CORRECTION FOR TOPOGRAPHY IN BIOMASS RETREIVAL FROM P-BAND BACKSCATTER IN BOREAL FORESTS

G. Sandberg[1]
M. J. Soja[1]
L. M. H. Ulander[1,2]

[1]Chalmers University of Technology
[2]Swedish Defence Research Agency (FOI)

1. INTRODUCTION

With the continued threat of global warming, the need to map forest biomass is continually strong. Several studies (e.g. [1], [2], [3] and [4]) have shown that P-band backscatter has great potential for estimation of forest biomass. However, most of these studies use test areas with little or no topographic variability. Thus, there is a need to investigate the impact of topography on P-band backscatter data and to develop methods which corrects for topographic effects. To address this issue, the BIOSAR 2008 experiment was conducted in northern Sweden during October 2008. In this experiment, a test site with strong topographic variations was imaged using P- and L-band SAR. To enable detailed analysis of the topographic influence, several flight directions were used. Previous studies on VHF-data have proved the usefulness of this approach [5]. Previous studies addressing the issue of topography at P-band (e.g. [3]) have not used data sets with multiple flight headings.

In this paper biomass inversion methods including corrections for tilted ground surfaces are developed. The topographic corrections are based on 1) statistical analysis of data from the BISAR 2008 campaign, 2) simple analytical models for backscatter from vegetation and 3) numerical simulations using advanced scattering models. Moreover, the performance of the biomass inversion models is evaluated using statistical methods. Preliminary results indicate that the proposed topographic corrections are able to mitigate the topographic influence on P-band backscatter data.

2. THE BIOSAR 2008 EXPERIMENT

The BIOSAR 2008 experiment, initiated and funded by the European Space Agency (ESA), was conducted in northern Sweden during October 2008. One of the main experiment objectives was to assess the impact of topography on P-band SAR data. To accomplish this task, an area with strong topographic variations was imaged from several directions, providing an excellent data set for analysis topographic effects. A detailed description of the BIOSAR 2008 experiment can be found in [6].

5.1. Test site

The studied test site was located in northern Sweden (64° 14’ N, 19° 46’E). It is a part of Vindeln Experimental Forest and belongs to the unit for field-based forest research at the Faculty of Forest Sciences, Swedish University of Agricultural Sciences (SLU). The test site has been extensively used for forestry and remote sensing research. The forest is classified as boreal and is dominated by mixed coniferous forest. The bedrock consists almost entirely of gneiss. The dominating soil is moraine with variations in thickness.

5.2. *In-situ* data

A total of 31 forest stands, ranging in size from 2.4 to 26.3 ha, were inventoried during the summer of 2008. In the selected stands, circular sample plots with a radius of 10 m were laid out in a systematic way with a grid spacing selected to obtain approximately 10 plots for each stand. In addition, 110 sample plots were positioned outside the 31 stands. On the sample plots all trees with a dbh (diameter at breast height) > 4 cm were callipered and the species registered. Approximately 1.5 trees per stand were randomly selected for measurements of tree height and age. Site variables such as vegetation and soil type were also recorded for each plot. The *in-situ* measurements were used to estimate several stand level measurements, including biomass and tree number density. Details of the field inventory and estimation of forest parameters can be found in [6]. To complement the *in-situ* measurements all but five of the 31 inventoried forest stands were visited during the campaign period and current conditions for the stands, e.g. air temperature and precipitation were noted. Measurements of soil moisture were also made for 10 of the stands. Finally, weather data from a research station located within the test site were also used.

5.3. Laser Scanning Data

A laser scanning of the test site was performed on the 5th and 6th of August 2008 with the TopEye system S/N 425 mounted on a helicopter, at a flight altitude of 500 m above ground level for main strips and 250 m above ground level for cross strips. Approximately 70 km^2 was covered using an average point density of approximately 5 points per square meter in the main strips and 15 points per square meter in the cross strips. The laser data was processed to obtain a Digital Elevation Map (DEM) and a map containing difference between minimum and maximum z-value (vertical). The second map corresponds to vegetation height in vegetated areas. Using *in-situ* data from all available sample plots, a model relating laser scanning data to biomass was obtained. Estimates of biomass were then made for 10 m by 10 m cells in a raster covering almost the entire test site. Additional details on the laser scanning data can be found in [6].

5.4. SAR Data

P- and L-band SAR data was acquired using the Experimental SAR (ESAR) during 14 and 15 October 2008. For an area of 10 km (azimuth) by 3 km (ground range), Polarimetric Interferometric SAR (PolInSAR) data was acquired for both frequency bands. Two PolInSAR data sets with 6 flight passes each were acquired for each frequency band. Moreover, polarimetric SAR data for 5 (P-band) and 4 (L-band) additional flight passes were acquired for a 3 km by 3 km area, located within the larger area. The radiometric calibration of the images was checked using trihedral corner reflectors. Measured deviations from expected values were limited by about 1 dB, which was within specification. Moreover, amplitude and phase imbalance between HH and VV polarizations were within the specifications for the ESAR systems. Additional details on the SAR data can be found in [6].

3. METHODOLOGY

A model relating backscatter to biomass is formulated. The model includes corrections for topography. The topographic corrections are based on analytic and numerical scattering models, as well as statistical analysis of the SAR data. Parameters for the model are then estimated using statistical analysis. The data used in this analysis consist of backscatter measurements from several imaging directions for a set of forest stands. Since backscatter measurements from the same forest stand are correlated, a two scale error model was required to obtain good estimates of the sought parameters. After obtaining parameter estimates, the model was inverted and used to estimate biomass. The performance of the inversion method was evaluated using various statistical methods, including splitting of data into training and test data sets.

4. RESULTS

The analysis shows that P-band backscatter is depend on biomass, especially for HV. Moreover, including corrections for a tilted ground surface significantly reduces the HV backscatter variability between different imaging directions. The paper will also compare different methods for correction of topographic effects. To provide a theoretical basis for these methods, numerical simulations of SAR backscatter from forests on a tilted ground surface will be made.

Inversion models for forest biomass, including corrections for topography, will be presented. The performance of the inversion methods will be assessed using various statistical models, including splitting of data into training and test data sets. Preliminary results indicate that after correction for topography, the effects of topography on the biomass inversion are mitigated.

11. REFERENCES

[1] A. Beaudoin, T. Le Toan, S. Goze, E. Nezry, A. Lopes, E. Mougin, C. C. Hsu, H. C. Han, J. A. Kong, and R. T. Shin, "Retrieval of forest biomass from SAR data", *International Journal of Remote Sensing,* vol. 15, pp. 2777-2796, 1994.

[2] T. Le Toan, A. Beaudoin, J. Riom, and D. Guyon, "Relating forest biomass to SAR data", *IEEE Transactions on Geoscience and Remote Sensing,* vol. 30, pp. 403-411, 1992.

[3] S. Saatchi, K. Halligan, D. Despain, and R. Crabtree, "Estimation of forest fuel load from radar remote sensing", *IEEE Transactions on Geoscience and Remote Sensing*, vol. 45, pp. 1726-1740, 2007.

[4] G. Sandberg, L. M. H. Ulander, J. E. S. Fransson, J. Holmgren, and T. Le Toan, "L-band versus P-band SAR for biomass retrieval in hemiboreal forest", *Remote Sensing of the Environment,* accepted for publication, 2009.

[5] K. Folkesson, G. Smith-Jonforsen, and L. M. H. Ulander, "Model-Based Compensation of Topographic Effects for Improved Stem-Volume Retrieval from CARABAS-II VHF-Band SAR Images", *IEEE Transactions on Geoscience and Remote Sensing,* vol. 47, pp. 1045-1055, 2009.

[6] I. Hajnsek, R. S. M. Keller, R. Horn, S. Lee, L. M. H. Ulander, A. Gustavsson, G. Sandberg, T. Le Toan, S. Tebaldini, A. M. Guarnieri, and F. Rocca, "BIOSAR 2008 Technical Assistance for the Development of Airborne SAR and Geophysical Measurements during the BioSAR 2008 Experiment: DRAFT Final Report – BIOSAR Campaign", 2009. *ESA contract no. 22052/08/NL/CT,*