Lab Exercise #3: Map Projections **Due Thursday, 9/19/2024**

CRP 4080: Introduction to Geographic Information Systems
Fall 2024

Instructor: Wenzheng Li, (wl563)
Lab TAs: Gauri Nagpal (gn247), Anika Sinthy (ats243), Shubham Singh (ss3736)
Location: Sibley 305, Barclay Gibbs Jones Computer Lab
Points Possible: 65

In this lab exercise, you will learn to:

- Project on the fly
- Define a projection
- Project Data

Today's lab session can be a bit "cumbersome and confusing", because we need to produce some "malfunctions" and assume many scenarios. To successfully fix and understand these hypothetical issues, you need to strictly follow the lab's operation sequence to add map layers, otherwise you may not be able to reproduce these results

Part 1: Projecting on the fly

Create a "Lab3" directory in your personal drive, so that you have a place to store the files necessary to complete this lab. Copy the lab materials to your directory.

The data directory includes the following files: *landmarks, ny_census_tracts, ny-counties, TCPars2014, and roads_cl.* Make sure you have copied the entire directory, including the Lab3_data and homework data. Do not add any of these layers to your map until the instructions tell you to do so.

Create a new Map in ArcGIS Pro and save a project to your lab folder.

In the map viewing area, notice the numbers listed at the bottom of the window (shown in Figure 1). These are the coordinates at the center of your map view. The units of these numbers are latitude and longitude, in decimal degrees. Notice that the first value ends with the letter "W", for "west", and the second value ends in "N", for "north". This is because Ithaca is North and West of the origin point for the default projection. The origin point is located at the intersection of the Equator and the line running through Greenwhich, in the UK, which is the east-west basis for time zones. You may have heard of Greenwhich Mean Time (GMT).

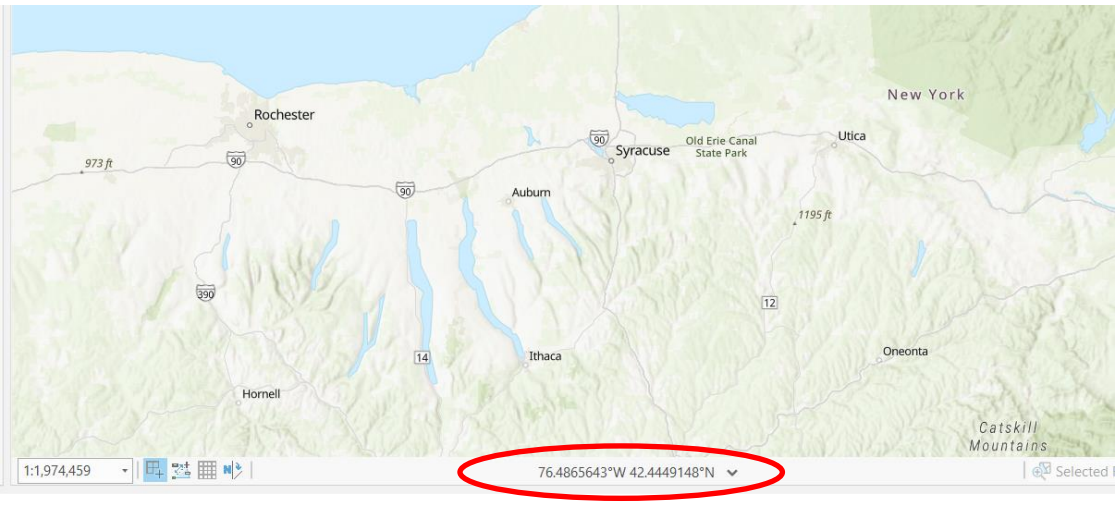

Figure 1. Main ArcMap window with the units highlighted

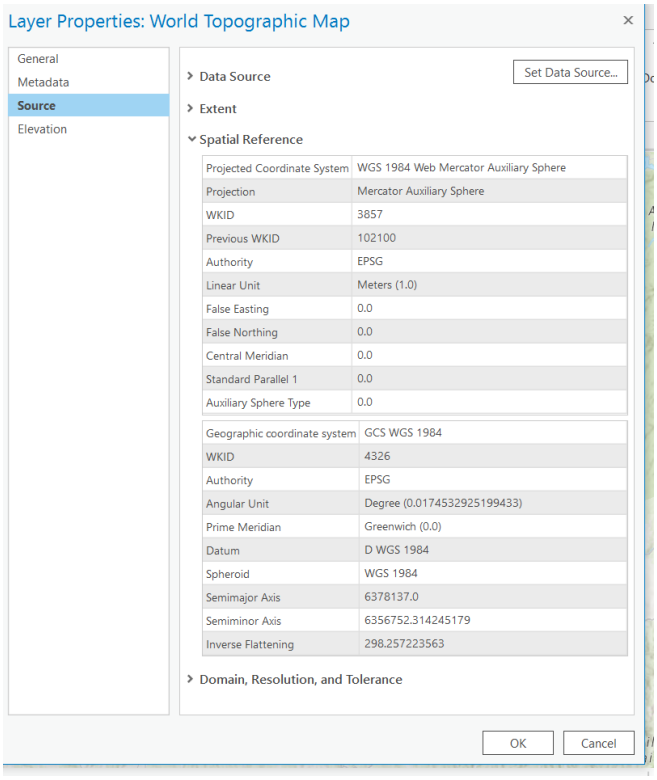

Figure 2: Spatial Reference of the World Topographic Map

Decimal degrees are the default units due to the existing data layers already added to our Map view (World Topogaphic map and World Hillshade). If check the World Topographic Map layer properties, then select Source and Spatial Reference, you can observe the projection information for that layer (WGS 1984). In a new, empty map or local scene, the default horizontal coordinate system is WGS84 Web Mercator.

Note that the geographic coordinate system (GCS) is GCS WGS 1984, a commonly used global coordinate system that you will encounter often when using GIS data. The projected coordinate system (PCS) is built on the GCS, and for this layer it is WGS 1984 Web Mercator Auxiliary Sphere. The PCS is analogous to a lens that allows us to look through the coordinate system and calculate linear measurements in real-world units. In this case, linear measurements will be converted to in meters, even though the units are still decimal degrees.

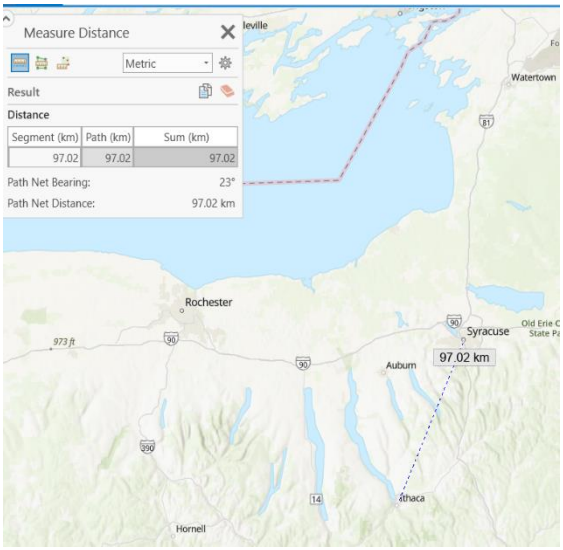

Figure 3: measure tool for measuring distance

We can test this using the measure tool 

under Appearance (Figure 3), in Map -> Inquiry on the top toolbar.

Next, if you right click on Map Frame instead of layers, and go to Properties, under Coordinate Systems (Figure 4): you will notice below the "Current XY" and "Current Z" headings show the current horizontal and vertical coordinate systems of the Map Frame (In this case, there is no vertical coordinate system defined).

Click **Details** for "**Current XY**" to see how they are defined. We can see it is defined as WGS 1984 Web Mercator (auxiliary sphere). This means without changing this projection under your current Map Frame, any additional layer we add to this Map frame will be automatically "projected on the fly" based on this coordinate system regardless of their own projection.

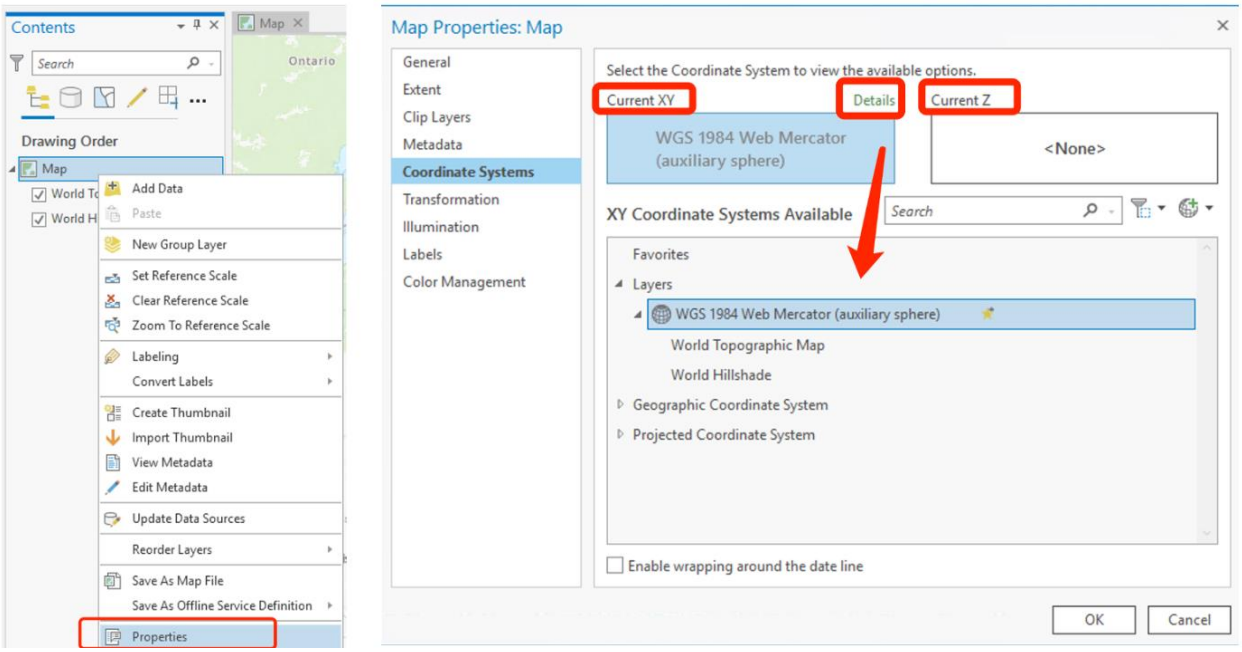

Figure 4: Map Properties—Coordinate system

Now, you may grasp what is the determined factor of projection on the fly: the coordinate system for your current Map Frame!

Changing the coordinate system for the Map Frame

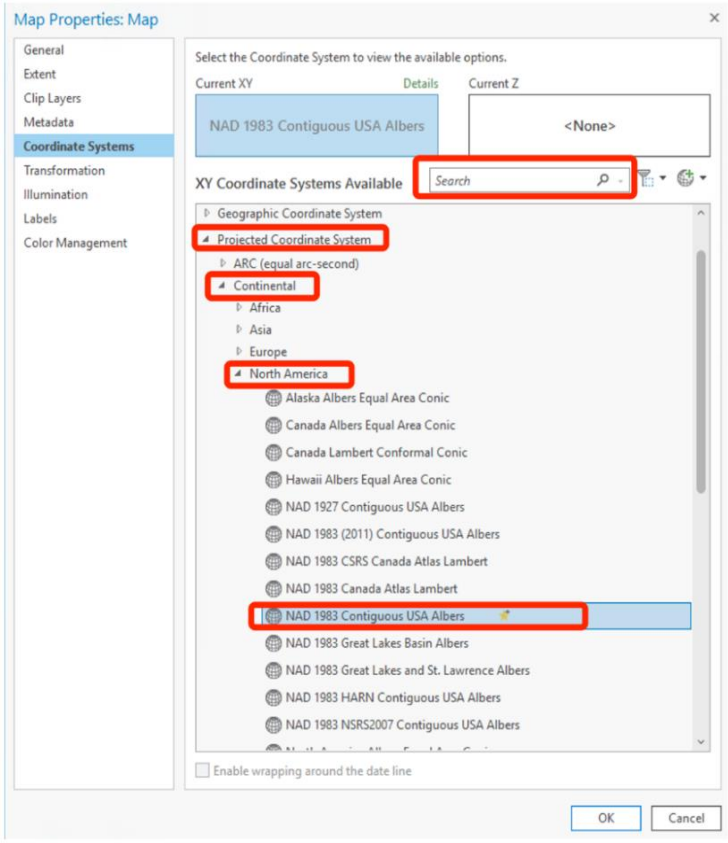

Figure 5. Finding the Albers projection

To change either the horizontal or vertical coordinate system, choose an appropriate coordinate system from the corresponding Coordinate Systems Available list. You can search keywords in the Search box to locate a specific coordinate system.

For this practice, go to Projected coordinate system —> Continental —> North America —> NAD 1983 (2011) Contiguous USA Albers, and click OK (Figure 5). Or simply copy and paste NAD 1983 (2011) Contiguous USA Albers into the search box on the top. Note how the orientation of your map changes.

Note how the orientation of the data changes. By zooming to full extent, you can see why this is an appropriate projection and coordinate system for the North American continent, but not so much for the rest of the world.

Figure 6. The Globe projected using NAD 1983 (2011) Contiguous USA Albers

If we look at the Layer properties for the World Topographic map, the projection for the World Topographic map has **not actually changed** (WGS 1984). We have projected this data "on the fly" to match the parameters of the Map frame. Check the layer properties to confirm that the projection information has not changed. If it did, something went wrong, and you should ask for help

Set the map or scene's coordinate system from a layer

1. Add the counties shapefile, TCPars2014. That doesn't look right (Figure 7)… What happened?

Open the Layer properties for TCPars2014 and note the spatial reference information: NAD 1983 State Plane Central. The data has been projected on the fly to match NAD 1983 (2011) Contiguous USA Albers.

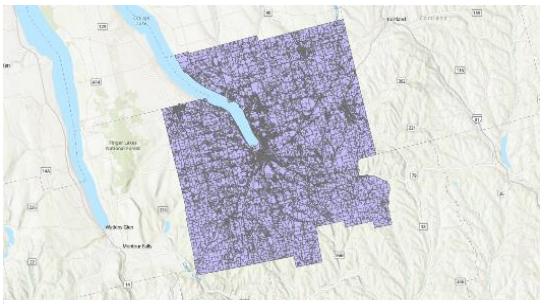

Figure 7. Tompkins County in the TCPars2014 projection.

2. To set the coordinate system of the map to match a layer, use the Map Properties dialog.

3. Under the XY **Coordinate Systems Available** list, expand **Layers (**Figure 8; Note that if you have added layers, you will see additional options.).This is an efficient way to examine all the coordinate systems of all layers in your map once you have added several layers.

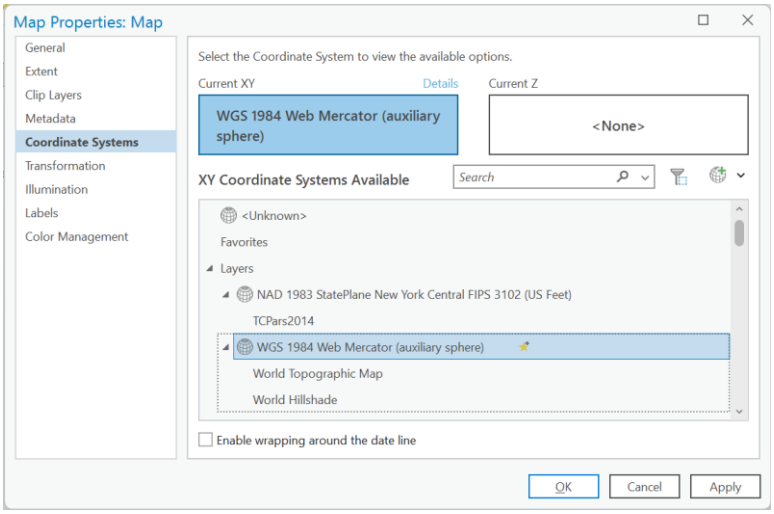

Figure 8. Set the coordinate system to be the same as that of a layer on the map

4. Set the coordinate system of the Map frame to the TCPars2014 by clicking the layer and selecting OK. This looks better! Now the entire map frame has assumed the properties of the State Plane coordinate system.

5. Note that the display units (as you mouse over the screen) are still in decimal degrees. In the Map properties box, under the General tab, you can set the display units (currently in Decimal Degrees) to match the map units (US Feet)

Exporting a layer with a new projection

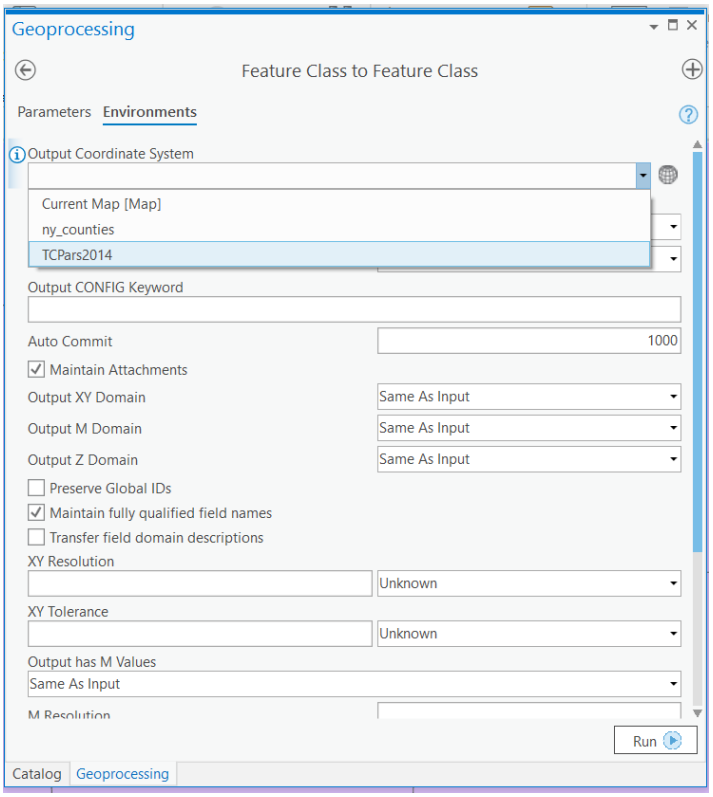

Figure 9. Projection transformation

Add ny_counties. Use the layer properties to identify the projection information: GCS NAD 1983. Note that Arc has projected this data on the fly.

Let's say you wanted to create a new shapefile of NY counties, but with State Plane coordinate (i.e. the coordinate system of the current data frame).

1. Right click on the Counties layer and
2. go to Data/Export Features. The 'Export Features' dialog box will open.
3. Under the Environments tab, you will be able to specify the Output Coordinate System to match TCPars2014 (or Current Map, as they are the same) (Figure 9).
4. Navigate back to the Parameters tab,
5. Save the new layer as NYcounties _stateplane into your folder. This will save a new version of the parcels data set, but this time using state plane coordinates.

Part 2: Defining a Projection when it is Unknown

In this section you will assign a projection to a layer that has an unknown projection. It is important to note that this process does not involve any sort of transformation of the data, but rather is concerned with defining an existing, but unknown, projection.

Figure 10. Add landmarks and find the on-the-fly function locates them near James Bay, Canada

1. Add the *landmarks* shapefile. This is a point dataset of Tompkins County landmarks. You will most likely not see the layer appear in your screen.

2. Right click on the layer in the Contents Pane and select "Zoom to layer". My layer is located (incorrectly) in northern Canada.

3. Right click on landmarks and open the layer properties.

4. Under Source/Spatial Reference you will note that the Coordinate System is unknown.

Why is this? To find out what's going on.

5. Using your file browser (not ArcGIS Pro's file browser), navigate to your lab 3 directory and look at the support files for landmark.shp.

6. Note that **there is no .prj file**. Because a .prj file is missing, ArcGIS Pro does not know the projection and coordinate system.

Now add ny_census_tracts, and roads_cl and note that they also do not have .prj files (you can use 'zoom to layer' to figure out where they landed. Since all geographic data must have a projection, how do we figure this out? Don't worry, let's define the projection (i.e., write a new .prj file) so that ArcGIS can readily interpret their projection.

In order to determine the actual projection of the unknown layer, you do have some clues:

First, let's start with ny_census_tracts.

1. Right click in the Contents pane and go to Layer properties and click the Source tab.
2. Expanding the Spatial Reference tab, we confirm the coordinate system is unknown.
3. Expanding the Extent tab, we do note the units fall within a familiar range: between 40 and 45 from top to bottom and -71 to -79 from right to left. Looks like Decimal degrees.
4. We can confirm this by opening up the Layer properties for ny_counties, and checking the spatial reference.

Now we will define the projection for the ny_census_tracts layer.

1. Under the Analysis Tab, go to Tools (Figure 11a). This opens the Geoprocessing Pane to the right (Figure b right side)
2. In ArcToolBox, search for "projection" in the search bar to see all the tools related to projection (Figure 11c).
3. Select, "Define Projection"
4. In Define Projection dialog box (Figure 11b), under 'Input Dataset or Feature class,' select the ny_census_tracts layer from the dropdown menu**.** Set the Coordinate System to ny_counties (it should default to 'GCS_North American_1983). Note that you can use the globe icon to also navigate the appropriate coordinate system.

In your file browser tab, not through ArcGIS Pro, verify that a .prj file has been written for the ny_census_tracts's shapefile.

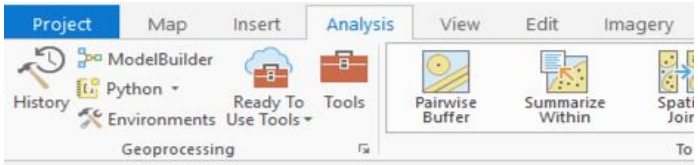

Figure 11a. Find the Tools button

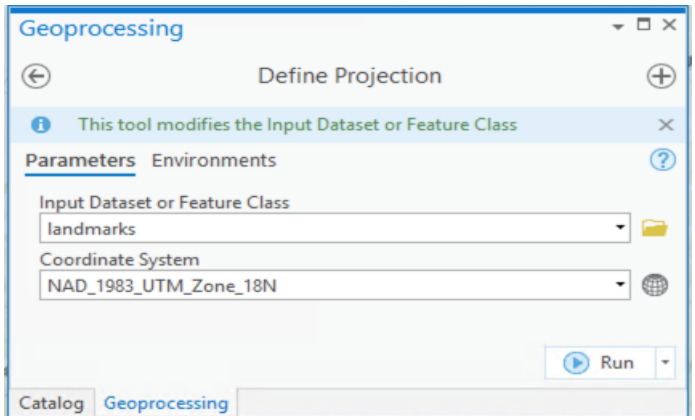

Figure 11c. Define a projection for the landmarks layer.

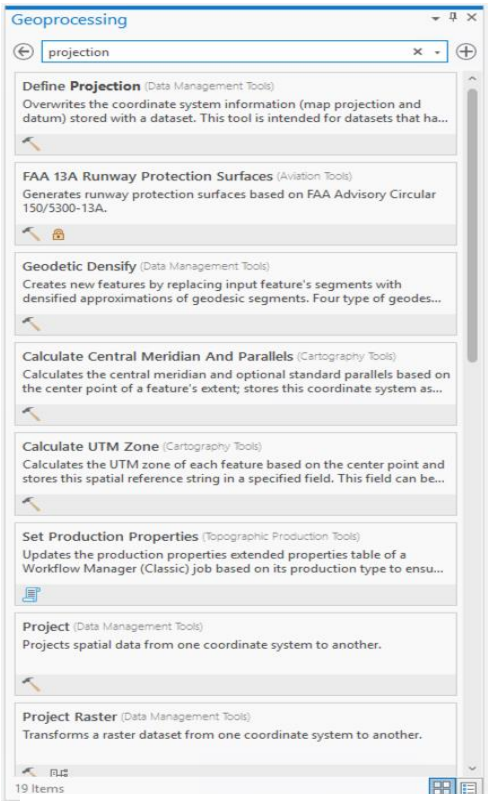

Figure 11b. Find define projection function in the ArcGIS toolbox

Now try identifying the projection information for roads_cl. Under the Layer properties we note the extent ranges are quite different, and not immediately obvious.

It may be helpful to examine another (known) dataset. Check the Layer properties for TCPars2014, which already has projection information: State Plane central. Are the ranges similar? If so, we can safely assume they have the same projection information.

Define the projection for roads_cl accordingly.

Right click on the *Landmarks* layer and go to Properties. Under source, examine the coordinates in the Extent box.

Note that they fall between 4.720 and 4.684 million (top and bottom) and around 362,000 and 396,000 (right and left). The differences are thus around 40,000 for the longitude and 30,000 for the latitude. Big numbers, but they do not match the extent of roads_cl. So, they must be a different projection.

We have to do a little critical thinking now, and we can guess what kind of unit might bound Tompkins County.

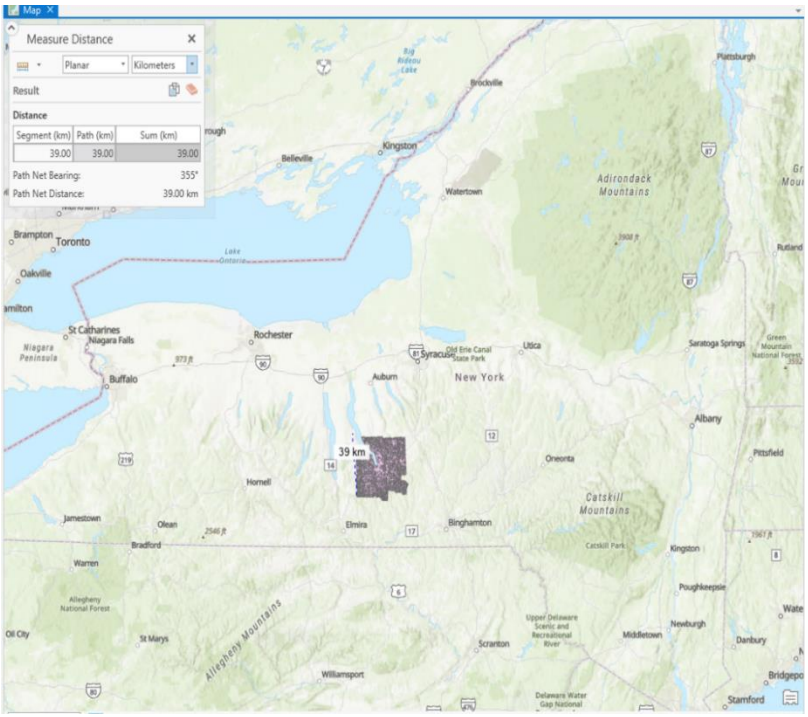

Figure 12. Measure the north-south dimension, or longitudinal dimension, of Tompkins County to find a clue of what the projection could be.

a. Use the measure tool to examine the dimensions of Tompkins County, based on the TCPars2014 layer.

b. Left click on the bottom left corner of Tompkins County. Notice the Measure Distance popup tracks the distance your mouse travels in several units. Select kilometers.

c. Right-click on the top left corner of Tompkins County to end the measurement.

The longitudinal distance of Tompkins County (the distance we just measured) is about 39 kilometers, or 39,000 meters. This matches the extent of the landmarks layer and supports the hypothesis that this layer was originally in a meter's projection.

Question: Consider the projections we discussed in the lecture. What are the ones using meters as a unit? Of these, which would be appropriate for the Tompkins County area?

Answer: Universal Transverse Mercator Zone 18, North (UTM 18N).

Define the projection for *Landmarks* accordingly: NAD_1983_2011_UTM Zone 18N. If you cannot find it, google NAD_1983_2011_UTM Zone 18N, and try to find its EPSG code (which is EPSG:6347). Entering the EPSG code in the search bar

We have utilized a number of different methods, and should now be able to define all of the unknown projections:

- *Landmarks:* Universal Transverse Mercator Zone 18, North (UTM 18N).
- *Roads_cl:* NY State Plane central (NAD 1983)
- *ny_census_tracts:* GCS NAD 1983

Part 3: Projecting Data

Although ArcMap automatically projects the files "on the fly" over the TCPars2014 layer, they are not actually in the same projection! You must use data sets with identical projections to do any geoprocessing. Now that we have defined the projections, we must reproject, or project, the files so they all have the same projection. We will use the TCPars2014 as the master projection. Although we can export these data sets to do so, thereby creating additional data, we can also use the Project tool to Project ny_census_tracts, landmarks, and roads_cl so that they all have the same projection: **NAD 1983 StatePlane New York Central FIPS 3102 (Feet).**

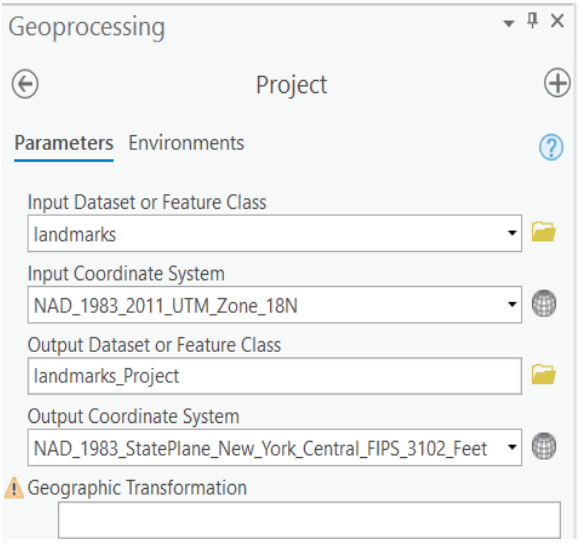

Figure 13: Project the landmarks.shp from the UTM 18N to NAD 1983 StatePlane New York Central FIPS 3102

1. In the Toolbox, search for the Project tool.
2. Click on the browse directory for "Input Dataset or Feature Class".
3. Add *landmarks* through the dropdown menu. This will automatically update the 'Input Coordinate System' to reflect the current projection (in this case UTM), and the "Output Dataset or Feature Class" will automatically be named *landmarks_Project.shp*
4. For the output coordinate system, click the dropdown.
5. Navigate the TCPars2014 layer. Note that the text switches to **NAD 1983 StatePlane New York Central FIPS 3102 (Feet)**. Click **Run**.
6. Now repeat this until all layers are in the NAD 1983 StatePlane New York Central FIPS 3102 (Feet) projection.

Add all of these layers to the map if they are already. Remove the other layers.

LAB 3 DELIVERABLES

In-Lab Assignment:

Map 1: Using the Lab data, make a map layout showing landmarks, roads, and census tracts for Tompkins County (include a state level context map). North arrow, scale bars, legend, title, and projection are all required. 10 points (2 each)

Lab Homework:

Answer the following questions (*italics* indicate an action item that requires answering). Also note that there are 5 map layouts necessary. From now on, be sure to include projection information as part of the notes on each map. Note that you are often ask to create a new map layout (this is so Arc does not return the projection information from the previous question).

1. Add Tompkins_County_Soils shapefile. *What is the unit of these measurements?* Check to see if Tompkins_County_Soils has a known projection (has a .prj file?). If not, identify the correct projection. Explain what method you utilized to do this. Discuss how you identified the units (2 points) and the location (2 point), and selected the projection (1 point if correct). 5 points

2. Now project Tompkins_County_Soils to UTM coordinates, using whatever method you wish. *Explain what you did (3 points for accurate description). What is the difference between defining a projection and projecting a layer (2 points)?* 5 points

3. Create a new map layout with the layers, WORLD30 and CNTRY92.

    a. Change the map frame projection to "Mollweide". *Is this a better choice for a world projection? Why or why not? Use a screenshot to illustrate your description (2 points total).*
    b. ***Map 2:*** *Create a layout using* 'The World from Space' projection. Make sure only the two layers above are showing. Remember to include all of the required elements: title section, name, projection, data source, etc *(3 points)*. (5 points)

4. **Map 3:** Create a new map layout with three map frames displaying the COUNTIES layer showing (1) the projection of the data as it is when you downloaded it and (2 and 3) additional projections of your choosing. Include all on the same layout. Discuss some of the differences between these projections.

5. **Map 4:** Create a new map layout, adding NY_counties first and then STATES. Zoom out to show the west coast of the US in the STATES layer. Discuss how issues of directional (5 points) and distance accuracy (5 points) affect your view. 10 points

6. **Discussion Question (10 points**): Create a succinct, step-by-step guide to project the following layers into the same projection and coordinate system. Use the data from the subfolder "Question 6":

- Tompkins_buildings2014
- Tompkins_munis2010
- Tompkins_roads
- Tompkins_pollingplaces2013.

Include a screenshot of each map layer's projection in the respective layer properties dialog (6 points, one for each of the 4 screenshot and 2 for the description). Create a map layout showing these 4 layers so that each one is clearly visible. Include a legend, north arrow, projection, title, and other standard map elements (4 points).