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An Innovative Application for SMOS: Characterization of Seasonal Soil Freezing

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Soil freezing and thawing, including the winter-time evolution of soil frost, are important characteristics influencing hydrological and climate processes at the regions of seasonal frost and permafrost, which include major land areas of North America and northern Eurasia. Changes in the seasonal behaviour of soil frost have a major effect on the surface energy balance, as well as on the intensity of CO_2 and CH4 fluxes. The monitoring of seasonal frost and the permafrost active layer is currently based mostly on sparse in-situ observations. Some research using satellite observations for global and continuous coverage has been conducted in the past using active and passive microwave data. The European Space Agency's (ESA) SMOS satellite (Soil Moisture and Ocean Salinity) is the first passive instrument using a low microwave frequency band (1.403 – 1.424 GHz) for Earth remote sensing. The output signal of the SMOS payload instrument MIRAS (Microwave Imaging Radiometer with Aperture Synthesis) is highly sensitive to changes in soil permittivity (i.e. soil liquid water content), with relatively low influence of surface vegetation. Due to the instrument's low operating frequency, information on the soil processes can be achieved from deeper layers than from previously available satellite instruments. SMOS sensitivity to changes in soil permittivity and the deeper soil layer monitoring capabilities ensure new possibilities for soil freeze/thaw cycle monitoring. Within the frame of SMOS programme, ESA has initialized several innovation projects to extend the applicability of SMOS data. One such project is SMOS+ Innovation Permafrost, coordinated by the Finnish Meteorological Institute (FMI) with GAMMA Remote Sensing as a Swiss partner. The main objectives of the project are (1) to develop methods and algorithms for detection and monitoring of soil freezing/thawing processes using L-band passive microwave data and (2) to demonstrate the developed methods with soil frost maps derived from SMOS observations representing the whole Northern Hemisphere. To meet these objectives we have applied data from an experimental three-year campaign using the SMOS reference radiometer, ELBARA-II, for monitoring the seasonal behaviour of the L-band emission signature of boreal soil. In addition, we have developed emission models for various soil systems, and collected in situ data from various locations in Finland, Canada and Siberia for use as reference to SMOS observations. The main regional test site is located in Sodankylä, Northern Finland. The site supports numerous in situ observations of soil, snow and atmosphere properties. Results indicate that the event and development of soil freezing can be monitored with SMOS. However, vegetation, land cover and soil type have a significant effect on the soil freezing processes and need to be taken into account. More future work is needed to improve the algorithms from the present experimental demonstration to an operational product.