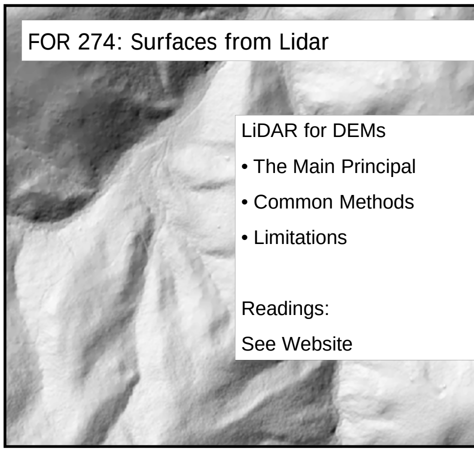
FOR 274: Surfaces from Lidar



LiDAR for DEMs

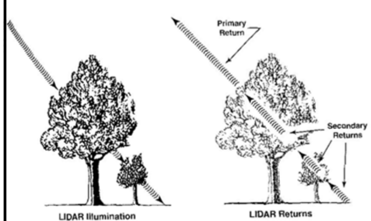
- The Main Principal
- Common Methods
- Limitations

Readings:

See Website

Lidar DEMs: Understanding the Returns

The laser pulse travel can travel through trees before hitting the ground. Secondary returns <u>might not be from the ground</u>

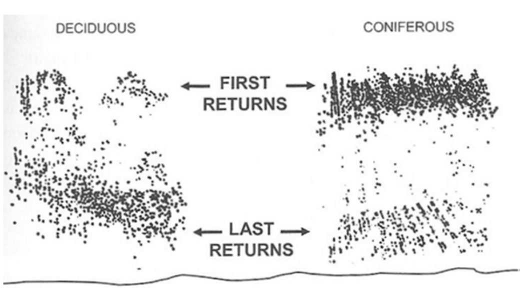


Non ground objects could include:

- Shrubs
- Ladder Fuels
- Seedlings
- Buildings
- Wildlife
- TANKS!!!

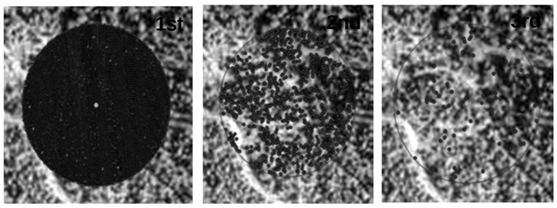
Lidar DEMs: Understanding the Returns

The different vertical structure of deciduous and coniferous forests can be highlighted by the returns



Lidar DEMs: Understanding the Returns

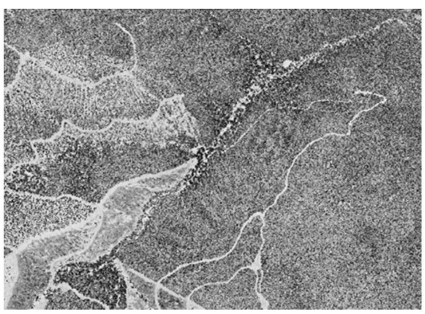
In modern lidar systems, 1-9 returns are possible depending on sensor. The returns from one pulse are not in the same horizontal or vertical location.



Source: Jeffrey Evans USFS RMRS-Moscow

Lidar DEMs: Understanding the Returns

The Intensity is an output of all Lidar acquisitions



Intensity

Intensity of the object reflecting the laser

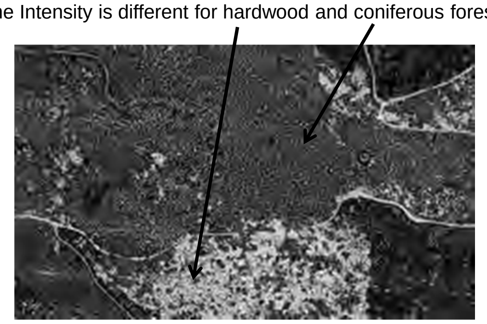
8-bit scale (0-255)
Adaptive Gain (values are not calibrated)

Orthorectified image

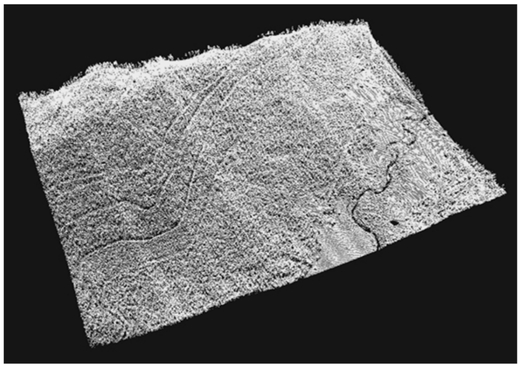
Source: Jeffrey Evans USFS RMRS-Moscow

Lidar DEMs: Understanding the Returns

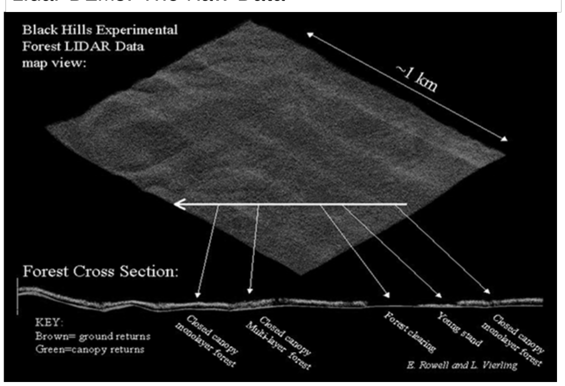
The Intensity is different for hardwood and coniferous forests



Lidar DEMs: The Raw Data

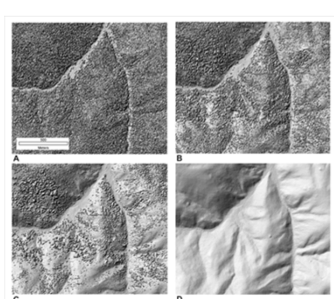


Lidar DEMs: The Raw Data



Lidar DEMs: The General Principal

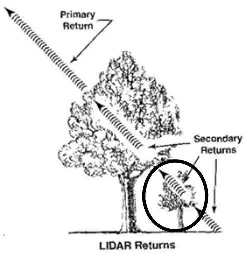
To generate a DEM from Lidar we identify what returns are associated with the ground reflections and delete all the rest.



Source: Jeffrey Evans USFS RMRS-Moscow

Lidar DEMs: The General Principal

Many different methods exist to identify the ground from non-ground returns. They are called “filtering” methods



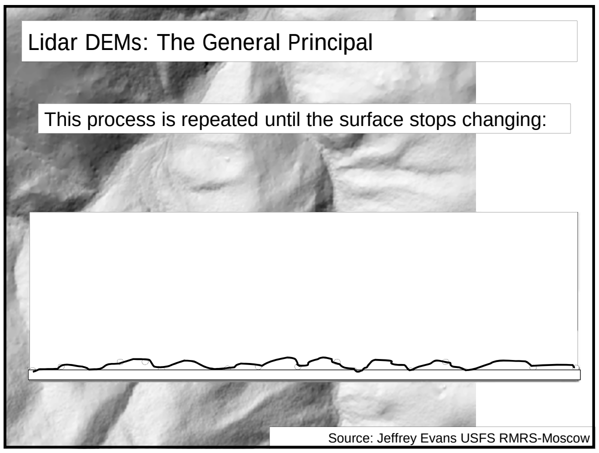
The challenge in forestry is that most of those filtering methods don’t cope well with non-ground objects beneath the first returns:

Shrubs, seedlings, wildlife, ladder fuels, coarse woody debris, slash, etc, etc, etc

Source: Campbell 2007

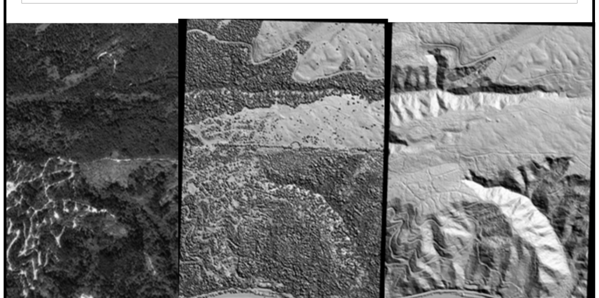
Lidar DEMs: The General Principal

This process is repeated until the surface stops changing:



Source: Jeffrey Evans USFS RMRS-Moscow

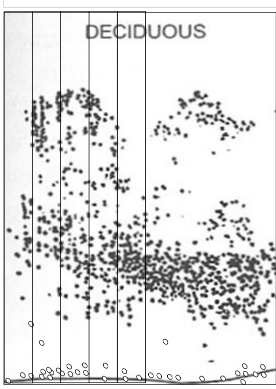
Lidar DEMs: The General Principal



Source: Jeffrey Evans USFS RMRS-Moscow

Lidar DEMs: The General Principal

Lidar DEMs: The Block Minimum Method

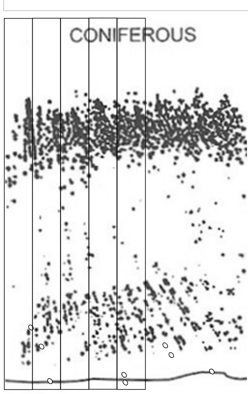


Block Minimum:

The Lidar points are divided into grid cells and the lowest point is chosen as the ground.

- Easy to Implement
- Does not work well in high canopy cover forests

Lidar DEMs: The Block Minimum Method



Block Minimum:

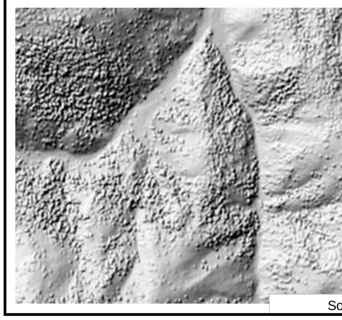
When canopy cover / biomass is high there may be very few ground returns in your “bin”

You might need select lowest point in 5x5m area instead of 1x1 m areas

If the bin is too large you might miss topographic features!!!

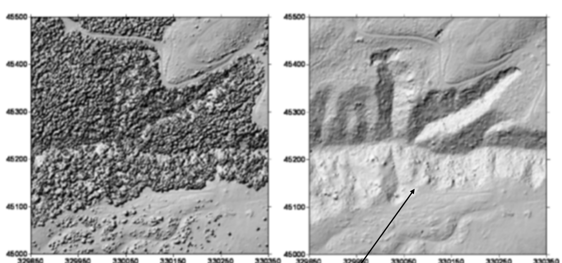
Lidar DEMs: The Block Minimum Method

In this case a Block Minimum 6 x 6 meter bin size was still not enough to “see” enough ground returns.



Source: Jeffrey Evans USFS RMRS-Moscow

Lidar DEMs: The Block Minimum Method



In general, Block Minimum has problems with shrub and understory or when canopy cover is high

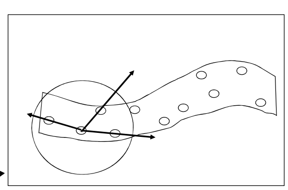
From Zang et.al, (2000)

Lidar DEMs: The Slope Threshold Method

Slope Threshold:

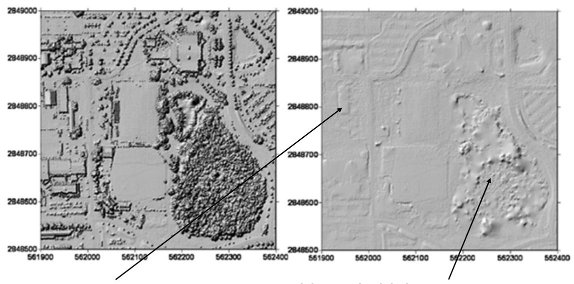
Starting at the 1st point, all points higher than a slope from the first point are deleted.

Then repeat at the next point



Lidar DEMs: The Slope Threshold Method

Problems where features have abrupt edges: buildings/cliffs



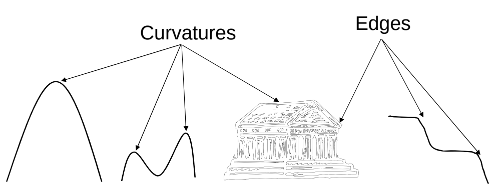
Building Footprint　　　Problems in high canopy cover

From Vosselman, (2000)

Lidar DEMs: The Progressive Curvature Filter

What is a curvature?

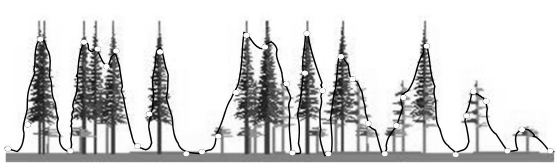
- An aberration from the ground
- A point higher than the surrounding points
- Not an edge!!!



Source: Jeffrey Evans USFS RMRS-Moscow

Lidar DEMs: The Progressive Curvature Filter

We have curvatures in Forestry.



This method is widely used by the USFS and other agencies (ARS, BLM, etc).

Source: Jeffrey Evans USFS RMRS-Moscow

Lidar DEMs: The Progressive Curvature Filter

We have curvatures in Forestry.

As the filter does each pass, the curvatures in the forest becomes less distinct

Source: Jeffrey Evans USFS RMRS-Moscow

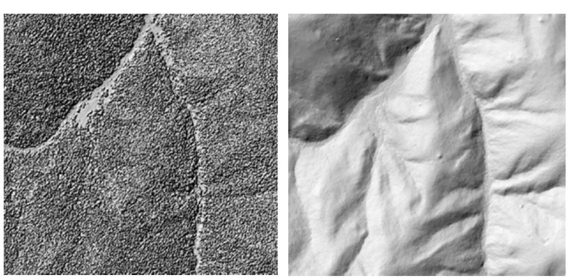
Lidar DEMs: The Progressive Curvature Filter

We have curvatures in Forestry.

This method repeats until a “smooth” surface remains

Source: Jeffrey Evans USFS RMRS-Moscow

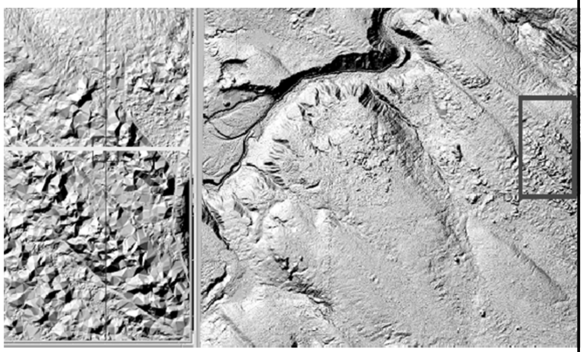
Lidar DEMs: The Progressive Curvature Filter



DEM produced in high biomass area.

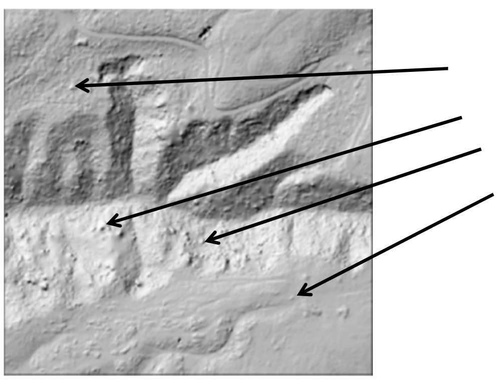
Source: Jeffrey Evans USFS RMRS-Moscow

Lidar DEMs: Common Errors - Les Moutons



Source Lefsky (2005)

Lidar DEMs: Common Errors - Les Moutons

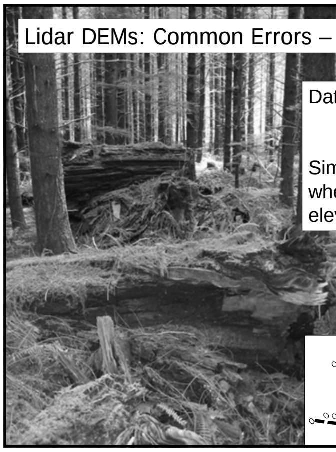


Lidar DEMs: Common Errors – Data Gaps

Data Gaps:

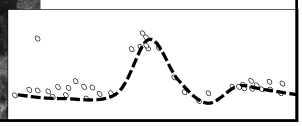
If too few ground returns are present the ground surface may miss “real” topographic features

Lidar DEMs: Common Errors – Data Gaps

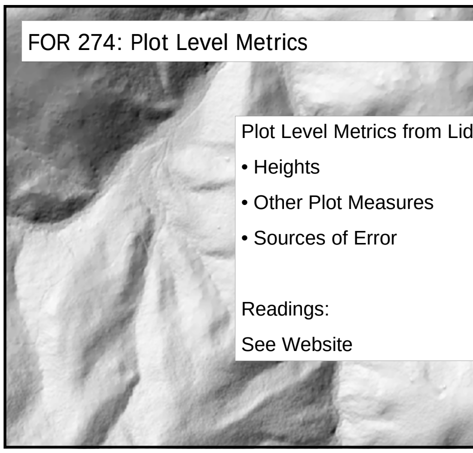


Data Gaps:

Similar problems can occur when the lowest return is from elevated vegetation



FOR 274: Plot Level Metrics



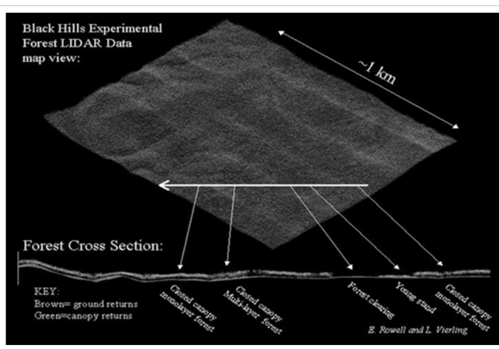
Plot Level Metrics from Lidar

- Heights
- Other Plot Measures
- Sources of Error

Readings:

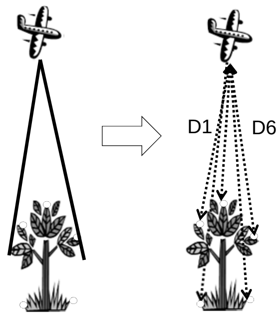
See Website

Plot Level Metrics: Getting at Canopy Heights



Heights are an Implicit Output of Lidar data

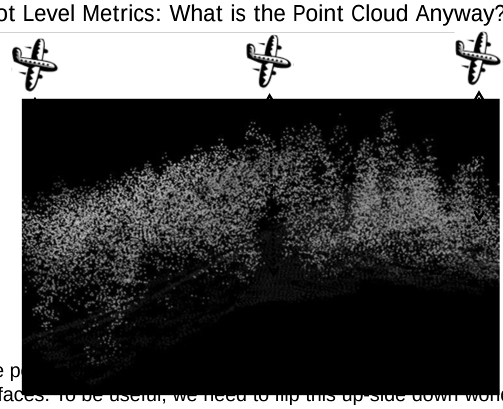
Plot Level Metrics: What is the Point Cloud Anyway?



Each distance from the plane to the surfaces is recorded:

Returns from surfaces further away from the sensor have a greater distance but a lower relative elevation than those “closer” returns

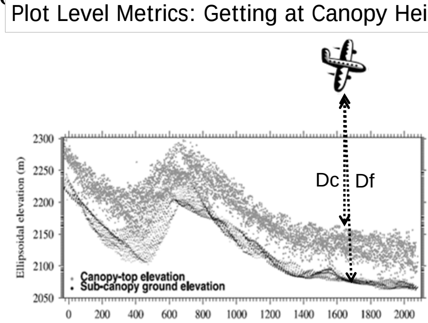
Plot Level Metrics: What is the Point Cloud Anyway?



The p

surfaces. To be useful, we need to flip this up-side down world.

Plot Level Metrics: Getting at Canopy Heights

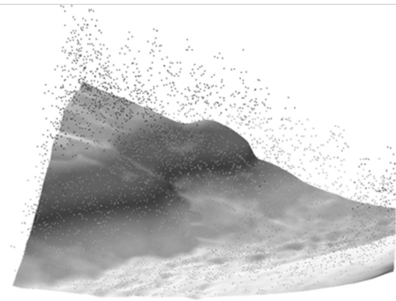


Heights = Df- Dc

We flip the data by subtracting the distance from the plane to the closer surfaces (Dc) from the distance from the plane to the furthest away surfaces (Df).

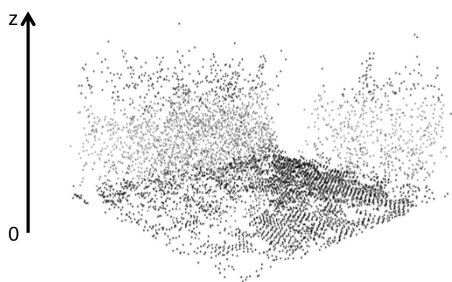
Plot Level Metrics: Getting at Canopy Heights

To get heights, subtract the “elevations” of the closer lidar points from the filtered “ground surface elevations” obtained from the Lidar DEM



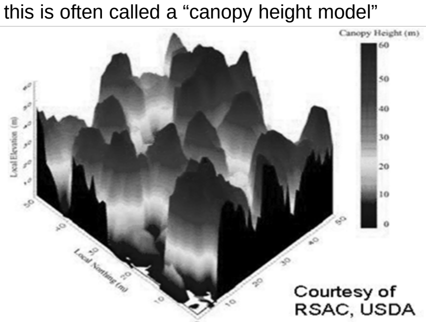
Plot Level Metrics: Getting at Canopy Heights

This produces a point cloud where the DEM has a height of zero and the returns closer to the sensor have increasingly higher “heights”



Plot Level Metrics: Getting at Canopy Heights

When in forestry continuous surfaces are fit to the non-ground heights this is often called a “canopy height model”



Plot Level Metrics: Canopy Height Models

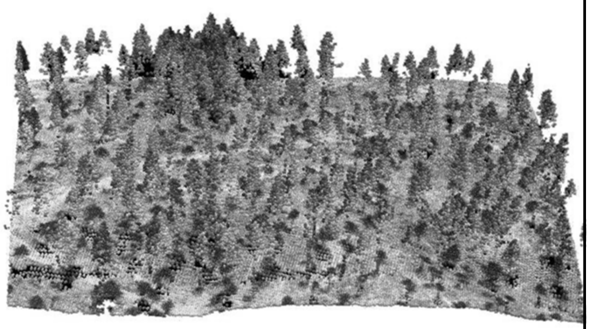


Image source: H-E Anderson

Plot Level Metrics: Canopy Height Models

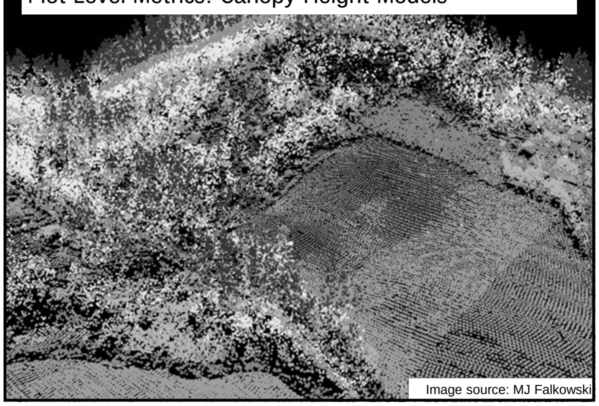


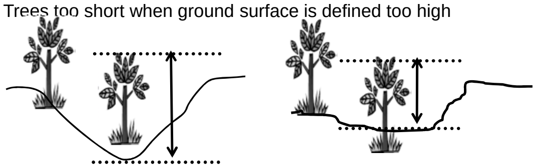
Image source: MJ Falkowski

Plot Level Metrics: Sources of Height Error

Interpolation Error:

The ground surface may be derived incorrectly due to insufficient ground returns at specific trees. Can occur in patches of high canopy cover or when sub-canopy features are present (seedlings, fuel buildup, etc)

- Trees too tall when ground surface is defined too low
- Trees too short when ground surface is defined too high

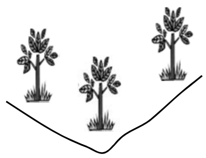


Plot Level Metrics: Sources of Height Error

Scale Error:

The ground surface may be derived incorrectly BUT have a consistent bias (up or down) due to insufficient ground returns across a series of trees.

This can also happen when the method to obtain the ground has been over-smoothed: i.e. too many returns deleted



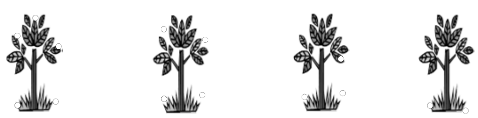
Plot Level Metrics: Sources of Height Error

Tree Measurement Errors:

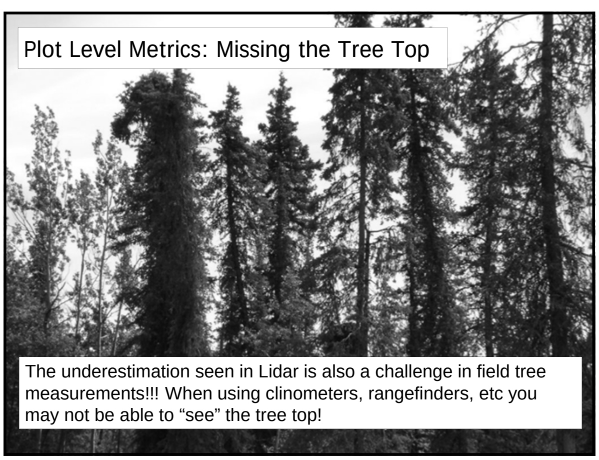
If too few returns are obtained per tree the maximum height may not be close to the actual tree height

In general Lidar will miss the tree top and will underestimate the true maximum tree height

Ideal Top Missed Tree Missed



Plot Level Metrics: Missing the Tree Top

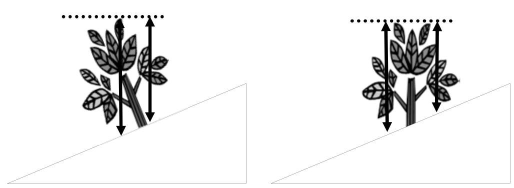


The underestimation seen in Lidar is also a challenge in field tree measurements!!! When using clinometers, rangefinders, etc you may not be able to “see” the tree top!

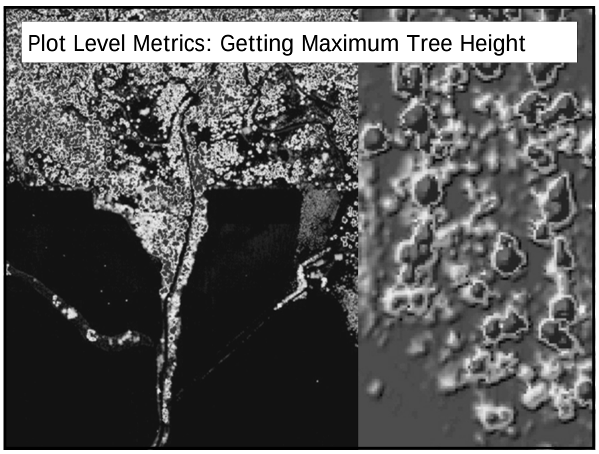
Plot Level Metrics: Sources of Height Error

Interaction between laser pulse (distance) and slope

This can be further influenced by scan angle

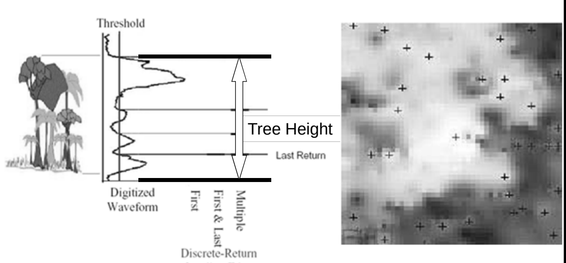


Plot Level Metrics: Getting Maximum Tree Height



Plot Level Metrics: Getting Maximum Tree Height

Assume each local maximum in the canopy surface is a tree-top

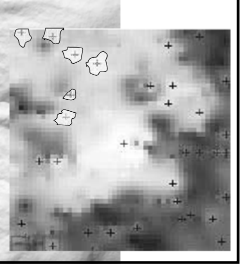


Popescu, S.C., Wynne, R.H. and Nelson, R.F. (2003.

Plot Level Metrics: Tree Crown Widths and Locations

Valley Following

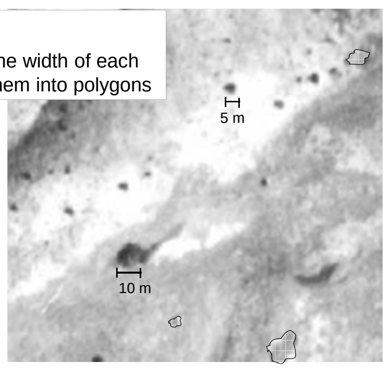
1. Assume each local maximum in the canopy surface is a tree-top
2. Apply contours to the canopy surface map
4. Find the local minimums surrounding each local maximum
5. Calculate Average N-S and E-W Diameter



Plot Level Metrics: Tree Crown Widths and Locations

Using a GIS:

Manually measure the width of each tree and delineate them into polygons



Plot Level Metrics: Tree Crown Widths and Locations

Using Allometric Equations:

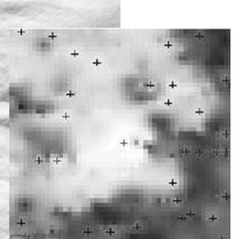
1. Assume each local maximum in the canopy surface is a tree-top
2. Derive crown diameter from height relations:

cd = 2.56 * 0.14h

From:

Falkowski, M.J., Smith, A.M.S., et al., (2006). Automated estimation of individual conifer tree height and crown diameter via Two-dimensional spatial wavelet analysis of lidar data, *Canadian Journal of Remote Sensing,* Vol. 32, No. 2, 153-161.

http://www.treesearch.fs.fed.us/pubs/24611



Plot Level Metrics: Tree Crown Widths and Locations

Using Automatic Methods

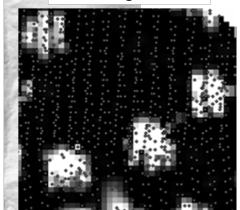
1. Convert each lidar canopy height model into a raster grid (via a GIS)
2. Use automated methods to 'detect' the location and crown width of each lidar tree

For more information see:

Falkowski, M.J., Smith, A.M.S., et al., (2006). Automated estimation of individual conifer tree height and crown diameter via Two-dimensional spatial wavelet analysis of lidar data, *Canadian Journal of Remote Sensing*, Vol. 32, No. 2, 153-161.

http://www.treesearch.fs.fed.us/pubs/24611

Lidar Height Data



Plot Level Metrics: Tree Crown Widths and Locations

Using Automatic Methods

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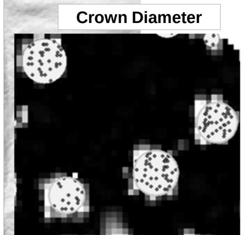
http://www.treesearch.fs.fed.us/pubs/24611

Crown Diameter

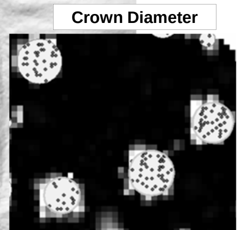


Plot Level Metrics: Crown Base Height

Crown Base Height:

1. Convert each lidar canopy height model into a raster grid (via a GIS)
2. Use automated methods to 'detect' the location and crown width of each lidar tree
3. Within the crown diameter find the lowest height > than a set value (e.g. assume heights < 1m from trees: shrubs, rocks, etc)

Crown Diameter



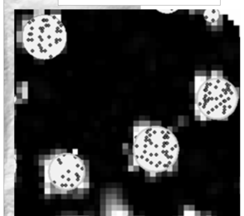
Plot Level Metrics: Crown Bulk Density

Crown Bulk Density

1. Convert each lidar canopy height model into a raster grid (via a GIS)
2. Use automated methods to ‘detect’ the location and crown width of each lidar tree
3. Assume trees have a specific shape – cone, cylinder → Volume
4. Use allometric equations via field measures to get foliar biomass

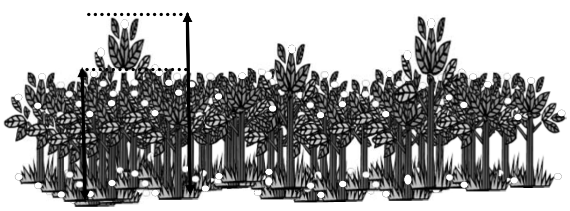
CBD = Foliar Biomass / Volume

Crown Diameter



Plot Level Metrics: Crown Class

Analysis of the Lidar data will be able to highlight trees above the canopy and importantly how tall the neighboring trees are.



What do you think the main limitation is?

Plot Level Metrics: Diameter at Breast Height

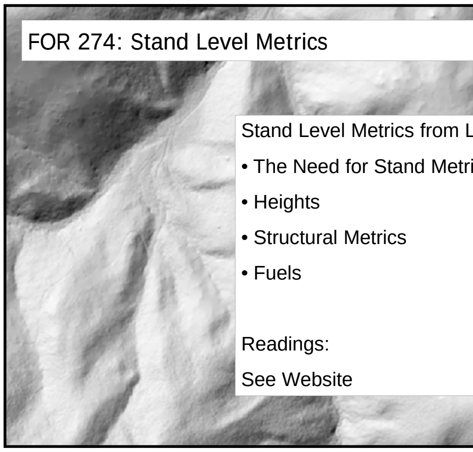
Lidar can’t yet measure DBH directly:

Must model DBH from tree heights and crown widths OR use other allometric methods to directly get Biomass. See Week 6 readings.

This creates a challenge as most Growth & Yield and Productivity models rely on a measure of DBH.

Therefore we need to develop “Lidar aware” allometric relationships!

FOR 274: Stand Level Metrics



Stand Level Metrics from Lidar

- The Need for Stand Metrics
- Heights
- Structural Metrics
- Fuels

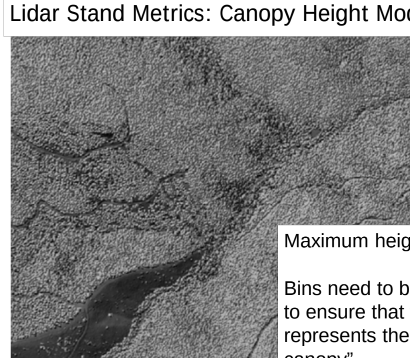
Readings:

See Website

Why Do We Care About Stand Metrics?

Forestry is rarely interested with the individual tree or a plot: Stand measures are of interest

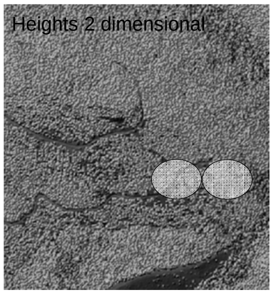
Lidar Stand Metrics: Canopy Height Model



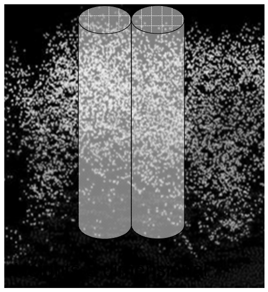
Maximum height in each bin

Bins need to be large enough to ensure that the height represents the local “top of canopy”

Lidar Stand Metrics: 2D and 3D perspective



Horizontal Distributions



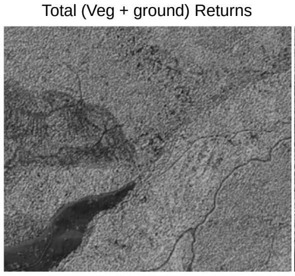
Vertical Distributions

Source: Jeffrey Evans USFS RMRS-Moscow

Lidar Stand Metrics: Canopy Cover & Density

Canopy Cover: $\frac{\text{Canopy Returns}}{\text{Total (Veg + ground) Returns}}$

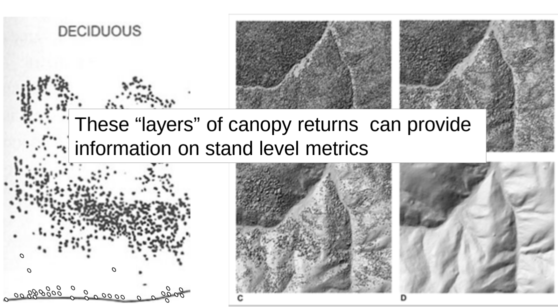
Canopy Density: $\frac{\text{Canopy Returns}}{\text{Total Veg Only Returns}}$



Source: Jeffrey Evans USFS RMRS-Moscow

Lidar Stand Metrics: Getting at Stand Metrics

When we created a DEM we identified what returns were associated with the ground reflections and deleted the rest.

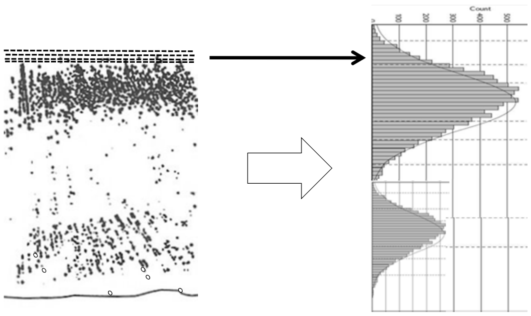


These “layers” of canopy returns can provide information on stand level metrics

Source: Jeffrey Evans USFS RMRS-Moscow

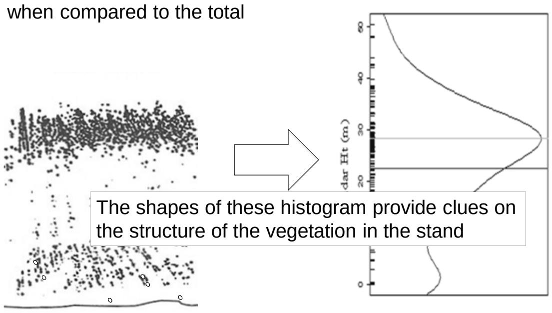
Lidar Stand Metrics: Getting at Stand Metrics

For a stand if we plot the count of returns that are present in 2m vertical “bins” we produce a Histogram of stand heights



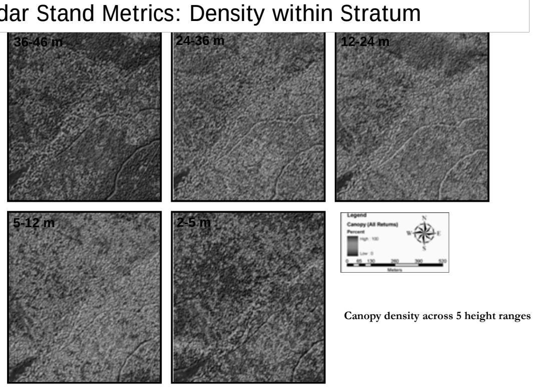
Lidar Stand Metrics: Getting at Stand Metrics

We can also plot a Histogram as a Density Function that shows the relative quantity of returns in a given height bracket when compared to the total



The shapes of these histogram provide clues on the structure of the vegetation in the stand

Lidar Stand Metrics: Density within Stratum



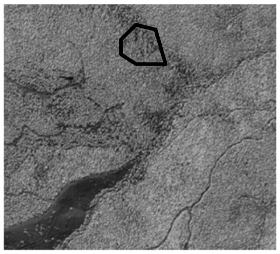
Canopy density across 5 height ranges

Forest Structure Models

Source: Jeffrey Evans USFS RMRS-Moscow

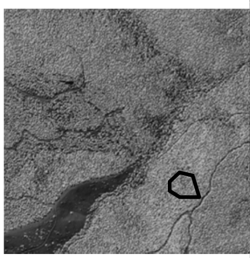
Lidar Stand Metrics: Stand Canopy Height Profiles

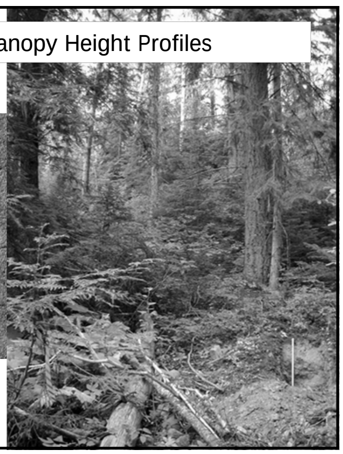
Canopy Height Map :



Lidar Stand Metrics: Canopy Height Profiles

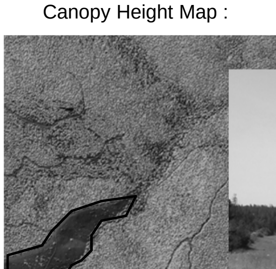
Canopy Height Map :



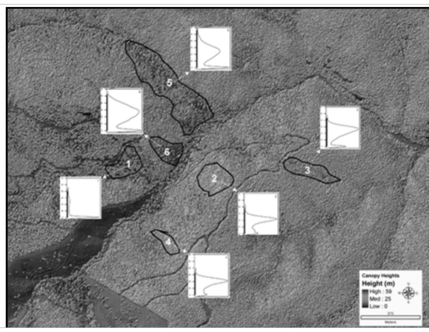


Lidar Stand Metrics: Canopy Height Profiles

Canopy Height Map :



Lidar Stand Metrics: Canopy Height Profiles



These curves can assist in delineating stands or identifying the successional stage of the vegetation within the stands