Introduction to lidar raster data products

{% include toc title="In This Lesson" icon="file-text" %}

Learning Objectives

After completing this tutorial, you will be able to:

- Describe the basic process of how a lidar point cloud is converted into a raster.
- Be able to describe the structural differences between a raster dataset and a lidar point cloud.

What You Need

You will need a computer with internet access to complete this lesson.

In the last lesson, we learned about lidar points clouds. In this lesson, we will learn how a point cloud is converted into a gridded or raster data format.

How A Lidar system records points

Remember that lidar is an active remote sensing system that records reflected or returned light energy. A discrete return lidar system, records the strongest reflections of light as discrete or individual points. Each point has an associated X, Y and Z value associated with it. It also has an intensity which represents the amount of reflected light energy that returned to the sensor.

An example LiDAR waveform. Source: NEON.

Gridded or Raster LiDAR Data Products

Point clouds provide a lot of information, scientifically. However they can be difficult to work with given the size of the data and tools that are available to handle large volumns of points. LiDAR data products are often created and stored in a gridded or raster data format. The raster format can be easier for many people to work with and also is supported by many different commonly used software packages.

LEFT: Lidar data points overlayed on top of a hillshade which represents elevationin a graphical 3-dimensional view. RIGHT: If you zoom in on a portion of the data, you will see that the elevation data consists of cells or pixels, And there are lidar data points that fall within most of the pixels.

A raster file is a composed of regular grid of cells, all of which are the same size. You've looked at and used rasters before if you've looked at photographs or imagery in a tool like Google Earth. However, the raster files that we will work with are different from photographs in that they are spatially referenced. Each pixel represents an area of land on the ground. That area is defined by the **resolution** of the raster.

A raster is composed of a regular grid of cells. Each cell is the same size in the x and y direction. Source: Colin Williams, NEON.

A few notes about rasters:

- Each cell is called a pixel.
- And each pixel represents an area on the ground.
- The resolution of the raster represents the area that each pixel represents the area it represents on the ground. So, a 1 meter resolution raster, means that each pixel represents a 1 m by 1m area on the ground.

A raster dataset can have attributes associated with it as well. For instance in a LiDAR derived digital elevation model (DEM), each cell represents an elevation value for that location on the earth. In a LIDAR derived intensity image, each cell represents a LIDAR intensity value or the amount of light energy returned to and recorded by the sensor.

Raster can be stored at different resolutions. The resolution simply represents the size of each pixel cell. Source: Colin Williams, NEON.

Creating A Raster From LiDAR Point Clouds

There are different ways to create a raster from LiDAR point clouds. Let's look at one of the most basic ways to create a raster file points - gridding. When you grid raster data, you calculate a value for each pixel or cell in your raster dataset using the points that are spatially located within that cell. To do this:

1. A grid is placed on top of the LiDAR data in geographic space. Each cell in the grid has the same spatial dimensions. These dimensions represent that particular area on the ground. If we want to derive a 1 m resolution raster from the lidar data, we overlay a 1m by 1m grid over the LiDAR data points.
2. Within each 1 m x 1 m cell, we calculate a value to be applied to that cell, using the LiDAR points found within that cell. The simplest method of doing this is to take the max, min or mean height value of all lidar points found within the 1 m cell. If we use this approach, we might have cells in the raster that don't contains any lidar points. These cells will have a "no data" value if we process our raster in this way.

Point to Raster Methods - Interpolation

A different approach is to interpolate the value for each cell. Interpolation considers the values of points outside of the cell in addition to points within the cell to calculate a value. Interpolation also often uses statistical operations (math) to calculate the cell value. Interpolation is useful because it can provide us with some ability to predict or calculate cell values in areas where there are no data (or no points). And to quantify the error associated with those predictions which is useful to know, if you are doing research.

We will not be talking about interpolation in today's class.

Animation Showing the general process of taking lidar point clouds and converting them to a Raster Format. Source: Tristan Goulden, NEON.

Open Raster Data in R

To work with raster data in `R`, we can use the `raster` and `rgdal` packages.

```r
# load libraries
library(raster)
library(rgdal)

# set working directory to ensure R can find the file we wish to import
# setwd("working-dir-path-here")
```

We can use the `raster("path-to-raster-here")` function to open a raster in R.

NOTE SWITCH THIS TO USE THE DEM INSTEAD.

```r
# open raster data
lidar_dem <- raster(x="data/week3/BLDR_LeeHill/pre-flood/lidar/pre_DTM.tif")

# plot raster data
plot(lidar_dem,
     main="Digital Elevation Model - Pre 2013 Flood")
```

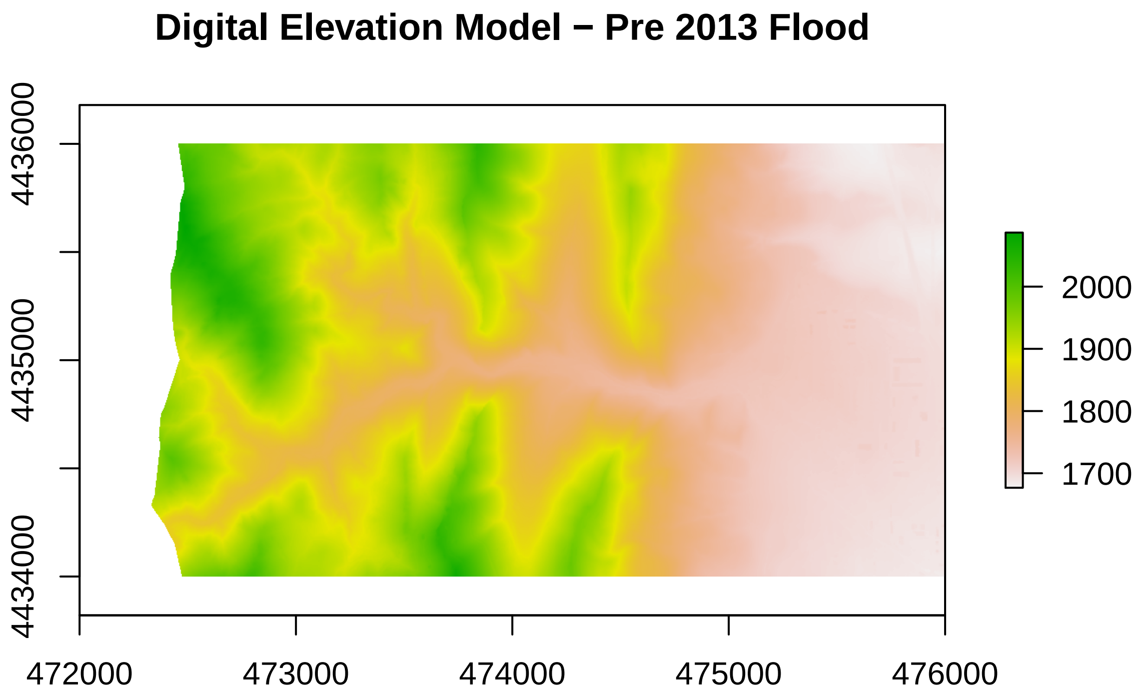

Figure 1: digital surface model raster plot

If we zoom in on a small section of the raster, we can see the individual pixels that make up the raster. Each pixel has one value associated with it. In this case that value represents the elevation of ground.

```r
plot(lidar_dem, xlim=c(473000, 473030), ylim=c(4434000, 4434030),
     main="Lidar Raster - Zoomed into one small region")
```

Raster Resolution

A raster has horizontal (x and y) resolution. This resolution represents the area on the ground that each pixel covers. The units for our data are in meters. Given our data resolution is 1 x 1, this means that each pixel represents a 1 x 1 meter area on the ground.

```r
# what is the x and y resolution for our raster data?
xres(lidar_dem)
## [1] 1
yres(lidar_dem)
## [1] 1
```

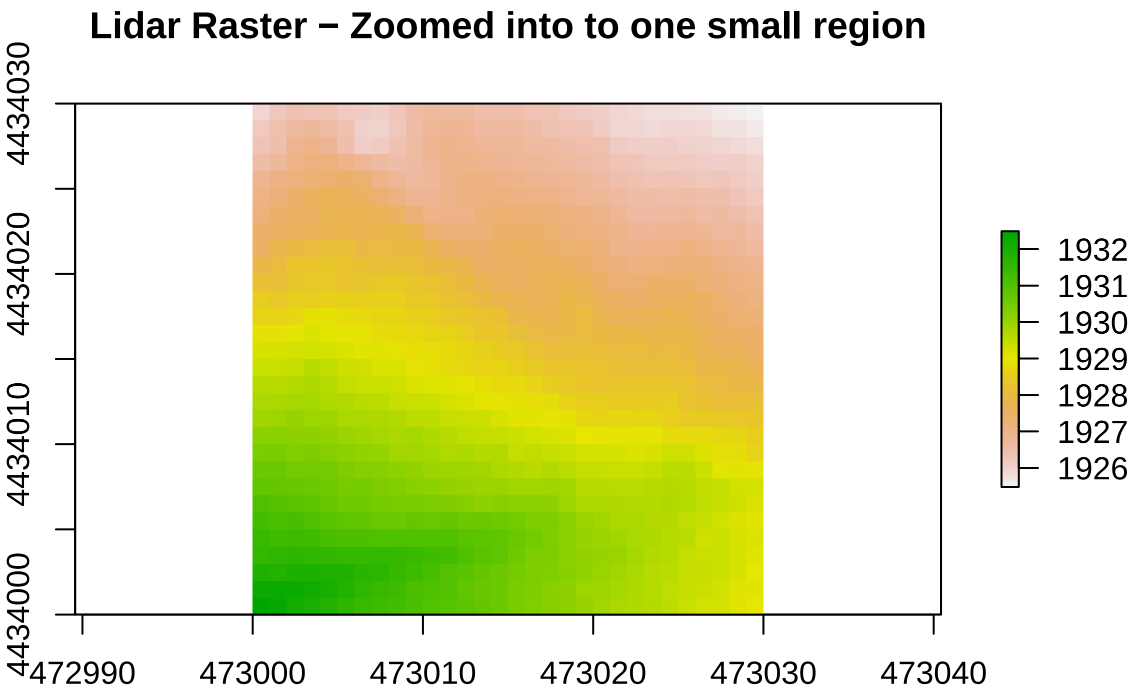

Figure 2: zoom in on a small part of a raster - see the pixels?

Resolution units

Resolution as a number doesn't mean anything unless we know the units. We can figure out the horizontal (x and y) units from the coordinate reference system string.

```
# view coordinate refence system
crs(lidar_dem)
## CRS arguments:
##  +proj=utm +zone=13 +datum=WGS84 +units=m +no_defs +ellps=WGS84
## +towgs84=0,0,0
```

Notice this string contains an element called **units=m**. This means the units are in meters. We won't get into too much detail about coordinate refence strings in this class but they are important to be familiar with when working with spatial data.

Distribution of elevation values

We can view the distribution of elevation values in our data too. This is useful for identifying outlier data values.

```
# plot histogram
hist(lidar_dem,
     main="Distribution of elevation values",
     xlab="Elevation (meters)", ylab="Frequency",
     col="springgreen")
## Warning in .hist1(x, maxpixels = maxpixels, main = main, plot = plot, ...):
## 1% of the raster cells were used. 100000 values used.
```

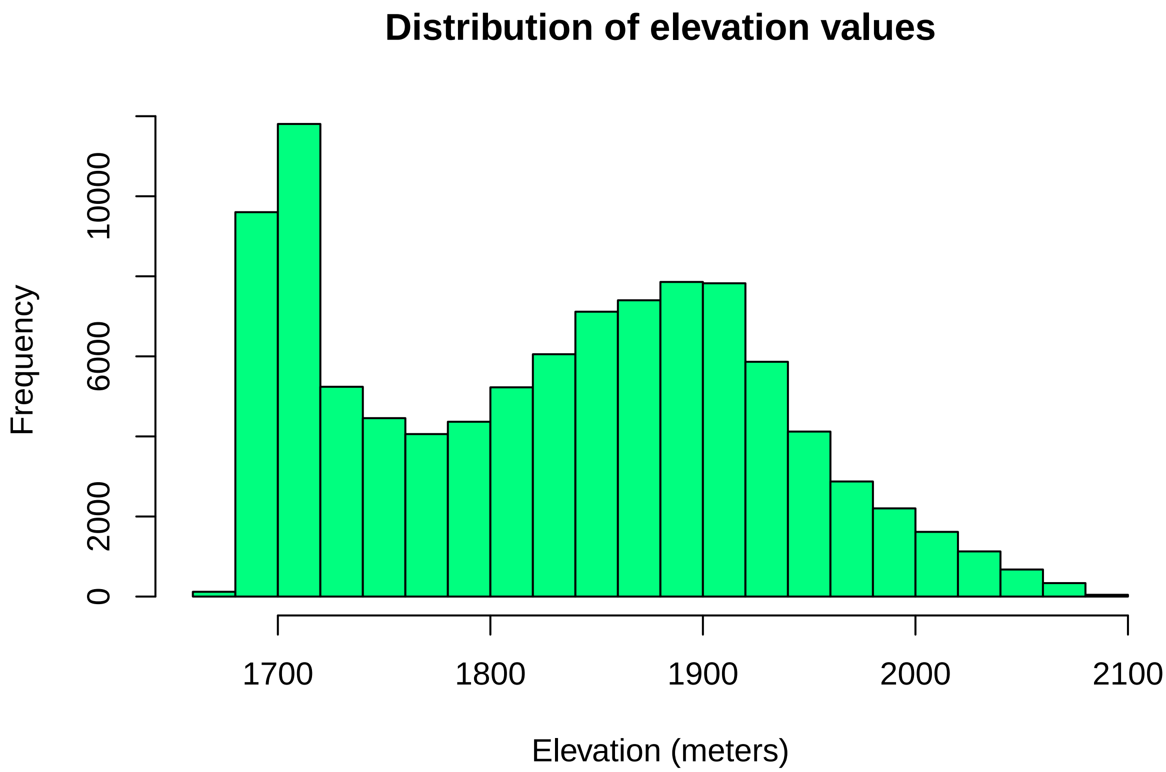

Figure 3: histogram of DEM elevation values