Above Ground Biomass estimation from SAR vertical reflectivity profiles

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First attempts for the estimation of above ground forest biomass (AGB) by means of SAR, have used allometric equations to calculate biomass from the estimated PolInSAR forest height. However, changes in forest density or structure bias the known allometric relations. Today, remote sensing systems like SAR are able to measure additional parameters like vertical forest structure [1] [2]. In this work, the potential of vertical forest structure information, estimated from SAR reflectivity profiles, will be investigated for the improvement of biomass inversions.

The structure characterization developed here is based on the principles proposed in [3]. These are explained as follows: high biomass forest stands are characterized by frequencies connected to tree stems approaching a homogeneous biomass distribution. However, for the same dominant height (H100) a stand with lower biomass, presents more gaps, and characterized by a higher proportion of frequencies connected to the crown compartments. Using the Legendre decomposition we propose a structure ratio (S_{rat}) to characterize the vertical biomass distribution, which is based on the proportion between stem (a_{01}), and crown frequencies ($a_{02}+a_{03}+a_{04}$): $S_{rat} = a_{01}/(a_{02}+a_{03}+a_{04})$.

In this work, airborne L-band data acquired with DLR's E-SAR during the TempoSAR 2008 campaign are used to investigate the capabilities of SAR tomography to invert forest biomass. Data were acquired on two days, one before a rain event and another after. Each dataset used is composed of 5 images (baselines 5, 10, 15, 25m). The Capon method is applied on phase calibrated images to derive the vertical reflectivity profiles [4]. The resulting image has a horizontal spatial resolution of ~12x12m.

The biomass inversion algorithm proposed here comprises three stages: a profile based height truncation, an extinction correction and the application of an empirically derived structure-to-biomass allometric relation.

Profile height detection, at which the profile will be truncated, is based on the distribution of the profile lobes, i.e. local profile maxima. It is possible that a vertical profile presents several physically relevant lobes [5], so the estimation of the height from vertical reflectivity profiles requires distinguishing between physically relevant lobes and side-lobes. As the ground location is kwon [4] the detection of the side-lobes is only necessary above the physically relevant lobes. Then, the reflectivity profile is truncated when the power amplitude of the last lobe with a power larger than a 20% of the absolute maximum power, is below a 30%.

Reflectivity profiles do not represent the exact vertical biomass distribution as obtained from ground measurements. Therefore, in order to apply the structure ratio, the reflectivity profiles need to be corrected. We have observed that SAR reflectivity profiles the range of the ratio is strongly reduced, due to the typical overemphasis of the power of the highest profile maxima induced by the signal extinction along forest height. In order to compensate for this effect, an exponential correction is applied for every profile. This correction is adapted for each profile, depending on the profile height and the proportion between the main profile maxima.

The biomass inversion needs to be adapted to the information contained in the SAR vertical reflectivity profiles. As introduced before, the low frequency coefficient a_{01} is mainly driven by the biomass concentration in the tree stems and long wavelengths, like L-band, are not so sensitive to them. As a consequence, a higher presence of biomass will be indicated by larger crown volumes along the profile and therefore by a higher proportion of crown frequencies (a_{02}, a_{03}, a_{04}) in the structure ratio. This will be translated in a change of the S_{rat} exponent sign in the biomass inversion. Inversion details will be shown.

Finally, we will show that the structure-to-biomass allometry, developed here, is able to improve the biomass inversion results obtained with height allometries in more than a 20%, in terms of correlation coefficient and RMSE, showing the potential of low frequency SAR data (L-band) for the estimation AGB. The structure descriptor based on Legendre polynomials is able to characterize vertical reflectivity profile and successfully connect it to forest biomass. The algorithm is tested for wet and dry forest conditions, as these can affect the shape of the reflectivity profiles, and a sensitivity analysis will evaluate the potential of this technique for biomass classification.

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