POLINSAR FORESTRY APPLICATIONS IMPROVED BY MODELING HEIGHT-DEPENDENT TEMPORAL DECORRELATION

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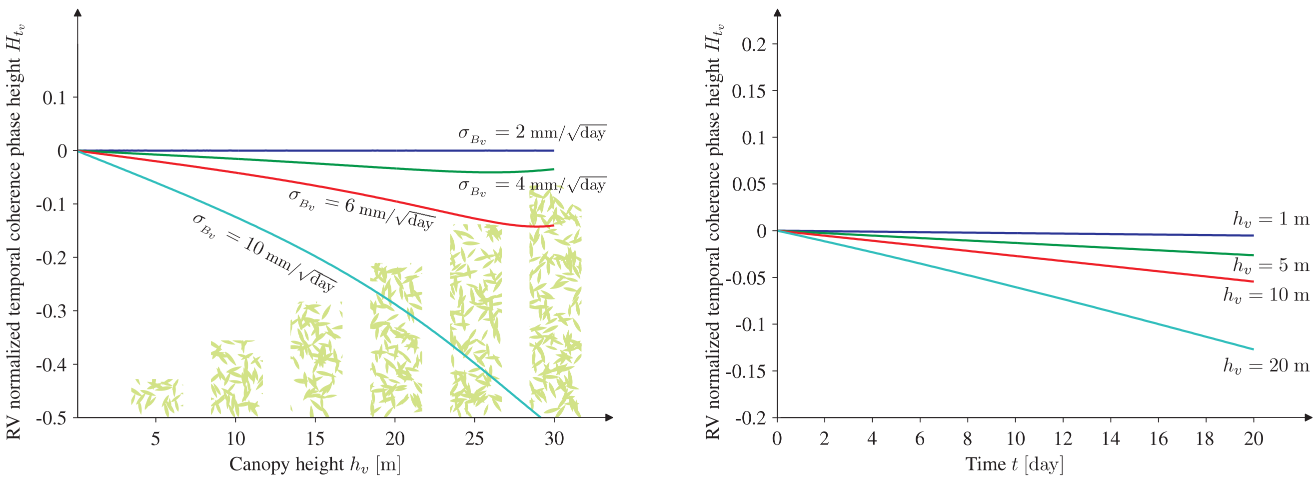
1. INTRODUCTION

The worldwide forest biomass distribution is one of the key unknown at global scale, whose uncertainty makes difficult forecasting the evolution of the terrestrial environment, directly depending on the carbon cycle [1]. The relatively recent technique that combines polarimetry and interferometry [2] has shown, using airborne SAR data, the potential to map the worldwide forest biomass. Polarimetric SAR Interferometry (POLINSAR) uses the prediction of a two-layer coherence model, namely the random volume over ground (RVOG) model, to retrieve the forest height and the ground topography. Among the current space-borne missions, ALOS/PALSAR is only candidate for testing and validating POLINSAR over forests. Although PALSAR performs excellent polarimetric acquisitions, its interferometric capabilities are limited by the large temporal baseline (46 days). This gives low coherence level and prevents in practice the quantitative model-based inversion for estimating forest parameters [3]. In general, temporal decorrelation in repeat-pass interferometry is a major source of error and modeling accurately temporal artifacts is a key step for the exploitation of POLINSAR data for forestry applications.
In this contribution, we first report our experience in processing PALSAR data for POLINSAR inversion. We show that interferograms at different polarizations contain important information correlated with forest height and coherence magnitude, but the full quantitative inversion is limited by temporal decorrelation. Secondly, we propose a novel temporal correlation model based on a height-dependent function in the forest canopy. The POLINSAR inversion procedure is adapted to include to the new temporal model and the results are discussed using airborne SAR data.

2. ALOS/PALSAR POLINSAR EXPERIENCE AND LIMITATION DUE TO TEMPORAL DECORRELATION

In the first part of the paper we show through a PALSAR case study the results of the POLINSAR processing over vegetated areas. We consider a pair of L1.0 products and perform the complete basic SAR, interferometric and polarimetric processing chain. Fundamental steps are the focusing using the ESA PALSAR processor, the polarimetric calibration and Faraday rotation correction, the coregistration, the spectral filtering and the interferogram flattening, the POLINSAR coherence optimization and the RVOG model inversion. Among the inversion strategies proposed in literature, we have found that a phase-based approach compensated by a magnitude-based term gives potentially the best result. In the case of ALOS/PALSAR, only the interferograms difference (i.e. the phase-based term) at two optima polarizations is demonstrated to be correlated with forest height. Due to temporal decorrelation, such a difference cannot be compensated by the magnitude term for quantitative inversion. Despite the low coherence level decreases the accuracy of the interferogram difference, we show how ALOS/PALSAR allows accessing to a sort of partial POLINSAR information and to derive an uncompensated measure of the scattering phase center height in semitransparent media.



(a) Relative phase height versus forest height

(b) Relative phase height versus temporal baseline

Fig. 1. Phase shift of the temporal correlation model that includes a height-dependent temporal decorrelation function. The phase height is expressed in meters and is normalized to the total canopy height. In the plots, h_v is the thickness of the canopy layer, σ_{B_v} id the motion standard deviation of the canopy at reference height and t is the temporal baseline.

3. HEIGHT-DEPENDENT TEMPORAL DECORRELATION MODEL

Temporal decorrelation origins from the instability of the target between two repeat-pass interferometric acquisitions and affects especially complex distributed targets such as vegetation [4]. In previous POLINSAR works [5], the temporal decorrelation has been modeled with a constant real-valued term affecting the coherence magnitude. In the two-layer model formulation, this term was associated with the canopy layer and the ground surface was assumed without temporal decorrelation.

In the second part of the paper, we consider a more accurate modelisation of temporal decorrelation based on a temporal decorrelation function that shapes the vertical structure of the canopy layer. This function is found by assuming Brownian motion of the canopy particles and a simple yet effective linear trend for the motion standard deviation along the vertical dimension of the canopy layer. The coefficients of the linear expression are model parameters that must be estimated from the data. If we assume zero temporal decorrelation on the ground, then at least one parameter needs to be estimated. This is similar with the old model of temporal decorrelation but still keeping the advantages of a height-dependent temporal decorrelation modelisation. As the function affects more the top-canopy than the particles close to the ground, our approach allows modeling the effects of the wind which are reasonably stronger for taller canopies. Indeed, one major consequence of this improvement is that the temporal correlation term is complex-valued, and its phase physically represents the shift that the scattering phase center undergoes between the interferometric acquisitions (Fig. 1). This peculiarity requires the height retrieval procedure to be adapted for the new temporal decorrelation model.

4. POLINSAR INVERSION STRATEGY AND RESULTS

The ground topography beneath the vegetation and the forest height are two important deliveries of POLINSAR inverse methods. The inversion strategy that we describe and apply is a variant of the inversion procedure already proposed in literature [6] but now includes the effects of the temporal correlation function that we have introduced. The procedure may be broken into four steps. The first step deals with the estimation of the temporal model parameters that constraint the expression of the temporal function. These parameters do not depend on the polarization and must be estimated and averaged on selected test sites for which the vegetation height and the ground topography are known. The second step is the estimation of the RVoG (line) model parameters for each SAR data sample. This step can be performed with different algorithms, such the optimization of the phase difference between any pair of coherence sample estimated at different polarizations. Once the line parameters have been estimated, the ground topography phase is identified at the third step. For simplicity, we assume at this stage that the ground temporal decorrelation is almost zero, although a more complex procedure might be envisioned if this assumption is relaxed. Finally, the forest height is retrieved from a volume-dominated coherence and by removing the effects of the temporal correlation function and of the ground topography. Since our temporal correlation model depends on forest height, and the forest height is retrieved in this stage, an iterative approach is required to estimate correctly the height and to remove the effects of the temporal decorrelation. The iteration, however, is expected to converge in few steps.

The results of the proposed temporal modeling and associated inversion strategy are shown using airborne acquisitions for which the ground truth is available and the temporal baseline can be easily controlled.

5. REFERENCES

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