BIOMASS ESTIMATION FOR BOREAL FORESTS USING FIELD, LIDAR AND L-BAND SAR DATA

D. K. Atwood[1], Hans Erik Andersen[2]

1) Geophysical Institute, University of Alaska Fairbanks.
903 Koyukuk Dr., Fairbanks, AK 99775-7320
e-mail: dkatwood@alaska.edu
2) USDA Forest Service PNW Research Station
Anchorage Forestry Sciences Laboratory
3301 C Street, Suite 200, Anchorage, AK 99503

1. BACKGROUND

The coupling of LIDAR and SAR for vegetation structure has been investigated in several terrestrial biomes [7, 4, 6]. In this paper, we explore the measurement of biomass in boreal forests. This ecosystem was selected since the boreal biome is environmentally important, yet significantly under-sampled. The boreal forest biome consists of a circumpolar region lying above 50º–60º latitude and extending through northern Russia (Siberia), Scandinavia, Canada, and Alaska. It is characterized by low temperatures and dominated by cold-tolerant coniferous tree species such as pine, fir, and spruce. Boreal forests are estimated to cover 9% of the Earth's land surface, but they contain a disproportionate share (23%) of the world's total carbon [3]. Although most of the carbon in cold boreal forests is stored in the soil, there are important interactions between forest canopy dynamics and below-ground soil processes. Therefore, remote sensing means to determine unbiased estimates of boreal biomass can play a significant role in our understanding of global carbon processes.

2. APPROACH

The goal of this paper is to outline an investigation into the interplay of three regimes of data in the determination of boreal biomass: 1) field plot measurements, 2) LIDAR measurements of forest canopy profile, and 3) polarimetric SAR. Field plot measurements offer the most accurate means to determine above ground boreal biomass [8]. Thus, these measurements serve as our ground control points. Airborne LIDAR offers important information on vegetation height and three-dimensional canopy structure [5]. After applying appropriate allometric equations to the vegetation measurements obtained on the field plots, we can accurately estimate biomass over the more extensive coverage of the airborne flight lines. Last, we incorporate a synoptic view using L-band polarimetric SAR (PolSAR) data from the ALOS PALSAR instrument to fill out our estimation of biomass over the entire extent of the SAR imagery. This "bootstrap" methodology enables us to validate the accuracy of our PolSAR biomass estimation algorithm.

3. SITE SELECTION

The study area for the project is within the upper Tanana Valley in interior Alaska. The forests in this area are characteristic of the boreal forests distributed over much of interior Alaska, and are composed primarily of quaking aspen (populus tremuloides), paper birch (betula papyrifera), white spruce (picea glauca), and black spruce (picea mariana). Spatial variability in forest stand structure and composition over the landscape in this area is largely determined by wildfires, which are common in this ecosystem – much of the study area has burned at some point within the last 25 years.

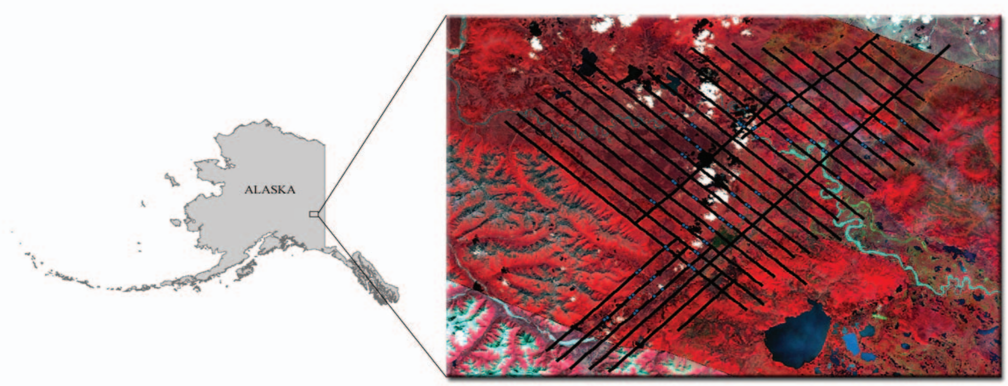

Figure 1. Location of study area, field plots (blue dots), and lidar strips (black lines).

4. FIELD PLOTS

Seventy-nine 1/30th hectare, fixed-area, circular field plots were established within the study area in the summer of 2009 (see Figure 1). At each plot, all trees above 7.6 cm were stem-mapped and measured; all trees greater than 2.5 cm were measured on a smaller (1/420th ha) micro-plot. Species, stem diameter, height, uncompacted crown ratio, condition (rot/cull), and crown class were recorded for each tree. In addition, crown radius was recorded for a selection of trees across a range of species, crown, and diameter classes. In addition, canopy cover was estimated at various levels in the canopy (ground, shrub, understory, and overstory). Each plot location was recorded using a survey-grade, differentially-corrected GPS receiver (< 1 meter error).

5. LIDAR MEASUREMENTS

Lidar data was collected in a strip sampling mode along 27 flight lines, with approximately 2.5 km between each swath in June, 2009 (see Figure 1). The nominal post spacing of the lidar was 0.5 meters (density = 4 pulses/m2), and each swath was approximately 240 meters wide.

.

6. POLSAR BIOMASS ESTIMATION

Since the first long wavelength airborne SAR systems became available in the late 1980s, numerous airborne campaigns have established the sensitivity of L-band radar backscattering intensity for measuring forest biomass in temperate, tropical and boreal forests. Most initial work focused on HV backscatter, which has the largest dynamic range and the highest correlation with biomass. More recent research has shown that HH and VV are also sensitive to above ground forest biomass and can improve the retrieval of biomass.

For our study we utilize the availability of ALOS PALSAR quad-pol data to estimate biomass. This permits the generation of a wide variety of polarimetric parameters offering varying degrees of sensitivity to forest biomass [1,2]. In regression analysis, it has been found that radar cross section saturates for biomass in excess of 150-200 Mg/Ha. Fortunately, our ecosystems are below this practical threshold, enabling the investigation of the dependencies of polarimetric parameters on biomass. Preliminary results indicate correlation between our PolSAR-derived metrics and plot–level observed biomass (see Figure 2).

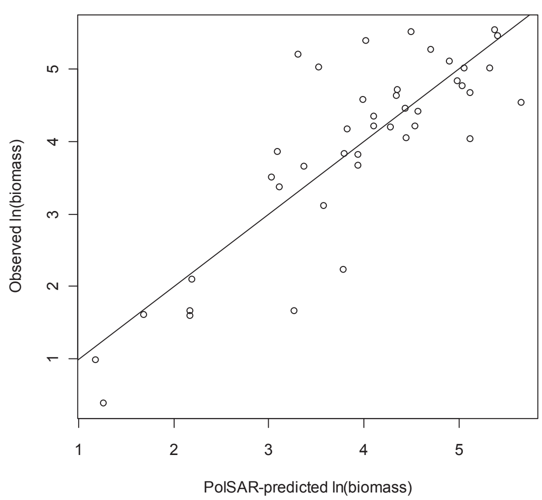

Figure 2. Plot of field-measured biomass vs. PolSAR model predictions.

7. RESULTS AND RECOMMENDATIONS

The experimental methods used on the field, LIDAR, and PolSAR data will be described in detail. Specific attention will be paid to the development of the PolSAR biomass estimation algorithms. More importantly, we will characterize the biomass regimes and ecosystems for which these algorithms yield acceptable accuracy. Finally, we will address the applicability of using our approach to fulfill our large scale goal of estimating the biomass of boreal forests throughout Interior Alaska.

8. REFERENCES

[1] Cloude S.R. and E. Pottier. 1997. An entropy based classification scheme for land applications of polarimetric SAR, IEEE Transaction on Geoscience and Remote Sensing, 35(1), 68-78.

[2] Freeman A. and S.L. Durden. 1998. A three-component scattering model for polarimetric SAR data, IEEE Transactions on Geoscience and Remote Sensing, 36(3), 963-973.

[3] Intergovernmental Panel on Climate Change (IPCC). 2000. Land Use, Land-Use Change, and Forestry, Cambridge University Press, Cambridge. Available at:
http://www.ipcc.ch/ipccreports/sres/land_use/index.htm [accessed September 14, 2008]

[4] Kellndorfer, J., W. Walker, L. Perce, C. Dobson, J.A. Fites, C. Hunsaker, J. Vona, and M. Clutter.2004. Vegetation height estimation from Shuttle Radar Topography Mission and National Elevation Datasets, Remote Sensing of the Environment, 93, 339-358.

[5] Lefsky, M.A., D.J. Harding, M. Keller, W.B. Cohen, C.C. Carabajal, F.D. Espirito-Santo, M.O. Hunter, and R. de Oliveira. 2005. Estimates of forest canopy height and aboveground biomass using ICESat. Geophysical Research Letters, 32, L22S02, doi:10.1029/2005GL023971.

[6] Simard, M., K. Zhang, V. Rivera-Monroy, M.S. Ross, P.L. Ruiz, E. Castañeda-Moya, R.R. Twilley, and E. Rodriguez. 2006. Mapping height and biomass of mangrove forests in Everglades National Park with SRTM elevation data, Photogrammetric Engineering and Remote Sensing, 72(3), 299-311.

[7] Slatton, K.C., M.M. Crawford, and B.L. Evans. 2001. Fusing interferometric radar and laser altimeter data to estimate surface topography and vegetation heights, IEEE Tranactions on Geoscience and Remote Sensing, 39(11), 2470-2482.

8] Yarie, J., E. Kane, and M. Mack. 2007. Aboveground biomass equations for the trees of interior Alaska. AFES Bulletin 115. Univ. of Alaska-Fairbanks.