Recent soil moistening and melting of permafrost in eastern Siberia

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Recently, based on our continuous observations, evidence of abrupt land surface moistening and synchronized rapid soil temperature warming has become apparent. The present study therefore focuses on the hydrothermal variations within the surface layer of the permafrost using intensive observational data from the central Lena River basin.

Soil temperature and moisture data at a boreal forest at Spasskaya-pad, Yakutsk and in the left and right bank of the Lena River in the Yakutsk area by the Permafrost Institute were used to analyze the spatial extent of these variations. In order to detect long-term and spatial variations in soil temperature and hydro-climatic conditions, routine observational data were used. Soil temperatures were obtained from hydrometeorological stations in eastern Siberia. Precipitation and daily snow depth data from 1986 to 2004 was obtained from the Baseline Meteorological Data in Siberia dataset. Data after 2004 was obtained from the NOAA/NCDC Global Summary of Day dataset. We also extend previous precipitation data using data from the Global Synoptic Climatology Network of the former USSR and snow depth data from the Historical Soviet Daily Snow Depth dataset.

According to the variations in soil temperature, moisture at the larch forest near Yakutsk from 1998 to 2007, the soil temperature increased abruptly after 2004, especially in winter. It appears that the temperature increase corresponds with a rapid increase in soil moisture. Similar increasing trends in both soil temperature and moisture within the surface layer of permafrost were observed at most monitoring sites in the Yakutsk area. Interestingly, increases in both soil temperature and moisture were observed to vary together regardless of vegetation or soil types. These observations strongly imply that the increased soil temperatures and moisture widely spreads in the central Lena River basin.

The cause of increased soil moisture with soil temperature is primarily due to interannual variations in the amount of both rainfall and snow. Before the 2000s, the amount of rainfall from July to September ranged from approximately 100 mm. On the other hand, rainfall in the summers of 2004 and 2006 exceeded 200 mm, which is likely to have resulted in the increased penetration of water into the active layer. In addition, the amount of snowfall has also increased markedly in the last three years, with maximum depths of approximately 50 cm of snow being recorded. Moreover, the dates of both the onset and disappearance of snow cover have tended to occur earlier since the 1990s. Based on these findings, the increase in soil moisture due to rainfall appears to have altered the thermal properties of soil, increasing both its thermal capacity and conductivity. In addition, the earlier occurrence of large amounts of snow produces an insulation effect earlier.

These results demonstrate that there has been an increase in soil moisture and temperature in the Yakutsk area. We analyzed rainfall and snow anomalies that have occurred in recent years. According to the regional distribution of normalized anomalies of rainfall in summer and autumn and of maximum snow depth after 2004 in the Lena River basin, large positive anomalies in both rainfall and maximum snow depth were observed in the central Lena River basin. In particular, the positive rainfall anomaly was observed to extend over the Lena River basin. In addition, the positive anomaly for maximum snow depth was observed to extend into the central and southern parts of the Lena River basin.

Future changes in rainfall and snow accumulation could seriously affect the Siberian permafrost region, which is particularly sensitive to global warming. The change in soil moisture and temperature regimes could have important consequences on feedback loops affecting both permafrost degradation and hydro-climatic processes in the Eurasian arctic region.