



Why learn about projections and coordinate systems? Quite simply, because the Earth is not flat, nor perfectly spherical. The most critical thing that the educator teaching with GIS must know is knowing what the projection is and having the correct coordinate system information associated with each data set used in a project. And to accomplish this, the educator must be familiar with a few terms and concepts.

A **geographic coordinate system** defines locations on the Earth using a 3-D spherical surface. A geographic coordinate system includes an angular unit of measure, a prime meridian, and a **datum**, which is based on a spheroid (a mathematical model of the shape of the Earth). A **projected coordinate system** represents the 3-D Earth defined on a flat, 2-D surface. Unlike a geographic coordinate system, it has the advantage that lengths, angles, and areas are constant across the two dimensions. A **map projection** is a mathematical transformation that transforms the 3-D earth onto a 2-D map sheet or computer screen. Map projections can preserve shapes (conformal), areas (equal area), distances (equidistant), or directions (azimuthal), but no map projection can preserve all 4 of these. Projection types can be conic, cylindrical, or planar.

Moving your data between coordinate systems sometimes includes **transforming** between the geographic coordinate systems and their associated, underlying spheroids, and thus, the between datums that describe those spheroids. If your data layers are far apart geographically, then they are in different projections. If they are close but do not exactly overlay, then they are probably in the same projection but likely are in different datums.

Although there are thousands of projections, coordinate systems, and datums around the world, you don't have to know about all of them. The most commonly used datums in North America are: (1) North American Datum (NAD) 1927, using the Clarke 1866 spheroid. (2) NAD 1983, using the GRS 1980 spheroid, and (3) World Geodetic System 1984, using the WGS 1984 spheroid.

The most commonly used coordinate systems in North America area: (1) Geographic; (2) UTM, including most data from the USGS and many other federal and state agencies; (3) State Plane, including much state and local government data. At least 1 state plane system is in effect for each state (some in m, some in feet).

Online and print resources abound regarding map projections. Some of the richest sources include:

- (1) ArcHelp—look up terms projections, and coordinate systems <http://webhelp.esri.com>
- (2) ESRI's Understanding Map Projections: [http://www.geo.utep.edu/pub/bkonter/geo\\_4385/ESRI\\_Projections.pdf](http://www.geo.utep.edu/pub/bkonter/geo_4385/ESRI_Projections.pdf)
- (3) Harvard's harnessing projections in ArcMap: <http://www.gsd.harvard.edu/gis/manual/projections/tutorial/index.htm>
- (4) ESRI's identifying an unknown coordinate system:  
[http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Identifying\\_an\\_unknown\\_coordinate\\_system](http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Identifying_an_unknown_coordinate_system)
- (5) USGS Map Projections poster: <http://egsc.usgs.gov/isb/pubs/MapProjections/projections.html>

#### **Key Projection Rules:**

1. If you are going to measure, buffer, or do anything else related to accurate distances and measurements, you should be using a projected coordinate system due to the convergence of longitude lines in the geographic coordinate system.
2. If you are going to be using your data layers for an extended period of time, it is best to use Define Projection (on unprojected data) or Project (both found in ArcToolbox) to set the projection of all of your layers, rather than rely on projection on the fly in your Data Frame.
3. Do not use Map Units in the data frame properties to change the map units. The only thing you should be changing here is the Display Units, so that your measurements are displayed in the desired units (degrees, meters, etc). The map units should be changed when you Define or Project data in ArcToolbox.

ArcGIS can transform the coordinate systems of GIS layers, aligning them on-the-fly, **if** the layers have embedded metadata that accurately describes their coordinate systems. If the GIS layers don't line up, it is because one data layer or another does not have this information. If no coordinate system information is associated with a data layer, ArcMap will examine the coordinate values to see if they fall within  $-180$  to  $180$  for x-values and  $-90$  to  $90$  for y-values. If they don't, ArcMap treats the values as planar x-y coordinates, and the map and display units are set to Unknown.

If you have data that has a coordinate system called GCS\_Assumed\_Geographic\_1, this is not the data's correct coordinate system. The "Assumed Geographic" definition was created to permit ArcMap to "guess" at the correct coordinate system for data which has coordinates in decimal degrees. You should determine the correct geographic coordinate system for your data and then use Define Projection in ArcToolbox.

Check the projection information on your data layers by (1) Data → View Metadata in ArcMap, or (2) the Metadata tab in ArcCatalog.



**STATUS:**  
Layers have no projection info (.prj or otherwise), and the data frame has an unknown projection.

**SOLUTION:**  
Assign each layer a projection (creates a prj file). Assign data frame a projection.



Data Management Tools → Projections and Transformations → Define Projection tool



Repeat for each data layer in TOC

Double click "Layers" data frame in TOC or View → Data frame properties → Coordinate System Tab → Choose Geographic or Predefined Folder → Choose projection you want to work in.

This will always work as long as you have chosen the correct projection that the data was created in.

**PROBLEM:**  
Map layers in your TOC (Table of Contents) are in two disconnected regions of the data frame when zoomed to full extent.



**STATUS:**  
One layer has no projection info (.prj or otherwise) but correctly overlays in the data frame because it is in the same projection as your data frame and can overlay on the fly until you change the projection.

**SOLUTION:**  
Assign the unprojected layers the projection of the data frame where they used to fit.



Data Management Tools → Projections and Transformations → Define Projection tool



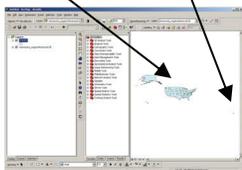
Repeat for each data layer in TOC

Double click "Layers" data frame in TOC or View → Data Frame Properties → Coordinate System Tab → Choose Geographic or Predefined Folder → Choose projection you want to work in.

This will always work as long as you have chosen the correct projection that the data was created in.



For example: USA is here, Minnesota image is here.



**STATUS:**  
Layers have projection information. You want to view the data differently in the data frame.

**SOLUTION:**  
Assign data frame a projection.



Double click "Layers" data frame in TOC, or View → Data Frame Properties. Access Coordinate System Tab → Choose Geographic or Predefined Folder → Choose projection you wish to work in.

**3 Different Projection Tools:**

1. ArcToolbox → Define Projection to define an unprojected data set.
2. ArcToolbox → Project to change previously projected data into a different projection. Do not use this on unprojected data!
3. View View → Data Frame properties → Change projection. This changes the way your data is displayed on the map. The data frame projection is set to the projection of the first data layer that is added to it, provided that layer has projection