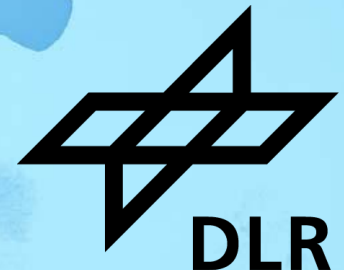


Improving Single-Pass DEM Performance through Alternating Bistatic Operation and Generalized Maximum Likelihood Processing

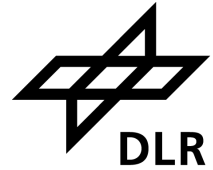
Maxwell Nogueira Peixoto and Michelangelo Villano

German Aerospace Center (DLR), Microwaves and Radar Institute

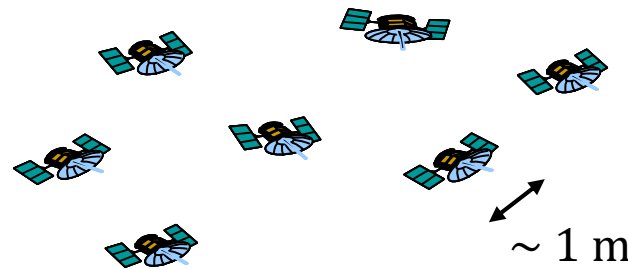
Multistatic Radar Workshop 2025
Milan, Italy
June 20th, 2025



ERC-Funded Project “Distributed Radar Interferometry and Tomography Using Clusters of Smallsats” (DRITUCS)



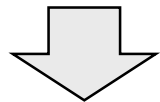
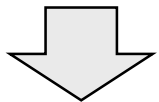
clusters of
smallsats



drones

image 1 image 2 ... image N

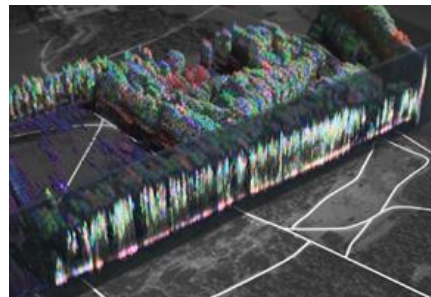
processing



digital
elevation
models



tomograms

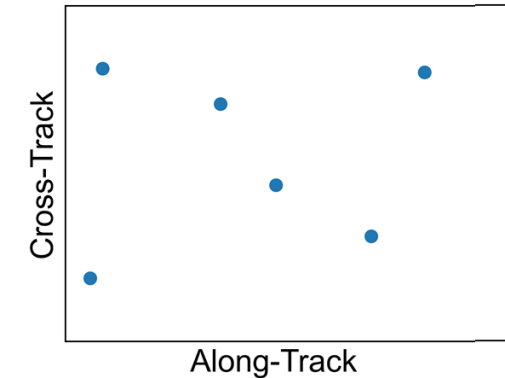


ocean
currents

multiple-input
multiple-output (MIMO)
SAR tomography

Distributed InSAR for DEM Generation

- Cluster of cubesats with small antennas flying in formation with various along- and cross-track baselines
- Challenge: Suppress azimuth ambiguities and exploit the multiple cross-track baselines for robust phase unwrapping
- Generalized maximum likelihood estimation of the height**



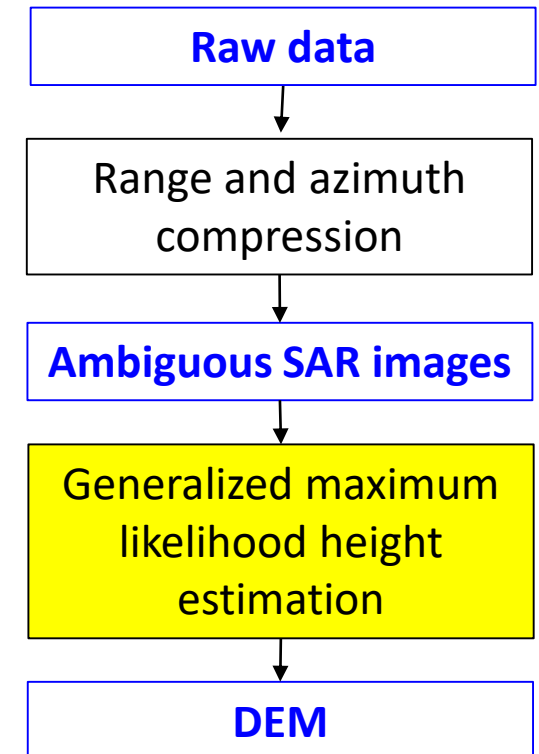
Model of the covariance matrix (for each sub-band)

$$C_b(\mathbf{h}, \boldsymbol{\gamma}, \boldsymbol{\sigma}^0) = \underbrace{C_{b_0}(h_0, \gamma_0, \sigma_0^0)}_{\text{main signal}} + \sum_{\rho \neq 0} \underbrace{C_{b_\rho}(h_\rho, \gamma_\rho, \sigma_\rho^0)}_{\text{ambiguities}}$$

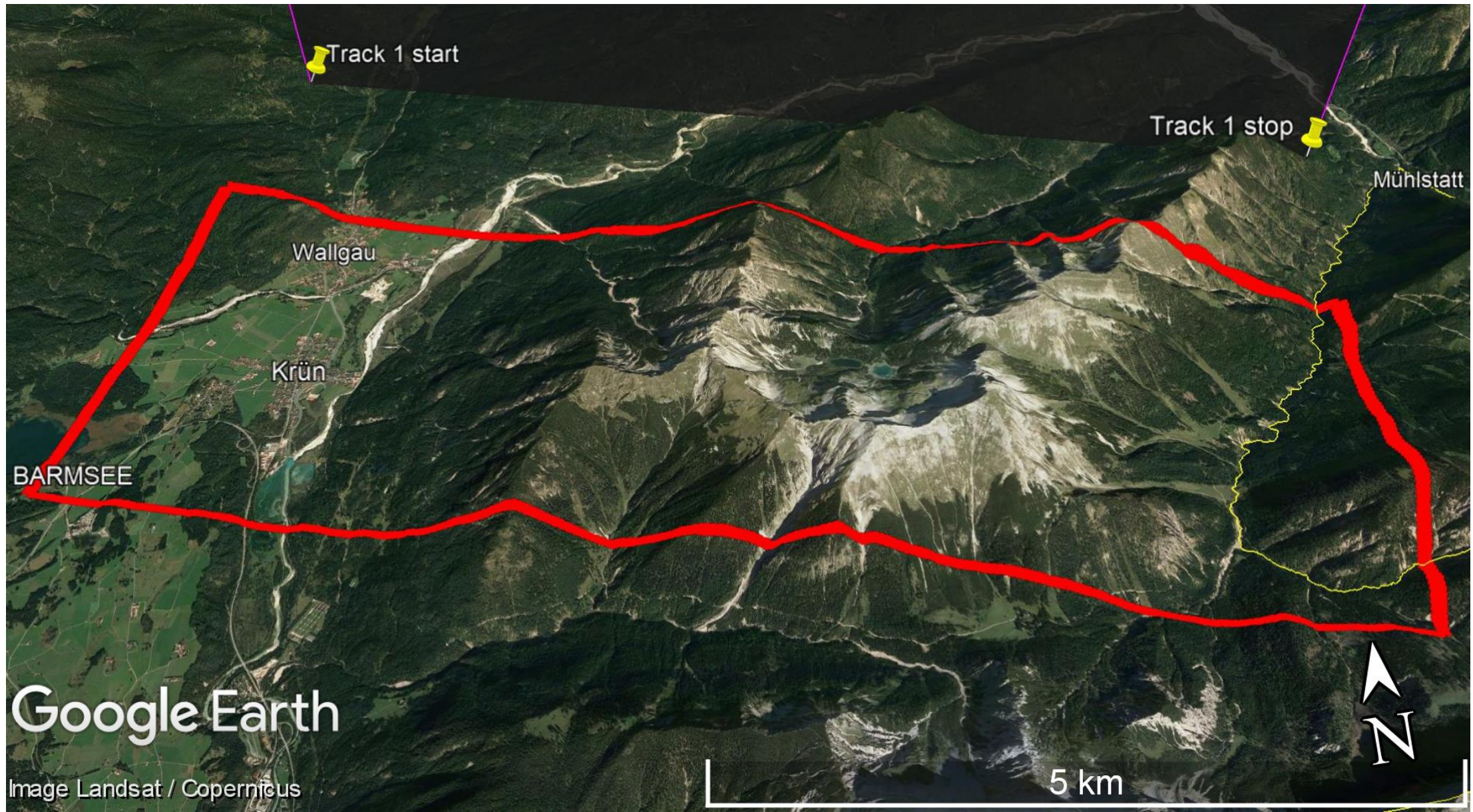
Estimate from data

$$\widehat{C}_b = \frac{1}{N_{\text{looks}}} \sum_{l=1}^{N_{\text{looks}}} \mathbf{u}_{bl} \mathbf{u}_{bl}^H$$

$$\begin{aligned} \widehat{\mathbf{h}}, \widehat{\boldsymbol{\gamma}}, \widehat{\boldsymbol{\sigma}}^0 &= \underset{\mathbf{h}, \boldsymbol{\gamma}, \boldsymbol{\sigma}^0}{\operatorname{argmax}} \ln L(\mathbf{h}, \boldsymbol{\gamma}, \boldsymbol{\sigma}^0; \widehat{C}) \\ &= \underset{\mathbf{h}, \boldsymbol{\gamma}, \boldsymbol{\sigma}^0}{\operatorname{argmin}} \sum_{\rho} \left[\operatorname{tr} \left(\widehat{C}_b^H C_b^{-1}(\mathbf{h}, \boldsymbol{\gamma}, \boldsymbol{\sigma}^0) \right) + \ln |C_b(\mathbf{h}, \boldsymbol{\gamma}, \boldsymbol{\sigma}^0)| \right] \end{aligned}$$



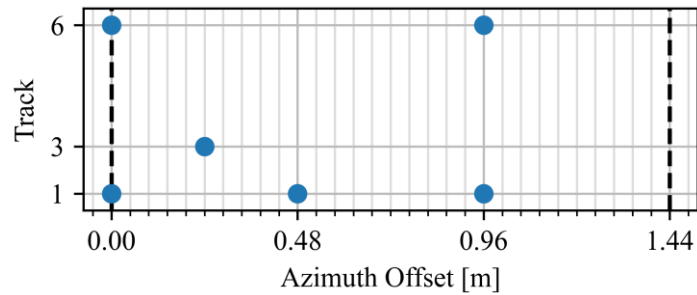
Demonstration of Distributed InSAR with F-SAR Data



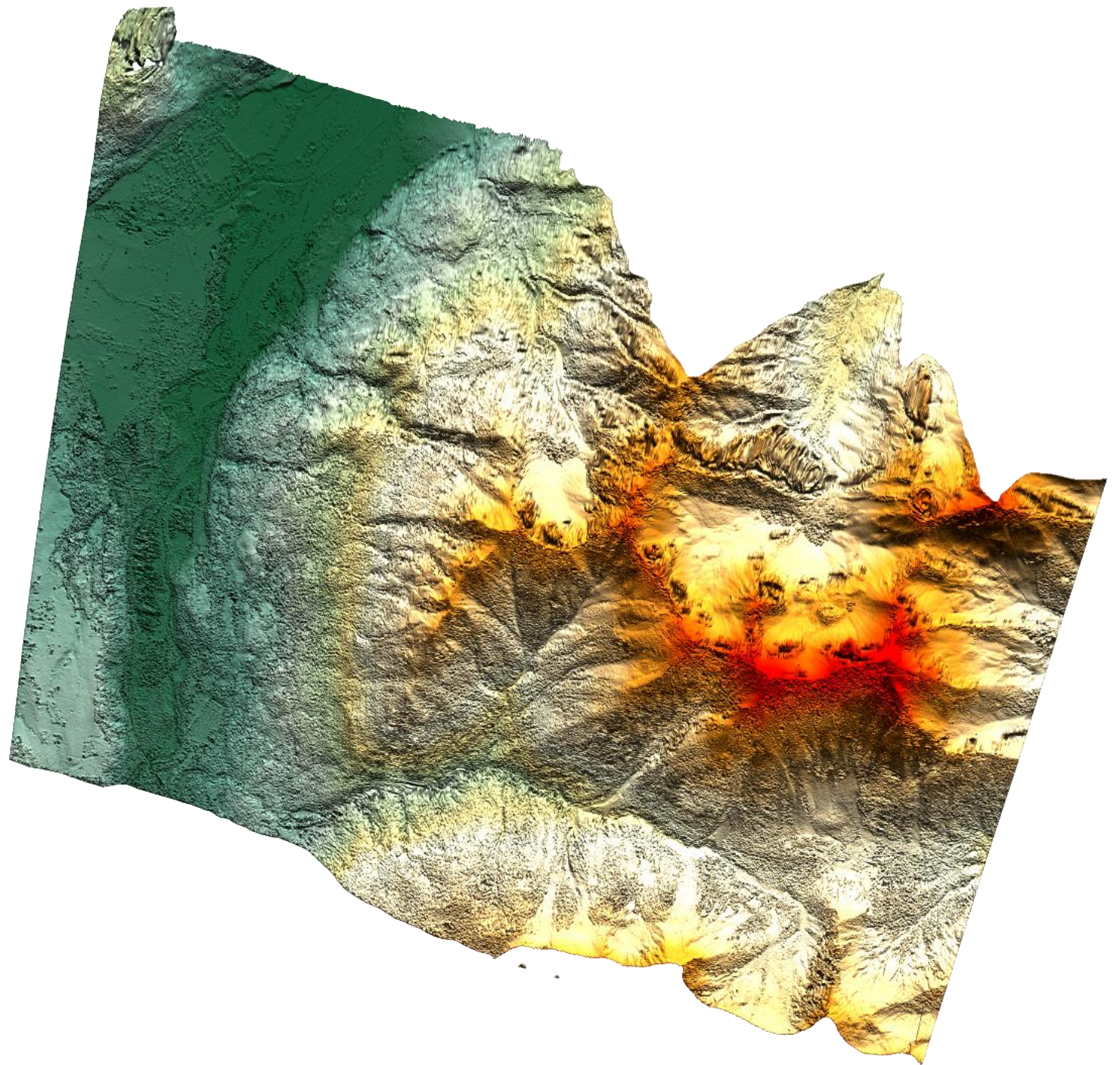
DEM Comparison

TanDEM-X DEM

6 receive satellites with
1-m antenna length



single-baseline
(conventional InSAR)

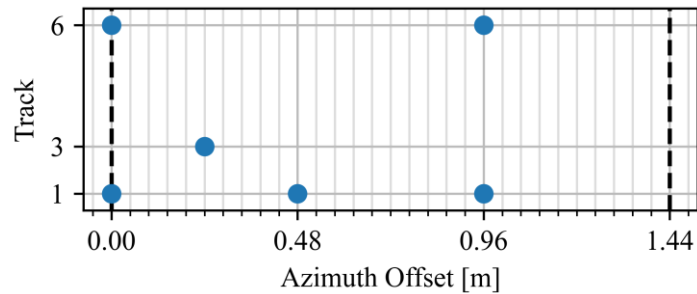


Height Offsets from TanDEM-X DEM

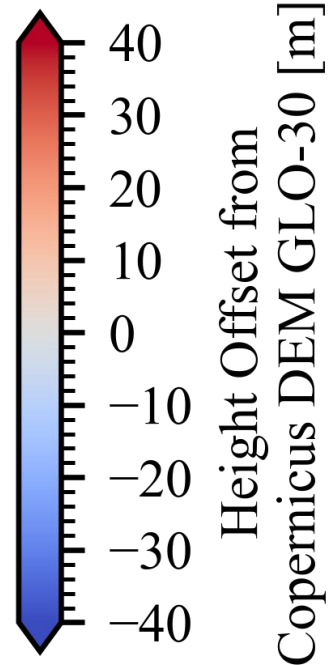
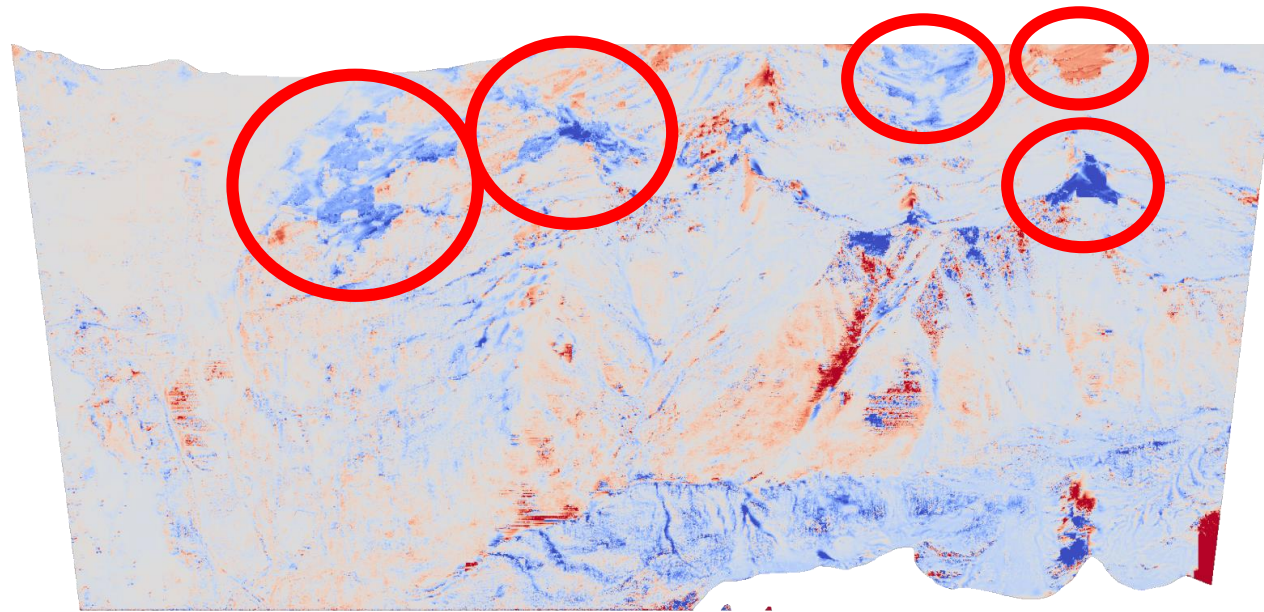


phase unwrapping errors

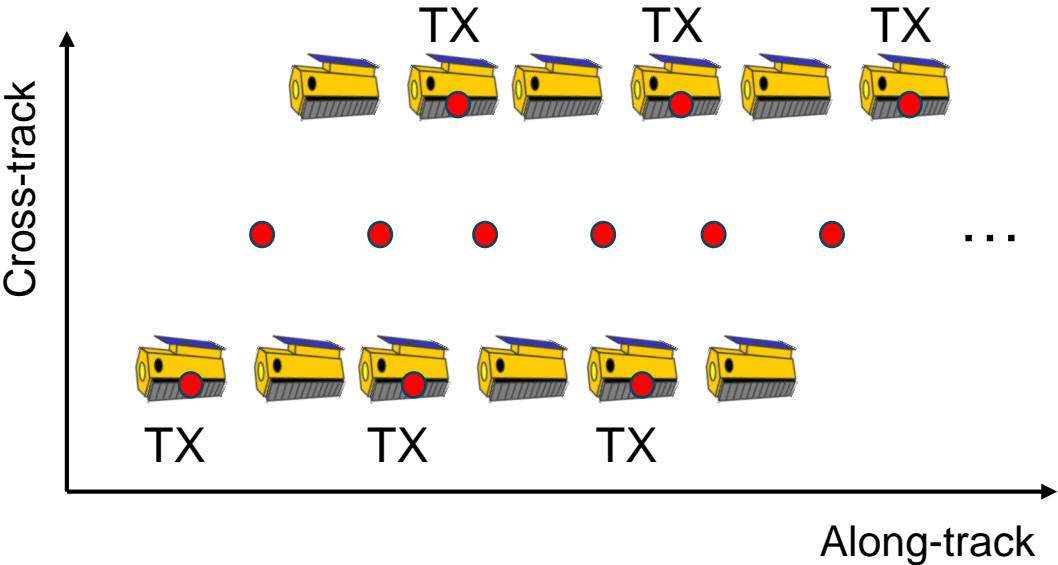
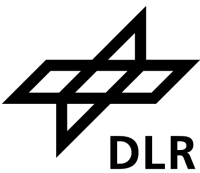
6 receive satellites with
1-m antenna length



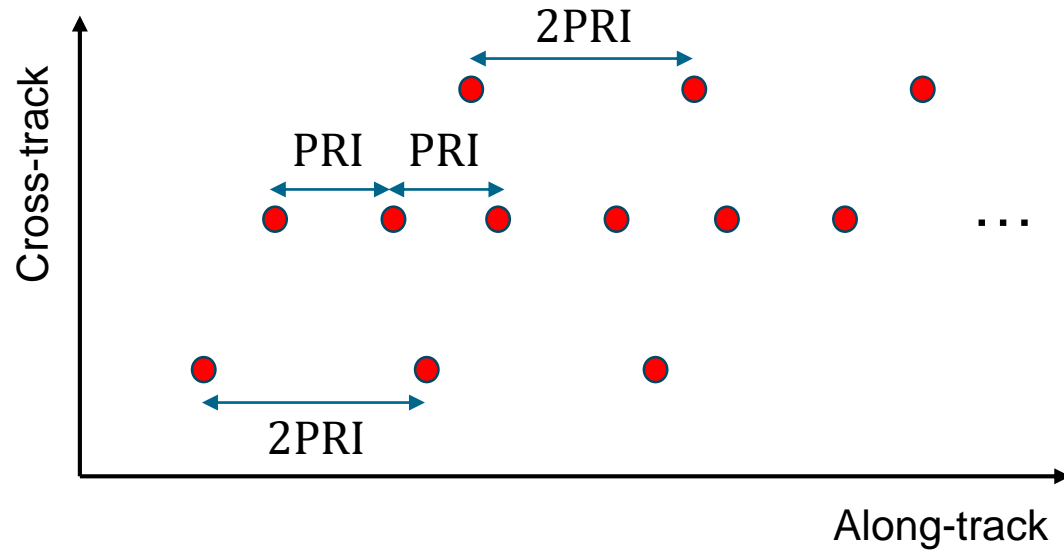
single-baseline
(conventional InSAR)



Processing of Alternated Bistatic Data



Processing of Alternated Bistatic Data



- Baseline diversity
- Reduced (monostatic) sampling compromises the swath width
- **Generalized maximum likelihood estimation of the height**
 - Enlarged mapped swath at the same accuracy
 - Better accuracy for the same swath

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Thank you for your attention!