GEO TUTORIAL

#QGIS #CloudCompare

Dealing with Coastal Flooding series, part 1:

CREATING RASTER DEM FROM LIDAR DATA

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The Geospatial Education and Outreach Project (GEO Project) is a collaborative effort among the Geosystems Research Institute (GRI), the Northern Gulf Institute (a NOAA Cooperative Institute), and the Mississippi State University Extension Service. The purpose of the project is to serve as the primary source for geospatial education and technical information for Mississippi.

The GEO Project provides training and technical assistance in the use, application, and implementation of geographic information systems (GIS), remote sensing, and global positioning systems for the geospatial community of Mississippi. The purpose of the GEO Tutorial series is to support educational project activities and enhance geospatial workshops offered by the GEO Project. Each tutorial provides practical solutions and instructions to solve a particular GIS challenge.

CREATING RASTER DEM FROM LIDAR DATA

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CRediT: 1: Conceptualization; 2: Methodology; 3: Verification; 4: Resources; 5: Data Curation; 6: Writing - Original Draft; 7: Writing - Review; 8: Visualization; 9: Supervision; 10: Project administration; 11: Funding acquisition

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REQUIRED RESOURCES

- QGIS 3+ and/or:
- CloudCompare 2+ (available for free)

FEATURED DATA SOURCES

- Click here to access dataset used in this tutorial (172.9 MB).

OVERVIEW

Coastal areas across the United States face increasing challenges from changing water levels, which can lead to more frequent flooding and infrastructure strain. In communities like Bay St. Louis, Mississippi, rising water can make roads impassable, damage property, and disrupt daily life—posing serious concerns for homeowners and local economies.

As part of a planning team, your role is to assess how changing sea levels may impact the safety, infrastructure, and long-term growth of this Gulf Coast community. The focus is on protecting property, ensuring economic stability, and strengthening community resilience. This is the theme of the *Dealing with Coastal Flooding* tutorial series, which includes the following topics:

- **Part 1: Creating Raster DEM from LiDAR Data**
- Part 2: Spatial Predicates: Preparing Residential Data
- Part 3A: Using Unsupervised Machine Learning for Land Use Land Cover Classification
- Part 3B: Using Supervised Machine Learning for Land Use Land Cover Classification
- Part 4: Hydrologic Raster Preparation: Resampling and Burning Stream Network
- Part 5: Generating Flooding Extent with Raster Calculator
- Part 6: Calculating Spatial Statistics of Inundated Areas
- Part 7: Creating 3D Maps of Flooding Projections
- Part 8: 3D Map Animations
- Part 9: Creating and Animating Timeseries

In this part, we will process LiDAR data to create a digital elevation model (DEM) and a digital surface model (DSM) for our project. LiDAR (Light Detection and Ranging) data consists of high-resolution spatial information in the form of point cloud. Data is usually collected by attaching a laser scanner to an aircraft or unmanned aerial vehicle (UAV, commonly known as a drone). Laser scanners emit brief pulses of light that reflect or scatter around. The return time is used to compute the distance between the scanner and the reflecting surface. This type of data is highly accurate, with vertical errors usually less than 10 centimeters, and has a high resolution. Unfortunately, this is usually reflected in the size of the dataset, commonly reaching terabytes (TB). It is also provided as an unprocessed point cloud, and if this information, e.g., elevation, is meant to be used in the form of DEM (Digital Elevation Model), it usually requires additional processing. For QGIS users, this process used to be burdened by additional costs related to processing plugin license costs or very time-consuming due to limitations in the free versions. In this tutorial, you will learn two ways to create a raster DEM from point cloud LiDAR data using freely licensed software. Make sure to check the remaining tutorials in the series to learn more about the entire analysis process.

DATA

For this tutorial, we will use the Coastal Mississippi LiDAR data available at the Mississippi Automated Resource Information System (MARIS) website. You can download the needed file from the **Featured Data Sources** link above or access it manually from the MARIS website. If you choose the second option, you can find LiDAR data under the 2015 Coastal tab. Simply click the LIDAR button to open the data catalog. From there, open the Hancock County folder and download the ***810300.las*** file—this will be our case file for this tutorial. Once the download is finished (if you used the featured link, remember that the .zip archive with data must be extracted before use), you can simply drag the downloaded file to the QGIS *Layers* panel to view it. If you are looking for a general extent coastal LiDAR product, be sure to check NOAA’s Digital Coast Data Catalog.

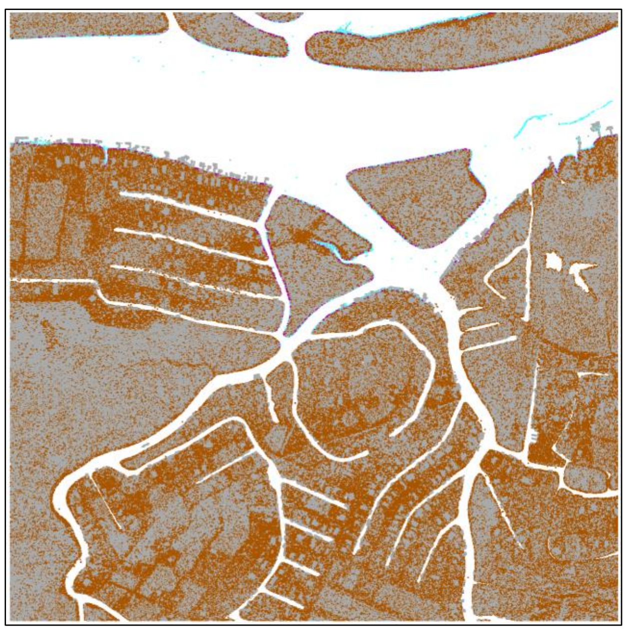

Fig. 1. *LiDAR data input layer imported to QGIS, providing the overview of the case study area.*

USING CLOUDCOMPARE

CloudCompare is a software dedicated to 3D point cloud and mesh processing. It is freely available and open-sourced. You can download the program from the project website, in an installer or portable version (the portable version does not require installation and can be stored even on a flash drive). To do so, on the main page, click *Windows 64 bits* under the *Latest Alpha Release* tab and choose the version to download. If you choose the installer version, install it, and then open the software. If you choose the portable version, extract the archive using software like 7-Zip, and then inside the extracted folder run *CloudCompare.exe*. The program's main window will open (Fig. 2). Let's add the data by clicking the Open icon (Fig. 2–A). Navigate to your folder and select ***810300.las*** file. Once you do so, the *Open LAS file* window will pop up. Leave all the options as they are (all turned on) and click *Apply*. Next, a coordinates translator will pop up. This is because our data is in the NAD83 Mississippi CRS, resulting in large X and Y values (in meters). The program must convert the *X* and *Y* values to a lower range to perform computations. You can click *Yes*, as we will be able to adjust CRS later. Once the data is imported, you will see the imported layer in the files list (Fig. 2–B), and the data will be loaded to the preview window (Fig. 2–C). Click on the data layer to display all its properties (Fig. 2–D), like dimensions, number of points, or CRS of the layer. In the *Scalar Fields*, make sure the *Active* option is set to ***Intensity***, which results in displaying the data as a monochromatic (grayscale) image.

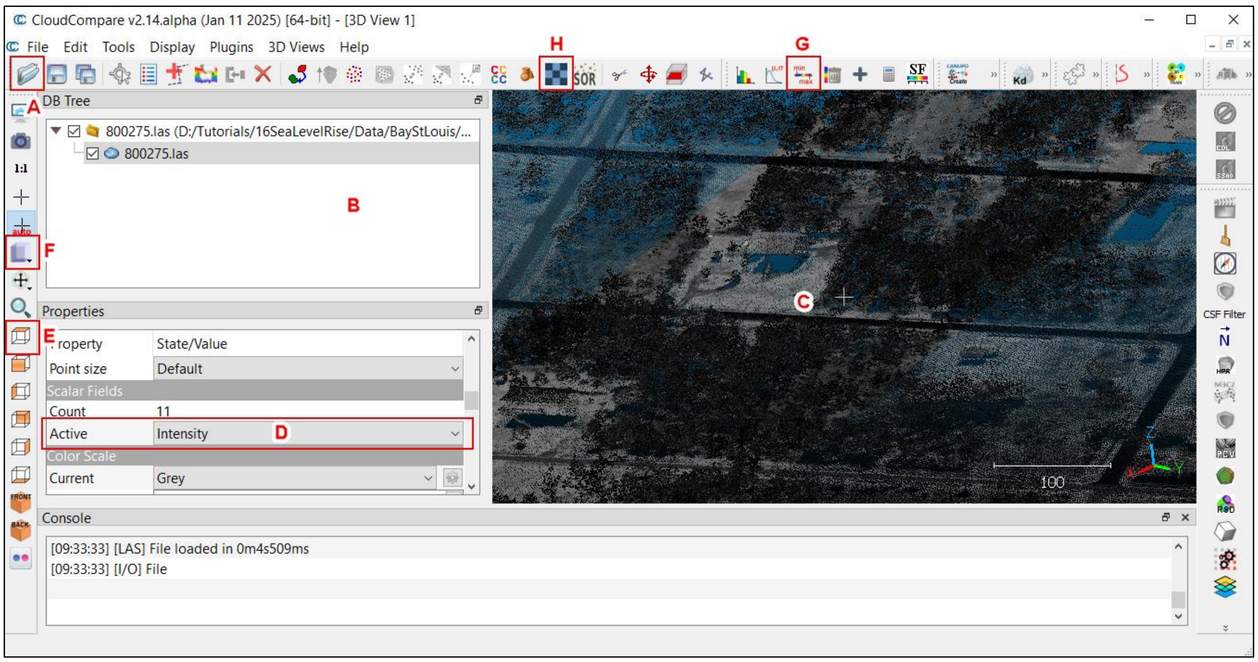

Fig. 2. Main window of the CloudCompare software.

In the preview window (Fig. 2–C), you can move around the data by holding the right mouse button (pan), rotate it by holding the left mouse button, and zoom in/out using the mouse wheel. If you would like to look at the data from the top view (like in QGIS), click the *Set top view* button (Fig. 2–E), you can also set *Orthographic projection* using *Set current view mode* (Fig. 2–F) button . From the properties of the file, we can read that it contains over 39 million points. That is a lot. Moreover, not all of them represent the elevation. In the properties, under *Scalar Fields*, change *Active* to ***Classification***. Let's use the *Filter points by value* option (Fig. 2–G) to limit the data range. By default, the ground surface in LiDAR data is classified as 2.In the *Filter by value* option, set the *range* slightly below and above this value, such as ***1.9*** to ***2.1*** (Fig. 3), then click *Export*.

Automatically, the old layer was deactivated, and a new one is now displayed. Change back *Scalar Fields*, *Active* to ***Intensity***. We have now successfully extracted the ground layer from the data, and by doing so, lowered the number of points to 13.5 million. Additionally, as you can see, everywhere the buildings were present, we now have missing values. We will handle this issue during raster creation.

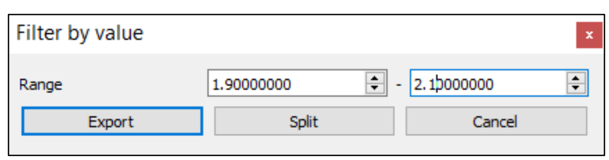

Fig. 3. By default, class 2 in LiDAR data contains ground surface.

After creating the data, we can prepare the raster file to make the DEM. To do so, select the newly created ground layer and select *Rasterize* tool (Fig. 2–H). This tool enables us to generate a raster file from our selected cloud point. There are a couple of parameters that we need to set to correctly generate the DEM. First, update the *step* option under the *Grid* settings. This parameter affects the resolution (cell size) in the final raster. The default value is ***1***, which means that the output raster will keep the initial data quality. In our case, that would result in a raster with an edge cell size of 0.3 meters (30 cm, or 11.8 inches), and the data would be available for cells where the point physically exists. Such a raster will be about 190 MB in size. Increasing the step will multiply the 30 cm by this value; e.g., setting the step to 5 will result in a raster with a cell size of 1.5 meters (150 cm, or 59 inches). Let's set the *step* to **3** to produce raster cells approximately 1 meter in size. For the *active layer*, set ***Z values*** (or ***Cell height values***, depending on the software version). Then in the *projection*, change *direction* to ***Z*** and *cell height* to ***minimum***. The cell height allows for computing cell value when multiple points are present in each cell. In general, most DEMs are produced as average values; however, since we will use our DEM for analyzing the potential water range, let's use the minimal value. The default *empty cells* setting for *Fill with* is set to ***leave empty***. In such a case, everything that is missing a value will have a no data flag. This situation applies to our buildings. Click the red button *Update grid*, and you will see how many areas are flagged as missing values (Fig. 4). There are multiple ways to handle missing data:

- ***leave empty*** – do not fill empty areas;
- ***minimum height*** – fill empty cells with minimal value found in the dataset;
- ***average height*** – fill empty cells with average value from the dataset;
- ***maximum height*** – fill empty cells with maximal value found in the dataset;
- ***user specified value*** – fill empty cells with same value provided be the user;
- ***interpolate*** – use triangle interpolation based on cells around missing area;
- ***kriging*** – use kriging to interpolate missing data.

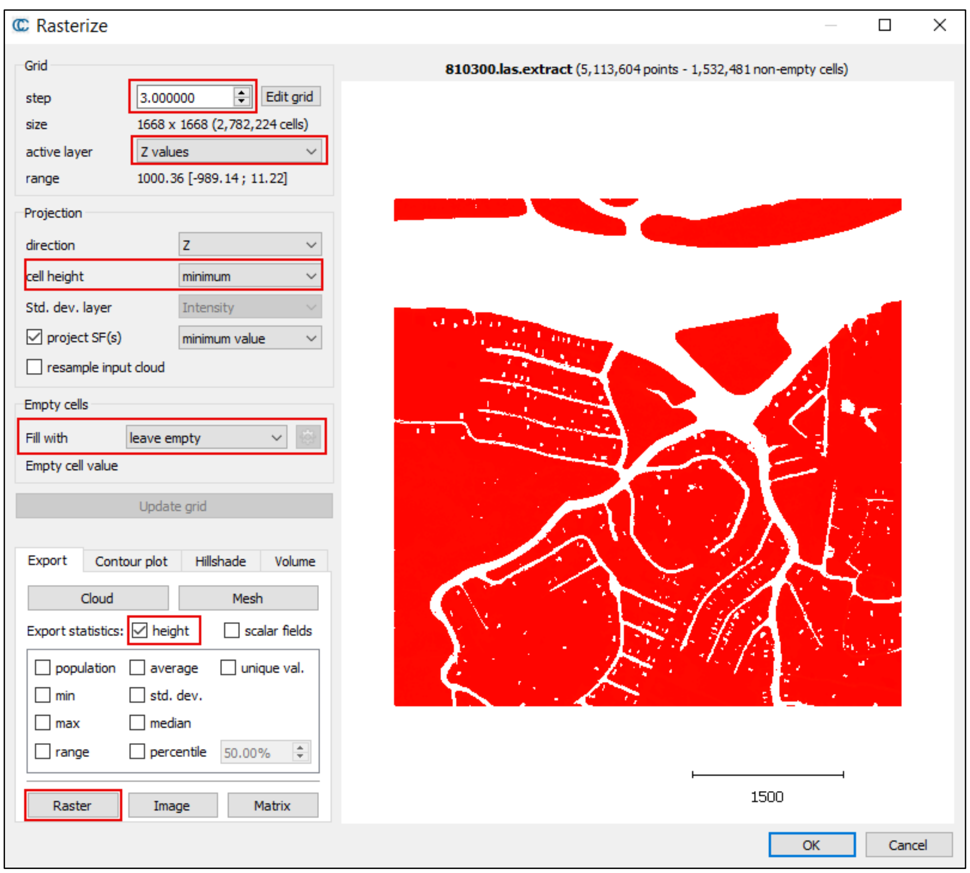

Fig. 4. Rasterization settings allow for different ways to create raster and handle missing data.

In our case, we will be dealing with water flowing over our DEM, therefore we need to fill the empty cells as accurately as possible. Either ***kriging*** or ***interpolate*** for the *Fill with* settings will work well for our case. If you chose *kriging*, simply click the *Update grid* button. If you decide to use *interpolate*, click the options icon on the right of the setting and set the *Triangles max edge length for the Delaunay triangulation* to ***0*** (which means no limit). Click *OK*, then *Update grid*. Once you've set everything up, the *Raster* button in the lower left corner will activate. Click it, then in the *Raster export options* window, make sure the ***export heights*** option is selected. Select the file's location and name to save it. After a moment, you will see a message in the console (the bottom of the main program window) saying that your file was successfully saved. You can now import the georaster into QGIS to continue the analysis. When you import the file to QGIS, make sure to set the projection in the layer properties to: ***NAD83(2011) / Mississippi East (ftUS)*** (EPSG: 6507). You can load the *OpenStreetMap* layer to make sure the DEM is positioned correctly (Fig. 5).

Fig. 5. *Using OpenStreetMap as a background layers helps verifying if the resulting DEM is correctly positioned.*

USING QGIS

Raster DEM can also be created directly in QGIS, although its capabilities are more limited than those available in the *CloudCompare*. To process LiDAR data to raster, open *Processing Toolbox* (*Processing* menu, *Toolbox*). Under *Point Cloud Conversion*, search for a tool called *Export to Raster* and open it. The tool is a simplified version of the *Rasterize* tool available in *CloudCompare*. You can simply set the *input layer* to the ***810300.las*** file imported to the project, set the attribute to ***Z*** (representing elevation), and set the *resolution of the density raster* to ***3*** (similar rule as for the *grid step* in *Rasterize*). Under *advanced parameters*, write in the *filter expression*:

```
Classification = 2
```

which will apply the filter to use only class 2 (ground surface) in the output computation. Save the output. Running the algorithm will result in the raster presenting DEM with empty cells in missing data areas, like building locations.

If we would like to have a DEM with missing data filled, similarly to the output of *CloudCompare* with *interpolation* or *kriging* settings used, there is another tool available. In the *Processing Toolbox*, under the same set of tools, open *Export to Raster (Using Triangulation)* and set all the parameters the same way (Fig. 6).

If you wish to create Digital Surface Model (DSM) which does not represent ground, but includes other structures, you should leave the filter expression empty. This will result in processing all the available points from the cloud into a raster file.

EXERCISE

Now, you know how to process LiDAR data to generate elevation models. For the next step in our analysis, we will need two datasets: the Digital Elevation Model (DEM) and the Digital Surface Model (DSM) of the study area. To strengthen the new knowledge you acquired in this tutorial, download all the LiDAR data files related to the study area from MARIS (Fig. 7) or use the NOAA's Digital Coast dataset (note the difference in point spacing between datasets). Then process them to generate the DEM and DSM of the area. Use the QGIS *Merge* tool (available in the *Raster* menu, under the *Miscellaneous* options) to merge processed layers into one file. To produce DSM, do not filter points from LiDAR classes in QGIS, and use the ***Maximal*** value setting when generating the raster in *CloudCompare*.

CONCLUSION

This concludes our GEO Tutorial, where you learned how to generate DEM and DSM raster files from point cloud LiDAR data using CloudCompare and QGIS. If you are interested in expanding your knowledge and working on similar topics, please check out the remaining tutorials in this series.

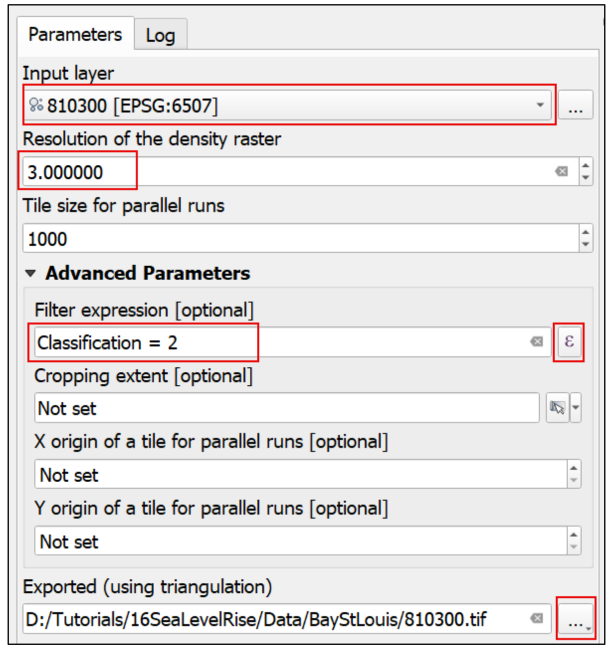

Fig. 6. Settings used in QGIS to compute DEM with empty cells filled.

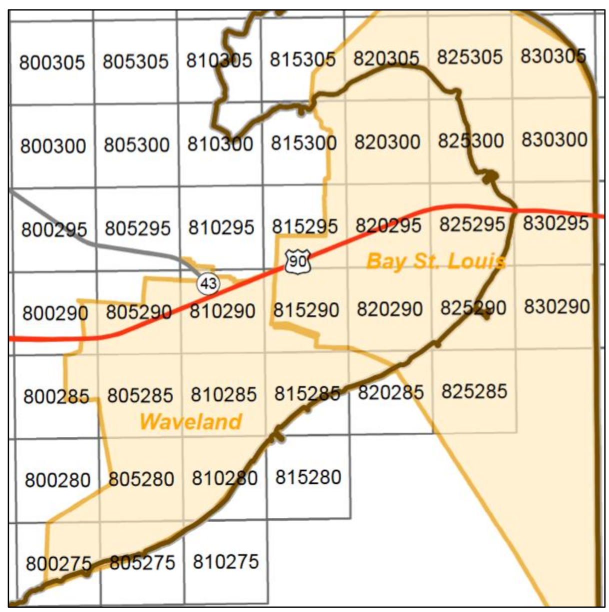

Fig. 7. Tile map with numbers of MARIS .las files needed to be downloaded and processed before moving to the next step of Sea Level Rise analysis for Bay St. Louis area.