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On the influence of soil moisture on intra-annual peat soil dynamics as observed from SAR amplitude and phase data

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Polders in the western Netherlands are often covered by pastures. Around 30 percent of the pastures are situated on peat soils, which are artificially drained. Consequently, the exposure to oxygen leads to a decomposition (oxidation) of the material and desiccation leading to shrinking. This results in a decadal subsidence, up to a few centimeters per year, which causes increasingly severe socio-economic impact. However, this long-term subsidence signal has a high spatial variability due to local soil morphology, and possibly high intra-annual temporal variability which is caused by precipitation and evaporation. The problem is that there are currently no geodetic methods that can reliably measure these soil dynamics over wide areas and with high temporal revisits.

Here we show how Sentinel-1 SAR interferometry (InSAR) can potentially be used to estimate the surface displacements, given prior information on precipitation and temperature. We observe intra-annual dynamics of surface elevation which seem to be one order of magnitude stronger than the decadal long-term subsidence. InSAR surface elevation measurements show discontinuities (hysteresis) in late summer and early autumn due to strong vegetation and changes in temperature and precipitation patterns. As soil moisture variability appears to be the main driving mechanism for the observed surface elevation dynamics, we investigate whether we can use the amplitude of the identical SAR acquisitions to estimate the soil moisture directly, to reduce the dependency on external precipitation and temperature data.

The analysis is performed on time series of the European Space Agency's Sentinel-1 mission. Subsidence and upheaval are estimated using a novel InSAR algorithm, which was specially designed for peat soil dynamics. The surface elevation dynamics are compared to surface soil moisture estimates from Sentinel-1 amplitude data. Soil moisture is retrieved from backscatter time series using a first-order radiative transfer model (RT1) developed at TU Wien. This model describes the scattering behaviour of both soil- and vegetation by using linear combinations of idealized scattering distribution functions. Clay Soil swelling and subsidence are likely influenced by soil layers much deeper than those associated with the surface soil moisture estimates. Therefore, the subsidence estimates are also compared to Soil Water Index (SWI) derived from the surface soil moisture product. This is considered an indicator of moisture availability in the top 100 cm. These results show that the same complex SAR data acquisitions can be used simultaneously, but independently, for estimating soil moisture and for estimating surface elevation dynamics. An integrated application is proposed and evaluated for further exploration.