AUTOMATIC MODEL INVERSION OF MULTI-TEMPORAL C-BAND COHERENCE AND BACKSCATTER MEASUREMENTS FOR FOREST STEM VOLUME RETRIEVAL

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Estimation of forest biophysical parameters from SAR data is a major topic of investigation in remote sensing. This is due to the high demand of reliable biomass information at regional to global scale and the assessed capability of SAR observables to allow retrieval of biomass. Typically low frequencies are indicated as most suitable for the purpose of retrieving forest biomass because of the stronger interaction of the radar wave with the dominant elements in a forest (trunks, branches) and therefore of the stronger sensitivity to forest biophysical properties. One aspect that however is not (yet) considered as a major variable in forest biomass estimation from SAR data is the strong dependence of both the radar backscatter and the coherence upon the environmental conditions at acquisition. In the case of SAR interferometry also the conditions between acquisitions play a significant role. Seasonal variations affect in different manner data acquired at different frequencies; nonetheless, it is an aspect to be considered for all frequencies.

The radar frequency for which the largest experience has been gathered on retrieval of forest biomass is C-band thanks primarily to data acquired by the ERS-1 and ERS-2 SAR and ENVISAT ASAR sensors. Despite the weak sensitivity to forest biophysical properties, the multi-temporal aspect of both SAR backscatter and interferometric coherence data have allowed detecting the best conditions for retrieval and the development of methods that exploit the variability of the environmental conditions to improve estimates of forest biomass based on one single image.

Typically the retrieval algorithms applied to ERS and ENVISAT data have exploited models, ranging from empirical to semi-empirical, which required a training phase before being usable for inversion. Model training means determining estimates for model parameters such as e.g. ground coherence and backscatter, vegetation coherence and backscatter etc. This requires the availability of training site(s), i.e. in situ measurements of biomass. These are not always available or can be obsolete, in particular in remote areas. In addition, in case of spatial variability of the backscatter and/or the coherence, in situ data are not able to capture such variations. These factors represent a major limit when it comes to exploiting SAR data in an automated and large-scale retrieval scheme.
Recently a number of approaches have been developed for automatic model training and inversion of models using observations from ERS and ENVISAT data at different scales and depending on the availability of a multi-temporal dataset or not. The main aspects of these approaches, their requirements and the results will be discussed in this paper.

The major limit in currently available retrieval methods based on ERS tandem coherence is that the relationship between the coherence and the forest biomass can be quite variable in space and in time. Also the C-band backscatter suffers from spatial differences due primarily to the moisture conditions of the ground; however, the variations are more foreseeable because they are linked to seasonal conditions. To be able to capture these variations without the need of local in situ measurements for tuning the model, other methods have to be used.

When a certain number of observations are available acquired under what are considered to be the best retrieval conditions (winter/frozen, with a layer of dry snow and moderate breeze) it is possible to use the temporal consistency of the repeated coherence observations to train the model. For a small area around the test site of Kättböle, Sweden, an automatic training approach based on consistency plots of four coherence images has been developed showing results comparable to those obtained when training the model with in situ measurements.

When the images have been acquired in different seasons and/or their number is limited this approach might encounter difficulties. To get around the problem a method that makes use of the similar information content of coherence and MODIS Vegetation Continuous Fields tree canopy cover percentage has been developed. Model parameters can be determined by masking the coherence image for low and high percentage of canopy cover and taking adequate statistics (e.g. the mode). In case of strong spatial variations of coherence image subsetting has been applied. The method has been developed at Central Siberian test sites and applied to a 1.5 km² area corresponding to Northeast China. For this region not more than 2 images were available.

Due to the unavailability of tandem coherence after 1999, the interest on C-band backscatter has increased despite the weak sensitivity of this observable to forest biomass. For several regions of the world a large archive of repeated acquisitions are available in ENVISAT ASAR Wide Swath and Global Monitoring modes. Here we present result from a 400,000 km² area in Central Siberia where an automated method similar to the one developed for Northeast China is used. Results are extremely promising and well agree with in situ observations, in particular in areas where a large number of measurements are available (> 20). Results improve when considering large area averages (> 10x10 km²). This is of high importance for vegetation modeling approaches which are not capable (yet) to describe small scale variations of biomass.

As outcome of these investigations we can conclude (i) repeated winter-time observations of ERS tandem coherence-like images are the best source for forest biomass retrieval in boreal forest thanks to the different temporal decorrelation of ground and vegetation, (ii) synergy of radar and other remote sensing products can be exploited to develop retrieval algorithm that do not depend on in situ data in case of an heterogeneous dataset of coherence data, (iii) C-band multi-temporal data are a good source for forest biomass retrieval, (iv) with relation to current available spaceborne data this is the only source for obtaining regional to global estimates of biomass that could be exploited for large scale assessment of biomass and in ecosystem modeling related to environmental change.