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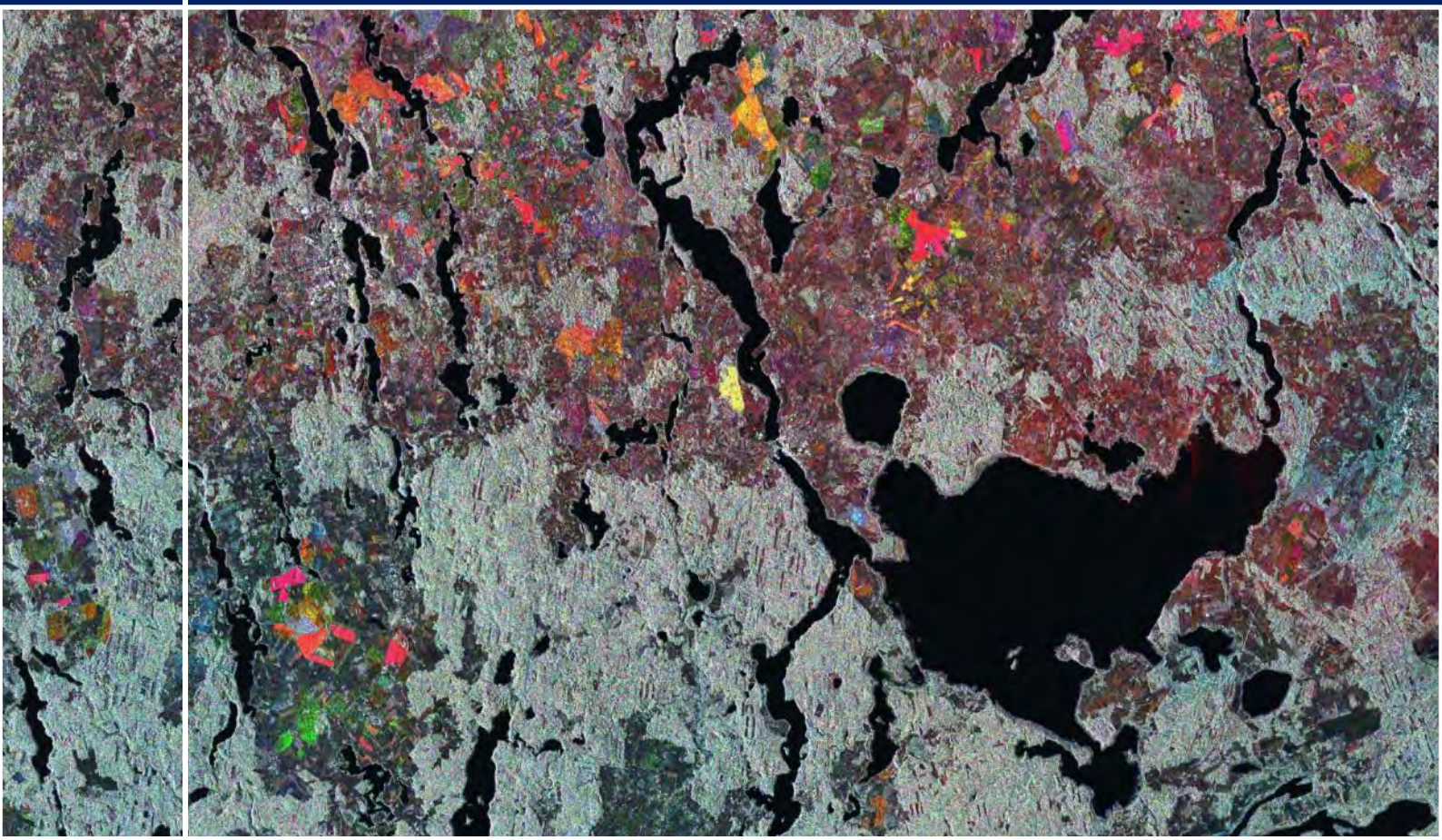

TRAINING KIT – HYDR01

WATER BODIES MAPPING FROM SPACE

JUNE – NOVEMBER 2017, NORTHERN POLAND

serco

NOVELTIS

ALONG-TRACK

ROMANIA

Research and User Support for Sentinel Core Products

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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

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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.

Flims, Switzerland Credits: Photo by Stephen Leonardi on Unsplash.

Water surfaces, whether they are lakes, rivers, dams or ponds are crucial part of our landscapes. Timely monitoring of surface water and delivering data on the dynamics of surface waters are essential for policy and decision-making processes.

Number of different methods has been developed for the extraction/delineation of waterbodies in remotely sensed data. Generally, we can split the basic methods to three categories: single band thresholding, band ratio indexes, more sophisticated methods (machine learning, etc.).

In this webinar, we will have look at the two first approaches. First, we will use Sentinel-2 optical data to calculate the Normalized Difference Water Index (NDWI). Then we will use the thresholding method with averaged stack of Sentinel-1 SAR data and see the advantages and disadvantages of each method.

2 Training

Approximate duration of this training session is two hours.

2.1 Data used

- One cloud-free Sentinel-2A Level 2A tile (Tile ID: T34UEE) acquired on August 16, 2017 [downloadable @ https://scihub.copernicus.eu/]

  S2A_MSIL2A_20170816T095031_N0205_R079_T34UEE_20170816T095031.zip

- Five Sentinel-1A IW GRDH products acquired in July and August 2017 [downloadable @ https://scihub.copernicus.eu/]

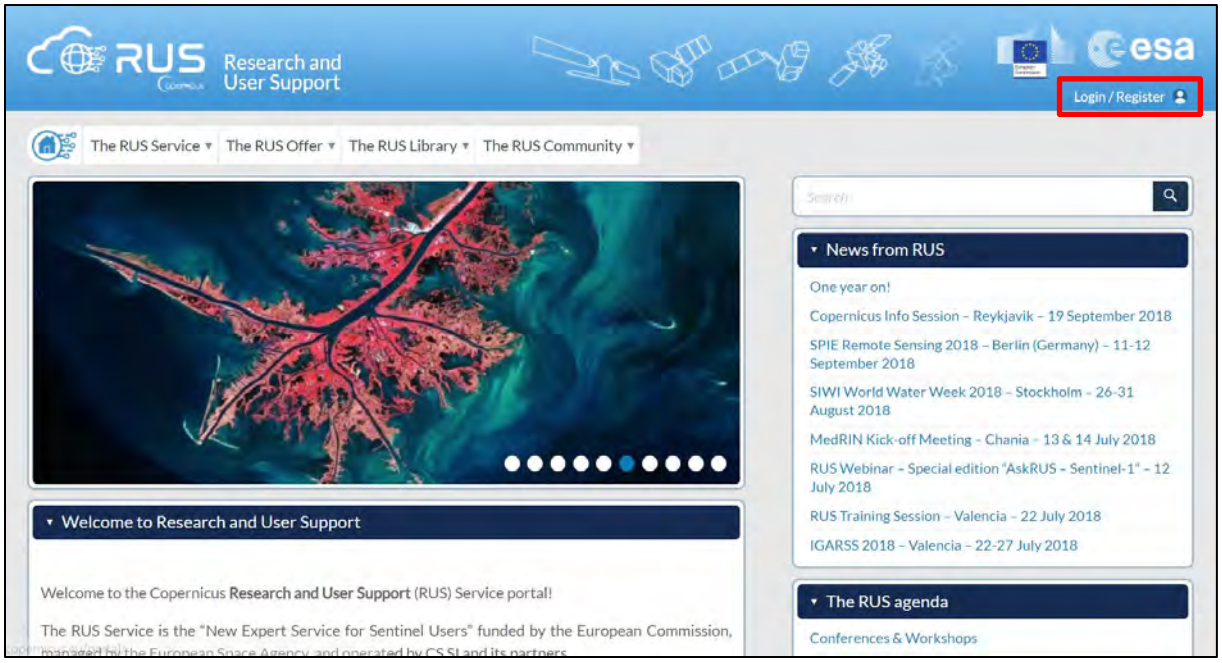
  S1A_IW_GRDH_1SDV_20170711T161931_20170711T161956_017426_01D1DE_4164.zip
  S1A_IW_GRDH_1SDV_20170723T161931_20170723T161956_017601_01D729_290F.zip
  S1A_IW_GRDH_1SDV_20170804T161932_20170804T161957_017776_01DC8A_4628.zip
  S1A_IW_GRDH_1SDV_20170816T161933_20170816T161958_017951_01E1D7_0173.zip
  S1A_IW_GRDH_1SDV_20170828T161933_20170828T161958_018126_01E722_FB07.zip

2.2 Software in RUS environment

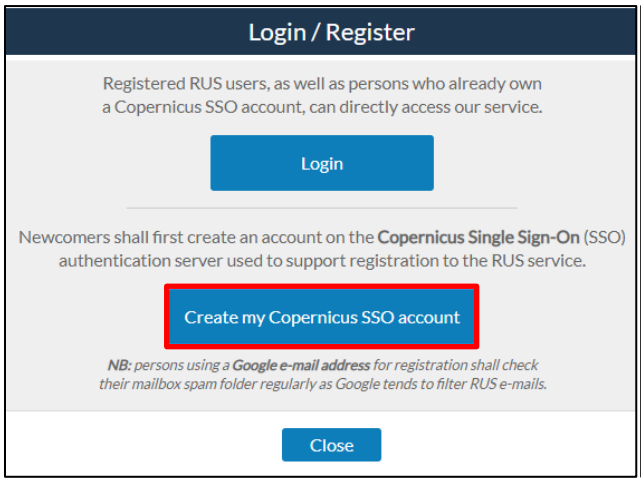
Internet browser, SNAP + Sentinel-2 Toolbox, QGIS, (Extra steps: Sen2Cor, Google Earth)

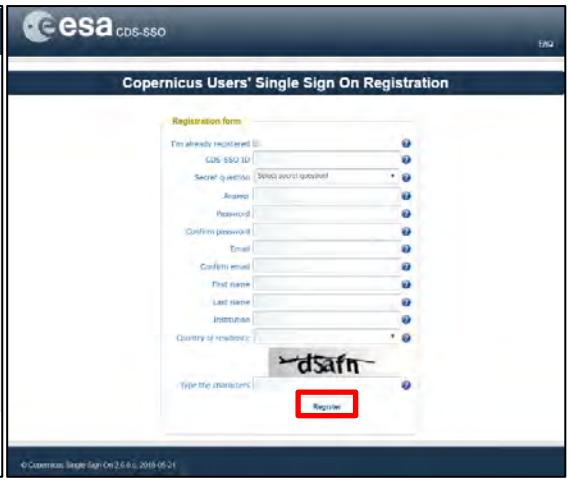
3 Register to RUS Copernicus

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.



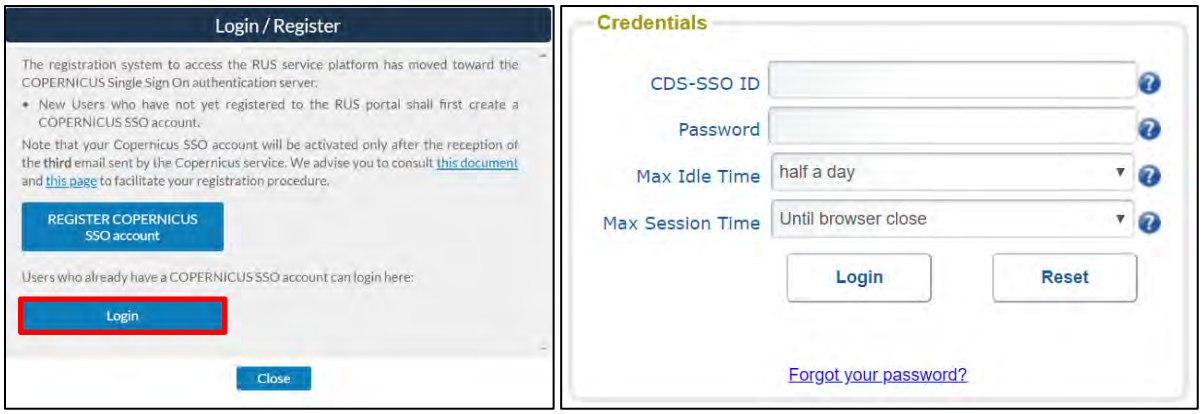
Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click ***Register***.



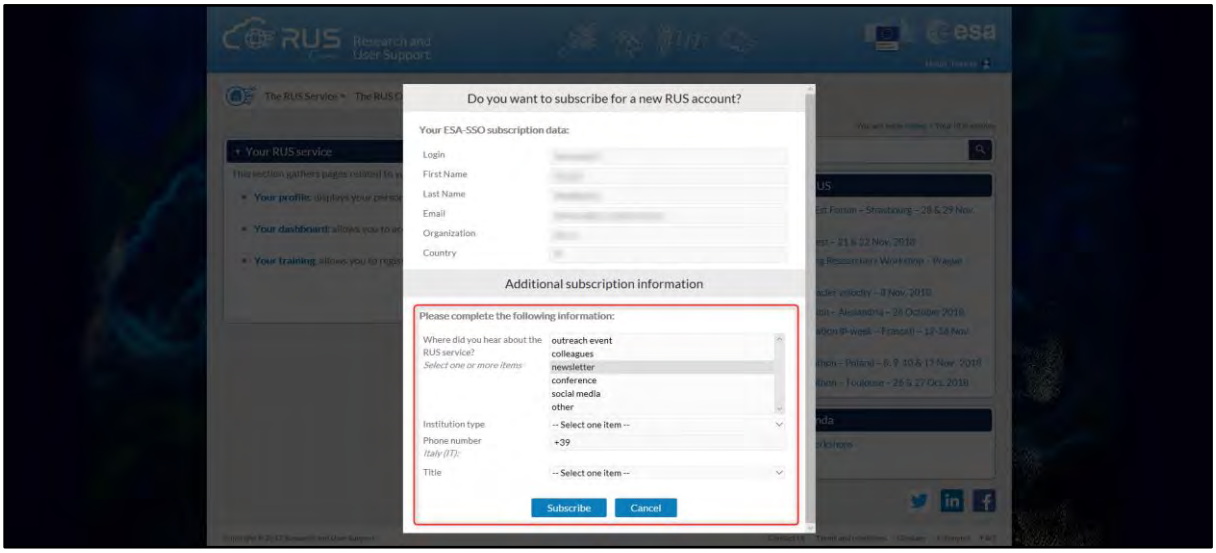


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

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

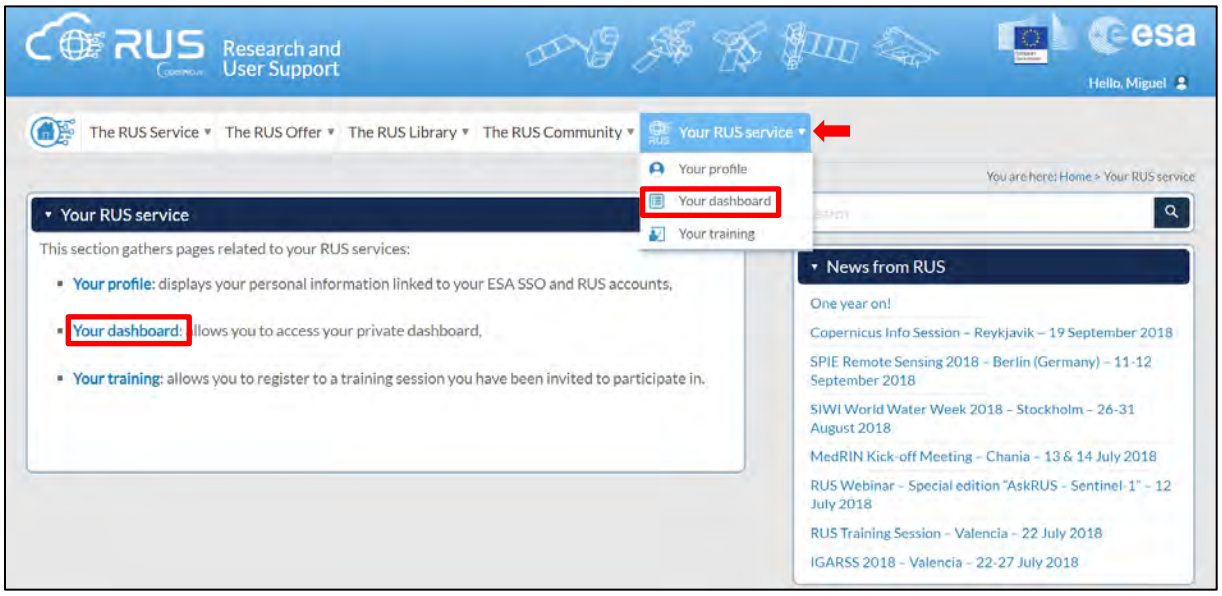


Upon your first login you will need to enter some details. You must fill all the fields.

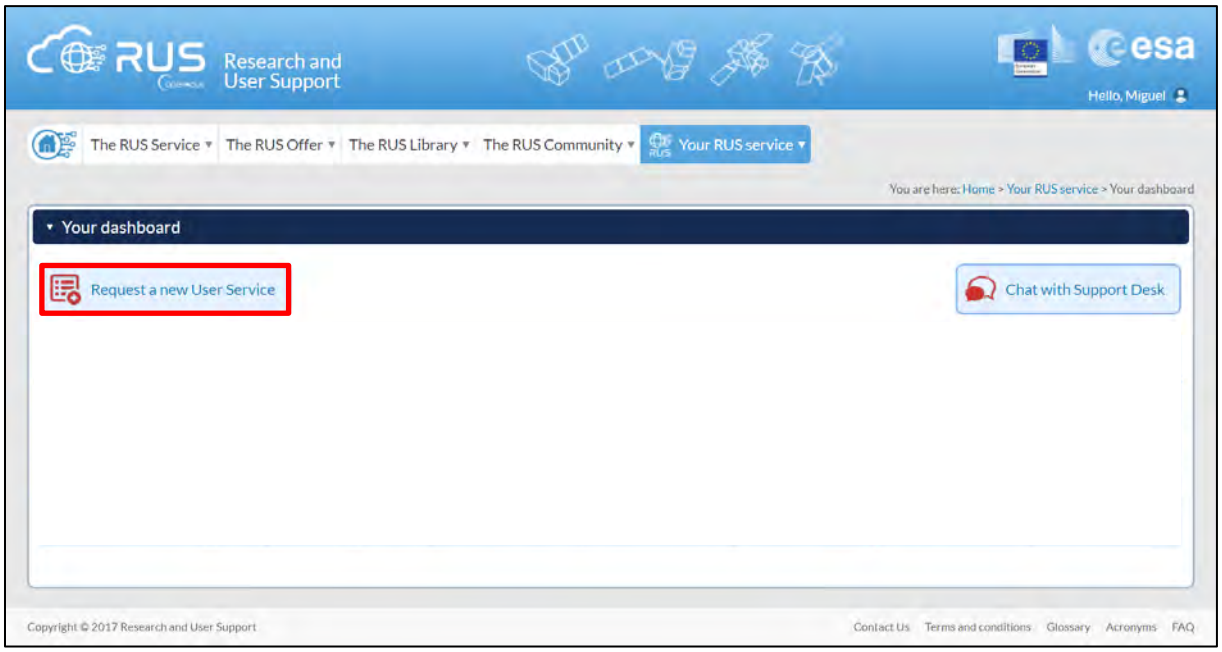


4 Request a RUS Copernicus Virtual Machine

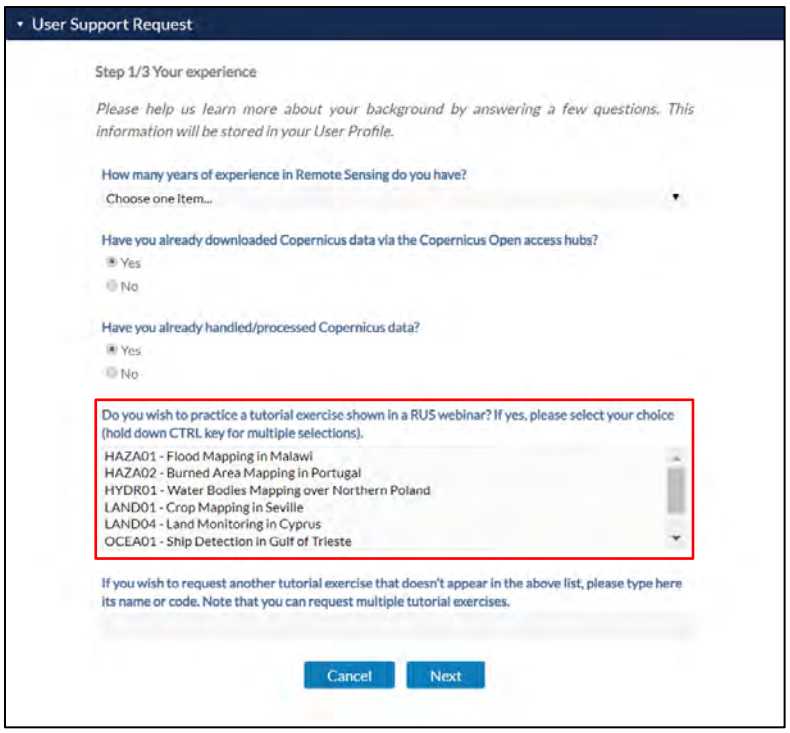
Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on ***Your RUS Service*** → ***Your Dashboard***.



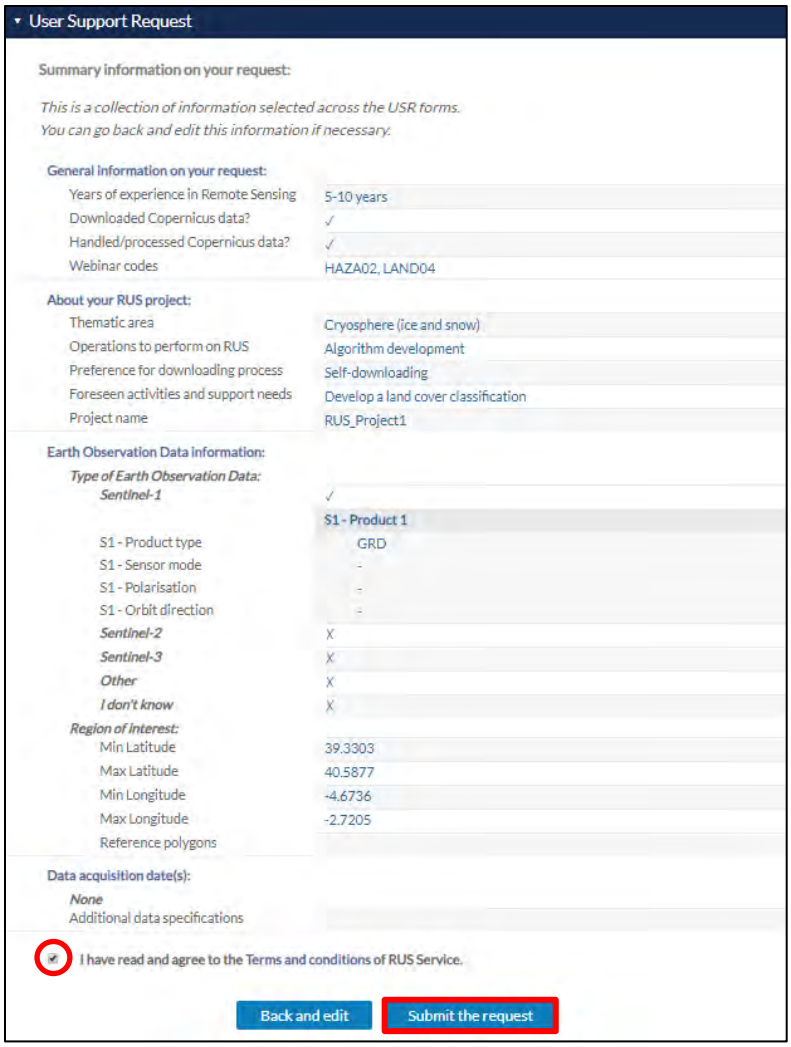
Click on ***Request a new User Service*** to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.



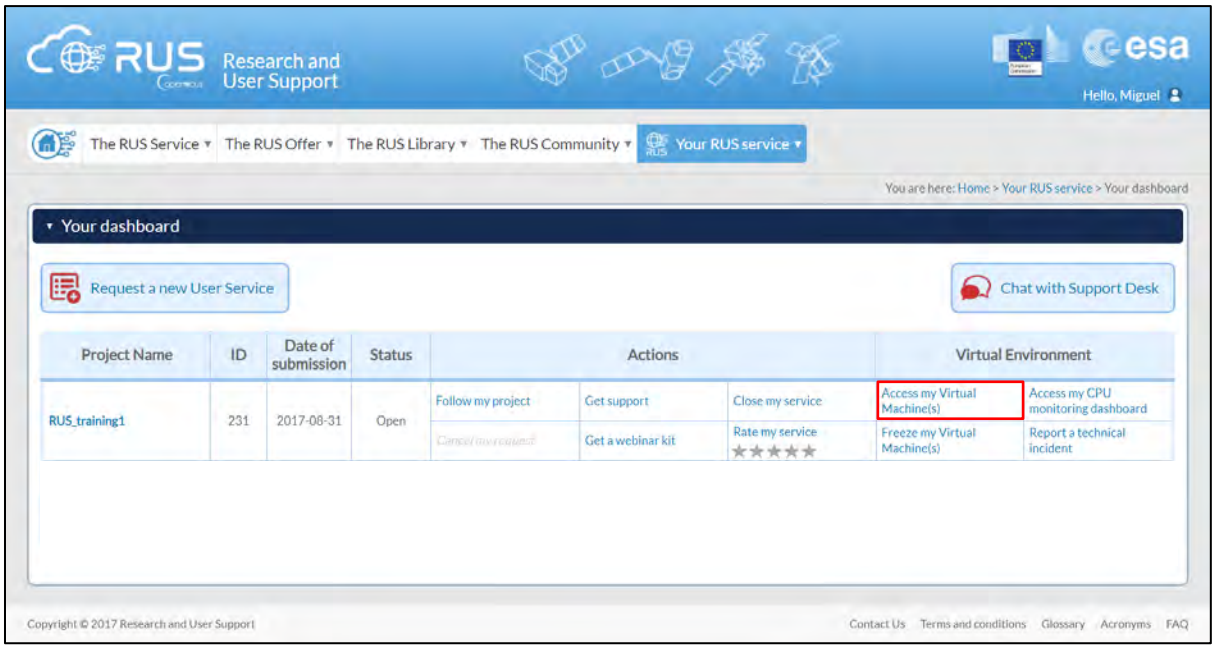
If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.



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.

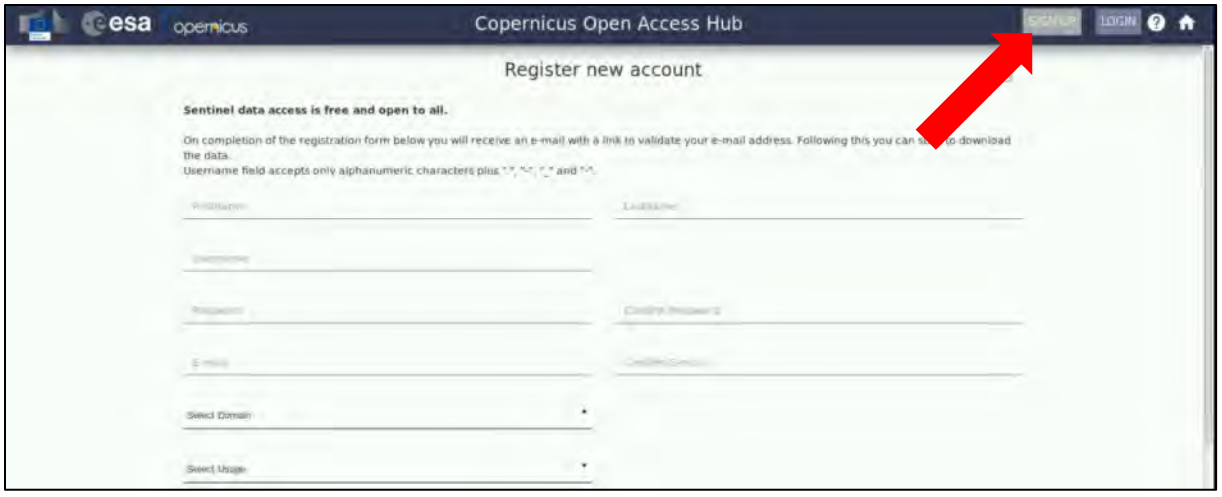
5 Step by step

5.1 Data download – ESA SciHUB

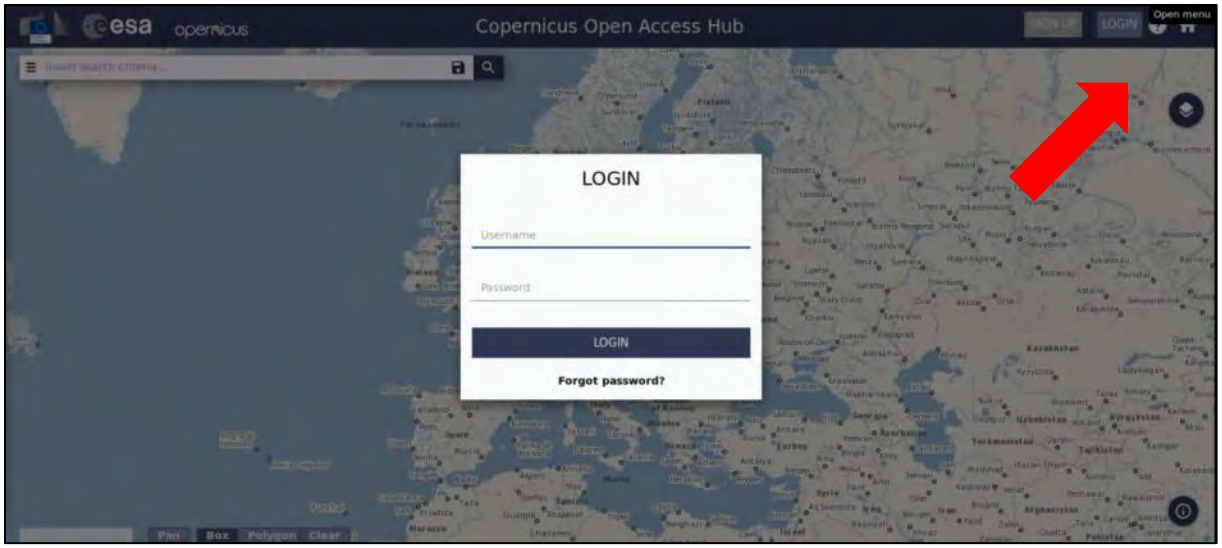
In this step we will download a Sentinel-2 scene from the Copernicus Open Access Hub using the online interface (**Applications → Network → Web Browser** or click the link below).

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

Go to "**Open HUB**", if you do not have an account please register by going to "**Sign-up**" in the LOGIN menu in the upper right corner.



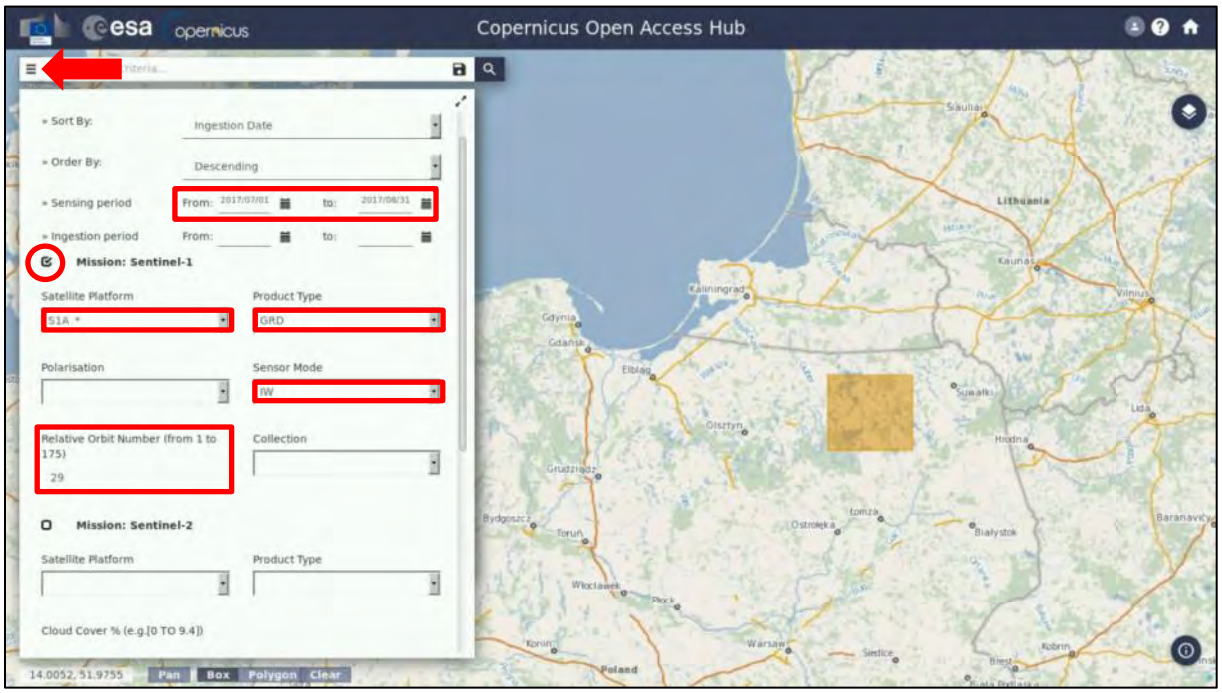
After you have filled in the registration form, you will receive an activation link by e-mail. Once your account is activated or if you already have an account, "**LOGIN"**.



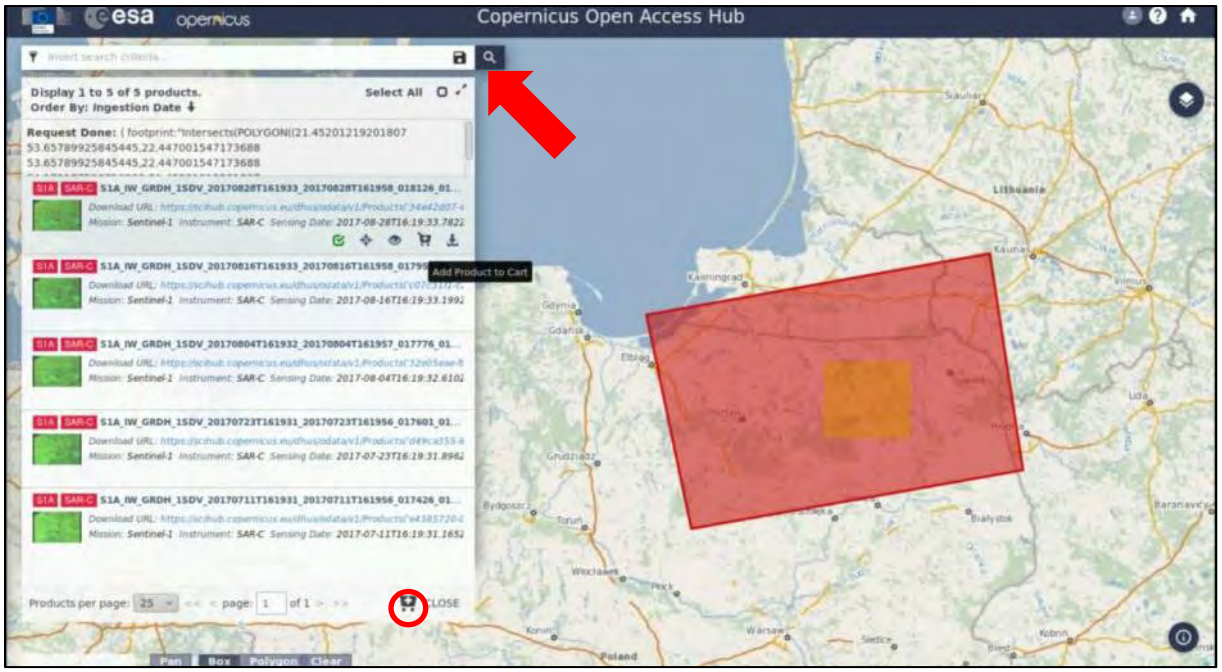
Switch the rectangle-drawing mode to pan mode by clicking on the "**Pan**" icon in the lower left corner of the map (**Green arrow**) and navigate over Portugal (**approximate area – blue rectangle**).

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 2017/07/01 to 2017/08/31
Check Mission: Sentinel-1
Satellite Platform: S1A*
Product Type: GRD
Sensor Mode: IW
Relative Orbit: 29



Press "**Search**" (red arrow below).

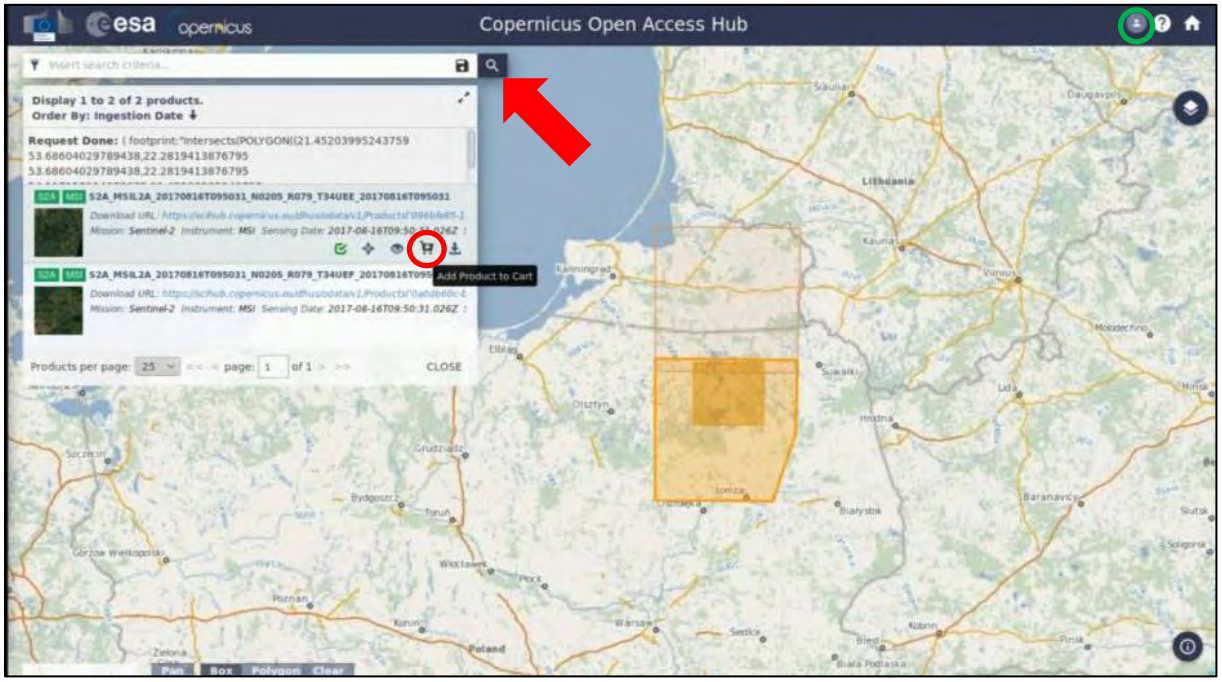


In our case, the search returns five results depending on the exact search area defined. Using the icon, import all six products to Cart.

Then open the search menu again and reset the parameters as defined below**, do not forget to deselect Mission: Sentinel-1** as this time we will search for Sentinel-2 data (See TIP 1):

Sensing period: From 2017/08/16 to 2017/08/16
Check Mission: Sentinel-2
Product Type: S2MSI2Ap

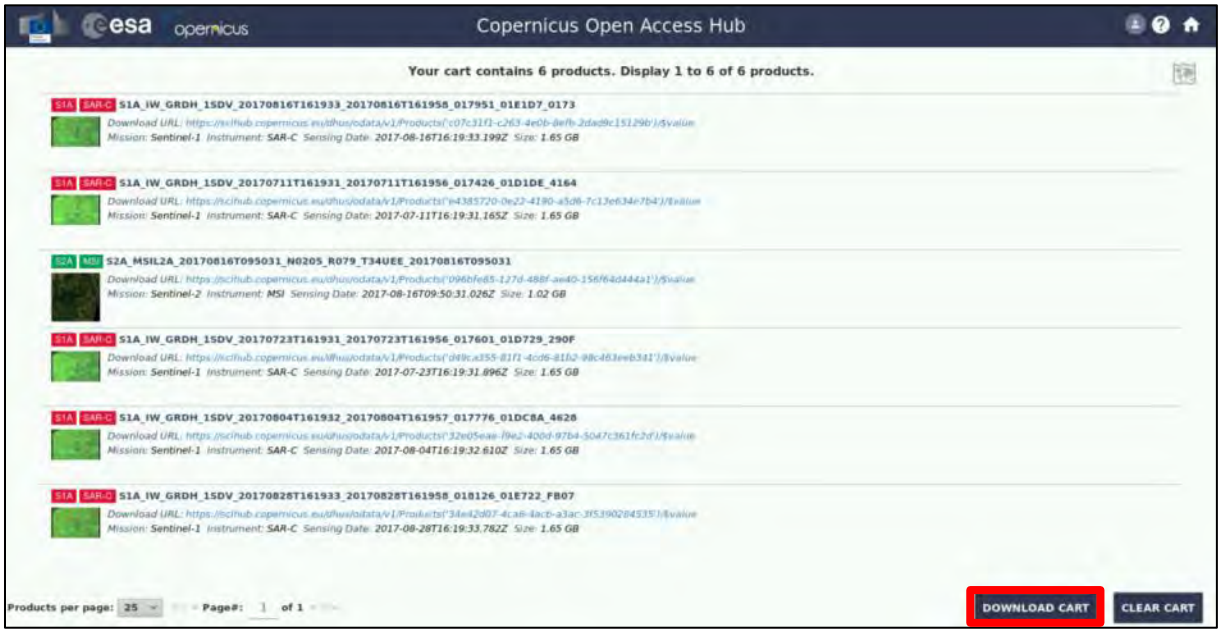
TIP 1: For the Level 2A products we are downloading, the atmospheric correction has already been applied (pre-processing of Level-1C product to a Level-2A is described in section **4.1**). Since April 2017, the Level-2A products available to download for acquisitions over Europe (such as this case). Global coverage of Level 2A products is available as of December 2018.



In our case, the search returns four results depending on the exact search area defined. Using the icon, import only the following product to **Cart**:

*S2A_MSIL2A_**20170921T101021**_N0205_R022_**T32TQQ**_20170921T101436*

Then click on the Profile icon in the upper left corner (marked with **green circle** above) and go to **Cart**. You should now have six products in your cart. Click **Download Cart**.



A ***products.meta4*** file will be downloaded to your ***/home/rus*** folder. To download our data, we will use **aria2** tool. To use the tool, we first need to place the **products.meta4** file to the folder where we wish our data to be downloaded to: ***/shared/Training/HYDR01_WaterBodies_TrainingKit/Original***

First let's test our aria2 installation. To do this we open the Command Line (in the bottom of your desktop window) and type:

```
aria2c
```

The correct response should be as follows:

If the response is "**-bash aria2c: command not found**" (see NOTE 1).

> NOTE 1: If (**and only if**) the response is "-bash aria2c: command not found". Then we have to install the tool, to do this in command line type: `sudo apt-get install aria2`
> When requested type: Y
> Then you can test your installation again.

If you have received the correct response, then we can run the tool by typing following commands in the command line (replace **<username>** and **<password>** with your login credentials for Copernicus Open Access Hub):

```
cd /shared/Training/HYDR01_WaterBodies_TrainingKit/Original

aria2c      --http-user='<username>'      --http-passwd='<password>'      --check-
certificate=false --max-concurrent-downloads=2 -M products.meta4
```

The first line changes our directory to the target directory. The second line runs the download tool (Type the red text all in single line). All six products will be downloaded to the ***Original*** folder two products in parallel automatically

(**Note** that the constraint of maximum 2 parallel downloads at a time is imposed by the Copernicus Access Hub, if you increase the number, your download will fail). This might take some time.

5.2 Optical data – Sentinel-2

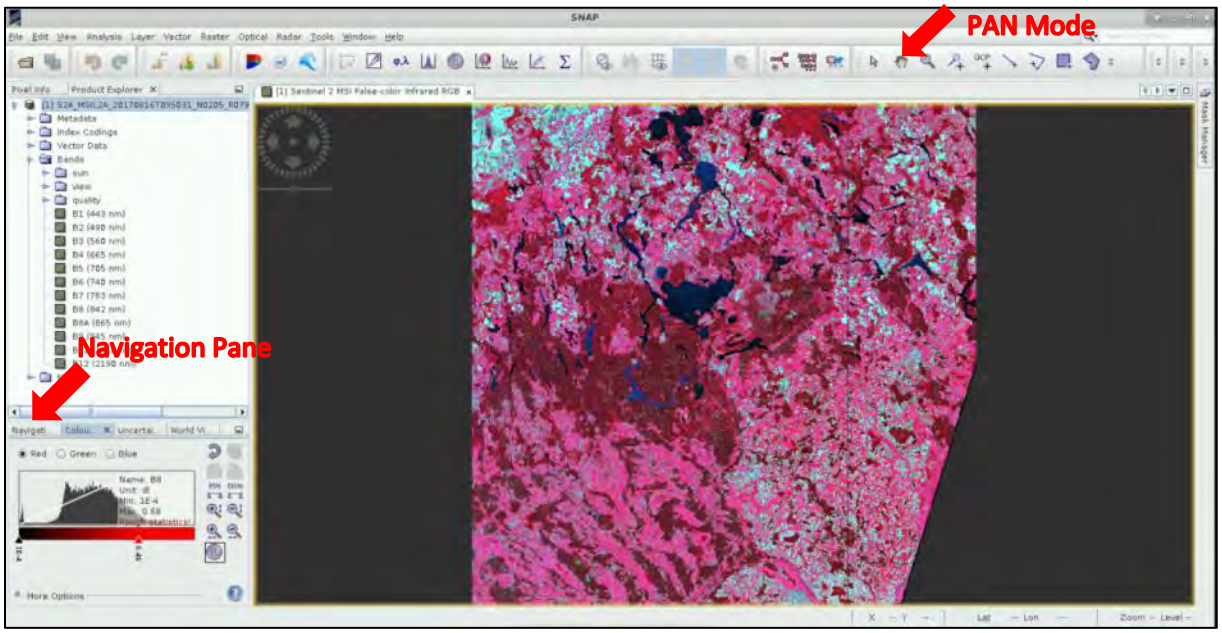
5.2.1 SNAP – open and explore data

Launch SNAP (icon on desktop). When the SNAP window opens click **Open product** and navigate to: ***/shared/Training/HYDR01_WaterBodies_TrainingKit/Original***

Open the S2 product. Now, we will look at the product. We could visualize it in true (natural) colours but for distinguishing water surfaces, it is better to use the false colour. **Right-click** the product and click **Open RGB image window,** a new window will open. From the drop-down menu select:

Profile: Sentinel 2 MSI False-colour-Infrared

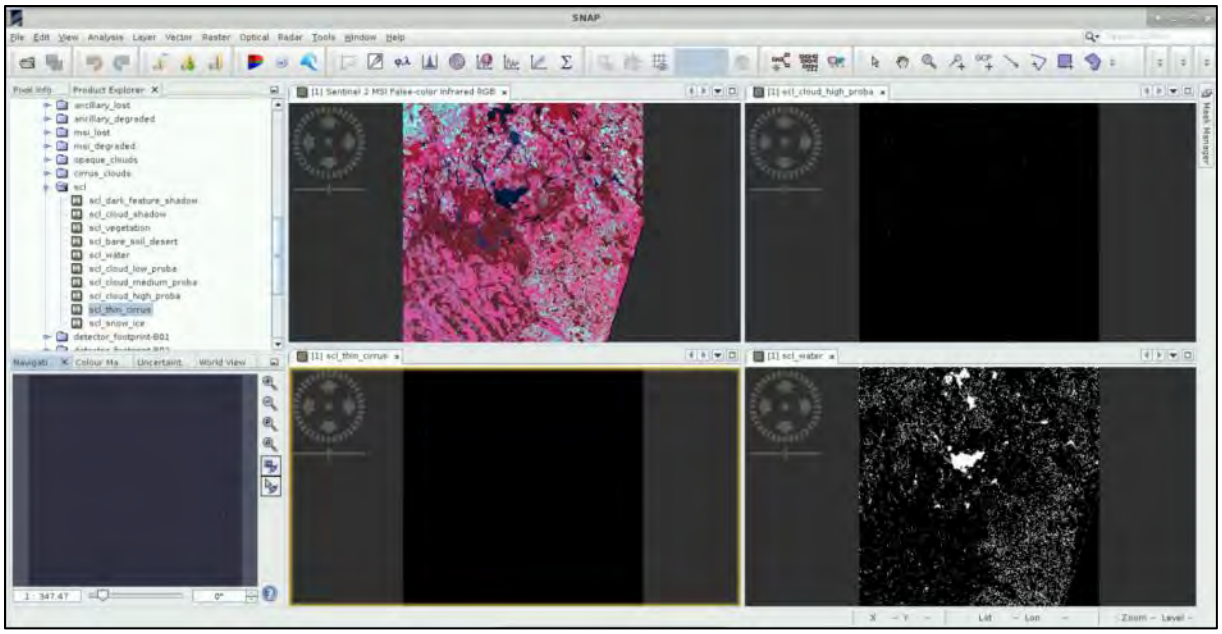
Click **OK**.



Now, let's investigate the **cloud cover** and **water mask** bands that are the result of atmospheric correction applied to the level 2 products.

Expand the product in the **Product Explorer** window and go to ***Masks*** → ***scl***. Open masks ***scl_cloud_high_proba*** (Cloud high probability), ***scl_water*** (Water) and ***scl_thin_cirrus*** (Thin cirrus). Pixels with detected clouds/cirus/water will appear white in the respective masks.

Now you should have four bands open in your **View** window. Go to **Window** → **Tile Evenly** and then go to the **Navigation** tab, click **Zoom All** .



We can see that as expected our image is cloudless. The default water mask distributed with the Level-2 product, however, does not look very accurate.

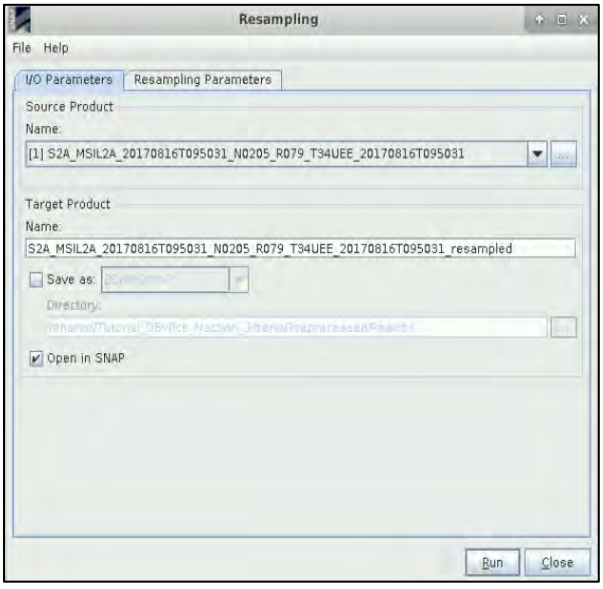
5.2.2 Resample

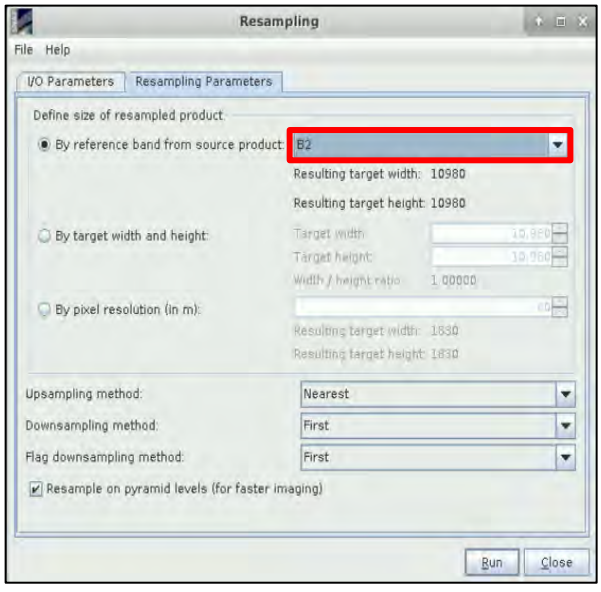
The 13 bands in Sentinel-2 products do not all have same resolution (therefore size, see NOTE 2). Many operators in SNAP toolbox do not support products with bands of different sizes so first we need to resample the bands to equal resolution.

Go to **Raster → Geometric Operations → Resampling** (See NOTE 3).

Do not change anything in the **I/O Parameters** tab.

In the **Resampling Parameters** tab under "**Define size of resampled product**", choose: **By reference band from source product: B2**

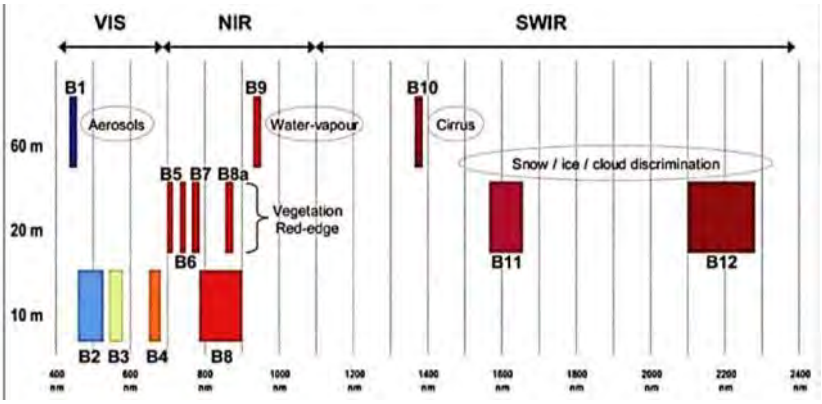




Click **Run**.

After the process is completed, if a window appears, click **Yes.**

NOTE 2: The input product contains 13 spectral bands in three different spatial resolutions (The surface area measured on the ground and represented by an individual pixel). When we open the RGB view all our input bands have 20 m resolution, however, the view is displayed in the full 10 m resolution.



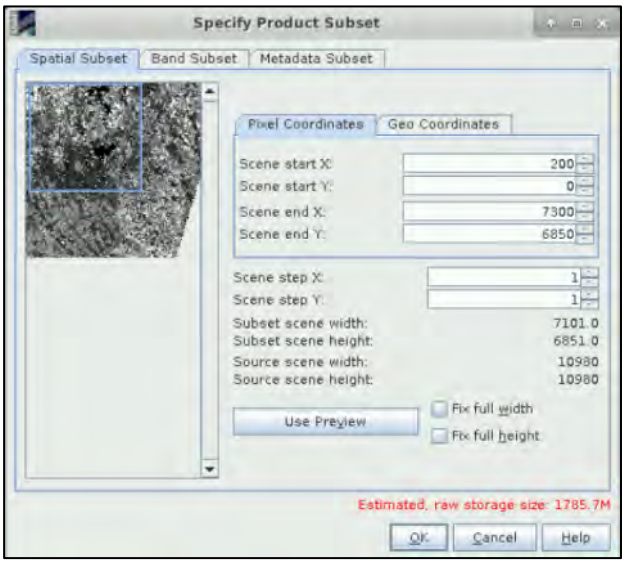
Credits: ESA 2015

NOTE 3: The resampling product appears in the Product Explorer window but it is not physically saved. Therefore, it will be lost if you close it or if you close the source product.

A new product [2] appeared in the Product Explorer tab. Now we will have a look at the product. Close all the views we have open and expand the product structure by clicking the **+** sign on the left of the product name, then expand the ***Band*** folder and double click ***B8* (842nm) - (NIR)**.

5.2.3 Subset

In the next step, we will subset the image to our area of interest. Click on the resampled product in the **Product Explorer** tab, to highlight it. Then go to **Raster → Subset** and in the **Spatial Subset** tab, set **Pixel coordinates** to:



Scene start X: 200

Scene start Y: 0

Scene end X: 7300

Scene end Y: 6850

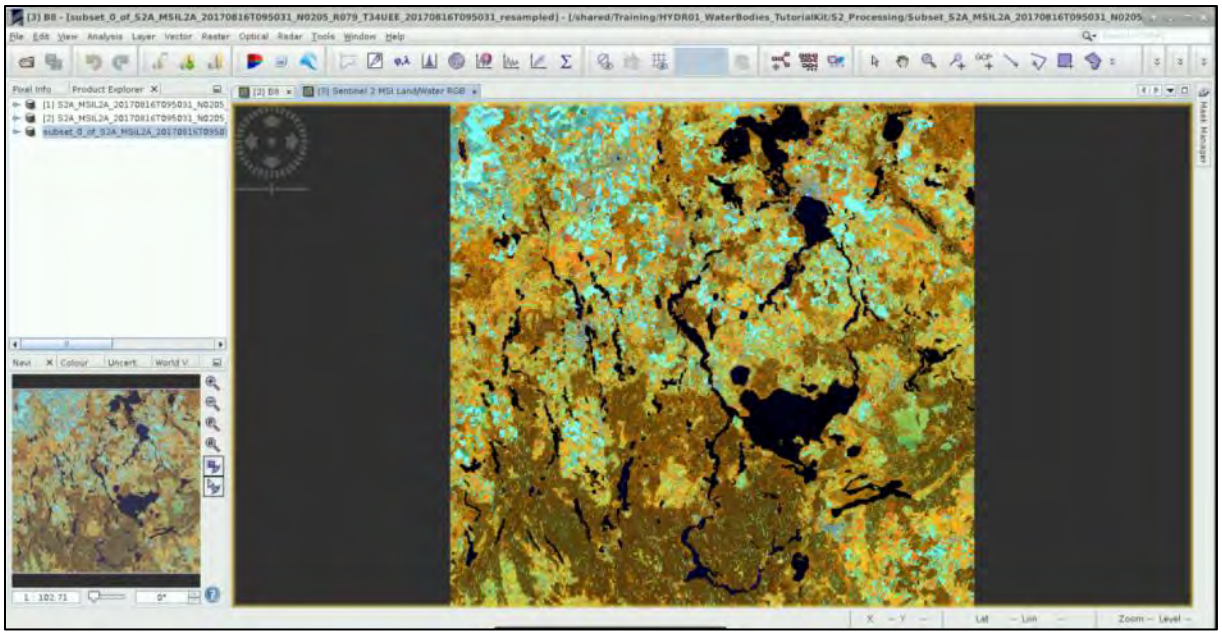
Keep the other Subset tabs as by default. Click **OK**.

A new product will appear in the **Product Explorer** tab [3]. Right-click the new product and click **Save Product**. In the pop-up window click **Yes**, in the next window navigate to ***/shared/Training/HYDR01_WaterBodies_TrainingKit/S2_Processing*** and save the subset data.

Right-click the product [3] and click **Open RGB image window** and from the dropdown menu select:

Profile: Sentinel 2 MSI Land/Water

Click **OK**.



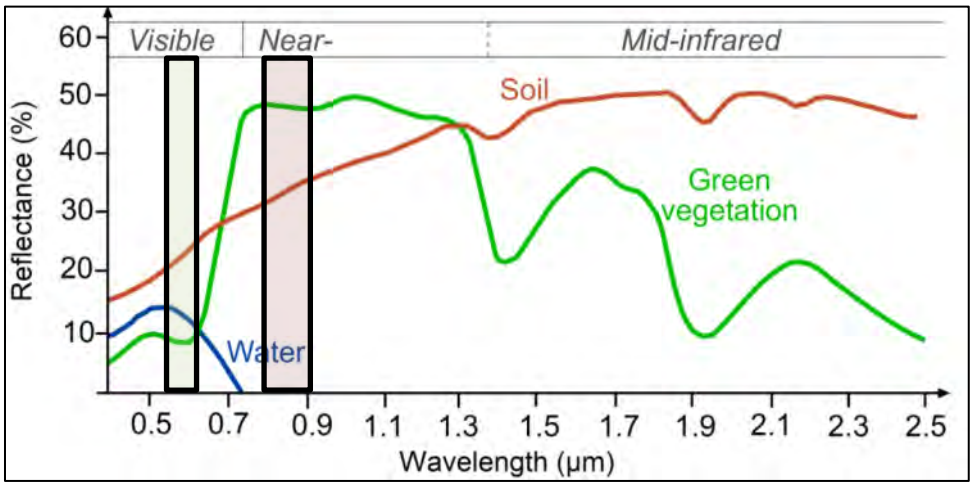
5.2.4 NDWI

To detect the water bodies, we will use the Normalized Difference Water Index – NDWI. It was proposed by McFeeters[2] and it is designed to:

i) maximize the reflectance of the water body in the green band;

ii) minimize the reflectance of water body in the NIR band. McFeeters's NDWI is calculated as:

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



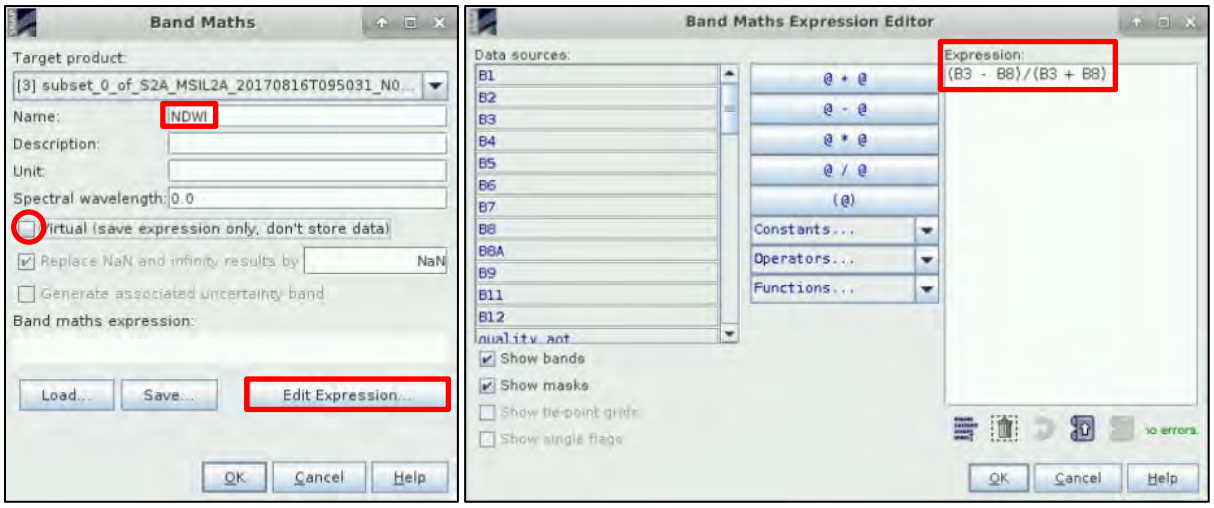
Right-click on the newly created subset product [3], select **BandMaths** and set:

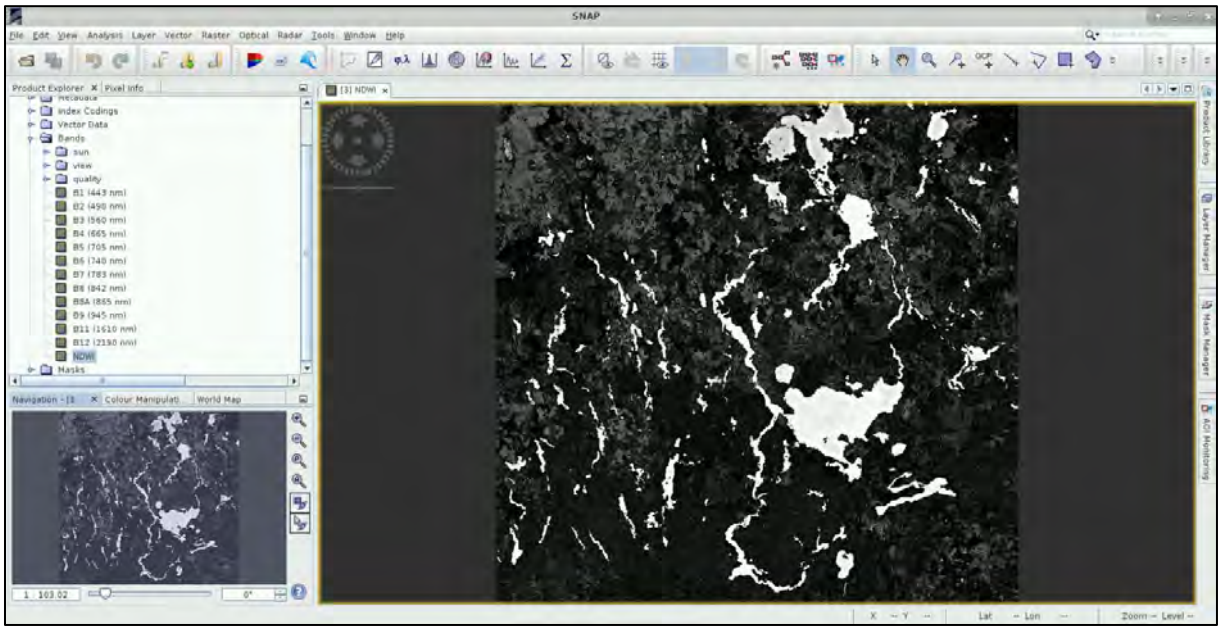
Name: NDWI

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

Click on "**Edit Expression**" and set as **Expression:** `(B3 – B8)/(B3 + B8)`

Click **OK** in both windows.





The open water pixels appear much brighter than other surfaces. Now, let's create another new band that will only contain water surfaces.

We will set the **threshold** for pixel to be classified as water to **>= 0**.

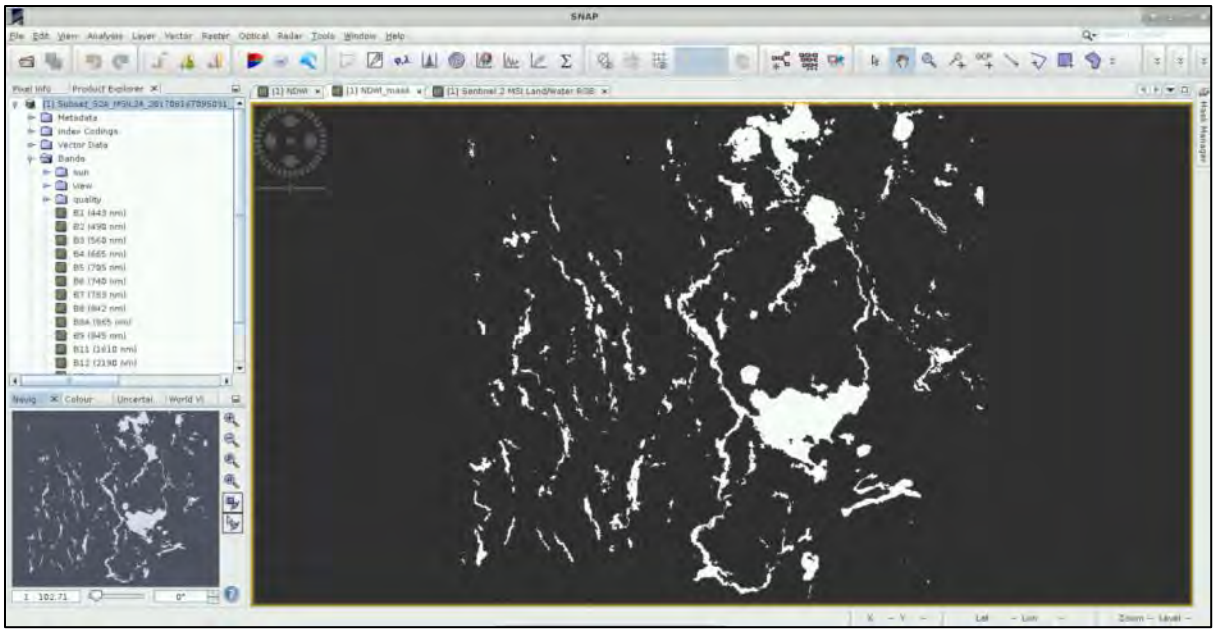
Right click the product [3] and go to **BandMaths** again. Set:

Name: NDWI_mask
Deselect "**Virtual (save expression only, don't store data)**" - we want the band to be stored!

Click on "**Edit Expression**" and set as **Expression:** `if NDWI >= 0 then 1 else 0`

Click **OK** in both windows.

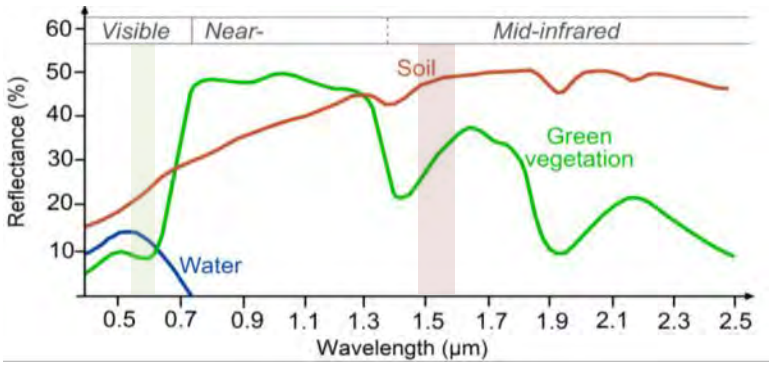
You can also go to **Window → Tile Horizontally** to see the difference between the *NDWI* and the *NDWI_mask* bands.



TIP 2: The NDWI can sometimes erroneously enhance also very bright build-up areas, and numerous modifications have been proposed. We will test a modified version designed to minimize the build-up noise. It uses the short wave infrared (SWIR) band instead the near infrared (NIR) as the absorption of water surfaces is greater in SWIR than in NIR. MNDWI is calculated as:

$$NDWI = \frac{Green - SWIR}{Green + SWIR} = \frac{B3 - B11}{B3 + B11}$$

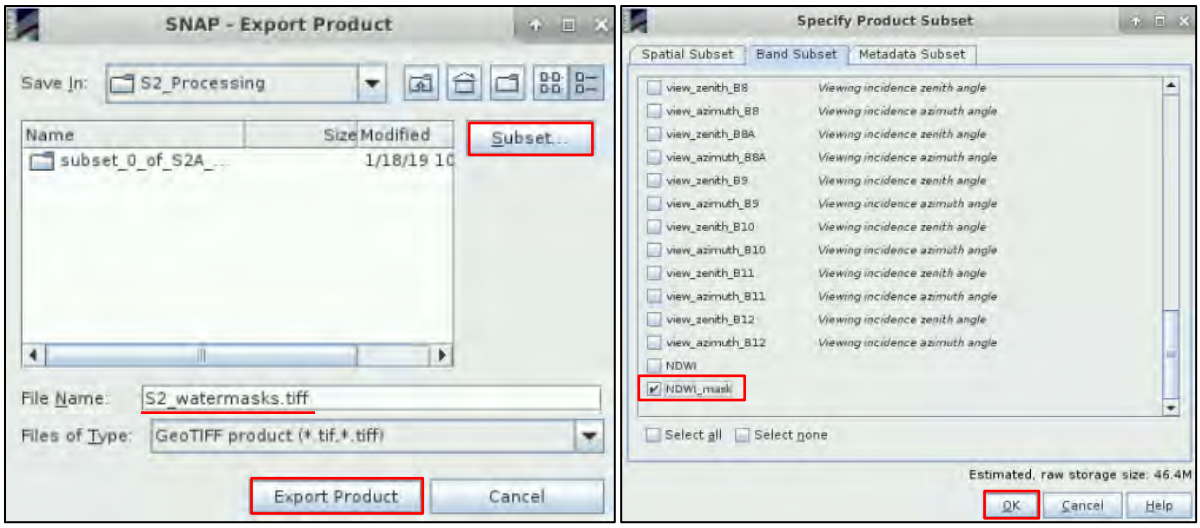
Right click on the newly created subset product [3], select BandMaths and set:
Name: NDWI
Deselect Virtual "(save expression only, don't store data)" – we want the band to be stored!
Click on "**Edit Expression**" and set as **Expression:** (B3 – B11)/ (B3 + B11)
Create mask the same way as for NDWI. Compare both masks. What are the differences? Are there differences in detail? Can you explain why?



Finally, right click on product [3] and go to **Save Product**. If a window appears click **Yes** and navigate to: ***/shared/Training/HYDR01_WaterBodies_TrainingKit/S2_Processing*** to save it. If another window appears, click **Yes** as well.

Then go to **File → Export → GeoTIFF**.

Click on **Subset** and go to **Band Subset** tab; select only ***NDWI_mask*** band and click **OK**. Save as **File name**: ***S2_watermasks.tiff***.
Finally click **Export Product**.



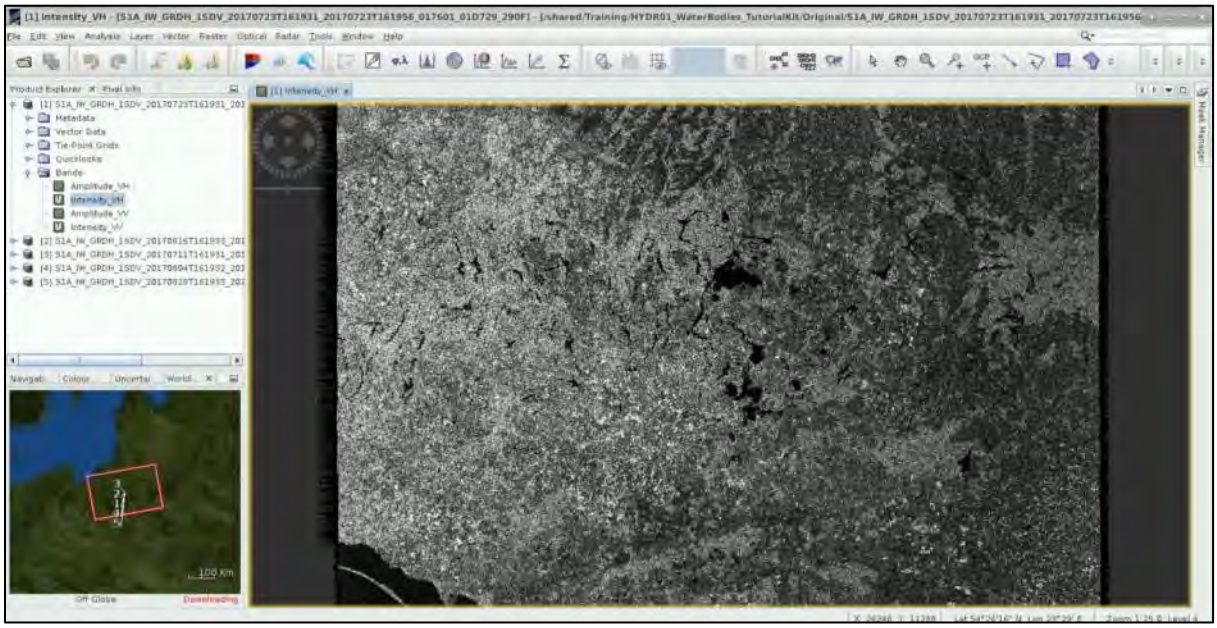
Our first water mask is ready. Take some time to compare it to the RGB image. Now, let's derive the water mask from SAR data so we can compare.

Close the SNAP window. Any dialog windows that might appear asking you to save the data, click **Yes**.

5.3 SAR data – Sentinel-1

5.3.1 SNAP – open and explore data

Launch SNAP (icon on desktop). When the SNAP window opens click **Open Product** , navigate to ***/shared/Training/HYDR01_WaterBodies_TrainingKit/Original*** and open the five S1 products. Right-click each product and expand the **Bands** folder. Then double click the ***Intensity_VH*** band.



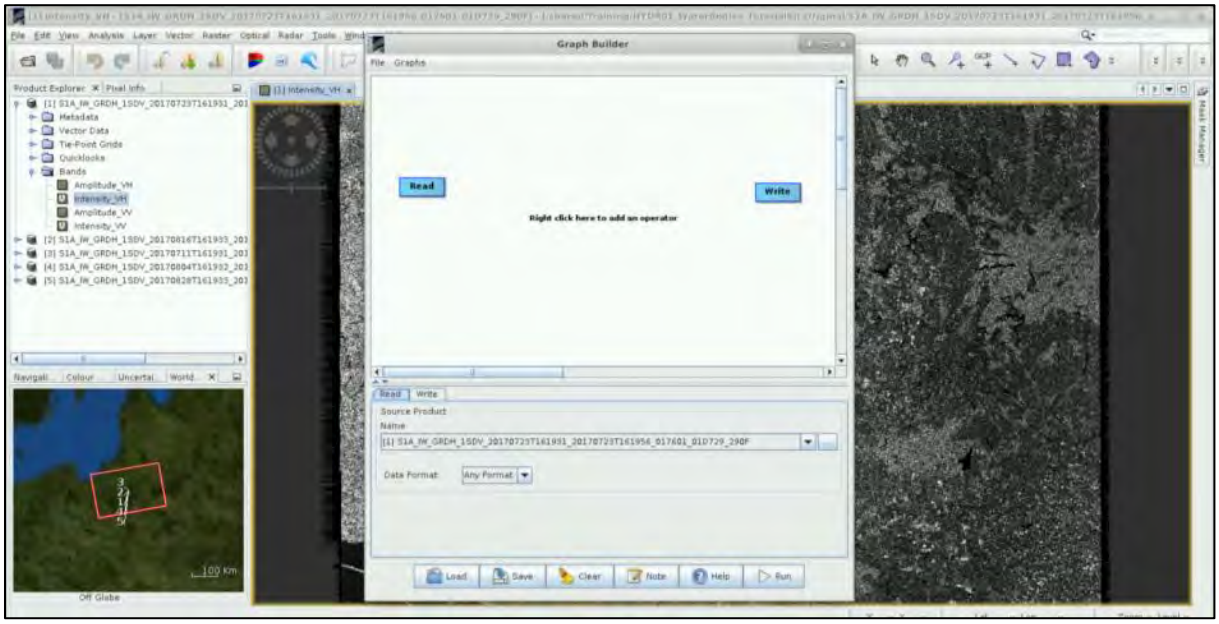
5.3.2 Build step-by step processing chain

We will now need to pre-process all five images but doing this one by one would be quite time consuming so let's use the **Batch Processing** tool available in SNAP to process all images at the same time.

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

Go to **Tools → GraphBuilder**.

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

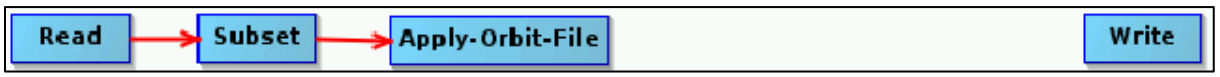


Since our Area of Interest (AOI) is quite small and there is no need to process the whole image, we start by adding a **Subset** operator. To add the operator right-click the white space in the graph builder and go to **Add → Raster → Geometric → Subset**.

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

In the next step, we will update the orbit metadata (See NOTE 4). To add the operator, right-click the white space between existing operators and go to **Add → Radar → Apply-Orbit-File**. Connect the new **Apply-Orbit-File** operator with the **Subset** operator.

> NOTE 4: The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with the precise orbit files, which are available days-to-weeks after the generation of the product. The orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated. (*SNAP Help*)



The next step will remove the thermal noise (See NOTE 5). We add this operator by right-clicking the white space somewhere left of the resample operator and going to **Add → Radar → Radiometric → ThermalNoiseRemoval.** Connect the **ThermalNoiseRemoval** operator with the **Apply-Orbit-File** operator.

NOTE 5: Thermal noise in SAR imagery is the background energy that is generated by the receiver itself. (*SNAP Help*) It skews the radar reflectivity to towards higher values and hampers the precision of radar reflectivity estimates. Level-1 products provide a noise LUT for each measurement dataset, provided in linear power, which can be used to remove the noise from the product.

Now, we can add the **Calibration** operator. The objective of SAR calibration is to provide imagery in which the pixel values can be directly related to the radar backscatter. Though uncalibrated SAR imagery is sufficient for qualitative use, calibrated SAR images are essential to quantitative use of SAR data (See NOTE 6).

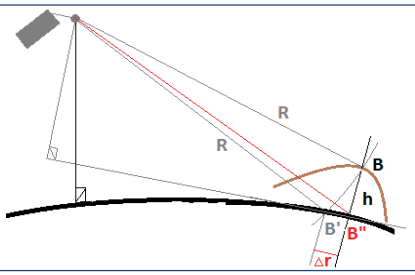
To add the operator go to **Add → Radar → Radiometric → Calibration.** Connect the **ThermalNoiseRemoval** operator to the **Calibration** operator.

NOTE 6: Typical SAR data processing, which produces level-1 images, does not include radiometric corrections and significant radiometric bias remains. The radiometric correction is necessary for the pixel values to truly represent the radar backscatter of the reflecting surface and therefore for comparison of SAR images acquired with different sensors or acquired from the same sensor but at different times, in different modes, or processed by different processors. (*SNAP Help*)

Our data are still in radar geometry, moreover due to topographical variations of a scene and the tilt of the satellite sensor, the distances can be distorted in the SAR images. Therefore, as the last step of our preprocessing, we will apply terrain correction to compensate for the distortions and reproject the scene to geographic projection (See NOTE 7).

To add the operator, go to **Radar → Geometric → Terrain Correction → Terrain-Correction** then connect the **Calibration** operator to it.

NOTE 7: The geometry of topographical distortions in SAR imagery is shown on the right. Here we can see that point **B** with elevation **h** above the ellipsoid is imaged at position **B'** in SAR image, though its real position is **B"**. The offset **Δr** between **B'** and **B"** exhibits the effect of topographic distortions. *(SNAP Help)*



At the moment, do not change anything in the parameter tabs and save the graph by clicking **Save** at the bottom of the window.

Navigate to:
/shared/Training/HYDR01_WaterBodies_TrainingKit/S1_Processing and save the graph with the **File Name**: ***Graph_preprocess.xml***.

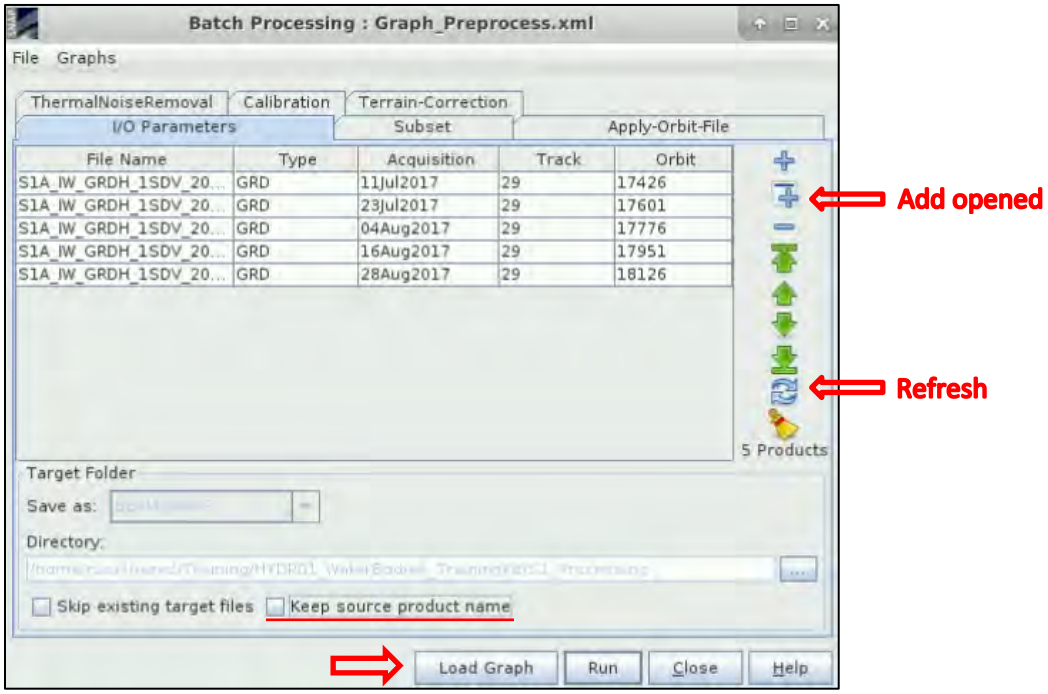
Close the **GraphBuilder** window.

5.3.3 Batch processing

In the **Product Explorer** window, we select (highlight) the product [1] (11 July 2017). Now we can open the Batch Processing tool (**Tools → Batch Processing**).

We will add the opened products by clicking **Add Opened** on the upper right (second icon from the top) and click **Refresh**. Then, we click **Load Graph** at the bottom of the window, navigate to our saved graph, and open it. We see that new tabs have appeared at the top of window corresponding to our operators with the exception of **Write**; this is correct, as these parameters will be set in the **I/O Parameters** tab.

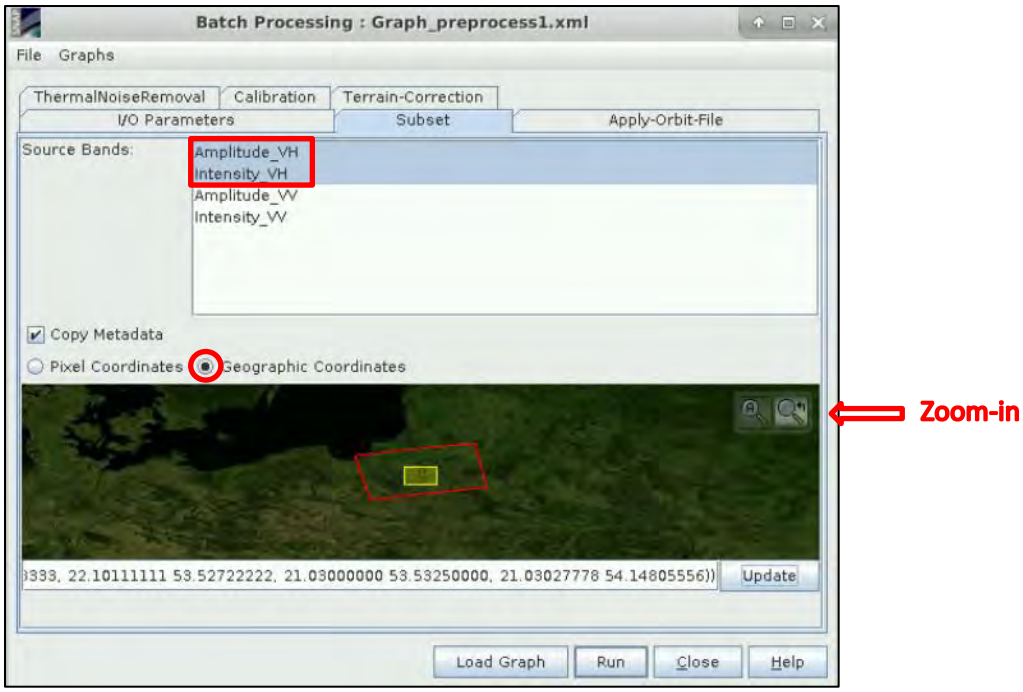
In the **I/O Parameters** tab set the directory to: ***/shared/Training/HYDR01_WaterBodies_TrainingKit /S1_Processing*** and then **deselect** the "**Keep source product name**".



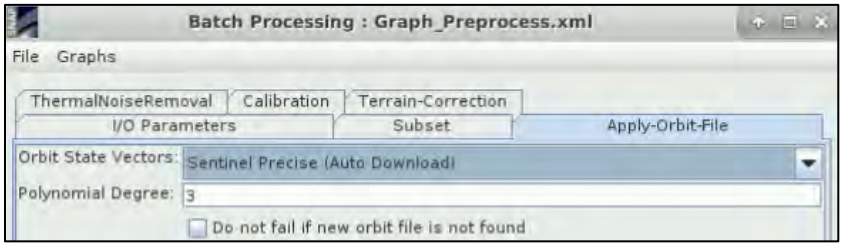
In the **Subset** tab press **Ctrl** and select bands ***Amplitude_VH*** and ***Intensity_VH*** and then click to select the **Geographic Coordinates** option. Paste the area of interest definition in WKT (well know text) format to the text window below the map.

```
POLYGON ((21.03027778 54.14805556, 22.11722222 54.14833333, 22.10111111
53.52722222, 21.03000000 53.53250000, 21.03027778 54.14805556))
```

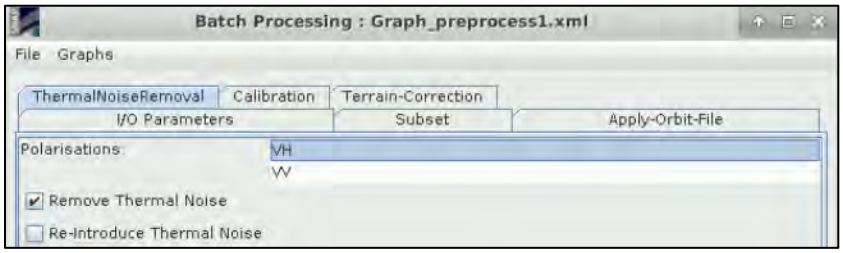
Click **Update** and then click the **Zoom-in** icon to see your subset on the map.



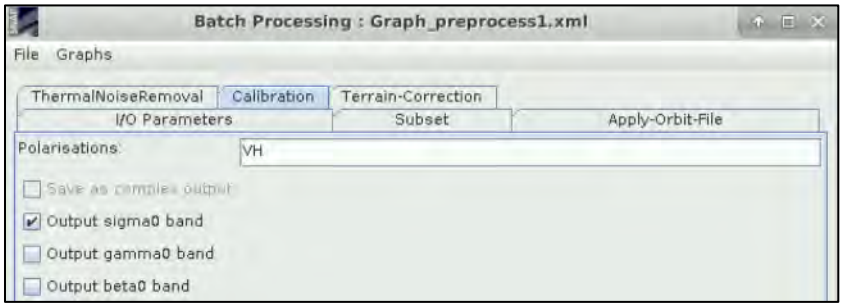
In the **Apply-Orbit-File** tab we can accept the default settings.



In the **ThermalNoiseRemoval** tab select **VH** polarization and make sure that "**Remove Thermal Noise**" option is selected.

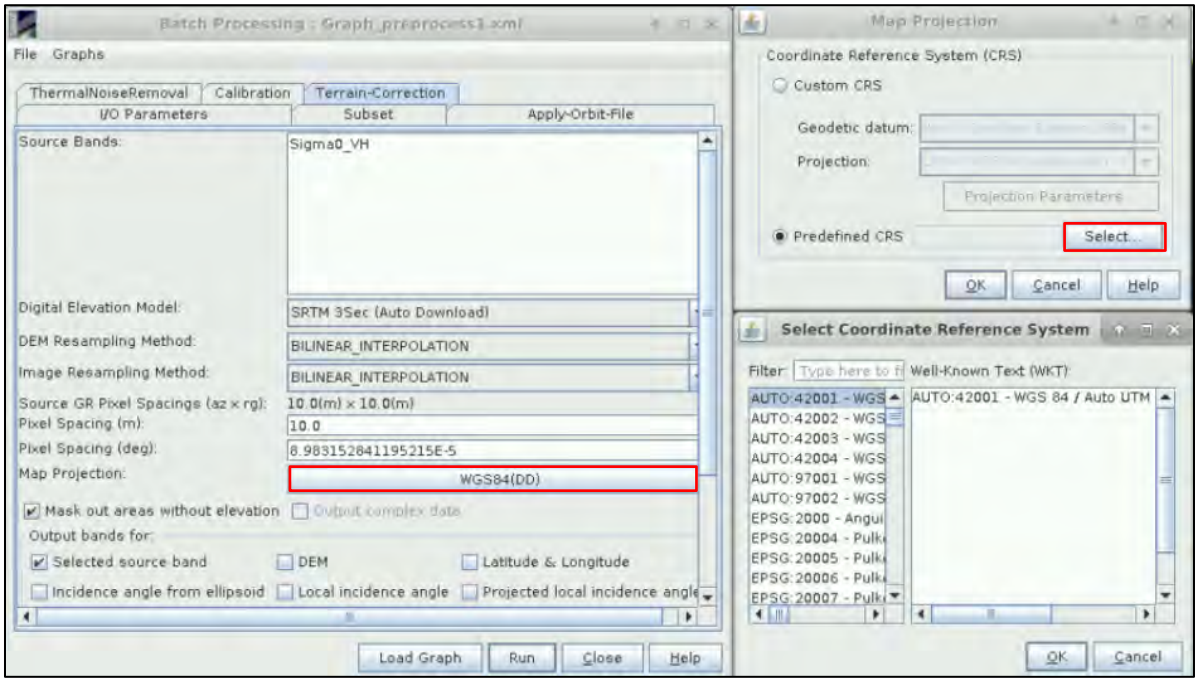


In the **Calibration** tab we will also accept all default settings.



In the **Terrain-Correction** tab: **Map Projection -> Predefined CRS**. Click on "**Select**" and choose: **AUTO: 42001 – WGS 84 / Auto UTM**. Leave all the other default settings.

Click **OK** in both windows and finally click **Run** to pre-process our images.



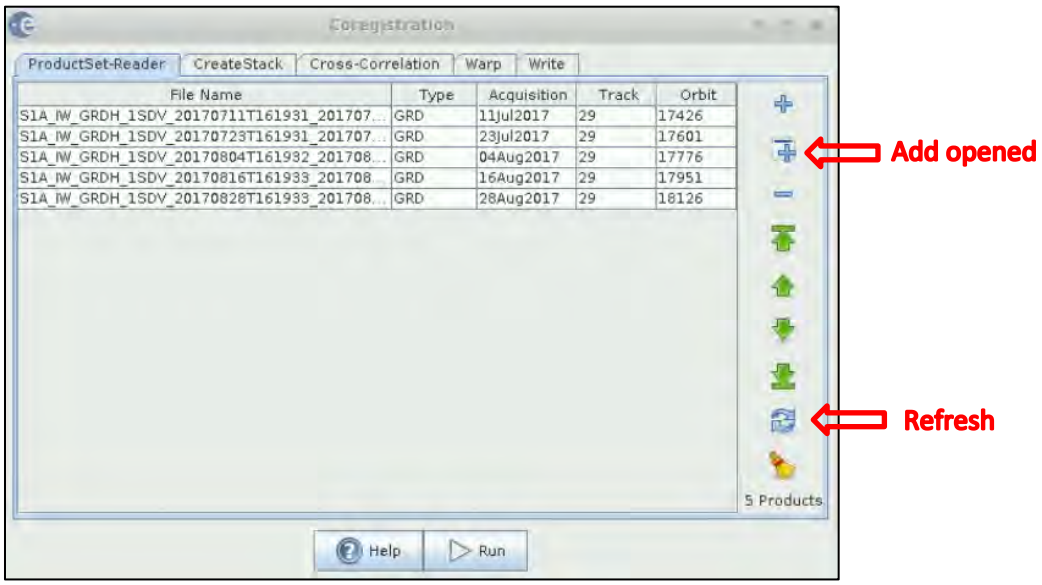
Approximate processing time: 10 minutes depending on machine

Close the **Batch Processing** window. Now you should have five new products in the **Product Explorer** tab. Select the original products [1-5], right-click on them and click **Close 5 Products**.

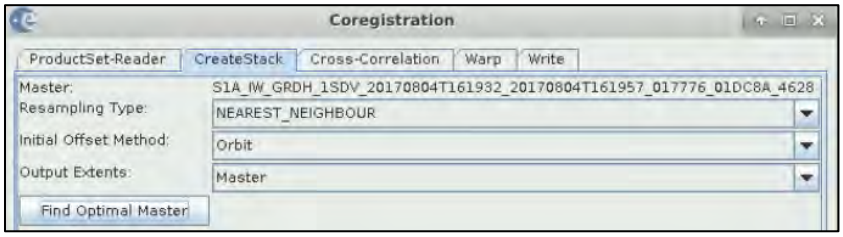
5.3.4 Coregister and average

Now, we need to add all our pre-processed products to a single coregistered stack, so we can calculate the 2-month mean. Unfortunately, coregistration is rather heavy and time consuming, so be patient. Averaging the observations will greatly decrease the speckle and make the delineation of water bodies much more accurate.

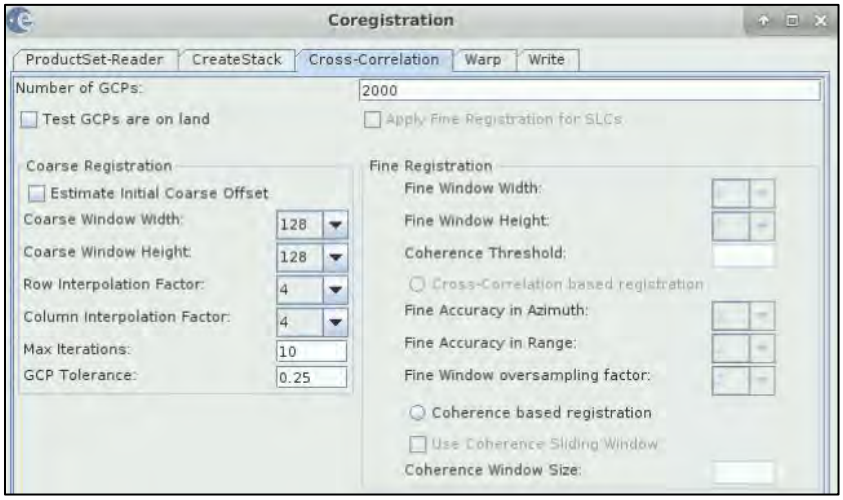
Go to **Radar → Coregistration → Coregistration**.
In the **ProductSet-Reader** tab, we will add the opened products by clicking **Add Opened** on the upper right (second icon from the top) and then click **Refresh**.



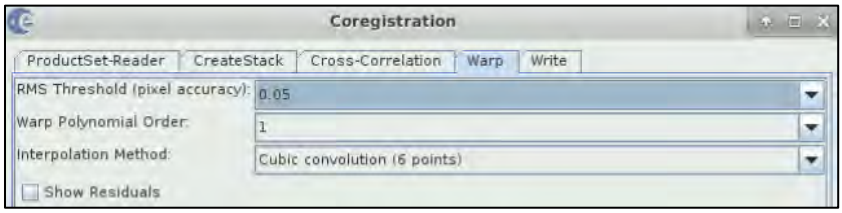
In the **CreateStack** tab, set **Resampling Type**: "**Nearest Neighbour"** and click **Find Optimal Master.**



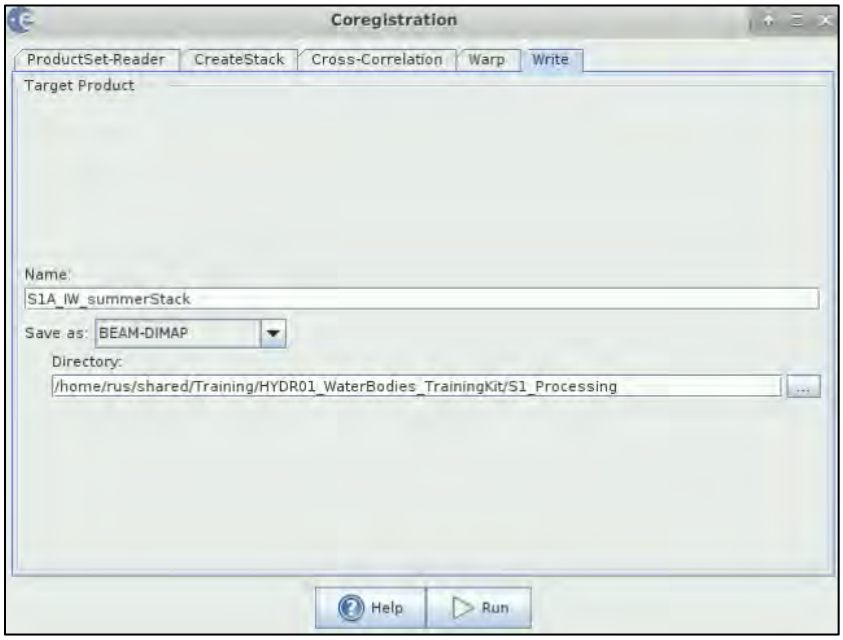
In the **Cross-Correlation** tab, leave the defaults.



In the **Warp** tab, leave the defaults.

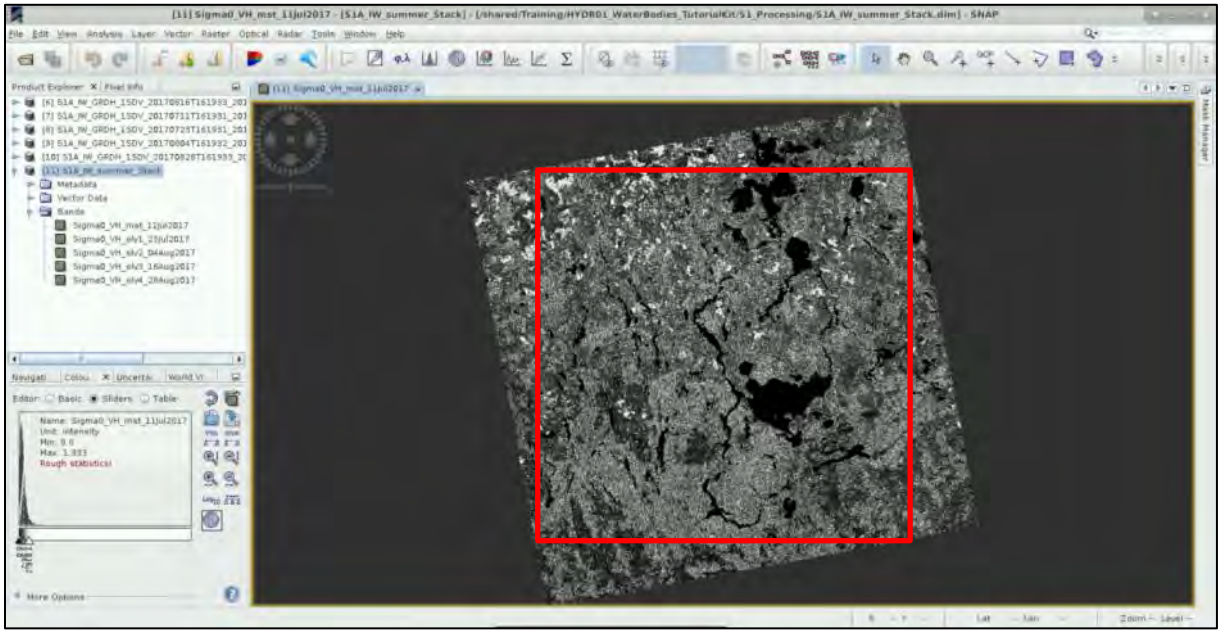


In the **Write** tab, change the name to ***S1A_IW_summerStack*** make sure that the output directory is: ***/shared/Training/HYDR01_WaterBodies_TrainingKit/S1_Processing***



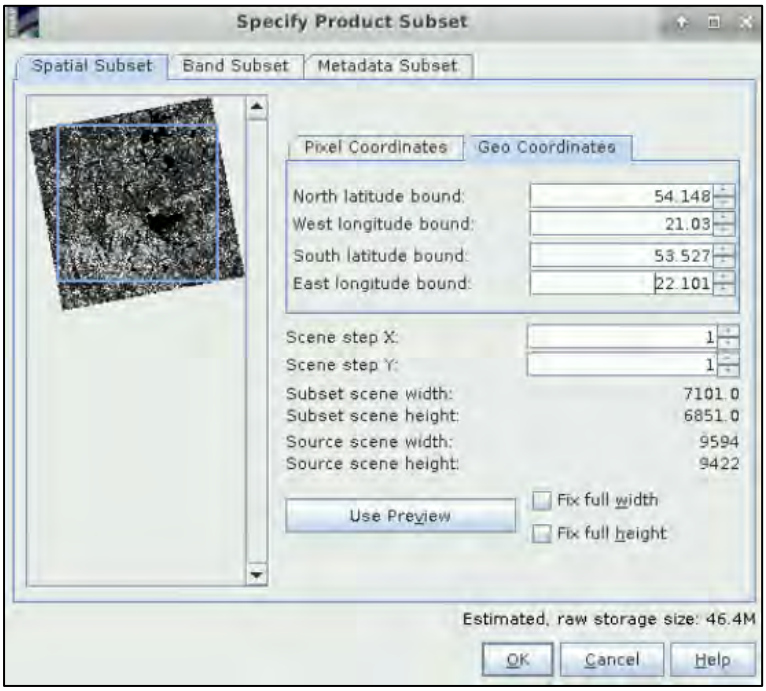
Click **Run**. *Approximate processing time: 20 minutes depending on machine*

Close the **Coregistration** window. A new product [11] has appeared in the **Product Explorer** window. Expand it and have a look at the contents of the **Bands** folder. It contains five bands, each corresponding to one acquisition date. Double click the first band to open it in **View** window.



We can see the extent of the image is larger than that of our S2 subset (marked in red above) although we have used the exact coordinates. This is because we have performed the subset before we have projected (assigned coordinate system) the product. We can correct this by using a simple subset again. Go to **Raster → Subset**.

In the **Spatial Subset** tab click on the **Geo Coordinates** and set:



North latitude bound: 54.148
West longitude bound: 21.030
South latitude bound: 53.527
East longitude bound: 22.101

Click **OK**.

New product [12] has appeared in the **Product Explorer** tab.

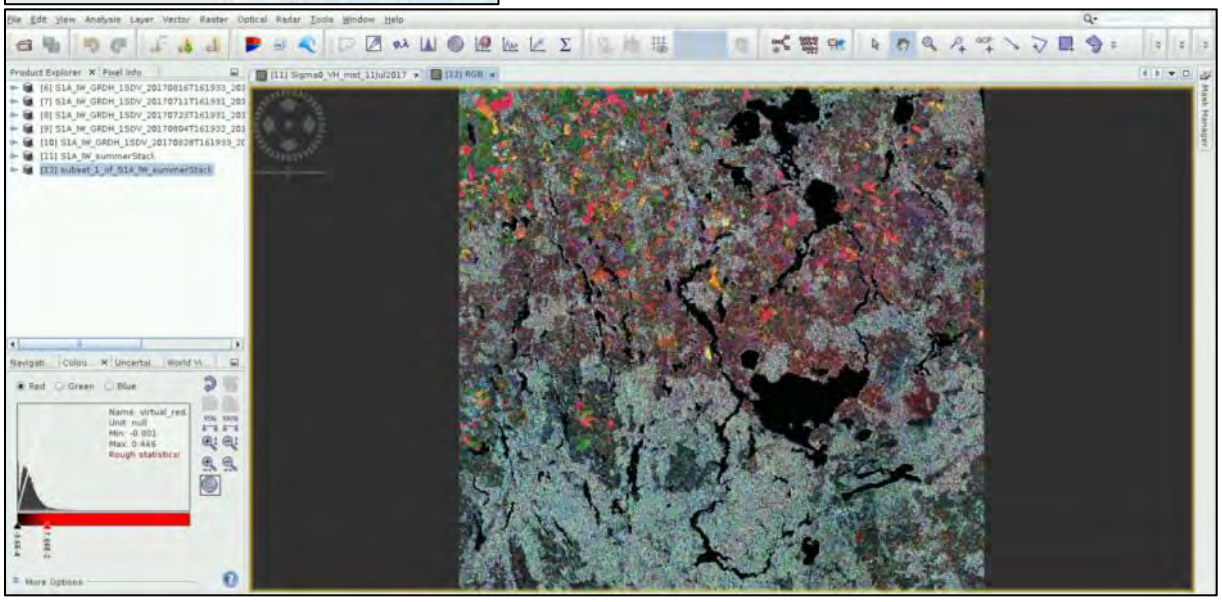
Right-click the product and go to **Open RGB Image Window**.

Set: Red: $12.Sigma0_VH_mst_11Jul2017

Green: $12.Sigma0_VH_slv2_04Aug2017

Blue: $12.Sigma0_VH_slv4_28Aug2017

Click **OK**.

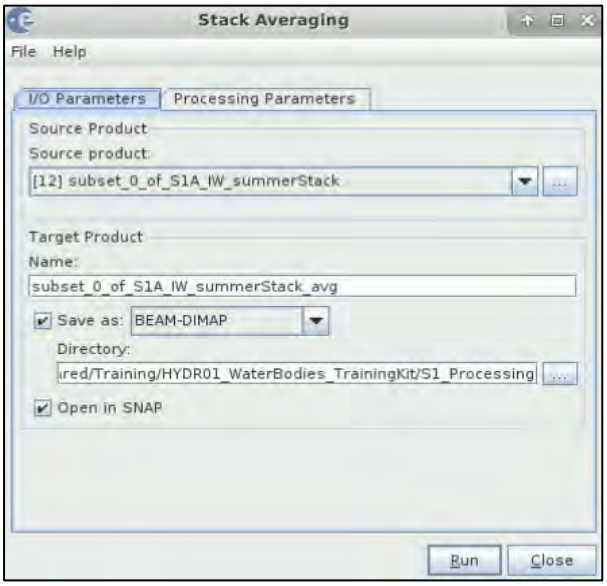


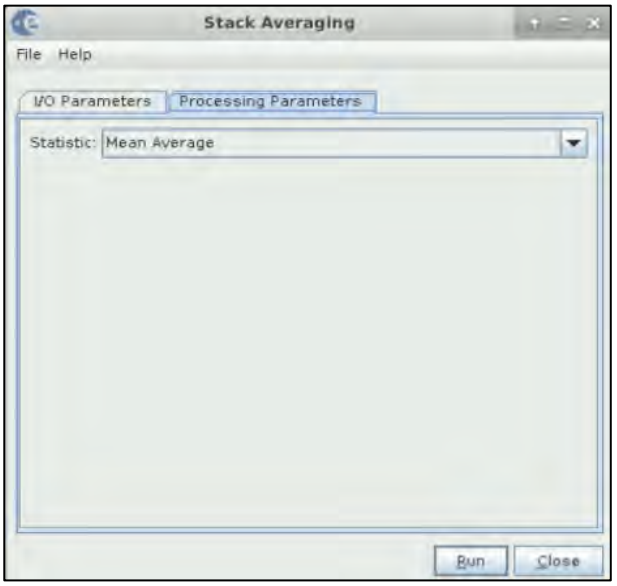
This we do just out of interest, by creating the multi-temporal RGB combination we can see the changes that have occurred between the acquisitions. These will mostly be related to harvested fields. We will not see many changes in the water bodies unless for example, the water level changed significantly, or an area was flooded. Now, let's calculate the average backscatter.

Go to **Radar → Coregistration → Stack Tools → Stack Averaging.** In the **I/O Parameters** tab make sure that the directory is: ***/shared/Training/HYDR01_WaterBodies_TrainingKit/S1_Processing***.

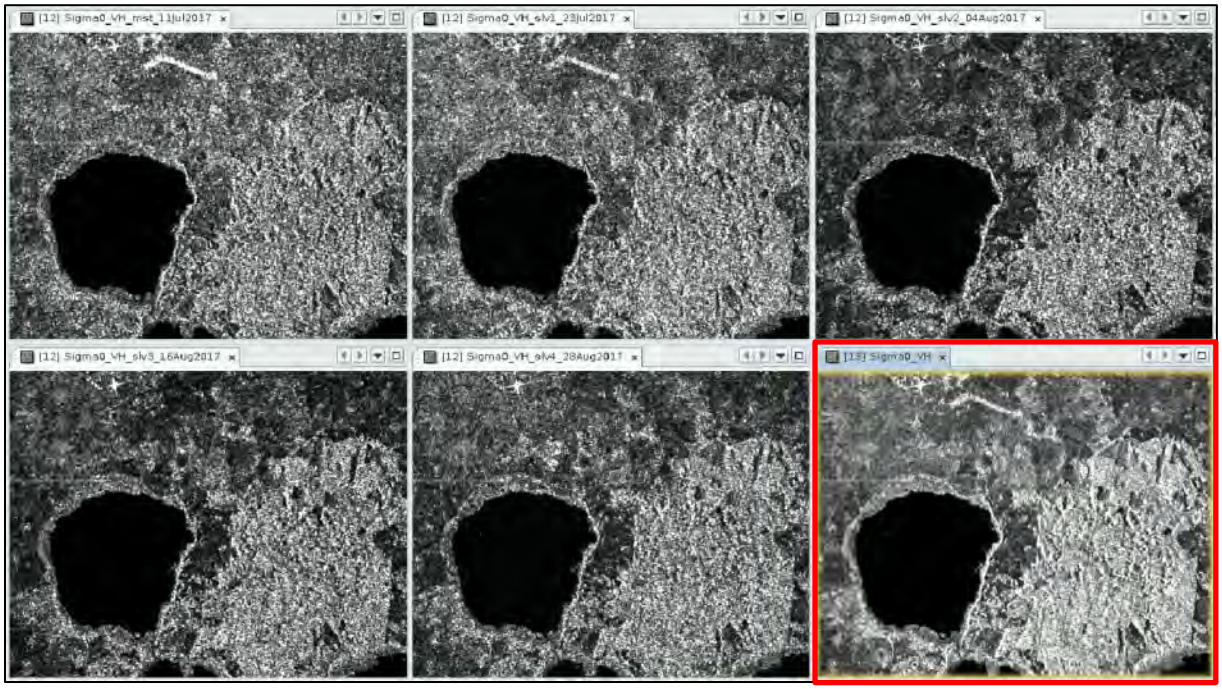
In the **Processing Parameters** tab, set **Statistics: Mean Average**.

Click **Run**.





A new product [13] was created; the **Bands** folder contains a single band with averaged values.



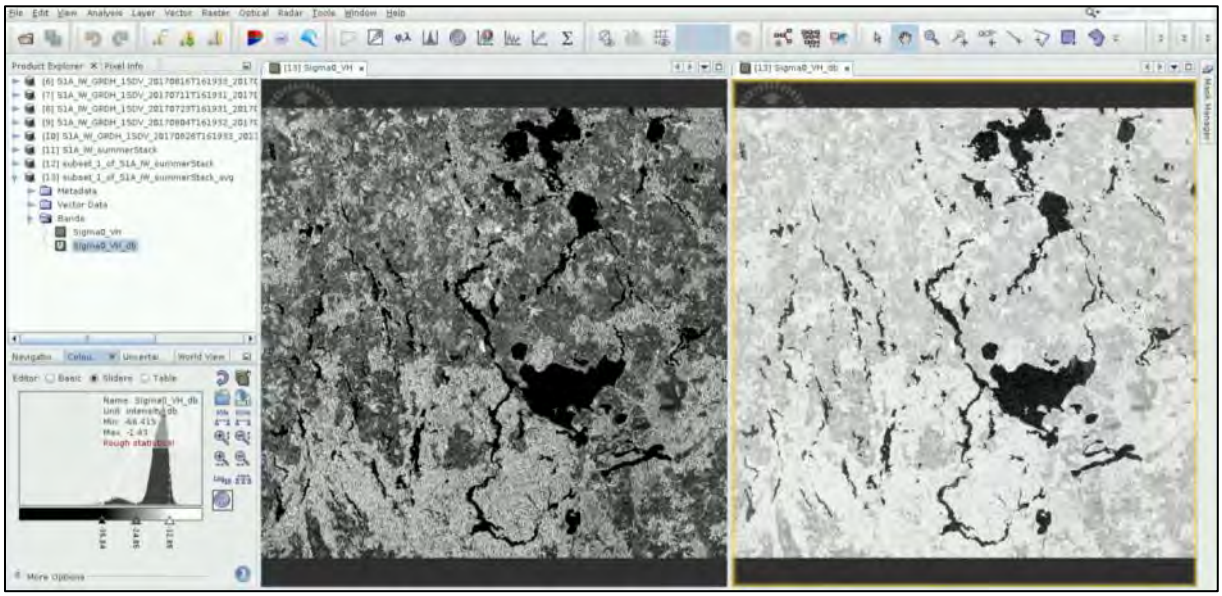
If we open all the bands of the stacked product and the averaged band and use the **Window → Tile Evenly** tool, then we can see that the averaged image appears much smoother.

5.3.5 Binarization

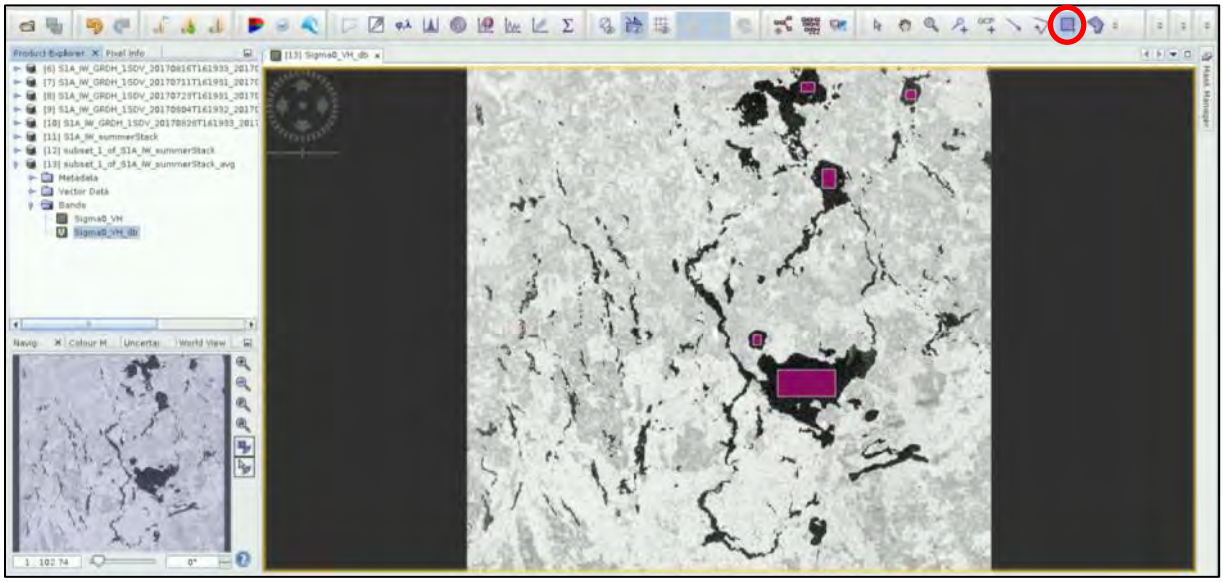
To separate water from non-water on an image we need to have enough separability between the two classes. Let's close all views except for the averaged band.

Then go to the **Product Explorer** window and **right-click** on the averaged band "**Sigma0_VH**".

Go to **Linear from/to dB** and click yes to add the dB band as new virtual band. This operation transforms the histogram to logarithmic scale and helps us to better distinguish between water and other surfaces.

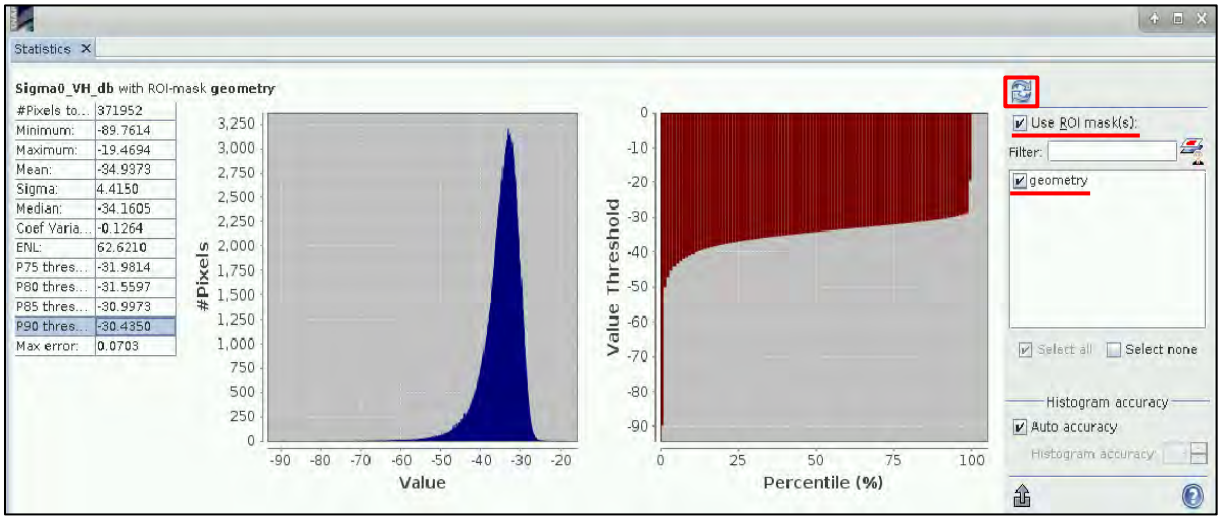


Let's inspect the histogram to find a good threshold value. In addition, we can also draw some polygons over water surfaces and extract statistics…



Then we can go to **Analysis → Statistics**.

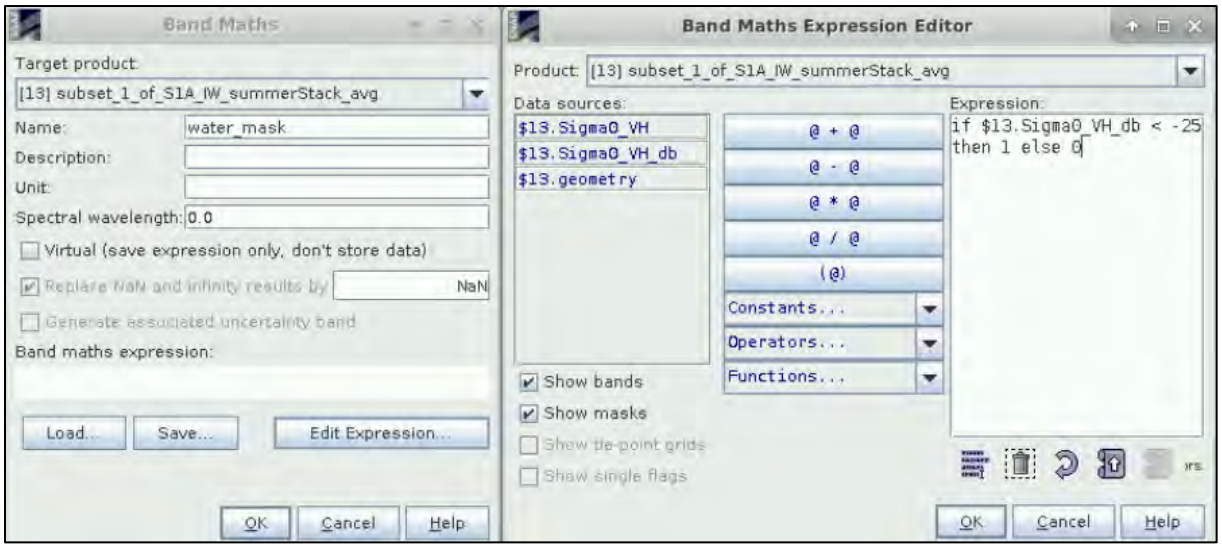
Tick the "**Use ROI mask**" option, select **geometry** and then click **Refresh**.



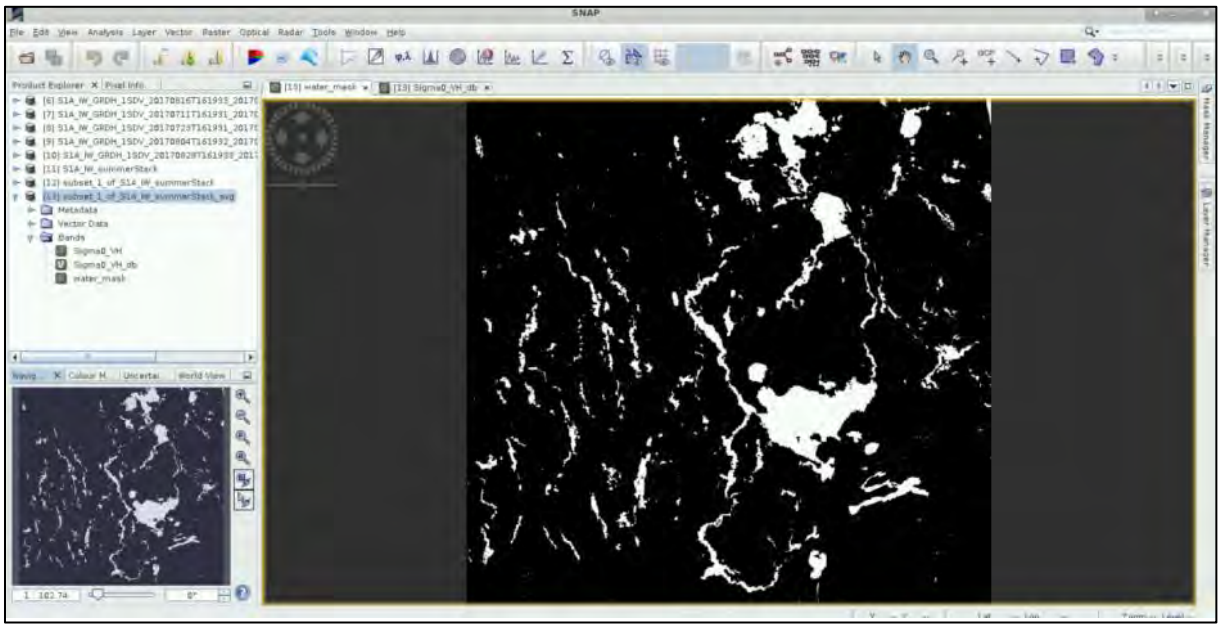
In our case, just by visual analysis we will select value -25 as our threshold. Go to **Product Explorer** tab and **right-click** the ***Sigma0_VH_dB*** band.

Select **Band Maths…** and set as **Name**: "***water_mask***". Deselect the **Virtual** option. Then click on **Edit Expression …** and type:

```
if $13.Sigma0_VH_db < -25.0 then 1 else 0
```

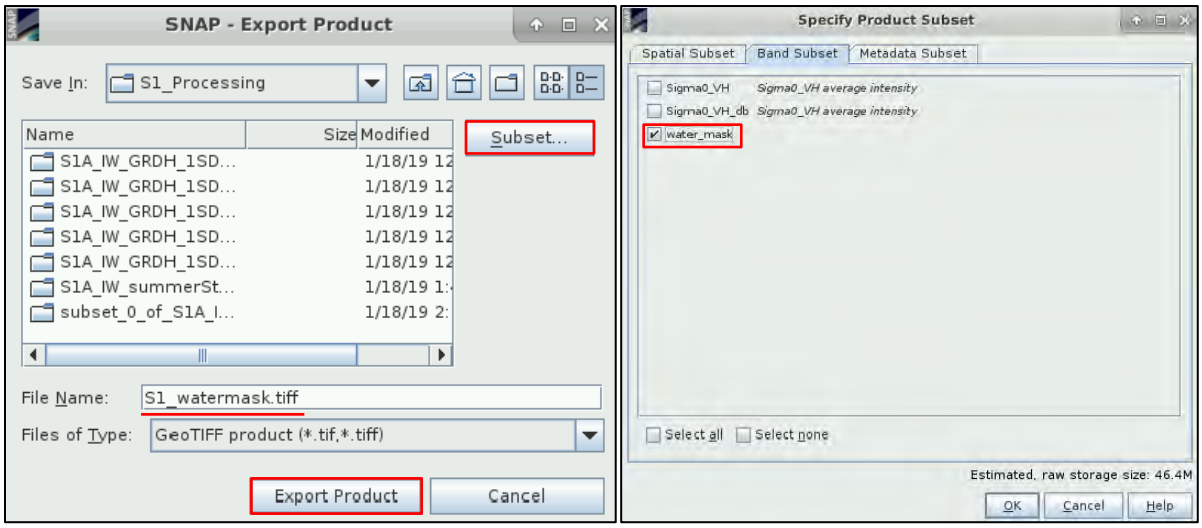


Click **OK** in both windows.



Finally, right click on product [13] and go to **Save Product**.

Then go to **File → Export → GeoTIFF**. Click on **Subset** and go to **Band Subset** tab; select only "***water_mask"*** band and save as ***S1_watermask.tiff*** at: ***/shared/Training/HYDR01_WaterBodies_TrainingKit/S1_Processing*** and click on **Export Product**.



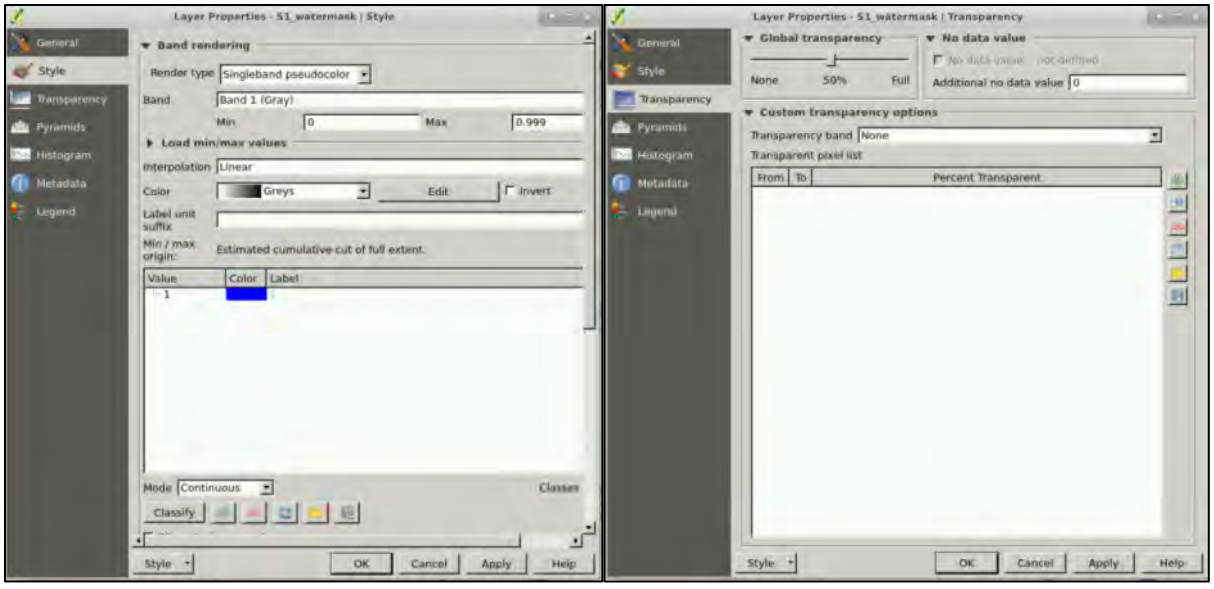
5.4 Visualization (QGIS) and comparison

Let's compare the 2 masks we have produced. To be able to do so, we will open the saved masks (GeoTIFF) in QGIS.

Go to ***Application → Processing → QGIS Desktop***. Click on the **Add Raster Layer** button located in the left panel ( ), navigate to: ***/shared/Training/HYDR01_WaterBodies_TrainingKit/S2_Processing*** select the saved ***S2_watermask.tiff*** and click **Open**.

Load also the ***S1_watermask.tiff*** from the ***S1_Processing*** folder.

Right click the ***S1_watermask*** in the **Layers Panel** and go to **Properties**. In the **Transparency** tab set:
Global transparency: 50 %
Additional no data value: 0



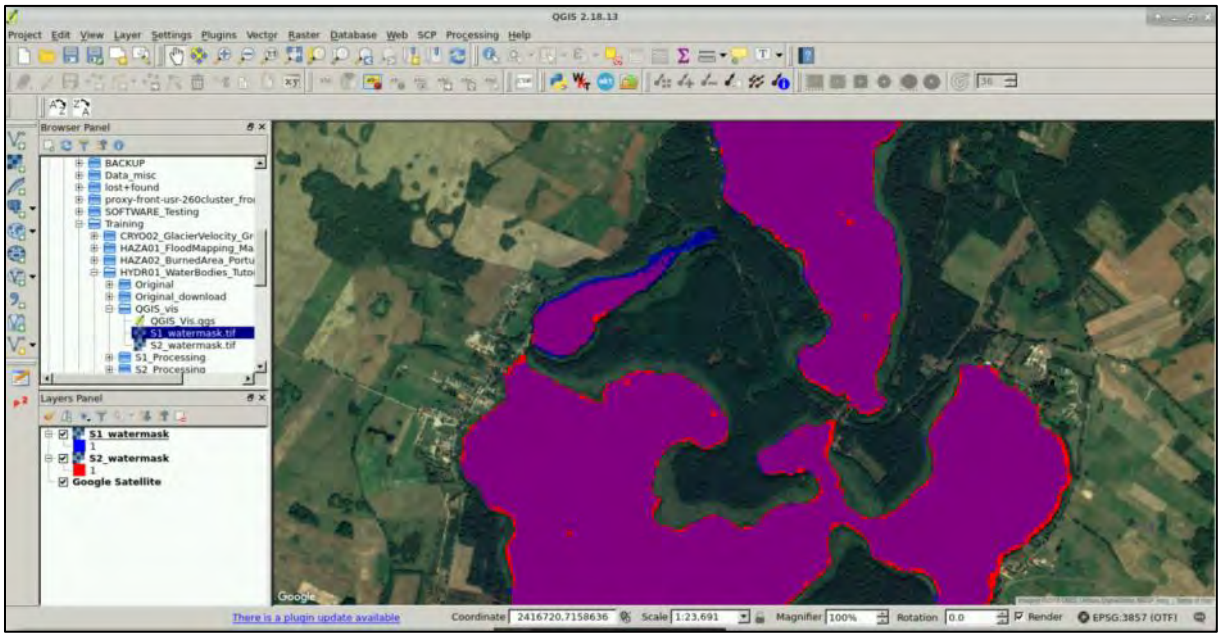
Then, go to **Style** tab and set Render type to ***Singleband pseudocolor***, scroll down and click to add a value to the colour table. Click the value 0 and change it to 1. Then double-click the Colour field and change the colour to **blue**. Click **OK**.

Now do the same for the S2_watermask but change the colour to **red** and leave the transparency at 0%.

Finally, we can add a base-map to link our water masks to GIS data. Click on **Web → OpenLayers plugin → Google Maps → Google Satellite** (See NOTE 8). Then in the **Layer Panel** click on the Google Satellite layer and drag it below our raster layers.

In case Google Satellite is not available for any reason, use a different layer, e.g. **Bing → Bing Aerial**.

> NOTE 8: 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.



THANK YOU FOR FOLLOWING THE EXERCISE!

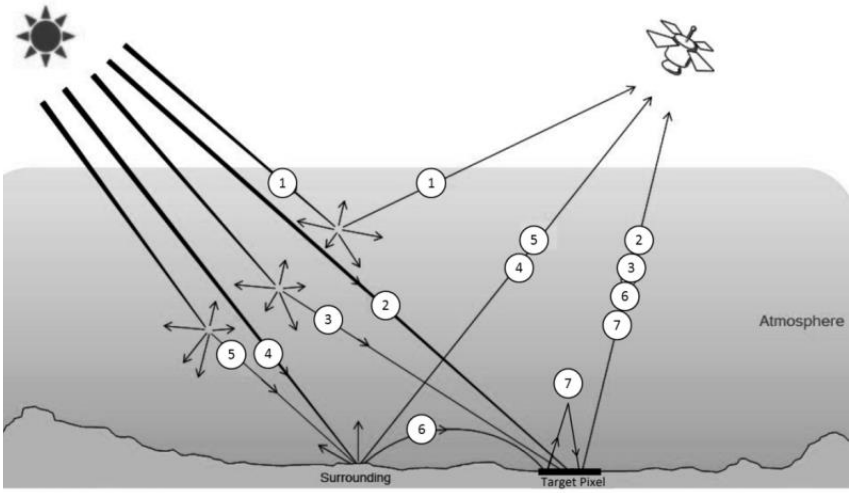
6 Extra steps

6.1 Atmospheric correction for S2

Solar radiation reflected by the Earth's surface to satellite sensors is affected by its interaction with the atmosphere. The objective of applying an atmospheric correction is to determine true surface (Bottom-Of-Atmosphere, BOA) reflectance values from the Top-Of-Atmosphere (TOA) reflectance values, by removing atmospheric effects. (See NOTE E1) Atmospheric correction is especially important in cases where multi-temporal images are compared and analysed as it is in our case (pre-fire and post-fire images).

NOTE E1: The radiance reaching the sensor is a result of following components:

1. Radiation from the sun and, scattered into the field of view of the sensor by the atmosphere without reaching the surface.
2. Direct radiation that goes through the atmosphere without being absorbed or scattered, reaches the sensor after being reflected by the target pixel.
3. Radiation scattered by the atmosphere into the target pixel and reflected back towards the sensor.
4. & 5. Direct or diffuse radiation reflected or scattered by the surrounding areas into the field of view of the sensor. This effect is so called "adjacency effect" or "blurring effect".
6. Diffuse radiation coming from the adjacent features into the field of view of the sensor.
7. So-called trapping effect and it is a part of the radiation reflected from the surface into the air column above the surface being scattered and ultimately reaches the sensor.



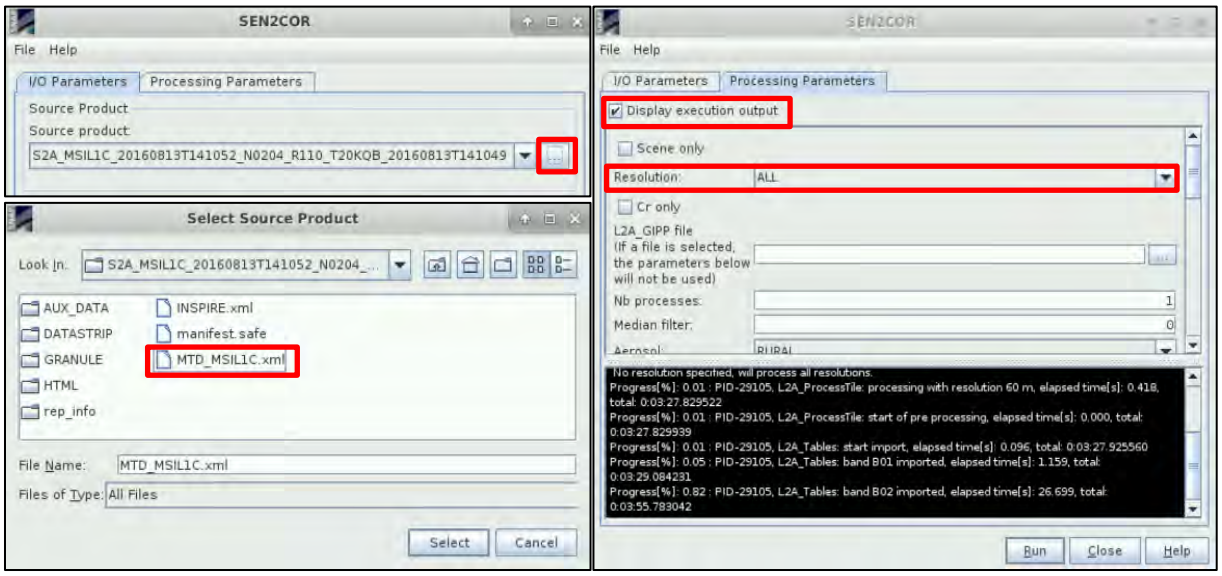
Credits: Mousivand et al., 2015[1]

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

To run the atmospheric correction, we first need to go out of SNAP and in File Manager navigate to the folder where our data are saved: ***/shared/Training/HYDR01_WaterBodies_TrainingKit/Original*** and unzip the product by right-clicking each and going to ***"Extract Here".*** This will create a folder with suffix "***.SAFE***".

Then go back to SNAP and go to **Optical → Thematic Land Processing → Sen2Cor**.

In the I/O Parameters we need to click on **…** next to the product name and navigate inside of the first product folder (“***.SAFE”*** suffix). Then, open the *MTD_MSIL1C.xml* file. In the **Processing Parameters** tab change the resolution to ***“ALL”*** and select ***“Display execution output”.*** Click **Run**.



This is rather a time demanding process and requires approximately 30 minutes per image (with 8GB RAM).

The process creates a new Level 2-A product in the *.SAFE* format in the original folder. Now let’s load the result to SNAP.

Click Open product , navigate to: ***/shared/Training/HYDR01_WaterBodies_TrainingKit/Original*** then open the Level-2A product folder for 2016: *S2*_**MSIL2A**_*.SAFE*
And open the ***MTD_MSIL2A.xml***

6.2 Downloading the outputs from VM

On your keyboard, press **Ctrl+Alt+Shift.** A pop-up window will appear on the left side of the screen. Click on the 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.**

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