

10TH ADVANCED TRAINING COURSE ON LAND REMOTE SENSING 20-24 September 2021 | Ljubljana, Slovenia & Online

SNAP S2-S3 exercise: Burned Area & Active Fires Detection

EXERCISE 1 (Burned area detection from Sentinel-2)

Data: Sentinel-2A Level-2A pre-processed:

Subset_S2A_MSIL2A_20170614T112111_N0205_R037_T29TNE_20170614T112422_10m.data Subset_S2A_MSIL2A_20170704T112111_N0205_R037_T29TNE_20170704T112431_10m.data

Sentinel-2 characteristics

Optical mission for the monitoring of land and coastal regions

Main features:

- → Constellation of two satellites (Sentinel-2A and Sentinel-2B)
- → Multi-Spectral Instrument (MSI)
- \rightarrow Polar, sun-synchronous orbit at 786km and LTDN 10h30
- → 10 days repeat cycle (5 days with both Sentinels 2A and 2B operational)
- → Swath of 290km



Sentinel-2 products



Comparison of Landsat 7 and 8 bands with Sentinel-2

SENTINEL-2 products available for users (either generated by the ground segment or by the SNAP) are:

Level-1C

- > Top-Of-Atmosphere reflectances in cartographic geometry
- > Systematic generation and online distribution
- ~600MB (each 100km x 100km)

Level-2A

- > Bottom-Of-Atmosphere reflectances in cartographic geometry
- Systematic and on-User side (using SNAP)
- > ~600MB (each 100km x 100km)



Products are a compilation of elementary granules of fixed size, along with a single orbit. A granule is the minimum indivisible partition of a product (containing all possible spectral bands).

For Level-1C and Level-2A, the granules, also called tiles, are 100x100 km² ortho-images in UTM/WGS84 projection.







The data have been atmospherically corrected, resampled at 10m, cropped spatially and spectrally (B2, B3, B4, B8, B11, B12) and exported in BEAM-DIMAP (SNAP native file format).

1. Open files

1.1. 'File' / 'Open Product'

1.2. Browse to:

\Day_2\S2\Input\Subset_S2A_MSIL2A_20170614T112111_N0205_R037_T29TNE_20170614T112422_10m.dim \Day_2\S2\Input\Subset_S2A_MSIL2A_20170704T112111_N0205_R037_T29TNE_20170704T112431_10m.dim 1.3. Click 'Open'

- 2. View RGB image view
 - 2.1. Select image name in "Product Explorer" window
 - 2.2. Select: 'Window' / 'Open RGB Image Window'
 - 2.3. Leave default natural colour combination and click OK
 - 2.4. Repeat for both of the products
- 3. View multiple viewers
 - 3.1. Synchronise views by selecting the relevant icons in the "Navigation" tab
 - 3.2. Select: 'Window' / 'Tile Horizontally'

4. NBR (Normalized Burn Ratio)

The Normalized Burn Ratio (NBR) was designed to highlight burned areas and estimate fire severity and is calculated applying the equation reported below:

$$NBR = \frac{(NIR - SWIR)}{(NIR + SWIR)} = \frac{(B8 - B12)}{(B8 + B12)}$$

Pre-fire, healthy vegetation has very high near-infrared reflectance and low reflectance in the shortwave infrared portion of the spectrum. Recently burned areas on the other hand have relatively low reflectance in the near-infrared and high reflectance in the shortwave infrared band. A high NBR value generally indicates healthy vegetation while a low value indicates bare ground and recently burned areas.



4.1. By Band Maths

- 4.1.1. Select: 'Raster' / 'Band Maths...'
- 4.1.2. Set up the I/O and the processing parameters as shown in the Figure below
- 4.1.3. Change the output name in 'NBR_June'
- 4.1.4. Deselect "Virtual"
- 4.1.5. Select "Edit Expression..."
- 4.1.6. Type in the following expression in the 'Expression' field: "(\$1.B8 \$1.B12) / (\$1.B8 + \$1.B12)"



🛃 Band Maths	×	<	Band Maths Expres	sion Editor		×
Target product: [1] Subset_S2A_MSIL2. Name: NE Description: Unit: Spectral wavelength: 0. Virtual (save expression)	A_20170614T112111_N0205_R037_T29TNE_20170614T112422_10m ~ R_June 0 ssion only, don't store data)		Product: [1] Subset_S2A Data sources: \$1.B2 \$1.B3 \$1.B4 \$1.B8 \$1.B1	_MSIL2A_20170614T112111_N02	005_R037_T29TNE_20170614T112422_10m Expression: (\$1.B8 - \$1.B12) / (\$1.B8 + \$1.B12)	~
Replace NaN and in Generate associate Band maths expression:	finity results by NaN d uncertainty band	7	\$1.B12	(0) Constants v Operators v Functions v		
Load Save	Edit Expression Edit Expression QK Gancel		Show tie-point grids		Ok, no et	rrors.

- 4.1.7. Click 'OK'
- 4.1.8. The newly created NBR band is added as band of the input product
- 4.1.9. Replicate the action for the second product [2] changing the output name 'NBR_July'

5. View NBR bands

- 5.1. Select 'NBR_June' band name in "Product Explorer" window and double click
- 5.2. Repeat for the 'NBR_July' band associated to the second image
- 5.3. Synchronise views by selecting the relevant icons in the "Navigation" tab
- 5.4. Select: 'Window' / 'Tile Horizontally'

6. Colour Manipulation

- 6.1. Select NBR_June image displayed
- 6.2. Select: "Colour Manipulation" tab
- 6.3. Click on "Auto-adjust to 100% of all pixels" as shown in figure below
- 6.4. [Min: Red]; [Mean: Orange]; [Max: Green]



6.5. Repeat for the NBR_July obtaining the following result





7. Burn Severity

Normalized Burn Ratio is frequently used to estimate burn severity. Imagery collected before a fire will have very high near infrared band values and very low mid infrared band values and a Imagery collected over a forest after a fire will have very low near infrared band values and very high mid infrared band values. Higher dNBR indicate more severe damage. Areas with negative dNBR values may indicate increased vegetation productivity following a fire.

 $dNBR \text{ or } \Delta NBR = PrefireNBR - PostfireNBR = NBR_{June} - NBR_{July}$

The meaning of the Δ NBR values can vary by scene, and for best results interpretation in specific instances should always be based on some field assessment. However, the table below from the USGS FireMon program can be useful as a first approximation for interpreting the NBR difference.

dNBR	Burn Severity
< -0.25	High post-fire regrowth
-0.25 to -0.1	Low post-fire regrowth
-0.1 to +0.1	Unburned
0.1 to 0.27	Low-severity burn
0.27 to 0.44	Moderate-low severity burn
0.44 to 0.66	Moderate-high severity burn
> 0.66	High-severity burn

- 7.1. Select: 'Raster' / 'Band Maths...'
- 7.2. Set up the I/O and the processing parameters as shown in the Figure below
- 7.3. Change the output name in 'dNBR'
- 7.4. Deselect "Virtual"
- 7.5. Select "Edit Expression..."
- 7.6. Type in the following expression in the 'Expression' field: "\$1.NBR_June \$2.NBR_July"



📕 Band Maths		×	Band Maths Expres	sion Editor		×
Target product:			Product: [1] Subset_S2A	_MSIL2A_20170614T112111_N02	205_R037_T29TNE_20170614T112422_10m	~
[1] Subset_S2A_MS	L2A_20170614T112111_N0205_R037_T29TNE_20170614T112422_10m	\sim	Data sources:		Expression:	
Name:	dNBR		\$1.B2	0 + 0	\$1.NBR_June - \$2.NBR_July	
Description:			\$1.B3			
Unit:			\$1.B4	0 - 0		
Spectral wavelength:	0.0		\$1.B8	0 * 0		
Virtual (save exp	ression only, don't store data)		\$1.B11	@ / @		
Replace NaN and	infinity results by	IaN	\$1.B12	(@)		
Generate associa	ted uncertainty band		\$1.NBR_June	Constants V		
Band maths expression	n:			Operators v		
			Show bands	Functions		
			Show masks			
Land D	Edit Europeanies		Show tie-point grids			
Loau Si	Edit Expression		Show single flags		🛒 (III) 🥔 🛍 💹 🛛 ok. 🖻	o errors.
	QK <u>C</u> ancel <u>H</u> el	p			QK <u>C</u> ancel	Help

7.7. The symbols "\$1." and "\$2." are the links to the different products7.8. Obtaining the following result



7.9. The brightest pixels represent high dNBR meaning high-severity burn.

8. Colour Manipulation

- 8.1. Select dNBR band displayed on the screen
- 8.2. Go to "Colour Manipulation" tab (bottom left) and select 'Basic' as editor
- 8.3. Import colour palette from text file clicking on the icon and selecting the file named 'dNBR_ColourPalette.cpd'
- 8.4. In order to take the range from the file click 'No' on the pop-up message



dNBR	Burn Severity	Colour Palette
< -0.25	High post-fire regrowth	
-0.25 to -0.1	Low post-fire regrowth	
-0.1 to +0.1	Unburned	
0.1 to 0.27	Low-severity burn	
0.27 to 0.44	Moderate-low severity burn	
0.44 to 0.66	Moderate-high severity burn	
> 0.66	High-severity burn	



European Space Agency Agence spatiale européenne



esa

EXERCISE 2 (Active fire detection from Sentinel-3 SLSTR)

Data: Sentinel-3A SLSTR Level-1b: S3A_SL_1_RBT____20170618T104548_20170618T104848_20181004T040944_0179_019_051____ LR1 **R_NT_003.SEN3** 20170618T220242 20170618T220542 20181004T042200 0179 019 058 S3A SL 1 RBT LR1 R NT 003.SEN3

Sentinel-3

Band

S1

S2 S3

S4 S5

S6

S7

S8

S9

F1

F2

SLSTR Spectral Bands

Central Vavelength (nm)	Bandwidth (nm)	Function	Comr	ments	Resolution (metres)
554.27	19.26	Cloud screening, vegetation monitoring, aerosol	VNIR Re	Solar eflectance Bands	500
659.47	19.25	NDVI, vegetation monitoring, aerosol			
868.00	20.60	NDVI, cloud flagging,Pixel co- registration			
1374.80	20.80	Cirrus detection over land	SWIR		
1613.40	60.68	loud clearing, ice, snow,vegetation monitoring			
2255.70	50.15	Vegetation state and cloud clearing			
3742.00	398.00	SST, LST, Active fire	Thermal IF	R Ambient	1000
10854.00	776.00	SST, LST, Active fire	bands (200	UK -320K)	
12022.50	905.00	SST, LST			
3742.00	398.00	Active fire	Therma	al IR fire	2
			emissio	unditus	

1. Open files

10854.00

1.1. 'File' / 'Open Product'

Active fire

776.00

1.2. Browse to:

\Day_2\S3\Input\S3A_SL_1_RBT____20170618T104548_20170618T104848_20181004T040944_0179_019_051___ LR1_R_NT_003.SEN3 and select 'xfdumanifest.xml' file

\Day 2\S3\Input\S3A SL 1 RBT 20170618T220242 20170618T220542 20181004T042200 0179 019 058 _LR1_R_NT_003.SEN3 and select 'xfdumanifest.xml' file

1.3. Click 'Open'

For the day-time S3 product we should apply the following pre-processing steps

emission bands

2. Radiance to Reflectance

In order to derive our cloud mask we need to convert radiance to reflectance

- 2.1. 'Optical' / 'Preprocessing' / 'Radiance-to-reflectance Processor'
- 2.2. Set up the I/O and the processing parameters as shown in the Figure below
- 2.3. Click on 'Run'



📓 Radiance-to-Reflectance Processor 🛛 🕹	Radiance-to-Reflectance Processor X
File Help	File Help
I/O Parameters Processing Parameters	I/O Parameters Processing Parameters
Source Product Name: [1] S3A_SL_1_RBT20170618T104548_20170618T104848_20181004T040944_0179_019_051LR1_R_NT_003.SEN3 v Target Product Name: S3A_SL_1_RBT20170618T104548_20170618T104848_20181004T040944_0179_019_051LR1_R_NT_003.SEN3_radreff Save as: BEAM-DIMAP Directory: C:\Users\Fabrizio Ramoino\Desktop\S2_Activities\Gas Flares V Open in SNAP	Sensor: SLSTR_500m V Conversion mode: RAD_TO_REFL V Copy tie point grids Copy flag bands and masks Copy non spectral bands
<u>R</u> un <u>C</u> lose	<u>R</u> un <u>C</u> lose

3. <u>Resampling</u>

Because we have bands a different spatial resolution we have to resample them at the same spatial resolution, we choose the 500m taking as reference band 'S1_reflectance_an'

- 3.1. 'Raster' / 'Geometric' / 'Resampling'
- 3.2. Set up the I/O and the processing parameters as shown in the Figure below
- 3.3. Click on 'Run'

Resampling ×	🞇 Resampling
File Help	File Help
I/O Parameters Resampling Parameters	I/O Parameters Resampling Parameters
Source Product	Define size of resampled product
Name: [3] S3A SL 1 RBT 20170618T104548 radrefi v	By reference band from source product: 51_reflectance_an
	Resulting target width: 3000
Target Product	Resulting target height: 2400
Name:	By target width and height: Target width: 3,000 -
53A_5L_1_KB1201706181104548_radrem_resampled	Vidth / beight ratio: 1,25000
Save as: BEAM-DIMAP	By pixel resolution (in m):
C:\Users\Fabrizio Ramoino\Desktop\S2_Activities\Gas Flares	Resulting target width:
✓ Open in SNAP	Resulting target height:
	Define resampling algorithm
	Upsampling method:
	Downsampling method:
	Flag downsampling method:
	Advanced Method Definition by Band
	Resample on pyramid levels (for faster imaging)
<u>Bun</u> <u>C</u> lose	

4. <u>Reproject</u>

Sentinel-3 L1b products are geolocated but they are not projected, for this reason we have to reproject choosing the same CRS of Sentinel-2 (UTM / WGS84) [Zone 29]

- 4.1. 'Raster' / 'Geometric' / 'Reprojection'
- 4.2. Set up the I/O and the processing parameters as shown in the Figure below
- 4.3. Click on 'Run'



Reprojection X	Reprojection X
File Help	File Help
I/O Parameters Reprojection Parameters	I/O Parameters Reprojection Parameters
Source Product	Coordinate Reference System (CRS)
Name: [4] S3A SL 1 RBT 20170618T104548 radrefi resampled v	Custom CRS
	Geodetic datum: World Geodetic System 1984 🗸 🗸
Target Product	Projection: UTM Zone 🗸
Name: S3A SL 1 RBT 20170618T104548 radrefi resampled reprojected	Projection Parameters
Bave as: BEAM-DIMAP	O Predefined CRS Select
Directory:	O Use CRS of
C: \Users\Fabrizio Ramoino \Desktop \\$2_Activities \Gas Flares	Output Settings
Open in SNAP	Preserve resolution Reproject tie-point grids
	Output Parameters No-data value: NaN
	Add delta lat/lon bands Resampling method: Nearest V
	Output Information
	Scene width: 1501 pixel Center longitude: 11°49'30" W
	CPS: LTM Zone 29 / World Geodetic System 1984 Show WKT
	CR3. OTH ZORE 27 WORD GEOLEGE SYSTEM 1964 SHOW WRT
Run Glose	<u>R</u> un <u>C</u> iose

5. <u>Subset</u>

We want to subset the product because we are interested in a small area and this will reduce the processing time. You will find the boundaries coordinates in the 'S3_Equations.txt' file.

- 5.1. 'Raster' / 'Subset'
- 5.2. Set up the I/O and the processing parameters as shown in the Figure below
- 5.3. Click on 'OK'

Specify Product Subset		×	🞇 Specify Product Subset	×
Spatial Subset Band Subset Meta	data Subset		Spatial Subset Band Subset Metadata Sub	bset
	Pixel Coordinates Geo Coordinate North latitude bound: West longitude bound: South latitude bound: East longitude bound: Scene step X: Scene step Y: Subset scene width: Subset scene width: Source scene height: Source scene height: Use Preview East preview	es 41.00 \$ -10.00 \$ 38.00 \$ -7.00 \$ 1 \$ 454.0 579.0 3001 2585 Fix full width Fix full height	S1_reflectance_an S2_reflectance_an S3_reflectance_an S5_reflectance_an S6_reflectance_an S1_reflectance_an S3_reflectance_an S1_reflectance_an S1_reflectance_an S1_reflectance_ao S2_reflectance_ao S3_reflectance_ao S4_reflectance_ao S5_reflectance_ao S6_reflectance_ao S6_reflectance_ao <t< td=""><td>Reflectance converted from radiance Reflectance converted from radiance</td></t<>	Reflectance converted from radiance Reflectance converted from radiance
	Estima	ated, raw storage size: 239.2M		Estimated, raw storage size: 241.9M
	<u>0</u>	<u>Lancer</u> <u>H</u> elp		<u>Q</u> K <u>C</u> ancel <u>H</u> elp

Now the next step is to calculate the **cloud mask** using a simple equation developed for day-time fire detection by Giglio et al. (2003b).



$\{(\rho_{0.65} + \rho_{0.86} > 0.9) \ OR \ (T_{12} < 265K)\} \ OR \ \{(\rho_{0.65} + \rho_{0.86} > 0.7) \ AND \ (T_{12} < 285K)\}$

Where, ρ_{λ} and T_{λ} correspond to reflectance and thermal bands (brightness temperature) at certain wavelength (λ [µm]). The **brightness temperature** is the temperature (K) of a black body "emitting" the same amount of radiance as the target pixel.

To calculate the cloud mask we use the SNAP BandMaths operator

- 6. BandMaths (to calculate the cloud mask day-time)
 - 6.1. 'Raster' / 'Band Maths'
 - 6.2. Set up the I/O and the processing parameters as shown in the Figure below and you can find all the information in the 'S3_Equations.txt' file.
 - 6.3. Click on 'OK'

👹 Band Maths	🖥 Band Maths 🛛 🕹				
Target product:					
[3] Subset_S3A_SL_	1_RBT20170618T104548_r	adrefl_resampled_reprojected	\sim		
Name:	CloudMask				
Description:					
Unit:					
Spectral wavelength:	0.0				
Virtual (save exp	ression only, don't store data)				
Replace NaN and	l infinity results by	1	NaN		
Generate associa	ated uncertainty band				
Band maths expression	on:				
1					
Load S	ave	Edit Expression			
		<u>O</u> K <u>Cancel H</u> el	p		

Band Maths Expression Editor			×
Data sources: S1_reflectance_an S2_reflectance_an S3_reflectance_an S4_reflectance_an S5_reflectance_an S1_reflectance_ao S2_reflectance_ao S2_reflectance_ao S2_reflectance_ao S3_reflectance_ao S3_reflectance_ao S4_reflectance_ao S5_reflectance_ao	^	@ + @ @ - @ @ * @ @ / @ (@) Constants ~ Operators ~ Functions ~	<pre>Expression: (((S2_reflectance_an + S3_reflectance_an) > 0.9) or (S9_BT_in < 265)) or (((S2_reflectance_an + S3_reflectance_an) > 0.7) and (S9_BT_in < 285))</pre>
Show single flags			📑 🗊 🔉 😰 💹 Ok, no errors.
			QK <u>C</u> ancel <u>H</u> elp

The new created band is added to the input product. Select the product and click 'File' / 'Save Product'

Now we should pre-process the S3 product acquired during night-time. The steps are the same of day-time except for the Radiance to Reflectance conversion because during the night the radiance bands cannot observe the Earth Surface due to the absence of the sun and we are going to use only the thermal channels. Therefore you should apply the previous steps from 3 to 5 (resampling, reprojection and subset). You can find the pre-processed night-time S3 product in:

\Day_2\S3\Preprocessed_Products\Subset_S3A_SL_1_RBT____20170618T220242_resampled_reprojected. dim



After pre-processed the S3 night-time data is time to derive its cloud mask applying the equation below. You can find the expression in the **'S3_Equations.txt'** file.

- $T_{12} < 265K$
- 7. BandMaths (to calculate the cloud mask night-time)
 - 7.1. 'Raster' / 'Band Maths'
 - 7.2. Set up the I/O and the processing parameters as shown in the Figure below and you can find all the information in the 'S3_Equations.txt' file.
 - 7.3. Click on 'OK'

Band Maths		×			
Target product:					
[4] Subset_S3A_SL_1_RBT20170618T220242_resampled_reprojected					
Name:	CloudMask				
Description:					
Unit:					
Spectral wavelength:	0.0				
Virtual (save exp	ression only, don't store data)				
Replace NaN and	infinity results by	NaN			
Generate associa	Generate associated uncertainty band				
Band maths expression	Band maths expression:				
S9_BT_in < 265					
Load Sa	ave	Edit Expression			
		<u>O</u> K <u>C</u> ancel <u>H</u> elp			

Now that we have our data pre-processed and with the related cloud mask we can work on active fire detection. We close all the open products on SNAP and open just the 2 intermediate results that includes the cloud mask: \Day_2\S3\Intermediate_Results\Subset_S3A_SL_1_RBT____20170618T104548_radrefl_resampled_reprojected_CM. dim

\Day_2\S3\Intermediate_Results\Subset_S3A_SL_1_RBT____20170618T220242_resampled_reprojected_CM.dim

To detect active fire we will take into account our cloud mask, and only the land pixels discarding water and inland water pixels.



Sentinel-3 SLSTR

Active Fire Detection Algorithms

	DAY	NIGHT
Initial test	T ₄ > 325 K	T ₄ > 315 K
Eliminate warm background	$(T_4 - T_{11}) > 18 K$	$(T_4 - T_{11}) > 15 K$
Eliminate clouds	<u>CloudMask</u> ==0	<u>CloudMask</u> ==0
Eliminate non land pixels	confidence_in_land and not confidence_in_inland_water	confidence_in_land and not confidence_in_inland_water

8. Band Maths (Fire detection Day-Time)

- 8.1. 'Raster' / 'Band Maths'
- 8.2. Set up the I/O and the processing parameters as shown in the Figure below and you can find all the information in the 'S3_Equations.txt' file.
- 8.3. Click on 'OK'

🞆 Band Maths		×
Target product:		
[1] Subset_S3A_SL_	1_RBT2017061	18T104548_radrefl_resampled_reprojected_CM <
Name:	FireDetection	
Description:		
Unit:		
Spectral wavelength:	0.0	
Virtual (save expression only, don't store data)		
Replace NaN and	infinity results by	NaN
Generate associated uncertainty band		
Band maths expression:		
F1_BT_in >325 and (F1_BT_in - F2_BT_in) > 18 and CloudMask==0 and confidence_in_land and not confidence_in_inland_water		
Load Sa	ive	Edit Expression
		<u>O</u> K <u>C</u> ancel <u>H</u> elp



9. Band Maths (Fire detection Night-Time)

- 9.1. 'Raster' / 'Band Maths'
- 9.2. Set up the I/O and the processing parameters as shown in the Figure below and you can find all the information in the 'S3_Equations.txt' file.
- 9.3. Click on 'OK'

Band Maths	X	
Target product:		
[2] Subset_S3A_SL_	1_RBT20170618T220242_resampled_reprojected_CM v	
Name:	FireDetection	
Description:		
Unit:		
Spectral wavelength:	0.0	
Virtual (save expression only, don't store data)		
Replace NaN and	infinity results by NaN	
Generate associated uncertainty band		
Band maths expression:		
F1_BT_in >315 and (F1_BT_in - F2_BT_in) > 15 and CloudMask==0 and confidence_in_land and not confidence_in_inland_water		
Load Sa	Edit Expression	
	QK <u>C</u> ancel <u>H</u> elp	