### UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



# EXERCISE 10 - TUTORIAL

Flood Monitoring with Sentinel-1 & Sentinel-2 using the SNAP software





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## 1 | Exercise outline

In this first exercise for mapping floods, we will:

- Detect floods on Sentinel-1 images
- Develop a graph for automated processing using Batch processing
- Create binary mask for flood mapping





### 2 | Background

Floods, a commonly occurring natural disaster, result in significant damage to both lives and property. Timely information critical on floods is for emergency response. Rapid estimation of flood extent is essential for disaster risk assessment and spatial planning. Remote sensing and satellite imagery play pivotal roles in flood monitoring and mapping. Optical remote sensina, for instance, is utilized for dynamic flood monitoring by exploiting water's low reflectance in infrared bands and high reflectance in blue/green bands.



However, during severe weather conditions with heavy rainfall and intense cloud cover, optical remote sensing may struggle to provide accurate information due to a lack of cloud-free, high-quality images and difficulty in detecting water under vegetation cover.

Since October 4, 2023, the Myanmar Department of Meteorology and Hydrology (DMH) has been issuing flood advisory warnings and weather system alerts regarding water levels in major rivers. Between October 5 and 9, heavy rainfall during the late monsoon season resulted in extensive flooding in southern Myanmar. On October 9, the DMH reported that Bago township received an unprecedented 7.87 inches (200 millimeters) of rainfall, the highest recorded in 59 years. By October 10, the water level of the Bago River rose 4 feet above the danger level, leading to widespread flooding in urban and suburban areas. The impact of this flooding has been significant, affecting families, croplands, and causing displacement of people in areas including Bago City, Yangon, Taik Kyi, Hlegu, and Hmawbi townships. (DREF OPERATION Myanmar Flood 2023)

Synthetic Aperture Radar (SAR) datasets offer significant benefits in flood observation as they emit electromagnetic waves that are unaffected by weather and time of day. The Sentinel-1 satellite, which provides extensive global data coverage, can effectively detect flooding in vegetated or urban areas due to its high penetration capability.







#### 2.1 Study area and data used

For this exercise, we will use two Sentinel-1 GRD images of the same area near Bago city, Myanmar, downloaded from the Dataspace Copernicus Open Access Hub [@https://dataspace.copernicus.eu/].



#### 2.2. SNAP - Open and explore product

Open SNAP Desktop, click Open Product and open 2 downloaded products by double click on them. The opened products will appear in Product Explorer window. Go to Windows – Tile them e.g. Horizontally.

S1A\_IW\_GRDH\_1SDV\_20230926T232505\_20230926T232530\_050505\_061540\_C745.SAFE.zip S1A\_IW\_GRDH\_1SDV\_20231008T232505\_20231008T232530\_050680\_061B43\_DCF8.SAFE.zip







#### 3.1 Pre-processing

We need to apply identical pre-processing steps to both of our scenes:

#### Apply orbit file

Navigate to Main Menu – Radar – Apply orbit file

In the I/O Parameters tab, select the first product and name the target product. There is no need to save the output as BEAM-DIMAP (we will save the time this way)

In the Processing Parameters accept the default settings and select the option "Do not fail if new orbit file not found"

Repeat for the second image.

💿 Apply Orbit File	×	C Apply Orbit File X
File Help		File Help
I/O Parameters Processing Parameters Source Product Source: [1] SIA_IW_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540_C745 ✓ Target Product Name: SIA_IW_GRDH_1SDV_20230926T232505_20230926T232530_050505_061540_C745_Orb Save as: [BEAM-DIMAP Directory: [2: \Pracovnici\onacliova\ESA_ENEUM\exercise_8 ] Open in SNAP		I/O Parameters Processing Parameters Orbit State Vectors: Sentinel Precise (Auto Download) ✓ Polynomial Degree: 3 ☑ Do not fail if new orbit file is not found
Run Clo	se	Run Close

#### Create subset

There is no need to process the whole image, instead, we can begin by narrowing down the scene to a more manageable size - creating subset. This approach will decrease processing time in subsequent stages, especially when the analysis is concentrated on a specific area rather than the entire scene.

	📸 Specify Product Subs	et		
Select the last product with applied	Spatial Subset Band Subs	set Tie-P	Point Grid Subset Meta	data Subset
orbit file.		^		
Go to the Subset tab and at "Pixel	and the second		Pixel Coordinates (	Geo Coordinates
Coordinates" set:	11		Scene start X:	9000 🖨
Scene start X: 9000	A CALL AND A		Scene start Y:	4000 🜩
			Scene end X: Scene end Y:	16700 +
Scene start Y: 4000				
Scene end X: 23000			Scene step X: Scene step Y:	
Scene end Y: 16700			Subset scene width:	14001.0
			Source scene width:	25570
Repeat for the second image.			Use Preview	Fix full width
		¥		Estimated, raw storage size: 678.







OK Cancel Help

#### Thermal noise removal

Navigate to Main Menu – Radar – Radiometric – S-1 Thermal Noise Removal In the I/O Parameters tab, select the last subset product with applied orbit file and name the target product. There is no need to save the output as BEAM-DIMAP (we will save the time this way)

In the Processing Parameters you can select both polarization and make sure that the "Remove Thermal Noise" option is selected.

Repeat for the second subset image.

😨 S-1 Thermal Noise Removal X	C S-1 Thermal Noise Removal	×
File Help	File Help	
I/O Parameters Processing Parameters Source product Source product: [5] subset_0_of_S1A_IW_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540  Target Product Name: subset_0_of_S1A_IW_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540_C745_Orb_thr Save as: BEAM-DIMAP Directory: [2:VPracovnici/pnacliova/ESA_ENELIM/exercise_8 ] Open in SNAP	I/O Parameters         Polarisations:       WH         W       W         Remove Thermal Noise       Output Noise         Re-Introduce Thermal Noise       V	

#### Calibration

With our image now subsetted and with TNR, we must apply image calibration. This step is necessary to normalize the values in the image into backscatter values so we can compare multiple images in a time series.

Navigate to Main Menu - Radar - Radiometric - Calibrate

In the I/O Parameters tab, select the product with thermal noise removal and name the target product. In the case of this final product of preprocessing, please, save it to your folder for this exercise

In the Processing Parameters select the VV band as input and accept all default settings and then click Run

Repeat for the second image. The saving might take some time.

Calibration X	Calibration X
File Help	File Help
I/O Parameters Processing Parameters Source Product source: [7] subset_0_of_S1A_IW_GRDH_1SDV_20230926T232505_202309 v	I/O Parameters Processing Parameters Polarisations: VH VV
Target Product Name: DV_20230926T232505_20230926T232530_050505_061540_C745_Orb_thr_Cal Save as: BEAM-DIMAP Directory: Z:\Pracovnici\onacillova\ESA_ENEUM\exercise_8 Q Open in SNAP	Save as complex output Output sigma0 band Output gamma0 band Output beta0 band
Run Close	Run Close





#### Speckle Filter

Despeckling removes thermal noise introduced by the sensor from the image to remove potential sources of error in analysis.

Navigate to Radar > Speckle Filtering Single Product Speckle Filter. In the Speckle-Filter tab, choose the simple Lee Sigma filter with default window sizes.

C Single Product Speckle Filter	×	Single Product S	Speckle Filter
File Help		File Help	
I/O Parameters Processing Parameters		I/O Parameters Pro	cessing Parameters
Source Product source: [9] subset_0_of_SIA_JW_GRDH_1SDV_202309267232505_202309267232530_050505_061540_C745 v		Source Bands:	Sigma0_VV
Target Product Name: subset_0_of_S1A_IV_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540_C745_0rb_thr_Cal_Sp	k		
Save as: BEAM-DIMAP		Filter: Number of Looks:	Lee Sigma v 1 v
Z: Pracovnici/pnacilova/ESA_ENEUM/exercise_8 .		Sigma:	7x7 ~
O ober in 2004.		Target Window Size:	3x3 v
Run Clos	ie		Run Close

#### Terrain-Correction

Navigate to Radar – Geometric – Terrain Correction – Range Dopler Terrain Correction. The last step in our graph for image pre-processing is to apply terrain correction to the product, ensuring that all the pixels are moved to the right locations (eg if the nadir angle of the image is off, it will align the pixels correctly so it is closer to a top-down view of the imagery).

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. We need to apply Terrain Correction to compensate for the distortions and reproject the scene to geographic projection.

Navigate to Main Menu: Radar - Geometric - Terrain Correction - Range-Doppler Terrain Correction

In the I/O Parameters tab set as "Source Product" the velocity product.

In "Target Product", keep the default name and set the Directory

In the Processing Parameters tab set:

Digital Elevation Model: ACE30 (Auto Download)

Map Projection: Click on the tab next to Map projection (WGS84(DD) – select Predefined CRS and dick on "Select". In "Filter" search for 32621 (EPSG: 32646 – WGS84 / UTM Zone 46N) and when you find it dick OK to both windows.

Keep defaults values for the other parameters. Click Run. Approximate processing time: 2.5 minutes.







C Range Doppler Terrain Correction X	C Range Doppler Terrain Correction
File Help	File Help
I/O Parameters Processing Parameters	I/O Parameters Processing Parameters
Source Product source: [11] subset_0_of_S1A_IW_GRDH_1SDV_20230926T232505_20230926T232530_050505_061540_C745_Orb_tn v	Source Bands: Sigma0_VV
Target Product Name: subset_0_of_S1A_JW_GRDH_ISDV_20230926T232505_20230926T232530_050505_061540_C745_0rb_tmr_Cal_Spk_TC	
Save as: BEAM-DIMAP	Digital Elevation Model: SRTM 3Sec (Auto Download) 🗸
Directory:	DEM Resampling Method: BILINEAR_INTERPOLATION V
Z:\Pracovnici\onadilova\ESA_ENEUM\exercise_8	Image Resampling Method: BILINEAR_INTERPOLATION V
Open in SNAP	Source GR Pixel Spacings (az x rg): 10.0(m) x 10.0(m)
	Pixel Spacing (in): 10.0
	Map Projection: NICC 94 / UTM zoon 46N
	Output bands for:
	Selected source band DEM Latitude & Longitude
	Incidence angle from ellipsoid Local incidence angle Projected local incidence angle
	Layover Shadow Mask
	Apply radiometric normalization
	Save Sigma0 band Use projected local incidence angle from DEM 🗸
	Save Gamma0 band Use projected local incidence angle from DEM
	Save Beta0 band
	Auxiliary File (ASAR only): Latest Auxiliary File
Run Close	Run Close
Map Projection ×	Select Coordinate Reference System
Coordinate Reference System (CRS)	Filter: 32646 Well-Known Text (WKT):
O Custom CRS	EPSG:32646 - WGS 84 / UTM zone 46N PROJCS["WGS 84 / UTM zone 46N", A GEOGCS["WGS 84",
Geodetic datum: World Geodetic System 1984	DATUM["World Geodetic System 1984",
Projection: Geographic Lat/Lop (W/CS 84)	SPHEROID["WGS 84", 6378137.0, 298.2572235
	PRIMEM["Greenwich", 0.0, AUTHORITY["EPSG", "E
Projection Parameters	UNIT["degree", 0.017453292519943295],
	AXIS["Geodetic longitude", EAST],
Preuenneu CKS EPSG:32646 - WGS 84 / UTM zone 46N     Select	AXISI Geodetic latitude", NORTHL
OK Cancel Help	OK Cancel

#### 3.2 Flood assessment

After execution, your resulting two preprocessed products should contain a single bands called Sigma0\_VV. Open all two (preprocessed) Sigma0\_VVs in the View and then go to Window -> Tile Horizontally

After ensuring that our products feature calibrated backscatter values, it's time to conduct flood assessments on the data to automatically ascertain the extent of flooding across the series of images. Areas with low backscatter indicate wet areas. Since our calibrated images contain calibrated backscatter coefficients, we can create a binary image from the products, highlighting areas below a cutoff threshold. Since the River traverses Bago city, it's crucial not to include recognized water sources in our flood mapping. To achieve this, we can incorporate the land cover band into our product in SNAP by right-clicking on the product in Product Explorer and selecting "Add Elevation Band."

[14] subset_1_of_S1A_IW_GRDH_1SDV_20231008T232505_20231008T232530_050680_061B43_DCF8_Orb_tnr_Cal_Spk_TC					
🗄 🧰 Metadata	Band Maths				
🕀 🧰 Vector Data	Add Elevation Band				
Sigma0 VV	Add Land Cover Band				







Additionally, we aim to include an elevation band to prevent misidentification of high-elevation regions as flooded. To add an elevation band, right-click on the product and choose "Add Elevation Band," then select "SRTM 1Sec HGT (Auto Download)."

🞇 Add Land Cover Band	×	🞆 Add Elevation Ba	ind X
Land Cover Model: AAFC Canada 2017 Crop AAFC Canada 2018 Crop AAFC Canada Clay Pct AAFC Canada Sand Pct CCILandCover-2015 GLC2000 GlobCover JaxaForestMap-2016 MODIS 2007 Tree Cover Percentage MODIS 2010 Tree Cover Percentage	<b>^</b>	Digital elevation model ACE2_5Min (Auto Down ACE30 (Auto Downloa ASTER 1sec GDEM CDEM (Auto Download Copernicus 30m Globa Copernicus 90m Globa GETASSE30 (Auto Dow SRTM 1Sec Grid	(DEM): vnload) d) d) d DEM (Auto Download) d DEM (Auto Download) vnload)
Resampling method:		SRTM ISEC HGT (Auto	Download)
NEAREST_NEIGHBOUR	$\sim$	SRTM 3Sec (Auto Dow	(nload)
Integer data types will use nearest neighbour Land cover band name:		Resampling method:	BILINEAR_INTERPOLATION ~
land_cover_CCILandCover-2015		Elevation band name:	elevation
OK Cance	el l		OK Cancel

Your product now should include land cover band and also elevation band



Now that we've added all the required bands, it's time to generate our new flooding band. Right-click on the product and choose "Band Maths." Enter the following expression into the text box:

#### Sigma0\_VV < 0.05 && land\_cover != 20 && elevation < 10

This will produce a binary mask indicating areas where the backscatter is below our threshold of 0.05, not categorized as water (Class 210) in land cover, and with an elevation below 10 meters above sea level.









Repeat the process for the second Sentinel product. Display the two masks to check they have been generated correctly. Our output flooding binary band should look like this (For September 26<sup>th</sup> – start of flodding and October 10<sup>th</sup> - peak of flooding):





#### 3.3 Export and open binary masks in QGIS

To export this product for viewing in other GIS software and to map the changes in flooding over time, you need to save our two binary mask (start of floods and peek of floods) in TIF format in the proper folder using File-> Export->GeoTiff/BigTiff tool.

To visualize the output of our multi-temporal flood analysis, we will open the masks saved in GeoTIFF format using QGIS:

In QGIS click on the Add Raster Layer button located in the left panel, navigate to the folder containing the binary masks in TIFF format, and click Open (or drag&drop).

#### Now we open the output image in QGIS

- We can overlay it to e.g. Google Satellite or Bing aerial image:
- Web->OpenLayers plugin->Google Maps->Google Satellite
- Move the Subset above the satellite
- Play with Transparency: Properties->Transparency (e.g. 80%)

As observed, the floodwaters gradually subside over time, yet areas near the riverbanks remain saturated, displaying low backscatter and thus continuing to appear flooded.



For more information, see the lectures: 10. SAR and optical remote sensing for mapping floods 11. SAR and optical remote sensing for post-flood assessment and recovery

### THANK YOU FOR FOLLOWING THE EXERCISE!





