Monitoring Shallow Peatland Subsidence from Spaceborne Radar Observations

Challenges and successes in the use of InSAR for observing and monitoring rapid soil displacements

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InSAR: Radar Interferometry

Satellite radar interferometry (InSAR) is regarded as the most promising technology to estimate land surface motion over wide spatial ranges. But for grasslands on soft soils, common in the polder landscapes of the Netherlands, further technical innovations are still required due to the rapid dynamics of the soils in combination with strong noise levels.

Here we demonstrate some of the important InSAR concepts relevant to solving this challenge, and show how we managed to produce the first reliable time series of surface motion for the Dutch peatlands.

SPAMS: Simple PAramterization for the Motion of Soils

We have developed a simple model that makes accurate predictions of ground motion that requires only four parameters and local weather data as input.

By using our good observations to characterize the parcel, i.e. learn its behaviour, we can then make estimations of what is happening during the loss-of-lock period.

The surface height of the soil at time t has two components: reversible (shinkage and swell), and irreversible" (oxidation and compaction in the Vadose zone), scaled by the unknown set of paramters in x:

$$H(x,t) = R(x,t) + I(x,t)$$

The reversible component is the cumulative balance of precipitation and evapotranspiration (the primary sources and sinks of groundwater), over the period of time, τ:

$$R(x,t) = \sum_{\tau} x_P P(t) - x_E E(t)$$

The irreversible component is assumed to be linear, but only considered active when there is a net loss of water in the system:

$$I(x,t) = \sum_{\tau} x_I \cdot f(t), \qquad f(t) = \begin{cases} 1, R(x,t) < 0 \\ 0, R(x,t) \geq 0 \end{cases}$$

What's Next?

With this methodology in place, we are now looking to scale up our processing to cover the full Groene Hart region.

By integrating these results into an overall geodetic framework with historical surveying data developed in collaboration with S. van Diepen (Regiodeal project), we can extend the overall time series to cover the previous century and estimate an accurate irreversible soil loss rate.

Recent Papers

[1] P. Conroy, S.A.N. van Diepen, F.J. van Leijen, R.F. Hanssen, "Bridging Loss-of-Lock in InSAR Time Series of Distributed Scatterers", *Transactions on Geoscience and Remote Sensing* (In review), 2023.

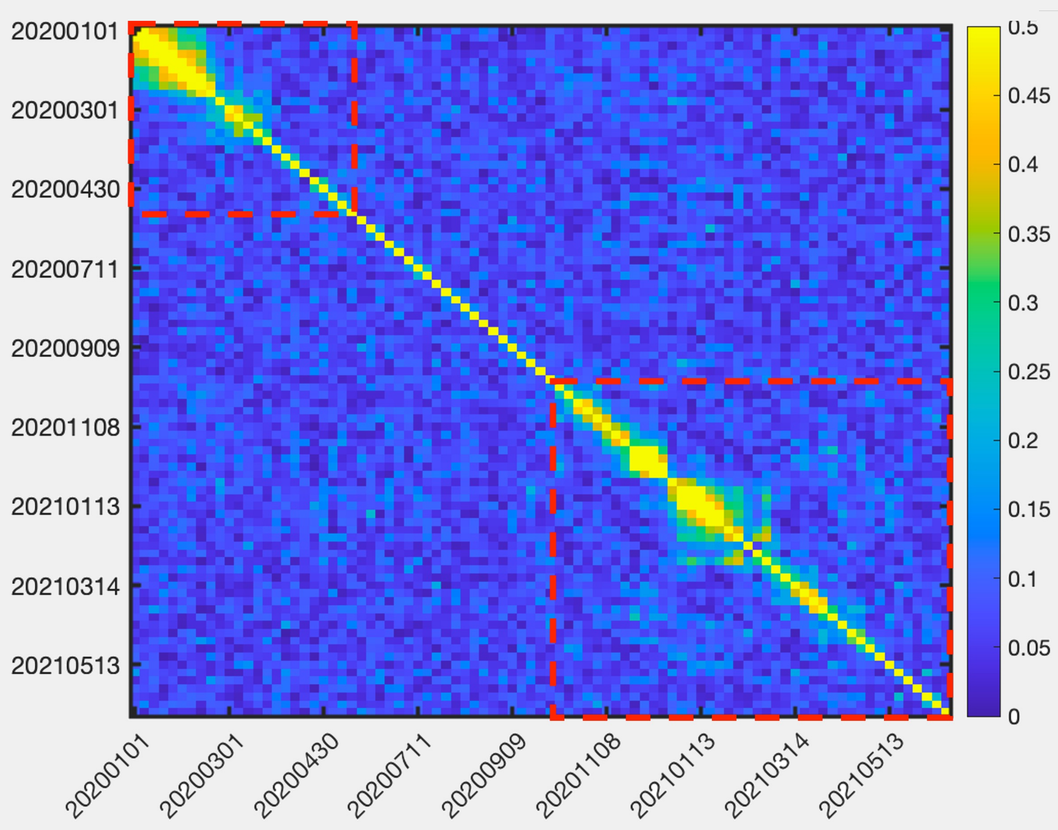
[2] P. Conroy, S.A.N. van Diepen, R.F. Hanssen, "SPAMS: A New Empirical Model for Soil Surface Displacement Based on Meteorological Input Data", *Geoderma* (Accepted for publication), 2023.

[1] [2]

Loss-of-Lock

Coherence is a quality measure which estimates the amount of information present in an interferometric combination of SAR images. Coherence is seasonally lost in the peaty grasslands of the Netherlands, as shown below.

These losses prevent any coherent combinations from being formed between the higher-quality winter observations (outlined in red), essentially cutting the time series apart. We call this condition *loss-of-lock*.

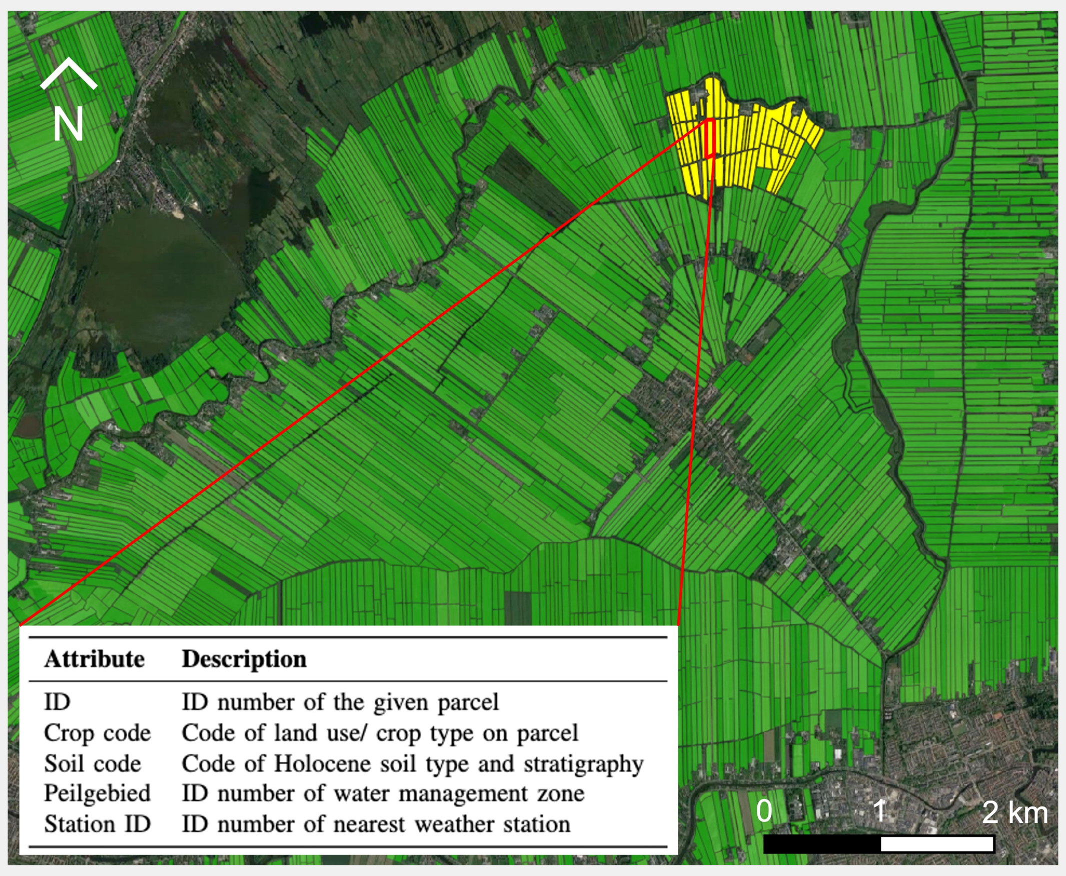


Grouping by Contextual Data

The loss-of-lock condition implies that there is not enough information in the SAR dataset alone to estimate a full displacement time series. We integrate spatial land and soil data into our processing which allows us to:

- Assign SAR pixels to a given land parcel
- Attribute parcels with land use, soil and water data
- Learn the expected motion of parcels

We can group parcels with the same expected behaviour together based on their contextual attributes.



Attribute	Description
ID	ID number of the given parcel
Crop code	Code of land use/ crop type on parcel
Soil code	Code of Holocene soil type and stratigraphy
Peilgebied	ID number of water management zone
Station ID	ID number of nearest weather station

Results

We present our first results with spatial and temporal subsidence estimations in the Rouveen (top) and Zegveld (bottom) regions for the years of 2017-2022. The time series correspond to the regions marked in red.