Characteristics of Snow Cover and Snow Melt in Northern Eurasia from Microwave Radiometer Observations: Relation to the Extent of Permafrost

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This paper focuses to the investigation of the evolution of snow cover of northern Eurasia based on the analysis of a 30-year long time-series of radiometer observations combined with ground-based data. The applied satellite sensors include SMMR, SSM/I and AMSR-E. The exact timing of snow melt (snow clearance) is determined for each year of the time period from 1979 to 2008 by analyzing the temporal behaviour of brightness temperature observations (channel difference indices). These estimates are calibrated against ground-based observations from 223 stations around Russia in order to obtain unbiased estimates on the day of snow melt. Additionally, the evolution of snow water equivalent (SWE) is estimated for each year by applying a data assimilation technique that combines microwave radiometer data with concurrent *in situ* snow depth observations.

Major factors effecting to the change in the extent of permafrost include the air temperature and the characteristics of snow cover. The main hypothesis here is that the exact timing of snow clearance is a highly relevant factor for permafrost extent, as it determines the on-set of the melt of the seasonally thawing active layer above the actual permafrost layer. Therefore, it is expected that the maximum annual thickness of the active layer is related to the day of snow melt. Additionally, the level of SWE has an effect to the permafrost as snow insulates the ground from the air the more, the thicker the snow pack is.

The obtained results indicate that the thickness of the active layer is about linearly related to the timing of the snow melt (day of snow clearance). This was quantitatively investigated by comparing *in situ* observations of active layer thickness from 29 sites around Siberia with radiometer data-derived snow melt dates. As active layer thickness is related to the type and continuity of permafrost, the results suggest that it is possible to map permafrost areas by utilizing space-borne microwave radiometer data.

Digital maps on permafrost extent for Eurasia are available representing conditions in around 1980's. Analysis of these data against satellite data retrievals showed that corresponding permafrost maps can be derived from the radiometer data-based snow melt estimates, when they are representing the same period of time. It is shown here that in regions with seasonal soil frost in 1980's, the timing of snow melt has changed the strongest towards an earlier day of year. In regions with continuous permafrost, the

change has been only modest, whereas regions with discontinuous permafrost exhibit behaviour between these two extremes. Analysis of satellite data retrievals also enables the estimation of the size of regions in which permafrost is possibly diminishing. This suggests that the strongest increase in the total area with potentially melting permafrost occurred in Eurasia during 1990's. In contrast to more stable conditions observed for 1980's and 2000's, the day of snow melt critically changed in extensive permafrost areas during that decade.