A BIOMASS ESTIMATE OVER THE HARVARD FOREST USING FIELD MEASUREMENTS WITH RADAR AND LIDAR DATA

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1. INTRODUCTION

The National Research Council's decadal survey [1] recommended DESDynI [2] as one of the high priority missions for NASA. The mission envisions an InSAR/Lidar instrument for observing surface deformation, ice dynamics and ecosystem structures on global scales with high spatial resolutions. DESDynI's InSAR would most likely be an L-Band synthetic aperture radar in a repeat orbit configuration for interferometric measurements, while the Lidar component is expected to be a high resolution multibeam full-waveform profiler. The use of InSAR for observing surface deformation and ice dynamics is more established, however, its use for estimating vegetation structure has been more recent. The characterization of vegetation structure can be used to derive estimates of above ground biomass. High resolution and consistent global maps of biomass and carbon stocks require highly accurate observations of vegetation, in fact it is expected that such accuracies would require a combination of the high precision and directness of Lidar observations and the large spatial extent of InSAR measurements [3]. In this text we assess the accuracy of radar and/or lidar estimates of above ground biomass using field measurements made in the Harvard forest in Massachusetts, USA.

2. FIELD CAMPAIGN

The Harvard Forest near Petersham, MA is a ecological research facility that has been managed by the Harvard University since 1907. It is spread over 3000 acres and is split mainly in three tracts; Prospect Hill, Tom Swamp and Slab City (see Figure 1). The forest type is Transition Hardwoods-White Pine-Hemlock, with dominant species of Red Oak, Red Maple, White Birch, White Pine and Eastern Hemlock. Most of the forest is artificially planted over reclaimed agricultural land. Different plantations of a certain species are maintained throughout the forest. There are permanent study cites spread over the forest where research is conducted in many areas such as biodiversity, conservation, forest-atmosphere exchange, soil warming etc.

During July 2009 ground validation data was collected from 15 hectares in the Harvard Forest. The survey area was divided into fifteen one hectare plots, with a plot measuring 200m by 50m. Each plot was was further divided into 16 subplots, each 25m by 25m. The orientation of a plot was chosen to be either 5 degrees for vertical plots, or 95 degrees for horizontal plots. These plots were set in the three Harvard Forest tracts of Prospect Hill, Tom Swamp and Slab City. Of the 15 plots, 10 were in Prospect Hill (titled PH01 through PH10), two in Tom Swamp (TS01, TS02) and one in Slab City (SC01). The remaining two plots were set in the nearby State Forest (SF02 and SF04). The choice of location of these plots was guided by species diversity, topography, accessibility and lidar/radar coverage. Plots PH1 and PH7 are set inside stands of predominantly tall and dense red pine trees, PH4 and PH2 are set inside a Hemlock stand, PH6 and PH10 are predominantly young deciduous trees etc. For each subplot the diameter at breast height (dbh) of every tree above 10cm was measured and cataloged with species information. In the last few decades numerous field studies have yielded regression curves for the above ground dry biomass and dbh. A comprehensive review of these studies has been presented in [4]. Biomass estimates from these equations have been used as the ground truth.

Fig. 1. *Harvard Forest Tracts and survey plots. The inset enlarges plot PH1 with the sixteen 25m by 25m subplots.*

3. REMOTE SENSING DATA SOURCES

JAXA's PALSAR (Phase Array L-band Synthetic Aperture Radar), a spaceborne instrument has been operational since February 2006 and has collected fully polarimetric and high resolution dual and single polarized data over the Harvard forest region on a regular basis. PALSAR has a 46 day repeat period which gives us a variety of perpendicular baselines for repeat-orbit interferometry. These baselines are summarized in Figure 2.
NASA's UAVSAR (Uninhabited Aerial Vehicle Synthetic Aperture Radar), an L-band airborne radar was flown over the Harvard forest from August 4-15, 2009 in a repeat-pass racetrack configuration. Data was collected with multiple-baselines and multiple look-angles.
NASA's LVIS (Laser Vegetation Imaging Sensor), an airborne full waveform scanning lidar has collected data over the Harvard forest previously (2003) and flew over the same region in July 2009.

4. ANALYSIS

The aim of this text is to analyze the efficiency of biomass estimates derived from remote sensing means, either on their own or through some combination of the techniques that will be available in the DESDynI platform. To this extent the ground validation data collected is considered the true value of above ground biomass. Moments of the Lidar waveform data are often related to ground validation data [5] using component analysis techniques and various correlative relationships. LVIS data collected in 2003 and 2009 is related to the ground validation data using similar techniques.
Various techniques have been proposed for relating radar observations to above ground biomass estimates. First, it has been shown ([6], [7], [8]) that above ground biomass estimates can be obtained directly from radar backscatter. This however is limited by issues of saturation ([9]), where increasing biomass does not increase backscatter intensity proportionately at high biomass levels. Techniques in radar interferometry can also provide estimates of carbon stocks through measurements of forest height and vertical structure. The topographic sensitivity of an interferometer can be used to invert for tree heights if knowledge of the true ground surface and canopy penetration characteristics are available ([10], [11], [12]). Polarimetric techniques in interferometry ([13], [14], [15], [16]) can be employed to measure structure over forested terrain. Interferometric correlation magnitude has also been shown to contain information of tree heights and stem volumes ([17], [18], [19]). This text analyzes

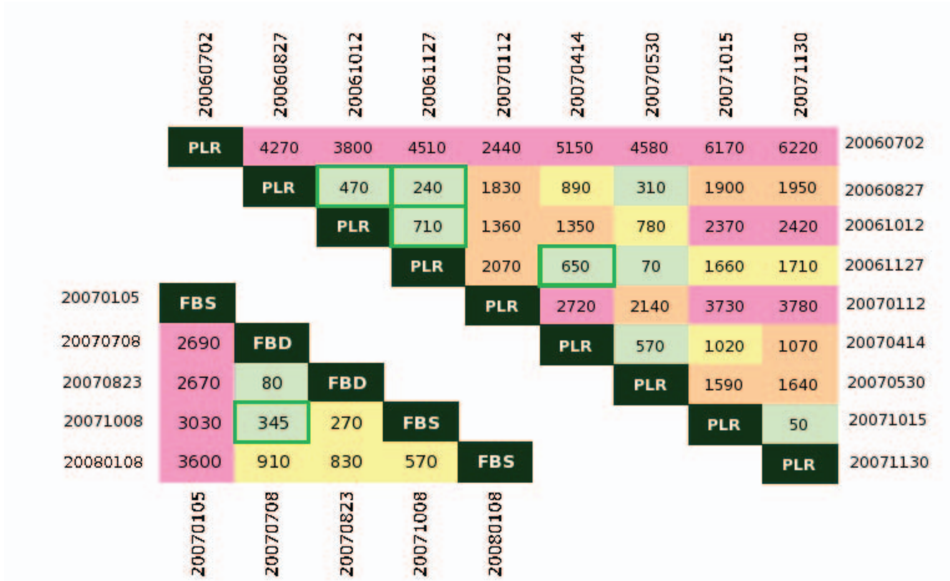

Fig. 2. *ALOS-PALSAR baselines for polarimetric and high resolution modes.*

these radar techniques using data collected from PALSAR and UAVSAR and assesses the efficiency of the biomass estimates derived from them with the ground validation data collected over the Harvard forest.

5. REFERENCES

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