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Permafrost Temperature Dynamics Along the East Siberian Transect and an Alaskan Transect (Extended Abstract)

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The "East Siberian Transect" GIS is under development. This transect is bounded by the Arctic Ocean in the north, 60°N latitude in the south, and by the 122° and 138° meridian (an area approximately the size of Alaska). The entire transect is located within the Sakha (Yakutia) Republic, Russian Federation. Currently, three layers of information are available: distribution of landscape types (including vegetation) (Figure 1), permafrost temperature, and active layer thickness.

Recently, new data for 21 stations were obtained from Russia. The data include air temperature, snow cover depth and ground temperature (0.05 m down to 3.2 m). The period of measurements range between 110 and 50 years for the air temperatures and about 40 to 20 years for the ground temperatures. Air temperatures show the large interannual variability (4-5°C) caused by continental climate conditions existing within the study area. Mean annual ground temperatures also vary significantly (within a range of 2-4°C) almost synchronously with the air temperatures.

These new data provide an opportunity to test the results of our numerical reconstructions of the active layer and upper permafrost temperature dynamics for the Yakutsk site. Numerical models used in these studies were described in (Romanovsky *et al.*, 1997). Site specific calibration of the models was accomplished using annually measured temperature profiles at the Yakutsk Permafrost Institute experimental site and daily mean temperatures measured at the ground surface and at several depths in the first three meters of soil. Daily air temperatures and decadal snow cover thicknesses from the Yakutsk meteorological station were used to complete the model calibration and to extend the calculations back in time. Drilling records were used to determine the lithology and the initial approximate thermal properties of the soils in the thawed and frozen states. The thermal properties (including unfrozen water content curves) were refined using a trial and error method (Osterkamp and Romanovsky, 1997; Romanovsky and Osterkamp, 2000). Results of calculations of the mean annual temperatures in the active layer and near-surface permafrost at the Yakutsk Permafrost Institute experimental site are shown in Figure 2.

These results show that during 1930-1996, there were several intervals with warmer soil temperatures in 1930s, late 1940s, late 1960s, late 1970s-early 1980s, and especially in late 1980s-early 1990s. Generally, the temperatures were decreasing from 1930s to early 1960s, and since then they were increasing (2°C average increase between 1960 and 1996). The comparison of these calculations with measured ground temperatures at the Churapcha site (100 km East from Yakutsk) shows good agreement (Figure 3).

Similar simulations of the past temperature regimes were made for several sites along the

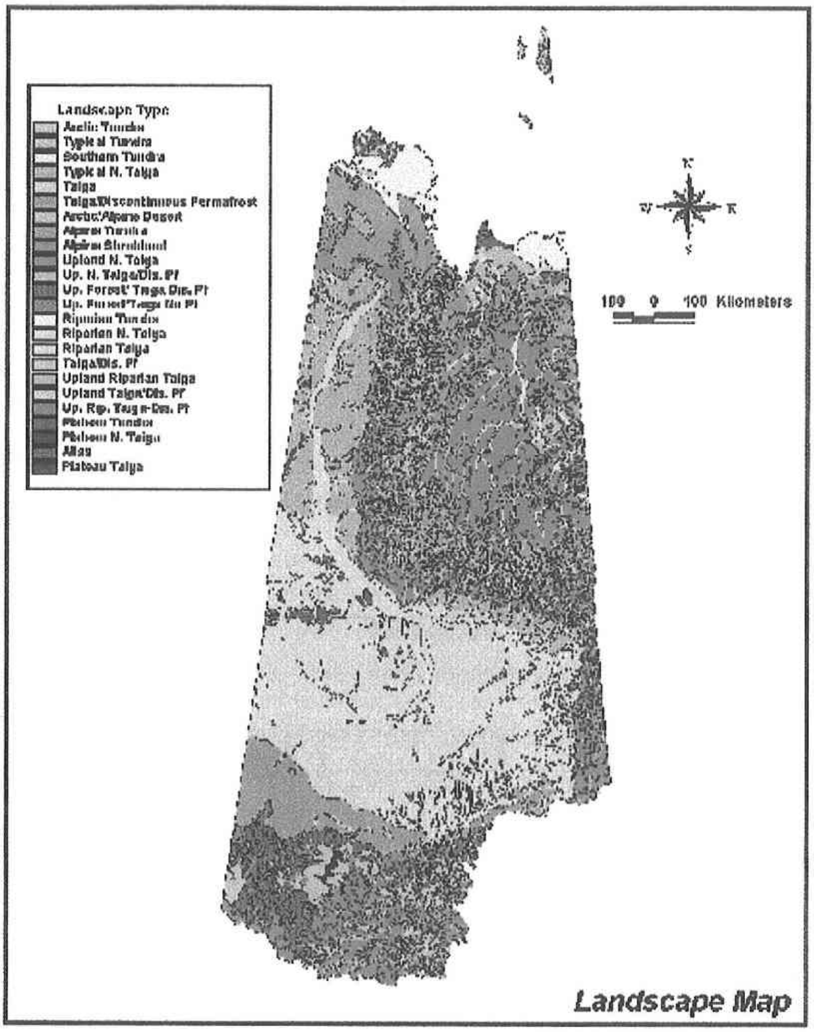

Fig. 1. Landscape/vegetation layer in the "East Siberian Transect" GIS

Alaskan transect (Osterkamp and Romanovsky, 1999). The reconstruction was made for 1929–1998 for the Fairbanks site (Figure 2). The calculations show that the ground temperatures during the 1940s were warmer than the 1930s, 1950s and 1960s but the mean annual temperatures in the active layer and near-surface permafrost were not as warm as the 1990s. Yakutsk and Fairbanks temperature time series show significant and somewhat surprising similarities (Figure 2). However, there is some seeming lag in the soil temperature variations at the Fairbanks site compared to Yakutsk. At Barrow, Alaska the ground temperatures were warmer for the late 1920s and 1940s than for the 1980s and 1990s. However, for the last two years the ground temperatures at Barrow were the highest for the entire period of calculations (1923–1998). The mean annual air temperature variations at the Tiksi site in Siberian Arctic show similar patterns.

Recently, we started calculations to predict the future changes in the active layer and upper permafrost temperatures for the Fairbanks and Yakutsk sites using the same calibrated numeri-

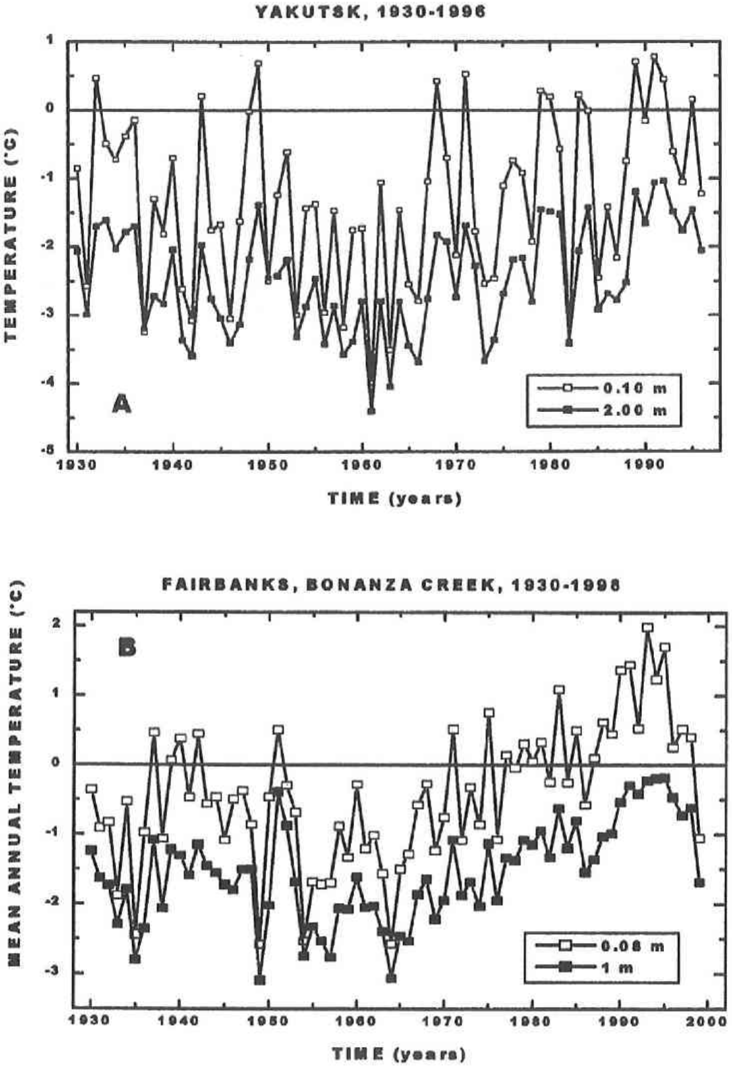

Fig. 2. Mean annual ground temperature dynamics within the active layer and near-surface permafrost at the Yakutsk Permafrost Institute experimental site (upper graph) and at the Bonanza Creek LTER site near Fairbanks, Alaska (lower graph).

cal models that we used for the reconstruction of the past temperatures. The calculations were conducted for the next 52 years starting from 1998 (Figure 4). We used three different scenarios for the future climatic change: 1) only natural variability in the air temperature with the same as for the previous 52 years snow thicknesses (Figure 4A), 2) natural variability plus 2.5°C trend (1.5°C during the summer and 3.5°C during the winter) with the same snow (Figure 4B), and 3) natural variability with trend and with increased by 20% snow thickness starting from 2020 (Figure 4C). The results show that in general interannual and decadal variability in the air temperatures significantly increases "inertia" of permafrost to degradation. Cold "extreme events" refreeze the shallow taliks developed during the warm periods, and "recharge" permafrost with additional cold. For the scenario with a trend, after 2040 permafrost at the Fairbanks

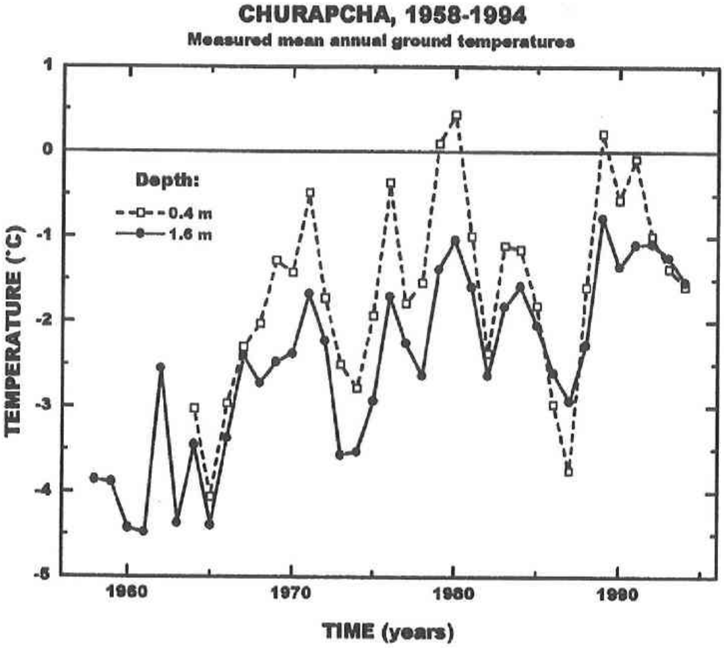

Fig. 3. Mean annual ground temperatures within the active layer and near-surface permafrost measured at the Churapcha meteorological station (Yakutia, Russia).

site shows continuous thawing.

However, for the both Fairbanks and Yakutsk sites, the period from 2015 to 2025 (2020 to 2030 for Yakutsk) will see the beginning of permafrost instability and degradation. During these times, thermokarst processes may become very active affecting ecosystems and infrastructures in these regions. It is possible that during this period significant areas of boreal forests will be degrading creating wetlands in some places within Interior Alaska and steppe-like grasslands in southern Central Yakutia. Increased snow thickness protects ground from the cold "extreme events" and diminishes their effect on the permafrost thermal regime, making the permafrost more vulnerable and more susceptible for degradation.

Disturbances related to forest fires significantly increase the probability of permafrost degradation in the near future. Our temperature measurements and calculations show that for most of the time after 1975, the mean annual ground surface temperatures at the Fairbanks sites were (and probably will be) above 0°C. Permafrost remains stable and survives only because of the insulating effect of the organic mat at the ground surface and the related thermal offset in the active layer. Severe forest fires usually destroy this organic layer exposing the underlying mineral soils to the surface. Drying of the active layer will further reduce the thermal offset. This can reset the mean annual temperatures at the bottom of the active layer to the level above 0°C. In this case, permafrost will start to thaw and if permafrost is ice-rich, the thermokarst processes will take off, significantly affecting ecosystems and creating numerous problems for infrastructure (Osterkamp *et al.*, 1997).

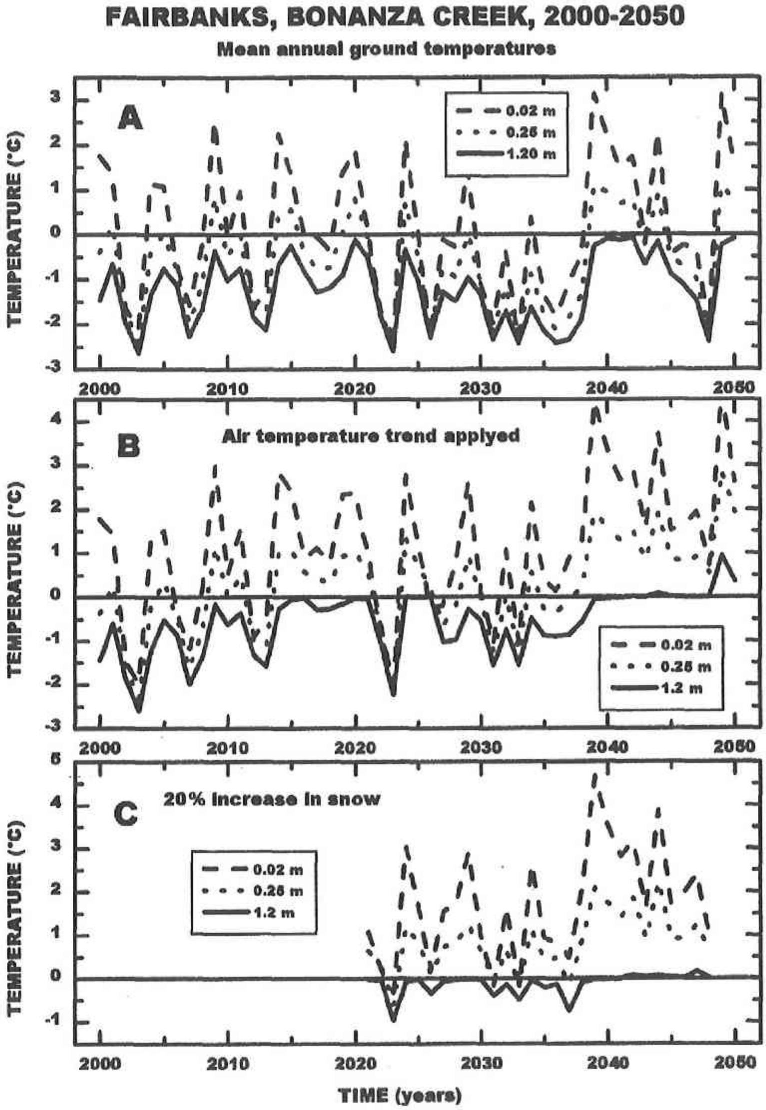

Fig. 4. Predicted mean annual temperature dynamics within the active layer and near-surface permafrost at the Bonanza Creek LTER site near Fairbanks, Alaska for three different scenarios of climatic change: (A) only natural variability in the air temperature, (B) natural variability with a warming trend superimposed, and (C) natural variability with trend and with increased by 20% snow thickness starting from 2020.

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