OPTIONS AND LIMITATIONS OF OPERATIONAL ABOVE-GROUND BIOMASS MAPPING – A SUMMARY OF 12 YEARS OF FOREST BIOMASS MAPPING WITH RADAR REMOTE SENSING IN SIBERIA, CHINA AND CANADA

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1. INTRODUCTION

Vegetation biomass is a crucial ecological variable for understanding the evolution and potential future changes of the climate system. Vegetation biomass is a larger global store of carbon than the atmosphere, and changes in the amount of vegetation biomass already affect the global atmosphere by being a net source of carbon, and having the potential either to sequester carbon in the future or to become an even larger source. Therefore, a global assessment of biomass and its dynamics is an essential input to climate change forecasting models and mitigation and adaptation strategies. Two other emerging issues contribute to the increasing importance of the biomass role as an essential climate variable: i) the growing use of biomass for energy production, so the increasing percentage of global GHGs emitted from biomass consumption, and ii) the increasing concern on the possibility to significantly reduce global GHGs emissions by avoiding biomass losses from deforestation and forest degradation.

The amount of biomass in the biosphere is stored in various compartments. These compartments are termed the woody (stem) biomass, the green (leaf) biomass, the fine root biomass and the amount of litter. Ideally quantification of all of these sources is required. In fact any spatial quantification of any of these stores would improve current knowledge about these systems. Unfortunately, these data are not available apart from in localised areas. Currently, biomass is ‘grown’ in models using information about the soil and the climate. There are no spatial maps of biomass with which to improve these biomass models. From these modelled ‘biomass’ maps various greenhouse gas flux components, carbon stores and sinks and ecosystem productivity are estimated. The errors associated with their biomass estimates are at least 50% and in most cases cannot be validated at all; there simply is not a validation dataset available. In landscape based approaches for greenhouse gas accounting, the forest biomass (phytomass) is derived from information on species, age, site index and relative stocking contained in forest inventory databases.

This paper 1) analyses advantages and shortcomings of existing optical global products that can be used as approximations for biomass, e.g. Vegetation Continuous Field (VCF) and LAI, 2) it presents current capabilities and limitations of radar biomass products from operational C- and L-sensors, and 3) we suggest a combined multi-scale radar-optical methodology using interferometric coherence, land cover maps based on temporal signatures, VCF and a new hyper-temporal algorithm.

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3. PROJECTS, DATA AND REGIONAL COVERAGE

This paper gives an overview of state-of-the-art methodologies for large area mapping of forest biomass with the radar sensors on board ERS-1/-2, Envisat ASAR, JERS-1 and ALOS PALSAR. The continuous acquisition of C-band data since 1991 and L-band data for 1991-97 and again since 2006, represents a great resource of information about very specific vegetation parameters only radar sensors are able to detect: height and density of forest. These parameters are especially crucial when time-relevant information is needed, e.g. after fire events or deforestation monitoring, and cloud cover is an obstacle. Large area forest mapping was performed in the projects SIBERIA (1998-2000), SIBERIA-II (2002-2005), GSE Forest Monitoring (2005-2008) and Forest DRAGON (2005-2008) where the first validated biomass maps were generated over more than 1 million square kilometres. These products were generated using 20-50 m resolution interferometric data. In our recent project BIOMASAR, we developed a new and validated algorithm for medium resolution mapping based on hypertemporal ASAR Wide-Swath and Global Monitoring data for Central Siberia, Canada and Sweden.

4. FIRST RESULTS AND DISCUSSION

We have analyzed the signatures of C-band and L-band backscatter intensities and tandem as well as long-term repeat-pass coherence of forests. The results suggest that long-term ERS and ASAR winter coherence can be used reliably for forest/non-forest mapping and detecting forest cover changes as well as estimation of a data-dependent number of growing stock volume classes.

In China, we followed a different approach due to limited forest inventory information. We developed a new approach that allows the training of a semi-empirical model on a frame-by-frame basis using the MODIS Vegetation Continuous Field product without further need of ground data. A comparison of the new approach with the traditional regression-based and ground-data dependent model training procedure using the Siberian data and the application of the new approach to a multi-seasonal and multi-baseline ERS-1/2 tandem coherence dataset are presented.

Envisat ASAR's additional multi-angle, multi-polarisation, multi-resolution capabilities add new dimensions to the forest product generation and a series of recently advanced parameter retrieval results are being presented. This sensor operates at C-band and in the Wide Swath mode has the possibility to acquire data over large swaths

(400 km) with a relatively good resolution for forestry (75 m). Because of the large swath, neighbouring swaths present a certain overlap which in turn means that multi-temporal datasets of backscatter values become available even on short time intervals. We have utilized the full ENVISAT ASAR Wide Swath dataset acquired between spring 2003 and summer 2004 over the SIBERIA-II project transect. More than 500 Wide Swath frames have been processed and geocoded using an automated chain and a spatial database approach. The spatial distribution of the forest biomass retrieved from ASAR Wide Swath images shows remarkable agreement with inventory-based estimates available for the whole region. This is far beyond what is commonly expected from C-band SAR backscatter and is an extremely relevant finding for SENTINEL-1 applications. In addition, for remote areas where inventory data have in the meantime become obsolete, ENVISAT ASAR can provide a valid update of the biomass.

5. CONCLUSIONS

The comparison of the ASAR Global Monitoring and Wide-Swath biomass maps with existing global biomass or carbon stock maps clearly indicated the relevance of the ASAR biomass product [1]. The main conclusions that can be drawn are:

- The comparison of the ASAR and VCF biomass maps confirmed the assumption that the ASAR maps are sensitive to biomass changes beyond the point of canopy closure. Although the canopy cover represents a major predictor for forest biomass, a VCF-based biomass retrieval leads to an underestimation of biomass in dense forests since biomass changes beyond canopy closure cannot be identified.
- The biomass maps that were produced by extrapolating default biome mean values of biomass to large forest areas are prone to high uncertainty. A well known problem of this approach is that compilations of typical biome average biomass values often reflect few ground measurements in mostly undisturbed forests. The values given in these maps, e.g. the Olson map, thus rather reflect the 'potential' biomass or carbon stocks as they hardly consider constraints imposed on forest growth, e.g. human influence, topography, land use history or poor site quality.
- Even though the use of biome mean values commonly leads to an overestimation of biomass, the analysis of the Tier-1 map revealed the opposite. The observed underestimation should not have been due to too low default biomass values in the IPCC guidelines but a result of considerable uncertainties in assigning the appropriate values when the only available information about the forest resources is a global land cover map.
- The comparison of the ASAR biomass maps with the LPJ-DGVM biomass simulation results pointed out the potential of the ASAR product to improve the model simulations. The ASAR biomass maps may aid tuning the model to better describe 1) the overall level of carbon sequestration in the biomass of forests and 2) the heterogeneity of the forest distribution resulting from disturbance or inferior site quality.

ALOS PALSAR data proved having great potential for forest stem volume estimation in Siberia [2]. Winter FBS coherence is the most powerful measure. Summer FBD coherence can provide additional information (e.g. for forest cover mapping), but the temporal baseline must be enlarged to increase temporal decorrelation of forest. However, this approach is very susceptible to variable environmental conditions. The computation of coherence based on FBS (winter) and FBD (summer) images is technically feasible but not very useful; it might - if at all - be used to support forest cover mapping.

6. REFERENCES

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