Procedures for Processing LIDAR Point Cloud Files to Create Digital Elevation Models, Contours, and Elevation Changes in ArcGIS 10.2.2

Version 1

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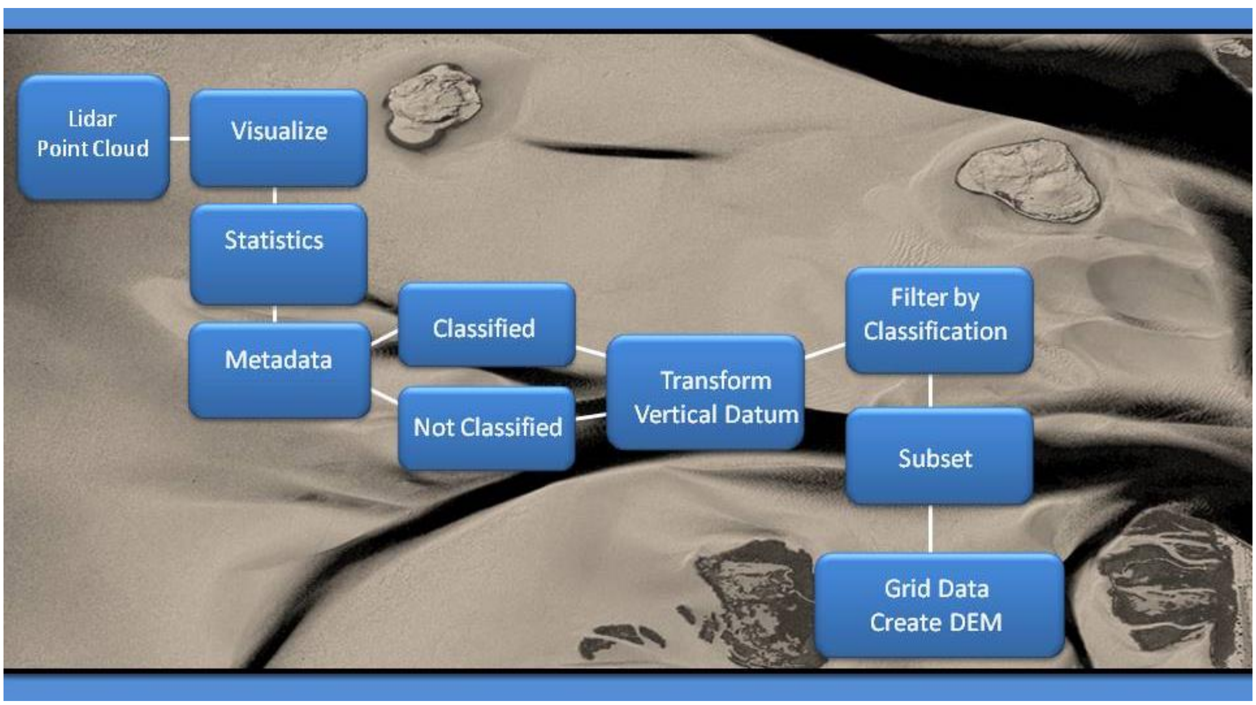
Software Used:
ArcGIS v.10.2.2 (ESRI)

Introduction

The purpose of this guide is to provide an overview of procedures and best practices for creating digital elevation models from bathymetric and topographic Lidar point clouds. There are several different programs and ways to grid data this document will look at using one program for a more straight forward workflow. This guide does not represent an endorsement of any particular software package. All Lidar processing should start with recognizing what the desired goal and product is from using this data, this will dictate the scale, storage, as well as the appropriate gridding method.

Data Processing Workflow

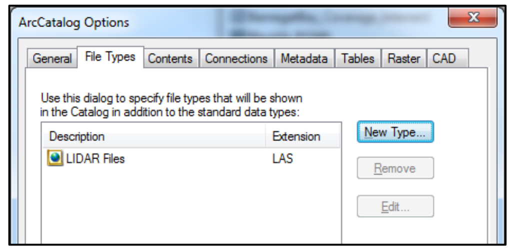


Setup

1. Start ArcCatalog

a. In the Catalog window, click the Connect to Folder. Use this to set up a folder connection to your main working folder, multiple folder connections can be made.

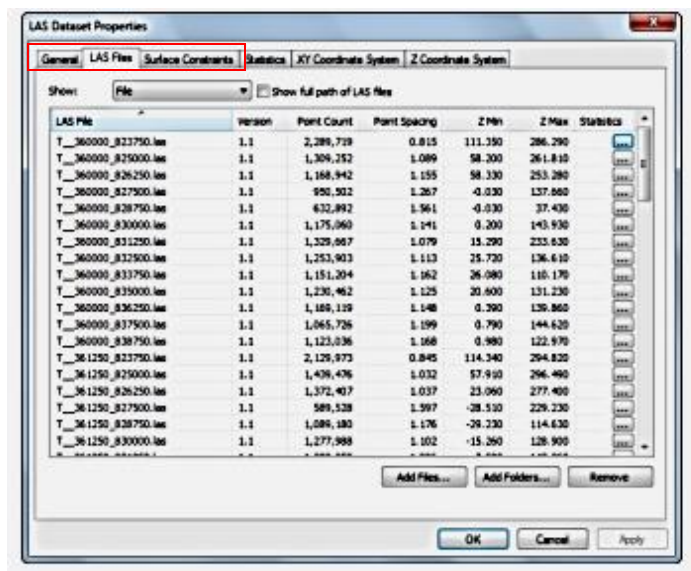
2. Change File Type settings to view LAS files in ArcCatalog



a. In ArcCatalog change settings under Customize ➔ ArcCatalog Options ➔ File Type.

b. Add New Type ➔ LAS ➔ Select a unique Icon for file type (LAS files are now visible in ArcCatalog).

3. Create a LAS Dataset



a. In ArcCatalog in desired workspace folder ➔ right click ➔ New ➔ LAS Dataset ➔ Rename.

b. Right click the new LAS Dataset ➔ Select Properties ➔ Select LAS Files tab ➔ Add Files (check include subfolders if data is broken into subfolders).

c. Under General tab ➔ Select Store Relative Path .

d. Under Surface Constraints tab ➔ Add boundary polygon, breaklines, or other surface features. Note: If a data coverage boundary does not exist, return to this step after creating a boundary or digitizing breaklines.

4. Create a project Geodatabase

a. In ArcCatalog in the desired working folder right click ➔ New ➔ File Geodatabase.

b. Select XY and Z tolerance – tolerance reflects the accuracy of the coordinate data and is the minimum distance between coordinates – the number is the unit in the metadata.

i. Accept the default for the M tolerance (tolerance of measure properties)

ii. Uncheck Accept default resolution and domain extent

iii. Resolution controls space requirement important for Lidar, it represents precision of data

c. Right click Geodatabase → New → Create feature dataset

5. Start ArcMap

a. Under Customize → Turn on extensions → Spatial Analyst and 3D Analyst.

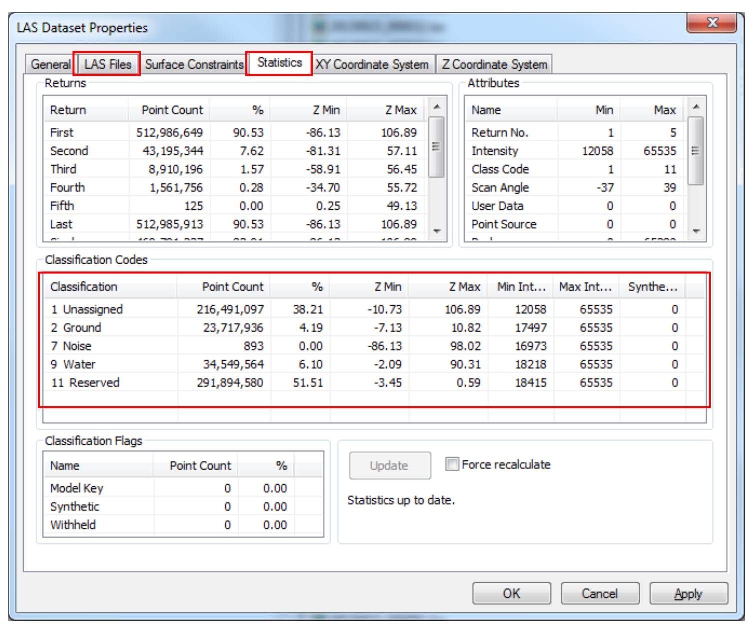
Note: when running geoprocessing tools if you know the name of the tool use the search feature and type in the tool name for quick access.

b. Click the Windows menu and click Image Analysis to open the Image Analysis window, dock this window on the side of the application.

c. Add imagery of the area of interest to your map, consistent with the time period of Lidar collection. ArcMap also has several base maps, however they have a long drawing time and will be slow to use, and having imagery stored in your workspace will create a faster workflow.

Metadata & Statistics

1. LAS Dataset Properties



a. In Arc Catalog → Right click LAS Dataset storing the LAS files of interest.

b. Navigate to the Statistics tab → Select Calculate to produce Statistics.

c. Review the XY and Z Coordinates System tab.

d. Under Las Files tab → Record the average point spacing for the entire collection.

2. **LAS Statistics to Raster**

   a. Creates a raster whose cell values reflect statistical information about measurements from LAS files referenced by a LAS dataset.

The type of statistics collected about the LAS points in each cell of the output raster.

PULSE_COUNT —The number of last return points. Sample Density.
POINT_COUNT —The number of points from all returns.
PREDOMINANT_LAST_RETURN —The most frequent last return value.
PREDOMINANT_CLASS —The most frequent class code.
INTENSITY_RANGE —The range of intensity values.
Z_RANGE —The range of elevation values.

Note: Consider Z Range method to determine locations with potential outliers.

   b. In ArcToolbox Select geoprocessing tool LAS Dataset Statistics to Raster Select Pulse Count Choose a cell size 4x the average point spacing.

3. **Point File Information Tool**

   a. In ArcToolbox Select geoprocessing tool Point File Information tool. This tool provides point boundary extents, average point spacing, and min and max Z values.

Visualization

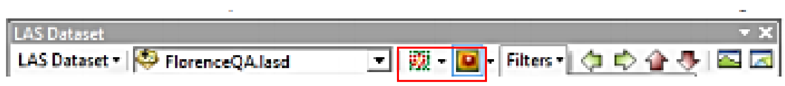
LAS Dataset displays thinned points for faster visualization.

1. **Add LAS Dataset to ArcMap**

   Note: Only footprints visible when the estimated number of points is too large to display, zoom in to see point cloud.

a. Right click the LAS dataset file in ArcMap Select properties, in the display tab you can change rendering preferences and increase point limit and use the scale to control full resolution.

b. View different data displays with Point View Display dropdown to render points by elevation, class, or return. View different rendered surfaces by elevation, aspect, slope, and contour.



c. View Profiles and 3D views of the point cloud. Measure distances and heights between points in Profile View.

2. Create Boundary Files

a. Create a point cloud coverage boundary file and no data boundary file.

i. Run LAS Dataset to Raster → Value Field Elevation → Interpolation Type → Binnning – Average – Void Filling Method – None → Accept Defaults

ii. With output run geoprocessing tool Raster Domain → Output polyline or polygon → Discard temporary raster

iii. Create New Shapefile → Digitize Bounding Box Polygon → Still in editor session select coverage boundary and in the editor drop down select Clip → Discard the area that intersects → Save edits and close editor session.

iv. Alternative method is to digitize a boundary file, right click in ArcCatalog → New → Shapefile → Polygon → Add polygon to ArcMap → On the Editor Toolbar click the Editor drop-down menu and click Start Editing. Repeat these steps but select polyline to manually digitize breaklines.

Transform

Download VDatum at http://vdatum.noaa.gov/

Create a consistent spatial reference for LAS files and the appropriate vertical datum dependent on overall product. VDatum v3.3 only accepts ASPRS Lidar Data Exchange Format 1.0, 1.1, and 1.2.

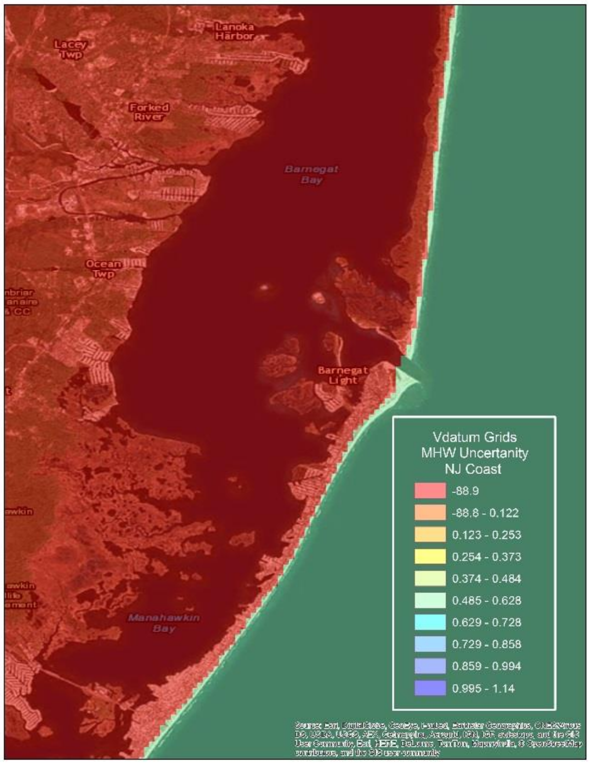
1. Overlay LAS point cloud coverage boundary file with VDatum Boundaries

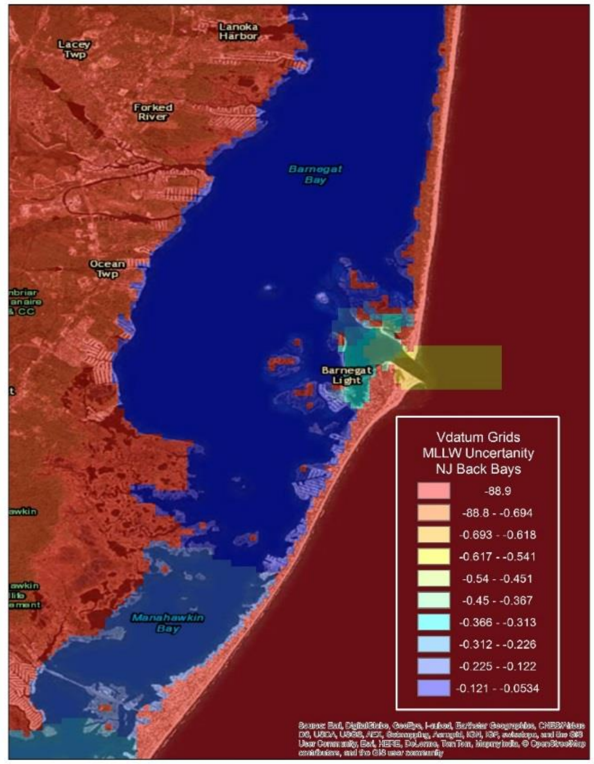
a. Within the VDatum folder is a list of VDatum regions using the MLLW Gridded data files (mllw.gtx) for the region of LIDAR data coverage.

b. Add both .gtx file and the boundary shapefile to ArcMap → Right click the color ramp of the mllw. gtx file in ArcMap and change the color ramp to a multicolored ramp to see the areas of VDatum coverage.

Coastal Barnegat Bay NJ

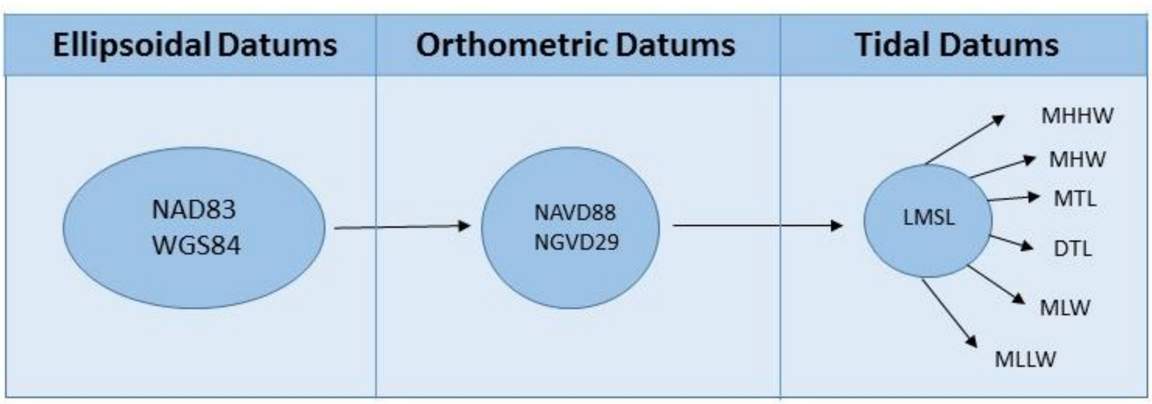
Back Bay Barnegat Bay NJ



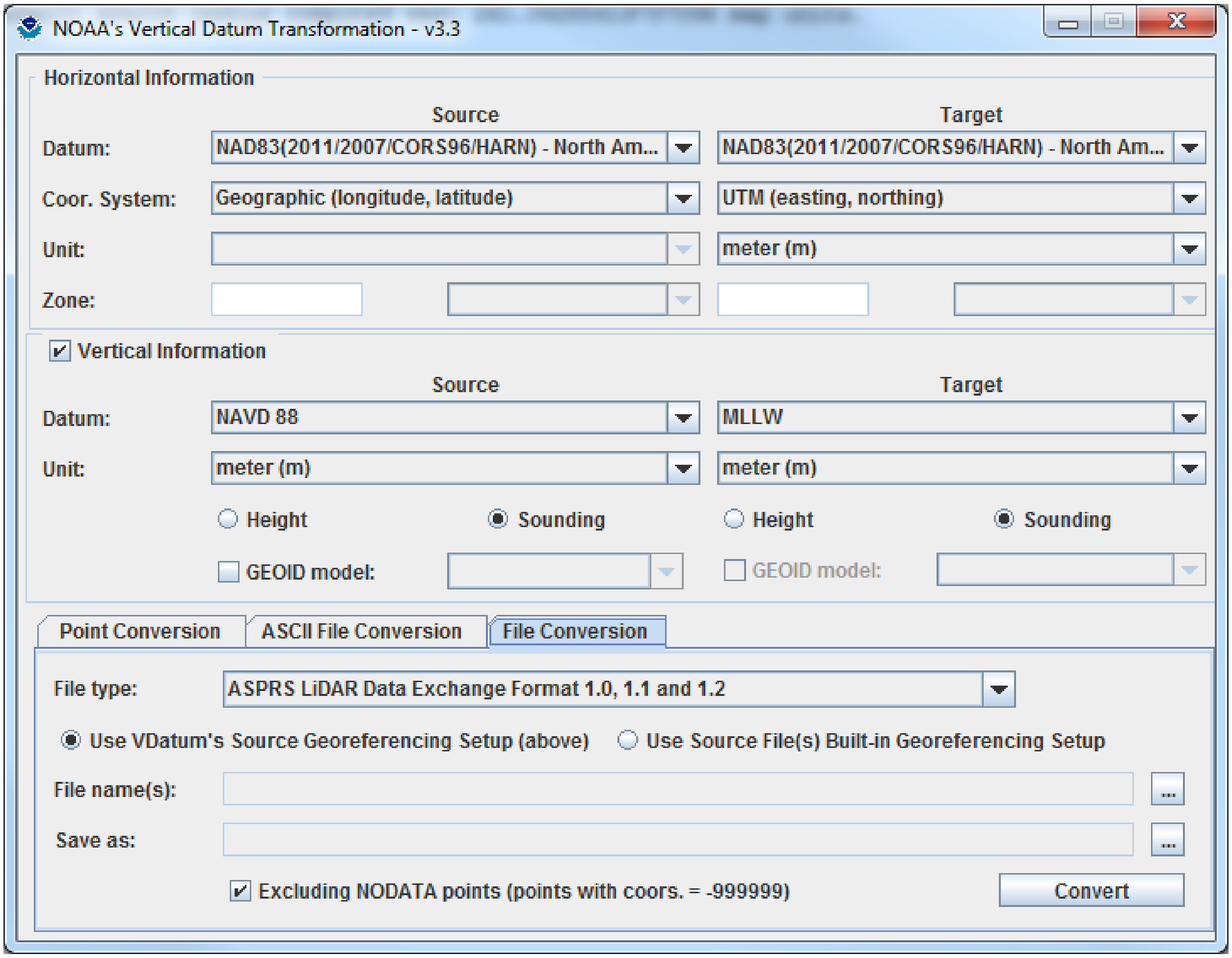


Note: Areas in red have no coverage.

2. NOAA's Vertical Datum Transformation v3.3 - VDatum Windows Batch File



a. Add files ➔ Input horizontal information ➔ Input vertical Information ➔ Select excluding no data points to remove any soundings that are not located within the VDatum transformation grid ➔ Convert.



Filtering/Subset

1. Filter by Classification

a. Run tool ➔ Make LAS Dataset Layer for each classification.
(This creates a temporary layer; each layer can be run separately using LAS Dataset Statistics to Raster or LAS Dataset to Raster for single class or single return raster outputs)

2. Change Class Codes

a. Create a profile of area of interest → In the Profile window → Use the Select Points tool to manually edit points or a group of points → Use the Edit button to launch the Change Class Codes dialog box.

b. Another method is to change class codes by using a point, line, or polygon → Use geoprocessing tool LAS Class Codes.

c. Use geoprocessing tool Locate Outliers, this tool identifies anomalous elevation measurements from LAS datasets that exceed a defined range of elevation values or have slope characteristics that are inconsistent with the surrounding surface. Reclassify outlier points as noise using LAS Class Codes Using Features Tools.

http://resources.arcgis.com/en/help/main/10.1/index.html#//00q900000013000000

- Consider using the Apply Hard Limit option when the range of valid elevation values for the surface is known. Point elevation measurements that fall outside of the range defined by the Absolute Z Minimum and Absolute Z Maximum values will be created in the output.
- Consider using the Apply Comparison Filter option to locate data points that exceed a height or slope difference relative to neighboring measurements. Each data point is tested for height and slope variances with its natural neighbors. The Exceed Tolerance Ratio is used to determine the number of points in the neighborhood of the test point for which the slope or height tolerance must be exceeded in order for a point to be considered an outlier.
- For any given point having X number of nodes connected by triangle edges, if the slope from it to a connected point is greater than the Slope Tolerance in m points (where m is n times the Exceed Tolerance Ratio), then the point is written to the output.
- The Outlier Cap limits the number of points that can be written to the output. Once this limit has been reached, the tool returns a warning and stops finding outliers.
- The output points will be attributed with an integer field named REASON whose values identify the outlier identification criteria that resulted in the inclusion of the point measurement.
- 0—Hard limit
- 1—Hard limit and comparison filter
- 2—Comparison filter

Gridding

Creating a digital elevation model, consider the previous steps taken to obtain this information:

- Extent of Lidar coverage
- Number of Lidar points and point density
- Desired output raster resolution from point spacing
- Extent of output raster
- Format of output raster
- End product derived from raster

1. **Formats**

    - TIFF 32-bit float format optimal format.
    - FLT—floating-point binary simple format—similar to 32-bit floating-point TIFF files but without a header. This is not a tiled format and is recommended only for small extents.
    - Integer - The advantages to using integer data are:

        - Reduced data volume (8 or 16 bits per sample vs. 32 for floating-point data).

        - Compression is simpler (faster to process, with a greater compression ratio).

        - Some ArcGIS tools require an integer raster.

        - Note: If integer elevation values are used, one disadvantage is that terraces may appear in hillshades due to rounding.

2. **Geoprocessing tool LAS Dataset to Raster**

    Notes:

    - Create an elevation, intensity, or RGB raster.
    - Create Rasters from each classification form the temporary LAS layers created in the filter and subset section, step 1.
    - To fill void the pixel size or cell size should be 4x the point spacing.

- Also point spacing should be calculated for each return the number may differ from the point spacing of all returns.

- Binning does not notice breaklines only soft or hard boundary clips, triangulation notices all types of constraints but takes longer to execute. Binnning is fast, reasonable for DSMs, void filling options.

- Triangulation is true interpolation, always fill voids, best for DEMs.

http://resources.arcgis.com/en/help/main/10.1/index.html#//001200000052000000
LAS Dataset to Raster

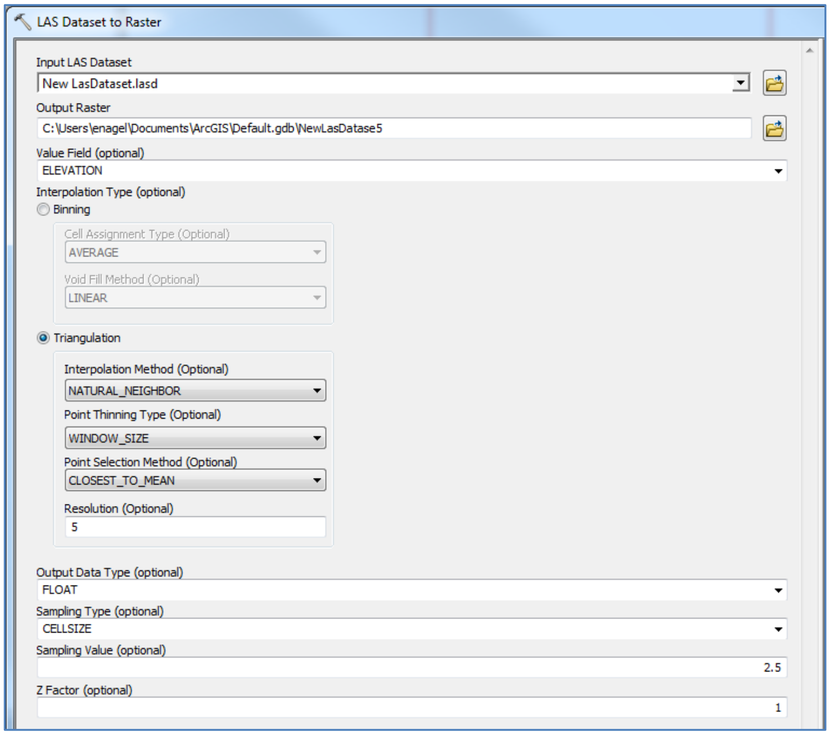
a. **BINNING—**Cell values are obtained using the points that fall in the extent of the cell, with the exception of cells that do not contain points in their extent. The following options are available for this technique:

    - **Cell Assignment Type—**Method used to define the value for any cell that contains points within its extent.
    - **Void Fill Method—**The interpolation method used to define values for cells that do not have points within their extent.

b. **TRIANGULATION—**Cell values are obtained by interpolating measurements from a triangulated representation of the LAS dataset. The following options are available for this technique:

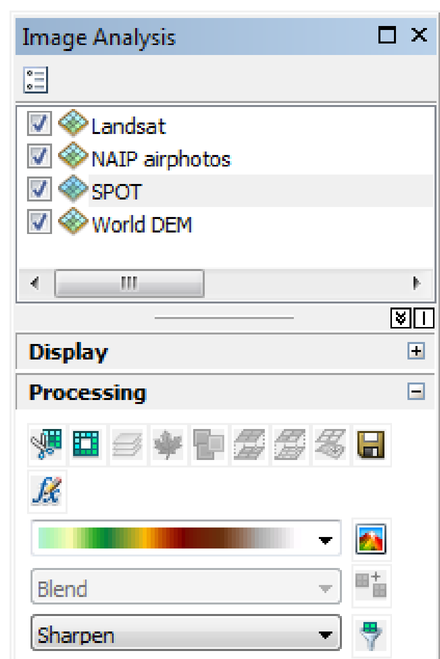
    - **Interpolation Method—**The interpolation method that defines cell values:
    - **Point Thinning Type—Determines if LAS data points are thinned:**
    - **Point Selection Method—**Selection method used for thinning LAS data points when using WINDOW_SIZE thinning:

(The window size pyramid level resolution is defined by equal area windows at each pyramid level scale range. It is recommended that the highest resolution) pyramid level uses a window size that is approximately twice the average point spacing.



c. Example: Select Value Field - Elevation ➔ Select Triangulation ➔ Select Natural Neighbor ➔ Select Point Thinning Type – Window Size ➔ Select Closest to Mean – Resolution 2x cell size ➔ Output Data Type – Float ➔ Sampling Type Cell Size – Average Point Spacing Select output raster location as the project Geodatabase.

Surface Analysis



1. Open Image Analysis

a. With the rasters created from the LAS files select each raster in the image analysis window ➔ Select shaded relief for on the fly hillshade representation.

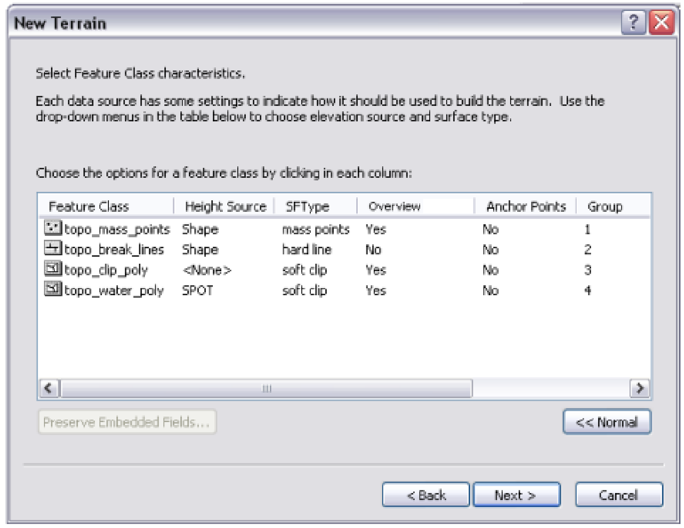
b. Select surface differences button this computes the change between two layers, using a pixel-over-pixel comparison, and outputs a temporary layer.

2. Create Contours

Contours from full resolution Lidar contain too much noise, Lidar points need to be thinned or resampled.

a. Run a Resample technique on rasters created from LAS files ➔ Use Bilinear resampling technique ➔ Output Cell Size anywhere from 4x to 10x the cell size ➔ Run Contour Tool to create contours.

b. Alternative method, Terrain to Raster



i. Las to Multipoint → Output in project Geodatabase – Feature Dataset **.**

ii. Right Click Feature Dataset → New Create → Terrain.

iii. Navigate steps in Terrain Wizard → Add multipoint output as mass points and set Height Source as Shape Z .

iv. Add any surface constraints, breaklines as hard line and boundary polygon as soft clip with no height source.

v. Enter Point Spacing.

vi. Defining Pyramid types:

Z tolerance pyramid type

- Thins points to produce surfaces that are within an approximate vertical accuracy relative to the full resolution data
- Build process is time consuming
- Appropriate for bare earth data
- Should not be used with first return Lidar surfaces

Window Size tolerance type

- Thins points for each pyramid level by partitioning the data into equal areas, called windows , and selecting one or two points from each area as representation
- Faster build time
- Effective for all data types
- Should be used with first return Lidar
- The window size pyramid level resolution is defined by equal area windows at each pyramid level scale range. It is recommended that the highest resolution pyramid level uses a window size that is approximately twice the average point spacing.

vii. Pyramid Properties:

Points	Levels of Detail	Vertical Tolerance	Scale
	0	0	1:1
	1	1	2500
	2	5	10,000
	3	10	50,000
	4	20	100,000

viii. Run geoprocessing tool Terrain to Raster
ix. Run geoprocessing tool Create Contours

Data Management

This lists the general design of the elevation data management.

- Create a mosaic dataset for each collection (source).
- Create a mosaic dataset from each collection (master).
- Create different mosaic datasets for visualization, analysis, user access, and to publish (referenced).

Mosaic Dataset is a composite layer of rasters, use as a catalog to search rasters, view metadata, add selected rasters to map, time aware.

http://resources.arcgis.com/en/help/

- **Cell Size Tolerance Factor**—Is used for controlling how mosaic dataset items with differing pixel sizes are grouped together for some operations, such as mosaicking or seamline generation. A factor of 0.1 means that all the LowPS values that are 10 percent larger than the lowest pixel size are considered to be the same. This value must be greater than or equal to 0.0. The results can be viewed in the Levels table (to access, right-click the mosaic dataset in the table of contents and click Open >Levels Table).

- **Allowed Mosaic Methods**—Defines the order of the rasters that are mosaicked together to create the image. You can choose one or more mosaic methods and which one will be the default. The user is able to choose from the methods you select.
  - **Closest to Center**—Enables rasters to be sorted based on the ZOrder, then PixelSize, and then by a default order where rasters that have their centers closest to the view center are placed on top.
  - **Closest to Nadir**—Enables rasters to be sorted by the ZOrder, then PixelSize, and then by distance between the nadir position and view center. This is similar to the Closest to Center method but uses the nadir point to a raster, which may be different than the center, especially for oblique imagery.
  - **Closest to Viewpoint**—Orders rasters based on the ZOrder, then PixelSize, and then by a user-defined location and nadir location for the rasters using the Viewpoint tool.
  - **By Attribute**—Enables raster ordering based on the ZOrder, then PixelSize, and then by the defined metadata attribute and its difference from a base value.
  - **North-West**—Enables raster ordering by the ZOrder, then PixelSize, and then by the shortest distance between the center of a raster and the northwest position.
  - **Seamline**—Cuts the raster using the predefined seamline shape for each raster, using optional feathering along the seams, and orders images based on the ZOrder and then the SOrder fields in the attribute table.
  - **Lock Raster**—Enables a user to lock the display of single or multiple rasters based on the ObjectID.
  - **None**—Orders rasters based on the order (ObjectID) in the mosaic dataset attribute table.

- **Default Mosaic Operator**—Allows you to define how to resolve the overlapping cells, such as choosing a blending operation.
  - **First—**The overlapping areas will contain the cells from the first raster dataset listed in the source.
  - **Last—**The overlapping areas will contain the cells from the last raster dataset listed in the source.
  - **Min—**The overlapping areas will contain the minimum cell values from all the overlapping cells.
  - **Max—**The overlapping areas will contain the maximum cell values from all the overlapping cells.
  - **Mean—**The overlapping areas will contain the mean cell values from all the overlapping cells.
  - **Blend—**The overlapping areas will be a blend of the cell values that overlap along the edge of each raster dataset in the mosaicked image. By default, the edge is defined by the footprint or the seamline for each raster.
  - **Sum—**The overlapping areas will contain the total cell values from all the overlapping cells.

1. **Create Mosaic Dataset**

a. LAS Files → LAS Dataset → Rasters → Mosaic Dataset → Image Service.

b. In ArcCatalog → Right Click the project Geodatabase created in the first step → New → Mosaic Dataset → Enter coordinate system → Number of bands – 1 → Pixel type – 32 bit floating.

c. Add rasters to Mosaic Dataset → Update Cell Ranges → Update Boundary → Update Overviews → Calculate statistics → Build pyramids.

d. In ArcCatalog → Right click → Mosaic dataset → Set Mosaic Dataset Properties to set compression methods and mosaic methods.

2. **Source & Master Mosaic Datasets**

a. Create a mosaic dataset for each collection year (source).

b. Create a time aware mosaic dataset from each collection (master), with mosaics from each collection year → Add mosaic dataset to ArcMap → Right click the footprint layer and click Open Attribute Table (a row is present for each mosaic dataset added) → Click the Table Options button and click Add Field. Type Year in the Name Text box → Click the type drop down arrow and select text → Select Ok.

c. Enter the year values → On the Editor Toolbar click the drop-down menu → click Start Editing.

d. For each row in the table, type the year into the new Year column.

e. Click the Editor drop-down menu, click Stop Editing, and then click yes to save the edits.

3. **Referenced Mosaic Dataset**

a. Create a referenced mosaic datasets for visualization, analysis, user access, and to publish.

b. Create referenced mosaic dataset tool within the same Geodatabase as the rasters and mosaics define the other mosaics datasets as the source.

c. Use Synchronize Mosaic Dataset Tool to link first the source mosaic dataset then the master mosaic dataset.

References

ArcGIS Resource Center
http://resources.arcgis.com/en/help/