

## Map Projections in ArcMap

Map projections in ArcMap can be a bit confusing, because the program often automatically reprojects data for display, and there are a ways to permanently project data to new data sets. This describes how ArcMap handles data with different projections, and how you can explicitly project data among coordinate systems.

Note that I show examples with data sets. The data sets are available on the class website, in a compressed file, among this week's materials, so you can reproduce the figures using ArcMap, if you wish. There are also videos that demonstrate the concepts and functions discussed below. The homework this week is also on the course website.

## Data Frame Coordinate System

When we first start Arc Map, we can right click on the **data frame name "Layers"** in the TOC for the default Data Frame, and then left click on **Properties** at the bottom of the menu, and this will open a set of tabs that describe the data frame properties (see figure below). We can review and set the data frame coordinate system through the **Coordinate System** tab (see figure at right)

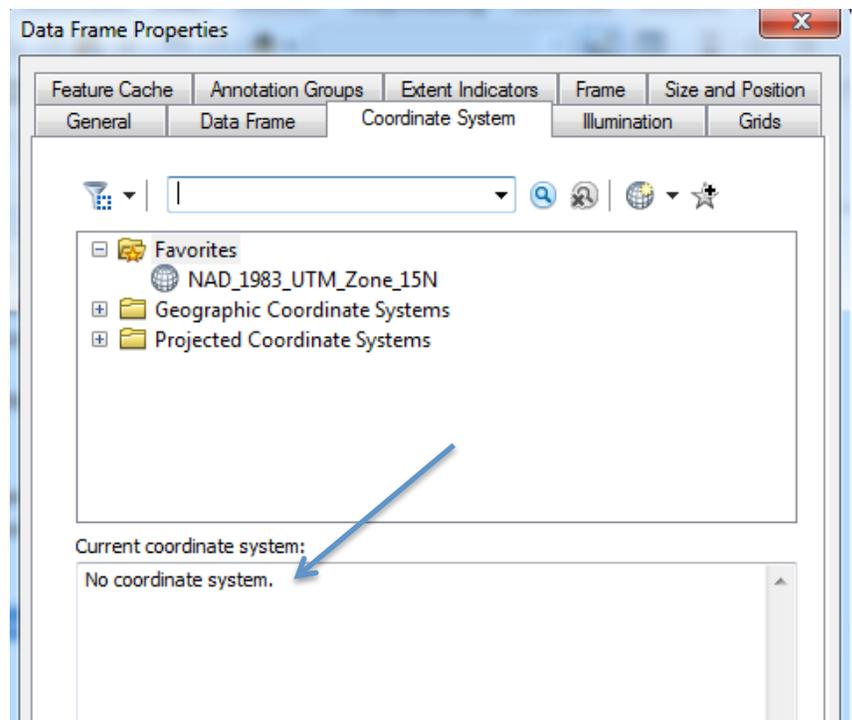
This will display various panes in a window.

The top pane shows a set of potential coordinate systems, and the bottom pane the current coordinate system for the data frame.

Note here that the data frame coordinate system is not set.

This is standard when you first create a data frame, before you've added data.

We could set the coordinate system manually through selection in the top pane by clicking on the folders, e.g., Projected coordinate systems, and selecting a pre-defined coordinate systems.



Alternately, we could load a layer that already has the coordinate system we want. The first time we add data to a new data frame, it will assign that layer's coordinate system to the data frame.

## Data Frame Coordinate Display Units

ArcMap displays the data frame coordinates of the last cursor position on the map. They appear in a preferred set of units, shown at the lower right of the data frame containing your data (see arrow, figure below/right). You can manually set the data frame coordinate system and the units, or ArcMap can establish them automatically when you first load data. Once a data frame coordinate system has been specified, ArcMap will display the approximate coordinates of the current cursor location in the lower-left of the frame (see the arrow in the figure below).

The figure shows the display when I created a new data frame, and added the minn\_count\_dd data, a data layer of Minnesota county boundaries stored in decimal degrees coordinates.

Note that loading a data layer into a new Data Frame automatically then sets the Data Frame coordinate system; all subsequent layers will be projected, if possible, on-the-fly to the same coordinate system as the initial layer before being displayed. Subsequent data are still stored in their original coordinate system, but projected into the data frame system before display.

If I move my cursor around the screen I notice change in the coordinate values displayed on the window frame at the lower right (arrow). The program displays the map projected coordinate values corresponding to the cursor position.

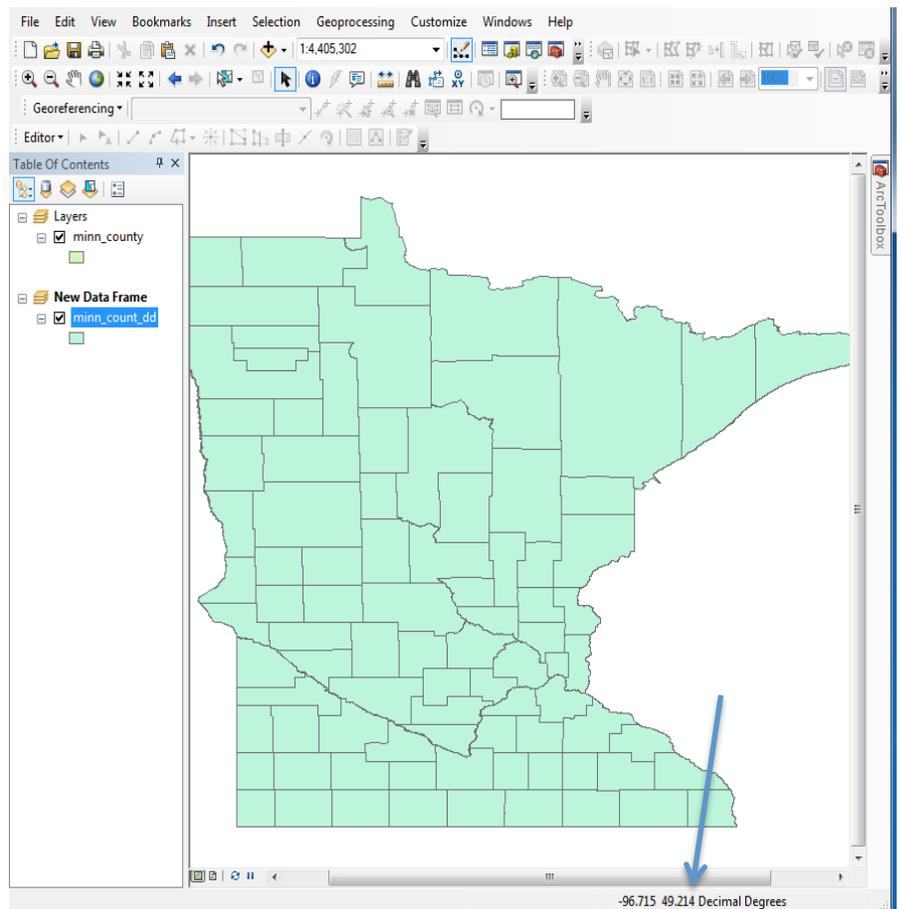
I can add multiple data frames, and each with different coordinate systems.

Don't confuse the data frame name (e.g., **Layers** or **New Data Frame**) with a data layer the TOC, (e.g., minn\_count\_dd).

The Data Frame Names are above the data the TOC, often with the default name of Layers or New Data Frame.

Data Frame Names are not indented, and have the yellow layer stack icon next to them.

You can change the units of the coordinates that are



displayed in the lower right corner of the data frame:

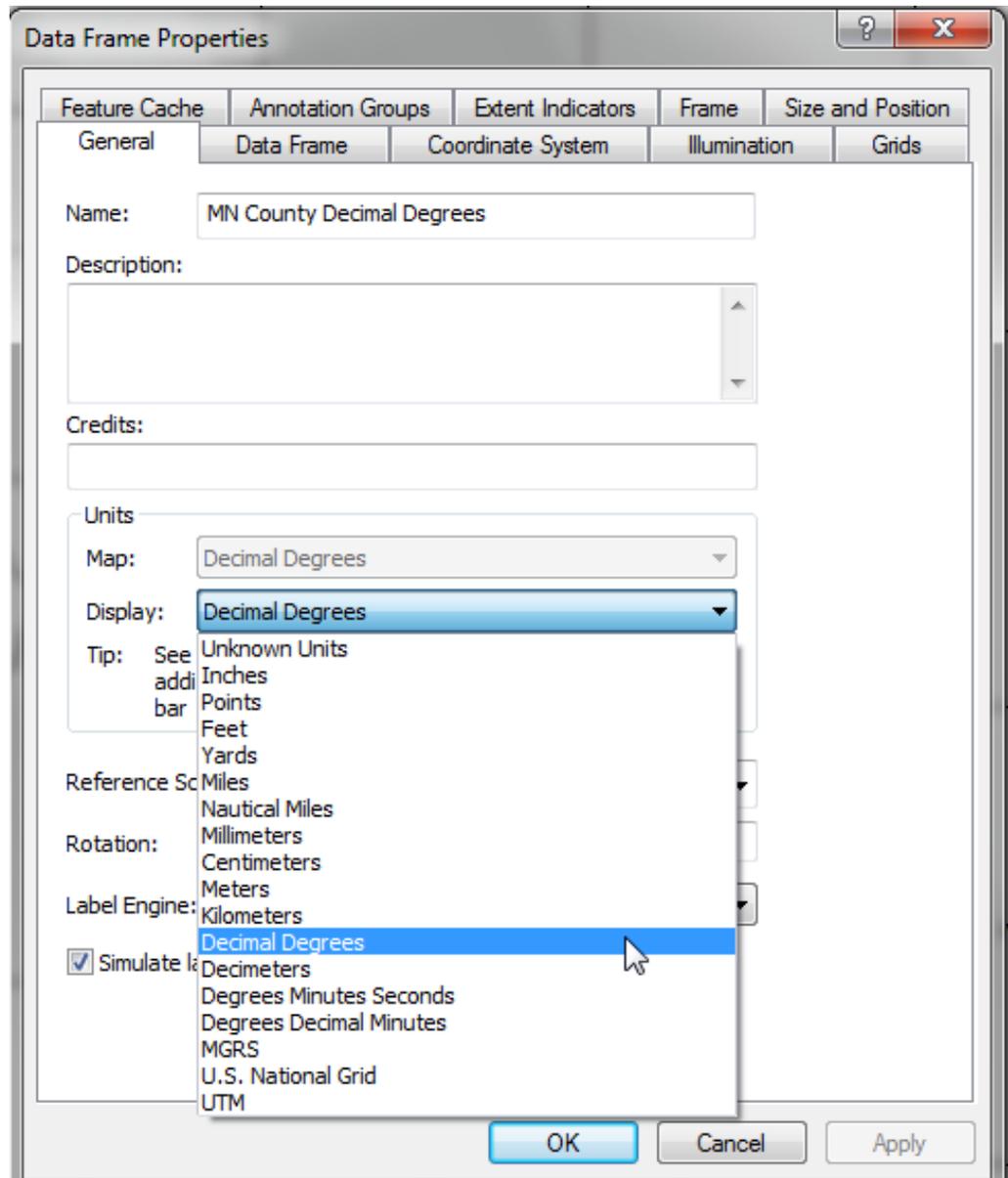
-right click on the data frame name in the TOC for the target Data Frame (our frame is named New Data Frame in the figure above), and this will open a set of tabs, then

-left click on **Properties**, then select the **General** tab

This will display various panes in a window (see figure below). About half-way down you can set the display units.

Next to Display, click on the drop-down menu, then select Decimal Degrees to indicate you want the cursor updates to display decimal degrees values.

After clicking OK and closing the window, coordinate values will be displayed in units of decimal degrees.



## Data Layer Coordinate Systems vs. Data Frame Coordinate Systems

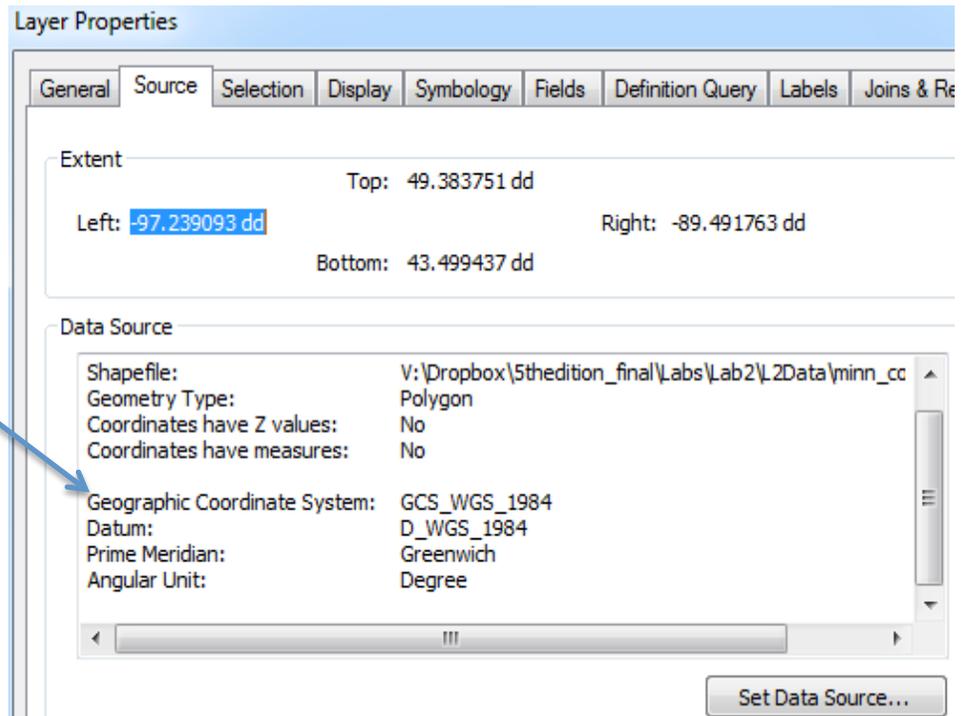
Every data layer has a coordinate system associated with it. The X and Y coordinates are expressed in some units, and they may be geographic (longitude/latitude), or projected (X,Y, or Easting/Northing).

These can (often are) a different coordinate system than the data frame in which the data are displayed.

After I add a data layer to a data frame,

I can see the data layer coordinates (not the same thing as data frame coordinates) by

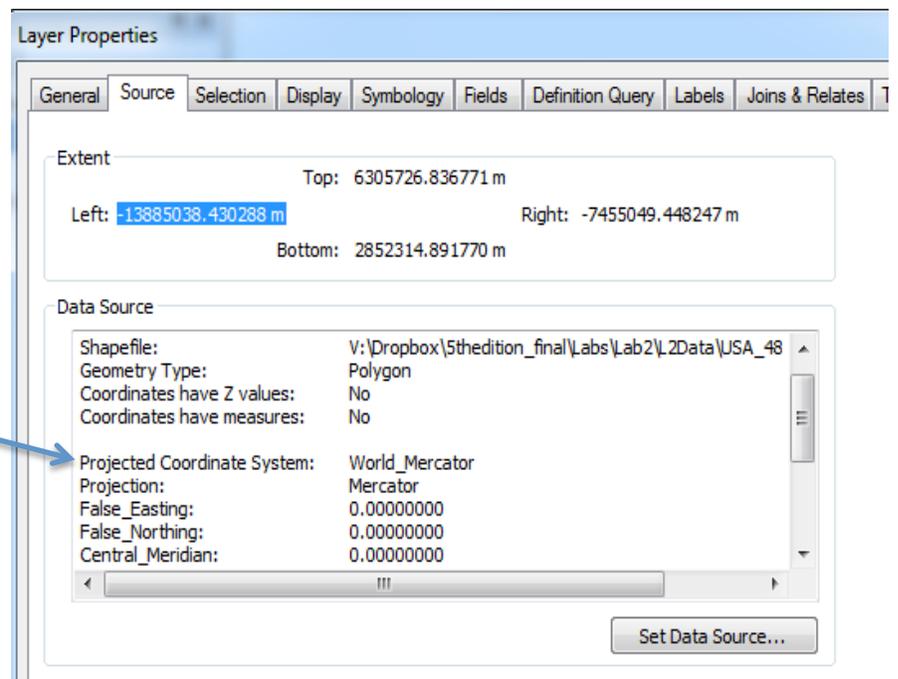
- A right click on a **data layer name** in the table of contents (TOC), then
- **Properties**, and
- click on the **Source tab** to show the data coordinate system, above the geographic coordinate system for a data set.



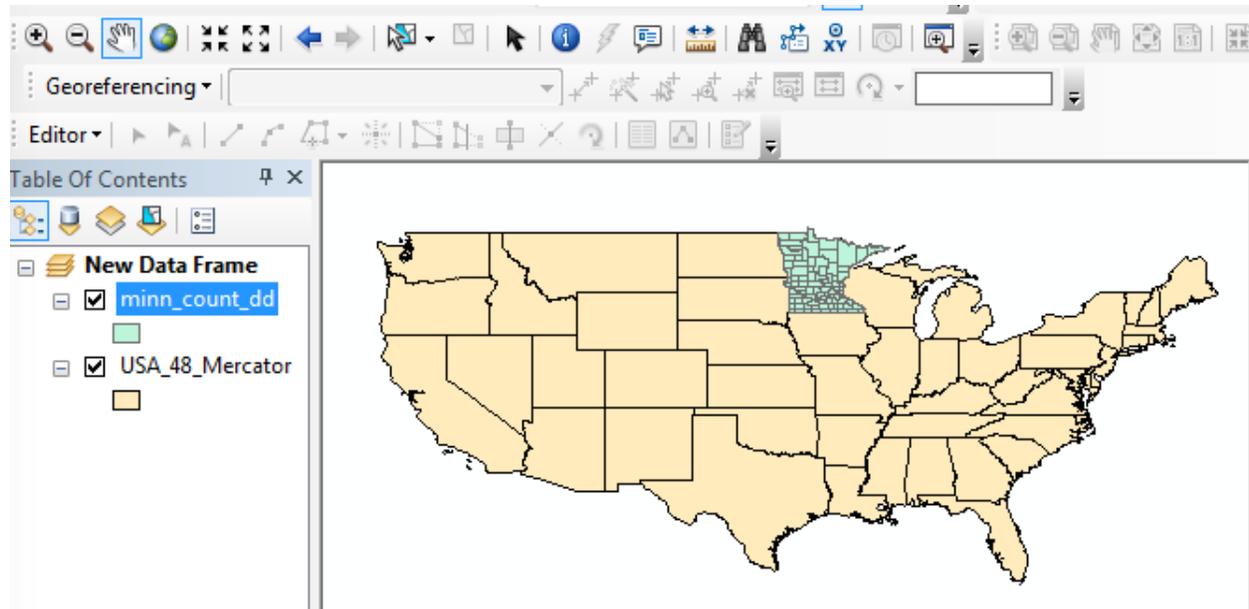
The data frame and data I add to it don't have to be in the same coordinate system as the data frame.

I can add data layers with different coordinate systems to my data frame, for example, a World Mercator data set for the lower 48 U.S. states.

I can inspect it's properties by opening the Properties – Source tab for this data layer, here, World\_Mercator



However, when I load these two files into the same data frame, I get a display similar to that below. Note that although the different data sets are in different projections, they line up on top of each other. Why?



**The layers line up because ArcMap allows a data frame to have a standard projection that is different from the projection for data added to the frame. ArcMap temporarily re-projects all added data to the specified data frame projection.**

The reprojection is temporary, when loading data to a data frame. It doesn't change the data on the disk, but re-calculates coordinates between reading it and displaying it.

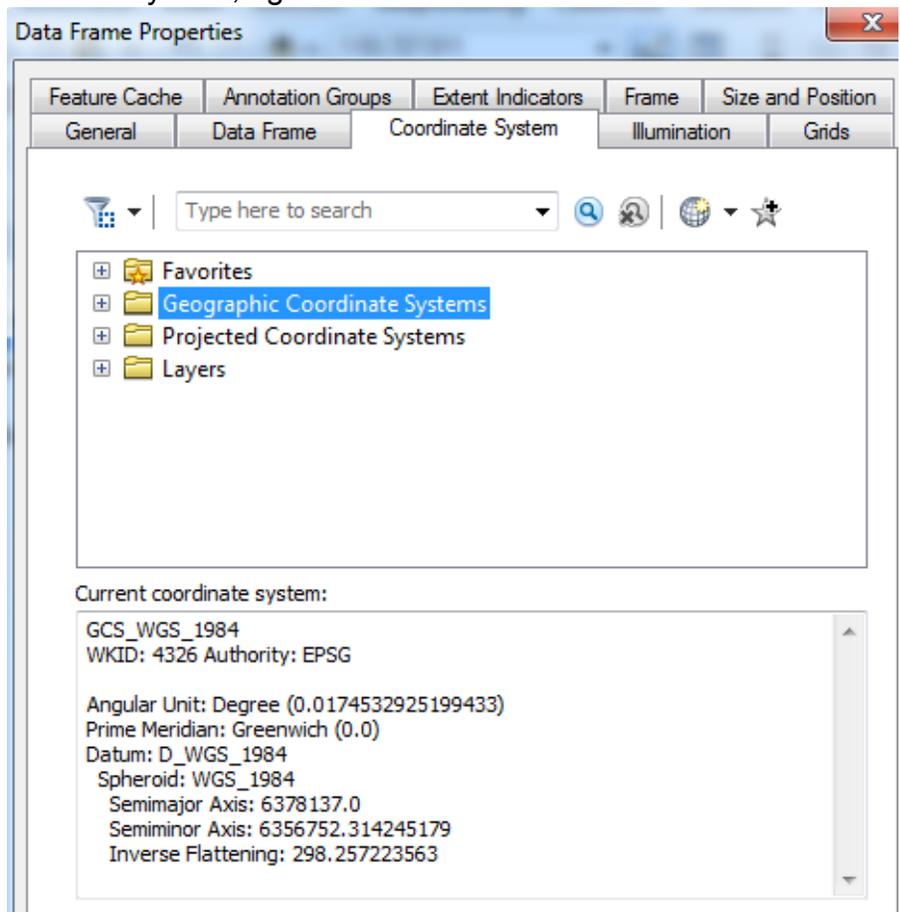
This can be helpful, because we can coherently display data that are in different coordinate systems, but it can be a trap, because it can obscure the true projection of a data layer. This can be quite confusing at first, but **you need make sure you understand this concept of a data frame coordinate system, with temporary reprojection, and a data layer coordinate system– the coordinate system the data are stored in. If you understand this difference, you will likely save yourself much confusion and grief.**

Why is this important? Some operations won't work correctly, for example some editing, overlays, area calculations, or distance measurements, if data layers are in different coordinate systems. You may think they are in the same system if you display them together, but your geo-calculations may be wrong. Sometimes you will be confused in interpreting data, or mis-identify the coordinates because data are re-projected temporarily for display. Remember, if you have any questions about the coordinate system of a layer, look at the layer properties, as shown above.

I can always inspect and set the current data frame coordinate system.

To set the default data frame coordinate system, right click on the name of the **DATA FRAME**, in the Table of Contents (TOC), then left click on **Properties** choice

Once you have the data frame properties displayed, click on the **Coordinate System tab**, and it should display something like the window at right.

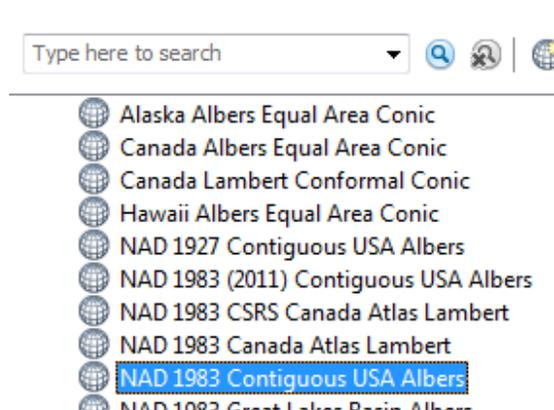


The bottom half displays the current coordinate system. The GCS\_WGS\_1984 is the label for that specific geographic (lat./long.) coordinate system.

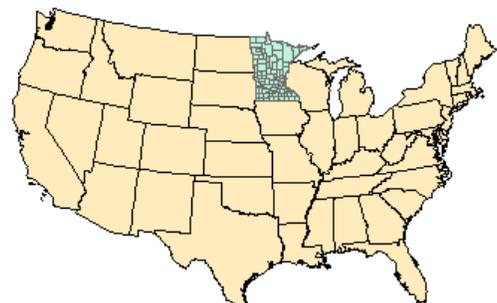
The top half displays a selection window that allows you to set the coordinate system.

You can use the top window pane shown in the figure above to change the data frame coordinate system. You click on the folders successively to the level of a listed projection, then double click on the projection to set it for the data frame.

In the figure below, I clicked on the Projected Coordinate Systems folder, then Continental, then North America, then the NAD83 Contiguous USA Albers, then O.K.



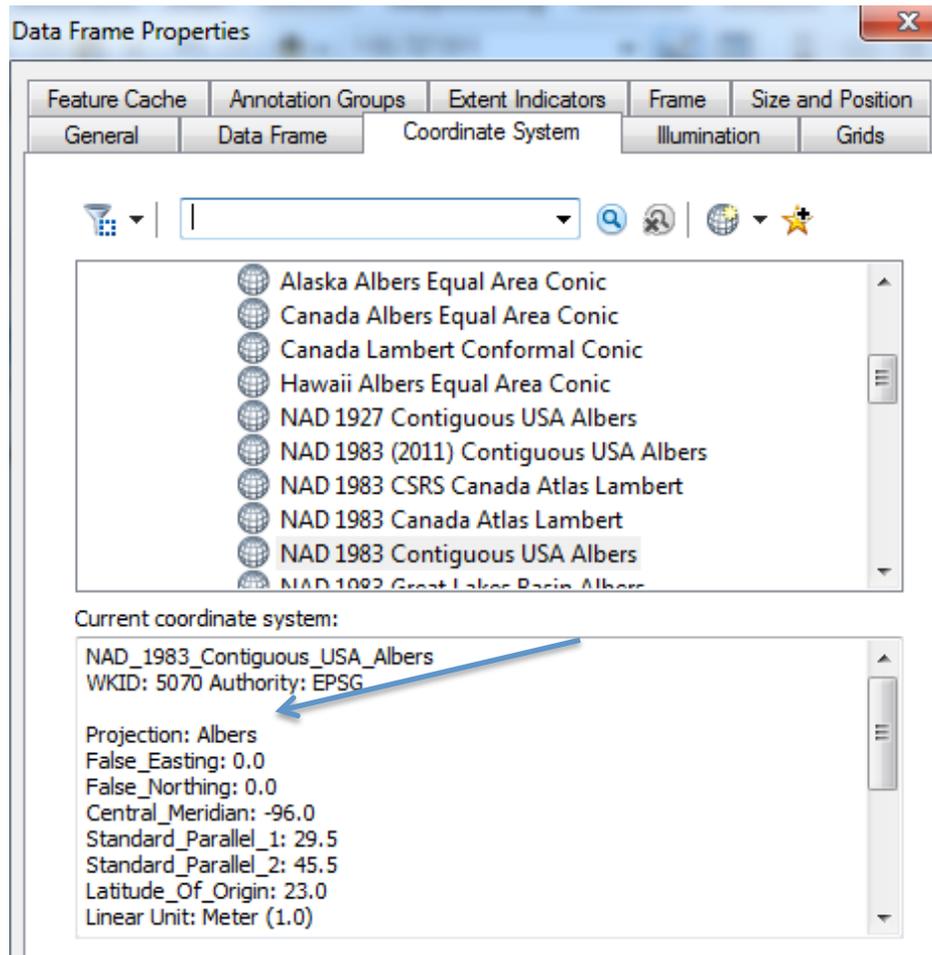
Zooming to the full layer shows it changes the shape of the US and Minnesota data, to look something like:



The data on disk haven't been changed, they've just been temporarily reprojected to this specific Albers coordinate system.

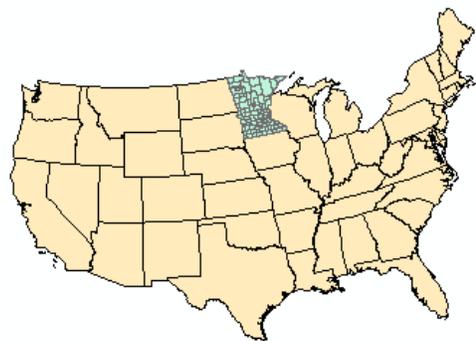
I verify the DATA FRAME coordinate system by right clicking on the data frame name in the TOC, then Properties, then the Coordinate System tab, it should look something like the right.

Note in the bottom window pane, it shows the new data frame coordinate system, here listed as Albers, with parameters.



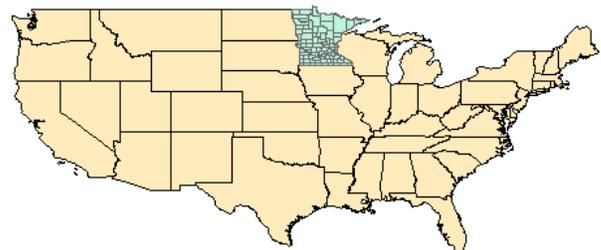
I can change the Data Frame coordinate system, e.g., using the coordinate system window to select **Projected Coordinate Systems** → **UTM** → **NAD** → **NAD83 UTM Zone 12 N**

And on zooming to full extent, note the change in the projection, as at right.



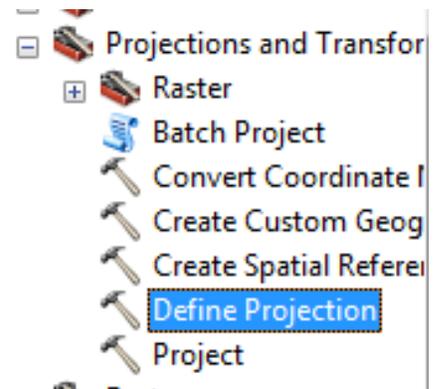
I can switch to geographic coordinates by selecting **Geographic Coordinate Systems** → **North American** → **NAD83 UTM**

and note the change in shape. None of this has changed the projection of the data on the disk, we've just told ArcMap to project on the fly, to a new system, before display.



There are a couple of additional points about on-the-fly-projections.

You may obtain data that has been projected to a coordinate system, but for which the identity of the coordinate system has been lost. This is most common with shapefiles, where the coordinate system information is stored in a .prj file, e.g., minn\_county.prj. If the .prj file is lost, damaged, mis-specified, or not copied with the rest of the shape files, then the ArcMap program can't identify the layer's coordinate system. If you know the coordinate system, you can add the prj file back or fix it for a geodatabase through the "Define Projection" tool in the ArcToolbox (shown at the right, we'll describe ArcToolbox more in the next section).



If you don't know what the projection is, you either need to try to figure it out by matching coordinates or overlaying with other data, or you will likely have to discard the data, because it isn't very useful without knowledge of the coordinate system.

Second, when you load some data you may get a message that says the datums may be incompatible, typically because there is not a datum transformation specified. As noted before in class, you may ignore these warnings for most instances when the difference is between the various modern versions of NAD83, that is, 1996, 2007, and 2011. You shouldn't ignore them otherwise, unless you know the datum transformation shift is less than your acceptable spatial error. From what you've learned in this class, you should have a know that datum transformation shifts depend on the source and target projections, and are important if they are larger than the required accuracy of the data and the goals of the analyses.

## Datum Transformations in ArcMap

Datum transformations from one geographic coordinate system to another are done as part of the Project command in ArcMap. There is no separate datum transformation utility.

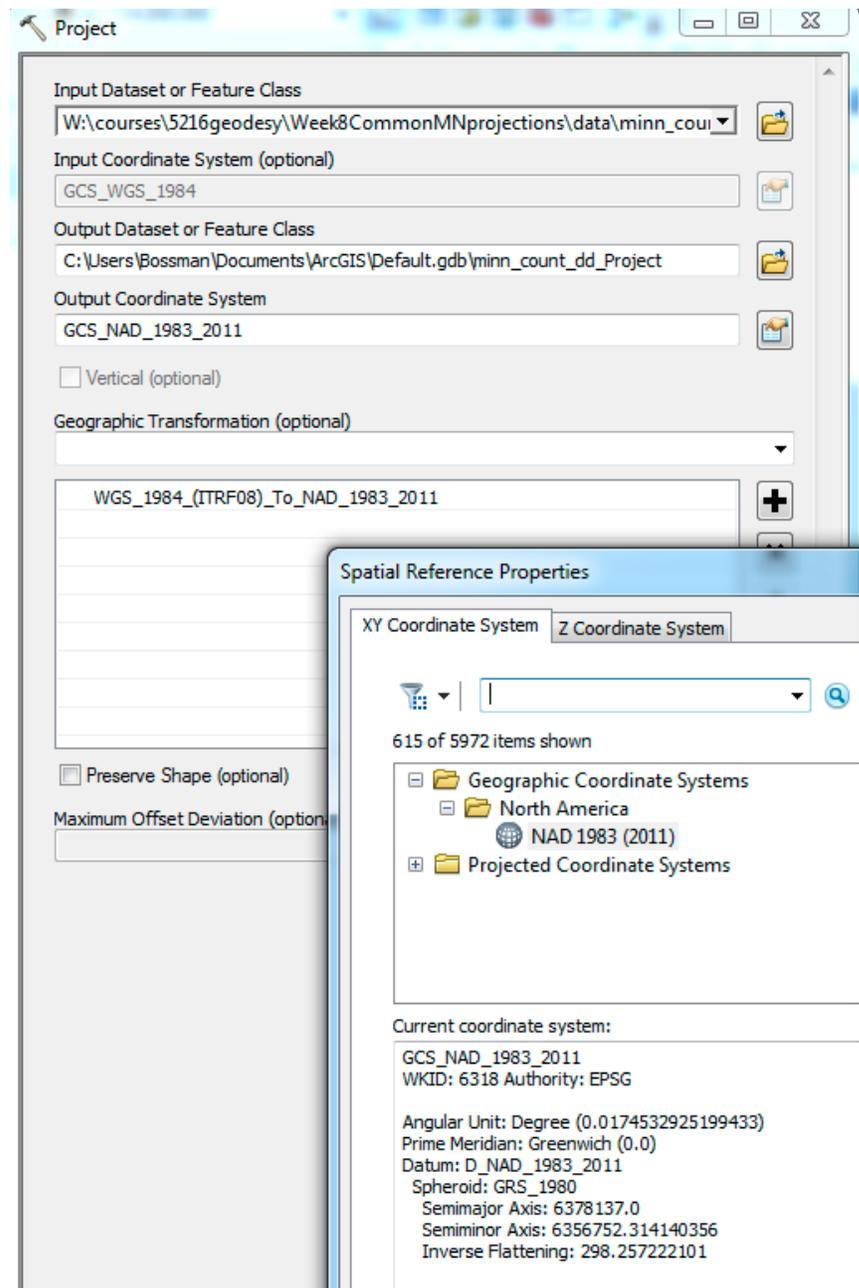
A datum transformation is implemented specifying an input geographic coordinate system and datum, and a distinct datum for an output geographic coordinate system.

ArcMap refers to the datum transformation as a Geographic Transformation.

The figure here shows an input coordinate layer in a WGS\_84 system, transformed to and NAD 1983(2011) coordinate system.

Note that the output coordinate system is in the Geographic Coordinate Systems folder, under North America.

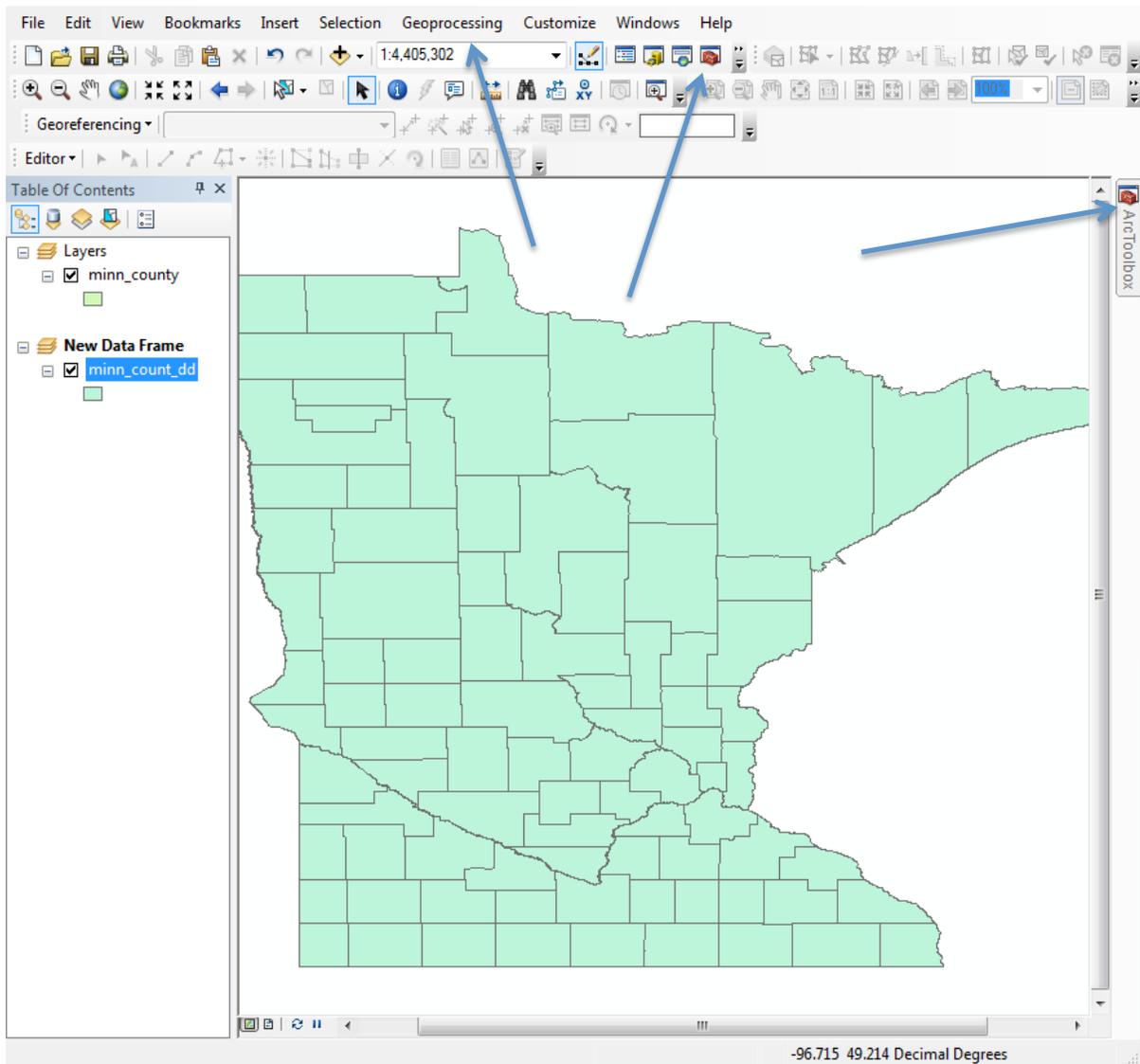
Also note that the datum transformation assumes we have the latest version of the ITRF that ArcMap represents, ITRF for 2008, continuing the ArcMap tradition of not differentiating between versions of WGS84 very transparently. You can select a different ITRF if it is appropriate.



## Projecting Data to a New File – The Project Tool

We use the **Project** tool to project existing files from in one coordinate system to new files in a different coordinate system. Each time we apply the projection tool, we identify the source data set, the output data set, and the output projection. Most source data sets have a coordinate system associated with them. The Project tool reads this coordinate system to determine the input. We then specify the output, including the datum transformation, if needed, and save the new file to a target location.

The Project tools is found in the **ArcToolbox**  along the icon ribbon, or available via the Geoprocessing menu listed along the top bar, or perhaps a side bar, or via the Tool Search menu (see arrows, below)



In the ArcToolbox (see right),

It is under

**Data Management Tools**

then

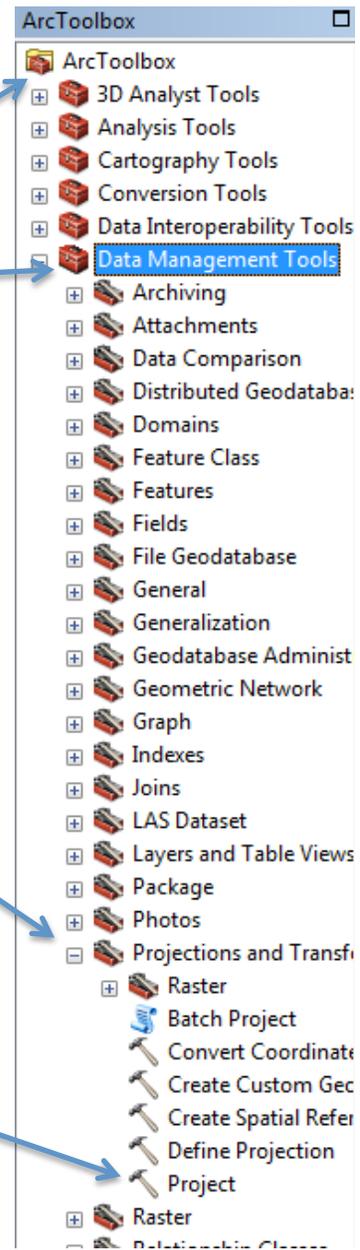
**Projections and Transformations**

then

**Project**

The general process is to start the Project tool, and then:

- Select a data layer containing the features you like to convert to a new coordinate system
- Specify an output location and name for a new data layer
- Specify the output projection, and if need be, a datum transformation (Arc calls it a Geographic Transformation, the same thing as the datum transformation described in the textbook)
- Apply the projection



Remember, ArcGIS shapefiles store information about the projection in a .prj file. For example, a layer named minn\_county may have projection information stored in the file minn\_county.prj. The .prj file is not mandatory, however, even though all data do have a coordinate system. Without a .prj, ArcMap is ignorant of the projection system, so you may have to specify the input as well as output projections in the general steps above.

Projection information is integral to a Feature Data Set in a geodatabase, so as long as a projected coordinate system has been specified, a contained feature class will have a specified coordinate system.

### ***Projecting a File***

Projecting a file to a new coordinate system is relatively straight-forward in the Project tool, you simply specify the input file, output file, target coordinate system, and any datum transformations that are applicable (see figure below).

If the input data set has the proper coordinate system documentation, the Project command automatically sets the input coordinate system.

If there is no input coordinate system defined, or if you know it is wrong, you can select an input coordinate system.

The figure at right shows a projection from a UTM coordinate system to an Albers Equal Area system.

The Project tool refers to a datum transformation as a Geographic Transformation.

Note that these two projections are in the same datum, so there is no Datum Transformation specified.

If there was a change in datum, Project tries to offer a set of the most appropriate datum transformations in the lowest window pane, which you select.

