

API-231 / GIS-PubPol

Meeting 19 (“Climate-Conflict Nexus” Walk Through)

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Overview Vignettes

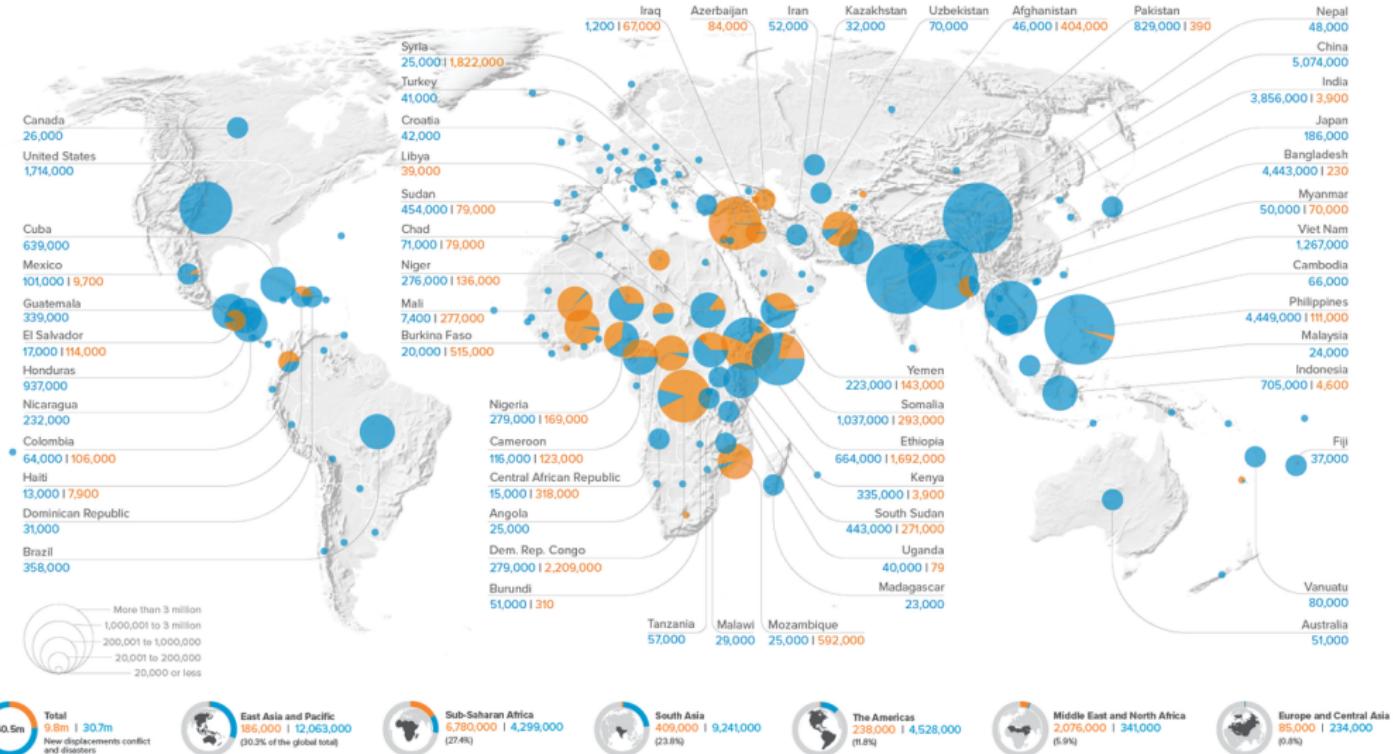


Figure 1: Displacement from natural disasters (blue) and conflict (orange) in 2020



Researchers Link Syrian Conflict to a Drought Made Worse by Climate Change

Share full article



Women working in fields in northeastern Syria in 2010. A new report suggests extreme drought in Syria was most likely a factor in the violent uprising that began there in 2011. Louai Beshara/Agence France-Presse — Getty Images

By Henry Fountain

March 2, 2015

Figure 2: Is this true?

MARCH 4, 2013 | 4 MIN READ

Climate Change and Rising Food Prices Heightened Arab Spring

The effects of climate change on the food supply exacerbated the underlying tensions that have led to ongoing Middle East instability

BY INES PEREZ & CLIMATEWIRE

Environment

If the Arab Spring taught us something, it is that the effects of climate change can serve as stressors, contributing to regional instability and conflict, experts said.

In a report published last week, researchers from the Center for American Progress, the Center for Climate and Security and the Stimson Center examined the role of climate change in the Middle East's upheaval during 2010 and 2011. Looking at long-term trends in rain, crops, food prices and migration, they were able to determine how these factors contributed to social instability in the region.

"The Arab Spring would likely have come one way or another, but the context in which it did is not inconsequential. Global warming may not have caused the Arab Spring, but it may have made it come earlier," the report says.

The Middle East and North Africa region is extremely vulnerable to fluctuations in food supplies and prices. According to the report, with little arable land and scarce water supplies, the region is one of the top food

Figure 3: Let's look into this

Overview

What do we mean by “climate and weather”?

1. Long-term climate trends
 - a) changes in average surface temperature
 - b) changes in average precipitation
 - c) sea level rise
 - d) sea ice melt
2. Short-term weather “shocks”
 - a) unusually hot/cold weather
 - b) unusually dry/wet weather
3. Discrete weather events
 - a) extreme weather (e.g. storms, tornadoes)
 - b) visibility obstructions (e.g. clouds, haze)
 - c) floods
 - d) droughts
 - e) tsunamis



Figure 4: The storm is coming?

Applications of Meteorological Data to the Study of Conflict

Climate change as a driver of armed conflict and violence

1. Direct links between temperature, precipitation and political violence (Kevane and Gray 2008, Hendrix and Salehyan 2012, Levy and Sidel 2014, Mares and Moffett 2016)
2. Indirect effects on violence, through migration, resource competition, food insecurity (Ash and Obradovich 2020, Jones et al. 2017)
3. Impacts on social unrest in specific settings, like urban areas (Koren et al. 2021, Koubi et al. 2021)



Figure 5: A cause of war?

Short-term weather and violence

1. Cloud cover as instrumental variable for drone strikes (Mahmood and Jetter 2019, Saeed and Spagat 2021)
2. Weather shocks as instrumental variable for famine (Rozenas and Zhukov 2019)
3. Rainfall shocks as instrumental variable for economic growth (Miguel et al 2004, Miguel and Satyanath 2010, Sarsons 2015, Mellon 2023)

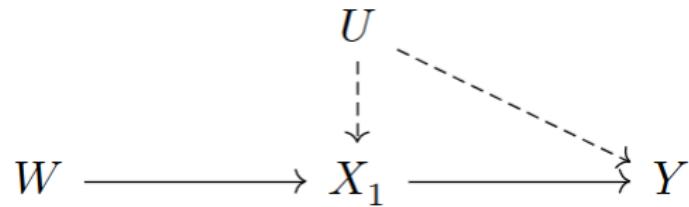


Figure 6: W is the instrumental variable

What do we know?

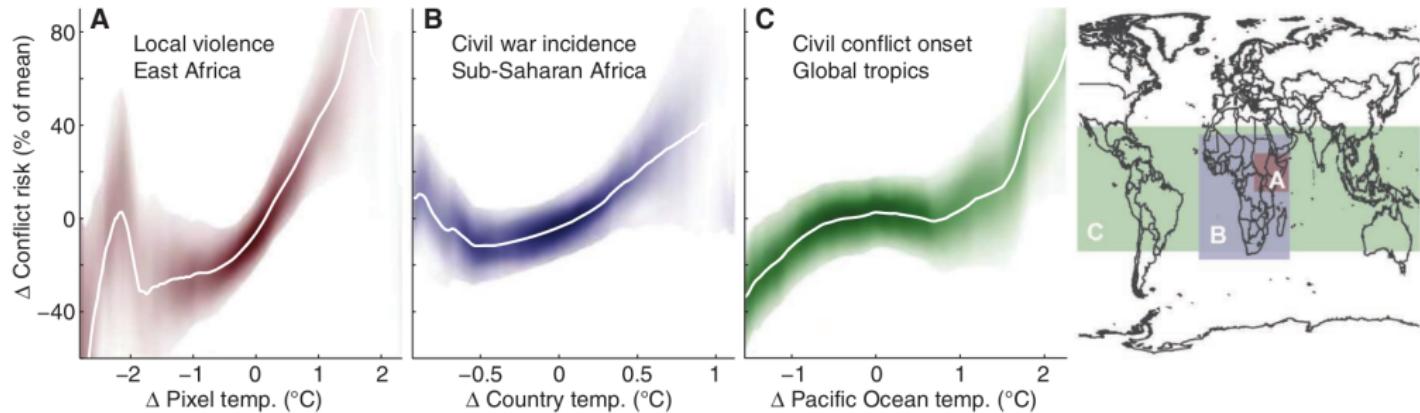


Figure 7: There is a positive correlation between higher temperatures and violence

At the macro level, civil conflict is more likely in hotter, drier times

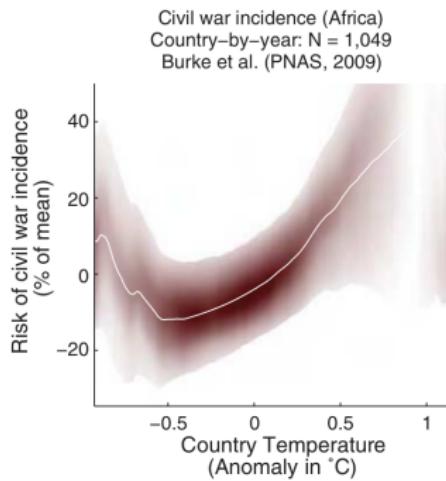
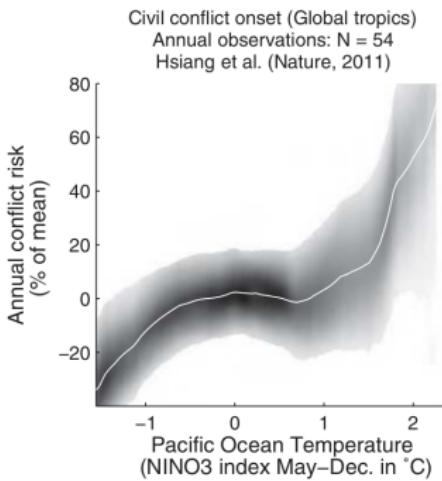
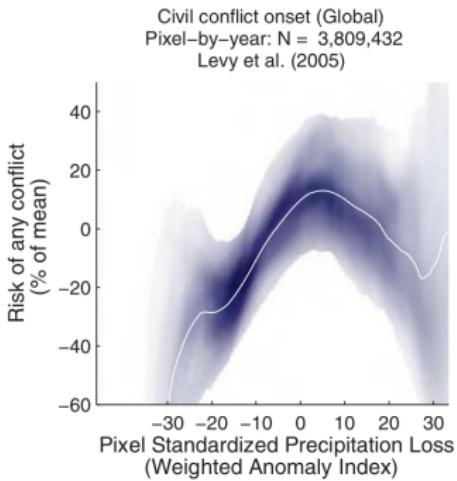


Figure 8: Around the globe

Figure 9: Conflict in tropics

Figure 10: Civil wars in Africa

Communal and inter-group conflict also more likely in climate-stressed times

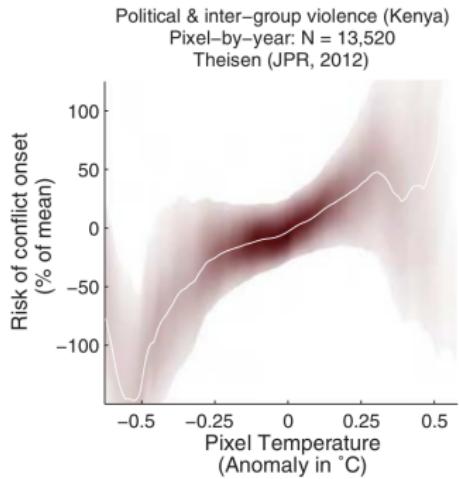


Figure 11: In Kenya

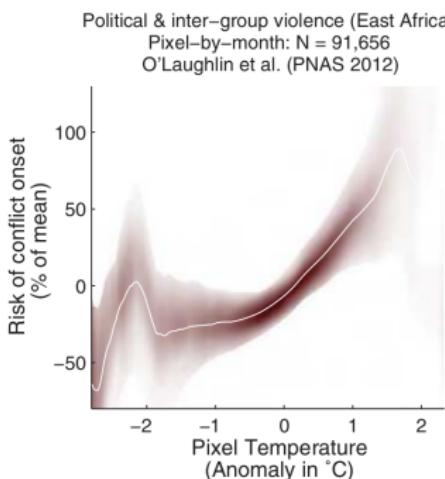


Figure 12: In East Africa

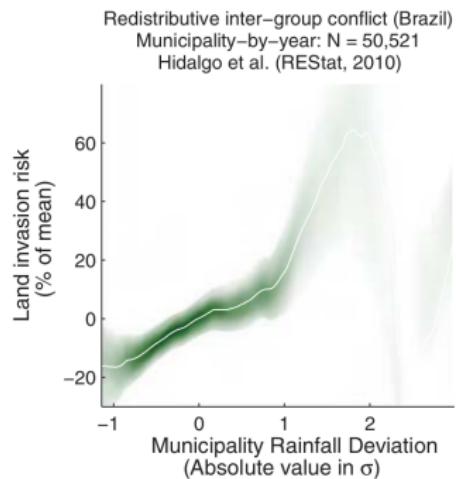


Figure 13: In Brazil

Similar correlations with other types of unrest across the globe

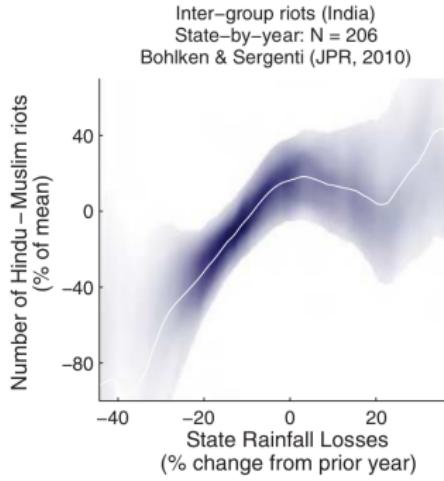
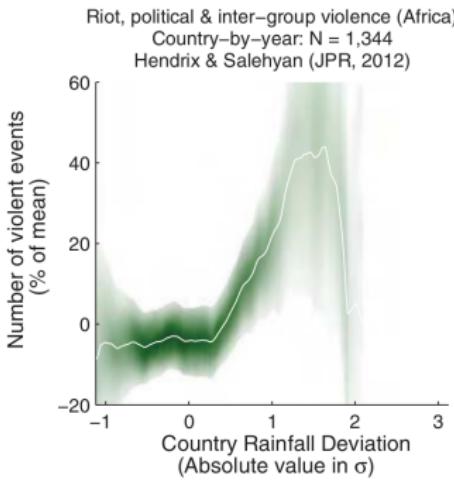
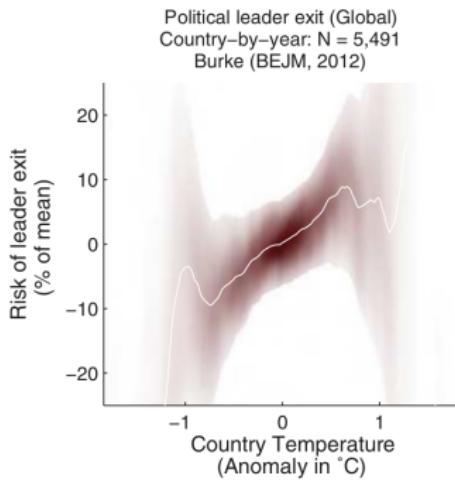


Figure 14: Regime change

Figure 15: Riots in Africa

Figure 16: Riots in India

As well as for crime, sexual assault and other violence in the U.S.

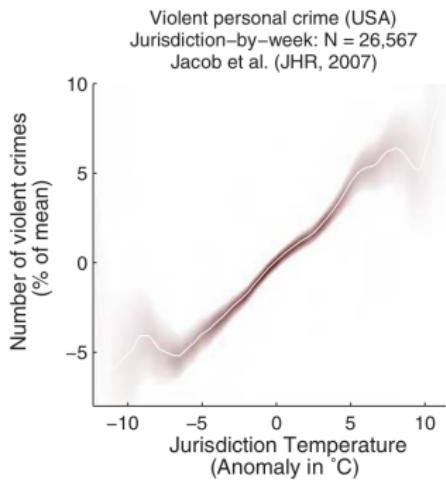


Figure 17: Crime in U.S.

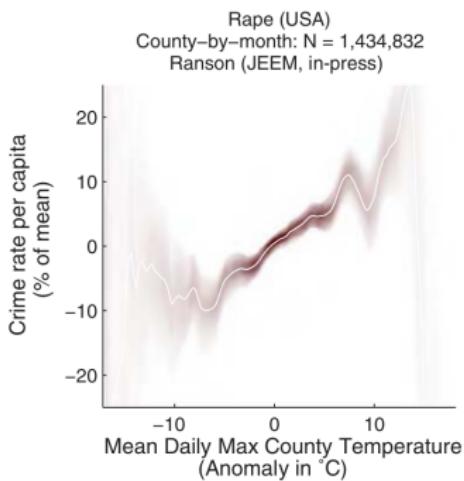


Figure 18: Rape in U.S.

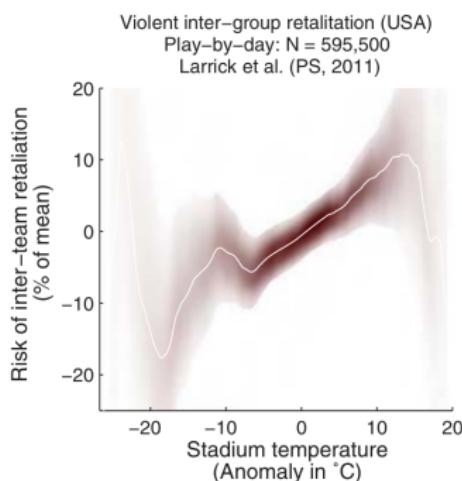


Figure 19: Fights at stadiums

Correlation ≠ causation

1. Emerging consensus that climate change by itself does not “cause” conflict (Hsiang and Burke 2014, Van Uexkull and Buhaug 2021)
2. Effect is likely indirect, though mechanisms like:
 - a) demographic changes (McAdam 2017, Dorward and Fox 2022, Koubi et al 2021)
 - b) resource competition (Njiru 2012, Harvey and Pilgrim 2011)
 - c) youth bulges (Barakat and Urdal 2009, Nordas and Davenport 2013)
 - d) migration (Adamson 2006, Nagabatla et al 2021, Nordas 2014, Menashe-Oren 2020)
 - e) state capacity (Koren and Sarbahi 2018)

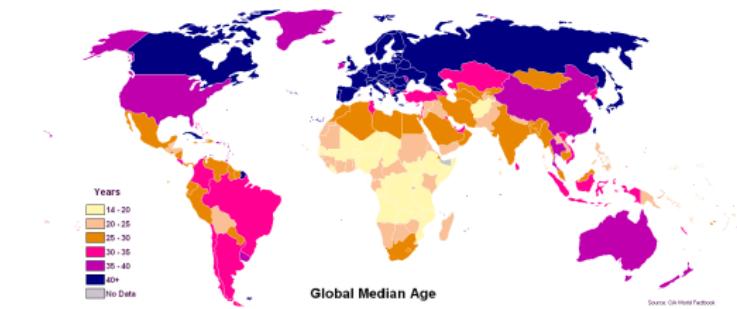


Figure 20: Demographic time bomb?

Varieties of Meteorological Data

Historical weather & climate raster data (partial list)

Source/link	Spatial resolution	Frequency	Availability	Free?	Global?
NOAA	0.5 × 0.5 degree	Monthly	1900-2014	✓	✓
CRUTS	0.5 × 0.5 degree	Monthly	1901-2022		✓
ERA5	0.25 × 0.25 degree	Hourly	1940-Present	✓	✓
GLDAS	0.25 × 0.25 degree	Hourly	1948-Present	✓	✓
FLDAS	0.1 × 0.1 degree	Monthly	1982-2016	✓	✓
TerraClimate	0.04 × 0.04 degree	Monthly	1958-2023	✓	✓

Climate model future predictions (partial list)

Source/link	Spatial resolution	Free?	Global?
CESM / CIME	0.5 × 0.5 degree	✓	✓
GFDL-ESM	1 × 1 degree	✓	✓
MPAS	Voronoi mesh	✓	✓
GISS Model E, E2R	1 × 1 degree	✓	✓
E3SM v2	1 × 1 degree	✓	✓

Greenhouse gas emissions (partial list)

Source/link	Spatial resolution	Frequency	Availability	Free?	Global?
EDGAR	0.1 × 0.1 degree	Annual	1970-Present	✓	✓
ESS-DIVE	1 × 1 degree	Annual	1751-2013	✓	✓
Global Carbon Atlas	City-level	Annual	1960-Present	✓	✓
EPA-FLIGHT	Facility-level	Annual	2010-Present	✓	

Extreme weather events (partial list)

Source/link	Spatial resolution	Availability	Free?	Global?
NOAA Storm Events	Points	1950-2023	✓	
EM-DAT	Points, admin units	1988-Present	✓	✓
GDIS	Points (centroids)	1960-2018	✓	✓

Words of caution

1. Existing research conceptualizes climate change and conflicts in diverse ways (Meierding 2013, Raleigh and Urdal 2007, Sharifi et al 2021, Van Uexkull and Buhaug 2021)
2. Complexity of causal pathways, patchy data, disagreement over measurement, analytical approaches (Adams et al 2018, Sakaguchi et al 2017, Sheffran et al 2012)
3. Differences in assumptions, data & methods lead to *vastly different conclusions* (Hsiang and Burke 2014, Buhaug et al 2014, Van Uexkull and Buhaug 2021)

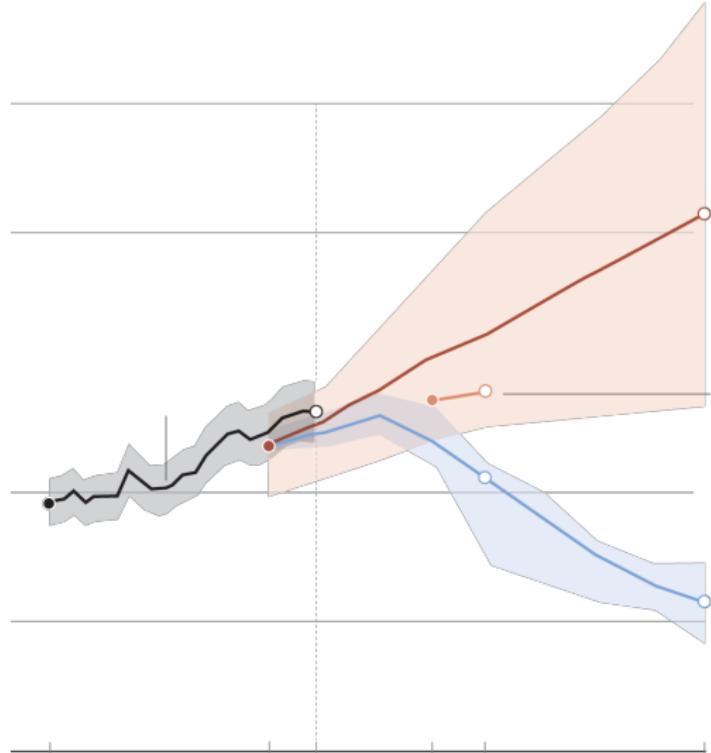


Figure 21: The answer is “it depends”

Vignettes

Overview of lab exercise

1. Changes in summer temperatures by country
2. Drought severity and violence during the 2011 Arab spring

We will compare average monthly high temperatures in July 2023 to July 1958

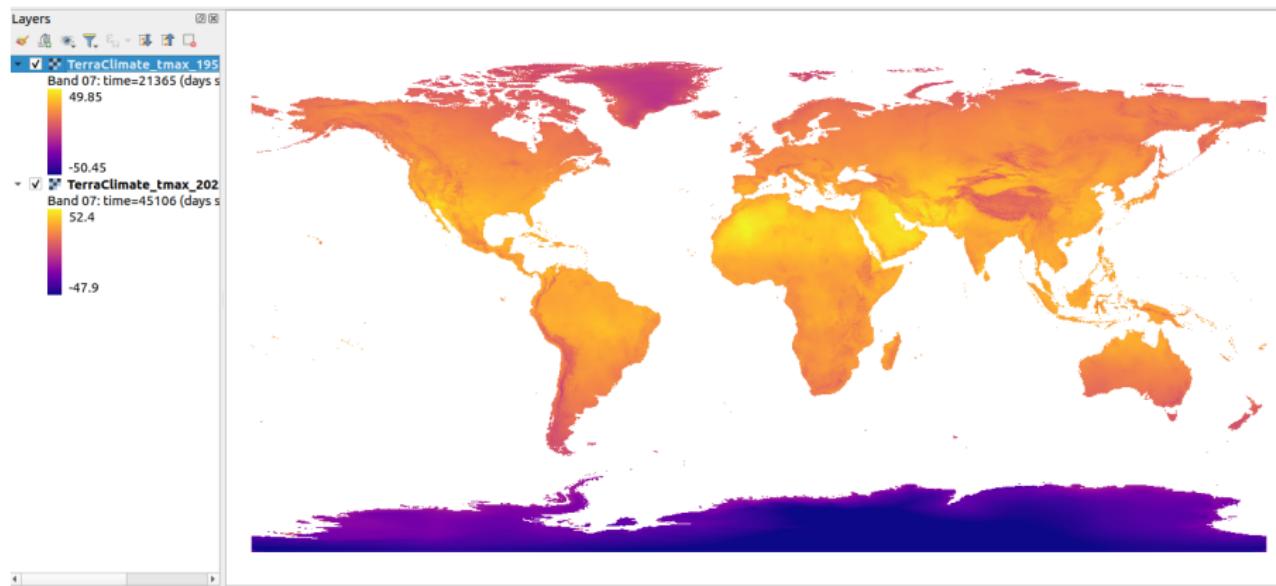


Figure 22: Vignette 1 / Step 1

And calculate a new raster that shows where the changes were lowest/highest

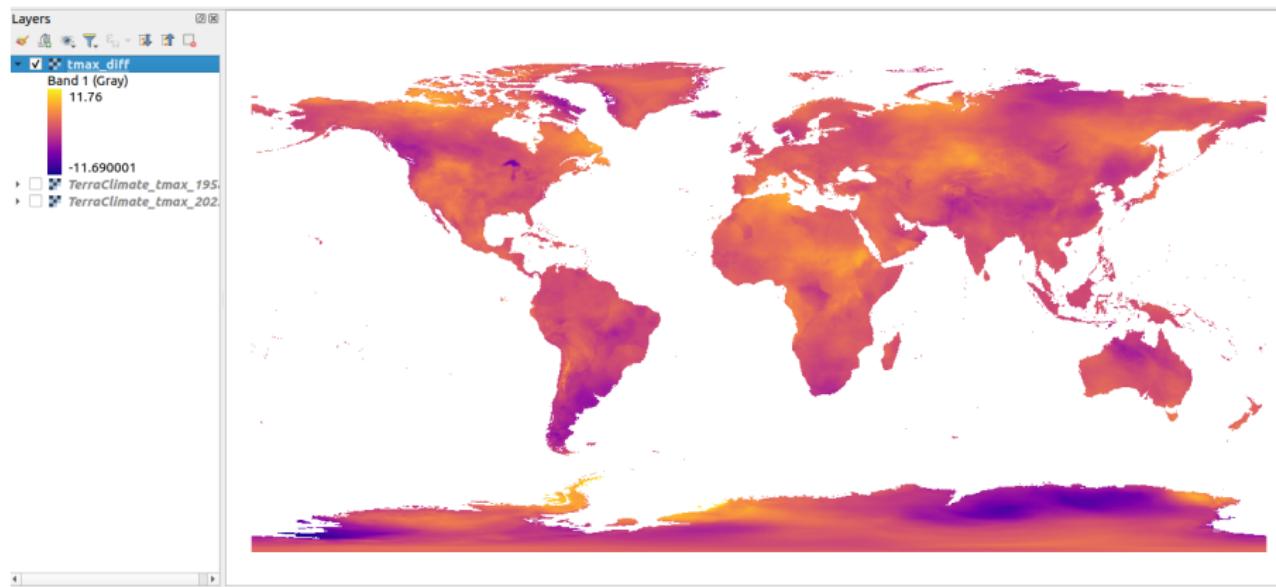


Figure 23: Vignette 1 / Step 2

We will then aggregate these changes by country, to see who was most affected

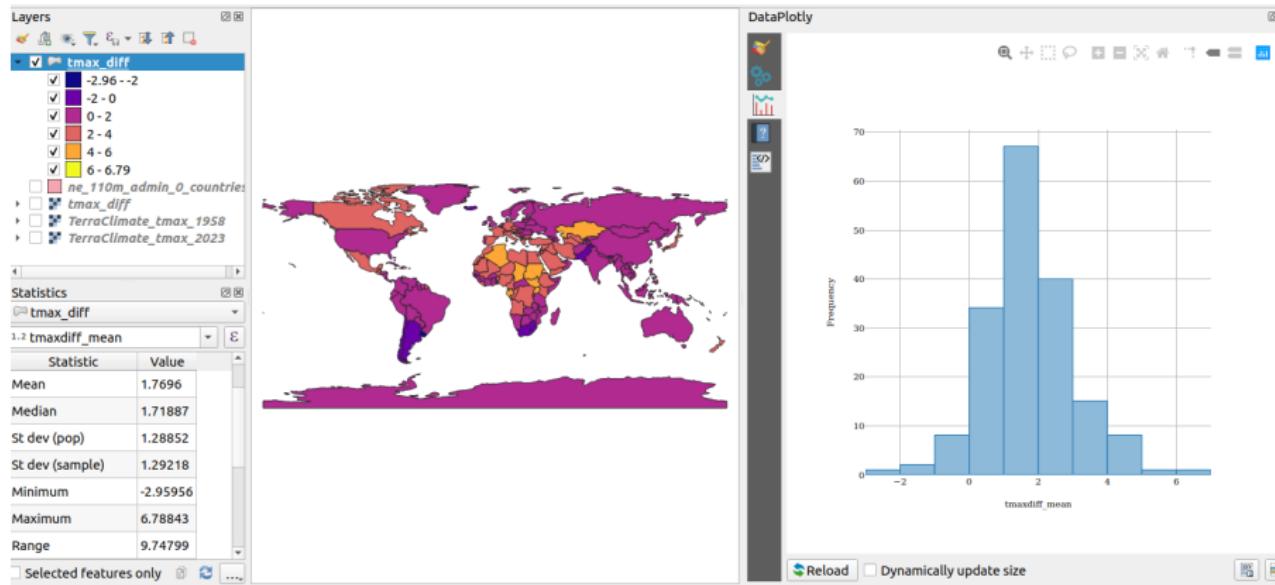


Figure 24: Vignette 1 / Step 3

We will then calculate yearly averages of severe drought indices

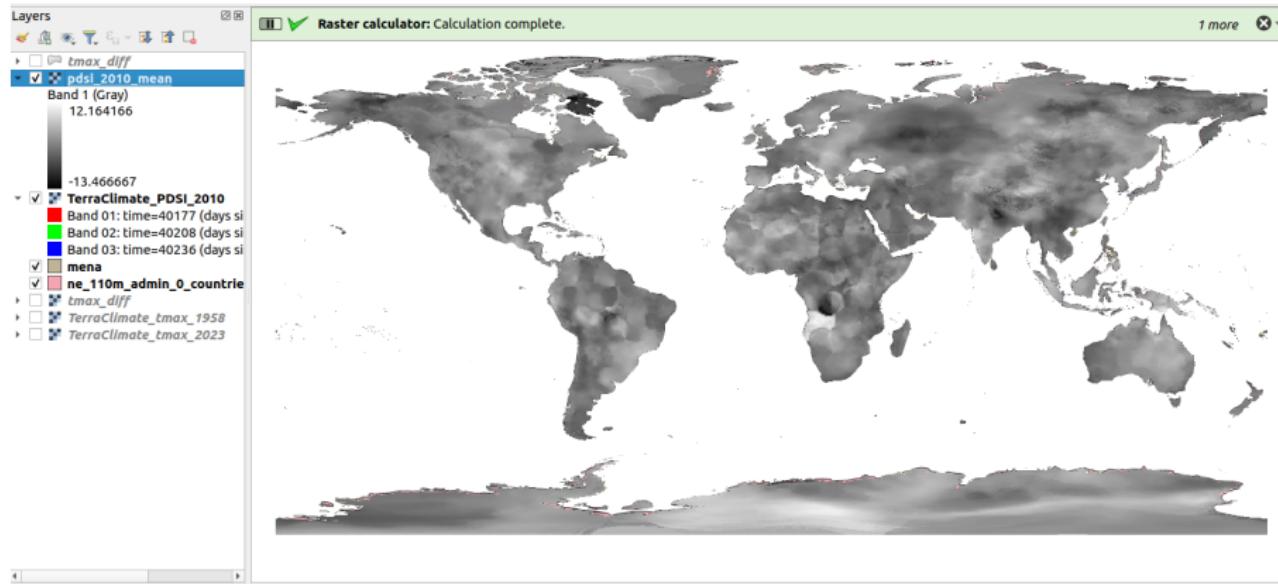


Figure 25: Vignette 2 / Step 1

We will extract drought indices for the Middle East and North Africa

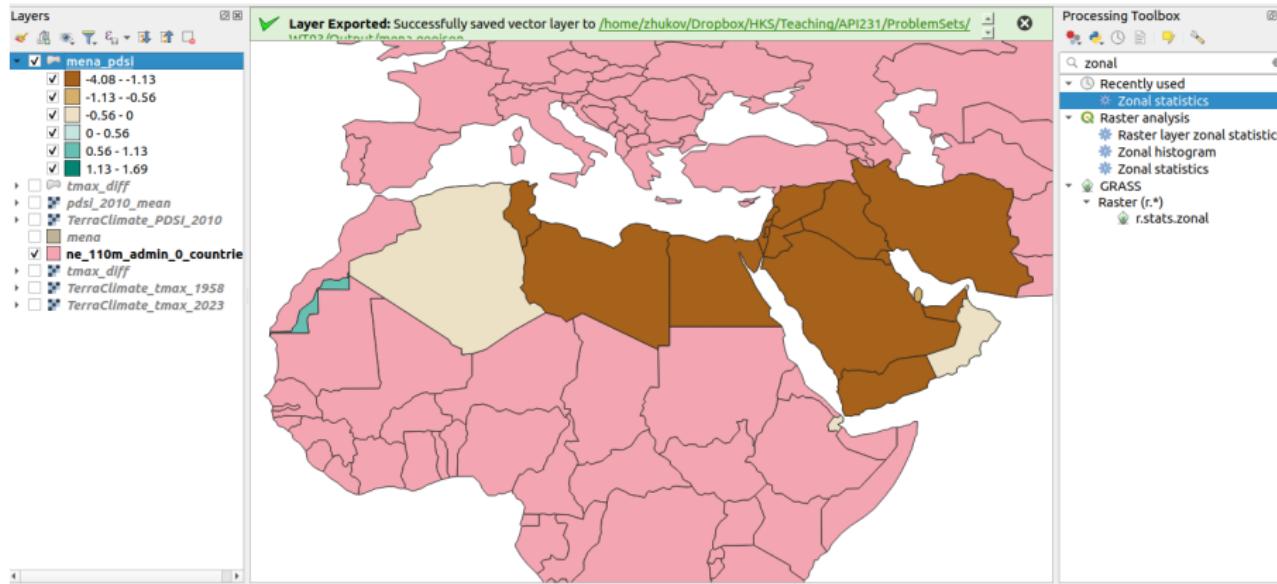


Figure 26: Vignette 2 / Step 2

And will see if countries more affected by drought saw more violence in 2011

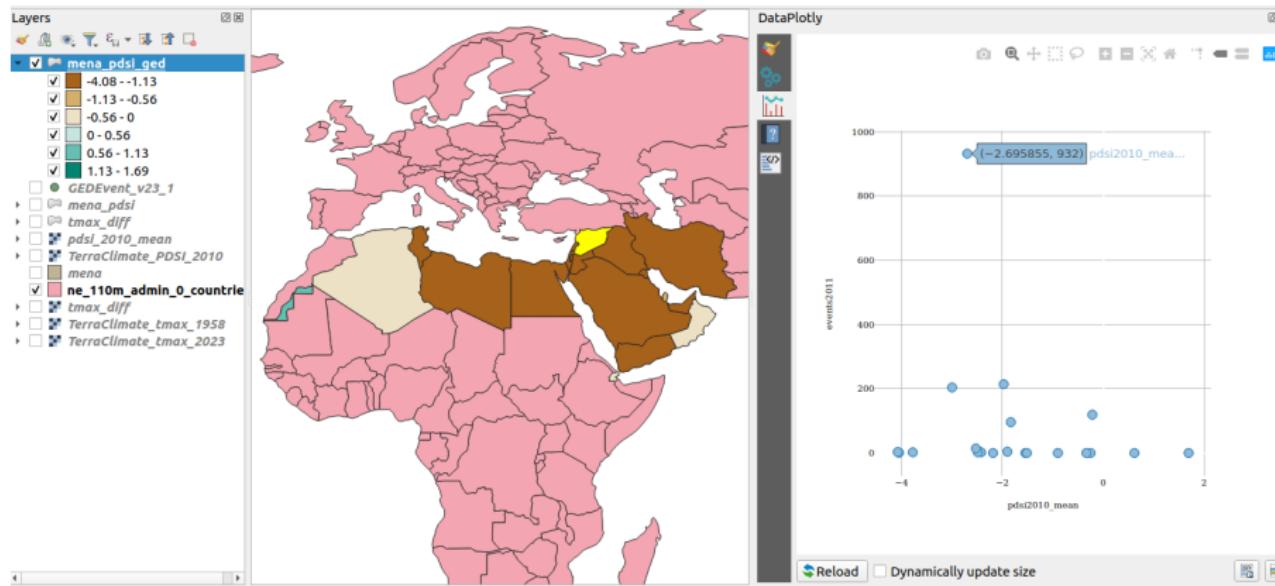
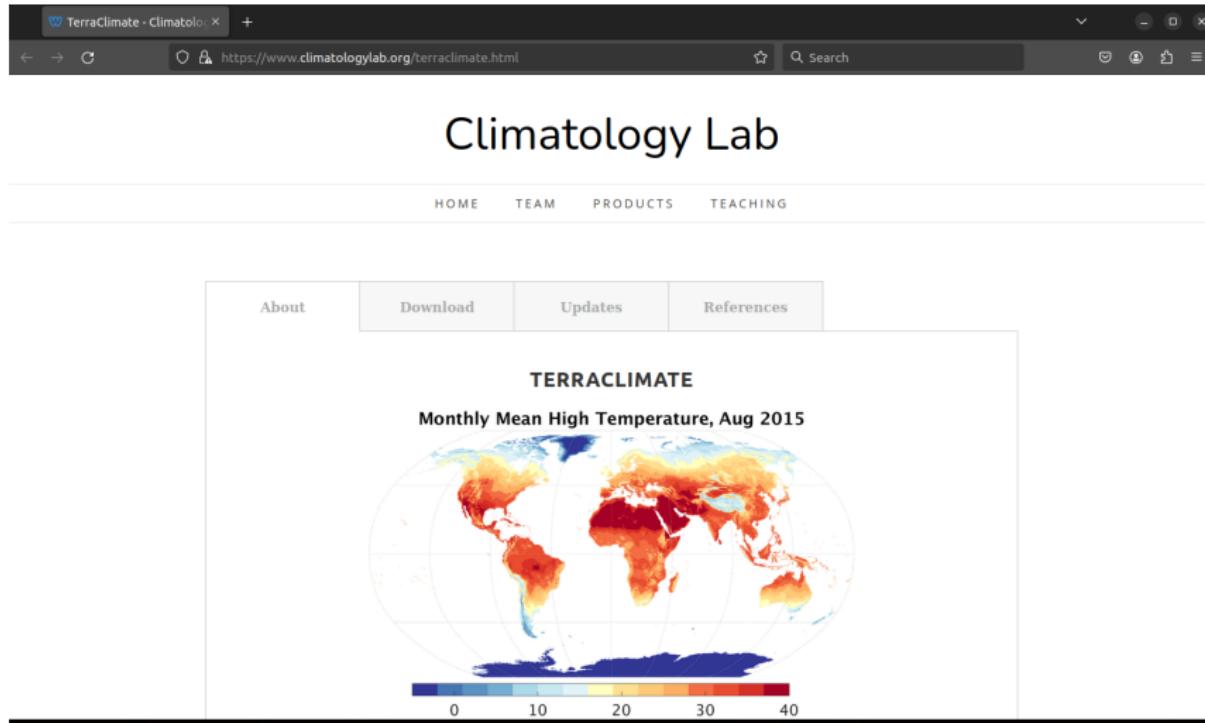


Figure 27: Vignette 2 / Step 3

We can obtain **monthly mean high temperature data** from [climatologylab.org/terraclimate.html](https://www.climatologylab.org/terraclimate.html)



There are several types of data here. See the “guide for dataset abbreviations”

The screenshot shows a web browser window for the TerraClimate website at <https://www.climatologylab.org/terraclimate.html>. The page has a navigation bar with links for About, Download, Updates, and References. Below this is a section titled "Netcdf files from THREDDS web server" which includes a link to a "guide for dataset abbreviations". A red box highlights this link. The section lists five types of datasets:

1. Individual years (1958-present)
2. Aggregated years (1958-present)
3. Individual years for +2C climate futures
4. Individual years for +4C climate futures
5. Climatologies (1961-1990 and 1981-2010; and +2C and +4C future scenarios)

Below this is a section titled "Read me first: Best practices for accessing our datasets" with the following steps:

1. Download individual netCDF files for individual variables and years
 1. directly from data catalogs
 2. using wget script tool to batch download files
2. Download subsets and point data using THREDDS web services
 1. using OPeNDAP and these example scripts
 1. rectangular subsets (MATLAB, Python, and R [alternative R version])
 2. point data (MATLAB, Python, and R)
 2. using NCSS and these example batch scripts for subsets and points
3. Google Earth Engine
 1. 'Get an account' -> https://earthengine.google.com/new_signup/

At the bottom of the page, there is a note: "https://www.climatologylab.org/terraclimate-variables.html in the playground" -> <https://developers.google.com/earth-engine/>

We want **tmax** (mean high temperatures) and PDSI (drought index)

The following variables are provided for download as 30-year climatological monthly summaries or monthly data for each year (1958-present). Data are available on [NKN THREDDS servers](#) or through Google Earth Engine. Note that data come as compressed netCDF. Be sure to reference scale_factor and offset commands when looking at the data.

aet (Actual Evapotranspiration, monthly total), units = mm
def (Climate Water Deficit, monthly total), units = mm
pet (Potential evapotranspiration, monthly total), units = mm
ppt (Precipitation, monthly total), units = mm
q (Runoff, monthly total), units = mm
soil (Soil Moisture, total column - at end of month), units = mm
srad (Downward surface shortwave radiation), units = W/m²
swe (Snow water equivalent - at end of month), units = mm
tmax (Max Temperature, average for month), units = C
tmin (Min Temperature, average for month), units = C
vap (Vapor pressure, average for month), units = kPa
ws (Wind speed, average for month), units = m/s
vpd (Vapor Pressure Deficit, average for month), units = kpa
PDSI (Palmer Drought Severity Index, at end of month), units = unitless

Let's download the "Individual years" data

TerraClimate - ClimatologyLab

<https://www.climatologylab.org/terraclimate.html>

About Download Updates References

Netcdf files from THREDDS web server ([guide for dataset abbreviations](#))

1. [Individual years \(1958-present\)](#)
2. [Aggregated years \(1958-present\)](#)
3. [Individual years for +2C climate futures](#)
4. [Individual years for +4C climate futures](#)
5. [Climatologies \(1961-1990 and 1981-2010; and +2C and +4C future scenarios\)](#)

Read me first: Best practices for accessing our datasets

1. Download individual netCDF files for individual variables and years
 1. directly from [data catalogs](#)
 2. using [wget](#) script tool to batch download files
2. Download subsets and point data using [THREDDS](#) web services
 1. using OPeNDAP and these example scripts
 1. rectangular subsets ([MATLAB](#), [Python](#), and [R](#) [alternative R version])
 2. point data ([MATLAB](#), [Python](#), and [R](#))
 2. using NCSS and these example batch scripts for [subsets](#) and [points](#)
3. [Google Earth Engine](#)
 1. 'Get an account' -> https://earthengine.google.com/new_signup/

thredds.northwestknowledge.net:8080/thredds/catalog/TERRACLIMATE_ALL/data/catalog.html [developers.google.com/earth-engine/]

The file naming convention is TerraClimate_[variable]_[year].nc. Go to TerraClimate_tmax_2023.nc

TerraClimate - Climatology

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Search

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tmax

Highlight All Match Case Match Diacritics Whole Words 1 of 66 matches

Download this file through the HTTPServer link

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 - THREDDS Data Server**
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 - Godiva2 (browser-based)
 - NetCDF-Java ToolsUI (webstart)
 - Integrated Data Viewer (IDV) (webstart)

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Do the same for the 1958 temperature data TerraClimate_tmax_1958.nc

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 - UDUC: [/thredds/uddc/TERRACLIMATE_ALL/data/TerraClimate_tmax_1958.nc](http://thredds/uddc/TERRACLIMATE_ALL/data/TerraClimate_tmax_1958.nc)
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 - Integrated Data Viewer (IDV) (webstart)

thredds.northwestknowledge.net:8080/thredds/fileServer/TERRACLIMATE_ALL/data/TerraClimate_tmax_1958.nc

And the 2010 drought index data `TerraClimate_PDSI_2010.nc`

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 - ID: TERRACLIMATE_ALL_SCAN/data/TerraClimate_PDSI_2010.nc
 - Access:**
 - OPENDAP: [/thredds/dodsC/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc](http://thredds.dodsC/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc)
 - HTTPServer: [/thredds/fileServer/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc](http://thredds/fileServer/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc)
 - NetcdfSubset: [/thredds/ncss/grid/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc](http://thredds/ncss/grid/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc)
 - WCS: [/thredds/wcs/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc](http://thredds/wcs/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc)
 - WMS: [/thredds/wms/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc](http://thredds/wms/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc)
 - ISO: [/thredds/iso/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc](http://thredds/iso/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc)
 - UDDC: [/thredds/uddc/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc](http://thredds/uddc/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc)
 - Dates:**
 - 2023-04-24T20:43:29Z (modified)
 - Viewers:**
 - Godiva2 (browser-based)
 - NetCDF-Java ToolsUI (webstart)
 - Integrated Data Viewer (IDV) (webstart)

thredds.northwestknowledge.net:8080/thredds/fileServer/TERRACLIMATE_ALL/data/TerraClimate_PDSI_2010.nc

We will use global country-level boundaries data from [naturalearthdata.com](https://www.naturalearthdata.com/downloads/)

The screenshot shows a web browser window with three tabs open: 'TerraClimate - Climatology', 'Catalog Services', and 'Natural Earth » Downloads'. The 'Natural Earth » Downloads' tab is active, displaying the website's main download page.

The page features a large logo for 'Natural Earth' with a globe icon. Below the logo, there is a search bar and a link to 'Free vector and raster map data at 1:10m, 1:50m, and 1:110m scales'. A navigation menu includes links for Home, Features, Downloads, Blog, Issues, Corrections, and About.

Downloads

Data themes are available in three levels of detail. For each scale, themes are listed on Cultural, Physical, and Raster category pages.

Stay up to date! Know when a new version of Natural Earth is released by subscribing to our [announcement list](#).

Overwhelmed? The [Natural Earth quick start kit](#) (219 mb) provides a small sample of Natural Earth themes styled in a QGIS document. Download all vector themes as SHP (576 mb), SQLite (423 mb), or GeoPackage (436 mb).

Natural Earth is the creation of many [volunteers](#) and is supported by [NACIS](#). It is free for use in any type of project. [Full Terms of Use](#) »

Large scale data, 1:10m

A thumbnail image shows a map of New York City. Below the image are three buttons: 'Cultural' (highlighted in green), 'Physical', and 'Raster'.

The most detailed. Suitable for making zoomed-in maps of countries and regions. Show the world on a large wall poster.

1:10,000,000
1° = 138 miles
1 cm = 100 km

Medium scale data, 1:50m

A thumbnail image shows a map of New York City.

We want the “Small scale data, 1:100m”. Click on the Cultural link

The screenshot shows a web browser window with three tabs open: "TerraClimate - Climatology", "Catalog Services", and "Natural Earth » Downloads". The "Natural Earth » Downloads" tab is active, displaying two map download options for New York.

Medium scale data, 1:50m

New York

[Cultural] [Physical] [Raster]

Suitable for making zoomed-out maps of countries and regions. Show the world on a tabloid size page.

1:50,000,000
1° = 790 miles
1 cm = 500 km

Small scale data, 1:100m

New York

[Cultural] [Physical]

Suitable for making detailed maps of regions and countries. Show the world on a full-page poster globe.

Click to view file listing. Files have been downloaded 913,000 times.

1:10,000
1° = 1,736 miles
1 cm = 1,100 km

Supported by:

- nacis
- CartoTalk
- mapgiving
- wcl
- Shaded Relief
- XNR Productions Inc.

<https://www.naturalearthdata.com/downloads/110m-cultural-vectors>

Click on the “Download countries” link under “Admin 0 - Countries” to get the zip

The screenshot shows a web browser window with the URL <https://www.naturalearthdata.com/downloads/110m-cultural-vectors/>. The page displays information about administrative divisions at level 0 (countries). It includes a note about version 5.1.1, a map of the world with country boundaries, and two download options: "Download countries" (210.08 KB) and "Download without boundary lines" (212.3 KB). Below these are links for "About", "Issues", and "Version History". The "Download countries" link is highlighted with a red box.

Download all 110m cultural themes (1.4 MB) version 5.1.1
Files have been downloaded 913,000 times.

NOTE: Version number indicates the update cycle when that theme was last updated. An older version number indicates updates have not been necessary since then.

Admin 0 - Countries

There are **238 countries** in the world. Greenland as separate from Denmark. Most users will want this file instead of sovereign states, though some users will want map units instead when needing to distinguish overseas regions of France.

Natural Earth shows **de facto** boundaries by default according to who controls the territory, versus **de jure**.

[Download countries](#) (210.08 KB) version 5.1.1
[Download without boundary lines](#) (212.3 KB) version 5.1.1

[About](#) | [Issues](#) | [Version History](#) »

Admin 0 - Details

There are **209 sovereign states** in the world, though only 199 issue passports. Auxiliary themes include 298 cartographic map units and 360 subunits optimized for labeling edge cases, like the four constitute countries of England, Scotland, Wales, and Northern Ireland in the United Kingdom.

[Download sovereignty](#) (203.99 KB) version 5.1.1
[Download map units](#) (213.64 KB) version 5.1.1
[Download scale ranks](#) (146.92 KB) version 5.1.0

https://www.naturalearthdata.com/http://www.naturalearthdata.com/download/110m/cultural/ne_110m_admin_0_countries.zip

We will be using the same event **data on violence** as in the last two labs:
UCDP GED version 23.1, in csv format

Layer Properties - TerraClimate_tmax_2023 — Information

Bands

Number	Band	No-Data	Min	Max
1	Band 01: time=44925 (days since 1900-01-01 00:00:00)	-32768	-31.6000000000	40.4000000000
2	Band 02: time=44956 (days since 1900-01-01 00:00:00)	-32768	-34.8000000000	40.5000000000
3	Band 03: time=44984 (days since 1900-01-01 00:00:00)	-32768	-42.5000000000	42.3000000000
4	Band 04: time=45015 (days since 1900-01-01 00:00:00)	-32768	-47.4000000000	43.0000000000
5	Band 05: time=45045 (days since 1900-01-01 00:00:00)	-32768	-50.1000000000	45.1000000000
6	Band 06: time=45076 (days since 1900-01-01 00:00:00)	-32768	-47.1000000000	47.9000000000
7	Band 07: time=45106 (days since 1900-01-01 00:00:00)	-32768	-47.9000000000	52.4000000000
8	Band 08: time=45137 (days since 1900-01-01 00:00:00)	-32768	-50.0000000000	54.0000000000
9	Band 09: time=45168 (days since 1900-01-01 00:00:00)	-32768	-46.0000000000	46.5000000000
10	Band 10: time=45198 (days since 1900-01-01 00:00:00)	-32768	-41.3000000000	42.1000000000
11	Band 11: time=45229 (days since 1900-01-01 00:00:00)	-32768	-31.9000000000	40.7000000000
12	Band 12: time=45259 (days since 1900-01-01 00:00:00)	-32768	-25.8000000000	39.0000000000

Help Style Apply Cancel OK

Type to locate (Ctrl+K) Unknown CRS

Yuri M. Zhukov

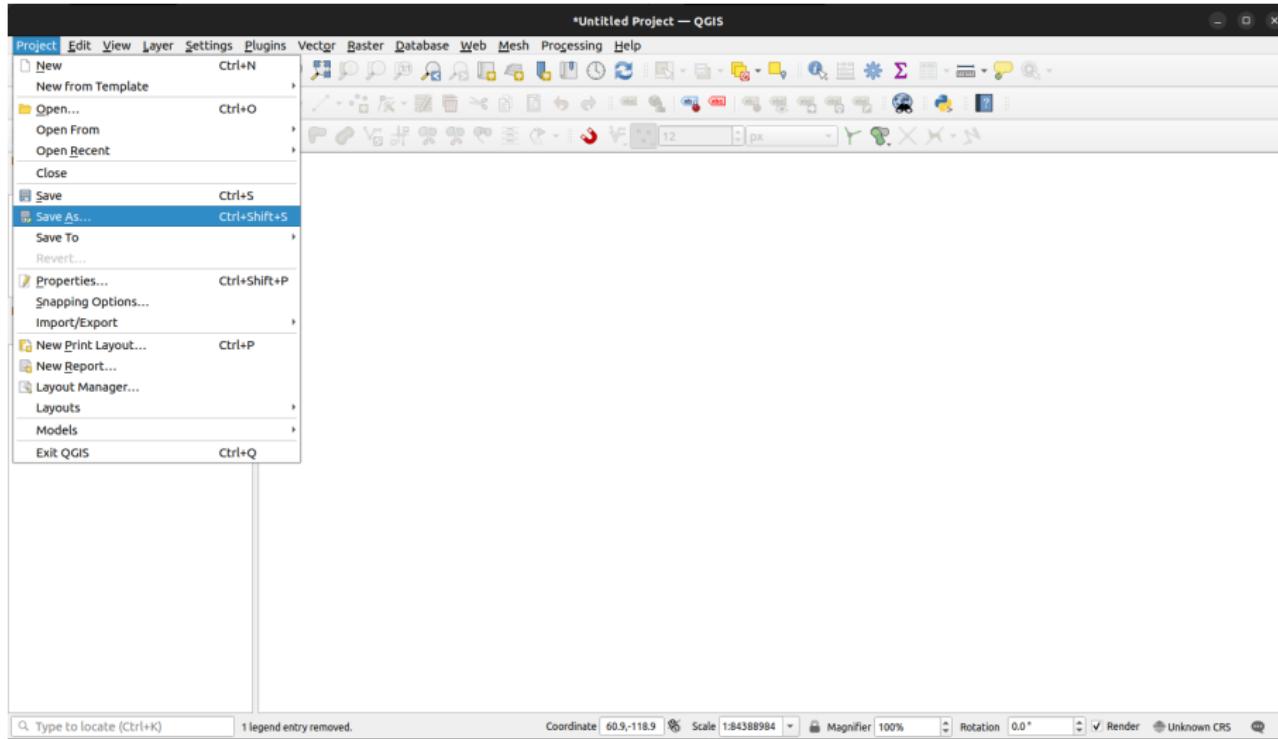
Here is the full list of data sources and links:

Category	Type	Format	Data source
Average monthly max temperature	Raster	.nc	TerraClimate
Palmer Drought Severity Index	Raster	.nc	TerraClimate
Country borders	Vector (polygons)	.shp	Natural Earth

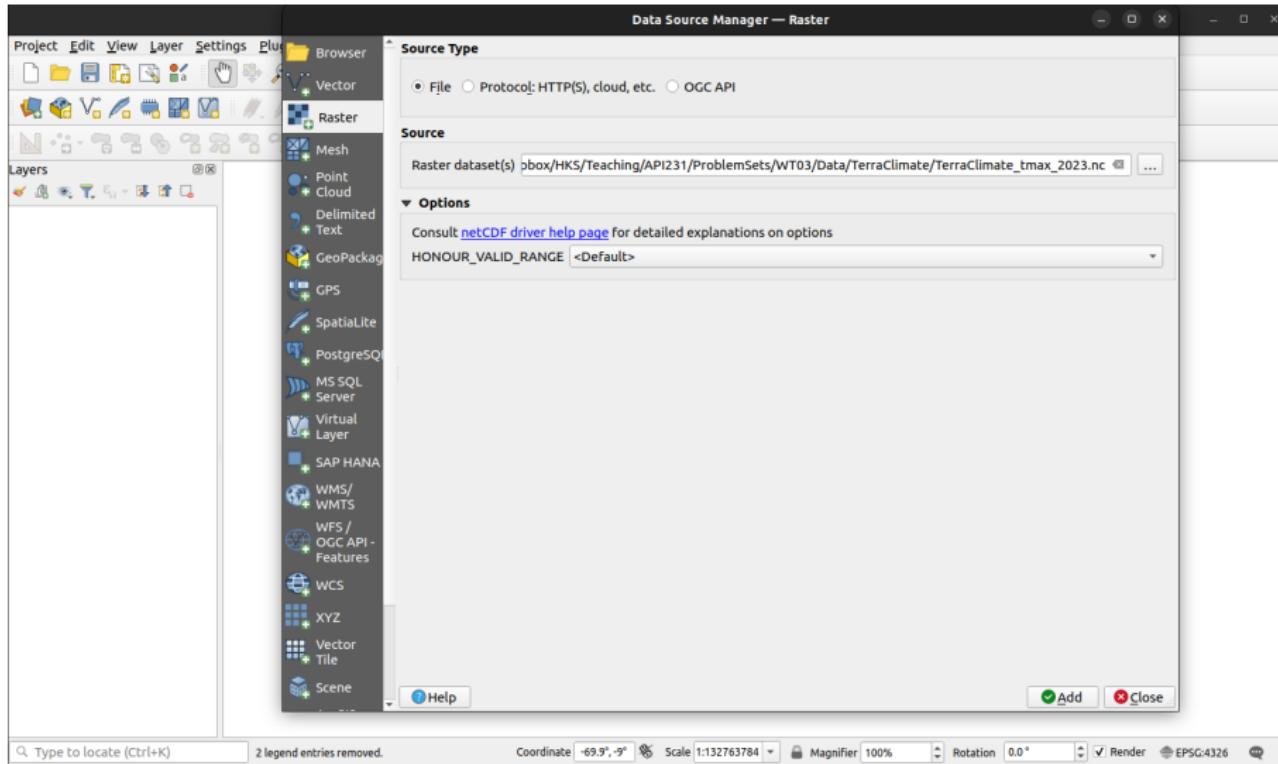
These are all in the WT03.zip file posted on Canvas.

Changes in summer temperatures by country

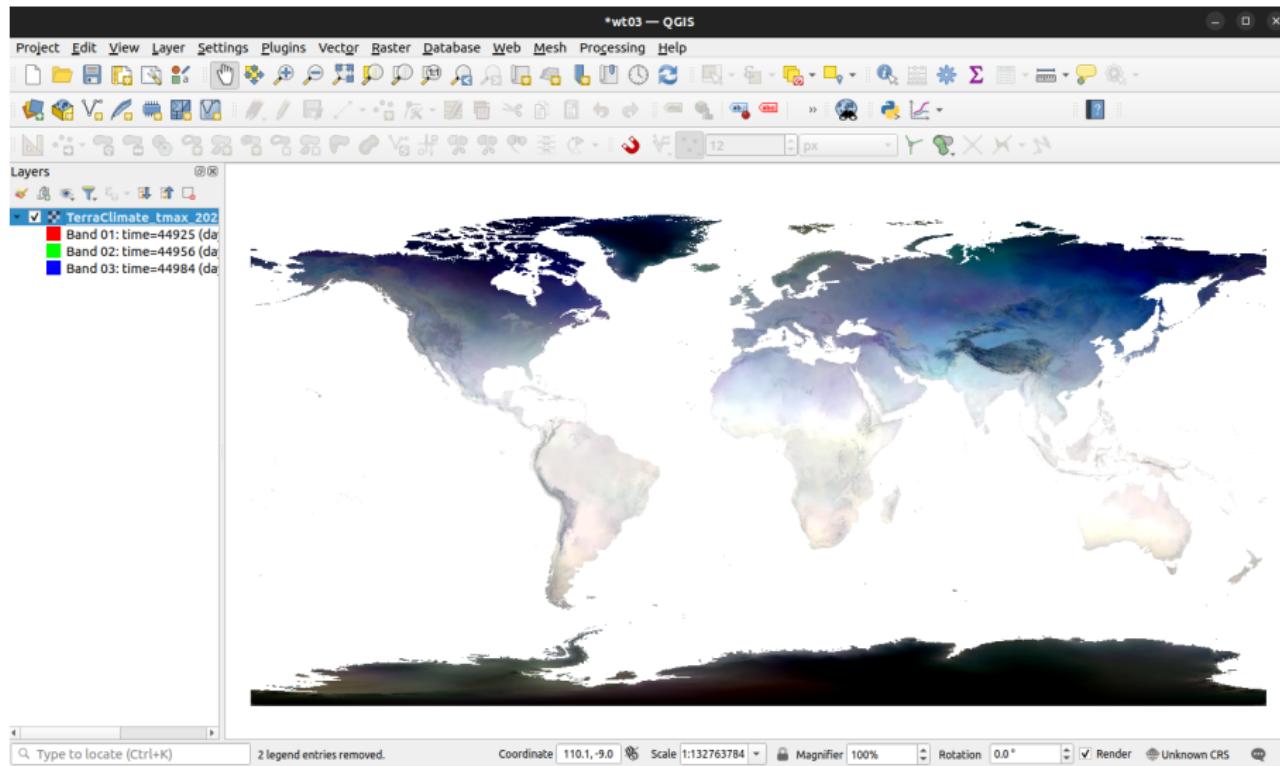
Always save your progress!
Go to Project → Save As...



Vignette 1. Load the 2023 temperature data (Layer → Add Layer → Add Raster Layer). TerraClimate_tmax_2023.nc file in Data/TerraClimate



This is a multi-band raster. Let's open up the layer Properties to see what these bands represent

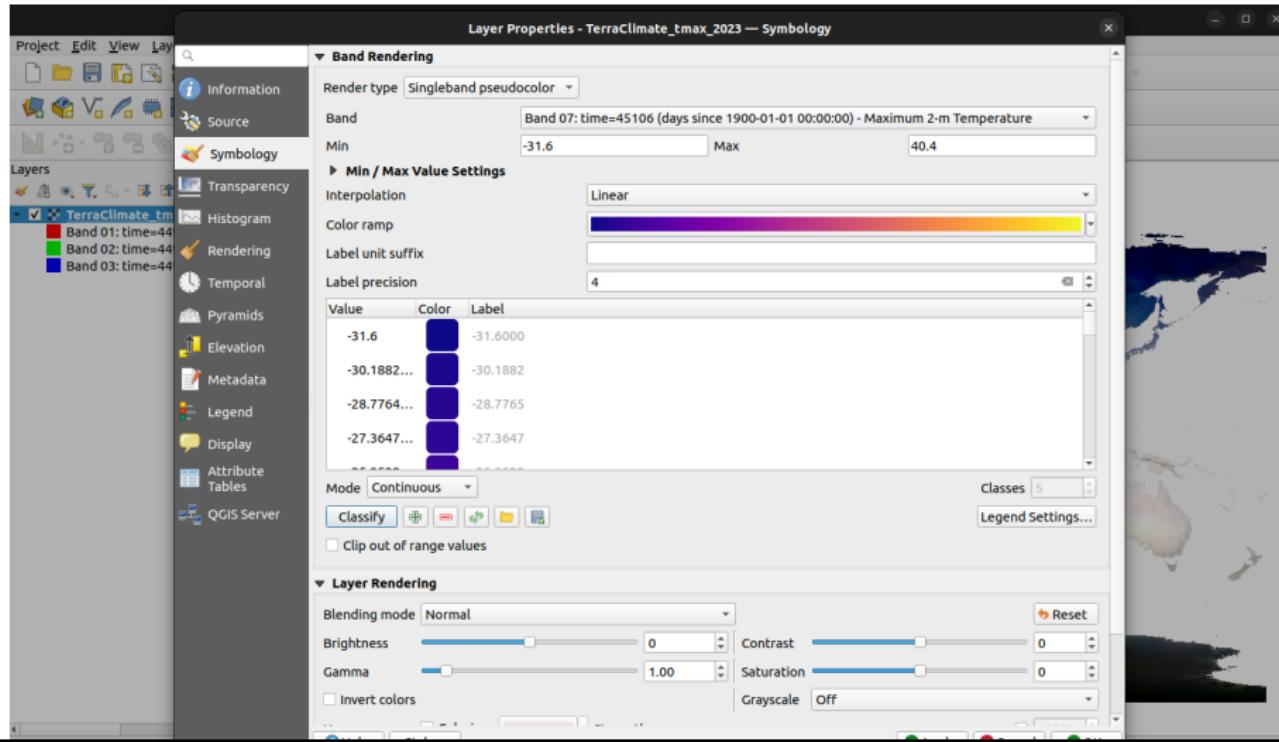


Go to the Information tab and scroll down to Bands. There are 12 bands, corresponding to months of the year (e.g. 1 = January, 12 = December)

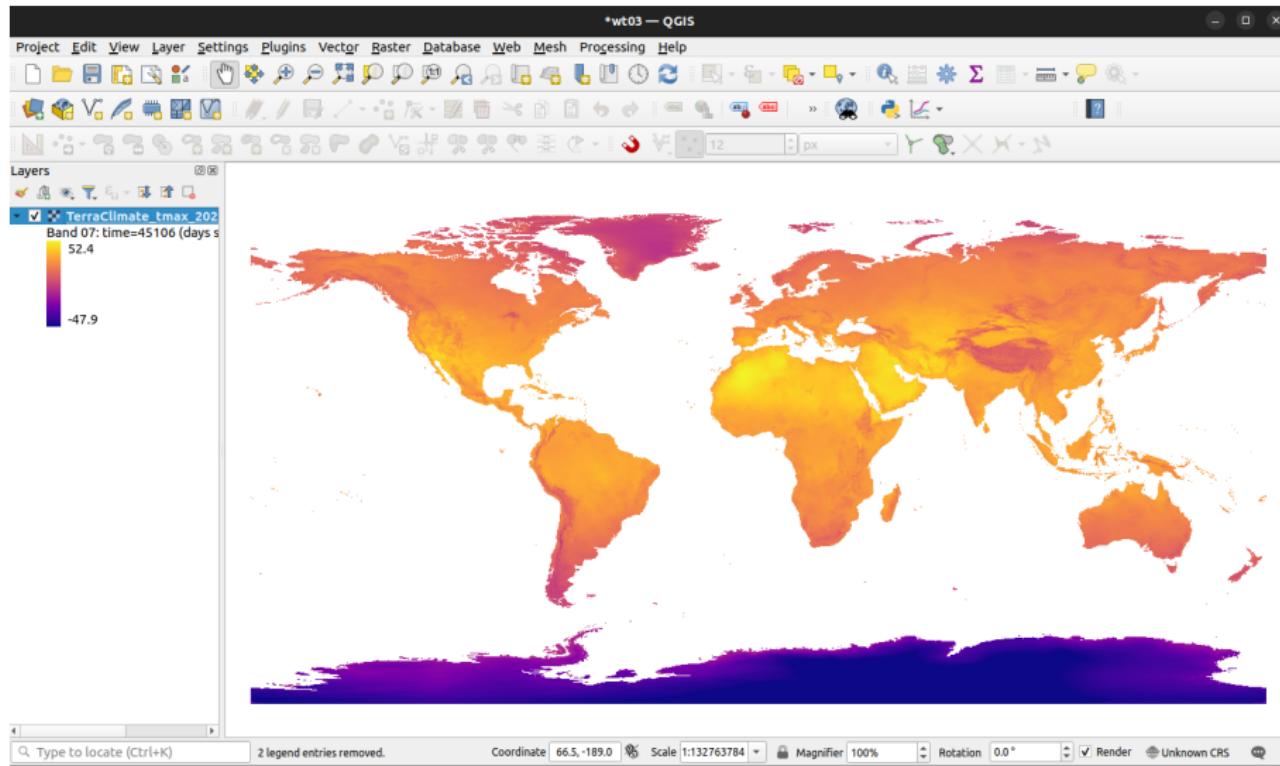
The screenshot shows the QGIS interface with the 'TerraClimate_tmax_2023' layer selected in the layers panel. The 'Information' tab is active in the properties dialog, displaying the 'Bands' table.

Number	Band	No-Data	Min	Max
1	Band 01: time=44925 (days since 1900-01-01 00:00:00)	-32768	-31.6000000000	40.4000000000
2	Band 02: time=44956 (days since 1900-01-01 00:00:00)	-32768	-34.8000000000	40.5000000000
3	Band 03: time=44984 (days since 1900-01-01 00:00:00)	-32768	-42.5000000000	42.3000000000
4	Band 04: time=45015 (days since 1900-01-01 00:00:00)	-32768	-47.4000000000	43.0000000000
5	Band 05: time=45045 (days since 1900-01-01 00:00:00)	-32768	-50.1000000000	45.1000000000
6	Band 06: time=45076 (days since 1900-01-01 00:00:00)	-32768	-47.1000000000	47.9000000000
7	Band 07: time=45106 (days since 1900-01-01 00:00:00)	-32768	-47.9000000000	52.4000000000
8	Band 08: time=45137 (days since 1900-01-01 00:00:00)	-32768	-50.0000000000	54.0000000000
9	Band 09: time=45168 (days since 1900-01-01 00:00:00)	-32768	-46.0000000000	46.5000000000
10	Band 10: time=45198 (days since 1900-01-01 00:00:00)	-32768	-41.3000000000	42.1000000000
11	Band 11: time=45229 (days since 1900-01-01 00:00:00)	-32768	-31.9000000000	40.7000000000
12	Band 12: time=45259 (days since 1900-01-01 00:00:00)	-32768	-25.8000000000	39.0000000000

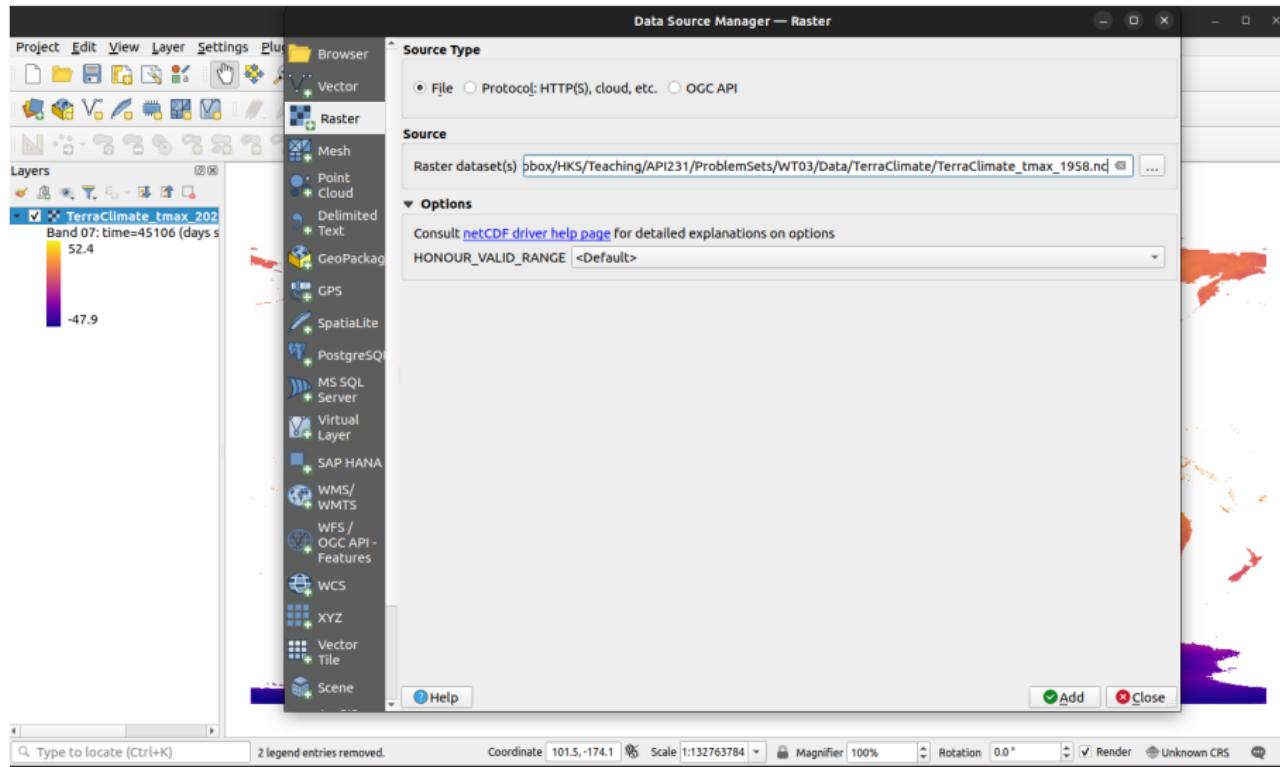
Let's display temperatures for July. In Symbology, change Render type to Singleband pseudocolor and set Band to Band 07.... Adjust the other graphical parameters to taste.



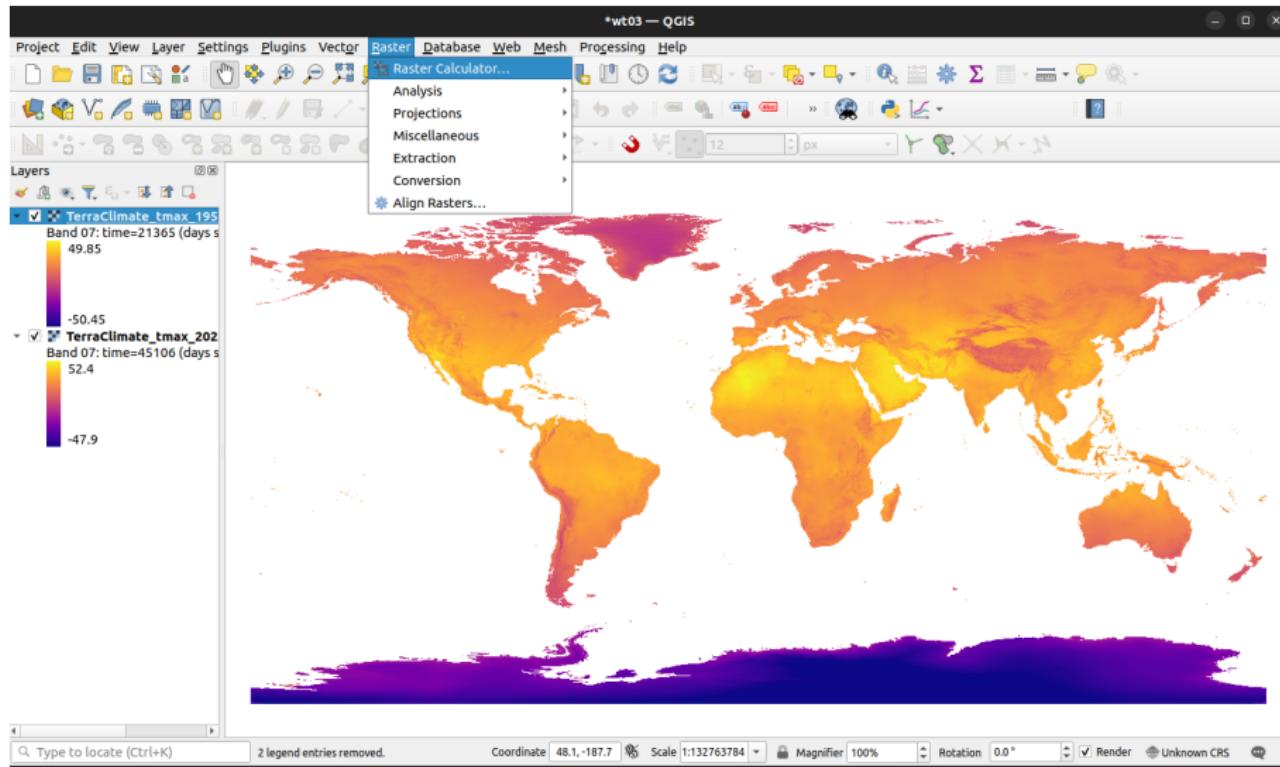
Places closer to the equator are hotter. Antarctica is very cold



Let's also load the `tmax` raster data for 1958

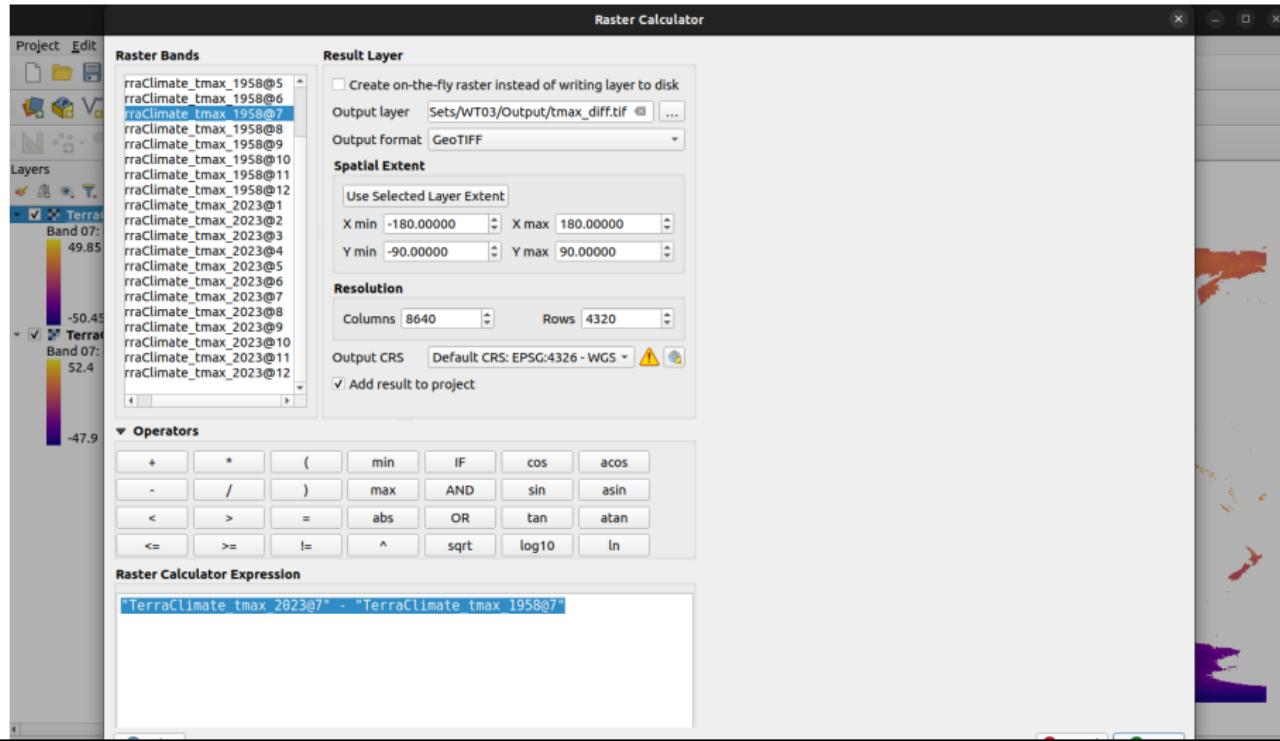


Once both rasters are loaded, open the Raster Calculator...

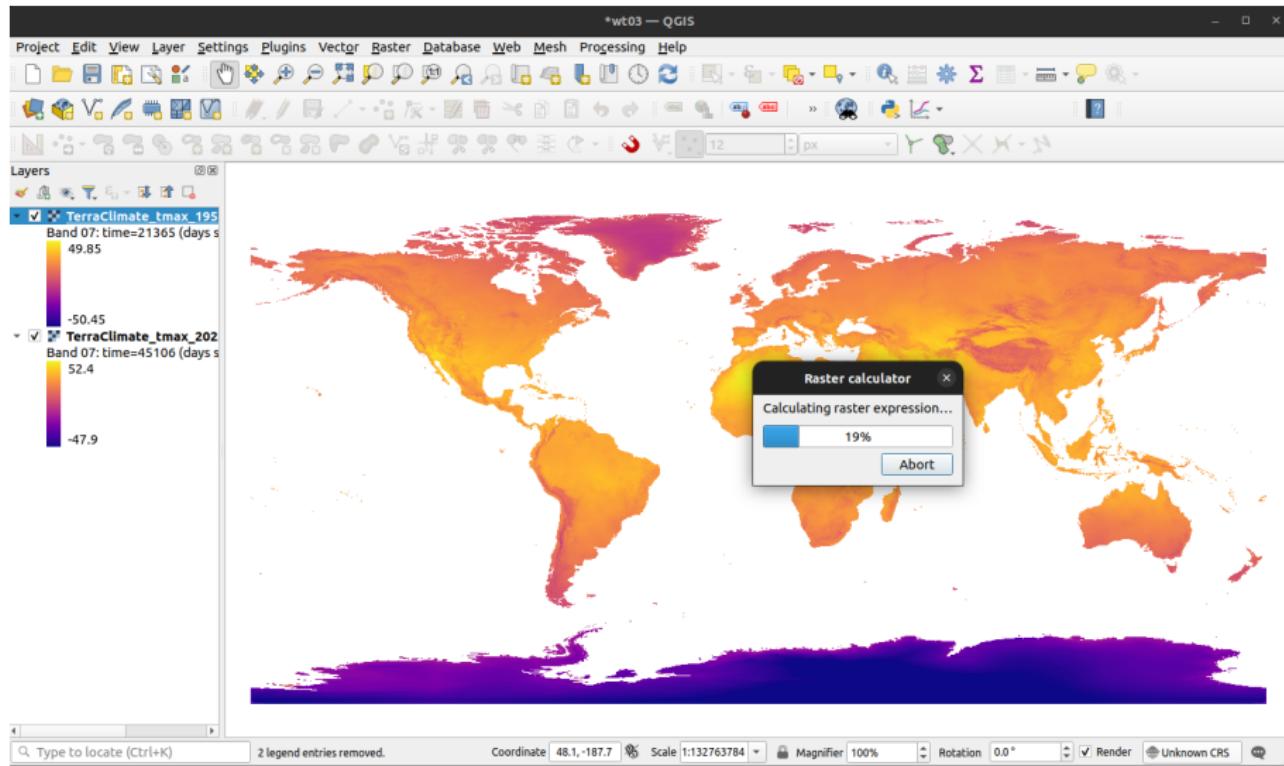


Set the Expression to

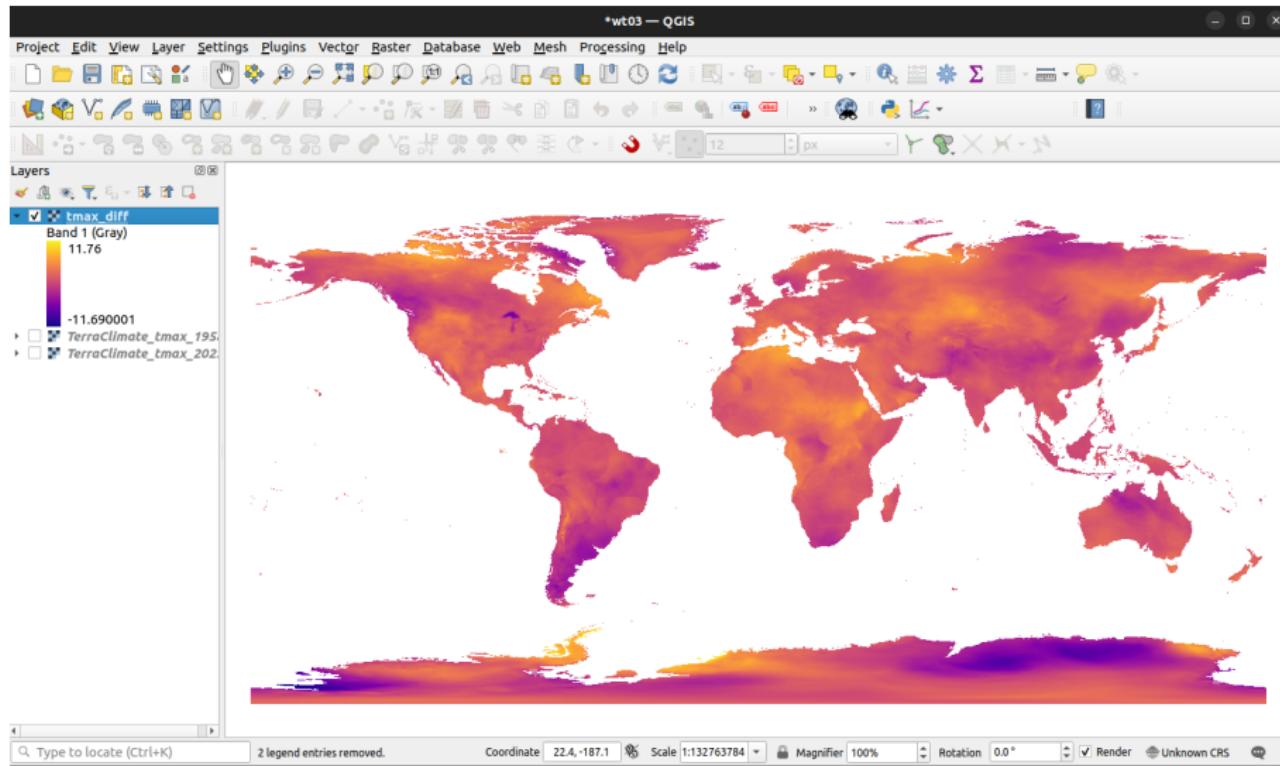
"TerraClimate_tmax_2023@7" - "TerraClimate_tmax_1958@7" (July temp in 2023 minus July temp in 1958). Save the output as `tmax_diff.tif`



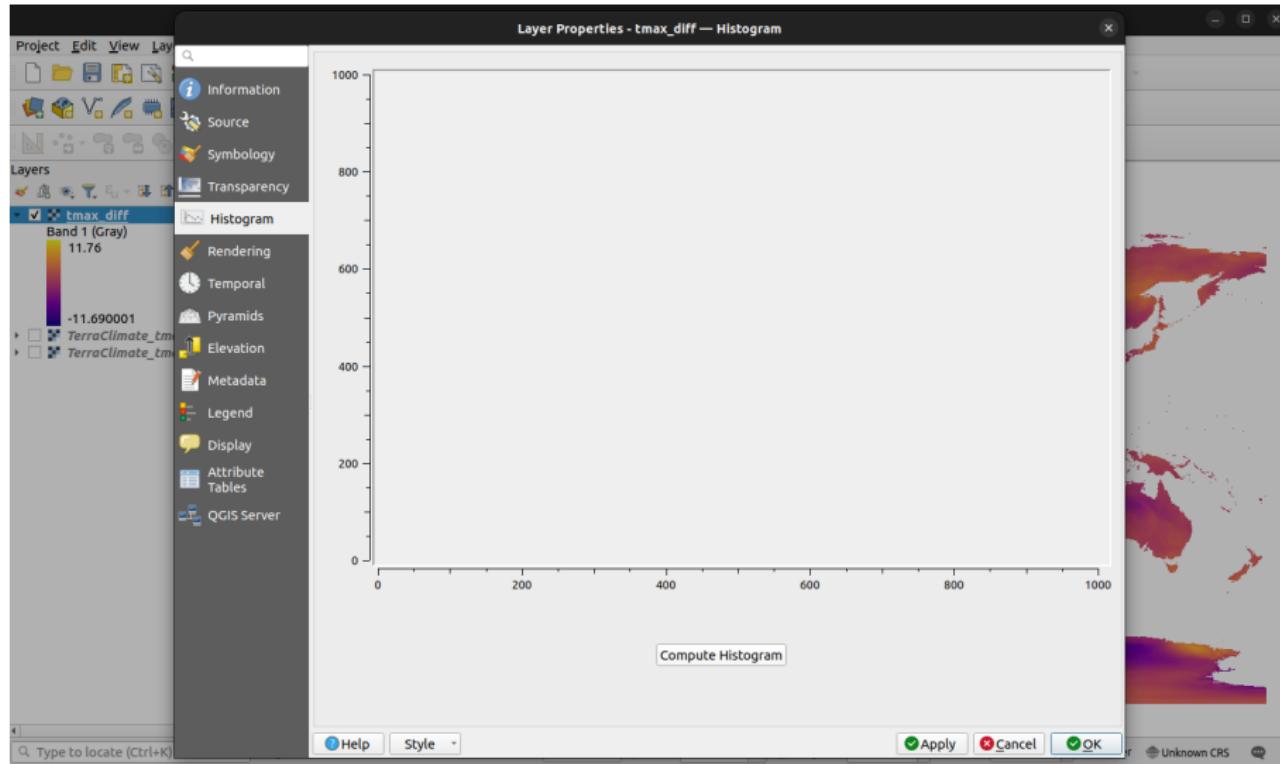
This will take a few minutes to compute



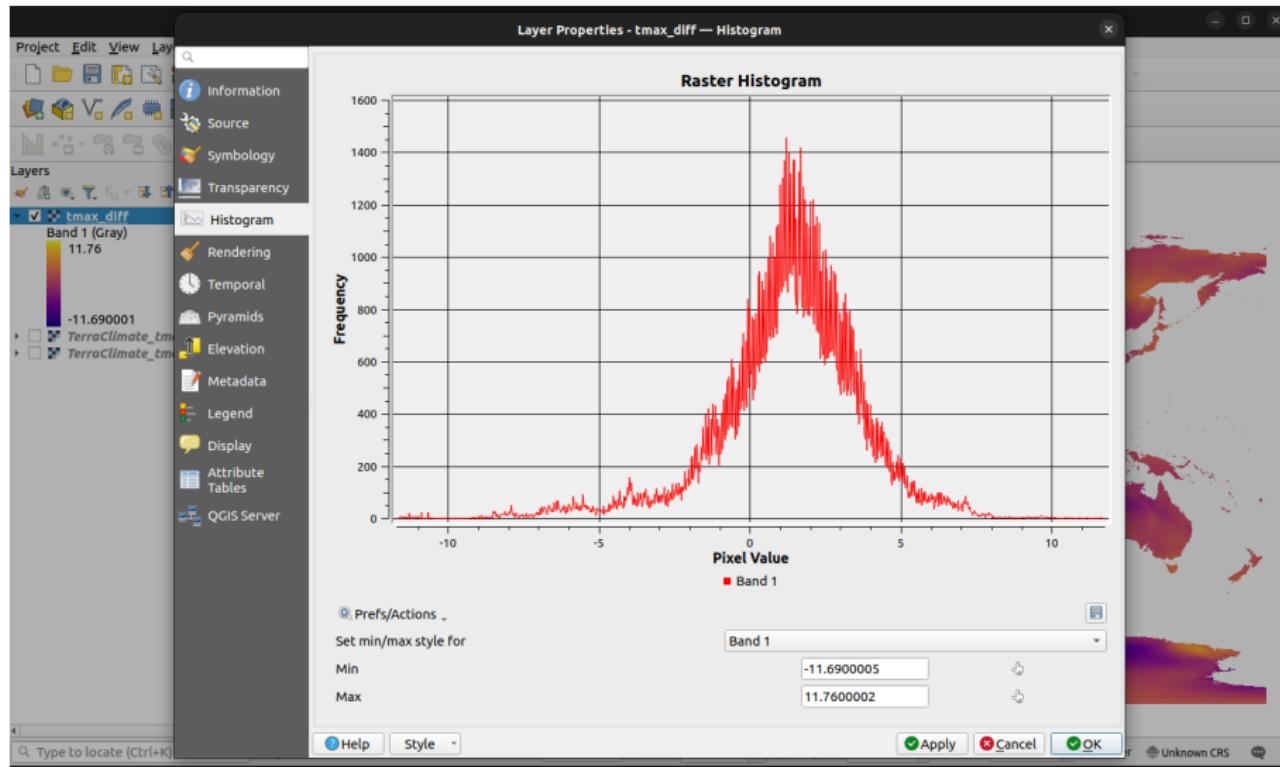
The `tmax_diff` raster should look something like this



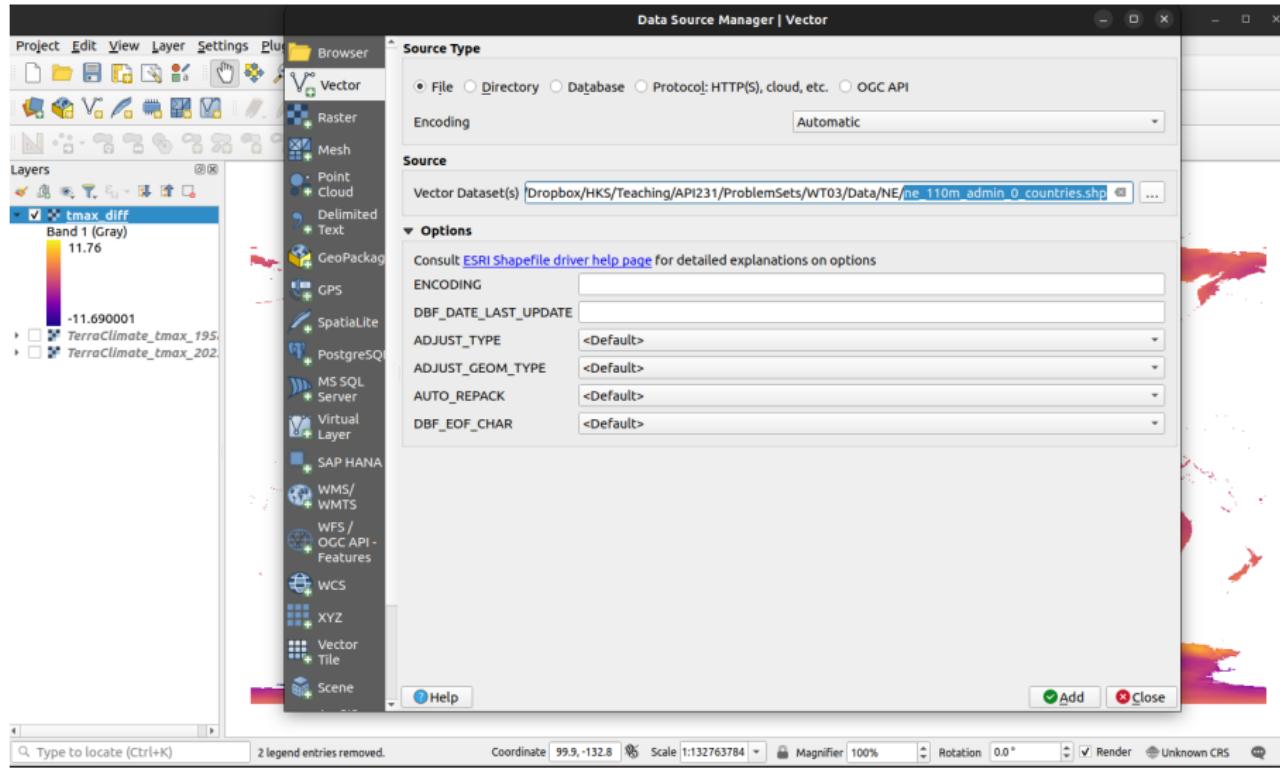
Let's examine the distribution of global temperature changes. In the layer Properties for `tmax_diff`, open the Histogram tab. Click Compute Histogram



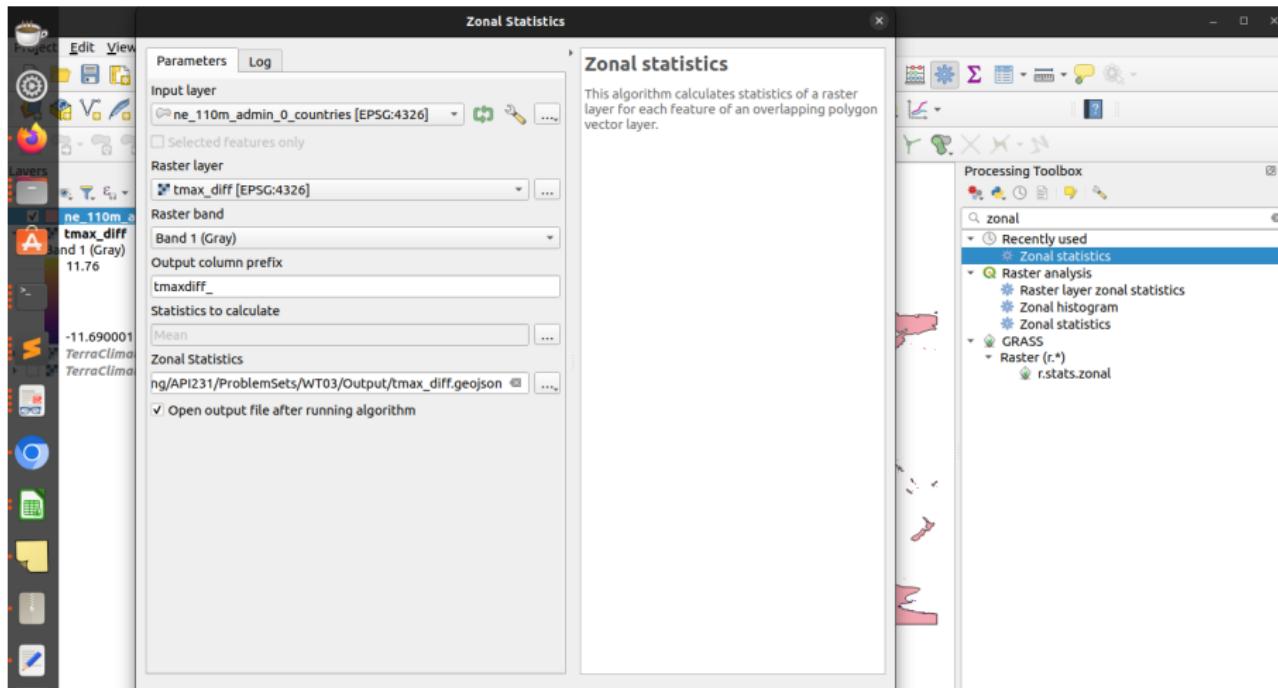
Most temperature changes were positive, with a mode around + 2 degrees Celsius



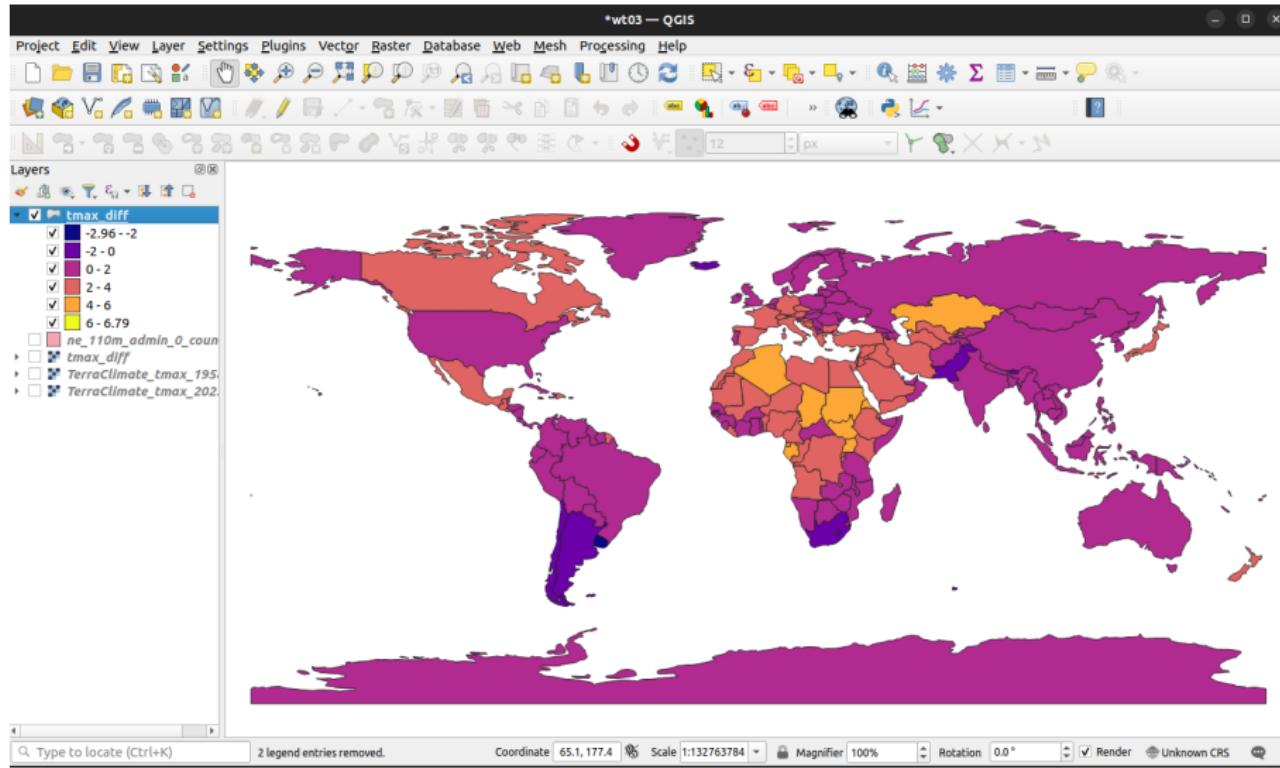
Let's calculate average changes by country. Load the ne_110m_admin_0_countries.shp file



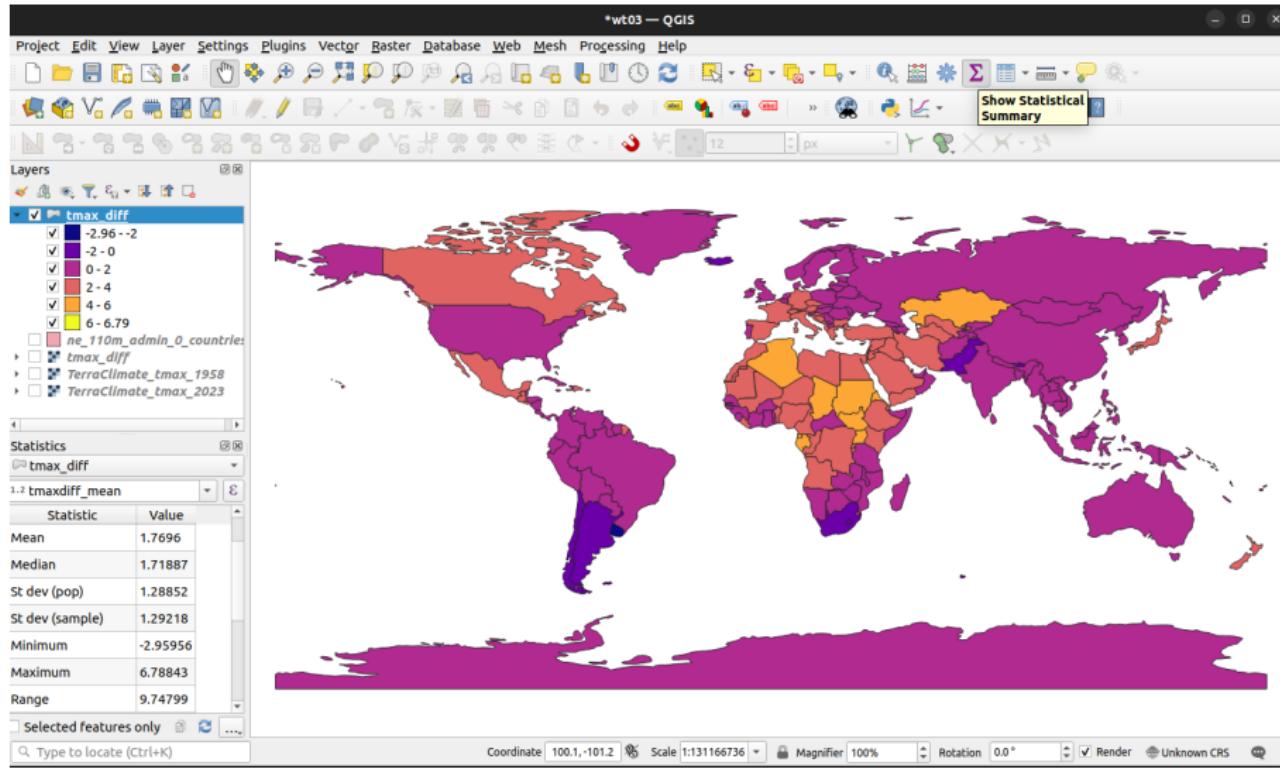
Once the borders are loaded, open Zonal Statistics from the Processing Toolbox. Set Input layer = ne_110m_admin_0_countries, Raster layer = tmax_diff, prefix = tmax_diff_, Statistics to calculate = Mean. Save the output as tmax_diff.geojson



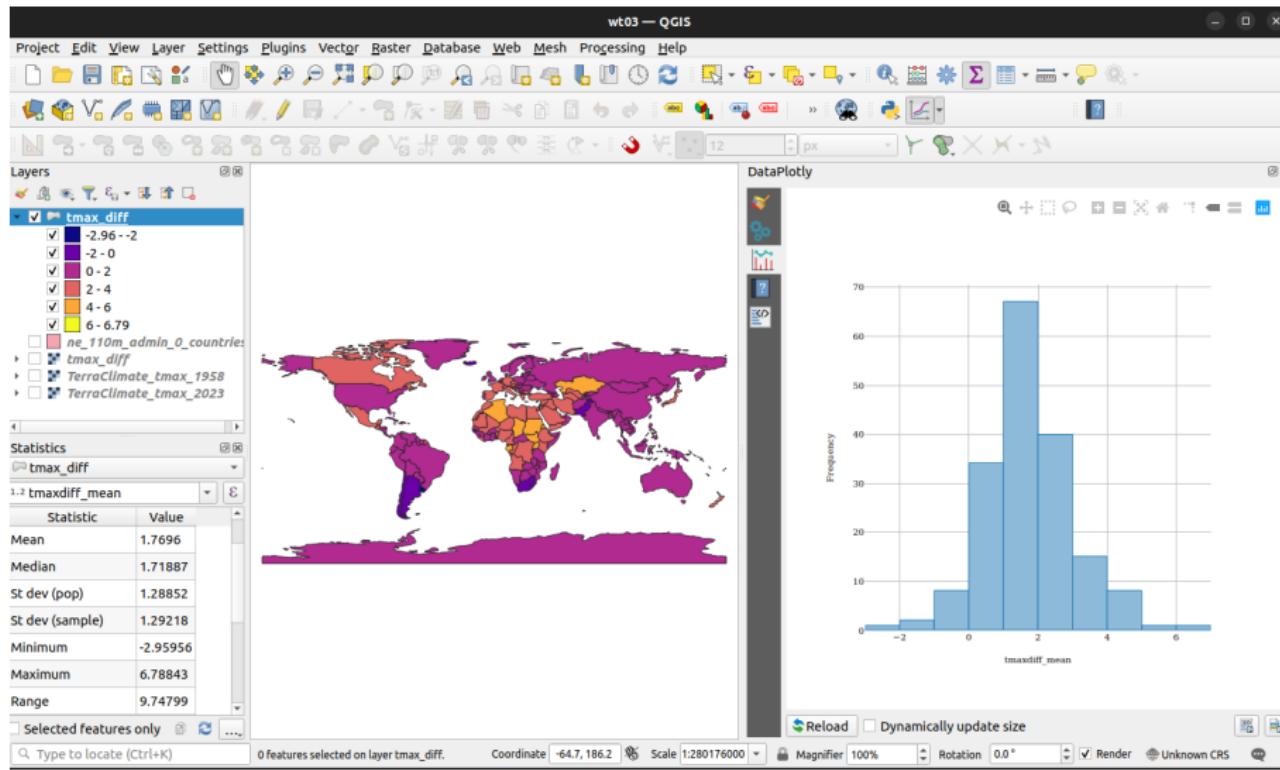
North Africa and Central Asia appear to have had the most acute increases in July temperatures



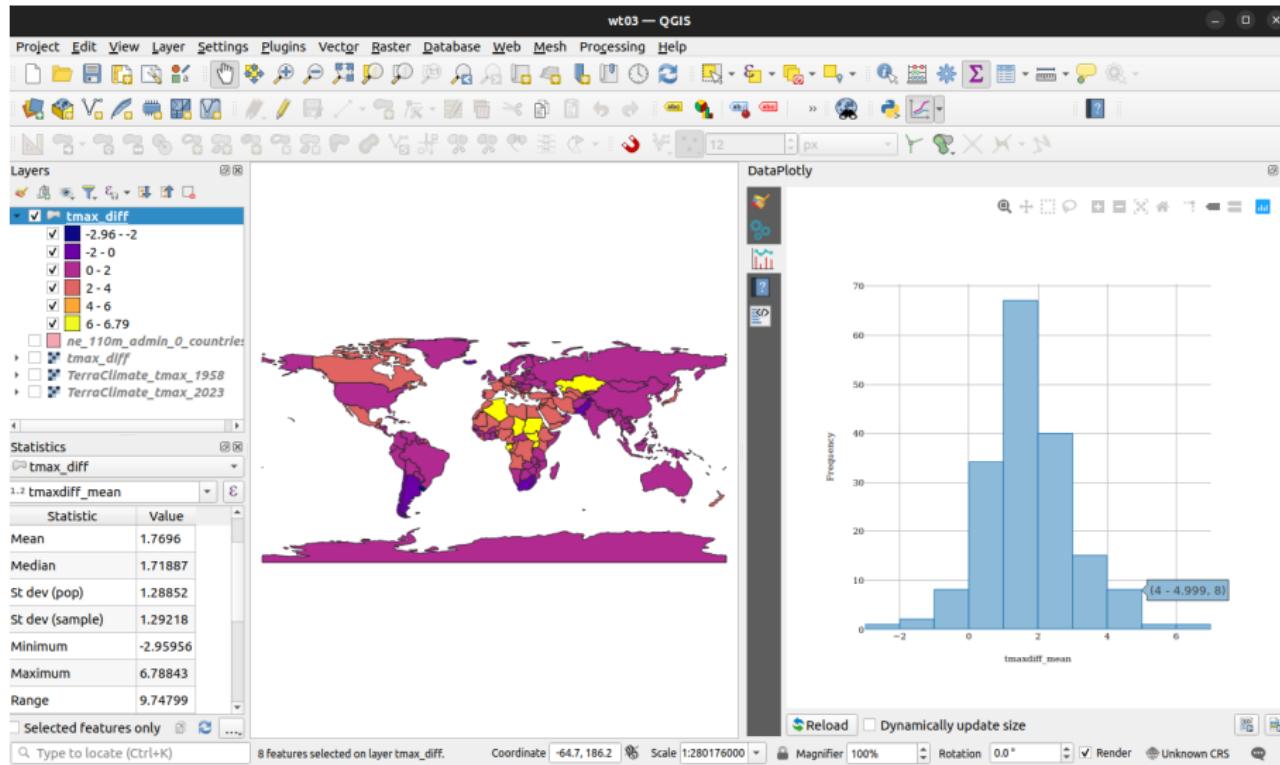
Clicking on the Σ button ("Show Statistical Summary"), we can look up some descriptive stats. The average country saw an increase of 1.77 degrees Celsius



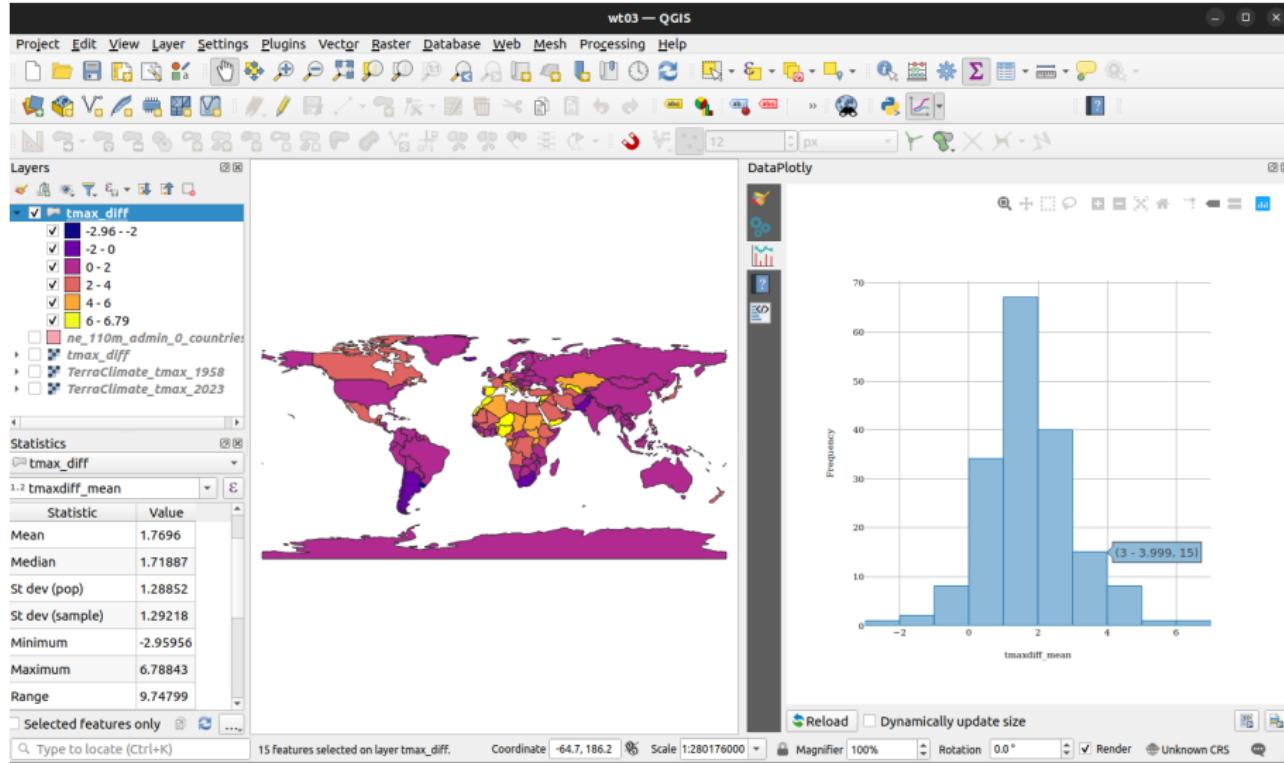
Let's create an interactive histogram with Plotly. Set Plot type = Histogram, Layer = tmax_diff, Grouping field = tmaxdiff_mean. Click Create Plot



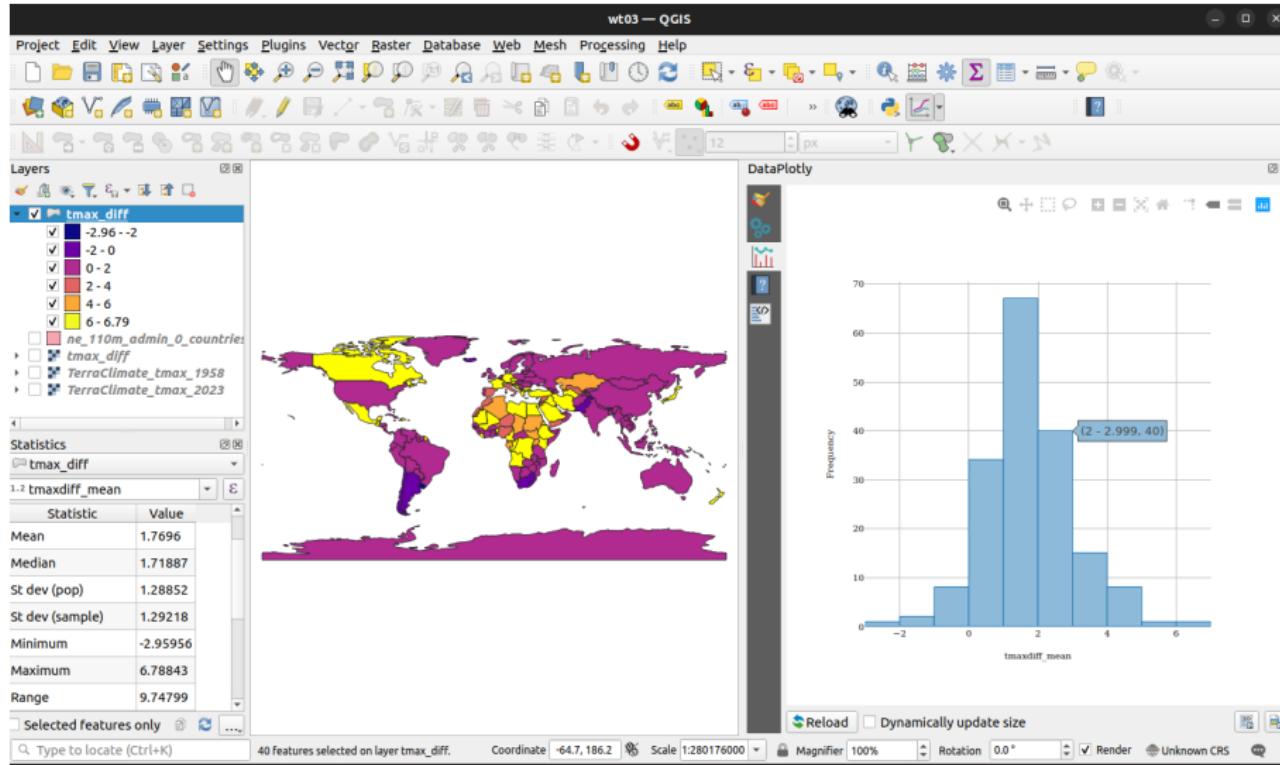
Clicking on the individual bars of the histogram will highlight the countries that fall into that bin, such as here for increases between 4 and 5 degrees



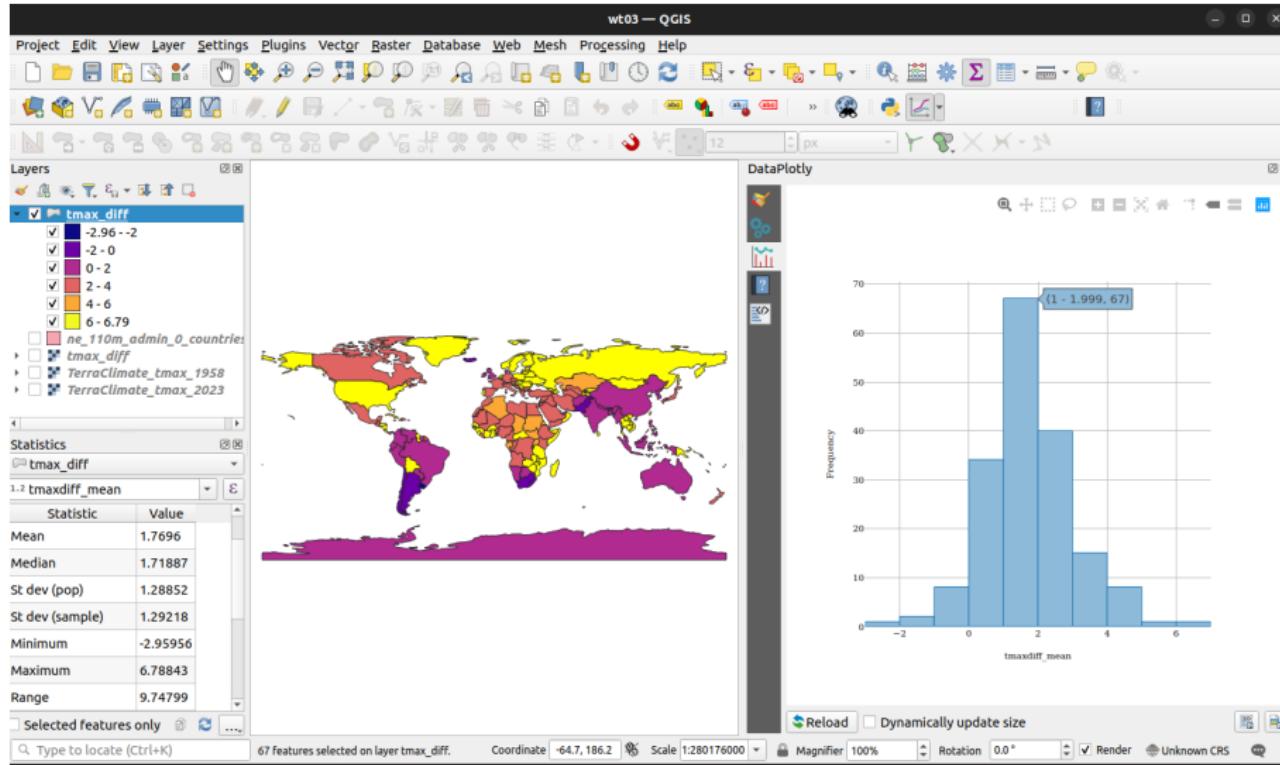
... increases of 3-4 degrees



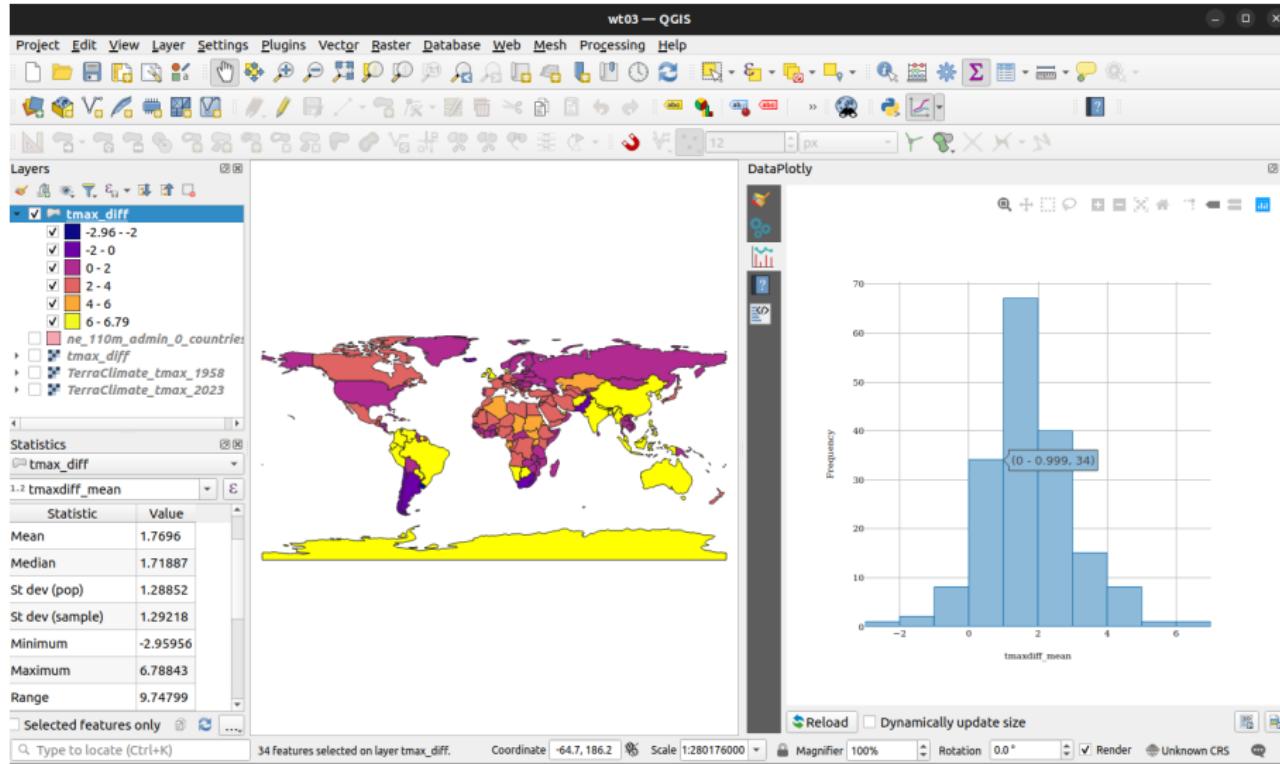
... increases of 2-3 degrees



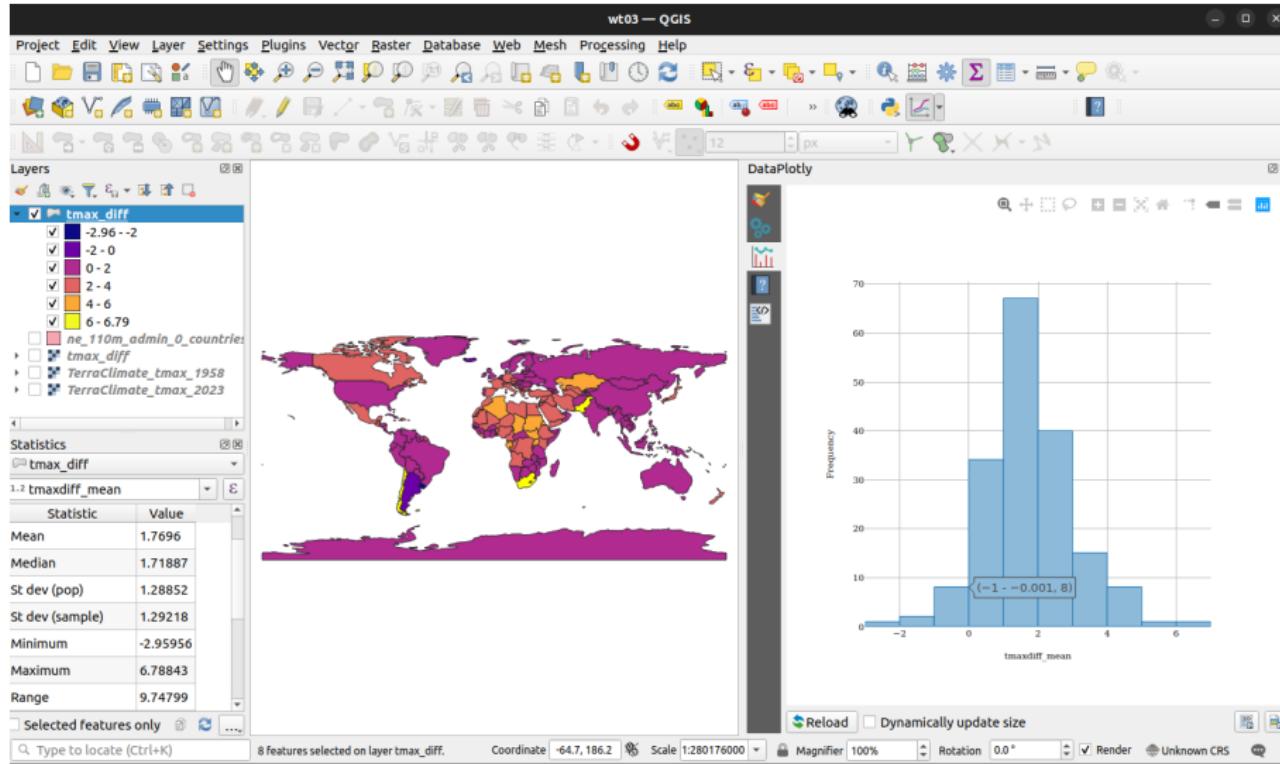
... increases of 1-2 degrees (the most numerous category)



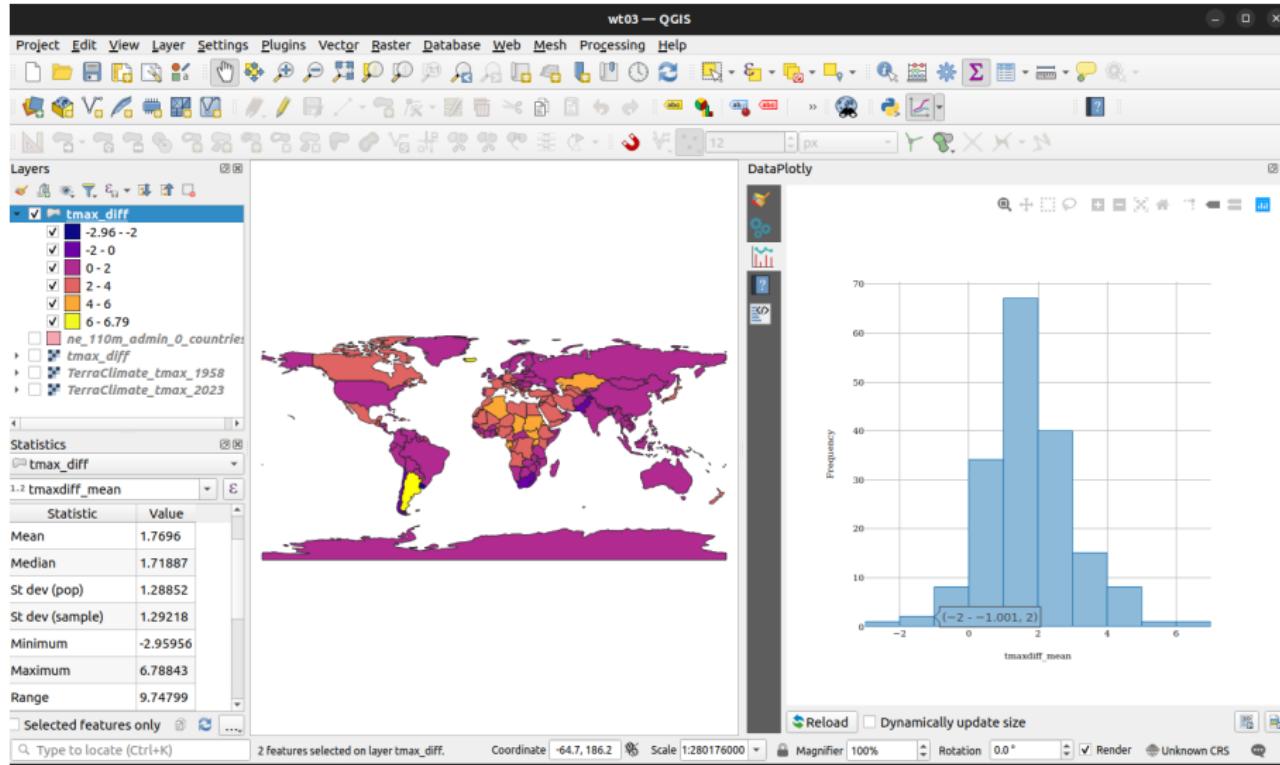
... increases between 0 and 1 degree



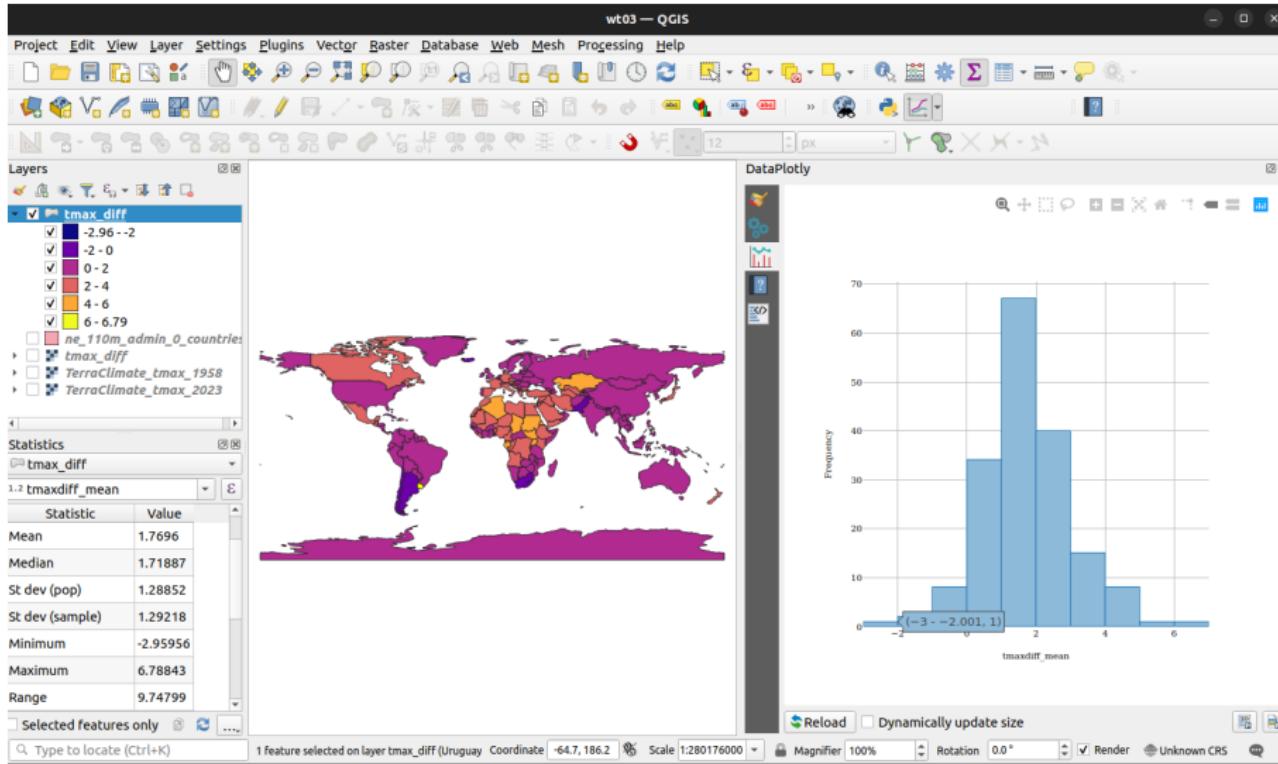
...decreases of 0 to 1 degree



...decreases of 1 to 2 degrees



... and decreases of 2 to 3 degrees (just Uruguay here)



Drought severity and violence during the 2011 Arab spring

Vignette 2! Let's create a regional subset of countries. The `ne_110m...` file has a variable called `REGION_WB`, where one of the categories is “Middle East & North Africa”

The screenshot shows a QGIS interface with a map of the Middle East and North Africa region. The countries are shaded in pink. Below the map is a table with the following data:

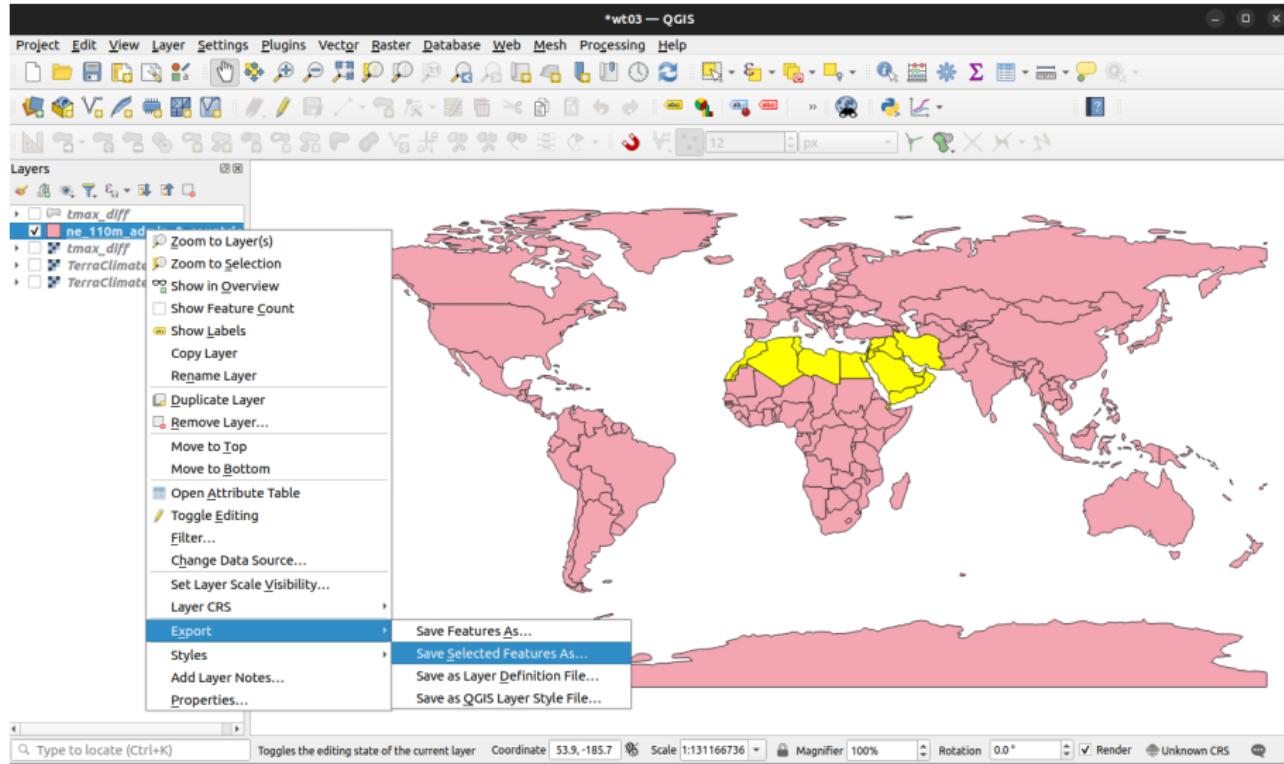
	A3_SE	ADM0_A3_BD	ADM0_A3_UA	ADM0_A3_UN	ADM0_A3_WB	CONTINENT	REGION_UN	SUBREGION	REGION_WB	NAME_LEN	LONG_LEN	ABBREV_LEN	TINY	HOM
1	FJI	FJI	-99	-99	Oceania	Oceania	Melanesia	East Asia & Pacific	East Asia & Pacific	4	4	4	-99	
2	TZA	TZA	-99	-99	Africa	Africa	Eastern Afr...	Sub-Saharan Africa	Sub-Saharan Africa	8	8	5	-99	
3	SAH	SAH	-99	-99	Africa	Africa	Northern A...	Middle East & North Africa	Middle East & North Africa	9	14	7	-99	
4	CAN	CAN	-99	-99	North Ame...	Americas	Northern A...	North America	North America	6	6	4	-99	
5	USA	USA	-99	-99	North Ame...	Americas	Northern A...	North America	North America	24	13	6	-99	
6	KAZ	KAZ	-99	-99	Asia	Asia	Central Asia	Europe & Central Asia	Europe & Central Asia	10	10	4	-99	
7	UZB	UZB	-99	-99	Asia	Asia	Central Asia	Europe & Central Asia	Europe & Central Asia	10	10	4	5	
8	PNG	PNG	-99	-99	Oceania	Oceania	Melanesia	East Asia & Pacific	East Asia & Pacific	16	16	6	-99	
9	IDN	IDN	-99	-99	Asia	Asia	South-East...	East Asia & Pacific	East Asia & Pacific	9	9	5	-99	

Go to Select by Expression, set Expression to REGION_WB='Middle East & North Africa', and click Select Features

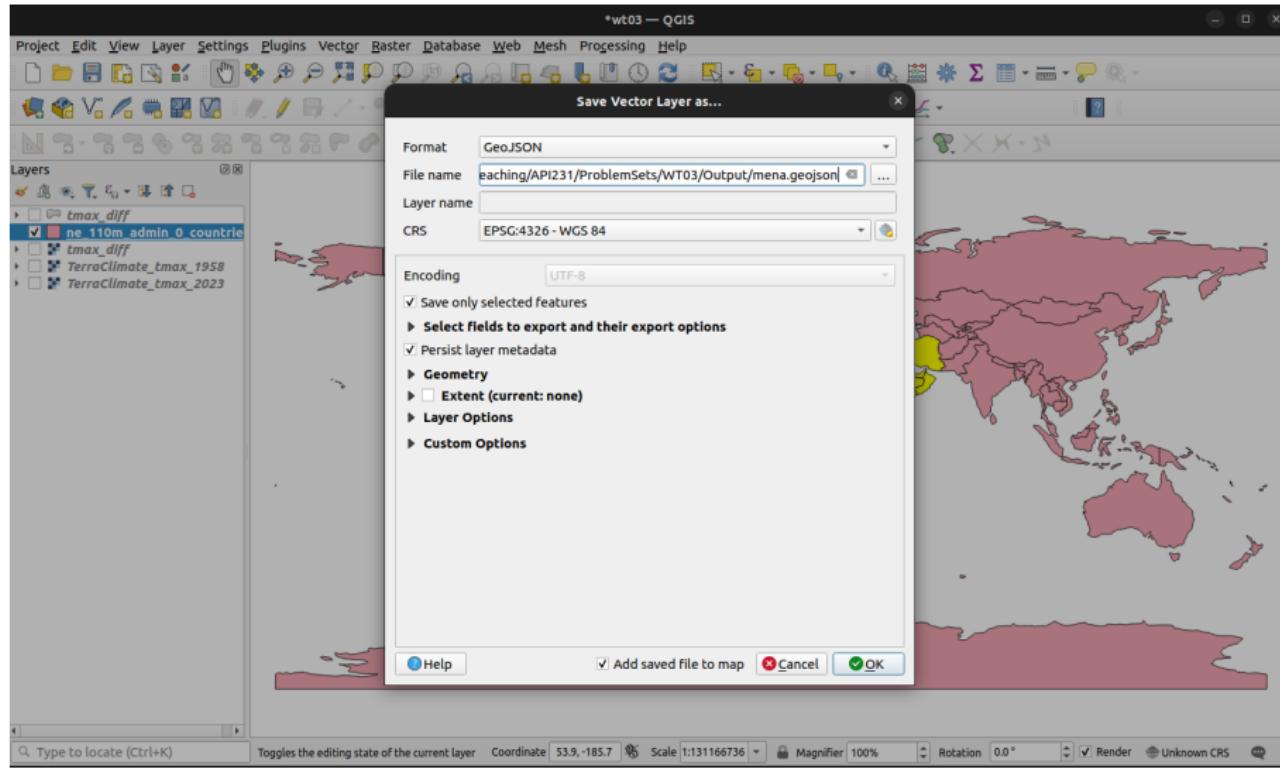
The screenshot shows a QGIS interface with a map of countries highlighted in pink. A message box at the top says "20 matching features selected". Below it, a table titled "ne_110m_admin_0_countries — Features Total: 177, Filtered: 177, Selected: 20" displays 20 rows of data. An "Expression" dialog box is overlaid on the bottom left. The expression field contains "REGION_WB='Middle East & North Africa'". The dialog also includes a function editor, a search bar, and a preview section showing "Preview: 1 Feature Algeria". The preview shows a pink-shaded area representing the selected country.

	A3_SE	ADMO_A3	BD	ADMO_A3	UA	ADMO_A3	UN	ADMO_A3_WB	CONTINENT	REGION_UN	SUBREGION	REGION_WB	NAME_LEN	LONG_LEN	ABBREV_LEN	TINY	HOM
1	FJI	FJI		-99	-99	Oceania	Oceania	Melanesia	East Asia & Pacific				4	4	4	-99	
2	TZA	TZA		-99	-99	Africa	Africa	Eastern Afr...	Sub-Saharan Africa				8	8	5	-99	
3	SAH	SAH		-99	-99	Africa	Africa	Northern Afr...	Middle East & North Africa				9	14	7	-99	
4													6	6	4	-99	
5													24	13	6	-99	
6													10	10	4	-99	
7													10	10	4	5	
8													16	16	6	-99	
9													9	9	5	-99	
10																	

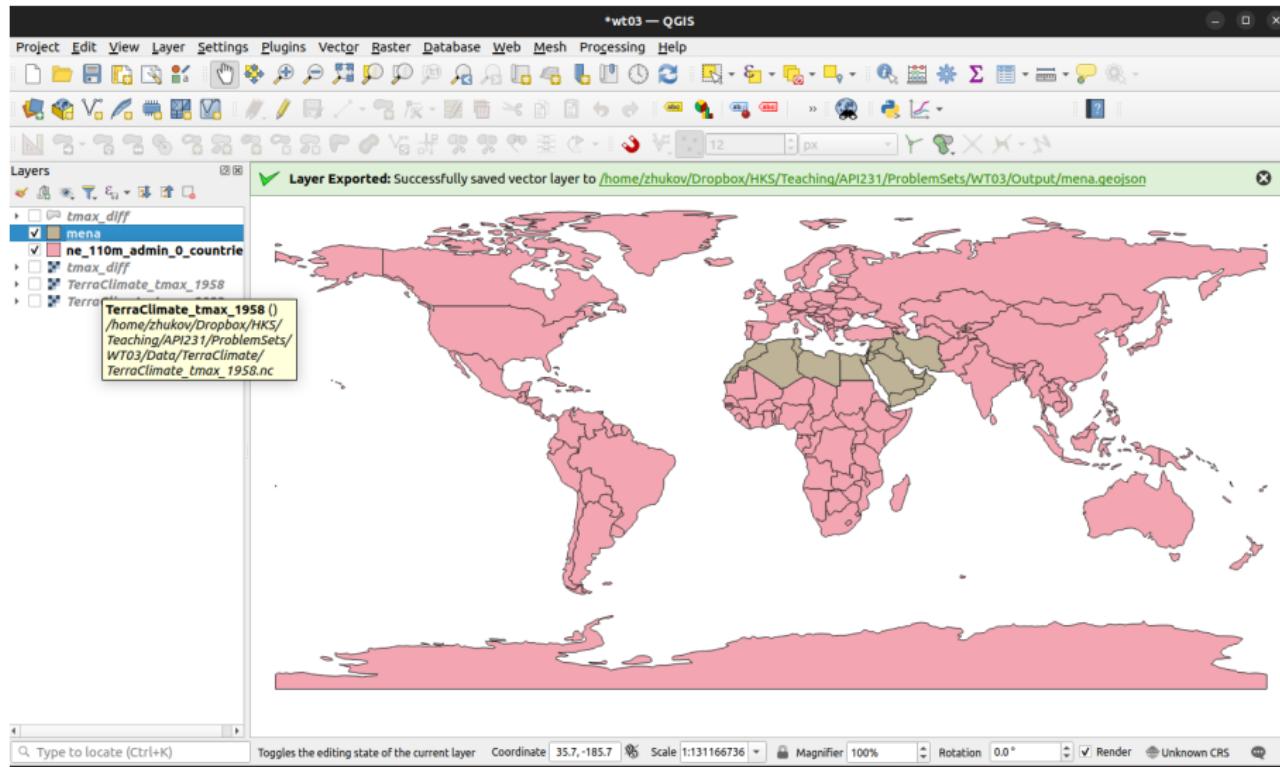
Export the selected features to a new file



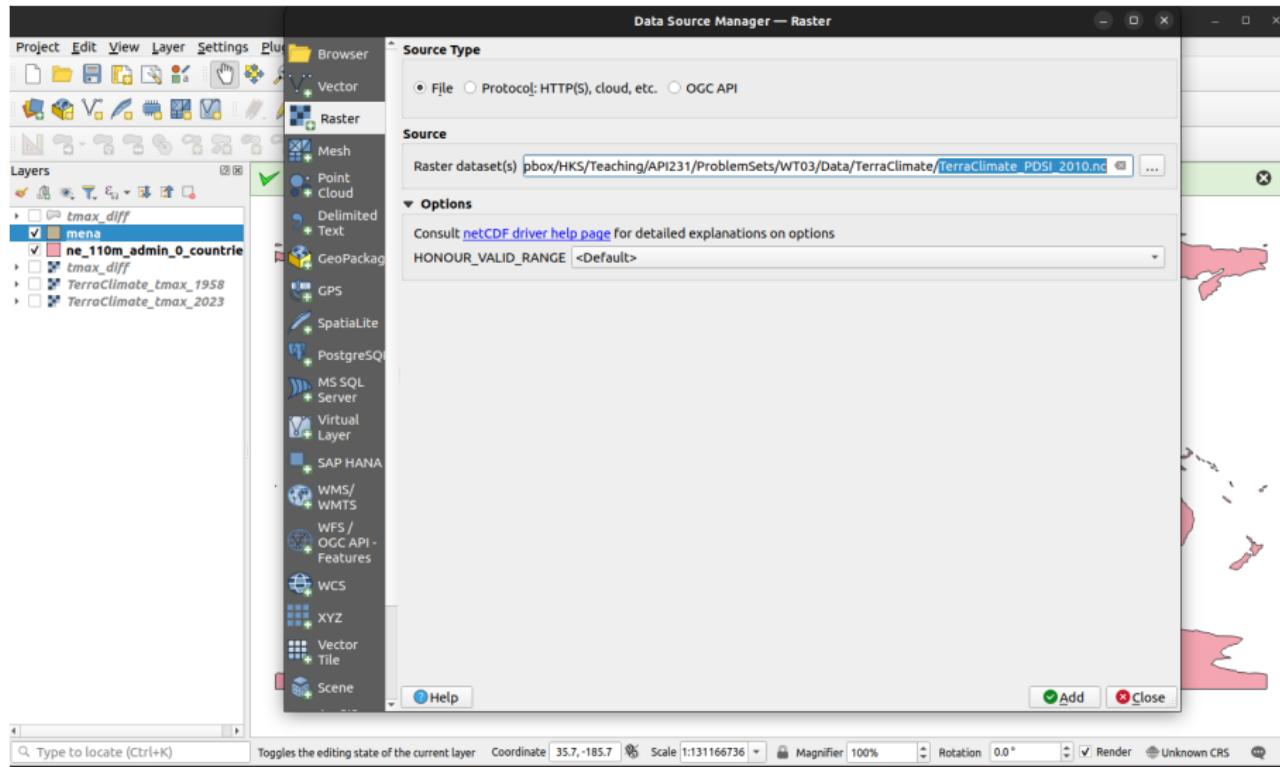
Save the layer as `mena.geojson`. Make sure the box is checked next to “Save only selected features”



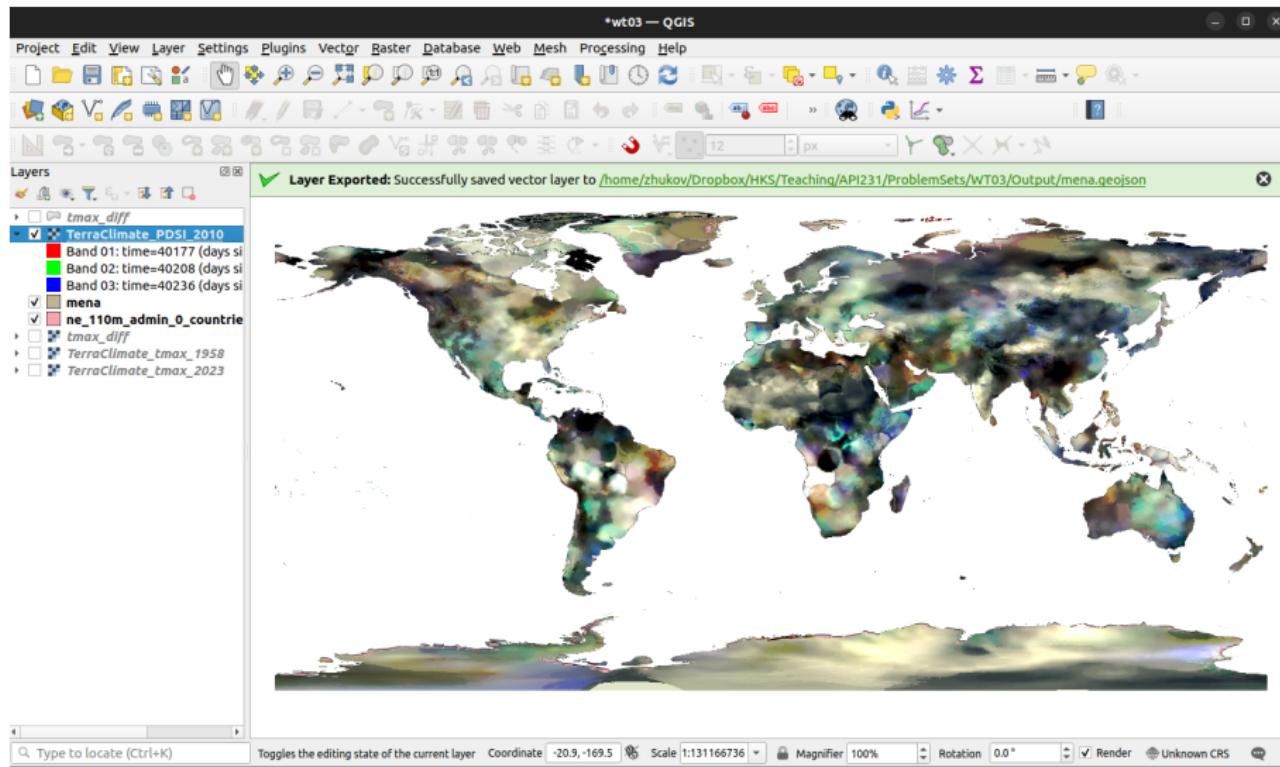
A new layer with 20 countries should appear in your project window



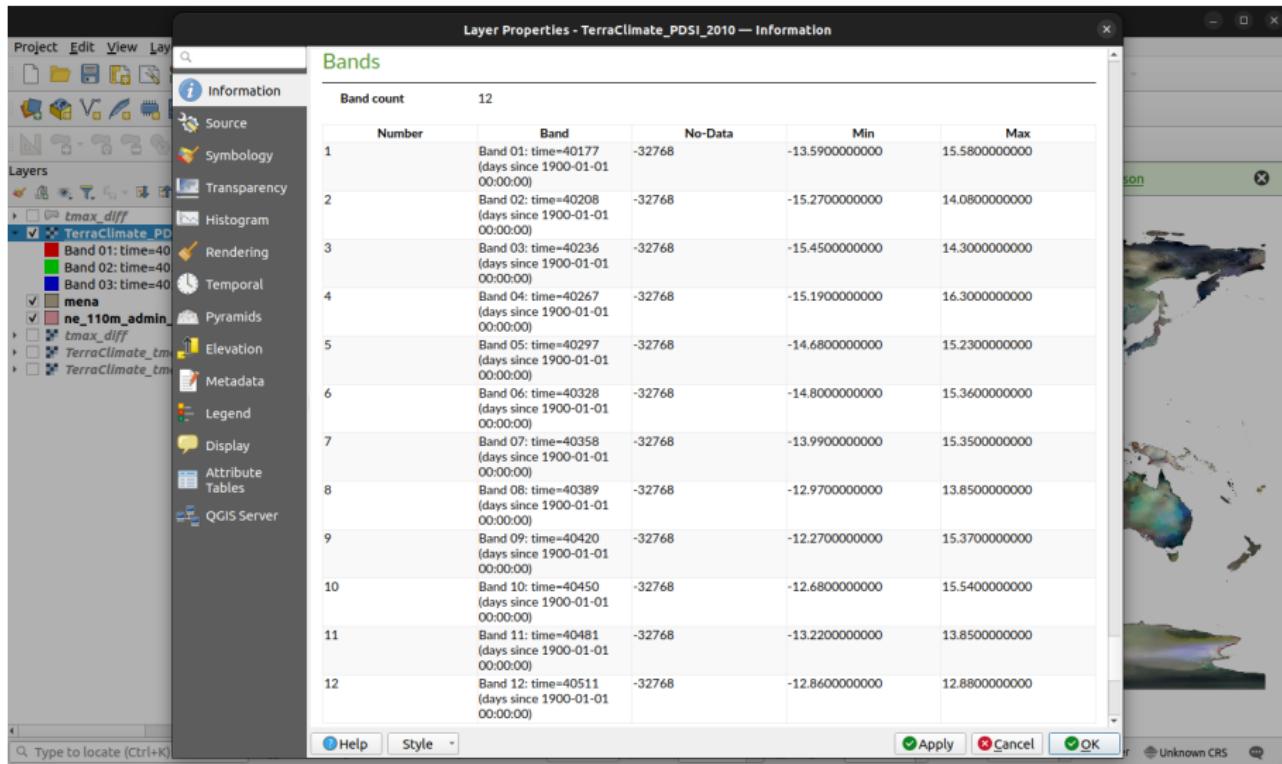
Load the drought index raster TerraClimate_PDSI_2010.nc



Another multiband raster. Open up the layer Properties to see the bands



As before, there are 12 bands here, one for each month



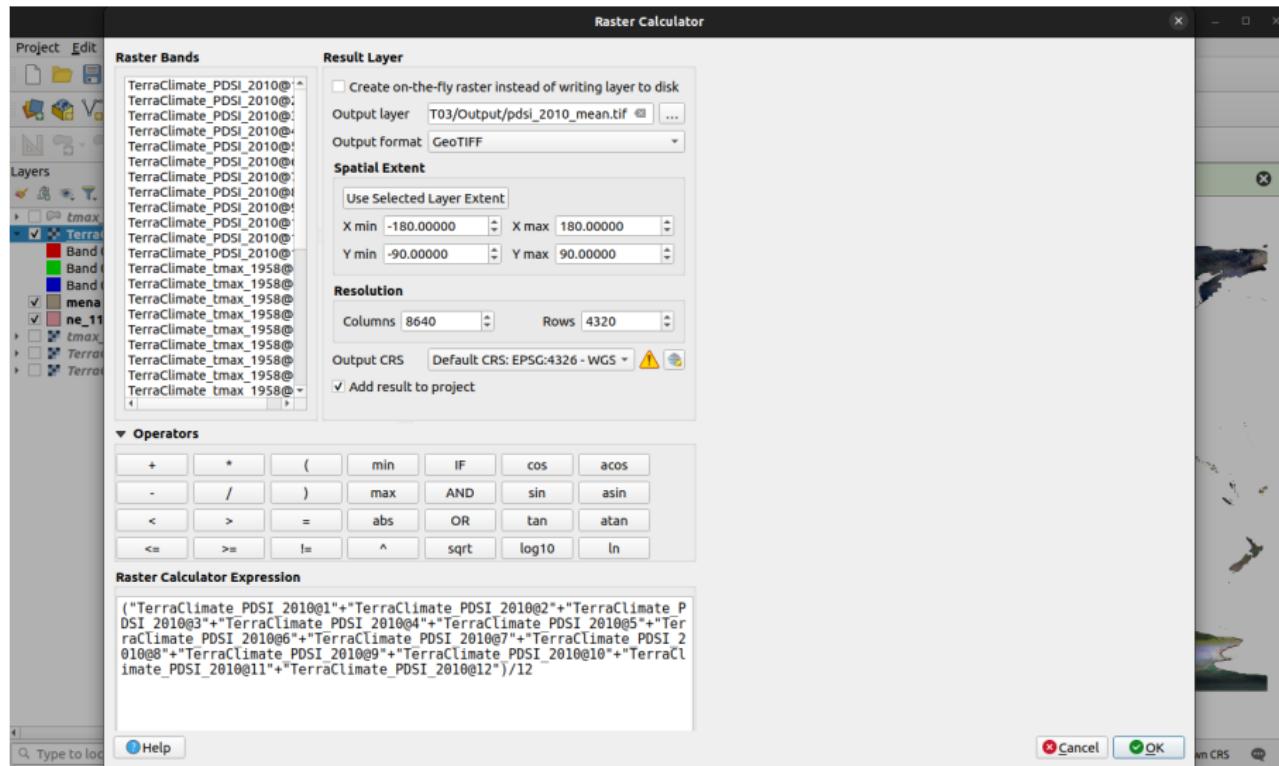
Let's calculate the average annual drought index, over all months.

Open the Raster Calculator and set Expression to

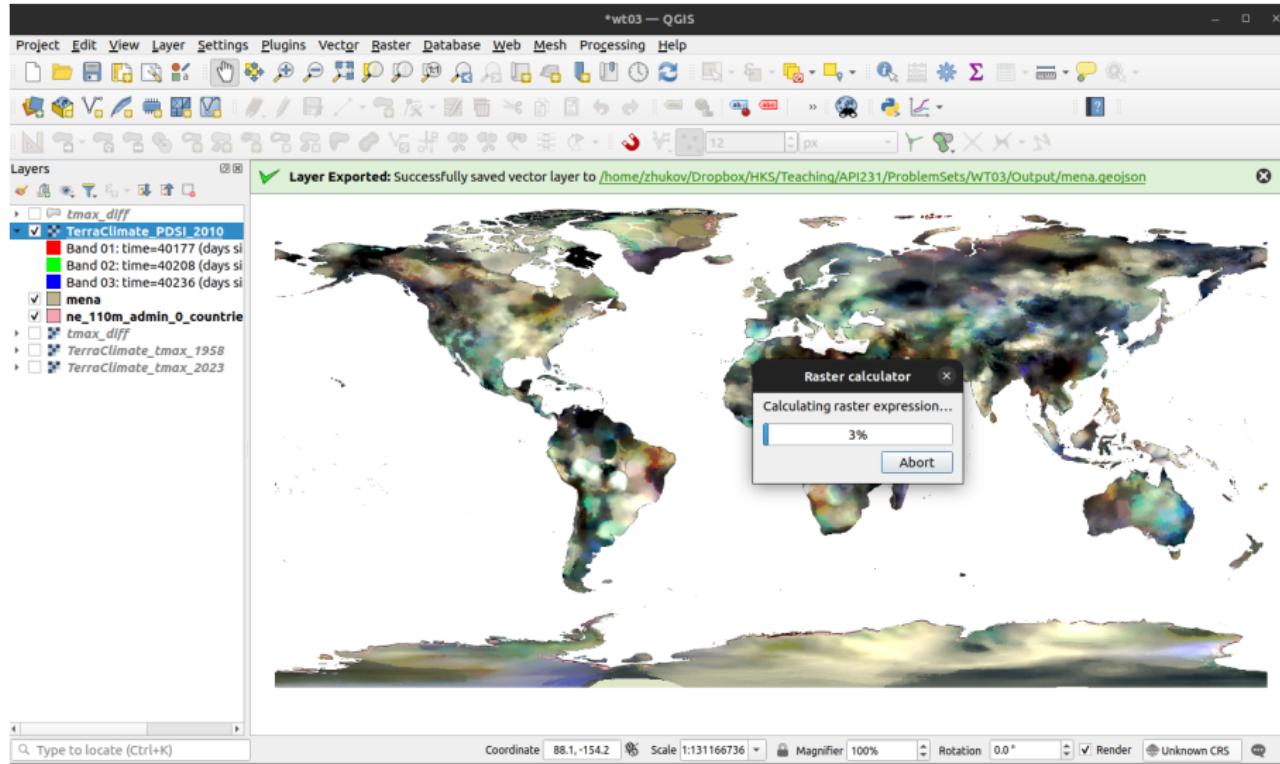
```
("TerraClimate_PDSI_2010@1"+ "TerraClimate_PDSI_2010@2" +  
"TerraClimate_PDSI_2010@3" + "TerraClimate_PDSI_2010@4" +  
"TerraClimate_PDSI_2010@5" + "TerraClimate_PDSI_2010@6" +  
"TerraClimate_PDSI_2010@7" + "TerraClimate_PDSI_2010@8" +  
"TerraClimate_PDSI_2010@9" + "TerraClimate_PDSI_2010@10" +  
"TerraClimate_PDSI_2010@11" + "TerraClimate_PDSI_2010@12")/12
```

(you may want to copy and paste this one). Save the raster as

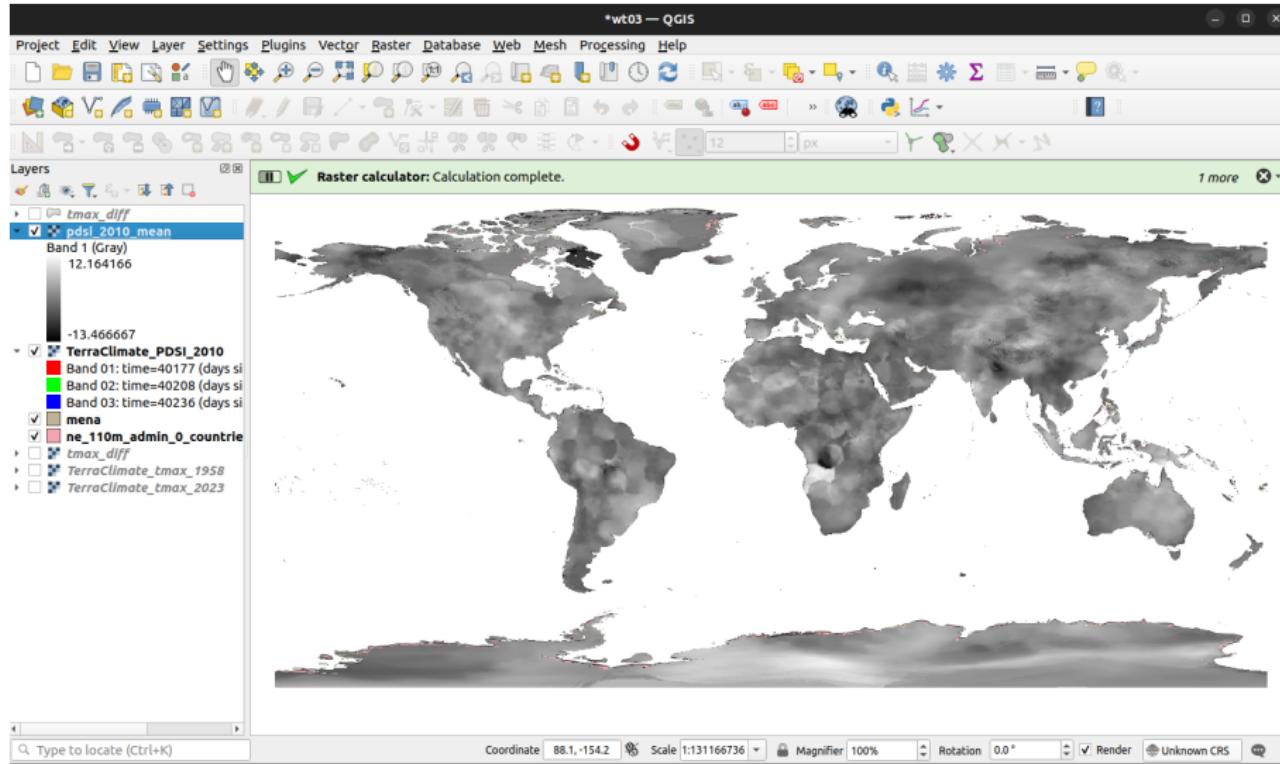
pdsi_2010_mean.tif



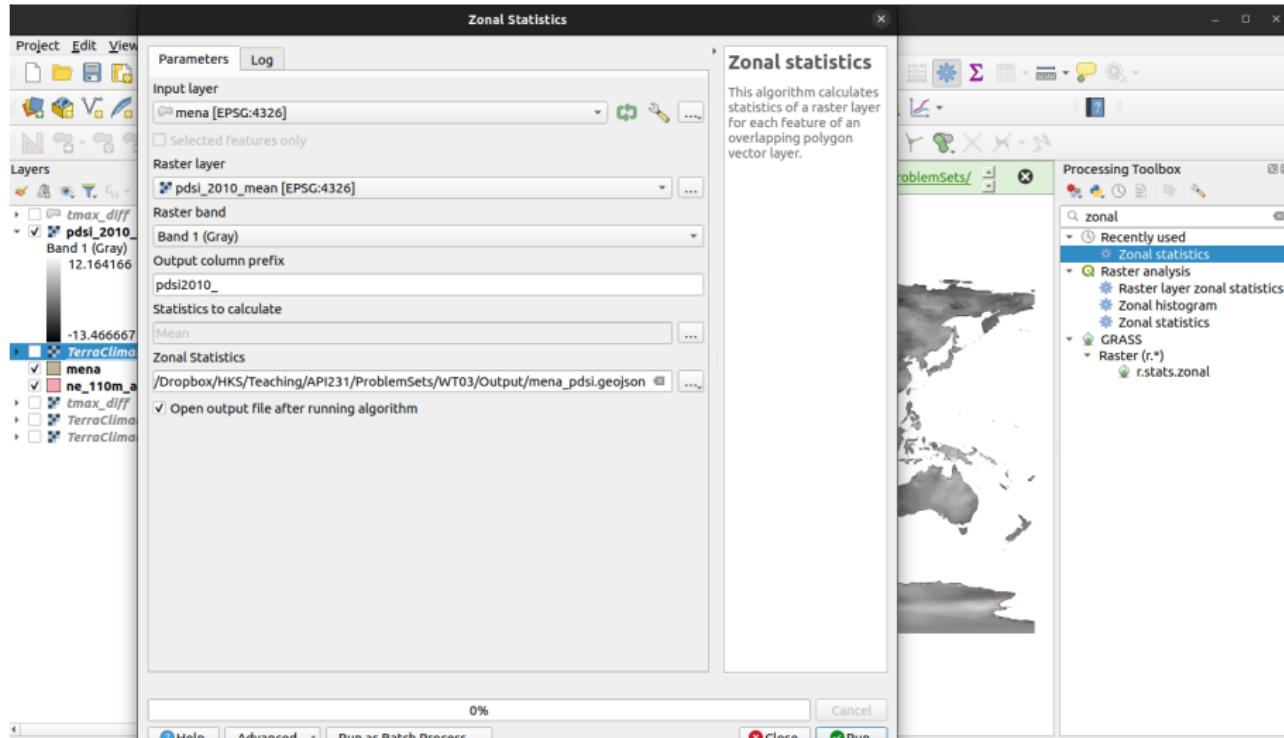
This will take a few minutes to process



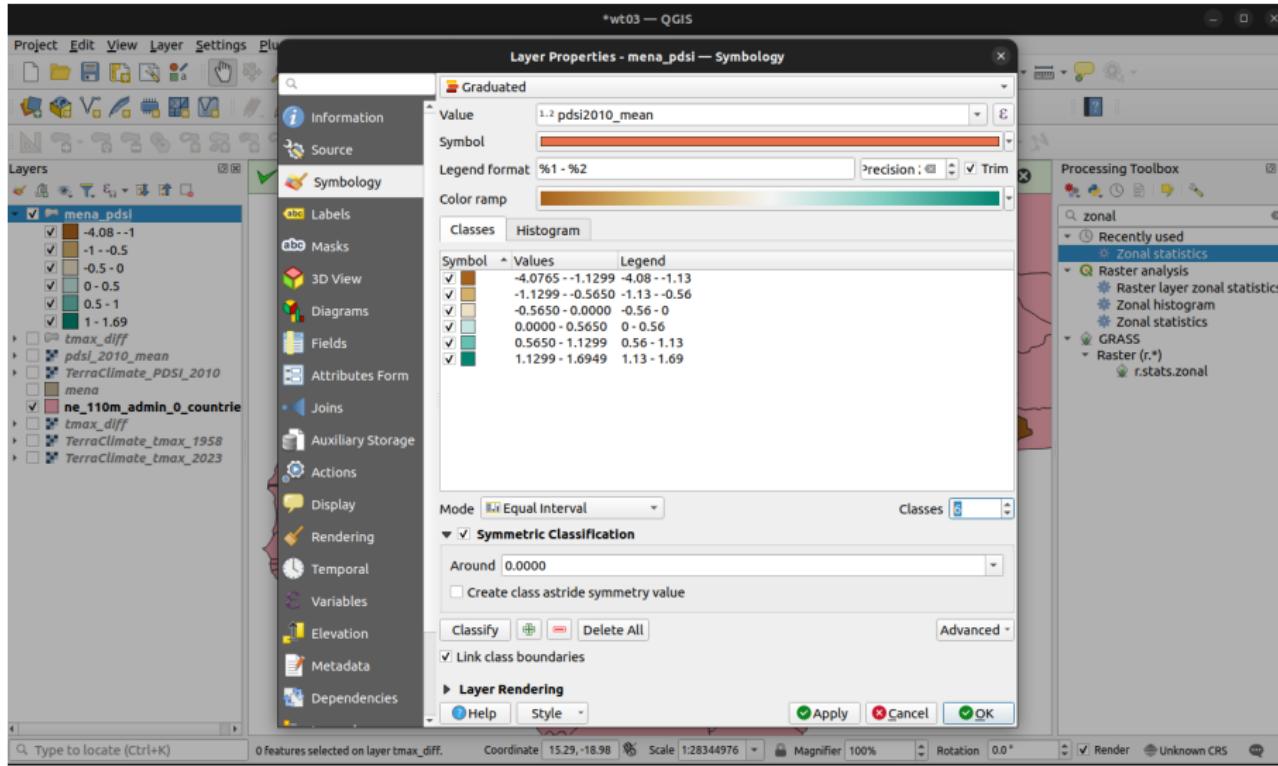
The output will look something like this: a single-band raster of averages



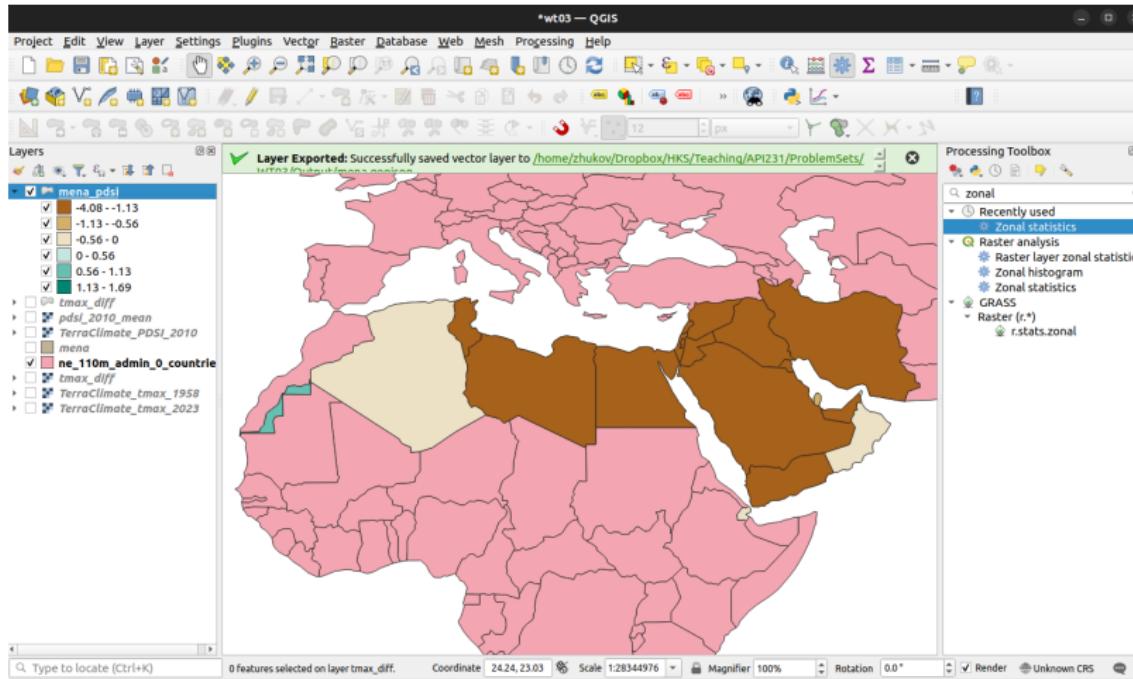
Calculate country averages. Open Zonal Statistics, set Input layer = mena, Raster layer = pdsi_2010_mean, prefix = pdsi2010_, Statistics to calculate = Mean. Save the output as mena_pdsi.geojson



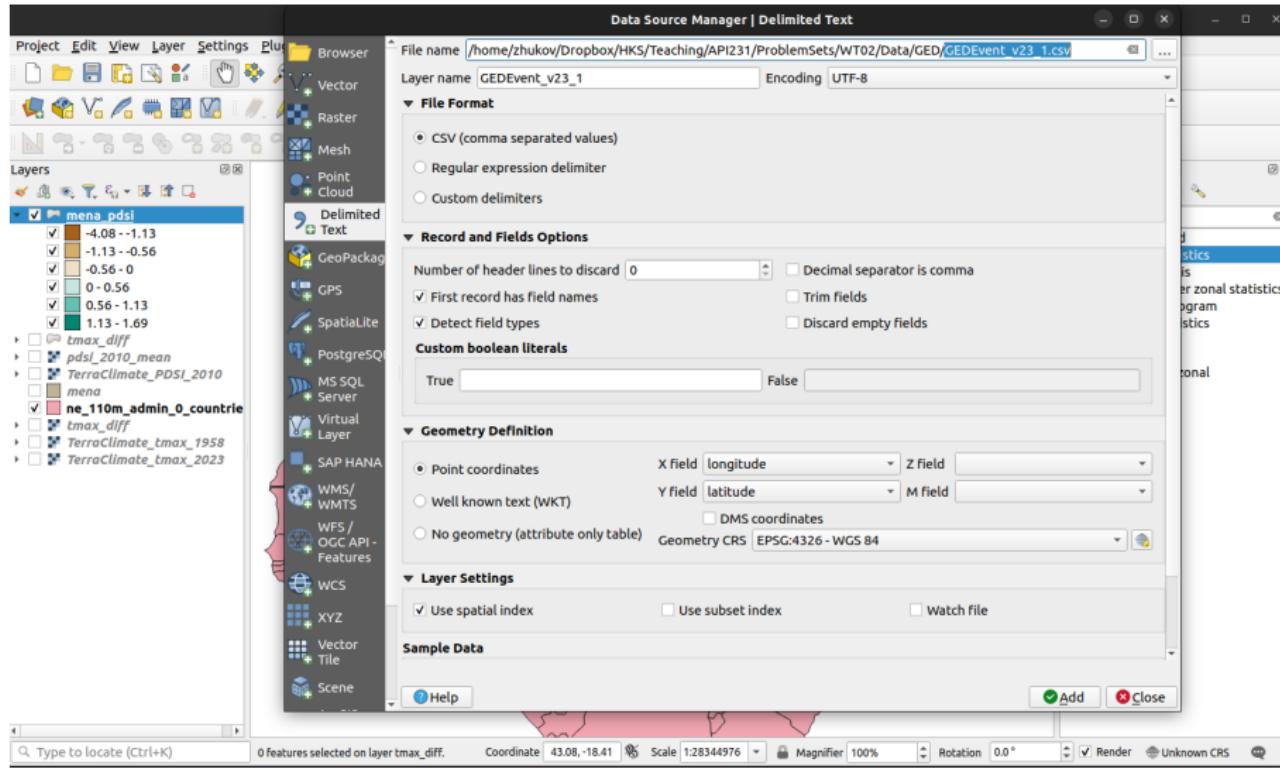
Try visualizing the country-level results. Lower index scores = worse drought



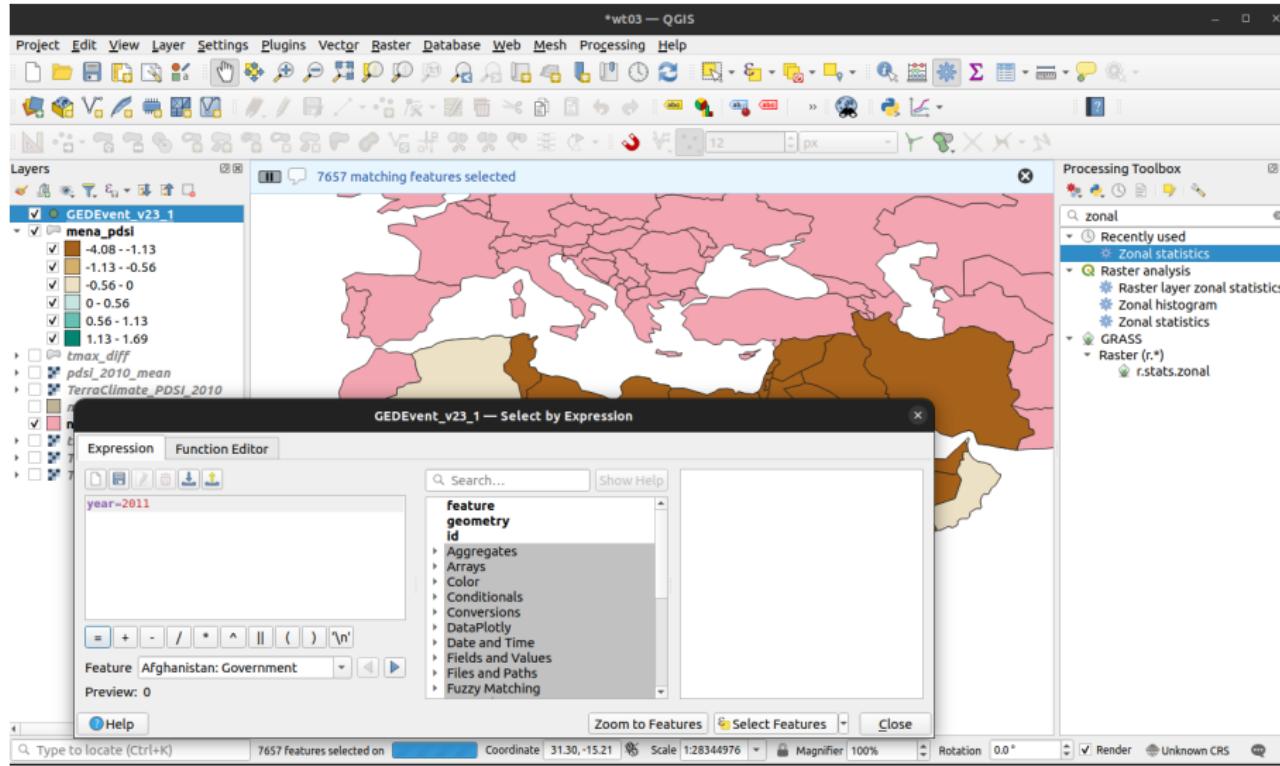
The drought index is negative virtually everywhere except Western Sahara



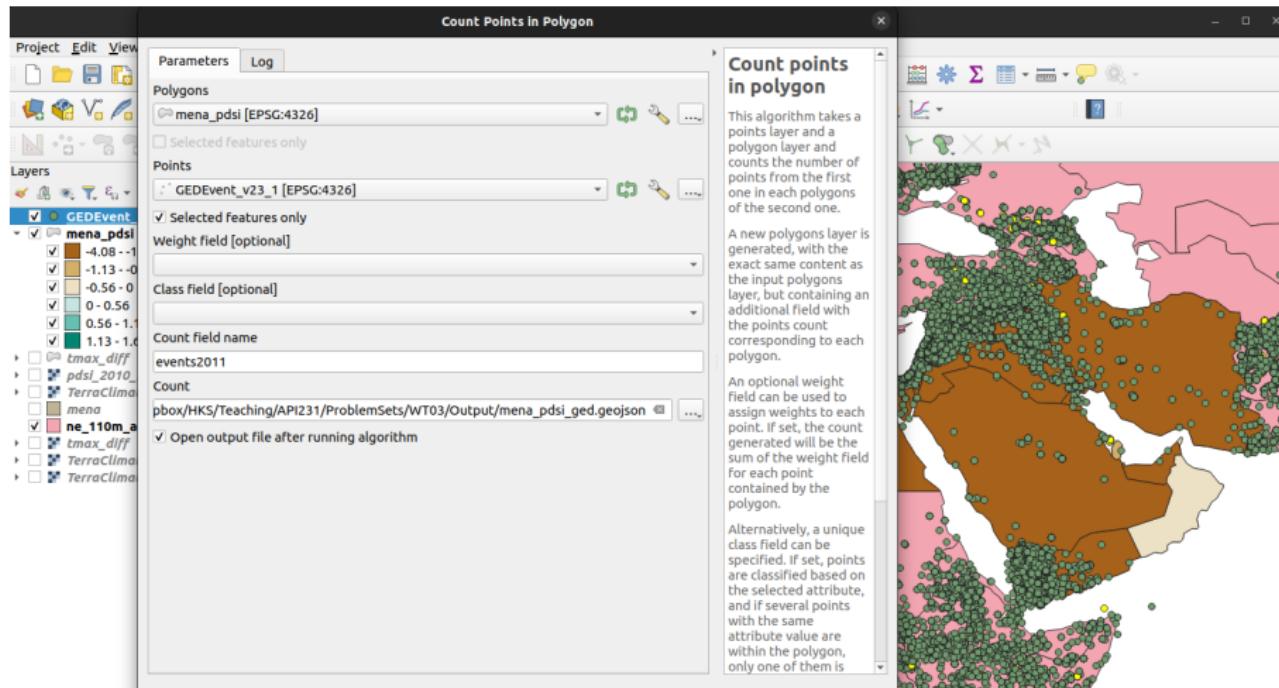
Finally, let's link this up with data on violent events. Load GEDEvent_v23_1.csv, with spatial index



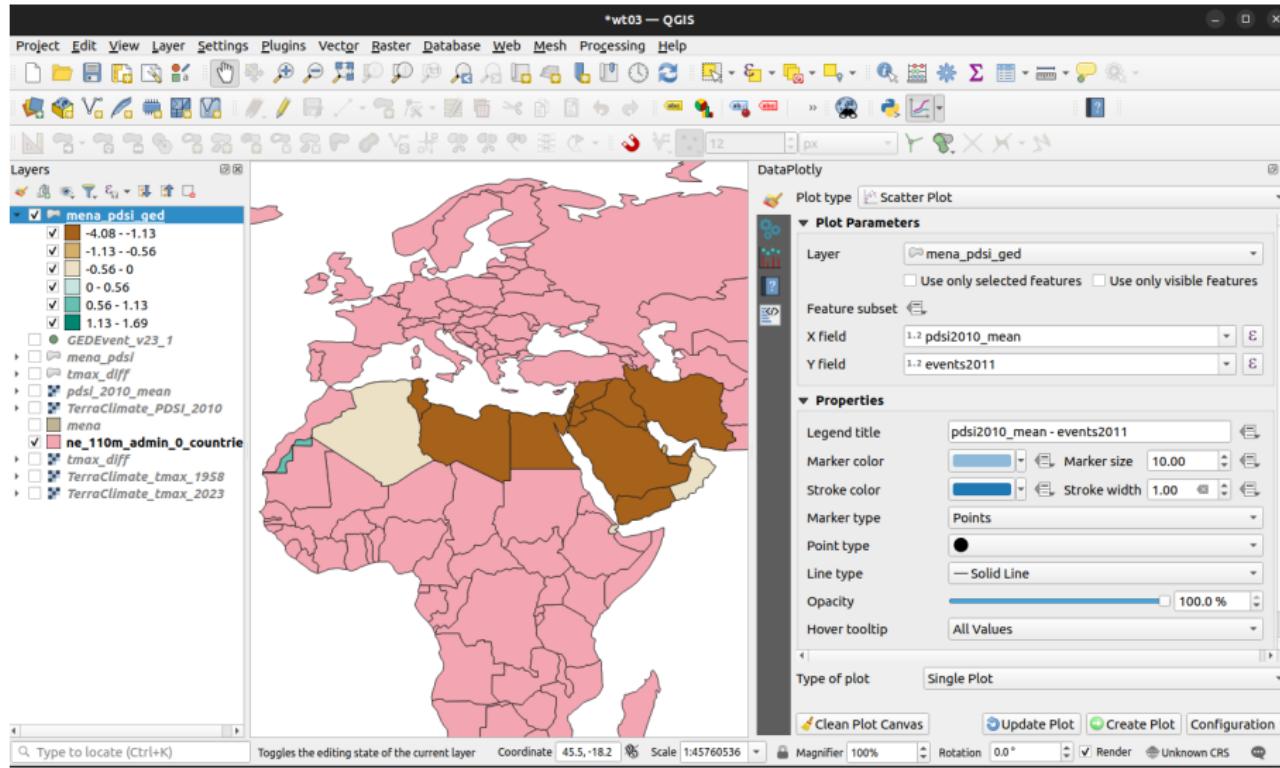
Select by Expression: year=2011. Click Select Features



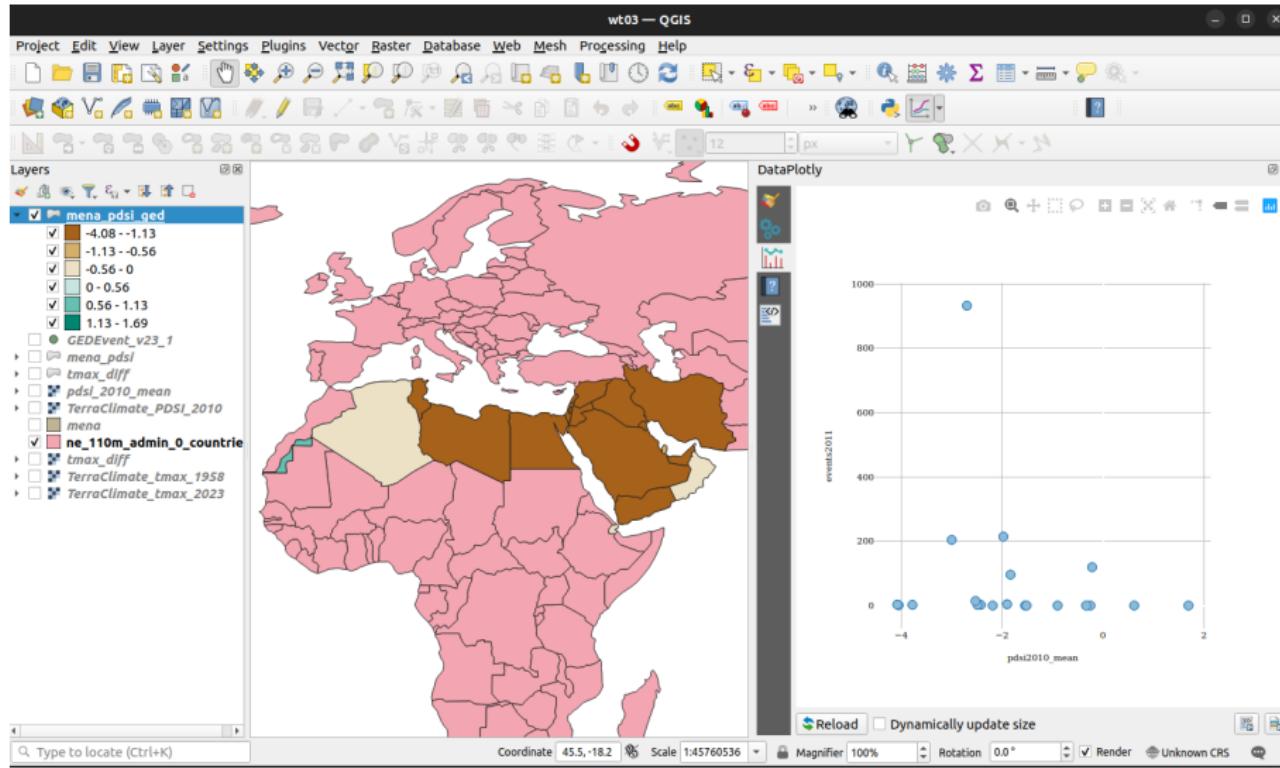
Open the Count Points in Polygon tool. Select Polygons = mena_pdsi, Points = GEDEvent_v23_1. Make sure the box is checked next to Selected Features Only for the points. Name the count field events2011, and save the output file as mena_pdsi_ged.geojson. Click Run



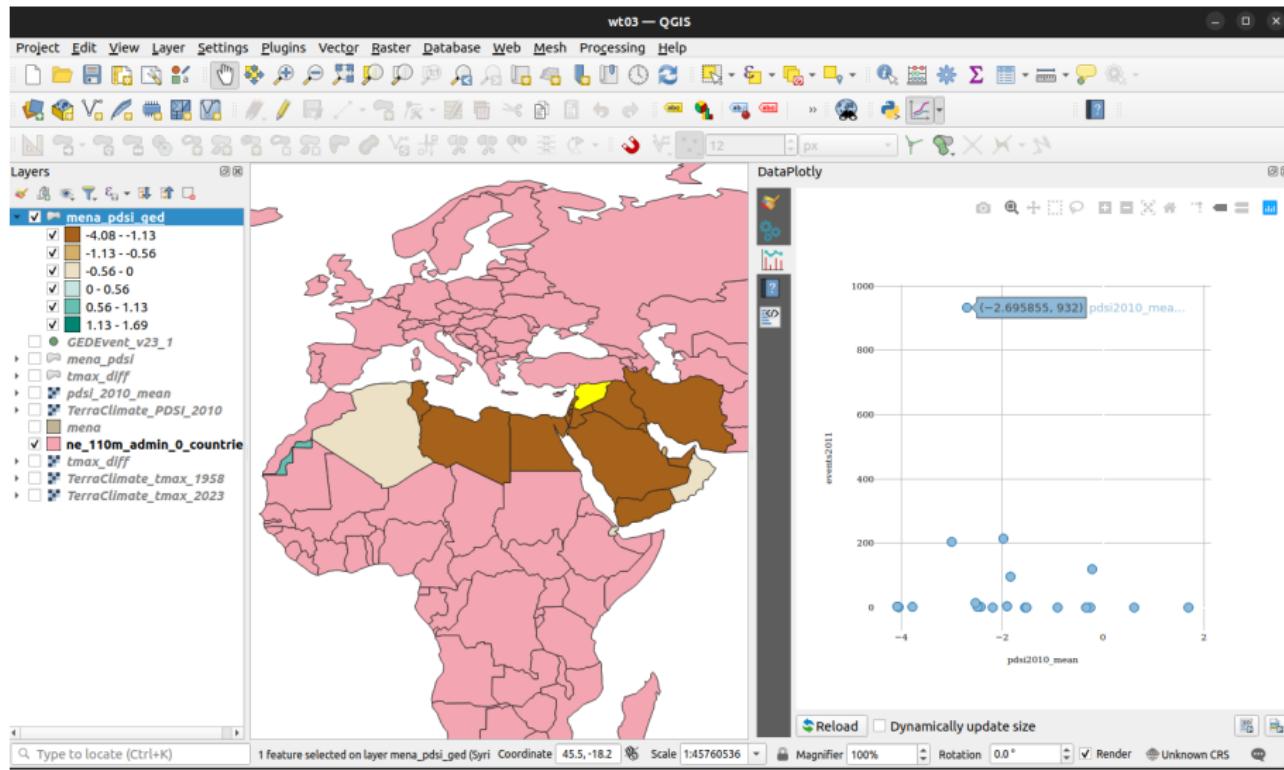
Open the Plotly tool. Set Plot type = Scatter Plot, Layer = mena_pdsi_ged, X field = pdsi2010_mean, Y field = events2011. Click Create Plot



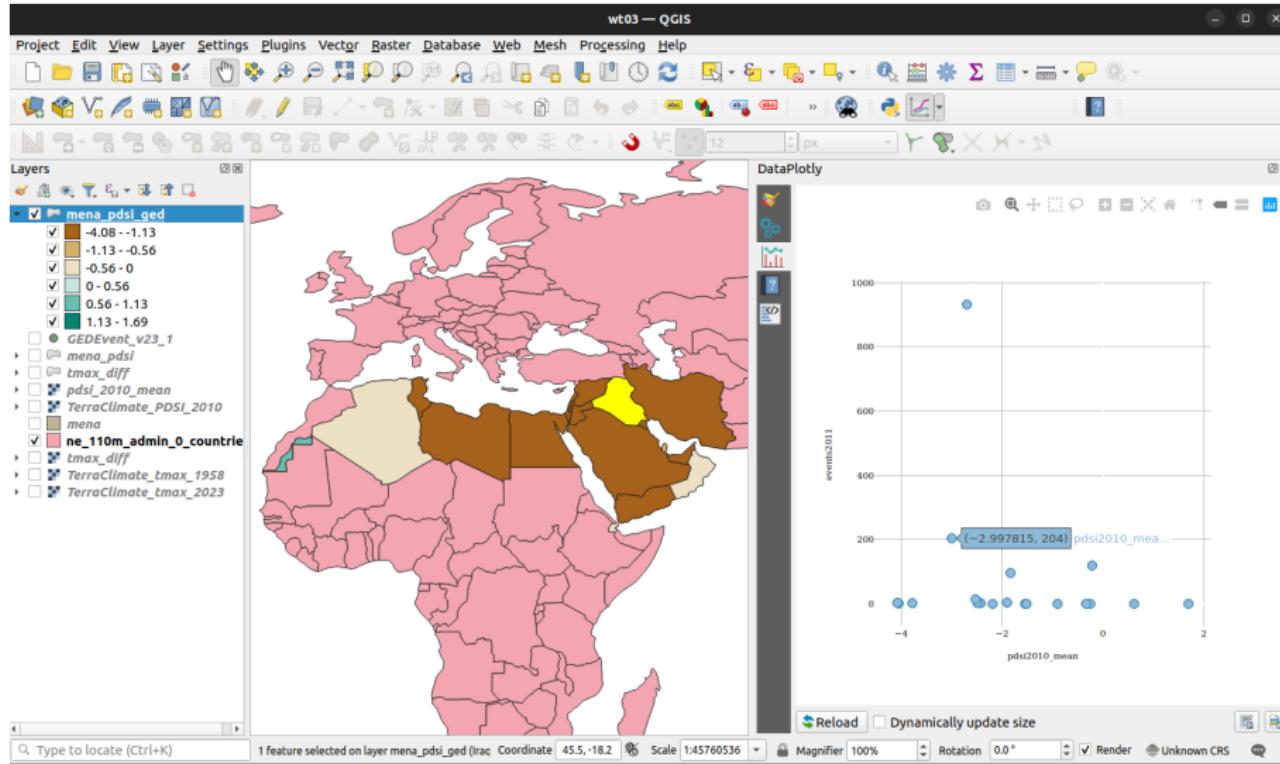
From the scatterplot, we can see that the highest levels of violence happened in countries with negative PDSI scores (more drought)



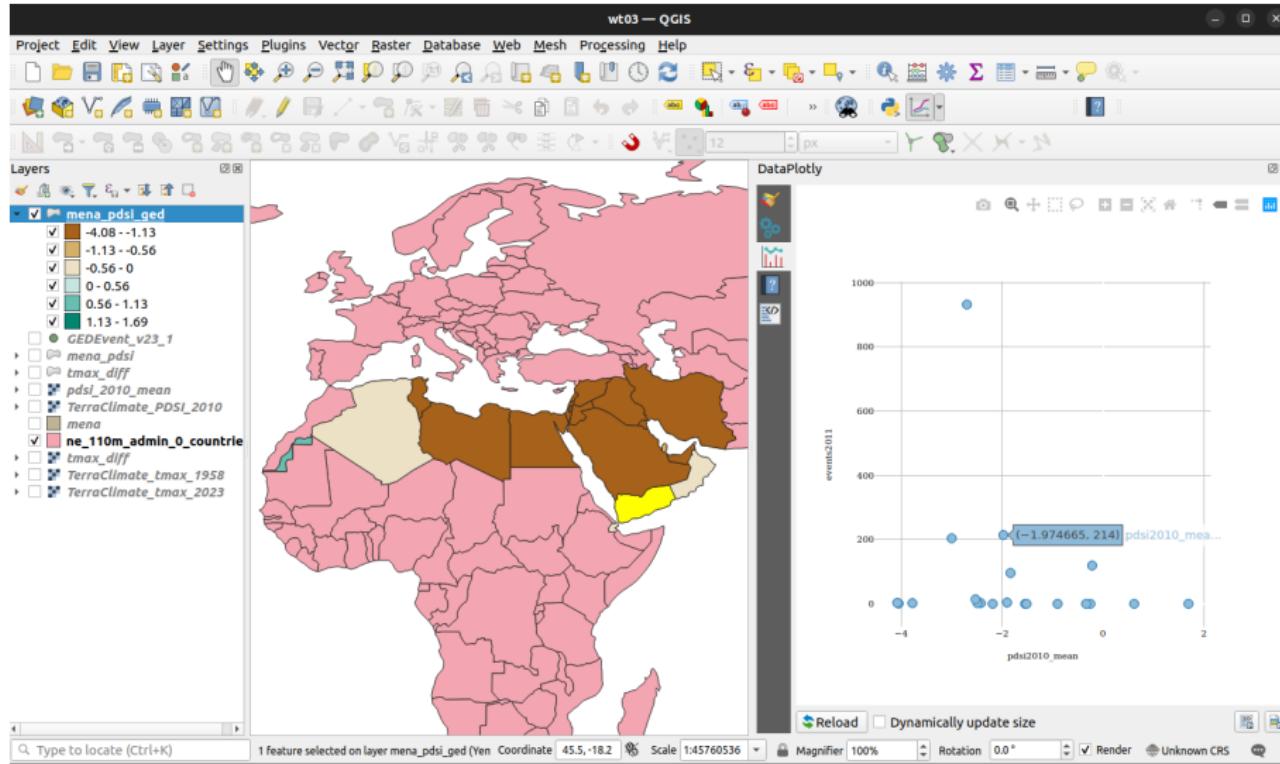
If we click on some of the points in the upper-left corner, we can see countries like Syria, which experienced severe drought in 2010 and high violence in 2011



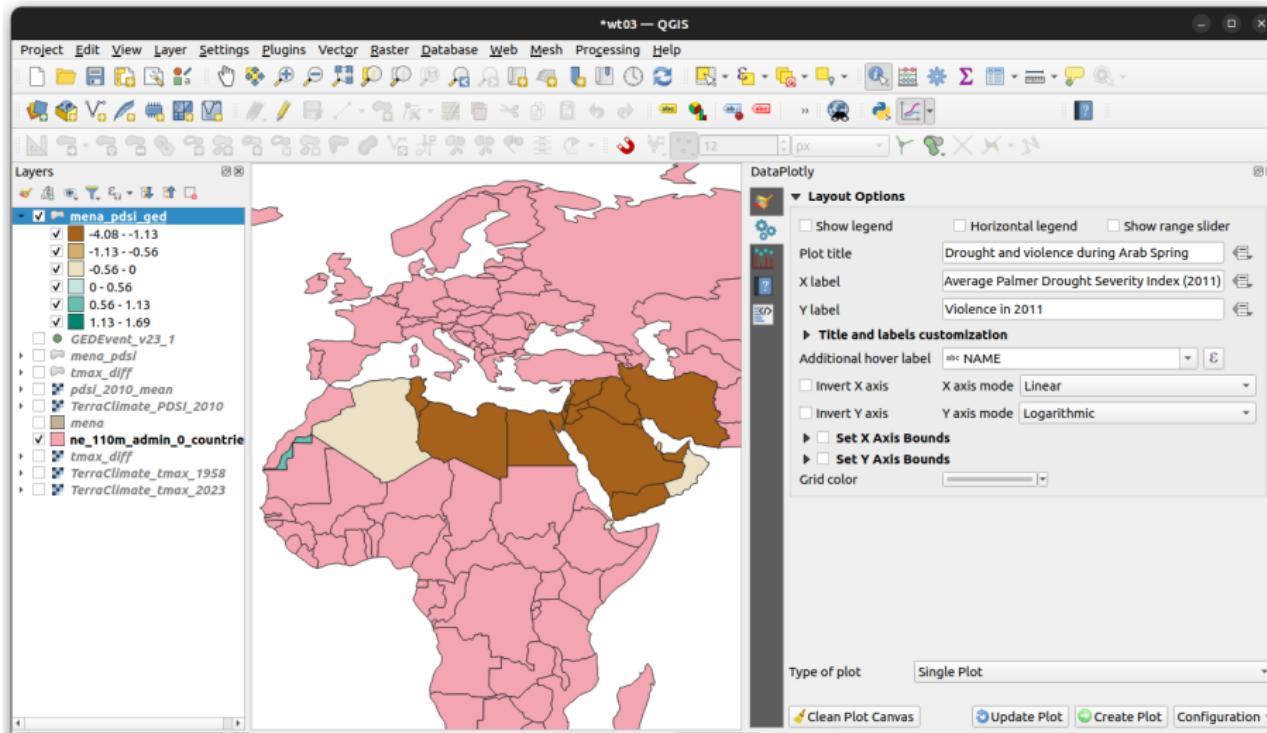
... or Iraq



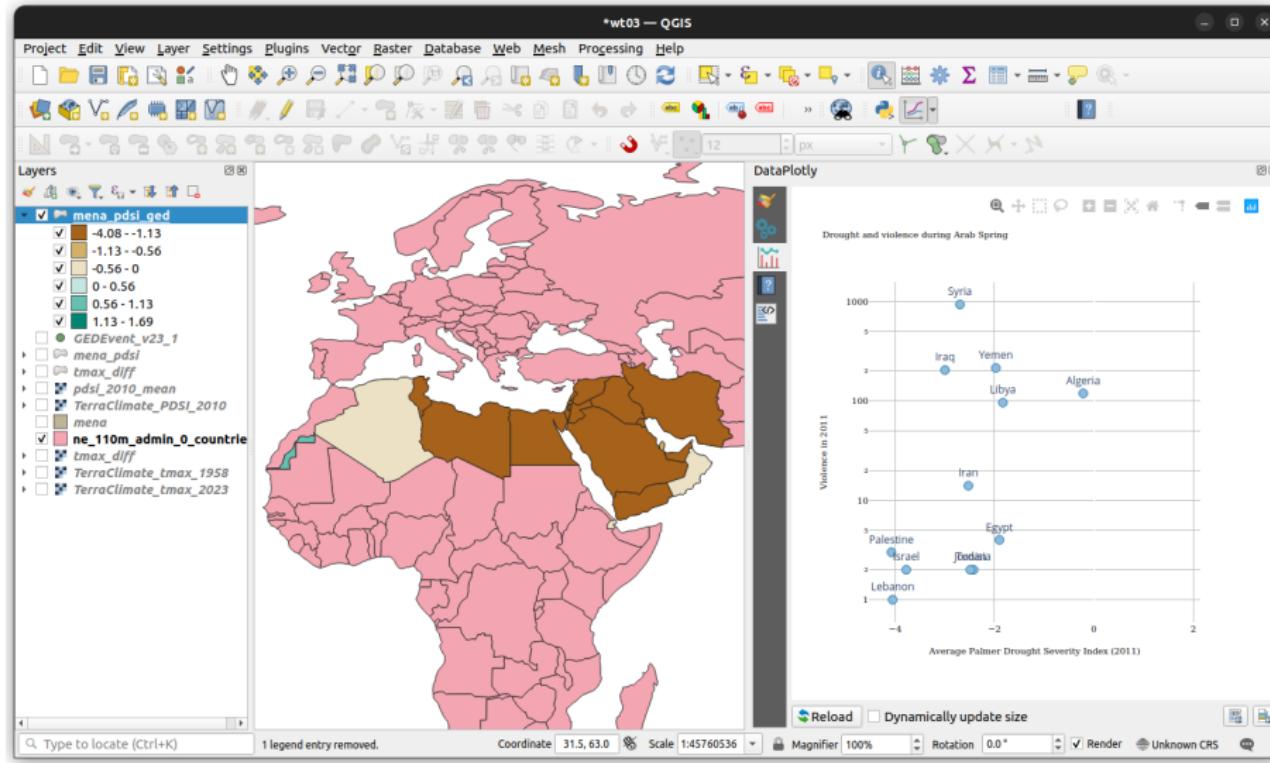
... or Yemen



We can adjust some of the graphical parameters to make the scatterplot more readable, like adding country labels and putting the violence variable on a logarithmic scale



Looks better now



You can also perform all these steps in R
(see replication code `wt03_demo.R` in `WT03.zip`)

Differences in average July high temperatures (2023 vs. 1958)

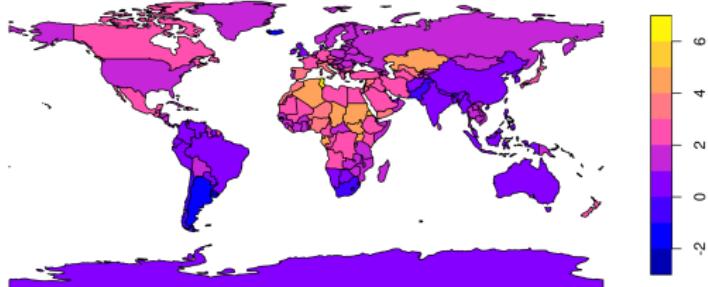


Figure 28: Vignette 1

Drought and violence during Arab Spring

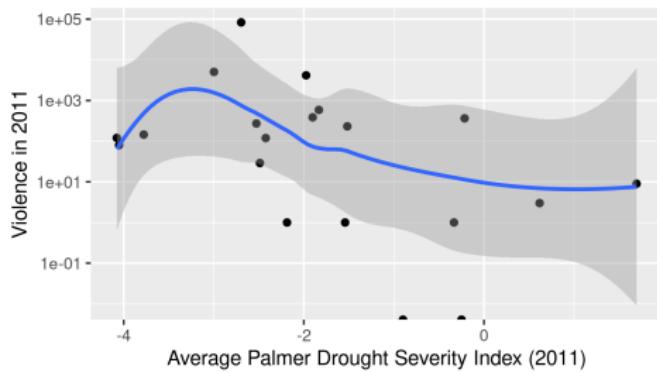
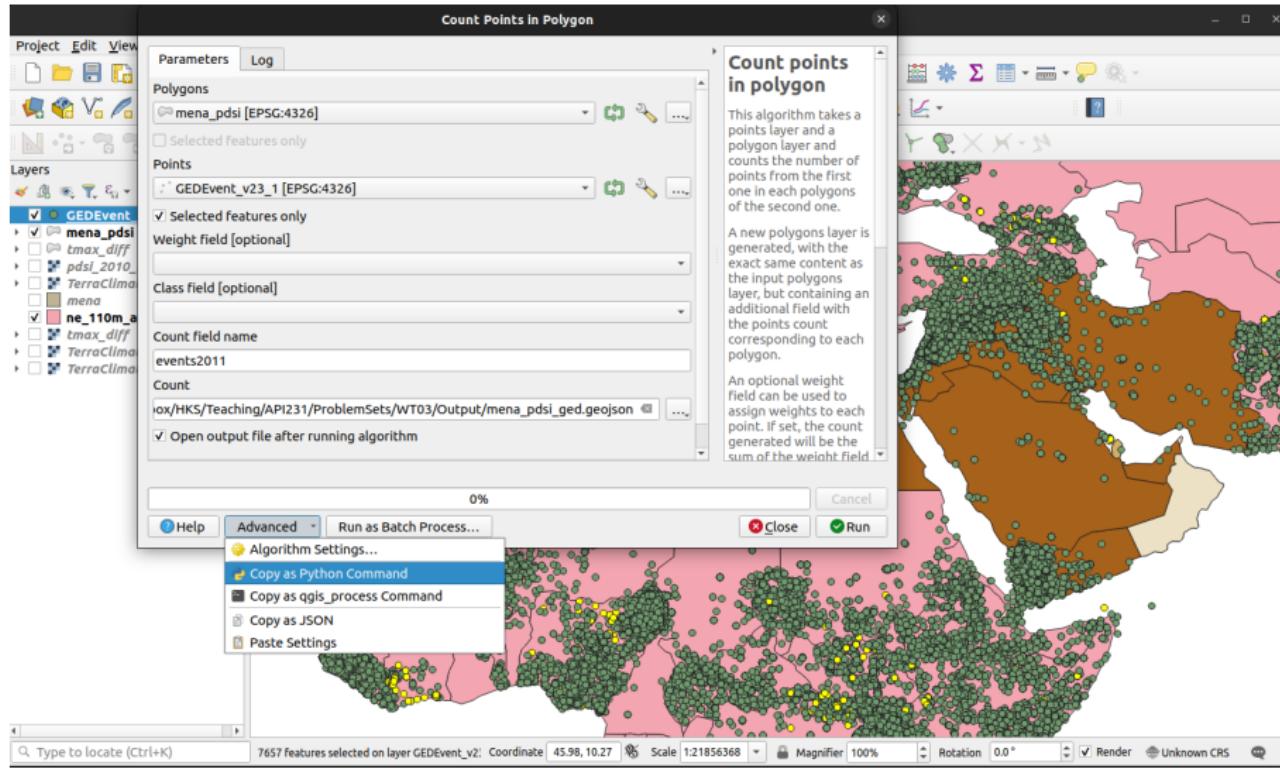


Figure 29: Vignette 2

Hot Tip: Scripting in Python QGIS

Tired on pointing and clicking? In almost every geoprocessing command, there is a menu called Advanced, with an option to Copy as Python Command

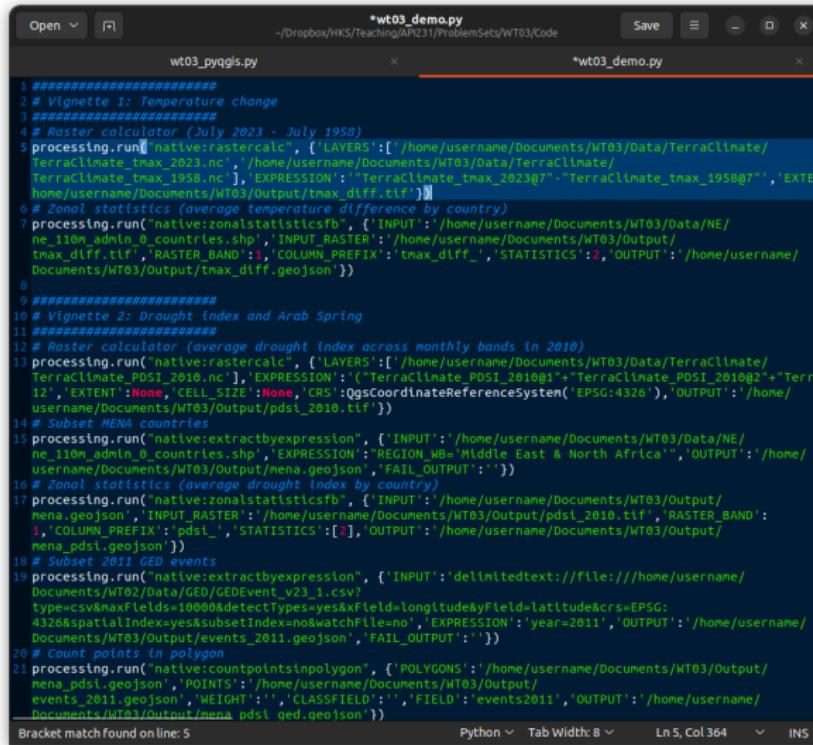


Paste it into a text file to see the code. The directory structure
(/home/username/*) will depend on where you saved the WT03 files

```
wt03.py
~/Dropbox/HKS/Teaching/API231/ProblemSets/WT03/Code
Save
Open ▾
1 # Count points in polygon
2 processing.run("native:countpointsinpolygon", {'POLYGONS': '/home/username/Documents/WT03/Output/
  mena_pdsi.geojson', 'POINTS': 'QgsProcessingFeatureSourceDefinition('file:///home/username/Documents/WT03/Data/GED/
  GEDEvent_v23_1.csv?type=csv&maxFields=10000&detectTypes=yes&xField=longitude&yField=latitude&crs=EPSG:
  4326&spatialIndex=yes&subsetIndex=no&watchFile=no', 'selectedFeaturesOnly': True, 'featureLimit': -1,
  'geometryCheck': 'QgsFeatureRequest.GeometryAbortOnInvalid'), 'WEIGHT': '', 'CLASSFIELD': '',
  'FIELD': 'events2011', 'OUTPUT': '/home/username/Documents/WT03/Output/mena_pdsi_ged.geojson'})
```

Python 2 ▾ Tab Width: 8 ▾ Ln 3, Col 1 ▾ INS

You can use these code snippets to assemble a Python script with all the commands we used today (see Code/wt03_demo.py script in the WT04.zip file)



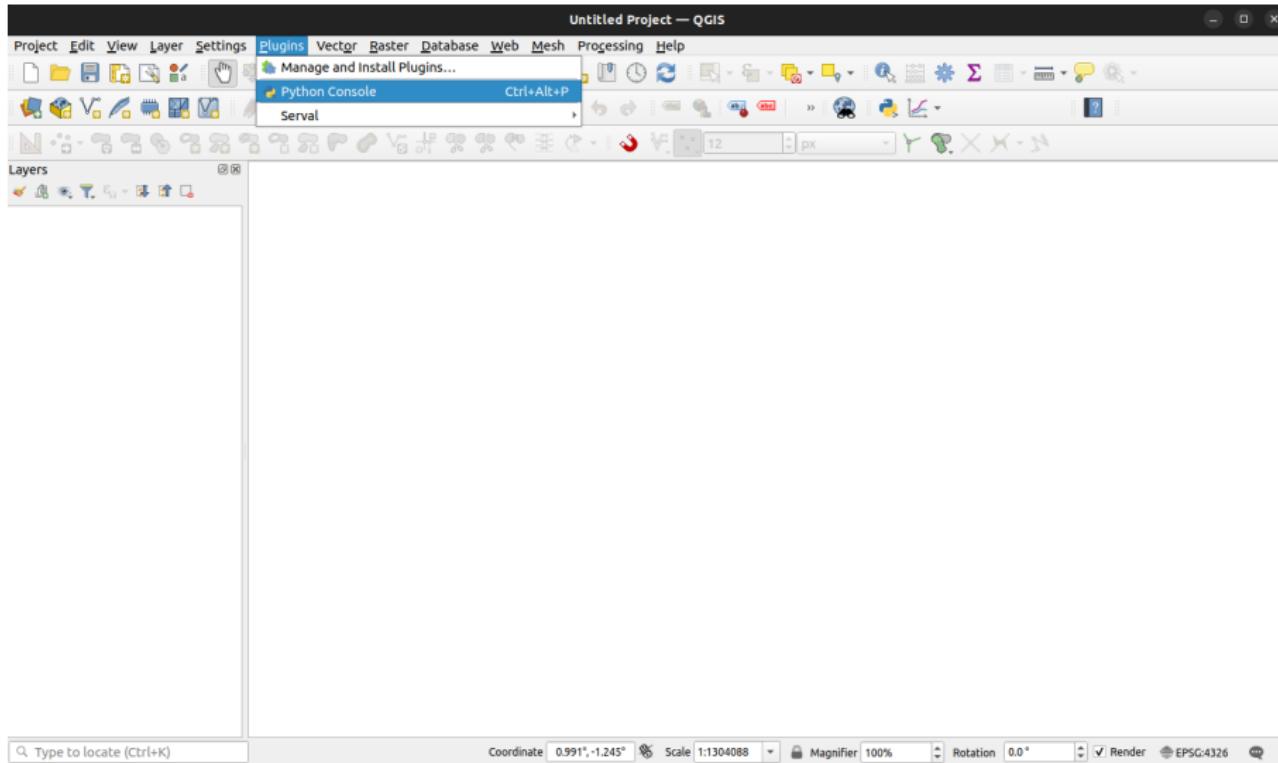
The screenshot shows a dual-pane code editor with two tabs open. The left pane contains the file 'wt03_pyqgis.py' and the right pane contains the file 'wt03_demo.py'. Both files appear to be identical, containing a series of processing steps for spatial analysis.

```
*wt03_demo.py
~/Dropbox/HKS/Teaching/API231/ProblemSets/WT03/Code
wt03_pyqgis.py
wt03_demo.py

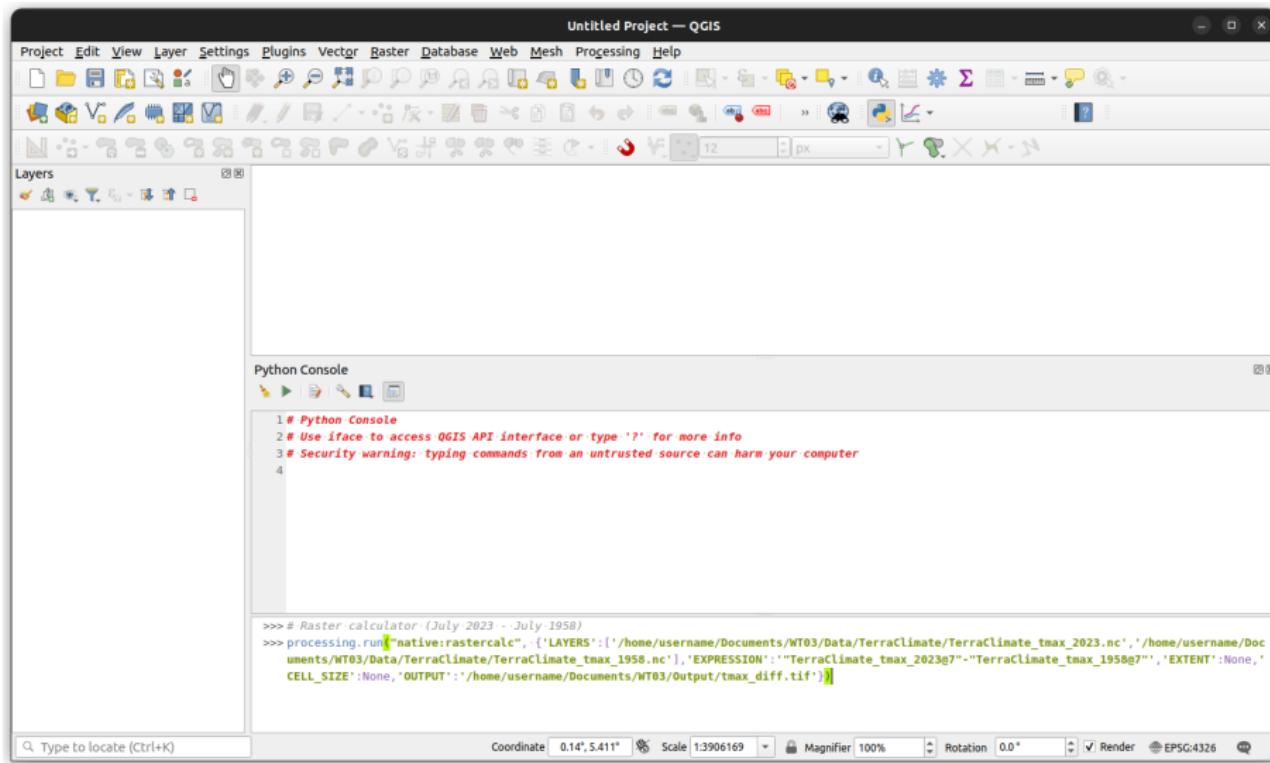
1 #####
2 # Vignette 1: Temperature change
3 #####
4 # Raster calculator (July 1950 - July 2023)
5 processing.run("native:rastercalc", {"LAYERS":['/home/username/Documents/WT03/Data/TerraClimate/TerraClimate_tmax_2023.nc', '/home/username/Documents/WT03/Data/TerraClimate/TerraClimate_tmax_1950.nc'], 'EXPRESSION':["TerraClimate_tmax_2023@7"-TerraClimate_tmax_1950@7", 'EXTENT':"/home/username/Documents/WT03/Output/tmax_diff.tif"]})
6 # Zonal statistics (average temperature difference by country)
7 processing.run("native:zonalfc", {"INPUT":'/home/username/Documents/WT03/Data/NE/ne_110m_admin_0_countries.shp', 'INPUT_RASTER':"/home/username/Documents/WT03/Output/tmax_diff.tif", 'RASTER_BAND':1, 'COLUMN_PREFIX':'tmax_difff_', 'STATISTICS':2, 'OUTPUT':'/home/username/Documents/WT03/Output/tmax_diff.geojson'})
8 #####
9 #####
10 # Vignette 2: Drought index and Arab Spring
11 #####
12 # Raster calculator (average drought index across monthly bands in 2010)
13 processing.run("native:rastercalc", {"LAYERS":['/home/username/Documents/WT03/Data/TerraClimate/TerraClimate_PDSI_2010.nc'], 'EXPRESSION':["TerraClimate_PDSI_2010@1"+TerraClimate_PDSI_2010@2+TerraClimate_PDSI_2010@3"], 'EXTENT':None, 'CELL_SIZE':None, 'CRS':QgsCoordinateReferenceSystem('EPSG:4326'), 'OUTPUT':"/home/username/Documents/WT03/Output/pdsi_2010.tif"})
14 # Subset MENA countries
15 processing.run("native:extractbyexpression", {"INPUT":'/home/username/Documents/WT03/Data/NE/ne_110m_admin_0_countries.shp', 'EXPRESSION': "REGION_WB = Middle East & North Africa", 'OUTPUT':"/home/username/Documents/WT03/Output/nea_mena.geojson", 'FAIL_OUTPUT':''})
16 # Zonal statistics (average drought index by country)
17 processing.run("native:zonalfc", {"INPUT":'/home/username/Documents/WT03/Output/nea_mena.geojson', 'INPUT_RASTER':"/home/username/Documents/WT03/Output/pdsi_2010.tif", 'RASTER_BAND':1, 'COLUMN_PREFIX':'pdsi_', 'STATISTICS':[2], 'OUTPUT':"/home/username/Documents/WT03/Output/nea_pdsi.geojson"})
18 # Subset 2011 GED events
19 processing.run("native:extractbyexpression", {"INPUT":'delimitedtext:///file:///home/username/Documents/WT02/Data/GEDEvent_v23_1.csv?type=csv&naxFields=1000&detectTypes=yes&xField=longitude&yField=latitude&crs=EPSG:4326&spatialIndex=yes&subsetIndex=no&watchFile=no', 'EXPRESSION': "year=2011", 'OUTPUT':"/home/username/Documents/WT03/Output/events_2011.geojson", 'FAIL_OUTPUT':''})
20 # Count points in polygon
21 processing.run("native:countpointsinpolygon", {"POLYGONS":'/home/username/Documents/WT03/Output/nea_pdsi.geojson', 'POINTS':"/home/username/Documents/WT03/Output/events_2011.geojson", 'WEIGHT':'', 'CLASSFIELD':'', 'FIELD':'events2011', 'OUTPUT':"/home/username/Documents/WT03/Output/nea_pdsi_qed.geojson"})
```

Bracket match Found on line: 5 Python Tab Width: 8 Ln 5, Col 364 INS

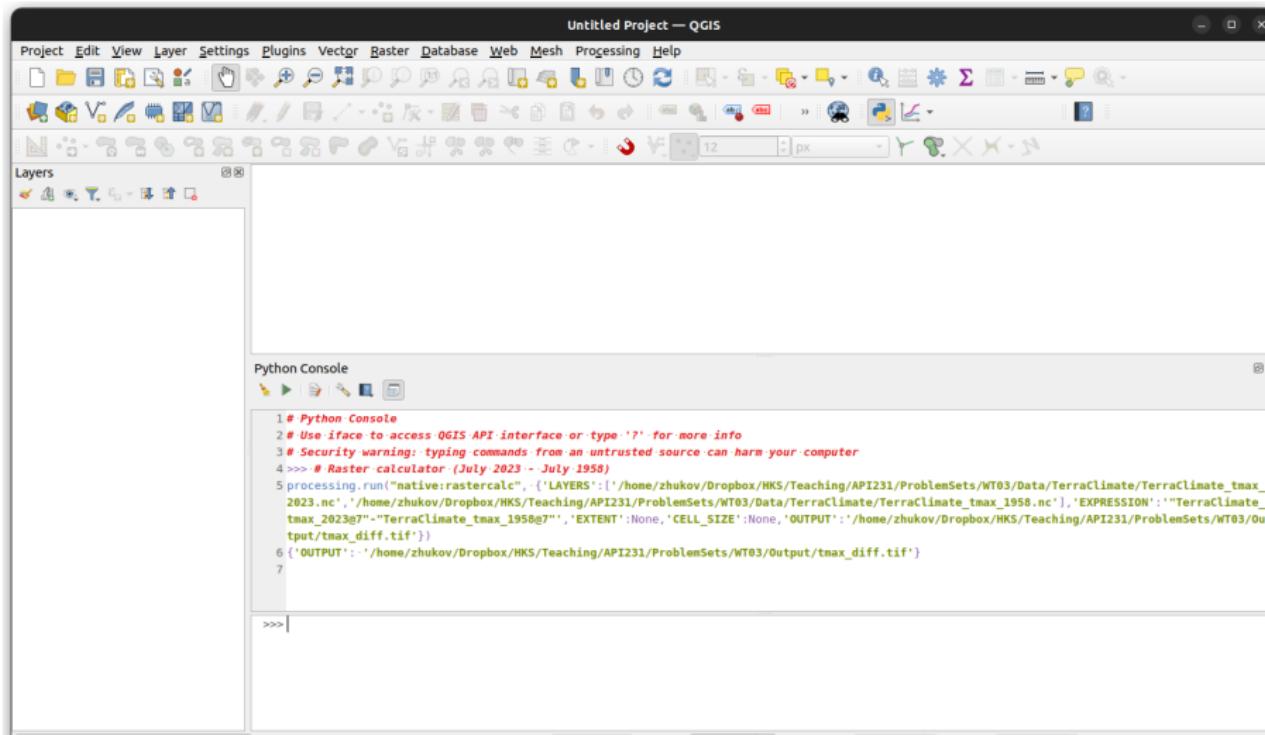
In QGIS, you can run this script through a Python console. Go to Plugins menu → Python Console



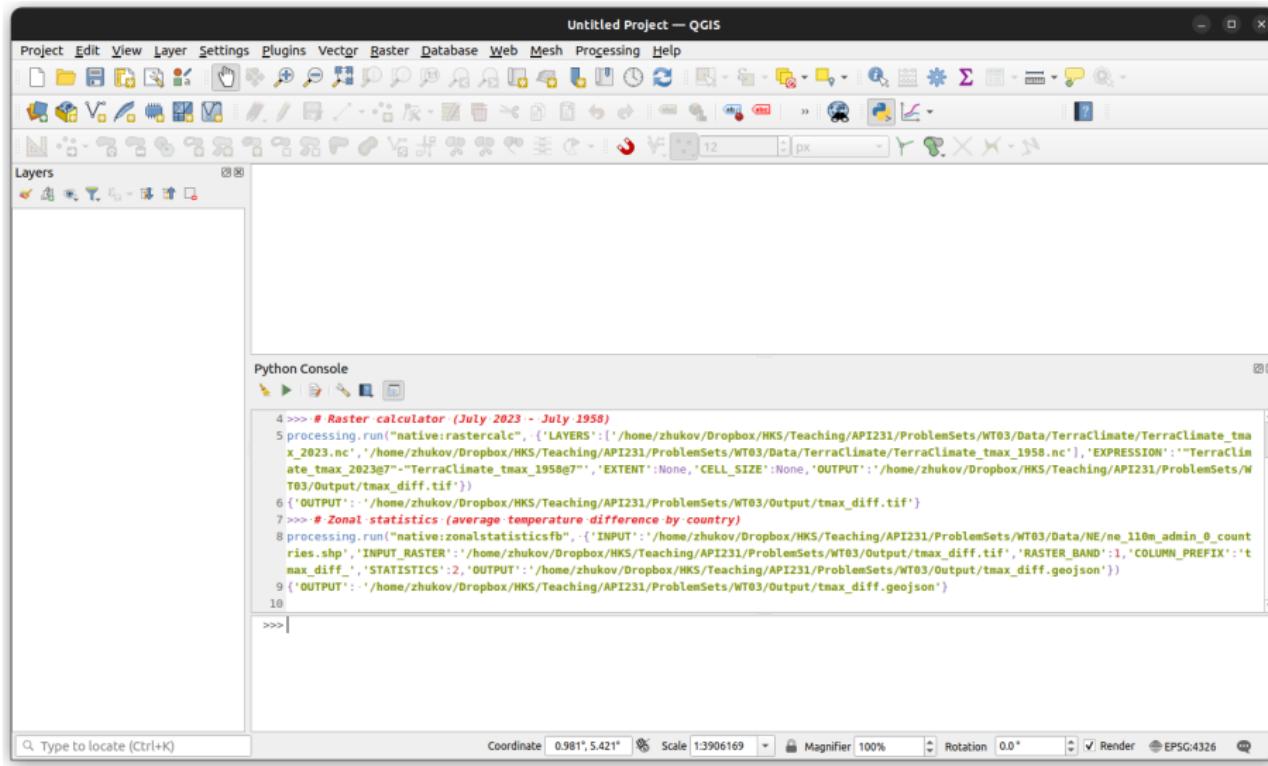
Copy a command into the console and click “Enter” (here we are re-calculating the temperature difference raster from Vignette 1)



When QGIS finishes processing, the console will print a line that starts with 'OUTPUT':..., telling you where the output file has been saved (note that this will not load the output automatically)



We can repeat this with the next line in the code (Zonal Statistics for temperature changes by country)



When we open up the Python-generated file, and re-create the histogram, we see that the results are identical to the one we created earlier. Scripting can be very handy if you are doing batch processing with repetitive, easily-automated tasks

