

Interferometric Polarimetric SAR Decomposition for BIOMASS Mission Ground Phase Calibration

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with contributions:

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Ludovic Villard – CESBIO

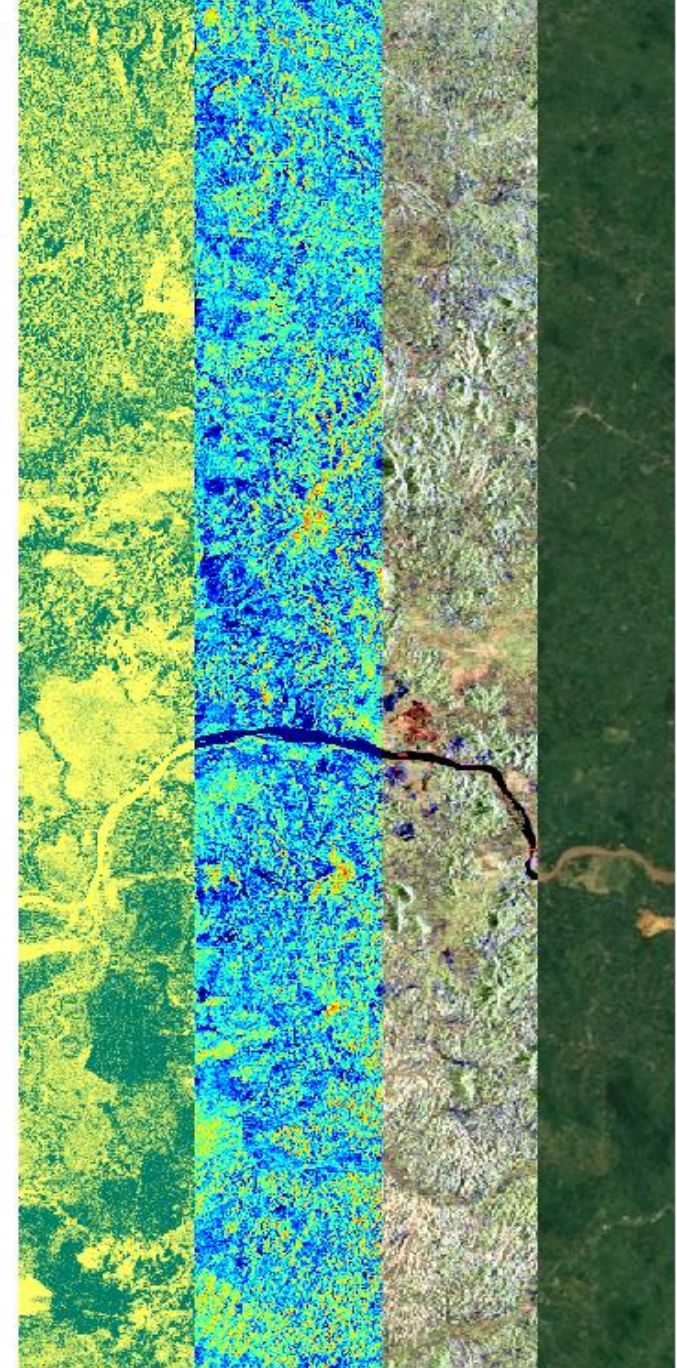
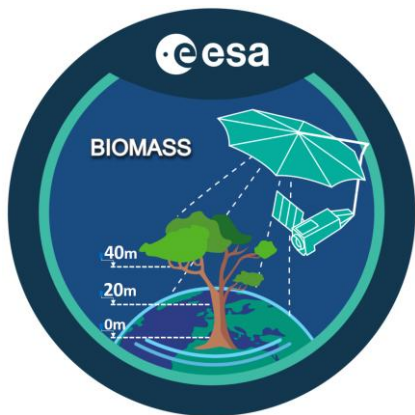
Laurent Ferro-Famil – CESBIO

Stefano Tebaldini – POLIMI

Guobing Zeng – Nanyang Technological University

Thu-Ha Nguyen – INRAE

Yen-Nhi Ngo – TomoSAR France



FRINGE 2026, June 18th

BIOMASS P-band radar stability

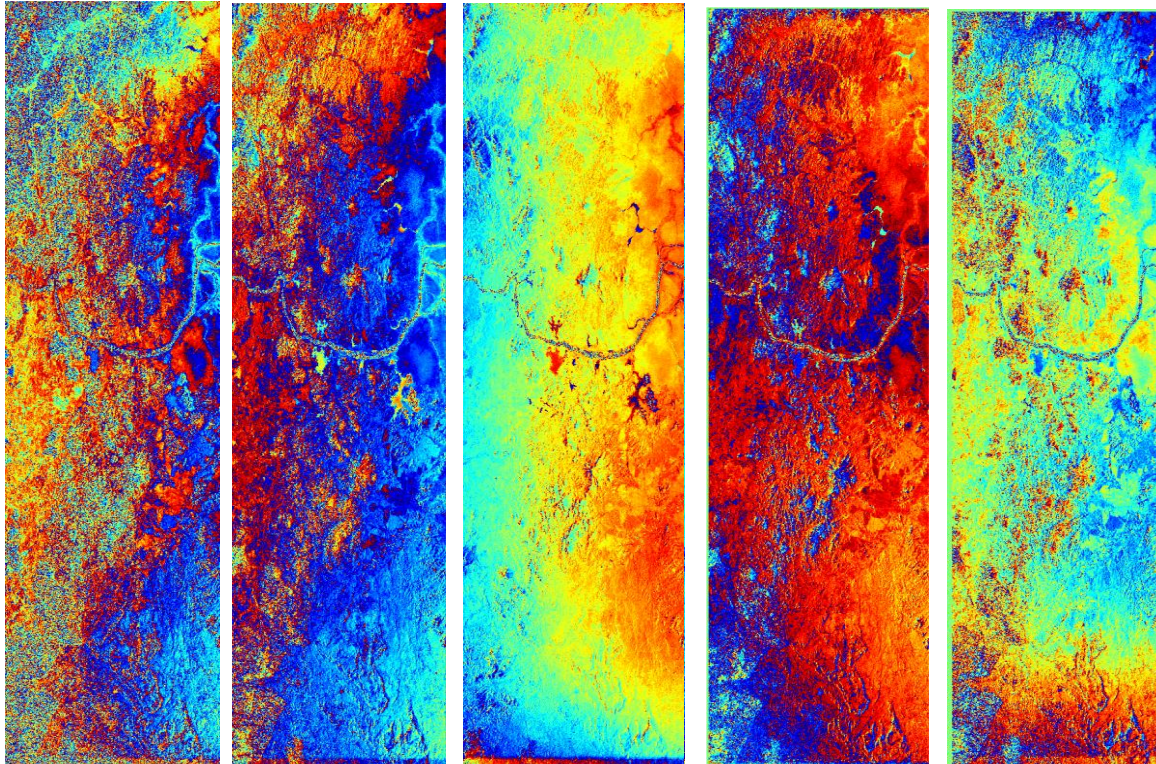
20251214

20251217

20251220

20251229

20260101



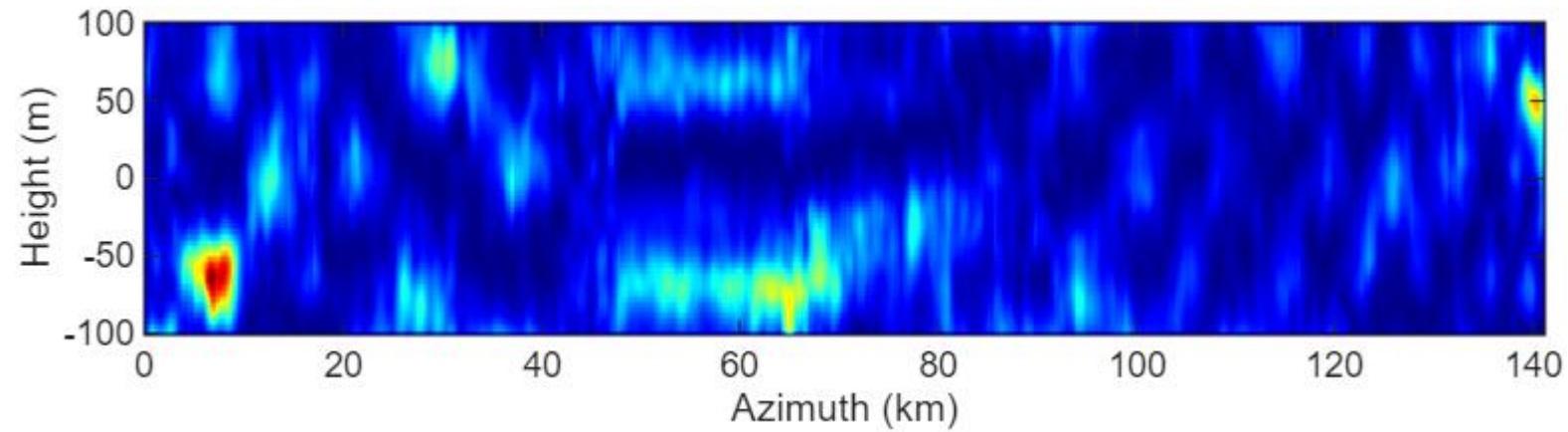
Reference: 20251223



- BIO_S2_SCS_1S_20251214T222735_20251214T222756_T_G01_M01_C02_T044_F001_01_DJO51F
- BIO_S2_SCS_1S_20251217T222737_20251217T222758_T_G01_M01_C03_T044_F001_01_DJTPAH
- BIO_S2_SCS_1S_20251220T222739_20251220T222800_T_G01_M01_C04_T044_F001_01_DJZA7P
- BIO_S2_SCS_1S_20251223T222741_20251223T222802_T_G01_M01_C05_T044_F001_01_DK4T2R
- BIO_S2_SCS_1S_20251229T222744_20251229T222805_T_G01_M01_C07_T044_F001_01_DKFZV2
- BIO_S2_SCS_1S_20260101T222745_20260101T222806_T_G01_M01_C08_T044_F001_01_DKCLKOK

Capon spaceborne tomographic profile

Before
phase calibration



Ground phase calibration

1. Phase calibration: to compensate for phase residuals potentially affecting 3D focusing.
 2. The ground level is used as a reference (0 m).
- > The signal coming from the ground must be estimated and removed from the signal.

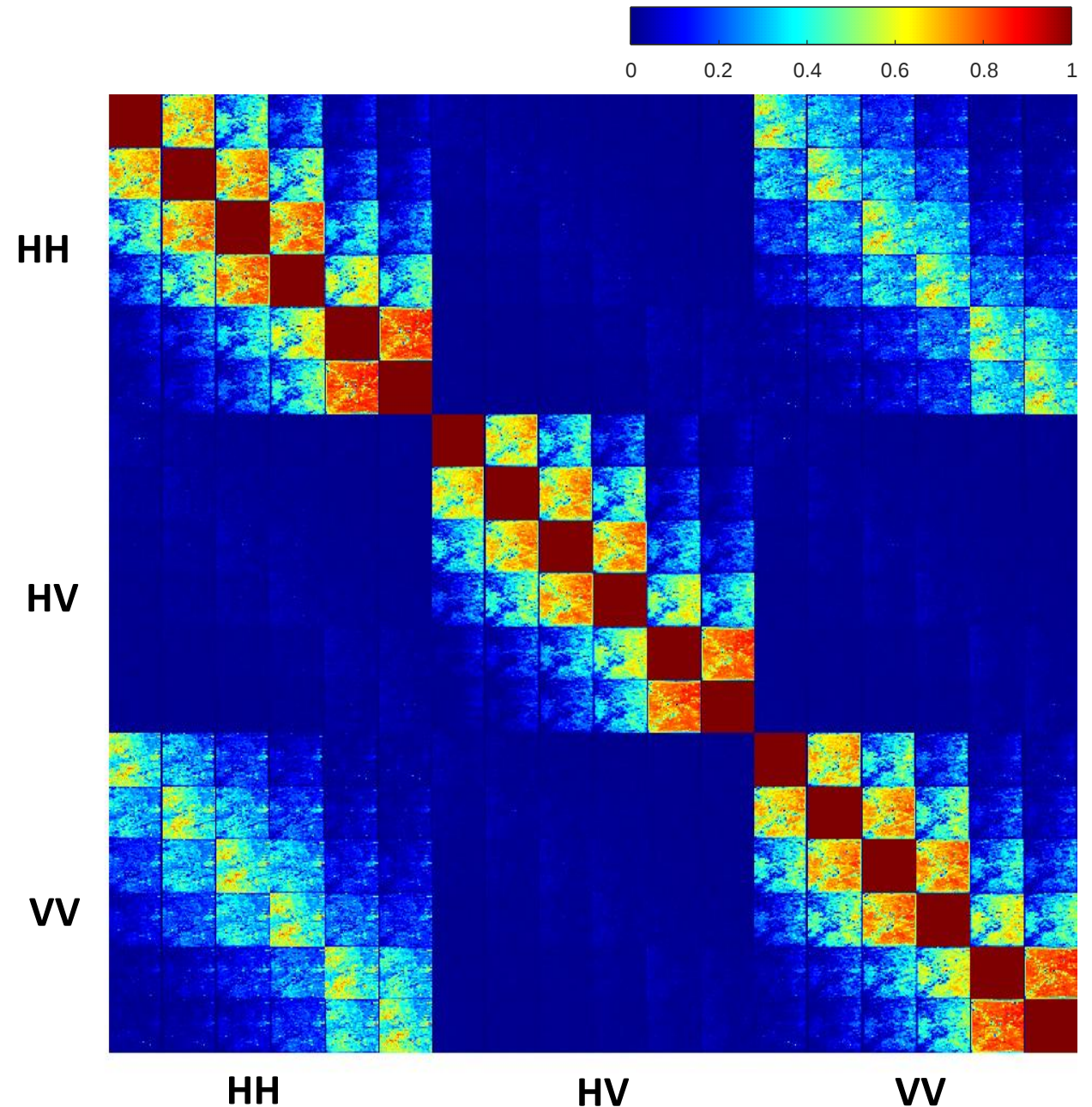
Jointly **interferometry** (R) - **polarimetry** (C)

$$W = \sum_{k=1}^K \lambda_k C_k \otimes R_k \approx C_g \otimes R_g + C_v \otimes R_v$$

C_k Polarimetric covariance (3×3 matrix)

R_k Interferometric covariance (N×N matrix)

λ_k Scaling eigenvalues



Ground phase calibration

Ground Component

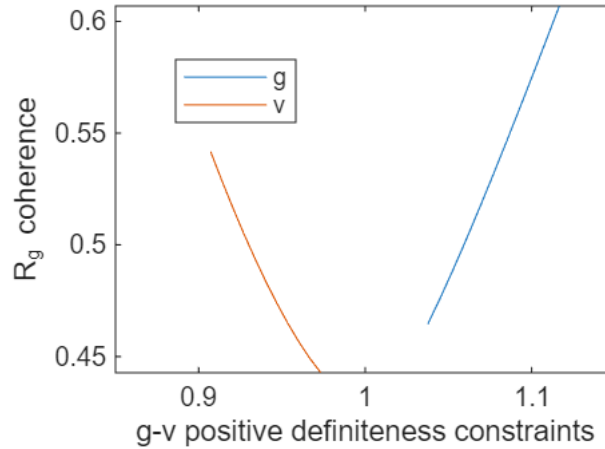
$$R_g = g \cdot R_1 + (1-g) \cdot R_2$$

$$C_g = (1-v) \cdot C_1 - v \cdot C_2$$

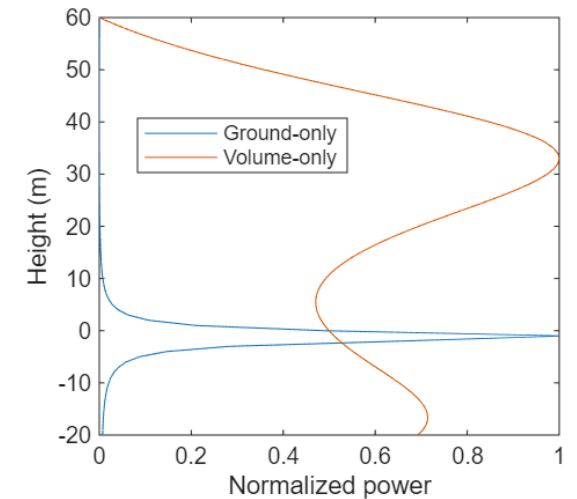
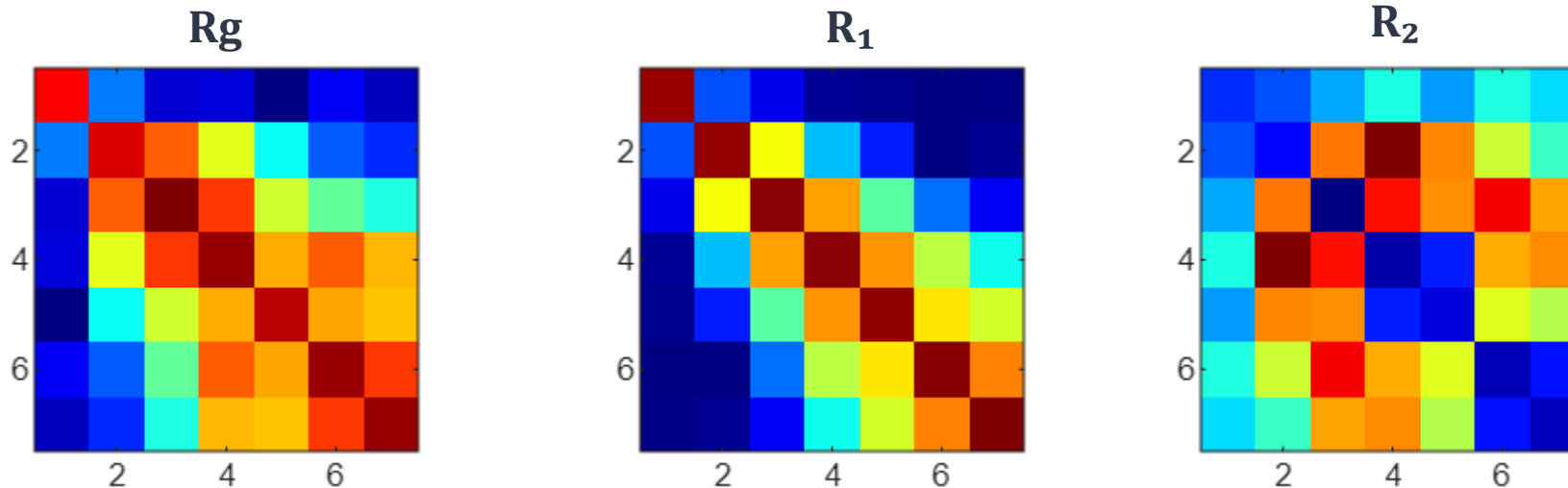
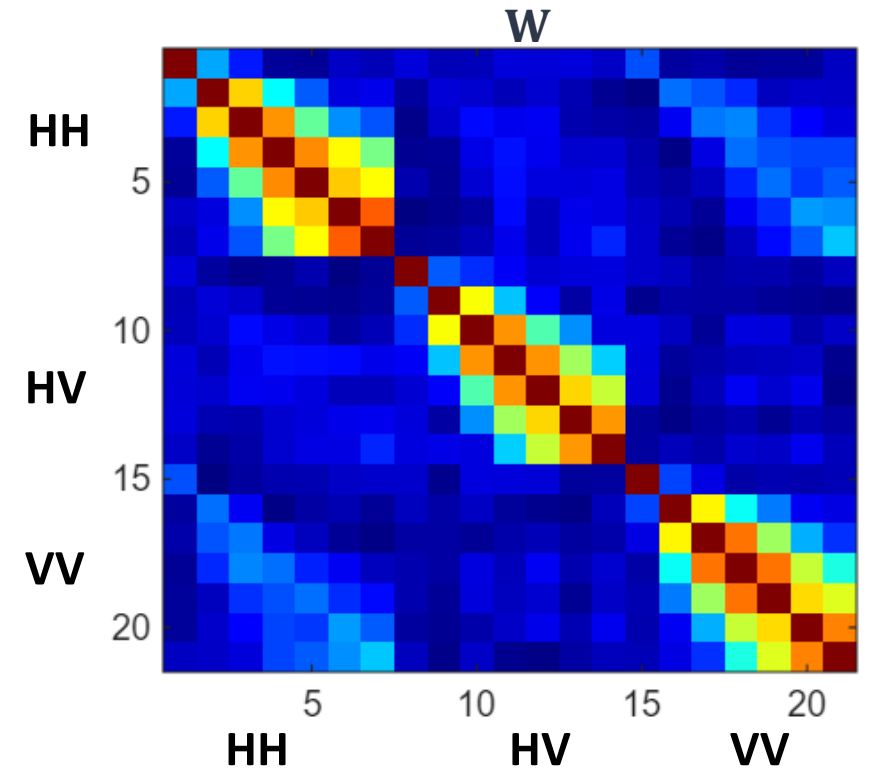
Volume Component

$$R_v = v \cdot R_1 + (1-v) \cdot R_2$$

$$C_v = -(1-g) \cdot C_1 + g \cdot C_2$$

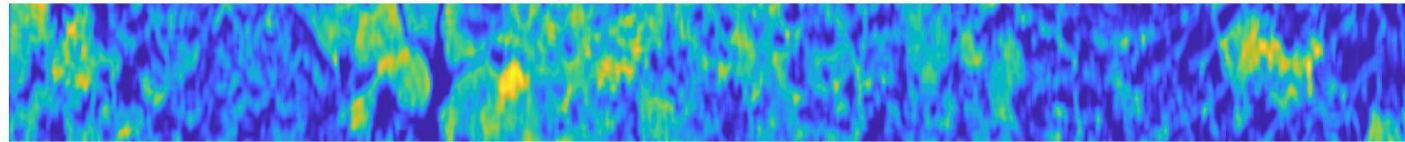


Apply phase-linking algorithms to R_g to obtain the ground phase.

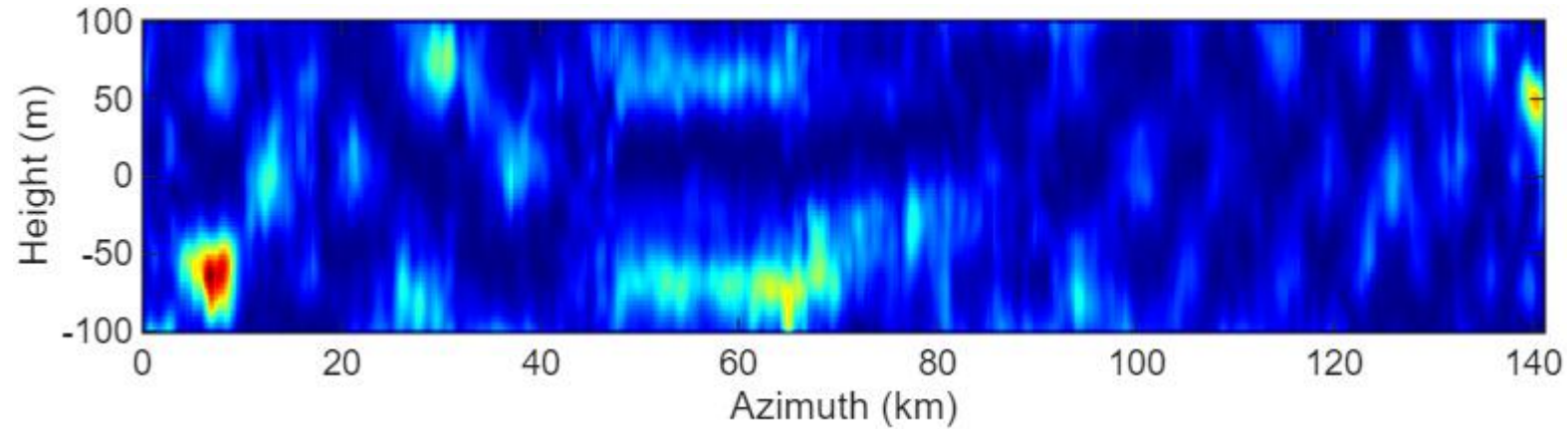


Capon spaceborne tomographic profile

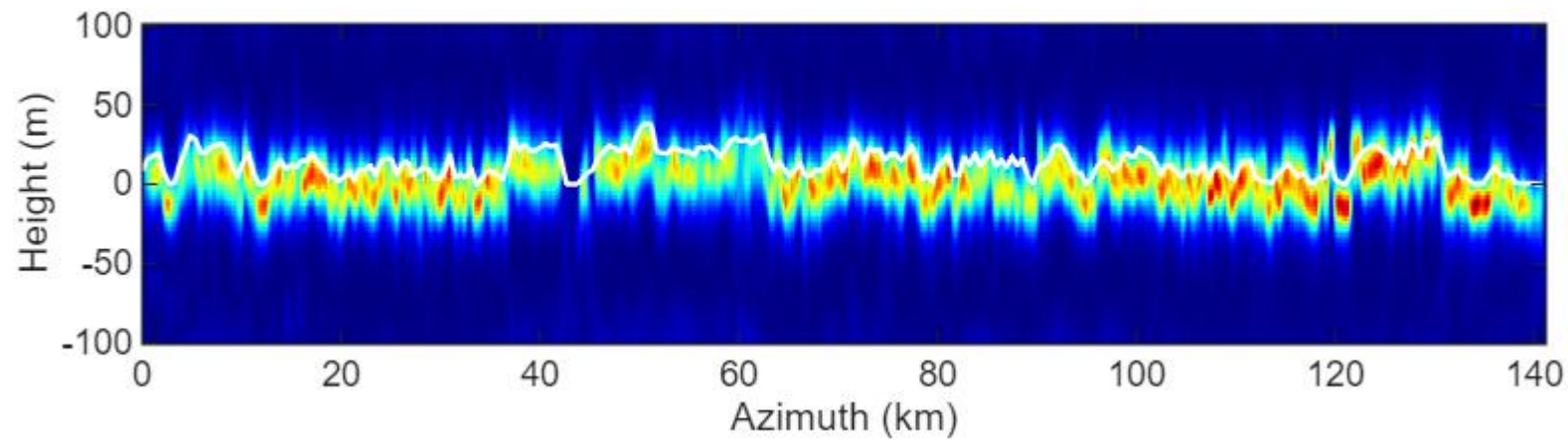
HH layer 30m



Before
phase calibration



After
phase calibration



The white line indicates the calibrated TomoSAR height retrieval.

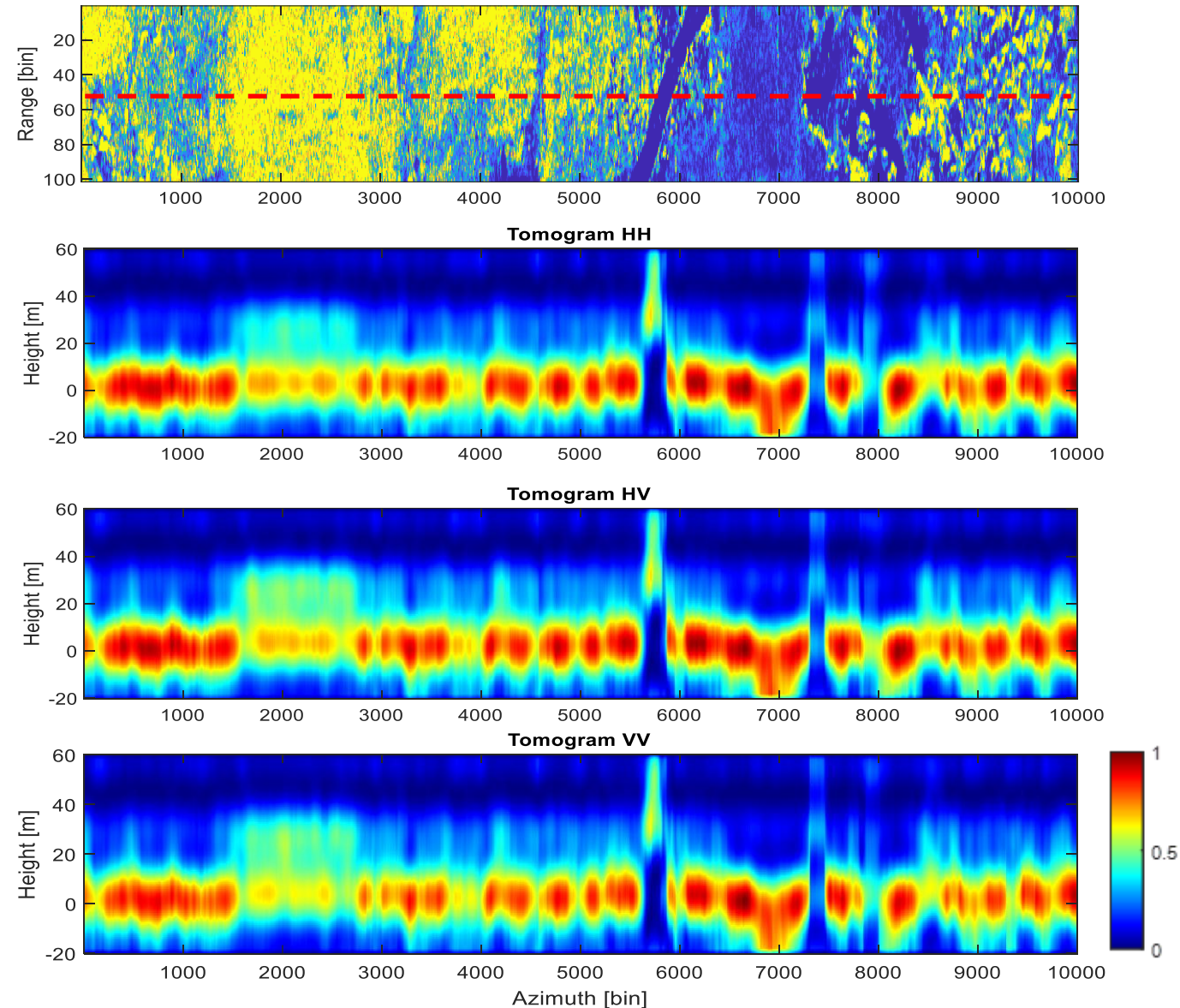
Beamforming spaceborne tomographic profile

Profile: a slice of the multi-layer data stack

Each panel is flattened to bring the terrain level to 0 m, for visualization and interpretation.

Similar airborne campaigns finding:

- **Significant surface scattering contributions are observed at the canopy level in HH and VV polarizations.**
- **The volume-scattering contribution dominates in HV polarization.**
- **Contributions from the ground level below the forest are observed, notwithstanding forest height.**



Approximate biomass prediction

110 km

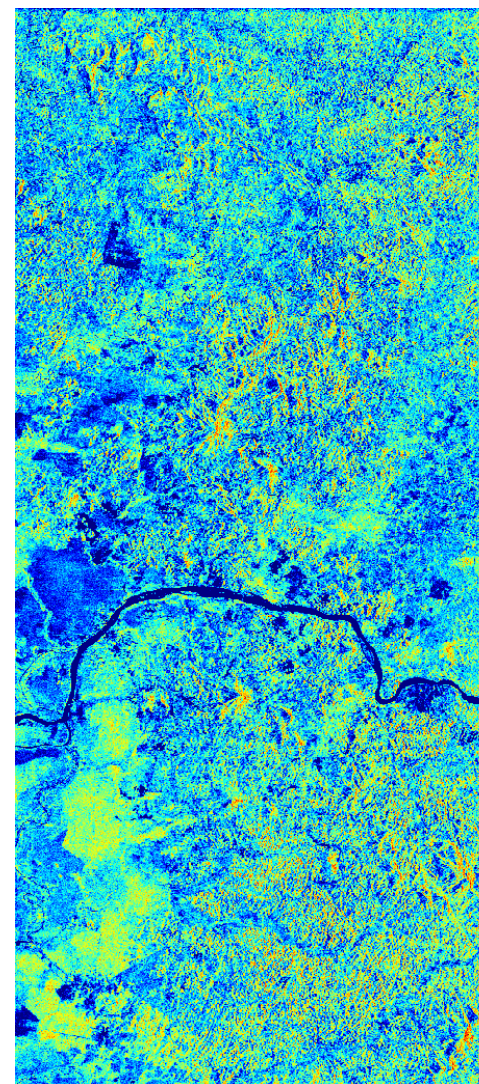
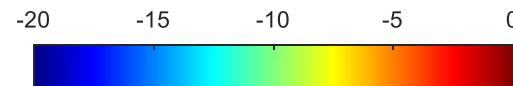
140 km



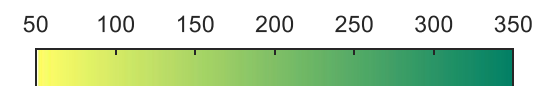
Optical



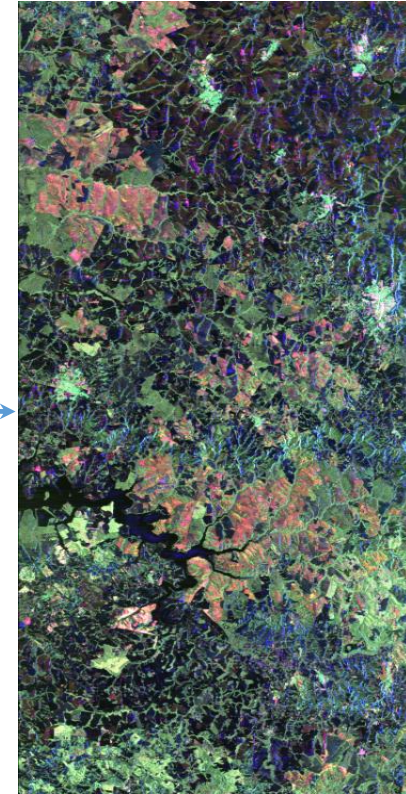
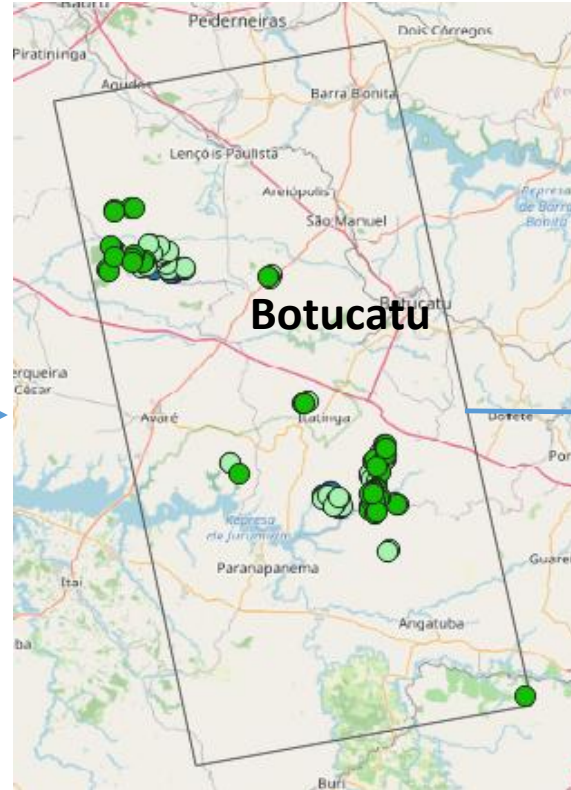
Pauli



HV 30m

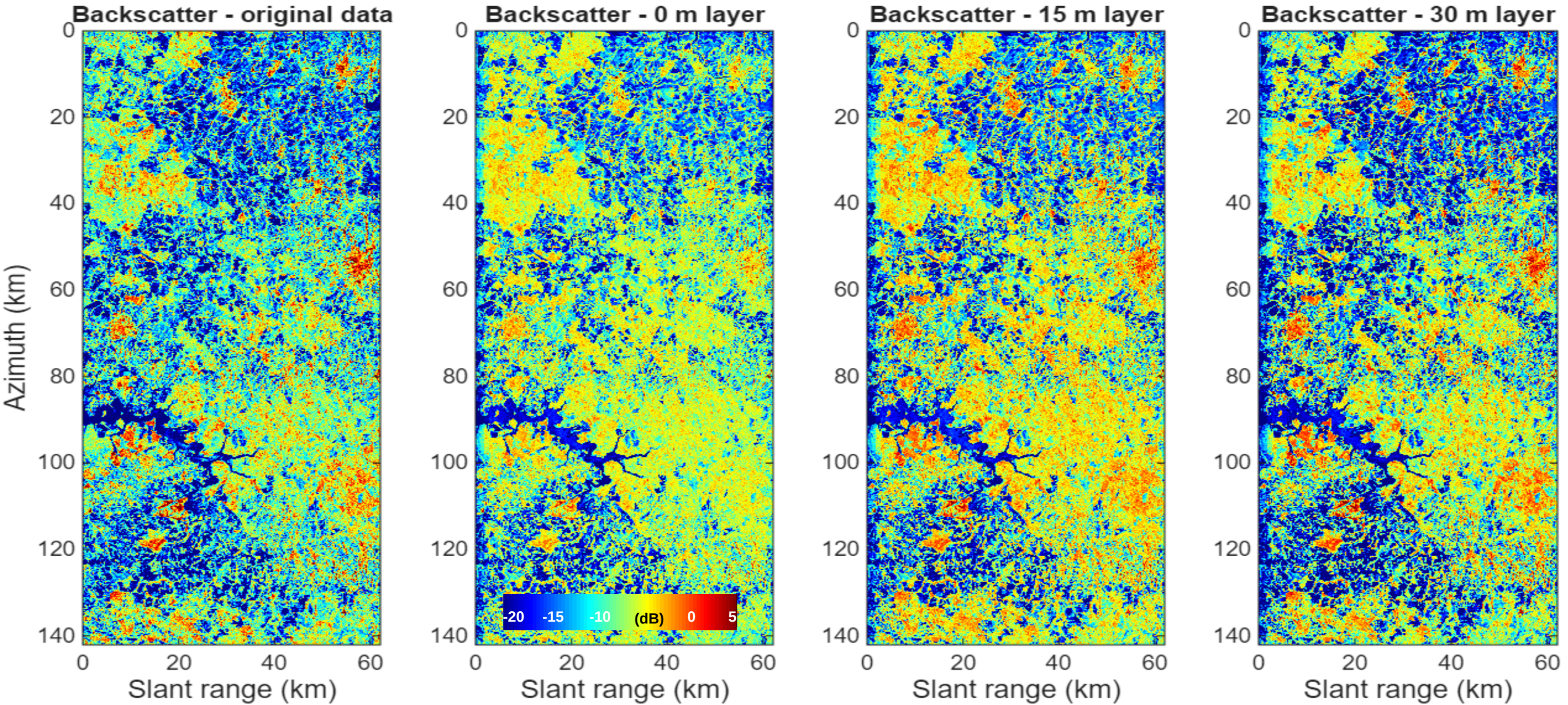


Biomass prediction



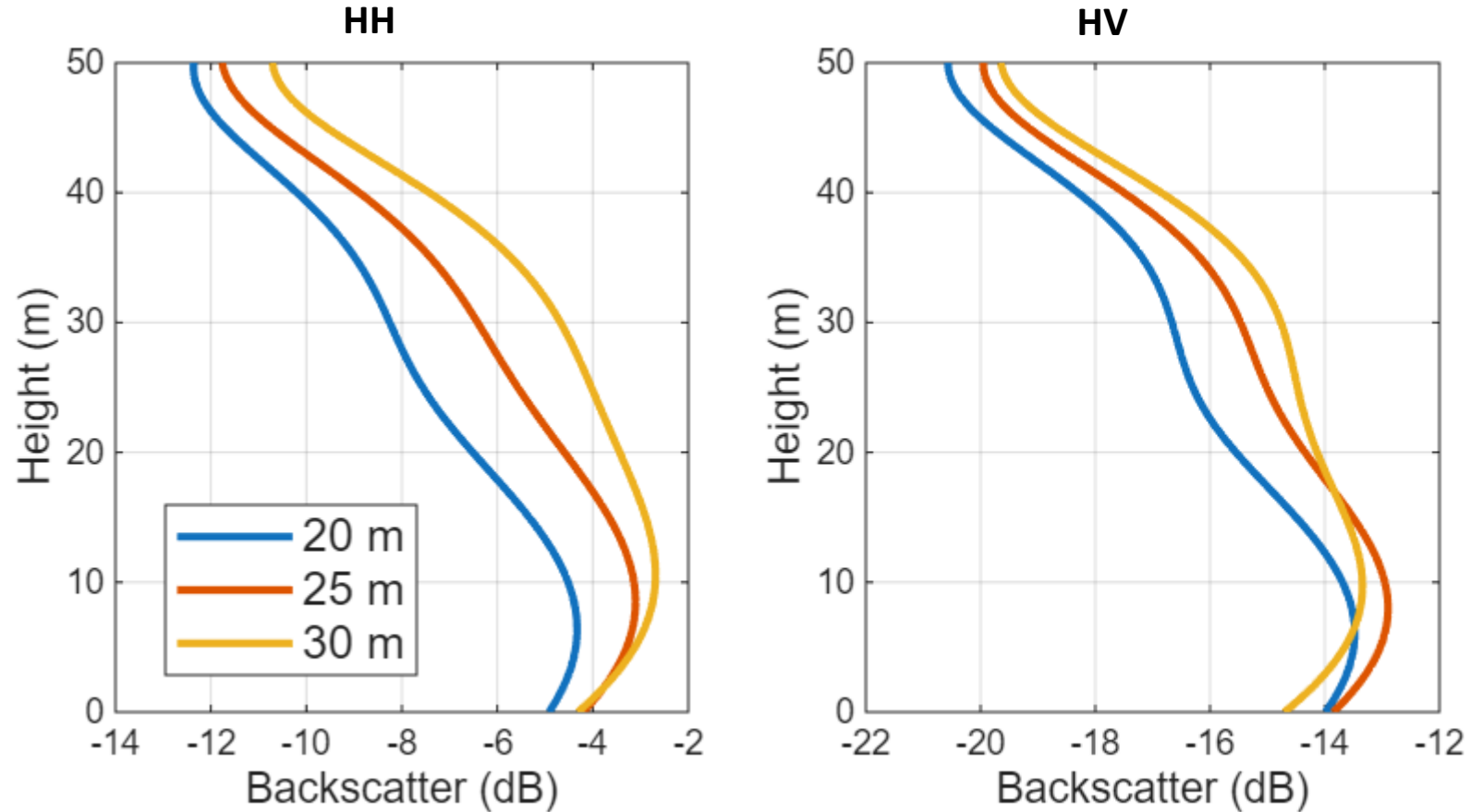
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- 📁 BIO_S2_SCS_1S_20251217T091549_20251217T091610_T_G01_M01_C02_T035_F291_01_DJSOCD
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- 📁 BIO_S2_SCS_1S_20251223T091553_20251223T091614_T_G01_M01_C04_T035_F291_01_DK3R28
- 📁 BIO_S2_SCS_1S_20251226T091555_20251226T091615_T_G01_M01_C05_T035_F291_01_DK9EWK
- 📁 BIO_S2_SCS_1S_20251229T091556_20251229T091617_T_G01_M01_C06_T035_F291_01_DKEY9H
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Beamforming spaceborne tomographic layers



Beamforming spaceborne tomographic profiles

The average reflected energy using samples within different CHM cluster.



Eucalyptus plantations: The superior sensitivity of the HH polarization over HV.

(Ho Tong Minh et al., Eucalyptus Plantations by P-band BIOMASS Tomography, submitted to RSE.)

Take home message

- ✓ BIOMASS P-band radar **stability** enables tomographic mapping in forests.
- ✓ BIOMASS provides unique data combining interferometry and polarimetry.
- ✓ Eucalyptus plantations: The superior sensitivity of the HH polarization over HV.
- ✓ Ground phase **calibration** is important to make it possible.
- ✓ **The first results are encouraging! Thank you, ESA, for making P-band available in space.**

☐ Next steps:

- Process sites where ground data available and higher biomass range
- Go beyond biomass: biodiversity, innodation, soil moisture, ...
- Exploit the Deep Learning with physics-informed models
- Encourage ESA to support more open-source toolbox on tomography