# Accuracy of DESDynI Biomass Estimates using LiDAR and Data Fusion Methods

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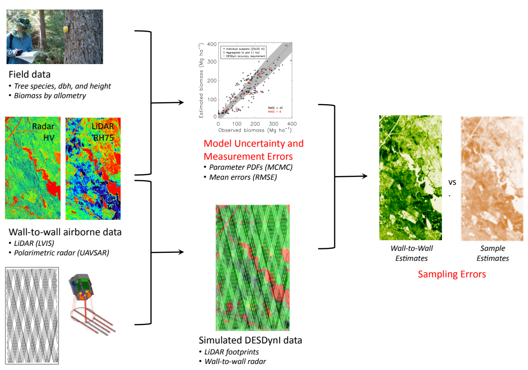
## Summary

**DESDynI (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 DESDynI 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 DESDynI 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, DESDynI orbits and cloud cover was simulated and used to subsample wall-to-wall LVIS 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




$$\text{LiDAR } SE_{Total} = (MSE_{Measurement} + MSE_{Sampling})^{1/2} / \sqrt{n}$$

$$\text{Radar } SE_{Total} = (MSE_{Measurement})^{1/2} / \sqrt{n}$$

## Instrument and Data Links

Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI)
http://desdyni.jpl.nasa.gov/

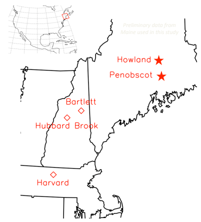
Laser Vegetation Imaging Sensor (LVIS)
https://lvis.gsfc.nasa.gov

Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR)
https://lvis.gsfc.nasa.gov

North American Carbon Program (search for campaign data under "DESDynI")
http://www.nacarbon.org

## Methods

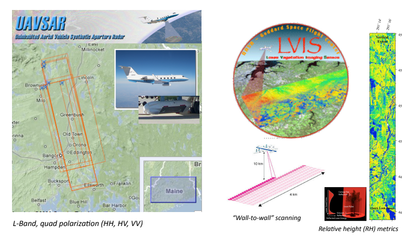
### Study Sites and Ground Measurements:




Participants: NASA GSFC/JPL, Univ. of Maryland, Univ. of Michigan, Univ. of Maine, Boston Univ., CUNY, Harvard Univ., UCLA, and others.

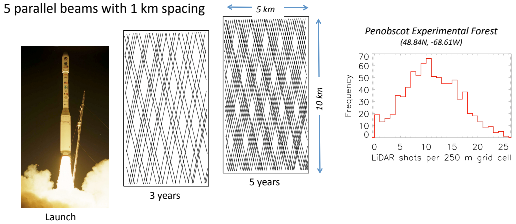
Filed measurements included tree species, DBH, and height in 1 ha plots (subdivided into 16 @ 25 m subplots).

### Airborne LiDAR and radar simulators




### DESDynI LiDAR Orbital Simulation

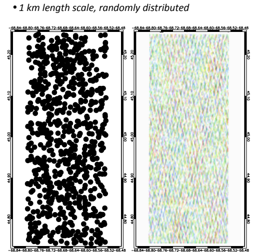
- 3 to 5 year mission life
- 25m beam and 30 m along-track spacing
- 5 parallel beams with 1 km spacing




### Cloud Cover Scenarios

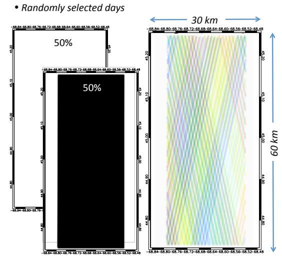
**Cumulus Cloud Cover***

- *50% cloud cover every day*
- *1 km length scale, randomly distributed*



**100% Cloud Cover***

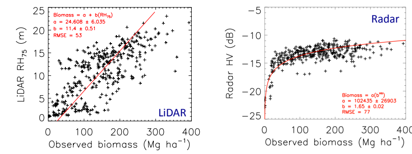
- *100% clear or cloudy sky*
- *Randomly selected days*



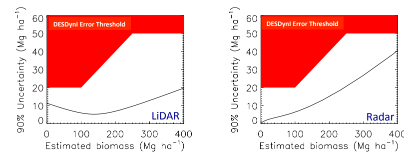

** Each scenario removes 50% of LiDAR samples*

## Results from a Case Study in Maine, USA

### Model Uncertainty and Measurement Errors

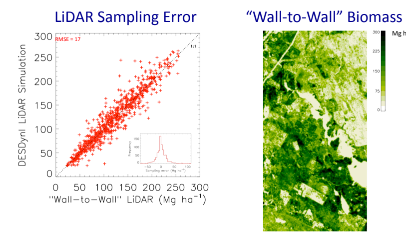



- The height at which 75% of the LiDAR energy was returned ($RH_{75}$) was linearly related to biomass at all levels.
- Radar was most sensitive to biomass <100 Mg $ha^{-1}$, and measurement errors were greater than LiDAR (77 and 53 Mg $ha^{-1}$, respectively).




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

### LiDAR Sampling Errors




- Biomass was estimated for simulated DESDynI tracks and compared with "wall-to-wall" estimates to estimate a sampling error of 17 Mg $ha^{-1}$.

### Error Summary and Conclusions

| | Grid cell | | RMSE (Mg $ha^{-1}$) | | |
|---|---|---|---|---|---|
| Instrument | Res, m | n | Measure | Sampling | $SE_{Tot} \times 1.65$ |
| LiDAR | | | | | |
| *no clouds* | 250 | 49 | 53 | 17 | 13 |
| *50% obscured* | 250 | 25 | 53 | 17 | 19 |
| Radar | | | | | |
| *≤150 Mg $ha^{-1}$* | 100 | 16 | 48 | 0 | 20 |
| *>150 Mg $ha^{-1}$* | 250100 | 100 | 0 | 17 | |

- 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.