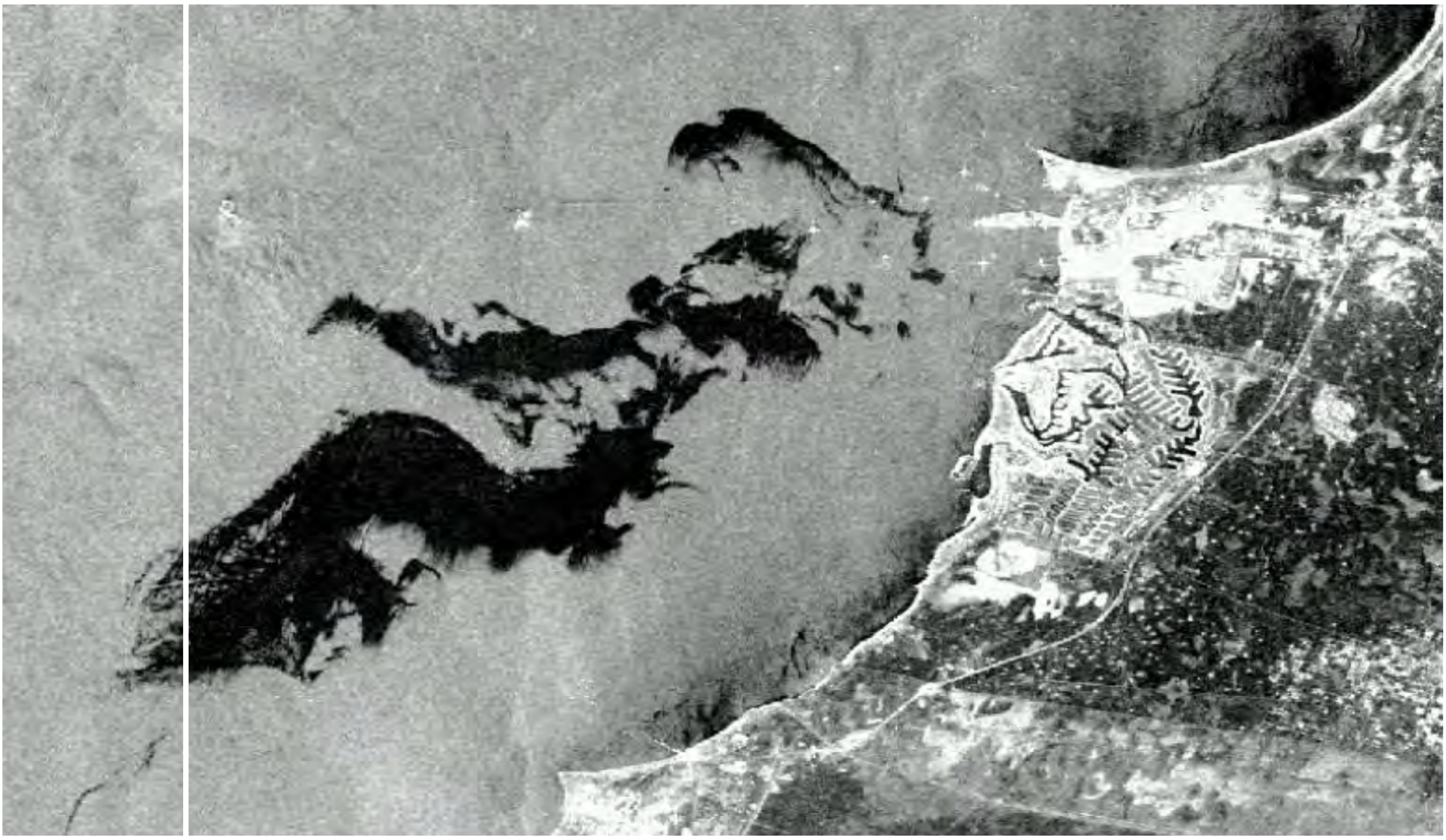

TRAINING KIT – OCEA03

OIL SPILL MAPPING WITH SENTINEL-1
AUGUST 2017, KUWAIT

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

Cover images produced by RUS Copernicus

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1 Introduction to RUS

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

In this tutorial, we will employ RUS to identify and map an oil spill in the south of Kuwait using Sentinel-1 satellite-borne SAR data.

2 Oil spill mapping – background

Oil spill near Al Khiran, Kuwait. Credits: Kuwait Environment Public Authority

Ocean pollution due to oil spills remains a major environmental hazard. Although oil tanker accidents are well known, they are not the main cause for this type of event. Illegal discharges from ships or offshore platforms, drilling rigs, pipeline accidents or natural leaks amongst others bring together most of the sources for oil pollution in the ocean.

Last August 10th, 2017, an oil spill was reported in the south of Kuwait, near the Al Khiran area where the Al Khafji offshore oil field is located. While the cause of the incident is not clear (tanker offshore, pipeline damage), almost 132500 liters have been leaked based on conservative estimations made by SkyTruth, a non-profit organization based on the United States.

3 Training

Approximate duration of this training session is one hour.

The Training Code for this tutorial is OCEA03. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the [RUS portal] and open a User Service request from Your RUS service -> Your dashboard.

3.1 Data used

- One Sentinel-1A IW GRD image acquire on 10/08/2017 [downloadable at @ https://scihub.copernicus.eu/

S1A_IW_GRDH_1SDV_20170810T024714_20170810T024738_017855_01DEF7_F48C

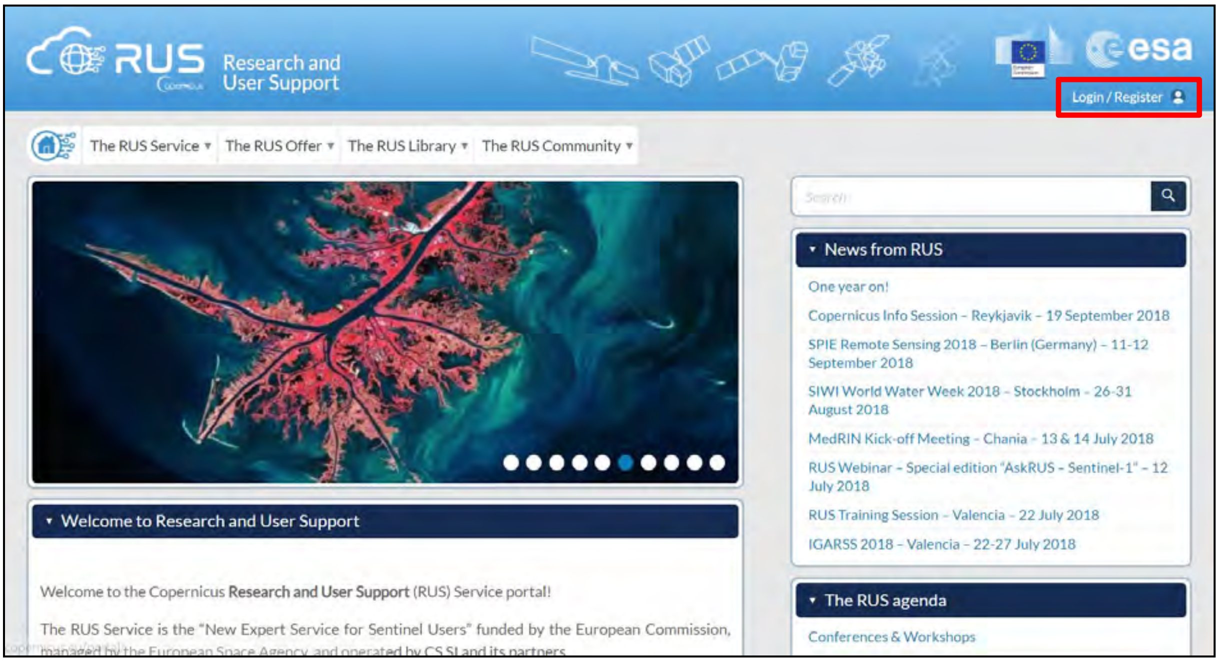
- Pre-processed data stored locally @shared/Training/OCEA03_OilSpill_Kuwait/AuxData

3.2 Software in RUS environment

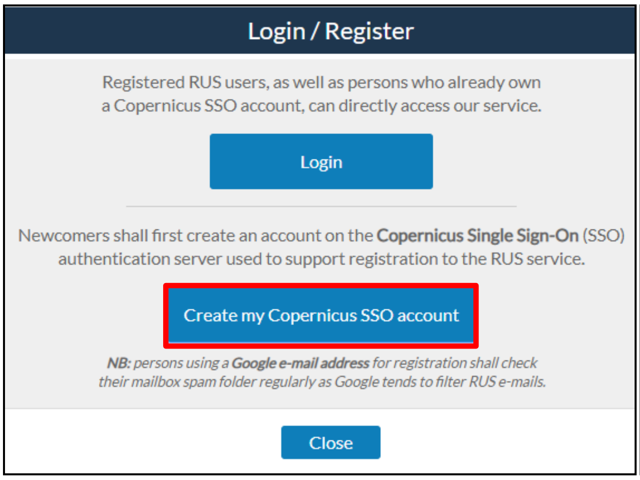
Internet browser, SNAP + Sentinel-2 Toolbox, QGIS

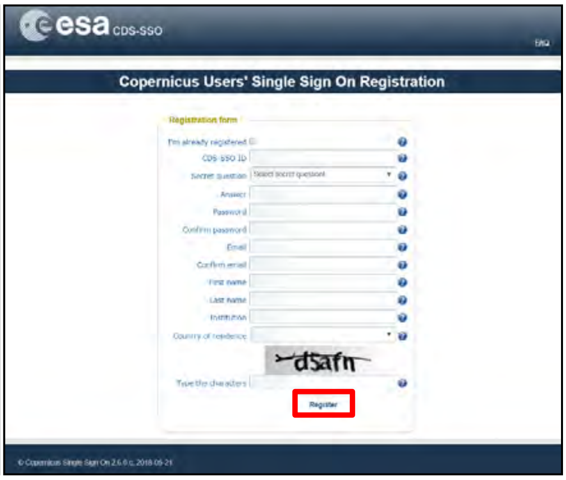
4 Register to RUS Copernicus

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.



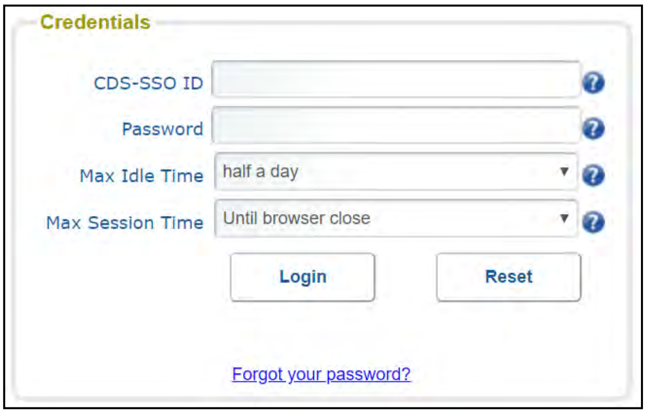
Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click ***Register***.



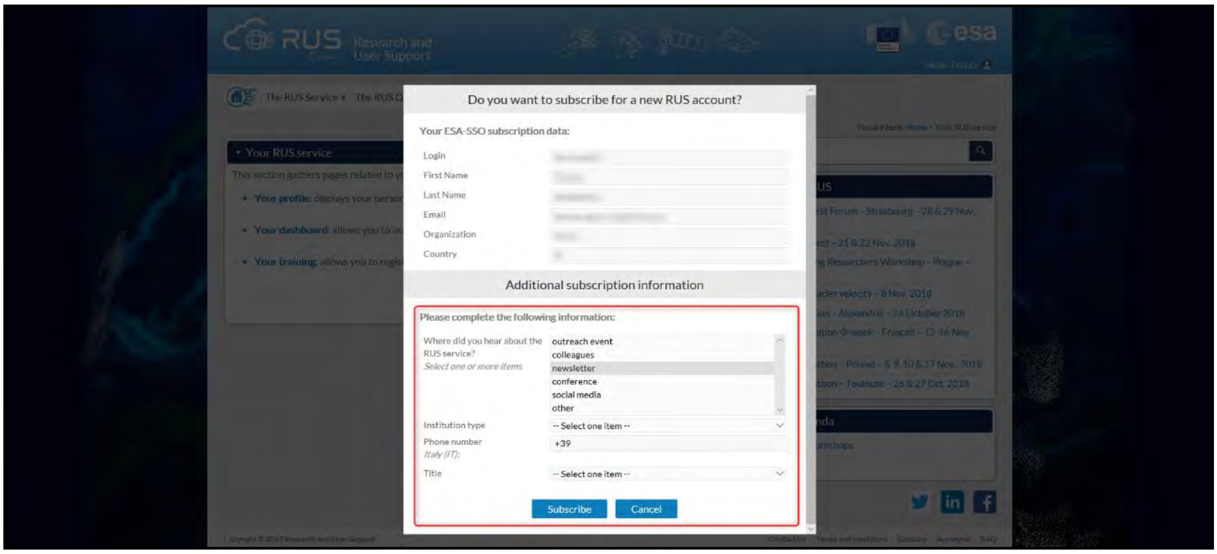


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

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

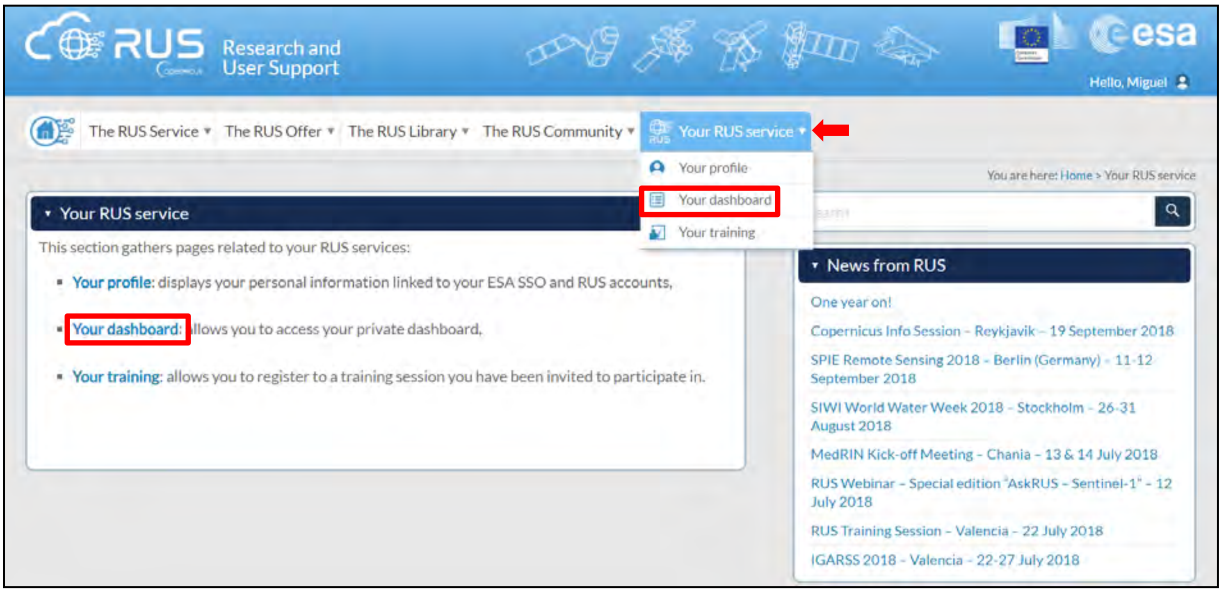


Upon your first login you will need to enter some details. You must fill all the fields.

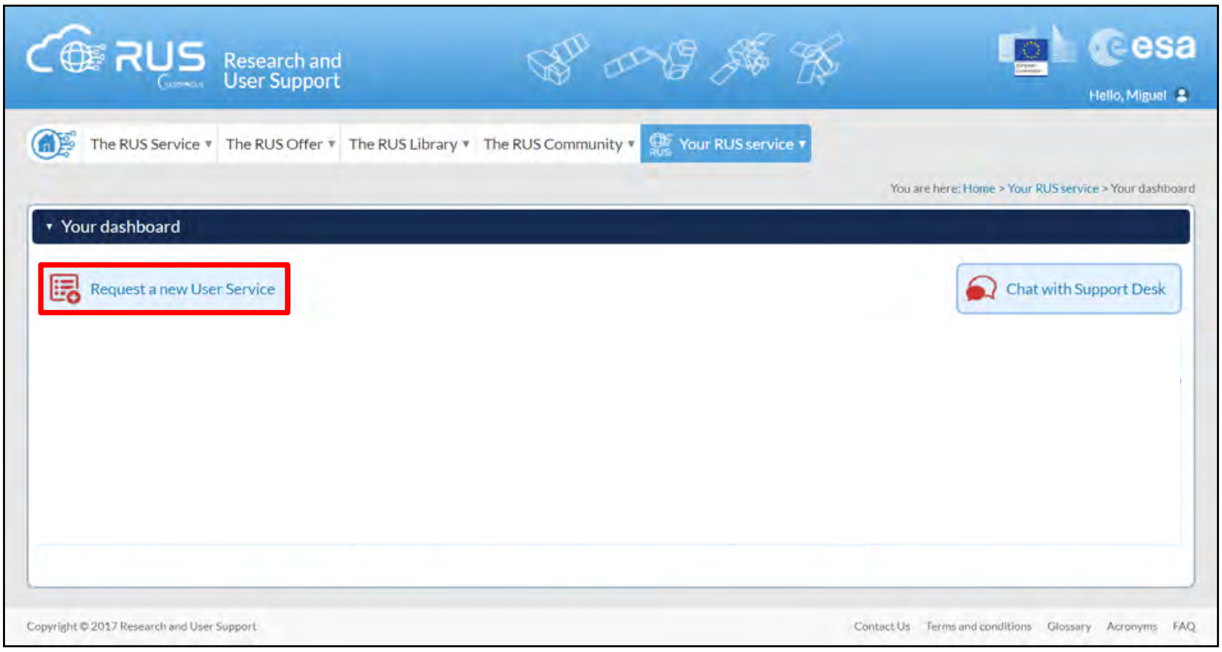


5 Request a RUS Copernicus Virtual Machine

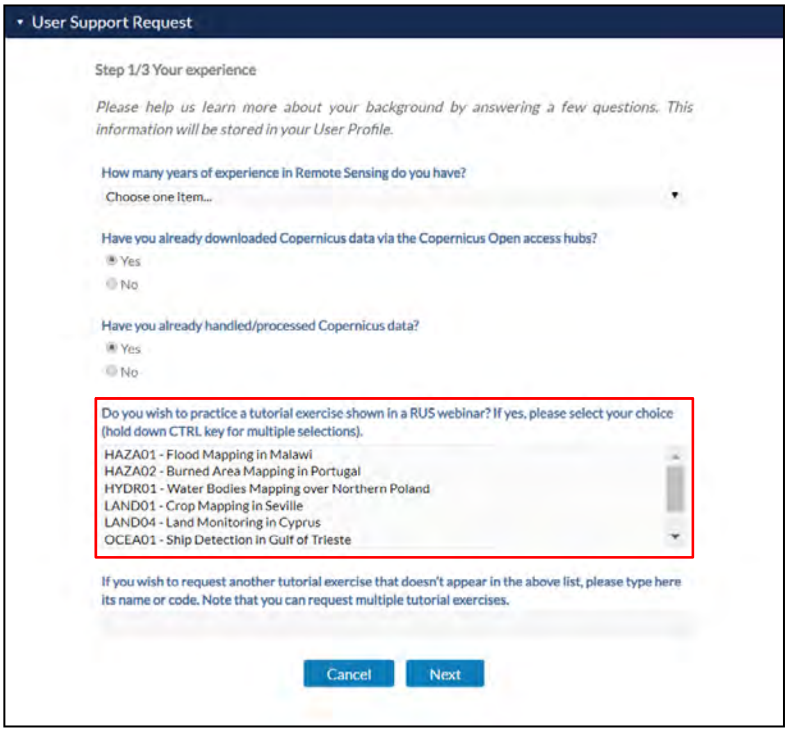
Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on ***Your RUS Service → Your Dashboard***.



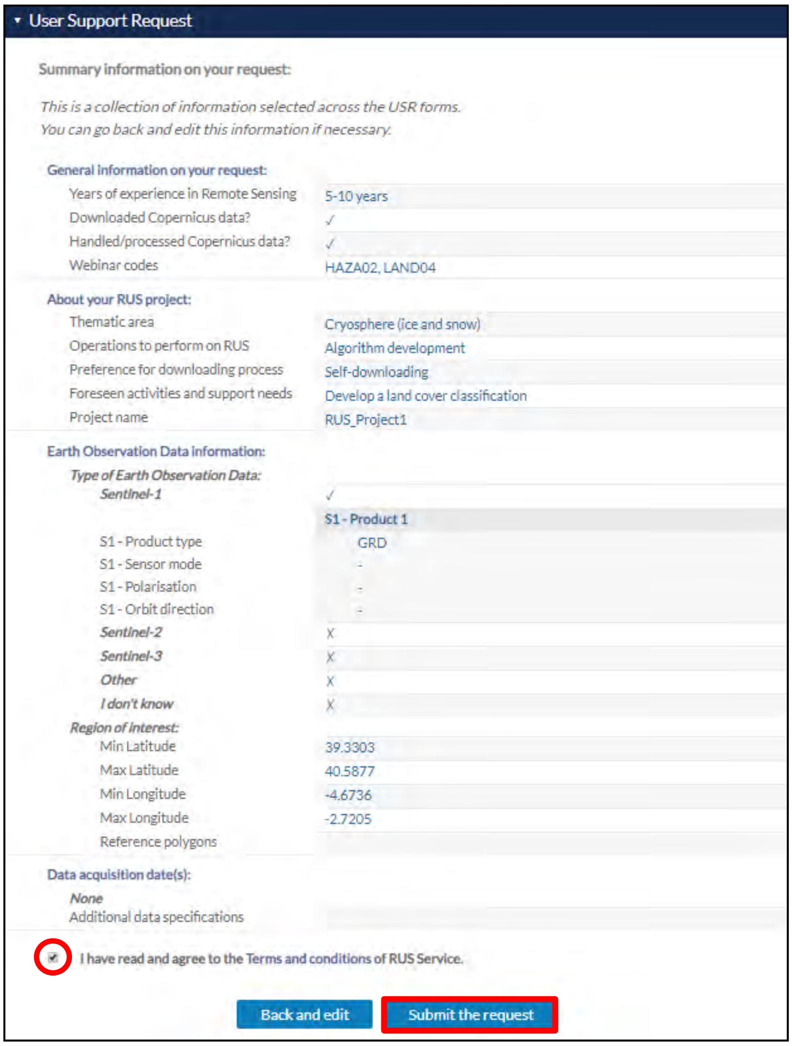
Click on ***Request a new User Service*** to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.



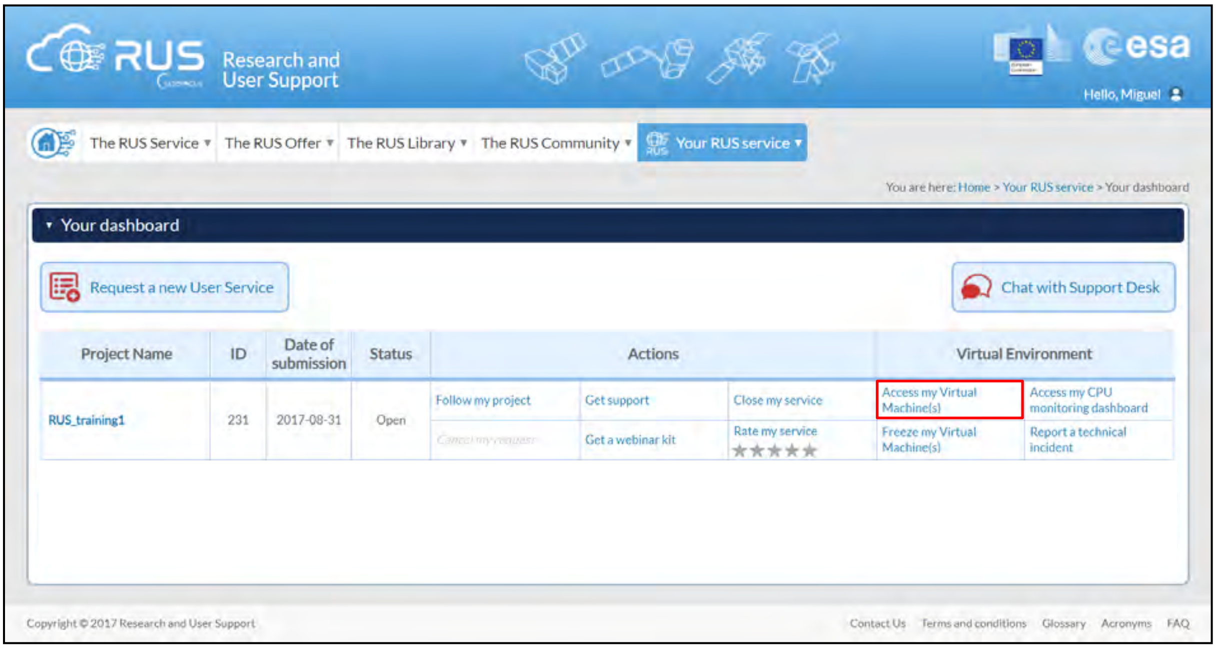
If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.



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.

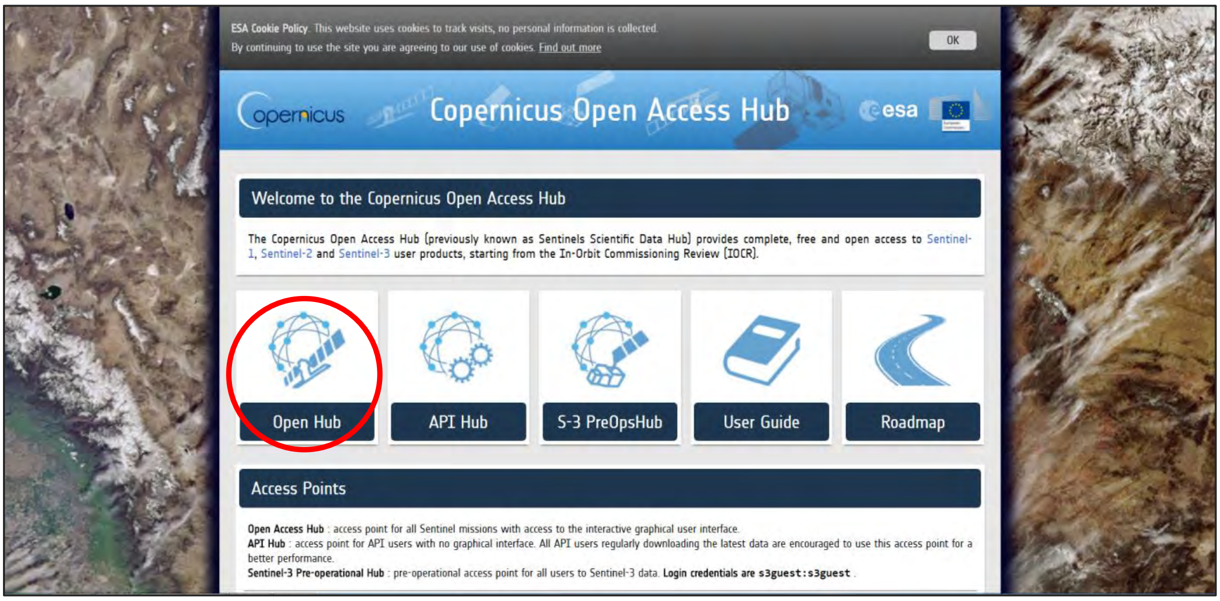
This is the remote desktop of your Virtual Machine.

6 Step by step

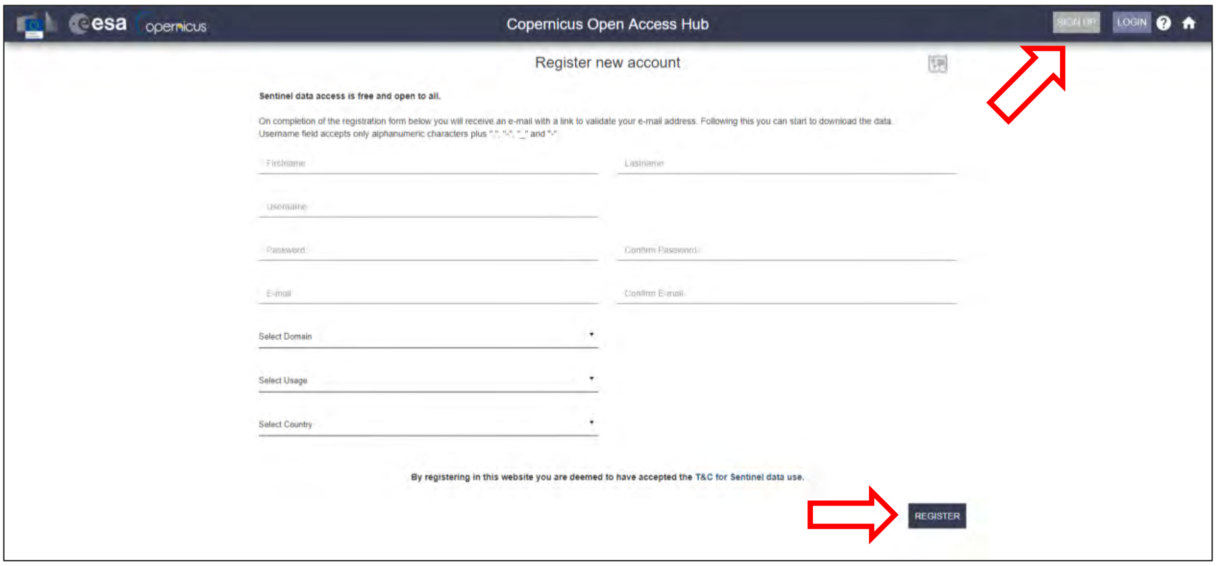
6.1 Data download – ESA SciHUB

In this step, we will download the Sentinel-2A level 2A image from the Copernicus Open Access Hub using the online interface.

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

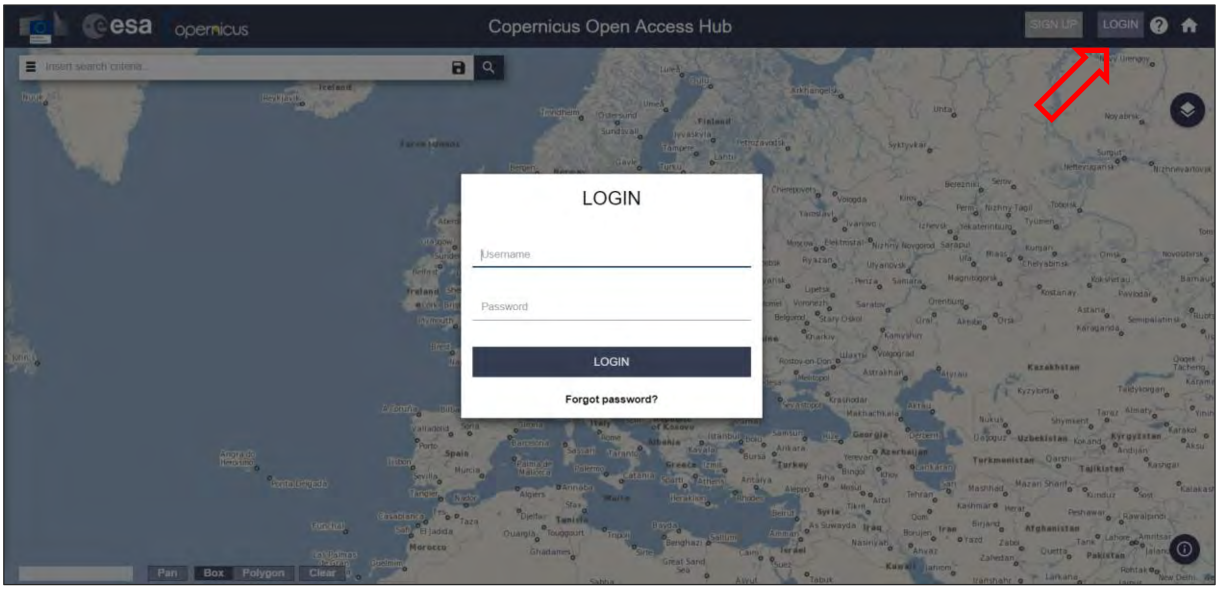


Go to *Open HUB*. If you do not have an account please sign up in the upper right corner, fill in the details and click register.

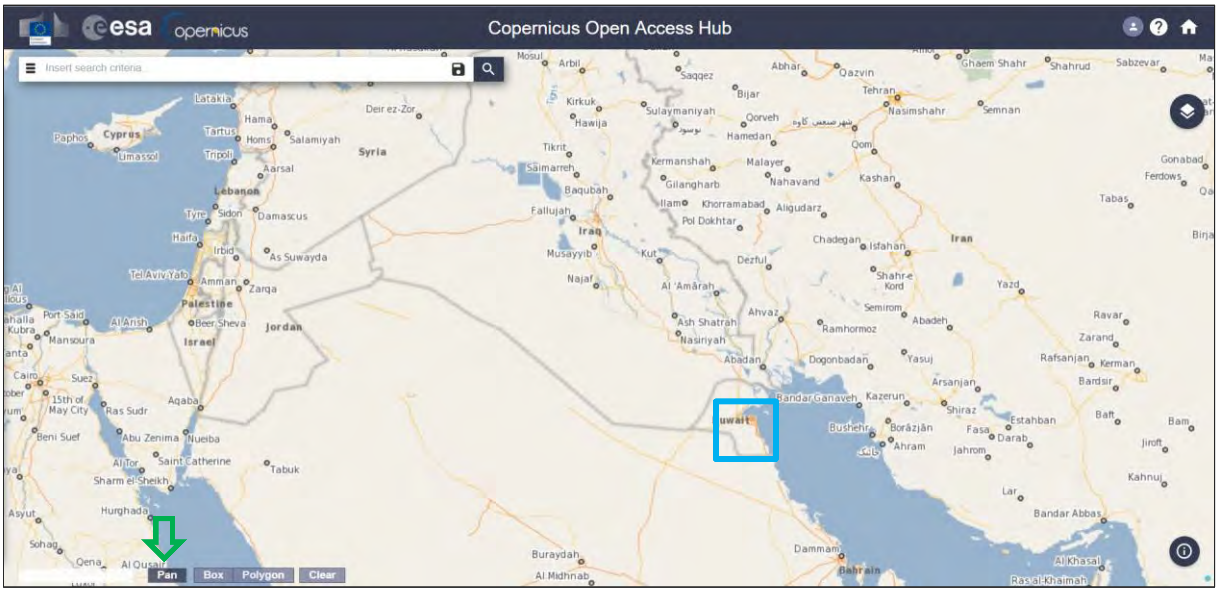


You will receive a confirmation email in the account you have specified: open the email and click on the link to finalize the registration.

Once your account is activated – or if you already have an account – log in.

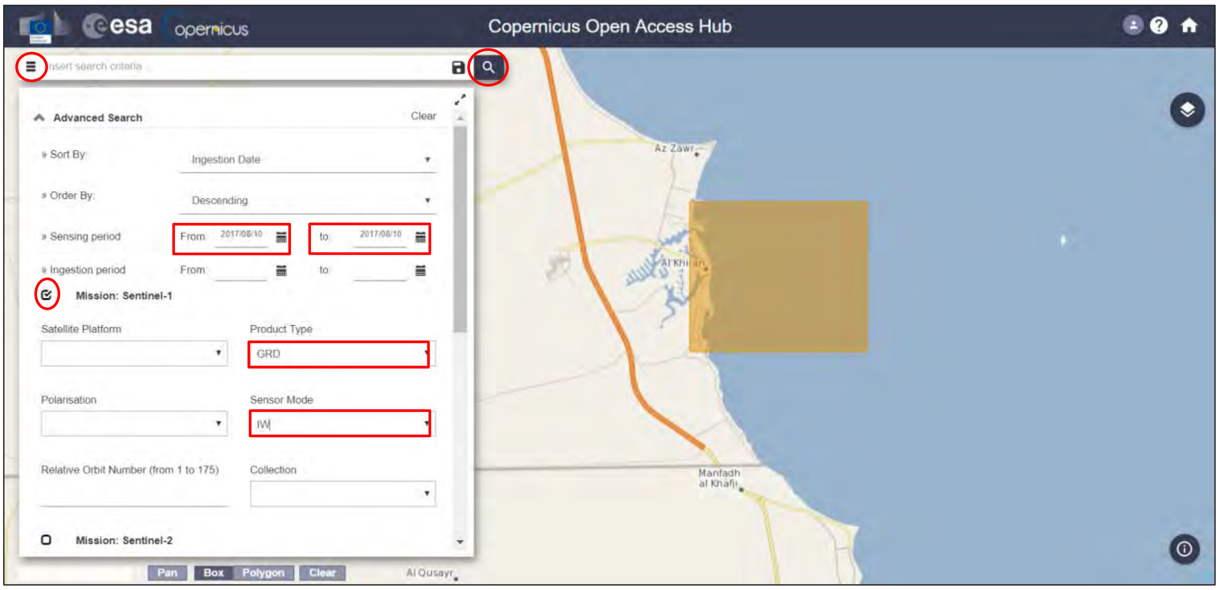


Switch the rectangle drawing mode to pan mode by clicking on the icon in the lower left corner of the map (**Green arrow**) and navigate to Kuwait (**approximate area – blue rectangle**).



Switch to drawing mode and draw a search rectangle approximately as indicated below. Open the search menu by clicking to the left part of the search bar (≡) and specify the parameters below. Press the search button ( ) after that.

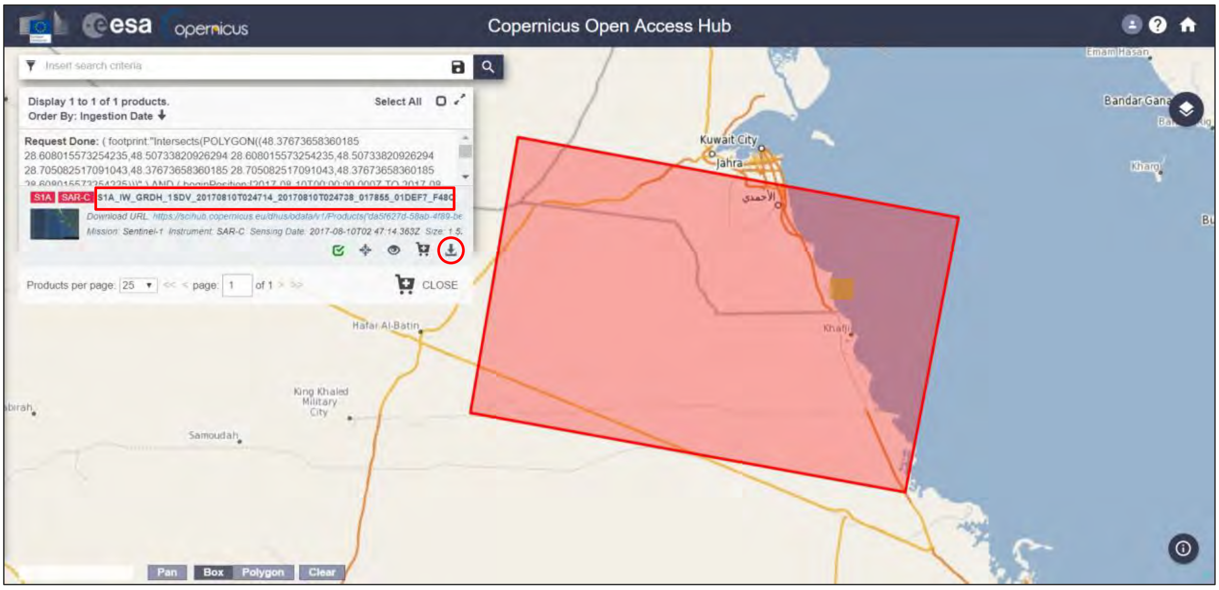
Sensing period: From 2017/08/10 to 2017/08/10
Check Mission: Sentinel-1
Product type: GRD
Sensor Mode: IW



The search returns one result. Download the following scene by clicking on the download icon.

Image ID: *S1A_IW_GRDH_1SDV_20170810T024714_20170810T024738_017855_01DEF7_F48C*

Move the downloaded scenes (desktop, */home/rus/Downloads*) to the following path and unzip it. Path: *shared/Training/OCEA03_OilSpill_Kuwait/Original*

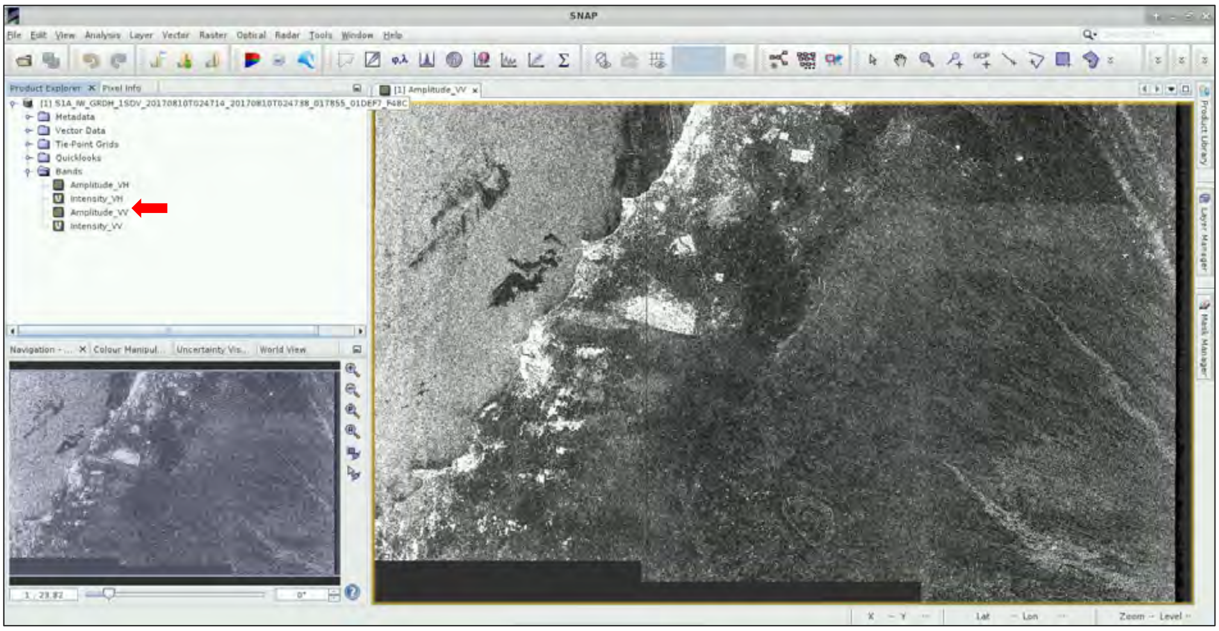


6.2 SNAP – open and explore data

Open SNAP (*Applications -> Processing*). To import the Sentinel-1 image, click File -> Open product ( ), navigate to the following path and open the product by double clicking on it.

Path: *shared/Training/OCEA03_OilSpill_Kuwait/Original*
File: S1A_IW_GRDH_1SDV_20170810T024714_20170810T024738_017855_01DEF7_F48C.zip

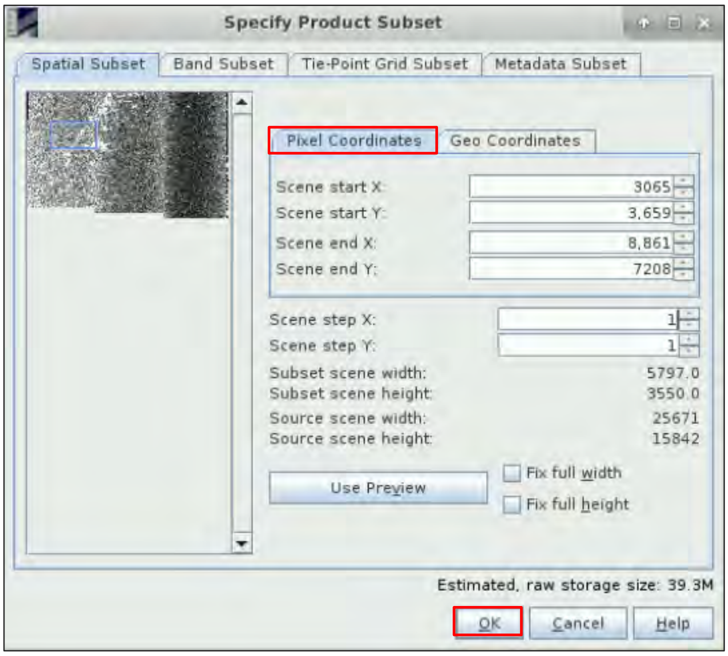
The opened product will appear in Product Explorer. Click + to expand the contents of the file, then expand the *Bands* folder and double click on the *Amplitude_VV* band to visualize it.



6.3 Subset

To reduce the processing time of the algorithm, we subset the image to our area of interest. Click on *Raster -> Subset.* In the *Spatial Subset* tab, set the following parameters in the *Pixel Coordinates* tab and click OK.

Scene start X: **3065** Scene start Y: **3659** Scene end X: **8861** Scene end Y: **7208**



The subset product will be created immediately but it is not saved on your hard disk. Right click on the subset product (index [2]) and select *Save Product*. Set the Output folder to the following path and click *Save*. If a window pops-up, click *Yes.* Then, click + to expand the contents of the file, expand the *Bands* folder and double click on the *Amplitude_VV* band to visualize it

Path: *shared/Training/OCEA03_OilSpill_Kuwait/Processing*

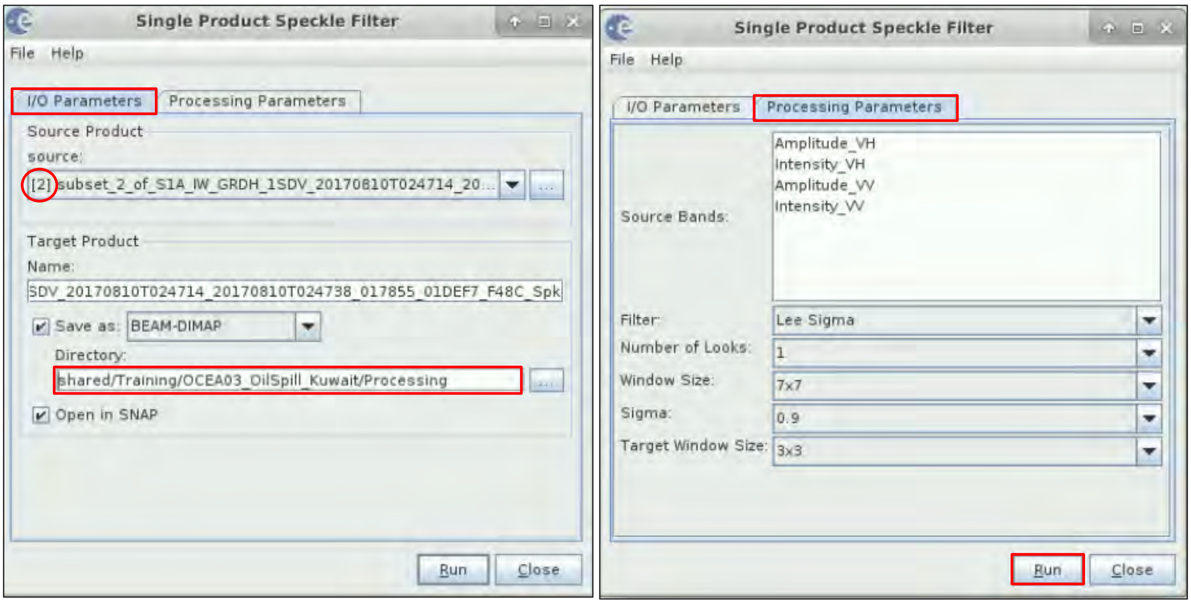
6.4 *Speckle filter*

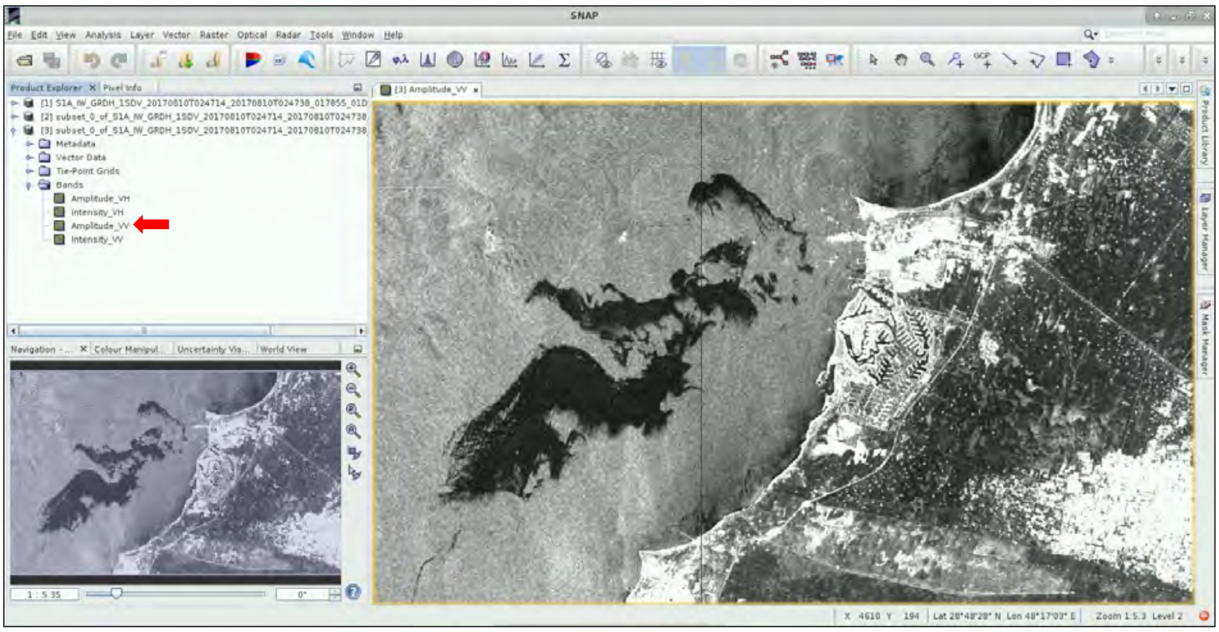
To reduce the usual salt and pepper like texturing of SAR images (See NOTE 1), a speckle filter is needed. Click on Radar -> Speckle Filtering -> Single Product Speckle Filter.

> NOTE 1: Speckle noise-like feature is a common phenomenon in SAR systems. It confers to SAR images a granular aspect and random spatial variation. The source of this noise is attributed to random interference between the coherent returns. The principle of speckle filtering is to reduce the variance of the complex speckled scattering and improve the estimate of the unspeckled scattering coefficient.

In the *I/O Parameters* tab, select as input the subset product created previously (index [2]) and set the output folder to the following path. In the *Processing Parameters* tab, all the settings remain as default. Click *Run* and display the result afterwards. Click + to expand the contents of the file (index [3]), then expand the *Bands* folder and double click on the *Amplitude_VV* band to visualize it.

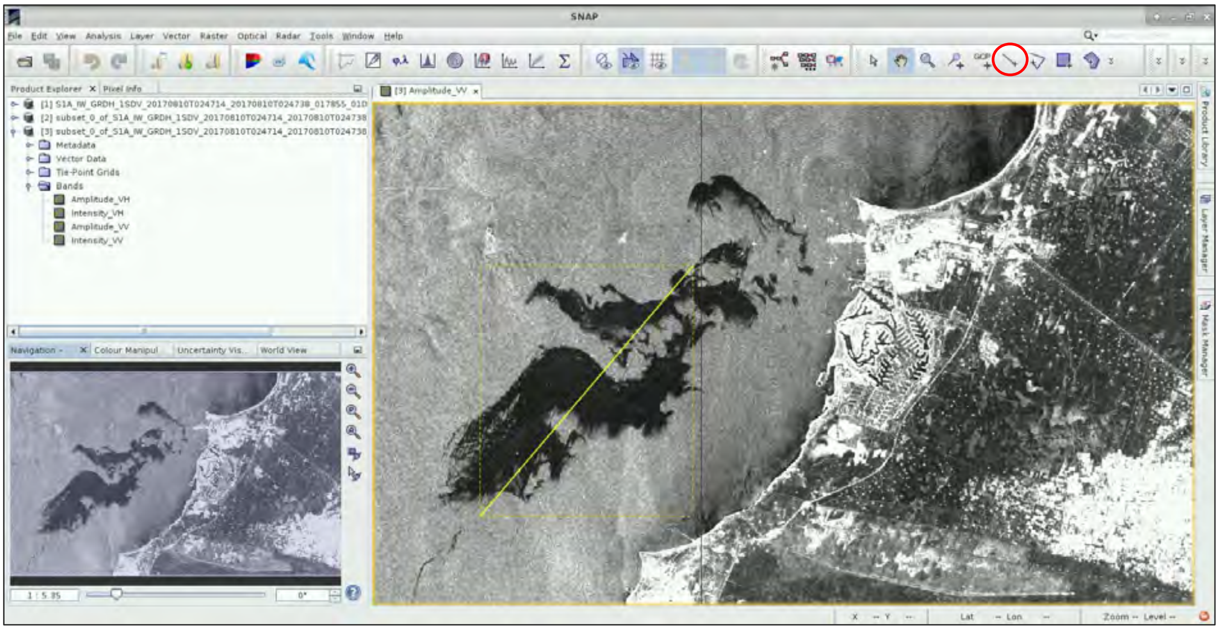
Path: *shared/Training/OCEA03_OilSpill_Kuwait/Processing/*



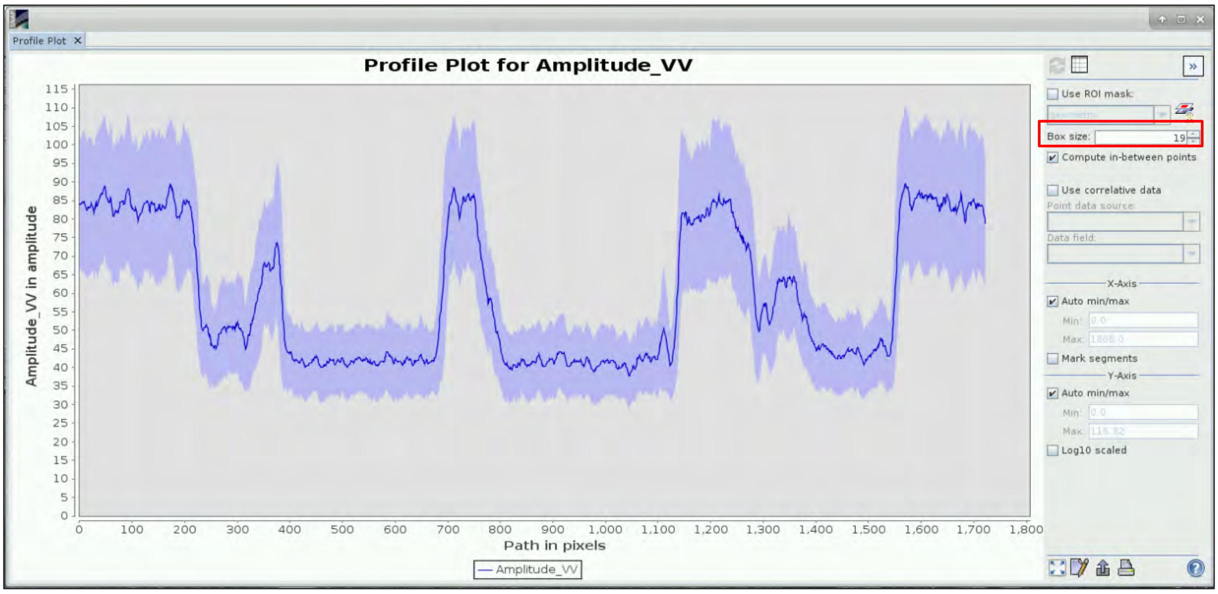


6.5 Oil spill profile plot

To visualize how an oil spill affects the reflectance of the SAR signal we can display a profile of the sigma nought (σ^0) value in the VV polarization mode. Click the line drawing tool icon – and draw a line trhough the oil spill that starts and ends in a non-oil spill area.



Click on *Analysis -> Profile Plot*. Change the *Box size* parameter to adjust the graph and analyze it.

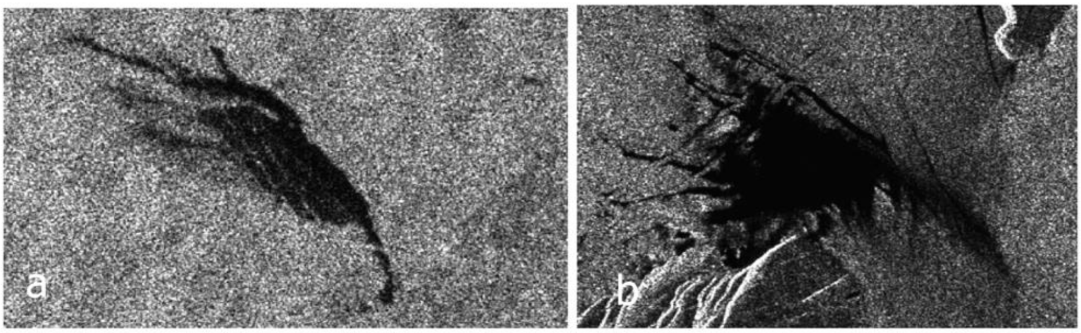


6.5.1 Oil Spill Mapping

To identify oil spills in the ocean, we will use Sentinel-1 data (See NOTE 2) and the dedicated tool that SNAP offers for this purpose. However, it has to be highlighted that only 'possible oil spills' are detected since some specific oceanic conditions can generate similar visual patterns to the ones of an oil spill (See NOTE 3).

NOTE 2: The all-weather and day-and-night sensing capabilities, spatial coverage, revisit time, and scattering of the SAR signal are some of the features that allow the use of Sentinel-1 as source of information for an oil spill surveillance program. The backscatter of the SAR signal over the ocean is mainly a result of sea roughness (i.e. short gravity-capillarity waves). Oil films decrease the sea surface roughness and hence the backscatter. This cause spills to appear darker in SAR images than spill-free areas. However, the contrast between polluted and non-polluted areas depends on different parameters such as wave height, wind speed, type of oil and sensor characteristics (wavelength, polarization, incident angle).

NOTE 3: SAR imagery over oceans usually contains oceanic and atmospheric phenomena referred to as look-alikes that can cause false alarm detections. They dampen the short waves and create dark patches on the surface, originating problems to distinguish them from oil spills. Look-alikes include natural films/slicks, grease ice, areas with specific wind speed, rain cells, internal waves, etc.

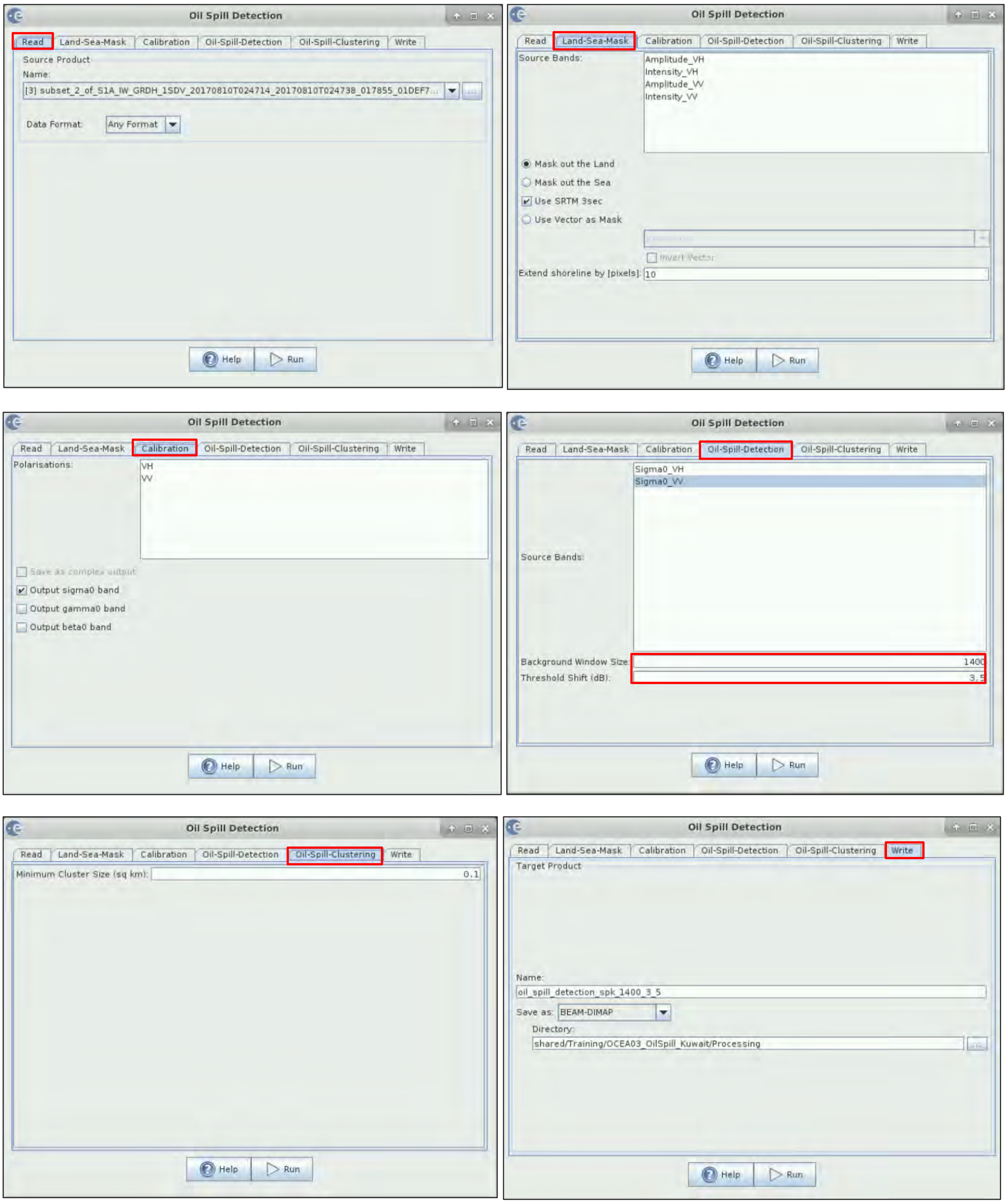


(a) Verified oil spill on a SAR image. (b) Verified look-alike on a SAR image (Stathakis et al., 2006)

Click on *Radar -> SAR Applications -> Ocean Applications -> Oil Spill Detection*. The tool includes some preprocessing steps such as land masking and calibration and the required algorithm to identify possible oil spills (See NOTE 4). Follow the instructions to complete the parameters of each tab.

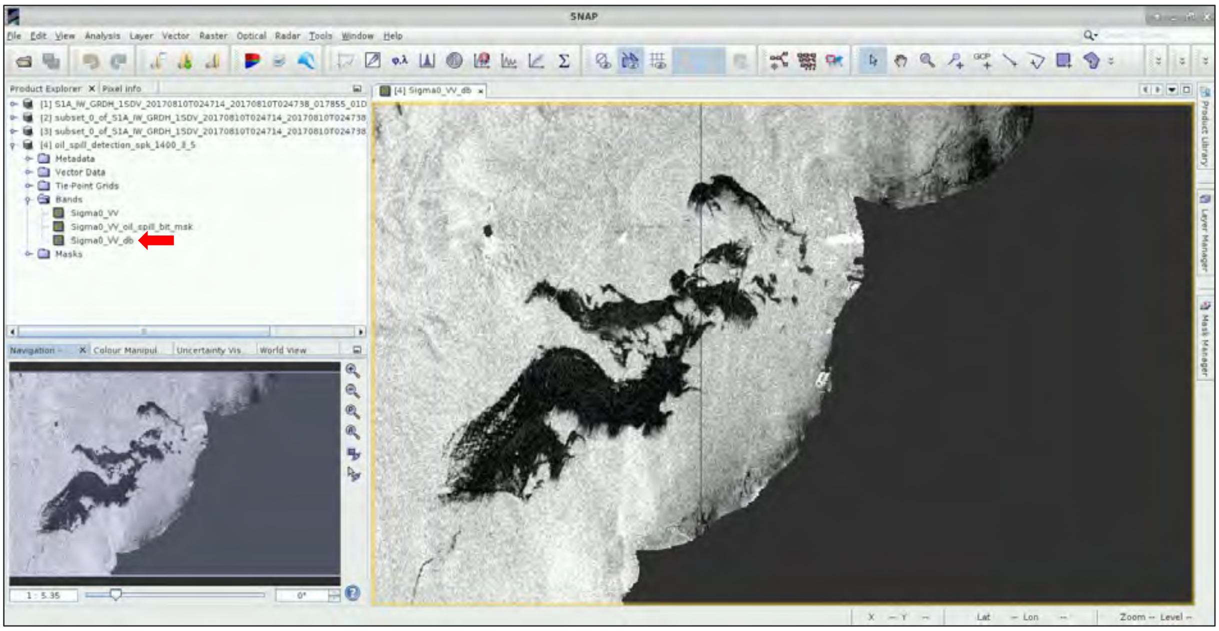
- *Read* → select the speckle filtered product (index [3].
- *Land-Sea-Mask and Calibration* → all the parameters remain as default.
- *Calibration* → Select only the *Sigma0_VV* as source band. Set the *Background Window Size* to **1400** and the *Threshold Shift (dB)* to **3.5**
- *Oil-spill-clustering → the parameter remains as default*
- *Write* → set the output name to '**Oil_Spill_detection_spk_1400_3_5**' and select the following path as directory: *shared/Training/OCEA03_OilSpill_Kuwait/Processing*

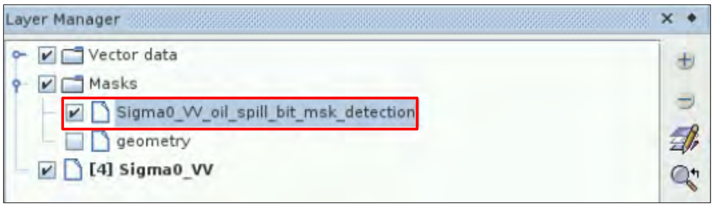
NOTE 4: The oil spill detection tool includes two preprocessing steps: mask out the inland areas and radiometric calibration so that pixel values truly represent the radar backscatter of the reflecting surface. After those preprocessing steps, dark spots are detected using an adaptive threshold algorithm where the local mean backscatter level is estimated using pixels in a large window. Then, a threshold is set to 'k' decibel below the local mean calculated before. Pixels within the window with values lower than the threshold are detected as dark spot. Finally, the detected pixels are clustered into a single cluster and those with sizes smaller than a predefined size selected by the user are eliminated.

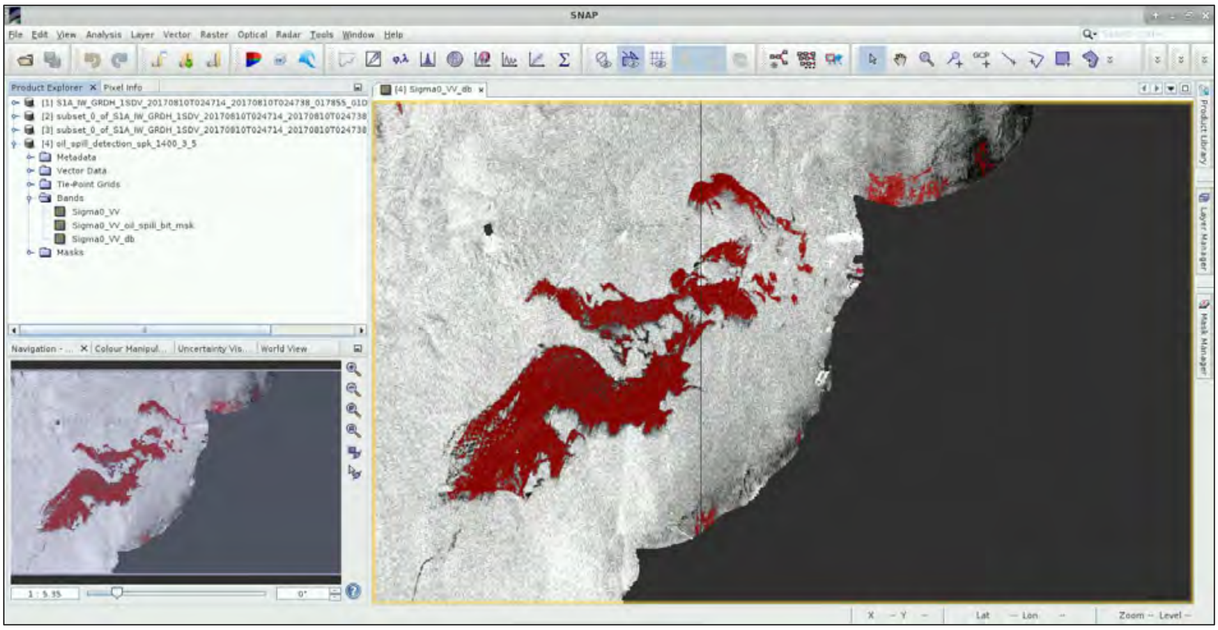


The output product is created as a binary mask that can be found on the *'Bands'* or *'Masks'* folders of the product [4]. Expand the bands folder and open the *Sigma0_VV* band. To improve the visualization and contrast, we can transform the pixel values using the decibels scale. For that, right click on the band *Sigma0_VV* and select *Linear to/from dB*. In the pop-up window, click *Yes.* The image will be created and store as a virtual band. To save it, right click on the band *Sigma0_VV_db* and select *Convert band.* Then, double click on it to visualize it.

To have a better visualization of the oil spill mask, display it on top of the SAR image. For that, open the *Layer Manager (Layer -> Layer Manager)*, expand the *'Mask'* folder and check the *Sigma0_VV_oil_spill_bit_msk_detection* band.







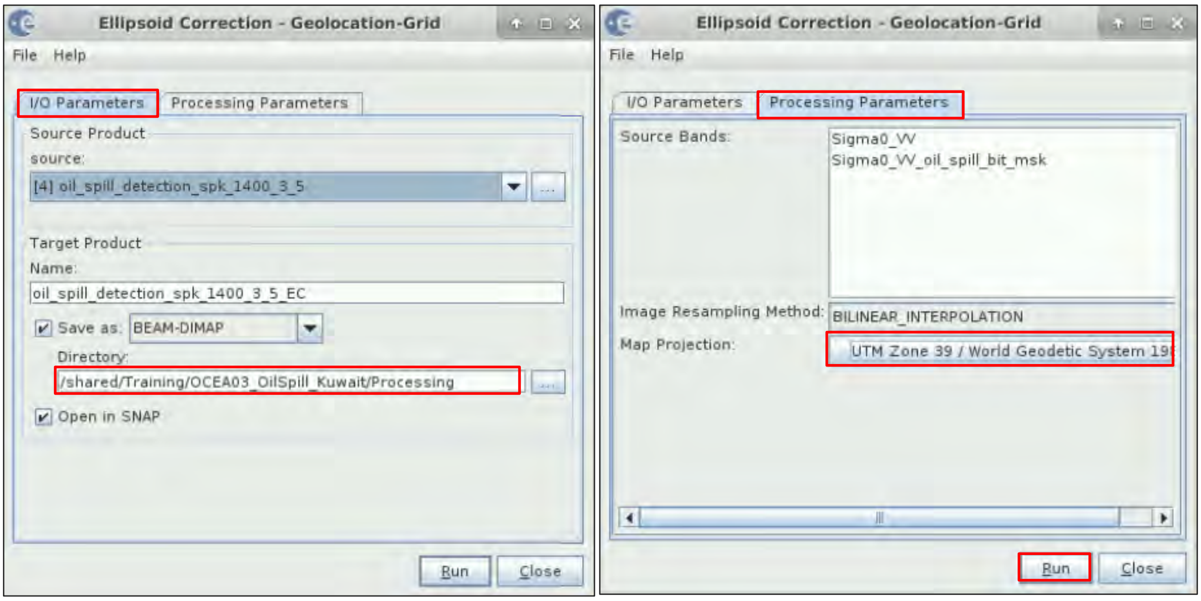
6.6 *Ellipsoid correction*

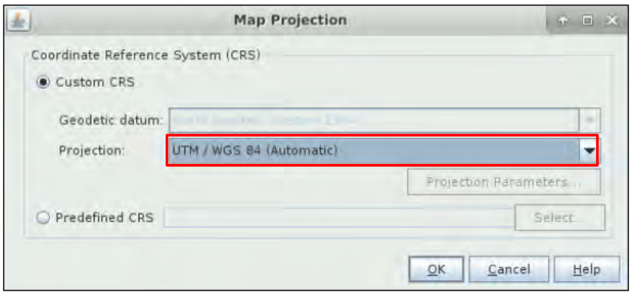
After the oil spill detection is completed, we can reproject our data into a specific coordinate reference system. To perform this step, we will use the Ellipsoid Correction (See NOTE 5).

> NOTE 5: Amongst the different options to perform geometric corrections in SANP we use in this case the Ellipsoid Correction and not the Range Doppler Terrain Correction. Since our study area is over the ocean, there are not topographic variations that can lead to geometric distortions of the SAR backscatter.

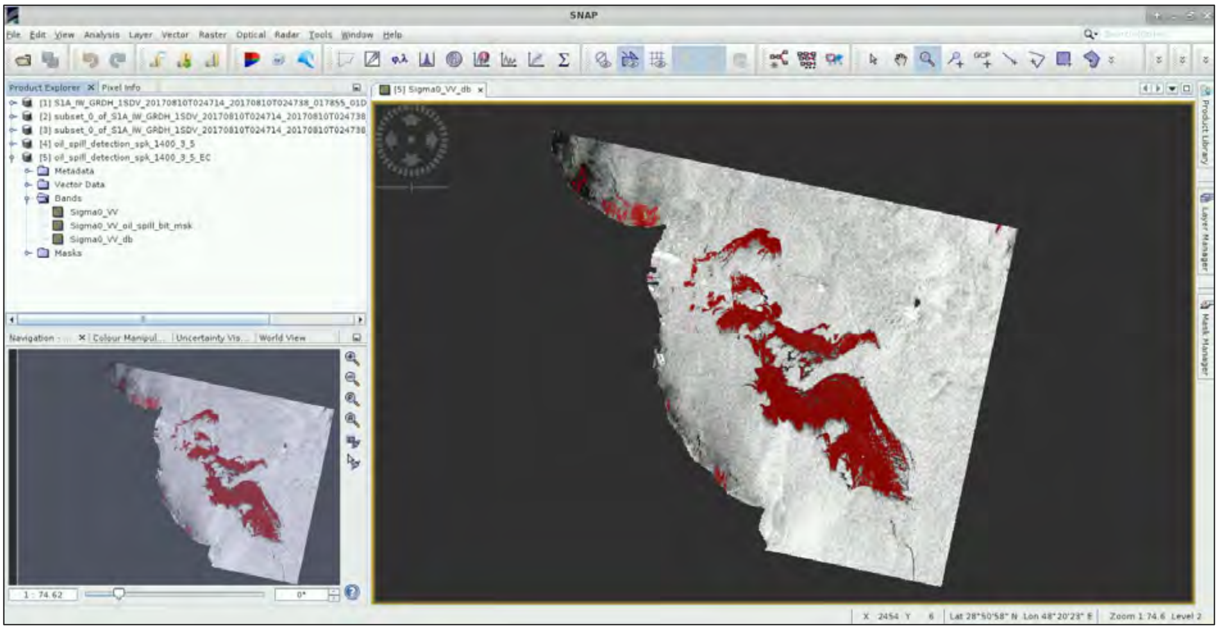
Click on *Radar -> Geometric -> Ellipsoid Correction -> Geolocation Grid*

On the *I/O Parameter* tab, select the oil spill detection product (index [4]) and make sure to select the correct output path: *shared/Training/OCEA03_OilSpill_Kuwait/Processing.* Then, click on the *Processing Parameters* tab, select the *UTM / WGS 84 (Automatic)* projection and click *Run*.





Follow the same procedure as before to produce the final visualization.



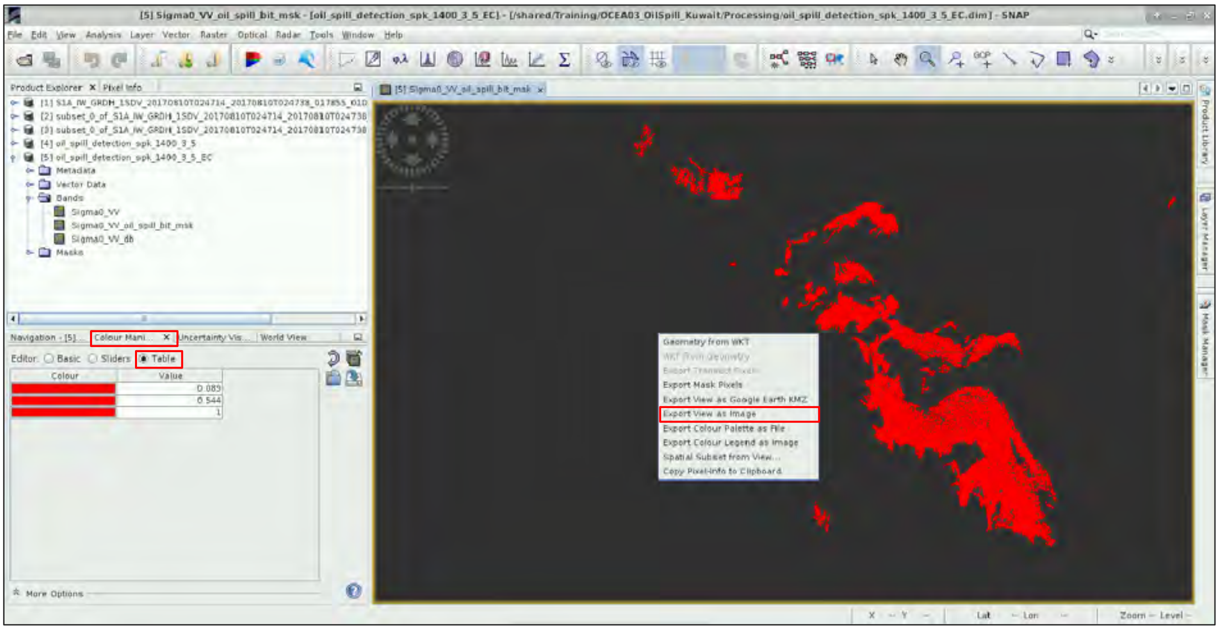
7 Extra steps

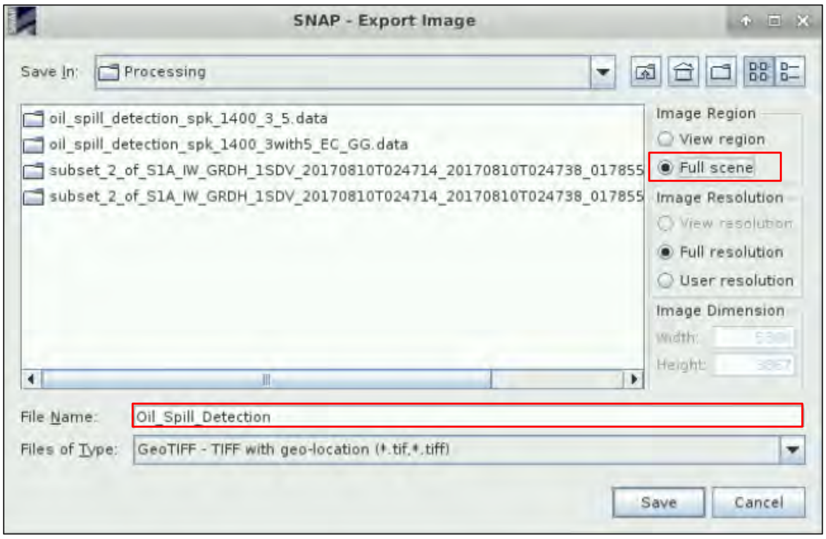
7.1 Visualization in QGIS

To export the result to QGIS, we will first change the color of the oil spill mask. Expand the reprojected product (index [5]), open the *'Bands'* folder and open the *Sigma0_VV_oil_spill_bit_msk.* Click on the *Colour Manipulation* tab (bottom left corner) (or *View -> Tool Windows -> Colour Manipulation*), select the *Table* editor and set all the colours to red.

Once the colour has changed, right click over the image. Select *Export View as Image.* Select the following path to save the product, choose the option *Full Scene* in the image region section and write *Oil_Spill_Detection* as name. Then, click *Save*.

Path: *shared/Training/OCEA03_OilSpill_Kuwait/Processing/*





Minimize SNAP and open QGIS (*Applications -> Processing -> QGIS Desktop*). Press the *Add Raster Layer* button ( ). Navigate to the following path and select the *Oil_Spill_Detection* GeoTIFF file. Click *Open*.

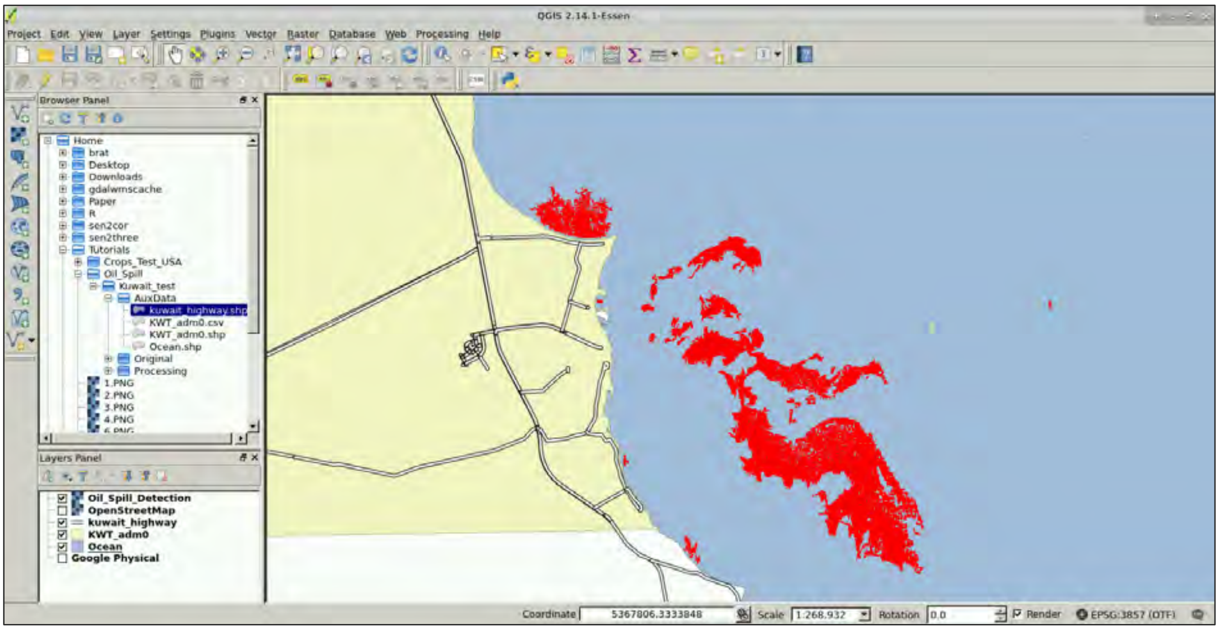
Path: *shared/Training/OCEA03_OilSpill_Kuwait/Processing*

For further analysis, you can add auxiliary data such as ocean, land and highways layers. Press the *Add Vector Layer* button ( ), navigate to the following path and add the following shapefiles: *kuwait_highways.shp, KWT_admn0.shp and Ocean.shp.*

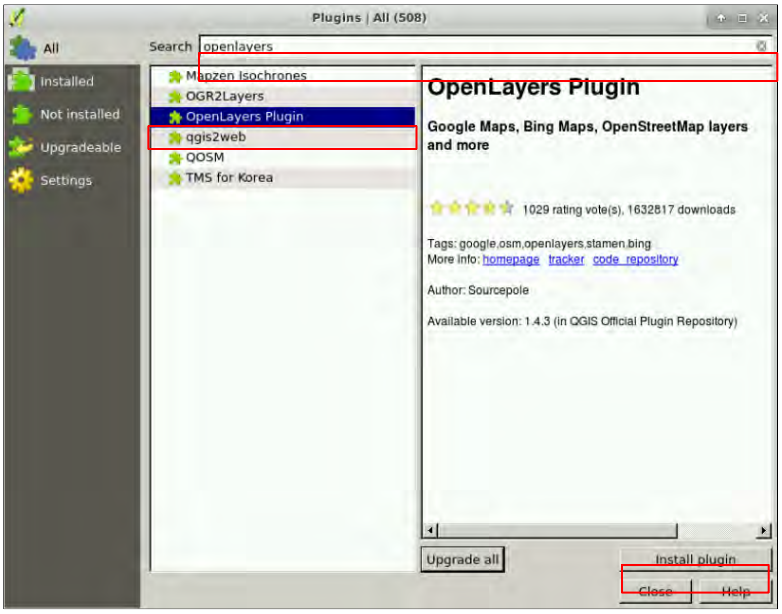
Path: *shared/Training/OCEA03_OilSpill_Kuwait/AuxData*

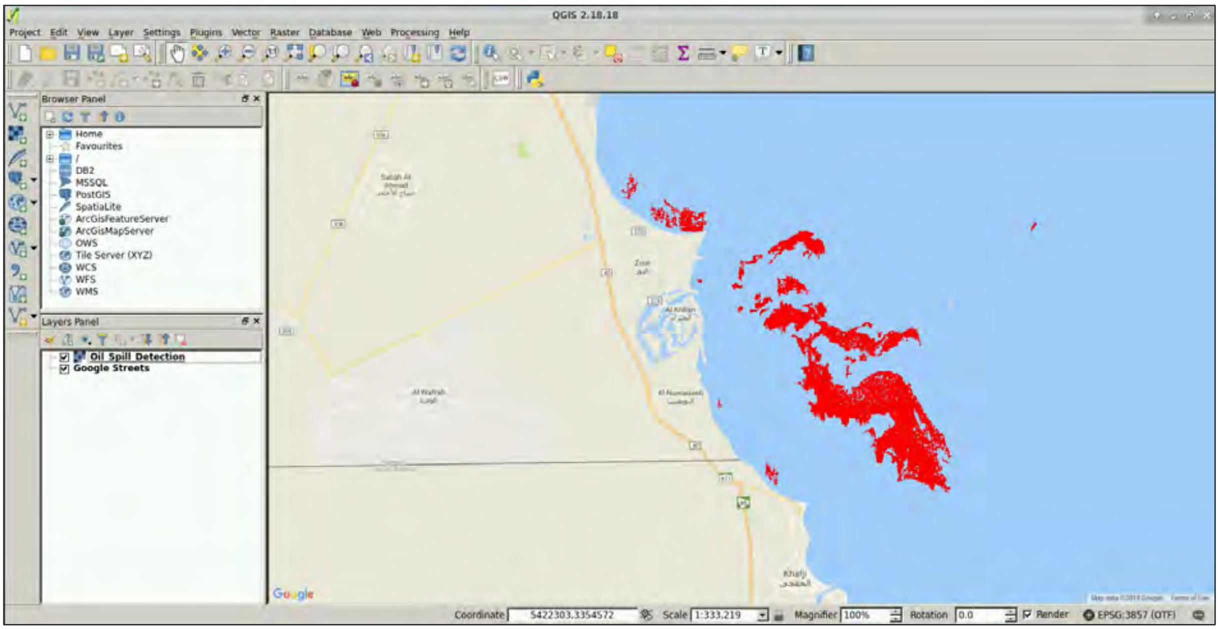
Drag the Oil Spill Detection layer to the top of all and then drag the *Kuwait_highways.shop*

Finally, you can also use the '*OpenLayers plugin*' (See NOTE 7) to display the result using OpenStreetMap as background map. Click on *Web -> OpenLayers plugin -> Google Maps -> Google Streets*. In case *Google Satellite* is not available, use a different layer, e.g. *Bing -> Bing Aerial.*



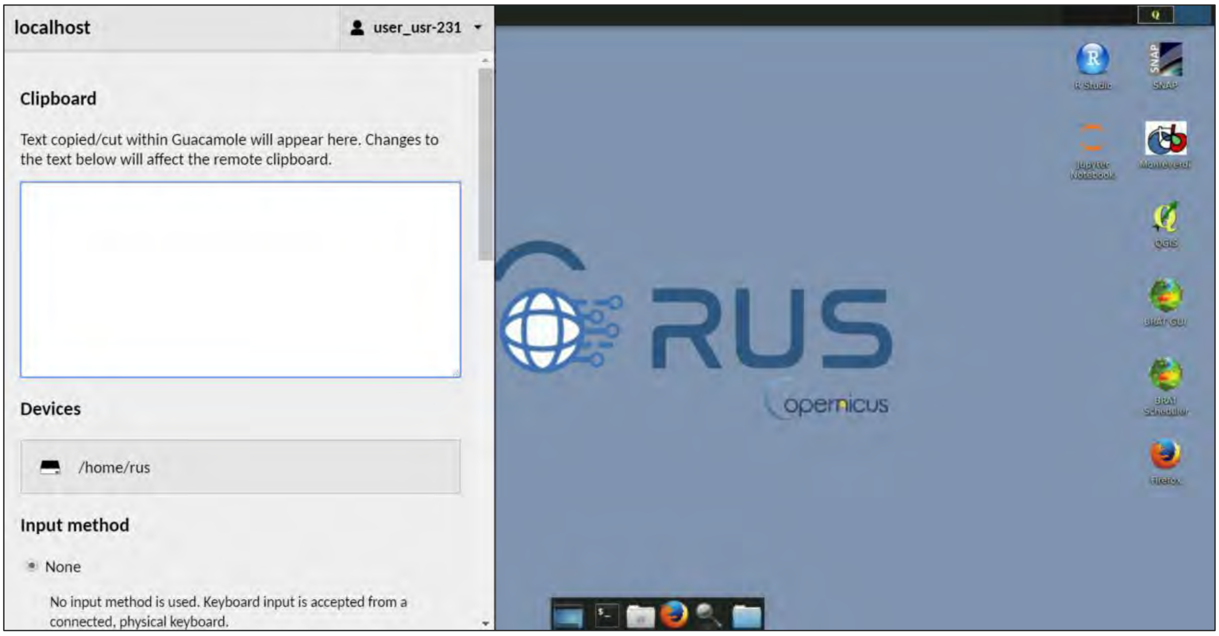
NOTE 7: If you do not have the '*OpenLayers*' plugin installed, click on the menu *Plugins -> Manage and install plugins.* Select the '*All*' section on the left side panel, *write* '*openlayers*' on the search box, select the '*OpenLayers Plugin*' and click install.





7.2 Download/Upload Virtual Machine/Local Computer

To download outputs from the RUS Virtual Machine to your local computer press **Ctrl+Alt+Shift** in your keyboard**.** A pop-up window will appear on the left side of the screen. Click on bar below **Devices.** The folder structure of your VM will appear. Navigate to the path where the file you are interested in is located and **double click on it to download it.** In case you want to download a folder, you will have to zip it beforehand.



THANK YOU FOR FOLLOWING THE EXERCISE!

8 Further reading and resources

[Sentinel-1 and oil spill detection - ESA]

[European Maritime Safety Agency (EMSA)]

Brekke, C., & Solberg, A. H. S. (2005). Oil spill detection by satellite remote sensing. *Remote Sensing of Environment*, *95*(1), 1–13. https://doi.org/10.1016/j.rse.2004.11.015

Schistad Solberg, A. H., Storvik, G., Solberg, R., & Volden, E. (1999). Automatic detection of oil spills in ERS SAR images. *IEEE Transactions on Geoscience and Remote Sensing*, *37*(4), 1916–1924. https://doi.org/10.1109/36.774704

Stathakis, D., Topouzelis, K., & Karathanassi, V. (2006). Large-scale feature selection using evolved neural networks (Vol. 6365, pp. 636513–636519). Retrieved from http://dx.doi.org/10.1117/12.688149

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