The Reference Library

Coordinates, Coordinate Systems and LIDAR Data (Part 3)

DarrickWagg
Karrie-Sue Simmers
January 9, 2015

In the previous articles we provided an introduction to coordinate systems, geoids, datums and projections. This background information was needed in order to delve into more details on transformations and changing projections in the various software packages to help you do more with LIDAR data. This article will provide the information into transformations and changing projections within LP360, GeoCue and Terrasolid.

Changing Coordinate Systems

It becomes necessary, at times, to change the coordinate system assigned to LIDAR data for a final delivery of the data. For instance, the LIDAR data may have been processed using the horizontal coordinate system NAD83 UTM 19N meters and vertical coordinate system of Ellipsoid meters. However, as part of the final delivery the LIDAR data needs to be put into horizontal coordinate system NAD83(2011) State Plane Maine West Feet and vertical coordinate system of NAVD88 Geoid 12A Feet.

In order for the data to be projected from one coordinate system to another, in the above example, a transformation needs to take place. The transformation that is defined will determine how the data is translated to the new coordinate system. The accuracy of the transformation can range anywhere between a couple of centimeters to a few meters dependent upon the transformation method and parameters that are chosen.

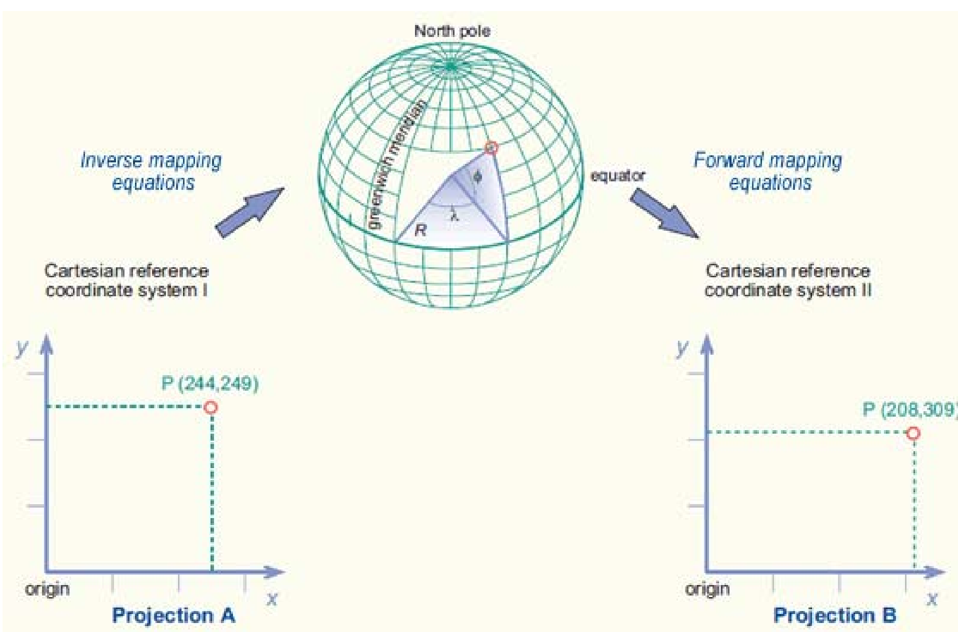

Figure 1 - Changing Projections - Images Courtesy of http://kartoweb.itc.nl

Coordinates, Coordinate Systems and LIDAR Data (Part 3)

Transformations

There are many different kinds of transformations that can be used to re-project data. The transformation method chosen is reliant upon the area of interest. If you're re-projecting the data to an area in Maine you would want to make sure you are using a transformation that is accurate for that area and usage.

The most common transformation methods are: Geographic (datum), equation-based and grid-based.

Geographic transformation methods make changes to the underlying spheroid, thus resulting in a change to the underlying datum. A geographic transformation is always defined in a specific direction, for instance from WGS84 to NAD83 and will be written in the following format: NAD_1983_To_WGS_1984_5.

The data first goes from the source coordinate to geographic coordinates and then from geographic coordinates to the target coordinates. Using the previous example going from UTM to State Plane a possible horizontal transformation that could be used is as follows:

NAD_1983_to_WGS_1984_5 + NAD_1983_2011_to_WGS_1984_epoch2010

Equation-based methods are transformations that occur based upon a specific equation. Three common methods are the Geocentric Translation, the Helmert 7-Parameter transformation and the Molodensky transformation.

The geocentric translation, or three-parameter transformation, method is the simplest datum transformation that can occur and relates two systems through three different translations. This method applies a linear shift between the centers of the two geocentric coordinate systems that are represented by the parameters DX, DY and DZ.

The 7-parameter transformation takes into account not only the linear shift along each axis but also angular rotations (R) around each axis and the scale factor (µ).

The Molodensky method is a direct conversion between two geographic coordinate systems without actually converting to a Cartesian coordinate system.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \text{Target} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \text{Source} + \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} S\ to\ T - \text{Geocentric Translation Maxtrix}$$

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \text{Target} = \mu \boldsymbol{R} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \text{Source} + \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} S\ to\ T - \text{7-Parameter Translation Maxtrix}$$

$$\begin{bmatrix} \varphi \\ \lambda \\ h \end{bmatrix} \text{Target} = \begin{bmatrix} \varphi \\ \lambda \\ h \end{bmatrix} \text{Source} + \begin{bmatrix} \Delta \varphi \\ \Delta \lambda \\ \Delta h \end{bmatrix} S\ to\ T - \text{Molodensky Translation Matrix}$$

Grid-based methods are designed to allow a user to convert between different geographic coordinate systems. NADCON (North American Datum Conversion) and HARN (High Accuracy Reference Networks) are used within the United States, while Ntv2 is used within Canada. “NADCON was developed in order to facilitate conversion between the datums. The grids used by the program are based on more than 150,000 horizontal control points whose coordinates reside in NGS’ (National Geodetic Survey) data base, and provide transformed positions based on the shifts of the control nearest to the input position”[1]. The accuracy for the contiguous United States is approximately 0.15 meters. HARN has an accuracy of approximately 0.05 meters.

Applying Transformations within GeoCue, LP360 and Terrasolid

GeoCue

GeoCue currently provides extensive support for both horizontal and vertical coordinate transformations in a user friendly interface – at least a relatively user friendly interface for such a complex functionality with an infinite choice of options. Infinite in that the program allows for user definable datum transformations such as those one would use in defining and using grid-to-ground, and Horizontal Time Dependent Positioning coordinate systems. This is in addition to the support for almost 4700 horizontal, and over 200 vertical coordinate systems, and their standard transformations built into the product. All data used within the workflow management software must have a coordinate reference system associated with it so that the program may assist users with ensuring that data aligns.

To define, or approve, a datum transformation select the Map Coordinate Systems icon within the GeoCue Client (Figure 2). Select the Coordinate System that requires the transformation and select either Approve, or Define, for the Horizontal and Vertical Transforms independently (Figure 3). Approving the transformation means the user agrees with the default transformation as defined by the program, so it is always recommended to review the default selections using the Define button before approving the transformation. Using the Define option allows the user to select from an available path, and the corresponding stages in the stage library, or to define a stage to be used for the transformation. Figure 4 is an example of a transformation defined by the user between NAD83 and NAD83(2011). The Review button allows users to see exactly what parameters are being used for the transformations being applied. The idea is to keep the information on transformations being applied to data clear and accessible for users.

Figure 2 - Map Coordinate Systems[1]

[1] http://www.ngs.noaa.gov/TOOLS/Nadcon/Nadcon.shtml

Coordinates, Coordinate Systems and LIDAR Data (Part 3)

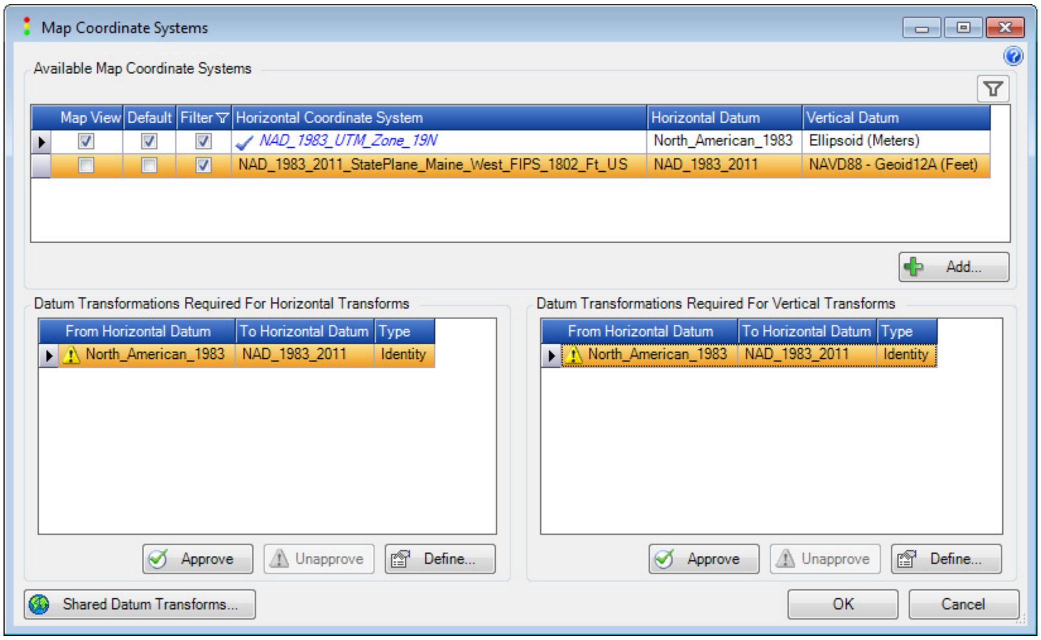

Figure 3 - Setting Transformations

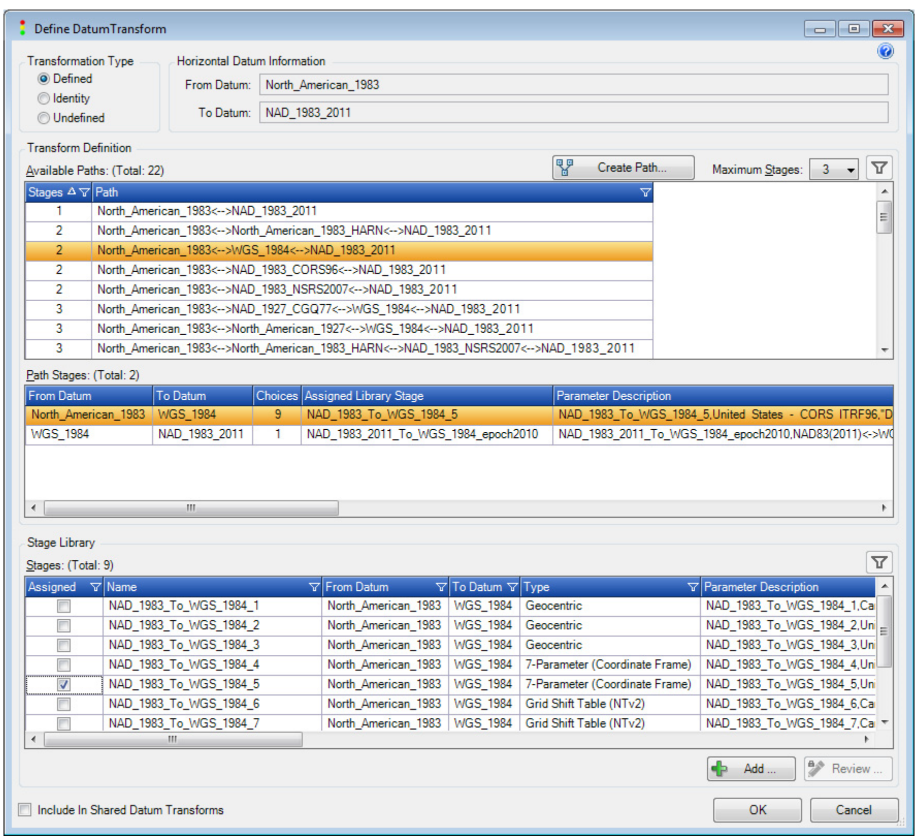

Figure 4 - Define Datum Transformation

It is important that all transformations be defined and approved at the beginning of a project so that when data is processed the appropriate transformation is applied. Additional information concerning coordinate reference systems within GeoCue can be located in the GeoCue Help Guide, along with the following CueTips “Adding a New Geoid Model in GeoCue”, “Creating Tidal Datum Grid Files”, “Horizontal Time Dependent Positioning”, “Using MHW Datums in GeoCue” and “WGS84 to NAD83” accessible from the Knowledge Center found at support.geocue.com.

LP360 for ArcGIS

LP360 for ArcGIS’s Reproject LAS Files Tool draws on ESRI’s transformation engine to determine the best transformation for the change in coordinate systems specified. This is currently automated without any direct input from the user, outside of specifying the incoming and outgoing coordinate systems (Figure 5). This means that the user doesn’t get the option for selecting or creating unique transforms. Hence, the user must rely on whatever preconfigured values ESRI is using in this process. There are currently no transformation capabilities within the LP360 for Windows™ products. Look for that to change in the near future.

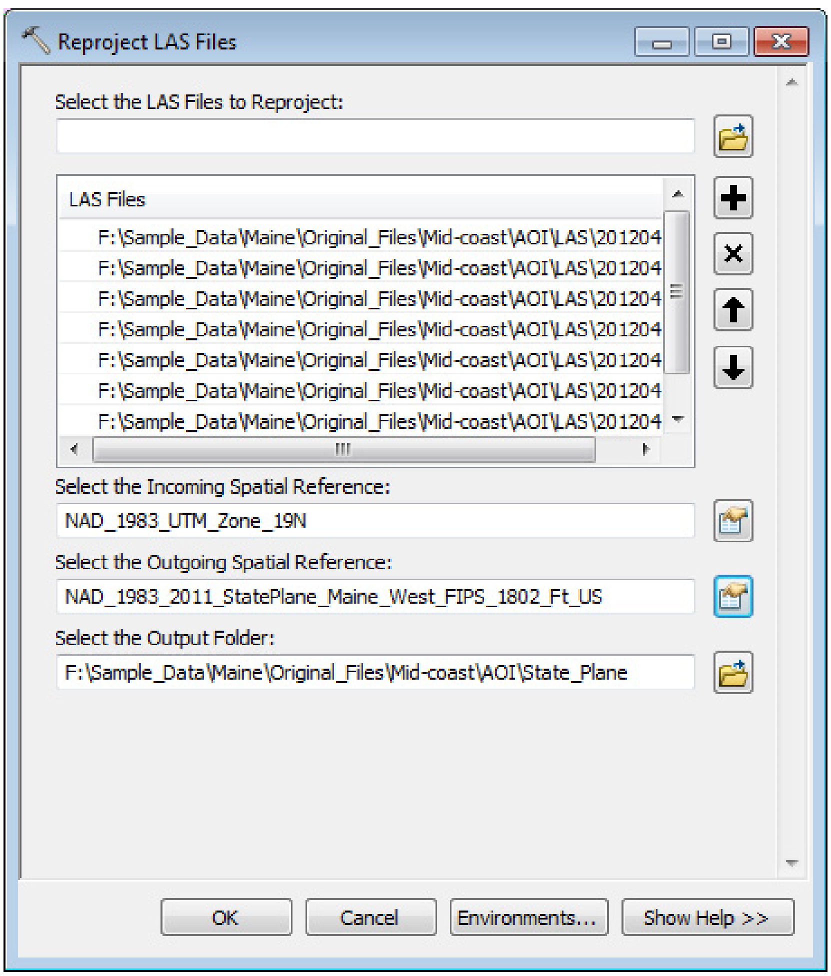

Figure 5 - Reprojecting LAS Files within LP360 for ArcGIS

Additional information concerning coordinate reference systems within LP360 can be located in the context sensitive LP360 Help, along with the previous articles on the Reproject and Define Projection tools within LP360 for ArcGIS.

Terrasolid

Terrasolid takes the approach that it isn't necessary to know the coordinate reference system for any data, and leaves it to a user to have to know when and how to apply transformations. TerraScan and TerraPhoto each provide the user methods for applying transformations to LIDAR and in some cases ancillary data. Located under the product Settings there is an option to define coordinate transformations within each product. Note that the modules do not share the information, but one may readily copy and paste the information from the settings of one product to the settings of the other. Figure 6 shows a list of the different transformation types that can be utilized within the Terrasolid software.

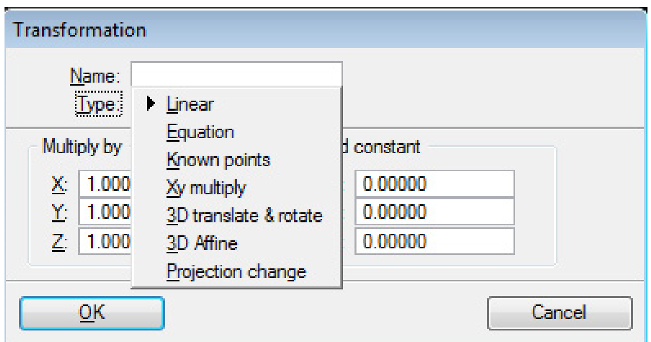

Figure 6 - Coordinate Transformations within Terrasolid

The two most commonly used transformations are Linear (Figure 7) and Projection Change (Figure 8). Linear Transformation is designed to scale and/or translate coordinate values. A common usage of the linear transformation is for converting between units of meters and feet. It can also be used for many grid-to-ground transformations. The Projection Change Transformation is used when converting from one projection system to another. The software transforms the coordinates from the source projection system into the WGS84 geocentric coordinate system, and then from there computes the transformation into the target coordinate system.

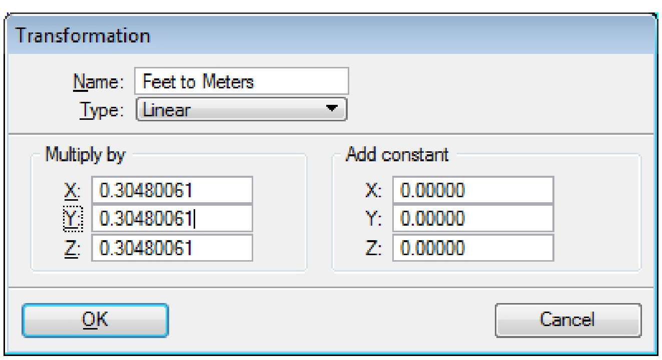

Figure 7 - Linear Transformation

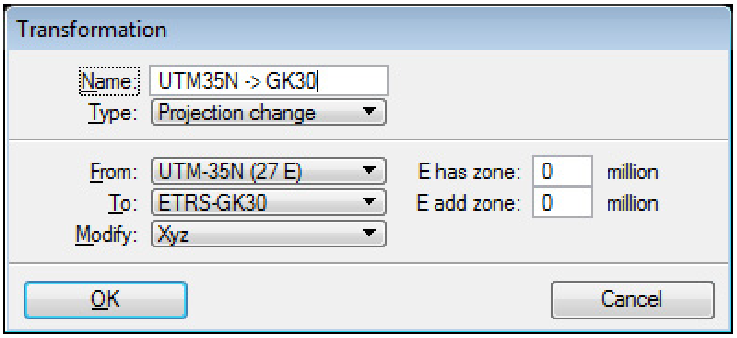

Figure 8 - Projection Change

For additional information concerning coordinate reference systems within the Terrasolid products please refer to the TerraScan User Guide, and the CueTip "Reprojections, Transformations and Geoid Corrections in TerraScan" accessible from the Knowledge Center found at support.geocue.com.

Conclusion

We hope that the past several articles have provided the basic concepts and information on coordinate systems, and how they come into play when working with LIDAR data. The LAS specification has for several years had a requirement for all data to contain the CRS information in the header of the LAS files. With LAS v1.4 the format has been modified slightly with the addition of Well Known Text (WKT) definitions for Coordinate Reference Systems. It is very important when producing, or using LIDAR data, to have a basic understanding of the coordinate reference systems in order to ensure that data is being produced in the intended manner and that the associated information accompanies the data for all future users. Coordinate systems can be very complex, but with a few general rules, and hopefully with the tools provided in our various product lines, can be fairly simplified for your survey and mapping applications. Feel free to contact us if you have any outstanding questions not covered in this article series or the referenced CueTip material.