Multi-Frequency Multi-Baseline Fully Polarimetric Forest Height Inversion. Perspectives of BIOMASS/TanDEM-X Data Fusion.

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Today, an increasing number of Earth observation Synthetic Aperture Radar (SAR) satellites, owned by both governmental and commercial parties, are operating in orbit, acquiring microwave backscatter data across a wide microwave spectrum (from cm to dm wavelengths). Beyond the diversity in frequency bands, SAR missions employ different polarisations, and follow various spatial and temporal baseline setups that define the angular and temporal diversity of their measurements. More and more missions are today capable of interferometric measurements while the next generation of missions will allow the implementation of tomographic techniques [1].

In this context, multi-modal SAR missions such as ESA's BIOMASS [2] (P-band) and DLR's TanDEM-X [3] (X-band) inspire new synergistic applications of their advanced capabilities. Moreover, the future ESA ROSE-L mission, NASA-ISRO's NISAR mission, JAXA's ALOS-2 and ALOS-4 missions, and DLR's bistatic TanDEM-L mission further motivate the integration of L-band into this study. Our research explores the potential of combining P-, L-, and X-band data using experimental airborne datasets and available satellite data.

In particular, this work investigates the potential of combining multi-frequency multi-modal SAR measurements / acquisitions for forest height inversion. Forests provide a natural scenario where frequency bands complement each other. The P-band, with its high penetration capability through dense vegetation, is more suitable for estimating ground elevation (topography). Other frequency bands (e.g., L-band, X-band) can be used to derive InSAR coherence and phase, to be employed in single-baseline forest height inversion.

InSAR coherence and phase are inherently sensitive to the vertical reflectivity profile, which is composed of contributions from both the ground and the volume scatterers [4]. This study further examines the use of vertical reflectivity profiles estimated through tomographic reconstruction at one frequency band and evaluates their applicability across other frequency bands. The research focuses on determining the limitations of this cross-band approximation and the necessity for specific parameterization for different frequency bands. Our results show a notable stability of forest height inversion, if several frequency bands data are employed. However, the availability of non-zero across-track interferometric baselines becomes essential for the proposed method. Additionally, the phase calibration is critical, if addressing distortions caused by the ionosphere, especially relevant for achieving accurate results using P-band.

The synergy between P- and L-band is demonstrated using data from airborne campaigns such as AFRISAR 2016 and GABONX 2023 [5], while X-band is included through bistatic TanDEM-X data, providing a multi-frequency perspective for forest height inversion. In the space-borne context, our method establishes a framework towards TanDEM-X/BIOMASS data fusion.

REFERENCES

[1] Moreira, Alberto, Pau Prats-Iraola, Marwan Younis, Gerhard Krieger, Irena Hajnsek, and Konstantinos P. Papathanassiou. "A tutorial on synthetic aperture radar." *IEEE Geoscience and remote sensing magazine* 1, no. 1 (2013): 6-43.

[2] S. Quegan, The European Space Agency BIOMASS mission: Measuring forest above-ground biomass from space. Remote Sensing of Environment, 227, 44-60, 2019

[3] Krieger, G., Moreira, A., Fiedler, H., Hajnsek, I., Werner, M., Younis, M. and Zink, M., 2007. TanDEM-X: A satellite formation for high-resolution SAR interferometry. IEEE Transactions on Geoscience and Remote Sensing, 45(11), pp.3317-3341.

[4] Guliaev, R., Kim, J.S., Pardini, M. and Papathanassiou, K.P., 2024. On the Use of Tomographically Derived Reflectivity Profiles for Pol-InSAR Forest Height Inversion in the Context of the BIOMASS Mission. IEEE Transactions on Geoscience and Remote Sensing.

[5] I. Hajnsek, M. Pardini, et al.,, "Technical assistance for the development of airborne SAR and geophysical measurements during the AfriSAR campaign, Final technical report, 2016