VERTICAL FOREST SRUCTURE ESTIMATION BY MEANS OF MULTI-BASELINE POL-INSAR AT L-BAND FOR GLOBAL BIOMASS MAPPING POTENTIAL & LIDAR SYNERGIES

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ABSTRACT

A central parameter of the terrestrial carbon budget is forest biomass which represents a proxy for the stored carbon. Despite its crucial role in the terrestrial carbon budget, forest biomass is poorly quantified across most parts of the planet due to the great difficulties in measuring biomass on the ground and consistently aggregating measurements across scales. Today's information is largely based on ground measurements on a plot basis and for many regions is still missing. Accurate and reliable estimation of forest biomass is today one of the "hot topics" within the radar and lidar remote sensing communities. In this paper, we propose and evaluate a new approach for biomass estimation based on the estimation of the forest vertical structure.

Biomass a Function of Vertical Structure and Height

In [7] a method for biomass estimation using the allometric relationship between biomass and forest height is described.

$$B = 1.66 \quad H^{1.58} \qquad \text{Eq.1}$$

B is the Biomass in Mg/ha and *H* the forest top height. This method provides reliable results for closed canopy forest systems without strong density variations. However, changes in forest density and structure caused for example by tree species composition, management system or disturbances introduce deviations in vertical structure. With increasing horizontal and/or vertical forest heterogeneity the variance of the biomass height relationship increases. An extension of the height to biomass allometry has been recently proposed in terms of vertical structure information

$$B = 1.44 * \sum_{i=0}^{H} \sum_{j=1}^{3} a_j \cdot P_j \qquad \text{Eq.2}$$

where *H* is the the forest top height and $\sum_{j=1}^{N} a_j \cdot P_j$ the vertical forest biomass distribution expressed in terms of a (orthogonal) shape functions P_j.

Estimation of forest vertical structure by means of SAR

The estimation of forest vertical structure by means of SAR, especially when addressed in terms of a space-borne mission implementation, is a challenge. While conventional SAR tomography has demonstrated the potential to "image" vertical structure by means of multiple acquisitions, the lack of multiple space-borne SAR configurations able to perform these acquisitions, combined with (temporal) scene decorrelation that limits the temporal baseline of the acquisitions, reduce the number of suitable (i.e. coherent) acquisitions in a realistic space-borne scenario drastically. Therefore, the application of conventional tomographic imaging becomes rather limited at least in terms of the actual state-of-art in space-borne SAR missions.

Given the availability of only a limited number of acquisitions, alternative approaches have to be used in order to assess vertical structure information by means of SAR. The proposed techniques can be distinguished into two main classes:

1. Interferometric approaches are based on the fact that the (volume) interferometric coherence is directly related to the vertical distribution of scatterers seen by the radar and thus to the vertical structure of forests. This information can be either extracted by model based inversion or by approximating the structure function through a weighted sum of a series of (orthogonal) basis functions.
2. (Complex) Reflectivity approaches separate the location of the phase centers associated to the individual vertical structure components. This is then used to reconstruct the vertical structure of forest scatterers.

Common in both approaches is the necessity to parameterize the vertical structure function using a limited number of parameters, a step that is challenging when accounting the complexity of forest structures. The individual parameterization has then to be inverted using a (limited) number of interferometric or reflectivity measurements at the same or different polarizations.

The biomass estimation performance by means of Eq. 2 will be investigated and discussed. The pros and cons of the different vertical structure estimation approaches by means of SAR at L-band are discussed with respect to biomass estimation and their performance in terms of required acquisitions (observation space), and acquisition scenario is assessed. The performance of individual techniques is demonstrated using multi-baseline SAR data acquired by DLR's E-SAR airborne sensor in the frame of different relevant and actual experiments. Finally the potential of combining lidar - that similarly measures vertical forest structure but at a different wavelength and with a different vertical resolution - and radar vertical structure estimates by means of Eq. 2 is discussed.

References

[1] S.R. Cloude and K.P. Papathanassiou 1998, "Polarimetric SAR Interferometry", IEEE Transactions on Geoscience and Remote Sensing, vol. 36, no. 5, pp. 1551-1565, September 1998.

[2] K.P. Papathanassiou and S.R. Cloude, ‘‘Single base-line Polarimetric SAR Interferometry’’, IEEE Transactions on Geoscience and Remote Sensing, vol. 39, no. 11, pp. 2352-2363, 2001.

[3] S.R. Cloude and K.P., Papathanassiou, “Three-stage inversion process for polarimetric SAR interferometry”, IEE Proceedings - Radar Sonar and Navigation, vol. 150, no. 3, pp. 125-134, 2003.

[4] I. Hajnsek, F. Kugler, S.-K. Lee, K. P. Papathanassiou, “Tropical-Forest-Parameter Estimation by means of Pol-InSAR: The INDREX II Campaign, IEEE Transactions on Geoscience and Remote Sensing, vol. 47, no. 2, pp. 481 – 493, February 2009

[5] S. Cloude, “Polarisation Coherence Tomography”, Radio Science, vol. 41, RS-4017, 2006.

[6] S. Cloude, “Dual Baseline Coherence Tomography”, IEEE Transactions on Geoscience and Remote Sensing letters, vol4, issue 1, pp: 127 – 131, Januar 2007

[7] T. Mette, K. P. Papathanassiou, I. Hajnsek, “Biomass estimation from polarimetric SAR interferometry over heterogeneous forest terrain”, Proceeding of IEEE Geoscience and Remote Sensing Symposium (IGARSS 2004), 20. - 24. September, Anchorage, Alaska, 2004