Estimating canopy cover from ICESat-2

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1. Introduction

Canopy cover is a fundamental vegetation structural parameter that is used to define a forest and support a range of vegetation applications, including habitat mapping (Lerman et al. 2014), modeling forest aboveground biomass (Narine et al. 2020) and assessing forest degradation (McCarley et al. 2017). NASA's Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) mission offers an extraordinary capability to capture up-to-date information about forest ecosystems with data acquired by its Advanced Topographic Laser Altimeter System (ATLAS) since 2018. The capability of a spaceborne lidar to contribute to estimating biophysical forest parameters has been proven with ICESat-2's predecessor, ICESat, which operated from 2003 to 2009. For example, observations from ICESat's Geoscience Laser Altimeter System (GLAS) were used to map global canopy heights (Lefsky, 2010; Simard et al., 2011) and AGB (Hu et al. 2016), and characterize forest volume (Pourrahmati et al. 2015), and canopy cover (Tang et al. 2016). With the enhanced capability to provide greater spatial coverage and observations at higher spatial resolutions with ICESat-2, there are exceptional opportunities to derive up-to-date vegetation information as well as spatially comprehensive products through synergistic approaches with data from longstanding space-based programs like Landsat. As a first step to generating a wall-to-wall canopy cover product, the overall goal of this study was to examine ICESat-2's vegetation product data, ATL08, and custom-processed geolocated photon data, ATL03, for characterizing canopy cover. For this study, comparisons with reference canopy cover were made at the 100-m segment level (ATL08) and canopy parameters were examined for the development of predictive models. Relationships were also examined at the 30-m pixel scale, consistent with Landsat imagery and National Land Cover Database (NLCD) products (Homer et al. 2015).

2. Data and Methods

2.1. Study area

Data over a study site located in southeast Texas in the Sam Houston National Forest (SHNF) (30˚ 42' N, 95˚ 21'W) were examined for this study. The area exhibits vegetation conditions that are typical for the southeastern United States, consisting primarily of longleaf pine (*Pinus palustris*) stands, stands of loblolly pine (*Pinus taeda*), slash pine (*Pinus elliottii*), bottomland hardwoods, mixed hardwoods and pine hardwoods. This site was used for an initial aboveground biomass mapping study with ICESat-2 and pre-launch investigations with simulated ICESat-2 data.

2.2. Airborne lidar

Airborne lidar data acquired in 2018-2019 from USGS 3D Elevation program (3DEP) were used. Point clouds were clipped based on ICESat-2 tracks, processed to derive aboveground level heights (vegetation) and to calculate canopy cover as the proportion of returns above 4.6 m (USDA Forest Service 2014) for each matching ATL08 segment (Narine et al. 2019). For pixel-level comparisons, the normalized point clouds were clipped to match selected 30-m NLCD pixels and canopy cover was computed at this scale.

2.3. ICESat-2 data and processing

ICESat-2 ATL08 and corresponding ATL03 data from release 003 were downloaded from the National Snow and Ice Data Center (NSIDC). The ATL03 granule examined for this study was

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ATL03_20181203072948_10030106_003_01. Using data from one strong beam (gt3r), custom noise filtering and photon classification algorithms (Popescu et al. 2018) were applied and ATL08 data were used to extract segments. Classified photons (noise, ground, canopy and top-of-canopy) in the ATL08 product were traced back to ATL03 and processed to compute canopy cover as the percentage of photons above 4.6 m withing a segment. Similarly canopy cover was computed from the custom-processed data and combined with corresponding ATL08 variables (Neuenschwander and Pitts 2019). To explore canopy cover at the 30 m pixel level, where ICESat-2 track lengths were at least 30 m across a pixel, photons from ATL08 and custom-processed data were used to compute canopy cover for those 30 m cells and were combined with reference estimates.

2.4. Data analysis

Canopy cover extracted from the custom processed ATL03 and ATL08 segments were compared with airborne lidar-derived canopy cover (reference) and the coefficient of determination (R^2) and RMSE values were used to assess the relationships. To understand the application of canopy parameters, linear regression models were used to relate canopy metrics (ATL08 and custom-processed ATL03) with reference canopy cover at the segment scale; 111 segments were used for model building and remaining 55 segments, for model evaluation. Comparisons at the 30-m scale were made with reference airborne lidar-derived canopy cover and NLCD canopy cover.

3. Results and Discussion

Segment-level comparisons between ICESat-2 derived canopy cover and reference airborne lidar estimates for the SHNF site, are shown in Figure 1.

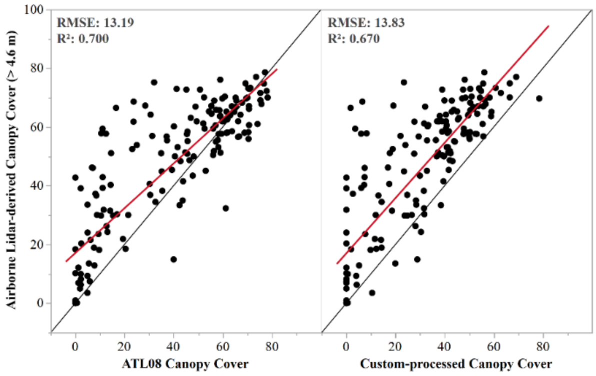

Figure 1: Airborne-lidar derived canopy cover versus ATL08 and custom-processed ATL03 canopy cover for segments over SHNF, Texas.

Canopy cover estimation using relative canopy height metrics from custom-processed dataset resulted in a model containing canopy cover (> 4.6 m) and maximum height (p-values < 0.001), which explained 70% variance of the airborne lidar-derived canopy cover (RMSE = 12%) with the test set (Figure 2). Similarly, ATL08 maximum height and canopy cover remained in the final canopy cover and yielded a R^2 and RMSE of 0.69 and 10% respectively (Table 1) (p-values < 0.001).

Table 1. Linear regression results for estimating canopy cover

Dataset	RMSE		R^2		Model
	Training	Test	Training	Test	
ATL08	9.17%	11.67%	0.80	0.70	-1.34 + 1.65*maximum height + 0.41*canopy cover
Custom-processed	12.05%	10.07%	0.77	0.69	6.51 + 1.37*maximum height + 0.50*canopy cover

Considering the full range of canopy cover computed at the pixel scale, ICESat-2-derived values were less correlated with reference airborne lidar estimates and weaker relationships were observed with NLCD canopy cover (2016 product) (Figure 2).

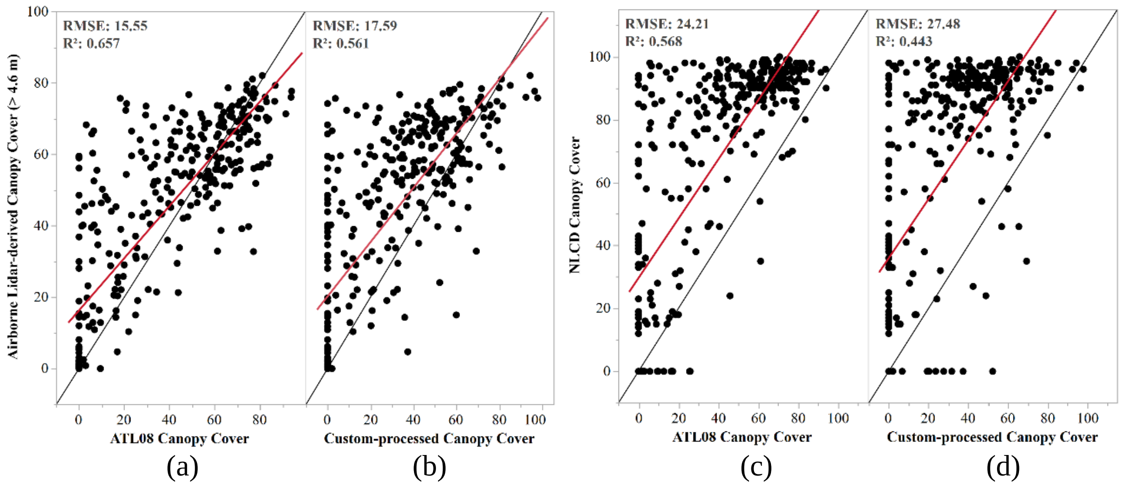

Figure 2: Airborne-lidar derived canopy cover versus ATL08 (a) and custom-processed ATL03 canopy cover (b); NLCD canopy cover versus ATL08 (a) and custom-processed ATL03 canopy cover (b) (*n* = 339).

4. Conclusions

While further investigations are needed to develop canopy cover characterizations with ICESat-2, current results for temperate forest conditions in the southern US highlight good agreements between ICESat-2-derived canopy cover from segments and reference airborne lidar estimates. Ongoing research serves to develop approaches for computing canopy cover over vegetated sites in the southern US and an examination of methods for developing a 30-m wall-to-wall product.

5. References and Citations

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