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

EXERCISE 1 (Burned area detection from Sentinel-2)

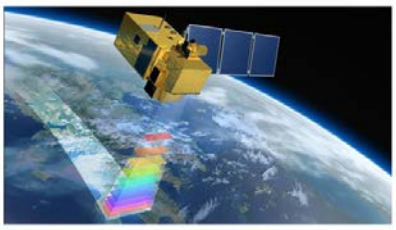
Data: Sentinel-2A Level-2A pre-processed:
Subset_S2A_MSIL2A_20170614T112111_N0205_R037_T29TNE_20170614T112422_10m.data
Subset_S2A_MSIL2A_20170704T112111_N0205_R037_T29TNE_20170704T112431_10m.data

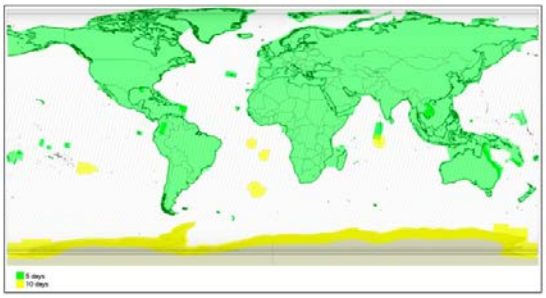
Sentinel-2 characteristics

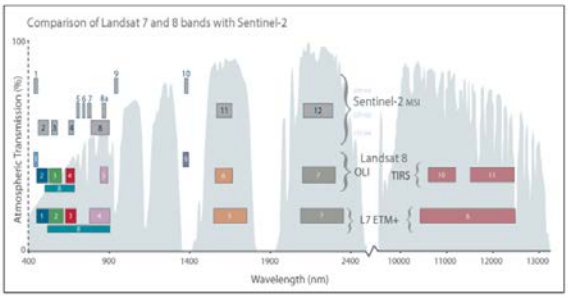
Optical mission for the monitoring of land and coastal regions

Main features:

- → Constellation of two satellites (Sentinel-2A and Sentinel-2B)
- → Multi-Spectral Instrument (MSI)
- → 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





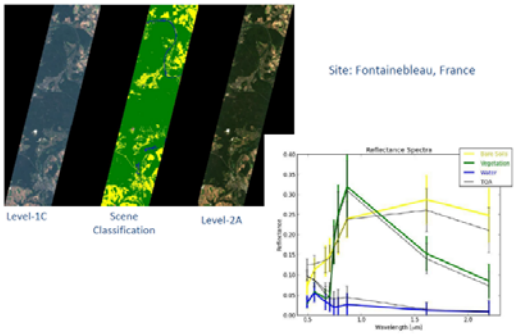


Sentinel-2 products

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 km^2 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.

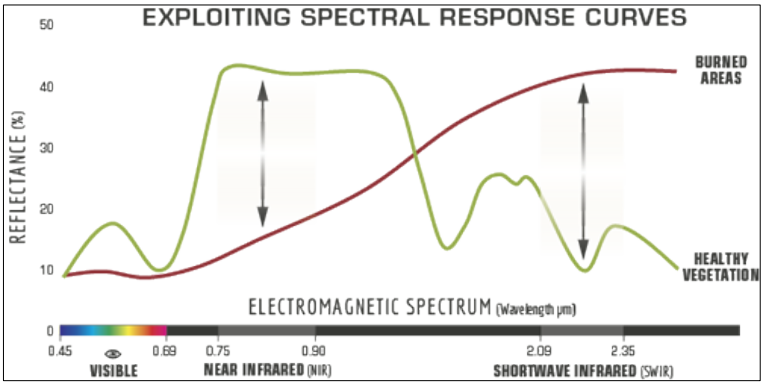
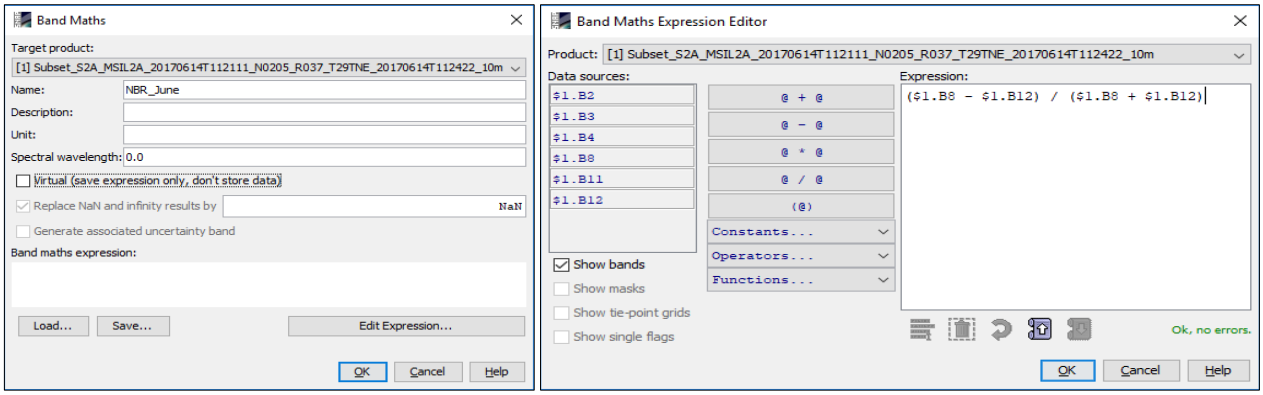


Image Credit: US Forest Service

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)"



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. <u>View NBR bands</u>

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'

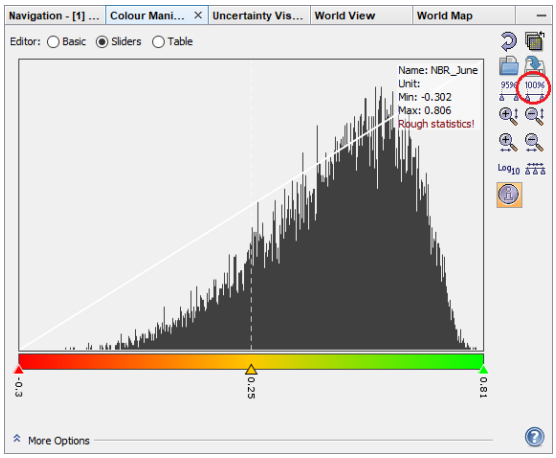
6. <u>Colour Manipulation</u>

6.1. Select NBR_June image displayed

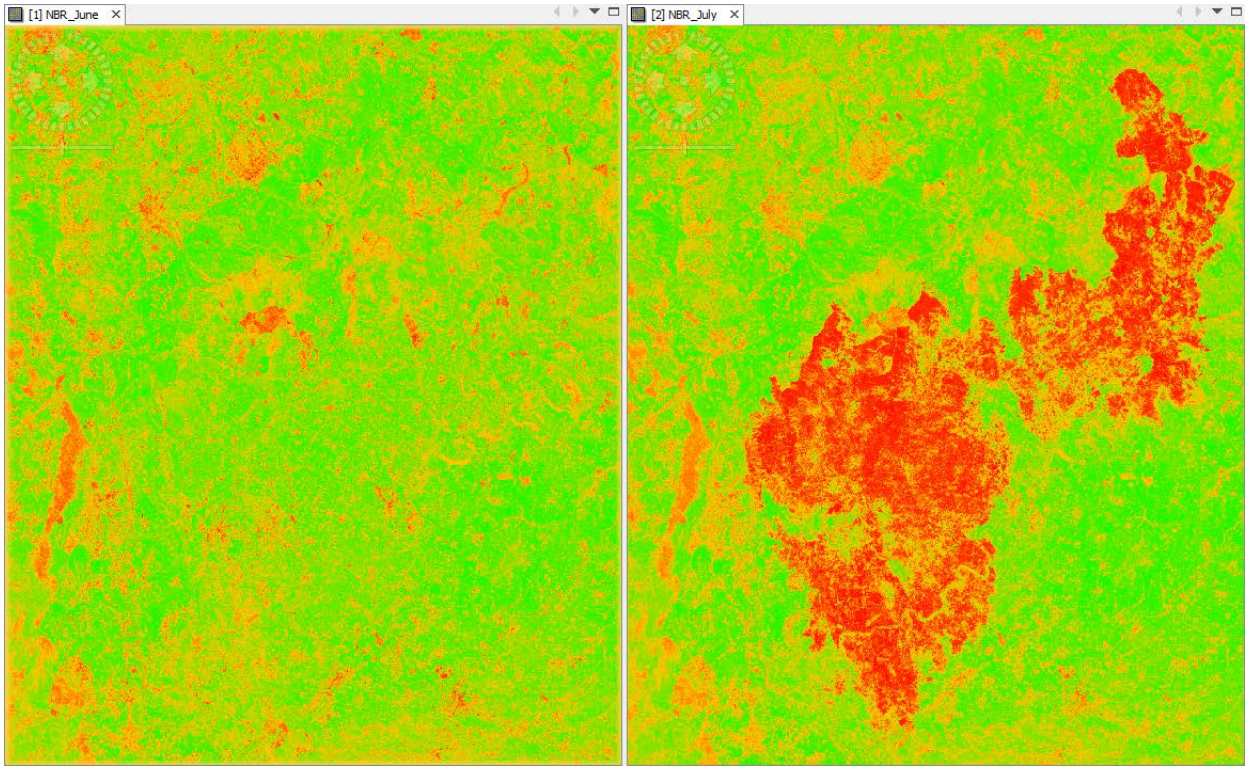
6.2. Select: "Colour Manipulation" tab

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

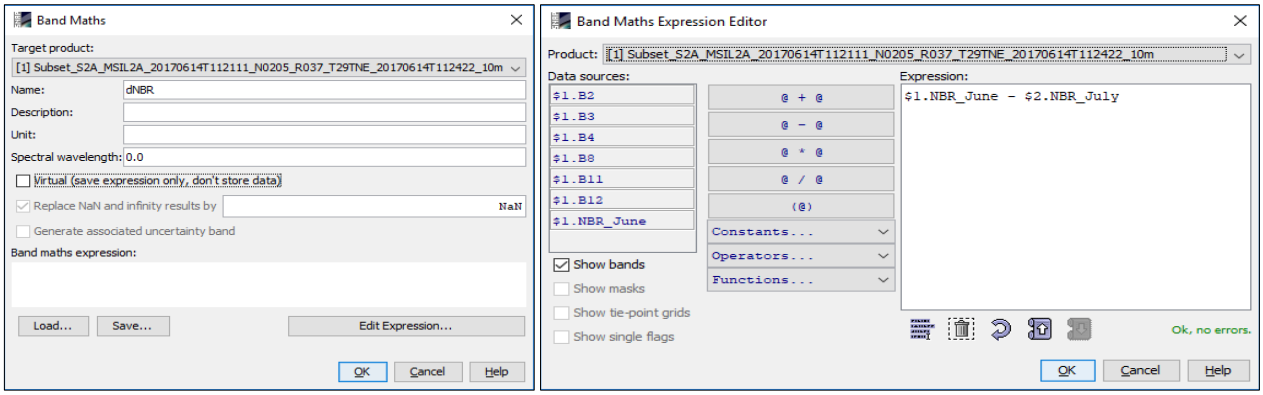
Normalized Burn Ratio is frequently used to estimate burn severity. Imagery collected before a fire will have very high near infrared band values and very low mid infrared band values and a Imagery collected over a forest after a fire will have very low near infrared band values and very high mid infrared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

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

The meaning of the ΔNBR 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.

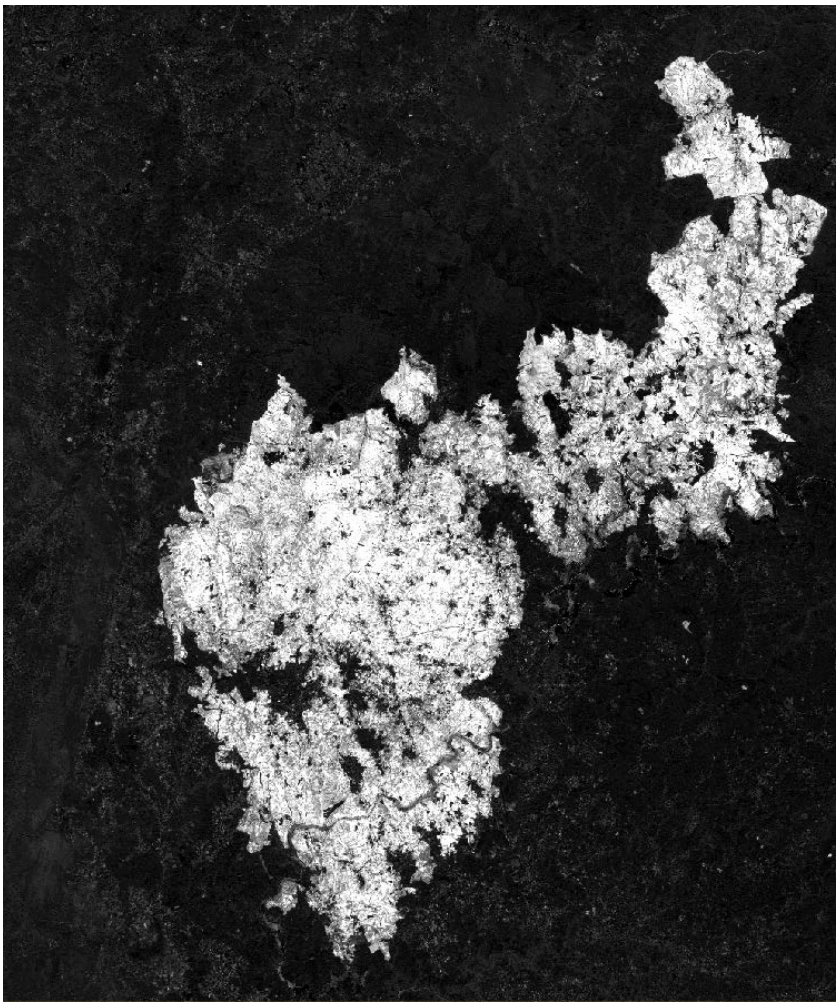
dNBR	Burn Severity
< -0.25	High post-fire regrowth
-0.25 to -0.1	Low post-fire regrowth
-0.1 to +0.1	Unburned
0.1 to 0.27	Low-severity burn
0.27 to 0.44	Moderate-low severity burn
0.44 to 0.66	Moderate-high severity burn
> 0.66	High-severity burn

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"



7.7. The symbols “$1.” and “$2.” are the links to the different products

7.8. Obtaining the following result



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

8. Colour Manipulation

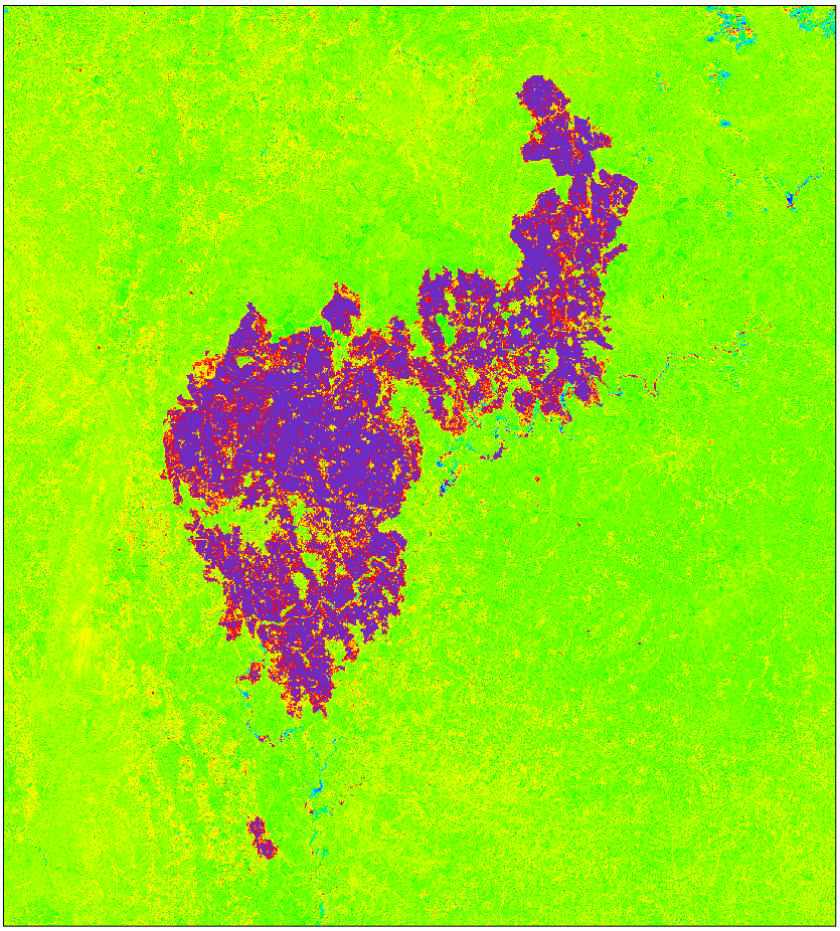
8.1. Select dNBR band displayed on the screen

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	



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
S3A_SL_1_RBT____20170618T220242_20170618T220542_20181004T042200_0179_019_058_____LR1_R_NT_003.SEN3

Sentinel-3

SLSTR Spectral Bands

Band	Central Wavelength (nm)	Bandwidth (nm)	Function	Comments		Resolution (metres)
S1	554.27	19.26	Cloud screening, vegetation monitoring, aerosol	VNIR	Solar Reflectance Bands	500
S2	659.47	19.25	NDVI, vegetation monitoring, aerosol			
S3	868.00	20.60	NDVI, cloud flagging,Pixel co-registration			
S4	1374.80	20.80	Cirrus detection over land	SWIR		
S5	1613.40	60.68	loud clearing, ice, snow,vegetation monitoring			
S6	2255.70	50.15	Vegetation state and cloud clearing			
S7	3742.00	398.00	SST, LST, Active fire	Thermal IR Ambient bands (200 K -320 K)		1000
S8	10854.00	776.00	SST, LST, Active fire			
S9	12022.50	905.00	SST, LST			
F1	3742.00	398.00	Active fire	Thermal IR fire emission bands		
F2	10854.00	776.00	Active fire			

An on-ground resolution of 0.5 km at nadir for all VIS and SWIR channels. Radiance measurements from these channels are used for both land and clouds daytime observations.

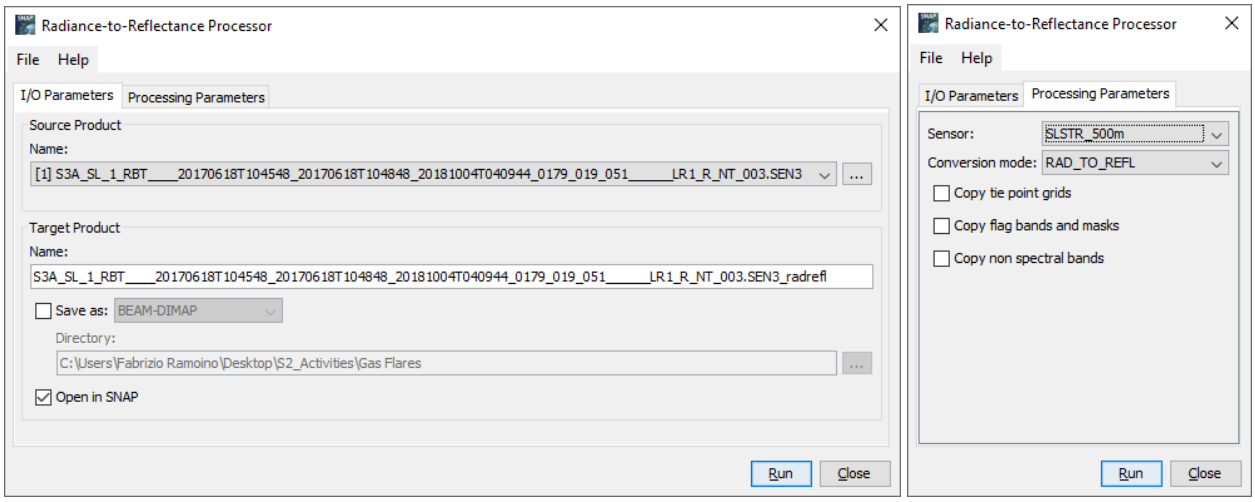
Two SWIR channels (at wavelengths of 2.25 μm and 1.375 μm) to allow improved cloud and aerosol detection to give more accurate SST/LST retrievals.

Two dedicated channels (F1 and F2) for fire and high temperature event monitoring at 1 km resolution (by extending the dynamic range of the 3.7 μm channel and including dedicated detectors at 10.8 μm that are capable of detecting fires up to ~650 K without saturation).

1. <u>Open files</u>
   1.1. 'File' / 'Open Product'
   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

2. <u>Radiance to Reflectance</u>
   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'



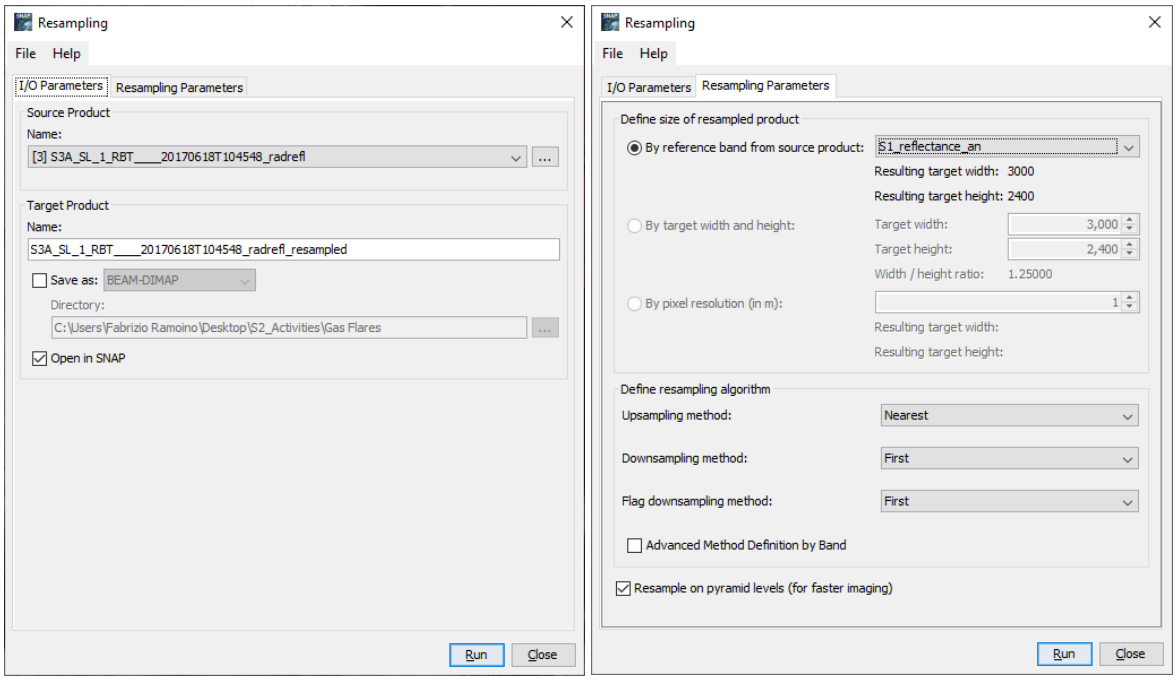
3. <u>Resampling</u>

   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'



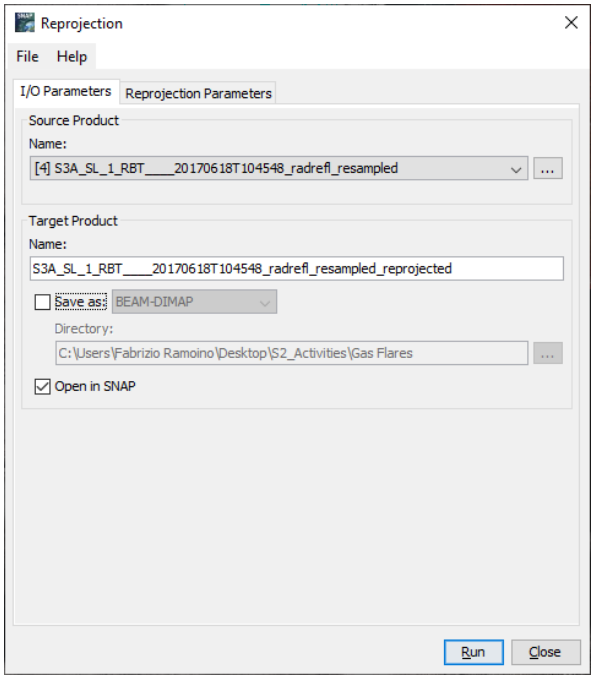
4. <u>Reproject</u>

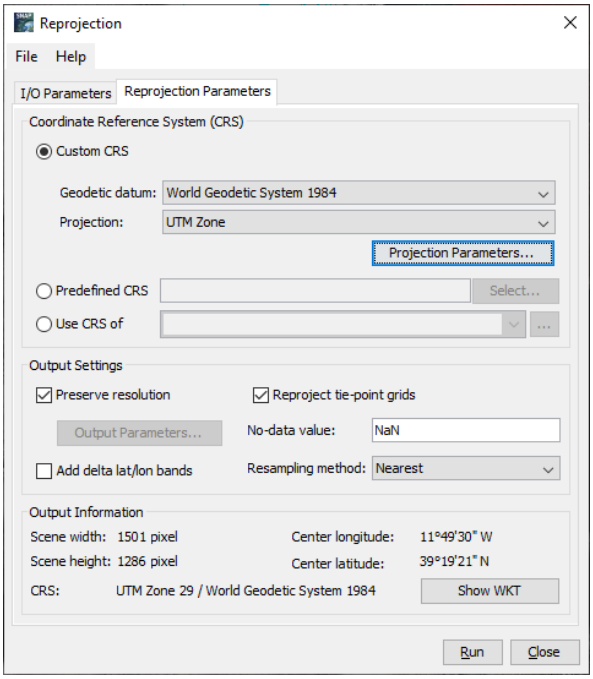
   Sentinel-3 L1b products are geolocated but they are not projected, for this reason we have to reproject choosing the same CRS of Sentinel-2 (UTM / WGS84) [Zone 29]

   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'





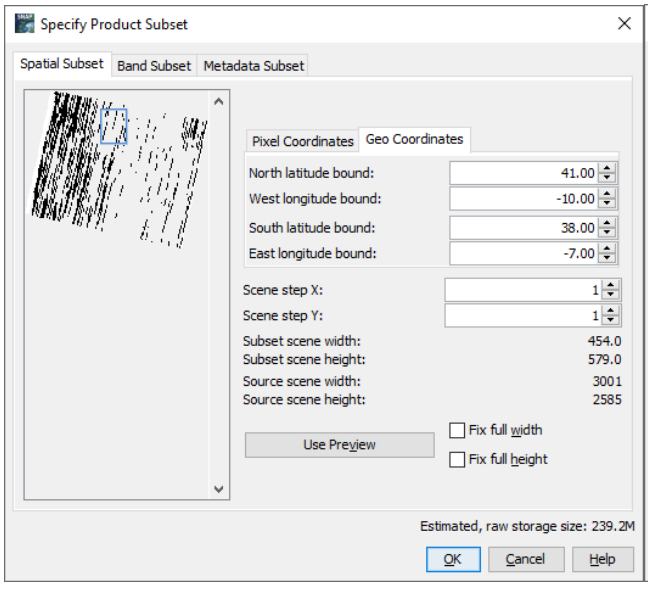
5. <u>Subset</u>

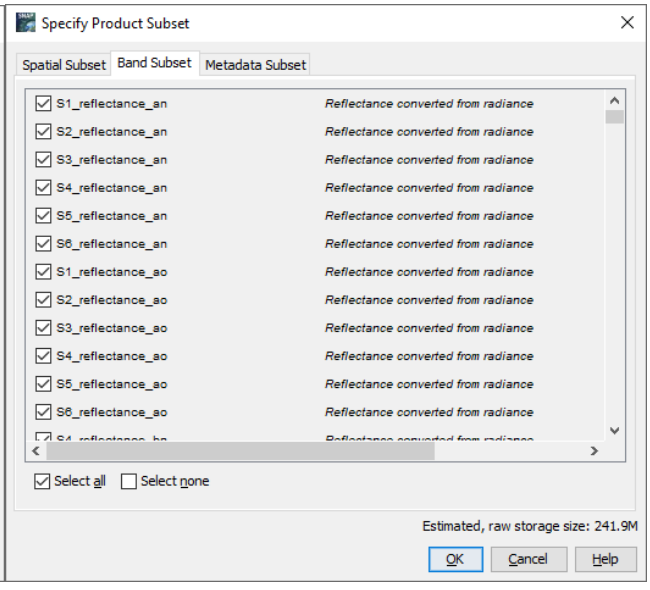
   We want to subset the product because we are interested in a small area and this will reduce the processing time. You will find the boundaries coordinates in the *'S3_Equations.txt'* file.

   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'





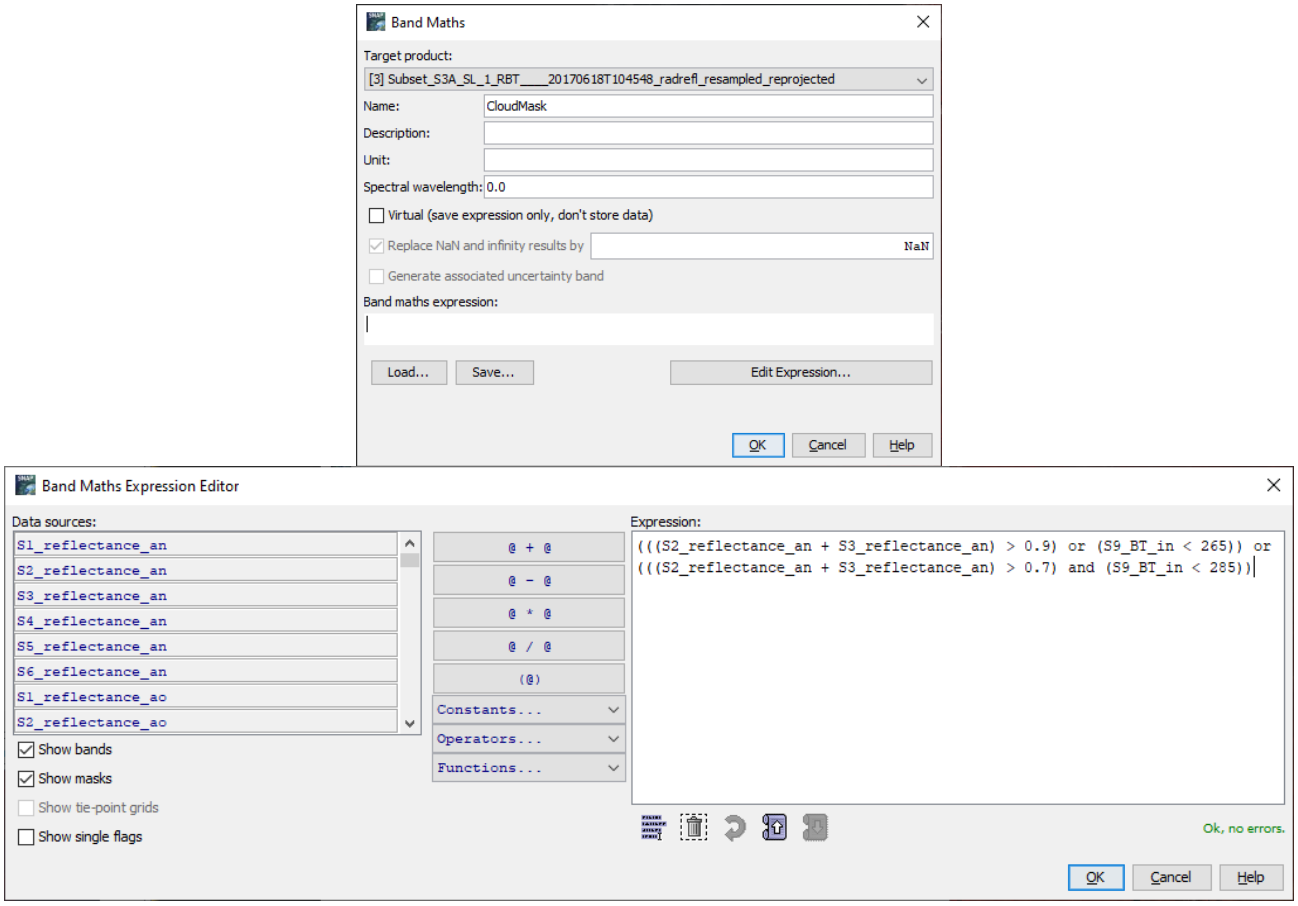
Now the next step is to calculate the **cloud mask** using a simple equation developed for day-time fire detection by Giglio et al. (2003b).

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

Where, $\boldsymbol{\rho_\lambda}$ and $\boldsymbol{T_\lambda}$ 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. <u>BandMaths (to calculate the cloud mask day-time)</u>
   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'



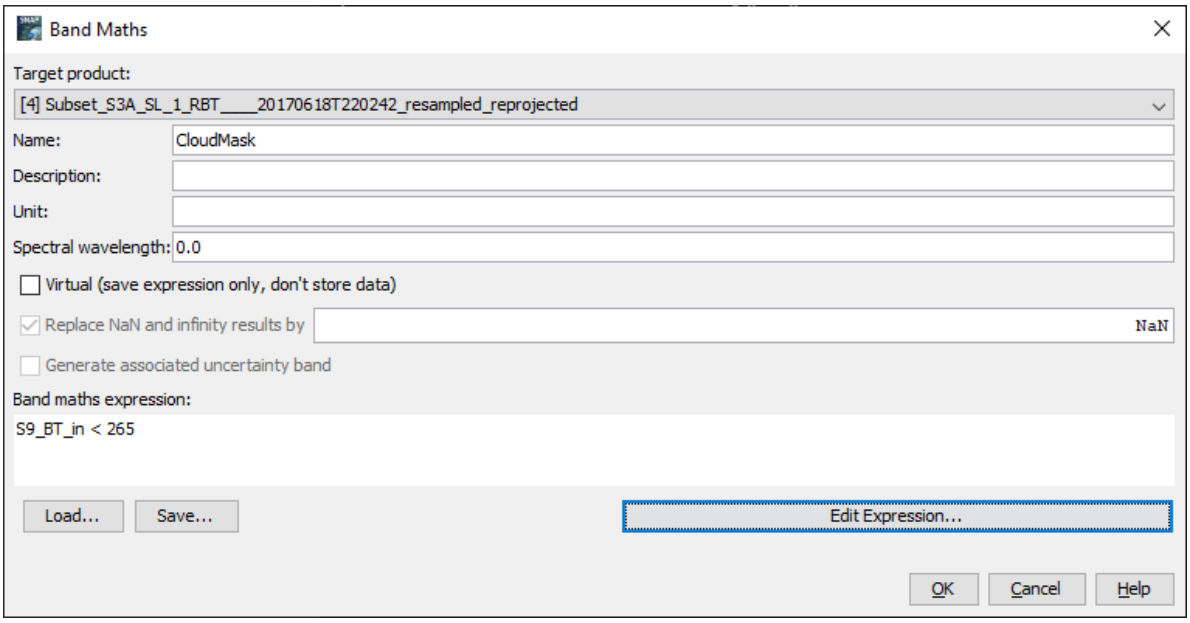
The new created band is added to the input product.
Select the product and click 'File' / 'Save Product'

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'

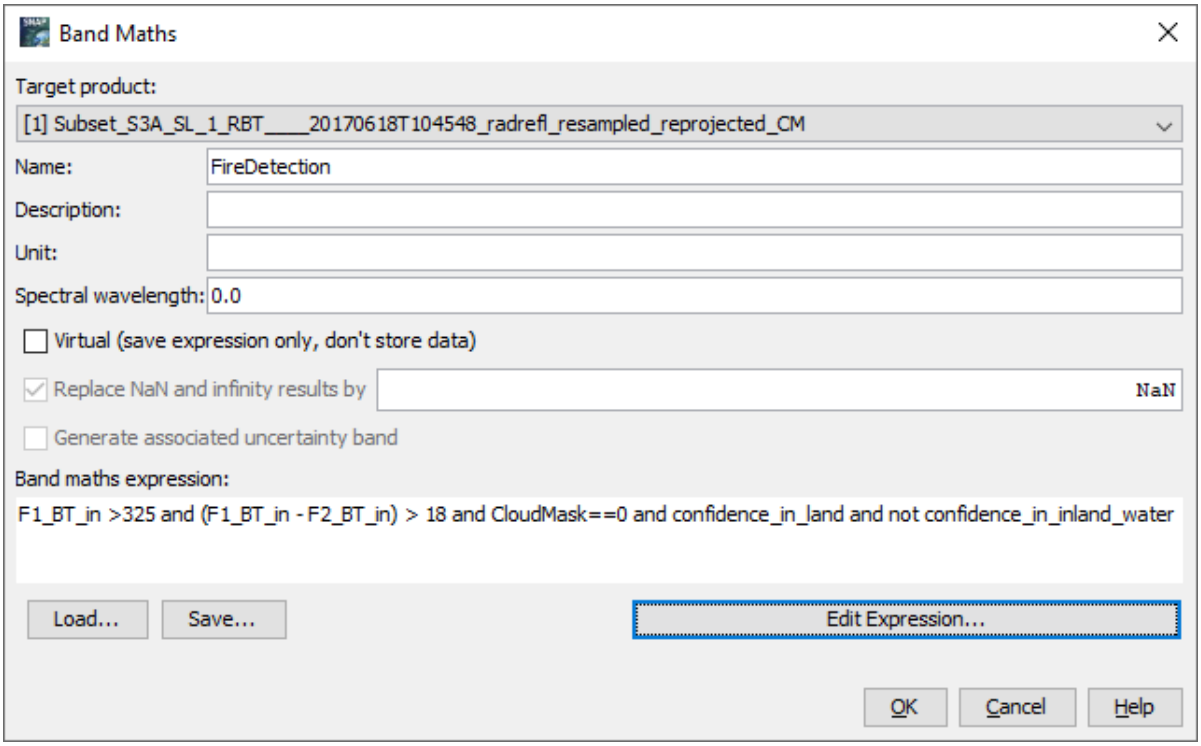


Now that we have our data pre-processed and with the related cloud mask we can work on active fire detection. We close all the open products on SNAP and open just the 2 intermediate results that includes the cloud mask:
\Day_2\S3\Intermediate_Results\Subset_S3A_SL_1_RBT____20170618T104548_radrefl_resampled_reprojected_CM.dim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

	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	*CloudMask==0*	*CloudMask==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'



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'