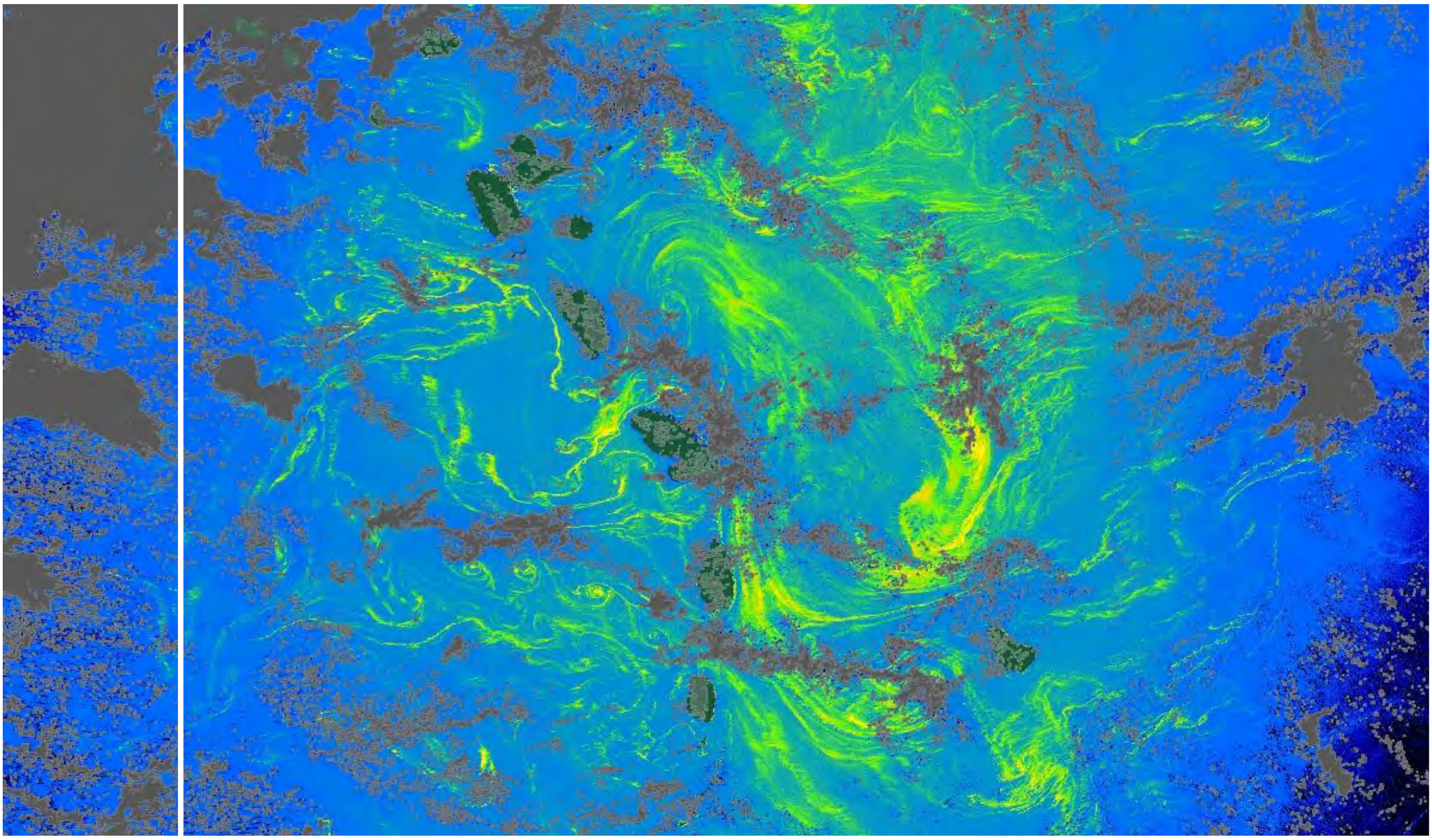

TRAINING KIT – OCEA08

SARGASSUM MAPPING WITH SENITNEL-3

Case Study: Caribbean Sea, June 2018

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 at simon.b@rus-copernicus.eu

Cover images produced by RUS Copernicus

The following training material has been prepared by NOVELTIS within the RUS Copernicus project.

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Table of Contents

1 Introduction to RUS

The **R**esearch and **U**ser **S**upport for Sentinel core products (RUS) service provides free and open scalable platforms 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.

In this tutorial, we will map Sargassum rafts in the Caribbean Sea on June 20th 2018 based on Sentinel-3 OLCI products. We will carry out this study in the SNAP software on RUS virtual machines.

2 Sargassum Mapping - Background

Pelagic Sargassum seaweed is a large brown alga floating at the ocean surface thanks to its gas-filled bladders. When present in reasonable amounts, it provides a safe habitat to many marine species such as the threatened loggerhead sea turtle. A large panel of fish species like mahi-mahi, jacks and amberjacks also use this floating vegetation as a nursery.

In the North Atlantic, pelagic Sargassum floats and grows at the sea surface during its entire lifetime, aggregating and forming mats carried by winds, waves and currents over very long distances. Since 2011, Sargassum algae have been aggregating in rafts several kilometres wide. Massive stranding episodes have increased in periodicity and intensity in the Caribbean Sea, summer 2018 being the historical record so far. Once on the beaches, the rafts rot and decompose, leading to dramatic consequences on the environment, the tourism economy and human health.

It has hence become of prime importance to monitor these disastrous events, but their irregularity makes their forecasting complex. Moreover, the mechanisms at stake in the apparition and arrival of the rafts on shores still need more studies. In situ observations from drones or boats constitute key tools to quantify the algae amount available for stranding, but their coverage in space and time remains limited.

With their high spatial and temporal resolution and coverage, ocean colour satellites can help to fill in the gaps. For example, the satellite-based Sargassum Watch System (SaWS) provides monthly reports on the Sargassum situation based on MODIS, VIIRS and Landsat 8 images. It has not incorporated data from OLCI so far. This case study demonstrates a simple and powerful way of detecting Sargassum rafts with the Sentinel-3 OLCI instrument on June 20th 2018. The methodology presented here is inspired from Ody et. al (2019).

3 Training

The approximate duration of this training session is **one** hour.

The Training Code for this tutorial is OCEA08. 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*.

3.1 Data used

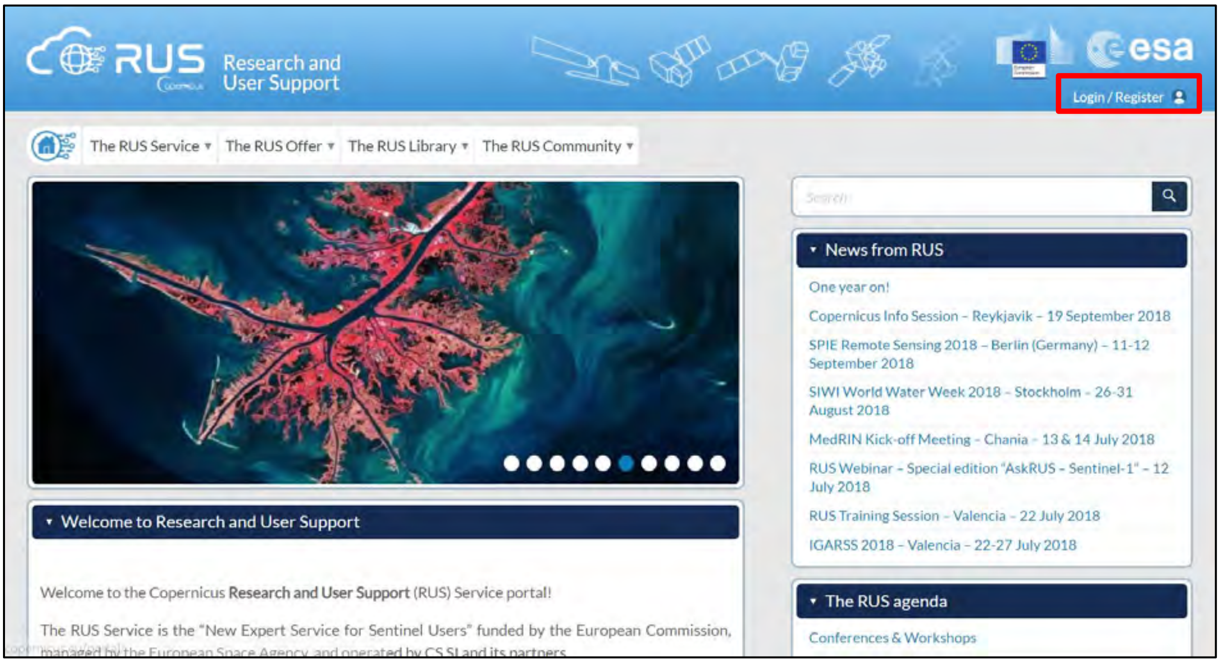
- 1 Sentinel-3A and 1 Sentinel-3B images acquired on June 20th 2018
  [downloadable @ https://scihub.copernicus.eu/]
  S3A_OL_1_EFR____20180620T135849_20180620T140149_20180621T175740_0179_032_281_2700_LN1_O_NT_002.zip
  S3B_OL_1_EFR____20180620T135828_20180620T140128_20200114T081656_0179_009_281_2700_MR1_R_NT_002.zip

3.2 Software in RUS environment

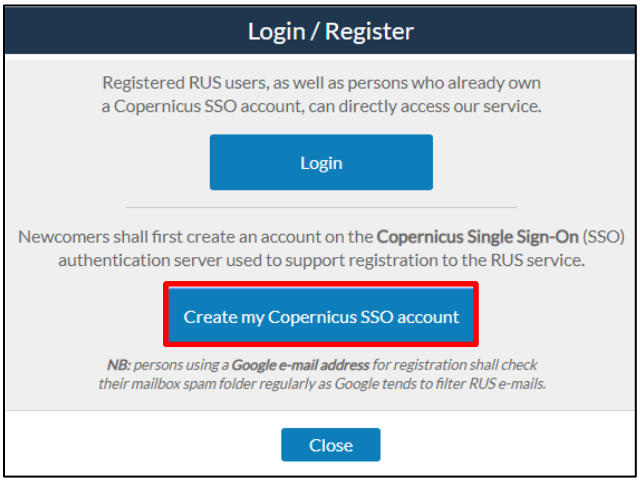
Internet browser, SNAP+Sentinel-3 Toolbox+IdePix Plugin, QGIS

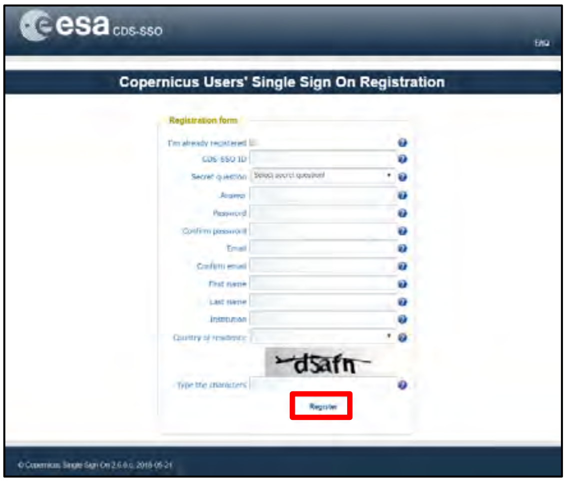
4 Register to RUS Copernicus

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.



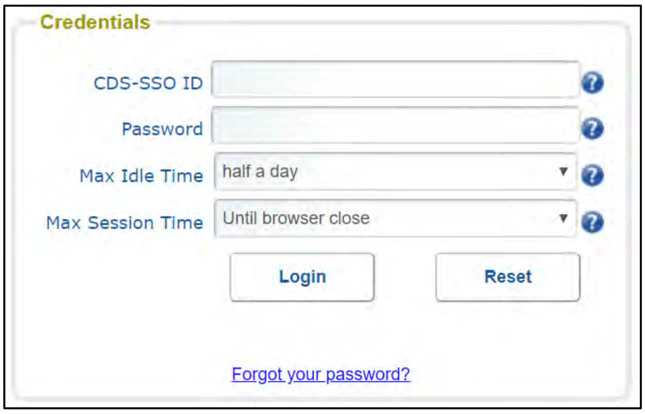
Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click ***Register***.



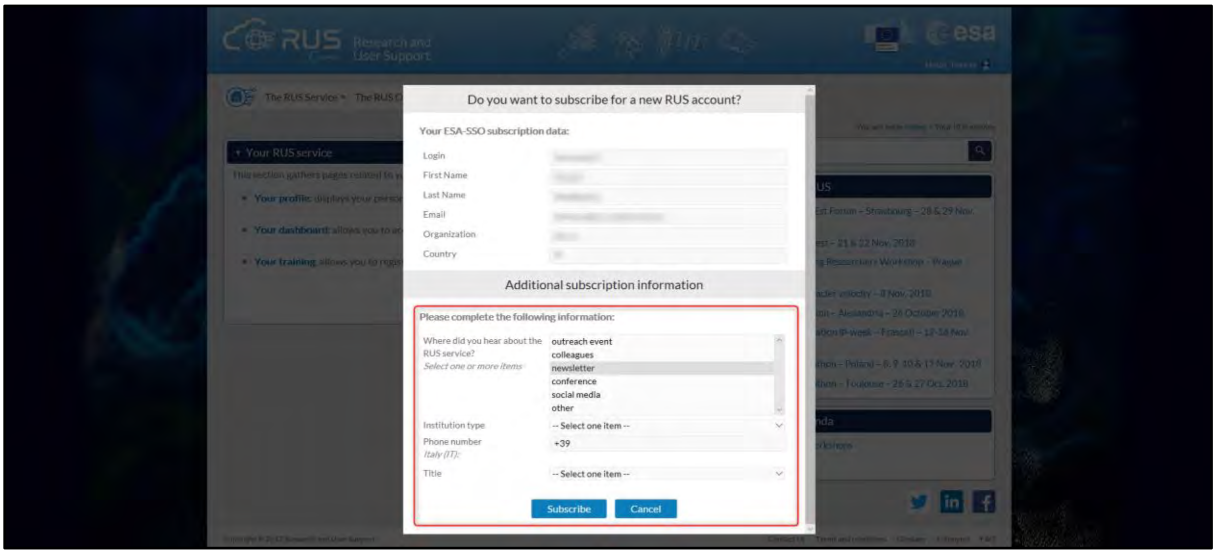


Within a few minutes, you will receive an e-mail with an activation link. Follow the instructions in the e-mail to activate your account.

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

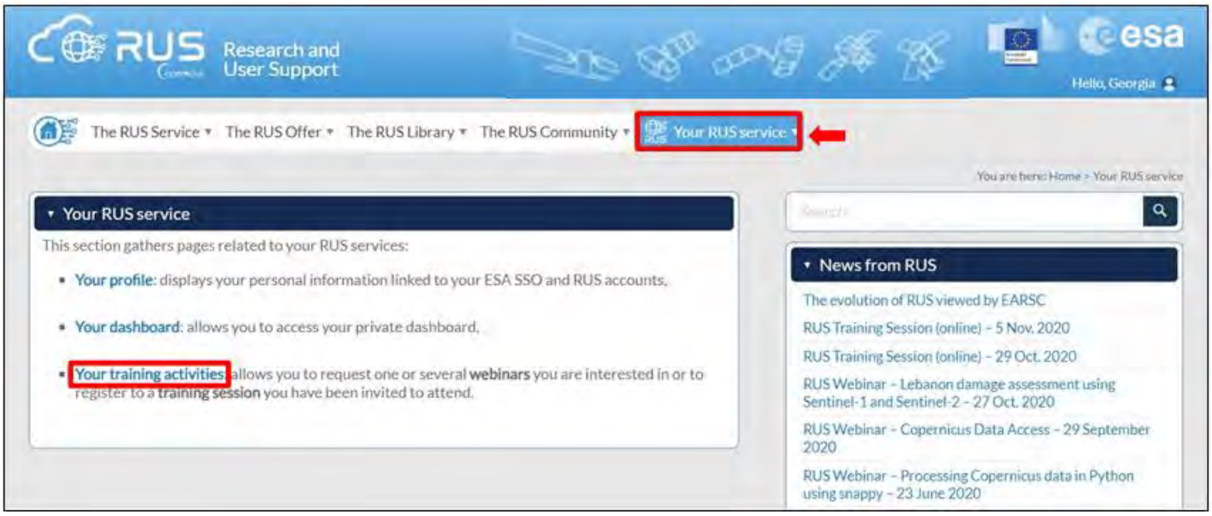


Upon your first login you will need to enter some details. You must fill all the fields.

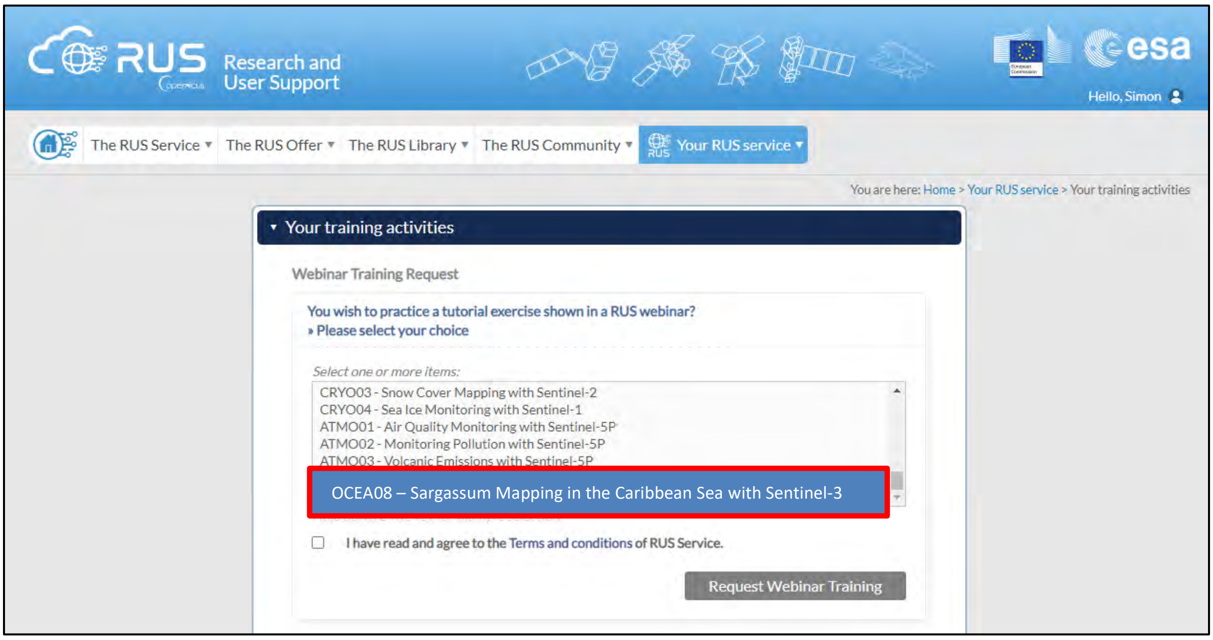


5 Request a RUS Copernicus Virtual Machine to repeat a Webinar

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***.



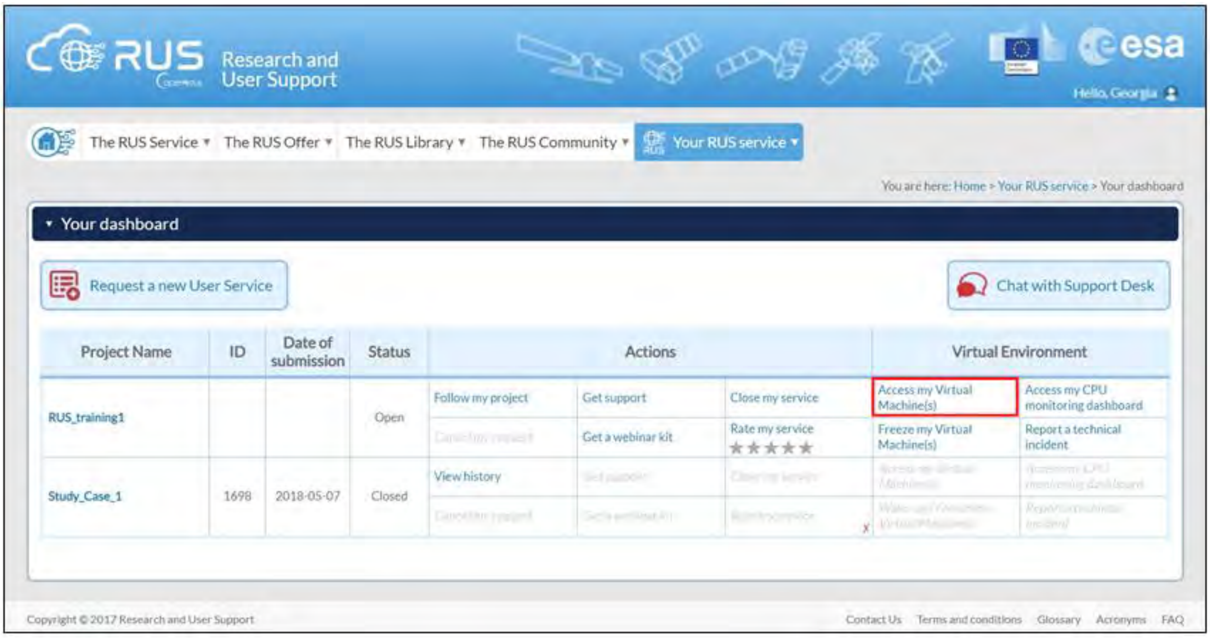
Select **OCEA08 – Sargassum Mapping in the Caribbean Sea with Sentinel-3**, check the field *"I have read and agree to the Terms and conditions of RUS Service"* and then click on ***Request Webinar Training*** to request your RUS Virtual Machine.



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.

6 Step by step

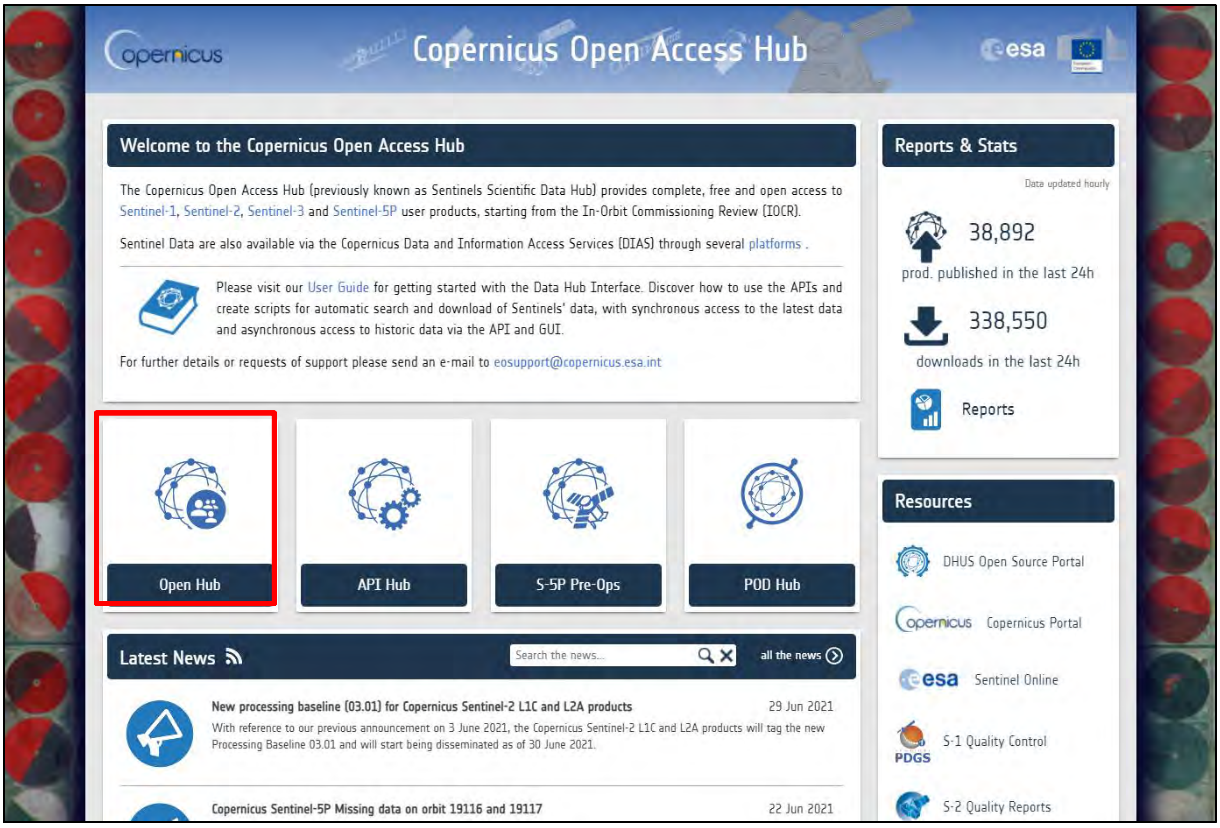
6.1 Data download – ESA SciHUB

In this step, we will download the Sentinel-3 scenes used for the exercise, from the Copernicus Open Access Hub using the online interface.

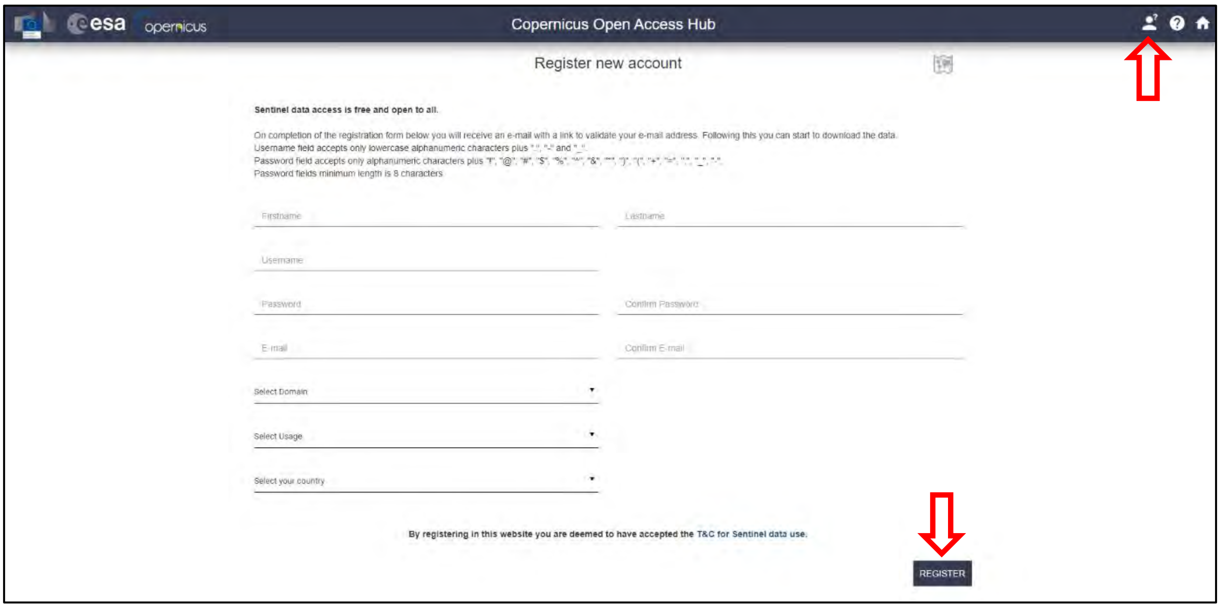
Go to **Applications → Network → Firefox Web Browser** or click the link below.

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

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



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



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

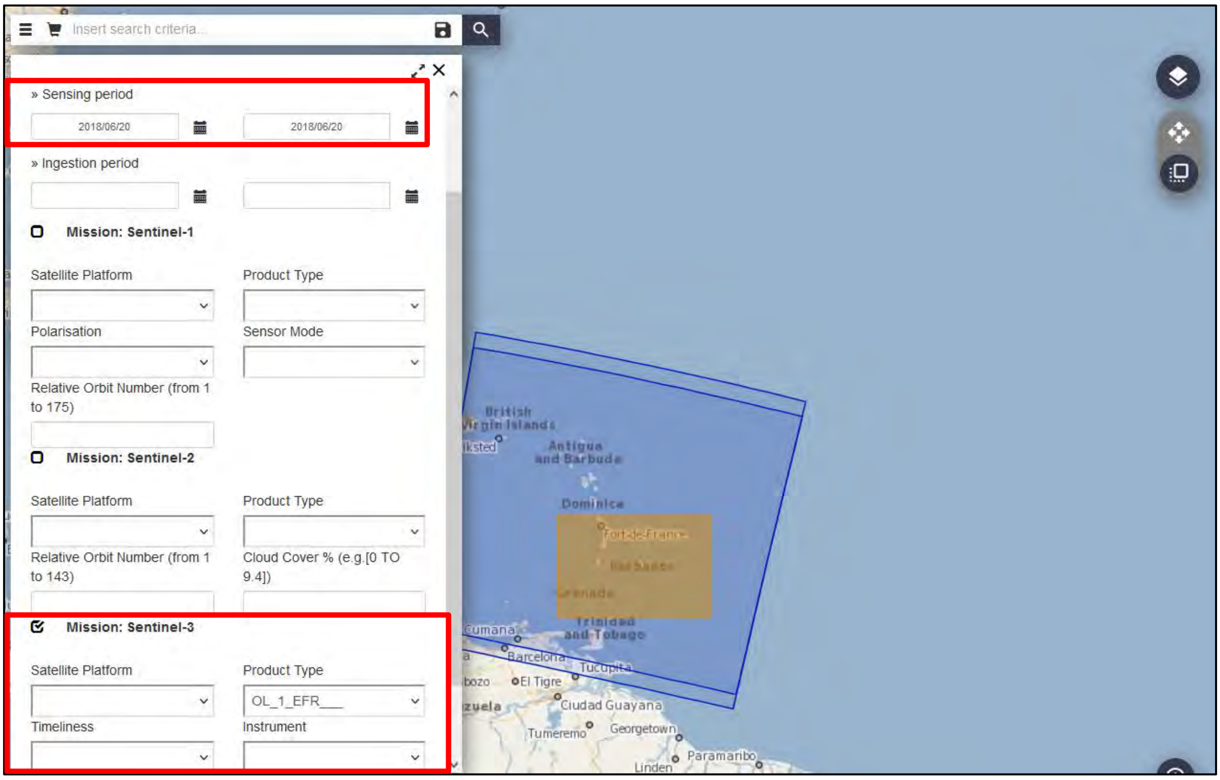
Once your account is activated – or if you already have an account – **LOGIN**.

In this guide, we describe the procedure to download the Sentinel-3 images for June 20th 2018. Drag the map to the Caribbean Sea and define the study area using the button (approximate area – **orange** rectangle). Then, open the search menu by clicking on the left part of the search bar ( ) and specify the parameters below. Press the search button ( ) after that.

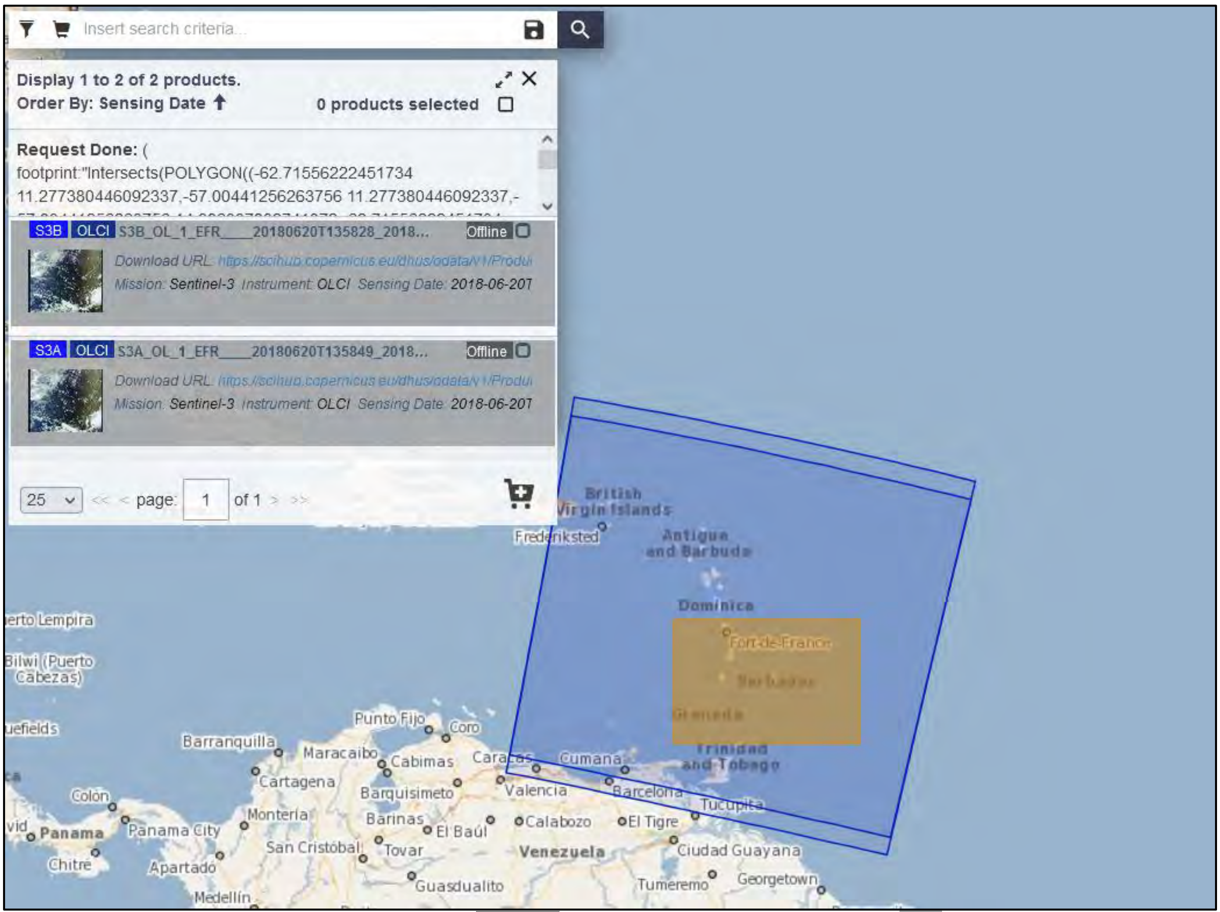
Sensing period: From 2018/06/20 to 2018/06/20

Check mission: Sentinel-3

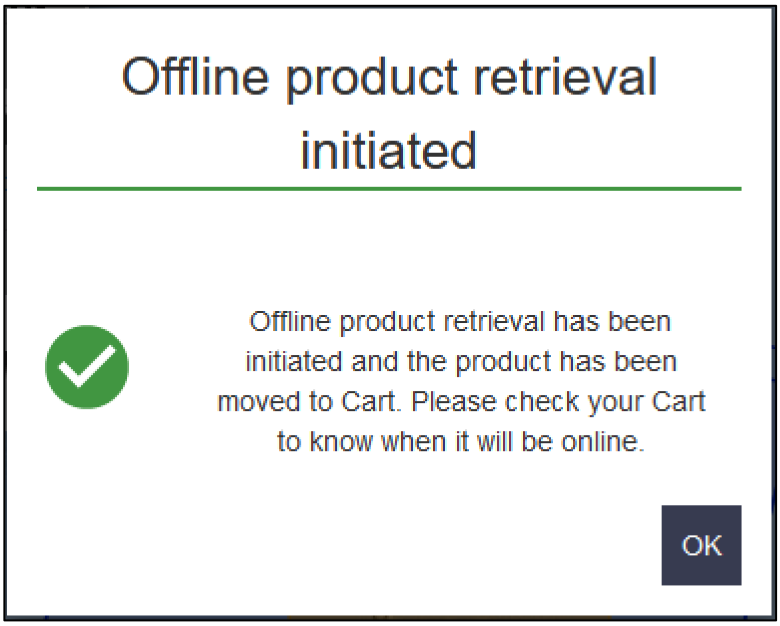
Product type: OL_1_EFR



In this case, the search returns 2 results (**blue** tiles). There is one S3A_OL_1_EFR product and one S3B_OL_1_EFR product, almost entirely overlapping.



As you can see, both products appear Offline. Hitting the download icon will trigger the offline product retrieval:



This will automatically add the product to the "**Cart**" . In case an error message appears, try again a bit later – you can request for one offline product per account per hour. (See NOTE 1 and NOTE 2). The product will be online within a few hours. Once online, the product will remain available for download for at least 3 days before it is moved back offline.

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

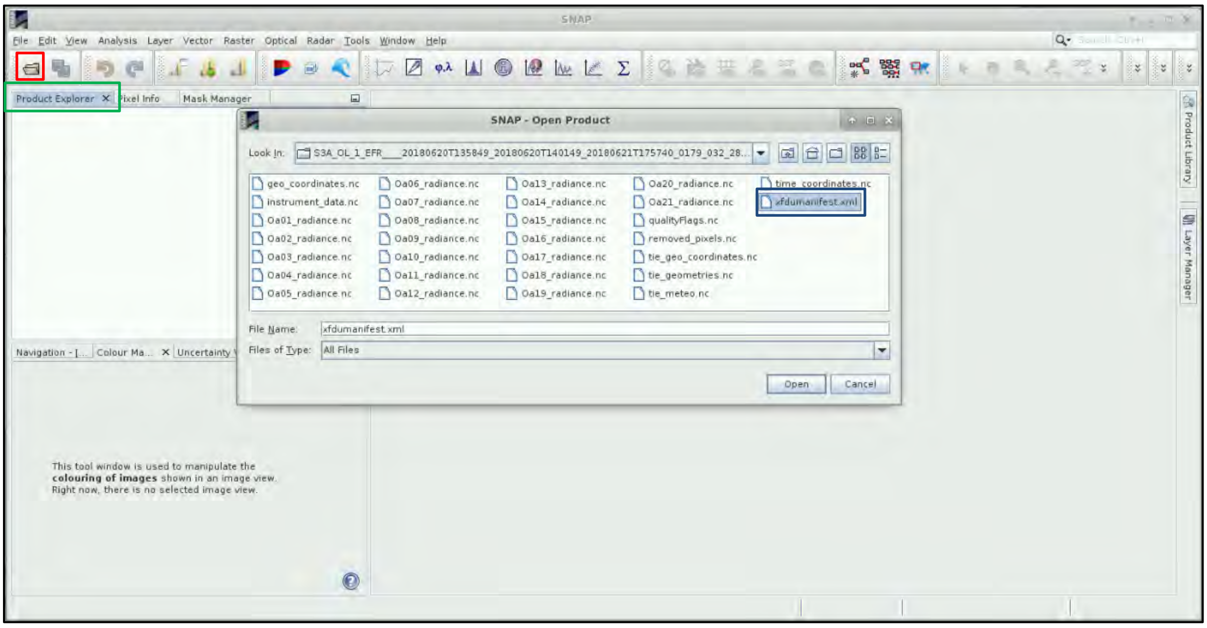
> NOTE 2: You can find more information about the retrieval of offline/long term archive products here:
>
> https://scihub.copernicus.eu/userguide/DataRestoration. Most Sentinel products remain online for a month after they are published. They are then moved offline and need to be requested back online as previously shown. In a more general way, the scihub user guide is a very useful resource to check.

You need to repeat the same process for both images. The products will be downloaded to **/home/rus/** as zip archive. Move them to the below path and unzip the archives: **Right-click on the product → Extract Here** Extract Here .

Path: */shared/Training/OCEA08_SargassumMapping_Caribbean/Original/*

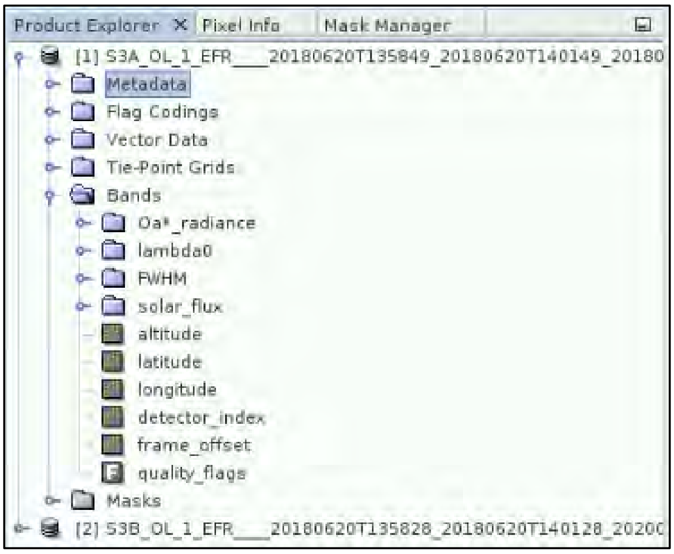
6.2 SNAP – Open and Explore data

Once you have extracted the archives, open the SNAP software from the icon located on the desktop. Hit the **Open Product** icon , browse to the *Original/* folder and open both Sentinel-3 products by selecting the **xfdunmanifest.xml** file of each product. You can also navigate to the product folder from a product browser and drag and drop the **xfdunmanifest.xml** file in the **Product Explorer Tab**.

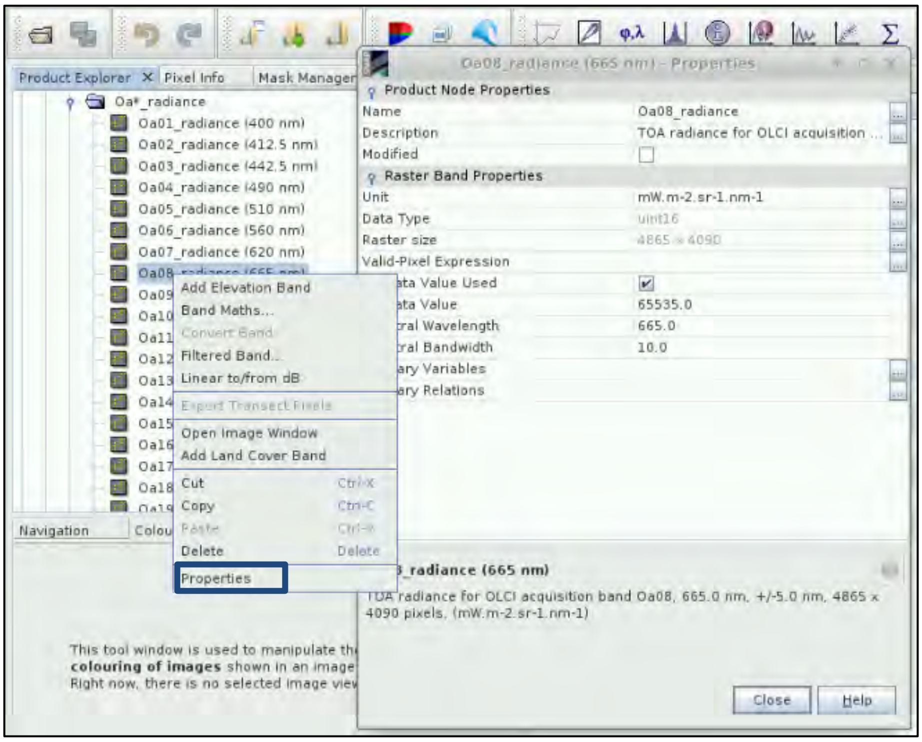


The products are now open in the **Product Explorer Tab** of the SNAP software. Feel free to expand the product trees by hitting the key button located left of each open product. Unfold the product content and appreciate how SNAP conveniently gathers the data into several folders.

The main data of interest (top of atmosphere radiances in the 21 spectral bands of OLCI) is stored in the **Bands → Oa*_radiance** folder. The other folders contain data that give additional information on the context of the measurements. For example, the **Mask** folder encloses very useful information on the quality of the retrieval. **MetaData** contains static information about the product such as the timestamp, the platform name, the observation mode, etc…

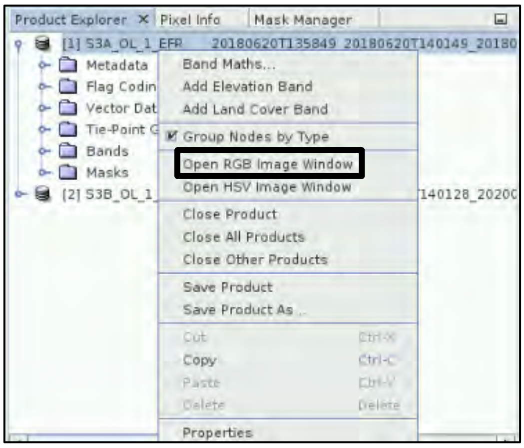


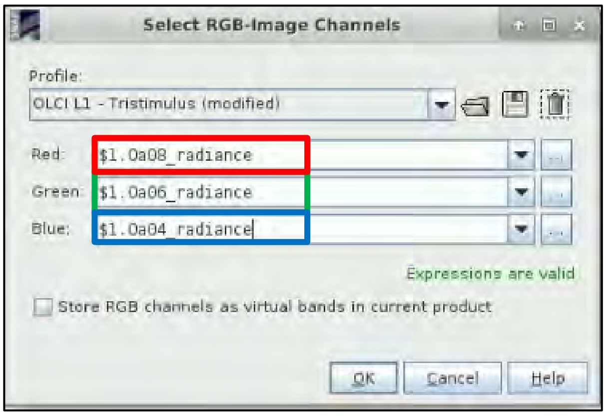
If you want to check the properties of a band, right-click on the band and hit **Properties.**



6.2.1 Create RGB Image – Natural Colours Oa08, Oa06, Oa04

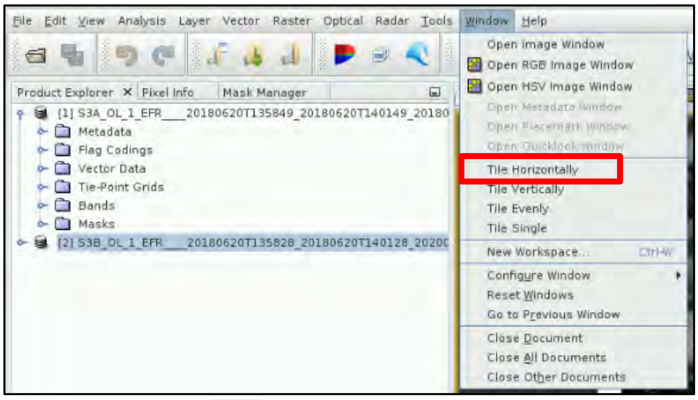
Right click on the S3A product and select **Open RGB Image Window**. Select **Oa08 for Red**, **Oa06 for Green** and **Oa04 for Blue**. Hit **OK** and the RGB view will open in the **View Window**



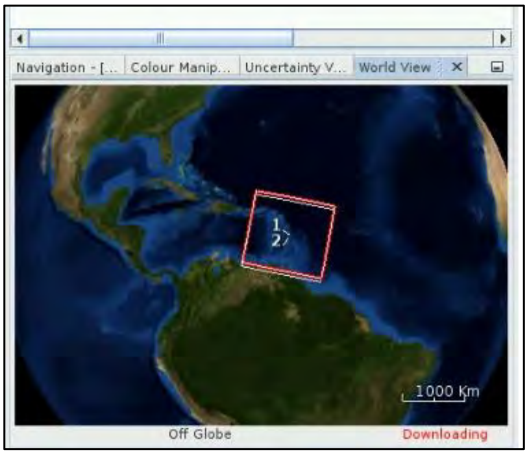


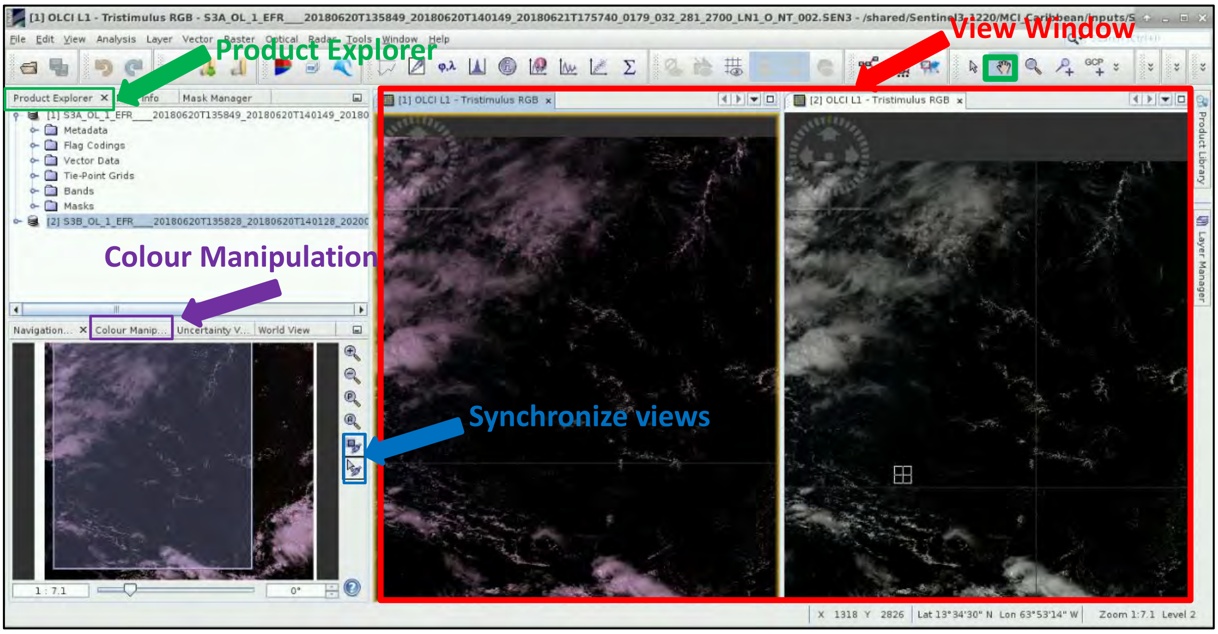
TIP 1: $1 Refers to the index number of the product in the **Product Explorer Tab**

Repeat the operation for the S3B product. Then go to **Window → Tile Horizontally** to have a simultaneous view of both RGB images.



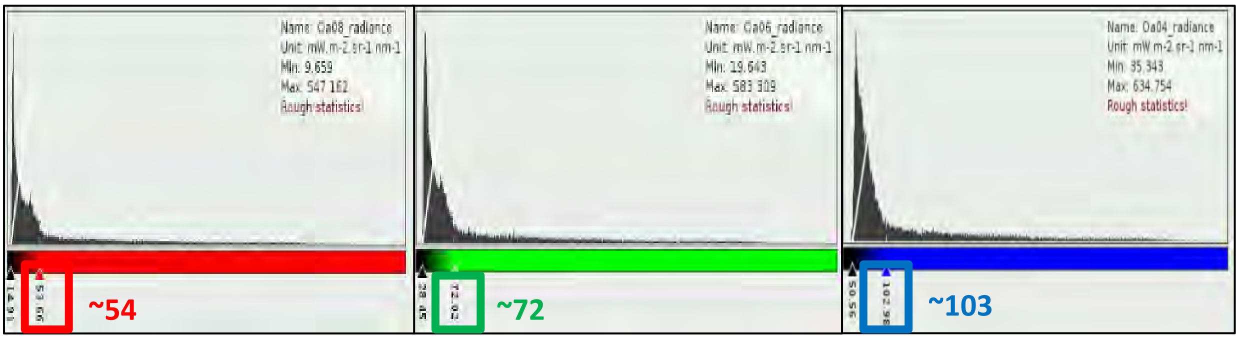
When on each view, select the Hand  button to drag the view to your area of interest. Simply use the centre wheel of your mouse to zoom in and out. You can go to the **World View** tab and zoom in to see the location of the opened product(s) on the globe.



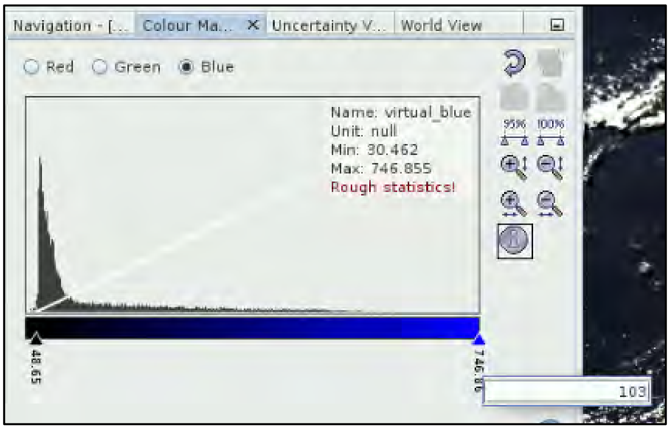


In the Navigation tab, click on the two icons shown within the **blue rectangle** below, to synchronize the views and the cursor position across the views.

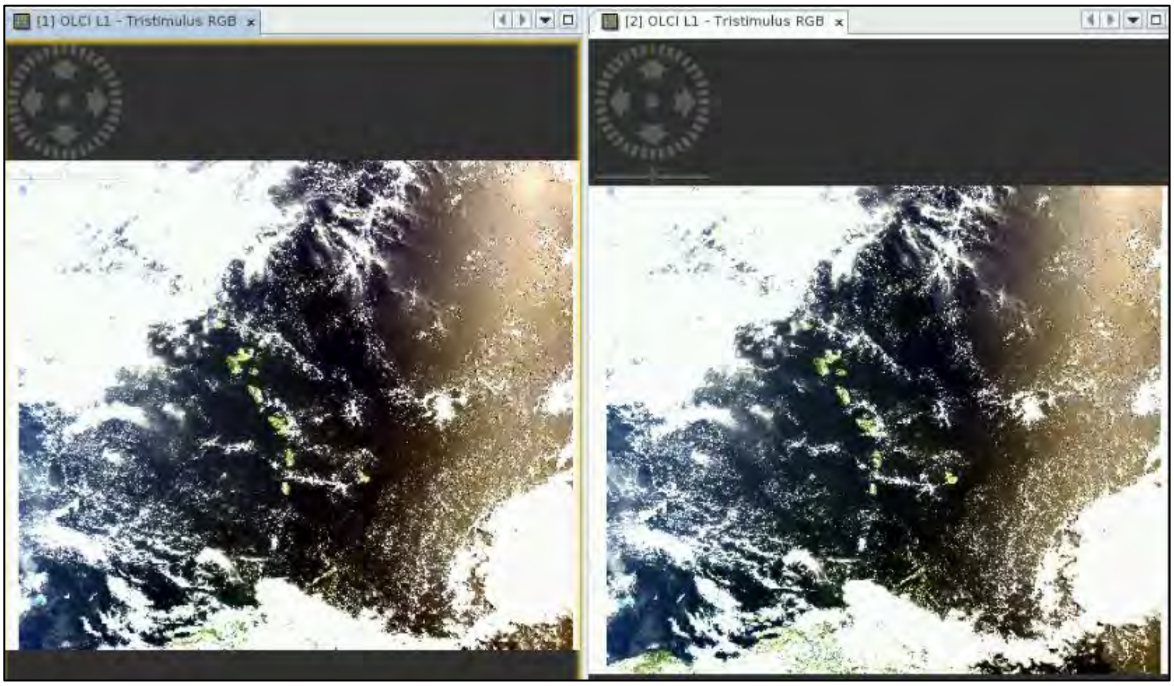
You probably noticed that the images are a bit dark and not much is visible on them. We are going to improve the visualisation. For this go to the **Colour Manipulation** panel and for each **Red**, **Green** and **Blue** component, drag the sliders to the below values. You need to repeat the operation for both images



You can also hit a slider value to change its defined value.



Once the views are clearer, we now distinguish different elements on our images.

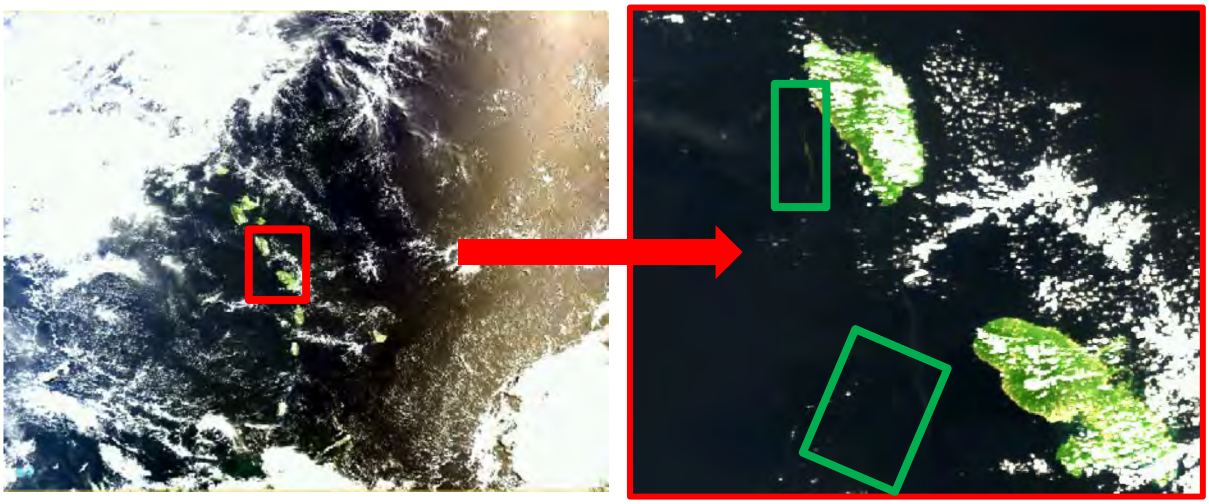


First, we notice that both OLCI-A and OLCI-B sensors show very similar patterns. This is normal as the products were acquired 20 seconds apart and roughly cover roughly the same area. The S3A product name indicates that the measurements were collected between 13:58:49 and 14:01:49 UTC on June 20th 2018 whereas S3B measurements were collected between 13:58:28 and 14:01:28 UTC on June 20th 2018. On both views, we find the following elements:

- Wide areas covered in clouds at the upper left and lower right corners
- Sun glint on the right of the images (see NOTE 3).
- Caribbean Islands at the centre

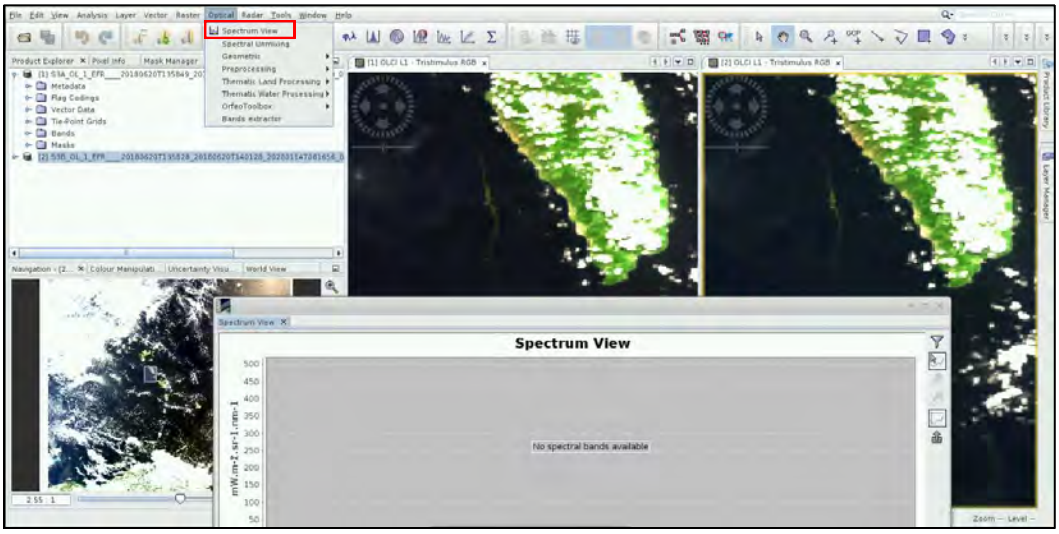
NOTE 3: Sun glint occurs when sunlight reflects off the surface of the ocean at the same angle that a sensor is viewing the surface

From these RGB views, it is very hard to distinguish where the potential Sargassum rafts are located. Zooming in on **particular areas** gives us a hint. As shown on the image below, **subtle dark green patterns** appear but they are not easy to spot with a bare eye on the RGB views.

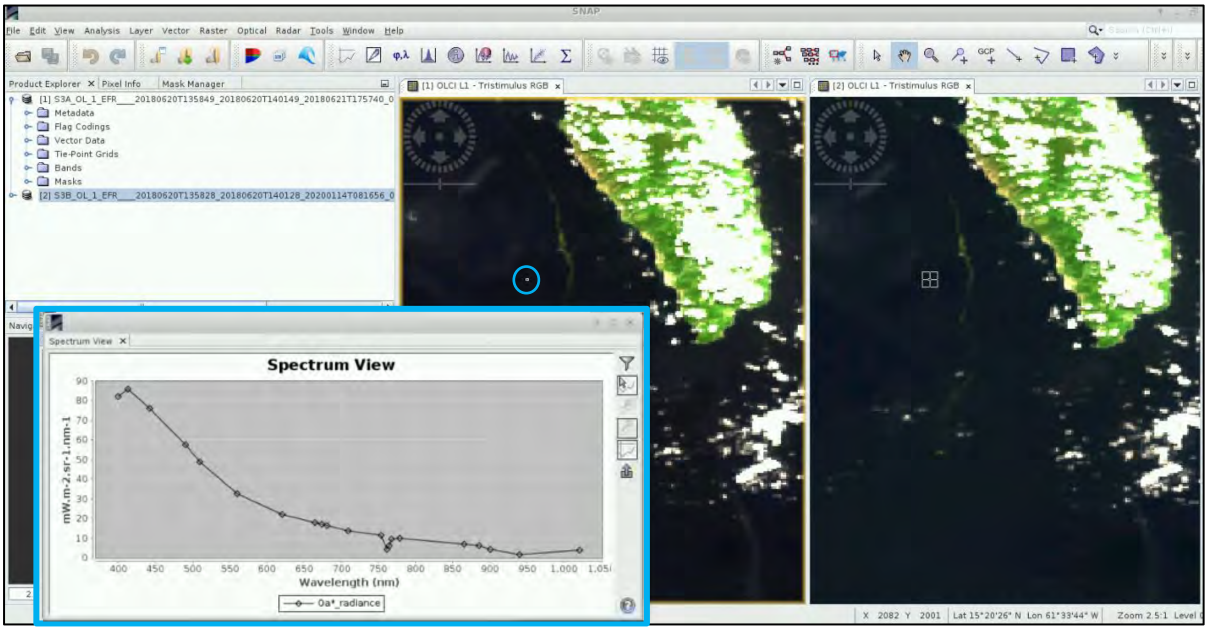


6.2.2 The ocean colour spectrum

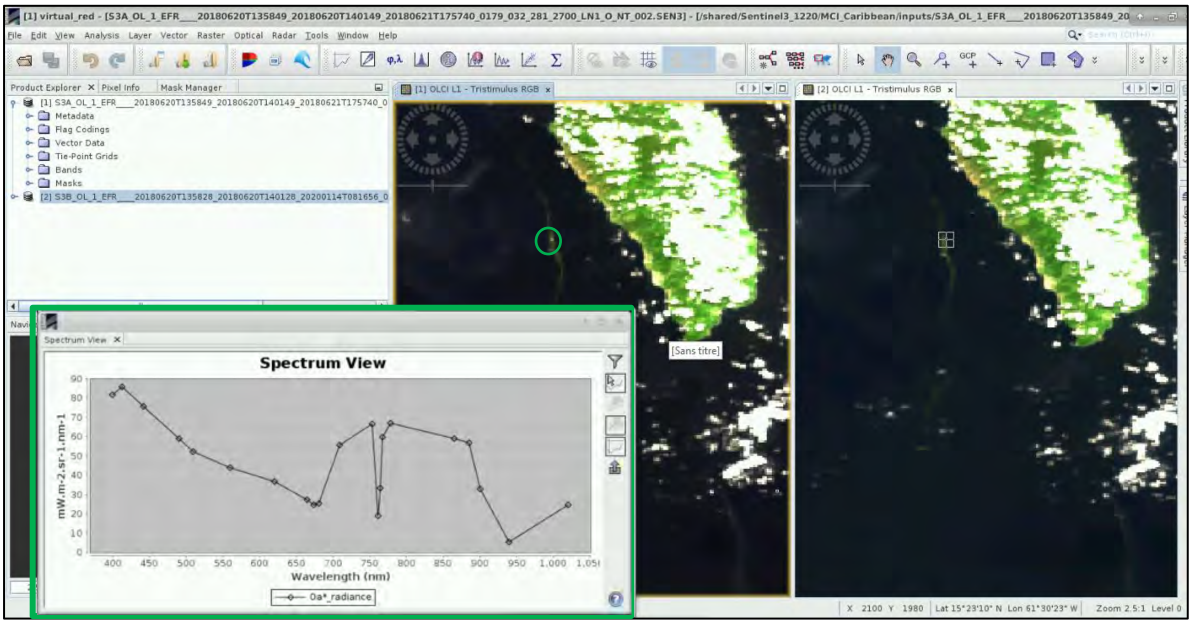
Another useful tool in SNAP is the **Optical→** **Spectrum View** that allows you to check the spectrum of the ocean colour signal per pixel.



When hovering over the image, you will see how the ocean colour signal evolves from a pixel to another. Holding the shift key will automatically adapt the scale of the spectrum view. For example, on **a dark blue pixel** the spectrum will have a strong component in the blue part (short wavelengths) and a weaker component in the red and infrared parts.



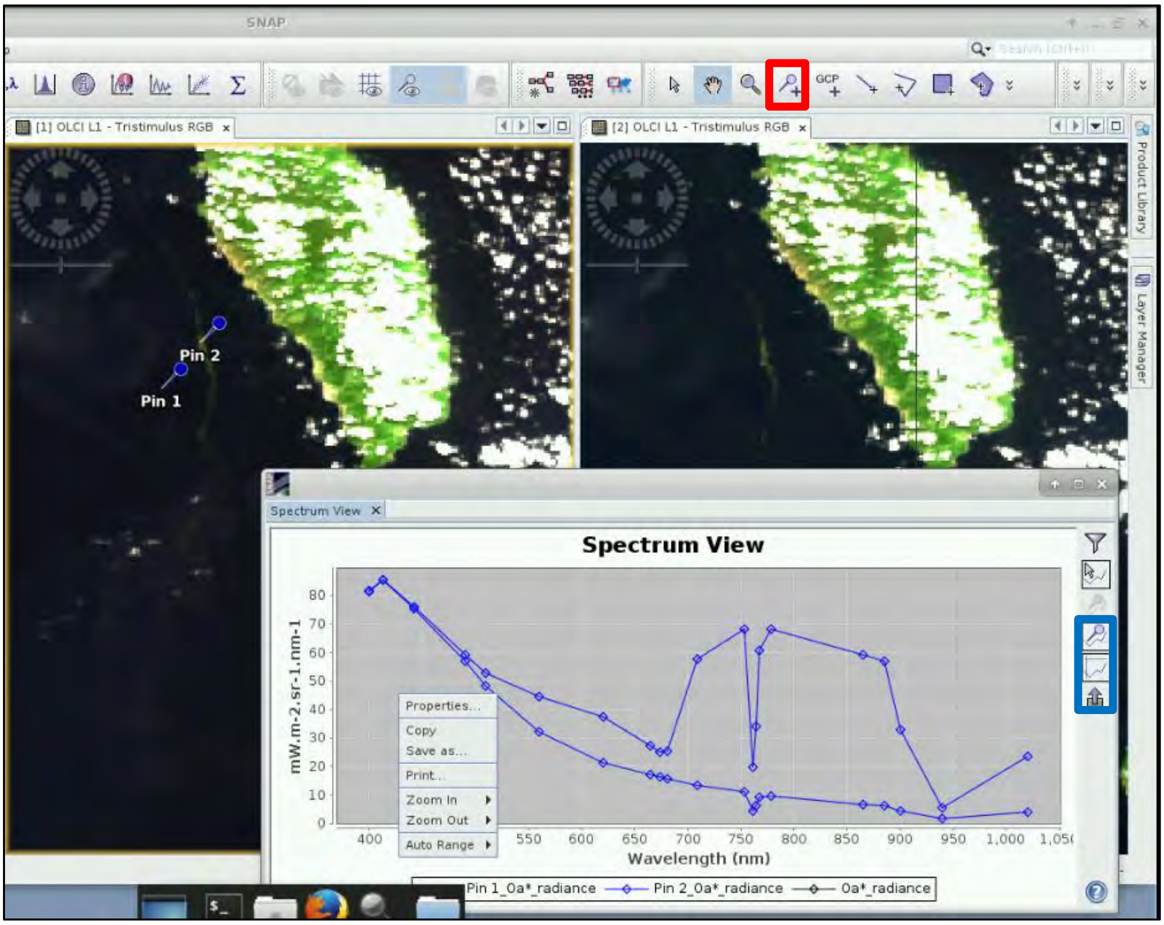
When the cursor is located over **a dark green pixel**, the ocean colour spectrum has a much stronger component in the Near Infrared (NIR) and Infrared part of the spectrum compared to a 'clear water' pixel:



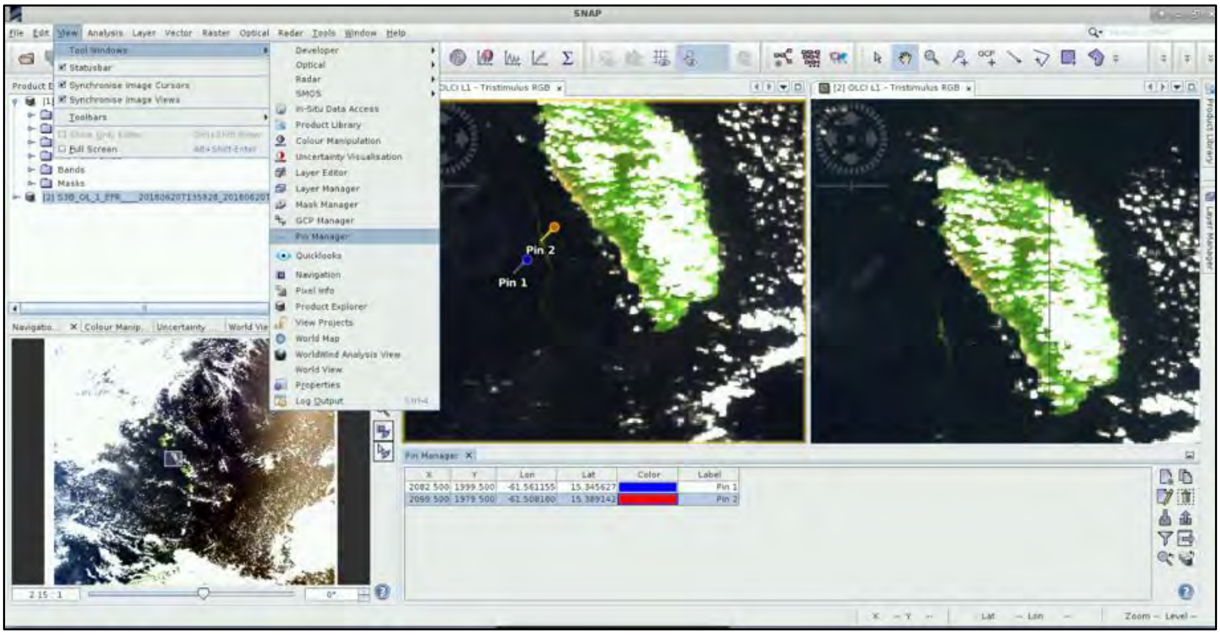
To better assess the spectrum differences between our pixels, it would be nice to plot both spectra on the same view. Good news: SNAP also has a functionality for this. We first need to place pins on our images. Select the **Pin Placing tool button**  and add one pin (Pin 1) over a dark blue water pixel and one pin (Pin 2) over a dark green water pixel. In your **Spectrum View** graph, select the

Show spectra for all pin button . Right clicking anywhere on the graph will display a selection of choices for:

- Setting your graph **properties** (Title, axes, labels etc)
- Export your graph as a PNG file (**Save as**…). It is also possible to export the spectra as a csv file with the button at the bottom right of the spectrum window.



To manage your pin colour and name or to delete a pin, go to **View→Tool Windows→Pin manager**. There you will be able to control your pin options. Changing a pin colour/name will also change the colour/name of its curve in the **Spectrum view**!



Analysing the ocean colour spectrum collected by OLCI can tell us a great deal about the ocean optical constituents content. We just saw that the spectrum collected by OLCI in the various bands varies a lot from one pixel to another.

It is this shift in the ocean colour spectrum that the Maximum Chlorophyll Index (MCI) exploits to highlight the areas where the probability of presence of Sargassum rafts is maximized (see NOTE 4).

NOTE 4: The Maximum Chlorophyll Index (MCI) is an algae index based on the red-edge effect of floating vegetation. As highlighted before, there is an increase of the Sargassum radiometric signal in the NIR part of the spectrum (650-1200nm).

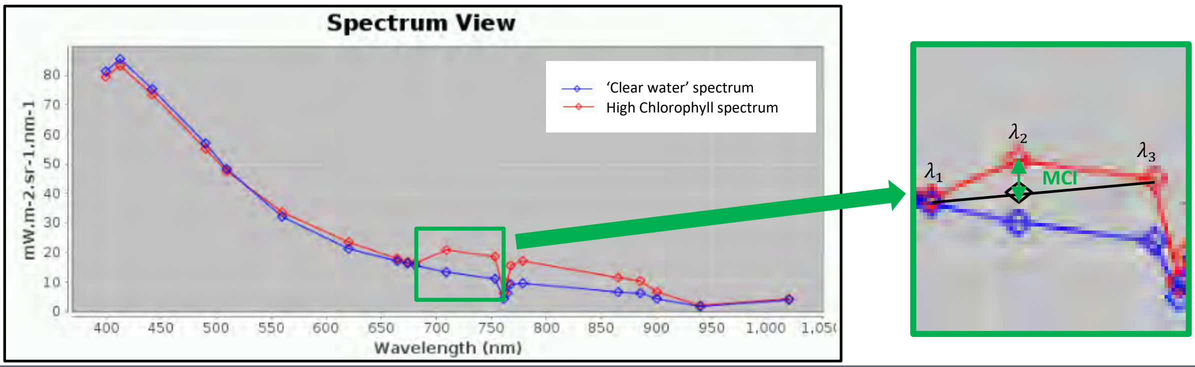
The MCI is computed from the difference between the Top of Atmosphere (TOA) radiances in the central waveband λ_2, where the red-edge effect of the floating algae signal is at a maximum, and a linear baseline drawn between the two surrounding bands $\lambda_1$and λ_3 :

$$MCI = r(\lambda_2) - [r(\lambda_1) + (r(\lambda_3) - r(\lambda_1)) * \frac{\lambda_2 - \lambda_1}{\lambda_3 - \lambda_1}]\text{-}$$

Where $r(\lambda_x)$ are the OLCI L1 EFR TOA radiances for bands:

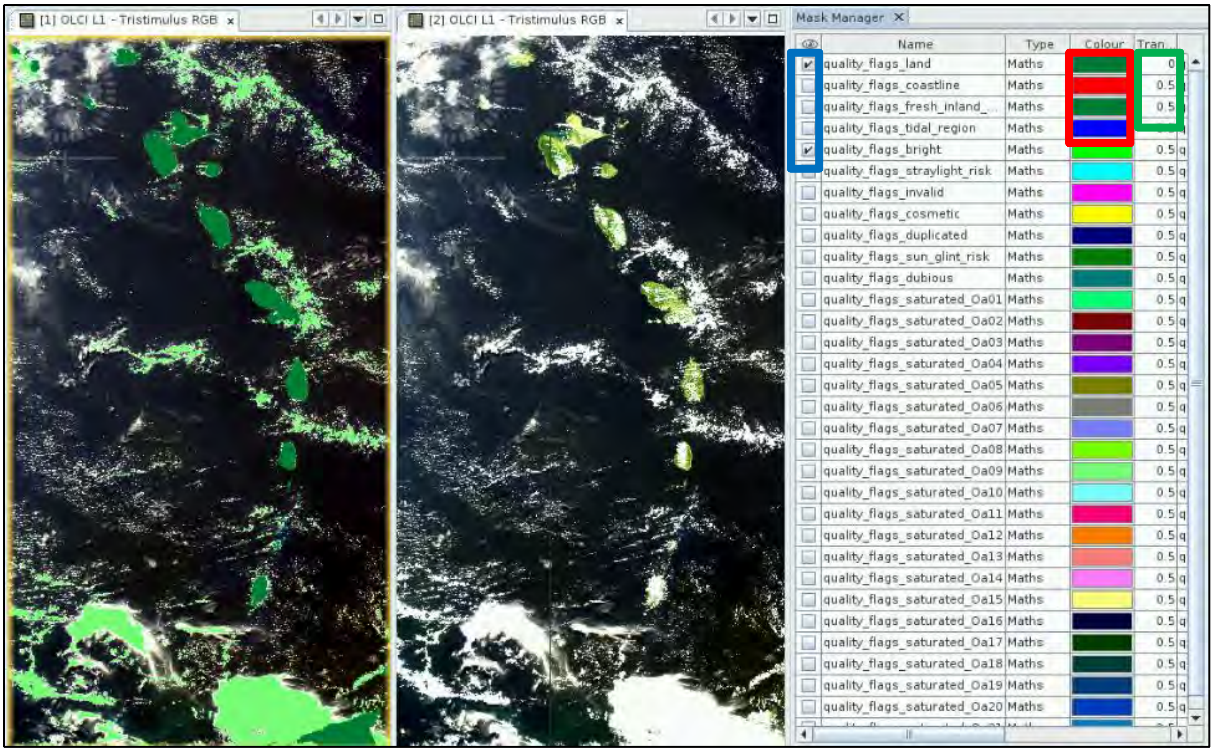
- $\lambda_1 = 681\ nm \rightarrow$ Oa10
- $\lambda_2 = 709\ nm \rightarrow$ Oa11
- $\lambda_3 = 754\ nm \rightarrow$ Oa12

For more details on MCI for OLCI, see Ody et al. (2019).



6.2.3 The quality flags

Alongside the TOA radiances in the 21 spectral bands, the OLCI L1 products contain a set of flags that give contextual elements around the measures. To display the different masks, as for the **Pin Manager**, go to **View→Tool Windows→Mask manager.** From there, you can **activate/deactivate a particular mask by ticking/unticking the boxes**, **change the colour of a mask** or set its **transparency**.

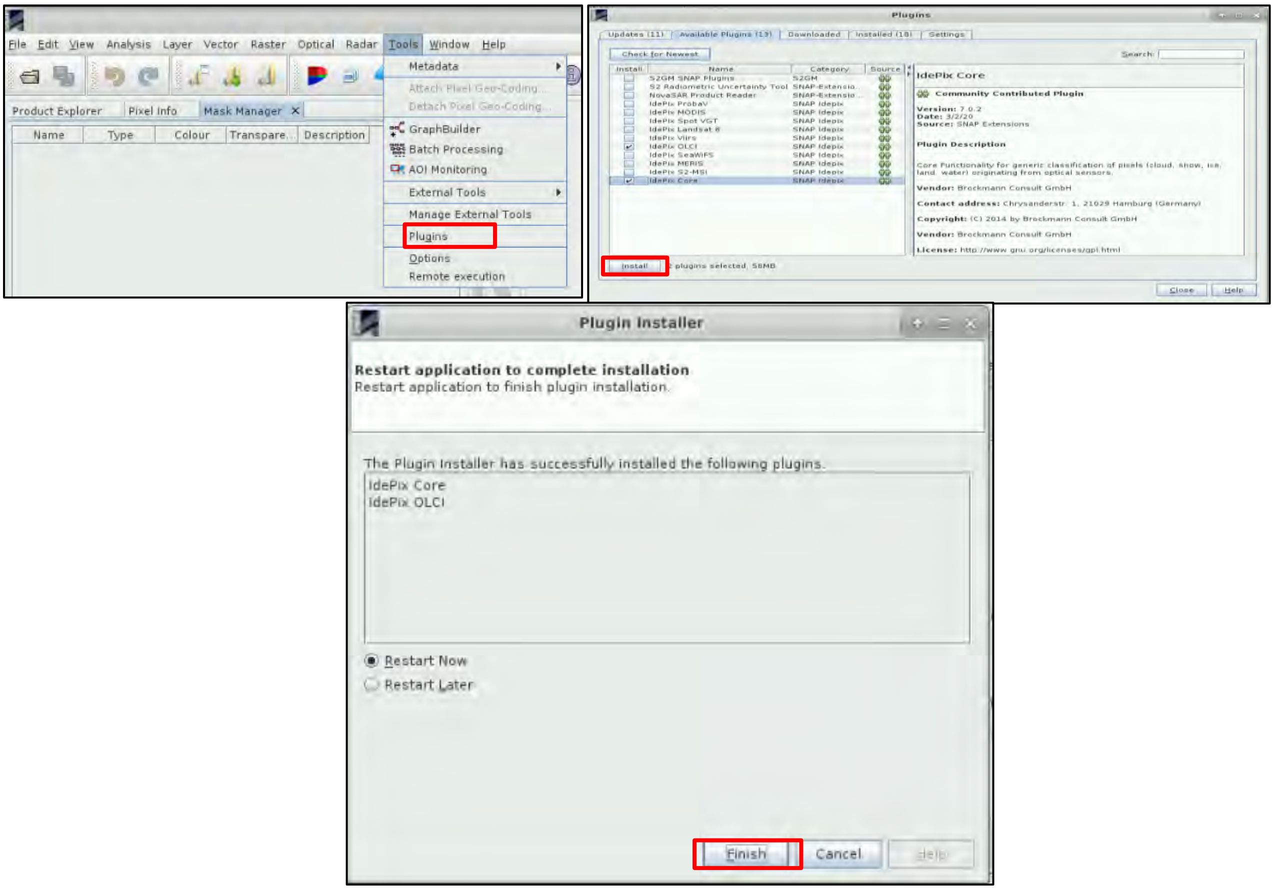


For this study, we would like to ignore land pixels (quality_flags_land) and cloudy pixels. However, there is no cloud flag in the OLCI L1 product. We will hence need to compute our own cloud mask using the SNAP **Idepix for OLCI Processor.**

6.3 SNAP – Idepix Processor

The Idepix processor for OLCI retrieves a set of pixel classification attributes such as clear/cloudy, land/water, snow/ice, etc. The implementation of the features calculation is instrument specific meaning there is an Idepix processor per supported instrument (including but not limited to: MSI on board Sentinel-2, OLCI on board Sentinel-3, MERIS on board ENVISAT, OLI on board Landsat 8, etc.). For cloud detection, the following features are used: brightness, whiteness, height, temperature, spatial pattern, temporal consistency, Neural Network probability.

If this is your first use of the Idepix processor, the plugin needs to be downloaded and installed in SNAP beforehand. Go to **Tools→Plugins** and select **IdepPix OLCI** & **IdePix Core** and hit **Install**. Then hit **Next** and agree to the terms and conditions. After the installation, hit **Finish** and SNAP will restart. You will need to import the OLCI products again following the beginning of section 6.2.



6.4 *SNAP – Sentinel-3 Processing*

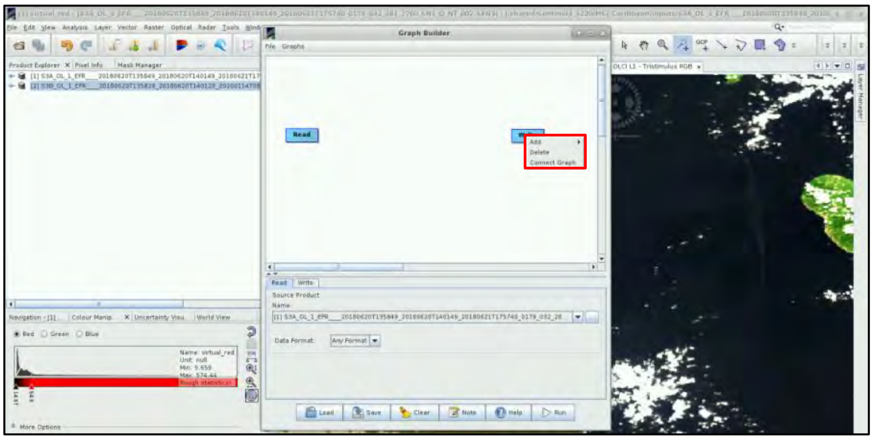
We are going to apply several processing steps to both products:

- Cloud identification with IdePix
- Spatial subset to crop the products to our area of interest
- MCI Computation in a new Band (BandMath)
- Addition of the new MCI band to the output product (BandMerge)
- Reprojection of the product to define a Coordinate Reference System (CRS)

Repeating these steps 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.

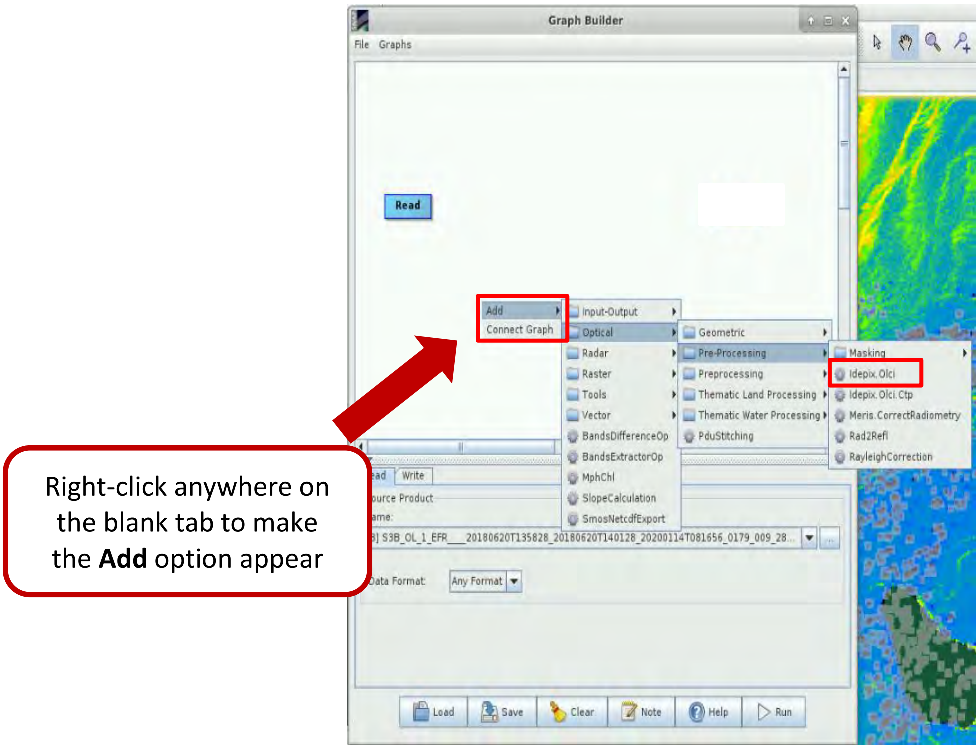
6.4.1 Graph Builder

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). To create an empty graph, go to ***Tools → GraphBuilder.*** At the creation, 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**.

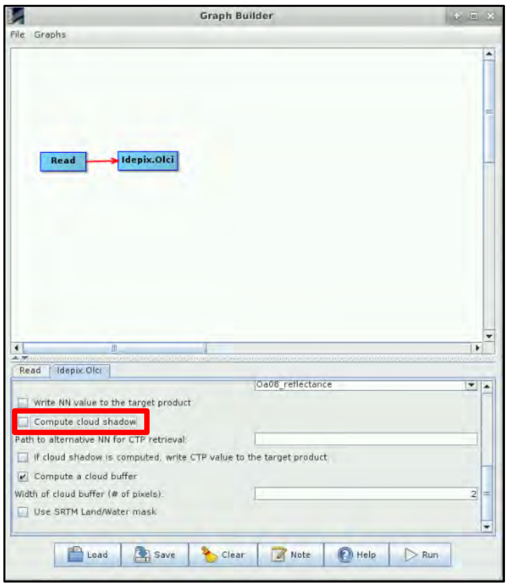


In the Graphbuilder, we will not define any parameters in the tabs (they will be defined in the Batch Processing step where we will apply this processing for both of the images we have downloaded, at once). We will only create and save the graph.

First, we compute the cloud mask out of the OLCI bands. To add the IdePix operator (be sure the plugin is installed first, see section 6.3), right click and go to **Add→Optical→Pre-Processing→IdePix.Olci.**

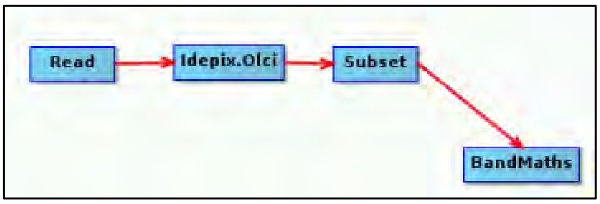


Immediately after adding the operator, make sure to **UNTICK the Compute cloud Shadow** option in the IdePix.Olci Tab as this option makes the SNAP software crash. Then, connect the Read operator to the IdePix Processor. To connect two blocks, start from the right of the block to create a red arrow and drag it to the following block

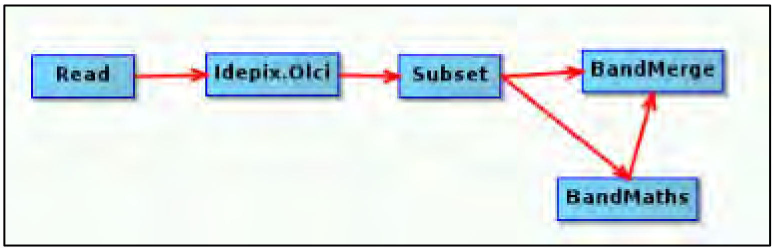


We then need to create a **Subset** of the image, since we want to focus only over a defined area and we do not need the whole extent of the products. To add the **Subset** operator, go to **Add→Raster→Geometric→ Subset**. Connect the IdePix.Olci operator to it.

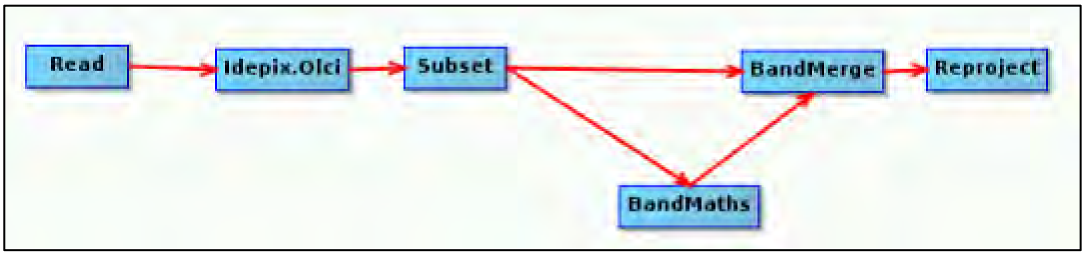
The next processing step will be to derive the MCI for the pixels that are not flagged as cloudy by the IdePix processor (*IDEPIX_CLOUD* flag) and that are not land pixels (*quality_flags_land*). For this task, we will use **Band Math**. To add the Band Math operator, right-click and go to **Add→Raster→BandMath**. Connect the operators as shown below.



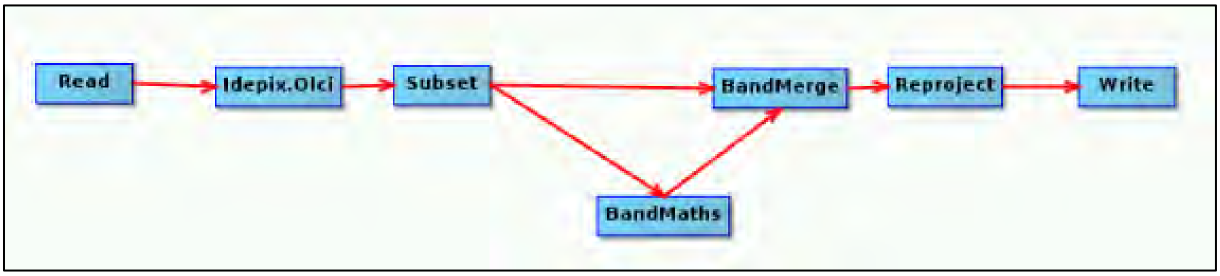
In batch processing mode, the output of the BandMaths operator is the computed band (MCI) only. In our output product, we would like to save some additional data such as reflectances and product flags. To merge the MCI band with the subsetted product bands we will use the **Add→Raster→BandMerge operator**.



Then let’s set a CRS to our product. We will use **Add→Raster→Geometric→ Reproject.**



Finally, we just need to properly save the output. Right click and navigate to **Add→Input-Output→Write**. Your final graph should be similar to the one shown below:



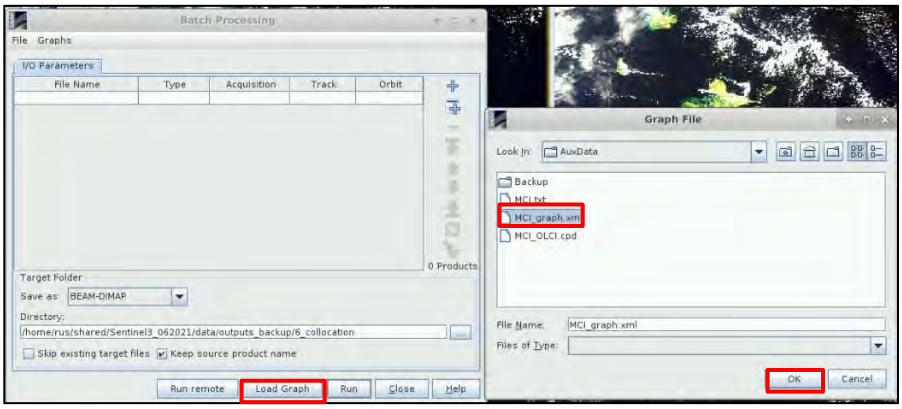
Finally, click on Save in the lower part of the panel and save the graph in the following path as *’MCI_Graph.xml’* without setting any parameter.

Path: */shared/Training/OCEA08_SargassumMapping_Caribbean/AuxData/*

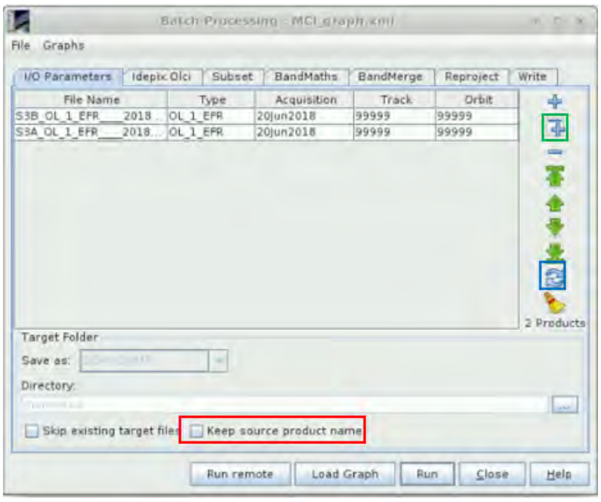
TIP 2: If you did not succeed to create the processing graph, you will find a backup version in /shared/Training/OCEA08_SargassumMapping_Caribbean/AuxData/Backup

6.4.2 Batch Processing

If the same processing scheme is applied to multiple images**,** the **Batch Processing** tool is what you are looking for. To use the **Batch Processing** tool go to **Tools→Batch Processing**. First, you need to **Load the Graph** you want to run. Hit **Load Graph**, browse to */shared/Training/OCEA08_SargassumMapping_Caribbean/AuxData/* and load *MCI_graph.xml*. New tabs corresponding to our operators appear at the top of the window.



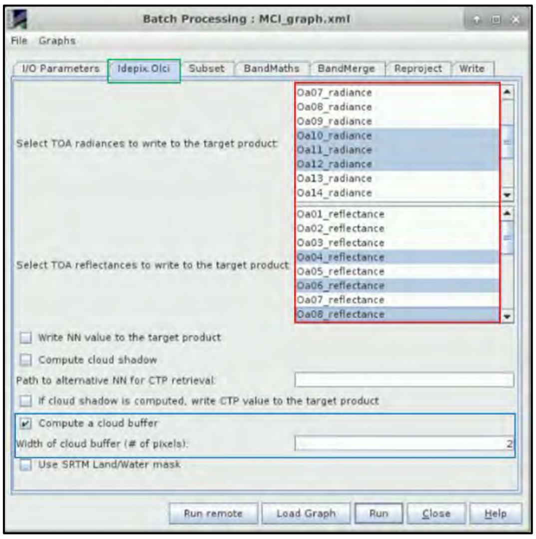
In the **I/O Parameters tab**, unselect the "**Keep source product name**" option. In the same tab, we will add all opened products from the Product Explorer window by clicking **Add Opened button** at the right and then hit **Refresh**. In our case, we have loaded the S3A and S3B images from June 20th 2018.



6.4.2.1 IdePix Olci Processor

In the IdePix.Olci tab, select the **Oa10, Oa11 and Oa12_radiance** bands (needed to compute the MCI). Select also the **Oa04, Oa06 and Oa08 reflectance** bands (to generate a RGB view later if you wish to) as shown below (see NOTE 5). To select multiple bands, hold the *Ctrl* key. Keep the **Compute cloud buffer ticked** and leave the default value of **2** for the width of cloud buffer. This option dilates the IdePix cloud mask with a 2-pixel buffer to deal with cloud edges and cloud shadows.

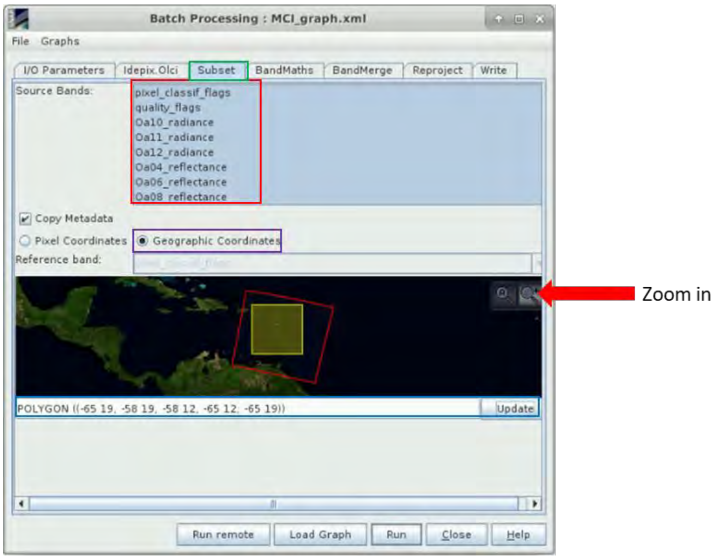
> NOTE 5: **Radiance** is the variable directly measured by remote sensing instruments. It is the amount of light seen by instrument from a surface of an object. In the OLCI products, it is given as 10-3 W.m-2.sr-1.µm-1
>
> **Reflectance** is the ratio (percentage) of the amount of light leaving a target to the amount of light arriving at the target. It has no units. It is the property of the observed object/material.



6.4.2.2 Subset

In the **Subset** tab, first select all **Source Bands**. Then select **Geographic Coordinates**, copy and paste the following Well-Known Text (WKT) in the box beneath the map, hit **Update** to define the area and then hit the button in the top righthand corner of the map to zoom-in.

POLYGON ((-65 19, -58 19, -58 12, -65 12, -65 19))

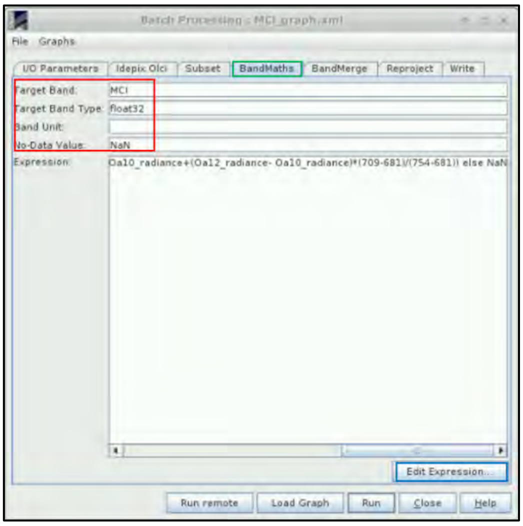


6.4.2.3 BandMath – MCI

Click now on the **BandMaths** tab, set the target band name to **MCI** set the **No-Data value to NaN**, click on **Edit Expression** and copy and paste the following expression into the box. Click OK afterwards.

if quality_flags_land==False and IDEPIX_CLOUD==False and IDEPIX_CLOUD_BUFFER==False then Oa11_radiance-(Oa10_radiance+(Oa12_radiance- Oa10_radiance)*(709-681)/(754-681)) else NaN

This expression means that the MCI gets computed only over clear-sky water pixels. Over land and/or cloudy pixels, the value will be set to NaN. You will also find the MCI expression in */shared/Training/OCEA08_SargassumMapping_Caribbean/AuxData/MCI.txt*

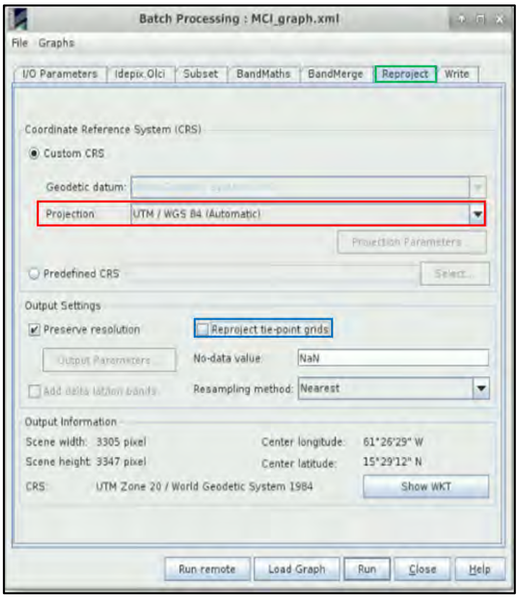


6.4.2.4 BandMerge

In the BandMerge Tab, select all source bands. You can select all source bands by selecting one band and then using the *Ctrl+A* keyboard shortcut.

6.4.2.5 Reproject

In the **Reproject Tab**, you can choose from a wide variety of CRS, for example the **UTM/ WGS 84 (Automatic)** towards the bottom of the list. Unselect the **Reproject tie-point grids** option.



6.4.2.6 Write

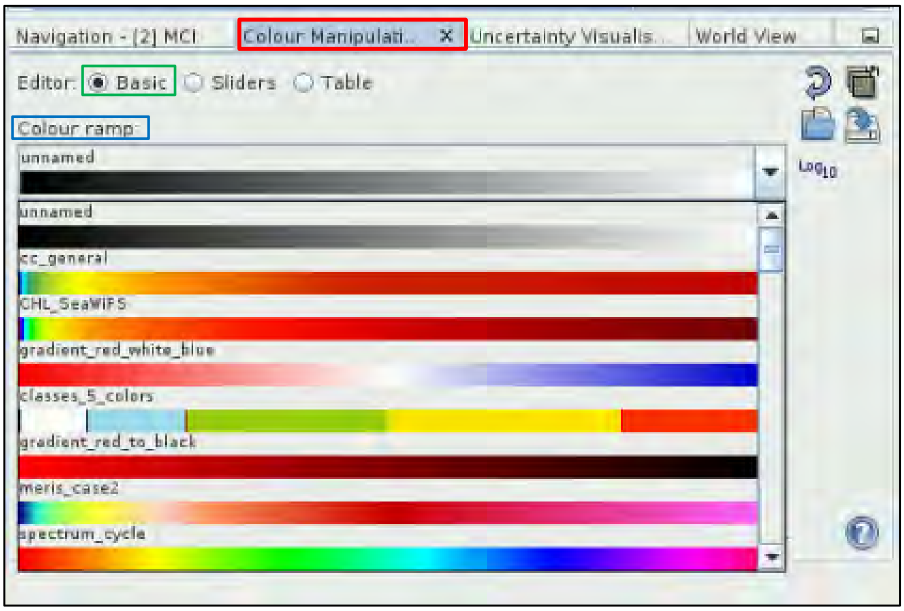
In the **Write** tab, under **Name** keep the default name (Projected, Subset and IDEPIX will be added). At the Directory set the path to ***/shared/Training/OCEA08_SargassumMapping_Caribbean/Processing/***

Finally Hit **Run**! The processing may take up to 15mn on a RUS VM. It might take more time if you are practicing on your own computer. The processed products will automatically open in the **Product Explorer Window** when the processing is completed ((see NOTE 6).

> NOTE 6: When executing the graph on a RUS VM, it may happen that SNAP suddenly closes without any warning because of a RAM shortage. If this happens, first go to */shared/Training/OCEA08_SargassumMapping_Caribbean/Processing/* and delete the written output(s) as they will only be partial. Then restart SNAP and open both Sentinel-3 products again (section 6.2). Then open the batch processing tool again and repeat all the steps of section 6.4.2.

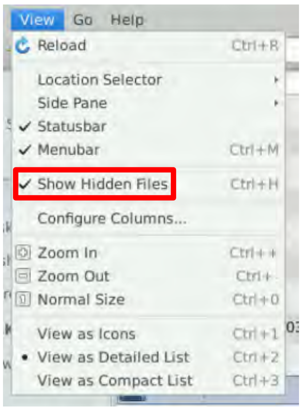
6.5 Analysis of the processed products

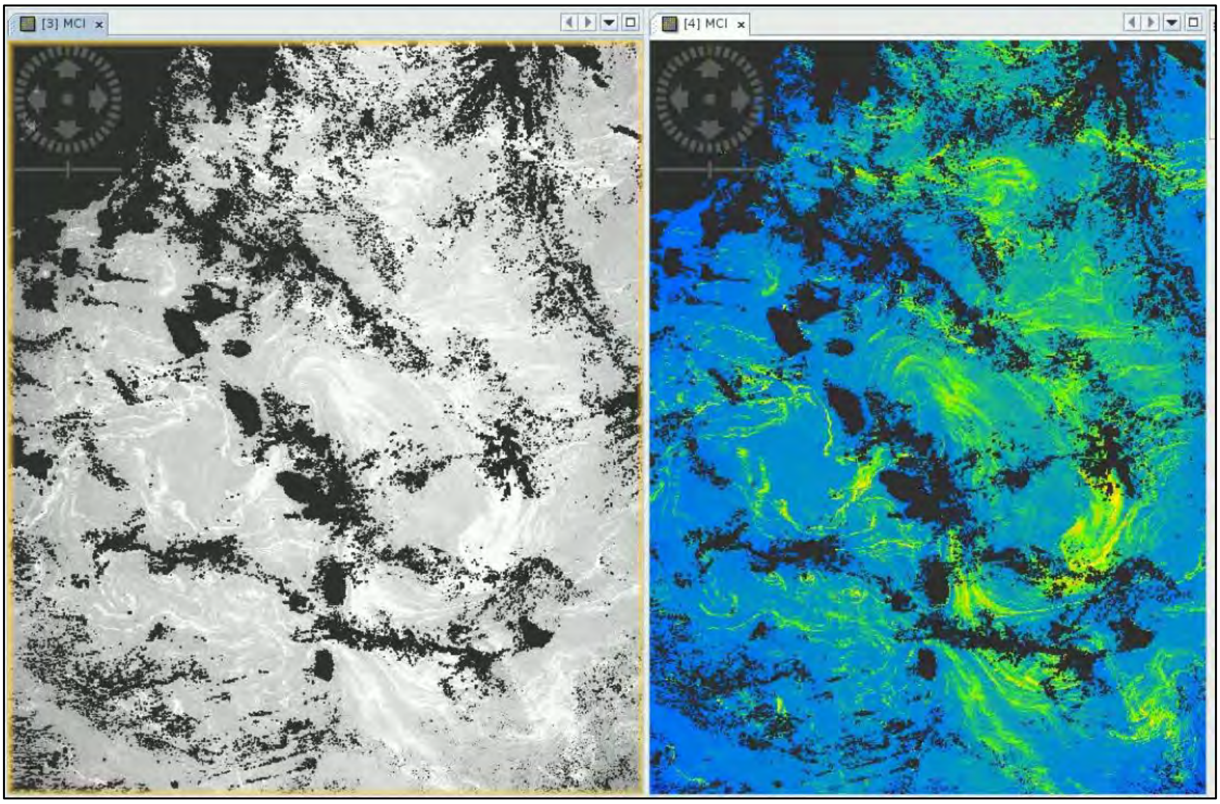
Both products now contain an MCI band. Let's open the MCI band from each product. The first view is black and white. To add a colour ramp, go to **Colour manipulation** → **Basic** → **Colour Ramp**. There, you will find a set of pre-defined colour bars.



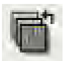
To correctly visualize the MCI, we are going to use a colour ramp created ahead if this webinar. For this, hit the **Import colour palette from text file** button  and navigate to */shared/Training/OCEA08_SargassumMapping_Caribbean/AuxData/* and select *MCI_OLCI.cpd*. When opening the file, a window will appear, hit No.

TIP 3: The SNAP default colour ramps are in /home/rus/**.snap**/auxdata/color_palettes/. You can copy the MCI_OLCI.cpd file to this folder and have it appeared as a default colour ramp. Once in the *home/rus/* folder, go to View→Show Hidden Files to make the ***.snap/*** folder appear.



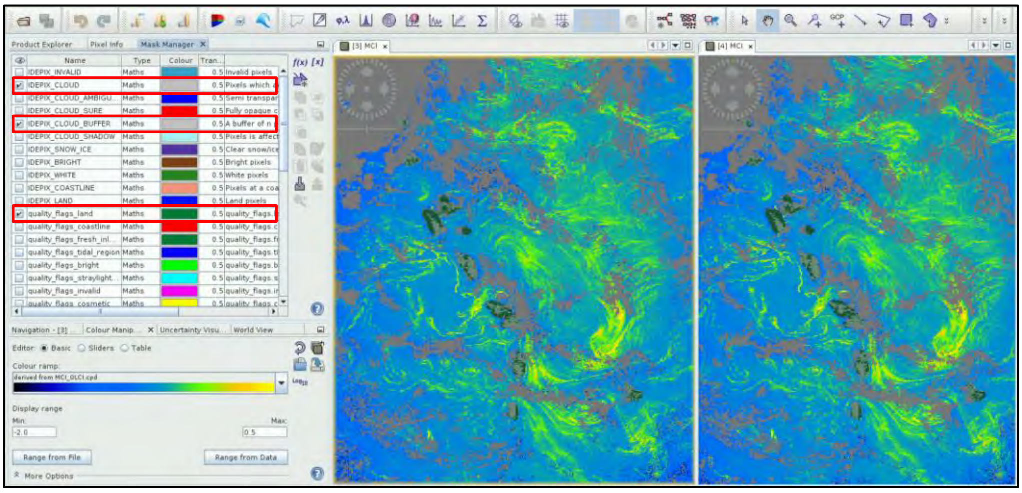


You need to repeat the operation for the second view.

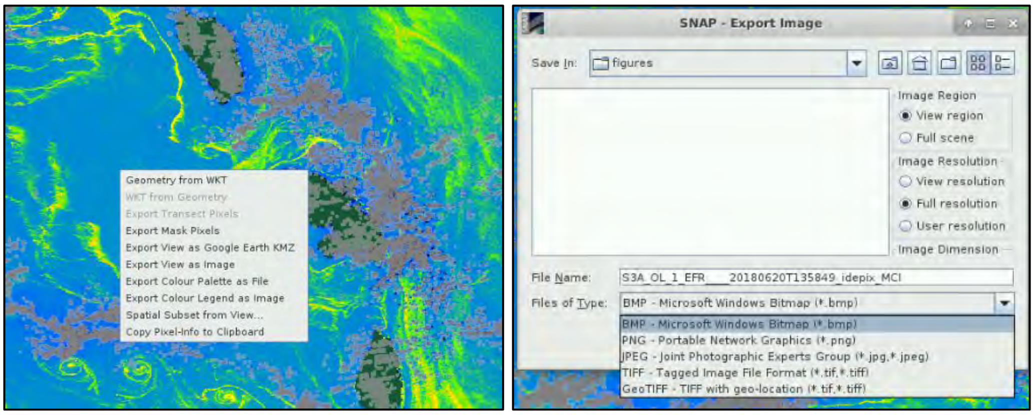
TIP 4: Once you have defined a convenient style for a view, you can apply this style to other views by hitting the  button from the **Colour Manipulation** tab. Then you just need to select the opened band you wish to apply the colour ramp to.

In the product the light blue areas correspond to the dark water regions. The Sargassum rafts are easily identified by the yellow stripes. The black pixels are the ones that were either flagged as land, or cloud/cloud_buffer by the **IdePix processor** and set to NaN in the **BandMath** operation.

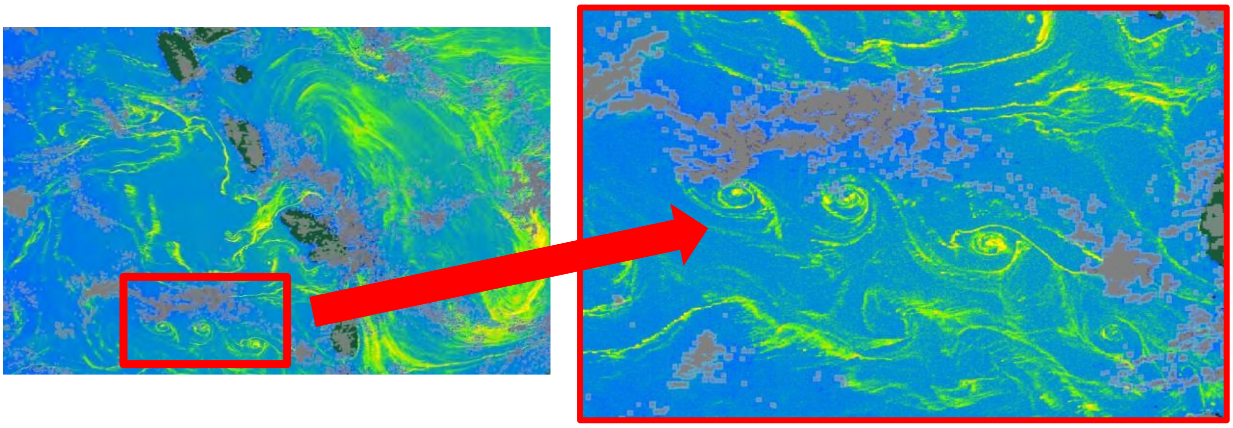
To further enhance the view, you can activate the *IDEPIX_CLOUD* and *IDEPIX_CLOUD_BUFFER* masks by selecting the check box to the left of the name of each mask in the Mask Manager and set their colour to light grey. You can also activate the *quality_flags_land* mask on both images.



If you want to export an interesting view, right-click anywhere on the view and select **Export View as Image**.



You can see how some rafts seem to mark current meanders and eddies borders and centres.



We also observe that most Sargassum rafts present east-west thin filament structures most probably caused by wind.

7 Conclusions

Satellite imagery is widely used to detect and map floating vegetation. Space-borne technologies offer a frequent and global coverage of our oceans. As this exercise highlighted, simple index computations based on the red-edge spectral properties of the Sargassum in the near infrared part of the spectrum allow for a relatively easy detection of large rafts. The Sentinel-3 constellation constitutes a valuable asset to map Sargassum distribution at large scales on a frequent basis. Furthermore, the OLCI products could be combined with other sensors to create multi-sensor products and hence ensure a gap-free coverage of the Caribbean Sea.

However, satellite data present some drawbacks and in situ data remain essential to create a reliable Sargassum monitoring system. OLCI spatial resolution (300m) limits the detection of smaller aggregations. The tropical Atlantic Ocean also often experiences Saharan dust plumes that may decrease the Sargassum signature in the near infrared and hence make the MCI computation unreliable. In addition to these dust episodes, sun glint, clouds and haze that are typical to tropical regions create further gaps in the observations. OLCI captures very well the floating algae at the very surface of the ocean but Sargassum located a few centimeters (10-15cm) below the surface are not well detected. It is also very challenging to discriminate Sargassum from other floating vegetation or even from other floating material such as plastic and oil that have a similar spectral signatures in the NIR.

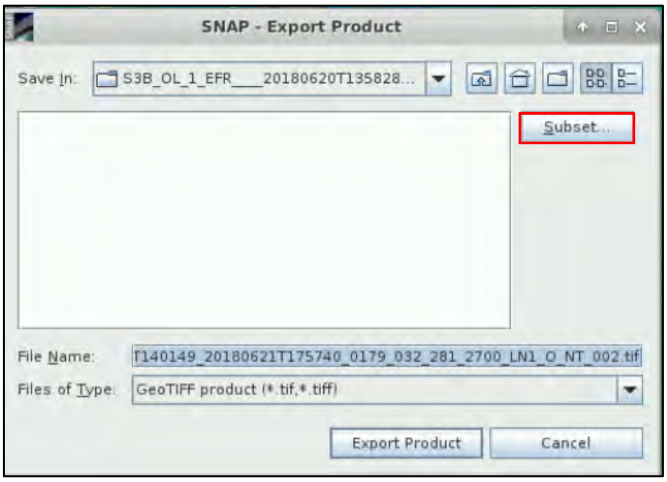
Finally, detecting rafts is not equivalent to accurately quantifying the Sargassum biomass available for strandings on coasts. MCI is not a concentration measure but an indicator to highlight the areas covered by potential Sargassum rafts. A pixel flagged by the MCI may be composed of several sub-pixel sized aggregations which can reach a depth of half a meter.

As a conclusion, the MCI computed out of OLCI products is a very efficient tool for detecting the position of floating material rafts under relatively clear sky conditions, but complementary information is needed to fill in the gaps in satellite ocean colour data and quantify the biomass available for stranding. Moreover, monitoring and forecasting these disastrous aggregations requires that other sea state parameters such as the wind strength and direction, wave height or currents be taken into account. For more explanation, do not forget to read the article from Ody et al. (2019) which inspired this exercise.

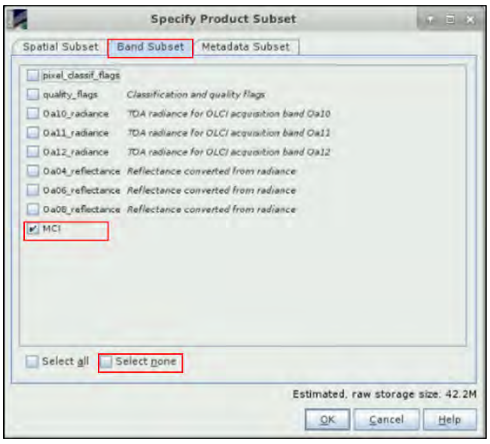
8 Extra steps – Export to QGIS

8.3 Export as a GeoTIFF

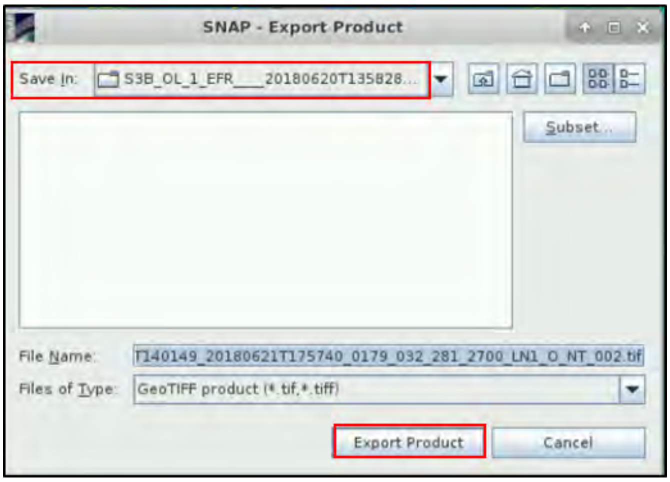
SNAP allows the user to export the outputs as GeoTIFF for further analysing and processing in a GIS software such as QGIS. To do this, **make sure to select the output product in the Product Explorer Tab**. Then from **File→Export**, choose the **GeoTIFF** option. In the dialog tab that opens, hit **Subset**.



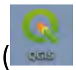
At the **Band Subset** (second tab) use the **Select none** button to unselect them all first and then select only the MCI band. Then go to the **Metadata Subset** tab and click **Select none**. Finally, hit **OK** and hit **No** in both dialog tabs that open.

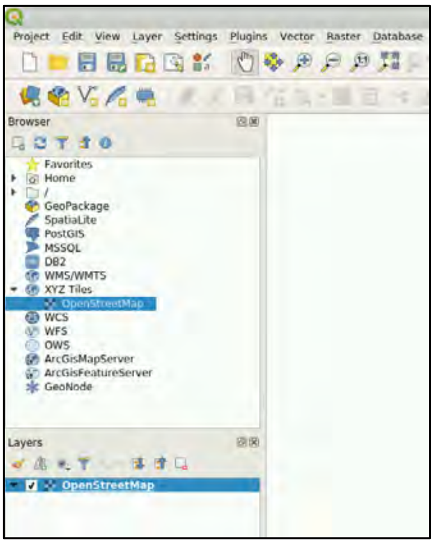


Define your export folder thanks to the Save in option and hit Export Product.

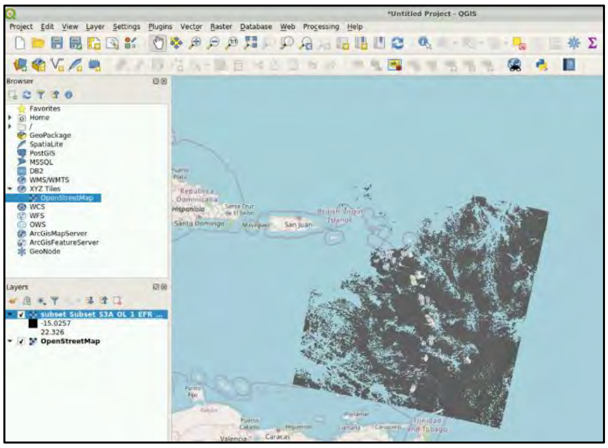


8.4 *Opening the File in QGIS*

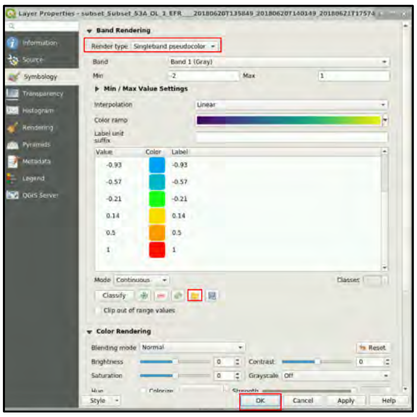
Your GeoTIFF is now ready to be opened in QGIS ( icon from your VM desktop)! First open the software. From the **left panel**, expand the **XYZ Tiles** and drag the **OpenStreetMap** and drop it to the **layer** panel.



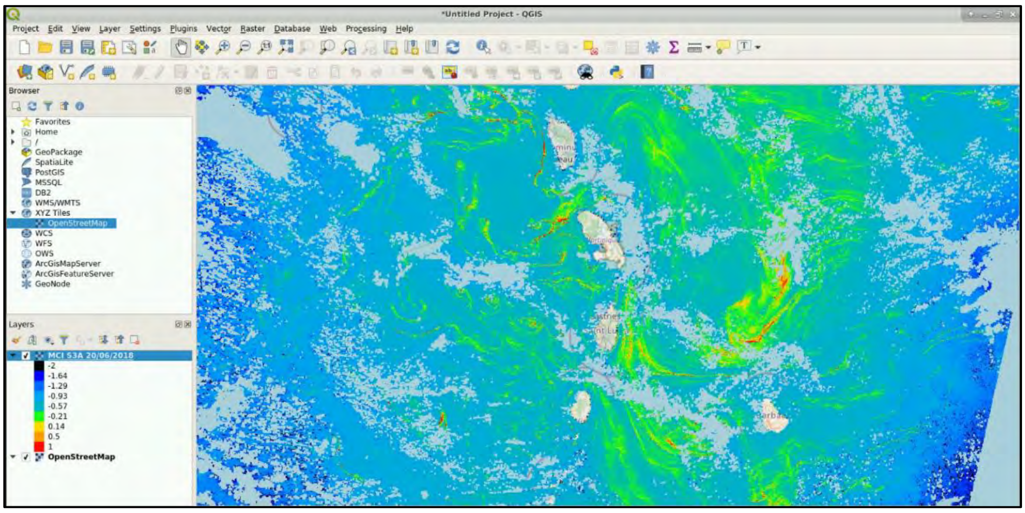
Then, from a file browser, drag and drop your generated GeoTIFF in QGIS and zoom in to the Caribbean Sea using the central wheel of your mouse. A black and white view of the MCI has opened.



Double-click on the GeoTIFF layer. This will open the properties of your layer. In the Symbology section, set the **Render Type** as **Singleband pseudocolor**. Then with the button, navigate to */shared/Training/OCEA08_SargassumMapping_Caribbean/AuxData/* and open the MCI_colour_QGIS.txt file which is a pre-defined colour ramp. Then simply hit OK.



Enjoy the result!



THANK YOU FOR FOLLOWING THE EXERCISE!

9 Further reading and resources

Sentinel-3 OLCI User Guide
https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-olci
Sentinel-3 OLCI Technical Guide
https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-3-olci
Sentinel-3 Marine User Handbook
https://earth.esa.int/eogateway/documents/20142/1564943/Sentinel-3-OLCI-Marine-User-Handbook.pdf
Sargassum Side Event, All Atlantic 2021 workshop
https://www.eu4oceanobs.eu/all-atlantic-2021/sargassumsideevent/
Satellite-based Sargassum Watch System (SaWS)
https://optics.marine.usf.edu/projects/saws.html
High quality Sargassum Mapping in the W-Atlantic with OLCI
https://people.mio.osupytheas.fr/doglioli.andrea/Ody_etal_IOCS17_OLCI.pdf

10 References

Ody A, Thibaut T, Berline L, Changeux T, André J-M, Chevalier C, et al. (2019) From *In Situ* to satellite observations of pelagic *Sargassum* distribution and aggregation in the Tropical North Atlantic Ocean. PLoS ONE 14(9): e0222584. https://doi.org/10.1371/journal.pone.0222584

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