



PROJECTING GEOGRAPHIC COORDINATES ONTO FLAT MAPPING SYSTEMS

BACKGROUND

The distance between two points is a property of their spatial relationship. We can, for example, use the distance between two cities to estimate the cost and time needed to fly between them. Because distance matters, how we measure distance also matters. The distance between two points can be calculated from their coordinates (Eq. 1)(Bolstad, 2017: p119, 174, 399, 470, 530, 626, 629, and 687)(Kimmerling et al., 2012: Chapter 11).

$$\text{Distance}_{1 \rightarrow 2} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad \text{Eq. 1}$$

where:

| | |
|-----------------|---|
| $1, 2$ | a counter {from point 1, to point 2} |
| x | the x or easting value |
| y | the y or northing value |
| <i>Distance</i> | the Euclidean distance between two points |

Using Eq. 1, the length of a line composed of multiple segments can be calculated if we know: a) how many vertices define the line; and b) the coordinates of those vertices (Equation 2).

$$\text{ShapeLength}_{1 \rightarrow n} = \sum_{i=1}^n \sqrt{(x_{i+1} - x_i)^2 + (y_{i+1} - y_i)^2} \quad \text{Eq. 2}$$

where:

| | |
|--------------------|---|
| i | a counter {from vertex 1, ... , to vertex n } |
| x | the x or easting value |
| y | the y or northing value |
| <i>shapeLength</i> | the calculated distance, or length, of a line |

The area of a polygon also can be calculated if we know: a) how many vertices define its perimeter; and b) the coordinates of each vertex (Equation 3).

$$\text{ShapeArea}_{1 \rightarrow n} = \frac{1}{2} \sum_{i=1}^n [(x_1 \times y_{i+1}) - (x_{i+1} \times y_i)] \quad \text{Eq. 3}$$

where:

| | |
|------------------|---|
| i | a counter {from vertex 1, ... , to vertex n } |
| x | the x or easting value |
| y | the y or northing value |
| <i>ShapeArea</i> | the calculated area of the polygon |



Using Shape_Area

The US Census Bureau produces an official count of the US population every ten years (years ending with zeros) and it samples the population to build inter-census estimates. Census counts and survey estimates are then aggregated up to the county, state, and national levels for people to use.

Calculating the population density for a county is simple (Equation 4). You need an accurate population value (either a count or an estimate) and an accurate area value (usually in sq.mi or sq.km). The US Census Bureau publishes reliable population data, but we have to use our GIS correctly to make sure our county areas are just as reliable.

$$\text{PopDensity}_i = \frac{\text{pop}_i}{\text{ShapeArea}_i} \quad \text{Eq. 4}$$

where:

| | |
|-------------------|---|
| <i>i</i> | a counter {county 1, county 2, county 3, ..., county <i>n</i> } |
| <i>pop</i> | the population count or estimate for county <i>i</i> |
| <i>ShapeArea</i> | the area of county <i>i</i> (see Eq. 3) |
| <i>PopDensity</i> | the population density value to be calculated |

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I'm showing you the methods used to calculate shape lengths (Eq. 2) and shape areas (Eq. 3) because I need you to understand that each method relies on each shape's coordinates only. No other variables are used to calculate Shape_Length or Shape_Area.

Ideally, when the geographic coordinates of two points are projected onto a flat mapping system, we want their flat map properties to mimic their geodesic properties (i.e., planar distance = geodesic distance). Unfortunately, it is impossible to preserve every geodesic distance between every pair of points during projection – especially when projecting hundreds or thousands of points over large extents. Some pairs of points will project farther apart than they should; the distorted lengths and areas we calculate from such coordinates will be inflated. Some pairs of points will project closer together than they should; the lengths and areas we calculate from those coordinates will be deflated. Projection distortions can propagate as errors in subsequent calculations (e.g., in Eq. 4).

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PURPOSE

The purpose of this lab is threefold: a) to help you develop a working knowledge of our national geographic coordinate system; b) to help you develop a working knowledge of commonly used planar mapping systems; and c) to help you understand how projecting geographic coordinates onto those planar mapping systems can create nasty distortions that lurk in your projected data. Take your time and take good notes. Work carefully and ask questions.

OBJECTIVES AND METHODS

Obj. 1. Get familiar with the geospatial data you downloaded

The data you need for this lab is available on the course website.

<https://webpace.ship.edu/sadrzy/geo363/>

For this lab, we're going to use a copy of the Census Bureau's 1:500,000 (500K) scale **Cartographic Boundary Shapefiles** for US counties (less AK and HI). I added two text fields to the county polygon attribute table so that you can see which county fits within which zone of the US State Plane mapping system (see Kimmerling et al., 2017; Fig. 4.5 on p67)(see Bolstad, 2016; p684).

We're also going to use two shapefiles that I created, which represent the direct connections to and the airports that are reachable via Harrisburg International Airport.

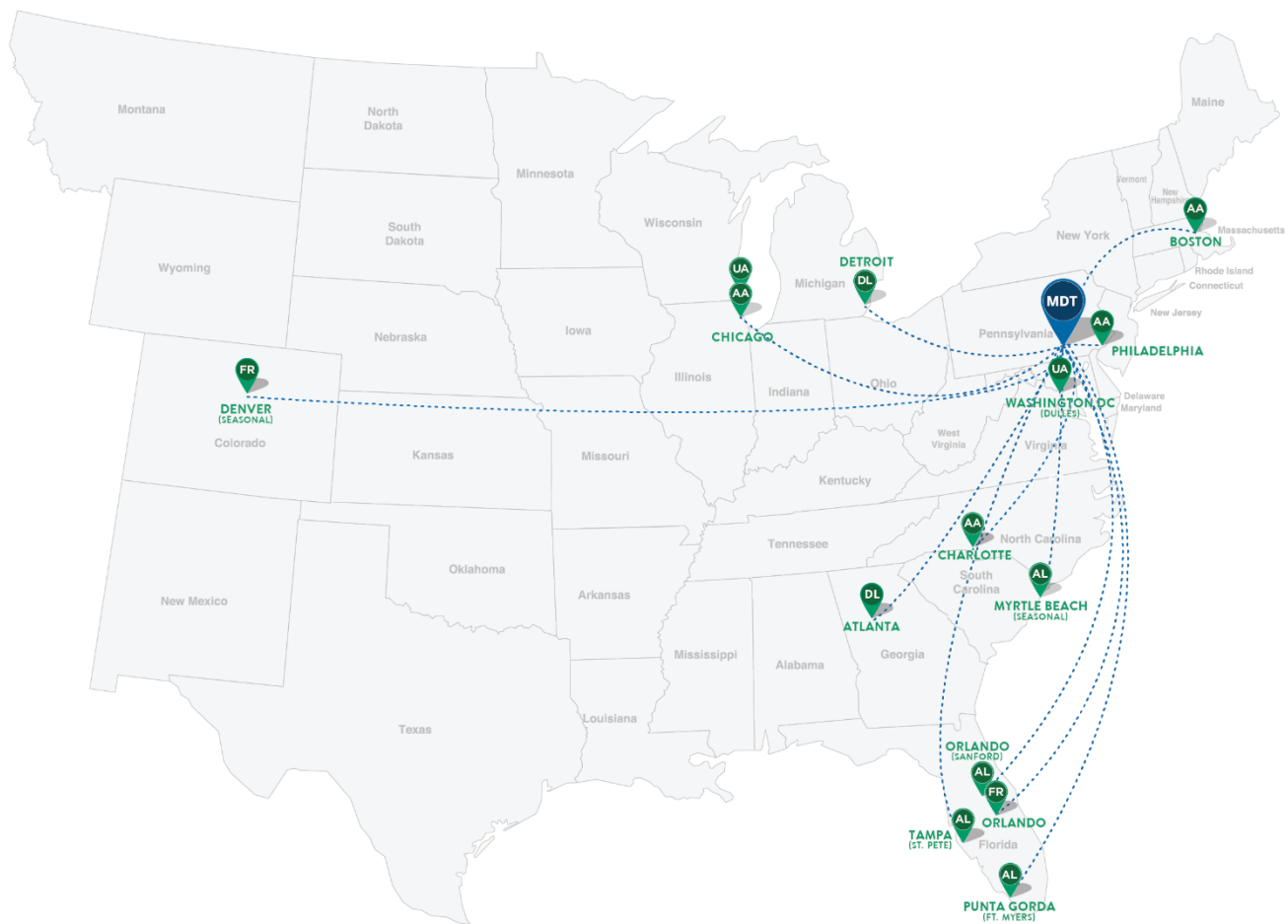


Figure 1. A stylized map of routes from Harrisburg International Airport to twelve destinations (last updated in November 2018).



Open your **ArcGIS Pro** project and use **Catalog** mode. The default metadata view is limited. Use **Project > Options > Metadata** and change the default view style **to** the **FGDC Metadata** style.

Use Catalog mode to find your airports shapefile - **airports.shp**:

1. Inspect your **Metadata**.
2. Inspect your point **Geography**; and
3. Inspect your attribute **Table**.

Question 1: According to the attribute table, which three airports are the northernmost airports?

Find your direct routes shapefile - **directRoutes.shp**:

1. Inspect your **Metadata**.
2. Inspect your polyline **Geography**; and
3. Inspect your attribute **Table**.

Question 2: According to the metadata, what is the geographic extent covered by these data? Report your answer using both the given DD *and* the DMS format for geographic coordinates.

Find your US county shapefile - **cb_2016_us_county_500k.shp**:

1. Inspect your **Metadata**.
2. Inspect your polygon **Geography**; and
3. Inspect your attribute **Table**.

Question 3: According to the metadata, what is the geographic extent covered by your **county** data? Report your answer using both the given DD *and* the DMS format for geographic coordinates.

Question 4: If you had a question about these **county shapefile** data that cannot be answered by looking at the metadata, then how would you contact the responsible party by phone or email?



Obj. 2. Convert your data from shapefile format to geodatabase format.

Use **Export > Feature class to feature class** to export the polygons in your **cb_2016_us_county_500k.shp** shapefile into new polygon features in your geodatabase. Name your output feature class **county**.

When data are saved into a geodatabase, polygon perimeter (**Shape_Length**, Eq. 2) and area (**Shape_Area**, Eq. 3) values are calculated automatically for polygons. Add your geodatabase polygon feature class as a layer to your [Map for previewing data](#) map.

Question 5: Inspect your new **county** attribute table. Compare and contrast the auto-calculated shape area (sq.m) of Cook County, IL against the given GEODESIC area of (sq.km) of Cook County, IL.

Use **Export > Feature class to feature class** to export the flight lines in your shapefile **directRoutes.shp** to make new line features in your geodatabase. Name your output line feature class **connections**.

New shape attributes values will be calculated automatically. Add your geodatabase polyline feature class as a layer to your [Map for previewing data](#) map.

Question 6: Preview your new **connections** attribute table. What are the perimeter (**Shape_Length**) and area (**Shape_Area**) values for the Harrisburg to Denver connection?

Use **Export > Feature class to feature class** to export the airports in your shapefile **airports.shp** to make new point features in your geodatabase. Name your output point feature class **airports**.

Add your geodatabase point feature class as a layer to your [Map for previewing data](#) map.



Obj 3. Prepare your attribute tables to store calculated values.

To keep track of how your auto-calculated Shape_Length and Shape_Area values get distorted during projection, we need to add some new fields to our attribute table that don't get auto-recalculated during geoprocessing.

Right-click your **county** layer to open its **Attribute Table**. Next, find **Table > View > Fields**. If you followed all the instructions properly, then your **Fields** window should look exactly like Figure 2 (sans arrows).

| Visible | Read Only | Field Name | Alias | Data Type | Allow NULL | Highlight | Number Format | Domain | Default | Length |
|-------------------------------------|-------------------------------------|--------------|-----------------------------|-----------|-------------------------------------|--------------------------|---------------|--------|---------|--------|
| <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | OBJECTID | OBJECTID | Object ID | <input type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | Shape | The coordinates in mapunits | | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | AFFGEOID | AFFGEOID | Text | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | 14 |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | NAME | NAME | Text | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | 22 |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | STUSPS | STUSPS | Text | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | 2 |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | SPZone | SPZone | Text | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | 6 |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | SPZoneName | SPZoneName | Text | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | 30 |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | GEODESIC_A | GEODESIC_A | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | Shape_Length | Shape_Length | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | Shape_Area | Shape_Area | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |

Click here to add a new field.

Figure 2. Fields dialog box.

Add a new field. Click into the empty box in the **Field Name** column and start typing the word “areaALBERS”. Under the **Data Type** column choose the **Double** data type, which will let the field hold large numbers with decimals. **Save** your change.

Next, add nine more fields (see Table 1). **Save**.



Table 1. The ten new fields we're adding to the county polygon attribute table.

| Field name | Data type |
|---------------|-----------|
| areaALBERS | double |
| distortALBERS | double |
| areaHIA | double |
| distortHIA | double |
| areaMNC | double |
| distortMNC | double |
| areaILE | double |
| distortILE | double |
| areaUTM13N | double |
| distortUTM13N | double |

When you've **Save**d your table edits, your Field properties should look like Figure 3. **Look** at your attribute table again to verify that your new fields were added. If your new fields are filled with NULL values, then you're doing things correctly. If your new fields are filled with zeros, however, then you haven't (yet) learned the difference between shapefile format and geodatabase format.

| Visible | Read Only | Field Name | Alias | Data Type | Allow NULL | Highlight | Number Format | Domain | Default | Length |
|-------------------------------------|-------------------------------------|---------------|---------------|-----------|-------------------------------------|--------------------------|---------------|--------|---------|--------|
| <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | OBJECTID | OBJECTID | Object ID | <input type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | Shape | Shape | Geometry | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | AFFGEOID | AFFGEOID | Text | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | 14 |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | NAME | NAME | Text | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | 22 |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | STUSPS | STUSPS | Text | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | 2 |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | SPZone | SPZone | Text | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | 6 |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | SPZoneName | SPZoneName | Text | <input checked="" type="checkbox"/> | <input type="checkbox"/> | | | | 30 |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | GEODESIC_A | GEODESIC_A | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Shape_Length | Shape_Length | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | Shape_Area | Shape_Area | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | areaALBERS | areaALBERS | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | distortALBERS | distortALBERS | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | areaHIA | areaHIA | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | distortHIA | distortHIA | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | areaMNC | areaMNC | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | distortMNC | distortMNC | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | areaILE | areaILE | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | distortILE | distortILE | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | areaUTM13N | areaUTM13N | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |
| <input checked="" type="checkbox"/> | <input type="checkbox"/> | distortUTM13N | distortUTM13N | Double | <input checked="" type="checkbox"/> | <input type="checkbox"/> | Numeric | | | |

Click here to add a new field.

Figure 3. New fields in the attribute table.

Save your project.

Read everything before doing anything



Right-click your **connections** layer to open its **Attribute Table**. Next, find **Table > View > Fields**. Add the ten new fields listed in Table 2.

Table 2. The new fields we're adding to the connections attribute table.

| <u>Field name</u> | <u>Data type</u> |
|-------------------|------------------|
| lengthALBERS | double |
| distortALBERS | double |
| lengthHIA | double |
| distortHIA | double |
| lengthMNC | double |
| distortMNC | double |
| lengthILE | double |
| distortILE | double |
| lengthUTM13N | double |
| distortUTM13N | double |

Save your edits. **Save** your project.

Last, **Preview** your line attribute table again to double-check your work. You should see a lot of new NULL values because nothing has been calculated yet.

Right-click your **airports** layer to open its **Attribute Table**. Next, find **Table > View > Fields**. Add the five fields listed in Table 3.

Table 3. The new fields we're adding to the airports attribute table.

| <u>Field name</u> | <u>Data type</u> |
|-------------------|------------------|
| northAlbers | long integer |
| northHIA | long integer |
| northMNC | long integer |
| northILE | long integer |
| northUTM13N | long integer |

Save your edits. Last, **Preview** your point attribute table again to double-check your work. You should see a lot of NULL values.

Congratulations! You just finished preparing your data for analysis. **Close [x]** all your attribute tables and **Close [x]** the map called **Map for previewing data**. **Save** your project.



Obj. 4. Calculate the distortions that are created during map projection.

Your project should have six maps. Open the map called “USAsystem – Albers Equal Area method” (Figure 4). All the data you see are shown using the software’s default rectangular map projection. Notice how all the lines of latitude do not converge at the poles as they should. Notice how distorted Antarctica looks. Notice how stretched things look across the northern latitudes. Notice how Russia has been torn into two pieces.

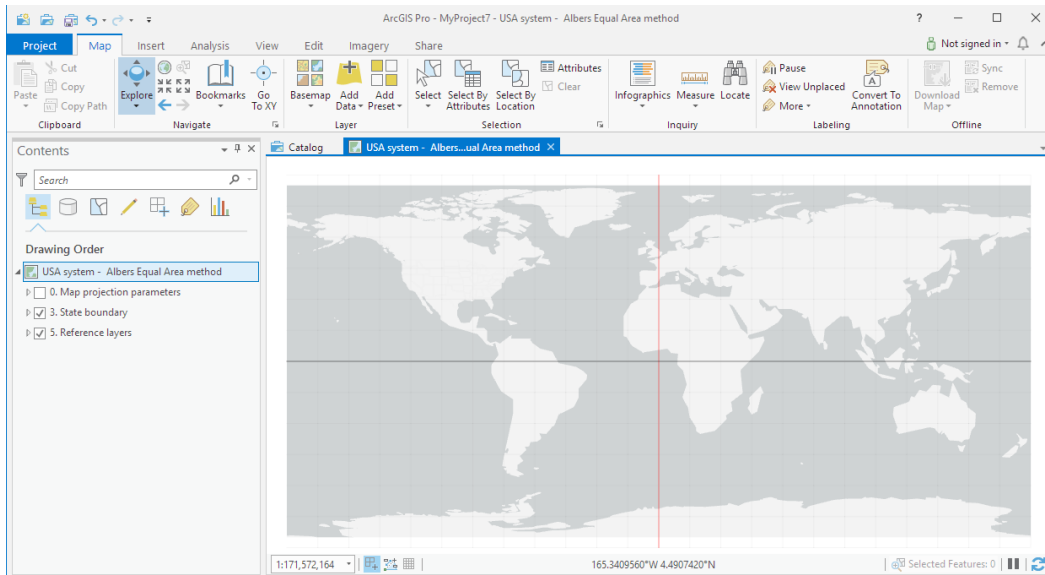


Figure 4: The ugly default rectangular projection.

Add your airports, connections, and counties as the 1st, 2nd, and 4th layers (Figure 5), respectively.

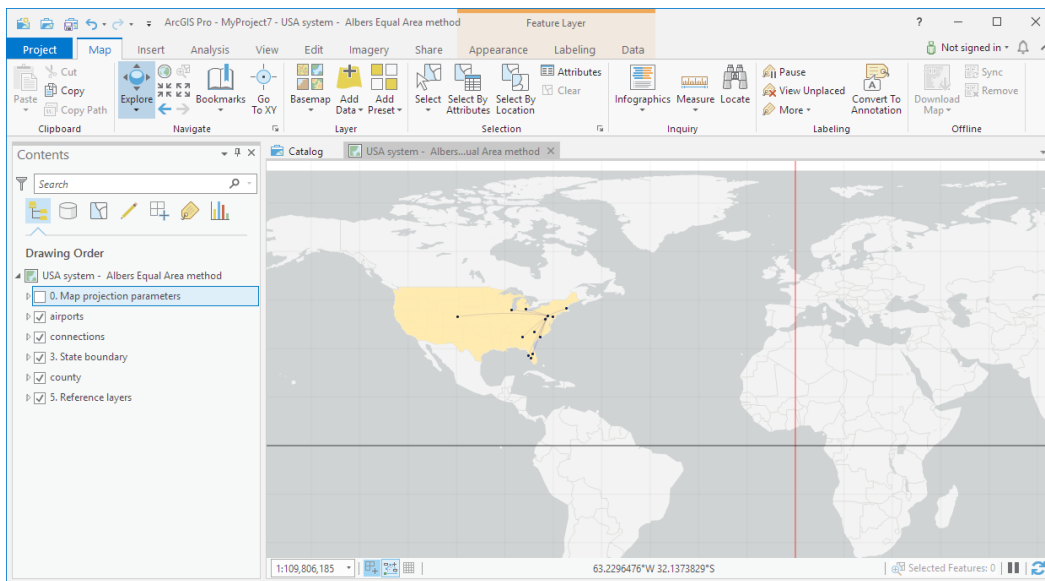


Figure 5. Airports, connections, and counties added as new layers. Notice the Drawing Order.

US mapping system – Albers Equal Area projection method

Right-click your “USA system – Albers Equal Area method” map to access its **Properties...**, then select the **Coordinate Systems** tab. You’ll notice that the *Current coordinate system* is set to “GCS_North_American_1983”, which is the *Geographic Coordinate System (GCS)* used to spatially reference locations on the “GRS_1980” ellipsoid.

You can project all the data in your map by changing the *Current coordinate system* or importing a new one (Figure 6). **Import...** the coordinate system that’s stored in the projection file named “NAD83 Contiguous USA Albers Equal Area.prj”. **Applying** this system will cause your data to be re-projected on screen. This particular instance of the Albers projection method was customized for the contiguous 48 states.

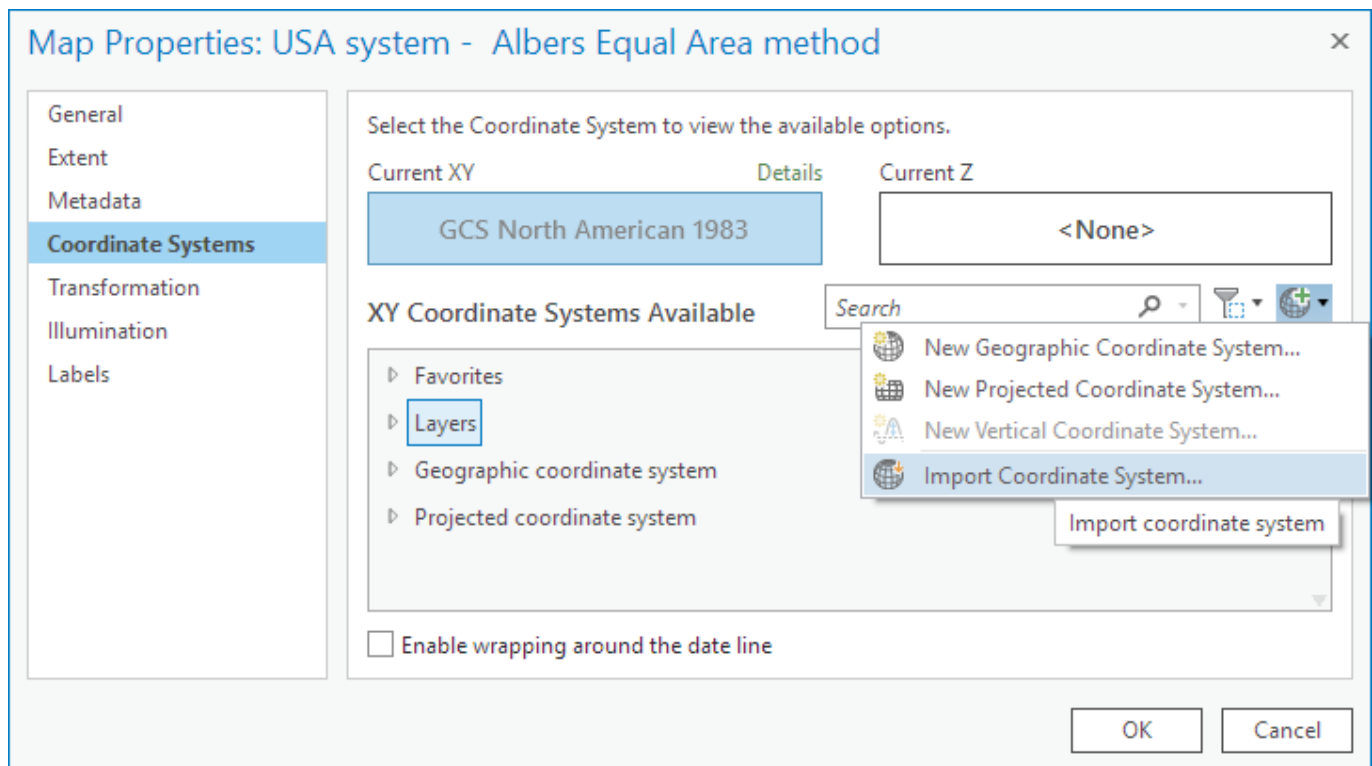


Figure 6. Projecting your data via the Data Frame Properties dialog box.

Next, **open** the **airports** attribute table. **Right-click** the northALBERS field to access the **Calculate Geometry** tool.

Calculate the “Y Coordinate of Point” in using the “Coordinate System of the Current Map.” You should now see the projected northing coordinates for these geographic points after they’ve been plotted on this metric mapping system.



Right-click the `northALBERS` field to sort your northing values in descending order.

Question 7: On the USA mapping system, which three airports were projected as the three northernmost airports?

Close the `airports` table and **open** the `connections` attribute table.

Right-click the `lengthALBERS` field to access the **Calculate Geometry** tool.

Calculate the “Length” of each feature in “Nautical miles (United States)” using the “Coordinate System of the Current Map.” You should now see the projected lengths.

Right-click the `distortALBERS` field to access the **Calculate Field** tool.

Calculate the amount of distortion in your flight lines using Equation 5:

$$!lengthALBERS! - !GEODESIC_L! \quad \text{Eq. 5}$$

Right-click the `distortALBERS` field to sort your values in descending order.

Question 8: On this US mapping system, which connection suffered the most inflation? The least distortion? The most deflation? Use your data to support your answer.

Next, **close** the `connections` table and **open** the `county` attribute table. **Right-click** the `areaALBERS` field to access the **Calculate Geometry** tool.

Calculate the “Area” of each feature in “Square kilometers” using the “Coordinate System of the Current Map.” You should now see the projected areas of these polygons.

Right-click the `distortALBERS` field to access the **Calculate Field** tool.

Calculate the amount of areal distortion in your projected counties using Equation 6:

$$!areaALBERS! - !GEODESIC_A! \quad \text{Eq. 6}$$

Right-click the `distortALBERS` field to sort your values in descending order.

Question 9: On this USA mapping system, which county area suffered the most inflation? The most deflation? The least distortion? Use your data to support your answer.

Read everything before doing anything



Okay – we’re done making calculations using this map, so you can close your attribute tables. Now we want to visualize the pattern of projected polygon distortions.

Right-click the **county** layer to access the **Symbology** tab.

Use **Import Symbology ...** to import the symbols stored in the layer file named `countyAreaDistortions.lyrx` (Figure 7).

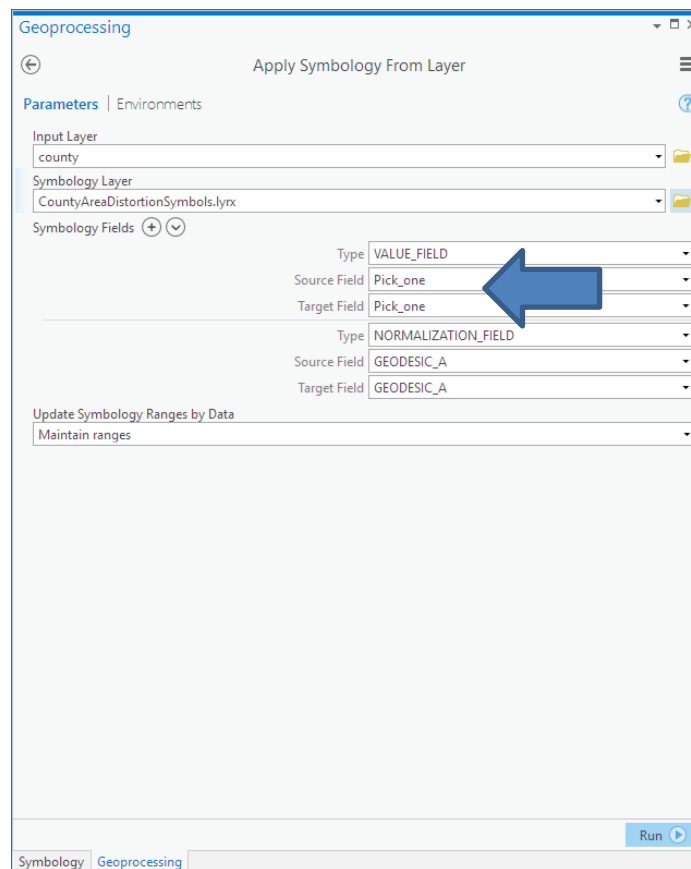


Figure 7. Importing symbols stored in a layer file.

Set both the **Source Field** and the **Target Field** = `areaALBERS` and set the **Normalization Field** = `GEODESIC_A`. **[Run]**

If you did everything right so far, then every county on your map should be symbolized with a light yellow hue. If everything is yellow (i.e., every county suffered minimal areal distortion), then congratulations! Close your map. Save your project.

If not, then go back to the brown paper airplane on page 10 and try again.



If you need a break, then this point is a natural break in the lab.



HIA mapping and coordinate system – Azimuthal Equidistant projection method

Open your “HIA system” map.

Right-click your “HIA system” map to access its **Properties...**, then select the **Coordinate System** tab. You’ll notice that the *Current coordinate system* is “GCS_North_American_1983”, which is used to reference locations on the “GRS_1980” ellipsoid.

You can project all the data in your data frame by changing the *Current coordinate system* of your data frame (Figure 6). **Import...** the coordinate system that’s stored in the projection file named “NAD83_Harrisburg_Intl_Airport_metric.prj”. **Applying** the Azimuthal Equidistant projection method will change how your data are projected on screen. This particular instance of the Azimuthal Equidistant projection method was customized for the control tower at Harrisburg International Airport.

Next, **open** the **airports** attribute table. **Right-click** the `northingHIA` field to access the **Calculate Geometry** tool.

Calculate the “Y Coordinate of Point” using the “Coordinate System of the Current Map.” You should now see the new projected northings of these geographic points.

Right-click the `northingHIA` field to sort your new northing values in descending order.

Question 10: On the HIA-centered mapping and coordinate system, which three airports were projected as the three northernmost airports?

Next, **close** the **airports** table and **open** the **connections** attribute table.

Right-click the `lengthHIA` field to access the **Calculate Geometry** tool.

Calculate the “Length” of each feature in “Nautical miles (United States)” using the “Coordinate System of the Current Map.” You should now see the new projected lengths after they been projected onto the HIA mapping system.

Right-click the `distortHIA` field to access the **Calculate Field** tool.

Calculate the amount of distance distortion in these flight lines using Equation 7:

$$!lengthHIA! - !GEODESIC_L!$$

Eq. 7



Right-click the `distortHIA` field to sort your values in descending order.

Question 11: On the HIA mapping and coordinate system, which connection length suffered the most inflation? The most deflation? Use your data to support your answer.

Next, **close** the **connections** table and **open** the **county** attribute table. **Right-click** the `areaHIA` field to access the **Calculate Geometry** tool.

Calculate the “Area” of each feature in “Square kilometers” using the “Coordinate System of the Current Map.” You should now see the new metric areas of these polygons after they’ve been projected onto the HIA mapping and coordinate system.

Right-click the `distortHIA` field to access the **Calculate Field** tool.

Calculate the amount of areal distortion in these flight lines using Equation 8:

$$!areaHIA! - !GEODESIC_A! \quad \text{Eq. 8}$$

Right-click the `distortHIA` field to sort your values in descending order.

Question 12: On this HIA mapping and coordinate system, which county suffered the most inflation? The most deflation? The least distortion? Use your data to support your answer.

Okay – we’re done making calculations in this map, so you can close your attribute tables. Now we want to visualize the pattern of county polygon area distortions across the county.

Right-click the **county** layer to access the **Symbolology** tab.

Use **Import Symbolology...** to import the same symbols stored in the same layer file named `countyAreaDistortions.lyrx`.

Set both **Value Fields** = `areaHIA` and set both **Normalization Fields** = `GEODESIC_A`. **[Run]**

If you did everything right so far, then every county on your map should NOT be symbolized with a light yellow color. You should see a projection that preserved geodesic distances from Harrisburg, yet increasingly distorted shape areas as distance from Harrisburg increases.

If yes, then congratulations! If no, then go back to the blue paper airplane on page 13 and try again.



Minnesota's Central mapping zone – Lambert's Conformal Conic projection method¹

Open your “State Plane zone MN-C” map.

If you successfully completed the work in the first two map, then you’ve probably recognized the workflow for the rest.

- Project all the data in your map by changing the map’s coordinate system.
- Calculate new geometric attributes based on the current map’s coordinate system.
- Calculate the amount of distortion to see what got messed up where.
- Symbolize the county polygons to reveal the national distortion pattern.

Use the instructions I provided for the HIA system as a guide for processing the data for Minnesota’s Central mapping zone. Just be sure to substitute “MNC” every time you see “HIA” in the instructions.

Question 13: On the mapping and coordinate system for Minnesota’s Central Zone, which three airports were projected as the three northernmost airports?

Question 14: On the mapping and coordinate system for Minnesota’s Central Zone, which connection suffered the most inflation? Least distortion? The most deflation? Use your data to support your answer.

Question 15: On the mapping and coordinate system for Minnesota’s Central Zone, which county area suffered the most inflation? The most deflation? The least distortion? Use your data to support your answer.

Illinois' East mapping zone – the transverse cylindrical Mercator projection method

Open your “State Plane IL-E” map.

Question 16: On the mapping and coordinate system for Illinois’ East zone, which three airports were projected as the three northernmost airports?

Question 17: On the mapping and coordinate system for Illinois East, which connection length suffered the most inflation? The most deflation? Use your data to support your answer.

Question 18: On the mapping and coordinate system for Illinois East, which county area suffered the most inflation? The most deflation? The least distortion? Use your data to support your answer.

¹ Why Minnesota’s Central mapping zone? Because that’s the zone that Bolstad (2016) discusses on pages 126-127.



UTM zone 13 N – a different instance of the transverse cylindrical Mercator projection method but customized for a much larger zone

Open your “UTM Zone 13N” map.

Question 19: On the mapping and coordinate system for the global UTM system’s zone 13N, which three airports were projected as the three northernmost airports?

Question 20: On the mapping and coordinate system for UTM Zone 13N, which connection length suffered the most inflation? The most deflation? Use your data to support your answer.

Question 21: On the mapping and coordinate system for UTM Zone 13 N, which county area suffered the most inflation? The most deflation? The least distortion? Use your data to support your answer.

Final layout and final questions

Close all of your maps and open the one Layout in this project. You should see five of your six maps, one symbol key (shared by all five maps), and a little abstract.

Make it easier to compare apples-to-apples by changing the extent (pan) and map scale (zoom level) of each map frame so that they’re all showing the same stuff at the same scale. You could, for example, right-click each **connections** layer and **Zoom to layer**.

Question 22a: The latest population estimate for Cook County, IL, is 5,211,263 people.² So, if you need to calculate the population density [Eq. 4] for Cook County, then which of your five projected polygons would give you an accurate result? Which mapping systems would lead you to overestimate population density? To underestimate it? Report and explain your results, and you’re your calculated population densities to support your claims.

DELIVERABLES

Given the long length of this lab and the relatively large number of questions, I am not requiring a complete written report for this lab. Instead, I’ve given you a map layout to print (on tablet size paper – 11” x 17”) and a worksheet to complete. You should see lines or boxes for each question listed above. Staple the printed layout behind your answer sheet before submitting them.

² Source: U.S. Census Bureau. 2018. *Population estimates, July 1, 2017*. Last accessed on March 23, 2018 at <https://www.census.gov/quickfacts/fact/table/cookcountyillinois/POP060210>