Forest height inventory from airborne Synthetic Aperture Radar

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This study assesses the capabilities of commercially available airborne short wavelength Synthetic Aperture Radar (SAR) Interferometry (InSAR) for retrieving individual tree and forest stand height. Individual tree and stand heights are of importance to the forest industry for a number of reasons. Tree height is a key variable for calculating the amount of wood volume in a tree stem, as well as for predictions of amount of timber for extraction. Forest stand height is an important indicator of standing biomass for management purposes as well as for the assessment of carbon storage. Height is also an important ecological parameter in its own right, and an important input parameter for line-of-site analysis. Remote sensing offers an alternative to destructive measurements for accurate, rapid and cost effective technique without user subjectivity. SAR provides the potential for direct height measurement over large areas, and can operate independently of lighting or weather conditions, which often restricts the use of other remote sensing techniques.

In this study, tree height is estimated by subtracting a ground surface elevation model (a UK Ordnance Survey DEM, OSDEM, or a Digital Terrain Model, DTM, from commercial Intermap Technologies) from a Digital Surface Model, DSM, (from Intermap Technologies) and the results are then compared to field measurements of tree and stand heights. The accuracy of Intermap Technologies STAR-3i InSAR DEM products are initially compared to national elevation data sets. Over various ground types, it was concluded that, within the test areas, over non-vegetated ground the mean difference between the DTM and OSDEM was 1.38m RMSE with a 1.05m Standard Deviation (SD), and this is within Intermap's stated accuracies. Over forested ground the mean difference was 13.51m RMSE (2.21m SD). This vegetation bias was primarily due to limitations of the interpolation procedure used to determine the DTM from the DSM.

Subsequently, the use of two airborne InSAR data sets is assessed for top height retrieval as an operational product, as well as a precursor and supplement to satellite data. Firstly, X-band data from Intermap are used to retrieve homogenous plantation top height over four UK study sites using the difference between the DSM and OSDEM with mean underestimations of 33.48% (6.99m mean difference). When assessed for single species, the DSM-OSDEM procedure gave height underestimations of 18-24% for Sitka spruce and 40% for Scots pine, indicating a dependency on canopy structure. Correcting retrieved height based on linear regression with ground reference data is shown to improve height estimation; as such, applying a generic correction to retrieved heights from all four UK study sites improves overall accuracy to 16.77% (3.12m mean difference). For trees greater than 18m measured height, the accuracy is increased to 12.27% (0.92m mean difference).

Secondly, X-band data are also used to retrieve tree total height over two heterogeneous woodland areas in Belize and the UK. In Glen Affric, UK, height retrieval using the X-band DSM-OSDEM procedure for individual trees produce mean underestimation of 94.87% (6.08m mean difference). In Belize, height retrieval using the X-band DSM-DEM procedure for individual trees produces a mean underestimation of 74.71% (6.85m mean difference). For the Belize test site, height retrieval using JPL Airsar C-band DSM-DEM procedure for individual trees produces retrieved heights with a mean underestimation of 55.97% (4.79m mean difference). The primary cause of error is that layover effects due to SAR geometry may result in the retrieved height from a specific image coordinate not representing the same geographical position as the measured height.

Relationships between radar retrieved height and forest parameters such as stocking density and tree height and radar dependent properties such as slope and edge effects are presented as possible explanations for variations across the collected data. Supporting work using a simple coherent interferometric scattering model is also used to characterise and explain the effects on tree height retrieval due to variations in slope, number density, stand height and forest edges.

The results indicate that top height retrieval over homogenous forest stands is feasible with similar accuracies to those found with other remote sensing techniques and ground survey. Individual tree location assessment does not appear to be a suitable technique for assessing height retrieval in heterogeneous environments, and further investigations are required to determine a more suitable approach. This new data set therefore potentially allows a rapid and timely management tool for use in cost-effective sustainable forest management and related applications.