

## TRAINING KIT – HAZA01

FLOOD MONITORING WITH SENTINEL-1 USING S-1  
TOOLBOX - JANUARY 2015, MALAWI



Research and User Support for Sentinel Core Products

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

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

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## 1 Introduction to RUS

The Research and User Support for Sentinel core products (RUS) service provides a free and open scalable platform in a powerful computing environment, hosting a suite of open source toolboxes pre-installed on virtual machines, to handle and process data derived from the Copernicus Sentinel satellites constellation.



Malawi floods January 2015 Credits: www.theguardian.com  
[February 10, 2015]

The Republic of Malawi declared a State of Disaster on 13 January 2015 in the 15 affected districts (out of a total of 28 districts). The southern districts of Nsanje, Chikwawa, Phalombe and Zomba were the most affected.

The area experienced heavy rains, more than 150% of normal rainfall, throughout December and January, partially related to Cyclone Bansi and Tropical Storm Chedza, which led to severe flooding. The flood left 276 people dead

and estimated 230 000 displaced with some areas completely inaccessible. It also caused extensive damage to crops, livestock and infrastructure with estimated 64 000 hectares of land damaged, further deepening the humanitarian disaster.

## 2 Training

Approximate duration of this training session is one hour.

The Training Code for this tutorial is **HAZA01**. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the [RUS portal](#) and open a User Service request from Your RUS service > Your dashboard.

### 2.1 Data used

- Four Sentinel-1A IW GRDH images with VV polarization acquired before the flood event on 29 December 2014 and during the flood event on 22 January, 27 February and 23 March 2015 [downloadable @ <https://scihub.copernicus.eu/>]  
S1A\_IW\_GRDH\_1SSV\_20150323T030724\_20150323T030752\_005153\_0067F3\_832F.zip  
S1A\_IW\_GRDH\_1SSV\_20150227T030723\_20150227T030752\_004803\_005F89\_DB68.zip  
S1A\_IW\_GRDH\_1SSV\_20150122T030723\_20150122T030752\_004278\_005347\_8809.zip  
S1A\_IW\_GRDH\_1SSV\_20141229T030724\_20141229T030753\_003928\_004B86\_DA25.zip
- Sentinel-1 Precise Orbits (PODs) for the corresponding dates (auxiliary data) automatically downloaded [downloadable @ <https://qc.sentinel1.eo.esa.int> ]

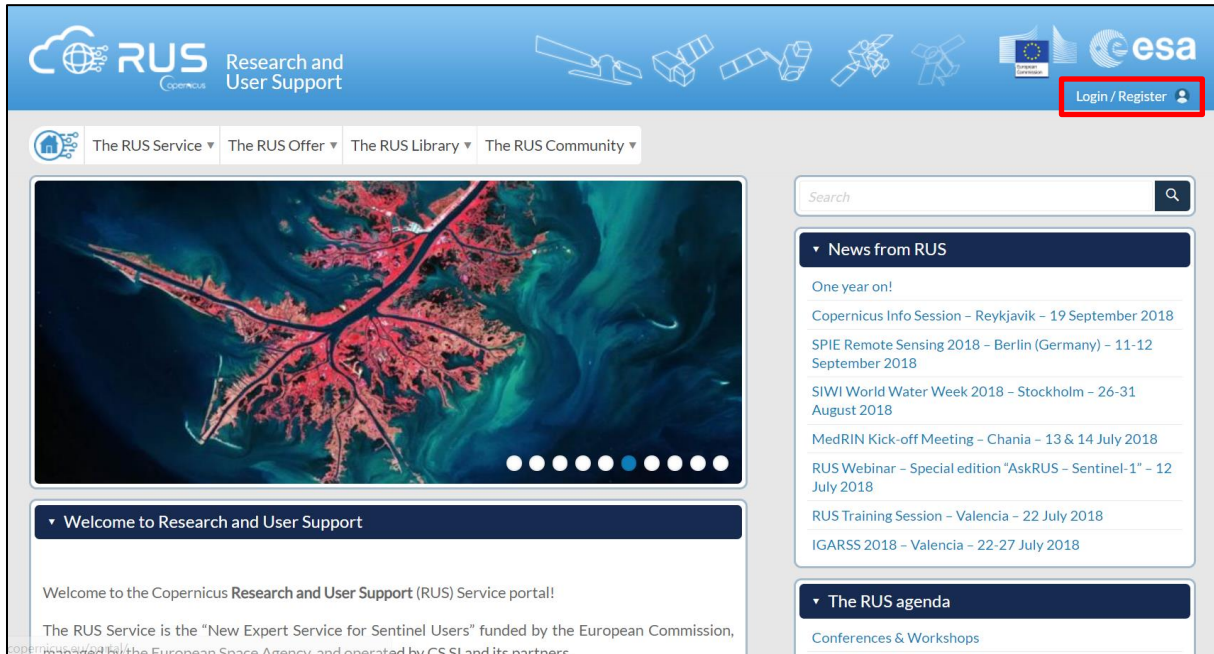
### 2.2 Software in RUS environment

Internet browser, SNAP + Sentinel-1 Toolbox, QGIS

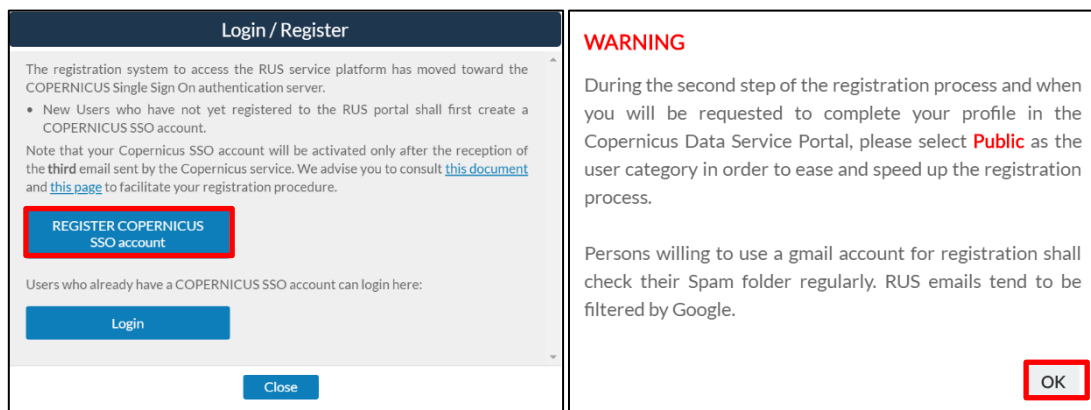


### 3 Register to RUS Copernicus

To repeat the exercise using a RUS Copernicus Virtual Machine (VM), you will first have to register as a RUS user. For that, go to the RUS Copernicus website ([www.rus-copernicus.eu](http://www.rus-copernicus.eu)) and click on *Login/Register* in the upper right corner.



Select the option *Register Copernicus SSO account*. A pop-up message will appear informing you that during the second step of the registration process, and when you will be requested to complete your profile in the Copernicus Data Service Portal, you should select **Public** as user category in order to ease and speed up the registration process. Click Ok



Then, fill in the fields on the Copernicus Users' Single Sign On Registration. Then click *Register*

esa CDS-SSO

FAQ

### Copernicus Users' Single Sign On Registration

Registration form

I'm already registered ☐

CDS-SSO ID

Secret question

Answer

Password

Confirm password

Email

Confirm email

First name

Last name

Institution

Country of residence

Type the characters

**Register**

© Copernicus Single Sign On 2.6.0.c, 2018-05-21

Once you click on the registration button, you will be requested to complete your profile in the Copernicus Data Service Portal. **WAIT UNTIL YOU ARE REDIRECTED.** This may take up to one minute. Make sure all your User Details are correct, set the company/institution details, select *Public* as user category and click *Submit*.

esa Copernicus user's personal area

Home

### User Registration Request

User Details

First Name

Last Name

Email

Username

Country

City

Postal Code

Address

Phone

Mobile phone

Account Details

Company/Institution

User Category\*

Copernicus\_Services

INT\_ORG\_NGO

**Public**

Public\_Auth

Csp Name

Csp Role

Clear **Submit**

Your Copernicus SSO account must be validated by an operator. You will then receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account and log-in.

Once you receive the third email, you will be able to Login. You can now return to <https://rus-copernicus.eu/>, click on Login/Register, choose Login and enter your chosen credentials.

### Login / Register

The registration system to access the RUS service platform has moved toward the COPERNICUS Single Sign On authentication server.

- New Users who have not yet registered to the RUS portal shall first create a COPERNICUS SSO account.

Note that your Copernicus SSO account will be activated only after the reception of the third email sent by the Copernicus service. We advise you to consult [this document](#) and [this page](#) to facilitate your registration procedure.

**REGISTER COPERNICUS SSO account**

Users who already have a COPERNICUS SSO account can login here:

**Login**

Close

### Credentials

CDS-SSO ID

Password

Max Idle Time

Max Session Time

**Login** **Reset**

[Forgot your password?](#)

## 4 Request a RUS Copernicus Virtual Machine

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

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

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

User Support Request

Step 1/3 Your experience

Please help us learn more about your background by answering a few questions. This information will be stored in your User Profile.

How many years of experience in Remote Sensing do you have?

Choose one item...

Have you already downloaded Copernicus data via the Copernicus Open access hubs?

☒ Yes
☐ No

Have you already handled/processed Copernicus data?

☒ Yes
☐ No

Do you wish to practice a tutorial exercise shown in a RUS webinar? If yes, please select your choice (hold down CTRL key for multiple selections).

HAZA01 - Flood Mapping in Malawi  
HAZA02 - Burned Area Mapping in Portugal  
HYDR01 - Water Bodies Mapping over Northern Poland  
LAND01 - Crop Mapping in Seville  
LAND04 - Land Monitoring in Cyprus  
OCEA01 - Ship Detection in Gulf of Trieste

If you wish to request another tutorial exercise that doesn't appear in the above list, please type here its name or code. Note that you can request multiple tutorial exercises.

Cancel

Next

Complete the remaining steps, check the terms and conditions of the RUS Service and submit your request once you are finished.

User Support Request

Summary information on your request:

This is a collection of information selected across the USR forms.  
You can go back and edit this information if necessary.

General information on your request:

Years of experience in Remote Sensing

5-10 years

Downloaded Copernicus data?

✓

Handled/processed Copernicus data?

✓

Webinar codes

HAZA02, LAND04

About your RUS project:

Thematic area

Cryosphere (ice and snow)

Operations to perform on RUS

Algorithm development

Preference for downloading process

Self-downloading

Foreseen activities and support needs

Develop a land cover classification

Project name

RUS\_Project1

Earth Observation Data information:

Type of Earth Observation Data:

Sentinel-1

✓

S1 - Product type

S1 - Product 1

S1 - Sensor mode

GRD

S1 - Polarisation

-

S1 - Orbit direction

-

Sentinel-2

X

Sentinel-3

X

Other

X

I don't know

X

Region of interest:

Min Latitude

39.3303

Max Latitude

40.5877

Min Longitude

-4.6736

Max Longitude

-2.7205

Reference polygons

Data acquisition date(s):

None

Additional data specifications

☒ I have read and agree to the Terms and conditions of RUS Service.

Back and edit

Submit the request

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 you *Your RUS Service* -> *Your Dashboard* and click on *Access my Virtual Machine*.



[The RUS Service](#)
[The RUS Offer](#)
[The RUS Library](#)
[The RUS Community](#)
[Your RUS service](#)

Hello, Miguel

You are here: [Home](#) > [Your RUS service](#) > [Your dashboard](#)

[Request a new User Service](#)

[Chat with Support Desk](#)

Project Name	ID	Date of submission	Status	Actions			Virtual Environment	
RUS_training1	231	2017-08-31	Open	Follow my project	Get support	Close my service	Access my Virtual Machine(s)	Access my CPU monitoring dashboard
				Cancel my request	Get a webinar kit	Rate my service ★★★★★	Freeze my Virtual Machine(s)	Report a technical incident

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[Acronyms](#)
[FAQ](#)

Fill in the login credentials that have been provided to you by the RUS Helpdesk via email to access your RUS Copernicus Virtual Machine.

[Not secure](#) | <https://usr-231.rus-copernicus.eu/#/>

**APACHE GUACAMOLE**

Username

Password

0.9.14

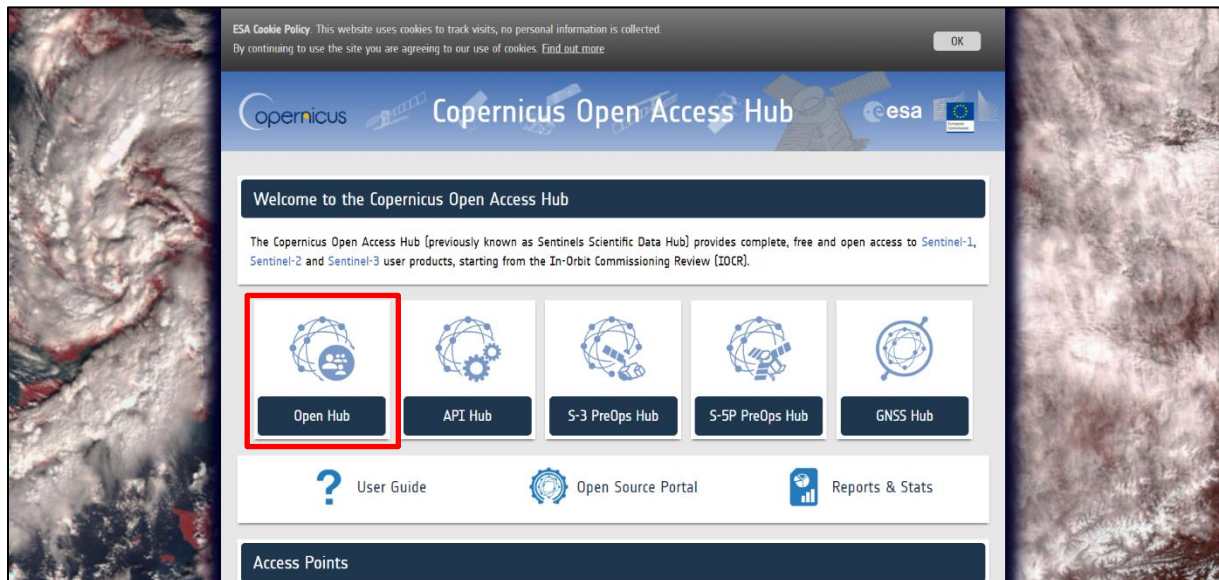


## 5 Step by step

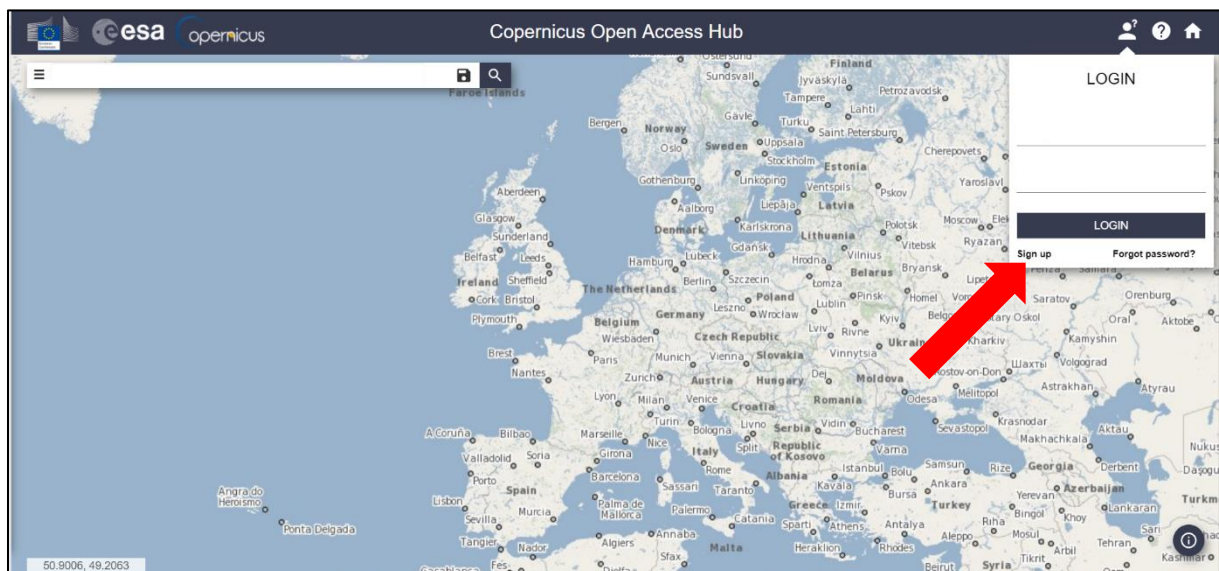
### 5.1 Data download – ESA SciHUB

In this step, we will download Sentinel-1 scenes from the Copernicus Open Access Hub using the online interface (**Applications -> Network -> Web Browser** or click the link below).

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

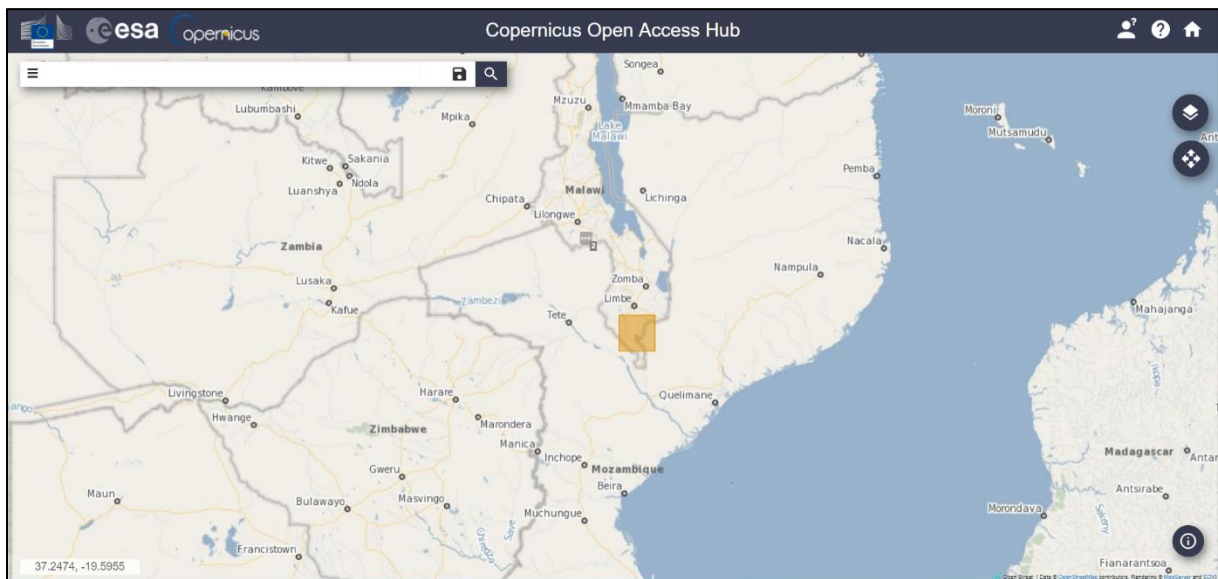


Go to Open HUB, if you do not have an account please register by going to “sign-up” in the LOGIN menu in the upper right corner.



After you’ve 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, log in.

Then click on the map and Navigate to the approximate location of south Malawi. Switch to drawing mode (**green arrow**) and draw search rectangle approximately as indicated below.



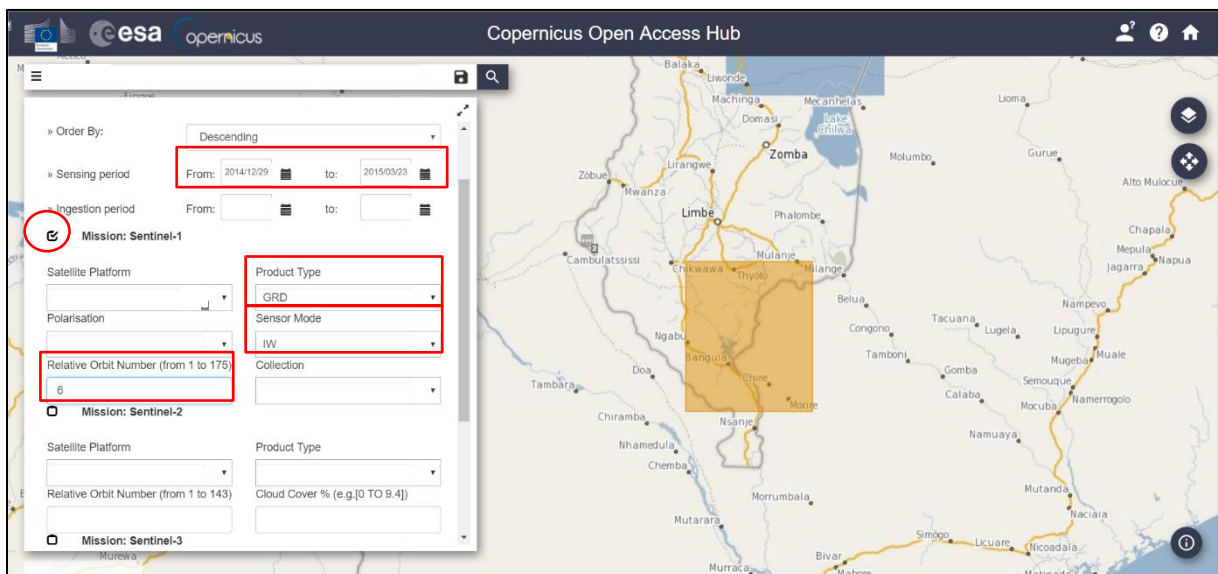
Open the search menu by clicking to the left part of the search bar and specify the following parameters:

**Sensing period:** From 2014/12/29 to 2015/03/23

**Check Mission:** Sentinel-1

**Product Type:** GRD (Ground-range-detected product)

**Relative Orbit number:** 6 (to ensure identical acquisition geometry for all scenes)



In our case, the search returns only 11 results but this will depend on the exact search area defined. Download the following scenes:

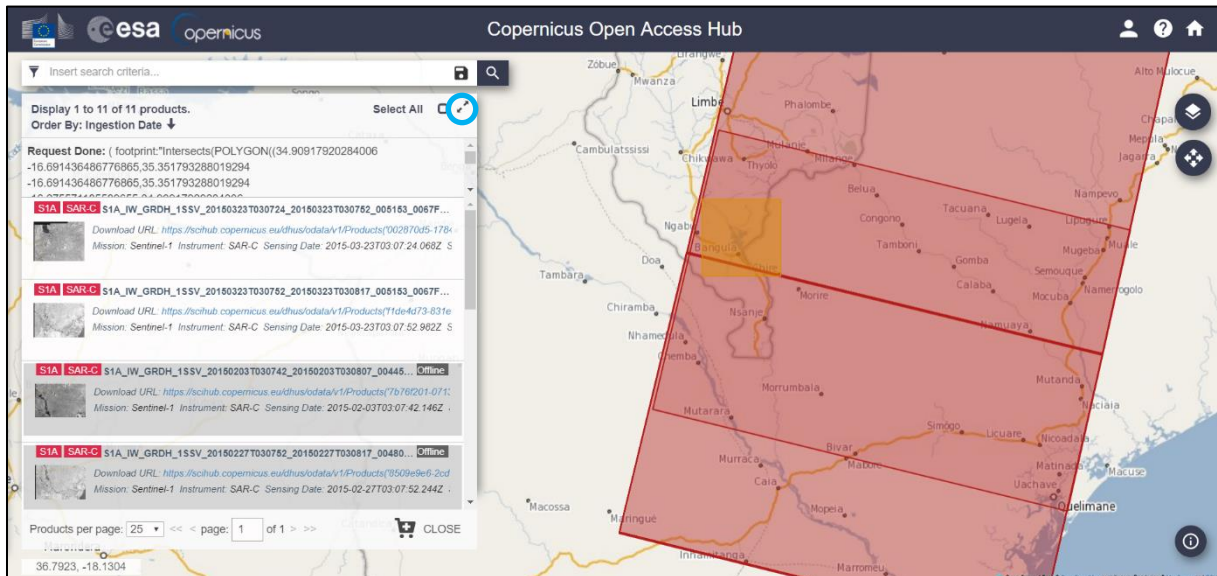
*S1A\_IW\_GRDH\_1SSV\_20150323T030724\_20150323T030752\_005153\_0067F3\_832F*  
*S1A\_IW\_GRDH\_1SSV\_20150227T030723\_20150227T030752\_004803\_005F89\_DB68*  
*S1A\_IW\_GRDH\_1SSV\_20150122T030723\_20150122T030752\_004278\_005347\_8809*  
*S1A\_IW\_GRDH\_1SSV\_20141229T030724\_20141229T030753\_003928\_004B86\_DA25*

Note that you can only download 2 scenes in parallel. To see the full name of the scene you can click the full screen view (indicated by blue circle below).






You can find instruction how to download larger numbers of products in the Copernicus Open Access Hub User Guide (<https://scihub.copernicus.eu/userguide/GraphicalUserInterface>)

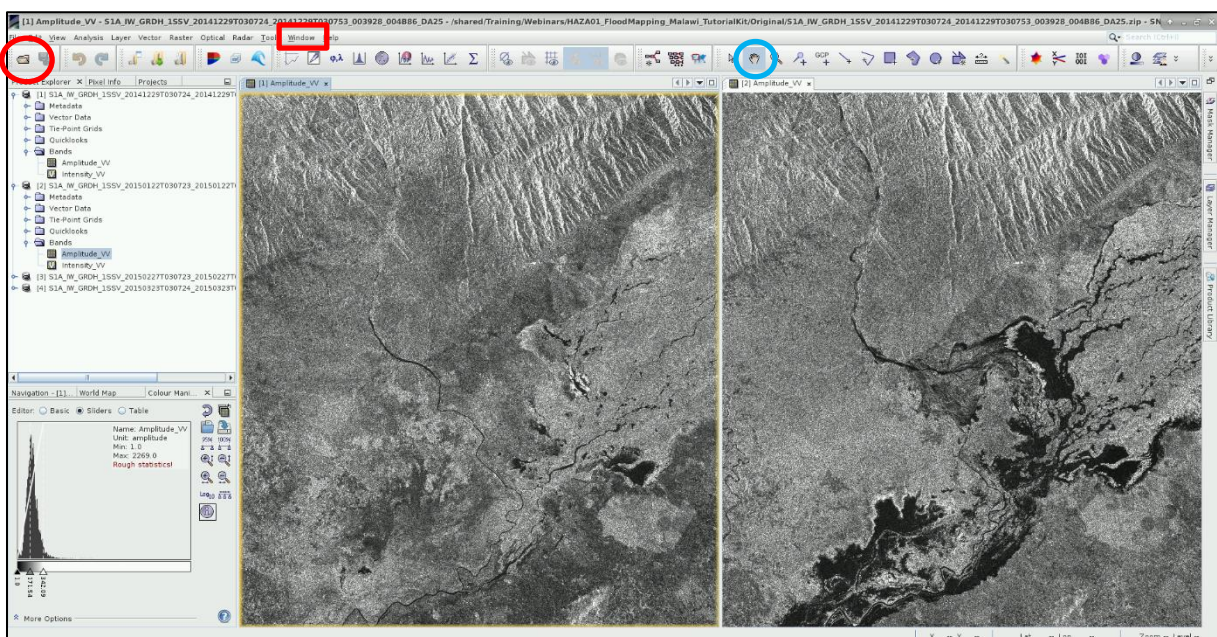


Move the downloaded scenes (desktop, /home/rus/Downloads) to:  
/shared/Training/HAZA01\_FloodMapping\_Malawi\_TutorialKit/Original

## 5.2 SNAP – open and explore data

In *Applications* -> *Other* open **SNAP Desktop**; click Open product , navigate to /shared/Training/HAZA01\_FloodMapping\_Malawi\_TutorialKit/Original and open all the downloaded files.

The opened products will appear in Product Explorer. Click + to expand the contents of the file from December 2014, then expand Bands and double click **Amplitude\_VV** to visualize the band. Then do the same for the image from 22 January 2015. To compare both images, go to **Window ->Tile Horizontally** and zoom-in to the lower left corner of the image.

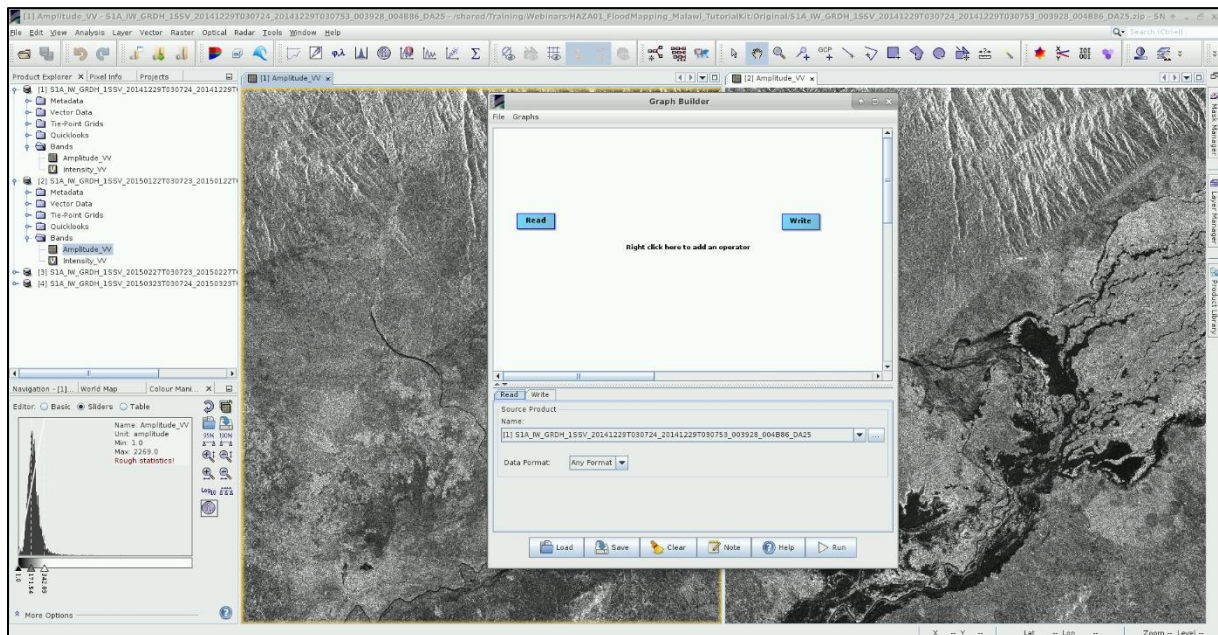


### 5.3 Pre-processing

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).

#### 5.3.1 Build the Graph

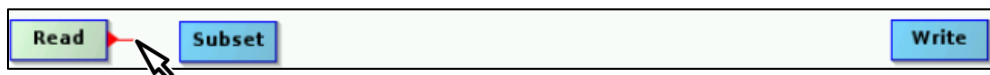
To use the tool, we first need to define the process we want to apply and all its steps. We can do this using the **GraphBuilder**. To build our graph, go to **Tools -> GraphBuilder**.





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

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

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





In the next step, we will update the orbit metadata (See  NOTE 1). To add the operator, right-click the white space between existing operators and go to **Add -> Radar -> Apply-Orbit-File**. Connect the new **Apply-Orbit-File** operator with the **Subset** operator.


 **NOTE 1:** 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 2). We do this by right-clicking the white space somewhere left of the resample operator and going to **Add -> Radar -> Radiometric -> ThermalNoiseRemoval**. Connect the **ThermalNoiseRemoval** operator with the **Apply-Orbit-File** operator.


 NOTE 2: 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 3). To add the operator go to **Add -> Radar -> Radiometric -> Calibration**. Connect the **ThermalNoiseRemoval** operator to the **Calibration** operator.

 NOTE 3: 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)

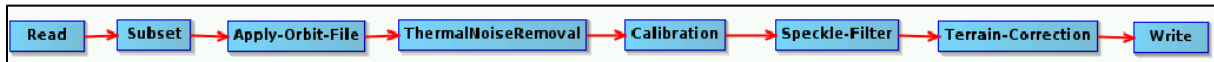
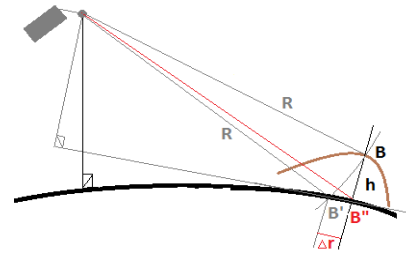


SAR images have inherent salt and pepper like texturing called speckles which degrade the quality of the image and make interpretation of features more difficult (See  NOTE 4). To reduce the speckle effect and smooth the image we apply speckle filter. To add the operator, go to **Radar -> Speckle Filtering -> Speckle-Filter** then connect the **Calibration** operator to it.

 NOTE 4: 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 preprocessing, we will apply terrain correction to compensate for the distortions and reproject the scene to geographic projection (See  NOTE 5). To add the operator, go to **Radar -> Geometric -> Terrain Correction -> Terrain-Correction** then connect the **Speckle-Filter** operator to it. Finally. Attach the **Terrain Correction** operator to the **Write** operator.

NOTE 5: 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  $\Delta r$  between **B'** and **B"** exhibits the effect of topographic distortions. (SNAP Help)



At the moment, do not change anything in the parameter tabs and save the graph as *Graph\_preprocess.xml* to */shared/Training/HAZA01\_FloodMapping\_Malawi\_TutorialKit/Processing* by clicking **Save** at the bottom of the window.

### 5.3.2 Batch processing

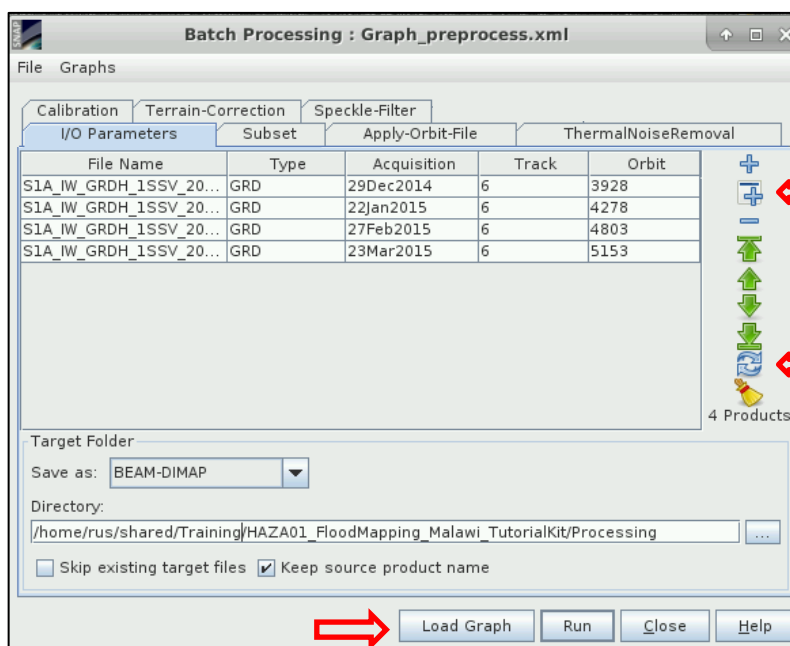
In the **Product Explorer**, we select (highlight) the product [1] (29 December 2014). Now we can close the **GraphBuilder** window and open the **Batch Processing** tool (**Tools -> Batch Processing**).

We will add the opened products by clicking **Add Opened** on the upper right (second icon from the top) and click refresh. Then we click **Load Graph** at the bottom of the window 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 with the exception of **Write**; this is correct as these parameters will be set in the **I/O Parameters** tab.

In the **I/O Parameters** tab set directory to:

*/shared/Training/HAZA01\_FloodMapping\_Malawi\_TutorialKit/Processing* and make sure the '**Keep source product name**' option is selected (See NOTE 6).

NOTE 6: 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.



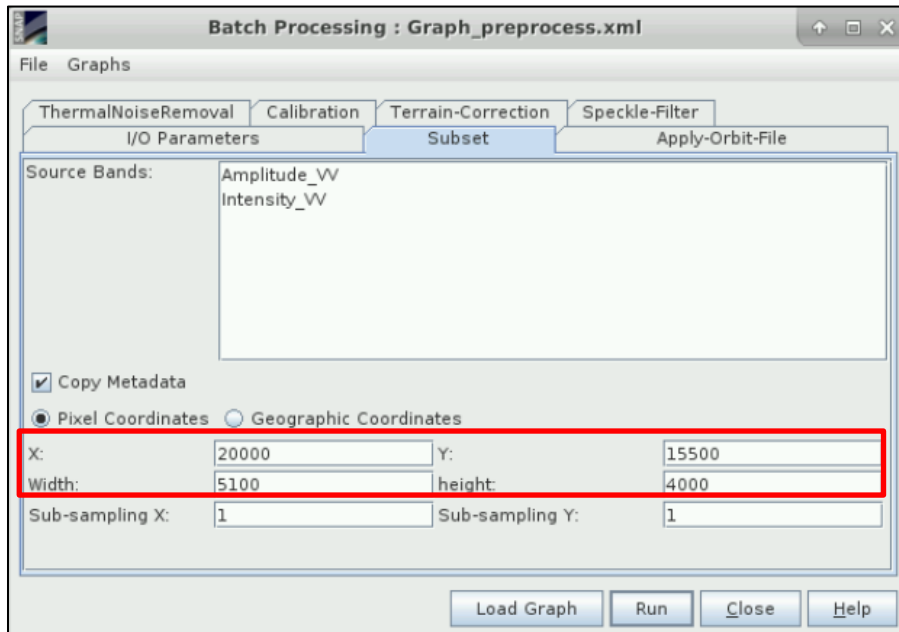
Now let's set the parameters. In the Subset tab set the extent of the AOI in pixel coordinates to:

X: **20000**

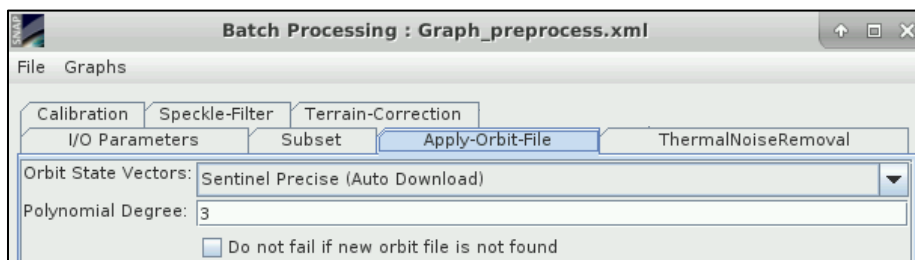
Y: **15500**

Width: **5100**

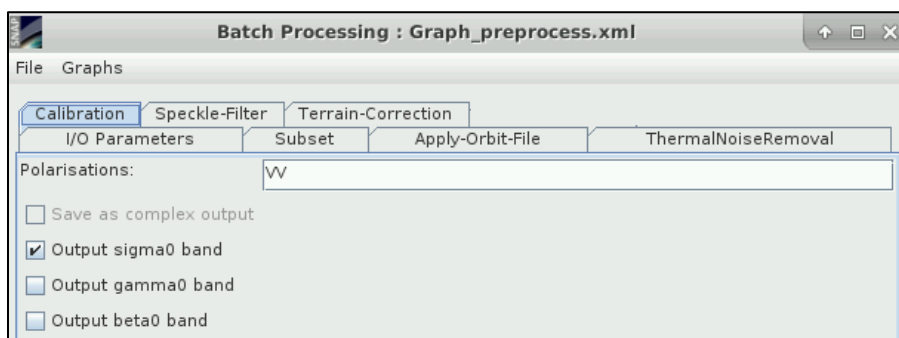
Height: **4000**



In **Apply-Orbit-File** tab we can accept the default settings. In the **ThermalNoiseRemoval** tab select VV polarization and make sure that "Remove Thermal Noise" option is selected.



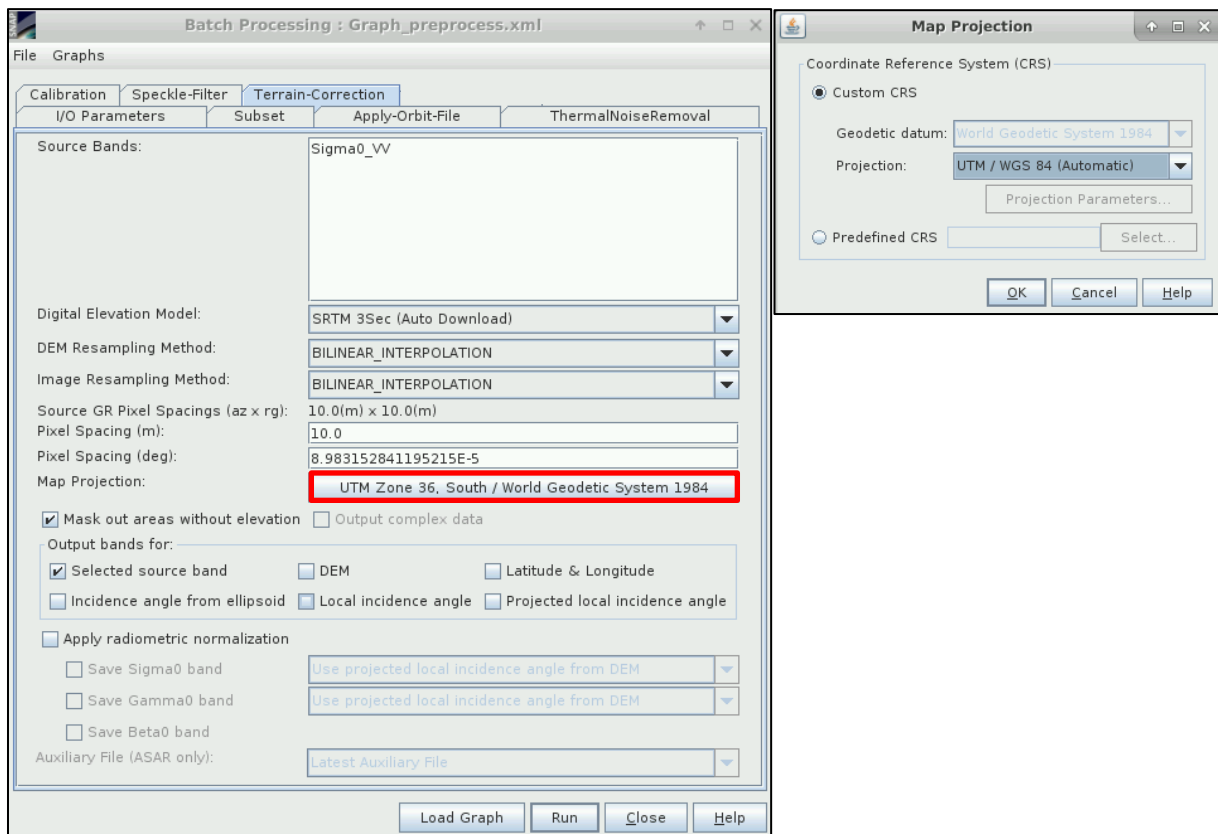
In the **Calibration** tab, we will also accept all default settings.



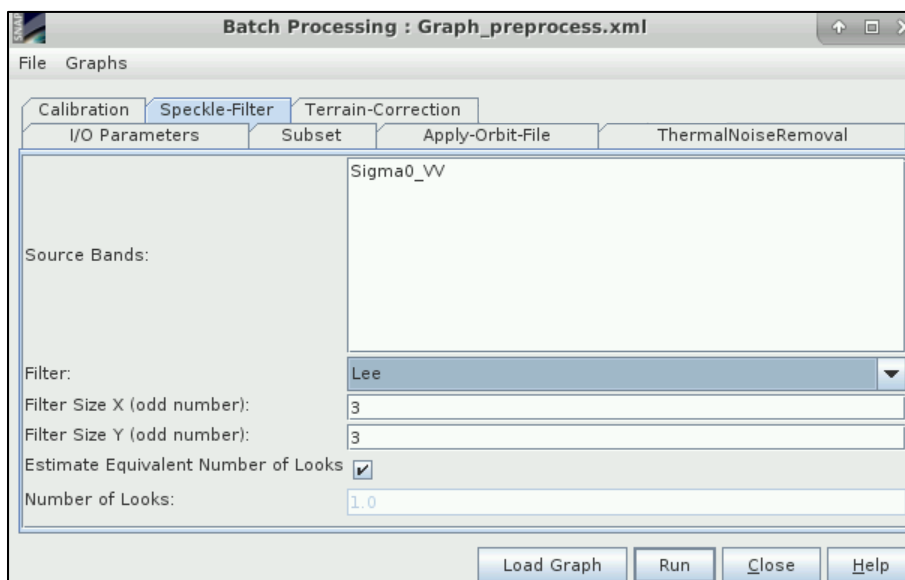
In the **Terrain-Correction** tab, set:

**Map Projection ->Projection : UTM / WGS84 (Automatic)**

Leave all the other default settings.



Last we go to the **Speckle-Filter** tab. For this exercise we choose the simple Lee filter with window size of 7x7 pixels (See NOTE 7).





**NOTE 7:** 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.

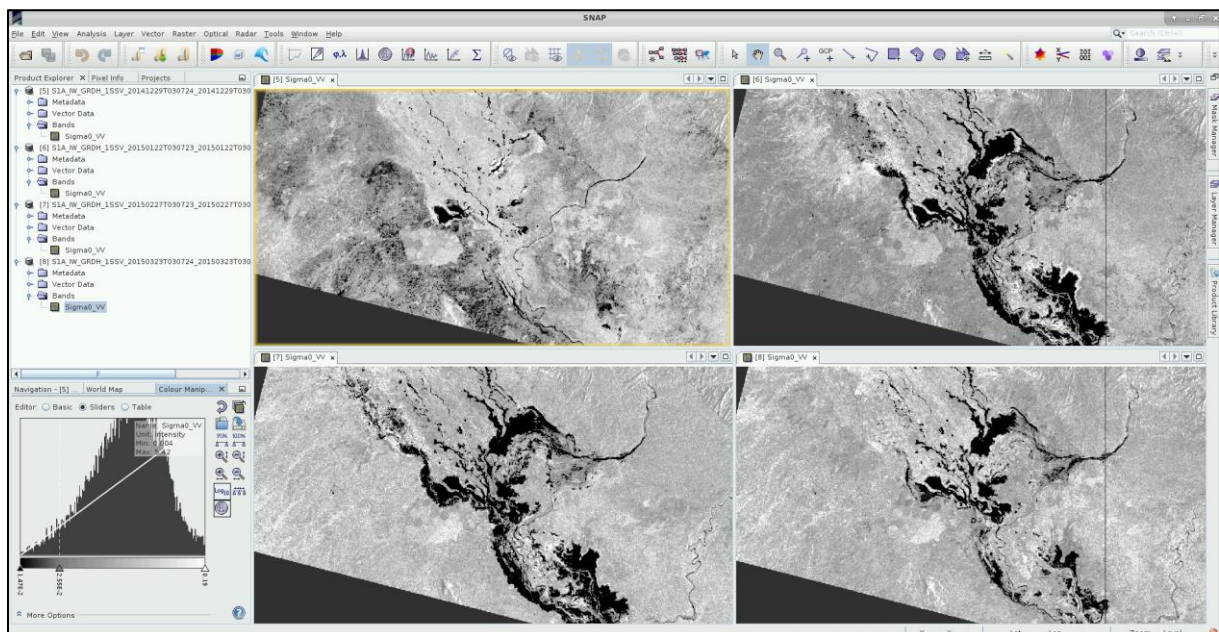
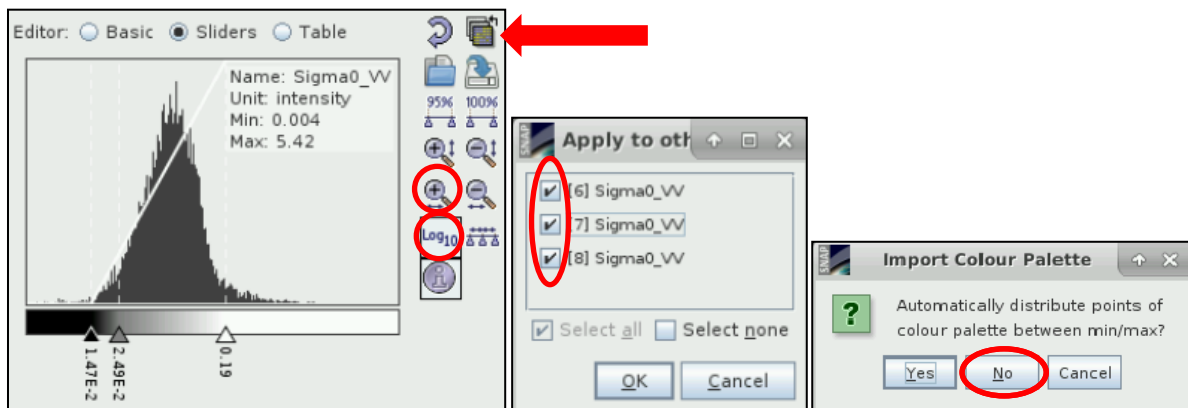
Then finally click **Run** to pre-process our images. *Approximate processing time: 5 minutes*

Now you should have four new products in the **Product Explorer**. Select the original products [1-4], right-click and click **Close 4 Products** (Click No if asked to save).

## 5.4 Binarization

To separate water from non-water a threshold can be selected for each image. For this, we will analyze the histogram of the filtered backscatter coefficient. Low values of the backscatter will correspond to the water, and high values will correspond to the non-water class.

First, open all four created products [5-8] in the View and then go to **Window -> Tile Evenly**. Click on the view [5]Sigma0\_VV to activate it (yellow boundary). On the left side panel select the **Color Manipulation** tab and click  (Stretch the histogram horizontally) on the left side of the tab. Then move the middle slider below on the histogram to approx.  $\sim 0.025$  and click on **Log<sub>10</sub>**. Now we can see the water bodies better. Let's apply the same histogram stretch to other three images. To do this click on  and select all three bands and click OK. In next dialog click No (for each band).

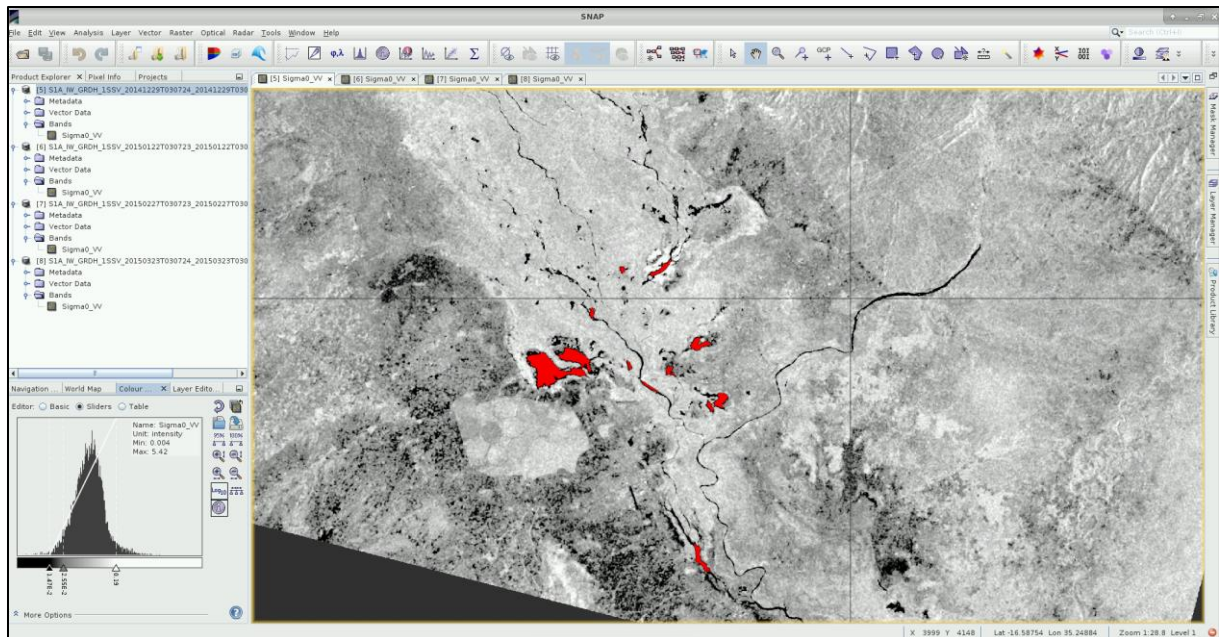
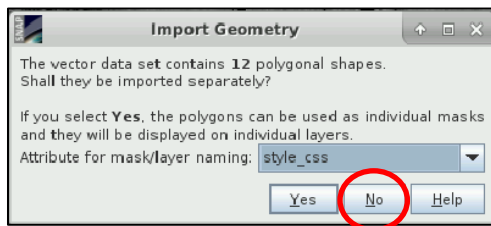


To create a binary mask of water and non-water pixels we create a new band and apply a conditional expression based on our threshold. To obtain our threshold value we will check the values occurring over the open water. **Go to Window -> Tile Single**. Go to View [5] Sigma0\_VV\_db.

You can create your own water body mask, but for this tutorial we will use one that has been prepared in advance and saved in the Auxdata folder. We can import it by clicking on the Product [5] in **Product Explorer** and then going to **Vector -> Import -> ESRI Shapefile**. Navigate to */shared/Training/HAZA01\_FloodMapping\_Malawi\_TutorialKit/Auxdata* and open the shapefile



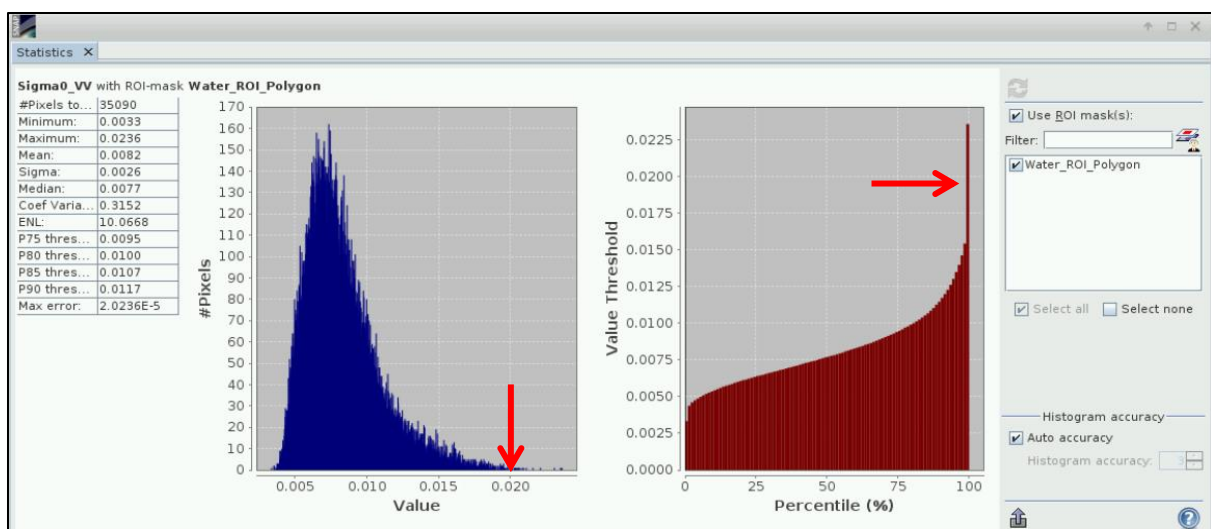
*Water\_ROI\_Polygon.shp*. Click **No** in the **Import Geometry** dialog (import all features into single mask).



Now let's have look at the statistics. In the product explorer, expand the bands folder in product [5] and click on band *Sigma0\_VV\_db* so it is highlighted. Then go to **Analysis -> Statistics**. A new window will appear. On the right side select ☒ **Use ROI Mask(s)**, select the *Water\_ROI\_Polygon* (See 💡 TIP 1) and click **Refresh**.



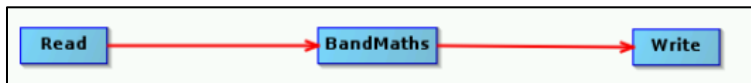
**TIP 1:** If the ROI/geometry does not appear in the window go to **Product Explorer**, expand the **Vector Data** folder in product [5] and click on *Water\_ROI\_Polygon*. Now it should appear in the statistics window as well and you can select it.



Now we can investigate the statistics. We can see that the maximum value in our Water polygons is 0.0236, the statistics also produces 90% percentile which gives a value of 0.0117. For our purposes we will adopt a value close to the 99% percentile which is not provided but can be estimated from the histograms. Let's choose 0.020 as our threshold (the statistics is of course always dependent on the ROI you choose and therefore can vary significantly).

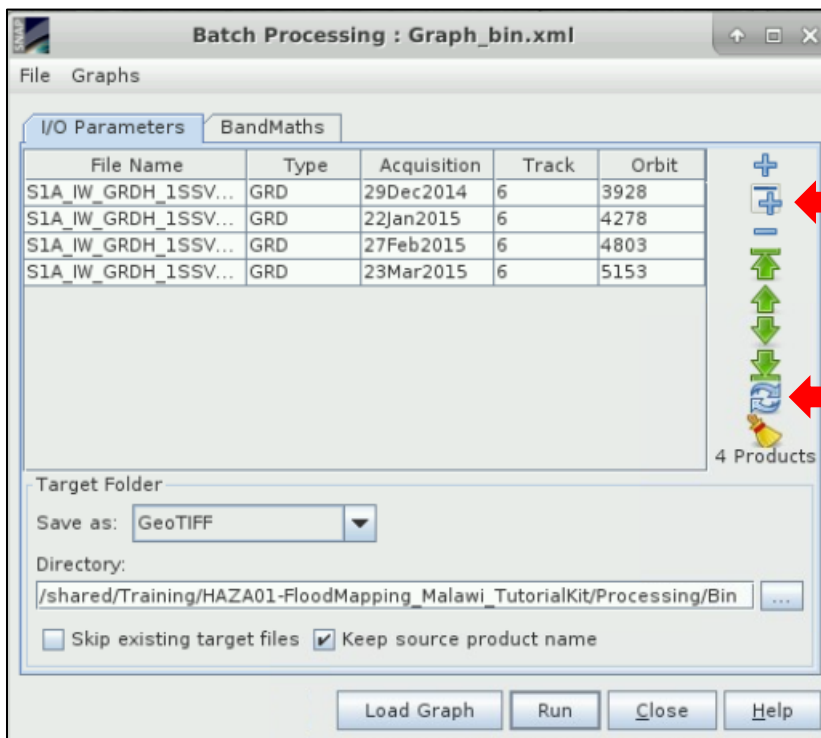
Now let's apply the threshold. We will apply the same threshold to all our images, therefore we can use the Batch processing again.

Firstly, let's build a very simple graph. Go to **Tools -> Graph Builder**, add Band Math operator (right-click on the white space and go to **Raster -> BandMaths**) and connect the operators as shown below. At the bottom of the window **Save** the graph to the *Processing* folder as *Graph\_binary.xml*. Close the **Graph Builder**.



Then go to **Tools -> Batch Processing** and click **Add Opened** on the upper right (second icon from the top) and click refresh. Click on the **Load Graph** button, navigate to our saved graph and open it. We can now see that the **BandMaths** tab has appeared at the top of window.

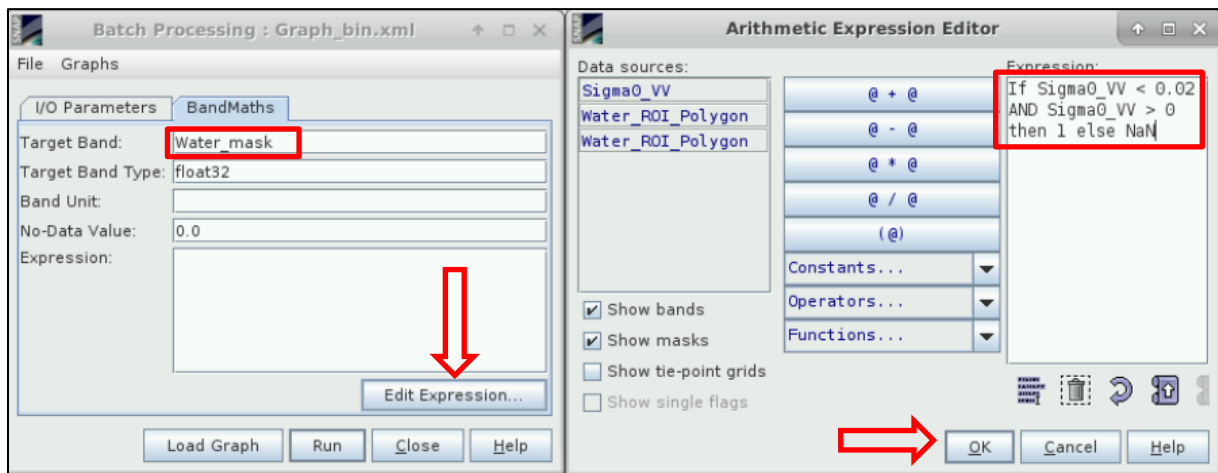
Make sure that the format is set to **GeoTIFF** in the **I/O Parameters** tab, the directory to */shared/Training/HAZA01\_FloodMapping\_Malawi\_TutorialKit/Processing/Binary* and the **Keep source product name** option is selected (See NOTE 6 - Page 8).



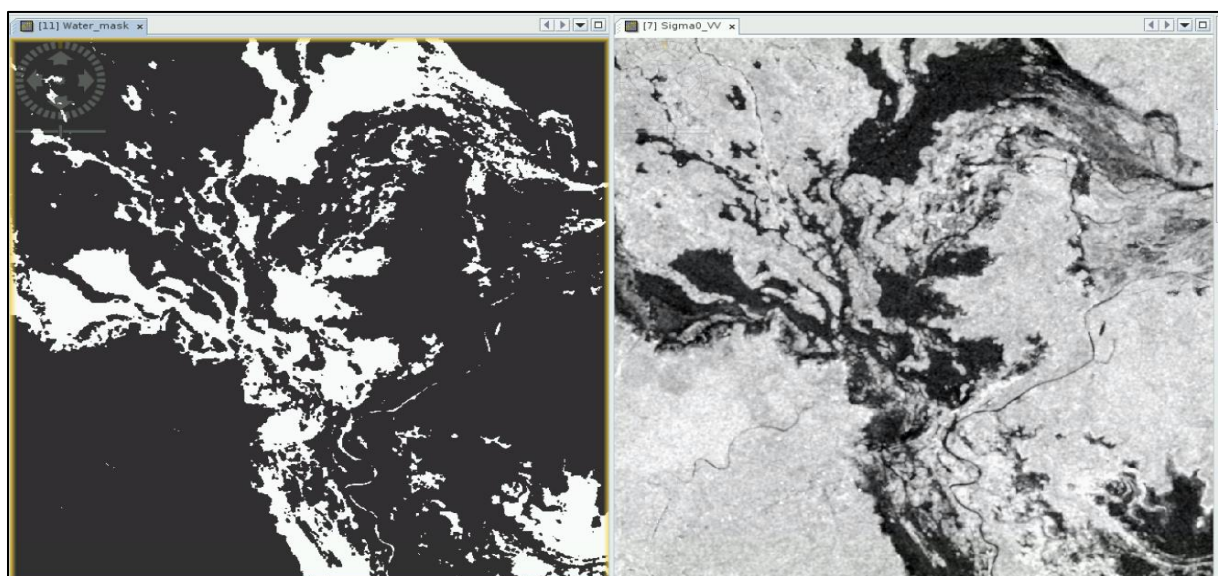
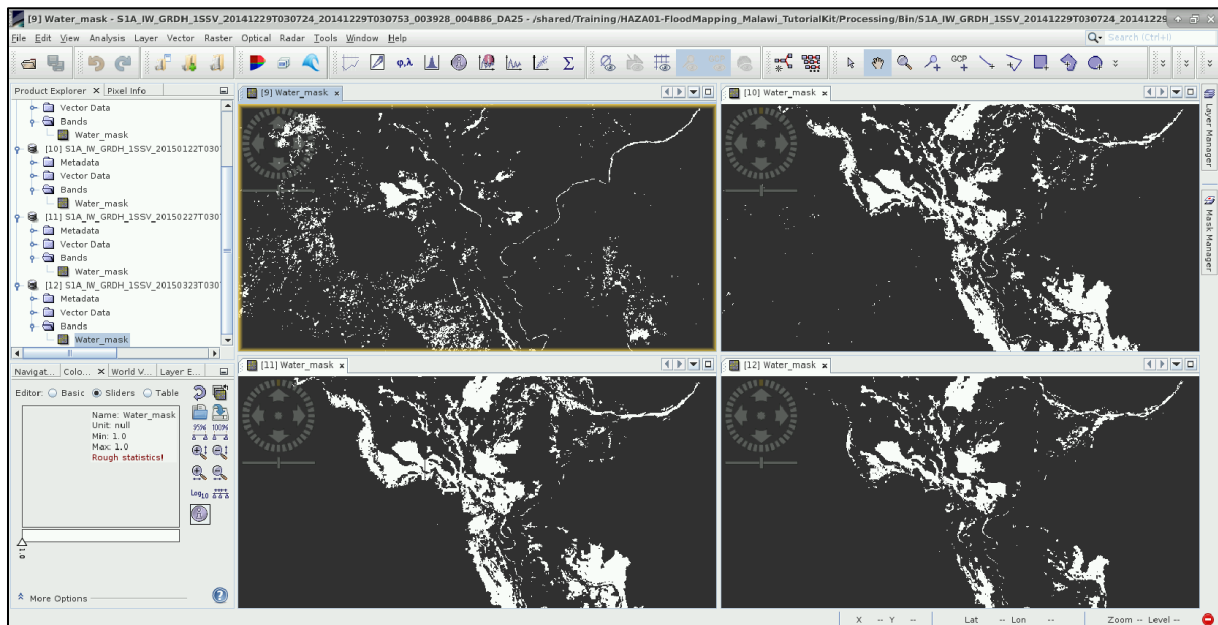
In the **BandMaths** tab rename the new band to *Water\_mask*, open the **Edit Expression...** and enter following expression:

```
If Sigma0_VV < 0.02 AND Sigma0_VV > 0 then 1 else NaN
```

If no errors are found close Expression editor by clicking OK and Run the process.




Four new products [9-12] have appeared in the **Product Explorer**. Close all opened view windows and open the Water\_mask band for all the new products. Use **Window -> Tile Evenly** to see all products at the same time.

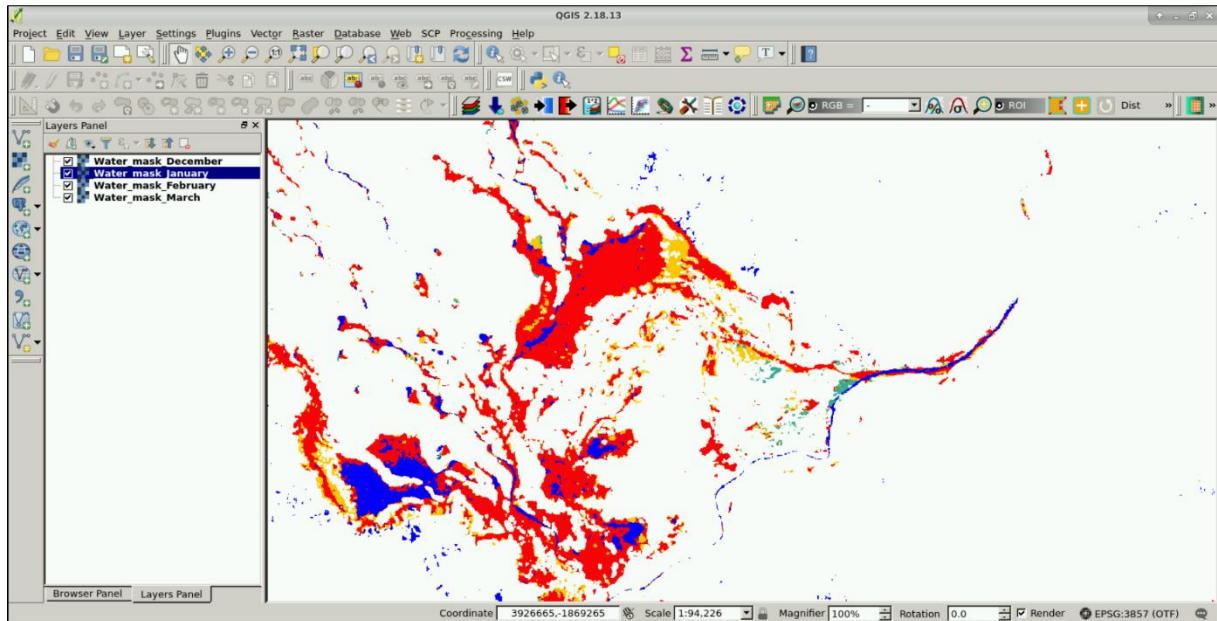




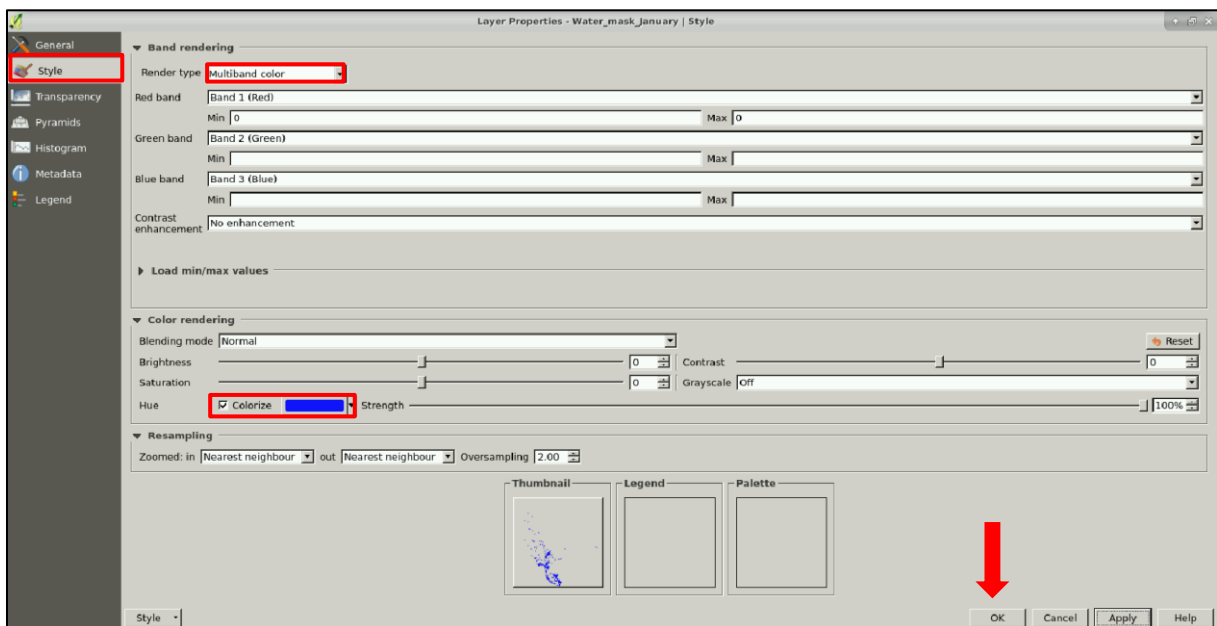
## 5.5 Visualization (QGIS)


To better visualize the output of our multi-temporal flood analysis, we will open the saved masks (GeoTIFF) in QGIS. Go to *Application -> Processing -> QGIS Desktop*. Click on the **Add Raster Layer** button located in the left panel (  ), navigate to:

*/shared/Training/HAZA01\_FloodMapping\_Malawi\_TutorialKit/Processing* select the four water masks and click **Open**.

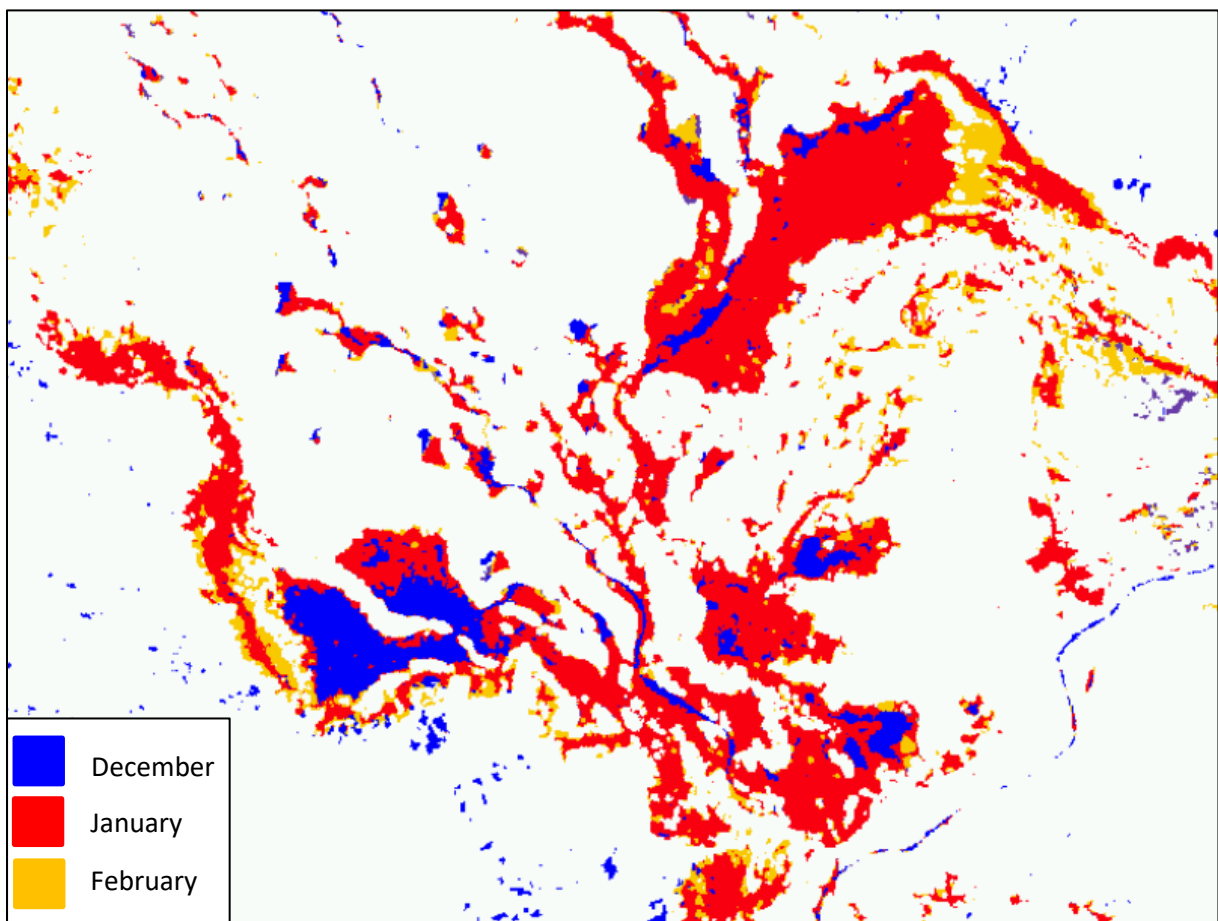
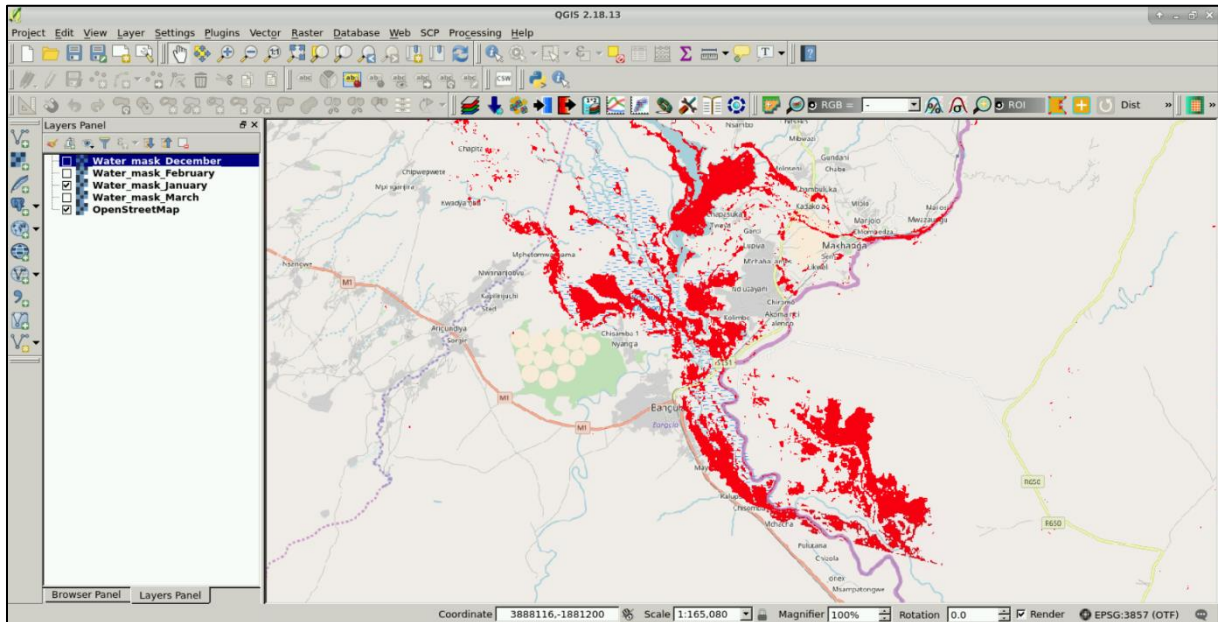


You can change the style of the layers on the properties menu. Right click on the product you want to change and select **Properties**. In the **Style** tab, select **Multiband color** as rendering type. In the **Color Rendering** section, activate the **Colorize** option, select a color and click OK.



Finally, we can add a base-map to link our water masks to GIS data. Click on **Web -> OpenLayers plugin -> OpenStreetMap -> OpenStreetMap** (See  NOTE 8).

NOTE 8: In case the **OpenLayers** plugin is not installed, click on **Plugins -> Manage and Install Plugins**. Select the 'All' tab on the right side panel and write "OpenLayers plugin" on the search box. Select the plugin on the list and click 'Install Plugin'. Restart QGIS to finalize the installation.



THANK YOU FOR FOLLOWING THE EXERCISE!



