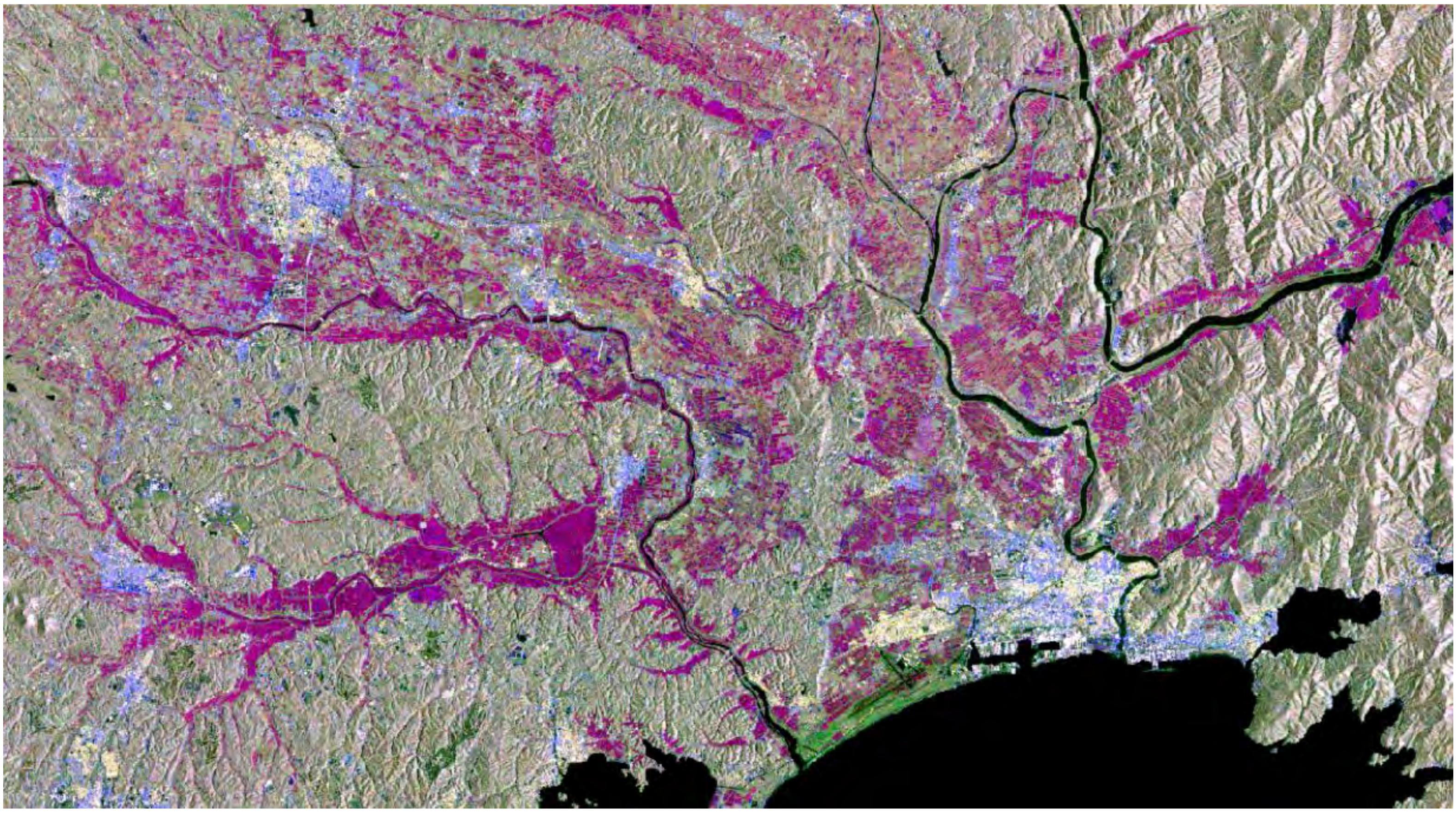

TRAINING KIT – HAZA06

WATCHING A TYPHOON USING SENTINEL-1
HAGIBIS, OCTOBER 2019

Research and User Support for Sentinel Core Products

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

Authors would be glad to receive your feedback or suggestions and to know how this material was used. Please, contact us on training@rus-copernicus.eu

Cover images produced by RUS Copernicus

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

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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.

2 Typhoon Hagibis

Damage caused by typhoon Hagibis Credits: japan-forward.com

Hagibis was the biggest typhoon to hit Japan in decades and was considered to be the most devastating typhoon to hit the Kantō region of Japan since Ida in 1958. The system reached tropical storm status late on 5 October as it travelled westward. On 12 October, Hagibis made landfall at Izu Peninsula as a Category 2.

With extreme events like this likely to increase in number and in severity as a consequence of climate change, satellites are playing an increasingly important role in understanding and tracking huge storms. Sentinel-1 is especially valuable as it can “see” through clouds and help map the scale of flooded areas immediately during the event and well as the damage afterwards even in absence of cloud free optical imagery.

In this exercise we will use two different Sentinel-1 Level-1 data products to look at different aspects of the typhoon. The **G**round **R**ange **D**etected product will be used to map flooded areas during the event, while the loss od coherence resulting from damage after the flooding subsided will be derived from the **S**ingle **L**ook **C**omplex data.

3 Training

Approximate duration of this training session is two hours.

The Training Code for this tutorial is HAZA06. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the [RUS portal (rus-copernicus.eu)](rus-copernicus.eu) and open a User Service request from Your RUS service > Your dashboard.

3.1 Data used

- Five Sentinel-1 images acquired between September 24 and October 18, 2019, two are GRD data products and three are the SLC data products. [downloadable @ https://scihub.copernicus.eu/]

  *S1B_IW_**GRDH**_1SDV_**20191012**T204154_20191012T204223_018447_022C0C_**B106***
  *S1A_IW_**GRDH**_1SDV_**20191006**T204235_20191006T204300_029343_0355EA_**C9CC***
  *S1A_IW_**SLC**__1SDV_**20191018**T204233_20191018T204300_029518_035BEF_**380F***
  *S1A_IW_**SLC**__1SDV_**20191006**T204233_20191006T204300_029343_0355EA_**AFB2***
  *S1A_IW_**SLC**__1SDV_**20190924**T204233_20190924T204300_029168_034FDF_**708B***

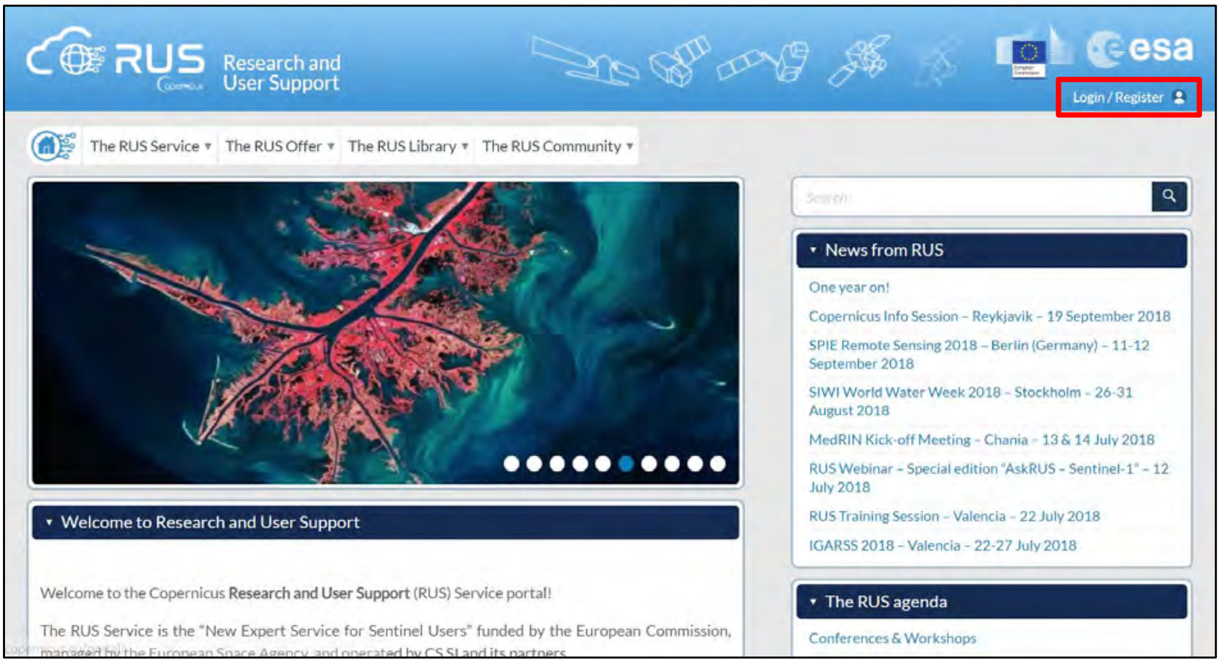
- Auxiliary data stored locally
  @/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/AuxData

3.2 *Software in RUS environment*

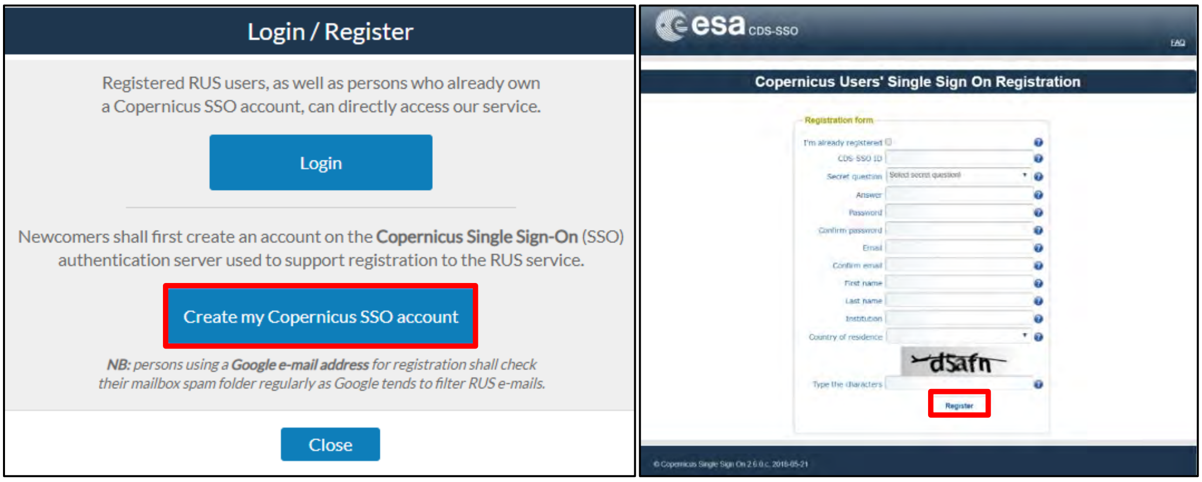
Internet browser, SNAP + Sentinel-1Toolbox

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.

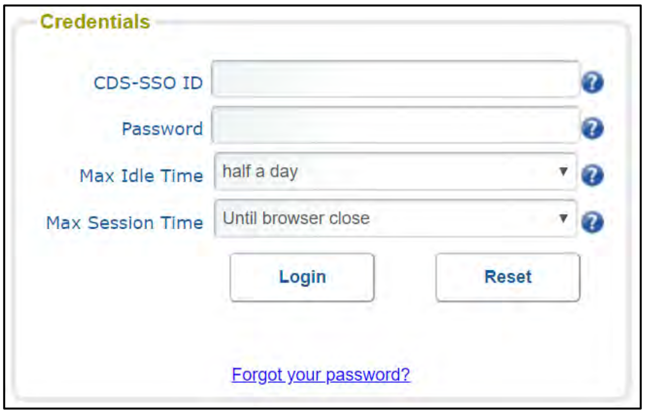


Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click ***Register***.

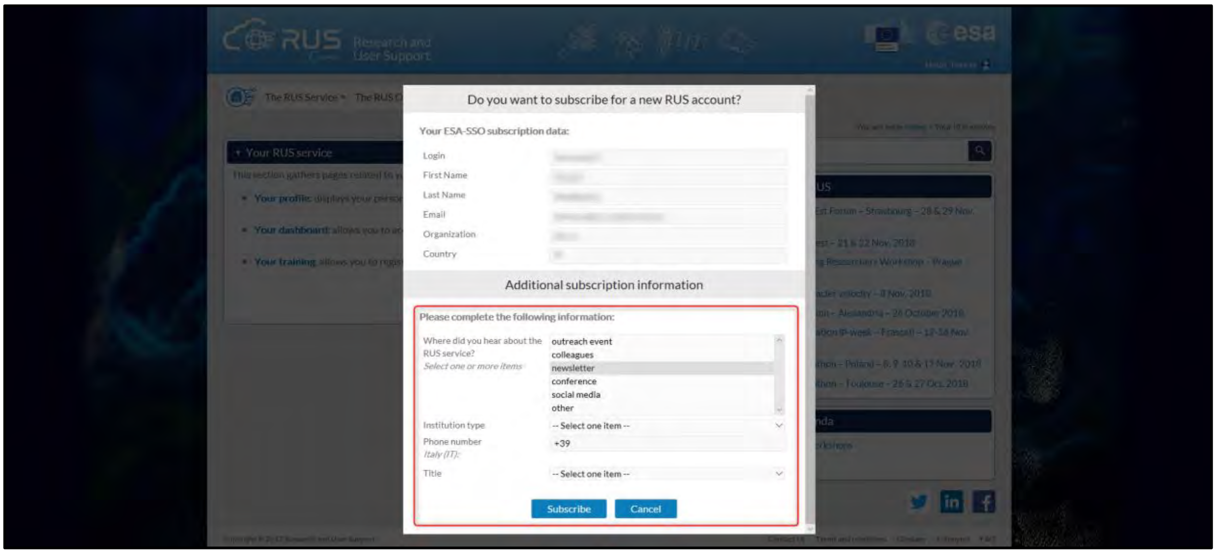


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

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

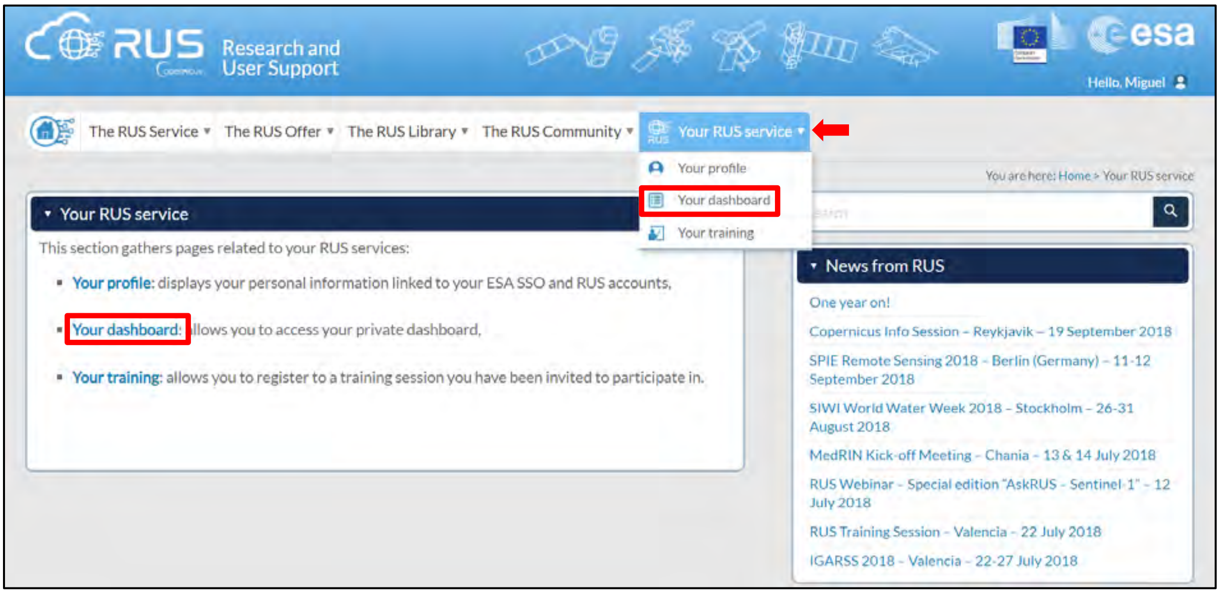


Upon your first login you will need to enter some details. You must fill all the fields.

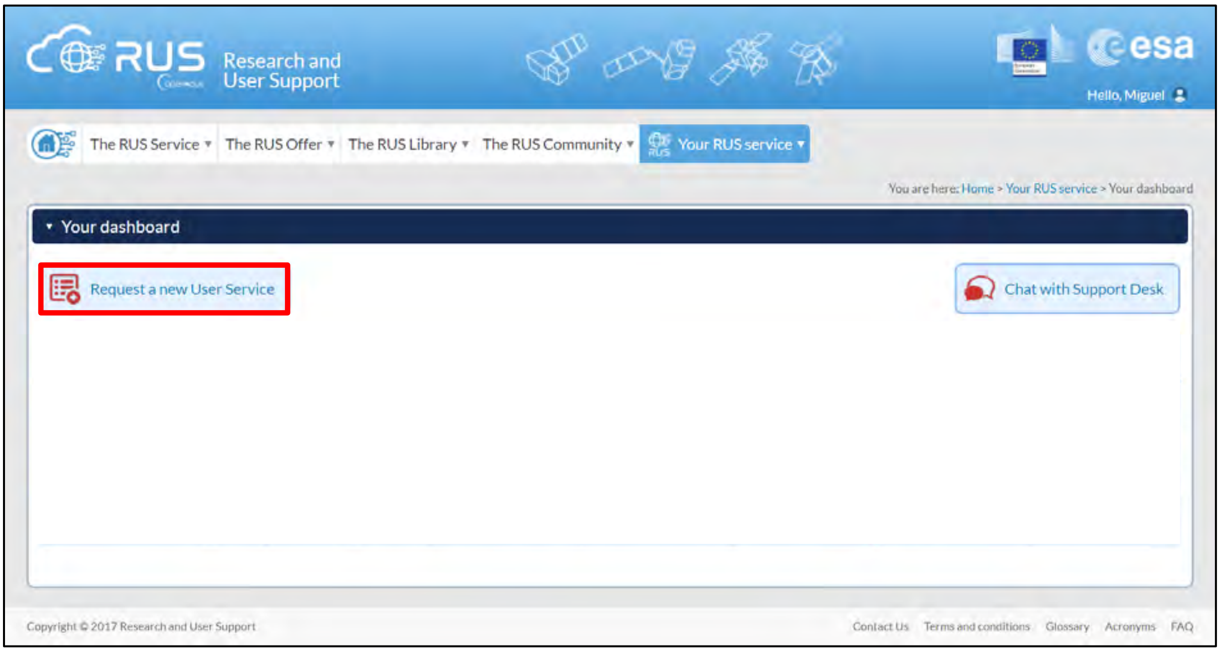


5 Request a RUS Copernicus Virtual Machine

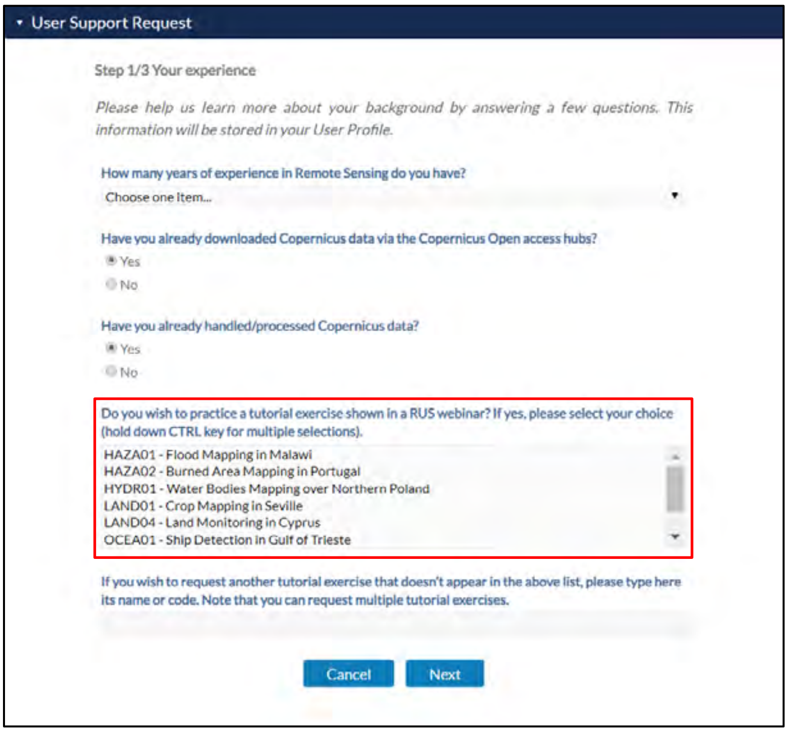
Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on ***Your RUS Service → Your Dashboard***.



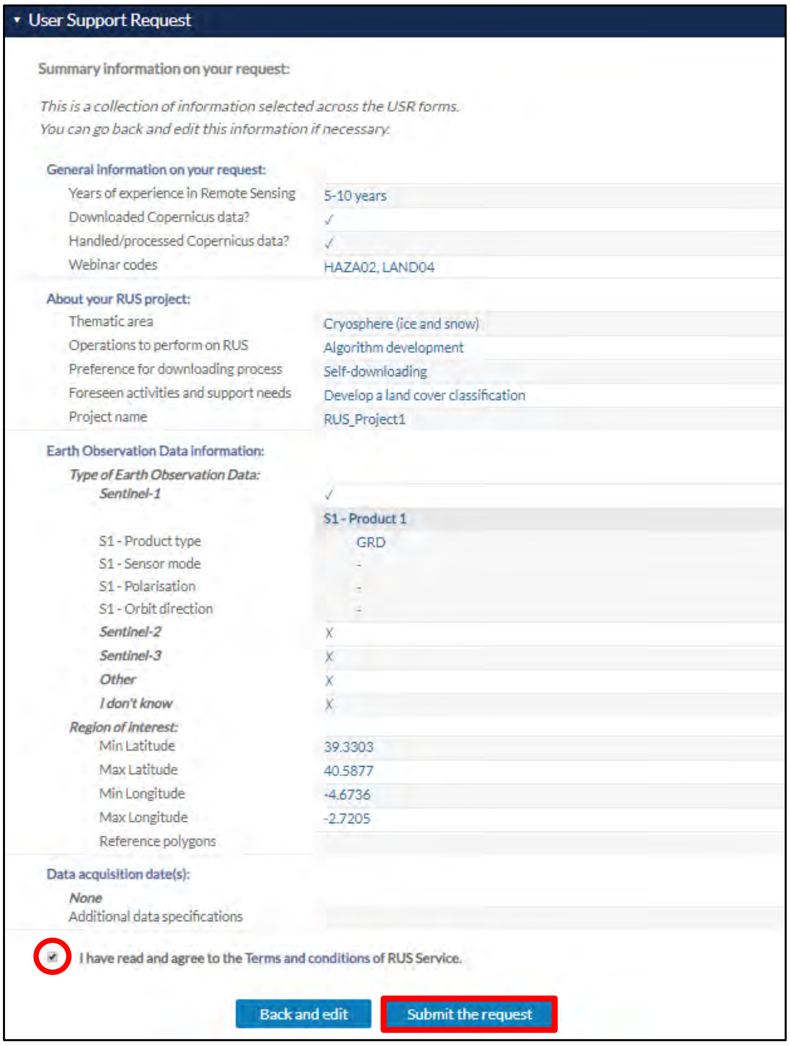
Click on ***Request a new User Service*** to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.



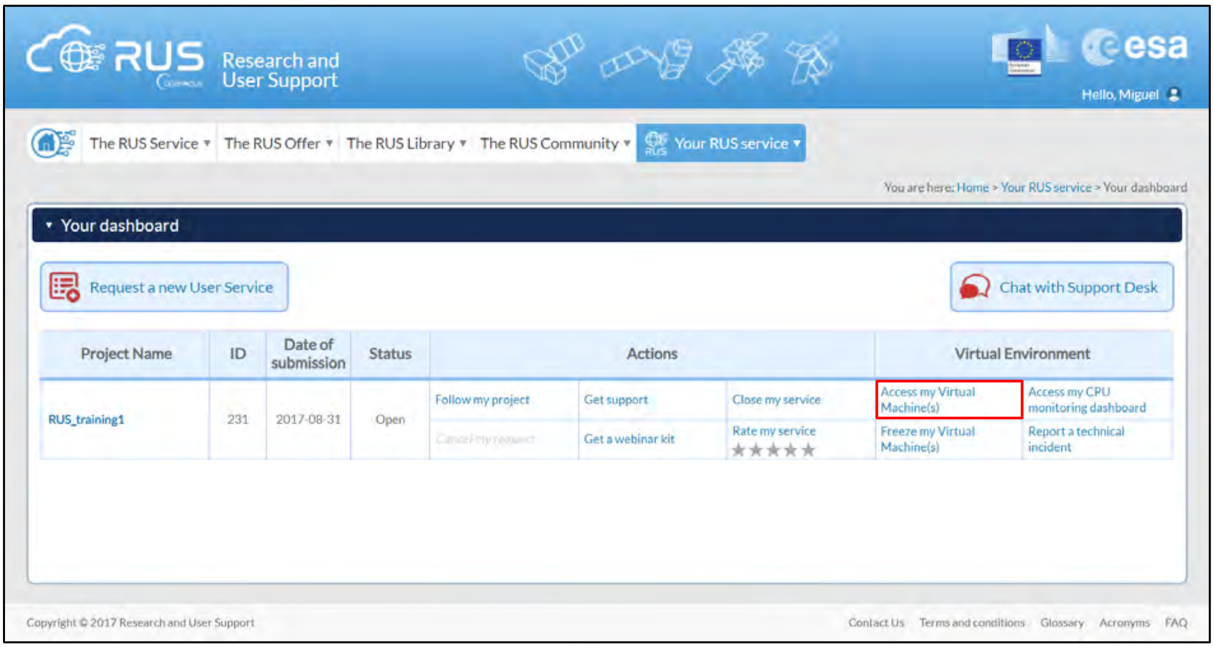
If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.



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.

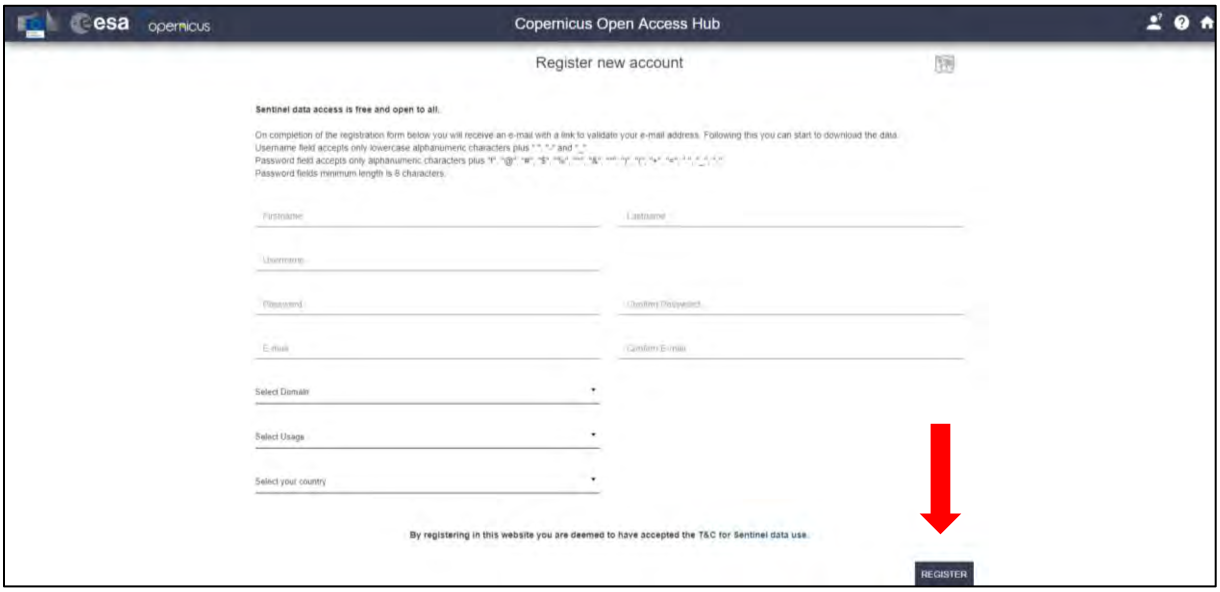
6 Step by step

6.1 Data download – ESA SciHUB

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

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

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

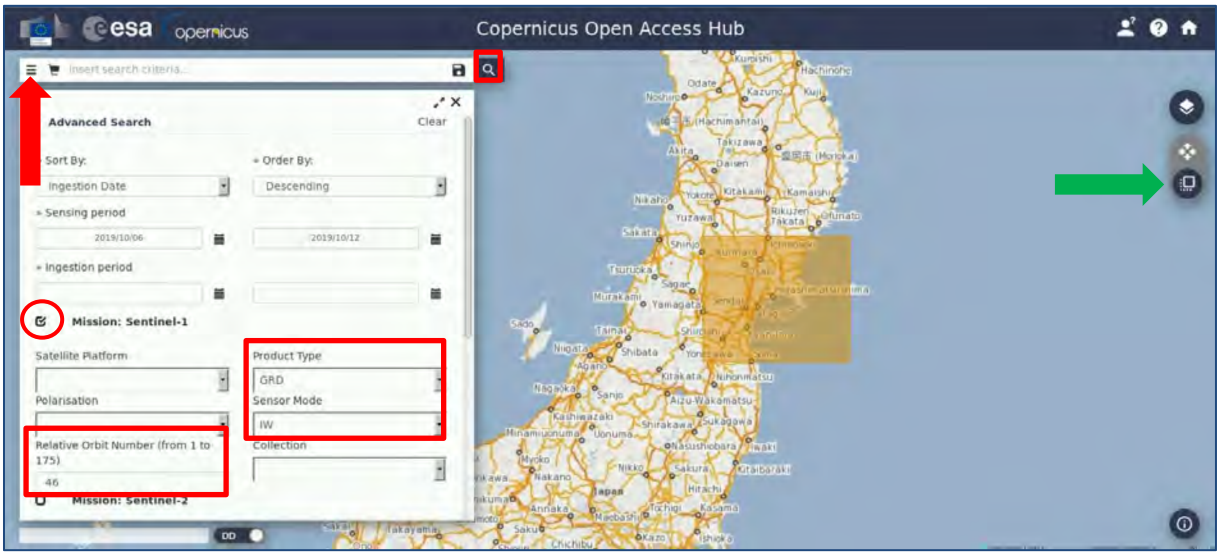


After you have filled in the registration form, you will receive an activation link by e-mail. Once your account is activated or if you already have an account, “**LOGIN**”.

Navigate on the map to the island of Honsu in Japan. Then change to the drawing mode (indicated by green arrow below) and draw a rectangle arround the city of Sendai.

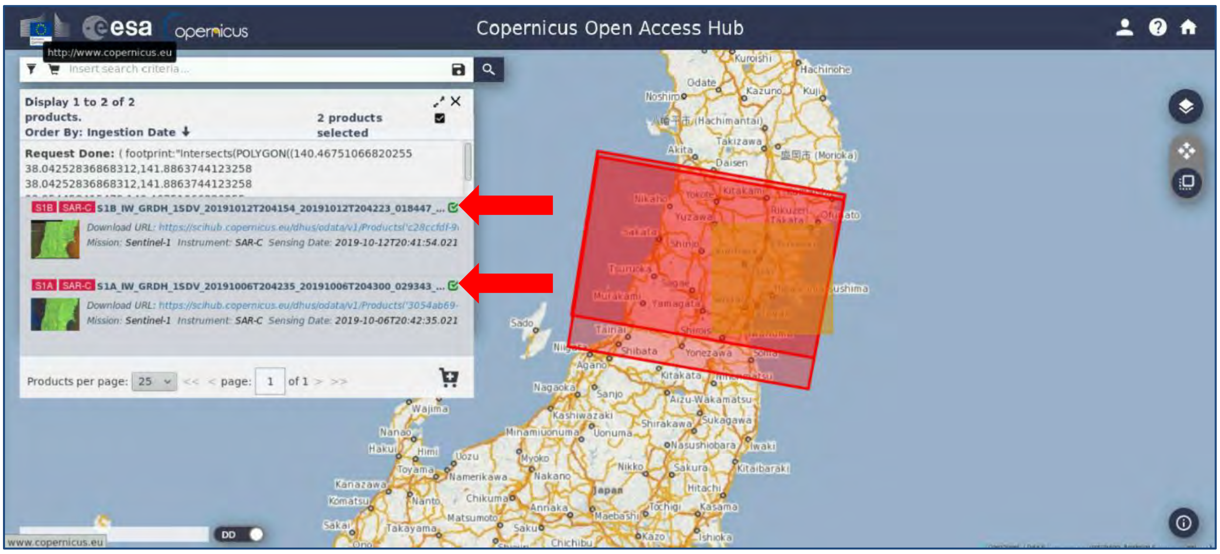
Open search menu by clicking to the left part of the search bar and specify following parameters:

Sensing period: From 2019/10/06 to 2019/10/12
Check Mission: Sentinel-1
Product Type: *GRD*
Sensor Mode: *IW*
Relative Orbit Number: *46*



Click on the magnifying glass symbol to start the search. In our case the search returns 2 results, but it will depend on the exact search rectangle you have defined.

TIP: It may sometimes happen that the data used to create this exercise are temporarily unavailable. In such case, you can use other date period for the same location.



Go through the list and select these **2 full** scenes by checking the box next to the product name:

- *S1B_IW_**GRDH**_1SDV_**20191012**T204154_20191012T204223_018447_022C0C_**B106***
- *S1A_IW_**GRDH**_1SDV_**20191006**T204235_20191006T204300_029343_0355EA_**C9CC***

Once they are all selected click on 🛒 to add the products to the cart. A little green cart symbol should appear next to the product name.

Then return to the search parameters and change them as follows:

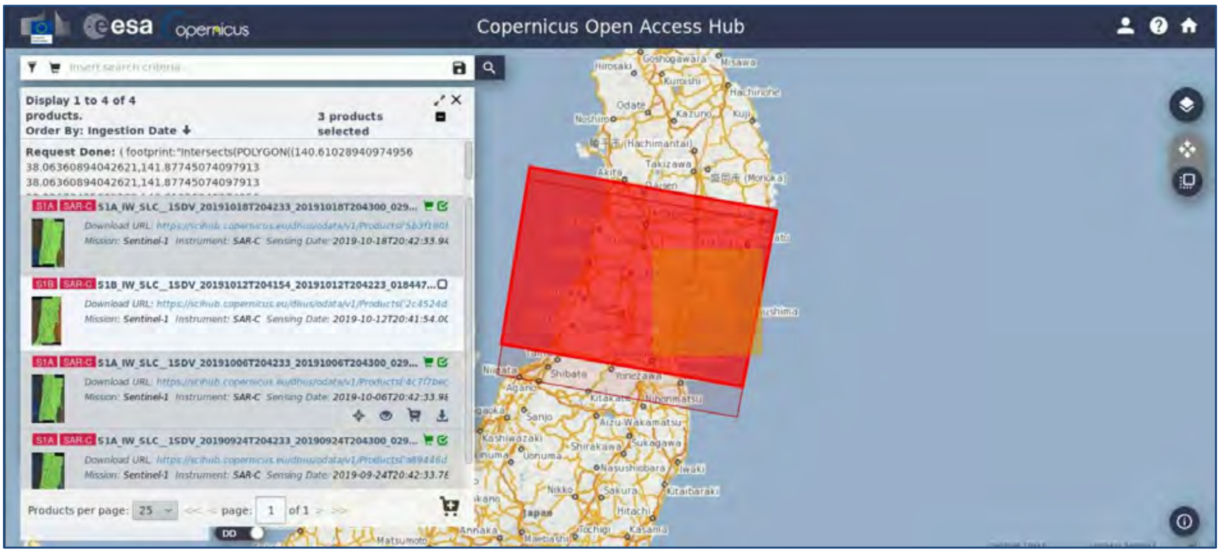
Sensing period: From 2019/09/24 to 2019/10/18
Check Mission: Sentinel-1
Product Type: *SLC*
Sensor Mode: *IW*
Relative Orbit Number: *46*

Then press search again. The search returns 4 results, but it will depend on the exact search rectangle you have defined.

Go through the list and select these **3 full** scenes by checking the box next to the product name:

- *S1A_IW_**SLC**__1SDV_**20191018**T204233_20191018T204300_029518_035BEF_**380F***
- *S1A_IW_**SLC**__1SDV_**20191006**T204233_20191006T204300_029343_0355EA_**AFB2***
- *S1A_IW_**SLC**__1SDV_**20190924**T204233_20190924T204300_029168_034FDF_**708B***

Once they are all selected click on 🛒 to add the products to the cart.



Then go to the cart by clicking on the green cart symbol left of the full text search. There should be 5 products in your cart.

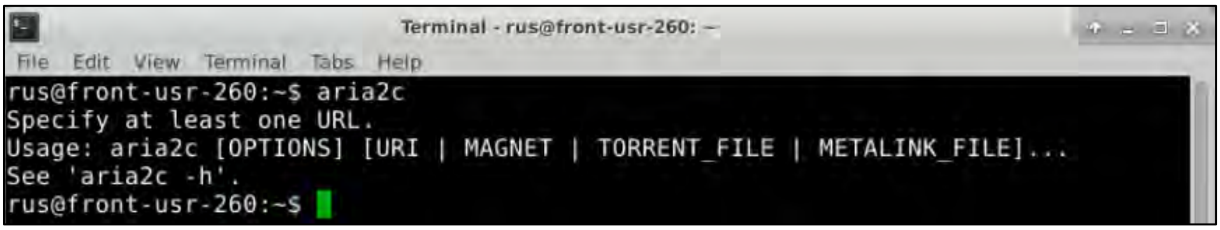
Finally, let's download the cart in the form of .meta file. The file contains links to each of the files, we will need the file and download client to download the actual data.

The *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 move the *products.meta4* file to the folder where we wish our data to be downloaded to - */shared/Training/HAZA06_WatchingATyphoon_Hagibis/Original/*

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

```
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/HAZA06_WatchingATyphoon_Hagibis/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 five products will be downloaded to the *Original* folder two products in parallel automatically (Note that the constraint of maximum two parallel downloads at a time is imposed by the Copernicus Access Hub, if you increase the number the download will fail). This might take some time.

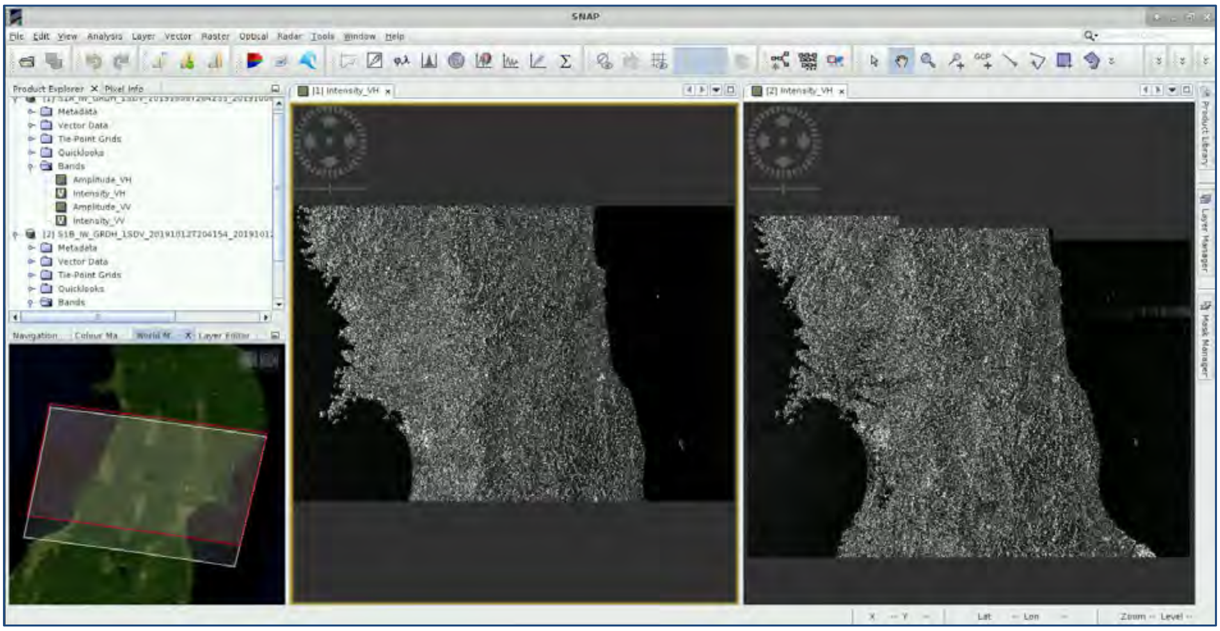
When the products are downloaded move them to the appropriate directories inside the ***/Original*** folder based on the product type.

6.2 Storm Surge and flooding – Sentinel-1 GRDH

In the first part of this exercise we will identify the area flooded when typhoon Hagibis made a landfall on 12 October 2019. We will use the Ground Range Detected (GRD) data, which consist of focused SAR data that has been detected, multi-looked and projected to ground range using an Earth ellipsoid model. Phase information is lost.

Launch SNAP . When SNAP window opens click Open product , navigate to */shared/Training/HAZA06_WatchingATyphoon_Hagibis_TutorialKit/Original/GRDH* and open the *.zip files.

The opened products will appear in **Product Explorer**. Click **+** or the to expand the contents of the file from 6 October 2019, then expand Bands and double click ***Amplitude_VV*** to visualize the band. Then do the same for the image from 12 October 2019. To compare both images, go to **Window → Tile Horizontally** and zoom-in to the coastal area on the mid left side of the image.



TIP: We can see that the view appears “mirrored to the side”: this is because the scene was acquired during descending pass (the satellite was moving in north to south direction looking to the west) and the view shows the pixels in order of data acquisition as the image is not yet projected into cartographic coordinates.

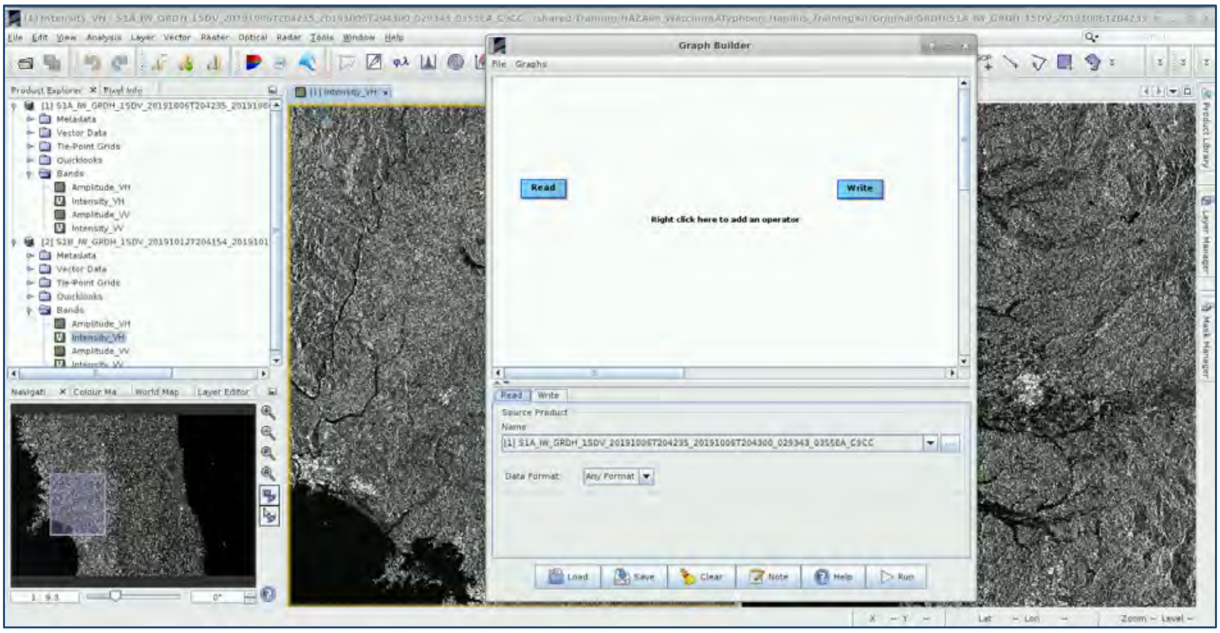
6.2.1 Pre-processing

We need to apply identical pre-processing steps to all our scenes. However, processing the data step by step and product by product would be time consuming and inconvenient. Luckily, we can use the

Batch Processing tool available in SNAP to apply all steps to both images in one go (this also saves disk space as only the final products are physically saved).

6.2.1 Build the Graph

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**. To build our 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).

First, we will update the orbit metadata (See NOTE 2). To add the operator, right-click the white space between existing operators and go to **Add → Radar → Apply-Orbit-File.** A new operator rectangle appears in our graph and a new tab appears below. Now connect the new **Apply-Orbit-File** operator to the **Read** operator by clicking to the right side of the **Read** operator and dragging the red arrow towards the **Apply-Orbit-File.**

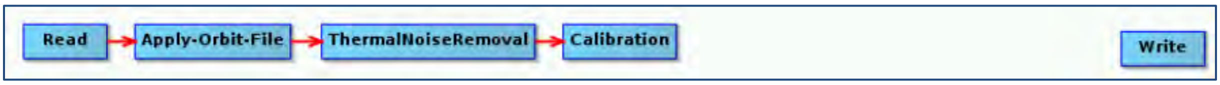
> NOTE 2: The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with the precise orbit files which are available days-to-weeks after the generation of the product. The orbit file provides accurate satellite position and velocity information. Based 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 3). We do this by right-clicking the white space and going to **Add → Radar → Radiometric → ThermalNoiseRemoval.** Connect the **ThermalNoiseRemoval** operator with the **Apply-Orbit-File** operator.

> NOTE 3: 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.

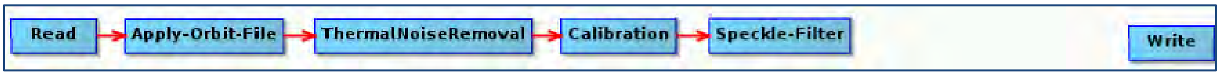
Now, we can add the **Calibration** operator. The objective of SAR calibration is to provide imagery in which the pixel values can be directly related to the radar backscatter. Though uncalibrated SAR imagery is sufficient for qualitative use, calibrated SAR images are essential to quantitative use of SAR data (See NOTE 4). To add the operator go to **Add → Radar → Radiometric → Calibration.** Connect the **ThermalNoiseRemoval** operator to the **Calibration** operator.

> NOTE 4: 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*)



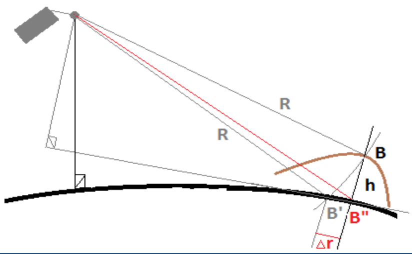
SAR images have inherent salt and pepper like texturing called speckles which degrade the quality of the image and make interpretation of features more difficult (See NOTE 5). To reduce the speckle effect and smooth the image we apply speckle filter. To add the operator, go to **Radar → Speckle Filtering → Speckle-Filter** then connect the **Calibration** operator to it.

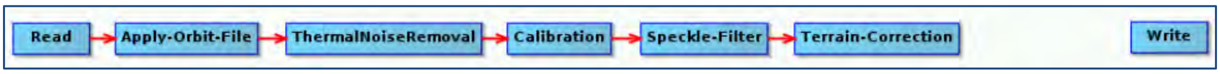
> NOTE 5: Speckle is caused by random constructive and destructive interference of the de-phased but coherent return waves scattered by the elementary scatters within each resolution cell. Speckle noise reduction can be applied either by spatial filtering or multilook processing. (*SNAP Help*)



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 pre-processing, we will apply terrain correction to compensate for the distortions and reproject the scene to geographic projection (See NOTE 6). To add the operator, go to **Radar → Geometric → Terrain Correction → Terrain-Correction** and then connect the **Speckle-Filter** operator to it.

> NOTE 6: 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)*





Next, since our Area of Interest (AOI) is quite small and there is no need to process the whole image, so we will add a **Subset** operator. To add the operator right-click the white space in the graph builder and go to **Add → Raster → Geometric → Subset.** Connect the new **Terrain-Correction** operator to the **Subset** operator.

Finally, we will convert the values to decibel to enhance the contrast. To do this go to **Raster → Data Conversion → LinearToFromDb**. Then connect the **Subset** operator to it and connect the **LinearToFromDb** operator to the **Write** operator.

For the moment, do not change anything in the parameter tabs and save the graph as ***Graph_preprocess.xml*** to: ***/shared/Training/Training/HAZA06_WatchingATyphoon_Hagibis/Processing/Flood_mapping/*** by clicking **Save** at the bottom of the window. After you save the graph, close the **GraphBuilder** window.

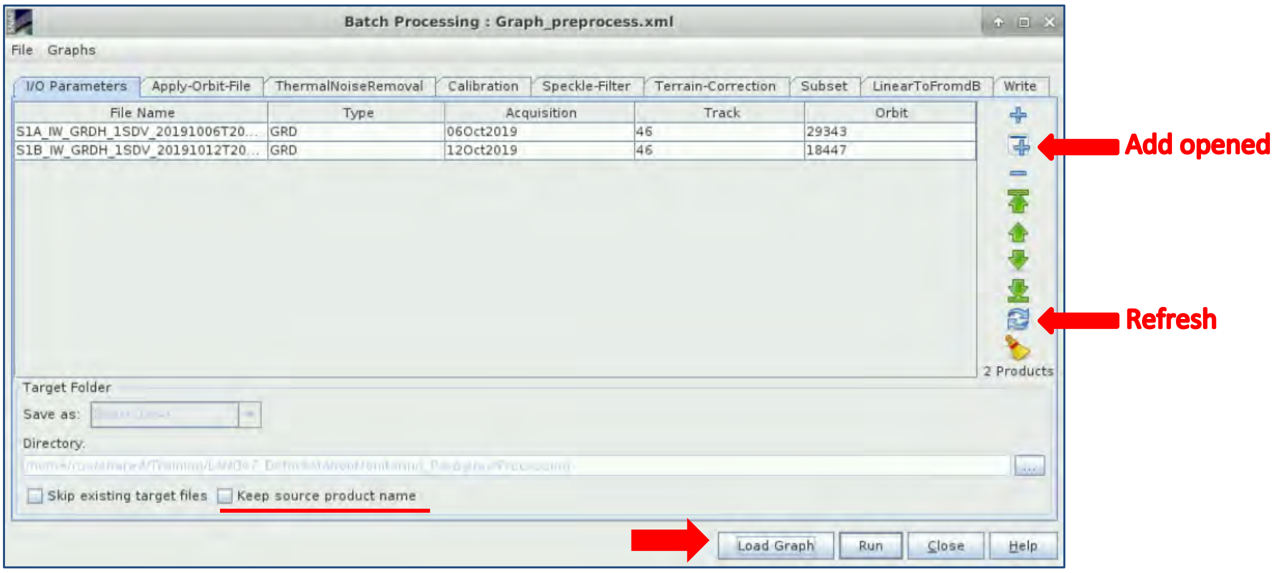
6.2.2 Batch processing

In the **Product Explorer**, we select (highlight) the product [1]. Now we can open the **Batch Processing** tool at **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 click **Load Graph** at the bottom of the window and navigate to our saved graph and open it. We see that new tabs have appeared at the top of window corresponding to our operators except for **Write**; this is correct as these parameters will be set in the **I/O Parameters** tab.

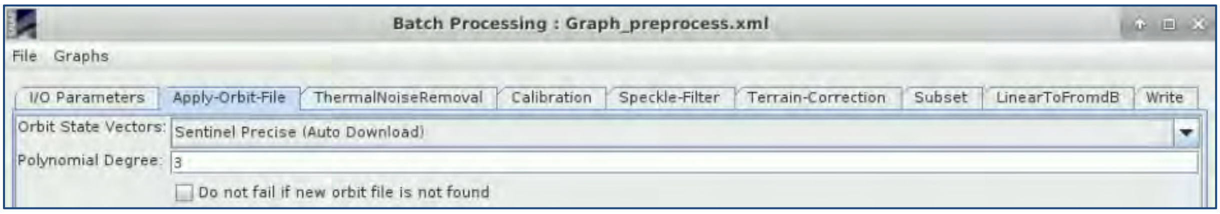
In the **I/O Parameters** tab, set directory to: ***/shared/Training/Training/HAZA06_WatchingATyphoon_Hagibis/Processing/Flood_mapping/*** and deselect the "**Keep source product name**" option. (See NOTE 7).

> NOTE 7: The product file names will be identical to the input file names. If you set your output directory to the folder that contains your input data, the input data will be overwritten!

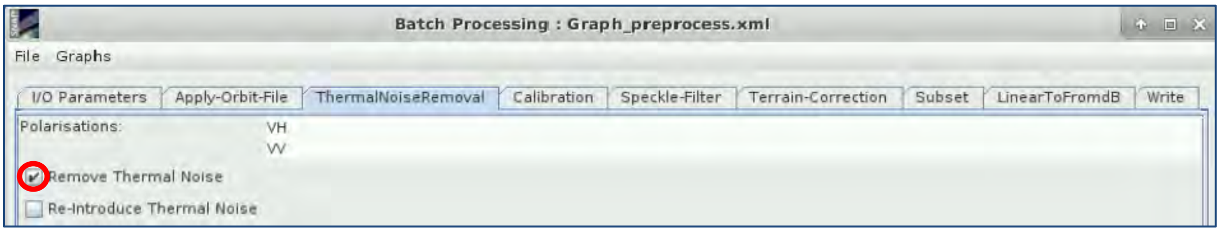


Now let's set the parameters.

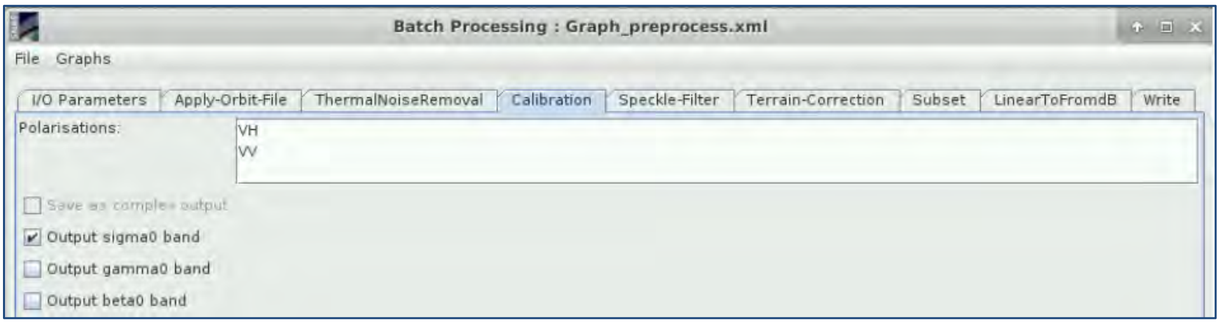
In the **Apply-Orbit-File** tab we well keep the default settings.



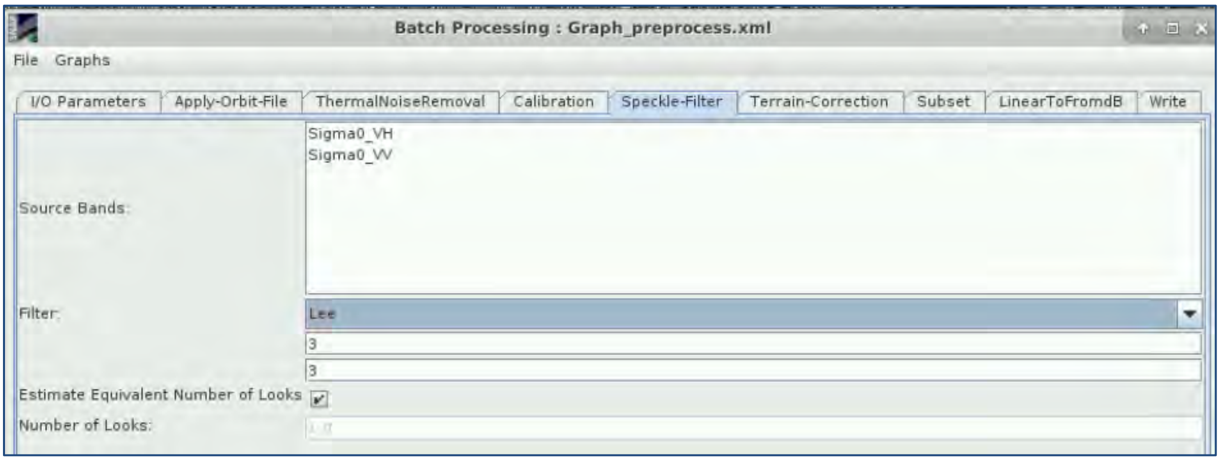
In the **ThermalNoiseRemoval** tab, select **VV** polarization and make sure that the "**Remove Thermal Noise**" option is selected.



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



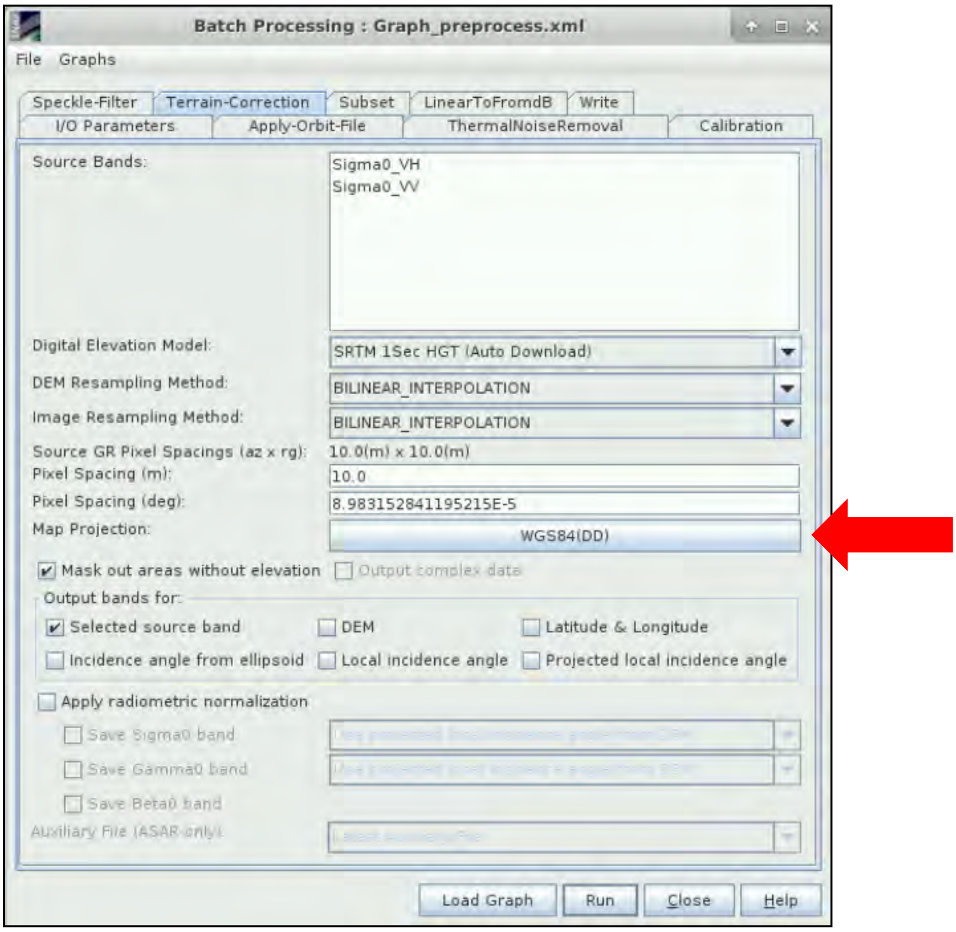
Now we go to the **Speckle-Filter** tab. For this exercise we choose the simple **Lee** filter with **Window Size** of **3x3** pixels (See NOTE 8).

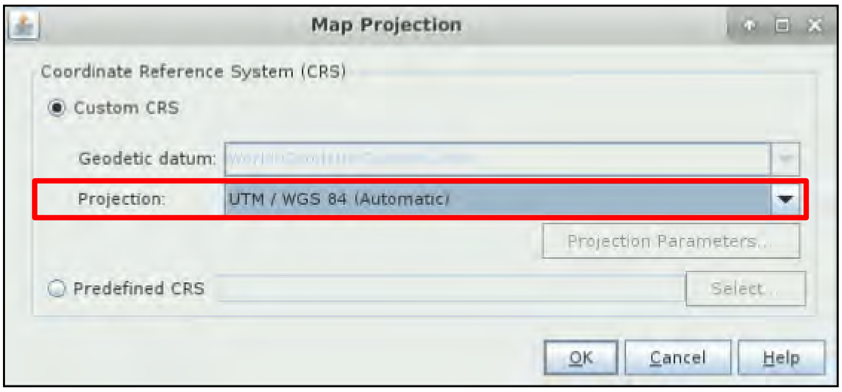


NOTE 8: Lee Filter, introduced by Jong-Sen Lee in 1980, is a widely used local statistics filter for speckle noise reduction. It is a pointwise linear filter minimizing the mean square error using measurements of the sample mean and sample variance of the noisy image and knowledge of the type of detection and number of looks.

Last, we go in the **Terrain-Correction** tab, set **Digital Elevation Model** to ***SRTM 1Sec HGT (Auto Download)***, then click on the **Map Projection** and set as Projection**: UTM / WGS84 (Automatic)**.

Click **OK**. At the “Map Projection” you will see: UTM Zone 36, South / World Geodetic System 1984.

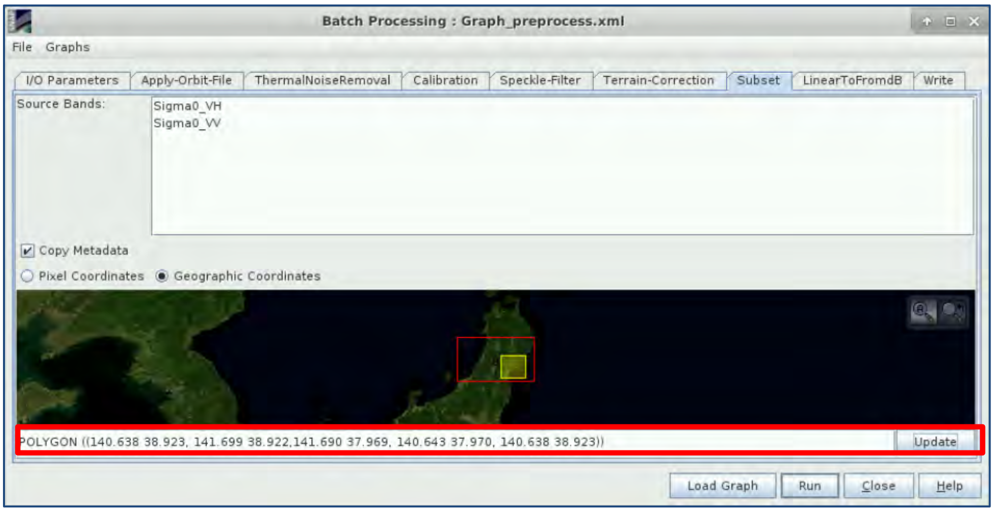




Leave all the other default settings.

In the **Subset** tab, click to select the **Geographic Coordinates** option and paste the area of interest definition in WKT (well know text) format to the text window below the map. Click **Update** and then click the **Zoom-in** icon to see your subset on the map.

```
POLYGON ((140.638 38.923, 141.699 38.922,141.690 37.969, 140.643 37.970, 140.638
38.923))
```



In the **LinearToFromdB**, leave the default settings. Finally, in the **Write** tab, set the output folder to: ***/shared/Training/Training/HAZA06_WatchingATyphoon_Hagibis/Processing/Flood_mapping/***

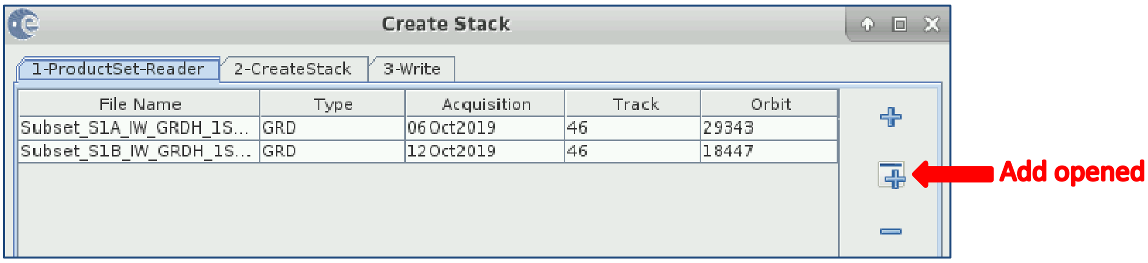
Click **Run** to pre-process our images. *Approximate processing time: 5 minutes*
Now you should have two new products in the **Product Explorer**. Select the original products [1-2], right-click on them and click **Close 2 Products** (Click **No** if asked to save).

6.2.3 Stack

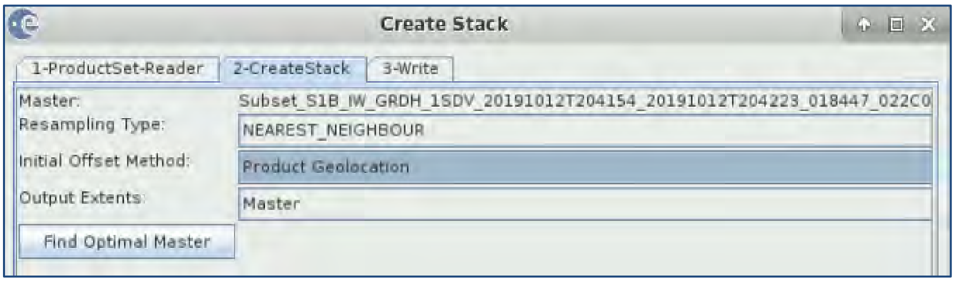
In this step we will stack our images into a single product to be able to compare the changes in values due to the flooded area.

To create a stack, we will go to **Radar → Coregistration → Stack Tools → Create Stack**.

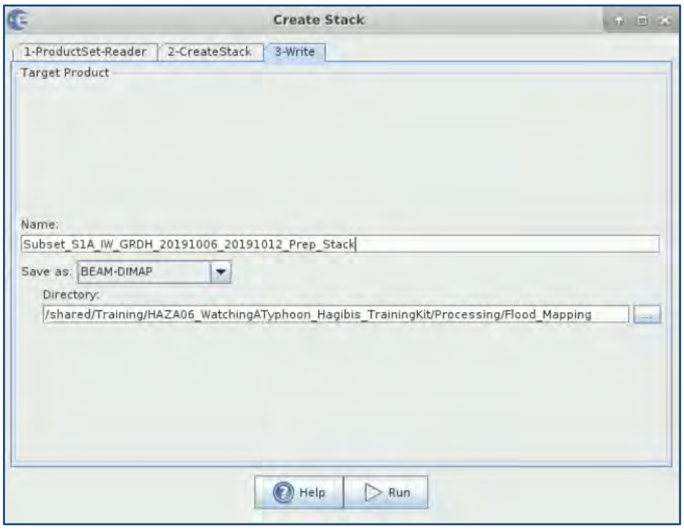
Similarly, as in Batch Processing, in the **1-ProductSet-Reader** tab, we will add the opened products by clicking **Add Opened** on the upper right (second icon from the top) and click **Refresh**.



Then in the **2-CreateStack** tab, click on ***Find Optimal Master*** and set:
Resampling Type: *NEAREST_NEIGHBOUR*
Initial Offset Method: *Product Geolocation*



In the **3-Write** tab, rename the product to ***Subset_S1A_IW_GRDH_20191006_20191012_Prep_Stack*** and change the Directory to:
/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Flood_Mapping

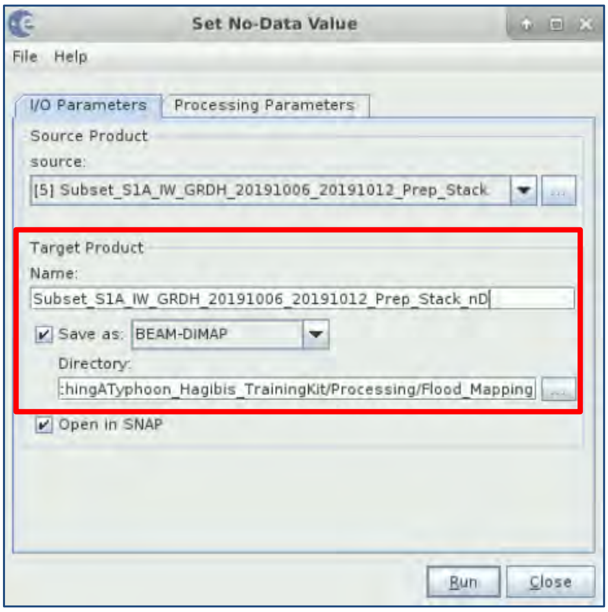


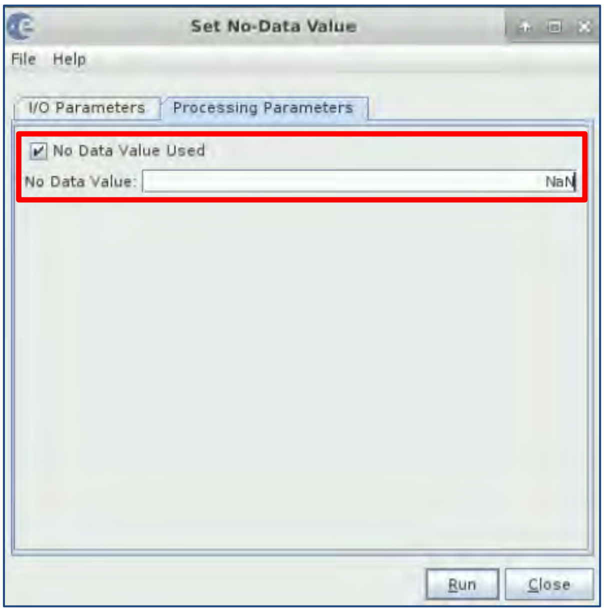
Then click **Run**. *Approximate processing time: 45 seconds*

In the next step we will reassign the NoData value to NaN ("Not a Number") to facilitate better visualization later. Go to **Raster → Data Conversion → Set No-Data Value**.

In the **I/O Parameters** tab, make sure that product [5] is selected and directory is set to ***.../Flood_Mapping*** and add ***"_nD"*** to the output name. In the **Processing Parameters** tab, set:

No Data Value: *NaN*

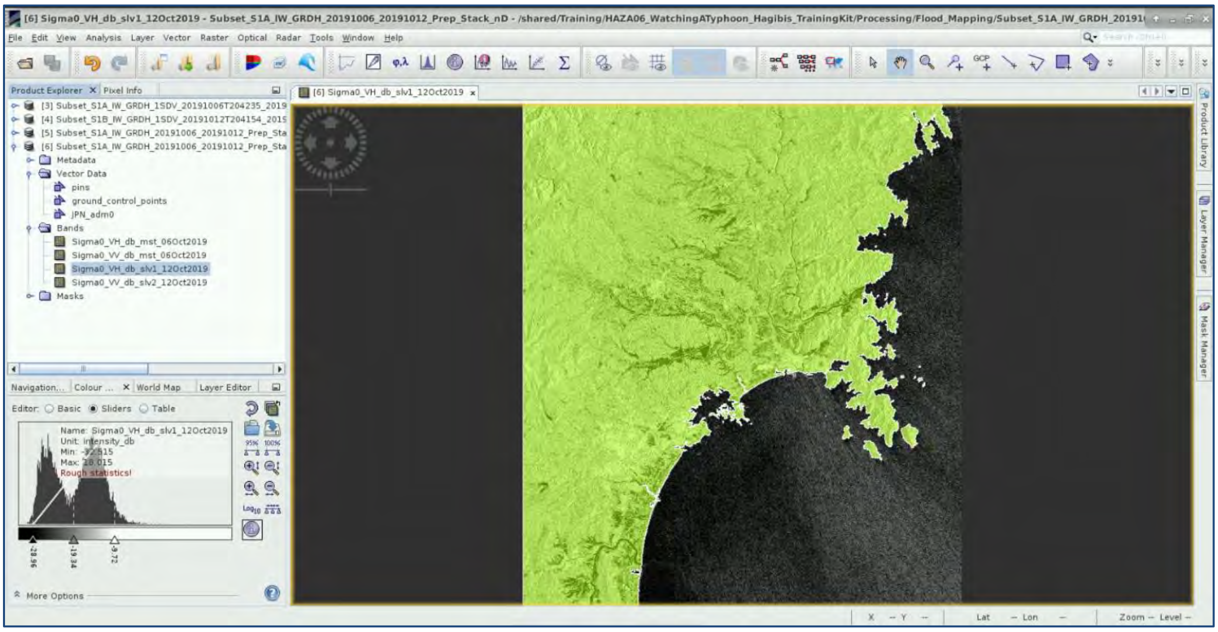




Click **Run**.

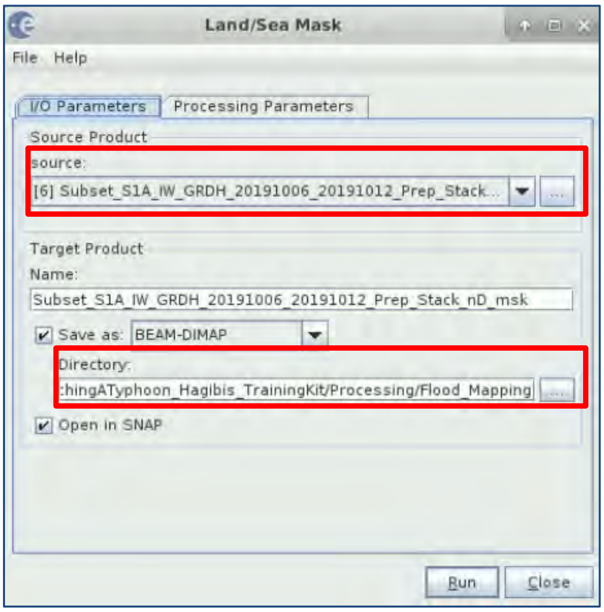
In the last step we will mask out the open ocean to make to the comparison clearer. To do this we will use a shapefile of Japan land mass. In the **Product Explorer** go to the stack product with No Data [6] and click on it to highlight it, then from *Bands* open *Sigma0_VH_db_slv1_12Oct2019* (double click). Then go to **Vector → Import ESRI Shapefile**.

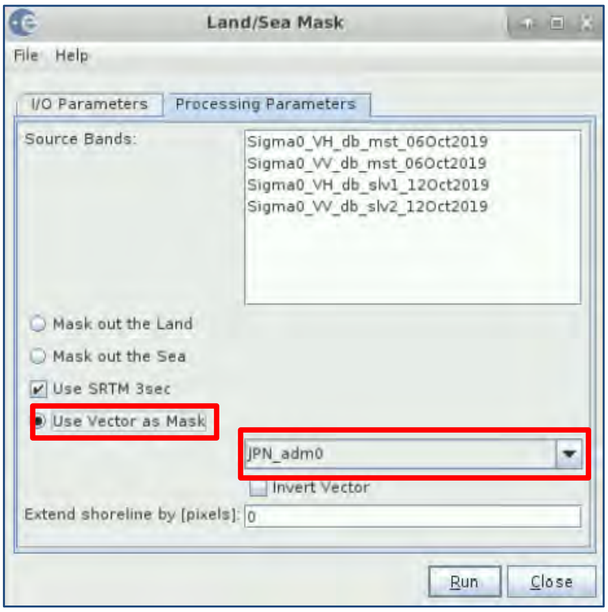
Navigate to ***/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/AuxData/Shapefile*** and select ***JPN_adm0.shp***, click **Open**. The shapefile will be overlaid on top of the view. It will also appear in the *Vector Data* folder in the product.



Then to apply the mask we will go to **Raster → Masks → Land/Sea Mask**.

In the **I/O Parameters** tab, make sure that product [6] is selected and directory is set to ***.../Flood_Mapping***. In the Processing Parameters tab, set ***"Use Vector Mask"*** the loaded vector ***JPN_adm0*** should be selected automatically.





Then click **Run**.

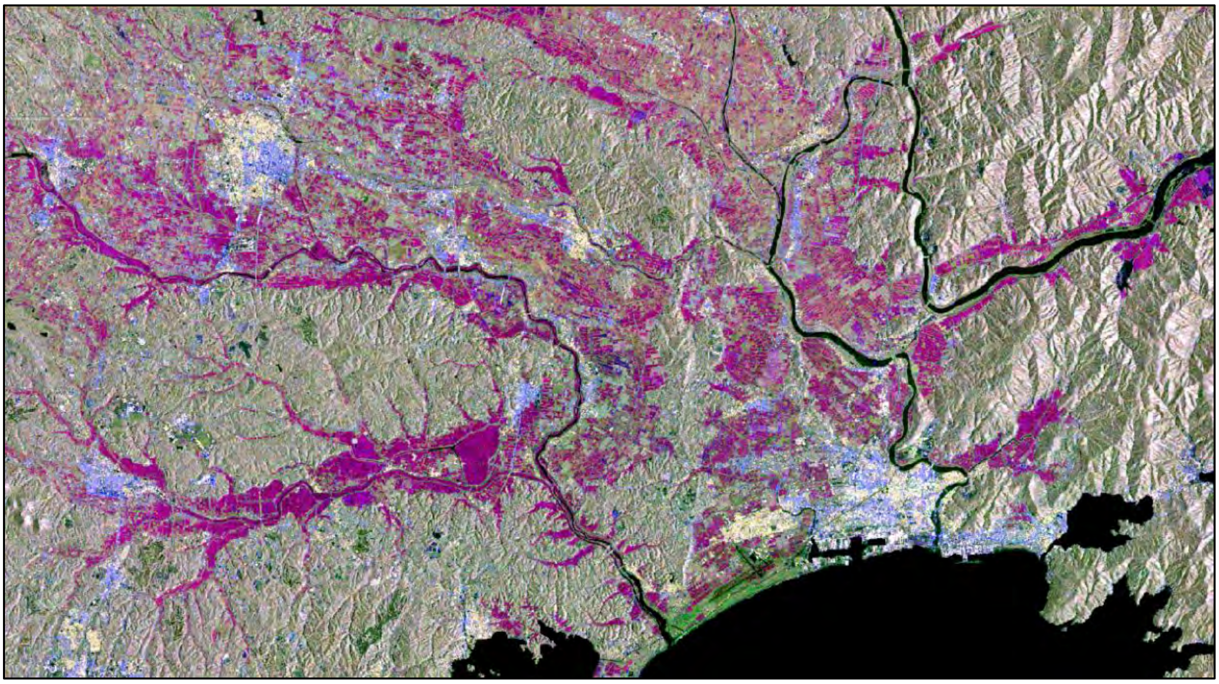
When the new product appears in the **Product Explorer**, go to the masked product [7] and in the ***Vector Data*** folder right-click on *JPN_adm0* and delete it.

Now, we can visualize multitemporal RGB composites to better identify the flooded area. First close all views if any are opened.

Now, in the **Product Explorer** right-click on the stack product [7] and go to **Open RGB Image Window**. (See NOTE 9).

Set: **Red:** $7.Sigma0_VH_db_mst_06Oct2019
Green: $7.Sigma0_VH_db_slv1_12Oct2019
Blue: $7.Sigma0_VV_db_mst_06Oct2019

NOTE 9: In this band combination the areas that appear purple represent pixels that were darker during the flood event than before → new open water surfaces. Brighter green areas represent pixels that are brighter during the event compared to pre event image → Wet soil and semi submerged vegetation. Blue and white areas represent build up.

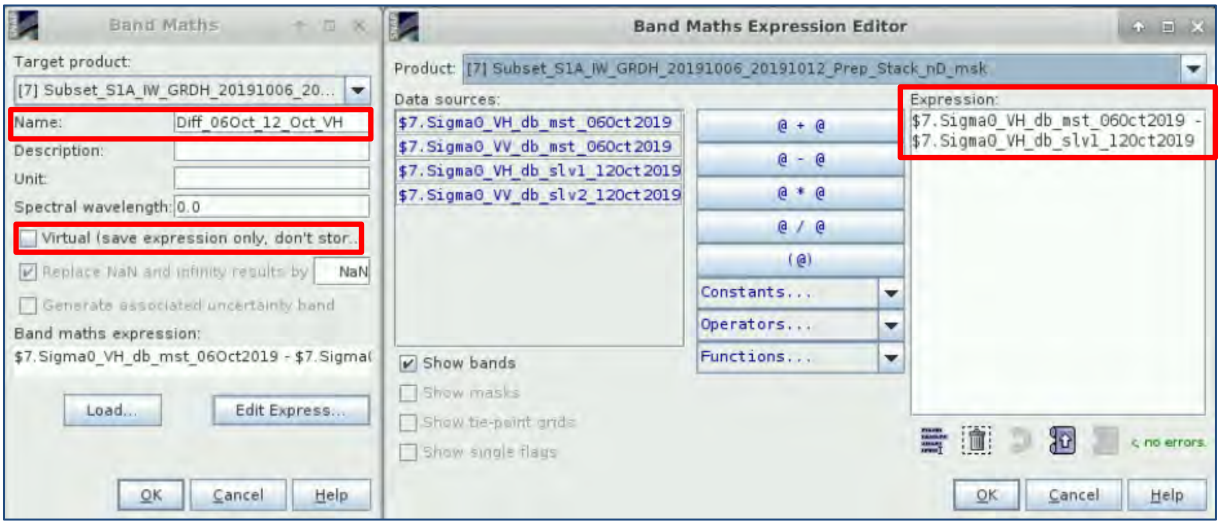


To separate new open water areas, we can use multiple methods. We can use classification, single band thresholding or difference-band thresholding among others. As is visible on the image above, flooded areas with open water will have significantly lower backscatter in VH than they had before the event (not flooded). Therefore, by subtracting the VH band of 12 October (during the event) from the VH band of 6 October (before the event) we should be able to isolate them.

In the **Product Explorer**, right-click on the masked product [7] and go to **Band Maths …** In the menu that appears set:

Name: *Diff_06Oct_12Oct_VH*
Deselect Virtual (save expression only don't save data)
Click on **Edit Expression…** and set as **Expression:**

```
Sigma0_VH_db_mst_06Oct2019 - Sigma0_VH_db_slv1_12Oct2019
```

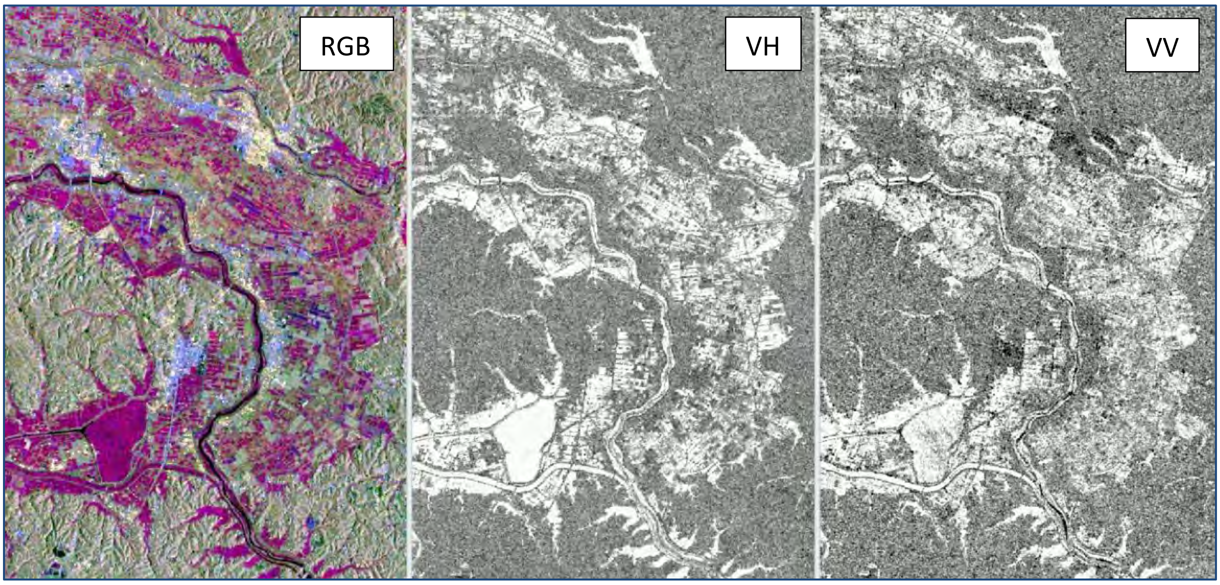


Click **OK**. The new band will be immediately opened in view. Repeat the step for VV.

Name: *Diff_06Oct_12Oct_VV*
Deselect Virtual (save expression only don't save data)
Click on **Edit Expression…** and set as **Expression:**

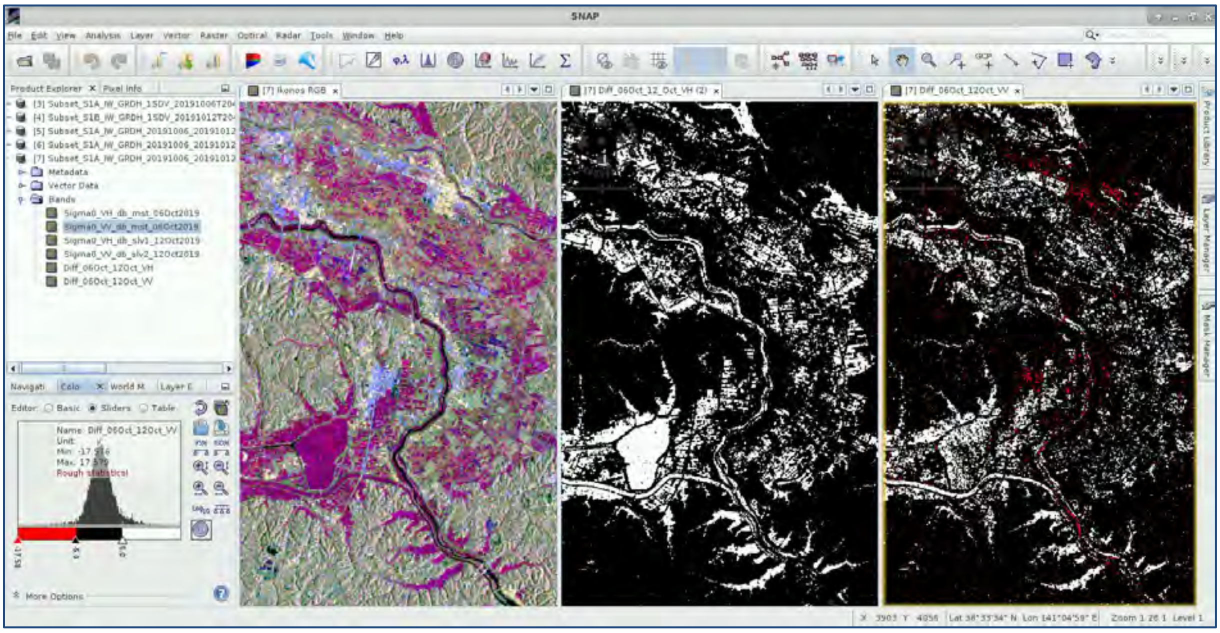
```
Sigma0_VV_db_mst_06Oct2019 - Sigma0_VV_db_slv2_12Oct2019
```

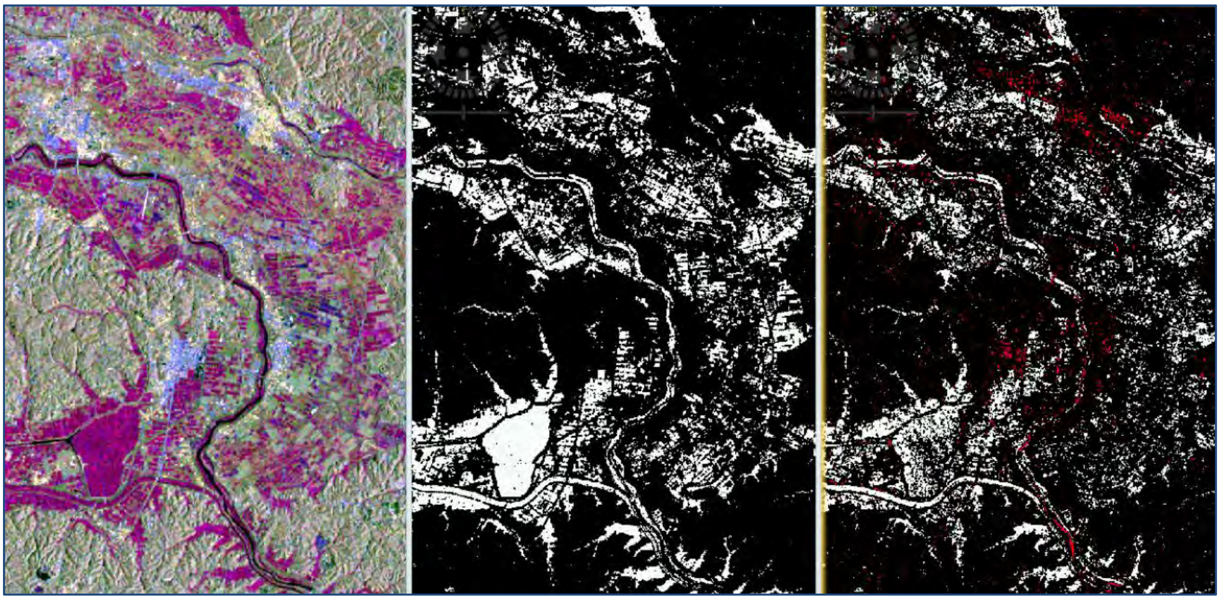
Once the band is opened go to **Window → Tile Horizontally**.



Click into the VH View and go to **Colour Manipulation** tab, right click on the middle slider and remove it (click on Delete). Then move the white slider to ***6.0***. at the bottom of the tab go to **More Options** and select **Discrete colours**.

For VV do not delete the middle slider but set it to ***-5.0*** set the white threshold to ***5.0***. We can also change the colour of the sliders by clicking on them (In this example we have changed the black slider to red and the grey to black).





The red areas in VV then correspond to areas where is potentially submerged vegetation as VV generally penetrates deeper in canopy than VH and newly submerged vegetation can appear brighter. However, the brighter values can also be caused by wet bare soil (higher backscatter due to higher dielectric constant).

We can apply the same thresholds using **Band Math …** to create binary bands with conditional expressions.

VH:

```
if Diff_06Oct_12Oct_VH > 6.0 then 1 else 0
```

VV:

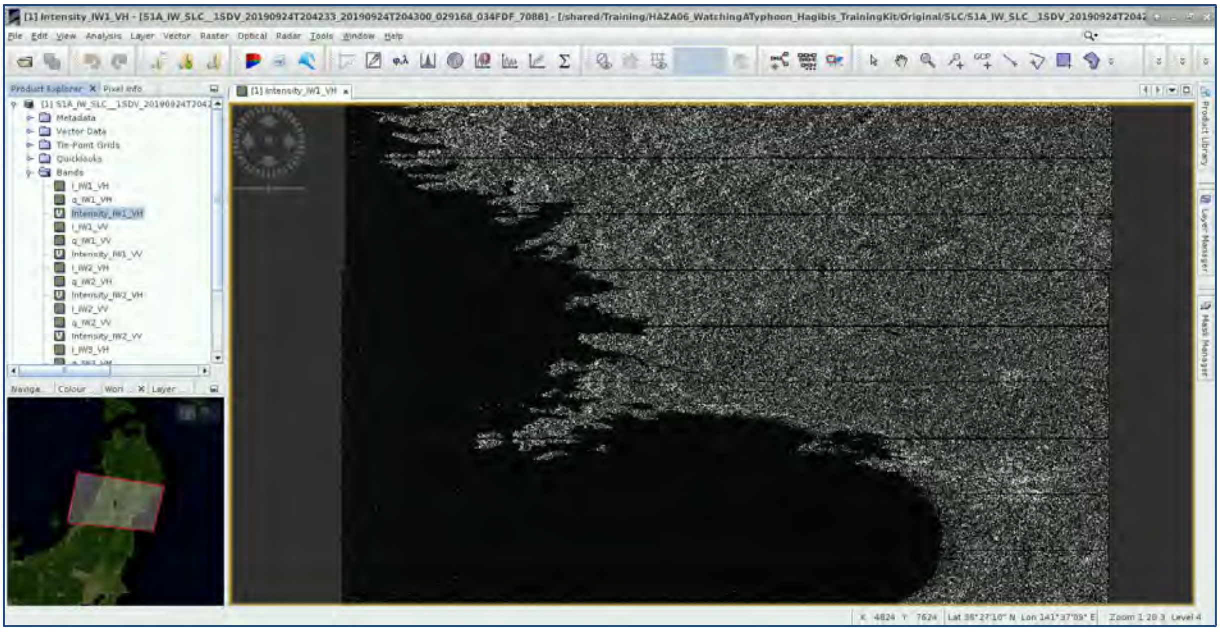
```
if Diff_06Oct_12Oct_VV > 5.0 then 1 else (if Diff_06Oct_12Oct_VV > -5.0 then 0 else -1)
```

6.3 *Damage detection – Sentinel-1 SLC*

In the second part of this exercise we will calculate difference in coherence for a pair prior to the event and a pair during the event. Then we can identify the areas with significant coherence loss presumed expected to correspond to damaged areas due to surface damage.

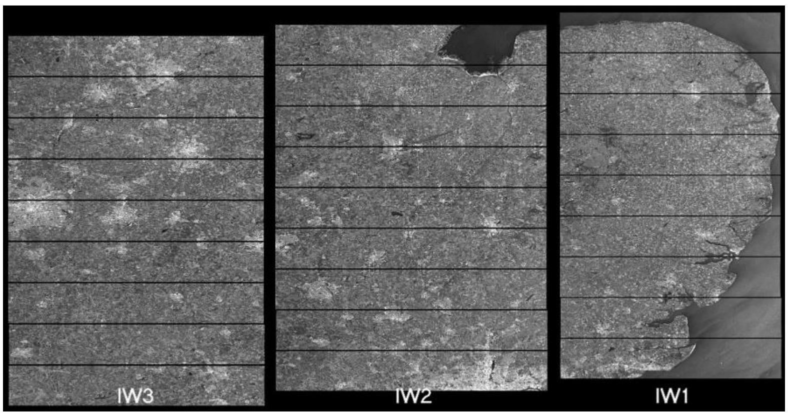
Re-start SNAP (). When SNAP window opens click Open product , navigate to */shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Original/SLC* and open the three *.zip files.

The opened products will appear in the **Product Explorer** on the left. Expand the first image to the left and select Bands. Right click on the "*Intensity_IW1_VH*" and select **Open Image Window** to create and visualize the image for the selected band. (See NOTE 10).



The image appears in the upper left corner of the **View** window. Do the same for the next products. To synchronize the views, go to **Navigation** pane in the lower left (red arrow) and make sure the cursor and the views are linked.

NOTE 10: The Interferometric Wide (IW) swath mode captures three sub-swaths using Terrain Observation with Progressive Scans SAR (TOPSAR). Each sub-swath image consists of a series of bursts. The input product contains 3 IW bands, and 9 bursts.



Credits: ESA User Guides for Sentinel-1 SAR

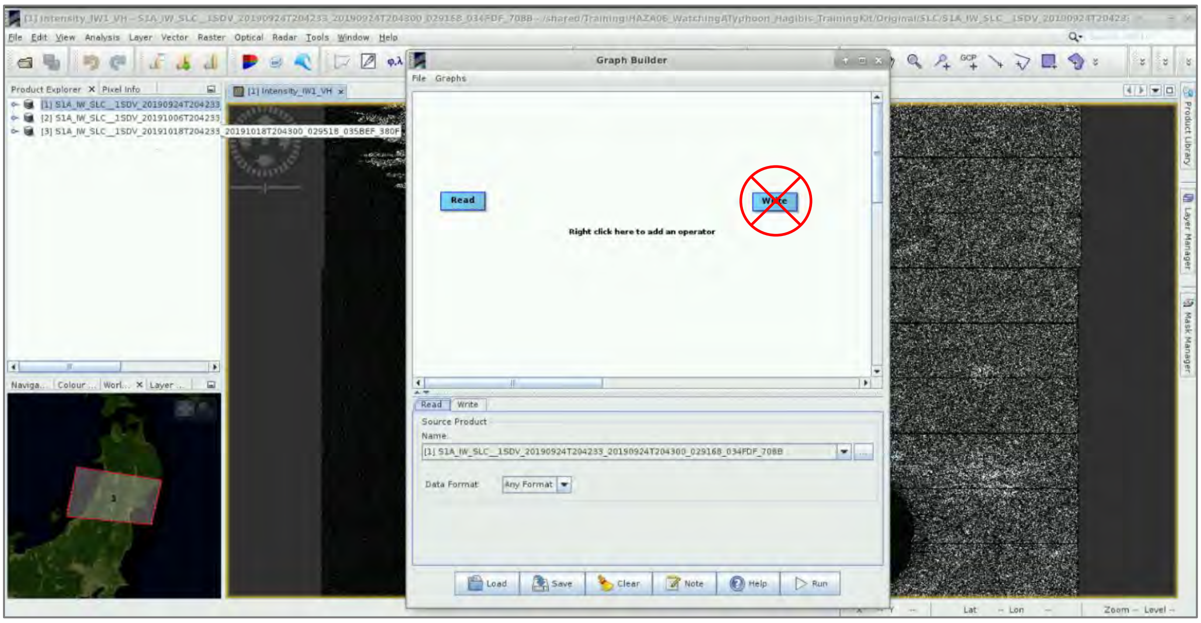
6.3.1 Coherence Estimation

Although in this step we cannot use batch processing we can use the graph builder to simplify the process instead of running each step manually. Therefore, the processing chain we will follow will be represented by a graph and saved as an XML file.

In order to open **Graph Builder** tool, go to **Tools → GraphBuilder**.

Initially, the graph has two operators: **Read** (to read the input) and **Write** (to write the output). First, **DELETE** the **Write** operator (right-click on it and select *Delete*).

With right-click on the top panel, you can add an operator, while a corresponding tab with all involving parameters is created and added on the bottom panel.



Our aim is to produce two coherence images that correspond accordingly to the period prior and during the event. For each we have to create a graph and process the image pair. Let's start with the first coherence image, for the pre-event period, by using the images of 24 September and 6 October 2019.

In the **Read** operator, select the input image:

*S1A_IW_SLC__1SDV_**20190924**T204233_20190924T204300_029168_034FDF_**708B***

To add a new **Read** operator for the second image, go to **Add → Input-Output → Read**. It will be denoted as **Read(2).** Then, select as input image:

*S1A_IW_SLC__1SDV_**20191006**T204233_20191006T204300_029343_0355EA_**AFB2***

Since the area of interest is included only in six bursts of the Sentinel-1 image, there is no need to process the entire sub-swath with all 9 bursts (See NOTE 11). The TOPSAR Split operator provides a convenient way to split each sub-swath with selected bursts into a separate product. To add the **S-1 TOPSAR Split** operator click **Radar → Sentinel-1 TOPS → S-1 TOPS Split.**

> NOTE 11: The extraction of bursts in a sub-swath covering the area of interest may differ in Sentinel-1 images acquired on different dates.

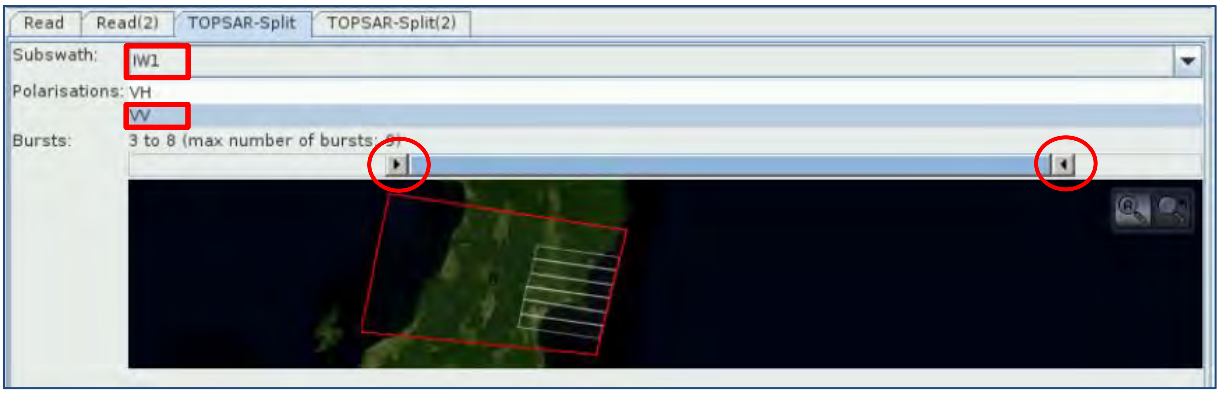
A new operator rectangle appears in our graph and a new tab appears below. Now connect the new **TOPSAR Split** operator with the first **Read** operator by clicking to the right side of the **Read** operator and dragging the red arrow towards the **TOPSAR Split** operator.

Repeat the same for the **Read(2)** operator to have graph as shown below.

In the **TOPSAR Split** tab, select the following parameters.

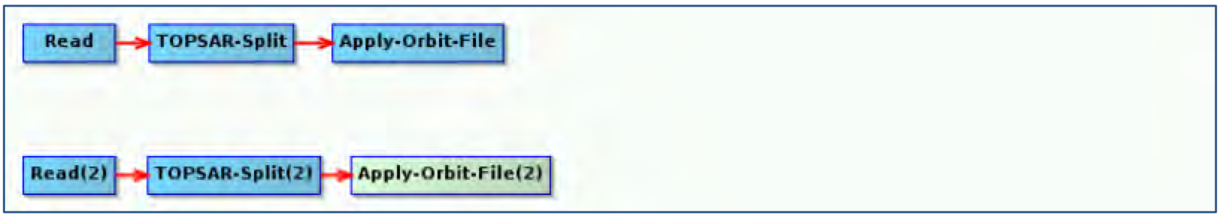
Subswath: IW1
Polarisations: VV
Bursts: 3 to 8

In bursts selection click on the arrows and drag up to the specified number of bursts.



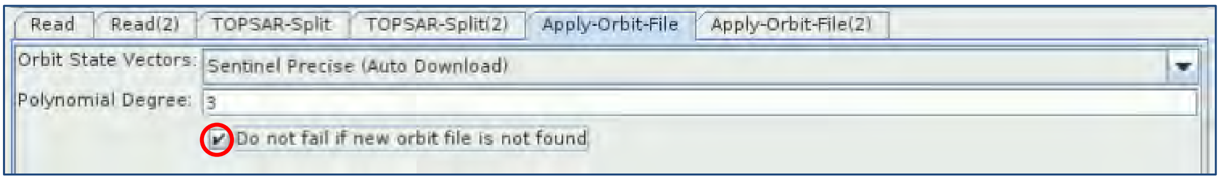
Repeat the same step for the **TOPSAR Split(2)**.

We now continue by applying the orbit files in Sentinel-1 products in order to provide accurate satellite position and velocity information. To add the operator, right-click to the right of the **TOPSAR-Split** operator and go to **Add → Radar → Apply-Orbit-File**, then connect the new operator to the **TOPSAR-Split**. Now do the same to add the **Apply-Orbit-File(2)**.



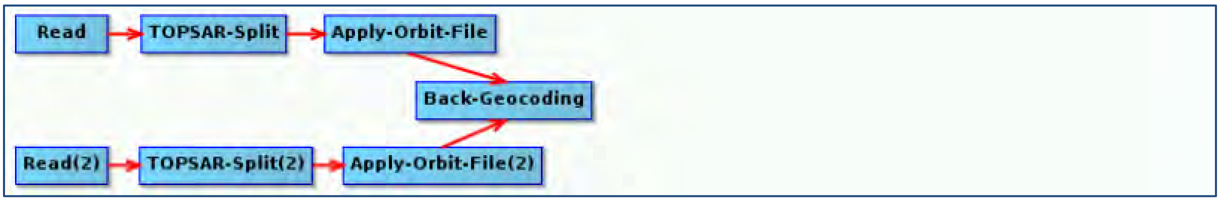
In the **Apply-Orbit File** tab, select the parameters:

Orbit State Vectors: Sentinel Precise (Auto Download)
Check "**Do not fail if new orbit file is not found**"

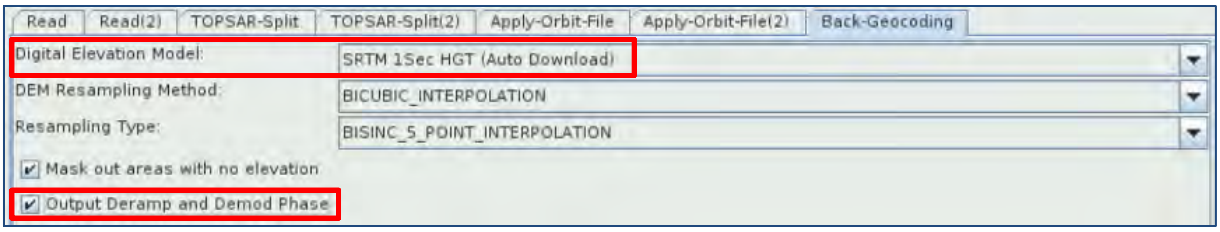


Now set the same parameters for the **Apply-Orbit-File(2)** operator.

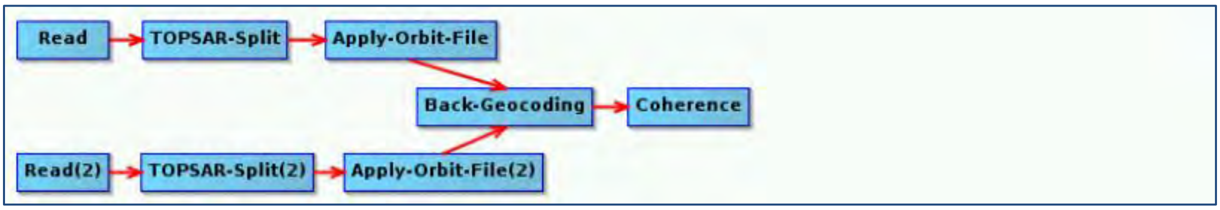
Next step will be to co-register the two Sentinel-1 images. For this reason, the second image (slave) will be co-registered with respect to the first image (master). Sentinel-1 **Back Geocoding** operator co-registers two S-1 split products (master and slave) of the same sub-swath using the orbits of the two products and a Digital Elevation Model (DEM). Right-click somewhere between the **Apply-Orbit-File** operators and go to **Add → Radar → Coregistration → S-1 TOPS Coregistration → Back-Geocoding.** Connect the **Back-Geocoding** operator with BOTH the **Apply-Orbit-File** operators.



In the **Back-Geocoding** tab, set *SRTM 1Sec HGT* as **Digital Elevation Model** to use and check **Output Deramp and Demod Phase**.

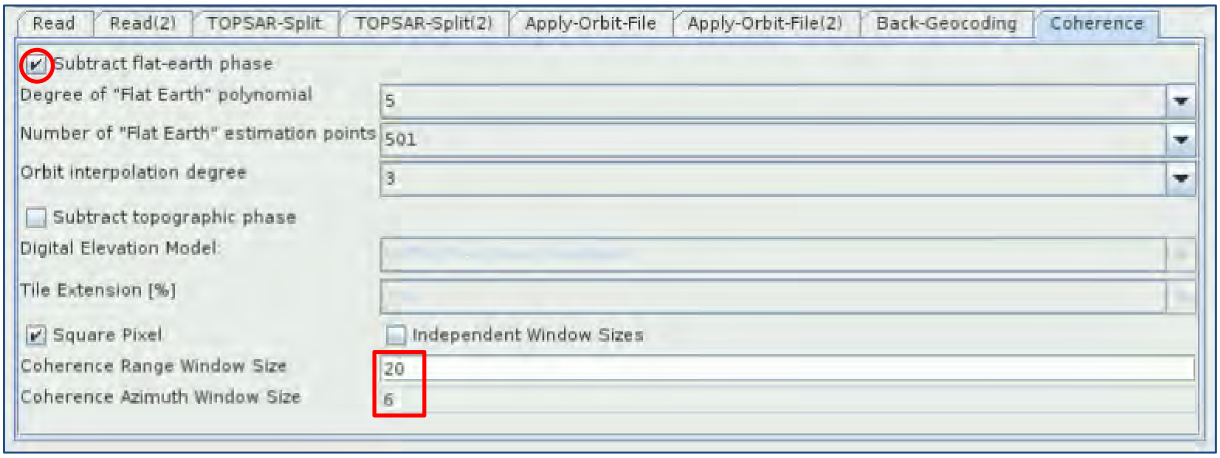


In this step, the coherence image is estimated from the stack of the coregistered complex images. To add the **Coherence** operator go to **Add → Radar → Interferometric → Products → Coherence** and then connect the **Coherence** operator to **Back-Geocoding** operator.

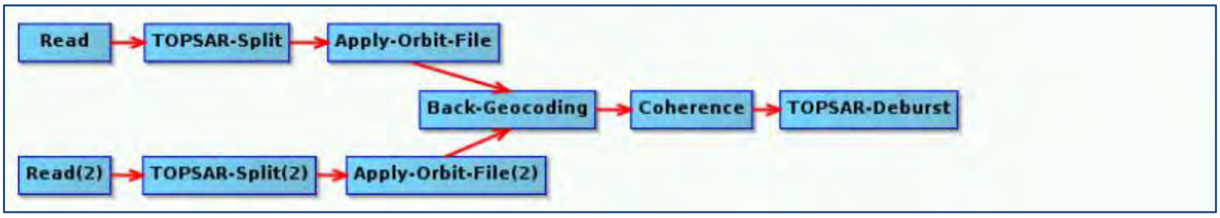


In the **Coherence** tab set the following parameters:

Check **Substract flat-earth phase**
Coherence Range Window Size: 20
Coherence Azimuth Window Size: 6 (changes automatically)

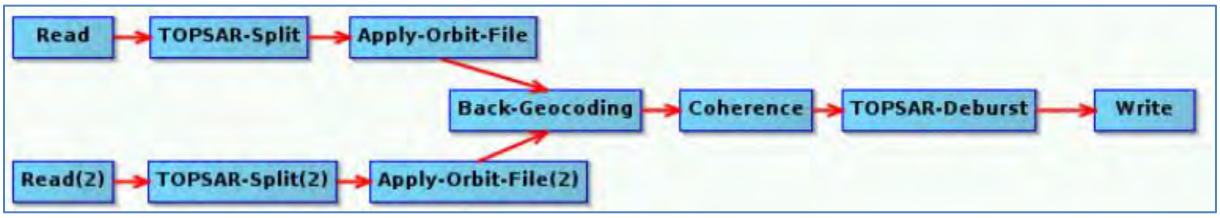


We continue the processing steps with **Sentinel-1 TOPSAR Deburst**. We have seen that each sub-swath image consists of a series of bursts, where each burst has been processed as a separate SLC image. The individually focused complex burst images are included, in azimuth-time order, into a single sub-swath image with black-fill demarcation in between. There is sufficient overlap between adjacent bursts and between sub-swaths to ensure the continuous coverage of the ground. The images for all bursts in all sub-swaths are resampled to a common pixel spacing grid in range and azimuth while preserving the phase information. To add **TOPSAR-Deburst** operator, go to **Add → Radar → Sentinel-1 TOPS → TOPSAR-Deburst**.



In the **TOPSAR-Deburst** tab, select **Polarizations**: *VV*. Then, connect the **TOPSAR-Deburst** operator with the **Coherence** operator.

Finally, add the **Write** operator again by going to **Add → Input-Output → Write**. Then connect the **TOPSAR-Deburst** operator with the **Write** operator and in the **Write** tab define the output directory as: ***/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Damage_Detection***



Set the name of the output product as: ***S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb***

At this moment, save the graph as ***Graph_Coherence_20190924_20191006.xml*** in ***.../Processing/Damage_Detection*** folder by clicking **Save** at the bottom of the window.

Then click **Run.** The new product will appear in the **Product Explorer** when the process finishes. *Approximate processing time: 45 seconds*

Once the process is finished, a new product will appear in your **Product Explorer** tab. Now we will generate the the coherence image also for the co-seismic period (period including the seismic event). Go back to our graph and in the **Read** and **Read(2)** tabs select the following Sentinel-1 scenes as input images:

Read *S1A_IW_SLC__1SDV_**20191006**T204233_20191006T204300_029343_0355EA_**AFB2***
Read(2) *S1A_IW_SLC__1SDV_**20191018**T204233_20191018T204300_029518_035BEF_**380F***

Then, in the **Write** tab set the name of the output product as:
S1A_IW_SLC_20191006_20191012_Orb_Stack_Coh_Deb

Save in the same folder (…/***Processing/Damage_Detection/).*** Once the second coherence product is generated, close the **Graph Builder** window. Then close all opened **Views**.

6.3.2 Multilooking

Go to **Product Explorer** and expand the first pre-processed product ***S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb***. Then go to *Bands* and open the coherence band by double clicking it. As the original SAR image contains inherent speckle noise, multilook processing is applied at this moment to reduce the speckle appearance and to improve the image interpretability (See NOTE 12). Go to **Radar → Multilook** to open the multilook operator.

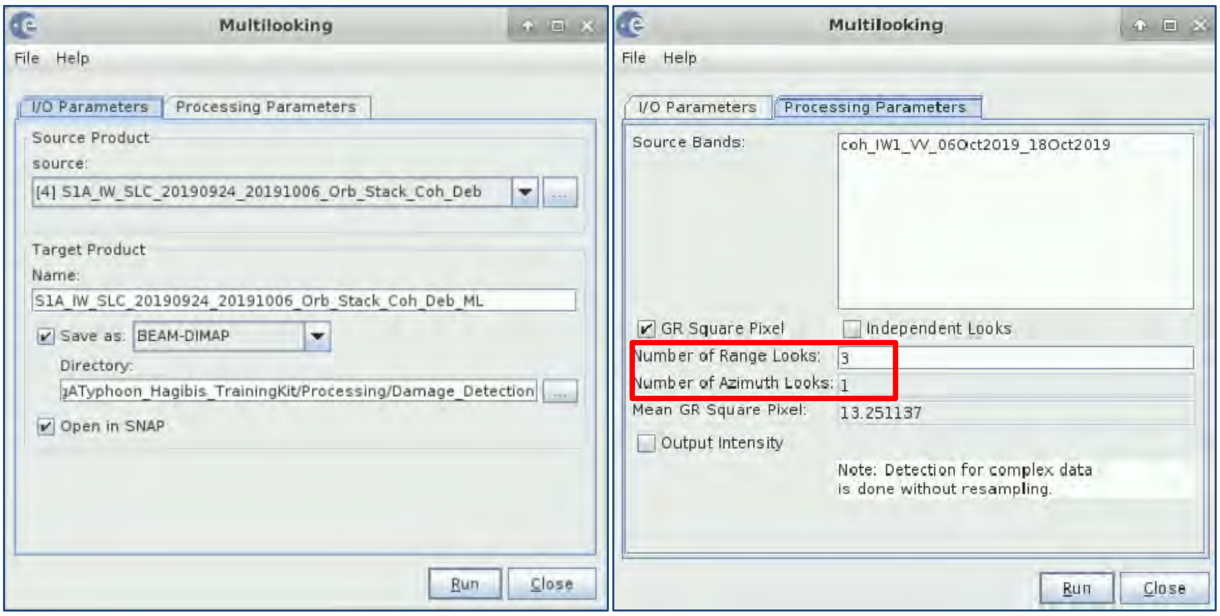
> NOTE 12: The multilooking factors are selected in a way to both obtain square pixels and to maintain as much as possible the spatial resolution.

In the **I/O Parameters** tab, set the following parameters:

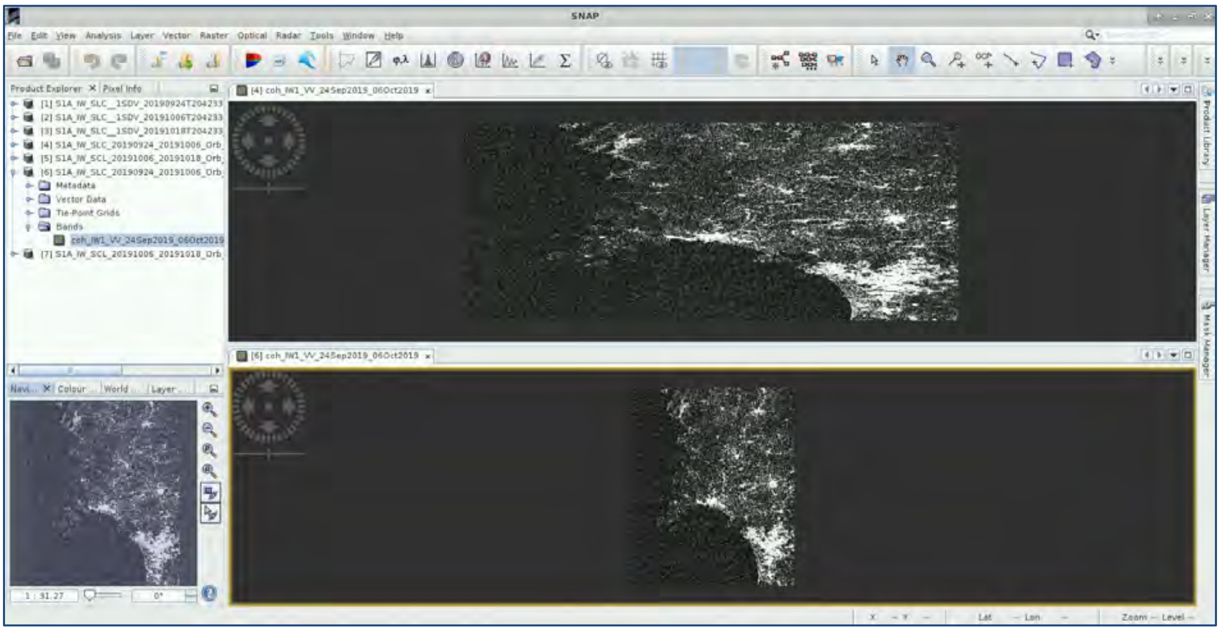
Input: *S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb*
Output: *S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb_**ML***
Directory: */shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Damage_Detection*

In the **Processing Parameters** tab, set the following parameters:

Number of Range Looks: 3
Number of Azimuth Looks: 1



Then click **Run**. A new product appeared in the **Product Explorer**, go to *Bands* and open the multilooked coherence band, then go to **Window → Tile Vertically**.



Repeat the same step for the second pre-processed product:
S1A_IW_SLC_20191006_20191012_Orb_Stack_Coh_Deb

6.3.3 Geocoding

Due to topographical variations of a scene and the oblique viewing angle of the satellite sensor, features appear distorted in SAR images. Terrain corrections are intended to compensate for these distortions, so that the geometric representation of the image will be as close as possible to the real world, based on selected map geometry. For geocoding the Sentinel-1 products we will use the **Range Doppler Terrain Correction** operator that implements the Range Doppler orthorectification method [1].

We will apply **Range Doppler Terrain Correction** operator to the multilooked products.

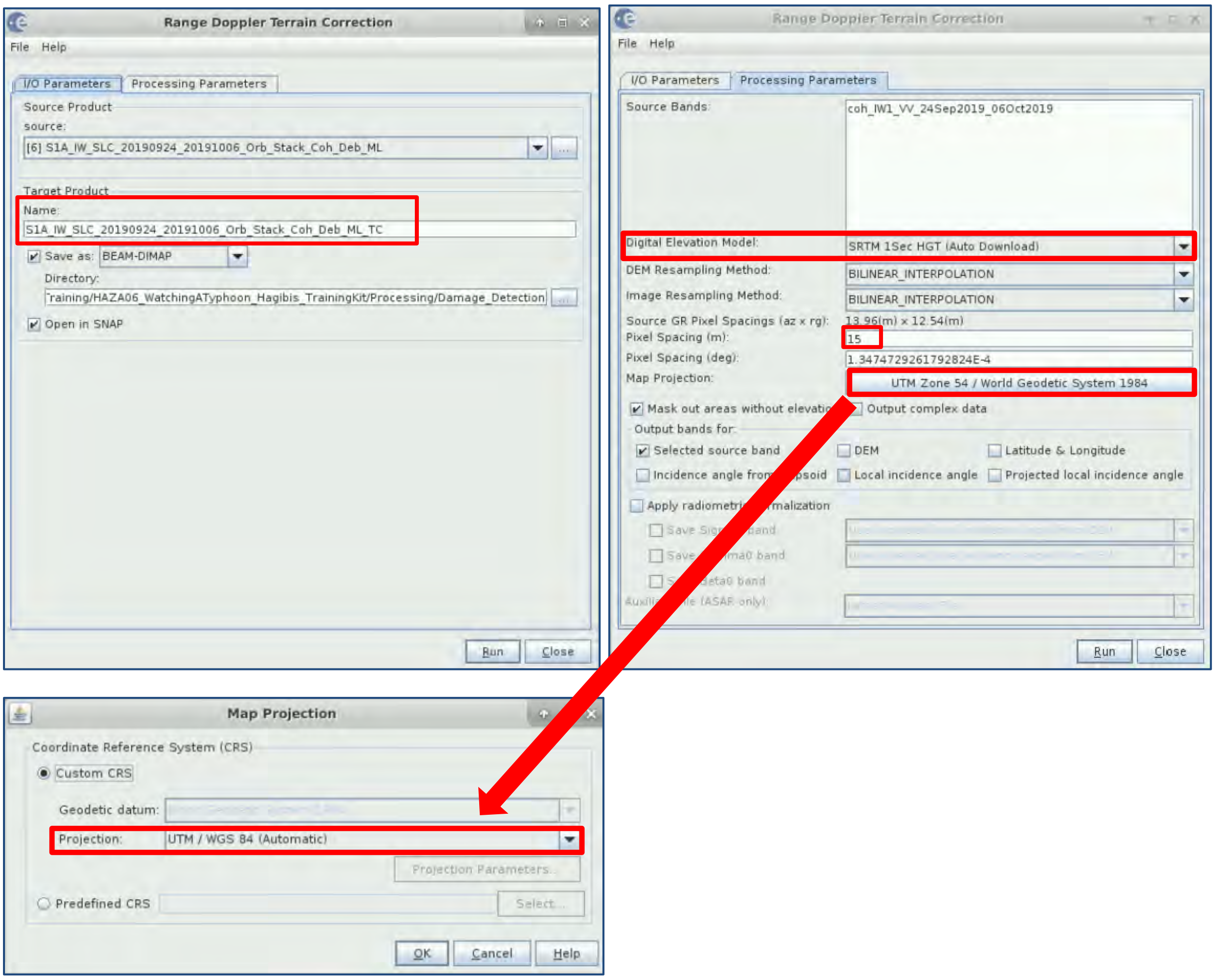
Go to **Radar → Geometric → Terrain Correction → Range-Doppler Terrain Correction** to open the operator.

In the **I/O Parameters** tab, set the following parameters:

Input: *S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb_ML* (first multilooked product)
Output: *S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb_ML_**TC***
Directory: */shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Damage_Damage*

In the **Processing Parameters** tab, set the following parameters:

Pixel Spacing (m): 15
Map Projection: WGS84(DD)



Now, click **Run**. Repeat the process for the second multilooked product:
S1A_IW_SLC_20191006_20191012_Orb_Stack_Coh_Deb_ML

6.3.4 Create Stack

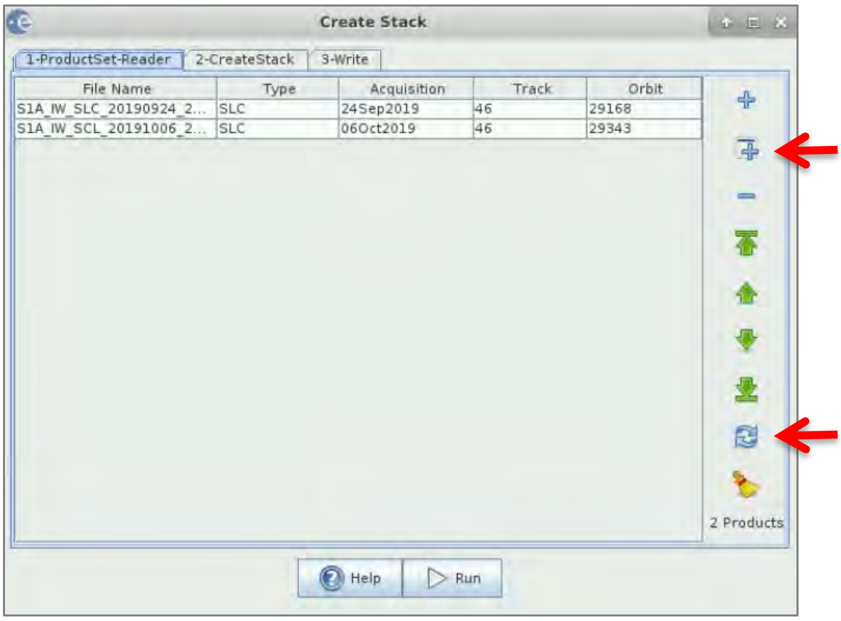
The **Create Stack** operator allows collocating two spatially overlying SAR products, where the pixel values of one product are resampled into the geographical raster of the other.

First, in the **Product Explorer** select product [1] to [7], right click and select **Close 7 products**. Now you should have only the two multilooked products open.

To apply **Create Stack** operator go to **Radar → Coregistration → Stack Tools → Create Stack**.

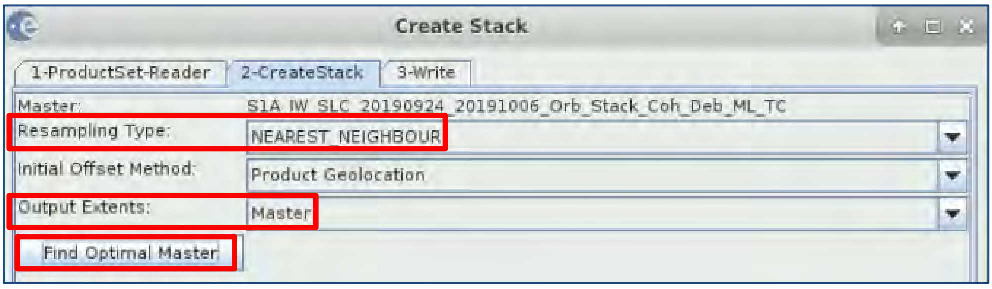
In the **ProductSet-Reader** tab, click **Add Opened** on the upper right to add the following opened products and then click refresh:

S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb_ML_TC
S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb_ML_TC



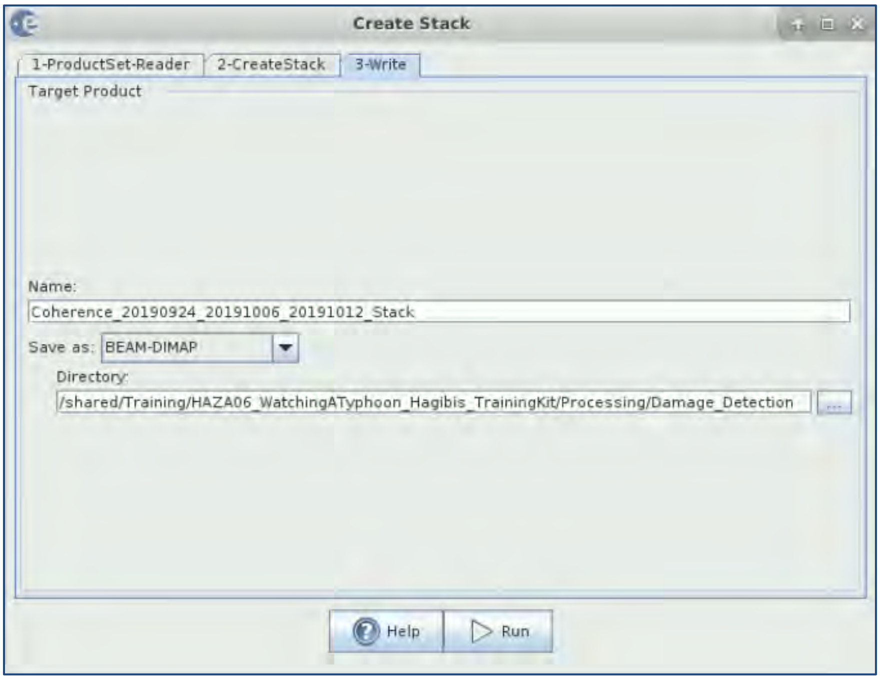
We proceed with **CreateStack** tab by defining the following parameters:

Resampling Type: *NEAREST_NEIGHBOUR*
Initial Offset Method: Product Geolocation
Click on **Find Optimal Master**.

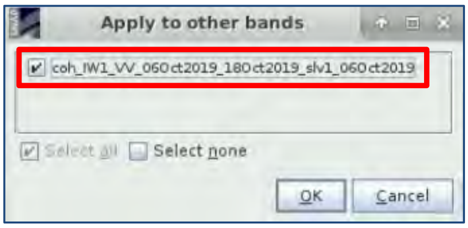


Finally, in the **Write** tab set the output parameters:

Name: *Coherence_20190924_20191006_20191012_Stack*
Directory:
/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Damage_Detection/



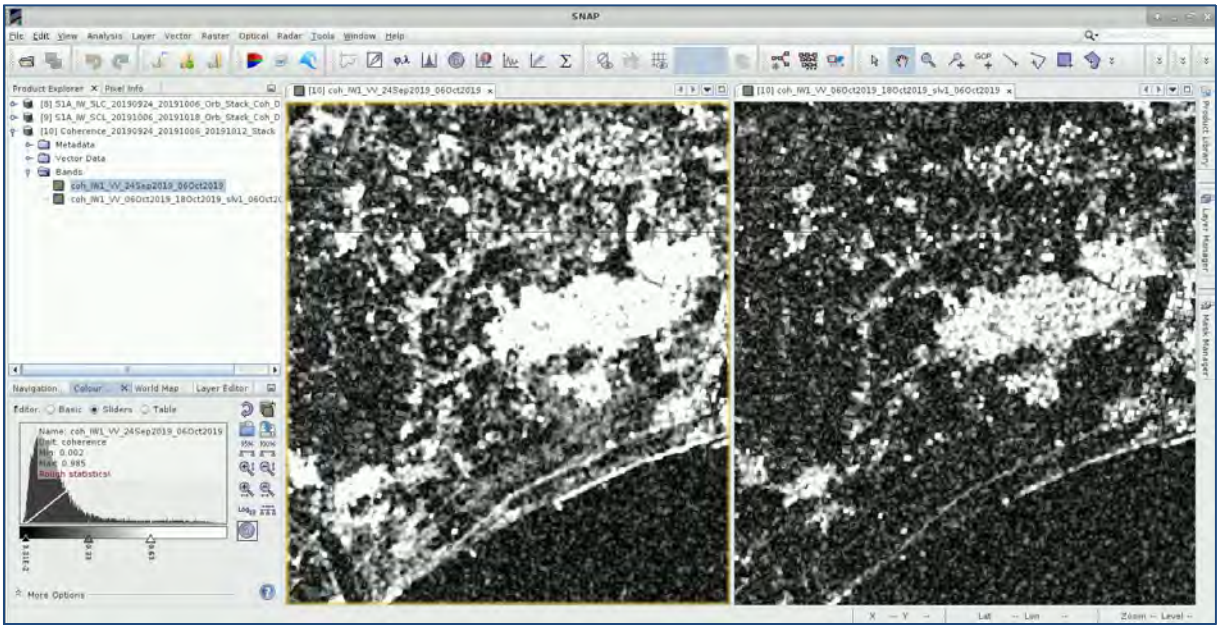
In the **Product Explorer** pane expand the new stack product and open both coherence bands in the **View** window. Then go to **Window → Tile Horizontally** to compare them visually. As you may see in the histogram in the **Colour Manipulation** tab, areas with low coherence are shown in black color, while areas of high coherence are shown in white.



Click on the view *[10]coh_IW1_VV_24Sep2019_06Oct2019*, then go to **Colour Manipulation** tab and click on and select:

coh_IW1_VV_24Sep2019_06Oct2019_slv1_06Oct2019

Then click **OK**. In the next dialog click **No.**



At a first sight, the coherence levels of the two images are quite different, denoting changes that might be attributed to the damage caused by the storm and flooding. To estimate the difference in the coherence levels between the two coherence images, we will use the SAR interferometric coherence difference (ICD) (See NOTE 13).

NOTE 13: When a pair of SAR images is available, further parameters (InSAR complex coherence and intensity correlation) can be computed. Both parameters can be derived combining the pre-seismic, the post-seismic and the co-seismic (i.e. one pre-seismic and one post-seismic image) pairs.
The complex coherence of two images is defined as follows:

$$\rho = \frac{E(s_1 s_2^*)}{\sqrt{E(s_1 s_1^*)E(s_2 s_2^*)}}$$

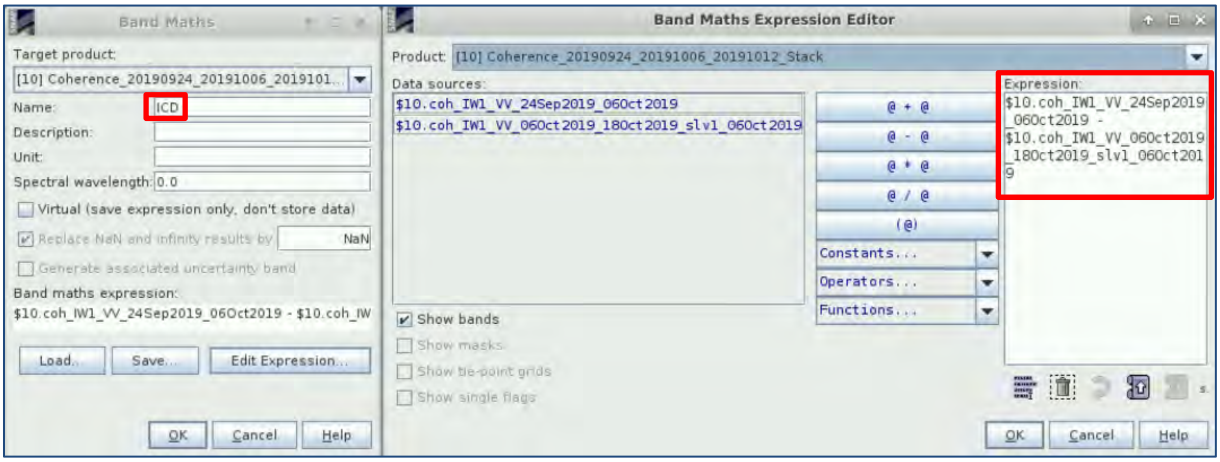
where s1 and s2 are the corresponding complex pixel values, and E( ) indicates the expected value.
The SAR interferometric coherence difference (ICD) is given by:

$$\text{ICD} = \rho(pre) - \rho(post)$$

Close all opened views. Right-click the *Coherence_20190924_20191006_20191012_Stack* product in the **Product Explorer** and go to **Band Maths...** Set the parameters:

Name: *ICD*
Untick option "Virtual (save expression only, don't store data)"

Then click on **Edit Expression...** and set:
Expression: `coh_IW1_VV_24Sep2019_06Oct2019 - coh_IW1_VV_24Sep2019_06Oct2019_slv1_06Oct2019`

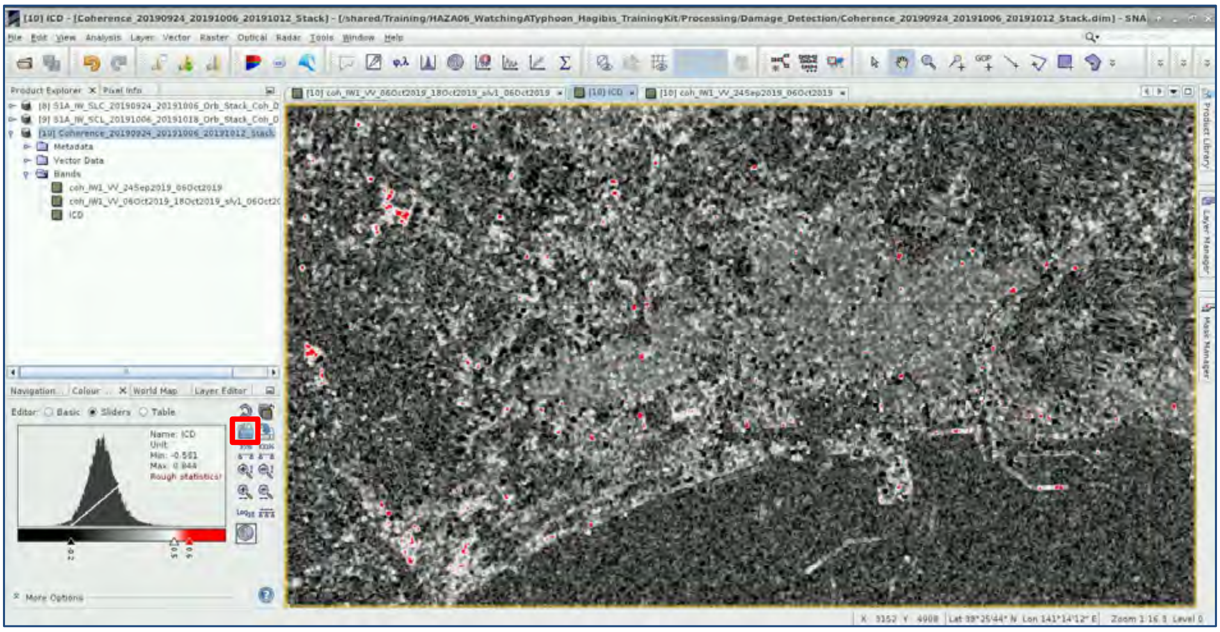


The new band will automatically open in view window. Go to **Window → Tile Single**.

With the **Colour Manipulation** tool, you can modify the colour visualization of the image to show in red the coherence differences possibly attributed to the earthquake induced damages. You can drag the sliders to new position and click to change their colour. For convenience, a colour palette has been created for you.

Click on the **Import Colour Palette** icon, navigate to following path and select the file ***S1_ICD_colour_palette.cpd***. Click **No** – we do not want to distribute points of colour palette between min/max – we want to keep the predefined points.

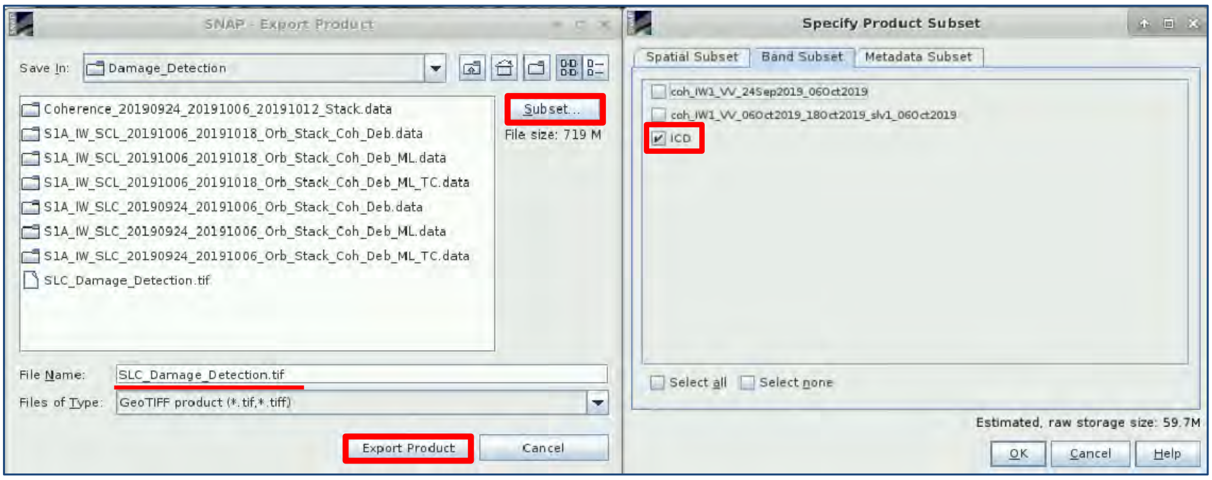
/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/AuxData/



6.3.5 Export as GeoTIFF

In **Product Explorer** select the product [10] and go to **File → Export → GeoTIFF** (NOT! GeoTIFF/Big TIFF). In the dialog that opens click **Subset → Band Subset** and select the band *IDC*. Then click **OK** and save the file as *SLC_Damage_Detection.tif* to:

/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Damage_Detection



Finally, click **Export Product** to proceed.

TIP: In some cases the export to GeoTIFF does not work. This is a bug of the current version of SNAP and can be bypassed (if exporting single band) by right-clicking the image in view and selecting Export View as Image, then select **Full scene**, **Full resolution** and **GeoTIFF – TIFF with geolocation**.

Now we can import the image to another GIS/Remote sensing software for further processing or map creation.

7 Extra steps

7.1 Downloading the outputs from VM

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

8 Further reading and resources

SENTINEL-1 SAR User Guide Introduction – link

ESA Sentinel Online - link

Science Toolbox Exploitation Platform (STEP) – link

9 References

1. Small D. and Schubert A., Guide to ASAR Geocoding, RSL-ASAR-GC-AD, Issue 1.0, March 2008.

2. Stramondo, S., Bignami, C., Chini, M., Pierdicca, N. and Tertulliani, A.(2006), 'Satellite radar and optical remote sensing for earthquake damage detection: results from different case studies', International Journal of Remote Sensing, 27:20,4433 —4447.

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