Mapping 30m Boreal Forest Heights Using Landsat and Sentinel Data Calibrated by ICESat-2

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ENVIRONMENTAL SCIENCES
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INTRODUCTION

The launch of the Advanced Topographic Laser Altimeter System (ATLAS) on board the NASA's Ice, Cloud and Land Elevation Satellite (ICESat-2) offers a great opportunity to observe forest structures especially at high latitudes (>52°N) (Abdalati et al., 2010). However, ICESat-2's current applications in boreal forest height mapping are still limited at sparse/track level (Neuenschwander et al., 2020). Owing to its adopted photon-counting lidar system, ICESat-2's observations contain high uncertainties over vegetated areas (Neuenschwander and Pitts, 2019), thereby requiring careful pre-processing before being applied to regional-scale canopy height modelling (CHM).

Objectives:
1) Evaluate the efficacy of ICESat-2 observed canopy heights under different scenarios (beam strength, signal-to-noise ratio, canopy cover, canopy height uncertainty, slope);
2) Develop a 30-m regional-scale CHM for boreal forests by integrating sparse ICESat-2 observations (response) with spatially continuous Landsat and Sentinel data.
3) Assess the importance of Landsat- or Sentinel- derived explanatory variables on CHM development.

STUDY MATERIALS AND METHODOLOGY

Site location: north side of Fairbanks, Alaska
Validation data: airborne lidar (ALS, 1m), Jul.-Aug. 2014, collected from G-LiHT
Canopy height response: ICESat-2 *Hcanopy* (orange tracks), 2019-2020
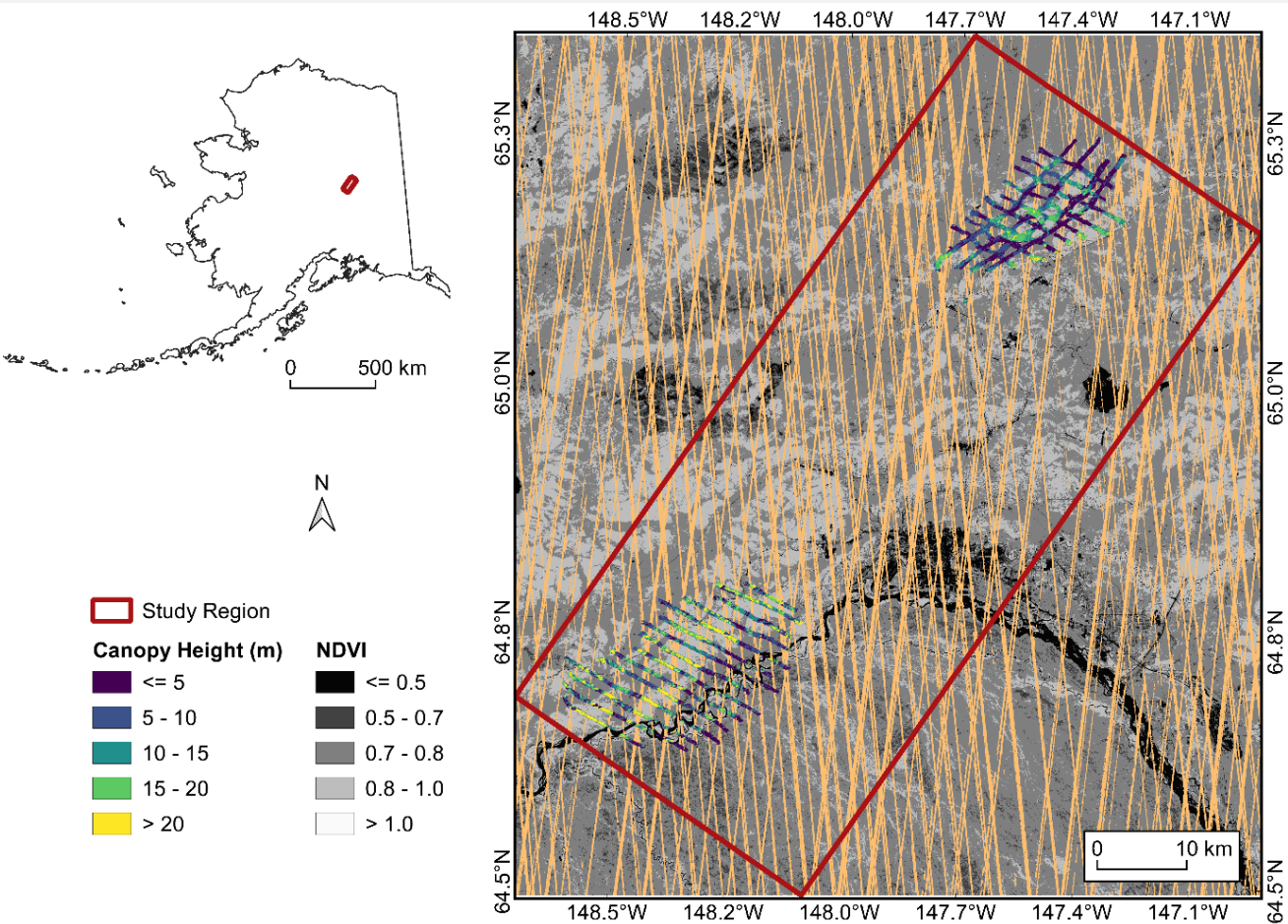**Explanatory variables*:** 2019
- Spectra (Landsat-8 (L8), Sentinel-2 (S2)), Sentinel-1 polarization (VV, VH).
- L8-/S2- derived: normalized difference vegetation index (NDVI), normalized different water index (NDWI), modified soil adjusted vegetation index (MSAVI), NDVI-derived gray-level co-occurrence texture index
- S1-derived: VVHH (VV/HH), VVH (Li et al., 2020)
- Auxiliary data (AUX): ArcticDEM (elevation, slope, roughness), location (xcoord, ycoord), Copernicus Global Land Service product (land cover, tree fraction)

*All data were resampled to 30m and reprojected to local coordinate system.

Method: random forest regression
Feature selection: remove variables highly correlated (R >0.9) with others meanwhile with lower correlations to ICESat-2 *Hcanopy*.
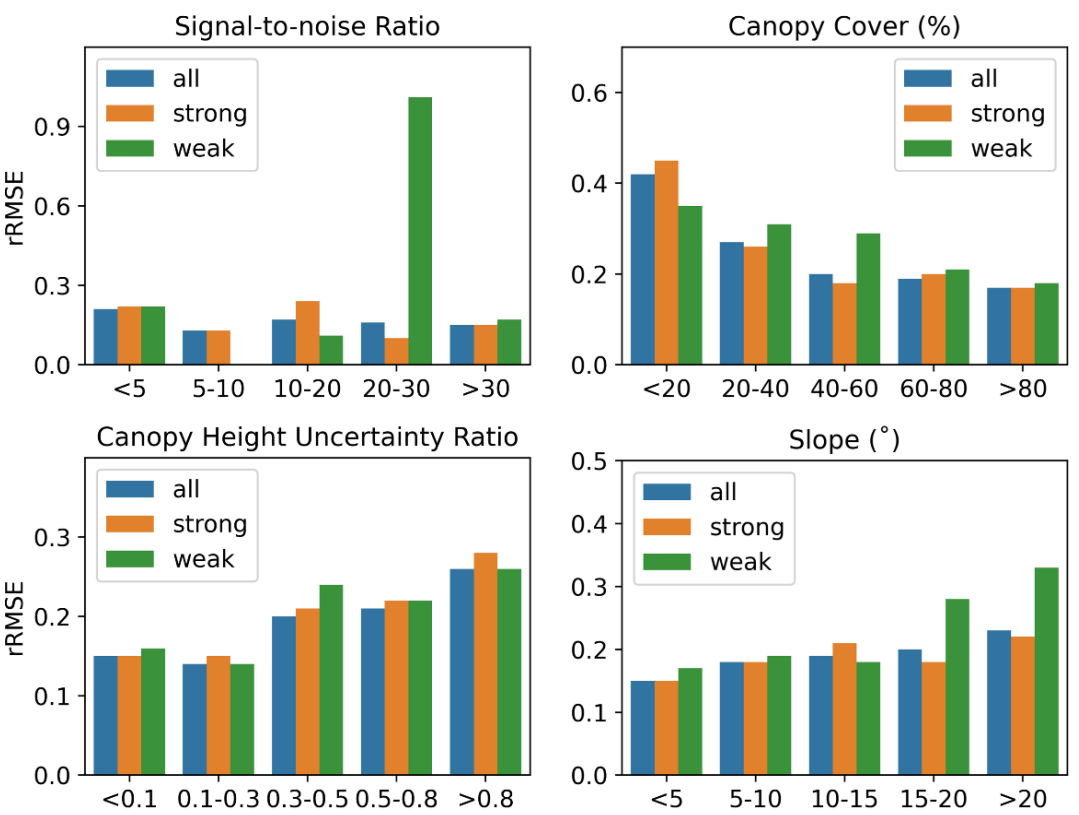

EVALUATION OF ICESAT-2 UNDER DIFFERENT SCENARIOS

ALS-derived canopy height metrics* vs ICESat-2 *Hcanopy*

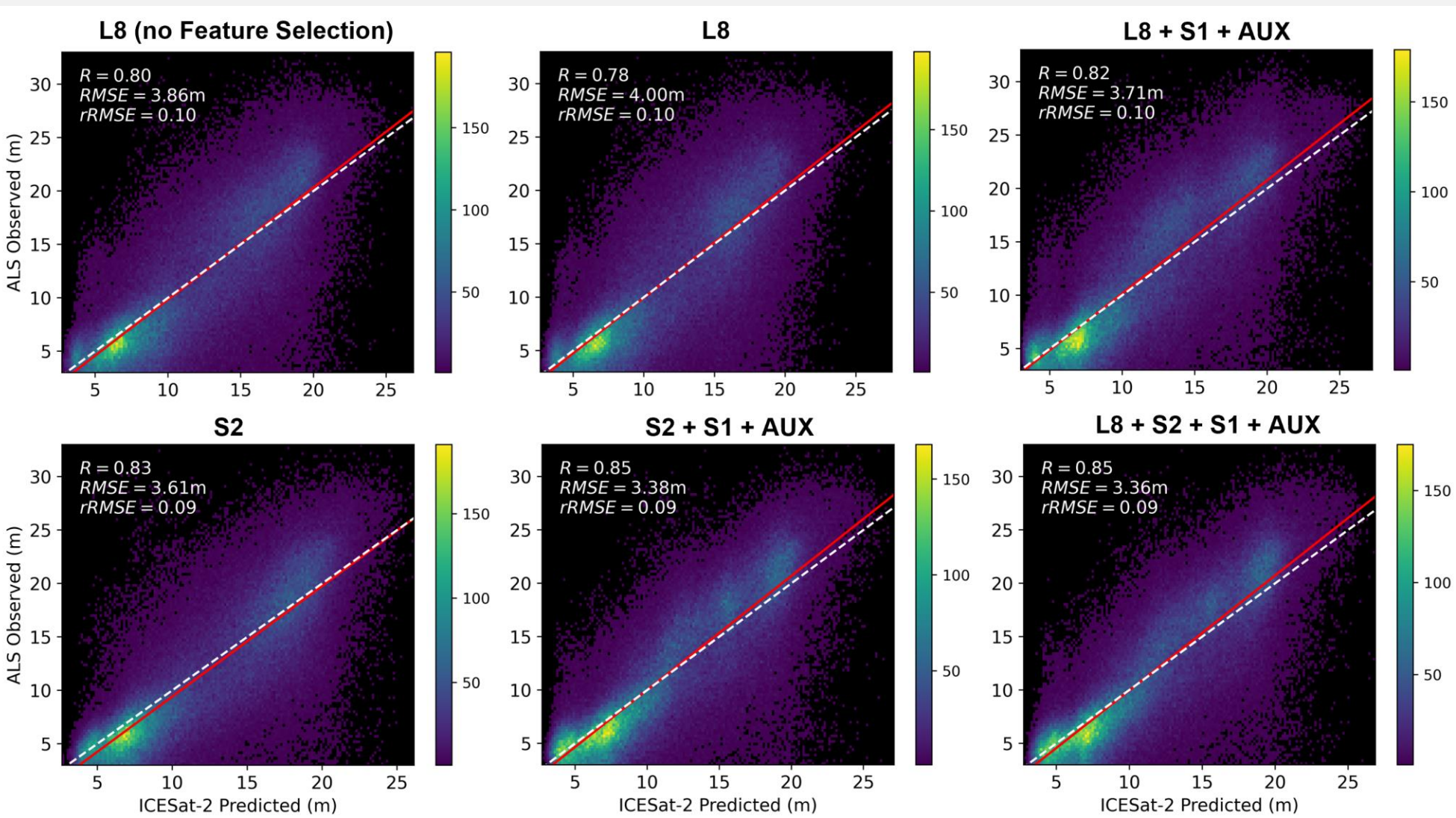| ALS	All Beams rRMSE	All Beams R	Strong Beams rRMSE	Strong Beams R	Weak Beams rRMSE	Weak Beams R
CHmean	0.42	0.60	0.43	0.64	0.42	0.51
RH50	0.39	0.53	0.39	0.57	0.40	0.45
RH75	0.25	0.64	0.26	0.69	0.27	0.55
RH90	0.18	0.69	0.17	0.73	0.20	0.60
RH95	0.16	0.70	0.15	0.74	0.18	0.61
RH98	0.16	0.70	0.14	0.75	0.19	0.61
RH100	0.20	0.68	0.19	0.73	0.23	0.60

*We locally aggregated the 1m ALS observations to 30m that matches L8's spatial resolution and then computed the percentile canopy heights (listed in the table) from the ALS point clouds within each 30×30m local grid.
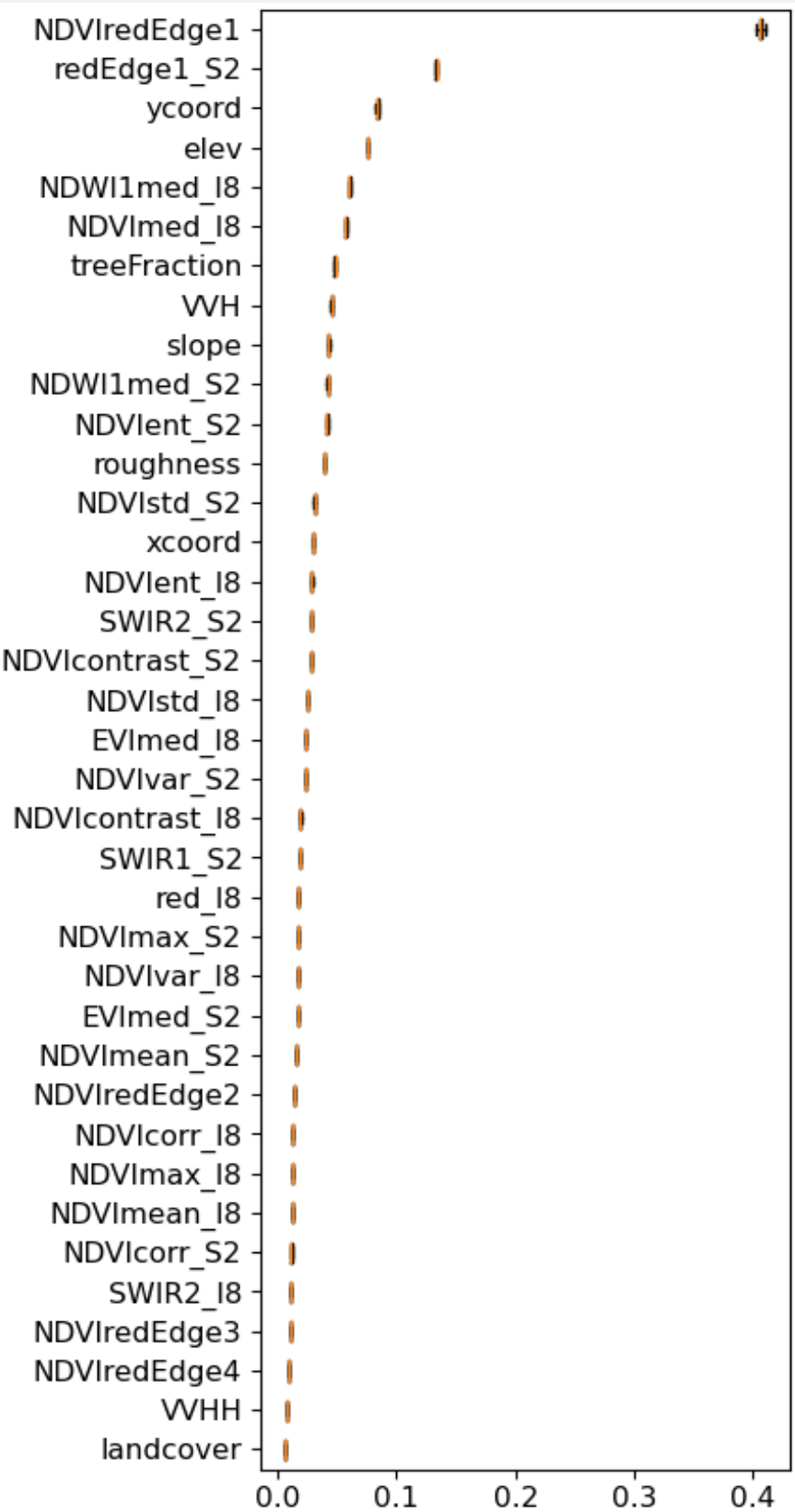

VERTICAL ACCURACY OF ICESAT-2 BEFORE/AFTER QUALITY CONTROL

CANOPY HEIGHT MODELS DEVELOPED BY DIFFERENT FEATURES

FEATURE IMPORTANCE

MAIN FINDINGS

1) The vertical accuracy of ICESat-2 observed canopy heights can be effectively improved with an appropriate quality control regardless of the beam strength.
2) Sentinel-2 derived features achieve better performance than Landsat-8 derived in modelling regional-scale forest heights.
3) NDVI generated from the first red edge band of Sentinel-2 is found the most significant feature in boreal forest height mapping while land cover appears the least important.

REFERENCES

1) Abdalati, et al., 2010. The ICESat-2 Laser Altimetry Mission. Proc. IEEE 98, 735–751.
2) Li, et al., 2020. Developing a method to estimate building height from Sentinel-1 data. Remote Sens. Environ. 240, 111705.
3) Neuenschwander, et al., 2020. Validation of ICESat-2 terrain and canopy heights in boreal forests. Remote Sens. Environ. 251, 112110.
4) Neuenschwander and Pitts, 2019. The ATL08 land and vegetation product for the ICESat-2 Mission. Remote Sens. Environ. 221, 247–259.

ACKNOWLEDGEMENT