

SIE 509 – Principles of GIS

Exercise 2: Map Projections and Coordinate Systems

Due: 9/28/17

Total Points: 40

Introduction: Within ArcGIS, every dataset has a coordinate system which is used to integrate it geographically with other layers. It is important that the user ensures that all datasets which they wish to use for a particular map or series of analysis are projected/reprojected according to the same coordinate system. Within ArcGIS, coordinate systems are classified either as geographic coordinate systems (latitude and longitude) or projected coordinate systems (such as the UTM or State Plane).

There are 3 situations in ArcGIS:

1. The original data has no coordinate system definition, you must assign one (**Define**)
2. The original data has a coordinate system definition, and you wish to convert it to another (**Project**).
3. You never touch the original data, but will project “on the fly” via the Data Frame in Arc Map.

The first two situations are dealt with in ArcToolbox and result in the creation of a projection file (*.prj), a simple text document containing coordinate information. ArcGIS provides projection files (.prj) for many predefined coordinate systems, but you can also create and save a projection file for a new coordinate system. That new file can be used to define or project other data sets.

The third situation happens automatically in ArcMap. When ArcGIS does not know what projection the original data is in (it cannot find the *.prj file) it will assume a “projection on the fly”. This is a geographic projection assuming the data is in latitude and longitude and with a WGS84 datum. This is often not the correct projection, and will cause severe consternation until you discover the problem.

Note that it is possible to map data without having defined a coordinate system. ArcGIS will inform you that your data do not have a spatial referencing system defined but it will enable you to proceed, and map the data without defining one. If you wish to undertake any spatial analysis involving the calculation of distances, areas etc. you must define a coordinate system. In general, it is good practice to define a coordinate system, even if you are not going to specifically undertake spatial analysis.

Procedures:

Setup

1. Download and extract the Exercise 2 data from the class website.
2. Open the Ex_02 Report Sheet and add your name.
3. Open ArcMap to a blank map.
4. From the Geoprocessing menu > Environments, set your work space to your Ex_02 folder.
5. Give your project a name and save it.



Part A: Addressing A Common Problem

1. a. Add the *UScities.shp*.
- b. The add the *States.shp*

Note: If you get a warning message, click OK to dismiss it.

Q1. Which data file do you see?

2. Right-click on the other data file and choose Zoom to Layer.
3. Right-click again and choose Properties and click on the Source tab.

Q2. What is the coordinate system for this layer?

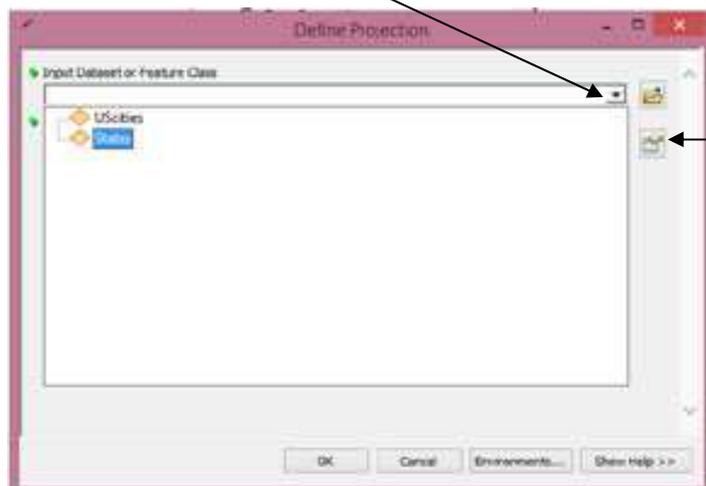
4. Close the Properties dialog box.
5. Now right-click on the other data file and Zoom to Layer.
6. Open the Properties dialog box and the Source tab.

Q3. What is the coordinate system for this layer?

7. Close the Properties dialog box.

ArcMap has drawn both layers, but not in the same space, as they are in different coordinate systems, and ArcMap knows only one of the two coordinate systems.

8. Open ArcToolbox and select Data management Tools>Projections and Transformations and double-click on Define Projection to open the Define Projection dialog box.
9. Click on the drop-down arrow and select States and click OK.



Select Coordinate System

10. Define the coordinate system as Geographic >North America > NAD83 (original).

This may take a minute. When the operation is complete a box should pop up in the lower right corner of your screen with the word "Define" and a green check mark.

Now ArcMap knows both coordinate systems it can reproject *States.shp* "on the fly" to match the *UScities.shp* file.

10. From the *UScities* Properties dialog box select the Symbology tab, and under Show: choose Categories.
 - a. In the Value Field select CAPITAL, and click the Add Values button.
 - b. Select "Y" and click OK..
 - c. Click on the symbol next to "Y" and choose Star 3, size 14.
 - d. Click OK.
11. Choose appropriate colors for a pleasing display. This data frame will be part of your final layout.

Part B: Observing How Distance Changes with the Map Projection

1. Right-click on the word Layers in the TOC.
 - a. Select Properties.
 - b. Select the General tab
 - c. Change the name to Albers and the Display Units to miles.
 - d. Click OK.
2. Measure the distance from Augusta, Maine, to Sacramento, California (Sacramento is hidden. To see it uncheck the symbol next to all other values in Symbology dialog box, but don't forget to check it again after making your measurements.

Q4. To the nearest whole mile, what is the distance between the two capitals on an Albers map?

3. From the Menu bar, select Insert, then Data Frame. This will insert a new blank data frame.
4. Name the new data frame Mercator, and click OK.
5. Hold down the control key and add the following shapefiles.
 - a. *Two_Capitals_Mercator.shp*
 - b. *States_Mercator.shp*
6. Measure the distance between the two capitals.

Q5. To the nearest whole mile, what is the distance between the two capitals on a Mercator map?

7. Insert another Data Frame and name it Equidistance
8. Add *Two-Capitals_Equidistant.shp* and *States_Equidistant.shp*.
9. Measure the distance between the two capitals.

Q6. To the nearest whole mile, what is the distance between the two capitals on an equidistance conic map?

The "on the ground" distance between the two cities is actually 2,666 miles. The difference in measurements between the three projections is due to unavoidable distortion when projecting the three dimensional earth to a flat surface. The Albers projection maintains areas (it is an equal area projection), while the Mercator projection retains angles and shapes (it is a conformal projection) and the equidistant conic projection keeps parallels evenly spaced along the meridians to preserve a constant distance scale along each meridian, typically the same or similar scale as along the standard parallels. .

10. Remove both the Mercator and the Equidistant layer by right-clicking on the layer name and choose Remove.

Part C: Projections and Transformations

1. Insert a new data frame.
2. Add *idll.shp* to the map.

Q7. What message appears?

3. This shapefile contains an outline of the state of Idaho created in geographic coordinates (lat/long - that's what the *ll* represents). But the message box is letting you know that it has not been defined.
4. Right-click on the filename (*idll*) to open the context menu, and select Properties->Source.

Q8. What does this tell you about the coordinate system?

5. Use ArcToolbox to define the coordinate system as Geographic Coordinate System > North America > NAD 1927 *Definition 1976).prj.
6. Right-click on the filename (*idll*) to open the context menu, and select Properties->Source.

Q9. What does this tell you about the:

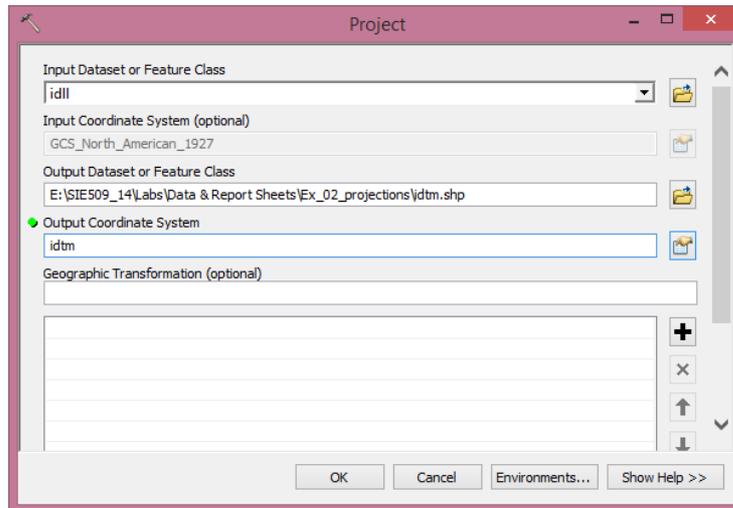
- a. coordinate system?
 - b. datum?
 - c. prime meridian?
7. Close the Properties dialog box.
 8. When the process is complete, right-click on the word Layers. Choose Properties, select the General tab and change the name from Layers to Geographic 27 and verify that the Map units are Decimal Degrees (select if necessary) and then change the Display Units to Miles.

9. Click OK to close the dialog box.

10. Insert a New Data Frame.

Next you will project *idll* to an Idaho Transverse Mercator (*idtm*) projection. This is not one of ArcGIS's predefined coordinate systems, so you will create a new custom coordinate system.

11. From ArcToolbox > Data Management > Projections and Transformations, select Project,.



12. Click on the Browse icon and navigate to your Ex_02 folder and select *idll*.

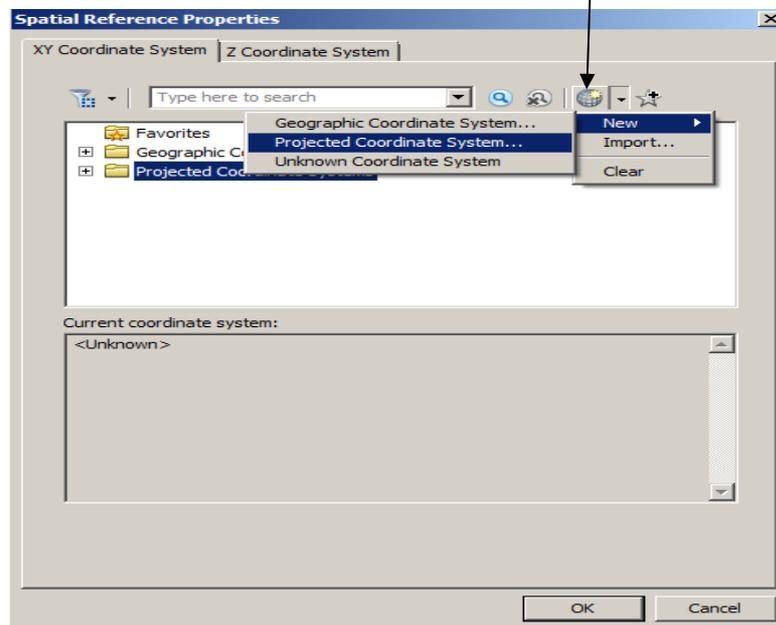
13. The output file is *idtm.shp* and should be saved to your Ex_02 folder.

14. Click the Select Coordinate System Button to open the Spatial Reference

15. Select the Add Coordinate System icon, and choose New > Projected Coordinate System.



Add Coordinate System



17. Enter *idtm* as the Name. Then you need to provide projection information in the Projection frame.
18. In the Projection frame, select Transverse_Mercator from the Name dropdown list. Edit the parameter values as shown below:

Projection: Transverse Mercator

Units: meters

Parameters:

False easting: 500000

False northing: 100000

Central meridian: -114.0

Scale factor: 0.9996

Reference latitude: 42.0 (Latitude of Origin)

19. Click OK and close all of the dialog boxes so that the procedure executes.

Q10. What is the purpose of applying a false northing and easting to the projection?

You have completed the projection of *idll.shp* to *idtm.shp*. Both shapefiles will be stored in your folder, as well as a new file called *idtm.prj*

20. If the *idtm.shp* is not automatically added to your empty data frame, add it now. Rename the data frame Transverse Mercator 27, and set the display units to miles.
21. Open *idtm.prj* with Notepad (in Accessories). If the file appears to be on a single line, choose Format->Word Wrap.

Q11. What information is contained in the projection file?

Next you will import the custom Transverse Mercator projection you just created and apply it to a different file. *Stationsll.shp* contains snow courses¹ in Idaho and is a shapefile in geographic coordinates (you will need to define it). You want it to have the same projection as *idtm.shp*. First you will define it as having the same projection as *idll.shp*, then you will project it to the custom projection created for *idtm.shp*.

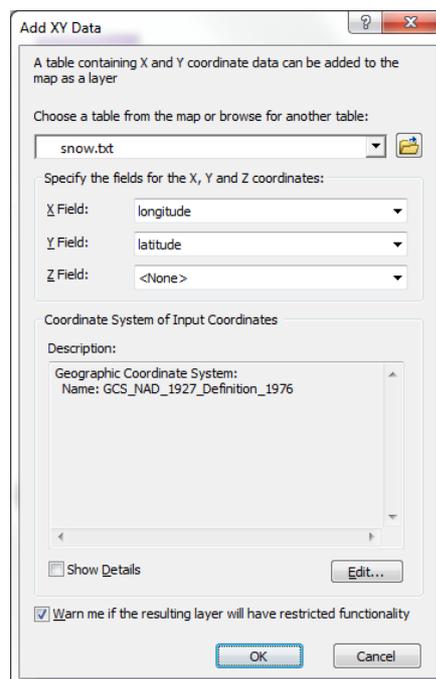
22. Return to the Projection and Transformations menu in ArcToolbox. Double-click the Define and browse (by clicking on the folder icon) to *stationsll.shp* as the input data set. 
23. Define it as a Geographic Coordinate System, North American Datum 1927 (1976 definition). When the process is complete it will be added to the map and automatically reprojected “on the fly” to the Idaho Transverse Mercator Projection. However, we want it to be saved with the custom projection.
24. In ArcToolbox, choose Project.. Specify *stationsll.shp* as the input file and *stationstm.shp* as the name for the output file.

¹ A snow course is a permanent site that represents snowpack conditions at a given elevation in a given area. The data is used to predict water supply for the following year. (<http://www.wcc.nrcs.usda.gov/snowcourse/>)

25. Open the Spatial Reference Properties dialog box and select Import. Select *idtm.shp* as the input projection and execute the program.
26. *Stationstm.shp* is now projected onto the same coordinate system as *idtm.shp*.
27. Remove *stationsll.shp* (right-click->remove) from the data frame. 

Next you will project a shapefile using a predefined coordinate system. Snow.txt is a text file containing the longitude and latitude values of 40 snow courses in Idaho. First you will create a point shapefile from this text file, then you will project this shapefile, which is measured in longitude and latitude, onto a predefined (UTM) coordinate system.

28. Activate the Geographic 27 Data Frame (right-click on the layer name and select Activate.)
29. To add snow.txt to the map, click the File menu and select Add Data->Add XY Data.
30. In the next dialog box, browse to your workspace and select *snow.txt* as the input file and longitude as the X field and latitude as the Y field.
31. Click on the Edit button and define the coordinate system as Geographic, NAD 1927 (1976 definition).
32. Click OK to close the first dialog box and OK again to close the second dialog box. A warning message will appear. Click OK to dismiss it, as we will deal with this problem in the next few steps.



33. To convert snow.txt Events to a shapefile, right-click snow.txt Events, -> Data -> Export Data.
34. In the Export Data dialog box enter *snow* as the output name and shapefile as the output type and click OK.

35. Use the same coordinate system as the layer's source data, and click OK to execute Export Data.
36. Add the exported data to your map.
37. Remove snow.txt Events.
38. Insert another data frame.
39. Reproject *idll.shp* to UTM, NAD 1983, UTM Zone 11N with the name *idutm.shp*.
40. Reproject *snow.shp* to UTM, NAD 1983, UTM Zone 11N with the name *snowutm.shp*.

NOTE: The transformation from NAD 1927 to NAD 1983 is built into ArcGIS and will happen automatically. All other datum transformations must be specified by the user.

41. Name the layer UTM 83 and verify that the Map units are Meters and then change the Display Units to Miles.
42. Create a layout with your four maps (one from part A and three from part C), you will need to move them around and resize them.
 - a. The map from Part A should be the major portion of your layout and requires a title and a legend.
 - b. The other three maps only require titles (use insert Text).

NOTE: If all three images from Part C do not appear to have a different projection, you have made an error.

Q12. When and why is it necessary to define a projection?

Q13. When would you choose to create a new (custom) projection?

Q14. When would you choose to import a projection?

Q15. Why is a geometric transformation necessary when switching from NAD 1927 to NAD 1983?

Deliverables:

The answers to the 15 questions (2 points each) and your layout (10 points).