TRAINING KIT – LAND04

LAND MONITORING WITH SENTINEL-3

Case Study: Cyprus, 2017

Research and User Support for Sentinel Core Products

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1 Introduction to RUS

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.

In this tutorial, we will employ RUS to analyze the temporal evolution of the **N**ormalized **D**ifference **V**egetation **I**ndex (NDVI) over Cyprus using Sentinel-3 OLCI data.

2 Land monitoring – background

Cyprus seen by Sentinel-2. Credits: RUS-Copernicus

Land surface dynamics represent one of the key drivers to assess environmental change at different scales. Monitoring activities play a relevant role to detect and understand those patterns and to measure the resilience of ecosystems.

Satellite based Earth observation methods are one of the best approaches to perform those tasks at local, regional and global scale. The Sentinel-3 **O**cean and **L**and **C**olor **I**nstrument (OLCI) provides continuous and high frequency data that can be used to gather information about vegetation state.

In this webinar, you will learn the basics of image processing for land dynamics monitoring. We will show you how to access the RUS Service and how to download, process, analyze and visualize the free data acquired by the Copernicus satellites. We will employ the ESA SNAP Sentinel-3 Toolbox to demonstrate the methodology for monitoring land surface dynamics.

3 Training

Approximate duration of this training session is one hour.

The Training Code for this tutorial is LAND04. 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.

3.1 Data used

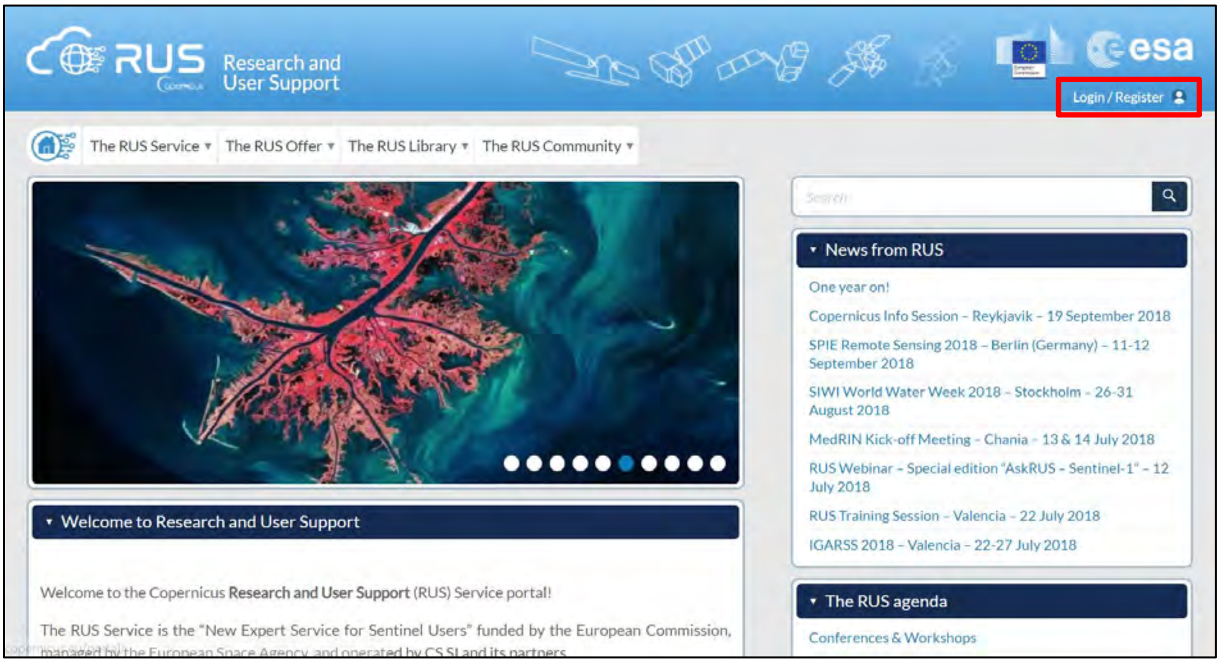
- 7 Sentinel-3A images acquired during May 2017 downloadable at https://scihub.copernicus.eu/
- Pre-processed data stored locally @ */shared/Training/LAND04_LandMonitoring_Cyprus/AuxData/*

3.2 Software in RUS environment

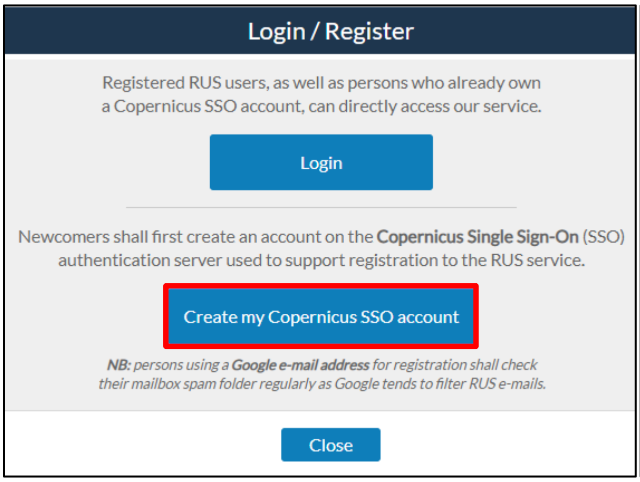
Internet browser, SNAP + Sentinel-3 Toolbox

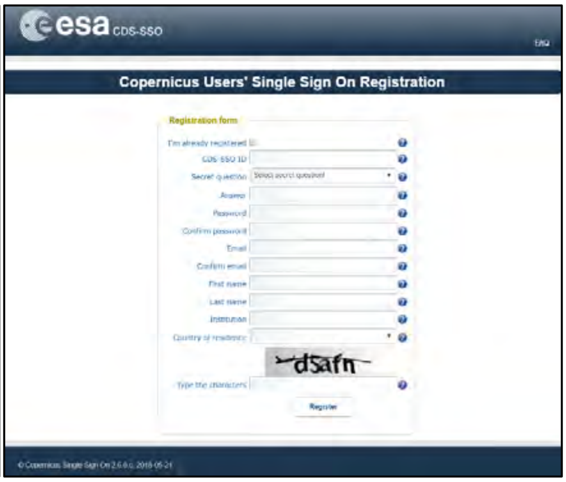
4 Register to RUS Copernicus

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.



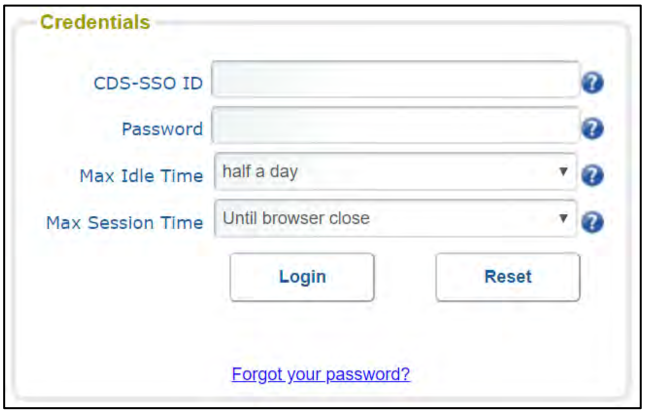
Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the Copernicus Users' Single Sign On Registration. Click ***Register***.



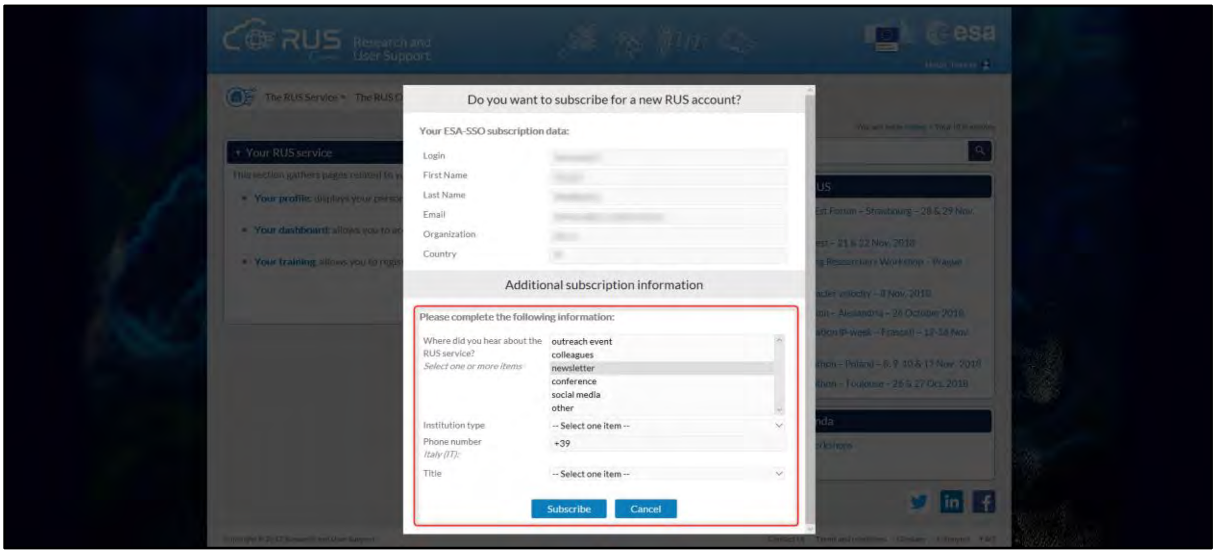


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

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

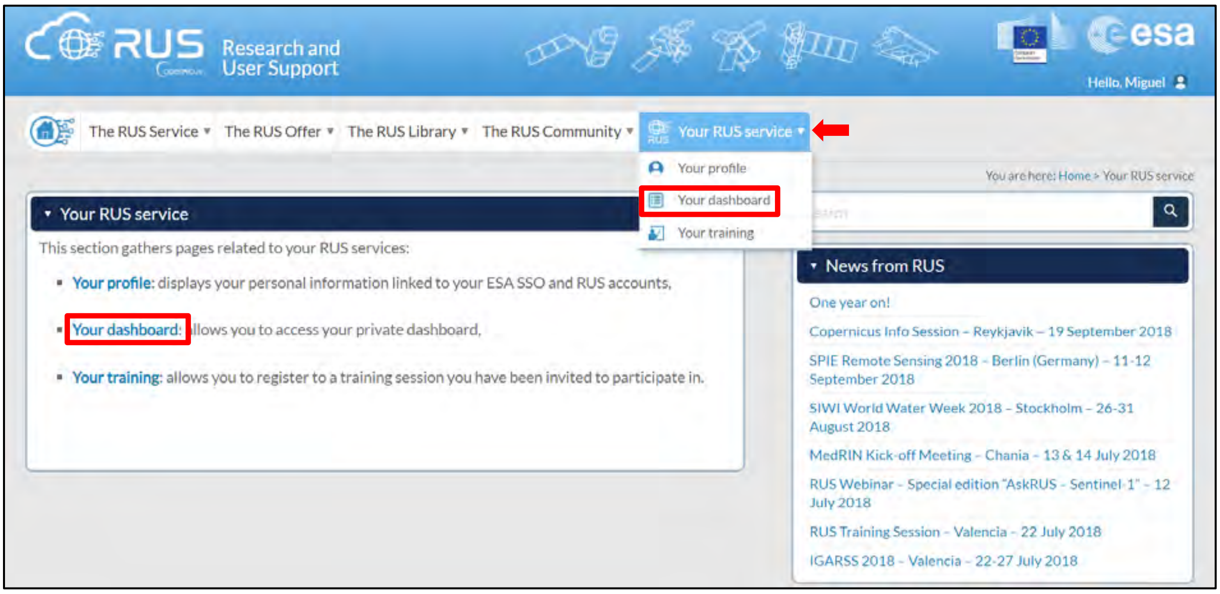


Upon your first login you will need to enter some details. You must fill all the fields.

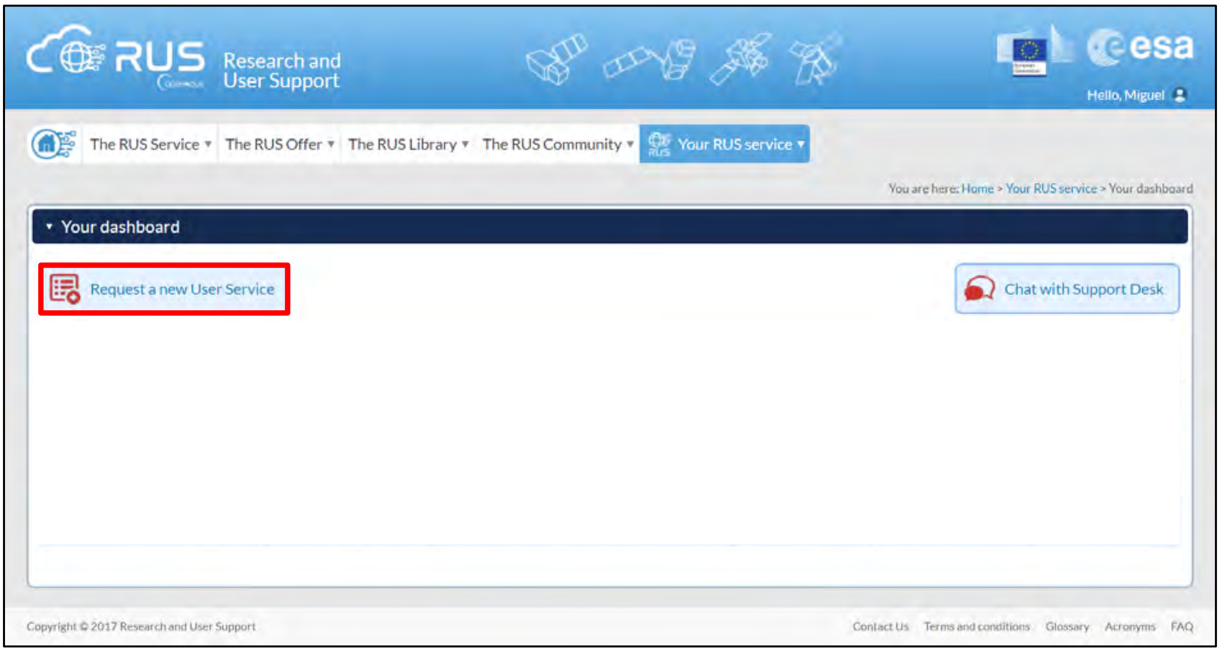


5 Request a RUS Copernicus Virtual Machine

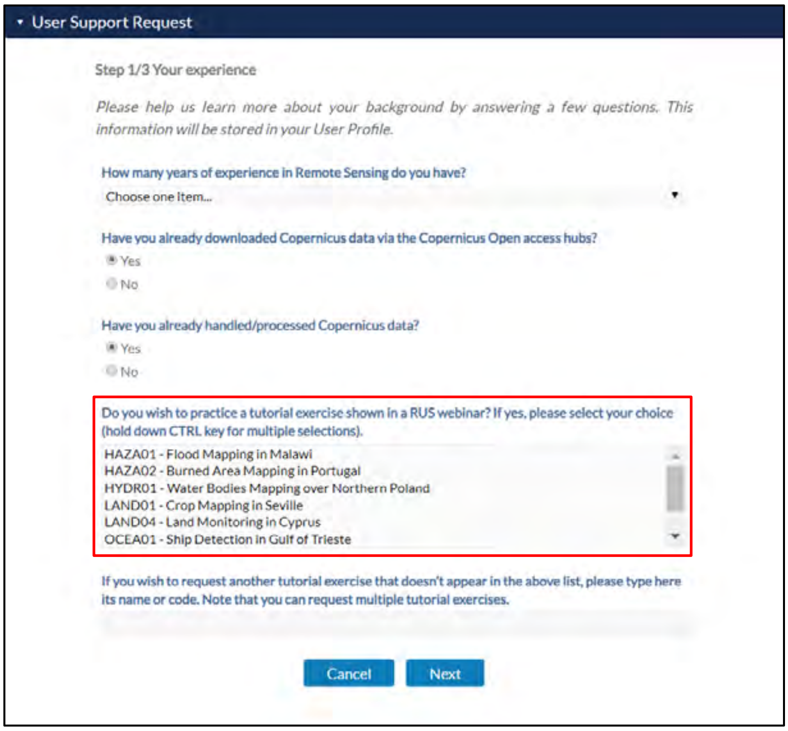
Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on ***Your RUS Service → Your Dashboard***.



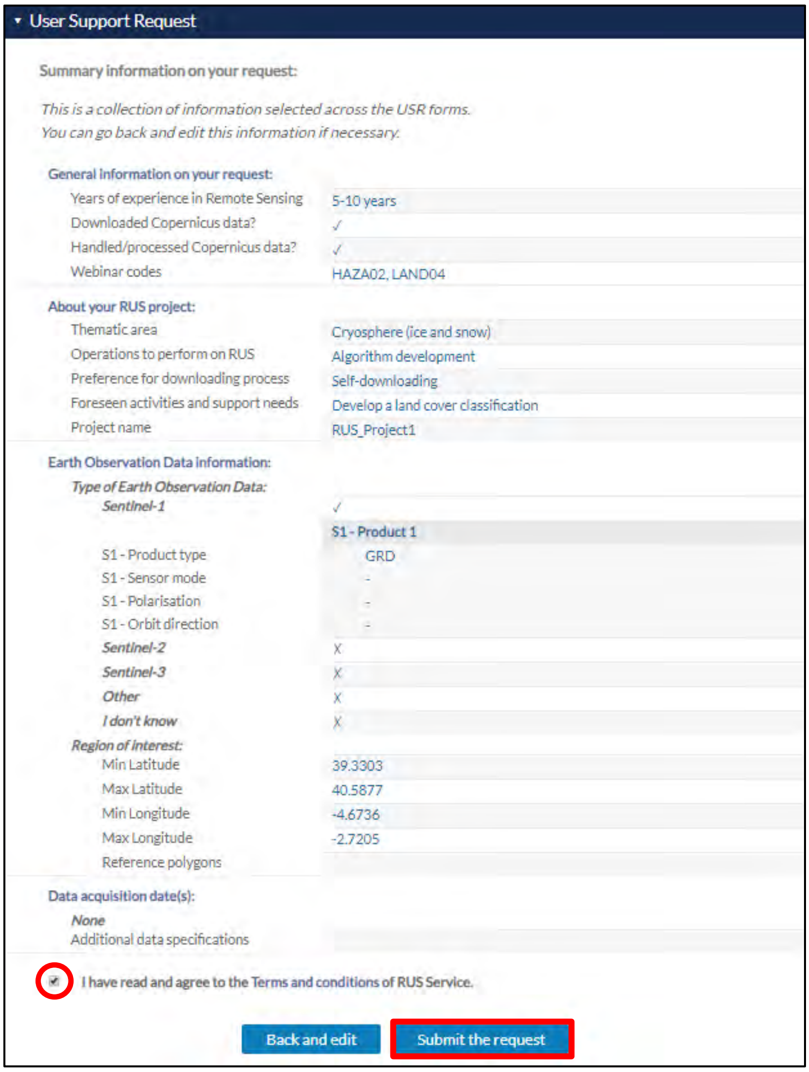
Click on ***Request a new User Service*** to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.



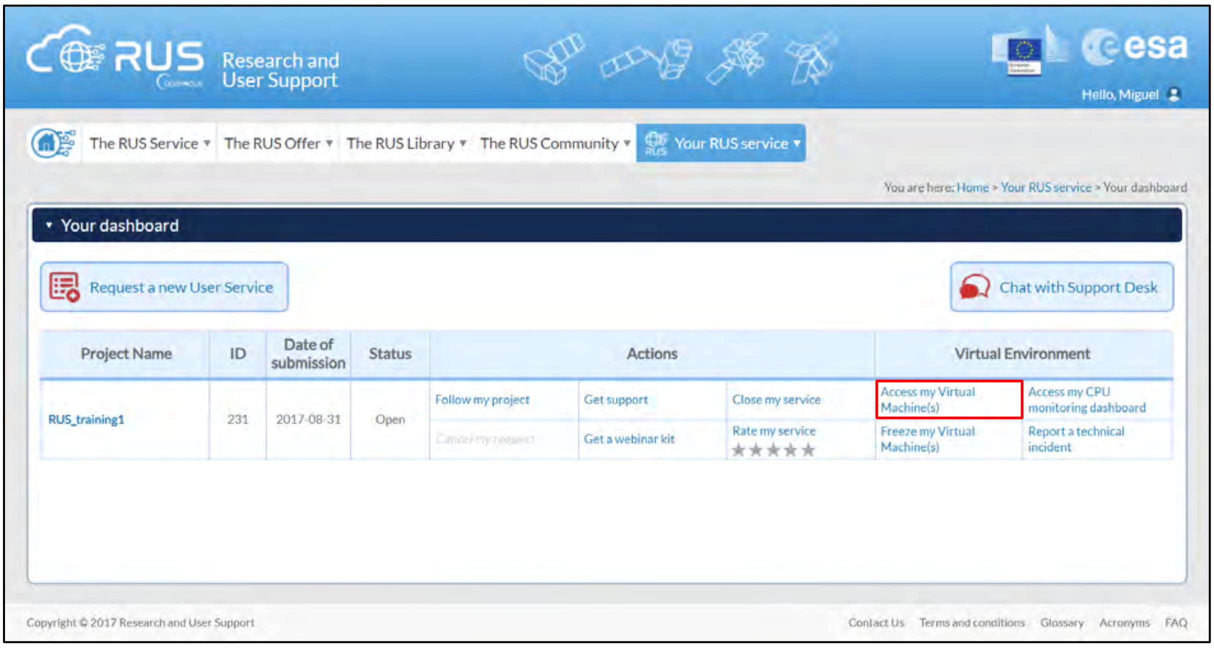
If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.



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.

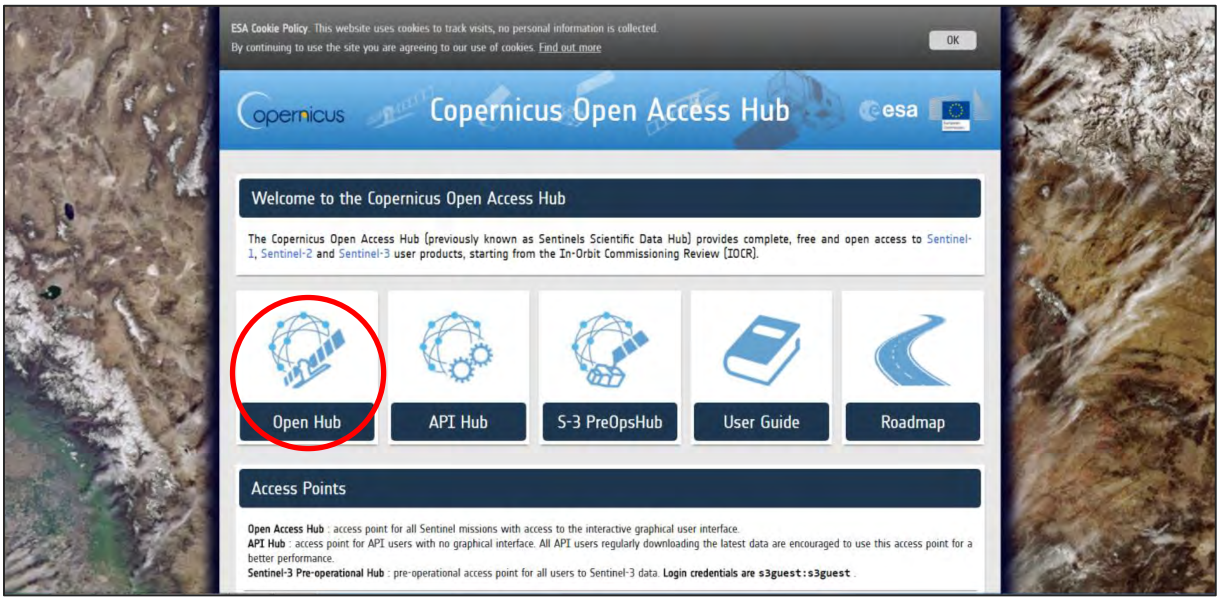
This is the remote desktop of your Virtual Machine.

6 Step by step

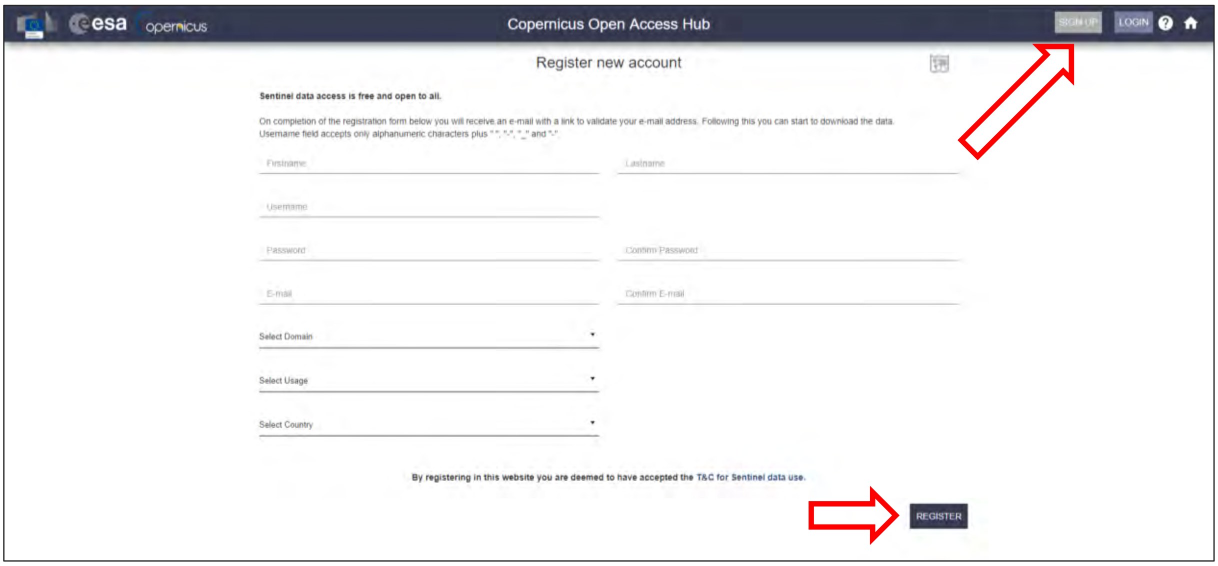
6.1 Data download – ESA SciHUB

Before starting the exercise, we need to make sure that we are registered in the Copernicus Open Access Hub so that we can access the free data provided by the Sentinel satellites.

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



Go to ***"Open Hub"***. If you do not have an account please sign up in the upper right corner, fill in the details and click register.



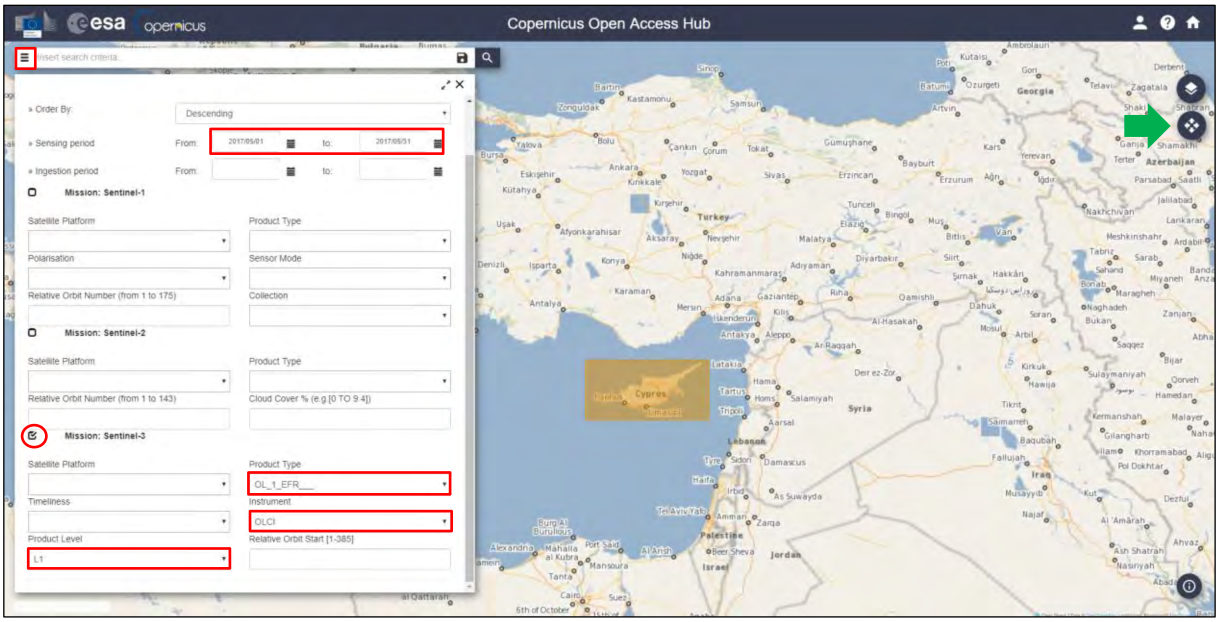
You will receive a confirmation email on the e-mail address you have specified: open the email and click on the link to finalize the registration.

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 icon in the upper right corner of the map (**Green arrow**), navigate to Cyprus *mode* and draw a rectangle approximately as indicated below.

Open search menu by clicking at the left of the search bar (≡), specify the following parameters press the search button ():

Sensing period: From 2017/05/01 to 2017/05/31
Check Mission: Sentinel-3
Product type: OL_1_EFR__
Instrument: OLCI
Product Level: L1



In our case, the search returns 22 results depending on the defined search area. Download the following scenes (See NOTE 1):

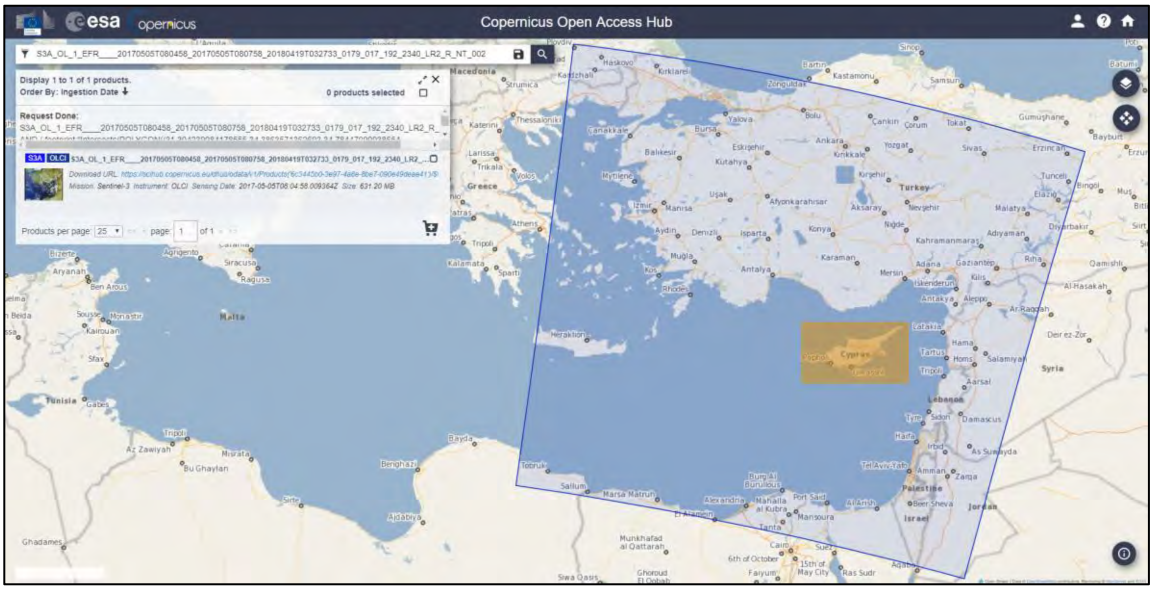
Date	S-3 Image name
2017-05-05	S3A_OL_1_EFR____20170505T080458_20170505T080758_20180419T032733_0179_017_192_2340_LR2_R_NT_002
2017-05-10	S3A_OL_1_EFR____20170510T073503_20170510T073803_20180419T173805_0179_017_263_2340_LR2_R_NT_002
2017-05-13	S3A_OL_1_EFR____20170513T075729_20170513T080029_20180420T025347_0179_017_306_2340_LR2_R_NT_002
2017-05-21	S3A_OL_1_EFR____20170521T075000_20170521T075300_20180421T065708_0179_018_035_2340_LR2_R_NT_002
2017-05-24	S3A_OL_1_EFR____20170524T081227_20170524T081527_20180421T154649_0179_018_078_2340_LR2_R_NT_002
2017-05-28	S3A_OL_1_EFR____20170528T080842_20170528T081142_20180422T032713_0179_018_135_2340_LR2_R_NT_002
2017-05-29	S3A_OL_1_EFR____20170529T074232_20170529T074532_20180422T061843_0180_018_149_2340_LR2_R_NT_002

Download the scenes by clicking the download icon on each product -

Once downloaded (*@/home/rus/Downloads*), copy them to the following path and unzip them (*right click -> Extract Here*)

Path: */shared/Training/LAND04_LandMonitoring_Cyprus/Original/May/*

NOTE 1: Copy-paste the S-3 Image name in the *Search Criteria* box (upper left corner) of the Copernicus Open Access Hub to find the images faster.



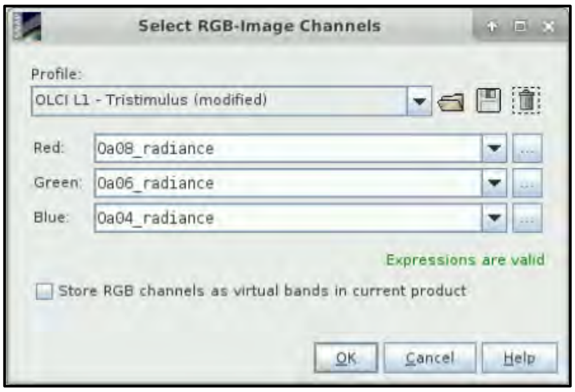
6.2 SNAP – Open and explore data

Open *SNAP Desktop* from your desktop (or *Applications -> Processing -> SNAP)*, click on the *Open product* icon ( ), navigate to the following path and open the Sentinel-3 product from 2017-05-10. Open the folder and select the file *xfdumanifest.xml.* Then, click *OK*.

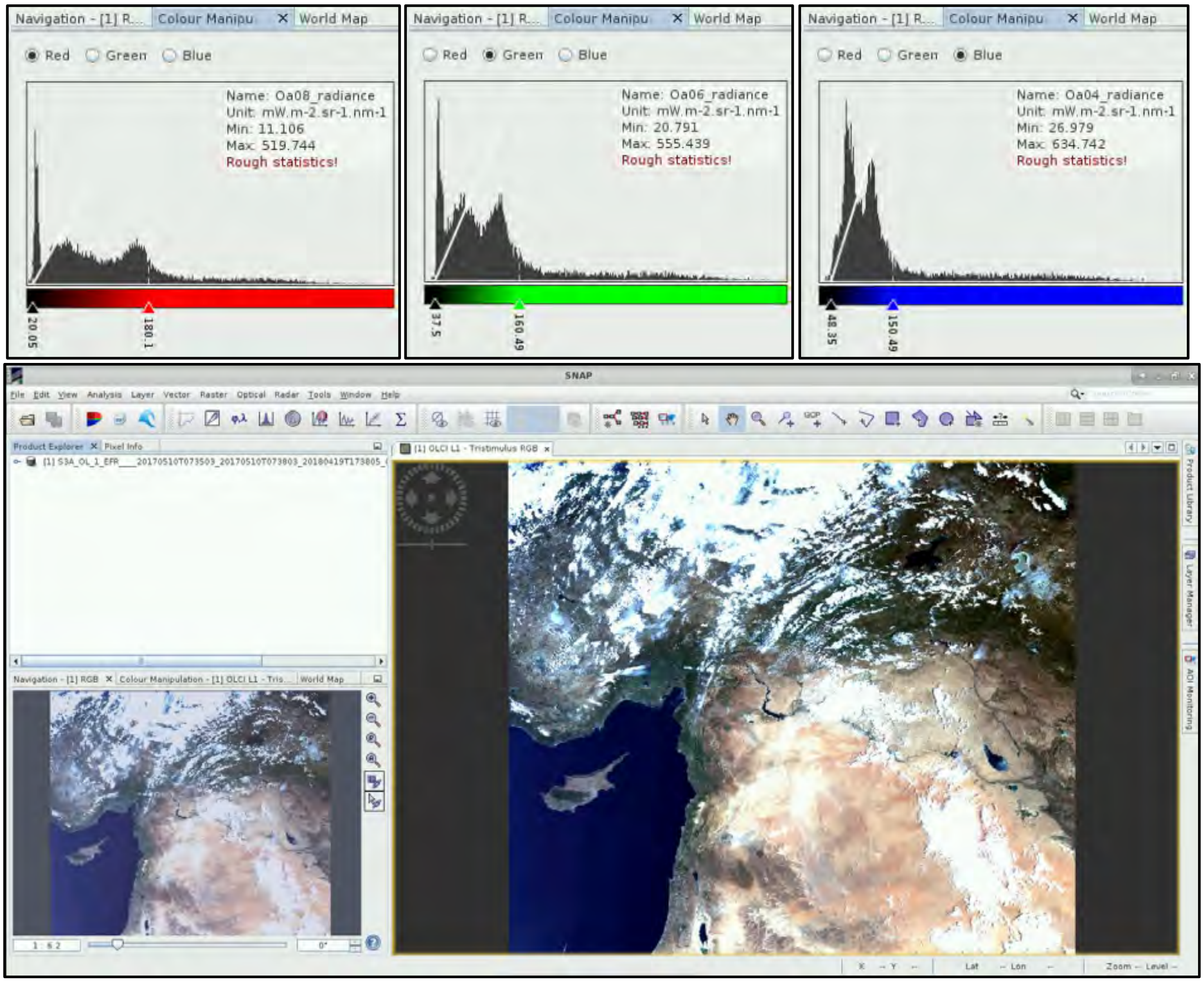
Path: */shared/Training/LAND04_LandMonitoring_Cyprus/Original/May/*

In *Product Explorer* tab, right click on the product and select *Open RGB Image Window* to create and visualize an RGB composition image. Select the following band combination to create a true color RGB composition and click OK.

Red: Oa08_radiance | **Green**: Oa06_radiance | **Blue**: Oa04_radiance



As the colors are distributed according to the image histogram, the view is very dark. To enhance it, we can change the color distribution for each RGB band in the *Color Manipulation* tab in the lower left corner of SNAP. Select the **red** channel, click on the right-hand slider below the histogram and move it to approx. 180. Change to the **green** channel at the top of the tab and set the slider to approx. 160. Last, change to **blue** and set the slider to approx. 150.



6.3 Graph Builder

For this exercise, we will process several Sentinel-3 images. Repeating the analysis for every image one by one would be very time consuming. For this reason, we can create a graph containing all the steps of our methodology and use the batch processing option of SNAP to run bulk processing. First, we need to open an empty 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). To avoid any confusion, right click on the *Write* operator and delete it.

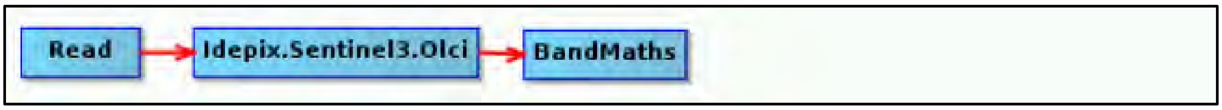
6.3.1 IdePix Processor

The first step of our methodology will aim to remove cloudy pixels from the image. For that, we will use the IdePix processor (See NOTE 2) available on SNAP, which provides a pixel classification into properties such as clear/cloudy, land/water, snow, ice etc. To add the operator, right-click on the white area and go to *Add -> Optical -> Pre-processing -> IdePix.Sentinel3.Olci.* Connect the new *Idepix.Sentinel3.Olci* operator with the *Read* operator by clicking to the right side of the *Read* operator and dragging the red arrow towards the *Idepix.Sentinel3.Olci* operator.

NOTE 2: The IdePix processor provided with the current SNAP version supports the following satellites/sensors: Sentinel-2 (MSI), Sentinel-3 (OLCI), Envisat (MERIS), Landsat-8 (OLI), Proba-V (Vegetation), SPOT (Vegetation), Terra/Aqua (MODIS), OrbView-2 (SeaWiFS), Suomi NPP (VIIRS). It calculates a certain set of physical features and a probabilistic combination of these features in order to calculate a set of pixel classification attributes. Only the implementation of how the features are calculated is instrument specific. For cloud detection, the following features are used: brightness, whiteness, height, temperature, spatial pattern, temporal consistency, Neural Network probability.

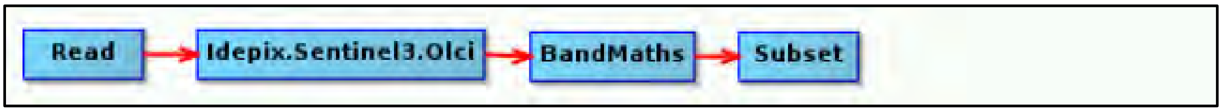
6.3.2 Band Math

The next processing step will be to derive the Normalized Difference Vegetation Index (NDVI) for the pixels that are not flagged as cloudy by the IdePix processor and that are not water pixels. For this task, we will use *Band Math.* Add the *Band Math* operator. Right-click and go to *Add -> Raster -> BandMaths.* Connect the operators as shown below.



6.3.3 Subset

Next, we need to reduce the spatial extent to focus on our study area. For that, add the *Subset* operator. Right-click and go to *Add -> Raster -> Geometric -> Subset.* Connect the operators as shown below.

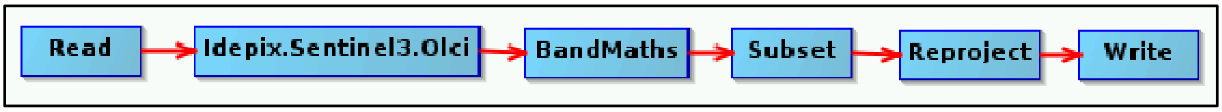


6.3.4 Reproject

The last step of the graph will consist of a reprojection. Sentinel-3 OLCI products are delivered georeferenced onto the Earth's surface. By reprojecting, we can assign a specific map projection and make sure all the inputs have the same spatial characteristics. Add the reproject operator by right-clicking *Add -> Raster -> Geometric -> Reproject*. Finally, *Right click -> Connect Graph* to connect all the operators. Connect the operators as shown below.

6.3.5 Write

Finally, we just need to properly save the output. For that, we first need to add the W*rite* operator to our graph. Right click and navigate to *Add -> Input-Output -> Write*.



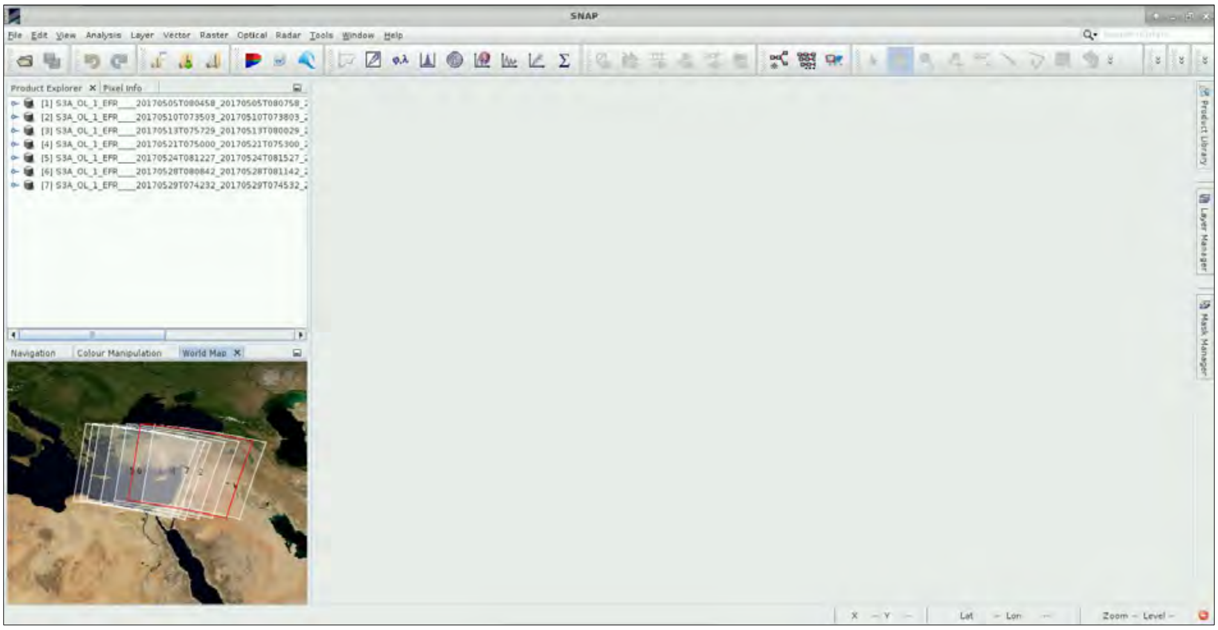
Finally, click on Save in the lower part of the pannel and save the graph in the following path as *'S3_Graph.xml'* without setting any parameter.

Path: */shared/Training/LAND04_LandMonitoring_Cyprus/AuxData/*

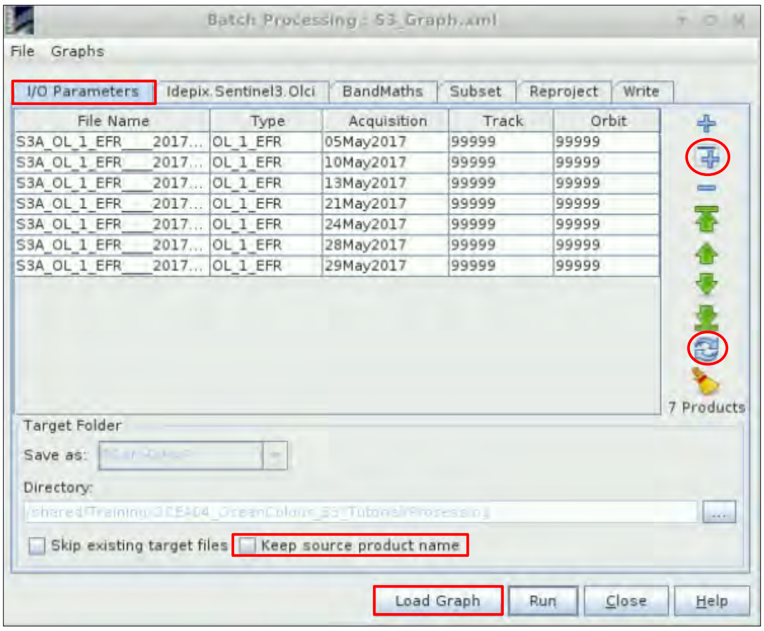
6.4 Batch processing

Before using batch processing, we need to load all the images we want to analyse in SNAP. An option would be to open one by one, but for convenience, we will use a saved SNAP session that already contains all the products loaded. Click on *File -> Session -> Open Session* navigate to the following path and select the session file *S3_May.snap*

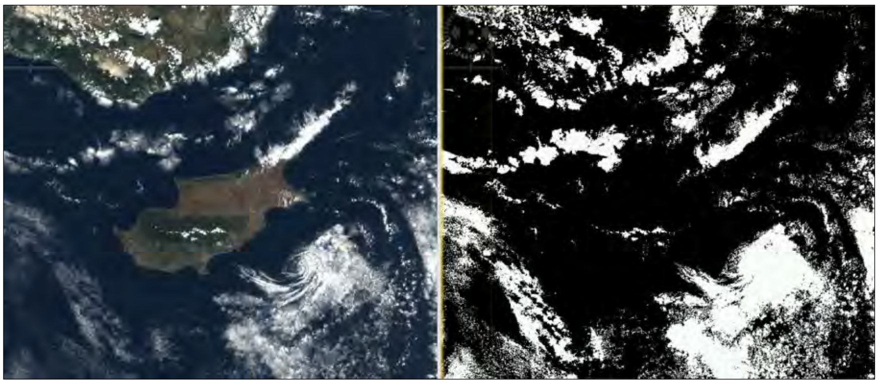
Path: */shared/Training/LAND04_LandMonitoring_Cyprus/AuxData/May/*



Click on *Tools -> Bath Processing.* Press the *Add Opened* icon on the upper right side (second from top) and click refresh. Then, unselect the *Keep source product name*. Click *Load Graph* at the bottom of the window, navigate to the saved graph and open it. We see that new tabs have appeared at the top of window corresponding to the operators previously defined on the graph.

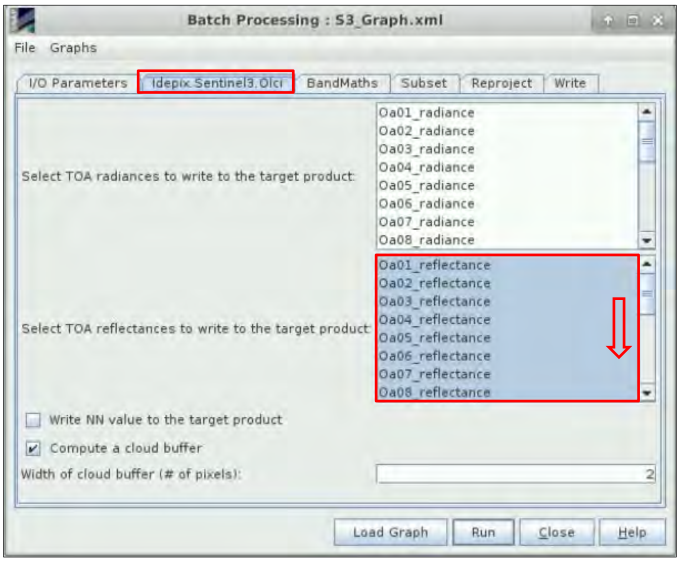


In the *Idepix.Sentinel3.Olci* tab, make sure you select all the bands in the '*Select TOA reflectances to write to the target product'***.** In that way, the IdePix processor output will contain already pixel values in reflectance and not radiance (See NOTE 3). For demonstration, the image below shows this intermediate output: a RGB true color composition and the binary cloud mask (*'IDEPIX_CLOUD'*) created using IdePix.



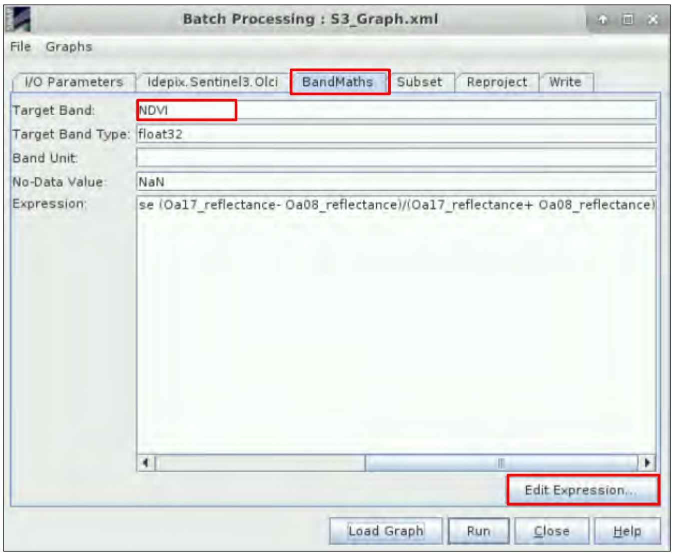
NOTE 3: **Radiance** is the variable directly measured by remote sensing instruments. It is the amount of light seen by instrument from a surface of an object. In the OLCI products, it is given as 10-3 W.m-2.sr-1.µm-1

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.



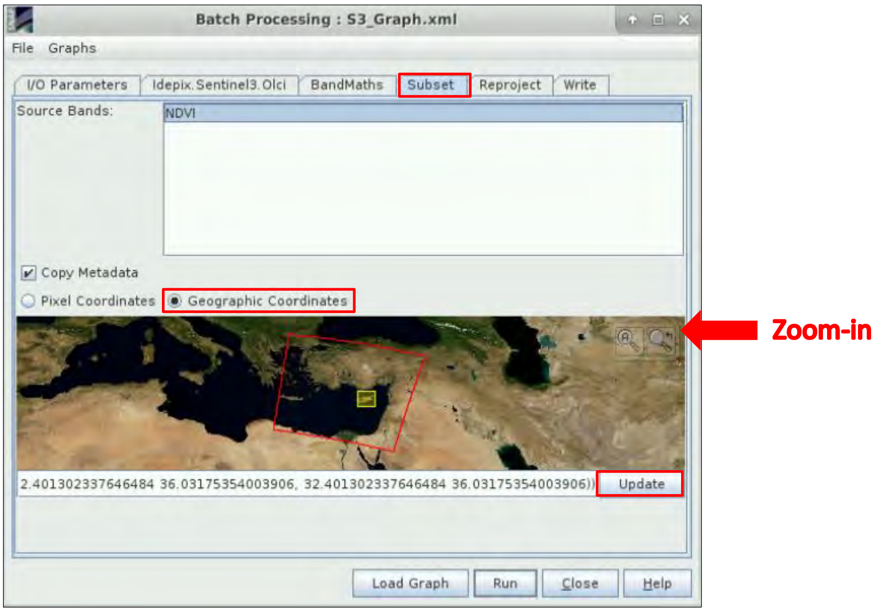
Click now on the *BandMaths* tab, set the target band name to *NDVI*, set the No-Data value to *NaN*, click on *Edit Expression* and copy-paste the following expression. Click Ok afterwards. For demonstration, the image below shows this intermediate output: a RGB true color composition and the NDVI calculated for land cloud-free pixels.

```
if IDEPIX_CLOUD == TRUE or IDEPIX_LAND == FALSE then 0 else (Oa17_reflectan
ce-Oa08_reflectance)/(Oa17_reflectance+Oa08_reflectance)
```

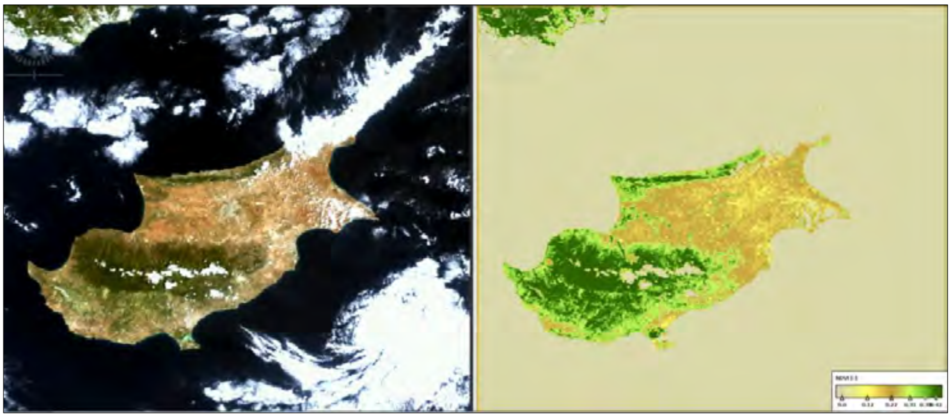


In the *Subset* tab, remember to select *Geographic Coordinates*, copy-paste the following Well-Known Text (WKT) and click *Update* to define the area and click to Zoom-in.

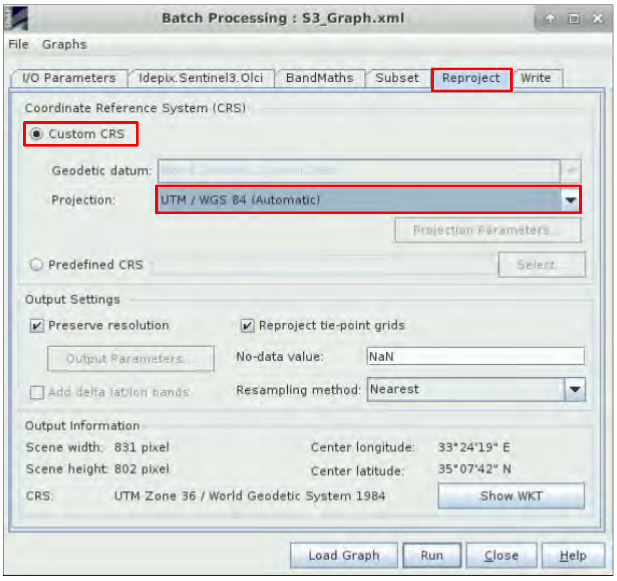
```
POLYGON ((32.401301 36.031754,34.667141 35.741352,34.374742 34.318205999999996,32.149456 34.612776,32.401301 36.031754))
```



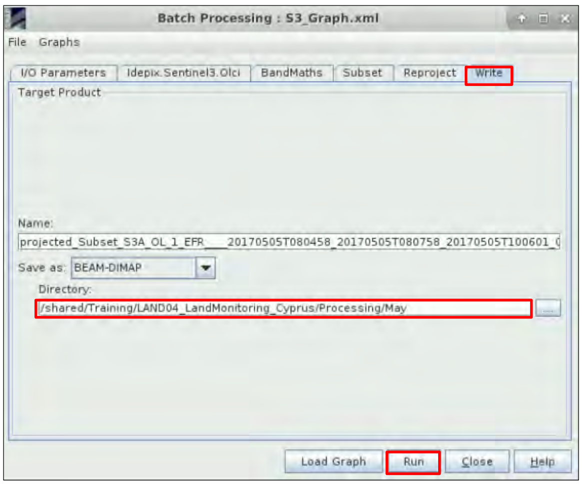
For demonstration, the image below shows the output of the processing chain: the cropped area shown as RGB (for reference purposes) and the corresponding NDVI calculated for land free-cloud pixels.



In the reproject tab, select *Custom CRS* to define the Coordinate Reference System. Select *UTM / WGS 84 (Automatic)* on the drop-down menu.



Finally, in the *Write* tab, make sure you select the following path as output directory. Click *Run* after that. Path: */shared/Training/LAND04_LandMonitoring_Cyprus/Processing/May/*



6.5 Collocate (two images)

The following step will aim at stacking all the NDVI outputs of the batch processing in a single product to allow further processing. For this task, we will use the *Collocation* tool*,* which allows collocating two spatially overlapping products. Collocating two products implies that the pixel values of one product (the *slave*) are resampled into the geographical raster of the other (the *master*). Click on *Raster -> Geometric Operations -> Collocation.*

Unfortunately, the collocation tool only allows processing one master and slave product at once. Due to this, to collocate all the NDVI images in a single product, we need to do it step-by-step. For this exercise, you will find the output of this process in the following path. Close all the previous products opened in SNAP, navigate to the path and open the file *Collocate_May.dim*.

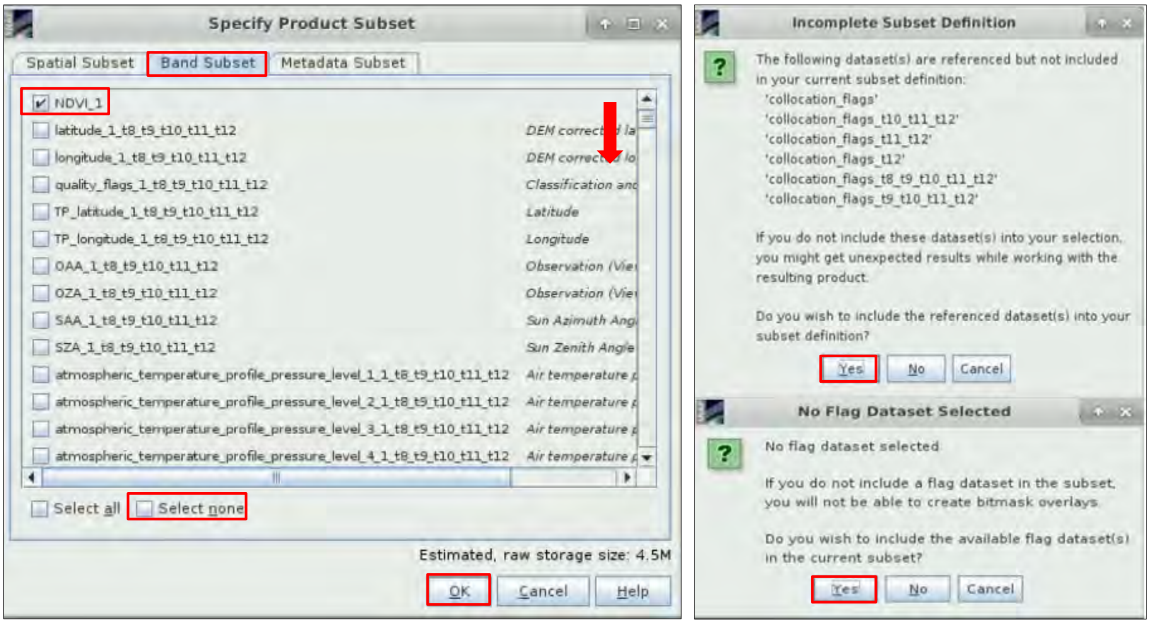
Path: */shared/Training/LAND04_LandMonitoring_Cyprus/AuxData/May/*

6.6 Band Subset

Expand the collocated product and open the *Bands* folder. Before deriving the mean NDVI value per pixel, we will remove some of the bands of the collocated product that are not needed anymore. Click on the *Collocate_May.dim* and go to *Raster -> Subset*. Select the *Band Subset* tab on the top part of the window. Check the *Select None* option on the lower part of the window to unselect all the bands by default. Now, select the bands we want to keep by checking them:

NDVI_1 | NDVI_2 | NDVI_3 | NDVI_4| NDVI_5| NDVI_6 | NDVI_7

Once selected, click OK. Two pop-up messages will appear asking to include the *collocation_flags* bands created during the collocation process and to add a flag dataset. Click YES in both cases.



Make sure to save to product. Right click on the subset product, select *Save Product,* navigate to the following path and set the name to *Collocate_May_subset.dim.* A window will appear asking you to convert the product to BEAM-DIMAP format. Click *Yes*.

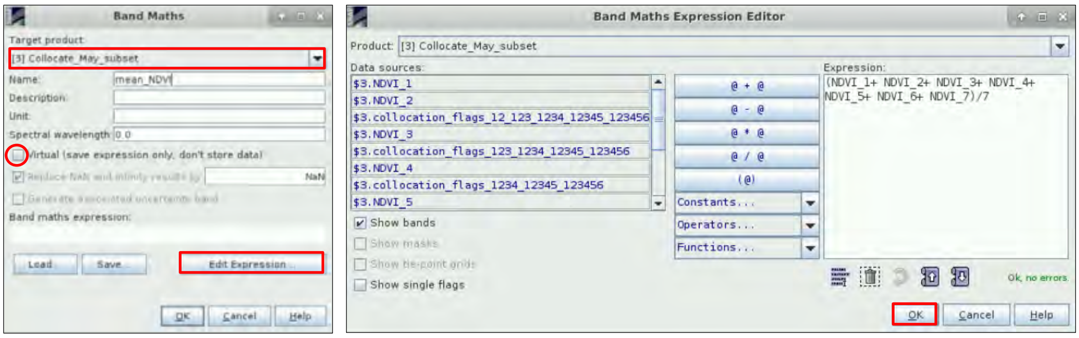
Path: */shared/Training/LAND04_LandMonitoring_Cyprus/AuxData/May/*

6.7 Mean NDVI

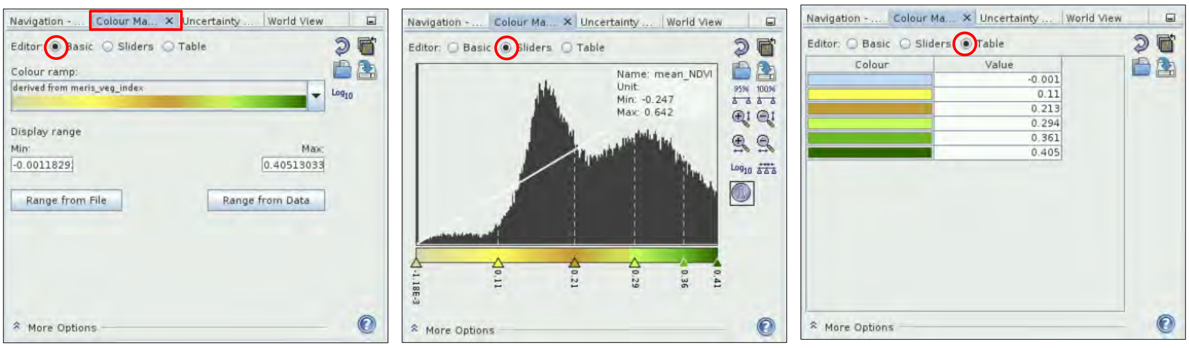
Now, we will derive the mean NDVI value for each pixel in the image. Right click on the *Collocate_May_subset* product and select *Band Math*. Set the name to *mean_NDVI,* unclick the option *Virtual (save expression only, don't store data)* and click on *Edit Expression.*

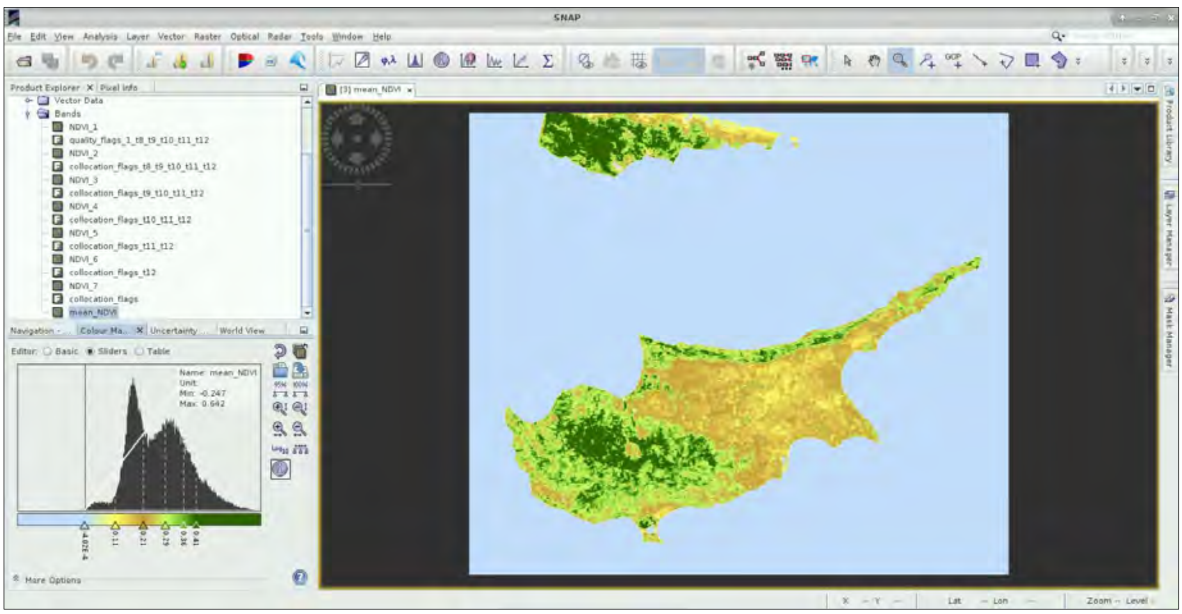
Copy-Paste the following expression and click Ok. Do not forget to save the product afterwards.

```
(NDVI_1+NDVI_2+NDVI_3+NDVI_4+NDVI_5+NDVI_6+NDVI_7)/7
```



Expand the *Bands* folder of the product and double click on the file *mean_NDVI.* You can change the colour on the *Colour* Manipulation tab in the lower left corner. First, select *Basic* as Editor. Change the colour ramp to *meris_veg_index.* Now, click the *Slider* Editor, and stretch the histogram to the 95% of the pixels by clicking on the icon. Finally, click *Table* and change the color of the first value (-0.001) to light blue.





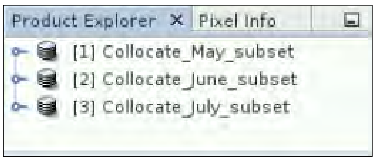
6.8 Time series

SNAP offers a time series analysis tools suitable to represent temporal evolution and improve monitoring activities. In our exercise, the same processing chain can be run to obtain the mean NDVI for consecutive months in our study area by changing the input images at the beginning of the methodology. For convenience, this analysis has been done in advance for the months of June 2017 and July 2017. Close all the files except *Collocate_May_subset* and open the mean NDVI files for each month located in the following path.

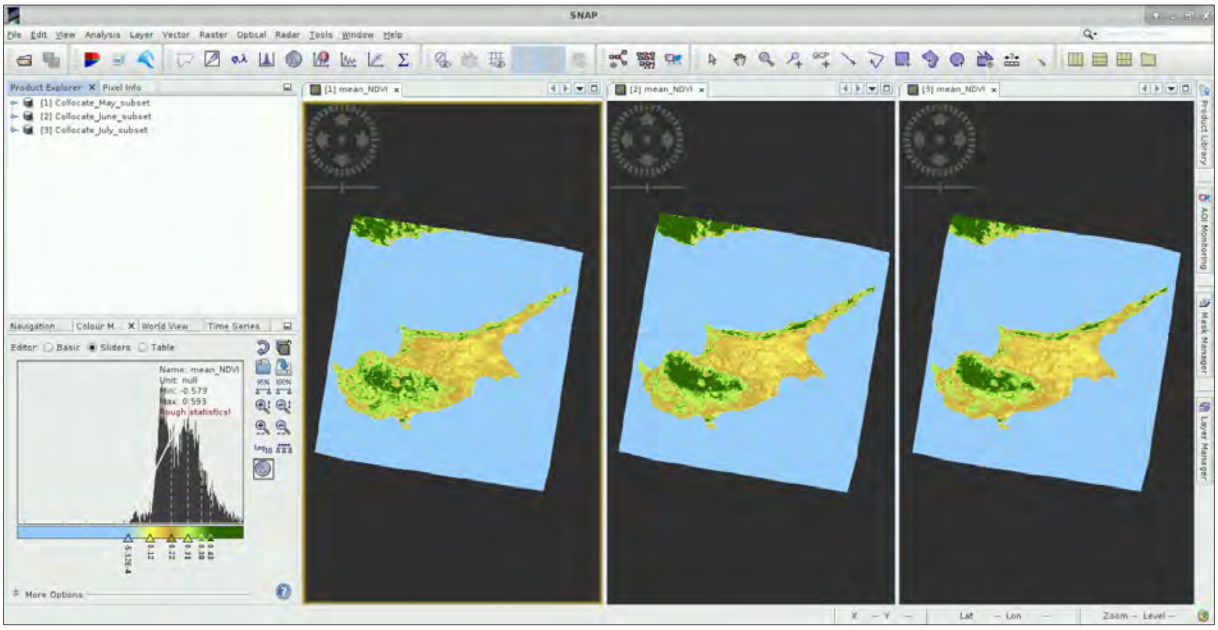
File 1: *Collocate_June_subset.dim* | **File 2**: *Collocate_July_subset.dim*

Path 1: */shared/Training/LAND04_LandMonitoring_Cyprus/AuxData/June/*

Path 2: */shared/Training/LAND04_LandMonitoring_Cyprus/AuxData/July/*

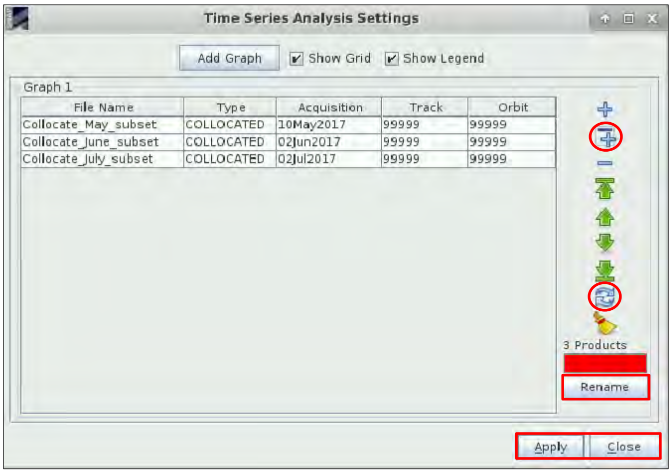


Expand each product and open the *Bands* folder. Double click on the *mean_NDVI* to visualize the mean NDVI image of each month. To make sure we are using the same colour distribution, select the first *mean_NDVI* visualization (index [1]) and press the *Apply to other bands* icon located in the upper right corner of the colour manipulation tab. A pop-up window will appear. Click *Select all* and press OK. Another pop-up window will appear, asking to whether to stretch the color palette between min/max values. Select No. Then, go to *Windows -> Tile Horizontally* to synchronize the three views.

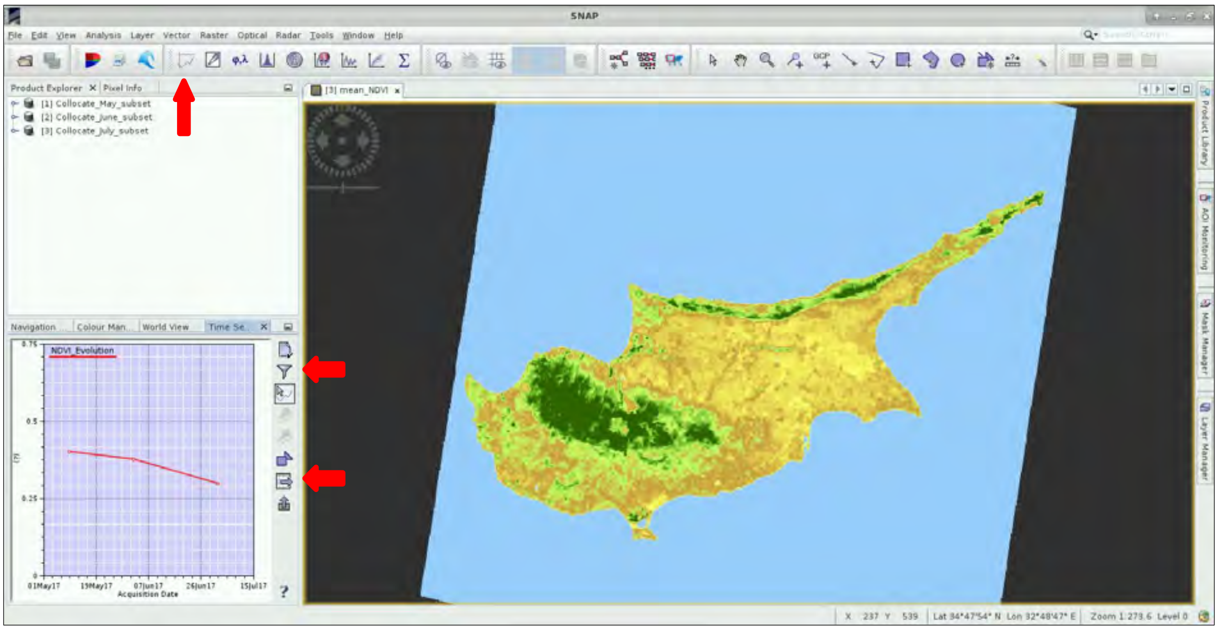


You might have noticed that the three images have identical names. This is a requirement of the Time Series Analysis Tool in SNAP.

Click on the Time Series Analysis button  on the main toolbar to open the toolview. In the Time Series Analysis window, press the  button to configure your graph and press the  icon to add all the open products in SNAP to the time series analysis. Press the refresh icon (), rename the graph to *NDVI_evolution* and change the colour to red. Then, click *Apply* and Close.



Now close two of the *mean_NDVI* views, click on the *Filter Bands* ( ) icon of the Time Series Analysis tool ( ), select *mean_NDVI* and click OK. You can now move the cursor over the image and see the evolution of the mean NDVI value of each pixel in the graph.

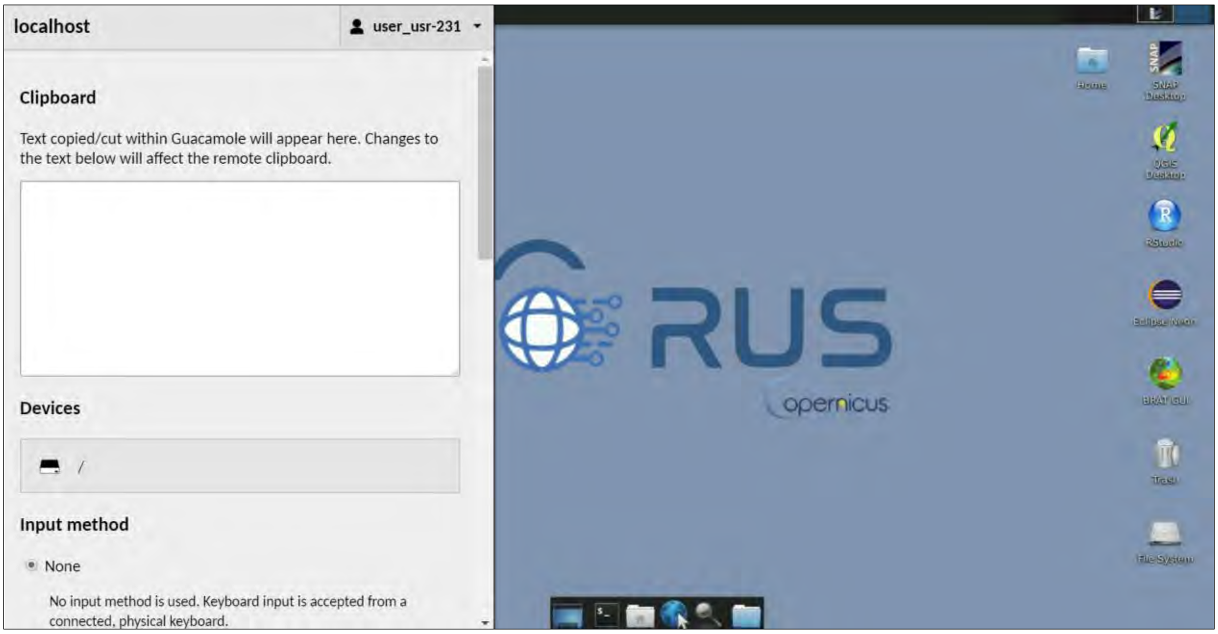


If you want to export the graph, you can do it as a text file (.csv) or as an image. Use the dedicated buttons in the lower right corner of the Time Series Analysis Tool (and).

In case you want to continue the temporal profile, download the corresponding Sentinel-3 OLCI images for each month and repeat the steps defined in this guide.

7 Extra steps

To download outputs from the Virtual Machine to your local computer 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 the path where the file you are interested in is located and **double click on it to download it.** In case you want to download a folder, you will have to zip it beforehand.



THANK YOU FOR FOLLOWING THE EXERCISE!

8 Further reading and resources

Sentinel-3 information
https://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-3

Sentinel-3 mission
https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-3

Sentinel-3 OLCI User Guide
https://sentinels.copernicus.eu/web/sentinel/user-guides/sentinel-3-olci

Sentinel-3 OLCI Technical Guide
https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-3-olci

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