QUANTIFYING THE RESULTS OFWIND AND RAIN ON IFSAR TREE HEIGHT ESTIMATION

Michael Benson, Leland Pierce, Kamal Sarabandi

The University of Michigan
The Radiation Lab, EECS Dept.
1301 Beal Ave, Ann Arbor, MI 48109-2122
mlbenson@umich.edu

1. INTRODUCTION

The horizontal and vertical (3D) structure of Earth's forested ecosystems are of great significance to their ecological functioning and societal uses. An IfSAR approach is one methodology whereby a forest's structure and height in particular can be successfully estimated. Critical to the successful estimation is a high correlation between multiple SAR images. Regardless of a forest's location on the Earth, wind and precipitation can significantly alter a forest's appearance to a SAR system operating in either the L or C bands and so too decrease this necessary correlation.

In order to investigate and quantize the decorrelation induced by factors such as wind and rain, we have developed a model for the repeat-pass interferometric SAR response of a forest including the application of a wind field and / or a rain storm. The simulation consists of multiple interconnected parts including the generation of fractal tree geometries, a wind simulator to apply apply variable wind forces to the generated trees, an electromagnetic model to allow us to calculate a Single Look Complex value for the SAR return of the combined target, an image forming technique based on antenna array theory, and an image processing algorithm. Results present polarmetric coherence as a function of platform look angle, wind speed, and moisture content. An important feature of this research is the usage of a physically based realistic wind model that is based on measurements of wind effects on trees as well as realistic models of fluid flow and simple harmonic branch segment resonators. Allowing branches to bend and move out of the plane of the incident wind field enables our model to capture numerous features of a physical tree blowing in the wind. This realistic model is necessary for a realistic simulation of the effects that wind has on a given InSAR imaging system as expressed in this study by the interferometric coherence.

Over 30\% of the Earth's landmass is covered by forests. These forests play an integral role in the global system specifically throttling the conversion of CO_2 to O_2 As a living system, the planet's forests change in time both naturally and as a result of human activity. These changes have had a profound impact on the planet's ability to sustain life. Various forms of radar remote sensing are used to monitor the global forest yet nature itself often serves to impede these efforts. A common radar implementation used to monitor tree heights is interferometric synthetic aperture radar (IfSAR) which requires two images to be formed of a target. These images are either taken simultaneously from different spatial positions (single pass) or from a relatively constant location at different points in time (repeat pass). Repeat pass systems have been shown to have a lower coherence compared to single pass systems[1] due to the fact that the target being observed can change dramatically between observations. While some of these changes are expected and quasi-permanent in nature, others are a result of a temporary environmental factor such as a blowing gust of wind or a passing rain storm. This study will focus on the effect of two such temporary changes, wind and rain, on a given target area under ifSAR observation.

2. ENVIRONMENTAL SIMULATION METHODOLOGY

In order to investigate the effects of wind and rain on a forest canopy we first needed a tree model capable of accurately representing a living tree and that tree's response to various external stimuli. The Michigan fractal-tree model has been previously studied and has been shown to accurately represent various kinds of trees [1].

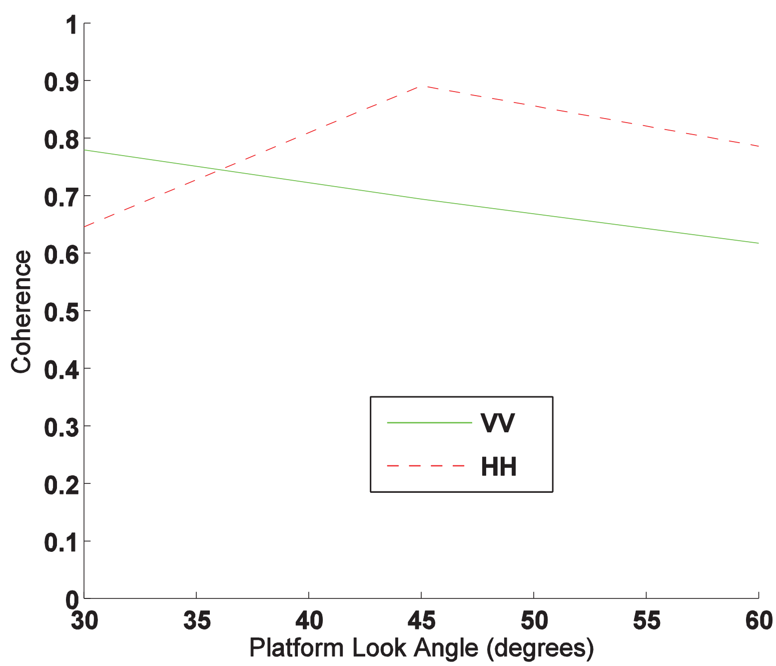
Using this method to generate trees, we generated 5 instantiations of a deciduous red maple. Each of these trees was generated with the base data set including a height of 16.7 m, a diameter at breast height (DBH) of 14.5 cm, and an intended biomass of 0.17 trees/m^2. Realistic modeling of complex plant structures such as a tree's branch system is achieved by iteratively combining a set of simple tree-specific patterns. The number of iterations specifies the complexity of the fractal tree and as will be shown in a later section, the level of reality in the tree's response to an incident wind field. Additional parameters including leaf radius, density, and thickness as well as parameters pertaining to the tree's trunk and the tree's overall dry biomass are provided to the model to further transform the fractal tree into a realistic representation of the desired species. This existing model has been enhanced to generate the basic data structures required to effect a change in geometry due to an incident wind field.[2]

The effect of precipitation is also examined in this study. Two wood moisture contents are examined representing a semi-humid environment and a rain soaked environment. Combinations of these moisture contents as well as various wind forces are examined thereby providing the first steps towards the generation of an algorithm capable of considering multiple environmental factors in determining the expected value for the change in coherence in a repeat-pass SAR system.

3. OVERVIEW OF METHODOLOGY

In order to rapidly construct a SAR image of a given scene, we have used antenna theory and an \textit{a priori} knowledge of the imaging platform's path relative to a target swath. By approximating the curvature of the

Earth's surface in the locality of a given tree as flat we are also able to approximate the platform's trajectory as flat and parallel to the ground in the target area. A satellite moving in space, such as ALOS PALSAR has a finite pulse repetition frequency as well as a limited chirp bandwidth which respectively serve to limit azimuth and range resolution on the ground. PALSAR is capable of numerous modes of operation including a high resolution mode with a chirp bandwidth of 28MHz and a swath width of over 40Km from an orbit altitude of 692Km.[3] Since all modern satellites convert an incoming signal from analog to digital format some form of sampling will be used. Noting that an antenna array forms its beam by utilizing multiple transmitters arranged in such a way as to yield the desired antenna pattern we choose to reverse this process for our beam forming needs. By selecting appropriately spaced points along the platform's trajectory, we were able to generate a "beam" from the virtual array comprised of the various platform transmit and receive points. This separation was limited by the PRF in that we couldn't reasonably move adjacent virtual antennas closer as any point between the two would be in the middle of a PRF and thus no data would be available. This separation distance was also constrained by the need to avoid side lobes near our target area. Using a virtual beam forming approach, we created numerous stands consisting of homogeneous trees and applied to each a unique combination of platform look angle, moisture content, and wind velocity. Figure 1 provides preliminary coherence comparisons between a stand with normal moisture content / 0 applied wind and another with an small level of applied wind. We will further flush these results in the paper and will look to draw conclusions based on the change in interferometric coherence as a result of these environmental conditions and the platform's look angle.



11. REFERENCES

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