TAT-11: Earth Observation and Machine Learning for Disaster Mapping
Mediterranean Agronomic Institute of Chania (CIHEAM Chania)
14–17 July 2024, Chania

Tutorial: Mapping recently burned area with pair of Sentinel-2 imagery

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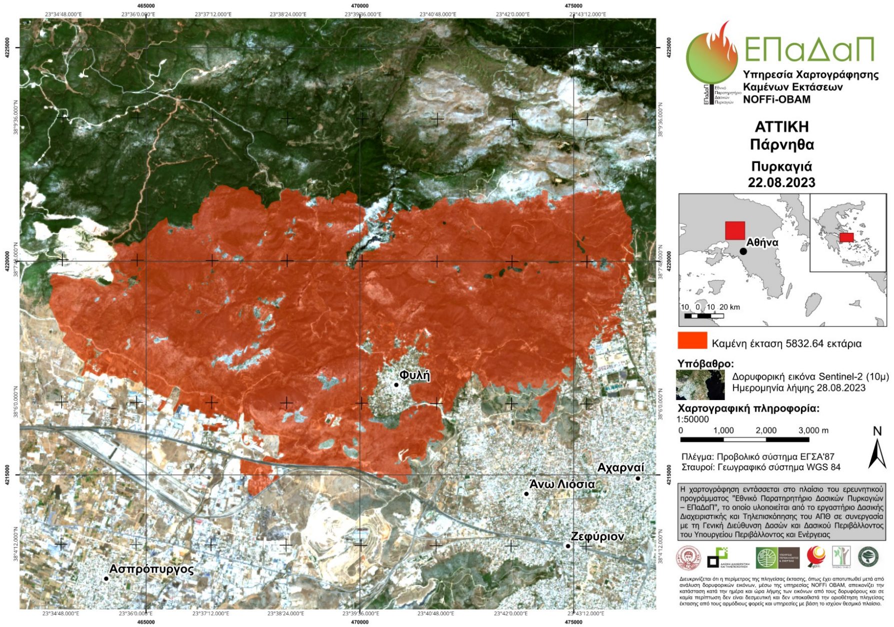
Objective

- The objective: Quickly map burn scar using a pre-fire and a postfire Sentinel-2 image in QGIS
- Test case: Parnitha mountain wildfire in Greece (northeast of Athens) in 2023 (started at 22/08/2023)
- Pre-fire image: 18/08/2023
- Postfire image: 28/08/2023
- Methodology: thresholding the difference Normalized Burn Ratio (dNBR) image



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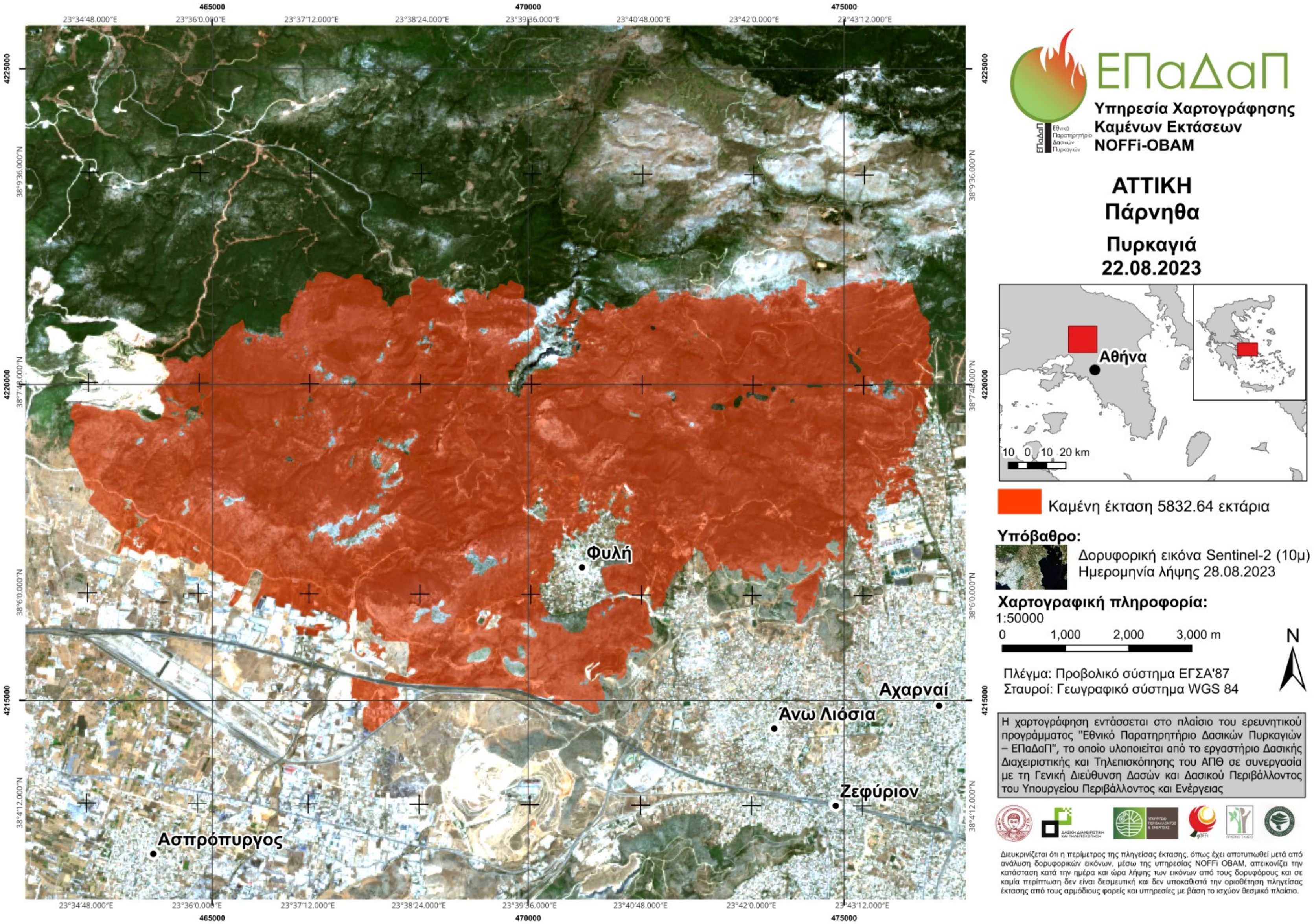
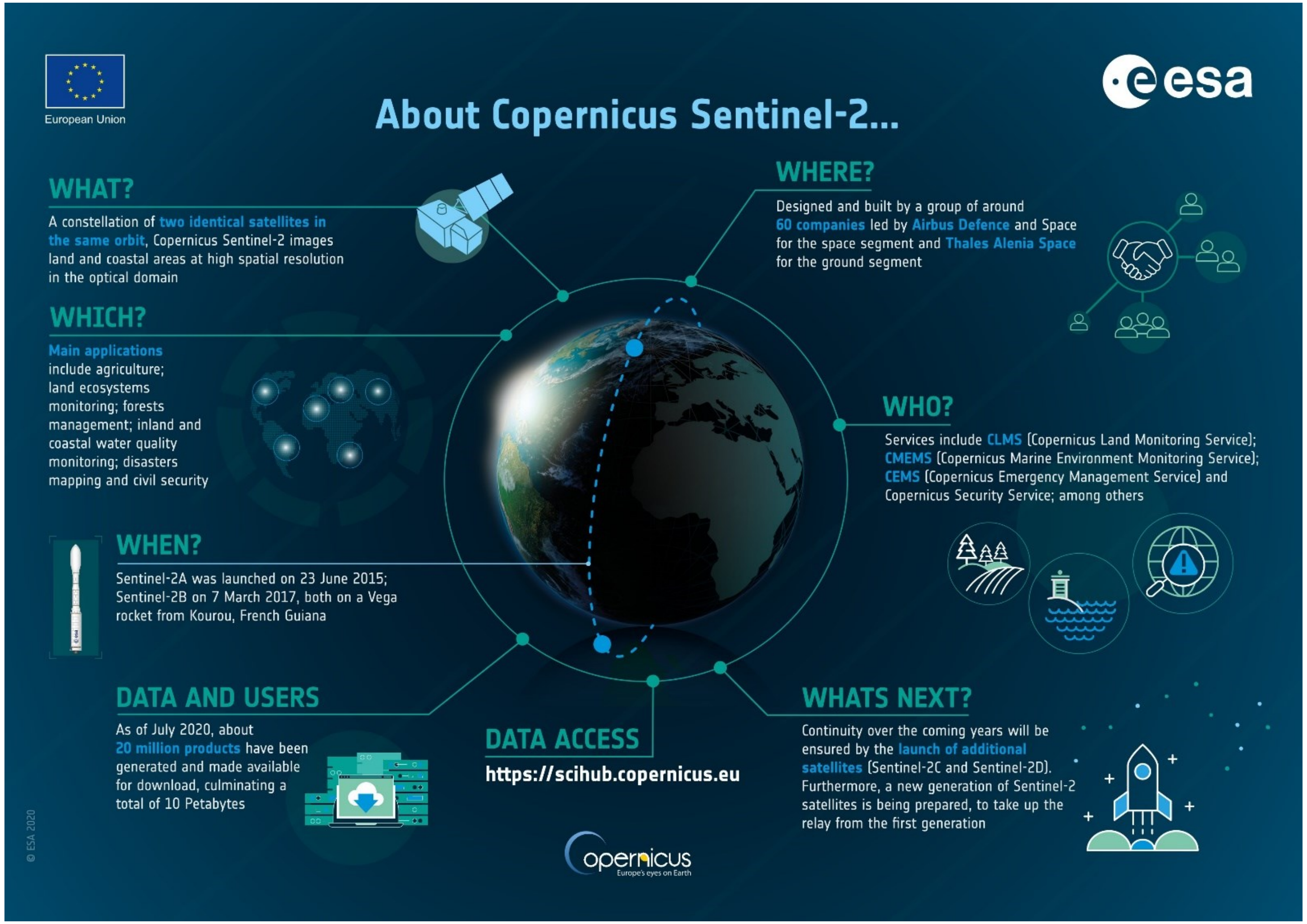


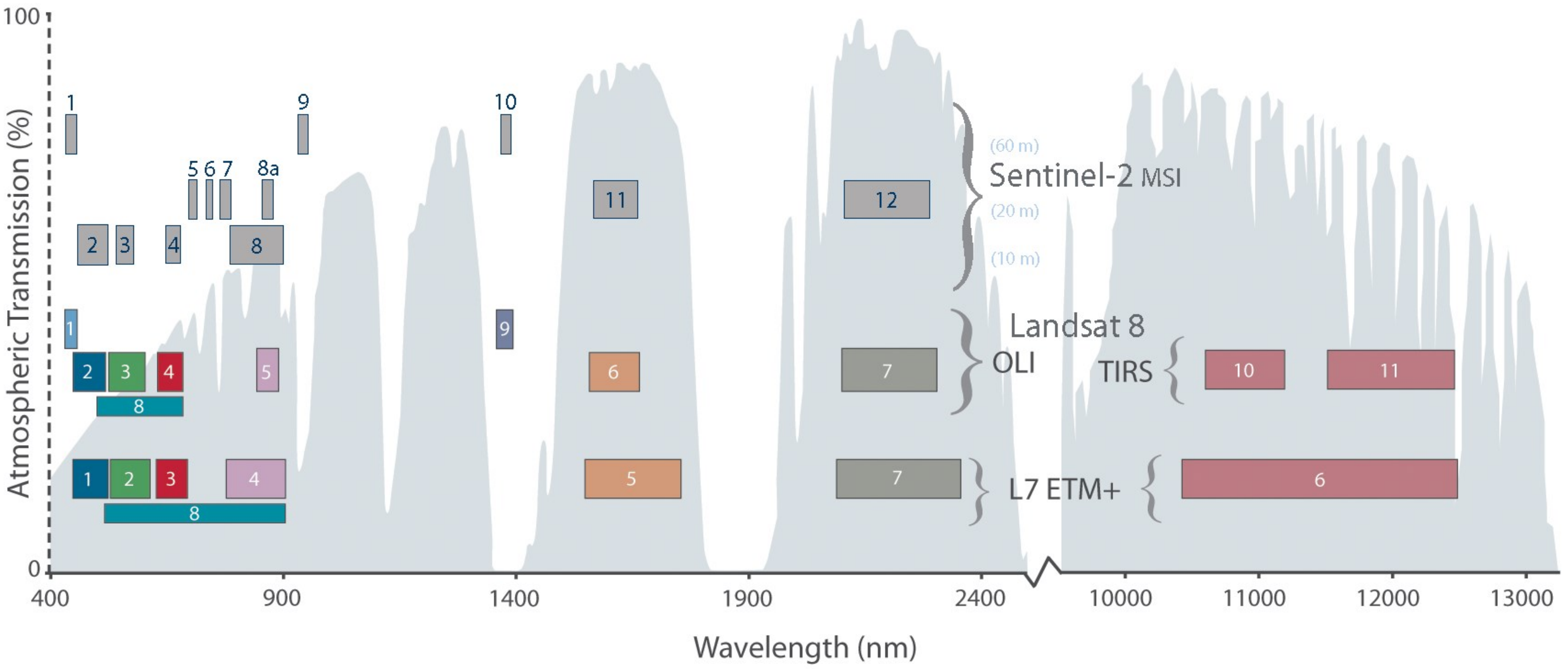
Sentinel-2



- **Optical** satellite high-resolution constellation (pixel size **10m**, **20m**, & **60m**)
- **Visible to Shorwave-infrared range (SWIR)**. 13 bands in total.
- **Pair** of satellites: Sentinel-2A & Sentinel-2B
- **Temporal** (combined) resolution: **5 days** (10 days each satellite)
- Along-track (pushbroom) system with a **swath width** of **290 km**
- https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2
- https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi

Sentinel-2

Comparison of Landsat 7 and 8 bands with Sentinel-2



Sentinel-2 spectral bands

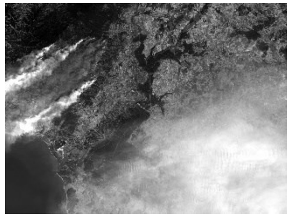
Spatial Resolution (m)	Band Number	S2A		S2B	
		Central Wavelength (nm)	Bandwidth (nm)	Central Wavelength (nm)	Bandwidth (nm)
10	2	496.6	98	492.1	98
	3	560.0	45	559	46
	4	664.5	38	665	39
	8	835.1	145	833	133
20	5	703.9	19	703.8	20
	6	740.2	18	739.1	18
	7	782.5	28	779.7	28
	8a	864.8	33	864	32
	11	1613.7	143	1610.4	141
	12	2202.4	242	2185.7	238
60	1	443.9	27	442.3	45
	9	945.0	26	943.2	27
	10	1373.5	75	1376.9	76

Sentinel-2 spectral bands

Spatial Resolution (m)	Band Number
10	2
	3
	4
	8
20	5
	6
	7
	8a
	11
	12
60	1
	9
	10

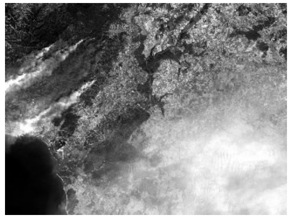
Band 2: Blue (10 m)

Band 2 is useful for soil and vegetation discrimination, forest type mapping and identifying man-made features.



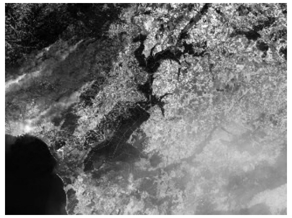
Band 3: Green (10 m)

It helps in highlighting oil on water surfaces, and vegetation. It reflects green light stronger than any other visible color. Man-made features are still visible.



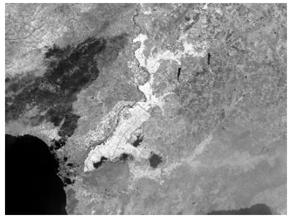
Band 4: Red (10 m)

It is strongly reflected by dead foliage and is useful for identifying vegetation types, soils and urban (city and town) areas. It has limited water penetration and doesn't reflect well from live foliage with chlorophyll.



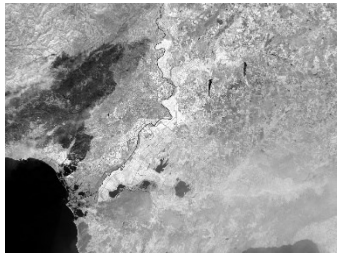
Band 8: Near-Infrared (10 m)

The near infrared band is good for mapping shorelines and biomass content, as well as at detecting and analyzing vegetation.



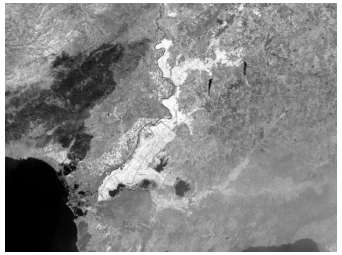
Sentinel-2 spectral bands

Spatial Resolution (m)	Band Number
10	2
	3
	4
	8
20	5
	6
	7
	8a
	11
	12
60	1
	9
	10



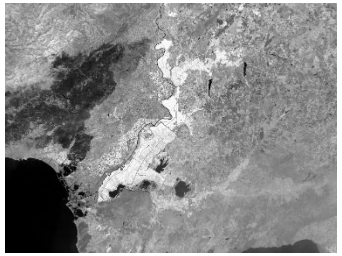
Band 5,6,7: Red-Edge (20 m)

For classifying vegetation.



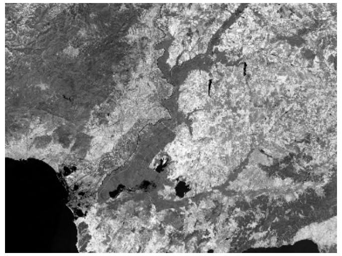
Band 8a: Narrow Near-Infrared (20 m)

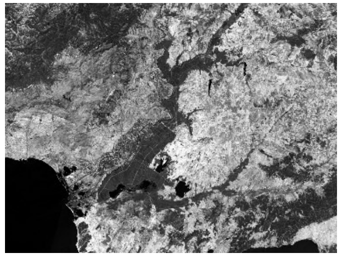
The near infrared band is good for mapping shorelines and biomass content, as well as at detecting and analyzing vegetation.



Band 11, 12: Shortwave Infrared (20 m)

It is useful for measuring the moisture content of soil and vegetation, and it provides good contrast between different types of vegetation. It helps differentiate between snow and clouds. On the other hand, it has limited cloud penetration.





Sentinel-2 spectral bands

Spatial Resolution (m)	Band Number
10	2
	3
	4
	8
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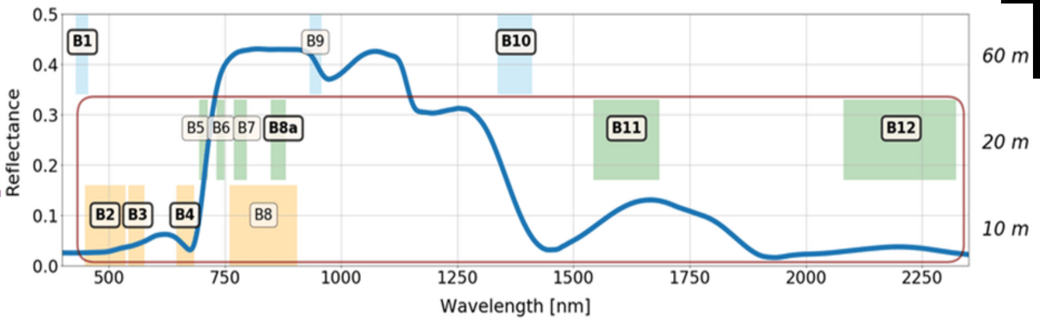
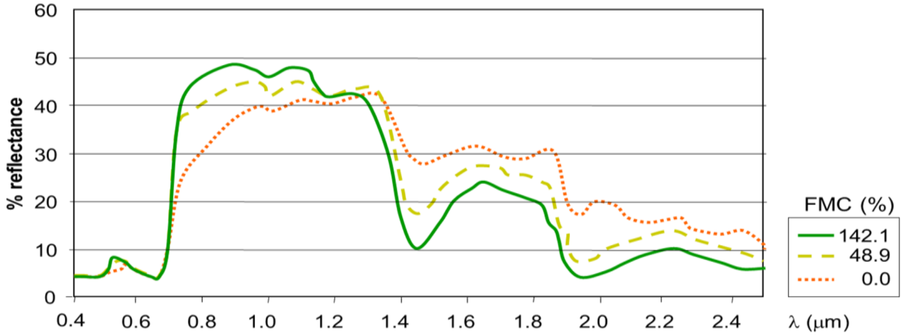
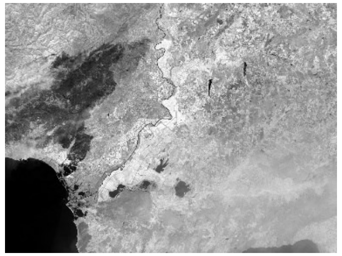
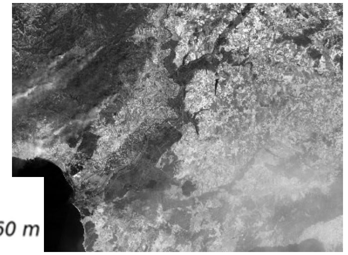
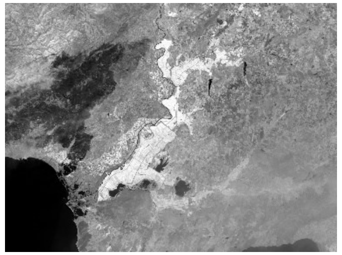
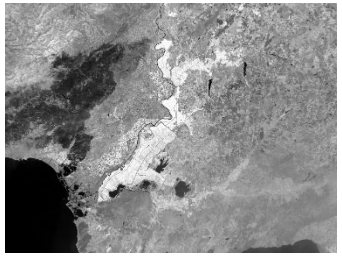
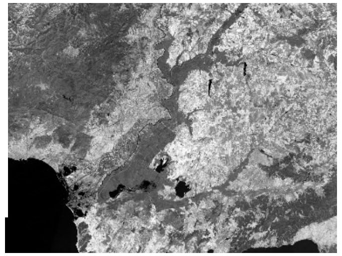
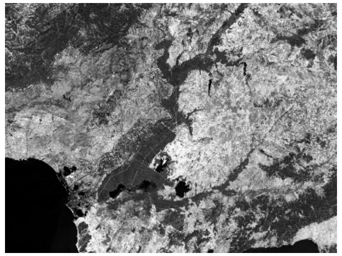
	6
	7
	8a
	11
	12
60	1
	9
	10

Band 5,6,7: Red-Edge (20 m)

For classifying vegetation.





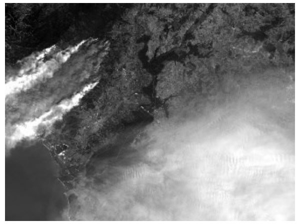







Sentinel-2 spectral bands

Spatial Resolution (m)	Band Number
10	2
	3
	4
	8
20	5
	6
	7
	8a
	11
	12
60	1
	9
	10

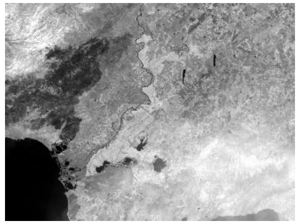
Band 1: Coastal/Aerosol (60 m)

For aerosol detection.



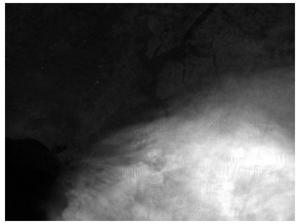
Band 9: Water Vapour (60 m)

It is good for detecting water vapour.



Band 10: Shortwave Infrared – Cirrus (60 m)

For cirrus cloud detection.



Sentinel-2 products

- The original Sentinel-2 data are subject to multiple levels of pre-processing before being distributed to users.
- The processed data are distributed to everyone free of charge, via the Copernicus Data Space Ecosystem platform (registration only required)
- Two levels of data are made available to all users:
  - **Level-1C:** Called ***Top of Atmosphere (ToA) reflectance*** and gives the energy recorded by the sensor divided by the solar irradiance at the satellite level, corrected only for the sun angle and having been orthorectified (correct georeferencing). This quantity has no direct physical interpretation, as there are errors in it due to the atmosphere.
  - **Level-2A:** Called ***Bottom of Atmosphere (BoA) reflectance*** and provides an estimate of the actual reflectance of objects on earth, after atmospheric and topographic correction. *It is preferred for data analysis*. In [0,1].

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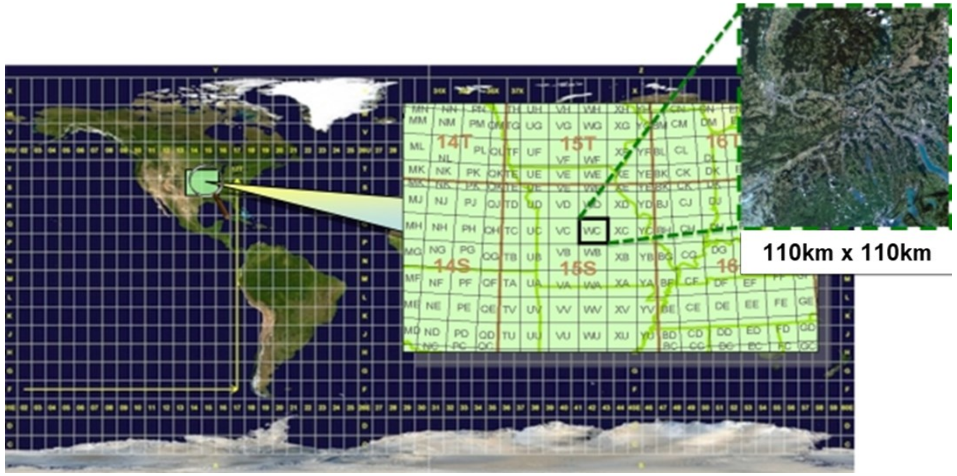
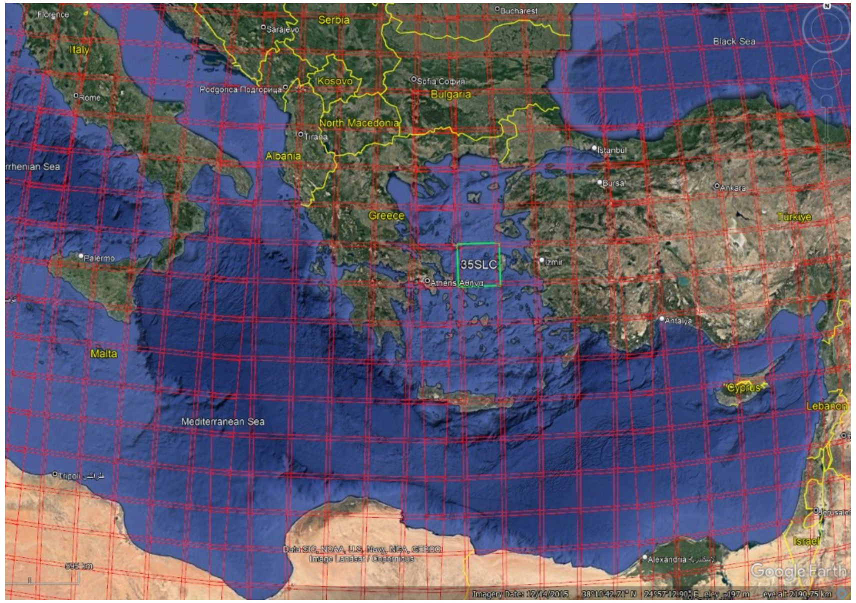
Sentinel-2 products

- The Sentinel-2 satellites are pushbroom systems, scanning the earth continuously in strips with a width of 290 km at ground
- The products are made available to users in sub-images, called tiles
- Each tile covers an area of 110×110 km² on the ground
- They are available in the WGS84 / UTM projection coordinate system (e.g., the zones for Greece being 34N and 35N)
- They are denoted as *TzzXXX*, where *zz* is the zone number and *XXX* three letters to separate them, e.g., **T34SGH**



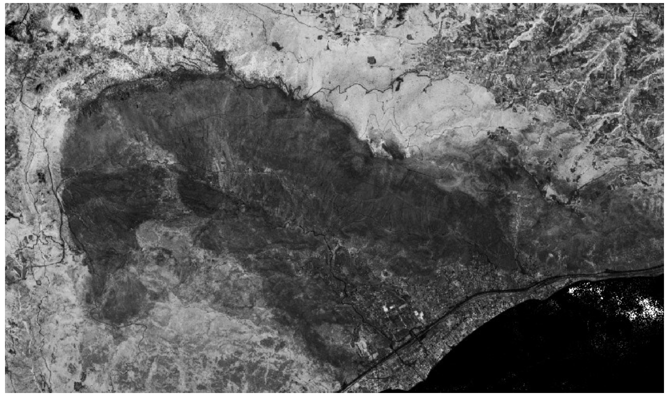


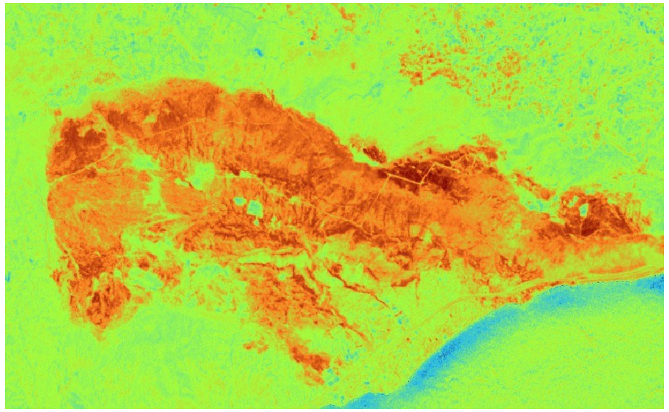
Sentinel-2 products

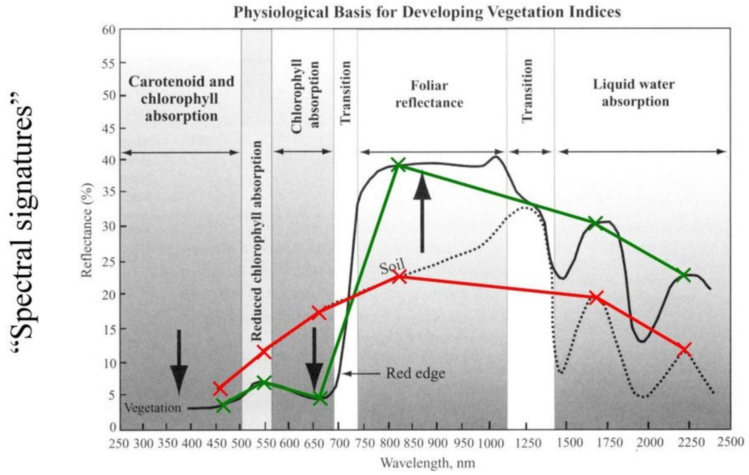
- The data products are distributed in the so-called SAFE format
- Each band in a separate file (JPEG2000), along with metadata and data quality information
- Bands in 16-bit unsigned integer format (UInt16)
- After January 2022 (older datasets being reprocessed), i.e., after Processing Baseline 04.00), original reflectance multiplied by 10,000 and 1,000 is added.
- I.e., to convert to reflectance in [0,1], you must **first subtract 1,000 and then divide by 10,000** (and saturate in [0,1]).

Spectral Indices

- **Spectral indices** are transformations (linear or non-linear) of the original image bands.
- They are based on the fact that **each surface reflects different portion of the incident light** at different wavelengths.
- Following theoretical derivations and field measurements (i.e., spectroradiometers), several indices have been proposed.







Spectral Indices

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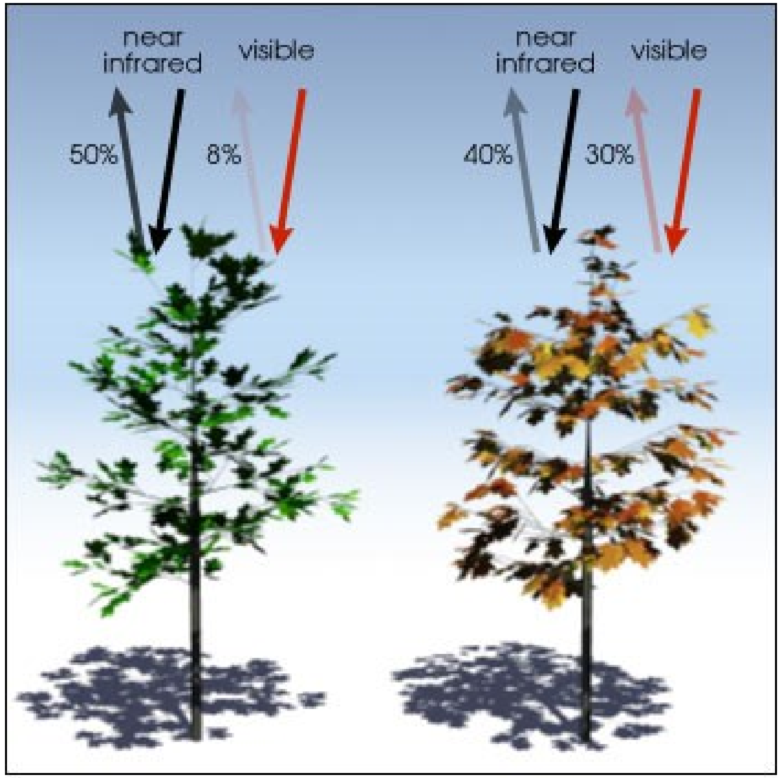
- Following theoretical derivations and field measurements (i.e., spectroradiometers), several indices have been proposed.
- The most well-known is the **Normalized Difference Vegetation Index (NDVI)**, which discriminates easily the green vegetation:

$$\text{NDVI} = \frac{\text{NIR} - \text{Red}}{\text{NIR} + \text{Red}}$$



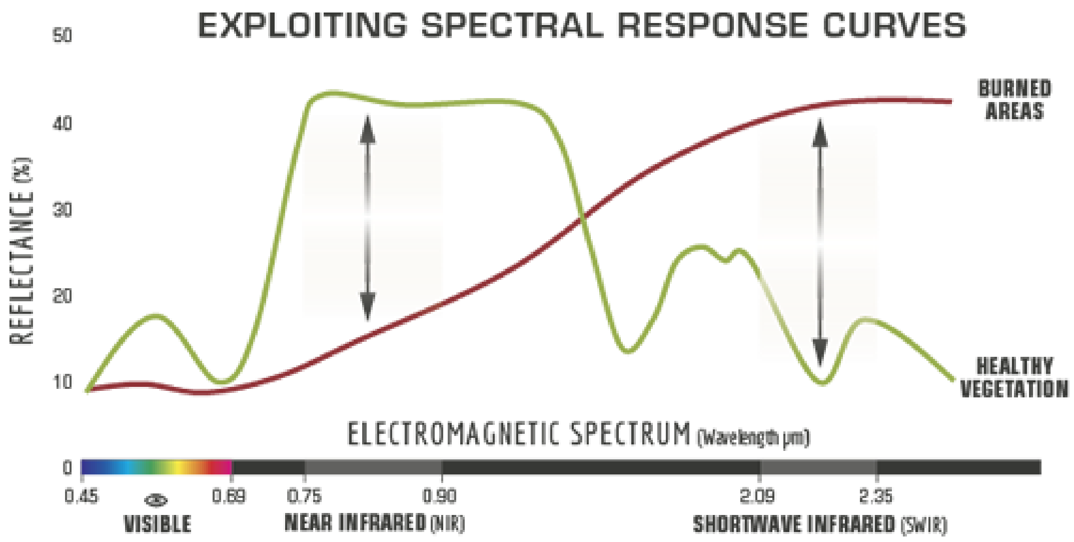
$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72$ $\frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$

Normalized Burn Ratio (NBR)

- For wildfires, the **Normalized Burn Ratio (NBR)** is frequently used:

$$NBR = \frac{NIR - SWIR2}{NIR + SWIR2}$$

- The SWIR channel (Band 12 in Sentinel-2) is sensitive to leaf moisture and so is the whole index
- Positive values in unburned areas, **negative in burned**

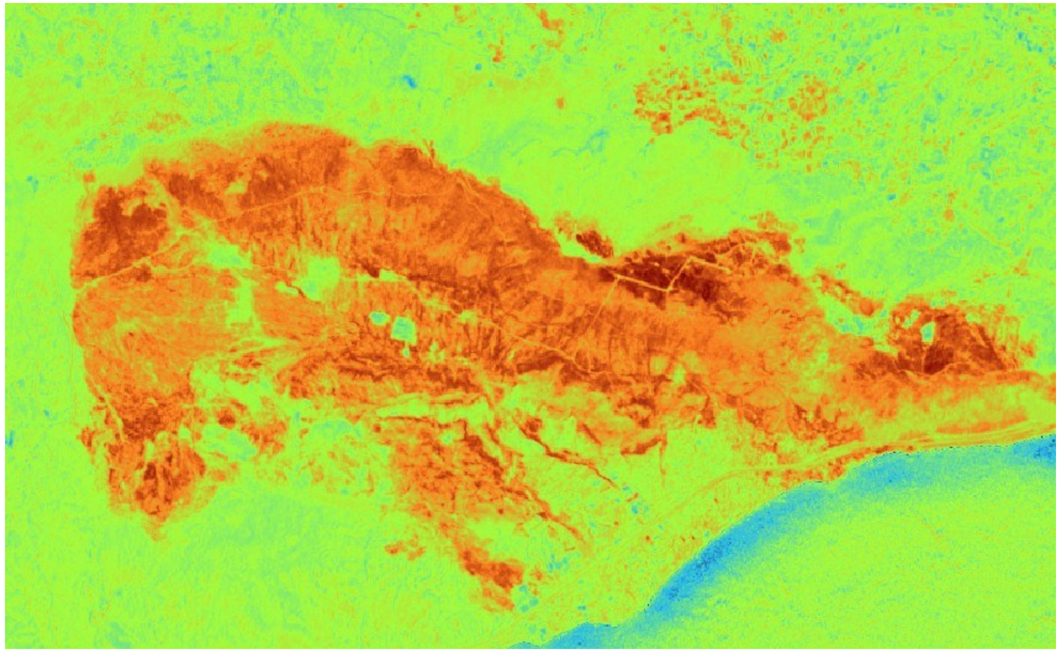


Normalized Burn Ratio (NBR)

- Key, Benson & Nathan (2003)* introduced the difference NBR before and after the fire:

$$\mathrm{dNBR} = \mathrm{NBR}_{\mathrm{prefire}} - \mathrm{NBR}_{\mathrm{postfire}}$$

- They found it correlated with so-called ***burn severity***, which is related to vegetation mortality.



* Key, Carl H.; Benson, Nathan C. 2003. The normalized burn ratio (NBR): A Landsat TM radiometric measure of burn severity. US Geological Survey Northern Rocky Mountain Science Center. U.S. Department of the Interior, U.S. Geological Survey, Northern Rocky Mountain Science Center.

Delta Normalized Burn Ratio (dNBR)

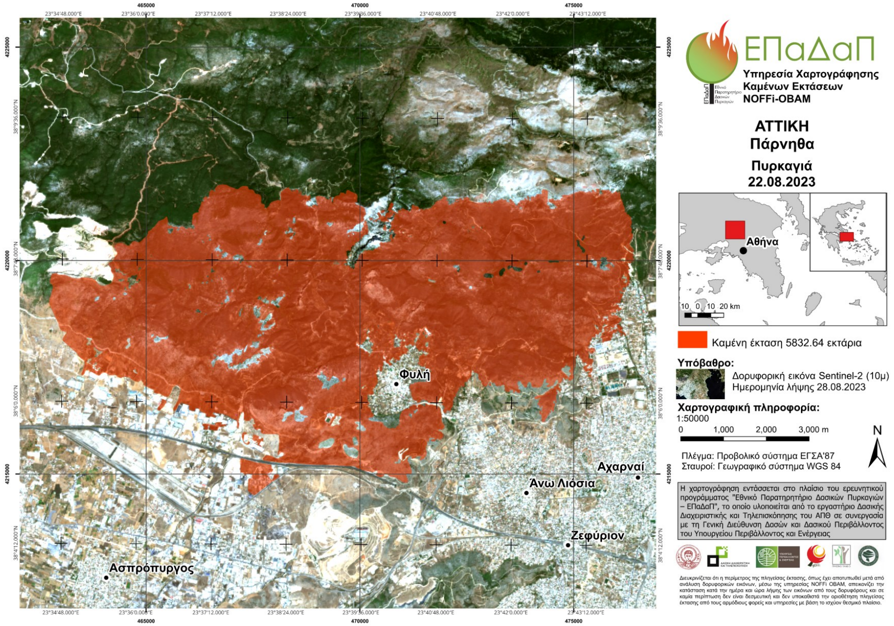
- They proposed **indicative** ranges for seven severity categories, but these may vary from region to region.
- Theoretically in the range [-2,2], although values lower than -0.5 or higher than 1.3 are rarely observed in practice.
- Higher threshold for each category is required if postfire image is acquired immediately after the fire.
- In any case, a ***threshold around 0.2 usually discriminates burned areas sufficiently***.

Severity Level	dNBR range
Enhanced regrowth, high rate	$[-0.5, 0.25)$
Enhanced regrowth, low rate	$[-0.25, -0.1)$
Unburned areas	$[-0.1, +0.1)$
Low severity	$[0.1, 0.27)$
Moderate-low severity	$[0.27, 0.44)$
Moderate-high severity	$[0.44, 0.66)$
High severity	$[0.66, 1.3]$

Key, C. H., & Benson, N. C. (2006). Landscape Assessment: Ground Measure of Severity, the Composite Burn Index; and Remote Sensing of Severity, the Normalized Burn Ratio. In D. C. Lutes, R. E. Keane, J. F. Caratti, C. H. Key, N. C. Benson, S. Sutherland, & L. J. Gangi (Eds.), FIREMON: Fire Effects Monitoring and Inventory System. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station, Gen. Tech. Rep. https://www.fs.usda.gov/research/treesearch/24066

Exercise

- Download pre-fire (18/08/2023) and postfire (28/08/2023) from area of interest; tile ID: 34SGH
- Insert into QGIS bands 8A & 12 from both images and convert to reflectance in[0,1]
  - GDAL Raster calculator: numpy.minimum(1.0, numpy.maximum(0.0, (A - 1000)/10000))
- Calculate NBR and dNBR
- Choose different thresholds for delineating the burned area, starting from 0.2



Thank you for your attention!

Communication

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