FOREST PARAMETER RETRIEVAL USING A GENERAL REPEAT–PASS POLARIMETRIC INTERFEROMETRIC VEGETATION MODEL

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1. ABSTRACT

This paper concerns forest parameter retrieval from multi–temporal polarimetric interferometric SAR data. A two–component polarimetric interferometric model, designed for geophysical parameter retrieval, is presented for volumetric media over ground. For forest vegetation observed at L–band, this model accounts for the ground topography, canopy layer and total tree heights, wave attenuation in the canopy, tree morphology in the form of orientation distribution and effective shapes of the branches, surface scattering contribution, and double–bounce ground–trunk interactions. A parameter retrieval framework is developed for repeat–pass acquisitions which aims to estimate and to compensate temporal decorrelation. The parameter estimation performance is evaluated on real airborne L–band SAR data in both single– and multi–baseline configurations. The contributions of the ground and the vegetation are separated to permit further analysis of ground properties and canopy layer morphology. The retrieved vegetation height is compared with ground–truth measurements, revealing for the given test–site an average root mean square error of about 5 meters for both single– and multi–baseline approaches in the repeat–pass configuration.

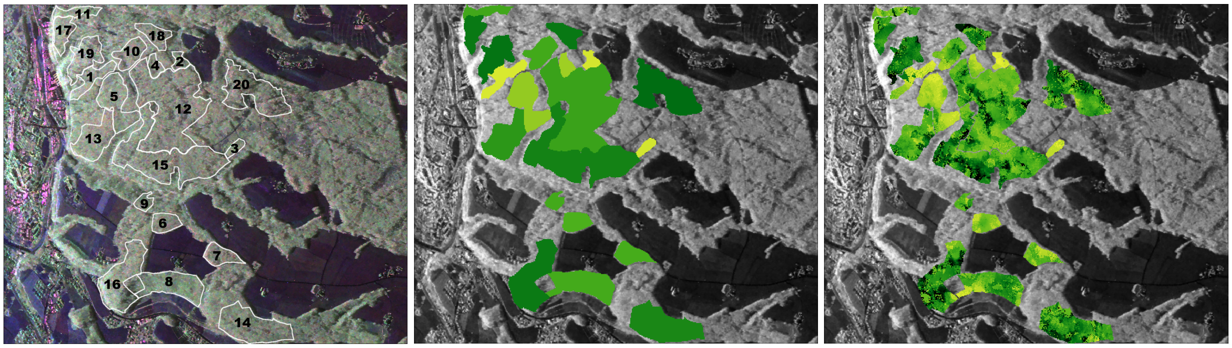
2. INTRODUCTION

Polarimetric SAR Interferometry (PolInSAR) provides strong means for vegetation parameter retrieval as it is sensitive to the vertical structure and the physical characteristics of the scattering media. On the one hand, polarimetry is sensitive to individual particle characteristics such as orientations, shapes and permittivities, as well as ensemble average entropy. Also, model–based polarimetric decompositions permit to separate main scattering contributions from vegetated areas which consist of surface, double–bounce and volume scattering. However, due to the limited number of observables (4 polarimetric degrees of freedom), only very simple geophysical media models have been used, limiting the applicability of model–based approaches. In particular, for surface and double–bounce scattering only first–order models are used, whereas for vegetation only randomly oriented volume is considered, with recent extension to a few discrete orientation states. One topic of this paper is to provide a more advanced physical model for vegetation parameter retrieval which is not constrained by these limits.

On the other hand, interferometry is sensitive to topography, vertical structure and density of the scattering media. The interferometric decorrelation in volumetric media has been recognized as an opportunity to measure vegetation depth and extinction. The combination of interferometry with polarimetry enhances estimation of the vertical structure by providing additional degrees of freedom. Several approaches have been developed using the polarization dependence of the interferometric coherence to evaluate the ground contribution and the linear ground–to–volume relationship, in order to estimate vegetation height, the underneath ground topography, and the extinction in the vegetation.

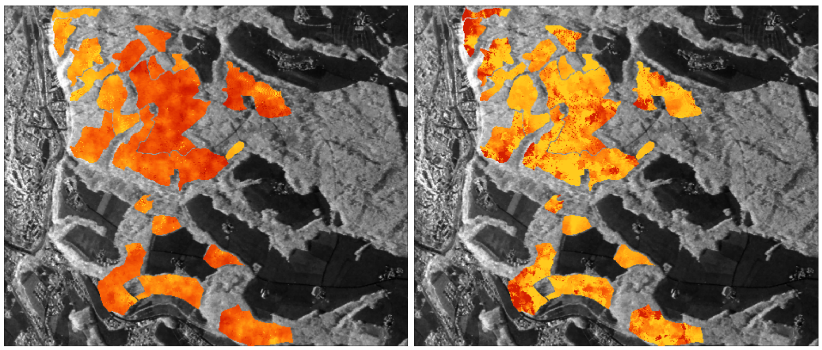
In this paper we address some of the simplifying limitations of the previous approaches and we present a general polarimetric interferometric model for vegetation parameter retrieval which offers a more flexible direct volume component and which does not constraint the surface and double–bounce scattering components to simple first–order forms. In particular, for forest vegetation observed at L–band, this model accounts for the ground topography, canopy layer and total tree heights, mean wave attenuation in the canopy, tree morphology in the form of orientation distribution and effective shapes of the branches, and general surface and double–bounce scattering contributions. The goal of this approach is to model separately ground and volume contributions, in order to enhance the estimation of structural vegetation parameters, and to permit the retrieval of morphological vegetation parameters as well as ground parameters under the vegetation for further analysis.

The repeat–pass acquisition of the data requires the adaptation of the parameter retrieval framework to temporal decorrelation. Temporal decorrelation is a significant error source for vegetation parameter estimation at L–band, caused on the given



(a) Test site in Pauli matrix basis. (b) Ground–truth forest height. (c) Estimated forest height.

Fig. 1. Forest height estimation: ground–truth and estimated height images.



(a) Orientation randomness (b) γ_{temp_1}

Fig. 2. Estimated orientation randomness and the degree of temporal decorrelation.

short temporal scale (minutes to hours) mostly by wind. The strategy to estimate the degree of temporal decorrelation, as presented in this paper, is based on the assumption that in ensemble average, temporal decorrelation does not affect the coherence phase, but only degrades the magnitude.

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