

COPER RUS Opermicus



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











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 <u>training@rus-copernicus.eu</u>

Cover images produced by RUS Copernicus

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

Date of publication: March 2020

Version: 1.1

Suggested citation:

Serco Italia SPA (2020). *Rapid Landslide Detection with Sentinel-1. (version 1.1).* Retrieved from RUS Lectures at <u>https://rus-copernicus.eu/portal/the-rus-library/learn-by-yourself/</u>



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# **1** Introduction

The Research and User Support for Sentinel core products (RUS) service provides a free and open scalable platform in a powerful computing environment, hosting a suite of open source toolboxes preinstalled 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/largestlandslide-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 7<sup>th</sup>, 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<sup>3</sup>.

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<sup>2</sup> 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 <u>RUS portal</u> and open a User Service request from Your RUS service  $\rightarrow$  Your dashboard.

## 2.1 Data used

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

*S1A\_IW\_SLC\_\_1SDV\_20180623T185856\_20180623T185923\_022488\_026F84\_32C6 S1A\_IW\_SLC\_\_1SDV\_20180717T185857\_20180717T185924\_022838\_0279F5\_B025* 

## 2.2 Software in RUS environment

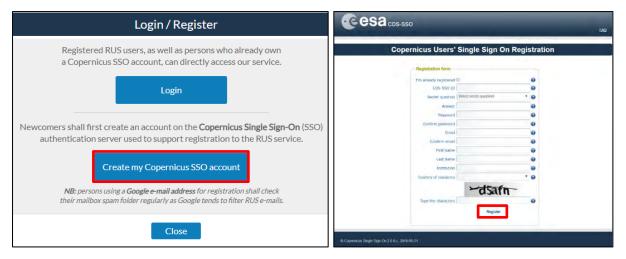
Internet browser, SNAP + Sentinel-1 Toolbox, (Extra steps: Google Earth)

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

CORRUS Research and User Support	G A Login/Register 💵
The RUS Service * The RUS Offer * The RUS Library * The RUS Community *	
	Senth
	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
	IGARSS 2018 - Valencia - 22-27 July 2018
Welcome to the Copernicus Research and User Support (RUS) Service portal!	▼ The RUS agenda
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			-
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 carl login here:	CDS-SSO ID Password Max Idle Time Max Session Time	half a day Until browser close	*	000000000000000000000000000000000000000
Login		Forgot your password?		

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

The RUS Service = The RUS C	Do you want t	o subscribe for a new RUS account?	
	Your ESA-SSO subscription	data:	We are not to come a www.in
+ Your RUS service	Login		
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· Your dashibment: allows you to en-	Organization	and the second sec	est - 21 a 22 Nov. 2018
· Your training allows you to regis	Country		Researchary Workshop - Washing
	Additio	onal subscription information	acter unlocky - 8 Nov-2018
	Please complete the followi	ing information:	Init - Alexandra - 24 October 2011
	Where did you hear about the RUS service? Select one or more items	outreach event colleagues newsletter	<ul> <li>a Door IP-Week - Financial - 12-3.6 fm arrans - Patient - 0. 9 10 &amp; 17 Nov 1</li> </ul>
		conference social media other	then - Foojouse - 25 % 27 Oct. 201
	Institution type	Select one item	~ nda
	Phone number /taly (17):	+39	print representation of the second
	Title	Select one item	~

# 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**.

CORRUS Research and User Support	A B	B - 14F		
		Hello, Miguel 💄		
The RUS Service * The RUS Offer * The RUS Library * The RUS Communit	HUS			
	A Your profile	You are here: Home > Your RUS service		
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This section gathers pages related to your RUS services:	Your training			
Your profile: displays your personal information linked to your ESA SSO and RUS a	counts	News from RUS One year on! Copernicus Info Session - Reykjavik - 19 September 2018 SPIE Remote Sensing 2018 - Berlin (Germany) - 11-12 September 2018		
Tour prome apprays your personal monitation in real to your Escape and not a	o o o o i i i i i i i i i i i i i i i i			
<ul> <li>Your dashboard: allows you to access your private dashboard,</li> </ul>				
<ul> <li>Your training: allows you to register to a training session you have been invited to p</li> </ul>	participate in.			
		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		
		IGAR55 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	🌾 🎓 💼 🤄 🚱 esa Hello, Miguel 🛔
The RUS Service * The RUS Offer * The RUS Library * The RUS Community *	Service   You are here. Home > Your RUS service > Your dashboard
Your dashboard	
Request a new User Service	Chat with Support Desk
Copyright & 2017 Research and User Support	Confact 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.

Step 1/3 Your experience	
Please help us learn more about your background by answ	vering a few questions. Thi
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 Op	pen access hubs?
Yes	
© No	
Have you already handled/processed Copernicus data?	
Yes.	
I No	
Do you wish to practice a tutorial exercise shown in a RUS webinar? If (hold down CTRL key for multiple selections).	yes, please select your choice
HAZA01 - Flood Mapping in Malawi	
HAZA02 - Burned Area Mapping in Portugal HYDR01 - Water Bodies Mapping over Northern Poland	
LAND01 - Crop Mapping in Seville	
LAND04 - Land Monitoring in Cyprus	
OCEA01 - Ship Detection in Gulf of Trieste	
If you wish to request another tutorial exercise that doesn't appear in	the above list, please type here
its name or code. Note that you can request multiple tutorial exercise:	5.

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

This is a collection of information selecte					
ou can go back and edit this information if necessary.					
General information on your request:					
Years of experience in Remote Sensing	5-10 years				
Downloaded Copernicus data?	1				
Handled/processed Copernicus data?	4				
Webinar codes	HAZA02, LAND04				
About your RUS project:					
Thematicarea	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:	8-1				
Min Latitude	39.3303				
Max Latitude	40.5877				
Min Longitude	-4.6736				
Max Longitude	-2.7205				
Reference polygons					
Data acquisition date(s):					
None					

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 dashb
<ul> <li>Your dashboard</li> </ul>								
Request a new U	Icor Sond						5	Chat with Support Desk
Co Nequest a new C	Jael Del VI	Le					-	Chat with Support Desk.
Project Name	ID	Date of submission	Status		Actions		Virtual	I 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	Report a technical

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.

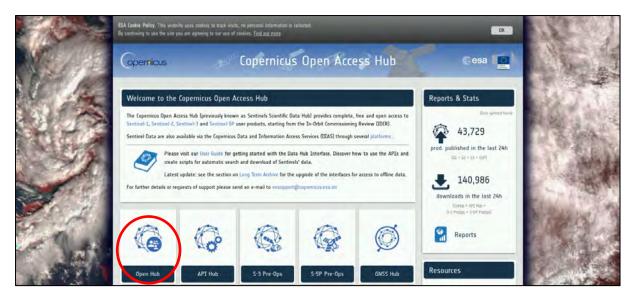
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# 5 Step by step

## 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**  $\rightarrow$  **Network**  $\rightarrow$  **Firefox Web Browser** or click the link below.

Go to <a href="https://scihub.copernicus.eu/">https://scihub.copernicus.eu/</a>



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.

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	Copernicus	Open Access Hub	2 @ ↑
	Register	new account	圓
	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 Username field accepts only apphasumenc, characters plus "* " and "* Password field accepts only apphasumenc, characters plus "* "@" "#", "#", "#", "#", "#", "#", "#",		
	Fustname	Lastaneol	
	Usarreang	-	
	Promound	1. Dans Berry 17/3 Upperland	
	E-mai	(Candaro Euran	
	Select Domain		
	Seleci Usaga		
	Seliect your country		
	By registering in this website you are deer	ted to have accepted the T&C for Sentinel data use.	RECESTER

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.

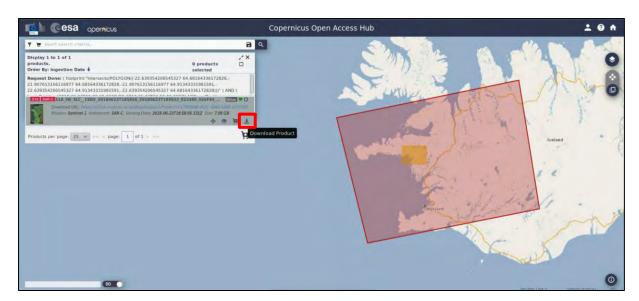
Zoom in a bit more, switch to "**drawing mode**" and draw a search rectangle approximately as indicated below. Open the search menu by clicking to the left part of the search bar. We will first specify the parameters for the product before the date of the landslide occurred and then for the one afterwards:

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

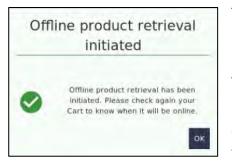
	Copernicus Open Access Hub	Ľ 0
🗑 Insett search criteria		
Advanced Search	Clear	
» Sort By: » Order By:		
Ingestion Date Descending	-	LACES AND A LEVEL
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2018/06/23 2018/06/23	a contractions	Rea Join No. 17
Ingestion period	A star	
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Mission: Sentinel-1		All destable
atellite Platform Product Type	Oranya	
• SLC		and a start of the
Polarisation Sensor Mode		Jan III III
elative Orbit Number (from 1 to 175) Collection	-	Since 10
16	- Britishing	have a state
Mission: Sentinel-2	a (	I with i a fill
atellite Platform Product Type		and a state
Lelative Orbit Number (from 1 to 143)	Att men.	SSI UNN
D Mission: Sentinel-3	Reykjavk	and the state of the
ateilite Platform Product Type	Hathangton 199	

Then click on the "**Search**" sicon. 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  $\square$  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.

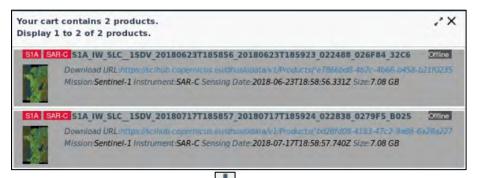
By the time the product turns online, it remains like that for 4 days and then it goes back to offline again. You need to frequently check your cart for the product availability.

NOTE 1: You can find more information about the retrieval of offline/long term archive products here: <u>https://scihub.copernicus.eu/twiki/do/view/SciHubUserGuide/LongTermArchive#Retrieval\_of\_offline\_products\_vi & https://scihub.copernicus.eu/userguide/LongTermArchive</u>

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.

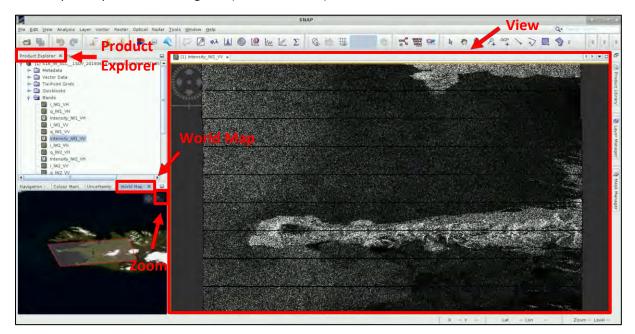


Click on the "**Download Product**" icon and the products will be downloaded at */home/rus* as zip files. Move them to: */shared/Training/HAZA07\_LandslideDetection\_Iceland\_TutorialKit/Original* 

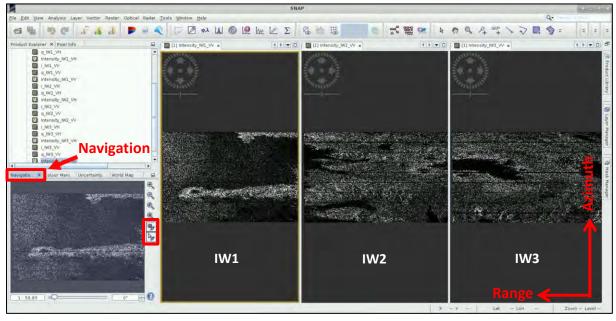
## 5.2 SNAP – open and explore data

Open SNAP software from the icon located on the desktop are 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 **b** 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 **1** NOTE 2).



Open the *Intensity\_IW2\_VV* and the *Intensity\_IW2\_V3* bands as well and go to **Window**  $\rightarrow$  **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  $\square$  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 6<sup>th</sup> 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  $\rightarrow$  Coregistration  $\rightarrow$  S1 TOPS Coregistration  $\rightarrow$  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.

e	_	_	S-1 TOPS ESD	Coregistration	_	
Read Read(2)	TOPSAR-Split	TOPSAR-Split(2)	Apply-Orbit-File	Apply-Orbit-File(2)	Back-Geocoding	Enhanced-Spectral-Diversity Write
Source Product Name:						
[1] S1A_IW_SLC_	1SDV_20180623	T185856_2018062	3T185923_022488_	026F84_32C6		
Data Format	Any Format	3				
			1 He	lp 🕞 Run		

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 <u>5.3.4 Back-Geocoding</u> chapter and set the parameters in that one!

6	_	_		S-1 TOPS ESD	Coregistration			• • •
Read	Read(2)	TOPSAR-Split	TOPSAR-Split(2)	Apply-Orbit-File	Apply-Orbit-File(2)	Back-Geocoding	Enhanced-Spectral-Diversity	Write
Source Name:	e Product							
[2] 51	A_IW_SLC_	1SDV_20180717	185857_20180717	T185924_022838_	0279F5_B025			× pres
Data	Format	Any Format	1					
ror: [N	odeld: Bacl	-Geocoding] Enti	re image is outside		a.Please use another	DEM.		
				I Hel	p 🕞 Run			

#### 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.

e				S-1 TOPS ESD	Coregistration	_		• • •
Read	Read(2)	TOPSAR-Split	TOPSAR-Split(2)	Apply-Orbit-File	Apply-Orbit-File(2)	Back-Geocoding	Enhanced-Spectral-Diversity	Write
Orbit State	Vectors:	Sentinel Precise	e (Auto Download)					-
Polynomial Degree: 3								
Do not fail if new orbit file is not found								
e	_		_	S-1 TOPS ESD	Coregistration	_	1	•
Read	Read(2)	TOPSAR-Split	TOPSAR-Split(2)	Apply-Orbit-File	Apply-Orbit-File(2)	Back-Geocoding	Enhanced-Spectral-Diversity	Write
Orbit State	Vectors:	Sentinel Precise	e (Auto Download)					-
Polynomial	Degree:	3						
		Do not fail if	Do not fail if new orbit file is not found					

and can be refined with <u>the precise orbit files</u> which <u>are available days-to-weeks after the generation of</u> <u>the product</u>. **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.

e		S-1 TOPS ESD Coregistration				• • ×	
Read Read(2) TOPSAR-Split	TOPSAR-Split(2)	Apply-Orbit-File	Apply-Orbit-File(2)	Back-Geocoding	Enhanced-Spectral-Diversity	Write	
Digital Elevation Model:	GETASSE30 (Au	GETASSE30 (Auto Download)					
DEM Resampling Method:	BILINEAR_INTERPOLATION					-	
Resampling Type:	BILINEAR_INTERPOLATION					-	
Mask out areas with no elevation	-						
🕑 Output Deramp and Demod Phase							

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.

e	S-1 TOPS ESD Coregistration	* = ×
Read Read(2) TOPSAR-Split TOPSAR	Split(2) Apply-Orbit-File Apply-Orbit-File(2) Back-Geocoding	Enhanced-Spectral-Diversity Write
Registration Window Width:	512	•
Registration Window Height:	512	
Search Window Accuracy in Azimuth Direction:	16	-
Search Window Accuracy in Range Direction:	16	•
Window oversampling factor:	128	•
Cross-Correlation Threshold:		0.1
Coherence Threshold for Outlier Removal:		0,15
Number of Windows Per Overlap for ESD:		10
Use user supplied shifts (please enter the	m below)	
The overall azimuth shift in pixels:		0.0
The overall range shift in pixels:		0.0

#### 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

6			S-1 TOPS ESD Coregistration				• •	
Read	Read(2)	TOPSAR-Split	TOPSAR-Split(2)	Apply-Orbit-File	Apply-Orbit-File(2)	Back-Geocoding	Enhanced-Spectral-Diversity	Write
Target Name:	Product							
Save a	V2_SLCVV is: BEAM-DI ectory:		0717_Orb_Stack					
	CONTRACTOR OF	ng/HAZA07_Land	slideDetection_Icela	and_TutorialKit/Pro	cessing			
				R Hel	p 🕞 Run			

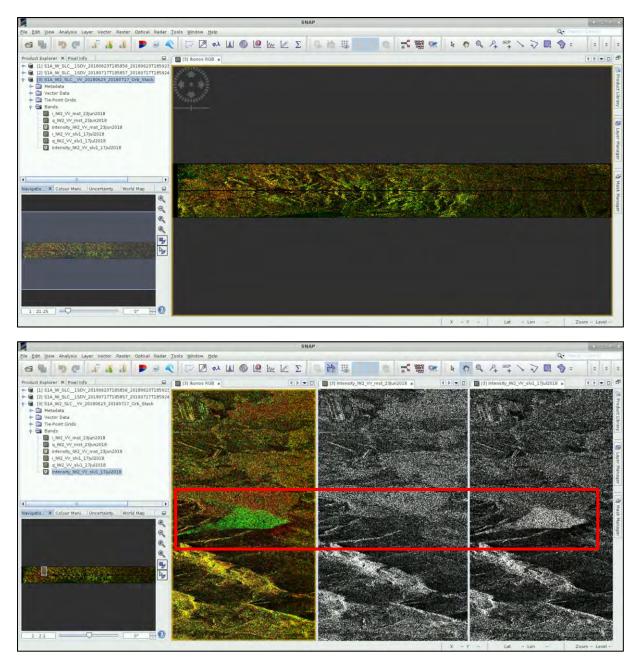
Finally click **Run** and the stack/coregistered product will be created and will automatically appear at the **Product Explorer** Window. You can expand it, open the bands folder, view the bands and create and RGB image as following.

## 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**.

Product Explorer × Pixel Info			Select RGB-Image Channels		
<ul> <li>♀ (1) S1A_IW_SLC_1SDV_20180623T1850</li> <li>♀ (2) S1A_IW_SLC_1SDV_20180717T1850</li> <li>♀ (2) S1A_IW_SLC_1SDV_20180623_201800</li> </ul>	857_20180717T185924	Profile: Ikonos	(modified)		
∽ 🗋 Metadata ∽ 🗋 Vector Data ∽ 📄 Tie-Point Grids	Band Maths Add Elevation Band Add Land Cover Band	Red: Green:	\$3.Intensity_IW2_VV_mst_23Jun2018 \$3.Intensity_IW2_VV_slv1_17Jul2018	-	
🛉 🖼 Bands – 🧾 i IW2 VV mst 23jun2018	🗹 Group Nodes by Type	Blue:		-	
- g IW2 VV mst 23jun2018	Open RGB Image Window		Expression	s are	valid
Intensity_IW2_VV_mst_23Jun2018	Open HSV Image Window	Stor	e RGB channels as virtual bands in current product		
	Close Product Close All Products Close Other Products		<u>OK</u> <u>C</u> ancel		telp

Once the RGB image is created, you can also open both the **Intensity** bands of the stack product and go to **Window**  $\rightarrow$  **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**  $\rightarrow$  **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.

		Graph Builder		+ = x
File Graphs				
		Right click here to add an operator	Right-click and delete the operator	=
Read			WILL	
Read Write				
Source Product				
Name: [3] SIA_IW2_SLC_VV_2018	0623 20180717 Orb Stack			<b>.</b>
Data Format Any Form	nat 💌			
	Load 🙆	Save 🏷 Clear 📝 Note	🕐 Help 🕞 Run	

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  $\rightarrow$  Radar  $\rightarrow$  Interferometric  $\rightarrow$  Products  $\rightarrow$  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.

Read 🔶 Interferogram
----------------------

In the Interferogram tab, keep the default parameters.

Read Interferogram		
🖌 Subtract flat-earth phase		
Degree of "Flat Earth" polynomial	5	-
Number of "Flat Earth" estimation points	501	•
Orbit interpolation degree	3	•
Subtract topographic phase		
Digital Elevation Model:	Provide and the second s	*
Tile Extension [%]	10 C	*
Output Elevation		
Output Orthorectified Lat/Low		
🕑 Include coherence estimation		
Square Pixel	🔲 Independent Window Sizes	
Coherence Range Window Size	10	
Coherence Azimuth Window Size	3	

#### 5.4.2 TOPS Deburst

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

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

Read	Interferogram TOPSAR-Deburst					
Polarisations. W						
	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  $\rightarrow$  Radar  $\rightarrow$  Interferometric  $\rightarrow$  Products  $\rightarrow$  TopoPhaseRemoval. Connect the **TOPSAR-Deburst** operator to it.

Read -Interferogram - TOPSAR-Deburst - TopoPhaseRemoval

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

Read Interferogram	TOPSAR-Deburst TopoPhaseRemoval	
Orbit Interpolation Degree	3	
Digital Elevation Model:	GETASSE30 (Auto Download)	-
Tile Extension [%]	100	-
	Output topographic phase band	
	Output elevation band	
	Output orthorectified Lat/Lon bands	

#### 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  $\rightarrow$  Radar  $\rightarrow$  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.

Read Interferogram	TOPSAR-Deburst TopoPhaseRemoval Multilook				
Source Bands:	i_ifg_V_23jun2018_17jul2018 q_ifg_V_23jun2018_17jul2018 Intensity_ifg_V_23jun2018_17jul2018_ifg_srd_V/23jun2018_17jul2018 Phase_ifg_srd_V_23jun2018_17jul2018 coh_iW2_V/_23jun2018_17jul2018				
GR Square Pixel	Independent Looks				
Number of Range Looks:	8				
Number of Azimuth Looks:	2				
Mean GR Square Pixel:	28.722685				
Output Intensity					
	Note: Detection for complex data is done without resampling.				

#### 5.4.5 Phase Filtering

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

Read Interferogram TOPSAR-Deburst TopoPhaseRemoval > Multilook GoldsteinPhaseFiltering

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

Read Interferogram TOP	SAR-Deburst TopoPhaseRemoval Multilook GoldsteinPhaseFiltering	
Adaptive Filter Exponent in (0,1)	H	1.0
FFT Size:	128	-
Window Size:	3	-
🔲 Use coherence mask		
Coherence Threshold in [0,1]:		0.2

#### 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 rightclick and go to **Add**  $\rightarrow$  **Input-Output**  $\rightarrow$  **Write.** Connect the **GoldsteinPhaseFiltering** operator to it.

Read -> Inter	erogram → TOPSA	R-Deburst 🔶 TopoPhaseR	lemoval → Multilook –	GoldsteinPhaseFiltering	→ Write
---------------	-----------------	------------------------	-----------------------	-------------------------	---------

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

Name: S1A\_IW2\_SLC\_\_VV\_20180623\_20180717\_Orb\_Stack\_lfg\_Deb\_DInSAR\_ML\_Flt

Directory: /shared/Training/HAZA07\_LandslideDetection\_Iceland\_TutorialKit/Processing

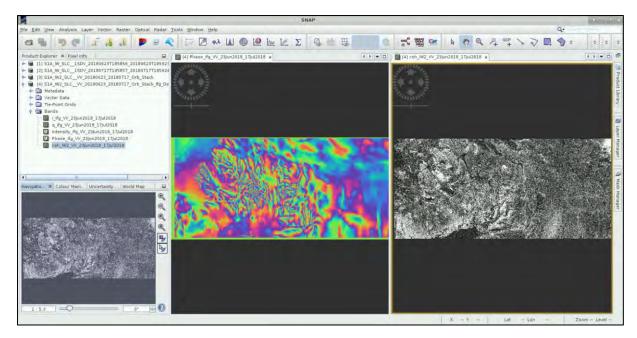
Read	Interferogram	TOPSAR-Deburst	TopoPhaseRemoval	Multilook	GoldsteinPhaseFilt	tering Write		
Target	Product							
Name:								
	2 SLC VV 2018	0623 20180717 Orb	Stack Ifg Deb_DInSAR	ML Flt				
	S: BEAM-DIMAP	-						1
	ectory:							
(management of the second seco		7407 LandslideDete	ction_Iceland_TutorialKi	t/Processing				
12.511	area, maning, nea	LAGY_Landshacecte	coon recording recording	errocessing				[
		1.0						
		Lo	ad 🔄 Save	No Clear	Note (	🕑 Help D	> Run	

	SNAP - Save Graph	· ·
Save In:	Processing	• 6 6 6 88 8
Name 🔺		Size Modified
51A_IW2_	SLC_VV_20180623_20180717_Orb_Stac	3/30/20 7:35 PM
SIA W2_	SLC_VV_20180623_20180717_Orb_Stac	3/30/20 7:35 PM
SIA_IW2_	SLC_VV_20180623_20180717_Orb_Stac	3/30/20 7:35 PM
SIA_IW2_	SLC_VV_20180623_20180717_Orb_Stac	3/30/20 7:35 PM
Subset_S	1A_IW2_SLCVV_20180623_20180717_0	3/30/20 7:35 PM
Subset_S	1A_IW2_SLC_VV_20180623_20180717_0	3/30/20 7:35 PM
Graph.xm		4 KB 3/30/20 3:23 PM
File <u>N</u> ame:	Graph.xml	
Files of Type:	Graph (*.xml)	
		Save Cancel

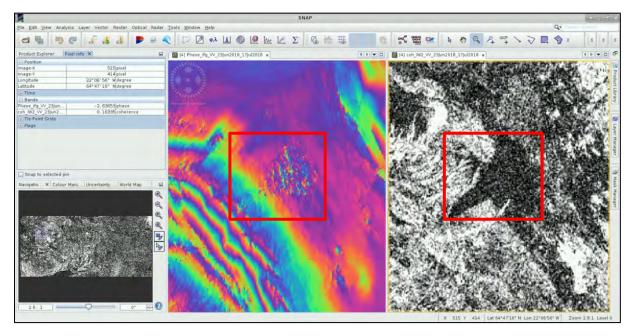
Once you have created the graph, you can save it for future use. Navigate to the path you want to save it e.g. to */shared/Training/HAZA07\_Land slideDetection\_Iceland\_TutorialKit/Processing* and save it with the Name: Graph.xml.

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.

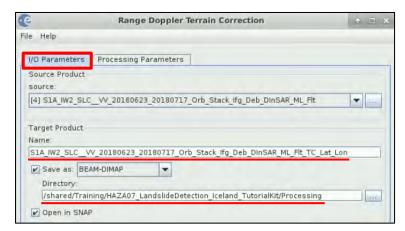
## 5.4.7 Geocoding

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  $\square$  NOTE 6).

Go to Radar  $\rightarrow$  Geometric  $\rightarrow$  Terrain Correction  $\rightarrow$  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.

Rang	e Doppler Terrain Correction	+ = ×			
le Help					
I/O Parameters Processing	Parameters				
Source Bands:	i_ifg_₩_23jun2018_17jul2018 g_ifg_₩_23jun2018_17jul2018				
	Intensity_ifg_VV_23Jun2018_17Jul2018 Phase_ifg_VV_23Jun2018_17Jul2018 coh_IW2_VV_23Jun2018_17Jul2018				
Digital Elevation Model:	GETASSE30 (Auto Download)	•			
DEM Resampling Method:	BILINEAR_INTERPOLATION	-			
Image Resampling Method:	BILINEAR_INTERPOLATION	-			
Source GR Pixel Spacings (az x	rg): 27.73(m) x 29.72(m)				
Pixel Spacing (m):	29.72				
Pixel Spacing (deg):	2.669793024403218E-4	2.669793024403218E-4			
Map Projection:	WGS84(DD)				
Mask out areas without ele Output bands for:	vation 🔲 Output complex data				
Selected source band	DEM Latitude & Longitude				
Incidence angle from ellips	soid 🔲 Local incidence angle 🔛 Projected local incide	ence angle			
Apply radiometric normalization	ation				
Save Sigmaŭ band	Disconstants in a mount allocation and	*			
Save Gamma0 band	The second second second by the second by the	-			
Save Betaŭ band					
Auxiliary File (ASAR only):	An and the second se	-			
	Run	<u>C</u> lose			

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

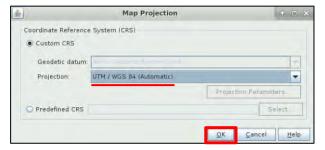
**Name:** S1A\_W2\_SLC\_\_VV\_20180623\_20189717\_Orb\_Stack\_Ifg\_Deb\_DInSAR\_ML\_Flt\_TC\_UTM and keep the rest settings same as for the previous one.

In the Processing Parameters tab:

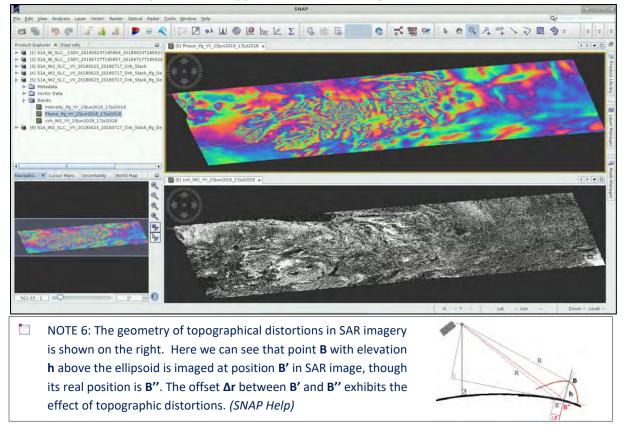
Go to **Map Projection**, click on it and at the Custom CRS, at the Projection, select:

#### UTM / WGS 84 (Automatic)

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



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



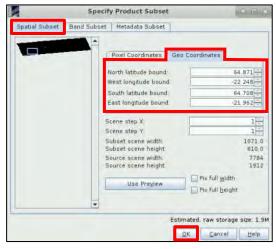
#### 5.5 Subset

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</u> <u>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:64.871West latitude bound:-22.248South latitude bound:64.708East latitude bound:-21.962

Then click OK.

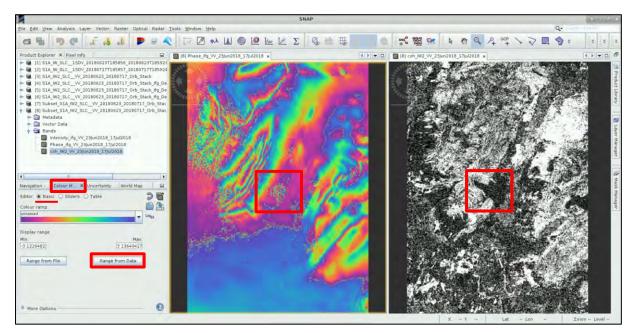


Repeat the same process for the second product as well. The subsets will appear at the Product Explorer Window but they are not physically stored. Right-click in each one of them and go to Save Product. At the window that will appear, click Yes, so that the product will be converted to BEAM-DIMAP format. 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\_FIt\_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**  $\rightarrow$  **Export**  $\rightarrow$  **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

	SNAP - Export Prod	uct	* = *	Specify Product Subset	• • ×
Name S1A S1A S1A S1A S1A S1A Subs	Processing W2_SLC_W_20180623_20180717_Orb_S W2_SLC_W_20180623_20180717_Orb_S W2_SLC_W_20180623_20180717_Orb_S W2_SLC_W_20180623_20180717_Orb_S w2_SLC_W_20180623_2018071 set_S1A_W2_SLC_W_20180623_2018071	Modified 3/30/20 7:35 PM 3/30/20 7:35 PM 3/30/20 7:35 PM 3/30/20 7:35 PM 3/30/20 7:35 PM 3/30/20 7:35 PM	77 2 888 8- Subset	Spatial Subset     Band Subset     Metadata Subset     Internety, Fg.VX, 20(u-2018, 17),42018     Internety from complex data     Phase, ifg.VX, 28(u-2018, 17),42018     Phase from complex data     Conj.W2,VV, 28(u-2018, 17),42018	
File <u>N</u> ame Files of <u>T</u>				📄 Select gil : 🛄 Select none	Then clicl Export
		Export Product	Cancel		Cancel Help 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:

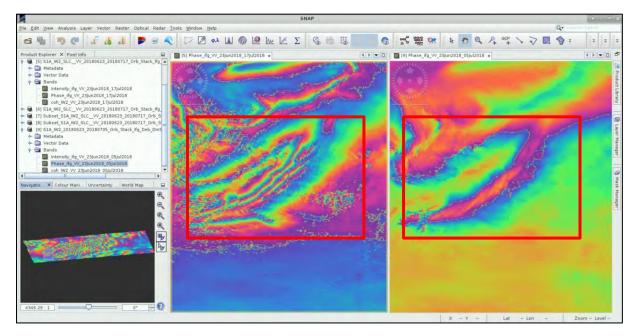
Phase\_ifg\_VV\_23Jun2018\_17Jul2018\_full.kmz Phase\_ifg\_VV\_23Jun2018\_17Jul2018\_subset.kmz Coherence\_IW2\_VV\_23Jun2018\_17Jul2018\_full.kmz Coherence\_IW2\_VV\_23Jun2018\_17Jul2018\_subset.kmz

# 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.

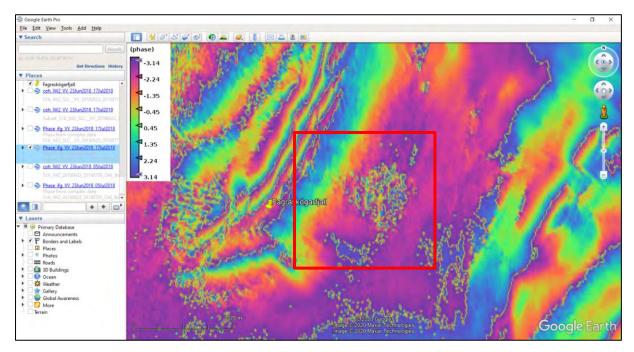
Once the KMZ files have been downloaded, you can load and visualize them in **Google Earth**.



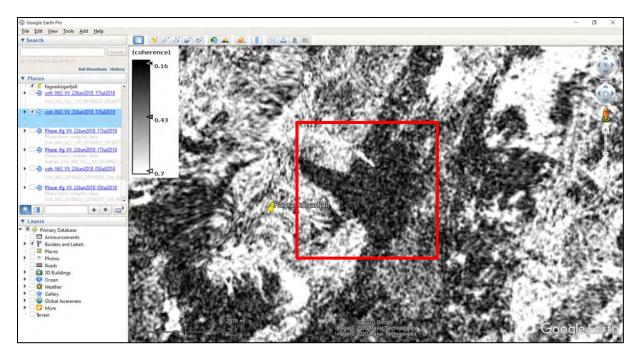
## 6.2 Visualization in Google Earth

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:

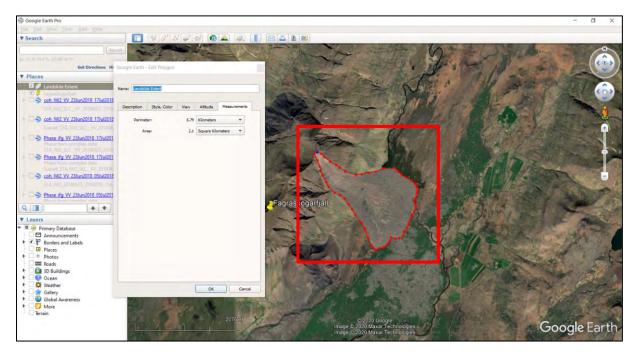
Phase\_ifg\_VV\_23Jun2018\_17Jul2018\_full.kmz Phase\_ifg\_VV\_23Jun2018\_17Jul2018\_subset.kmz Coherence\_IW2\_VV\_23Jun2018\_17Jul2018\_full.kmz Coherence\_IW2\_VV\_23Jun2018\_17Jul2018\_subset.kmz Phase\_ifg\_VV\_23Jun2018\_05Jul2018\_Pre-event.kmz Coherence\_IW2\_VV\_23Jun2018\_05Jul2018\_Pre-event.kmz



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<sup>2</sup> 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\_Interfero metry\_Processing\_and\_Interpretation\_br\_ESA\_TM-19 - InSAR Principles
- <u>https://sentinel.esa.int/web/sentinel/missions/sentinel-1</u> Sentinel-1 Mission
- https://www.researchgate.net/publication/209802944 Landslide Types and Processes

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