Forest Height Estimation Using Multi-Baseline Polarimetric SAR Interferometry and Machine Learning

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ABSTRACT

We have used data collected by NASA’S Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) sensor to estimate forest height using multi-baseline polarimetric synthetic aperture radar interferometry (PolInSAR). UAVSAR is a fully polarimetric airborne SAR system which can be used to collect repeat-pass interferometry, enabling estimation of forest height through the inversion of theoretical models such as the Random Volume over Ground forest model. The use of multiple interferometric baselines can improve forest height estimation accuracy compared to the use of a single interferometric baseline, but the individual baselines must be selected or weighted in order to arrive at a combined forest height estimate for each pixel in the SAR imagery. We have explored the use of machine learning techniques to solve this baseline selection problem. A support vector machine (SVM) classifier is used to determine the weighting for each baseline using a feature set derived from the PolInSAR data. The features include the PolInSAR coherence magnitudes and phase centers, as well as features based on the PolInSAR coherence region shape and a statistical estimate of the phase center height variance for each baseline. The SVM is trained using a sparse subset of airborne lidar data coincident with the SAR imagery from which the best baseline for each pixel can be derived. We demonstrate the technique using UAVSAR data collected in Pongara National Park in the country of Gabon. The PolInSAR forest height estimates were validated using airborne lidar data collected by NASA’s Land, Vegetation, and Ice Sensor (LVIS). Results using the machine learning baseline selection yielded improved forest height estimation errors compared to a number of other baseline selection criteria from the literature, with a root mean square error around 5 m (for trees in excess of 30 m), and $r^2$ around 0.7. The technique demonstrates the potential for improved forest height estimation using data fusion of multi-baseline PolInSAR data with data from future spaceborne lidar missions such as the upcoming Global Ecosystems Dynamics Investigation (GEDI) lidar.