C-Band Tomographic Profiling (TP) of a Conifer Forest Stand

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Currently, many issues remain to be understood on the interaction of a radar wave with a tree canopy and the retrieval of various forest parameters. One of the most significant is forest biomass, which is of global importance in understanding carbon stocks. Biomass cannot be measured directly, but various schemes seek to determine it using backscatter strength, multi-temporal and interferometric coherence, and stand height as proxies. Because SAR provides no direct information on the height of features in a scene, complimentary interferometric techniques have been employed, of which polarimetric SAR interferometry (PolInSAR) is the most prominent such scheme. Interferometric techniques use a pair of images slightly displaced from each other in order to determine an apparent 'effective' scattering height within a canopy, but it provides no detail on the vertical backscatter distribution within the target's volume.

Tomographic profiling (TP) is a recent innovation which offers new measurement opportunities in radar remote sensing. The technique does not provide a fully 3D tomographic image in the conventional sense. However, the presented result has many similarities to the final image product from tomographic schemes, namely a 2D vertical profile of the backscatter through a volume but with a greatly reduced data-collection requirement – requiring only a single-pass collection. Polarization coherence tomography is an attempt to provide a 3D description of a target, but with the acquisition requirements of PolInSAR using as little as a single interferometric image pair. However, the retrieval algorithm is model-based, relying on a priori assumptions about the backscattering pattern.

In this work, we provide a demonstration of the TP technique, here applied to forestry for the first time. The portable Ground-Based SAR (GB-SAR) system was used to capture profiles of the vertical polarimetric backscattering patterns through a ~7m-tall stand of Norway spruce trees. The TP scheme collects data as for normal SAR imaging, but with the antennas aligned in the along-track direction. Adaptive post-processing meant that each TP scan simultaneously captured along-track image transects over the incidence angle range 0º-60º. An important feature of the derived image products is that incidence angle is constant at every point within an image. The measured HH, VV height backscatter profiles were very similar, and showed very little variation with height through the stand. Together with a ~6dB cross-/co-polarisation ratio, it indicates the radar likely saw the canopy volume as a random collection of scatterers, and which doesn´t significantly change in structure (expect in density) through the canopy. Backscattering profiles showed closest agreement with the branch biomass distribution through the canopy, rather than with trunk or branch+trunk biomasses. Equivalent interferometric tree heights were estimated from the centre-of-mass of the backscatter-height distribution. They displayed increasing apparent height with increasing incidence angle, appearing over a metre taller at 60° relative to 0°. There was no significant vertical separation between the cross- and co-polarisation returns.