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InSAR vertical displacements for Infrastructure and settlement monitoring application

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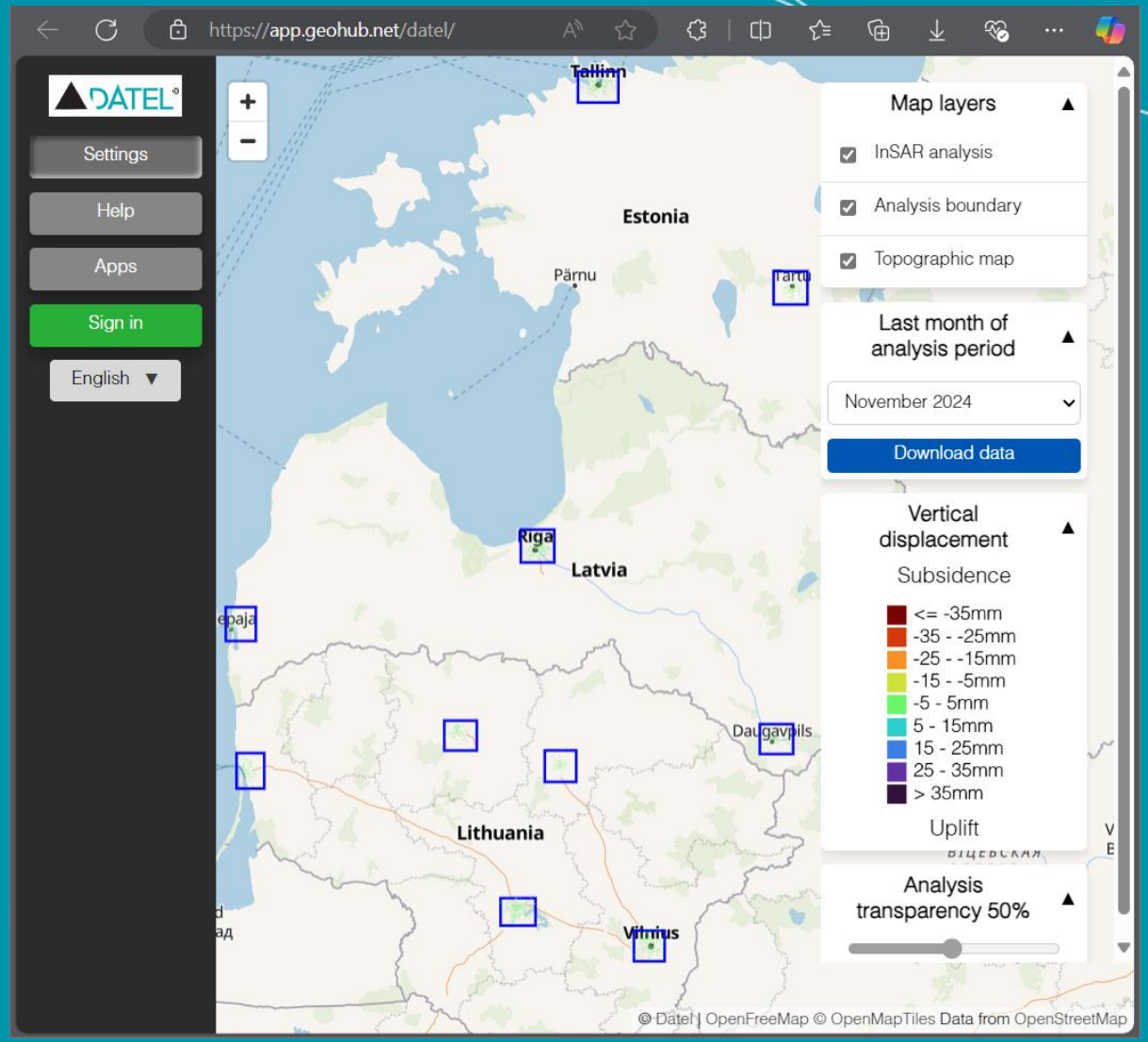
SILLE

Infrastructure and settlement monitoring

- To observe **subsidence/uplift** in Baltic cities with population > 60k

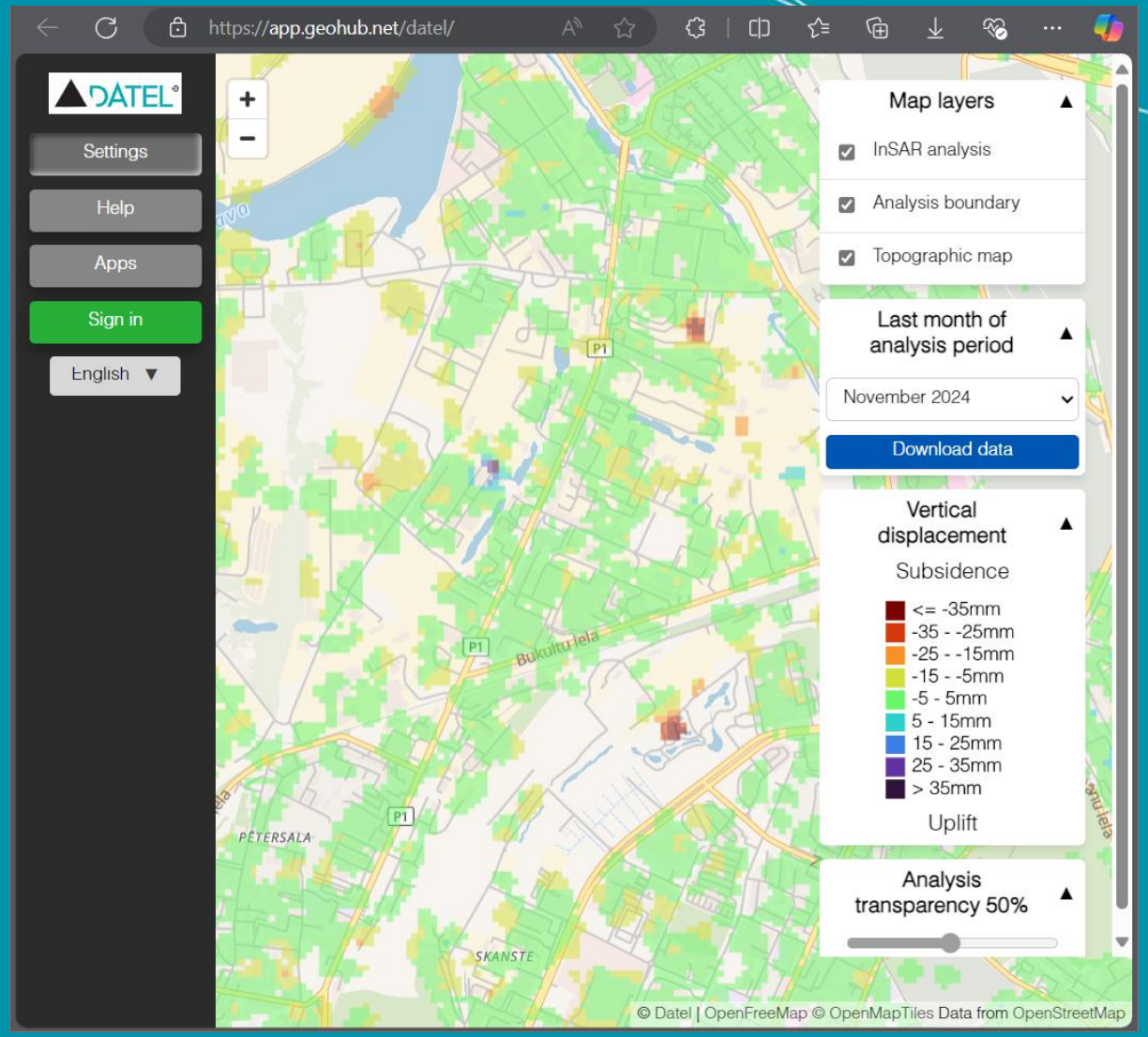


https://app.geohub.net/datel/

Infrastructure and settlement monitoring

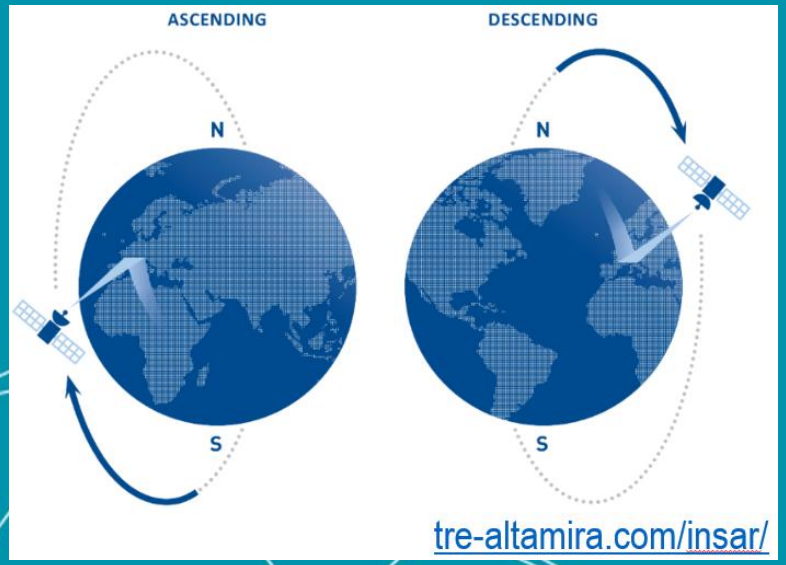
- To observe **subsidence/uplift** in Baltic cities with population > 60k
- **Vertical displacement** grids (unit mm) from the analysis of **Multi-Temporal Interferometric SAR** (MT-InSAR)
- Analyses for the time period of one year (at least 30 radar images) calculated monthly
- The precision of displacements 2-2.5 mm on average (1-sigma)

https://app.geohub.net/datel/



SAR data

- Sentinel-1 SAR SLC images
  - Active microwave radar satellite mission
  - Central frequency $f \approx 5.4$ GHz → wavelenght $\lambda \approx 5.6$ cm
  - Spatial resolution 5 m x 20 m
  - Data from 2014, orbit repetition 12-days or 6-days (2016-2021, 2025- ...)



The following table contains a summary of useful orbital information for Sentinel-1A and –1B:

Altitude	Inclination	Period	Cycle	Ref. tube deviation	Local Time at Descending Node
693 km	98.18 deg	98.6 min	12 days	+- 100 m	18:00 hours

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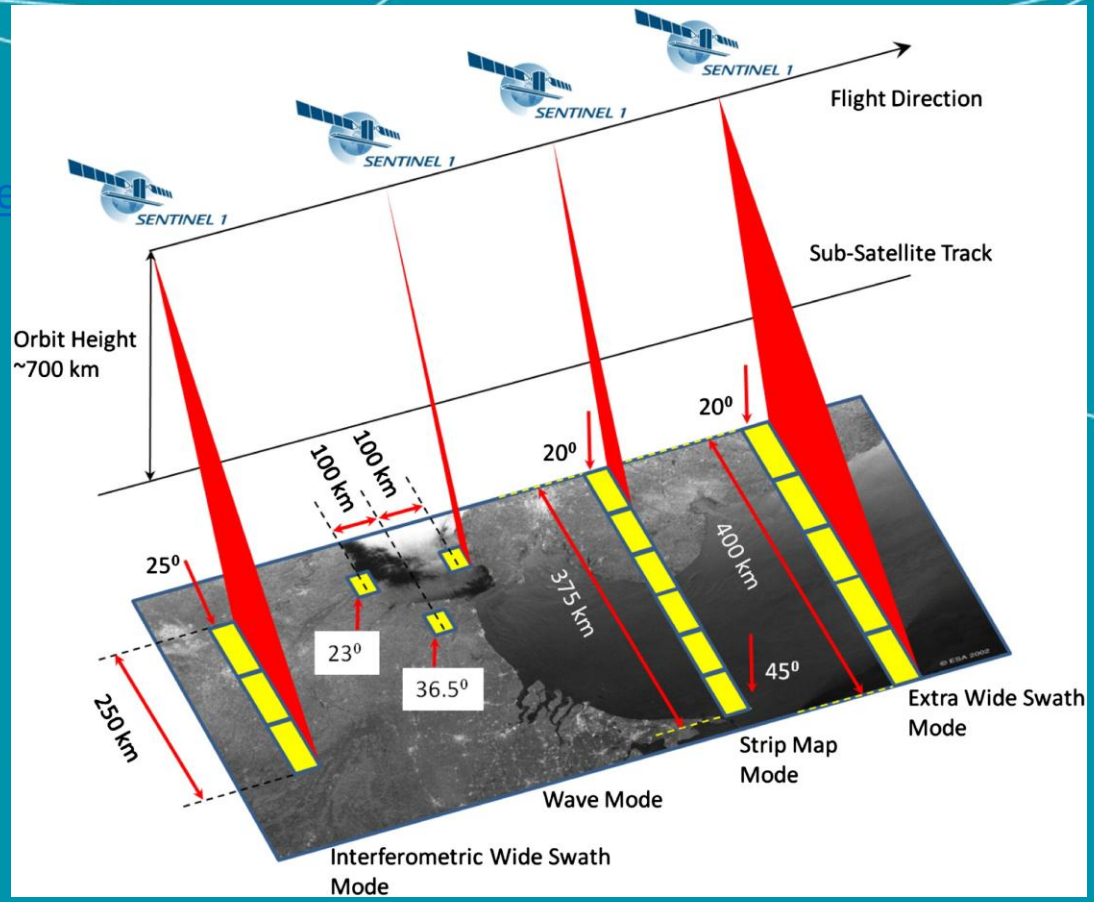
  - Interferometric Wide swath (IW) mode to measure ...



SENTINEL-1 Modes

SAR data

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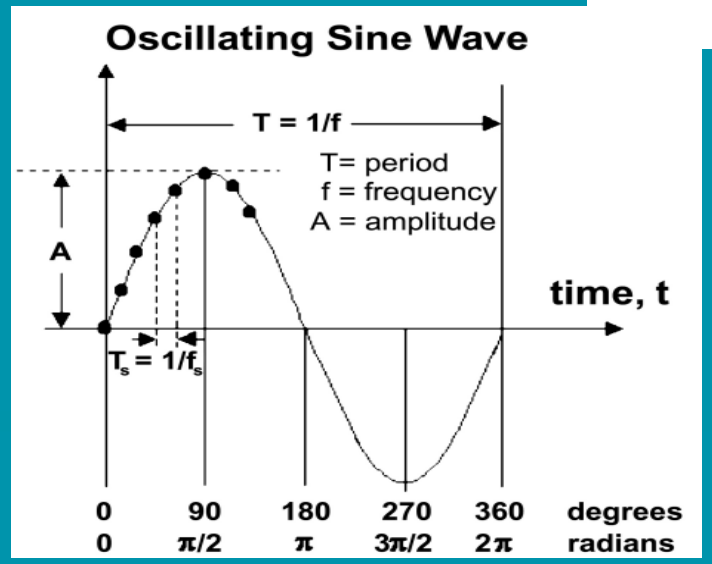
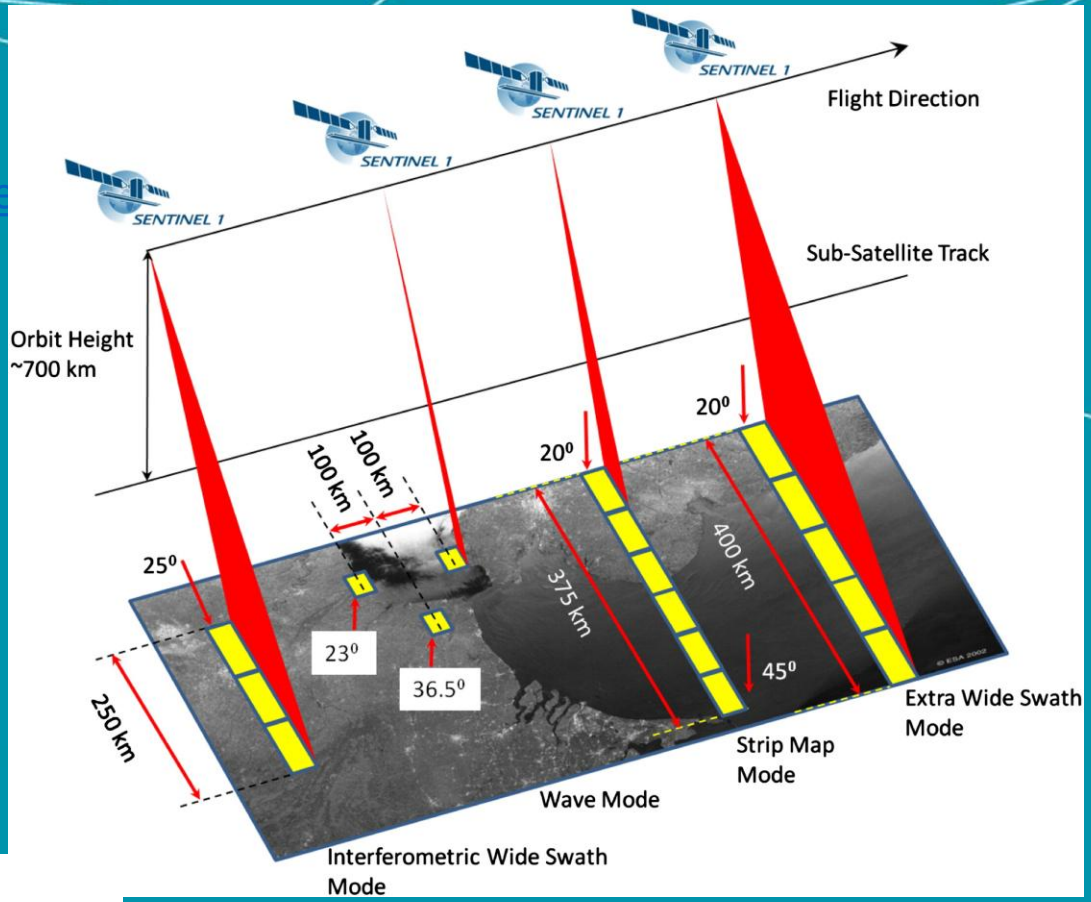
Sine function:

$$y(t) = A\sin(\omega t + \varphi) = A\sin(2\pi f t + \varphi)$$

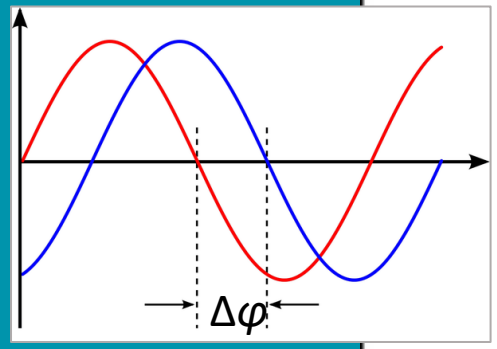


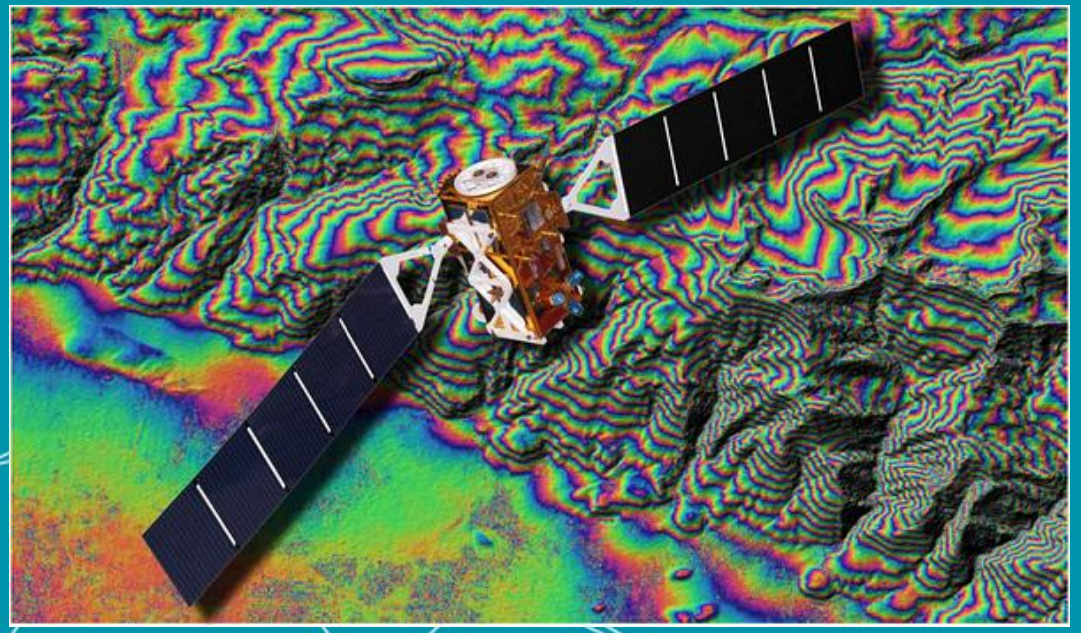


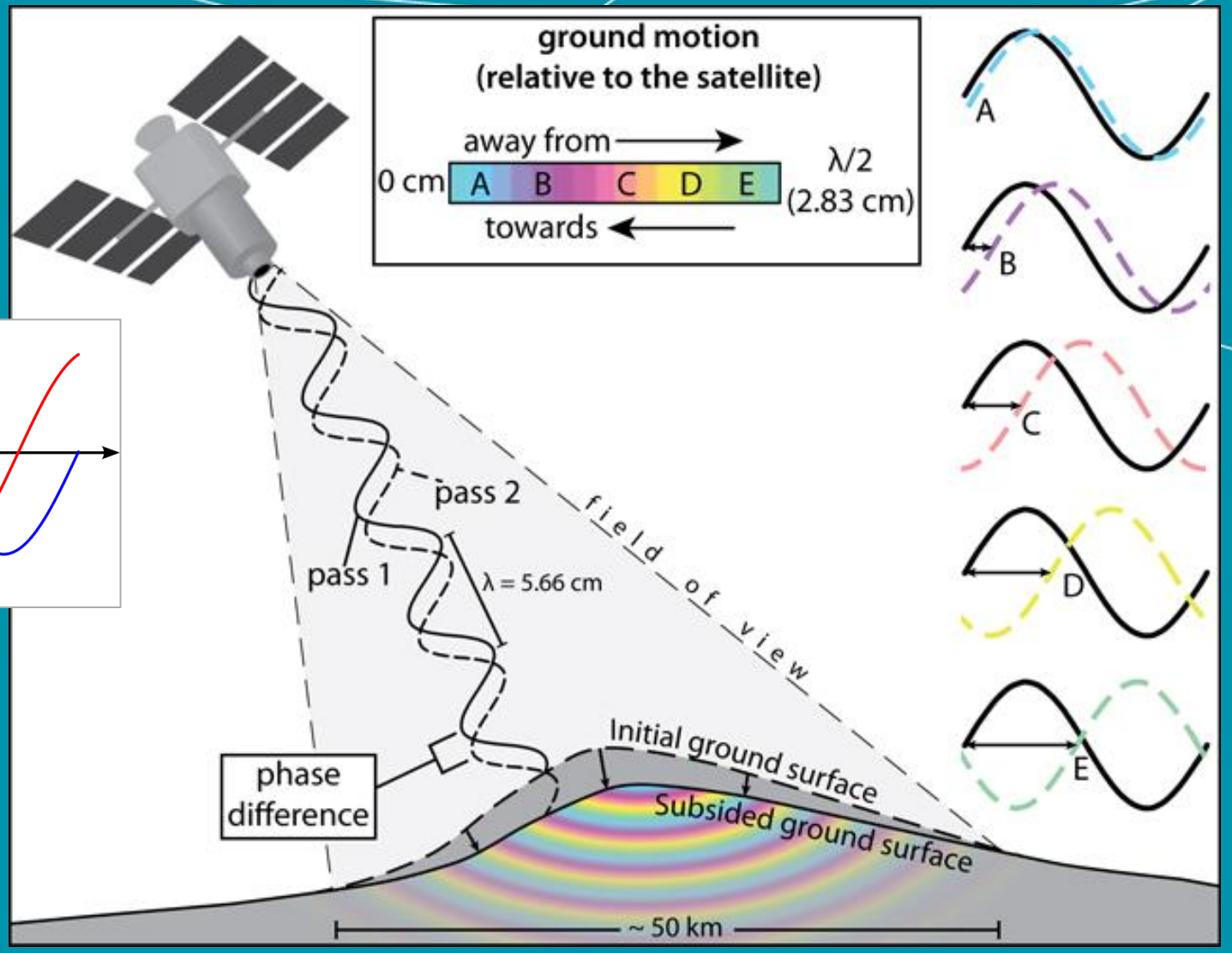
SENTINEL-1 Modes

InSAR method

- By measuring the phase differences $\Delta\varphi = \varphi_2 - \varphi_1$
- ... the displacements of ground surface can be monitored







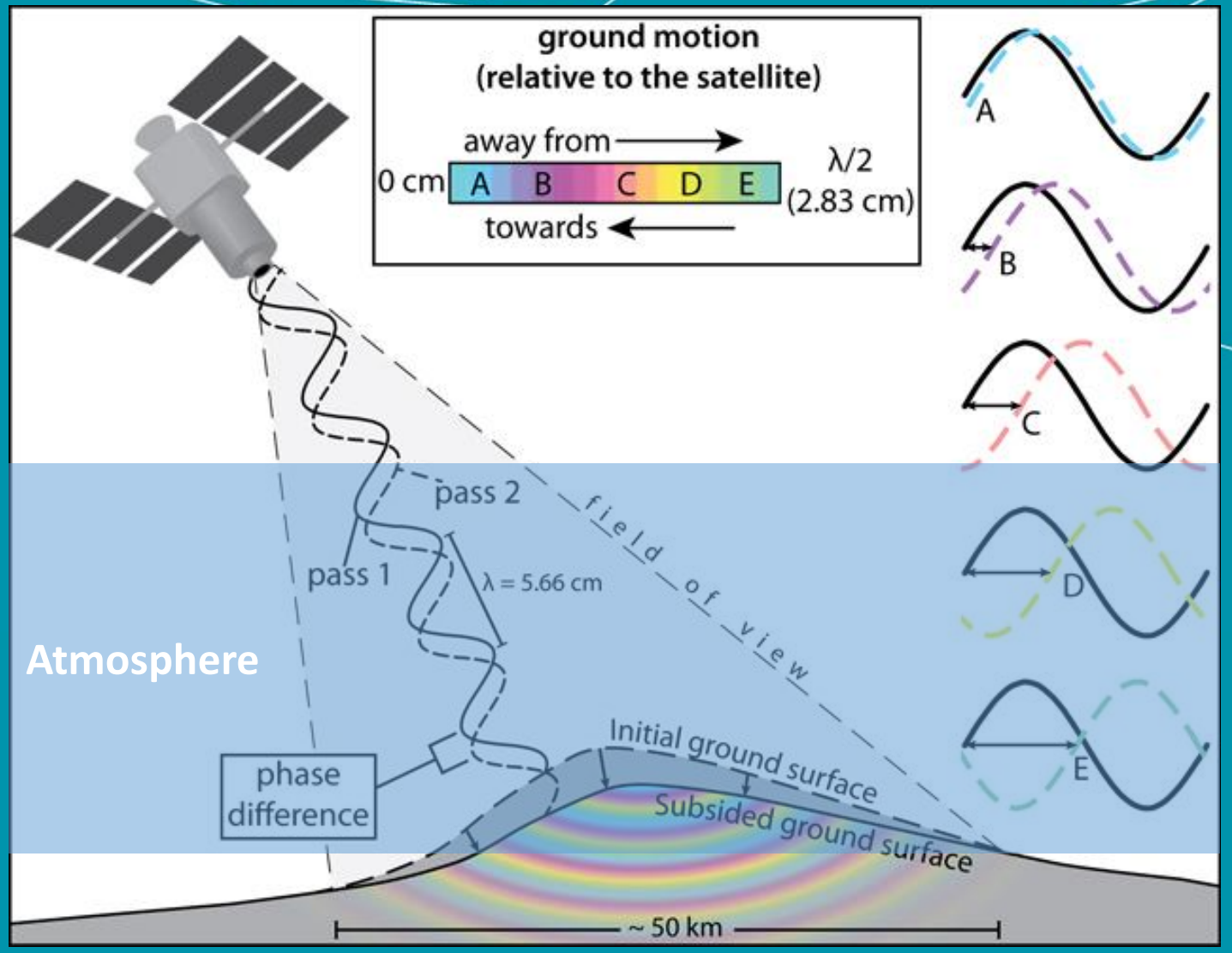
InSAR of repeated SAR imagery (volcano.si.edu)

Interferometric fringes from Sentinel-1 SAR imagery (Braun 2021)

InSAR method

- Error sources:
  - Atmospheric delay
  - Topography
  - Measurement noise
- Phase difference from InSAR

$$\varphi^n = \varphi^n_{topo} + \varphi^n_{defo} + \varphi^n_{aps} + \varphi^n_{noise}$$



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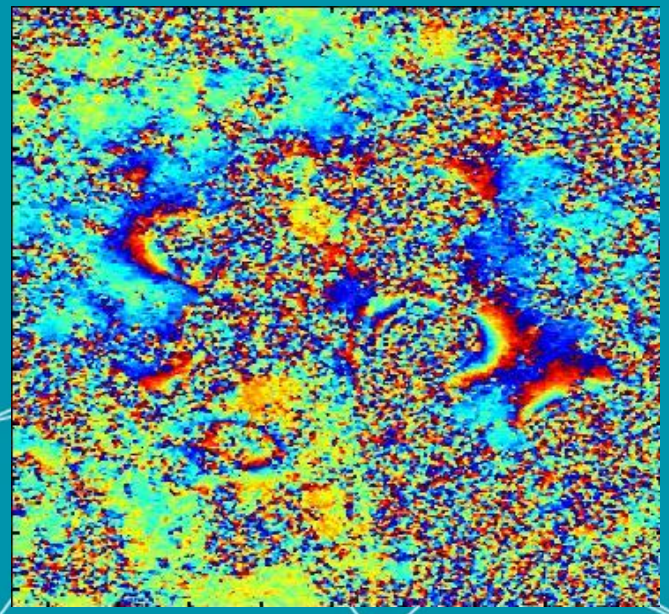
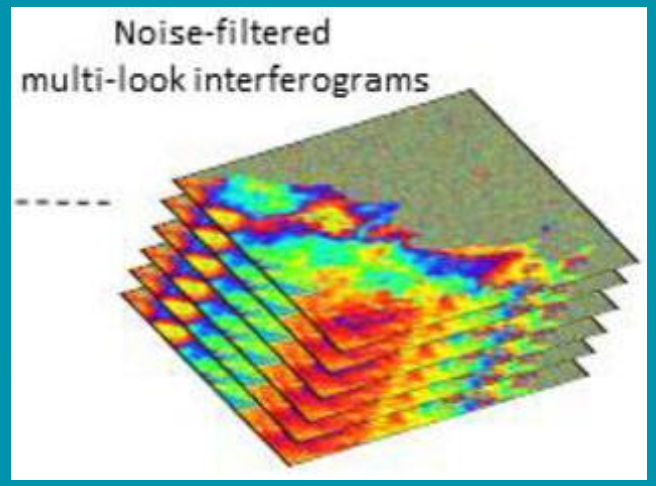


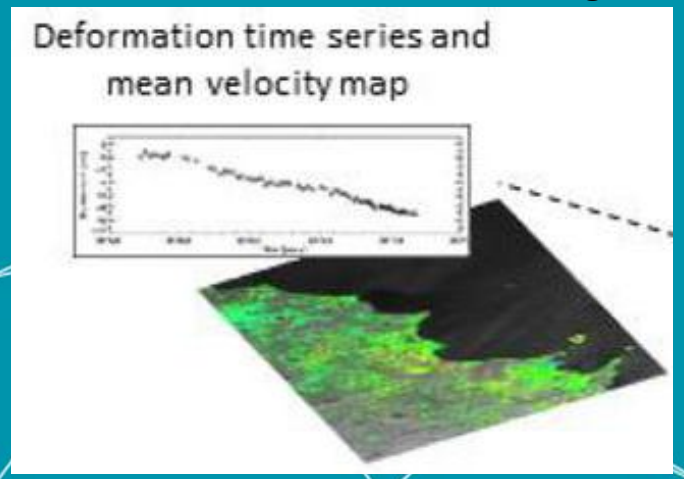
Noisy interferogram from InSAR

InSAR method

- Solution: multi-temporal InSAR
- By using stack of SAR images

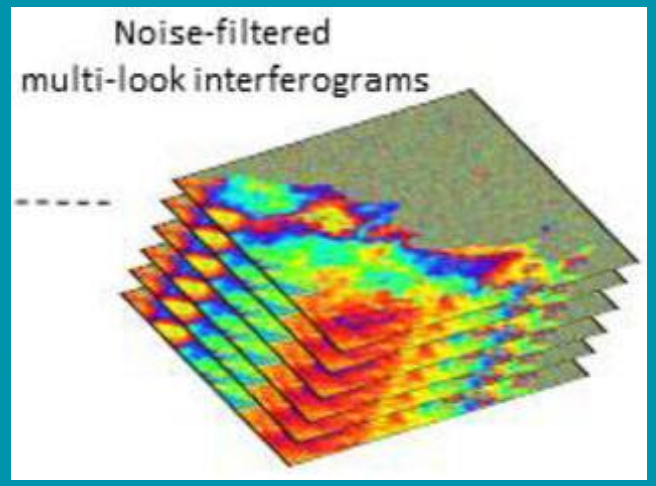


Minh et al 2020 Remote Sensing



InSAR method

- Solution: multi-temporal InSAR
- By using stack of SAR images and persistent scatterers (PS) with APS



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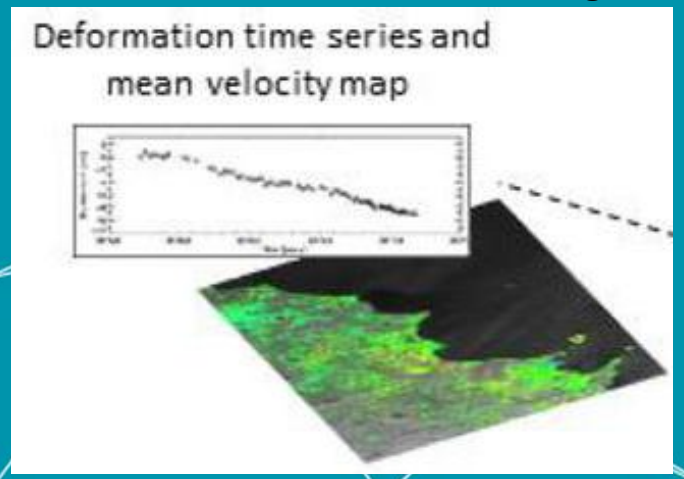
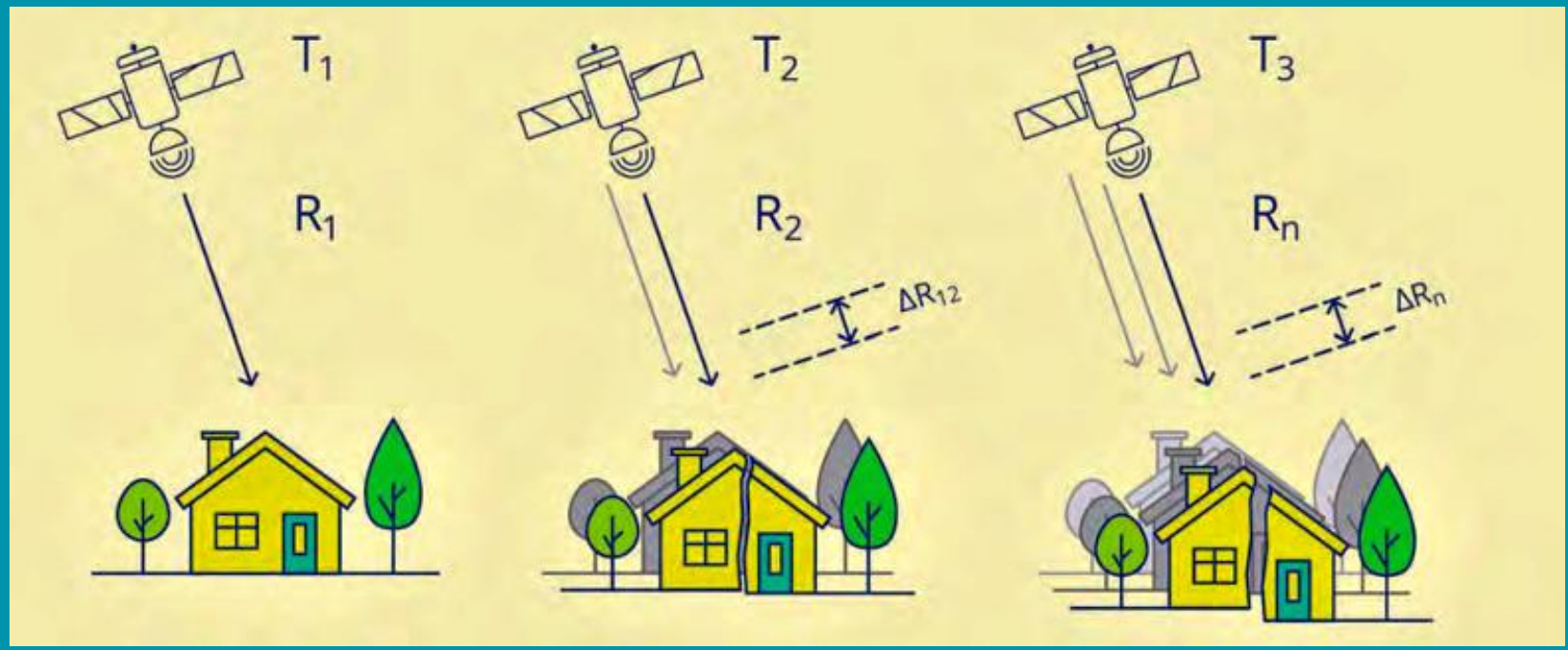
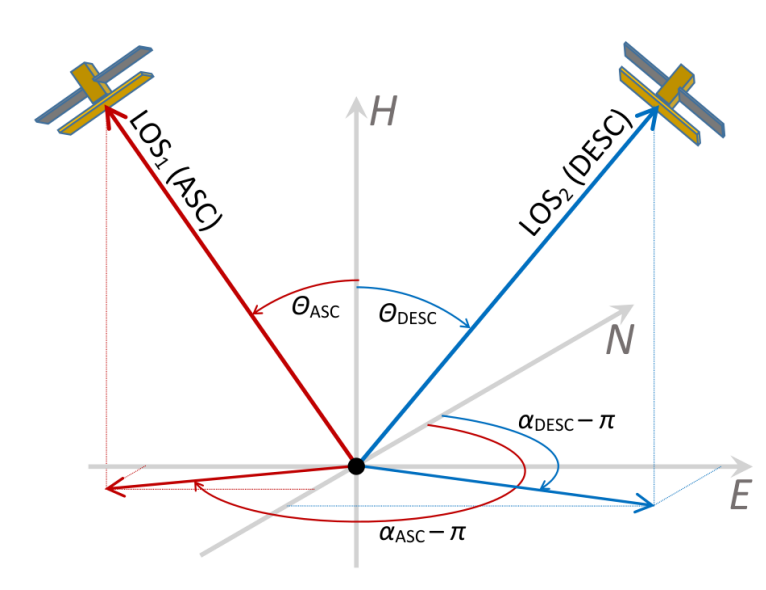


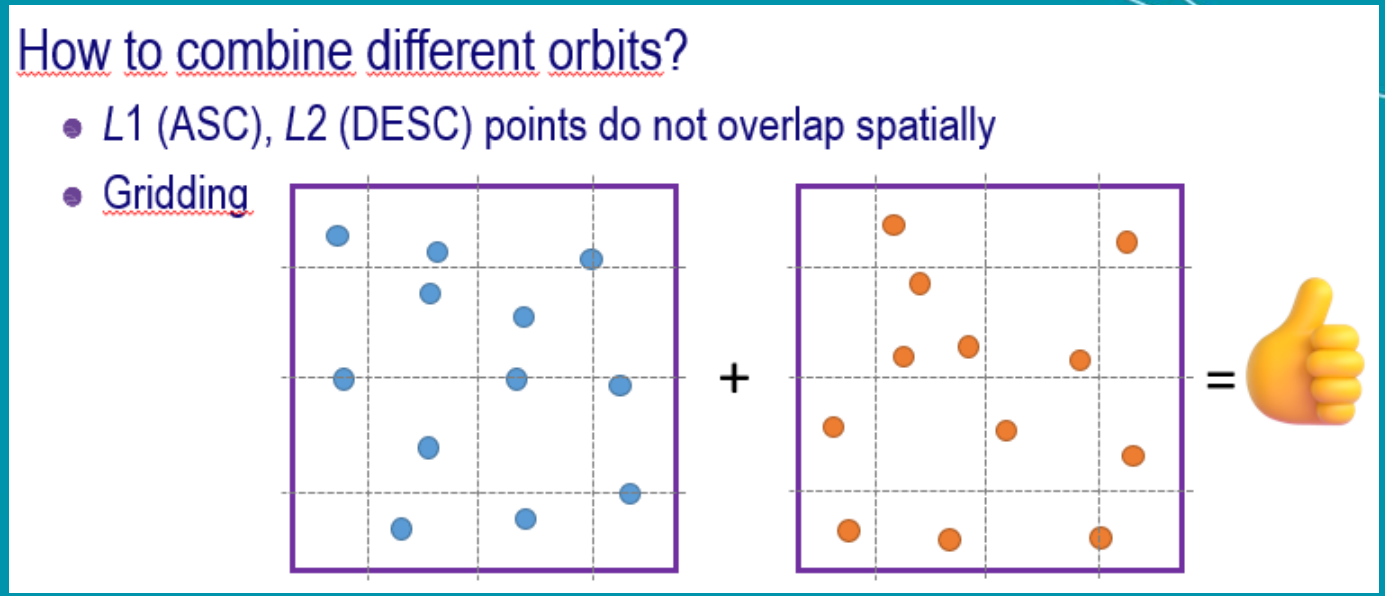
Kiik & Gruno, Horisont 2019/1



Vertical displacements of surface and objects on the ground from InSAR analyses



Trigonometric relations between 1D LOS and 3D NEH displacements



- Vertical displacement solutions
  - Regular grids (with 20 m*20 m pixels)
  - Precision of vertical displacements 2-3 mm

Details can be found from paper: Oja, T., Gruno, A. (2023) **Monitoring of millimeter-scale deformations in Tallinn using repeated leveling and PS-InSAR analysis of Sentinel-1 data**. Advances in Geodesy and Geoinformation, Vol. 72, No 1

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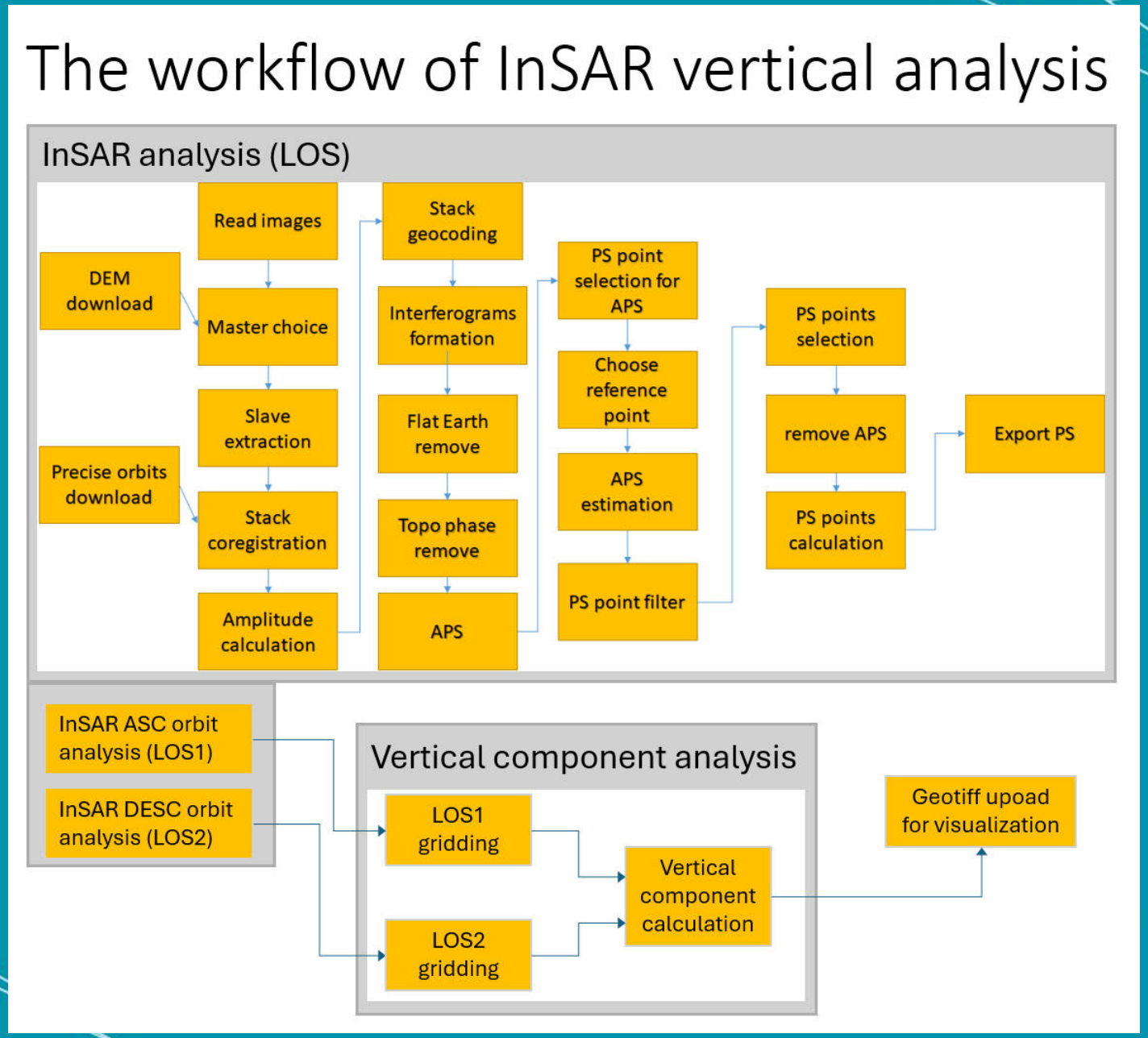
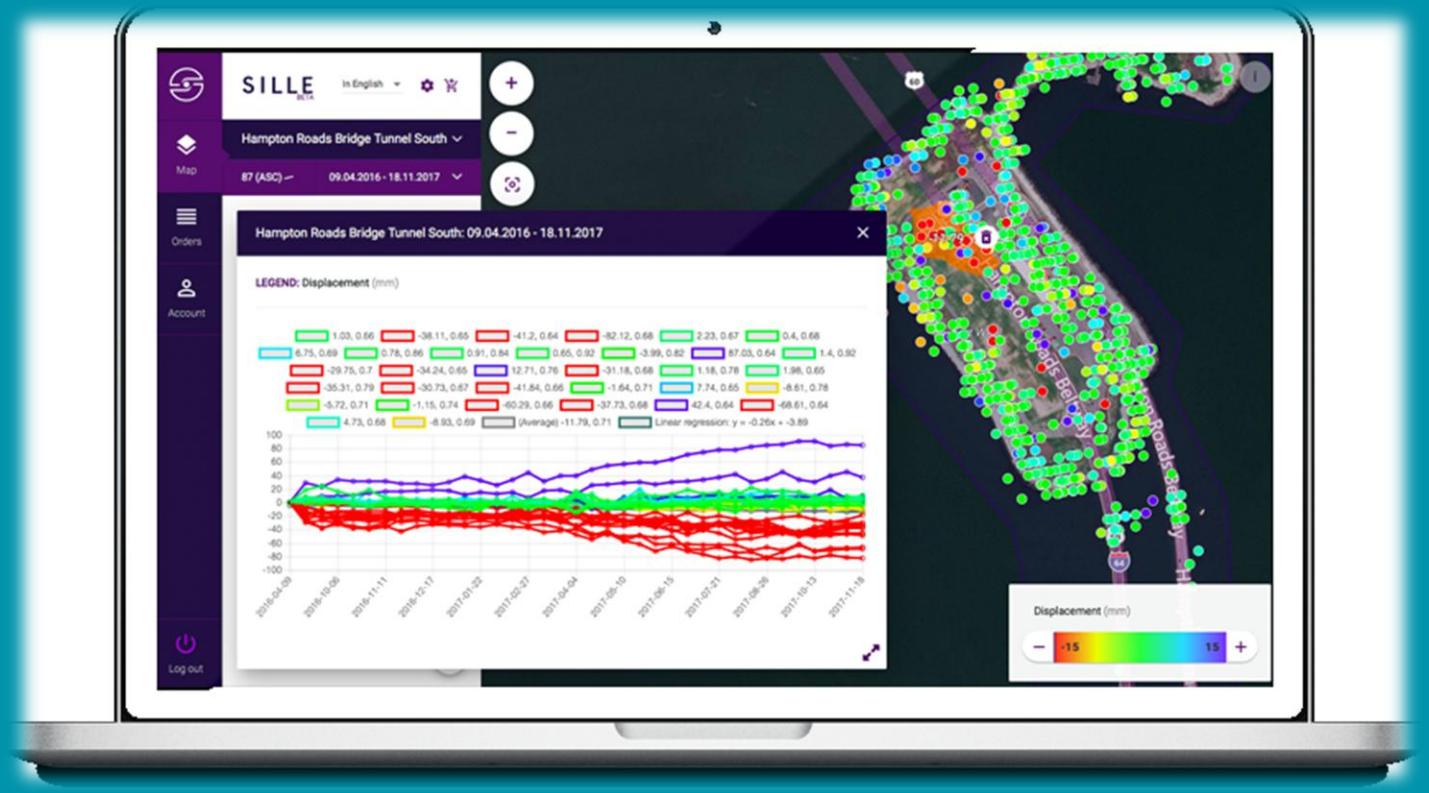
Vertical displacement computation by Sille.Space e-service:



Sille.Space – satellite-based monitoring e-service

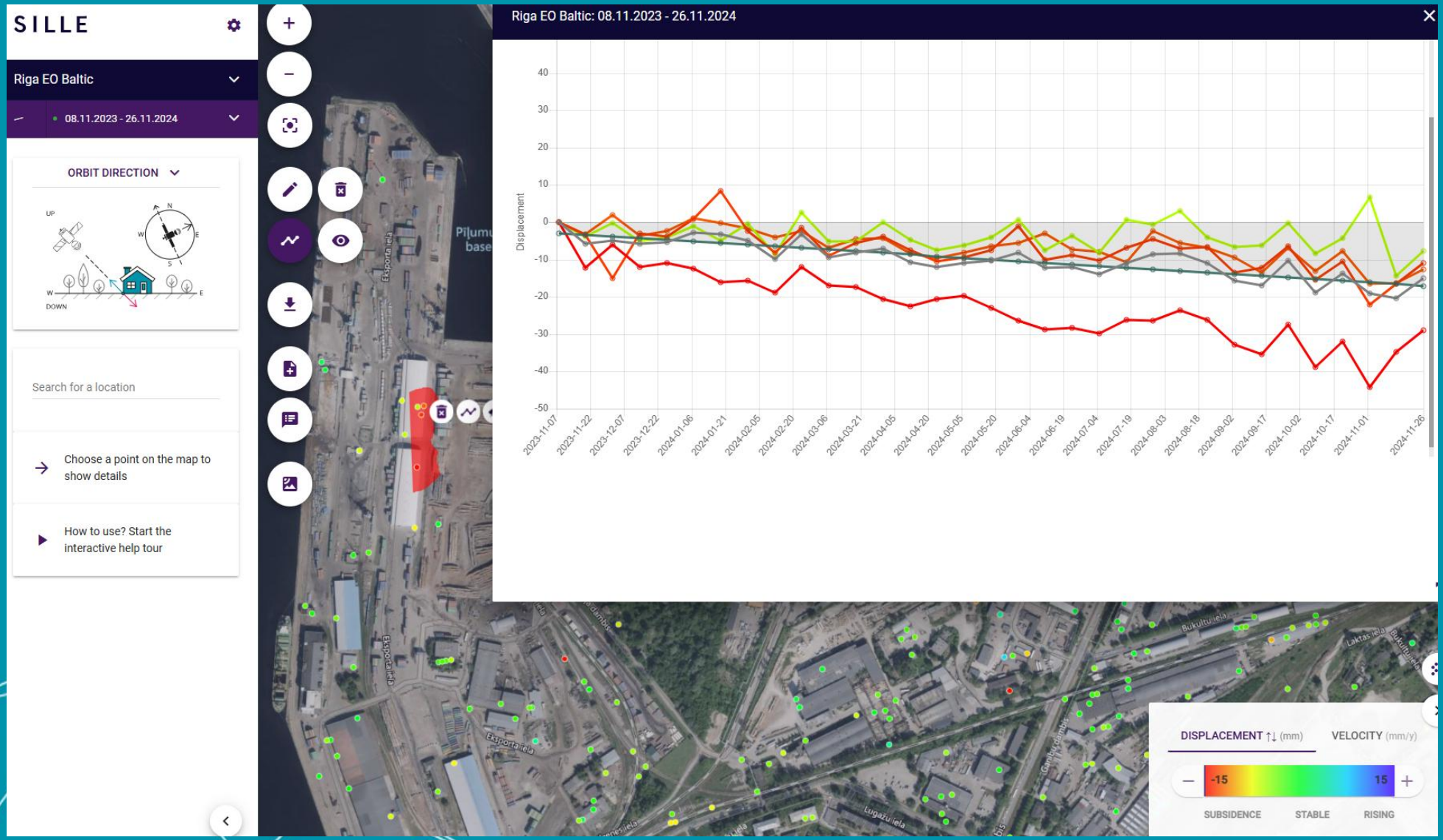
- Hazards, changes, processes and damage can be identified and monitored:
  - Infrastructure in urban areas
  - Buildings, dams
  - Mining, landslides
  - Ports, airports
  - Tunnels, railways
  - Power-/pipelines
  - Groundwater/oil extraction
  - …



www.sille.space

Datel's service for visualizing InSAR analyses results

SILLE - an early warning system for infrastructure monitoring



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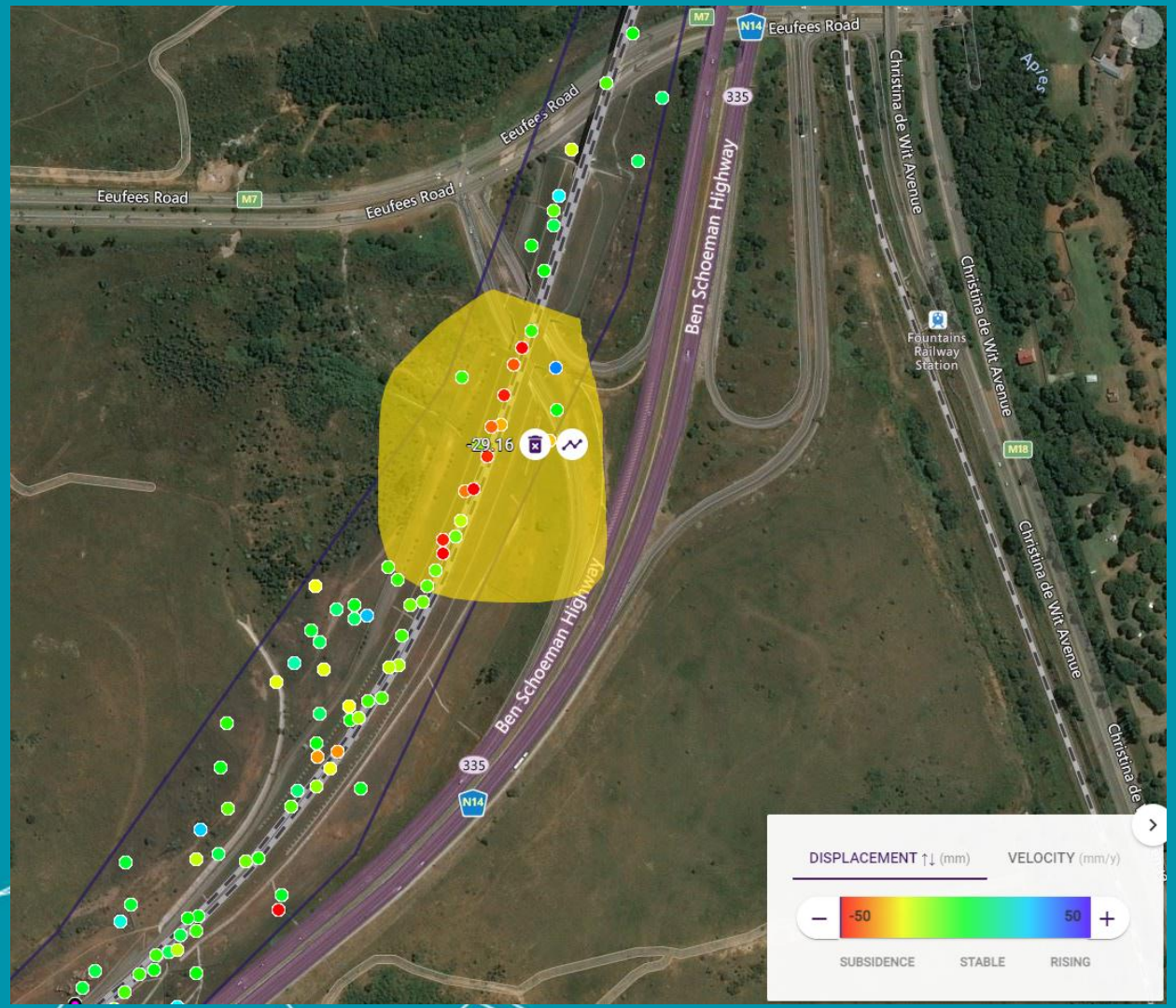

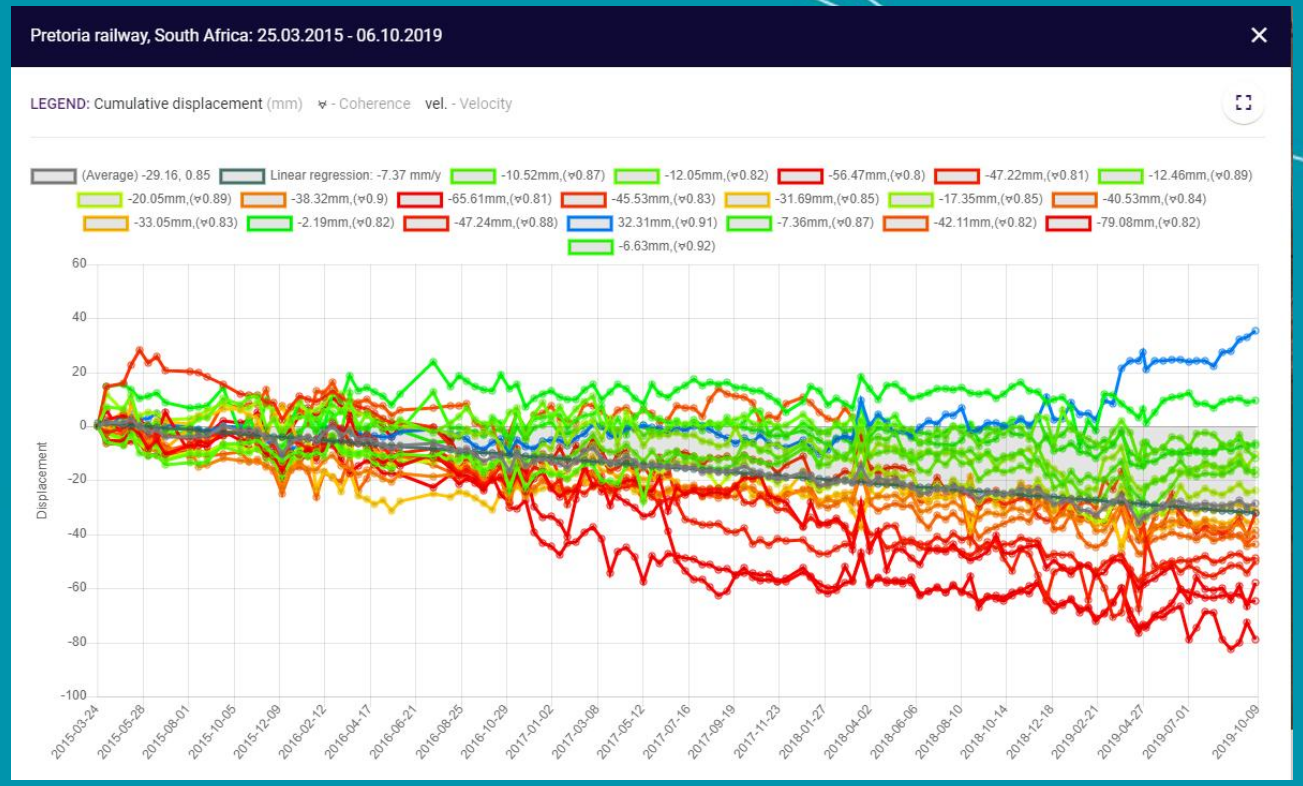

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Thank you!

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Infrastructure and Settlement Monitoring Service

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Infrastructure and settlement monitoring application allows to observe subsidence in cities with population more than 60 thousand. The service supports monitoring and analyzing how construction activities affect nearby buildings/infrastructure, identifying and preempting potential issues. InSAR analysis shows vertical displacement grids for the biggest 10 Baltic cities. The grids are derived from the persistent scattered interferometric analysis (PS-InSAR) of Sentinel-1 satellite radar images. Multitemporal InSAR analyzes for the time period of one year are calculated monthly. The precision of InSAR derived displacements is 2 mm on average.

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