Accuracy of DESDynl Biomass Estimates using LiDAR and Data Fusion Methods

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Summary

DESDynl (Deformation, Ecosystem Structure and Dynamics of Ice) is a NASA satellite mission that will provide global estimates of aboveground biomass using LiDAR (Light Detection and Ranging) and L-band radar. LiDAR waveforms and radar backscatter coefficients at different wave polarizations are sensitive to forest height, structure, and composition, and can be used to make quantitative estimates of standing biomass and carbon stocks. Accuracy requirements for the DESDynl biomass product are 20 Mg ha\(^{-1}\) or 20% (errors not to exceed 50 Mg ha\(^{-1}\)), at a spatial resolution of 250 m globally at end of mission, and 100 m for areas of low biomass annually (< 100 Mg ha\(^{-1}\)).

A NASA field campaign was conducted in New England, USA, during 2009 to quantify sources of errors associated with biomass estimates. Coincident data from DESDynl airborne simulators (Laser Vegetation Imaging Sensor, LVIS; Uninhabited Aerial Vehicle Synthetic Aperture Radar, UAVSAR) and ground-based forest inventory measurements provided data needed to quantify model uncertainty and measurement errors.

To compute sampling errors, DESDynl orbits and cloud cover was simulated and used to subsample wall-to-wall LiDAR data. Model uncertainty and measurement errors for LiDAR-derived biomass were less than radar, but the gridded estimates of LiDAR biomass also included a sampling error that was greater than model uncertainty and measurement errors. Radar estimates are important for filling gaps in LiDAR sampling, and a “fused” data product will have greater accuracy, primarily in areas of low biomass.

Data Sources and Error Analysis

Methods

Study Sites and Ground Measurements:

Set up field plots at main study site (48.84N, -68.61W) in southern Maine used in this study. Preliminary data from 3 years (2009-2011) of research were used to establish baseline conditions.

Airborne LiDAR and radar simulators

DESDynl LiDAR Orbital Simulation

- 3 to 5 year mission life
- 25m beam and 30 m along-track spacing
- 5 parallel beams with 1 km spacing

Cloud Cover Scenarios

Cumulus Cloud Cover*
- 50% cloud cover every day
- 1.5 km length scale, randomly distributed

100% Cloud Cover*
- 100% cloud cover every day
- Accelerated retrieval

Results from a Case Study in Maine, USA

Model Uncertainty and Measurement Errors

- The height at which 75% of the LiDAR energy was returned (RH\(_{75}\)) was linearly related to biomass at all levels.
- Radar was most sensitive to biomass < 100 Mg ha\(^{-1}\), and measurement errors were greater than LiDAR (77 and 53 Mg ha\(^{-1}\), respectively).

LiDAR Sampling Errors

- MCMC analysis of model uncertainty indicated that DESDynl estimates can be achieved with these simple models, but footprint-scale estimates require averaging to reduce individual measurement errors (see above).

Error Summary and Conclusions

- LiDAR measurement errors are general less than radar, but are more comparable in areas of low biomass density.
- Sampling error due to incomplete coverage and cloud obscuration contributes to the total error of LiDAR measurements, but not radar.
- Radar estimates can be used to estimate areas of low biomass at a fine spatial scales (1 ha), and may be adequate for filling gaps in LiDAR sampling.

Error Summary

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Grid cell</th>
<th>RMSE (Mg ha(^{-1}))</th>
<th>Percentage</th>
<th>Sampling</th>
<th>SE(_{rad}) × 1.65</th>
</tr>
</thead>
<tbody>
<tr>
<td>LiDAR</td>
<td>no clouds</td>
<td>250 49 53 17 13</td>
<td>50% observed</td>
<td>Radar</td>
<td>≤150 Mg ha(^{-1})</td>
</tr>
<tr>
<td></td>
<td>250 53 13 19</td>
<td></td>
<td></td>
<td></td>
<td>250/100 16 48 0 20</td>
</tr>
<tr>
<td></td>
<td>≥150 Mg ha(^{-1})</td>
<td></td>
<td></td>
<td></td>
<td>250/100 100 0 17</td>
</tr>
</tbody>
</table>

* Each scenario removes 50% of LiDAR samples

Wall-to-Wall LiDAR LiDAR Simulation

- “Wall-to-Wall” Biomass
- Biomass was estimated for simulated DESDynl tracks and compared with “wall-to-wall” estimates to estimate a sampling error of 17 Mg ha\(^{-1}\).