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Tropospheric delay models based on GNSS and spaceborne SAR interferometry at ETH Zurich

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Motivation

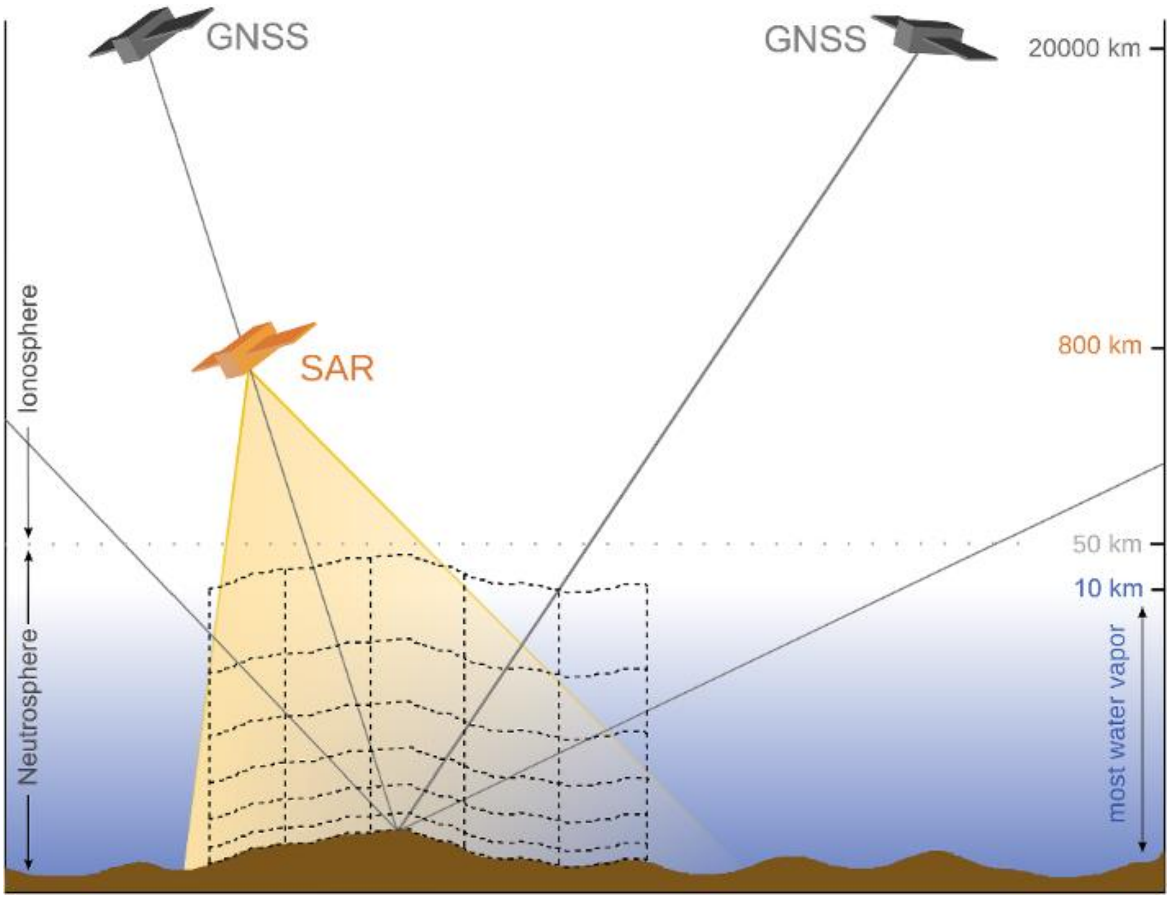
- All space-borne microwave techniques are subjected to the atmospheric delay.
- The delays estimated by one technique can be useful for mutual corrections.

GNSS

- high temporal resolution
- low spatial density

SAR

- only relative measurements
- high spatial density
- low temporal resolution (repeat pass of several days)



source: Heublein M. et al. 2018

Objectives

1. Comparison of the tropospheric delays derived from GNSS and SAR persistent scatterer interferometry (PSI)

2. Study on the tropospheric models based on combination of the techniques (for example for NWP assimilation)

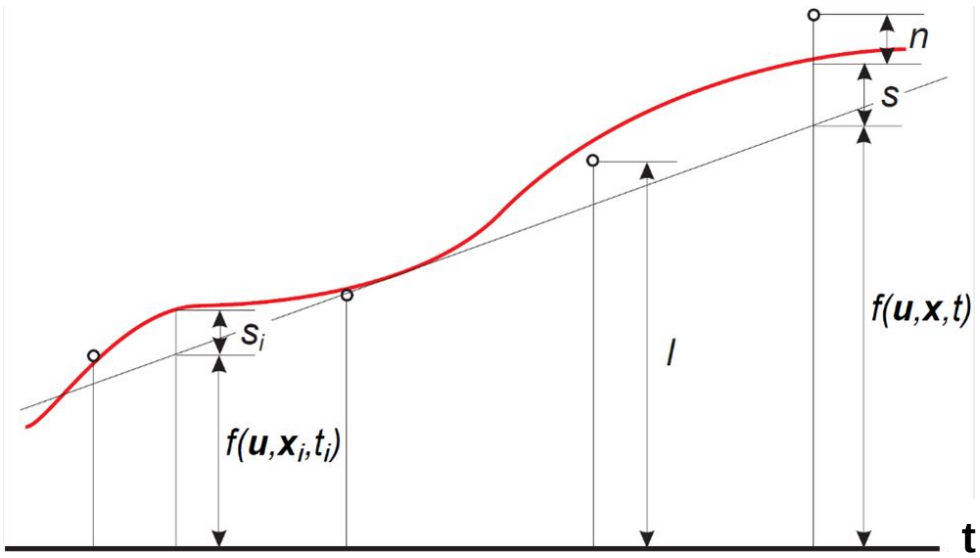
3. First attempts of application of GNSS-based tropospheric models into SAR processing in two case-studies:
   - Switzerland
   - Hawaii

Methodology – GNSS interpolation

- COMEDIE: least-squares collocation software developed at ETH Zürich
- Stochastic and deterministic interpolation and screening of meteorological/tropospheric data

$$l = f(u, x, t) + s(C_{ss}, x, t) + n$$

f: deterministic function
s: stochastic correlated signal
n: stochastic uncorrelated noise



More about methodology:
Wilgan K et al. J Geod (2017)
doi.org/10.1007/s00190-016-0942-5

Difference STDs from GNSS

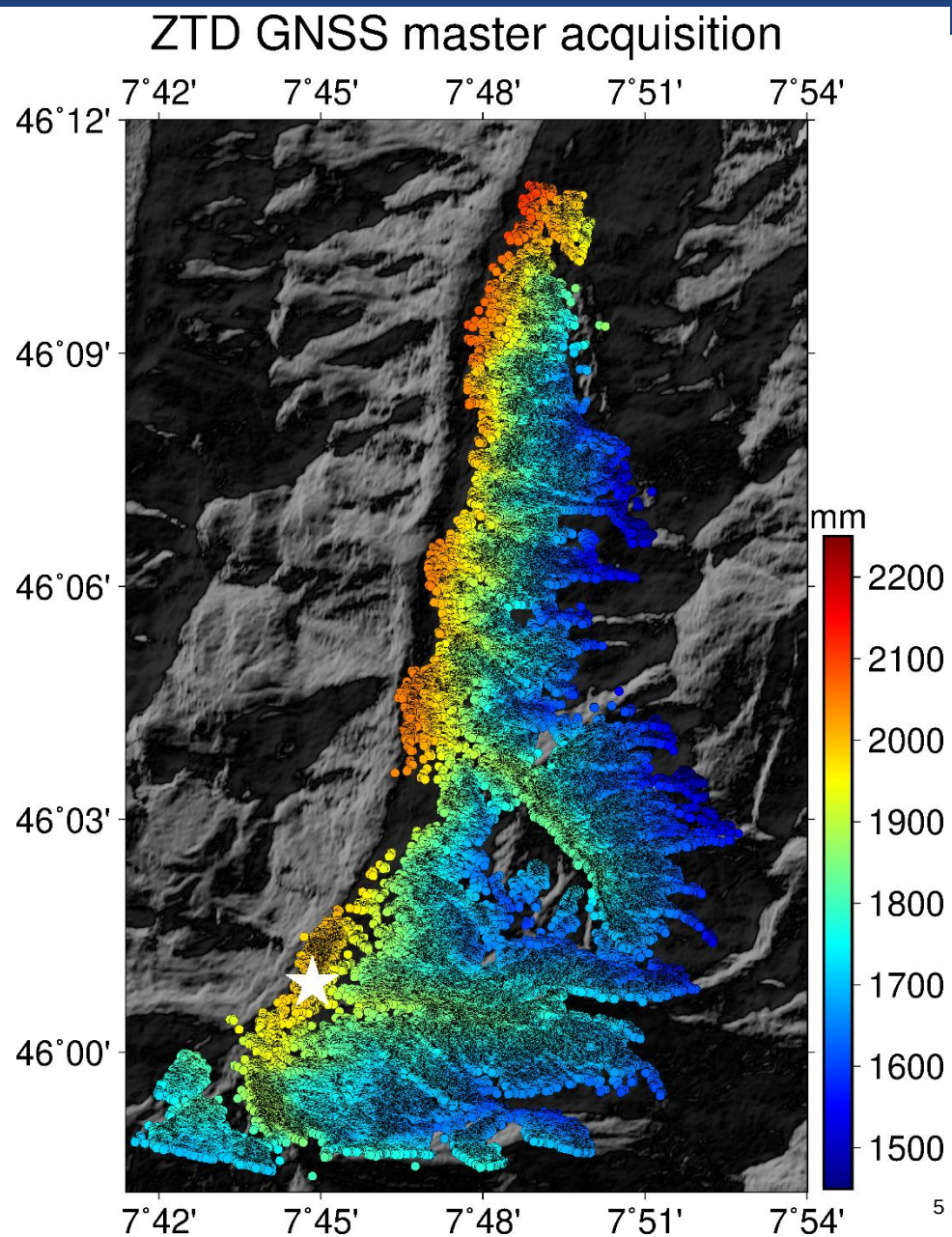
$$STD = \frac{1}{cos\theta} ZTD$$

θ – incidence angle

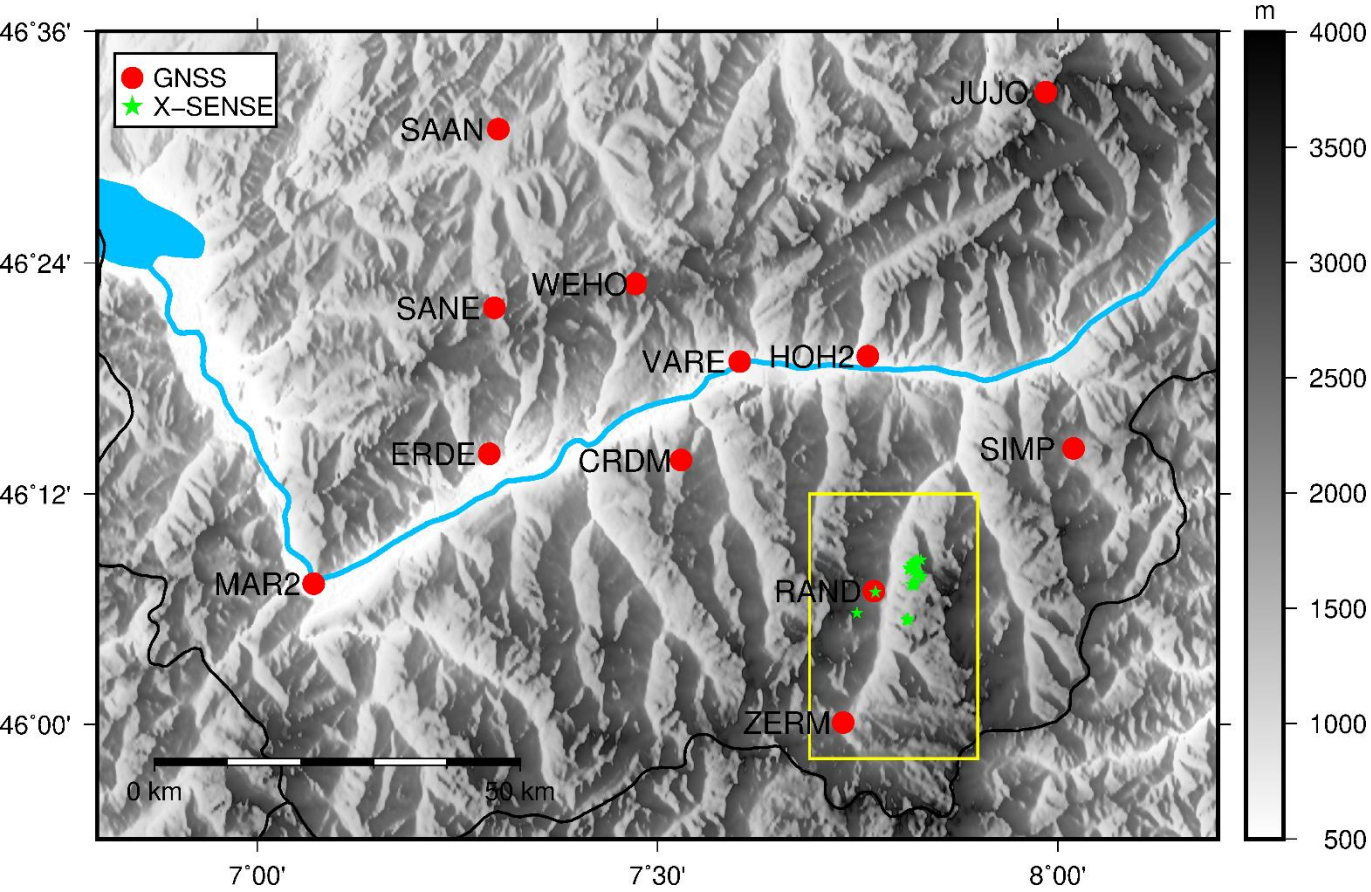
$$dSTD(x,t) = \\ = \left(STD(x,t) - STD(x,t_m)\right) \\ - \left(STD\left(x_{ref},t\right) - STD\left(x_{ref},t_m\right)\right)$$

t_m - master acquisition
x_{ref} - reference point

More about ZTD models in the Alps:
Wilgan K & Geiger A J Geod (2018)
doi.org/10.1007/s00190-018-1203-6



First comparisons – study area



Alpine region Valais, Switzerland

test area: ~12 km x 25 km
height: 1200 m – 4100 m a.s.m.l.

Data period:
2008 – 2013

29 SAR acquisitions (June – October)

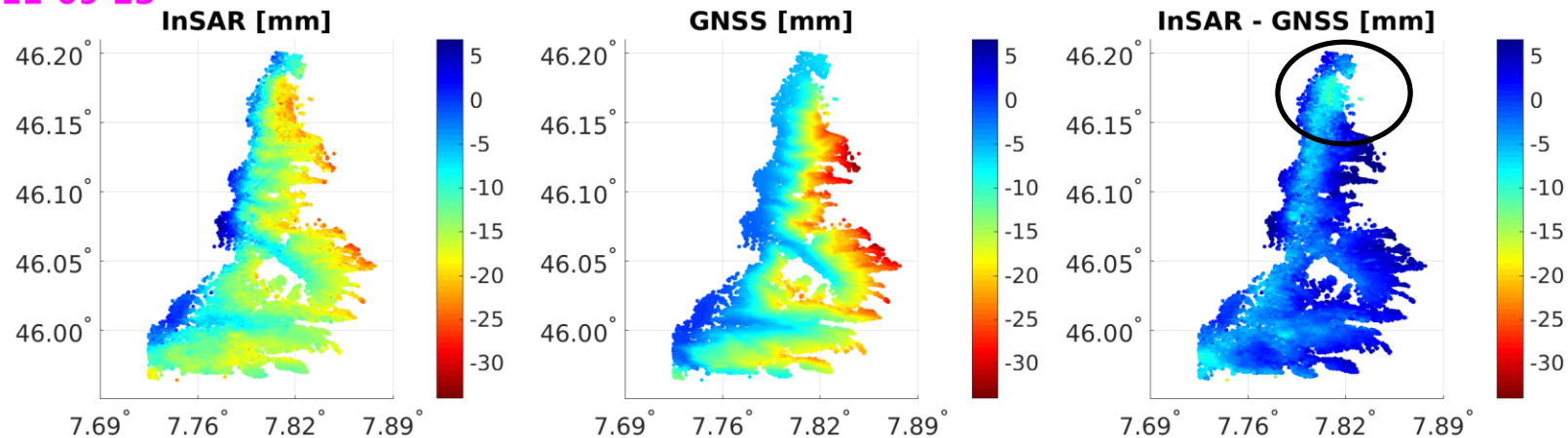
Cosmo-SkyMed
X-band, λ=3.12 cm

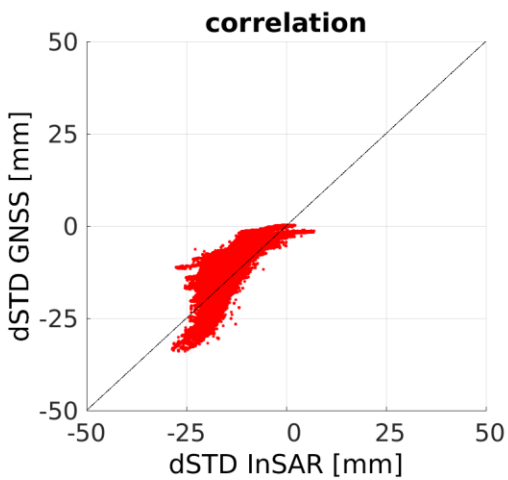
>300'000 identified persistent scatterers

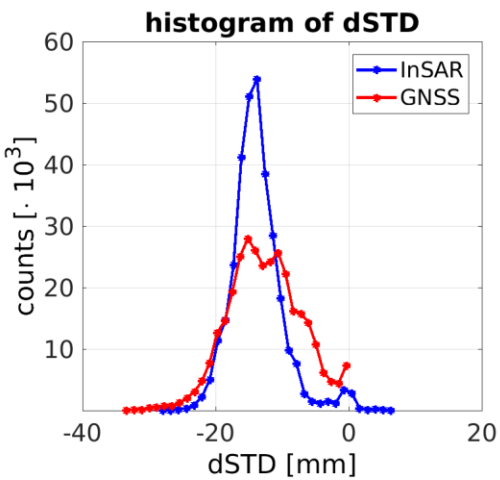
GNSS vs InSAR – good agreement

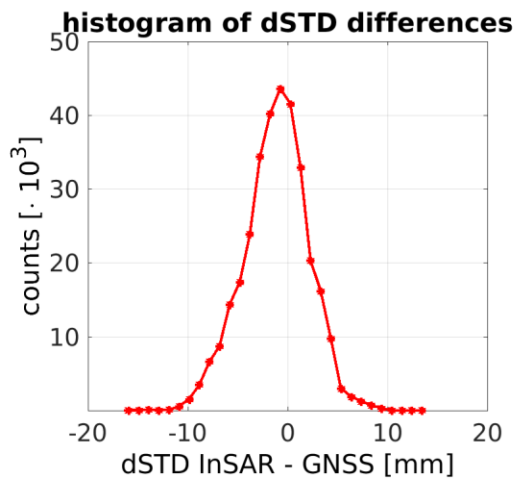
R	bias	SD
0.82 [-]	-1.2 [mm]	3.2 [mm]

2011-09-23





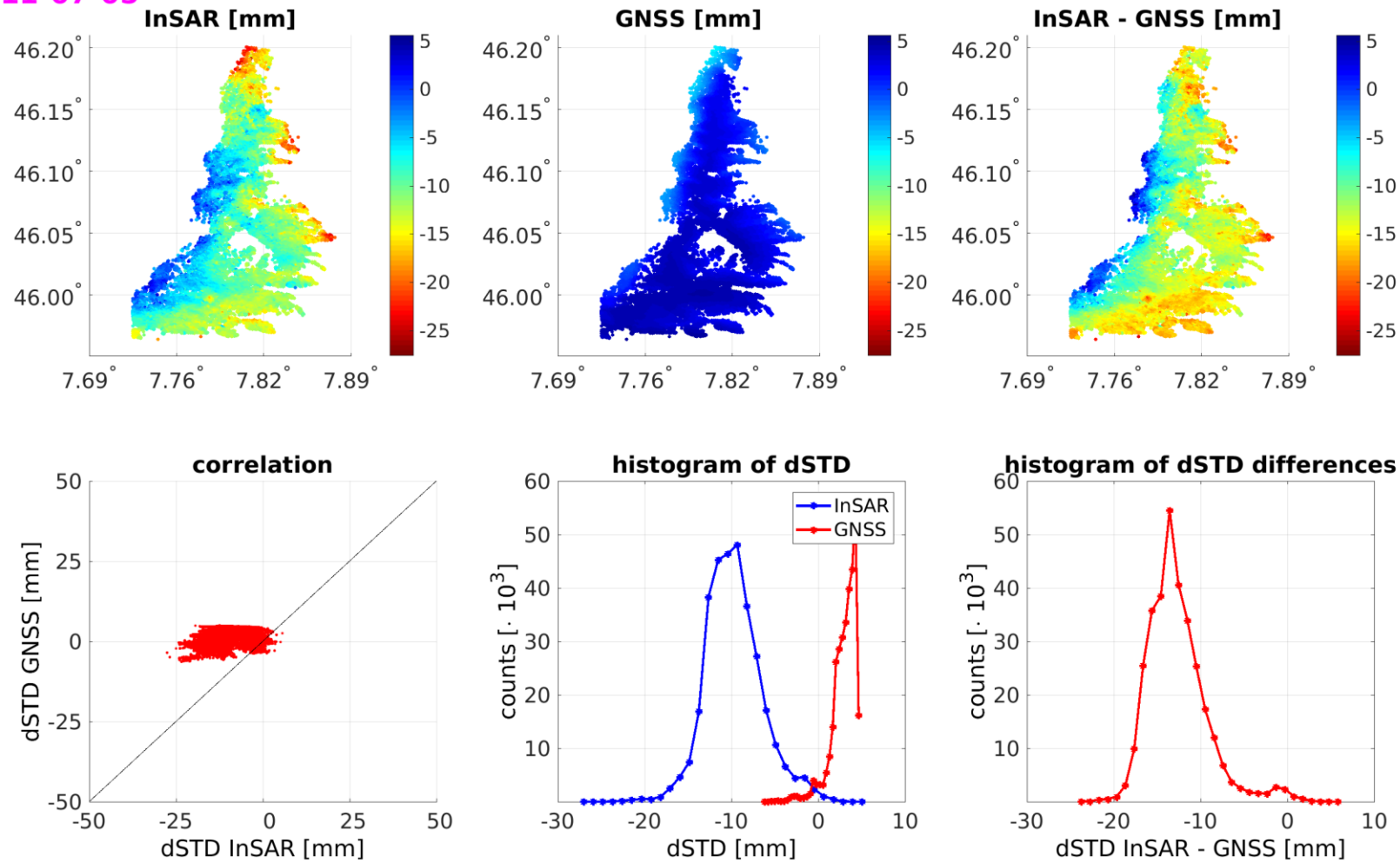




GNSS vs InSAR – poor agreement

R	bias	SD
0.07 [-]	-12.6 [mm]	3.4 [mm]

2011-07-05



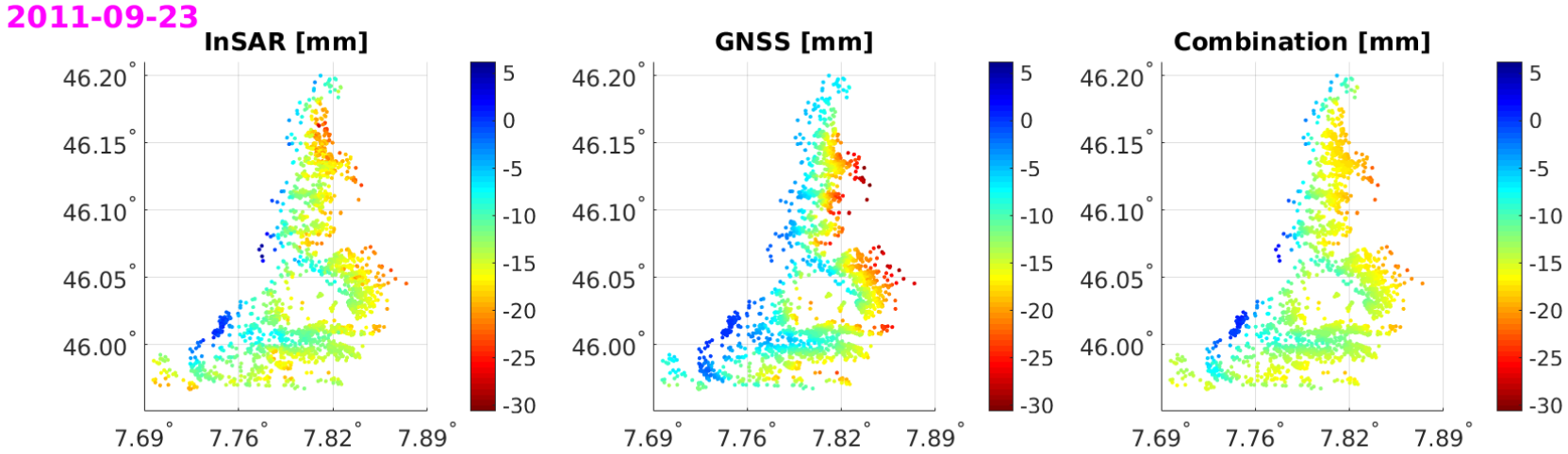
Comparisons - overview

- **7** days of **good** agreement
- **8** days of **moderate** agreement
- **8** days of **poor** agreement
- **5** days of **very poor** agreement

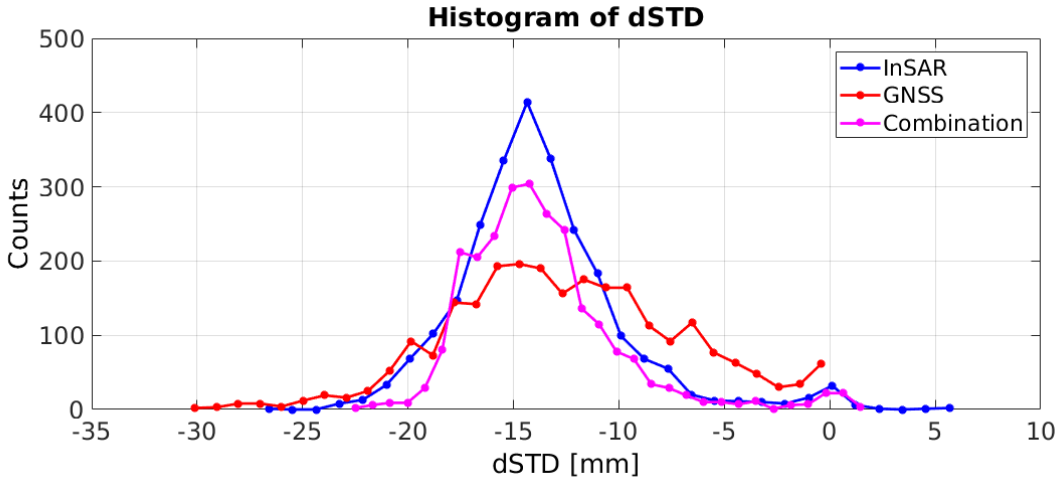
Better agreement for days with:

1. more variability of water vapor
2. more variability of GNSS dSTDs (relative to master acqiusition)
3. more stations

GNSS/SAR combination

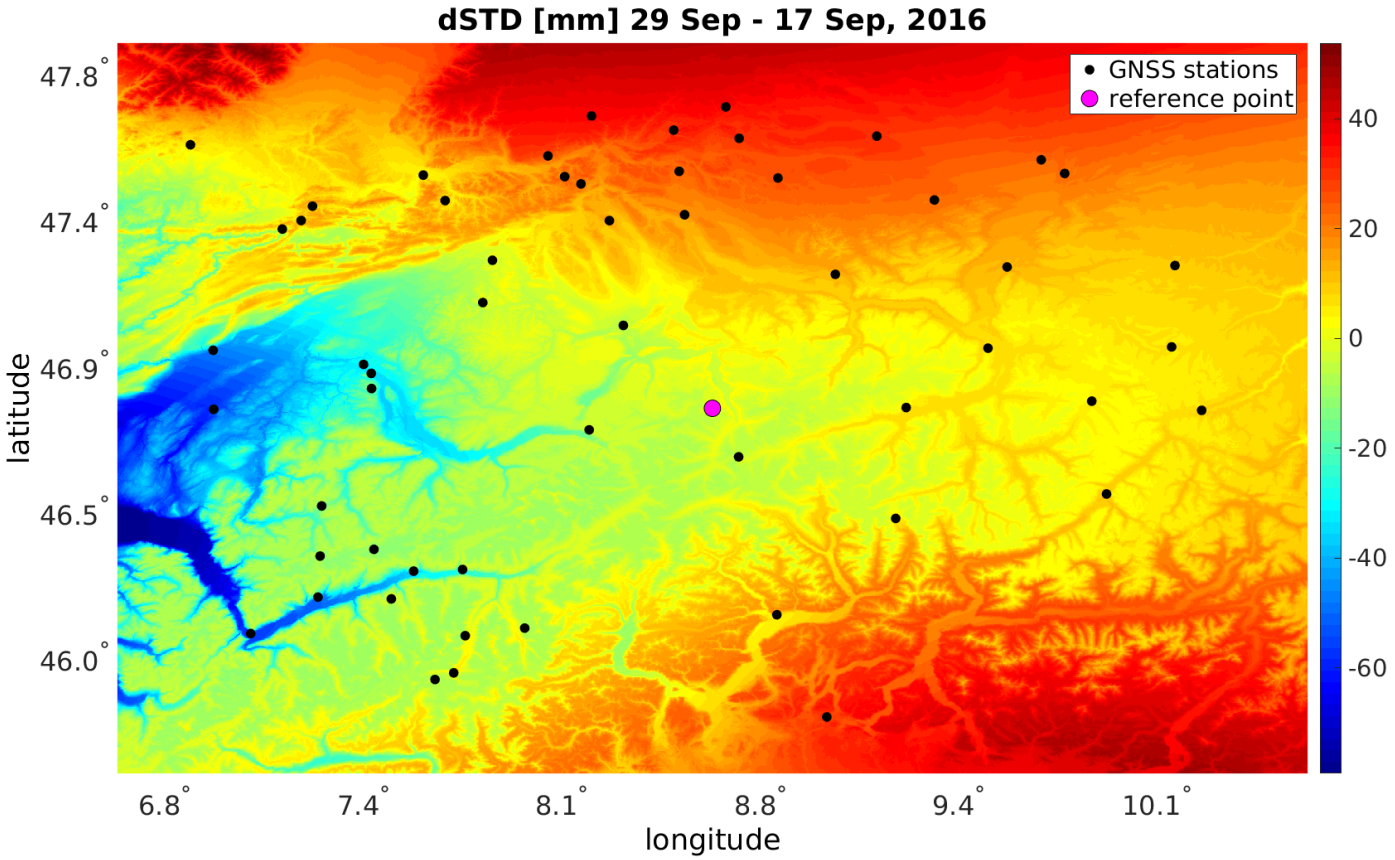


- 5000 SAR points to build the model
- different 5000 points for interpolation (validation)



Application - Switzerland

- First tests for two pairs of Sentinel-1 (C-band) acquisitions (Sep 2016)
- Models of dSTDs for the entire Switzerland
- GNSS data from 63 permanent stations
- Interpolated to over 30 million points (~100 m resolution)

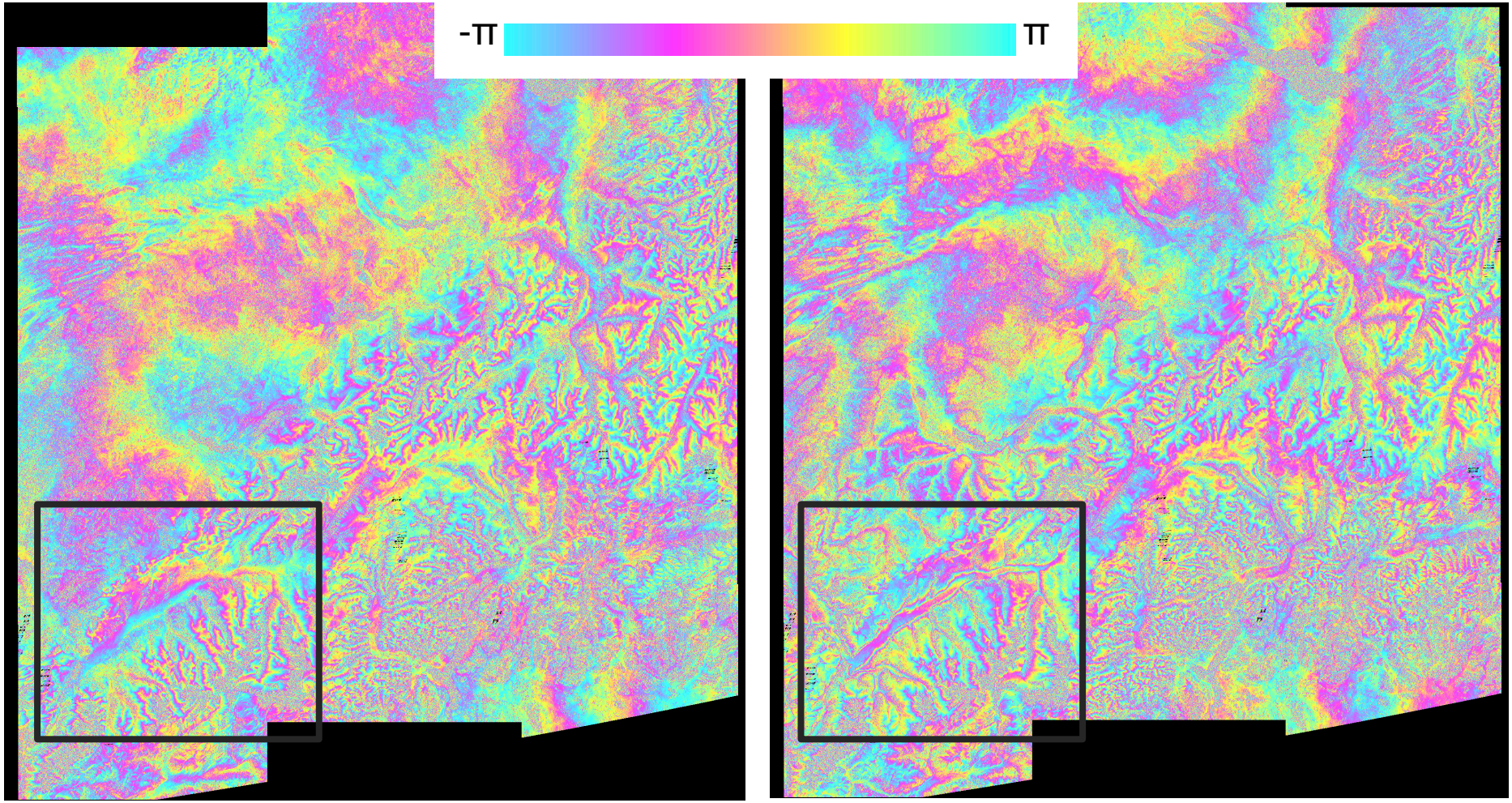


Application - Switzerland

one interferogram: Sep 17- Sep 29, 2016

no correction

GNSS-based correction



Application - Switzerland

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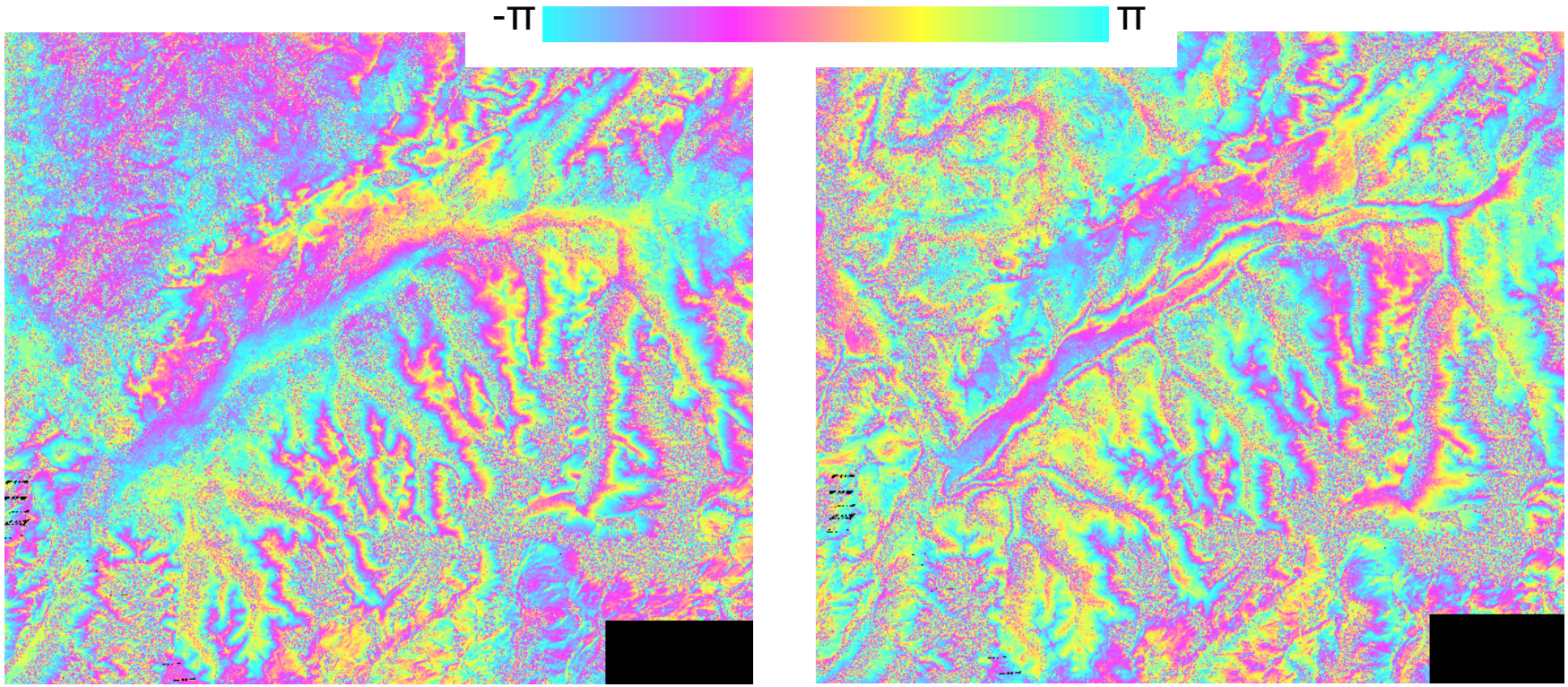
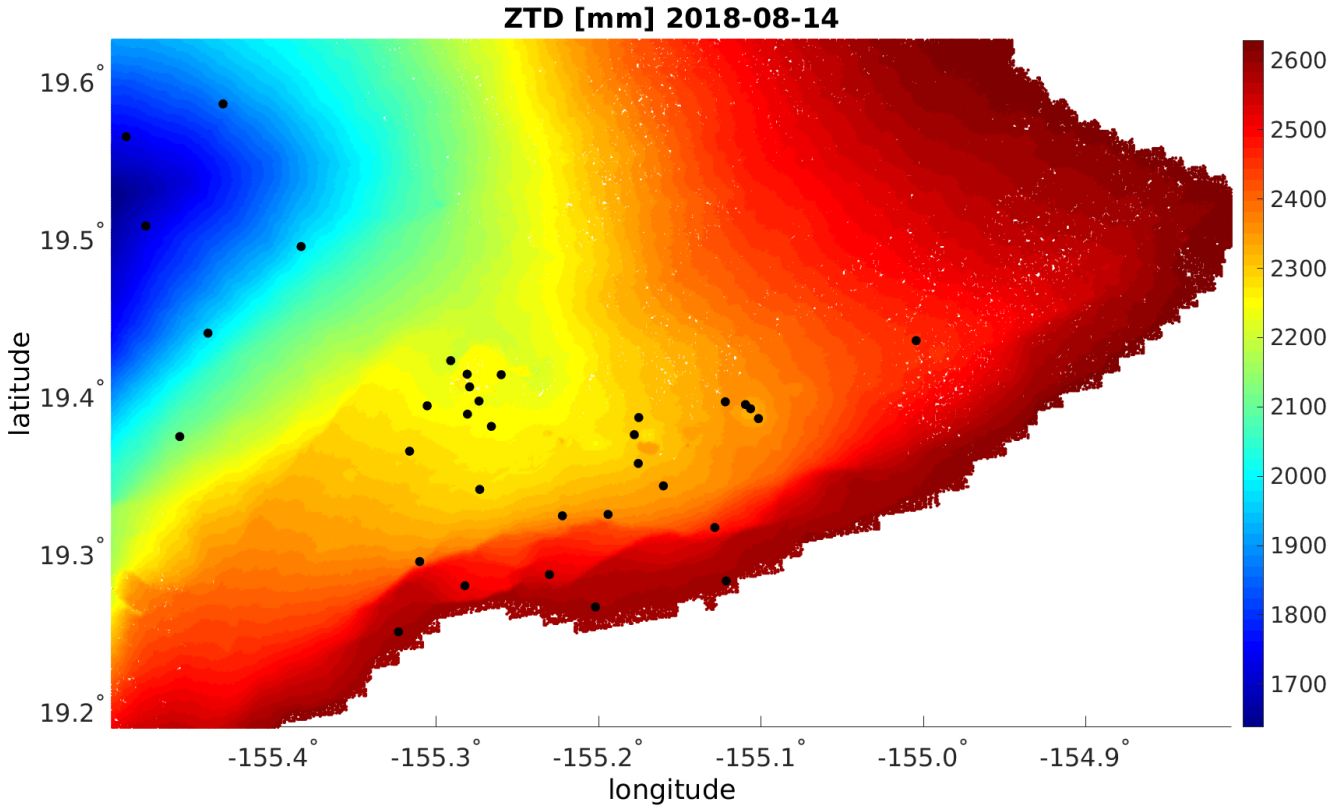
GNSS-based correction

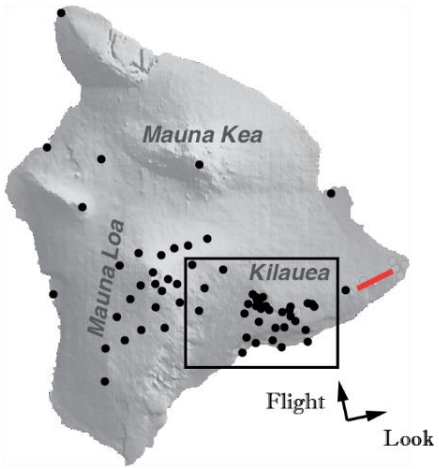


large part of the atmospheric stratification was removed

Application - Hawaii

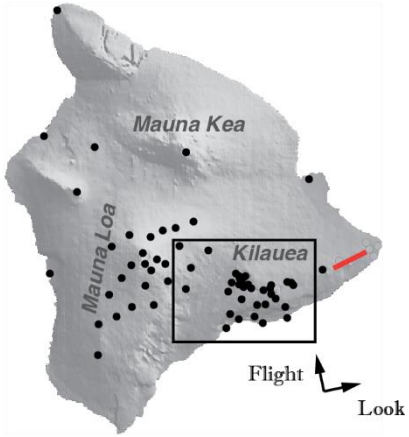
- Kilauea volcano eruption and M6.9 earthquake in May 2018
- 57 Sentinel-1 acquisitions from April to October 2018
- 77 GNSS stations located in Big Island, Hawaii
- Interpolated to ~200'000 points

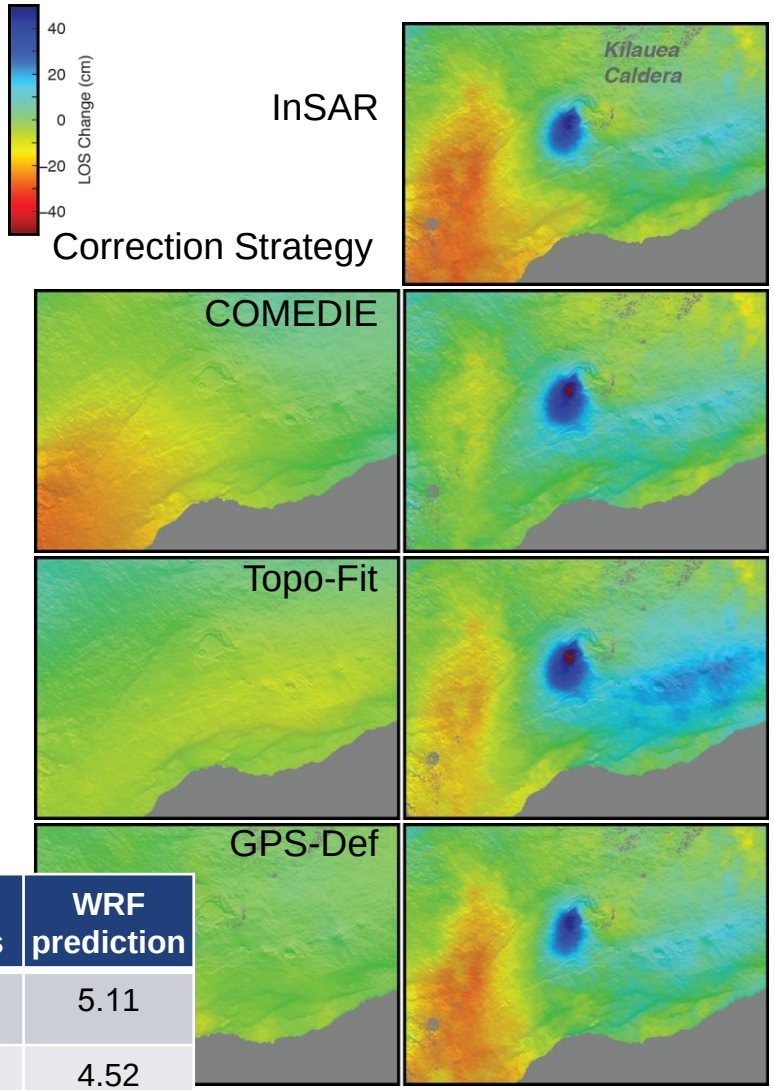




Application - Hawaii

Sentinel−1 May 14 − May 20, 2018 (ascending)





During evolving hazard events, we want the best possible image/data for the most recent time interval.

COMEDIE provides **best RMS reduction** for 21 ascending and 23 descending Sentinel-1 scenes

	InSAR	GPS-Def	Topo-fit	COMEDIE	WRF Analysis	WRF prediction
Ascending	5.66	5.07	4.27	**4.22**	4.54	5.11
Descending	4.67	3.62	3.54	**3.43**	3.99	4.52

Conclusions

- We compared the GNSS and InSAR-derived dSTDs:
  - the **best agreement** is for days of **varying troposphere (relative to master acquisition)**
- We combined InSAR and GNSS measurements into one model:
  - the combination models are **closer to InSAR** estimates
- We applied the COMEDIE GNSS estimates for Sentinel-1:
  - Switzerland: **improvement in the Alps**
  - Hawaii: the best **RMS reduction** for 44 scenes

Thank you for your attention! Questions?

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This work is a part of Swiss Federal Office of Environment (FOEN) project "Geodetic Geomonitornig" and DACH project "AtmoWater"

We thank swisstopo for providing AGNES GNSS data, Italian Space Agency for providing COSMO-SkyMED data and ESA for providing Sentinel-1 data