Title: Achieving accuracy requirements for forest biomass mapping: a data fusion method for estimating forest biomass and LiDAR sampling error with spaceborne data

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Abstract
The synergistic use of active and passive remote sensing (i.e., data fusion) demonstrates the ability of spaceborne light detection and ranging (LiDAR), synthetic aperture radar (SAR) and multispectral imagery for achieving the accuracy requirements of a global...
forest biomass mapping mission. This data fusion approach also provides a means to extend 3D information from discrete spaceborne LiDAR measurements of forest structure across scales much larger than that of the LiDAR footprint. For estimating biomass, these measurements mix a number of errors including those associated with LiDAR footprint sampling over regional - global extents. A general framework for mapping above ground live forest biomass (AGB) with a data fusion approach is presented and verified using data from NASA field campaigns near Howland, ME, USA, to assess AGB and LiDAR sampling errors across a regionally representative landscape. We combined SAR and Landsat-derived optical (passive optical) image data to identify forest patches, and used image and simulated spaceborne LiDAR data to compute AGB and estimate LiDAR sampling error for forest patches and 100m, 250m, 500m, and 1km grid cells. Forest patches were delineated with Landsat-derived data and airborne SAR imagery, and simulated spaceborne LiDAR (SSL) data were derived from orbit and cloud cover simulations and airborne data from NASA’s Laser Vegetation Imaging Sensor (LVIS). At both the patch and grid scales, we evaluated differences in AGB estimation and sampling error from the combined use of LiDAR with both SAR and passive optical and with either SAR or passive optical alone. This data fusion approach demonstrates that incorporating forest patches into the AGB mapping framework can provide sub-grid forest information for coarser grid-level AGB reporting, and that combining simulated spaceborne LiDAR with SAR and passive optical data are most useful for estimating AGB when measurements from LiDAR are limited because they minimized forest AGB sampling errors by 15 – 38%. Furthermore, spaceborne global scale accuracy requirements were achieved. At least 80% of the grid cells at 100m, 250m, 500m, and 1km grid levels met AGB density accuracy requirements using a combination of passive optical and SAR along with machine learning methods to predict vegetation structure metrics for forested areas without LiDAR samples. Finally, using either passive optical or SAR, accuracy requirements were met at the 500m and 250m grid level, respectively.

Keywords
Data fusion; lidar; radar; sar; biomass; sampling error