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| **Nationwide estimation of boreal forest above-ground biomass using ICESat-2 data** |
| **Aim:**  ICESat-2 (I2) remains as the only spaceborne lidar sensor that can collect forest resource information from the boreal zone above 52° N. Our objective was to train nationwide I2 models for estimation of above-ground biomass (AGB) and its uncertainty for the boreal forests of Finland. The estimates are validated regionally and against official statistics from the Finnish National Forest Inventory (NFI).  **Materials and methods:**  The nationwide I2 model was trained using data from six practical forest inventory projects implemented in 2021. The inventory projects were evenly spread throughout Finland, and each included its own field measurements (236-923 plots per site) and airborne laser scanning (ALS) data acquisition. A separate ALS proxy AGB model was trained for each project and applied to predict AGBs for 15 x 90 m I2 track segments that overlapped with the project area. The final I2 model was trained using a pooled data set of 9491 segments from the different projects. The I2 segments included both day and night observations but were required to have at least 100 classified photons and >60% high-quality photons. Segments with snow or cloud cover were removed.  The I2 model was applied to all forested I2 segments (n = 288391) obtained from Finland in 2021. The forest area was determined using a mask layer provided by the Finnish Forest Centre and covered a total of 267510 km2. The nationwide total AGB and its uncertainty were estimated using a hybrid approach that only used the sample of overlapping I2 tracks, i.e. no wall-to-wall mapping was done. The uncertainty estimates included error contributions from the allometric tree biomass models, the regional proxy models, the nationwide I2 model, and the I2 track sampling.  Six additional inventory projects were used as test sites, where the segment-level predictions from the nationwide I2 model were validated against local ALS proxy models. In the nationwide level, the estimated biomass total was compared with an official NFI statistic obtained from field sampling.  **Results and conclusion:**  The nationwide I2 model for AGB had an RMSE = 45% in the pooled segment-level training data, and 37%–82% when it was validated at the six test sites. The total AGB estimated for Finland was 1229.7±144.5 million tons, while the reference value from NFI was 1308 million tons. Thus, the reference value was within the 95% confidence interval of our estimate. The slight underestimation may have been influenced by quality issues observed in ATL08 product, where canopy signal can sometimes be classified as noise. Nevertheless, our results show that ICESat-2 can provide reasonably accurate AGB estimates for large areas. |