Elements of LiDAR technology

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USDA Forest Service
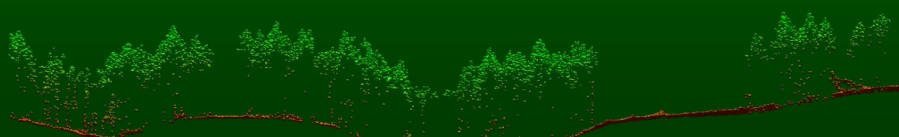*PNW Research Station*
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Elements of LiDAR technology

◆ *Light Detection and Range (LiDAR)*
◆ *Active remote sensing technology*
◆ *Scanning from various platforms*
  • *Airborne (by far the most common)*
  • *Satellite (couple of data acquisition missions)*
  • *Ground (gaining steam)*

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Elements of LiDAR technology

◆ *Airborne laser scanning equipment*
- *LiDAR instrument (transmits and receives pulses of light in a certain wavelength)*
- *Computer processes and stores the received signal*
- *INU records attitude of aircraft*
- *GPS records location of aircraft*
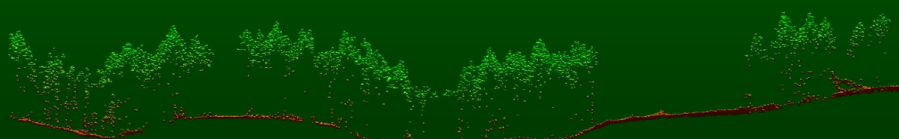- *Ground rover station (within 50-75 miles)*

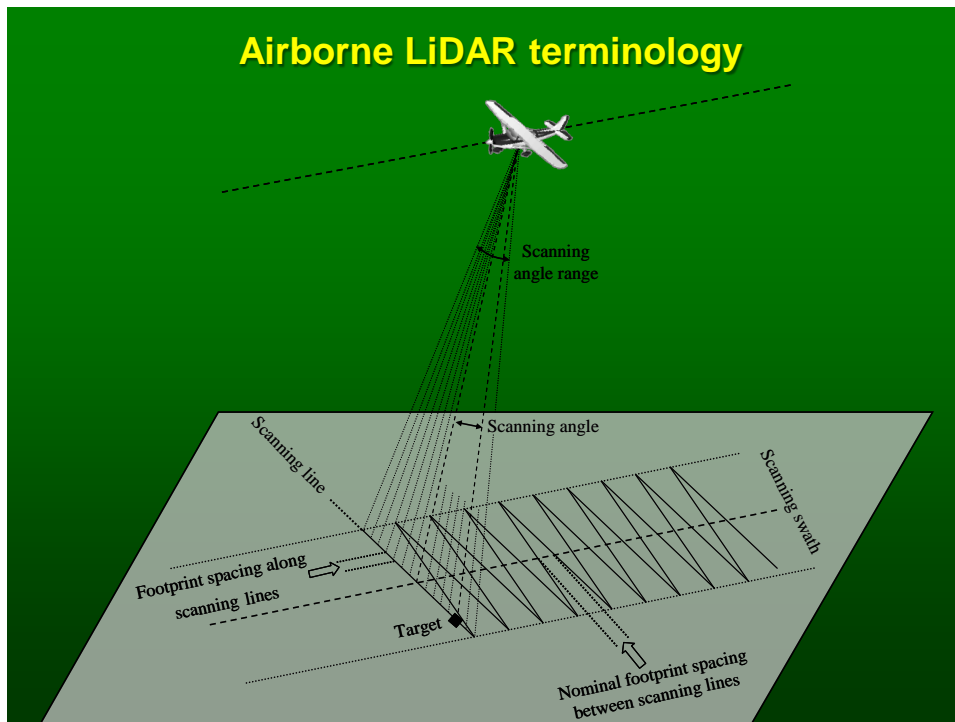USDA Forest Service , Pacific Northwest Research Station, Vegetation Monitoring & Remote Sensing Team

Elements of LiDAR technology

◆ *LiDAR types*
- *Discrete return*
- *Waveform*
- *Terrestrial*
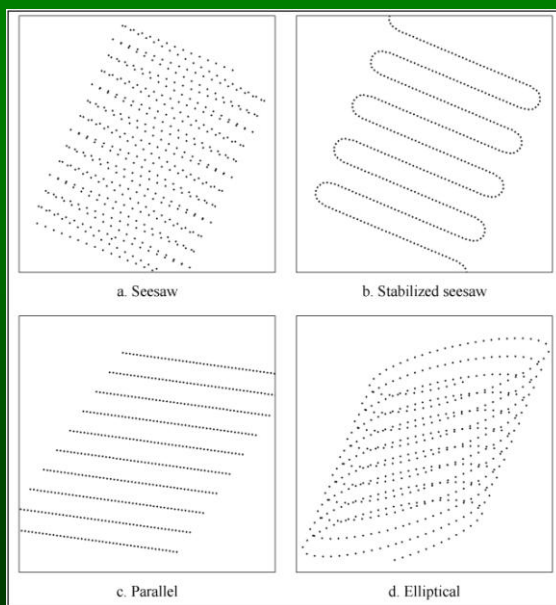
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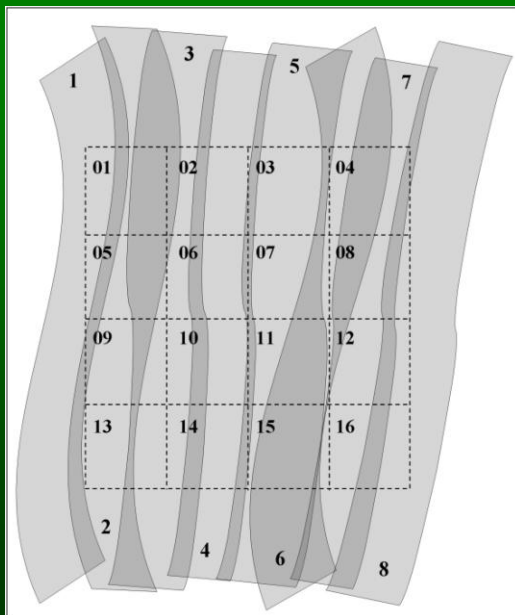
Airborne LiDAR terminology

Scanning angle range

Scanning line

Scanning angle

Scanning swath

Footprint spacing along scanning lines

Target

Nominal footprint spacing between scanning lines

Scanning patterns

a. Seesaw

b. Stabilized seesaw

c. Parallel

d. Elliptical

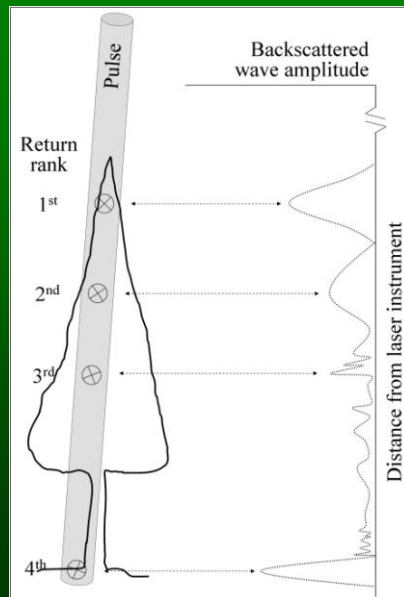## Spatial arrangement of adjacent scanning swaths

Elements of LiDAR technology

- ◆ *Discretization (not for waveform)*
  - • *Identification of discrete returns (points) precisely registered in 3D space*
- ◆ *Scanning Frequency*
  - • *Up to 150 kHz (is there a limit ?)*
- ◆ *Density (pulses or returns / m²)*
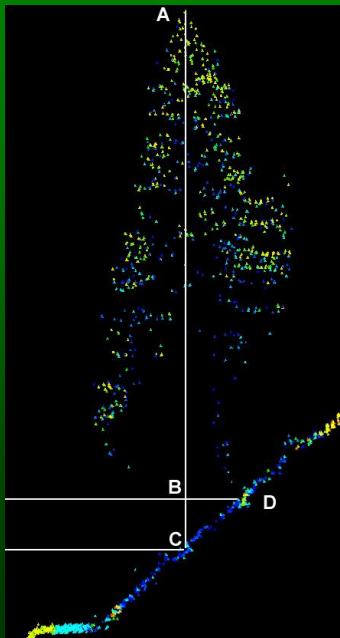- ◆ *Beam divergence*
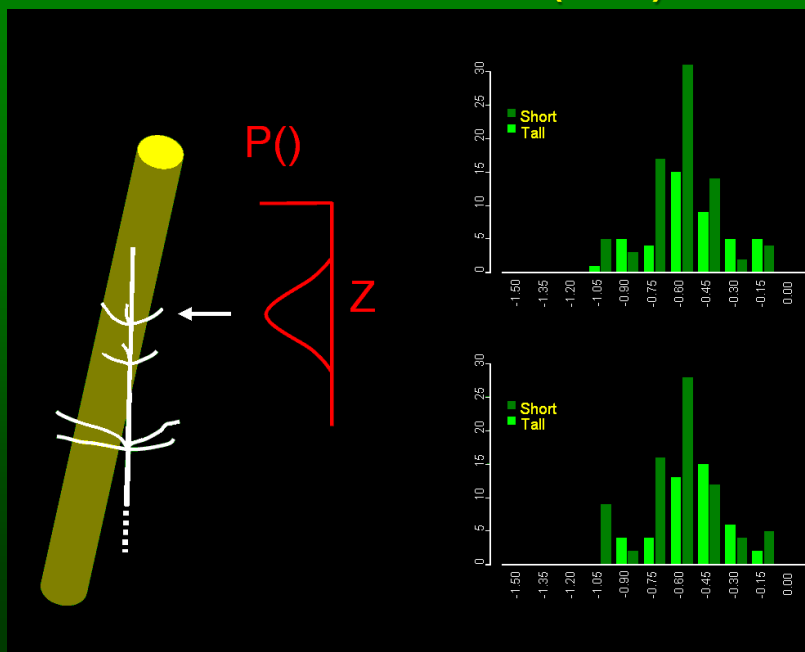- ◆ *Output power (is there also a limit ?)*

Pulse discretization

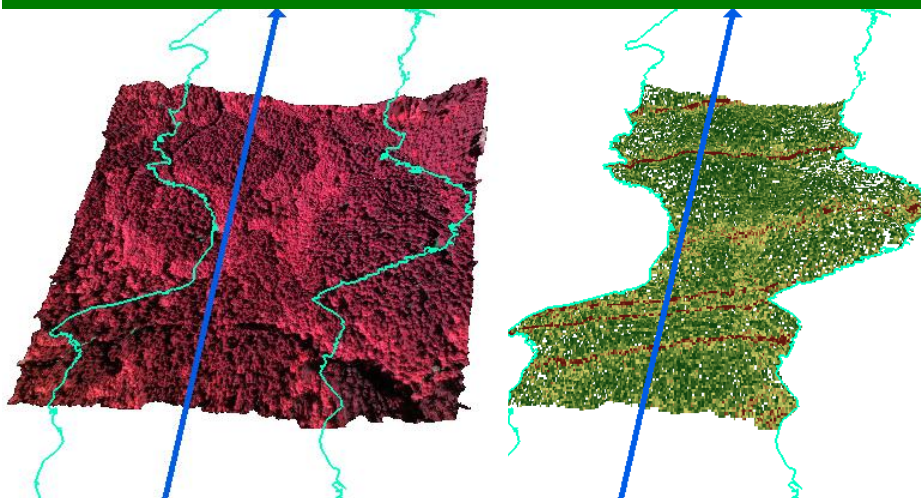# Discretization results

Discretization results (cont.)

Elements of LiDAR technology

◆ *Discretization (not for waveform)*
- *Identification of discrete returns (points) precisely registered in 3D space*

◆ *Scanning Frequency*
- *Up to 150 kHz (is there a limit ?)*

◆ *Density (pulses or returns / m²)*

◆ *Beam divergence*

◆ *Output power (is there also a limit ?)*
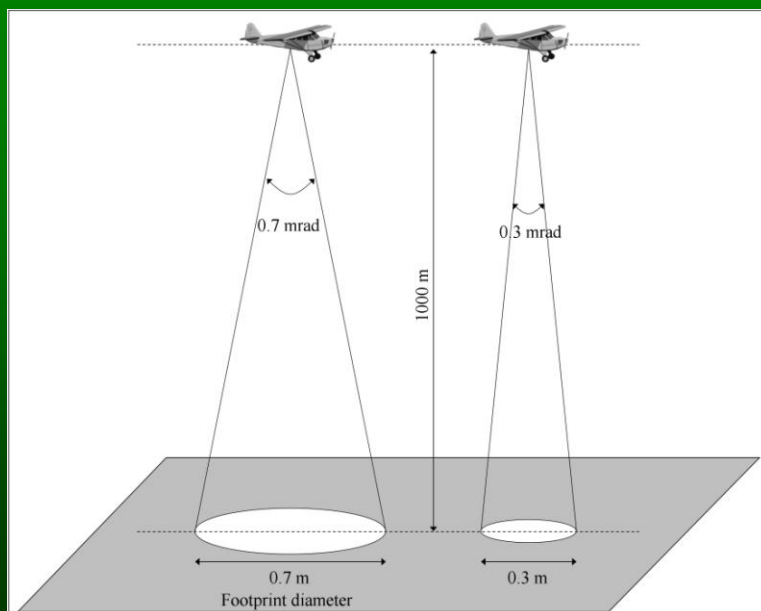
Variability in scan density

Elements of LiDAR technology

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- ◆ *Output power (is there also a limit ?)*

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Laser pulse / beam divergence

0.7 mrad   0.3 mrad

1000 m

0.7 m   0.3 m
Footprint diameter

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Effects of (mostly) reduced pulse energy
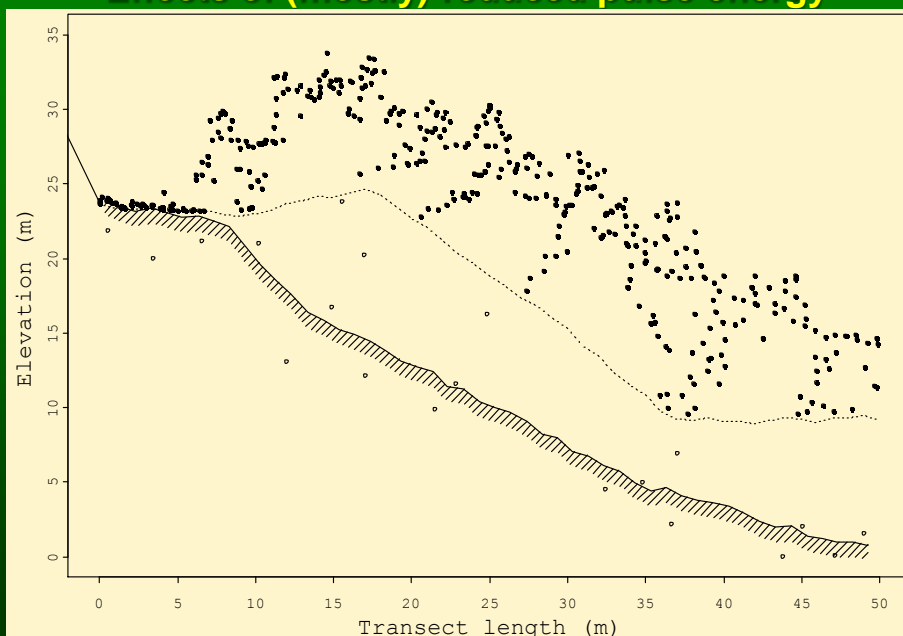
## LiDAR data attributes

- ◆ *Intensity*
  - • *Amount of backscattered pulse energy received by the sensor*
  - • *Of target discrimination potential*
  - • *Noisy (subject to variation in range, sensor dynamic gain adjustment, etc)*
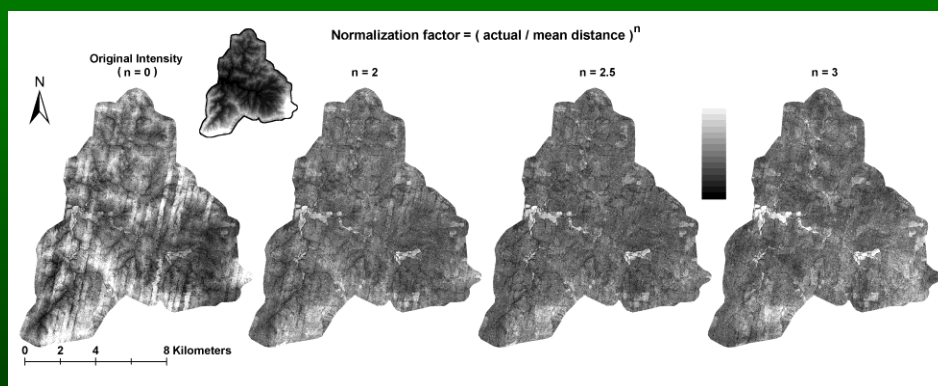 - • *Increasingly used lately thanks to advances in normalization efforts*

LiDAR intensity = f (range)

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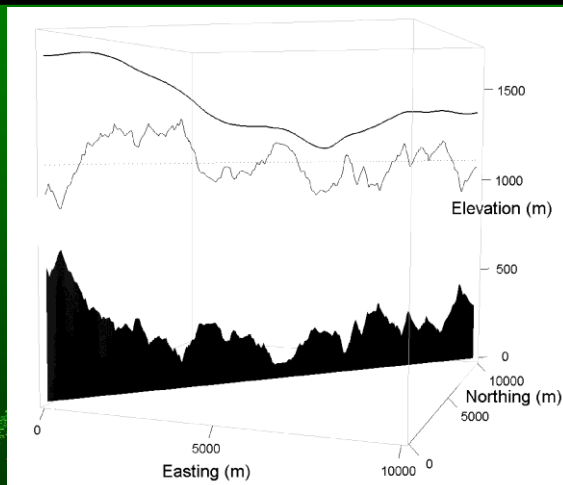
LiDAR intensity = f (range)

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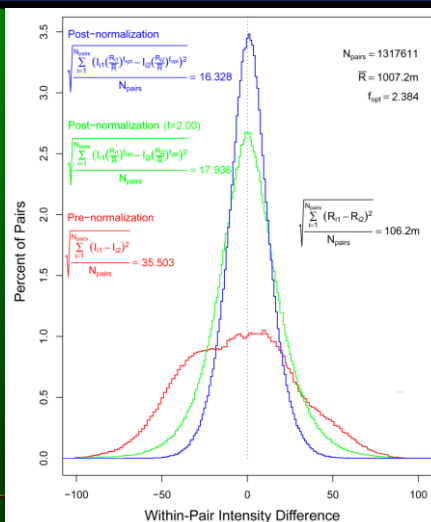## LiDAR intensity normalization

LiDAR data attributes

- ◆ **Return rank**
  - **1st, intermediate, last**
- ◆ **# of returns in parent pulse**
  - **1 to maximum of four (maximum may increase in the future)**
- ◆ **Scan angle**
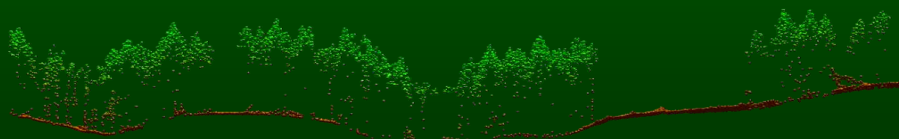- ◆ **Flight line ID**
- ◆ **GPS time**

LiDAR data attributes

◆ *Classification (after processing)*
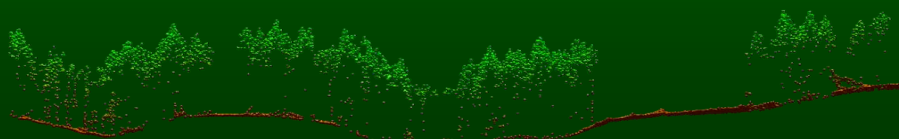- *Ground*
- *Above ground*
- *Outlier*

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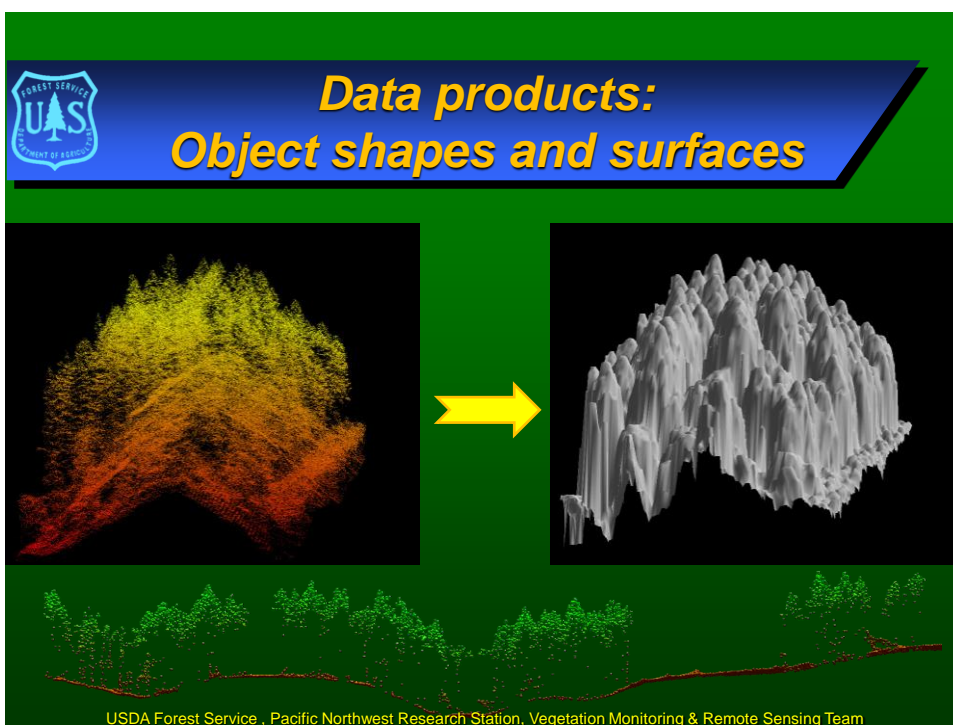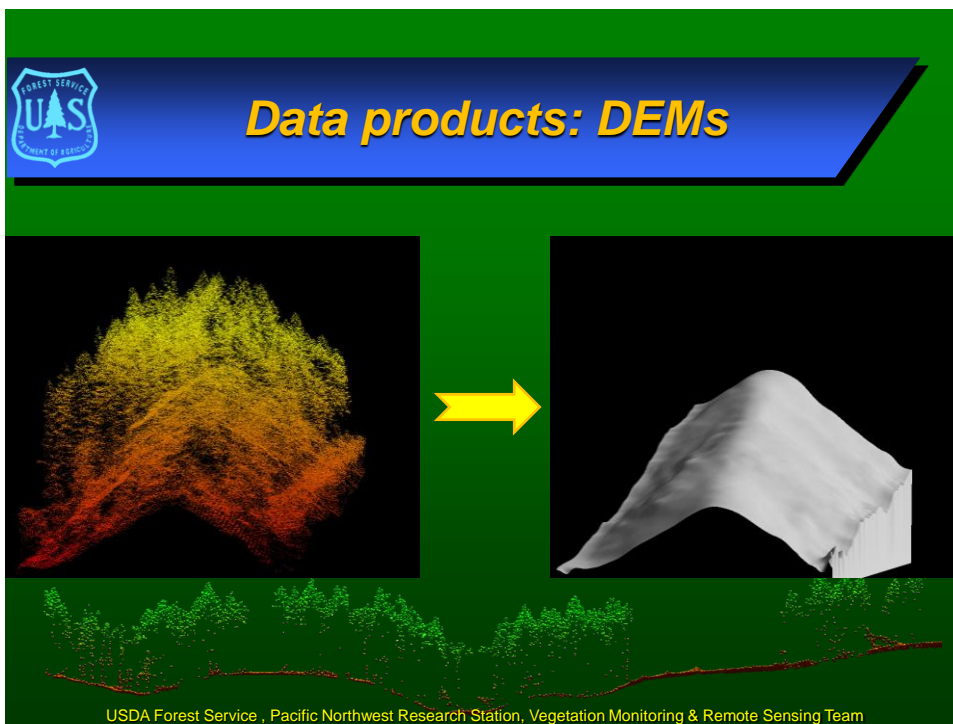
Standard data products

◆ *Digital terrain models*
◆ *Object height*
◆ *Object shape (2D or 3D)*
◆ *Tons of custom data products*

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Data products: DEMs

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Data products:
Object shapes and surfaces
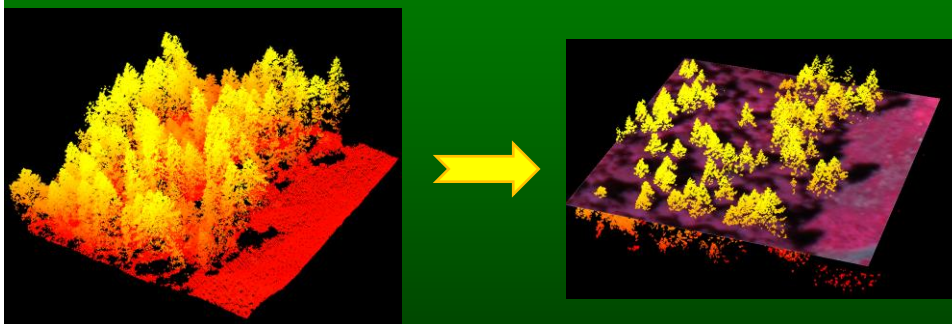
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Fusion with spectral imagery

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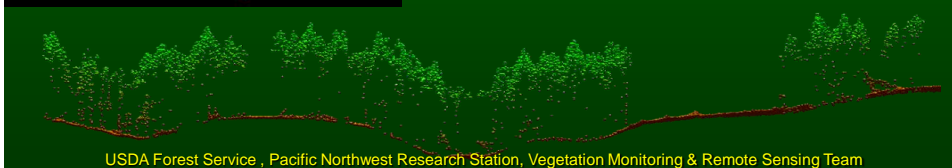
High-resolution imagery vs LiDAR data

| NAIP Imagery	LiDAR data
• High resolution • 5-year time interval • National coverage (image server) • Spectral information	• Nearly perfect registration • Rich information content on vegetation structure • Independent of illumination conditions
• Often oblique and with multipixel misregistration • Lack of radiometric consistency • Shadowing effects	• Available only sporadically and costly • Single wavelength • Very high data volume • Demanding on computational resources

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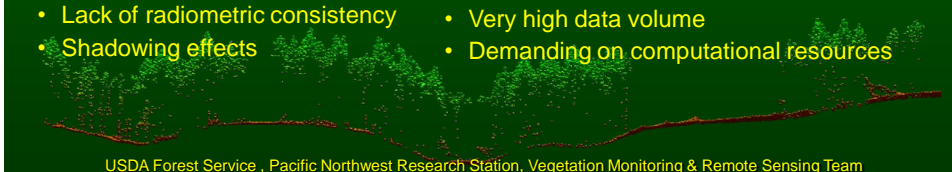
Estimation of canopy cover (photointerpretation vs LiDAR)
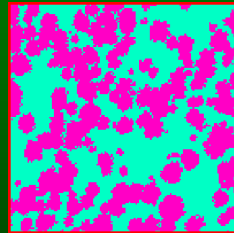
LiDAR = 50.2 %

PI = 49.5 %

Estimation of canopy cover (cont.)

LiDAR = 63.1 %
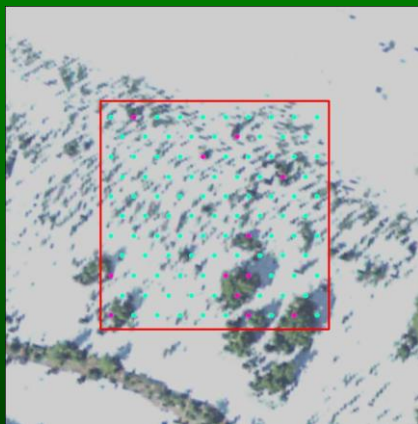
PI = 11.4 %
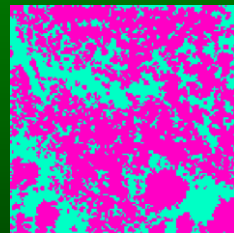
Estimation of canopy cover (cont.)

Canopy cover estimates
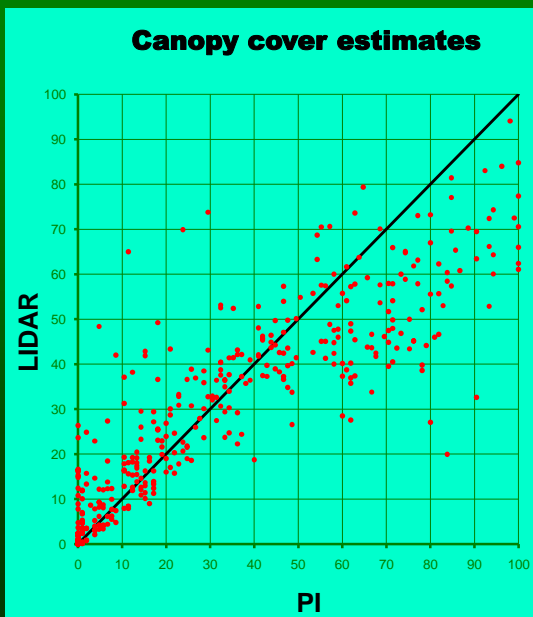
- **397 90x90m plots**

- **0.70 m LiDAR-derived rasters of CC**

- **2 m height threshold**

- **RMSD 15.2 %**

Terrestrial LiDAR

Leica ScanStation II

Wavelength	532 nm
Footprint diameter	6 mm at 50 m
Range precision	4 mm
Field of view	360° horizontal
	270° vertical
Intensity	12-bit

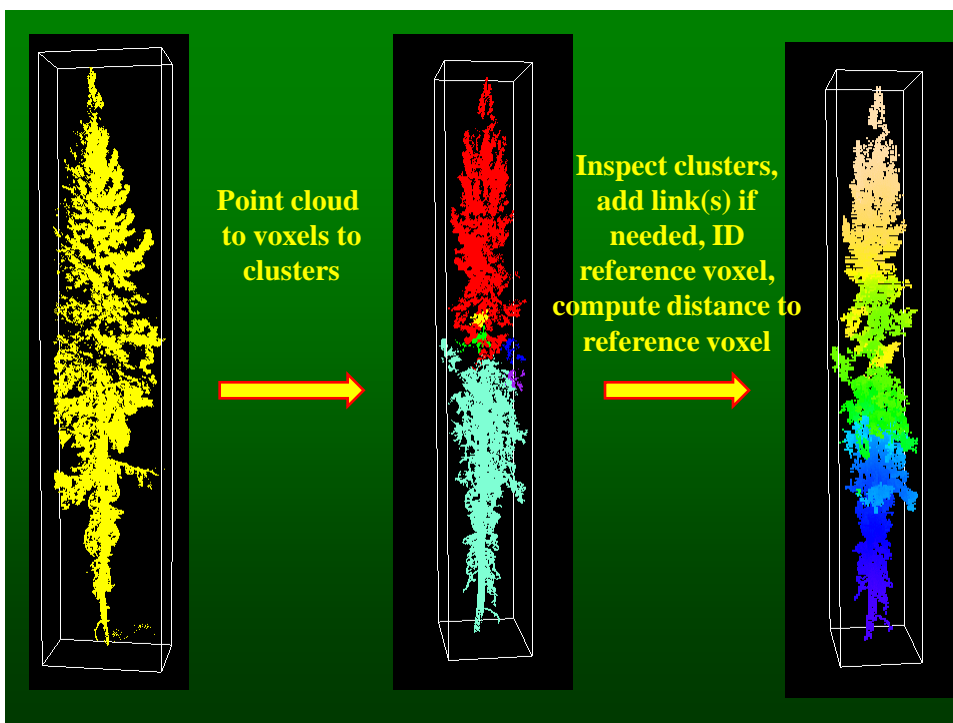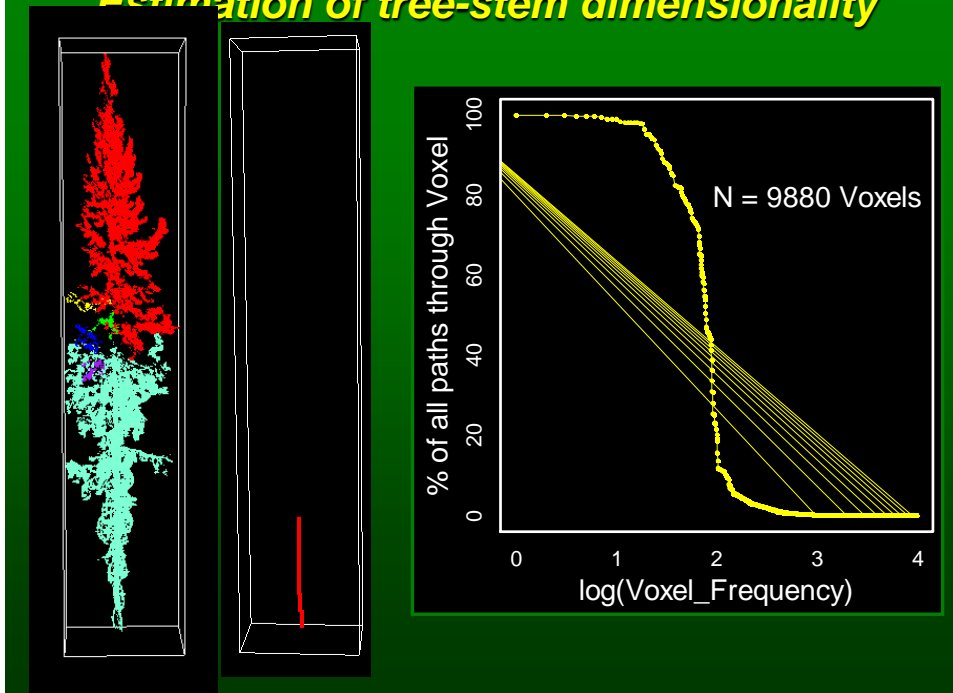| **Scan resolution**	(at 50 m)
Omnidirectional	10x10 cm
Directional	1x2 to 5x5 cm

Estimation of tree-stem dimensionality
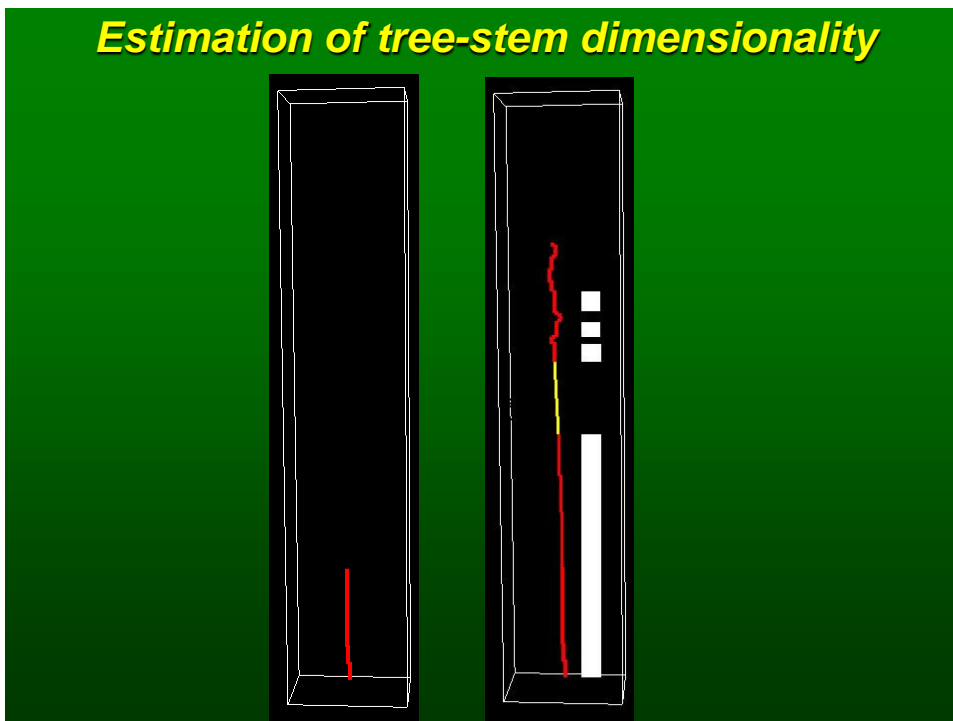
Methodology
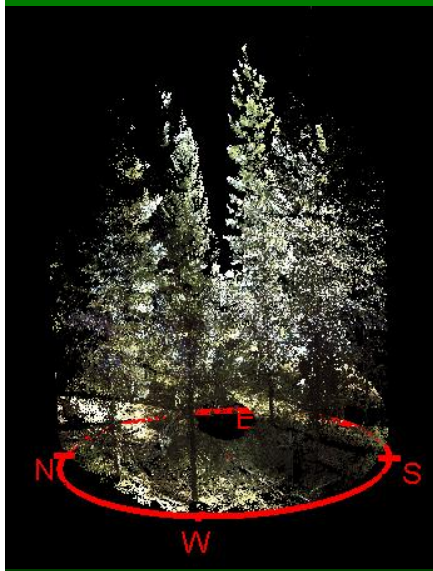
- 25 cm DEMs via TIFFs
- Density rasters of points at 1 to 2 m height
- Discretization to ~10 cm voxels
- Voxels to clusters (3D connected components algorithm)
- Cluster inspection
- Selection of 'reference' voxel (or node) at base of tree
- Computation of minimum distance between reference and all other voxels (Dijkstra's algorithm, 3D version)
- Computation of node dominance
- Retrieval of main stem axis
- Cylinder fitting to points in vicinity of stem axis

Point cloud to voxels to clusters

Inspect clusters, add link(s) if needed, ID reference voxel, compute distance to reference voxel

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Estimation of tree-stem dimensionality

Estimation of tree-stem dimensionality

Estimation of tree-stem dimensionality