BOREAL FOREST HEIGHT ESTIMATION WITH SAR INTERFEROMETRY AND LASER MEASUREMENTS

Jaan Praks,
Martti Hallikainen
Jaakko Seppänen

Department of Radio Science and Engineering
Helsinki University of Technology
FIN-02015 TKK, Finland
Email: jaan.praks@tkk.fi

Juha Hyyppä

Finnish Geodetic Institute
Geodeetinrinne 2
FIN-02431 Masala, Finland

1. INTRODUCTION

In this paper we discuss and summarize the results of the FINSAR campaign, where X- and L-band SAR interferometric and polarimetric techniques were evaluated for forest remote sensing. The main emphasis of the work was on polarimetric interferometry of L-band and forest height estimation; also X-band interferometry and polarimetric coherence tomography for X- and L-band were evaluated. Our results show that polarimetric coherence tomography can distinguish between forest types, when the ground phase is accurately known. The results were compared against helicopter based scatterometer (HUTSCAT) measurements, forest inventory database and laser measurements. Our results show that L-band polarimetric SAR interferometry can estimate well forest height in the boreal zone. Also X-band interferometry shows good potential, because boreal forest is sparse and has relatively low attenuation. The attenuation of the forest was estimated by RVoG model inversion with supplemental laser measurement and by means of scatterometer measurement. SAR appears to be more accurate in forest height measurement than forest inventory database, but not as accurate as laser measurement.

2. MATERIAL

The SAR data in our study was collected during the FINSAR campaign [1], carried out in autumn 2003 in Finland. The main instruments of the campaign were E-SAR [2] and HUTSCAT ranging scatterometer [3]. Part of the test site was later covered also by laser scanning, providing very accurate ground elevation and tree height measurements. The test site in southern Finland (N 600 11′, E 240 29′) comprises forest, fields and lakes. The forest in the area is heterogeneous and consists of rather small stands. The dominant tree species are Scotch pine, Norwegian spruce, birch and alder.

2.1. E-SAR measurements

On 29 September the E-SAR instrument collected from 3 km altitude four L-band (1.3 GHz) repeat pass fully polarimetric interferometric images and an X-band (9.6 GHz) single-pass single-pol (VV) interferometric image pair. The images were processed to a 2×2 m (range and azimuth) resolution grid

2.1. HUTSCAT measurements

The helicopter-borne HUTSCAT scatterometer measurement was carried out two days later. The HUTSCAT collected a vertical backscattering profile along the 36 km flight track at C-band (5.4 GHz) and X-band (9.8 GHz). The incidence angle was vertical and the helicopter location was measured by a GPS receiver. Most of the HUTSCAT measurements were concentrated on a 2x2 km area covering the E-SAR near and mid range. The HUTSCAT range resolution is 0.65 m and the system along-track sampling distance is 1.25 m when helicopter moves with ideal speed. The HUTSCAT and E-SAR slant range images are co-registered according to the pixel coordinates.

2.1. Laser scanning

The laser scanning was performed on 12 July 2005 using laser scanner Optech ALTM 3100 with 100 kHz PRF and 1 km flight altitude and providing 3-4 pts/m2 point density on the target. The strip adjustment (matching adjacent slight strip data) was made using TerraMatch. Ground hits were classified using TerraScan based on initial work of Axelsson [4]. Digital Surface Model (DSM) relevant to treetops was obtained by taking the highest point within a 1-m grid and missing points were interpolated by Delaunay triangulation. The canopy height model (CHM) was then obtained by subtracting the DTM from the corresponding DSM. The crown DSM was calculated by means of the first pulse echo and the DTM with the last pulse echo. The accuracy of the obtained DTM is better than 20 cm for forested terrain.

4. METHODS

For L-band forest height retrieval we used polarimetric interferometric SAR images and Random Volume over Ground (RVoG) model [5] inversion [6]. The inversion was made for the optimal region of imaging parameters only. For single polarization X-band, restricted inversion and direct phase estimation were used to calculate the forest height. Polarimetric coherence tomography (PCT) [7] was done for L- and X-band. The PCT method approximates the coherence vertical function with Legendre polynomial series. The approximation accuracy is dependent on the available amount of baselines, but even for one baseline the general shape of single layered volume can be calculated. The calculations for single polarization interferometry were done with the help of laser and scatterometer measurements.

5. RESULTS

Our results show that POLinSAR methods can give valuable information about boreal forest. Even the short wavelengths like X-band can be used because boreal forest is mainly sparse and there is ground contribution in the signal, making RVoG model based approaches suitable. The supplemental terrain model makes possible the calculation of coherence tomograms for non-polarimetric single baseline SAR data. The laser terrain model improves also the accuracy of fully polarimetric PCT, mainly by giving more accurate ground phase estimate than RVoG model inversion.

The SAR based methods cannot compete in accuracy with laser measurements, but high resolution satellite SAR images pairs give promising prospects for the method to be very cost effective for the future, when fully polarimetric SAR satellites are more common.

6. REFERENCES

[1] J. Praks, F. Kugler, K. Papathanassiou, I. Hajnsek, M. Hallikainen, Height estimation of boreal forest: interferometric model based inversion at L- and X-band vs. HUTSCAT profiling scatterometer, IEEE Geoscience and Remote Sensing Letters, vol. 4, no. 3, pp., 466-470, July 2007.

[2] A. Moreira, R. Spielbauer, W. Pötzsch, Conceptual design, performance analysis and results of the high resolution real-time processor of the DLR airborne SAR system, Proceedings of 1994 IEEE Geoscience and Remote Sensing Symposium (IGARSS'94), Pasadena (USA),, vol. 2, pp. 912-914, 1994.

[3] M. Hallikainen, J. Hyyppä, T. Tares, P. Ahola, J. Haapanen, J. Pulliainen, M. Toikka, A helicopter-borne 8-channel ranging scatterometer for remote sensing, Part I: Technical characteristics. IEEE Transactions on Geoscience and Remote Sensing, vol. 31, no. 1, pp. 161-169, 1993.

[4] P. Axelsson, DEM generation from laser scanner data using adaptive TIN models, In International Archives of Photogrammetry and Remote Sensing, 33, Part B4, pp. 110-117, 2000.

[5] S.R. Cloude and K.P., Papathanassiou, Three-stage inversion process for polarimetric SAR interferometry, IEE Proceedings - Radar Sonar and Navigation, vol. 150, no. 3, pp. 125-134, 2003.

[6] K.P. Papathanassiou and S.R. Cloude, Single baseline polarimetric SAR interferometry, IEEE Transactions on Geoscience and Remote Sensing, vol. 39, no. 11, pp. 2352-2363, 2001.

[7] S. R. Cloude, Polarization Coherence Tomography, Radio Science, 41, RS4017 doi:10.1029/2005RS003436, September 2006.