





TRAINING KIT – HAZA06

WATCHING A TYPHOON USING SENTINEL-1 HAGIBIS, OCTOBER 2019









Research and User Support for Sentinel Core Products

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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 derived from the Copernicus Sentinel satellites constellation.

2 Typhoon Hagibis



Hagibis was the biggest typhoon to hit Japan in decades and was considered to be the most devastating typhoon to hit the Kantō region of Japan since Ida in 1958. The system reached tropical storm status late on 5 October as it travelled westward. On 12 October, Hagibis made landfall at Izu Peninsula as a Category 2.

With extreme events like this likely to increase in number and in severity as a consequence of climate change, satellites are playing an

Damage caused by typhoon Hagibis Credits: japan-forward.com

increasingly important role in understanding and tracking huge storms. Sentinel-1 is especially valuable as it can "see" through clouds and help map the scale of flooded areas immediately during the event and well as the damage afterwards even in absence of cloud free optical imagery.

In this exercise we will use two different Sentinel-1 Level-1 data products to look at different aspects of the typhoon. The **G**round **R**ange **D**etected product will be used to map flooded areas during the event, while the loss od coherence resulting from damage after the flooding subsided will be derived from the **S**ingle Look **C**omplex data.

3 Training

Approximate duration of this training session is two hours.

The Training Code for this tutorial is HAZA06. If you wish to practice the exercise described below within the RUS Virtual Environment, register on the <u>RUS portal (rus-copernicus.eu)</u> and open a User Service request from Your RUS service > Your dashboard.

3.1 Data used

• Five Sentinel-1 images acquired between September 24 and October 18, 2019, two are GRD data products and three are the SLC data products. [downloadable @ <u>https://scihub.copernicus.eu/</u>]

S1B_IW_**GRDH**_1SDV_**20191012**T204154_20191012T204223_018447_022C0C_**B106** S1A_IW_**GRDH**_1SDV_**20191006**T204235_20191006T204300_029343_0355EA_**C9CC** S1A_IW_**SLC**__1SDV_**20191018**T204233_20191018T204300_029518_035BEF_**380F** S1A_IW_**SLC**__1SDV_**20191006**T204233_20191006T204300_029343_0355EA_**AFB2** S1A_IW_**SLC**__1SDV_**20190924**T204233_20190924T204300_029168_034FDF_**708B**

• Auxiliary data stored locally @/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/AuxData

3.2 Software in RUS environment

Internet browser, SNAP + Sentinel-1Toolbox

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.



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*.

Login / Register	
Registered RUS users, as well as persons who already own a Copernicus SSO account, can directly access our service. Login Newcomers shall first create an account on the Copernicus Single Sign-On (SSO) authentication server used to support registration to the RUS service. Create my Copernicus SSO account NB: persons using a Google e-mail address for registration shall check their mailbox spam folder regularly as Google tends to filter RUS e-mails. Close	Copernicus Users' Single Sign On Registration
	© Copenicus Single Sign Ch 2.6.0.c. 2016/05/21

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 can login here: Login	CDS-SSO ID Password Max Idle Time Max Session Time	half a day Until browser close Login Reset	Ŧ	0000

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	to subscribe for a new RUS account?		
	Your ESA-SSO subscription	data:	Was and the property of the local division o	a na manaistean
+ Your RUS service	Login			9
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· Your profile: diaptays your prints	Last Name	Teachers .	US	
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	RUS service?	colleagues	The second	1000 No. 1000
	Select one or more items	newsletter	THEN - PRIMOU - D. T 2015-13 More	COM COMPANY
		social media	Rhen - Tokioune - 25 is 17 foct 20	and the second sec
		other		
	Institution type	Select one item	× da	
	Phone number Italy (IT):	+39	arkainare -	100
	Title	Select one item	~	L VILLAN

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** \rightarrow **Your Dashboard**.

The RUS Service * The RUS Offer * The RUS Library *	
	Your profile You are here; Home > Your RUS sen Your dashboard
• Your RUS service This section gathers pages related to your RUS services:	Your training News from PLIS
Your profile: displays your personal information linked to your Your dashboard: Illows you to access your private dashboard.	ESA SSO and RUS accounts, One year on! Copernicus Info Session – Reykjavik – 19 September 2018
Your training: allows you to register to a training session you h	ve been invited to participate in. 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 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	
The RUS Service The RUS Offer The RUS Library The RUS Community Y Stor RUS Service The RUS Library The RUS Community The RUS Service The RUS S	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 c	Sontact 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 information will be stored in your User Profile.	a few questions. Th
How many years of experience in Remote Sensing do you have?	
Choose one Item	
Have you already downloaded Copernicus data via the Copernicus Open acco	ess 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, plo (hold down CTRL key for multiple selections).	ease 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 Guif of Trieste	*
If you wish to request another tutorial exercise that doesn't appear in the abo	ove list, please type here
its name or code. Note that you can request multiple tutorial exercises.	

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

summary mornadon on your request.		
This is a collection of information selected	d across the USR forms.	
You can go back and edit this information	if necessary.	
General information on your request:		
Years of experience in Remote Sensing	5-10 years	
Downloaded Copernicus data?	1	
Handled/processed Copernicus data?	1	
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	a.	
S1 - Orbit direction		
Sentinel-2	x	
Sentinel-3	x	
Other	x	
I don't know	×	
Region of Interest: Min Latitude	30 3303	
MaxLatitude	40 5977	
Min Longitude	-46736	
MaxLongitude	-2 7205	
Reference polygons	27203	
Data acquisition data/el-		
Alana		
Additional data specifications		
I have read and agree to the Terms and	conditions of RUS Service.	

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					5	Chat with Support Desk
Project Name	ID	Date of submission	Status		Actions		Virtual	Environment
	1	Same S		Follow my project	Get support	Close my service	Access my Virtual Machine(s)	Access my CPU monitoring dashboard
RUS_training1	231	2017-08-31	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.

Applications						1.0
alla System			ESAN Schwelling	992 2000	R	SNAP
	Commanie Con			SKAT GLU	Jupy Kar Addabacija	Aberbarterd
disign	Tieste	~				
		opernicus				

6 Step by step

6.1 Data download – ESA SciHUB

In this step, we will download a Sentinel-2 scene from the Copernicus Open Access Hub using the online interface (Applications \rightarrow Network \rightarrow 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 on the map to the island of Honsu in Japan. Then change to the drawing mode (indicated by green arrow below) and draw a rectangle arround the city of Sendai.

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

Sensing period: From 2019/10/06 to 2019/10/12 Check Mission: Sentinel-1 Product Type: *GRD* Sensor Mode: *IW* Relative Orbit Number: 46



Click on the magnifying glass symbol to start the search. In our case the search returns 2 results, but it will depend on the exact search rectangle you have defined.



Go through the list and select these **2 full** scenes by checking the box next to the product name:

- S1B_IW_GRDH_1SDV_20191012T204154_20191012T204223_018447_022C0C_B106
- S1A_IW_GRDH_1SDV_20191006T204235_20191006T204300_029343_0355EA_C9CC

Once they are all selected click on 📅 to add the products to the cart. A little green cart symbol should appear next to the product name.

Then return to the search parameters $\overline{\mathbf{Y}}$ and change them as follows:

```
Sensing period: From 2019/09/24 to 2019/10/18
Check Mission: Sentinel-1
Product Type: SLC
Sensor Mode: IW
Relative Orbit Number: 46
```

Then press search again. The search returns 4 results, but it will depend on the exact search rectangle you have defined.

Go through the list and select these **3 full** scenes by checking the box next to the product name:

- S1A_IW_SLC__1SDV_20191018T204233_20191018T204300_029518_035BEF_380F
- S1A_IW_SLC__1SDV_20191006T204233_20191006T204300_029343_0355EA_AFB2
- S1A_IW_SLC__1SDV_20190924T204233_20190924T204300_029168_034FDF_708B

Once they are all selected click on 😟 to add the products to the cart.



Then go to the cart by clicking on the green cart symbol left of the full text search. There should be 5 products in your cart.

Finally, let's download the cart in the form of .meta file. The file contains links to each of the files, we will need the file and download client to download the actual data.



The *products.meta4* file will be downloaded to your */home/rus* folder. To download our data, we will use **aria2** tool. To use the tool, we first need to move the *products.meta4* file to the folder where we wish our data to be downloaded to - */shared/Training/HAZA06_WatchingATyphoon_Hagibis/Original/*

Then, let's test our aria2 installation. To do this we open the Command Line 🔚 (in the bottom of your desktop window), type the following and press Enter:

aria2c

The correct response should be as follows:



If the response is "-bash aria2c: command not found" (see 🛄 NOTE 1).

NOTE 1: If (and only if) the response is "-bash aria2c: command not found". Then we have to install the tool, to do this in command line type: sudo apt-get install aria2 When requested type: Y Then you can test your installation again.

If you have received the correct response, then we can run the tool by typing following commands in the command line (replace <username> and <password> with your login credentials for Copernicus Open Access Hub):

```
cd /shared/Training/HAZA06_WatchingATyphoon_Hagibis/Original/
aria2c --http-user='<username>' --http-passwd='<password>' --check-
certificate=false --max-concurrent-downloads=2 -M products.meta4
```

The first line changes our directory to the target directory. The second line runs the download tool (Type the red text all in single line). All five products will be downloaded to the *Original* folder two

products in parallel automatically (Note that the constraint of maximum two parallel downloads at a time is imposed by the Copernicus Access Hub, if you increase the number the download will fail). This might take some time.

When the products are downloaded move them to the appropriate directories inside the **/Original** folder based on the product type.

6.2 Storm Surge and flooding – Sentinel-1 GRDH

In the first part of this exercise we will identify the area flooded when typhoon Hagibis made a landfall on 12 October 2019. We will use the Ground Range Detected (GRD) data, which consist of focused SAR data that has been detected, multi-looked and projected to ground range using an Earth ellipsoid model. Phase information is lost.

Launch SNAP Men SNAP window opens click Open product , navigate to /shared/Training/HAZA06_WatchingATyphoon_Hagibis_TutorialKit/Original/GRDH and open the *.zip files.

The opened products will appear in **Product Explorer**. Click + or the \frown to expand the contents of the file from 6 October 2019, then expand Bands and double click **Amplitude_VV** to visualize the band. Then do the same for the image from 12 October 2019. To compare both images, go to **Window** \rightarrow **Tile Horizontally** and zoom-in to the coastal area on the mid left side of the image.



TIP: We can see that the view appears "mirrored to the side": this is because the scene was acquired during descending pass (the satellite was moving in north to south direction looking to the west) and the view shows the pixels in order of data acquisition as the image is not yet projected into cartographic coordinates.

6.2.1 Pre-processing

We need to apply identical pre-processing steps to all our scenes. However, processing the data step by step and product by product would be time consuming and inconvenient. Luckily, we can use the **Batch Processing** tool available in SNAP to apply all steps to both images in one go (this also saves disk space as only the final products are physically saved).

6.2.1 Build the Graph

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



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

First, we will update the orbit metadata (See \square NOTE 2). To add the operator, right-click the white space between existing operators and go to Add \rightarrow Radar \rightarrow Apply-Orbit-File. A new operator rectangle appears in our graph and a new tab appears below. Now connect the new Apply-Orbit-File operator to the Read operator by clicking to the right side of the Read operator and dragging the red arrow towards the Apply-Orbit-File.

NOTE 2: The orbit state vectors provided in the metadata of a SAR product are generally not accurate and can be refined with the precise orbit files which are available days-to-weeks after the generation of the product. The orbit file provides accurate satellite position and velocity information. Based on this information, the orbit state vectors in the abstract metadata of the product are updated. (*SNAP Help*)



The next step will remove the thermal noise (See \square NOTE 3). We do this by right-clicking the white space and going to Add \rightarrow Radar \rightarrow Radiometric \rightarrow ThermalNoiseRemoval. Connect the **ThermalNoiseRemoval** operator with the **Apply-Orbit-File** operator.

NOTE 3: Thermal noise in SAR imagery is the background energy that is generated by the receiver itself. (*SNAP Help*) It skews the radar reflectivity to towards higher values and hampers the precision of radar reflectivity estimates. Level-1 products provide a noise LUT for each measurement dataset, provided in linear power, which can be used to remove the noise from the product.

Read - Apply-Orbit-File - ThermalNoiseRemoval

Now, we can add the **Calibration** operator. The objective of SAR calibration is to provide imagery in which the pixel values can be directly related to the radar backscatter. Though uncalibrated SAR imagery is sufficient for qualitative use, calibrated SAR images are essential to quantitative use of SAR data (See \square NOTE 4). To add the operator go to Add \rightarrow Radar \rightarrow Radiometric \rightarrow Calibration. Connect the **ThermalNoiseRemoval** operator to the **Calibration** operator.

NOTE 4: Typical SAR data processing, which produces level-1 images, does not include radiometric corrections and significant radiometric bias remains. The radiometric correction is necessary for the pixel values to truly represent the radar backscatter of the reflecting surface and therefore for comparison of SAR images acquired with different sensors or acquired from the same sensor but at different times, in different modes, or processed by different processors. (*SNAP Help*)

Read - Apply-Orbit-File - ThermalNoiseRemoval - Calibration

SAR images have inherent salt and pepper like texturing called speckles which degrade the quality of the image and make interpretation of features more difficult (See \frown NOTE 5). To reduce the speckle effect and smooth the image we apply speckle filter. To add the operator, go to Radar \rightarrow Speckle Filtering \rightarrow Speckle-Filter then connect the Calibration operator to it.

NOTE 5: Speckle is caused by random constructive and destructive interference of the de-phased but coherent return waves scattered by the elementary scatters within each resolution cell. Speckle noise reduction can be applied either by spatial filtering or multilook processing. (*SNAP Help*)

Read Apply-Orbit-File ThermalNoiseRemoval Calibration Speckle-Filter

Our data are still in radar geometry, moreover due to topographical variations of a scene and the tilt of the satellite sensor, the distances can be distorted in the SAR images. Therefore, as the last step of our pre-processing, we will apply terrain correction to compensate for the distortions and reproject the scene to geographic projection (See \frown NOTE 6). To add the operator, go to Radar \rightarrow Geometric \rightarrow Terrain Correction \rightarrow Terrain-Correction and then connect the Speckle-Filter operator to it.



Next, since our Area of Interest (AOI) is quite small and there is no need to process the whole image, so we will add a **Subset** operator. To add the operator right-click the white space in the graph builder and go to Add \rightarrow Raster \rightarrow Geometric \rightarrow Subset. Connect the new Terrain-Correction operator to the Subset operator.

Write

Write

Read	-> Apply-Orbit-File	-> ThermalNoiseRemoval	> Calibration	> Speckle-Filter	> Terrain-Correction	-> Subset	Write

Finally, we will convert the values to decibel to enhance the contrast. To do this go to **Raster** \rightarrow **Data Conversion** \rightarrow **LinearToFromDb**. Then connect the **Subset** operator to it and connect the **LinearToFromDb** operator to the **Write** operator.

Read Apply-Orbit-File ThermalNoiseRemoval Calibration Speckle-Filter Terrain-Correction Subset LinearToFromdB Write

For the moment, do not change anything in the parameter tabs and save the graph as *Graph_preprocess.xml* to:

/shared/Training/Training/HAZA06_WatchingATyphoon_Hagibis/Processing/Flood_mapping/ by clicking **Save** at the bottom of the window. After you save the graph, close the **GraphBuilder** window.

6.2.2 Batch processing

In the **Product Explorer**, we select (highlight) the product [1]. Now we can open the **Batch Processing** tool at **Tools** \rightarrow **Batch Processing**.

We will add the opened products by clicking **Add Opened** on the upper right (second icon from the top) and click **Refresh**. Then click **Load Graph** at the bottom of the window and navigate to our saved graph and open it. We see that new tabs have appeared at the top of window corresponding to our operators except for **Write**; this is correct as these parameters will be set in the **I/O Parameters** tab.

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

/shared/Training/Training/HAZA06_WatchingATyphoon_Hagibis/Processing/Flood_mapping/ and deselect the "Keep source product name" option. (See 📜 NOTE 7).

		Batch Proce	essing : Graph_pre	process.xml		+ = ×	
e Graphs							
/O Parameters	Apply-Orbit-File	ThermalNoiseRemoval	Calibration Speck	le-Filter Terrain-Correction	Subset LinearToFromdE	3 Write	
File	Name	Туре	Acquisition	Track	Orbit	4	
A_IW_GRDH_1SD	V_20191006T20	GRD	06Oct2019	46	29343	÷.	
W_GRDH_1SD	V_20191012T20	GRD	120ct2019	46	18447	1	Aud ope
						-	
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rget Folder						2 Products	
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arget Folder ave as:						2 Products	

Now let's set the parameters.

In the Apply-Orbit-File tab we well keep the default settings.

Batch Processing : Graph_preprocess.xml						1	• • •	
File Graphs							-	
1/O Parameters	Apply-Orbit-File	ThermalNoiseRemoval	Calibration	Speckle-Filter	Terrain-Correction	Subset	LinearToFromdB	Write
Orbit State Vectors:	Sentinel Precise	(Auto Download)						-
Polynomial Degree:	jree: 3							
	Do not fail if r	new orbit file is not found						

In the **ThermalNoiseRemoval** tab, select **VV** polarization and make sure that the "**Remove Thermal Noise**" option is selected.

Batch Processing : Graph_preprocess.xml							•	×	
File Graphs									
VO Parameters	Apply-Orbit-File	ThermalNoiseRemoval	Calibration	Speckle-Filter	Terrain-Correction	Subset	LinearToFromdB	Write	1
Polarisations:	VH VV								Ì
Remove Therm	nal Noise								
Re-Introduce T	hermal Noise								

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

	Batch Processing : Graph_preprocess.xml						• = ×	
File Graphs			_					
1/O Parameters Apply-	Orbit-File	ThermalNoiseRemoval	Calibration	Speckle-Filter	Terrain-Correction	Subset	LinearToFromdB	Write
Polarisations:	VH VV							
Save as comple-outpu	-							
🖉 Output sigma0 band								
🔲 Output gamma0 band								
Output beta0 band								

Now we go to the **Speckle-Filter** tab. For this exercise we choose the simple **Lee** filter with **Window Size** of **3x3** pixels (See $\stackrel{\frown}{=}$ NOTE 8).

Batch Processing : Graph_preprocess.xml						+ E ;		
ThermalNoiseRemoval	Calibration	Speckle-Filter	Terrain-Correction	Subset	LinearToFromdB	Write		
Sigma0_VH Sigma0_VV								
Lee						-		
3								
3								
V								
1.11								
	Batch Proce	Batch Processing : Graj	Batch Processing : Graph_preprocess. ThermalNoiseRemoval Calibration Speckle-Filter Sigma0_VH Sigma0_VV Lee 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Batch Processing : Graph_preprocess.xml ThermalNoiseRemoval Calibration Speckle-Filter Terrain-Correction Sigma0_VH Sigma0_VV Lee 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Batch Processing : Graph_preprocess.xml ThermalNoiseRemoval Calibration Speckle-Filter Terrain-Correction Subset Sigma0_VH Sigma0_VV Lee 3 3 2 2 2 3 3 2 2 3 3 2 3 3 3 3 3 3 3	Batch Processing : Graph_preprocess.xml ThermalNoiseRemoval Calibration Speckle-Filter Terrain-Correction Subset LinearToFromdB Sigma0_VH Sigma0_VV Lee 3 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2		

NOTE 8: Lee Filter, introduced by Jong-Sen Lee in 1980, is a widely used local statistics filter for speckle noise reduction. It is a pointwise linear filter minimizing the mean square error using measurements of the sample mean and sample variance of the noisy image and knowledge of the type of detection and number of looks.

Last, we go in the **Terrain-Correction** tab, set **Digital Elevation Model** to *SRTM 1Sec HGT (Auto Download)*, then click on the **Map Projection** and set as Projection: **UTM / WGS84 (Automatic)**.

eckle-Filter Terrain-Correctio	n Subset LinearToFromdB Write	
I/O Parameters Apply-0	Orbit-File ThermalNoiseRemoval Calibration	
source Bands:	Sigma0_VH Sigma0_VV	
Digital Elevation Model	SRTM 1Sec HGT (Auto Download)	
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mage Resampling Method:		
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vixel Spacing (m):	10.0	
ixel Spacing (deg):	8.983152841195215E-5	
lap Projection:	WGS84(DD)	1
Mask out areas without elevati	ion Outout complex data	
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Save Gammaŭ band Save Betaŭ band Save Betaŭ band unihary File (ASAR-oniyu Coordinate Reference System Coordinate Reference System Geodetic datum: Projection: UTM / W Projection: UTM / W	Load Graph Run Close Help Map Projection (CRS) GS 84 (Automatic) Projection Parameters Salect QK Cancel Help	×

Click OK. At the "Map Projection" you will see: UTM Zone 36, South / World Geodetic System 1984.

Leave all the other default settings.

In the **Subset** tab, click to select the **Geographic Coordinates** option and paste the area of interest definition in WKT (well know text) format to the text window below the map. Click **Update** and then click the **Zoom-in** icon see your subset on the map.

```
POLYGON ((140.638 38.923, 141.699 38.922,141.690 37.969, 140.643 37.970, 140.638 38.923))
```

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I/O Parameters	Apply-Orbit-File	ThermalNoiseRemoval	Calibration	Speckle-Filter	Terrain-Correction	Subset	LinearToFromdB	Write
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] Copy Metadata Pixel Coordinate	s 🖲 Geographic	Coordinates		10				e o
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)LYGON ((140.638	38.923, 141.699	38.922,141.690 37.969, 1	40.643 37.97	0, 140.638 38.92	3))			Update

In the LinearToFromdB, leave the default settings. Finally, in the Write tab, set the output folder to: /shared/Training/Training/HAZA06_WatchingATyphoon_Hagibis/Processing/Flood_mapping/

Click **Run** to pre-process our images. *Approximate processing time: 5 minutes* Now you should have two new products in the **Product Explorer**. Select the original products [1-2], right-click on them and click **Close 2 Products** (Click **No** if asked to save).

6.2.3 Stack

In this step we will stack our images into a single product to be able to compare the changes in values due to the flooded area.

To create a stack, we will go to **Radar** \rightarrow **Coregistration** \rightarrow **Stack Tools** \rightarrow **Create Stack**.

Similarly, as in Batch Processing, in the **1-ProductSet-Reader** tab, we will add the opened products by clicking **Add Opened** on the upper right (second icon from the top) and click **Refresh**.

• • ×	
	Add opened
_	
	+ • ×

Then in the **2-CreateStack** tab, click on *Find Optimal Master* and set: **Resampling Type:** *NEAREST_NEIGHBOUR* **Initial Offset Method:** *Product Geolocation*

e	Create Stack	↑ □ ×
1-ProductSet-Reader	2-CreateStack 3-Write	
Master:	Subset_S1B_IW_GRDH_1SDV_20191012T204154_20191012T	204223_018447_022C0
Resampling Type:	NEAREST_NEIGHBOUR	
Initial Offset Method:	Product Geolocation	
Output Extents	Master	
Find Optimal Master		

In the **3-Write** tab, rename the product to *Subset_S1A_IW_GRDH_20191006_20191012_Prep_Stack* and change the Directory to:

/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Flood_Mapping

E	Create Stack	7 E 20
1-ProductSet-Reader 2-Cre	ateStack 3-Write	
Target Product		
Name: Subset_SIA_IW_GRDH_20191	006_20191012_Prep_Stack	
Save as: BEAM-DIMAP	*	
Directory:		
yana su/naming/us∠ou	waterminger yphoon integrals in anningster i deesamyn ood i rieppin	9
	🕖 Help 🕞 Run	

Then click Run. Approximate processing time: 45 seconds

In the next step we will reassign the NoData value to NaN ("Not a Number") to facilitate better visualization later. Go to **Raster** \rightarrow **Data Conversion** \rightarrow **Set No-Data Value**.

In the **I/O Parameters** tab, make sure that product [5] is selected and directory is set to *.../Flood_Mapping* and add *"_nD"* to the output name. In the **Processing Parameters** tab, set:

No	Data	Value:	NaN
----	------	--------	-----

G	Set No-Data Value	+ = x 🧿	Set No-Data Value	* = *
File Help		File Help		
I/O Paramet	Processing Parameters	1/O Par	ameters Processing Parameters	
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[5] Subset	S1A_IW_GRDH_20191006_20191012_Pre	ep_Stack	r Value:	NaN
Target Prod	uct			
Subset_S14	W_GRDH_20191006_20191012_Prep_5	Stack_nD		
Save as	BEAM-DIMAP			
hingAT	y- /phoon_Hagibis_TrainingKit/Processing/S	Flood_Mapping		
Ø Open in	SNAP			
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		Tau Zioze		<u>Run</u> <u>C</u> lose

Click Run.

In the last step we will mask out the open ocean to make to the comparison clearer. To do this we will use a shapefile of Japan land mass. In the **Product Explorer** go to the stack product with No Data [6] and click on it to highlight it, then from *Bands* open *Sigma0_VH_db_slv1_12Oct2019* (double click). Then go to **Vector** \rightarrow **Import ESRI Shapefile**.

Navigate to */shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/AuxData/Shapefile* and select *JPN_adm0.shp*, click **Open**. The shapefile will be overlaid on top of the view. It will also appear in the *Vector Data* folder in the product.



Then to apply the mask we will go to **Raster** \rightarrow **Masks** \rightarrow **Land/Sea Mask**.

In the **I/O Parameters** tab, make sure that product [6] is selected and directory is set to *.../Flood_Mapping*. In the Processing Parameters tab, set *"Use Vector Mask"* the loaded vector *JPN_adm0* should be selected automatically.

Land/Sea Mask	+ = ×	C	Land/Sea Mask	(* E X
File Help		File Help	Description Descriptions	
VO Parameters Processing Parameters Source Product source: [6] Subset_SIA_W_GRDH_20191006_201910	012_Prep_Stack 💌	Source Bands:	Sigma0_VH_db_mst_0 Sigma0_VV_db_mst_0 Sigma0_VV_db_skv1_1 Sigma0_VV_db_skv1_2	60ct2019 60ct2019 20ct2019 20ct2019 20ct2019
Target Product Name: Subset_SIA_IW_GRDH_20191006_20191012	Prep_Stack_nD_msk	O March out the		
Save as: BEAM-DIMAP	ssing/Flood_Mapping	Mask out the Use SRTM 3 Use Vector	e Sea Isec	
K open in ande		Extend shoreling	JPN_adm0 I_Invert Vector e by (pixels); 0	
	<u>R</u> un <u>C</u> lose			<u>R</u> un <u>C</u> lose

Then click Run.

When the new product appears in the **Product Explorer**, go to the masked product [7] and in the **Vector Data** folder right-click on JPN_adm0 and delete it.

Now, we can visualize multitemporal RGB composites to better identify the flooded area. First close all views if any are opened.

Now, in the **Product Explorer** right-click on the stack product [7] and go to **Open RGB Image Window**. (See NOTE 9).

Set: Red: \$7.Sigma0_VH_db_mst_06Oct2019 Green: \$7.Sigma0_VH_db_slv1_12Oct2019 Blue: \$7.Sigma0_VV_db_mst_06Oct2019



NOTE 9: In this band combination the areas that appear purple represent pixels that were darker during the flood event than before → new open water surfaces. Brighter green areas represent pixels that are brighter during the event compared to pre event image → Wet soil and semi submerged vegetation. Blue and white areas represent build up.



To separate new open water areas, we can use multiple methods. We can use classification, single band thresholding or difference-band thresholding among others. As is visible on the image above, flooded areas with open water will have significantly lower backscatter in VH than they had before the event (not flooded). Therefore, by subtracting the VH band of 12 October (during the event) from the VH band of 6 October (before the event) we should be able to isolate them.

In the **Product Explorer**, right-click on the masked product [7] and go to **Band Maths** ... In the menu that appears set:

Name: Diff_06Oct_12Oct_VH Deselect Virtual (save expression only don't save data) Click on Edit Expression... and set as Expression:

Sigma0_VH_db_mst_060ct2019 - Sigma0_VH_db_slv1_120ct2019

Band Maths + 🗆 🛪	Band	Maths Expression E	dito	r + = X
Target product:	Product: [7] Subset SIA IN GRDH 20	191006_20191012_Pre	p Sta	ck_nD_msk
[7] Subset_S1A_IW_GRDH_20191006_20 Name: Diff_06Oct_12_Oct_VH	Data sources: \$7.Sigma0_VH_db_mst_060ct2019 \$7.Sigma0_VV_db_mst_060ct2019	@ + @	-	Expression: \$7.Sigma0_VH_db_mst_060ct2019 - \$7.Sigma0_VH_db_slv1_120ct2019
Unit:	\$7.Sigma0_VH_db_slv1_120ct2019 \$7.Sigma0_VH_db_slv2_120ct2019 \$7.Sigma0_VV_db_slv2_120ct2019	@ - @ @ * @		
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Generate associated uncertainty bend Band maths expression:		Constants Operators	•	
\$7. Sigma0_VH_db_mst_06Oct2019 - \$7. Sigma(Load Edit Express	Show bands Show masks Show tie-point grids Show single flags	Functions		The second secon
QK <u>Cancel</u> <u>Help</u>	Thereau endre mege			<u>O</u> K <u>Cancel</u> <u>H</u> elp

Click **OK**. The new band will be immediately opened in view. Repeat the step for VV.

Name: Diff_06Oct_12Oct_VV Deselect Virtual (save expression only don't save data) Click on Edit Expression... and set as Expression:

Sigma0_VV_db_mst_060ct2019 - Sigma0_VV_db_slv2_120ct2019

Once the band is opened go to **Window** \rightarrow **Tile Horizontally**.



Click into the VH View and go to **Colour Manipulation** tab, right click on the middle slider and remove it (click on Delete). Then move the white slider to *6.0*. at the bottom of the tab go to **More Options** and select **Discrete colours**.

For VV do not delete the middle slider but set it to **-5.0** set the white threshold to **5.0**. We can also change the colour of the sliders by clicking on them (In this example we have changed the black slider to red and the grey to black).



The red areas in VV then correspond to areas where is potentially submerged vegetation as VV generally penetrates deeper in canopy than VH and newly submerged vegetation can appear brighter. However, the brighter values can also be caused by wet bare soil (higher backscatter due to higher dielectric constant).

We can apply the same thresholds using **Band Math** ... to create binary bands with conditional expressions.

VH:	if Diff_06Oct_12Oct_VH > 6.0 then 1 else 0
VV:	<pre>if Diff_06Oct_12Oct_VV > 5.0 then 1 else (if Diff_06Oct_12Oct_VV > - 5.0 then 0 else -1)</pre>

6.3 Damage detection – Sentinel-1 SLC

In the second part of this exercise we will calculate difference in coherence for a pair prior to the event and a pair during the event. Then we can identify the areas with significant coherence loss presumed expected to correspond to damaged areas due to surface damage.

Re-start SNAP (Mathematical SNAP window opens click Open product , navigate to /shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Original/SLC and open the three *.zip files.

The opened products will appear in the **Product Explorer** on the left. Expand the first image to the left and select Bands. Right click on the "*Intensity_IW1_VH*" and select **Open Image Window** to create and visualize the image for the selected band. (See \square NOTE 10).



The image appears in the upper left corner of the **View** window. Do the same for the next products. To synchronize the views, go to **Navigation** pane in the lower left (red arrow) and make sure the cursor and the views **P** are linked.

NOTE 10: The Interferometric Wide (IW) swath mode captures three sub-swaths using Terrain Observation with Progressive Scans SAR (TOPSAR). Each sub-swath image consists of a series of bursts. The input product contains 3 IW bands, and 9 bursts.



Credits: ESA User Guides for Sentinel-1 SAR

6.3.1 Coherence Estimation

Although in this step we cannot use batch processing we can use the graph builder to simplify the process instead of running each step manually. Therefore, the processing chain we will follow will be represented by a graph and saved as an XML file.

In order to open **Graph Builder** tool, go to **Tools** \rightarrow **GraphBuilder**.

Initially, the graph has two operators: **Read** (to read the input) and **Write** (to write the output). First, **DELETE** the **Write** operator (right-click on it and select *Delete*).

With right-click on the top panel, you can add an operator, while a corresponding tab with all involving parameters is created and added on the bottom panel.

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Our aim is to produce two coherence images that correspond accordingly to the period prior and during the event. For each we have to create a graph and process the image pair. Let's start with the first coherence image, for the pre-event period, by using the images of 24 September and 6 October 2019.

In the **Read** operator, select the input image:

S1A_IW_SLC__1SDV_20190924T204233_20190924T204300_029168_034FDF_708B

To add a new **Read** operator for the second image, go to $Add \rightarrow Input-Output \rightarrow Read$. It will be denoted as **Read(2).** Then, select as input image:

S1A_IW_SLC__1SDV_**20191006**T204233_20191006T204300_029343_0355EA_**AFB2**

Since the area of interest is included only in six bursts of the Sentinel-1 image, there is no need to process the entire sub-swath with all 9 bursts (See \square NOTE 11). The TOPSAR Split operator provides a convenient way to split each sub-swath with selected bursts into a separate product. To add the S-1 TOPSAR Split operator click Radar \rightarrow Sentinel-1 TOPS \rightarrow S-1 TOPS Split.

NOTE 11: The extraction of bursts in a sub-swath covering the area of interest may differ in Sentinel-1 images acquired on different dates.

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

Repeat the same for the **Read(2)** operator to have graph as shown below.

Read TOPSAR-Split		
Read(2) TOPSAR-Split(2)		

In the **TOPSAR Split** tab, select the following parameters.

Subswath: IW1 Polarisations: VV Bursts: 3 to 8

In bursts selection click on the arrows and drag up to the specified number of bursts.

Read Re	ad(2) TOPSAR-Split TOPSAR-Split(2)	
Subswath:	IW1	
Polarisations	VH	
	W	
Bursts:	3 to 8 (max number of bursts 3)	
		Q

Repeat the same step for the **TOPSAR Split(2)**.

Read TOPSAR-Split		
Read(2) TOPSAR-Split(2)		

We now continue by applying the orbit files in Sentinel-1 products in order to provide accurate satellite position and velocity information. To add the operator, right-click to the right of the **TOPSAR-Split** operator and go to Add \rightarrow Radar \rightarrow Apply-Orbit-File, then connect the new operator to the **TOPSAR-Split**. Split. Now do the same to add the Apply-Orbit-File(2).

Read TOPSAR-Split Apply-Orbit-File	
Read(2) TOPSAR-Split(2) Apply-Orbit-File(2)	

In the **Apply-Orbit File** tab, select the parameters:

Orbit State Vectors: Sentinel Precise (Auto Download) Check **"Do not fail if new orbit file is not found**"

Read	Read(2)	TOPSAR-Split	TOPSAR-Split(2)	Apply-Orbit-File	Apply-Orbit-File(2)	
Orbit St	ate Vectors:	Sentinel Precise	e (Auto Download)			-
Polynomial Degree: 3						
		Do not fail if	new orbit file is no	t found		

Now set the same parameters for the **Apply-Orbit-File(2)** operator.

Next step will be to co-register the two Sentinel-1 images. For this reason, the second image (slave) will be co-registered with respect to the first image (master). Sentinel-1 **Back Geocoding** operator co-registers two S-1 split products (master and slave) of the same sub-swath using the orbits of the two products and a Digital Elevation Model (DEM). Right-click somewhere between the **Apply-Orbit-File** operators and go to Add \rightarrow Radar \rightarrow Coregistration \rightarrow S-1 TOPS Coregistration \rightarrow Back-Geocoding. Connect the Back-Geocoding operator with BOTH the Apply-Orbit-File operators.

Read TOPSAR-Split Apply-Orbit-File	
Back-Geocoding	
Read(2) TOPSAR-Split(2) Apply-Orbit-File(2)	

In the **Back-Geocoding** tab, set *SRTM 1Sec HGT* as **Digital Elevation Model** to use and check **Output Deramp and Demod Phase**.

Read Read(2) TOPSAR-Spli	t. TOPSAR-Split(2)	Apply-Orbit-File	Apply-Orbit-File(2)	Back-Geocoding		
Digital Elevation Model:	SRTM 1Sec HGT	(Auto Download)			-	
DEM Resampling Method:	BICUBIC_INTERP	DLATION			-	
Resampling Type:	BISINC_S_POINT	BISINC_5_PDINT_INTERPOLATION				
Mask out areas with no elevat	tion					
Output Deramp and Demod P	hase					

In this step, the coherence image is estimated from the stack of the coregistered complex images. To add the **Coherence** operator go to Add \rightarrow Radar \rightarrow Interferometric \rightarrow Products \rightarrow Coherence and then connect the **Coherence** operator to **Back-Geocoding** operator.



In the **Coherence** tab set the following parameters:

Check Substract flat-earth phase

Coherence Range Window Size: 20

Coherence Azimuth Window Size: 6 (changes automatically)

Subtract flat-earth phase		
Degree of "Flat Earth" polynomial	5	
Number of "Flat Earth" estimation po	nts 501	
Orbit interpolation degree	3	-
Subtract topographic phase		
Digital Elevation Model	I management and the second se	1
Tile Extension [%]		1
Square Pixel	Independent Window Sizes	
Coherence Range Window Size	20	
Coherence Azimuth Window Size	6	

We continue the processing steps with **Sentinel-1 TOPSAR Deburst**. We have seen that each sub-swath image consists of a series of bursts, where each burst has been processed as a separate SLC image. The individually focused complex burst images are included, in azimuth-time order, into a single sub-swath image with black-fill demarcation in between. There is sufficient overlap between adjacent bursts and between sub-swaths to ensure the continuous coverage of the ground. 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. To add **TOPSAR-Deburst** operator, go to Add \rightarrow Radar \rightarrow Sentinel-1 TOPS \rightarrow **TOPSAR-Deburst**.

Read TOPSAR-Split Apply-Orbit-File Back-Geocoding Coherence TOPSAR-Deburst	
Read(2) TOPSAR-Split(2) Apply-Orbit-File(2)	

In the **TOPSAR-Deburst** tab, select **Polarizations**: *VV*. Then, connect the **TOPSAR-Deburst** operator with the **Coherence** operator.

TOPSAR-Split TOPSAR-Split(2) Apply-Orbit-File Apply-Orbit-File(2) Back-Geocoding Coherence TOPSAR-Deburst Polarisations: W

Finally, add the Write operator again by going to Add \rightarrow Input-Output \rightarrow Write. Then connect the TOPSAR-Deburst operator with the Write operator and in the Write tab define the output directory as: /shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Damage_Detection



Set the name of the output product as: S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb

At this moment, save the graph as *Graph_Coherence_20190924_20191006.xml* in *.../Processing/Damage_Detection* folder by clicking **Save** at the bottom of the window.

Then click **Run.** The new product will appear in the **Product Explorer** when the process finishes. *Approximate processing time: 45 seconds*

Once the process is finished, a new product will appear in your **Product Explorer** tab. Now we will generate the the coherence image also for the co-seismic period (period including the seismic event). Go back to our graph and in the **Read** and **Read(2)** tabs select the following Sentinel-1 scenes as input images:

 Read
 S1A_IW_SLC__1SDV_20191006T204233_20191006T204300_029343_0355EA_AFB2

 Read(2)
 S1A_IW_SLC__1SDV_20191018T204233_20191018T204300_029518_035BEF_380F

Then, in the **Write** tab set the name of the output product as: *S1A_IW_SLC_20191006_20191012_Orb_Stack_Coh_Deb*

Save in the same folder (.../*Processing/Damage_Detection/).* Once the second coherence product is generated, close the **Graph Builder** window. Then close all opened **Views**.

6.3.2 Multilooking

Go to **Product Explorer** and expand the first pre-processed product **S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb**. Then go to *Bands* and open the coherence band by double clicking it. As the original SAR image contains inherent speckle noise, multilook processing is applied at this moment to reduce the speckle appearance and to improve the image interpretability (See \square NOTE 12). Go to **Radar** \rightarrow **Multilook** to open the multilook operator.

NOTE 12: The multilooking factors are selected in a way to both obtain square pixels and to maintain as much as possible the spatial resolution.

In the I/O Parameters tab, set the following parameters:

Input: S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb Output: S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb_ML Directory: /shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Damage_Detection

In the **Processing Parameters** tab, set the following parameters:

Number of Range Looks: 3 Number of Azimuth Looks: 1

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File Help		File Help		
I/O Parameters Processing Parameters		//O Parameters Pro	cessing Parameters	
Source Product source:		Source Bands:	coh_IW1_VV_06Oct2019_18Oct2019	9
[4] S1A_IW_SLC_20190924_20191006_Orb_St	ack_Coh_Deb 🔻			
Target Product Name:				
SIA IW SLC 20190924 20191006 Orb Stack	_Coh_Deb_ML	CD CD Course Divel		
Save as: BEAM-DIMAP		Number of Range Looks	s' 3	
Directory:	Damage Detection	Number of Azimuth Loo	ks: 1	
	groundge betechen tan	Mean GR Square Pixel:	13.251137	
Den in Sivar		Output Intensity		
			Note: Detection for complex data is done without resampling.	
L	<u>Bun</u> <u>Close</u>		Bun	Close

Then click **Run**. A new product appeared in the **Product Explorer**, go to *Bands* and open the multilooked coherence band, then go to **Window** \rightarrow **Tile Vertically**.



Repeat the same step for the second pre-processed product: S1A_IW_SLC_20191006_20191012_Orb_Stack_Coh_Deb

6.3.3 Geocoding

Due to topographical variations of a scene and the oblique viewing angle of the satellite sensor, features appear distorted in SAR images. Terrain corrections are intended to compensate for these distortions, so that the geometric representation of the image will be as close as possible to the real world, based on selected map geometry. For geocoding the Sentinel-1 products we will use the **Range Doppler Terrain Correction** operator that implements the Range Doppler orthorectification method [1].

We will apply Range Doppler Terrain Correction operator to the multilooked products.

Go to **Radar** \rightarrow **Geometric** \rightarrow **Terrain Correction** \rightarrow **Range-Doppler Terrain Correction** to open the operator.

In the I/O Parameters tab, set the following parameters:

Input: *S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb_ML* (first multilooked product) Output: *S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb_ML_TC* Directory: /shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Damage_Damage

In the **Processing Parameters** tab, set the following parameters:

Pixel Spacing (m): 15 Map Projection: WGS84(DD)

C	Range Doppler Terrain Correction	* = ×	Ran	ge Doppier Terrain Correction	TEX
File Help			File Help		
1/O Parameters P	Processing Parameters		VO Parameters Processin	g Parameters	
Source Product			Source Bands:	coh IW1 VV 24Sep2019_06Oct2019	
source:					
[6] S1A_IW_SLC_201	190924_20191006_Orb_Stack_Coh_Deb_ML	×			
Target Product					
Name:	and the second sec				
S1A IW_SLC_201909	924_20191006_Orb_Stack_Coh_Deb_ML_TC		Digital Elevation Model:	PRTH TO A LOT IN A Double of	
Save as: BEAM-	DIMAP		DEM Resampling Method	SRIM ISEC HGT (Auto Download)	
Directory:	Watching AT inchases Manihin Tesining/it/Descarsi	na/Damage Detection	image Resampling Method	BILINEAR_INTERPOLATION	
	watchingkryphoon_hagions_frainingkovProcessi	ng/banage_betection	Source GR Pixel Sparings (az	s rai: 13.96(m) x 12.54(m)	
IN Ober in Sinth			Pixel Spacing (m):	15	
			Pixel Spacing (deg):	1.3474729261792824E-4	1
			Map Projection:	UTM Zone 54 / World Geodetic Syst	em 1984
			Mask out areas without el	evation Output complex data	
			Output bands for:	DEM Distitude & Long	itude
			Incidence angle from	soid Local incidence angle Projected local i	incidence angle
			Seal and sealer and		
			Apply radiometry amain	zation	1
			Disave site mail hand		
			Severated hand		
			Auxilia de lASAF only!		
		Bun <u>C</u> lose			Run <u>C</u> lose
	Man Projection				
	Map Projection				
Coordinate Refer	ence System (CRS)				
Custom CRS					
Geodetic dat	um:				
Projection	UTM / WGS 84 (Automatic)				
. representativ		Parastian Department			
	P	rojection Parameters.			
O Predefined CF	RS	Select .			
		K Cancel Hele			
	1	Zaucei Heib			

Now, click **Run**. Repeat the process for the second multilooked product: *S1A_IW_SLC_20191006_20191012_Orb_Stack_Coh_Deb_ML*

6.3.4 Create Stack

The **Create Stack** operator allows collocating two spatially overlying SAR products, where the pixel values of one product are resampled into the geographical raster of the other.

First, in the **Product Explorer** select product [1] to [7], right click and select **Close 7 products**. Now you should have only the two multilooked products open.

To apply **Create Stack** operator go to **Radar** \rightarrow **Coregistration** \rightarrow **Stack Tools** \rightarrow **Create Stack**.

In the **ProductSet-Reader** tab, click **Add Opened** on the upper right to add the following opened products and then click refresh:

S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb_ML_TC S1A_IW_SLC_20190924_20191006_Orb_Stack_Coh_Deb_ML_TC

1-ProductSet-Reader 2-CreateStack		3-Write				
	-		1	e la	-	
File Name	Type	Acquisition	Track	Orbit	- 4	
STA_IW_SEC_20190924_2	SLC	24Sep2019	46	29168	-	
STA_IW_SCL_20191006_2	ISLC	060002019	40	29343		
					52	
					-	
					-	
					-	
					*	
					*	
					*	
					*	
					* * *	
					*	
					*	
					*	
					* * * * * * * * * * * * * * * * * * * *	

We proceed with **CreateStack** tab by defining the following parameters:

Resampling Type: *NEAREST_NEIGHBOUR* Initial Offset Method: Product Geolocation Click on Find Optimal Master.

e	Create Stack	↑ □ ×
1-ProductSet-Reader	2-CreateStack 3-Write	
Master:	SIA IW SLC 20190924 20191006 Orb Stack Coh Deb	MLTC
Resampling Type:	NEAREST_NEIGHBOUR	+
Initial Offset Method:	Product Geolocation	(÷
Output Extents:	Master	-
Find Optimal Master		

Finally, in the **Write** tab set the output parameters:

Name: Coherence_20190924_20191006_20191012_Stack

Directory:

/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Damage_Detection/

Ē	Create Stack
1-ProductSet-Reader 2-CreateStack	3-Write
Target Product	
Name: Coherence_20190924_20191006_20191	.012_Stack
Save as: BEAM-DIMAP	
Directory:	
//shared/iraining/HA2A06_Watching/	Alyphoon_Hagibis_TrainingKit/Processing/Damage_Detection
	W Help D Run

In the **Product Explorer** pane expand the new stack product and open both coherence bands in the **View** window. Then go to **Window** \rightarrow **Tile Horizontally** to compare them visually. As you may see in the histogram in the **Colour Manipulation** tab, areas with low coherence are shown in black color, while areas of high coherence are shown in white.



Click on the view [10]coh_IW1_VV_24Sep2019_06Oct2019, then go to **Colour Manipulation** tab and click on **(1)** and select:

coh_IW1_VV_24Sep2019_06Oct2019_slv1_06Oct2019

Then click **OK**. In the next dialog click **No.**



At a first sight, the coherence levels of the two images are quite different, denoting changes that might be attributed to the damage caused by the storm and flooding. To estimate the difference in the

coherence levels between the two coherence images, we will use the SAR interferometric coherence difference (ICD) (See 13).

NOTE 13: When a pair of SAR images is available, further parameters (InSAR complex coherence and intensity correlation) can be computed. Both parameters can be derived combining the pre-seismic, the post-seismic and the co-seismic (i.e. one pre-seismic and one post-seismic image) pairs. The complex coherence of two images is defined as follows: $E(s_1s_2^*)$

$$\rho = \frac{E(s_1 s_2)}{\sqrt{E(s_1 s_1^*)E(s_2 s_2^*)}}$$

where s1 and s2 are the corresponding complex pixel values, and E() indicates the expected value. The SAR interferometric coherence difference (ICD) is given by:

 $ICD = \rho(pre) - \rho(post)$

Close all opened views. Right-click the *Coherence_20190924_20191006_20191012_Stack* product in the **Product Explorer** and go to **Band Maths...** Set the parameters:

Name: ICD

Untick option "Virtual (save expression only, don't store data)"

Then click on **Edit Expression...** and set:

Expression: coh_IW1_VV_24Sep2019_06Oct2019 - coh_IW1_VV_24Sep2019_06Oct2019_slv1_06Oct2019

Band Maths	Band Maths Expres	sion Editor		• = ×
Target product;	Product: [10] Coherence_20190924_20191006_20191012_Sta	ick.		-
[10] Coherence_20190924_20191006_2019101 💌	Data sources:			Expression:
Name: ICD	\$10.coh_IW1_VV_24Sep2019_060ct2019	0 + 0		\$10.coh_IW1_VV_24Sep2019
Description:	\$10.coh_IW1_VV_060ct2019_180ct2019_slv1_060ct2019	0 - 0		\$10.coh IW1 VV 060ct2019
Unit:		0 * 0	_	_180ct2019_slv1_060ct201
Spectral wavelength: 0.0		0/0	-	9
Virtual (save expression only, don't store data)		(@)	_	
Replace NaN and infinity results by NaN		Constants	-	
Generate associated uncertainty band		Constants	-	
Band maths expression:		operators		4
\$10.coh_IW1_VV_24Sep2019_06Oct2019 - \$10.coh_IW	Show bands	Functions	-	
	Show masks			
Load. Save Edit Expression	Show be-point grids			mm (141)
	Show single flags			
QK Cancel Help			E	OK Cancel Help

The new band will automatically open in view window. Go to **Window** \rightarrow **Tile Single**.

With the **Colour Manipulation** tool, you can modify the colour visualization of the image to show in red the coherence differences possibly attributed to the earthquake induced damages. You can drag the sliders to new position and click to change their colour. For convenience, a colour palette has been created for you.

Click on the **Import Colour Palette** icon, navigate to following path and select the file **S1_ICD_colour_palette.cpd**. Click **No** – we do not want to distribute points of colour palette between min/max – we want to keep the predefined points.

/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/AuxData/



6.3.5 Export as GeoTIFF

In **Product Explorer** select the product [10] and go to **File** \rightarrow **Export** \rightarrow **GeoTIFF** (NOT! GeoTIFF/Big TIFF). In the dialog that opens click **Subset** \rightarrow **Band Subset** and select the band *IDC*. Then click **OK** and save the file as *SLC_Damage_Detection.tif* to:

/shared/Training/HAZA06_WatchingATyphoon_Hagibis_TrainingKit/Processing/Damage_Detection

	SNAP - Export Product	- 5 X		Specify Product Subset	+ = ×
Save In:	Damage_Detection	• 600 885	Spatial Subset Bar	nd Subset Metadata Subset	
Coherend SIA_W_S SIA_W_S SIA_W_S SIA_W_S SIA_W_S SIA_W_S SIA_W_S SIA_W_S SIA_W_S SIA_W_S	re_20190924_20191006_20191012_Stack.data SCL_20191006_20191018_Orb_Stack_Coh_Deb_data SCL_20191006_20191018_Orb_Stack_Coh_Deb_ML_d SCL_20191006_20191018_Orb_Stack_Coh_Deb_ML_T SLC_20190924_20191006_Orb_Stack_Coh_Deb_data SLC_20190924_20191006_Orb_Stack_Coh_Deb_ML_d SLC_20190924_20191006_Orb_Stack_Coh_Deb_ML_T mage_Detection_tif	<u>Subset</u> File size: 719 M ata Codata ata Codata	ich_W3_VV_245ep2 ceh_W1_VV_060ct2 ⊮icb	019_060d2019 019_180d2019_sk/1_060d2019	
File <u>N</u> ame: Files of <u>T</u> ype	SLC_Damage_Detection.tif GeoTIFF product (#.tif,#.tiff) Export Pro	duct Cancel	Select <u>a</u> ll Select	ect <u>pone</u> Ei	stimated, raw storage size: 59.7M

Finally, click **Export Product** to proceed.

TIP: In some cases the export to GeoTIFF does not work. This is a bug of the current version of SNAP and can be bypassed (if exporting single band) by right-clicking the image in view and selecting Export View as Image, then select **Full scene**, **Full resolution** and **GeoTIFF – TIFF with geolocation**.

Now we can import the image to another GIS/Remote sensing software for further processing or map creation.

7 Extra steps

7.1 Downloading the outputs from VM

Press **Ctrl+Alt+Shift.** 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 your Processing folder and **double click any file you want to download**.



8 Further reading and resources

SENTINEL-1 SAR User Guide Introduction – link

ESA Sentinel Online - link

Science Toolbox Exploitation Platform (STEP) – link

9 References

1. Small D. and Schubert A., Guide to ASAR Geocoding, RSL-ASAR-GC-AD, Issue 1.0, March 2008.

2. Stramondo, S., Bignami, C., Chini, M., Pierdicca, N. and Tertulliani, A.(2006), 'Satellite radar and optical remote sensing for earthquake damage detection: results from different case studies', International Journal of Remote Sensing, 27:20,4433 —4447.

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