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# Comparing Biomass Retrieval from Temperate, Boreal and Tropical Forests using Spaceborne SAR Imagery

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**Abstract.** Databases of spaceborne SAR imagery from three different types of forest have been compiled for the study of the relationship between SAR backscatter and biomass density. Imagery of temperate forest at Thetford in the UK, boreal forest at Siggefora in Sweden and tropical forest at Tapajós in Brazil have been acquired from SAR instruments on the ERS-1, JERS-1 and SIR-C spaceborne platforms. These data have been combined with biomass density ground data collected on various field campaigns to compare the dependence of backscatter on forest biomass density between the three different forest types. The analysis is complete for the temperate and tropical test sites and will be achieved soon for the boreal test site. preliminary results indicate that L-band HV imagery is most sensitive to forest biomass and that biomass dependencies are comparable for all types of forest. It is estimated that the maximum biomass that could be retrieved using L-band SAR data is approximately 63 tonnes/hectare which would make it suitable for monitoring regenerating tropical forest, young temperate forest or medium-aged boreal forest.
**Keywords:** SAR, biomass estimation

## 1 Extended abstract

There has been much recent interest in using Synthetic Aperture Radar (SAR) remote sensing to retrieve biophysical characteristics from forest targets. Although radar backscatter from forests is influenced by their structural properties (Imhoff, 1995), many studies have demonstrated a useful relationship between backscattering coefficient and the areal density of above-ground biomass within particular types of forest (Le Toan, 1992; Baker, 1994; Luckman, 1995).

To investigate the dependence of SAR backscatter on forest biomass within different forest types, we have developed several databases of imagery from various age over a wider area, derived from multi-temporal optical imagery or forest management history. Ground data collection campaigns were made to Thetford in 1989, Tapajós in 1994 and Siggefora in 1994 and 1995 during which measurements of trunk diameter, tree

SAR instruments including JERS-1 (Japanese Earth Resources Satellite), ERS-1 (European Remote Sensing Satellite) and SIR-C (Shuttle Imaging Radar). These databases cover Thetford Forest in the East Anglia, UK, the Tapajós National Forest in Pará State, Brazil and the Siggefora Forest near Uppsala in Sweden, which represent three major forest types: temperate, tropical and boreal.

In addition to SAR imagery, each database includes field measurements made to estimate the biomass density in selected forest plots, and information on forest compartment

height and species composition were made so as to estimate the biomass density of selected areas of forest.

As expected, the longer the wavelength of the SAR instrument, the greater the penetration of the microwave radiation into the forest canopy and the more useful is the relationship between backscattering coefficient and biomass density. Hence the better instruments for this application have proven to be JERS-1 (L-band, HH polarisation) and SIR-C (L-band HH and HV polarisation). ERS-1 imagery (C-band VV) can be used merely to differentiate between bare soil and vegetated surfaces and only during dry periods when the backscatter from the ground surface has a small contribution to the total.

The Tapajós and Thetford databases include SIR-C data and the HV polarized imagery from this instrument exhibits a greater variation with biomass density than the HH. This is anticipated by models of backscatter from forest canopies which suggest that the cross-polarized signal is due predominantly to crown scattering mechanisms. Comparisons of the relationships between forest biomass and SAR backscatter for the three different forest types are easiest to make using the JERS-1 instrument which is an operational sensor providing repeat global coverage and from which imagery is available for all three sites.

Relationships between biomass density and backscattering coefficient, as measured by JERS-1, have been quantified for Thetford Forest and Tapajós and will be completed soon for the boreal test site in Sweden. The relationships follow the form of a sigmoid curve as noted by other researchers (Imhoff 1995), with an initial positive correlation with biomass density tending at higher biomass towards an asymptote. Sigmoid curves have been fitted by least squares to the biomass density - backscatter responses to investigate the possibility of using such empirical relationships to retrieve biomass density from other data sets. In the case of Thetford Forest, the parameters of this sigmoid curve were constrained by a second order radiative transfer model of predicted backscatter (Saitch 1995). The parameters of these curves are used to indicate the likely maximum biomass density that could be retrieved from each forest type using JERS-1 SAR data.

Assuming that the relationship between biomass and backscatter is valid up to a level at which the backscatter is 90% of its asymptote then the maximum retrievable biomass density is approximately 63 tonnes/hectare for both tropical and temperate forests. It is encouraging that the biomass density - backscatter relationships for these two test sites are very similar. However, the estimated maximum biomass density is small compared with the potential maximum for tropical forests of over 400 tonnes/hectare. We propose that JERS-1 can be used to estimate the biomass density and quantify the area covered by forests that have been disturbed and are now regenerating. This may be an especially useful application since disturbed and regenerating forests have most influence on the carbon budget and JERS-1 data is being made available at survey level for the whole of the Amazon basin.

Future work will concentrate on completing a similar analysis for the boreal test site which is likely to prove more fruitful due to the relatively lower levels of forest biomass density found in northern latitudes. Retrieval algorithms will be validated using similar data from other tropical, temperate and boreal test sites.

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