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VALIDATION OF DTMS BENEATH FOREST CANOPY DERIVED FROM P-BAND POLARIMETRIC INSAR

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Many applications require the creation of a DTM (Digital Terrain Model) beneath forest canopy. This is often a difficult or expensive task particularly if the forest area of interest is extended. InSAR has proven itself valuable for acquiring DEMs (Digital Elevation Models) over large areas relatively inexpensively. However X-Band and C-Band InSAR, which are the major sources of DEM data from airborne and satellite platforms respectively, are usually measuring the elevation of the upper part of the canopy, not the ground below. Methods for ground elevation recovery have been developed that work reasonably well in situations of sparse forest cover. However, as the canopy cover becomes more extensive, the performance of these methods deteriorates. Therefore a robust method, based on penetration through the forest canopy is desirable.

Longer wavelength InSARs - for example L-Band and P-Band (wavelengths ~24 cm and ~75 cm respectively) - have demonstrated the ability to penetrate to or close to the ground in several forest cover situations. However the interaction of radar waves with the foliage and the ground is quite complex. The separation of the ground components from the above-ground contributions to the observed interferometric phase is desired. Models have been developed to help in this process, but show acute sensitivity to various system characteristics and to the properties of the foliage and the ground scattering components. In particular, forest properties that relate to biomass (such as tree height and stem density) as well as topographic characteristics (such as slope), are expected to influence the ultimate accuracy with which the DTM will represent the ground. Because the observed phase of the back-scattered signal responds to the contributions of scattering centers above the ground as well as at ground level, polarization information may be used to discriminate between these situations. PolInSAR methodology for L-Band is well advanced although the emphasis has been mainly on recovering the forest parameters rather than the ground itself.

In this paper we summarize the results of two P-Band projects in heavily forested but well ground-truthed areas in the Pacific Northwest rain-forest region of Washington State, USA. The TopoSAR platform which acquired the data, is a dual frequency (X and P-Band) airborne InSAR system. The X-Band component is single-pass InSAR with HH polarization which provides information about the canopy height and other parameters. The P-Band component is repeat-pass and can operate in either a fully polarized Quad-Pol or HH-only acquisition mode. In the P-Band quad-pol part this work, we do not present explicit PolInSAR modeling apart from a coherence optimization process that is used for the Quad-Pol case with the implicit assumption that one of the optimized coherence sets corresponds to the ground component. This assumption is based on the premise that the bulk of the P-Band response originates from the ground return (mainly ground-trunk interaction) and that the additional information contained in the eigenvalues associated with the upper part of the canopy would not contribute sufficiently to justify the application of the standard 'random vegetation over ground' model that is often applied. The validated ground elevation results will therefore either support or oppose this conjecture. Of particular interest for purposes of operational application, are the extracted DTM vertical accuracies achieved, and how they vary with respect to the forest and terrain characteristics tested.

Of the two test areas addressed in this study, one was a well ground-truthed coniferous forest research area (Capitol Forest) with a range of stem densities, levels of maturity and with heights ranging to 50 meters. Slope and aspect angle are also diverse. Ground-truth available for the area included several hundred points measured on the ground beneath the canopy. These ground points were used to validate a lidar data set which was used then over the whole of the test area as a source of 'truth' at the 50cm level against which the radar results could be validated. Aerial photography was also available for interpretive purposes. The second test area was a mixed urban and forest area east of Seattle, Washington, with canopy heights ranging to about 35 meters. Of particular interest, for test purposes, this area included a large sloped area, sub-sets of which were well suited to addressing performance issues related to terrain slope. Lidar data and aerial photography were also available in support of the validation efforts in this area.

Depending on the particular circumstances, observed P-Band ground elevation accuracies ranged from less than two meters to more than four meters RMSE in heavily forested situations. This appears to justify the forementioned approach, at least to a first order. The observed coherence and accuracies recovered from the data are strongly dependent on slope, look-angle and canopy parameters. In this work, the effect of tree height as well as stem density on the derived accuracy of the DTM will be summarised. Slope by itself was not the major determinant for either accuracy or coherence. It appeared that the loss of double-bounce geometry with increasing slope (up to 25 degrees at least) had less impact than expected. On the other hand, there appeared to be a look-angle cut-off, beyond which the performance deteriorated dramatically. These and other observations will be addressed in the presentation.