School of Geography & Earth Sciences
McMaster University

EARTH SC/ENVIR SC/GEOG 2GI3: GEOGRAPHIC INFORMATION SYSTEMS

EXERCISE 2: PROJECTIONS AND COORDINATE SYSTEMS

Introduction

At the beginning of any GIS project or mapping exercise, a decision must be made on how to project geographic data. Projection is concerned with defining and changing coordinate systems. This decision is nontrivial as it affects both analysis and visualization of the results. Care must be taken to ensure that properties crucial for the analysis are preserved (area, shape, distance, direction). ArcMap offers multiple methods for projection, which are explored in this exercise.

Due:	Beginning of your lab period on Week 7.
Instructions:	Answers must be typed using MS Word, OpenOffice, or some other word-processing package.
Grading:	Style and format is worth 20% of your mark. 1 mark is deducted for each mistake up to a total of 6 marks since your exercise is worth 29 marks. Please consult lab notes for Exercise 2 (Exercise 2: Overview, which is found under Exercises) for style and format.

Exercise (29 marks)

Part A: Setting the Work Environment

A. The data are located on Avenue under Exercises in a zip file called EX2.zip. Copy the file to C:\Student or to your flash drive and unzip it. Please ensure that the resulting path is C:\Student\EX2. If you saved the data to your flash drive, then the path will be different (for example, E:\EX2).

B. Open ArcMap. A popup window appears. Under Existing Maps choose "Browse for more…" In the popup window, navigate to C:\Student\EX2. Once in this directory, click on Map1.mxd and press Open. You should now see four city names on the screen. In the Table of Contents, you will see exclamation marks beside each of the thematic layers listed. Since you are using a map document that was created in a different work environment, you have to reestablish linkages to the data. To do this, right click on a thematic layer in the Table of Contents. In the context menu that appears, select Properties. In the popup window entitled Layer Properties, click on the Source tab. You can see in the Data Source window the type of data, the name of the feature class, and the location that the map document expects to find the layer. Click the Set Data Source button and navigate to where the file is stored. Select the file to reestablish the linkage. Repeat this process for all layers displayed in the Table of Contents.

C. You will notice that lakes are not visible on the map. ArcMap draws all features in the order in which they are listed in the Table of Contents. Using your mouse, click on the Lakes layer and drag it above the Countries layer. You should now see all lakes on your map.

D. Set the current and scratch workspaces to appropriate locations for data input and output. At this point, be sure to save your map document.

Part B: Working with the World Map

In the Table of Contents, a *data frame* groups layers that you want to display together. The default name for a data frame is Layers. Map units and display units are important properties of a data frame. *Map units* are the units in which the layers in a data frame are drawn (feet, meters, decimal degrees, etc.). Map units remain unknown until a coordinate system (i.e., spatial reference) is specified for a data frame or they are set manually. *Display units* are the units associated with the map coordinate readout in the Status Bar (lower right-hand corner of ArcMap). The World Map data frame is missing a coordinate system. However, the layers in the data frame have geographic coordinate systems (GCSs). With this in mind, you need to change the map and display units accordingly.

A. In order to set or change map and display units, you must access a data frame's properties. Go to View on the menu bar, then Data Frame Properties (alternatively, you can right click on Layers in the Table of Contents and select Properties). In the General tab on the popup window, change the name of the data frame from Layers to World Map. Below you will find the pull down windows that allow you to change map and display units. Change the map and display units to appropriate units.

Questions (3 marks)

1. What map units did you choose? Why? (1)
2. What display units did you choose? Why? (1)
3. What are Darwin's coordinates? (zoom in to Darwin and read the coordinates from the Status Bar; to receive full marks, you must show coordinate units) (1)

Part C: Examining Coordinate Systems

An integral property of a data frame is its coordinate system. In order to see the coordinate system of the World Map, go back to Data Frame Properties and click the Coordinate System tab. Note that the data frame does not have a coordinate system. However, it is possible to define one given that its thematic layers have GCSs.

A. Two folders contain coordinate systems: Geographic Coordinate Systems (GCSs) and Projected Coordinate Systems (PCSs). GCSs are based on 3-dimensional representations of the Earth and describe locations on its surface by longitude and latitude.

B. Expand the GCS folder. It contains several subfolders for different parts of the world. Since you are working with a map of the entire world, expand the folder named World, select WGS 1984, and click Apply.

C. Go back to the General tab. You should now see that map units have been dimmed. This occurs because you can no longer alter it since decimal degrees are the only map units applicable to WGS 1984. Change the display units to kilometers and click OK.

Question (2 marks)

4. What are the coordinates of Darwin now? (zoom in to Darwin and read the coordinates from the Status Bar; to receive full marks, you must show coordinate units) (1) What does this information tell you about Darwin's location? (1)

By default, the data frame will take on the coordinate system of the first data layer added to it. In this part of the exercise, you had to define the coordinate system as WGS 1984. This was necessary because coordinate systems were not defined for any of the thematic layers. ArcMap does, however, have the ability to **display** maps in any coordinate system, geographic or projected. PCSs convert longitude and latitude to linear units (feet, meters, etc.) through a system of mathematical equations. When this conversion takes place, layers are converted on the fly, affecting only their appearance. They not altered physically.

D. Change the coordinate system of the data frame to Robinson (world) (found in the World folder under Projected Coordinate Systems) and press OK.

E. Now zoom to the full extent of the map (press the button with the Earth on it).

Question (2 marks)
5. Provide a brief description of what happened to the map after executing step D. (1)
6. Provide a brief description of what happened to the map after executing step E. (1)

This behavior is tied to the fact that the underlying shapefiles are missing coordinate systems. In order to move forward, they must be defined.

F. Switch the data frame back to WGS 1984.

Part D: Defining Coordinate Systems

A. When a shapefile is missing its coordinate system (i.e., spatial reference), and **you are sure what it is supposed to be**, you can use the Define Projection tool to set it. This tool is found in ArcToolbox, the geoprocessing toolkit of ArcGIS. To access ArcToolbox, click the button on the Standard toolbar that looks like a toolbox. The ArcToolbox window appears containing many toolboxes. All geoprocessing tools are organized logically in these toolboxes.

B. The Define Projection tool is found under Data Management Tools. Expand that toolbox, and then expand the Projections and Transformations toolset. You should now see the Define Projection tool (there is a hammer beside it). Double click on Define Projection. A popup window will appear.

C. Click the down arrow under Input Data Set or Feature Class. You will find a listing of all of the layers in the current map document. Select 4cities. Click the button under Coordinate System to produce a popup window entitled Spatial Reference Properties. You now have the option to select a predefined geographic or projected coordinate system, import one from an existing data set, or create an entirely new one. You would only use the last option if the projection or coordinate system you require is not currently found in ArcMap (this is quite rare).

D. You will select a predefined coordinate system. This is done in the same way as for the data frame. Navigate to where WGS 1984 is stored (under Geographic Coordinate Systems) and select it. When you click OK, you should see GCS_WGS_1984 in the Coordinate System window. Click OK and wait until the popup window tells you that defining is complete (the popup will appear in the lower right-hand corner of the screen).

E. Repeat the process for all other layers in the map document. For any one of the remaining layers, define the coordinate system using the import option. Since you have defined the coordinate system for the 4cities shapefile already, you can import the coordinate system from that. Also, you can select the coordinate system from the Favorites folder if it is saved there (you can save coordinate systems to this folder).

F. Once all of the shapefiles have had their respective coordinate systems defined, close ArcToolbox (click on the x in the upper-right corner), minimize ArcMap, and navigate to the Windows folder where your data are stored. You should now see a new file added to each of your shapefiles. This is the .prj file, or projection file. This is what defines a shapefile's coordinate system.

G. Return to ArcMap. For each layer, look at the Source tab in the Layer Properties popup window. You should see that each layer has a coordinate system.

Part E: Applying Projections to a Data Frame (Understanding Map Distortion)

Continuing with the World Map, you will explore how different projections impact a map. Projections always distort map properties, so it is important to keep in mind the properties that you wish to preserve when selecting a projection. In this exercise, you will explore how different projections impact area.

A. Change the coordinate system of the data frame to Eckert II (world), found in the World folder under Projected Coordinate Systems. Press OK. Notice the difference in appearance.

Questions (4 marks)

7. Using Help, describe briefly the properties of the Eckert II (world) projection. (2)
8. Provide a screen capture of your result. To take a screen capture, hold the Shift key and press the Print Screen key on the keyboard. Next, paste the screen capture in your Word or OpenOffice document. Your screen capture must not be cropped in any way – that is, all parts of the screen must be shown – otherwise, you will receive a 0 on this question. (1)
9. Using the Measure tool, how far from the projection's origin in kilometers (to within 100 km) is each of the cities? (zoom in a bit to ensure accuracy; to receive full marks, you must show distance units) (1)

B. In the Table of Contents, right click on the Countries layer and open its attribute table. This part of the exercise focuses on the SQKM_CNTRY and NEW_AREA fields. The SQKM_CNTRY field contains the areas of each country in the data set, while NEW_AREA is currently an empty field (contains only zeros).

C. Right click on the field heading "NEW_AREA" and select Calculate Geometry. A popup window will appear allowing you to compute area, perimeter, and the X and Y coordinates of centroids (in this case, points representing the geographic centers of countries). Ensure that area is selected, that you are using the coordinate system of the data frame, and that your units are in square kilometers. Once these are selected, press OK. You should notice that the NEW_AREA field is now populated. Write down the areas of Argentina, China, Kenya, and the United Kingdom (round to the nearest square kilometer) as you will need them to answer Question 10.

D. Change the coordinate system from Eckert II (world) to Mercator (world). Repeat step C for this new projection, and once again, write down the areas for the countries listed. Change the coordinate system from Mercator (world) to Robinson (world) and repeat step C again.

Questions (7 marks)

10. Create a table comparing the areas computed for the specified countries under each of the three projections to their actual area values found under SQKM_CNTRY. (to receive full marks, you must include values for SQKM_CNTRY in your table) (3)
11. Referring to the results presented in the table that you created for Question 10, comment briefly on whether the projections chosen preserve area. (1)
12. What are the uses of each type of projection? (use the Help menu to answer this question) (3)

Part F: Hard Projecting Shapefiles

Up until now, coordinate systems have been changed on the fly without altering the underlying shapefiles – a process called *soft projection*. *Hard projection*, on the other hand, involves recalculating XY coordinates and saving the results permanently to new shapefiles. In this part of the exercise, you will explore two ways to hard project data. Each way is tied to a specific scenario.

Scenario 1:

A. For this part of the exercise, you will create a new map document. Click the New button on the Standard toolbar. In the popup window that appears, select Blank Map and press OK.

B. Click the Add Data button (the button with a plus sign on it). Navigate to the Canada folder and add both shapefiles to the data frame. These layers represent the Census Divisions of Canada and the surrounding water bodies. Rearrange the layers so that the water layer is shown on top of the Census Divisions. To change the colors of any layer, click once on its symbol in the Table of Contents. Change the water to blue, and change Canada to coral.

Question (1 mark)

13. What is the coordinate system of the data frame? (1)

C. Through Data Frame Properties, change the coordinate system to NAD 1983 Statistics Canada Lambert.

Question (1 mark)

14. What projection is associated with the NAD 1983 Statistics Canada Lambert coordinate system? (1)

D. One way to save the layers with the new coordinate system (i.e., make the changes permanent) is to export the data. This is done by right clicking on a layer, choosing Data | Export Data. On the popup window that appears, navigate to where the Output Feature Class is to be saved. Provide a name for the data and make sure that Save As Type is set to Shapefile. Click Save. Before pressing OK, make sure that the data are exported using data frame's coordinate system. Use this procedure to save both layers with the new coordinate system.

E. Open a new map document and add the newly projected shapefiles. You will see that they are stored in the previously viewed projection. Once again, change the water to blue, and change Canada to coral.

Question (1 mark)

15. Provide a screen capture of the result shown in step E. Your screen capture must not be cropped in any way – that is, all parts of the screen must be shown – otherwise, you will receive a 0 on this question. (1)

Scenario 2:

Sometimes you may have multiple shapefiles of the same location that are stored in different coordinate systems. In ArcMap, the Project tool allows you to convert shapefiles from one coordinate system to another. In the following exercise, you will use this tool to help you overlay two layers.

A. Create a new map document. Navigate to the Hamilton folder and add the two shapefiles to the data frame.

B. Right click on each of the layers and click Zoom to Layer. You should notice that the layers do not overlay on one another. If you zoom to the full extent, you will notice that Hamilton appears to be very small at the top of the map, while Roads does not appear at all. This occurs because the data sets are in different coordinate systems.

Question (2 marks)

16. Explain briefly how else you could have determined that the data sets are in different coordinate systems. (2)

C. You have been given documentation informing you that Hamilton's coordinate system is NAD 1983 UTM Zone 17N and Roads' coordinate system is NAD 1983. Since these two layers have been provided to you in different coordinate systems, you need to project one of them so that they can line up spatially. However, prior to using the Project tool, you need to use the Define Projection tool to define each layer's current coordinate system. Remember that hard projection changes a shapefile's coordinates, so ArcMap must know what the initial coordinate systems are before any calculations can be done.

Question (1 mark)

17. What UTM Zone does Hamilton belong in? (1)

D. Define both layers using the above information. Then use the Project tool to hard project the Roads layer to match the Hamilton layer.

E. Create a new map document showing the projected Roads layer superimposed on the Hamilton layer. Change the color of Roads to black (Major Roads) and change the color of Hamilton to yellow.

Question (1 mark)

18. Provide a screen capture of your work shown in step E. Your screen capture must not be cropped in any way – that is, all parts of the screen must be shown – otherwise, you will receive a 0 on this question. (1)

Part G: Working with Datums

This part of the exercise deals with data sets in different datums. When datums are different, the same coordinate location will fall in a slightly different spot, causing misalignment between data sets.

A. Open a new map file and navigate to the Datum folder, which contains two shapefiles. The shapefiles represent the road network used in Part F (Scenario 2). Add the shapefiles to the data frame. When prompted, **do not** transform coordinate systems. Simply, click on the Close button.

Questions (2 marks)

19. What is the datum for Roads27? (1)
20. What is the datum for Roads83? (1)

B. Using the Zoom In tool and the Identify tool, zoom in closely to the corner of West 5 St. and Stone Church Rd. W.

Question (2 marks)

21. What is the difference (in meters) between NAD27 and NAD83 at this location in both the north-south and east-west directions? Be sure to take the distance measures parallel to the line segments. Round your answers to two decimal places. To receive full marks, you must show measurement units. (2)