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Climate change: evidence from Russian historical soil temperature measurements

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Soil temperature is a combined product of energy and mass exchange between the atmosphere and the land surface. Air temperature variations propagating through the ground surface, with intervening vegetation and seasonal snow cover, are recorded in the subsurface as perturbations on the long-term equilibrium geothermal gradient. Change in soil temperature is a sensitive climate indicator and integrator and plays an important role in physical, biological and microbiological processes occurring in the soil. In this study, soil temperature data measured from more than 250 stations in Russia, together with air temperature and precipitation data, were analyzed to reveal signals of climatic change for the period from 1930 through 1990. Over this 51 year period, mean annual soil temperature at 40 cm depth has increased approximately 0.9 to 1.0 deg. C. The increase is more pronounced from 1970-1990. Mean annual air temperature decreased slightly about 0.5 deg. C from 1930 to late 1960s and then increased more than 1.0 deg. C from 1970 to 1990. Obviously, changes in air temperature alone cannot explain the changes in soil temperature. Precipitation increased about 40 mm from 1930 to late 1950s and decreased steadily from 1960 to the mid 1970s. A small increase was observed from the mid 1970 to 1990. Further analysis indicates that soil temperature increases are greatest during winter months (DJF), at about 1.8 deg. C, or at a rate of 0.030 deg. C/year over the period of record. This is followed by spring (MAM), which shows an increase of about 1.0 deg. C or at a rate of 0.016 deg. C/year. Corresponding increases in summer (JJA) and autumn (SON) are slightly less than 0.4 deg. C with a rate of 0.006 deg. C/year. The observed increases in soil temperature during winter months are related to increases in both air temperature and precipitation (mostly as snowfall). Variations in snow cover thickness

have an overall positive impact on soil temperature due to its insulating effects. During spring months, air temperature may play a major role but the timing of snowmelt and soil moisture may also be important. The small changes in soil temperature during summer and autumn are in accord with the small changes in air temperature although changes in precipitation are substantial. This study indicates that changes in soil temperature in Russia are probably controlled by changes in air temperature, with some modification by precipitation. However, at individual stations, this may not be true. For example, soil temperature actually decreased up to 4 deg. C during summer months at Irkutsk, Russia, while air temperature increased slightly. This may be explained by changes in rainfall and hence soil moisture during summer due to a soil moisture feedback mechanism. On the other hand during winter, air temperature increased about 4 to 6 deg. C, while soil temperature increased by up to 9 deg. C. This suggests a strong role of the insulating impacts of snow cover.