# Enabling InSAR Observations of the Dutch Peatlands

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## Intro

Satellite radar interferometry (InSAR) is regarded as the most promising technology to estimate surface motion over wide spatial ranges with sufficient precision. Yet for grasslands on peat soils, common in the polder landscapes of the Netherlands, further technical innovations are still required due to the extreme dynamics of the soils in combination with the strong variation in radar backscatter. 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.

## Seasonal Loss-of-Lock

*Coherence* is a measure of the information present within an interferogram, and is often used as a quality measure when assessing an InSAR time series. Seasonal losses of coherence during Spring and Summer are a trait of InSAR observations of the peaty grasslands of the Netherlands, as shown below. This seasonal loss of coherence prevents any coherent interferogram from being formed between coherent winter observations, essentially cutting the time series into multiple coherent segments. We call this cutting a *loss-of-lock* event, which is fundamentally unbridgeable without additional information.

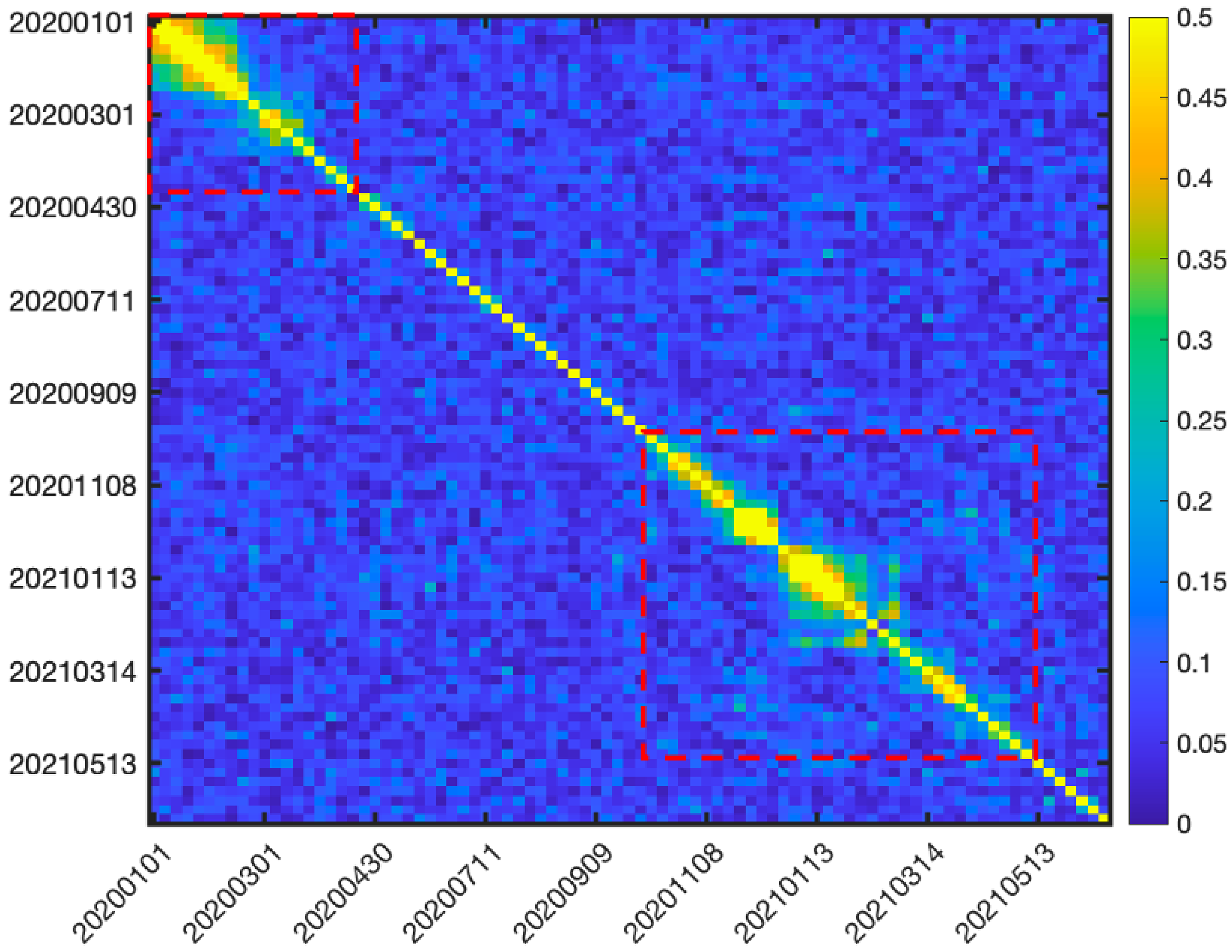


*Figure 1: Coherence matrix, showing the level of correlation (coherence) between any two satellite acquisitions in the data stack.*

## Segmented Processing

We have developed a strategy—segmented processing—for dealing with loss-of-lock events by first detecting each coherent segment, and identifying overlapping epochs in similarly-behaving regions, with similar land cover, elevation, and soil stratigraphy, and nearby to extend the coherent periods. At any given time, some regions remain coherent, allowing us to estimate a coherent average throughout the entire time series, effectively 'bridging' the loss-of-lock events.

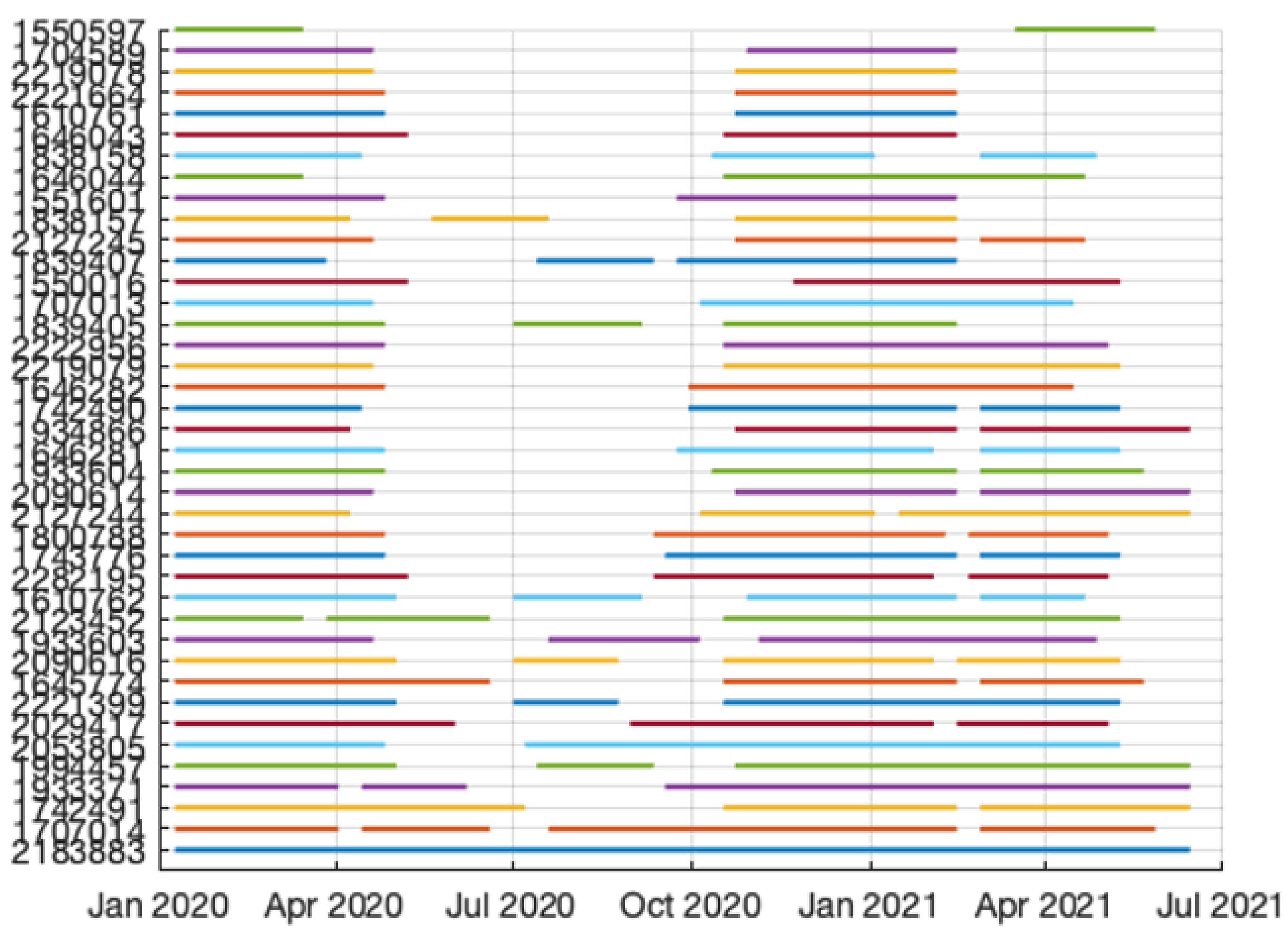


*Figure 2: Coherence "Gantt chart", showing parcel numbers on the vertical axis. Line segments identify temporal periods during which a parcel can be considered sufficiently coherent. The selected parcels have comparable land cover, soil stratigraphy, elevation, and vicinity. Only a small portion of the full set are shown here for legibility.*

## Complex Coherence Averaging

SAR images of peaty grasslands are very noisy observations. We can reduce this noise by averaging the coherent segments that we have identified. This is justified as long as we average signals which come from the same ergodic process. In doing so, this gives us a mean deformation model which can be used to bridge the incoherent segments of the individual time series. Here we take advantage of contextual data such as crop types, soil stratigraphy, and AHN heights.

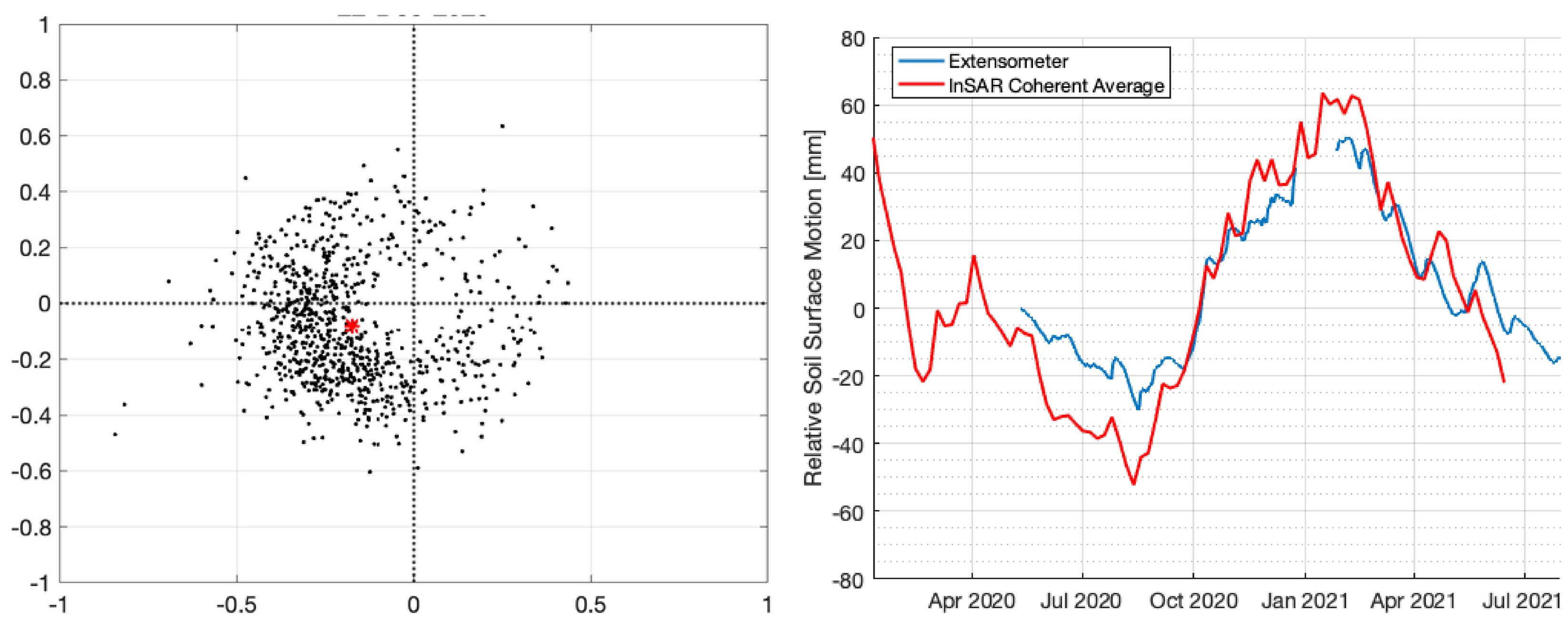


*Figure 3: **Left:** single epoch representation of the complex coherence of all the parcels (black dots) in the complex plane. The red star represents the complex mean. The amplitude of the complex coherence is the coherence magnitude. Argument of the the complex coherence represents displacement $\mathrm{mod}(2\pi)$. **Right:** in red the resulting time series of surface displacement over a period of 16 months, projected onto the vertical. In blue the extensometer "ground truth" as observed in Zegveld.*

***Segmented processing*: Bridging loss-of-lock by identifying coherent neighbours**

## Bridging Loss-of-Lock: Segment Reconnection

Each individual parcel-segment is treated as its own time series. The segment is unwrapped in time, and subsequently shifted vertically so as to best match the mean deformation model obtained by coherent averaging. While this causes heteroscedasticity, this results in the first realistic dynamic time series of grasslands over peat soils.

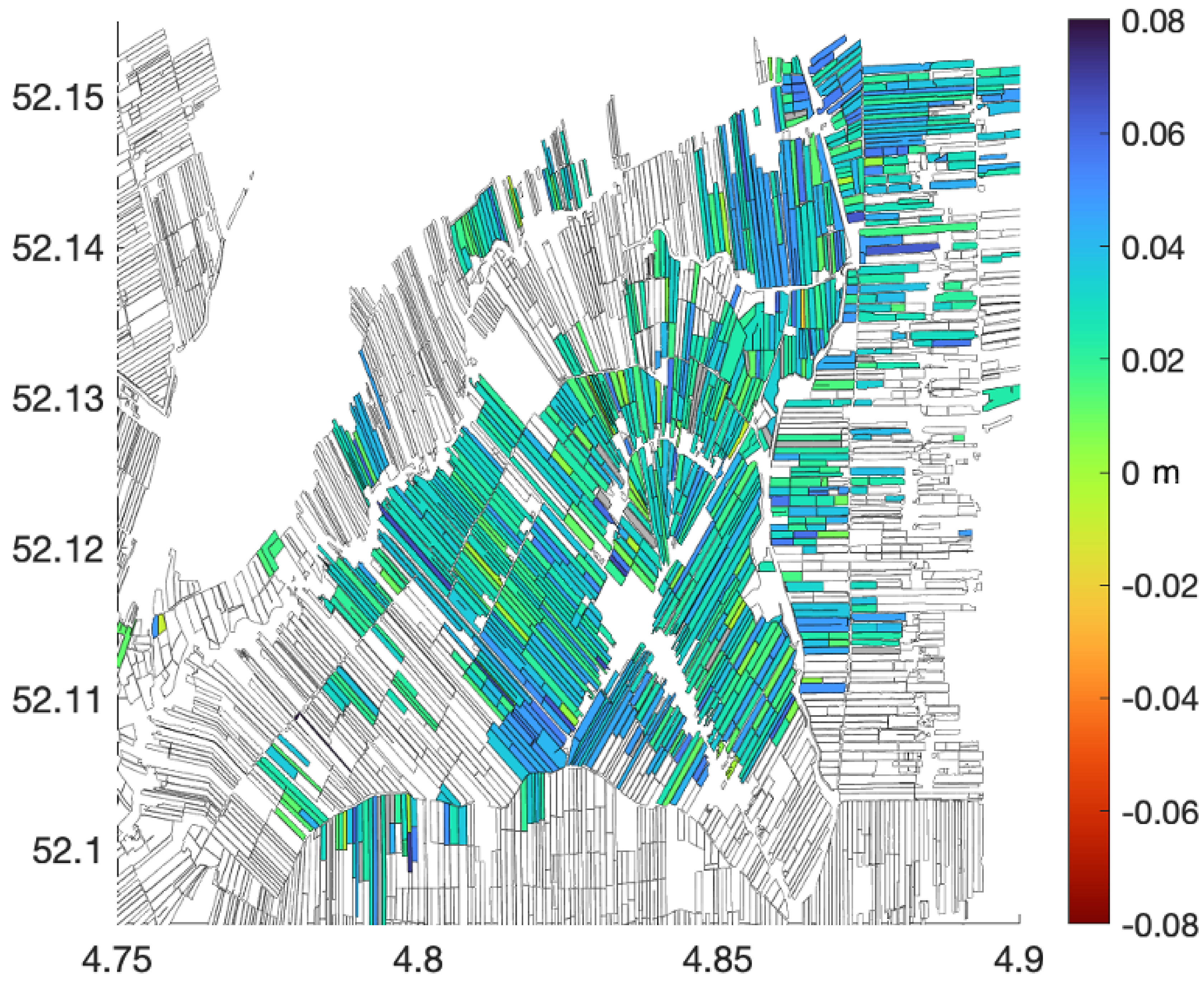


*Figure 4: Single-epoch overview of surface elevation of parcels of the wider Zegveld region. Color values are given in meters. This figure is one still in a time series animation with a 6-day refresh rate.*

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