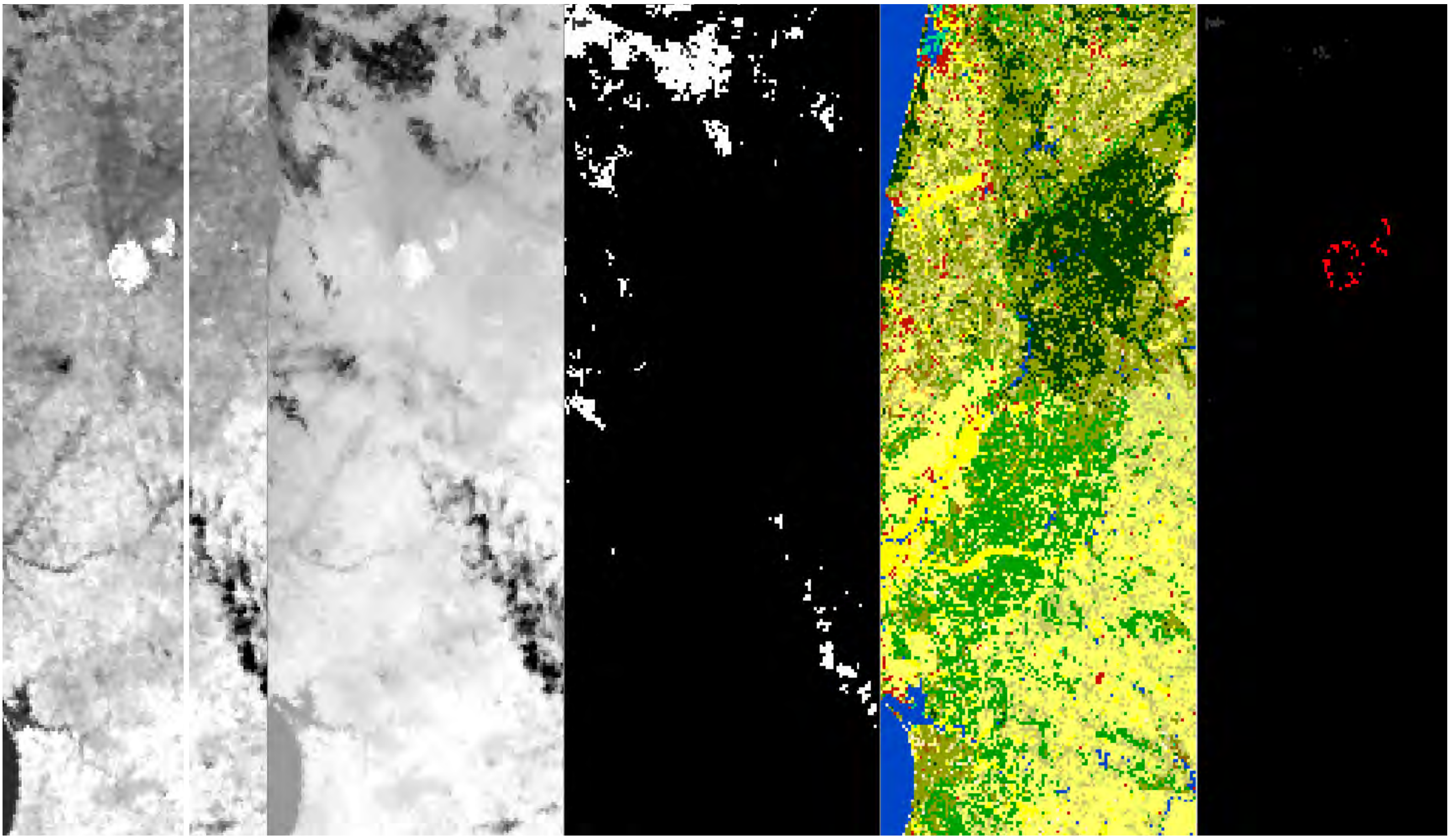

TRAINING KIT – HAZA04

ACTIVE FIRE DETECTION WITH SENTINEL-3 SLSTR (SNAP)
JUNE 2017, PORTUGAL

Research and User Support for Sentinel Core Products

The RUS Service is funded by the European Commission, managed by the European Space Agency and operated by CSSI and its partners.

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

Cover images produced by RUS Copernicus

The following training material has been prepared by Serco Italia S.p.A. within the RUS Copernicus project.

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Table of Contents

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. 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, 156 fires erupted across the country, particularly in mountainous areas 200 km (120 mi) north-northeast of Lisbon.

Portugal's fires have burnt 520,000 hectares of forest this year, 52 times the size of Lisbon and representing nearly 60 % of the total area burnt in the entire European Union in 2017. The amount of land burnt is the highest ever in Portugal's history.

2 Training

Approximate duration of this training session is two hours.

The Training Code for this tutorial is HAZA04. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the RUS portal and open a User Service request from Your RUS service → Your dashboard.

2.1 Data used

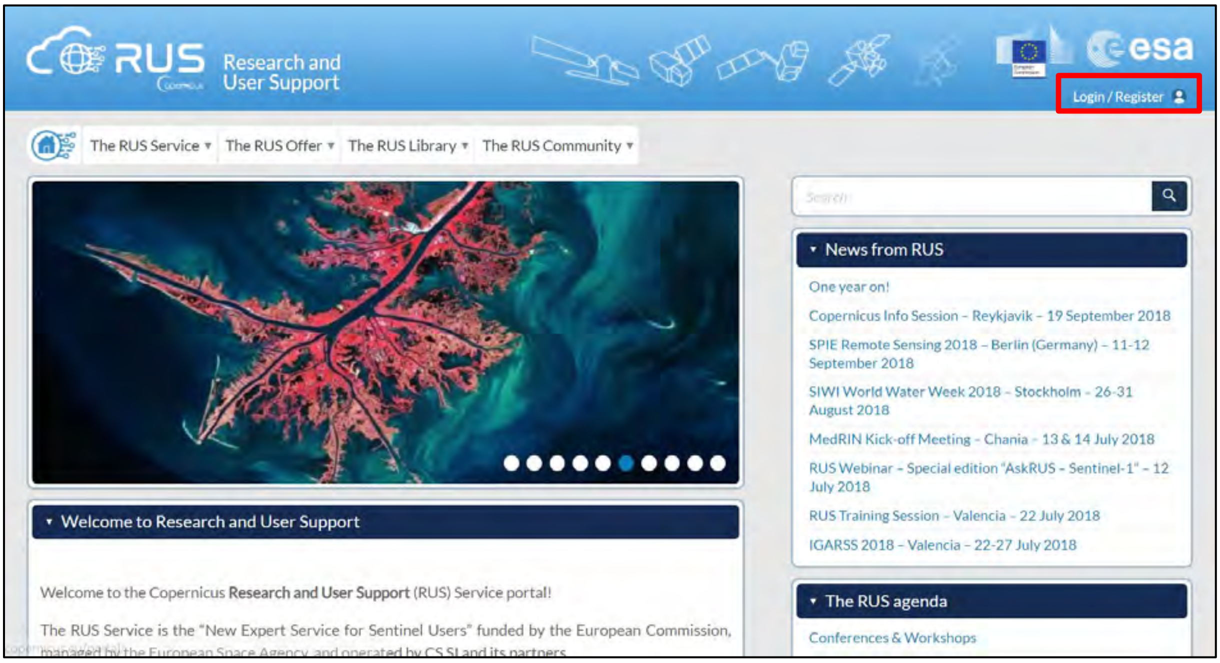
- Two cloud-free Sentinel-3A Level 1B RBT products acquired on June 18, 2017 (after the main event). [downloadable @ https://scihub.copernicus.eu/]
  S3A_SL_1_RBT____20170618T104548_20170618T104848_20170618T125104_0179_019_051_2340_SVL_O_NR_002.zip
  S3A_SL_1_RBT____20170618T220242_20170618T220542_20170619T003422_0179_019_058_0539_SVL_O_NR_002.zip

2.2 Software in RUS environment

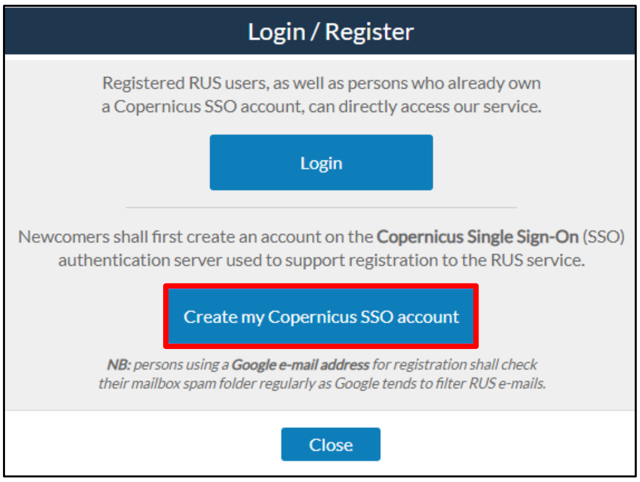
Internet browser, SNAP + Sentinel-3 Toolbox, QGIS, (Extra steps: Google Earth)

3 Register to RUS Copernicus

To repeat the exercise using a RUS Copernicus Virtual Machine (VM), you will first have to register as a RUS user. For that, go to the RUS Copernicus website (www.rus-copernicus.eu) and click on ***Login/Register*** in the upper right corner.

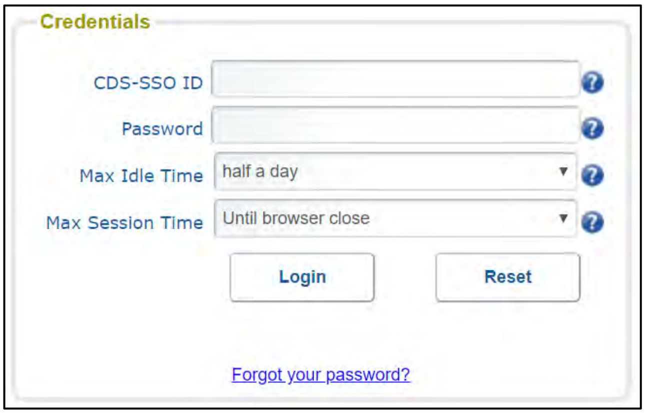


Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click ***Register***.

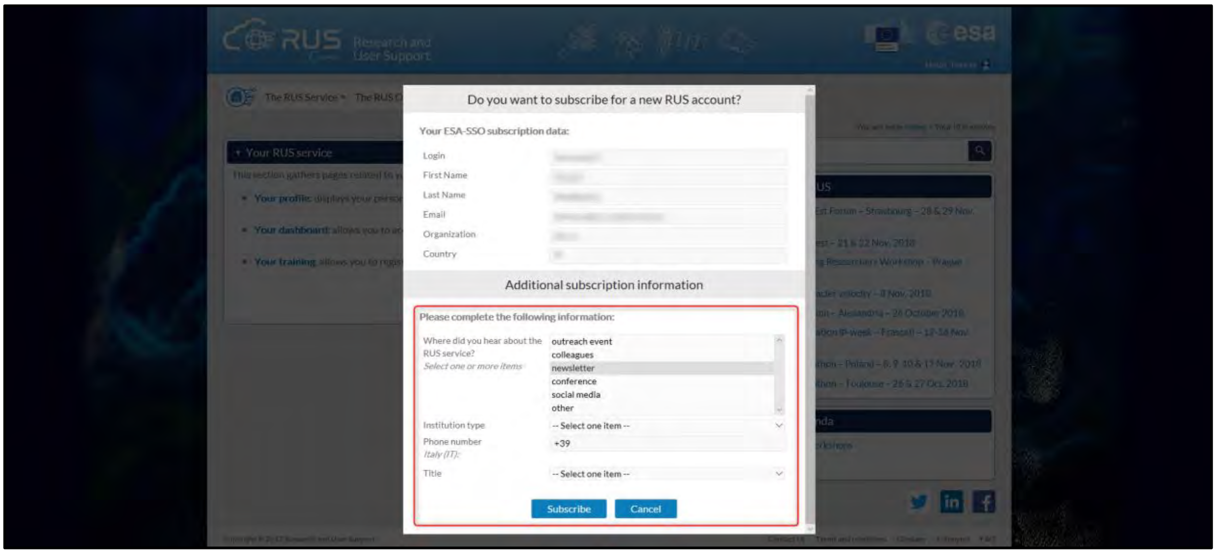


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

You can now return to https://rus-copernicus.eu/, click on ***Login/Register***, choose ***Login*** and enter your chosen credentials.

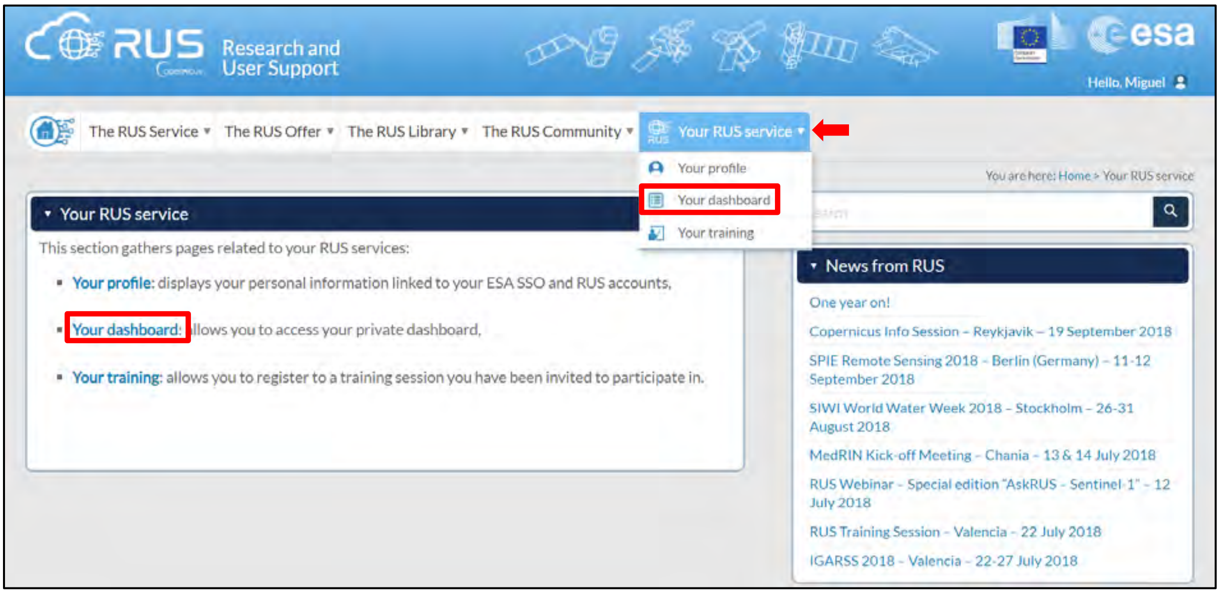


Upon your first login you will need to enter some details. You must fill all the fields.

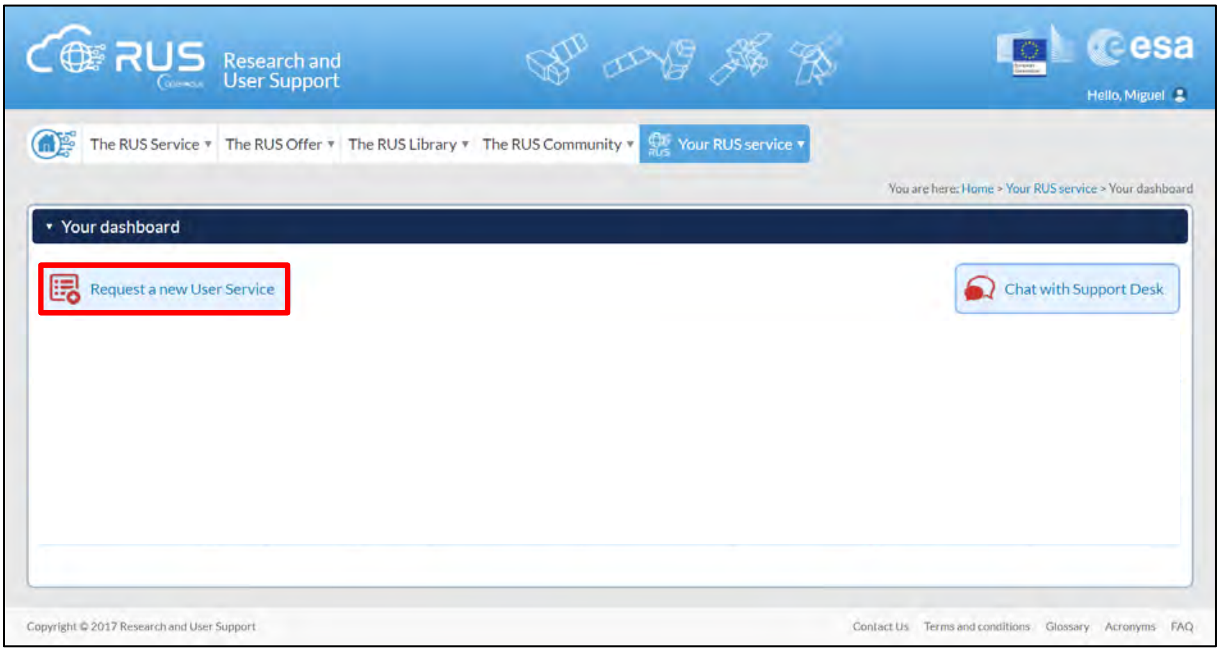


4 Request a RUS Copernicus Virtual Machine

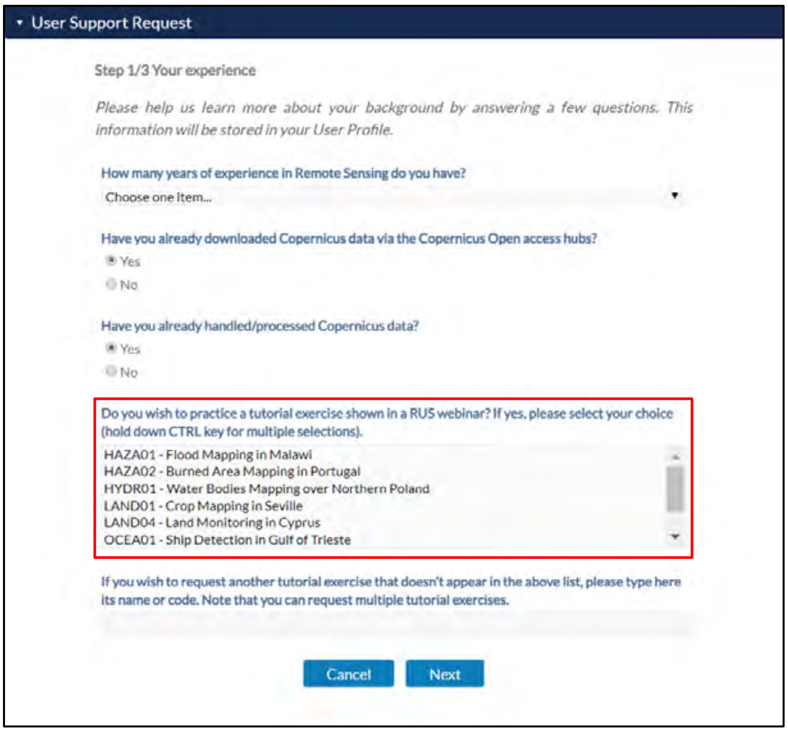
Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on ***Your RUS Service* → *Your Dashboard***.



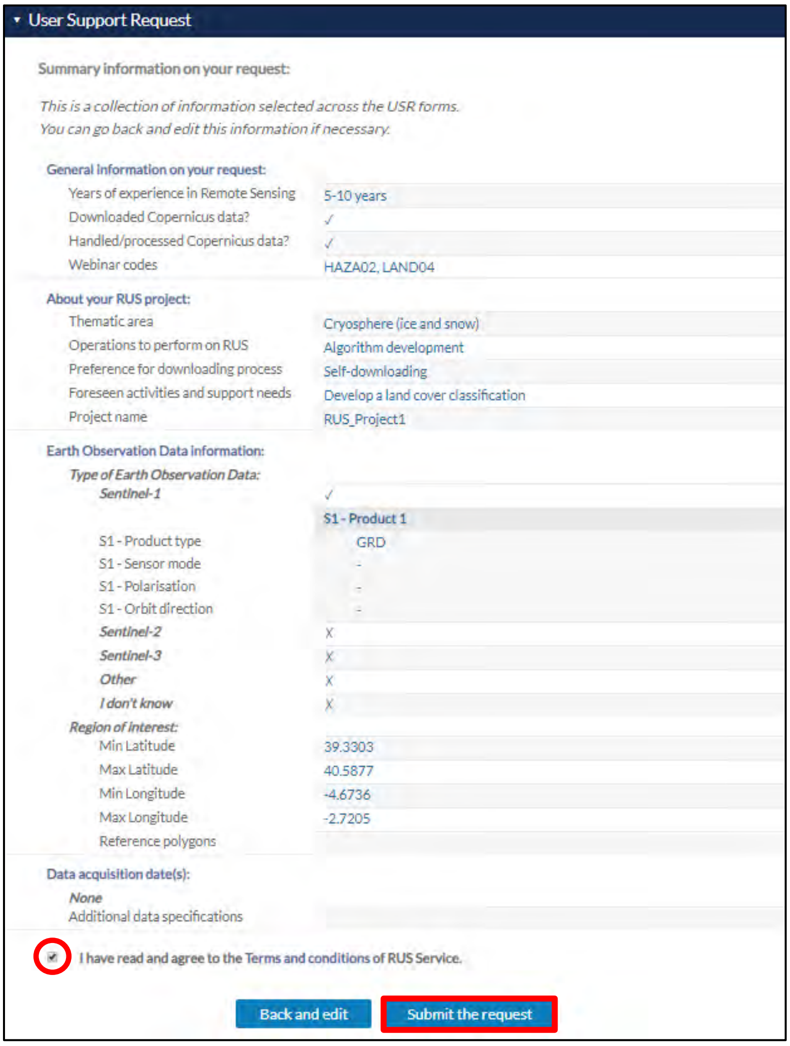
Click on ***Request a new User Service*** to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.



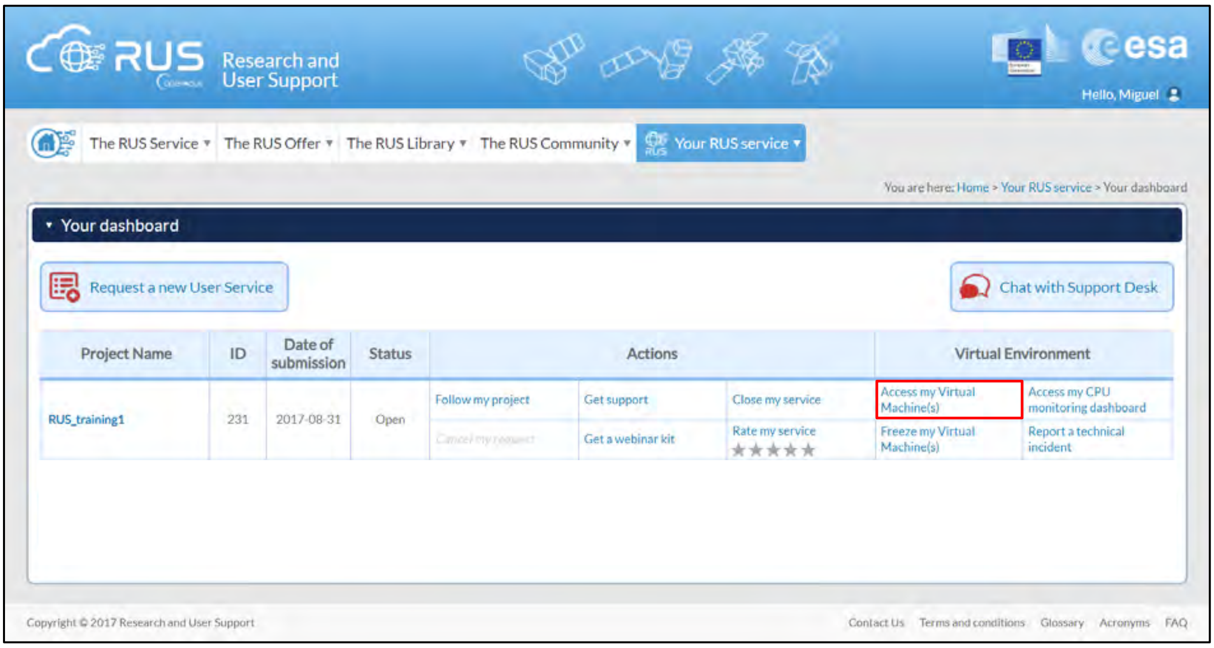
If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.



Complete the remaining steps, check the terms and conditions of the RUS Service and submit your request once you are finished.



Further to the acceptance of your request by the RUS Helpdesk, you will receive a notification email with all the details about your Virtual Machine. To access it, go to ***Your RUS Service* → *Your Dashboard*** and click on ***Access my Virtual Machine***.



Fill in the login credentials that have been provided to you by the RUS Helpdesk via email to access your RUS Copernicus Virtual Machine.

This is the remote desktop of your Virtual Machine.

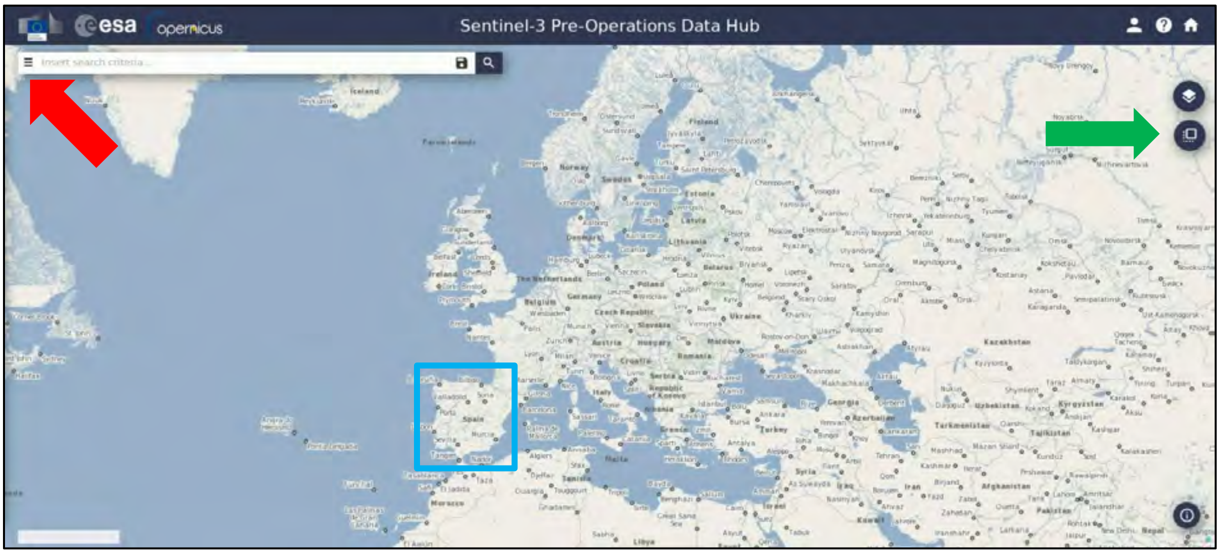
5 Data download – ESA SciHUB

In this example, we will download a Sentinel-3 scene from the Copernicus S-3 PreOpsHub using the online interface (**Applications → Network → Web Browser** or click the link below).

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

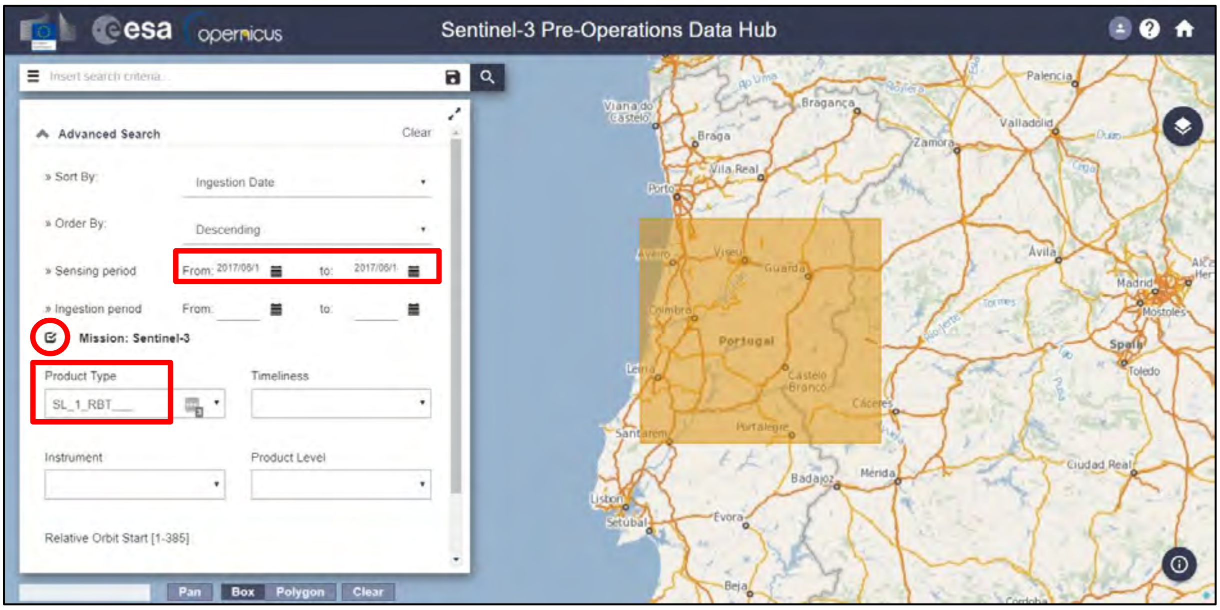
Go to “**S-3 Pre-Ops**”, click “**Login**” in upper right corner and login using the credentials provided at the top of the login window.

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:

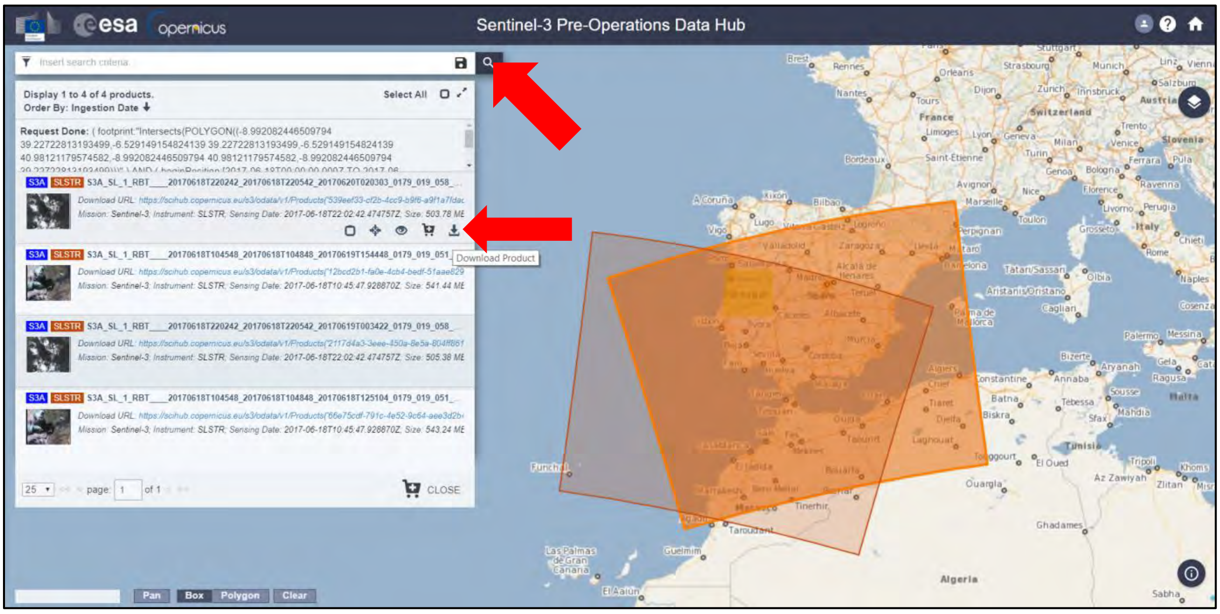
Sensing period: From 2017/06/18 to 2017/06/18
Check Mission: Sentinel-3
Product Type: SL_1_RBT___



In our case, the search returns 4 results. However, the second pair is the same data processed at different facility. Therefore, let's download the first pair (pay attention to date and time of acquisition, below in red):

*S3A_SL_1_RBT____**20170618T220242**_20170618T220542_20170620T020303_0179_019_058_6599_LN2_O_NT_002*
*S3A_SL_1_RBT____**20170618T104548**_20170618T104848_20170619T154448_0179_019_051_2340_LN2_O_NT_002*

Data will be downloaded to ***/home/rus/Downloads*** as ZIP archives. Move the archives to ***/shared/Training/HAZA04_ActiveFire_Portugal_TutorialKit/Original***
Right-click each archive and use "**Extract Here**" to unzip the folders. To open them in SNAP, go to open file and in the product, folder select **xfdumanifest.xml.**



6 Sentinel-3 SLSTR

SLSTR stands for **S**ea and **L**and **S**urface **T**emperature **R**adiometer. It is a dual scan temperature radiometer in the low Earth orbit (800 - 830 km altitude) on board of the Sentinel-3 satellite. It employs along track scanning dual view (nadir and backward oblique) technique for 9 channels in the visible (VIS), thermal (TIR) and short wave (SWIR) infra-red spectrum.

It also provides two dedicated channels for fire and high temperature event monitoring at 1 km resolution (by extending the dynamic range of the 3.74µm channel and including dedicated detectors at 10.85µm that are capable of detecting fires at ~650 K without saturation). (Sentinel-3 SLSTR User Guide, ESA).

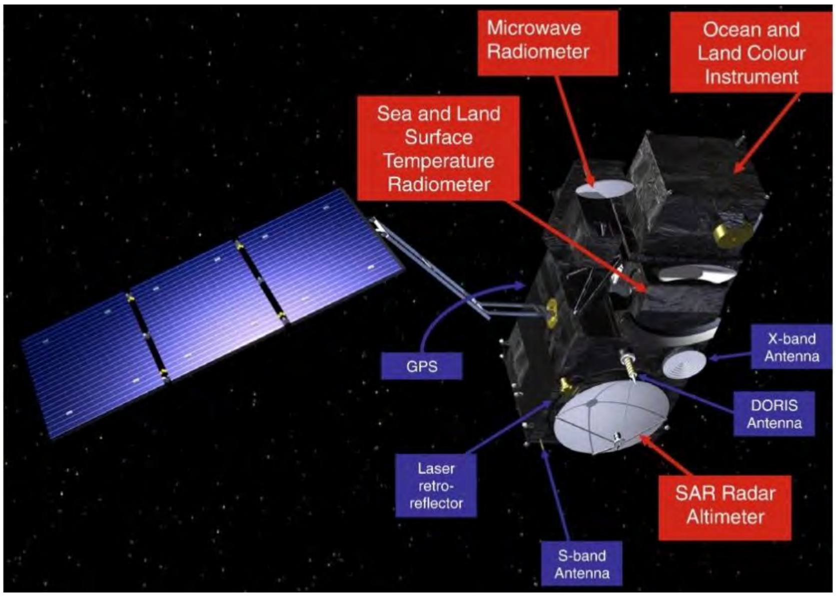
Band	Λ centre (µm)	Width (µm)	Function	Comments		Res. (m)
S1	0.555	0.02	Cloud screening, vegetation monitoring, aerosol	**Visible Near IR**	**Solar reflectance bands**	**500**
S2	0.659	0.02	NDVI, vegetation monitoring, aerosol			
S3	0.865	0.02	NDVI, cloud flagging, Pixel co-registration			
S4	1.375	0.015	Cirrus detection over land	**Short-Wave IR**		
S5	1.61	0.06	Cloud clearing, ice, snow, vegetation monitoring			
S6	2.25	0.05	Vegetation state and cloud clearing			
S7	3.74	0.38	SST, LST, Active fire	**Thermal infra-red Ambient bands (200 K - 320 K)**		**1000**
S8	10.85	0.9	SST, LST, Active fire			
S9	12	1	SST, LST			
F1	3.74	0.38	Active fire	**Thermal infra-red fire emission bands**		
F2	10.85	0.9	Active fire			

The nine bands in VNIR/SWIR/TIR (Credits: Sentinel-3 SLSTR User Guide, ESA)

It is distributed as Level-1b product (1 product - BRT) or Level-2 (4 products – WCT, WST, LST, FPR) products, based on the type and level of pre-processing applied to the raw data (not all products are available to public). In this training we will use the Level-1b RBT product, which consists of the full-resolution geolocated radiometric measurements for each view (n - nadir, o - oblique) and for each channel.

- on a 1 km grid for brightness temperatures (notation *"_**in**"* or *"_**io**"* - bands S6 to S9 and F1 and F2 "**fire bands**")
- on a 0.5 km grid for radiances (S1 to S5). In this case, three stripes are distinguised: A *("_**an**", "_**ao**")*, B *("_**bn**", "_**bo**")*, and TDI *("_**cn**", "_**co**")*, with TDI a derived product from A and B stripes.

IMPORTANT! In this tutorial, we will only use the nadir ("*_**in**"*) brightness temperature bands and nadir stripe A ("*_**an**"*) radiance bands.



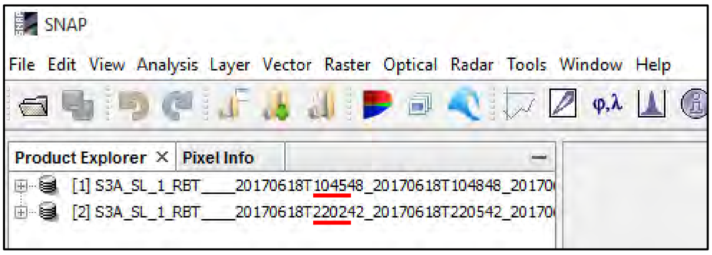
Sentinel-3 sensors (Credits: Sentinel-3 SLSTR User Guide, ESA)

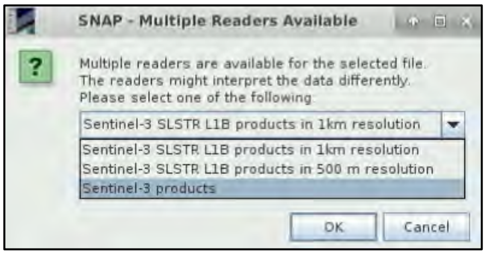
7 Step by step

7.1 SNAP – open project and explore data

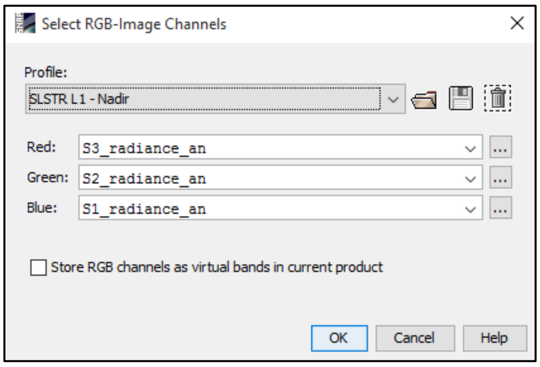
Launch SNAP (icon on desktop). When the SNAP window opens click **Open Product** , navigate to: ***/shared/Training/HAZA04_ActiveFire_Portugal_TutorialKit/Original*** and open the S3 products by opening each folder and selecting the ***xfdumanifest.xml*** file.

At the pop-up window, choose "**Sentinel-3 products**" and click **OK**.



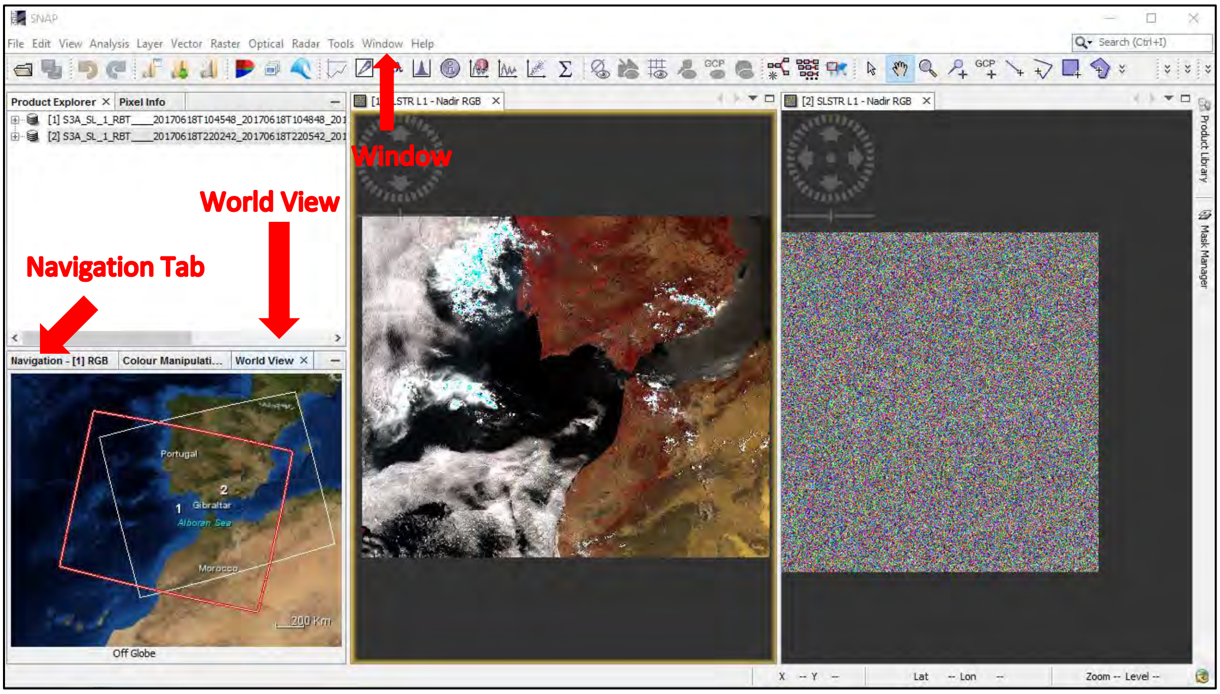


Now, we will look at the products. Right-click the first loaded product acquired at **10:45** and click **Open RGB image window,** a new window will open. Set:



Profile: **SLSTR L1 Nadir**

Now open the RGB view for the night product (acquired at **22:02**) as well. When you have both Views opened go to **Navigation** tab in the lower left and make sure the cursor and the views are linked. Then, go to **Window → Tile Evenly**. Go back to **Navigation** tab and click **Zoom All** to center the Views.



NOTE: If "**World View**" tab is not available, go to **View → Tool Windows** and open the "**World Map**".

Since we are creating the RGB View with radiance bands (reflected solar radiation), we cannot see anything in the night RGB composite, as expected. Go to the World View tab. We can see that the products do not cover exactly the same area - they correspond to different passes of the satellite.

Take a little time to explore the structure of the S3 products (expand them). During this exercise, we process two images - one acquired during the day (10:45) and one acquired during the night (22:02). You will notice that the RBT product contains many bands and even more masks, we do not need to worry about all of them though.

As mentioned before, we will only use the nadir bands with suffix *"**_in**"* (corresponding to 1 km brightness temperature bands **S6 – S9** and fire bands **F1** and **F2**) or *"**_an**"* (corresponding to radiance bands **S1 – S5** in stripe A) in their name. Read about Sentinel-3 SLSTR RBT product and its organization and contents in section **6 Sentinel-3 SLSTR**.

The processing of day and night acquisitions differ slightly, and we will go through the steps separately.

7.2 Pre-processing DAY

Cloud masking is essential to the detection of active fire pixels because optically thick clouds make it impossible to identify active fires through passive remote sensing. Moreover, solar reflected MIR radiation from certain clouds can appear similar to fire signals and some cloud-contaminated pixels will likely be falsely classified as fires if they are not masked out prior to fire detection. (Wooster et al., 2012).

The Level-1B product contains cloud mask, however some cloud mask algorithms also identify optically thick smoke as cloud, even though fire detections can typically be made through smoke. Smoke is generally relatively transparent at MIR wavelengths unlike meteorological cloud. This makes the cloud masks available in the product unsuitable for active fire detection and we need to derive our own mask.

We will use simple cloud test developed for daytime fire detection by Giglio et al. (2003).

$$\{(\rho_{0.65} + \rho_{0.86} > 0.9)\ OR\ (T_{12} < 265\ K)\}\ OR\ \{(\rho_{0.65} + \rho_{0.86} > 0.7)\ AND\ (T_{12} < 285\ K)\}$$

Where, ρ_λ and T_λ correspond to reflectance and thermal bands at certain wavelength (λ [µm]).

7.2.1 Radiance to reflectance

As the Level-1B product contains TOA radiance, our first step will be to convert the solar radiance bands to reflectance (See NOTE 1).

NOTE 1: The conversion from TOA radiance (L_{TOA}) to TOA reflectance (R_{TOA}) is defined by the following equation:

$$R_{TOA}(\lambda) = \frac{\pi L_{TOA}(\lambda)}{E_0(\lambda)\cos(\theta)}$$

Where, E_0 and θ are the solar spectral irradiance and the sun zenith angle at the time of acquisition, respectively. The solar spectral irradiance values are taken from the L1 product metadata of the SLSTR product.

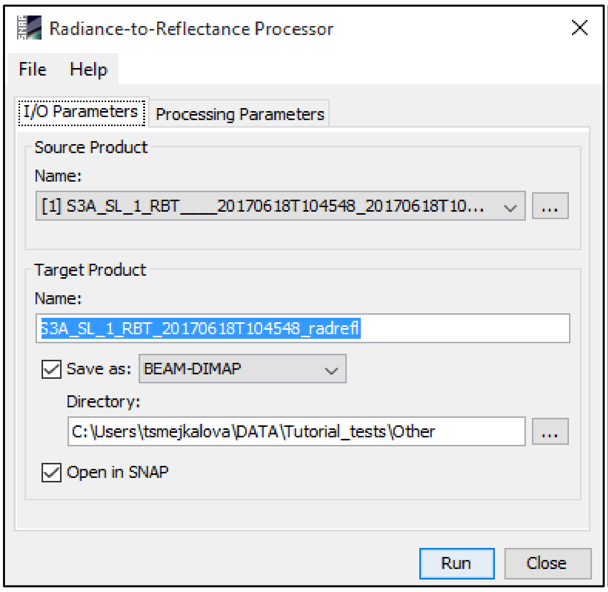
Radiance is the variable directly measured by remote sensing instruments. It is the amount of light seen by instrument from a surface of an object. In the SLSTR products is given as radiance of a surface per unit wavelength [$mW{*}m^{-2}{*}sr^{-1}{*}nm^{-1}$ = watt per square meter per nanometre].

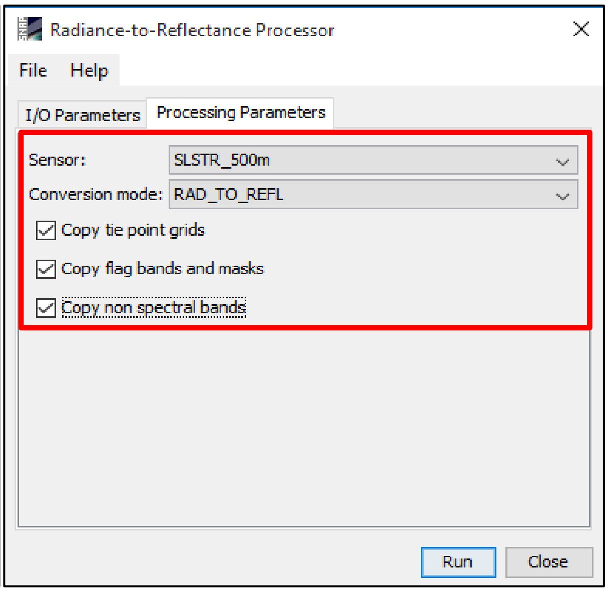
Reflectance is the ratio (percentage) of the amount of light leaving a target to the amount of light arriving to the target. It has no units. It is the property of the observed object/material.

Go to **Optical → Preprocessing → Radiance-to-Reflectance Processor**.

In the **I/O Parameters** tab, make sure that the **DAYTIME** product is selected as input. Set the **Name** of the target product to ***S3A_SL_1_RBT_20170618T104548_radrefl*** and the target folder under **Directory** to: ***/shared/Training/HAZA04_ActiveFire_Portugal_TutorialKit/Processing***

In the **Processing Parameters** tab set:
Sensor: SLSTR_500m
Conversion mode: RAD_TO_REFL
Check all fields to "**Copy tie point grids, flag bands and masks** and **non-spectral bands**".





Click **Run**. A new product [3] has been created. Click **OK** to the pop-up window and close the **Radiance-to-Reflectance Processor** window. If we expand the Bands folder in the product, we can see that the **brightness temperature** folders (*BT) have not changed but the **radiance** folders were replaced by **reflectance** folders. **Close all view windows**.

7.2.2 Resample

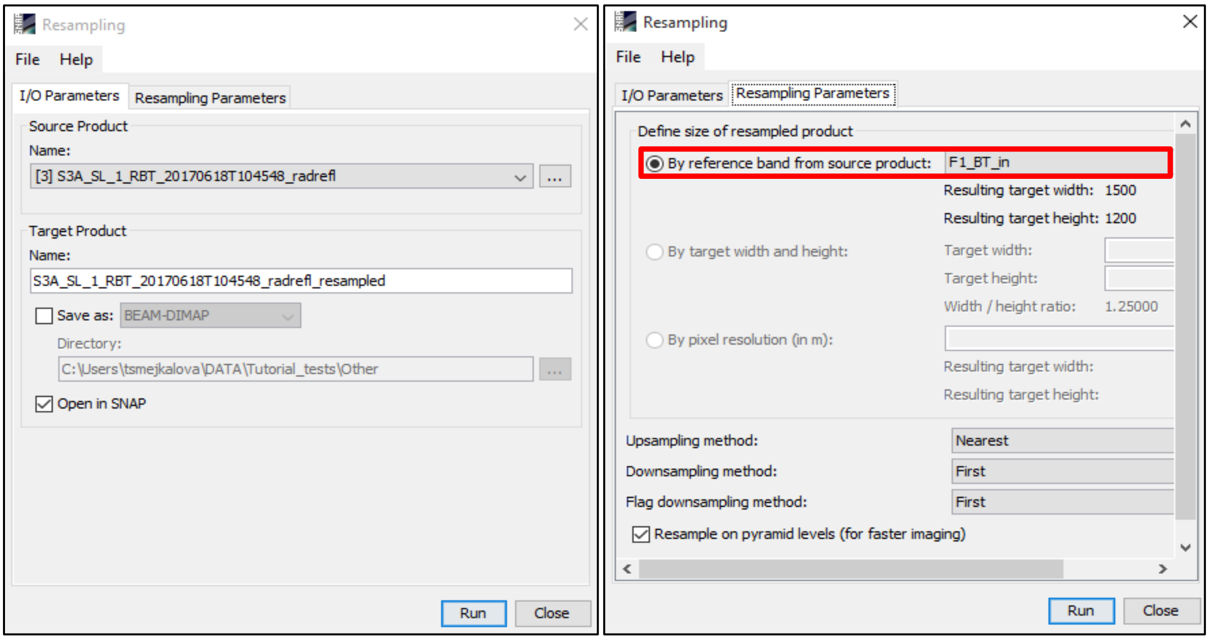
As mentioned previously, the brightness temperature (BT) bands of S3 RBT product have resolution of 1000 m while the radiance (now reflectance) bands have resolution of 500 m. For further processing, it is necessary to have all bands in the same resolution. As for the active fire detection we will use the BT bands and we will resample all the reflectance bands to 1000 m.

Go to **Raster → Geometric Operations → Resampling**.

In the **I/O Parameters** tab, make sure that the daytime reflectance product [3] is selected as input. Select **Save as**: ✓.

Set the **Name** of the target product to: ***S3A_SL_1_RBT_20170618T104548_radrefl_resampled*** and the target folder under **Directory** to: ***/shared/Training/HAZA04_ActiveFire_Portugal/Processing***

In the **Processing Parameters** tab set: **By reference band from source product:** F1_BT_in



Click **Run**. A new product [4] has been created. Click **OK** to the pop-up window and close the **Resampling** window.

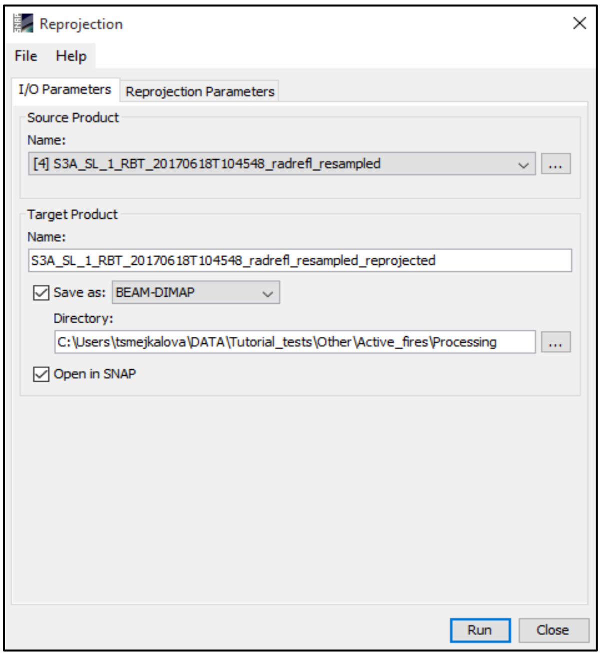
7.2.3 Reproject

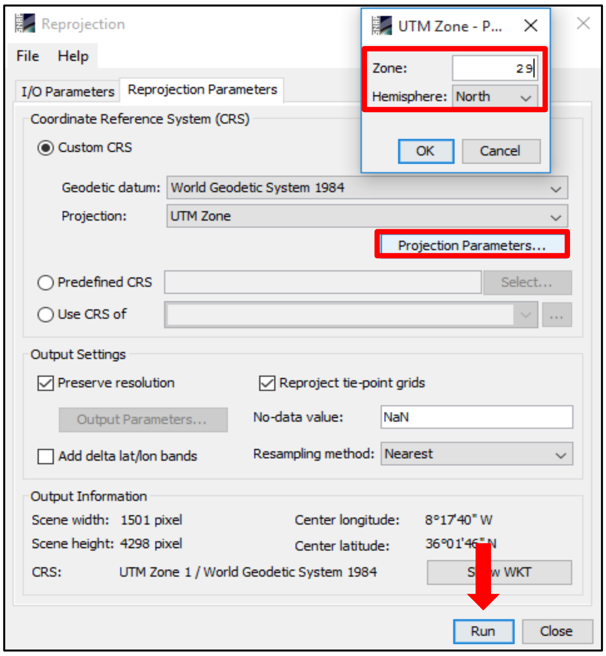
The Sentinel-3 Level-1B products are geocoded but not projected, therefore in this step we will reproject the data.

Go to **Raster → Geometric Operations → Reprojection**.

In the **I/O Parameters** tab, make sure that the daytime resampled product [4] is selected as input. Set the name of the target product to: ***S3A_SL_1_RBT_20170618T104548_radrefl_resampled_reprojected*** and the target folder under **Directory** to: ***/shared/Training/HAZA04_ActiveFire_Portugal_TutorialKit/Processing***

In the **Reprojection Parameters** tab set:
Under **Coordinate Reference System (CRS)** choose: **Custom CRS** and at **Projection**: UTM Zone
Click on Projection Parameters and set as **Zone**: 29 and as **Hemisphere**: North





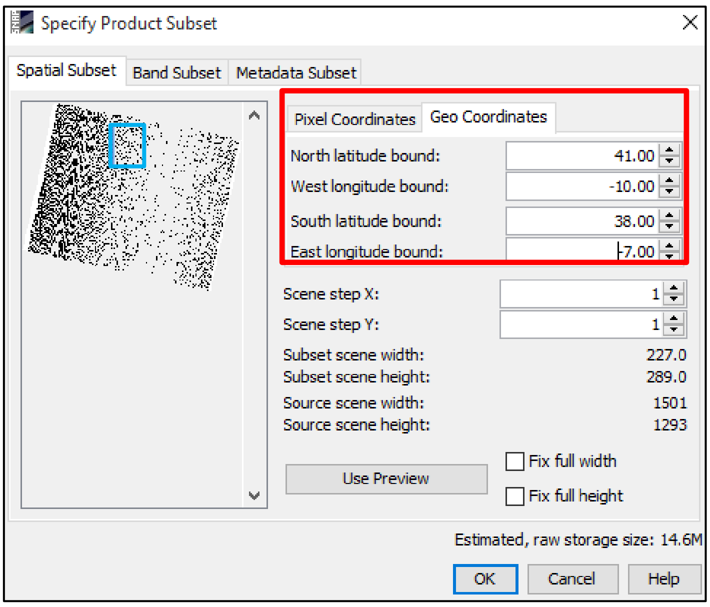
Click **OK** and then click **Run**. A new product [5] has been created. Click **OK** at the pop-up dialog and close the **Reprojection** window.

7.2.4 Subset

In the last pre-processing step, we will create a subset of our area of interest. Click on the new product [5] in the **Product Explorer** window to highlight it.

Go to **Raster → Subset.**

In the **Spatial Subset** tab, at the **Geo Coordinates** tab, set the following coordinates:

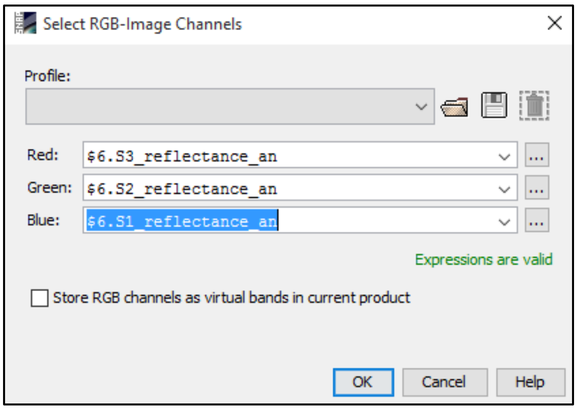


North latitude bound:	41.00
West longitude bound:	-10.00
South latitude bound:	38.00
East longitude bound:	-7.0

The subset area is indicated by the blue rectangle on the left of the dialog window. Click **OK.**

The subset product [6] will appear in the **Product Explorer** window but is not physically saved. We will save it after the creation of the cloud mask.

Right-click the product again and select **Open RGB Image Window** and set:

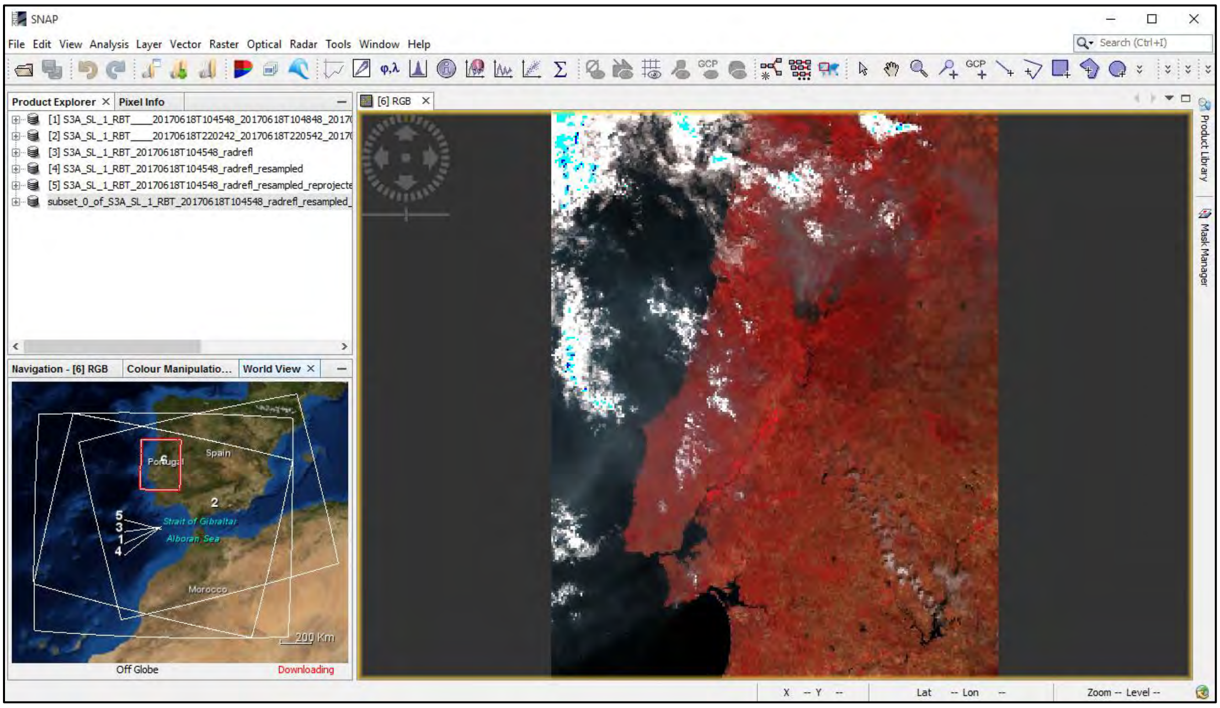


Red: $6.S3_reflectance_an

Green: $6.S2_reflectance_an

Blue: $6.S1_reflectance_an

Click **OK**.



7.2.5 Create a cloud mask band

As discussed before, we will create our own cloud mask. Right-click on the subset product [6] and click **Band Maths**. A new window will open.

> TIP: All expressions you will be using during this tutorial are available to copy-paste them from the ***Expressions_AF.txt*** file in ***/shared/Training/HAZA04_ActiveFire_Portugal_TutorialKit/Auxdata/*** folder.

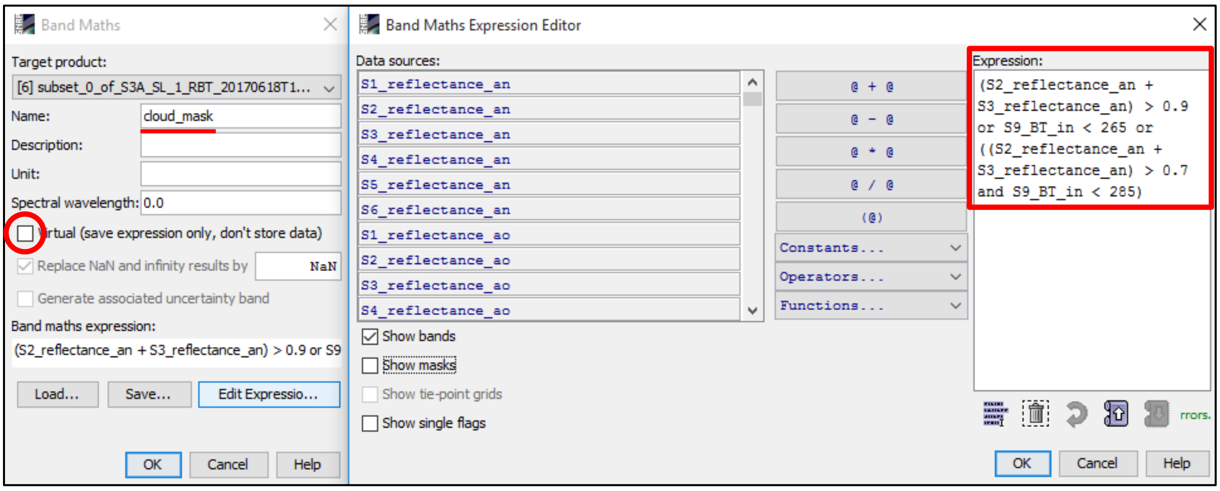
Set as **Name**: *"cloud_mask"*

Deselect "**Virtual (safe expression only, don't store data)**"

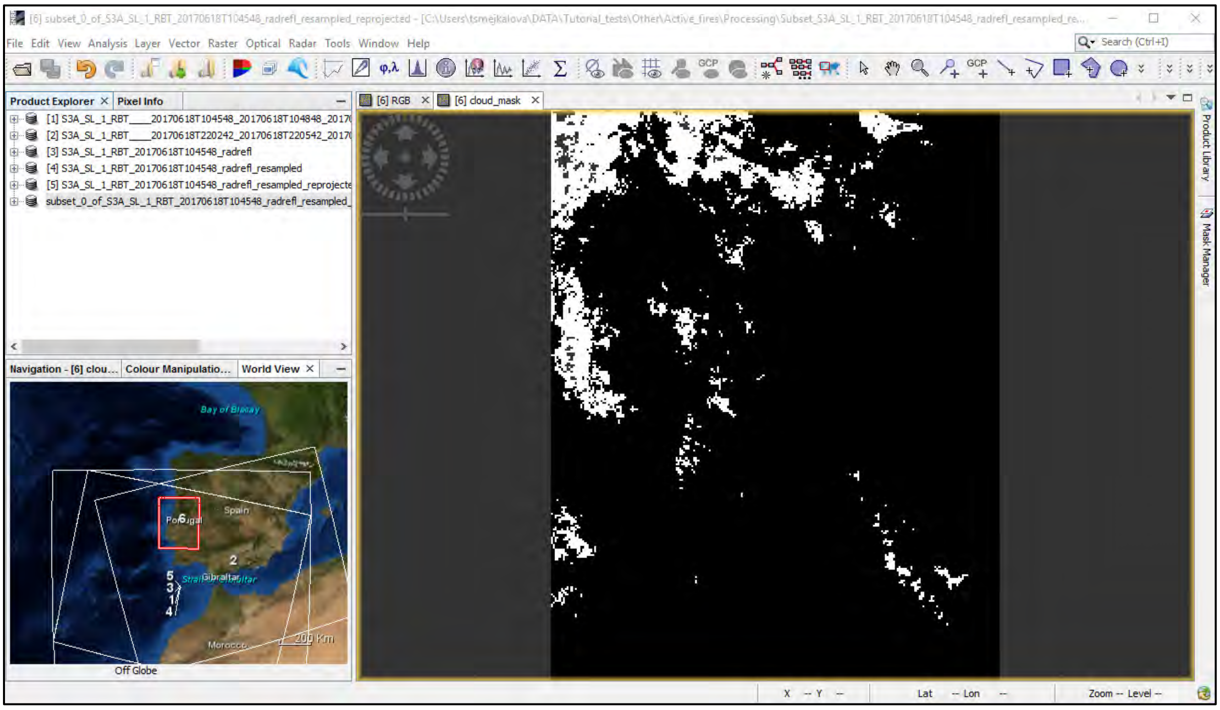
Then click on "**Edit Expression...**" and enter the following statement:

```
(S2_reflectance_an + S3_reflectance_an) > 0.9 or S9_BT_in < 265 or
((S2_reflectance_an + S3_reflectance_an) > 0.7 and S9_BT_in < 285)
```

Click **OK** in both windows.



The new band will automatically open in a new “**View**” window.



TIP: You can also build the expression yourself using the **Expression Editor**.

Right-click the subset product [6] and go to **Save Product**. In the next dialog click **Yes** and save the product as ***Subset_S3A_SL_1_RBT_20170618T104548_radrefl_resampled_reprojected*** to ***/shared/Training/HAZA04_ActiveFire_Portugal_TutorialKit/Processing***

7.3 Pre-processing NIGHT

The preprocessing steps are the same for the night product with the exeption of the radiance to reflectance conversion. To derive the night cloud mask we do not need the reflectances, only the brightness temperature bands therefore only the **Resampling**, **Peprojection** and **Subset** steps will be applied.

Similarly as for the day-time product, Night-time pixels are flagged as cloud if the single condition is satisfied. (Giglio et al. (2003)).

$$T_{12} < 265\ K$$

Where, T_{12} correspond to thermal band S9, at central wavelength of 12 µm.

7.3.1 Resample

Follow the steps described in section 7.2.2 Resample.

Go to **Raster → Geometric Operations → Resampling**.

In the **I/O Parameters tab**, make sure that the **NIGHT-**time product [2] is selected as input.
Select **Save as**: ✓.

Set the **Name** of the target product to ***S3A_SL_1_RBT_20170618T220242_resampled*** and the target folder under **Directory** to: ***/shared/Training/HAZA04_ActiveFire_Portugal_TutorialKit/Processing***.

In the **Processing Parameters** tab set: **By reference band from source product:** F1_BT_in

Click **Run**. A new product [7] has been created. Click **OK** to the pop-up window and close the **Resampling** window.

7.3.2 Reproject

Follow the steps described in section 7.2.3 Reproject.

Go to **Raster → Geometric Operations → Reprojection**.

In the **I/O Parameters tab**, make sure that the night-time resampled product [7] is selected as input.
Set the name of the target product to: ***S3A_SL_1_RBT_20170618T220242_resampled_reprojected*** and the target folder under **Directory** to:
/shared/Training/HAZA04_ActiveFire_Portugal_TutorialKit/Processing

In the **Reprojection Parameters** tab set:
Under **Coordinate Reference System (CRS)** choose: **Custom CRS** and at **Projection**: UTM Zone
Click on **Projection Parameters** and set as **Zone**: 29 and as **Hemisphere**: North

Click **OK** and then click **Run**. A new product [8] has been created. Click **OK** at the pop-up dialog and close the **Reprojection** window.

7.3.3 Subset

Follow the steps described in section 7.2.4. Subset. Click on the new product [8] in the **Product Explorer** window to highlight it.

Go to **Raster → Subset.**

In the **Spatial Subset** tab, at the **Geo Coordinates** tab, set the following coordinates:

North latitude bound:	41.00	**West longitude bound**:	-10.00
South latitude bound:	38.00	**East longitude bound:**	-7.0

Click **OK**. The subset product [9] will appear in the **Product Explorer** window but is not physically saved. We will save it after the creation of the cloud mask.

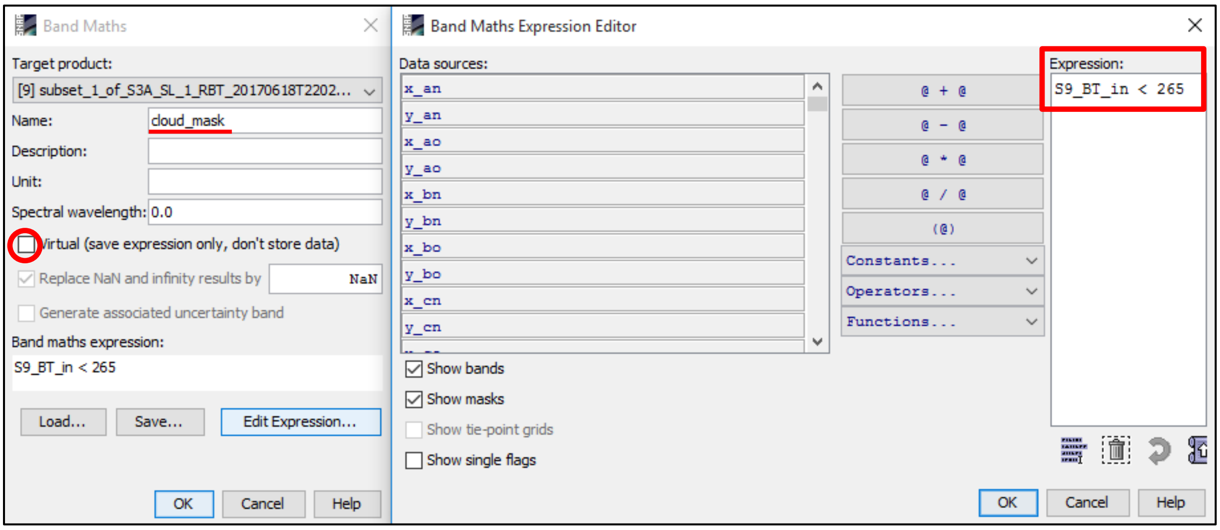
7.3.4 Create a cloud mask band.

As discussed before, we will create our own cloud mask. Right-click on the subset product [9] and click **Band Maths**. A new window will open.

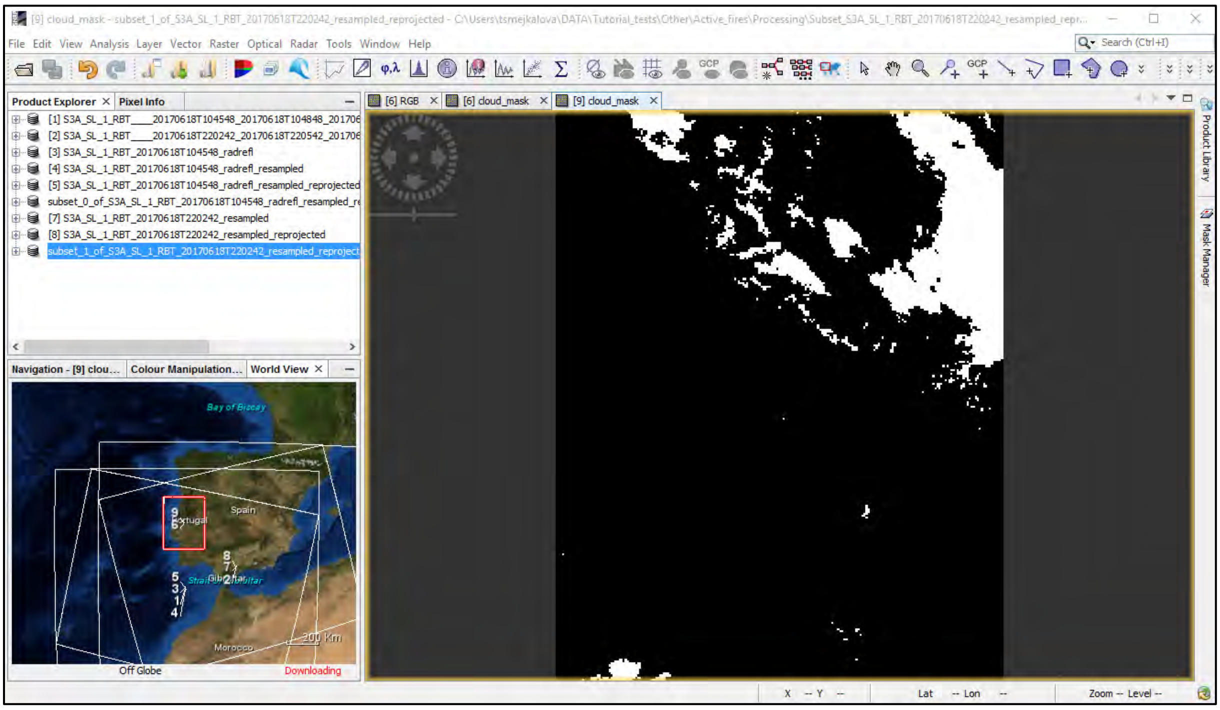
Set as **Name**: *"cloud_mask"*

Deselect "**Virtual (safe expression only, don't store data)**"

Then click on "**Edit Expression...**" and enter the following statemen `S9_BT_in < 265`



The new band will automatically open in a new "**View**" window.



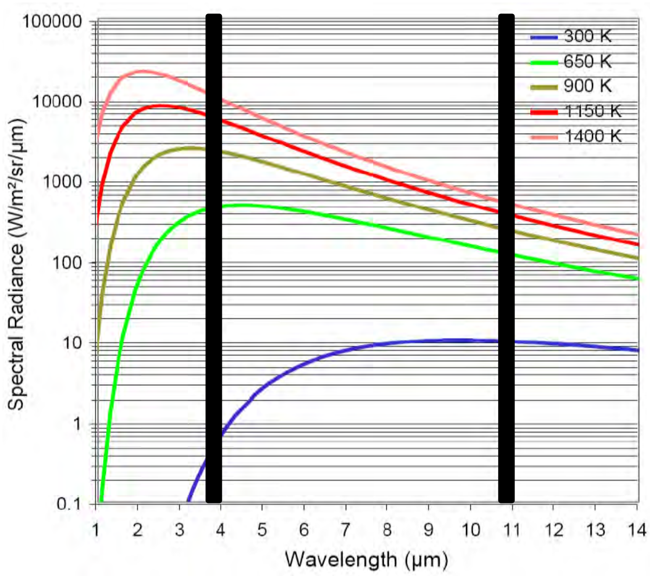
Right-click the subset product [9] and go to **Save Product**. In the next dialog click **Yes** and save the product as ***Subset_S3A_SL_1_RBT_20170618T220242_resampled_reprojected*** to ***/shared/Training/HAZA04_ActiveFire_Portugal_TutorialKit/Processing***

Now both of our products are ready for Active Fire Pixel Detection. Let's close SNAP window completely and open a new one.

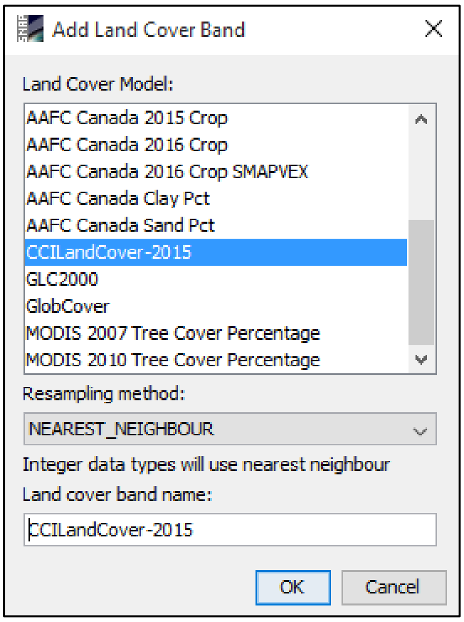
7.4 Active fire detection

In this step, we will apply a simple algorithm to identify pixels containing one or more active fires at the time of the satellite overpass. This approach exploits the different responses of middle-infrared (MIR) and thermal-infrared (TIR) bands to hot subpixel targets. In particular, the algorithm looks for a significant increase in radiance (brightness temperature) at 3.74µm in comparison to observed radiance (BT) at 10.85µm as well as in absolute value (See NOTE 2).

NOTE 2: This characteristic active fire signature is the result of the large difference in blackbody radiation at 4µm and 11µm, emitted at vegetation combustion temperatures, as described by the Planck function. The image below shows the spectral radiance emitted from blackbodies at Earth ambient temperature (300 K) and a range of possible vegetation fire temperatures (650 - 1400 K). The approximate central wavelengths of the Sentinel-3 SLSTR MIR (3.74µm) and TIR (10.85µm) channel are also indicated.



Credits: Sentinel-3 Active Fire: Fire Detection and Fire Radiative Power Assessment (ESA)



As described in section ***7.1 SNAP – Open Project and Explore Data*** there are two bands (F1 and F2, “fire channels”) dedicated to fire detection (greatly increased saturation temperature threshold).

In the new SNAP window, click **Open Product**, navigate to: ***/shared/Training/HAZA04_ActiveFire _Portugal_TutorialKit/Processing*** and open both subset products we have created during the pre-processing phase.

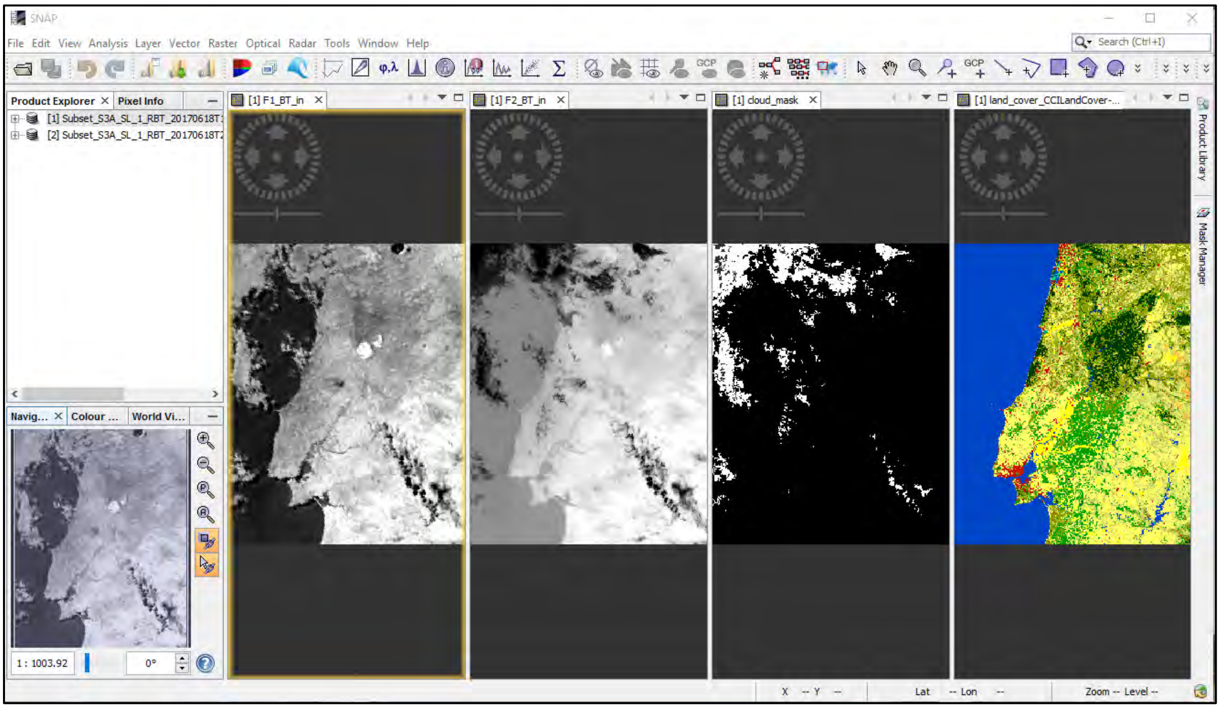
Right-click the daytime product and select **Add Land Cover Band**, in the dialog that appears, scroll down and select “**CCILandCover-2015**”, and then click **OK**.

This will add a new band containing the land cover layer. Repeat the same for the night-time product.

7.4.1 Daytime fire detection

Now, let's visualize all the bands we will use to define the fire detection algorithm for the daytime product. Expand the daytime product folder go to **Bands → "F*BT_in"** folder, double-click both bands [**"F1_BT_in (3742 nm)", "F2_BT_in (10854 nm)"**] to open them both in the **View** Window. Next, scroll down to the bottom of the **Bands** folder and double-click "**cloud_mask"** and "**land_cover_CCILandCover-2015"** band.

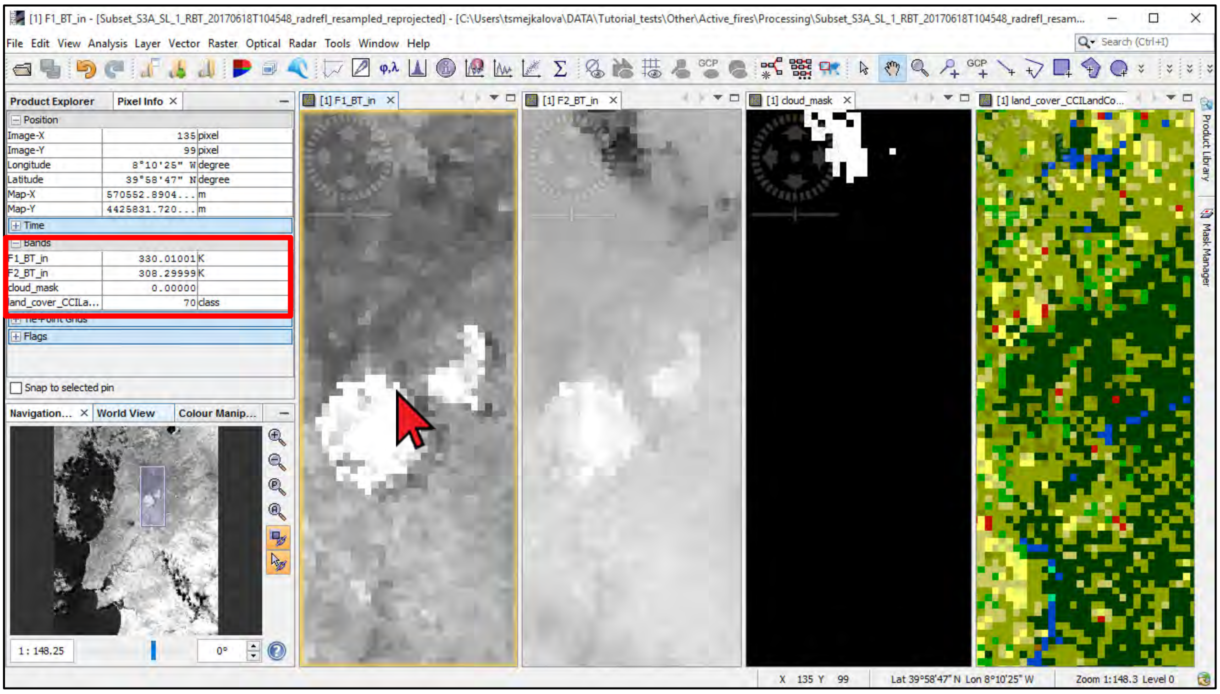
Go to **Window → Tile Horizontally** and in **Navigation** tab select **Zoom all**. In the **Product Explorer** window, collapse all the expanded folders.



Click on the "**land_cover_CCILandCover-2015**" view, go to **Colour Manipulation** tab and inspect the classes in the land cover layer. Which classes will be correlated with forest fires?

Label	Colour	Value	Freque…
0 No data		0	0.000%
10 Cropland, rainfed		10	0.000%
11 Herbaceous cover		11	0.000%
12 Tree or shrub cover		12	0.000%
20 Cropland, irrigated or post?…		20	0.000%
30 Mosaic cropland (>50%) / n…		30	0.000%
40 Mosaic natural vegetation (…		40	0.000%
50 Tree cover, broadleaved, e…		50	0.000%
60 Tree cover, broadleaved, d…		60	0.000%
61 Tree cover, broadleaved, d…		61	0.000%
62 Tree cover, broadleaved, d…		62	5.705%
70 Tree cover, needleleaved, …		70	10.054%
71 Tree cover, needleleaved, …		71	2.492%
72 Tree cover, needleleaved, …		72	0.000%
80 Tree cover, needleleaved, …		80	0.000%
81 Tree cover, needleleaved, …		81	0.000%
82 Tree cover, needleleaved, …		82	0.000%
90 Tree cover, mixed leaf type…		90	0.000%
100 Mosaic T and shrub (>50…		100	0.000%
110 Mosaic herbaceous cover (…		110	0.000%
120 Shrubland		120	2.692%
121 Shrubland evergreen		121	0.000%
122 Shrubland deciduous		122	0.000%
130 Grassland		130	0.000%
140 Lichens and mosses		140	0.000%
150 Sparse vegetation (tree, s…		150	0.000%
151 Sparse tree (<15%)		151	0.000%
152 Sparse shrub (<15%)		152	0.000%
153 Sparse herbaceous cover …		153	0.000%
160 Tree cover, flooded, fresh…		160	0.000%
170 Tree cover, flooded, salin…		170	5.668%
180 Shrub or herbaceous cove…		180	0.000%
190 Urban areas		190	0.000%
200 Bare areas		200	0.000%
201 Consolidated bare areas		201	0.000%
202 Unconsolidated bare areas		202	0.000%
210 Water bodies		210	0.000%
220 Permanent snow and ice		220	0.000%

Now zoom to the bright spot in the center of "**F1_BT_in band (3742nm)"**. All other views will zoom to the same area. Inspect other opened bands by going to the **Pixel Info** window; there you can see the values of the pixel over which you move your cursor in all opened bands.



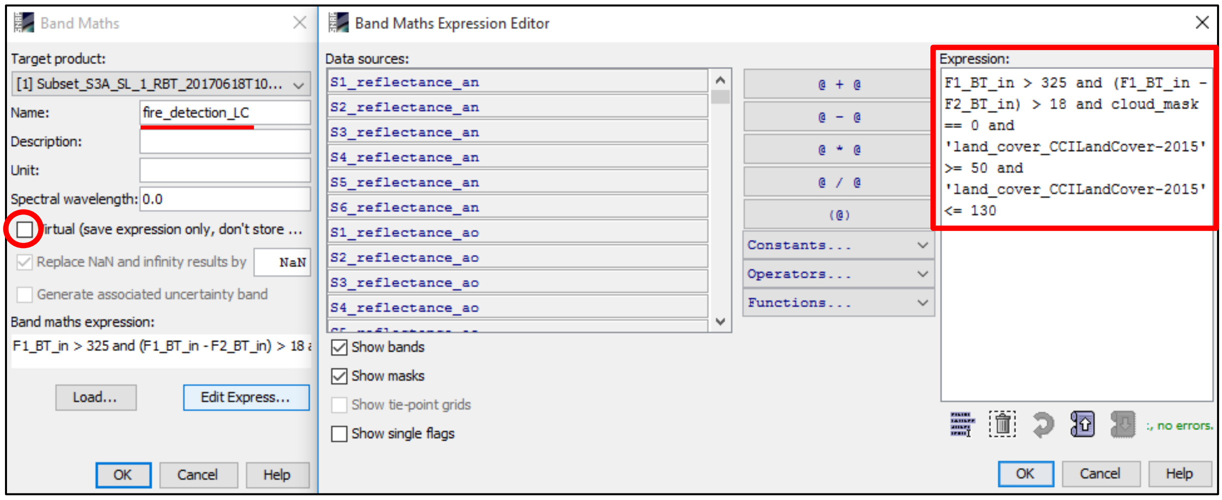
Now go back to **Product Explorer** window and let's design our test to detect active fire pixels. Pixel is classified as fire-pixel if the following conditions are true:

Initial test	*F1_BT_in > 325 K*
Eliminate warm background	*(F1_BT_in - F2_BT_in) > 18 K*
Eliminate clouds	*cloud_mask == 0*
Eliminate non-forest pixels	*'land_cover_CCILandCover-2015' >= 50 and 'land_cover_CCILandCover-2015' <= 130*

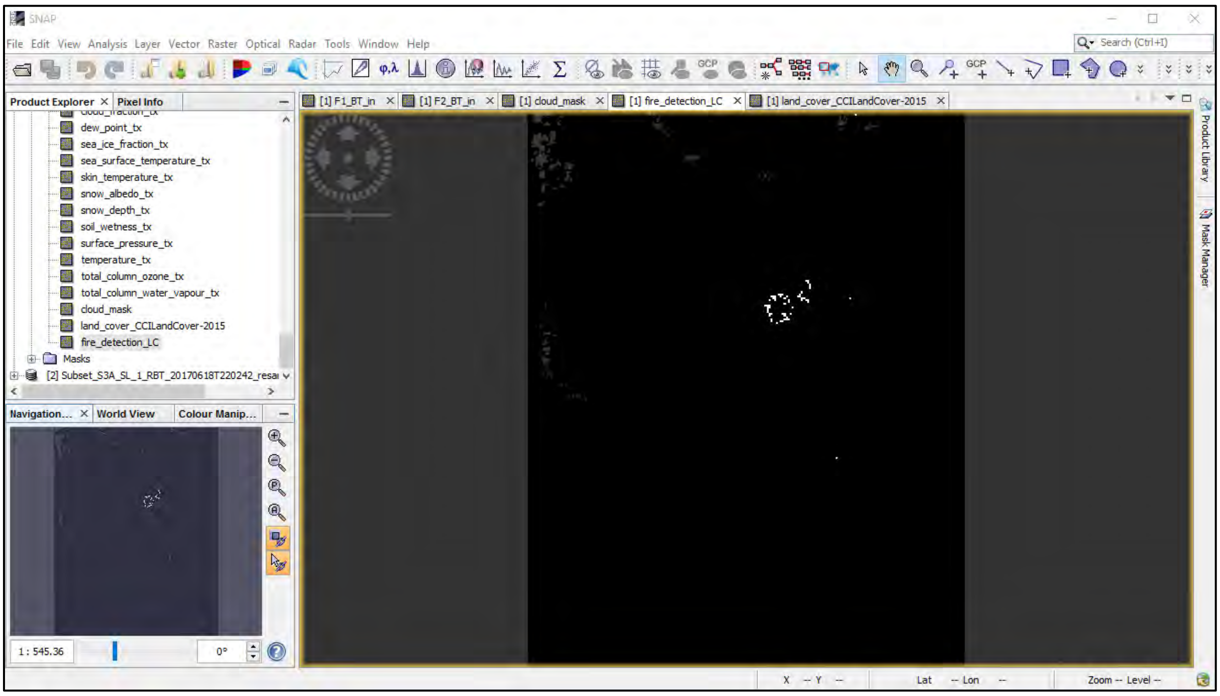
Right-click the daytime product and go to **Band Maths…**. A new window will open.

Set as **Name**: **fire_detection_LC**
Deselect the "**Virtual (safe expression only, don't store data)**" option.
Then click "**Edit Expression…**" and enter the following conditions under **Expression**:

```
F1_BT_in > 325 and (F1_BT_in - F2_BT_in) > 18 and cloud_mask == 0 and
'land_cover_CCILandCover-2015' >= 50 and 'land_cover_CCILandCover-2015'
<= 130
```



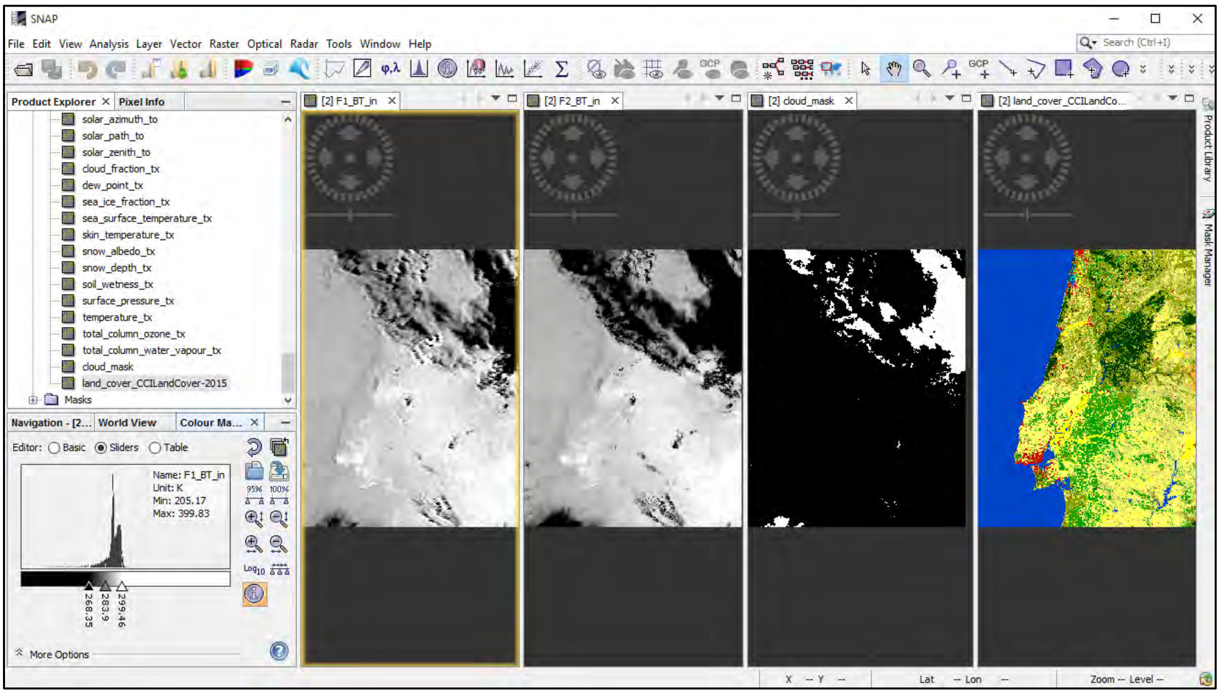
Click **OK** in both windows. The new band "**fire_detection_LC**" will be created and added in the **Bands** folder at the daytime product.



Go to **Window → Tile Single**. In **Navigation** tab select **Zoom all.** Now, we can see the active fire pixels for 18 June 2017 at 10:45:48. To save our results, right-click the daytime product and select **Save Product**. Finally, close all our opened views.

7.4.2 Night-time fire detection

Now let's adapt our thresholds for the night-time image. First, let's open all our input bands to inspect them as we did for the daytime detection. Open and view the bands as at 7.4.1 Daytime fire detection chapter.

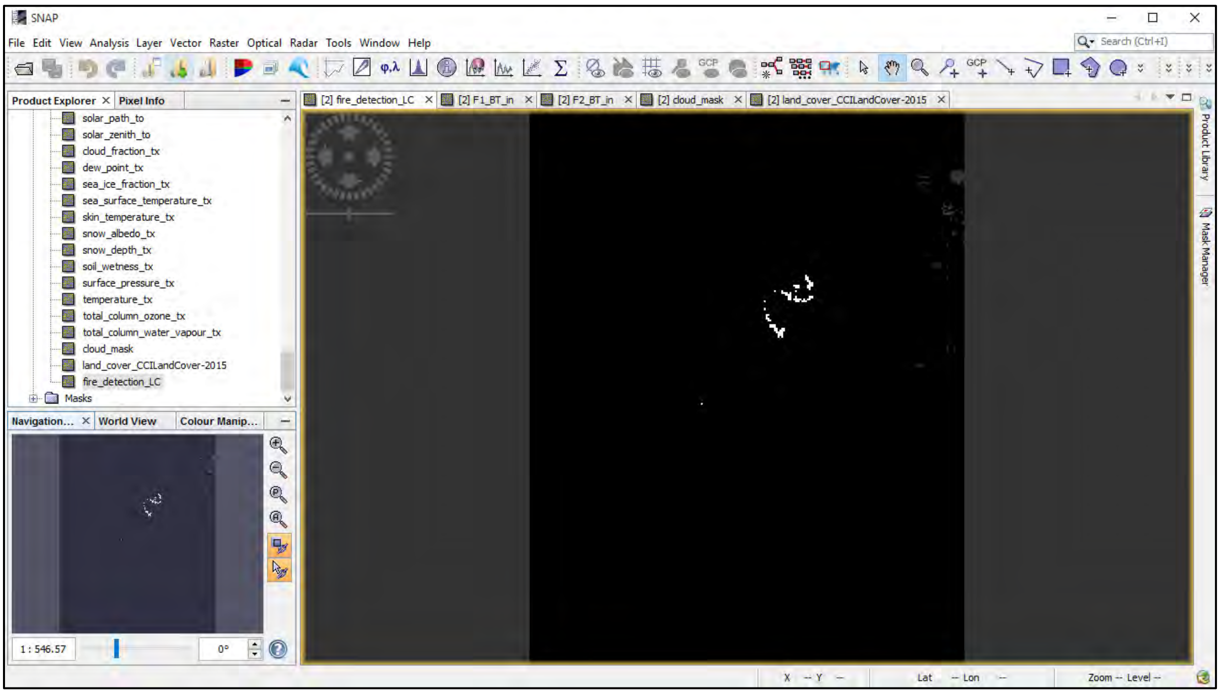


We can see that the distinction between the **BT** of land and ocean is not clearly visible during the night as it was during the day. We can also see some clouds covering over the area where we have detected the active fire pixels during the day. Use the **Pixel Info** tool again to explore the pixel values in our input bands. Think how you would change the thresholds we had used for the daytime detection.

The conditions for cloud mask and land cover will remain the same but due to the cooler background response during night, we need to slightly lower our thresholds. Let's set the initial test to 315 K and the warm background check to 15 K. Right-click the daytime product and go to **Band Maths…**. A new window will open.

Set as **Name**: *"fire_detection_LC"*
Deselect the "**Virtual (safe expression only, don't store data)***"* option.
Then click **Edit Expression…** and enter the following conditions under "Expression":

```
F1_BT_in > 315 and (F1_BT_in - F2_BT_in) > 15 and cloud_mask == 0 and
'land_cover_CCILandCover-2015' >= 50 and 'land_cover_CCILandCover-2015'
<= 130
```

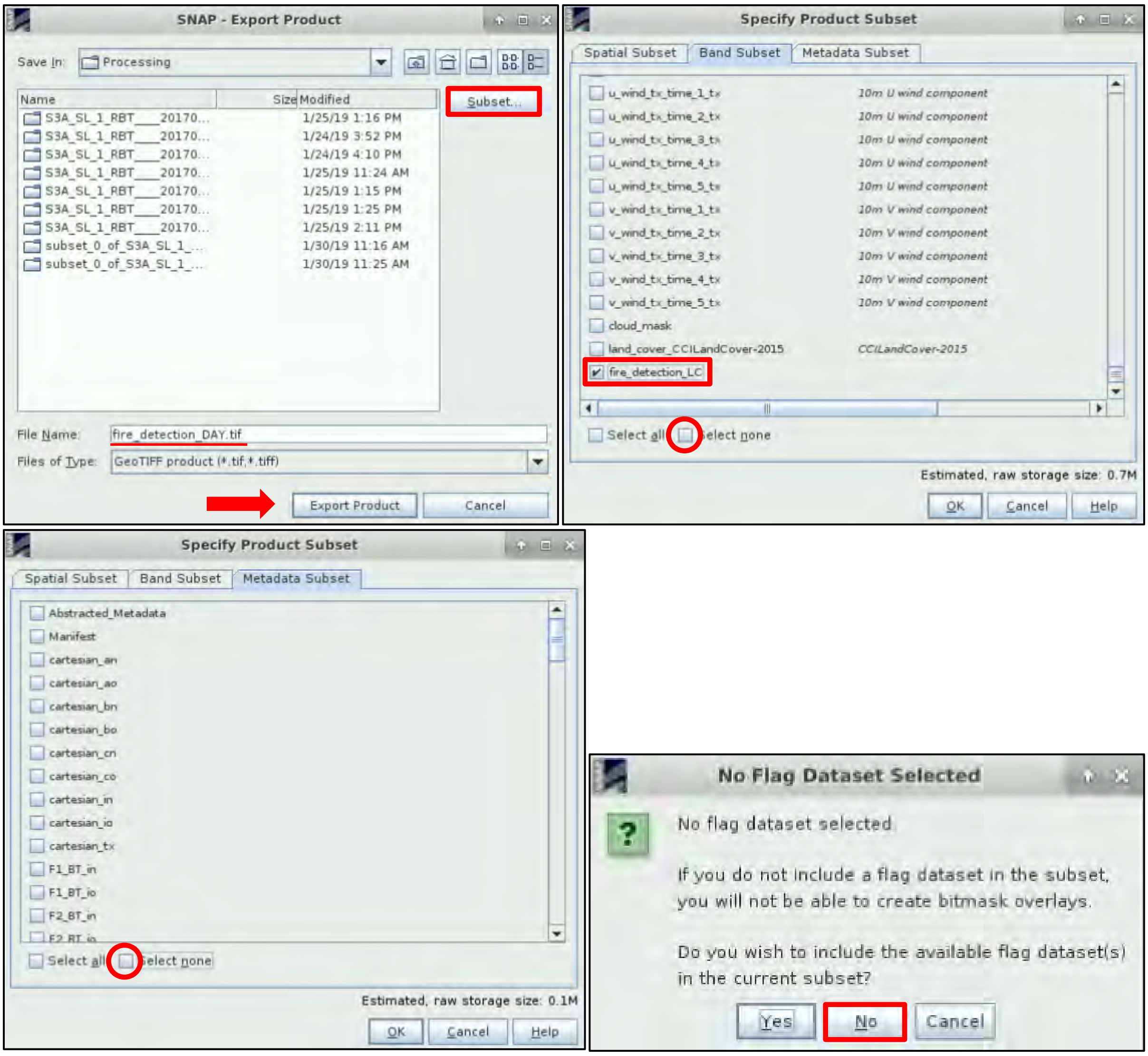


Go to **Window → Tile Single**. In **Navigation** tab select **Zoom all.** Now, we can see the active fire pixels for 18 June 2017 at 22:02:42. To save our results, right-click the night-time product and select **Save Product**. However, in this case we need to be aware that some active cloud pixels could have been obscured by clouds. Close all view windows.

7.5 Export as GeoTIFFs

Open only the "***fire_detection_LC"*** band of the day-time product. In **Product Explorer** tab, select (highlight) the daytime product.

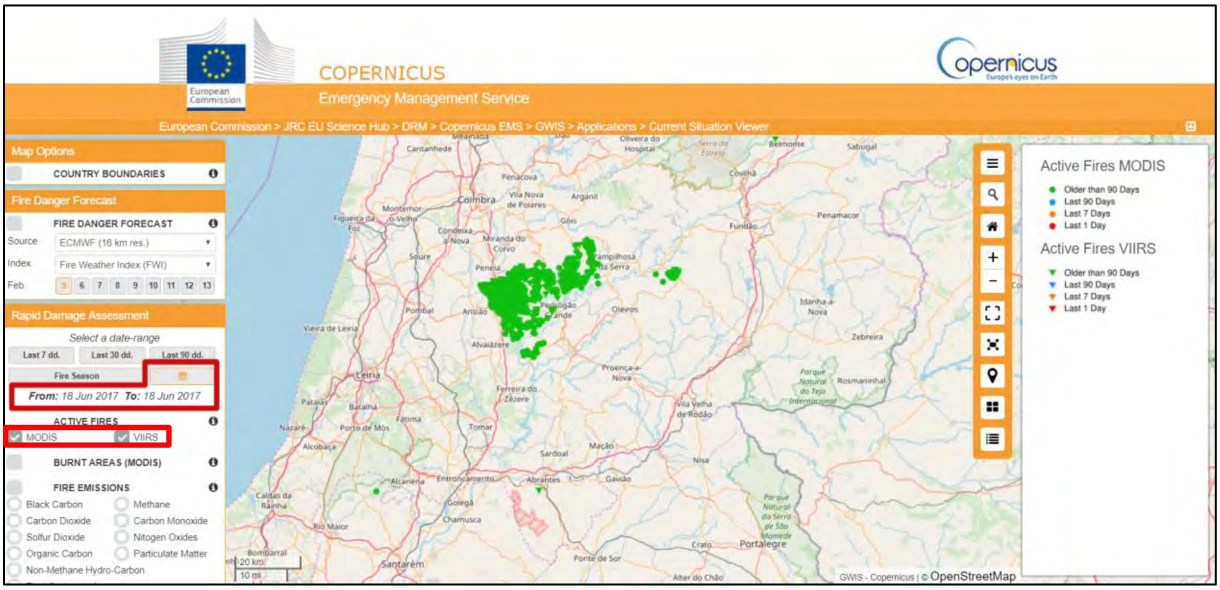
Then go to **File → Export → GeoTiff** (**NOT!** Geotiff/Big Tiff). In the dialog, that opens click **Subset → Band Subset** (second tab) and select only band "***fire_detection_LC"*** (last in the list, use the **Select none** button to deselect all), then go to the **Metadata Subset** tab and click **Select none**. Click **OK**. In the dialog that appears, click **No** and save the file with the **File Name**: ***fire_detection_DAY.tif*** to the ***Processing*** folder by clicking on **Export Product**. Repeat the same for the night-time product (save as ***fire_detection_NIGHT.tif***).



Now, we can import the image to another GIS/Remote sensing software for further processing or map creation (section **8.2 Convert to vector**). In the extra steps of this tutorial, we will use QGIS. To download the results to your local computer, see section **8.1 Downloading the outputs from VM**.

7.6 Compare results with operational monitoring

Now, you can compare your results with operationally derived products using different sensors such as **VIRS**, **MODIS** etc. Go to **Global Wildfire Information System – GWIS** (http://gwis.jrc.ec.europa.eu/static/gwis_current_situation/public/index.html) and see how your result compares. Be aware that the site provides daily summary as compared to our product showing a snapshot in time. (Set: date-range **from 18 June 2018 to 18 June 2017**, select **MODIS** and **VIRES** and zoom in to the area of our interest).



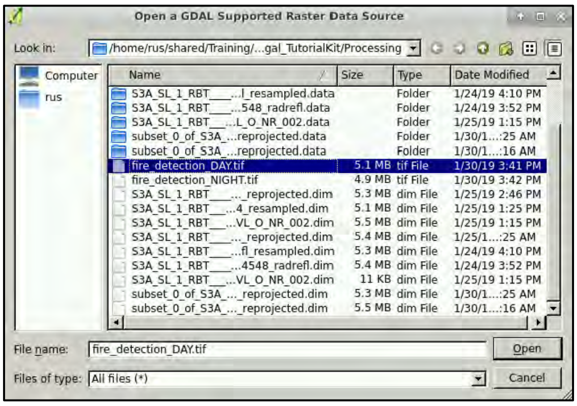
THANK YOU FOR FOLLOWING THE EXERCISE!

8 Extra steps

8.1 Downloading the outputs from VM

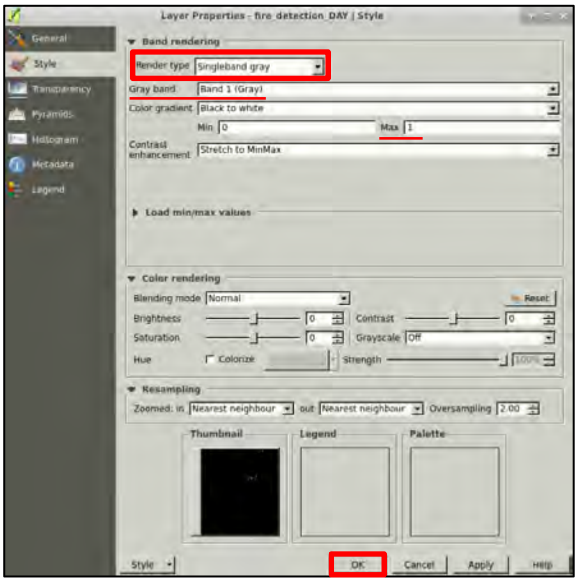
Press **Ctrl+Alt+Shift.** A pop-up window will appear on the left side of the screen. Click on bar below **Devices**, the folder structure of your VM will appear. Navigate to your **Processing** folder and **double click any file you want to download.**

8.2 Convert to Vector



Go to **Application → Processing → QGIS Desktop** (or use the desktop icon).

Click on the **Add Raster Layer**, navigate to: ***/shared/Training/HAZA04_ActiveFire_Portugal_TutorialKit/Processing*** select the ***fire_detection_DAY.tif*** and click **Open**.



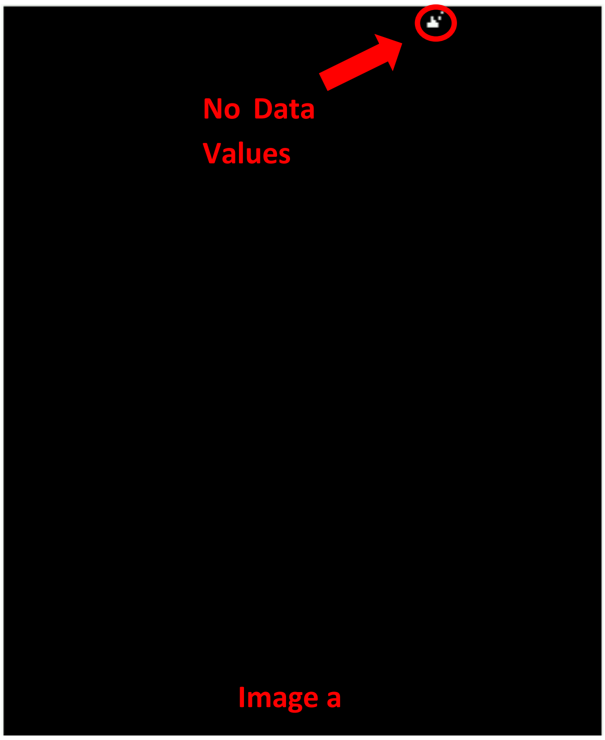
It will appear completely black (***Image a***), except for some No Data values which will appear in white. This happens because the No Data values are transparent, and our background is white. This means that if you set the background colour to a different one than white, e.g. red, the No Data values will appear red as well.

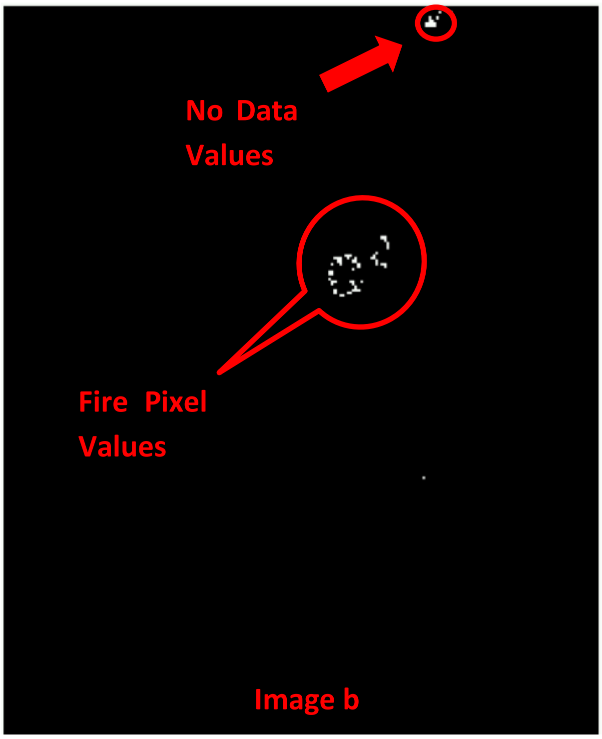
Right-click on the opened raster-layer in the **Layers Panel** (lower left) and go to **Properties**.

In the **Style** tab set:

Render type: Singleband gray
Band: Band 1 (Gray)
Max: 1

Click **OK** to see the fire pixel values at the band (they will appear in white, ***Image b***).

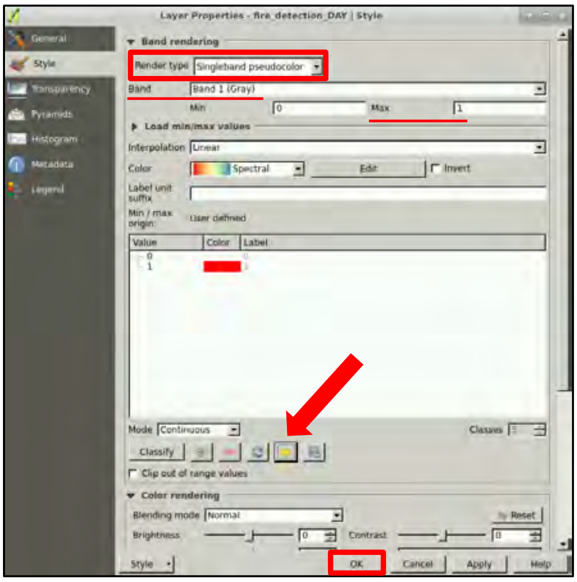


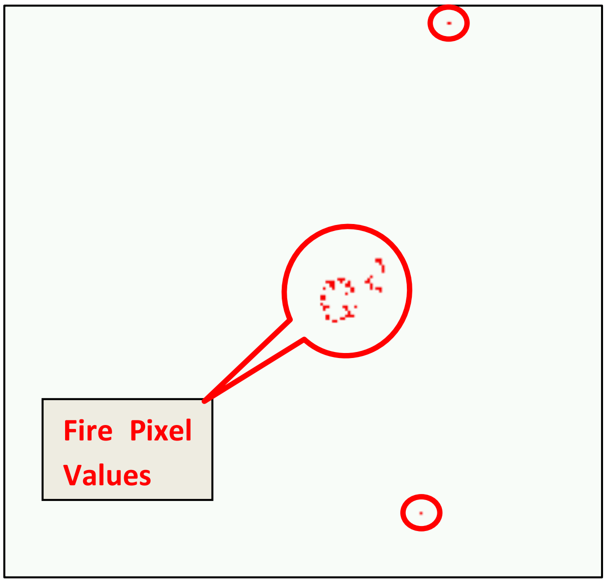


Right-click again on the opened raster-layer in the **Layers Panel** (lower left) and go to **Properties**.

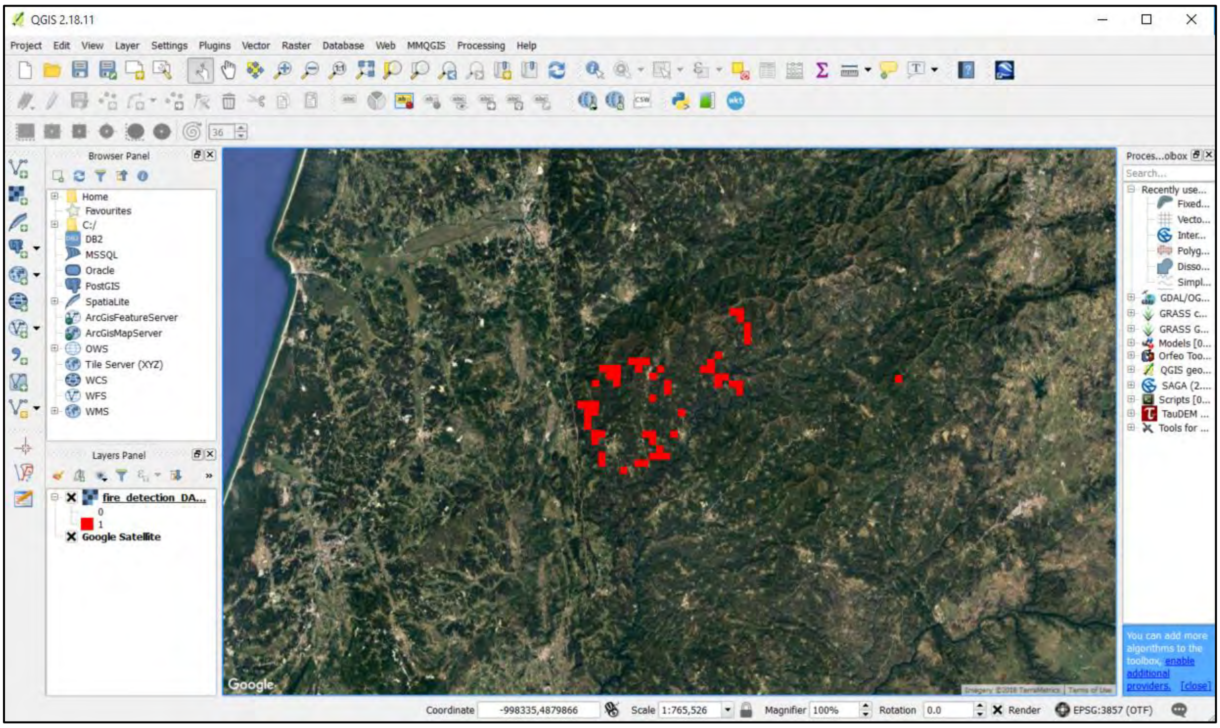
In the **Style** tab set: **Render type:** Singleband pseudocolor
Band: Band 1 (Gray)
Max: 1

Then click **Load colour map from file** to import predefined colour map. Navigate to the ***Auxdata*** folder and open ***Active_fire_no_background.txt***. Or design your own (fire pixels have value 1, background pixels have value 0). Click **OK**.





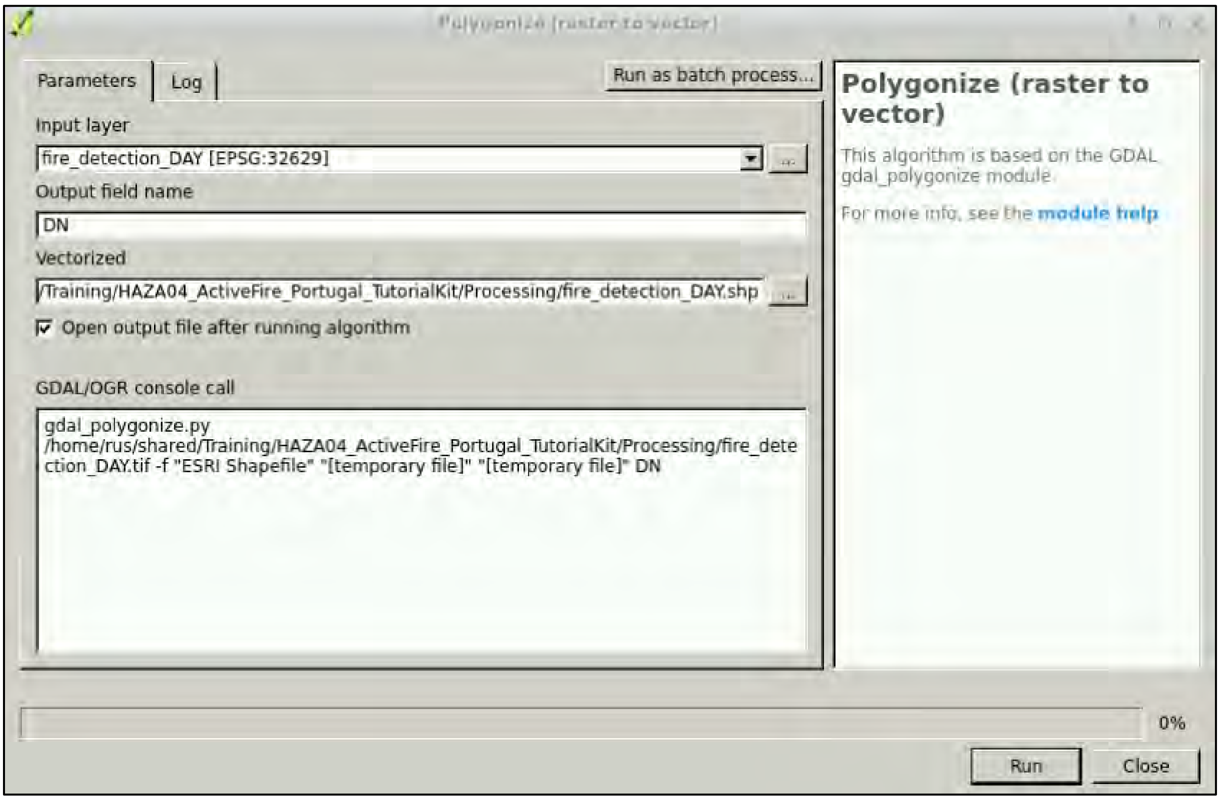
We can also add a base map layer. Go to **Web → OpenLayers plugin → Google Maps → Google Satellite**. Drag the Google Satellite layer below the fire_detection layer in the **Layers Panel** (See NOTE E2).



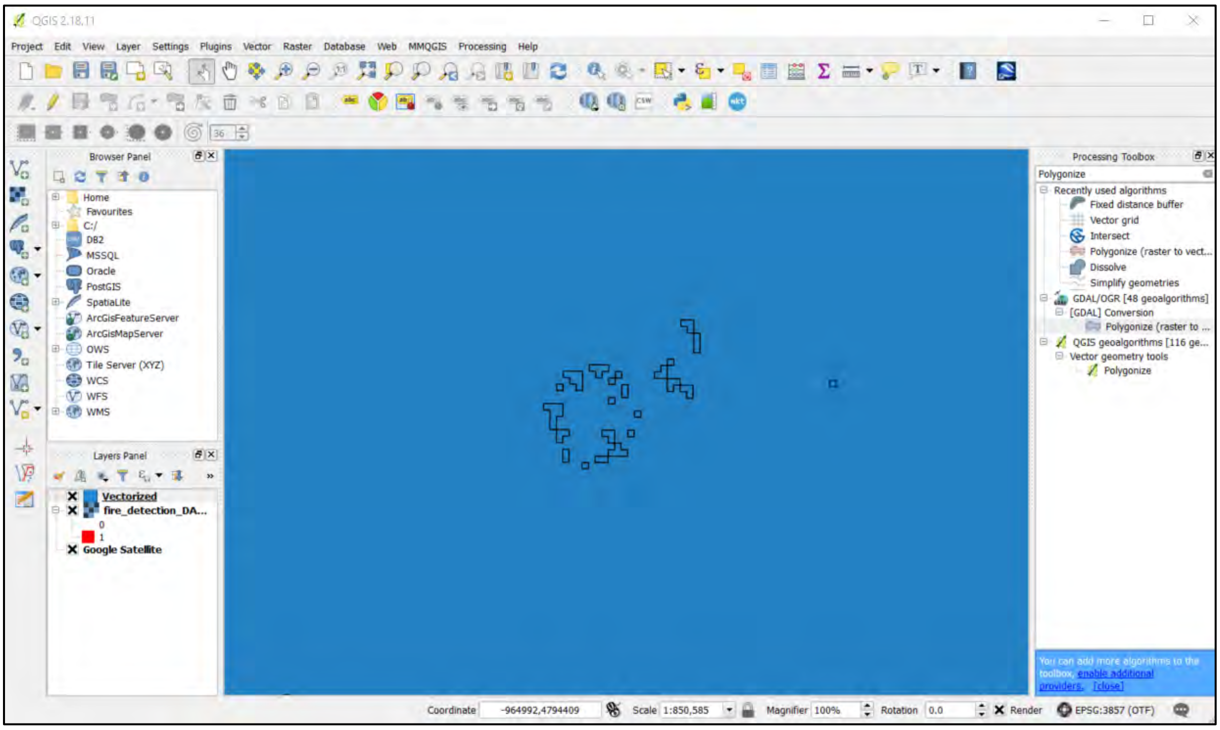
NOTE E2: In case the **OpenLayers** plugin is not installed, click on **Plugins →Manage and Install Plugins.** Select the *"All"* tab on the left side panel and write "**OpenLayers plugin**" on the search box. Select the plugin on the list and click "**Install Plugin**". Restart QGIS to finalize the installation.

Then go to **Processing → Toolbox**, expand **GDAL/OGR**, then expand **[GDAL] Conversion** and double click the **Polygonize (raster to vector)** tool.

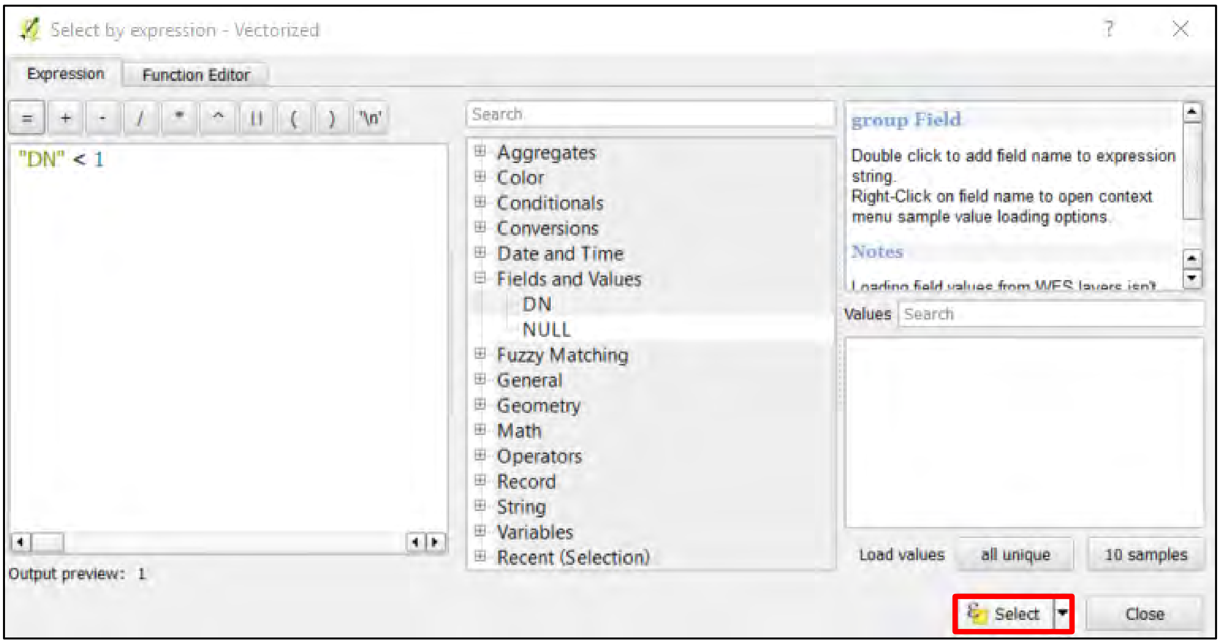
In the **Parameters** tab, check your input layer to be "**fire_detection_DAY [EPSG:32629]**", keep the "**Output field name**" as default and at "**Vectorized"** select "**Save to file…**" and save it at the ***Processing*** folder with "**File name**": "***fire_detection_DAY***")



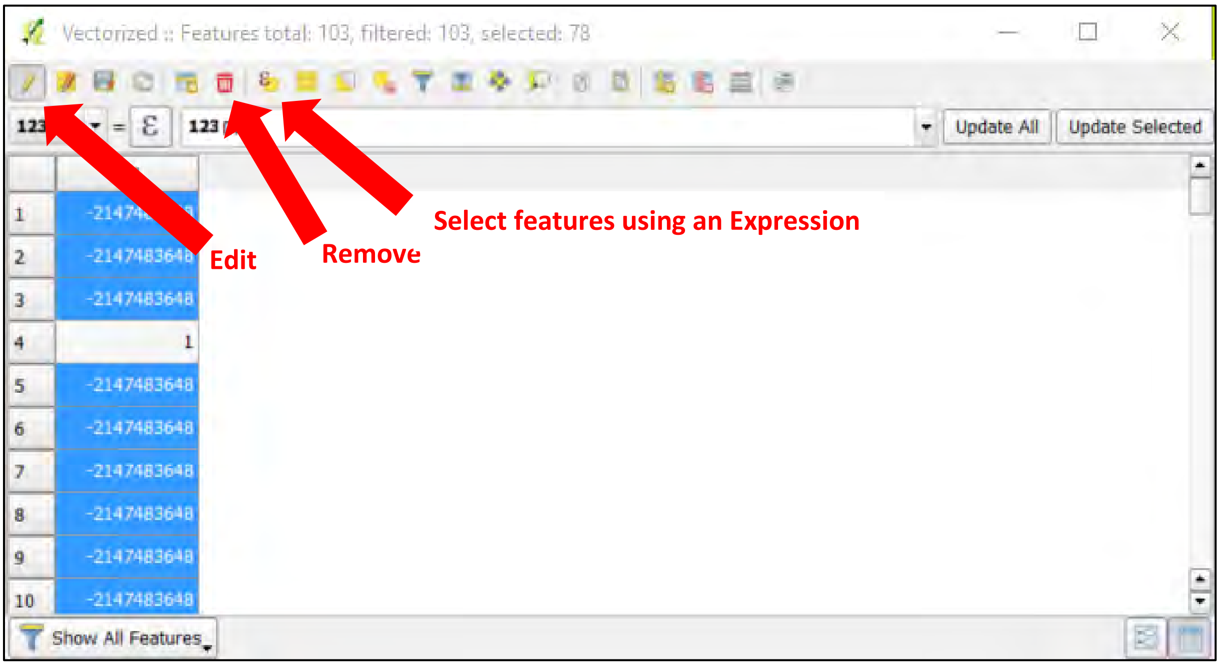
Click **Run**.



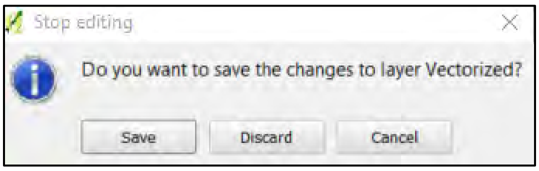
You can see that the 0 values and No Data have been polygonised as well. We can remove them by right-clicking the **Vectorized** layer in the **Layers Panel** and going to **Open Attribute Table**. Then click "**Select features using an Expression**" and enter **"DN" < 1** (including quotation marks). Click at the lower right " **Select**" and then click **Close**.



All polygons except the ones with value 1 (fire) have been selected. Click **Edit** and then click **Remove.** This will remove all selected polygons.

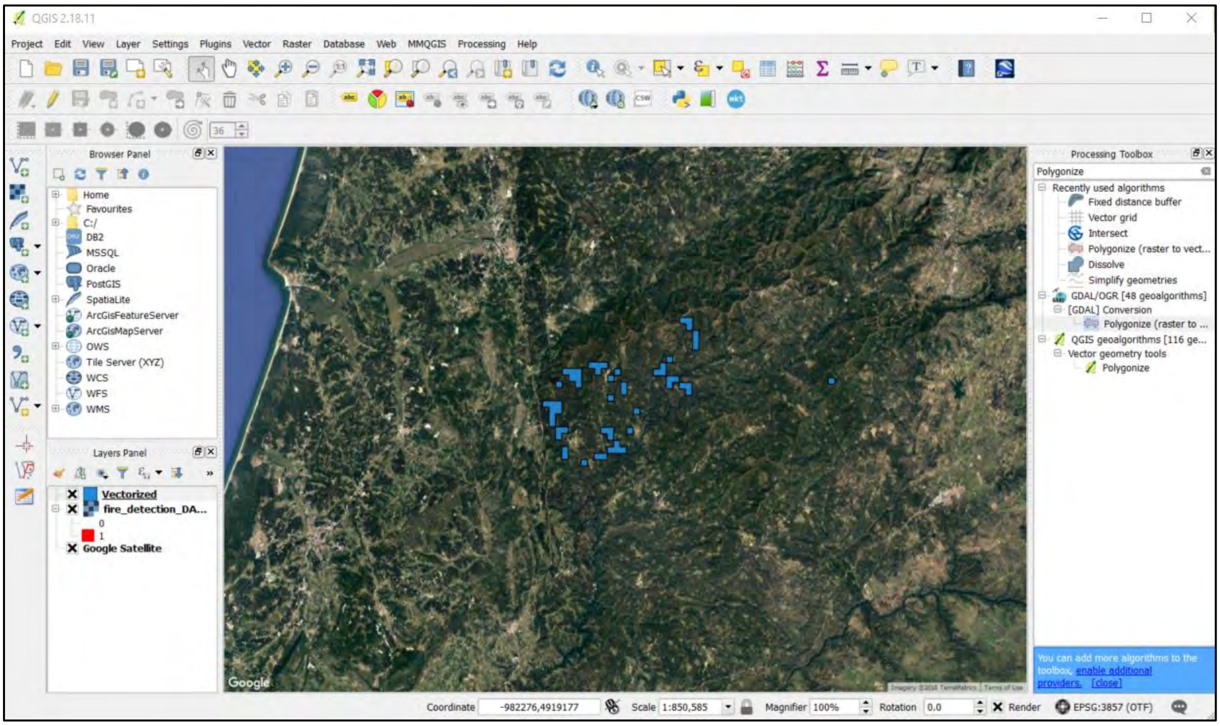


Now, click on **Edit** again to finish editing. Then click **Save** to save your edits. Close the Attribute Table.



Now we have a shapefile layer containing only our fire pixels.

You can repeat the 8.2 Convert to Vector chapter for the night band as well.



9 Further reading and resources

Global Wildfire Information System (GWIS)
(http://gwis.jrc.ec.europa.eu/static/gwis_current_situation/public/index.html)

Global Forest Watch - Fires (http://fires.globalforestwatch.org/map/)

CCI Land Cover (http://maps.elie.ucl.ac.be/CCI/viewer/index.php)

10 References

Giglio, L., Descloitres, J., Justice, C.O., and Kaufman, Y.J. (2003). An Enhanced Contextual Fire Detection Algorithm for MODIS. Remote Sens. Environ. *87*, 273–282.

Wooster, M.J., Xu, W., and Nightingale, T. (2012). Sentinel-3 SLSTR active fire detection and FRP product: Pre-launch algorithm development and performance evaluation using MODIS and ASTER datasets. Remote Sens. Environ. *120*, 236–254.

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