Satellite-based InSAR Geodesy and Collocation with GNSS

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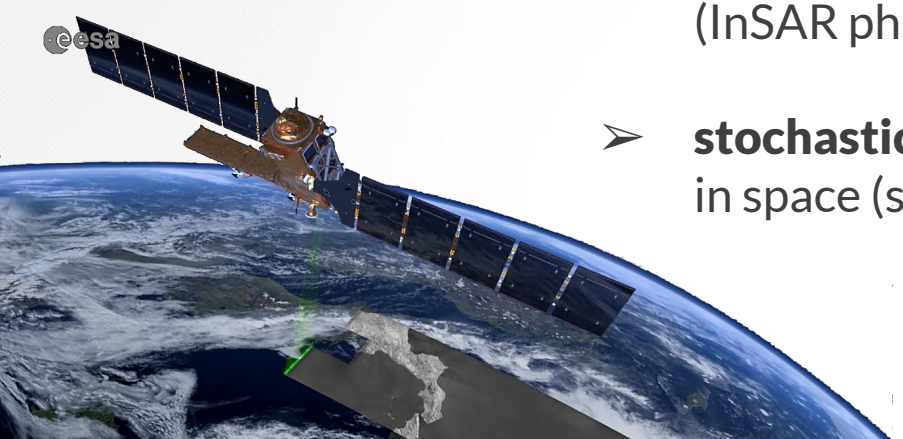
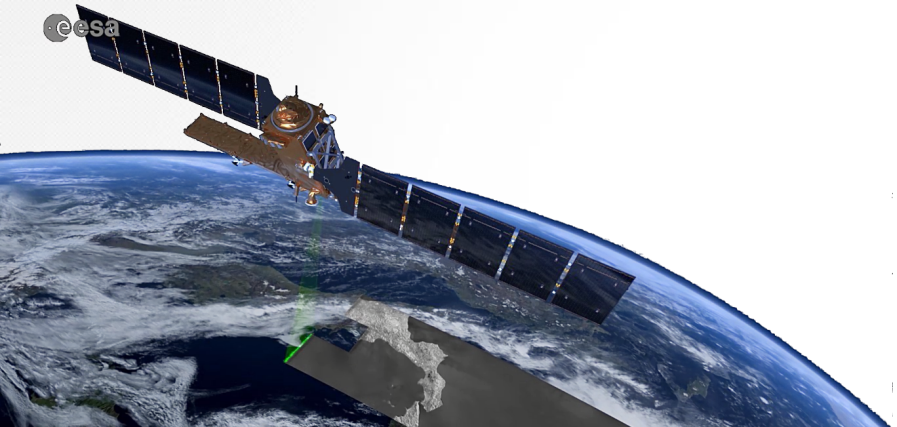
InSAR

InSAR (Interferometric **S**ynthetic **A**perture **R**adar)

- **precise radar imaging**
  (SAR point positioning)
- **millimetre-level deformation monitoring**
  (InSAR phase measurements)
- **stochastic properties of measurements**
  in space (sampling), and time (Earth's dynamics)

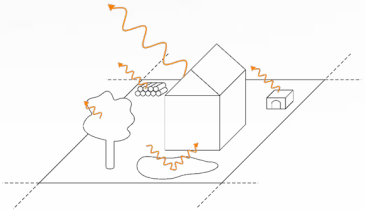


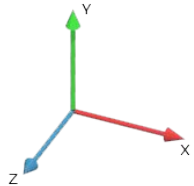
“Why and how to collocate InSAR and GNSS?”



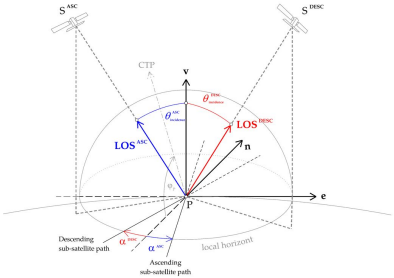
InSAR vs. “Conventional” geodetic techniques

- different **datum (ref. frame)**
- different **geometry**
- different **benchmarks**
- different **observation time**





$\{\Delta X, \Delta Y, \Delta Z\}; \{\Delta h\}$



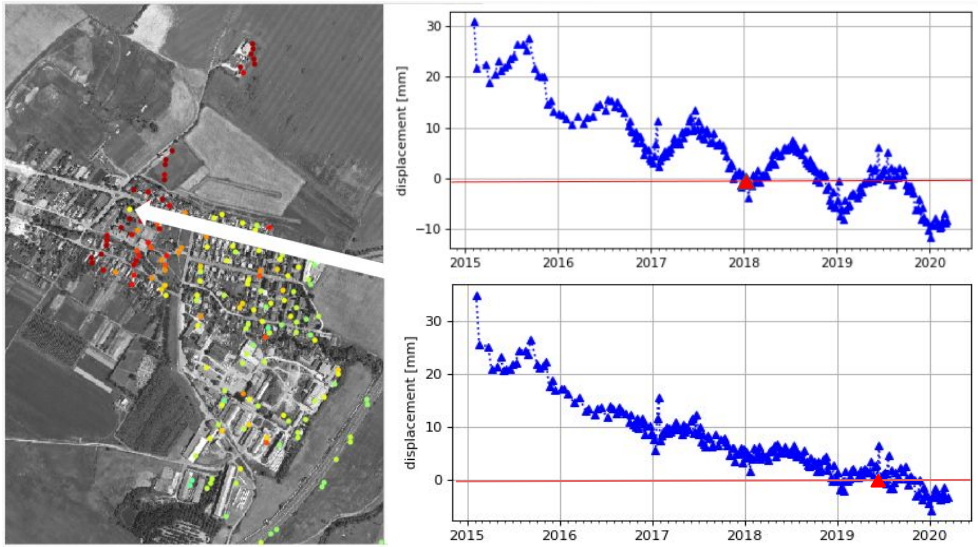
$\{\Delta LOS\}_{ASC}; \{\Delta LOS\}_{DSC}$

Limitations and challenges for InSAR geodesy

1. InSAR network = “free network”

- **1 spatial reference**
  (arbitrary ref. point with postulated zero-displacement)
- **1 temporal reference**
  (arbitrary ref. epoch)

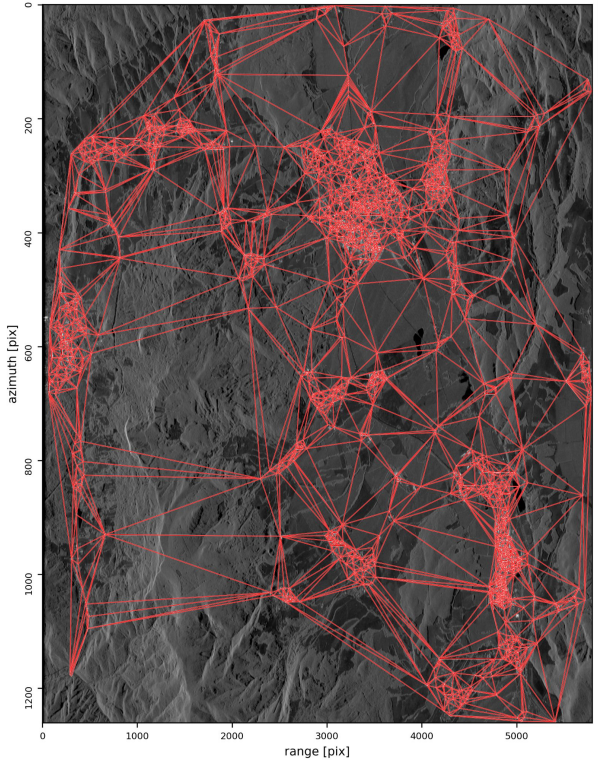
The same point, different processing (reference datum):



Limitations and challenges for InSAR geodesy

1. InSAR network = “free network”

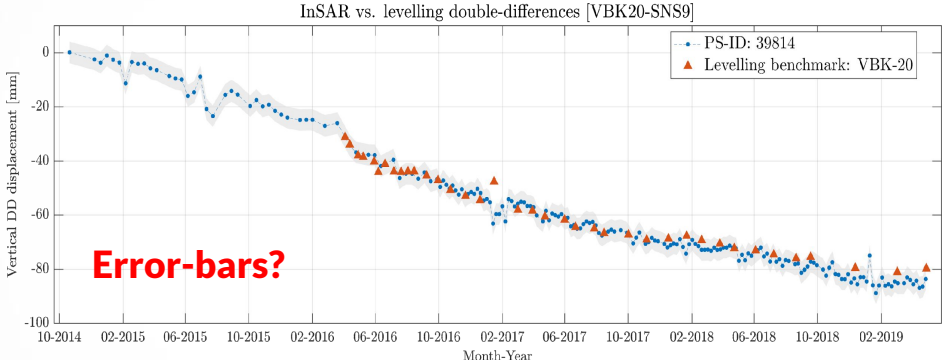
- we **do not choose** the position of the points a priori, position is given by the presence of objects (of natural reflectors) on the ground
- **without reference** to reference system, e.g. ETRS89, EVRS

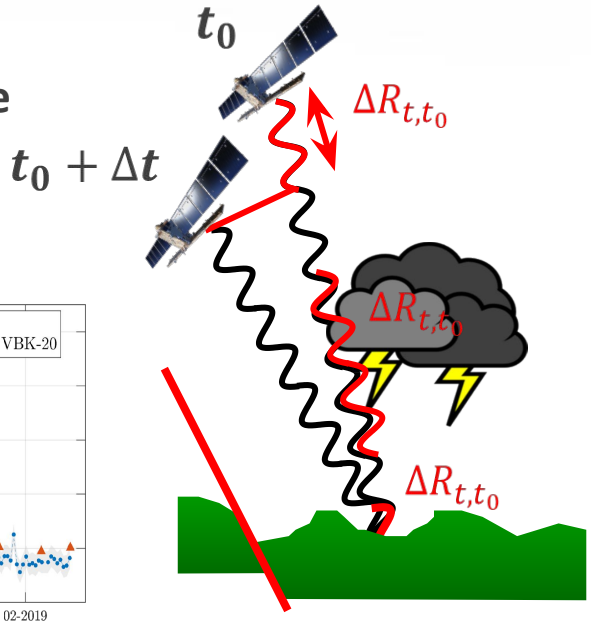


Limitations and challenges for InSAR geodesy

2. Very high theoretical precision < 1 mm, but **local/relative**

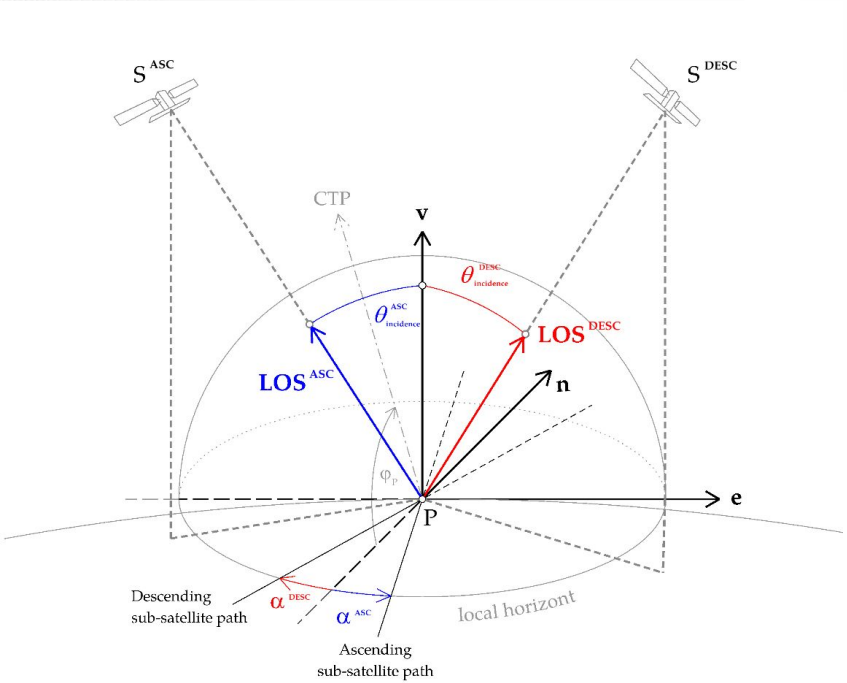
- accuracy **significantly decreases** over large PS networks
- **positional accuracy is significantly worse in comparison to accuracy of the differences in time**
- apriori variances not known (in comparison with GNSS)





Limitations and challenges for InSAR geodesy

3. difficult-to-interpret 1D “line-of-sight” (LOS) geometry of different satellite tracks
debatable assumptions used to transform to local 3D system



Limitations and challenges for InSAR geodesy

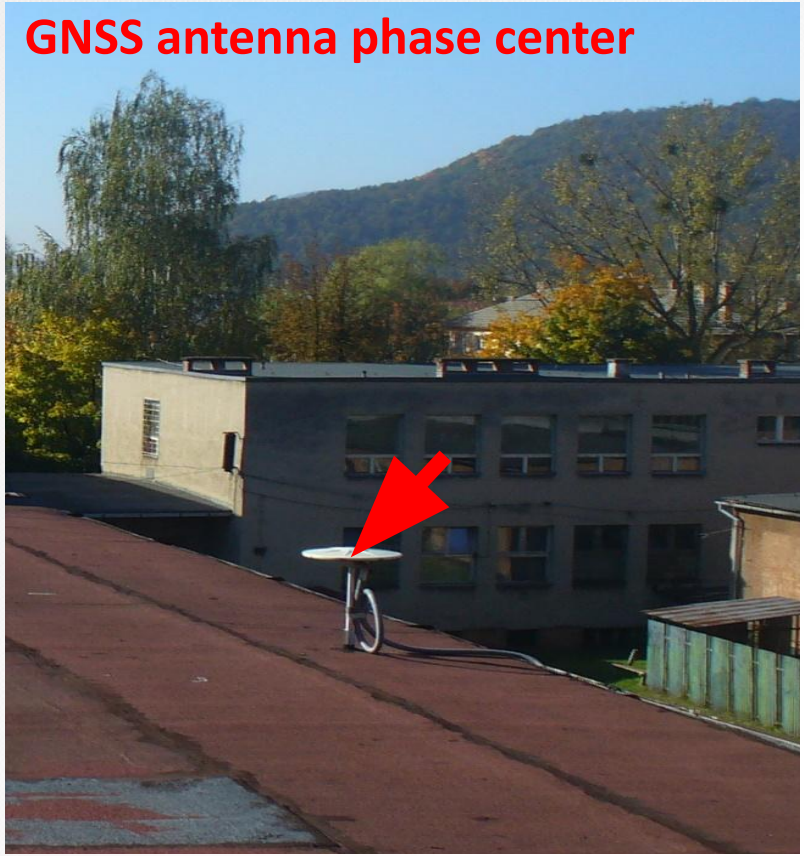
Solution:

Collocation with permanent GNSS measurements

Ensure:

- **linking of InSAR networks from individual Sentinel-1 satellite tracks**
- **InSAR measurements in the national implementation of the ETRS89 system**
- **absolute deformation time series**
- **calibration of systematic effects**

InSAR & GNSS



Artificial SAR reflector

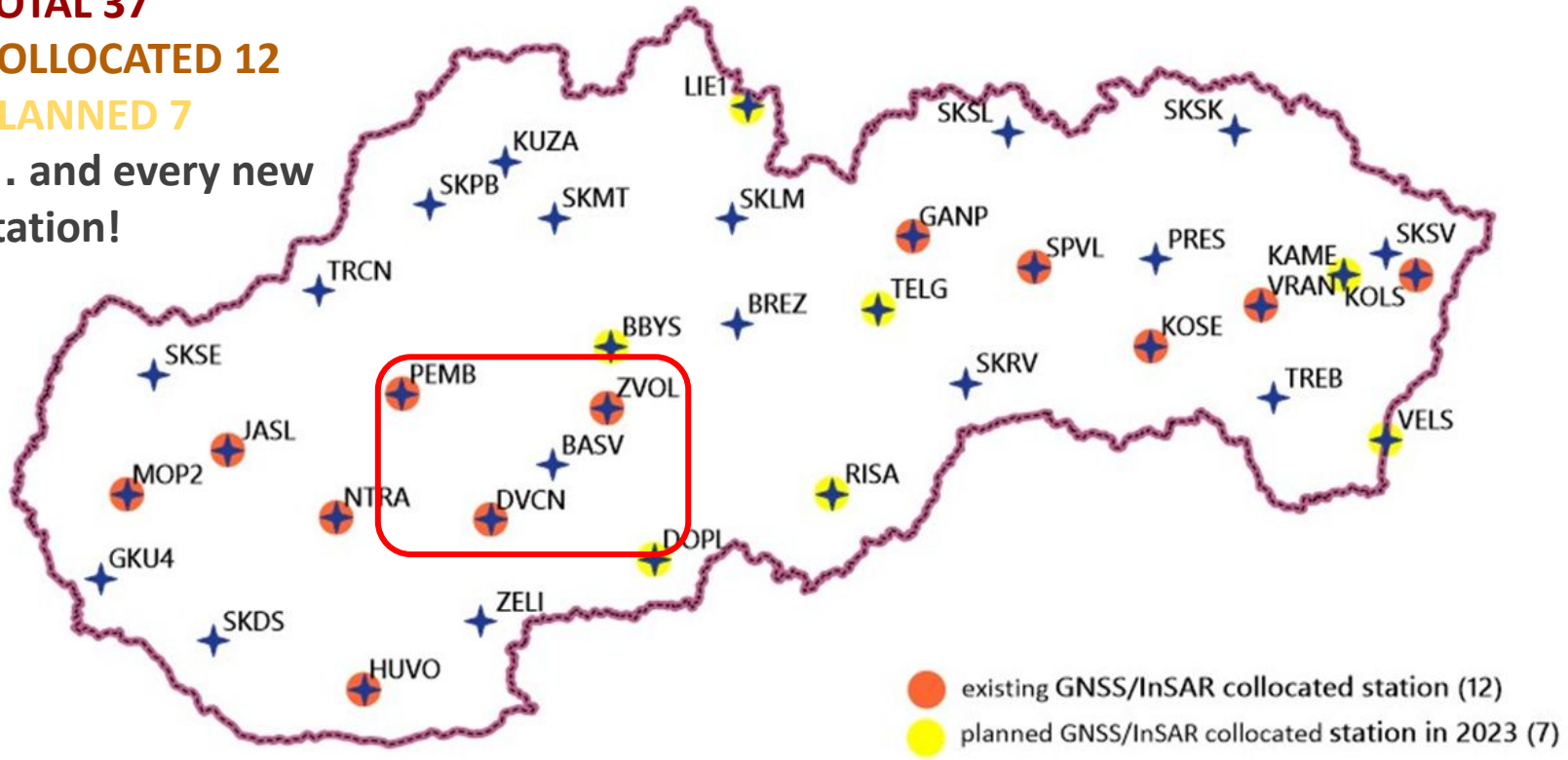
A.) Passive: corner reflector

B.) Active: radar transponder

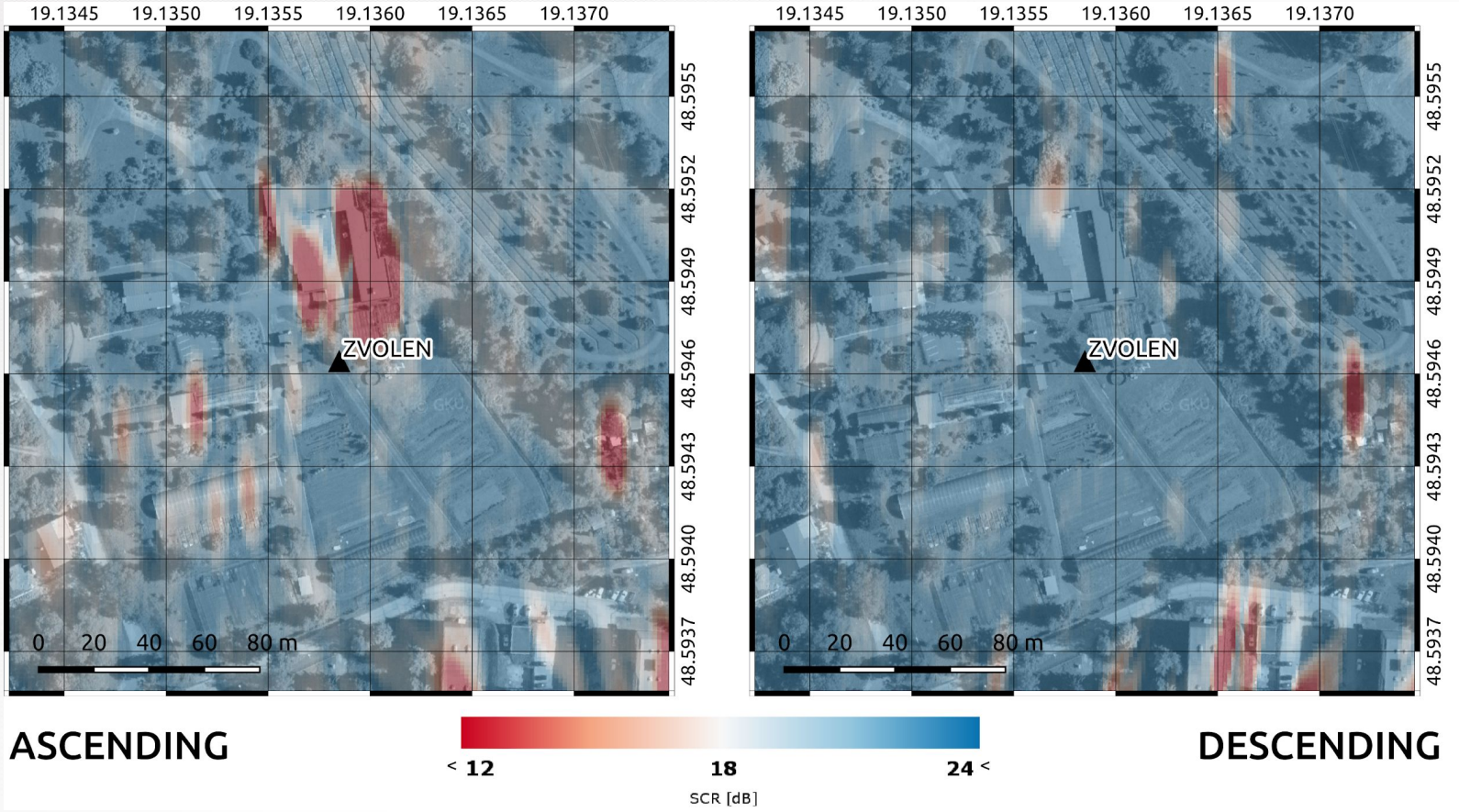
Known phase center

Practical experiment - SKPOS InSAR & GNSS collocation

TOTAL 37
COLLOCATED 12
PLANNED 7
… and every new station!

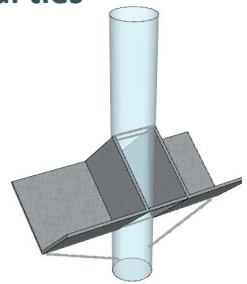


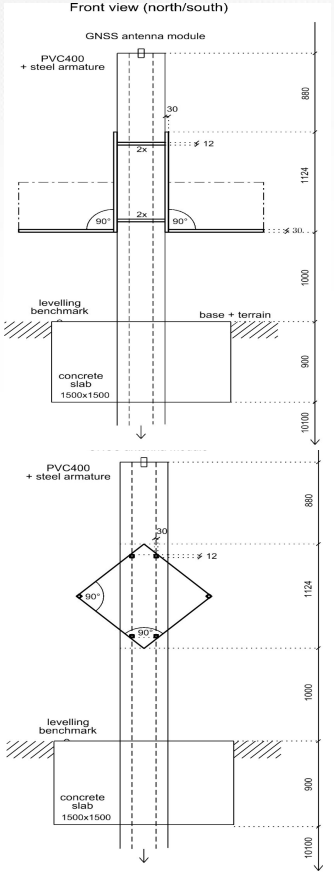
InSAR GNSS collocation site suitability - SCR - before



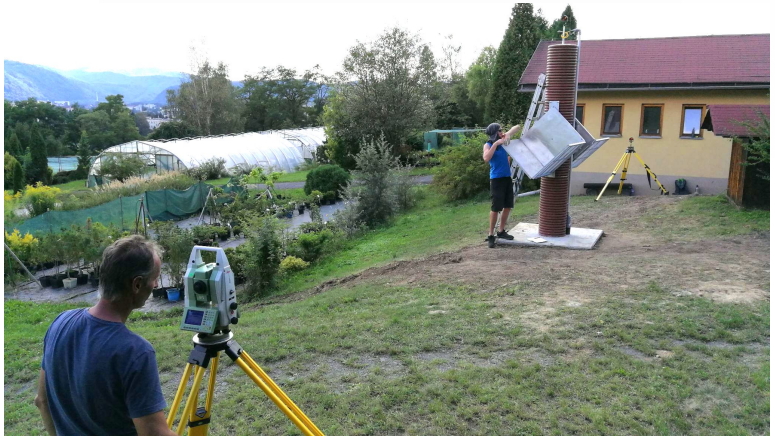
Collocation station - design

- **InSAR:**
  - no secondary reflection
  - > 1 m over terrain
  - > 20 dB SCR
- **GNSS:**
  - no effect multipath
  - > 1.3 m over InSAR reflector
- robust construction
- methodology for local ties determination (~ mm level)





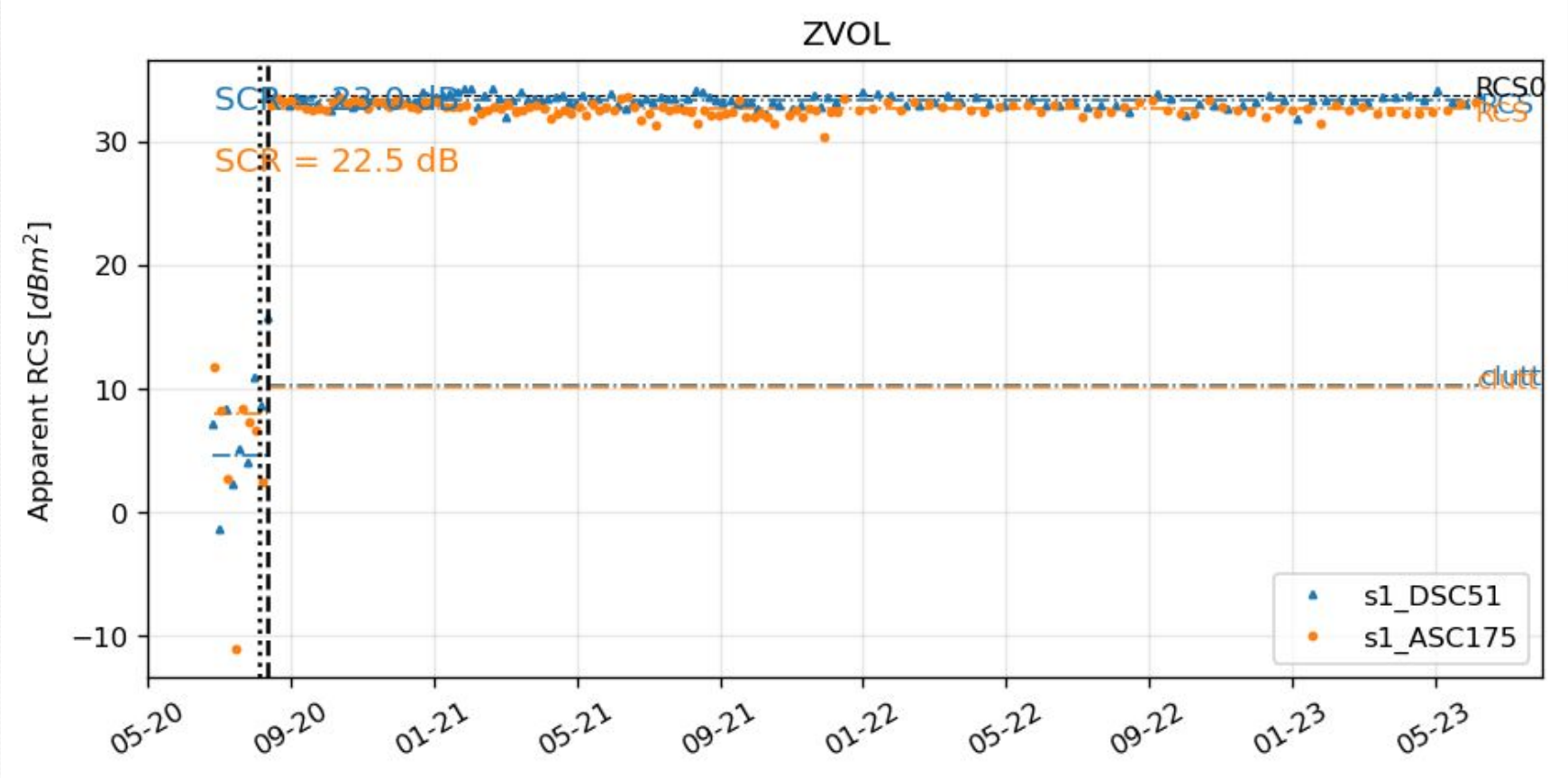
InSAR GNSS phase center local ties determination



ZVOL (Zvolen, SR)

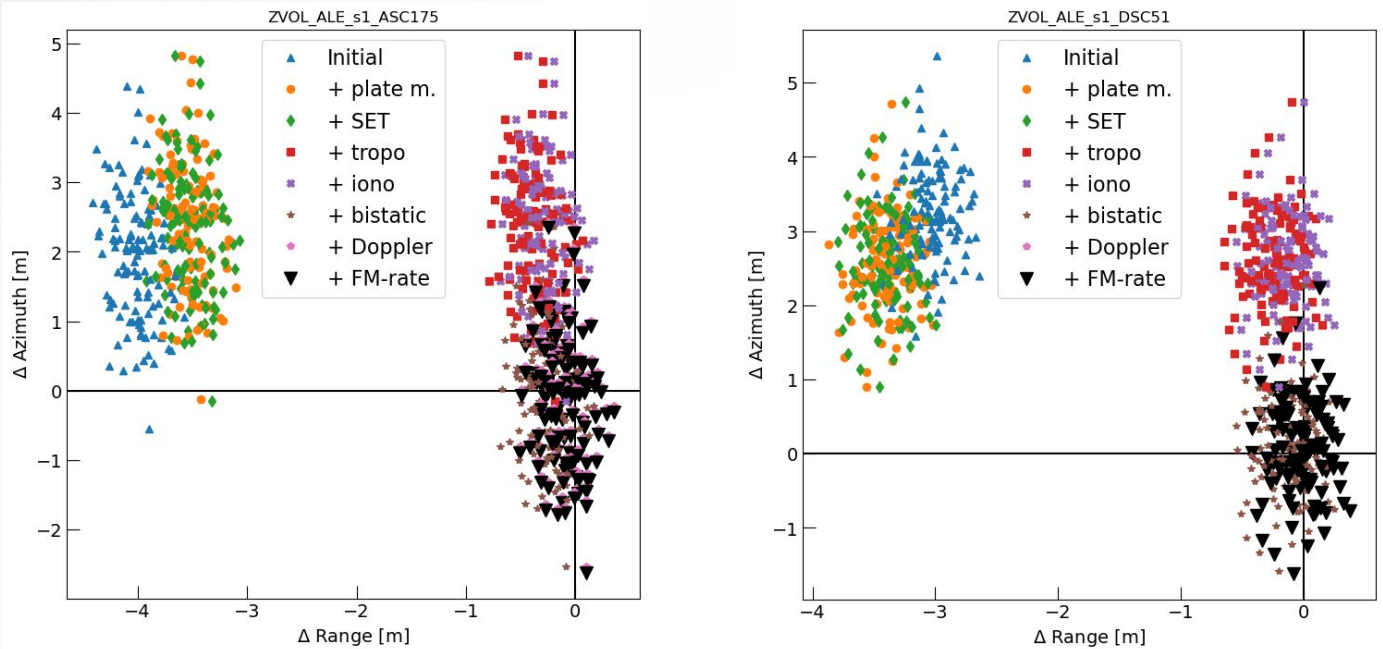
SKPOS®

InSAR GNSS collocation site suitability - SCR - after



Absolute positioning errors

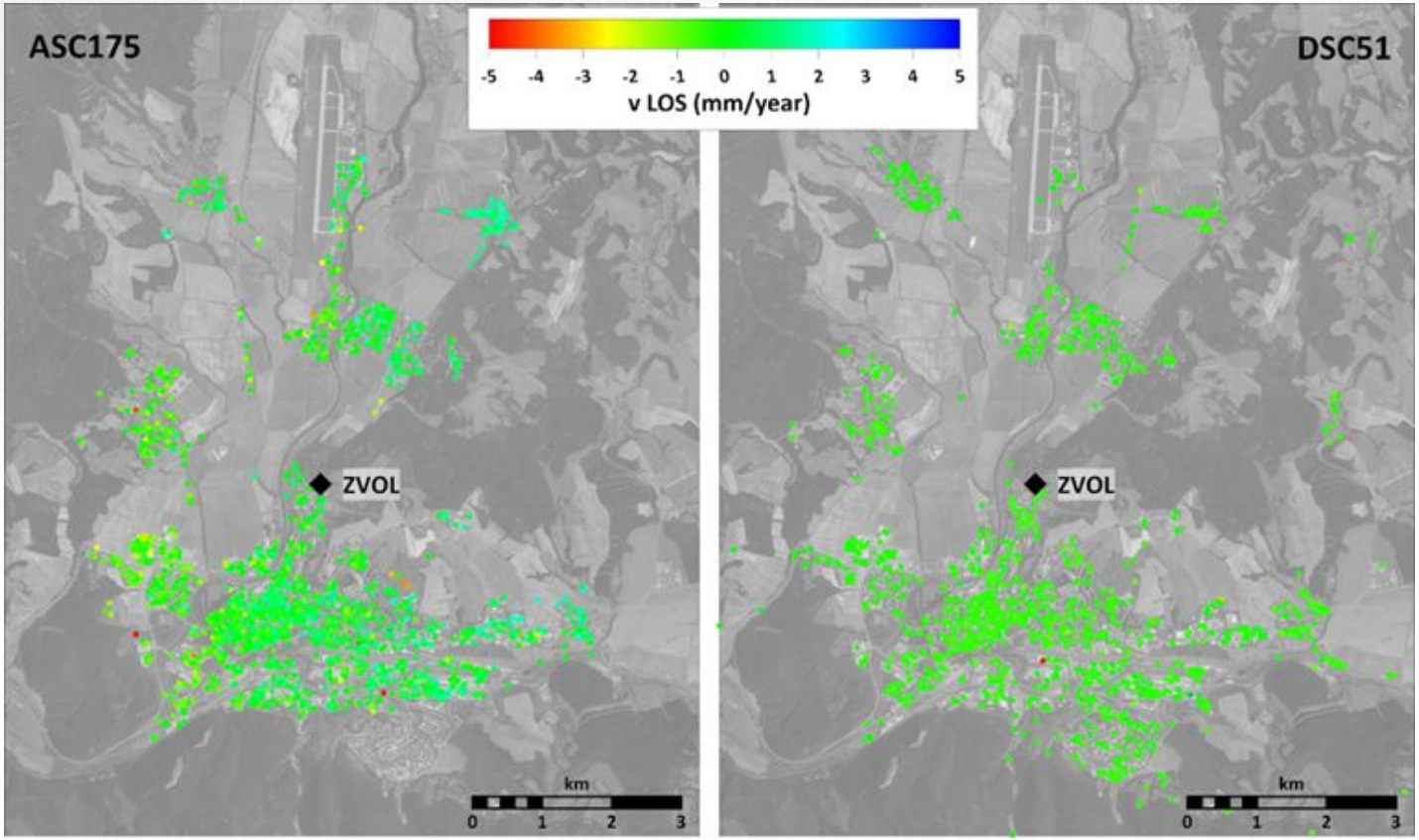
epoch-wise differences between the detected subpixel peak coordinates and the expected radar coordinates computed from the precise TRF positions via the inverse range-Doppler equations, while reintroducing all SAR timing biases (similar like ESA ETAD)



Local InSAR processing results

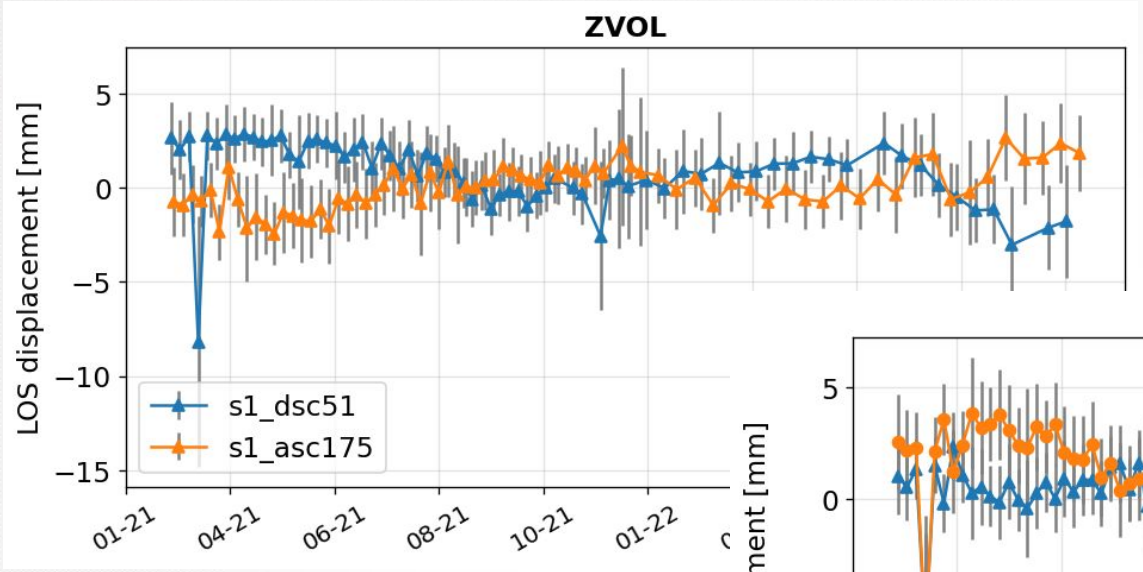
GECORIS
(Czikhardt et al. 2021)

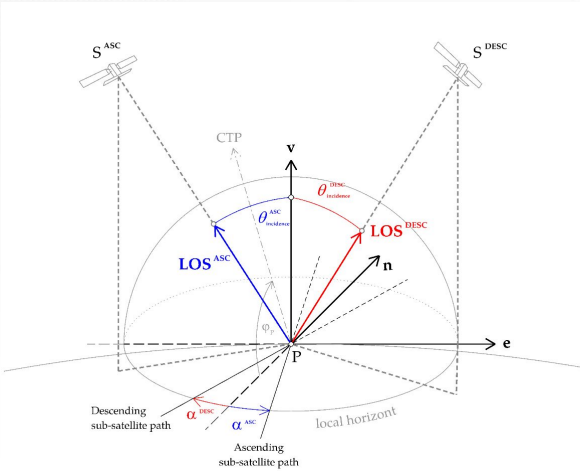
SNT1 ASC175/DSC51
2021/02 - 2022/10

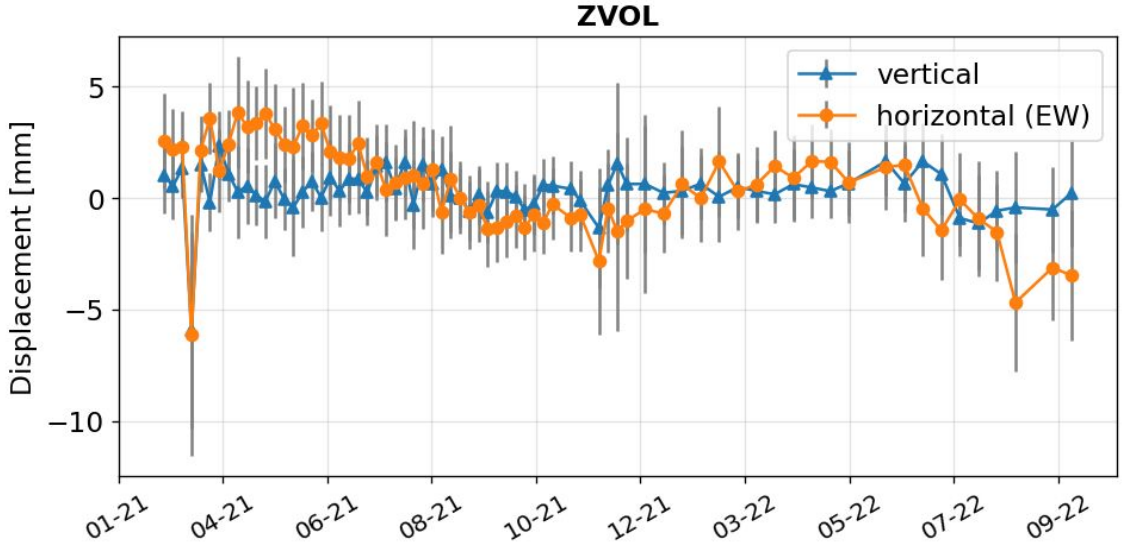


Czikhardt et al. (2021): Gecoris: An open-source toolbox for analyzing time series of corner reflectors in insar geodesy, DOI: 10.3390/rs13050926

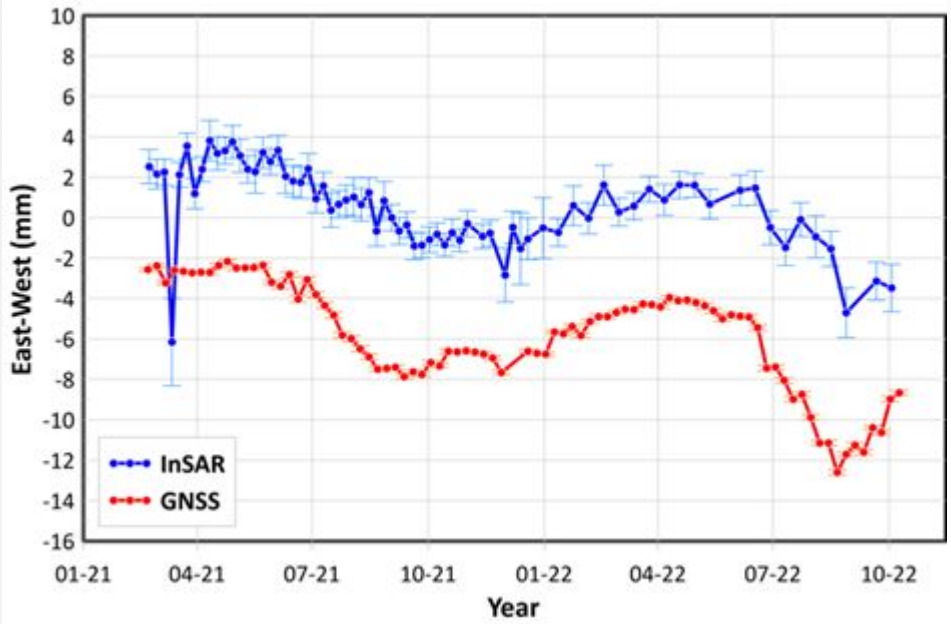
LOS displacement and decomposition

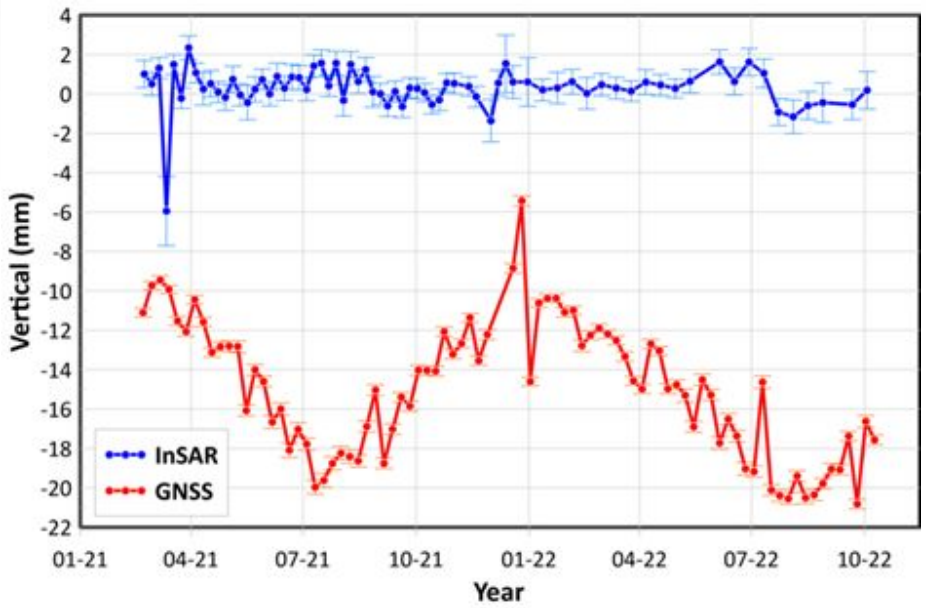






InSAR vs. GNSS





Conclusion

"InSAR using collocation stations has the characteristics of a geodetic technique for monitoring displacements as we know them - with known accuracy characteristics, and minimized systematic errors."

Questions?