Measuring and Monitoring Leaf Area Index and Foliage Profile Using Three-dimensional Forest Reconstructions Assembled from Ground-Based Full-Waveform Lidar Scans

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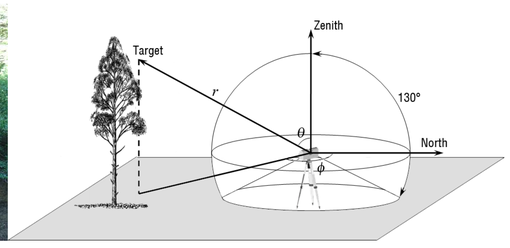
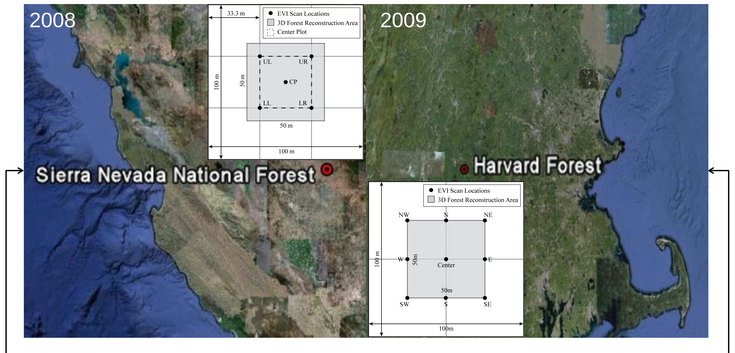
❖ Overview

Voxelization of 3-D point clouds of scattering events identified by full-waveform, ground-based lidar scans of conifer and broadleaf forests provides a new technique to measure the vertical and horizontal distribution of leaf area and woody biomass in a forest stand. The lidar scanner, the Echidna® Validation Instrument (developed by Australia's CSIRO), allows differentiation of trunk and leaf scattering events, which is of interest to both land biogeoscientists who require bulk vegetation biomass measures and to atmospheric biogeoscientists, who require information on surface roughness, photosynthesis, and respiration processes. Comparisons of voxelized 3-D reconstructions through time can be used to document forest change, including both growth and disturbance. The voxelized reconstructions also provide a pathway for calibration and validation of airborne and spaceborne methods of forest structure retrieval.



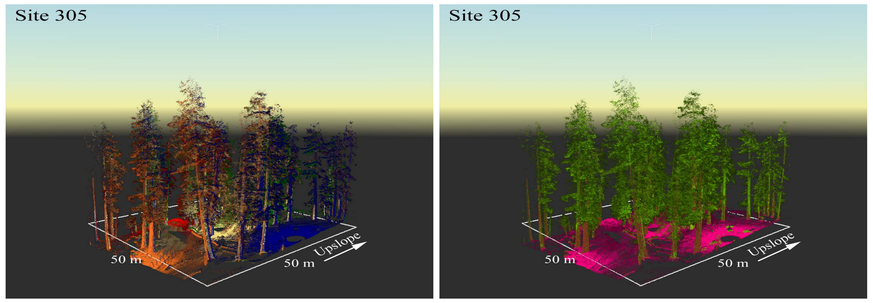
❖ Site Characteristics



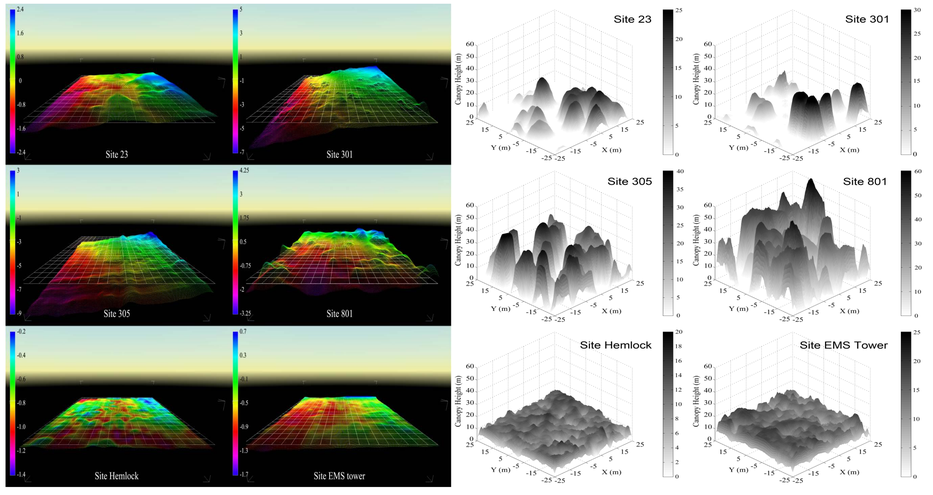
Site ID	Leading dominants	Top canopy height[1] (m)	Mean DBH (m)	Stem count density[2] (ha–1)	Leaf Area Index[3] (m^2/m^2)	Above-ground biomass[4] (t ha–1)
23	Jeffery pine	29.2	0.41±0.02	110±29	0.65 ± 0.24	115±64
301	Red fir	25.3	0.37±0.02	231±64	0.58± 0.14	361±60
305	Red fir	45.2	0.58±0.02	284±40	2.03 ± 0.50	1215±150
801	Sequoia, red fir	61.8	0.87±0.09	156±12	2.42 ± 0.47	2664±250
Hemlock	Hemlock	22.6	0.24±002	906±71	4.32 ± 0.27	234±7
EMS Tower	Red maple, red oak	26.4	0.28±0.02	951±69	3.71 ± 0.11	373±36

[1]Mean height of 5 tallest trees in the field measurements at each site. [2]For standard errors, *n* = 5 subplots for the Sierra sites ; *n* = 9 for the New England forest sites. [3]From LAI-2000 measurements. [4]Calculated based on the allometric equations described in Jenkins *et al*. (2004).

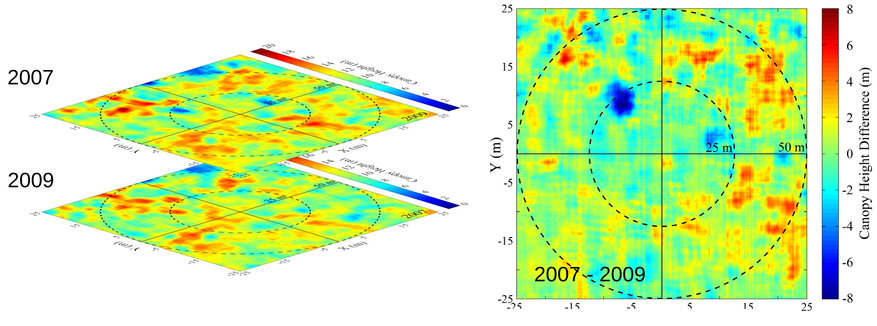
❖ Three-dimensional Forest Reconstruction



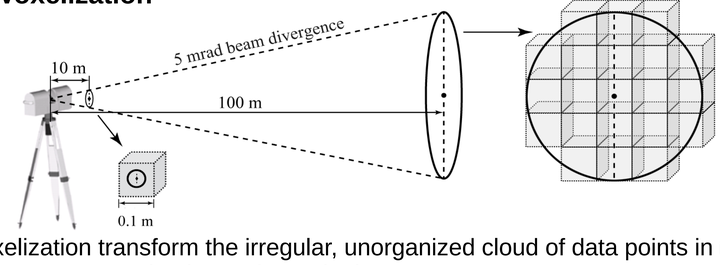
❖ Digital Terrain Model & Canopy Height Model



❖ Change in Canopy Height Due to 2008 Ice Storm (Hemlock site)



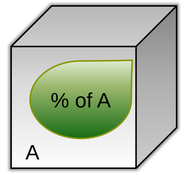
❖ Voxelization



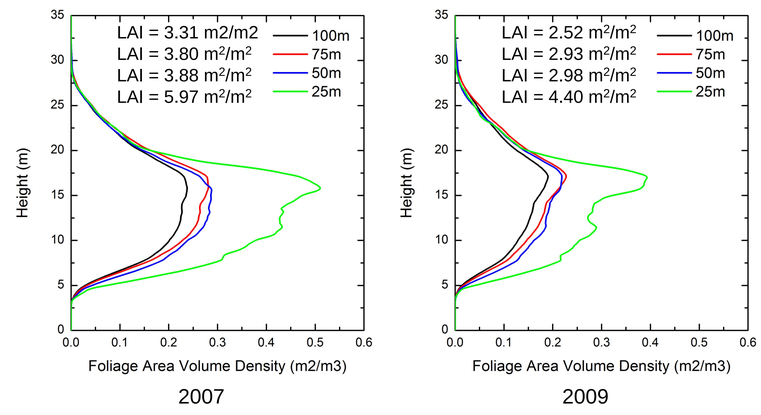
Voxelization transform the irregular, unorganized cloud of data points in the 3-D forest reconstruction into volumetric datasets

❖ Leaf area index and foliage area volume density

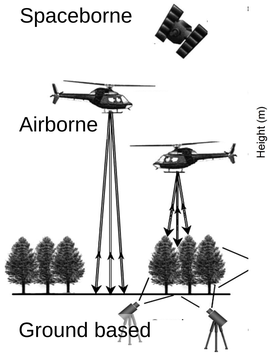
- Assumption
  - $\max[\rho_{app}(r)_w]$ represents a voxel with cross sectional area fully occupied by leaves of branchlets
- Leaf area of a voxel
  - $LA(x',y',z') = \frac{1}{G(\theta)} \cdot A \cdot \frac{\rho_{app}(x',y',z')_w}{\max[\rho_{app}(r)_w]}$
- Foliage area volume density profile
  - $f(z) = \frac{\sum_{x',y'} LA(x',y',z')_{z'=dz}}{S \cdot dz}$
  - $LAI = \int_{z=0}^{z_{max}} f(z)\, dz = \frac{\sum_{x',y',z'} LA(x',y',z')}{S}$



❖ Foliage Area Volume Density (Hemlock site)



❖ Terrestrial (EVI) vs. Airborne (LVIS) Lidar (Hemlock site)



Diameter	LVIS shots No.
25 m	1
50 m	8
75 m	16
100 m	26