Lab 2 Report – Part 1

Title: Exploring Depth Visualizations with ArcPro and ArcPy
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Date: March 4, 2021

Project Repository: https://github.com/Tuletara/GIS5572.git

Abstract
There are several methods of data analysis and visualization that capitalize on often freely available and incredibly dense data. Understanding the various data formats is key to working with these open source datasets. The computational demands of large data such as LiDAR as well as 3 dimensional visualization techniques can bog down the process and reduce capabilities. Therefore, familiarity with these aspects is helpful. This study explores some of the multidimensional tools that best utilize rich topographical and temporal data such as TINs, DEMs, and Spacetime Cubes. The workflows can be rather complex but the results offer pleasing and powerful outputs that allow for much greater understanding and questioning of the data. These formats can also aide in communication with the public on issues depicted in the map with an visually pleasing interactive display that enables deeper explorations. Results can be more accurately portrayed with the increased functionality of elevation viewing and vertical accessibility to information.

Problem Statement
This is an exploratory analysis of different visualization methods using ArcGIS Pro and ArcPy. The data currently available offers more detailed, more continuous, and more voluminous information about our world than ever before. Data types and formats are also continuously evolving to meet the growing needs of data collection, storage, transformation, and interrogation. This brief exploration will touch on the different processes and accessibilities of LiDAR and temporal data in .laz, .las, and .bil formats; and conversion of these data into triangular irregular network (TIN), digital elevation model (DEM), and Spacetime Cube transformations.

This overview serves as a learning experience for working with computationally intensive datasets and methods. A better familiarity now will facilitate working with even more extensive data and processes in the future. A preview of the capabilities and limitations of these powerful tools will help guide future research work and allow for a more efficient use of these process and analysis functionalities. Additionally, a deliverable which enables a more dynamic and interactive interface for viewers, as created via animations and 3 dimensional viewing, promotes further exploration and interest in the topic. It also enhances the learning process by creating more pathways to deeper investigations.

Table 1. Required Data for Depth Visualizations.

#	Requirement	Defined As	Spatial Data	Attribute Data	Dataset	Preparation
1	LiDAR	All elevation in meters	Any	Any	MN GOV Elevation	Convert to .las
2	Averaged Annual Precipitation	30 – year normals precipition in millimeters	Continental USA	Volume	PRISM	Project to map Coordinate System

Input Data

As Table 2 shows, the necessary data was acquired from two publicly available and free sources. The state of Minnesota offers elevation data in downloadable compressed las files split into several smaller tiles. One tile was randomly chosen for the purpose of this lab.

The precipitation data was sourced from the Northwest Alliance for Computational Science & Engineering PRISM website which offers nationwide climate variables beginning in 1895. The 30-year normals precipitation data used here is for the time period of 1981 – 2010 with precipitation measured in millimeters.

Table 2. Acquired Data for Depth Visualizations.

#	Title	Purpose in Analysis	Link to Source
1	Minnesota LiDAR	Raw input dataset for MN elevation	MN GOV Elevation
2	PRISM_ppt_30yr_normal_800mM2_03_bil.zip	Raw input data for climate variables	PRISM

Methods

The process for creating the TIN and DEM layers from LiDAR data began by downloading and unzipping .laz files through the MN DNR's File Transfer Protocol (FTP) server. This format must be uncompressed before it can be opened by ArcGIS Pro (esri Technical Support). From here, TIN and DEM conversion tools were a simple means to create the transformations. A map layout was then created in the Pro graphical user interface (GUI) and then exported as a PDF with ArcPy to deliver the final product. Figure 1 illustrates the step by step process.

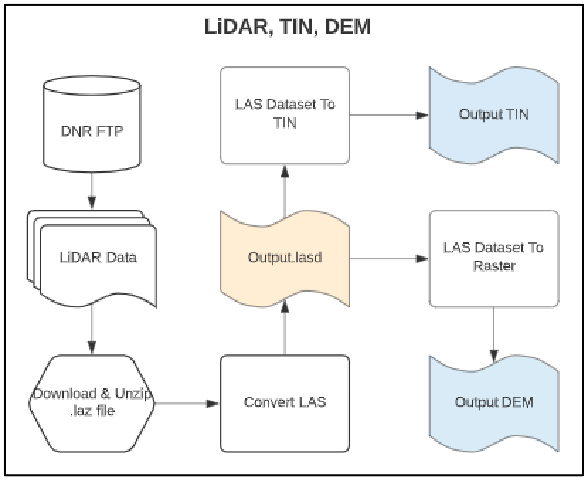

Figure 1. Conceptual Model for .laz conversion to TIN and DEM.
Orange indicates an intermediary output while blue indicates final layers.

To accomplish a side by side multidimensional comparison of the LiDAR data, a 3D scene was created by accessing the Convert To Local Scene option in the View tab and group in the main Arc Pro Ribbon. The Map and Scene were then linked with the Scale and Center option available in the Link Views menu and displayed by right clicking the scene tab and making a New Vertical Tab Group. See Figure 2 the workflow. The 3D scene was flipped vertically to view the 'elevation' differences of the data points with navigation icon, Figure 10 in the Results section.

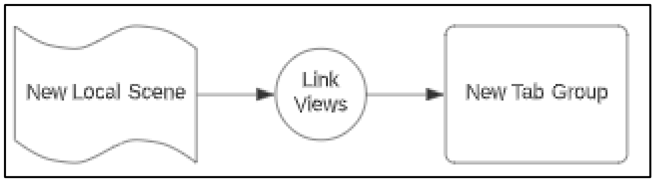

Figure 2. Workflow to create a 3D scene, link, and display alongside the 2D map.

For the final process in this study the 30 year normals precipitation data was visualized through a Spacetime Cube as well as a timeseries GIF animation. This was a complex process laid out in Figure 3. Many of the steps were initially performed through the ArcGIS Pro interface and then translated into code to provide an accommodating Extract-Transfer-Load routine (ETL). However the data was collected and initially prepared in the ETL.

Using the PRISM Application Programming Interface (API) a Uniform Resource Identifier (URL) was generated and an API request made with requests.get. Once the files were unzipped they were projected into the Albers Equal Area projection coordinate system. An empty mosaic dataset was created to hold the multiple files with two new fields created in the Attribute Table and then Calculated to handle the precipitation variable along with the timestamp. The time property must be temporarily disabled to prevent unintended filtering. This was done in the mosaic layer properties through the GUI as no arcpy code was discovered to accomplish this task. Now the multidimensional layers were built with the following cascade of tools: Build Multidimensional Info, Make Multidimensional Raster Layer, Create Space Time Cube MD Raster Layer, Visualize Space Time Cube 3D. The final results were then displayed in the map frame. They were also pulled into a 3D scene with arcpy.management.Create3DObjectSceneLayerPackage and saved to a scene layer with arcpy.management.SaveToLayerFile. This is an optional step that provides another viewing platform for the data. Please note that it does add significant computational demands and draw time.

The final animated GIF was achieved by enabling Time in the Layer Properties for the multidimensional layer. This enables the Time and Animation Ribbons. In the Time tab in the Current Time group, the span was set to 1 month and the correct layer was selected in the Step group. In the Animation tab in the Playback group, Duration was set to 8 milliseconds which is standard for this type of time series (Digital Geography). Click Movie in the Export group and pick the GIF icon. Another standard setting is 5 Frames Per Second (Digital Geography). This keeps the file size reasonable. The animated GIF was then exported and saved to disk.

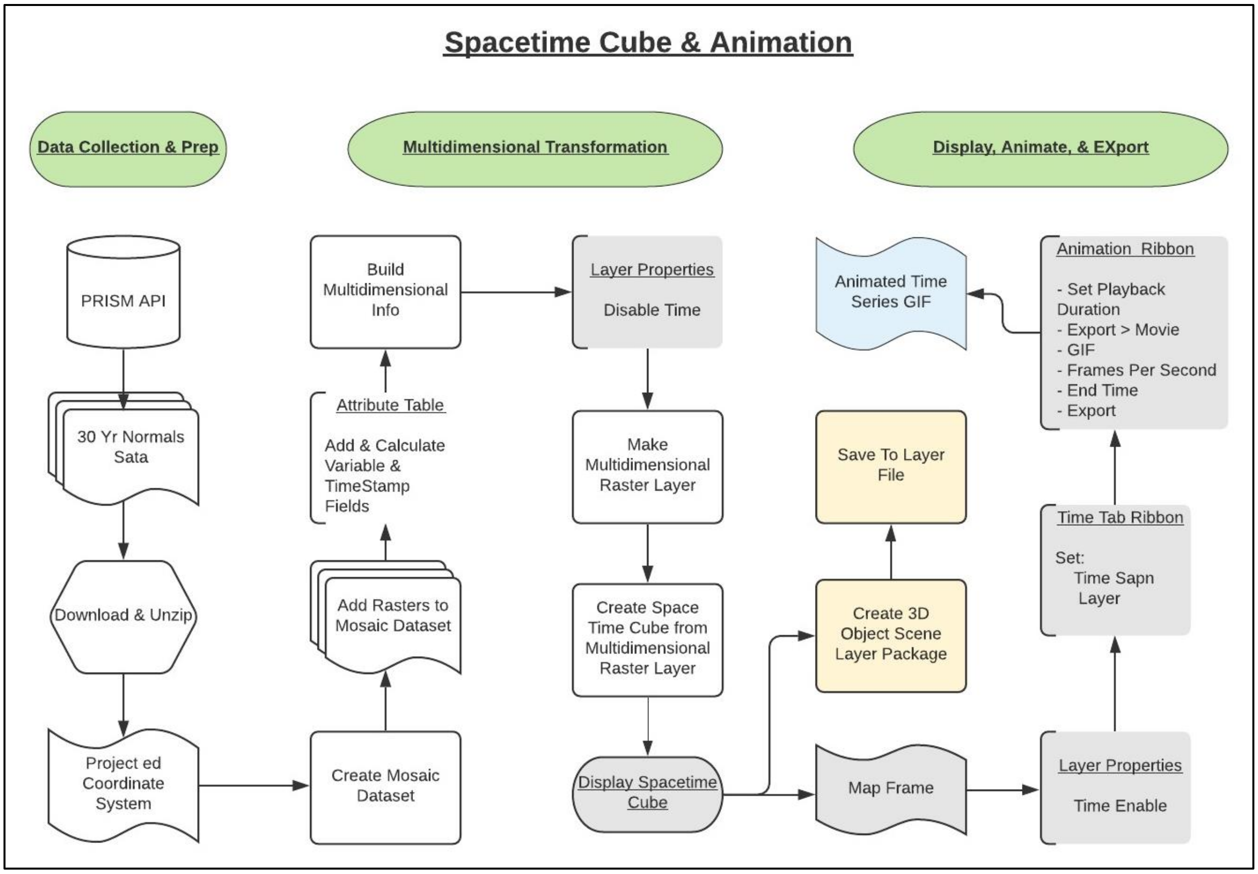

Figure 3. Workflow for Spacetime Cube & Animated Time Series. The process is broken down into three functions indicated by the blue headers. The grey boxes indicate work done in the Arc GUI while yellow highlights the optional steps to create a 3D scene.

Results

The original LiDAR data was successfully transformed into TIN and DEM layers. As seen in Figure 4 each format illustrates the landscape quite differently and offers unique evaluation opportunities. These layers can also be inputs into several other operations, creating more tools for analyses; including a 3D Local Scene to aide in viewing the dense data packets. To further explore this functionality, the LiDAR point cloud was displayed in a side by side comparison in both 2- and 3- dimensional formats. The results are discussed in more detail below and can be seen in Figure 10.

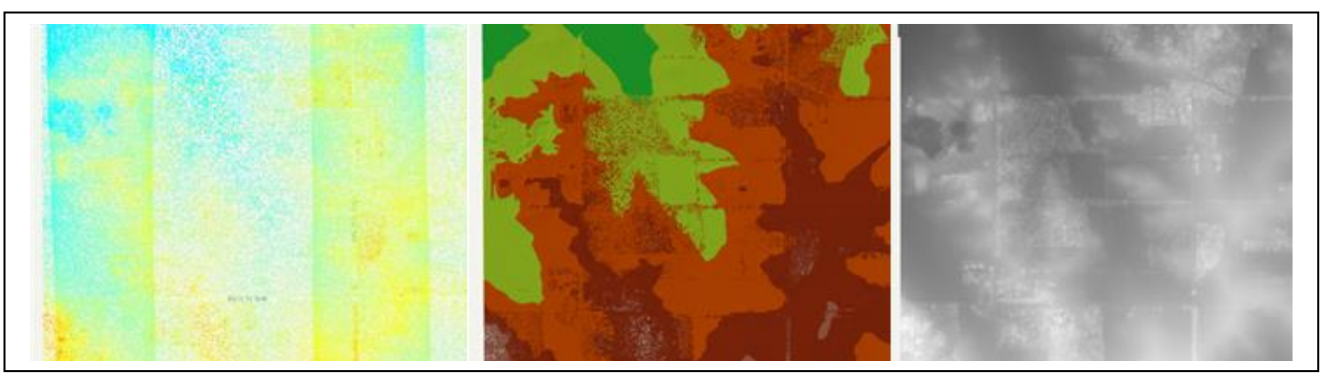

Figure 4. LiDAR data uncompressed into .las format (left) then converted into TIN (center) and DEM (right) layers. Displayed in 2D.

Generating a Spacetime Cube from the .bil files did achieve the desired results. Figure 5 shows an overview of a zoomed in section of Washington state as well as a vertical image of the stacked cubes viewed in Planar Navigation Mode. It was necessary to zoom in to limit excessive draw requests which triggered frequent warnings in Arc Pro. The Distance Visibility Limit was also decreased to the smallest possible option in the cube Layer Properties to handle this error. The image on the right shows how much more accessible the data is when viewed vertically with each cube representing a month of normals precipitation data.

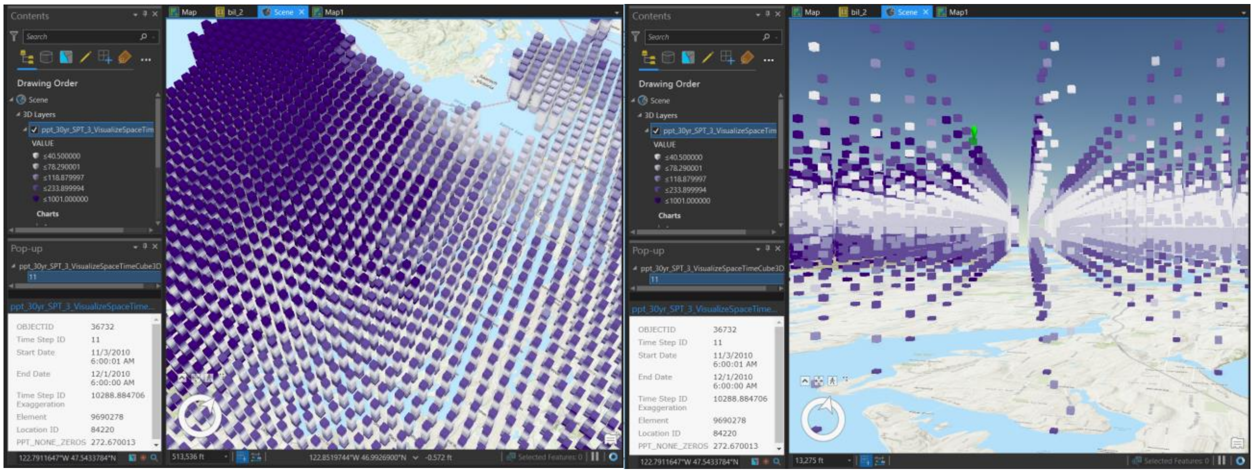

Figure 5. Spacetime Cube in a 3D scene viewed both in Standard (left) and Planar (right) Navigation Mode.

The timeseries animation, however, was not completely successful. As Figure 6 shows, an animated GIF was created but I could not achieve proper scaling to include the entire West coast and Maine in the final product. This is despite altering and locking the scale extent, locking the View Size, or working with the Keyframe Gallery. Either this is a Pro glitch or, more likely, I just missed some setting that can resolve this issue. There is also one time step that displays coarse pixilation in both Pro and the GIF in which I was unable to resolve through any settings changes. The timestamp also needs some adjustment as it shows a specific time and year inappropriately since this is a 30 year average, see Figure 7. Despite these errors, the timeseries and animation were created and through further exploration of the tools, a more refined product is possible.

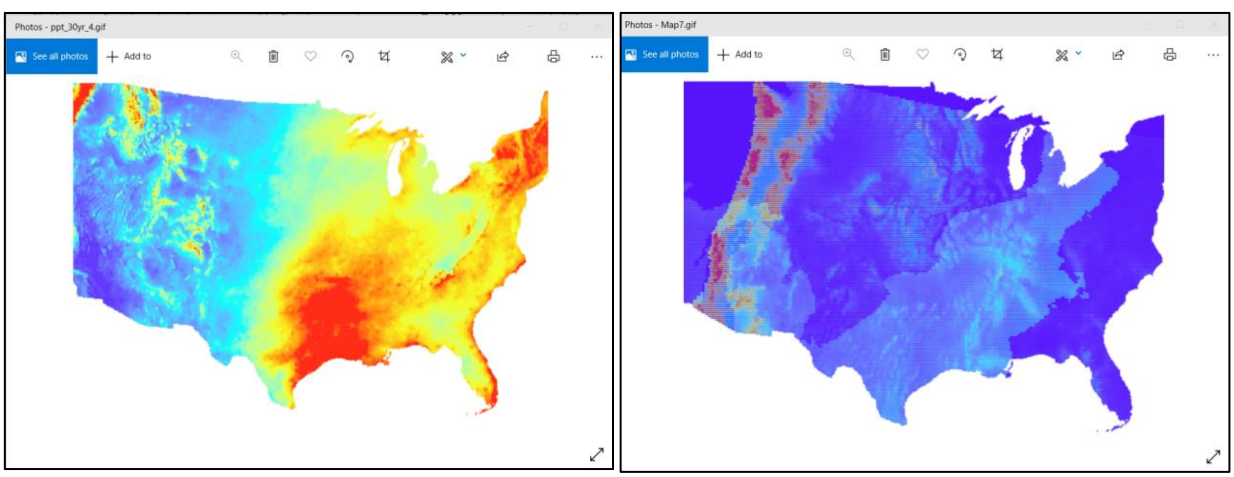

Figure 6. The animated timeseries GIF of U.S. 30-year normals precipitation. The right frame shows the pixilation that occurs during one of the frame changes.

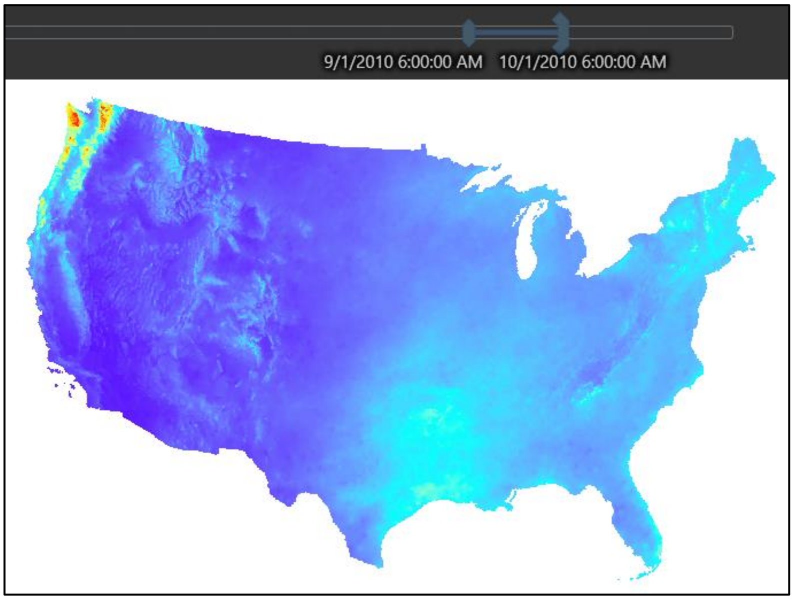

Figure 7. The timeseries in ArcGIS Pro displaying the entire continent but with a mislabeled year and time.

Results Verification

All results were confirmed through visual inspection of each respective output as well as successful completion of the tool, as indicated in either the GUI or by ArcPy. The three elevation formats all show the same elevation for the same location and the side by side comparison shows the same landmarks in both the 2D and 3D screens. The 30 year precipitation amounts were confirmed by doing spot checks against the original data on the PRISM website.

Discussion and Conclusion

Creating a TIN and DEM from LiDAR data is a rather simple process but the results offer the ability for extensive analyses. Each format presents very different views of the same surface as illustrated in Figure 8. This image appears to be a gravel pit with a mound in the middle of an elevation ‘bowl.’ The topography is hinted at in the satellite image with the steep northern slope visible as well as in the LiDAR and DEM images with the darker circular patterns located in the center of the image. However, the mound and pit really stand out in the TIN image. The attributes shown in Figure 9 also offer different information for each layer. While they all indicate the elevation, LiDAR reveals much more detail about the point while the TIN draws out the slope and aspect .

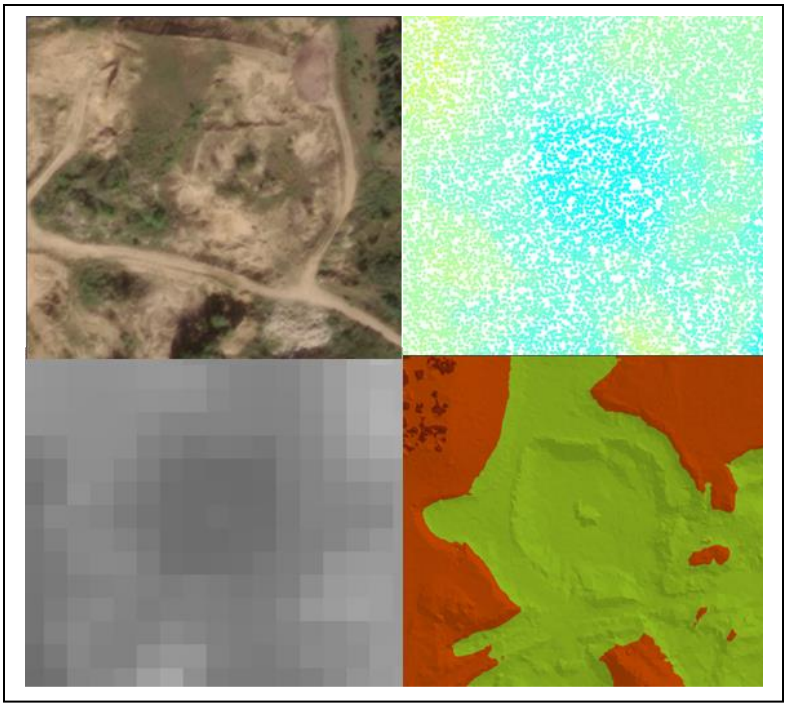

Figure 8. Comparison of elevation visualization between satellite imagery (upper left), LiDAR (upper right), DEM (lower left), and TIN (lower right). Each image depicts the same location of a gravel pit.

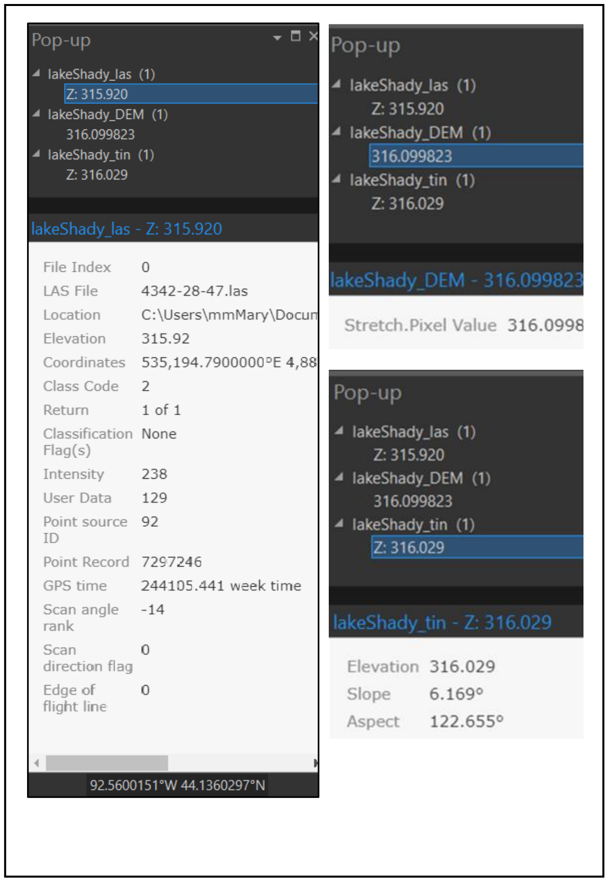

Figure 9. Attribute information for the same point in each layer showing a consistent elevation but also different data depending on the layer. From left to top right to bottom right shows the Identify Pop-up for LiDAR, DEM and TIN layers.

In regards to the 2D and 3D side by side comparison, I found it most useful by flipping the 3D scene horizontally, Figure 10. This made it easy to see the point densities while the 2D scene aided with overall navigation. The surface created with this tool really helps the visualization process in a way that viewing flat data cannot. The land features stand out incredibly well and accessing the individual data points within the stack is easier with the component of vertical space to separate them. Features in the scene are literally formed and encoded with information. It brings the realm of analysis to whole new heights!

Revisiting the previous gravel pit, the elevation bowl is easier to detect in a 3D scene, even when viewed from nadir, Figure 11. This angle also shows rooftops and tree canopies quite clearly. Both 3D view angles from Figures 10 and 11 clearly reveal individual trees and even a lone fallen tree trunk is easily identifiable in the southwestern area of the image. None of these details are apparent in the 2D image as seen in figure 10.

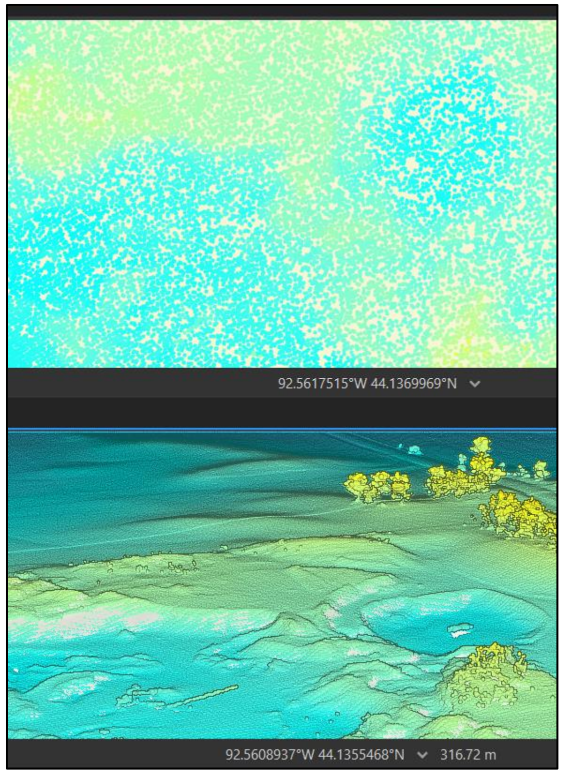

Figure 10. A split screen view of the gravel pit from figure 8 with a 2D scene in the top tab group and 3D in the bottom. The pit and mound, individual trees, and even a log jutting out of the ground are clearly distinguished in the 3D pane while none of these objects appear in 2D.

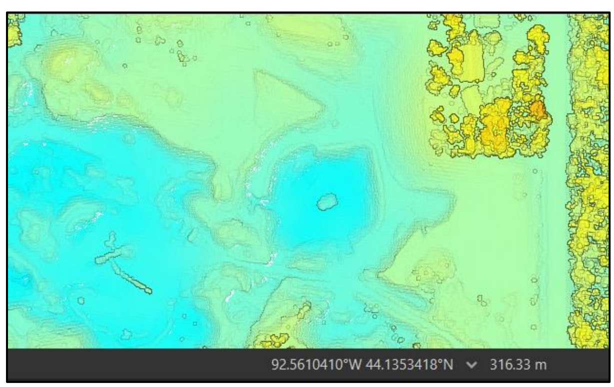

Figure 11. A nadir view of a 3D scene of LiDAR data. This area is the same gravel pit as referenced above in figure X.

As mentioned in the Methods section, the Spacetime Cube was a complex multi-step process and it's absolutely critical to have the data in order before the process is initialized. There were difficulties caused by a poor understanding of the original data and how the Spacetime Cube workflow flows. My misunderstanding was that .bil files in themselves are multiple files and the normals data is averaged on a monthly basis over a 30 year period. It seemed like selecting annual values would provide the necessary multidimensional data. The appropriate selection was the 'All Normals Data' designated through the ETL with '_all' rather than '14' (annual). Once this error was discovered it was simply a matter of following the transformation process.

There were issues with translating all the necessary steps into code as well. I could not discover a way to Disable or Enable Time in the layer properties or animate and export the time series. Therefore, these steps were solely performed in the GUI. Despite the benefits of the GUI, or perhaps because of its limited workability; the layer scaling refused to be corrected to the full extent of the feature during the exporting process. Regardless of what scale was in the map frame, whether the extent was locked or not, the West coast and part of Maine was cut off over repeated efforts to display properly.

More refinement with this process is clearly needed but the complexities prove how intensive the analyses possibilities are. Once the methodology is understood, the Cube and animated time series offers powerful and appealing tools for analysis and presentation. The multidimensional nature of the data literally allows you to dig into it interactively. This level of conceptualization of place and data can lead to a stronger understanding of the holistic picture and inspire clearer questions.

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Self-score

Category	Description	Points Possible	Score
Structural Elements	All elements of a lab report are included **(2 points each)**: Title, Notice: Dr. Bryan Runck, Author, Project Repository, Date, Abstract, Problem Statement, Input Data w/ tables, Methods w/ Data, Flow Diagrams, Results, Results Verification, Discussion and Conclusion, References in common format, Self-score	28	**28**
Clarity of Content	Each element above is executed at a professional level so that someone can understand the goal, data, methods, results, and their validity and implications in a 5 minute reading at a cursory-level, and in a 30 minute meeting at a deep level **(12 points)**. There is a clear connection from data to results to discussion and conclusion **(12 points)**.	24	**22**
Reproducibility	Results are completely reproducible by someone with basic GIS training. There is no ambiguity in data flow or rationale for data operations. Every step is documented and justified.	28	**26**
Verification	Results are correct in that they have been verified in comparison to some standard. The standard is clearly stated **(10 points)**, the method of comparison is clearly stated **(5 points)**, and the result of verification is clearly stated **(5 points)**.	20	**18**
		100	**94**