Retrieving Vegetation Height of Forests and Woodlands over Mountainous Areas in the Pacific Coast Region Using Satellite Laser Altimetry

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Vegetation height is one of the leading dimensions of ecological variations among tree species and is central to ecosystem functioning [1]. Since its launch in 2003, GLAS (Geoscience Laser Altimeter System) on board ICESat (Ice, Cloud,and land Elevation Satellite) has produced unprecedented dataset at the global scale [2]. However, the challenge to retrieve canopy height from large-footprint satellite lidar waveforms over mountainous vegetated areas is formidable given the complex interaction of terrain and vegetation. Only a paucity of studies have explored the use of GLAS for vegetation height retrieval [3]-[9]. This study investigates the potential of GLAS for retrieving vegetation height over mountainous areas in the Pacific Coast region, including two conifers sites (one in California and the other in Washington) and one woodland site in California.

The previous studies have used either direct ([6],[7],[9]) or statistical ([3]-[5], [8]) methods to extract canopy height from GLAS data. The direct methods work well over flat areas [7]. However, over mountainous areas with large relief and complex terrain, the peaks from ground and surface objects can be broadened and mixed, making the identification of ground elevation difficult [10]. For the complex terrain, the lowest peak might correspond to objects (e.g. short trees at the lower side of a footprint) or minor terrain features that do not represent the central tendency of terrain elevation within a footprint (e.g., flat surface such as waters and valleys passing through the footprints). Unlike the direct methods, the statistical models are essentially site-specific. Therefore, it is critical to investigate the model generalizability over sites with different vegetation and terrain conditions.

The main objectives of this study are to examine 1) how canopy height can be estimated from GLAS data over mountainous areas using both direct and statistical methods, and 2) how a specific method can be applied across different vegetation types including forests and woodlands. Given their ability to measure 3D vegetation and terrain properties precisely over large areas, airborne lidar data are used to derive an accurate and spatially-extensive dataset of canopy height and terrain elevation over each GLAS footprint to evaluate different methods.

Both direct methods and statistical models are developed and tested for canopy height estimation using spatially extensive coincident airborne lidar data. The major findings include: 1) the direct methods tend to overestimate the canopy height and are complicated by the identification of waveform signal start and terrain ground elevation, 2) the regression models driven by the ancillary lidar DEM information have better performance than the models driven by the waveform edge-extent metrics. The nonlinear edge-extent models have better performance than the linear edge-extent models at the individual sites, 3) nevertheless, the nonlinear edge-extent statistical models have less model generalizability than the linear models across woodland and conifer sites, 4) the simulations indicated that the errors and uncertainty in canopy height estimation can be significantly reduced by decreasing the footprint size. It is recommended that the footprint size of the next-generation satellite lidar systems be at least 10 m or so if we want to achieve meter-level accuracy of canopy height estimation using direct and statistical methods.

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