre for Climate Modelling and Analysis (CCCma) coupled general circulation model (GCM) is presented. Our goal was to develop a scheme that is general enough to be applied at a global scale and sufficiently robust so that it can be used in transient climate change simulations. CTEM uses a carbon-gain based scheme that initiates leaf onset only when it is beneficial for the leaves in carbon terms to grow new leaves. For leaf offset the conventional day length, temperature, and soil moisture controls are used. Comparison of simulated leaf onset and offset times with observation-based estimates for temperature and boreal deciduous, tropical evergreen, and tropical deciduous plant functional types (PFTs) at selected locations indicates that the phenology scheme performs satisfactorily. Model simulated leaf area index (LAI) and stem and root biomass are also compared with observational estimates to illustrate that the overall performance of CTEM is reasonable.

B23A-03 1330h POSTER

Energy, Moisture and Carbon Flux at the ARM/SGP Site: Model Simulations using the CSU General Circulation Model coupled to the Simple Biosphere Model (SiB).

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Year 2000 simulations of surface fluxes at the Atmospheric Radiation Measurement Program Southern Great Plains (ARM/SGP) site made with SiB Version 2.5 coupled to the Colorado State University GCM (CSU-BUGS5) in Single Column Mode (SCM) result in a spuriously large Bowen Ratio and anomalously low precipitable water during several periods over the summer. While initially thought to be a result of soil water stress on transpiration, anomalously dry intervals during the summer months were instead the result of pathological relationships between energy, moisture and carbon fluxes as simulated in this numerical model. We have replaced SiB2.5 with the latest version of the Simple Biosphere model (SiB3.0) in the coupled BUGS5-SiB model system, and repeated the simulations. SiB3.0 provides a more realistic treatment of fluxes within the surface layer, as well as a more sophisticated soil module. The resultant fluxes of latent heat, sensible heat and carbon more accurately reproduce the observations.

B23A-04 1330h POSTER

Interannual Variability in the Atmospheric CO₂ Rectification Over Boreal Forests Based On A Coupled Ecosystem-Atmosphere Model

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Ecosystem CO₂ exchange and the planetary boundary layer (PBL) are correlated diurnally and seasonally. The simulation of this atmospheric rectifier effect is important in understanding the global CO₂ distribution pattern. A 12-year (1990-1996, 1999-2003), continuous CO₂ measurement record from Fraserdale, Ontario (located 150 km north of Timmons), along with a coupled Vertical Diffusion Scheme (VDS) and ecosystem model (Boreal Ecosystem Productivity Simulator, BEPS), is used to investigate the interannual variability in this effect over a boreal forest region. The coupled model performed well in simulating CO₂ vertical diffusion processes. Simulated annual atmospheric rectifier effects, (including seasonal and diurnal), quantified as the variation in the mean CO₂ concentration from the surface to the top of the PBL, varied from 2.8 to 4.1 ppm, even though the modeled seasonal variations in the PBL depth were similar throughout the 12-year period. The differences in the interannual rectifier effect primarily resulted from changes in the biospheric CO₂ uptake and heterotrophic respiration. Correlations in the year-to-year variations of the CO₂ rectification were found with mean annual air temperatures, simulated gross primary productivity (GPP) and heterotrophic respiration (Rh) (r²=0.5, 0.46, 0.42, respectively). A small increasing trend in the CO₂ rectification was also observed. The year-to-year variation in the vertical distribution of the monthly mean CO₂ mixing ratios (reflecting differences in the diurnal rectifier effect) was related to interannual climate variability, however, the seasonal rectifier effects were found to be more sensitive to climate variability than the diurnal rectifier effects.

B23B CC: 524 A Tuesday 1330h

Mercury Biogeochemistry at the Terrestrial-Aquatic Interface II (joint with H)

Presiding: B A Branfireun, University of Toronto at Mississauga; M Marvin-DiPasquale, U.S. Geological Survey

B23B-01 1330h

Factors Influencing Enhanced Mercury Bioaccumulation in Riverine Mixing Zones of Lake Superior

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Very low concentrations of total mercury (HgT - less than 0.6 ng/L) and methyl mercury (MeHg 0 - 13 pg/L) have been measured in the offshore waters of Lake Superior, while inflowing tributaries reflected higher HgT (up to 20 ng/L) and MeHg (50 to 220 pg/L) concentrations, depending on the individual watershed characteristics and flow regimes. Watershed export of HgT and MeHg is function of not only land use/land cover, slope and soil characteristics but for MeHg, also a function of hyporheic zone transformations. In regions influenced by forest and wetland areas, Hg is effectively transported with dissolved organic carbon. In agricultural regions and clay-dominated soils, Hg is mainly delivered on the particulate phase. A preliminary mass balance suggests that about 30 percent of HgT and 50 percent of the MeHg is exported in the colloidal phase from rivers in the basin. Transformations of dissolved, colloidal and particulate phases within riverine mixing zones lead to enhanced bioaccumulation of MeHg in phytoplankton and zooplankton relative to offshore regions of the lake.

B23B-02 1400h

An Assessment of Aquifer Storage and Recovery and Mercury Methylation in the south Florida Everglades Ecosystem

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In an attempt to restore natural hydroperiods, vital to the Everglades ecosystem, Aquifer Storage and Recovery (ASR) technology is proposed in south Florida. ASR is used to store excess surface water and shallow groundwater during wet periods for recovery during seasonal or longer-term dry periods. Studies suggest methylmercury is formed in anoxic environments where there is active sulfate reduction; however, no known published studies have considered methylmercury formation in deep subsurface environments. Similarly, few studies evaluate ASR and water chemistry. The proposed storage zone is the Upper Floridan Aquifer, which is anaerobic, suggesting the potential for mercury methylation during storage periods. Additionally, the recovered water may stimulate mercury methylation when released to the Everglades. Using water samples from Florida municipal wells and cores from pre-existing ASR wells to simulate ASR conditions, a series of 9 columns were set up using Floridan Aquifer materials, native surface water, and mercury isotopes. Five