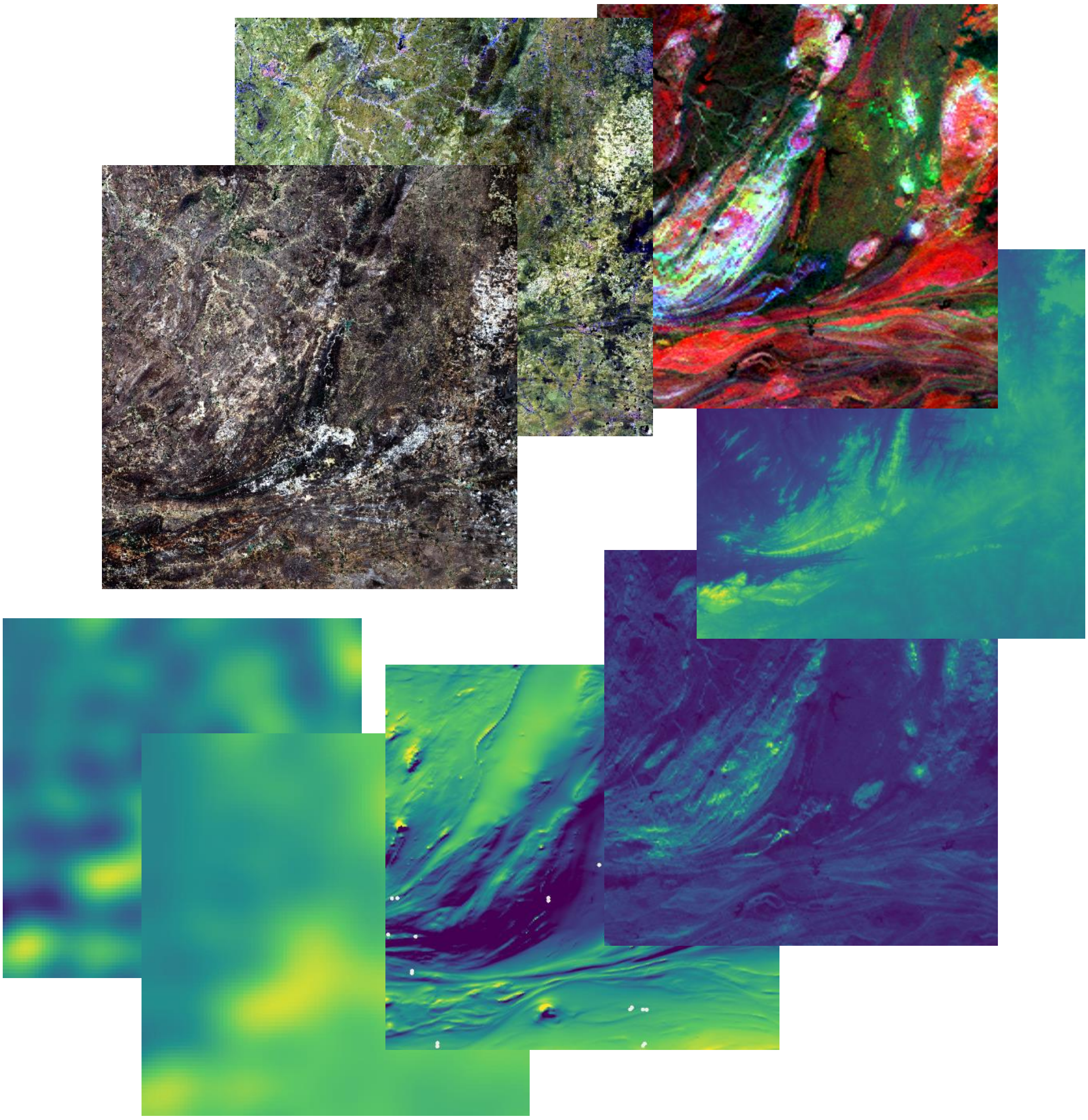
Mineral Exploration Targeting

PART 1 – Data Preparation



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Visit https://gdatasystems.com

What is mineral exploration targeting?

Mineral exploration targeting is the identification of potential areas or zones favorable for the development of economic production of a certain mineral. It is based on existing data, new interpretation of existing data and integration of the information gathered.

The main goal is to expedite the exploration process and, consequently, reduce the cost of doing it.

Targeting, under other names, was always used by geologists to narrow down the prospect area and to achieve the best results possible. Modern geologists with today's technological advancements (such as better computing power, access to geospatial and geophysical data, and Geological Surveys making available their databanks) allowed us, using some new software and programming scripts, to delineate zones (targets) in a process called mineral exploration targeting. This will be the subject of this material and detailed description of this process will be covered using real data in a real case study. Reinforcing that the goal here is to demonstrate how to execute mineral targeting, and not necessarily achieving a positive outcome.

We will cover here:

Part 1

- **Gathering the data**
- **Data Loading**
- **AOI and CRS**
- **Raw Data**
- **Reprojection and Mosaic**

Part 2

- Data Validation – Visually and Statistically
- Organizing and extracting information for the targeting process

Part 3

- Target identification
- Sources of Ranking data

Part 4

- Ranking
- Result Evaluation

Gathering the data

A large area of approximately 150 by 200 km, located in the Borborema Geological Province in Brazil Northeast region, was selected for this tutorial. The area was chosen based on the availability of good airborne geophysical data at a reasonable spacing, presence of several (and distinct) mineralized areas, and a very interesting geological framework. The targeting will be executed over a smaller portion of the data obtained but, a larger base will be created here for further processing.

The goal here is to illustrate how to get freely available data from several sources.

Image data

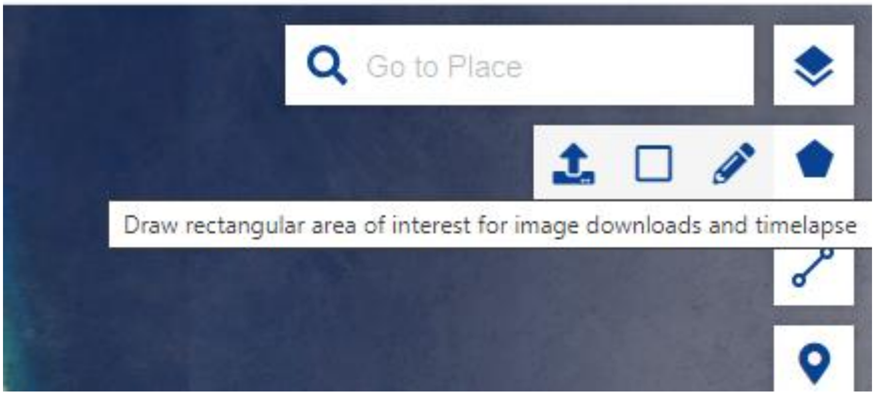
Sentinel2 images and DEM can be downloaded from the ESA Copernicus data hub. Just create an account and download the necessary scenes.

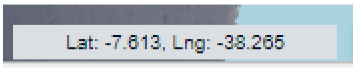
https://dataspace.copernicus.eu/

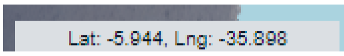
After the login, the following dashboard hub will appear.

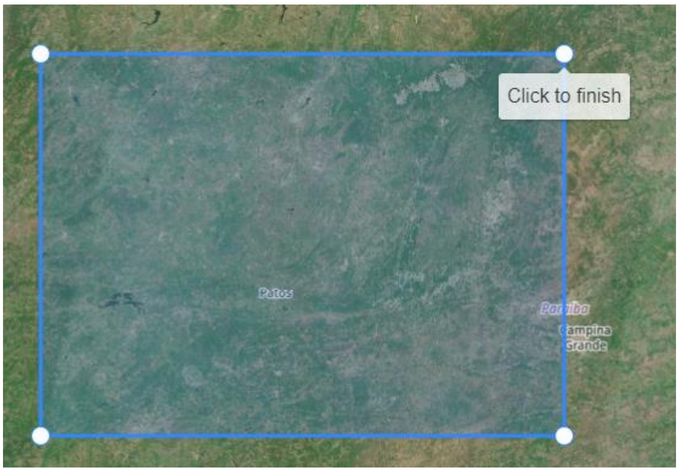
Please pan to the location of interest:

Now, using the following tool, make a square covering our zone of interest.

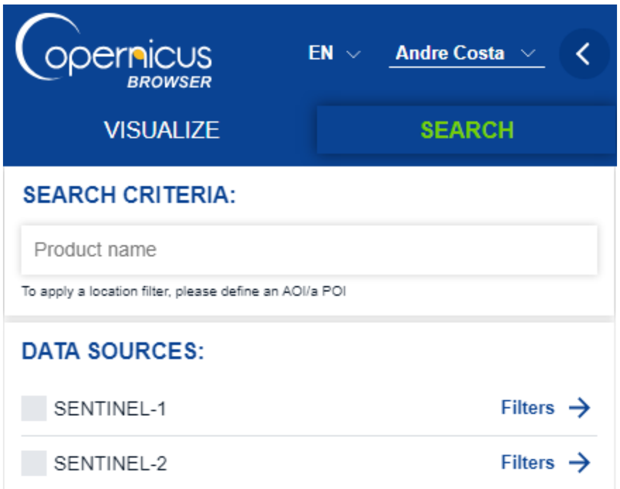


Place the first vertex at: 

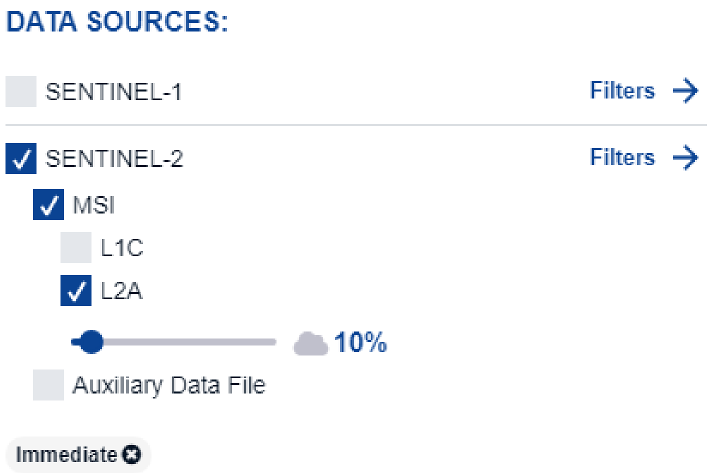
The final vertex will be: 



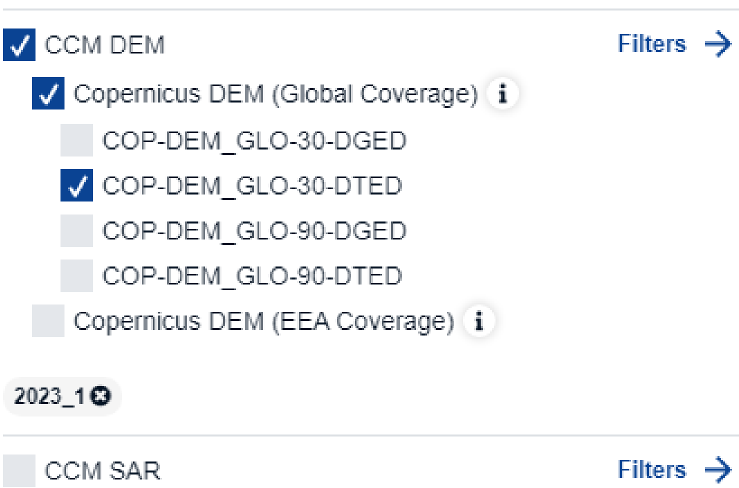
Now click on the SEARCH button:



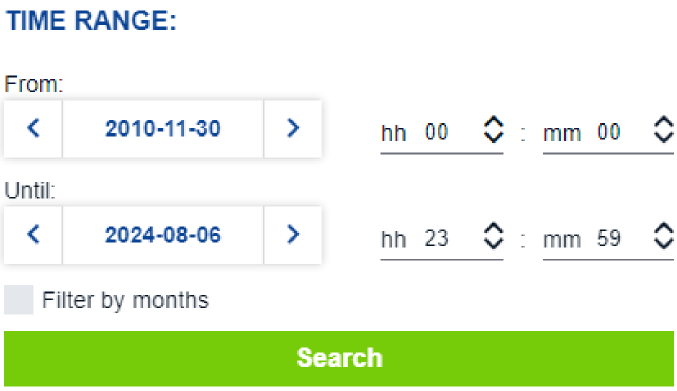
Select Sentinel 2, L2A 10% max cloud cover:



Also select the CCM DEM data provider:

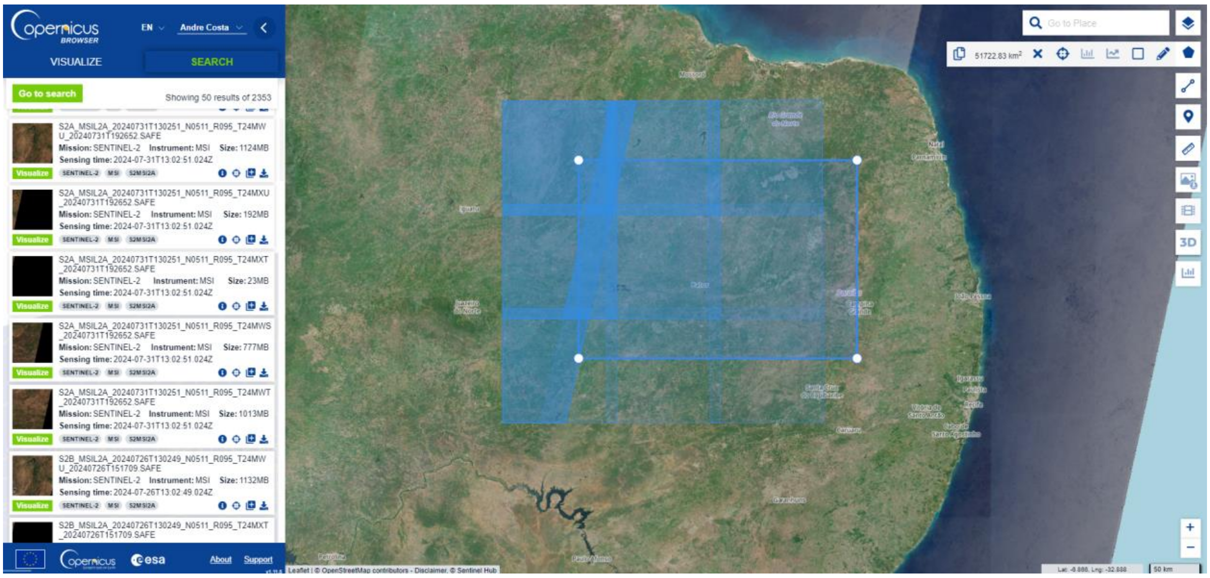


In the Time Range select the date From as:



And click the Search button.

A list of available Sentinel2 scenes and DEM from the period selected will appear.

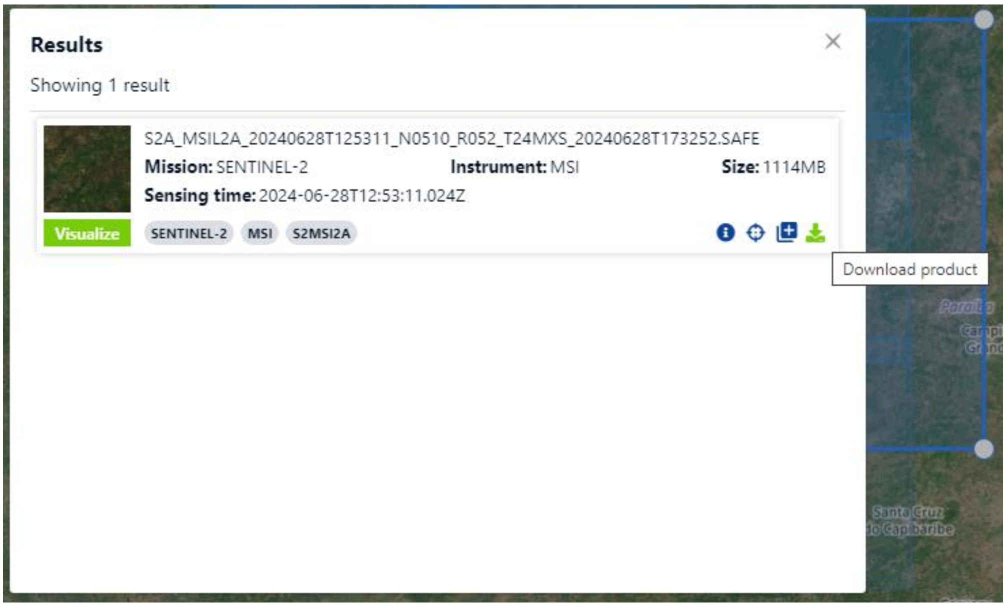


They are not loaded at once and you must click on this button (Load More) to load more scenes. They are listed from the most recent to the oldest.

The following Sentinel2 scenes were used in this tutorial:

- S2B_MSIL2A_20231126T125259_N0509_R052_T24MXS_20231126T150155.SAFE
- S2B_MSIL2A_20231126T125259_N0509_R052_T24MXT_20231126T150155.SAFE
- S2B_MSIL2A_20231126T125259_N0509_R052_T24MXU_20231126T150155.SAFE
- S2B_MSIL2A_20231126T125259_N0509_R052_T24MYS_20231126T150155.SAFE
- S2B_MSIL2A_20231126T125259_N0509_R052_T24MYT_20231126T150155.SAFE
- S2B_MSIL2A_20231126T125259_N0509_R052_T24MYU_20231126T150155.SAFE

Navigate to until they are listed in the list on the left a click on the scene to be downloaded, the following dialog will appear:



Just click on the button “download product”. You can download up to 4 concurrent scenes.

The same process for the DEM files. The ones used in this tutorial are:

- DEM1_SAR_DTE_30_20101220T080714_20130426T080910_ADS_000000_GnWw_9afe815d.DEM
- DEM1_SAR_DTE_30_20101220T080714_20130426T080910_ADS_000000_hKdH_9afe815d.DEM
- DEM1_SAR_DTE_30_20101231T080715_20121112T080940_ADS_000000_YGnO_9afe815d.DEM
- DEM1_SAR_DTE_30_20110213T080712_20121101T080857_ADS_000000_XI0N_9afe815d.DEM

Save all the downloaded zip file into a folder. You can close the Copernicus hub now and move to the next step.

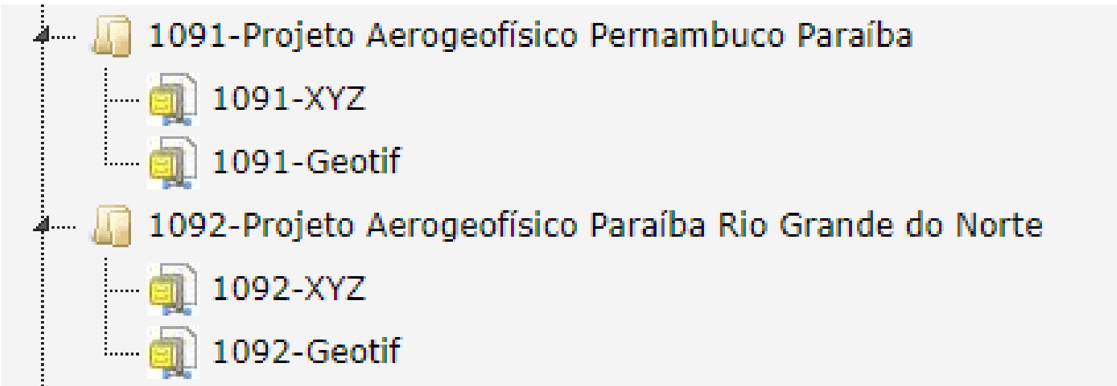
Geophysical data

The geophysical data used in this tutorial was downloaded from:

https://geosgb.sgb.gov.br/geosgb/downloads.html

Browse to this folder:

And download these two projects (geotif and raw XYZ data) that will be used in this tutorial:



Save the downloaded zip file into the same folder we loaded the Sentinel2 and DEM image data.

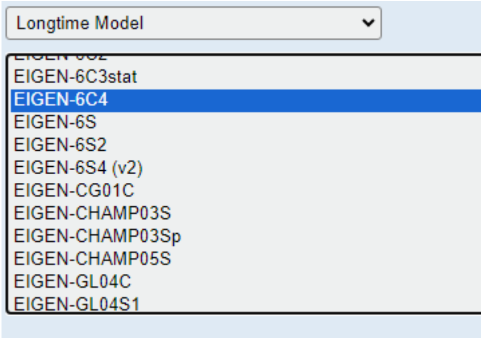
Gravity data

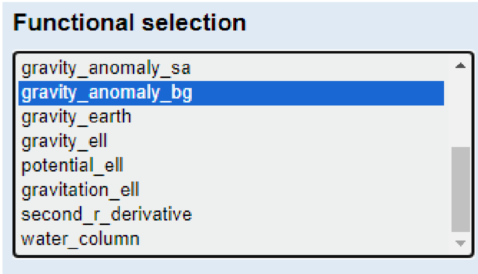
The semi-quantitative gravity geophysical data can be downloaded from:

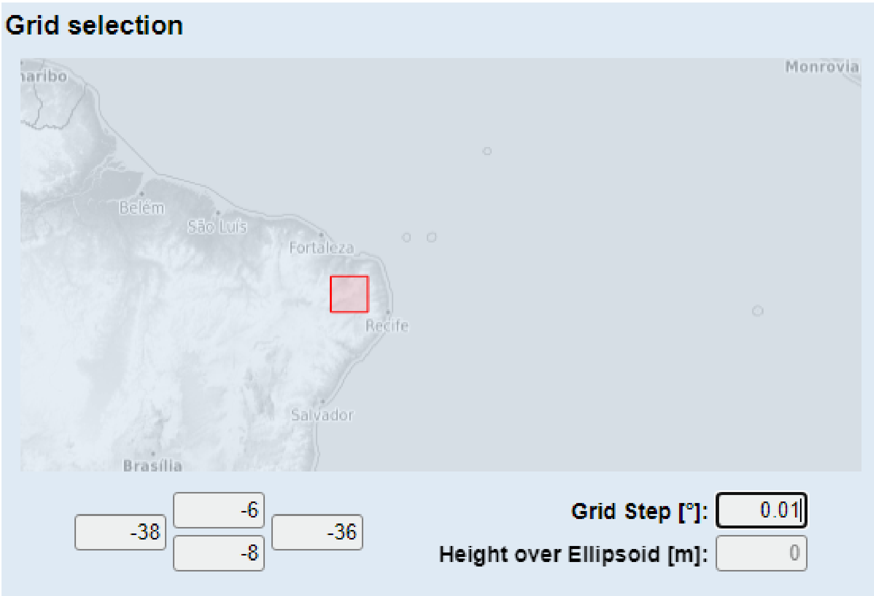
https://icgem.gfz-potsdam.de/calcgrid

This data may be useful when doing targeting over large areas since the grid is at low resolution (~1km grid spacing).

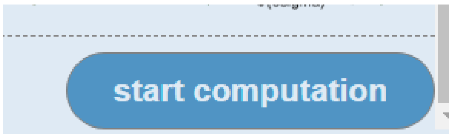
Three products will be downloaded here. Select the longtime model, The functional selection and the grid as following:



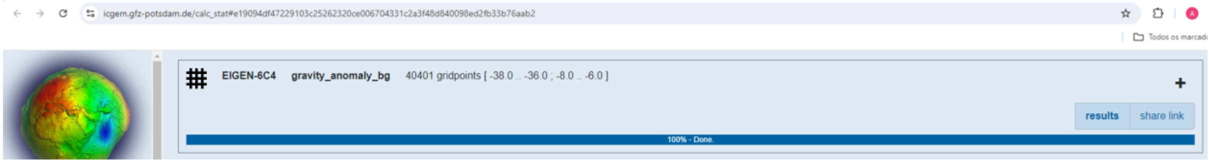




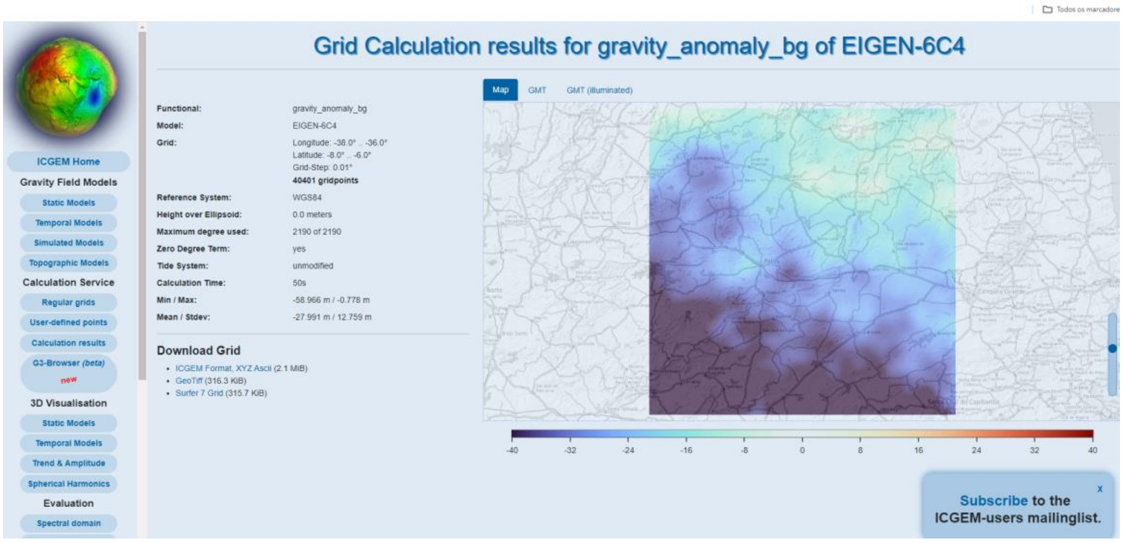
Click on “start computation” button.



A new page will open, and the processing is executed. When finished the following should appear:

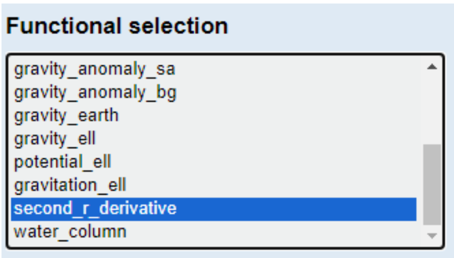


Click on results and this page should appear:

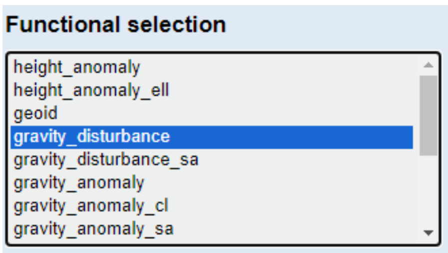


Download the grid in ascii and geoTiff formats:

Repeat for



And:



Save the downloaded files into the same folder we loaded the Sentinel2, DEM image data, and other geophysical data. Now we are going to organize and prepare the data for preprocessing.

Data Loading

Once all the data is downloaded, and we conclude the uncompressing of these files we will load the data using QGIS to preview and organize the several sources of data starting with the Sentinel2 scenes.

We downloaded six scenes and now it is time to open these scenes grouped by bands. Nine bands will be used in this tutorial. They are:

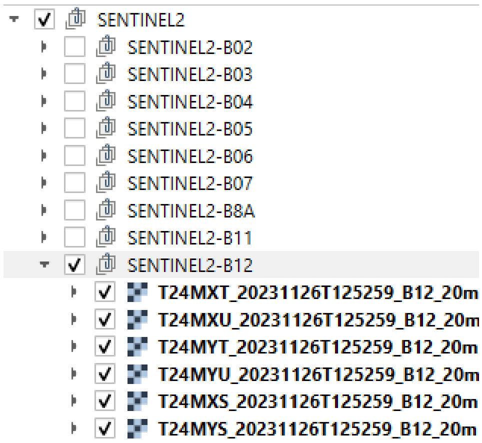
Bands 2, 3 and 4 corresponding to the visible spectra.

Bands 5 ,6 and 7 corresponding to the VNIR spectra.

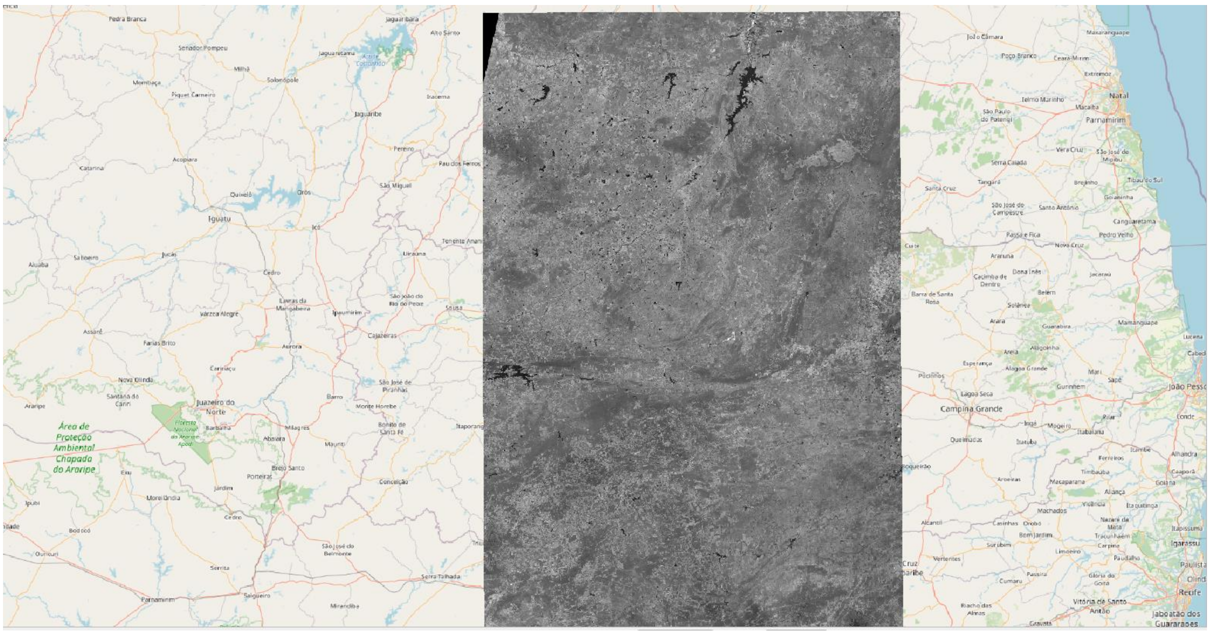
Band 8A corresponding to the NIR spectra.

Bands 11 and 12 corresponding to the SWIR spectra.

After opening all files, the structure grouped by bands should look similar to:

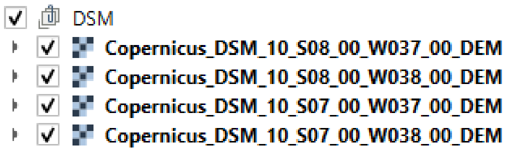


And the images will be displayed as:

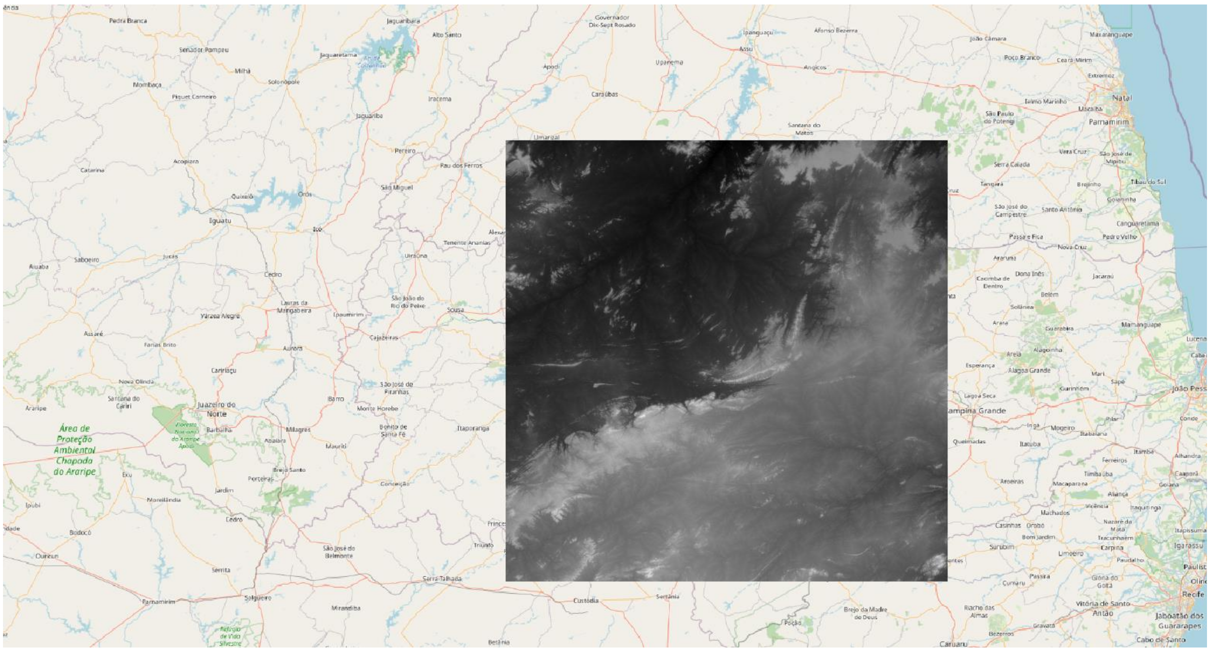


Note - use the same interval of values to get a homogeneous image of the 6 scenes. Example: 0 to 8000.

Using a similar procedure, open the 4 DEM scenes structured as illustrated below:



And the images will be displayed as:

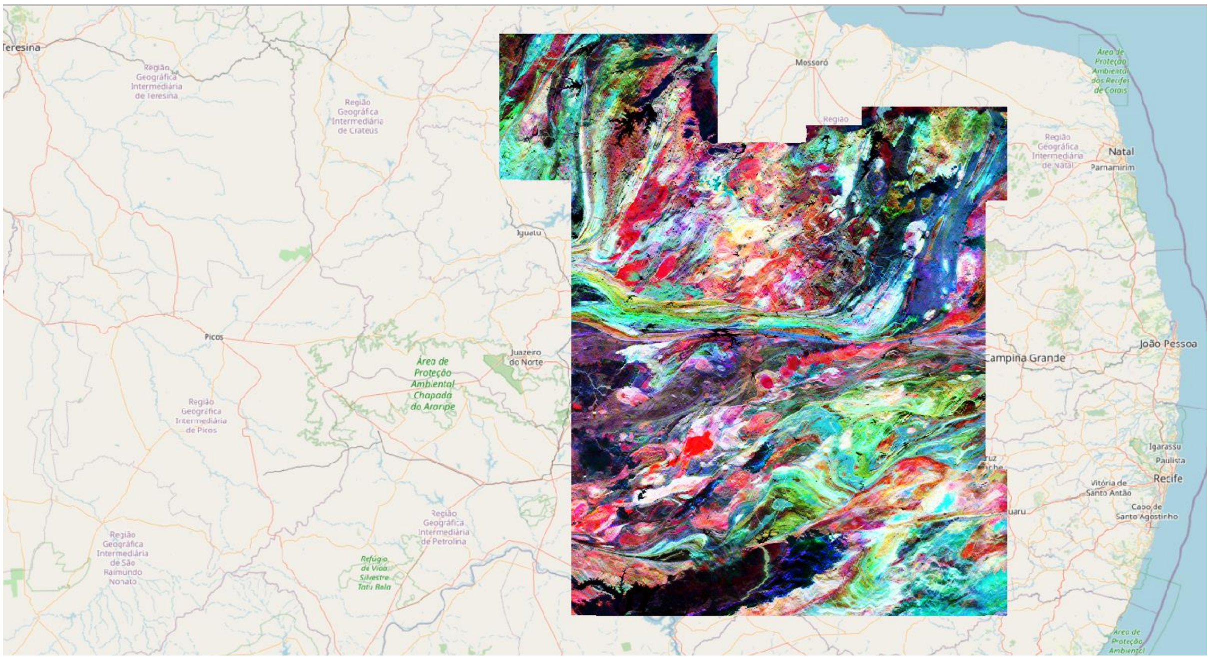


Note - use the same interval of values to get a homogeneous image of the 4 DEM scenes. Example:50 to 1200.

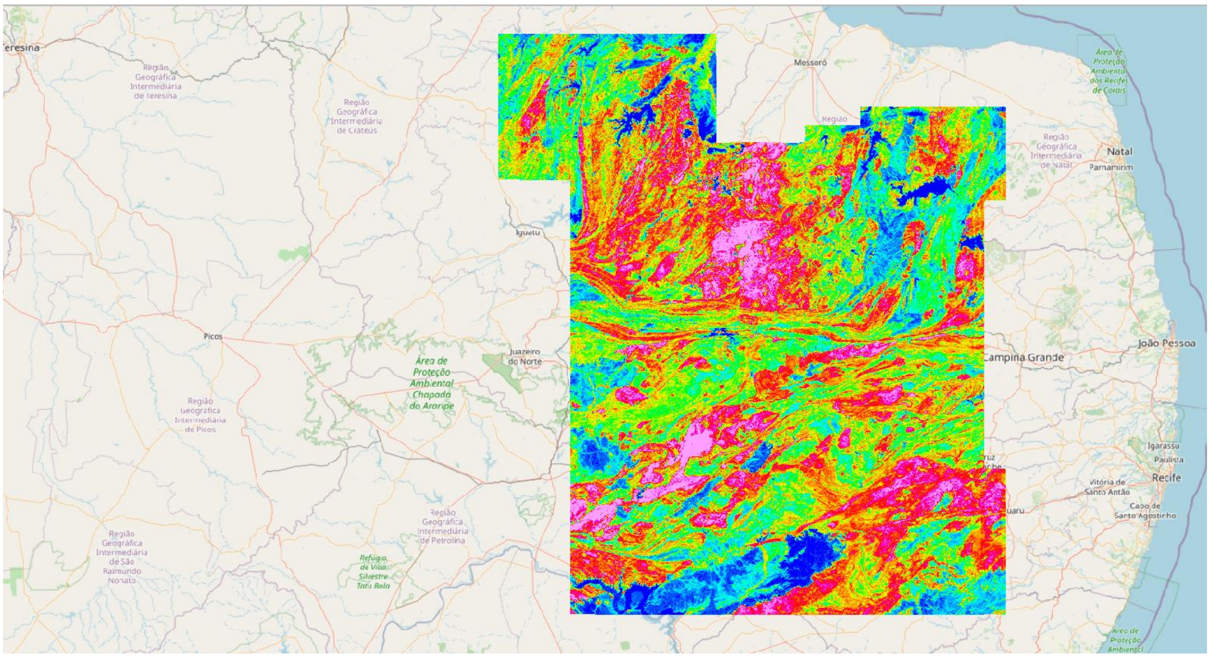
Now we will load the geophysics data initially using the final product images (3 bands RGB file). This is not the appropriate format to work with targeting and we will see further down how to retrieve the geophysical data in the right format for targeting using the XYZ raw data and interpolation.

Airborne Gammaspectrometry

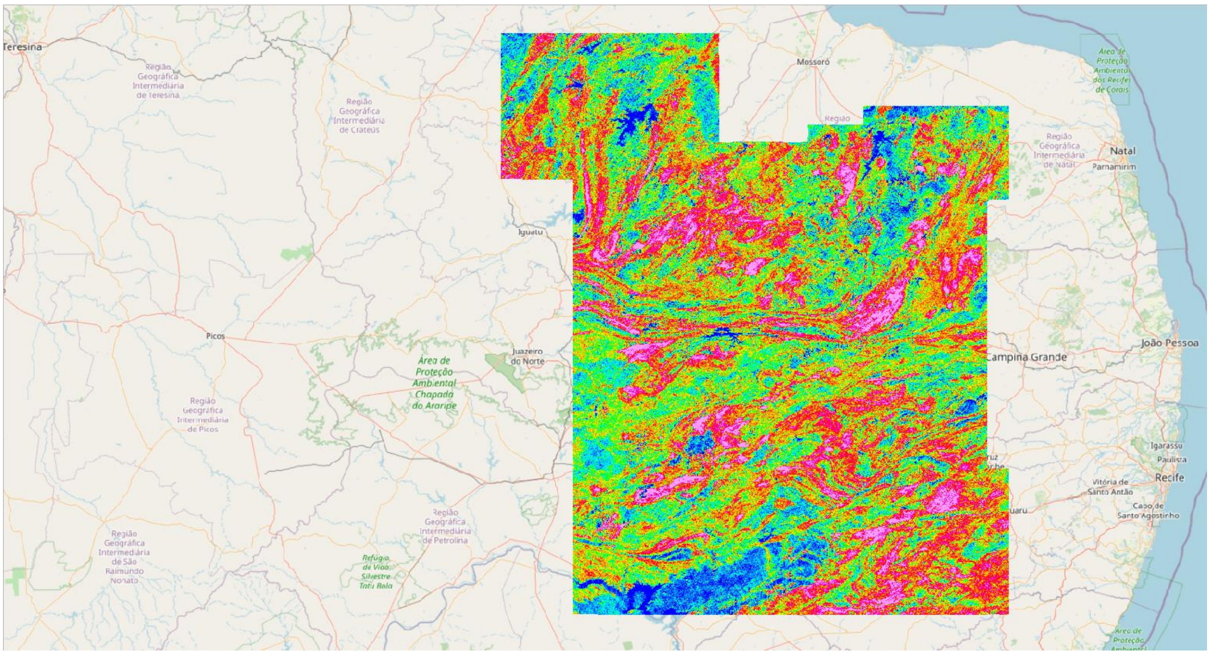
Ternary



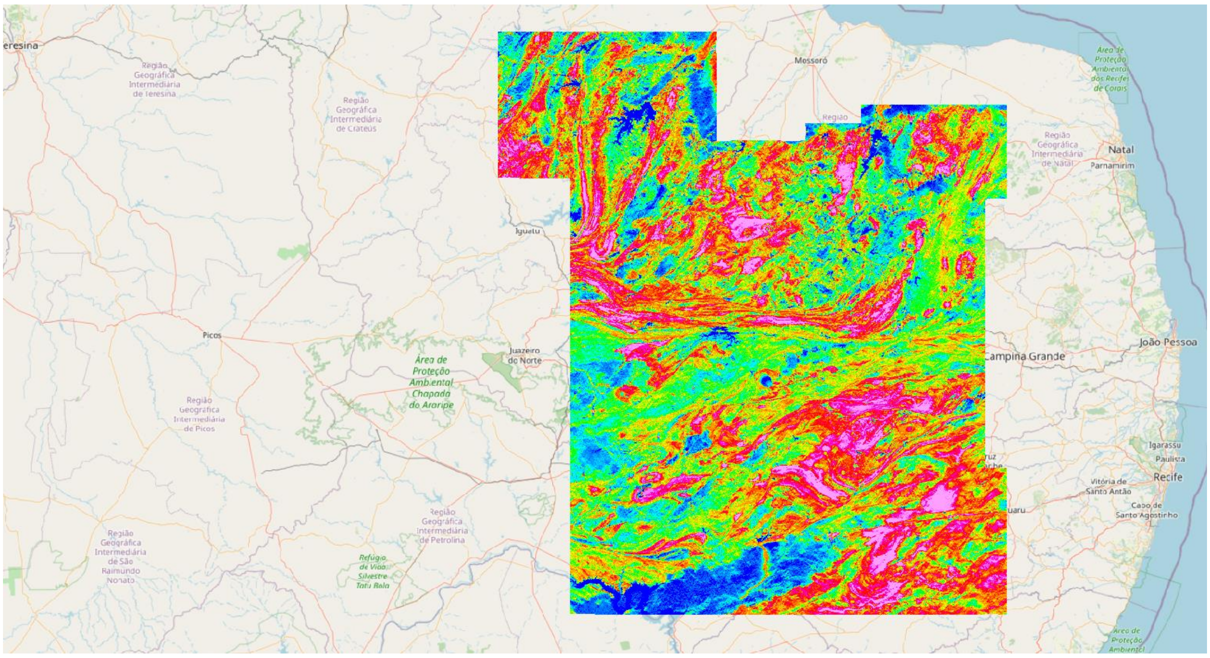
K



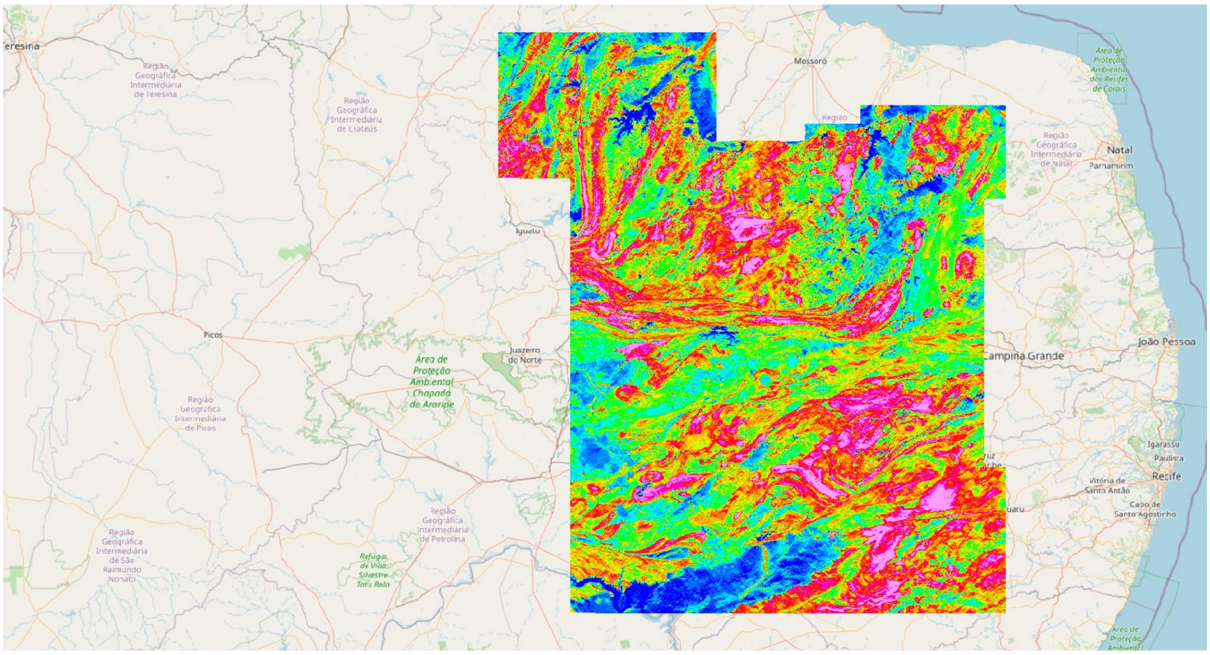
U


Teresina
Mossoró
Natal
Parnamirim
Iguatu
Picos
Juazeiro do Norte
Área de Proteção Ambiental Chapada do Araripe
Campina Grande
João Pessoa
Igarassu
Paulista
Recife
Vitória de Santo Antão
Cabo de Santo Agostinho

Th

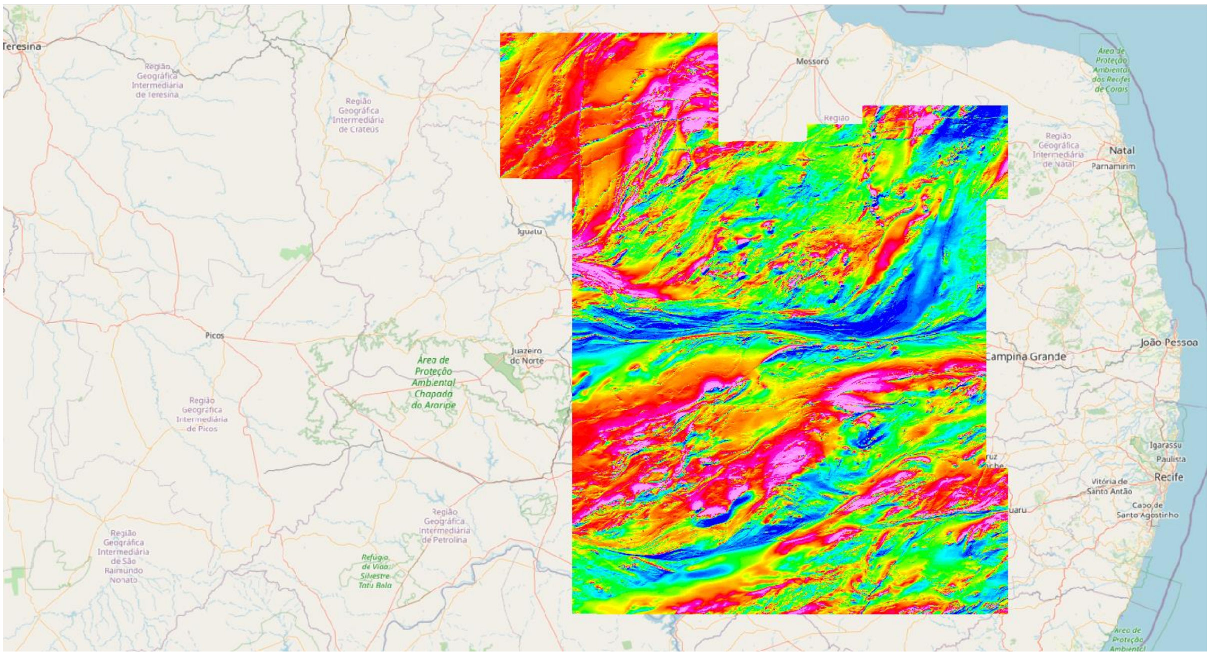

Mossoró
Natal
Parnamirim
Iguatu
Picos
Juazeiro do Norte
Área de Proteção Ambiental Chapada do Araripe
Campina Grande
João Pessoa
Igarassu
Paulista
Recife
Vitória de Santo Antão
Cabo de Santo Agostinho

Total Count

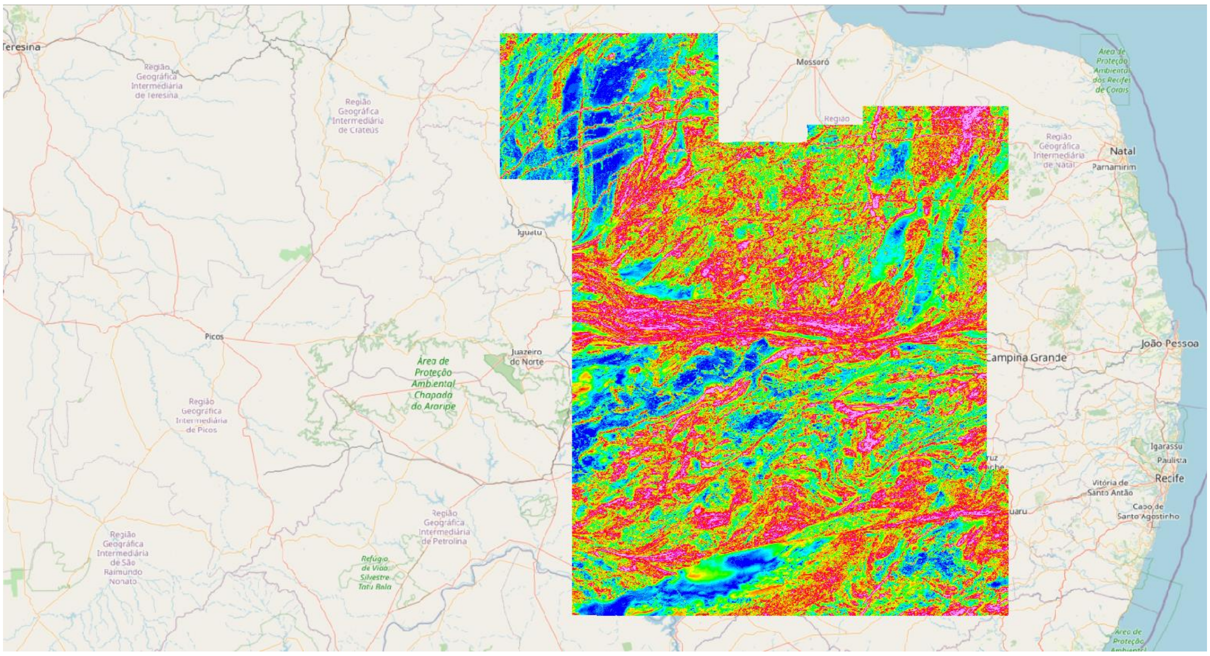


Airborne Magnetometry

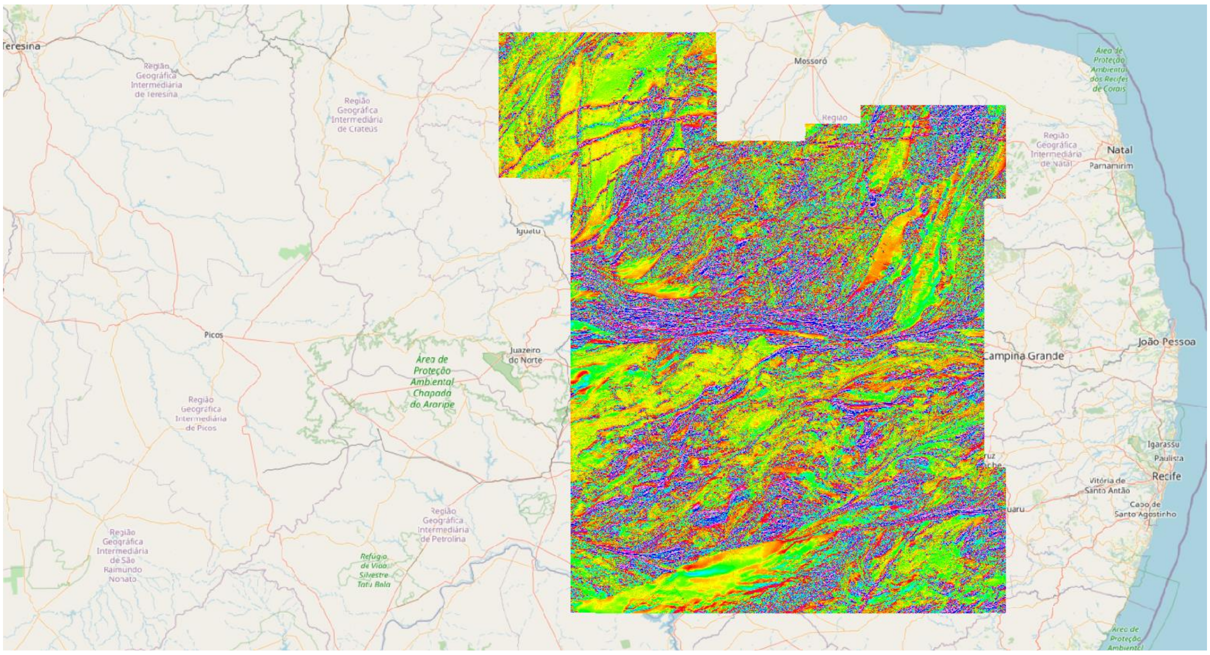
Total Field



Analytical Signal



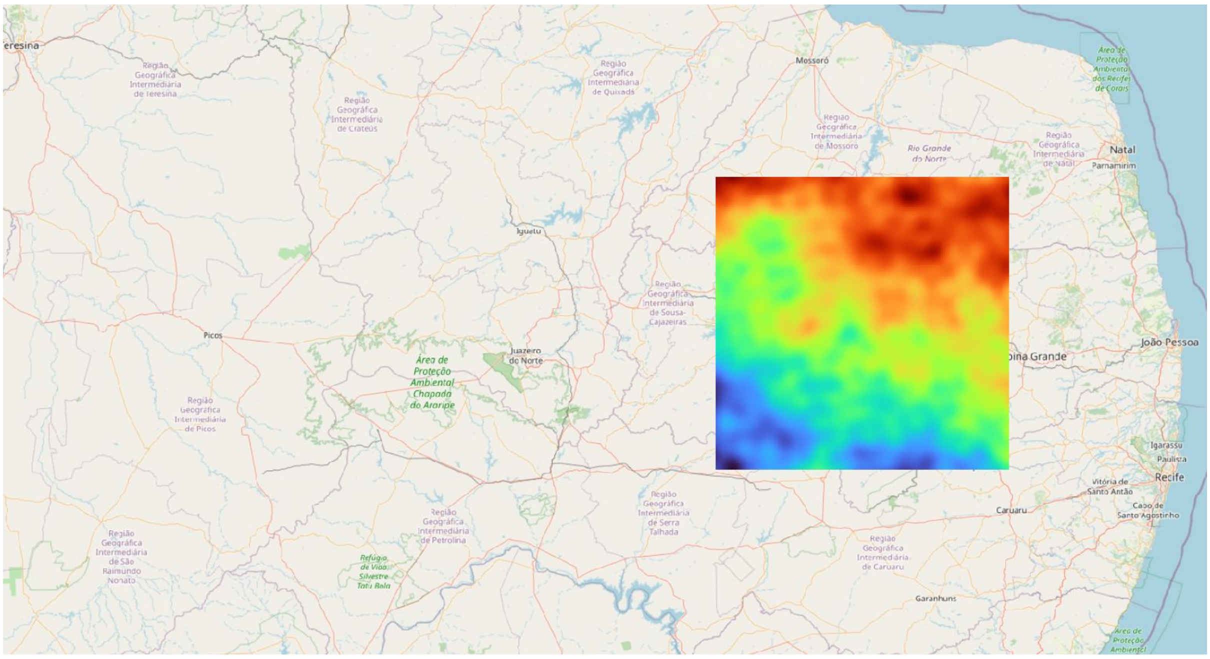
First Derivative



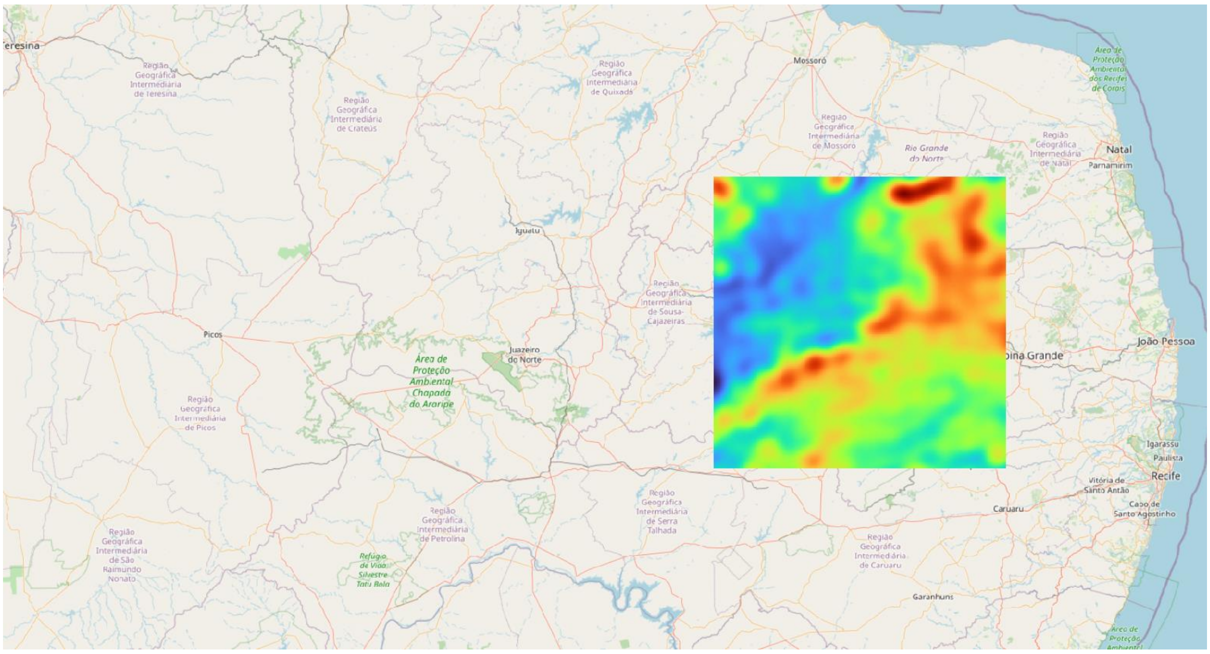
Modeled Gravity Data

The gravity tif files must be adjusted to float 32 type to plot properly. You can do this using the QGIS converter tool.

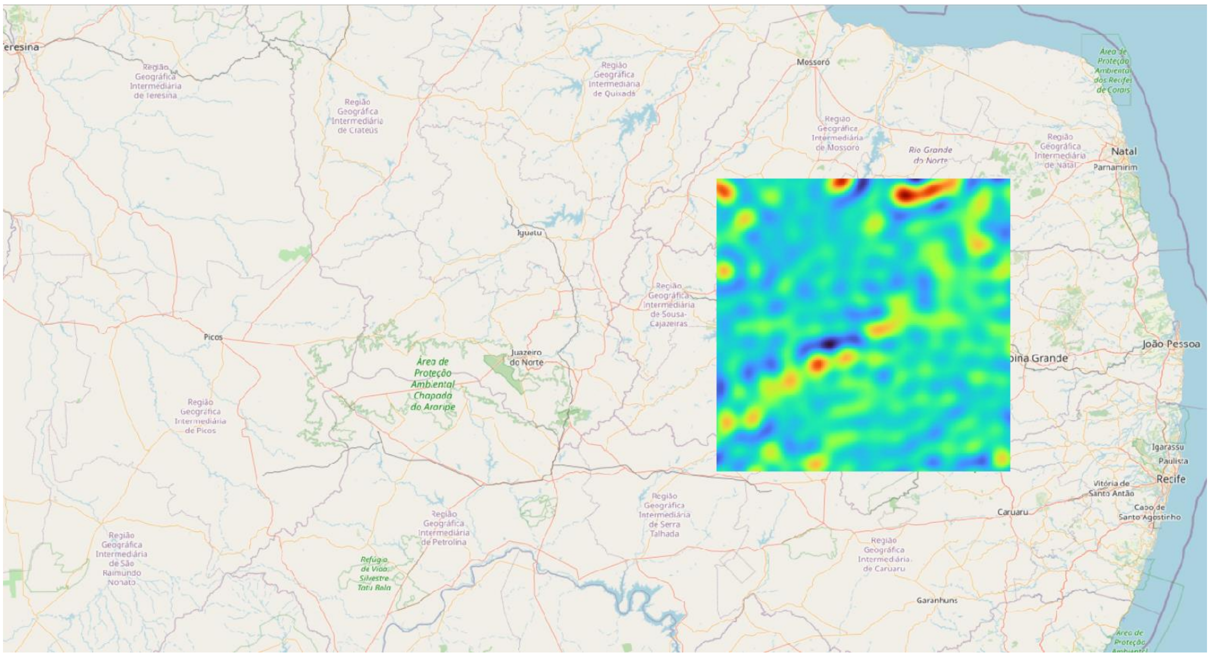
Bouguer Anomaly



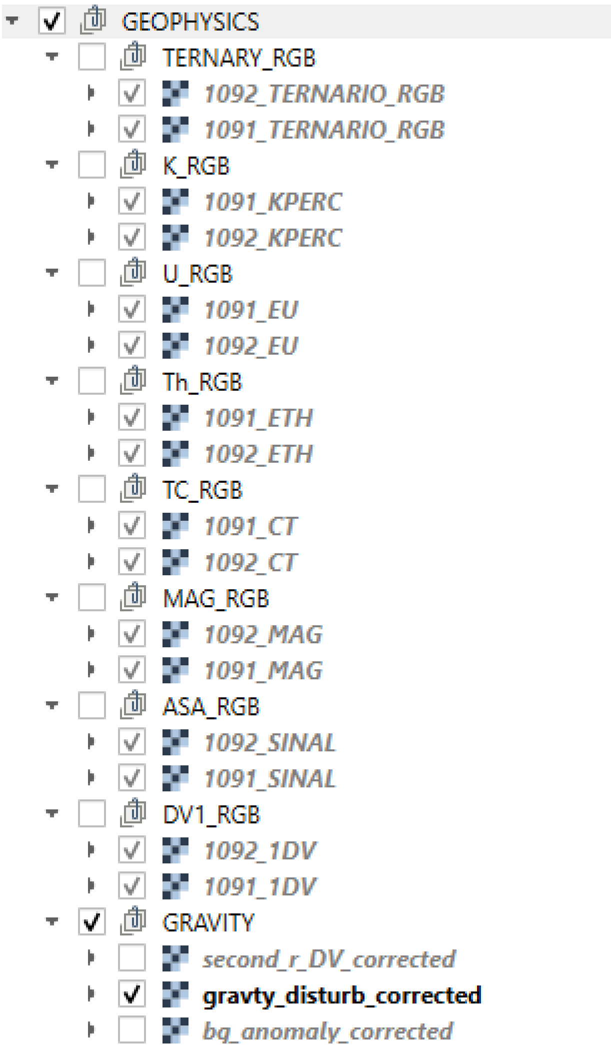
Grav Disturbance



Second derivative of Grav disturbance



At this stage the GEOPHYSICS folder on QGIS should look like:



AOI and CRS

The dataset covers most of the Borborema Province. It is a huge area, and the targeting exercise here will cover only a portion of it.

For this tutorial we will define our Area of Interest (AOI) as:

Coordinate Reference System:	**EPSG:32724 – WGS 84 UTM ZONE 24S**
Resolution:	**20x20 metres**
Easting:	**699,960 to 809,760**
Northing:	**9,190,240 to 9,300,040**

Geophysics Raw Data

Geophysical surveys presented as RGB Images quite often are subject to squeezing and stretching that always do not represent the real value (quantity) of the data. A new approach is necessary using the XYZ raw data to extract/interpolate the right quantity that will be needed in the targeting ranking process that will be executed later.

The following R script will extract the relevant to us fields from the **gammaspectrometry** survey and convert it to a vector point with the relevant attributes. We will extract the points into single point shapefiles files with the real values of Total Count, K, U and Th for the Gammaespectrometry. The Total magnetic field will be extracted too with the second script. This procedure, due to the large area, will take a considerable time to process (10 minutes and 85 minutes respectively). You can download the final shapefiles here if you are in a hurry.

```
xmi<-699960
xma<-809760
ymi<-9190240
yma<-9300040
lin<-c('a')
o<-1
wd<-'C:/Users/User/Desktop/R algo/PBRN/1091/XYZ'#adjust according to your system
setwd(wd)
flcon<-file('1091_GamaLine.XYZ',open='r')#adjust according to your system
tmp <- readLines(flcon, n=5)
coluna <-c(strsplit(substring(readLines(flcon, n=1),11),"\\s+")[[1]])
tmp <- readLines(flcon, n=4)
wd<-'C:/Users/User/Desktop/R algo/PBRN/1092/XYZ'#adjust according to your system
setwd(wd)
flcon2<-file('1092_GamaLine.XYZ',open='r')#adjust path according to your system
tmp <- readLines(flcon2, n=10)
while (length(line <- readLines(flcon, n = 1, warn = FALSE)) > 0) {
   if(substring(line,1,4)=='    ' & substring(line,21,21)!='*' ){
      v<-as.numeric(strsplit(line, "\\s+")[[1]][2])
      w<-as.numeric(strsplit(line, "\\s+")[[1]][3])
      if(v>xmi & v<xma & w>ymi & w<yma){
        lin[o]<-line
        o<-o+1
      }
    }
}
```

```
close(flcon)
while (length(line <- readLines(flcon2, n = 1, warn = FALSE)) > 0) {
   if(substring(line,1,4)=='    ' & substring(line,21,21)!='*' ){
      v<-as.numeric(strsplit(line, "\\s+")[[1]][2])
      w<-as.numeric(strsplit(line, "\\s+")[[1]][3])
      if(v>xmi & v<xma & w>ymi & w<yma){
        lin[o]<-line
        o<-o+1
      }
    }
}
close(flcon2)
wd<-'C:/Users/User/Desktop/R algo/PBRN/1091/XYZ'#adjust according to your system
setwd(wd)
r <- strsplit(sub("^\\s+","",lin), "\\s+")
s <-as.data.frame(do.call(rbind, r))
names(s)<- coluna
cols = c(1:(ncol(s)-3))
s[,cols] = apply(s[,cols], 2, function(x) as.numeric(as.character(x)))
snew<-s[c('X','Y','CTexp','Kperc','eU','eTh')]
library(terra)
sgeo<-vect(snew, geom=c("X", "Y"), crs="epsg:32724")
e<-ext(699960,809760,9190240,9300040)
extrc<-crop(sgeo,e)
writeVector(extrc, 'gamma.shp', overwrite=TRUE)
```

The same procedure will extract the relevant to us fields from the **magnetometry** survey.

```
xmi<-699960
xma<-809760
ymi<-9190240
yma<-9300040
lin<-c('a')
o<-1
wd<-'C:/Users/User/Desktop/R algo/PBRN/1091/XYZ' #adjust according to your system
setwd(wd)
flcon<-file('1091_MagLine1.XYZ',open='r') #adjust according to your system
tmp <- readLines(flcon, n=5)
coluna <-c(strsplit(substring(readLines(flcon, n=1),11),"\\s+")[[1]])
tmp <- readLines(flcon, n=4)
flcon2<-file('1091_MagLine2.XYZ',open='r') #adjust according to your system
tmp <- readLines(flcon2, n=10)
wd<-'C:/Users/User/Desktop/R algo/PBRN/1092/XYZ' #adjust according to your system
setwd(wd)
flcon3<-file('1092_MagLine1.XYZ',open='r') #adjust according to your system
tmp <- readLines(flcon3, n=10)
flcon4<-file('1092_MagLine2.XYZ',open='r') #adjust according to your system
tmp <- readLines(flcon4, n=10)
while (length(line <- readLines(flcon, n = 1, warn = FALSE)) > 0) {
   if(substring(line,1,4)=='    ' & substring(line,21,21)!='*' ){
      v<-as.numeric(strsplit(line, "\\s+")[[1]][2])
      w<-as.numeric(strsplit(line, "\\s+")[[1]][3])
      if(v>xmi & v<xma & w>ymi & w<yma){
        lin[o]<-line
        o<-o+1
      }
    }
}
close(flcon)
while (length(line <- readLines(flcon2, n = 1, warn = FALSE)) > 0) {
   if(substring(line,1,4)=='    ' & substring(line,21,21)!='*' ){
      v<-as.numeric(strsplit(line, "\\s+")[[1]][2])
```

```
        w<-as.numeric(strsplit(line, "\\s+")[[1]][3])
        if(v>xmi & v<xma & w>ymi & w<yma){
          lin[o]<-line
          o<-o+1
        }
      }
}
close(flcon2)
while (length(line <- readLines(flcon3, n = 1, warn = FALSE)) > 0) {
    if(substring(line,1,4)=='    ' & substring(line,21,21)!='*' ){
        v<-as.numeric(strsplit(line, "\\s+")[[1]][2])
        w<-as.numeric(strsplit(line, "\\s+")[[1]][3])
        if(v>xmi & v<xma & w>ymi & w<yma){
          lin[o]<-line
          o<-o+1
        }
      }
}
close(flcon3)
while (length(line <- readLines(flcon4, n = 1, warn = FALSE)) > 0) {
    if(substring(line,1,4)=='    ' & substring(line,21,21)!='*' ){
        v<-as.numeric(strsplit(line, "\\s+")[[1]][2])
        w<-as.numeric(strsplit(line, "\\s+")[[1]][3])
        if(v>xmi & v<xma & w>ymi & w<yma){
          lin[o]<-line
          o<-o+1
        }
      }
}
close(flcon4)
wd<-'C:/Users/User/Desktop/R algo/PBRN/1091/XYZ' #adjust according to your system
setwd(wd)
r <- strsplit(sub("^\\s+","",lin), "\\s+")
rm(lin)
s <-as.data.frame(do.call(rbind, r))
rm(r)
names(s)<- coluna
cols = c(1:(ncol(s)-3))
s[,cols] = apply(s[,cols], 2, function(x) as.numeric(as.character(x)))
snew<-s[c('X','Y','MAGIGRF')]
rm(s)
library(terra)
sgeo<-vect(snew, geom=c("X", "Y"), crs="epsg:32724")
e<-ext(699960,809760,9190240,9300040)
extrc<-crop(sgeo,e)
writeVector(extrc, 'mag.shp', overwrite=TRUE)
```

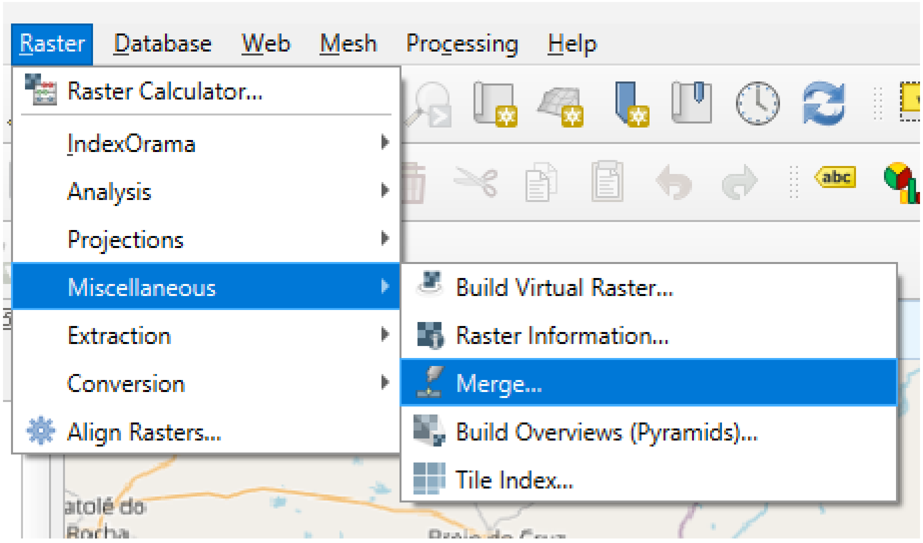
Reprojection and Mosaic

It is important now to make sure that all the raster data are at the right resolution (20x20), CRS (EPSG:32724) and extension. The Sentinel scene bands meet these criteria. We will have to interpolate the raw geophysics data points, adjust the Gravity data, the DEM data and the interpolated Geophysics of Total Count, K, U, Th and Mag Total Field.

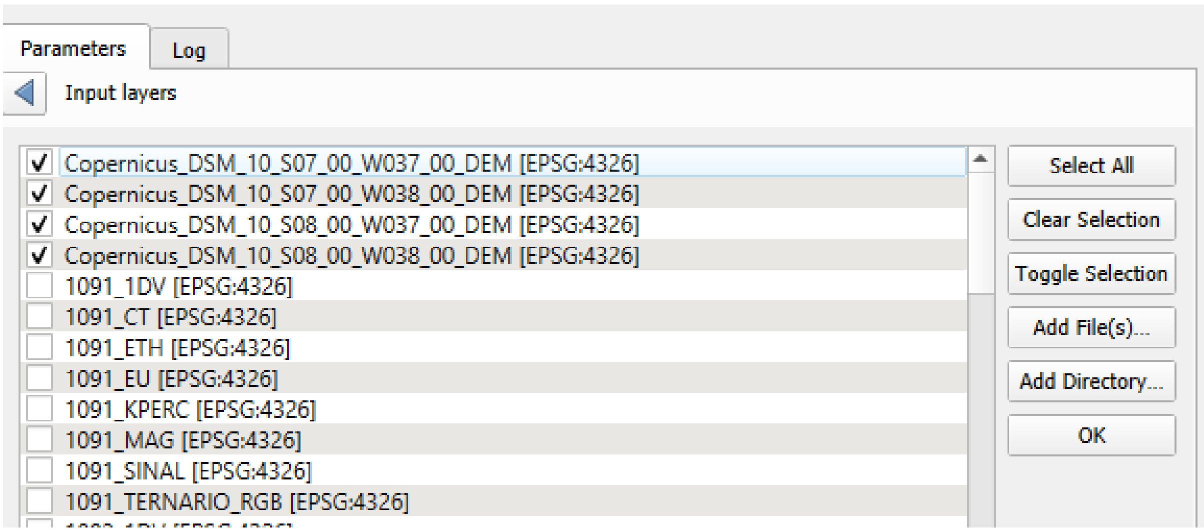
We can use QGIS to do this effectively.

DEM

In the menu Raster select Merge.

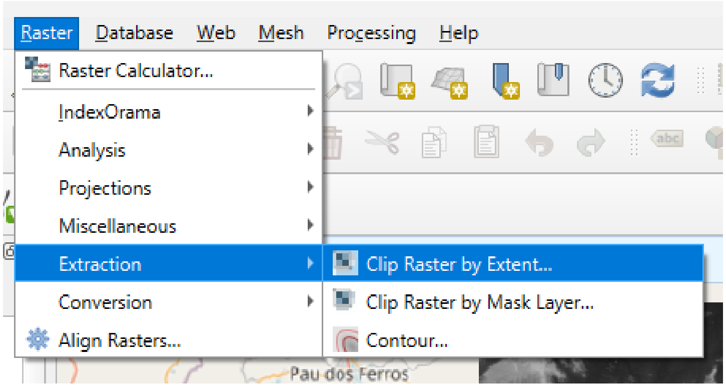


In Input layers select the four DSM files:

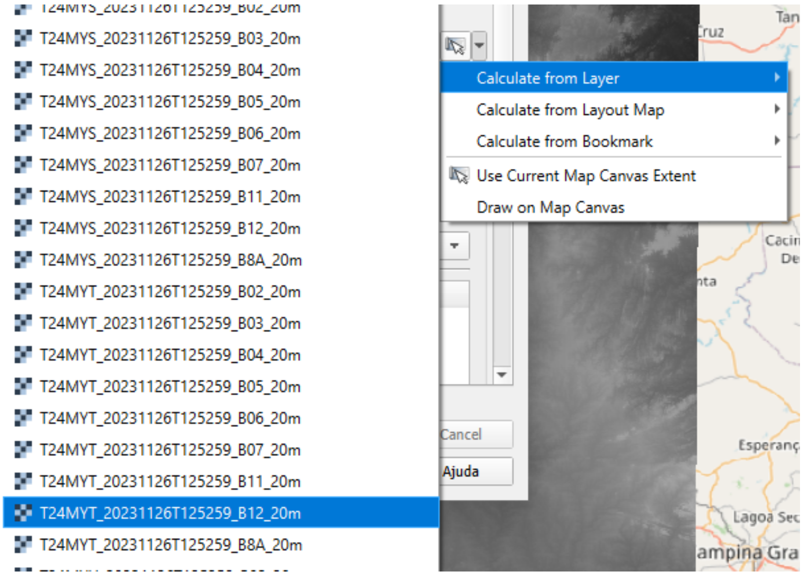


Click run and a temporary file **Merged** will be created and open.

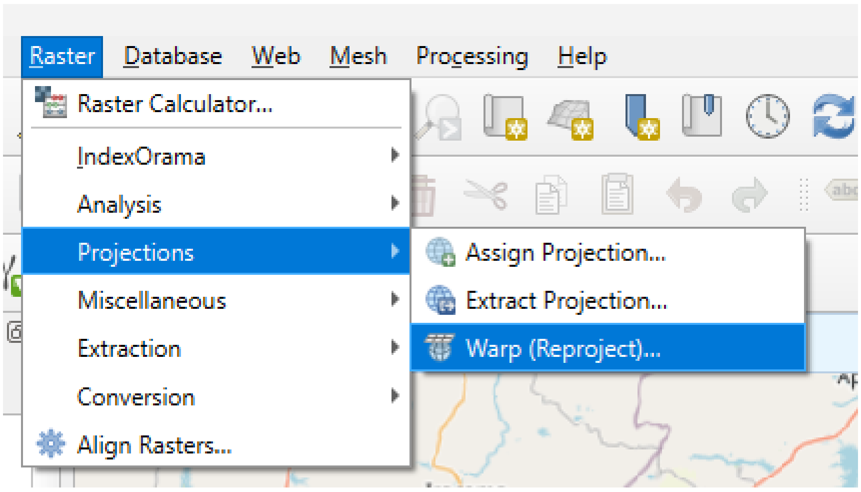
Now we will crop this temporary file to the extension of our Sentinel2 Scene using one of its bands. Open the Raster menu and select Extraction → Clip Raster by Extent.



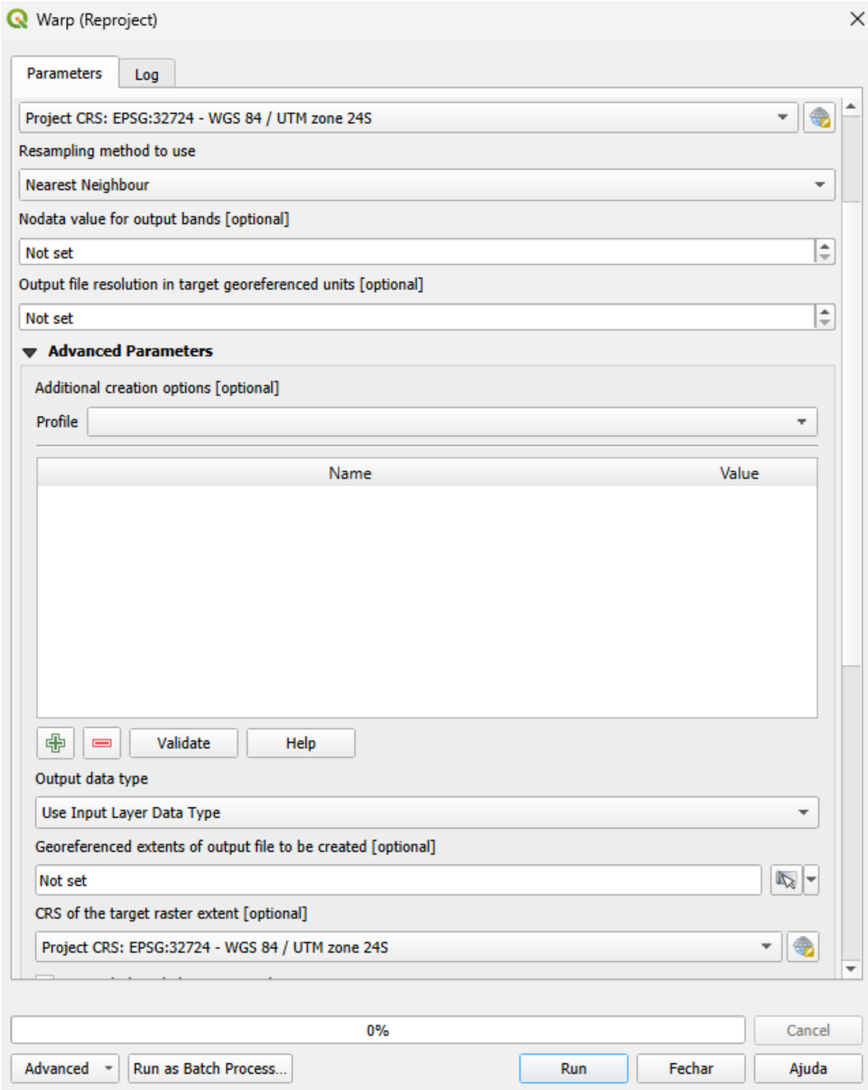
Select Merged as Input layer and Select the clipping extent from any layer T24MYT.... and Run.



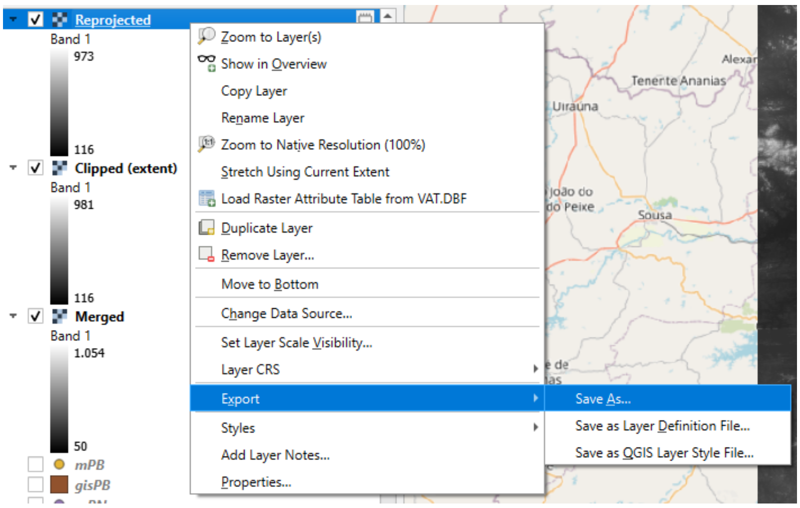
Change the layer CRS using Raster→Projections→Warp(reproject).



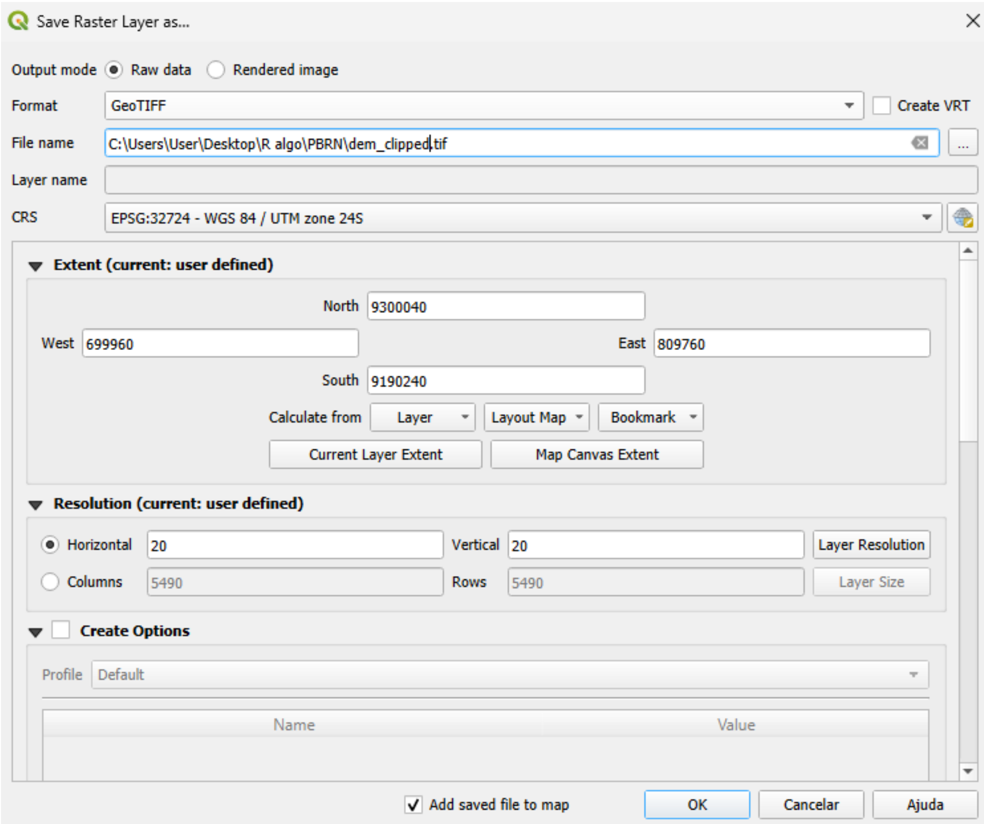
Enter the field as below and click Run:



The final step is exporting the temporary memory Layer **Reprojected** as a tif file and fine tune the extension.

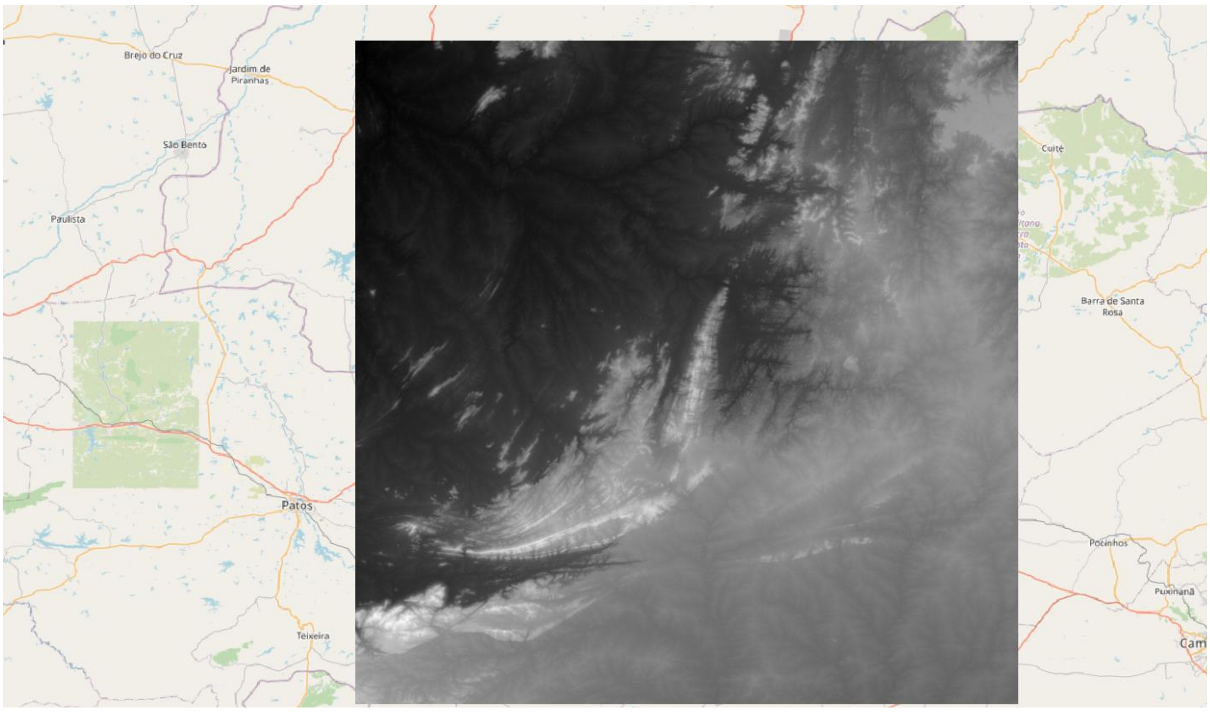


Name the file and dem_clipped.tif and use the GeoTIFF format. Change the CRS to EPSG:32724 set the resolution to 20 and adjust the extent as below:

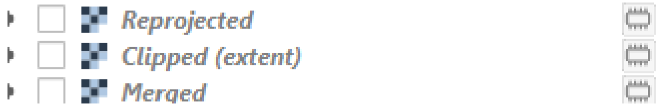


Click OK.

The following dem_clipped layer will open:



Delete the temporary memory files.



Now create a group called **Final Preparation** and move the layer to this group folder. Also move the nine (9) Sentinel2 bands (2, 3, 4, 5, 6, 7, 8a, 11 and 12) of T24MYT_20231126T125259_B??_20m to this folder.

Repeat the following procedure with the three (3) gravity layers and move them to the **Final Preparation** folder too.

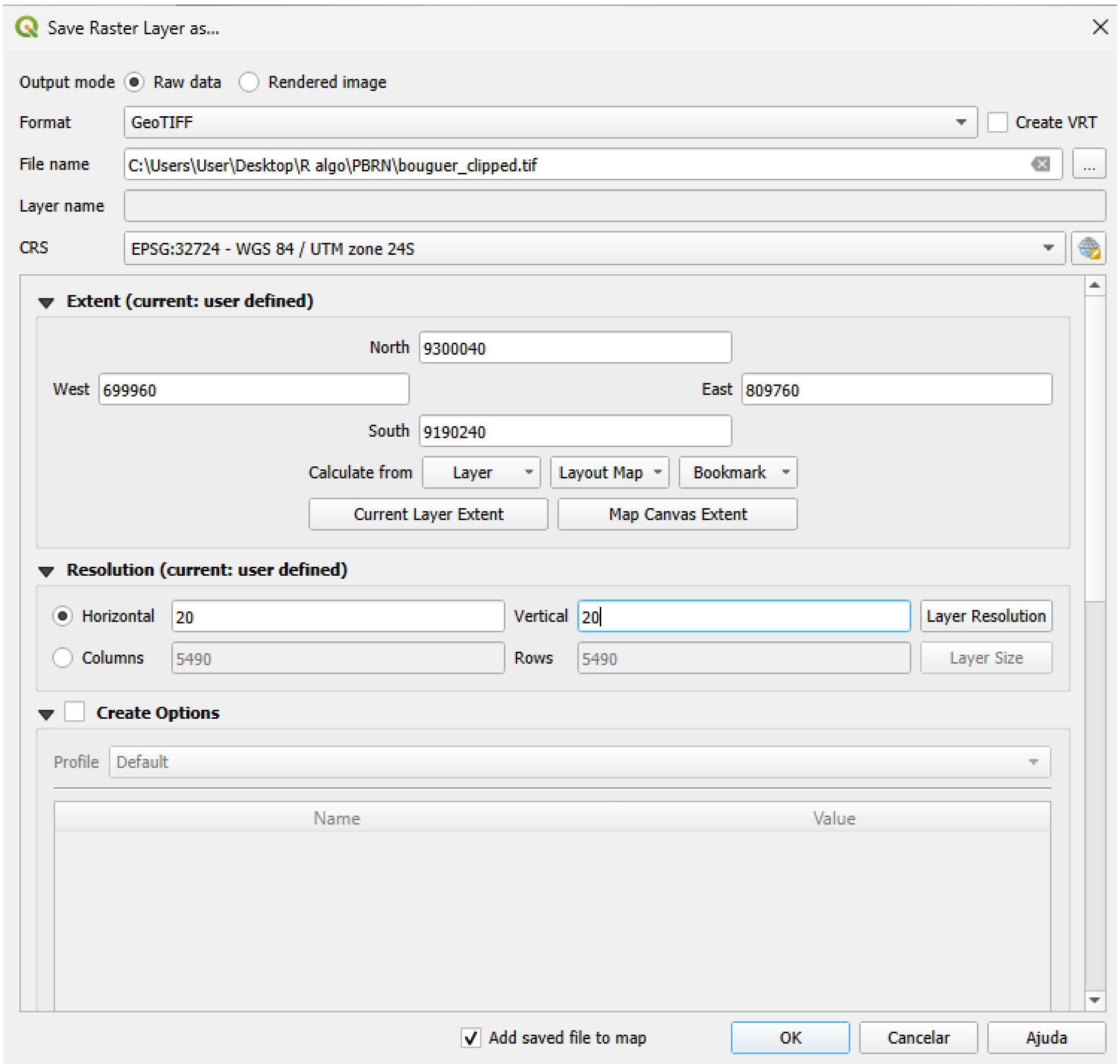
Bouguer Anomaly

Open the Raster menu and select Extraction → Clip Raster by Extent.

Change the layer CRS using Raster→Projections→Warp(reproject)

Export the temporary memory Layer **Reprojected** as a tif file and fine tune the extension.

Name the file and bouguer_clipped.tif and use the GeoTIFF format. Change the CRS to EPSG:32724 set the resolution to 20 and adjust the extent as below:



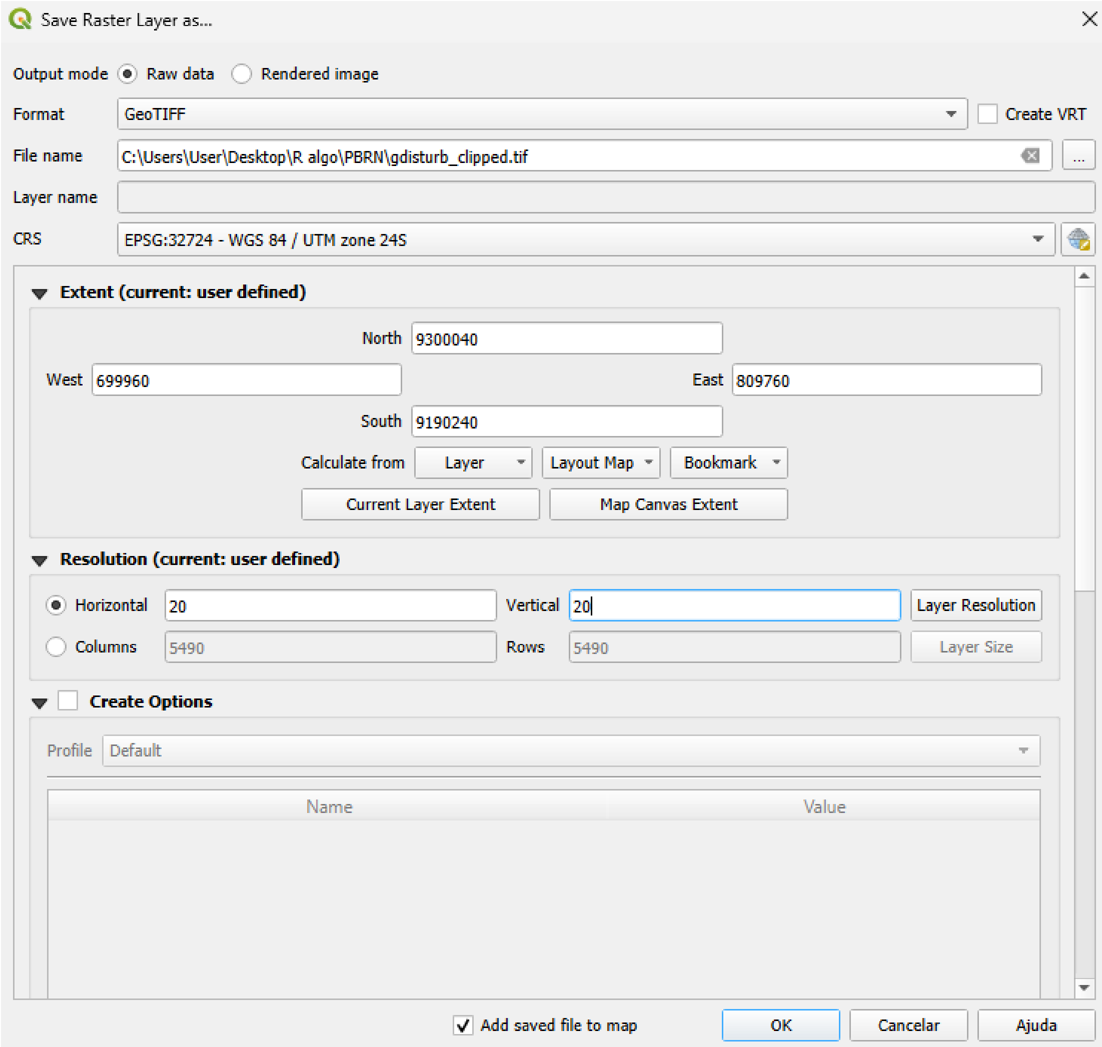
Gravity Disturb

Open the Raster menu and select Extraction → Clip Raster by Extent.

Change the layer CRS using Raster→Projections→Warp(reproject)

Export the temporary memory Layer **Reprojected** as a tif file and fine tune the extension.

Name the file and gdisturb_clipped.tif and use the GeoTIFF format. Change the CRS to EPSG:32724 set the resolution to 20 and adjust the extent as below:



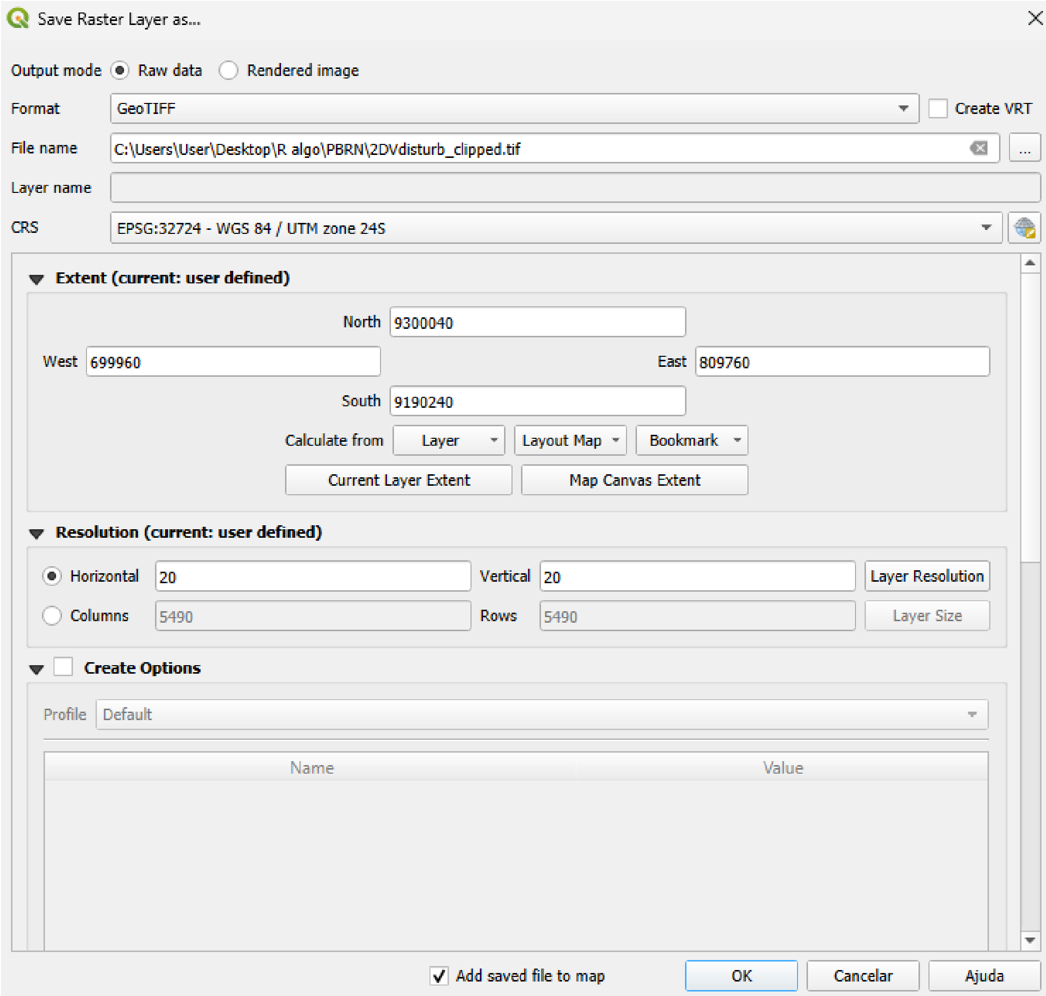
Disturbance Second Derivative

Open the Raster menu and select Extraction → Clip Raster by Extent.

Change the layer CRS using Raster→Projections→Warp(reproject)

Export the temporary memory Layer **Reprojected** as a tif file and fine tune the extension.

Name the file and 2DVdisturb_clipped.tif and use the GeoTIFF format. Change the CRS to EPSG:32724 set the resolution to 20 and adjust the extent as below:



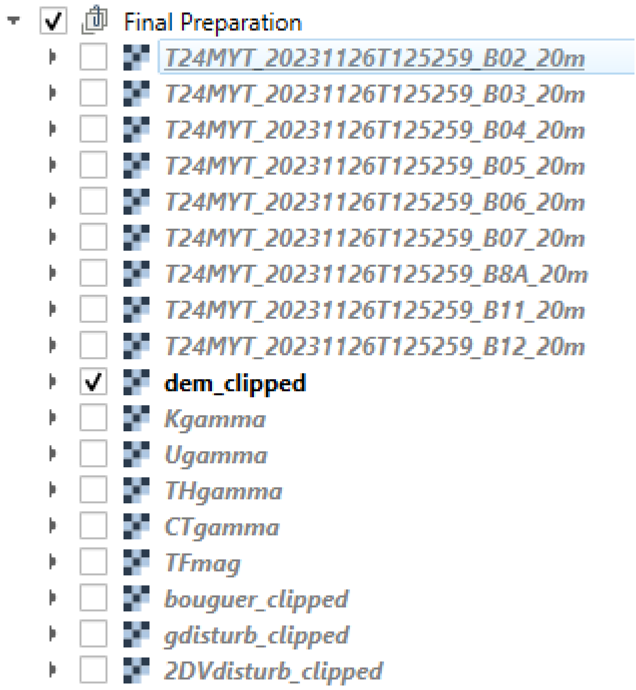
Interpolating raw geophysics data points

The following script will be used to create the tif images from the interpolated gammaspectrometry data.

```
library(terra)
#Working directory first file
wd<-'C:/Users/User/Desktop/R algo/PBRN/1091/XYZ' #adjust according to your system
setwd(wd)
dado<-vect('gamma.shp')
e<-ext(699960,809760,9190240,9300040)
r<-rast(ext=e,res=20,crs="epsg:32724")
ct <- interpIDW(r, dado,'CTexp',radius=550)
writeRaster(ct,'CTgamma.tif',overwrite=T)
k <- interpIDW(r, dado,'Kperc',radius=550)
writeRaster(k,'Kgamma.tif',overwrite=T)
u <- interpIDW(r, dado,'eU',radius=550)
writeRaster(u,'Ugamma.tif',overwrite=T)
th <- interpIDW(r, dado,'eTh',radius=550)
writeRaster(th,'THgamma.tif',overwrite=T)
#open mag file
dado<-vect('mag.shp')
m <- interpIDW(r, dado,'MAGIGRF',radius=550)
writeRaster(m,'TFmag.tif',overwrite=T)
```

Load the gravity, the magnetometry raster and the gammaspectrometry raster created above into the Final Preparation Group in QGIS.

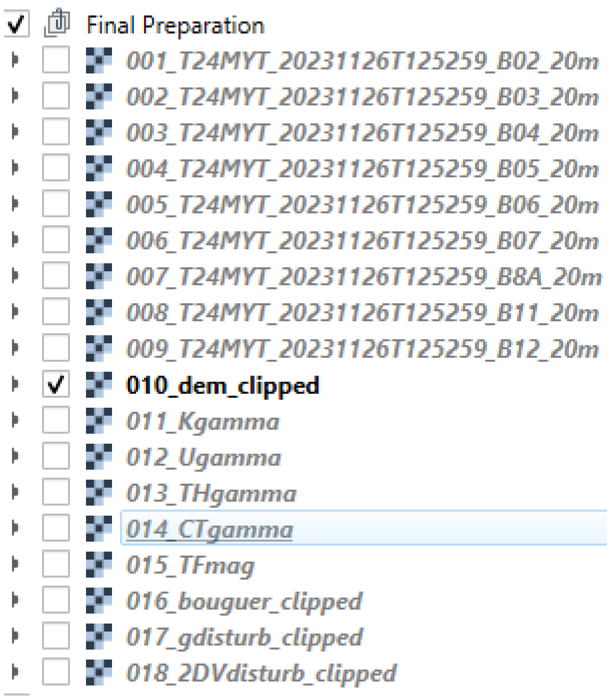
The Final Preparation Group should be like this:



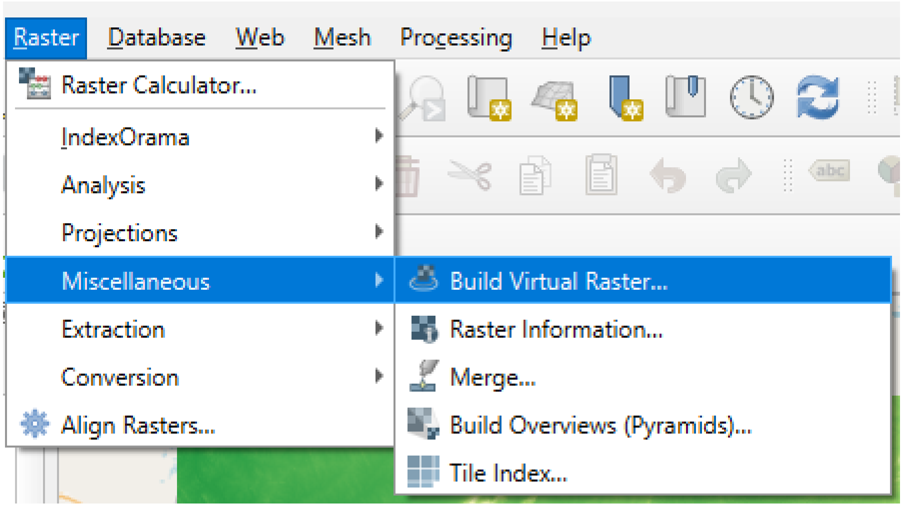
Part 1 Conclusion

Now we create a stacked scene with all the raster layer above using QGIS. This tif file will be used in the nest Part.

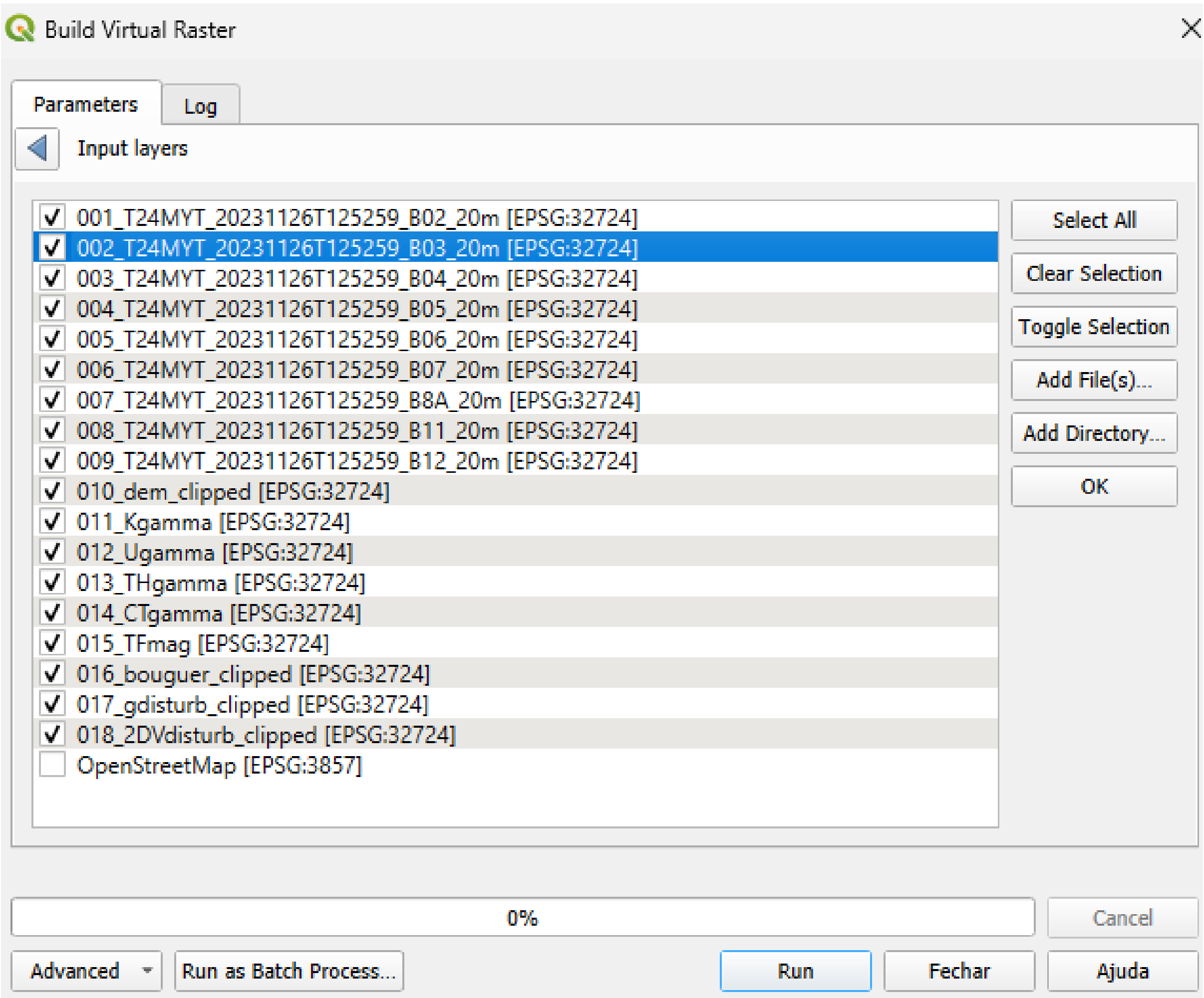
First, we will rename the layer as following:



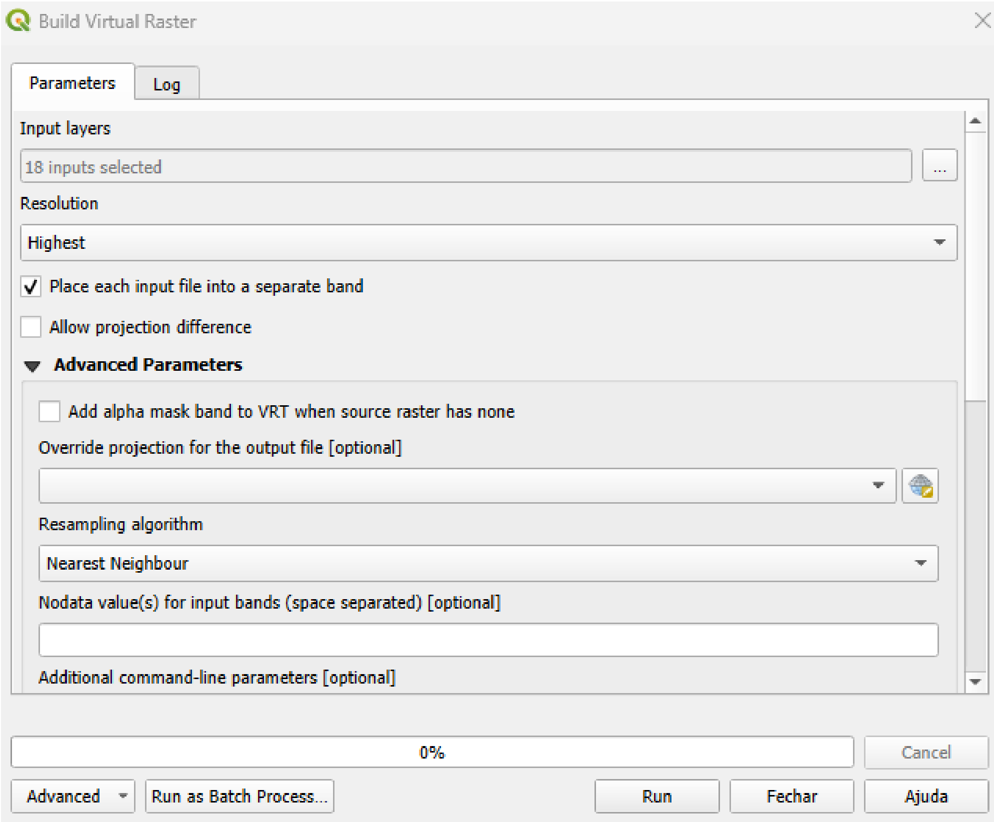
Select Raster→ Miscellaneous→Build Virtual Raster.



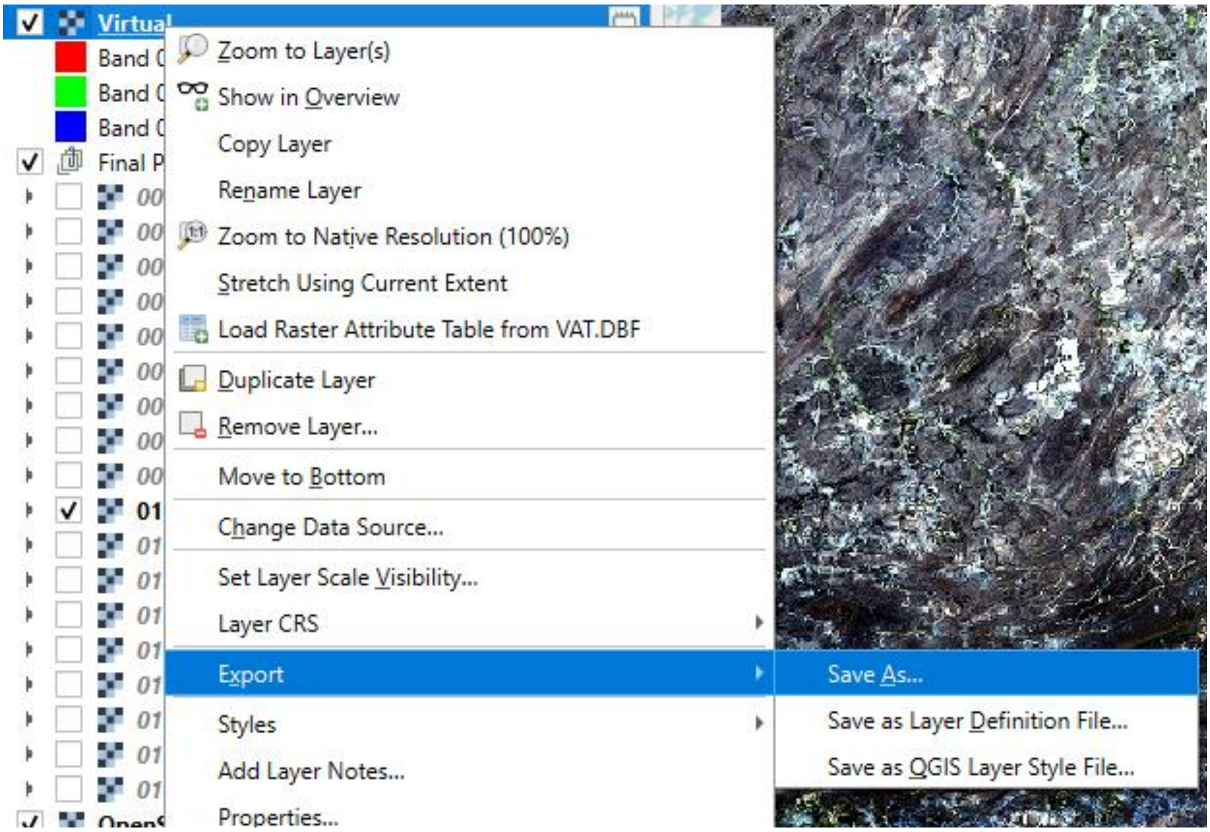
Select the 18 layers as input layer is the order showed below:

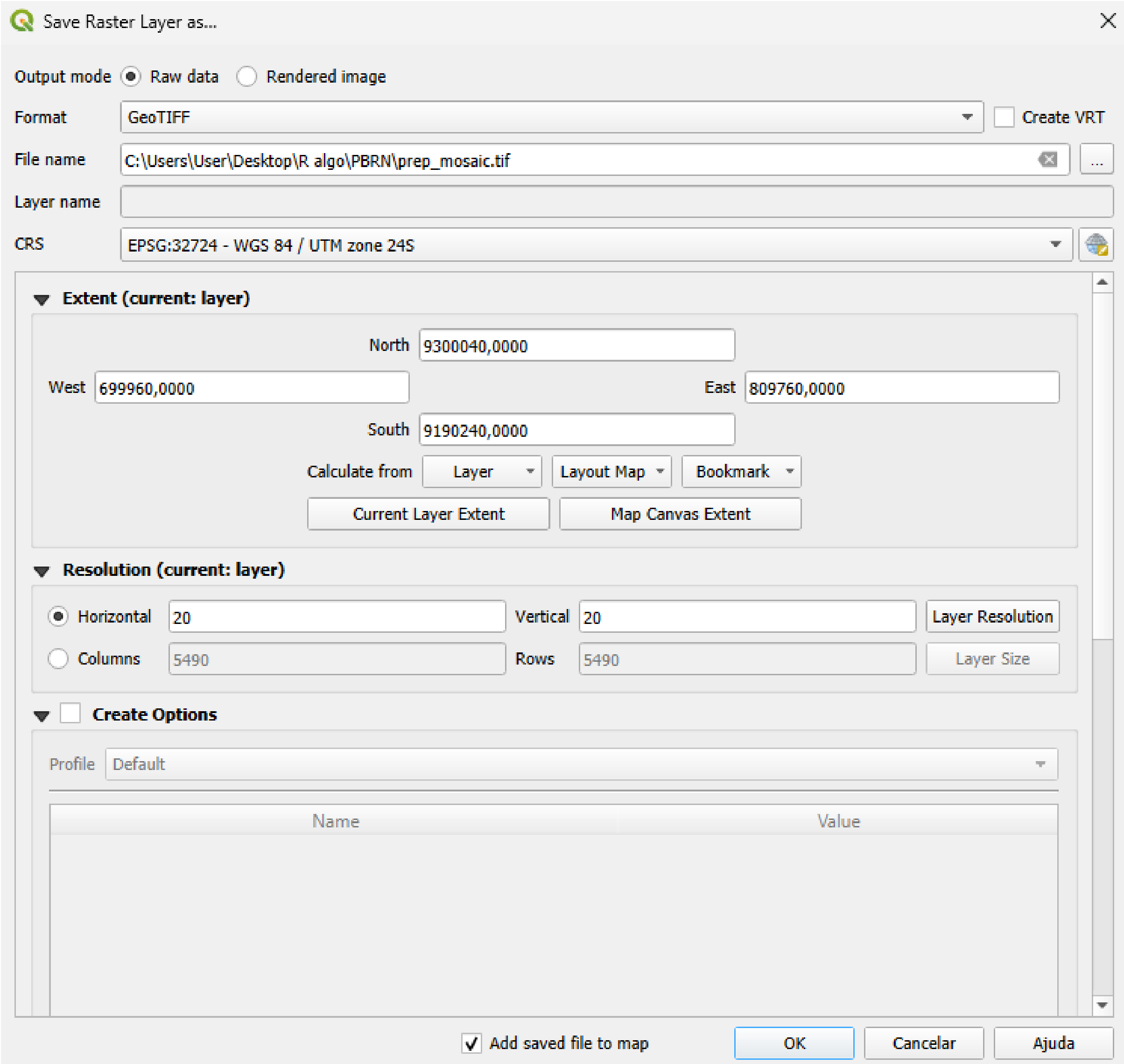


Mark “Place each input file into a separate band” and Select Resolution as Highest.



Now save the Virtual layer as **prep_mosaic.tif** using:

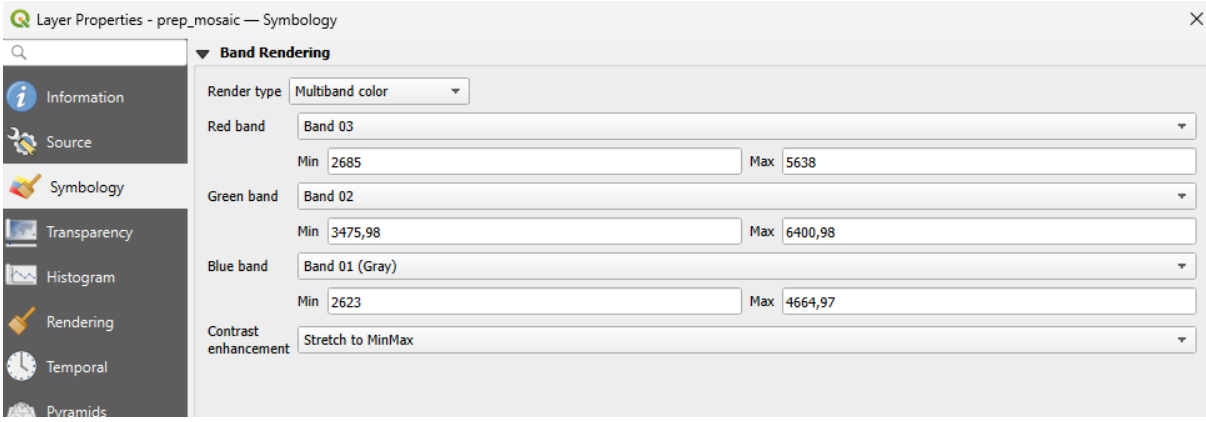


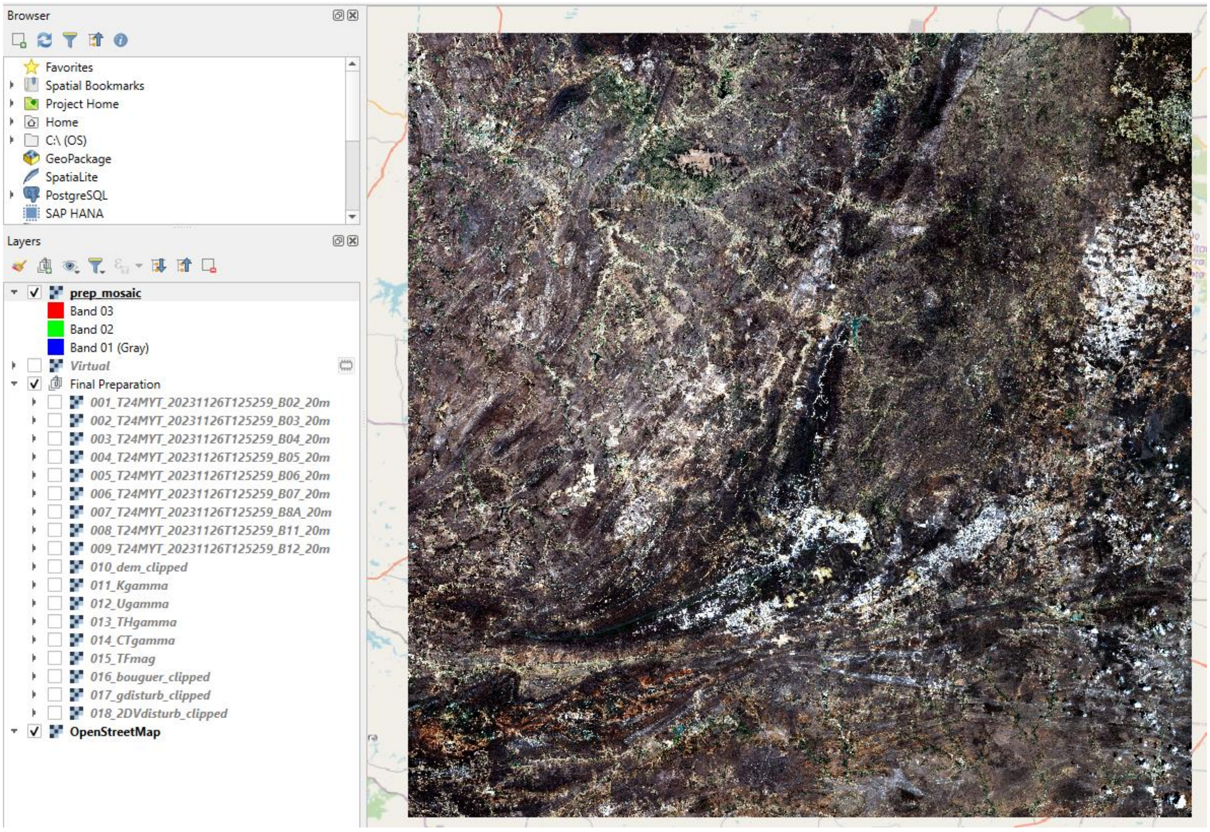


What we did until this point was to organize and level the different data into a common raster dataset with real quantities and same resolution that will be used in the next Part of this targeting exercise.

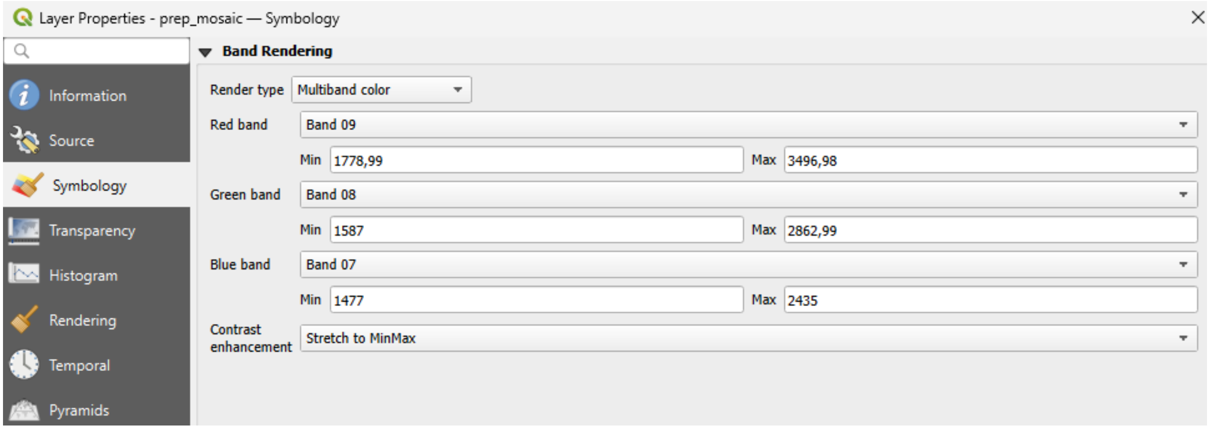
Before we move into the next Part, let's preview each individual layer (or group of layers).

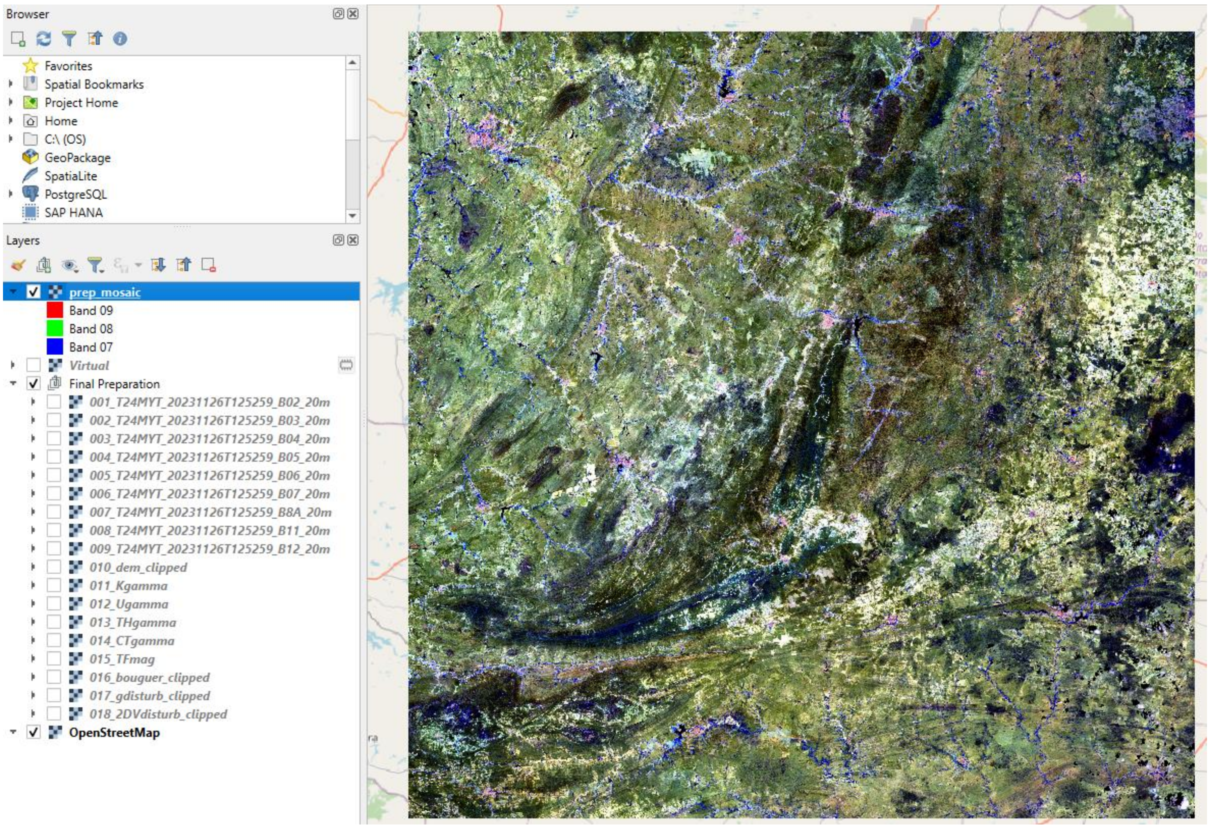
On QGIS double-click **prep_mosaic** and select the following bands 3 as red 2 as green and 1 as blue and a True color (TCC) composite will be displayed.



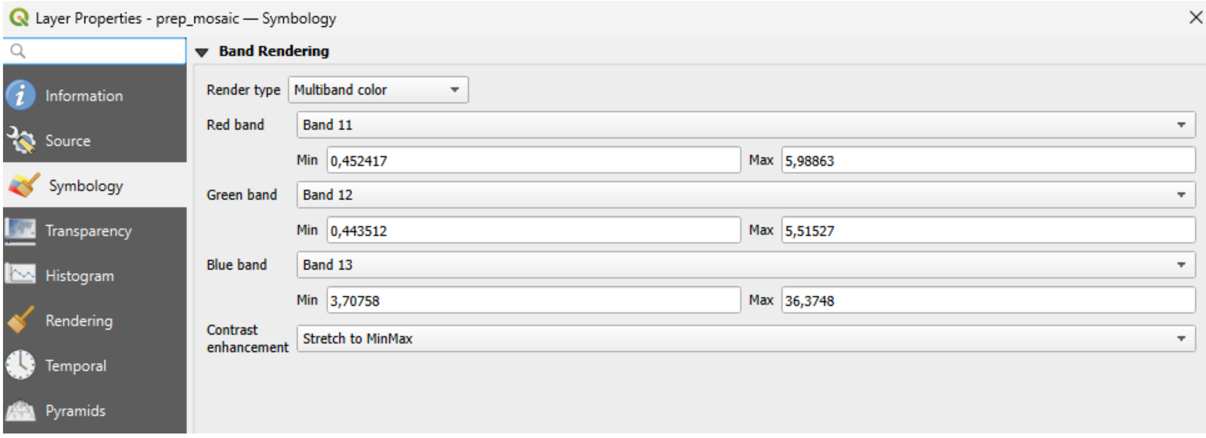


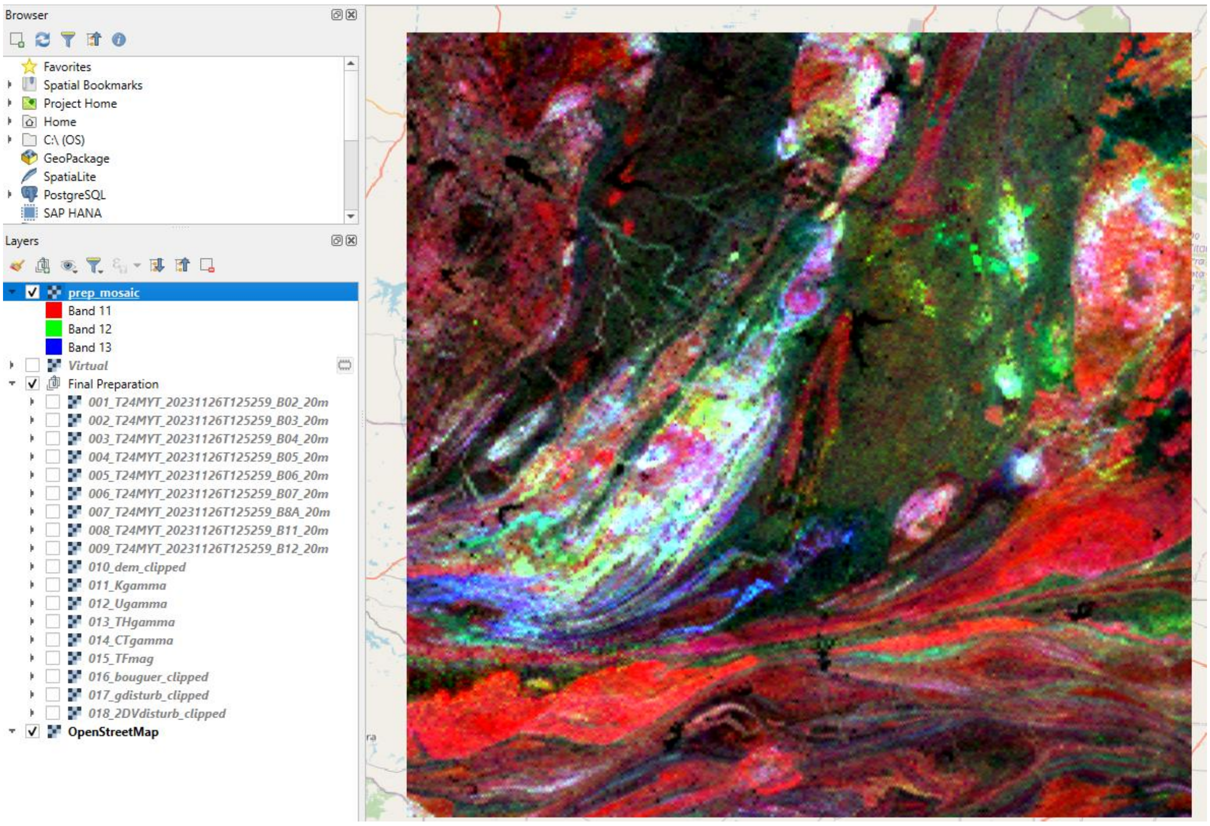
Select bands 9 as red 8 as green and 7 as blue and a “geology” false color composite (FCC) corresponding to SWIR+SWIR+NIR will be displayed.



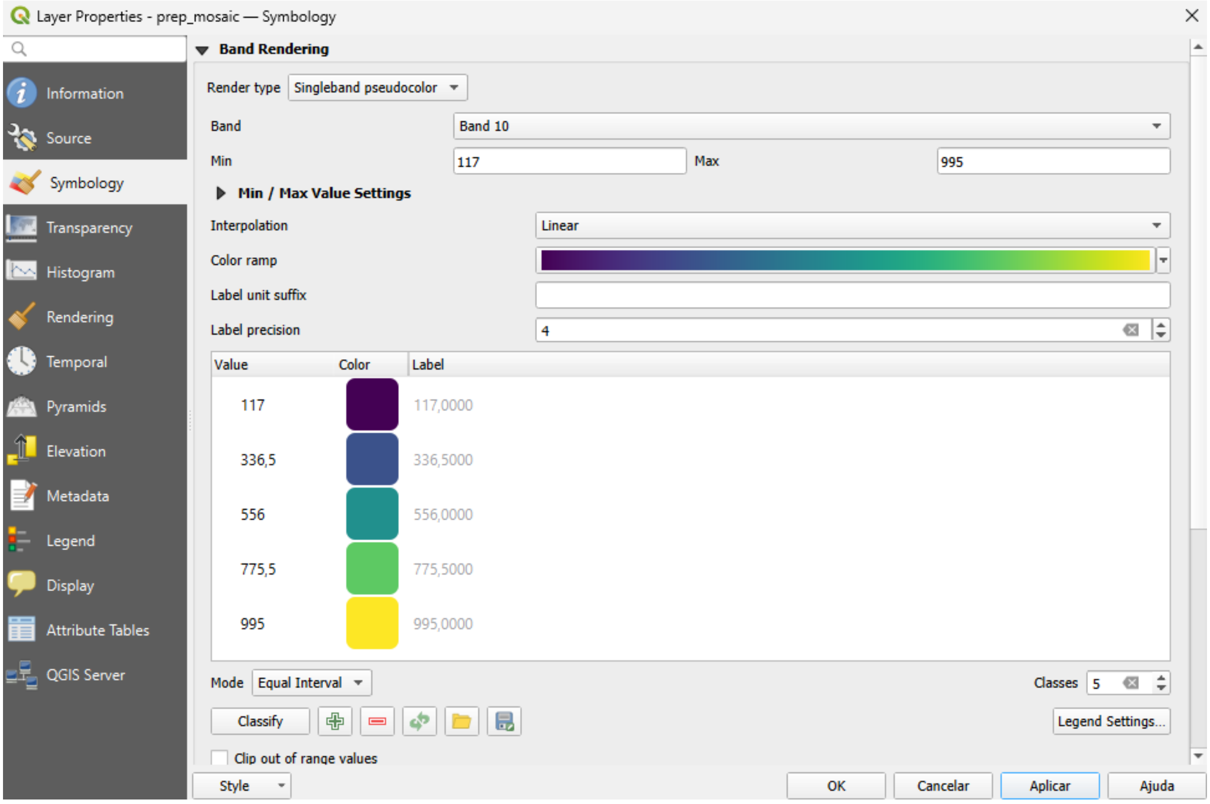


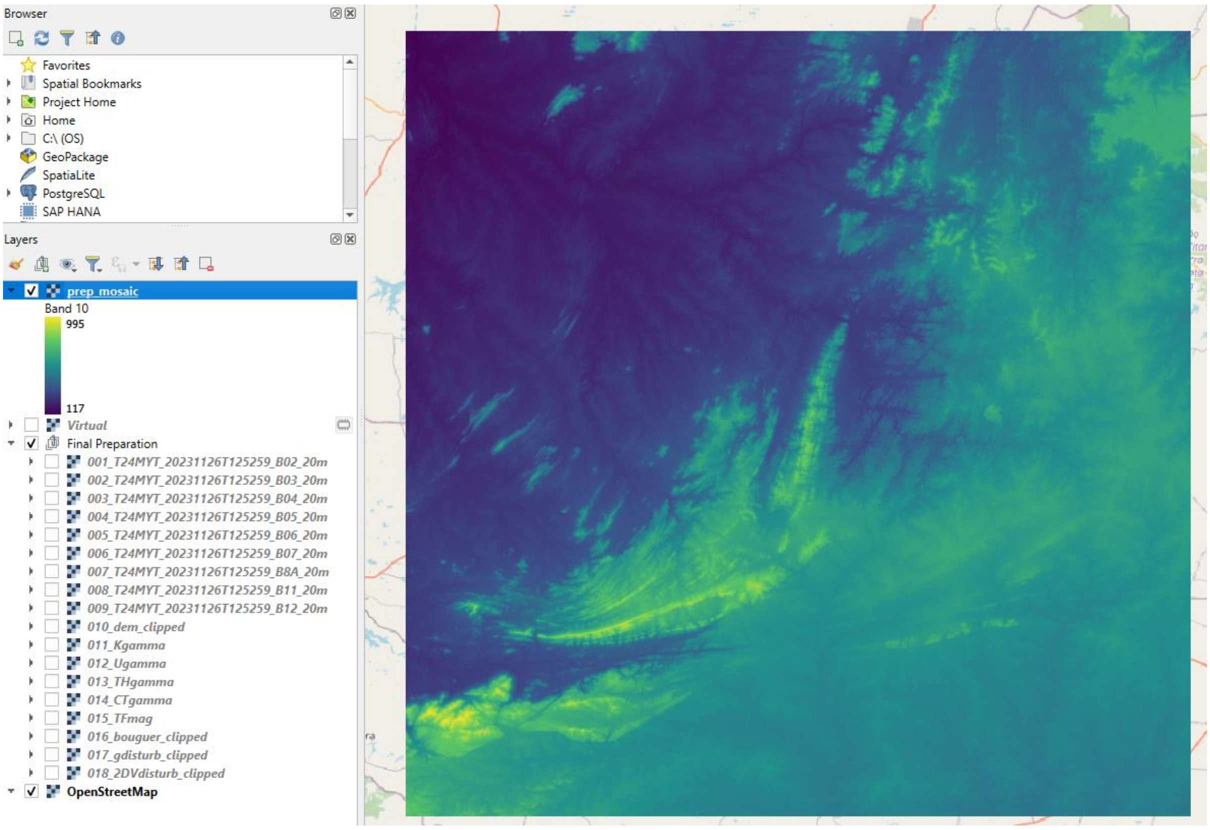
Select bands 11 as red 12 as green and 13 as blue and a Ternary K-U-Th false color composite (FCC) gammaspectrometric response will be displayed.



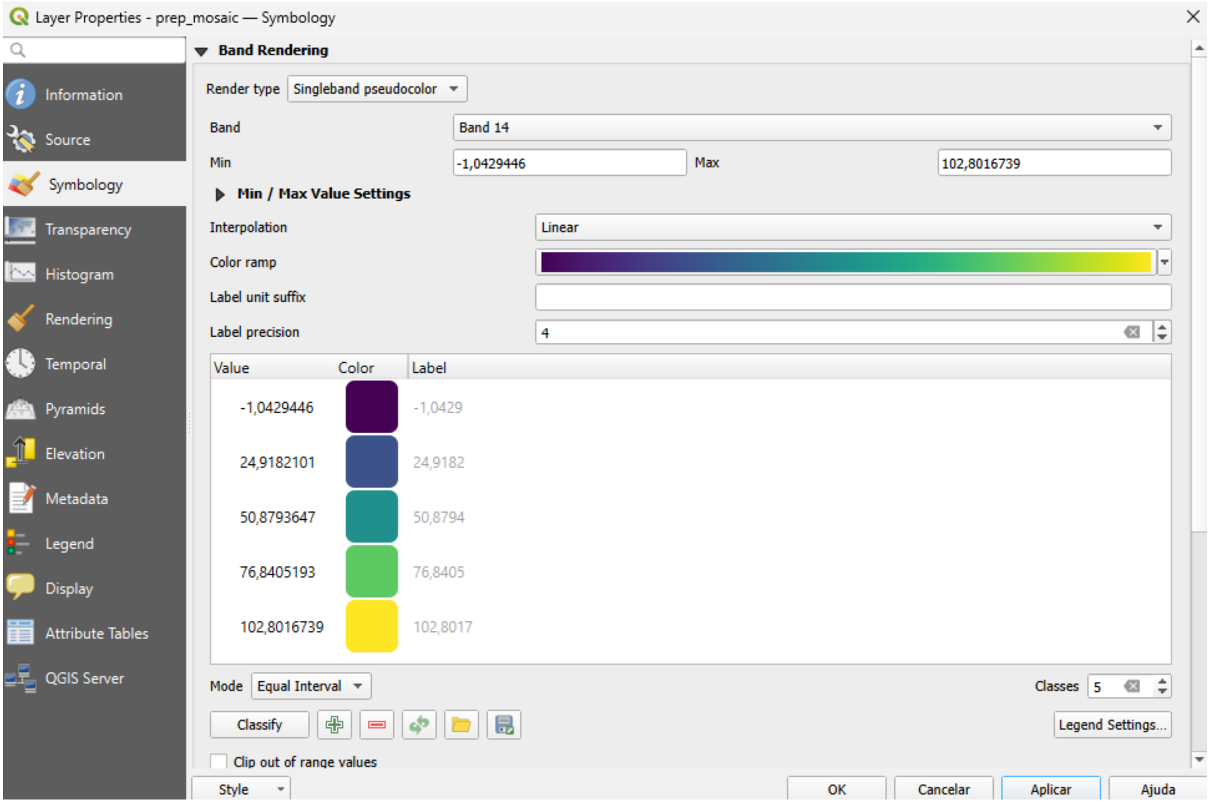


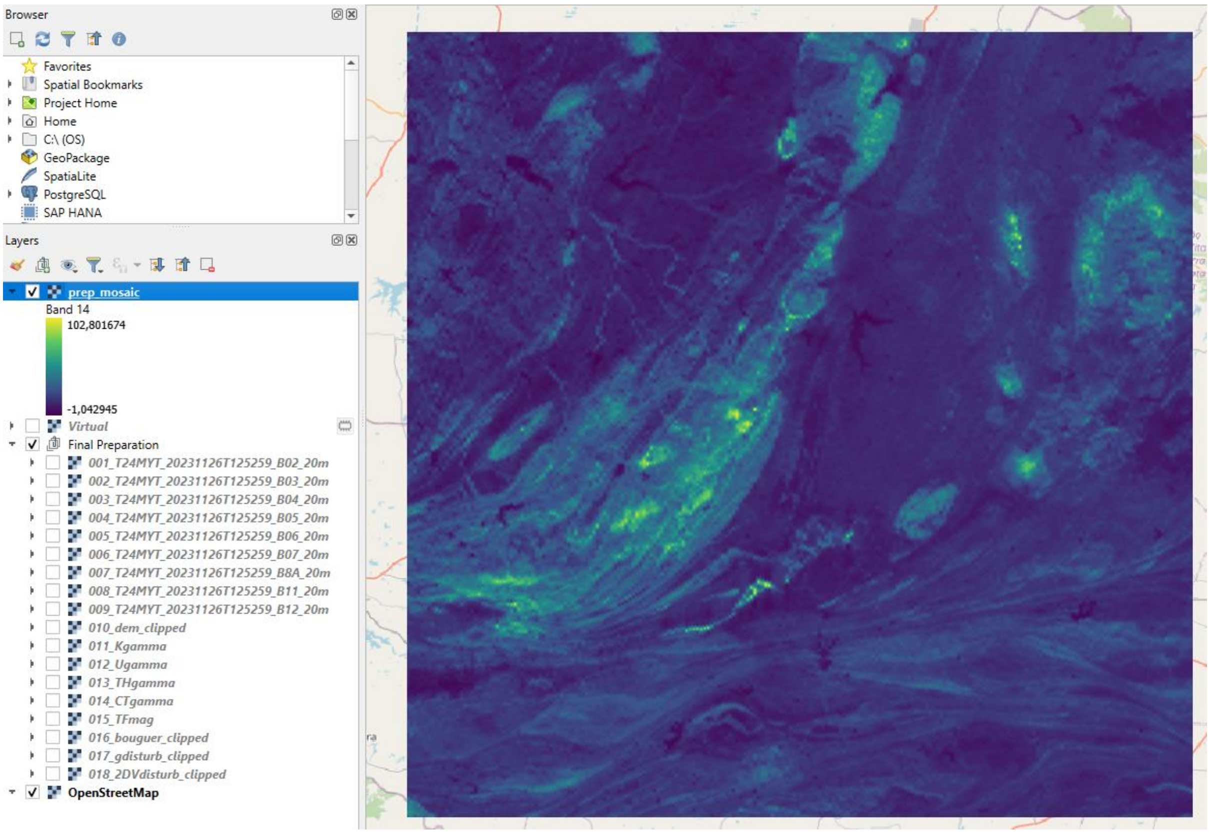
Checking single bands starting with the DEM. Select band 10.



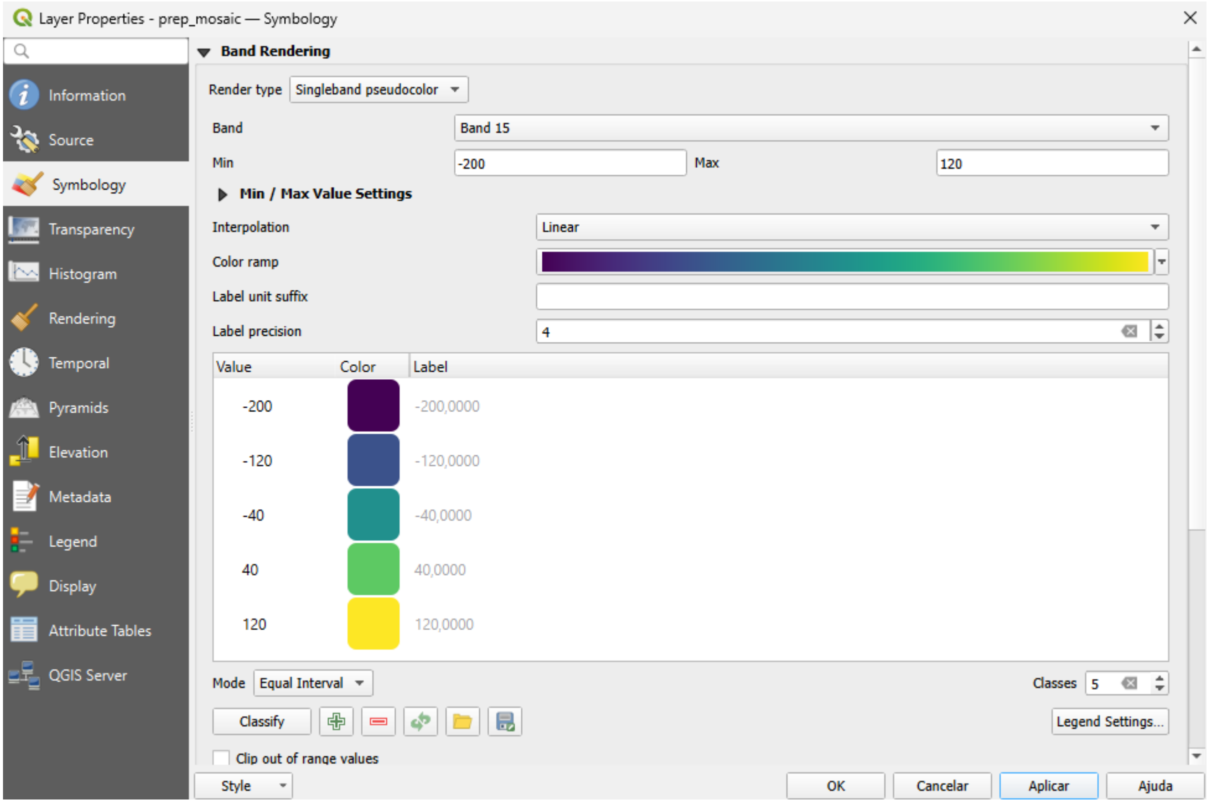


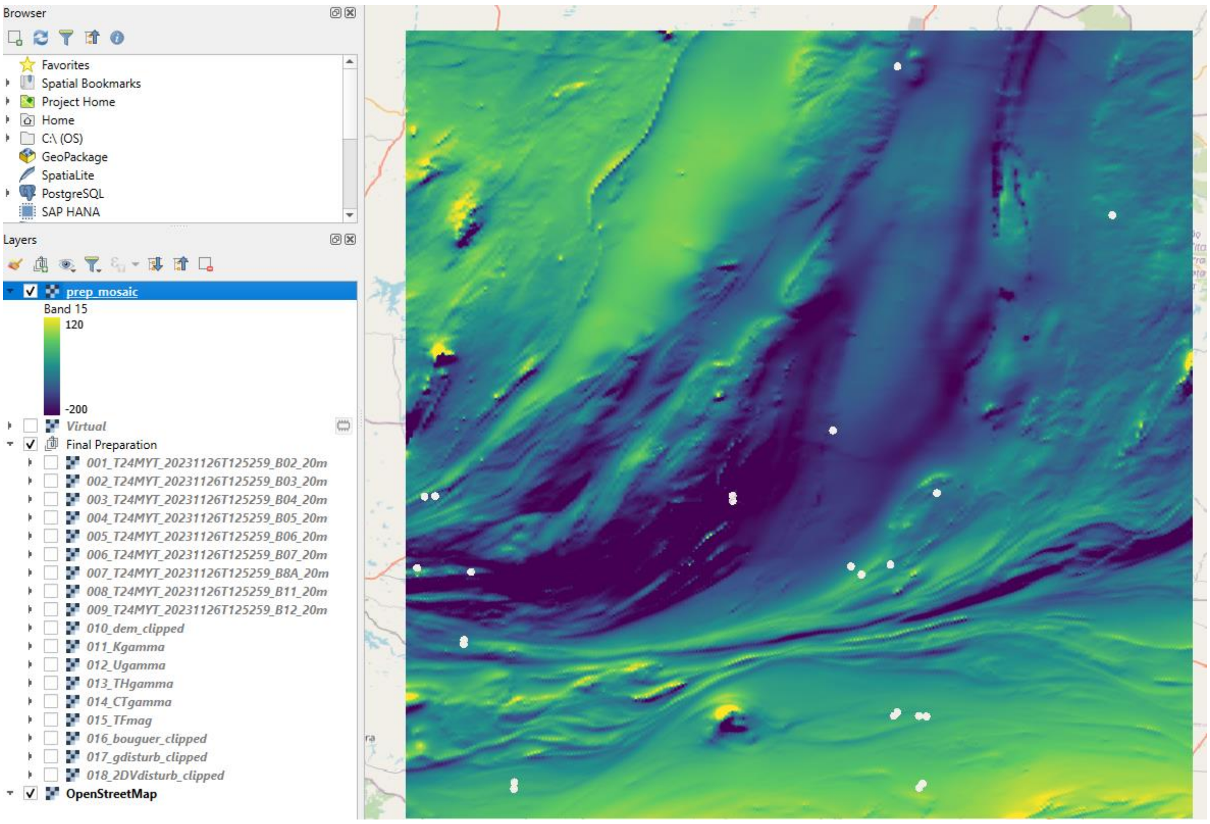
Select band 14 for gamma total count.



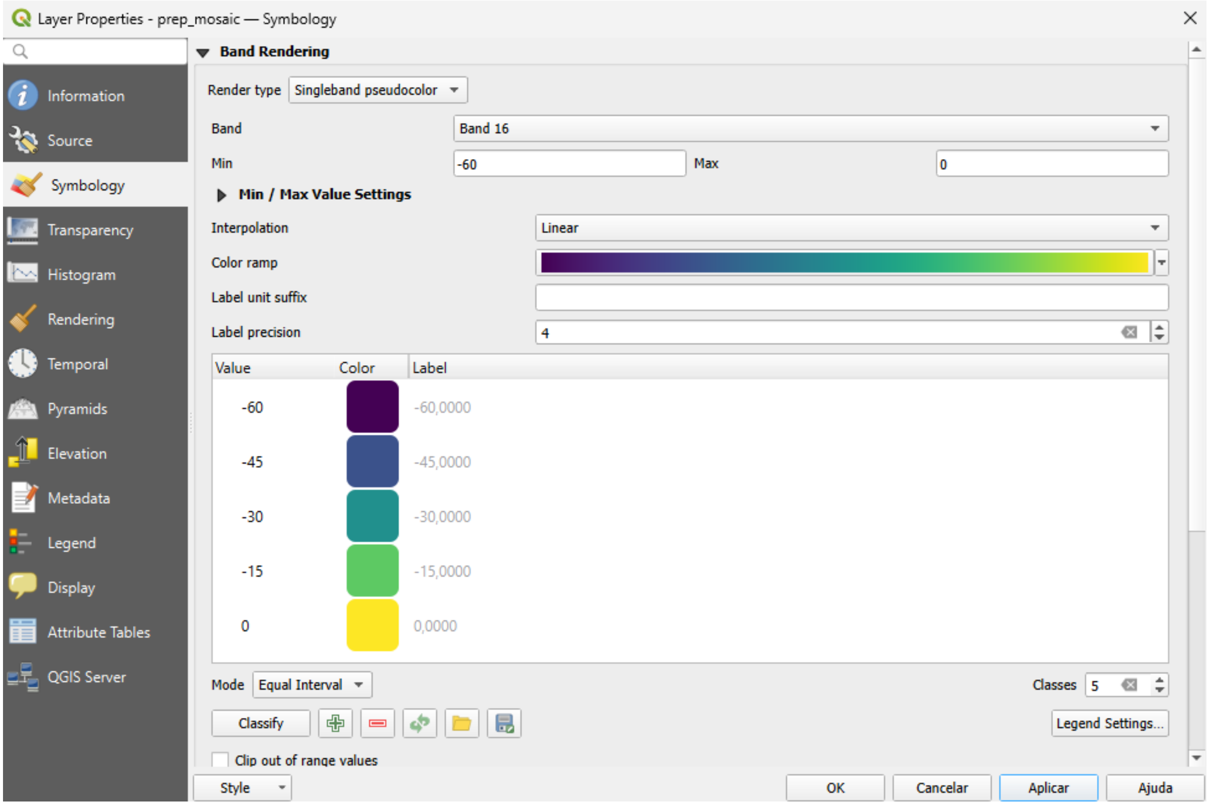


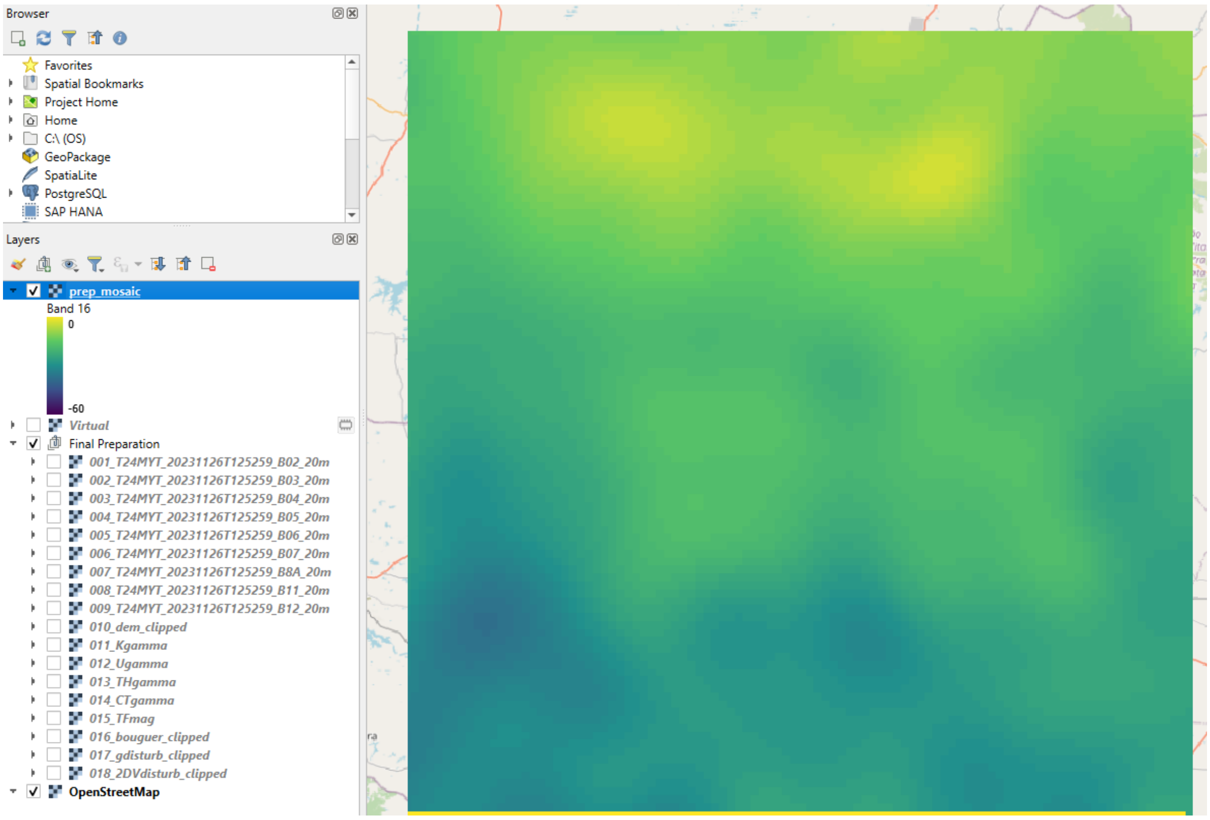
Select band 15 for Mag Total Field residual.



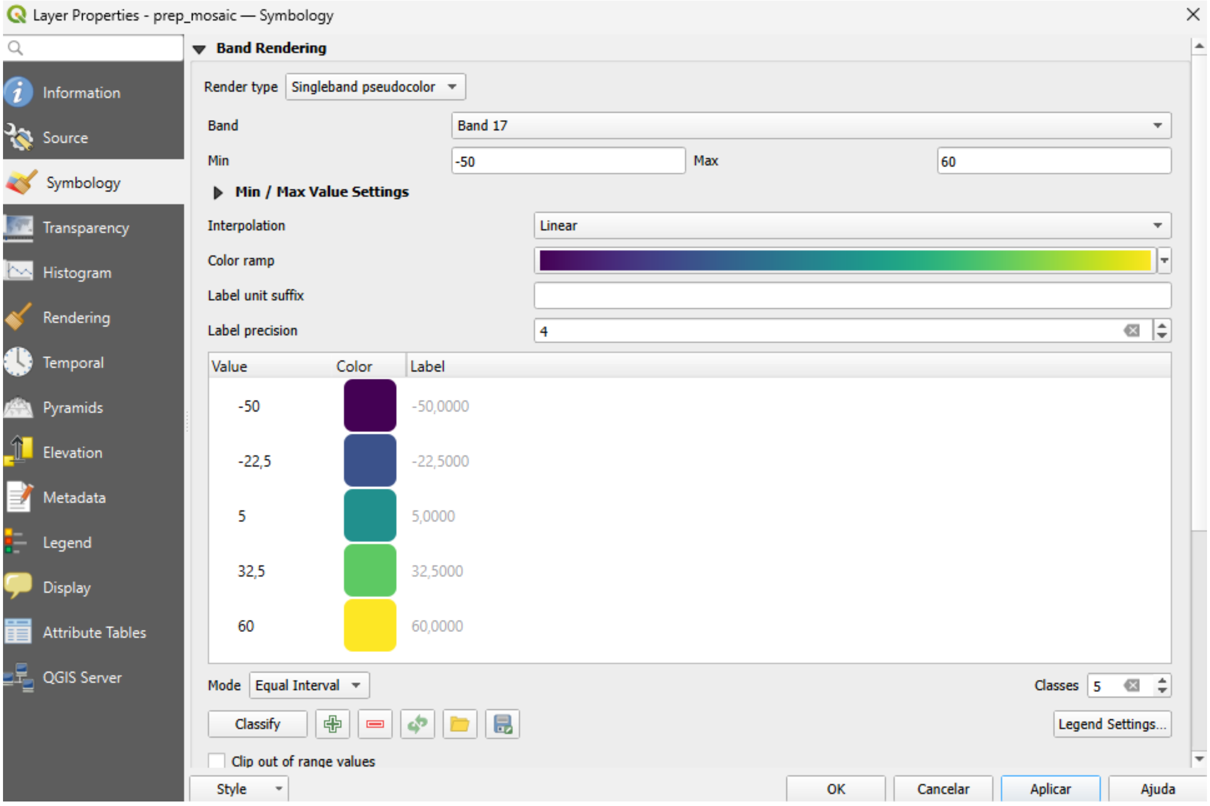


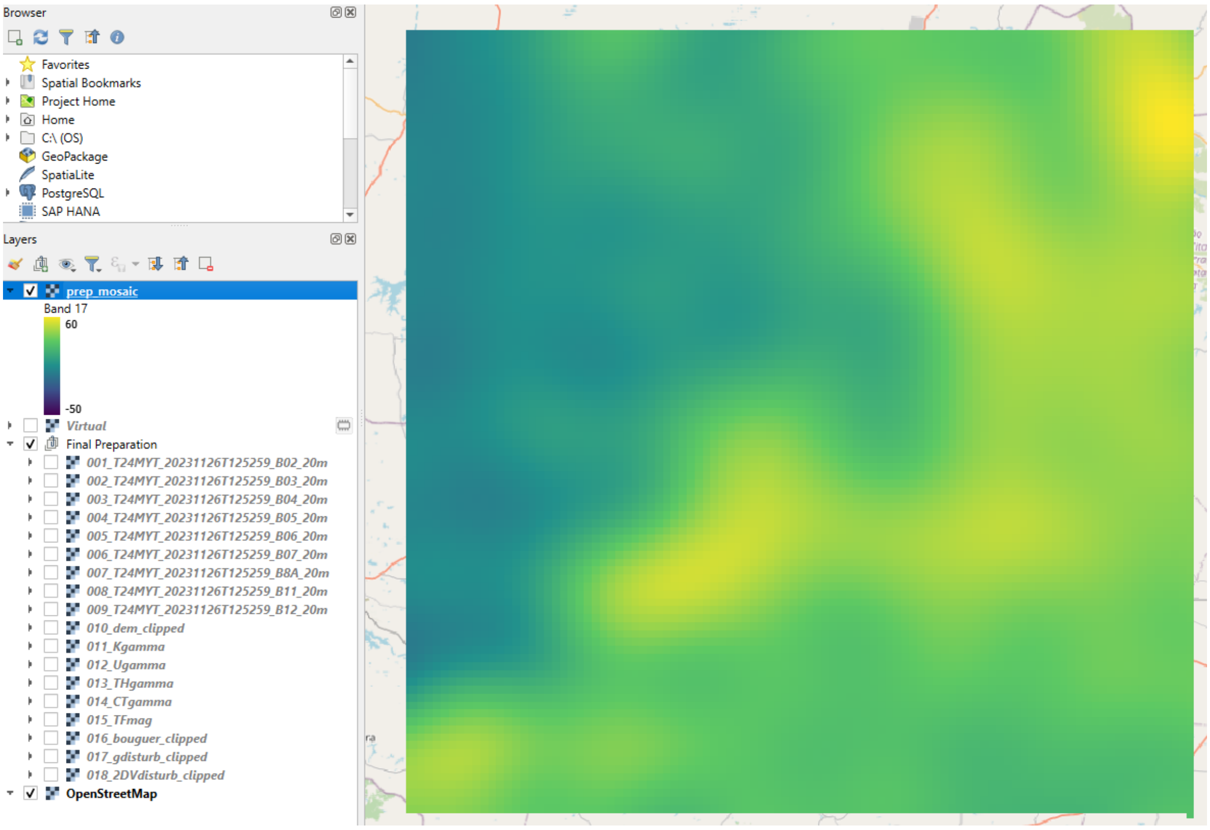
Select band 16 for Modelled Grav Bouguer.



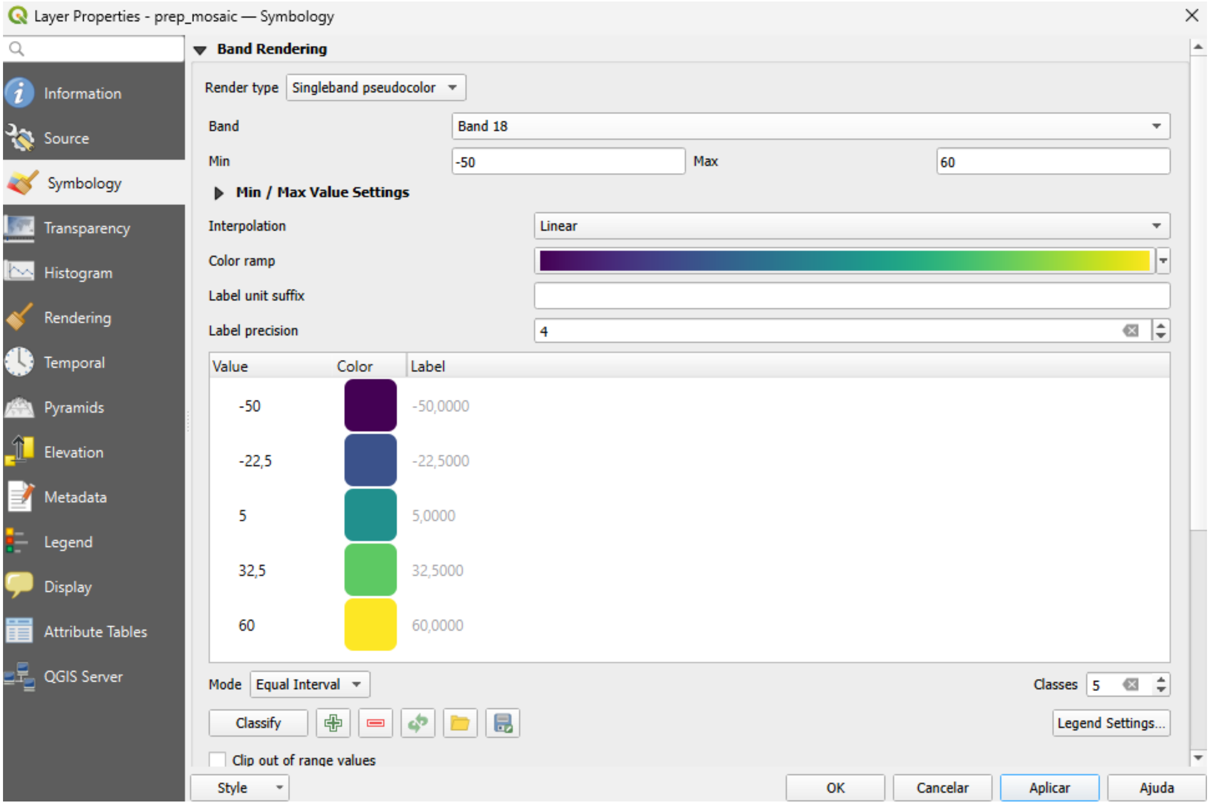


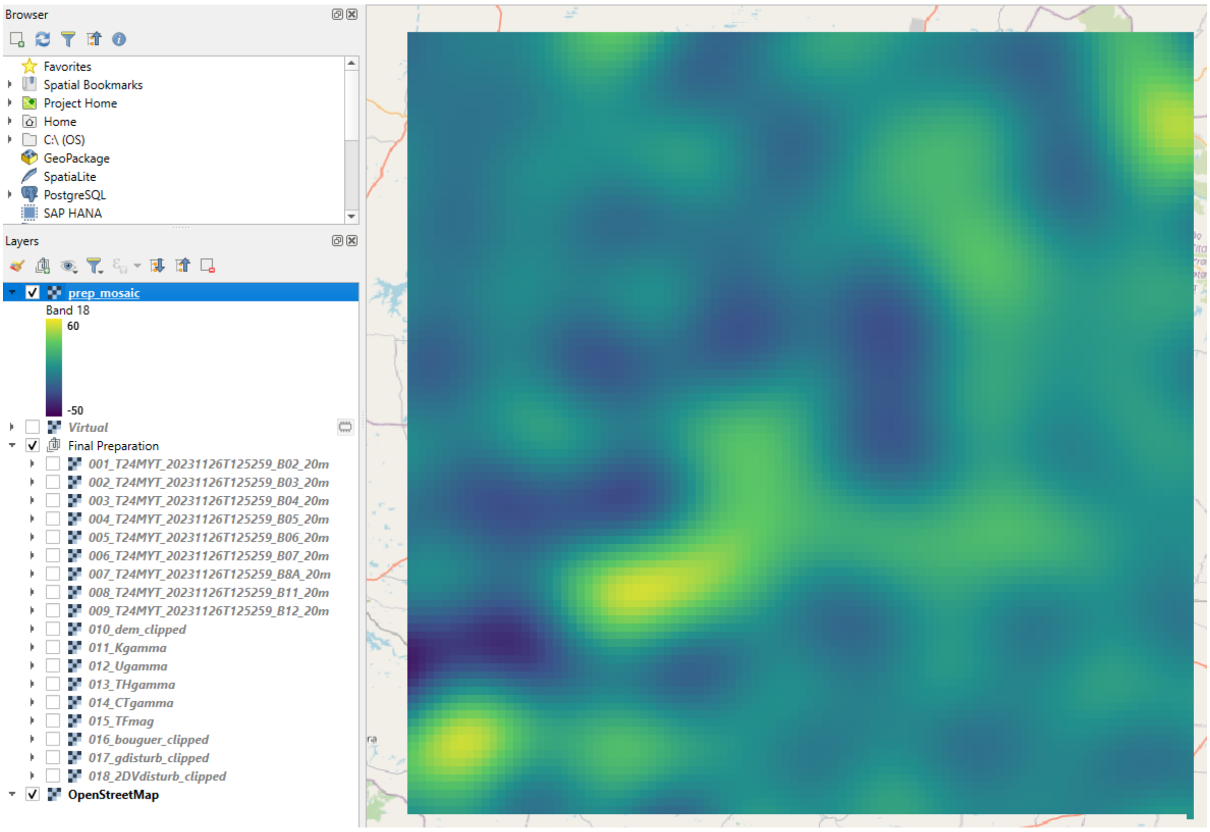
Select band 17 for Grav Disturbance.





Select band 18 for Grav Disturbance 2nd Derivative.





The dataset preparation is an important step and from this resulting file with stacked raster based on satellite images, digital elevation model, airborne geophysical survey and gravity models we will generate in the next Part new layers that will be applied in the final mineral exploration targeting.