Lab 8: Projecting Geographic Data

What you'll Learn: Basic methods for map projections in ArcGIS Pro.

What You'll Produce: A map of Minnesota in three different statewide projections, a map of re-projected Minnesota county boundaries with an inset global view, and notes recording areas and coordinates for various projections and measurements.

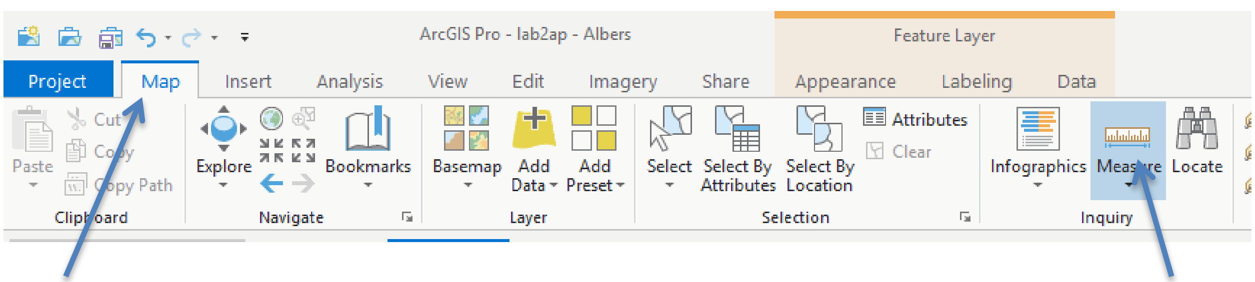
Note that in the instructions below we often use the terms "map projection," "projection," and "coordinate system" interchangeably. A map projection is associated with a specific coordinate system, and to project data is to convert from one coordinate system to another.

Observing How Distance May Change with a Map Projection

Start ArcGIS Pro, and add two Maps (see last week's instructions if you've forgotten how). Remove any default base topography and map layers that ArcGIS Pro might have added. Name one of the Map windows Albers, and name the other Map Mercator (***Video: Rename map & set measure units***)

Activate the Alber's Layer (right click map tab along the top edge of the map view)

Add the layers twocity_Albers.shp, and USA_48_Albers.shp from the Lab2 folder.



Make sure the Map tab is selected/active.

Left click on the Measure Tool to enable it, and set the Distance Units to Miles, and Mode to Planar.

Left-click once on Los Angeles, then move the mouse to New York and double left-click on New York.

The distance between the two cites is displayed in a drop-down window.

Your measured distance should be approximately 2,440 miles.

Activate the Mercator Map. Add the layers twocity_Mercator.shp, USA_48_Mercator.shp

Re-measure the distance from LA to NY. The new measurement should be approximately 3,127 miles.

The on the "ground distance" between LA and NY is actually 2,444 miles. The difference in measurements between the "Albers" and "Mercator" is due to unavoidable distortion caused when we stretch measurements from the curved Earth surface to a flat map surface. Notice that the distortion is different for different projections.

Change the Mode in the measure tool to "Geodesic" and repeat the two distance measurements.

You should get approximately the same number. Under the Geodesic option, the calculations approximate as close as possible the true distance measurement on the surface of the earth. The Loxodromic and Great Elliptical options are only slightly different than the Geodesic differences, but are approximately equal to the Geodesic distance in this application. The big difference is with the planar method, which assumes both projections are good approximations of a Cartesian surface. You can see, with the almost 700 mile error, that a Cartesian measurement assumption can be substantially wrong.

Coordinates and On the Fly Projection

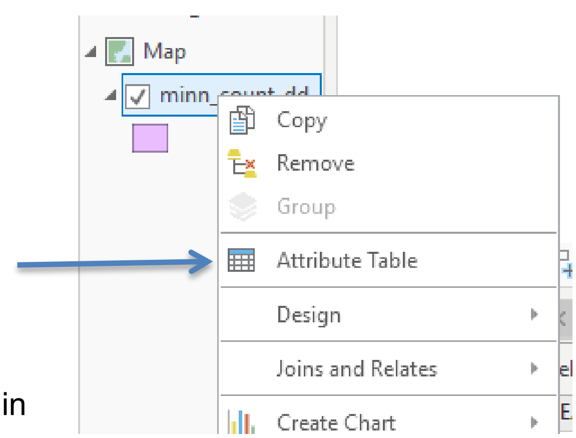
We want to introduce the idea of a temporary, or "on the fly" projection, something that ArcGIS Pro often does when you add data to a Map (*Video:* ***On the fly projection***).

A Map usually has a specified coordinate system. You can manually set the system, or ArcGIS Pro can establish one automatically when you first load data. Once a coordinate system for a Map has been specified, ArcGIS Pro will display the approximate coordinates of the current cursor location along the bottom of the Map frame (see the arrow below).

Create a new Map, and add the minn_count_dd data. This is a data layer of Minnesota county boundaries in decimal degrees coordinates.

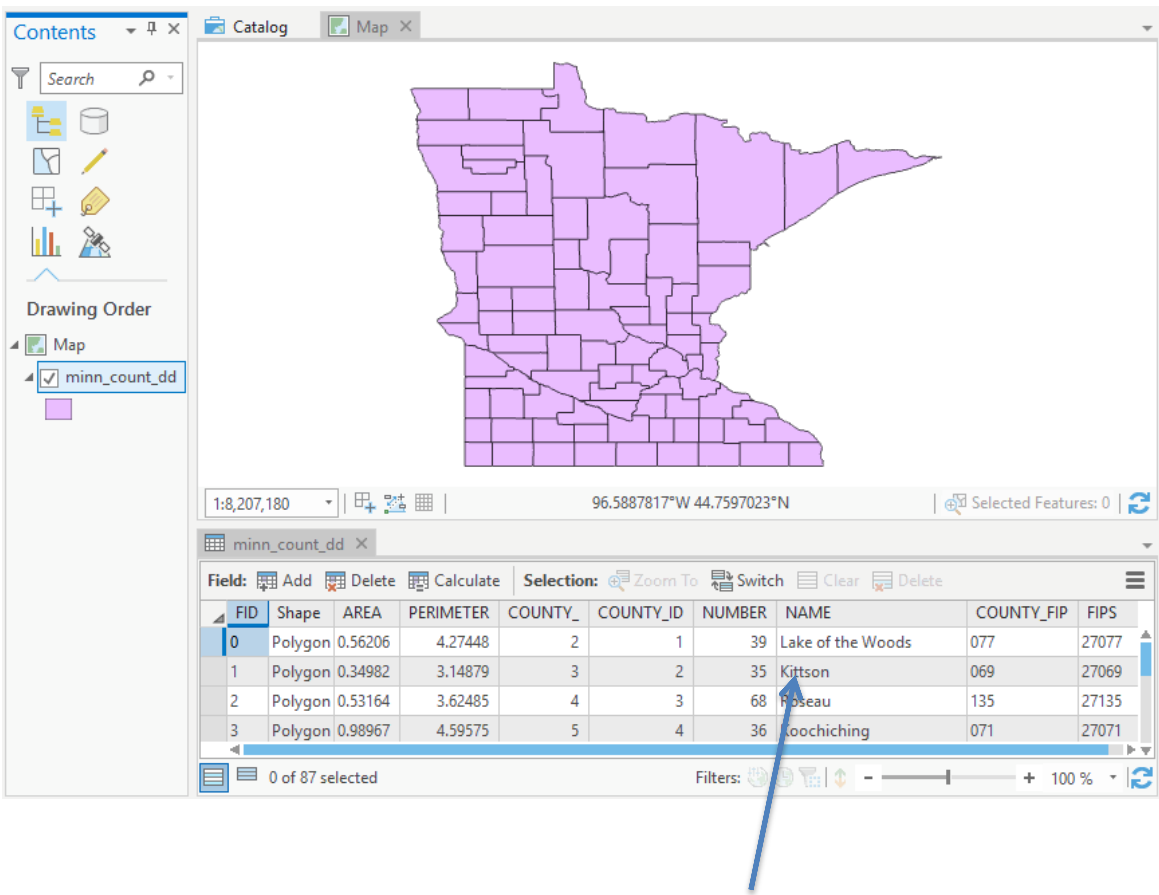
First look at the attribute table.

Right click over the layer name in the table of contents (on the left of your window), and then left click on the Attribute Table option in the dropdown list:



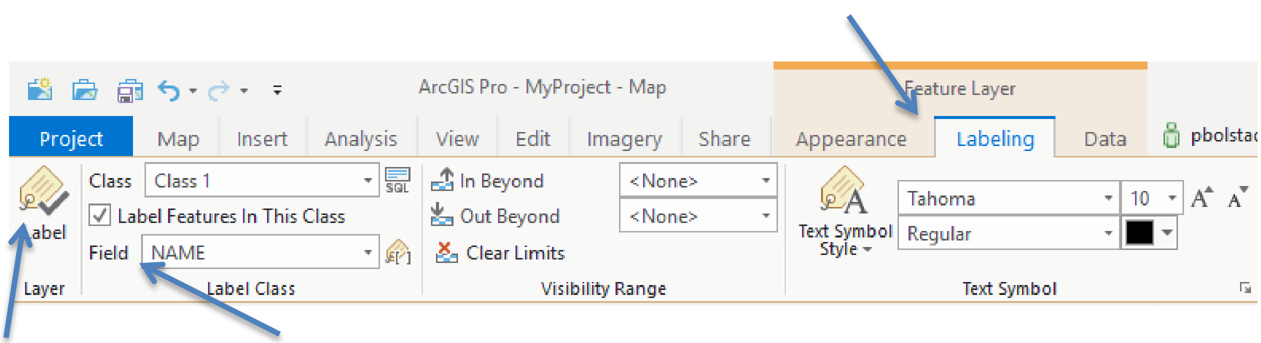
This should display the attributes associated with this polygon layer. Note that the table may be tiled in with your other open windows, so you may have to "grab" the edges with your cursor to resize the panes.

There is a "Name" item, containing the name of each county. We'll use this to label the counties *(See the Video: **Labels**).*



We'll use this column to label each polygon with the county name.

Left click on the tab toward the right center of the main window, under "Feature Layer," "Labeling."



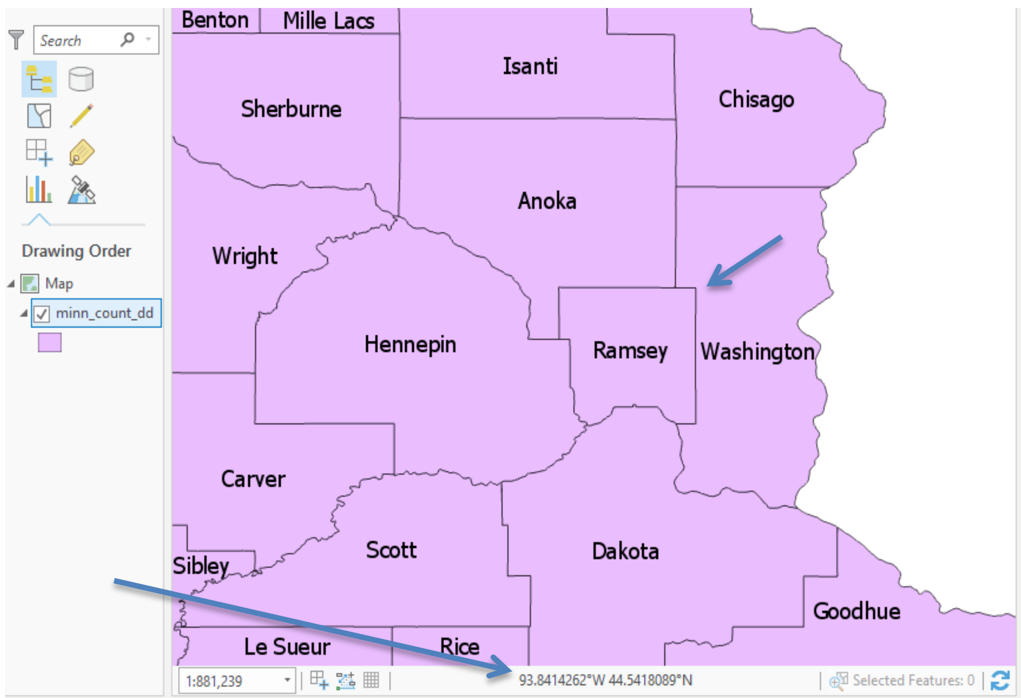
This will display the labeling ribbon, as shown above. We select and style labels using these tools.

Select “Name” in the field window at the lower left (see figure above), and then click on the label icon at the extreme left to turn labeling on. You should see the labels appear on your Map. Depending on the settings, they may not show up at first, and you may have to zoom in on the Map for them to display. You can set threshold scales above/below which labels appear, and also rules that omit overlapping labels.

You can use the tools to change the font properties, label angles, and other characteristics.

Close the table (click on the x at the right edge of the tab), and then zoom to display the northeast corner of Ramsey County, in the east-central portion of Minnesota (see figure at right)

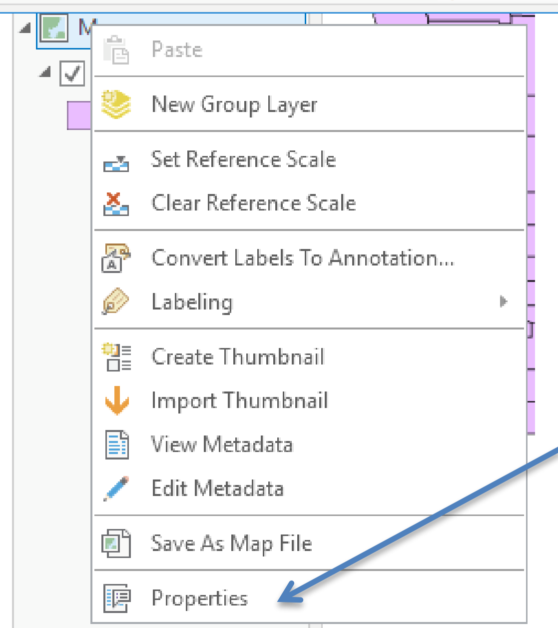
Move your cursor and notice the coordinates near the bottom-center of the Map. These are cursor coordinates, in this case for the data layer you first loaded to the Map, here decimal degrees (*Video: **Coordinate Query***).



Your Map may be displaying some other coordinate units, depending on if you displayed another layer previously, or your system default preferences are different from those we used.

To change the display coordinate units while navigating around the map:

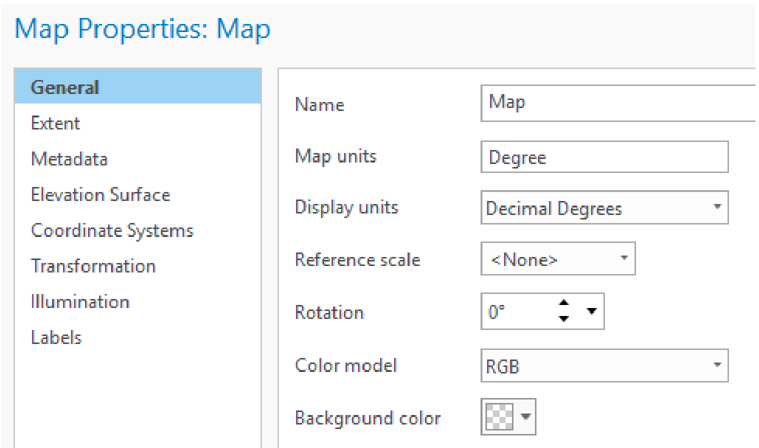
-right click on the Map name in the Table of Contents



at the left of the Map, then

-left click on **Properties**, then select **General** from the displayed list (***Video: Rename Map and Set Measure Units***)

This will reveal several options, including setting the map units, and display units.



About half-way down you can set the display units, make sure they are set to Decimal Degrees.

Click on OK to close the window, and verify that the units at the base of the Map are displayed as decimal degrees.

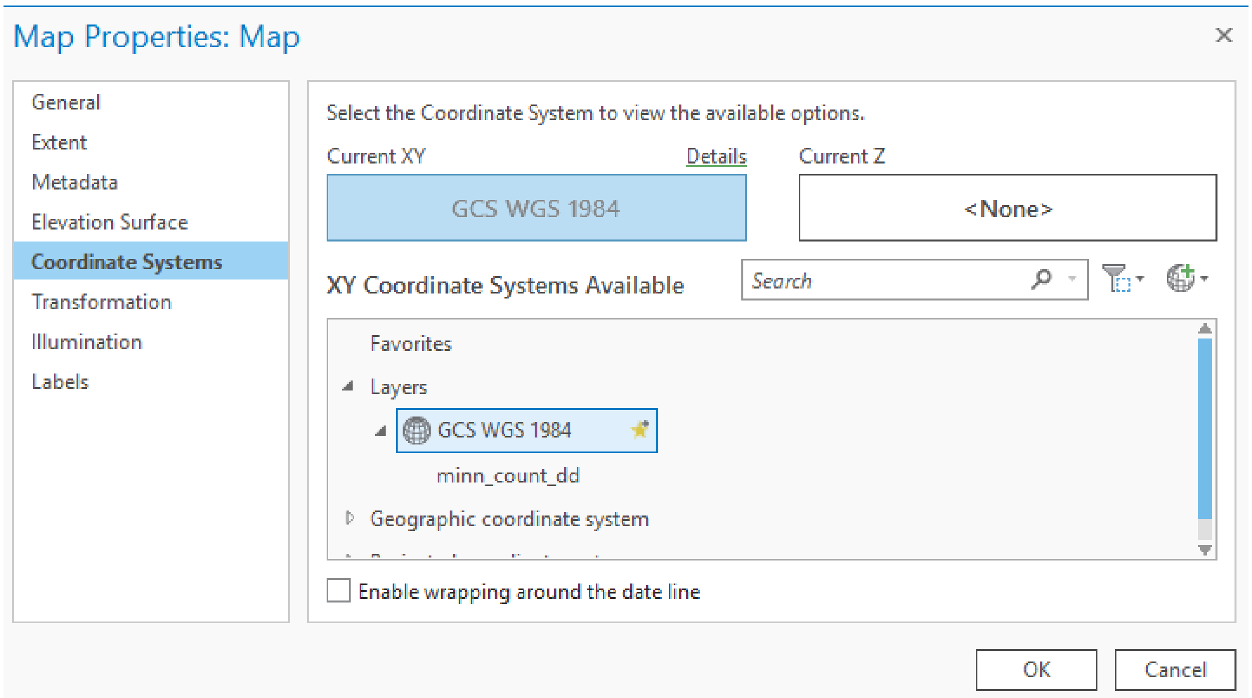
Zoom in and reposition the cursor successively until you have an accurate reading for the coordinates of the northeast corner of Ramsey County (see the figure above).

You'll know you're zoomed in enough when the coordinate values don't change or only change in the third decimal place when you move slightly off of the displayed corner.

Record (write down) the decimal degree coordinates of the northeast corner of Ramsey County. Keep this written information, as you will have more coordinates to look up later in this exercise.

Every data layer has a coordinate system associated with it. A Map may have a different coordinate system. ArcGIS Pro will temporarily convert the layer coordinates to the Map system (if it can), so that data will be displayed in the proper relative locations. This way we can display data from several different sources, each in different coordinate systems, together at the same time. The layer data are not changed in storage, they are only temporarily projected "on the fly" to align correctly. Sometimes this doesn't work, for example, when the information on the coordinate system for a layer is missing or corrupted, but usually everything works as planned.

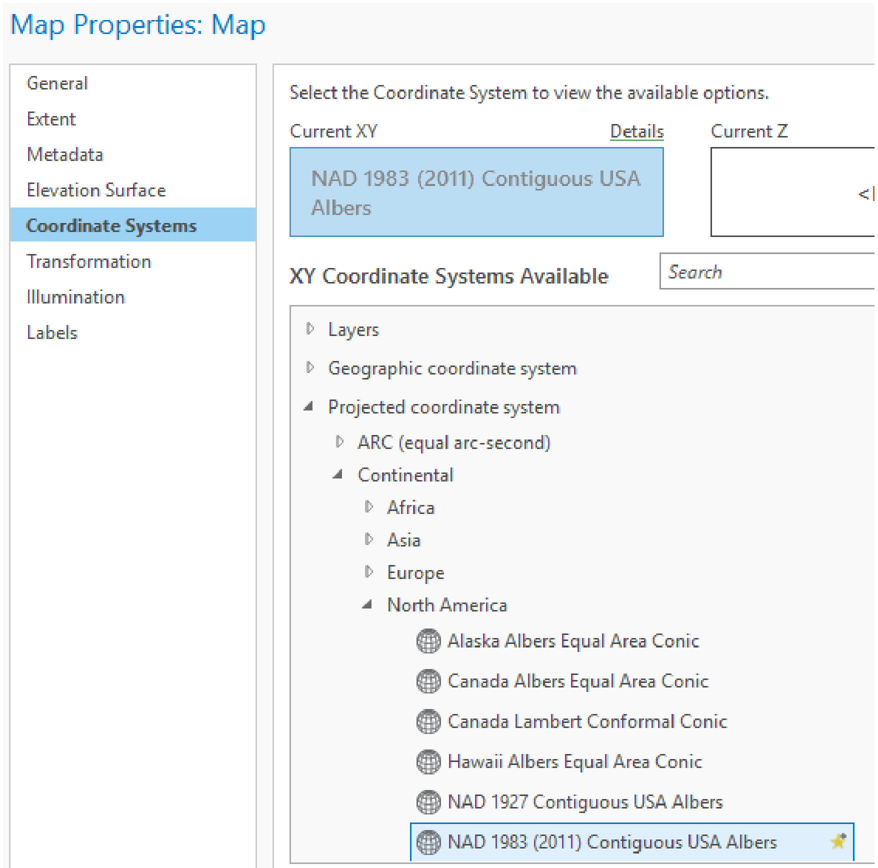
You may view and set the coordinate system for a Map, to which every layer is temporarily projected by right clicking on the Map, and then selecting Properties from the dropdown (as you did earlier), but this time
left clicking on Coordinate System in the displayed window:



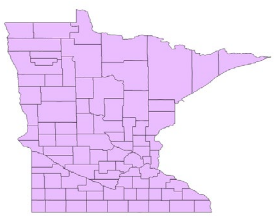
This shows the Map is set to the WGS84 GCS, or Geographic Coordinate System. All data will be projected to this system when displayed.

We can change this (***Video: Set the Map Window Projection***). For example, in the Map Properties/Coordinate Systems window select :

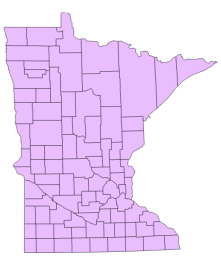
- Projected coordinate system
- Continental
- North America
- NAD83(2011) Contiguous USA Albers



On hitting OK, the properties window should disappear and the counties change shape and orientation a bit, from this:



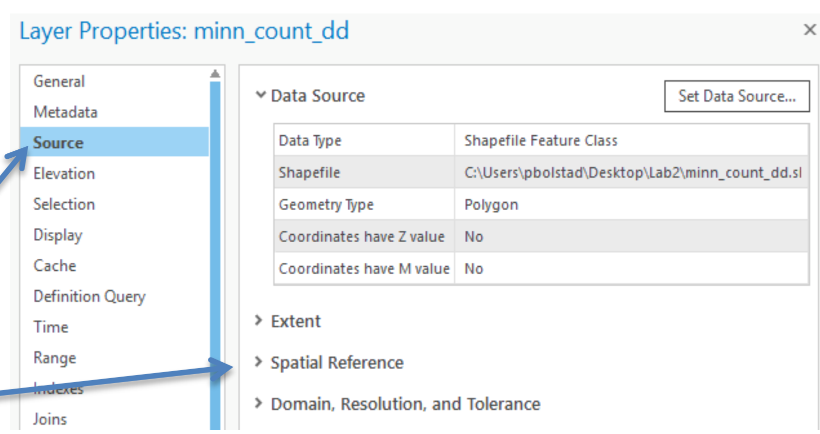
To a less flattened:



Switch the Map coordinate system back to the WGS84 (with the Map selected, right click for Properties, then left click Coordinate systems, Geographic coordinate system, World, WGS84)

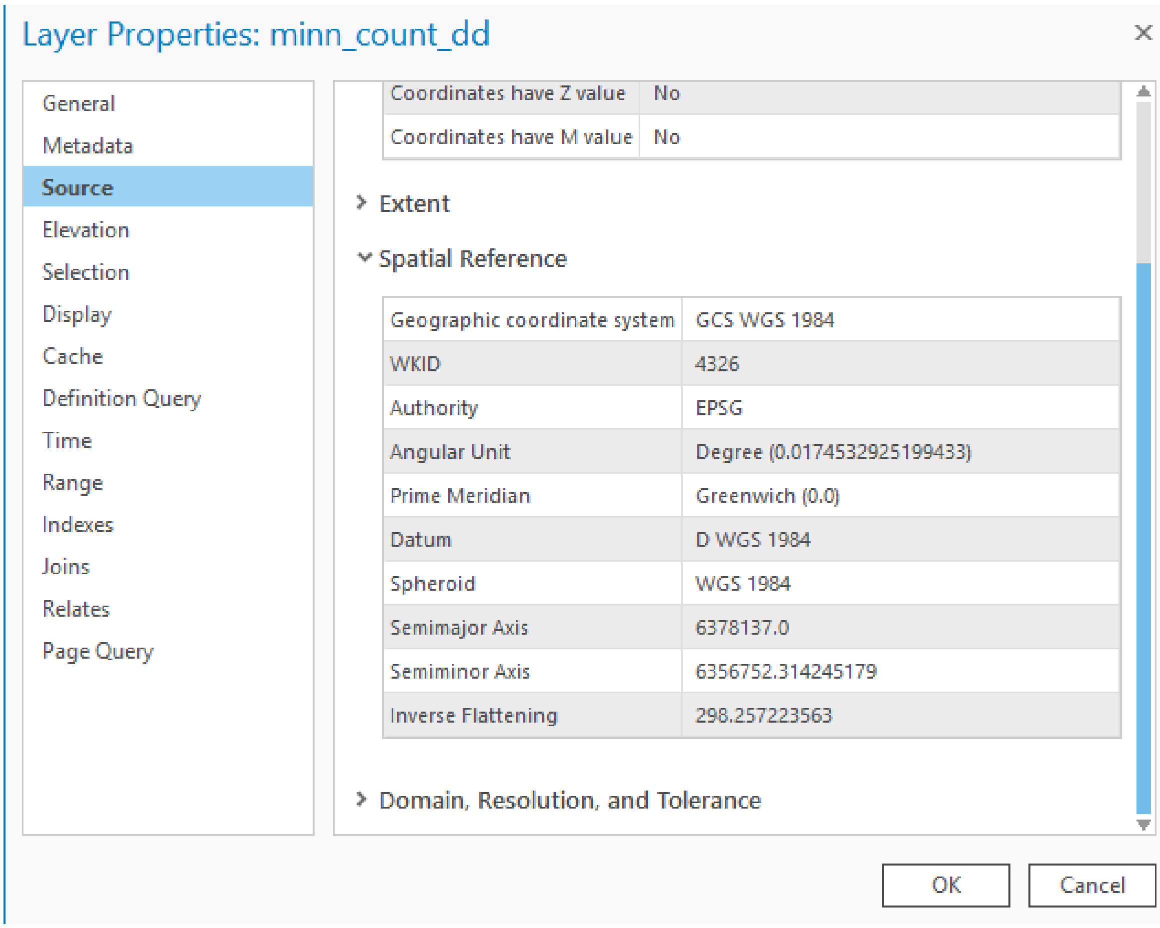
We can view the coordinate system for a data layer (not a Map) by

- right clicking on the data layer,
- then left click on Properties,
- then Source



This allows us to inspect layer properties including the Spatial Reference, describing the coordinate system.

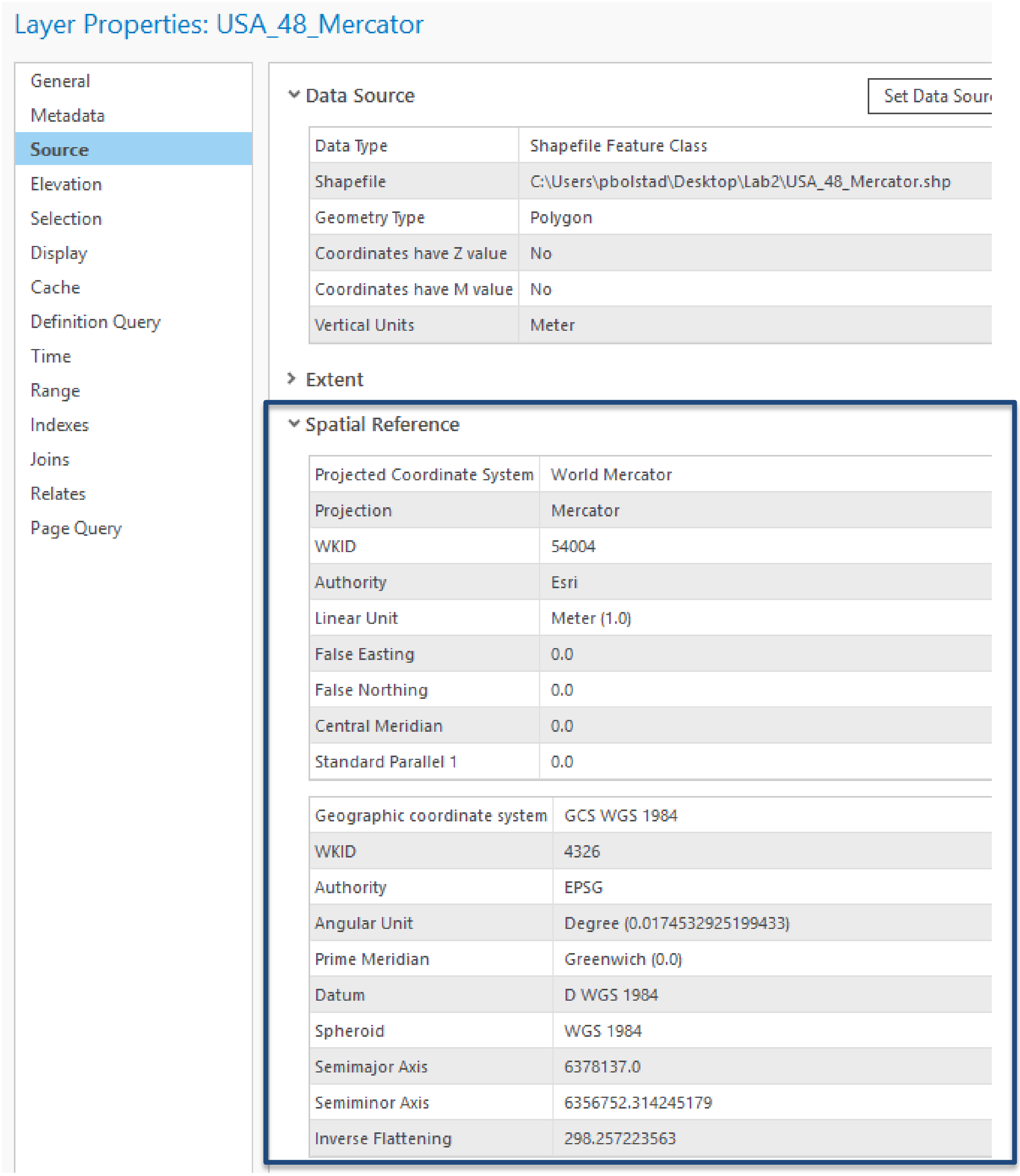
Left click on the Spatial Reference option, and view the spatial reference information, in a window similar to the figure below. This shows the characteristics of the layer's coordinate system. This is a geographic coordinate system (latitudes/longitudes), and the data show the particular properties



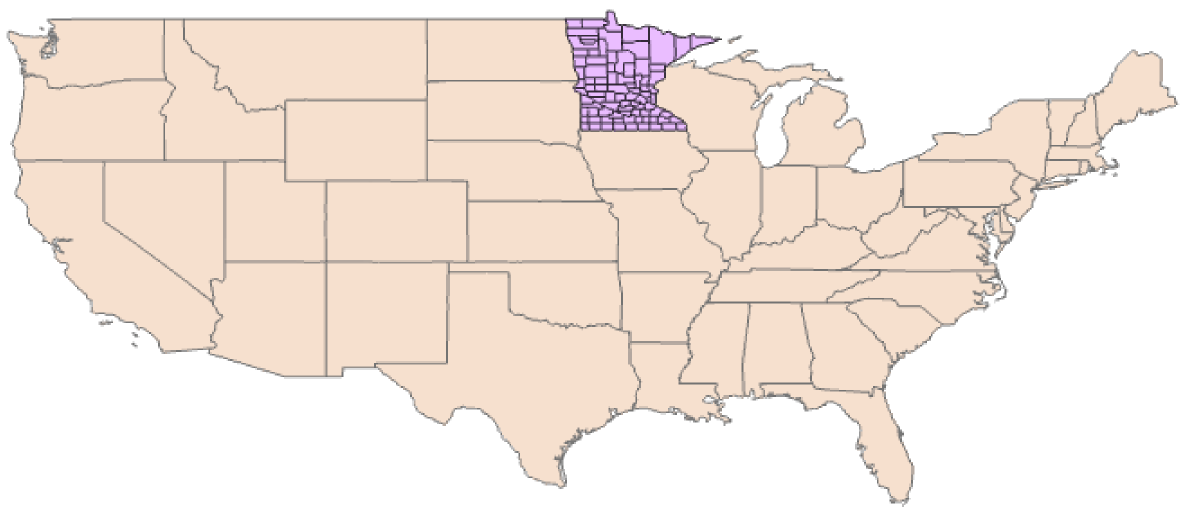
Add the USA_48_Mercator to the same Map. Position the layers so the Minnesota county data are on top (click and drag up/down layers).

Open the Properties – Source tab for this data layer, and it should display something like the window on the next page.

Note it displays more information than the GCS WGS84 for the minn_count_dd layer, above. The Mercator layer has both a projection, here a World Mercator, and an underlying GCS. As noted in the readings, projected coordinate systems have both parts, and underlying GCS and then a projection, while geographic systems have only a GCS, but are not projected.


Layer Properties: USA_48_Mercator
General
Metadata
Source
Elevation
Selection
Display
Cache
Definition Query
Time
Range
Indexes
Joins
Relates
Page Query
Data Source
Set Data Sour
Data Type Shapefile Feature Class
Shapefile C:\Users\pbolstad\Desktop\Lab2\USA_48_Mercator.shp
Geometry Type Polygon
Coordinates have Z value No
Coordinates have M value No
Vertical Units Meter
Extent
Spatial Reference
Projected Coordinate System World Mercator
Projection Mercator
WKID 54004
Authority Esri
Linear Unit Meter (1.0)
False Easting 0.0
False Northing 0.0
Central Meridian 0.0
Standard Parallel 1 0.0
Geographic coordinate system GCS WGS 1984
WKID 4326
Authority EPSG
Angular Unit Degree (0.0174532925199433)
Prime Meridian Greenwich (0.0)
Datum D WGS 1984
Spheroid WGS 1984
Semimajor Axis 6378137.0
Semiminor Axis 6356752.314245179
Inverse Flattening 298.257223563

Zoom to the full extent of the USA_48_Mercator, you should have something like the image below:



Note that although the different data sets are in different projections, they line up on top of each other. Why?

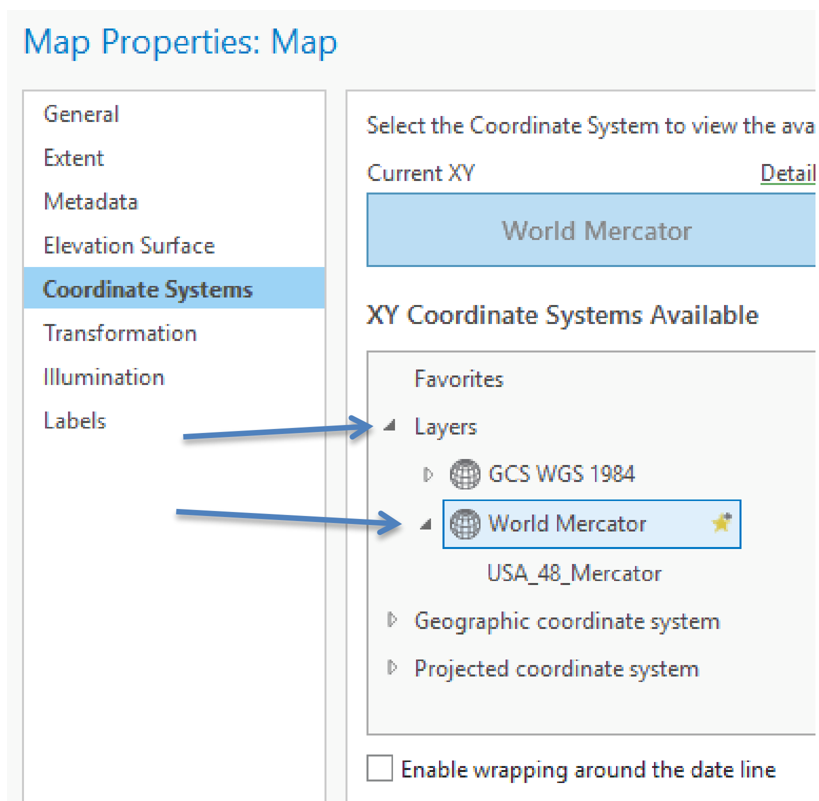
The layers line up because ArcGIS Pro is doing an “on the fly” projection, as described earlier.

Now set the Map coordinate system to that of the USA_48_Mercator layer. Do this with through

- a left click on the Map in the TOC, then
- select Properties,
- Coordinate System, then
- Layers,
- World Mercator

You’ll notice ArcGIS Pro puts the coordinate systems for all layers in a Map in a list at the top of the Map Properties window, for easy selection.

Notice after you click OK, the layers change shape slightly, as they are temporarily reprojected



to this new coordinate system.

This can be quite confusing at first, but **you need make sure you understand this concept of a Map 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**.

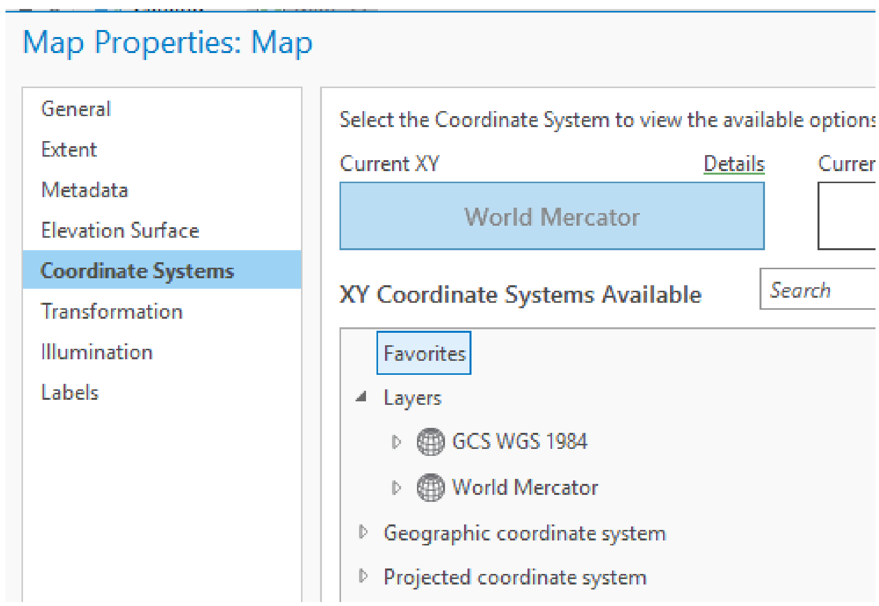
Why is this important? Some operations won't work correctly if data layers are in different coordinate systems, for example some editing, overlays, or distance measurements. You may think they are in the same system if you display them together, but your geo-calculations may be wrong. Sometimes you will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

Let's explore this further, by changing the Map coordinate system via the Map Properties window:

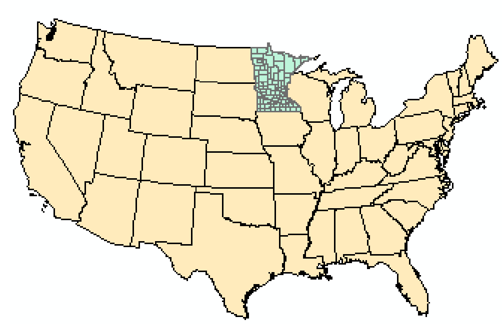
Click on the

- Projected Coordinate Systems, then
- Continental, then
- North America, then the
- NAD83 Contiguous USA Albers, then
- O.K.

This is a common projection for the lower 48 U.S. states.



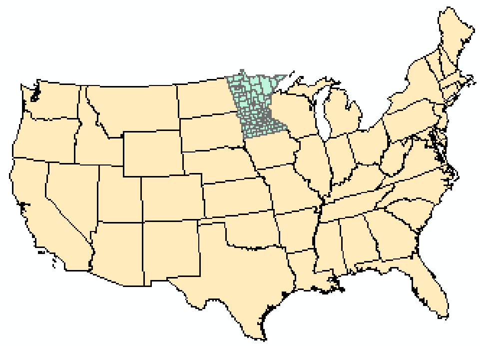
Zoom to full layer, and notice it changes the shape of the US and Minnesota data, to look something like:



Notice the curve on the western half of the northern border, compared to previous views.

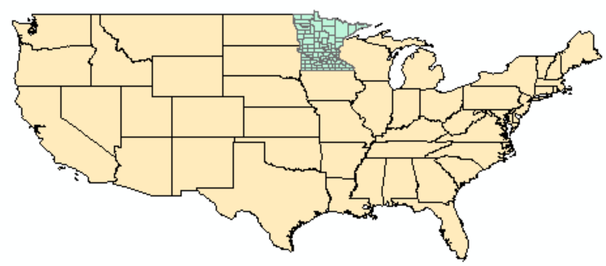
The data on disk have not been changed, they've just been temporarily reprojected to this specific Albers coordinate system.

Change the Map coordinate system again, this time selecting **Projected Coordinate Systems → UTM → NAD → NAD83 UTM Zone 12 N**



Zoom to full extent, and display the data, noting the change in the projection, as at right.

Finally, switch the Map coordinate system again, this time back to the **Geographic Coordinate Systems → North America->USA and territories → NAD83**



Note the change in shape. We haven't changed the projection of the data on the disk, we've just told ArcGIS Pro to project on the fly, to a new system, before display.

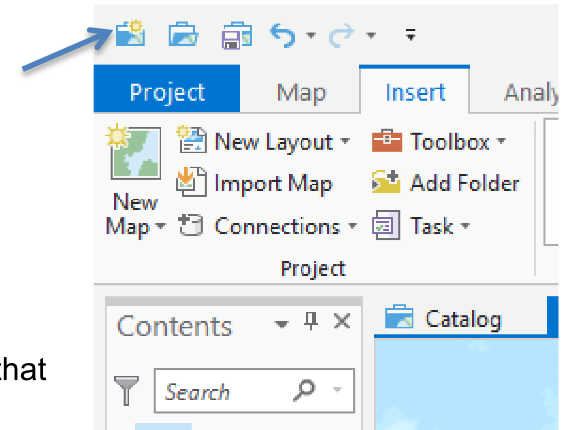
It is generally o.k. to mix data from several coordinate systems in a Map. However, you should be careful when performing operations that alter or create new coordinates, because there could be some ambiguity in which coordinate system ArcGIS Pro will choose to use. It is best to either run a small test to verify the specific ArcGIS tool, or to convert all the data to a common coordinate system permanently, saving to new layers (we'll show how to do this later in the lab), so that all your data are in the same coordinate system before manipulating x-y values.

You should also be careful when performing area calculations with mixed data sets, because it is easy to become confused about the units of the outputs.

Creating an Inset Map

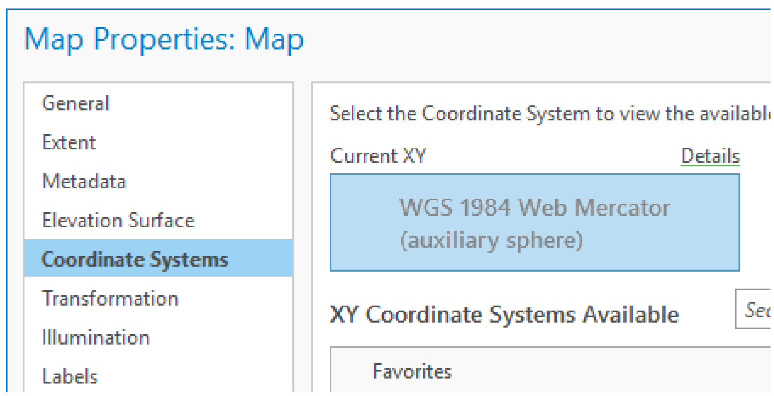
We can use this temporary projection to create an inset map in a different coordinate system. You created an inset map last week, but both the main and thumbnail maps had the same coordinate system. This time we'll different coordinate systems for the inset and main map.

<u>First, if you haven't saved and closed your last project, do so now, and create a new ArcGIS Pro project by clicking on the upper-leftmost icon for the main window</u>:



After the Map opens, remove any default layers that might be loaded.

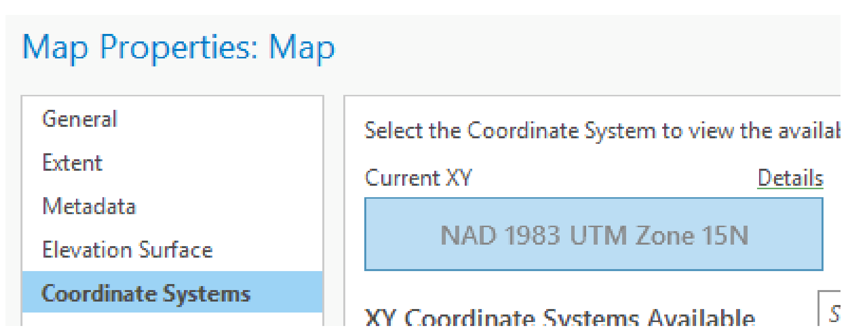
Open the Map Properties window, note that the Current XY coordinate system is set to WGS 1984 Web Mercator.



We can change the defaults. You don't need to, but if you're curious, left click on the Project tab in the main window, then Options about half way down, then Maps and Scenes. You can set a default basemap, coordinate system, and affect the behavior of added layers.

Note that if the first layer we load has a different coordinate system than the default, ArcGIS Pro will change the coordinate system for the layer to the Map, but only for the first layer. To reiterate, loading a data layer into a new Map sets the Map coordinate system to that of the layer; all subsequent layers will be projected, if possible, on-the-fly to this original system while being displayed.

To illustrate, Add the minn_county.shp layer to the empty Map. Verify via Map Properties that the Map coordinate system has now been changed to NAD_1983_UTM_Zone_15N.



Adding layers with different

coordinate systems after this first one will not change the Map coordinate system automatically.

Rename this first Map “Minnesota Counties.”

Now, insert a new Map, and name it “Earth From Space.”

Again, verify that the Map has the WGS Mercator coordinate system

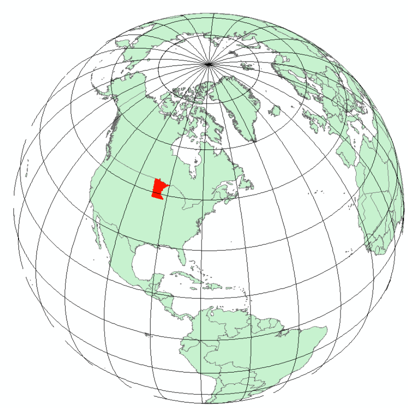
Now change the coordinate system for the Map manually:

Open the Map properties, and set the Coordinate System for the Map to:
Projected Coordinate Systems → World → The World from Space

Add three data layers to this new Map:

- Countries (boundaries of the World’s countries in 1990, in geographic coordinates)
- minn_county (Minnesota counties, in UTM Zone 15N coordinates), and
- graticule15 (lines of constant latitude and longitude, at 15 degree intervals)

Re-arrange the layers so the graticule is on top in the TOC, then the minn_count layer second, with the Countries layer at the bottom. Symbolize the minn_count layer so it is a solid bright color, and Countries polygons so they are a light or pastel, and the graticule as a thin black line, so that you have something like the figure at right.



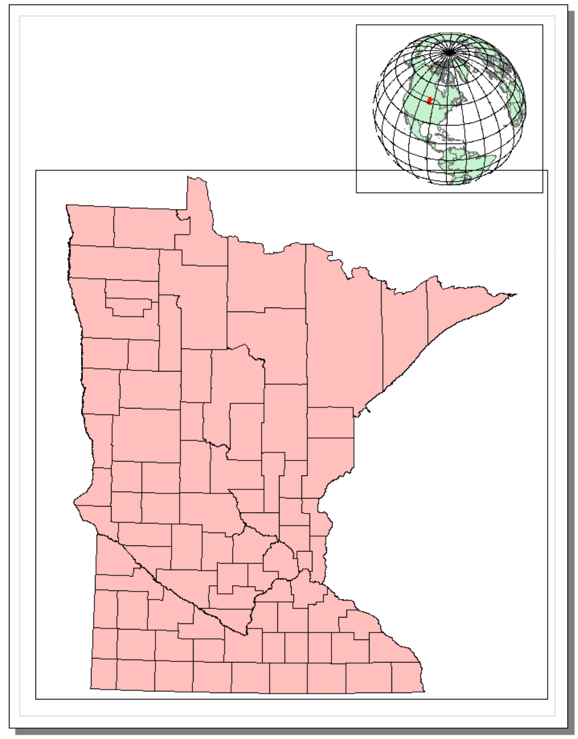
Rename the Map something like “Space View” (right click on the map in the Catalog on right (not Table of Contents, on left), and select rename; see earlier instructions, if unsure).

Now switch to the Map, “Minnesota Counties”.

Zoom to the data layer full extent so that all of the data are visible in your Minnesota Counties Map, then switch to the Space View Map, and also zoom to full extent.

Create a layout view (see last week’s lab). Notice there are boxes for each frame. They may overlap, so you may have to click one and hold to drag aside. Move and resize the boxes, perhaps also going back to the data view and panning/zooming, so that the Minnesota State box is larger, and the US/Minnesota combined data are about 1/6th the size, as in many inset maps (see figure below).

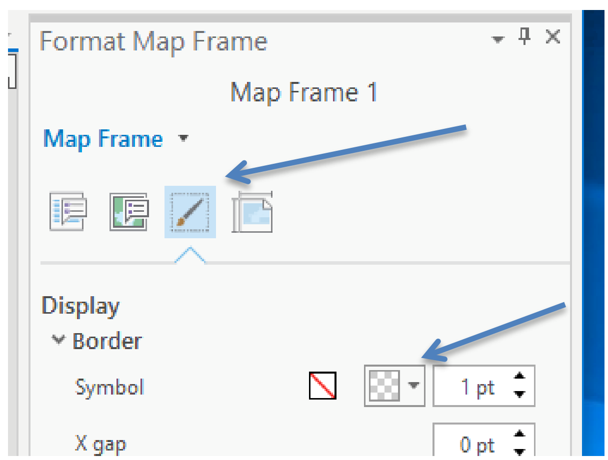
You may have to change the scale, particularly for the globe inset, use the scale box on an active map as described in last week's lab.



You have two different Maps in this common map design, with a small inset showing general location in one coordinate system, and a larger panel in a different coordinate system showing detail for the highlighted portion of the inset.

Note that each panel has a bounding box or frame around it in the layout view. The larger bounding box interferes with the inset

You can remove this bounding box by:

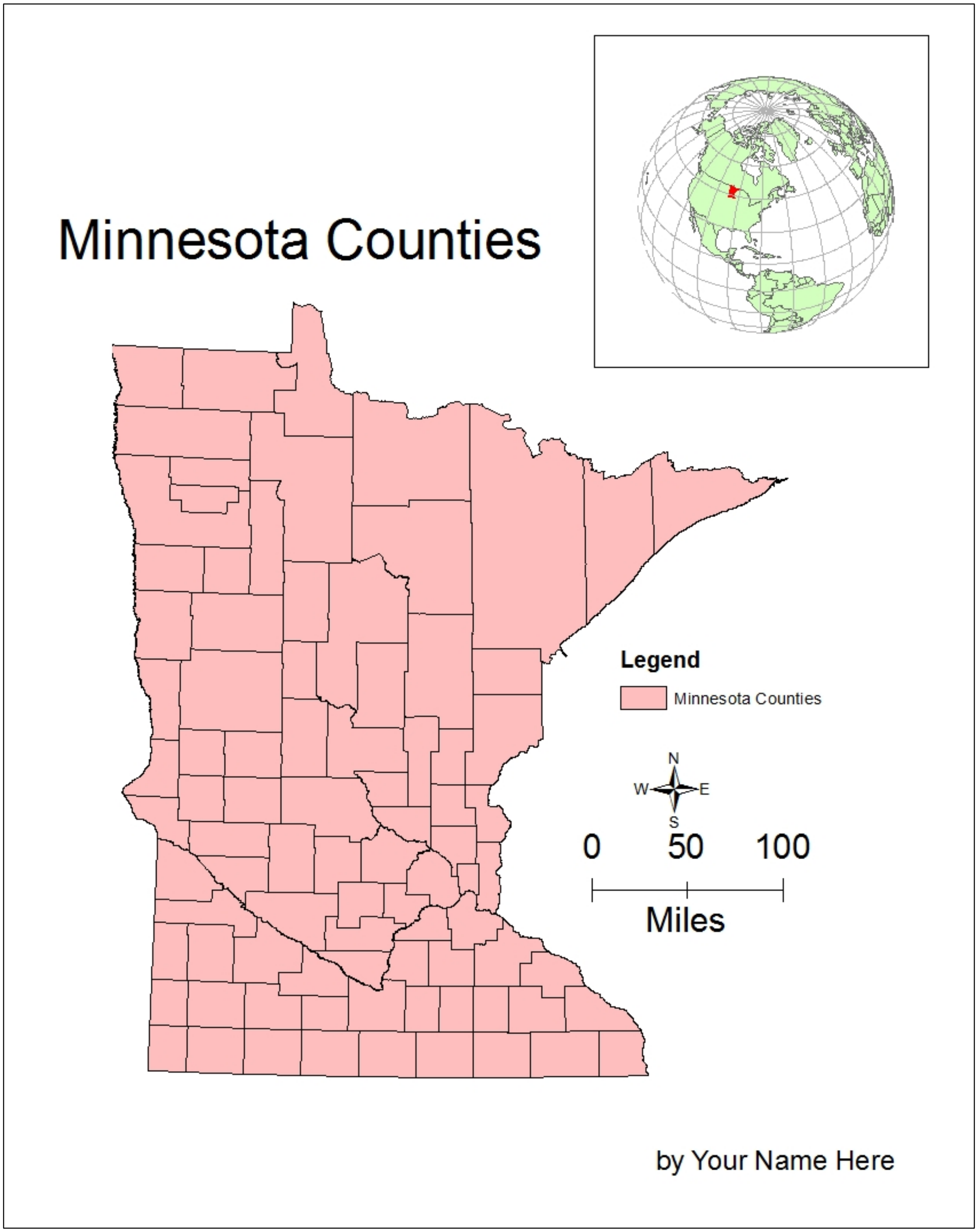


- right clicking on the box, opening a map formatting option panel on the right side of your main window:
- left click on the paintbrush icon, and
- modify the border symbol to make it colorless

Add a North arrow, caption, your name, a legend, and descriptive title, and export/print a PDF, as instructed last week.

See an example below of the map you should produce. Although you need not exactly match the colors and positions, make sure to include a proportioned main map and inset, a descriptive title, your name, a north arrow, and scale bar.

A final point 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 file is lost, damaged, mis-specified, or not copied with the rest of the shape files, then the ArcGIS Pro program can't identify the layer's coordinate system. If you know the coordinate system for a file, you can add the prj file back or fix it for a geodatabase through a tool we'll describe in the next section.


Minnesota Counties
Legend
Minnesota Counties
N
W
E
S
0
50
100
Miles
by Your Name Here

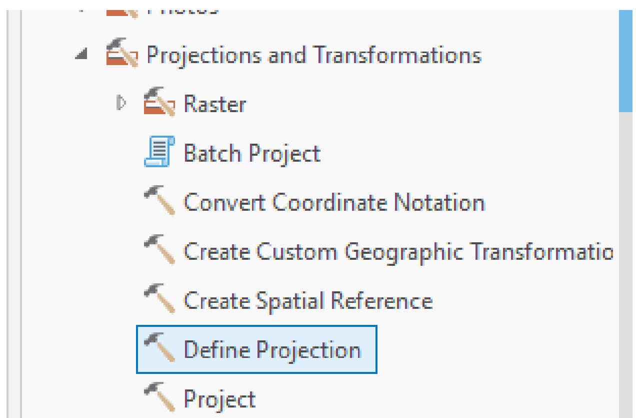
Projecting Data to a New File – The Project Tool

The above section describes on the fly projection, which changes coordinate values temporarily so they may be viewed together. However, we often want to permanently project a data set from one coordinate system to another, creating a new data set in a different projected coordinate system.

We accomplish this in ArcGIS with the ***Project*** tool. Each time we apply the Project 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.

There is another tool, the ***Define Projection*** tool, which is much more rarely used. The Define Projection tool changes information within a layer about the name of the projection. It doesn't change any coordinates. You ONLY use the Define Projection tool when you know the projection name for a layer is missing or incorrectly recorded.

The toolbox is shown at the right, but don't look for it or try to use it now, we'll describe how in the next section of this lab.



We include it here to emphasize that these two tools that are often confused. You only use the Define Projection tool when you have a projected data layer, you know what the projection identity is, but that projection identity has been corrupted or erased from the layer.

If you don't know a layer's projection, you need to either 1) identify it unambiguously by matching coordinates or overlaying with other data, or 2(discard the data, because it isn't very useful without knowledge of the projected coordinate system.

The Define Projection tool is often confused with the Project tool, listed just below Define Projection in the figure above). The Project tool is more commonly used, and converts a layer from one coordinate system to another. It reads the information in a layer about its coordinate system, and then re-projects the data to another known coordinate system, and modifies the information in the layer. DON'T USE THE DEFINE PROJECTION TOOL WHEN YOU SHOULD USE THE PROJECT TOOL. Sorry for the all caps shouting, but this is a very common mistake in the remainder of this exercise, and worse, in practice. You can easily ruin data and not know it by mis-applying the Define Projection tool. It's too bad ESRI named them as they did, as this often confuses the new or occasional user, but such is life.

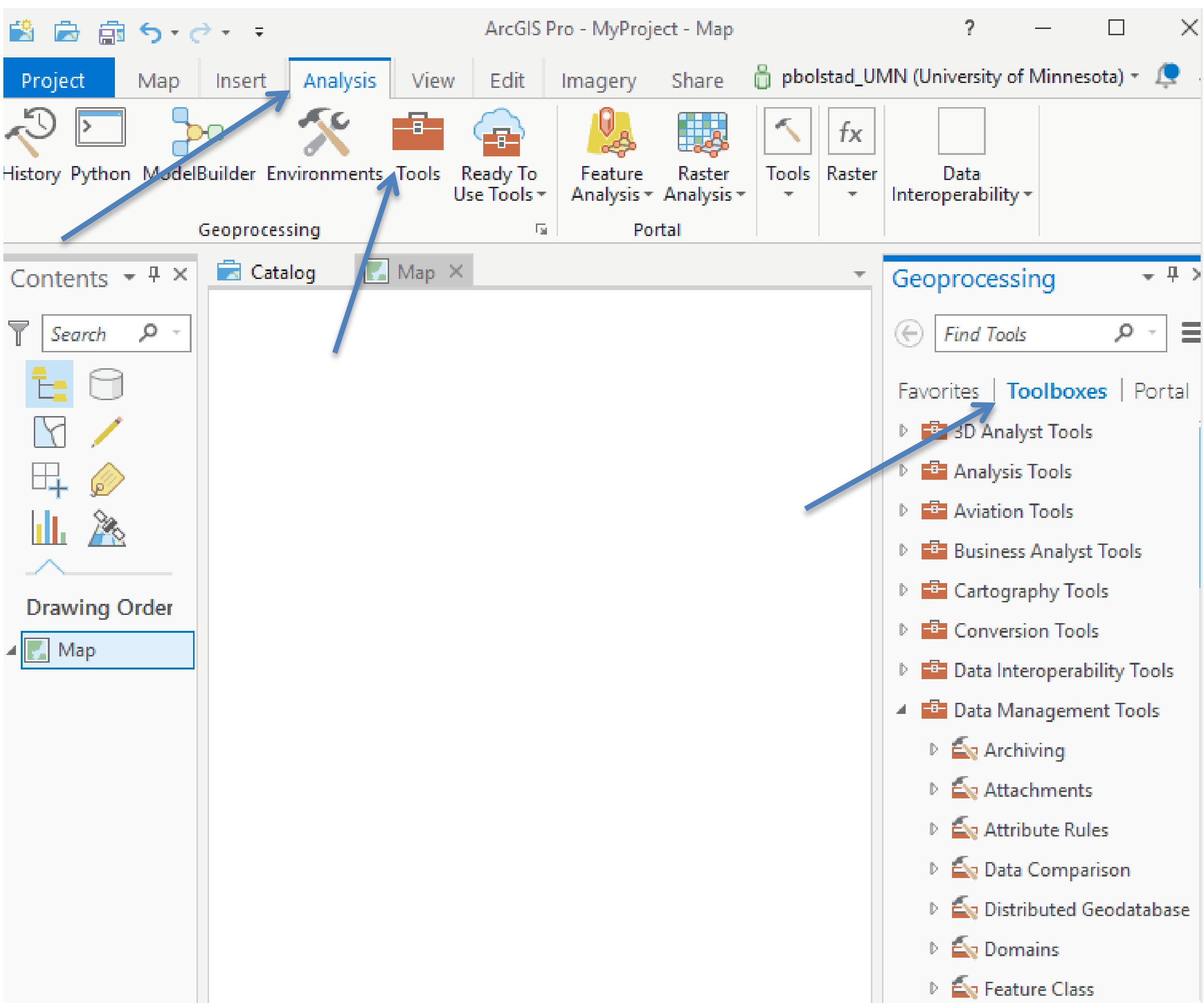
(***Video: Project***).

Save your previous work and close any open projects. Open a new one, insert three new empty Maps; remove any default layers that might be loaded.

Name the Maps Albers, UTM, and Mercator

- Left click on the Analysis Tab along the top margin, then
- click on the Tools toolbox, the little red toolbox along the icon ribbon, then
- click on Toolboxes, the middle label in the right-side column (see arrows, below).

This should display a list of available tools along the right side of your window, as shown.



To project data, click on

Data Management Tools

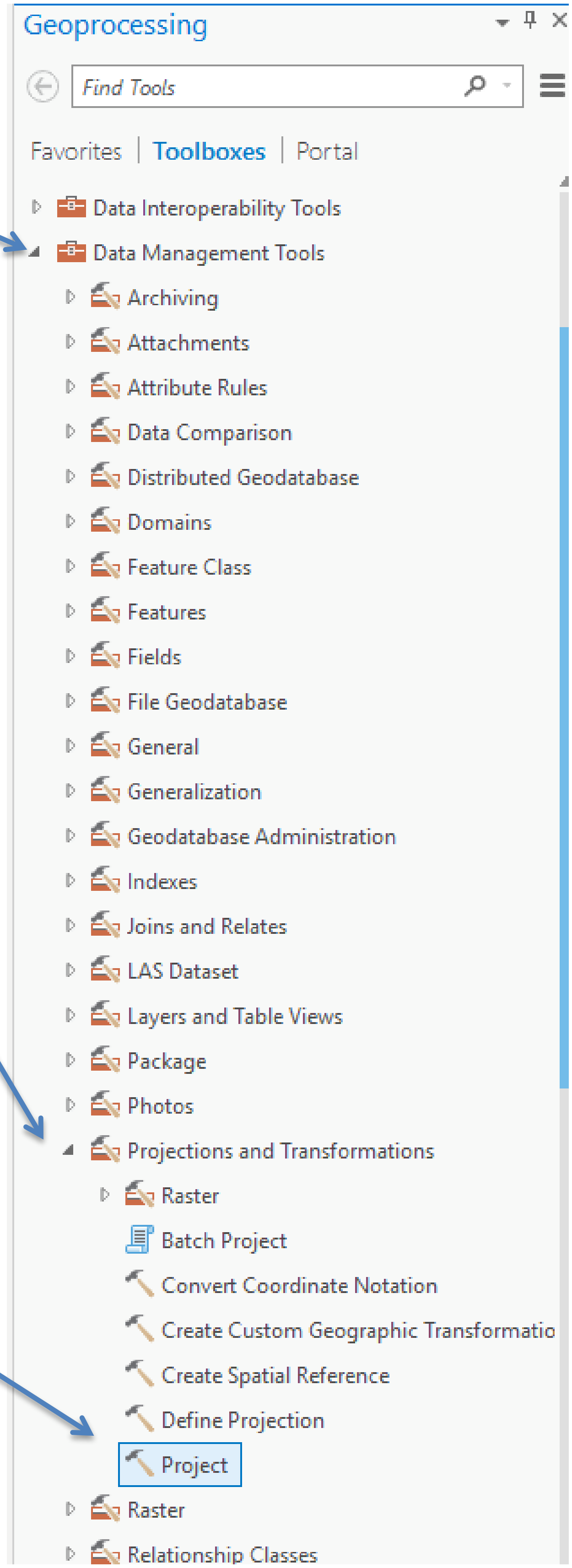
then

Projections and Transformations

then

Project

The Project tool converts data from one coordinate system to another, saving the projected data to a new file.



Detailed instructions for specific projection examples are provided a bit further on in this document, but the general process is to start the Project tool, and then:

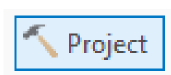
- Select a data layer containing the features you want to convert to a new coordinate system
- Specify an output location and name for a new data layer
- Specify the output projection, and if need be, a datum transformation (Arc calls it a Geographic Transformation, the same thing as the datum transformation 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_dd may have projection information stored in the file minn_county_dd.prj. Without a .prj, ArcGIS Pro is ignorant of the projection system, so you may have to specify the input as well as output projections in the general steps above.

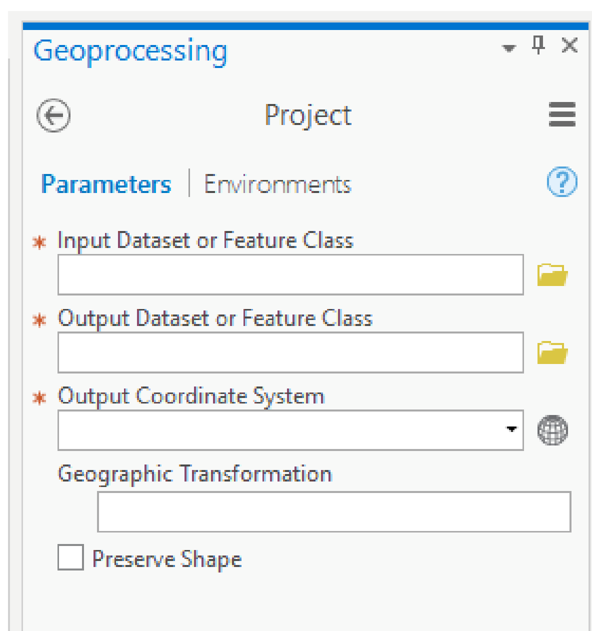
Using the Project Tool

This section will step you through the projection screens. You will have to use these steps several more times in this Lab (***Video: Project***). **In later iterations, refer back to this sequence**.

We assume you have three empty Maps in the same project, one named Albers, one UTM, and one named Mercator. If not, create them now. Make the Albers Map active.

Double click on the Project Tool 

in the ArcToolbox, located as shown in the previous figure.



This should open a Geoprocessing tab and menu in the right-most column of the main ArcGIS Pro window:

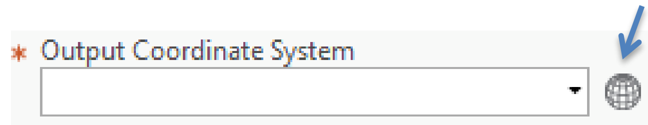
This allows you to specify the input and output files, the Output coordinate system, and if needed, a Geographic Transformation (more commonly called a Datum Transformation).

Click on the folders to the right of the input and output data set windows to specify the input and output files.

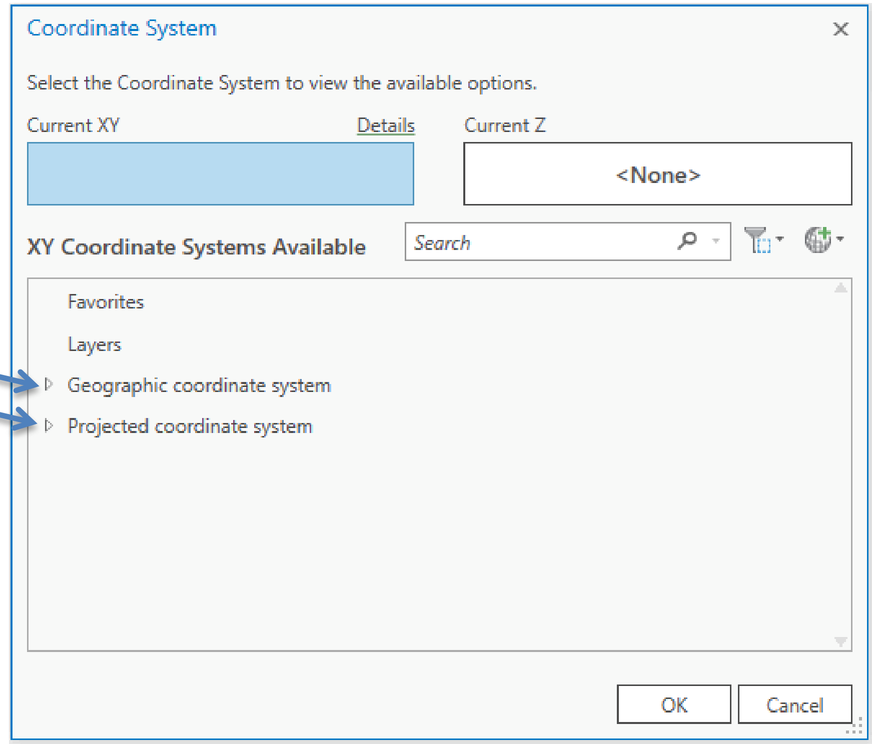
Use the mn_count_dd.shp as the input.

Name the output MN_Count_Alb, and place it in the L:\home directory with your input data and project.

Next, specify the output coordinate system by clicking on the globe to the right of the entry row in the Geoprocessing window:



This should open a window in which you specify the target cooridinate system. The window looks quite like the one used to specify a Map coordinate system:



You use the carets to drop down lists, until you eventually select a specific output projection.

The Geographic caret accesses all geographic coordinate systems (GCS), meaning you would project to a lat/lon, spherical system.

The Projected caret accesses common Cartesian projections.

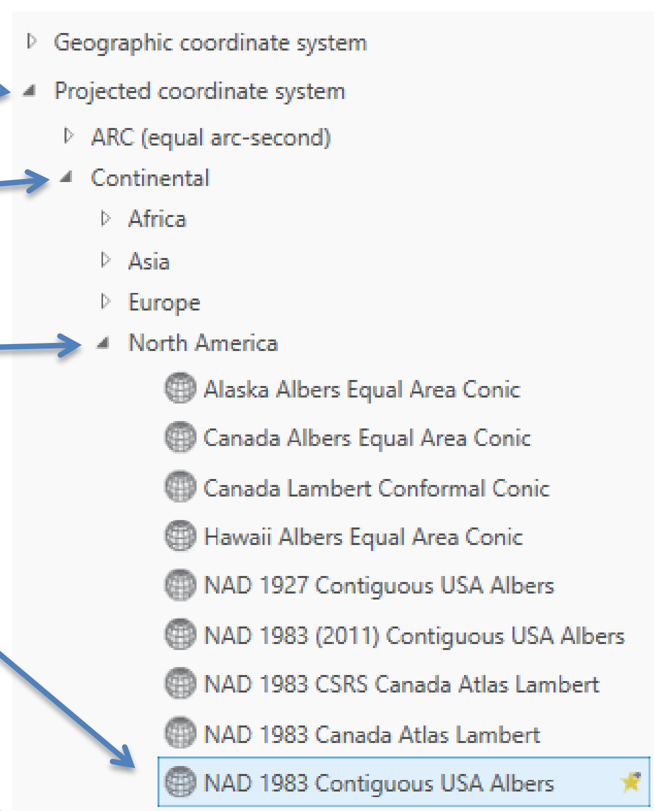
Left click on Projected coordinate system

then Continental

then North American

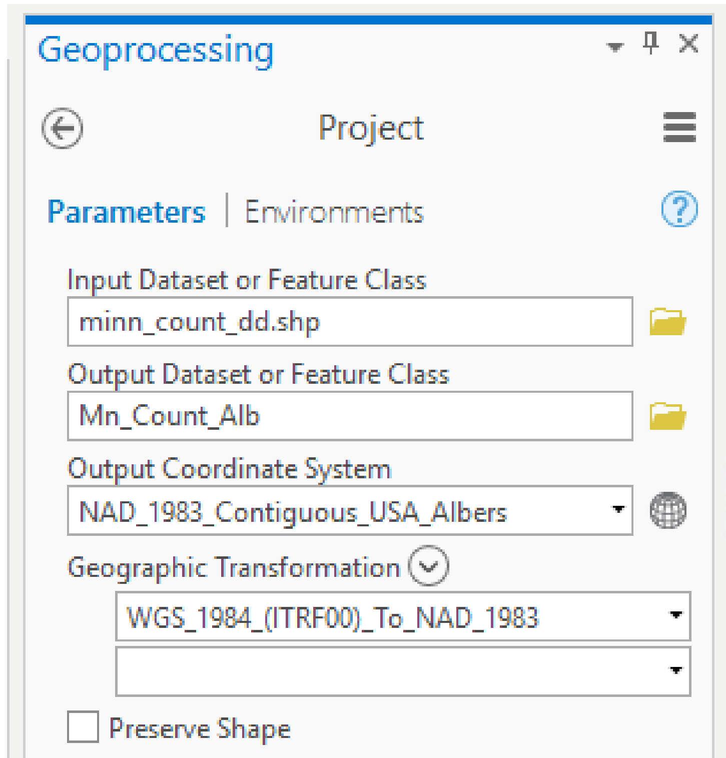
Then NAD 1983 Contiguous USA Albers

then



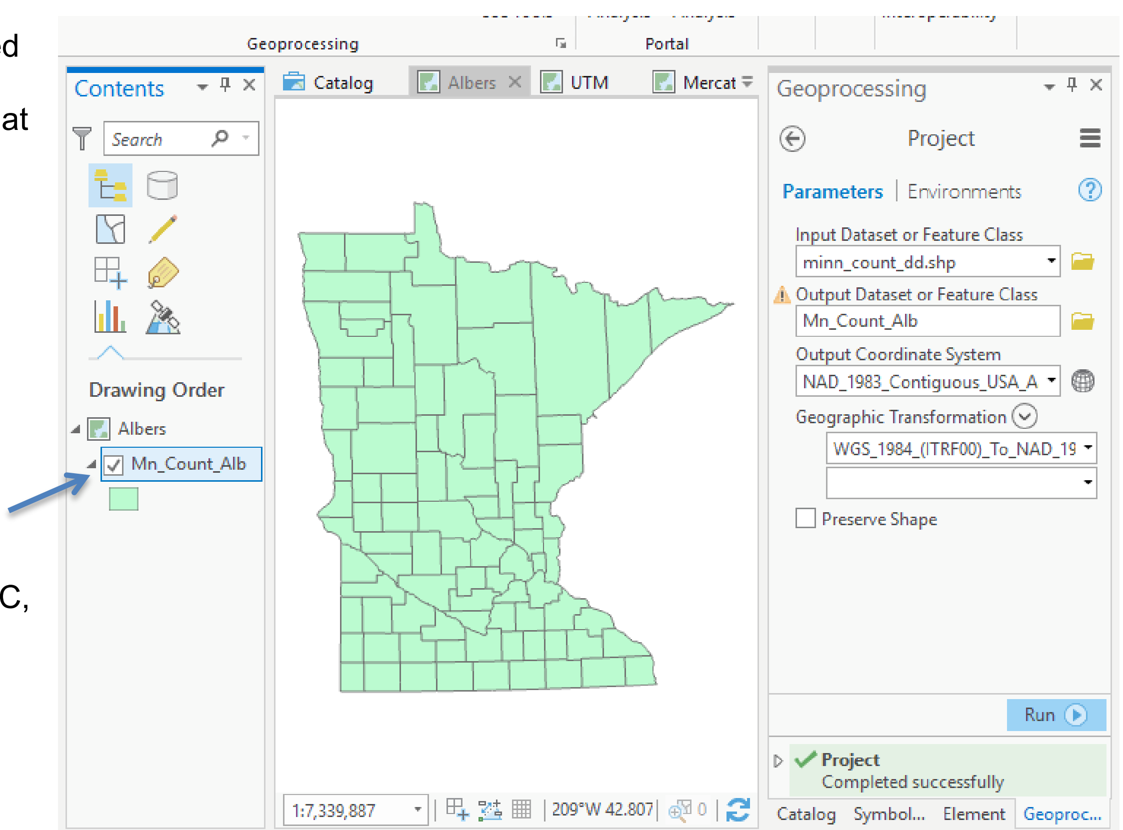
OK at the bottom of the window.

This should automatically choose the appropriate Geographic Transformation, WGS84(ITRF00)_To_NAD_1983:



Click on the Run button in the lower right corner of the Geogprocessing column:

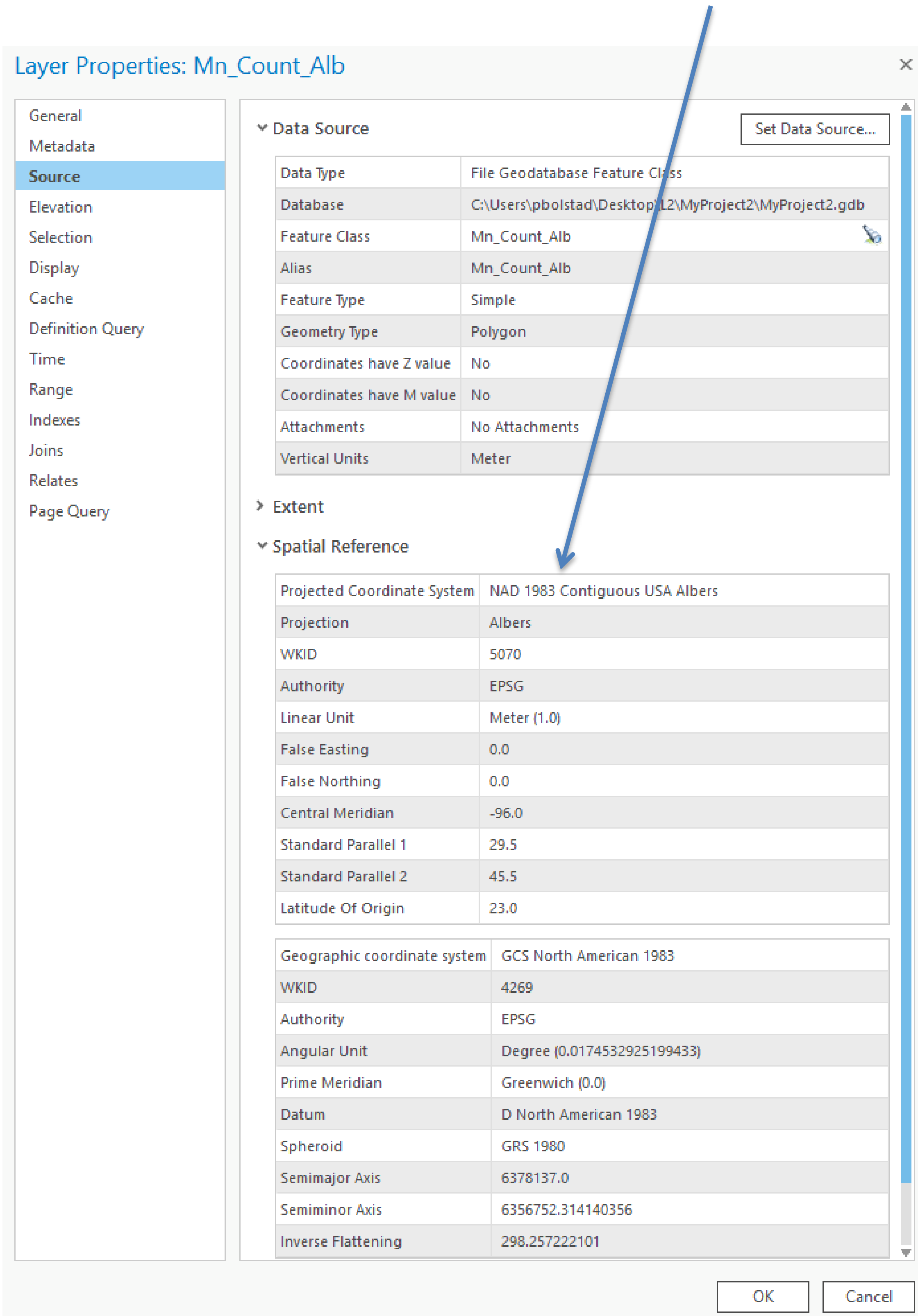
After a bit of processing, a message should show across the bottom of the Geoprocessing column indicating successful completion, and the projected data should be placed in your active map window (that you named Albers):



Inspect the coordinate system for the MN_Count_Alb data layer you just created, remember, by first right clicking on the name in the TOC, then

- Properties,
- Source,
- Spatial Reference

This should display the spatial reference information for the layer, showing NAD 1983 Contiguous USA Albers as the projected coordinate system:



Project to a UTM Coordinate System

Activate Map you name UTM,

Use the Project tool again, with

- input as the minn_county_dd data
- a new output data set, named UTM15_minncounty,
- an output coordinate system via
    - Projected Coordinate Systems, then
    - UTM, then
    - NAD83, then
    - NAD83 UTM Zone 15N

Click on OK to apply the projection, which should load the data to your Map named UTM Zone 15N.

Again, verify that you have the correct output by inspecting the information on the layer.

Project to a Mercator Coordinate System

Activate your last Map, that you named Mercator

Use the Project tool in ArcToolbox one more time, with

- input once again as the minn_county_dd data
- a new output data set, named MN_county_Mercator,

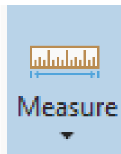
* Projected Coordinate Systems, then
* World, then
* Mercator (world)

Again, verify the projection on the output data layer after it displays in your Mercator map.

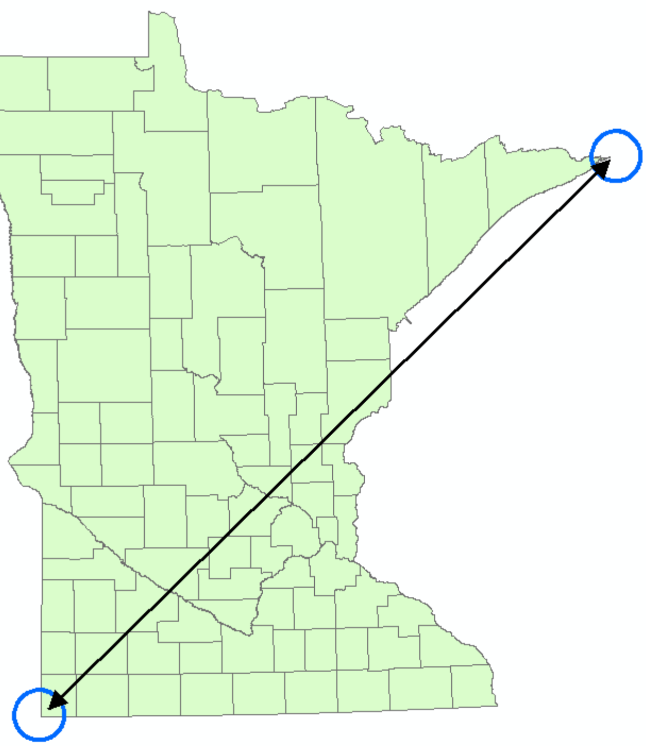
Now you should have three different Maps, with three different versions of the Minnesota counties – an Albers, a UTM, and a Mercator.

Notice the shapes are different, not so much between the Albers and UTM, but noticeably so for the Mercator relative to the other two.

Activate the measure tool,



Set the mode to distance units to **kilometers**, and the Mode to **Planar**



Measure Distances from the northeastern-most point of Minnesota to the southwester most point for each of your three projections.

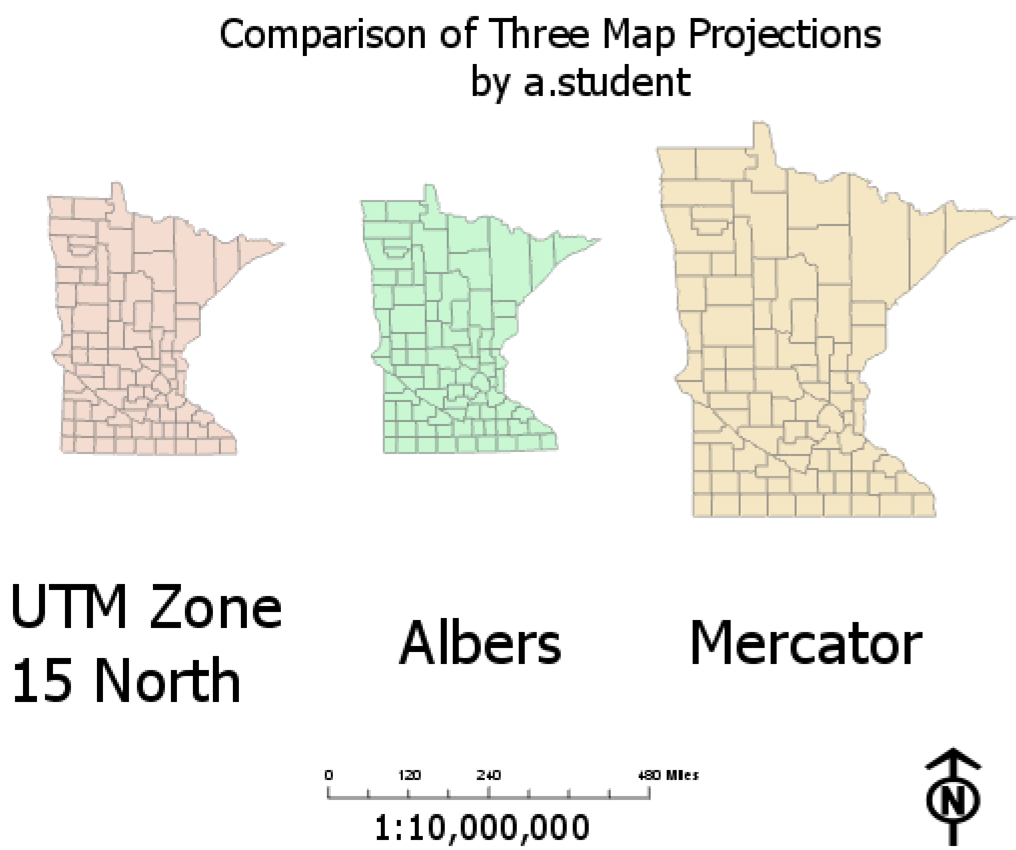
Do this as carefully as you can, it pays to expand the Map window to as large as will fit on your screen.

Write down the distances, perhaps on the lab 2 worksheet at the back of this lab, to be entered for online grading later.

Also, **record the coordinates for the northeast corner of Ramsey County for all three coordinate systems**, as you did for the decimal degrees display at the start of this lab. Remember to zoom way in on the northeast corner of the county to get the most accurate coordinates: 1:10 at least. Write the coordinates down for the Albers, UTM, and custom Mercator projection layers. Submit your two PDF's for the lab, and enter the distances in the worksheet at the end of these lab instructions.

Create a map with all three Minnesota projections
We wish to create a map with all three projections:

remove any default layers that might be loaded.

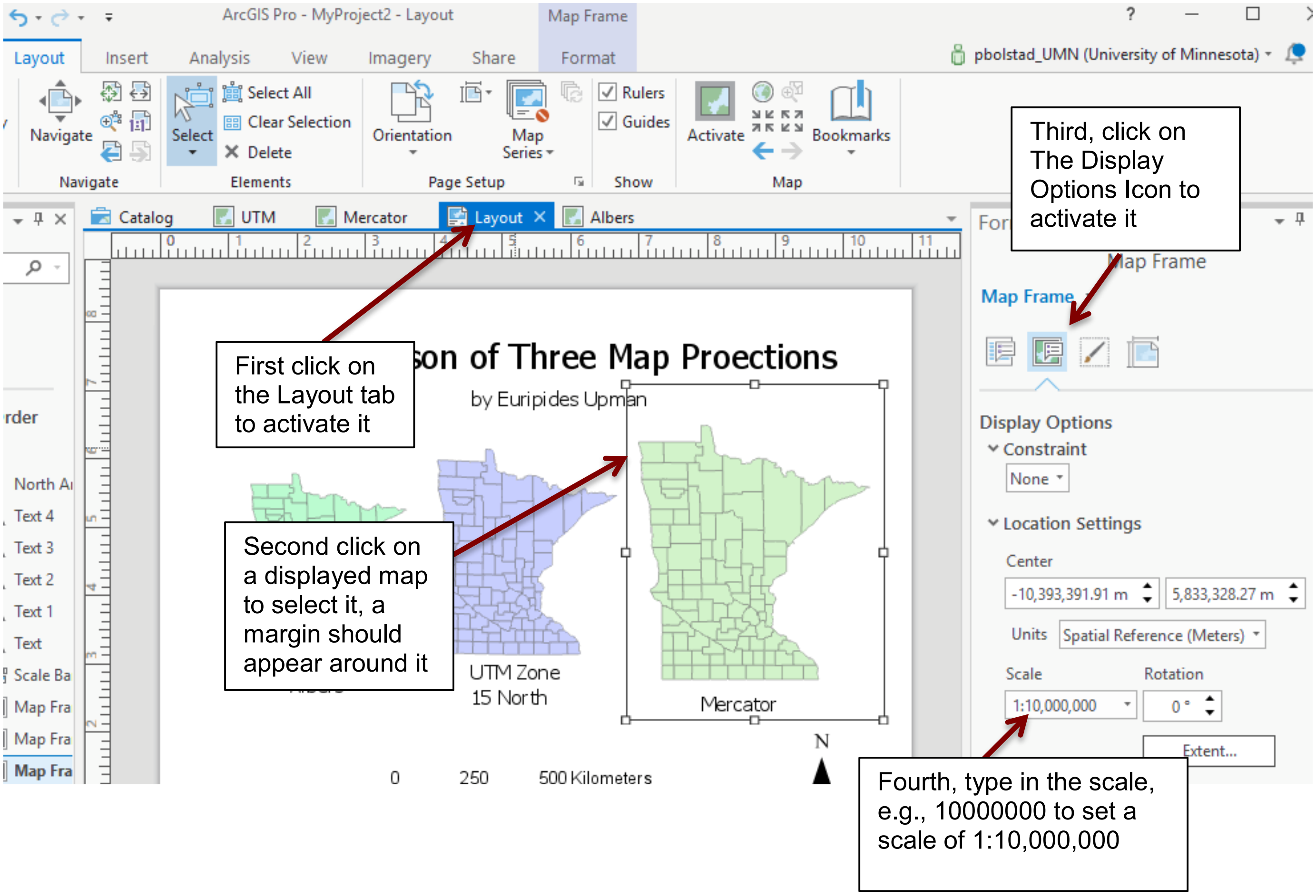


For a fair comparison, we'll need to set a fixed scale for each of the Maps.
(***Video: SetLayoutScale***)

First, Select the Insert tab, then select New Layout, then select the ANSI-Landscape Letter mode

Drag each of the Map boxes from the Catalog column (you may have to first select the Catalog tab at the lower part of the right column), and arrange them to be side by side and about the same size. You may want to change the colors of the layers in each data view for easy identification, you do this by activating the respective maps, and changing the layer color in the TOC.

First click on the layout if it isn't activated, then a Map, then Display Options, and type in the desired scale (see figure below).



Set the scale for each Make each the same scale, something near 1:10,000,000 or so. Note you shouldn't type in the 1: or the commas into the window, we show them here for clarity.

Make sure you choose the same fixed scale for each Map.

Note the default is a border around each Map in the layout view, and the map looks better if you remove them, as shown before (click on Map in Layout, then on the Format Map Frame tab, click on the paintbrush icon and modify the border).

Add a name, North Arrow, title, and scalebar, and individual titles for each Map (see example), and create a pdf to turn in.

Below is a worksheet for recording values measured in this lab.

Distance across Minnesota, from northeast to southwest, in kilometers:

Albers:

UTM Zone 15N:

Custom Mercator:

Coordinates of northeast corner of Ramsey County:

Projection	x-coordinate	y-coordinate
Albers (Meters)		
UTM Zone 15 (Meters)		
Custom Mercator (Meters)		