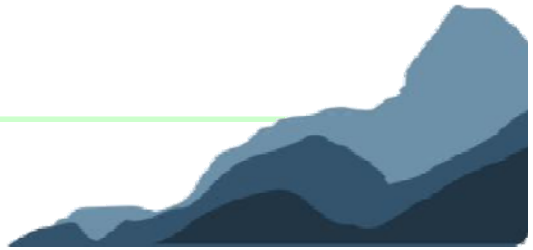
SNAMP Spatial Team

California Cooperative Snow Surveys Program

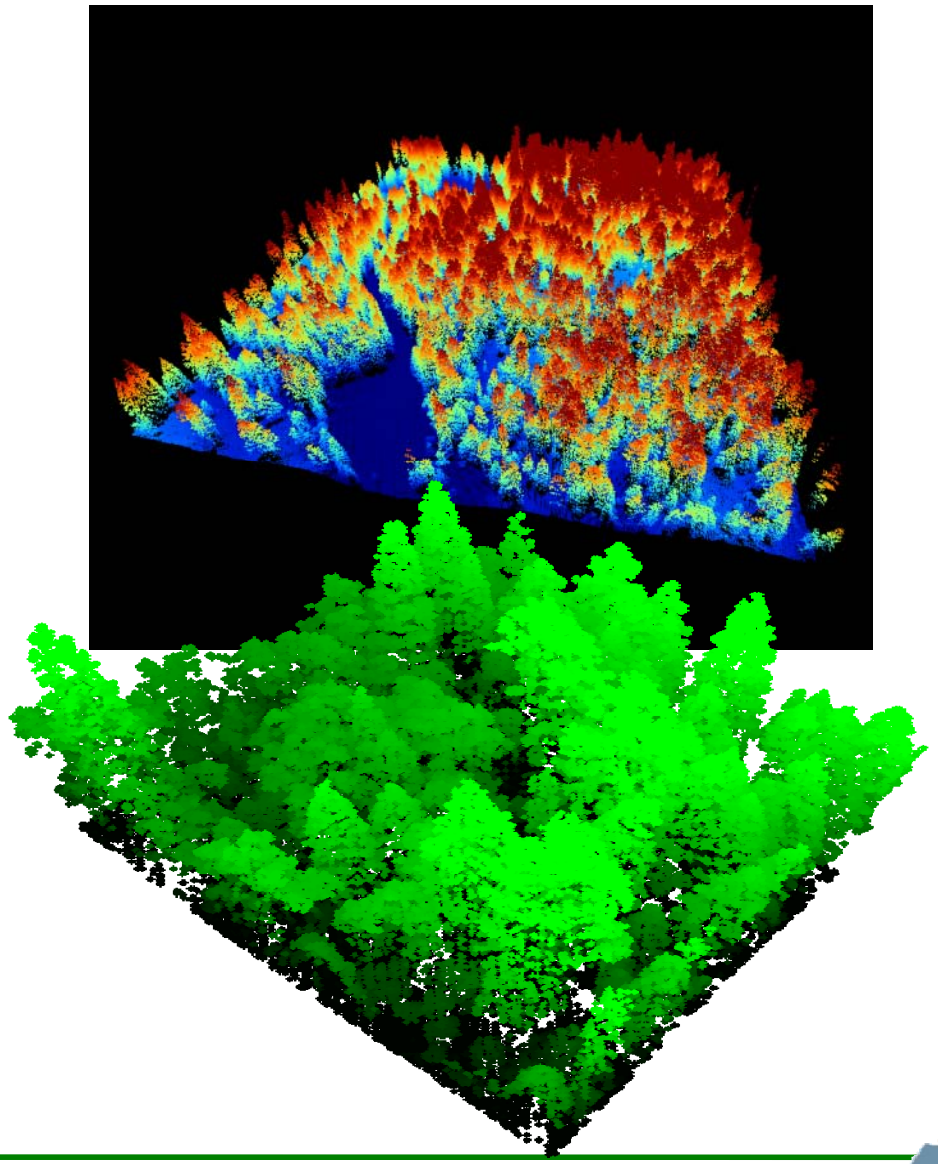
Jacob Flanagan

UC Merced



Overview

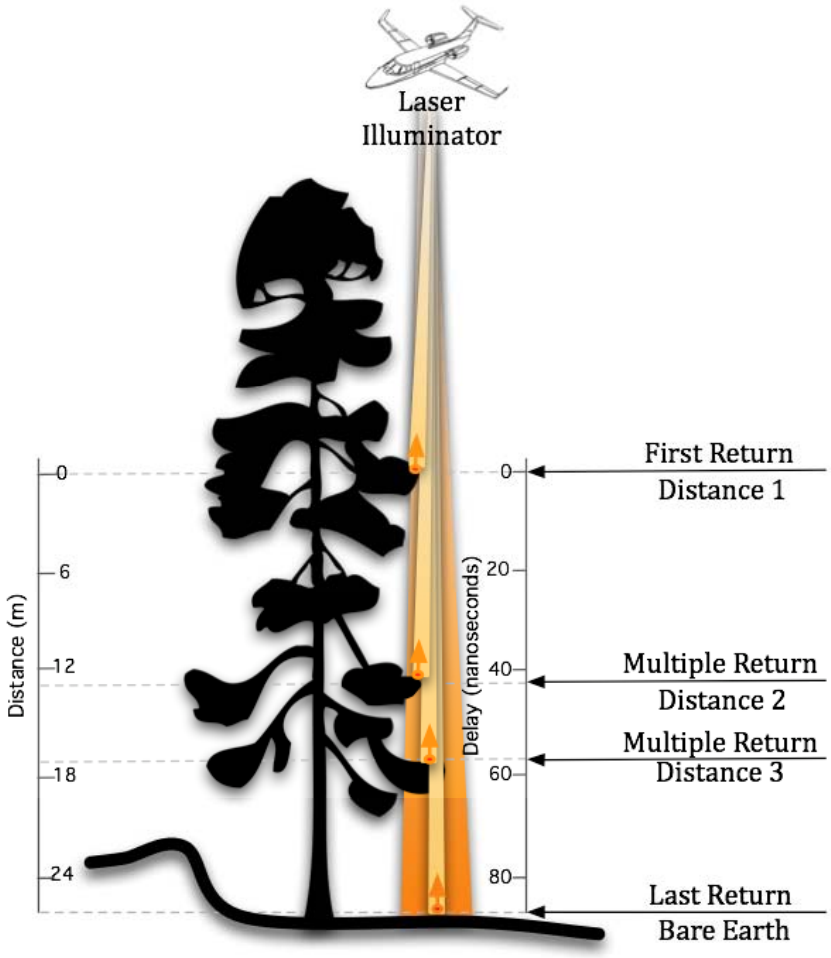
- Lidar (Light Detection and ranging)
  - Remote sensing tool
  - Measures distance to a remote object
  - Other properties
    - Intensity
    - …
- Format
  - Point Cloud

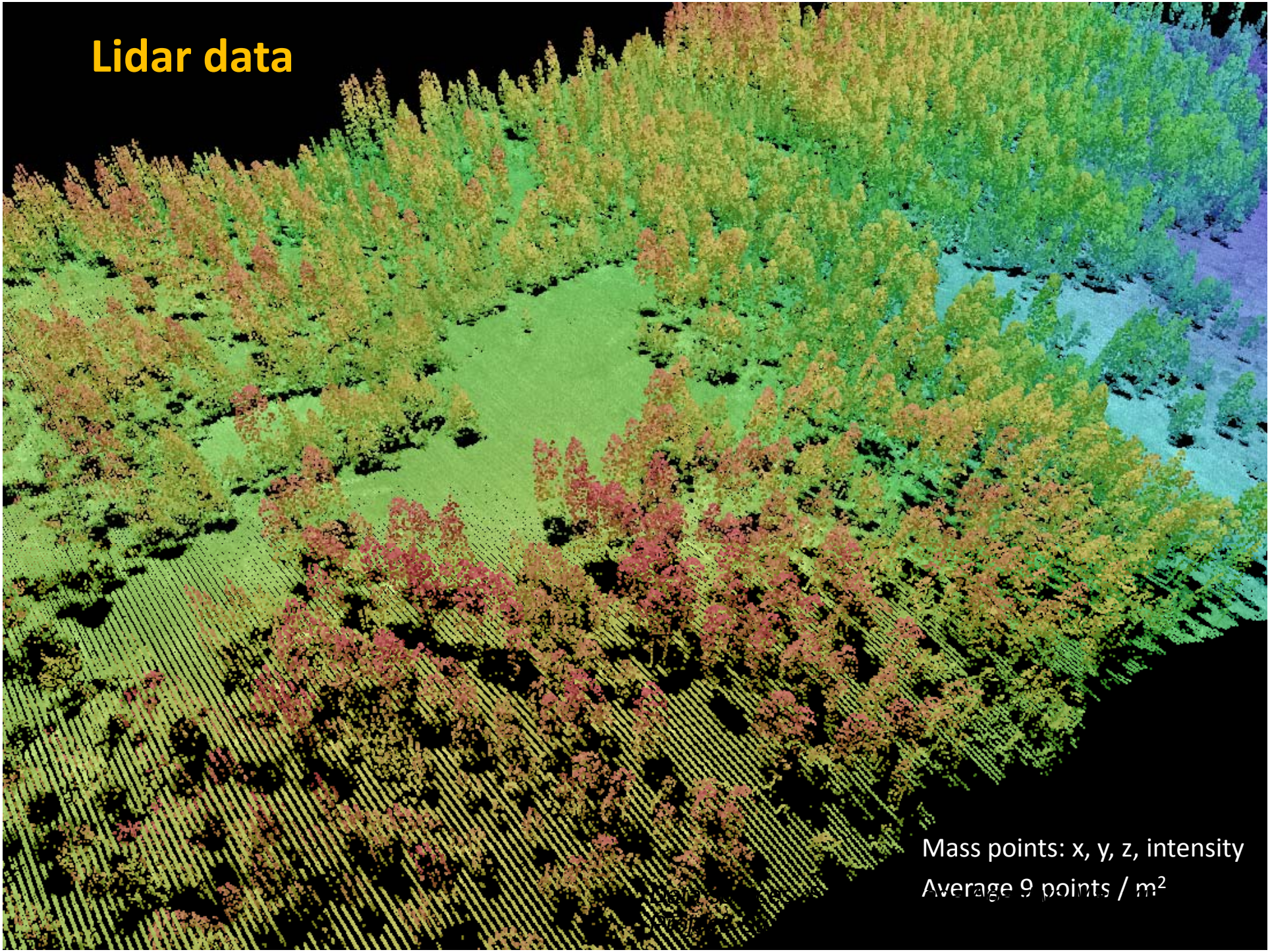


Lidar Collection

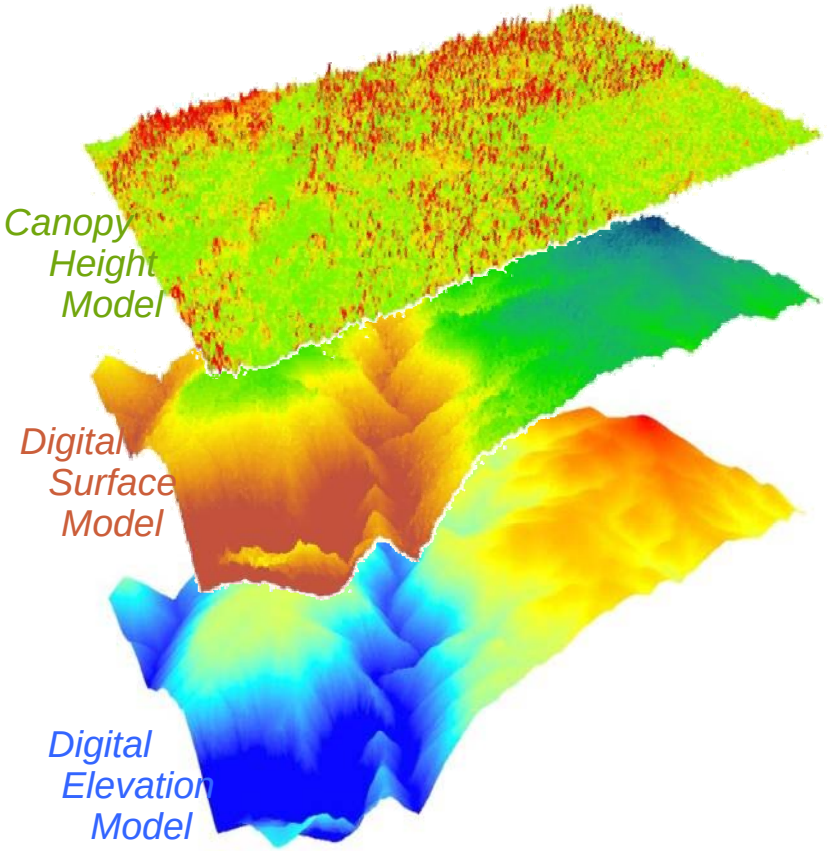
- **Range**. The measurement of the speed which a pulse of light returns to a sensor is converted to elevation above sea level.

- R = ½(*tc*)
  - R = range
  - *t* = time
  - *c* = speed of light




Lidar data
Mass points: x, y, z, intensity
Average 9 points / m²

Lidar Products

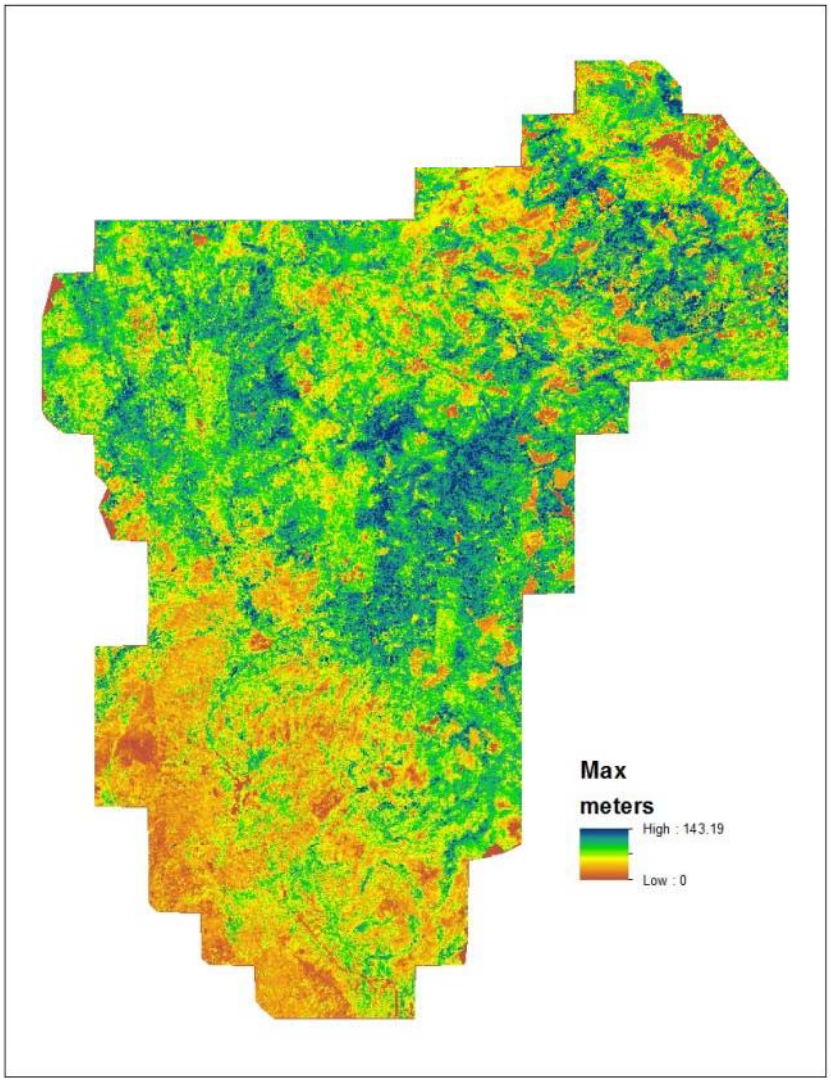


- Lidar Classification
  - Ground Points
- Common Lidar Products
  - DEM (Digital Elevation Model)
  - DSM (Digital Surface Model)
  - CHM (Canopy Height Model)
- Vegetation Products
  - Vegetation Metrics

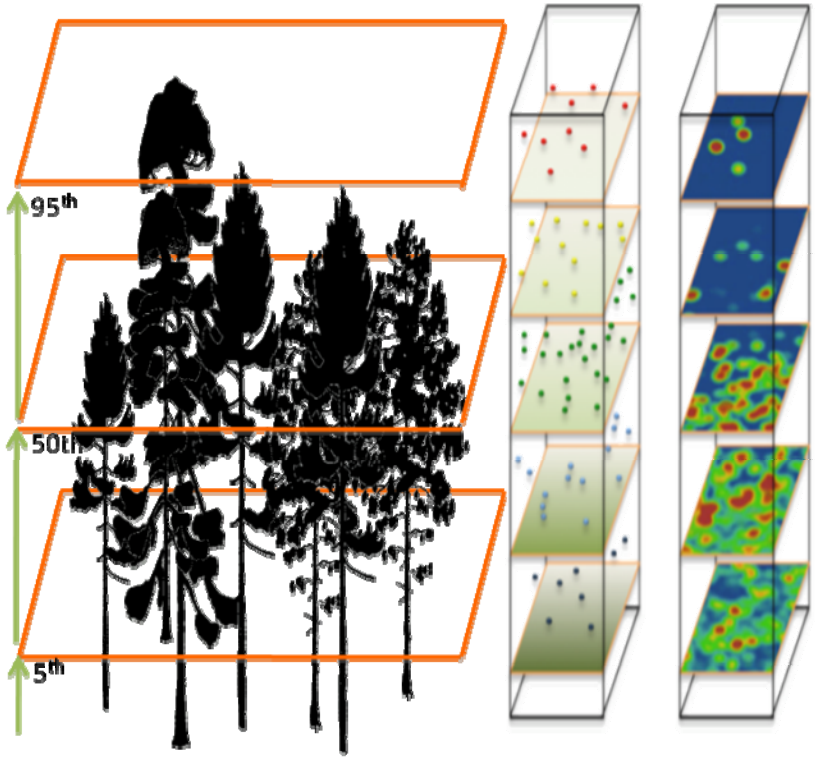
Vegetation Products

- Vegetation Products
  - Mean Height
  - Max Height
  - Diameter at Breast Height
  - Canopy Base Height
  - LAI

- Regression Analysis with Ground truth data in conjunction with Lidar



Plot Analysis



- Ground Truth Collected
  - Relation made with Lidar data
- Height Profiling
  - Lidar cut to match plot
  - 1^{st}, 5^{th}, 10^{th}, 20^{th}, …, 80^{th}, 90^{th}, 99^{th}, max, std, cv
- Regression analysis
  - Correlation between ground truth and lidar

		In Model Equation
DBH	**Model**	$20.5238+0.66002*X_{75\%}+0.356*X_{90\%}$
	R^2	0.68
Mean Height	**Model**	$5.3081+0.49125*X_{75\%}+0.678*X_{std}$
	R^2	0.76
Max Height	**Model**	$=10.9962+0.66002*X_{80\%}+0.72078*X_{99\%}$
	R^2	0.81

FFEH/Spatial Teams

SUGAR PINE

Preliminary Vegetation Map
(raster version)

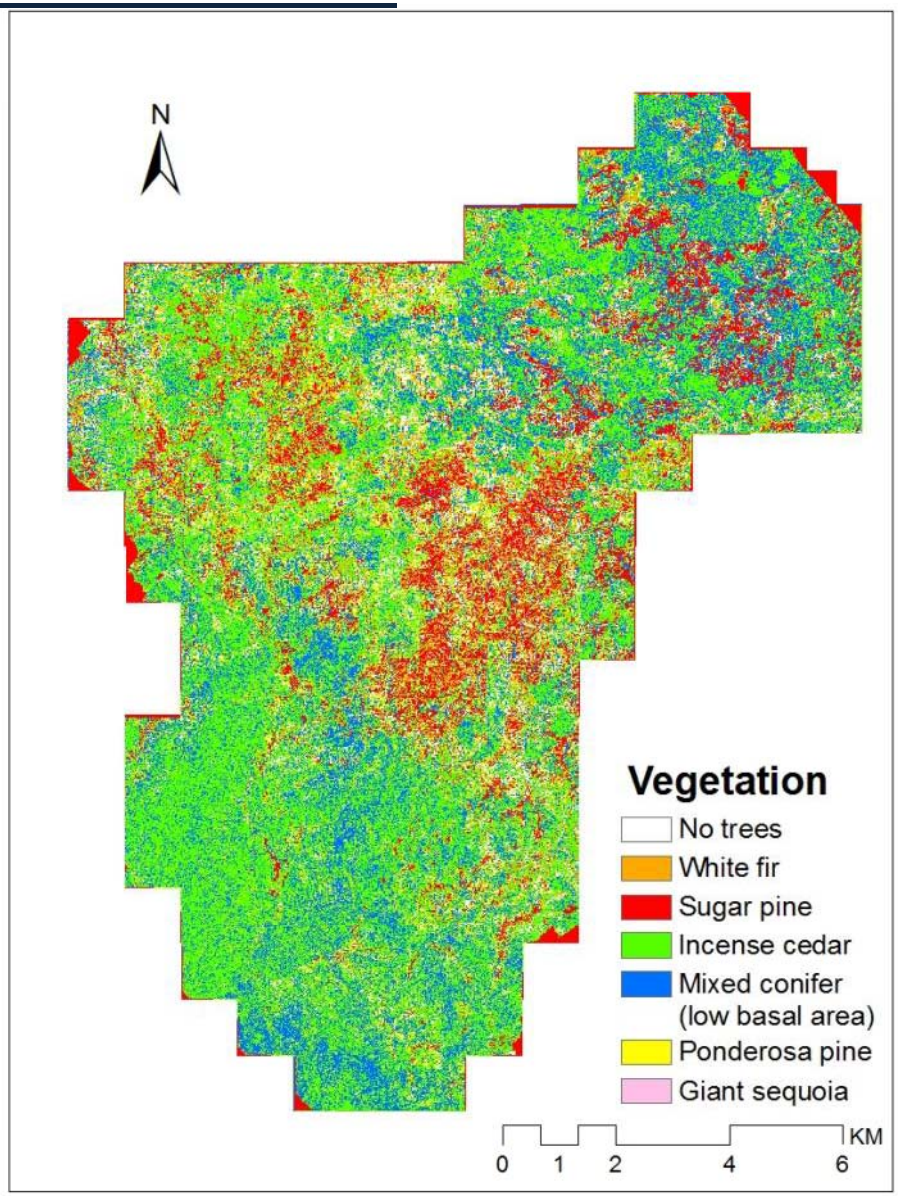
INPUTS
Remote sensing
NAIP imagery (color)
Lidar (structure)

Plot network
Clustering from field data

TRAINING
"Teach " computer
based on plot grid (284 plots)

EXTRAPOLATE
Use remote imagery to produce wall-to-wall map

VALIDATE



Lidar Visualization

Photo

Simulation

Using Tree Segmentation

Key Research: Lidar and SNAMP

- *Fuel and fire models*: lidar can be used to map broad fuel classes, and many of the direct measures needed for fire behavior modeling.
- *Individual tree detection*: the point cloud can be mined to map individual trees. These data are useful in many other studies.
- *Lidar pulse density*: many of our important metrics can be mapped using 1 pulse/m^2. Individual tree work needs higher density.
- *Owl habitat*: despite small sample size, lidar can map important habitat features in the areas surrounding owl nesting trees.
- *Fisher habitat*: lidar can characterize denning trees and forest habitat in ways that optical remote sensing cannot. Still need to broaden this analysis to cover landscape.
- *Biomass*: Model using regional allometric equations and lidar- and individual tree-based metrics produced the highest adjusted R^2 and lowest RMSE.
- *Visualization*: fast and powerful tool to look at the virtual forest from a more realistic perspective than point clouds alone.

Spatial Publications

Newly Published Papers

- Li, et al. 2011 ***Segmenting Individual Trees***.... *Photogrammetric Engineering and Remote Sensing* 78(1): 75-84
- Garcia-Feced, et al. 2011. ***Characterizing California Spotted Owl nest sites***... *Journal of Forestry* 108(8): 436-443
- Blanchard, et al. 2012. ***OBIA + Downed Logs***. *Remote Sensing* 3(11): 2420-2439
- Jakubowski et al. ***Fuel models and stand structure metrics..***. In Press in *Photogrammetric Engineering and Remote Sensing*
- Zhao, et al. 2012. ***Allometric Equations and Biomass***… *Agriculture and Forest Meteorology* 165: 64–72
- Zhao, et al. 2012. ***Fisher denning trees and forest structure***... *Forest Ecology and Management* 280: 112–119

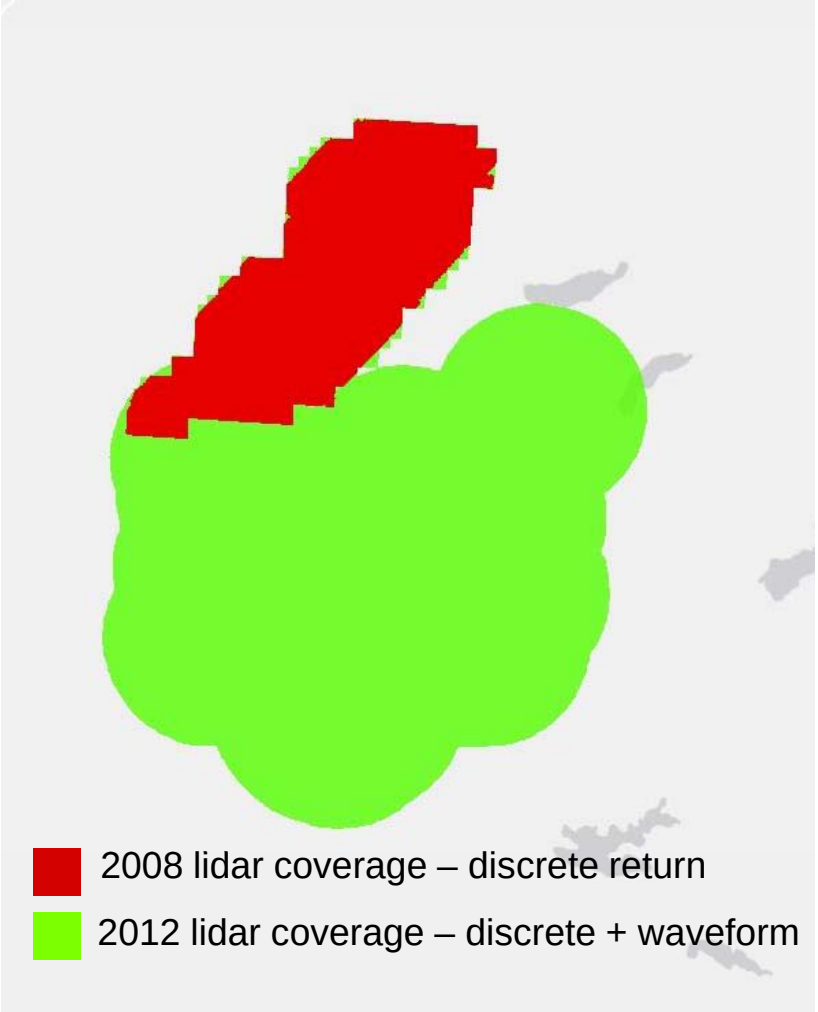
Publications in Review

- Jakubowski, et al. Tradeoffs between lidar pulse density and forest measurement accuracy. Submitted to *Remote Sensing of Environment*

Research Priorities for Coming Year

- NEW LIDAR ANALYSIS!
  - Change products
  - Waveform data

- CONTINUING WORK:
  - Plot-level vegetation type mapping of both sites
  - Extend biomass results and create wall-to-wall maps of biomass estimates (with uncertainty (RMSE)).
  - Continue fisher results to include some key variables: distance to gaps, heterogeneity, etc.
  - Fisher home range characterization.

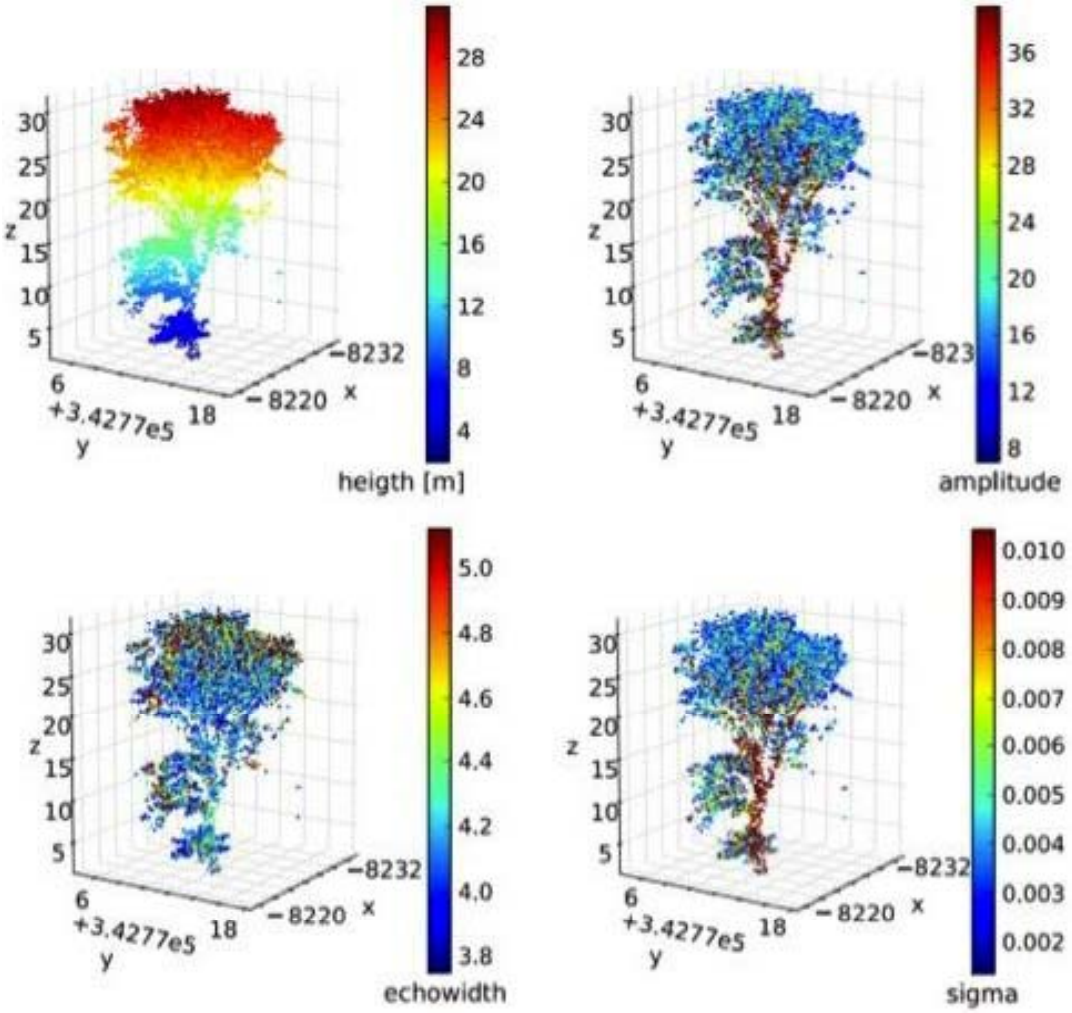


Northern site lidar footprint

Waveform targets

In addition to height, we can analyze three other characteristics of the lidar return:

1. Echo width: distribution of returns, rougher objects give larger widths
2. Amplitude: strength of reflection (reflectance and area size of target)
3. Backscatter cross-section (E x A): electromagnetic energy intercepted and reradiated by objects



Graphics from Bernhard Hoefle, University of Heidelberg

Lidar and Snow

Snow Layer

- Bare Earth DEM
- Snow DEM
- Snow Layer =

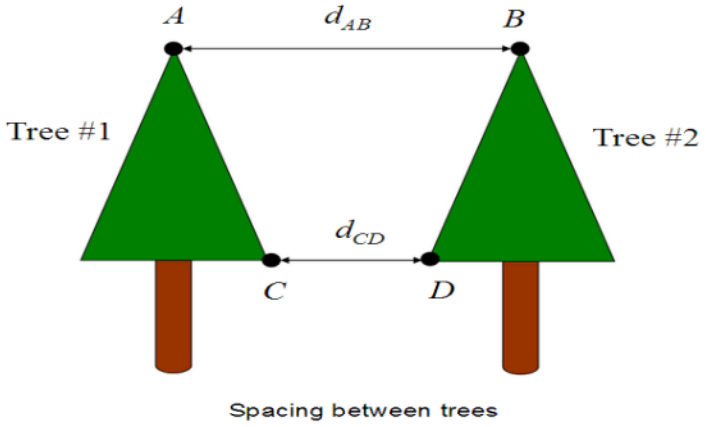
  Bare Earth DEM – Snow DEM

- Snow Layer
  - Snow Height at sample points
  - SWE calculations
  - …

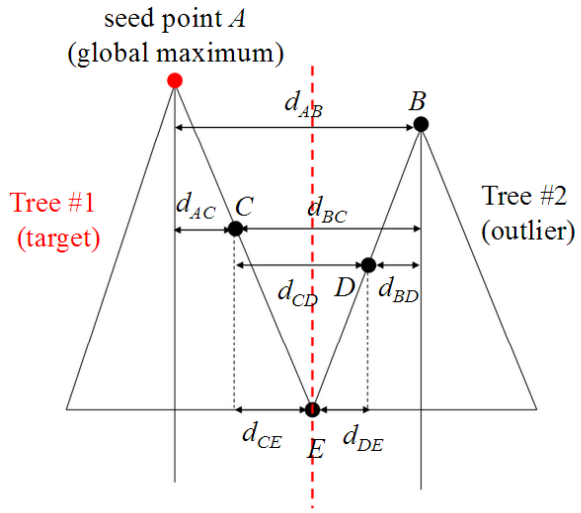
Snow Layer Issue

- Snow DEM product has little/no consideration for vegetation
  - Under tree canopy
  - Tree Wells
- Solutions
  - Vegetation grid influence
  - Consider individual trees

Tree Segmentation



Spacing between trees



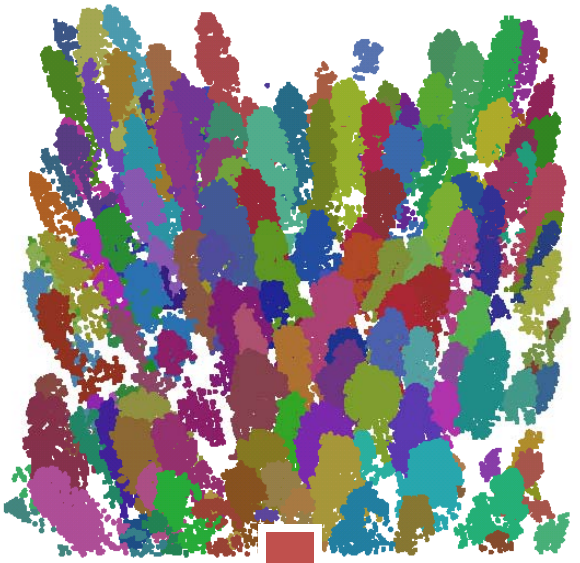
Classify the points one by one, from the highest to the lowest

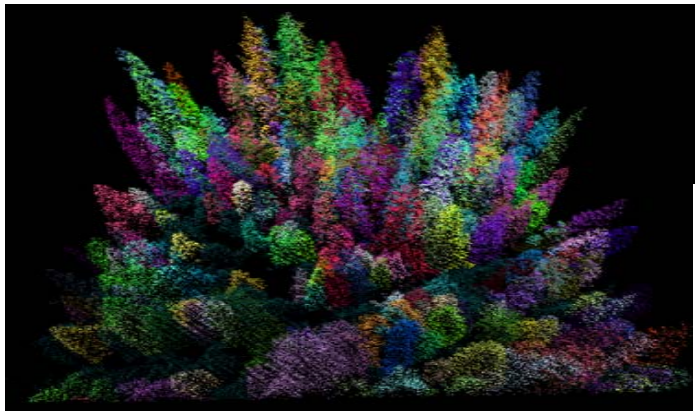
- Use Lidar point cloud to detect individual trees
- Find maximum points (tree tops)
  - Detect individual trees tops through isolated maximas
    - Distance Threshold
  - Use as seeds to categorize all points
- Categorize remaining points
  - Compare distances to already categorized points

Images courtesy of Wenkai Li

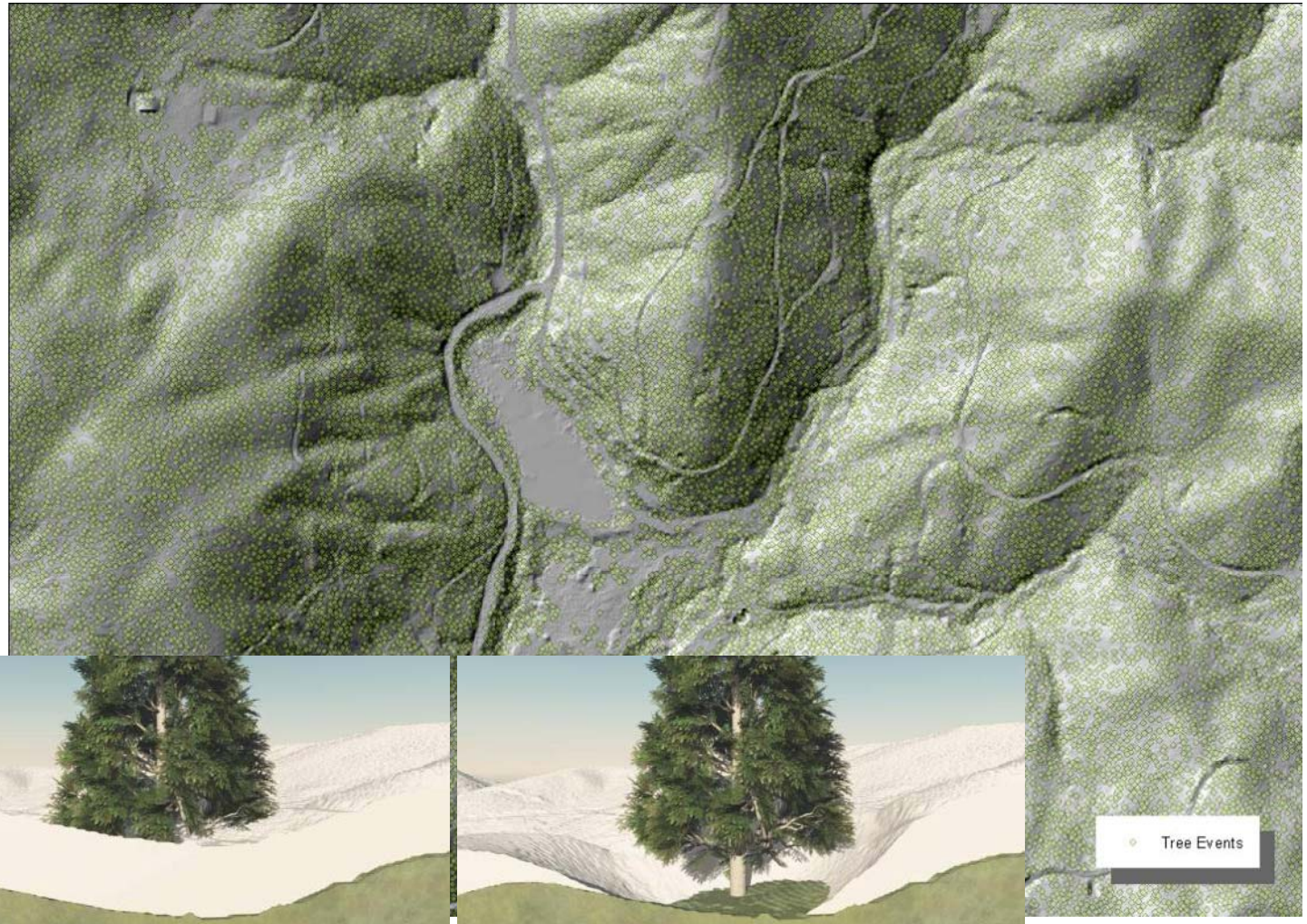
Tree Segmentation

- Individual tree extraction
- Extracted Tree Attributes
  - Tree height
  - Crown size
  - Species detection…
  - Individual tree location
  - LAI…
  - DBH





Snow Layer Correction



Spatial Team Members

UC Merced

- Qinghua Guo
- Wenkai Li*
- Hong Yu*
- Jacob Flanagan*
- Otto Alvarez **
- Lawrence Lam **

UC Berkeley

- Maggi Kelly
- Marek Jakubowski **
- Stefania Di Tommaso

Former members

- *Feng Zhao*
- *Celia Garcia-Feced* **
- *Sam Blanchard* **

* augmented with other funds

** Visitors/no cost to SNAMP