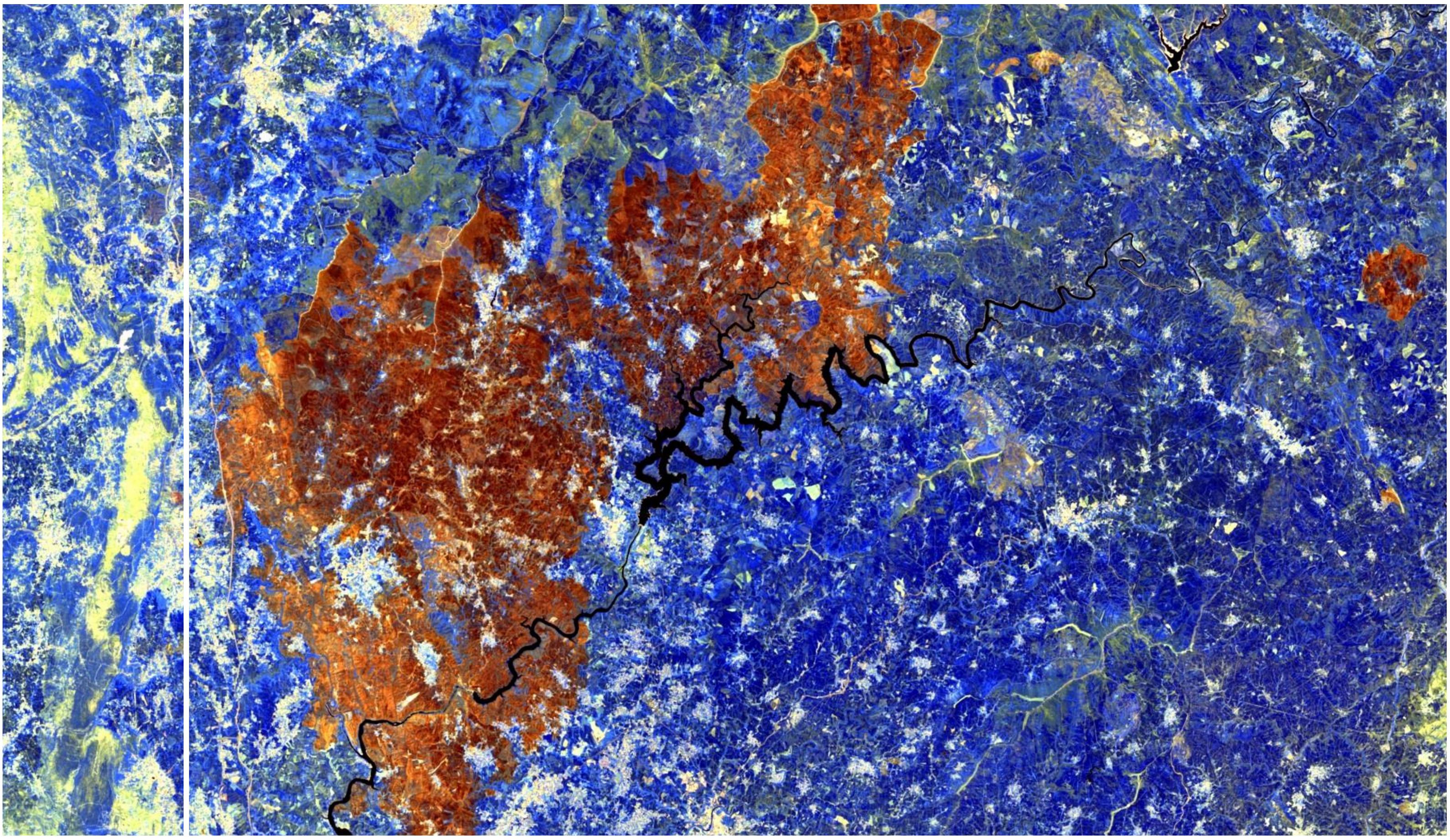


TRAINING KIT – HAZA02

BURNED AREA MAPPING WITH SENTINEL-2 using SNAP JUNE 2017, PORTUGAL

Table of Contents

Did you find this material useful?

Authors would be glad to receive your feedback or suggestions and to know how this material was used. Please, contact us on training@rus-coperenicus.eu

Enjoy RUS!

1 Introduction

The Research and User Support for Sentinel core products (RUS) service provides a free and open scalable platform in a powerful computing environment, hosting a suite of open source toolboxes pre-installed on virtual machines, to handle and process data derived from the Copernicus Sentinel satellites constellation.

Portugal wildfires June 2017 Credits: www.theguardian.com [June 18, 2017]

A series of four initial deadly wildfires erupted across central Portugal in the afternoon of 17 June 2017 within minutes of each other, resulting in at least 64 deaths and 204 injured. An intense heat wave preceded the fires, with many areas of Portugal, seeing temperatures in excess of 40 °C (104 °F).

During the night of 17–18 June, a total of 156 fires erupted across the country, particularly in mountainous areas 200 km (120 mi) north-northeast of Lisbon. The fires began in the Pedrógão Grande municipality before spreading to others and causing a firestorm. A total of 44,969 hectares of land was burned by the fires as of 20 June. Of this, 29,693 hectares (73,370 acres) was in the Pedrógão Grande area.

2 Training

Approximate duration of this training session is two hours.

The Training Code for this tutorial is HAZA02. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the [RUS portal (rus-copernicus.eu)](rus-copernicus.eu) and open a User Service request from Your RUS service > Your dashboard.

2.1 Data used

- Two Sentinel-2A Level 2A tiles (Tile ID: T29TNE) acquired between on June 4, 2017 (before the main event) and July 4, 2017 (after the main event).
  [downloadable @ https://scihub.copernicus.eu/]

S2A_MSIL2A_ 20170604T112121_N0205_R037_T29TNE_20170604T112755.zip
S2A_MSIL2A_ 20170704T112111_N0205_R037_T29TNE_20170604T112431.zip

2.2 Software in RUS environment

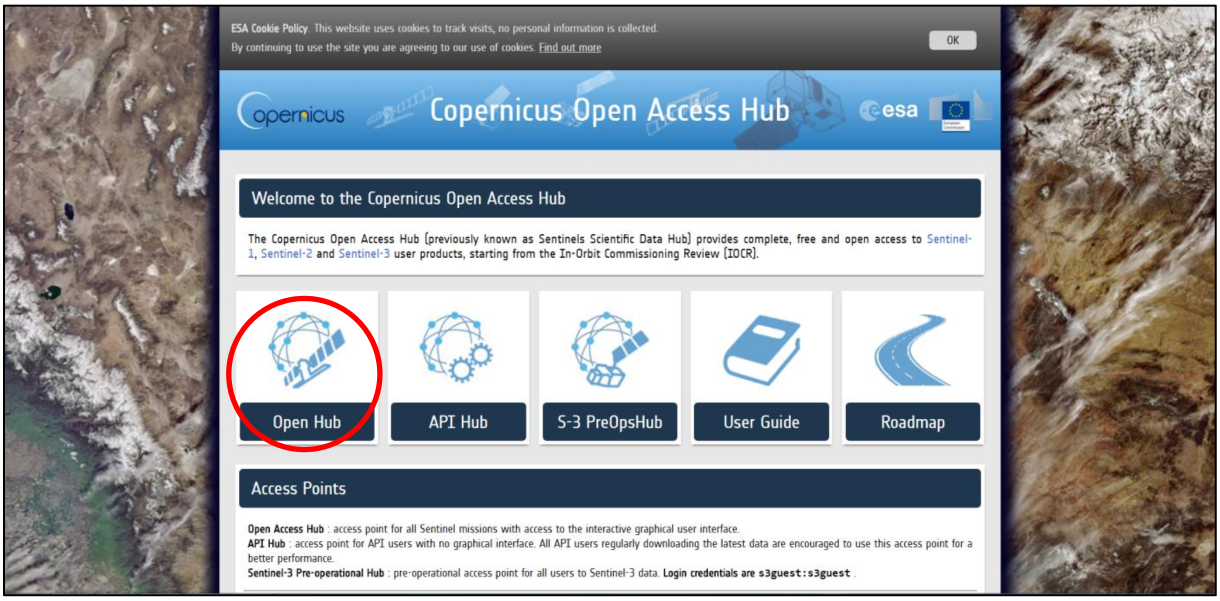
Internet browser, SNAP + Sentinel-2 Toolbox, QGIS, (Extra steps: Sen2Cor, Google Earth)

3 Step by step

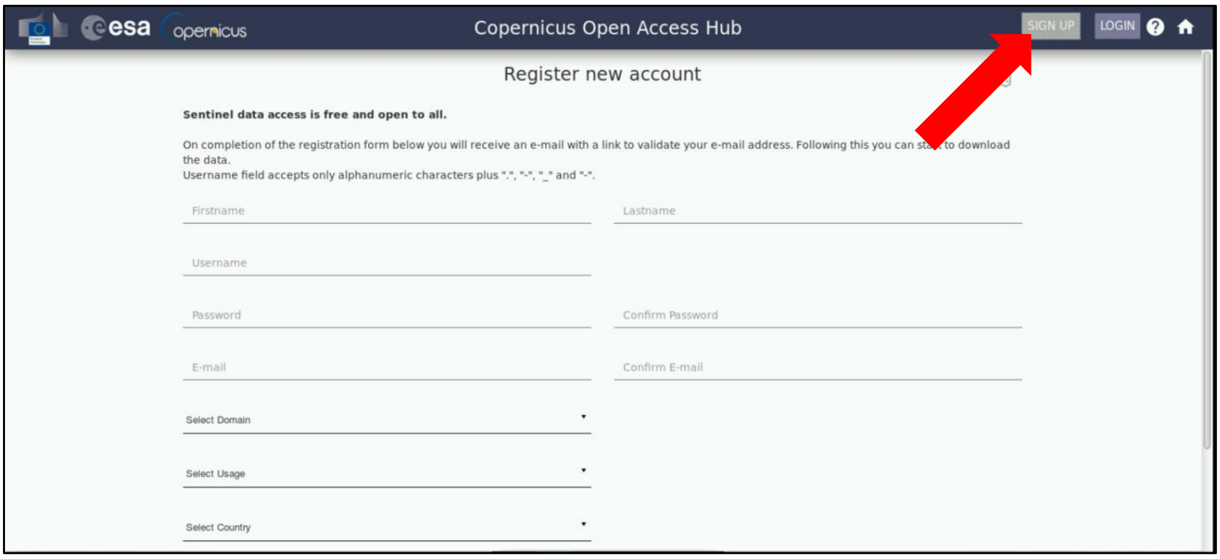
3.1 Data download – ESA SciHUB

In this step we will download a Sentinel-2 scene from the Copernicus Open Access Hub using the online interface (**Applications -> Network -> Web Browser,** or click the link below).

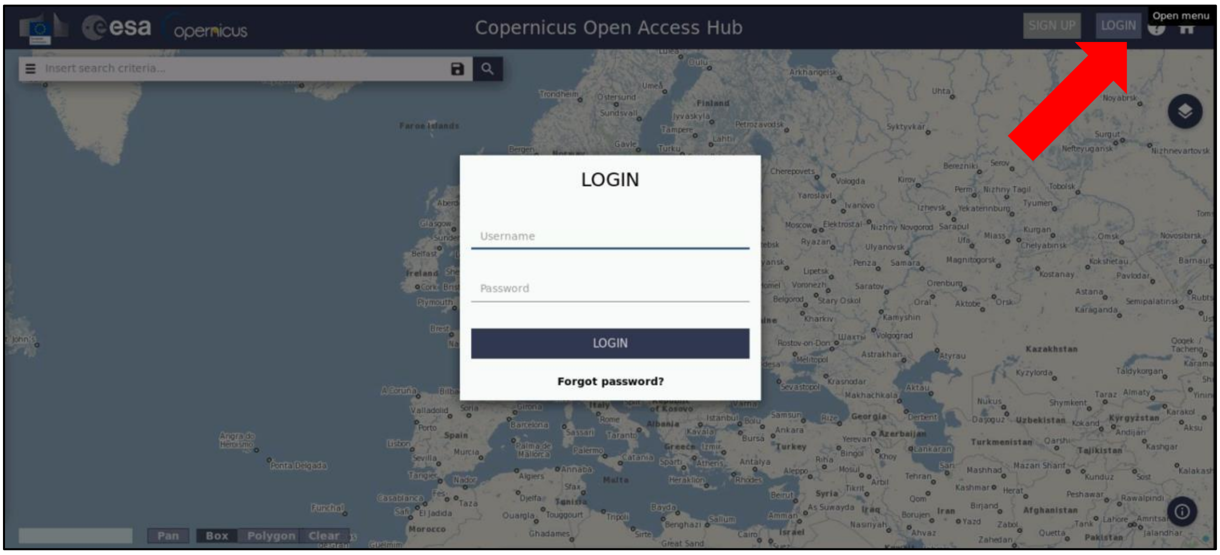
Go to https://scihub.copernicus.eu/



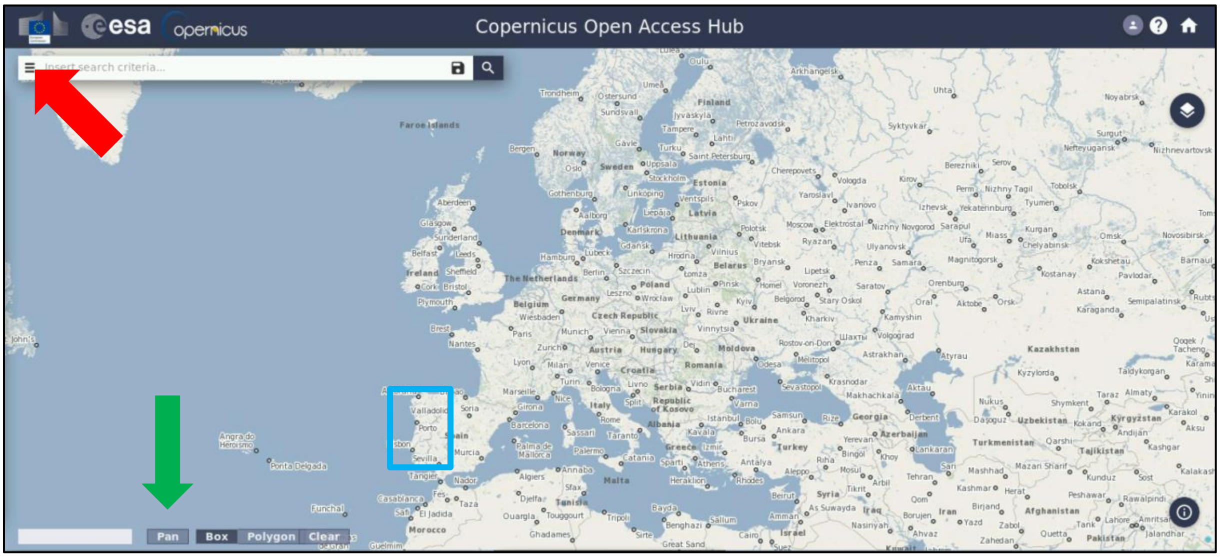
Go to Open HUB, if you do not have an account please register in upper right corner.



After you've filled in the registration form you will receive an activation link by e-mail. Once your account is activated or if you already have an account, log in.



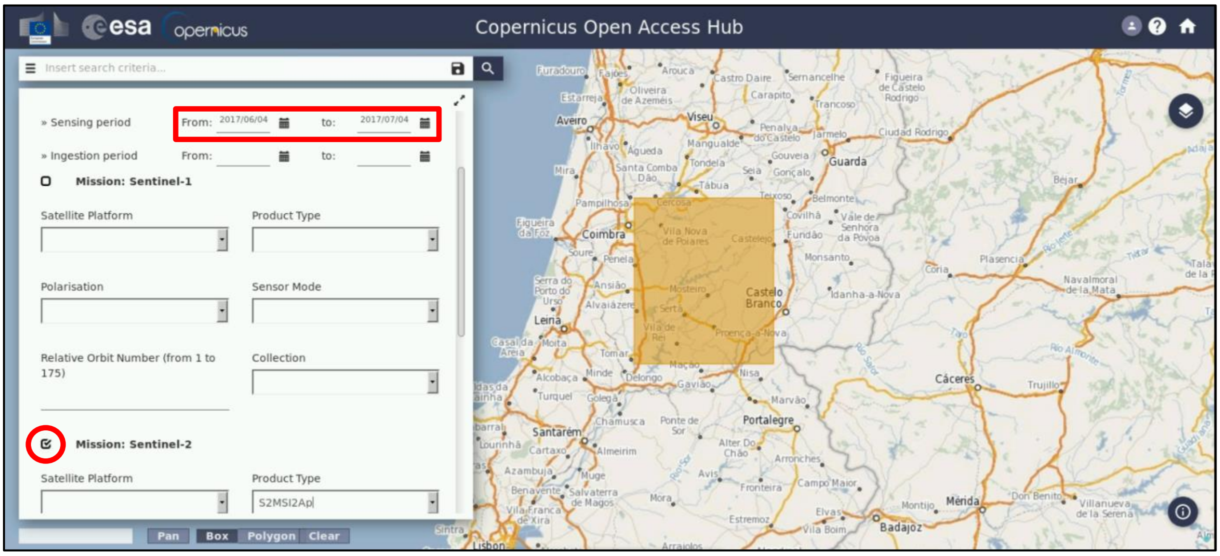
Switch the rectangle drawing mode to pan mode by clicking on the ‘Pan’ icon in the lower left corner of the map (**Green arrow**) and navigate over Portugal (**approximate area – blue rectangle**).

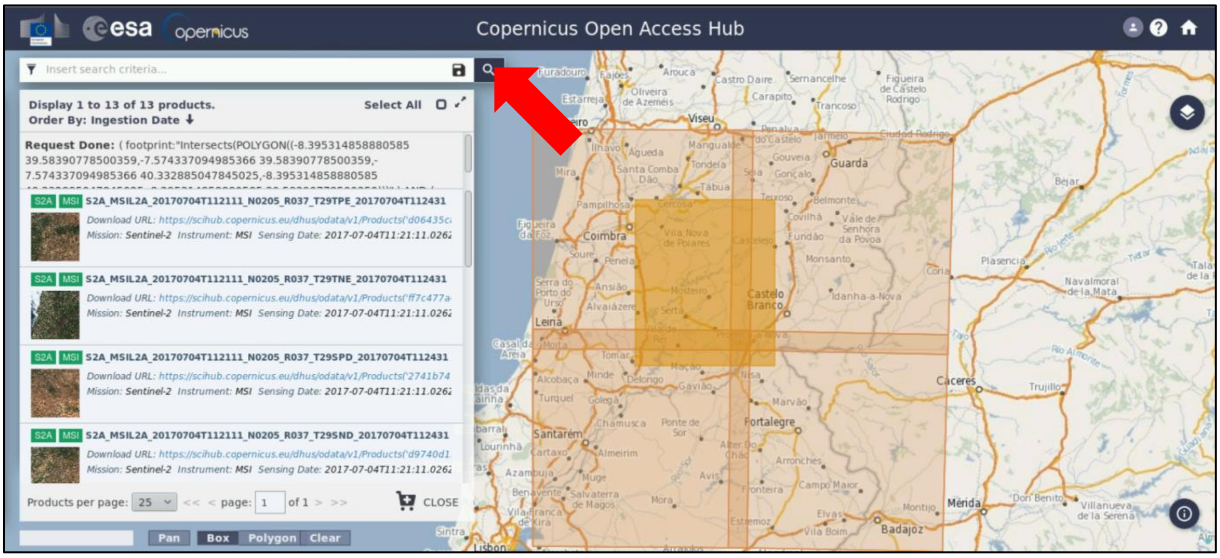


Switch to drawing mode and draw a search rectangle approximately as indicated below. Open the search menu (red arrow) and specify the following parameters (See TIP 1):

Sensing period: From 2017/06/04 to 2017/07/04
Check Mission: Sentinel-2
Product Type: S2MSI2Ap

TIP 1: For the Level 2A products we are downloading the atmospheric correction has already been applied (pre-processing of Level-1C product to a Level-2A is described in section **4.1**). Atmospheric correction using Sen2Cor algorithm is a computationally heavy process and takes approximately 30 minutes per image to be completed depending on your machine. However, since April 2017 the Level-2A products have already been generated and are available to download for acquisitions over Europe (such as this case). If you want to try to run the atmospheric correction (section **4.1**) nevertheless, you can change:
Product Type: S2MSIL1





In our case the search returns 13 results depending on the exact search area defined. Download the scenes (pay attention to the tile ID, below in red):

S2A_MSIL2A_ 20170604T112121_N0205_R037_T29TNE_20170604T112755
S2A_MSIL2A_ 20170704T112111_N0205_R037_T29TNE_20170704T112431

Data will be downloaded to */home/rus/Downloads* as ZIP archives. Move the archives to: */shared/Training/HAZA02_BurnedArea_Portugal_TutorialKit/Original*
Right click each archive and use Extract Here to unzip the folders.

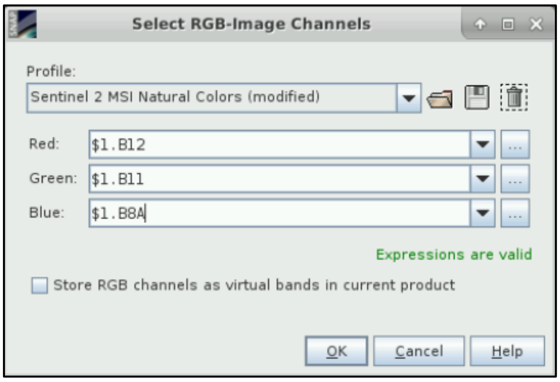
3.2 SNAP – open and explore data

Launch SNAP (icon on desktop). When the SNAP window opens click Open product, navigate to */shared/Training/HAZA02_BurnedArea_Portugal_TutorialKit/Original*

In each folder navigate to *.SAFE folder and open the MTD_MSIL2A.xml file. At the end you will have both products opened in the Products Explorer pane on the left.

Now, we will look at the products. We could visualize them in true (natural) colours but for distinguishing the burned areas it is better to use the Near InfraRed (NIR) and Short Wave InfraRed (SWIR) bands as these provide the best separability (for more explanation, check the graph in

NOTE 2). Right click the pre-fire product from 4 June and click **Open RGB image window,** a new window will open.

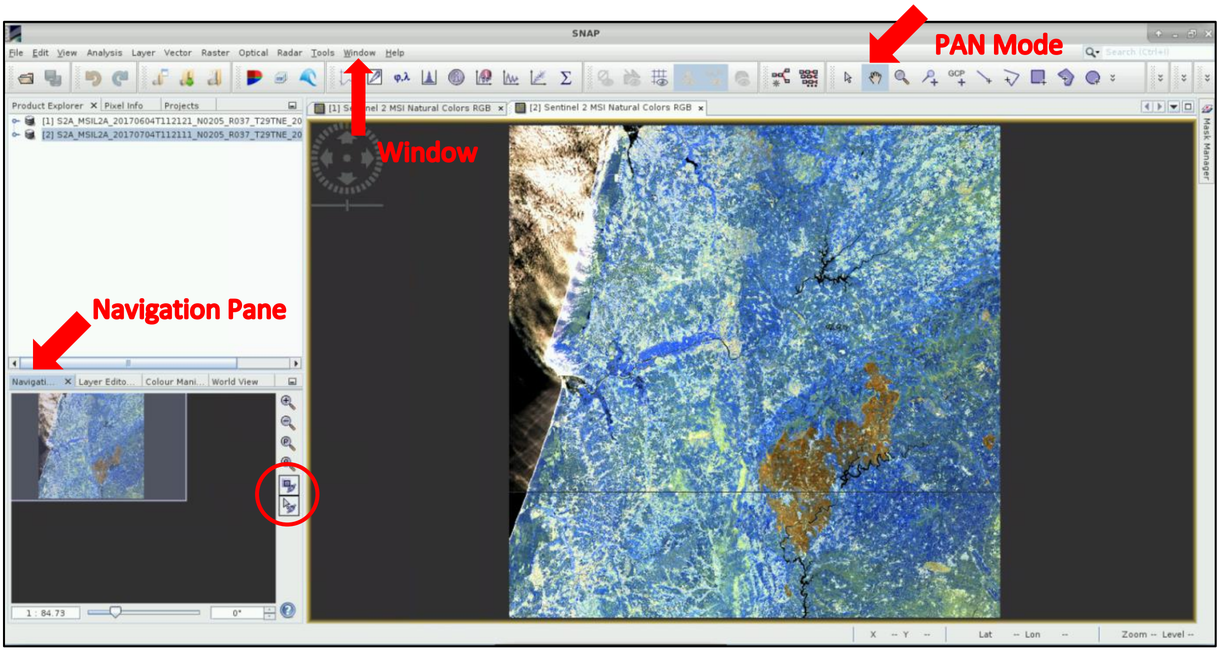


Set: **Red:** B12

Green: B11

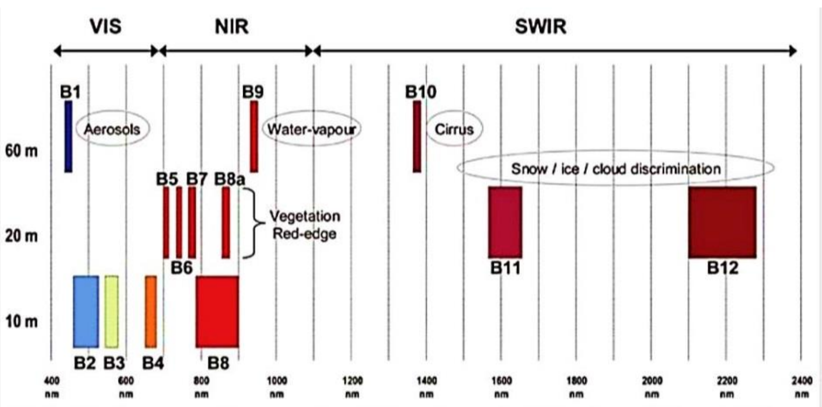
Blue: B8A

Do the same for the post fire product from 4 July. Now we will have 2 windows opened.

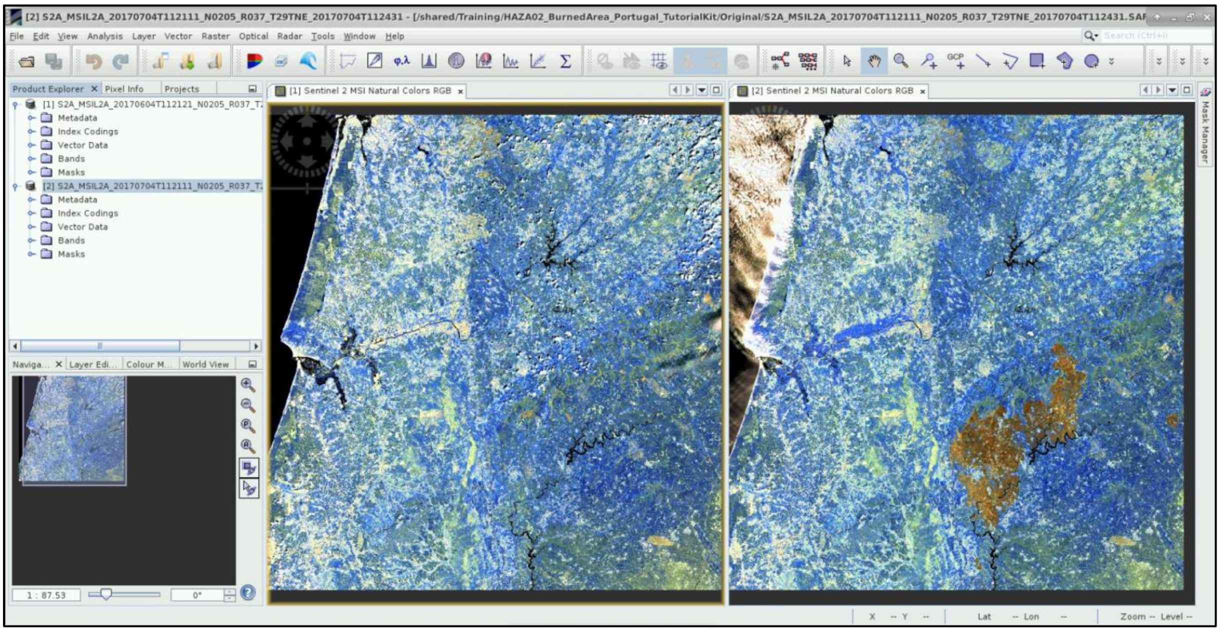


Now go to Navigation pane in the lower left and make sure the cursor  and the views  are linked. Then, go to **Window -> Tile Horizontally**. The image appears in the upper left corner of the view window. Click on the Pan mode on View [2] and zoom in to the burned area – orange-brown colour. (See  NOTE 1).

 NOTE 1: The input product contains 13 spectral bands in 3 different spatial resolutions (The surface area measured on the ground and represented by an individual pixel). When we open the RGB view all our input bands have 20 m resolution, however, the view is displayed in the full 10 m resolution.



Credits: ESA 2015



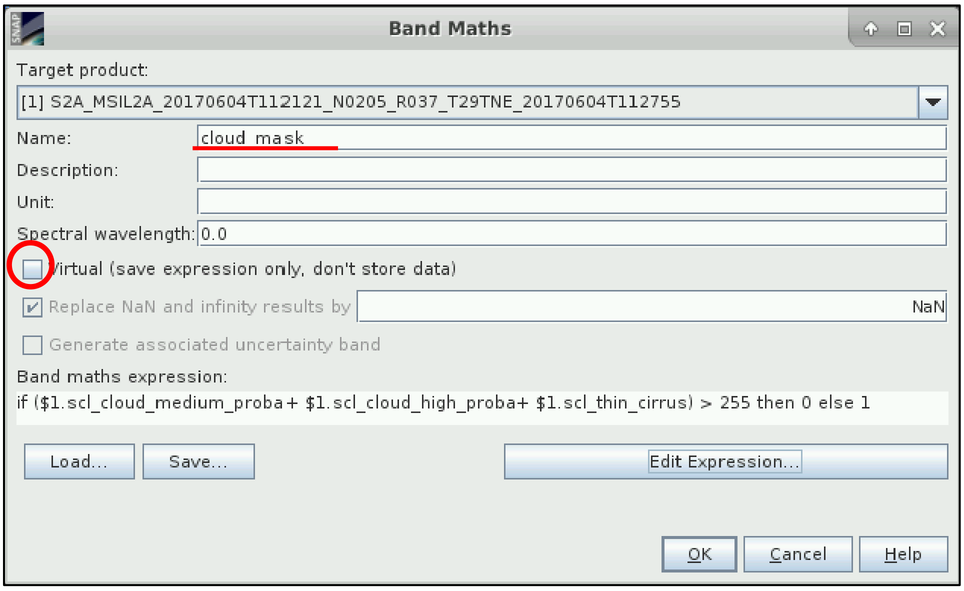
3.3 *Creating a cloud mask band*

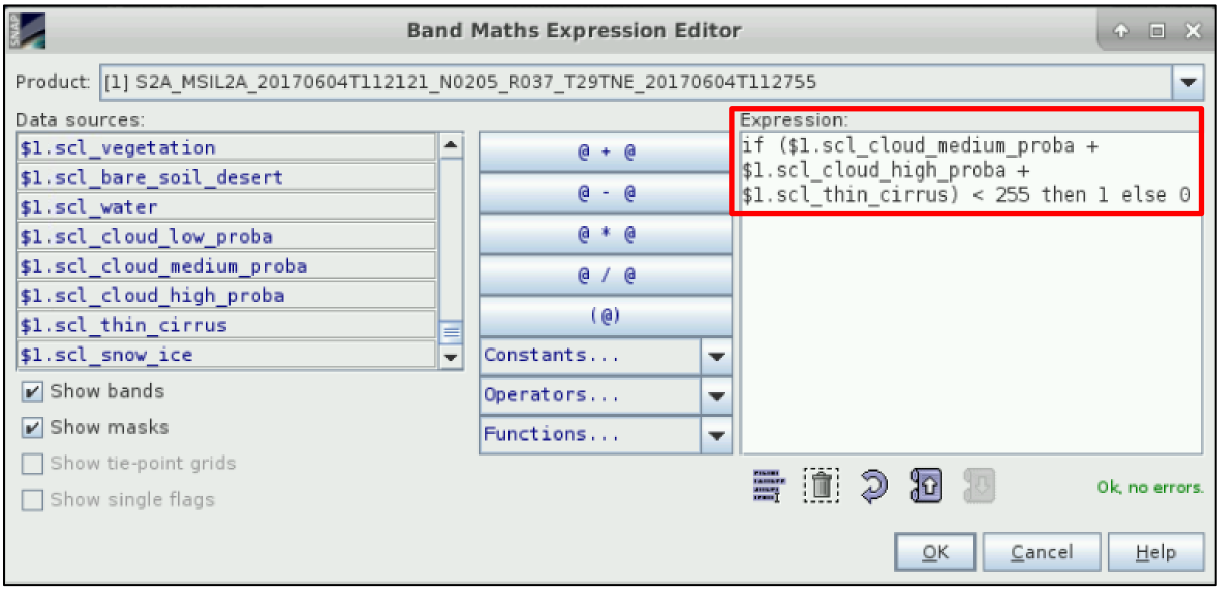
The Sentinel-2 L2-A product conveniently contains vector cloud and cirrus masks, which are created as a product of the atmospheric correction, however, applying the mask on all bands and full scene takes some time. We can subset the product but the vector products are lost by that operation. So in our case to preserve the information we will create a new band containing a cloud mask. This is currently not possible to do using batch processing so we need to add the cloud_mask band to each product separately.

Right-click on the first open product from 4 June [1] and click **Band Math**s. A new window will open.
Set name to: cloud_mask (the **name must be the same in both products!!!**)
And deselect Virtual (safe expression only, don't store data)

Then click **Edit Expression…** and enter the following statement:

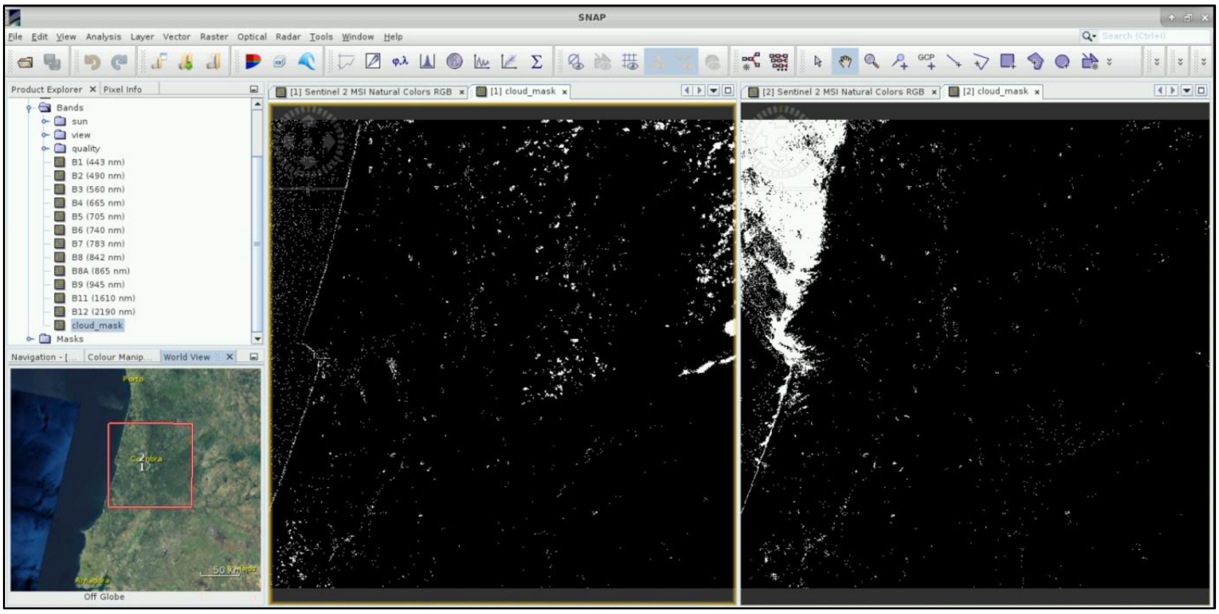
```
if (scl_cloud_medium_proba + scl_cloud_high_proba + scl_thin_cirrus)
< 255 then 0 else 1
```





The new band will automatically open in a new view; we can click in the view name tab and drag the view window to the appropriate RGB view. And in Navigation tab click Zoom All .

Do the same for the post-fire products (you can copy paste the expression to the Band maths expression without clicking on Edit Expression. Don't forget to change the product number in the expression).

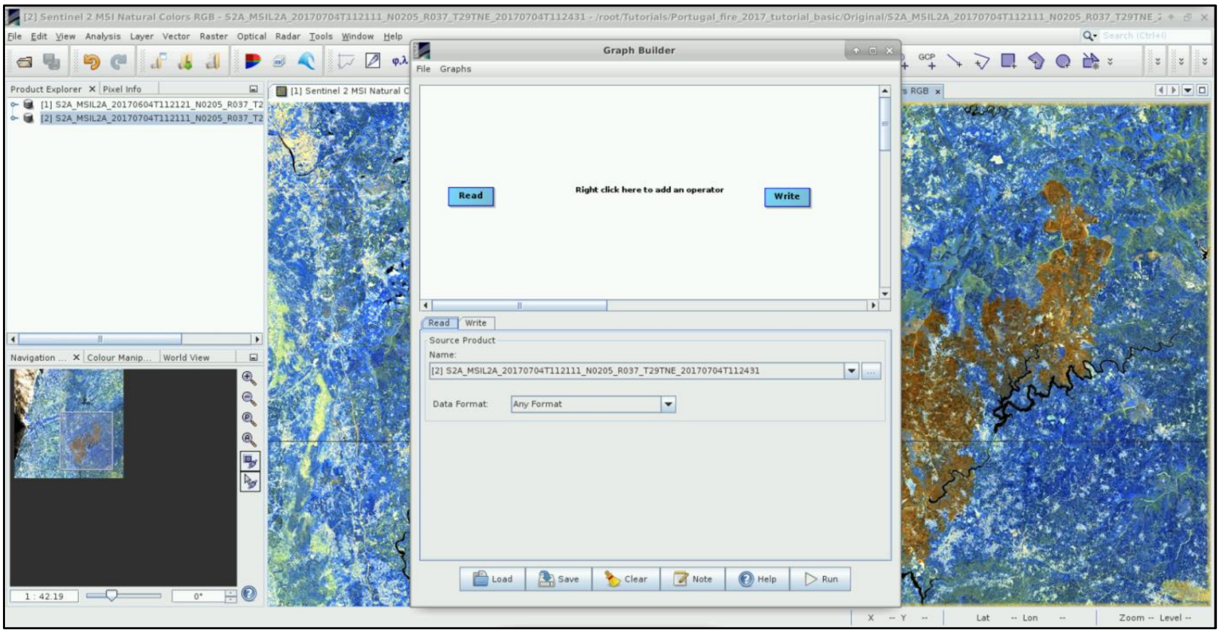


3.4 *Pre-processing*

As we have seen in the previous step, processing the data one by one would be very time consuming and inconvenient. However, we can use the **Batch Processing** tool available in SNAP to process all images at the same time.

To use the tool we first need to define the process we want to apply and all its steps. We can do this using the **GraphBuilder** tool. The nice thing about the **GraphBuilder** is also that no intermediate product will be physically saved, only the end product which saves valuable disk space.

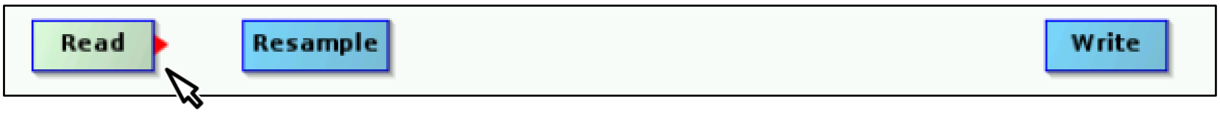
So let's build our graph. Go to **Tools -> GraphBuilder**.



At the moment the graph only has two operators: **Read** (to read the input) and **Write** (to write the output).

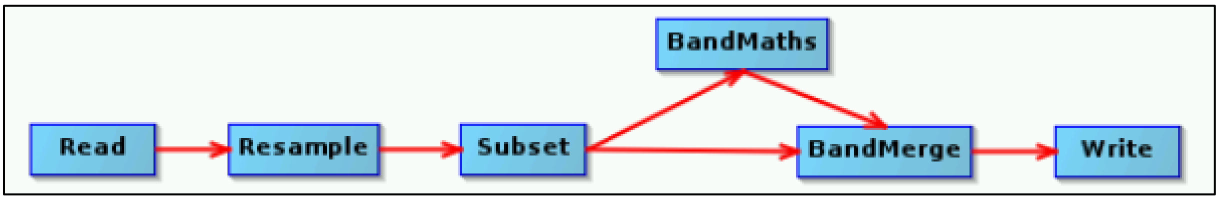
The 13 bands in Sentinel-2 products do not all have same resolution (therefore size) as mentioned in NOTE 1. Many operators do not support products with bands of different sizes so first we need to resample the bands to equal resolution. To add the operator right-click the white space between existing operators and go to **Add -> Raster -> Geometric -> Resample**

A new operator rectangle appears in our graph and new tab appears below. Now connect the new **Resample** operator with the **Read** operator by clicking to the right side of the **Read** operator and dragging the red arrow towards the **Resample** operator.



Next step will be to subset the images to the area of interest, we do this by right-clicking the white space somewhere left of the resample operator and going to **Add -> Raster -> Geometric -> Subset.** Connect the **Subset** operator with the **Resample** operator.

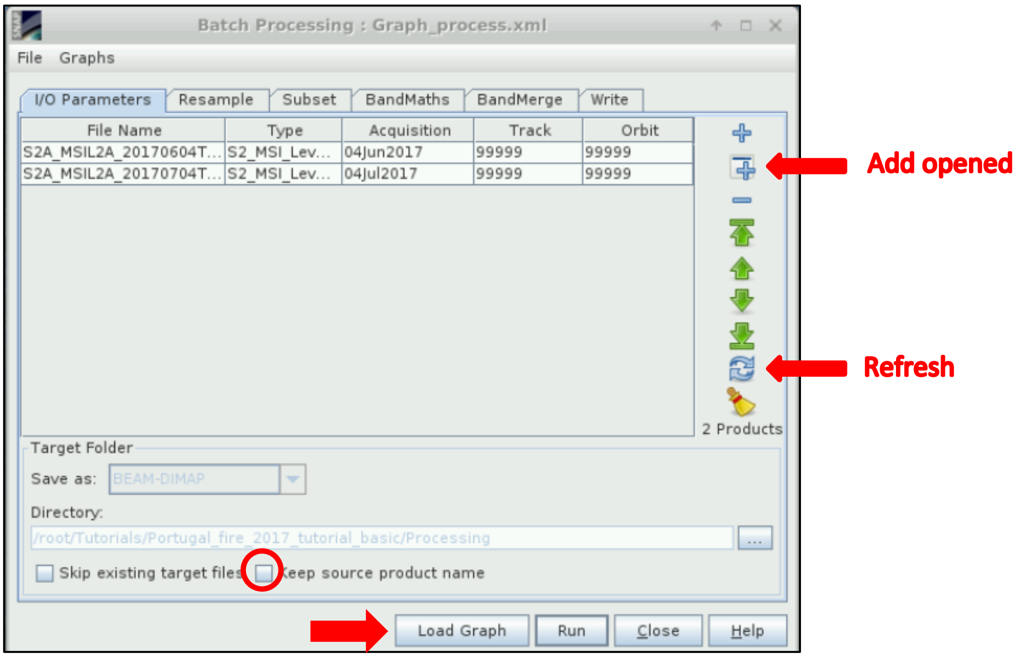
Now, we will add the BandMath operator from **Add -> Raster -> BandMaths** connect it to the **Subset** operator. Last, we add **BandMerge** operator from **Add -> Raster -> BandMerge.** Connect both, the **Subset** operator and the **BandMaths** operator, to the **BandMerge** operator. And then connect the **BandMerge** operator with the **Write** operator.



At the moment, do not change anything in the parameter tabs and save the graph as *Graph_process.xml* in */shared/Training/HAZA02_BurnedArea_Portugal_TutorialKit/Processing* by clicking **Save** at the bottom of the window.

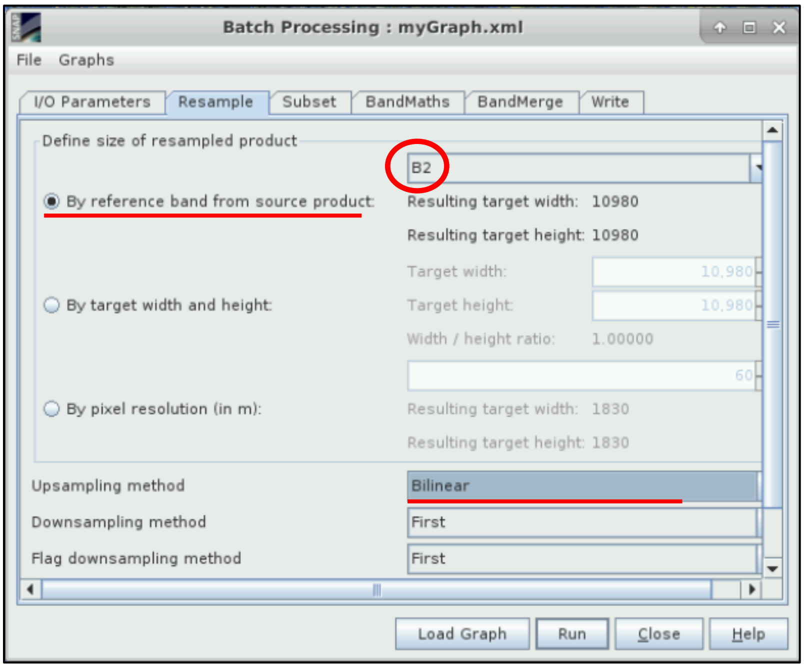
In the Product Explorer, we select (highlight) the product [1] (4 June 2017). Now we can close the GraphBuilder window and open the Batch Processing tool (**Tools -> Batch Processing**).

Now, we will add both opened products by clicking **Add Opened** on the upper right (second from top). And click refresh. Unselect the **Keep source product name**. Then we click **Load Graph** at the bottom of the window and navigate to our saved graph and open it. We see that new tabs have appeared at the top of window corresponding to our operators.



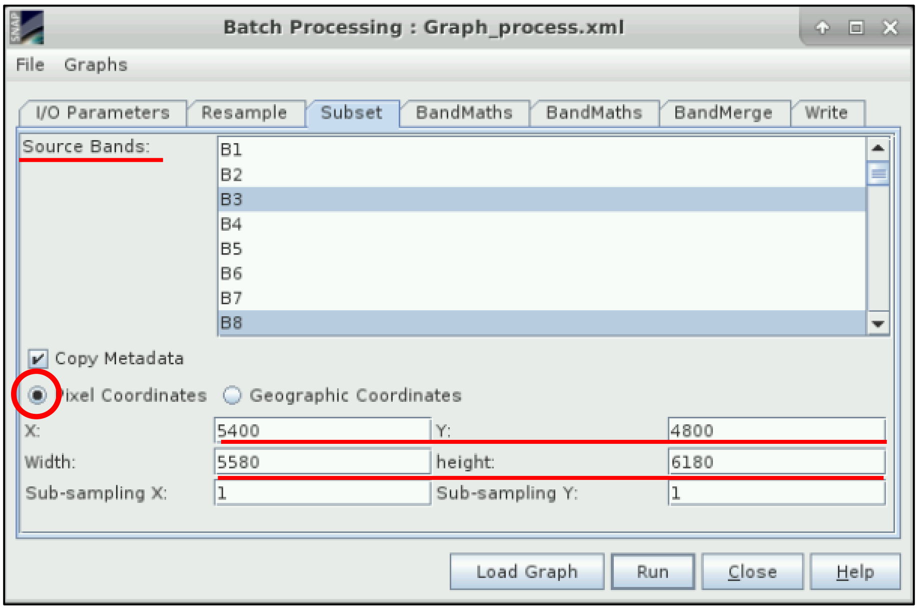
Now, let's set the parameters. In **Resample tab** we set:

Define size of resampled product: By reference band from source product: B2 (we will resample all the bands to 10m resolution). And at the bottom set **Upsampling method: Bilinear**



In the Subset tab we select bands: **B3, B8, B12** and **cloud_mask** (to select multiple hold Ctrl). And set:

Pixel coordinates to: **X: 5400 Y: 4800 Width: 5580 Height: 6180**



Next, we set the expression for the calculation of Normalized Burn Ratio (NBR). (See NOTE 2) In the **BandMaths** tab set:

Target band: NBR

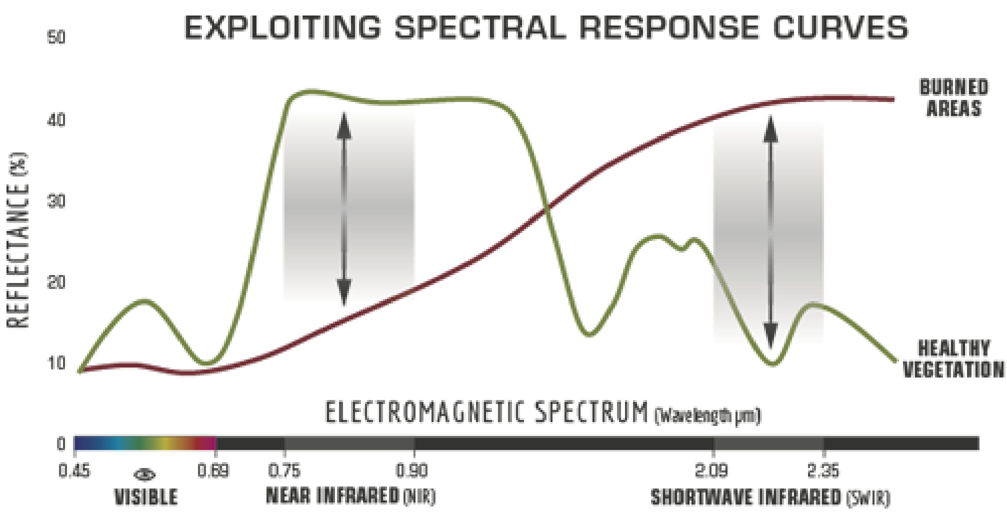
No-Data Value: NaN

Expression: `(B8 – B12)/(B8 + B12)`

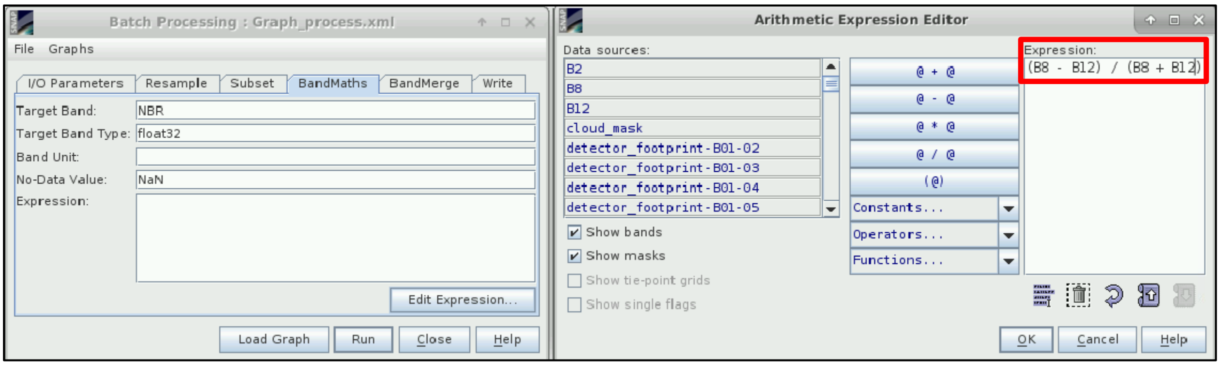
NOTE 2: The most commonly used metrics for burned area and burn severity mapping, derived from satellite data, is the normalized burn ratio (NBR).

$$NBR = \frac{NIR - SWIR}{NIR + SWIR}$$

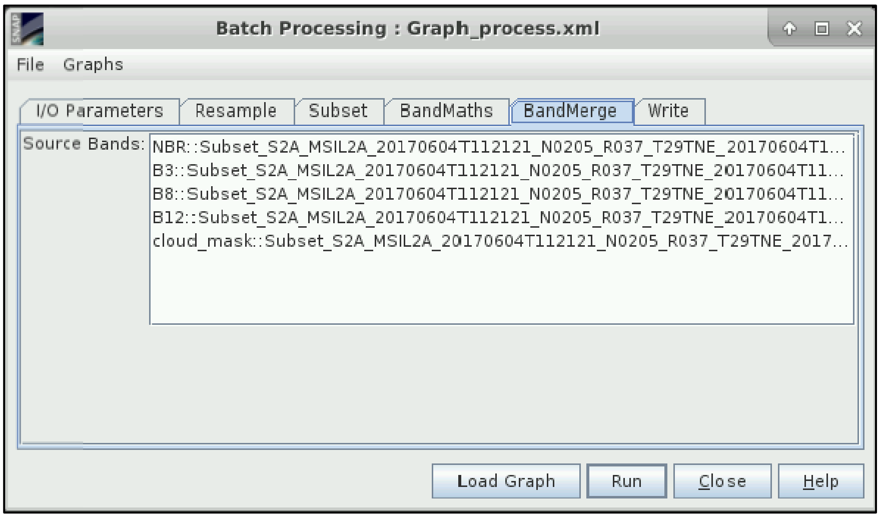
Healthy vegetation has very high near-infrared reflectance and low reflectance in the shortwave infrared portion of the spectrum. Burned areas on the other hand have relatively low reflectance in the near-infrared and high reflectance in the shortwave infrared band. A high NBR value generally indicates healthy vegetation while a low value indicates bare ground and recently burned areas.



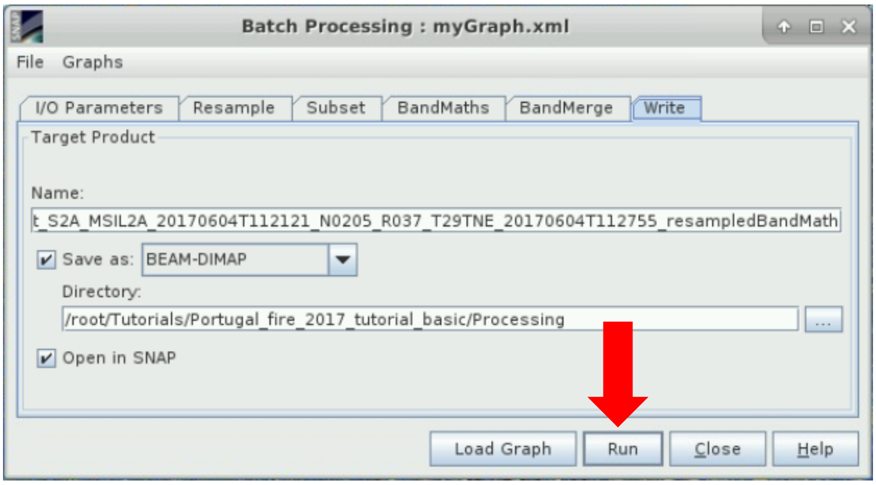
Credits: U.S. Forest service



Leave the defaults in the **BandMerge** tab.

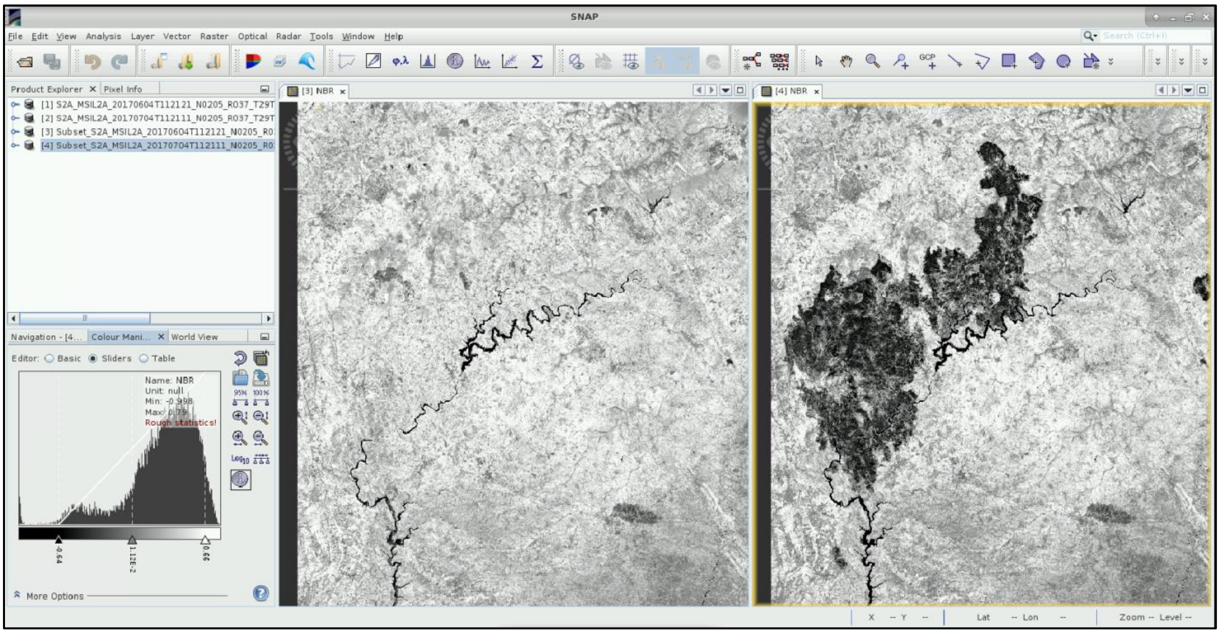


In the **Write** tab check that the name contains 20170604 but do not change anything. Set the output directory: */shared/Training/HAZA02_BurnedArea_Portugal_TutorialKit/Processing*



And let's click **Run.** This might take approximately 7 minutes depending on your machine.

Now, you should have two new products in the Product Explorer. Let's have a look at the subset products. For that, close all the view windows and Expand product [3]. In Bands double click the NBR band. Now do the same for product [4]. Go to **Window -> Tile Horizontally** and then in Navigation tab click Zoom All .

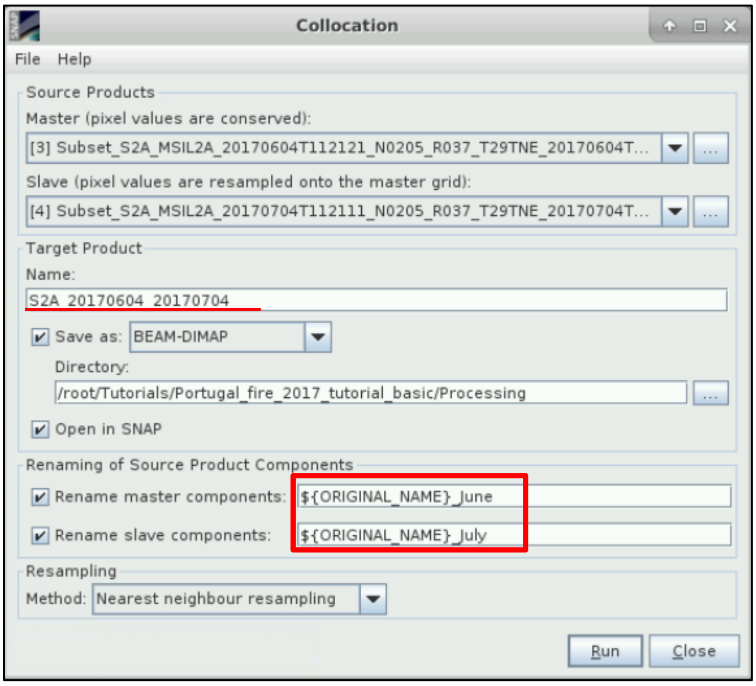


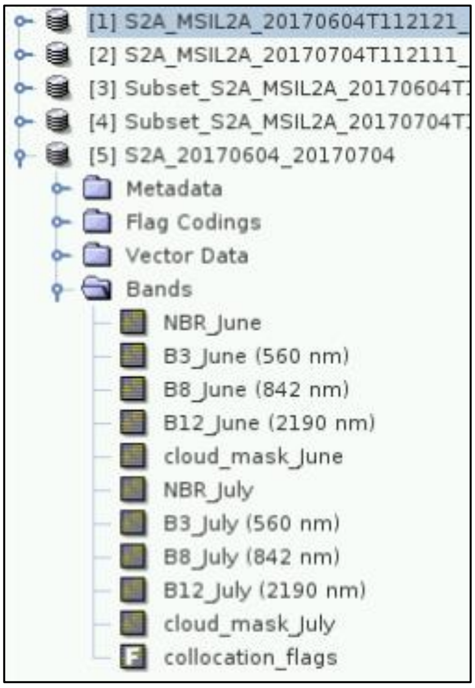
Close all view windows.

3.5 Collocation

Now we will merge the two pre-processed products so we can easily calculate the change in the pre- and post-fire NBR values. Go to **Raster -> Geometric Operations -> Collocation.**

In **Source Products** set product [3] as **Master** and product [4] as **Slave**.
In **Target Products** set **Name**: *S2A_20170604_20170704*





In **Renaming of Source Product Components** change to *${ORIGINAL_NAME}_June* and *${ORIGINAL_NAME}_July.*

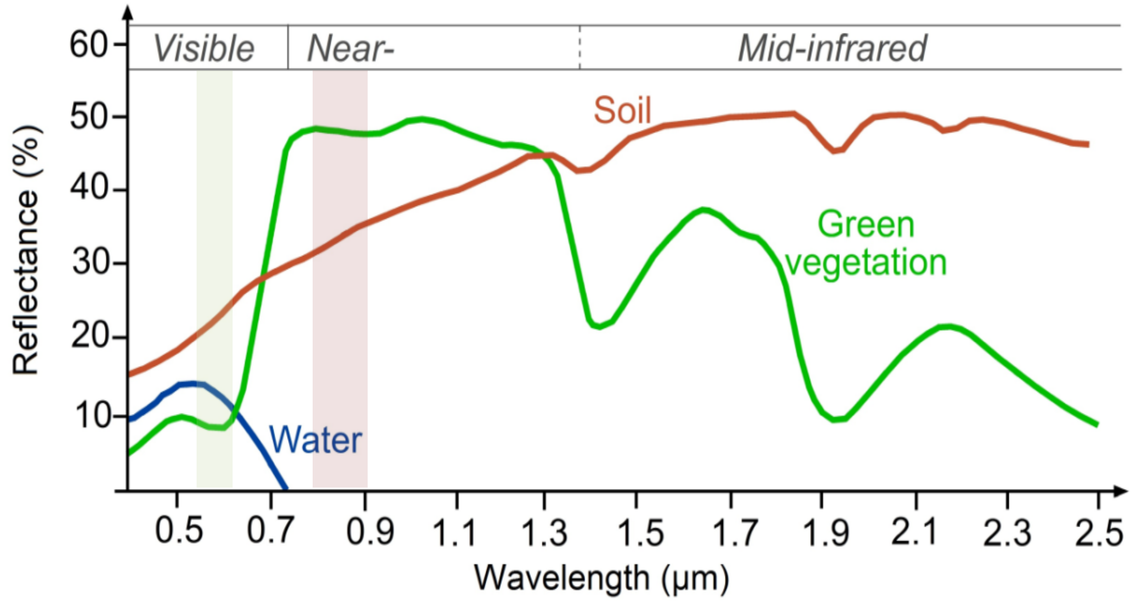
Set output **directory** to */shared/Training/HAZA02_BurnedArea_Portugal_TutorialKit/Processing.* Click **Run**. A new product [5] has been created in Product Explorer.

3.6 Water and cloud mask

Water bodies can show similar NBR difference in certain circumstances, therefore, it is necessary to mask them out. We also need to mask out clouds occurring in either input image. For this purpose, we will create a single combined water and cloud mask. To detect the water bodies we will use the Normalized Difference Water Index - NDWI (See NOTE 3).

NOTE 3: The Normalized Difference Water Index (NDWI) proposed by McFeeters[2] is designed to: maximize the reflectance of the water body in the green band; minimize the reflectance of water body in the NIR band. McFeeters's NDWI is calculated as:

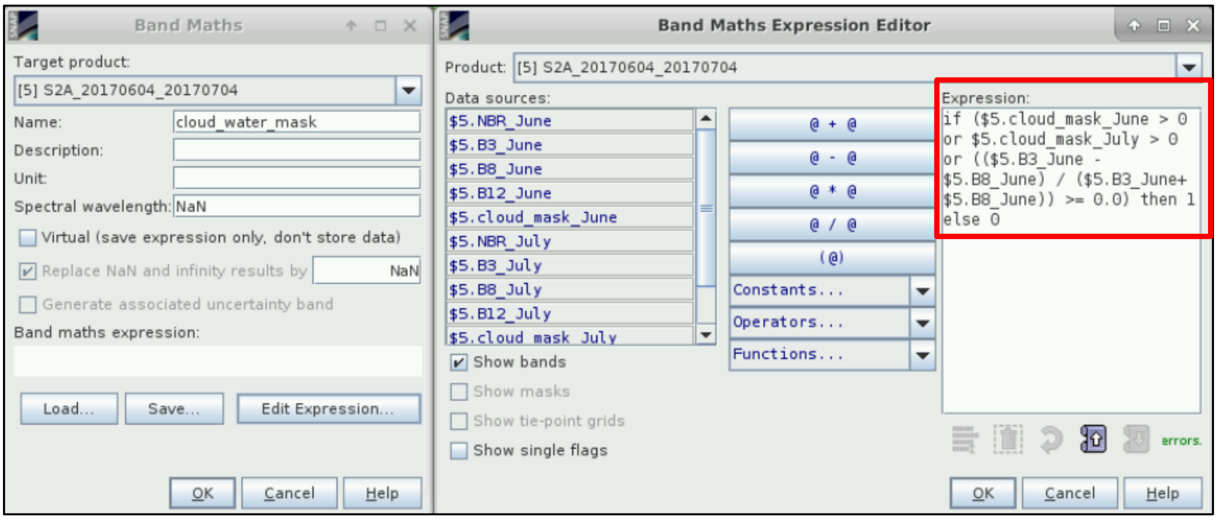
$$NDWI = \frac{Green - NIR}{Green + NIR} = \frac{B3 - B8}{B3 + B8}$$

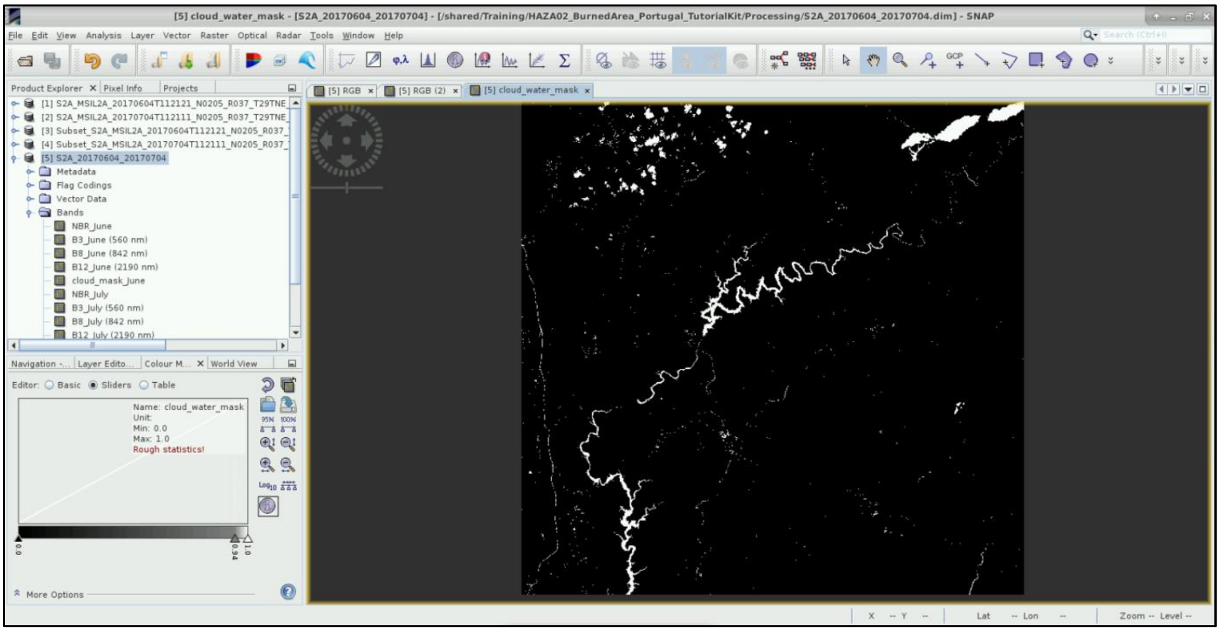


Right click on the newly created stacked product [5], select BandMaths and set:

Target band: cloud_water_mask

Expression: `if (cloud_mask_June > 0 or cloud_mask_July > 0 or ((B3_June - B8_June)/ (B3_June + B8_June))>= 0.0) then 1 else 0`





3.7 *Burned areas and burn severity*

To identify recently burned areas and differentiate them from bare soil and other non-vegetated areas the difference between pre-fire and post-fire NBR, the delta Normalized Burn Ratio (dNBR) is frequently used.

$$dNBR = NBR_{pre-fire} - NBR_{post-fire}$$

However, the dNBR is an absolute difference which can present problems in areas with low pre-fire vegetation cover, where the absolute change between pre-fire and post-fire NBR will be small. In such cases the relativized version of burn severity is advantageous. In this tutorial we will use the Relativized Burn Ratio (RBR)[3].

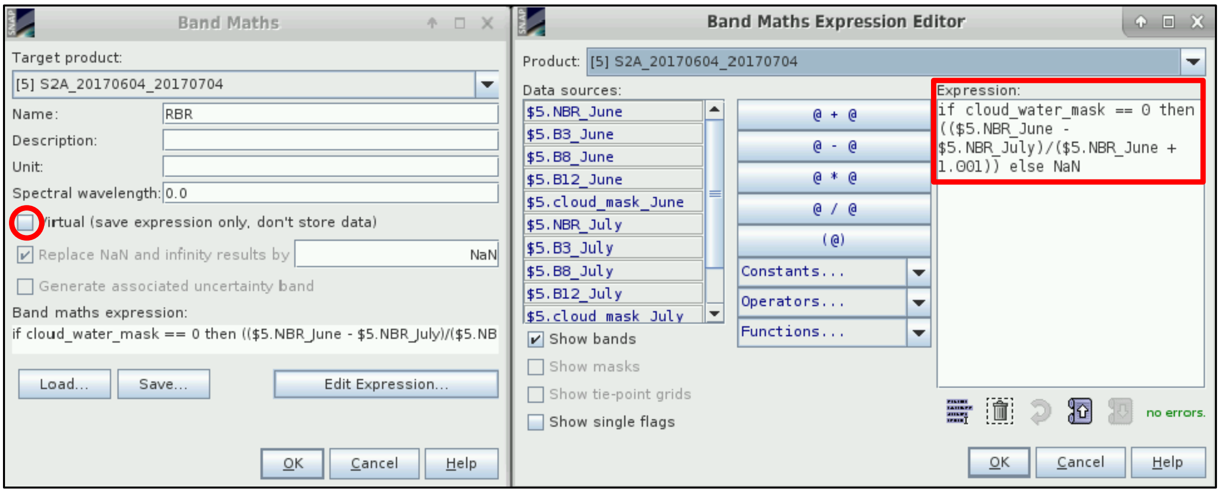
$$RBR = \left(\frac{dNBR}{(NBR_{pre-fire} + 1.001)}\right) = \left(\frac{NBR_{pre-fire} - NBR_{post-fire}}{(NBR_{pre-fire} + 1.001)}\right)$$

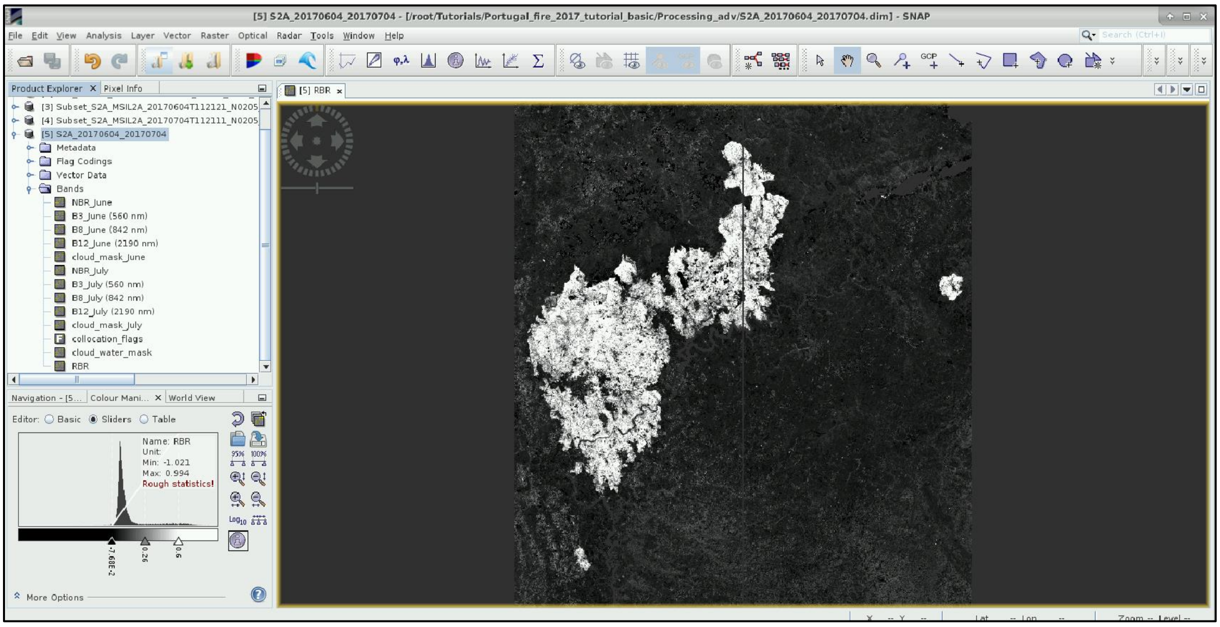
In this step we will also apply the cloud and water mask we have created. Again, we will create new band by going to BandMaths in product [5] and we set:

Target band: RBR

Expression: `if cloud_water_mask == 0 then ((NBR_June - NBR_July)/(NBR_June + 1.001)) else NaN`

Deselect **Virtual (save expression only, don't store data)** – we want the band to be stored!

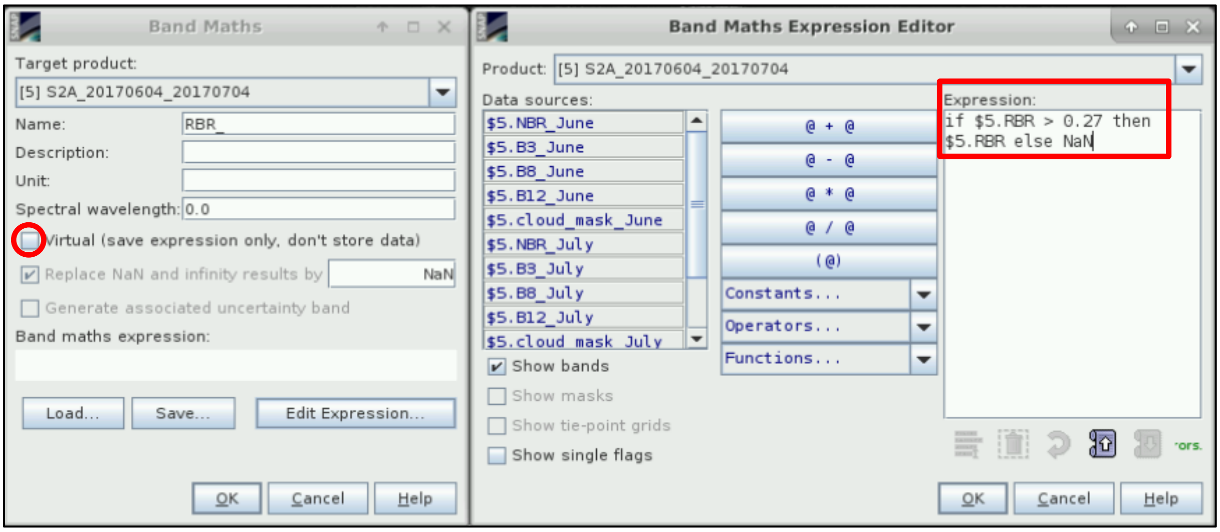


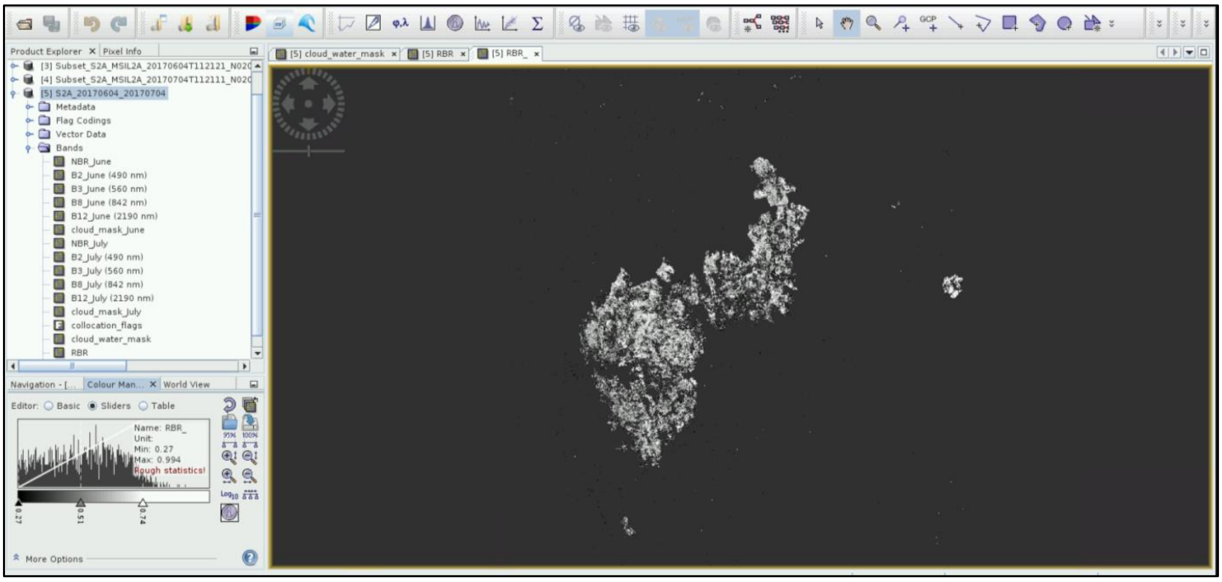


The burned pixels appear much brighter as the change in between pre- and post-fire values is much higher. Now let’s create another new band that will only contain burned areas. We will set the threshold for pixel to be classified as burned to > 0.27. Right click product [5] and for to **BandMaths** again. Set:

Target band: RBR_
No-Data Value: NaN
Expression: `if RBR > 0.27 then RBR else NaN`

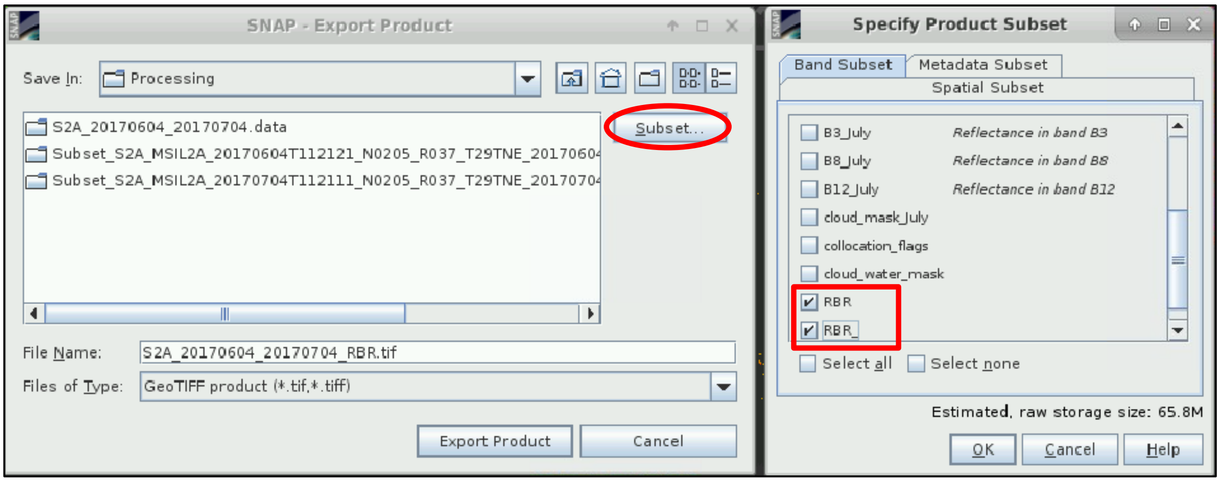
Deselect **Virtual (save expression only, don’t store data)** – we want the band to be stored!





3.8 *Export as GeoTIFF*

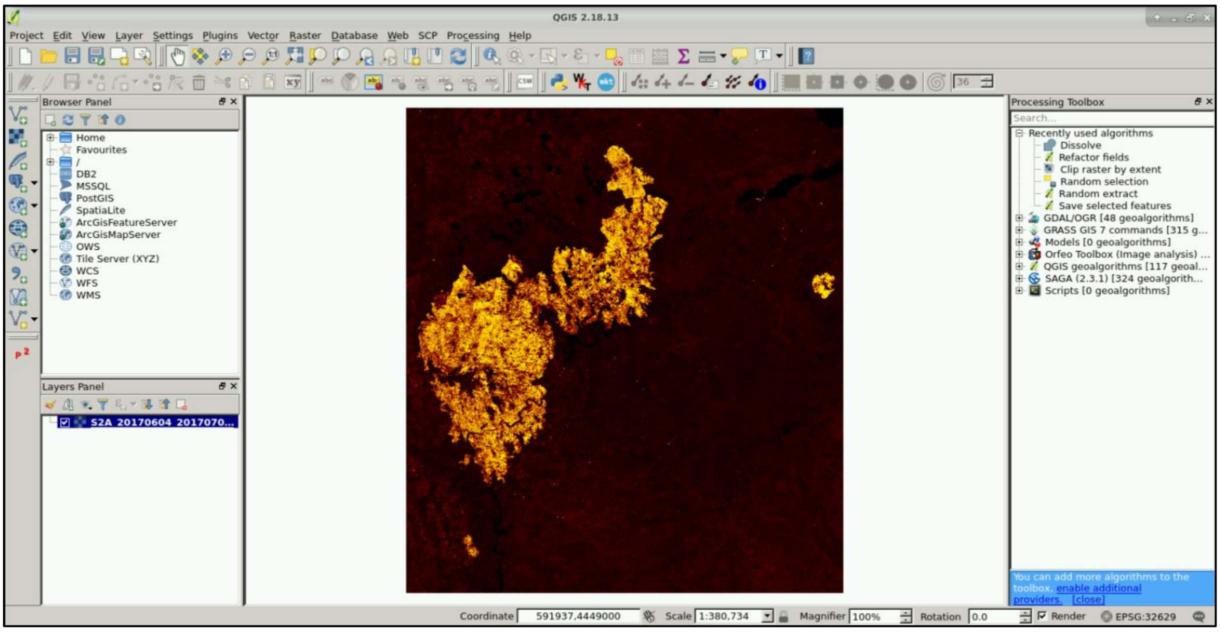
Close all view windows. In Product Explorer select (highlight) product [5], go to **File -> Export -> GeoTiff** (NOT! Geotiff/Big Tiff). In the dialog that opens click **Subset -> Band Subset** (second tab) and select only bands RBR and RBR_ click Ok and save the file as *S2A_20170604_2017_0704_RBR.tif* to the *Processing* folder. In the dialog that appears (No Flag Dataset Selected) click **No**.



Now we can import the image to another GIS/ Remote sensing software for further processing or map creation. In this tutorial we will use QGIS.

3.9 Visualization

Go to *Application -> Processing -> QGIS Desktop* (or use the desktop icon). Click on the **Add Raster Layer** button located in the left panel ( ), navigate to:
/shared/Training/HAZA02_BurnedArea_Portugal_TutorialKit/Processing
select the *S2A_20170604_2017_0704_RBR.tif* and click **Open**.



We can change the colour scheme to classes proposed by the United States Geological Survey (USGS) to interpret the burn severity (See NOTE 4).

NOTE 4: The United States Geological Survey (USGS) proposed a classification table to interpret the burn severity (dNBR), which can be seen in the table below[4]. In our data the lowest value is -0.08, demonstrating that there were no values related to detectable regrowth. The large number of ambiguous pixels (yellow) is caused by the one month difference between our pre- and post-fire images. Due to the severe drought the vegetation likely degraded significantly between these two dates producing similar NBR difference as low severity burn.
While we are using RBR and not dNBR, we will apply the same classes as defined below for visualization. It is generally difficult to derive the burn severity without ground data to relate the values to.

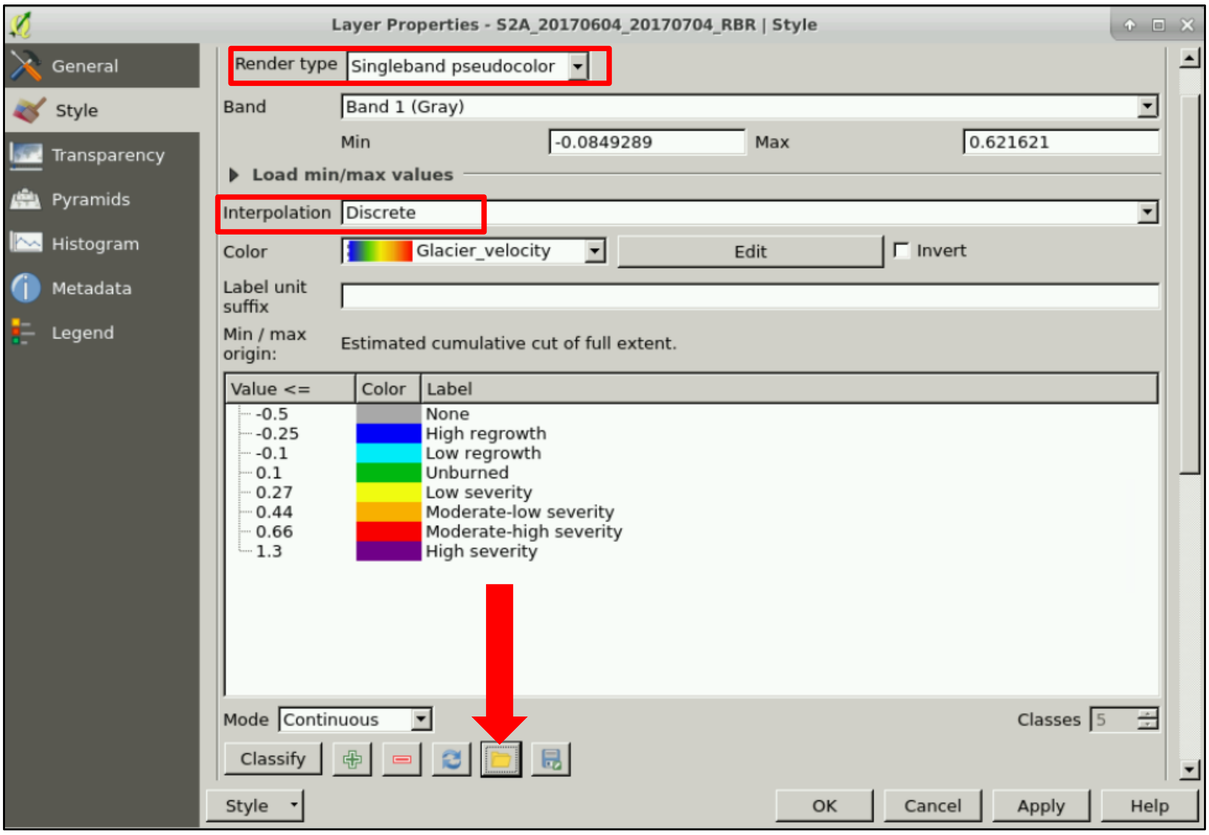
Severity Level	dNBR range (scaled by 10^3)		dNBR range (not scaled)
Enhanced Regrowth, high (post-fire)	-500 to -251		-0.500 to -0.251
Enhanced Regrowth, low (post-fire)	-250 to -101		-0.250 to -0.101
Unburned	-100 to +99		-0.100 to +0.099
Low Severity	+100 to +269		+0.100 to +0.269
Moderate-low Severity	+270 to +439		+0.270 to +0.439
Moderate-high Severity	+440 to +659		+0.440 to +0.659
High Severity	+660 to +1300		+0.660 to +1.300

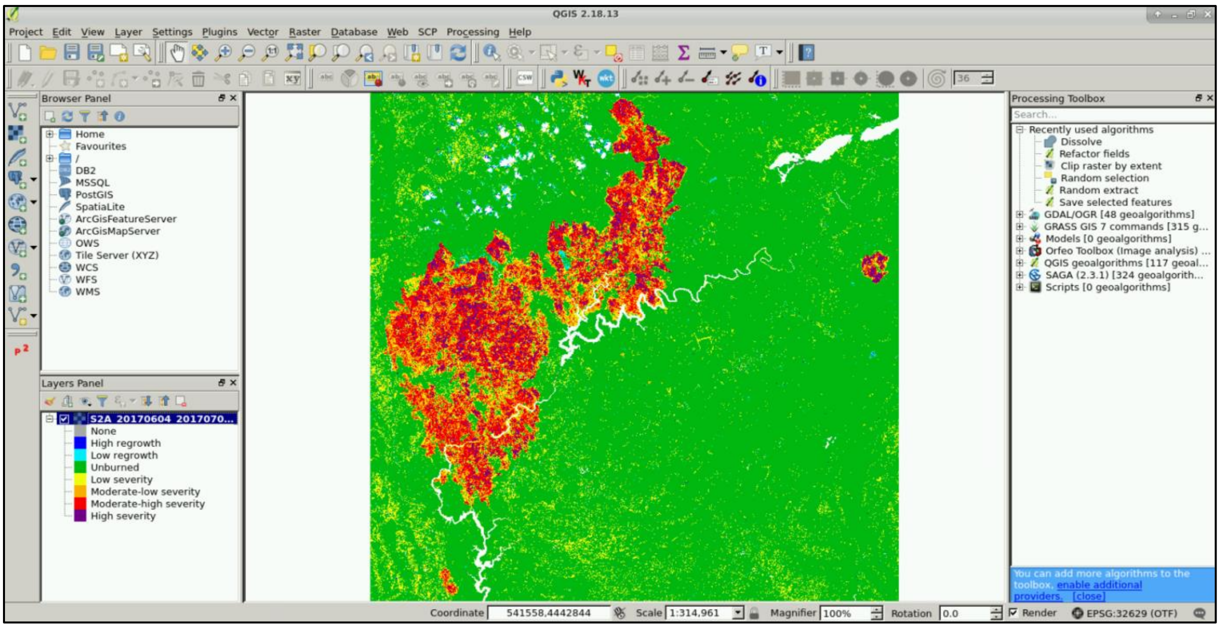
Credits: UN-SPYDER Knowledge Portal

We will use a predefined file to import the colour pallete. Right-click on the opened raster-layer in the **Layers Panel** (lower left) and go to **Properties**. In the **Style** tab set:

Render type: Singleband pseudocolor
Interpolation: Discrete
Band: Band 1 (BRB)

Then click **Load colour map from file** to import predefined colour map. Navigate to the *Auxdata* folder and open *Colour_palete_RBR.txt*. Click OK.

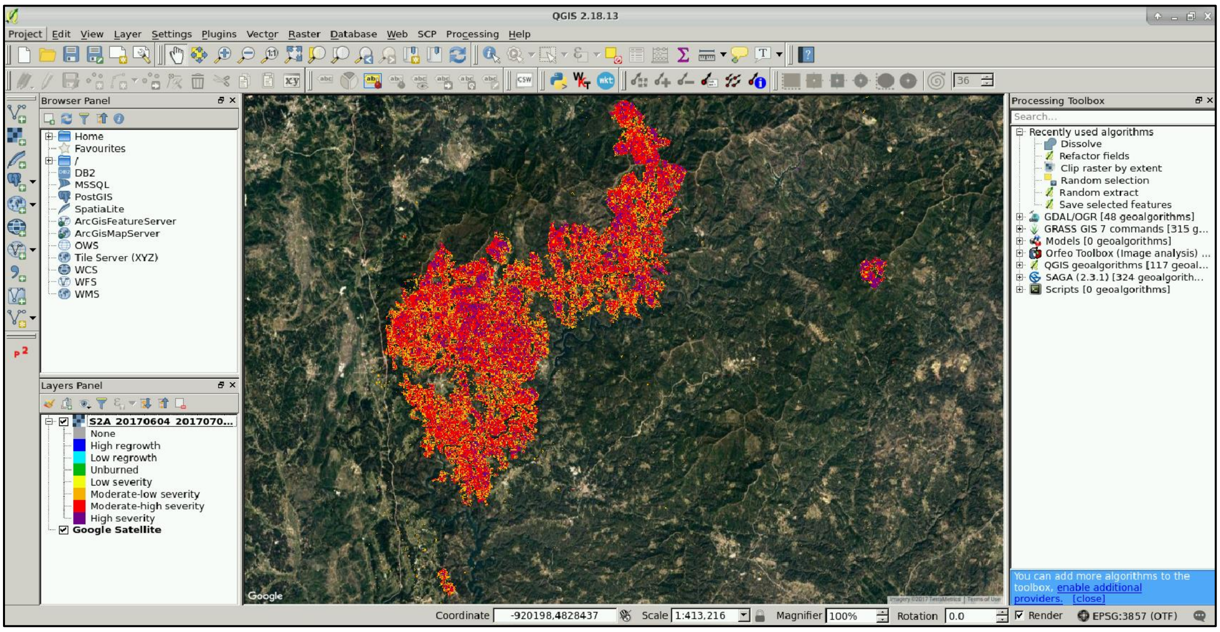




To visualize only the Moderate to High severity areas go to **Properties** again and **in Style** tab set band to *Band 2*. You will have to import the colour map again the same way as we have done for Band 1. Click OK.

Finally, we can add a base-map to link our water masks to GIS data. Click on **Web -> OpenLayers plugin -> Google Maps -> Google Satellite** (See NOTE 5). Then in the Layer Panel click on the Google Satellite layer and drag it below our raster layer.

> NOTE 5: In case the **OpenLayers** plugin is not installed, click on **Plugins -> Manage and Install Plugins.** Select the *'All'* tab on the right side panel and write "OpenLayers plugin" on the search box. Select the plugin on the list and click 'Install Plugin'. Restart QGIS to finalize the installation.



To download the results to your local computer see section **4.2 Downloading the outputs from VM**.

THANK YOU FOR FOLLOWING THE EXERCISE!

4 Extra steps

4.1 Atmospheric correction (TIP 1)

Solar radiation reflected by the Earth's surface to satellite sensors is affected by its interaction with the atmosphere. The objective of applying an atmospheric correction is to determine true surface (Bottom-Of-Atmosphere, BOA) reflectance values from the Top-Of-Atmosphere (TOA) reflectance values, by removing atmospheric effects. (See NOTE 6) Atmospheric correction is especially important in cases where multi-temporal images are compared and analysed as it is in our case (pre-fire and post-fire images).

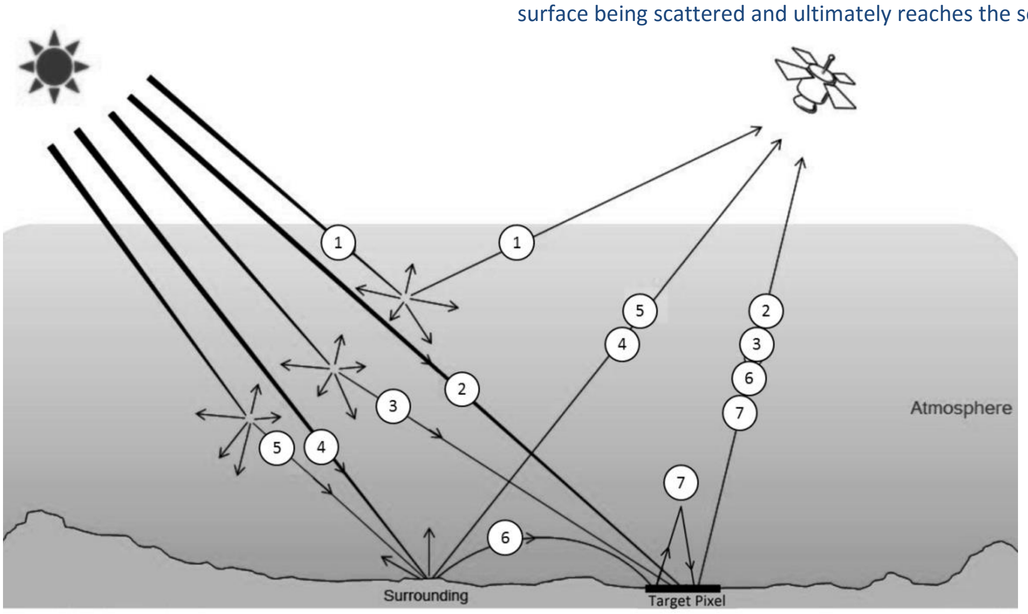
NOTE 6: The radiance reaching the sensor is a result of following components:

1. Radiation from the sun and, scattered into the field of view of the sensor by the atmosphere without reaching the surface.
2. Direct radiation that goes through the atmosphere without being absorbed or scattered, reaches the sensor after being reflected by the target pixel.
3. Radiation scattered by the atmosphere into the target pixel and reflected back towards the sensor.

4. & 5. Direct or diffuse radiation reflected or scattered by the surrounding areas into the field of view of the sensor. This effect is so called "adjacency effect" or "blurring effect".

6. Diffuse radiation coming from the adjacent features into the field of view of the sensor.

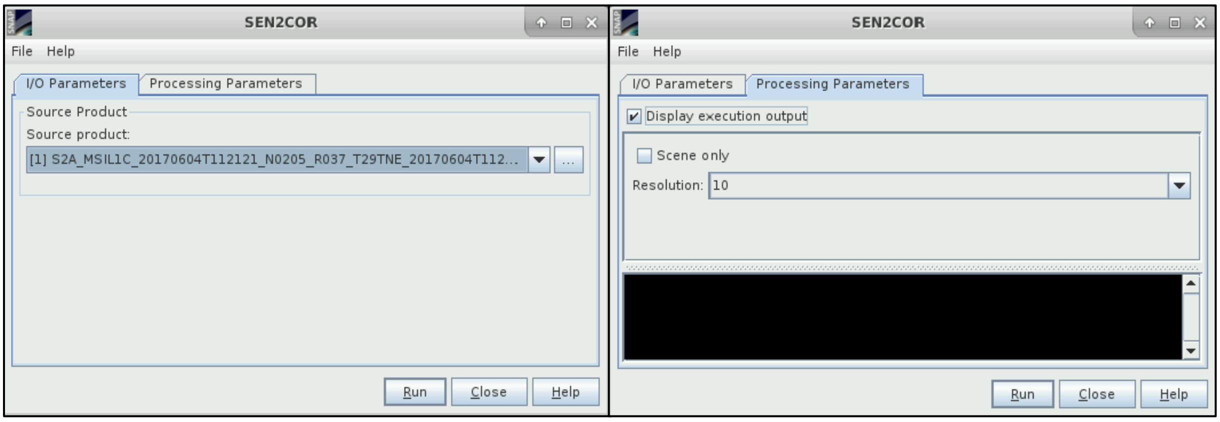
7. So-called trapping effect and it is a part of the radiation reflected from the surface into the air column above the surface being scattered and ultimately reaches the sensor.



Credits: Mousivand et al.. 2015[1]

In this tutorial we will use the Sen2Cor processor. Sen2Cor is a processor for Sentinel-2 Level 2A product generation and formatting; it performs the atmospheric, terrain and cirrus correction of Top-Of-Atmosphere Level 1C input data. Sen2Cor creates Bottom-Of-Atmosphere, optionally terrain and cirrus corrected reflectance images; additional, Aerosol Optical Thickness, Water Vapour, Scene Classification Maps and Quality Indicators for cloud and snow probabilities.

In the I/O Parameters make sure product [1] is selected. In the Processing Parameters tab change the resolution to 10 m. Click Run …

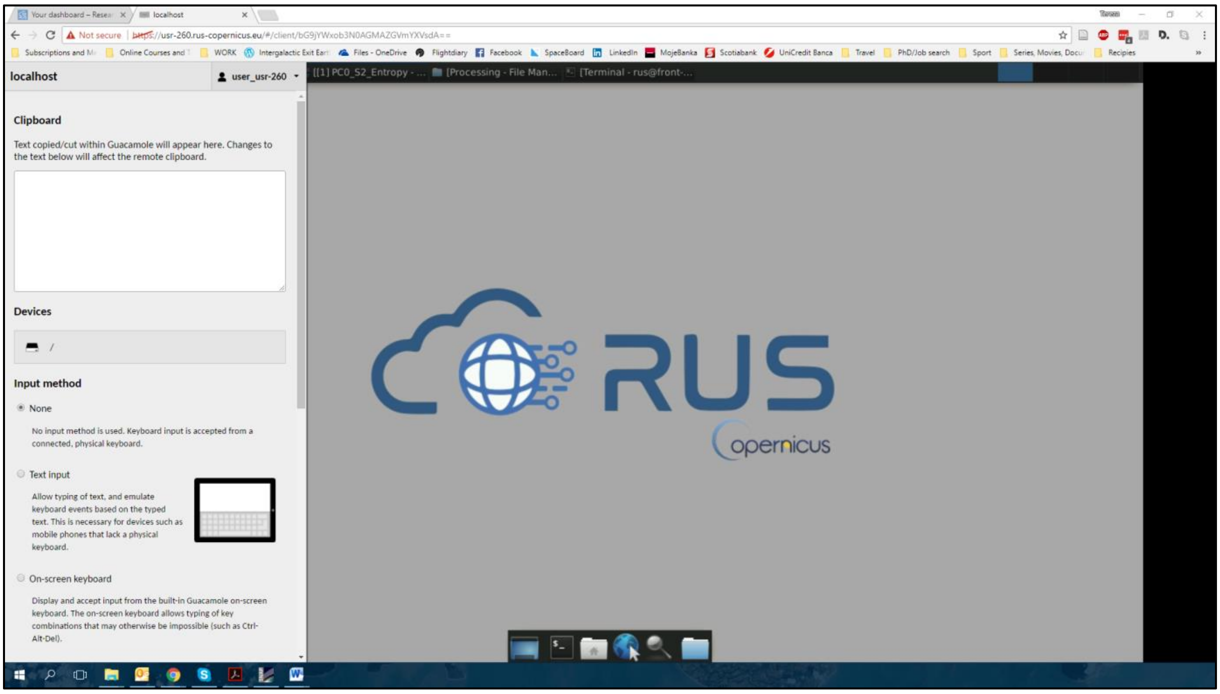


Repeat for product [2]. This is rather a time demanding process and requires approximately 30 minutes per image (with 8GB RAM).

The process creates two new Level 2-A product in the .SAFE format in the
/shared/Training/HAZA02_BurnedArea_Portugal_TutorialKit/Original

4.2 Downloading the outputs from VM

Press **Ctrl+Alt+Shift.** A pop-up window will appear on the left side of the screen. Click on bar below **Devices**, the folder structure of your VM will appear. Navigate to your Processing folder and **double click any file you want to download.**

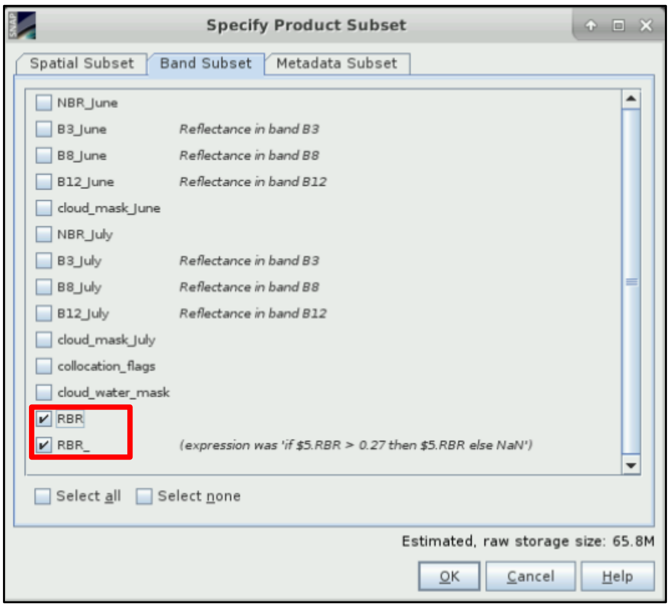


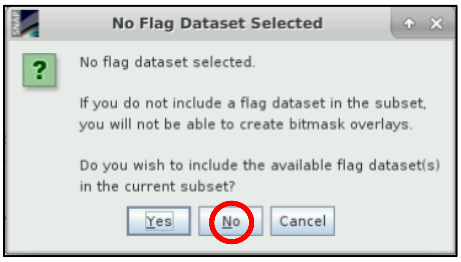
4.3 Export as KMZ (Google Earth)

If we want to view the product for example in Google Earth, unfortunately we must first reproject it to WGS 84 Lat/Lon coordinate system (EPSG 4326), as the KMZ format does not accept other projections, set colour scheme, export to KMZ format readable by Google Earth and then download results to our local PC for visualization as the RUS VM does not support Google Earth installation.

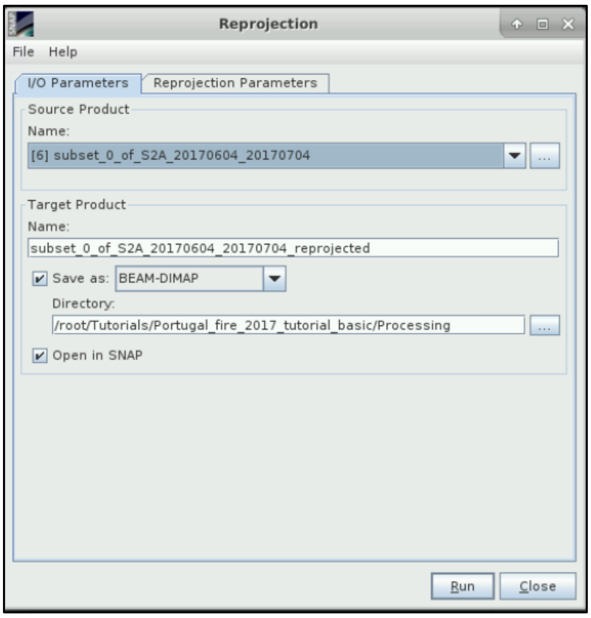
It is time consuming and unnecessary to reproject the whole product [5] therefore we will first apply band subset. Click on product [5] so it is highlighted and then go to **Raster -> Subset**. Do not change anything in the **Spatial Subset** tab and go to the **Band Subset** tab. Deselect all the bands except RBR and RBR_. Click OK.

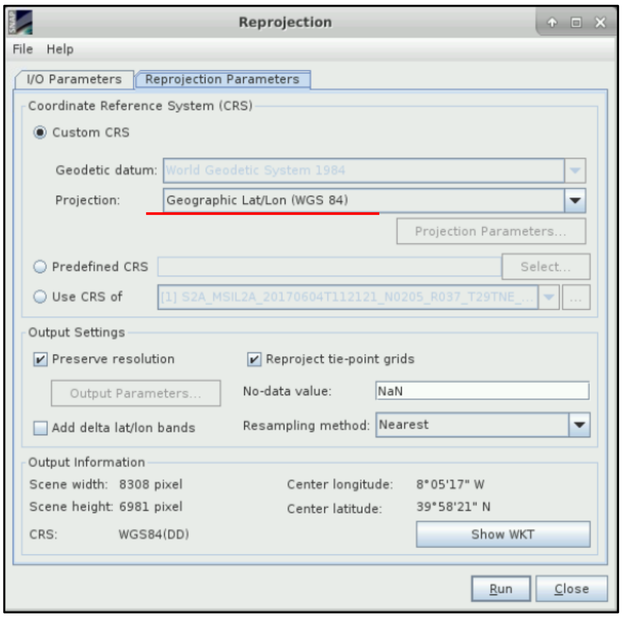
In the **“No Flag dataset selected”** dialog click “**No**”.





Product [6] was created containing only the two selected bands. To reproject from the default UTM33 projection to Lat/Long we go to **Raster -> Geometric Operations -> Reproject**. Check that the new subset [6] is selected as input and the Processing folder is set as the target directory. In the **Projection Parameters** tab make sure the Projection is set to Geographic Lat/Lon (WGS84) and click Run.





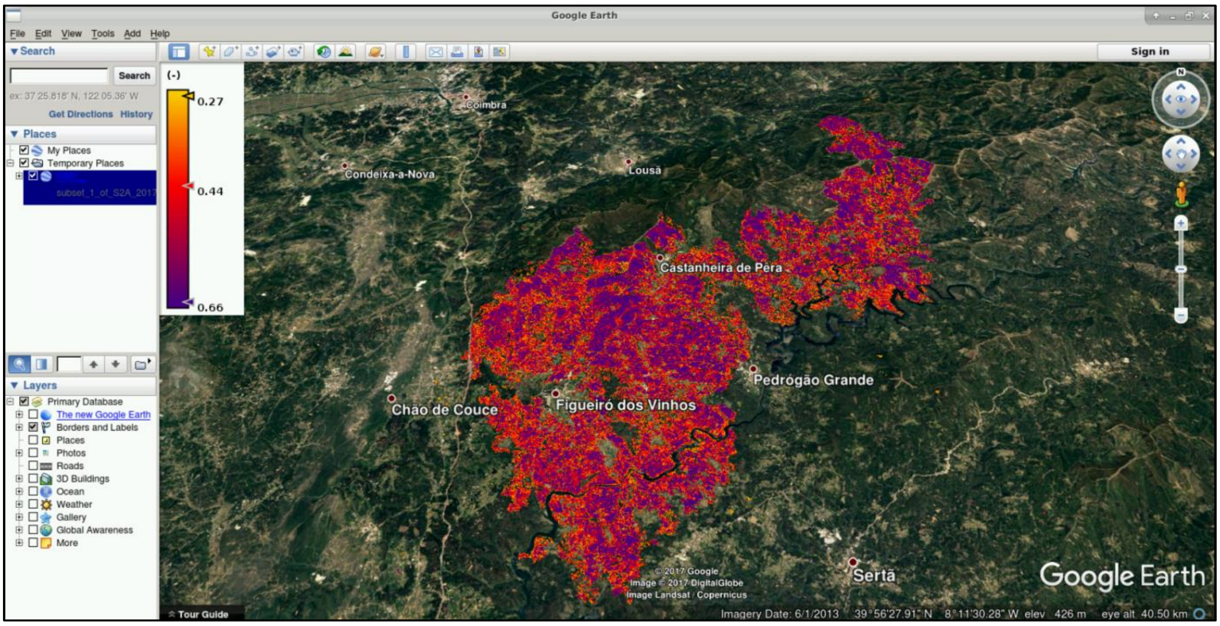
Go to **Colour Manipulation** Tab in the lower left corner and right click the colour bar between existing sliders – add 2 new sliders. Then go to table and set colours and values as in the table in NOTE 5.

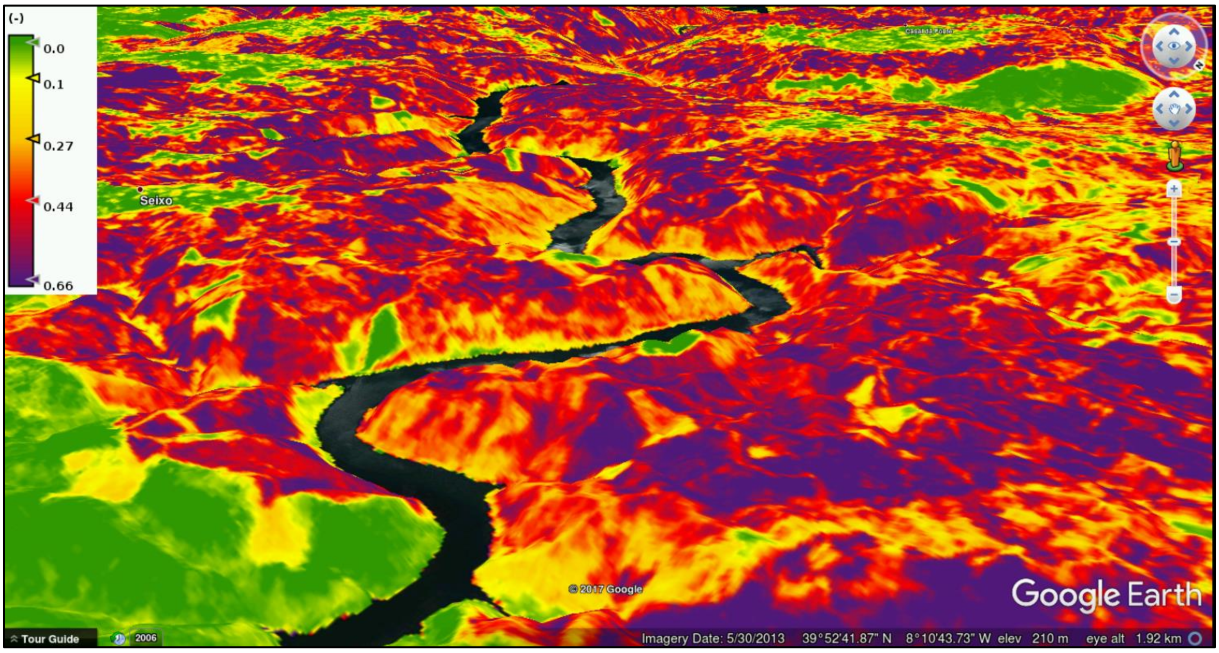
To export the KMZ layer, click on the RBR View to activate it and go to **File -> Export -> Other -> View as Google Earth KMZ** (only the active band open in the view window will be saved)

Save to the Processing folder as: *Burn_severity_20170704.kmz*. Now open or activate the BRB_ layer and export it as well (*Burned_area_20170704.kmz)*

Download the KMZ files to your laptop following instructions in section 4.2.

Open Google Earth (Applications -> Internet -> Google Earth) if you have in installed. Go to **File -> Open** and open the downloaded layers. Both layers will appear as overlays in the Places panel on the left (activate and deactivate layer and legend) with the name of the original band (not the saved KMZ).





5 Further reading and resources

The European Forest Fire Information System (EFFIS) – link

Normalized Burn Ratio by Humbold State University – link

UN-SPYDER Knowledge Portal – Normalized Burn Ratio – link

6 References

1. Mousivand, A., Verhoef, W., Menenti, M. & Gorte, B. Modeling Top of Atmosphere Radiance over Heterogeneous Non-Lambertian Rugged Terrain. *Remote Sens.* **7,** 8019–8044 (2015).
2. Du, Y. *et al.* Water Bodies' Mapping from Sentinel-2 Imagery with Modified Normalized Difference Water Index at 10-m Spatial Resolution Produced by Sharpening the SWIR Band. *Remote Sens.* **8,** 354 (2016).
3. Parks, S. A., Dillon, G. K. & Miller, C. A New Metric for Quantifying Burn Severity: The Relativized Burn Ratio. *Remote Sens.* **6,** 1827–1844 (2014).
4. Keeley, J. E. Fire intensity, fire severity and burn severity: a brief review and suggested usage. *Int. J. Wildland Fire* **18,** 116–126 (2009).

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