

# TRAINING KIT – OCEA03

OIL SPILL MAPPING WITH SENTINEL-1 AUGUST 2017, KUWAIT









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

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Date of publication: May 2018

Version: 1.2

Suggested citation:

Serco Italia SPA (2018). *Oil spill mapping with Sentinel-1 (version 1.2).* Retrieved from RUS Lectures at <u>https://rus-copernicus.eu/portal/the-rus-library/learn-by-yourself/</u>



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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



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.

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

Last August 10<sup>th</sup>, 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 <u>RUS portal</u> 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

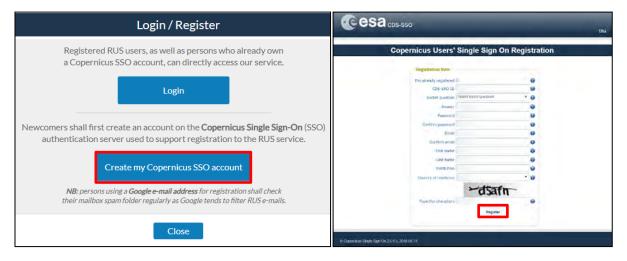
Internet browser, SNAP + Sentinel-2 Toolbox, QGIS

## 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 (<u>www.rus-copernicus.eu</u>) and click on *Login/Register* in the upper right corner.

CORRUS Research and User Support	C Star Login / Register
The RUS Service * The RUS Offer * The RUS Library * The RUS Community *	
	Seattle
	News from RUS
	One year on!
	Copernicus Info Session – Reykjavik – 19 September 2018
	SPIE Remote Sensing 2018 – Berlin (Germany) – 11-12 September 2018
	SIWI World Water Week 2018 - Stockholm - 26-31 August 2018
	MedRIN Kick-off Meeting - Chania - 13 & 14 July 2018
	RUS Webinar – Special edition "AskRUS – Sentinel-1" – 12 July 2018
Welcome to Research and User Support	RUS Training Session - Valencia - 22 July 2018
	IGAR55 2018 - Valencia - 22-27 July 2018
Welcome to the Copernicus Research and User Support (RUS) Service portal!	<ul> <li>The RUS agenda</li> </ul>
The RUS Service is the "New Expert Service for Sentinel Users" funded by the European Commission,	Conferences & Workshops

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 email to activate your account.

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

Login / Register	Credentials			-
Login/ Kegister      Degin/ Kegister      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	CDS-SSO ID Password Max Idle Time Max Session Time	formation of the second	Y	0000
Close		Forgot your password?		

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

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The RUS Service * The 6	RUS O Do you want	to subscribe for a new RUS account?		
	Your ESA-SSO subscription	n data:	You at a high House - You RUS service	
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This section gathers pages relate	d to yr First Name			
Your profile: displays your 1	Last Name	and and a second se	US	
	Email	Street State (State State )	Est Finum - Strasbourg - 28.6,29 Nov.	
Your dashboard: allow: you	Organization	and the second s	est - 21 6.22 Nov. 2016	
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		onal subscription information		
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	Please complete the follow	ing information:	adon - Augumento - Enacati - 12-16 Nov.	
	Where did you hear about the RUS service?		ADDITION TO A PROCEED BY SETTING	
	Select one or more items	colleagues newsletter	then - Poland - 6, 9, 10 5, 17 Nov. 2018	
		conference	thon - Toulouse - 26 & 27 Oct 2010	
		social media other		
	Institution type	Select one item	🗸 nda	
	Phone number Italy (17):	+39	amstape	
	Title	Select one item	·	

## 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**.

CORRUS Research and User Support	9 % K	Helto, Miguel 😩
The RUS Service      The RUS Offer      The RUS Library      The RUS Commu      Your RUS service	nity Vour RUS service	You are here: Home > Your RUS service
<ul> <li>This section gathers pages related to your RUS services:</li> <li>Your profile: displays your personal information linked to your ESA SSO and RU</li> <li>Your dashboard: Illows you to access your private dashboard,</li> <li>Your training: allows you to register to a training session you have been invited.</li> </ul>	IS accounts,	News from RUS One year on! Copernicus Info Session - Reykjavik - 19 September 2018 SPIE Remote Sensing 2018 - Berlin (Germany) = 11-12 September 2018 SIWI World Water Week 2018 - Stockholm - 26-31 August 2018 MedRIN Kick-off Meeting - Chania - 13 & 14 July 2018 RUS Webinar - Special edition "AskRUS - Sentinel-1" - 12 July 2018 RUS Training Session - Valencia - 22 July 2018 IGARSS 2018 - Valencia - 22-27 July 2018

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.

CORRUS Research and User Support	
The RUS Service * The RUS Offer * The RUS Library * The RUS Community * 👯 Your RUS service	• •
▼ Your dashboard	You are here: Home > Your RUS service > Your dashboard
Request a new User Service	Chat with Support Desk
Copyright © 2017 Research and User Support	Contact Us Terms and conditions Glossary Acronyms FAQ

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

Please help us learn more about your background by answering a few questions. 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 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). HAZA02 - Burned Area Mapping in Malawi HAZA02 - Burned Area Mapping over Northern Poland. LAND01 - Crop Mapping in Seville LAND01 - Crop Mapping in Guite These	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 choic (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 Selile LAND04 - Land Monitoring in Cyprus	Step 1/3 Your experience	
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OCEA01 - Ship Detection in Gulf of Trieste	OCEA01 - Ship Detection in Guif of Trieste		
		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 he	its name or code. Note that you can request multiple tutorial exercises.	its name or ends. Note that you can request multiple tutorial mersion	

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

his is a collection of information selected ou can go back and edit this information		
	( needeer).	
General Information on your request:		
Years of experience in Remote Sensing	5-10 years	
Downloaded Copernicus data?	1	
Handled/processed Copernicus data?	1	
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	1	
	S1-Product 1	
S1 - Product type	GRD	
S1 - Sensor mode	-	
S1 - Polarisation		
S1 - Orbit direction Sentinel-2		
Sentinel-2 Sentinel-3	X	
Other	x	
I don't know	X	
Region of Interest:	x	
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		

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**.

							You are here: Home >	Your RUS service > Your dash
Your dashboard								
Request a new l	Jser Servi	ce					2	Chat with Support Desk
Project Name	ID	Date of submission	Status		Actions		Virtual	Environment
				Follow my project	Get support	Close my service	Access my Virtual Machine(s)	Access my CPU monitoring dashboard
RUS_training1	231	2017-08-31	Open		Get a webinar kit	Rate my service	Freeze my Virtual Machine(s)	Report a technical incident

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.

2 Applications				
Elle System Redex	Bistr Scheduler	QGIS	Risuere	SNAP
Home Documental		BRAT GU	Jupsker Notebooz	otonteverd
tiblet Tests				
opernicu	S			

## 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.

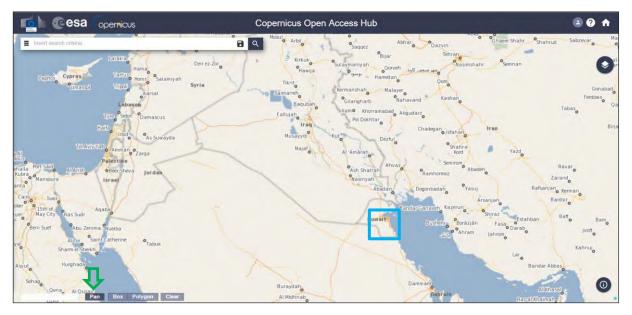
Copernicus Op	en Access Hub	SIGALIE LOGIN 🖓 🛧
Register ne	ew account	· · · · · · · · · · · · · · · · · · ·
Sentinel data access is free and open to all.		
On completion of the registration form below you will receive an e-mail with a link to valida Username field accepts only alphanumeric characters plus "" "" and ""	te your e-mail address. Following this you can start to download the data.	×
Firshiame	Lasinarile	
Usemaine		
Pansword	Confirm Password	
Esmail	Contem Esmail	
Select Domain		
Select Usage		
Select Country		
By registering in this website you are deemed t		RE CHISTER

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.

esa @esa	opernicus	Copernicus Open Access Hub		
insert search cateria.	Level 1975	Conditions of the second states of the second state	ennanela unas servicia	
i anti	nto Gener Fratan Vice Vice Vice	Username Password	Construction of the second sec	a boota turna boo
		Forget password?	A CONTRACT OF A	VERYNAM CONSTRUCTION OF CONSTRUCTUOE OF CONSTR

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 ( $\equiv$ ) and specify the parameters below. Press the search button ( $\bigcirc$ ) after that.

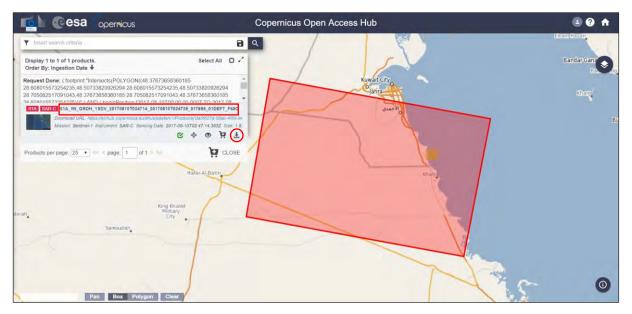
Sensing period: From 2017/08/10 to 2017/08/10 Check Mission: Sentinel-1 Product type: GRD Sensor Mode: IW

📥 @esa	opernicus	Copernicus Open Access Hub	3 Ø A
nsert search criteria			
Advanced Search		Clear	9
* Sort By	Ingestion Date	Az Zawi	
# Order By:	Descending		
» Sensing period	From 2017/08/10 to 2017/08/10		
* Ingestion period	From:   to:		
Satellite Platform	Product Type	<u>&gt;</u>	
	• GRD		
Polarisation	Sensor Mode		
Relative Orbit Number (fr	rom 1 to 175) Collection	Manfadh al Kraft	
O Mission: Sentine	el-2		6
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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* 

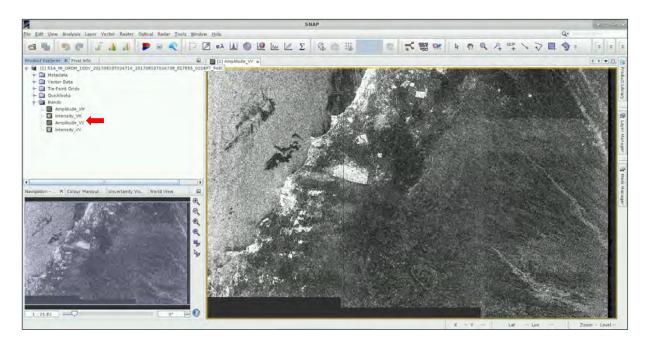


## 6.2 SNAP - open and explore data

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.

4	Specify Product Subset	
Spatial Subset B	and Subset   Tie-Point Grid Sub	set Metadata Subset
	Pixel Coordinates	Geo Coordinates
	Scene start X:	3065
TO ALCON MERCENCIAL AND ADDRESS OF	Scene start Y:	3,659
	Scene end X:	8,861
	Scene end Y;	7208
	Scene step X:	1-2
	Scene step Y:	1
	Subset scene width:	5797.
	Subset scene height:	3550
	Source scene width: Source scene height:	2567 1584
		Fix full width
	Use Pre <u>v</u> iew	Fix full height
	*	
	E	stimated, raw storage size: 39.
		OK Cancel Help

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 1 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.

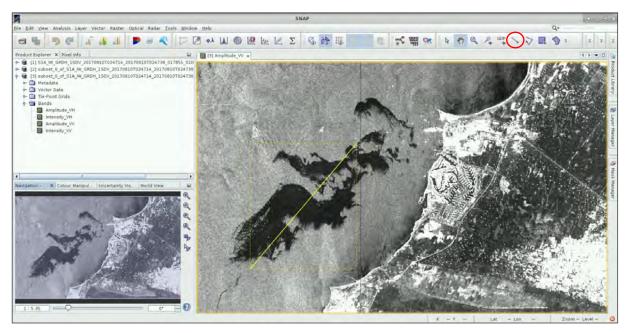
In the *I/O Parameters* tab, select as input the subset product created previously (index [2]) and set the output folder to the following path. In the *Processing Parameters* tab, all the settings remain as default. Click *Run* and display the result afterwards. Click + to expand the contents of the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

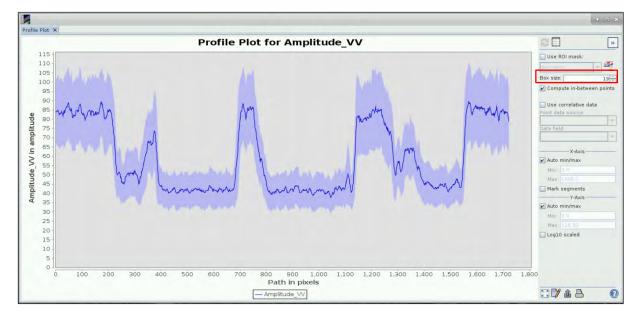
No Parameters   Processing Parameters Source Product Source Product Source Product Source Product Source Product Source Product Source Bands: Intensity_VH Amplitude VI Intensity_VH Source Bands: Intensity_VH I		C Sin	igle Product Speckle Filter	- E
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Image: Source Bands:     Intensity_VH     Amplitude Z_O (SIA_M_GRDH_ISDY_20170810T024714_20     Image: Source Bands:     Image: Source Bands: <td>Source Product</td> <td>1/0 Parameters</td> <td></td> <td></td>	Source Product	1/0 Parameters		
Image: Product   Source Bands:   Intensity_W	source:			
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## 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 ( $\sigma^0$ ) value in the VV polarization mode. Click the line drawing tool icon –  $\searrow$  and draw a line trhough the oil spill that starts and ends in a non-oil spill area.



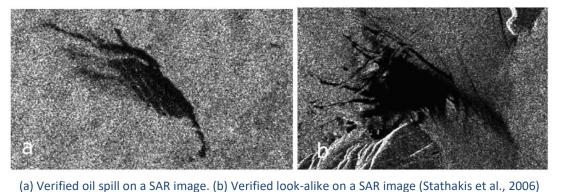
Click on Analysis -> Profile Plot. Change the Box size parameter to adjust the graph and analyze it.



#### 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.



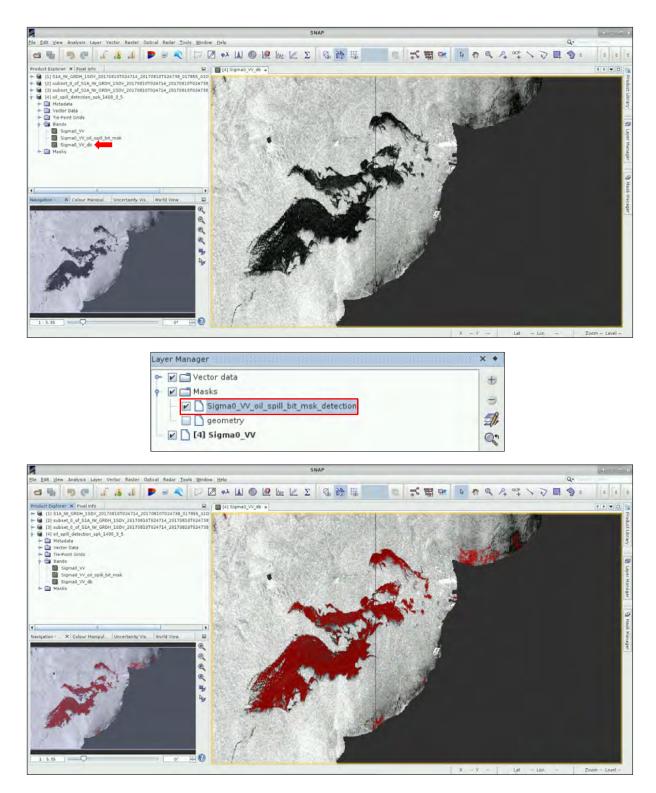
Click on *Radar -> SAR Applications -> Ocean Applications -> Oil Spill Detection*. The tool includes some preprocessing steps such as land masking and calibration and the required algorithm to identify possible oil spills (See 1 NOTE 4). Follow the instructions to complete the parameters of each tab.

- Read  $\rightarrow$  select the speckle filtered product (index [3].
- Land-Sea-Mask and Calibration  $\rightarrow$  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  $\rightarrow$  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.

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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 SigmaO\_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 SigmaO\_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 SigmaO\_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 1 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.

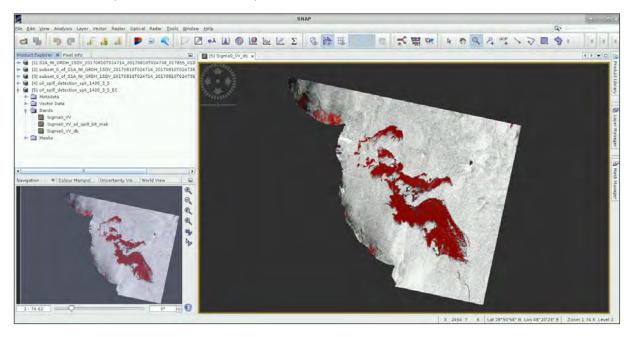
#### Click on Radar -> Geometric -> Ellipsoid Correction -> Geolocation Grid

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*.

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



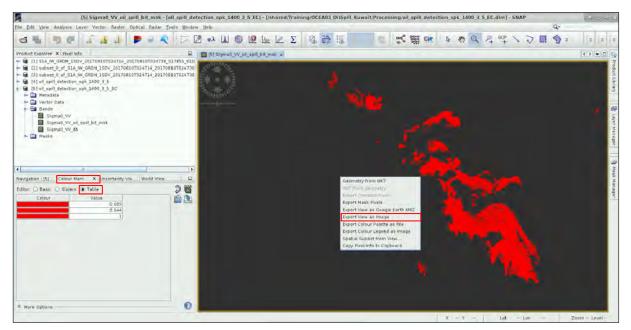
## 7 Extra steps

#### 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 SigmaO\_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/



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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*.

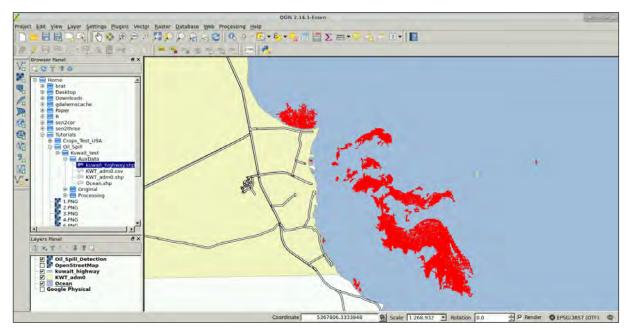
#### Path: shared/Training/OCEA03\_OilSpill\_Kuwait/Processing

For further analysis, you can add auxiliary data such as ocean, land and highways layers. Press the Add Vector Layer button ( $\mathbb{M}_{3}$ ), 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

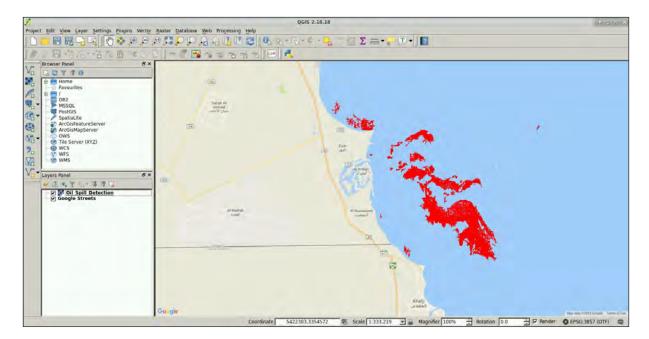
Drag the Oil Spill Detection layer to the top of all and then drag the Kuwait\_highways.shop

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.

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all 👘	Search openlayers	
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#### 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.

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## THANK YOU FOR FOLLOWING THE EXERCISE!

## 8 Further reading and resources

Sentinel-1 and oil spill detection - ESA

European Maritime Safety Agency (EMSA)

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- 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
- Topouzelis, K., & Singha, S. (2016). Oil Spill Detection: Past and Future Trends. ESA Living Planet Symposium, SP-740(July).

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