P-BAND TOMOGRAPHIC ANALYSIS OF THE REMNINGSTORP FOREST SITE

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1. ABSTRACT

This paper is devoted to reporting the results of the tomographic analysis of the forest site of Remningstorp, Sweden, that have been partially presented at IGARSS 2008 in Boston, see [1]. The analysis has been based on a data-set of 9 P-Band, fully polarimetric SAR images acquired by the DLR airborne system E-SAR. The acquisition campaign has been carried out in Spring 2007, in the framework of the ESA project BioSAR, aiming at the investigation of radar signatures of boreal forests. Thanks to the availability of multi-baseline and multipolarimetric data, both the polarimetric signature and the vertical structure of the Remningstorp forest have been analyzed. As a result, the following analyses will be presented: 1) Analysis of the polarimetric signature; 2) Single and multi-polarimetric spectral analysis of the forest vertical structure; 3) Parametric estimation of the forest vertical structure in terms of ground and canopy elevation and spatial decorrelation; 4) Separation of the polarimetric signatures associated the ground and canopy. The problems of vertical structure retrieval from single-pol observations and from small bandwidth data will be discussed as well.

2. DATA MODEL

Letting $\mathbf{y}_{MB} = \begin{bmatrix} y_1 & y_2 & \cdots & y_N \end{bmatrix}^T$ represent the stack of the *multi baseline* data at a given location in the range, azimuth plane, and under the assumption of statistical independence among different mechanisms, the data covariance matrix is given by:

$$\mathbf{W}_{MB} = E\left[\mathbf{y}_{MB}\mathbf{y}_{MB}^H\right] = \sum_{k=1}^{K}\mathbf{R}_k \tag{1}$$

where $\mathbf{R}_k$, hereinafter referred to as structure matrix, is the single polarimetric, multi baseline covariance matrix of the data due to the *k-th* scattering mechanism. In order not to raise excessively the number of the unknowns, we let each structure matrix depend upon *two* parameters:

- Mean elevation, h_k. This parameter affects the phase of the off-diagonal terms of the structure matrices according to the law:

$$\angle\left\{\mathbf{R}_k\right\}_{nm} = \left(k_z\left(n\right) - k_z\left(m\right)\right)\cdot h_k \tag{2}$$

  where $k_z\left(n\right)$ is the height to phase conversion factor for the *n-th* image.

- Decorrelation constant, ρ_k. This parameter affects the absolute value of the off-diagonal terms of the structure matrices according to the law:

$$\left|\left\{\mathbf{R}_k\right\}_{nm}\right| = \rho_k^{-\left|k_z(n)-k_z(m)\right|\zeta} \tag{3}$$

  where ζ is a normalizing constant such that the exponent in (3) is dimensionless.

The role of the decorrelation constant is to describe in a simple fashion the degree of correlation among the acquisitions, avoiding the dependence upon a particular target model. Given the definition above the decorrelation constant ranges from 0 to 1, corresponding to the cases of pure noise and of a perfectly coherent received signal (i.e. a point-like scatterer), respectively.

3. RESULTS

3.1. Elevation Estimates

The top row of Fig. (**??**) shows the map of the estimates relative ground elevation. The black areas correspond to area dominated by an unstructured scattering mechanism, as it is the case of lakes. The identification of such areas has been carried out after the analysis of the spatial decorrelation constant, as discussed hereinafter. The estimates relative to canopy elevation are visible in the bottom row of Fig. (**??**). In this case, the black areas have been identified by the algorithm as being characterized by the presence of (at most) a single target. LIDAR measurements relative to ground and canopy elevation, provided by the Swedish Defence Research Agency (FOI), have been exploited as a validation tool. As for ground elevation, a rather good agreement has been observed between T-SAR estimates and LIDAR measurements, the dispersion of the difference, $z_{SAR} - z_{LIDAR}$, being assessed less than 1 m, see Fig. (2). The result relative to canopy elevation is not that brilliant as the one relative to ground elevation, see the right panel of Fig. (2). This discrepancy is clearly imputable to the fact that the estimates yielded by T-SAR are relative to average the phase center elevation inside the estimation window, whereas LIDAR is only sensitive to the top height of the canopy. In particular, it is interesting to note that the canopy elevation provided by T-SAR appears to be slightly under-estimated with respect to LIDAR measurements, as a result of the under foliage penetration capabilities of P-band microwaves. Nevertheless, the overall agreement between T-SAR and LIDAR is satisfactory, as shown by Fig. (**??**).

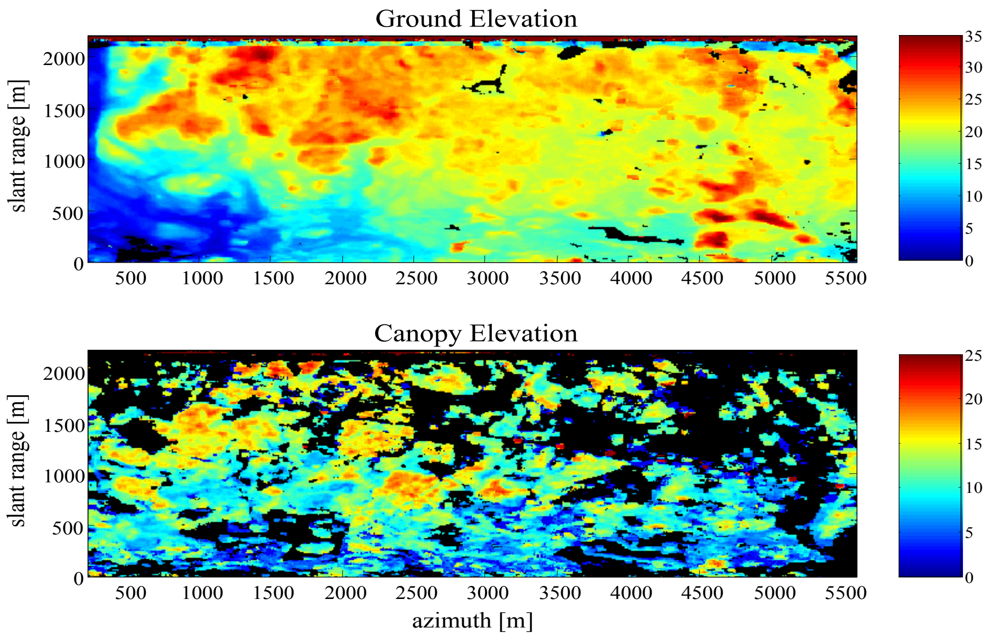

Fig. 1. Top row: estimated ground elevation. Black areas correspond to an unstructured scattering mechanism. Bottom row: estimated canopy elevation. Black areas correspond to absence of canopy.

3.2. Other results

The final paper will show results relative to

- Estimation of the decorrealtion constant
- Estimation of the polarimetric signatures associated to ground and volume scattering
- Elevation estimates obtained by processing each polarimetric channel separately
- Elevation estimates obtained by processing a 6 MHz pulse bandwidth data

4. REFERENCES

[1] S. Tebaldini, F. Rocca, and A. Monti Guarnieri, "Model based sar tomography of forested areas," *Geoscience and Remote Sensing Symposium, 2008. IGARSS 2008. IEEE International*, July 2008.

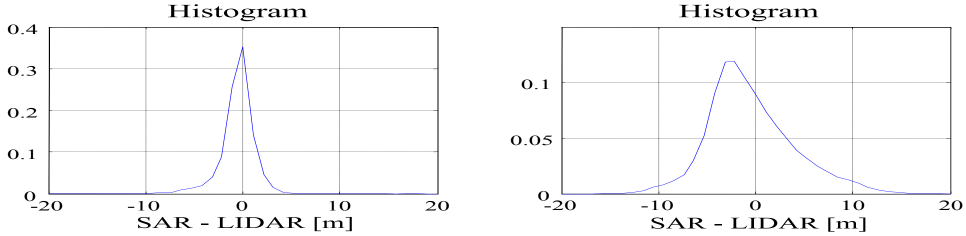

Fig. 2. Histograms of the differences of the elevation estimates relative to the ground and the canopy yielded by T-SAR and LIDAR measurements.