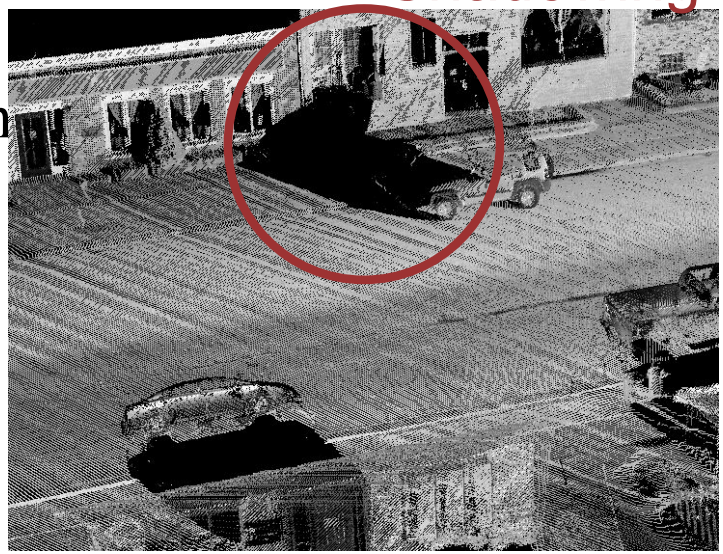
LiDAR Data Preprocessing

- Quality Control
  - Data Evaluation
- Data Management
  - Data Statistics
  - Data Classification
  - Data Rasterization
- LiDAR Data Tools
  - ArcGIS 10 Tools
  - LAS Tools

Common Errors

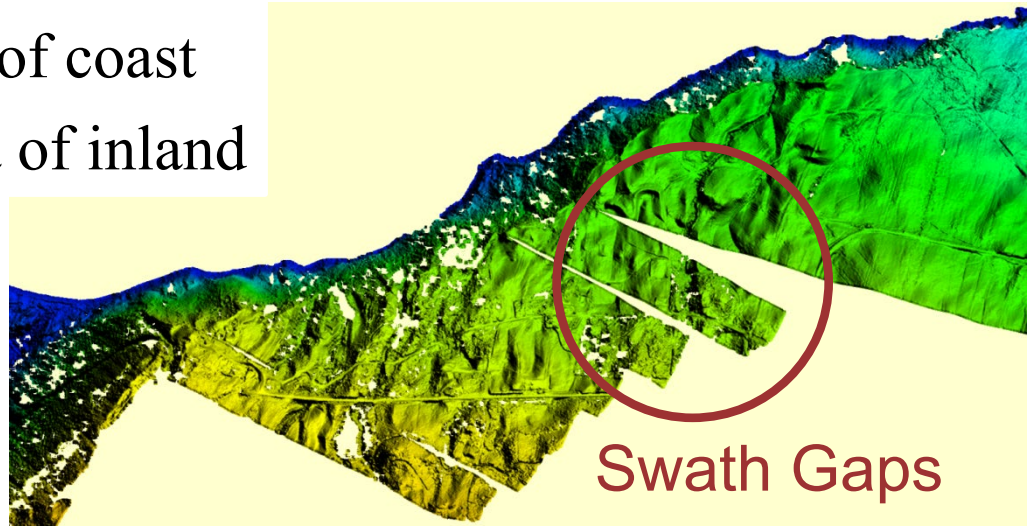
- LiDAR Data Gaps
  - Represents the lack of data that should be there
    - Results in missing data within the coverage area
  - Causes of data gaps:
    - Non-overlapping LiDAR swath
    - Shadowing Effect
      - Large vertical obstructions
      - e.g. Buildings, Ridges, etc…
    - Highly reflective surfaces
    - Absorption by water surfaces
  - Verify with aerial or satellite imagery data



https://www.LiDARusa.com/shadowing.html

Common Errors

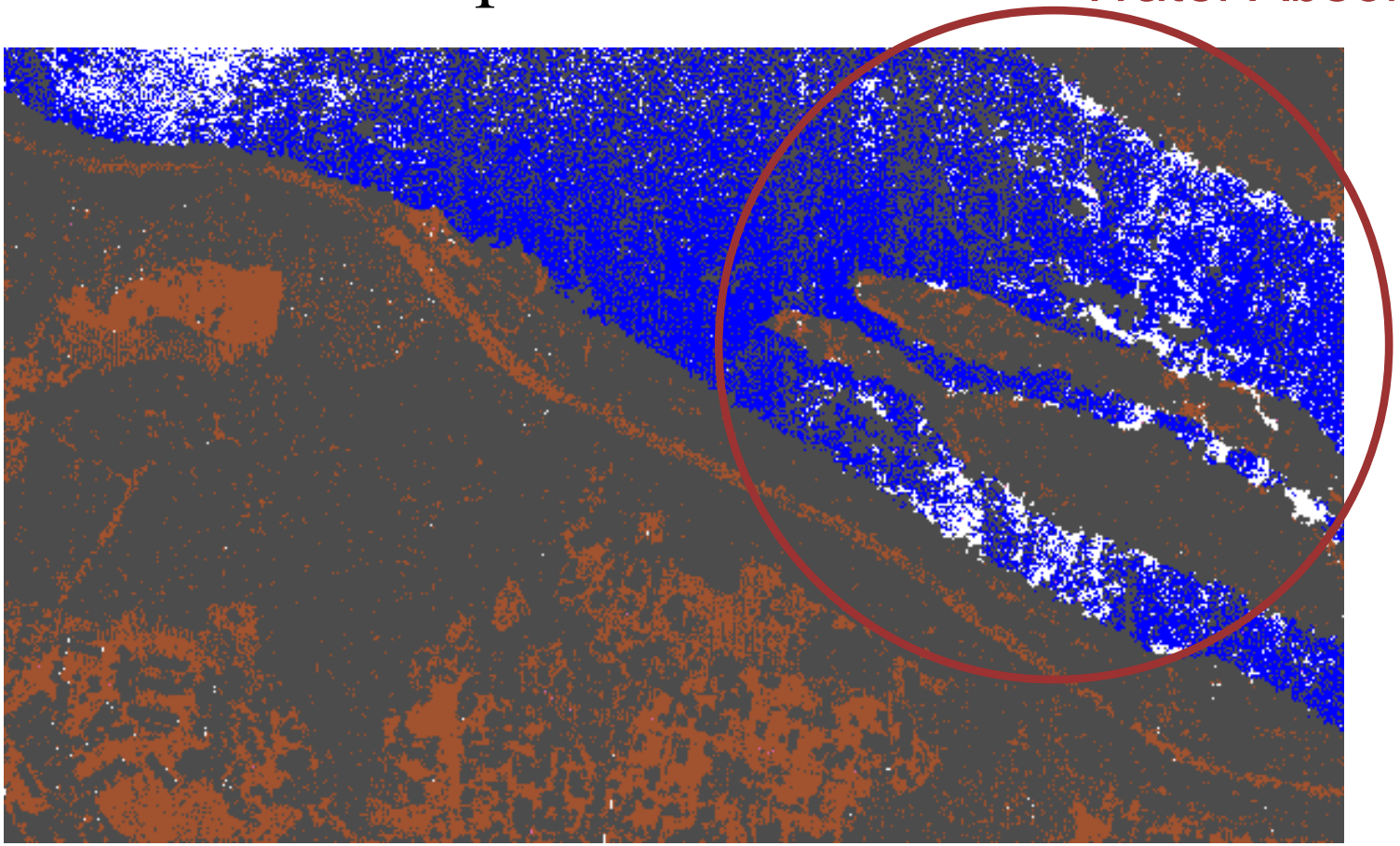
- LiDAR Data Gaps
  - Download imagery data for the site and compare
  - Does the LiDAR dataset cover the area of interest?
  - Are there any gaps in the dataset?
  - Ex: 2007 USACE LiDAR – Hawaiian Islands
    - Complete coverage of coast
    - Gaps and noisy data of inland



http://vterrain.org/Hawaii/Elevation/

Common Errors

- LiDAR Data Gaps



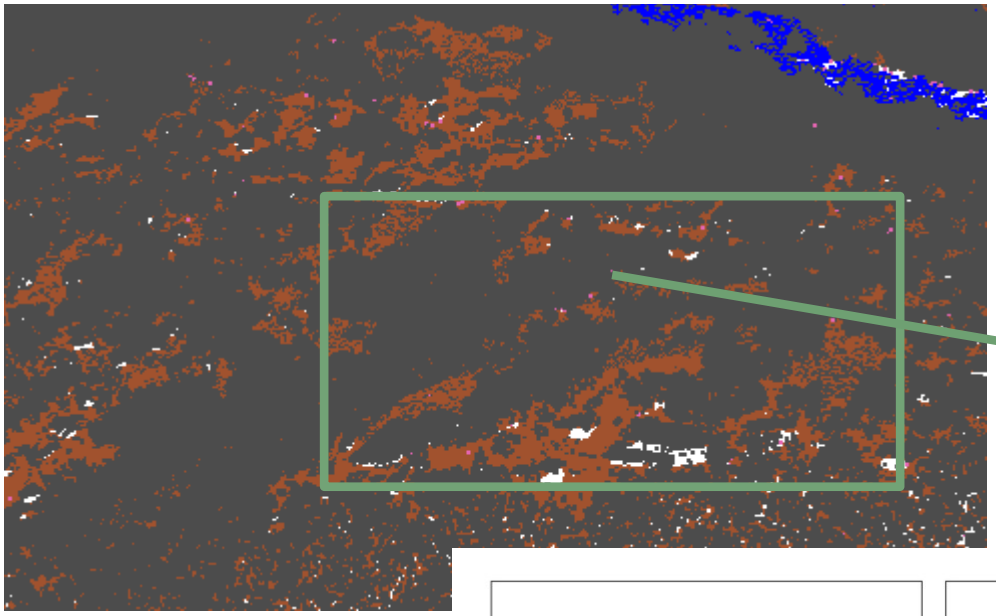
Common Errors

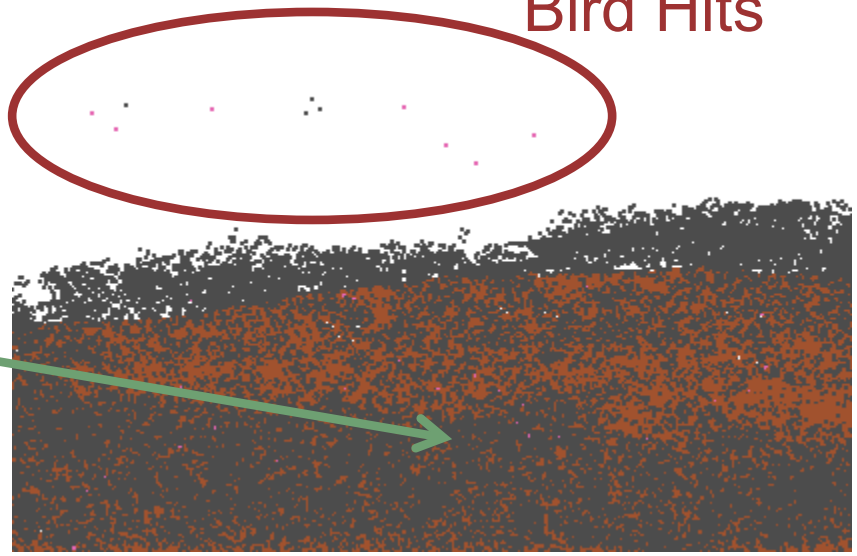
- LiDAR Data Artifacts
  - Represents data noise that should not be there
    - Results in unwanted data that could affect analysis
  - Causes of data artifacts:
    - Atmospheric aerosols (dust, moisture, etc.)
    - Birds and other moving objects (AKA Bird Hits)
  - Need to be filtered out of LiDAR datasets
    - Manual section and removal
    - Automatic classification
  - Do not delete! Use LAS Class Code = 7 (Noise)

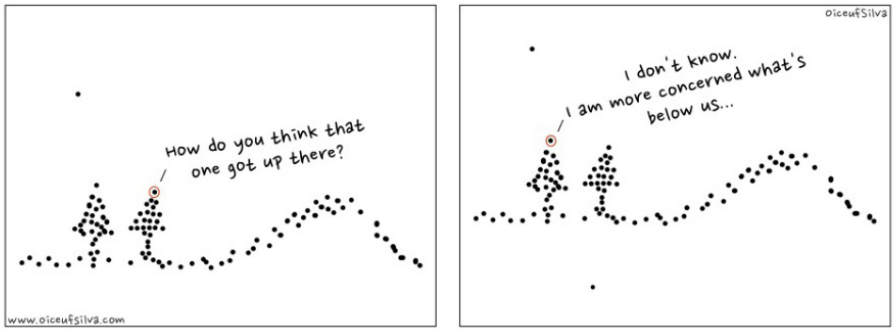
https://geonet.esri.com/blogs/larry-zhang/2014/10/29/noise-removal-and-manual-classification-in-las-cloud-points

Common Errors

- LiDAR Data Artifacts







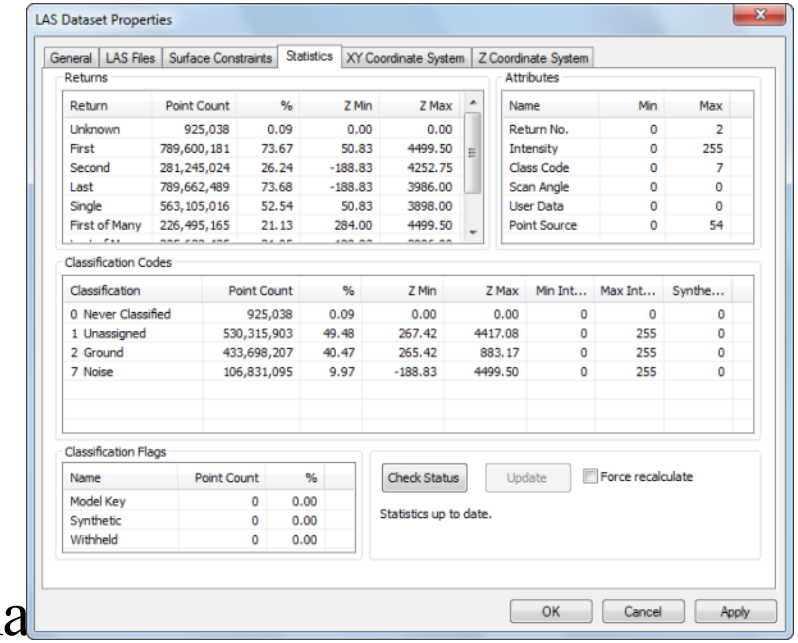
LiDAR Points

Data Management

- Some simple tools and methods we can use to get the most of out our LiDAR datasets
  1. Data Statistics (This Lecture)
     - Ways that LiDAR data can be summarized
  2. Data Classification (Lecture 6)
     - Makes further analysis easier if done accurately
     - Manual (This Lecture) vs. Automated (Lecture 6)
  3. Data Rasterization (Lecture 3)
     - Creating digital elevation models from point clouds

Data Statistics

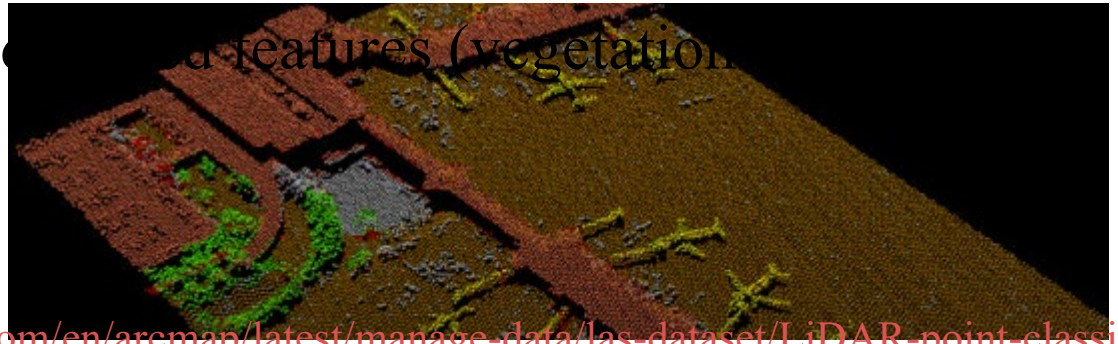
- Basic LiDAR Statistics in ArcGIS
  - Found in the LAS Dataset Properties
    - Return Numbers
    - Classifications
    - Elevation Range
    - Intensity Range
    - Scan Angle Range
  - ArcGIS Tools
    - LAS Dataset Statistics
    - LAS Point Statistics As Ra
  - LAStools - LASinfo



http://desktop.arcgis.com/en/arcmap/latest/tools/data-management-toolbox/las-dataset-statistics.htm

Data Classification

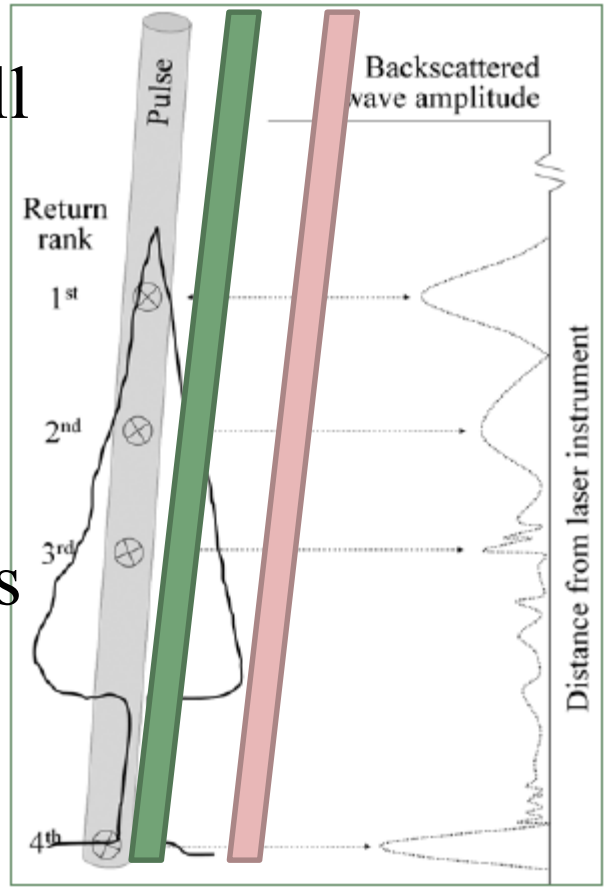
- Overview
  - Stored per point as the LAS Classification Code
  - LiDAR vendor will perform some basic classification
    - Usually results in ground and "unclassified"
  - Up to the user to further classify the data
    - Reclassify data (ground vs. non-ground)
    - A[illegible] features (vegetation



http://desktop.arcgis.com/en/arcmap/latest/manage-data/las-dataset/LiDAR-point-classification.htm

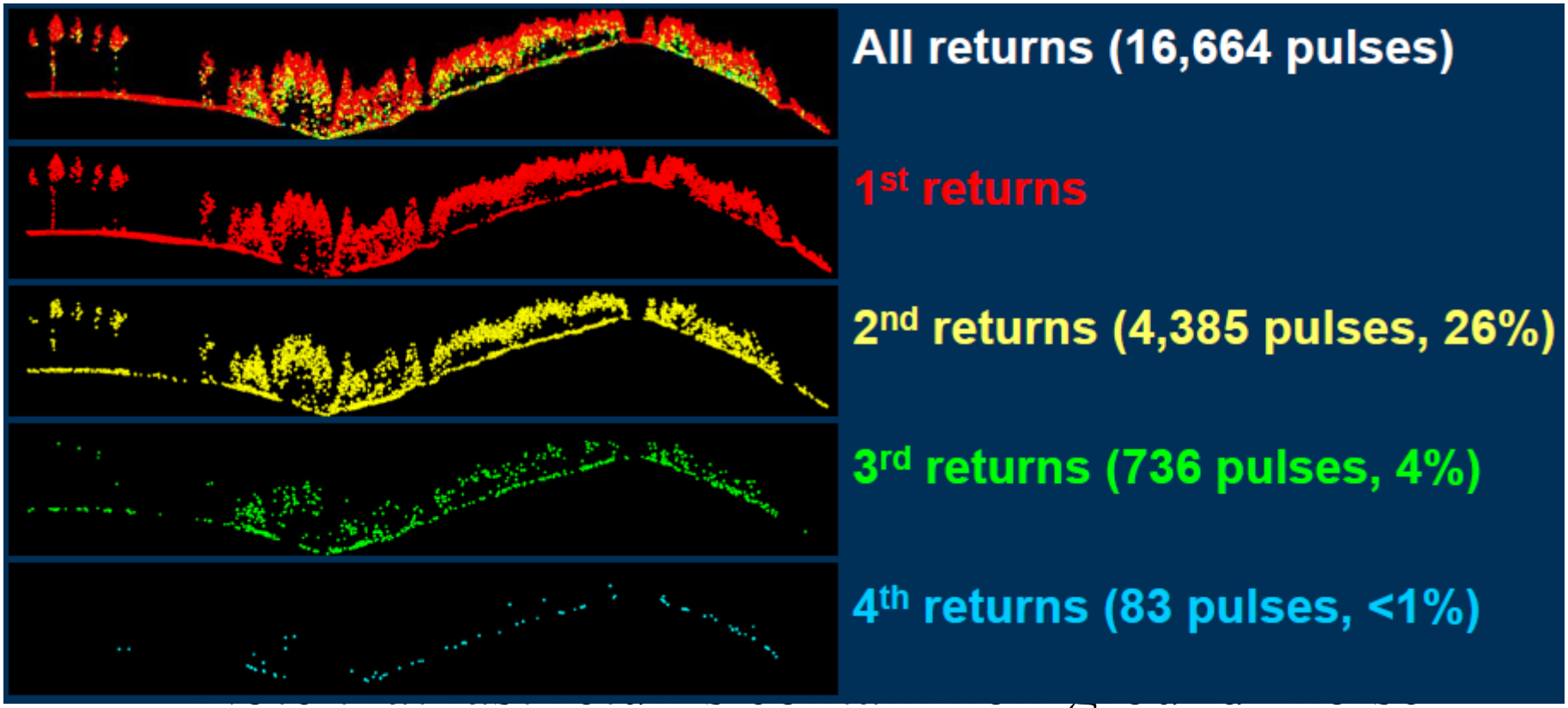
Data Classification

- Discrete LiDAR Systems
  - Remember, each LiDAR pulse will have numerous returns / photons
  - However, discrete LiDAR records only a few of these returns
    - Typically this is 1 to 5 Returns
  - A LiDAR designed for five returns will not always record five
    - Depends on the topography which influences the amplitude of returns



Data Classification

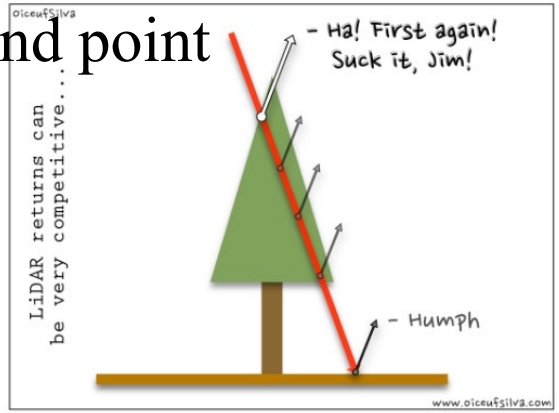
- Discrete LiDAR Systems



http://LiDAR.cr.usgs.gov/downloadfile2.php?file=Nayegandhi_LiDAR_Technology_Overview.pdf

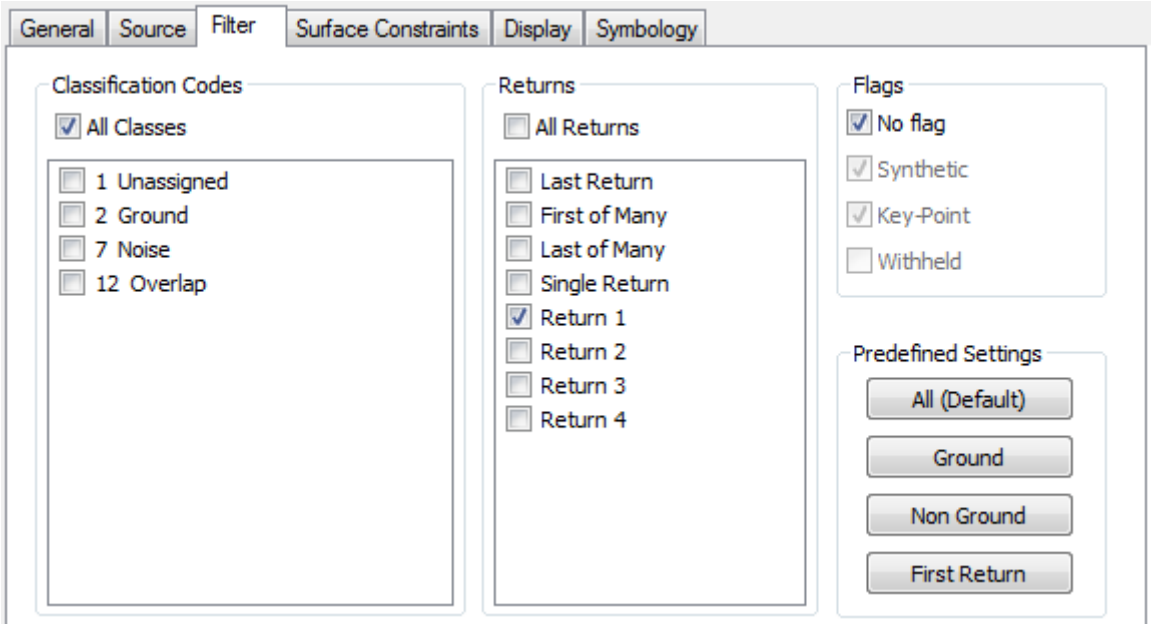
Data Classification

- Return Classes
  - Provide more info than the Return Number
  - Can be determined by simple algorithms
  - Example Classes:
    - Single Return → Possible ground or solid surface point
    - First Return of Many → Possible tree top point
    - Last Return of Many → Possible ground point
  - Why bother?
    - Aids with filtering LiDAR data
    - Aids with creating surface models



Data Classification

- Filtering LiDAR Data in ArcGIS
  - Right click the dataset in the Table of Contents
  - Filtering effects both display and analysis

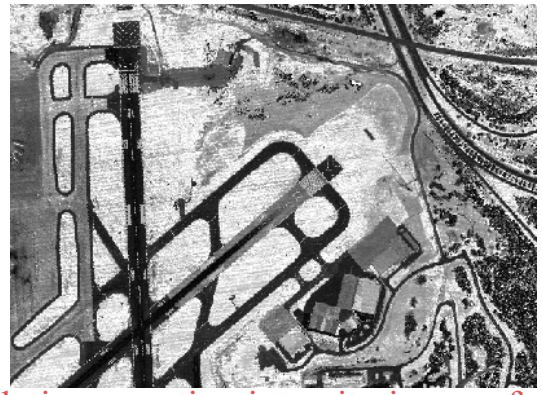


Data Rasterization

- Converting 3-D data to 2.5-D data
  - 3-D = Multiple z values for any x,y coordinate
  - 2.5-D = Single z value for each x,y coordinate
  - Binning
    - Selecting a Cell Size and putting LiDAR data in each cell
  - Filtering
    - Removing points of particular class, height, etc...
  - Interpolation
    - Implementing a method for filling in "No Data" gaps
  - More on this next Lecture…

Data Rasterization

- Elevation Raster → Digital Elevation Model
  - More next Lecture…
- Intensity Raster → Intensity Map / Image
  - LAS Dataset to Raster tool
    - The average return strength of the pulse at each point
    - ESRI recommends filtering by first returns

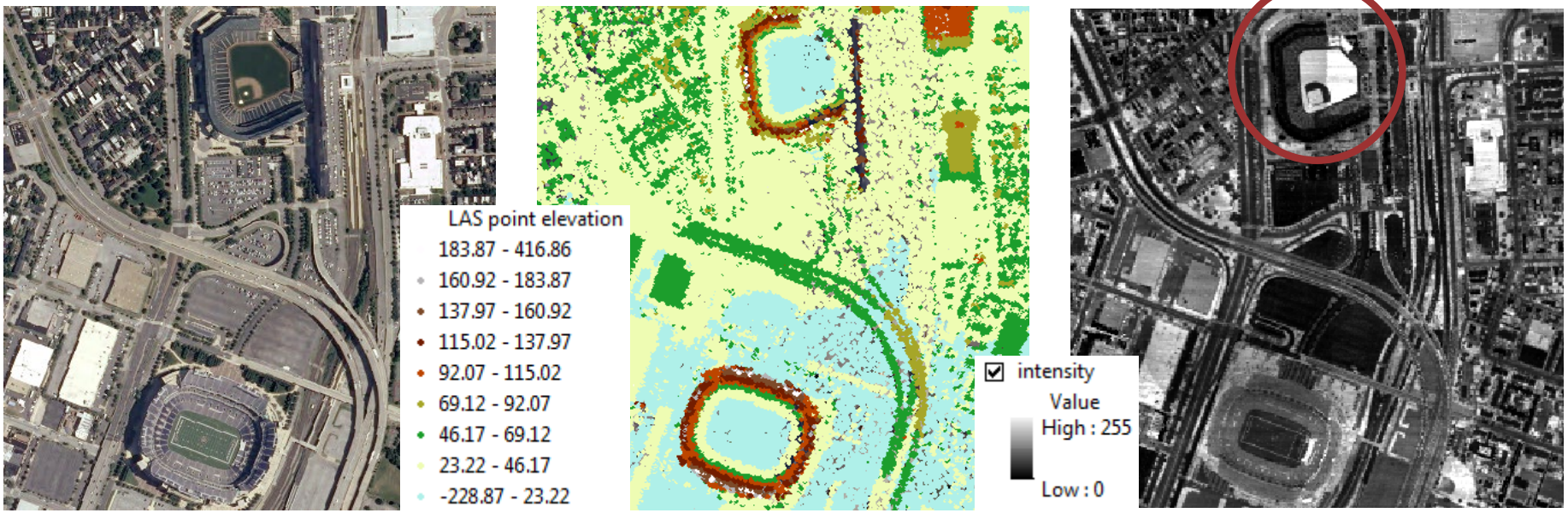


http://desktop.arcgis.com/en/arcmap/latest/manage-data/las-dataset/LiDAR-solutions-creating-intensity-images-from-LiDAR.htm

Data Rasterization

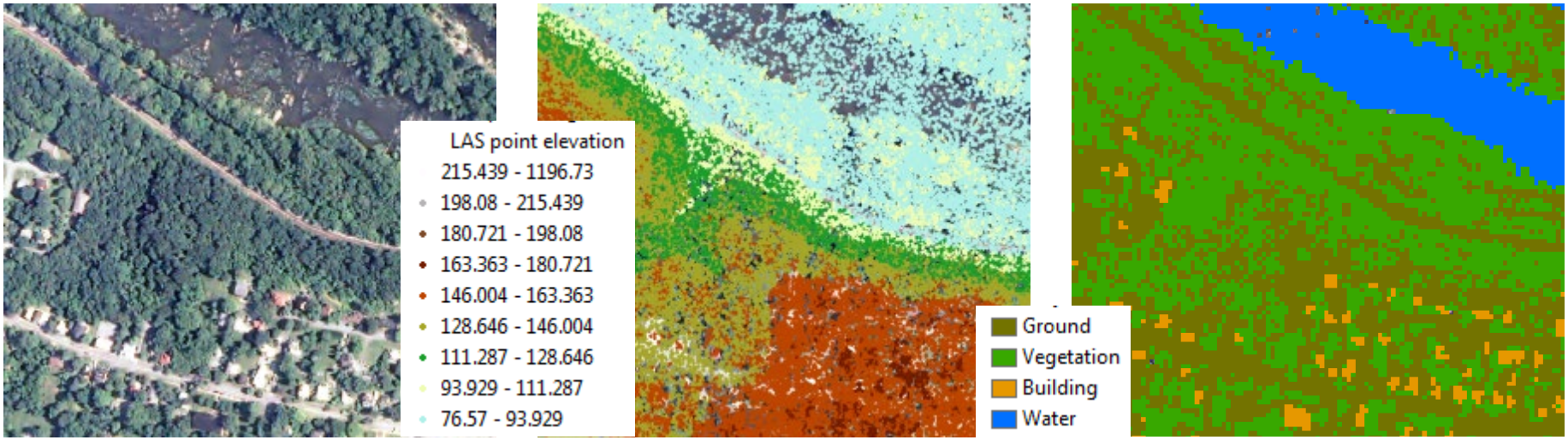
- Example – Baltimore, MD
  - Intensity returns can be highly inconsistent!
    - Dependent on the reflectivity of the object hit
    - Dependent on return number, scan angle, etc..

Intensity Inconsistency



Data Rasterization

- Classification Raster → Feature Class Map
  - LAS Point Statistics As Raster tool
    - Convert LiDAR to a land use land class raster
- Example – Harper's Ferry, WV



http://desktop.arcgis.com/en/arcmap/latest/tools/data-management-toolbox/las-point-statistics-as-raster.htm

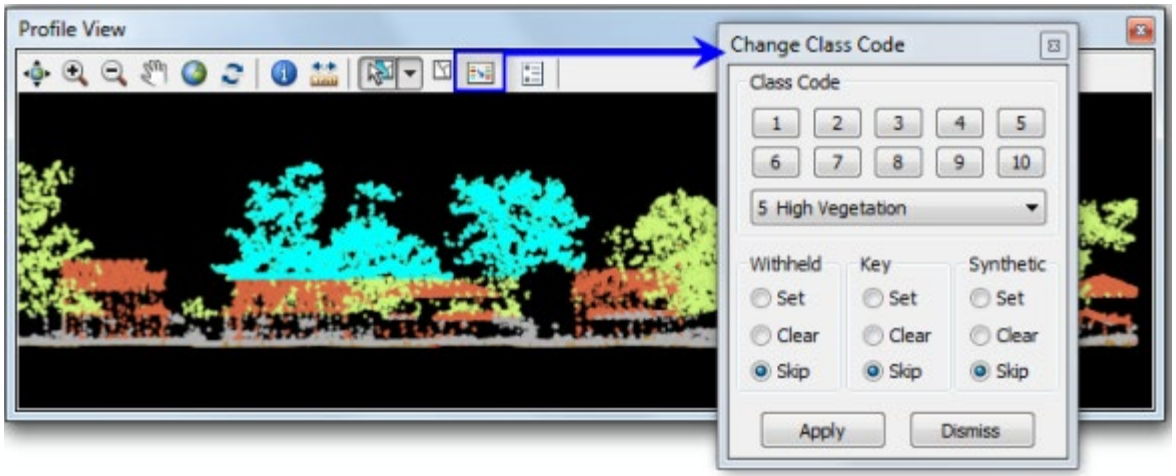
ArcGIS LiDAR Tools

- LiDAR Classification
  - Manual classification of LiDAR data
  - Change LAS Class Codes tool
    - Reclassify one set of classification codes into another
    - Works globally on the entire LAS file
    - Useful for updating the classification of LAS files generated prior to LAS 1.1 specification
  - Set LAS Class Codes Using Features tool
    - Uses a reference feature class (line, polygon)
    - Ex: Classifying water using a polygon breakline

http://desktop.arcgis.com/en/arcmap/latest/tools/3d-analyst-toolbox/change-las-class-codes.htm

ArcGIS LiDAR Tools

- LiDAR Classification
  - Manual classification of LiDAR data
  - Using the LAS Dataset Profile View tool
    - Select points manually and then change code

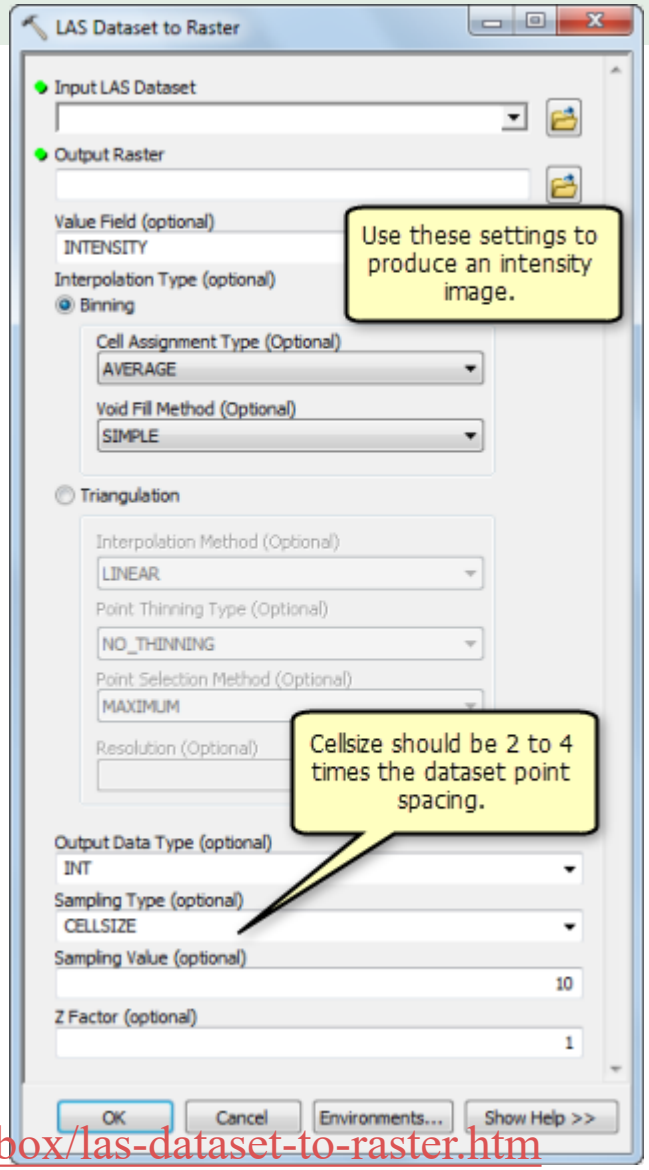


  - Automated classification methods in Lecture 6…

http://desktop.arcgis.com/en/arcmap/latest/manage-data/las-dataset/editing-las-dataset-points.htm

ArcGIS LiDAR Tools

- LiDAR Rasterization
  - LAS Dataset to Raster tool
    - Need to filter before running tool
  - For Intensity (This Lecture)
    - Use Average Value, First Returns
  - For Elevation (Lecture 3)
    - DTM = Min Value, Ground Points
    - DSM = Max Value, Non-ground
  - ESRI recommends a Cell Size ~4 times the "Point Spacing"



http://desktop.arcgis.com/en/arcmap/latest/tools/conversion-toolbox/las-dataset-to-raster.htm

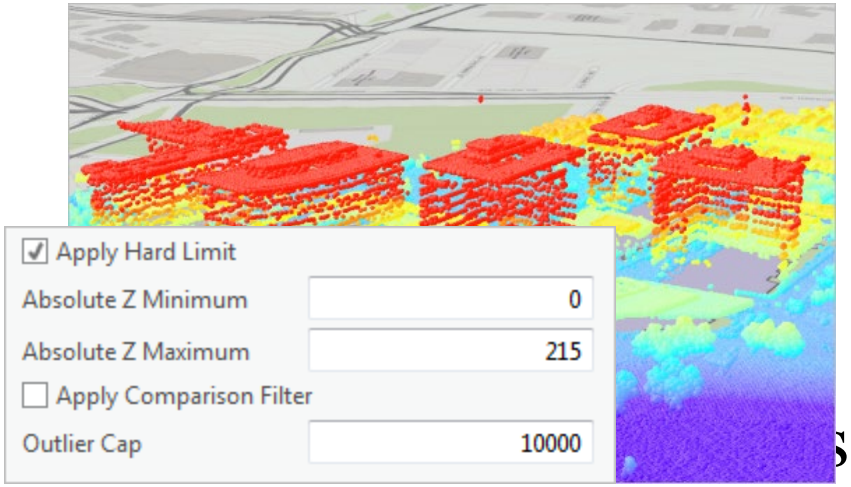
ArcGIS LiDAR Tools

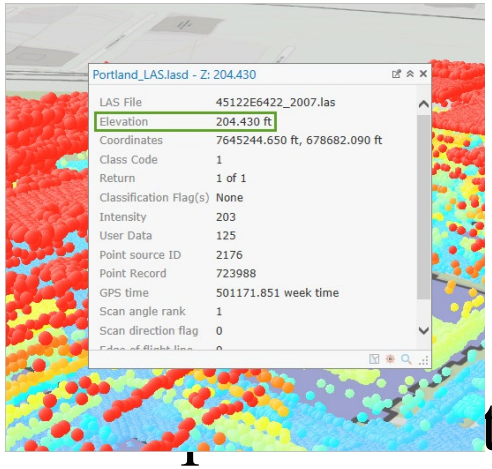
- Noise Detection
  - Locate Outliers tool
  - Identifies possible erroneous LiDAR points
  - Tool Parameters:
    - Hard Limit
      - Finds outliers based on max and min Z values
    - Comparison Filter
      - Finds outliers based on height difference relative to neighbors
      - Calculates local changes in elevation and slope
    - Outlier Cap
      - Maximum number of outliers to be identified

http://desktop.arcgis.com/en/arcmap/latest/tools/3d-analyst-toolbox/locate-outliers.htm

ArcGIS LiDAR Tools

- Locate Outliers
  - Example – Extracting Roof Forms from LiDAR
    - Goal is to create realistic 3-D Building Models
    - Locate Outliers tool is used to limit the maximum and minimum point elevations in the dataset

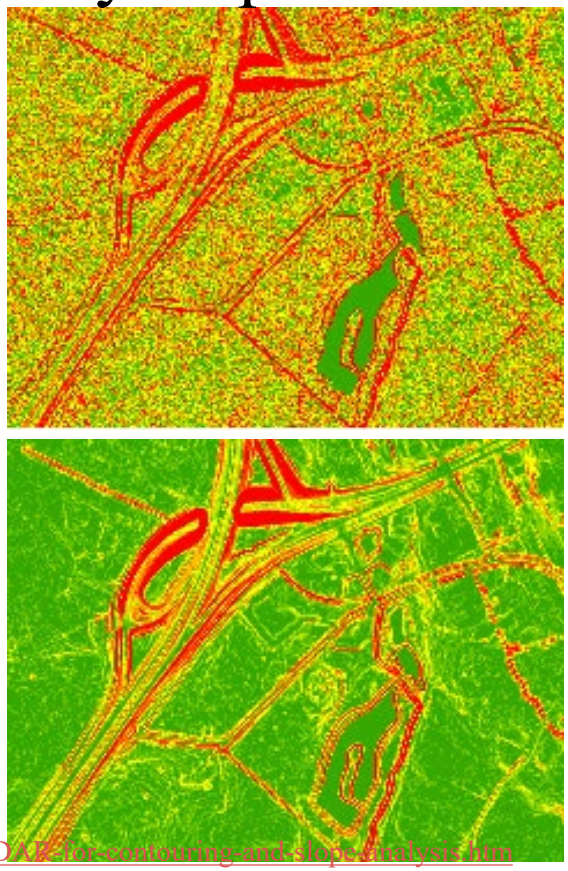


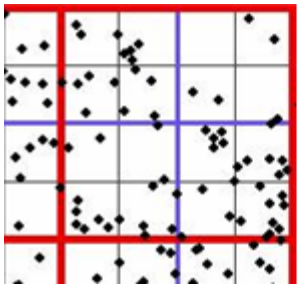


https://learn.arcgis.com/en/projects/extract-roof-forms-for-municipal-development/lessons/create-elevation-layers.htm

ArcGIS LiDAR Tools

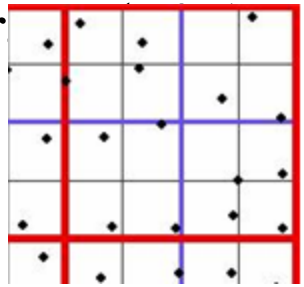
- Noise Minimization
  - Problem – LiDAR data can make messy slope maps
  - One Possible Solution
    - Convert LiDAR to terrain dataset
    - Use pyramiding to thin the data
    - Use a window size equal to the





Full Resolution Point Data

No window size pyramid level has been applied to the points.



Window Size Pyramid Level 1

One point is selected in each black window to represent the terrain at the present scale range.

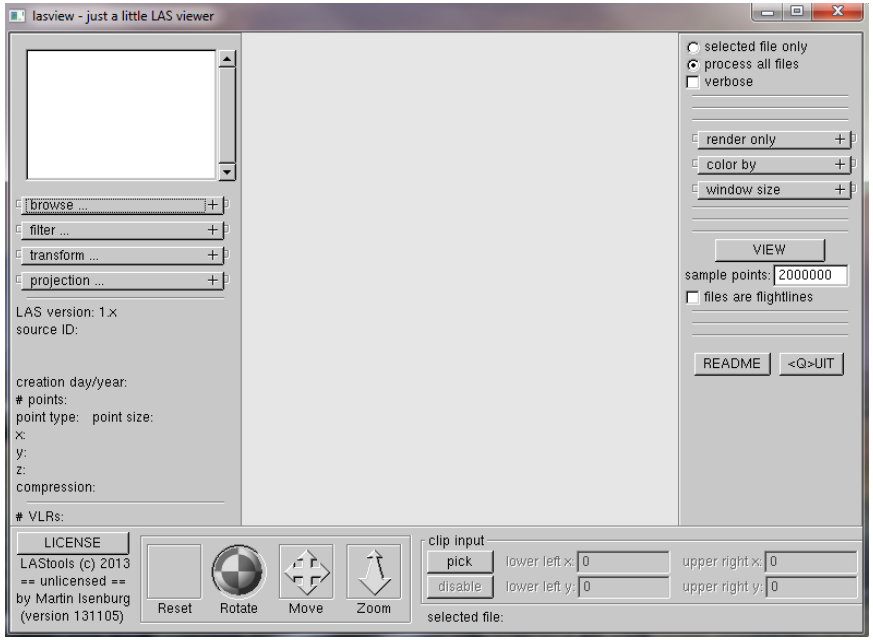
http://desktop.arcgis.com/en/arcmap/latest/manage-data/las-dataset/LiDAR-solutions-minimizing-noise-from-LiDAR-for-contouring-and-slope-analysis.htm

LAStools

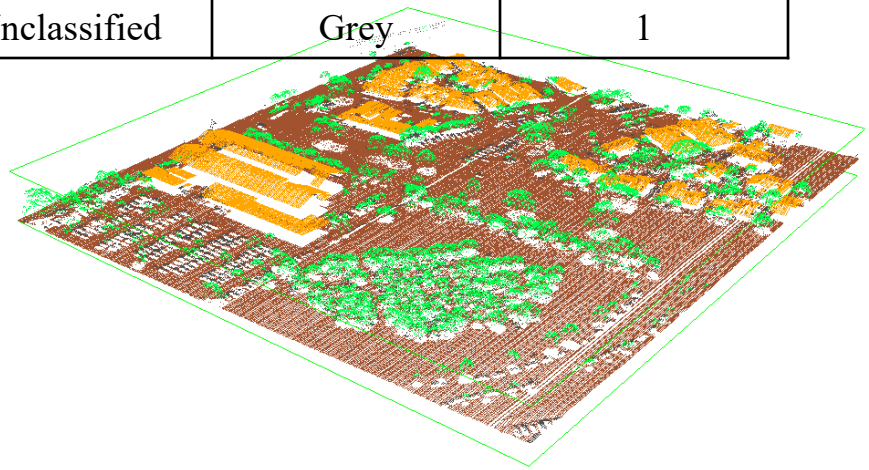
- LAStools
  - http://rapidlasso.com/lastools/
  - Suite of LiDAR processing tools
  - Free for personal use
  - License required for personal use
  - Run as executable or through ArcGIS or QGIS
  - Includes blogs, workshops, and tutorials
  - Low memory overhead and can run on multicores
  - Before using any tool, see the README file
  - We'll expand on these tools throughout the course

LAStools

- LASview – A simple LiDAR data viewer
  - A bit bare bones, but very fast
  - Allows multiple classification schemes



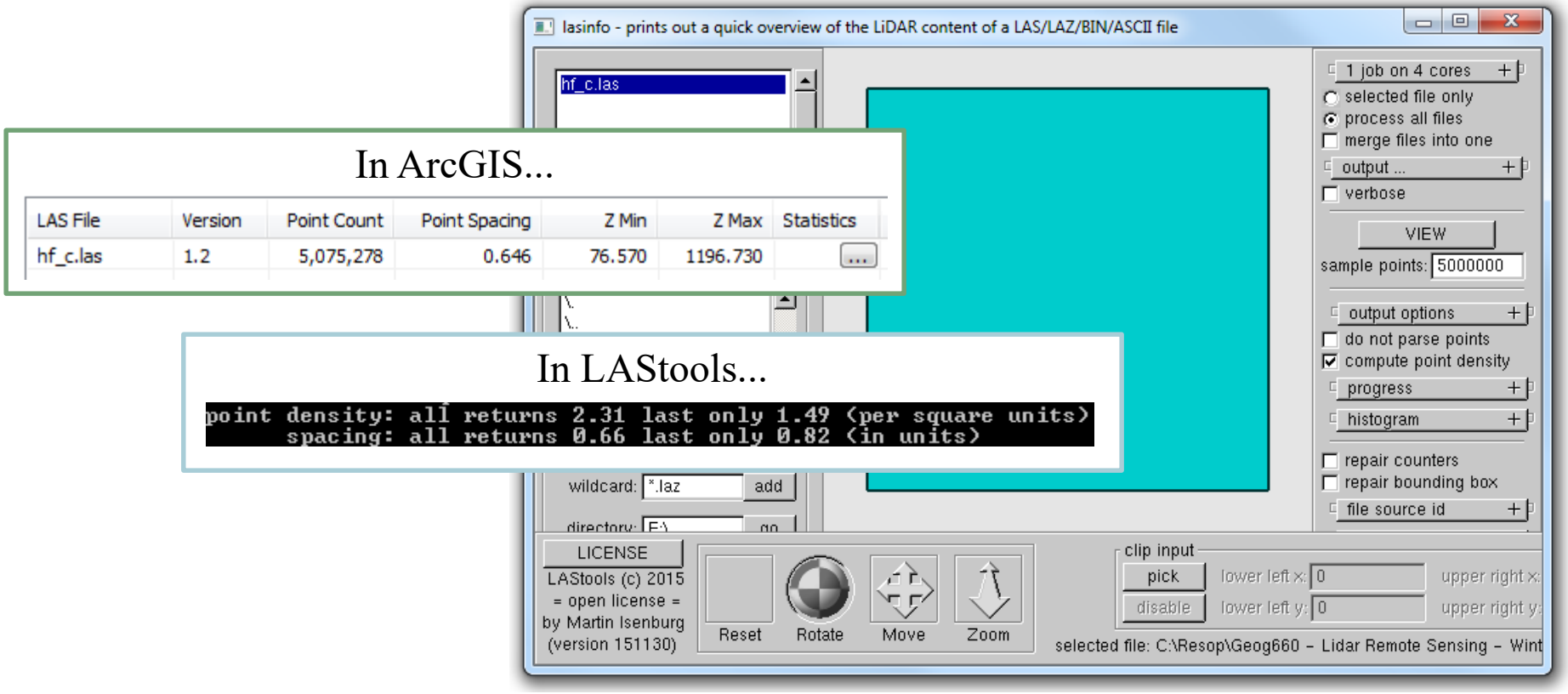
Description	Color	Class
Ground	Brown	2
Building	Yellow	6
High Vegetation	Green	5
Unclassified	Grey	1



http://rapidlasso.com/lasview/

LAStools

- LASinfo – Calculates Simple Data Statistics

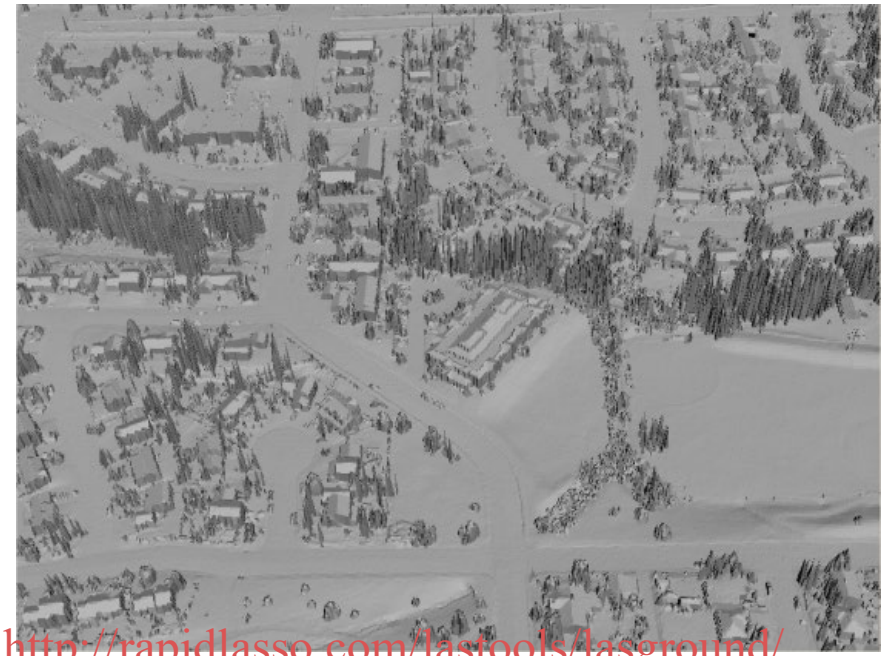


http://rapidlasso.com/2014/03/20/density-and-spacing-of-LiDAR/

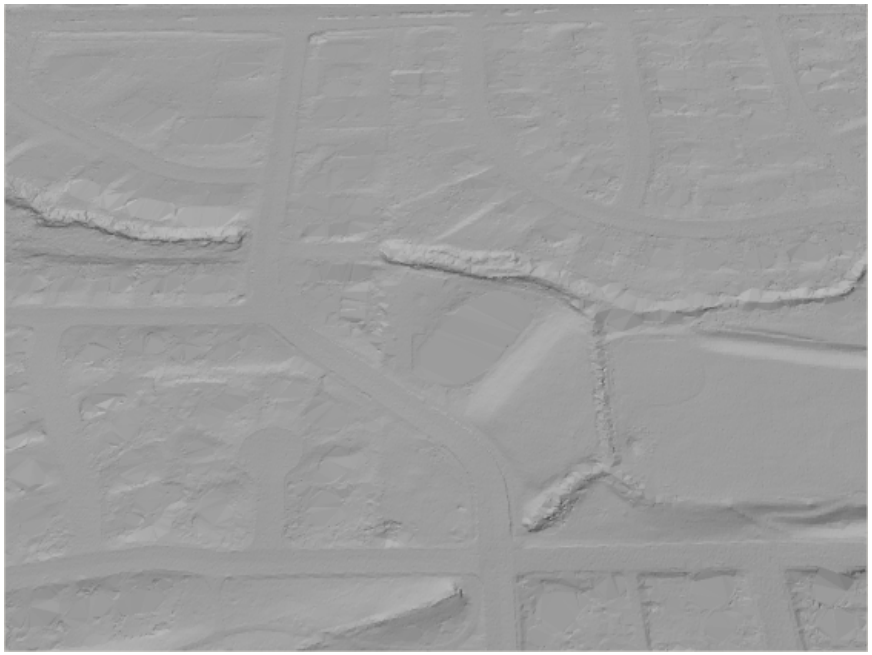
LAStools

- LASground – Bare Earth Extraction
  - Classifies LiDAR data points as either ground (class = 2) or non-ground (class = 1)

Before, Raw Data



After, Ground Points



http://rapidlasso.com/lastools/lasground/

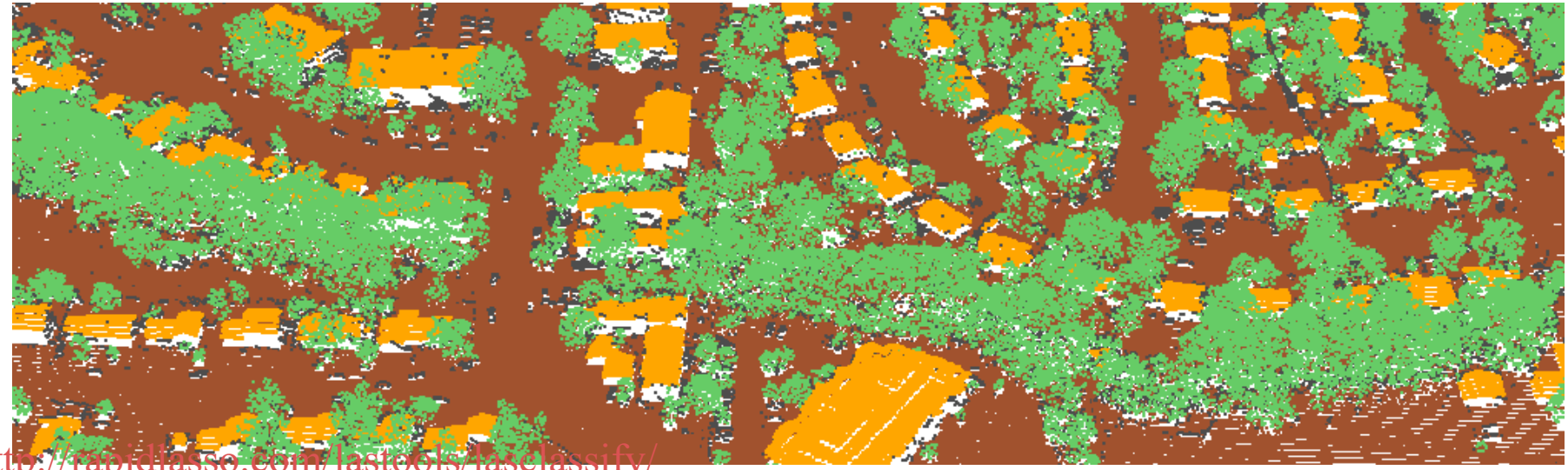
LAStools

- LASheight – Calculates height above ground
  - Assumes ground classified as (class = 2)
    - First run LASground
  - Creates a temporary bare earth model TIN
  - Stores height in the "user data" field of LAS file
  - Allows the user to overwrite the Z values with height values (if they desire)
  - A possible method to develop canopy height models; we'll go more into this next Lecture
  - Can also use to filter out outliers and artifacts

http://rapidlasso.com/lastools/lasheight/

LAStools

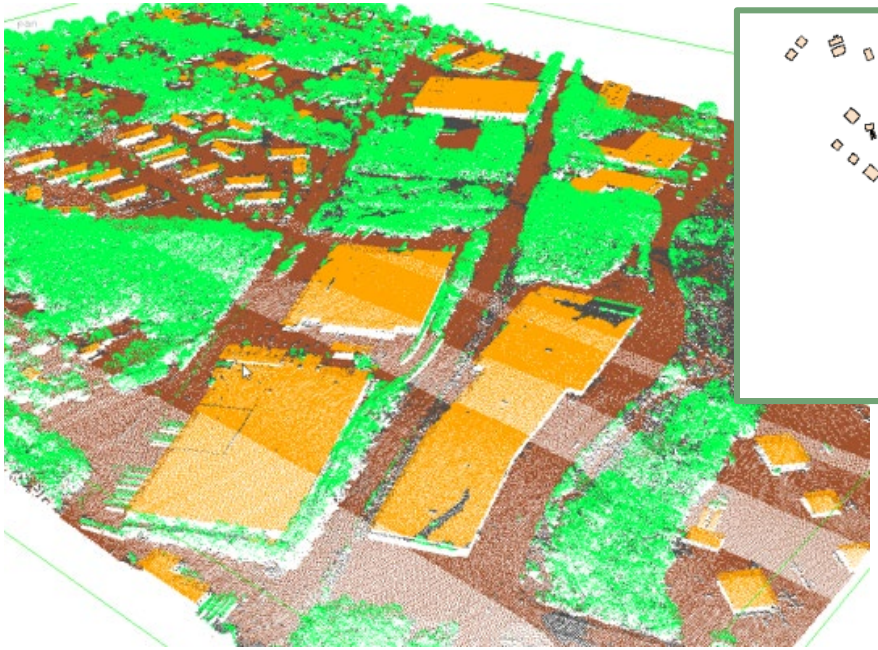
- LASclassify – Automated classification script
  - Classifies buildings (class = 6), vegetation (class = 5)
  - Requires that ground points are already classified AND that height above ground is calculated
    - First run LASground and LASheight

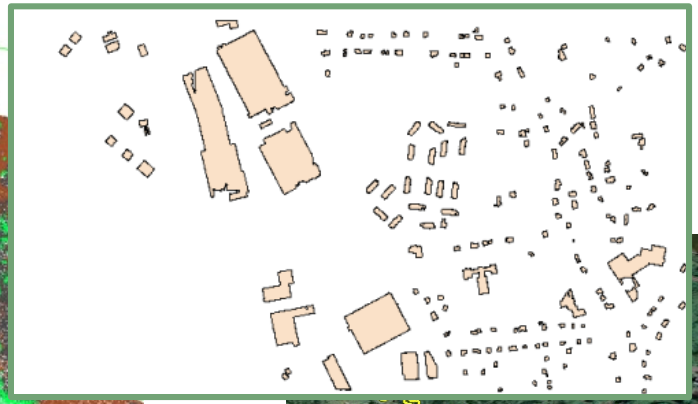


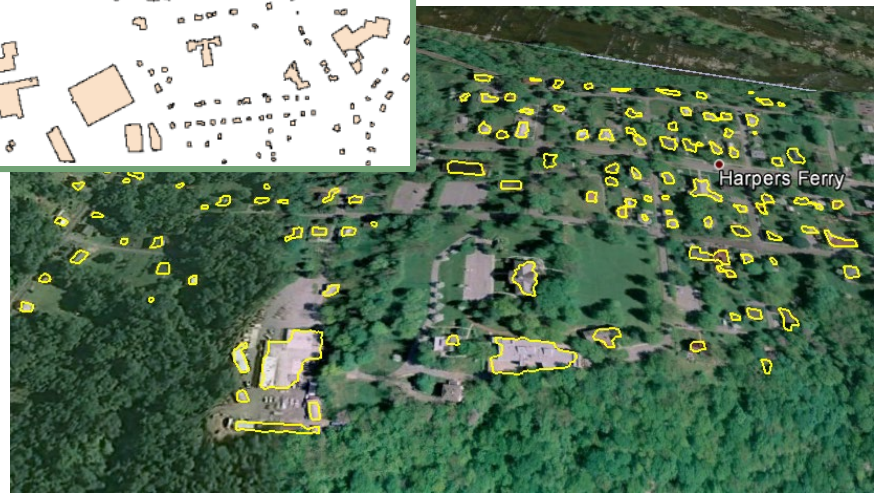
http://rapidlasso.com/lastools/lasclassify/

LAStools

- LASboundary – Create boundary polygons
  - Heavily parameterized, pay attention to the lab
  - Validate results in Google Earth or with imagery







http://rapidlasso.com/lastools/lasboundary/

LAStools

- Other Useful LAStools
  - LAS2txt
    - Converts from binary LAS/LAZ to an ASCII text format
  - LASoverlap
    - Computes and displays the area of flight line overlap
  - LASoverage
    - Removes overlap that is not in the flight line "sweet spot"
  - LASclip
    - Removes points outside of a polygon feature shapefile
  - LASnoise
    - Removes isolated noise points from a LiDAR dataset
  - Too many to list!