Retrieval of aboveground biomass using multi-frequency SAR

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Abstract

Aboveground biomass (AGB) is an important variable in carbon accounting and climate science. The estimation of AGB in the boreal forests is of special concern as it constitutes the largest biome in the world and has substantial carbon accumulation capability. Russia, as a country with the largest forest area in the world (809 million ha (FAO 2010)), provided more than 90% of the carbon sink of the world's boreal forests between the years 2000 and 2007 (FAO 2012). Despite this importance, Russia's boreal forest has the highest (Pan et al. 2011) uncertainty (Nilsson et al. 2007) in carbon stock calculations. This is mostly due to poor measurements of biomass stocks, forest degradation, deforestation, and forest growth. Additionally, due to the lack of financial support, some forested regions in Siberia have not been inventoried for more than 20 years (Shvidenko et al. 2011). Therefore, there is a strong need for earth observation (EO) methods of biomass monitoring, which will reduce costs and improve the estimations.

The objective of this study was to use the multi-frequency Synthetic Aperture Radar (SAR) L-band and C-band data for improved AGB estimation in Siberian forests. The L-band ALOS-2 PALSAR-2 and C-band RADARSAT-2 data in single (HH) and dual (HH and HV) polarizations in Single Look Complex format (SLC) were used in this study. The data have been obtained within the ALOS Kyoto and Carbon Initiative Project (K&C) and the RADARSAT-2 Science and Operational Applications Research and development program (SOAR2). The backscattering coefficient was calculated taking into account local incidence angles. The SAR data were used as predictor variables for AGB retrieval. As the response data the forest inventory data were used. The datasets were provided as a Geographical Information System (GIS) database by the Russian State Forest Inventory. The database contains information of growing stock volume (GSV) at stand level. In order to convert GSV into AGB a non-linear relation was developed employing the regional data from the International Institute for Applied Systems Analysis (IIASA) Russian live biomass plot database (IIASA 2007).

The SAR data and the forest inventory data were used as inputs for a non-parametric data fusion machine learning algorithm – Random Forests (Breiman 2001). The Random Forests are widely used for classification in ecology (Prasad, Iverson, and Liaw 2006; Hüttich et al. 2011; Cutler et al. 2007) as well as for AGB estimation (Baccini et al. 2008; Simard et al. 2011; Houghton et al. 2007; Walker et al. 2007; Avitabile et al. 2012; Cartus et al. 2012; Cartus et al. 2014; Wilhelm et al. 2014). Recent study showed (Fassnacht et al. 2014) that the Random Forests is superior to other methods such as support vector machine (SVM), k-nearest neighbour (KNN), Gaussian processes (GP), step-wise linear models. The AGB was estimated for an area located in Krasnoyarskiy Kray in the Southern part of Central Siberia, Russia, approximately 120 km North-East of the city Krasnoyarsk – part of the Bolshe Murtinsky forest enterprise.

The AGB retrieval was done at 0.5 ha. The estimation error was calculated of approximately 25% by validation against an independent dataset. In the previous studies using only L-band or C-band data the reported errors were in the range of 30-40% for Siberian boreal forests (Santoro et al. 2006; Wilhelm et al. 2014; Rodriguez-Veiga et al. 2014; Chowdhury, Thiel, and Schmullius 2014).

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