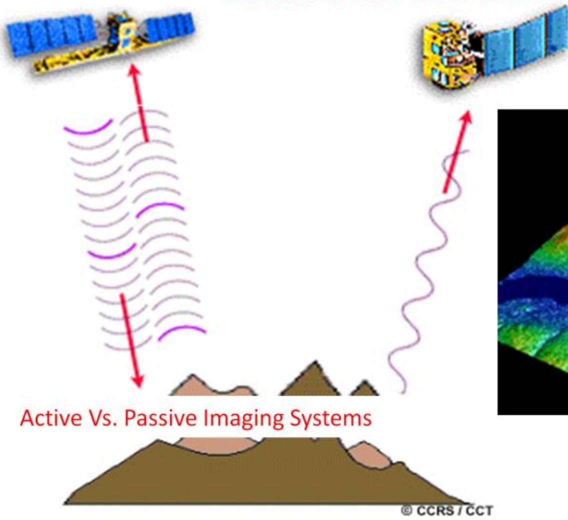
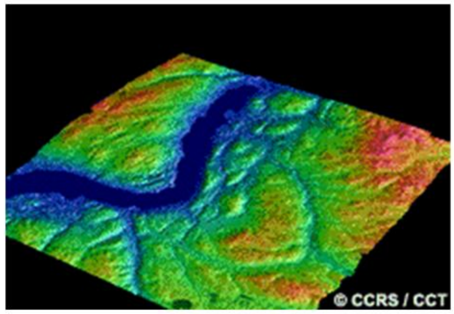
Iran's military site in Parchin

http://news.yahoo.com/photos/un-atomic-agency-suspects-iran-conducted-nuclear-warhead-photo-115115817.html

Satellite image received courtesy of the Institute for Science and International Security, shows Iran's military site in Parchin. The UN atomic agency suspects Iran has conducted nuclear warhead design experiments at its military facility in Parchin. The UN atomic agency has sought fresh thinking in its impasse with Iran after two fruitless visits probing Tehran's suspected nuclear weapons drive. (AFP Photo/)

Lecture 18: LiDAR Principles

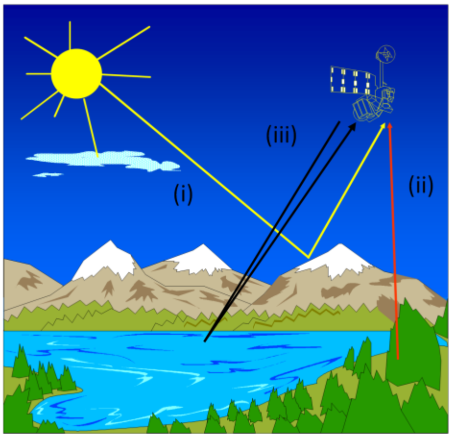




Active Sensors: LiDAR Principles Chapter 10

February 8, 2012

What is an active sensor?



Chuvieco,2002

Passive instruments

(i) Reflection

(ii) Emission

Active instruments

(iii) Emission-Reflection

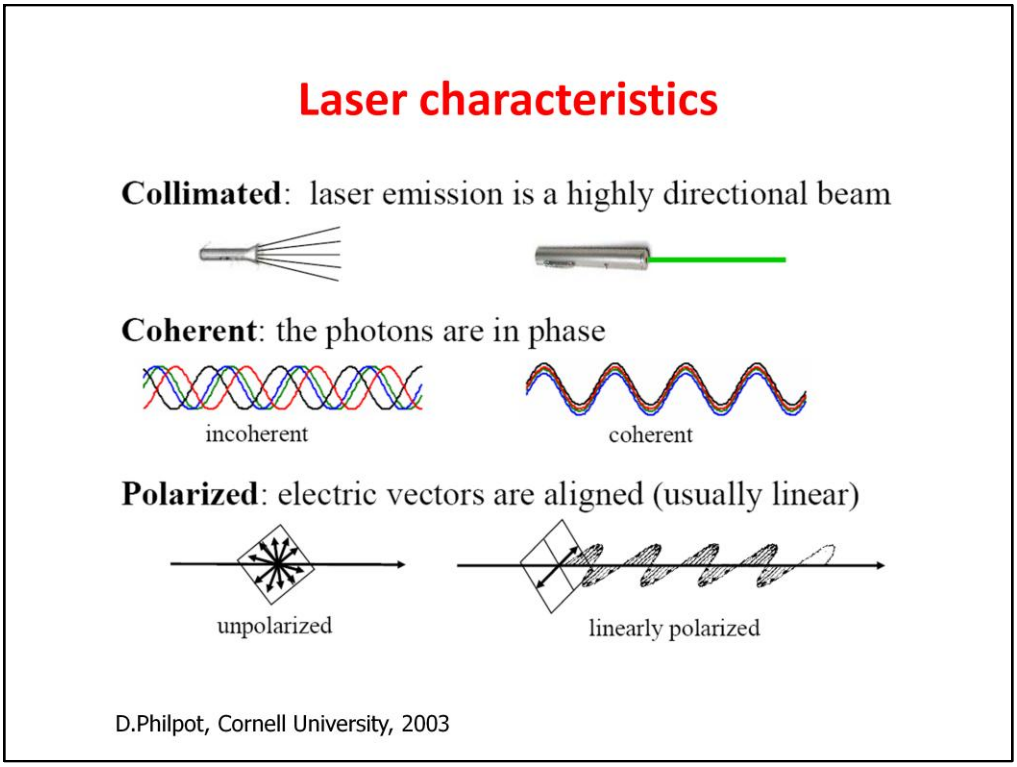
Ex. LiDAR, Sounders, Radar

Question to students what is an active sensor?

LiDAR Definition

- **LiDAR**: Light Detection and Ranging
- **Laser**: Light Amplification of Stimulated Emission of Radiation

- Active sensor: emits high energy pulses of short wavelength (R or NIR) light highly collimated: coherent and polarized
- Measures the distance to the intercepted point on the ground based on the time delay between an emitted and received laser pulse



Example with laser pointer

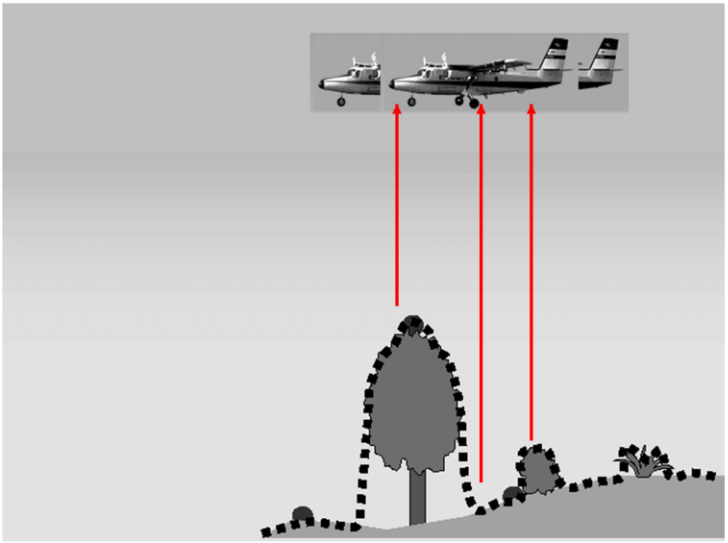
How does Lidar work?

Travel Time:

$$t = 2\frac{R}{c}$$

Range (distance):

$$R = \frac{1}{2}tc$$

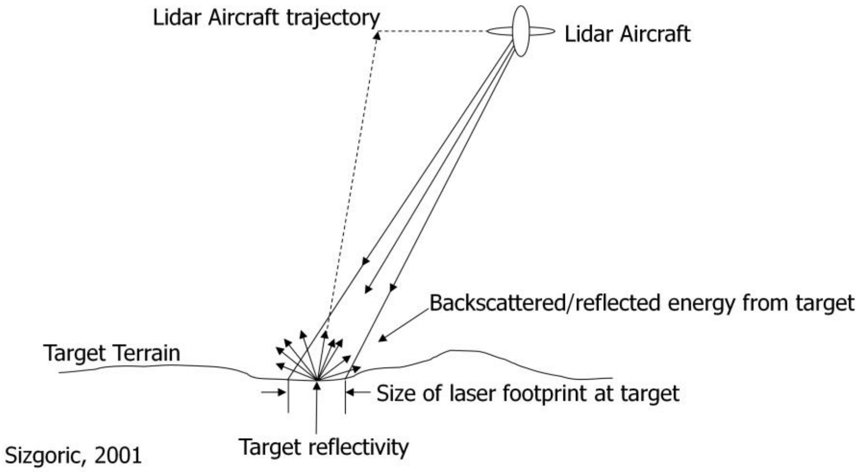


From airplane or satellite space shuttle:

LIDAR systems can emit pulses at rates >100,000 pulses per second referred to as *pulse repetition frequency*. A pulse of laser light travels at *c*, the speed of light (3 x 108 m s-1). LIDAR technology is based on the accurate measurement of the laser pulse travel time from the transmitter to the target and back to the receiver. The *traveling time* of a pulse of light, *t*, is: t = 2 * R/c

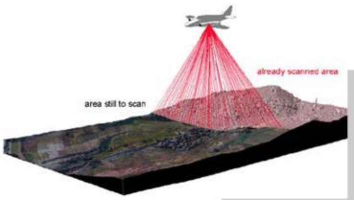
where *R* is the range (distance) between the LIDAR sensor and the object. The range, *R* is determined by rearranging the equation:

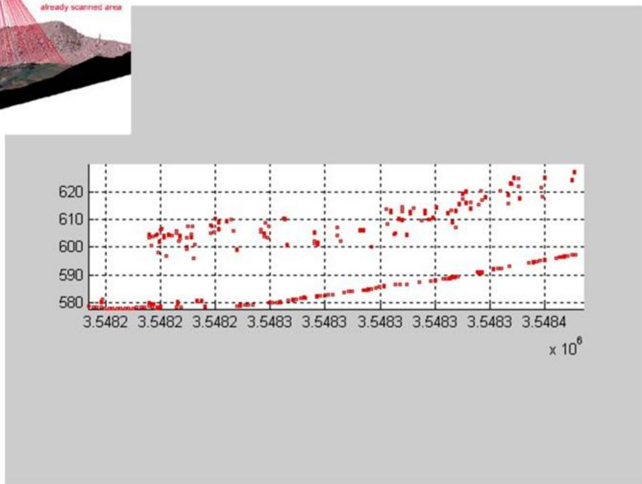
Laser footprint diameter



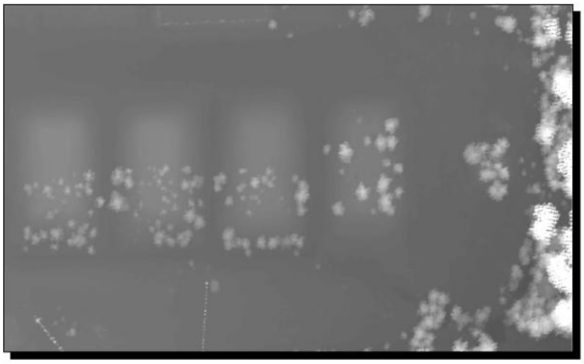
Mention beam divergence
Lambertian surface, but is not perfect
What would happen if it is not Lambertian?
We will not get any response back to the receiver

Lidar Scanning Method

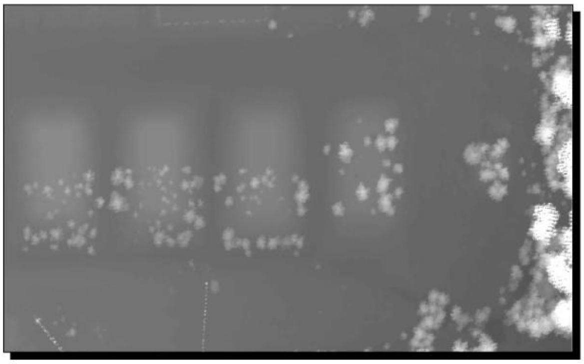




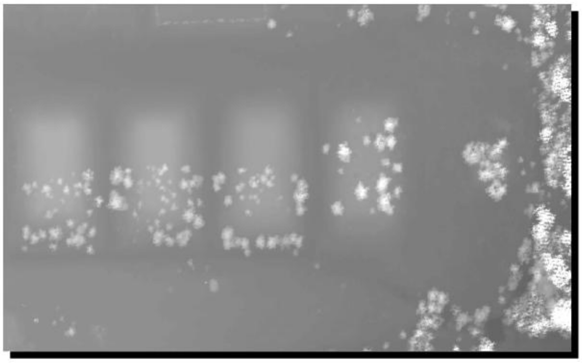
Orthophotograph
1 x 1 m



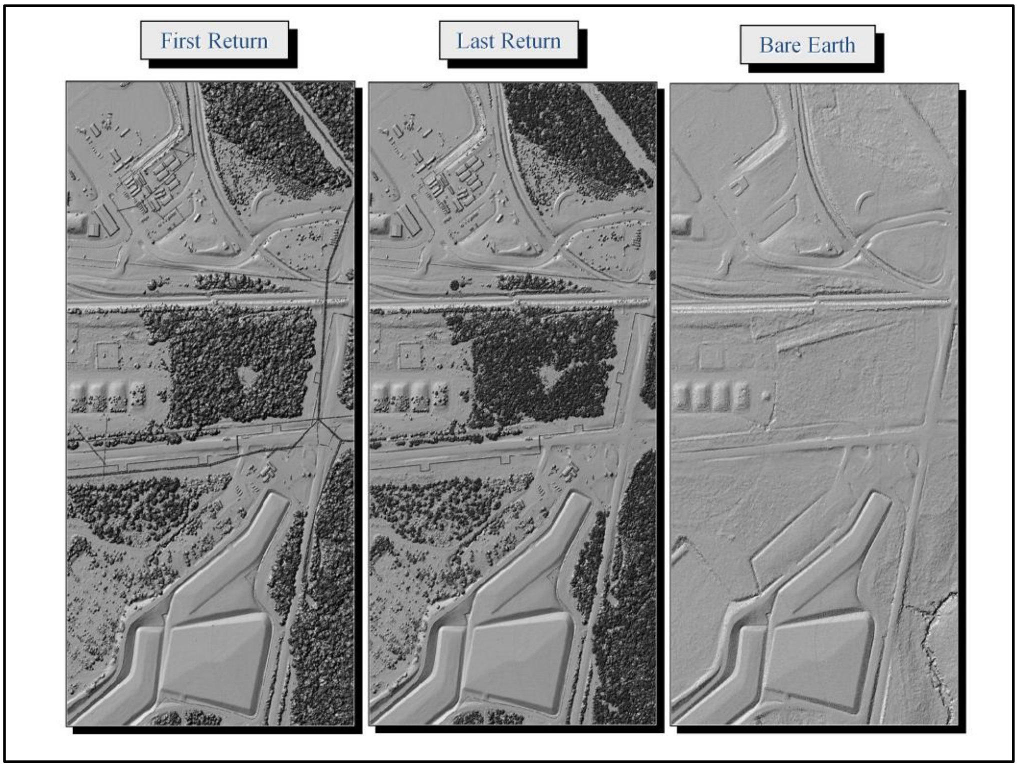
Rasterized First Return



Rasterized First Return



Rasterized Last Return

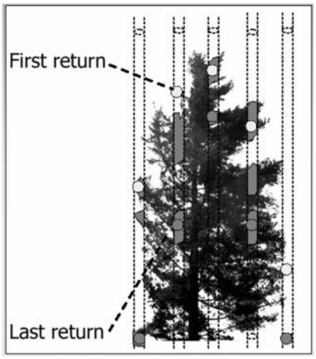


Interpolated lidar data showing the detected returns and the estimated bare earth, derived from last returns.

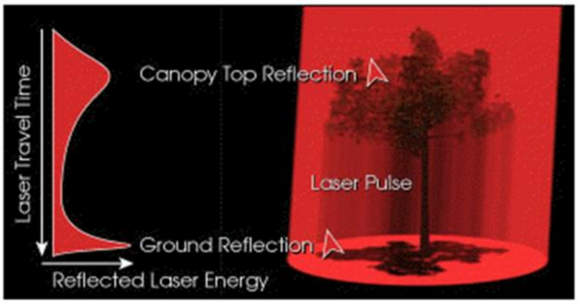
Lidar Elevation Accuracy

Footprint size

- Small footprints - a few cm
- Large footprints – tens of m



Dubayah, 2003

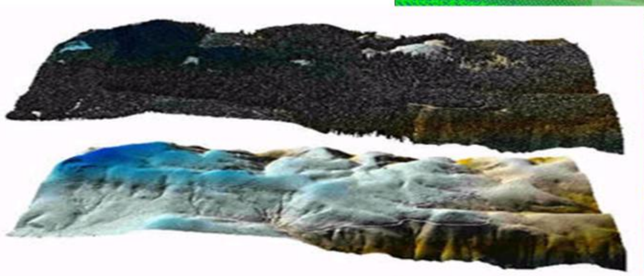


http://earthobservatory.nasa.gov

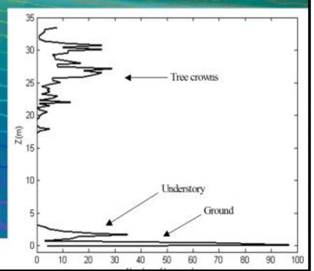
Small Footprint LiDAR

New Ecologically Relevant Data Products:

- Vegetation height
- Distribution of structural elements in canopy
- Canopy-top topography
- Biomass
- Life form diversity

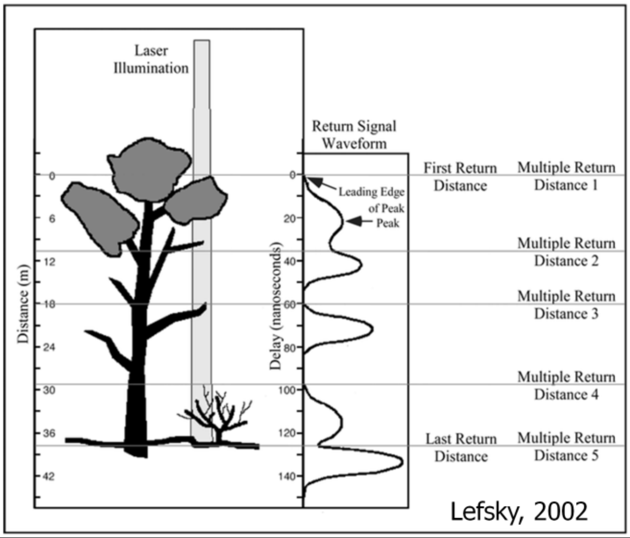


Canopy Surface Topography & Bathymetry



Recording capability

- Discrete pulses
  - First and/or last pulse
  - Up to five pulses
  - with intensity?
- Full waveform

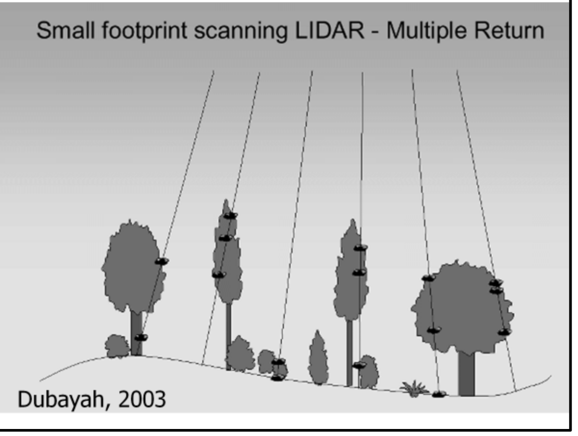


If intensity is being recorded draw just a line for the discrete pulses

Single versus multiple discrete pulses

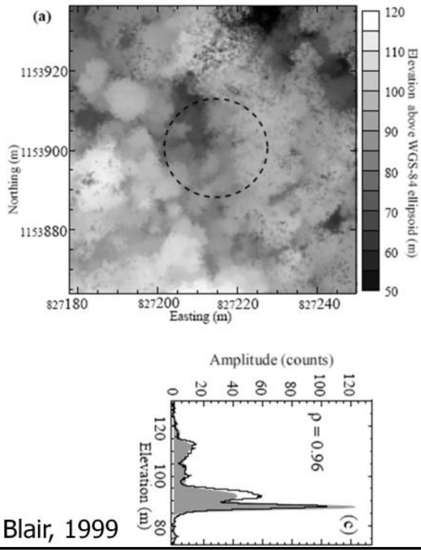
- Discrete pulses
  - First and/or last pulse
  - Up to five pulses

- Full Waveform
  - Continuous return pulses



Many small discrete ≡ Large full waveform

- High density small discrete
  - Locate individual trees
  - Locate ground easier
- Large full waveform
  - Less amount of data
- Conversion to frequency
- Gaussian laser intensity
- Example:
  - FLI-MAP
    - 10 cm footprint size
    - 33 cm across and along track spacing
  - LVIS
    - 25 m



Blair, 1999

Give an example on how to do it.

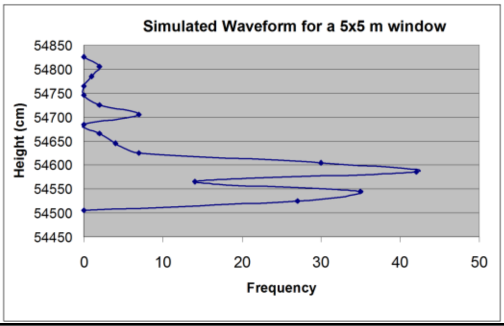
1. Draw in X and Y different small footprints with a specific pattern.
2. Draw a large footprint
3. Draw X and Z
4. Draw intervals every for example 10 cm
5. Draw waveform

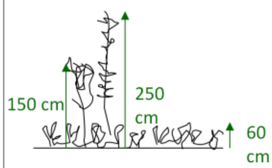
Gaussian shape of the laser beam intensity

Why less amount of data

Simulation of large full waveform

– Selection of size of the large full waveform
– Selection of height interval
– Generation of frequency





Draw area

Scanning pattern

- Vertical profiling (no scanner)
- Zig-Zag
  - Oscillating mirror
- Parallel lines
  - Multifaceted mirror
  - Fiber scanner
- Elliptical
  - Nutating mirror (Palmer scan)

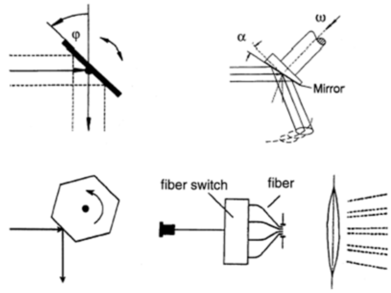
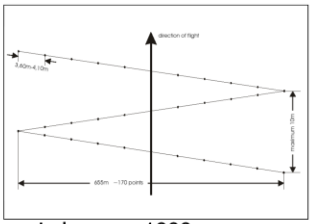
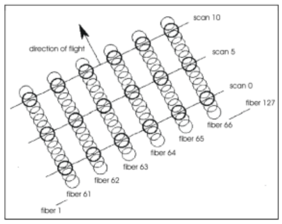


Fig. 6. Scanning mechanisms (from top left, clockwise): oscillating mirror, Palmer scan, fiber scanner, rotating polygon.





Lohmann, 1999

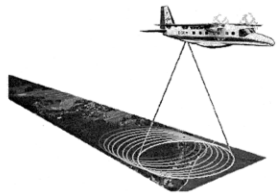
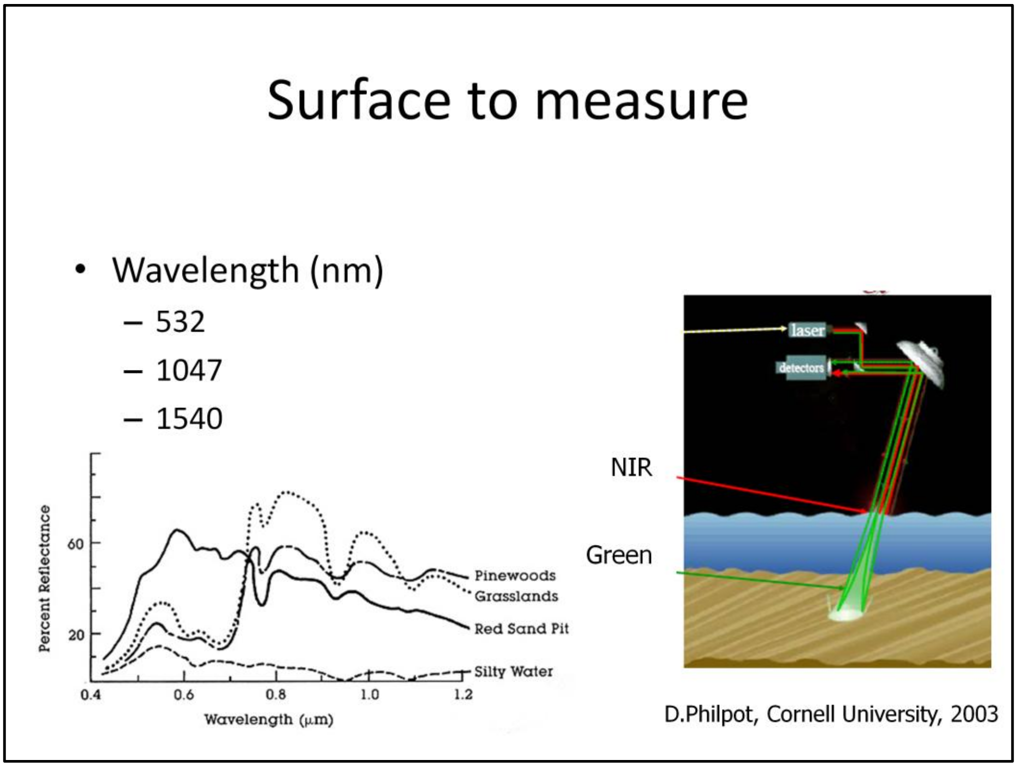


Fig. 10. Progressing Palmer scan.

Wehr, 1999

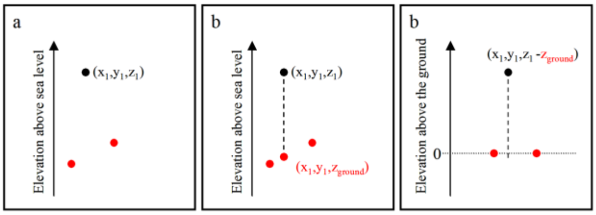


Explain that uses NIR for the surface of water and Green for the botton. Higher reflectance of green means also higher trasmittance. So the green trasmits better to the botton of the surface, whereas the NIR absorbs everthing and can not reach the botton
Toposys at 1535 nm less harmful to eye can emit higher power

Aki me quedé

Generation of canopy height of individual laser pulses

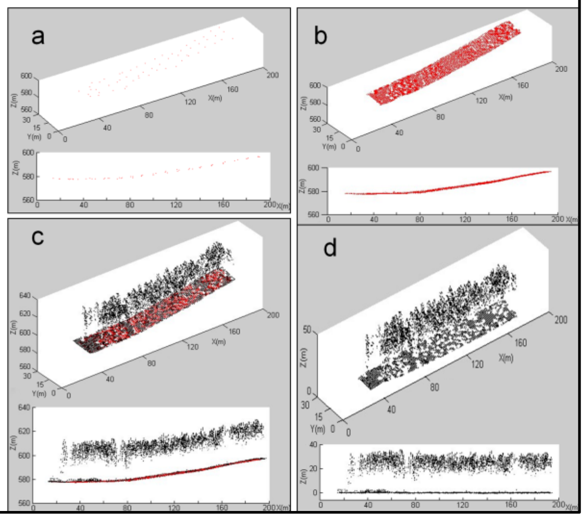
- Point X, Y, Z
- Interpolate: selection of Z_{ground} for X and Y, from DGM or classified ground points
- Canopy height = $Z - Z_{ground}$



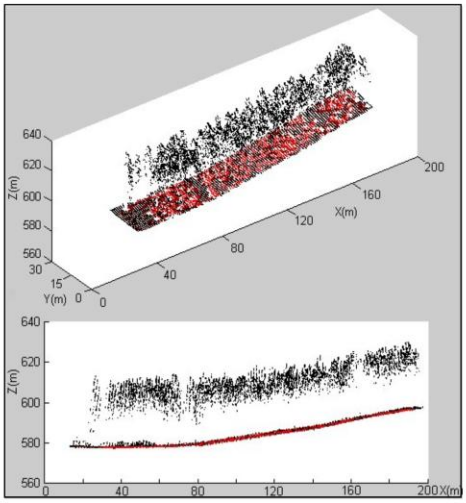
Draw an X and Y graph
Center of pixel of DGM

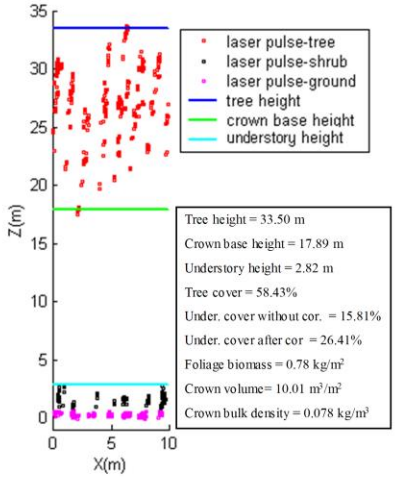
Generation of canopy height of individual laser pulses

- Ground points
- Interpolate: selection of Z_{ground} for X and Y
- Canopy height = $Z - Z_{ground}$
- Elevation above ground



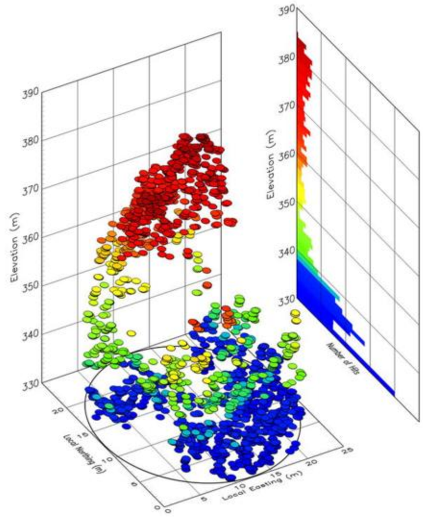
Forest Structure & Biomass from Small Footprint LIDAR





Riano et al., 2004

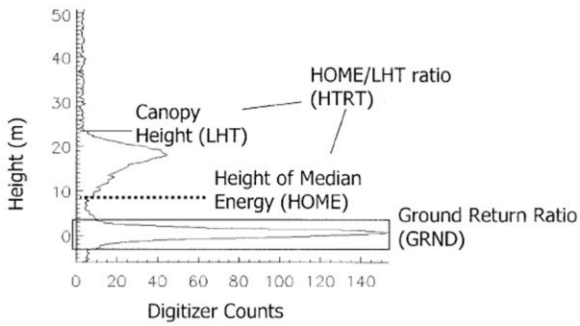
Density of points at each interval



Lefsky, 2002

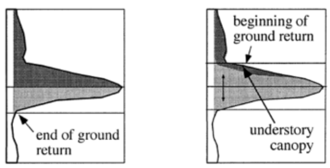
Feature extraction from Lidar

- Large full waveform

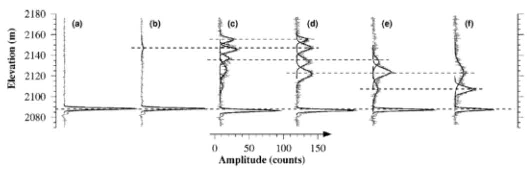


Surface canopy height

- Large full waveform
  - Difficult to obtain from large footprints
  - Bare ground is mixed with surface canopy signals on steep slopes due to the spreading of the ground return
  - Ground from the vegetation signal: copy and flip vertically the lower half of the ground return to define the higher half of the ground return.
  - Surface canopy height: gap between the ground and shrubs
    - Decomposed in Gaussian components: trees, underlying vegetation and ground



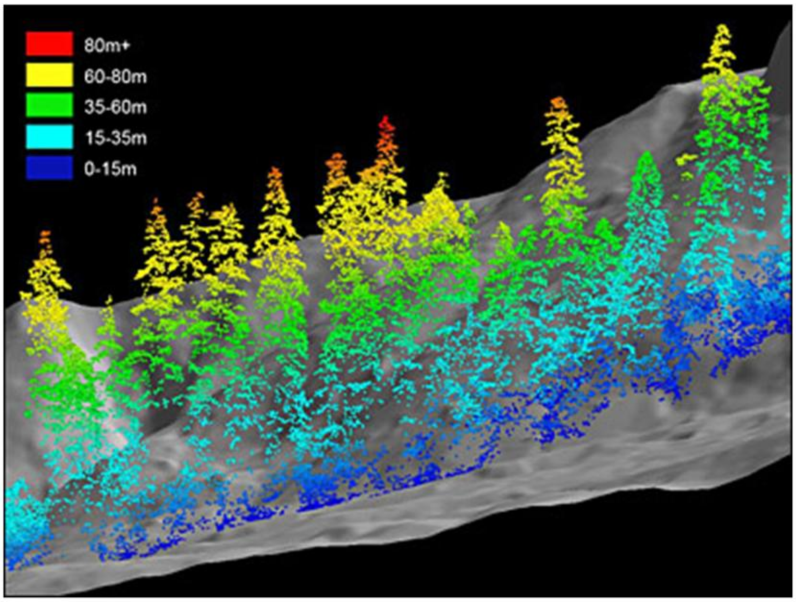
Lefsky, 1999

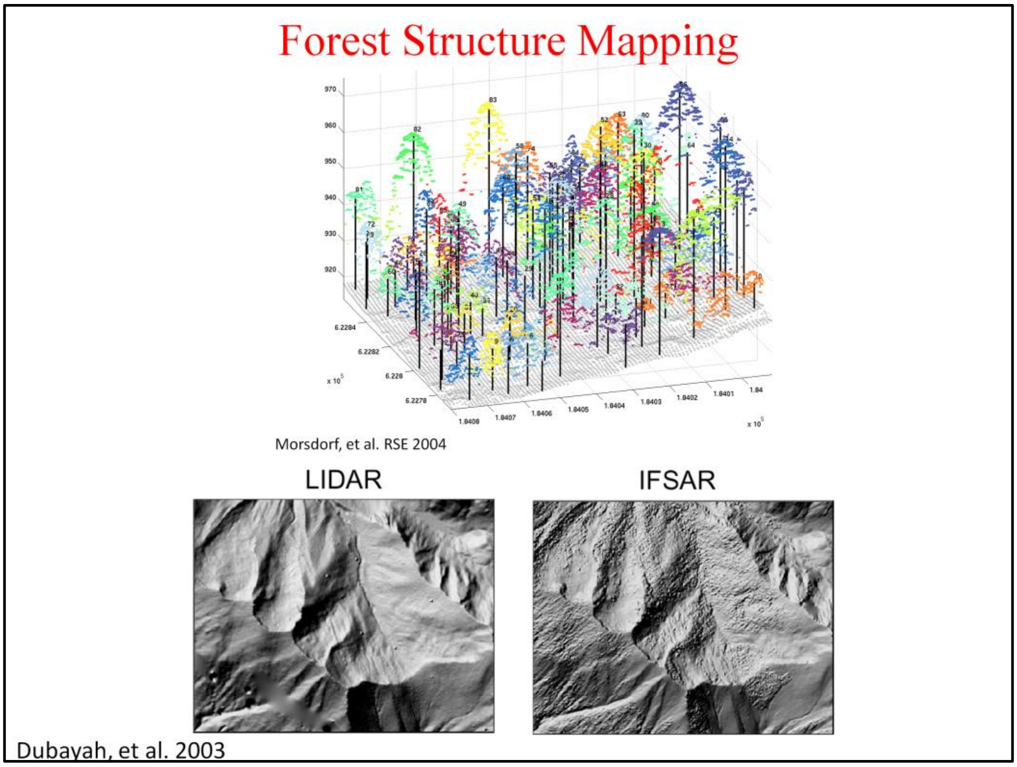


Hofton, 1999

Draw a waveform from the ground and a waveform from the vegetation. Superimpose them. If you do this on homogeneous vegetation the distribution is going to be the same but it will not be if it is heterogeneous. Power greater than the level established by the ground return is assumed to be vegetation canopy.
The *LIDAR data for the generation of forest parameters* in the highest part of the gaussian component represents the underlying vegetation would be the surface canopy height.
Difficult to separate if more than 3 gaussians

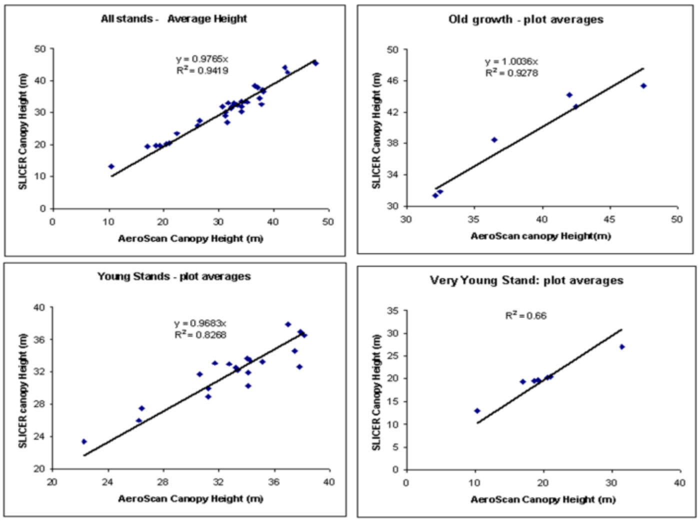
Forest, Blue River, OR



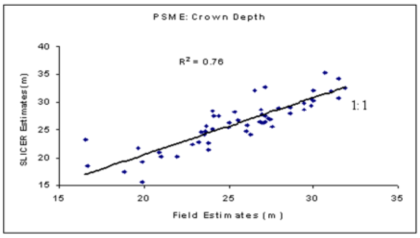


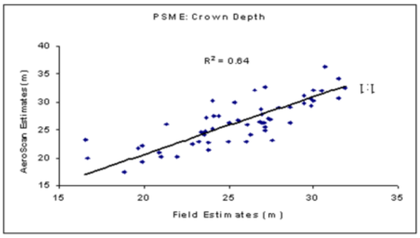
Drake JB, Knox RG, Dubayah, RO, Clark, DB, Condit, R, Blair, JB, Hofton, M. 2003. Above-ground biomass estimation in closed canopy Neotropical forests using LIDAR remote sensing factors affecting the generality of relationships. Global Ecology and Biogeography 12(2) 147-159.

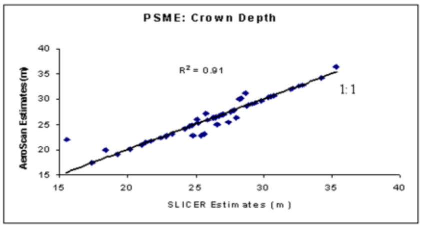
LIDAR Canopy Height Retrievals



Wind River Experimental Forest







1:1

LiDAR Crown Depth

PSME: *Pseudotsuga menziesii* at Wind River

Large footprint (SLICER) out performs

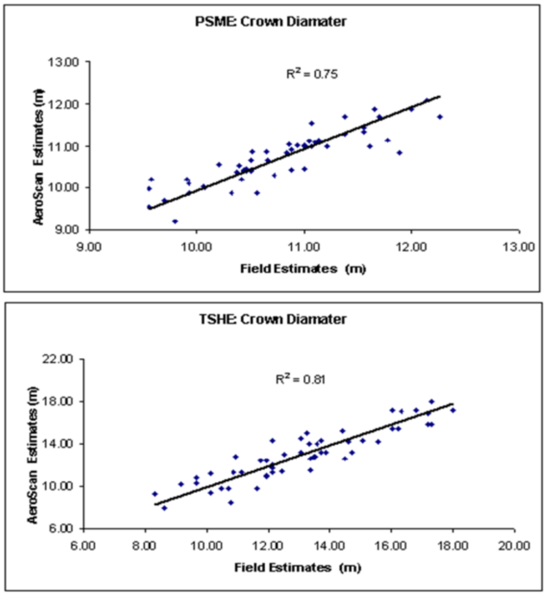
Synthetic waveform from small foot print (Aeroscan)

Both match 1:1 line

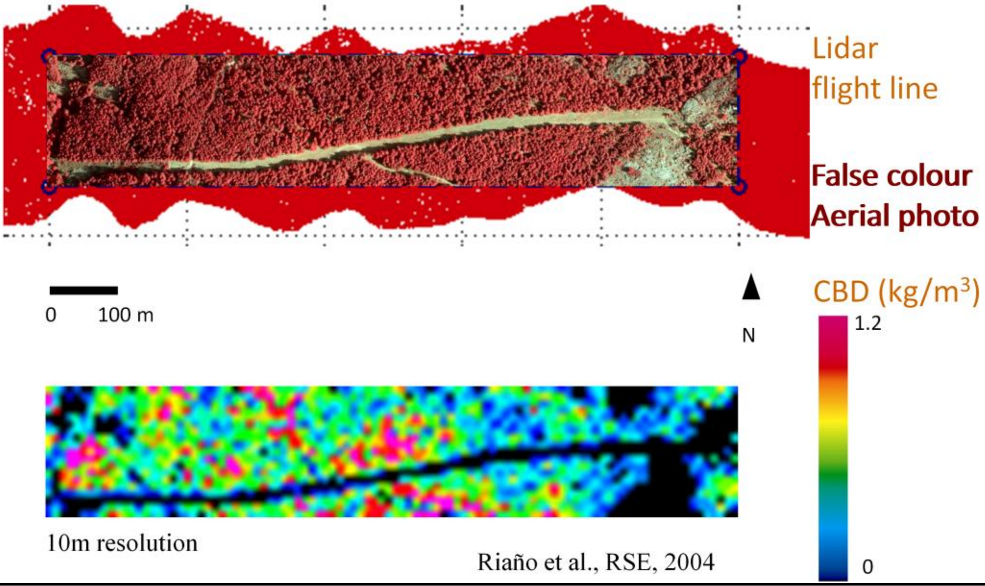
Similar results for TSHE

LIDAR Crown Diameter

Derived from multi step process for delineating crowns automatically from LIDAR

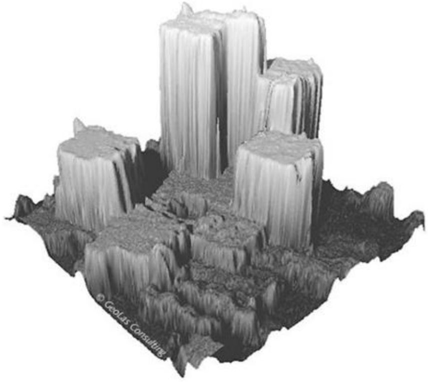


Generation of Crown Bulk Density From These Equations



Riaño et al., RSE, 2004

Urban architecture



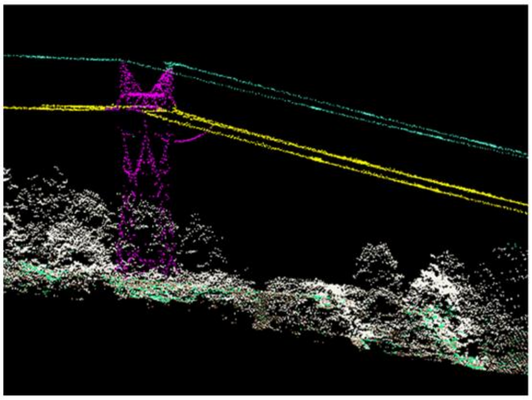
http://www.geolas.com/Pages/Building.html

Urban architecture

Manheim, Germany

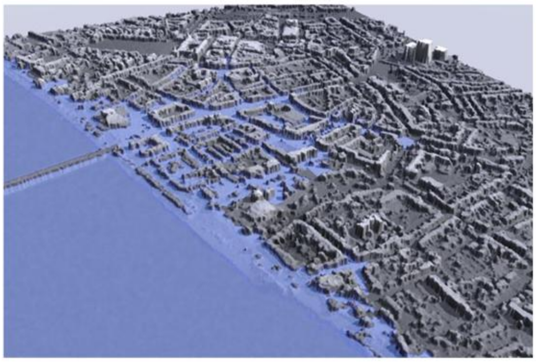
www.toposys.com

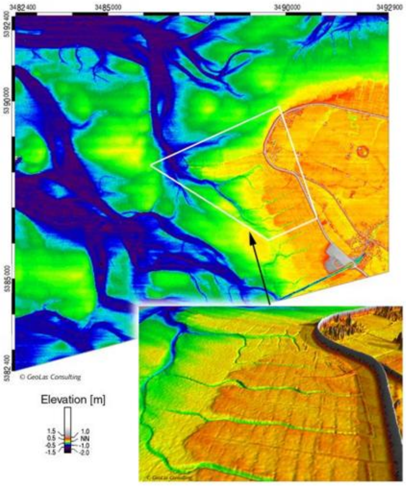
Infrastructure



http://www.helica.it/eng/prod/elettro.asp#

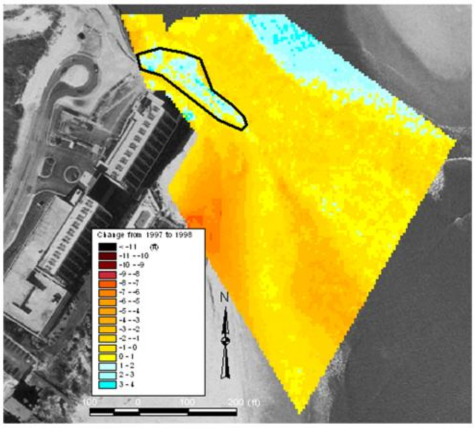
Floods





http://www.geolas.com/

Coastal erosion

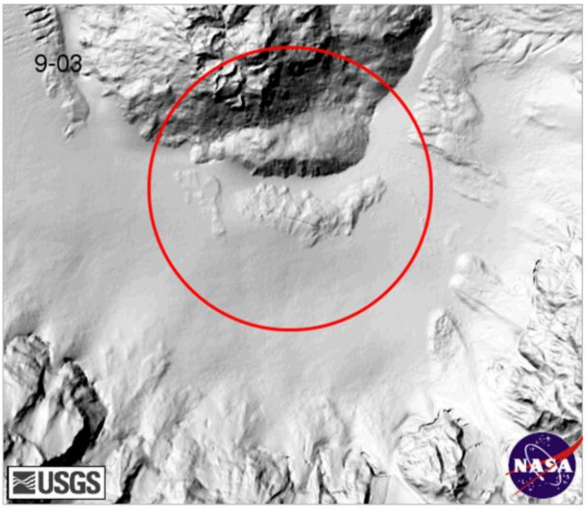


Changes between 1997 and 1998 in coastal area of North Carolina (North Wrightsville Beach)

http://www.csc.noaa.gov/products/nchaz/htm/lidtopo.htm#lidar

Volcano

- Mt St Helen



http://vulcan.wr.usgs.gov/Monitoring/LIDAR/framework.html

Bathymetry

- SHOALS
- Blue-Green from the bottom and NIR from the top
- Blue-Green reflects more but transmits more

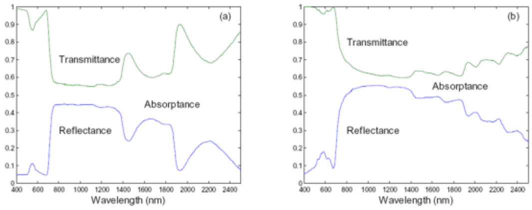
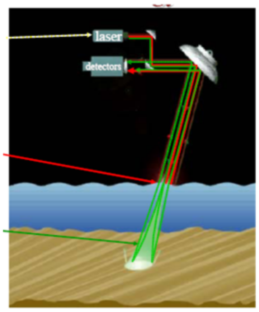


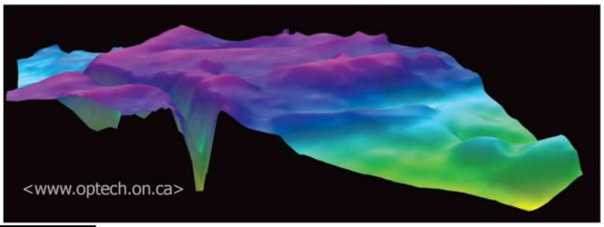
Fig. 2: Reflectance and transmittance spectra of (a) fresh and (b) dry poplar leaves



U.S. Army Corps of Engineers <shoals.sam.usace.army.mil>

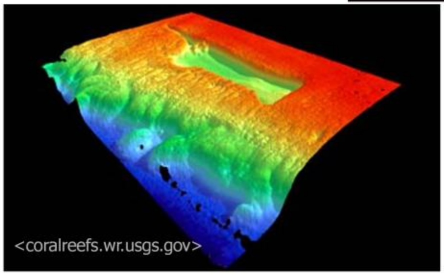
Draw water spectrum

Bathymetry



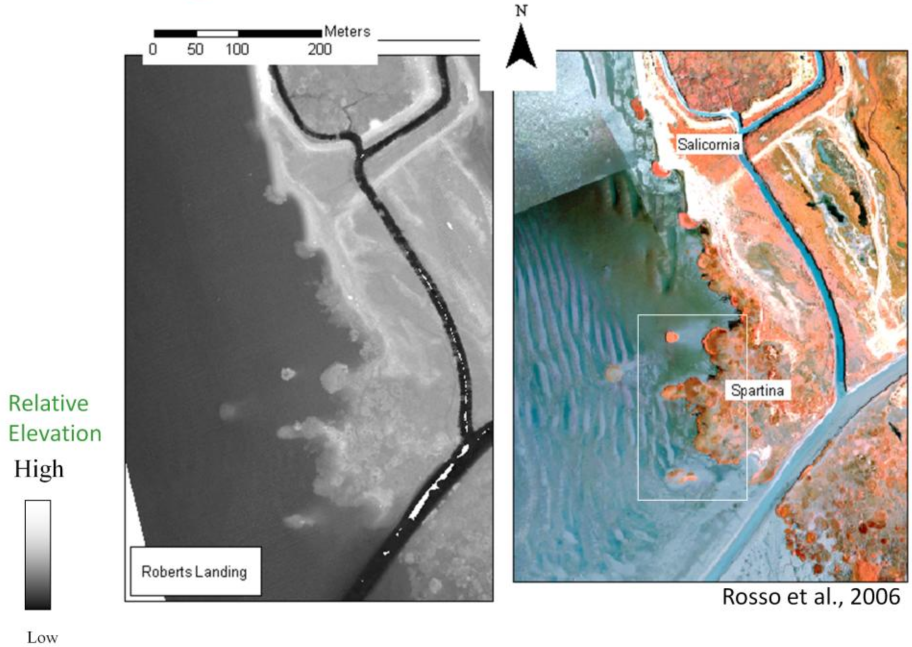
Molokai, Hawaii

Looe Key, Florida



James Goodman

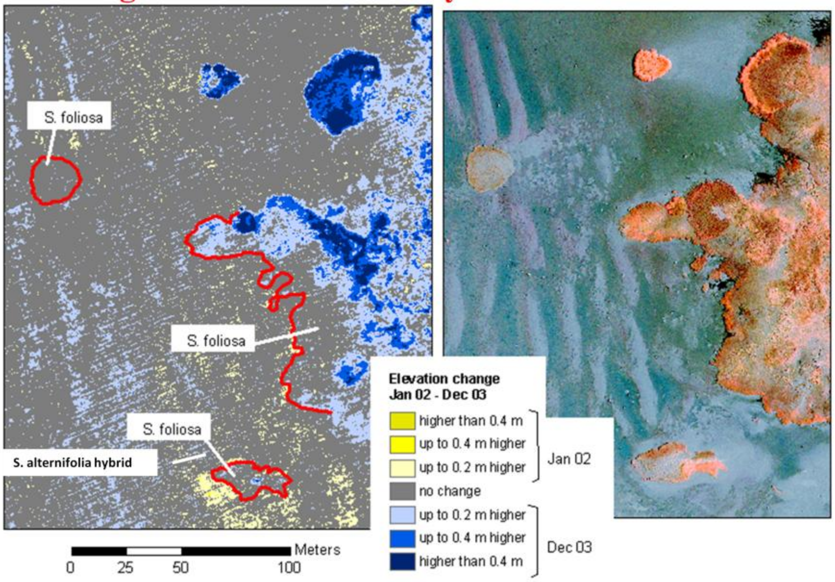
Change Detection in Extent of Salt Marsh



Rosso et al., 2006

Change Detection

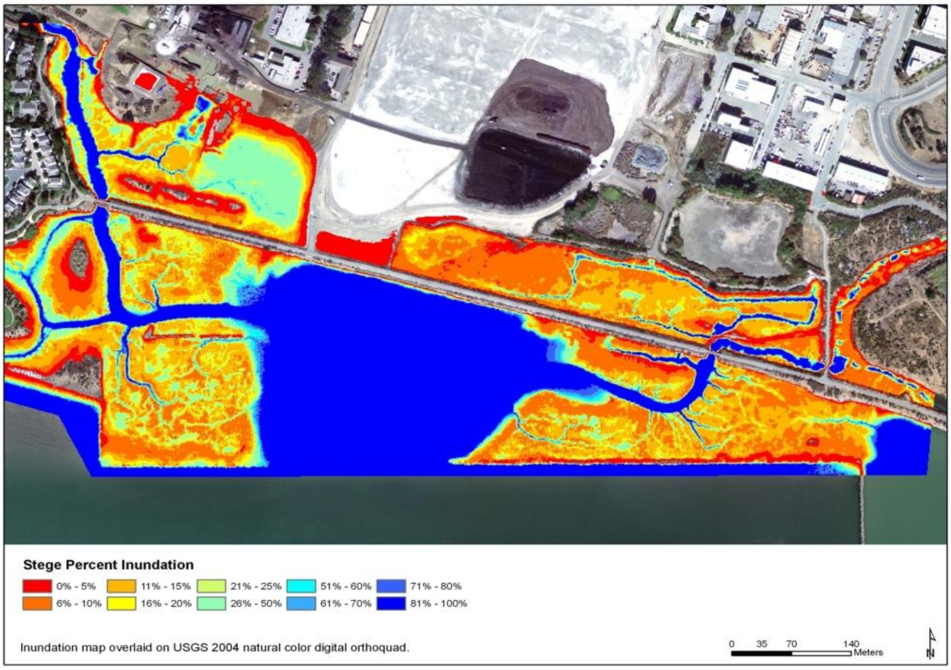
LiDAR Height Difference: January 2002 and December 2003



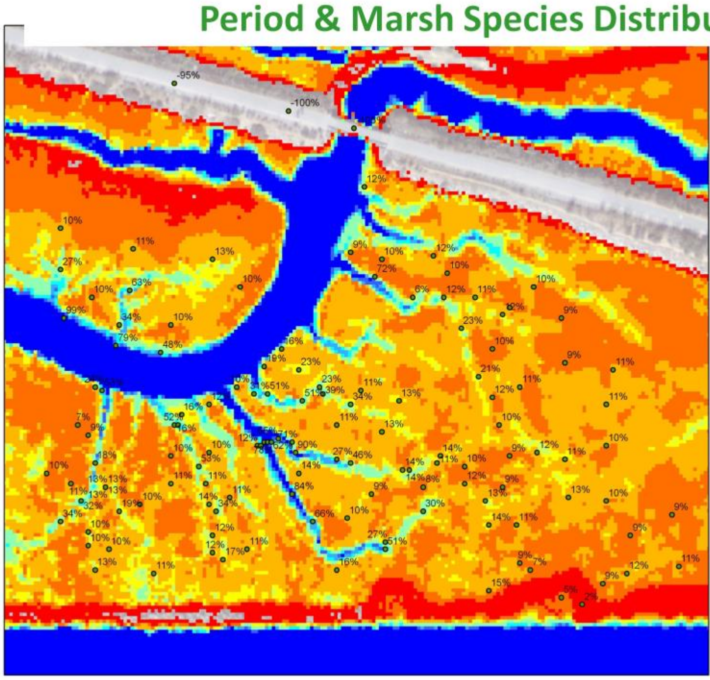
Roberts Landing marsh

Rosso et al., 2006

LiDAR Marsh Height: Estimate % Time Inundated



Micro-topography Controls Length of Inundation Period & Marsh Species Distribution



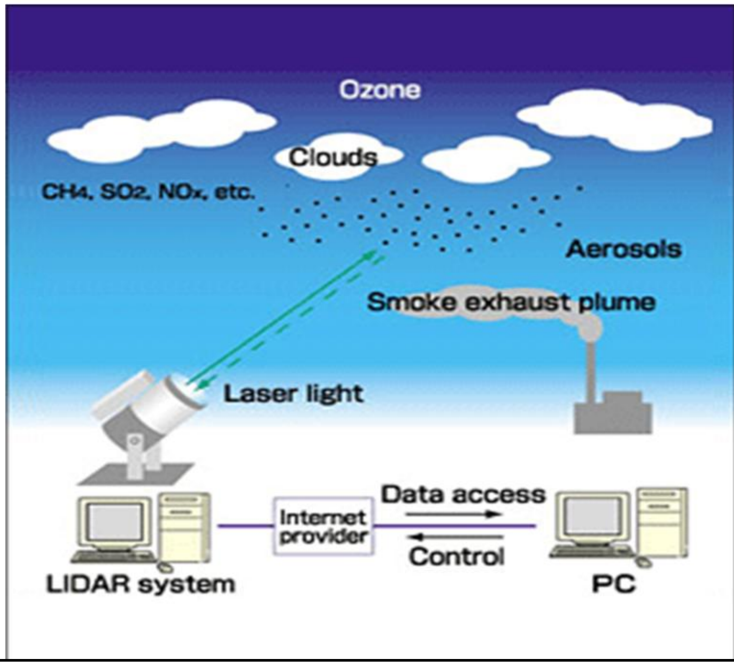
Stege Marsh

% of TIme Inundated

- 0% - 5%
- 6% - 10%
- 11% - 15%
- 16% - 20%
- 21% - 25%
- 26% - 50%
- 51% - 60%
- 61% - 70%
- 71% - 80%
- 81% - 100%
- Lidar inundation

0 5 10 20 Meters N

Upward looking LiDAR



Advantages of LiDAR Instruments

- Day/night data acquisition
- Captures detailed vertical and horizontal landscape structure
- Sensitive to height/structure differences in short stature & sparse vegetation
- Relatively inexpensive, lightweight/power instruments
- Use has become common with many vendors
- Most terrestrial lidars flown with bands in the NIR; land surface materials are relatively well understood

Disadvantages of LiDAR Instruments

- Generally need video or images to aid interpretation
- Difficult to identify individual trees in dense vegetation
- Power requirements make satellite operation challenging

What you should know about LiDAR Data

1. Active systems
2. Measurement Principles: nomenclature, wavelengths (bands), backscatter,
3. How do these technologies work? How are signals transmitted?
4. Examples of unique measurements for this technology.