UNIVERSITY COURSE EARTH OBSERVATION WITH ESA MISSIONS

TUTORIAL FOR EXERCISE 3

Active Fire detection using Sentinel-3

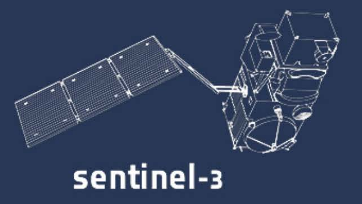

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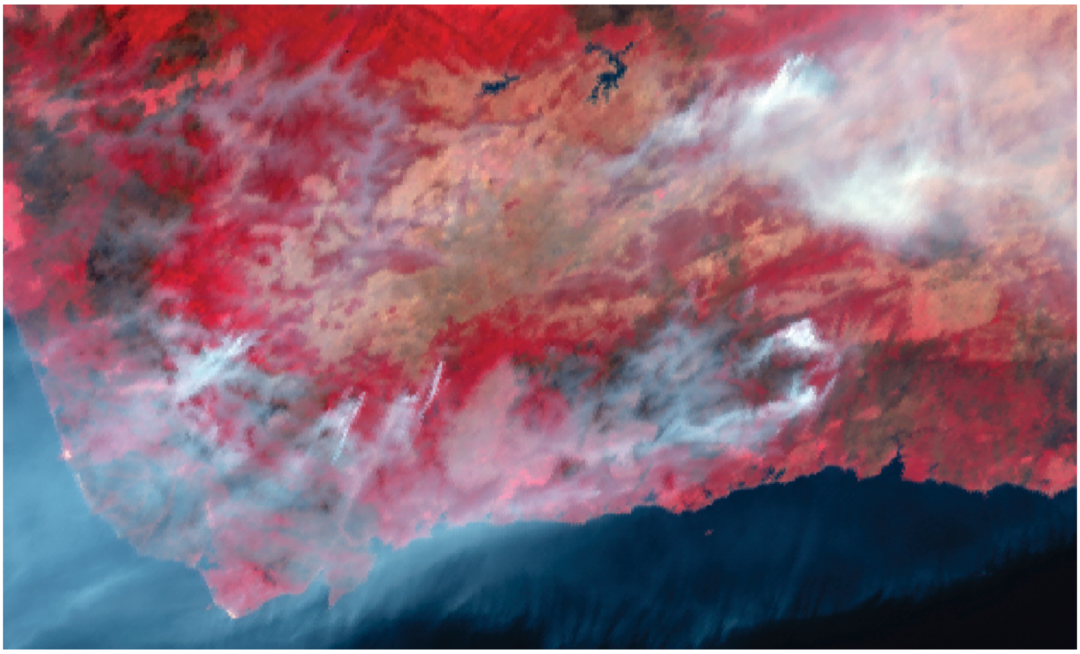
Table of Content

1 Exercise outline

In this exercise we will learn how to use Sentinel-3 Level 1B data products – full resolution, geo-located, radiometric measurements:

- We will convert radiation values to reflectance values, as these are input data into other algorithms.
- We will perform resampling of bands to the same pixel size.
- Then, we will perform reprojection to WGS 84, UTM Zone according to the image location.
- Bands S2, S3 and S9 will be used to create a cloud mask, which is a crucial step in the processing since clouds can be detected as false positive fire pixels in passive RS.

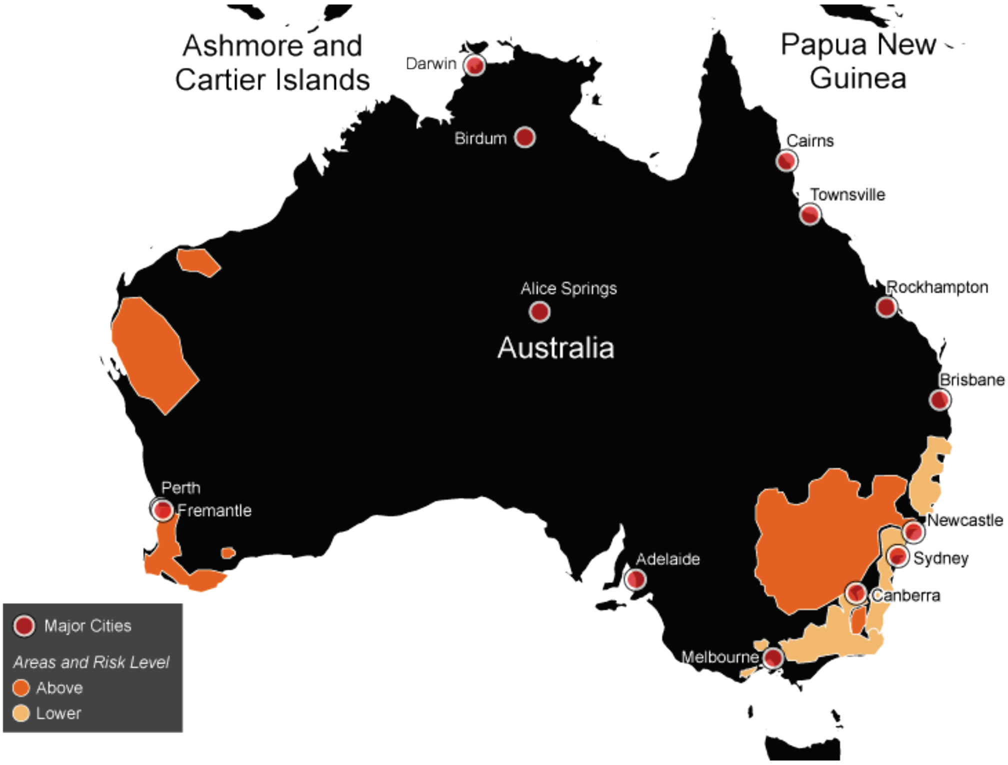
  Level 1B of the product contains cloud masks, which use an algorithm to flag positive cloud pixels rather than dense smoke.
- In the final step, F1 and F2 bands will be used to detect active fires.



2 Active Fire detection using Sentinel-3

Data from RS can play an important role in planning for and responding to wildfires on forest lands. Such data and derived products on tree cover, species, and volume/biomass estimates can be used to input spatially explicit fire load models. Once a wildfire becomes active, imagery acquired near real-time can be critical to fire management and control efforts.

In 2021, catastrophic wildfires hit Australia, resulting in loss of human and animal life, property damage, economic loss and damage to infrastructure.



2.1. Study area and image download

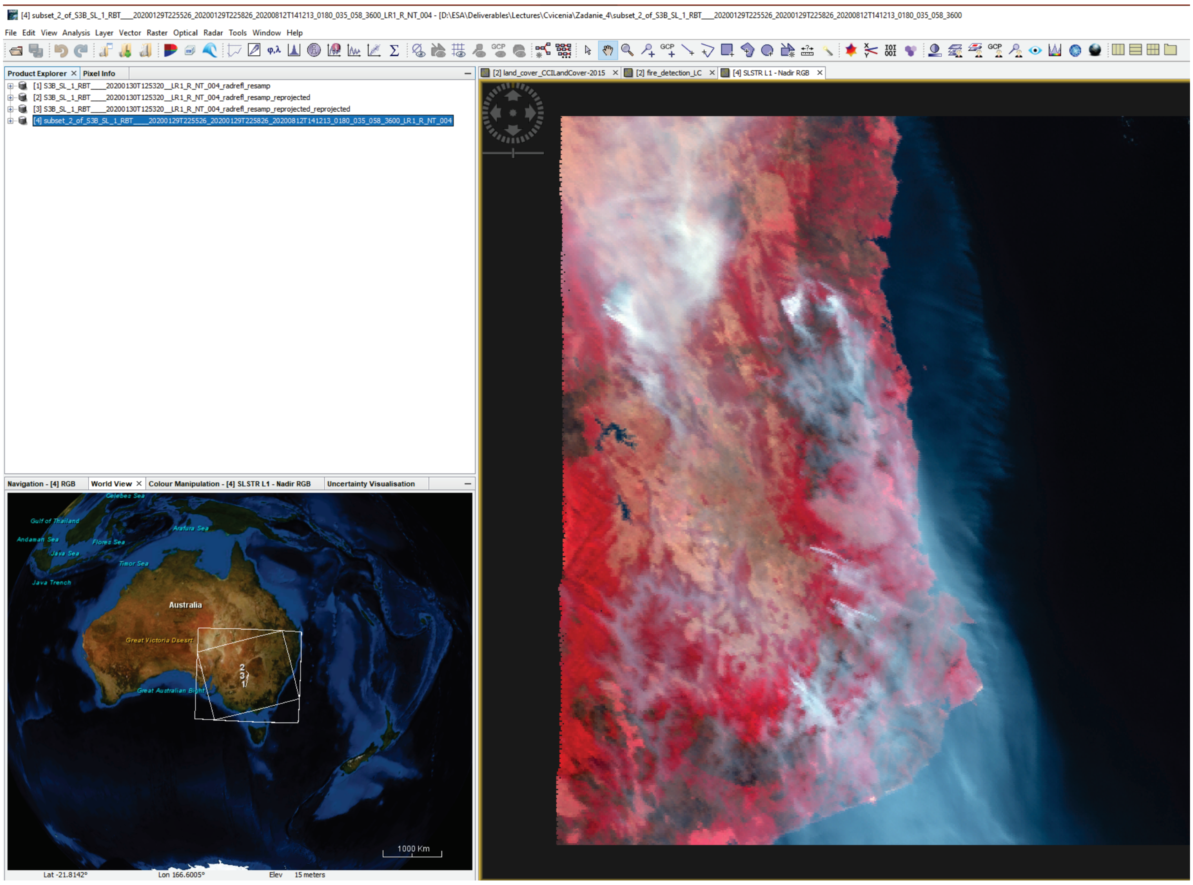
In this exercise, we will use 2 images from Sentinel-3 satellite, product line SL1_RBT, which detected active fires on 29.01.2020 at 22:55 (night image) and 30.01.2020 at 12:53 (day image).

These images can be downloaded from the Copernicus Open Access Hub.

S3B_SL_1_RBT____20200129T225526_20200129T225826_20200812T141213_0180_035_058_3600_LR1_R_NT_004

S3B_SL_1_RBT____20200130T125320_20200130T125620_20200812T142406_0179_035_066_5400_LR1_R_NT_004

[*https://scihub.copernicus.eu/dhus/#/home*]



Sentinel-3 SLSTR image:

- SLSTR - Sea and Land Surface Temperature Radiometer
- Nadir and oblique view
- 9 spectral bands:
    - S1 to S5 - 0.5 km grid
    - S6 to S9 and F1 and F2 (fire bands) - 1km grid with extended dynamic range so they are able to detect high temperature objects - i.e. active fires up to 650 Kelvin without saturation with sub-pixel accuracy.

Band	λ centre (μm)	Width (μm)	Function	Comments		Res. (m)
S1	0.555	0.02	Cloud screening, vegetation monitoring, aerosol	Visible Near IR	Solar reflectance bands	500
S2	0.659	0.02	NDVI, vegetation monitoring, aerosol			
S3	0.865	0.02	NDVI, cloud flagging, Pixel co-registration			
S4	1.375	0.015	Cirrus detection over land	Short-Wave IR		
S5	1.61	0.06	Cloud clearing, ice, snow, vegetation monitoring			
S6	2.25	0.05	Vegetation state and cloud clearing			
S7	3.74	0.38	SST, LST, Active fire	Thermal infra-red Ambient bands (200 K - 320 K)		1000
S8	10.85	0.9	SST, LST, Active fire			
S9	12	1	SST, LST			
F1	3.74	0.38	Active fire	Thermal infra-red fire emission bands		
F2	10.85	0.9	Active fire			

2.2. Image pre-processing

Radiation is the amount of radiation coming from the sensing area. The upper atmosphere reflectance (or *Top Of Atmosphere reflectance*) is the reflectance measured by a sensor flying higher than the Earth's atmosphere. These reflectance values will include the effect from clouds and atmospheric aerosols and gases.

$$Radiance = pixelValue * \cos(radians(incidenceAngle)) * solarIrradiance * scale / (\pi * d_2)$$

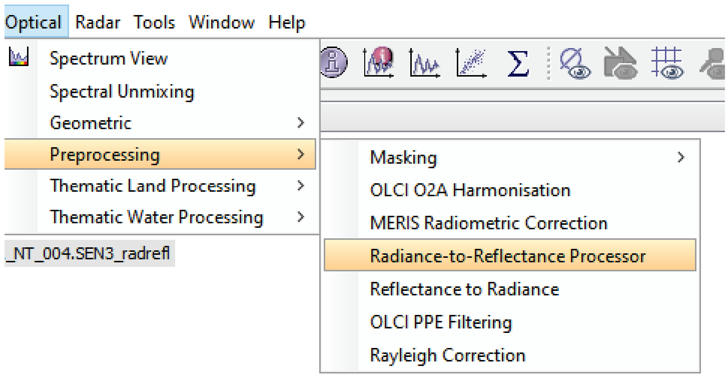
where:

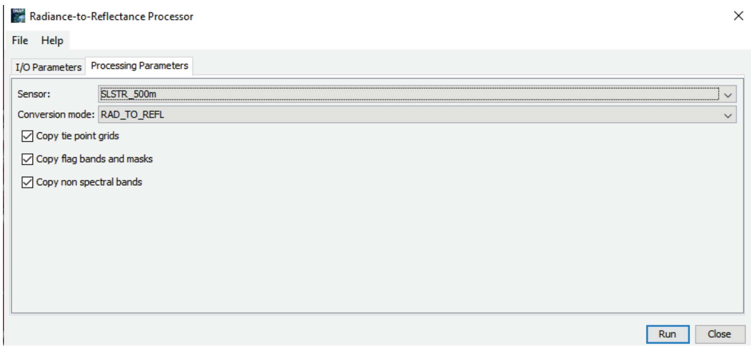
$d_2 = 1.0 / U$ (the sun-earth distance)

solarIrradiance = the mean solar exoatmospheric irradiances for each band

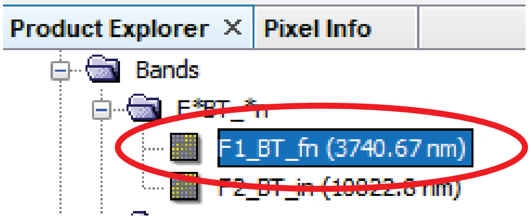
scale = 1 / (0.001 * 1000) = 1 (default)

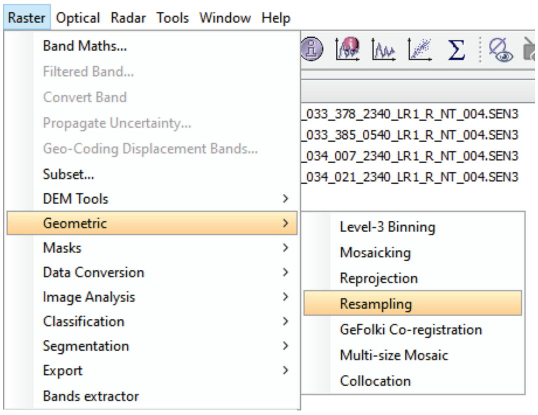
In the case of a day image, it is necessary to convert the radiance values to reflectance values.

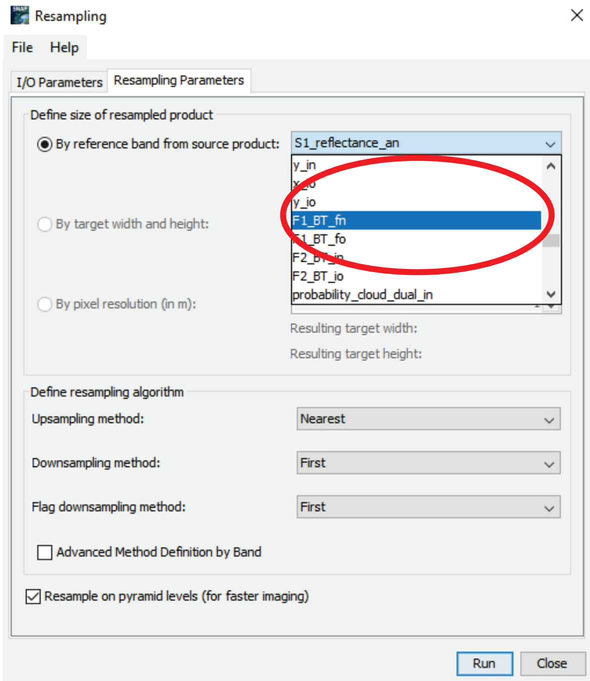




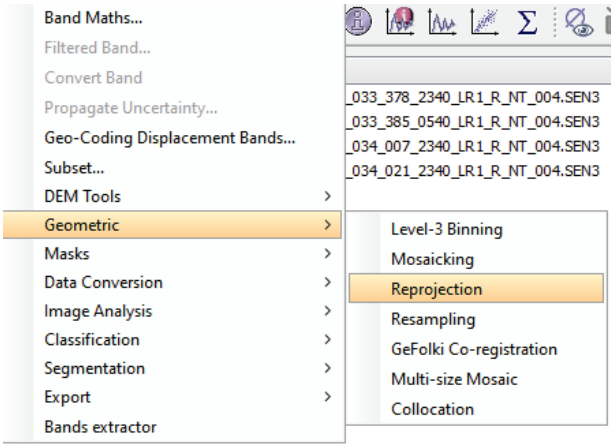
Then, we can do resampling to the same pixel size using *Raster - Geometric – Resampling*.

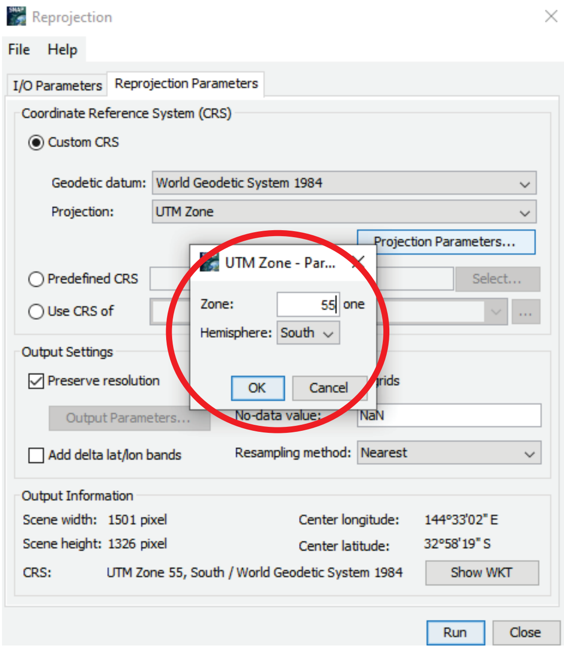


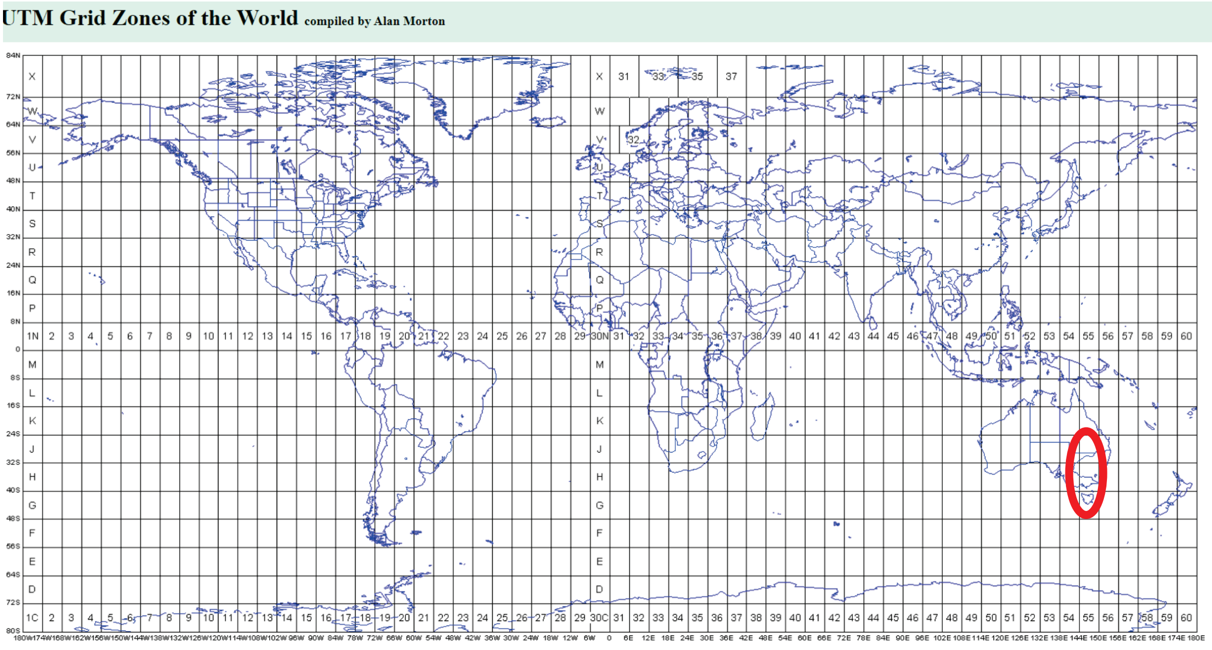




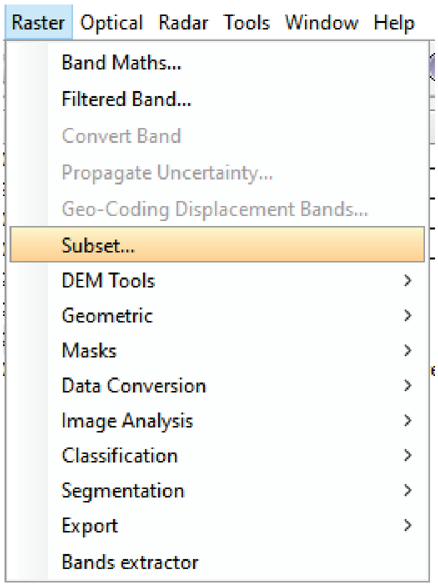
In the next step, we will Make a reprojection to WGS 84, UTM zone 55 South for the region of Australia.

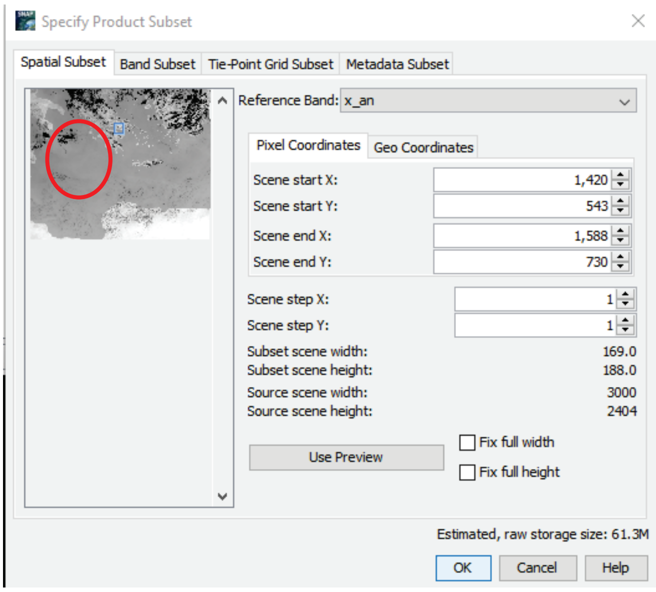






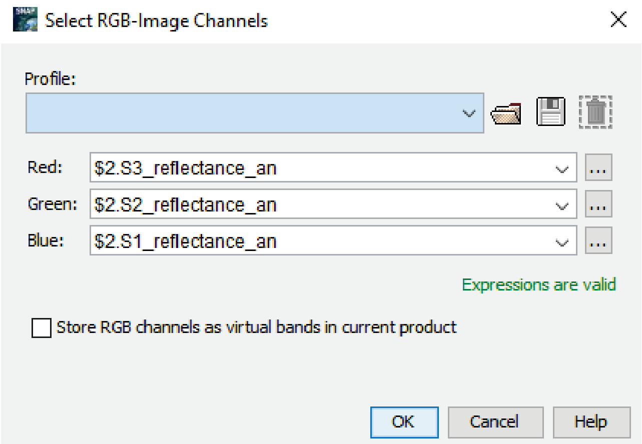
Then, we will create a subset by setting the active window:

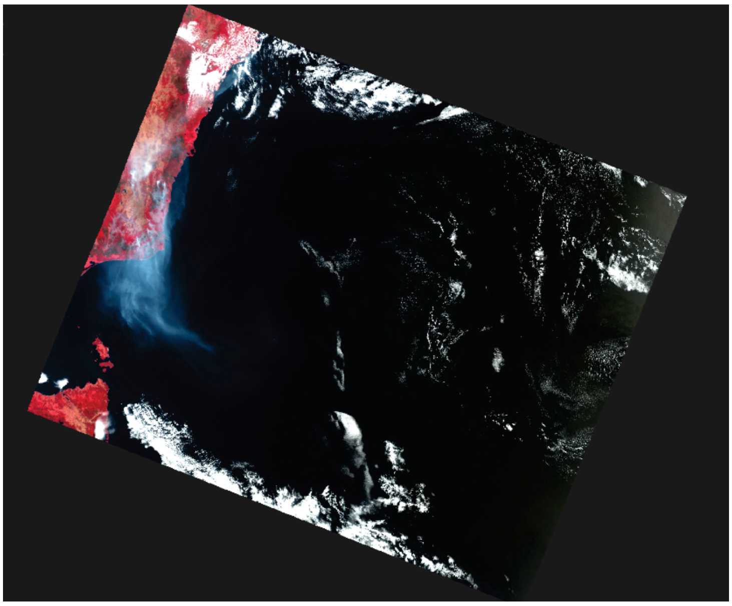




2.3. Processing the image

Open the visible and near-IR and shortwave IR band product.





We use a test to create a cloud mask for the time of day, employing an algorithm combining spectral reflectance bands with wavelengths of 0.65 µm and 0.89 µm and applying thresholds of 0.7 and 0.9 to exclude cloud pixels and a thermal band of 12 µm. Two theorems are established where each pixel is tested to see if it falls within the specified values. If it does, the pixel is determined to be a "cloud".

- We will use simple cloud test developed for daytime fire detection by Giglio et al. (2003b).

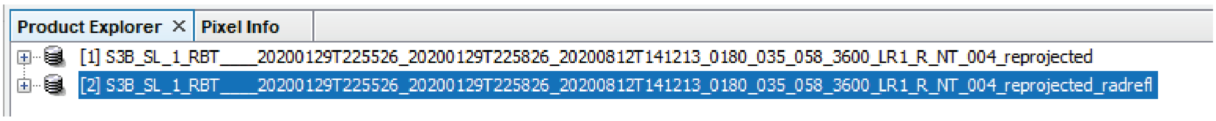
$$\{(\rho_{0.65} + \rho_{0.86} > 0.9)\ OR\ (T_{12} < 265\ K)\}$$
$$OR$$
$$\{(\rho_{0.65} + \rho_{0.86} > 0.7)\ AND\ (T_{12} < 285\ K)\}$$

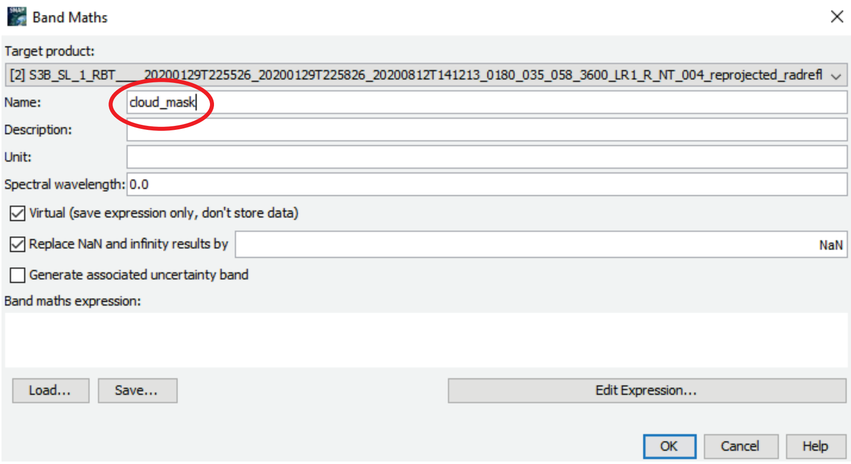
- Where, ρ_λ and T_λ correspond to reflectance and thermal bands (brightness temp.) at certain wavelength (λ [µm]).
- **Brightness temperature** – the temperature (K) of a black body "emitting" the same amount of radiance as the target pixel

Source: ESA, https://www.youtube.com/watch?v=l_WiXEsLHaE&t=3000s

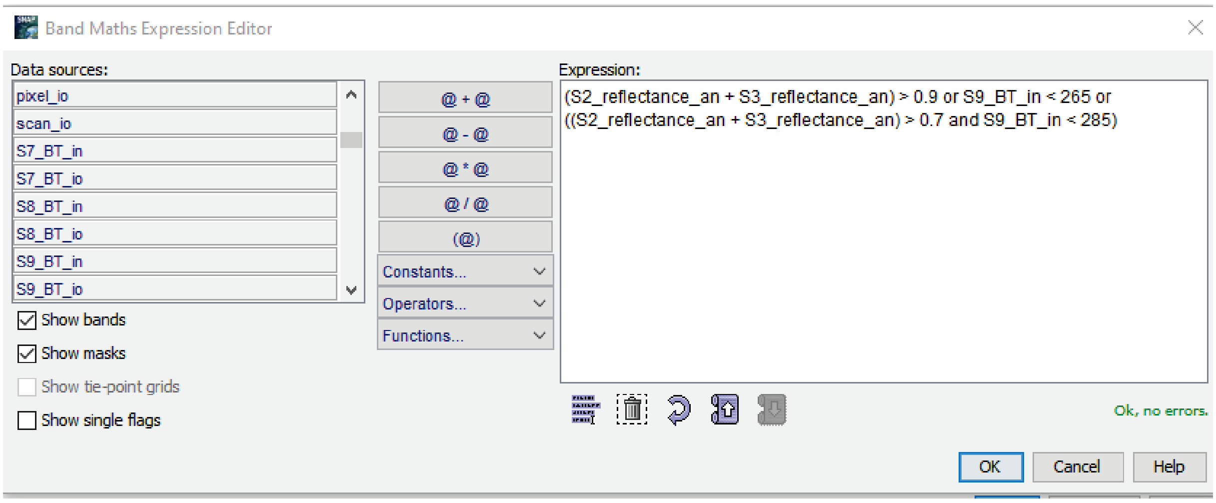
The S3 thermal bands indicate the brightness temperature of the reflected radiation, which is converted to the temperature that would be produced by a blackbody. The value of T_{12} is in Kelvin.

Then, we will use *BandMath*: cloud_mask

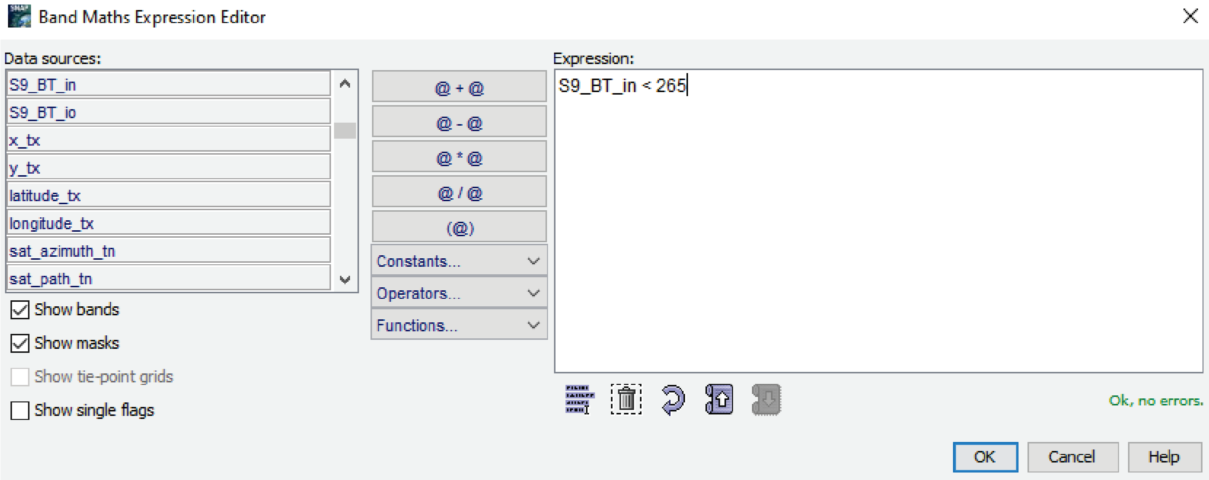




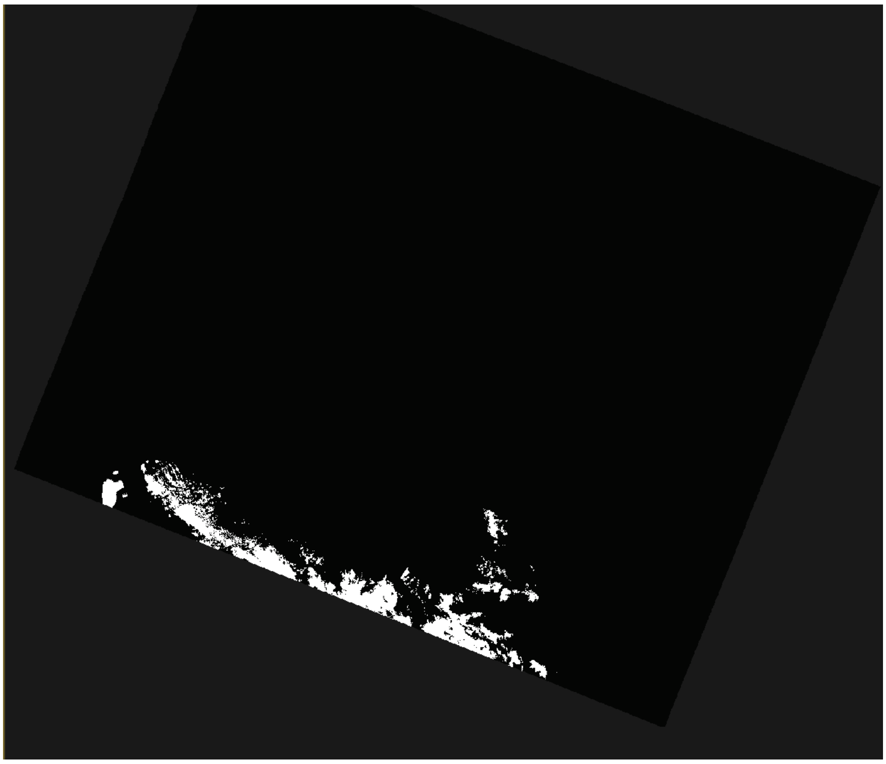
Cloud_mask for day image:



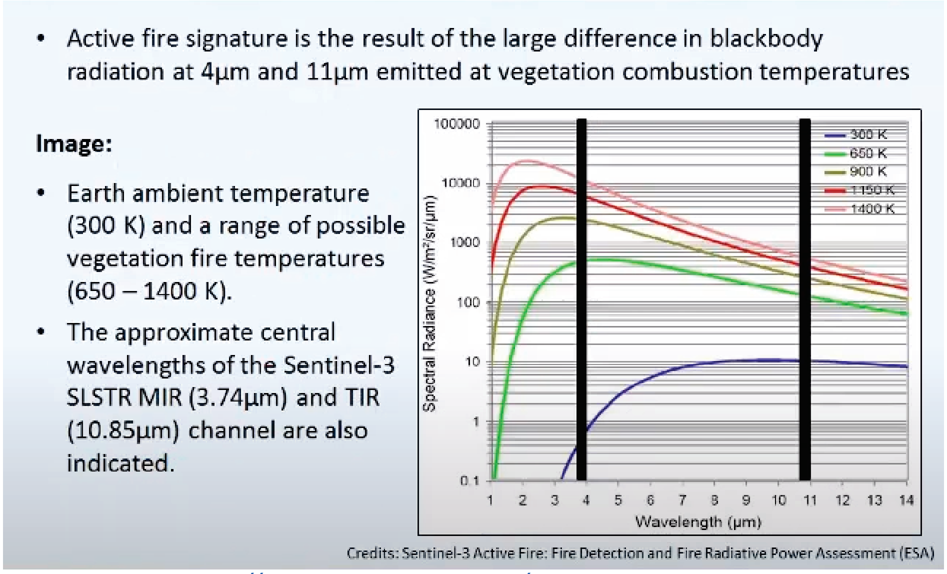
Cloud_mask for night image:



And the resulting cloud mask should look like:

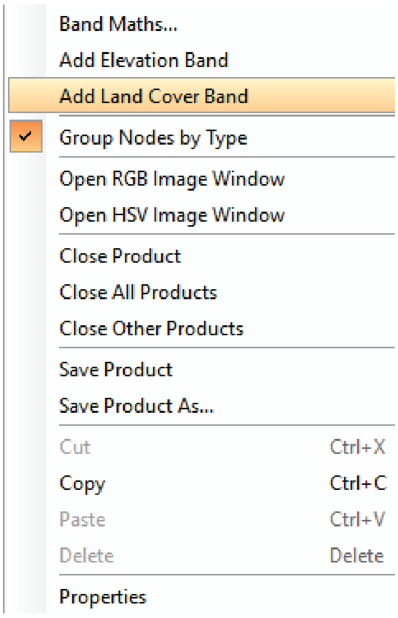


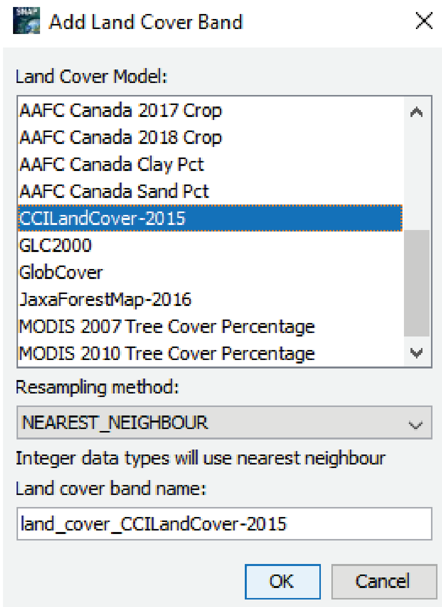
The blue curve in the next figure shows the radiation of the Earth and the green curve shows the radiation of burning vegetation. The plot shows the significant difference between the two types of radiation at wavelengths of 3.74 µm and 10.85 µm.



Source: ESA, https://www.youtube.com/watch?v=l_WiXEsLHaE&t=3000s

Now, we will open of the CCI Land Cover 2015 layer – classified land cover map:



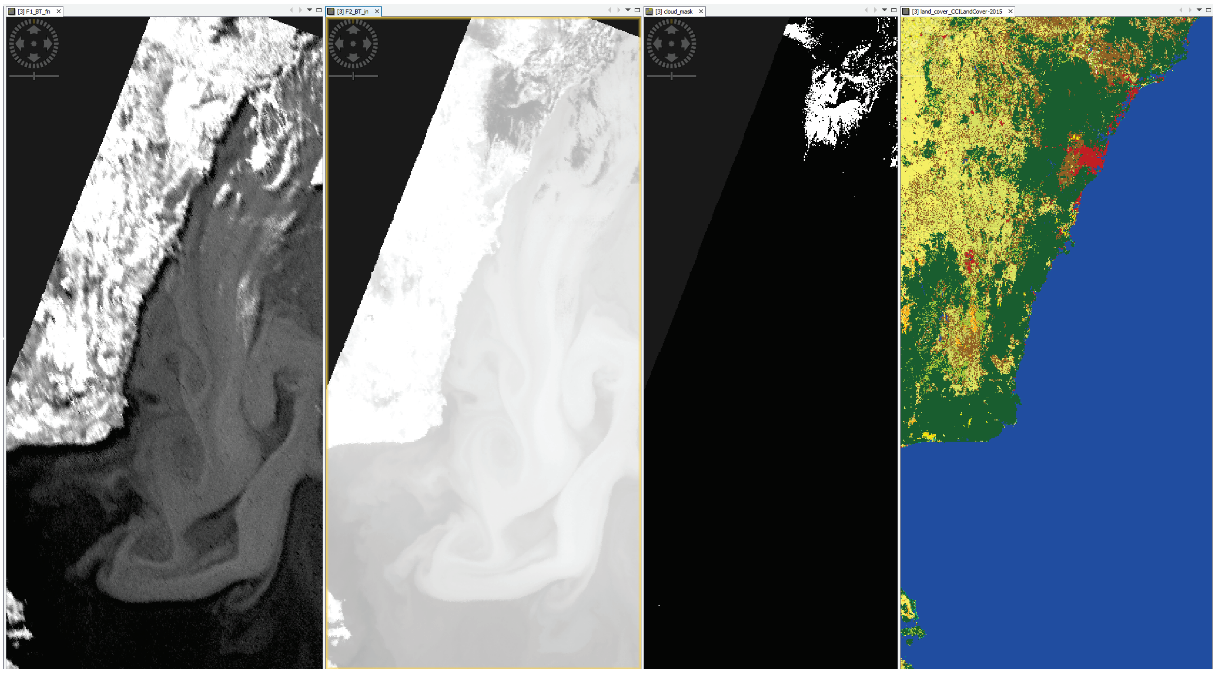


CCI_land_cover_2015 land cover contains classes of trees, shrubs and plants that are included in the computational algorithm.

Label	Colour	Value	Freque...
0 No data		0	0.000%
10 Cropland, rainfed		10	0.000%
11 Herbaceous cover		11	0.000%
12 Tree or shrub cover		12	0.000%
20 Cropland, irrigated or post?...		20	0.000%
30 Mosaic cropland (>50%) / n...		30	0.000%
40 Mosaic natural vegetation (...		40	0.000%
50 Tree cover, broadleaved, e...		50	0.000%
60 Tree cover, broadleaved, d...		60	0.000%
61 Tree cover, broadleaved, d...		61	0.000%
62 Tree cover, broadleaved, d...		62	5.705%
70 Tree cover, needleleaved, ...		70	10.054%
71 Tree cover, needleleaved, ...		71	2.492%
72 Tree cover, needleleaved, ...		72	0.000%
80 Tree cover, needleleaved, ...		80	0.000%
81 Tree cover, needleleaved, ...		81	0.000%
82 Tree cover, needleleaved, ...		82	0.000%
90 Tree cover, mixed leaf type...		90	0.000%
100 Mosaic T and shrub (>50...		100	0.000%
110 Mosaic herbaceous cover (...		110	0.000%
120 Shrubland		120	2.692%
121 Shrubland evergreen		121	0.000%
122 Shrubland deciduous		122	0.000%
130 Grassland		130	0.000%
140 Lichens and mosses		140	0.000%
150 Sparse vegetation (tree, s...		150	0.000%
151 Sparse tree (<15%)		151	0.000%
152 Sparse shrub (<15%)		152	0.000%
153 Sparse herbaceous cover ...		153	0.000%
160 Tree cover, flooded, fresh...		160	0.000%
170 Tree cover, flooded, salin...		170	5.668%
180 Shrub or herbaceous cove...		180	0.000%
190 Urban areas		190	0.000%
200 Bare areas		200	0.000%
201 Consolidated bare areas		201	0.000%
202 Unconsolidated bare areas		202	0.000%
210 Water bodies		210	0.000%
220 Permanent snow and ice		220	0.000%

Now, we can open all 4 products, and display them all together by horizontal tiling:

- Cloud mask, land cover CCA, F1_BT_in and F2_BT_in



2.4. Detecting fire

For the fire detection, we will use BandMaths for day and night image:

BandMath: fire_detection_LC for day image:

F1_BT_fn > 325 and (F1_BT_fn- F2_BT_in) > 18 and cloud_mask == 0 and 'land_cover_CCILandCover-2015' >= 50 and 'land_cover_CCILandCover-2015' <= 130

BandMath: fire_detection_LC for night image:

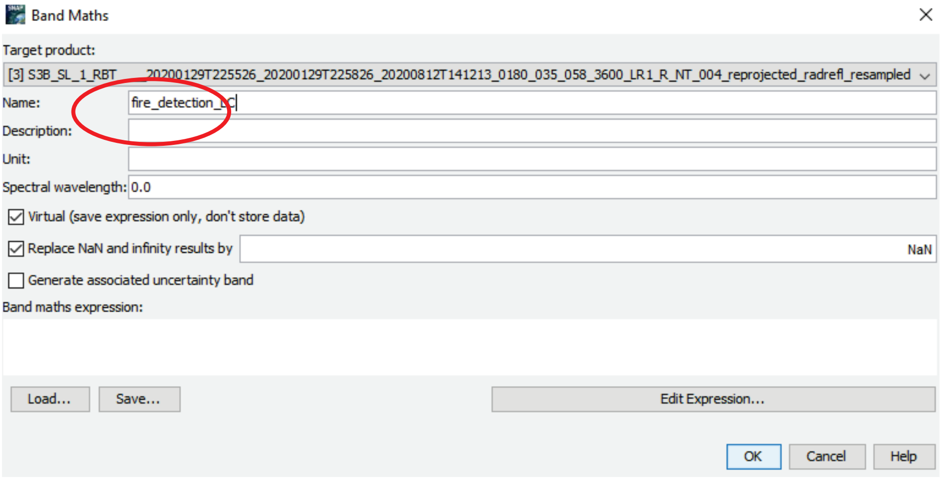
F1_BT_fn > 315 and (F1_BT_fn- F2_BT_in) > 15 and cloud_mask == 0 and 'land_cover_CCILandCover-2015' >= 50 and 'land_cover_CCILandCover-2015' <= 130

These BandMaths are based on determining the condition for active fire pixel detection on all 4 data products:

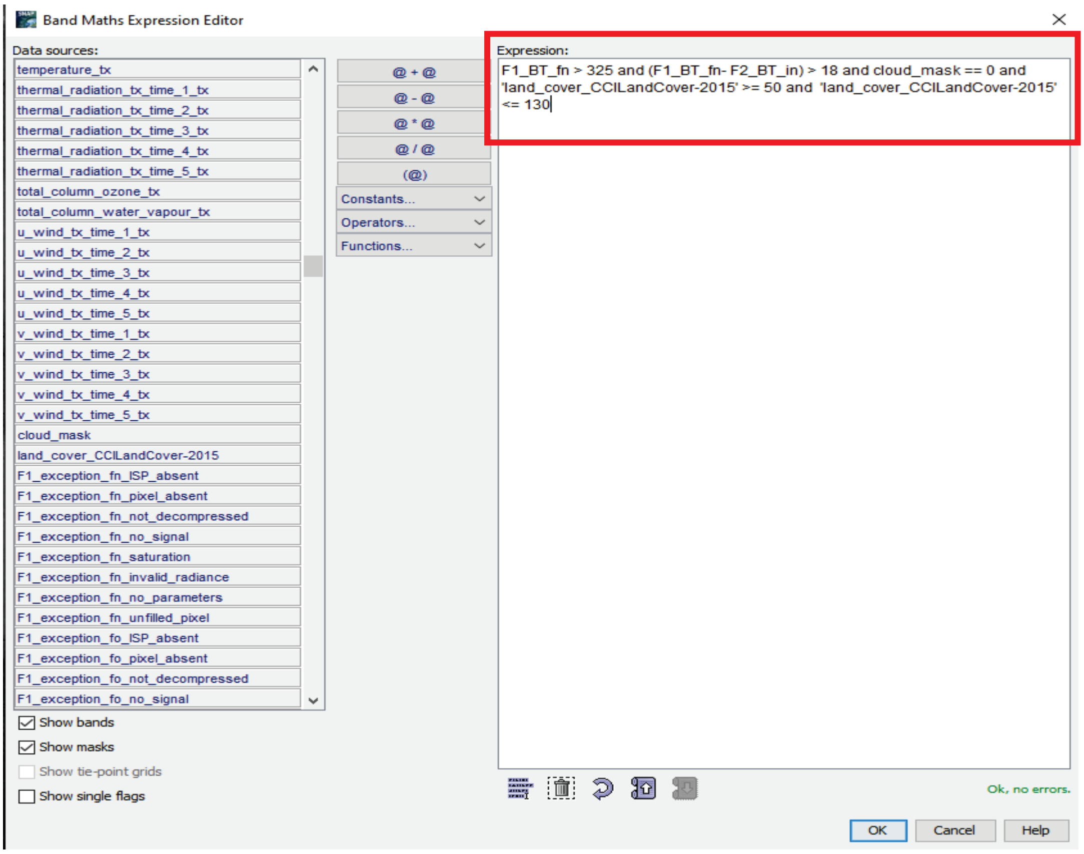
	DAY	NIGHT
Initial test	$T_4 > 325\ K$	$T_4 > 315\ K$
Eliminate warm background	$(T_4 - T_{11}) > 18\ K$	$(T_4 - T_{11}) > 15\ K$
Eliminate clouds	*cloud_mask == 0*	*cloud_mask == 0*
Eliminate non-forest pixels	*'land_cover_CCILandCover-2015' >= 50 and 'land_cover_CCILandCover-2015' <= 130*	*'land_cover_CCILandCover-2015' >= 50 and 'land_cover_CCILandCover-2015' <= 130*

Source: ESA, https://www.youtube.com/watch?v=l_WiXEsLHaE&t=3000s

Now we can create an active fire detection mask.

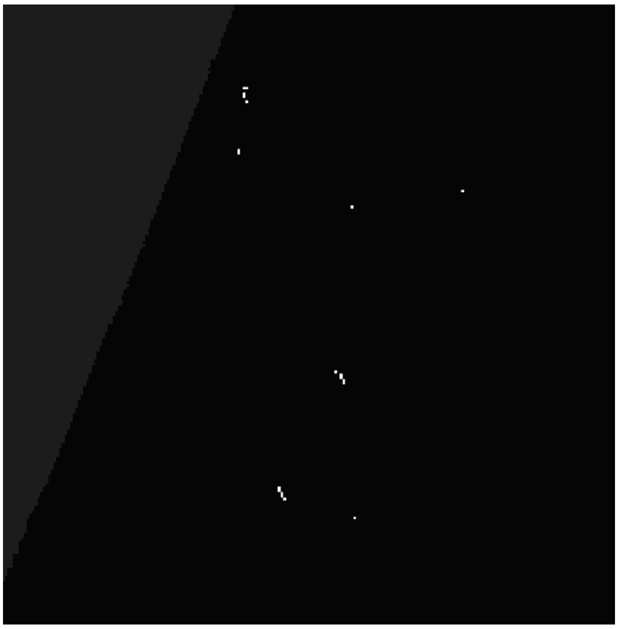


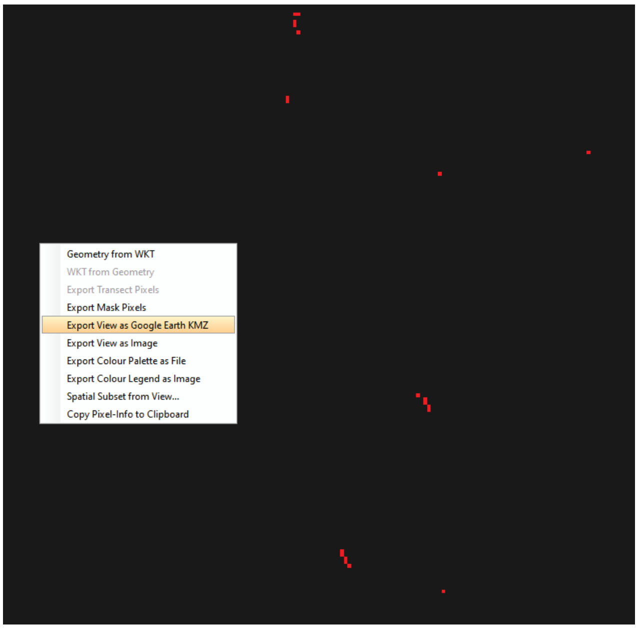
By determining the condition for finding pixels of active fire:



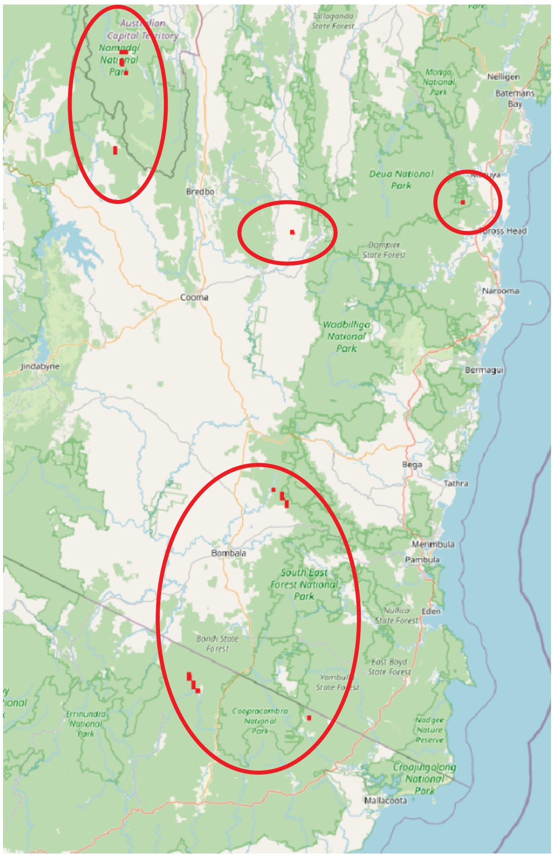
2.5. Visualisation of results

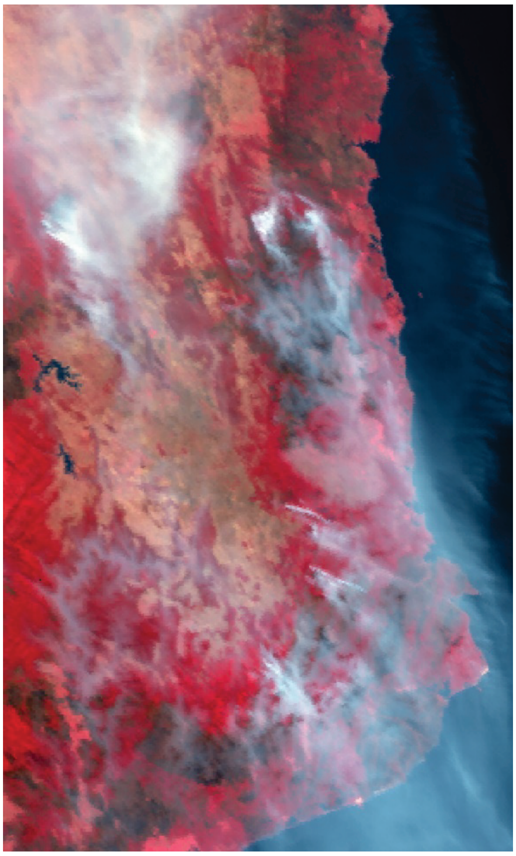
By opening the resulting image we can display active fire pixels and export it to *.kmz or GeoTIFF format.





The resulting QGIS display with pixel location of the active fire on a given day and the comparison with the Sentinel 3 satellite imagery.





THANK YOU FOR FOLLOWING THE EXERCISE!