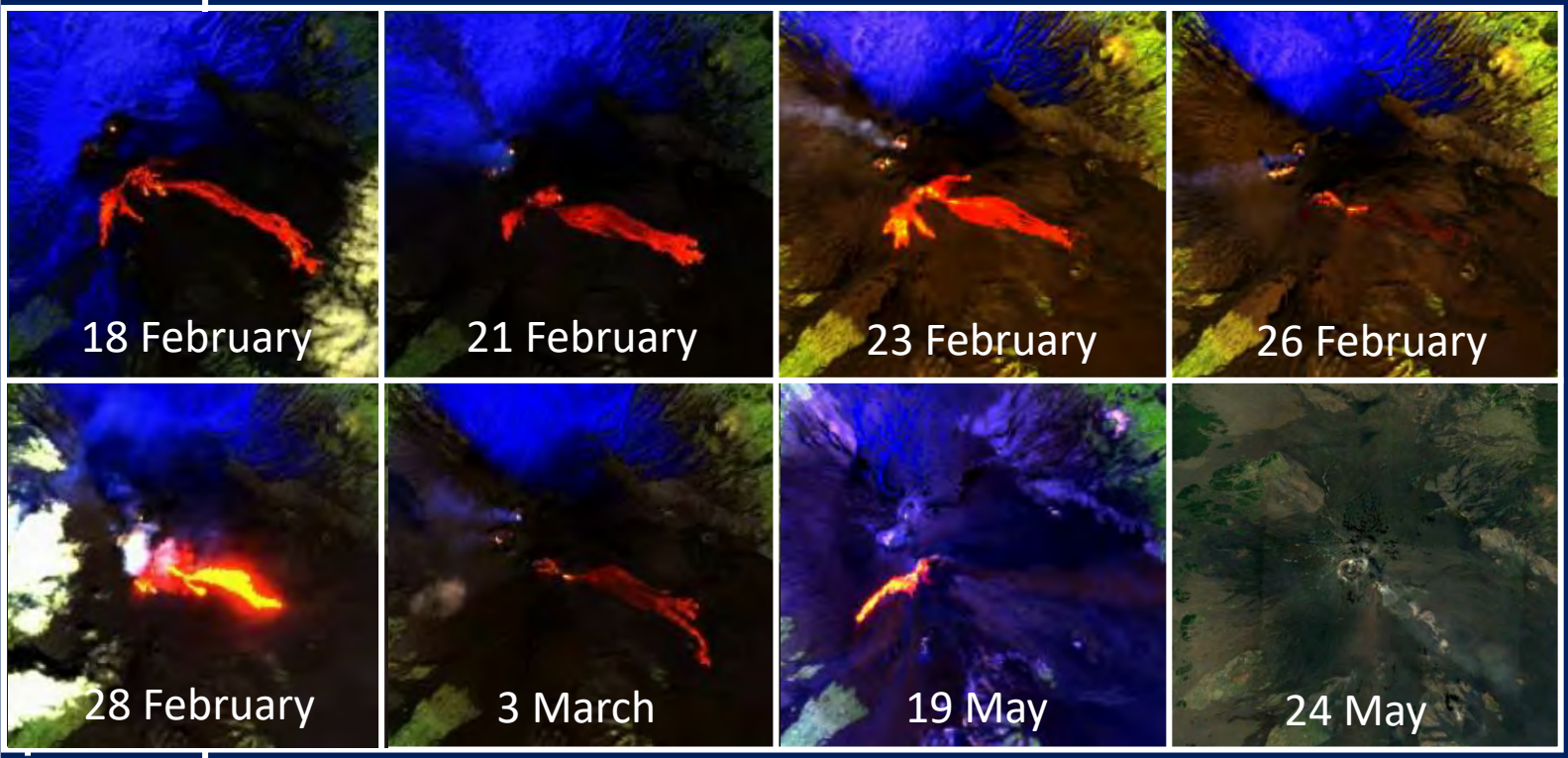


TRAINING KIT – HAZA11

VOLCANO MONITORING WITH SENTINEL-2 – February - May 2021 (Mount Etna, Sicily)

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-copernicus.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.

Date of publication: May 2021

Version: 1.1

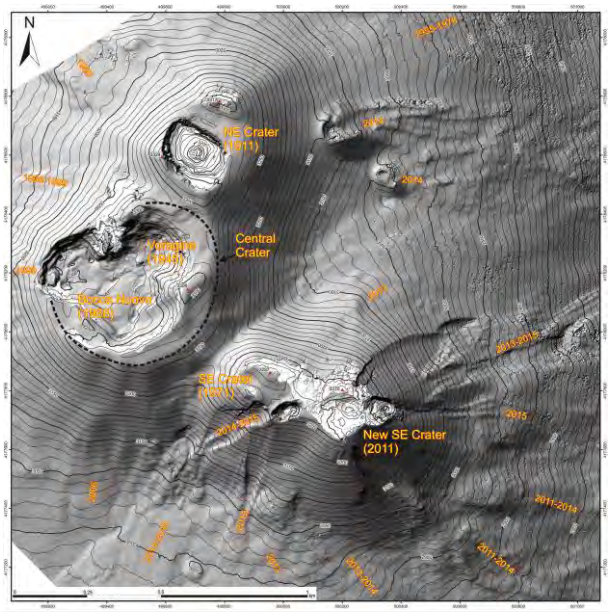
Suggested citation:

Serco Italia SPA (2021). *Volcano Monitoring with Sentinel-2. (version 1.1).* Retrieved from RUS Lectures at https://rus-copernicus.eu/portal/the-rus-library/train-with-rus/

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 acquired by the Copernicus Sentinel satellites constellation.



Neri M., et al., 2017 - Topographic Map of Mount Etna's Summit Craters. DOI: 10.1080/17445647.2017.1352041

Mount Etna is one of the three active volcanoes in Italy and one of the most active in the world, with an almost constant state of activity. It is a stratovolcano, located on the east coast of Sicily, Italy and more specifically at the province of Catania.

Parts of the volcano are shared among different local municipalities. It is the largest volcano in Italy, covering an area of around 1,190 km^2, and it also is one of the tallest active volcanoes in Europe. Currently, it is of a height of 3,326 m.

Etna's eruptions are of multiple patterns. They can be either flank or occur at the summit, which has five distinct craters.

There are also plenty of vents that provide relevant material systematically. The volcano is known for many eruptions, with the volcanic activity to have firstly started taking place at about 500,000 years ago. There has been an increase at the eruptive events recorded the last few years, and the most recent summit eruptions have started in February 2021. The city of Catania has been affected by this recent event, mainly by the volcanic ash that covered most of the area.

Mount Etna lies above the convergent plate margin between the African Plate and the Eurasian Plate. The African continental plate is constantly moving towards Europe and subducts underneath the Eurasian plate. In the image here on the left, we see the thrust tectonics prevailing the Italian Peninsula and its surroundings.

Some eruptions apart from being highly explosive, they may also threaten the inhabited areas around the volcano. Several injuries, deaths, damages and loss of properties have been recorded because of volcanic eruptions and the following to them natural phenomena all over the world.

Due to the history of recent activity and nearby population, Mount Etna has been designated a Decade Volcano by the United Nations. In June 2013, it was added to the list of UNESCO World Heritage Sites.

2 Training

Approximate duration of this training session is **two** hours.

The Training Code for this tutorial is HAZA11. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the RUS portal to request a Virtual Machine. Go to Your RUS Service → Your training activities and *Request a Webinar Training*.

2.1 Data used

- 46 Sentinel-2 MSIL2A images are available over Etna volcano for the period 1 February 2021 until 24 May 2021, every 2-3 days available [downloadable at https://scihub.copernicus.eu/]. 20 out of the 46 were covered by clouds, therefore they are not appropriate for our processing. It is advised to download only those from the list below, that do not have the "*clouds*" as description.

S2B_MSIL2A_20210201T095129_N0214_R079_T33SVB_20210201T121019 - clouds
S2A_MSIL2A_20210203T094211_N0214_R036_T33SVB_20210203T122614
S2A_MSIL2A_20210206T095201_N0214_R079_T33SVB_20210206T120655
S2B_MSIL2A_20210208T094049_N0214_R036_T33SVB_20210208T120726 - clouds
S2B_MSIL2A_20210211T095029_N0214_R079_T33SVB_20210211T121618
S2A_MSIL2A_20210213T094111_N0214_R036_T33SVB_20210213T122449 - clouds
S2A_MSIL2A_20210216T095101_N0214_R079_T33SVB_20210216T120430
S2B_MSIL2A_20210218T094029_N0214_R036_T33SVB_20210218T141009
S2B_MSIL2A_20210221T095029_N0214_R079_T33SVB_20210221T115149
S2A_MSIL2A_20210223T094031_N0214_R036_T33SVB_20210223T122213
S2A_MSIL2A_20210226T095031_N0214_R079_T33SVB_20210226T122801
S2B_MSIL2A_20210228T094029_N0214_R036_T33SVB_20210228T123605
S2B_MSIL2A_20210303T095029_N0214_R079_T33SVB_20210303T113435
S2A_MSIL2A_20210305T094031_N0214_R036_T33SVB_20210305T121638 - clouds
S2A_MSIL2A_20210308T095031_N0214_R079_T33SVB_20210308T121258
S2B_MSIL2A_20210310T094029_N0214_R036_T33SVB_20210310T122941 - clouds
S2B_MSIL2A_20210313T095029_N0214_R079_T33SVB_20210313T115645 - clouds
S2A_MSIL2A_20210315T094031_N0214_R036_T33SVB_20210315T120006 - clouds
S2A_MSIL2A_20210318T095031_N0214_R079_T33SVB_20210318T113807 - clouds
S2B_MSIL2A_20210320T094029_N0214_R036_T33SVB_20210320T113342 - clouds
S2B_MSIL2A_20210323T095029_N0214_R079_T33SVB_20210323T113649 - clouds
S2A_MSIL2A_20210325T094031_N0214_R036_T33SVB_20210325T114733
S2A_MSIL2A_20210328T095031_N0214_R079_T33SVB_20210328T113651 - clouds
S2B_MSIL2A_20210330T094029_N0300_R036_T33SVB_20210330T124902
S2B_MSIL2A_20210402T095029_N0300_R079_T33SVB_20210402T133211
S2A_MSIL2A_20210404T094031_N0300_R036_T33SVB_20210404T122544 - clouds
S2A_MSIL2A_20210407T095031_N0300_R079_T33SVB_20210407T143611 - clouds
S2B_MSIL2A_20210409T094029_N0300_R036_T33SVB_20210409T120755
S2B_MSIL2A_20210412T095029_N0300_R079_T33SVB_20210412T121559
S2A_MSIL2A_20210414T094031_N0300_R036_T33SVB_20210414T123112
S2A_MSIL2A_20210417T095021_N0300_R079_T33SVB_20210417T121415
S2B_MSIL2A_20210419T094029_N0300_R036_T33SVB_20210419T121500 - clouds
S2B_MSIL2A_20210422T095029_N0300_R079_T33SVB_20210422T130900 - clouds
S2A_MSIL2A_20210424T094031_N0300_R036_T33SVB_20210424T123436 - clouds
S2A_MSIL2A_20210427T095031_N0300_R079_T33SVB_20210427T121331
S2B_MSIL2A_20210429T094029_N0300_R036_T33SVB_20210429T124306
S2B_MSIL2A_20210502T095029_N0300_R079_T33SVB_20210502T121950 - clouds
S2A_MSIL2A_20210504T094031_N0300_R036_T33SVB_20210504T122449 - clouds
S2A_MSIL2A_20210507T095031_N0300_R079_T33SVB_20210507T151839 - clouds

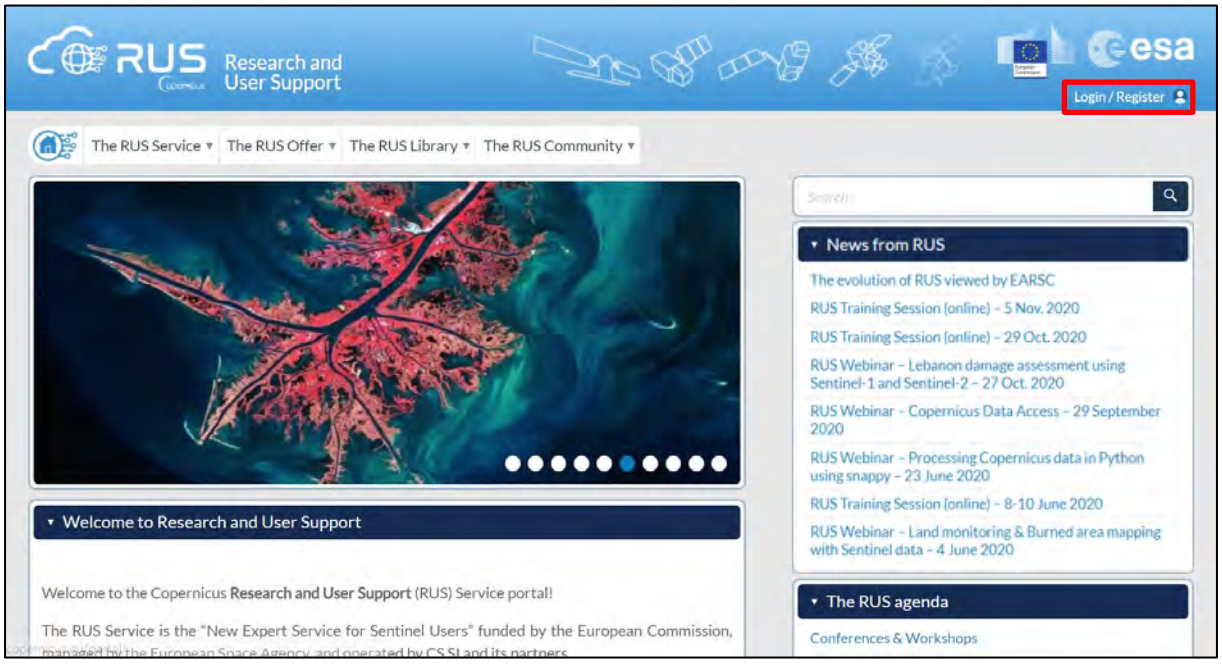
S2B_MSIL2A_20210509T094029_N0300_R036_T33SVB_20210509T120133
S2B_MSIL2A_20210512T095029_N0300_R079_T33SVB_20210512T132953
S2A_MSIL2A_20210514T094031_N0300_R036_T33SVB_20210514T123226 - clouds
S2A_MSIL2A_20210517T095031_N0300_R079_T33SVB_20210517T120344
S2B_MSIL2A_20210519T094029_N0300_R036_T33SVB_20210520T124025
S2B_MSIL2A_20210522T095029_N0300_R079_T33SVB_20210522T113428
S2A_MSIL2A_20210524T094031_N0300_R036_T33SVB_20210524T122558

2.2 Software in RUS environment

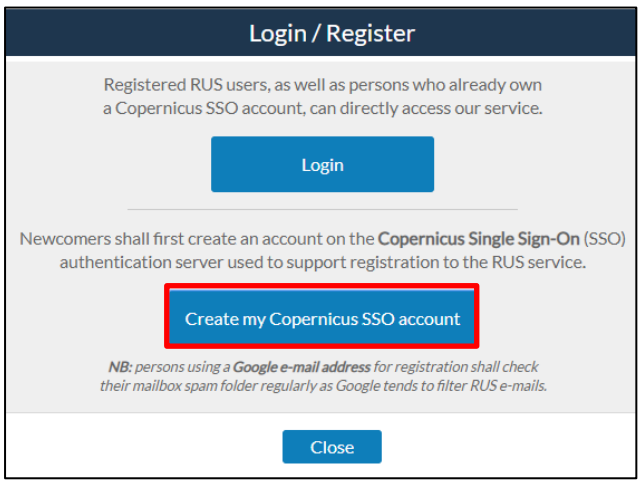
Internet browser, SNAP + Sentinel-2 Toolbox, QGIS, Google Earth.

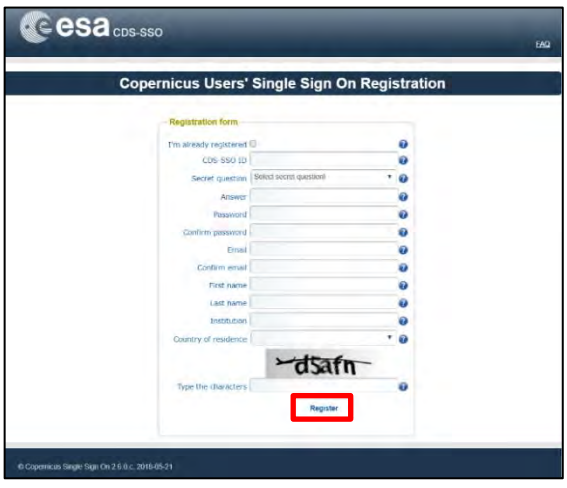
3 Register to RUS Copernicus

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.

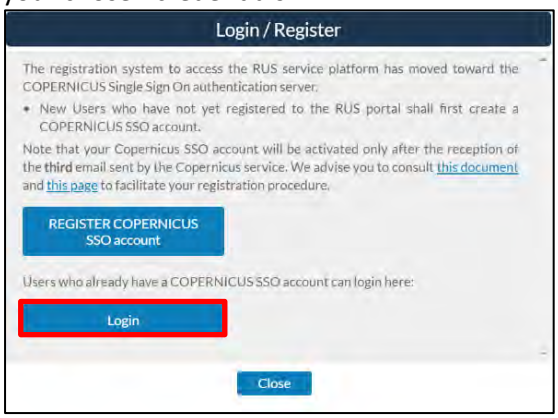


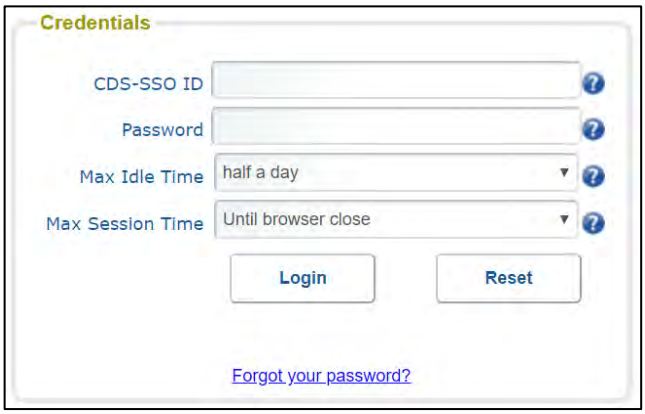
Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click ***Register***.



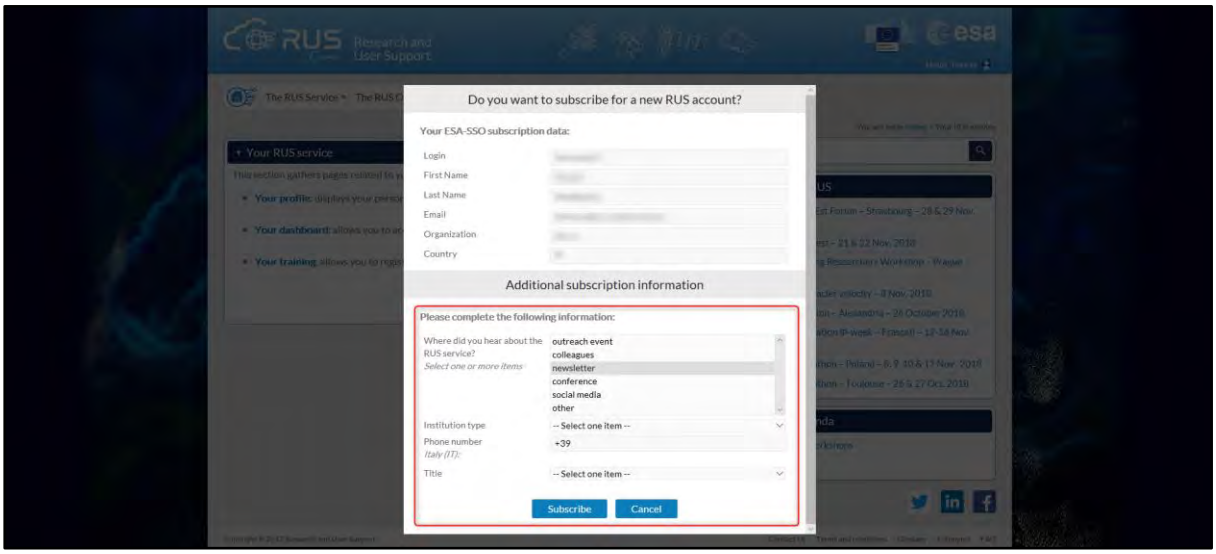


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.
You can now return to https://rus-copernicus.eu/, click on ***Login/Register***, choose ***Login*** and enter your chosen credentials.



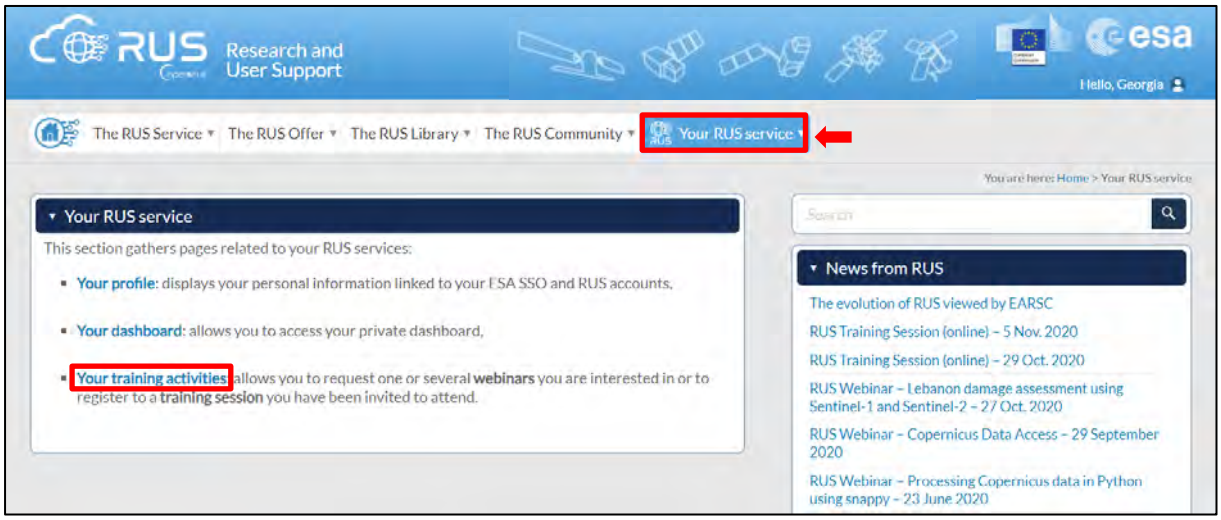


Upon your first login you will need to enter some details. You must fill all the fields.

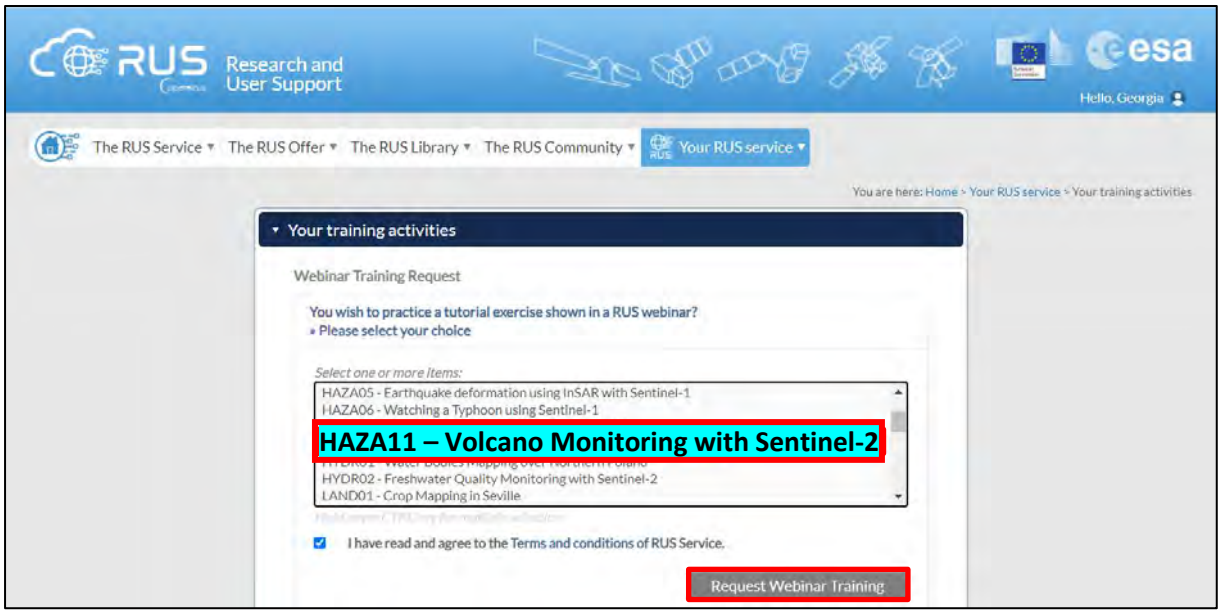


4 Request a RUS Copernicus Virtual Machine to repeat a Webinar

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 training activities***.



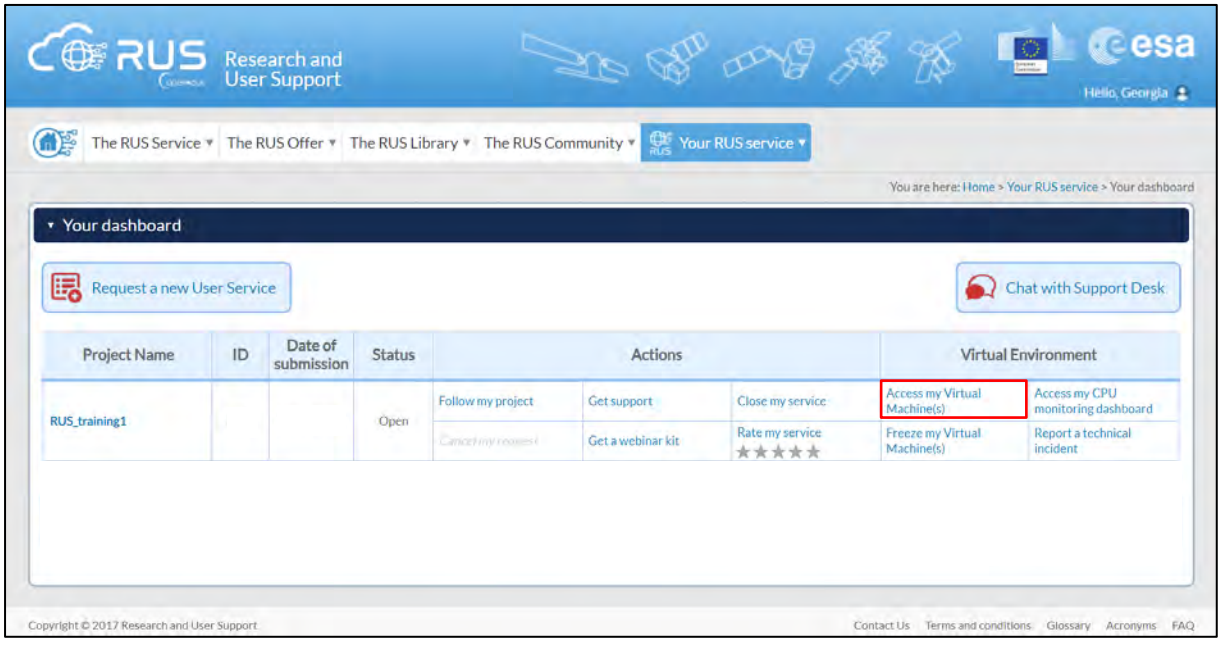
Select **HAZA11 – Volcano Monitoring with Sentinel-2**, check the field *"I have read and agree to the Terms and conditions of RUS Service"* and then click on ***Request Webinar Training*** to request your RUS Virtual Machine.



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***.

NOTE: If the "***Access my Virtual Machine***" is greyed out, please access your VM from the direct link you have received at the email informing you about the creation of your VM.



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 Step by step

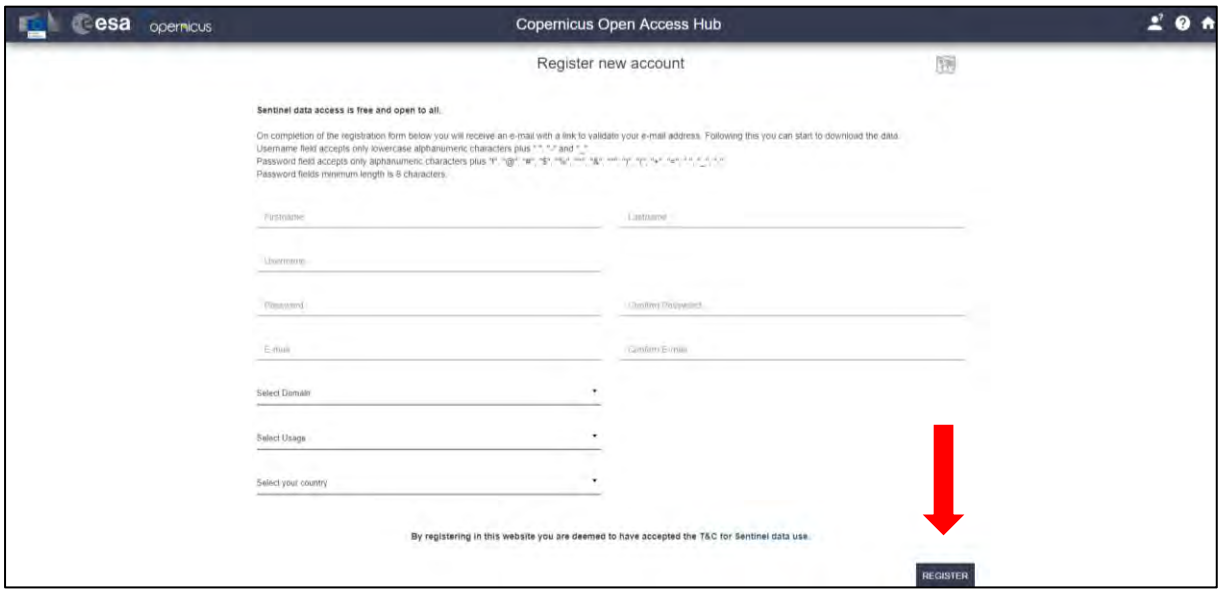
5.1 Data download – ESA SciHUB

In this step, we will download the Sentinel-2 scenes we will use for the exercise, from the Copernicus Open Access Hub using the online interface.

Go to **Applications → Network → Firefox 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 by going to "**Sign-up**" in the LOGIN menu in the upper right corner.



After you have 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, "**LOGIN**".

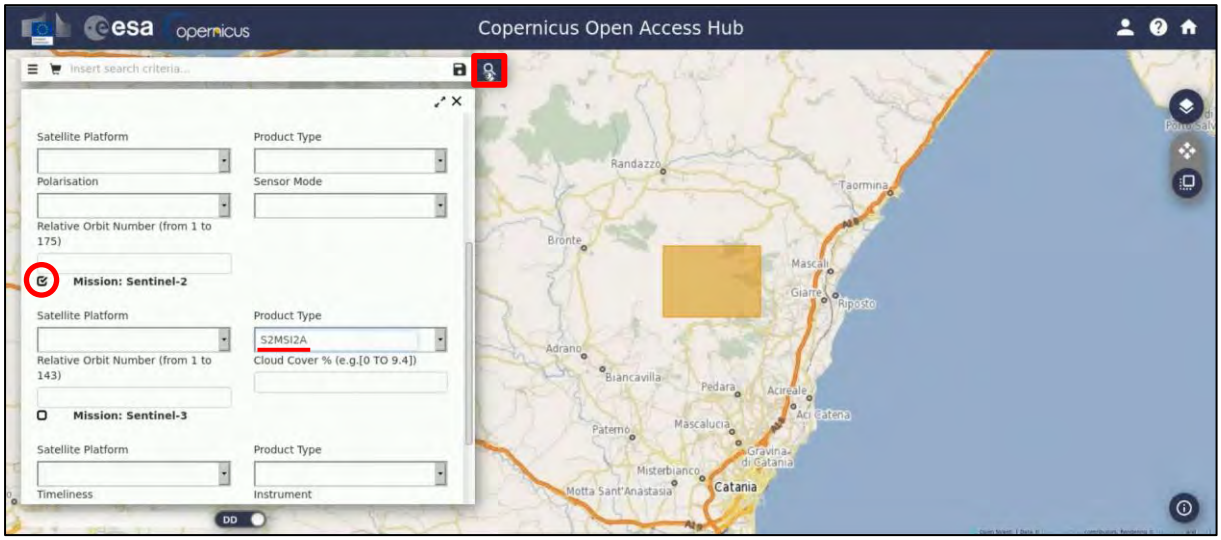
Navigate over Mount Etna, in Sicily (**approximate area – green rectangle**).

We need to download 26 Sentinel-2 cloud free images over the area of interest.

Zoom in a bit more, switch to "**drawing mode**" and draw a search rectangle approximately as indicated below. Open the search menu by clicking to the left part of the search bar. We will specify at once the parameters for all products:

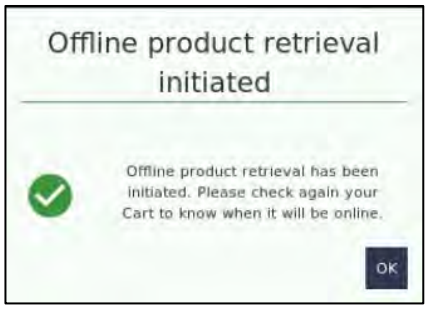
<u>For Sentinel-2:</u>

Sensing period: From 2021/02/01 to 2021/05/24
Select: Mission: Sentinel-2
Product Type: S2MSIL2A



Then click on the "**Search**" icon. The search will return too many results for the time period we set. We need to download only some specific, so select one, click on the "**View Product Details**" icon as shown below and check under the "**Product**", which is the "*Relative Orbit*" it belongs to. In our case we need products that belong to the **Relative Orbit Number:** 36 and 79. Then, by going back to the main menu, you can run the search once for **Relative Orbit Number** 36 and once for 79.

As you can see, some of the products we need appear to be "Offline". For those products, once we click on the download icon of the first one, the following message will appear. Click **OK**.



The product is automatically added in the "Cart". In case an error message appears, try again a bit later – you can request for one product per account per hour. (See NOTE 1 and NOTE 2):

The product will be online within few minutes.

By the time the product turns online, it remains like that for 4 days and then it goes back to offline again. You need to frequently check your cart for the product availability.

NOTE 1: Please keep in mind that you cannot download more than 2 products at the same time, per account from SciHub.

NOTE 2: You can find more information about the retrieval of offline/long term archive products here: https://scihub.copernicus.eu/twiki/do/view/SciHubUserGuide/LongTermArchive#Retrieval_of_offline_products_vi & https://scihub.copernicus.eu/userguide/LongTermArchive

You need to repeat the same process for all downloadable images mentioned in Chapter 2.1, the products will be downloaded at ***/home/rus*** as zip files. Move them to: ***/shared/Training/HAZA11_VolcanoMonitoring_Etna/Original*** folder. You will find subfolders with the ***Original*** folder, based on the month the data were retrieved (02, 03, 04 and 05). Paste them accordingly.

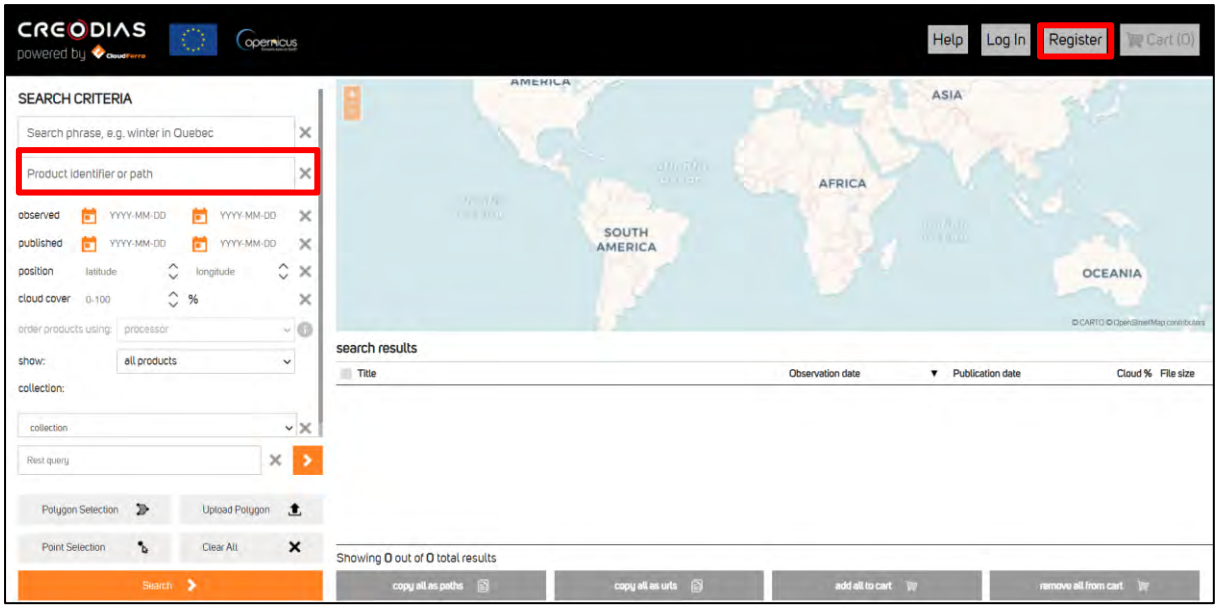
Instead of waiting until you will retrieve all this data, you can alternatively follow the instructions on the next chapter, and download immediately all the images you wish.

5.2 Data download – CREODIAS

As you are using **Firefox Web Browser,** go to the CREODIAS Finder: https://finder.creodias.eu/#

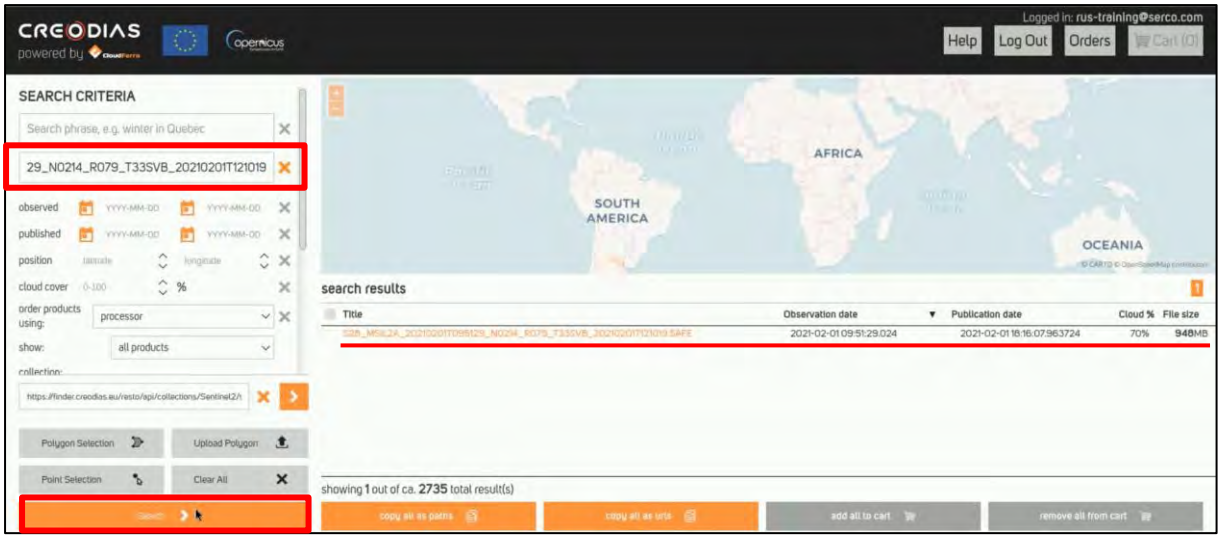
If you do not have an account, click on "**Register"** and sign up. After you have completed the process, just "**Log In"**, and you are ready to proceed.

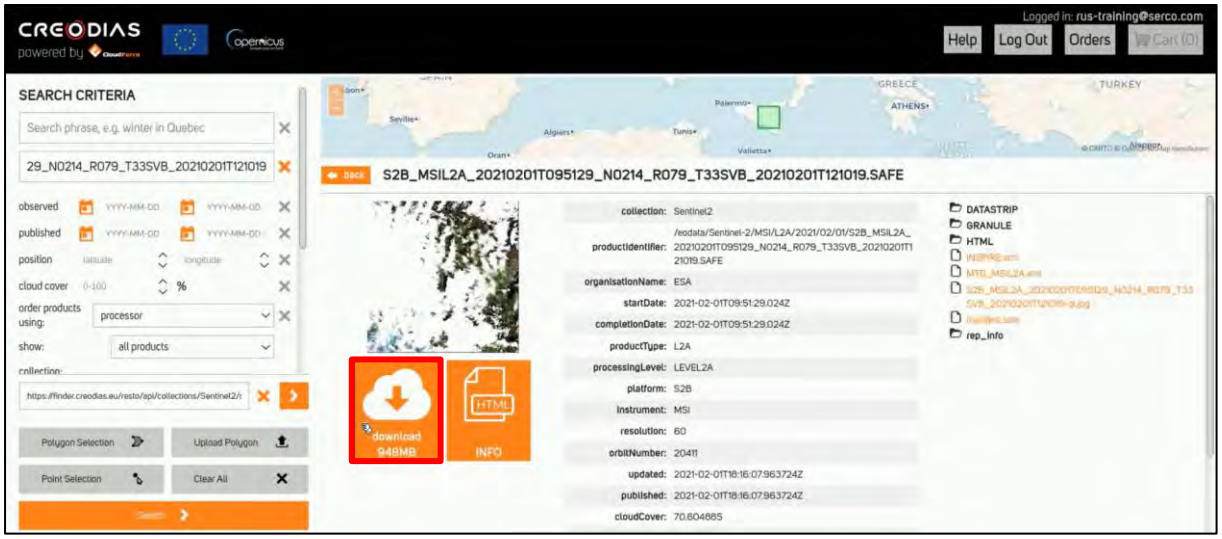
Then go to the "***Product Identifier or path***" field, and copy and paste the images from the list below, one by one.



S2A_MSIL2A_20210203T094211_N0214_R036_T33SVB_20210203T122614
S2A_MSIL2A_20210206T095201_N0214_R079_T33SVB_20210206T120655
S2B_MSIL2A_20210211T095029_N0214_R079_T33SVB_20210211T121618
S2A_MSIL2A_20210216T095101_N0214_R079_T33SVB_20210216T120430
S2B_MSIL2A_20210218T094029_N0214_R036_T33SVB_20210218T141009
S2B_MSIL2A_20210221T095029_N0214_R079_T33SVB_20210221T115149
S2A_MSIL2A_20210223T094031_N0214_R036_T33SVB_20210223T122213
S2A_MSIL2A_20210226T095031_N0214_R079_T33SVB_20210226T122801
S2B_MSIL2A_20210228T094029_N0214_R036_T33SVB_20210228T123605
S2B_MSIL2A_20210303T095029_N0214_R079_T33SVB_20210303T113435
S2A_MSIL2A_20210308T095031_N0214_R079_T33SVB_20210308T121258
S2A_MSIL2A_20210325T094031_N0214_R036_T33SVB_20210325T114733
S2B_MSIL2A_20210330T094029_N0300_R036_T33SVB_20210330T124902
S2B_MSIL2A_20210402T095029_N0300_R079_T33SVB_20210402T133211
S2B_MSIL2A_20210409T094029_N0300_R036_T33SVB_20210409T120755
S2B_MSIL2A_20210412T095029_N0300_R079_T33SVB_20210412T121559
S2A_MSIL2A_20210414T094031_N0300_R036_T33SVB_20210414T123112
S2A_MSIL2A_20210417T095021_N0300_R079_T33SVB_20210417T121415
S2A_MSIL2A_20210427T095031_N0300_R079_T33SVB_20210427T121331
S2B_MSIL2A_20210429T094029_N0300_R036_T33SVB_20210429T124306
S2B_MSIL2A_20210509T094029_N0300_R036_T33SVB_20210509T120133
S2B_MSIL2A_20210512T095029_N0300_R079_T33SVB_20210512T132953
S2A_MSIL2A_20210517T095031_N0300_R079_T33SVB_20210517T120344
S2B_MSIL2A_20210519T094029_N0300_R036_T33SVB_20210520T124025
S2B_MSIL2A_20210522T095029_N0300_R079_T33SVB_20210522T113428
S2A_MSIL2A_20210524T094031_N0300_R036_T33SVB_20210524T122558

Click on ***Search*** and the image will appear on the right (see below). Then click on the Product Name, and once it opens, click on the download icon  .





Repeat the same process for all Sentinel-2 images mentioned above. The products will be downloaded at ***/home/rus*** as zip files. Move them to: ***/shared/Training/HAZA11_VolcanoMonitoring_Etna/Original*** folder. You will find subfolders with the ***Original*** folder, based on the month the data were retrieved (02, 03, 04 and 05). Paste them accordingly.

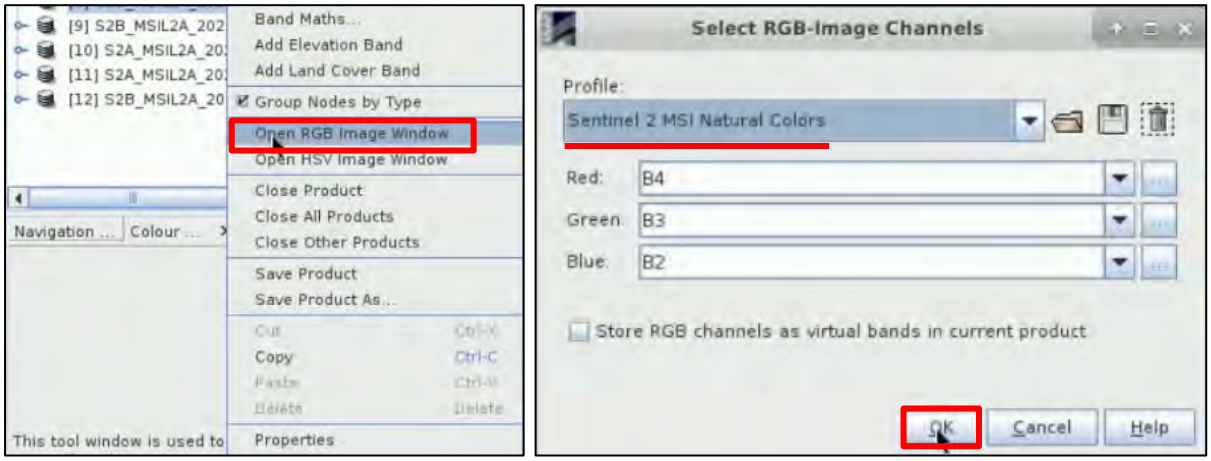
5.3 SNAP – open and explore data

Open **SNAP** software from the icon located on the desktop or go to **Applications → Processing → SNAP Desktop**. Click the **Open Product** icon , navigate to: ***/shared/Training/HAZA11_VolcanoMonitoring_Etna/Original/02*** folder and open all Sentinel-2 products (from oldest to the most recent), that were acquired on February 2021.

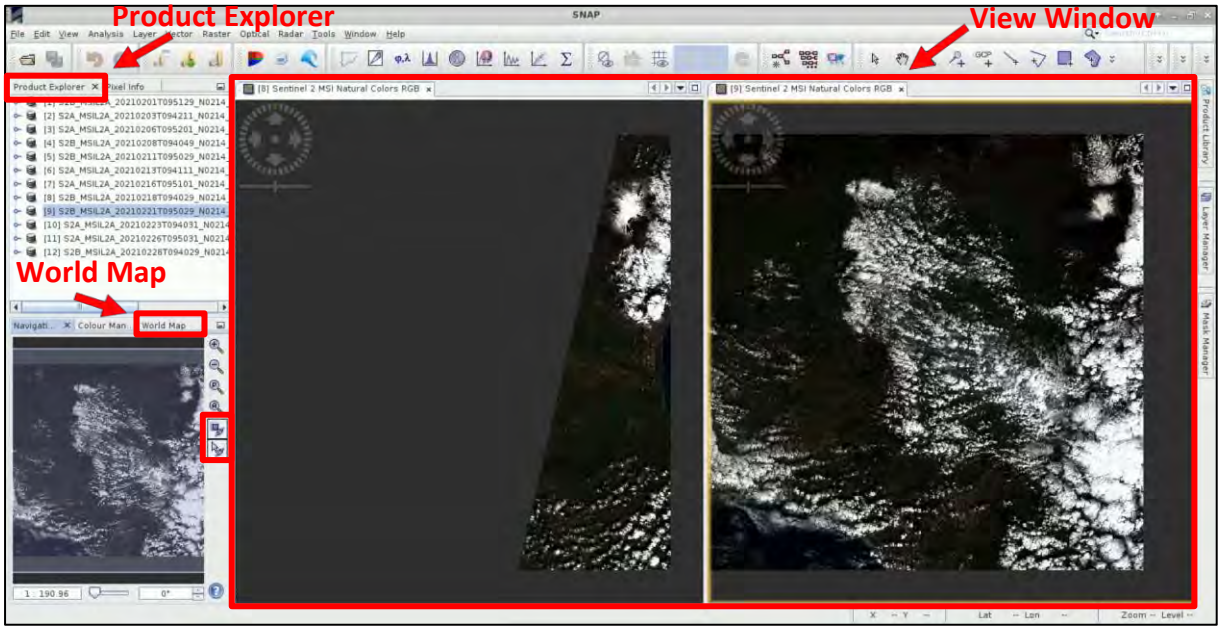
Navigate to the path mentioned above and drag the products from the folder one by one and drop them to the **Product Explorer** Window. The opened products will appear in **Product Explorer** window. Click **+** or to expand the contents of product from **18 February 2021** and see the information it includes.

5.3.1 Create RGB image – Natural Colors B4, B3, B2

Right click on the product from **18 February 2021** and **Open RGB Image Window**. At the Profile, select: **Sentinel 2 MSI Natural Colours**. The B4, B3 and B2 bands will be selected. Click **OK**. Then right click at the product from **21 February 2021** as well and open another RGB image.



Go to **Window → Tile Horizontally** to see the two RGB images created side by side.
You can go to the **World Map** tab and zoom in to see the location of the opened product on the globe.



In the **Navigation** tab, click on the two icons shown within the red rectangular below, to synchronize the views and the cursor position between the views.

5.4 Sentinel-2 Processing

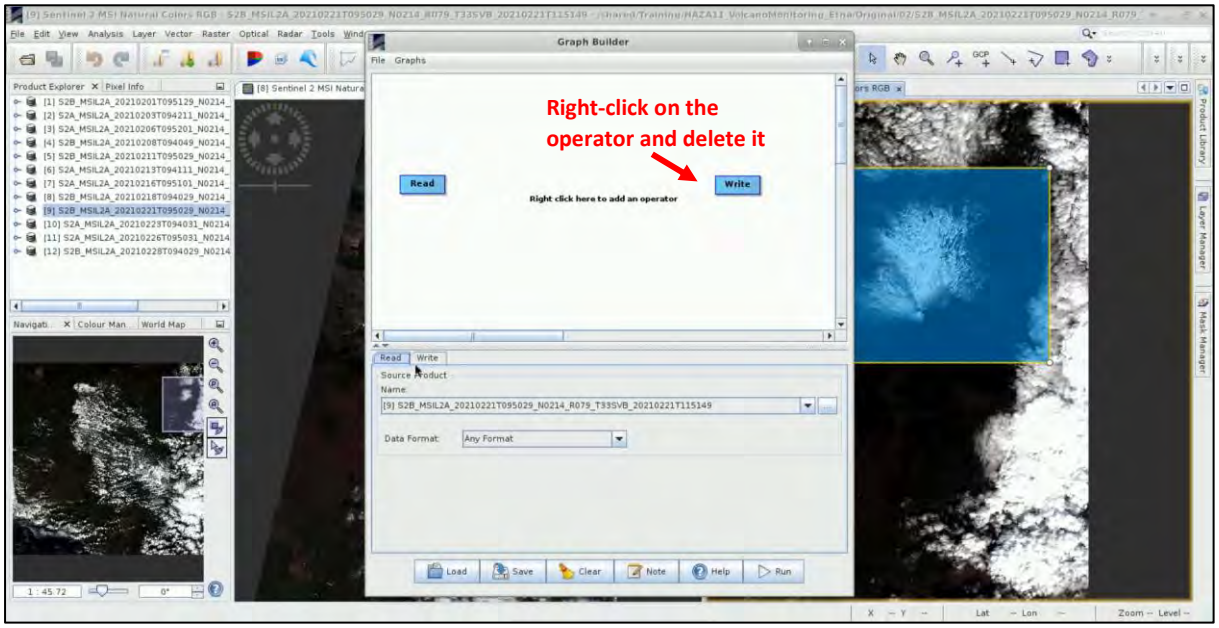
5.4.1 Graph Builder

We need to create a Graph, where we will insert all the necessary operators, in order to prepare our data for the processing, so that they are in a form where we can create an RGB image that will be able to distinguish which of the white-grey areas are snow/volcanic ash and which are clouds. We will also manage to "see" the hot lava that is flowing from the crater.

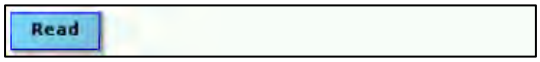
We will use the **GraphBuilder** tool, to create a chain with the processing steps we want to apply and at the end, only the final product will be physically saved (this way we will also save disk space since the products of the intermediate steps will not be stored).

For now, we will not define any parameters in the tabs (they will be defined in the **Batch Processing** step where we will apply this processing for the rest images we have downloaded, at once), we will only create and save the graph.

Go to **Tools** → **GraphBuilder**. Right-click on the **Write** operator and **Delete** it.

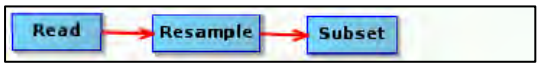


As mentioned, we will set the parameters at the **Batch Processing** step later on. We have only the **Read** operator in the graph for now.



We first need to resample all the Bands so that they have a common resolution, otherwise we cannot proceed with the next steps. To add the **Resample** operator, right-click and go to **Add** → **Raster** → **Geometric** → **Resample**. Connect the **Read** operator to it.

We then need to create a Subset of the image, since we want to focus only over a certain area and we do not need the whole extent of it. To add the **Subset** operator, go to **Add** → **Raster** → **Geometric** → **Subset**.



To create the output of this processing, we will add the **Write** operator. Right-click and go to **Add** → **Input-Output** → **Write**. Connect the **Subset** operator to it.

Click on the 

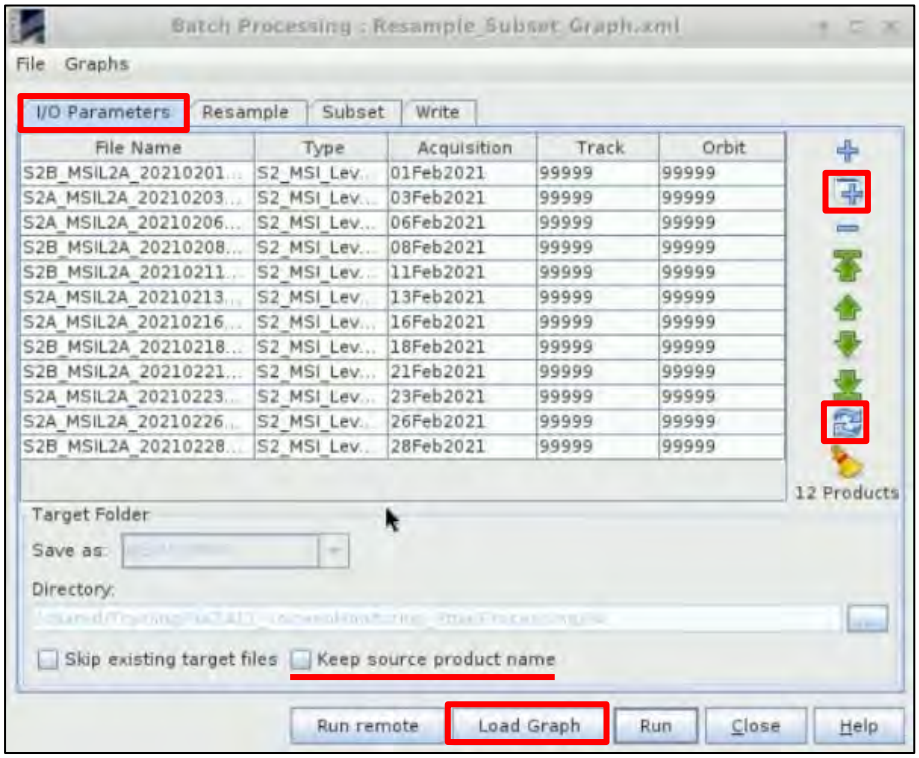
icon to save the graph. Go to the: ***/shared/Training/HAZA11_VolcanoMonitoring_Etna/Processing*** folder and save it with the name: **Resample_Subset_Graph**.

5.4.2 Batch Processing

Batch Processing is used when we want to apply identical pre-processing steps at once, to multiple images. Open the **Batch Processing** tool by going to **Tools → Batch Processing**.

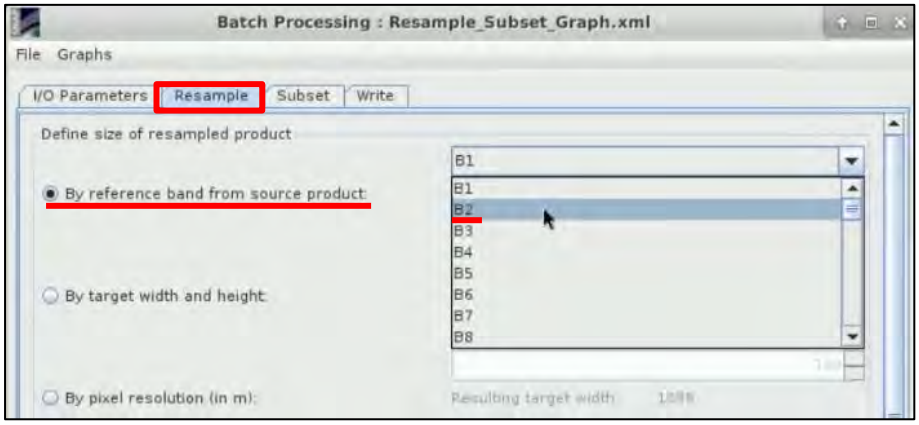
Deselect the "**Keep source product name**" option. In the **I/O Parameters** tab we will add all opened products from the **Product Explorer** window by clicking **Add Opened** at the right (second icon from the top of the column at the right) and then click **Refresh** (second icon from the bottom). In this case we have loaded all images from February 2021. We should repeat the same for the rest of the images afterwards.

Then we will click on **Load Graph** at the bottom of the window, navigate to the path of our saved graph and open it. We see that new tabs have appeared at the top of window corresponding to our operators.



5.4.2.1 Resample

In the **Resample** tab, select under the "Define size of resampled product" select the option: **By reference band from source product** and then select **B2**. This way we will resample all the bands in 10m resolution.

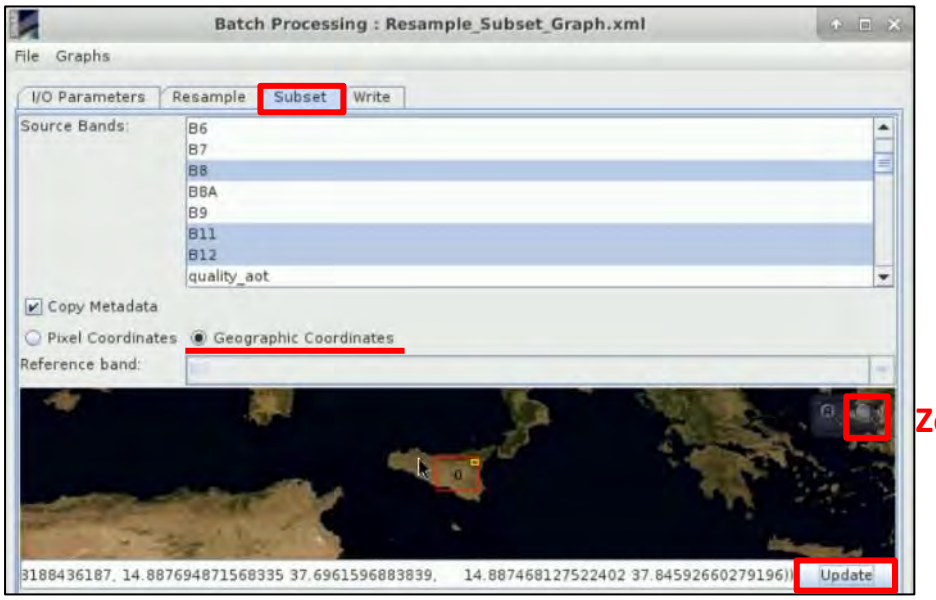


5.4.2.2 Subset

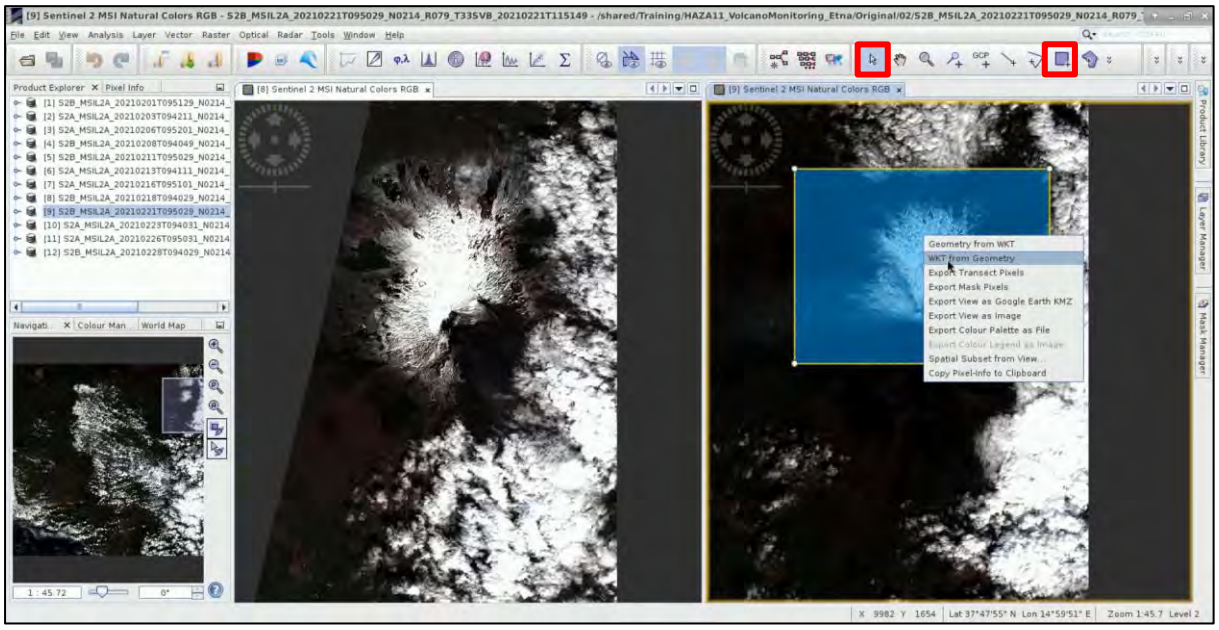
At the **Subset** tab, under the **Source Bands**, select only the **B2**, **B3**, **B4**, **B8**, **B11** and **B12** bands, by having the Ctrl selected on your keyboard. If you want to keep more or all bands, you do not need to select anything. Then select the **Geographic Coordinates** option and copy the WKT (well known text) from the ***Subset Geometry*** file in the ***/shared/Training/HAZA11_VolcanoMonitoring_Etna/AuxData*** folder and paste it to the text window below the map. WKT:

POLYGON ((14.887468127522402 37.84592660279196, 15.086066763207151 37.84594891816823, 15.085893344366365 37.69618188436187, 14.887694871568335 37.6961596883839, 14.887468127522402 37.84592660279196))

Click **Update** and then click the **Zoom-in** icon  to see your subset on the map.

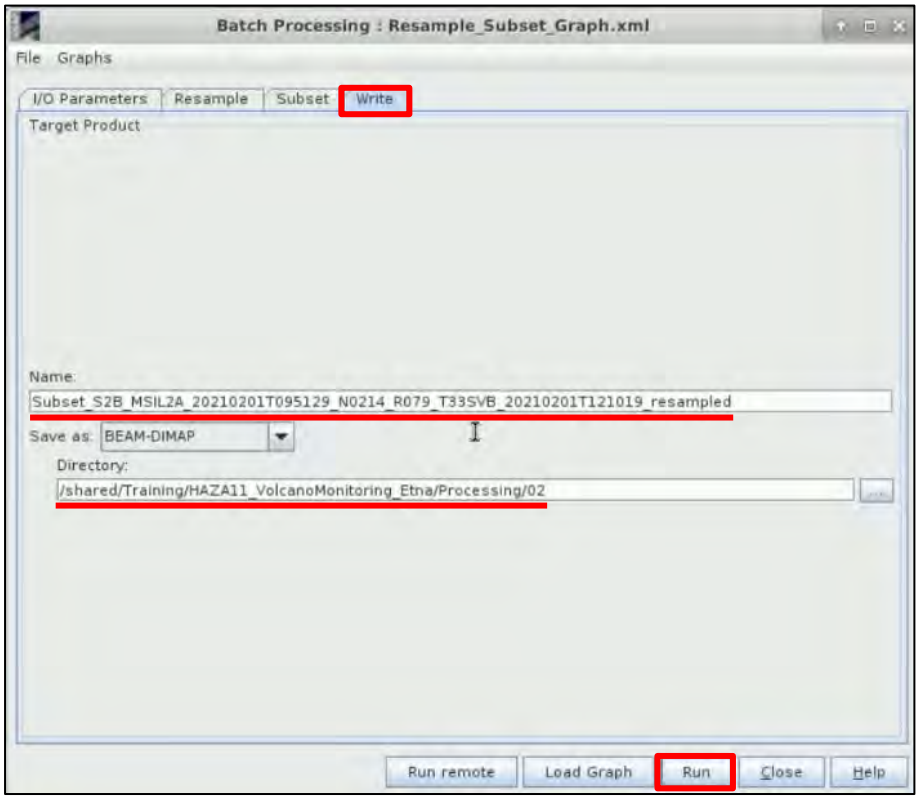


In order to find which is the WKT you need for your Subset, select the ***Rectangle drawing tool*** and draw an area you wish to subset. Then click on the ***Selection tool*** and click on the rectangle you have created. Right click on it and select "*WKT from Geometry*". Copy and paste the text in a file.



5.4.2.3 *Write – create the outputs*

In the **Write** tab, under **Name** keep the default name (Subset and resampled will be added). At the Directory set the path to ***/shared/Training/HAZA11_VolcanoMonitoring_Etna/Processing/02*** for February. Change the paths for the next images of the rest months, accordingly.



Click **Run**. Once the processing is completed for all products, they will appear at the **Product Explorer** Window.

5.4.3 Create RGB image – False-Color B12, B11, B4

Right click again on the product from **18 February 2021** and **Open RGB Image Window**. At the Profile, select: **Sentinel 2 MSI Natural Colors**. The B4, B3 and B2 bands will be selected. Click **OK**. Then right click at the same product again and this time at the Profile, select: **Sentinel 2 MSI False-color Urban** and the B12, B11 and B4 bands will be selected. Click **OK**.

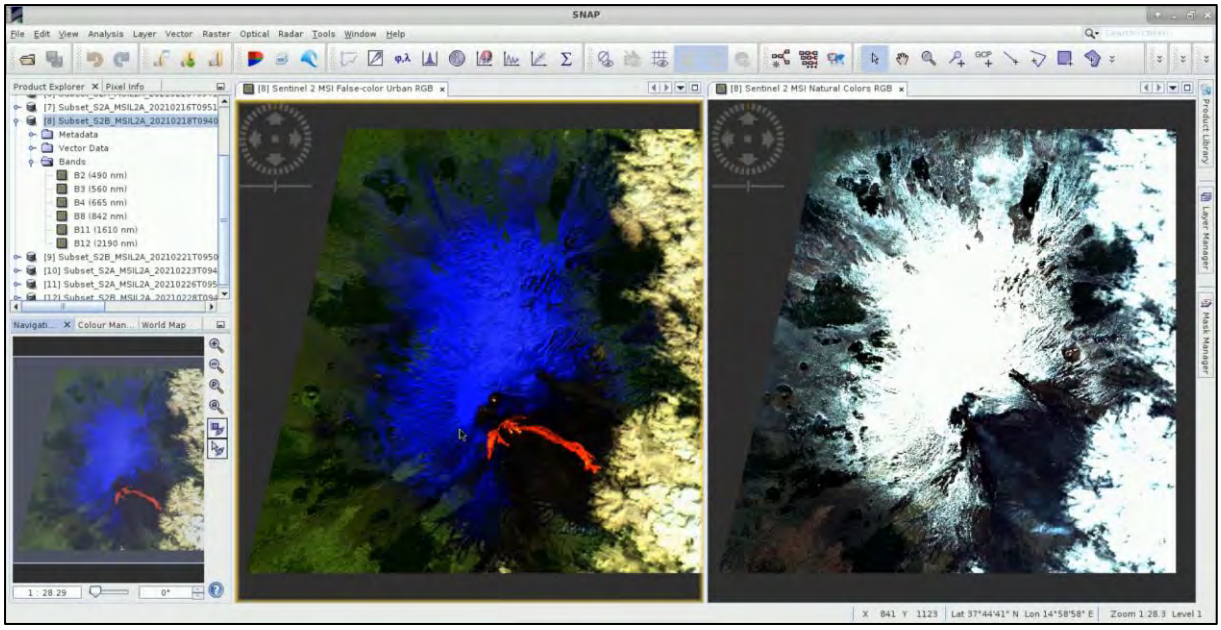
Go to **Window → Tile Horizontally** to see the two RGB images created side by side.

As we compare the two images, we see that while in the one on the right with the natural colours we cannot see any of the lava, when we use Band 12 in the red channel and Band 11 in the green channel in the left one, we start to better understand the area.

These two bands are in frequencies of the Shortwave Infrared part of the electromagnetic spectrum, moreover, B11 is ideal for distinguishing different soil types.

With this combination (also by using Band 4 in the blue channel) we can “read” the heat of the lava that has not cooled down yet and it is being depicted it in red. Also, we can separate which of the white parts correspond to clouds and which correspond to snow or volcanic ash.

Feel free to try more bands combinations of the available in SNAP when creating a RGB image, to see what are the different results you can get.



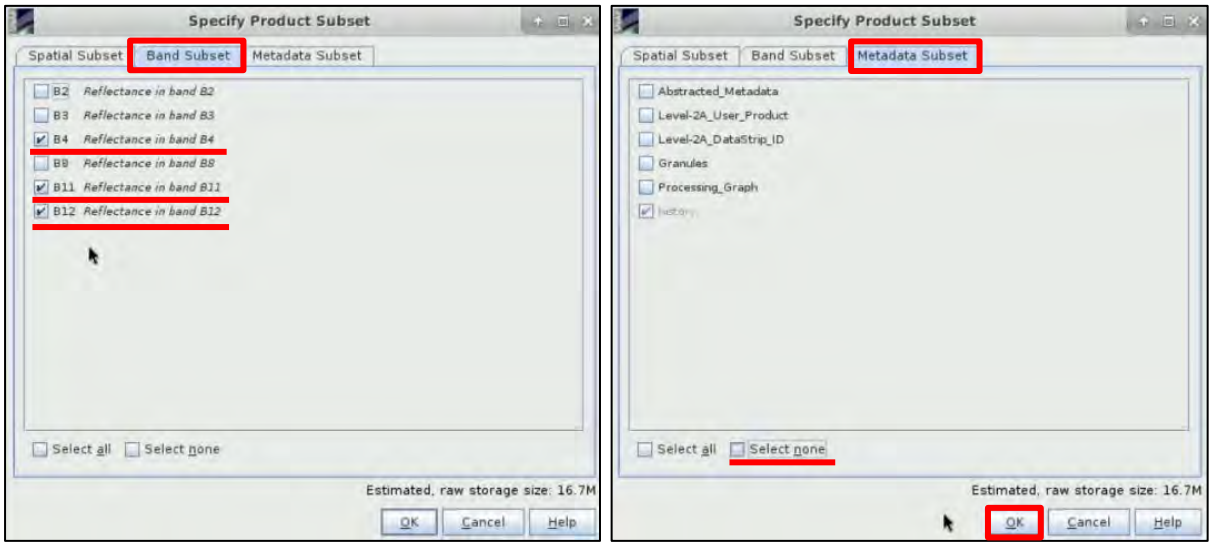
5.5 Export products

In order to further process the outputs and combine them with any other kind of data in a GIS environment or in Google Earth, we first need to export them to the compatible format.

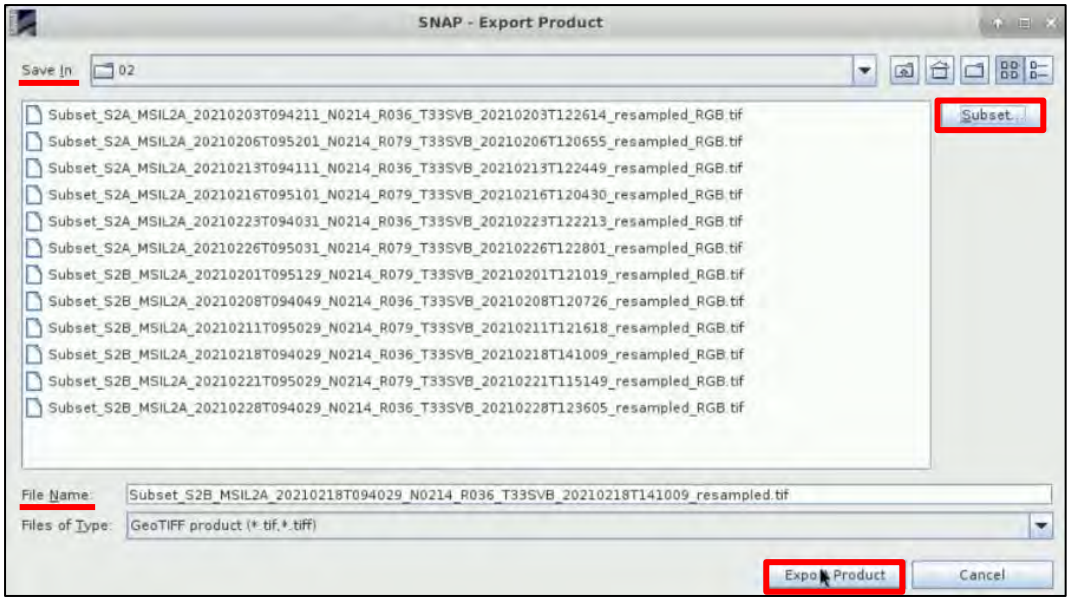
For GIS processing:

Select each product that is at the **Product Explorer** Window, one by one, and go to **File → Export → GeoTIFF.**

Click on the "**Subset**" on the right side and at the window that opens, go to the **Band Subset** tab. Select only those bands you want to use for the final visualization e.g. for a natural-colour image, select B4, B3 and B2, while for the false-colour that we want to use in this case, select only the **B12**, **B11** and **B4**. In the **Metadata Subset** tab, choose the option "***Select none***". Click **OK**.



Then set the product to be exported with the name you wish, and then set the path you want to save the **tif** file at the **Save in** field e.g. ***shared/Training/HAZA11_VolcanoMonitoring_Etna/Export/GeoTIFF_for_QGIS/02***. Click **Export Product**.



For Google Earth processing:

If you want to export the products for use is **Google Earth**, first you need to have them projected in "*Geographic Lat/Lon*". Let's create another graph in the *Graph Builder* to reproject the products, and let's use again the *Batch Processing*, in order to apply it at once to all images.

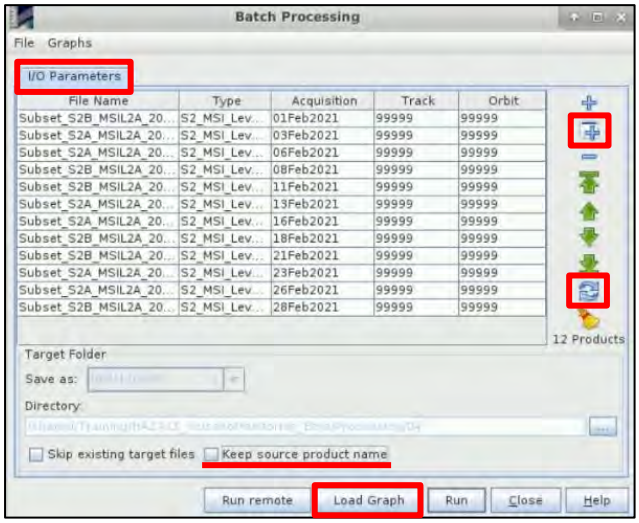
Go to **Tools** → **GraphBuilder**. Right-click on the **Write** operator and **Delete** it. Again, do not set yet any parameters, just create the graph.

We need to reproject the products. Right-click and go to **Add** → **Raster** → **Geometric** → **Reproject**. Connect the **Read** operator to it. To create the output, we will add the **Write** operator. Right-click and go to **Add** → **Input-Output** → **Write**. Connect the **Reproject** operator to it.

Click on the 

icon to save the graph. Go to the: ***/shared/Training/HAZA11_VolcanoMonitoring_Etna/Processing*** folder and save it with the name: **Reprojection_Graph**.

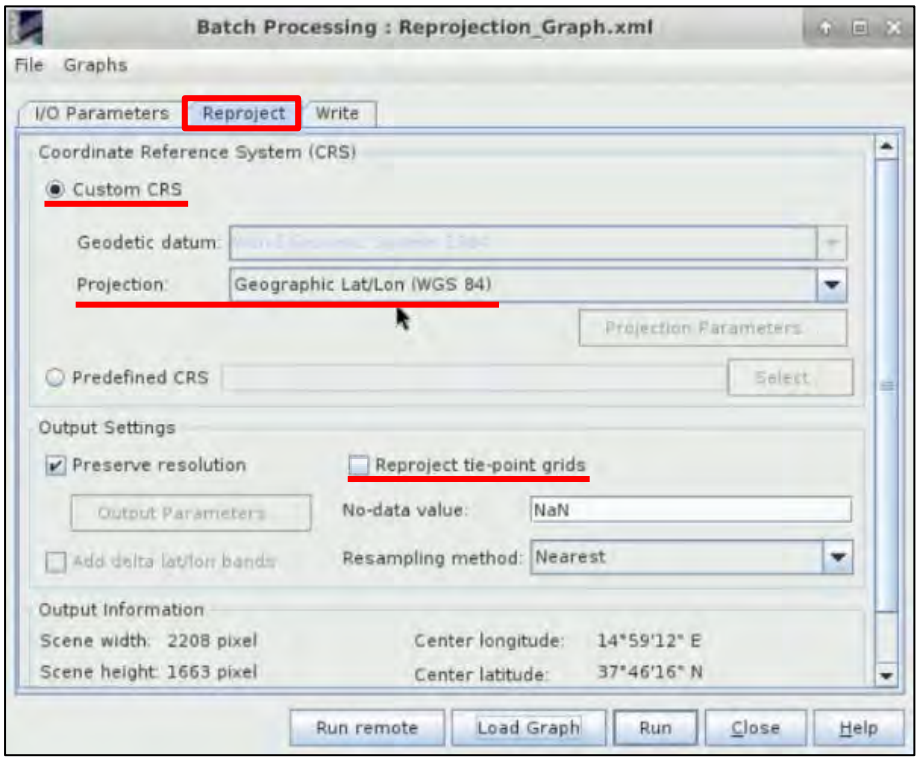
Open the **Batch Processing** tool by going to **Tools** → **Batch Processing**.



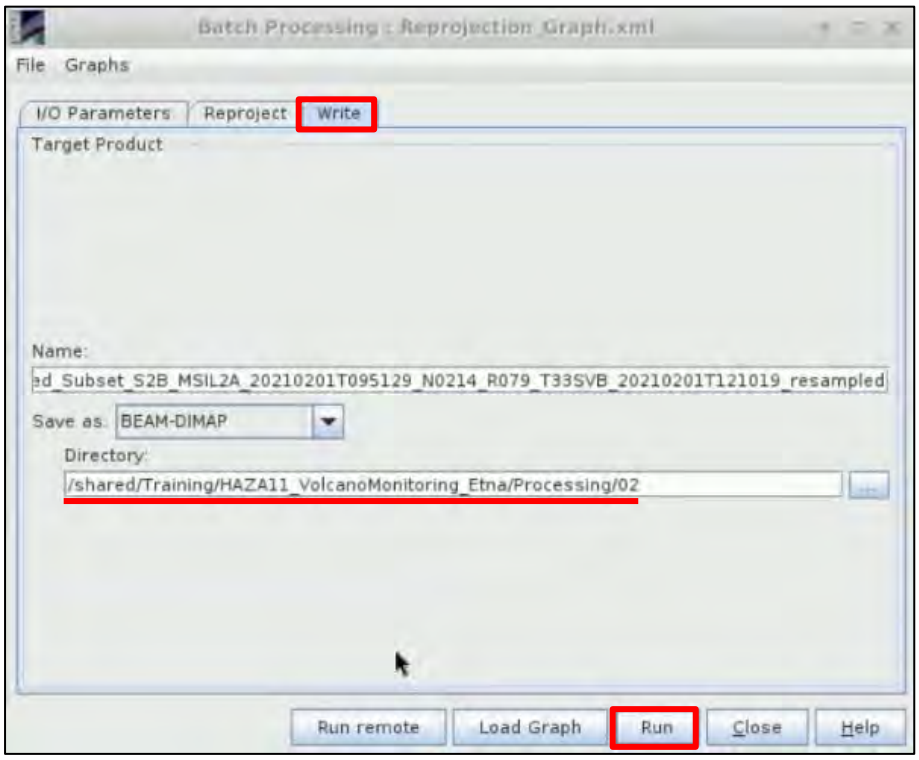
Deselect the "**Keep source product name**" option. In the **I/O Parameters** tab we will add all opened products from the **Product Explorer** window by clicking **Add Opened** at the right (second icon from the top of the column at the right) and then click **Refresh** (second icon from the bottom).

If you have not have the products you want to reproject opened in the **Product Explorer** Window, click on the first icon from the top, the **Add**, and go to the path where the images are stored so that you load them in the batch processing window manually.

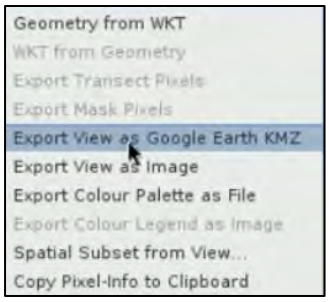
In this case we have loaded all the Subset images from February 2021. We should repeat the same for the rest of the images afterwards.
Then we will click on **Load Graph** at the bottom of the window, navigate to the path of our saved graph and open it. We see the two tabs have appeared at the top of window corresponding to our operators. In the **Reproject** tab, at the **Custom CRS**, at the *Projection*, select the "**Geographic Lat/Lon (WGS 84)**" option. Also, **deselect** the "**Reproject tie-point grids**" option.



Finally, in the **Write** tab, keep the default name (projected will be added), set as **Directory: *shared/Training/HAZA11_VolcanoMonitoring_Etna/Processing/02*** for the images of February, and click **Run**.



Once the products have been created and opened in the **Product Explorer** Window, select each one and go to **File → Export → Other → View as Google Earth KMZ**.



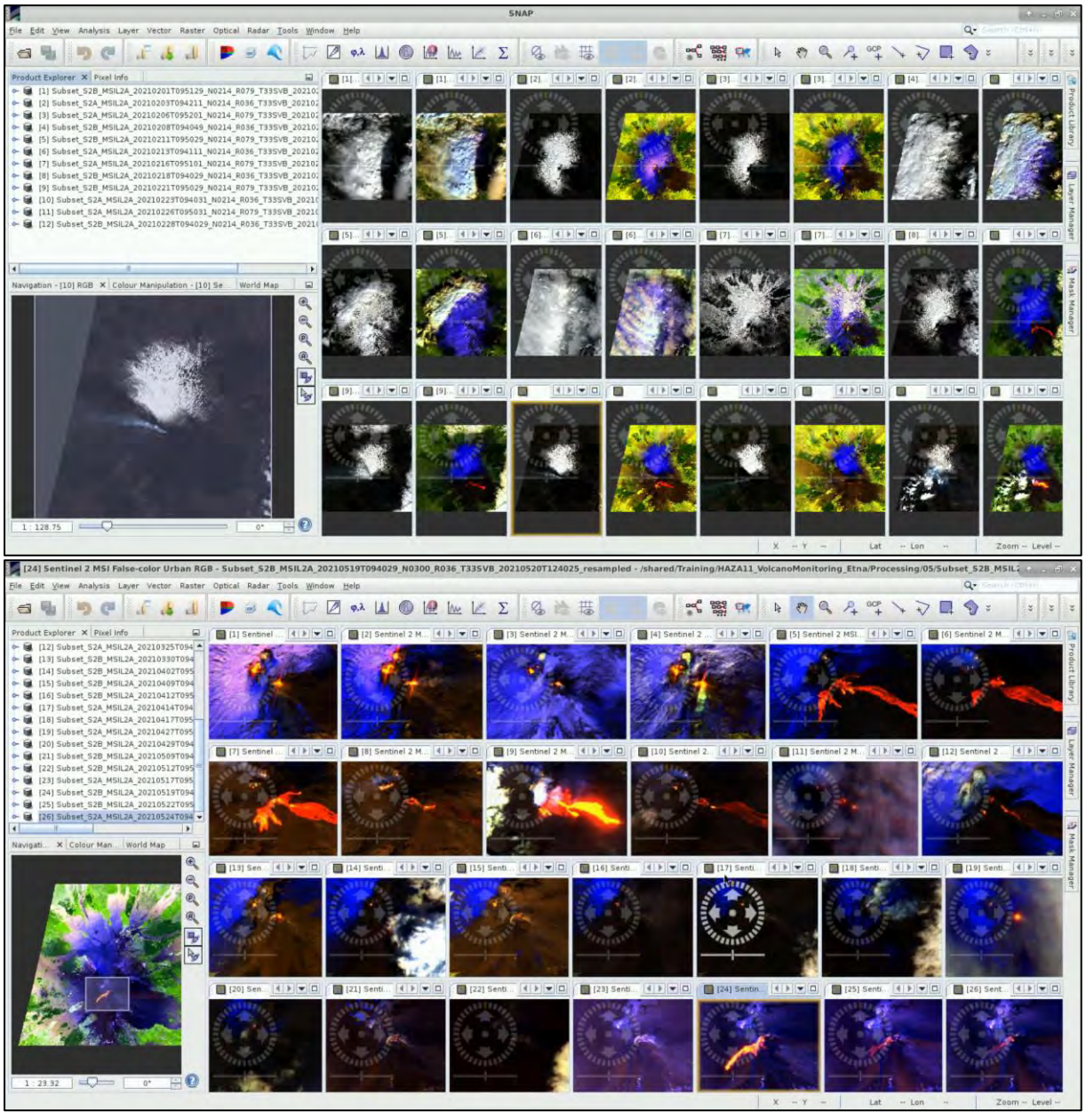
Alternatively, if you have the relative RGB image opened in the **View** Window, right-click on the image and select "**Export View as Google Earth KMZ"**.

Then set the path to which you want to save it, e.g. ***shared/Training/HAZA11_VolcanoMonitoring_Etna/Export/Kmz_for_GoogleEarth/02*** for the month of February.

Finally, use as **File Name** something you consider representative, e.g. *20210218-12-11-4.kmz* and click **Save**.

6 Data Visualization

Below you can see a comparison of all available images over Etna, even those with clouds, for the month of February (Natural-colour vs False-colour RGB images). In the next one, you can see all the cloud free RGB False-colour images from February to May 2021 and monitor the lava flow along time.



7 QGIS Visualization and Processing

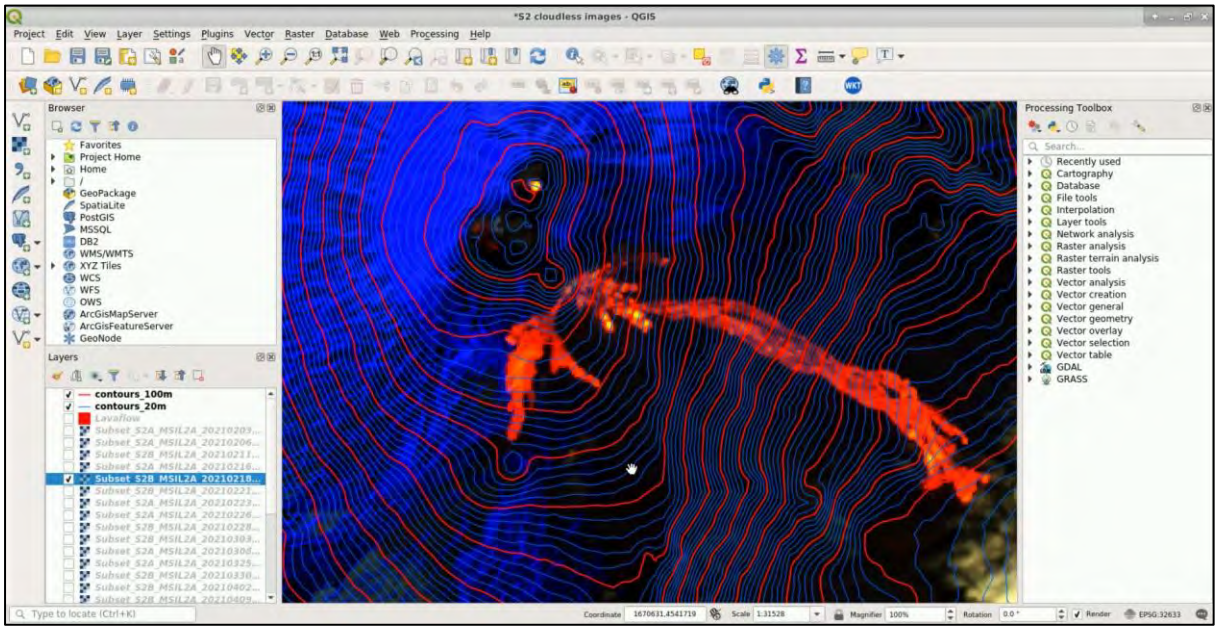
Open **QGIS Desktop** and load all the cloudless images over Etna volcano at the **Layers** panel. You will find them under the path ***shared/Training/HAZA11_VolcanoMonitoring_Etna/Export/GeoTIFF_for_QGIS/*** and the suitable subfolder: **02**, **03**, **04** and **05**.

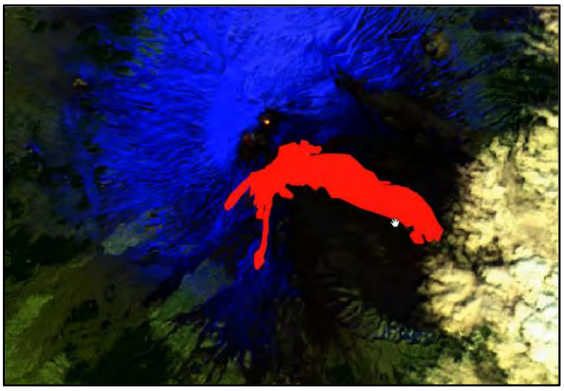
Also, add from the ***shared/Training/HAZA11_VolcanoMonitoring_Etna/AuxData/Contour lines*** folder the ***contours_20m.shp*** and ***contours_100m.shp*** files and continue with the ***Lavaflow.shp*** file from the ***shared/Training/HAZA11_VolcanoMonitoring_Etna/AuxData/*** folder.

Finally, go to **Web → OpenLayers plugin → Bing Maps → Bing Aerial with labels** in order to add a basemap layer (See NOTE 3).

> NOTE 3: 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. If you cannot find it, go to "Settings" and select the "Show also experimental plugins" option. Go back to the *"All"* tab, select the plugin on the list and click "Install Plugin". Restart QGIS to finalize the installation.

You can select and deselect the layers loaded, and see how the lava has been flowing during this period from February to May 2021 around Etna. Below there is an example of how the area looks like on 18 February 2021.





On this image, we see the pattern of the total lava that has been flowing during the whole period we study.

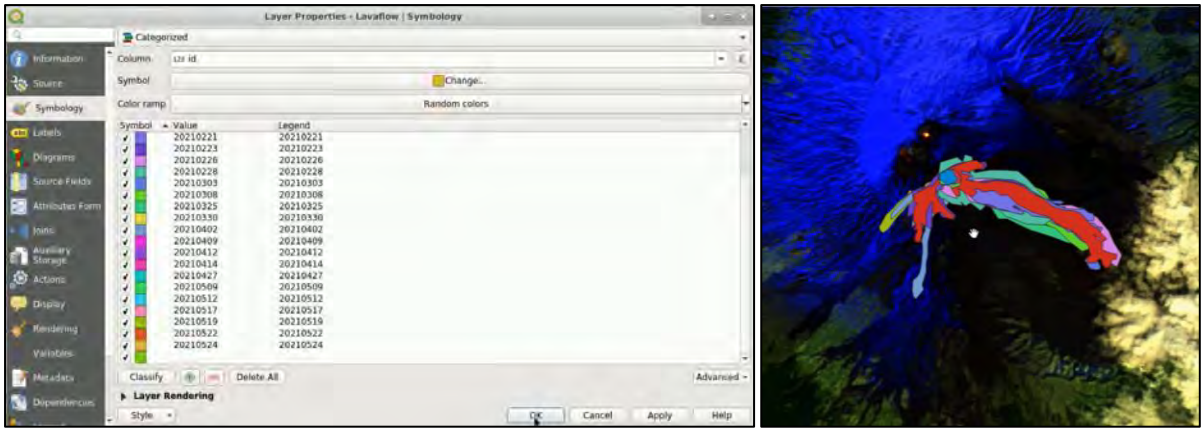
Right-click on the ***Lavaflow*** layer and go to "Properties".

In the "Symbology" tab, select **Categorized**.

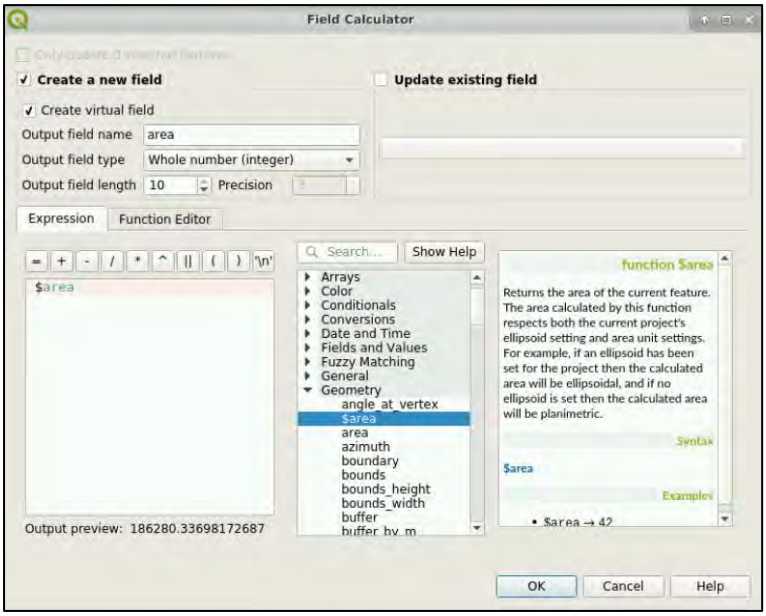
On "Column", select **id**.

On "Colour ramp" select **Random Colors**.

Click on **Classify** and then click **OK**. Below you see the lava flowing every single day in a different colour.



Right-click on the ***Lavaflow*** layer again and go to "Open Attribute Table".



Click on the "Open field calculator"  icon and set the following parameters, in order to calculate the extent of the area covered on each image, by lava:

Select the "**Create virtual field**" option.

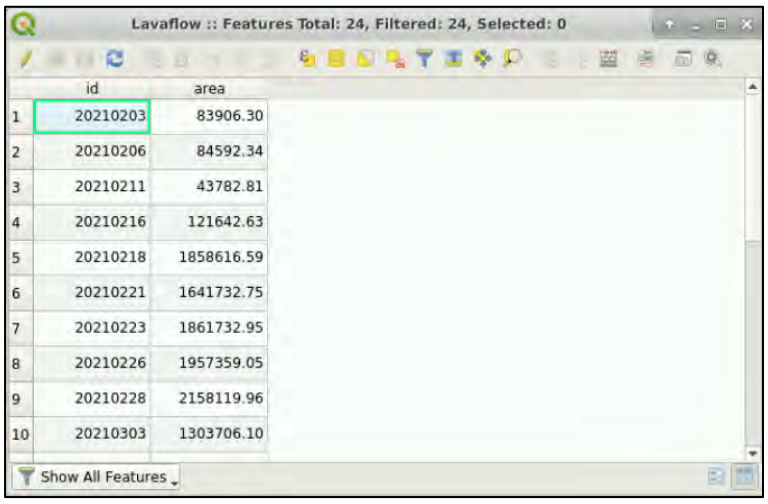
Set at the "**Output field name**": **area**.

In the column at the center, expand **Geometry**.

Double click on **$area**.

Click **OK**.

As you can see below, an extra column will be created at the Attribute Table, where you will have the extent of the lava that was flowing in every image of the ones processed, in m^2.



	id	area
1	20210203	83906.30
2	20210206	84592.34
3	20210211	43782.81
4	20210216	121642.63
5	20210218	1858616.59
6	20210221	1641732.75
7	20210223	1861732.95
8	20210226	1957359.05
9	20210228	2158119.96
10	20210303	1303706.10

You can include as many additional data as you have for your area of interest, so that they will assist you for the processing you need to perform.

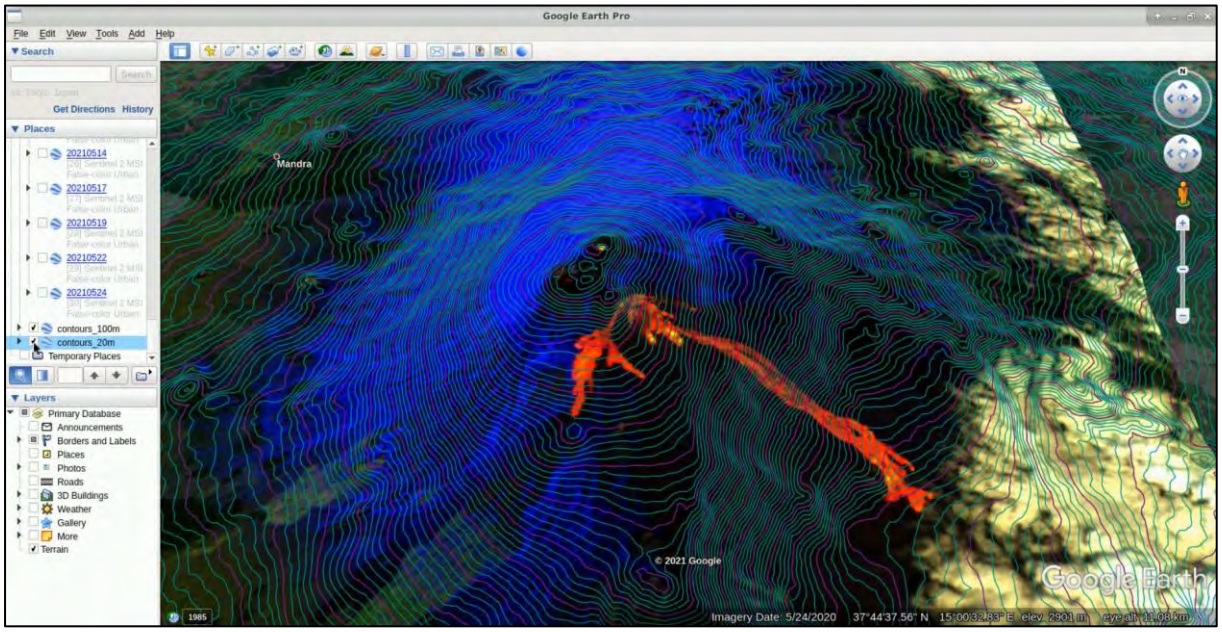
8 Google Earth Visualization and Processing

Launch **Google Earth** and load all the cloudless .kmz files of the Etna volcano. You will find them under the path ***shared/Training/HAZA11_VolcanoMonitoring_Etna/Export/Kmz_for_Google Earth/*** and the suitable subfolder: **02**, **03**, **04** and **05**.

NOTE: If there is no Google Earth icon on the desktop of your VM, **open a terminal**, type **Google-Earth-pro**, click **Enter** and it will be launched.

Also, add from the ***shared/Training/HAZA11_VolcanoMonitoring_Etna/AuxData/Contour lines*** folder the ***cont20m.kmz*** and ***cont100m.kmz*** files.

You can view the results in any combination you prefer. Below you can see in 3D how the lava that was flowing on 18 February 2021 from the New SE crater looks like.



You can download images after May 2021 to continue monitoring how the volcanic activity of Mount Etna has been evolving.

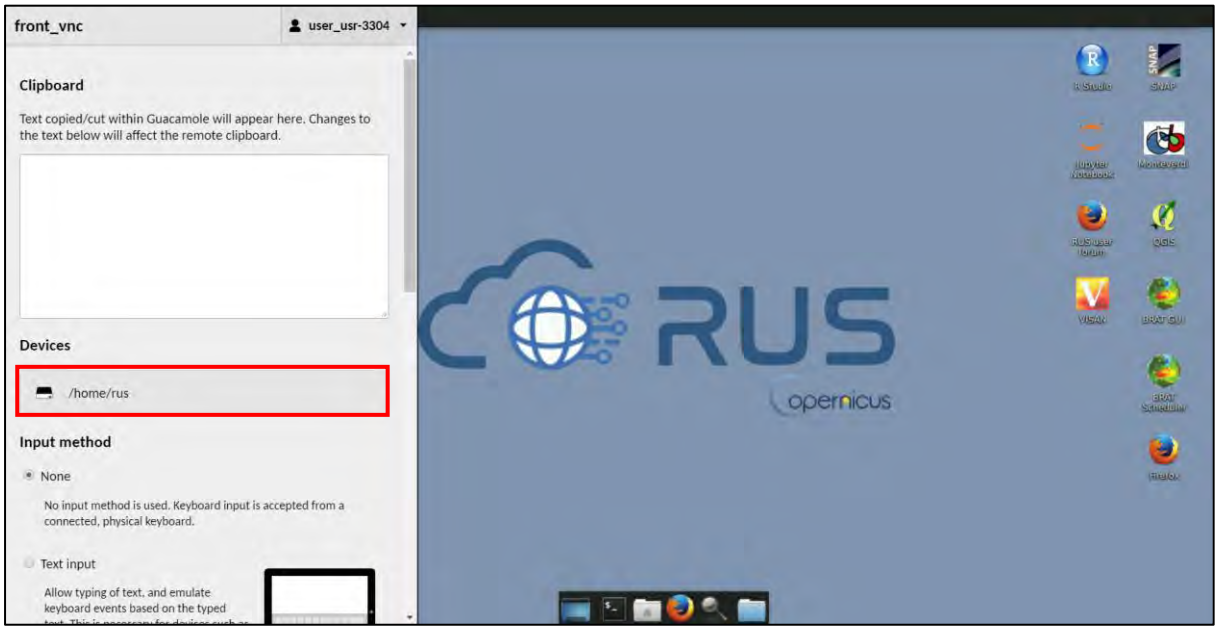
Also, you can adopt this methodology for another area of study, and benefit from the different band combinations.

9 Extra Steps

9.1 Download files from VM

In your VM, press **Ctrl+Alt+Shift.**

A pop-up window will appear on the left side of the screen. Click on the bar below **Devices**, navigate to the folders you have saved the files you want to download and **double click** on them. The downloading process to your local computer will start automatically.



THANK YOU FOR FOLLOWING THE EXERCISE!

10 Further reading and resources

- Barreca, G., Branca, S., & Monaco, C. (2018). Three-dimensional modeling of Mount Etna volcano: Volume assessment, trend of eruption rates, and geodynamic significance. Tectonics, 37, 842–857. https://doi.org/10.1002/2017TC004851
- Marco Neri, Marina De Maio, Stefano Crepaldi, Enrico Suozzi, Muriel Lavy, Federico Marchionatti, Sonia Calvari & Maria Fabrizia Buongiorno (2017) Topographic Maps of Mount Etna's Summit Craters, updated to December 2015, Journal of Maps, 13:2, 674-683, DOI: 10.1080/17445647.2017.1352041 http://dx.doi.org/10.1080/17445647.2017.1352041
- Tanguy, JC., Condomines, M., Le Goff, M. *et al.* Mount Etna eruptions of the last 2,750 years: revised chronology and location through archeomagnetic and ^{226}Ra-^{230}Th dating. *Bull Volcanol* **70,** 55–83 (2007). https://doi.org/10.1007/s00445-007-0121-x
- https://sentinel.esa.int/web/sentinel/missions/sentinel-2 - Sentinel 2 mission
- https://srtm.csi.cgiar.org/srtmdata/ - Download the contours

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