in the control plots within minutes of a precipitation event. Soil respiration declined to pre-wetting values at the same time that the litter layer dried, about 48 hours after wetting. The $\Delta^{14}CO_2$ from soil respiration ranged from 95 to 141$^o/_{oo}$ in the control plots and from 88 to 263$^o/_{oo}$ in the exclusion plots. The $\Delta^{14}CO_2$ from root respiration and recently fixed carbon (within 1 year) should be 77$^o/_{oo}$ (the value of the atmosphere in 2001), so the observed values indicate that the decomposition of older C substrates (>1 year) with higher $\Delta^{14}C$ values contributed to the total CO_2 efflux. Variation between treatments and among dates revealed higher $\Delta^{14}C$ when CO_2 concentrations were lower, which occurred when the soil dried due to natural summer drought in the control plots and more severe drought in the exclusion plots. When the soil was moist, high rates of root respiration and decomposition of young substrates resulted in high soil CO_2 concentrations with relatively low $\Delta^{14}C$. Under dry conditions, root respiration produced less CO_2, while gradual decomposition of old, radiocarbon-rich substrates continues at low rates, resulting in low CO_2 concentrations with high $\Delta^{14}C$. Hence, drought responses differed between heterotrophic decomposition of old C substrates and root and microbial respiration of recently fixed C substrates.

B11C-0768 0830h POSTER

More New Carbon in the Soil of a Poplar Plantation Under Free Air Carbon Enrichment

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Early 1999 three FACE (Free Air Carbon Enrichment) and three control rings were installed on former agricultural fields near Viterbo, Italy. A 9 ha poplar plantation was established using hardwood cuttings. Within the rings two Populus species and one hybrid were planted (P. nigra, P. alba, P.x euramericana) at a density of 10000 per ha. The 314 m2 circular plots were divided in six sectors, with two sectors per species. Carbon enrichment was achieved by injection of pure CO2 through laser drilled holes in tubing mounted on telescopic poles. The average CO2 concentration was 544 +/- 48 micromol mol-1.

During the first year the total C content of the soils decreased on average from 1.05% to 0.95%. During the second and third year the total soil carbon content remained more or less stable, while no treatment effects could be detected due to the large C pool as compared to the annual C influx.

The d13C signature of the CO2 enrichment gas was close to that of ambient CO2, and could therefore not be used as an isotopic signal to follow the incorporation of new carbon into the soil carbon pool. Instead we used root ingrowth cores (40 cm deep, 4 cm in diameter) filled with sieved and well mixed C4 soil. This C4 soil with a d13C value of 18.33 was obtained from a similar soil that had been under corn for many years. For each incubation period, species and rings, two ingrowth cores were placed in the C3 soil. Fractions of new carbon were calculated with a simple mixing model. Multiplying these fractions with the total C content yielded the new C contents (by weight percentage).

During the first year no treatment effect was detected. During the second year, new soil C% under P. alba was respectively 0.12 under ambient and 0.15 under increased CO2 treatment (P= 0.07). The third year showed the same effect on new soil C%, i.e. with P. alba respectively 0.07 under ambient and 0.13 under increased CO2 treatment (P= 0.02), and with P. nigra respectively 0.08 under ambient and 0.15 under increased CO2 treatment (P= 0.01).

B11C-0769 0830h POSTER

Mathematical Modeling and In-Situ Measurements of Soil CO2/O2 Flux Dynamics

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Gaseous exchange between soil and atmosphere consist primarily of CO2 and O2 fluxes induced by concentration gradients resulting from respiration within the soil profile. Despite their crucial role in the biosphere, dynamics of CO2/O2 concentrations in soil and surface fluxes are rarely measured continuously. A new gradient-based method for continuous monitoring of soil CO2/O2 concentrations was tested in the laboratory and in the field and compared to closed-chamber measurements. In situ measurements were made in different plant communities within a semi-arid ecosystem. A one-dimensional vertical model for soil CO2/O2 fluxes that considers bio-geo-chemical and environmental factors within the basic governing equations for gaseous transport in porous media was developed. Comparisons between model simulations and continuous in-situ measurements of CO2 and O2 concentrations (and fluxes) were in reasonable agreement. Simultaneous measurements of soil CO2 and O2 concentrations provide insights on soil respiration characteristics such as the respiratory quotient (CO2/O2) that ranged from 0.7 to 1.2 and tended to remain remarkably stable under particular experimental conditions. Conversion of measured concentration gradients into surface fluxes was critically dependent on proper estimation of water content profile that affects soil diffusion coefficients. Continuous monitoring in the soil is particularly important following rainfall events where spatial (vertical) and temporal patterns of gaseous fluxes are complex and are unobservable by common surface chamber methods.

B11C-0770 0830h POSTER

Nitrogen Leaching During a Deciduous-to-Coniferous Successional Transition in Alaskas Boreal Forest.

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We measured lysimeter nitrate (NO3), ammonium (NH4) and dissolved organic nitrogen (DON) concentrations in order to assess the potential for nitrogen leaching over the course of a plant primary successional sequence in the boreal forest. Our study sites were floodplain stands of balsam poplar and white spruce in interior Alaska. These stand types encompass a major successional transition during which there is a decline in soil nitrogen cycling, plant primary productivity and soil temperatures. Soil water was collected weekly during the summers of 2000 and 2001 from lysimeters installed in the organic-mineral interface (~12 cm) and in deeper mineral soil (~40cm) of each stands type. NH4 levels were generally below detection limits (<10 ppb) throughout the course of the study with the NO3 concentrations accounting for the vast majority of inorganic N. Soil water NO3 concentrations in white spruce were significantly higher at 40 cm depth (0.572 mg NO3-N/L) than at 12 cm depth (0.129mg NO3-N/L) and were also significantly higher than the 40 cm depth in balsam poplar (0.198 mg NO3-N/L). DON concentrations decreased with depth in both stand types. Our results suggest that N leaching losses (as NO3) increase over primary succession from a deciduous- to a coniferous-dominated community. We speculate that NO3 losses in white spruce stands may be higher as assimilation by soil micro flora is retarded due to a reduction in soil temperature and available carbon.

B11C-0771 0830h POSTER

Predicting CO2 and Heat Sources-Sinks and Fluxes Within a Forest Canopy Using a Lagrangian Dispersion Model

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This study proposes a two-dimensional Lagrangian stochastic dispersion model for estimating spatial and temporal variation of scalar sources, sinks, and fluxes within a forest canopy. Carbon dioxide and heat dispersion experiments were conducted for field testing the model. These experiments also provided data for field testing a newly developed one-dimensional Lagrangian analytical dispersion model by Warland and Thurtell (2000). In general, these two models produce similar scalar source-sink and flux distribution patterns. However, when advective transport is significant, the two-dimensional model marginally better reproduces the flux measurements. To drive these Lagrangian models, velocity statistics through the canopy volume must be a priori specified. The sensitivity of the computed sources, sinks, and fluxes to the description of the flow statistics was further examined. All in all, we found good agreement between model predicted and eddy-correlation measured CO2 and sensible heat fluxes.

B11C-0772 0830h POSTER

Xylem-transported Glucose as an Additional Carbon Source for Leaf Isoprene Formation in *Quercus Robur* L.

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Isoprene is emitted from mature, photosynthesizing leaves of many plant species, particularly of trees. Current interest in understanding the biochemical and physiological mechanisms controlling isoprene formation is caused by the important role isoprene plays in atmospheric chemistry. Isoprene reacts with hydroxyl radicals (OH) thereby generating oxidizing agents such as ozone and organic peroxides. Ozone causes significant deterioration in air quality and can pose threats to human health therefore its control is a major goal in Europe and the United States.

In recent years, much progress has been made in elucidating the pathways of isoprene biosynthesis. Nevertheless the regulatory mechanisms controlling isoprene emission are not completely understood. Light and temperature appear to be the main factors controlling short-term variations in isoprene emission. Exposure of plants to $^{13}CO_2$ showed instantaneous assimilated carbon is the primary carbon source for isoprene formation. However, variations in diurnal and seasonal isoprene fluxes, which cannot be explained by temperature, light, and leaf development led to the suggestion that alternative carbon sources may exist contributing to isoprene emissions.

The aim of the present study was to test whether xylem-transported carbohydrates act as additional sources for isoprene biosynthesis. For this purpose, [U-^{13}C]α-D-glucose was fed to photosynthesizing leaves via the xylem of *Quercus robur* L. seedlings and the incorporation of glucose derived ^{13}C into emitted isoprene was monitored in real time using Proton-Transfer-Reaction Mass Spectrometry (PTR-MS).

A rapid incorporation of ^{13}C from xylem-fed glucose into single (mass 70) and double (mass 71) ^{13}C-labeled isoprene molecules was observed after a lag phase of approximately 5 to 10 minutes. This incorporation was temperature dependent and was highest (up to 13 % ^{13}C of total carbon emitted as isoprene) at the temperature optimum of isoprene emission (40 - 42 ^{o}C) when net assimilation was strongly reduced.

Fast dark-to-light transitions led to a strong single or double ^{13}C-labeling of isoprene from xylem-fed [U-^{13}C] glucose. During a time period of 10 - 15 minutes up to 86 % of all isoprene molecules became single or double ^{13}C-labelled, resulting in a ^{13}C-portion of up to 30 % of total carbon emitted as isoprene.

The results provide potential evidence that xylem-transported glucose or its degradation products can be used as additional precursors for isoprene biosynthesis and this carbon source becomes more important under conditions of limited photosynthesis.

B11D MCC: 132 Monday 0830h

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

Presiding: **C Ping,** University of Alaska, Fairbanks**; B Hallet,** University of Washington

B11D-01 0830h INVITED

Occurrence and origin of Talik in permafrost near Yakutsk in east Siberia

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An internal thawed layer in permafrost layer, termed a Talik, was detected by means of Time Domain Electro-Magnetic method at Neleger near Yakutsk. The taliks develop between 80m and 200 deep in permafrost at thermokarst depressions, where the maximum depth of permafrost was estimated as 400m deep. Once permafrost is disturbed by forest fire, then ground surface energy budget is changed. After disturbance, the warmer ground surface causes thawing of ground ice in permafrost and the surface subsides to form thermokarst depressions. Ephemeral water ponds tend to form in thermokarst depressions. As the annual mean temperature at the bottom of pond is higher than 0 degrees, thawing of permafrost proceeds afterward. Prevailing evaporation causes drying of the pond and the ground surface is subjected to severe cold. The cycle of warming and cooling of permafrost results in formation of internal thawed layer in permafrost. The age of lake sediment obtained by 14C dating using organic materials indicates the age of initiation of thermokarst formation. The process and occurrence of talik are reconstructed by numerical analysis based on non-linear heat conduction equation. The required time period for thawing permafrost at the depth of 200m is about 3000-5000 years. Refreezing of uppermost permafrost which was developed at the base of the thermokarst depression must have started about 300 years ago to develop permafrost at the depth of 80m.

B11D-02 0850h

New Challenges to the Permafrost Community: Construction of the Qinghai-Xizang (Tibetan) Railroad

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The Qingahi-Xizang (Tibetan) railroad, running from Golmud in the Qinghai Province to Lhasa in the Xizang Autonomous Region of China, is under contruction. The project is planned to be completed by 2007. Approximately 630 km of the railroad is within the Tibetan Plateau permafrost region, of which about a half of the 630 km consists of ice-rich permafrost. Permafrost temperature along the railroad mostly is within about 2 degree C of thawing. New challenges to the permafrost community are: What is the potential response of permafrost to climatic change, and to railroad construction and operation? How do changes in permafrost conditions impact climatic, hydrologic, and ecosystem processes on the Qinghai-Xizang (Tibetan) Plateau? To answer these questions, scientists and engineers in China have conducted a series of field investigations, laboratory experiments, long-term monitoring, GIS-based and numerical modeling. In this paper, we present some results of permafrost-related studies conducted as aprt of the Qinghai-Xizang (Tibetan) railroad project and introduce some measures for protecting permafrost and environemnts.

B11D-03 0905h

Impact of Mountain Topography and Altitudinal Zonation on Alpine Permafrost Evolution and Ground Water Hydrology

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We study the influence of mountain topography and different types of latitudinal zonation on the evolution of alpine permafrost (AP) using two-dimensional finite difference model. In the model and performed calculations, different types of altitudinal zonation of mean annual ground temperature (MAGT) were taken in consideration. 1 - normal maritime zonation (decreasing MAGT with elevation increasing); 2 - absence of any zonation; 3 - continental (inversion) zonation (increasing MAGT with elevation). The spatial nonhomogeneity of thermal properties and the water content of rocks and deposits in mountains and intermountain depressions were included in the model. It has been recognized that 100 kyr cycle is an important component of a long-term climate variation affecting permafrost thickness. Temporal variation of MAGT was specified in the calculations by means of these cycles.

Simulation was performed for conditions of continuous and discontinuous permafrost. It was established that changes in permafrost thickness had lag in comparison with climate change. The geothermal heat flux density distribution is affected by mountain topography. This phenomenon exists under conditions of all three mentioned above types of altitudinal zonation. The thickness of permafrost below the mountaintops is enlarged in comparison with depression bottoms regardless of the altitudinal zonation type.

In addition to the long-term temporal variations, we simulated the areal permafrost dynamics under influence of shorter-term climate fluctuations (millennium time scale). This study demonstrated that subaeral open taliks within discontinuous permafrost zone were developed on mountaintops during extremes of climate warming. These taliks store the surface waters during the summertime and enlarge ground water resources and river water discharge during the wintertime (so called water critical period, when there is no liquid water in the active layer).

Alpine permafrost simulations are very useful for understanding present permafrost and hydrological conditions and for prediction of their changes under influence of climate variations.

B11D-04 0920h

Water and Energy Fluxes over Tundra near Tiksi, Siberia

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In order to better understand the water cycle over tundra, micro-meteorological and hydrological observations have been carried out near Tiksi, Eastern Siberia and seasonal variation of energy budget components were estimated. The heat budget equation at the tundra surface was solved approximating the surface temperature by iteration. In the equation, sensible and latent heat fluxes were expressed by a bulk method and the soil heat flux by the gradient method. The bulk coefficient was a function of the bulk Richardson number and the evaporation efficiency and the thermal conductivity of the surface soil was a function of surface soil moisture. The seasonal@change of heat balance components were obtained for 1998 and 1999. Net radiation is partitioned to sensible, latent and soil conductive heat fluxes and the ratios of these components to the net radiation are: 0.25-0.30 for sensible heat flux, 0.50-0.55 for latent heat flux and 0.20 for soil conductive heat flux. The energy budget over tundra changed with wind direction. The southwesterly wind was warm and dry, make the sensible heat flux small or towards the ground surface, and the northeasterly wind was cold, gave the large sensible heat flux to the atmosphere from the tundra surface. Since the energy fluxes over tundra were strongly dependent on the wind direction, warming of the tundra climate would lead to two, opposite results depending on which wind direction increases by warming: northeasterly or southwesterly.

B11D-05 0935h

The History of Offshore Permafrost in the Siberian Arctic

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The Arctic comprises some of the most sensitive elements of the global environment, which are considered to respond rapidly to climate change. In this context the Laptev Sea and its Siberian hinterland are of particular interest because they link the polar margins to the Arctic Ocean and the World Oceans circulation system. The north Siberian margin today is comprised of a permafrost landscape that has undergone major changes during Quaternary times. Moreover, there is evidence from modern data that the stability of the permafrost is in threat due to global warming. Such a change of the permafrost in the future is of major climatic relevance, considering a potential release of gashydrates that are now trapped in the frozen ground.

A major step forward with regard to both scientific and technological achievements in Arctic paleoclimate research was the successful conduction of the TRANSDRIFT VIII expedition in summer 2000. This first scientific drilling campaign to the outer Laptev Sea shelf had the goal to recover sediments from the Cenozoic rift system of the eastern Laptev Sea to study Arctic climate changes on time scales beyond the Holocene. Because of the shallow water depth of the Laptev Sea shelf, this region became strongly affected by the cyclic global sea-level changes of the Pleistocene leading to the deposition of alternated marine and terrestrial sediments. A major objective of the expedition was therefore to investigate whether past sea-level lowstands caused the development of permafrost also in this outer shelf region and whether it became preserved in spite of ensuing marine transgressions which resulted in the deposition of non-frozen sediments. The sediments recovered show that submarine permafrost exists below Holocene marine sediments. The results verify for the first time the existence of submarine permafrost below unfrozen marine sediments of Holocene age for this part of the Siberian Arctic.

B11D-06 0950h

The Comparison of East Siberian and Alaskan Transects in terms of Permafrost Dynamics (in the past, present and future) using Geographical Informational System.

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Permafrost is the product of severe climate conditions and is more vulnerable to climatic changes than any other part of a landscape. At present time, due to development of General Circulation Models and growing needs of understanding the impact of global climate change on the ecosystems and infrastructure, it becomes necessary to assess permafrost conditions for the circumpolar region in order to include them into GCMs. The purpose of this research is to validate the transect method in permafrost dynamics evaluation. Two components of the permafrost dynamics are: changes in active layer thickness, and variations of mean annual ground temperatures. Almost all biological processes and activities take place within active layer. Mean annual ground temperatures reflect the thermal stability and mechanical properties of the permafrost and affect active layer thickness. At present, it is practically impossible to gather all necessary information for the entire circumpolar region needed to evaluate permafrost dynamics. We used the transect approach to evaluate permafrost dynamics in well studied transects in order to find differences and similarities. On this base it is feasible to interpolate and extrapolate data between them to get a picture of permafrost conditions within larger regions. For our studies we chose two transects Alaskan North Slope transect which includes the area of the Kuparuk and Sagavanirktok River basins, and the Tiksi-Yakutsk East Siberian transect, designated as the Far East Siberian transect in the IGBP Northern Eurasia Study project (IGBP-NES). The East-Siberian transect is centered on the 135° meridian. The GIS database for the two transects was created in order to get the picture of present permafrost conditions. The GIS includes climate, topography, geology and vegetation layers. Active layer thickness and permafrost

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temperature were evaluated by using Kudryavtsevs formulas. According to these formulas, mean annual air temperatures and seasonal air amplitudes as well as mean annual snow thickness; thermophysical properties of the soils (heat capacity and thermal conductivity) determine active layer thickness and mean annual ground temperatures. Hadley 2 Scenario based on actual measurements of meteostations was used as a reference point for the evaluation of the permafrost dynamics over the past 100 years. Other five scenarios from Arctic Climate Impact Assessment (ACIA) project were used to evaluate the permafrost dynamics in the future. For each of these scenarios, maps of active layer thickness and mean annual ground temperature in Alaska and East-Siberia were created. Similarities and differences in future and past permafrost dynamics have been found. This analysis will let us interpolate the permafrost data between two transects and include three or four other transects to get the whole picture of the permafrost dynamics for the entire circumpolar region.

B11E MCC: 132 Monday 1020h

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

Presiding: **F E Nelson,** University of Delaware**; J M Kimble,** USDA Natural Resources Conservation Service

B11E-01 1025h INVITED

Recent Permafrost Warming in Northwest Canada

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Ground temperature records, mostly collected by industry, are available for the Mackenzie delta area and western Arctic coast of Canada from the late 1960s and early 1970s. At Garry Island, the mean annual ground temperature (MAGT) is -6C, 2C warmer than previously. Similar data are available for northern Richards Island, and at the Illisarvik drained lake site, on Richards Island, MAGT in the early 1980s was -7C. At Herschel Island, the MAGT is -8C. There are no prior records from Herschel, but similar sites in the region distant from the Mackenzie River discharge plume previously recorded -9 to -10C. These data point to a relatively rapid response of near-surface permafrost temperatures to regional climate warming, due to the minimal phase change at these relatively cold temperatures in the continuous permafrost zone. In contrast, permafrost temperatures close to 0C in central and southern YT show relatively little response to climate warming due to the large amount of latent heat required for a small increase in ground temperature, and to the cooling achieved in separate winters with little or late snowfall.

B11E-02 1045h INVITED

Effect of Climate Change on Permafrost in Alaska: Short-Term (Decadal) Variability and Long-Term (Millennial) Changes.

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Permafrost, in general, is a product of cold climates, which are typical for high latitudes or high elevations. Hence, the air temperature is one of the most important parameters, which determine the existence of permafrost and its stability. However, because of the effects of intervening snow cover, vegetation, and active layer and because of the effects of possible changes in other climatic variables, particularly precipitation, somewhat different changes are generated at the surface of permafrost. Our recent study shows that permafrost temperatures reflect the longer time scale changes in climate (air temperatures) much better than the interannual variations. The recent climate warming brought soil temperatures at the North Slope sites to a surprisingly high level, about 3°C warmer than long-term averages. In Interior Alaska recent permafrost temperatures are 1°C to 1.5°C warmer than they were in the 1970s. At the same time, comparison between borehole temperature measurements in Barrow from the 1950s and recently measured temperatures at the same boreholes shows a significant similarity in the temperature profiles within the upper 20 meters of permafrost. Application of our calibrated numerical model shows that measured 1°C difference at 15 meters in permafrost temperatures between 1950 and 2001 is the result of very recent warming during the late 1990s. Much colder permafrost temperatures (up to 2 to 3°C colder) were typical for Barrow during 1970s.

In the long-term perspective, the recent climate is somewhat cooler than it was during the Holocene Optimum (six to eight thousands years ago in Alaska). However, there is much evidence based on proxy climatic data, that the climate in 1980s and 1990s was the warmest during the last millennium. Moreover, several researchers reported thawing of permafrost from the surface at several undisturbed locations in Alaska. It is important from the ecological and engineering point of view to understand what is the age of this recently thawing permafrost. In this paper, some speculations on possible long-term (millennial time scale) changes in permafrost as a reaction to the long-term climatic variations will be presented.

B11E-03 1105h

A Trend of Fast Climate Warming in Northern Quebec Since 1993. Impacts on Permafrost and Man-made Infrastructures.

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From about 1945 to the early 1990s,the climate of the Ungava Peninsula and Ungava Bay area followed a cooling trend that was documented both in Environment Canadas stations and in permafrost temperatures measured with thermistor cables spread across the region. This trend was also invoked to explain the observed increase of ice-wedge cracking and the thinning of the active layer. Despite some logistical difficulties, continued monitoring of permafrost temperatures in many communities now document a radical change of trend. In summer, the warming trend began in 1993 while winters started to become warmer in 1995. Winters 1997-1998 and 1998-1999 were particularly warm. The temperature increases at climatic stations such as Kuujjuaraapik and Kuujjuaq are unprecedented in the instrumental record. In the continuous permafrost zone, this recent and fast warming is translated into the shifting of permafrost temperature profiles by as much as 1.9°C at depths down to 20 m and into an important increase in active layer depth. A smaller number of ice wedges are now apparently active. In the discontinuous zone, palsas in particular are degrading and thermokarst landscape in wetlands is expanding. As a result of the fast climate change, one dimensional thermal modelling suggests that permafrost thickness in the discontinuous zone is now greater than what it should be at equilibrium with present atmospheric temperatures. On some of the monitoring sites, an increase in snow cover thickness was probably also a contributing factor; precipitation data, however, are insufficient to assess that factor at the regional scale. One active layer slide provoked the moving of 20 houses in a community. Signs of thaw settlement under roads and airstrips are gradually showing up. Continued monitoring will determine coming trends and variations.

B11E-04 1120h

Large Permafrost Warming in Northern Alaska During the 1990's Determined from GTN-P Borehole Temperature Measurements

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The U.S. Department of the Interior currently maintains 9 automated active-layer monitoring stations and an array of 21 deep boreholes in northern Alaska as part of the Global Terrestrial Network for Permafrost (GTN-P). The GTN-P network is used both for climate change detection and for documenting the sensitivity of permafrost to climate change; GTN-P is one component of the Global Terrestrial Observing System (GTOS), which in turn is part of the long-term Global Climate Observing System (GCOS).

During August 2002, temperatures were remeasured in the majority of the DOI/GTN-P boreholes to determine the present thermal state of deep permafrost in northern Alaska. A preliminary comparison with earlier temperature logs from the borehole array shows that permafrost on the Alaskan Arctic Coastal Plain and Alaskan Arctic Foothills has warmed $\sim$ 3 K since the late 1980's. This warming of the Arctic cryosphere coincides with the shift in atmospheric dynamics described by the Northern Hemisphere Annular Mode (NAM) that also began in the late 1980's.

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European Mountain Permafrost: Geothermal Change and Associated Geomorphological Impacts

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Geothermal measurements are reported from six recently drilled permafrost boreholes that form a transect extending from the European Alps, through the Scandinavian mountains to Svalbard. Boreholes were drilled in frozen bedrock to depths of at least 100 m by the EU PACE Project (Permafrost and Climate in Europe). In each borehole, 30 thermistors were installed at standard increasing down-hole depth intervals. All boreholes show non-linear thermal profiles with near-surface warm-side temperature deviations from the deeper thermal gradient. A first estimate of ground temperature change is made by assuming constant bedrock properties and comparing the observed thermal profile with linear extrapolation of the deeper geothermal gradient. At 20m depth the largest permafrost temperature deviation from the extrapolated thermal gradient is +0.51°C at the most northerly location (Janssonhaugen, Svalbard). In mainland Scandinavia the deviation decreases southwards, being +0.35°C at Tarfalaryggen, Sweden and +0.29°C at Juvasshöe, Norway. In the European Alps, the steeper topography and greater influence of aspect is reflected in greater variation in thermal profiles, with 20 m warm-side deviations ranging from +0.10°C to +0.40°C.

Inversion modeling offers the potential for estimating the evolution of former surface temperatures. However, a realistic parameterization of the complex three-dimensional topography at each of the drill sites is a critical component of such inversion modeling. We are presently developing this analysis by (a) numerical simulation of summits with assumed surface temperatures and (b) measuring surface temperatures around specific summits in order to calibrate our rock-wall temperature models.

Permafrost is sensitive to thermal change and warming will likely lead to increased slope instability in mountain terrain. Field studies of thaw-related slope instability are hampered by the natural variability of geomorphic processes, both in space and time. An alternative approach, using scaled geotechnical centrifuge modeling of degrading permafrost slopes, was developed within the PACE project, and results are briefly reviewed in the context of process-based permafrost hazard assessment.

URL: http://www.cf.ac.uk/earth/pace/

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Climate-Change-Induced Emergent Behavior in Melting Permafrost

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Melting of permafrost owing to climate change commonly is treated as a linear reaction to change in mean temperature. However, it is broadly recognized that nonlinearities, such as geomorphic feedbacks, can dominate melting (IPCC, 2001). In polar lowland regions underlain by ice-rich permafrost, roughly 5 % of Earth's land surface, growth of thaw lakes is thought to be a principal means by which permafrost melts.

Rates and spatial distribution of thawing permafrost owing to climate change are estimated for scenarios derived from IPCC projections with a model that