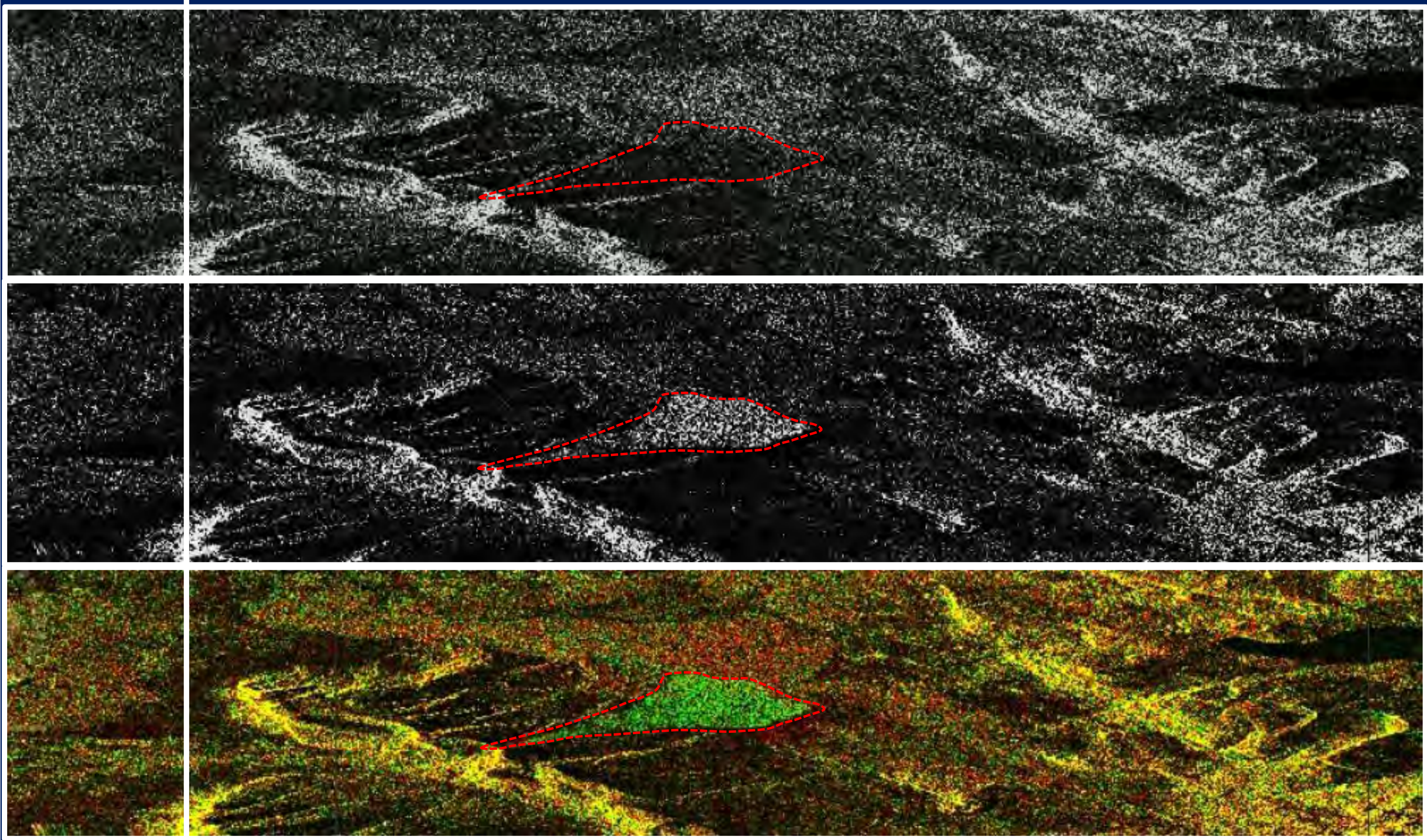
RUS Copernicus



TRAINING KIT – HAZA07

RAPID LANDSLIDE DETECTION WITH SENTINEL-1 – JULY 2018 (Fagraskógarfjall, ICELAND)

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

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Table of Contents

1 Introduction 4

2 Training 4

2.1 Data used 4

2.2 Software in RUS environment 4

3 Register to RUS Copernicus 5

4 Request a RUS Copernicus Virtual Machine 6

5 Step by step 9

5.1 Data download – ESA SciHUB 9

5.2 SNAP – open and explore data 13

5.3 Data Coregistration 14

5.3.1 Read the input products 14

5.3.2 TOPS Split 15

5.3.3 Apply Orbits 16

5.3.4 Back-Geocoding 16

5.3.5 Enhanced Spectral Diversity 16

5.3.6 Write-create the output 17

5.3.7 RGB Composition 17

5.4 Interferometric Processing 18

5.4.1 Interferogram formation 19

5.4.2 TOPS Deburst 20

5.4.3 Topographic Phase Removal 20

5.4.4 Multilooking 20

5.4.5 Phase Filtering 21

5.4.6 Write-create the output 21

5.4.7 Geocoding 22

5.5 Subset 24

5.6 Export products 25

5.7 Comparison with other data 26

6 Extra Steps 26

6.1 Download files from VM 26

6.2 Visualization in Google Earth 27

7 Further reading and resources 29

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 acquired by the Copernicus Sentinel satellites constellation.

View of the landslide on Fagraskógarfjall mountain in West Iceland (Source: https://www.icelandreview.com/nature-travel/largest-landslide-icelandic-history/

The primary driving force for a landslide to occur is gravity, but there are other factors that affect the slope stability as well. In many cases, a landslide is triggered by a specific event, such as a heavy rainfall or an earthquake.

The Fagraskógarfjall landslide was likely triggered by the large volume of rainfall that Iceland received during the 2018 summer. It occurred on a remote part of Iceland on July 7th, 2018 and based on former satellite data, the hillside was known for its instabilities since 2015. It was one of the largest recorded landslides and has a volume of around 10-20 million m^3.

The landslide crossed the river below, partially blocked it creating a dam, and a lake was formed above the debris tongue. Since the landslide fell from an area that showed evidence of earlier ground displacements it might be considered to have been an old landslide deposit. The area of the debris tongue is around 1,5-1.8 km^2 and the debris is up to 20–30 m thick.

By detecting and monitoring such movements before a critical failure, we can stabilize the slope or evacuate the areas that could be affected. SAR data and techniques allow us to remotely identify and monitor potential landslides before the main failure occurs, at a low cost, complementing other ground-based techniques.

2 Training

Approximate duration of this training session is **two** hours.

The Training Code for this tutorial is HAZA07. 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

- Two Sentinel-1A IW SLC images acquired on 23 June 2018 and on 17 July 2018 [downloadable at https://scihub.copernicus.eu/]

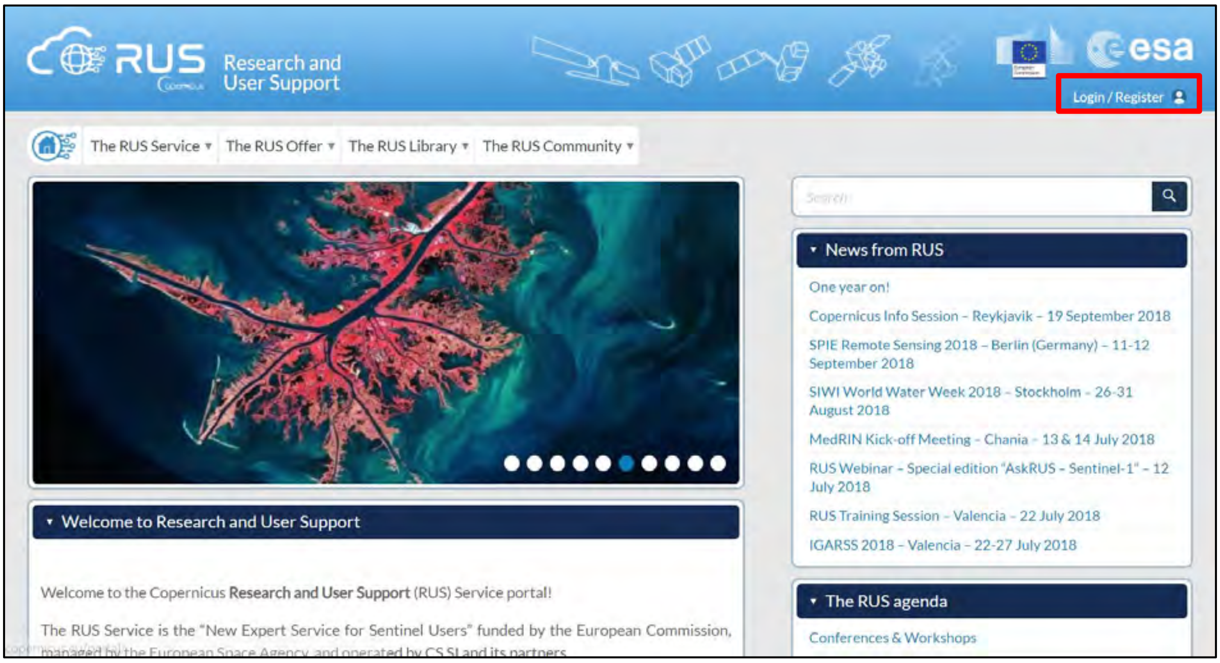
  S1A_IW_SLC__1SDV_20180623T185856_20180623T185923_022488_026F84_32C6
  S1A_IW_SLC__1SDV_20180717T185857_20180717T185924_022838_0279F5_B025

2.2 Software in RUS environment

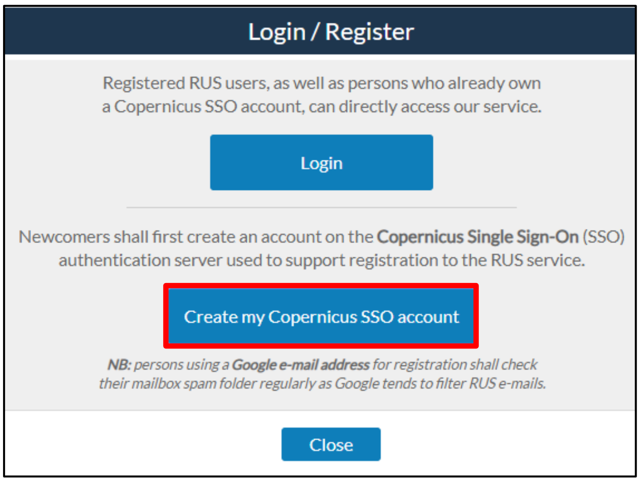
Internet browser, SNAP + Sentinel-1 Toolbox, (Extra steps: Google Earth)

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) and click on ***Login/Register*** in the upper right corner.

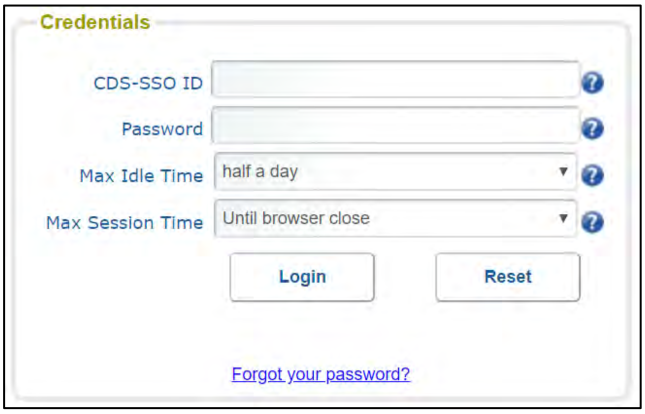


Select the option ***Create my Copernicus SSO account*** and then fill in ALL the fields on the **Copernicus Users' Single Sign On Registration**. Click ***Register***.

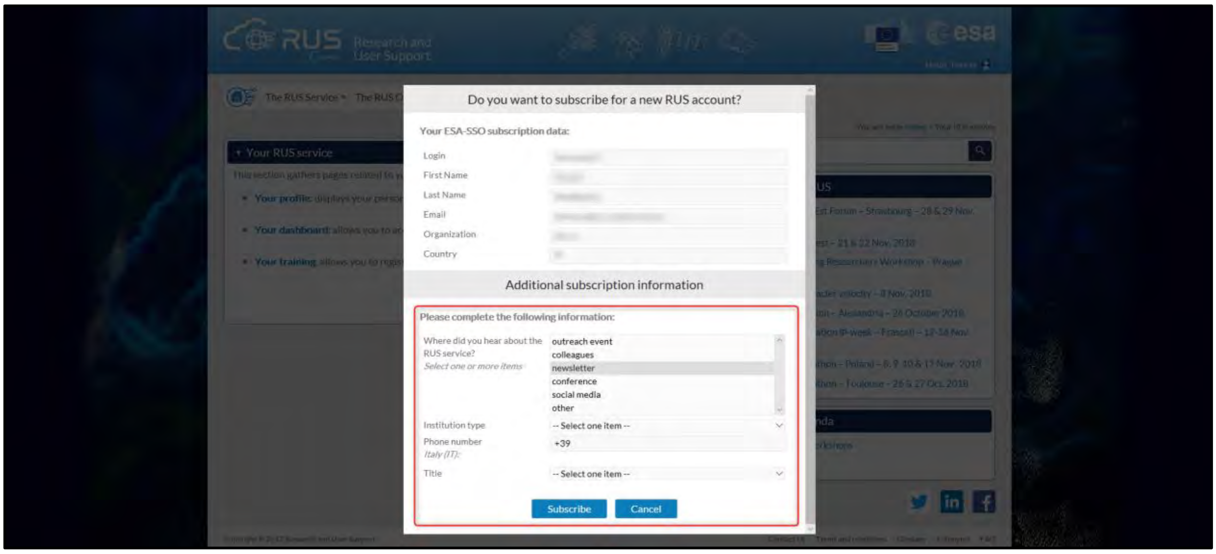


Within a few minutes you will receive an e-mail with activation link. Follow the instructions in the e-mail to activate your account.

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

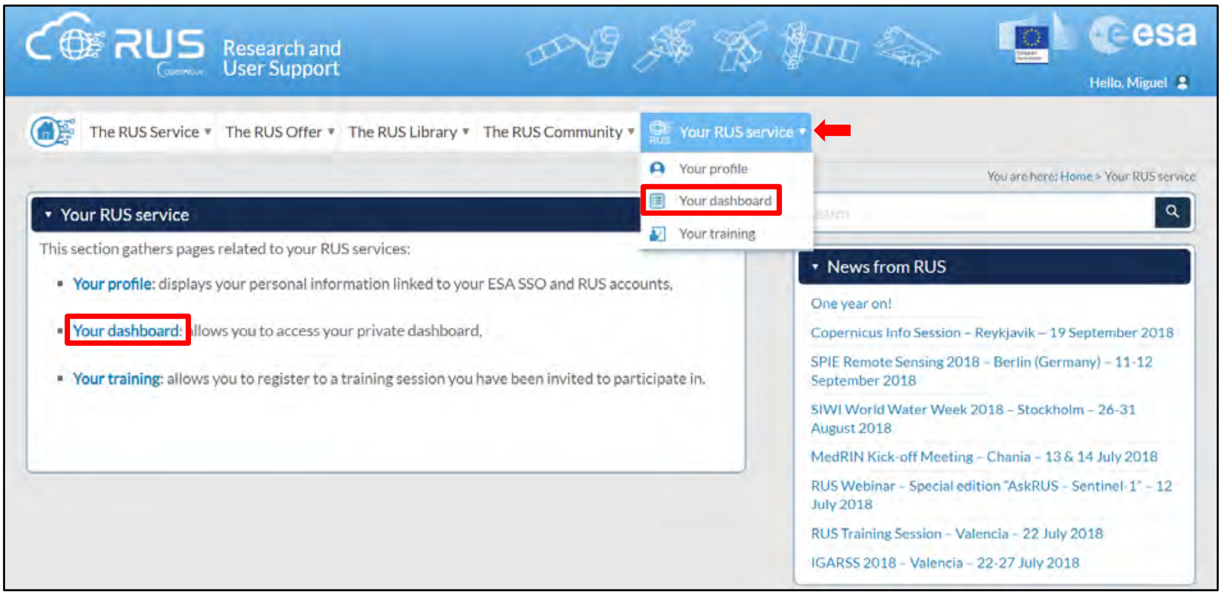


Upon your first login you will need to enter some details. You must fill all the fields.

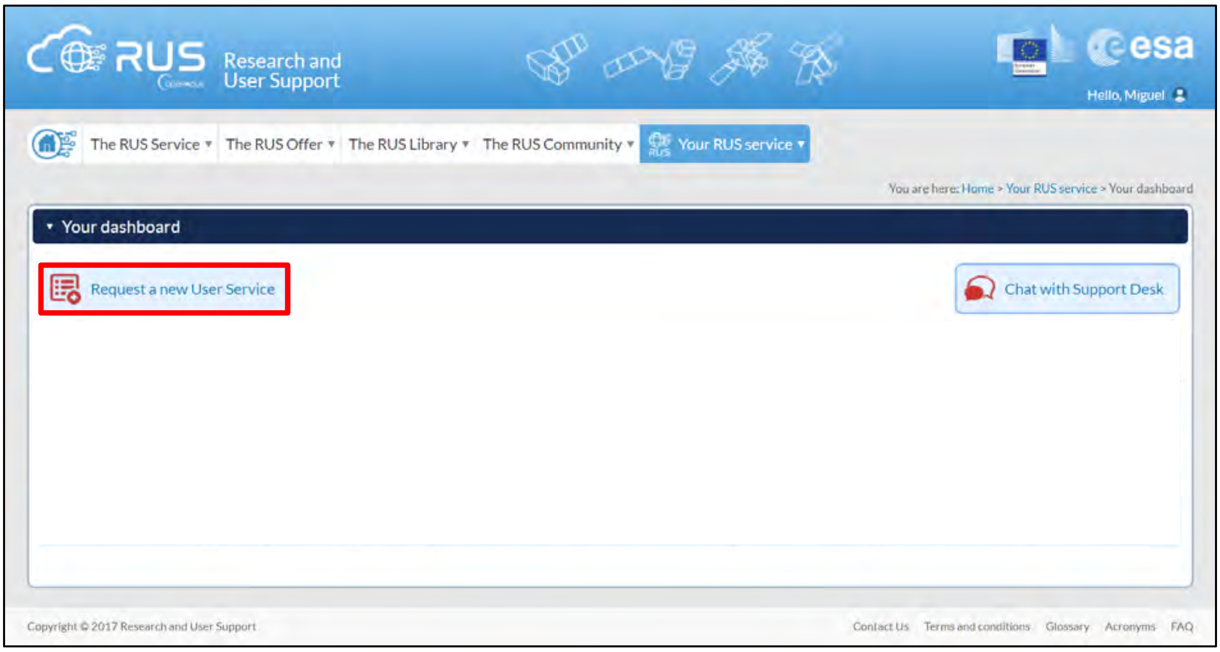


4 Request a RUS Copernicus Virtual Machine

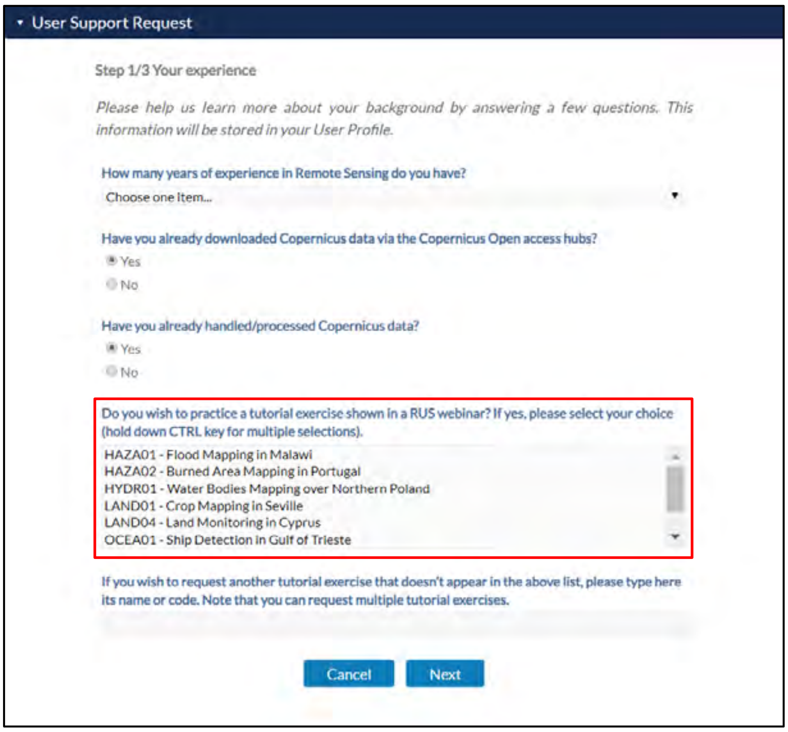
Once you are registered as a RUS user, you can request a RUS Virtual Machine to repeat this exercise or work on your own projects using Copernicus data. For that, log in and click on ***Your RUS Service → Your Dashboard***.



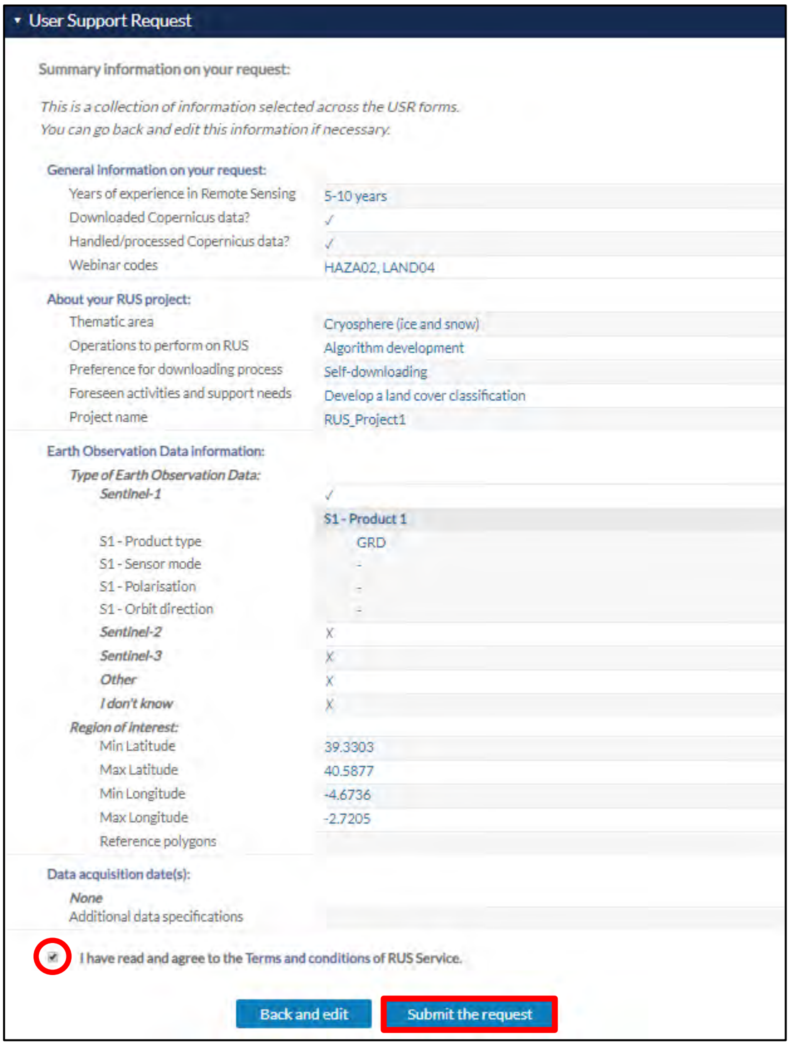
Click on ***Request a new User Service*** to request your RUS Virtual Machine. Complete the form so that the appropriate cloud environment can be assigned according to your needs.



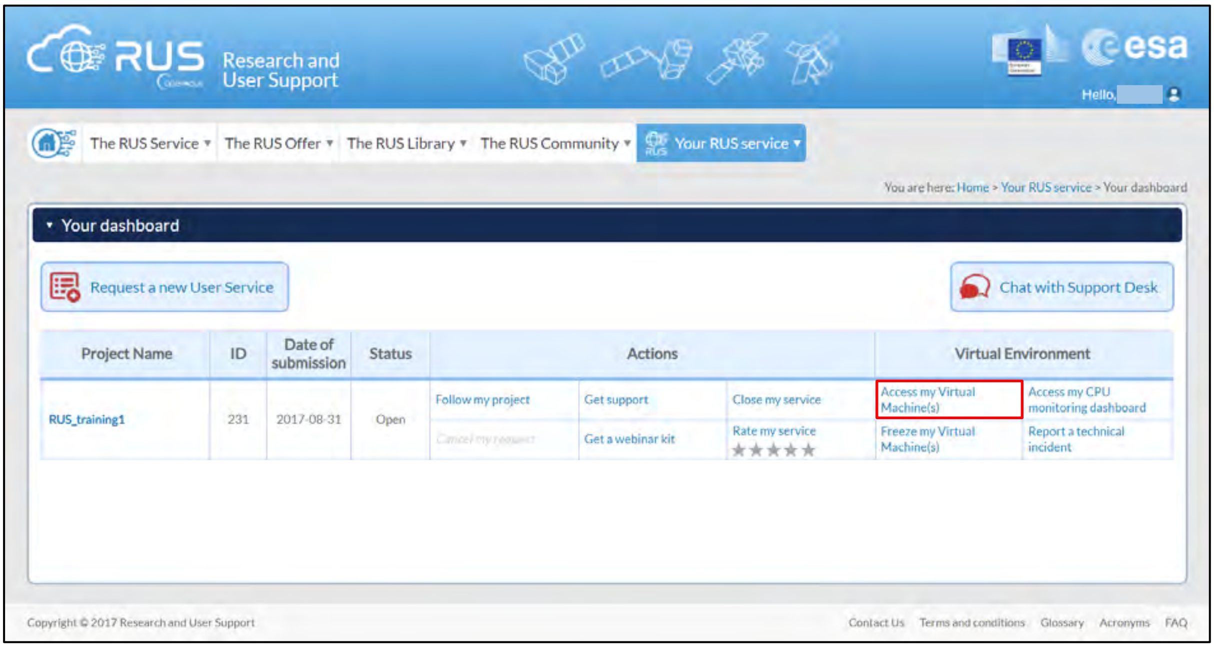
If you want to repeat this tutorial (or any previous one) select the one(s) of your interest in the appropriate field.



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.

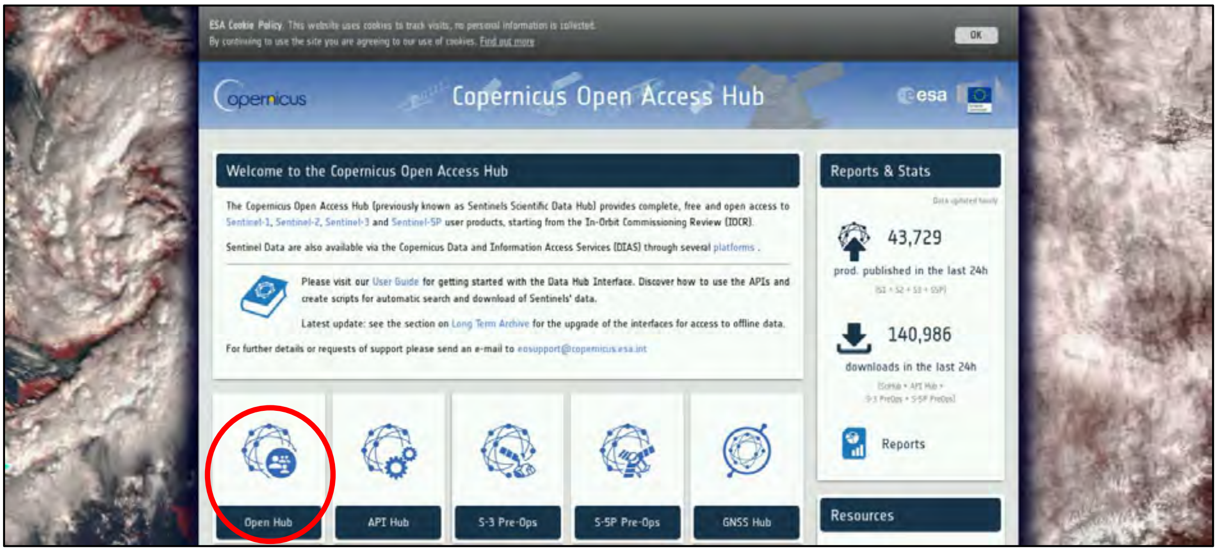
This is the remote desktop of your Virtual Machine.

5 Step by step

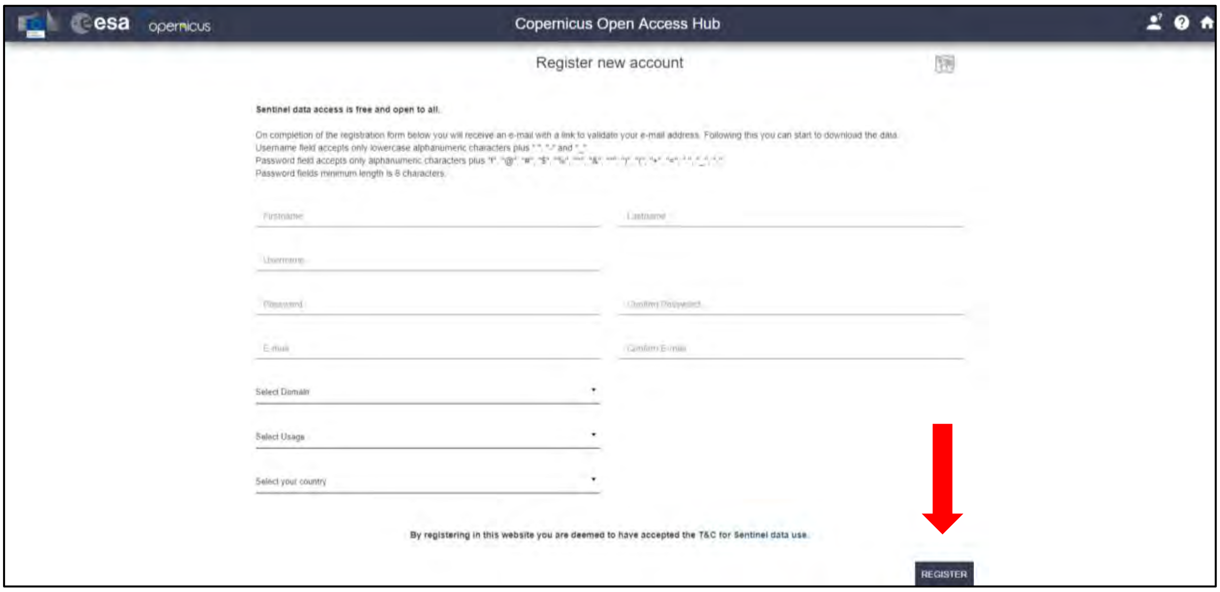
5.1 Data download – ESA SciHUB

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

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



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.



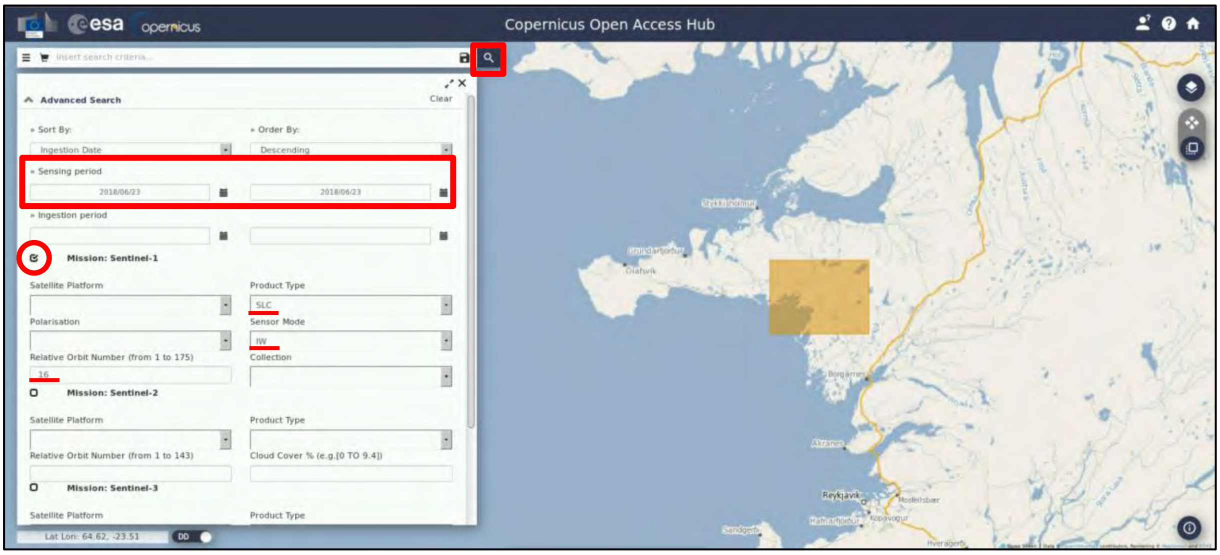
After you have filled in the registration form, you will receive an activation link by e-mail. Once your account is activated or if you already have an account, “**LOGIN**”.

Navigate over West Iceland (**approximate area – green rectangle**).

We need to download 2 images over the area of interest, one before the event and one after it.

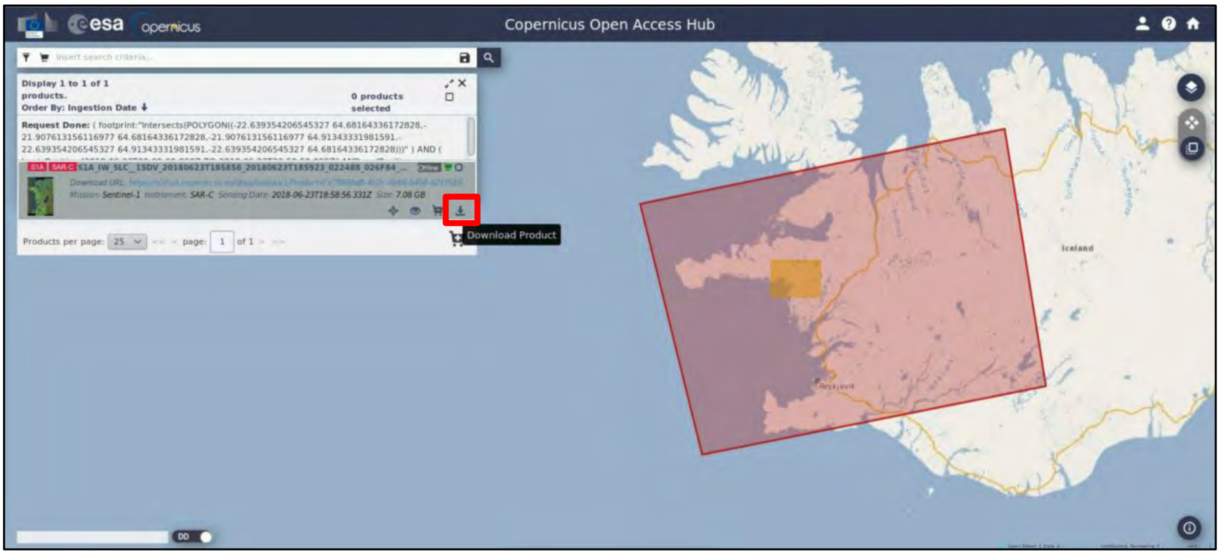
Zoom in a bit more, switch to “**drawing mode**” and draw a search rectangle approximately as indicated below. Open the search menu by clicking to the left part of the search bar. We will first specify the parameters for the product before the date of the landslide occurred and then for the one afterwards:

Sensing period: From 2018/06/23 to 2018/06/23
Select: Mission: Sentinel-1
Product Type: SLC
Sensor Mode: IW
Relative Orbit Number: 16

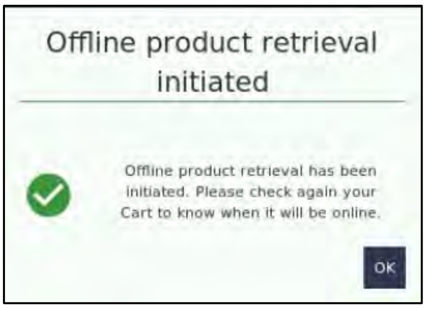


Then click on the “**Search**” icon. The search returns 1 result for the time period we set. To download the following image, click on the “**Download Product**” icon:

S1A_IW_SLC__1SDV_20180623T185856_20180623T185923_022488_026F84_32C6



We can see that the product is “Offline” (See NOTE 1). Once we click on the download icon, the following message will appear.



The product is automatically added in the “Cart”. In case an error message appears, try again a bit later – you can request for one product per account per hour.

The product will be online within few minutes.

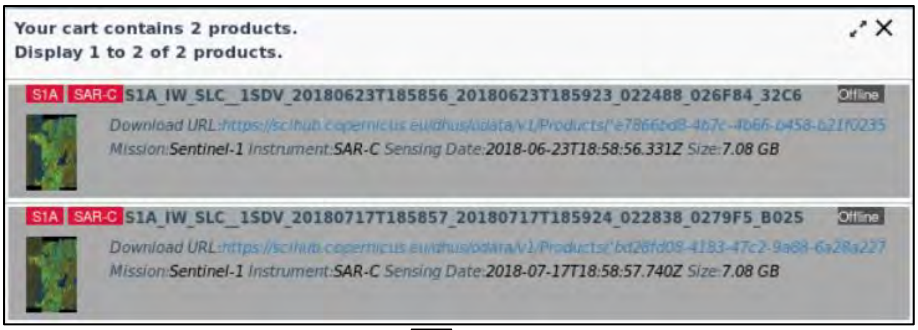
By the time the product turns online, it remains like that for 4 days and then it goes back to offline again. You need to frequently check your cart for the product availability.

NOTE 1: You can find more information about the retrieval of offline/long term archive products here: https://scihub.copernicus.eu/twiki/do/view/SciHubUserGuide/LongTermArchive#Retrieval_of_offline_products_vi & https://scihub.copernicus.eu/userguide/LongTermArchive

Return to the search menu and set the parameters for the second product. Specify as **Sensing period:** From 2018/07/17 to 2018/07/17 and keep all the rest settings as above. The search will return the following 1 result for the time period we set:

S1A_IW_SLC__1SDV_20180717T185857_20180717T185924_022838_0279F5_B025

If we go now to the cart, we will see both our products in there at offline mode. Once they are available for download, the grey background will turn white.

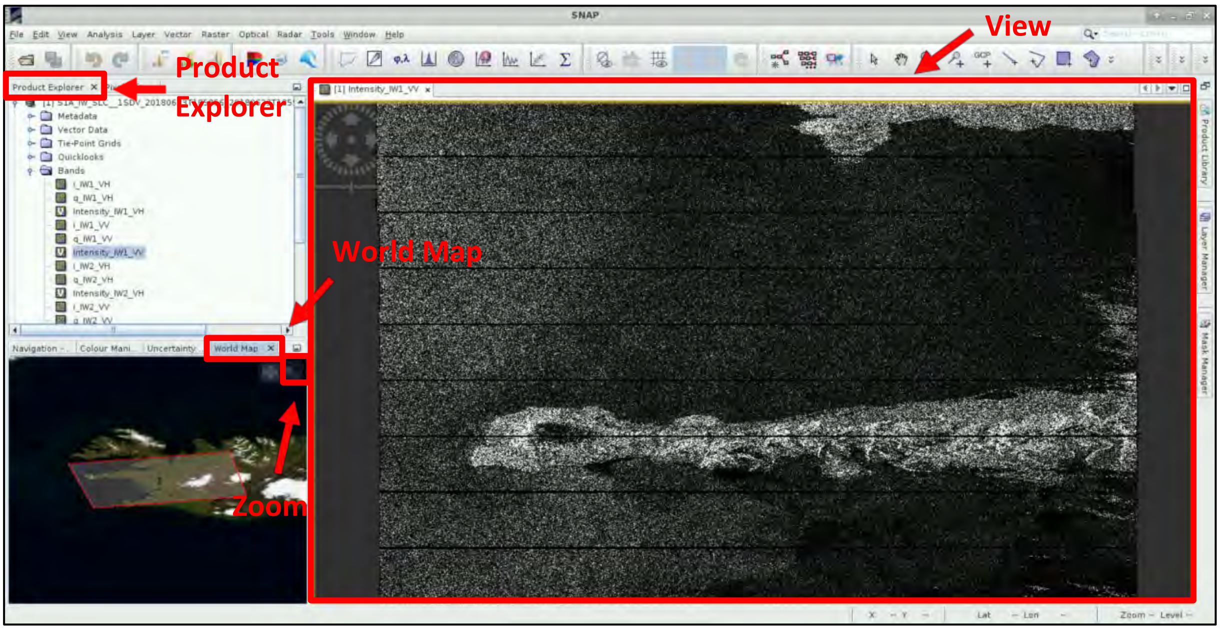


Click on the “**Download Product**” icon and the products will be downloaded at ***/home/rus*** as zip files. Move them to: ***/shared/Training/HAZA07_LandslideDetection_Iceland_TutorialKit/Original***

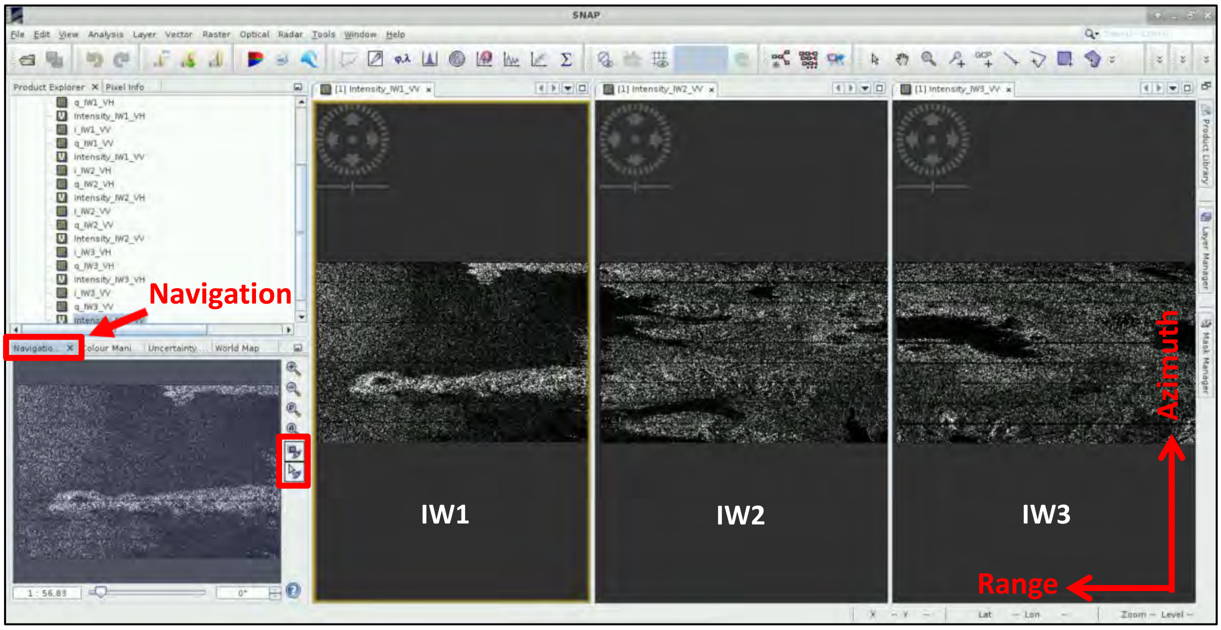
5.2 SNAP – open and explore data

Open **SNAP** software from the icon located on the desktop or go to **Applications → Processing → SNAP Desktop**. Click the **Open Product** icon , navigate to: ***/shared/Training/ HAZA07_Landslide Detection_Iceland_TutorialKit/Original*** folder and open both Sentinel-1 products or just open a folder in your VM, navigate to the path mentioned above and then drag the products from the folder one by one and drop them to the **Product Explorer** Window (first the **20180623** and then the **20180717**).

The opened products will appear in **Product Explorer** window. Click **+** or to expand the contents of product **[1]** from **23 June 2018**, then expand **Bands** folder and double click on ***Intensity_IW1_VV*** band to visualize it in the **View** window. You can go to the **World Map** tab and zoom in to see the location of the opened product on the globe (See NOTE 2).



Open the ***Intensity_IW2_VV*** and the ***Intensity_IW2_V3*** bands as well and go to **Window → Tile Horizontally.** Go to the **Navigation** tab and click on the two icons shown within the red rectangular below to synchronize the views and the cursor position between the views. (See NOTE 3).



NOTE 2: The Interferometric Wide (IW) swath mode captures three sub-swaths using Terrain Observation with Progressive Scans SAR (TOPSAR). IW SLC products contain one image per sub-swath and one per polarisation channel, for a total of three (single polarisation) or six (dual polarisation) images in an IW product. Each sub-swath image consists of a series of bursts, where each burst has been processed as a separate SLC image. 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. *(Source: https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar/acquisition-modes/interferometric-wide-swath)* The Fagraskógarfjall landslide is located on the IW2 sub-swath, on the 6th burst.

NOTE 3: The RADAR instrument onboard Sentinel-1 carries an antenna that is looking always to the right during its pass. These two scenes were acquired during **ascending** pass (the satellite was moving in direction from south to north). That is why we see that the view of the image appears as if "mirrored" in the horizontal dimension, because the view shows the pixels in order of the data acquisition.

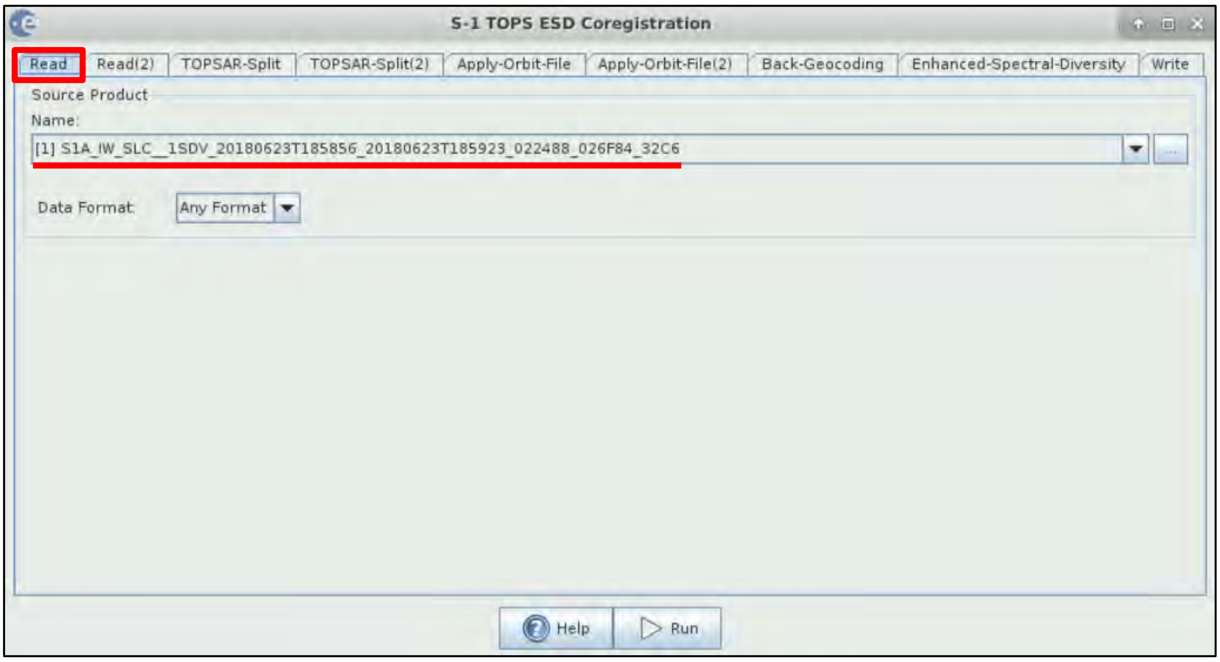
5.3 Data Coregistration

Close the previously opened Views and collapse the products at the **Product Explorer** Window. Image coregistration is the alignment of master and slave images, the pixels of the slave images correspond to those of the master and represent an identical area.

To do so, go to **Radar → Coregistration → S1 TOPS Coregistration → S1-TOPS Coregistration with ESD** and the following window will appear.

5.3.1 Read the input products

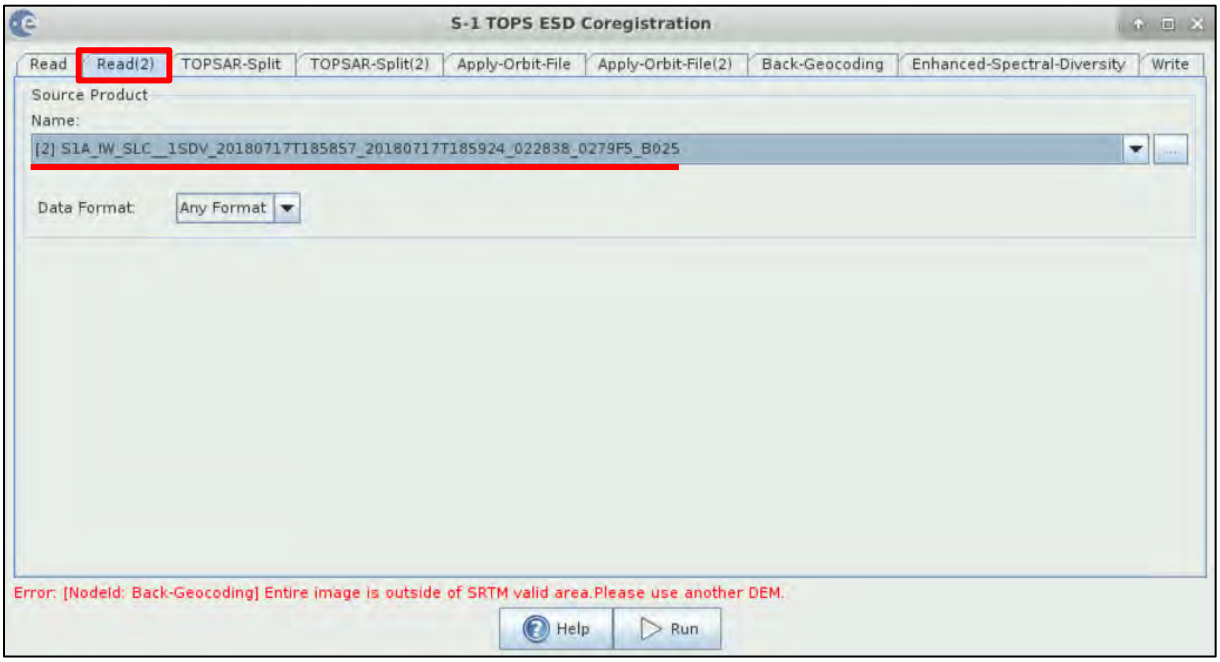
First of all, we need to specify the two input images that we want to coregister. In the **Read** tab choose the product **[1] S1A_IW_SLC__1SDV_20180623T185856_20180623T185923_022488_026F84_32C6** which will be the master one.



Move to the next tab, **Read(2)** tab and choose the second product that will be used as the slave one: **[2] S1A_IW_SLC__1SDV_20180717T185857_20180717T185924_022838_0279F5_B025**

We can see that an error appears at the lower part of this tab. This happens because the default DEM the operator is using is the SRTM which covers areas that are between -60° to +60° geographic latitude. Our area of study is located a bit northern that that and for this reason we need to select another DEM available in the operator that covers this geographic region.

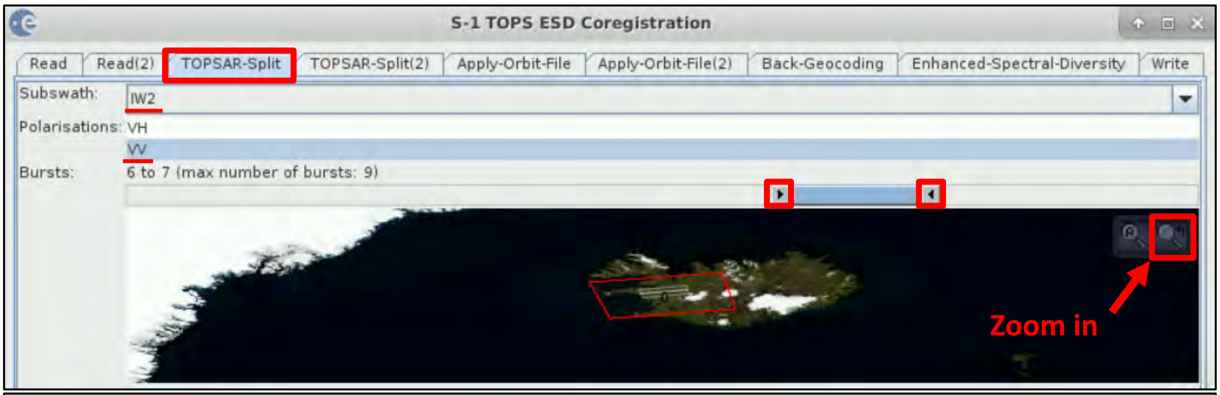
NOTE: Before we continue to the next step, we need to go first to the *5.3.4 Back-Geocoding* chapter and set the parameters in that one!

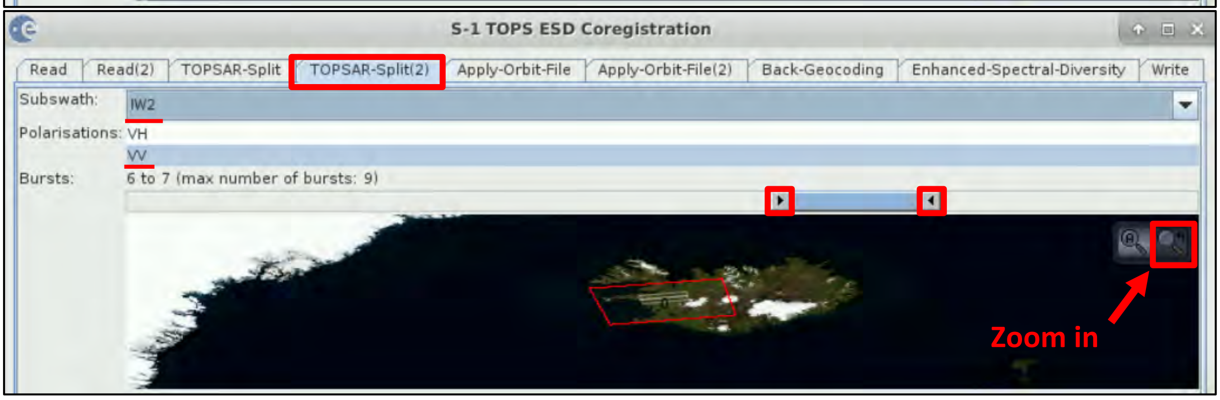


5.3.2 TOPS Split

Every Interferometric Wide swath (IW) consists of 3 sub-swaths and each one of maximum 9 bursts. In our case, we do not need to process all the bursts of the swath, the area of interest is located in the IW2 and is covered by one burst. SNAP cannot accept only one burst as input for further processing and for this reason we will choose two. In the **TOPSAR-Split** tab **Zoom in** to the product and choose:

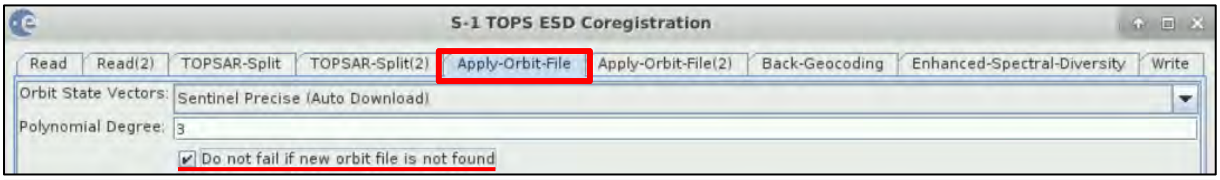
Subswath: IW2
Polarisations: VV
Bursts: 6 to 7 (drag the two sliders accordingly). Set the same parameters for the **TOPSAR-Split(2)** tab.

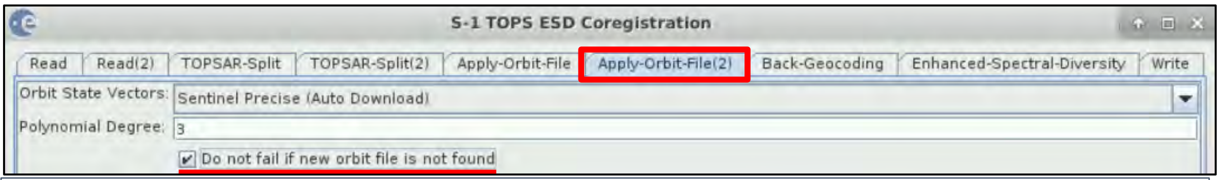




5.3.3 Apply Orbits

Next we will apply the updated orbits to the products (See NOTE 4). In both the **Apply-Orbit-File** tab and the **Apply-Orbit-File(2)** tab, we will keep the default settings and make sure that you will **select** the "**Do not fail if new orbit file is not found**" option.

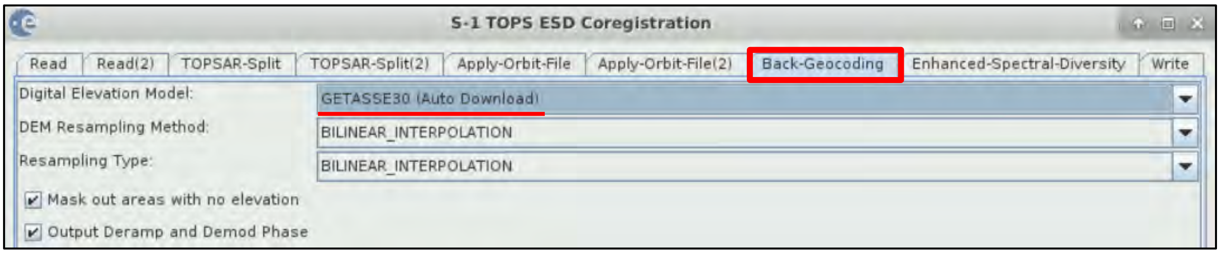




NOTE 4: The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with the precise orbit files which are available days-to-weeks after the generation of the product. **The orbit file provides accurate satellite position and velocity information**. Based on this information, **the orbit state vectors in the abstract metadata of the product are updated**. (*SNAP Help*)

5.3.4 Back-Geocoding

In the **Back-Geocoding** tab set as **Digital Elevation Model:** GETASSE30 (Auto Download) – (or any other that is available for the area of study) and keep the rest parameters by default as indicated below.



Now we can go back to **Read(2)** tab, the error will not appear anymore and we can continue with the next steps (*Go to 5.3.2 TOPS Split chapter* to continue).

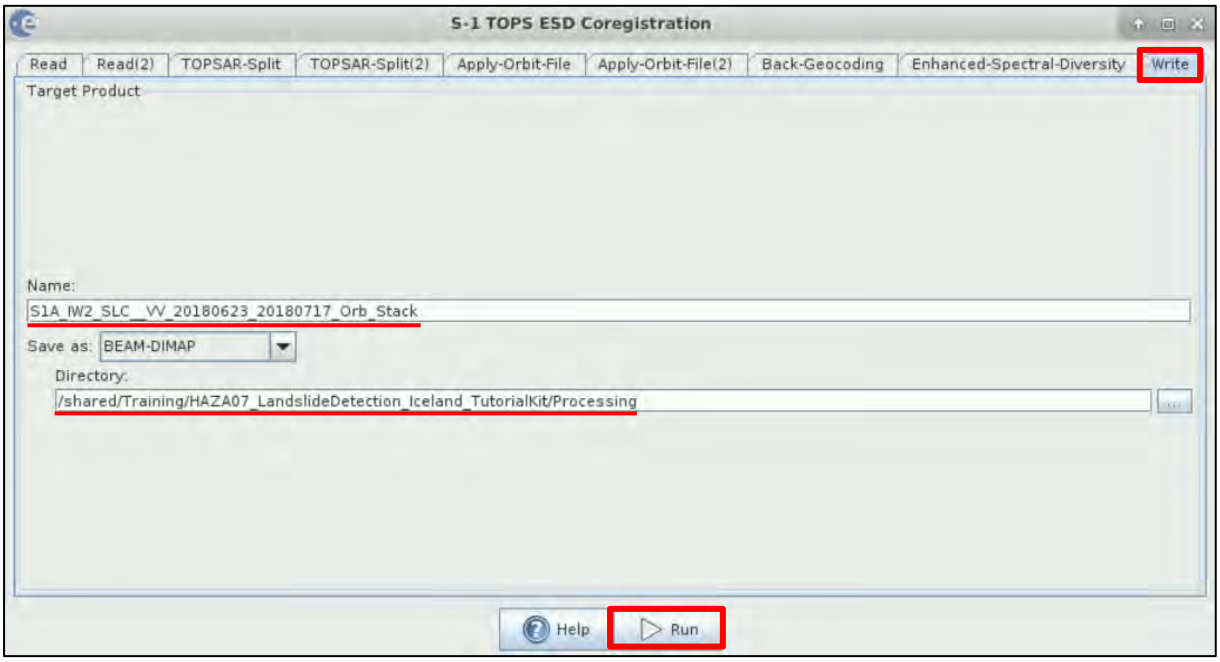
5.3.5 Enhanced Spectral Diversity

This **Enhanced Spectral Diversity** operator follows the **Back-Geocoding** operator, it first estimates a constant range offset for each burst using a small block of data in the center of the burst and then it estimates a constant azimuth offset. Finally, the estimates from all bursts are averaged to get the final constant range and azimuth offset for the whole image. Keep the default parameters.

5.3.6 Write-create the output

In the **Write** tab we see that some suffixes have been added at the end of the Name of the product. Remove some parts of it and keep as Name **S1A_IW2_SLC__VV_20180623_20180717_Orb_Stack**. This way you will know which sub-swath you selected, of which polarization and which dates.

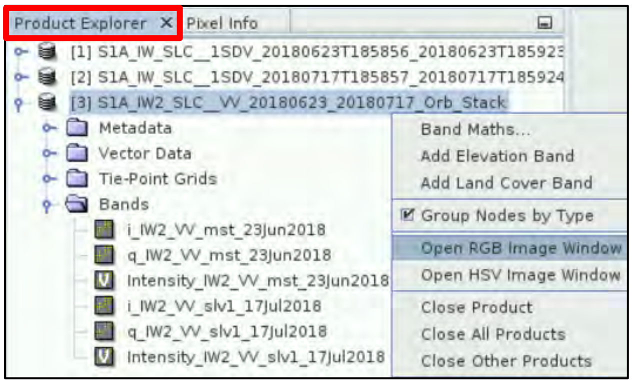
Then click on ... icon, navigate throw the folders and set as Directory the following path: ***/shared/Training/HAZA07_LandslideDetection_Iceland_TutorialKit/Processing***

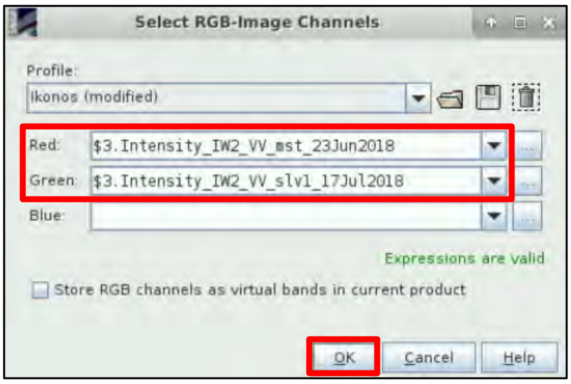


Finally click **Run** and the stack/coregistered product will be created and will automatically appear at the **Product Explorer** Window. You can expand it, open the bands folder, view the bands and create and RGB image as following.

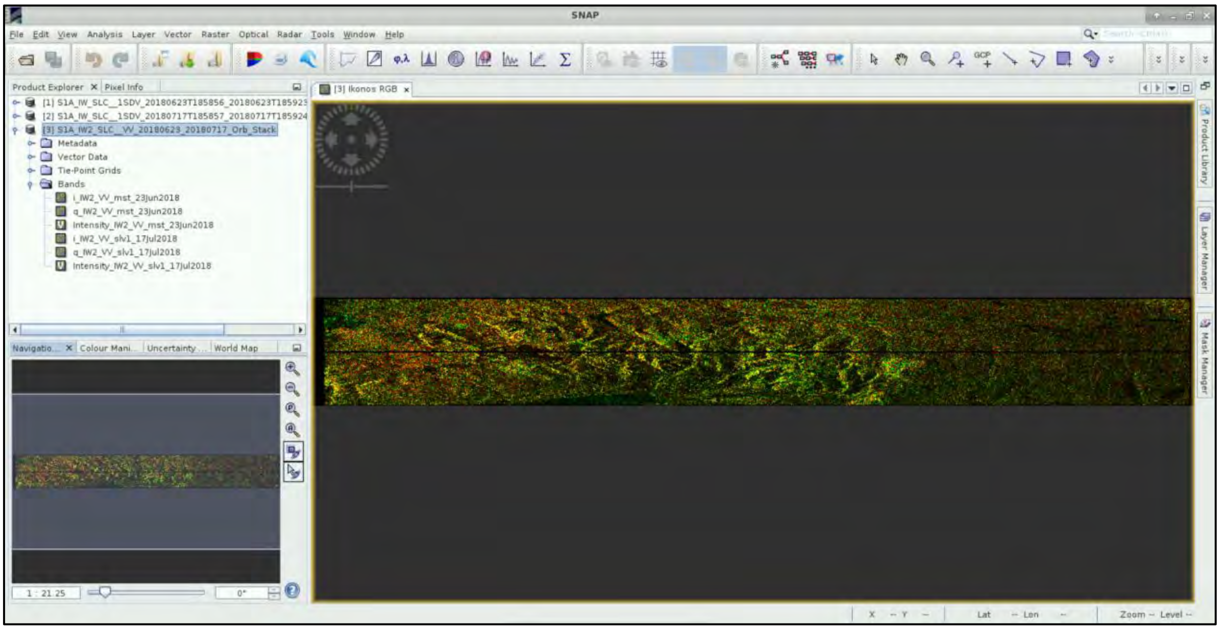
5.3.7 RGB Composition

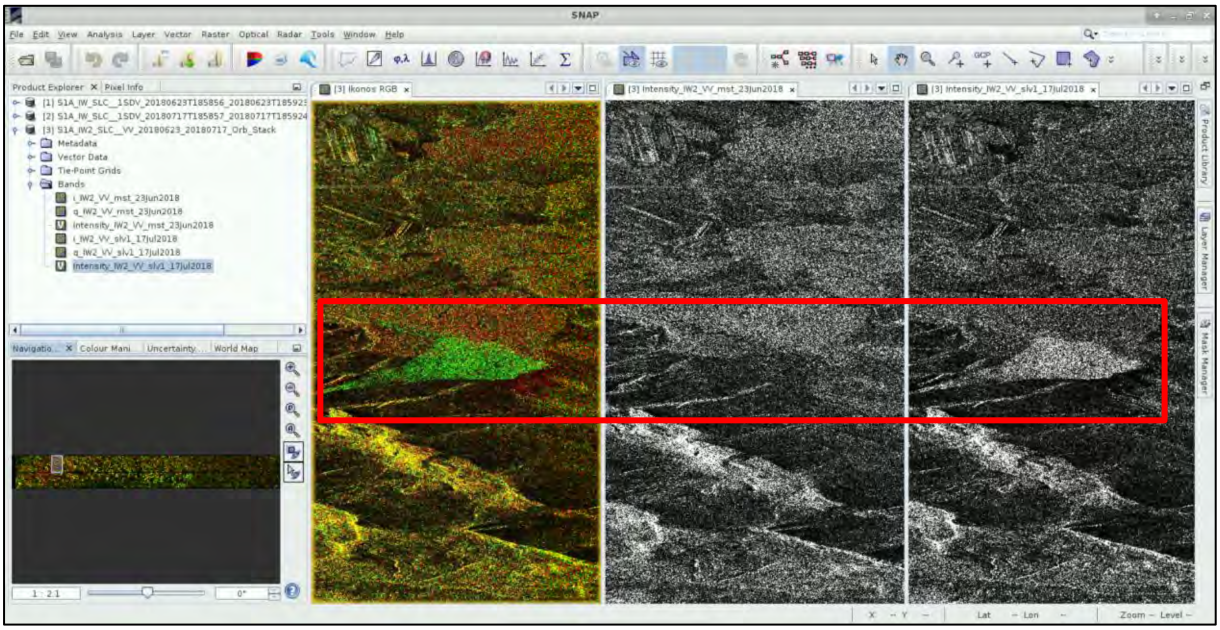
Go to the stack product in the **Product Explorer** window, right click on it, and select from the menu "**Open RGB Image Window**". Set as Red band $3.Intensity_IW2_VV_mst_23Jun2018, as Green band $3.Intensity_IW2_VV_slv1_17Jul2018 and leave the Blue empty. Then click **OK.**





Once the RGB image is created, you can also open both the **Intensity** bands of the stack product and go to **Window→ Tile Horizontally** to compare and interpret them. Zoom in over the area of the landslide.



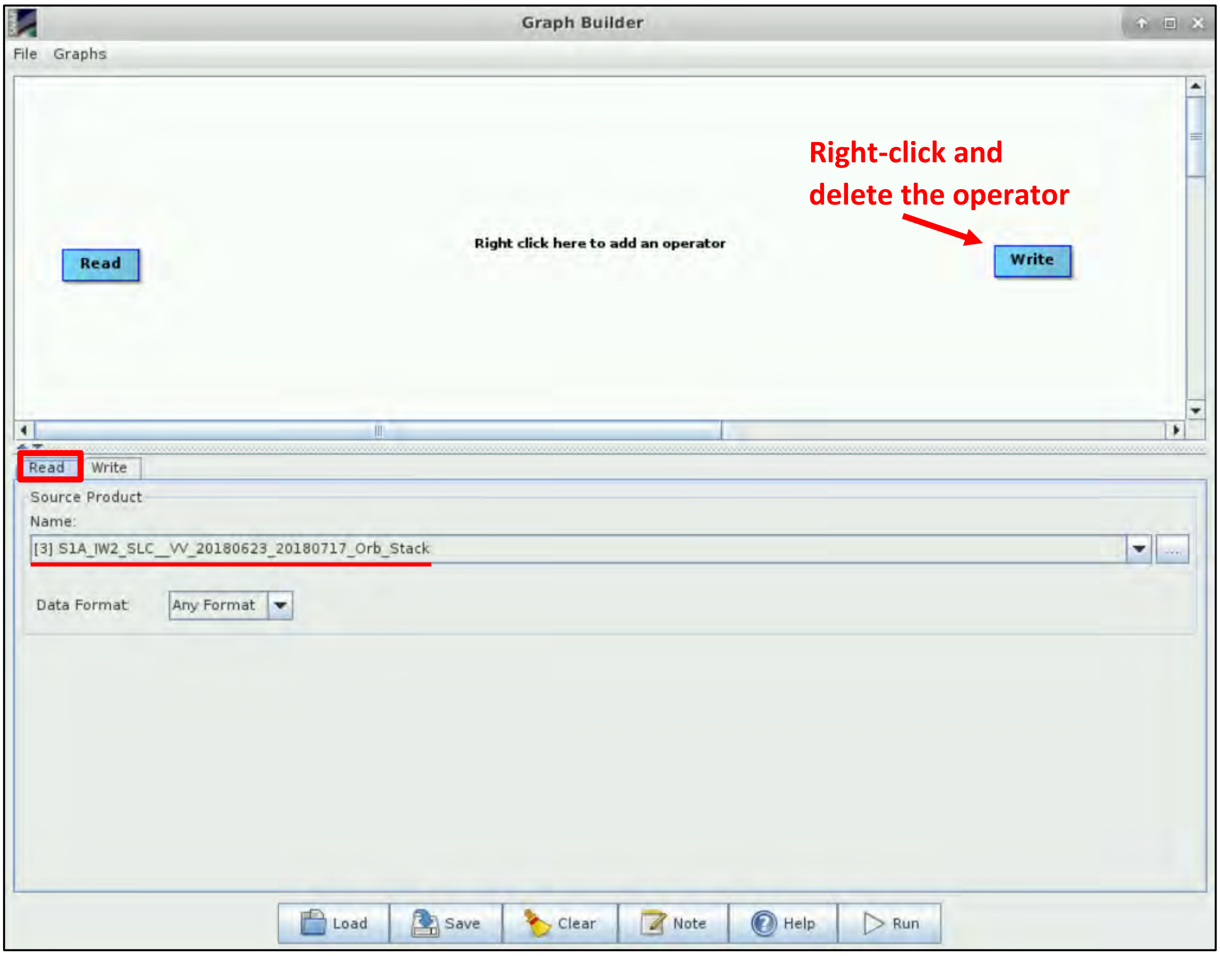


With red colour we see the pixels that exist only in the image before the landslide, with green the pixels that exist only in the image after the landslide and the rest that appear in both, are of a yellowish colour. From this comparison, we can clearly locate the area of the landslide with green pixels in the RBG composition. This change can be confirmed from the high Intensity values mentioned in the image after the landslide, while there is nothing like that in the image before the event.

5.4 Interferometric Processing

In order to create our interferogram, we will build a graph with some operators that we will see analytically below. By using the **GraphBuilder** tool, we can define the steps of the process we want to apply and at the end only the final product will be physically saved (this way we will also save disk space since the products of the intermediate steps will not be stored). Let's open a **GraphBuilder** window. Go to **Tools → GraphBuilder**. We can see that the graph has only two operators: **Read** (to read the input) and **Write** (to write the output). Below there also are the corresponding to the operators' tabs. First, right-click on the **Write** operator and **Delete** it. The corresponding tab will be removed as well. The **Write** operator will be added again at the end.

In the **Read** tab select the **S1A_IW2_SLC__VV_20180623_20180717_Orb_Stack** product.



5.4.1 Interferogram formation

We will create an interferogram from the two images used for the stack product. To add the **Interferogram** operator right-click and go to **Add → Radar → Interferometric → Products → Interferogram**. Connect the **Read** operator to it by dragging the red arrow from the right side of **Read** operator towards the **Interferogram** operator. A **phase** and a **coherence band** will be created.

In the **Interferogram** tab, keep the default parameters.

5.4.2 TOPS Deburst

Now we will remove the “black space” between the two bursts (See NOTE 5). To add the **TOPSAR-Deburst** operator right-click and go to **Add → Radar → Sentinel-1 TOPS → TOPSAR-Deburst**. Connect the **Interferogram** operator to it.

In the **TOPSAR-Deburst** tab keep the default settings (Polarizations: **VV**).

NOTE 5: There is overlapping information in every burst with its neighbouring ones, both in range and azimuth direction in order to provide contiguous coverage of the ground. Until now each burst has been processed as a separate SLC image We will merge the bursts (in azimuth direction) and preserve the phase information as well. For the overlapping region in range, merging is done between subswaths.

5.4.3 Topographic Phase Removal

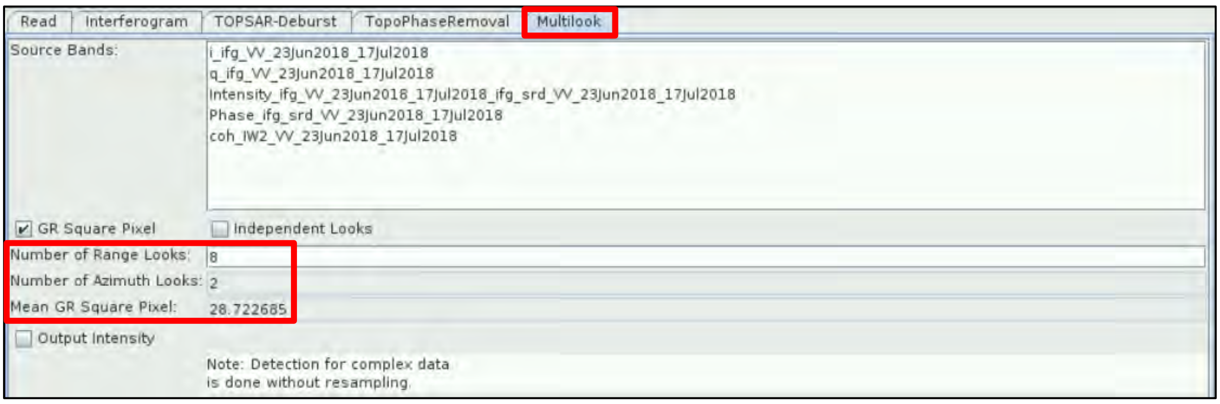
This is to estimate and subtract the topographic phase from the deburst interferogram. To add the **TopoPhaseRemoval** operator right-click and go to **Add → Radar → Interferometric → Products → TopoPhaseRemoval**. Connect the **TOPSAR-Deburst** operator to it.

In the **TopoPhaseRemoval** tab set as **Digital Elevation Model**: GETASSE30 (Auto Download).

5.4.4 Multilooking

By applying this operator, we will reduce the inherent speckle noise that originally appears to the SAR images and we will obtain square pixels. To add the **Multilook** operator right-click and go to **Add → Radar → Multilook**. Connect the **TopoPhaseRemoval** operator to it.

In the **Multilook** tab keep the “**GR Square Pixel**” option selected and set **Number of Range Looks**: 8. The **Number of Azimuth Looks** will change to 2 and the **Mean GR Square Pixel** to 28.722685.



5.4.5 Phase Filtering

Phase filtering reduces the phase noise. To add the **GoldsteinPhaseFiltering** operator right-click and go to **Add → Radar → Interferometric → Filtering → GoldsteinPhaseFiltering.** Connect the **Multilook** operator to it.

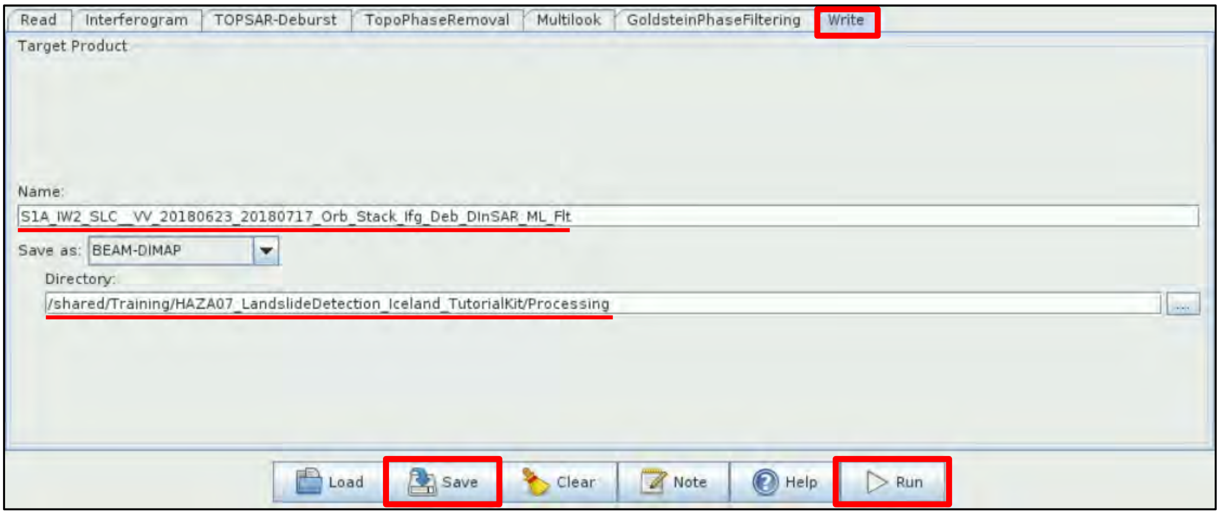
In the **GoldsteinPhaseFiltering** tab set the **FFT Size** to 128 and keep the rest parameters as by default.

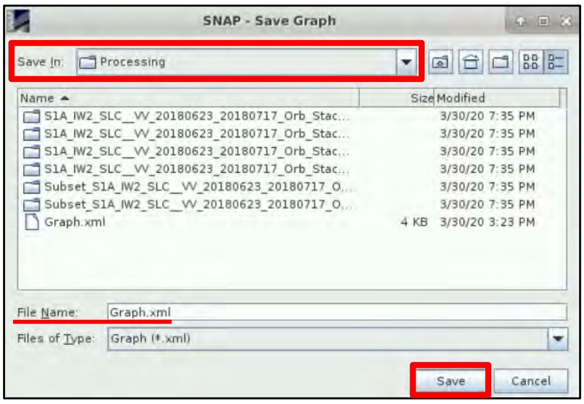
5.4.6 Write-create the output

Finally we will save the product and we will also export it for SNAPHU. To add the **Write** operator right-click and go to **Add → Input-Output → Write.** Connect the **GoldsteinPhaseFiltering** operator to it.

In the **Write** tab set the following:

Name: S1A_IW2_SLC__VV_20180623_20180717_Orb_Stack_Ifg_Deb_DInSAR_ML_Flt
Directory: */shared/Training/HAZA07_LandslideDetection_Iceland_TutorialKit/Processing*

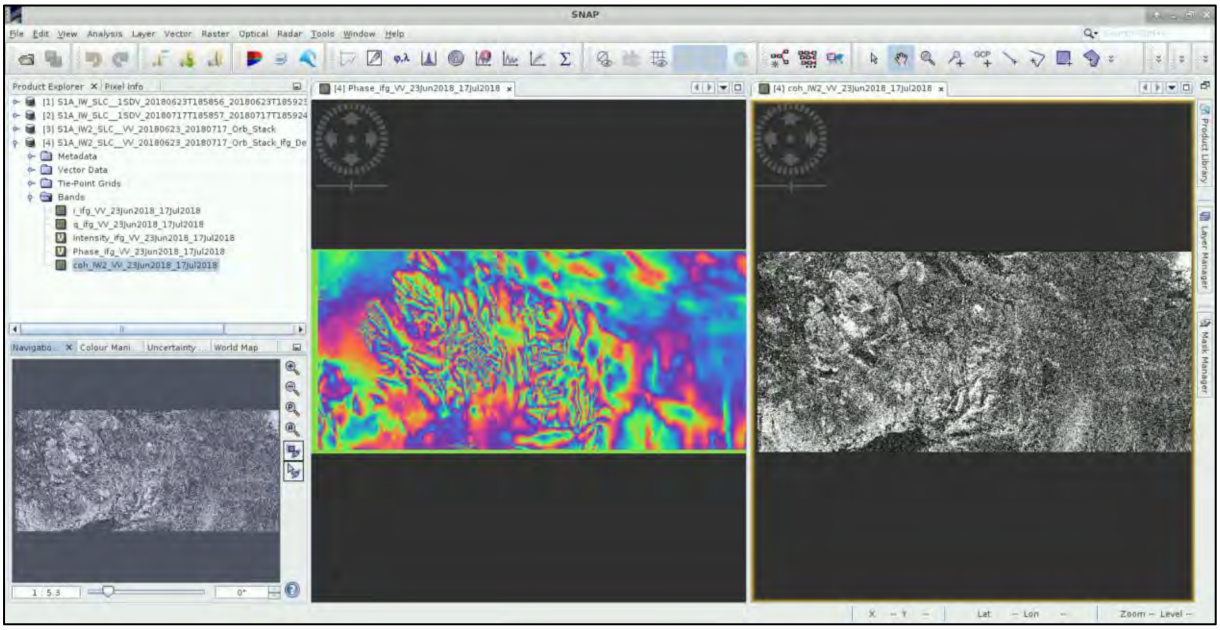




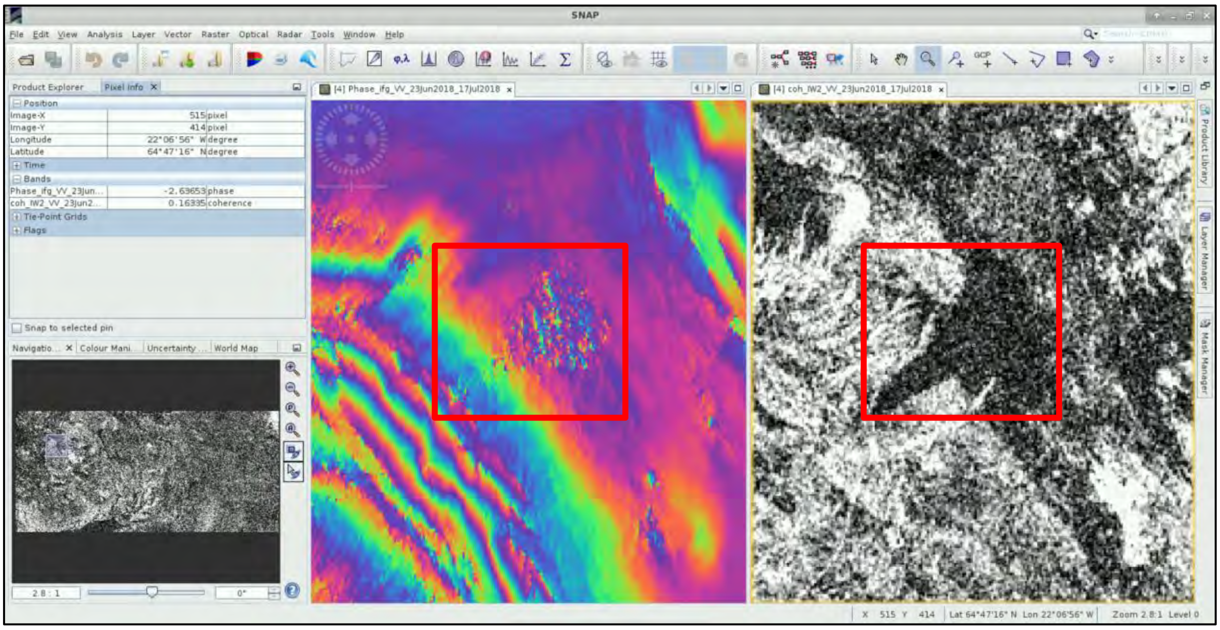
Once you have created the graph, you can save it for future use. Navigate to the path you want to save it e.g. to ***/shared/Training/HAZA07_LandslideDetection_Iceland_TutorialKit/Processing*** and save it with the Name: **Graph.xml**.

Then click **Run** and the new product will appear at the Product Explorer Window.

Open the **Phase** and **Coherence** bands and view them in parallel.



We can zoom in over the landslide to see what information we can obtain from the phase and the coherence bands. We can also go to the **Pixel Info** Window where by passing the mouse over the pixels of the image, we can see their value.



In this case, we can see that the area over the landslide consists of very low coherence values (in black) and there is a loss of phase as well. This is expected since the changes of the area happened rapidly. You can go to **Colour Manipulation** tab and see the corresponding histogram and range of values.

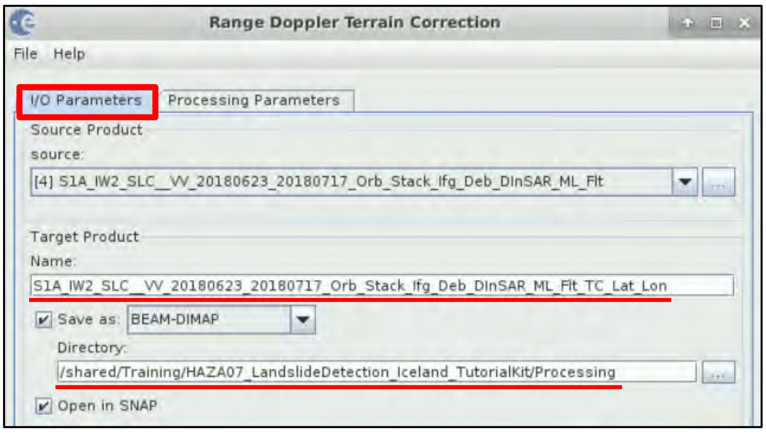
5.4.7 Geocoding

We now need to convert the data that are still in radar geometry, into geographic coordinates. Moreover, this is necessary because the distances can be distorted in the SAR images, due to topographical variations of a scene and the tilt of the satellite sensor (See NOTE 6).

Go to **Radar → Geometric → Terrain Correction → Range-Doppler Terrain Correction**. We will geocode the final product both in geographic coordinates for use in Google Earth and in UTM for further processing in QGIS.

For **Google Earth** visualization, in the **I/O Parameters** tab, set the following:

Source: S1A_W2_SLC__VV_20180623_20189717_Orb_Stack_Ifg_Deb_DInSAR_ML_Flt
Name: S1A_W2_SLC__VV_20180623_20189717_Orb_Stack_Ifg_Deb_DInSAR_ML_Flt_TC_Lat_Lon
Directory: */shared/Training/HAZA07_LandslideDetection_Iceland_TutorialKit/Processing*

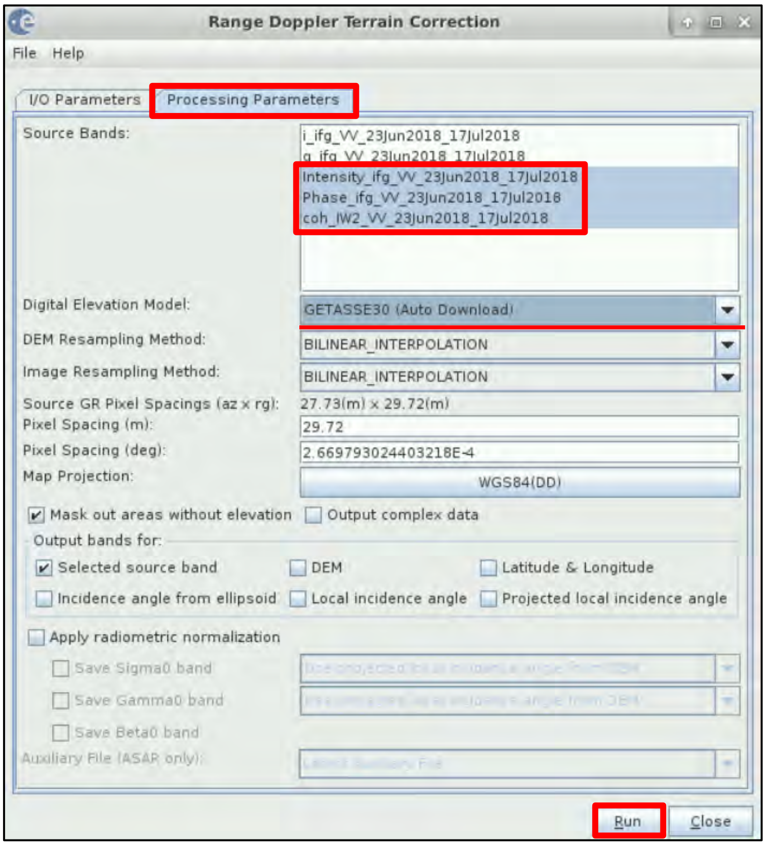


In the **Processing Parameters** tab select as:

Source bands: Intensity_ifg_VV_23Jun2018_17Jul2018
Phase_ifg_VV_23Jun2018_17Jul2018
coh_IW_ VV_23Jun2018_17Jul2018

Digital Elevation Model: GETASSE30 (Auto Download)

Keep the rest parameters as by default.



Click **Run**.

For **QGIS** visualization, in the **I/O Parameters** tab, set as:

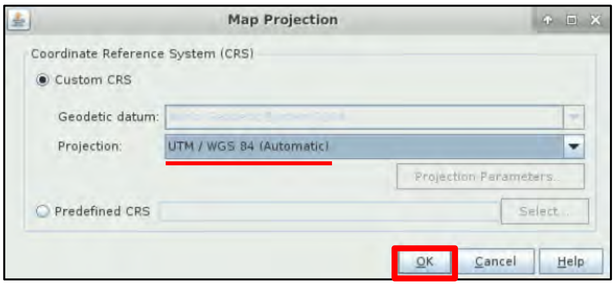
Name: S1A_W2_SLC__VV_20180623_20189717_Orb_Stack_Ifg_Deb_DInSAR_ML_Flt_TC_UTM and keep the rest settings same as for the previous one.

In the **Processing Parameters** tab:

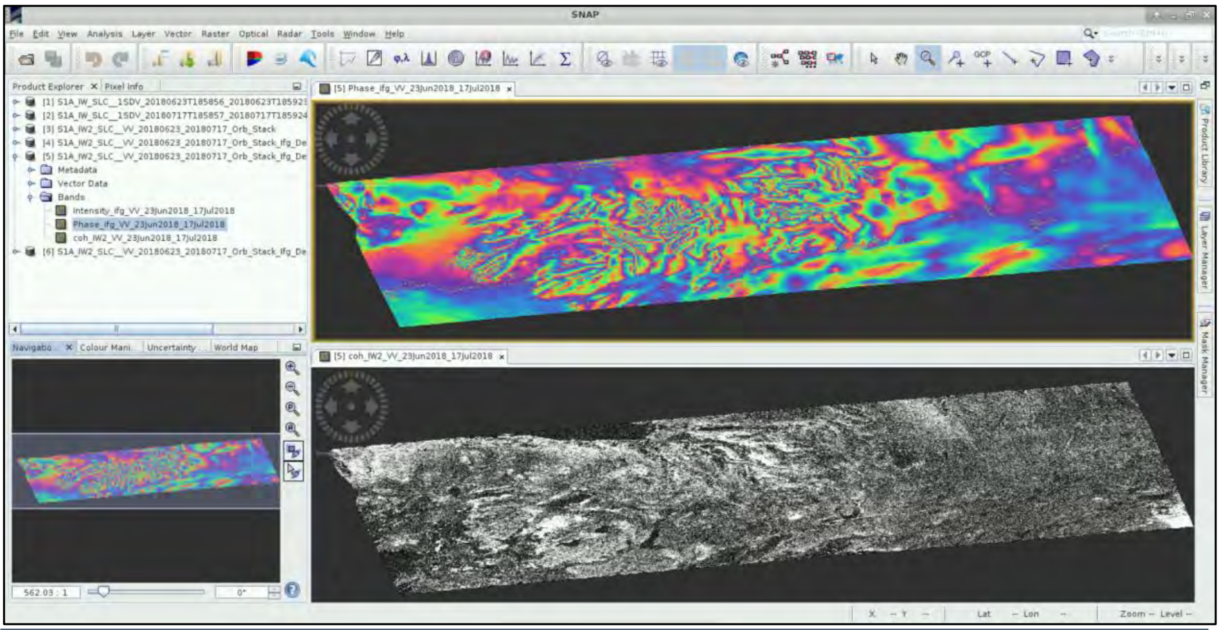
Go to **Map Projection**, click on it and at the Custom CRS, at the Projection, select:

UTM / WGS 84 (Automatic)

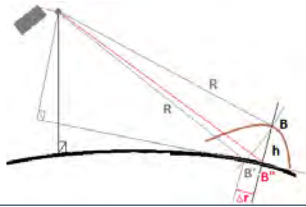
Click **OK** and then click **Run**.



Both Terrain Corrected products will appear at the **Product Explorer** Window.



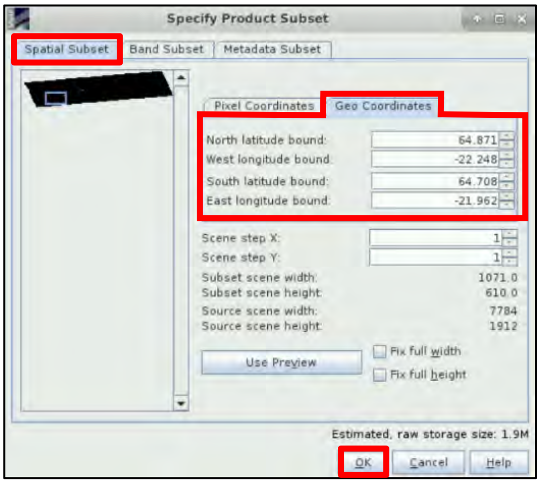
NOTE 6: The geometry of topographical distortions in SAR imagery is shown on the right. Here we can see that point **B** with elevation **h** above the ellipsoid is imaged at position **B'** in SAR image, though its real position is **B''**. The offset **Δr** between **B'** and **B''** exhibits the effect of topographic distortions. *(SNAP Help)*



5.5 Subset

We know that our area of interest occupies an area much smaller than the one we processed. For this reason, we can create a subset, for <u>both geocoded products</u>, which consequently we will export.

First, select the product you want to subset and then go to **Raster → Subset**. In the **Spatial Subset** tab, in the **Geo Coordinates** tab, set as:



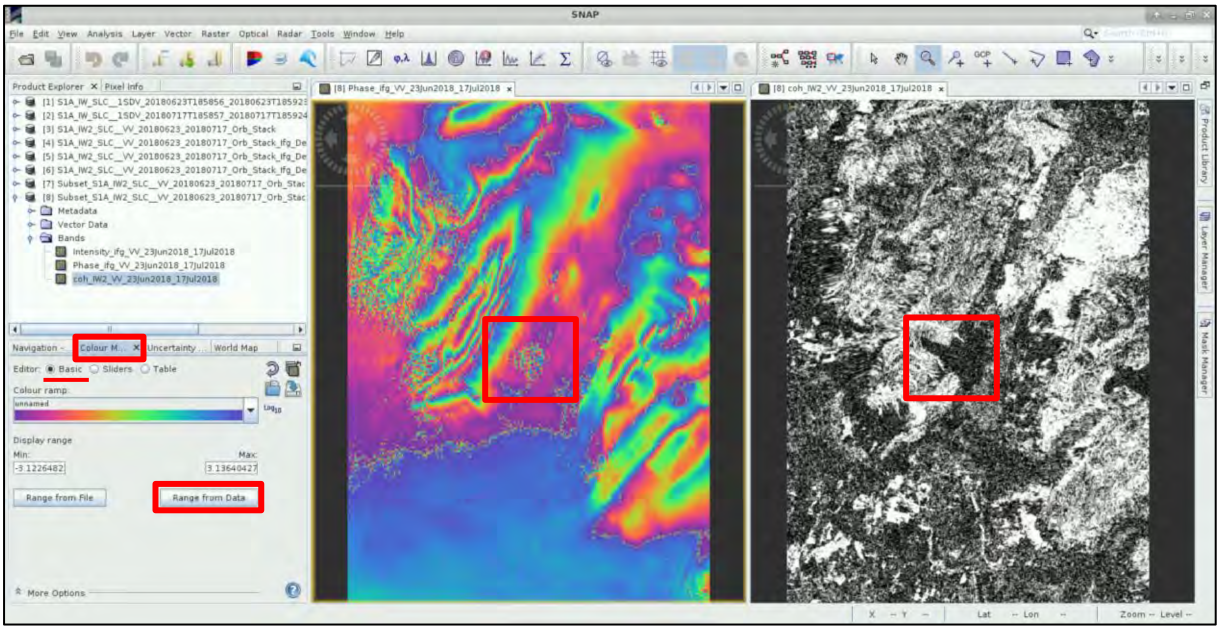
North latitude bound: 64.871
West latitude bound: -22.248
South latitude bound: 64.708
East latitude bound: -21.962

Then click **OK**.

Repeat the same process for the second product as well. The subsets will appear at the **Product Explorer** Window but they are not physically stored. Right-click in each one of them and go to **Save Product**. At the window that will appear, click **Yes**, so that the product will be converted to BEAM-DIMAP format. This way you will be able to use it later again in SNAP.

Then, navigate to ***/shared/Training/HAZA07_LandslideDetection_Iceland_TutorialKit/Processing*** folder and save them in there with an appropriate name, e.g.:
Subset_S1A_W2_SLC__VV_20180623_20189717_Orb_Stack_Ifg_Deb_DInSAR_ML_Flt_TC_Lat_Lon
Subset_S1A_W2_SLC__VV_20180623_20189717_Orb_Stack_Ifg_Deb_DInSAR_ML_Flt_TC_UTM

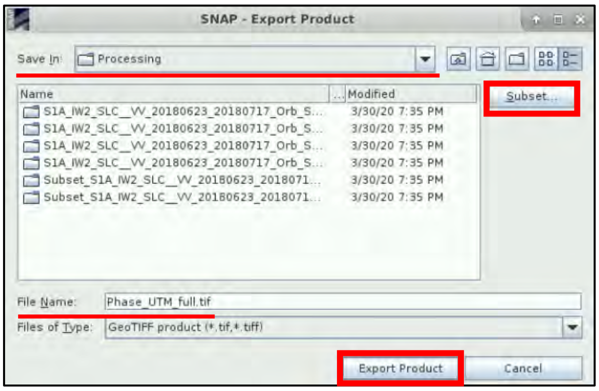
Open the Phase and Coherence bands of the subset UTM product. Select the Phase band and go to **Colour Manipulation** tab. At the **Editor** select the **Basic** and then click on **Range from Data**. The min and max values at the Display range will automatically become -3.14 to 3.14.

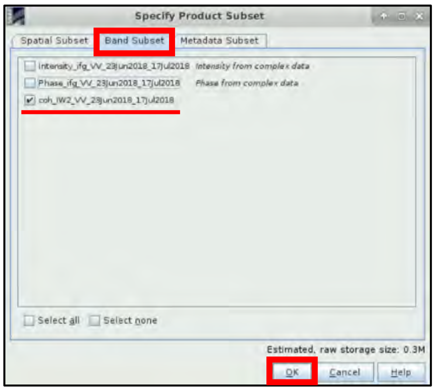


5.6 Export products

Let's export first the bands we want to visualise in **QGIS**. Select the appropriate band from the products at the **Product Explorer** window. Go to **File → Export → GeoTIFF.**

Set in **Save In:** ***/shared/Training/HAZA07_LandslideDetection_Iceland_TutorialKit/Processing*** path and go to **Band Subset** tab. Select only the band you want to export and click **OK**. Then at **File Name** you can optionally set the followings, based on the product you export:
Phase_UTM_full.tif   Phase_UTM_subset.tif   Coherence_UTM_full.tif   Coherence_UTM_subset.tif





Then click **Export Product**.

In order to export the views you need for visualization in Google Earth, just **right click** on the opened View window in SNAP and select **Export View as Google Earth KMZ**. Define the path as mentioned above and set the following names to the outputs:

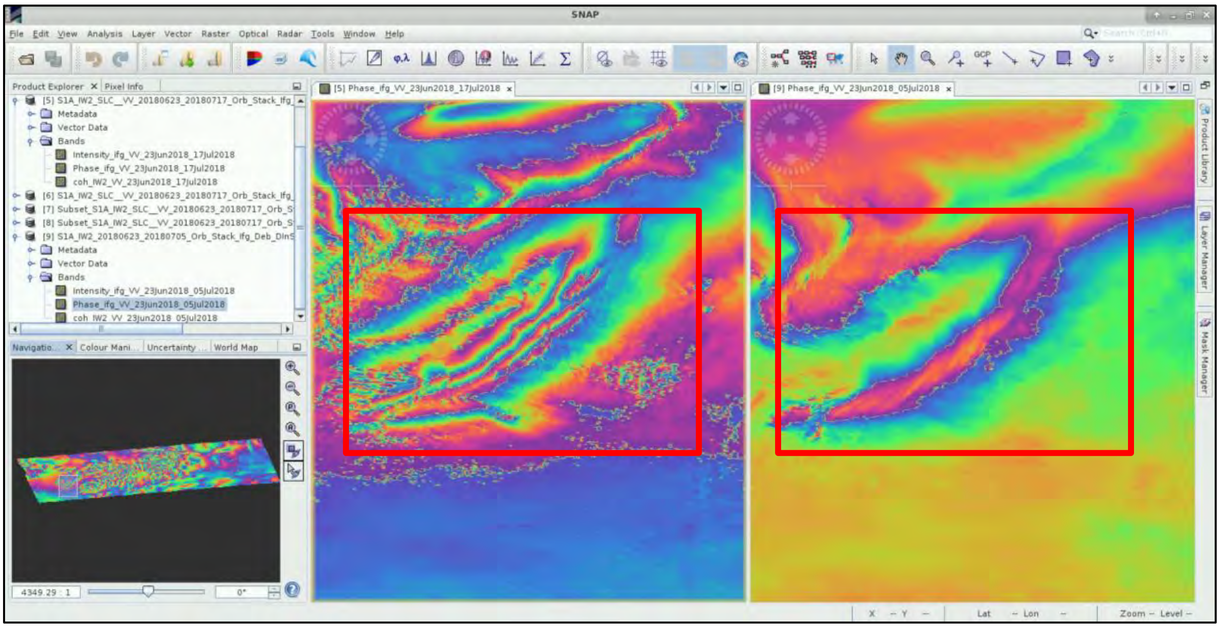
Phase_ifg_VV_23Jun2018_17Jul2018_full.kmz
Phase_ifg_VV_23Jun2018_17Jul2018_subset.kmz
Coherence_IW2_VV_23Jun2018_17Jul2018_full.kmz
Coherence_IW2_VV_23Jun2018_17Jul2018_subset.kmz

5.7 Comparison with other data

In the ***/shared/Training/HAZA07_LandslideDetection_Iceland_TutorialKit/Auxdata*** folder, you will find the Pre-event folder, which contains a geocoded pair of images in Lat/Lon. The images of this stack were acquired on 23 June 2018 and 5 July 2018, both of them, before the landslide. This is to compare the results and see how the area was before and how it has been affected from the landslide.

You will also find the .kmz files of the phase and the coherence.

On the left is the result after the landslide and on the right before. After the event has happened, we can see the creation of fringes at the northwest part of the mountain and the loss of phase at the area of the landslide.



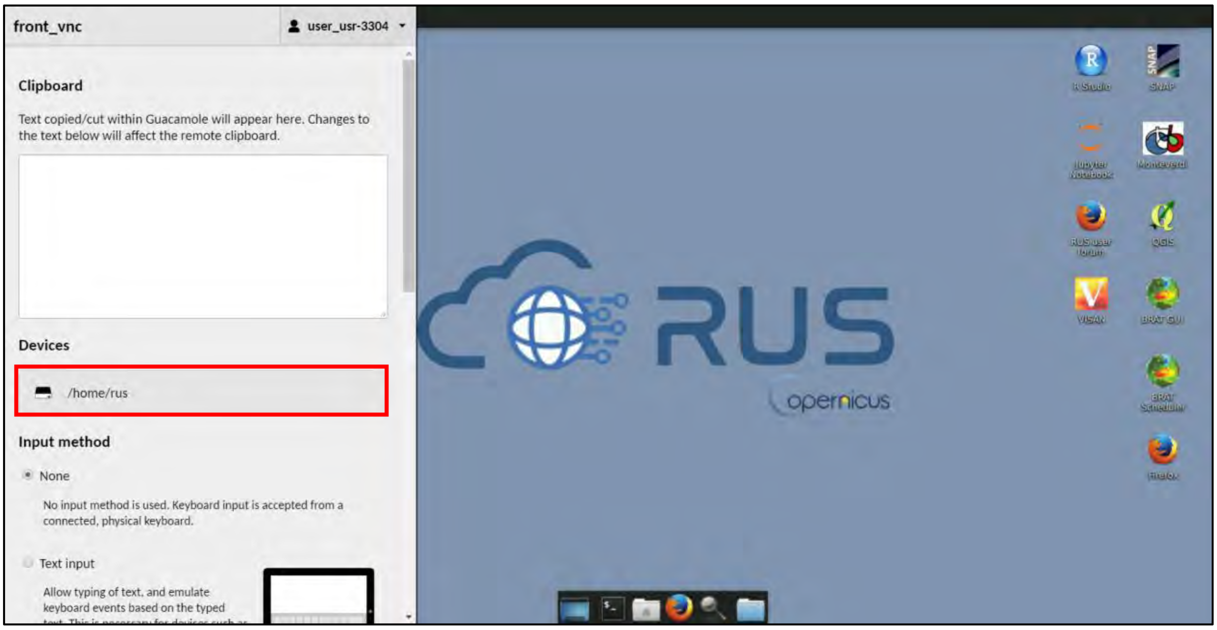
6 Extra Steps

6.1 Download files from VM

In your VM, press **Ctrl+Alt+Shift.**

A pop-up window will appear on the left side of the screen. Click on the bar below **Devices**, navigate to the folders you have saved the files you want to download and **double click** on them. The downloading process to your local computer will start automatically.

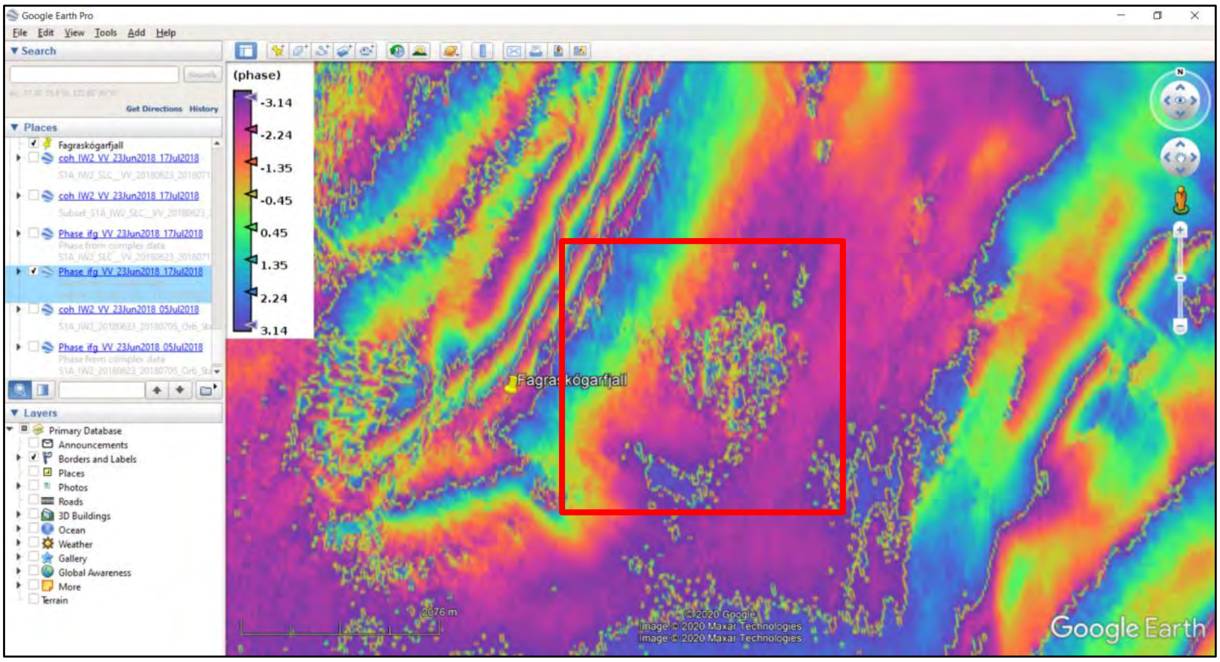
Once the KMZ files have been downloaded, you can load and visualize them in **Google Earth**.



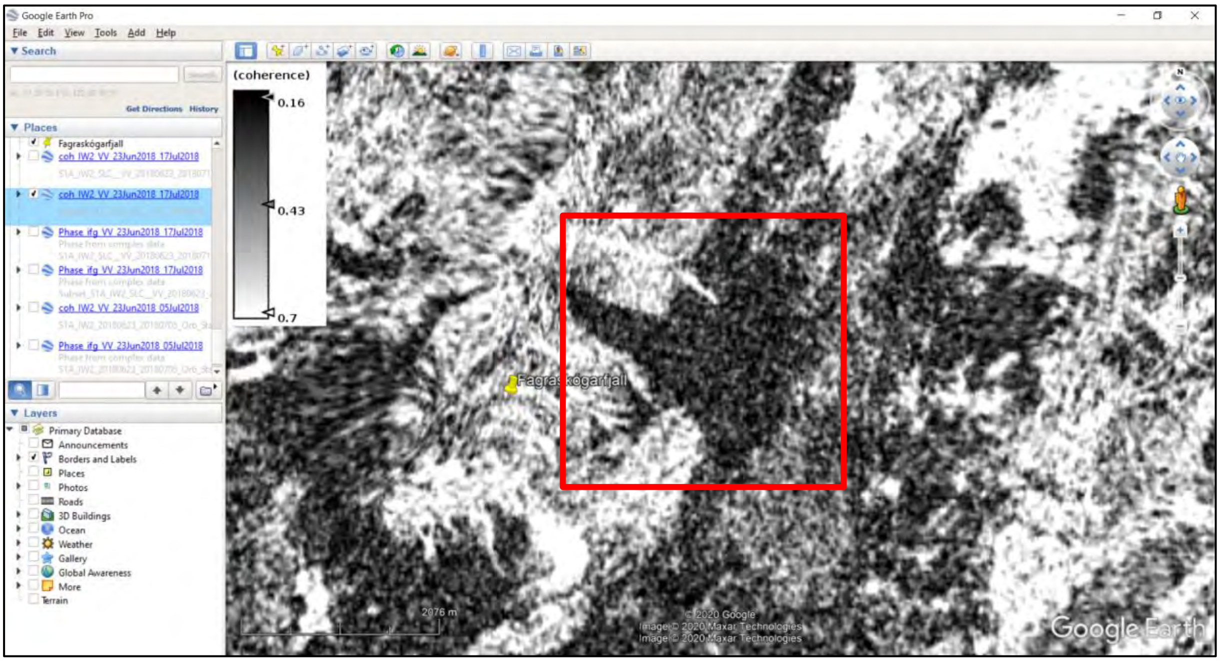
6.2 Visualization in Google Earth

Google Earth is not pre-installed in RUS VMs and if you want to visualise the results, you need to download them to your local computer. We have already exported the results to **KMZ** format. Download the following products and then load them in Google Earth:

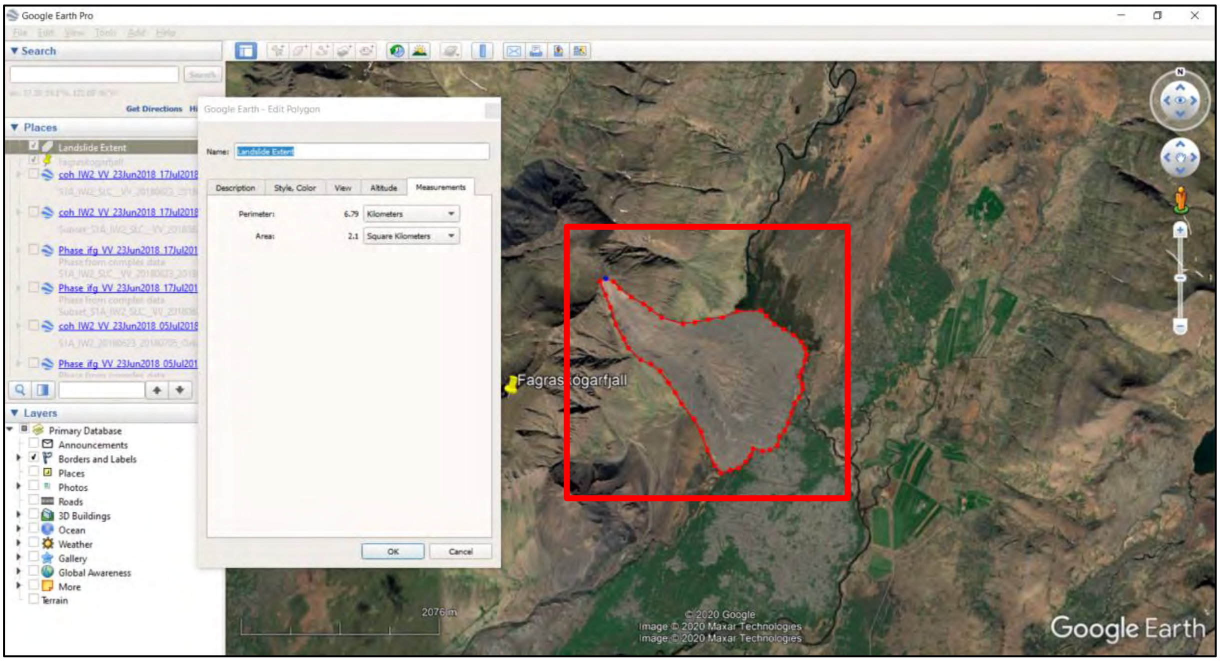
Phase_ifg_VV_23Jun2018_17Jul2018_full.kmz
Phase_ifg_VV_23Jun2018_17Jul2018_subset.kmz
Coherence_IW2_VV_23Jun2018_17Jul2018_full.kmz
Coherence_IW2_VV_23Jun2018_17Jul2018_subset.kmz
Phase_ifg_VV_23Jun2018_05Jul2018_Pre-event.kmz
Coherence_IW2_VV_23Jun2018_05Jul2018_Pre-event.kmz



View of the **Phase_ifg_VV_23Jun2018_17Jul2018_subset.kmz** in Google Earth.



View of the **Coherence_IW2_VV_23Jun2018_17Jul2018_subset.kmz** in Google Earth. In the center of the picture in black, we see the loss of coherence indicating the landslide



View of the extent of the lanslide in Google Earth. We can see that it is around 2.1 km^2 and it is still blocking the old river channel. You can navigate to past dates before the event to see how the area was formed.

THANK YOU FOR FOLLOWING THE EXERCISE!

7 Further reading and resources

- Mondini C.A., Santangelo M., Rocchett M., Rossetto E., Manconi A., Monserrat O., 2019. *Sentinel-1 SAR Amplitude Imagery for Rapid Landslide Detection*. Remote Sens. 2019, 11, 760; doi:10.3390/rs11070760
- Varnes DJ., 1978. Slope movement types and processes. In: Schuster RL, Krizek RJ (eds) Landslides, analysis and control, special report 176: Transportation research board, National Academy of Sciences, Washington, DC., pp. 11–33
- http://www.esa.int/About_Us/ESA_Publications/InSAR_Principles_Guidelines_for_SAR_Interferometry_Processing_and_Interpretation_br_ESA_TM-19 - InSAR Principles
- https://sentinel.esa.int/web/sentinel/missions/sentinel-1 - Sentinel-1 Mission
- https://www.researchgate.net/publication/209802944_Landslide_Types_and_Processes

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