

ESTIMATING SEMIARID VEGETATION HEIGHT FROM GLAS DATA

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Abstract - The Geoscience Laser Altimeter System (GLAS) aboard the Ice, Cloud and land Elevation Satellite (ICESat), was designed primarily for ice information measurement, but has been recently used to characterize vegetation structure and estimate canopy heights and biomass over a range of forest types and topography. GLAS data, however, have not been used to estimate semiarid vegetation, with typically low height stature. We investigate the ability of GLAS data to estimate vegetation height and density at the Idaho National Laboratory (INL) in southeastern Idaho, USA, an area of low topographic relief, minimizing within-footprint topographic and vegetation variation. Vegetation derivatives obtained from GLAS data are compared to airborne LiDAR data collected over the same area in 2006 for uncertainty estimates. Accurate vegetation canopy characterization with GLAS will provide large-scale biomass estimates, along with roughness estimates for surface energy balance models and weather forecasting.

Keywords: GLAS, LiDAR, full waveform, shrub steppe, semiarid, vegetation height

1. INTRODUCTION

Semiarid rangeland ecosystems make up 18% of the world's land area (White and Nackoney, 2003) and thus quantifying the biomass held in these ecosystems has global significance. Traditional methods of remote sensing, i.e. passive imagery, is difficult due to the vegetation cover being low in stature and spectrally indeterminate (Mitchell and Glenn, 2009). Light detection and ranging (LiDAR) offers the ability to capture the 3D structure of the vegetation and has proven effective in estimating height of semiarid rangeland vegetation (Glenn et al., in press, and Mitchell et al., in press). However, standard practices for collecting LiDAR data from an airborne platform are expensive, especially over large areas. Satellite based LiDAR systems, such as the Geoscience Laser Altimeter System (GLAS) on board the Ice, Cloud and land Elevation Satellite (ICESat) offer world coverage, and therefore hold great promise.

Designed primarily for ice sheet monitoring, GLAS data have been used to characterize vegetation structure and estimate canopy heights and biomass over a range of forest types and topography (Lefsky et al. 2007, Duncanson et al. 2010). Traditional methods of quantifying vegetation height from full waveform data use the distance between first energy peak (vegetation) and last energy peak (ground). Full waveform LiDAR does not return a separate energy peak for rangeland vegetation and ground, instead low vegetation causes the ground return pulse to widen (Duong et al. 2007, Hug et al. 2004). Therefore, unique methods of quantifying vegetation height are needed to quantify rangeland vegetation height.

In this study, we report (1) results from comparing airborne LiDAR derived bare ground elevations and GLAS full waveform derived bare ground elevations; and (2) the applicability to use GLAS full waveform LiDAR to measure semiarid rangeland vegetation heights.

2. MATERIALS AND METHODS

The study area is located in the cold desert shrub-steppe environment on the Idaho National Lab in eastern Idaho, USA. The area of analysis is covered by an airborne LiDAR dataset collected in Fall 2007 (fig. 1). Topographic relief is low, with 42 m of relief over 18.6 km².

2.1 GLAS Data

GLAS/ICESat L1A Global Altimetry Data (GLA01) and GLAS/ICESat L2 Global Land Surface Altimetry Data (GLA14) were downloaded from the National Snow and Ice Data Center (NSIDC) data pool for the State of Idaho.

2.2 GLAS Data Processing

A total of 385 GLAS footprints were found within the study area. GLA14 footprints were filtered to remove saturated and cloudy footprints. A total of 191 footprints remained after filtering. GLA14 footprint locations were converted to ellipses using the transmit pulse azimuth (*i_tpazimuth_avg*), transmit pulse eccentricity (*i_tpeccentricity_avg*), and the transmit pulse major axis (*i_tpmajoraxis_avg*). GLA01 and GLA14 records were matched and waveform information from the GLA01 product were added to the GLA14 product.

2.3 Airborne LiDAR Data Processing

Airborne discrete return LiDAR data for INL were height filtered using the publically available BCAL LiDAR tools (<http://bcal.geology.isu.edu/envitools.shtml>) as described in Streutker and Glenn (2006), Glenn et al. (in press), and Mitchell et al. (in press). The LiDAR point clouds were height filtered to separate ground returns from vegetation returns using a 7 m natural neighbor interpolation method. Height filtered data (ground and non-ground returns) were rasterized using the BCAL LiDAR tool into several 1 m raster products, including bare ground and maximum vegetation height.

2.4 GLAS and Airborne LiDAR Comparisons

The bare ground raster values were extracted for each GLAS footprint. Mean signed error (MSE) was used to compare the bare ground calculations to the GLAS ground elevation for each GLAS footprint. The maximum vegetation height minimum, maximum, and mean were calculated for each GLAS footprint. Linear regression was used to explore relationships between max vegetation height and GLAS raw waveform characteristics including skewness (*i_skew1*), amplitude (*i_Gamp*), area (*i_Garea*), and width (*i_Gsigma*) of the GLAS waveform.

3. RESULTS

3.1 Bare Ground Comparison

Mean signed error (MSE) between the GLAS and LiDAR-derived bare earth elevations was -0.35 m and -0.72 m for the minimum and mean, respectively. GLAS elevation values are lower than the discrete return LiDAR-derived bare earth elevations.

3.2 Vegetation Comparison

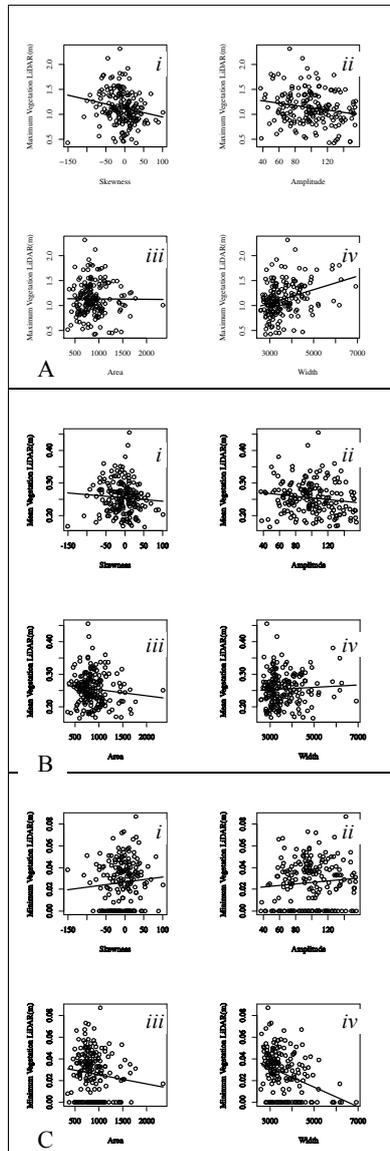


Fig. 1. Plots showing: (A) Maximum value of maximum vegetation height raster, (B) Mean value of maximum vegetation height raster, (C) Minimum value of maximum vegetation raster, vs. Waveform (i) Skewness, (ii) Amplitude, (iii) Area under waveform, (iv) Width.

4. DISCUSSION AND CONCLUSIONS

Overall, GLAS underestimated bare ground elevation when compared to Airborne LiDAR bare ground elevation. Chen et al. (2010) also found the lowest peak to underestimate ground elevation (-0.97 m), however, their study focused on sloped and vegetated surfaces. When footprint size, ~ 60 m, and distance from sensor to the earth's surface are taken into consideration, an underestimation of 0.72 m is promising for semiarid rangeland ecosystems.

The vegetation comparison showed that existing NSIDC product GLA14 variables (i_skew1), amplitude (i_Gamp), area (i_Garea), and width (i_Gsigma) are not sensitive to low height vegetation. The next step of this research is to develop new waveform characteristics with increased sensitivity for rangeland vegetation.

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