TROPICAL FOREST BIOMASS RECOVERY USING GEOSAR OBSERVATIONS

[(1)]M L Williams, [(2)]T Milne, [(3)] I Tapley, [(1)]T Carson, [(1)]J J Reis, [(1)]M Sanford, [(1)]B Kofman, [(4)]S Hensley

[(1)]Fugro-EarthData Inc., 7320 Executive Way, Frederick, MD 21704, USA.
mlwilliams@earthdata.com
[(2)] School of BEES, UNSW Sydney NSW 2052, Australia.
[(3)]Horizon Geoscience Consulting, Perth, WA, Australia
[(4)]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA.

1. ABSTRACT

Tree height may be considered the key parameter for recovery of tropical forest biomass, and a general relationship is that biomass is proportional to some power of tree height. This has been demonstrated for tropical forests in Malaysia, French Guyana, Venezuela/Paraguay, Mexico and Brazil [1,2,3]. Improved accuracy in biomass estimates is evident for large (1ha) plot sizes, as is the applicability of a single relationship for both primary and disturbed tropical forest. Tree height in this context is h_{100}: the mean height of the 100 trees in the sample area with the largest diameters. Relating this height to any height estimated from remote sensing data is an important step in the use of SAR for biomass recovery.

GeoSAR collects X-Band (VV, 9.7GHz), and P-Band, (HH, 0.35GHZ) interferometric data in single-passes, over swaths of width 11km and that may extend to several hundred kilometres, from which are derived digital elevation models (DEMs) [4]. Notionally scattering at X-band arises predominantly from the upper canopy, and the X-band VV interferometric phase-centre is anticipated to be close to the top of vegetation canopies. By contrast, P-band HH returns are more strongly influenced by ground-volume interactions, and the P-band HH phase centre is expected to lie closer to the ground. The difference in DEM heights between X-band and P-band yields a surrogate vegetation height, h_{int}, which has been used in the retrieval of biomass for areas of tropical forest when combined with the P-band HH backscattering coefficient [5]. By virtue of design, GeoSAR has a combination of wide-area mapping capability and sensitivity to forest height, making the system suited to the estimation and monitoring of forest biomass on a wide scale.

GeoSAR is used to produce DEMs of high accuracy (2m (X-band) and 3.5m (P-band) absolute height), typically at 3m or 5m posting. Radiometric and polarimetric calibrations are often not repeated as they are not generally required for mapping purposes. This strategy is set to change, and plans are being implemented to deploy calibration targets during all future campaigns. In 2006 GeoSAR was used to collect IFSAR data over a wide area of Papua New Guinea for the generation of topographic maps. Although the imagery was processed using existing calibration parameters, the collected data were not radiometrically calibrated using *in-situ* targets. Thus use of the IFSAR data for biomass recovery was problematic: the surrogate vegetation height measurement was available, but did not correspond to the h_{100} height required for straightforward conversion to biomass. The P-band HH backscattering coefficient was not available, so that biomass recovery using the combination of this with h_{int} was also not immediately possible.

Fortunately approximately 55,000ha of the area imaged by GeoSAR in 2006 had been imaged previously by TOPSAR in 1998 using the same geometry. The imagery is compared in Figure 1: despite the large time interval separating the two acquisitions the images show a remarkable degree of correlation. In particular there appear to be large areas of undisturbed tropical forest that may be used to validate a radiometric calibration for the GeoSAR data, if it is assumed that the undisturbed forest has retained high biomass and has therefore a persistent backscattering coefficient close to the P-band HH saturation value for tropical forest of this type [5].

Registered TOPSAR data were therefore used to calibrate the GeoSAR data by matching the intensity distribution: preferentially weighting the high backscattering coefficients associated with high biomass forest areas. We have then used the radiometrically calibrated GeoSAR dataset to recover biomass for the coincident area of observation. The procedure we have adopted is to first obtain the surrogate height (h_{int}) image from the X-band and P-band DEM difference. We then combine this with the P-band HH and HV GeoSAR data, and jointly segment the images using our implementation of the SIDE algorithm

[6]. The use of segmentation permits the evaluation of mean height with variance over large, homogeneous areas, typically 0.3ha or greater, thus reducing the error in biomass estimates. Using the segmentation, surrogate height, and calibrated GeoSAR image intensity, we derive an object-based classification indicating forest, shrub, clear areas, and water classes. Within the forest class we have estimated biomass using the formula reported in [5] for tropical forest. Recovered biomass values are consistent with our calibration assumptions. We note that this formula can predict negative biomass values for regions of forest that are unusually dark for their height, and setting the estimate of biomass to zero in such regions reduces somewhat the coverage of the biomass estimated in this fashion.

We also determine an estimate of the h_{100} height using the distribution of h_{int} heights within segments. We reason that the 100 trees with the greatest diameters correspond closely to the 100 tallest trees. Given some knowledge of the stem density, h_{100} may be approximated as h_{int} plus some multiple of the standard deviation of the interferometric height within segments. Using this height estimate we form a second biomass estimate using the simple relationship between biomass and height [1,2,3]. We note that this technique will reliably yield positive biomass estimates for shorter tree stands.

Comparison of the two biomass estimates indicates that the second appears to underestimate the biomass in high biomass regions, whilst the first has reduced coverage by virtue of limited applicability to shorter, darker forest stands. Using the estimated h_{100} in segments we derive a new simple relationship between this derived height and the biomass estimated from h_{int} and P-band backscattering coefficient. This new model agrees well with the h_{100}+HH model for high biomass, whilst guaranteeing positive biomass estimates for shorter forests, and therefore extending the area for which biomass estimation is possible. In addition the new model permits us to estimate forest biomass automatically for the entire area of PNG mapped by GeoSAR since it depends only on the interferometrically derived surrogate height.

We have demonstrated that by using calibrated GeoSAR observations, and calibrating the estimation algorithm, the automatic recovery of tropical forest biomass on a wide scale is possible with GeoSAR data. The principle appears sound, even though in this instance we have perforce employed an *a-posteriori* radiometric calibration to the GeoSAR data. Further refinement of the techniques and testing against ground data will, we hope, help to establish the GeoSAR system as a prime candidate for carbon stock estimation and monitoring.

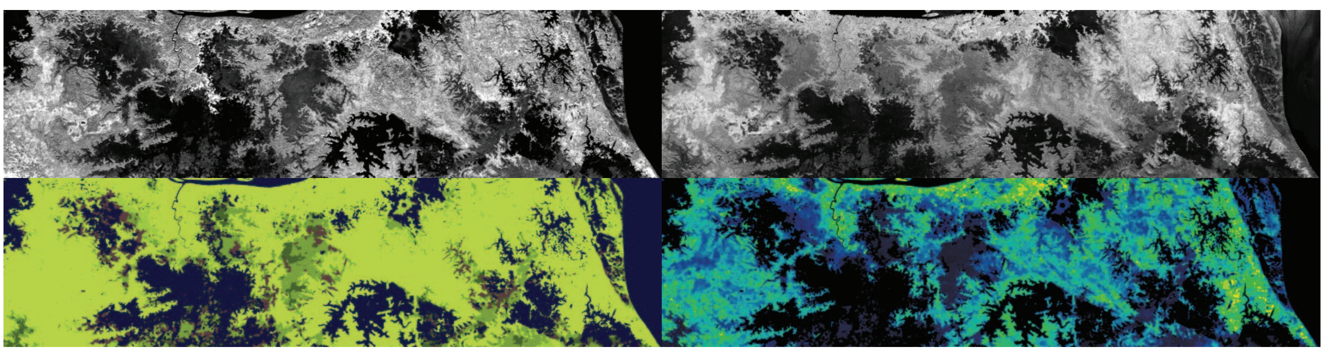

Figure 1. *Top-left*: GeoSAR HH, P-band, *top-right*: TOPSAR HH, P-band, *bottom-left*: object-based classification derived from GeoSAR data, and *bottom right*: map of forest biomass recovered from the calibrated height-based retrieval algorithm.

2. REFERENCES

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