

SEST-6577
Geographic Information Systems for Security Studies
Lab 10 (+ Walk Through 2)

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Figure 1: US nighttime lights data, 1994 (DMSP, composite from 29 orbits)



Figure 2: US nighttime lights data, 1995 (DMSP, composite from 236 orbits)

Overview

Nearly all production and consumption after sundown requires (and emits) light

1. Household appliances
2. Office equipment
3. Transportation
4. Sporting events
5. Street markets
6. Restaurants
7. Factory operations
8. Roadworks
9. Construction
10. Studying and homework

Remote sensing of nighttime lights allows us to observe human activity from space



Figure 3: Emitting light

Applications of Luminosity Data

Economic activity, income, growth

1. Persistent economic data challenges
 - a) in most countries, GDP stats not available at the sub-national level
 - b) national accounts & surveys are sometimes unreliable
 - c) some locations too costly, dangerous for field & survey work
2. Luminosity has some advantages
 - a) more spatially fine-grained than standard income accounts
 - b) regular, frequent time intervals
 - c) recorded homogeneously across national borders
 - d) available in hard-to-reach areas
3. Not a bad proxy measure
 - a) nighttime lights found to be positively correlated with GDP, GRP at multiple spatial scales

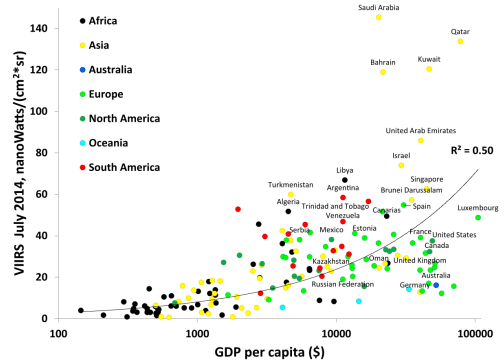


Figure 4: Luminosity and GDP/capita

Urbanization

1. First applications of luminosity data:
 - a) delineate urban extents
 - b) track electrification, street lighting
2. Luminosity captures things surveys, census can't
 - a) growth of informal, illegal settlements
 - b) communities with inadequate infrastructure
 - c) emergence of new local urban centers
 - d) characterize urban growth over time

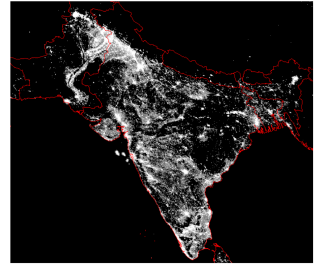


Figure 5: South Asia, 1994

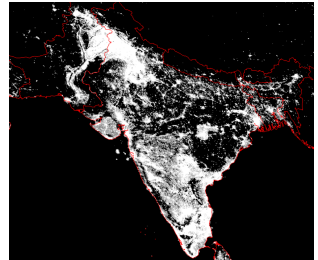


Figure 6: South Asia, 2010

Emergency management, recovery

1. Luminosity captures impact of emergencies
 - a) disasters cause damage to power lines, disrupt electric utility services
 - b) luminosity data can detect power outages, also fires, flares, other sudden increases in light
2. But not everything is visible from space
 - a) cloud cover prevents real-time storm damage tracking and assessment
 - b) luminosity better suited for monitoring non-meteorological events (e.g. earthquakes, accidents), long-term tracking of recovery efforts

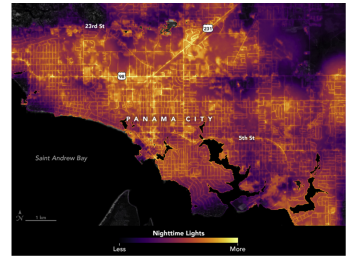


Figure 7: Before landfall

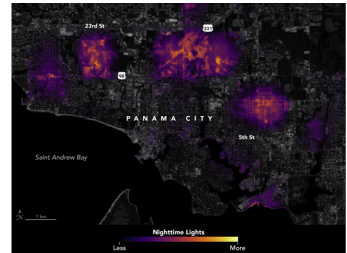


Figure 8: After landfall

Armed conflict

1. War creates darkness
 - a) direct: power grid damage
 - b) indirect: population displacement, curfews, intentional dimming to avoid detection
2. Danger lurks in darkness
 - a) power disruptions constrain economic development, harm public health
 - b) fall in light emissions is warning that civilians, hospitals lack stable electricity supply
3. Data can illuminate the physical impact of war
 - a) luminosity data allow us to track impact of war on public services, utilities, urban economic activity
 - b) this analysis can be near-real time



Figure 9: October 2021



Figure 10: October 2022

Technological change

1. Outdoor lighting technology evolves
 - a) wood, dung → oil
 - b) oil → gas
 - c) gas → incandescent
 - d) incandescent → LED, HID
2. Ecological and social impacts
 - a) each change increases emissions, changes spectrum of visible light
 - b) spectral change affects perception of artificial lights by animals
 - c) LEDs are more easily dimmed, lighting becomes more temporally dynamic
3. This is also a measurement challenge
 - a) change in spectrum can be mistaken for change in light intensity



Figure 11: Alles ist erleuchtet

Varieties of Luminosity Data

Space-based sensors for night-lights (partial list)

Sensor	Spatial resolution	Temporal resolution	Availability	Free?	On-board calibration
DMSP/OLS	3km	Monthly	1992-2013	✓	
Landsat 8	30m	Irregular	2013-	✓	
VIIRS/DNB	740m	Daily	2012-	✓	✓
EROS-B	<1m	Daily	2013-		✓
Jilin-1	<1m	Daily	2017-		✓

Defense Meteorological Satellite Program (DMSP)

1. History

- a) 1960s: starts as DoD's meteorological program
 - goal: prevent spy satellites from wasting resources when targets are cloud-covered
- b) 1992: images available in digital form
- c) 1994: NOAA launches global nightlights program

2. Limitations

- a) data from different years not directly comparable due to different atmospheric conditions, sensor settings and degradation
- b) temporal analysis requires intercalibration
 - use invariant pixels as training data
 - calibrate raw images to same radiometric level as base image
- c) images blurred due to scattering, saturation



Figure 12: DMSP-5D2

Link: eogdata.mines.edu/products/dmsp/

Visible Infrared Imaging Radiometer Suite (VIIRS)

1. History

- a) 2011: sensor launches onboard Suomi NPP satellite
- b) quickly becomes industry standard
- c) main product: Day and Night Band (DNB)

2. Advantages over DMSP

- ☒ on-board calibration enables temporal comparisons
- ☒ higher spatial precision
- ☒ sensitive to lower light levels
- ☒ no saturation in urban areas
- ☒ cloud-free, stray light corrections
- ☒ free daily images + monthly, annual composites

Link: eogdata.mines.edu/products/vnl/



Figure 13: Suomi NPP

Not all orbits make good data

Requirements for nighttime light observation:

1. Center half of orbital swath
 - (i.e. area being imaged by satellite)
2. No sunlight
 - (no high-latitude zones in summer)
3. No moonlight
 - (within-month variation)
4. No solar glare
 - (e.g. from solar panels)
5. Cloud-free
 - (sorry, Seattle. hello, Dubai)
6. No auroral emissions
 - (why Santa has evaded detection)
7. No forest fires
 - (no intense sources of natural light)

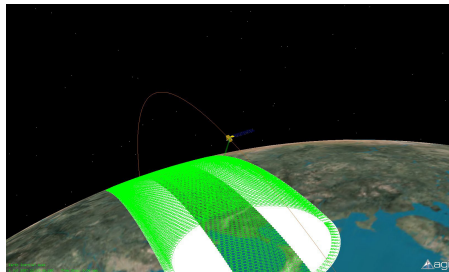


Figure 14: Swath path

Vignettes

Overview of lab exercise

1. Vignettes on differences in luminosity across borders
 - a) Korean peninsula
 - b) Island of Hispaniola
2. Vignette on differences in luminosity over time
 - a) Syrian Civil War

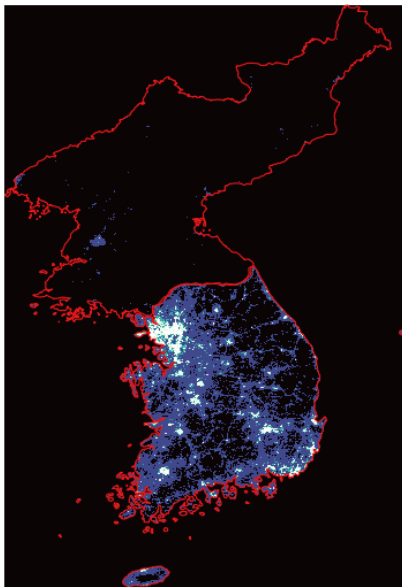


Figure 15: Vignette 1 / Korea

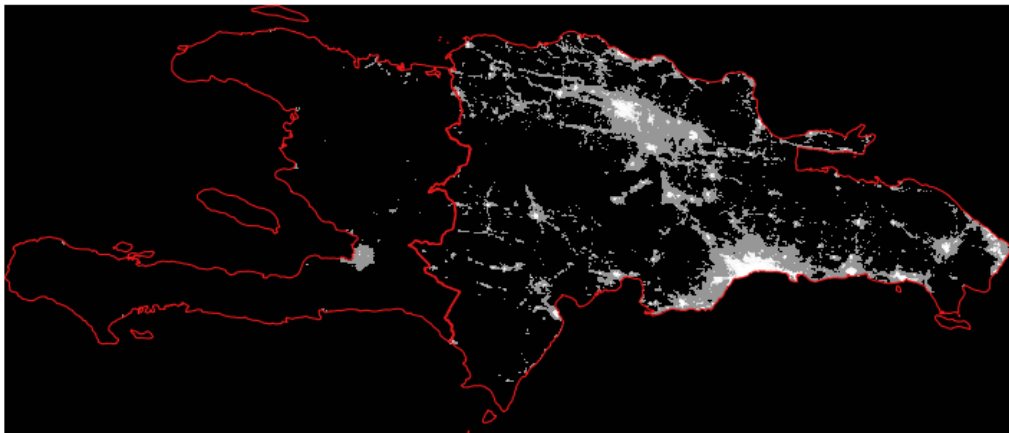


Figure 16: Vignette 2 / Hispaniola

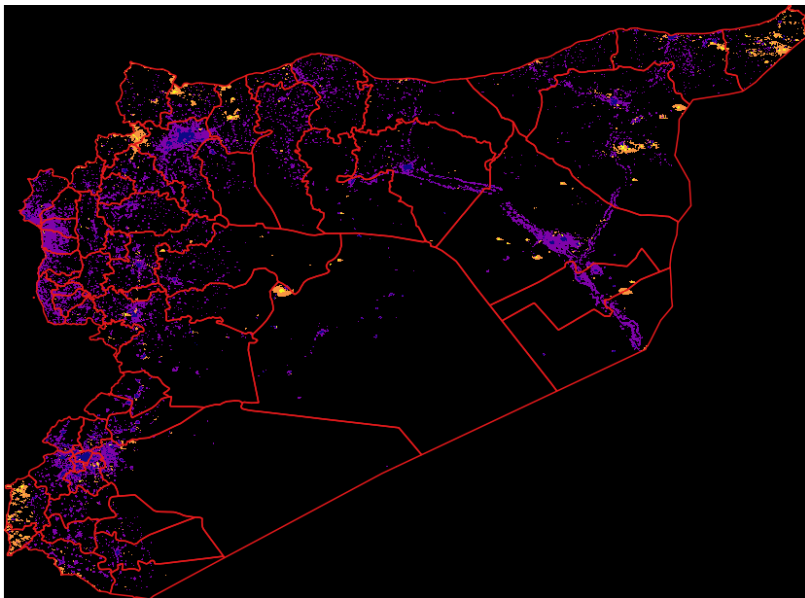
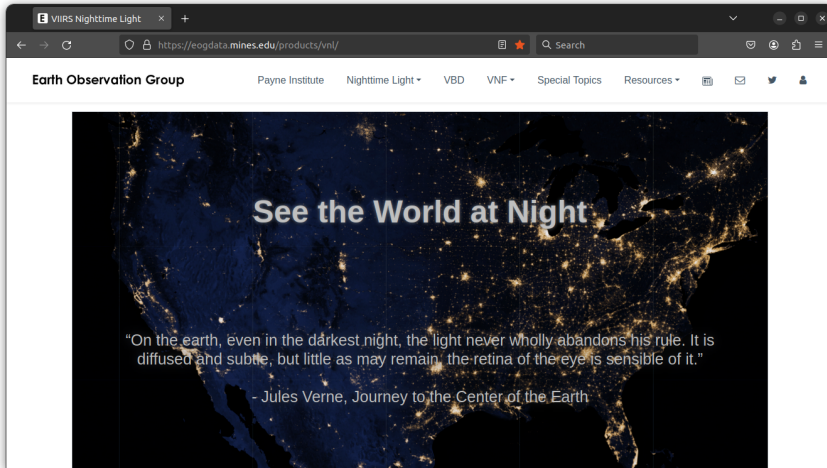


Figure 17: Vignette 3 / Syria

We can obtain **VIIRS nighttime luminosity (vnl)** data from `eogdata.mines.edu/products/vnl/`



Scroll down to the “Annual VNL V2” section

The screenshot shows a web browser window with the URL https://eogdata.mines.edu/products/vnl/#annual_v2. The page is titled "Annual VNL V2" and is part of the "Earth Observation Group" website. The navigation bar includes links to "Payne Institute", "Nighttime Light", "VBD", "VNF", "Special Topics", and "Resources". The main content area describes the new consistently processed time series of annual global VIIRS nighttime lights, produced from monthly cloud-free average radiance grids spanning 2012* to 2020. It mentions that the new methodology is a modification of the original method based on nightly data (Annual VNL V1). A note states: "* For 2012 annual VNL V2, there are two sets. (A) 201204-201212, and (B) 201204-201303. Only set (B) has masked median and average, as well as lit area mask." The text continues to explain the methods used, including initial filtering to remove sunlit, moonlit, and cloudy pixels, and the use of scattergrams for outlier removal. A sidebar on the right contains a table of contents with links to various sections: Introduction, Monthly DNB Composite, Annual VNL V1, Annual VNL V2, Nightly DNB Mosaic and Cloud, Nightly DNB Profile and Analysis, Country and City VNL Study, For Artists, Lumen Watch, and a partially visible link at the bottom.

Earth Observation Group

Payne Institute Nighttime Light VBD VNF Special Topics Resources

Annual VNL V2

A new consistently processed time series of annual global VIIRS nighttime lights has been produced from monthly cloud-free average radiance grids spanning 2012* to 2020. The new methodology is a modification of the original method based on nightly data (Annual VNL V1).

** For 2012 annual VNL V2, there are two sets. (A) 201204-201212, and (B) 201204-201303. Only set (B) has masked median and average, as well as lit area mask.*

In both methods there is an initial filtering to remove sunlit, moonlit and cloudy pixels, leading to rough composites that contains lights, fires, aurora and background. In the original method, the rough annual composites are made from a full year of nightly DNB data. In the new method, the rough composites are made on monthly increments and then combined to form rough annual composites. Both methods employ outlier removal to discard biomass burning pixels and isolate the background.

In the original method the outlier removal is performed on scattergrams generated for each 15 arc second grid cell, with outliers clipped off from both the high and low radiance sides of the scattergram. The discard of outlier pixels proceeds until the scattergram's standard deviation stabilizes. The new method uses the twelve-month median radiance to discard high and low radiance outliers, filtering out most fires and isolating the background. Background areas are zeroed out in both methods using the data range (DR) calculated from 3x3 grid cells. In both methods, the DR threshold for background is indexed to cloud-cover levels, with higher DR thresholds in areas having low numbers of cloud-free coverages. In the new method, particular attention is given to setting a single DR threshold for distinguishing lit grid cells from background for each 15 arc second grid cell. This is achieved by setting

Introduction

Monthly DNB Composite

Annual VNL V1

Annual VNL V2

Nightly DNB Mosaic and Cloud

Nightly DNB Profile and Analysis

Country and City VNL Study

For Artists

Lumen Watch

Click on the “Go to Download V2.2” button for the most recent year’s data

Earth Observation Group Payne Institute Nighttime Light VBD VNF Special Topics Resources

2016

2012

Reference
Elvidge, C.D, Zhizhin, M., Ghosh T., Hsu FC, Taneja J. Annual time series of global VIIRS nighttime lights derived from monthly averages:2012 to 2019. Remote Sensing 2021, 13(5), p.922, [doi:10.3390/rs13050922](https://doi.org/10.3390/rs13050922)

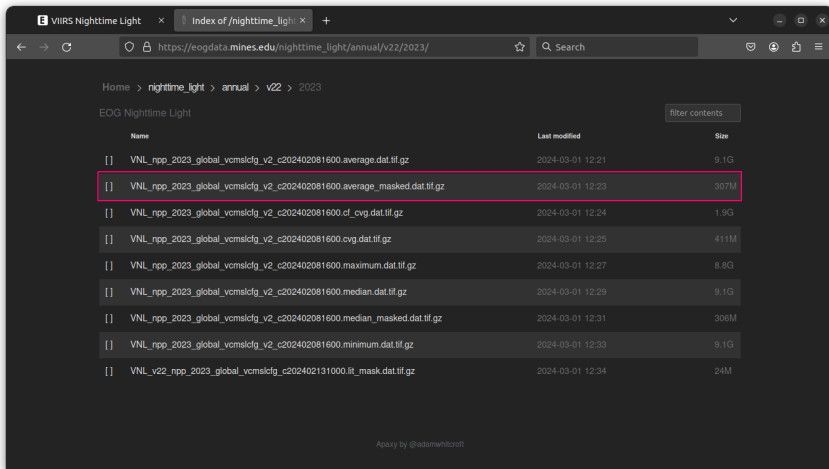
[Go to Download V2](#) [Go to Download V2.1](#) [Go to Download V2.2](#)

* The latest update is VNL v2.2. Please find the 'readme' for all the versions of Annual VNL v2 [HERE](#)

https://eogdata.mines.edu/nighttime_light/annual/v22/

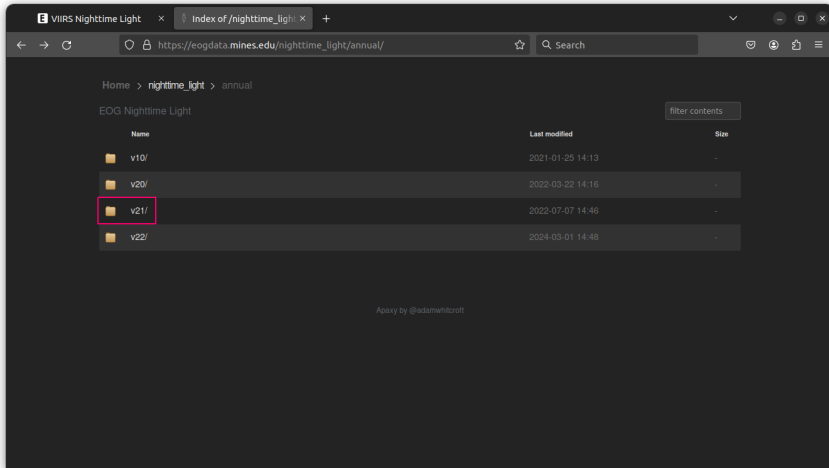
Introduction
Monthly DNB
Composite
Annual VNL V1
Annual VNL V2
Nightly DNB Mosaic and Cloud
Nightly DNB Profile and Analysis
Country and City VNL Study
For Artists
Lumen Watch

Download the file ending with `.average_masked.dat.tif.gz`

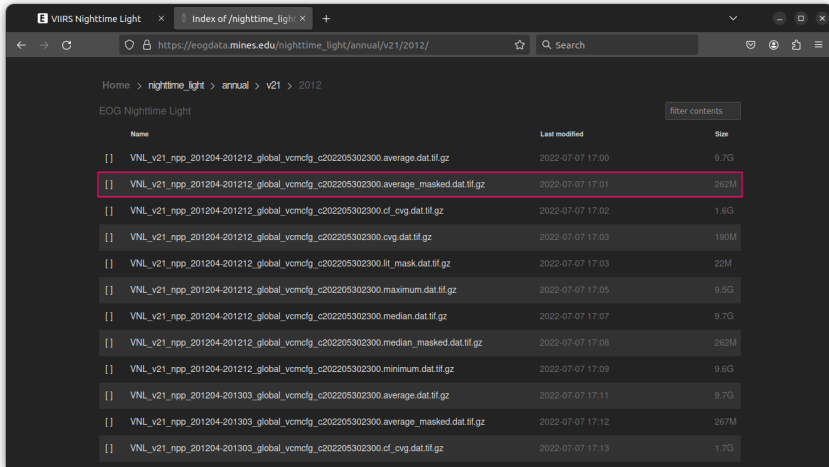


Let's also grab data for the “oldest” year available.

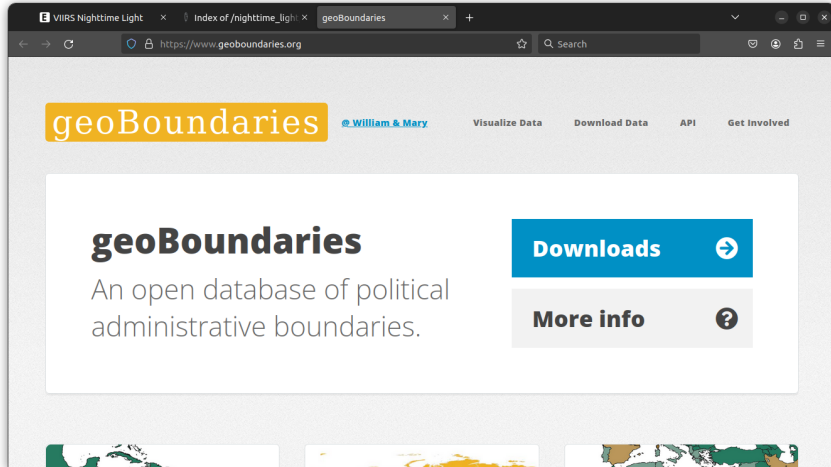
Navigate to the parent directory and find the annual data in the v21/ folder



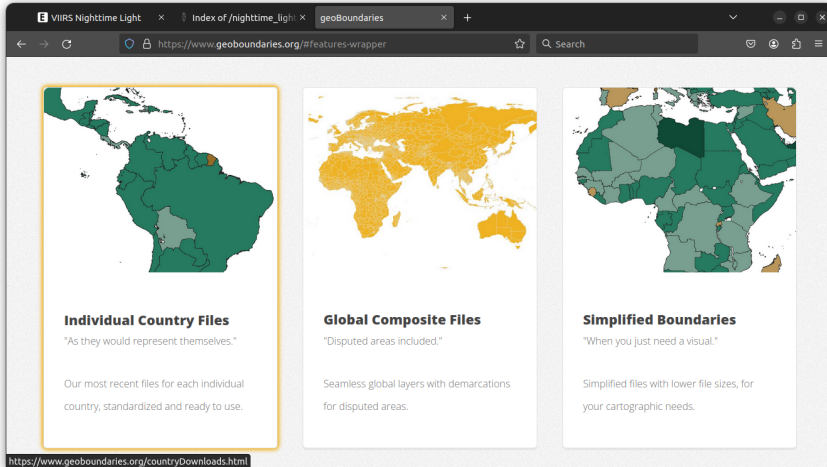
There are two files ending in `.average_masked.dat.tif.gz` here.
Download the first one (April through December)



Let's get some **country and administrative boundaries** from `geoboundaries.org`



Navigate to the “Individual Country Files” section



Download country-level (ADM0) data for South and North Korea (KOR, PRK)

Individual Country Files

The geoBoundaries open license ([CC-BY 4.0](#)) country dataset seeks to represent every nation "as they would represent themselves", with no special identification of disputed areas. If you would prefer data that explicitly includes disputed areas, please see the global composite dataset. [Attribution](#) is required for all uses of this dataset.

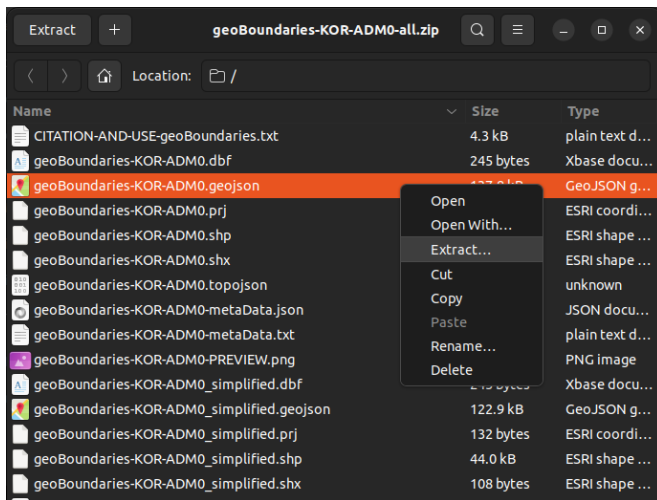
Single Country Files
Files for individual countries

Global Files
A single file for the entire globe

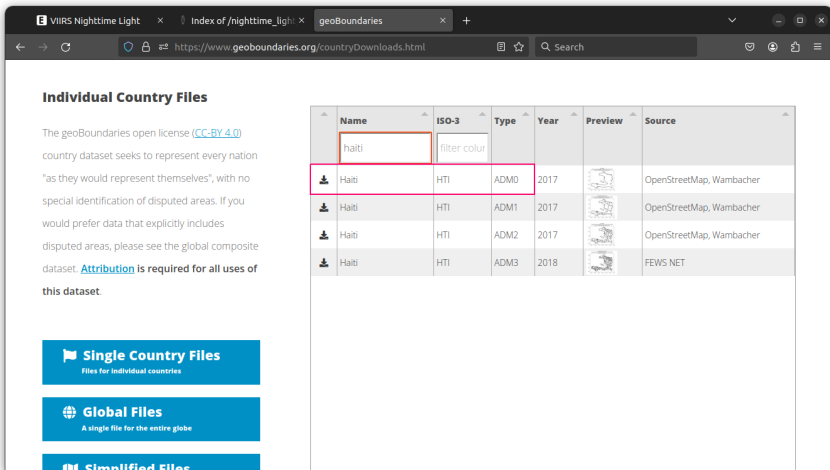
Simplified Files

Name	ISO-3	Type	Year	Preview	Source
korea	filter colour				
Republic of Korea	KOR	ADM0	2021		Natural Earth, geoBoundaries
Republic of Korea	KOR	ADM1	2021		Natural Earth
Republic of Korea	KOR	ADM2	2020		geoBoundaries, citypopulation.de
Republic of Korea	KOR	ADM3	2018		Justin Meyers, KoStat
Dem. People's Repub...	PRK	ADM0	2018		World Food Programme, OCHA RO...
Dem. People's Repub...	PRK	ADM1	2018		World Food Programme, OCHA RO...
Dem. People's Repub...	PRK	ADM2	2019		World Food Programme, OCHA RO...

When you unzip, the only file you need to extract is one ending in `ADM0.geojson`



Repeat this process for country-level (ADM0) data for Haiti (HTI)...



The screenshot shows a web browser window with the URL <https://www.geoboundaries.org/countryDownloads.html>. The page is titled "Individual Country Files". On the left, there is a text block explaining the geoBoundaries open license (CC-BY 4.0) and a note about the country dataset. Below this, there are three buttons: "Single Country Files" (Files for individual countries), "Global Files" (A single file for the entire globe), and "Simplified Files". On the right, there is a table with columns: Name, ISO-3, Type, Year, Preview, and Source. The table lists data for Haiti (HTI) for ADM0, ADM1, ADM2, and ADM3 levels. The first row (ADM0) is highlighted with a pink border.

Individual Country Files

The geoBoundaries open license ([CC-BY 4.0](#)) country dataset seeks to represent every nation "as they would represent themselves", with no special identification of disputed areas. If you would prefer data that explicitly includes disputed areas, please see the global composite dataset. [Attribution](#) is required for all uses of this dataset.

Single Country Files
Files for individual countries

Global Files
A single file for the entire globe

Simplified Files

Name	ISO-3	Type	Year	Preview	Source
haiti	filter colour				
 Haiti	HTI	ADM0	2017		OpenStreetMap, Wambacher
 Haiti	HTI	ADM1	2017		OpenStreetMap, Wambacher
 Haiti	HTI	ADM2	2017		OpenStreetMap, Wambacher
 Haiti	HTI	ADM3	2018		FEWS NET

and country-level (ADM0) data for Dominican Republic (DOM)...

The screenshot shows a web browser window with the URL <https://www.geoboundaries.org/countryDownloads.html>. The page is titled "Individual Country Files". On the left, there is a text block explaining the open license (CC-BY 4.0) and the goal of the dataset. Below this, there are three buttons: "Single Country Files", "Global Files", and "Simplified Files". On the right, there is a table with the following columns: Name, ISO-3, Type, Year, Preview, and Source. The search term "dominican" is entered in the "Name" filter, and "filter colour" is in the "ISO-3" filter. The table lists three results for the Dominican Republic (DOM) at the ADM0 level.

Name	ISO-3	Type	Year	Preview	Source
dominican	filter colour				
Dominican Republic	DOM	ADM0	2020		Caribbean GeoPortal, N/A
Dominican Republic	DOM	ADM1	2022		Natural Earth
Dominican Republic	DOM	ADM2	2020		Caribbean GeoPortal, N/A

and district-level (ADM2) data for Syria (SYR)

Individual Country Files

The geoBoundaries open license ([CC-BY 4.0](#)) country dataset seeks to represent every nation "as they would represent themselves", with no special identification of disputed areas. If you would prefer data that explicitly includes disputed areas, please see the global composite dataset. [Attribution](#) is required for all uses of this dataset.

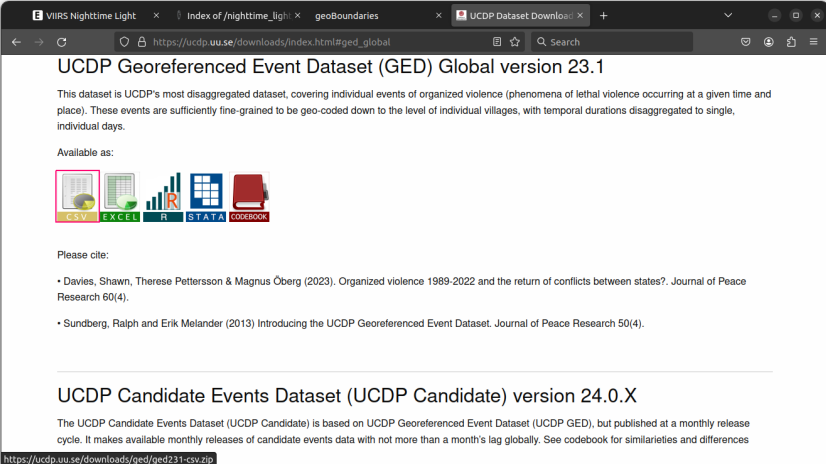
Single Country Files
Files for individual countries

Global Files
A single file for the entire globe

Simplified Files

Name	ISO-3	Type	Year	Preview	Source
syria	filter colour				
Syrian Arab Republic	SYR	ADM0	2017		OpenStreetMap, Wambacher
Syrian Arab Republic	SYR	ADM1	2017		United Nations Cartographic Sectio...
Syrian Arab Republic	SYR	ADM2	2017		United Nations Cartographic Sectio...
Syrian Arab Republic	SYR	ADM3	2017		United Nations Cartographic Sectio...

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



UCDP Georeferenced Event Dataset (GED) Global version 23.1

This dataset is UCDP's most disaggregated dataset, covering individual events of organized violence (phenomena of lethal violence occurring at a given time and place). These events are sufficiently fine-grained to be geo-coded down to the level of individual villages, with temporal durations disaggregated to single, individual days.

Available as:

CSV EXCEL R STATA CODEBOOK

Please cite:

- Davies, Shawn, Therese Pettersson & Magnus Öberg (2023). Organized violence 1989-2022 and the return of conflicts between states?. *Journal of Peace Research* 60(4).
- Sundberg, Ralph and Erik Melander (2013) Introducing the UCDP Georeferenced Event Dataset. *Journal of Peace Research* 50(4).

UCDP Candidate Events Dataset (UCDP Candidate) version 24.0.X

The UCDP Candidate Events Dataset (UCDP Candidate) is based on UCDP Georeferenced Event Dataset (UCDP GED), but published at a monthly release cycle. It makes available monthly releases of candidate events data with not more than a month's lag globally. See codebook for similarities and differences

<https://ucdp.uu.se/downloads/ged/ged231-csv.zip>

Here is the full list of data sources and links:

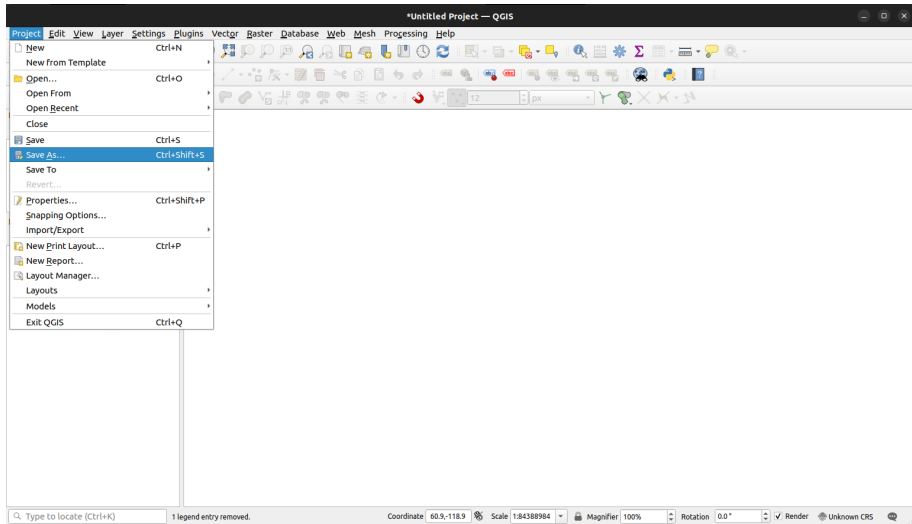
Category	Type	Format	Data source
Nighttime luminosity	Raster	.tif	VIIRS
Administrative units	Vector (polygons)	.geojson	geoBoundaries
Political violence	Table (non-geo)	.csv	UCDP GED

These are all in the Lab10WT02.zip file posted on Canvas.

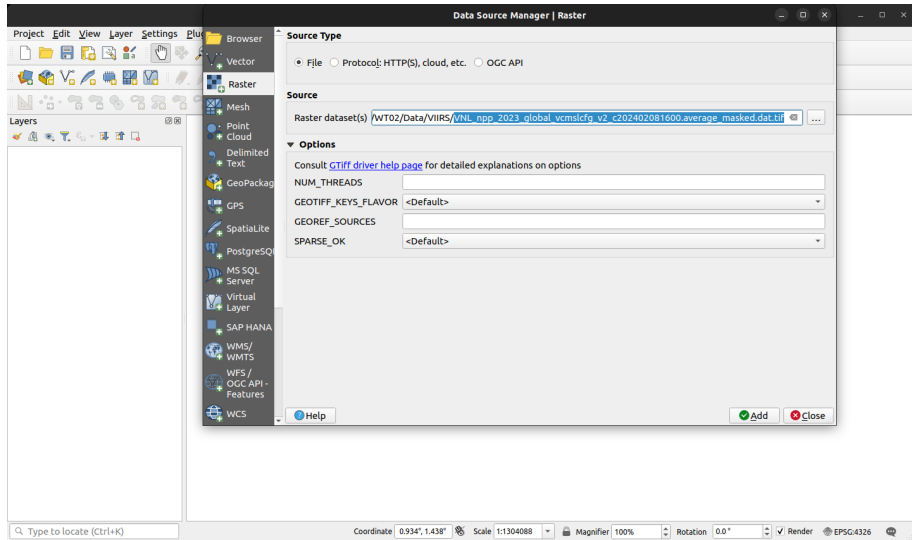
Differences in Luminosity Across Countries (Korea and Hispaniola)

Always save your progress!

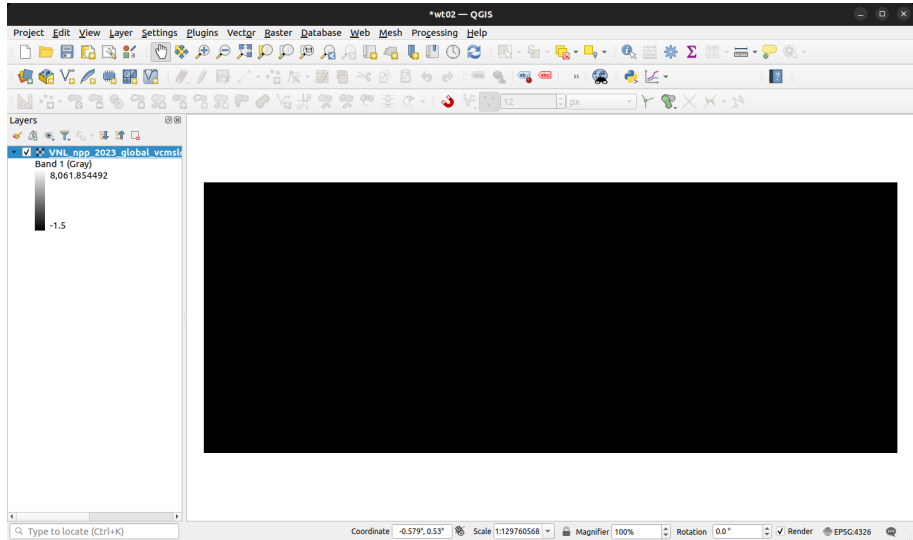
Go to Project → Save As...



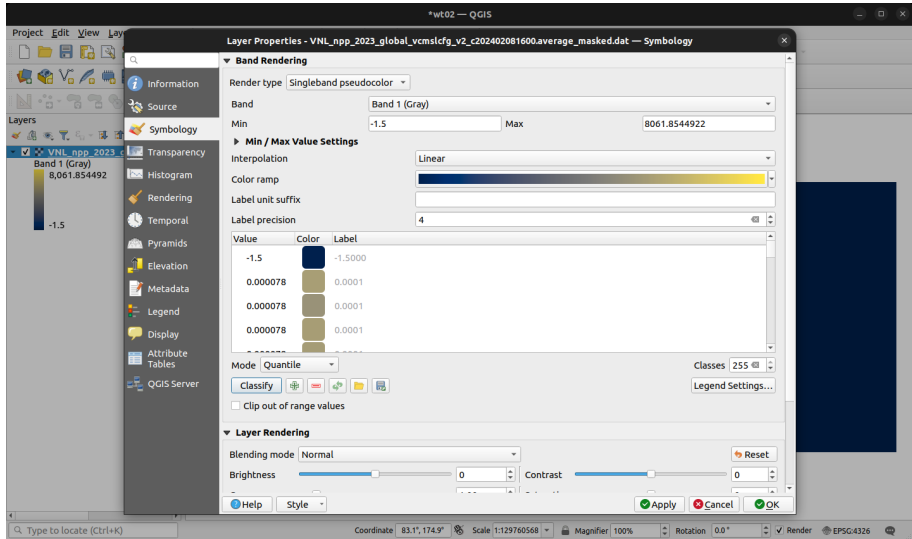
Vignette 1. Load the *2023 VNL data* (Layer → Add Layer → Add Raster Layer). VNL_npp_2023_....tif file in Data/VIIRS folder



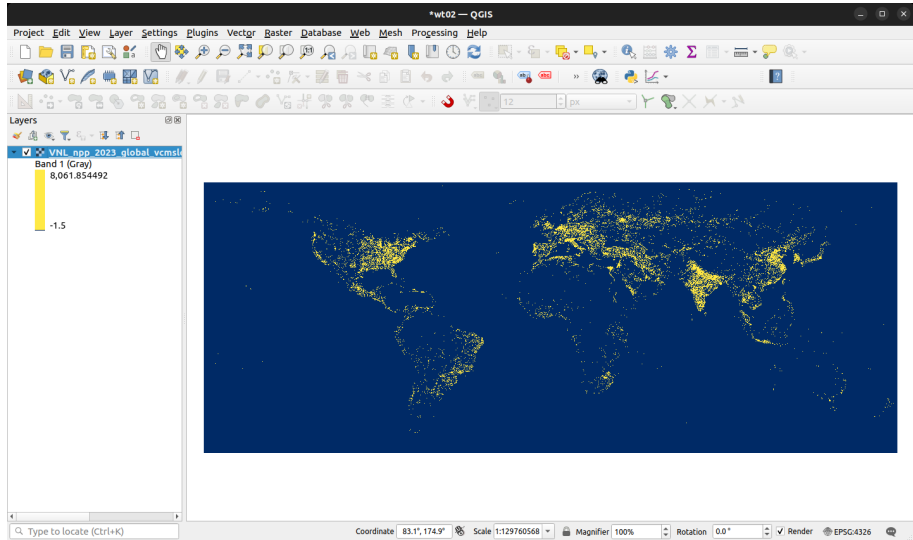
The default color scheme is too dark. Let's see if we can add some contrast



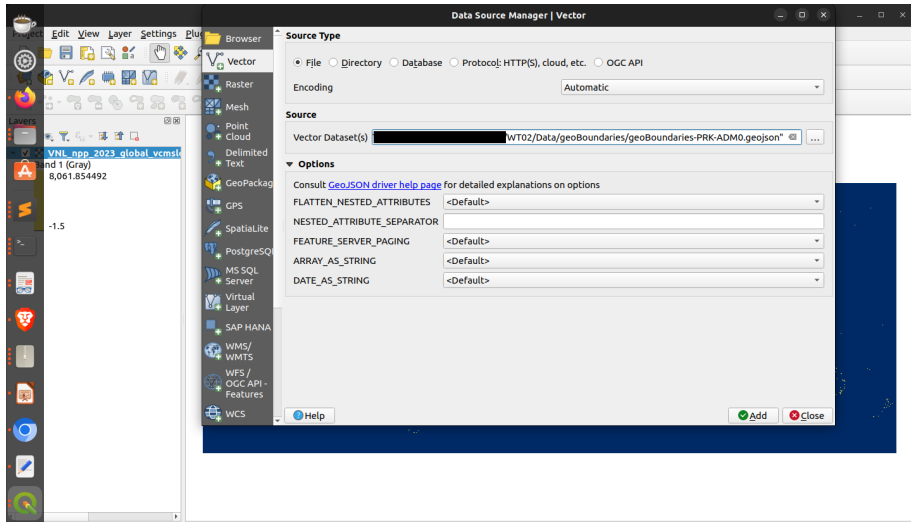
In the layer's Properties, change Render type to Singleband pseudocolor and set Mode to Quantile. Click Classify and OK



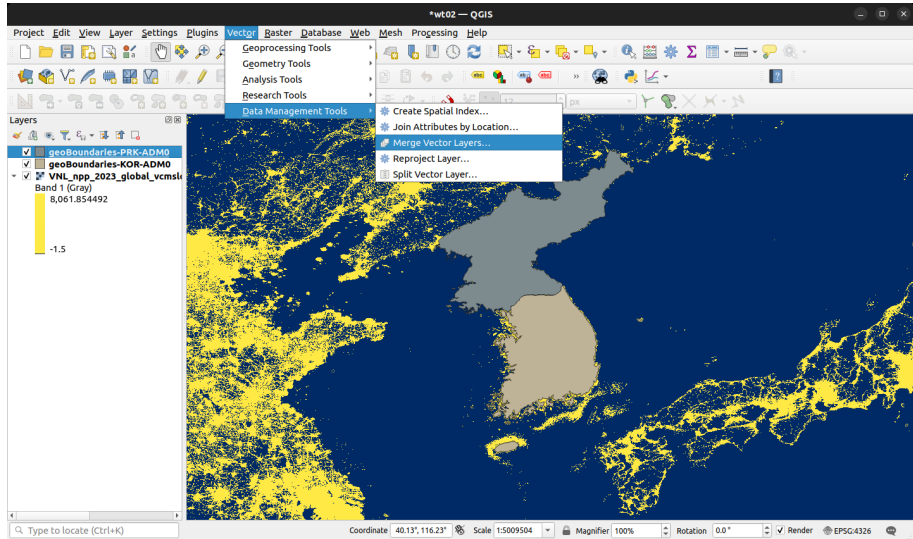
This is probably too much contrast, but at least we can see the distribution



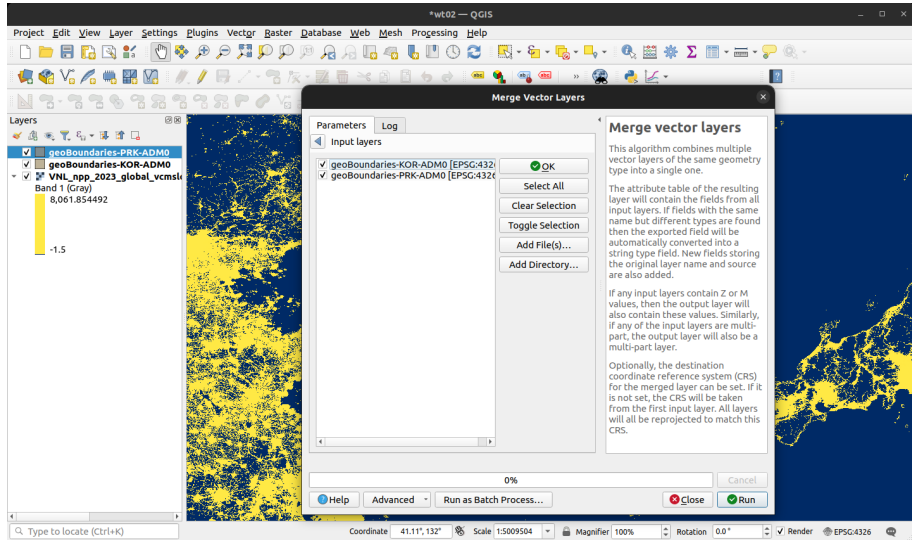
Load *country boundaries* for the two Koreas (Layer → Add Layer → Add Vector Layer). 2 files: geoBoundaries-PRK-ADM0.geojson and geoBoundaries-KOR-ADM0.geojson from Data/geoBoundaries folder.



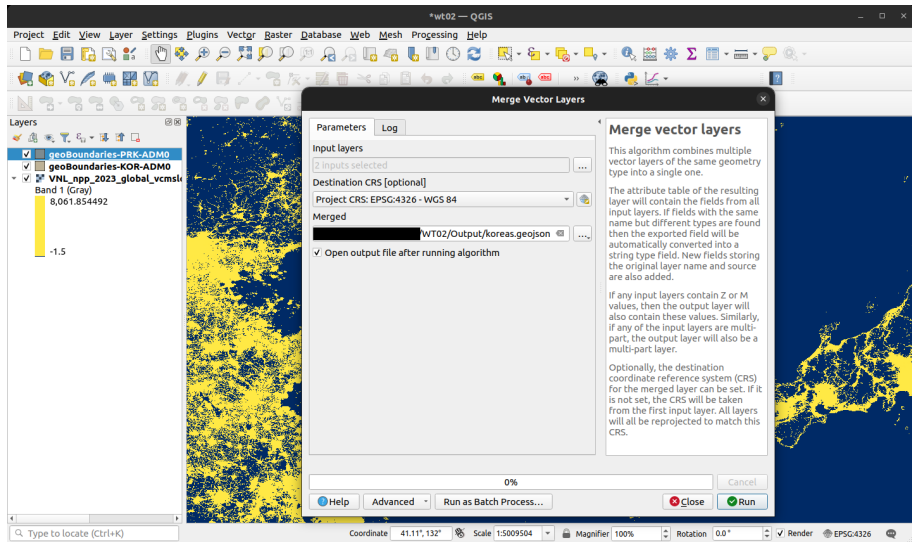
Let's merge the two Koreas into a single layer (Vector menu → Data Management Tools → Merge Vector Layers...)



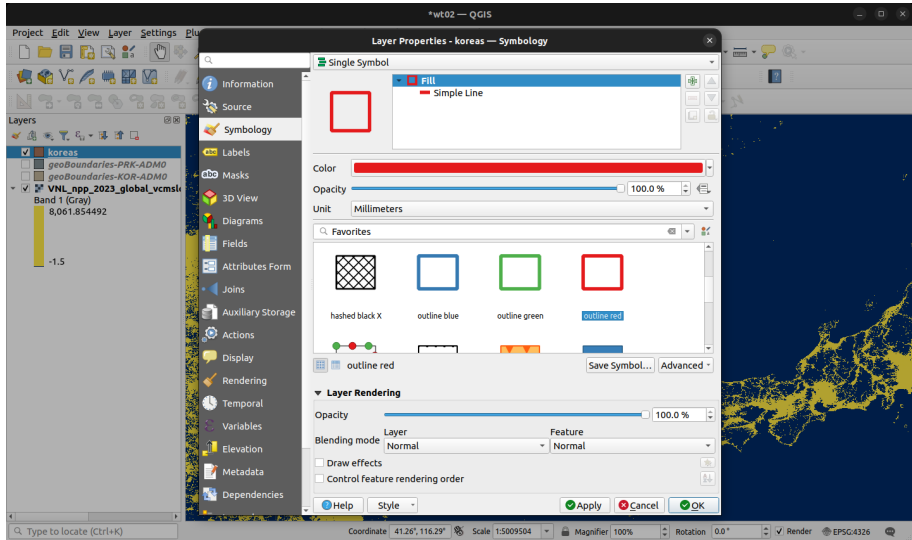
Input layers = geoBoundaries-KOR-ADM0 and geoBoundaries-PRK-ADM0



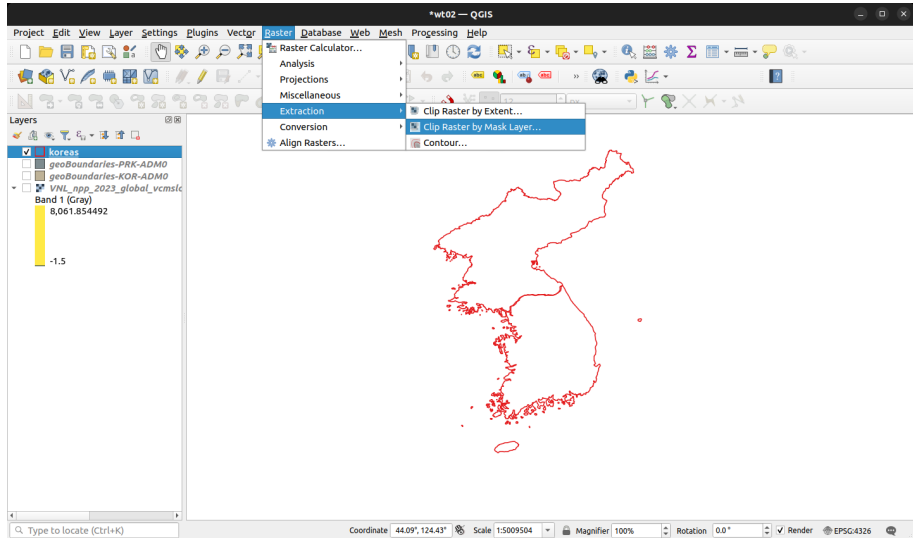
Save the merged file as koreas.geojson



Change the symbology of the new layer, to make all but the borders transparent

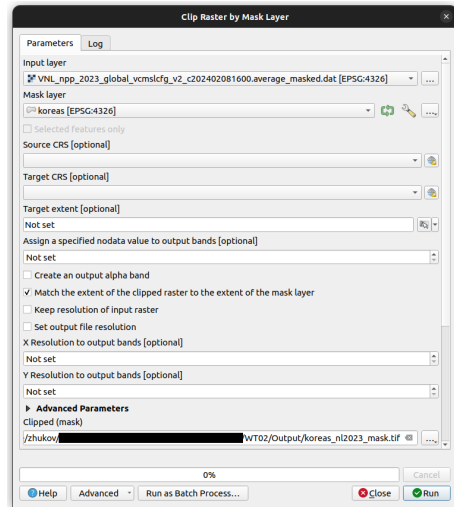


Let's extract the part of the global VNL raster that overlaps with the Koreas.
Go to Raster menu → Extraction → Clip Raster by Mask Layer...

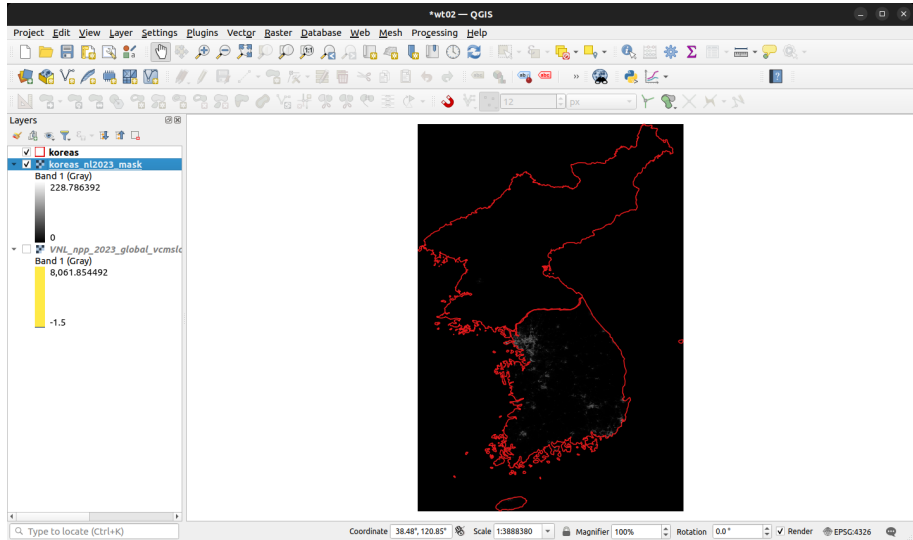


Set parameters

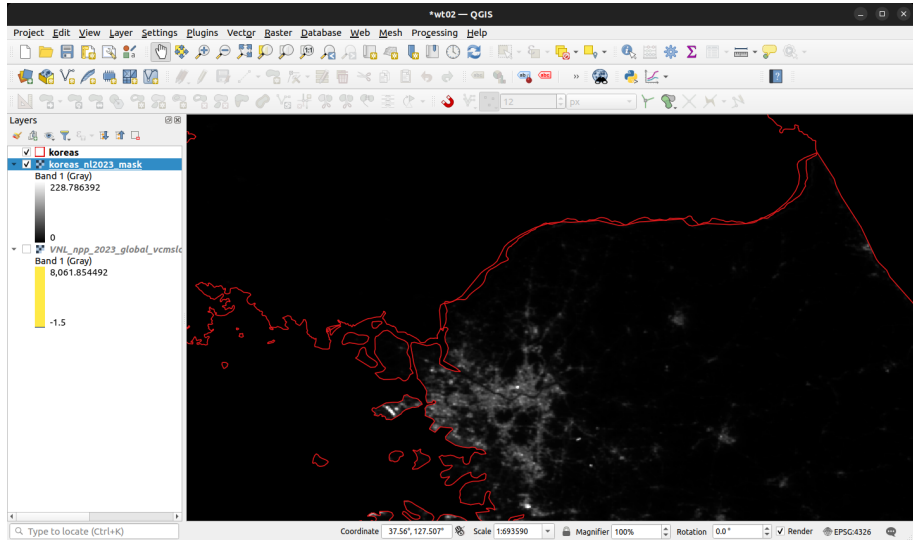
- Input layer = VNL_npp_2023...
- Mask layer = koreas
- ✓ Match the extent of the clipped raster to the extent of the mask layer
- Save file as koreas_n12023_mask.tif



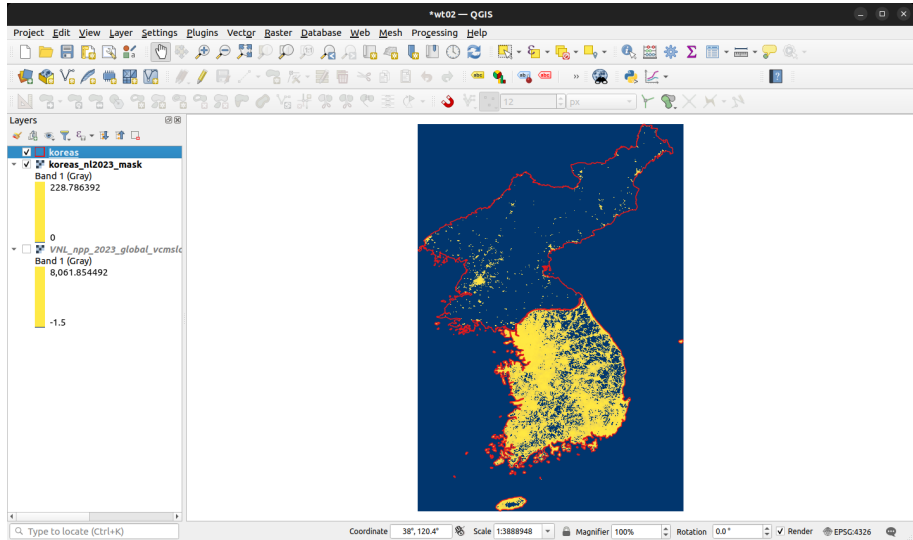
The clipped raster should look something like this



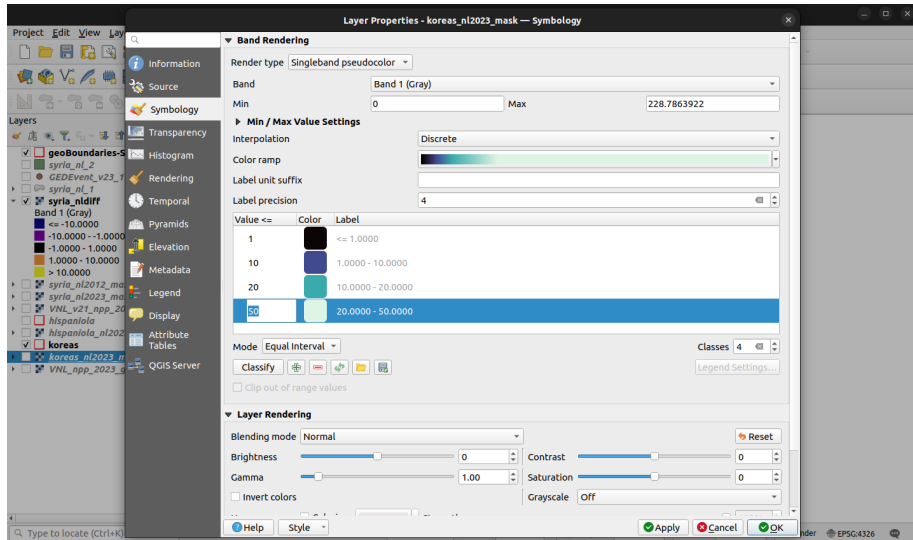
You can zoom in to see Seoul in greater detail



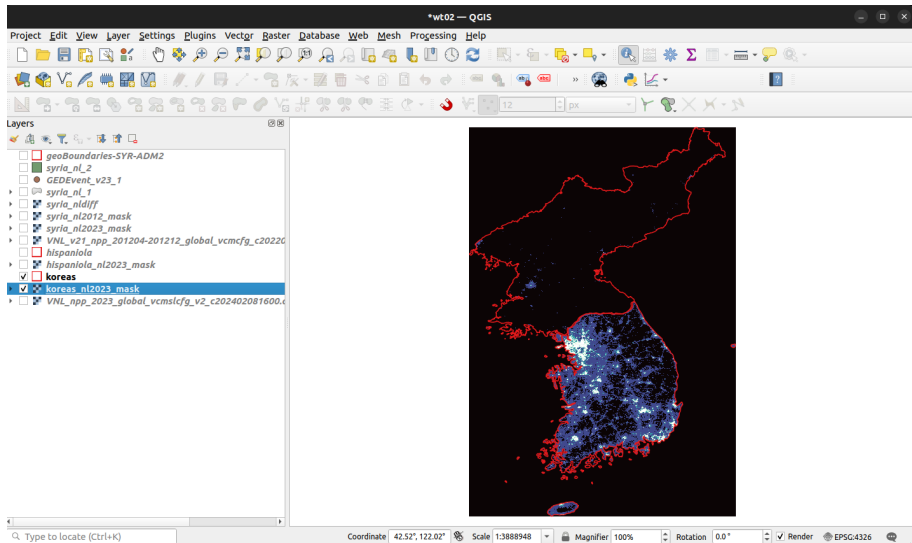
Change color scheme to Singleband pseudocolor, Quantile again for contrast



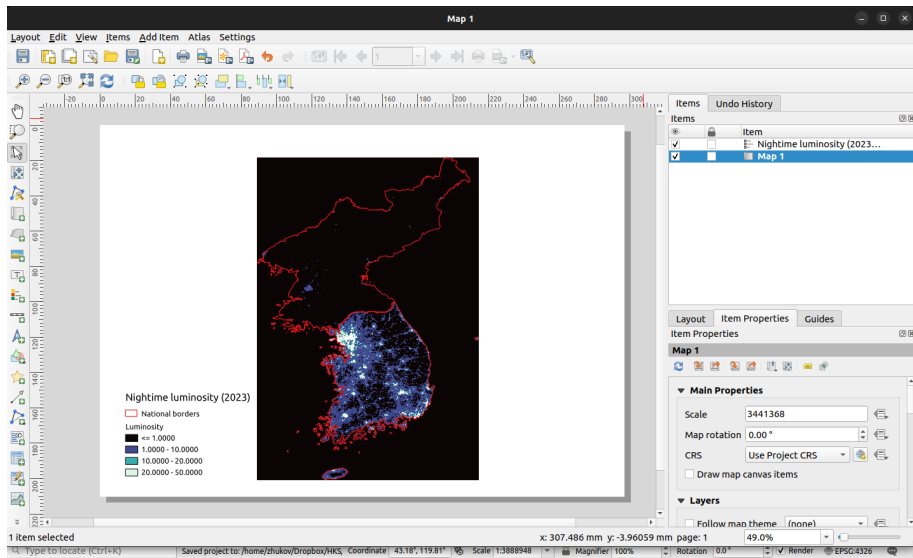
General tip: set Interpolation = Discrete, Mode = Equal interval and *manually edit the cutpoints* like this



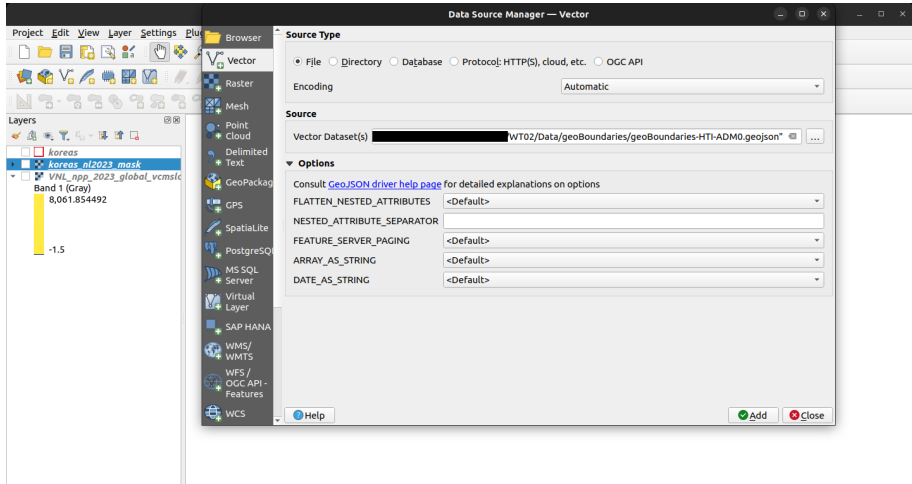
This way, you can customize the appearance of the map for your needs



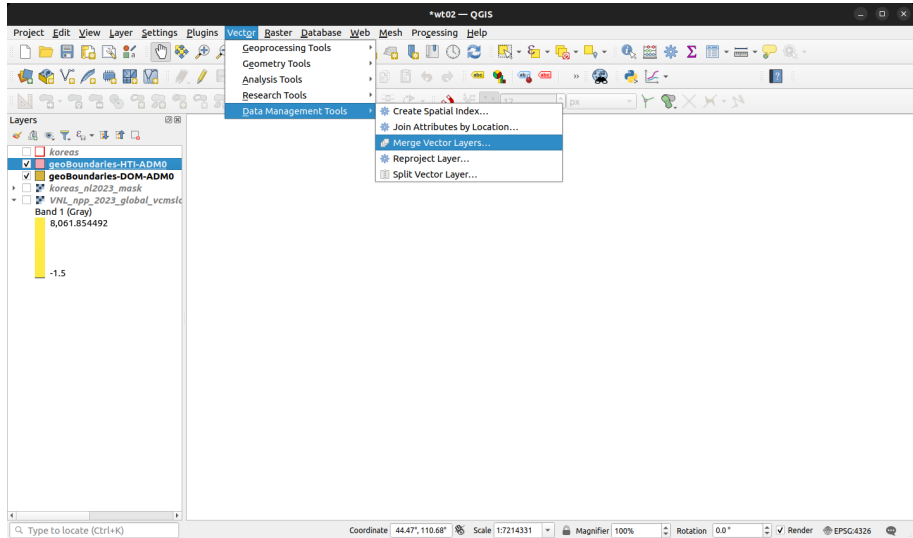
This map is ready to be exported (you know how to do this)



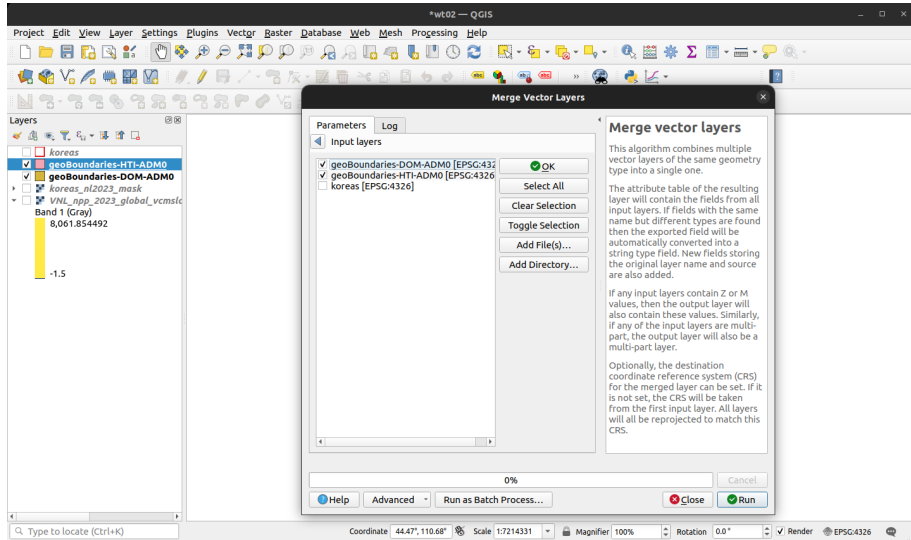
Now for **Vignette 2**, let's repeat this process for the island of Hispaniola. Load *country boundaries* for Haiti and the Dominican Republic (2 files: geoBoundaries-HTI-ADM0.geojson and geoBoundaries-DOM-ADM0.geojson from Data/geoBoundaries).



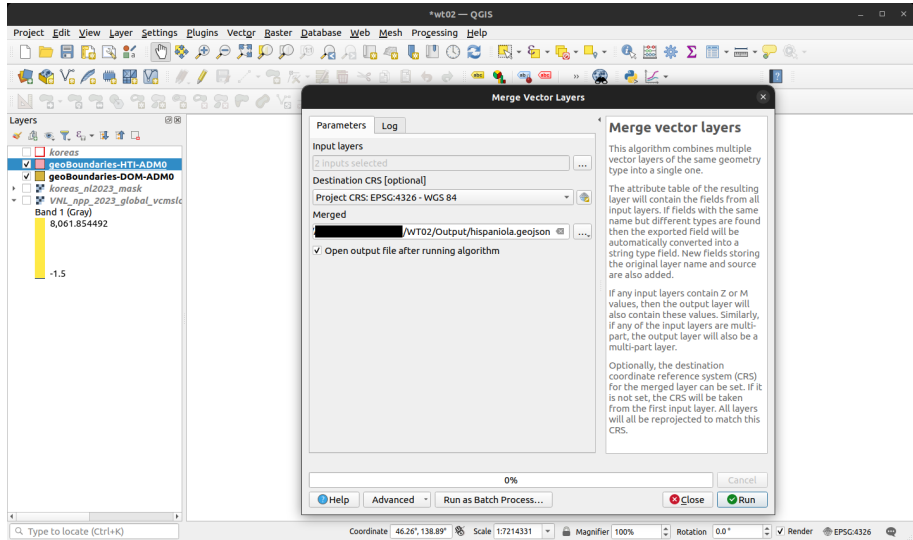
Once loaded, let's merge the two countries into a single layer again (Vector menu → Data Management Tools → Merge Vector Layers...)



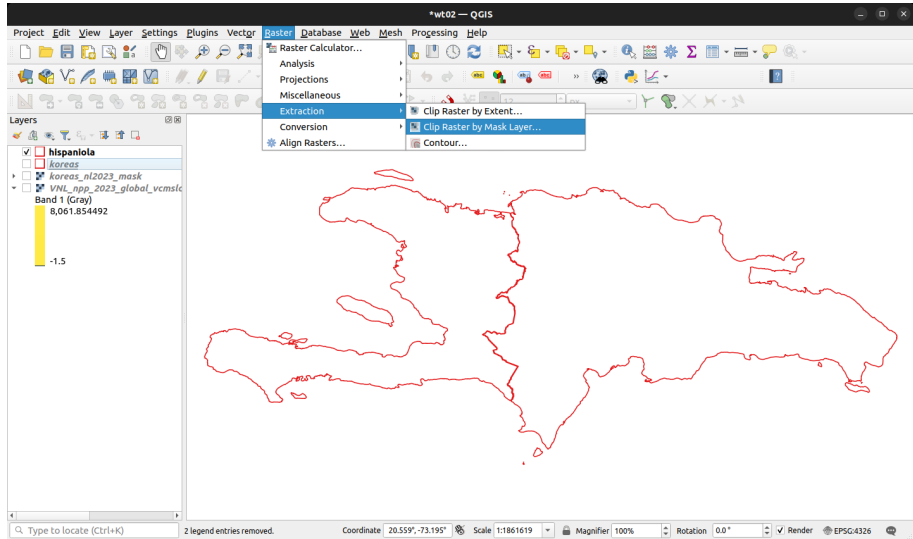
Input layers = geoBoundaries-DOM-ADM0 and geoBoundaries-HTI-ADM0



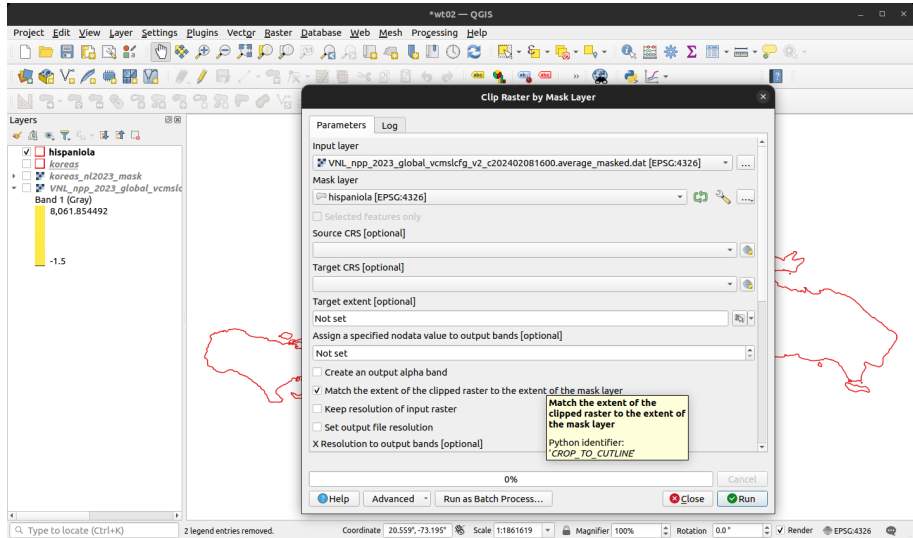
Save the merged file as `hispaniola.geojson`



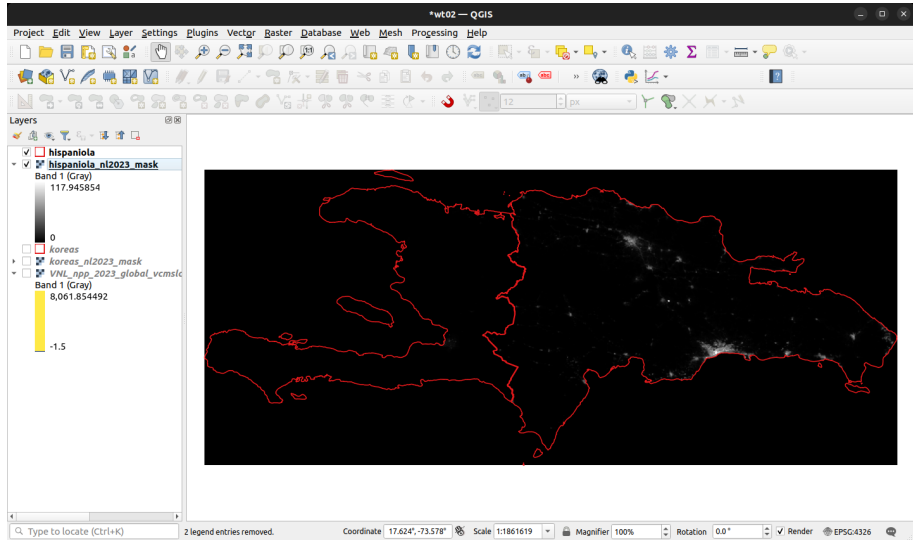
Let's extract the part of the global VNL raster that overlaps with the island.
Go to Raster menu → Extraction → Clip Raster by Mask Layer...



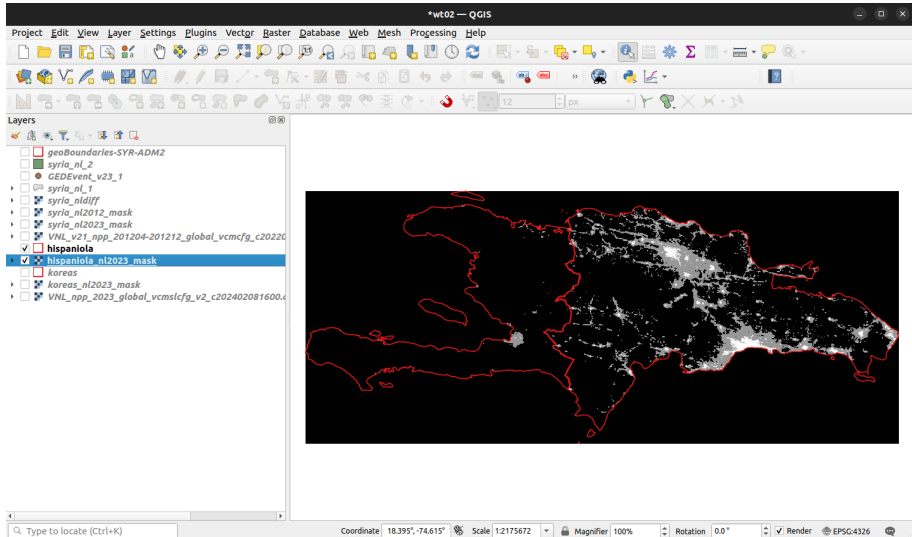
Set Input layer = VNL_npp_2023..., Mask layer = hispaniola. Save file as hispaniola_nl2023_mask.tif



The clipped raster should look something like this

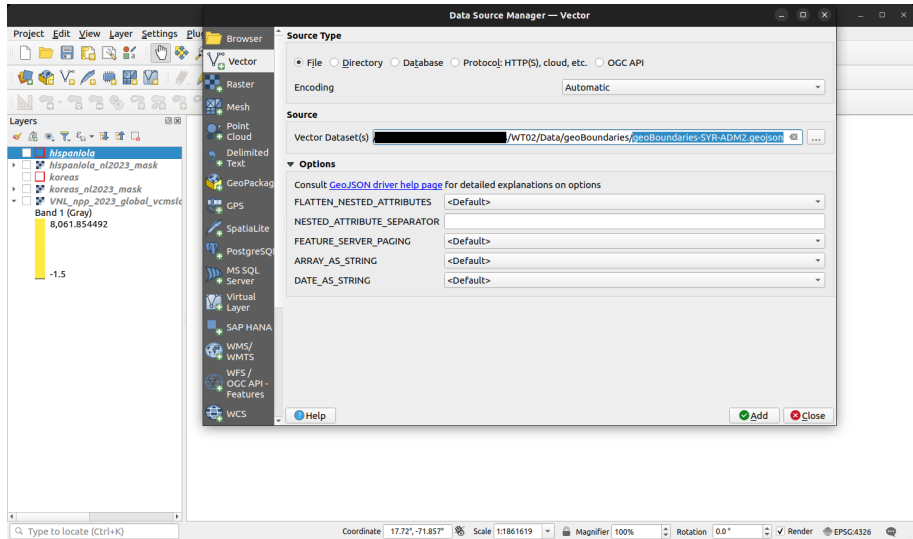


Customize the color ramp and export the map (just like last time)

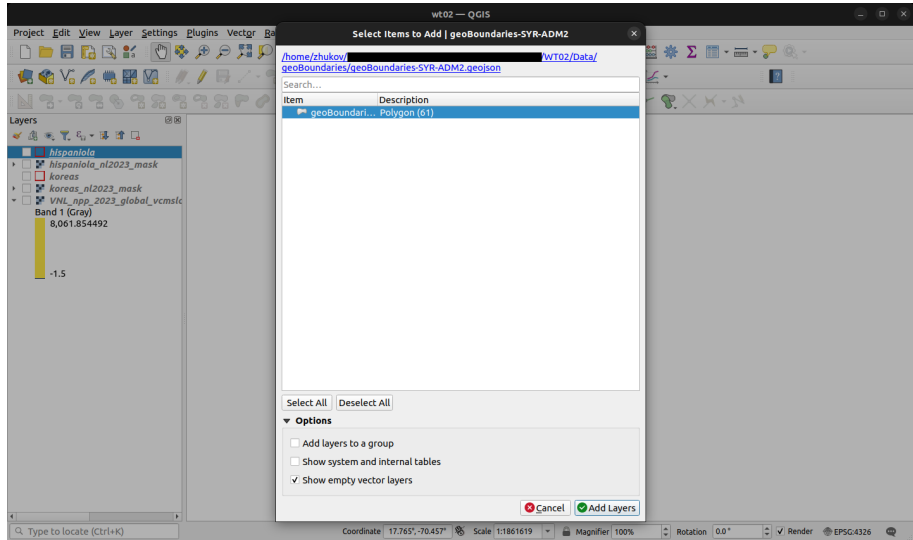


Differences in Luminosity Over Time (Syrian Civil War)

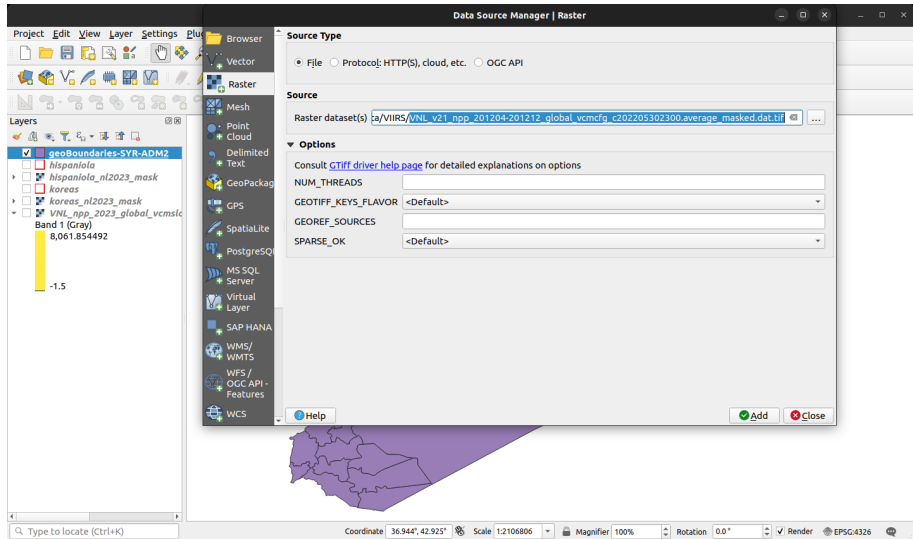
Vignette 3! Load *administrative boundaries* for Syria. File is `geoBoundaries-SYR-ADM2.geojson` from `Data/geoBoundaries` folder.



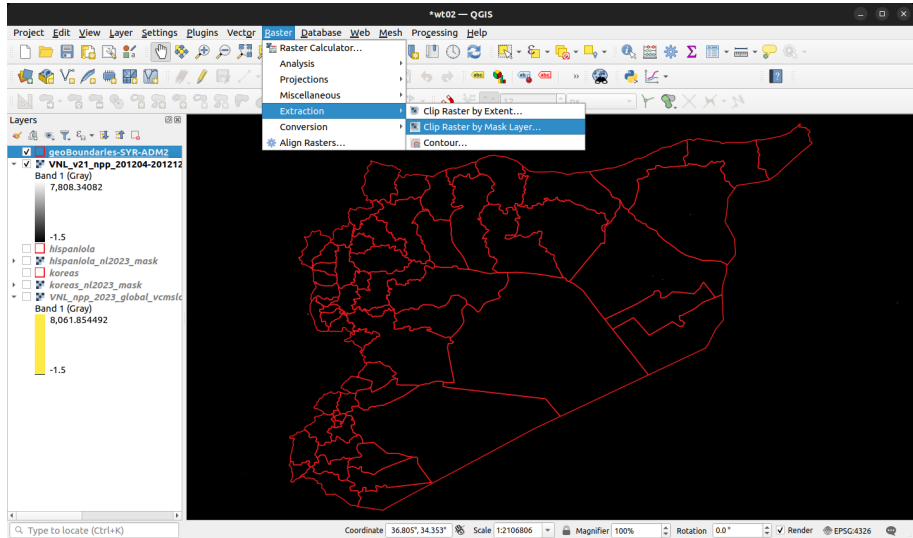
You may see a “Select Items to Add” screen after clicking Add. Click Add Layers



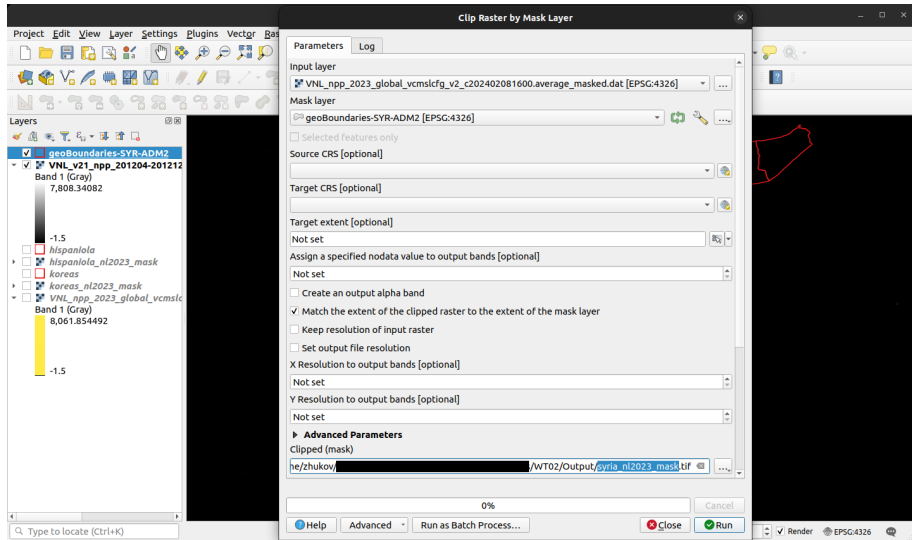
To compare current luminosity to a period earlier in the Syrian Civil War, load the *2012 VNL data* (VNL_v21_npp_201204...tif file in Data/VIIRS folder)



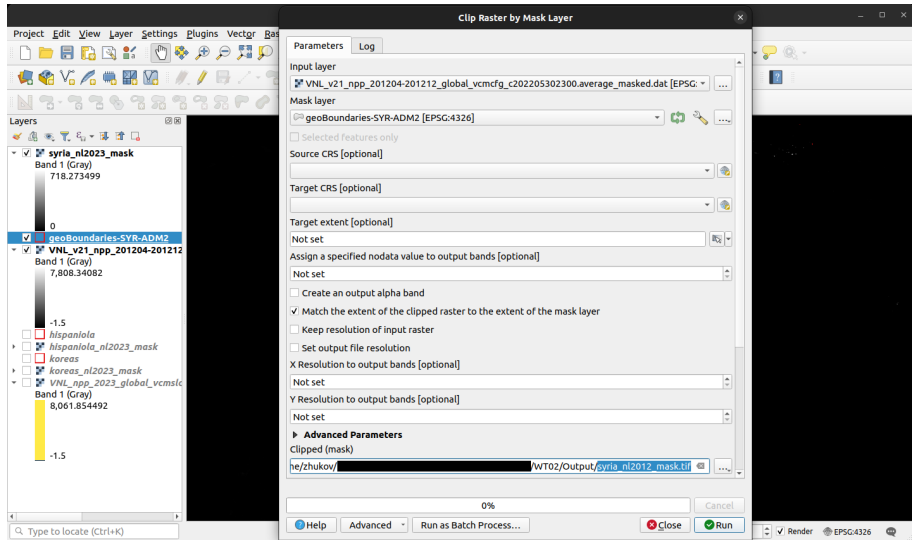
Let's extract the parts of both the 2023 and 2012 global VNL rasters that overlap with Syria. Raster menu → Extraction → Clip Raster by Mask Layer...



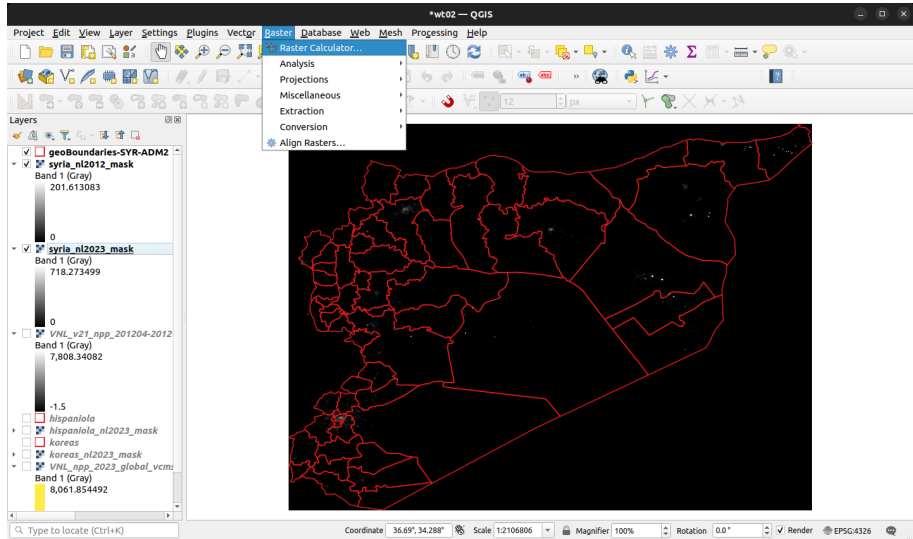
Set Input layer = VNL_npp_2023..., Mask layer = geoBoundaries-SYR-ADM2. Save file as syria_nl2023_mask.tif



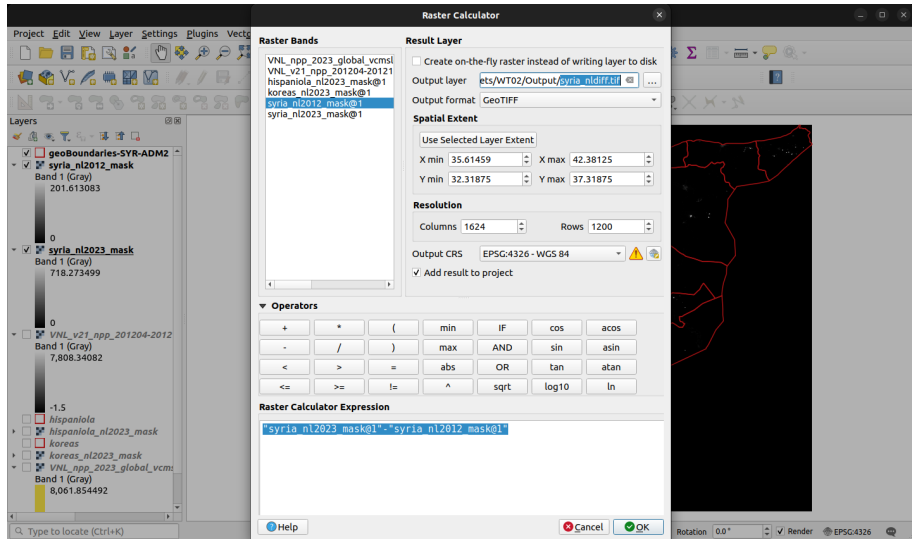
Repeat with Input layer = VNL_v21_npp_2012..., Mask layer = geoBoundaries-SYR-ADM2. Save file as syria_n12012_mask.tif



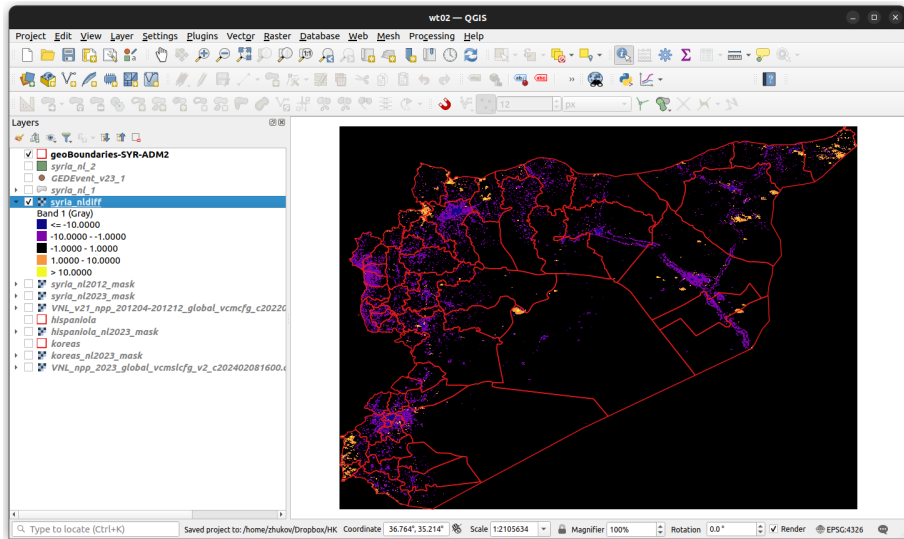
Let's now *calculate the difference between 2023 and 2012*. Go to Raster menu → Raster Calculator...



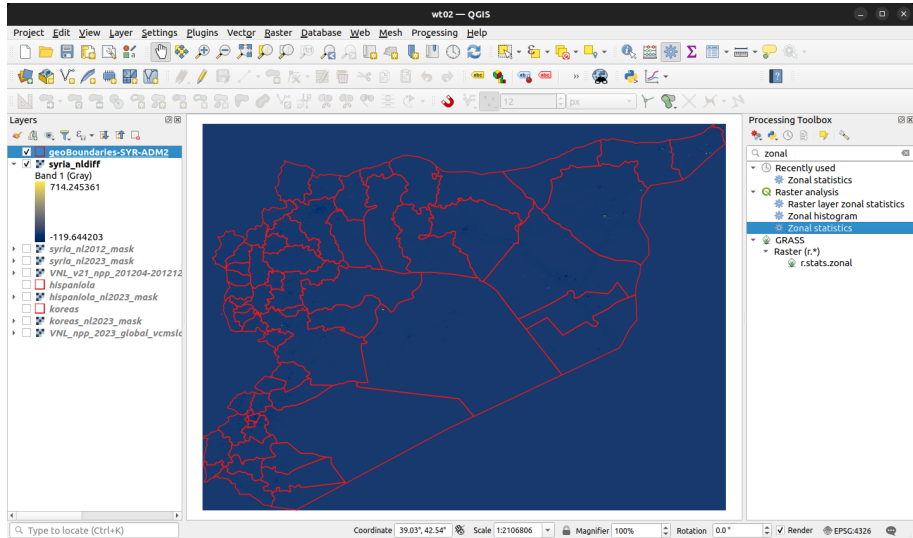
Set the expression to "syria_nl2023_mask@1" - "syria_nl2023_mask@1",
save output layer as syria_nldiff.tif



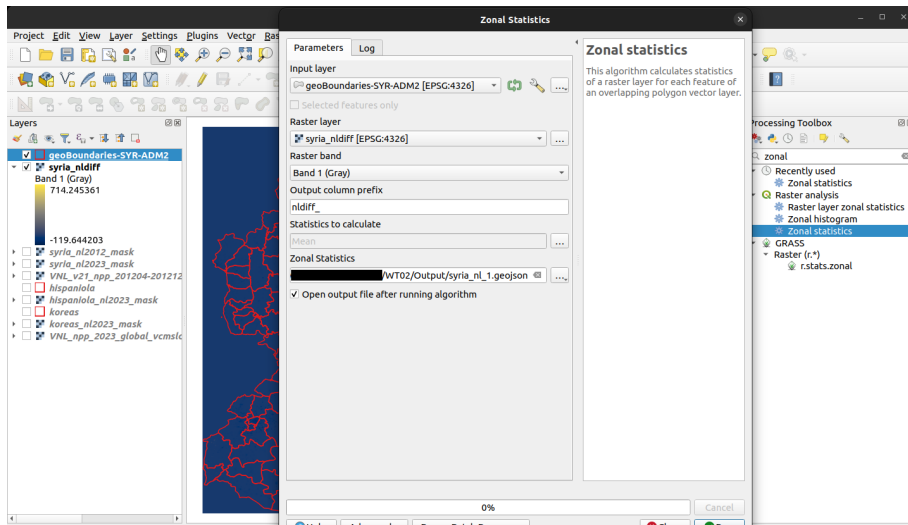
Explore the distribution of this new raster by modifying the color scheme
(here, purple areas lost luminosity, orange areas gained luminosity)



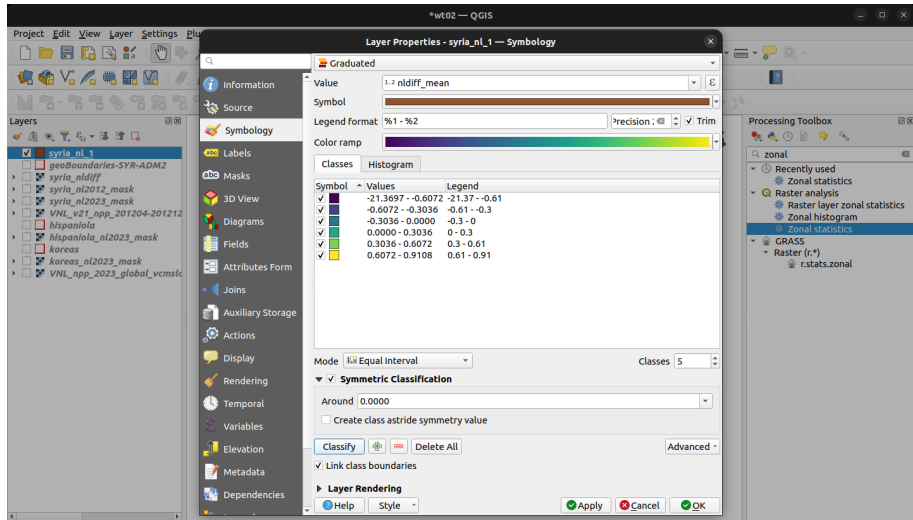
We can now calculate average differences in luminosity per district, using Zonal statistics (in the Processing Toolbox)



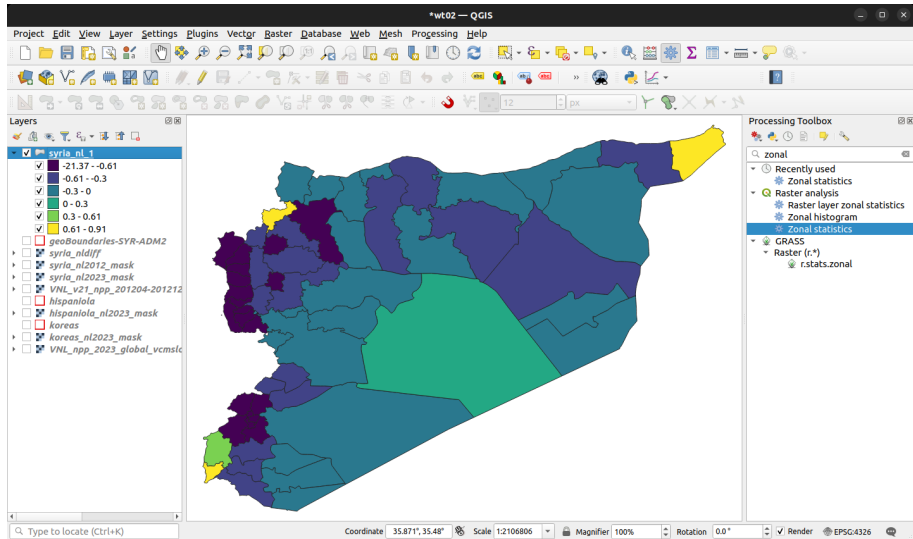
Set the Input layer = geoBoundaries-SYR-ADM2, Raster layer = syria_nldiff, Output column prefix = nldiff_. Save the output as syria_nl_1.geojson



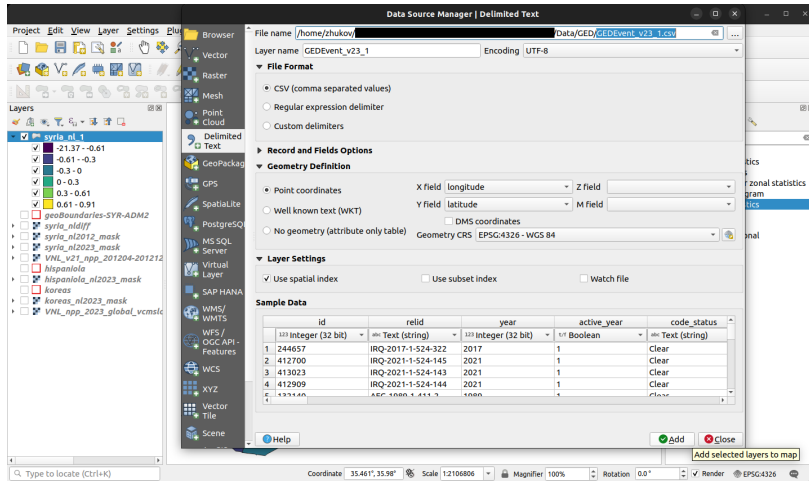
Adjust the symbology in the new syria_nl_1 layer to visualize the nldiff_mean variable with graduated colors, Equal Interval mode and Symmetric Classification around 0.00



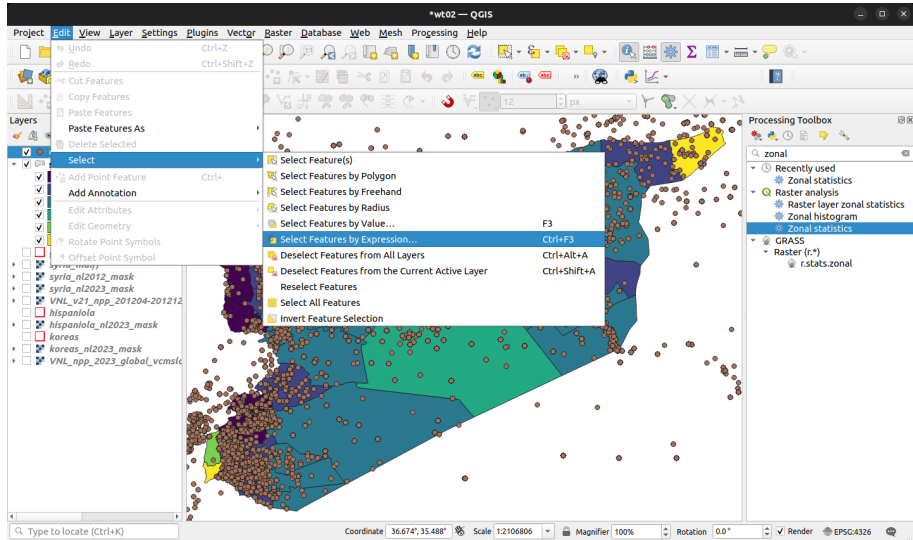
The district-level luminosity differences should look something like this.
Now let's see if places hardest-hit by violence saw the biggest declines. . .



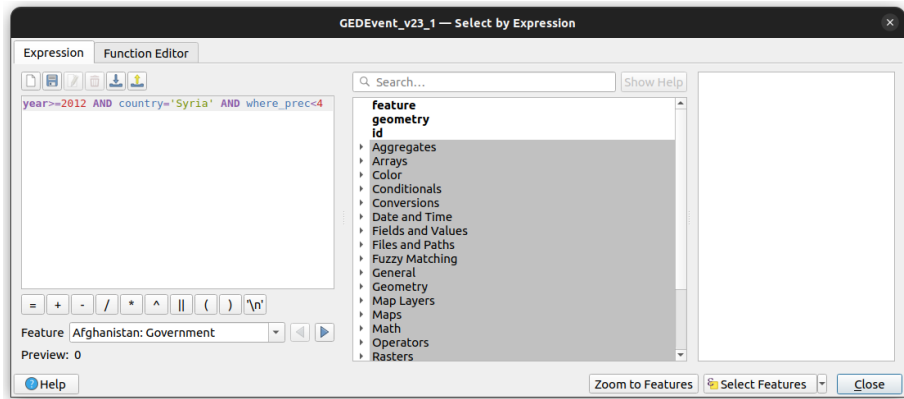
Add the *Syrian Civil War violence data* to the project, using Add Delimited Text Layer.... Load the GEDEvent_v23.csv file in Data/GED folder. Set X field = longitude and Y field = latitude. Check box ☒ Use spatial index



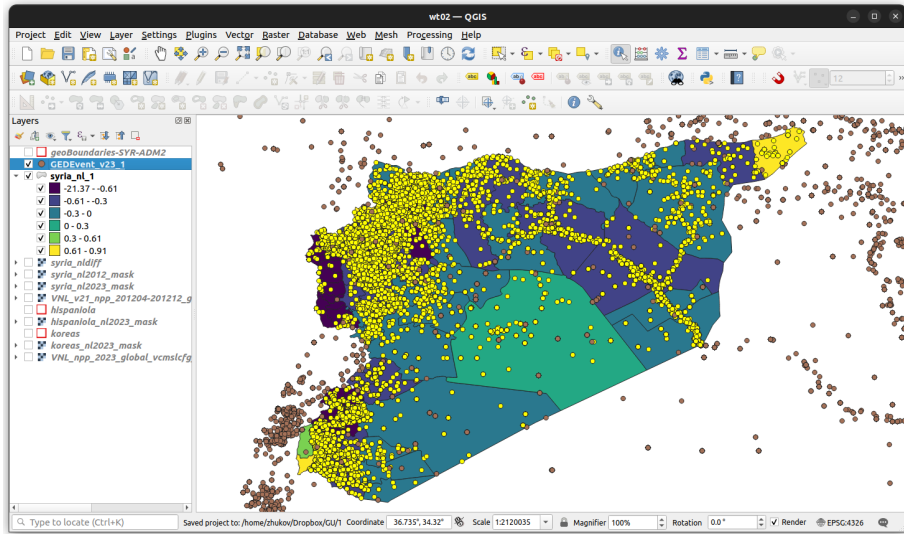
Highlight GED layer and go to Edit → Select → Select by Expression...



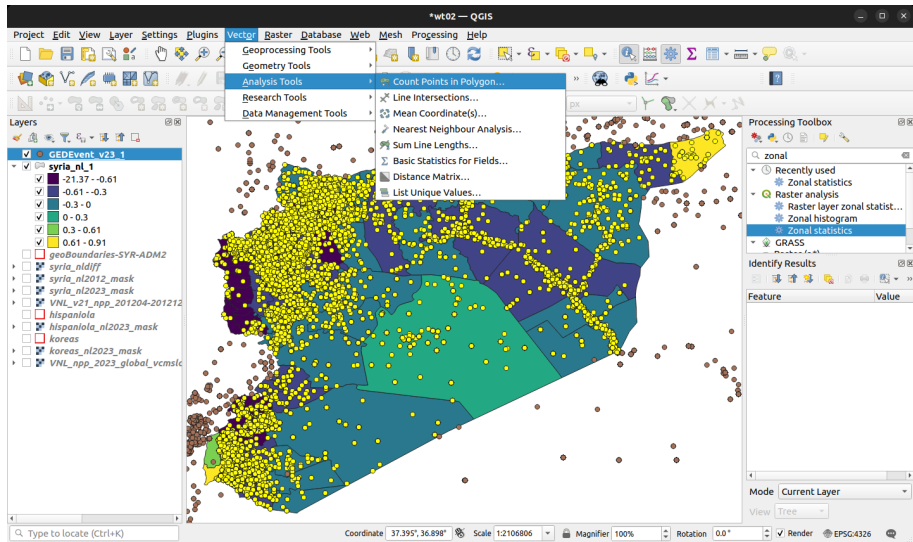
Expression: `year>=2012 AND country='Syria' AND where_prec<4`
Click Select Features



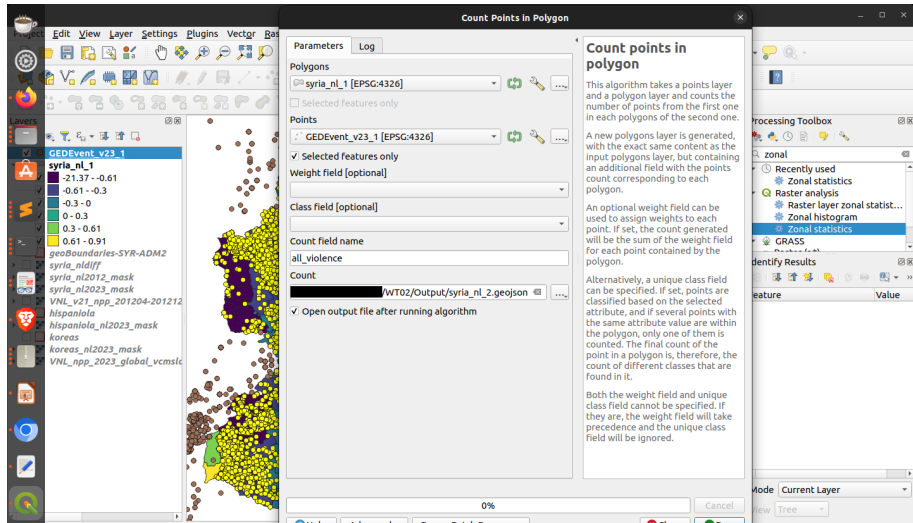
This procedure should have selected about 72 thousand events within Syria.
Now let's calculate the **number of violent events per district**



Open the Count Points in Polygon tool

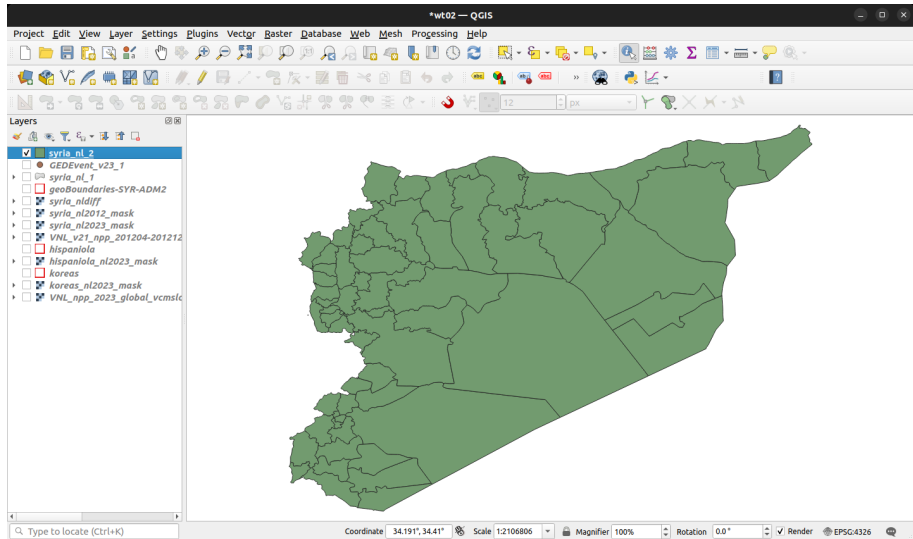


Select Polygons = syria_nl_1, Points = GEDEvent_v23_1. Make sure the box is checked next to Selected Features Only for the points. Name the count field all_violence, and save the output file as syria_nl_2.geojson. Click Run



The new layer `syria_n1_2` should appear in your project window.

Now, let's see if there is a relationship between violence and change in luminosity



Let's run a simple **regression model** in R to see how violence impacted luminosity.

This code chunk imports the `syria_n1_2.geojson` file we created into an object called `syr`, and then lists the variable names:

```
syr = sf::read_sf("Output/syria_n1_2.geojson")  
names(syr)
```

```
## [1] "shapeName"      "shapeISO"       "shapeID"        "shapeGroup"     "shapeType"  
## [6] "nldiff_mean"    "all_violence"   "geometry"
```

This code chunk estimates an **Ordinary Least Squares** model that regresses dependent variable `nldiff_mean` on explanatory variable `all_violence`

```
mod = lm(nldiff_mean~all_violence,data=syr)
summary(mod)

##
## Call:
## lm(formula = nldiff_mean ~ all_violence, data = syr)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -19.3243   0.0181   0.4239   0.8397   2.6816
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.4000160  0.4428367  -0.903   0.3700
## all_violence -0.0004699  0.0002258  -2.081   0.0418 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.754 on 59 degrees of freedom
## Multiple R-squared:  0.06839,    Adjusted R-squared:  0.0526
## F-statistic: 4.331 on 1 and 59 DF,  p-value: 0.04176
```

Let's rescale the variable `all_violence` to make the coefficient more interpretable.

```
mod = lm(nldiff_mean~I(all_violence/100),data=syr)
summary(mod)
```

```
##
## Call:
## lm(formula = nldiff_mean ~ I(all_violence/100), data = syr)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -19.3243   0.0181   0.4239   0.8397   2.6816
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    -0.40002     0.44284  -0.903   0.3700
## I(all_violence/100) -0.04699     0.02258  -2.081   0.0418 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.754 on 59 degrees of freedom
## Multiple R-squared:  0.06839,    Adjusted R-squared:  0.0526
## F-statistic: 4.331 on 1 and 59 DF,  p-value: 0.04176
```

For every 100 violent events, the change in luminosity falls by 0.047.

You can perform all these steps in R
(see replication code `wt02_demo.R` in `Lab10WT02.zip`)

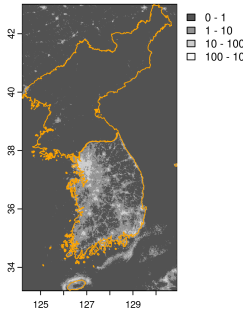


Figure 18: Vignette 1

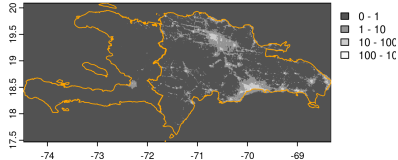


Figure 19: Vignette 2

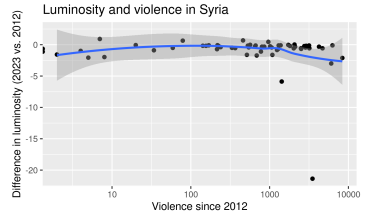


Figure 20: Vignette 3