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Monitoring freeze/thaw cycles using Sentinel-1 time-series

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This study explores the potential of using Sentinel-1 backscatter time-series for freeze/thaw (FT) cycle monitoring. The test site is selected to understand backscatter processes and develop a novel monitoring method; it is situated at the ecotone between the forest-tundra and the shrub-tundra environment, representing land cover variability and topographic complexity in a typical sub-arctic region..

The study first analyzes a backscatter time series against measurements taken at eight in situ sites, which represent land cover variability and topographic complexity; including peatland, lichen dominated, shrub-dominated, and spruce dominated vegetation cover and different micro-topographies. The sensitivity of Sentinel-1 backscatter to FT state is different for various land covers; from high to low is peatland, forest-dominated, lichen-dominated, bare sand, shrub-dominated terrain, and rock. Both VV and VH polarization exhibit a response to the freeze-thaw transition. VH polarization shows higher sensitivity to the FT state and proves more suitable for FT state monitoring.

A least square fitting of piecewise step function is used to determine FT transition dates. The method concept is to determine the transition date by minimizing the sum of squared residuals between time-series backscatter and the piecewise step function. The method is improved by using the backscatter evolution pattern instead of the noisy backscatter time series to determine the function' parameters. Moreover, the method takes account of open water bodies and areas having an ambiguous FT transition signal, like rock outcrops and the bare sandy area where soil moisture level and change is very low. The refined method increases the method's robustness, as it reduces the dependence on temporal sampling frequency and influence of backscatter noise. The retrieved result is validated against in situ measurements and proves that the method can be an effective and robust approach in operational monitoring of FT state using Sentinel-1 backscatter time series.

The derived thaw onset dates are largely influenced by snow cover conditions. The snow distortions manifest in two aspects: i) a wet snowpack substantially decreases the backscatter and creates a false frozen state interpretation, consequently leading to delayed retrieved thawing transition dates and ii) when melted surface snow layers refreeze, an ice crust forms on the top of the snow cover and increases the backscatter; then the Sentinel-1 thaw signal is advanced.

In all, the initial results of using time series Sentinel-1 backscatter to monitor FT state are very encouraging. Fine resolution Sentinel-1 observation offers new possibilities to determine the spatial heterogeneity in FT monitoring. However, the disadvantage of relatively low temporal resolution remains and should be further improved by combing images from different tracks and different observation modes.