Next-Generation Ecosystem Experiments – NGEE Arctic

Quarterly Report
March 31, 2011

A progress report submitted to

Mike Kuperberg
Program Manager
Department of Energy, Office of Science, Biological and Environmental Research

Prepared by

Stan D. Wullschleger
Environmental Sciences Division
Oak Ridge National Laboratory

and

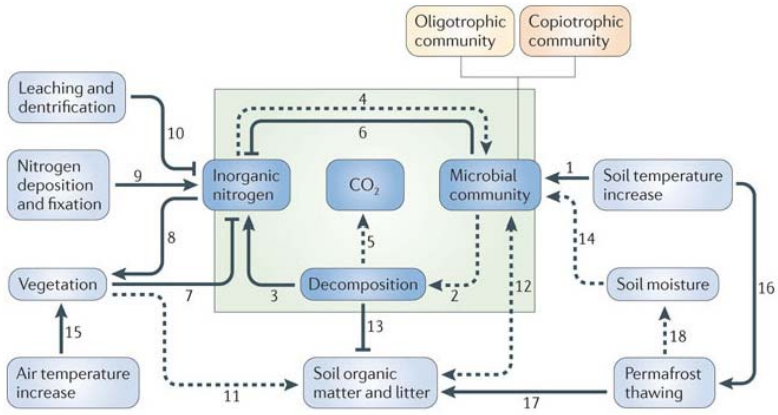
Cathy Wilson, Nathan McDowell, Joel Rowland, Rodman Linn, Phillip Cunningham, Bryan Travis, Chonggang Xu, Thomas Rahn, and Claudia Mora
Earth and Environmental Sciences Division & Computational Earth Sciences Division
Los Alamos National Laboratory

Contents

Item	Page
Incorporation of Microbiology in Global Climate Models	2
Details at a Glance	2
Progress and Accomplishments	3
Interactions with other Agencies, Universities, and National Laboratories	8
Publications, Presentations, and Posters	9
Press Releases and News Clips	10
Appendix	11

Can Microbial Community Composition be Incorporated into Earth System Models?

Accurate projections of greenhouse gas fluxes by Earth System Models require that they contain process-level representation of critical feedbacks and interactions that arise between terrestrial ecosystems and climate. For tundra and boreal ecosystems, the increase in soil temperature with global warming could enhance microbial community activity which could in turn lead to faster soil organic matter decomposition and more inorganic nitrogen in the soil. The mechanisms that connect microbial dynamics, nitrogen cycles, and feedbacks to ecosystem productivity and greenhouse gas emissions are not currently represented in climate models. Chonggang Xu, a post-doctoral research associate at the Los Alamos National Laboratory and his colleagues highlight in a recent Nature Reviews Microbiology commentary that the feedback between nitrogen availability and microbial community composition can play a key role in regulating the response of soil respiration and biogeochemical cycles to rising temperatures, and that this is an important mechanism to incorporate into climate models. A conceptual model is presented that shows how temperature-induced increases in inorganic nitrogen may stimulate certain soil enzymes more than others within microbial communities. These differential effects on enzyme production could lead to a shift in community composition for microbes involved in carbon and nitrogen cycle processes. Although we currently have a good understanding of how nitrogen affects microbial community activity and structure, further interdisciplinary research is needed to better understand the feedback loop between nitrogen cycling and microbial community composition and to mechanistically represent the complex plant-microbe-soil system in Earth System Models. Xu et al. (2011)



Feedback loop between inorganic nitrogen dynamics and microbial communities, and related factors in the heterotrophic soil respiration response to global warming in high-latitude ecosystems.

Details at a Glance

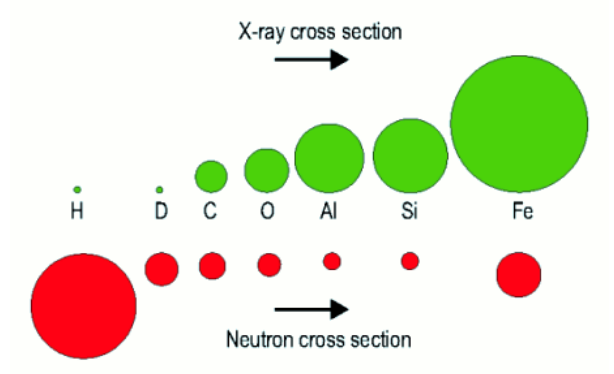
Activities during the January 1 to March 31, 2011 quarter include:

- Permafrost carbon dynamics to be studied using ORNL high-flux isotope reactor (HFIR).
- Editorial targets microbial genomics in understanding thawing permafrost dynamics.
- ARCHY model simulations of thermokarst.
- Polygonal ground characterized using high-resolution Lidar imagery.
- Multiple NGEE workshops planned for coming year.

Progress and Accomplishments

Ice distribution and water migration in thawing permafrost soil:

Alex Johs, Liyuan Liang, and Stan Wullschleger (ORNL) will use neutrons to investigate geophysical properties of permafrost. In permafrost, ground ice occurs in two forms, as structure-forming ice, bonding the enclosing sediments, and as large bodies of more or less pure ice. Thawing of ice-rich soils exceeding the void volume of enclosing sediments can result in weakening or settlement of the soil (e.g., subsidence). The structure-forming ice comprises segregated ice, intrusive ice, reticulate vein ice, ice crystals, and coatings on soil particles. Even at subzero ambient temperatures, however, it is generally accepted that liquid water is present within permafrost, existing as a very thin film surrounding soil and ice. It is suggested that these films are important for transport of nutrients and metabolic products, and could serve as carbon and nutrient sources for microbial communities. Since neutrons are particularly sensitive to hydrogen, Johs and colleagues will use the high-flux isotope reactor (HFIR) to (1) obtain optimal contrast of permafrost samples from Fairbanks, Alaska for neutron imaging and tomography; (2) correlate experimentally determined permafrost water content with neutron absorption; (3) determine achievable resolution for pore structures, voids and water distribution; (4) find conditions that could enable distinction of frozen and liquid water boundaries to characterize the thawing process; and (5) neutron tomography to determine the spatial distribution of water of permafrost samples. The results of this proof-of-principle study will be used to design field sampling and analysis protocols for NGEE Phase 1 activities.



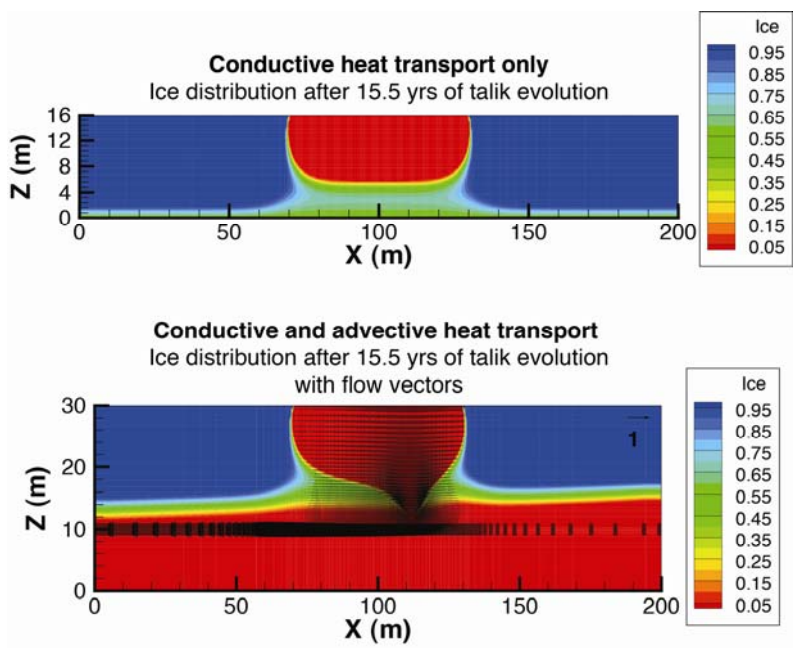
Microbes in thawing permafrost: The unknown variable in the climate change equation:

Permafrost soils represent one of the great frontiers for biological exploration. Considering that 25% of Earth's terrestrial surface is underlain by permafrost soils and that permafrost contains approximately 25% to 50% of the total global soil organic carbon pool, our understanding of the diversity of microbial life in this extreme habitat is surprisingly limited. In a commentary written for the International ISME Journal, David Graham (ORNL) and others explore the notion that widespread permafrost thaw will lead to the release of massive amounts of carbon dioxide and methane into the atmosphere. It was long assumed that microbes were either dead or dormant when frozen; however, given the recent advent of molecular approaches, evidence now suggests that microbial activity below 0°C can be significant. Currently, for quantitative land and climate models, the relative temperature sensitivity of carbon conversion rates in thawing permafrost is a black box. Nonlinear, temperature-dependent changes in protein structure and conformation, protein adsorption, substrate occlusion in aggregates, altered protein expression, and shifts in microbial populations could all contribute to carbon flux due to enhanced microbial activity. We might expect permafrost warming to select for microbes producing enzymes that degrade and metabolize complex organic substrates released from newly thawed permafrost more efficiently

at higher temperatures. Recent advances in metagenomics and metaproteomics promise to address how changes in temperature and associated environmental variables impact soil microbial populations and enzymatic activities. New bioinformatic methods and parallel techniques such as genome sequencing of cultivated permafrost isolates and single-cell genome sequencing can circumvent many of these hurdles, enhancing the analysis of metagenomics data. Finally, Graham and his co-authors conclude that the new "omics" techniques of metagenomics, metatranscriptomics, metaproteomics and metabolomics are developing at an opportune time to provide detailed insights into microbial communities in the midst of rapidly changing environments. As a community, we should find new ways to integrate these results with geochemical measurements to predict the magnitude of feedback on warming in permafrost systems. Graham et al. (2011).

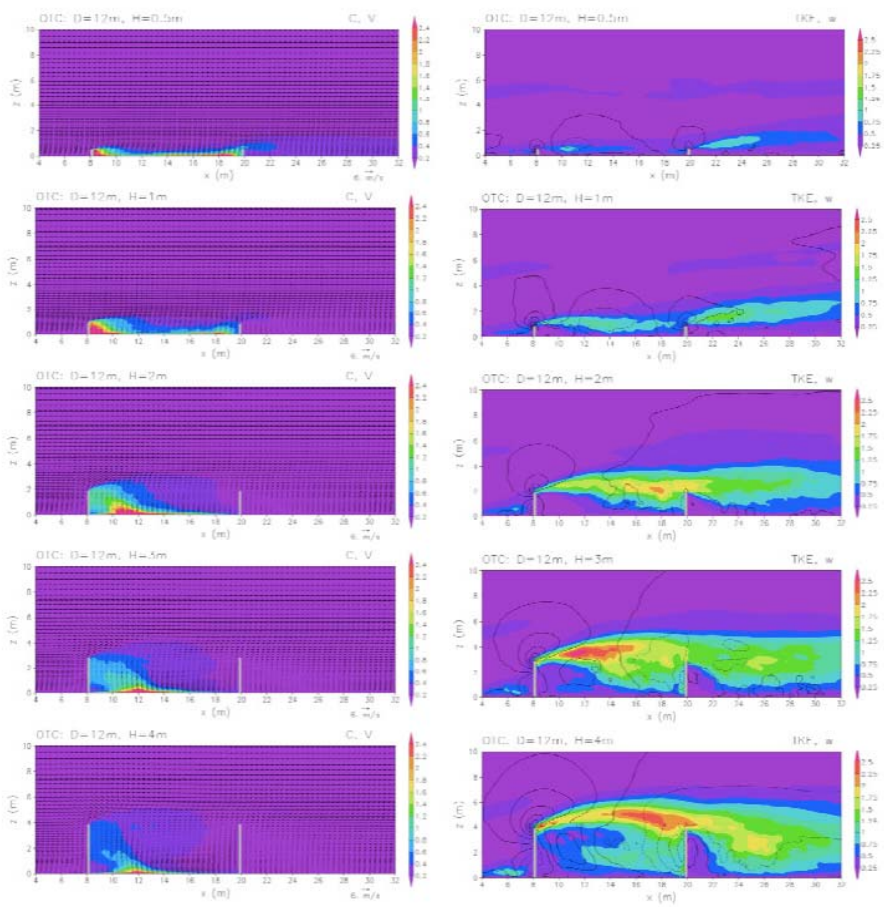
<u>ARCHY model simulations of thermokarst</u>:

Model simulations were conducted at LANL to quantify the role of advective heat transport and regional groundwater flow on talik development beneath lakes in ponds in regions of thin, warm permafrost. Based on conditions reported for lakes shrinking the Council area of the Seward Peninsula (Yosikawa and Hinzman, 2003) models runs were set up to represent an area with a mean annual ground surface temperature of -2 °C and an mean annual lake bottom temperature of 4 °C. The model was initially run for 250 years without a lake to allow for a stable permafrost thickness to develop in the presence of groundwater flow at the base of the permafrost. Two simulations were then carried out with a lake at the upper boundary. In the first, no advective heat transport was allowed and the permafrost was set to a uniform thickness of 16m. In the second simulation, a lake was added to the steady state conditions developed in the presence of regional groundwater flow. With groundwater flow and the effect of flow downward into thawing permafrost, talik penetrated the permafrost in 15.5 years. In contrast, in the same amount of time the base of the developing talik only advanced 10 m in the simulation with only conductive heat transport. A through-going talik took an additional 5 years to develop without advective heat transport by groundwater flow beneath and through the thawing permafrost. The results highlight: (1) the importance of advective heat transport in permafrost systems where groundwater and surface water interactions are likely; and (2) the sensitivity of warm thin permafrost in transitional settings to small changes in surface water distributions and mean annual temperature.



HIGRAD simulations of open-top chambers:

The LANL atmospheric model HIGRAD is being used to simulate the fine-scale turbulent flows within and around open-top chambers (OTCs) of configurations possibly relevant to NGEE, and to explore the effects of these turbulent flow fields on various temperature control strategies. Recent activity has been focused primarily on validation of the HIGRAD model. Effort in this regard has consisted of: (1) validation of HIGRAD simulations of flow around solid cylindrical obstacles, for which a significant peer-reviewed literature exists; and (2) application and extrapolation of these results to open cylinders, focusing primarily on the dependence of airflow and turbulent mixing on the geometry of the chamber. In this regard, the figure below shows HIGRAD simulations of wind, time-averaged tracer concentration (e.g., CO_2) given a constant surface flux within the chamber, and turbulent kinetic energy for OTCs of 12 m diameter with heights varying from 0.5 m to 4 m. This simulation illustrates how turbulent mixing increases, and hence how tracer concentration becomes more nonuniform, as chamber height increases. This effort will culminate in two publications, the first of which describes the fundamental dynamics of flow and turbulence within and around OTCs of different heights. The second publication will consider the effects of different heating strategies in OTCs.



Left column, passive tracer concentration (shaded) and wind vectors; right column, turbulent kinetic energy (shaded) and vertical component of mean velocity (contours, negative values dashed), in a vertical plane through the center of the OTC for chamber heights of 0.5 m, 1 m, 2 m, 3 m, and 4 m.

Landscape-scale features due to permafrost degradation to be focus of Phase 1 NGEE:

Thermokarst forms as ice-rich permafrost thaws and the ground surface subsides into the resulting voids. The important and dynamic processes involved in thermokarsting include thaw, surface subsidence, and formation of drainage networks that can rapidly modify the landscape (see photo). Such landscape-scale features have significant implications for vegetation dynamics, net energy balance and albedo, subsurface biogeochemistry, flux of carbon dioxide and methane from the land surface to the atmosphere, and resulting feedbacks to climate. NGEE has selected these features for intensive study during Phase 1 of the project. Thus, while we recognize that climate-driven controls on processes are importance, we additionally acknowledge that the landscape in which those processes operate is also important. Climate models currently do not incorporate landscape-scale changes or their consequences to ecosystem-climate feedbacks, and this represents a unique and important contribution of Phase 1 NGEE activities to observations and models.

Barrow and Council, Alaska selected as NGEE sites:

The multi-disciplinary research proposed to be undertaken in the NGEE Arctic activity could be pursued in several ways ranging from plot and landscape observations conducted at single sites or nested watersheds to schemes where measurements are conducted across bioclimatic transects or transects that stratify sampling across ecosystem transitions. Given our overarching goal of quantifying landscape dynamics associated with permafrost degradation and the underlying physical, chemical, and biological processes of thermokarst features, we contend that intensive sampling at two strategic sites is warranted. Hinzman et al. (2003) summarized the climate and physical characteristics of various sites across the North Slope, Interior, and Seward Peninsula of Alaska (Table 1).

Table 1. Climatic and physical characteristics of study sites in northern Alaska.

Alaskan Study Sites	Latitude (ºN)	Average Annual Air Temperature (ºC)	Average January Air Temperature (ºC)	Average July Air Temperature (ºC)	Average total snowpack (cm)	Average total summer rainfall (mm)	Average active layer depth (cm)	Estimated Permafrost Thickness (m)
Barrow	71°18'	-11.3	-25.9	5.4	25.5	73.1	32	~300
Betty	70°18'	-8.5	-22.9	7.2	43.0	67.1	54	~600
Franklin Bluffs	69°50'	-9.3	-24.9	10.5	37.2	79.0	64	~350
Sagwon	69°25'	-7.9	-21.3	10.1	28.2	151.4	NA	~300
Imnavait Creek	68°37'	-6.0	-17.1	9.4	26.0	247.9	52	~300
Ivotuk (met site 1)	68° 29'	-7.3	-24.7	11.3	62.0	181.5	55	295
Kougarok (K2)	65° 27'	-2.4	-23.1	11.0	82.0	102.1	56	15-50
Council (C1)	64° 54'	-3.4	-18.0	11.4	72.0	317.2	63	Discon-tinuous

Careful consideration of these climatic and permafrost characteristics coupled with discussions of site access, logistics, safety, and scientific objectives led us to select Barrow and Council as two sites for Phase 1 research activities. Barrow lies within the Alaskan Arctic Coastal Plain, a relatively flat region bordered on the north by the Arctic Ocean and on the south by the foothills of the North Slope. Permafrost at the site is continuous and is present to depths greater than 300 m. Mean annual temperature at 10 m depth is -9.2^{o}C. The active layer is shallow and averages 30 to 35 cm. Mean annual air temperature is -11.3^{o}C; mean annual precipitation is 73 cm. Soils are classified as Gelisols and are characterized by an organic-rich surface layer, underlain by a horizon of silty clay to silt loam textured mineral material, and a frozen organic-rich mineral layer. Council is located on the Seward Peninsula and is representative of subarctic transitional regions where boreal forests give way to tundra regions located on warm permafrost. This region provides relatively easy access to fully developed tussock tundra, mature spruce forests, thick deciduous shrub zones composed of birch, alder and willow, and ecotones between these dominant vegetation types. Shrub expansion onto the tundra is prominent in this area, as are thermokarst features associated with permafrost degradation. The active layer is deeper than in Barrow and averages 60 to 60 cm. Mean annual air temperature is -3.4^{o}C; mean annual precipitation is 317 cm. Loamy soils range from fine to coarse.

Degradation of Arctic polygonal patterned ground:

Polygonal patterned landscape is one of the key features emerging in anticipated climate driven landscape degradation in the Arctic and Sub-Arctic. The collapsing polygonal trough over ice wedges are the initial state of degradation which subsequently leads to different polygonal pattern formations based on climate, vegetation, geological forcing system. These polygonal features alter the arctic landscape (supposedly undergoing rapid landscape evolution process) which in turn alters the arctic geomorphic and hydrologic processes. The characteristics size, shape, spacing, and extent of the patterned ground can vary by geographic locations where variation in climate and other factors such as vegetation influence the thermal and hydrologic processes of the active layer and underlying permafrost. Some striking pattern regularity suggests that some characteristics of local ecosystem such as climate and vegetation, might have dictated the particular polygonal pattern spacing when the pattern first developed. On the other hand quantifying the spatial and spectral characteristics of the polygonal patterned features could provide information about the ground ice, permafrost distribution, active layer thickness, as well as past ecosystem at the time when the pattern first developed. Further, relating the landscape geomorphic attributes such as slope, curvature, flow distributions etc., with pattern specific characteristic scales will allow us to estimate landscape evolution model parameters which could possibly explain the pattern ground evolution process in a warming arctic landscape. In that sense, developing a proper quantitative toolset to characterize the patterned ground landscape is highly important and improves our understanding about the effect of climate change on the arctic landscape processes.

Scientists at LANL are working on several novel approaches to quantify the Arctic patterned ground landscape using high-resolution Lidar topography measurements. They are using a sophisticated machine learning tool, Genie-Pro (developed by LANL), to identify the pattern ground at global scale. Genie-Pro can work well with the high-resolution imagery such as workview-2 as well and Lidar derived products such as local slopes, curvature, hill shape to

identify the pattern ground locations globally. A Fourier spectral analysis is also being used to spectrally quantify the polygonal terrain and their power distributions across the range of frequencies. The energy distributions of the polygonal terrain might vary by geographic locations, level of degradation, and climate and vegetation forcing system. The sub-grid scale features of the polygonal patterned ground are characterized by localizing 2-D wavelets with polygonal features. Based on a 2-d wavelet framework, LANL can successfully map polygonal boundaries. They have further introduced a distance based scale parameter to obtain the slope, curvature, flow accumulation metrics to understand the slope and curvature distributions of the polygonal landscape and relate those geomorphic patterns with landscape model parameters.

US-Russia collaboration on permafrost pursued:

Improving climate change prediction in high-latitude systems requires an accurate understanding of permafrost degradation and impacts on the soil biogeochemistry, vegetation dynamics, land-atmospheric interactions, and landscape processes. A joint US-Russia workshop will identify critical knowledge gaps in our understanding of permafrost-dominated landscapes and links to climate change. Subject matter experts from US, Russia, and the larger international community will be invited to discuss:

- Thermal state of permafrost and its dynamics on inter-annual, decadal, and centennial time scales.
- Microbial dynamics in the active layer and the upper 5 to 20 m of permafrost.
- Relic shallow gas hydrates in permafrost and their role in carbon fluxes to the atmosphere.
- Thermokarst, thermal erosion, and other land surface processes in climate change.
- Sub-marine arctic permafrost.
- Development of a new circum-polar permafrost map that will reflect changes in climate.

The joint workshop will be held in late summer or early fall, 2011 in the San Francisco, CA area. Invited speakers will provide an overview of permafrost dynamics in the Arctic and sub-arctic and then sessions will focus discussions on each of the topics identified above. A session will prioritize permafrost-related research topics and develop a research agenda that could be undertaken as part of a future US-Russia collaboration. See appendix for more details.

Interactions with other Agencies, Universities, and National Laboratories

In March, Howard Epstein from the University of Virginia visited ORNL and gave a seminar on vegetation modeling in the Arctic. Howie has developed an ArcVeg model that allows for changing species composition with time (e.g., successional dynamics) and with changing climate. Potential improvements to the model were discussed, especially in areas related to nitrogen cycling and vegetation dynamics and how that model could be used to support NGEE activities. The seminar was videotaped and broadcast live. It is also archived and available at the NGEE web site: http://ngee.ornl.gov/

Stan Wullschleger and Colleen Iversen (ORNL), Susan Hubbard (LBNL), Larry Hinzman (UAF), and Cathy Wilson and Joel Rowland (LANL) discussed potential research collaborations with Dan Rothman (MIT). Dan has applied physical theory to complex environmental systems

and has recently employed a number of approaches to the study of carbon cycle science. We talked to Dan about approaches that might be use din the context of NGEE objectives, especially focusing on the Arctic as a complex, permafrost-dominated system in transition due to a changing climate.

Publications, Presentations, and Posters

Publications:

Xu, C., C. Liang, S.D. Wullschleger, C.J. Wilson and N. McDowell. 2011. Importance of feedback loop between soil inorganic nitrogen and microbial community in the heterotrophic soil respiration response to global warming. Nature Reviews Microbiology 9: 222-223.

Wullschleger, S.D., L.D. Hinzman and C.J. Wilson. 2011. Climate change experiments in high-latitude ecosystems. *EOS* (in press).

Graham D.E., M.D. Wallenstein, T.A. Vishnivetskaya, M.P. Waldrop, T.J. Phelps, S.M. Pfiffner, T.C. Onstott, L.G. Whyte, D. Gilichinsky, D.A. Elias, R. Mackelprang, N.C. VerBerkmoes, R.L. Hettich, D. Wagner, S.D. Wullschleger and J.K. Jansson (2011) Microbes in thawing permafrost: The unknown variable in the climate change equation. The ISME Journal: Multidisciplinary Journal of Microbial Ecology (in review).

Presentations: None

Posters: None

Upcoming Meetings:

Joint Genome Institute Strategic Planning Meeting, April 3-5, 2011. Asilomar, CA.

Symposium on the Application of Geophysics to Environmental and Engineering Problems; April 10-14, 2011, Charleston, SC. This AGU-sponsored workshop provides geophysicists, engineers, geoscientists and end-users from around the world an opportunity to meet and discuss near-surface applications of geophysics and learn about recent developments in near-surface geophysics. This year Beth Astley, one of our CRREL collaborators from Anchorage, will chair a session on "Near-Surface Geophysics in Cold Climates". SDW will attend to learn more about geophysical characterization of permafrost. Web site: http://www.eegs.org/sageep/

Subsurface Biogeochemistry Research (SBR) PI Meeting, April 26-28, 2011. Washington DC.

SBR Data Management workshop, April 28-29, 2011. Washington DC.

Vulnerability of Permafrost Carbon: Research Coordination Network; June 1-3, 2011, Seattle, WA. This activity will host a series of workshops and synthesis meetings over the next two years to quantify the role of permafrost carbon in driving climate change in the 21st century and beyond. This will be achieved by synthesizing current information in a format that can be assimilated by biospheric and climate models, and that can contribute to the next assessment of

the Intergovernmental Panel on Climate Change (IPCC). This NSF-sponsored workshop will be hosted Ted Schuur, David McGuire, Valdimir Romanovsky, and others. Several NGEE participants have been invited because of the obvious overlap of goals and objectives of this RCN and NGEE.

Third Santa Fe Conference on Global and Regional Climate Change, October 31 to November 3, 2011. Santa Fe, New Mexico. This conference will focus on climate change and variability from observational and modeling perspectives, climate forcings and feedbacks on global and regional scales including polar.

Press Releases and News Clips

Stephen Ornes is a freelance science writer who works out of Nashville, TN. He visited ORNL on December 8, 2010 with the specific goal of hearing about the SPRUCE project and touring the prototype site. We also had the opportunity to discuss the NGEE project with Stephen and show him some of our plans that obviously closely parallel some of the plans for the northern Minnesota peatland site. His article on SPRUCE appeared in the Spring 2011 issue of OnEarth magazine under the title of "Step into My Time Machine". The article emphasizes that even the best computer models can go only so far; researchers are running climate change in fast-forward to test predictions about the future. More information…
http://www.onearth.org/gallery/photos-tennessee-time-machine

Appendix

SEMINAR ANNOUNCEMENT

Howard E. Epstein, Ph.D.
Department of Environmental Sciences
University of Virginia
Charlottesville, VA

Thursday, March 10, 2011
11:00 a.m.
Building 1505, Ocoee Conference Room

Contact: Stan Wullschleger, 574-7839

Spatial patterns, recent temporal dynamics, and future projections of arctic tundra vegetation

Changes in climate over the past several decades in the northern high latitudes have elicited responses in numerous arctic system components, including an apparent increase in the productivity of arctic tundra vegetation. The recent dynamics and potential future trajectories of tundra vegetation are presently being assessed through a variety of techniques: 1) large spatial transects of tundra ecosystems in both North America and Eurasia are being uniformly sampled to determine the present relationships between climate and tundra vegetation communities; 2) coarse-resolution remotely sensed imagery provides a circumpolar picture of vegetation "greenness" dynamics since the 1980s, 3) high-resolution remotely sensed imagery can elucidate some of the details of plant community change for specific areas since the 1960s, and 4) tundra vegetation dynamics modeling can project the future effects of global change on these ecosystems. A synthesis of approaches clearly indicates extensive but variable "greening" of arctic tundra, most visible at present in the expansion of tall shrubs, but certainly not limited to this particular vegetation type. Vegetation changes produce a complex array of feedbacks for arctic ecosystem processes, such as carbon cycling and energy partitioning.

Planned Workshops

Geophysical Quantification of Active Layer Properties and Processes in Arctic Permafrost

Improving climate change prediction in high latitude systems requires an accurate understanding of both continuous and threshold-dominated active layer dynamics and their impacts on the soil biogeochemistry, vegetation dynamics, land-atmospheric interactions, and landscape processes. The complexity of these permafrost dynamics and associated impacts on carbon fluxes warrants further development of advanced geophysical characterization and monitoring approaches for high latitude systems. This workshop will discuss geophysical quantification of permafrost dynamics, including: petrophysical relationships for frozen soils; optimized rugged sensor networks for multi-scale imaging; diagnostic geophysical signatures of warming-induced permafrost transitions; and methodologies for integrating multi-scale geophysical, hydrological, biogeochemical, and geomechanical data for improved process understanding.

Tentative Date: October, 2011
Tentative Location: Rockford, MD and DC area
Workshop Leaders: Susan Hubbard and Stan Wullschleger

Permafrost Dynamics in the Arctic

Arctic landscapes are influenced to a considerable extent by the presence of permafrost. Degradation of permafrost due to rising temperatures and disturbance can intensify thermokarst formation, causing localized but dramatic influences on ecological, hydrological, and biogeochemical properties and processes. These impacts at local scales can have cascading effects on drainage networks; carbon, nutrient and sediment fluxes, and vegetation distribution across the broader landscape. Thus, understanding the current and future state of permafrost and active layer dynamics is a necessary step toward accurately projecting changes in arctic ecosystems and their implications for regional and global climate. This joint US-Russia workshop will identify critical knowledge gaps in our understanding of permafrost-dominated landscapes. Given the potential breadth of this topic the workshop will focus on terrestrial and ocean processes with direct links to land surface-climate feedbacks and interactions.

Tentative Date: August, 2011
Tentative Location: Seattle, WA
Workshop Leaders: Stan Wullschleger, Vladimir Melnikov, and Vladimir Romanovsky

Critical Needs in Modeling Climate Feedbacks: Process to Landscape Dynamics

Critical gaps exist in our understanding of and ability to predict dynamics at the landscape scale in permafrost regions. The processes leading to formation of patterned ground, frost boils, raised-center and sunken-center polygons, and thermokarst are only poorly understood, and our ability to predict the distribution and evolution of these landscape types is weak. Progress is being made to improve process representation in one-dimensional (column), landscape scale, and coupled climate-biogeochemistry models, with active research concerned with the specific problems of arctic system dynamics. This workshop will assess the current state of process understanding and representation across scales, and consider a coordinated multi-scale modeling approach that integrates process and landscape properties in regions dominated by permafrost.

Tentative Date: September, 2011
Tentative Location: Berkeley, CA or Oak Ridge, TN
Workshop Leaders: Bill Riley and Peter Thornton

US-Russia Presidential Commission

Clean Energy Technology Working Group

"Permafrost in the Arctic"

Statement of Workshop Goals, Objectives, and Outcomes:

This joint US-Russia workshop will identify critical knowledge gaps in our understanding of permafrost-dominated arctic landscapes. Participants will focus on terrestrial and marine processes that hold direct relevance to climate feedbacks and surface-atmosphere interactions. Specific objectives are to highlight and discuss research strategies and needs shared by both the US and Russian scientific communities and identify opportunities for potential collaboration. The primary deliverables from this workshop will be (1) an increased understanding of research priorities for the two countries, (2) a listing of research topics for potential collaboration, and (3) a work plan to facilitate future interactions.

Organizing Committee:

Anatoli Brouchkov – Geocryology Department, Moscow State University

Dmitry Drozdov – Earth Cryosphere Institute, Russian Academy of Science

Larry Hinzman – International Arctic Research Center, University of Alaska Fairbanks

Susan Hubbard – Lawrence Berkeley National Laboratory

Marina Leibman – Earth Cryosphere Institute, Russian Academy of Science

Vladimir Melnikov – Earth Cryosphere Institute, Russian Academy of Science

Vladimir Romanovsky – Department of Geology and Geophysics, University of Alaska Fairbanks

Stan Wullschleger – Oak Ridge National Laboratory

Expanded Session Descriptions:

Session 1: Thermal state and dynamics of permafrost on annual to centennial time scales

Permafrost is a product of cold climates. As such, the thermal state of permafrost reflects the past and present climatic conditions and will be strongly affected by future changes in climate. Establishing continuous observations of changes in permafrost temperature is essential for any aspect of permafrost-related studies. Permafrost temperatures are increasing in most permafrost regions of the planet Earth, bringing permafrost to the edge of widespread thawing and degradation. The thawing of permafrost that already occurs at the southern limits of the permafrost zone can generate dramatic changes in ecosystems and infrastructure functioning. The projected warming during the 21st century may ultimately result in the disappearance of warmer and thinner permafrost in the southernmost zones. Negative consequences of this degradation are already pronounced and will continue as the high ice content in the upper several tens of meters continues to melt. These observed and predicted changes in permafrost stress the necessity to monitor permafrost dynamics (particularly temperatures) for timely assessment and predictions of the possible negative impacts of permafrost degradation on ecosystems and infrastructure. The Alaskan and Eurasian borehole temperature data sets provide the baseline to reconstruct past surface temperatures, to

assess the future rates of change in near-surface permafrost temperatures and permafrost boundaries, and to provide spatial data for validation of climate scenario models and temperature reanalysis approaches. In this session we will discuss the possibilities to sustain the already existing network of permafrost observatories in Alaska and Russia and to enhance this observational system by filling the gaps in spatial distribution of permafrost observatories. We will also address the necessity of further development of existing permafrost models.

Session 2: Microbial dynamics in the active layer and upper permafrost

Permafrost soils represent one of the great frontiers for biological exploration. Despite the area and amount of organic matter contained within Pan-Arctic soils and its vulnerability to decomposition, our understanding of the diversity of microbial life in this extreme habitat and the connection to past and present climates is surprisingly limited. In this session we will explore the possibility that widespread permafrost thaw will lead to the release of massive amounts of carbon dioxide and methane into the atmosphere. It has long been assumed that microbes were dormant when frozen; however, given the recent advent of molecular approaches, evidence now suggests that microbial activity at and below 0°C can be significant. Nonlinear, temperature-dependent changes in protein structure and conformation, altered protein expression, and shifts in microbial populations could all contribute to carbon flux due to enhanced microbial activity. Participants will review recent advances in microbial molecular biology and evaluate their utility as tools to address how changes in temperature potentially impact soil microbial populations and enzymatic activities involved in the decomposition of soil organic matter.

Session 3: Relic shallow gas hydrates in permafrost and their role in carbon fluxes to the atmosphere

Relic gas hydrates exist within the permafrost, but they do so in a potentially unstable or metastable state. Climate changes and increasing anthropogenic impact due to exploration of the Arctic shelf can disturb the equilibrium state of the gas hydrates at the upper horizons of permafrost and provoke their dissociation. In this session we will investigate the kinetic stability of relic gas hydrates and its fundamental significance for estimating possible sources of gas emission into the atmosphere and safety of engineering works in the zone of relic gas hydrates. Will we also discuss the current situation and assess the potential for increased loss of methane under a warmer environment.

Session 4: Thermokarst, thermal erosion, and other land surface processes in climate change

Permafrost degradation, thermokarst formation, and thermal erosion are happening due to climatic warming. The sequence and intensity of affects may be different in northern continuous and southern discontinuous permafrost regions. In southern areas that are characterized by discontinuous to sporadic permafrost distribution, further warming will lead to the decreasing of permafrost areal extend. Due to relatively low ice content of soil and a general absence of large subsurface ice bodies typical to this zone, permafrost processes may not have strong impact on the geomorphology. In more northern regions with continuous permafrost the occurrence of large subsurface ice wedges are more common and climate warming here can cause broad thermal degradation. In this session we will focus on how these spatially-distinct processes might be represented in coupled climatic models. Analysis of existing data will allow participants to judge what environmental variables control these processes. Mapping of the ice content in the upper horizons of permafrost using remote sensing data, results of drilling, and laboratory studies will also be considered as GIS-based models of permafrost dynamics are developed.

Session 5: Sub-marine arctic permafrost

Accurate projections of the distribution and properties of coastal and submarine permafrost are required for informed decisions regarding the impact of climate change on off-shore permafrost. Despite the

importance of this information, existing maps mostly reflect only expert estimations of permafrost extent and condition and are based on very fragmentary data. In this session we will review data currently used to describe climate and marine permafrost dynamics.

Session 6: Developing new circum-polar permafrost map that will reflect recent changes in climate.

Estimating the modern state of permafrost in a changing climate and under effect of intensive technogenic impacts is getting more and more important. Maps of permafrost distribution have been developed for many regions of the world, but these maps are based on the permafrost studies that were accomplished during the period from the 1960s to the end of the 1980s, when the topic of global warming had not received too much attention. In this session we will assess observations and modeling results to better understand significant changes in permafrost conditions in the northern hemisphere. Participants will focus on increasing of mean annual ground temperature, partial thawing of permafrost from the surface and replacement of the seasonal thawing by the seasonal freezing as controls on permafrost condition and related biogeochemical processes. Discussion will center on whether new maps can be developed and if so, can circumpolar permafrost maps reflect modern state of permafrost and its evolution trends taking into account climatic changes. Such maps will become an important baseline for forecasting future permafrost dynamics.

Tentative List of Invitees:

Russian Participants (Name and expertise)

Anatoli Brouchkov; microbiology

Dmitry Drozdov; thermal state and permafrost mapping

David Gilichinsky; microbiology

Mikhail Grigoryev; subsea permafrost

Marina Leibman; thermal erosion and thermokarst

Vladimir Melnikov; permafrost

Anatoly Nesterov; gas hydrates

Alexander Vasiliev; seafloor permafrost

U.S. Participants (Name and expertise)

Howard Epstein; permafrost

David Graham; microbiology

Larry Hinzman; thermal erosion and thermokarst

Susan Hubbard; permaforst

Janet Jannson; microbiology

Torre Jorgenson; permafrost mapping

Dmitry Nicolsky; subsea permafrost

Vladimir Romanovsky; thermal state and permafrost mapping

Igor Semiletov; gas hydrates

Natalia Shakhova; gas hydrates

Yuri Shur; thermal erosion and thermokarst

Mark Waldrop; microbiology

Skip Walker; permafrost

Stan Wullschleger; permafrost

Tentative Workshop Dates: August, 2011

Tentative Workshop Location: San Francisco, CA area