Exercise 2: Identifying Drought Using Precipitation and Vegetation

Introduction

In this exercise we will use the TMPA precipitation and MODIS NDVI data we downloaded in Session 1 to analyze 2015 drought conditions over California.

Objectives

By the end of this exercise, you will be able to:

- Open and display precipitation and NDVI maps in QGIS
- Calculate long-term NDVI average based on 2001-2010 images
- Generate precipitation and NDVI anomalies by taking the difference between 2015 precipitation and the long-term average

Data Requirements

For this exercise you will need the TMPA and NDVI data over California that you downloaded from Session 1 Exercise. These should include the following:

- TMPA raster files in NetCDF (.nc) format:
  - January to December monthly precipitation climatology files based on 2001-2010 data
  - January to December monthly precipitation files for 2015
- NDVI images in GeoTIFF format:
  - The NDVI image for each year from 2001-2010
  - The NDVI image for 2015 in mid-July

We recommend that all data for this exercise be well organized and remain in the same location. You may also find it useful to open up the QGIS project you created in the last session that contains your NDVI data.

Prerequisites and Additional Informational Websites

QGIS and associated plugins should already be downloaded as one of the prerequisites for this course. See Downloading and Installing QGIS on the ARSET website for more information. This introduction assumes that you have a basic background with

geospatial software. If you are not familiar with any geospatial software we suggest spending some time exploring QGIS prior to the webinar. Additionally, QGIS has very useful user tutorials.

Note: To process the precipitation data, you must be using the current version of QGIS (2.18.9 or 2.18.10) to work with the NetCDF files.

Homework

In order to complete the homework for this training, complete all of the steps outlined in this exercise. Use the homework link below, or find it on the ARSET website, to complete the Google Form. Some of the homework questions will come from the lecture, and some will come from completing this exercise. Homework Link: https://goo.gl/forms/QA78yYnojliKvQy12

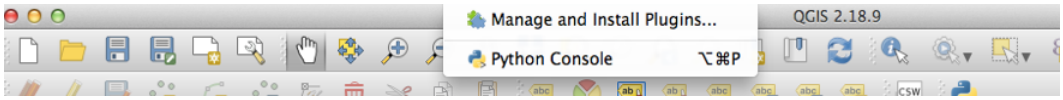
Outline

- Part 1: Display TMPA Climatological Precipitation
- Part 2: Calculate Precipitation Anomalies
- Part 3: Scale MODIS Images
- Part 4: Display MODIS Images
- Part 5: Calculate NDVI Average and Anomaly
- Part 6: Clip precipitation and NDVI Images to California
- Part 7: Co-analyze Precipitation and NDVI Anomalies

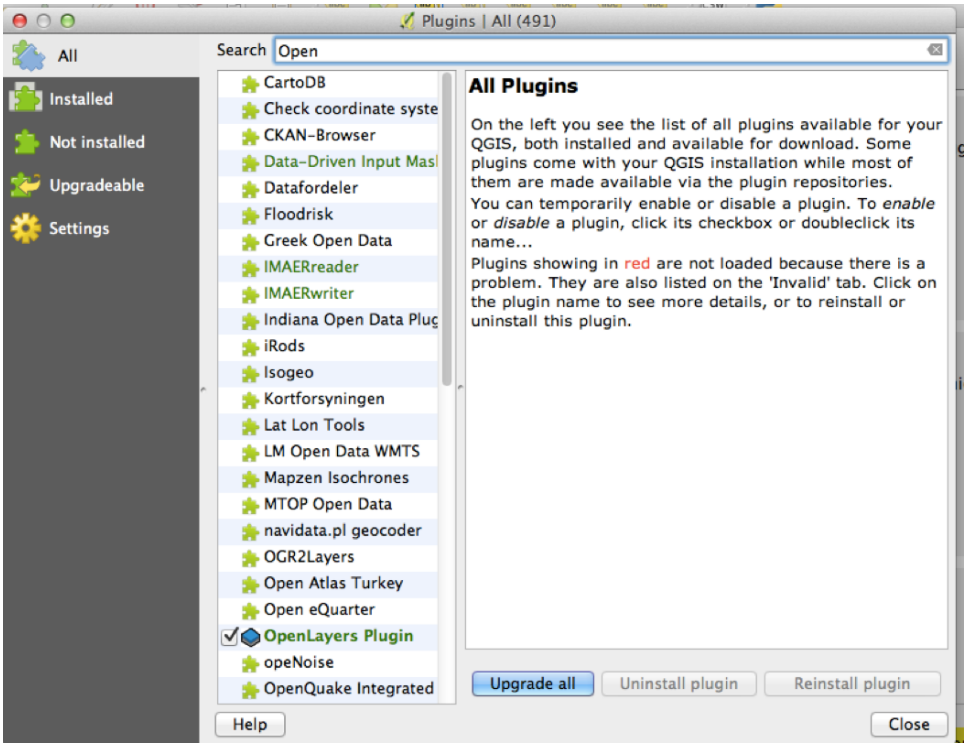
Part 1: Display TMPA Climatological Precipitation

If you have stored your TMPA data in a folder with a long filename from Giovanni, you may want to rename your files with a short name (e.g. TMPA-Clim_Jan.nc for January climatology and TMPA-2015_Jan.nc for January 2015). This will keep you from receiving errors when you add the data and will look cleaner in your map.

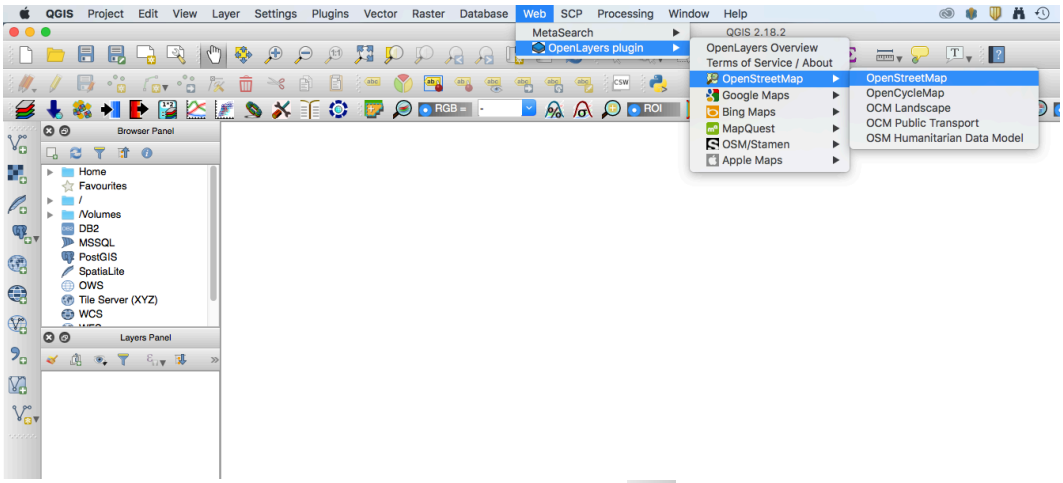
1. Open QGIS and start a new project
2. On the top menu bar, click on **Web** to check if you have **OpenLayers Plugin**
    a. If you do not have **OpenLayers Plugins**
    b. From the top menu bar select **Plugins** and choose **Manage and Install Plugins**



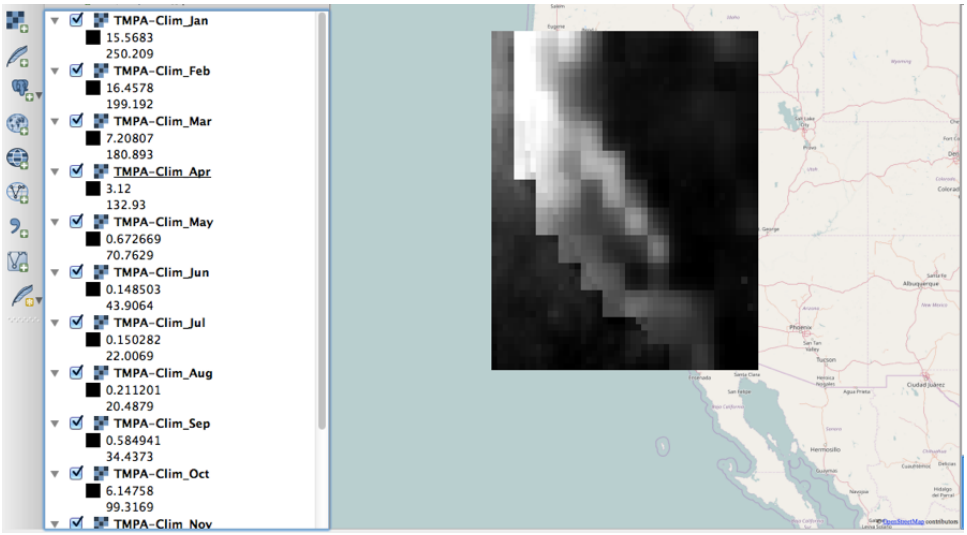
    c. You will get a window with options for Plugins
    d. Enter OpenLayers in the search window
    e. Select by clicking on the **OpenLayers Plugin** and press **Install** in the bottom right
    f. After the installation is complete you will be able to access the **OpenLayers Plugin** through the **Web** dropdown in the top menu bar



3. From the top menu bar, click on **Web**, select **Open Layer Plugin** and select a background map
    a. This exercise uses the plugin **OpenStreet Map**



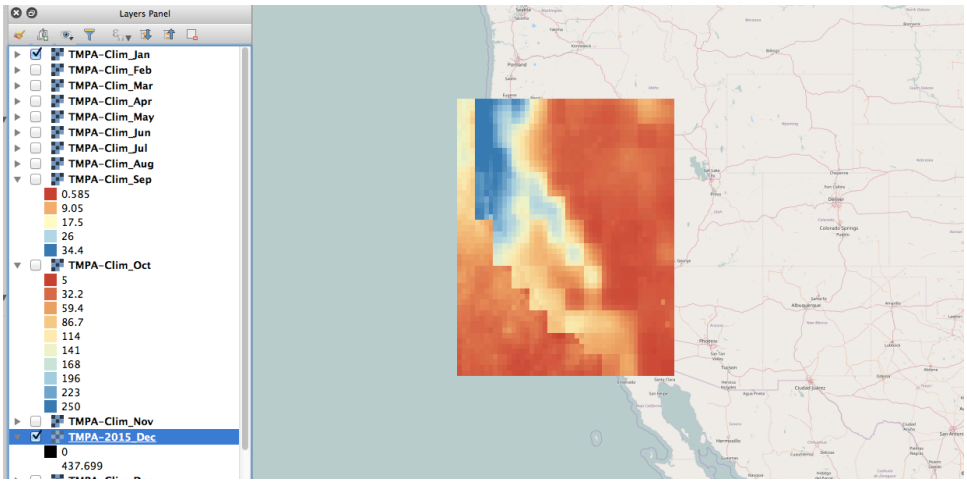
4. In your QGIS map, click on the **Add Raster** function on the left
5. Navigate to your saved TMPA climatology data files and click on **Open** to add each monthly data file from January to December. You can do this all at once by highlighting each file.
    a. You may be prompted to select a coordinate reference system for each layer. If this window pops up, select **WGS84,** Authority ID **EPSG:4326.** You can narrow the options by typing WGS84 into the **Filter** option at the top. Click **OK.** You will need to repeat the NAD83 selection for all layers.
    b. You may have to reorder your data files in the **Layers** panel by selecting and dragging them into the correct order.



c. From the top Menu Bar you can zoom in and out on the layer

You will notice that the images show as grayscale colors in QGIS. To be able to see the precipitation variations more clearly, we will display the images in color.

6. Right click on the layer file and go to **Properties** > **Style**.
7. Select the **Render Type** as **Singleband Pseudocolor**.
8. Next to **Color**, make sure the color palette Red-Yellow-Blue selected (RdYlBu).
9. Select **Min** value to be 5 mm/month and **Max** value to be 250 mm/month
10. Below the color display, change the **Mode** to **Equal Interval** and **Classes** to 10. Click **Classify**. Click **Apply**.
11. Without closing the **Properties** window, move it over to take a look at the image. It should have the color designations you just selected.
12. Click **OK** to close the Change Color box.



13. Change all the files in the map to have the same color scheme.
    a. As an alternative to repeating these steps manually, you can save your color palette.
    b. Click on the **Export color map**  to file icon in the layer properties.
    c. Save the color scheme as Precip_colors.
    d. Right click on the next file (e.g. TMPA-Clim_Feb.nc) and go to Layer Properties.
    e. Make sure that the **Render Type** is set to **Singleband Pseudocolor**
    f. Make sure **Min** and **Max** are set for 5 and 250, respectively

g. Make sure that the **Mode** is set to **Equal Interval**
h. Click on the **Load color map from file** icon  and select your Precip colors.txt file. This will automatically load the same color scheme.

14. Make the layer transparent to see the map underneath
    a. Right click on the layer file and go to **Properties** > **Transparency**
    b. Set the Transparency level to 50%
    c. Click on **Apply** and then **OK**

As a reminder, it is always a good idea to save your QGIS project along the way so your work is not lost.

Part 2: Calculate Precipitation Anomalies

1. In the QGIS map, click on the **Add Raster**  function again
2. Navigate to your saved 2015 TMPA data files and click on **Open** to add each monthly data file from January to December. You can do this all at once by highlighting each monthly 2015 file.
3. Next we will create a precipitation anomaly map for 2015. What you are essentially doing here is subtracting each month of climatological data from corresponding 2015 precipitation values.
4. Go to **Raster/Raster Calculator**.
5. Put this expression in the Raster calculator expression:

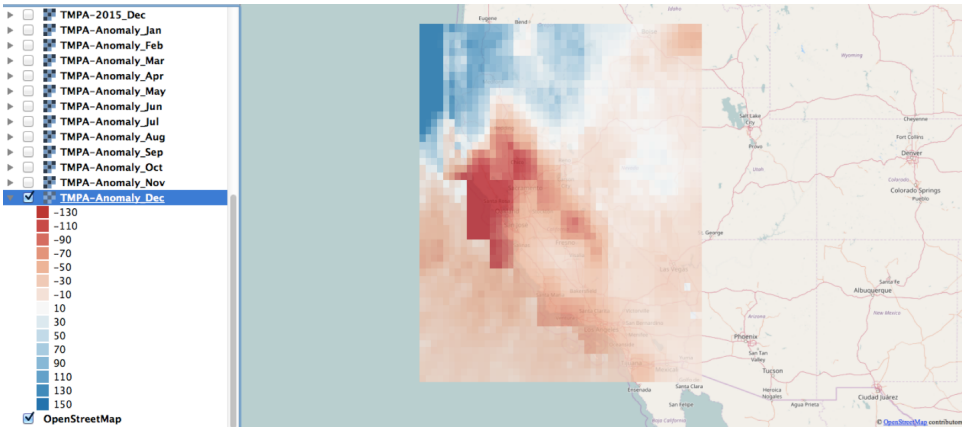
   "TMPA-2015_Dec@1" - "TMPA-Clim_Dec@1"

6. Click on the button with 3 dots next to the Output Layer box, to ensure that you save your image in the correct folder.
   a. Your X min should be -126.000000, X max should be -114.0000, Y min should be 32.00000, and Y max should be 44.00000. If it isn't, make sure one of your TMPA files on the left is selected, and click **Current Layer Extent.**
7. Give your output layer a name (Precip_anomaly-Dec).
8. Click **OK**.

Once this process runs, you will see the Precip_anomaly-Dec map layer added back to the map as grayscale.

9. Follow the procedure to change the layer image colors as before with the color scheme RdBu
10. Select **Min** value to be -130 mm/month and **Max** value to be 150 mm/month
11. Change the **Mode** to **Equal Interval** and **Classes** to 15. Click **Classify**. Click **Apply**.
12. Change the transparency of the layer as before.

Now you have successfully created your own Precipitation anomaly images for December 2015. Repeat the same procedure to create anomaly maps for all months of 2015.



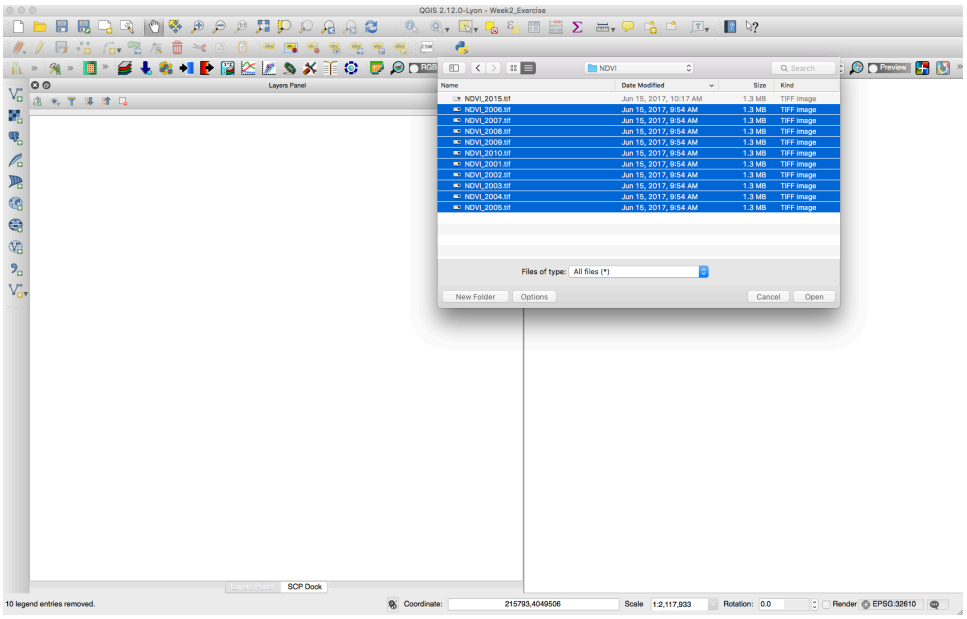
Examine the anomaly maps. The negative anomalies indicate deficit and positive anomalies indicate excess of precipitation in December 2015 compared to December climatological mean. In California, the majority of the precipitation falls between November and March. If you look at the anomaly images for those months, you will see negative anomalies throughout the state but particularly in north central California, the Sierra Nevada mountain range in the east and Southern California.

Next we will examine NDVI anomalies. We will also learn how to clip the images to the state of California.

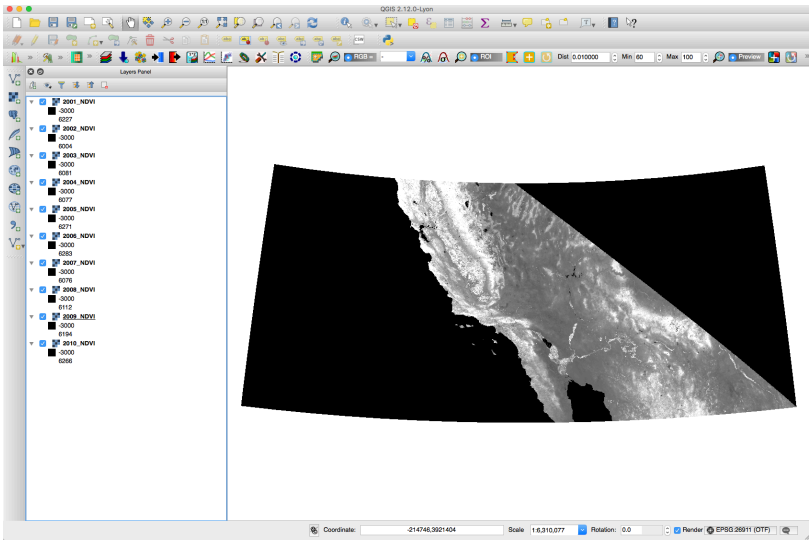
Part 3: Scale MODIS Images

If you have stored your images in a folder with a long directory, you may want to copy all images to one folder and rename your individual images with a short name (e.g. NDVI_2001.tif). This will keep you from receiving errors when you add the data, and will look cleaner in your map.

1. In your QGIS map, click on the **Add Raster**  function on the left
2. Navigate to your saved MODIS NDVI images and click on **Open** to add each image from 2001-2010. You can do this all at once by highlighting each image.
3. Navigate to your saved MODIS NDVI images and click Open to add the 2015 image



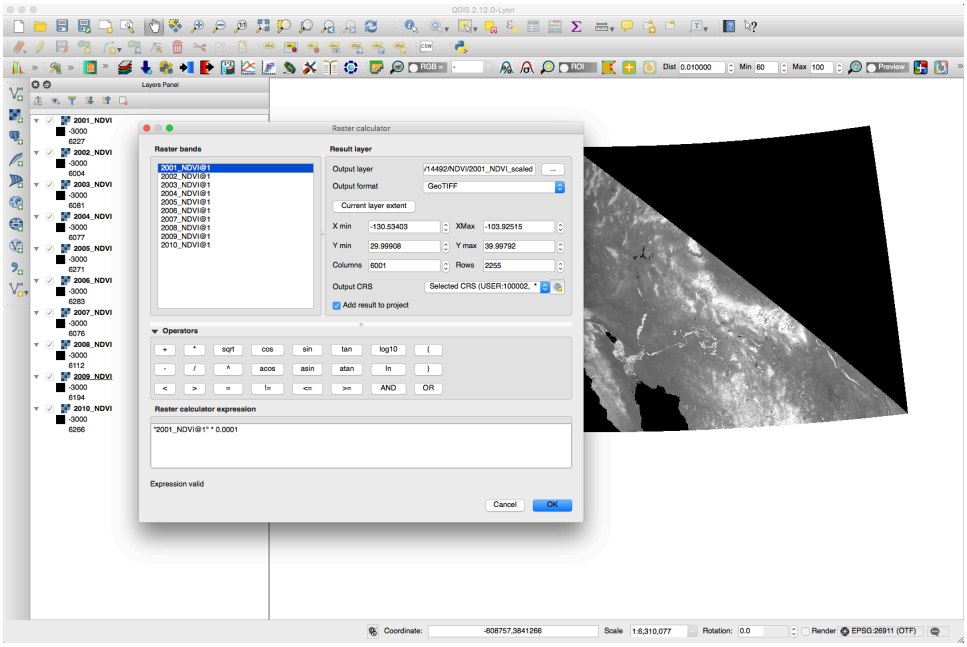
4. Reorder your images in the Layers panel by selecting and dragging them into chronological order.



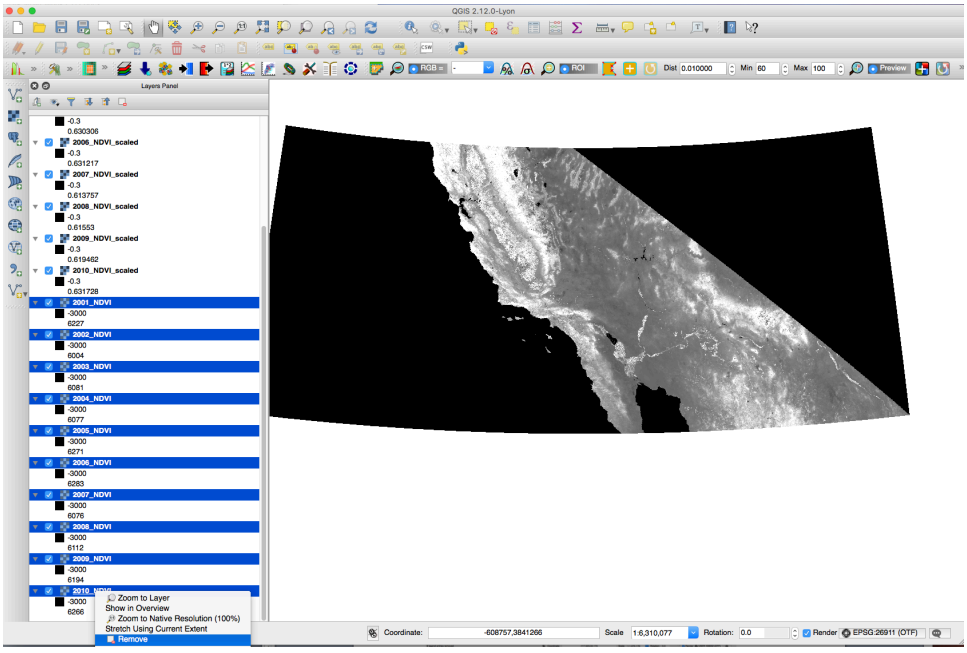
You will notice that the images show as greyscale colors in QGIS. The numbers do not range from -1 to 1 so you need to multiply each image by .0001. This is the scaling factor for MODIS images. You can find more information about this product and the scaling factor on the product information page.

5. Along the top of your QGIS map, go to **Raster > Raster Calculator**. This function allows you to perform specific mathematical expressions to your raster layers.
6. In the box on the top left, double click on the **2001_NDVI@1** layer in the **Raster bands** to move that layer into the **Raster calculator expression**.
7. Click on the multiplication function (*)
8. Type in **.0001**
    - The formula should look like this:
        i. **"2001_NDVI@1" * 0.0001**.
9. Give it an output name (2001_NDVI_scaled) in the Output layer box
    - Click on the button with 3 dots next to the box, to ensure that you save your image in the correct folder.
    - Leave all other settings as default, and make sure the **Add results to project** box is checked. Click **OK**.
    - When the process runs, it should add the layer to your map.

10. Complete the same process for all of your images (2001-2010 and 2015).



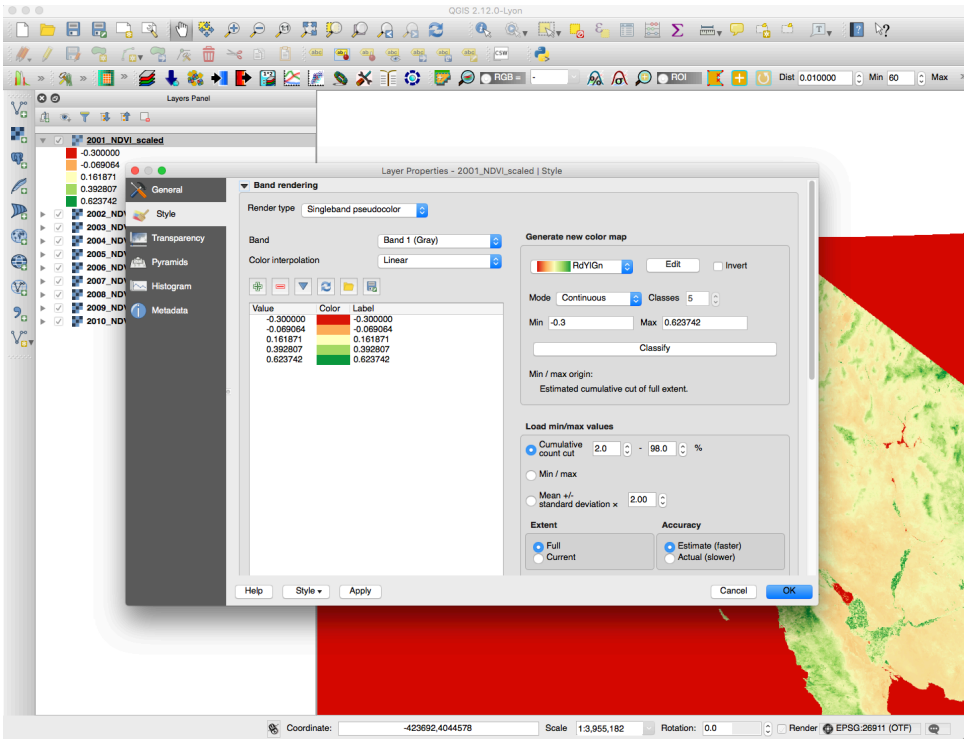
11. Once you have all the new scaled NDVI images in your map, you can remove all the original images. You can do this by right clicking on the layer in the **Layers Panel**, and clicking **Remove**.
    - Double check to ensure all your scaled NDVI images have values ranging from -1 to 1.



Part 4: Display MODIS Images

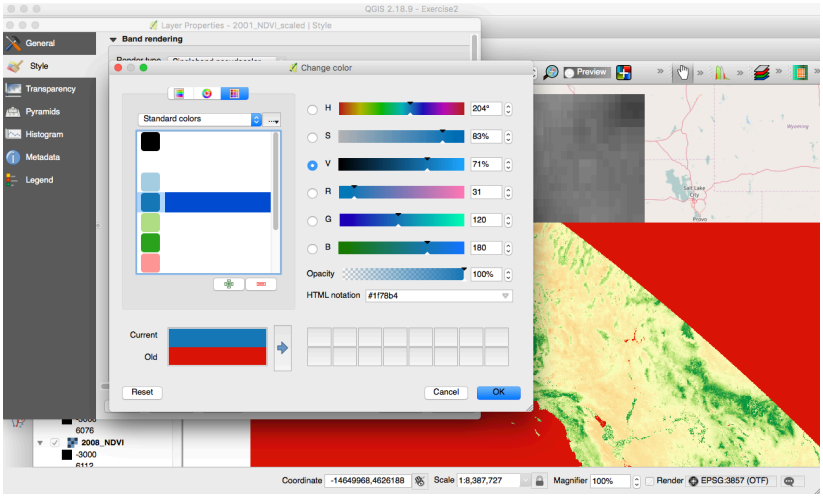
The MODIS NDVI images are currently in black and white. The lighter the color, the higher the NDVI value. The darker the color, the lower the NDVI value. As you recall, NDVI values range from -1 to 1, with 0 having no vegetation and 1 having the highest density vegetation. Generally, a good way to view an NDVI image is with a color ramp ranging from red (low NDVI values) to green (high NDVI values). For this portion we will change the display of our images.

1. Right click on the 2001_NDVI_scaled layer file and go to **Properties > Style**.
2. Select the **Render Type** as **Singleband Pseudocolor**.
3. Under **Color**, make sure the color palette Red to Green is selected (RdYlGn).
4. Leave the **Mode** as **Continuous** and **Classes** as **5**. Click **Classify**. Click **Apply**.
5. Without closing the **Properties** window, move it over to take a look at the image. It should have the color designations you just selected.

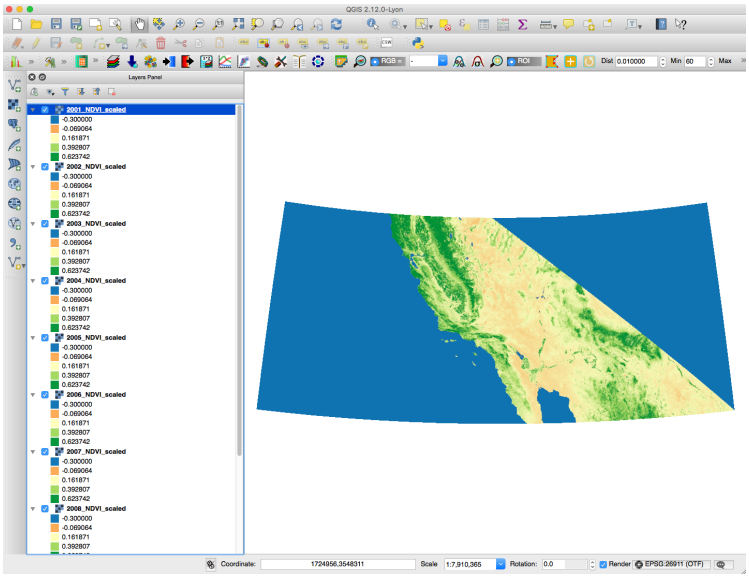


6. Because we have an image with large water bodies (the Pacific Ocean) and no value regions (to the east) these regions are negative and colored red.

7. Change the red color to blue by double clicking on the red box. When the **Change Color** box comes up, select pick blue.



8. Click **OK** to close the Change Color box. Click **Apply** to apply the color to the image.
9. Change all the files in the map to have the same color scheme.
    - As an alternative to repeating these steps manually, you can save your color palette as you did for the precipitation images.
    - Click on the **Export color map to file** icon  in the layer properties.
    - Save the color scheme as NDVI_colors.
    - Right click on the next file (2002_NDVI_scaled) and go to **Properties**.
    - Click on the **Load color map from file** icon  and select your NDVI colors.txt file. This will automatically load the same color scheme

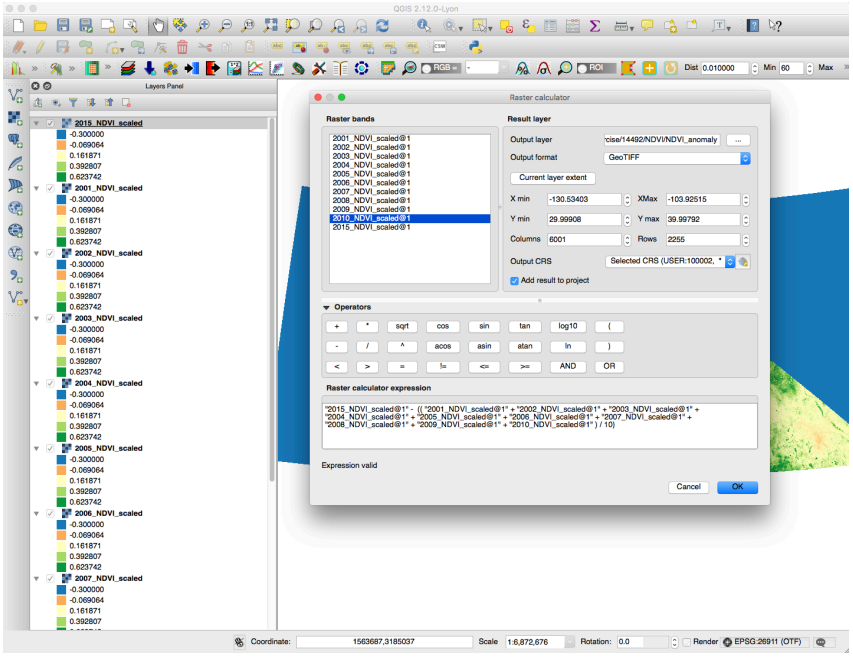


As a reminder, it is always a good idea to save your QGIS project along the way so your work is not lost.

Part 5: Calculate NDVI Average and Anomaly

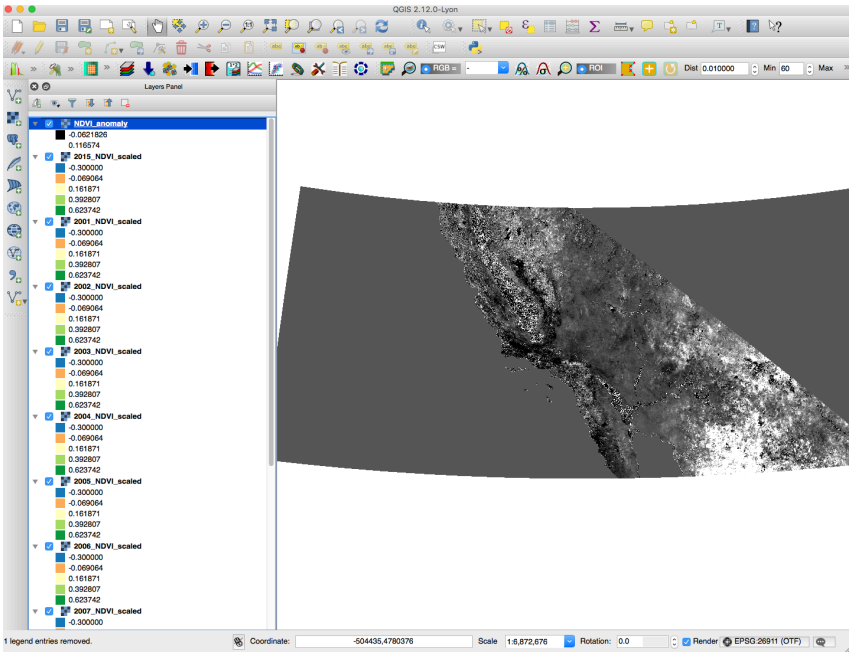
Next we will create an NDVI anomaly image from your subset images. Essentially, what you are doing here is creating an average NDVI for July from the 2001 to 2010 images, then subtracting that average from the July 2015 values.

1. Go to **Raster > Raster Calculator**.
2. Put this expression in the Raster calculator expression:
3. "2015_NDVI_scaled@1" - (("2001_NDVI_scaled@1" + "2002_NDVI_scaled@1" + "2003_NDVI_scaled@1" + "2004_NDVI_scaled@1" + "2005_NDVI_scaled@1" + "2006_NDVI_scaled@1" + "2007_NDVI_scaled@1" + "2008_NDVI_scaled@1" + "2009_NDVI_scaled@1" + "2010_NDVI_scaled@1") / 10)
4. Click on the button with 3 dots next to the box , to ensure that you save your image in the correct folder.
5. Give your output layer a name (NDVI_anomaly).
6. Click **OK**.



Once this process runs, you will see the NDVI_anomaly map layer added back to the map as grayscale.

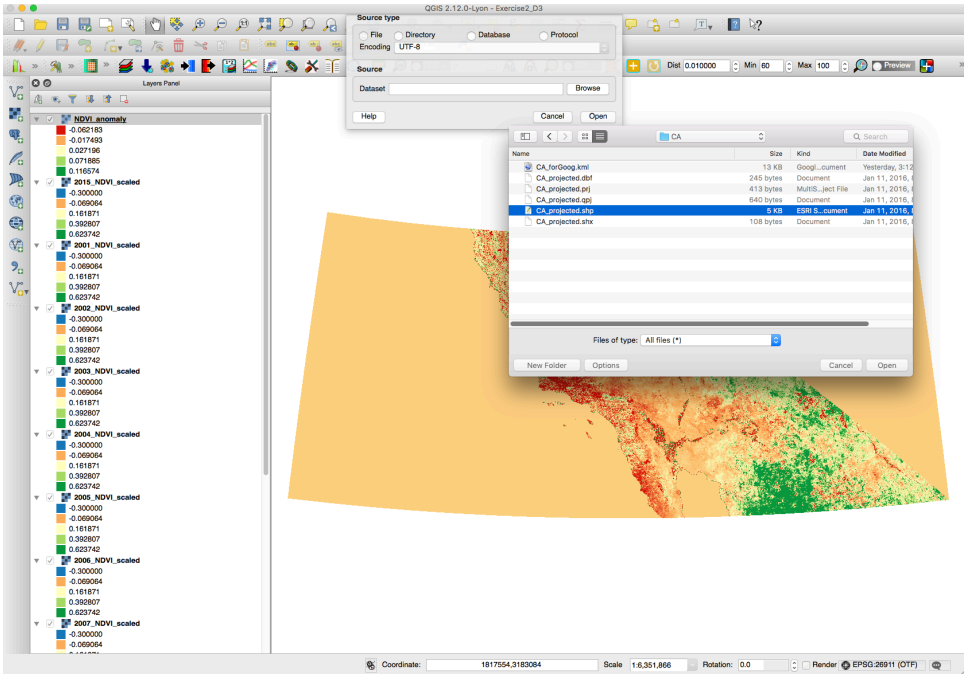
7. Change the color scheme to the same RdYIGn as before. You will notice that the background (Pacific Ocean) will appear tan in color because there is no change.



Part 6: Clip NDVI Image to California

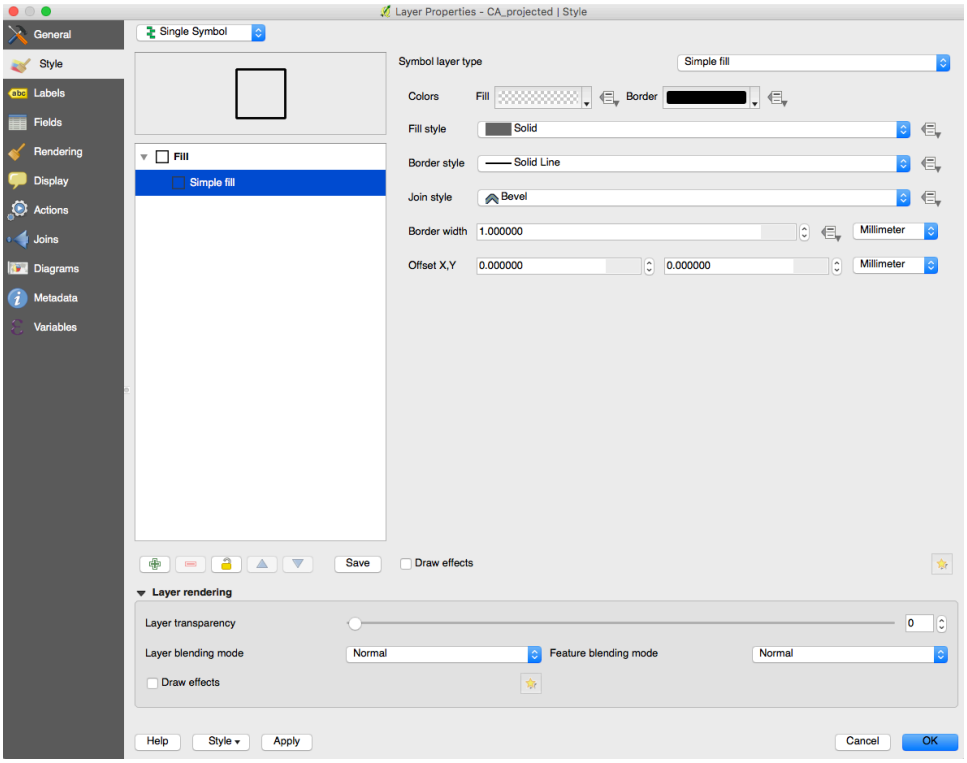
As a next step, let's clip the NDVI anomaly map to California.

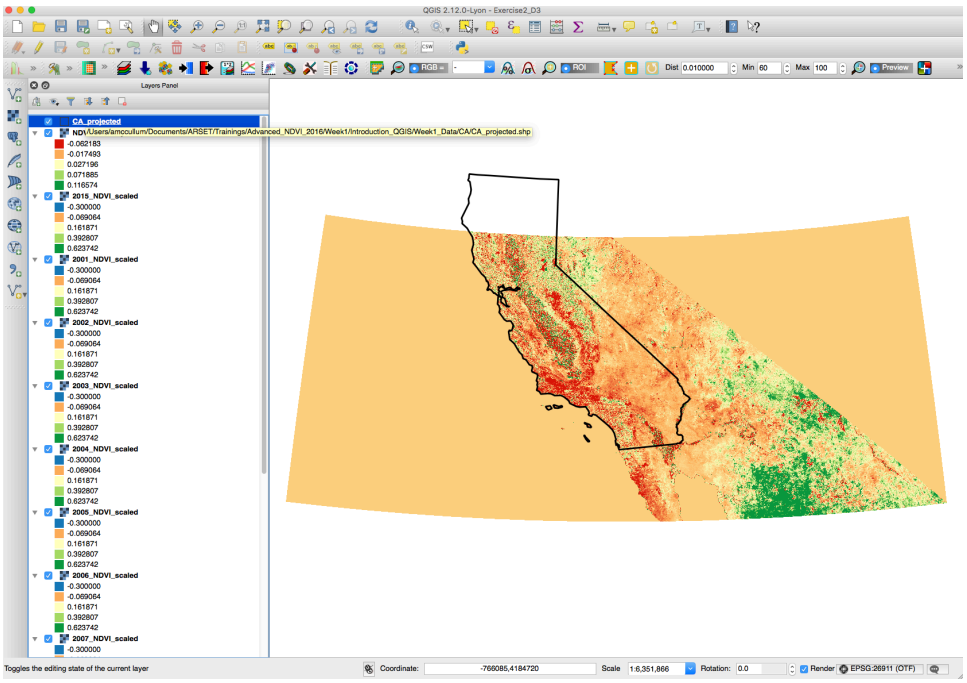
1. Go to the ARSET page for this training: https://arset.gsfc.nasa.gov/water/webinars/drought17 and download the zipped California folder. This is a vector of the state of California. We will use this as the boundary to remove portions of the MODIS NDVI image where we do not want to perform the anomaly calculation.
2. Click on the **Add Vector Layer** icon  and navigate to the CA_projected.shp file and click **Open**.



3. Right click on the **CA_projected** layer and go to **Properties > Style**
    - As an alternative you can double click on the layer color in the **Layers Panel** and you will be taken to the **Style**.
4. Click on **Simple Fill** and next to **Colors** click on the down arrow to change the **Fill** to **Transparent**
5. Change the **Boarder Width** to 1

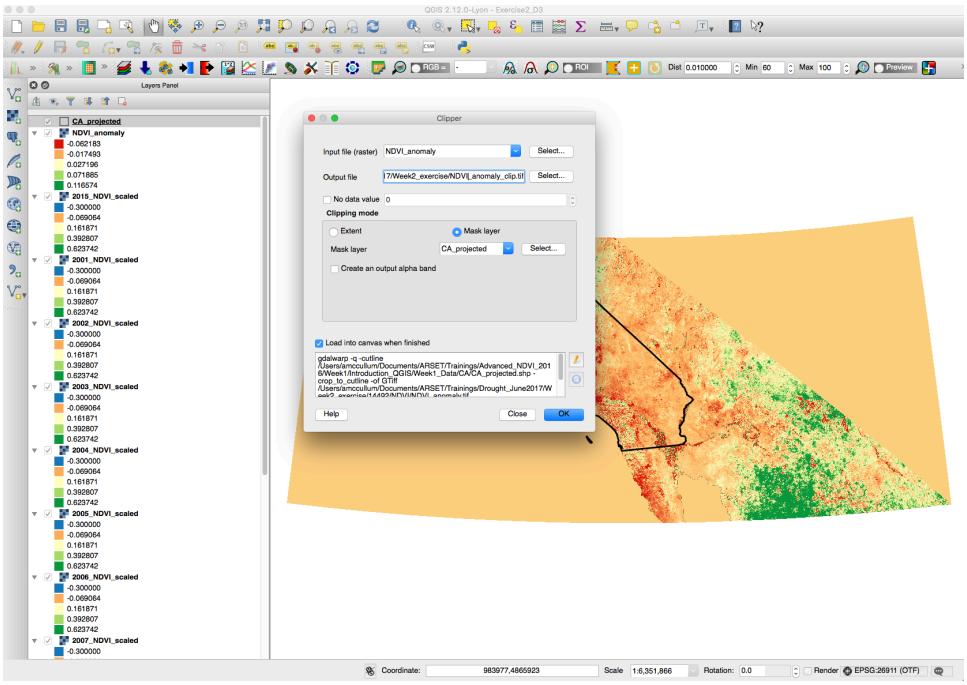
6. Click **OK**



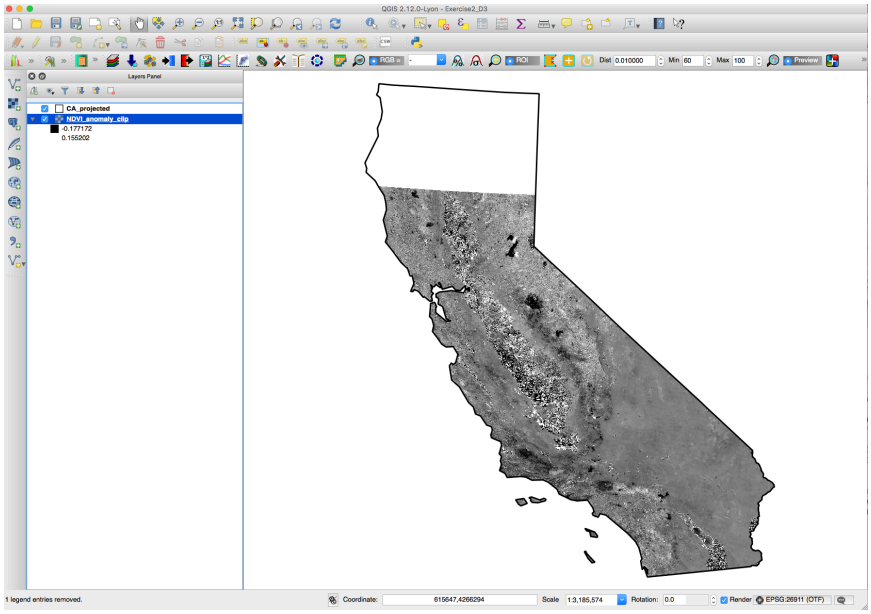


7. Along the top panel select **Raster** > **Extraction** > **Clipper**
8. Select the NDVI_anomaly layer in the **Input file (raster)**

9. Click on **Select** next to **Output file**, and navigate to your week 2 folder and save the file as NDVI_anomaly_clip
10. Under the clipping mode select **Mask layer**
11. Click **OK**



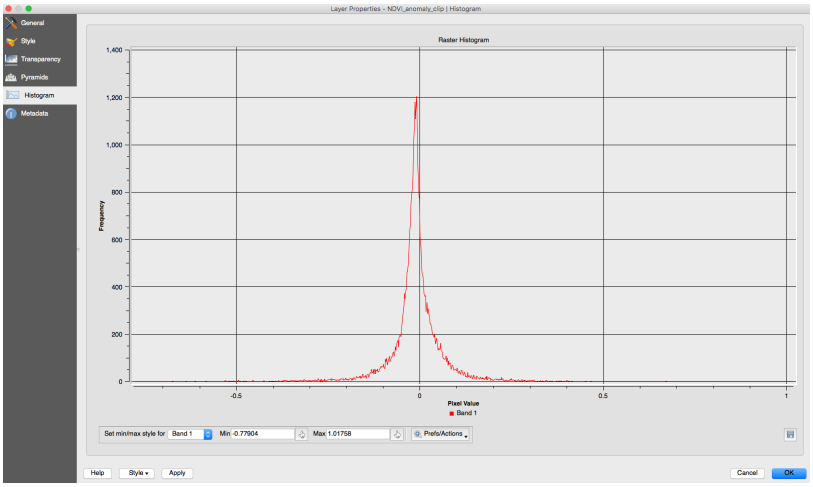
12. Once the processing is finished, the clipped NDVI anomaly will be added to the map.
13. Click **Close** to exit the **Clipper** tool.
14. To clean up your QGIS interface, remove all files except the CA_projected and the NDVI_anomaly_clip.
    - You can do this for all files at once by selecting them all, right clicking on the files, then selecting Remove.



15. The image will be grayscale, so you can change the color scheme to see the anomalies more clearly.
16. Go to **Properties > Style**
17. Change the **Render Type** to **Singleband pseudocolor**
18. Choose the **RdYlGn** colors, use the **Continuous** mode and 5 classes
19. Click **Classify**

This will automatically select classes based on the distribution of the NDVI anomaly values. Let's take a look at the distribution of the data.

20. Right click on the **NDVI_anomaly_clip** file in your **Layers Panel**
21. Go to **Properties > Histogram**
22. This shows you the distribution of your data. You can see the minimum, maximum, and the slightly left (negative) skew of the data.

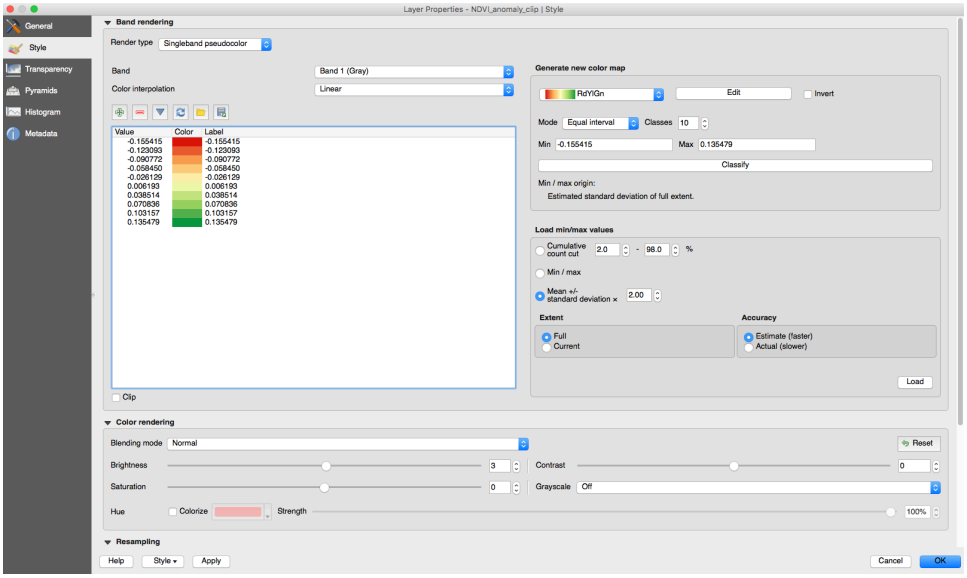


23. Click on the **Metadata** tab and scroll down to **Properties**
24. Under **Band 1** you can see the data layer statistics.

You can use the information about the data statistics to make decisions on how to modify the color scheme and the classes. So let's add a few classes to more clearly identify regions that may be affected by drought.

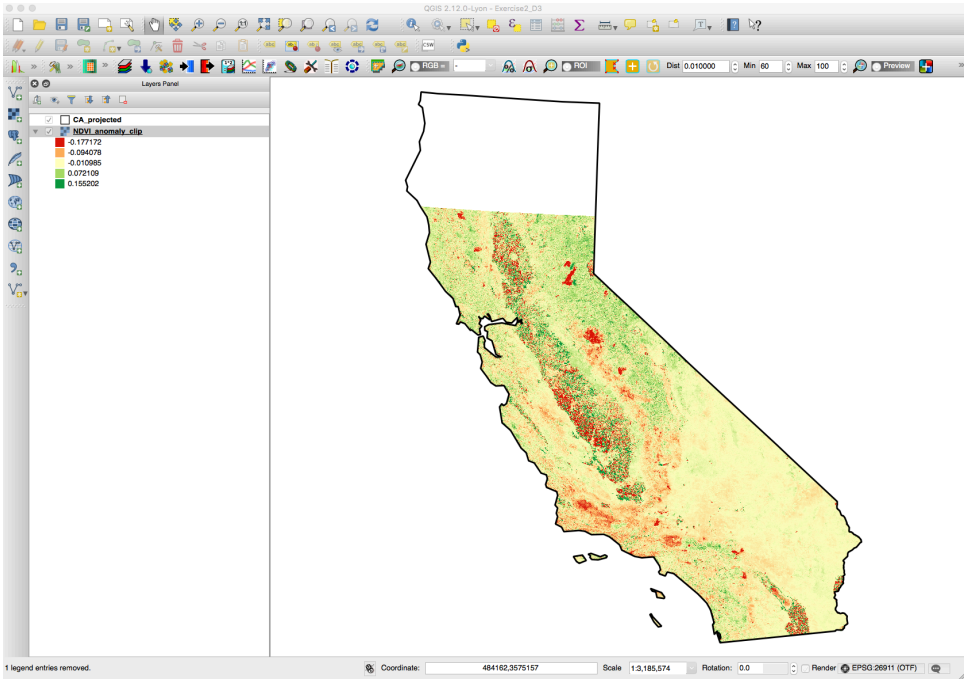
25. Click on the **Style** tab
26. Under **Generate new color map**, change the **Mode** to **Equal Interval** and specify 10 classes.
27. Under **Load min/max values** select **Mean +/- standard deviation x** and type in 2
28. Click **Load**

Now you have successfully created your own NDVI anomaly images for July 2015 with red colors indicating negative anomalies or less healthy vegetation. On the screenshot above, you can see that many places within California's Central Valley have negative



NDVI anomalies when compared to the 2001-2010 average. This could indicate drought and potentially fallowed land. There also appears to be some large fire scars in specific regions of the Sierra Nevada.

You may also note that the MODIS swath we choose does not cover the entire state of California. If you are interested in statewide NDVI, you can download the other two MODIS swaths necessary and repeat the steps.



Part 7. Co-analyze the Precipitation and NDVI Anomalies

Now we will look at all of the anomaly images together.

1. In the layers panel you will have 1 NDVI anomaly and 12 precipitation anomaly maps
2. Now you can compare the precipitation anomaly images to the vegetation anomaly images. You can turn the layers off and on by clicking in the layer list to see how anomalies change. Remember that most of the precipitation in California falls between November and March. Notice that most of the negative precipitation anomalies are occurring where the negative vegetation anomalies occur. Keep in mind that there is often lag time between observing negative precipitation anomalies and negative vegetation anomalies. California has been experiencing drought conditions for several years, exacerbating the negative impacts on vegetation.
3. You can zoom in and focus on a location where negative precipitation anomalies are large between January and March 2015 and check the corresponding NDVI anomaly in July.

Discussion: How would you monitor and assess different types droughts in the area of your interest?