Lab 2: Projecting Geographic Data

What You'll Learn: To use map projections in QGIS.

Data for this exercise are located in the Taller2_Datos.rar file.

What You'll Produce: Two maps, 1) of three different statewide projections, and 2) reprojected county boundaries and lakes in central Minnesota, and 3) a worksheet that records areas and coordinates under various projections.

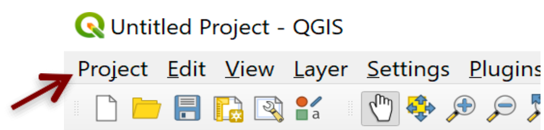
Background: The Earth's surface is curved. We introduce unavoidable distortion when we flatten this curved surface onto a map, typically changing areas, lengths, and shapes. Different map projections introduce different types of distortion, and organizations choose the projection which limits distortions to levels they can accept. Different map projections represent the same points with different X and Y (or E and N) coordinate values. We often cannot mix map projections in an analysis. If data aren't in the same projection, they must be re-projected to the same projection, or they will not align correctly.

Observing How Shapes and Distances Changes with the Map Projection

Start QGIS.

Before you add any data, ***open the Project-Properties*** (*right click on Project in the main QGIS menu near the top of the screen, Mac, right, above,*

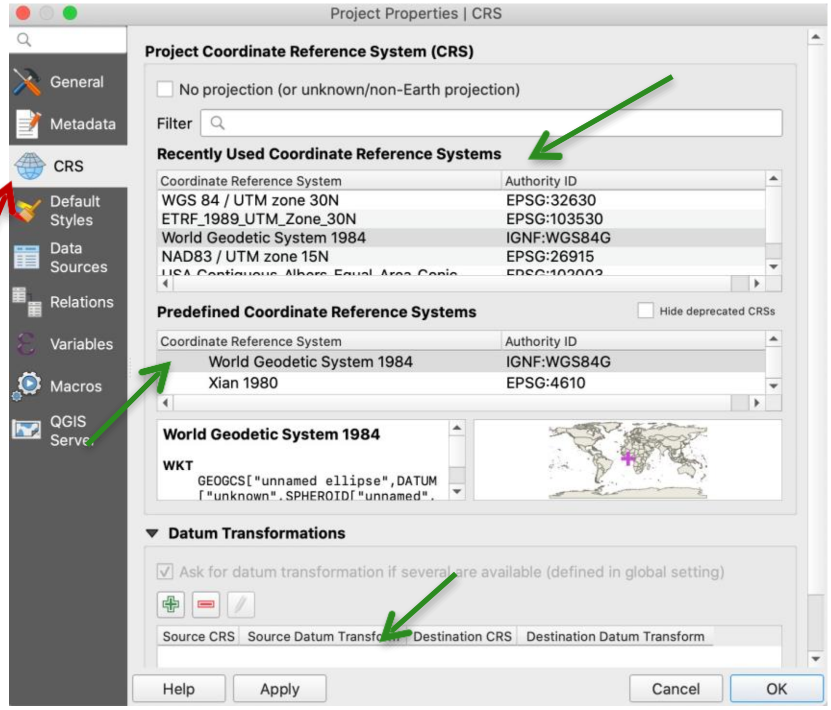
or top of main QGIS window, Windows, right, below ***),***



*This should display a drop-down list****. Left click on Properties*** in the dropdown list and ***click on CRS*** in the left-most panel (red arrow, figure on the following page).

A pane near the top lists recently used coordinate systems, the middle one lists those suggested from among pre-defined coordinatesystems, and below it, details for the currently selected coordinate system (WGS 1984, here, indicated in grey in the window). The current data transformation, if any, is listed below (noneused here).

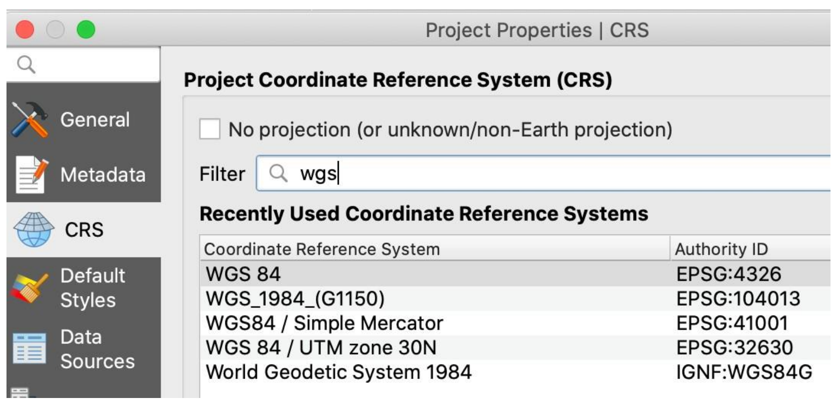
Although it depends on your settings, a new project will often default to a commonly used coordinate system before you've added any data.



Note the filter option near the top. This filters the available coordinate systems by a phrase, e.g., entering "UTM" there would only list coordinate systems with UTM in their name.

Also note the "No projection" check box near the top, to be used if you are using a non-standard coordinate system, e.g., a scanned image in screen coordinates. Also note the "Hide deprecated CRSs" check box near the middle right. This may be checked to not list "obsolete" coordinate system versions, and hence reduce clutter and searches.

Notice that each listed coordinate system has an "Authority ID", often an EPSG, typically a 4- or 5-digit number. You can use these numbers as shortcuts when filtering or specifying coordinate systems.



Type **wgs** into the filter pane, near the top of the CRS properties window (figure at right).

This should display a set of WGS 84 related coordinate systems. Choose the first in the list, WGS 84, with an Authority ID specified as EPSG:4326

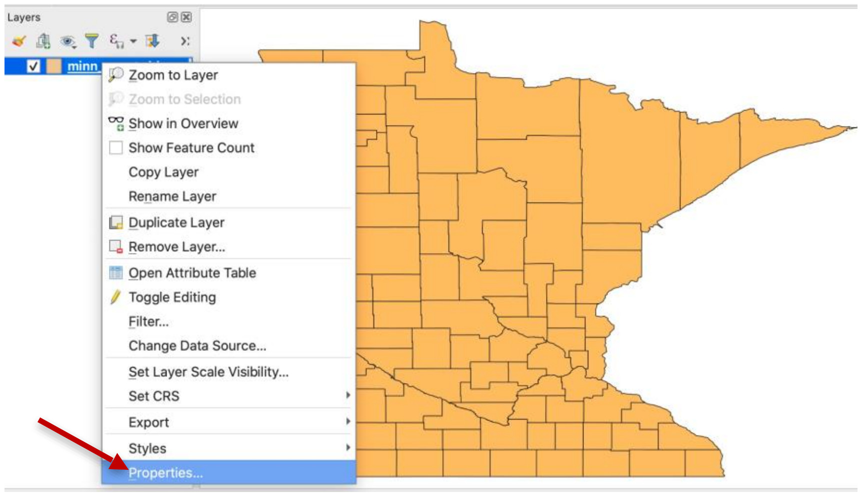
This is the first version of a latitudes/longitude system specified by the U.S. Department of Defense. The latest version (at this writing), is listed second, as WGS_1984(G1150), with an EPSG of 104013. These are recognized as different coordinate systems, as indicated by the different Authority IDs. Any single point on Earth will have different latitudes/longitudes in the two systems.

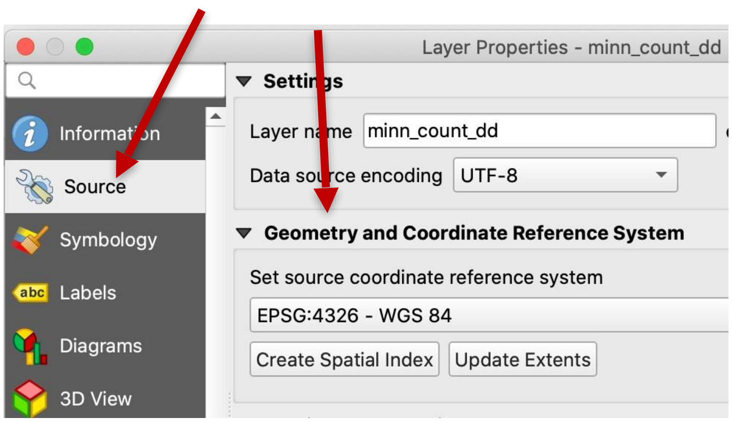
Click to select the first WGS 84, with EPSG of 4326, as the default coordinate system for this project.

Close the Properties panel and inspect the lower right-hand corner of the main QGIS window. Notice the EPSG: 4326 near the lower right corner of the main window? This window displays the data pane coordinate system, here the WGS 84 coordinate system that you just selected, denoted by its Authority ID. Also note the globe with a "hat" just to the left of the EPSG number. You can click on the icon or number as a shortcut to the CRS menu you just displayed through Project-Properties.

Add the minn_count_dd shapefile data to your QGIS project.

This should display the state of Minnesota, with county boundaries. Right click on the name in the table of contents, and select Properties from the drop-down menu.





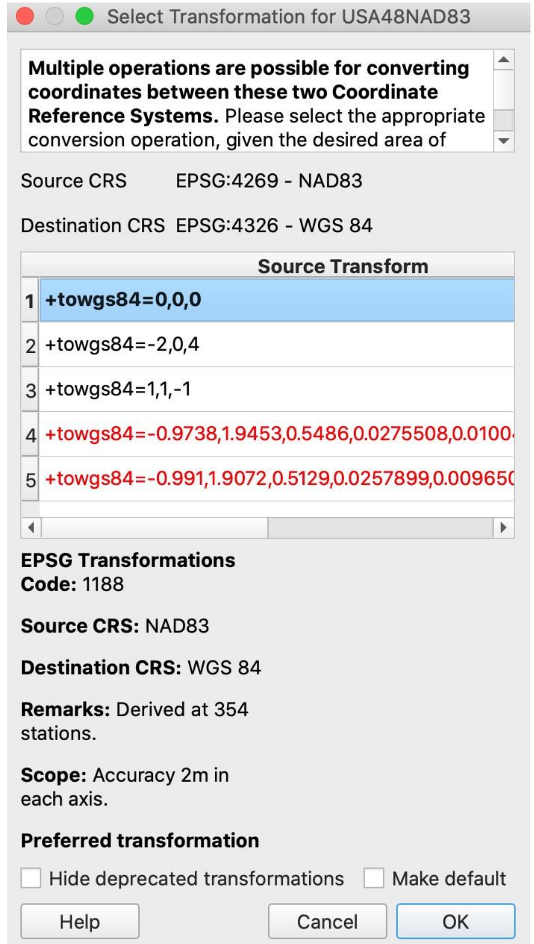
Clicking on the "Source" category in the left pane should display the layer properties, including the coordinate reference system (see figure at left). Here it is the WGS 84, with ESPG: 4326, the same as you selected as the default for the project.

Here the data layer coordinate system matched the project coordinate system. What happens if you try to load data that has been saved with one coordinate system into a project in another coordinate system?

Any data layer that has a properly recorded, "standard" coordinate system is converted to the Project's default coordinate system "on the fly". This means a coordinate projection is applied to the data read from the disk, but before it is displayed, so that features align, within the limits of the data's inherent accuracy, with any other layers also displayed, even if they have different coordinate system. This projection is "temporary" in that it doesn't affect the data stored on the disk – it only reprojects the data temporarily, for display. This allows us to display many data sets even if the data sets are stored in different map projections, without having to go to the trouble of manually reprojecting each data set and saving a new version of the data set. We can mix data stored in different coordinate systems, e.g., a state plane system and a UTM system, without the data misaligned.

You should remember from the course that coordinates for any location on Earth are specified both by:
1) the projection defined for a layer's coordinate reference system, and
2) by the geodetic datum.

You may have the same coordinate reference system, but different datums, and QGIS or any other software may balk at displaying them unless you specify which of the datums to use. Let's observe this.



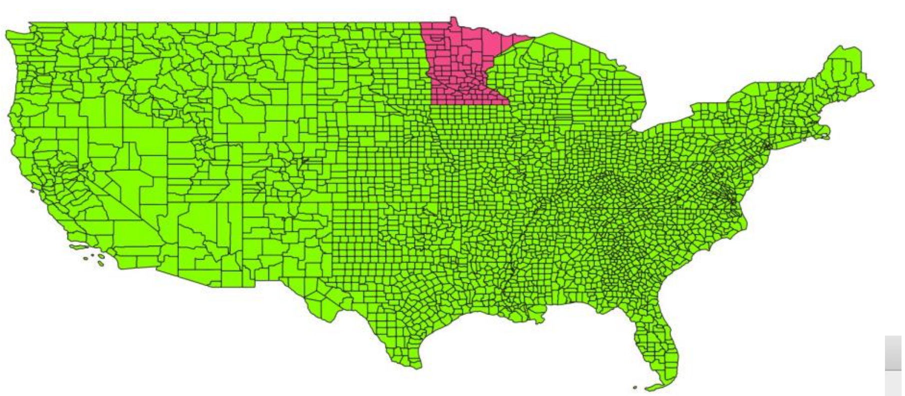
Add the layer **USA48NAD83.gpkg** to your project. These data are in the NAD83 (1986) latitude/longitude system. From the readings, you should remember that this system is different from the WGS 84 latitude/longitude system.

Note you get window, shown at right, asking you to select a datum transformation, because there are multiple ways to transform the data from the source coordinate system (geographic coordinates in an NAD83 datum), to the target coordinate system (WGS 84 geographic coordinates). It can't do an "on-the-fly" projection until this ambiguity is resolved, and so asks you to choose among the most likely datum transformations. The most common one, +towgs84=0,0,0 is selected here, highlighted in blue at the top of the list.

You often have to specify a datum transformation when projecting, because data layers are often in different base datums.

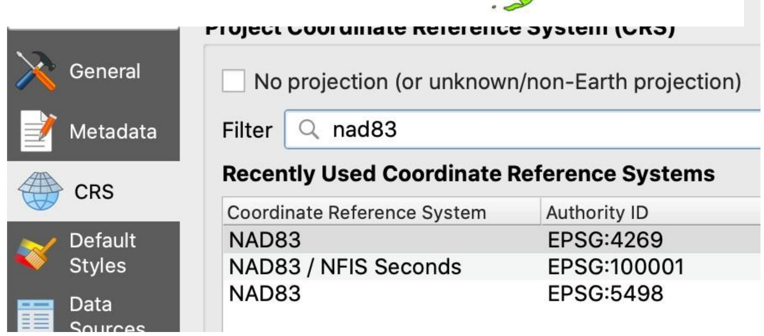
You select a datum transformation to apply by clicking on the row. You can specify this choice as the default when transforming between these two datums by clicking the check box near the lower right of the window.

OK applies the datum transformation. Display the data and note you should get something that looks like the figure below-right, perhaps after repositioning the county_dd data on top of the USA48 data. Note the data align correctly with the Minnesota counties in their proper location.



We may change a projects coordinate system or datum, and it will project all the contained layers to this new system.

Open the main Project – Properties window, and type NAD83 in the filter for CRS (see figure).

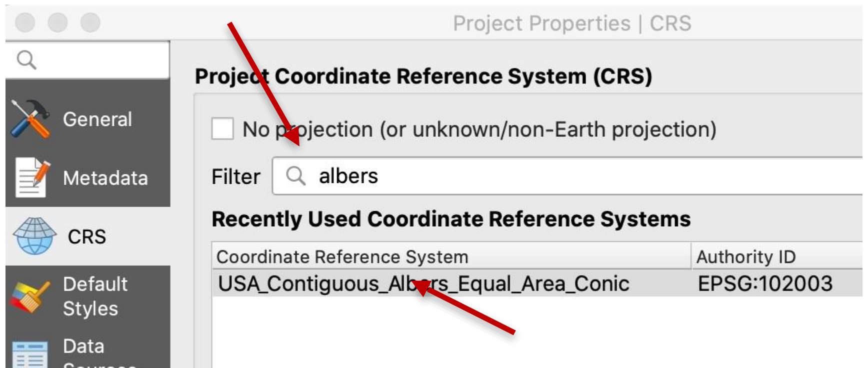


The first in the list, EPSG:4296, is a commonly used datum/coordinate system in North America. This is the original NAD83(1986) geographic coordinate system. Select it by clicking, then Apply it.

The data don't appear to change much, but note that they should still overlay. QGIS has projected the Minnesota_dd data from WGS 84 to NAD 83 (1986) coordinates.

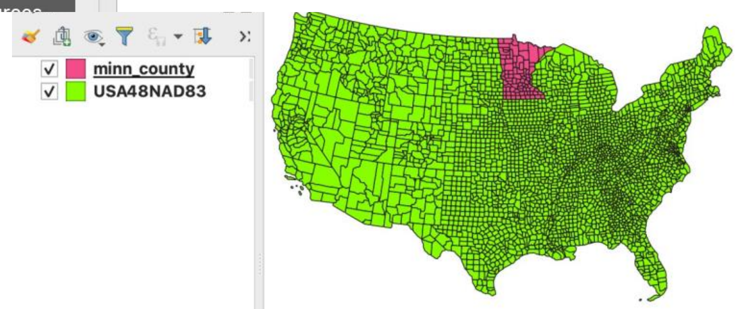
Let's do one more on the fly transformation.

Click on Project-Properties, select CRS, and type "albers" in the filter option:



Select the USA_Contiguous_Albers Equal Area Conic, EPSG:102003 that displays, then Apply-OK.

Notice how this changes the shape of both the U.S. lower 48 states/counties, including those in Minnesota. The northern border is now curved, and the area shorter east-west relative to the geographic coordinate system display.

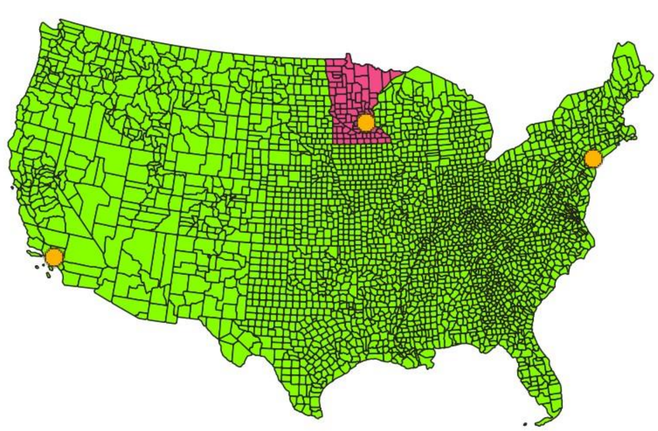


Both data sets have been projected "on the fly" to the Albers coordinate system. Sometimes this "on-the-fly" projection process doesn't work, and coincident data don't line up. This may be because the data layer is in one coordinate system, but the file documentation says it is in another. Lack of matching may also be due to a non-standard coordinate system, e.g., one that isn't included in the "standardized" list that QGIS uses. When there is a problem with a data set, it is best to go back to the source and attempt to identify the true coordinate system assigned to a layer.

Automatic, "on-the-fly" reprojection can sometimes complicate analysis because some spatial operations may not work properly, often when combining multiple data layers in different coordinate systems. Some operations automatically reproject the data into the same coordinate system before applying the operation, some don't. You may get the impression the data are in the same coordinate system when you display them together because "on-the-fly" reprojection ensures they line up. However, they may not be in compatible projections, and your spatial operation won't work, and you'll wonder why.

Different Projections Result in Different Distances for the Same Lines

Add the data Cities.gpkg to your project.

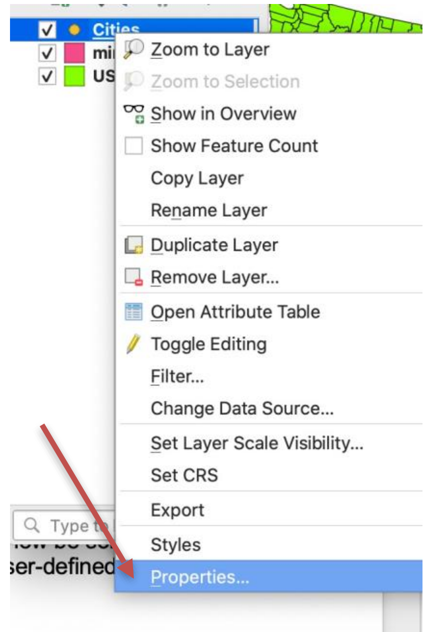


Alter the symbology, making the circles larger and changing the color so they're easy to see.

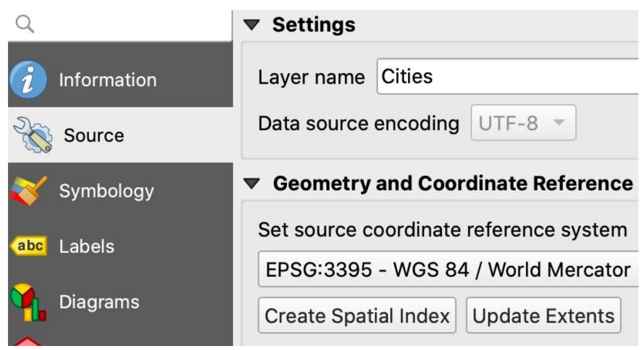
This point layer has the locations of Los Angeles, New York, and the Twin Cities.

What is the coordinate system for this data layer?

You can always check a data layer's coordinate system by clicking on a layer in the table of contents, then selecting Properties at the bottom of the dropdown menu (figure at right, arrow).

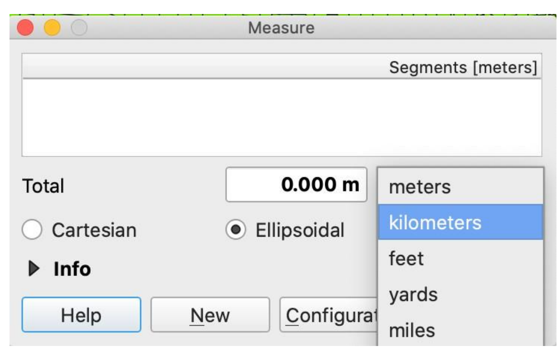


Clicking on Source in the window that opens will display the current coordinate system, in this case EPSG:3395, a WGS 84/World Mercator:



Find and left click on the measure tool, to measure distance. It looks like a ruler and is often by default near the upper right of the row of icons across the top of the QGIS map pane, although as with most tools, it is dockable, so you may find it somewhere else.

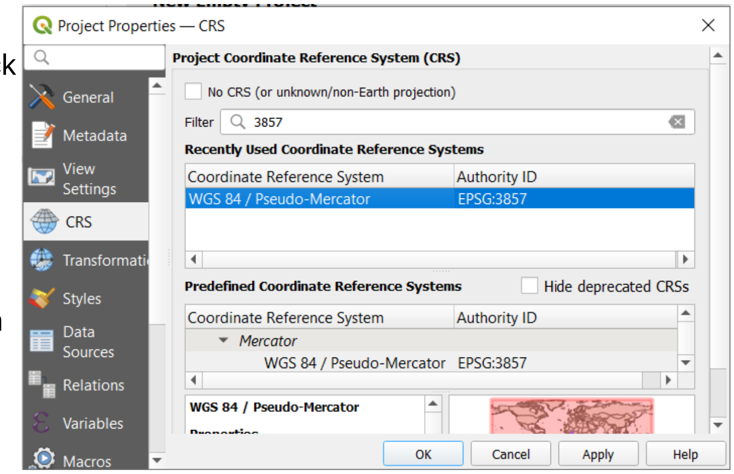
You should see the measure window, with an option to set the units, here we'll use kilometers:



Hover over Los Angeles and left click once. Move the cursor toward New York City, you should see a line trailing back to Los Angeles, and the distance increment in the Measure window.

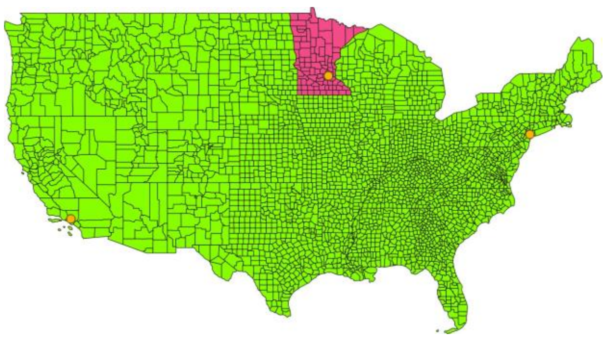
Left click on New York. The distance between the two cities should be about 3,940 kilometers.

Right click to stop measuring your current track.



Let's change coordinate system on the fly. Click on Project in the main QGIS bar, and select Properties ->CRS, and choose the WGS84/ Pseudo-Mercator projection, with an EPSG of 3857.

Notice the shape of the country has changed, with a straight northern boundary from Washington to Minnesota, and "squished" in an east-west direction:



Remeasure the distance from LA to NY. The new measurement should be approximately 5,040 kilometers, about 20% longer than when using the Albers projection above.

Which do you think is closer to the truth, and why?

The surface distance between LA and NY is actually about 3,960 kilometers. The difference in measurements between the Albers and Mercator projections is due to unavoidable distortion caused when we convert locations from the curved Earth surface onto a flat map surface. The shapes are different, so something has to give. The Mercator projection has a large error here, because it fits our mapped area more poorly. In other areas or conditions, the Mercator may be more accurate, so we must choose our projections wisely.

Projecting Layers Permanently

You often need to project data from one coordinate system to a different coordinate system and save them in a new file. We will perform several different projections and produce one map illustrating the differences between the separate projections. We will also look at the resulting area for one feature (in our case a county) in each projection.

Start QGIS to create a new empty map.

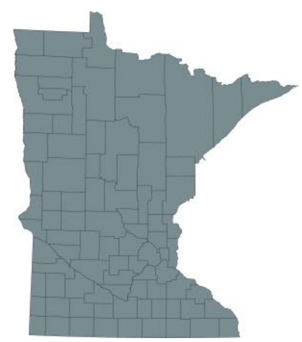
Place the minn_county.shp file in your data frame. You should see a county map of Minnesota displayed in your screen, similar to the figure to the right.

Note in the lower right corner of the main window frame, the EPSG is set to 26915. If you look at the minn_county.shp coordinate system (right click on layer in TOC, then Properties→ Information, CRS), you see that this is the NAD83 (original), UTM zone 15N coordinate system.

Move your cursor around the screen and notice the coordinate values in the narrow window below the main data pane, at the lower-center (see right).

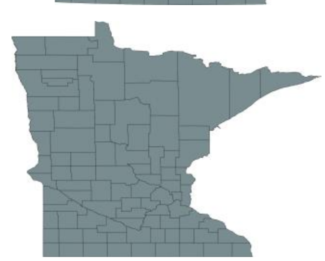
Note how the coordinates change when you move the cursor. The program displays the map projected coordinate values corresponding to the cursor position. These data in the minn_county shapefile are in UTM NAD83 projection. Each coordinate value is measured in meters, so a value X = 512,349 indicates an X value of 512,349 meters to the east of the origin.

I might have another data set of roads, or cities, which is stored in geographic coordinates (latitude/longitude), or in state plane Minnesota South Zone coordinates, and more data in another coordinate system, e.g., and Albers conformal conic projection. We already learned that when we load these data to the QGIS map canvas, they are converted on-the-fly to the current canvas coordinate system, in this case the NAD83 zone 15N coordinates. Let’s verify this.



Add the data file minn_count_dd.shp. Note it has the same shape as the previous data set. Look at the layer’s Properties->Information, and note that it is in the WGS84 – Geographic coordinate system. It doesn’t change shape because it is projected on the fly.

Change the Project’s coordinate system to that of the minn_county_dd.shp coordinate system, WGS84. Remember, Project-> Properties->CRS, then select the WGS84,EPSG:4326 coordinate system.



Notice how the Minnesota’s shape changes, becoming shorter and wider? This is because the geographic system, plotted on a Cartesian grid, represents the state differently than the UTM projection system. Shapes, areas, distances, and directions usually change when you change a coordinate system.

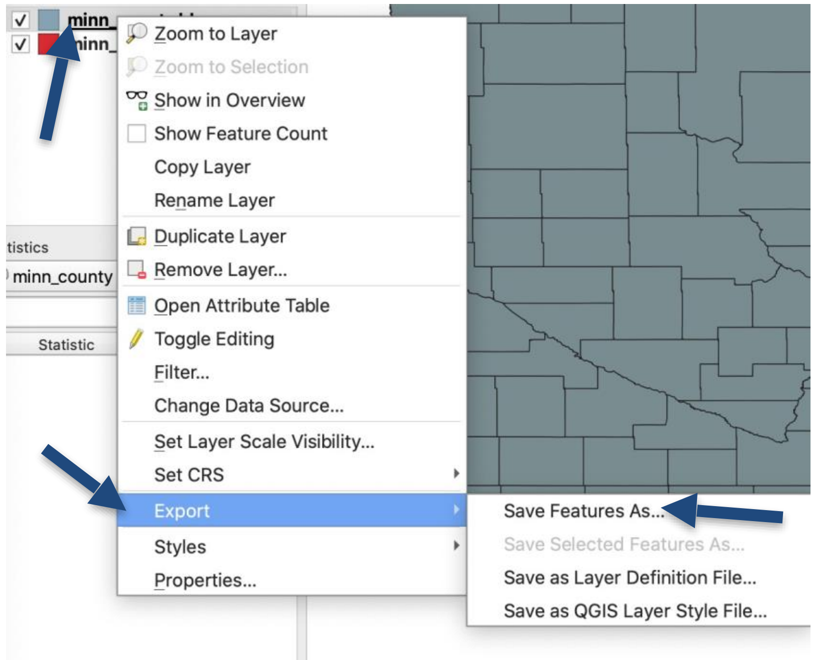
We may wish to convert the minn_county_dd.shp, or other data sets, to a different coordinate system, and save them in this new coordinate system. Here suppose we wish to save the data set to the NAD83/UTM zone 15N coordinates permanently. We can do this through an Export -> Save As, operation.

We can project while saving by

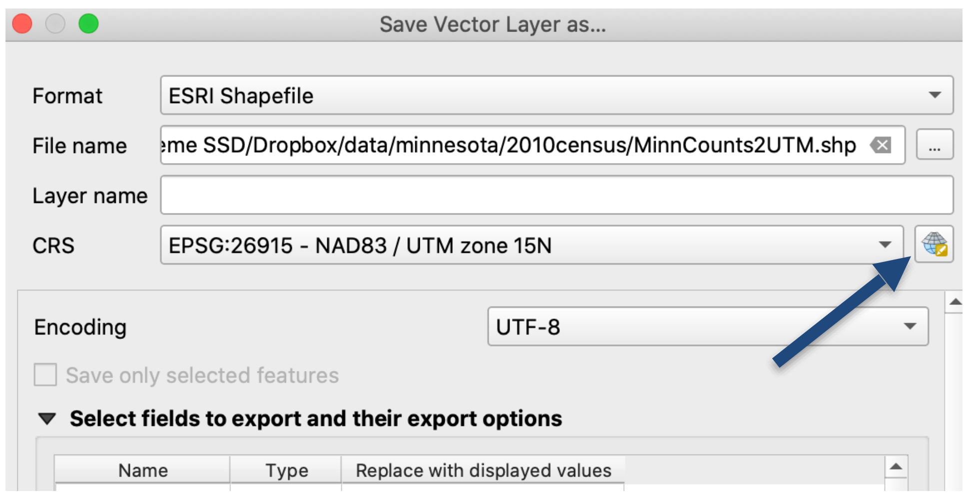
1) right clicking on the minn_county_dd.shp layer name in the table of contents, then

2) navigate down the menu opened by the right click, above, and then left click Export->Save Feature As… to open a projection window.

   The click sequence to above may depend on the mouse and mouse setup your using, e.g., for some you click-hold and roll down the list, for other mice/ configurations the list remains open, and you must right click on Export to open the sub-menu, then left click on “Save Features As….”



   When successful, a window pops up that allows us to specify, among other things, the output coordinate system:



Here we click on the globe (figure right) to set the now familiar NAD83 UTM 15N coordinate system, EPSG:26915, from among the list of supported output coordinate systems.

When you click OK, the new data layer named MinnCounts2UTM.shp (see File name in figure above) should be created and displayed over the existing layer. Note that the new data doesn’t change shape, as the input data (in the UTM 15N coordinates) are changed on-the-fly to the coordinate system we have currently specified for this QGIS Project, still set as WGS84 geographic coordinates. Check the new data layers TOC->properties->Information to make sure the CRS has been set to NAD83/UTM 15 coordinates.

Create two new versions of the Minnesota county data layer, using the “Export->Save Features As” method shown above,

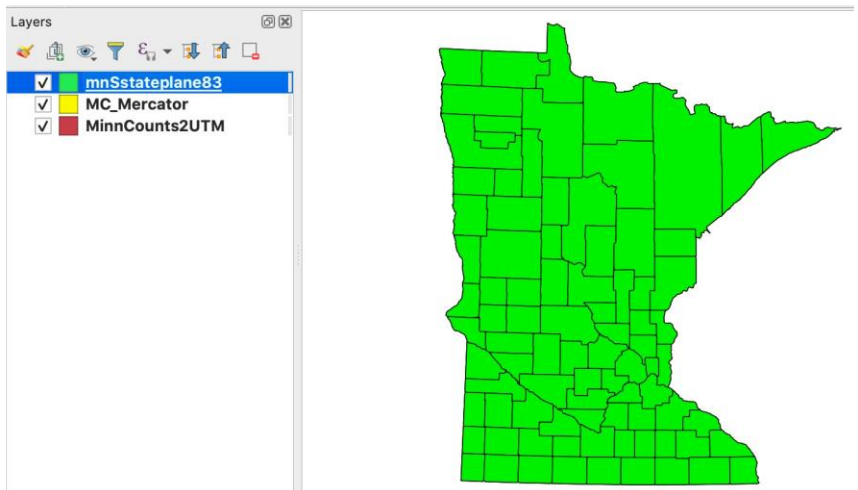
1) A MC_Mercator.shp, using the Google Mercator projection, EPSG:900913
2) A MnSstatePlane83.shp, usingNAD83 Minnesota State Plane South Zone, Feet, EPSG: 102693

Changing a Projection Will Change a County's Reported Area

Clear the current project or open a new QGIS Project and add the following layers you created:

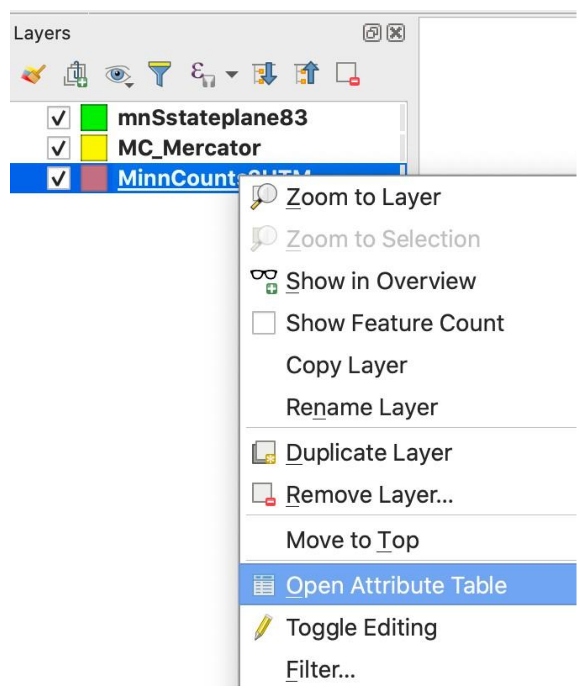
1) NAD83 UTM Zone 15N (named MinnCounts2UTM in our instructions above),
2) Google Mercator (named MC_Mercator above), and
3) NAD83 Minnesota State Plane South, feet (named mnSstateplan83 above)

Your table of contents and main map canvas should look something like the figure at right:

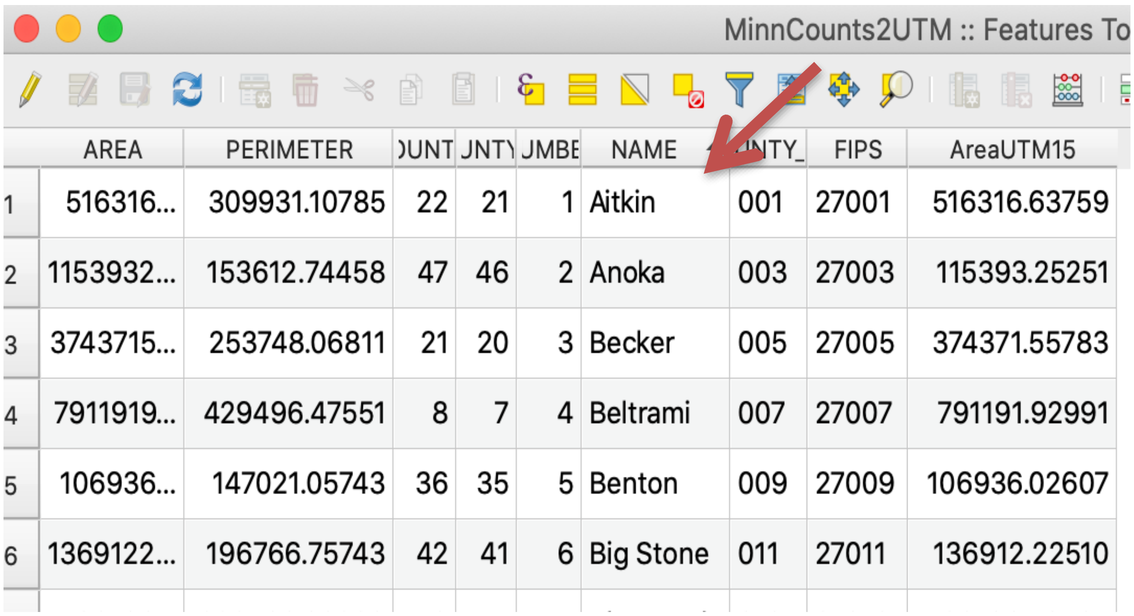


The shape of Minnesota may vary somewhat, because as you know, it depends on what coordinate system has been specified for the Project. Here it is the NAD83 UTM 15N, because I created a new project and loaded the MinnCounts2UTM, so the Project took that coordinate system as the default.

Open the attribute table for the UTM Zone 15N layer (right click on the layer and select "Open Attribute Table").



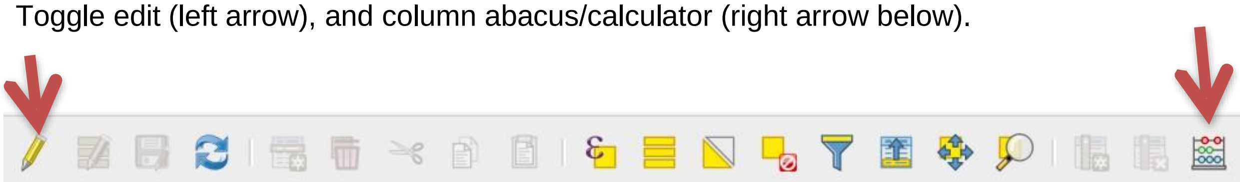
This should display an attribute table, with a row for each county, and a column for each variable reflecting data values for that county. The county name is a column near the center of the table:



MinnCounts2UTM :: Features To

	AREA	PERIMETER	)UNT	JNTY	JMBE	NAME	NTY_	FIPS	AreaUTM15
1	516316...	309931.10785	22	21	1	Aitkin	001	27001	516316.63759
2	1153932...	153612.74458	47	46	2	Anoka	003	27003	115393.25251
3	3743715...	253748.06811	21	20	3	Becker	005	27005	374371.55783
4	7911919...	429496.47551	8	7	4	Beltrami	007	27007	791191.92991
5	106936...	147021.05743	36	35	5	Benton	009	27009	106936.02607
6	1369122...	196766.75743	42	41	6	Big Stone	011	27011	136912.22510

Notice the row of icons at the top of the attribute table. We will be using two in this exercise: Toggle edit (left arrow), and column abacus/calculator (right arrow below).



To calculate area, you must

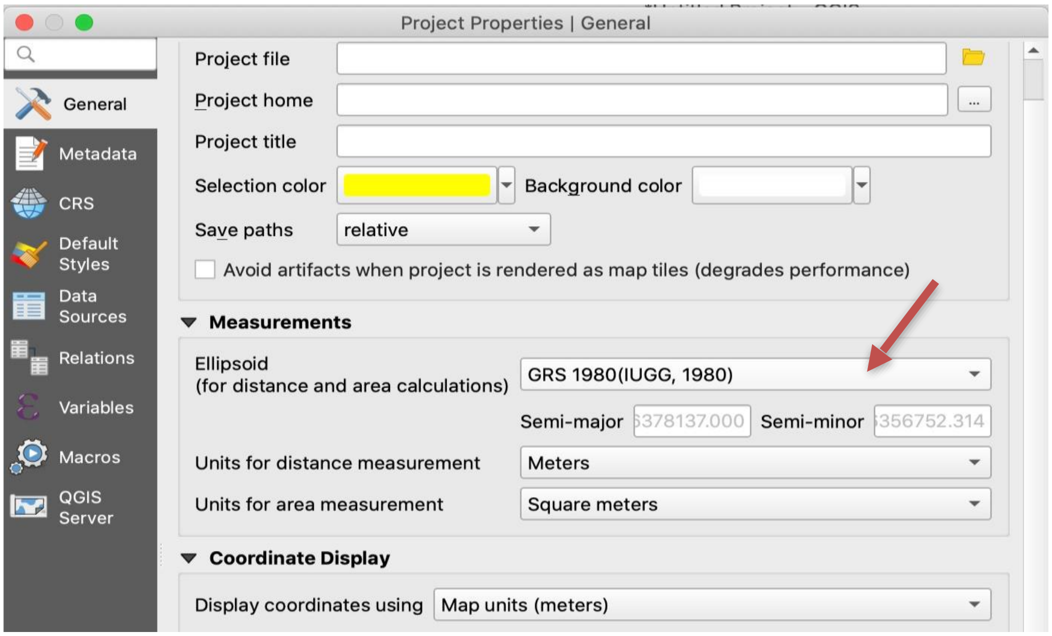
1) Toggle the editing on (click the pencil icon),

2) Click the calculator (abacus icon in figure) to open a window, and use that window create a new column and compute the area for each county polygon.

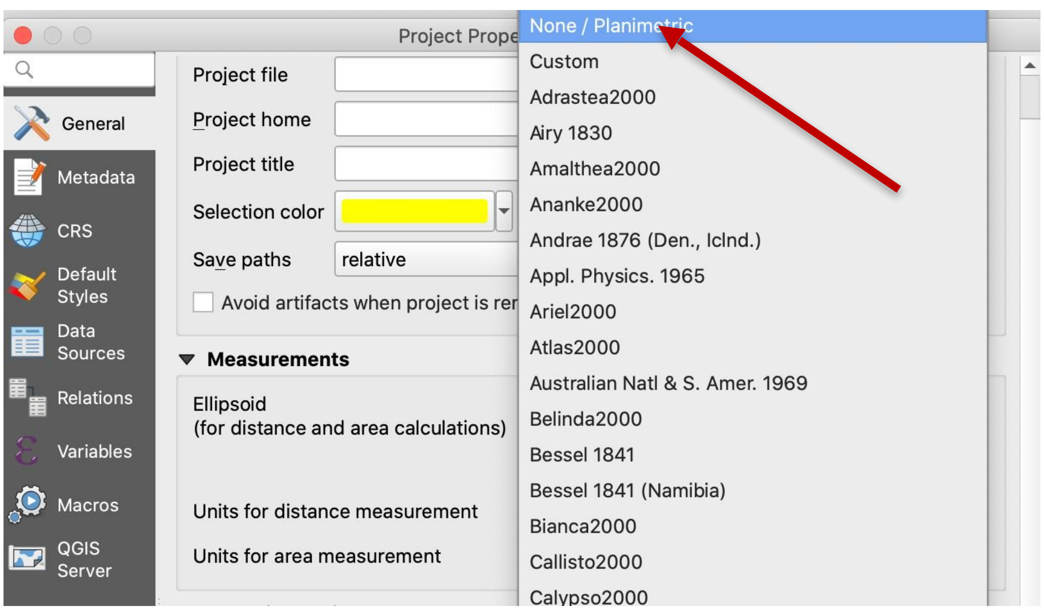
The area calculation defaults to the units (meters, feet) used in your data layer. If the coordinates are specified in meters for your projection, the calculator will default to square meters in the calculated column. If you want to calculate hectares, square kilometers, or acres, will have to add suitable conversion factors to your calculation.

You can change the default output units, and change the kind of area calculated, via a Project setting.

Open the Project properties, then select the general tab. About half-way down the menu there is a measurements section, expand it if need be, and then look at the Ellipsoid setting:



Click on the caret to open the ellipsoid list, and scroll to the very top, to None/Planametric:



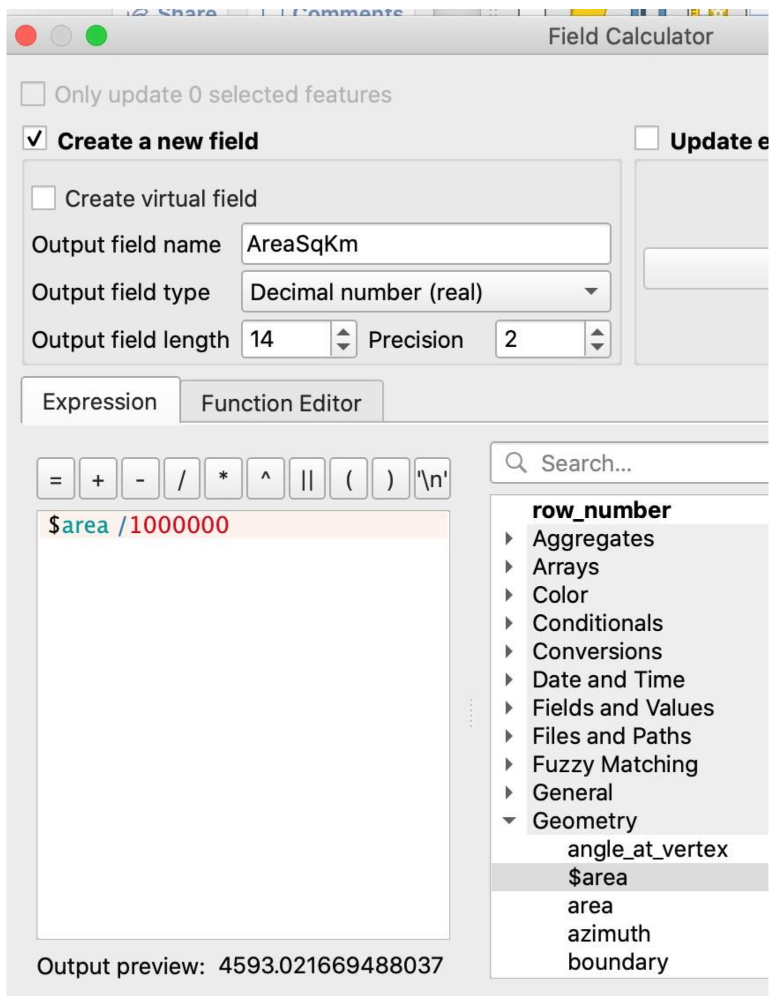
Selecting this option will ask for area calculations using Cartesian equations .

If you have set an ellipsoid, usually the GRS80 or WGS84, then a more complicated set of ellipsoid-based calculations will be performed. Here we'll use None / Planimetric. Select then Apply this option, then close the Project-Properties windows.

Go back to the open table for your Minnesota UTM data layer, toggle for editing, click the abacus/calculator icon and click on the menu option to create a new field. This will open a field calculation window (figure below). You may create a new field, or update an existing one. We'll create a new one now. Here fill fields with AreaSqKm for name, type=Decimal, field width=14, and precision=2.

There is a function list (lower right panel), and an expression window (lower left panel). You create an expression by clicking and typing on operators, variables, and numbers.

Build the expression shown. Here we want to calculate area, so we click on the caret next to the Geometry group, and select the $area function, a built-in tool that calculates areas for polygon. We divide by 1000000 (six zeros, or 1 million) to convert from square meters, the units of the data layer, to square kilometers, the units we want in our field.



After entering the expression, click O.K.

Scroll/search the table to find the area of St. Louis County, and record it on the worksheet provided at the end of this exercise.

Repeat these steps for the data layers with the Mercator and State Plane projections that you created. Be careful to convert units correctly, that is, make sure you know the units of the projection, and any constants you need to convert from those units to square kilometers.

There are 10,763,910 square feet in a square kilometer.

Record the calculated values for St. Louis County's area on the worksheet for each projection.

Create a Multipanel Map

We now wish to display Minnesota counties in a multi-panel layout, each panel with a different coordinate system. This is basically a repeat application of the inset map you learned last

We will specify the same map scale across all three maps, so you can see how different projections change the size, shape, and orientation of a data set.

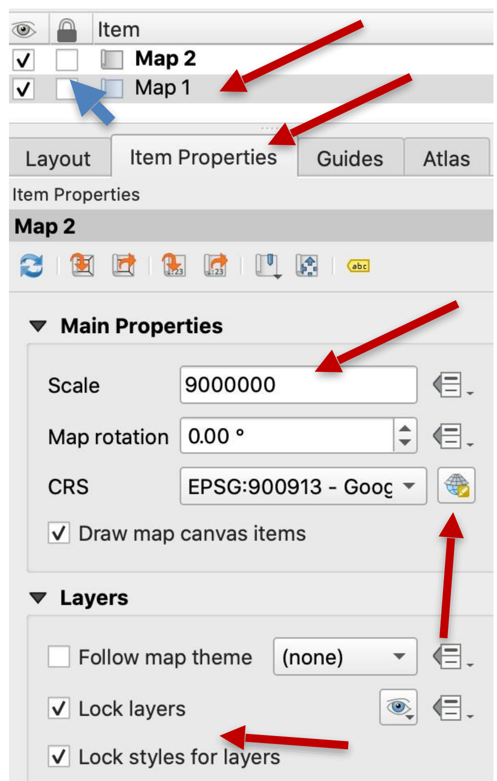
Open a new print composer (as last week, Project - New Print Composer)

This should open a Layout window. Load any one of the three data sets you created above into the data window, and modify the symbology to something you like. Then:

Add a new map to the layout, with the map box spanning about a third of your horizontal width of your page.

Add a second map, this time centered on the layout.

You might remember seeing the set of tabs shown at right from a previous exercise, usually displayed in a panel to the right of the main data window (not the layout window).



If you activate the Item Properties tab, you'll see that you can alter the scale, coordinate system, rotation, and other map characteristics.

Make sure the first map is selected (click on it in the Item list, top).

We will be setting the scale to 9,000,000 for all of our three maps, and changing the coordinate system/CRS for each. Note, don't enter the commas.

Click on the familiar globe with a hat, and set the coordinate system to the familiar EPSG:26915 – NAD83 UTM Zone 15N.

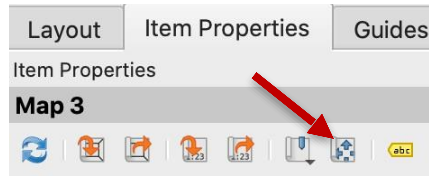
Finally, <u>check mark the Lock layers and Lock styles</u> for layers near the bottom of the layers section (arrow), and then check the item at the top (blue arrow) to lock the map. In theory, the lock layers/styles should keep the symbols from changing, but at the time of this writing, the map sometimes changed color when we modified other maps.

Now activate Map 2 by clicking on it in the item list so that it has a grey colored bar through it.

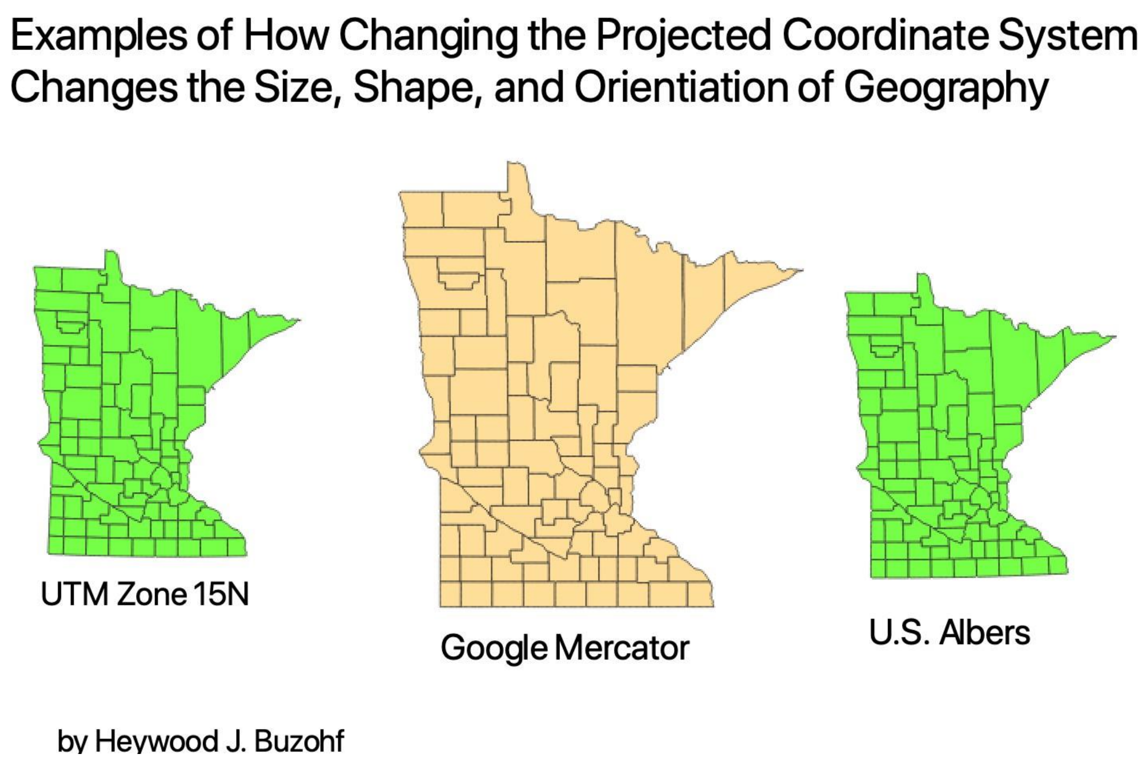
Change the scale to 9000000 to match map one, and the CRS to EPSG:900913 – the Google Maps Mercator. You may have to resize the map box by clicking on it, and dragging the handles if your layer doesn't fit. If you do that, note that the map scale will likely reset, and so you'll have to change it back to 9000000. Be sure to lock layers and styles when you've composed this map.

Add a third map, and this time give it a new coordinate system, EPSG: 102003 – the USA Albers Equal Area Conic. Set the scale to 9000000.

You may have to reposition the layer within the map. You can use the "interactively edit map extent" button to change the location within the map. If you inadvertently change the size, you can go back to the scale window and reset it to 9000000.



Label the three maps with text boxes to create a layout similar to that shown below.



Notice how the Mercator projection renders a state and counties that are much larger than the other two projection.

Also note that although the U.S. Albers is about the same size as the UTM Zone 15N version of Minnesota, it is slightly smaller, and slightly rotated counter-clockwise.

These are visual illustrations of the important observation that changing a map projection will usually change the shape, size, and orientation of any feature.

Fixing an Erroneous or Missing Coordinate System Reference

While all data layers are in some coordinate system, at times QGIS can't identify the coordinate system. This is usually because a key file is missing. The coordinate system for a shapefile is stored in a .prj file, e.g., roads.prj should contain the projection information for the roads.shp and related shapefiles (as noted last week, there are three base files in the group of files that compose a complete shapefile layer: a .shp, a .shx, and a .dbf file, e.g., roads.shp, roads.shx, and roads.dbf). If the roads.prj file is missing or corrupted, QGIS has no way of identifying the coordinate system of the collection of files that make up a shapefile layer.

A more insidious problem arises when a data layer has an erroneously documented projection. The data are in one projected system, but the metadata for the data say it is in another coordinate system.

We'll fix a data layer that lacks proper metadata.

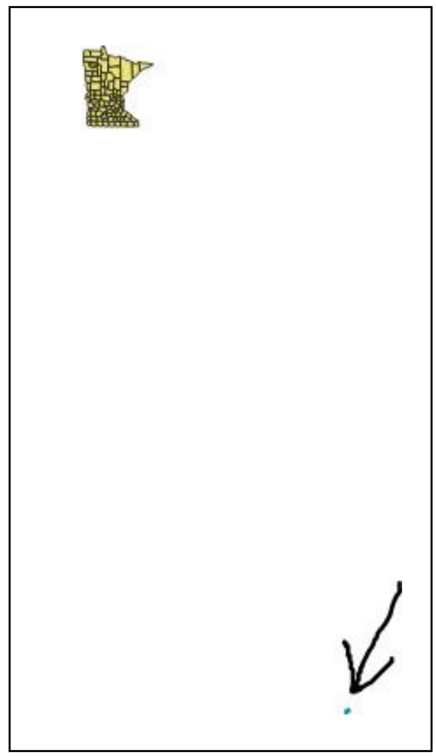
Close any open QGIS projects and open a new one.

Add the minn_county dataset, and the hlakes_not_projected data set.

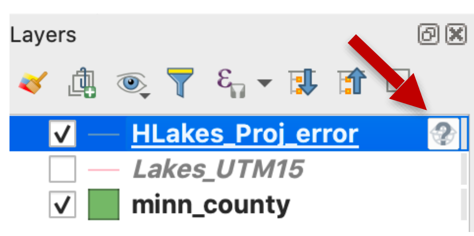
Display the data at the full zoom.

You should have a panel similar to that on the right, with Minnesota counties in the upper portion, and a small speck of lakes in the lower right, near the drawn arrow.

These lakes should be displayed near the metro area, in Washington County in the east-central part of the state



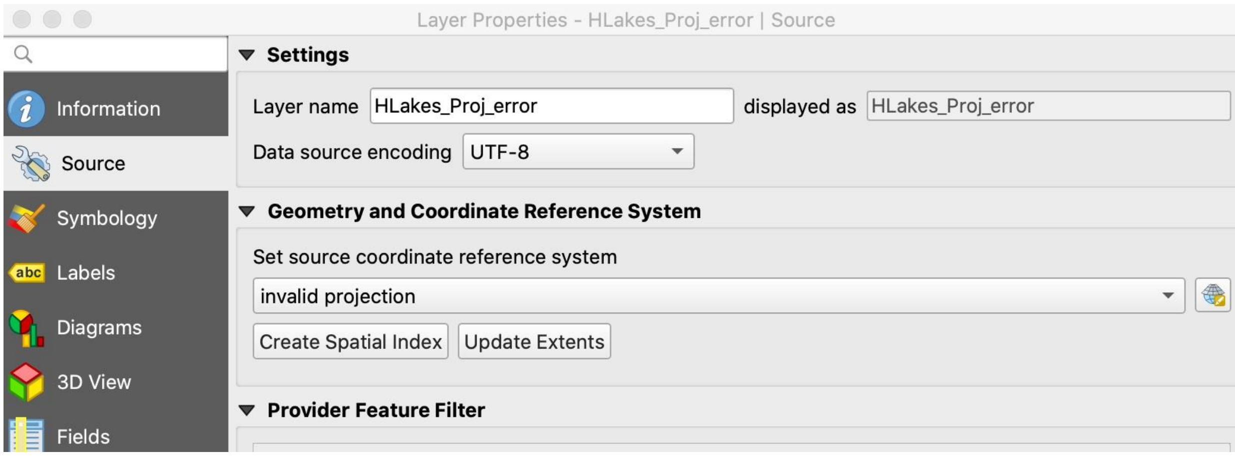
Also note that there is a question mark listed with the layer in the Table of Contents, with an outlined globe and "hat" behind it:



You can repair a vector layer that is lacking a projection by:

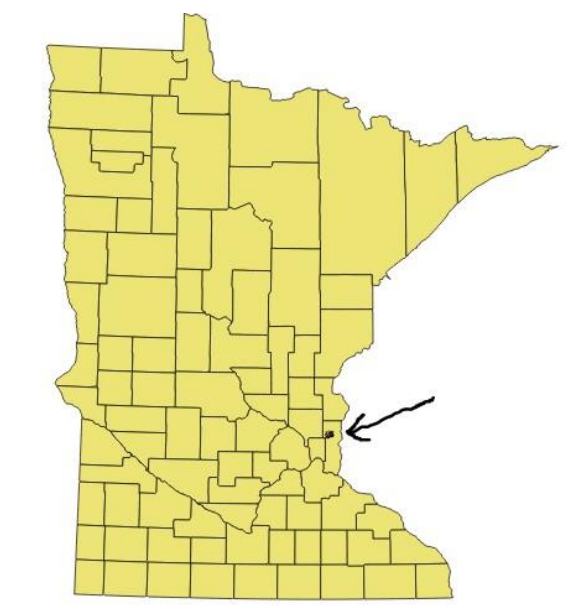
Right click on the vector layer in the TOC, and then select Properties -> Source.

This should display a window with a line that notes that there is an invalid projection, and our familiar projection globe to its right:



-Click on the Choose button, then from the familiar list of possible coordinate systems, select the EPSG:26792 - NAD27/Minnesota Central coordinate system.

-Click OK on the various menus to apply the change, until the menus are closed and the main project window is displayed.



Notice that nothing has changed your lakes data are still in the wrong place. This is because the window does not automatically refresh.

-Click on the zoom to full button again, and the lakes should now appear in their correct location, as shown by the arrow in the figure to the right.

Remember, you only assign a coordinate system when it is missing, and you know the correct system. <u>You can ruin a data set by assigning the wrong coordinate system definition</u>.

Turn in the following for this lab:
1) the map of Minnesota with the Mercator, Albers, and UTM coordinate system
2) the metro region map with counties and reprojected lakes

Area of St Louis County, Square Kilometers:

UTM zone 15:

Albers:

Google Mercator: