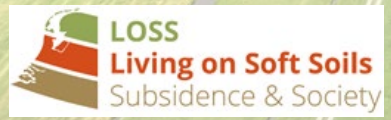
Estimating Peatland Surface Motion With Discontinuous InSAR Time Series Data

Philip Conroy, Simon van Diepen, Freek van Leijen and Ramon Hanssen



TU Delft

Challenges

- Ex: Extensometer measurement

Challenges

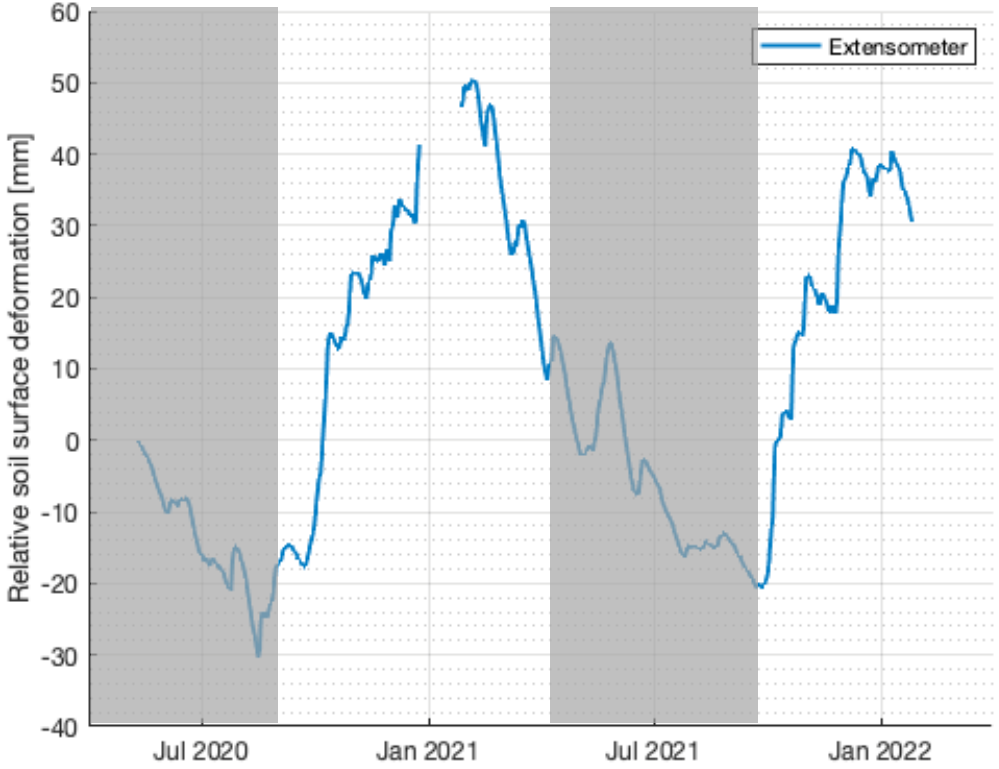
- Ex: Extensometer measurement
- Strong deformation rates

Challenges

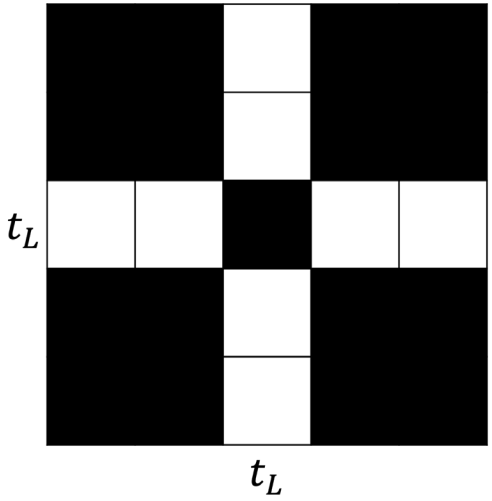
- Ex: Extensometer measurement
- Strong deformation rates
- High dynamic range

Challenges

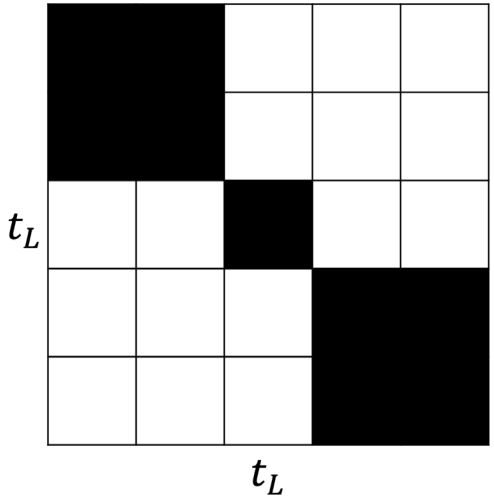
- Ex: Extensometer measurement
- Strong deformation rates
- High dynamic range
- Loss of coherence in summer



Loss-of-Lock



Intermittent loss of coherence
(ex. short snowfall)

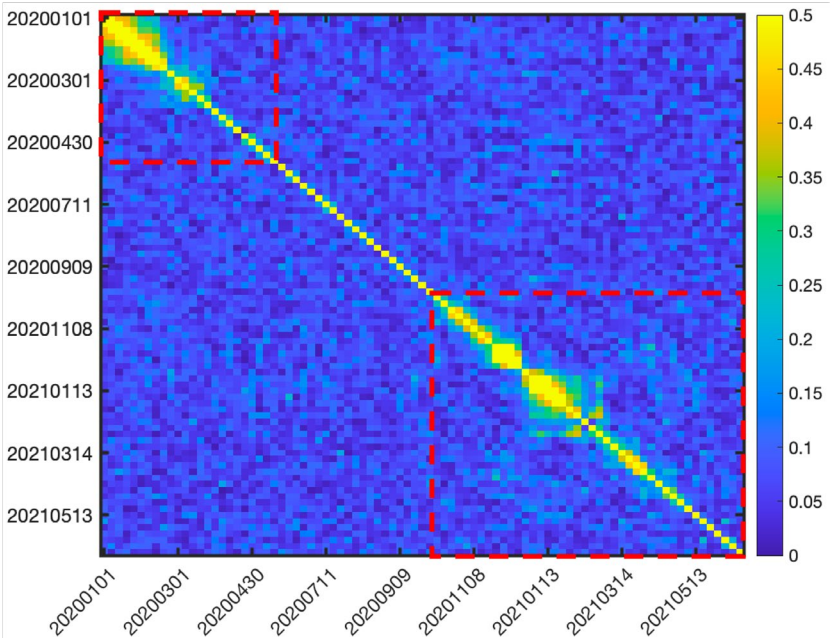


Loss-of-lock
(ex. plowing, harvesting)

Loss-of-Lock in Spring/Summer

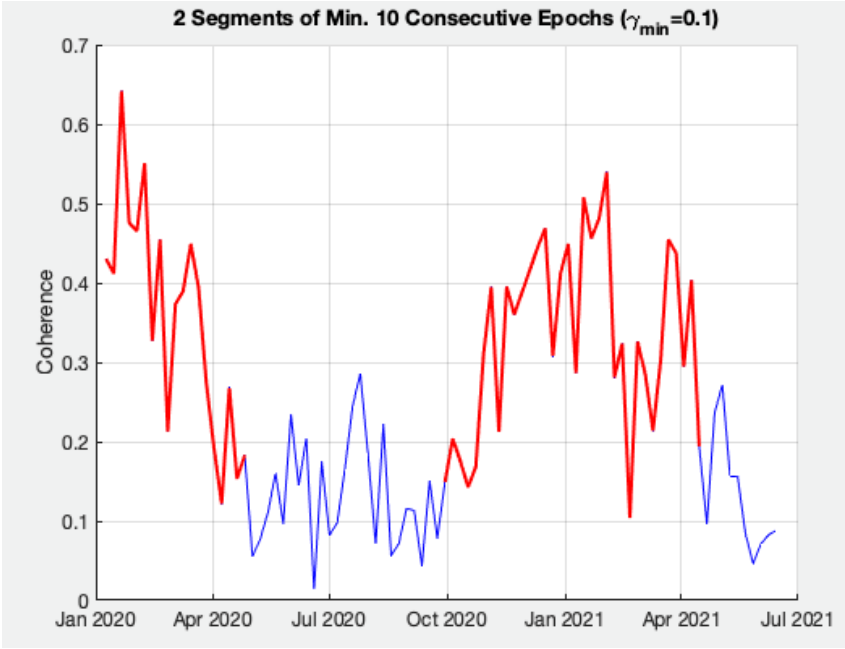
- InSAR observations of Dutch grasslands commonly show a complete loss of coherence in the spring and summer
- Practically speaking, this sustained long-term loss of coherence results in a cutting of the time series into disconnected segments

Typical Coherence Matrix (Sentinel-1)



Segmentation by Coherence

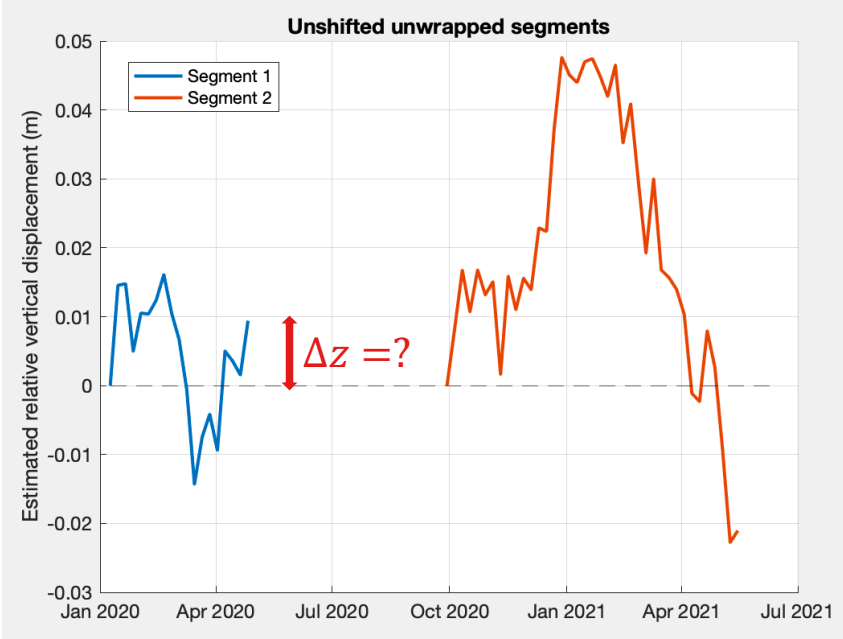
- We identify coherent time series segments where we are confident in the data quality
- Each segment is treated as an independent time series
- We can unwrap the time series with an acceptable level of error within the segment[1]
  - ~90% success rate at $\gamma = 0.1$
  - ~98% success rate at $\gamma = 0.2$



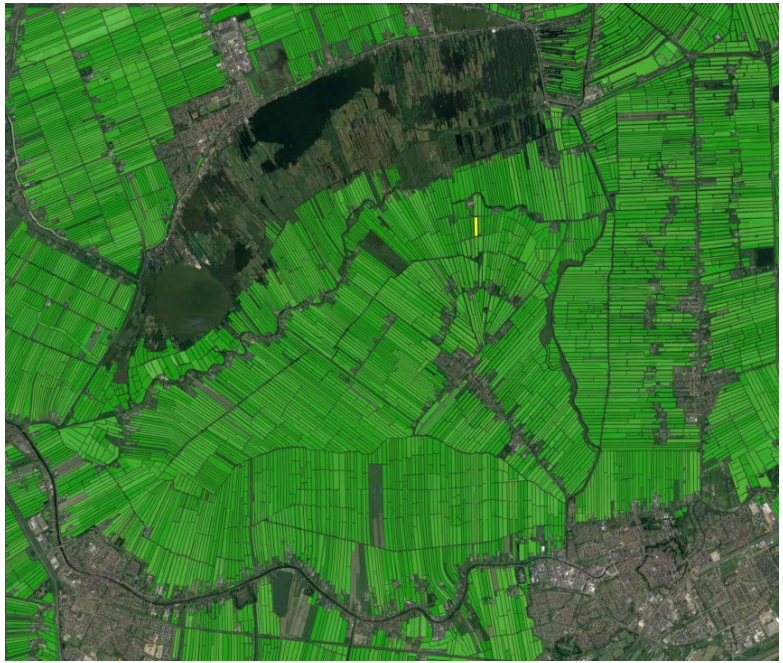
[1] *Probabilistic Estimation of InSAR Displacement Phase Guided by Contextual Information and Artificial Intelligence*, IEEE Transactions on Geoscience and Remote Sensing. 2022.

Partial Time Series Reconstruction

- We obtain an unwrapped time series for each segment
- Displacement is referenced to the first epoch
- How to reconnect the segments?



Contextual Data Integration



zegveld_parcel_attributes_full [4]	
objectid	1646282
(Derived)	
(Actions)	
objectid	1646282
gewascateg	Grasland
gewas	Grasland,blijvend
gewascode	265
length	766.330184259988982
area	20757.373033329498867
objectid_2	NULL
aanid	27336
versiebron	luchtfoto
type	BTR-landbouw
soil_unit_	hVb
ahn_05_dsm	-2.428999901000000
ghg_mbgl	NULL
glg_mbgl	0.8 - 1.0
EERSTE_BOD	hVb
EERSTE_GWT	II

Parcels form a natural averaging (multilooking) "unit"

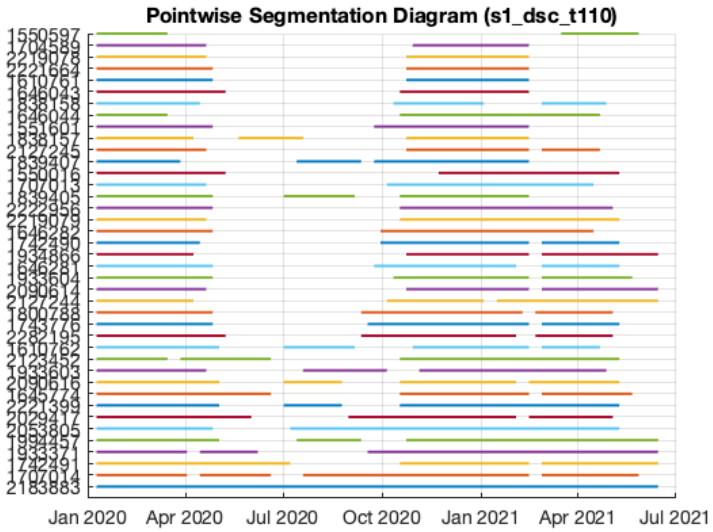
Grouping Observations

Key parameters:

- Land cover
- Soil type
- Water management zone (“Peilgebied”)

Ergodicity and representativity vs. noise suppression

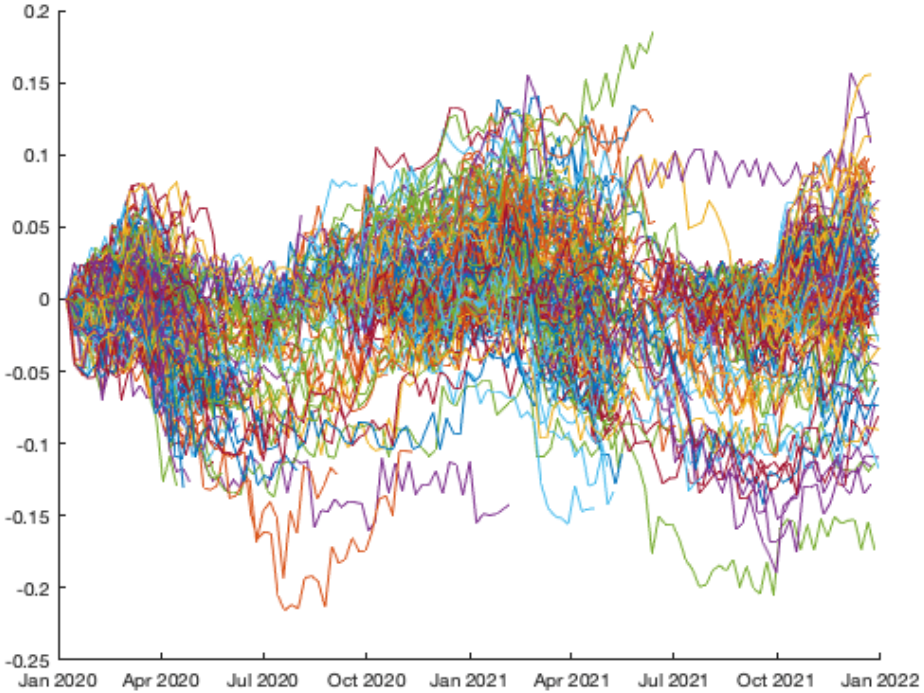
Filling in the Gaps



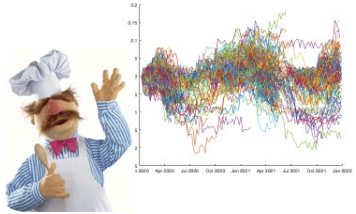
Enough coherent data to fill in the missing gaps!

Model Estimation

- Many vertically unaligned segments



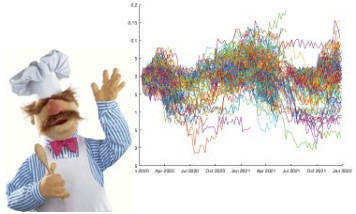
Model Estimation



- Many vertically unaligned segments:

$$\phi_n(t) = \frac{4\pi \cos\theta}{\lambda} \cdot [M(x,t) + \Delta z_n] + \epsilon$$

Model Estimation



- Many vertically unaligned segments:

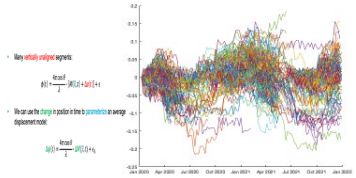
$$\phi_n(t) = \frac{4\pi \cos\theta}{\lambda} \cdot [M(x,t) + \Delta z_n] + \epsilon$$

- We can use the change in position in time to parameterize an average displacement model:

$$\Delta\phi_n(t) = \frac{4\pi \cos\theta}{\lambda} \cdot \Delta M(x,t) + \epsilon_\Delta$$

TU Delft

Model Estimation



- Many vertically unaligned segments:

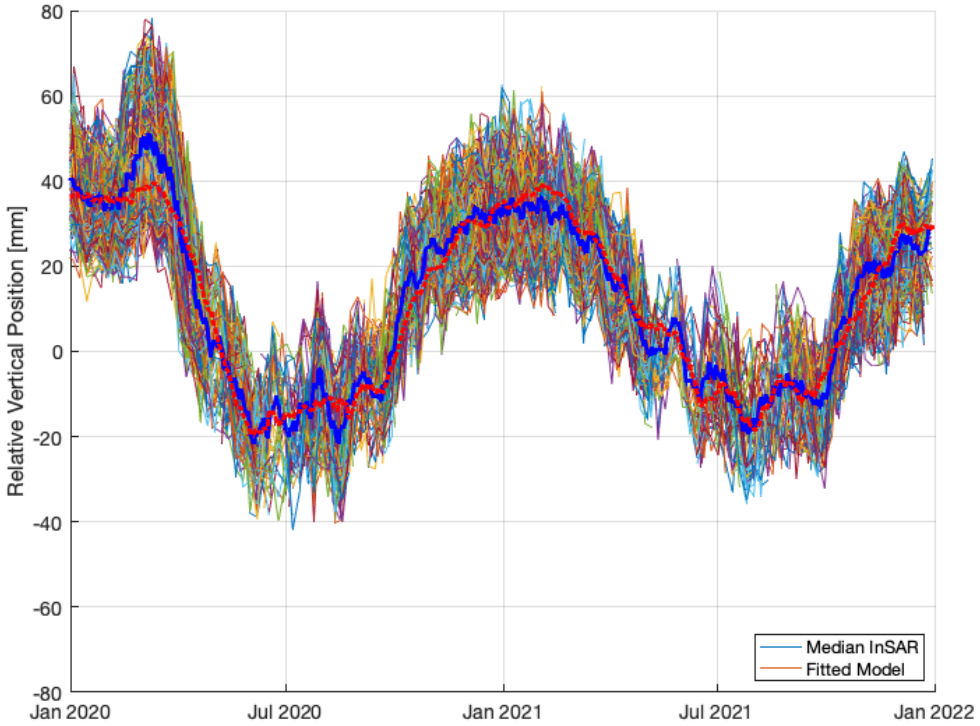
$$\phi(t) = \frac{4\pi \cos\theta}{\lambda} \cdot [M(\hat{x}, t) + \Delta z(t)] + \epsilon$$

- We can use the change in position in time to parameterize an average displacement model:

$$\Delta\phi(t) = \frac{4\pi \cos\theta}{\lambda} \cdot \Delta M(\hat{x}, t) + \epsilon_{\Delta}$$

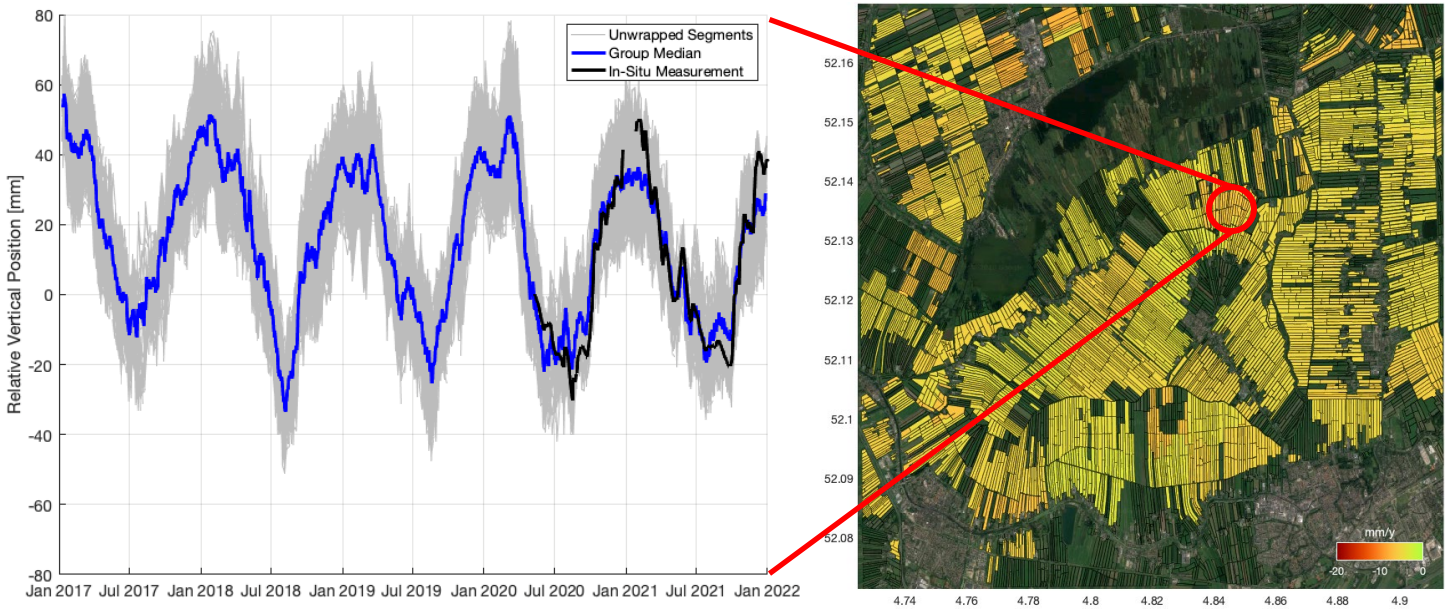
Model Estimation

- Many unaligned segments
- We can use the change in position over time to parameterize an average displacement model
- Estimated model can be used to *realign* the segments



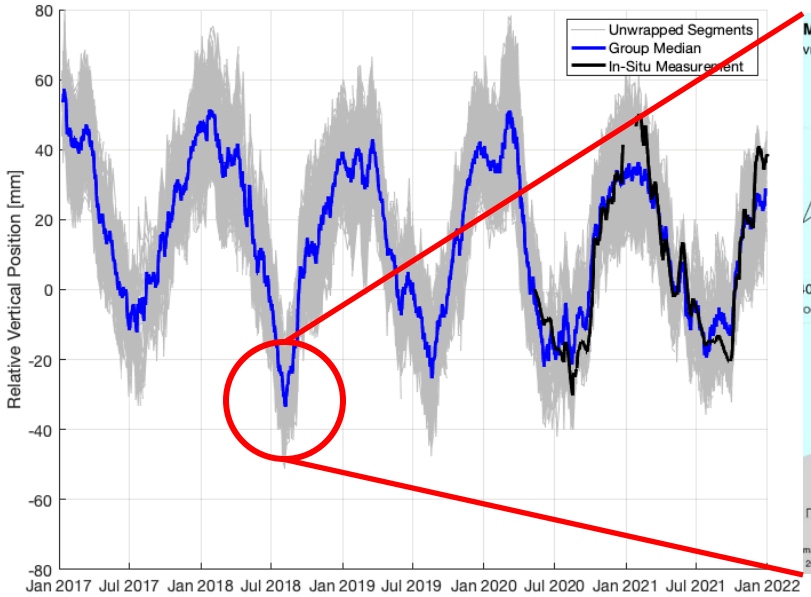
Displacement Time Series

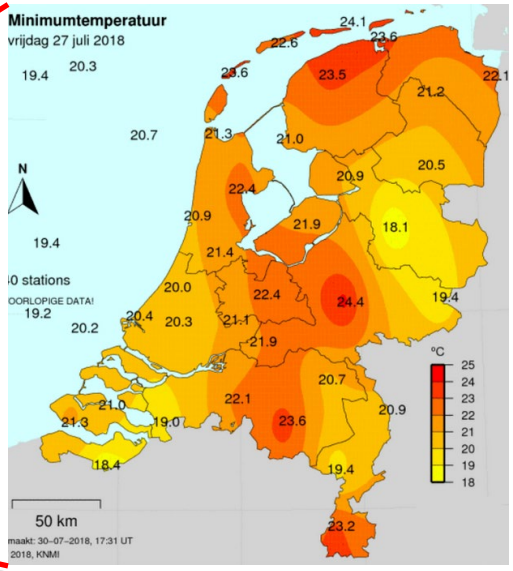
Zegveld, NL



Displacement Time Series

Zegveld, NL





Conclusions

- Loss-of-lock cuts the InSAR time series into disconnected segments
- Contextually similar scatterers are used to estimate a mean displacement model
- The effects of climate stresses are visible in the ground subsidence
- *First accurate time series of surface motion of the Dutch peatlands!*

Check out the preprints!

InSAR Workflow

Soil Model