SAFElevee workshop

Leren van dijkdoorbraken

Dijkmonitoring met satellieten

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Hydraulic Structures & Flood Risk

Dike Inspection

- **> 20,000** km of flood defences in the NL

- **Current inspection methods**
  - Essential in achieving the demanded safety level
  - Challenging logistics & labor intensive
  - Based on visual inspections, ~ yearly

- **Remote sensing and other advanced methods**
  - Locations with high risk
  - Small scale & costly

Source: IVW, 2011

⇒ Innovative and cost-effective techniques

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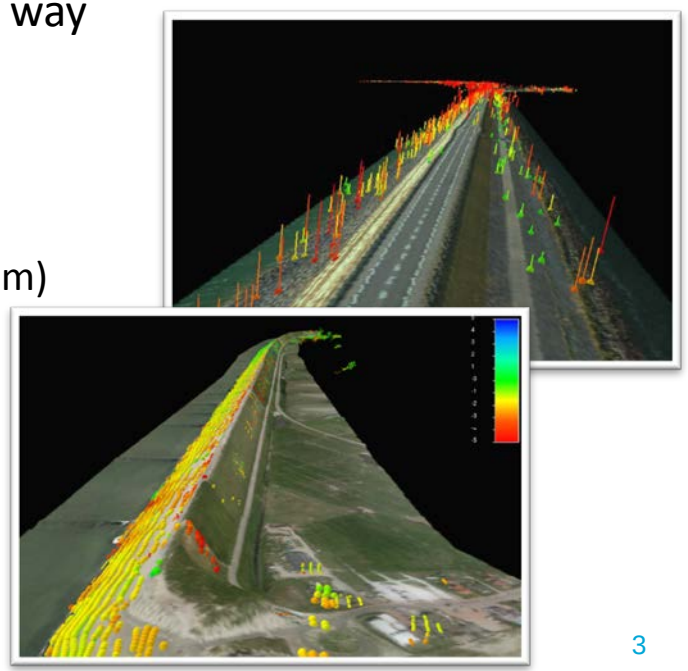
Dike Deformation Monitoring

➡ The use of Satellite Radar Interferometry

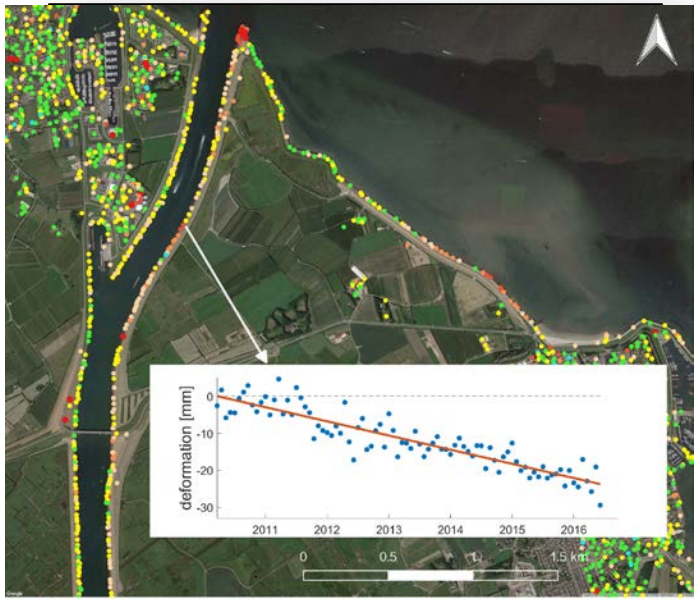
- Innovative, frequent and cost-effective way
  - Millions of observations
  - Wide areal coverage (over km's)
  - From 1992 till today
  - High measurement accuracy (in mm)
  - Reasonably low-costs
  - Frequent repeat (~6-35 days)



Dike Deformation Monitoring

➡ The use of Satellite Radar Interferometry

- Deformation maps along the dikes
- Deformation time-series per point [mm]
- Quality of the estimated deformations
- Deformation decomposition



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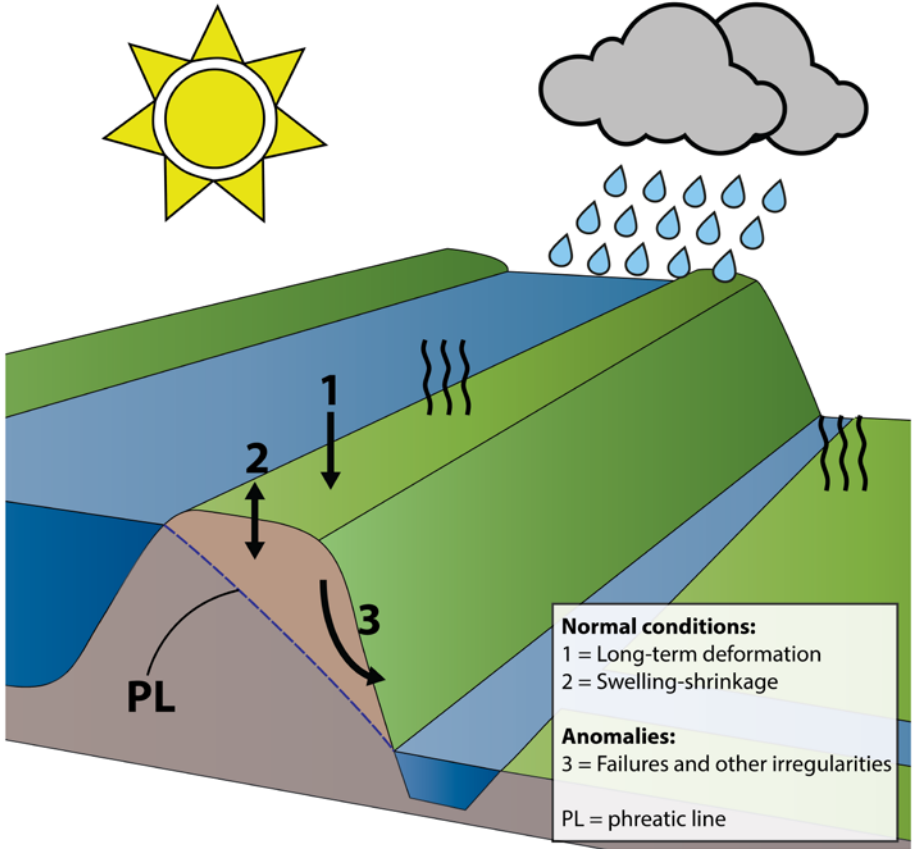
What do we want?

- Ability to provide early warnings
  - Frequent monitoring
  - Over the entire dike structure

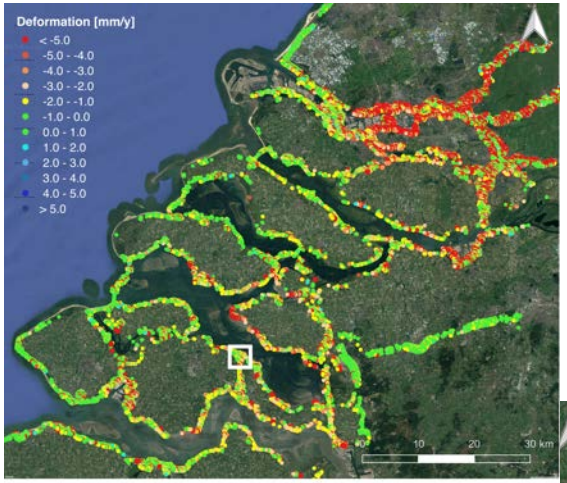
What do we need to get there?

- Understanding of the ‘normal’ conditions
- Detection capability for anomalies

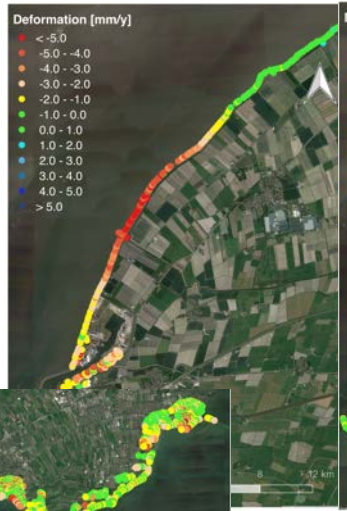
Overview of a dike behavior



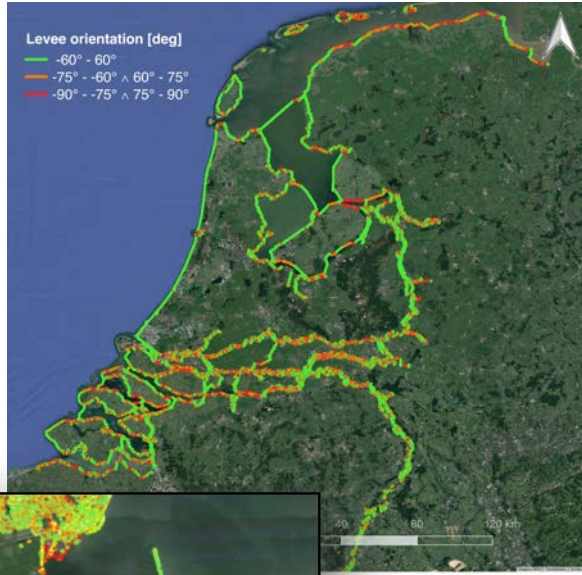
1. Long-term deformation– primaire waterkeringen



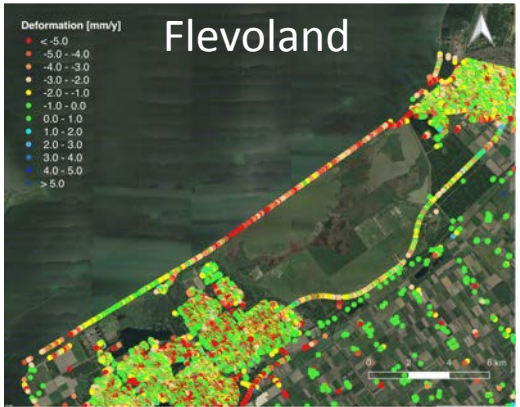
Zeeland



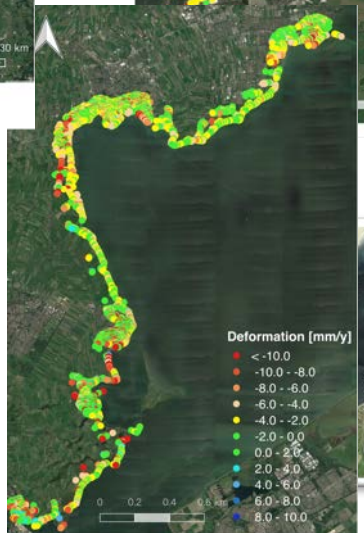
Harlingen

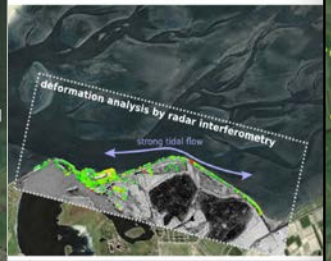


Nederland



Flevoland





Markermeer

Marken

Study Area

- Regionale waterkeringen in Delft-Zuid

Satellite	TerraSAR-X
Time period	2009-2015
Temporal resolution	Min. every 11 days
Spatial resolution	3 x 3 m

1. Long-term dike deformation - Delft-Zuid

2. Seasonal deformation patterns: Swelling-Shrinkage

- Safety of the regional flood defences
- Extreme conditions, i.e. too dry or highly saturated soil
  → a reduction in the soil strength of the dike
- Due to the heavy rainfall
  Wilnis, 1874
- Extreme warm and dry weather
  Zoetemeer,1947
  Bleiswijk near Rotterdam,1990
  Oostzaan near Amsterdam,1990
  Wilnis, 2003

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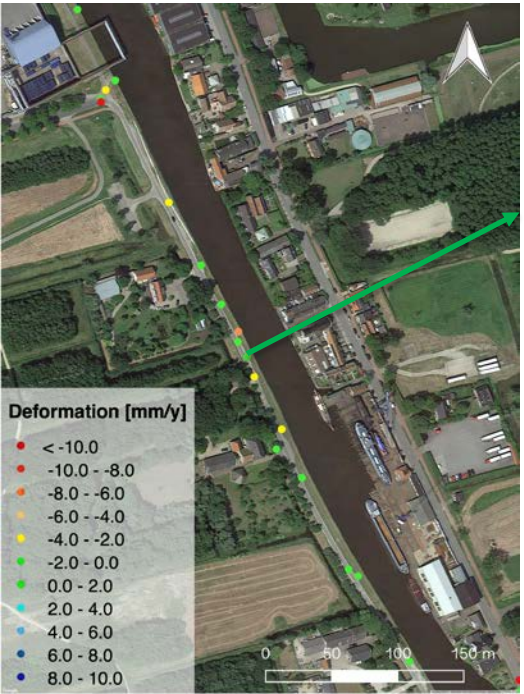
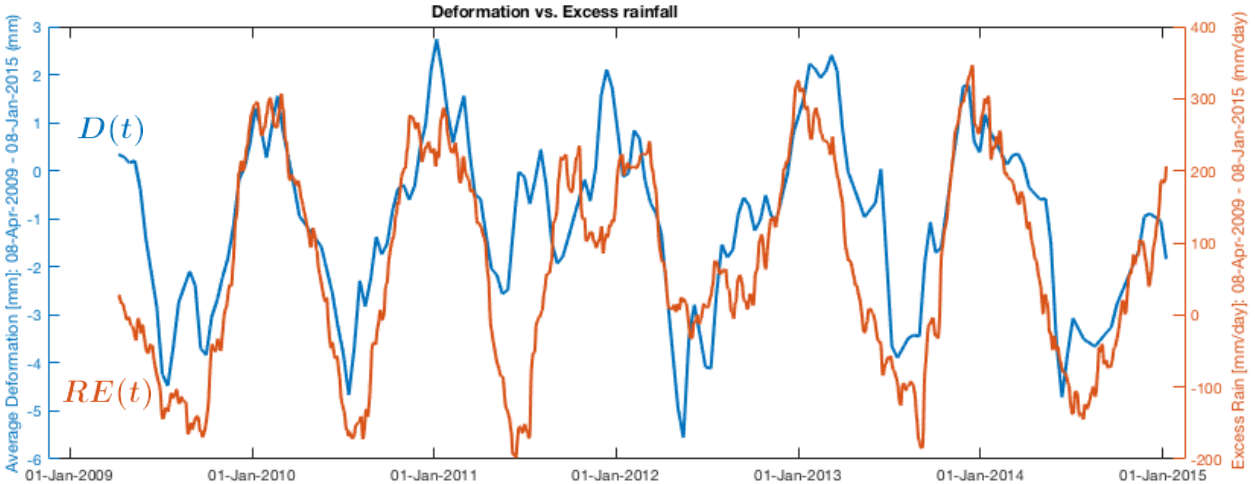
2. Swelling-Shrinkage

Correlation between dike deformations obtained from satellites and rainfall excess (RE)

$$RE(t) = P(t) - E(t)$$





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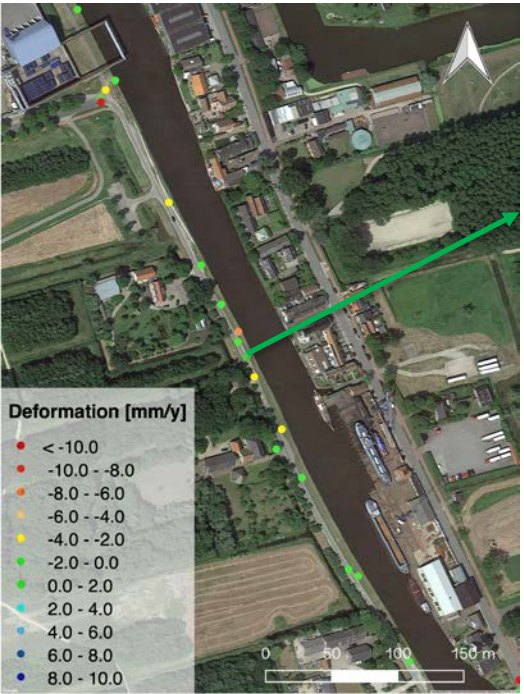

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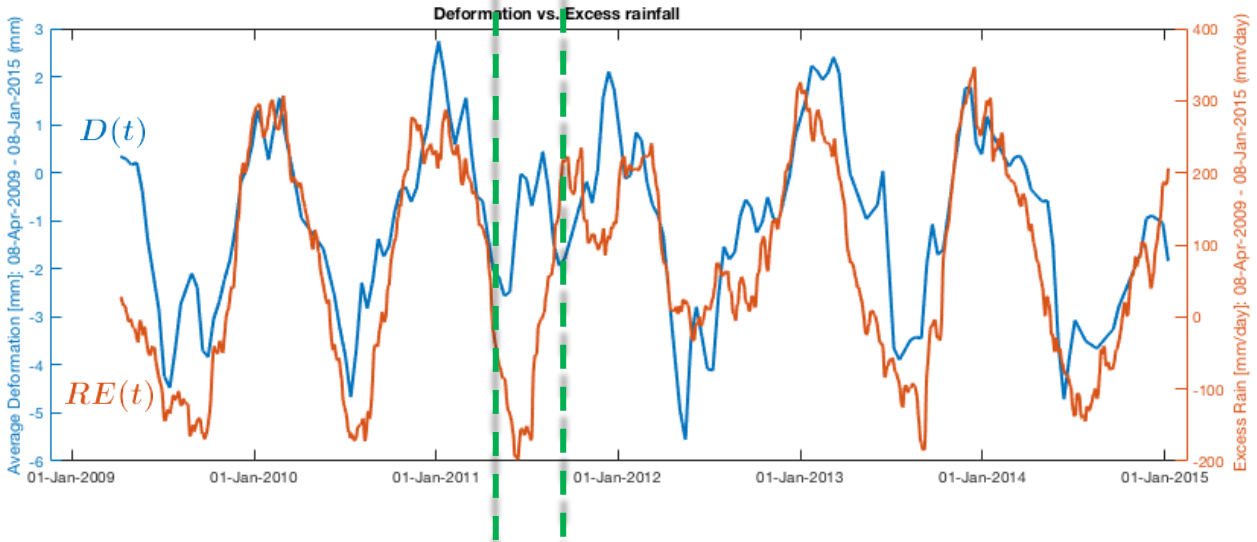
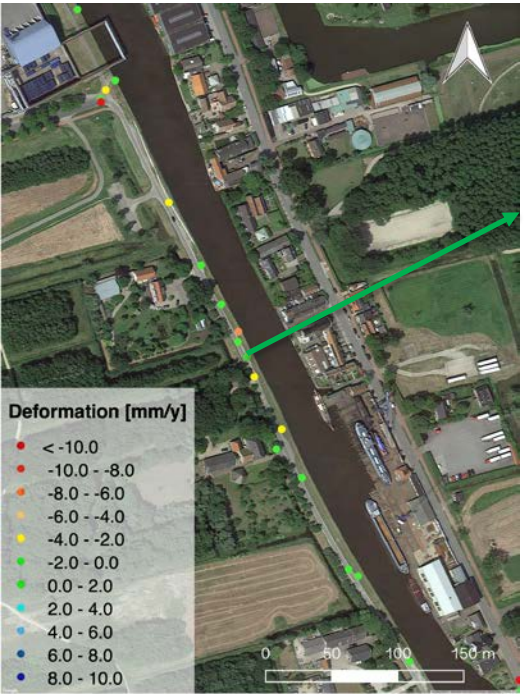
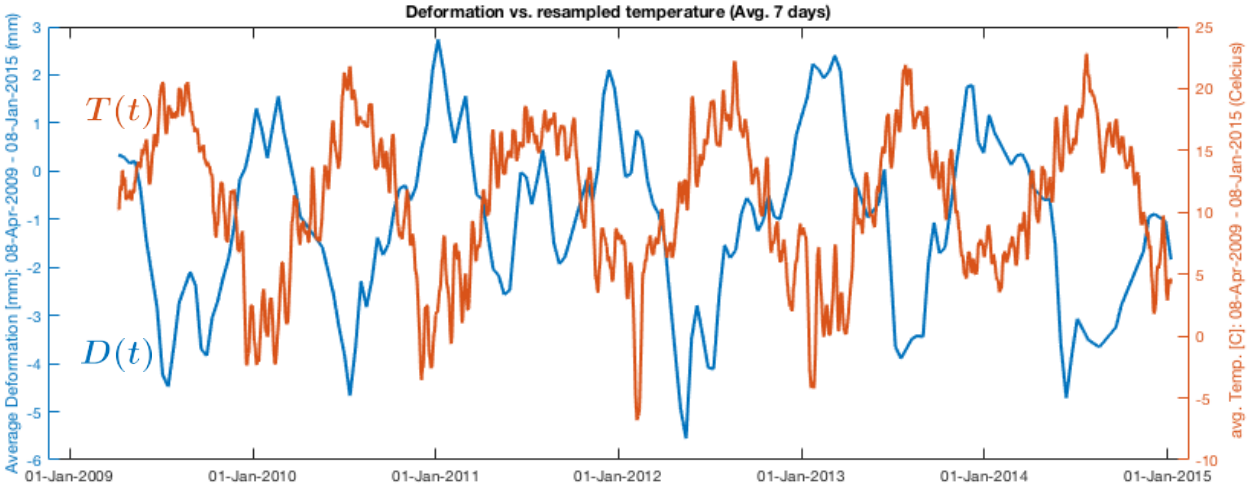


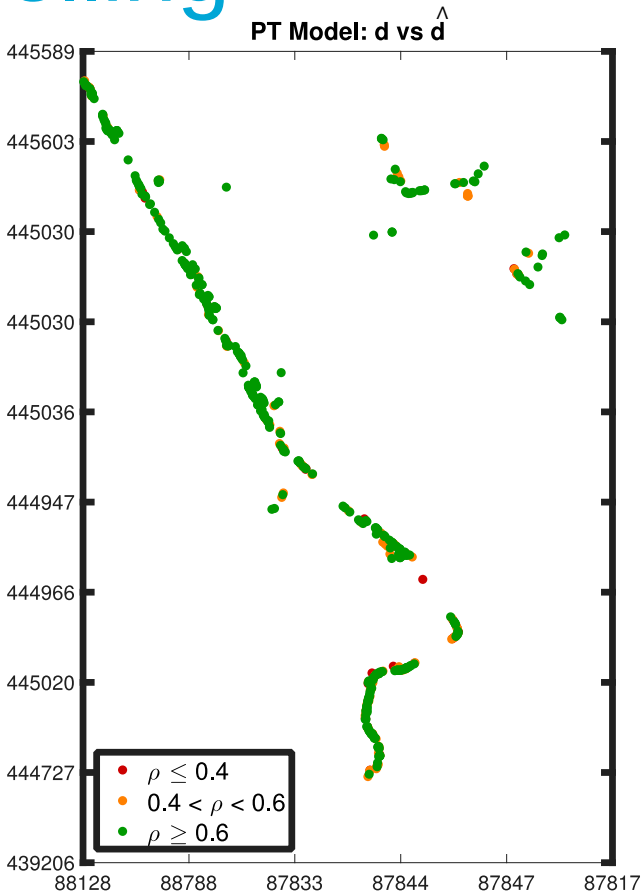
2. Swelling-Shrinkage

Correlation between dike deformations obtained from satellites and temperature (T)



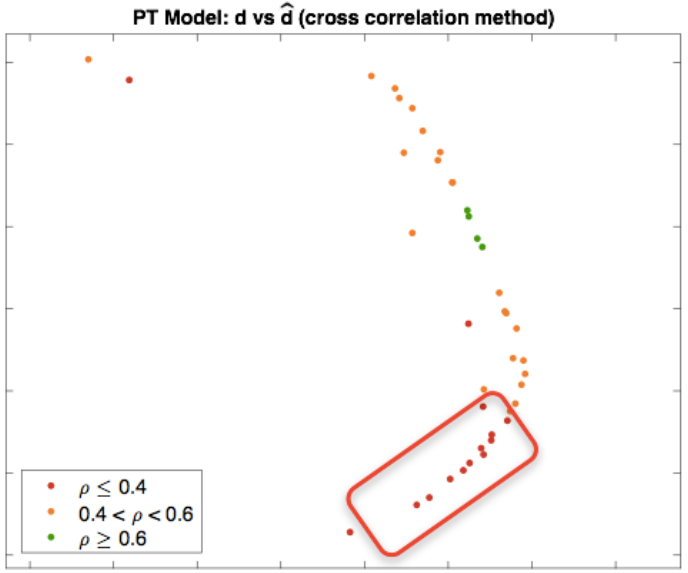


Deformation Modelling



~ 70% of the points

Deformation Modelling



Conclusions

- **Satellite technology -** Complementary technique for dike monitoring

→ Regional flood defences:

- **Short-term elastic deformations** obtained from monitoring a dike with satellites can be observed **on a weekly basis**,
- Differs from the current practice, i.e. long-term behavior,
- These deformations are correlated with the changes in **meteorological conditions,**
  - to estimate the deformation time series from meteorological data, and;
  - to analyze the influence of the loading conditions on the behavior of a dike

Broader application

- Understanding the normal behavior of dikes is a necessary step to detect anomalies on dikes
    - to predict the expected shrinkage/swelling due to weekly variations of the loading conditions
    - to identify critical situations based on extreme meteorological events
- Basis for the development of an automated early warning system

Coming years

Part-1

Deformation monitoring using satellite technology

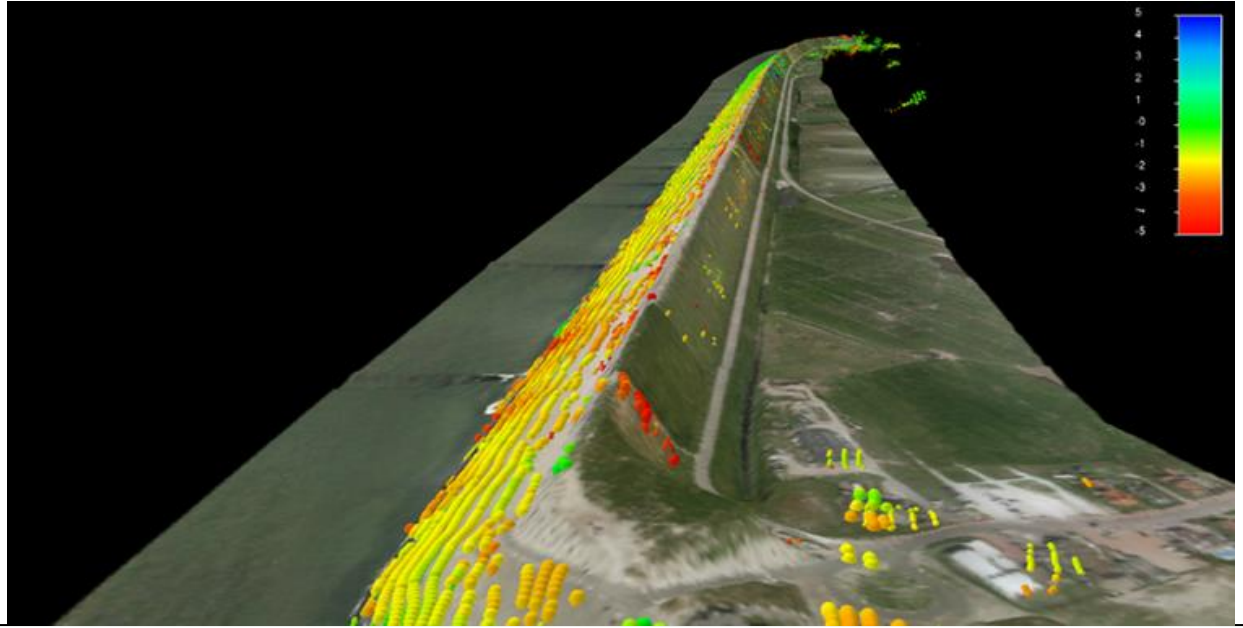
Part-2

Investigating dike failure patterns

Better understanding of failure mechanisms and their underlying factors

- Insights into the real failure processes and conditions
- More reliable predictions of failures

➡ Contribute to the existing approaches for assessing dike safety



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