LESSON 1 Global Analysis in Quantum GIS – Exploring Global Climate Model Output

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In lesson 1 we are going to use the desktop GIS application Quantum GIS (QGIS) to explore and map global climate and demographic data. QGIS is an Open Source Geographic Information System and is officially a part of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, Unix, Mac, and Windows and is a powerful GIS for vector and raster data analysis and mapping. To learn more about QGIS visit http://www.qgis.org/.

In this first exercise, we will be working with global climate model output from the Community Earth System Model (CESM) in order to map possible future temperature and precipitation change by the middle of the 21st century. We will map temperature change thresholds and identify which regions may be affected by these changes. This first exercise will focus on global change.

STEP 1 Exploring the QGIS interface

Type in your working directory here. This is the location in which you copied that course data.
<your working directory> = _____

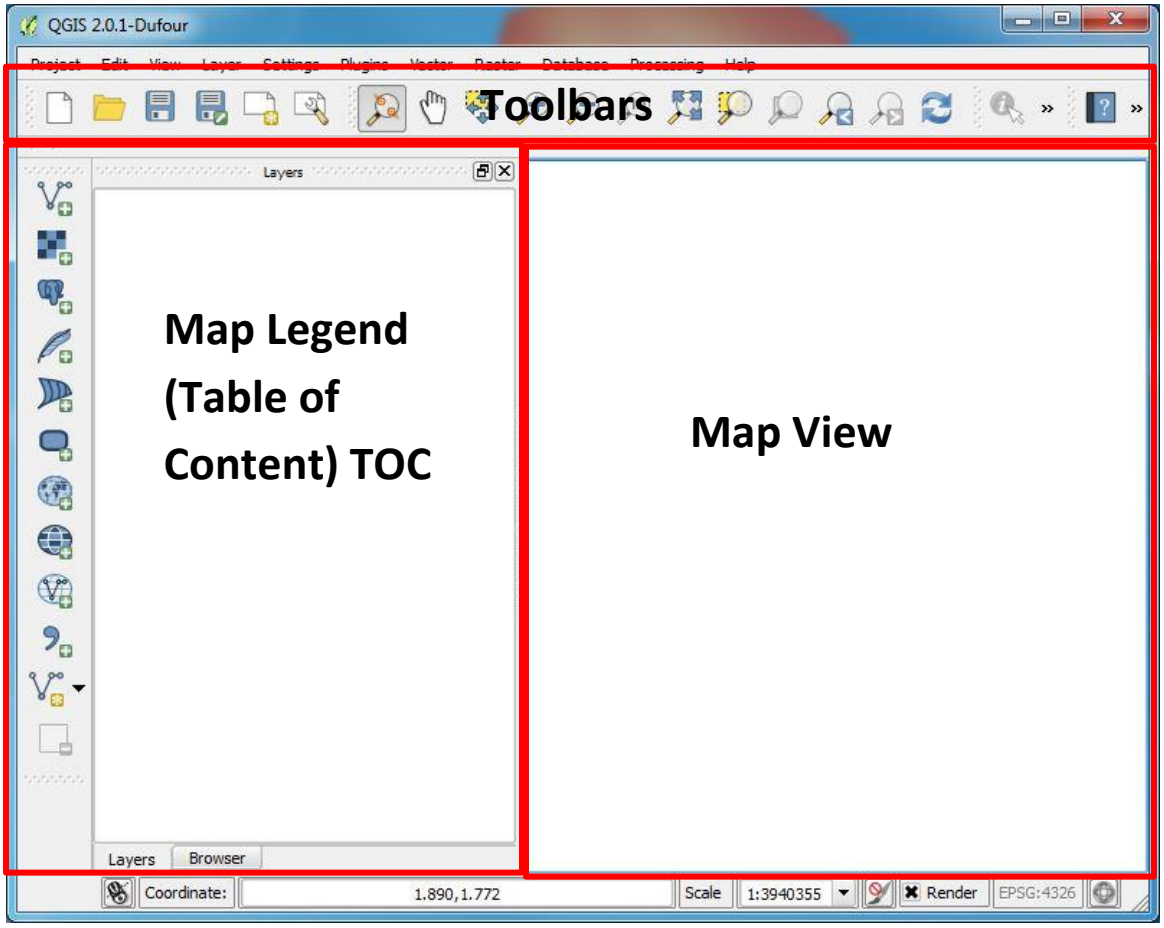
We will start off by exploring output from a global climate model (CCSM3) in QGIS.

- Open the QGIS Desktop application.
    - For Windows **Start > All Programs > Quantum Dufour > Quantum GIS Desktop 2.0.1**
    - For Mac Open the Applications folder and click on **QGIS**.

QGIS Desktop is a user friendly application for performing spatial data analysis, and making maps. We will now explore some of the features of QGIS.

- When you open QGIS a QGIS Tip will appear. Click **OK** to close this window.

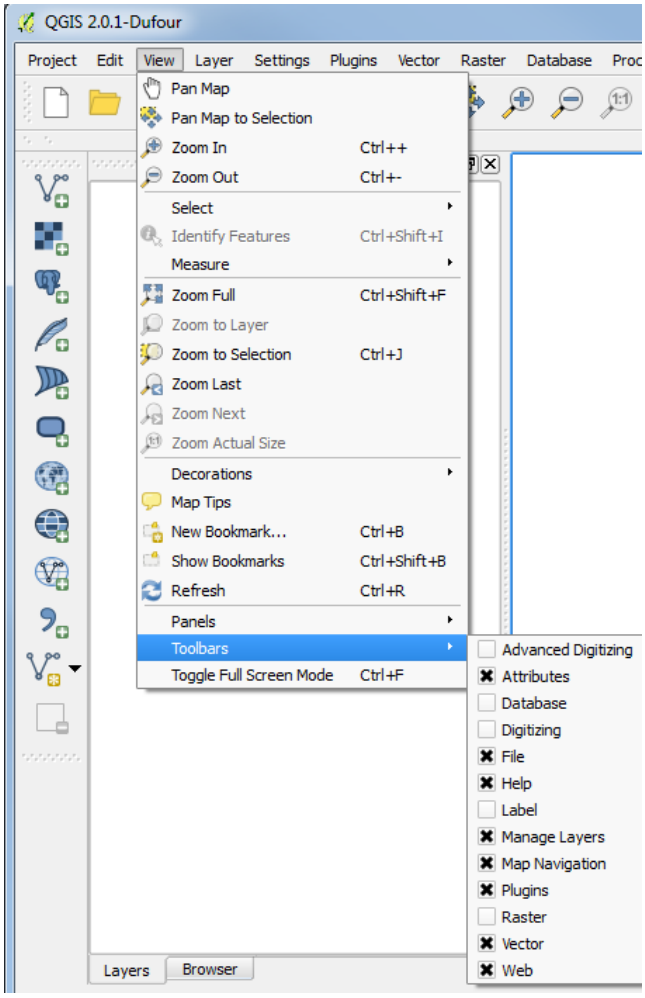
Below is the basic layout of the QGIS Desktop window. There is a map legend (or Table of Content), toolbars, and a map view where the data is displayed.



- Hover your mouse over the buttons on the tool bar to see what they do.

On the toolbar you may see tools followed by **>>**. This means that the toolbar is too large to fit in the area and it tells us that there are more tools associated with that toolbar. In order to make more space for the toolbars we are going to be using we will turn off some toolbars which we will not be using in this course.

- Click **View > Toolbars.**
- Turn off the following toolbars: Digitizing, and Label (see screenshot on the following page).

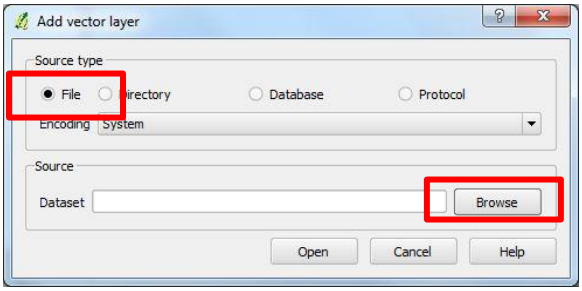


You can also move toolbars around the QGIS interface by clicking on the left-hand side of the toolbar and dragging the toolbar to a new location.

- Rearrange your toolbars so that all the tools are visible.

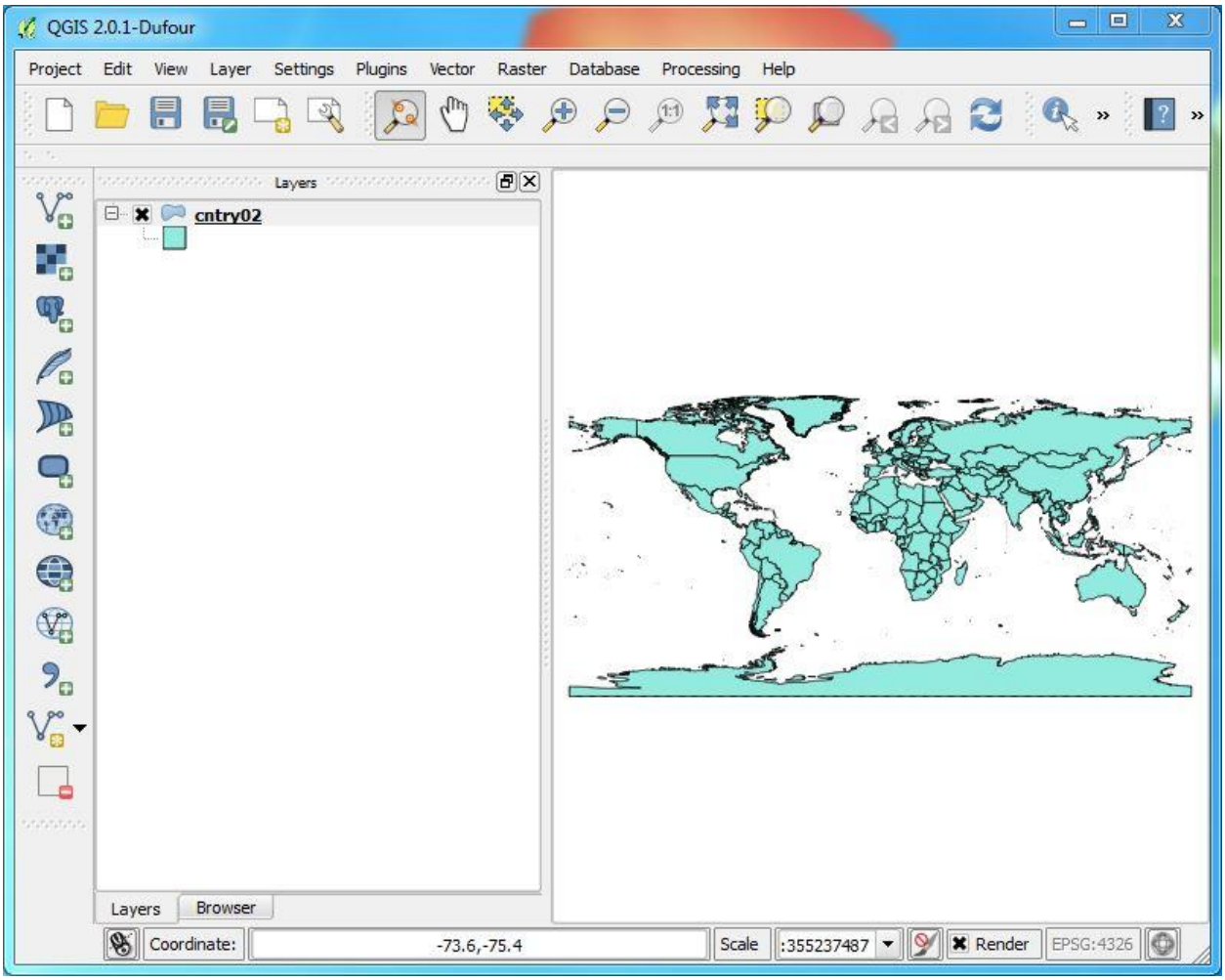
Now that the interface is less cluttered, we will start by adding data into QGIS Desktop and symbolizing it.

- Click the **Add Vector Layer**  button on the File toolbar (toolbar located on the left hand side of the Table of Content).



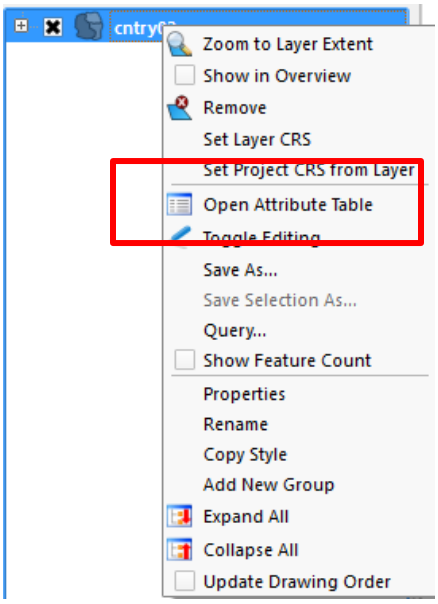
- In the dialog which appears make sure **File** is selected.
- Click the **Browse** button.
- Make sure that the file type is set to **ESRI Shapefiles[OGR] (*.shp).**
- Navigate to **<your working directory>\data** and add **cntry02.shp**, then click **Open**.
- Click **Open** again to add the layer to your map.

The shapefile gets added to QGIS as a layer and is displayed using a default symbology. You will see in your map view all of the countries in the world displayed using the same color.



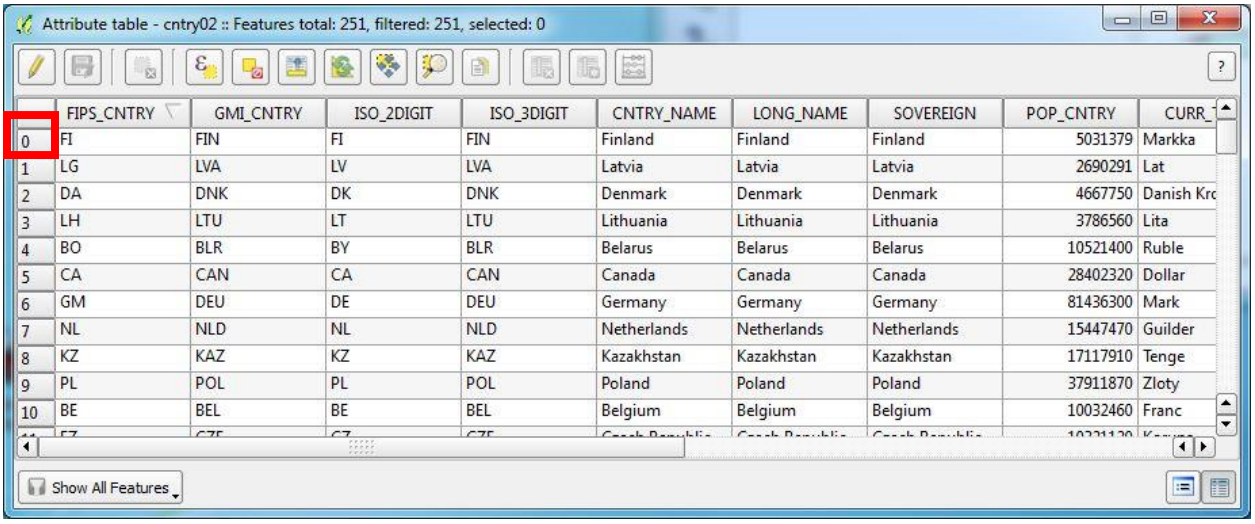
STEP 2 Working with tables and selections in QGIS

A powerful aspect of GIS is that each spatial feature (e.g. each country) is a row in a database and each row (e.g. country) can have many attributes associated with it in order to better describe the feature. To explore attribute (non-spatial) information for this dataset, open the attribute table:



- In the TOC, right click on the layer *cntry02* .
- Select **Open Attribute Table** from the context menu.

The attribute table for the dataset will open.



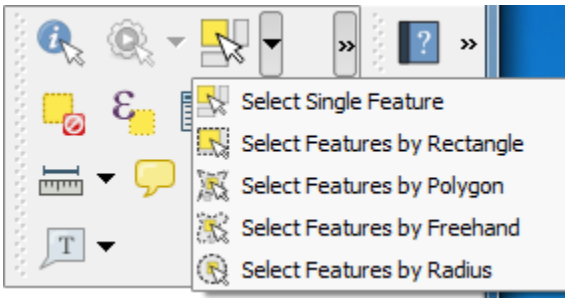
	FIPS_CNTRY	GMI_CNTRY	ISO_2DIGIT	ISO_3DIGIT	CNTRY_NAME	LONG_NAME	SOVEREIGN	POP_CNTRY	CURR_
0	FI	FIN	FI	FIN	Finland	Finland	Finland	5031379	Markka
1	LG	LVA	LV	LVA	Latvia	Latvia	Latvia	2690291	Lat
2	DA	DNK	DK	DNK	Denmark	Denmark	Denmark	4667750	Danish Kr
3	LH	LTU	LT	LTU	Lithuania	Lithuania	Lithuania	3786560	Lita
4	BO	BLR	BY	BLR	Belarus	Belarus	Belarus	10521400	Ruble
5	CA	CAN	CA	CAN	Canada	Canada	Canada	28402320	Dollar
6	GM	DEU	DE	DEU	Germany	Germany	Germany	81436300	Mark
7	NL	NLD	NL	NLD	Netherlands	Netherlands	Netherlands	15447470	Guilder
8	KZ	KAZ	KZ	KAZ	Kazakhstan	Kazakhstan	Kazakhstan	17117910	Tenge
9	PL	POL	PL	POL	Poland	Poland	Poland	37911870	Zloty
10	BE	BEL	BE	BEL	Belgium	Belgium	Belgium	10032460	Franc

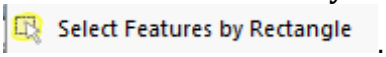
- Click in the grey box numbered 0 (see red box shown on the screenshot above).

You will see the entire row is highlighted. By selecting a feature in the table, you can also select this feature on the map (Finland): the polygon (e.g. country boundary) that you have selected is highlighted on the map. Further, the number of selected features is noted along the top of the attribute table, where it says "Features total: 251, filtered: 251, selected:1". You can select ranges of features by holding down the "Shift" key and clicking another row, or by using the "Ctrl" button (Windows) or the Command button (Mac) to select and de-select multiple features. Selection is a powerful tool in GIS and can be performed by location or non-spatial information available in the attribute table.

- Position the attribute table so you can see the selected features on the map.
- Back in the map view click on the **Select Feature** tool on the *Attributes* toolbar.

HINT In order to see the Select tool you may need to click the >> beside the Identify tool

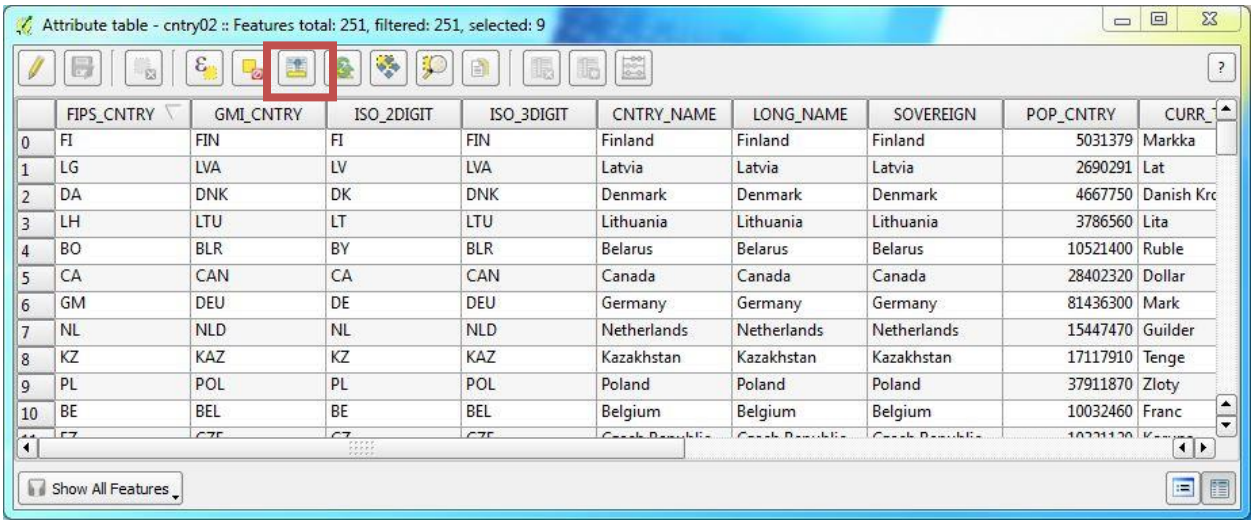


- Click the downward arrow beside the **Select Single Feature**  tool.
- Choose **Select Features by Rectangle** 

.
- Draw a box around a few countries in South America.

- Position the QGIS Desktop map and the attribute table beside each other so you can see both windows.

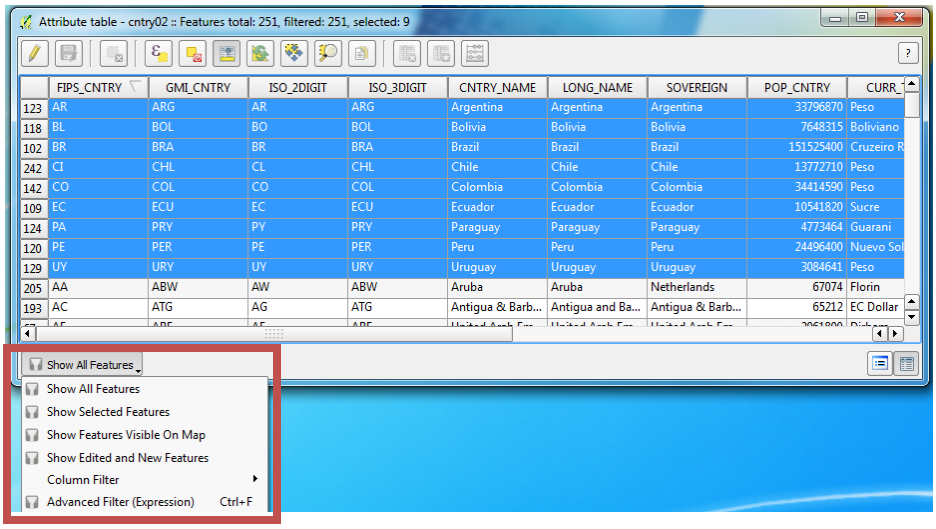
The selected features will appear highlighted on the map and in the attribute table.



- In the Attribute Table, click the **Move Selection to top**  button.

Now the selected features are located at the top of your attribute table.

- Click the button that says **Show All Features**. A dropdown will appear. Now click on **Show Selected Features.**



Now you should only see the selected features in your attribute table.

- The button at the bottom left now reads Show Selected Features. Click this button and select **Show All Features**.
- Click the **Unselect All** button in the Attribute table 
- Close the Attribute table window.

STEP 3 Working with qualitative symbology and the layer properties

Quantum GIS contains the ability to create color ramps in order to suit your data symbology needs.

- Right click on the layer *cntry02* in your Table of Content (TOC) and select **Properties** in order to open the **Layer Properties dialog box.**

The Layer Properties dialog box is the area where we can change the way our data is displayed (symbolized).

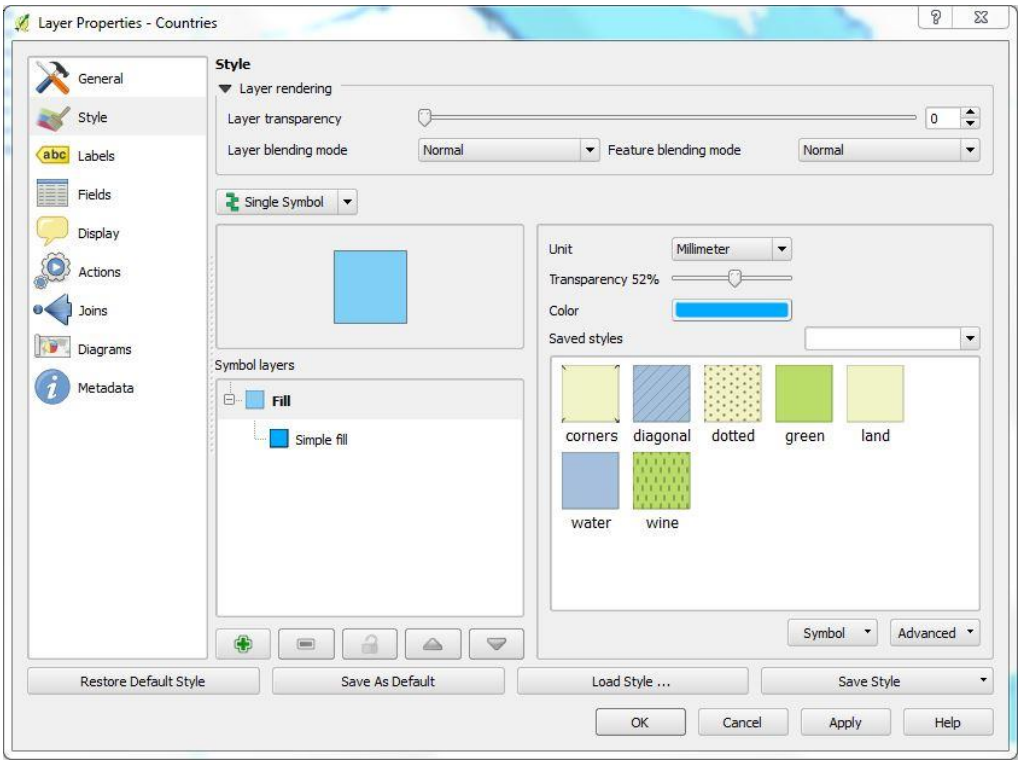
- Click the **Style** options on the left hand side.

Notice that right now every country (polygon) is displayed using the same color.

- In the Style area move the Layer transparency slider towards the right. Stop around 50%.
- Click Apply.
- Move the Layer transparency back to 0 and click Apply.
- You will see another Transparency slicer below the Layer rendering.
- Move this slider to 50% and click Apply.

Do you notice the difference in the transparency? The Layer transparency will make everything transparent, the fill and the outline. The transparency below if for the fill only. This region gives you the ability to manipulate the fill color, style, and transparency.

- Change the fill color to a bleu and click Apply.



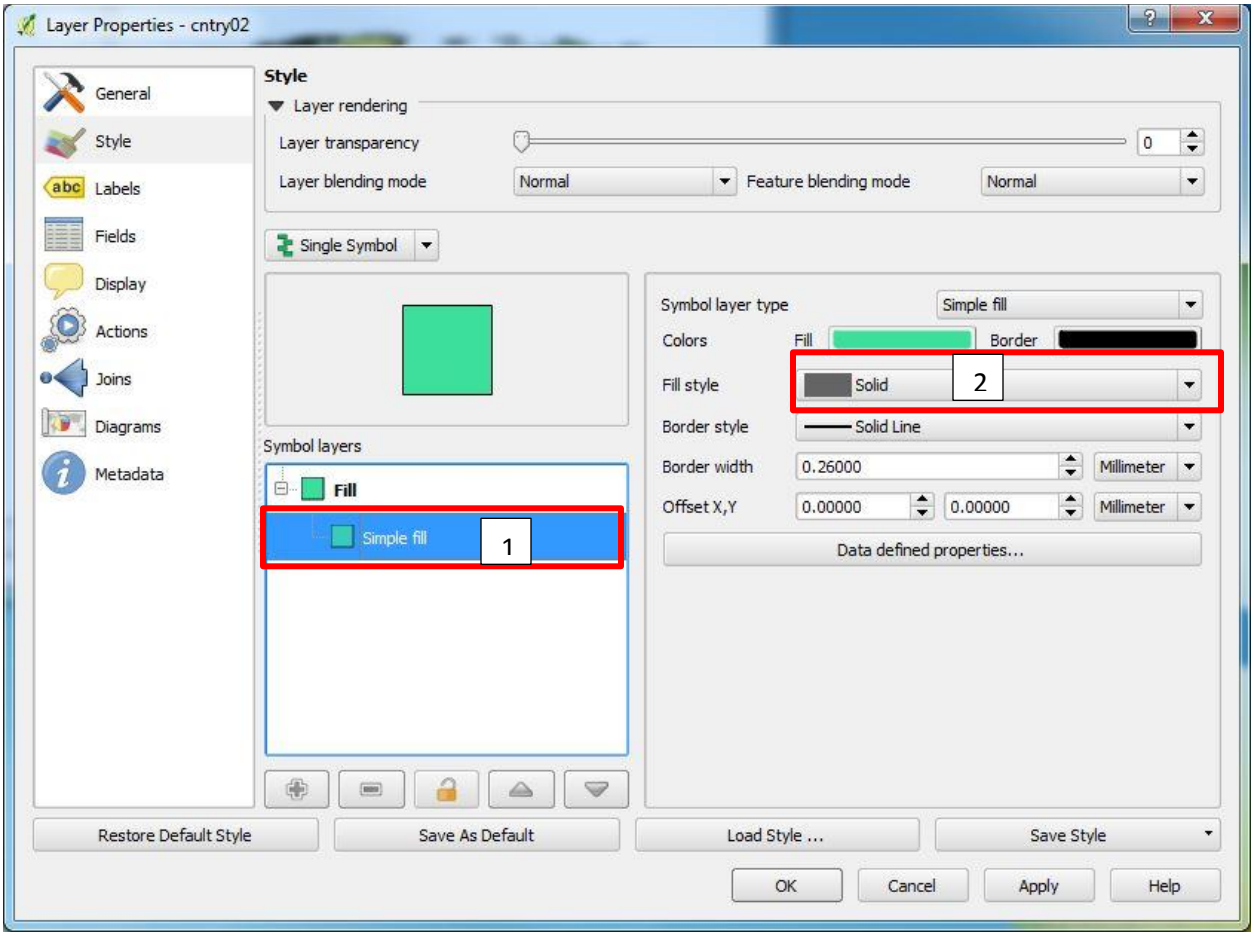
Another way to display Qualitative data is by displaying each unique polygon (country) with a unique color.

- Click the *Single Symbol* drop down and select **Categorized**.
- For *Column* select **CNTRY_NAME**
- Back in the Layer Properties dialog box click the **Classify** button and click Apply.

Notice that each unique entry in the CNTRY_NAME field has been categorized with a color.

We have just explored using the single symbol and category symbology. These two methods of symbolizing data work well for qualitative data. Qualitative data can describe features but are not numerical in nature. In the previous example *country* name is a qualitative attribute.

- In the Layer Properties dialog box, xcange the Categorized back to **Single Symbol**.
  1. Click **Simple fill** in the Symbol layers box.
  2. Click the **Solid** drop down for the *Fill style* and select **No Brush**.



- Click Apply.

Notice that the countries are now display as outlines with no fill color.

- Click on the **Labels** option in the left hand side menu.

Currently labels are turned off.

- Click the **Fields** option.

Notice the fields and their type definition. Each field is a column in the attribute table.

- Click the **General** option.
- Change the **Layer name** from cntry02 to *Countries*.
- Click **Apply**.
- Click the **Display** option.
- Change the **Field** to CNTRY_NAME.
- Click **OK** to save your changes and close the Layer Properties dialog box.

Notice now that in the Table of Content (TOC) the countries layer name has changed.

- Click the **Identify**  tool on the Attributes toolbar.
- Place your mouse over Mexico and **click**.

In the Identify dialog box the first field you see is CNTRY_NAME, this is the Display field you set in the properties.

What is the population of Mexico? (write your answer below)

- Close the Identify dialog box.

STEP 4 Working with quantitative symbology

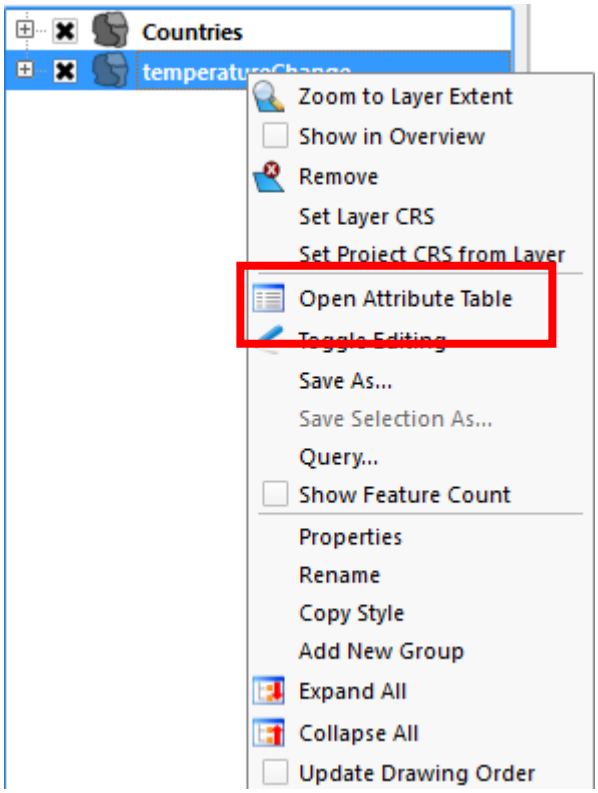
Quantitative data is numerical information, such as counts or measurements. In this next step we will explore options for symbolizing quantitative data.

- Click the **Add Vector Layer**  again, this time add the file **temperatureChangeMid.shp** from **<your working directory>\data.**

The data in the map view are displayed from the bottom up. However, when you add new data to your map it will be placed as the top layer. Since we added temperatureChangeMid.shp to our maps this data is now being displayed on top of the *Countries* layer.

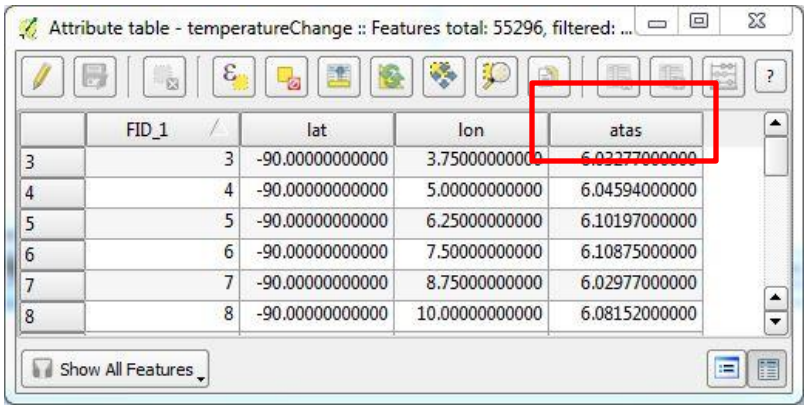
- In the Table of Content (TOC), click the *Countries* layer and drag it above the *temperatureChangeMid* layer.

The *temperatureChangeMid* layer contains information for each cell about the annual mean temperature change (in degrees Celsius) between the "present" (1986-2005) annual mean temperature and the middle of the 21st century (2040-2059) annual mean temperature as projected by CCSM using the RCP 8.5 emission scenario. This dataset came from the NCAR Climate Change Scenarios Portal (http://GISClimateChange.ucar.edu).



- Right click on the layer *temperatureChangeMid* in the map legend and choose **Open Attribute Table.**

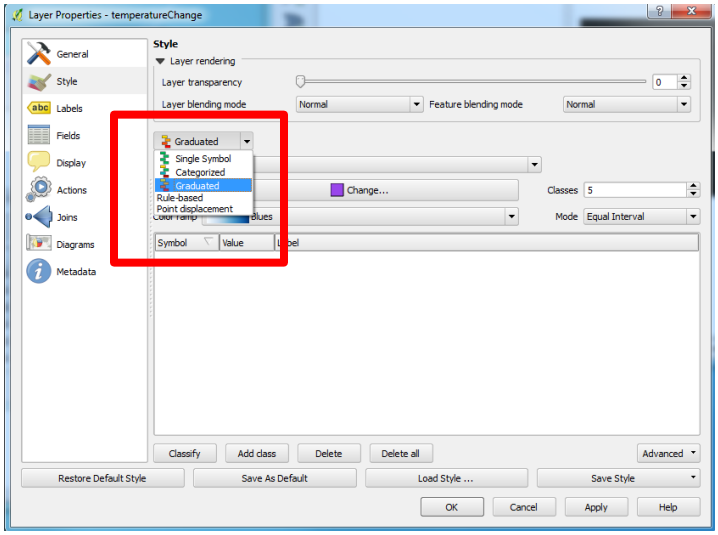
- Find and click on the field *"atas"*. Notice an arrow appears which points up and the data is now sorted ascending.



- Click the field *"atas"* again to see the data sort descending.

In the table, you will notice that in some areas temperature change exceeds 5 degrees Celsius.

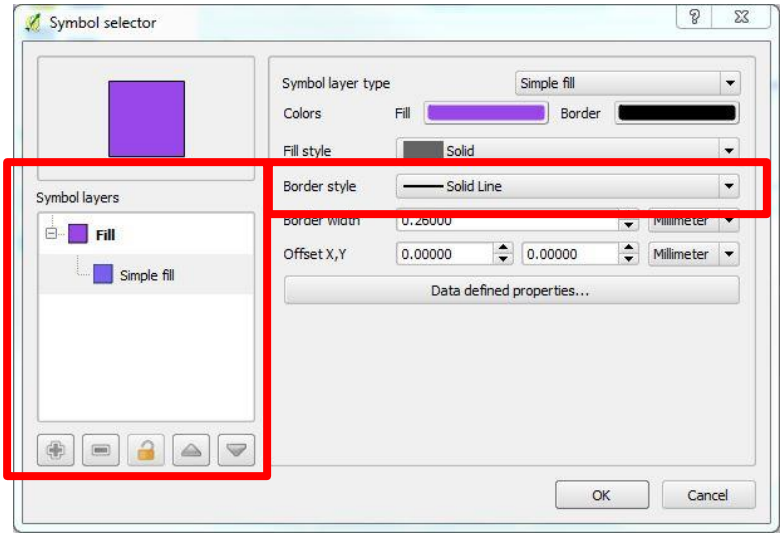
We will now symbolize *temperatureChangeMid* based upon the field atas in order to visually see where annual temperature change may be most severe.



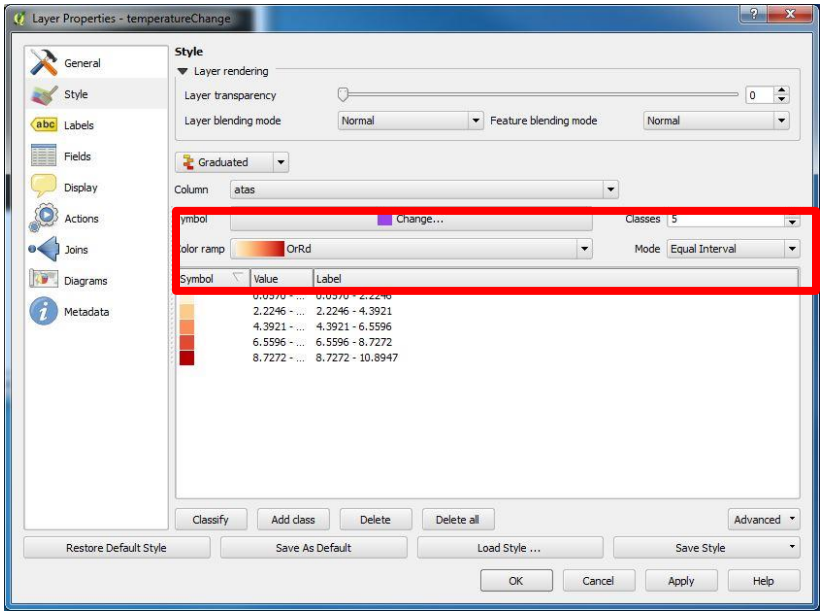
- Close the attribute table.
- Double click on *temperatureChangeMid* in the Table of Content (TOC) in order to open the Layer Properties window.
- Make sure the **Style** option is activated.
- Change the drop down for Single Symbol to **Graduated**.
- For Column select a**tas**.

Note that the colors are associated with data values from the attribute table. You can also choose the number of classes to display as well as the classification method (Mode).

- Click the Change button for the Symbol option in order to open the **Symbol selector.**



- In the Symbol selector dialog box click the **Simple fill** Symbol layers.
- Change the Border style from Solid Line to **No Pen**. This will eliminate any border from being displayed.
- Click **OK** to close the Symbol properties box.



- For Color ramp select **OrRd**.
- Make sure the Mode is **Equal Interval**.
- Click **Classify**.
- Click **Apply**.
- Take a look at your map.
- Change the Mode to **Quantile**, click **Apply**.

Take a look at your map.

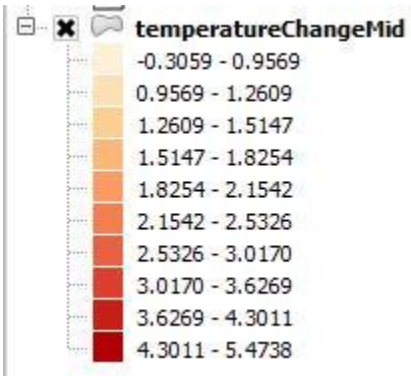
- Play around with the different classification methods and colors available through the **Mode** drop-down.

Below is a table with various other classifications and a description of each method:

Natural Breaks	Classes are based on natural groupings of data values (Jenk's method)
Quantile	Each class contains an equal number of features.
Equal interval	Divides your data into equally spaced classes.
Standard deviation	Classifies the amount a feature's attribute value varies from the mean.
Pretty Breaks	Breaks data into groups which are easily understood by non-statisticians.

- Once you are done experimenting with the different classification methods, change the Mode to **Natural Breaks**.
- Make sure the *Classes* are set to **10.**
- Make sure the *Color ramp* is **OrRd.**
- Click **OK** to apply the changes.

If the legend for this layer is not visible, then click the plus sign (Windows) and arrow (Mac) in the Table of Content (TOC) next to *temperatureChangeMid* to reveal the symbology of the layer.



This map illustrates the mean annual temperature change from the present to the middle of century. This layer is symbolized using the natural breaks classification method. The regions in darker red will experience more warming at the end of the century than those in lighter orange.

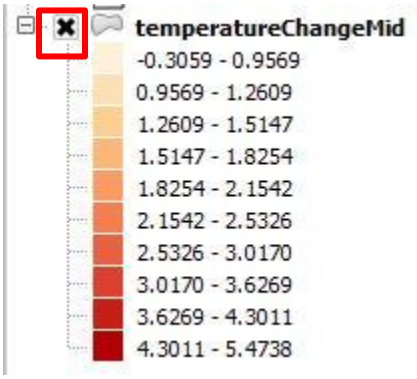
- Then click the **Zoom In** tool on the Navigation toolbar and draw a box around the continental United States.

Which regions in the continental US according to this dataset appears will have some of the most warming come the middle of the century?

- Click the Zoom Full tool in order to return to the full extent of the data.

Which regions globally according to this dataset appears will have some of the most warming come the middle of the century?

- Turn off the *temperatureChangeMid* layer, by unchecking the box beside the name *temperatureChangeMid* in the Table of Content (TOC).



- Click **Project > Save Project**.
- Save your map in **<your working directory>\maps** and name it **exercise1**.

STEP 5 Symbolize and Explore Precipitation Change

In the previous step we added a shapefile which contained information about future temperature change. In this step we will explore future precipitation change.

The data we are about to work with was downloaded from http://GISClimateChange.ucar.edu. This data is freely available and is available in shapefile and textfile format.

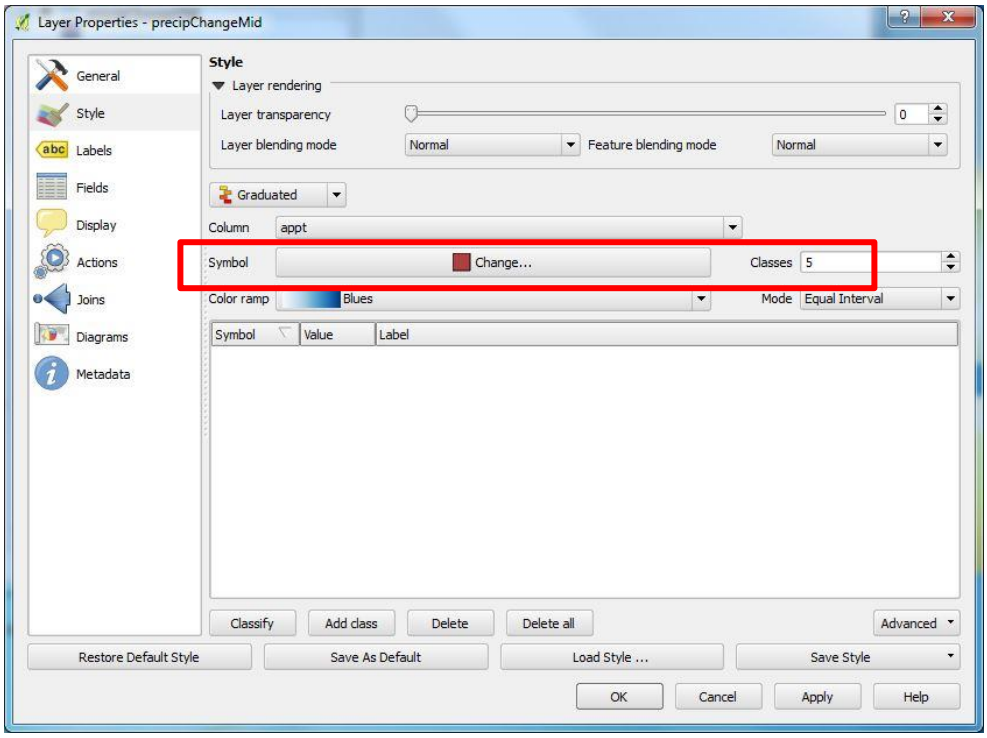
- Click the **Add Vector Layer**  button on the main toolbar.
- Click **Browse** and navigate to **<your working directory>\data** and select **precipChangeMid.shp**.
- Right click on *precipChangeMid* in the TOC and select  **Open Attribute Table**.

Notice that this shapefile contains one fields. This field contains the precipitation change for the mean of 2040-2059 compared to present day (1986-2005). This data is in mm/year.

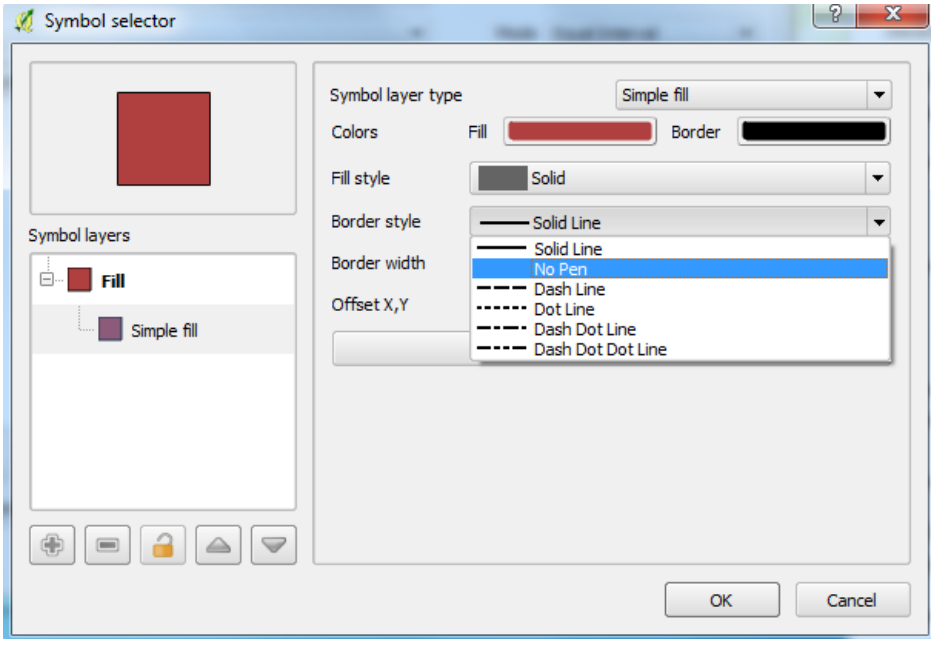
- **Close** the Attribute table.

We are now going to symbolize the *precipChangeMid* layer based on the field "appt".

- Right-click on the layer *precipChangeMid* in your TOC and select **Properties**.
- Make sure the **Style** option is activated.
- Change the drop down from Single Symbol to **Graduated**.
- For Column select **appt**
- Click **change…** button



- In the Symbol properties dialog box, change the Border style from Solid Line to **No Pen**.
- Click **OK** to close the Symbol properties box.



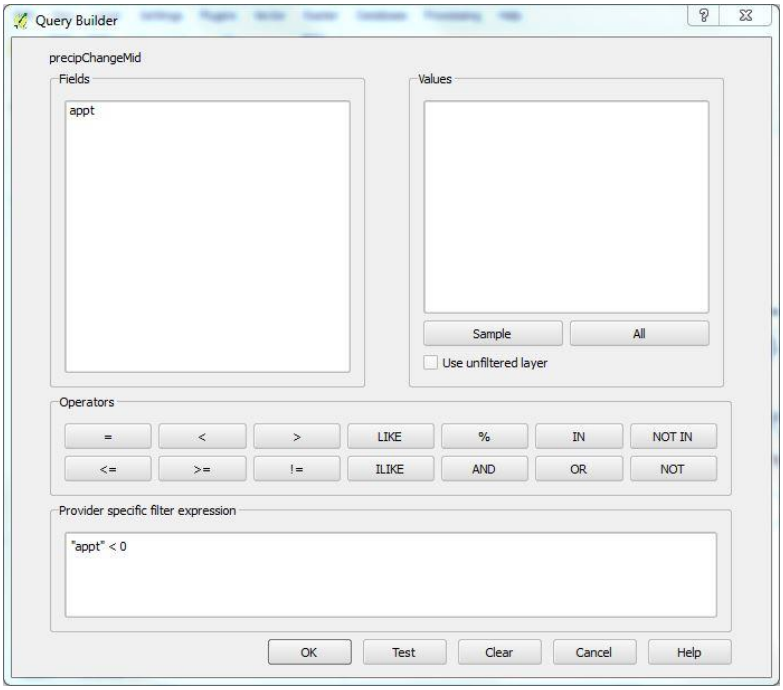
- For Color ramp select **RdBu**. This is a red-to-blue color ramp.
- Make sure the Mode is **Standard Deviation**.

- Change the number of Classes to **10**.
- Click **OK**.
- Drag the layer countries above *precipChangeMid* in the TOC, if it is not on top already.
- Take a look at your map.

The regions in dark red may experience a much drier climate in the future, while those in blue may receive more annual precipitation in the future

QGIS also has some powerful query tools. We can set up a Structured Query Language (SQL) query to see what regions are going to experience different magnitude of climate change.

- Right click on the layer *precipChangeMid* and select **Filter…**



- In the dialog which appears double-click on a**ppt** so that it appears in the SQL where clause box.
- Click on **<**.
- Click on the SQL where clause text box.
- Type in **0**.

Your SQL statement should look like the one to the right.

- Click the **Test** button to test the query and find out how many features are returned.
- Click **OK** to run the query builder.

The only data you will see on your map are those features which matched the query. These regions are areas which may experience a decrease in precipitation at the middle of the 21st century.

- Using the skills you have already learned change the symbology for *precipChangeMid* from **Standard Deviation** to **Natural Breaks** Mode. (HINT: Look in the Layer Properties)
- Change the Color ramp to **RdYlBu** and click **Classify**.
- Click OK.
- Use the **Zoom In** Tool on the Navigation toolbar zoom into the Americas.

Now the areas in red will have the most drying and those in blue will still have drying but less drying. Remember you are only see data which will have a dryer future climate according to the climate model. The area in white are those regions which may have a wetter climate.

Where do you see some of the most drying in the Americas? (Zoom in if needed)

- Right-click on *precipChangeMid* layer in your TOC and select **Filter…**
- Change your query to see what regions may experience negative annual precipitation anomalies (drying) more than 50 mm (ppt_change < -50) (*HINT: Clear your previous expression).*
- Click to the Zoom Full tool 

Where do you see some of the most drying globally?

- Right-click on *precipChangeMid* in the TOC and select **Filter…**
- Click **Clear**.
- Click **OK.**

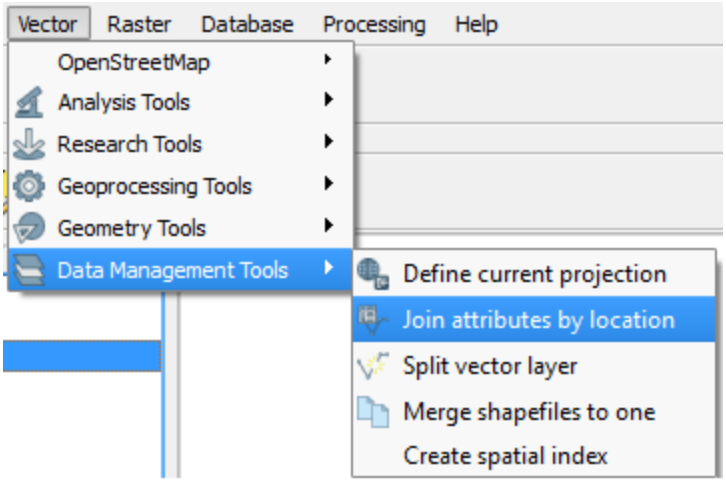
Since we have symbolized our data using Natural Breaks when we had a filter active, only the data which matched that query was used in the classification method for symbolizing our data. So now that we have cleared the query we still only see the data which matched our SQL query.

- Double click on *precipChangeMid* in your TOC and change the symbology Mode to **Pretty Breaks**.
- Change the Color Ramp to **RdYlBu**.
- Click **Classify**.
- Click **Ok**.

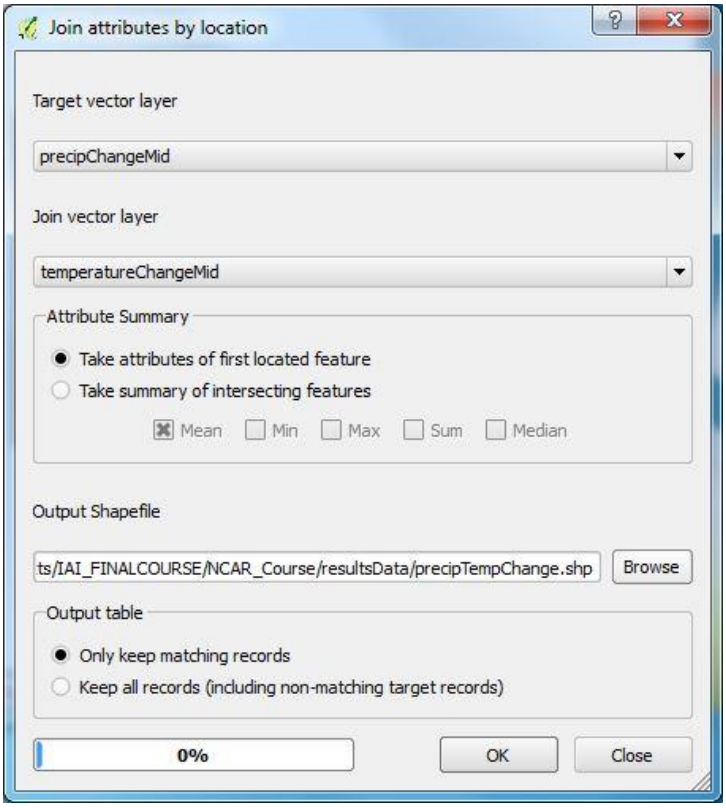
Step 6 – Identify regions of warming and drying

Next we will join the temperature change and the precipitation change datasets together in order to identify regions which may see a warming and drying by the middle of the 21st century.

- Click **Vector > Data Management Tools > Join attributes by location.**



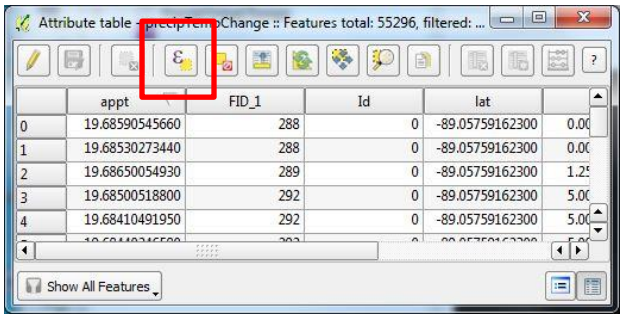
- In the dialog set the following parameters: **precipChangeMid** as the *Target vector layer*.
- Set **temperatureChangeMid** as the *Join Vector layer*.
- Make sure "*Take attributes of first located features is selected*".
- Save the *output shapefile* to **<your working directory>\data\results\precipTempChange.shp.**
- Once the dialog looks like the one below, click **OK**.



- Click **Yes** when asked to add this new layer to your map.
- Close the dialog box.

A new layer is now added to the TOC.

- Make sure the only two layers which are turned on are *Countries* and *precipTempChange*.
- Right click on the layer *precipTempChange* in the TOC and select **Open Attribute Table**.
- In the Attribute table click the **select features using an expression** button. 



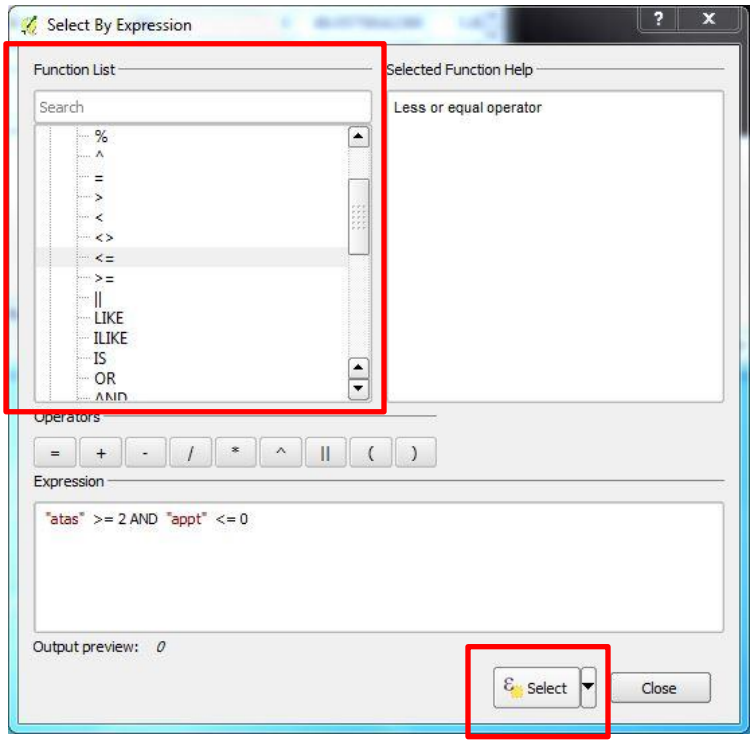
- In the *Select By Expression* dialog scroll to the bottom of the *Function* List box and open the **Fields and Values** option.

You should see both the variable apt (precipitation change) and atas (temperature change).

- Double-click on a**tas** in the fields list.

Make sure you see "atas" appear in the SQL where clause text box.

- In the *Function List* Open the *Operators* option and double click **>=**.
- Click in the SQL where clause and type in **2.**
- Double click **AND**.
- Back in the Fields and Values options, double click **appt**.
- Double click **<=**
- Type in 0.
- Your expression should look like the one below.

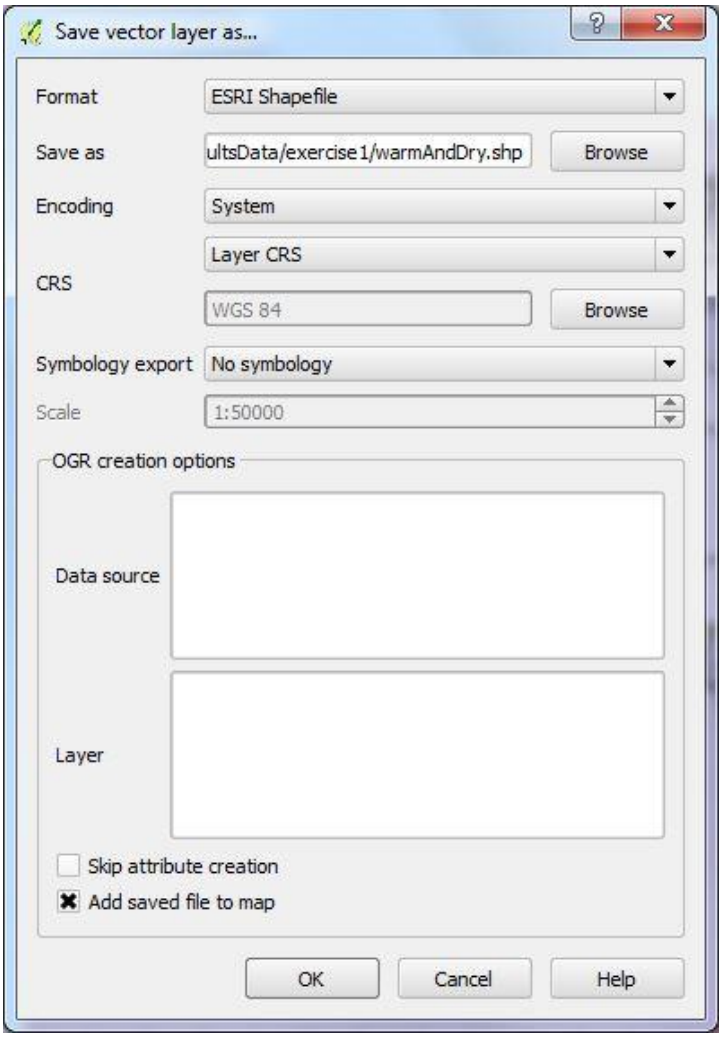


- Once your expression looks like the one above click the **Select** button.
- Click **Close**.

You should have 1391 features selected on your map and table. The grid cells highlighted in yellow are those which may experience greater than 2 degrees warming and drying by the middle of the 21st century.

- **Close** the Attribute table.

- Right-click on *precipTempChange* in your TOC and select **Save Selection As….**
- In the *Save vector layer as…* make sure the *Format* is set **to ESRI shapefile**.
- Click the **Browse** button to set he *Save as* file.
- Navigate to **<your working directory>/data/results** and type in the output file name to be **warmAndDry.shp**
- Click **Save**.
- Make sure the **Add saved file to map** is checked.



- Click **OK** to save your output selected grid cells to a new shapefile.

The warmAndDry shapefile has all the grid cells where the temperature change may be 2 degrees or greater by the middle of the century and which may experience drying.

Which regions may experience this warming and drying by the middle of the 21st century?

What may be some impacts from this change in climate in these regions?

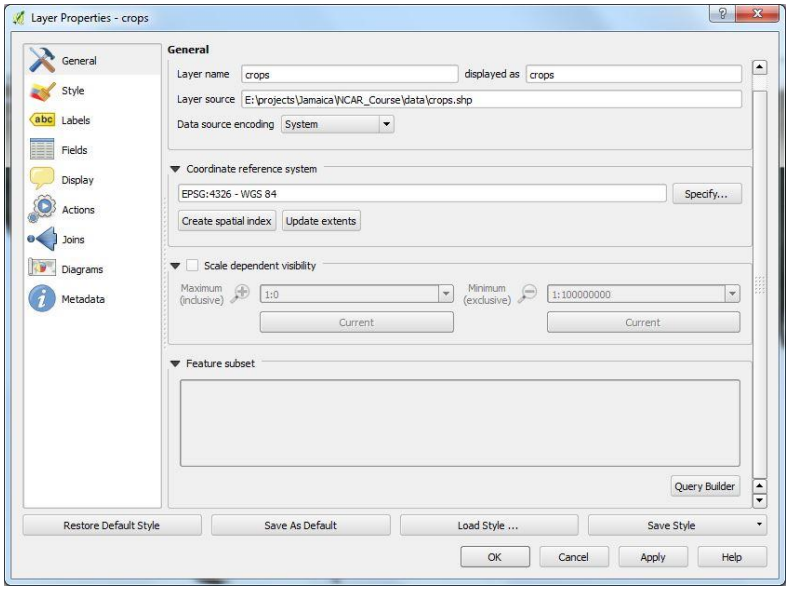
- **Save** your project.

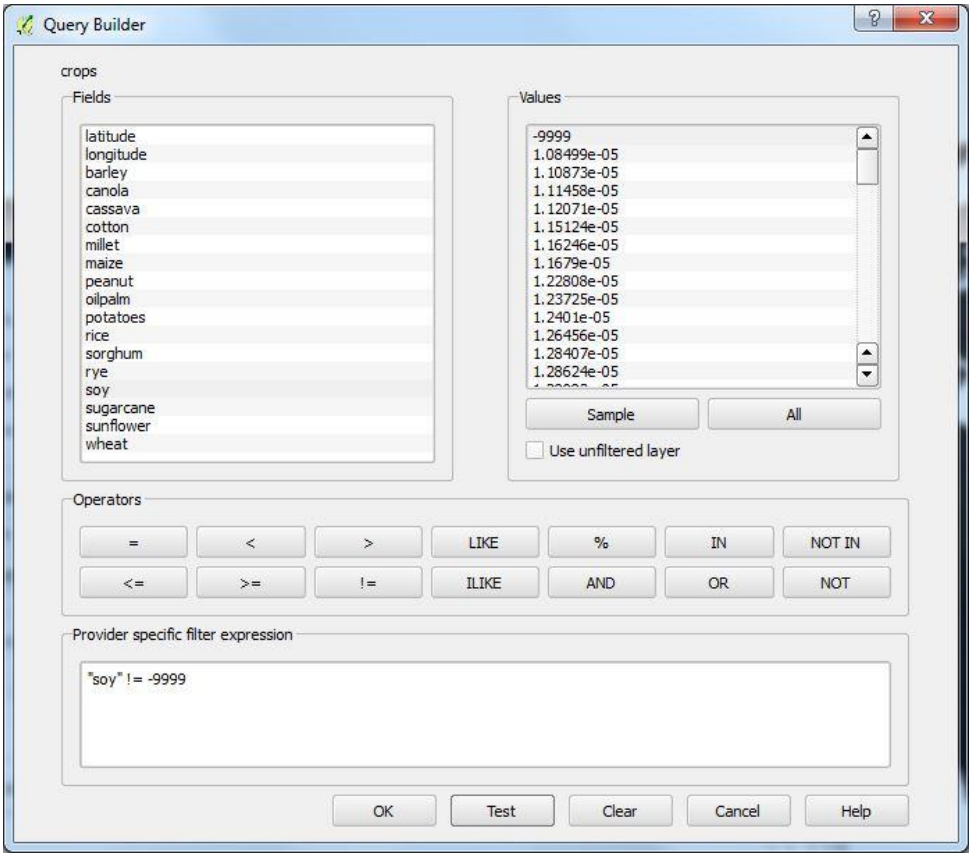
Step 7 – Identify which crops are currently within this region of possible future warming and drying

- Click the **Add Vector Layer** button on the main toolbar.
- Click **Browse** and navigate to **<your working directory>\data** and select **crops.shp**.
- Right click on *crops* in the TOC and select **Open Attribute Table**.

This shapefile are 0.5 degree grids in shape. Each attribute is a crop type. The values for each row tell us the fraction that this crop is grown in that grid cell. First let us symbolize the layer crops for a few types of crops.

- Close the Attribute table.
- Double click on the layer crops and make sure the General option is selected.
- We will set up a Feature subset so that we are only mapping features which contain some level of Soy agriculture.
- Click the Query Builder button in the Feature subset section of the dialog box.





- In the Fields double click on Soy so that it appears in the expression box.
- Click "!="
- And type in -9999.
- Once your expression looks like the one above click OK.
- Back in the Layer Properties click Apply.

This expression will virtually remove all features which have the value of -9999 from our visual display. This means that we will now map only those features which have some soy agriculture.

- Click the Style option.
- Change the way we will symbolize the data from Single Symbol to Graduated.
- Change the Column to Soy.
- Change the Color Ramp to Greens
- Click the Change… button
- In the Symbol Selector click the Simple fill option and change the Border Style to No Pen.
- Click OK to close the Symbol Selector.
- Click OK to apply the symbolige and close the Layer Properties dialog box.

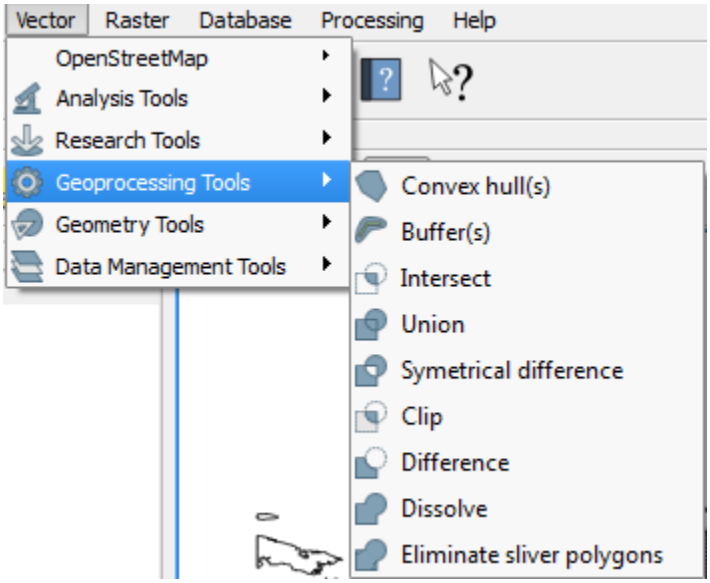
Where are some of the highest concentrations of Soy agriculture?

- Turn on the layer warm and Dry.

Does the highest regions of Soy agriculture correspond with the regions which may experience the most warming and drying?

An easier way to identify what crops fall within the region of warming and drying is to perform a process called Intersect. An Intersect will take two layers and extract all features from one layer which intersect the second layer. In this case our first layer will be crops (this is the layer we wish to extract) and we want to extract all crop grids which intersect with the warmAndDry layer.

- Double click on the layer crops in order to open the Layer Properties box.
- In the General Option click Query Builder.
- Click Clear in order to clear the query, and click OK.
- Click OK again to close the Layer Properties dialog box.
- Click Vector > Geoprocessing Tools > Intersect.



- In the Intersect tool set the Input vector layer to crops and set the Intersect layer to warmAndDry.
- For the output shapefile save the new file to <your working directory>\data\results and call it WarmDryCrops.shp.
- Click Ok to run the tool.

This tool will extract all polygons from the layer crops which intersect with the warmAndDry layer. So the resulting shapefile will be all crop polygons which may have a warmer and dryer future according to the CESM climate model.

- When asked say Yes to adding the new layer to your map.
- Close the Intersect tool.
- Turn off the layers crops and warmAndDry. The only layers you need to have turned on are Countries and warmDryCrops.

Using the skills you have learned in this lesson symbolize WarmDryCrops using Graduated Colors for some of the different crop types. Experiment symbolizing using different methods such as Equal Interval, Standard Deviation, Pretty and using different color ramps.

Working with the symbology answer the questions below.

What may be some impacts from this warming and drying on crops in the United States?

Which crops are found in the warming and drying regions of Europe?

- Once you are happy with your maps Save your map and close QGIS.

Summary : In exercise 1 we learned how to add vector data to QGIS. We symbolized vector data based on qualitative and quantitative fields. Using the Filter and Selection tools we were able to see the range of possible temperature and precipitation change a region may experience. And finally using QGIS's advanced integration tools we were able to see which regions and crop types may be affected by a 2 degree temperature increase and a drying by the middle of the century.