Estimation of Tropical Forest Height and Aboveground Biomass from Dual-band InSAR measurements in Peruvian Amazon

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1. Introduction

In July 2009, Earthdata Inc. acquired Synthetic Aperture Radar (SAR) data over a lager part of the Peruvian lowland Amazon and mountain forests (more than 5000 km^2). The project was designed to provide high spatial resolution imagery to the science community to estimate and map forest above-ground biomass and to assess the capability of the measurements for REDD baseline applications.

GeoSAR collects X-Band (VV, 9.7GHz), and P-Band, (HH, 0.35GHZ) interferometric synthetic aperture radar (SAR) data in single-passes, over swaths of width ~11km, that may extend to several hundred kilometres, and from which are derived digital elevation models (DEMs) [1]. In this study, we develop a fusion approach by combining the dual-band InSAR phase and coherence with backscatter power at P-band HH and HV polarizations to estimate forest vertical structure (height) and aboveground biomass. The results are verified using forest structure and estimated biomass over a suite of field inventory plots distributed across landscapes over the study area. The estimation errors and spatial uncertainties in forest biomass are examined to provide realistic guidelines for REDD baseline carbon stock assessments.

2. Methodology

The GeoSAR system comprises of four X-band and four P-band antennae mounted permanently on a Gulfstream-II jet aircraft, permitting simultaneous port and starboard acquisition, and includes a nadir-looking LiDAR used primarily for high-density ground control. LiDAR data points are filtered and those associated with bare surfaces provide control in the DEM generation process, and data for quality control. Use of calibration targets and LiDAR control, plus an acquisition scheme with high redundancy, permits the generation of accurate DEMs, with typically a 1m RMSE error associated with the X-band

DEM at 5m posting. Primary products generated from GeoSAR observations are represented in Figure 1.2. These are the X-band and P-band magnitude and DEM data. Note that for X-band GeoSAR collects VV polarization, whilst at P-band we collect on both P-HH and P-HV, but only interferometrically on P-HH. The combination of channels provide five important measurements that can be directly incorporated in an estimation algorithm to quantify forest height and biomass. The algorithms have the following functional forms:

$$h = f^{-1}\{\gamma_{HH}, \phi_{HH}, H_{X-P}\}$$
$$AGB = g^{-1}\{\sigma_{HH}, \sigma_{HV}, \gamma_{HH}, \phi_{HH}, H_{X-P}\}$$

where h and AGB are forest dominant height and aboveground biomass respectively, and σ_{HH}, σ_{HV} are backscatter coefficients at HH and HV polarizations, γ_{HH}, ϕ_{HH} are the coherence and phase of InSAR measurement at P-band, and H_{X-P} is a height index computed from difference in height of scattering phase centers at X-band and P-band. The height index is a key component of measurements from the dual-band GeoSAR data. X-band phase center is from direct returns from upper forest canopy and the P-band phase center primarily from the underlying ground surface. The difference is directly proportional to the forest canopy height or basal area weighted height (Lorey's height) [2,3].

The methodology will focus on two applications of the data: 1. To estimate AGB from a physically-based model inversion using an scattering model developed for Pol-InSAR measurements [4], and 2. To develop a nonlinear regression model combining field data with the backscatter power and the height index [3]. We compare the results from both methods with the field data and quantify the errors and uncertainties associated with AGB estimation at 1-ha scale.

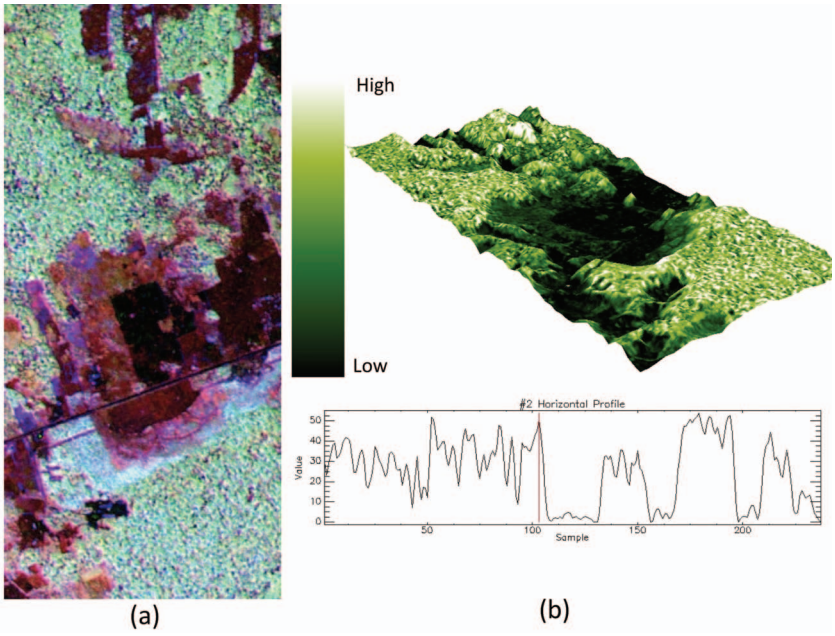

Figure 1. GeoSAR data products: (a) composite image of backscatter power and height index (R: XVV, G: PHH, B: H_{X-P}), (b) three-dimensional features of the height index over the landscape and normalized profile of forest height index along a transect across the image

3. Results and Discussion

The results of the study provides quantitative assessment of dual-band InSAR sensors for forest structure and biomass estimation. The study will also allow us to develop and end-to-end process for evaluation of the study areas for a REDD baseline project by providing the following products and assessments from the AGB spatial distribution maps:

1. Develop a total carbon storage maps of the study areas by using available data and allometric relations for the region to include the total vegetation carbon including above-ground and below-ground.
2. Assess impact of the scale on the accuracy of the maps and produce the final map at the best scale with the least uncertainty.
3. Use the forest structure (height and biomass) derived from ground and GeoSAR data and field data of permanent plots to assess the potential productivity and sequestration of forests in the study area.
4. Use the carbon storage map to assess the impact of degradation within the study area in terms of carbon loss.

4. REFERENCES

[1] A K Wheeler, and S Hensley, *The GeoSAR airborne mapping system*, Record of the IEEE 2000 International Radar Conference, 2000, Page(s):831 – 835.

[2] Saatchi, S., Despain, D. Halligan, K., Crabtree, R. Yu, Y. (2007). Estimating forest fire fuel load from radar remote sensing, IEEE Geoscience and Remote Sensing, vol. 45:1726-1740.

[3] Saatchi, S., Marlier, M., Chazdon, R., Clark, D., Russell, A. (2009). Impact of spatial variability of forest structure on radar estimation of aboveground biomass in tropical forests. Remote Sensing of Environment, In Press.

[4] Oveisghara, S. and S. Saatchi . (2009). Modeling Pol-InSAR Measurements of Vegetation Three-dimensional Structure. In Review, IEEE Transactions on Geoscience and Remote Sensing.