John D Albertson[1] (919-660-5468; john.albertson@duke.edu)

[1]Department of Civil and Environmental Engineering, Duke University, Durham, NC 27708, United States

There are outstanding questions surrounding the measurement and modeling of carbon and water fluxes over complex landscapes. Typically, forest fluxes are measured with the eddy covariance technique from a single tower. A unique study over a loblolly pine stand in the Duke Forest yielded high frequency velocity, temperature, water vapor and carbon dioxide fluxes from a network of six instrumented towers, simultaneously. In this talk we explore the canopy-atmosphere dynamics active during this experiment through the use of a Large Eddy Simulation (LES) code. The LES includes a numerical representation of the plant canopy structure, a biophysical process sub-model, and mixes the sources and sinks through the boundary layer with a filtered form of the Navier-Stokes equations. Through this combination of a spatially distributed dataset and a 3D model of canopy flows and processes we investigate the relative influences of canopy structure and meteorological forcing on observed and modeled fluxes. This work has implications for our understanding of the effects of canopy turbulence on eddy covariance flux measurements.

B72C-04 1415h INVITED

Two-Dimensional Airflow within Canopies on Hilly Terrain: Implications for Flux Monitoring, Inverse Models, and Data Assimilation

Gabriel Katul[1] (919-613-8033; gaby@duke.edu)

John Finnigan[2] (john.finnigan@cbr.clw.csiro.au)

[1]Duke University, Nicholas School of the Environment and Earth Sciences, Box 90328, Duke University, Durham, NC 27708-0328, United States

[2]CSIRO Atmospheric Research, FC Pye Laboratory, CSIRO Black Mountain,, Canberra, ACT 2601, Austria

Topography influences almost all aspects of forest-atmosphere carbon exchange, yet only a limited number of studies have investigated the role of topography on the structure of turbulence within vegetation and its ultimate effect on photosynthesis and turbulent fluxes. Here, we limit our attention to the interplay between radiative transfer, flow dynamics, and ecophysiological controls on CO2 sources and sinks within a canopy situated on an idealized two-dimensional sinusoidal ridge. In particular, we address how topography alters the forest-atmosphere CO2 exchange rate when compared to uniform flat terrain. Towards this end, a first order closure model that accounts for the flow dynamics, radiative transfer, and the nonlinear ecophysiology within the canopy volume is proposed. The model shows that the horizontally averaged and vertically integrated photosynthesis departs from its flat terrain value by a factor comparable in magnitude to the mean hill-slope. In contrast, as we traverse the hill, Fc, the surface-normal eddy flux of CO2 above the canopy, departs from its flat terrain counterpart by factors as large as 3 while its horizontally averaged value differs from that on flat terrain by 100%. The difference between Fc and the integrated biological sources and sinks (Sc) is supplied by horizontal and vertical advection terms that are individually much larger than the Sc we wish to measure. By demonstrating that the variations in advection and Fc across the hill are relatively independent of the source-sink distribution of CO2 in the canopy, we show that we can correct systematically for advection using standard techniques of data assimilation and inverse modelling.

B72C-05 1430h

Using Flux Measurements Over Forests to Improve Climate Predictions by the GISS GCM

Andrew D Friend (212-678-5587; afriend@giss.nasa.gov)

NASA/GISS and Columbia University, 2880 Broadway, New York, NY 10025, United States

A physiologically-based canopy photosynthesis and stomatal conductance model is described and included in the Goddard Institute for Space Studies (GISS) GCM modelE land surface scheme. The model is parameterized and tested using energy, moisture, and carbon flux data collected using the eddy covariance technique over conifer, deciduous broadleaf, and evergreen tropical forest types. Canopy conductance is assumed to depend on canopy photosynthesis, vapor pressure deficit (vpd), and soil moisture. Photosynthesis is predicted from leaf biochemistry. Predicted transpiration and photosynthesis are particularly sensitive to the amount of photosynthetic machinery and the assumed dependence of the leaf surface carbon dioxide gradient on vpd and soil moisture - parameterizations specified directly from the observations.

Predicted climate is significantly improved compared to previous simulations with the GCM, especially surface temperature and precipitation over the Amazon region, south-eastern United States, and the Sahel. Mean seasonal temperatures are improved by over 2 degree C and precipitation by 50 per cent in some regions. Soil moisture is greatly increased in many regions where it was previously too low - especially the Americas, southern and eastern Africa, the Sahel, and central Eurasia. The response of canopy conductance to vpd plays a major role in these improvements. Land surface annual gross primary productivity, the driver of the biotic terrestrial carbon cycle, is predicted to vary 76-84 Gt[C] between years, about two thirds the mean annual value inferred from observations. This difference is due to remaining problems with precipitation over South America, Africa, and southern Asia.

B72C-06 1445h

Is the size of the Carbon Sink caused by "Woody Encroachment" of U.S. Grasslands overestimated? One DGVM calculates an answer.

Dominique Bachelet[1] (360 570 2015; bachelet@fsl.orst.edu)

Raymond J Drapek[2] (541 750 7483; drapek@fsl.orst.edu)

. Team MAPSS[2] (541 750 7303; neilson@fsl.orst.edu)

[1]Oregon State University, Dept of Bioengineering, Corvallis, OR 98503, United States

[2]USDA Forest Service, PNW Station, Corvallis, OR 98501, United States

The DGVM MC1 includes a modified version of the biogeochemistry model CENTURY that simulates soil processes and also simulates wild fires occurrence and effects. MC1 simulated all the locations in the conterminous U.S. that had switched from a period of dominance by grasses (at least 30 years) to a period of dominance by woody vegetation during the historical period (1895-1993) using VEMAP transient climate as input. The model simulated the size of the carbon pools in live plant biomass and in the soil under the different vegetation types. Simulations show decreased soil organic carbon with increased vegetation biomass as woody vegetation replaces grass vegetation. At high precipitation sites, the decrease in soil carbon associated with the conversion to woody vegetation is greater than at low precipitation sites, agreeing with Jackson et al. (2002). The negative relationship between annual average precipitation and simulated changes in soil carbon mimics that found by Jackson et al. (2002). Biomass consumed by wildfires during the grassland phase was compared to that consumed during the shrubland phase. Even though there was an increase in aboveground carbon associated with the conversion to woody vegetation, total biomass consumed by wildfires was 35 percent lower during the shrubland phase. In conclusion, potential carbon storage in live plant biomass increases when shrublands invade the grasslands as trees can store more carbon and are less likely to be consumed by wildfires. However the soil carbon sequestration potential decreases in those sites. In our study, MC1 simulates a decrease in total system carbon storage as the decrease in soil carbon exceeds the increase in vegetation carbon when woody vegetation invade the grasslands.

B72D MCC: 132 Sunday 1520h

Interactions of Permafrost With Climatic, Hydrologic, and Ecosystems Processes I *(joint with C, H, GC)*

Presiding: **W C Oechel,** San Diego State University**; J Brown,** U.S. Permafrost Association

B72D-01 1520h INVITED

Impacts of Changing Permafrost Extent on Vegetation Transitions on the Seward Peninsula, Alaska

Andrea H Lloyd[1] (802-443-3165; lloyd@middlebury.edu)

Christopher L Fastie[1] (802-443-2638; fastie@middlebury.edu)

Kenji Yoshikawa[2] (907-474-6090; ffky@uaf.edu)

Larry D Hinzman[2] (907-474-7331; ffldh@uaf.edu)

Matthew Fraver[2] (ftmrf@aurora.uaf.edu)

[1]Middlebury College, Department of Biology Middlebury College, Middlebury, VT 05753, United States

[2]University of Alaska, Water and Environmental Research Center University of Alaska Fairbanks, Fairbanks, AK 99775, United States

Permafrost is an important control over the distribution of major vegetation types in the low arctic, and temporal changes in permafrost extent may thus be tightly coupled to changes in plant community distribution. For example, spruce trees have become more widespread during the 20th century on the Seward Peninsula, but in permafrost-affected areas with low topographic relief spruce have invaded tundra only where permafrost has thawed. Two hypotheses may explain the apparent dependence of treeline advance on permafrost. First, increased soil temperature associated with thawing permafrost may enhance spruce success. Second, degradation of permafrost may increase soil drainage in areas with low topographic relief, and thus create more favorable conditions for spruce. We investigated these hypotheses at a thaw pond complex on the Seward Peninsula, comparing the relationships between soil properties (thaw depth, surface and subsurface soil moisture) and woody plant communities in three sites: within the partially drained basin of the thaw pond, along the thaw pond banks and on the flat tundra surface surrounding the thaw pond.

White spruce (*Picea glauca*) occurred primarily on or within 10 m of the top of pond banks. Spruce have established there continuously since at least 1820, and are present in groves with densities > 1500 trees/ha. Since 1960, spruce have successfully established at lower densities (1,000 trees/ha) in tundra sites within 10 m of the top of the banks. We found no spruce > 20 m from the banks. Live spruce occur within the pond basin only on palsas, but several dead spruce were found in the basin itself. Shrub community structure also varied significantly among sites. Two relatively large-stature shrubs,*Betula nana* and *Salix* sp., were more abundant on banks than in other sites, and the height of the shrub canopy was > 50% greater on banks than in other sites. Late summer thaw depth did not differ significantly among the three site types, but soil moisture was highest in the pond basin, intermediate on the tundra sites, and lowest on the banks. These data thus confirm previous findings that in tundra areas with low topographic relief spruce establishment occurs only in close proximity with thawing permafrost, and suggest that improved soil drainage is the most likely explanation for that relationship.

Permafrost melting may therefore promote the growth and establishment of spruce in certain tundra landscapes by providing new, well-drained microhabitats in which trees are able to establish in relatively high densities. Changes in microtopography that accompany permafrost degradation may thus lead to an expansion of forest-tundra and tall shrub-tundra vegetation into areas currently occupied by low shrub tundra or tussock tundra. Conversely, forest-tundra vegetation may be unlikely to establish in this type of landscape in the absence of permafrost degradation. This potential dependence of vegetation change on permafrost melting in areas with low topographic relief may cause vegetation in these areas to show a nonlinear response to climate warming, and thus has important implications for our understanding of likely trajectories of vegetation change in the low arctic.

B72D-02 1540h

Vegetation-Soil-Active Layer Relationships Along a Low-Arctic Bioclimate Gradient, Alaska

Donald A. Walker[1] (907-474-2460; ffdaw@uaf.edu); Gensuo J. Jia[2] (jiong@virginia.edu); Howard E. Epstein[2] (hee2b@virginia.edu); Nikolay Shiklomanov[3] (shiklom@udel.edu); Frederick Nelson[3] (fnelson@udel.edu); Larry D. Hinzman[4] (ffldh); Vladimir E. Romanovsky[5] (ffver@uaf.edu)

[1]Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, AK 99775, United States

[2]Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22904, United States

[3]Department of Geography, University of Deleware, Newark, DE 19716, United States

[4]Water and Environmental Research Center, University of Alaska Fairbanks, Fairbanks, AK 99775, United States

[5]Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK 99775, United States

Northern Alaska has three of five Arctic bioclimate subzones, which are representative of the circumpolar Low Arctic. This portion of the Arctic has more or less continuous tundra plant cover and well-developed moss canopies. We examined the biomass and remotely sensed spectral properties of the vegetation canopy, active-layer thickness, and the soil properties at 21 sites on the Arctic Slope and Seward Peninsula of Alaska. The sites were grouped into three bioclimate subzones according the summer warmth at the sites. The summer warmth index (SWI) is the sum of the mean monthly temperatures greater than 0 degrees C. Subzone C, the coldest subzone, occurs in a narrow strip along the northern coast of the Alaska. Subzone D covers most of the Arctic Coastal Plain and the northwest portion of the Seward Peninsula, and Subzone E covers most of the Foothills and most of the unforested portion of the Seward Peninsula. The SWIs in Subzones C, D, and E are generally less than 10-15 degrees C, 15-25 degrees C, and 25-35 degrees C respectively. The average active layer depths were 44, 55, and 47 cm respectively The shallow active layer in Subzone E is to a large degree a response to the denser vegetation canopies in Subzone E. Total plant biomass in Subzone C, D, and E averaged 421 g m-2, 503 g m-2, and 1178 g m-2 respectively. The much higher biomass in Subzone E was due primarily to woody shrubs (40 g m-2 in Subzone C, 51 g m-2 in Subzone D, and 730 g m-2 in Subzone E). The normalized difference vegetation index (NDVI) is one measure of greenness. Highest NDVI values were obtained from acidic tundra regions in Subzone E, and the lowest NDVI values were obtained in the nonacidic areas of Subzone C. In summary, the insulative properties of the vegetation play a very important role controlling the thickness of the active layer, and the amount of vegetation biomass differs according to summer warmth and soil properties. Acidic soils in the warmest parts of the Arctic (Subzone E) generally have well-developed shrub and moss canopies that shade the soils, resulting in relatively shallow active layers, whereas nonacidic soils in equivalent climates generally have shorter-stature sedge-dominated canopies and many frost boils that result in deeper active layers. The trends in biomass associated with the present-day Arctic bioclimate gradient may be useful for helping to infer the changes in vegetation biomass that are associated with 20-year trend of increasing NDVI that has been noted in the Arctic. Our data suggest that the increased warming associated with climate change will not necessarily lead to uniform thickening of the active layer. Thicker moss layers and more dense shrub cover may induce a reduction in active layer thickness in some areas of the Arctic, and could lead to a decrease in its variability.

B72D-03 1555h

Relationships Between Permafrost and Vegetation in Different Geographical Environments: Antarctica and Alps.

Nicoletta Cannone[1] (+39 0392459239; cannone.guglielmin@virgilio.it)

Francesco Dramis[2] (+39 06 54888022; dramis@uniroma3.it)

Mauro Guglielmin[3] (+39 02 69666287; m.guglielmin@arpalombardia.it)

[1]University of Ferrara, Dept. of Natural and Cultural Resources, Corso Porta Mare 2, Ferrara, FE 44100, Italy

[2]University of Rome Third, Dept. of Geological Sciencies, Largo L. San Murialdo, 1, Rome, Rom 00146, Italy

[3]Arpalombardia, Viale Restelli 1a, Milan, MI 20124, Italy

Permafrost is a particularly sensitive system whose existence and conservation is strictly dependent on local climatic conditions and surface energy balance. Permafrost occurs in deglaciated areas, characterised by the presence of associated biological components.

Among these, particualrly important are vegetation communities. They are in fact the product of both the present site environmental conditions and ecological evolution, which in turn are related to the site biogeographical, climatic, geological and geomorphological history.

Considering the wide latitudinal permafrost distribution and the variability of relationships with environmental and biological contitions, we selected four investigation sites: two in maritime and continental Antarctica (King George Island, Southern Shetland and Terra Nova Bay) and two in the periglacial belt of the Italian Central Alps (Foscagno and Stelvio-Livrio, located at 2500-3000 m a.s.l.), where two boreholes have been drilled within the EU-PACE Project.

Permafrost distribution and active layer characteristics have been analysed through geophysical soundings, geomorphological survey, cryological and chemical analyses of sampling trenches and pits and, above all, thermal monitoring. Vegetation ecosystems have been studied by phytosociological approach, recording the percentage of vegetation cover as well as the occurrence and per cent coverage of each species on representative homogeneous plots.

In Antarctica, where the active layer is generally thin (20-150 cm), we observed a very good correspondence between active layer thickness, vegetation communities and drainage conditions. In particular, vegetation communities dominated by mosses are related to thin active layers, where the drainage is limited by the near-surface permafrost table. On the other hand, macrolichen dominated communities are preferentially correlated with thicker active layer and better drainage conditions.

In the Alpine sites, vegetation cover doesnt directly reflect active layer thickness, which is normally more than 2 m. However, vegetation characteristics can be used as ecological indicators of some key climatic parameters, such as snow cover, that are involved in the ground surface energy balance and therefore in the permafrost occurrence conditions.

B72D-04 1610h

Effects of surface fuel consumption on patterns of permafrost in a black spruce forest complex in interior Alaska

Eric S. Kasischke[1] (3014052179; kk169@umail.umd.edu)

Marilynn F. Walker[2] (9074742424; ffmdw@uaf.edu)

Jill F. Johnstone[2] (9074742424; ffjfj@uaf.edu)

[1]University of Maryland, Department of Geography 2181 LeFrak Hall, College Park, MD 20742, United States

[2]USFS PNW Research Station, Boreal Ecology Cooperative Research Unit School of Agriculture and Land Resources Management P.O. Box 756780 University of Alaska Fairbanks, Fairbanks, AK 99775-6780, United States

A common characteristic of black spruce forests underlain by permafrost in interior Alaska is the presence of a deep (10 to greater than 50 cm) layer of organic material consisting of live and dead moss, lichen, grass tussocks, and organic soil This layer of organic material promotes permafrost development through insulation of the ground layer, as well as retention of soil moisture. This organic layer is also part of the fuel matrix that burns during the periodic (every 50 to 200 years) fires that are common to this forest type, and the level of surface fuel consumption strongly influences post-fire patterns of soil temperature and moisture. In this paper, we present the results of a study of the patterns of surface fuel consumption (SFC) in a black spruce forest complex in interior Alaska. In a single fire event from 1994, there was a wide range in SFC, from less than 20 percent to greater than 90 percent of the ground-layer organic material present before the fire. Based on field observations, a model of SFC is presented that takes into account seasonal climatic patterns, degree of permafrost melt at the time of the fire, and underlying site drainage. This model is used to explain the wide range of permafrost conditions observed in the mature, unburned black spruce forests in the study region.

B72D-05 1625h

The Consequences of Microbial Processes for the Methane Emission From Siberian Permafrost Environments

Dirk Wagner[1] ("49-331-288-2159"; dwagner@awi-potsdam.de)

Eva-Maria Pfeiffer[2] ("49-40-42838-4194"; e.-m.pfeiffer@ifb-uni-hamburg.de)

Hans-W. Hubberten[1] ("49-331-288-2100"; hubbert@awi-potsdam.de)

[1]Alfred Wegener Institute for Polar and Marine Research, Telegrafenberg A43, Potsdam 14473, Germany

[2]Institute of Soil Science,University of Hamburg, Allende-Platz 2, Hamburg 20146, Germany

The moist lowland areas of the Siberian permafrost landscapes are natural sources of the climate relevant trace gas methane (CH4). Climate models predict significant changes in temperature and precipitation patterns in these ecosystems. More than 25% of the world's soil carbon is preserved in the permafrost. The dynamics of microbial carbon turnover in permafrost soils (Gelisols) and the interactions between temperature and moisture regime of Gelisols are not completely understood by now.

Responsible for the CH4 production and oxidation are highly specialized microorganisms (MO): Within the anoxic soil layers the methanogenic archaea transform substances like acetate into CH4. In the top layers of Gelisols methane-oxidising bacteria oxidise up to 70% of the formed CH4 into CO2.

Own investigations in Siberia show that Gelisols (3-80 mg m-2 d-1) and lake sediments (2-300 mg m-2 d-1) are important CH4 sources in the Lena Delta. In situ CH4 production varied between 0.3-38.9 nmol h-1 g-1. Even the incubation of soil material at temperatures below zero degrees Celsius showed a significant CH4 production. This points to a methanogenic microflora adapted to low temperatures in the cold permafrost habitat.

The CH4 oxidation is controlled by soil moisture, which was reflected by the seasonal variability of the CH4 emission.

Since substantial parts of the carbon conversion are catalysed exclusively by MO, the search for key-organisms as well as the identification and diversity studies of the microbial community is an essential future task. Therefore, modern methods like the fluorescence in situ hybridisation (FISH) is used to examine the composition of the permafrost microflora. These studies help to comprehend the understanding on the adaptation and tolerance of MO to the cold environment and their reaction under predicted changing climate conditions.

URL: http://www.awi-potsdam.de/www-pot/geo/modernperm.html

B72D-06 1640h

Use Of Amino Acid Racemization To Investigate The Metabolic Activity Of ?Dormant? Microorganisms In Siberian Permafrost

Alexandre Tsapin[1] (tsapin@jpl.nasa.gov)

Gene McDonald[1] (Gene.D.McDonald@jpl.nasa.gov)

[1]Jet Propulsion Laboratory, 4800 Oak Grove Dr., POasadena, CA 91109, United States

Permafrost occupies a significant part of North America and Eurasia, and accounts for around 20% of Earth?s land surface. Permafrost represents a temperature-stable environment that allows the prolonged survival of microbial lineages at subzero temperatures. Microorganisms from ancient permafrost have been revived and isolated in pure cultures. Permafrost is a unique environment serving as a "natural gene bank", with many species frozen in time (i.e. preserved in an unchanging evolutionary state). Permafrost presents a golden niche for future biotechnology, and is also a unique environment for studying longevity and survivability microorganisms (pro- and eukaryotes). Permafrost, alone among cold environments, offers a sedimentary column in which, in one borehole made in the thick permafrost, we can observe in the preserved genetic material the history of biological evolution during the last several hundred thousand or maybe even a few million years. A thorough study of the phylogenetic relationships of organisms at each depth, as well as comparisons between different depths of permafrost, using molecular evolution techniques, will give us a unique window into the process of evolution of microbial communities over geologic time.

The longevity of (micro)organisms in cold environments is of great interest to astrobiology since cryospheres are common phenomena in the solar system, particularly on satellites, comets and asteroids, and on some of the planets. Recent data from the Mars Global Surveyor mission suggest the possibility of permafrost or perhaps even liquid water under the Martian surface. The probability of finding life on Mars, if it exists, is probably higher in such environments. In addition, the evaluation of the possibility of transfer of living organisms between planets via impact ejecta needs the information on the maximum time over which microorganisms in cold environments can remain dormant and subsequently revive and reproduce. Our strategy for the search for extraterrestrial life or its remnants is based on studying the most probable environments in which life (extant or extinct) may be found, and determining the maximum period of time over which such life could be preserved. The terrestrial permafrost, inhabited by cold adapted microbes, can be considered as an extraterrestrial analog environment. The cells and their metabolic end-products in Earth's permafrost can be used in the search for possible ecosystems and potential inhabitants on extraterrestrial cryogenic bodies. The study of microorganisms (or their remnants) that were buried for a few million years in permafrost provides us with a unique opportunity to determine the long-term viability of (micro)organisms.

We have analyzed the degree of racemization of aspartic acid in permafrost samples from Northern Siberia (Brinton et al. 2002, Astrobiology 2, 77), an area from which microorganisms of apparent ages up to a few million years have previously been isolated and cultured. We find that the extent of aspartic acid racemization in permafrost cores increases very slowly up to an age of approximately 25,000 years (around 5 m depth). The apparent temperature of racemization over the age range 0-25,000 years, determined using measured aspartic acid racemization rate constants, is ?19 C. This apparent racemization temperature is significantly lower than the measured environmental temperature (?11 to ?13 C), and suggests active recycling of D-aspartic acid in Siberian permafrost up to an age of around 25,000 years. This indicates that permafrost organisms are capable of repairing some molecular damage incurred while they are in a ?dormant? state over geologic time.