UNIVERSITY COURSE APPLIED RADAR REMOTE SENSING



EXERCISE 7 – TUTORIAL

Wildfire Mapping with Sentinel-1 & Sentinel-2 using the SNAP software





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1 | Exercise outline

In this exercise, we will:

- Detect wildfires on Sentinel-1 and Sentinel-2 images
- Export subset as image to perform another analysis in QGIS
- Map burned areas and quantify burn severity using Normalised Burn Ratio index
- Develop a graph for automated processing using Batch processing
- Create Stack and RGB composites for two Sentinel-1 temporal datasets to observe wildfire burn scars





2 | Background

Fires in the grasslands close to a vital South American river delta present serious threats to both nearby wetland ecosystems and human well-being, caution environmental experts.



The wildfires around the important riverside port of Rosario, essential for transporting Argentina's extensive grain harvest, have raised concerns among local residents and activists.

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The Parana River, South America's second-longest river after the Amazon, experienced its lowest water levels since 1944 in 2021 as reported by official data. This decline is attributed to multiple cycles of drought and reduced rainfall in upstream Brazil. In August 2022, the water level remained exceptionally low. The wildfires, many intentionally set by farmers preparing the land for new crops, generated a thick haze that reached Buenos Aires, located approximately 190 miles (300 km) south of Rosario. Residents were displeased with the presence of soot in the air, leading popular weather apps to issue forecasts simply describing the conditions as "smoke."



Wildfires burning in the wetlands of the Paraná River Delta, Argentina, 19 August, 2022







2.1 Study area and data used

For this exercise, we will use two Sentinel-2 images and two Sentinel-1 GRDH images of the same area in Paraná River Delta, Argentina, using the Tile Number *20HQJ* downloaded for two days of summer 2022 (before and after the wildfires) 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 (unzipped) by double click on the metadata "MTD MSIL2A.xml" inside the folder. The opened products will appear in Product Explorer window. S2A MSIL2A 20220730T135711_N0400_R067_T20HQJ_20220730T210856.SAFE.zip S2A_MSIL2A_20220819T135721_N0400_R067_T20HQJ_20220819T211159.SAFE.zip

A: Detecting wildfires on Sentinel-2 image

- 1. Select the first product in the Product Explorer window.
- 2. Right click on the product.
- 3. Open RGB Image Window.
- 4. In the pop-up window select 'Sentinel 2 MSI Natural colors (Red: B4; Green: B3; Blue: B2)'.

Product Explorer × Pixel Info	-	Select RGB-Image Channels	×
 ⊕ ■ [1] S2A_MSIL2A_20220730T135711_N0400_R067_T: ⊕ ■ [2] S2A_MSIL2A_20220819T135721_N0400_R067_T: 	20HQJ_20220730T210856 20HQJ_20220819T211159 Pro Se	ofile: entinel 2 MSI Natural Colors	→ 🚭 💾 :11: Li
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- 5. Repeat the process for the second product.
- 6. Tile two opened RGB Windows, e.g. horizontally
- 7. In the Navigation window, zoom in to the wildfire region and syhnchronise views to see the same area before and after wildfires







Do the same process for obtaining the color composition in false colors:

- 1. Select the first product in the Product Explorer window.
- 2. Right click on the product.
- 3. Open RGB Image Window.
- 4. In the pop-up window select 'Sentinel 2 MSI Atmospheric penetration (Red: B12; Green: B11; Blue: B8A)'.
- 5. Apply color manipulation (stretching) for RGB
- 6. Repeat the process for the second product.
- 7. Tile opened RGB Windows, e.g. evenly
- 8. If necessary, in the Navigation window, zoom in again to the wildfire region and synnchronise views to see area before and after wildfires



Now let's detect the smoke plume:

- 1. Keep only the Sentinel 2 MSI Atmospheric penetration composition with visible smoke plume from 19 August open
- 2. Go to Mask Manager, and scroll down to the Maths masks
- 3. Select: "scl_cloud_medium_prob" and "scl_cloud_high_proba"
- 4. To visualize the masked areas better, lower the transparency(e.g. 0.1)



Fire + cloud plume map





Let's export this View as an image and safe as a GeoTIFF:

Because of multiple S2 spatial sizes, we first have to resample the data. Resample to highest spatial resolution: 10 m (e.g. B2).



Raster->Geometric->Resampling:

- Keep I/O names
- In Resampling Parameters, select B2 (10 m)

Resampling X	🎬 Resampling	×
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Target Product		Resulting target height: 10980
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Save as: BEAM-DIMAP		Width / height ratio: 1.00000
Directory: C:\Users\Onačillová	By pixel resolution (in m):	20 - Resulting target width: 5490
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	Flag downsampling method:	First v
	Advanced Method Definition by Band	
	Resample on pyramid levels (for faster image	ging)
Run Close	L	Run Close







Let's create a subset based on the current view

• Display the image. Note that now many more color options are available. Select MSI Atmospheric penetration

🞆 Select RGB-Image Channels	≺ 📓 Select RGB-Image Channels ×
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Sentinel 2 MSI Land/Water Sentinel 2 MSI Natural with Atmospherical Removal	fixed range min max
Blue: B2 V	Blue: B8A ~
fixed range min max	fixed range min max
Store RGB channels as virtual bands in current product	Store RGB channels as virtual bands in current product
OK Cancel Help	OK Cancel Help

• Make a zoom and add the cloud masks again

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 Right-mouse button -> Spatial Subset from View - in the Band Subset you can select all or only few bands to be exported

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Pixel Spacing: -- m -- m



2

Let's reproject the image in Latitude & Longitude coordinates

- Raster->Geometric Operations->Reprojection
- Select the default: Geographic Lat/Ion (WGS 84)
- Run (writing might take some time)

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File Help	File Help
File Help I/O Parameters Reprojection Parameters Source Product Name: [4] subset_0_of_52A_MSIL2A_20220819T135721_N0400_R067_T20HQJ_20220819T211159_resampled v Target Product Name: subset_0_of_S2A_MSIL2A_20220819T135721_N0400_R067_T20HQJ_20220819T211159_resampled_reprojecte V Save as: BEAM-DIMAP v Directory: Z:[FSA_ENELM[exerdse_S]	File Help I/O Parameters Coordnate Reference System (CRS) © Custom CRS Geodetic datum: World Geodetic System 1984 V Projection: Geographic Lat/Lon (WGS 84) Projection: Geographic Lat/Lon (WGS 84) V Projection: Output Settings Select Output Settings Output Varameters No-data value: NaN Add deta lat/lon bands Resampling method; Output Information Verest
	Scene width: 7846 pixel Center longitude: 60°01'S8' W Scene height: 6929 pixel Center latitude: 33°07'20' S CRS: WGS84(DD) Show WKT
Run Cic	e Run Close

Now we can export View as GeoTiff

- Right mouse button: Export View as Image
- Select: Full scene, Full resolution, GeoTIFF









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%)







B: Burned area mapping with Sentinel-2

How to quantify the impact of the Paraná wildfire?

Let's have look to the before & after images:

- Open RGB Image Window:
- Select: MSI Atmospheric penetration
- Window-> Tile horizontally, zoom in



Let's create a cloud mask:

- Go to Mask Manager, and scroll down to the Maths masks
- Select: cloud medium & cloud high probability & Thin cirrus
- To visualize them better, lower the transparency (e.g. 0.1)



Now we make a cloud band based on the selected mask

Band math expression







9

We make a cloud band based on the selected mask

- Navigate to Raster Band Maths
- Name the new mask: *clouds*

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Adding the cloud mask as a band

- On the image, right click-> Band Maths
- Make sure to deactivate "Virtual". We want to store the data!
- Go to "Edit Expression"
- Select Clouds

Repeat for the second image

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	OK Cancel Help						OK	(Cancel	Help







Vizualize all products

- Windows: Tile evenly
- Navigation: zoom all



Tools – Graph Builder



- Add->Raster->Geometric->Resample
- Add->Raster->Geometric->Subset
- Add->Raster->BandMaths
- Add->Raster->BandMerge
- Save your created graph

SNAP - Save	Graph		×
Save in:	exercise_9	 E 💣 III • 	
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Tools – Batch processing

This allows to process both images at the same time.

- Click on Add opened
- Load your graph
- Make sure to refresh



🚪 Batch Processing

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Resample

- Select a reference band: B2 at 10 m.
- Resampling method: Bilinear

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Define size of resampled product			^
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Subset

- Select bands: B3, B8, B12, Cloud_mask
- Select Geographic coordination
- Click on A, zoom in to the area of interest
- Select a yellow box within the red square

	Resample	Subset	BandMaths	BandMerge			
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Band merge

• Keep the source bands: NBR, B3, B8, B12, cloud_mask









Running and visualizing the NBR band

Try a color table:

• Colour manipulation: Open color table, choose a color gradient, e.g. ,derived from meris_cloud"









You can also set the position of sliders and color them for better visualization or change ranges of values in the Table tab.

NBR ranges between -1 and 1. A high NBR value indicates healthy vegetation. A low value indicates bare ground and recently burnt areas. Non-burnt areas usually have values close to zero.



Burn severity - dNBR

The difference between the pre-fire and post-fire NBR obtained from the images is used to calculate the delta NBR (dNBR or Δ NBR), which then can be used to estimate the burn severity. A higher value of dNBR indicates more severe damage, while areas with negative dNBR values may indicate regrowth following a fire. The formula used to calculate dNBR is illustrated below:

dNBR or $\triangle NBR = PrefireNBR - PostfireNBR$

Go to Raster – Band Maths and Edit Expression

Band Maths ×	👔 📓 Band Maths Expression Editor	×
Target product: [5] subset_3_of_S2A_MSIL2A_20220730T135711_N0400 Name: dNBR Description:	Product: [5] subset 3 of S2A MSIL2A 20220730T135711 N0400 R067 T2 Data sources: Expression: \$5.B3 @ + @ \$5.B8 @ - @ \$5.B12 @ * @ \$5.SNBR @ / @ (@) Constants ~ Operators ~ Functions ~ Show bands Functions ~	0HQJ_2022073 ~
Load Save Edit Expression OK Cancel	Show tie-point grids Show single flags OK	Ok, no errors.





Set the position of sliders and color them for better visualization or change ranges of values in the Table tab.

NBR ranges between -1 and 1. A high NBR value indicates healthy vegetation. A low value indicates bare ground and recently burnt areas. Non-burnt areas usually have values close to zero.

dNBR values can vary from case to case, and so, if possible, interpretation in specific instances should also be carried out through field assessment; in order to obtain the best results. However, the United States Geological Survey (USGS) proposed a classification table to interpret the burn severity, which can be seen below in the table.



Severity Level	dNBR Range (scaled by 10 ³)	dNBR Range (not scaled)
Enhanced Regrowth, high (post-fire)	-500 to -251	-0.500 to -0.251
Enhanced Regrowth, low (post-fire)	-250 to -101	-0.250 to -0.101
Unburned	-100 to +99	-0.100 to +0.99
Low Severity	+100 to +269	+0.100 to +0.269
Moderate-low Severity	+270 to +439	+0.270 to +0.439
Miderate-high Severity	+440 to +659	+0.440 to +0.659
High Severity	+660 to +1300	+0.660 to +1.300

ÚSTAV GEOGRAFIE

Comparison: Severity map, NDVI and false color composition

To compare different views of the same area and explore it more in detail, create also NDVI and false color composition. You can observe, that areas with high NDVI values correspond to the barren areas affected by wildfires. False color composition also depicts areas affected by fire – these areas are shown in dark pixels. False color composite B8-B4-B3 of the Sentinel 2 image (during fire), with superimposed ongoing wildfire sites, note that the smoke direction is corresponding to the wind direction.

C: Burned area mapping using Sentinel-1

Load both Sentinel-1 products (pre-fire and post-fire) that you have in the folder for this exercise by navigating to File - Open Product.

S1A_IW_GRDH_1SDV_20220724T091506_20220724T091531_044240_0547C3_961B.SAFE S1A_IW_GRDH_1SDV_20220829T091508_20220829T091533_044765_055873_EED3.SAFE

Visualize the input products – open e.g. Intensity_VH for both products by double-click on it under the Bands folder.

1. Pre-processing

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

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.

Select the first product and Go to the Subset tab and at "Geo Coordinates" set: North latitude bound: -33.19 West longitude bound: -58.50 South latitude bound: -33.60 East longitude bound: -60.70

Repeat for the second image.

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	×	S-1 Thermal Noise Remov	al	×
File Help	_	File Help		
I/O Parameters Processing Parameters Source product Source product Source product Source product Source product Source product Target Product Source product		File Help I/O Parameters Processing Par Polarisations: Remove Thermal Noise Re-Introduce Thermal Noise	rameters WH W Output Noise	
Run Clos	e			

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 both bands 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	I/O Parameters Processing Parameters
Source Product source: [5] subset_0_of_S1A_IW_GRDH_1SDV_20220829T091508_202208 v	Polarisations: VH VV
Target Product Name: H_1SDV_20220829T091508_20220829T091533_044765_055873_EED3_thr_Cal Save as: BEAM-DIMAP Directory: Z:\Projekty\2023_ESA_ENEUM\07_ucebne_materialy\Aplikacie_DP2\pr 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 X	C Single Product S	peckle Filter	<
File Help	File Help		
I/O Parameters Processing Parameters	I/O Parameters Pro	cessing Parameters	
Source Product source: [7] subset_0_of_S1A_IW_GRDH_1SDV_20220829T091508_202208 v	Source Bands:	Sigma0_VH Sigma0_VV	
Target Product Name: DV_20220829T091508_20220829T091533_044765_055873_EED3_tnr_Cal_Spk	Filter:	Lee Siama 🗸 🗸	
Save as: BEAM-DIMAP	Number of Looks:	1 ~	
Directory: Z:\Projektv\2023 ESA ENELIM\07 ucebne materialv\Anlikacie DPZ\nr	Window Size:	7x7 ~	
	Sigma:	0.9 ~	
	Target Window Size:	3x3 ~	
Run Close		Run Close	

Terrain-Correction

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 speckle-filtered product.
- In "Target Product", keep the default name and set the Directory
- In the Processing Parameters tab set:
- Digital Elevation Model: SRTM 3Sec (Auto Download)
- Keep defaults values for the other parameters. Click Run.

Approximate processing time: 2.5 minutes.

📀 Range Doppler Terrain Correction	× C Range Doppler Terrain	Correction X
File Help	File Help	
I/O Parameters Processing Parameters	I/O Parameters Processin	g Parameters
Source Product source: [9] subset_0_of_S1A_IW_GRDH_1SDV_20220829T091508_20220829T091533_04 v	Source Bands:	Sigma0_VH Sigma0_VV
Target Product Name: V GRDH 1SDV 20220829T091508 20220829T091533 044765 055873 EED3 tnr Cal Sok TC		
	Digital Elevation Model:	SRTM 3Sec (Auto Download) v
Directory:	DEM Resampling Method:	BILINEAR_INTERPOLATION V
rojekty\2023_ESA_ENEUM\07_ucebne_materialy\Aplikacie_DPZ\practicals\exercise_6	Image Resampling Method:	BILINEAR_INTERPOLATION V
Open in SNAP	Source GR Pixel Spacings (a	az x rg): 10.0(m) x 10.0(m)
	Pixel Spacing (m):	10.0
	Pixel Spacing (deg):	8.983152841195215E-5
	Map Projection:	WGS84(DD)
	Mask out areas without	t elevation
	Output bands for:	
	Selected source band	DEM Latitude & Longitude
Source Product source: [9] subset_0_of_\$1A_IW_GRDH_1SDV_20220829T091508_20220829T091533_04 Target Product Name: V_GRDH_1SDV_20220829T091508_20220829T091533_044765_055873_EED3_tnr_Ca Directory: Directory: rojekty\2023_ESA_ENELM\07_Lucebne_materialy\Aplikacie_DP2\practicals\exercise Open in SNAP	Incidence angle from	ellipsoid 🗌 Local incidence angle 📄 Projected local incidence angle
	Layover Shadow Mas	k
	Apply radiometric norm	alization
	Save Sigma0 band	Use projected local incidence angle from DEM $\qquad \lor$
	Save Gamma0 ban	Use projected local incidence angle from DEM \sim
	Save Beta0 band	
	Auxiliary File (ASAR only):	Latest Auxiliary File \checkmark
Run Close		Run Close

Do not forget to save these two output terrain corrected products. We will need them saved for the next step.

Create stack

Go to Radar > Coregistration > Stack Tools > Create Stack

In the Product-Set-Reader tab select the last three products from the previous step.

📀 Create Stack					×
1-ProductSet-Reader 2-CreateStack 3-Write					
File Name	Туре	Acquisition	Track	Orbit	
subset_0_of_S1A_IW_GRDH_1SDV_20220829T091508	GRD	29Aug2022	68	44765	
subset_1_of_S1A_IW_GRDH_1SDV_20220724T091506	GRD	24Jul2022	68	44240	

In the CreateStack tab, select Product Geolocation as Initial Offset Method (Note: we did not use apply orbit file function, but the product geolocation is accurate enough for the purpose of our analysis)

Create Stack								\times
1-ProductSet-Reader	2-CreateSta	k 3-Write						
Reference:	subset	_0_of_S1A_1	W_GRDH_1SDV_2022	0829T091508_	20220829T09	1533_044765_0	55873_EED3_tnr_C	al_Spk_TC
Resampling Type:	NONE							\sim
Initial Offset Method:	Produ	ct Geolocatio	1					~
Output Extents:	Maste	r						\sim
Find Optimal Referen	nce							

In the Write tab, adjust the stack name if needed, adjust the output folder and click Run. This step will might take few minutes.

After the process is finished, we can see the new final "Stack" product in the Product Explorer window.

2 Display RGB time series

Now let 's have a look at some RGB composite of this time series Right-click on the last "Stack" product – Open RGB Image Window and select different band combinations to see the change of backscatter signal for different dates:

Right-click on the last "Stack" product – Open RGB Image Window and select different band combinations to see the change of backscatter for different acquisitions. For this, select :

Red: Sigma0_VH_slv_24Jul2022

Green:Sigma0_VV_slv2_24Jul2022

Blue: Sigma0_VH_mst_29Aug2022

Red:	\$13 Sigma0_VH_slv1_24Jul2022		
	fixed range min	max	
Green:	\$13.Sigma0_VV_slv2_24Jul2022	~	
	fixed range min	max	
Blue:	\$13.Sigma0_VH_mst_29Aug2022	~	
	fixed range min	max	
		Expressions are	valid
Stor	e RGB channels as virtual bands in current pro	oduct	

Explore the final RGB composite to identify wildfires.

For more information, see the lecture: <u>7. SAR and optical remote sensing</u> for mapping wildfires

THANK YOU FOR FOLLOWING THE EXERCISE!

