EXTRACTING TREE HEIGHT FROM REPEAT-PASS POLINSAR DATA: EXPERIMENTS WITH JPL AND ESA AIRBORNE SYSTEMS

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1. INTRODUCTION

In this paper we present our latest developments and experiments with the random-motion-over-ground (RMoG) model [1, 2] used to extract canopy height and other important forest parameters from repeat-pass polarimetric-interferometric SAR (Pol-InSAR) data. More specifically, we summarize the key features of the RMoG model in contrast with the random-volume-over-ground (RVoG) model [3], describe in detail a possible inversion scheme for the RMoG model and illustrate the results of the RMoG inversion using airborne data collected by the Jet Propulsion Laboratory (JPL) and the European Space Agency (ESA).

2. BACKGROUND

The success of Pol-InSAR in monitoring forests using repeat-pass radar data is predicated on understanding temporal decorrelation and having robust algorithms that compensate for its effects. Users of forthcoming radar missions, such as ALOS-2, and proposed missions, such as BIOMASS and DESDynI, will face the problem of temporal decorrelation inevitably. This motivated us to investigate the potentials and limitations of the RMoG model and to design an algorithm that helps the ecosystem science community to monitor forests at regional and global scales using Pol-InSAR technique and radar technology.

Canopy height has been traditionally extracted from measures of *volumetric* coherence [3]. In a repeat-pass scenario, however, the radar collects data at different times, and the dynamic changes occurring in the forest corrupt the coherence resulting in large errors when forest parameters are estimated. In previous approaches, temporal decorrelation was estimated from external data (e.g. zero-baseline data) and then removed from long-baseline data to isolate volumetric decorrelation. This approach has two major limitations. First, temporal decorrelation is not a systematic effect, therefore the level of temporal decorrelation estimated from one dataset is not necessarily applicable to other datasets. Secondly, in this approach temporal decorrelation is considered a real-valued number, which does not compensate for complex phenomena, leaving the estimates with large uncertainty.

3. APPROACH

In the proposed approach, we do not try to remove temporal decorrelation from the data. Instead, we *model* temporal decorrelation and extract the canopy height from measures of *temporal-volumetric coherence*. The extraction is based on the RMoG model, which relates a small number of forest parameters to the temporal-volumetric coherence. In the RMoG model the vegetation is idealized as a two-layer scenario constituted by a penetrable layer of randomly oriented scattering elements (i.e., the canopy layer) above a dielectric rough surface (i.e., the ground layer).

The scattering formulation of the RMoG model is based on the RVoG model, which was designed to predict the volume coherence in single-pass interferometry [3]. To extend the model to repeat-pass interferometry and account for temporal decorrelation, we assume the temporal changes in the canopy layer and on the ground surface to be caused by a Gaussian-statistic motion of the scattering elements. The RMoG model is derived considering the first-order expansion of the function that defines the motion along the vertical direction in the canopy layer. The assumption of first-order Gaussian-statistic motion has been validated with zero-baseline Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) data [1].

In the RMoG model the polarimetric-interferometric coherence is predicted by 6 real parameters: the ground topography, the canopy height, the mean wave extinction, the ground-to-volume scattering ratio, the motion variance of the scattering elements at ground level and the motion variance of the scattering elements at a reference height in the canopy layer. A key feature of the RMoG model is the dependence of temporal decorrelation on polarization and on vegetation structure. This feature makes the model attractive for the inverse problem.

4. RESULTS

We designed a possible RMoG inversion scheme using a least-square optimization approach based on the interior-point algorithm. Tests of the inversion algorithm were conducted on numerical simulations and actual L-band UAVSAR data collected over Harvard Forest in Massachusetts (United States) [2]. We have also obtained data from the BIOSAR campaign series and TROPISAR campaign and we plan to test our RMoG model-based algorithms on these data. We will illustrate the outcome of these additional experiments and discuss the implications for the exploitation of forthcoming satellite radar data.

[1] M. Lavalle, M. Simard, and S. Hensley, "A temporal decorrelation model for polarimetric SAR interferometers," IEEE Trans. Geosci. Remote Sens., vol.50, no.7, pp.2880-2888, July 2012.
[2] M. Lavalle and S. Hensley, "Repeat-pass polarimetric SAR interferometry," IEEE Trans. Geosci. Remote Sens., 2012 (in review).
[3] S. Cloude and K. Papathanassiou, "Polarimetric SAR interferometry," IEEE Trans. Geosci. Remote Sens., vol. 36, no. 5, pp. 1551–1565, Sep. 1998.