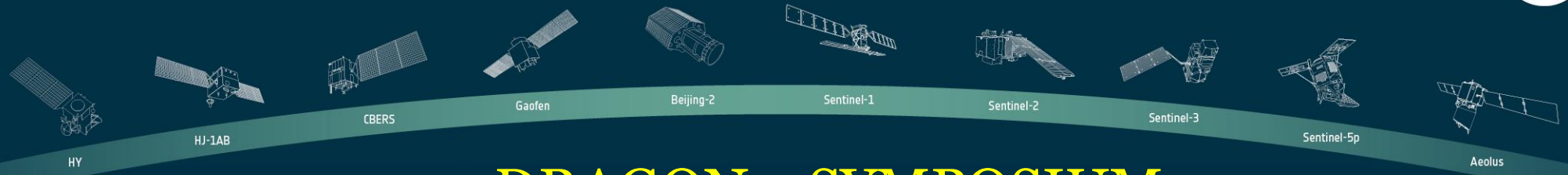

2023 DRAGON 5 SYMPOSIUM

MID-TERM RESULTS REPORTING

11-15 SEPTEMBER 2023

PROJECT ID. 59332

GEOPHYSICAL AND ATMOSPHERIC RETRIEVAL FROM SAR DATA STACKS OVER NATURAL SCENARIOS

Dragon 5 Mid-term Results Project

SEPTEMBER 15, 2022

ID. 59332

PROJECT TITLE: GEOPHYSICAL AND ATMOSPHERIC RETRIEVAL FROM SAR DATA STACKS OVER NATURAL SCENARIOS

LEAD INVESTIGATORS:

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PROF. MI JIANG, SUN YAT-SEN UNIVERSITY

PROF. FABRIZIO LOMBARDINI, UNIVERSITY OF PISA

PRESENTED BY: ZHANG LU

Objectives

Overarching goal: development and application of processing methodologies for future stack-based spaceborne applications.

Two specific sub-topics:

- ***Subsurface target detection and imaging***

⇒ internal structure of natural media

- ***Monitoring atmospheric phase field and surface deformations***

⇒ joint estimation of deformation and water vapour maps

The activities are intended to support use of multi-pass data stacks from:

- the upcoming P-Band mission BIOMASS
- future L-Band missions, such as the SAOCOM constellation, the upcoming Chinese L-Band bistatic Mission Lu-Tan1, and potentially Tandem-L and Rose-L
- C-Band Sentinel Missions and X-Band Cosmo-Skymed Missions

EO Data Delivery

Data access (list all missions and issues if any). NB. in the tables please insert cumulative figures (since July 2020) for no. of scenes of high bit rate data (e.g. S1 100 scenes). If data delivery is low bit rate by ftp, insert “ftp”

ESA, Explorers & Sentinels data	No. Scenes
1.Sentinel-1	700
2. ASAR (04/2007- 02/2009)	19

ESA Third Party Missions	No. Scenes
1.TerraSAR-X/TanDEM-X and PAZ constellation	60
Other data sources	**No. Scenes**
1. ALOS-2 PALSAR-2	60
Total:	

Issues:

ESA Campaigns	No. Scenes
1.TomoSense P	40
1.TomoSense L	40x2
1.TomoSense C	40x2
4. AlpTomoSAR	32
5. AfriSAR	10
Total:	≈ 242

European Young scientists contributions in Dragon 5

Name	Institution	Poster title	Contribution
Marco Manzoni	Politecnico di Milano	Large scale SAR Atmospheric Phase Screens estimation with GNSS cross-calibration	Main author, data procurement, signal processing
Naomi Petrushevsky	Politecnico di Milano	Large scale SAR Atmospheric Phase Screens estimation with GNSS cross-calibration	Co-author, data procurement, signal processing

Chinese Young scientists

Chinese YS	Institution	Current position
Chuanjun Wu	Wuhan University, *Academic exchange at PoliMi for a period of two years(since Jun.,,2022)*	**Ph.D. student**
Ru Wang	Wuhan University, *Academic exchange at University of Leeds for a period of two years(since Sep.,2021)*	**Ph.D. student**
Yi'an Wang	Wuhan University, *Academic exchange at Polytechnic University of Catalonia for a period of a year and a half (since Oct.,2022)*	**Ph.D. student**

Project schedule

2020-2021:

- Procurement of satellite stacks.
- Acquisition of campaign data.
- Data pre-processing, preliminary analysis.
- Presentation at Dragon symposium 2021.

2021-2022:

- Advanced analysis of satellite data.
- Advanced analysis of campaign data.
- Presentation at Dragon symposium 2022.
- Preparation of one or more journal papers

2022-2023:

- Advanced data analysis.
- Presentation at Dragon symposium 2023.

2023-2024:

- Presentation of final results
- Preliminary analysis of BIOMASS data.
- Presentation at Dragon symposium 2024.
- Preparation of one or more journal papers

Expected results

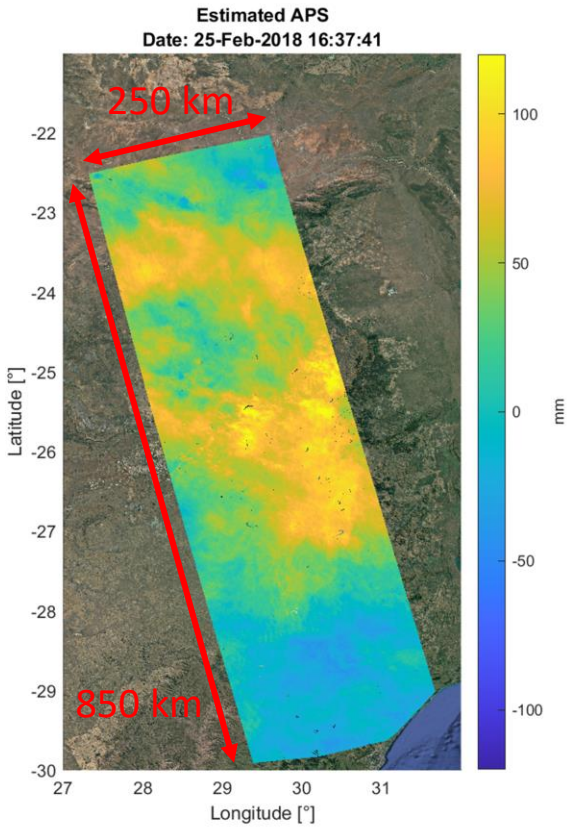
- Development and testing of methodologies for the characterization of the internal structure of forested areas.
- Development and testing of methodologies for estimation and compensation of ionospheric and tropospheric phase screens.
- Validation against reference data from airborne campaigns.
- Validation on simulated P- and L-band spaceborne bistatic data.
- Development of an efficient method to estimate and remove ionospheric phase from C band Sentinel-1 stacks already coregistered and DEM compensated (i.e. output from SNAP tool)
- Develop of a method to generate (1) absolute water-vapor maps at fine resolution by integrating GNSS, SAR (long term PS and short term DS) and meteorological mode – over very wide area and aiming to near real time, (2) deformation series, local and high resolution
- Validation of developed methods
- Analysis of data from BIOMASS after launch.

Preliminary results from Year 3

Monitoring atmospheric phase field and surface deformations

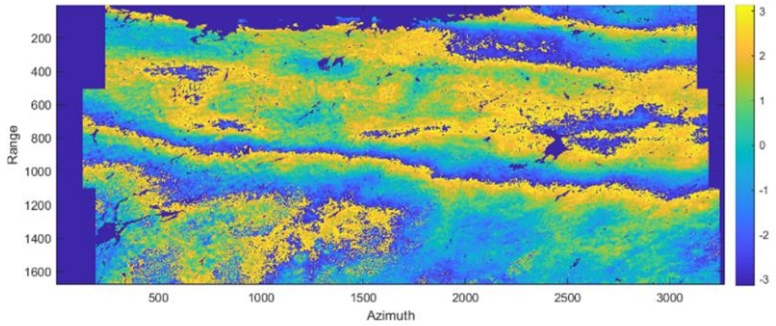
Large scale, wide and dense APS maps can be generated with InSAR. A novel algorithm has been proposed that exploits Permanent Scatterers (PS) and Distributed Scatterers (DS).

South Africa test site

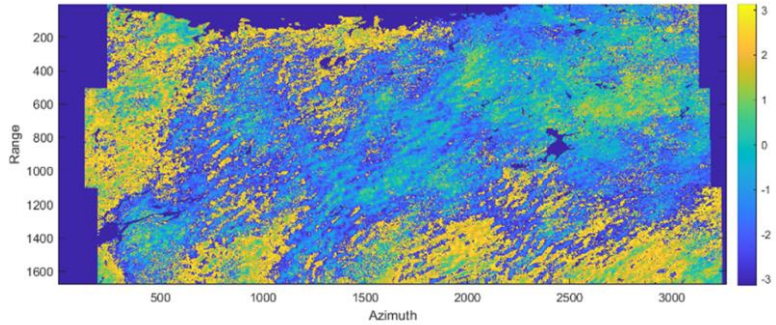


Sweden test site

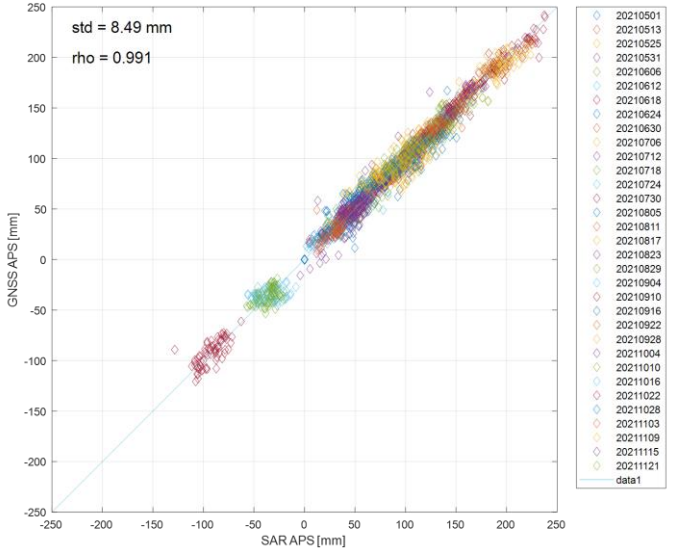
6 days temporal baseline



6 months temporal baseline



- Very high correlation of the estimated maps with GNSS measurements.
- Maps still reliable even after a very long temporal baseline.

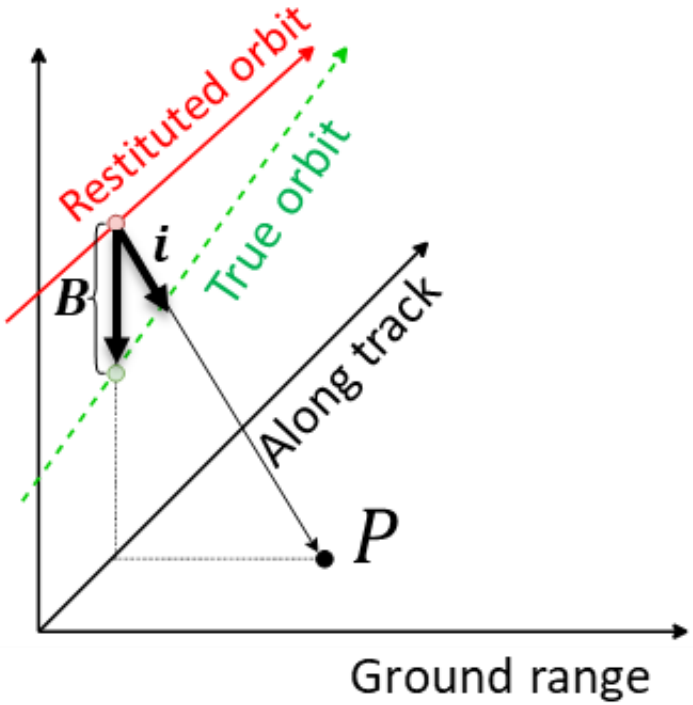


Preliminary results from Year 3

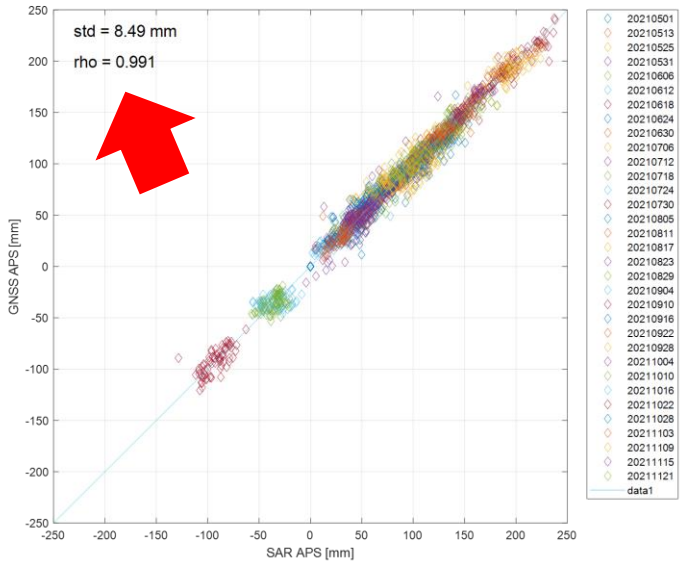
Monitoring atmospheric phase field and surface deformations

Orbital errors are particularly dangerous for InSAR atmospheric monitoring. Such errors generates phase trends in the interferogram that can corrupt the estimate of the atmospheric component. We implemented a calibration procedure that relies on a network of GNSS stations.

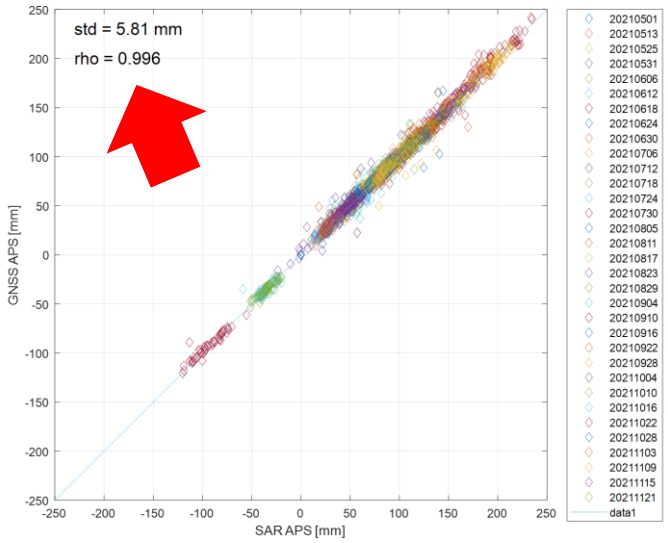
The validation with an independent set of GNSS stations shows how the correlation between GNSS-derived APS and SAR-derived APS increases up to value very close to 1. The standard deviation also decreases by almost 50%.



Before orbital calibration



After orbital calibration



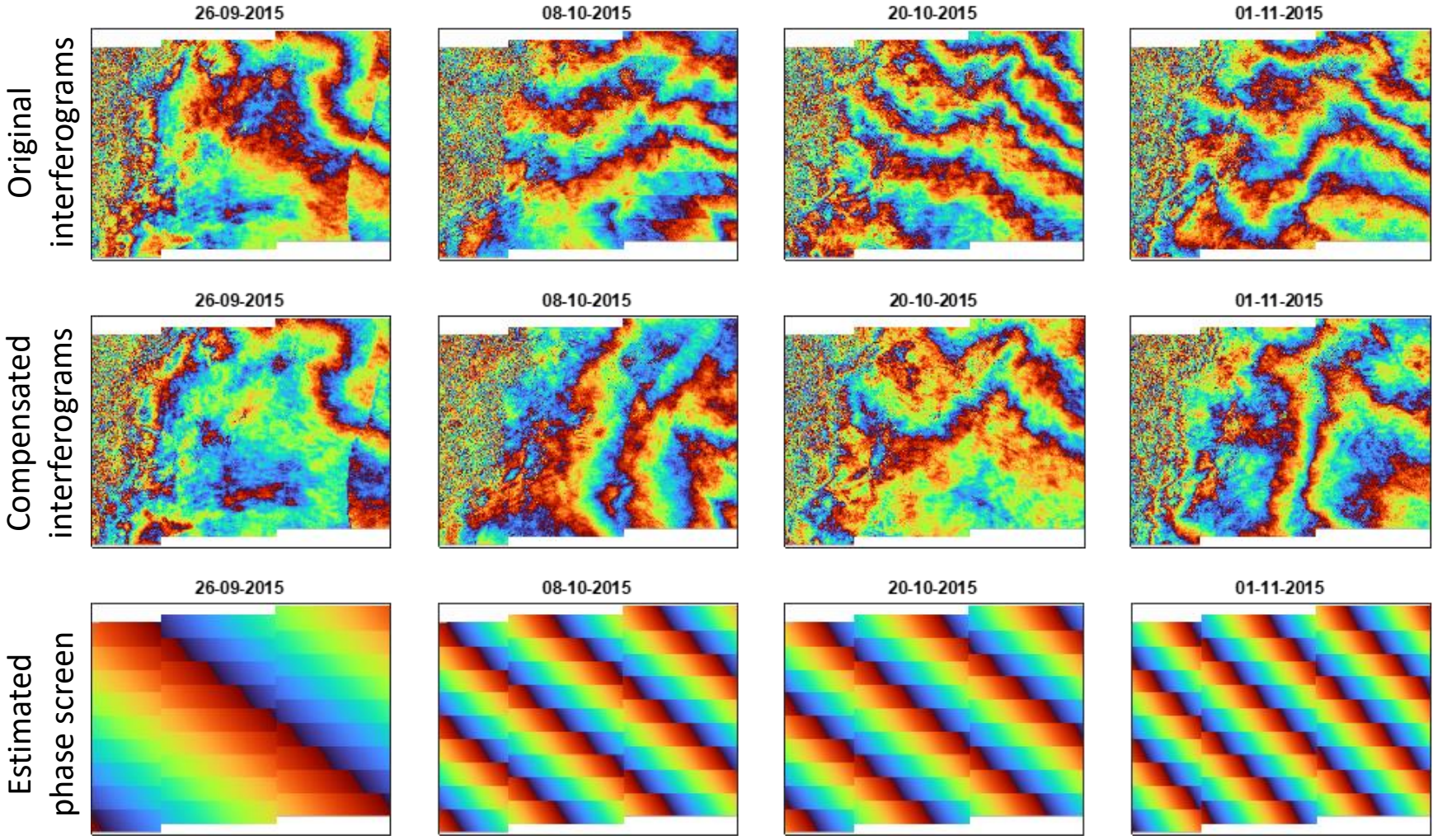
Preliminary results from Year 3

Ionosphere estimation and compensation

Estimation of Sentinel-1 ionospheric phase screen by the split spectrum algorithm.

- Joint estimation over a stack.
- Directly from coregistered data, processing is adapted to handle existing interferometric stacks.

Test site

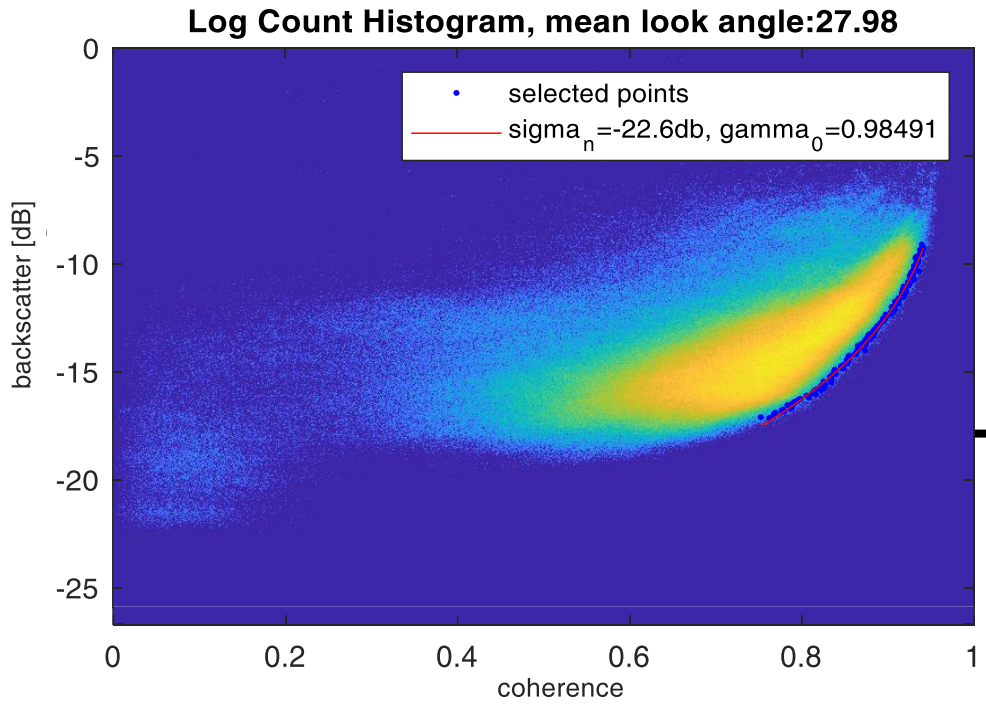


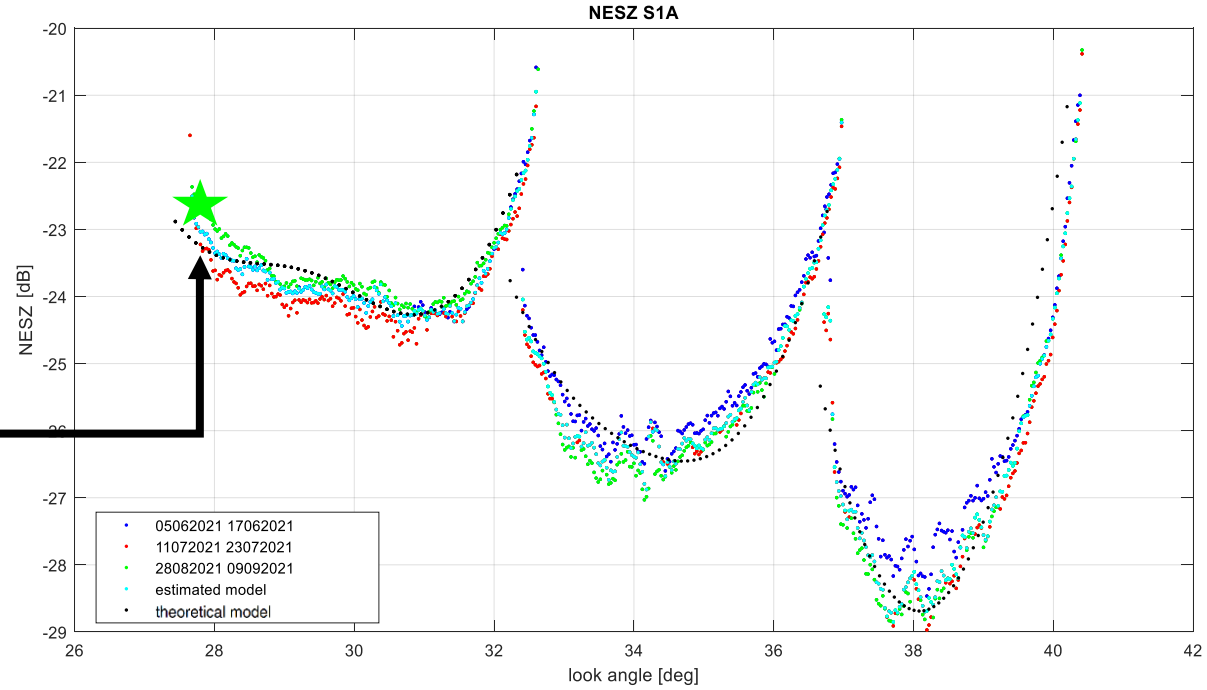
Noise equivalent sigma zero (NESZ) estimation over land

Precise knowledge of the noise level is important for modeling SAR data and calibration of new missions.

NESZ value can be estimated for data observed over land by fitting the measured backscatter and coherence to the theoretical model:

$$\gamma = \frac{\gamma_0}{1 + \frac{\boldsymbol{\sigma_{NESZ}}}{\sigma^0}}$$





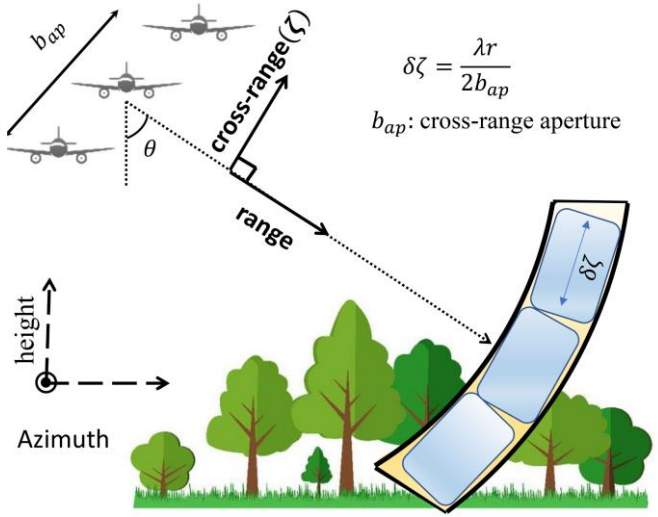
Preliminary results from Year 3

Subsurface target detection and imaging

A comparison between SAR Tomography and the Phase Histogram Technique for Remote Sensing of Forested Areas

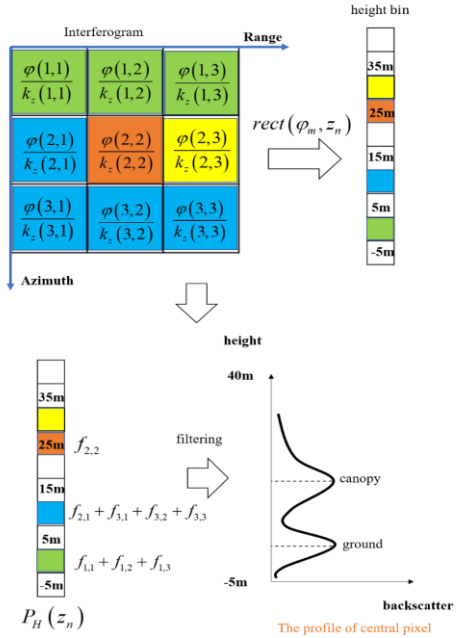
TomoSAR allows for direct imaging of the three-dimensional structure of the vegetation

- Need for many interferometric baselines
- Model-free



The Phase Histogram technique estimates the forest vertical structure by accumulating pixels magnitudes within a given spatial window

- Only one interferogram needed
- Relies on the assumption of the dominant scatterer model

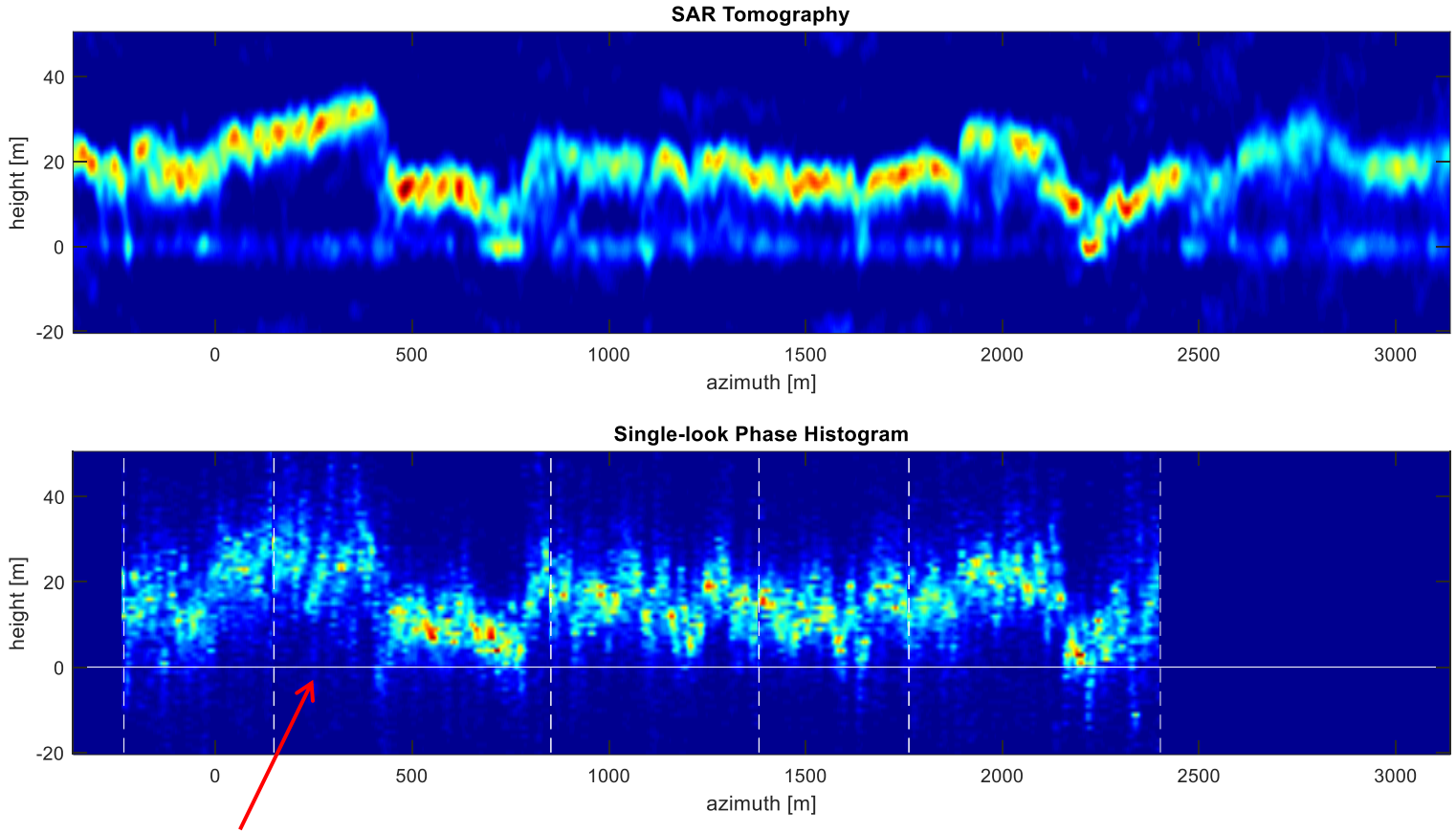


Preliminary results from Year 3

Subsurface target detection and imaging

A comparison between SAR Tomography and the Phase Histogram Technique for Remote Sensing of Forested Areas

Both algorithms are validate based on L-Band tomographic data acquired by MetaSensing in 2020 at the Eifel Park, North-West Germany, in the context of the ESA campaign TomoSense



Preliminary results from Year 3

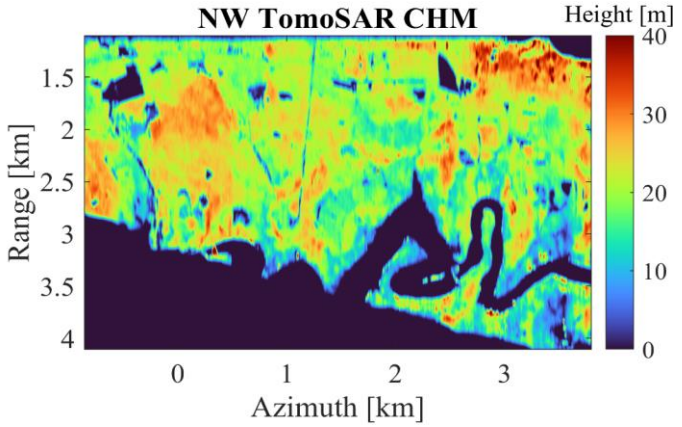
Subsurface target detection and imaging

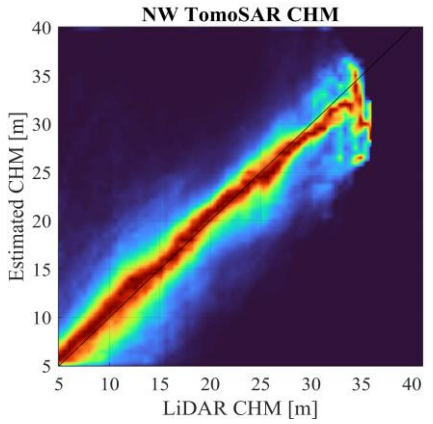
A comparison between SAR Tomography and the Phase Histogram Technique for Remote Sensing of Forested Areas

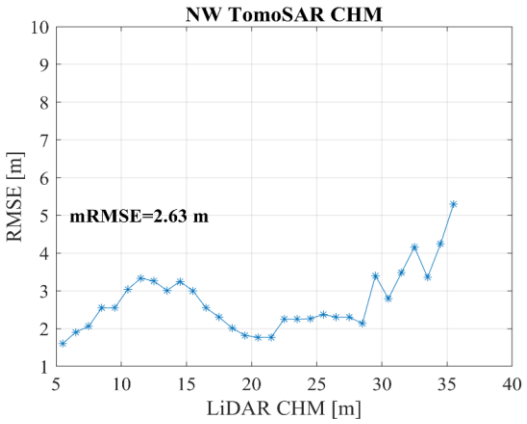
Forest height retrieval by the Power Loss method

Validation against Canopy Height from aerial Lidar

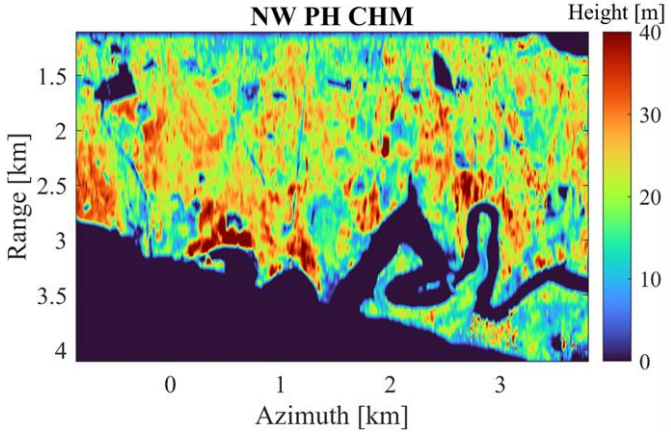
Forest height retrieval from tomograms

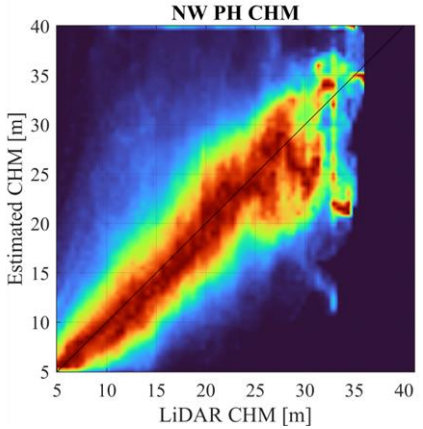


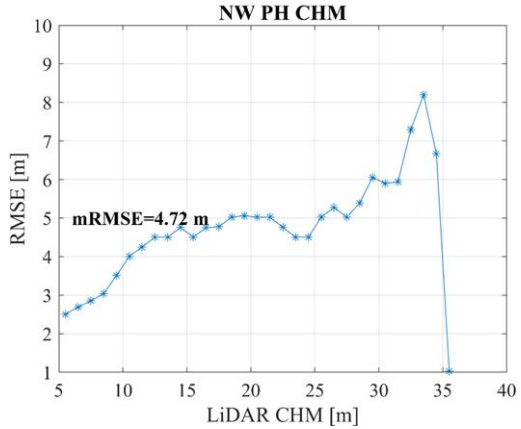




Forest height retrieval from phase histograms







Preliminary results from Year 3

Subsurface target detection and imaging

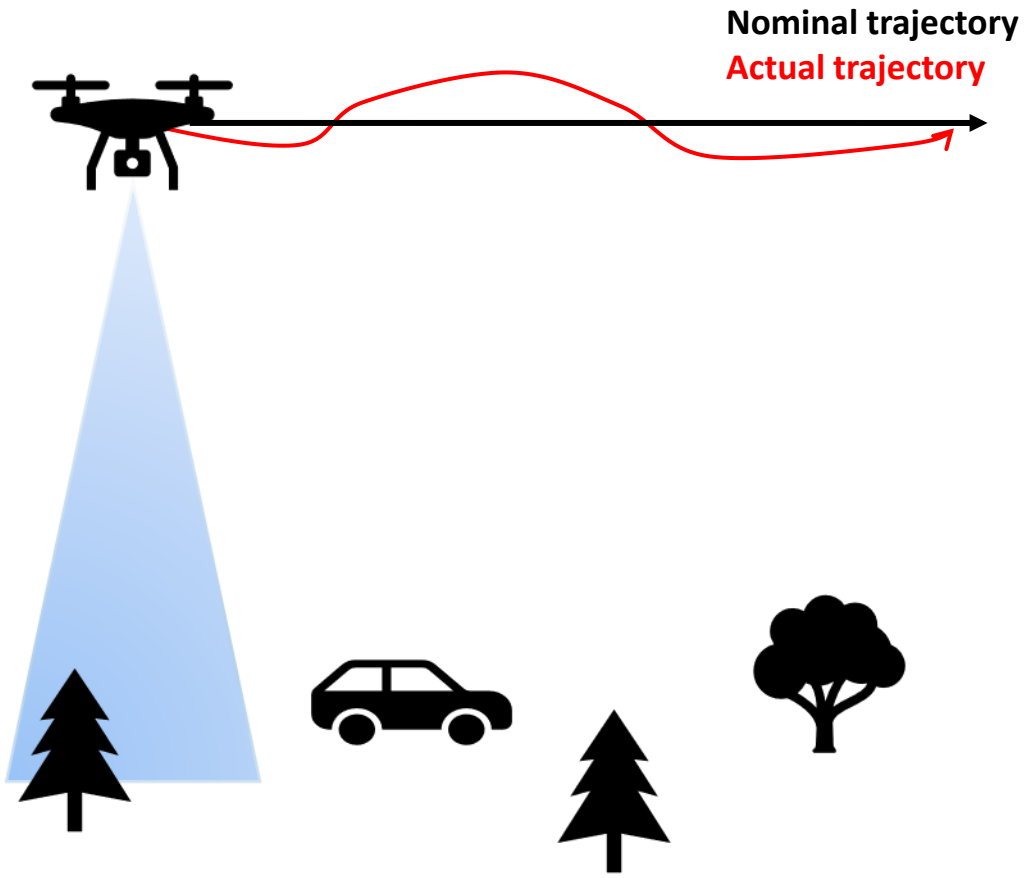
In order to have highly focused images **the coordinates of the travelled trajectory must be known with precision**

The position of the radar along the travelled trajectory is given by the **on board localization systems**

The accuracy should be better than fraction of the wavelength

Autofocusing algorithms are signal processing tools employed to focus SAR images in the presence of inaccurate information about sensor trajectory.

Idea: characterize the measured phase history of detected point targets through a **geometrical model** to obtain a direct estimation of navigation parameters from SAR data



Preliminary results from Year 3

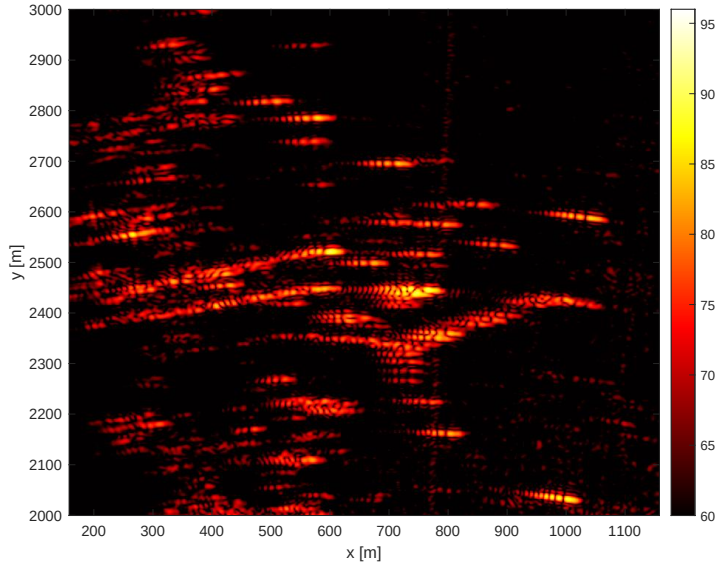
Subsurface target detection and imaging

Implemented algorithm

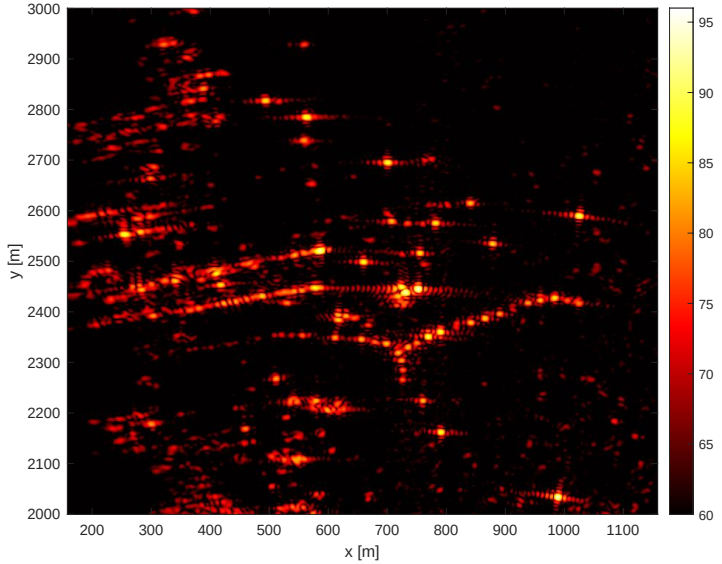
- Range Compressed Matrix
- ⇓
- Focusing in Polar Coordinates
- ⇓
- Prominent Points Selection
- Windowing
- Defocusing
- Phase Residuals computation
- Geometrical Trajectory Corrections retrieval
- ⇓
- Focusing with Corrected Trajectory

Validation based on real P-Band SAR data acquired by CORISTA in Morocco in 2018 in the context of research activities funded by the Italian Space Agency (ASI) [1]

Focusing with corrupted nav data



Focusing with corrected nav data



[1] *Perna, S.; et al. The ASI Integrated Sounder-SAR System Operating in the UHF-VHF Bands: First Results of the 2018 Helicopter-Borne Morocco Desert Campaign. Remote Sens.* ***2019****, 11, 1845.*

Summary

ID. 59332

PROJECT TITLE: GEOPHYSICAL AND ATMOSPHERIC RETRIEVAL FROM SAR DATA STACKS OVER NATURAL SCENARIOS

4 Universities: PoliMi, Wuhan, Sun Yat-Sen, Pisa

2 European and 3 Chinese Young scientists

Topics reported:

- Development of airborne and spaceborne signal processing methods for SAR data stacks
- Vertical structure of forested areas
- Tropospheric estimation and correction

感谢您的关注

Grazie per l'attenzione!

Thanks for your attention!