ESA 6th Advanced Training Course on Radar Polarimetry

The SARSIM database

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Forested areas

SARSIM and SARSIM+

The SARSIM and SARSIM+ data-bases have been created in the frame of the ESA study “L- and P-band SAR Tomography Synergies Consolidation Study”

Study team: PoliMi, Chalmers, Rennes 1, DLR, ONERA

Goal: build a reference data-set for current and future researches on the application of SAR Tomography for the remote sensing of boreal, temperate, and tropical forests at P- and L-Band.

- SARSIM includes L1 SLC images from airborne campaign, simulated spaceborne SLCs, and ancillary information
- SARSIM+ includes processed tomographic voxels as obtained in airborne and spaceborne configuration

Note: the two data-bases are provided are unified in a single deliverable item

SARSIM and SARSIM+

These two data-bases were built to provide a set of reference data for current and future users interested in the use of SAR Tomography for forestry applications. Relevant features of SARSIM and SARSIM+ are:

- The inclusion of campaign data from boreal, temperate, and tropical forests
- The inclusion of both P-Band and L-Band polarimetric SAR data
- All data have been accurately phase calibrated
- An accurate Digital Terrain Model (DTM), either derived from Lidar of directly from SAR data, is provided along with each data-sets
- Simulated spaceborne data derived from campaign data are provided along with each data-sets
- 3D Tomographic voxels are provided along with each data-sets
- All data are provided in TIFF format to ensure compatibility with different platforms.
- DEMO Matlab codes are provided to show new users how to load the data, visualize them, and implement basic tomographic processing.

SARSIM and SARSIM+

The intended users of SARSIM and SARSIM+ are:

- Signal processing researchers interested in developing new tomographic processing approaches without having to implement any pre-processing operation
- Remote sensing and ecology researchers interested in using tomographic data for the retrieval of forest parameters
- Researchers interested in developing 3D forest scattering models
- Graduate and Ph.D. students willing to learn SAR tomographic processing and/or experiment with tomographic data.

⇒ SARSIM includes:

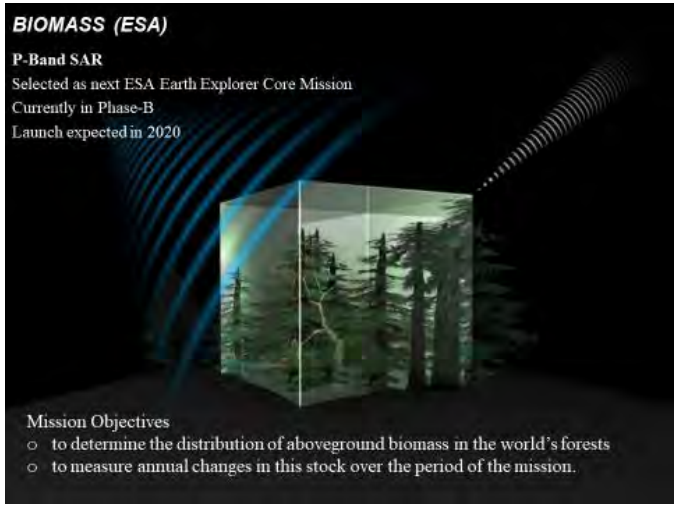
1. Stack of SLC SAR images from airborne campaigns and derived synthetic spaceborne data
   - Coregistered on a common grid
   - Phase calibrated for tomography
   - Phase flattened w.r.t. flat Earth or a Digital Terrain Model (DTM) (either from TomoSAR or Lidar)
2. Ancillary data:
   - Maps of Kz w.r.t. a common Master
   - DTM used for phase flattening
   - Ground to SAR range coordinate transformation
   - Clear information about the coordinate system
3. Matlab scripts (.m) to:
   - Load SLC and ancillary data
   - Implement Tomography by linear beamforming in SAR coordinates

⇒ SARSIM+ includes:

- Three 3D cubes (voxels) representing multi-looked intensities in HH, HV, VV, and one complex 3D cube representing HHVV coherence
  - Multilooking is performed at 50 x 50 m (ground range, azimuth)
- The cubes are delivered in a Cartesian coordinate system: x = reference linear flight track, y = ground range, z = height above the DTM
- Tomo cubes generated from airborne data are obtained either by 3D back-projection, beamforming, or correlation tomography

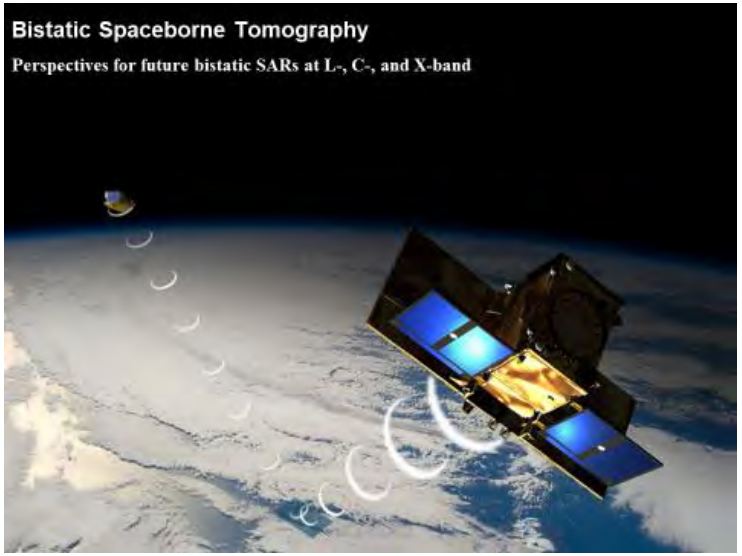
SYNTHETIC SPACEBORNE DATA

Spaceborne data were derived from airborne data to mimic future spaceborne acquisitions at P- and L-Band will be like at the campaign sites



P-Band spaceborne data were produced with reference to BIOMASS

- 6 MHz pulse bandwidth
- 12 m azimuth resolution
- Tomographic cubes produced by coherent tomography



L-Band spaceborne data were produced with reference to SAOCOM-CS

- 40 MHz pulse bandwidth
- 7.5 m azimuth resolution
- Tomographic cubes produced by correlation tomography

SARSIM and SARSIM+: data-sets

ID	Campaign	Site	Forest type	Operator	Band	Sensor	Data processing
1	AfriSAR	Lopé	Tropical	ONERA	P-Band	Airborne	PoliMi
2	AfriSAR	Lopé	Tropical	ONERA	P-Band	Spaceborne	PoliMi
3	AfriSAR	Lopé	Tropical	ONERA	L-Band	Airborne	PoliMi
4	AfriSAR	Lopé	Tropical	ONERA	L-Band	Spaceborne	PoliMi
5	AfriSAR	Lopé	Tropical	DLR	P-Band	Airborne	PoliMi
6	AfriSAR	Lopé	Tropical	DLR	P-Band	Spaceborne	PoliMi
7	AfriSAR	Lopé	Tropical	DLR	L-Band	Airborne	DLR
8	AfriSAR	Lopé	Tropical	DLR	L-Band	Spaceborne	DLR
9	AfriSAR	Lopé	Tropical	JPL	L-Band	Airborne	JPL & POLIMI
10	AfriSAR	Lopé	Tropical	JPL	L-Band	Spaceborne	JPL & POLIMI
11	BioSAR	Remningstorp	Semi-boreal	DLR	P-Band	Airborne	PoliMi
12	BioSAR	Remningstorp	Semi-boreal	DLR	P-Band	Spaceborne	PoliMi
13	BIOSAR 2008	Krycklan	Boreal	DLR	L-Band	Airborne	Rennes
14	BIOSAR 2008	Krycklan	Boreal	DLR	L-Band	Spaceborne	Rennes
15	Traunstein	Traunstein	Temperate	DLR	L-Band	Airborne	DLR
16	Traunstein	Traunstein	Temperate	DLR	L-Band	Spaceborne	DLR

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4	AfriSAR	Lopé	Tropical	ONERA	L-Band	Spaceborne	PoliMi
5	AfriSAR	Lopé	Tropical	DLR	P-Band	Airborne	PoliMi
6	AfriSAR	Lopé	Tropical	DLR	P-Band	Spaceborne	PoliMi
7	AfriSAR	Lopé	Tropical	DLR	L-Band	Airborne	DLR
8	AfriSAR	Lopé	Tropical	DLR	L-Band	Spaceborne	DLR
9	AfriSAR	Lopé	Tropical	JPL	L-Band	Airborne	JPL & POLIMI
10	AfriSAR	Lopé	Tropical	JPL	L-Band	Spaceborne	JPL & POLIMI
11	BioSAR	Remningstorp	Semi-boreal	DLR	P-Band	Airborne	PoliMi
12	BioSAR	Remningstorp	Semi-boreal	DLR	P-Band	Spaceborne	PoliMi

ACKNOWLEDGMENT

The AfriSAR data-set acquired by JPL's UAVSAR was included in SARSIM and SARSIM+ in the frame of a friendly collaboration with JPL, for which we wish to warmly thank Dr. Marco La Valle and Dr. Scott Hensley.

DEMO CODES AND UTILITIES

SARSIM_DEMO.m

Implemented functions:

- Data-set selection, e.g.: operator, site, polarization, etc.
- Data loading (SLC, DTM, Kz, range and azimuth coordinates)
- Display SAR Intensity
- Interferogram generation
- Display interferogram phase
- Evaluate and display vertical resolution

SARSIM_PLUS_DEMO.m

Implemented functions:

- Data-set selection, e.g.: operator, site, polarization, etc.
- Load a tomographic at user-specified height
- Load section coordinates (ground-range, azimuth)
- Display Tomographic Intensity or Tomographic coherence
- Load all tomographic sections
- Extract and display vertical sections

SAR_TOMOGRAPHY_DEMO.m

Implemented functions:

Data-set selection, e.g.: operator, site, polarization, etc

- Interferogram generation
- Display intensities, coherence magnitude, and phase
- Tomographic processing via Beamforming (see equation 11) or via Correlation Tomography (see equation 14) to obtain a vertical section in the height, range plane
- Display the obtained vertical section

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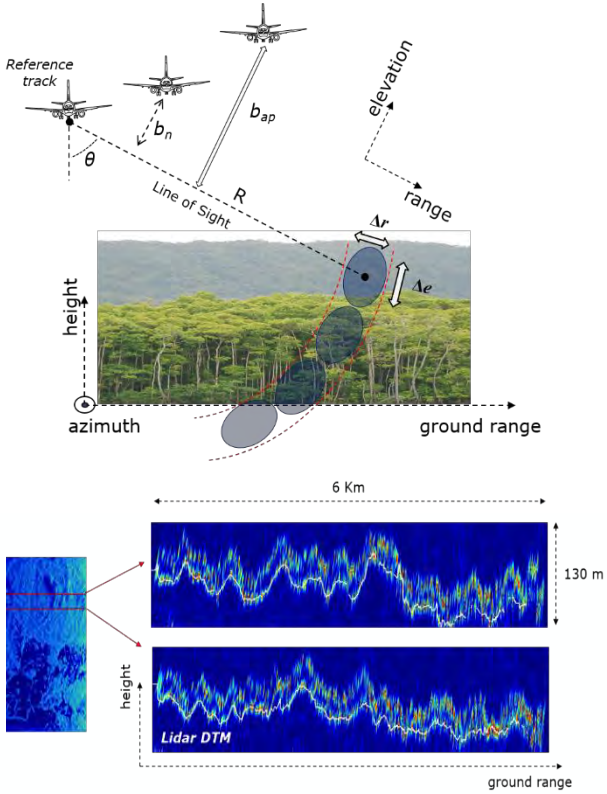
Tomograpic imaging principles



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Mathematical models

$$I_n = \int s(y,z) \cdot exp\left(j\frac{4\pi}{\lambda}R_n(y,z)\right)dydz$$

$$I_n \approx \int P(e) \cdot exp\left(j\frac{4\pi}{\lambda}\frac{b_n}{R} \cdot e\right)de$$

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Tomographic focusing

- 3D Backprojection
- 2D Backprojection
- Beamforming

$$T(x,y,z) = \sum_n \int d_n\left(t = \frac{2}{c} R_n(x,y,z,\tau), \tau\right) \cdot exp\left(-j\frac{4\pi}{\lambda} R_n(x,y,z,\tau)\right) d\tau$$

$$T(x,r,z) = \sum_n I_n(r,x) \cdot exp(-jK_z(n) \cdot z)$$

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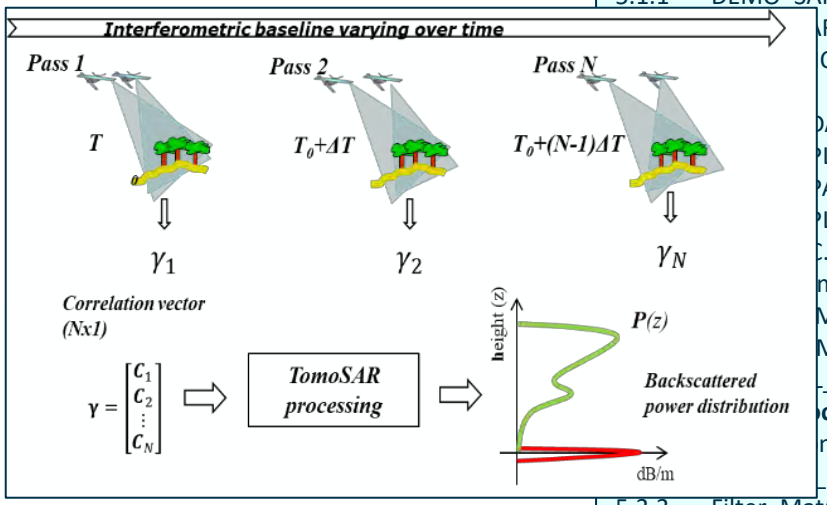
Correlation tomography

$$\hat{P}(x,r,z) = 1 + 2Re\left(\sum_{n=1}^{N}\left(\frac{N+1-n}{N+1}\right)C_n(x,r)e^{-jK_z(n)z}\right)$$



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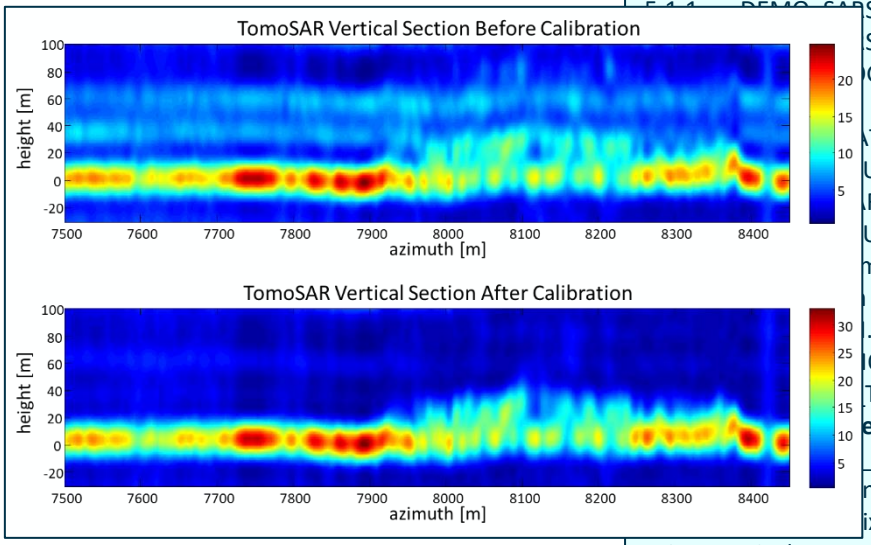
Phase calibration:
Basic information about the need for phase cal



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Spaceborne simulation:

- P-Band: geometrical simulation (spaceborne geometry)
- L-Band: filtering (airborne geometry)

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4.1.2 AFRISAR DLR DATA-SETS

Tomographic processing:

- P-Band Airborne data: 2D Time Domain Back Projection, see equation 10
- L-Band Airborne data: Beamforming, see equation 11
- P-Band Spaceborne data: 2D Time Domain Back Projection, see equation 10
- L-Band Spaceborne data: Correlation Tomography, see equation 14

Approach for simulating spaceborne data:

- P-Band: Spaceborne Geometry Simulator
- L-Band: Airborne Geometry Simulator

Vertical resolution

- P-Band Airborne data: 15 m to 20 m (near range – far range)
- P-Band Spaceborne data: 23.6 m (mid-range)
- L-Band Airborne data: 5 m to 7.5 m (near range – far range)
- L-Band Spaceborne data: 5 m to 7.5 m (near range – far range)

References to be added in publications using these data-sets:

[1] Technical Assistance for the Deployment of Airborne SAR and Geophysical Measurements during the AFRISAR Experiment, Final Report to ESA, 2017

[2] M. Pardini, K. Papathanassiou, "A two-step phase calibration method for tomographic application with airborne SAR data," Proc. 10th European Conf. Synthetic Aperture Radar, Berlin, Germany, Jun. 2014.

Suggested format: "… DLR data from the AfriSAR campaign [1]. Phase calibration was carried out according to the procedure described in [2]."

Examples

SARSIM example

9	AfriSAR	Lopé	Tropical	JPL	L-Band	Airborne	JPL & POLIMI

```
%%%
```

SARSIM example

9	AfriSAR	Lopé	Tropical	JPL	L-Band	Airborne	JPL & POLIMI

```
%%%
```

SARSIM example

9	AfriSAR	Lopé	Tropical	JPL	L-Band	Airborne	JPL & POLIMI

```
%%%
```

SARSIM example

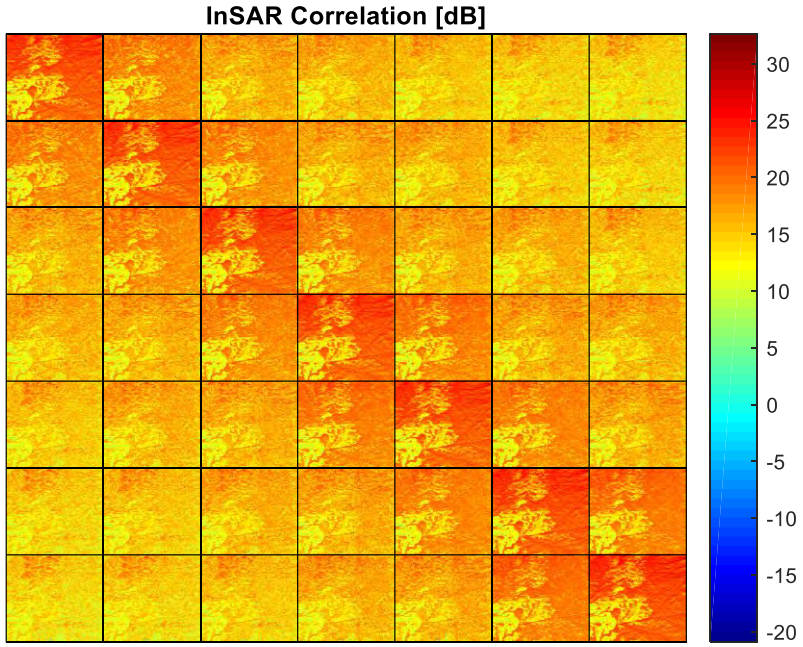
9	AfriSAR	Lopé	Tropical	JPL	L-Band	Airborne	JPL & POLIMI

SAR_TOMOGRAPHY_DEMO.m

Implemented functions:

Data-set selection, e.g.: operator, site, polarization, etc

- Interferogram generation
- Display intensities, coherence magnitude, and phase
- Tomographic processing via Beamforming (see equation 11) or via Correlation Tomography (see equation 14) to obtain a vertical section in the height, range plane
- Display the obtained vertical section



SARSIM example

9	AfriSAR	Lopé	Tropical	JPL	L-Band	Airborne	JPL & POLIMI

SAR_TOMOGRAPHY_DEMO.m

Implemented functions:

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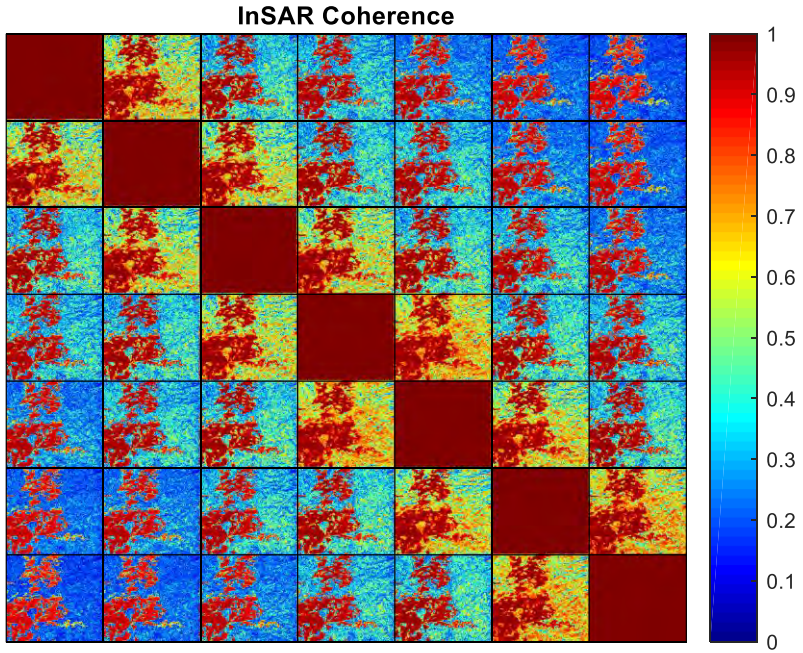

SARSIM example

9	AfriSAR	Lopé	Tropical	JPL	L-Band	Airborne	JPL & POLIMI

SAR_TOMOGRAPHY_DEMO.m

Implemented functions:

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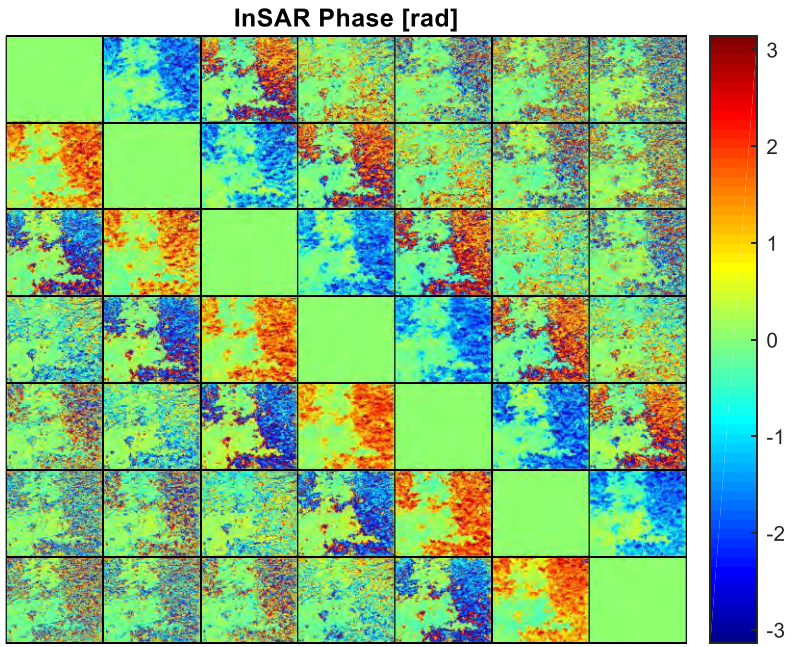
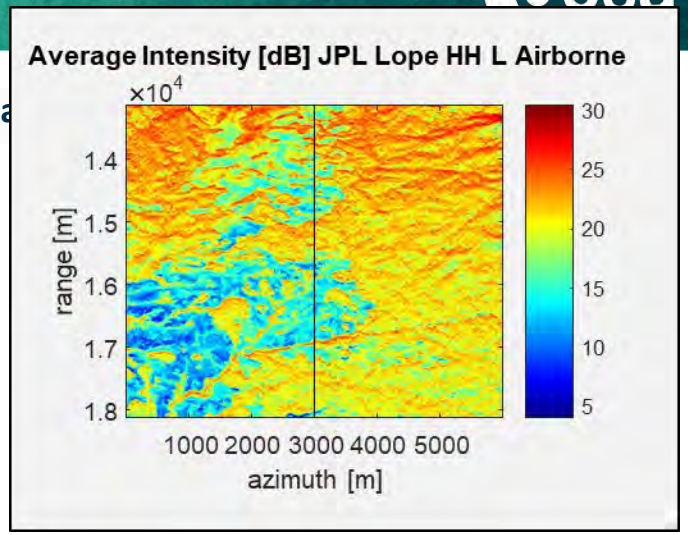
- Display the obtained vertical section



SARSIM example

9	AfriSAR	Lopé	Tropical	JPL	L-Ba

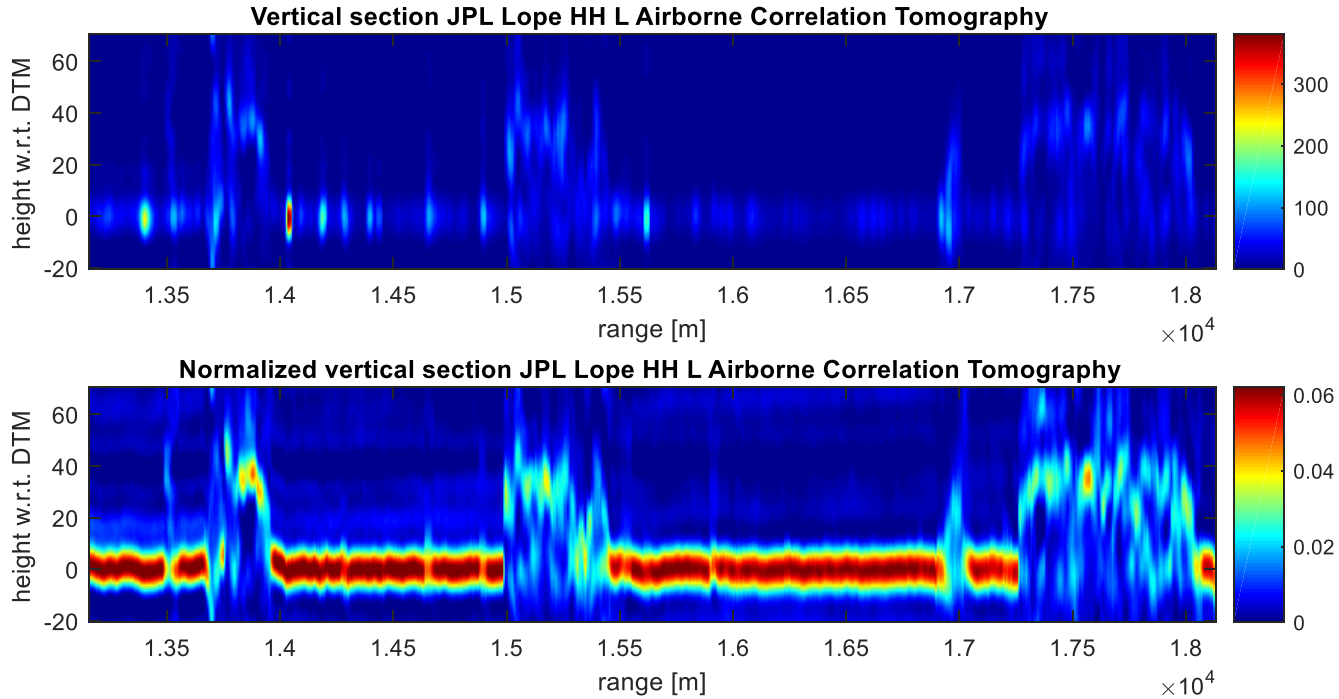


SAR_TOMOGRAPHY_DEMO.m

Implemented functions:

Data-set selection, e.g.: operator, site, polarization, etc

- Interferogram generation
- Display ir magnitude,
- Tomograph Beamformi or via Cor (see equat vertical se range plane
- Display th section



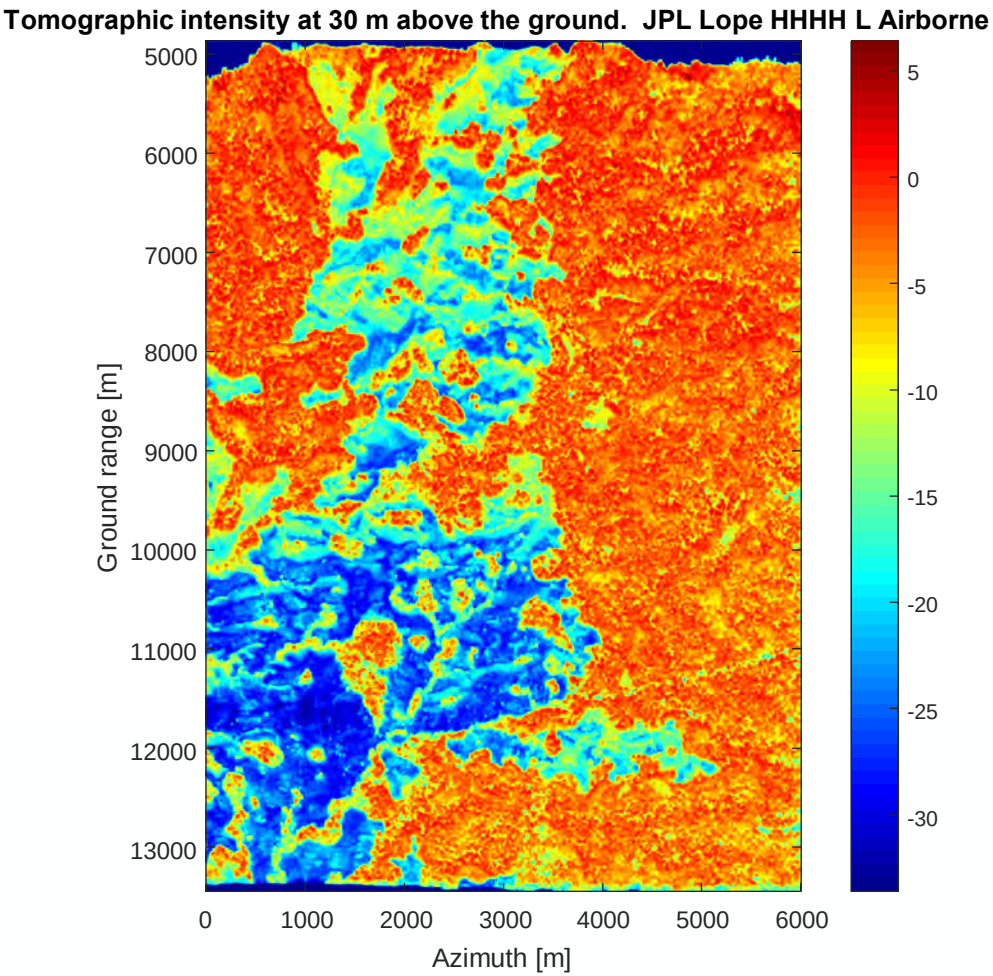
SARSIM+ example

9	AfriSAR	Lopé	Tropical	JPL	L-Band	Airborne	JPL & POLIMI

SARSIM_PLUS_DEMO.m

Implemented functions:

- Data-set selection, e.g.: operator, site, polarization, etc.
- Load a tomographic at user-specified height
- Load section coordinates (ground-range, azimuth)
- Display Tomographic Intensity or Tomographic coherence
- Load all tomographic sections
- Extract and display vertical sections



SARSIM+ example

9	AfriSAR	Lopé	Tropical	JPL	L-Band	Airborne	JPL & POLIMI

SARSIM_PLUS_DEMO.m

Implemented functions:

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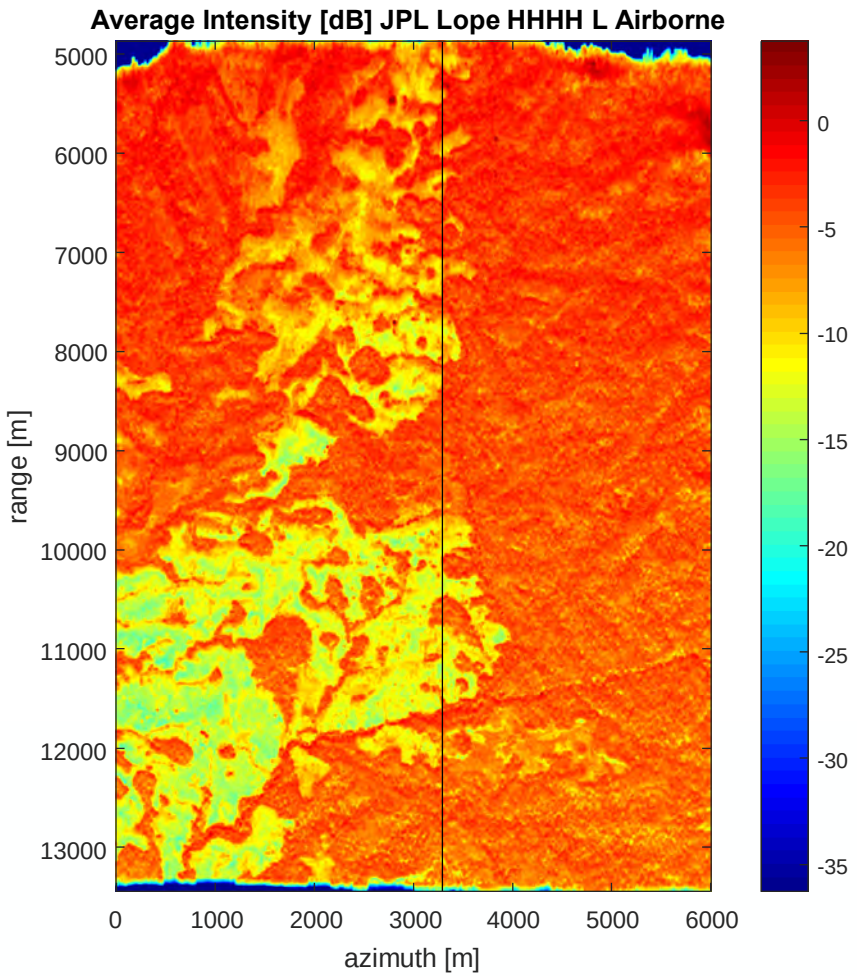

SARSIM+ example

9	AfriSAR	Lopé	Tropical	JPL	L-Band	Airborne	JPL & POLIMI

SARSIM_PLUS_DEMO.m

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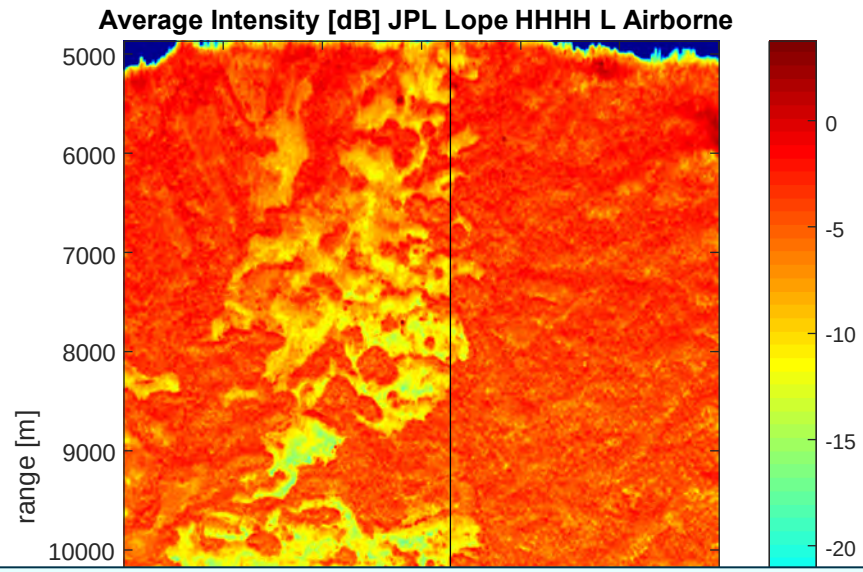
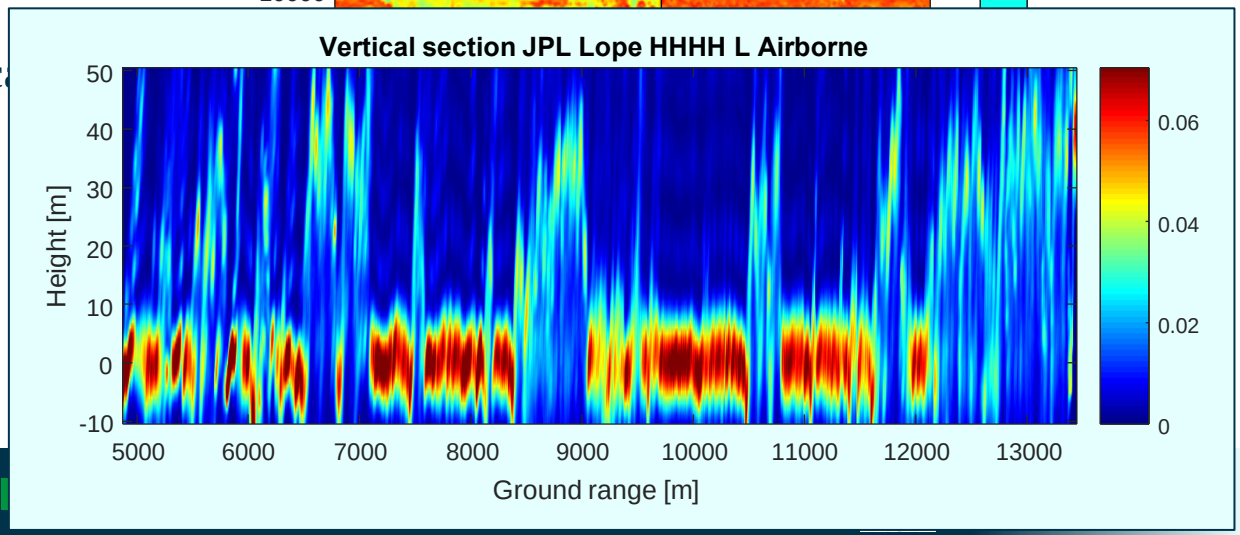
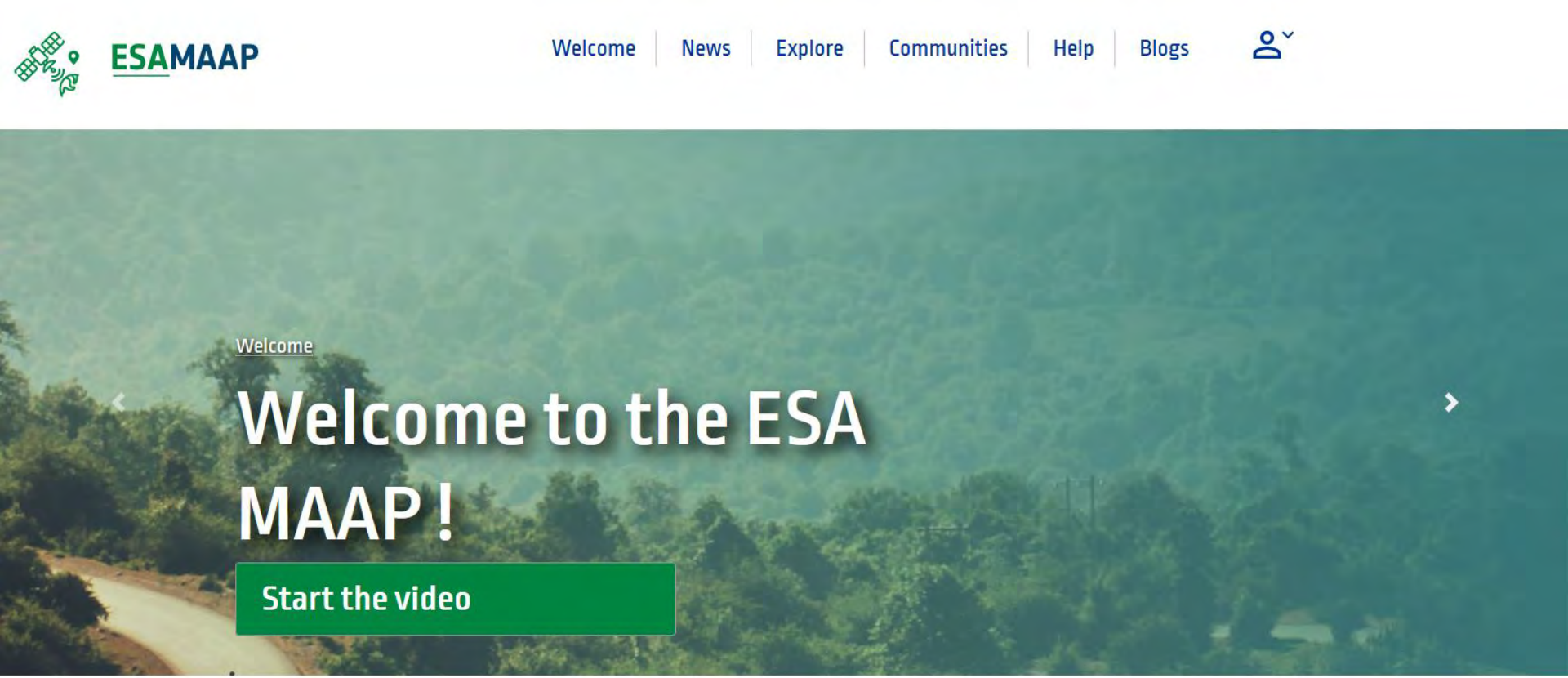




How to access SARSIM

THE SARSIM DATA-BASES WILL SOON BE AVAILABLE ON ESA'S MAAP



How to access SARSIM

THE SARSIM DATA-BASES WILL SOON BE AVAILABLE ON ESA'S MAAP

FOR TOMOGRAPHY DIE-HARDS: A SMALL SUBSET OF SARSIM (BUT WITH USER MANUAL AND WORKING CODES) IS ALSO AVAILABLE ON MY PERSONAL ONE-DRIVE FOLDER

To get the link, just write me at stefano.tebaldini@polimi.it