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Synergistic method for boreal soil moisture and soil freeze retrievals using active and passive microwave instruments

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Soil moisture and soil freezing are important for diverse hydrological, biogeochemical, and climatological applications. They affect surface energy balance, surface and subsurface water flow, and exchange rates of carbon with the atmosphere. Soil freezing controls important biogeochemical processes, like photosynthetic activity of plants and microbial activity within soils. Permafrost covers approximately 24% of the land surface in the Northern Hemisphere and seasonal freezing occurs on approximately 51% of the area.

The retrieval method presented is based on an inversion technique and applies a semiempirical backscattering model that describes the dependence of radar backscattering of forest as a function of stem volume, soil permittivity, the extinction coefficient of forest canopy, surface roughness, incidence angle, and radar frequency. It gives an estimate of soil permittivity using active microwave measurements. Applying a Bayesian assimilation scheme, it is also possible to use other soil permittivity retrievals to regulate this estimate to combine for example low resolution passive observations with high resolution active observations for a synergistic retrieval. This way the higher variance in the active retrieval can be constricted with the passive retrieval when at the same time the spatial resolution of the product is improved compared to the passive-only retrieval. The retrieved soil permittivity estimate can be used to detect soil freeze/thaw state by considering the soil to be frozen when the estimate is below a threshold value. The permittivity retrieval can also be used to estimate the relative moisture of the soil.

The method was tested using SAR (Synthetic Aperture Radar) measurements from ENVISAT ASAR instrument for the years 2010-2012 and from Sentinel-1 satellite for the years 2015-2016 in Sodankylä area in Northern Finland. The synergistic method was tested combining the SAR measurements with a SMOS (Soil Moisture Ocean Salinity) radiometer based retrieval. The results were validated using in situ measurements from automatic soil state observation stations in Sodankylä calibration and validation (CAL-VAL) site, which is a reference site for several EO (Earth Observation) data products.