VHF Radar Mapping of Forest Biomass in Panama

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Abstract- In 1998 a VHF (80-116 MHz) synthetic aperture radar (BioSAR) mounted on NASA’s C-130 aircraft collected data over a series of Smithsonian Tropical Research Institute (STRI) test sites along the Panama Canal Zone in the Republic of Panama. A biomass surface map of the area was generated by interpolating between BioSAR measurement points for a set of parallel flight lines. Accuracy testing showed that there was good agreement (±10%) between the sensor-derived estimates of above ground biomass and the field data.

I. INTRODUCTION

The remote detection of the above ground component of forest biomass is a primary goal of scientists interested in Earth’s carbon cycle [1,2]. Because of persistent cloud cover and the difficulty in penetrating large structurally complex tropical forest canopies, there is a need to explore the use of VHF radar approaches [3-5]. NASA recently developed a VHF system (BioSAR), in cooperation with ZAI-AMELEX Corp. of Vienna, Virginia USA to measure the biomass of forest stands above 100 tons/ha. In 1998, the BioSAR instrument was installed on NASA’s C-130 and flown to Central America to take part in a series of flights over the dense tropical forests of the Panama Canal Zone.

II. SYSTEM OVERVIEW

The BioSAR instrument is a pulse-coherent radar system that collects data in up to six channels between 80 and 120 MHz in a nadir (downward-looking) mode at low altitude (300 meters above ground level). Both the downward looking mode and the low operating altitude were designed to limit the system power requirements and diminish the possibility of electromagnetic interference. In this respect, it is considerably different from side-looking imaging SAR systems.

The instrument illuminates the ground directly beneath the aircraft along the flight line in a 600-meter wide swath. Doppler sorting is used to collect the radar signal in 5° incidence angle increments fore and aft of nadir. Radar response values for all incidence angles between +/− 5° and 45° for each cell are averaged together to provide a single response value for each frequency. The BioSAR processed resolution cell is approximately 300 meters wide (across track) by 30 meters along track. The across-track dimension is limited by range gating, and the along track dimension is achieved by the Doppler/SAR processing. The polarization of the antenna is linear with the vertical element aligned with the flight path. The radar returns recorded by the system are the average power received at each frequency within each Doppler-sorted bin along track. The system provides built-in calibration (BIT) matched to 16 dB above the system noise floor with AM modulation at 50Hz for verification of system gain parameters. A complete description of the BioSAR system and its operation can be found in Imhoff et al. [6].

III. PANAMA CANAL ZONE STUDY SITES

We used forest research sites directly along the Panama Canal Zone (PCZ) [(UL) N9.5° W83°, (LR) N7° W77°]. The PCZ runs from the Northwest on the Atlantic side to the Southeast on the Pacific side and contains the canal, Gatun Lake, and the surrounding watersheds required to drive the extensive system of locks. Elevations differences are less than a few hundred meters. Field data were collected in eleven sites from the Atlantic side (Evergreen Seasonal Tall Forest) to Barro Colorado Island in the mid-Canal area (Semi-deciduous Seasonal Tall Forest). Field data for the sites were collected by the Smithsonian Tropical Research Institute (STRI). Measurements for over 6800 trees were made (species I.D., dbh., height) and biomass was estimated using allometric methods [7-8].

IV. RESULTS

Data from BioSAR were collected in a series of parallel flight lines approximately 20 km in length along the PCZ intersecting the STRI field sites. A terrain correction algorithm using digital terrain elevation data (91.5 m resolution) was developed to normalize the BioSAR response with respect to slope and aspect. The backscatter data for each cell (except nadir) were then averaged by both incidence angle and frequency to provide a single pan-angle pan-frequency response value for each ground cell.

A physics based semi-empirical model was used to relate biomass to normalized radar cross section. The scattering geometry is complicated enough that an analytical model of reasonable accuracy is not tractable, and there is insufficient data to construct an empirical model. In the future, however, as our knowledge grows, the use of empirical modeling based upon collected data and ground truth will be explored.
The biomass model was applied to the radar signal data and biomass estimates were made for each cell. An interpolation routine was then applied to construct a biomass surface map for the largest segment of parallel flight lines (Fig. 1).

V. CONCLUSIONS

A VHF radar system operating between 80-116 MHz was successfully used to map above ground biomass in dense tropical forest. While the test was constrained by a limited number of field sites, the influence of terrain on the signal was effectively eliminated as a source of excessive noise and a simple physics based model produced biomass estimates directly from the sensor that compared well (within ±10%) with ground truth. This test, taken into consideration with other successful uses of VHF radar to map heavy forest biomass, should be ample evidence that this technology could be extraordinarily useful for mapping forest biomass and addressing related issues of both commercial and scientific value. While there are still outstanding technological challenges and risks for putting VHF sensors into orbit, the value of creating sub-orbital systems such as high altitude UAV's of varying design should not be discounted.

REFERENCES


