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Practical tools to reconstruct wildfire spread

NERO – european **N**etwork on **E**xtreme fi**R**e behavi**O**r (CA22164)
https://nero-network.eu

Akli Benali (University of Lisbon)
Marcos Campos (Força Especial de Proteção Civil)

Overview

(1) The NERO network

(2) Reconstruction of wildfire spread using satellite data;

(3) The NERO fire collection app

This webinar will be recorded and shared.

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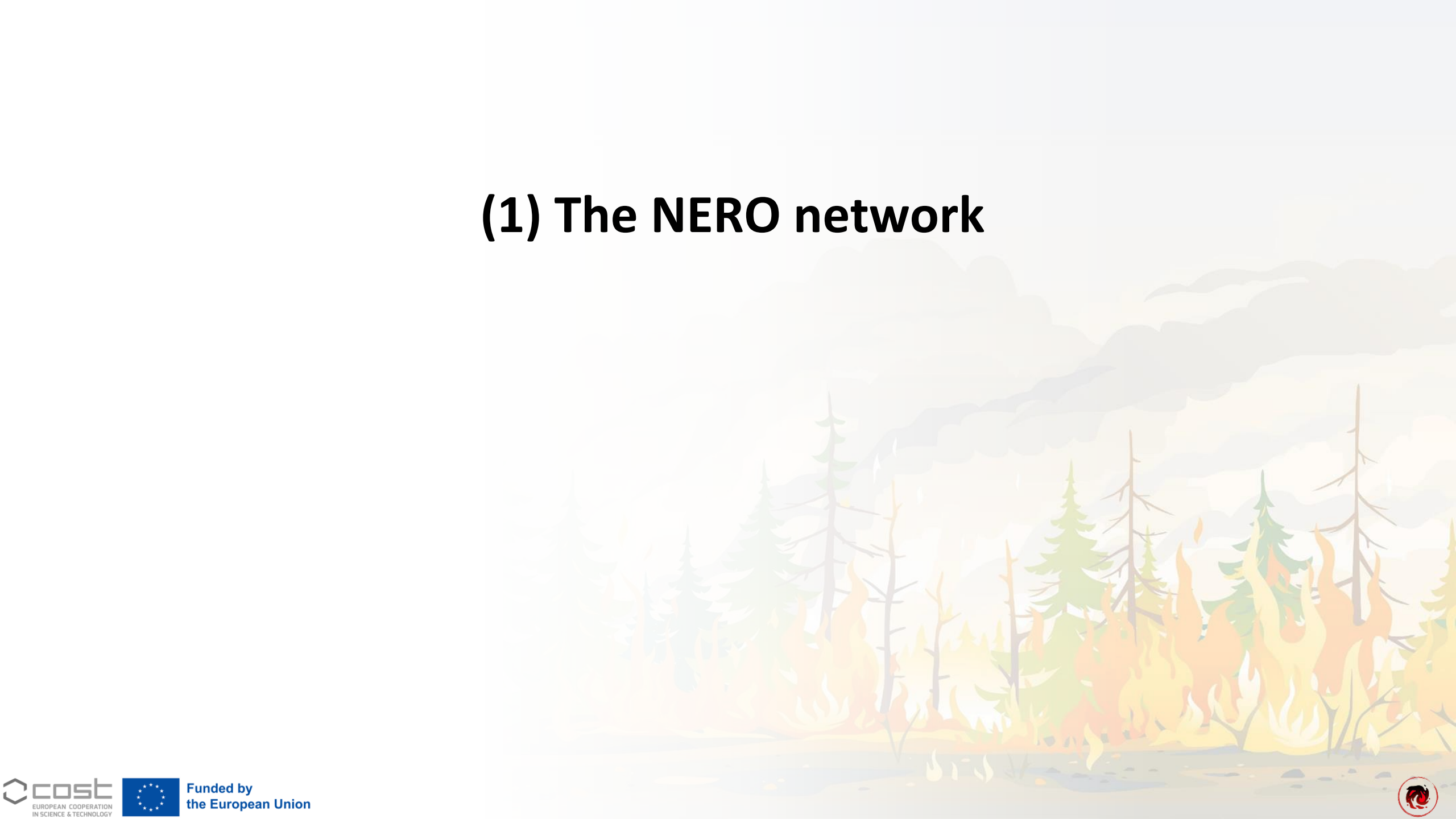
(1) The NERO network



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The NERO network: in a glance

Challenge

- Coordinate international research on extreme wildfires
- Make research outcomes applicable to the operations' field
- Engage researchers and practitioners in knowledge co-creation
- Foster capacity building
- Increase fire operatives and public awareness of extreme wildfires

Approach

- Collate data to support the systematic analysis of extreme wildfires
- Establish the process-based analysis of extreme wildfires
- Raise awareness and enhance capacity to anticipate and respond to extreme wildfires

Vision

- Break silos to open up new avenues of research on extreme wildfires
- Bridge the gap between science and practice
- Enhance operational capacity at the European level and beyond

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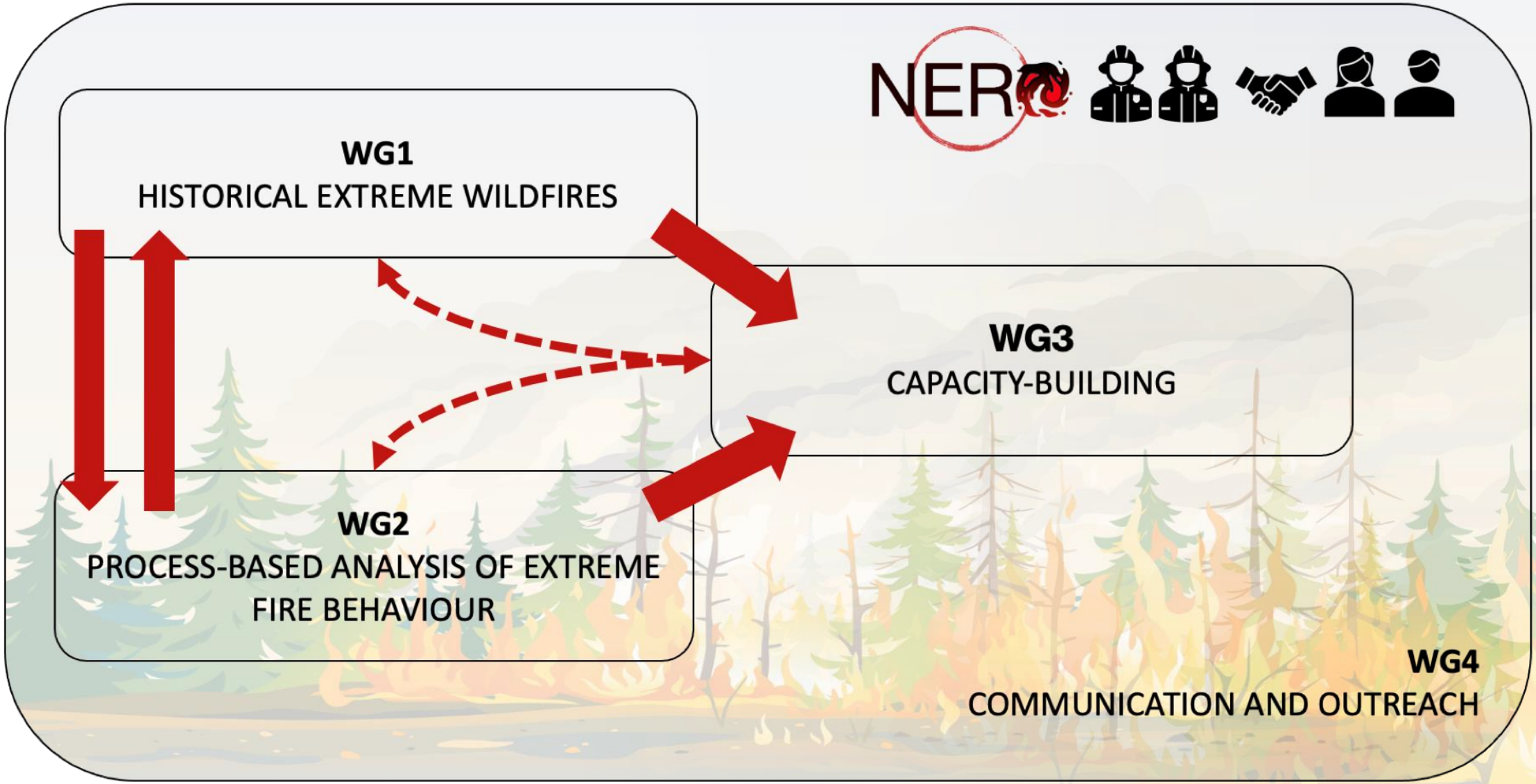
The NERO network: implementation plan



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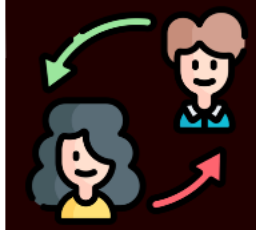
The NERO network: what NERO can offer you?



Short-Term Scientific Missions (STSM)

STSMs are exchange visits aimed to support the mobility of researchers and innovators, strengthen the Action network, and promote collaborations between Action participants.

Learn More and Apply!

Virtual Mobility (VM)

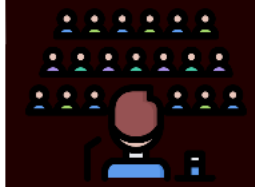
VMs are exchange visits implemented in a virtual environment aimed to strengthen the Action network and promote collaborations between Action participants.

Learn More and Apply!

ITC Conference

Grants aimed to support Young Researchers and Innovators (YRIs) affiliated with an entity in an Inclusiveness Target Country (ITC) or Near-Neighbour Country (NNC) to attend and present their work (oral or poster presentation) at a high-level international conference organised by a third party (i.e., not organised or co-organised by the Action).

Learn More and Apply!



Dissemination Conference

Grants aimed to support Action participants to attend and present (oral presentation) the work of the Action at a high-level international conference organised by a third party (i.e., not organised or co-organised by the Action).

Learn More and Apply!

NERO gives you **access to funds** for:

- In-person **exchange visits**
- **Virtual exchange** visits
- **Conference** participation

Visit:
https://nero-network.eu/grants
For detailed information on how to apply for a grant!

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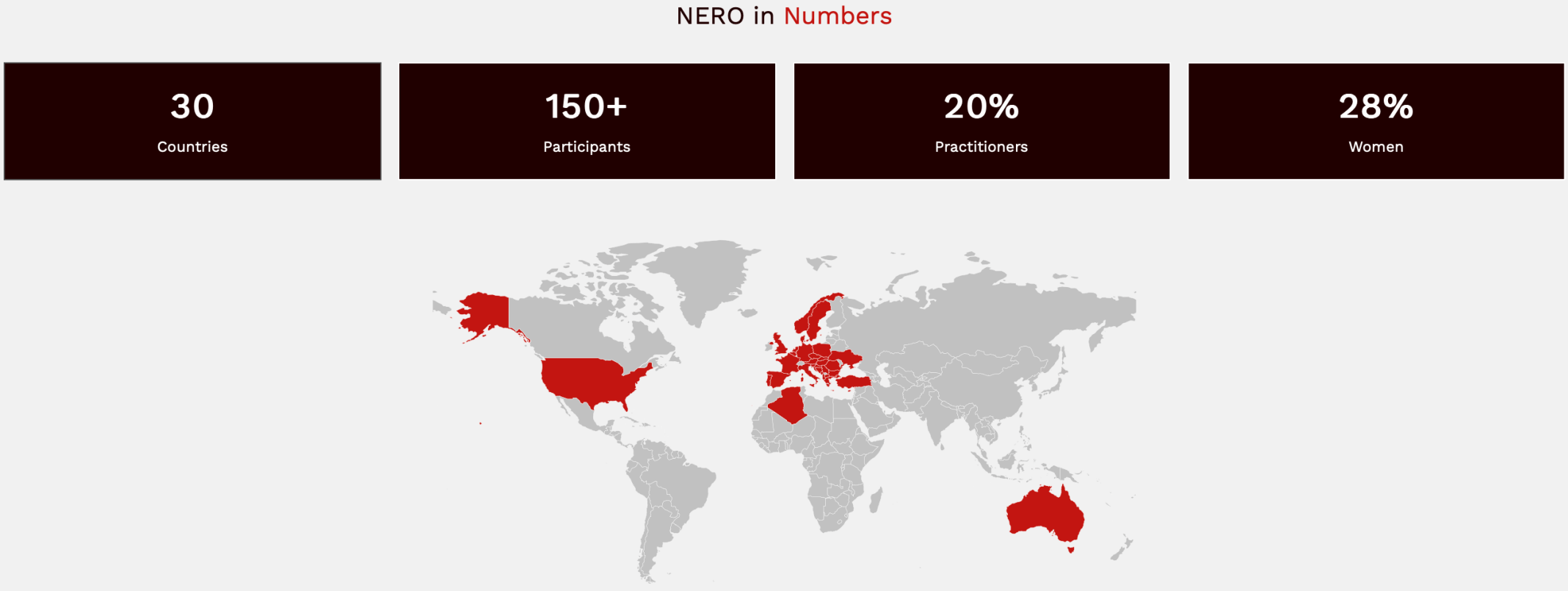
The NERO network

Join us! https://nero-network.eu/



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(2) Reconstruction of wildfire spread using satellite data

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Reconstruction of wildfire spread using satellite data

Outline

1. Fundamentals of remote sensing
2. Satellites & Products
3. Practical example

Main objective

Provide researchers and practitioners:

- Basic knowledge on remote sensing and satellites;
- Practical and easy-to-use to tools to reconstruct the spread of a wildfire in any part of the world.

WG1 & WG3

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Reconstruction of wildfire spread using satellite data

Multiple data sources can be used to reconstruct fire spread

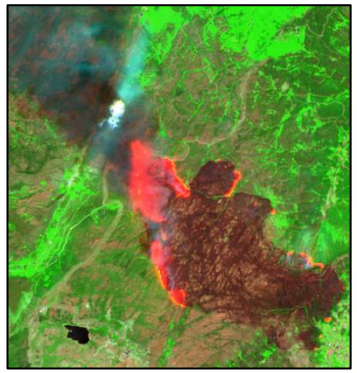
Field photos

source: FEPC

Airborne photos (visible)

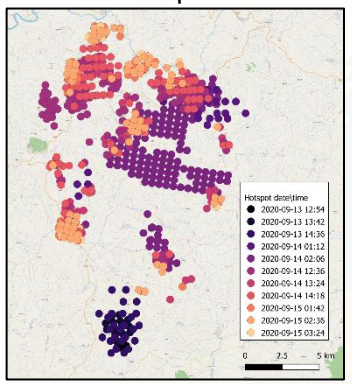
source: UEPS

Satellite imagery

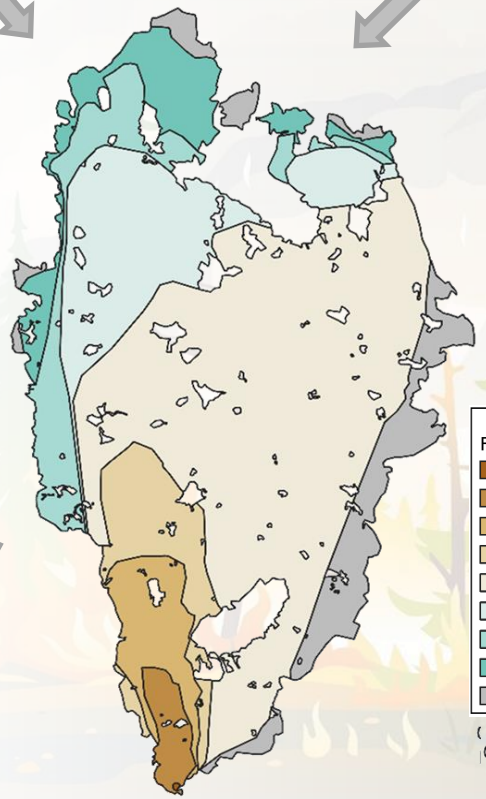


source: Sentinel-2

Satellite "hotspots"



source: VIIRS



Airborne photos (thermal)

source: ANEPC

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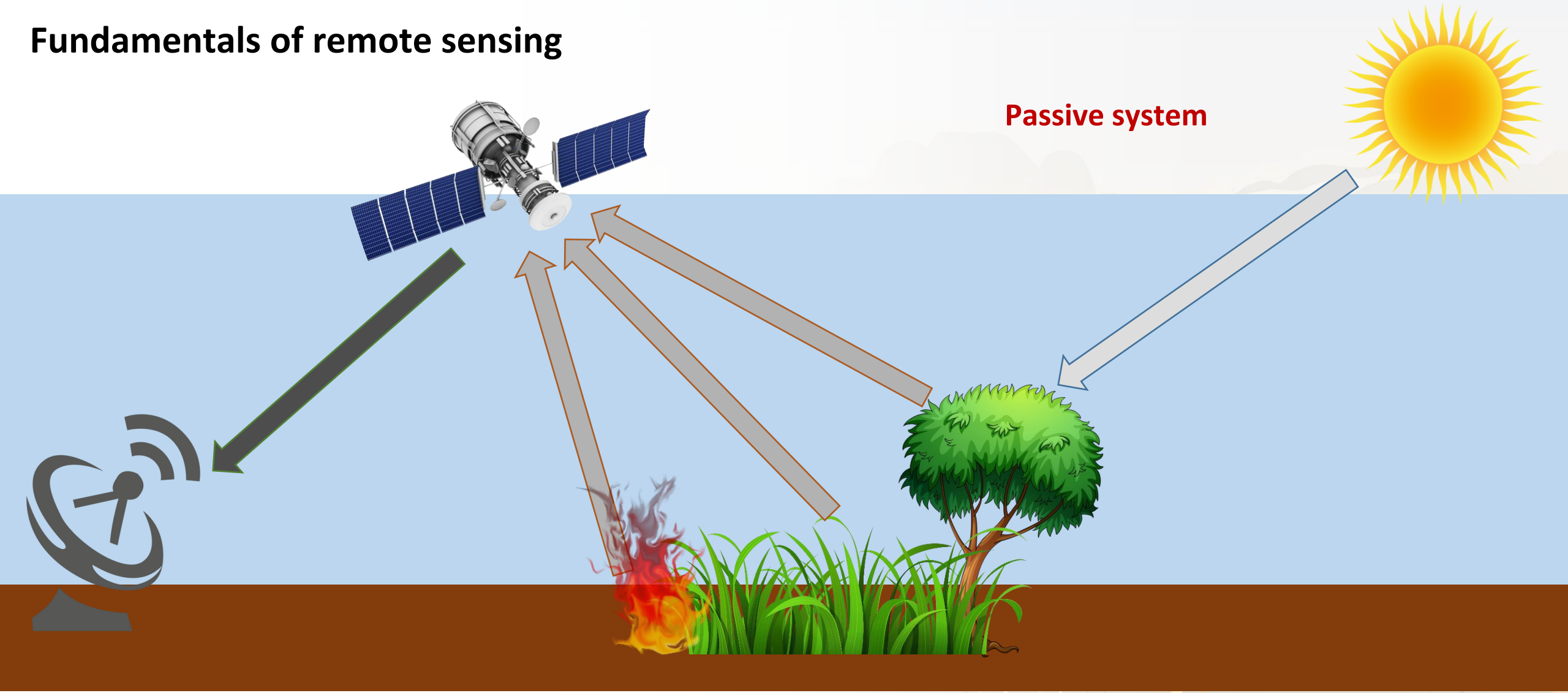
Reconstruction of wildfire spread using satellite data

Fundamentals of remote sensing



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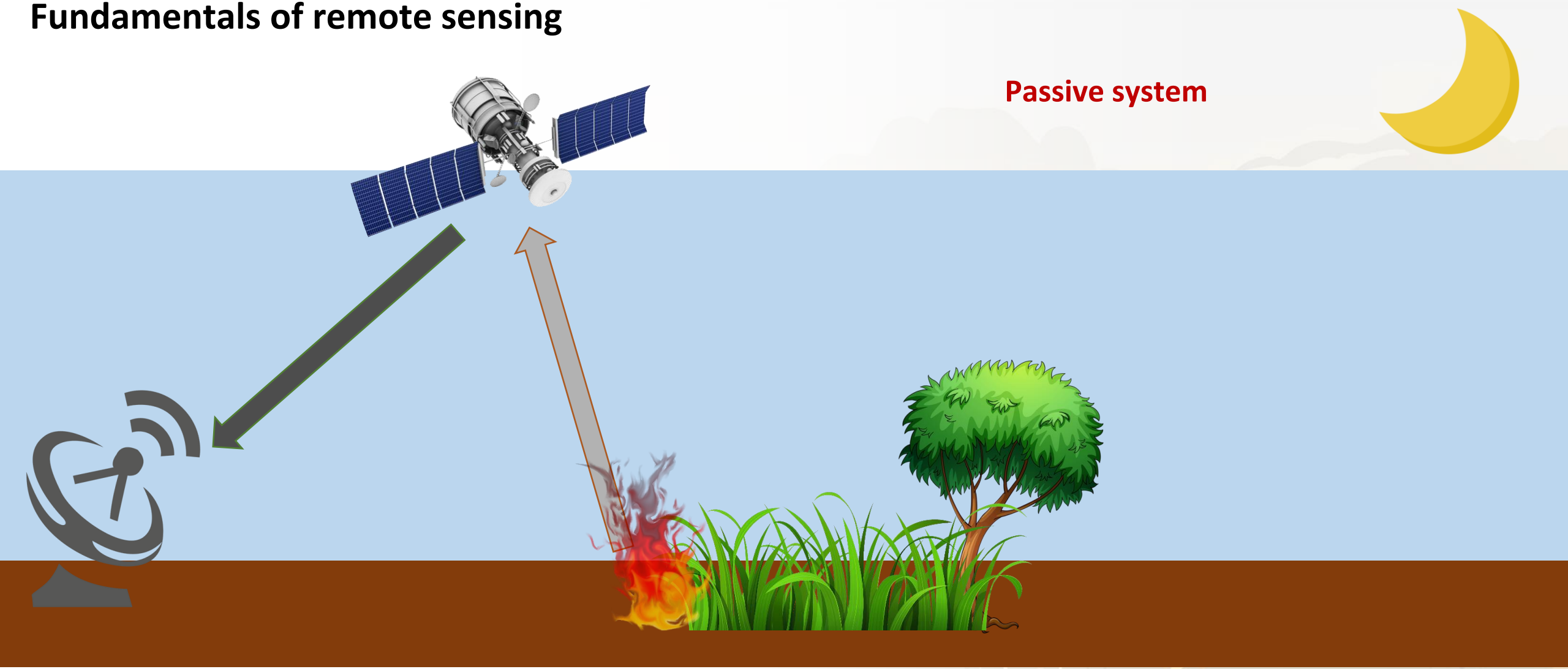
Reconstruction of wildfire spread using satellite data

Fundamentals of remote sensing



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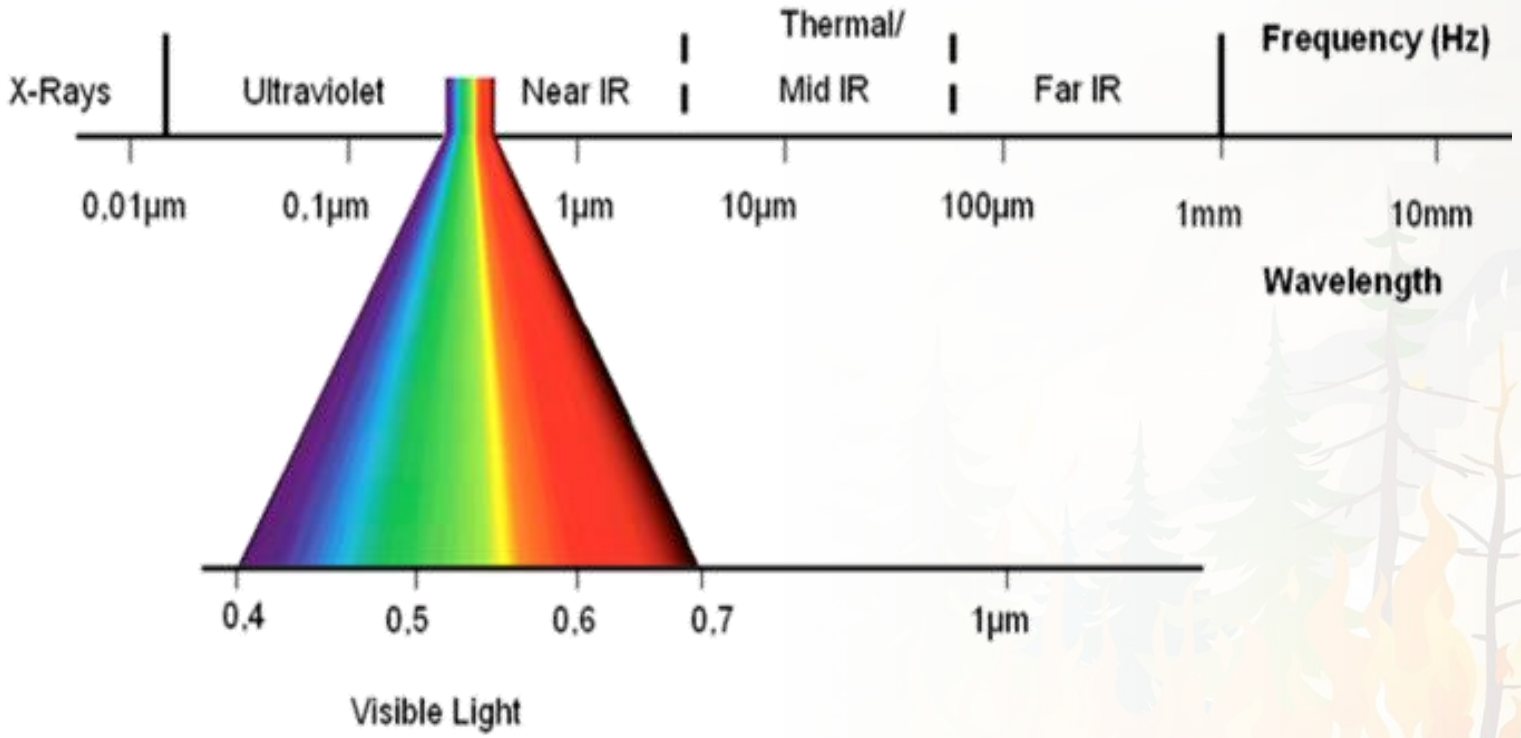
Reconstruction of wildfire spread using satellite data

Fundamentals of remote sensing

Electromagnetic spectrum



Contains all possible frequencies of electromagnetic frequency (or wavelength)

The human eye can only see a very small part of the spectrum (**visible**)

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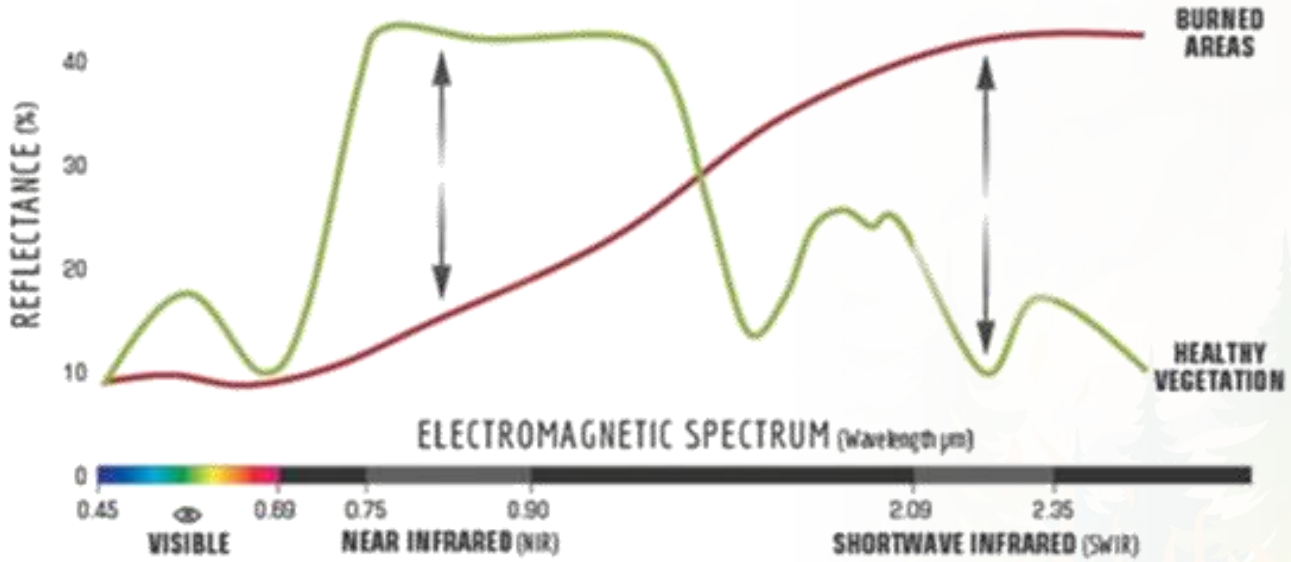
Reconstruction of wildfire spread using satellite data

Fundamentals of remote sensing

Spectral response curves (or signatures)



Source: U.S. Forest service

Different objects reflect radiation in different ways

Distinguishing them is usually done in non-visible areas of the spectrum

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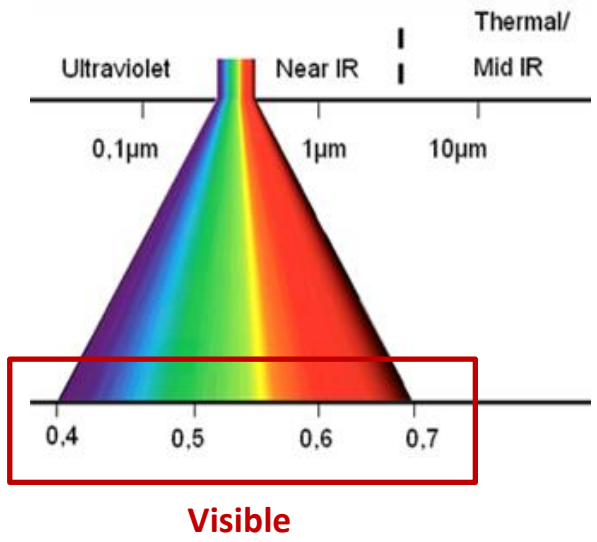
Reconstruction of wildfire spread using satellite data

Fundamentals of remote sensing

How can we “see” beyond the visible part of the spectrum?



Sentinel 2 (Copernicus)

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Reconstruction of wildfire spread using satellite data

Fundamentals of remote sensing

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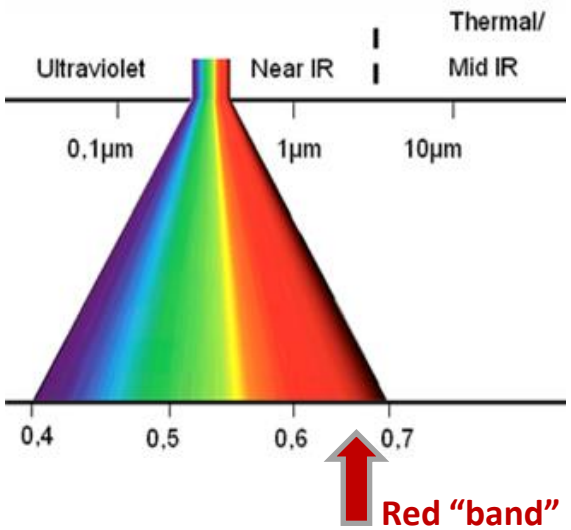

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Fundamentals of remote sensing

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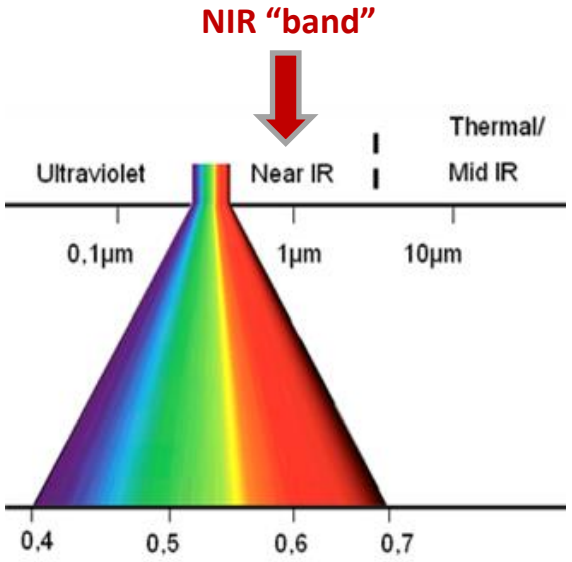

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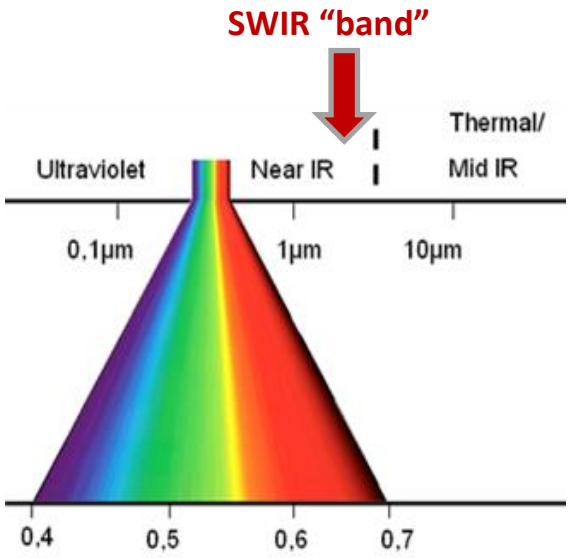
Reconstruction of wildfire spread using satellite data

Fundamentals of remote sensing

How can we “see” beyond the visible part of the spectrum?



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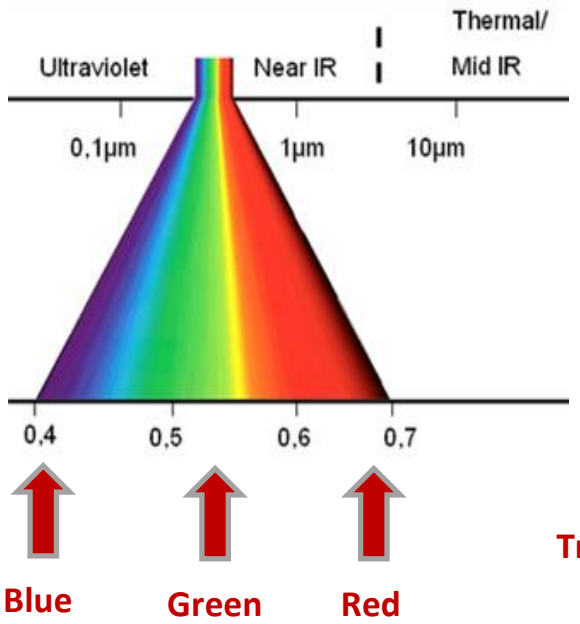
Reconstruction of wildfire spread using satellite data

Fundamentals of remote sensing

How can we “see” beyond the visible part of the spectrum? **Color composites**



True Color Composite

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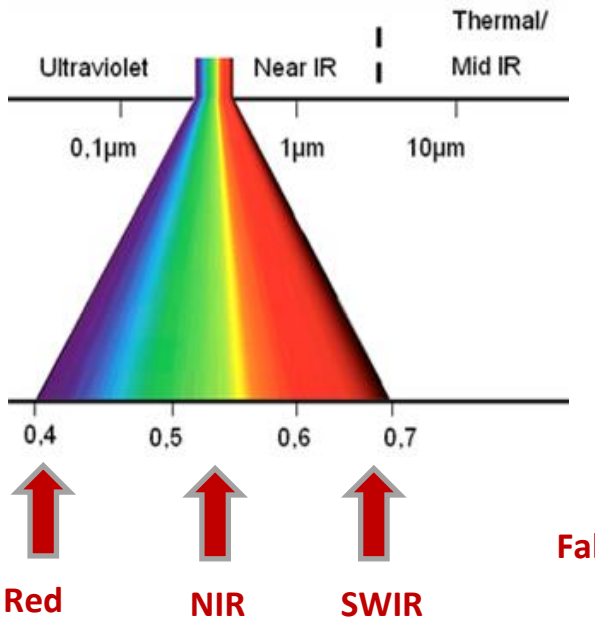
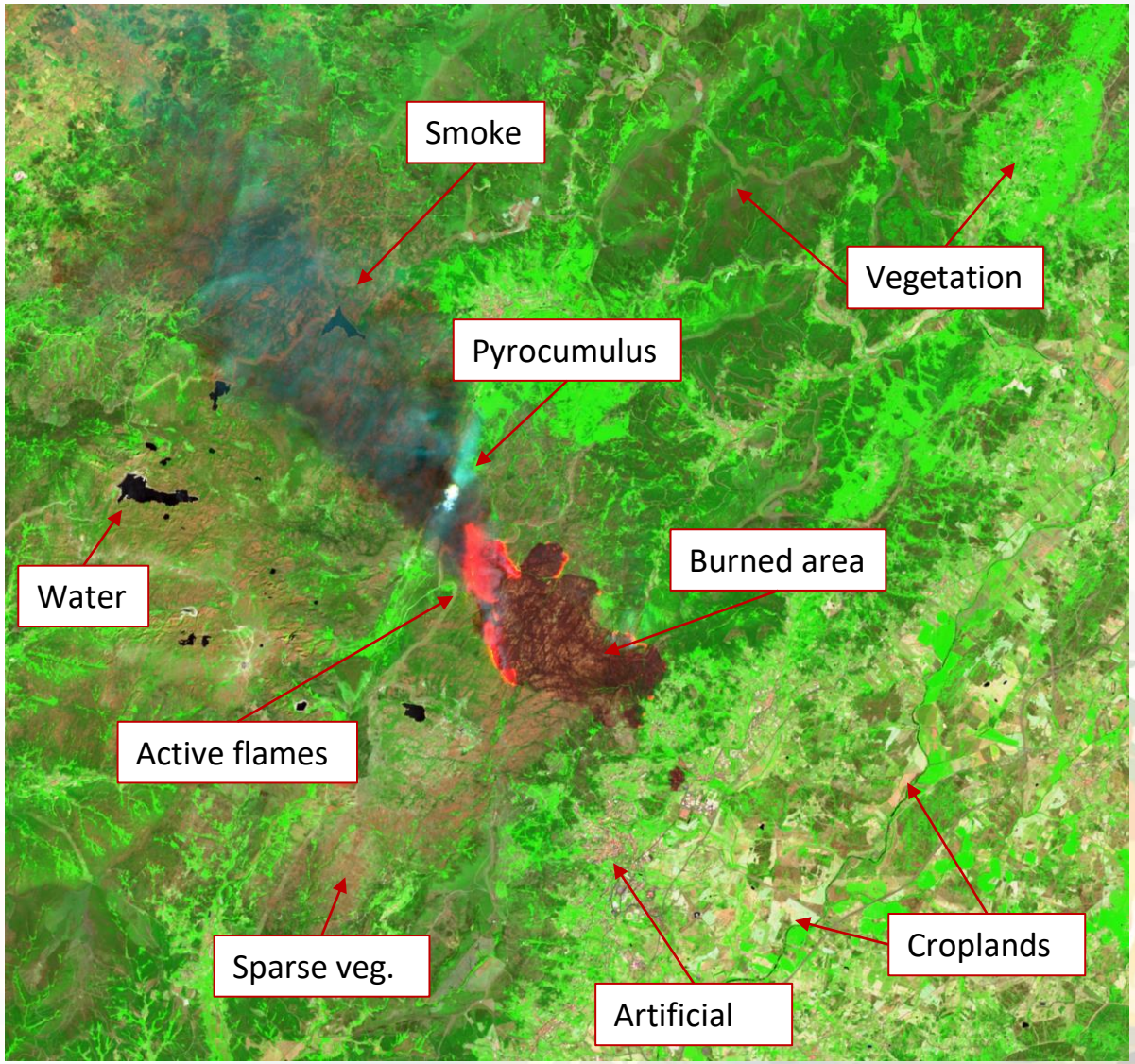
Reconstruction of wildfire spread using satellite data

Fundamentals of remote sensing

How can we “see” beyond the visible part of the spectrum? **Color composites**



False Color Composite



Sentinel 2 (Copernicus)

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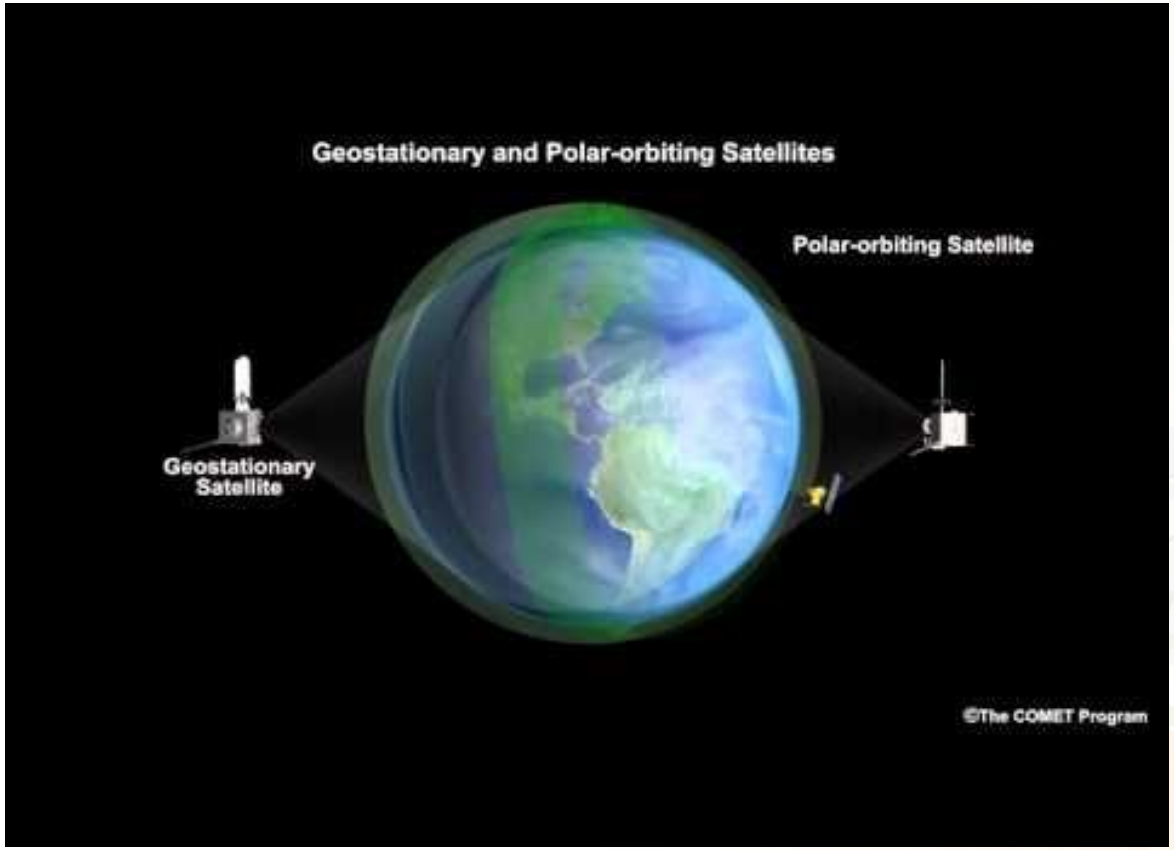
Reconstruction of wildfire spread using satellite data

Satellites: polar vs. geostationary



Geostationary: very high acquisition frequency (e.g. Meteosat Second Gen)

Polar orbit: moderate\low acquisition frequency (e.g. MODIS, VIIRS, Sentinel)

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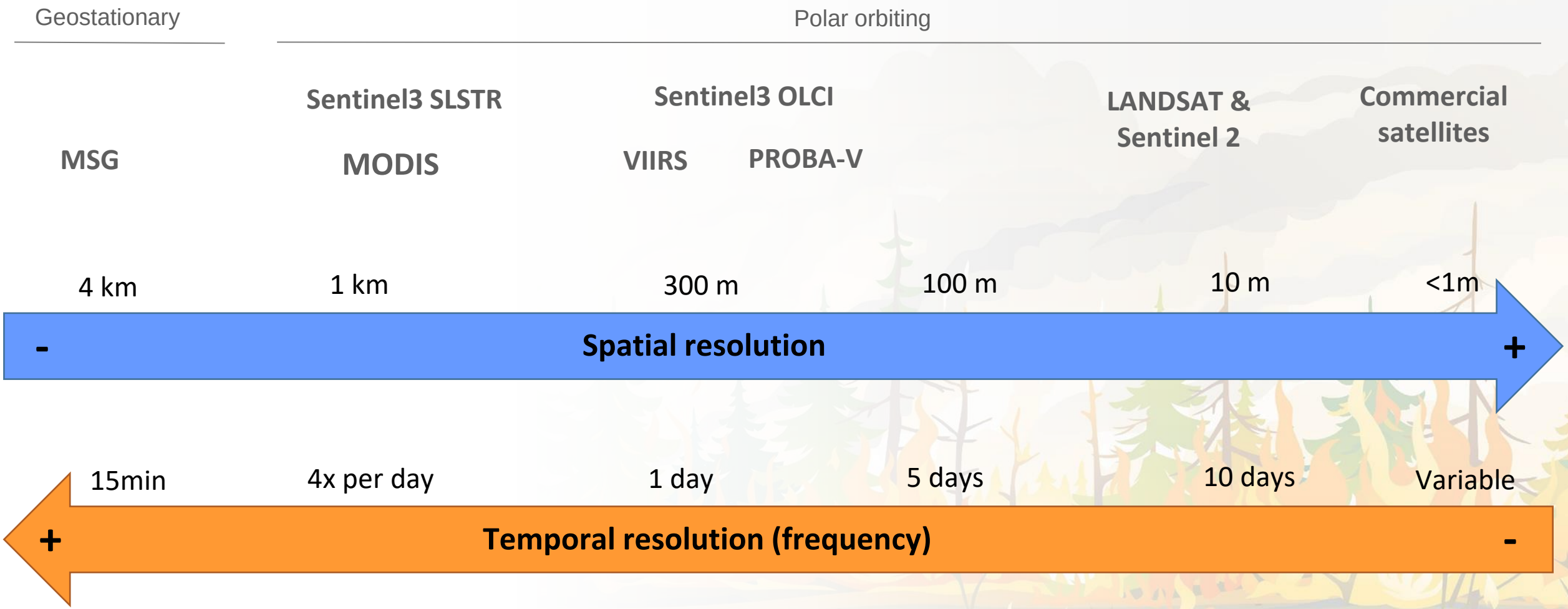
Reconstruction of wildfire spread using satellite data

Satellites: major tradeoffs



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Reconstruction of wildfire spread using satellite data

Satellites: the most relevant ones for fire spread mapping

Sensor	Number of satellites	Spatial Resolution (nadir)	Frequency (average)	Number of spectral bands	Responsible
Sentinel 2	2 (A & B)	10-60m	5 days combined	13	ESA
Landsat 8 & 9	2 sensors 2 instruments	15-100m	8 days combined	11	NASA
VIIRS	3 (NPP, NOAA-20, & NOAA-21)	375-750m	4 times per day	22	NOA
MODIS	2 (Terra & Aqua)	250m-1000m	4 times per day	36	NASA
Sentinel 3	2 (A & B) 2 instruments (OLCI & SLSTR)	300m (OLCI) 500-1000m (SLSTR)	4 times per day	21	ESA and EUMETSAT
MSG-Seviri	2	4,000 m	Every 15 min	12	EUMETSAT

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Reconstruction of wildfire spread using satellite data

Satellites: important notes

- Satellite have different bands with different orders (e.g. NIR band in Sentinel 2 is band 8, in MODIS is band 2, in Landsat 8 is band 5). **Annex #1**
- Whenever possible use reflectances that have the influence of atmosphere corrected ("atmospherically corrected reflectances" or "top of the canopy"). **Annex #2**
- The pixel size is not the same in a satellite image: pixel deformation increases with viewing angle. **Annex #3**
- Satellites have different time spans. **Annex #4**
- All satellites record the time of acquisition in UTC time

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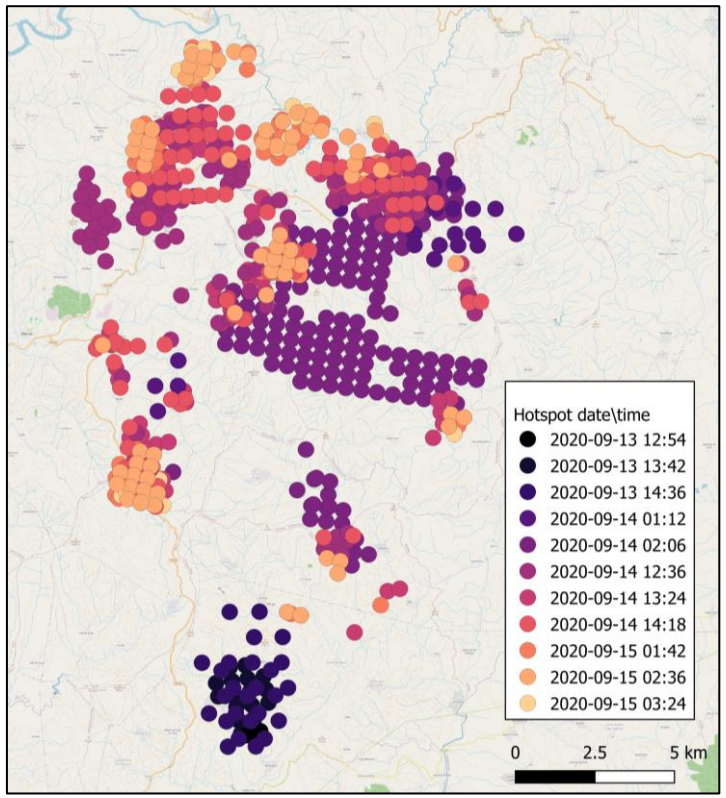
Reconstruction of wildfire spread using satellite data

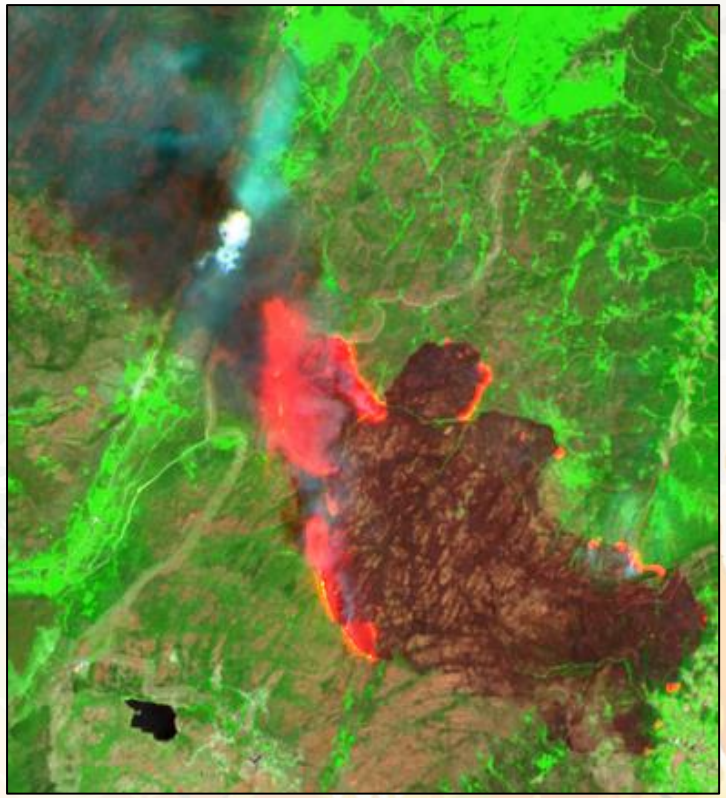
The most relevant products for fire spread mapping

Thermal anomalies or “hot-spots”



source: VIIRS

Reflectance Composites



source: Sentinel-2

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Reconstruction of wildfire spread using satellite data

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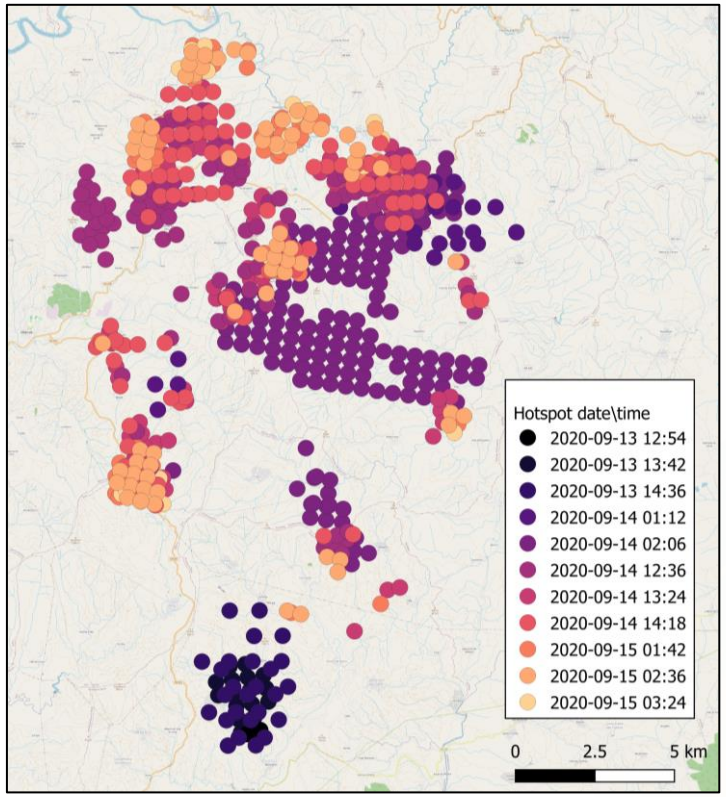
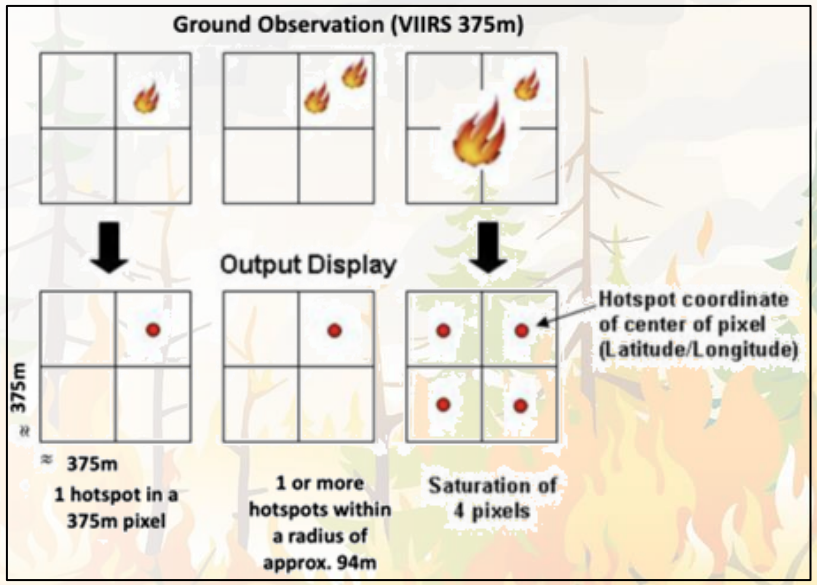


source: VIIRS

- Identify the center coordinate of a pixel where a (or part of a) fire is burning.
- Location, date and time (UTC) are recorded.



source: NASA

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Reconstruction of wildfire spread using satellite data

Questions?

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Reconstruction of wildfire spread using satellite data

Useful and very practical links:

1. Sentinel EO Browser

https://apps.sentinel-hub.com/eo-browser/

2. WorldView

https://worldview.earthdata.nasa.gov/

3. Fire Information for Resource Management System (FIRMS)

https://firms.modaps.eosdis.nasa.gov/map/

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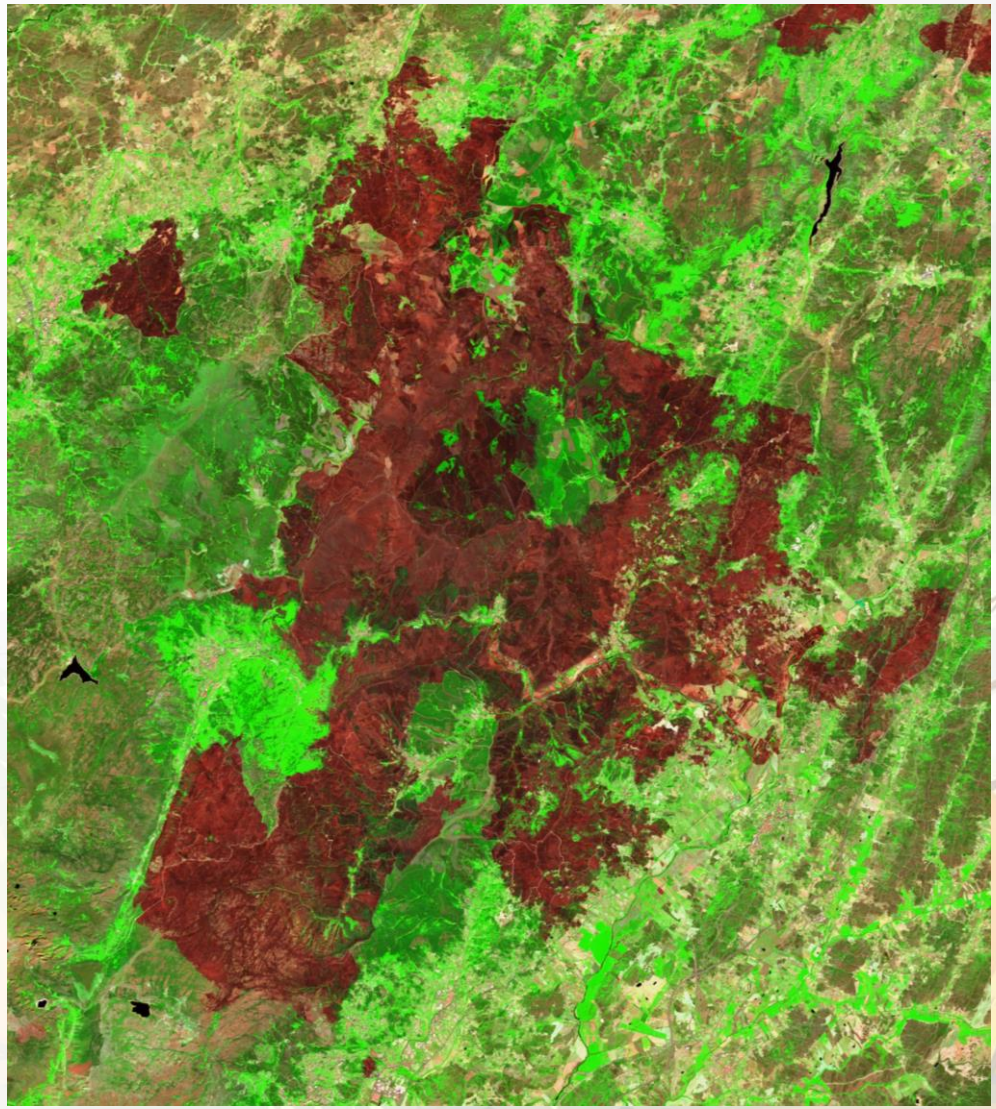
Reconstruction of wildfire spread using satellite data

Case study: **2022 Serra da Estrela wildfire (Portugal)**

- Started on August 6th of 2022
- Ended on August 17th of 2022 (small rekindles afterwards)
- Total burned area extent: 24,462 ha



source: Sentinel-2

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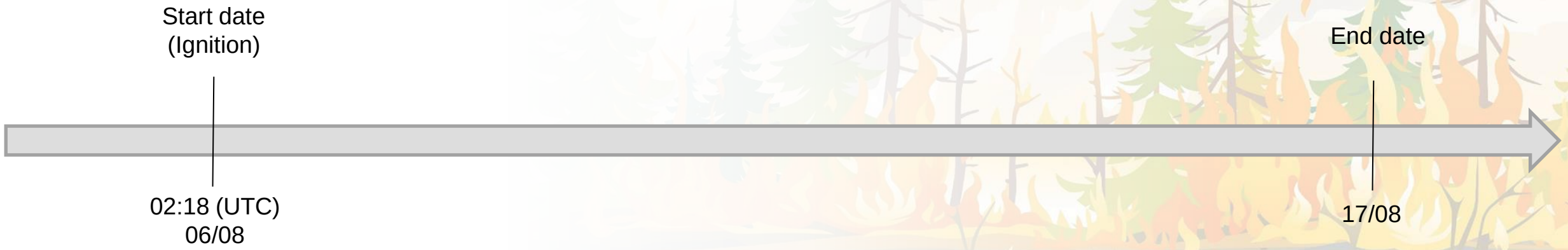
Reconstruction of wildfire spread using satellite data

Step #1. Define a **timeline**



source: Sentinel-2

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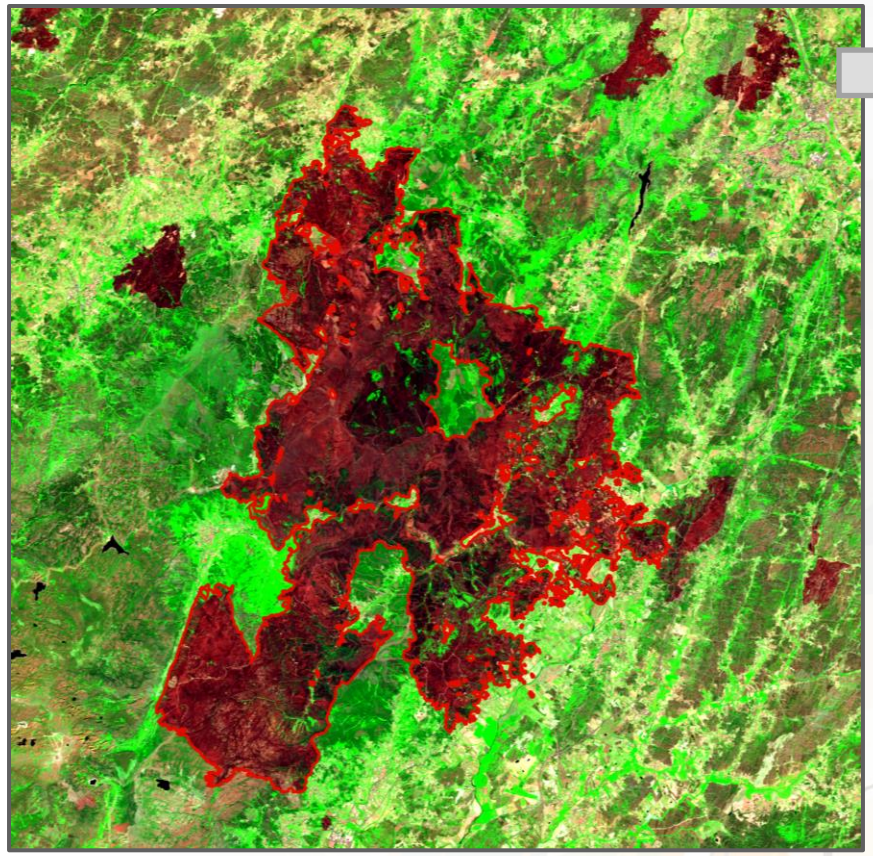
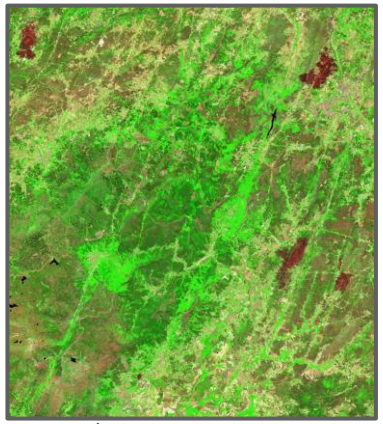
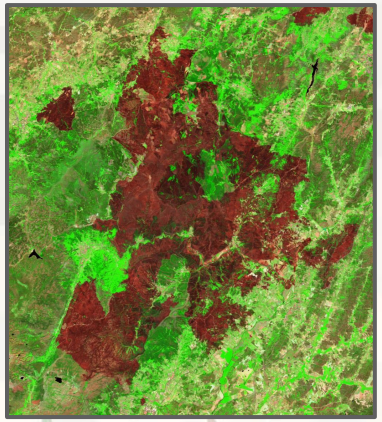
Reconstruction of wildfire spread using satellite data

Step #2. Isolate the final burned perimeter



Official data OR draw it from Sentinel 2 or Landsat 8\9 data: false composite, Sentinel EO Browser





Start date
(Ignition)

End date

02/08

02:18 (UTC)
06/08

17/08

22/08

source: Sentinel-2

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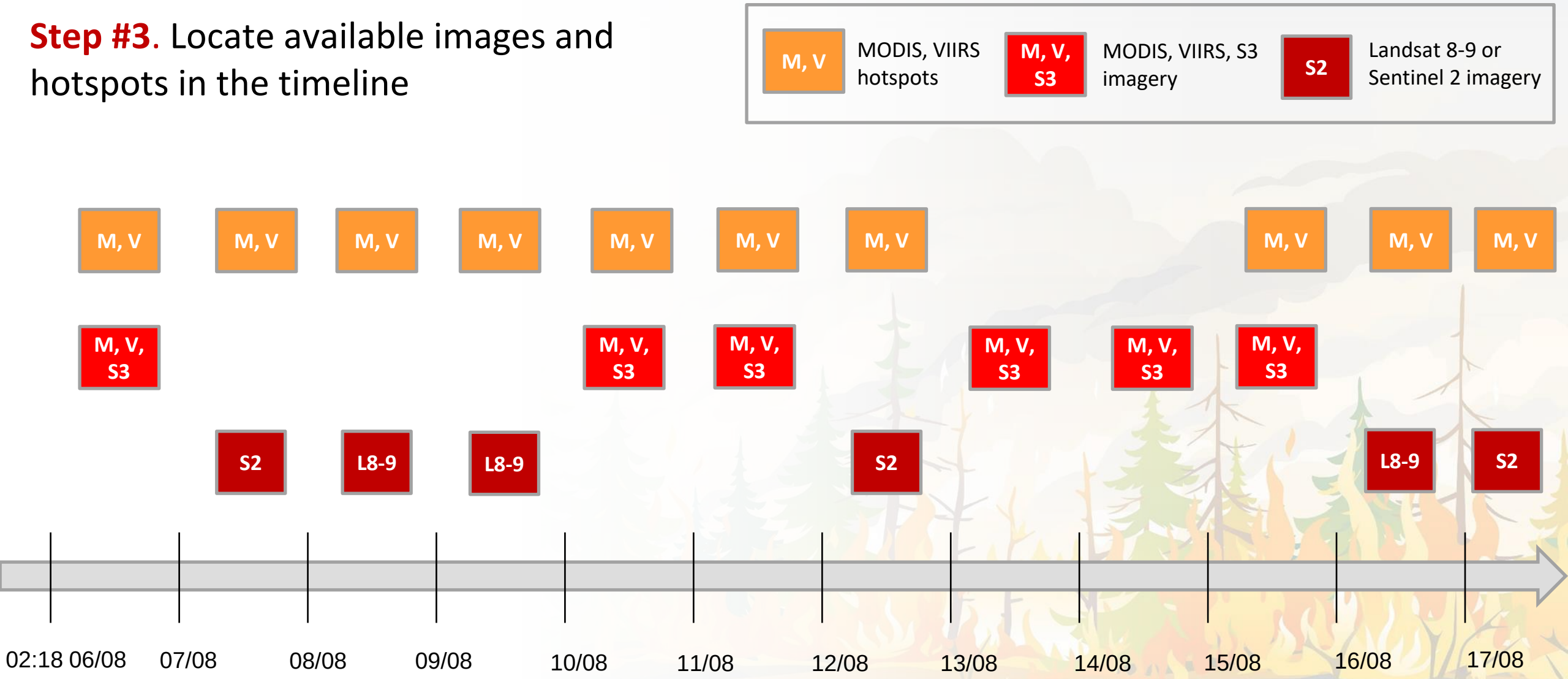
Reconstruction of wildfire spread using satellite data

Step #3. Locate available images and hotspots in the timeline



source: Sentinel-2

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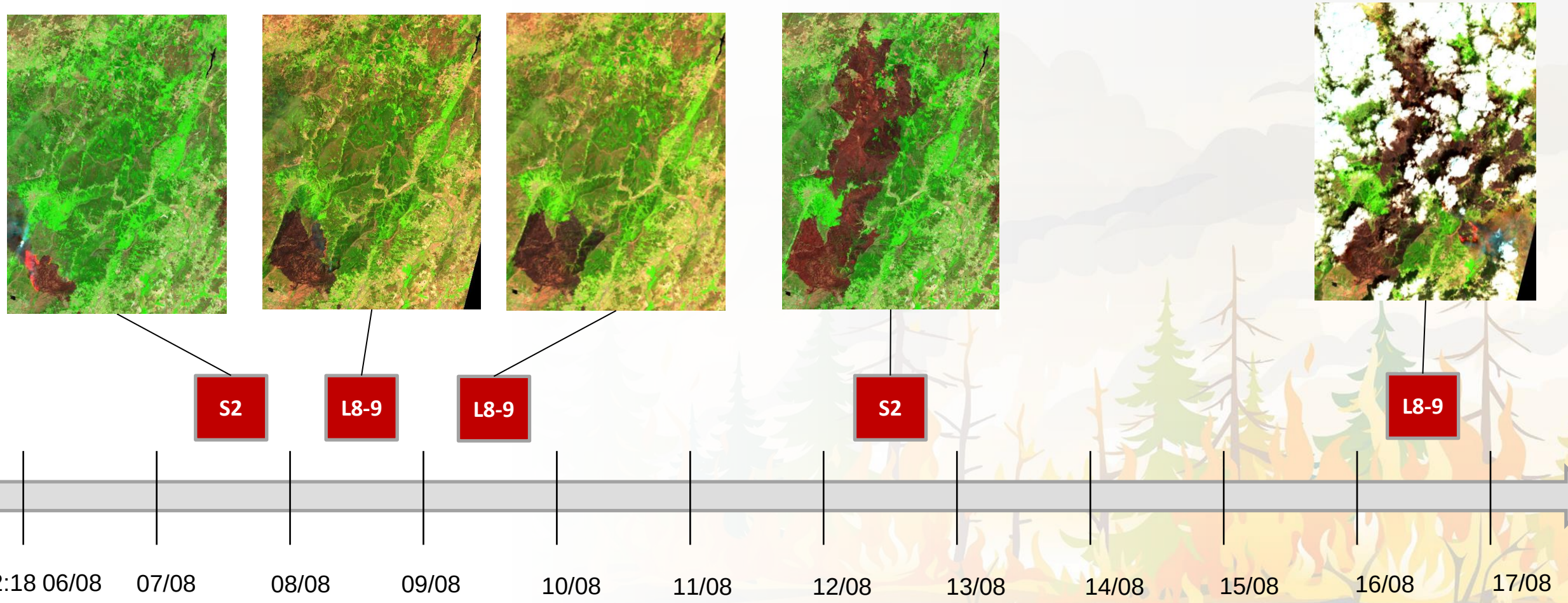
Reconstruction of wildfire spread using satellite data

Step #4. Break the final perimeter in intermediate perimeters using **high-res imagery**



source: Sentinel-2

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Reconstruction of wildfire spread using satellite data

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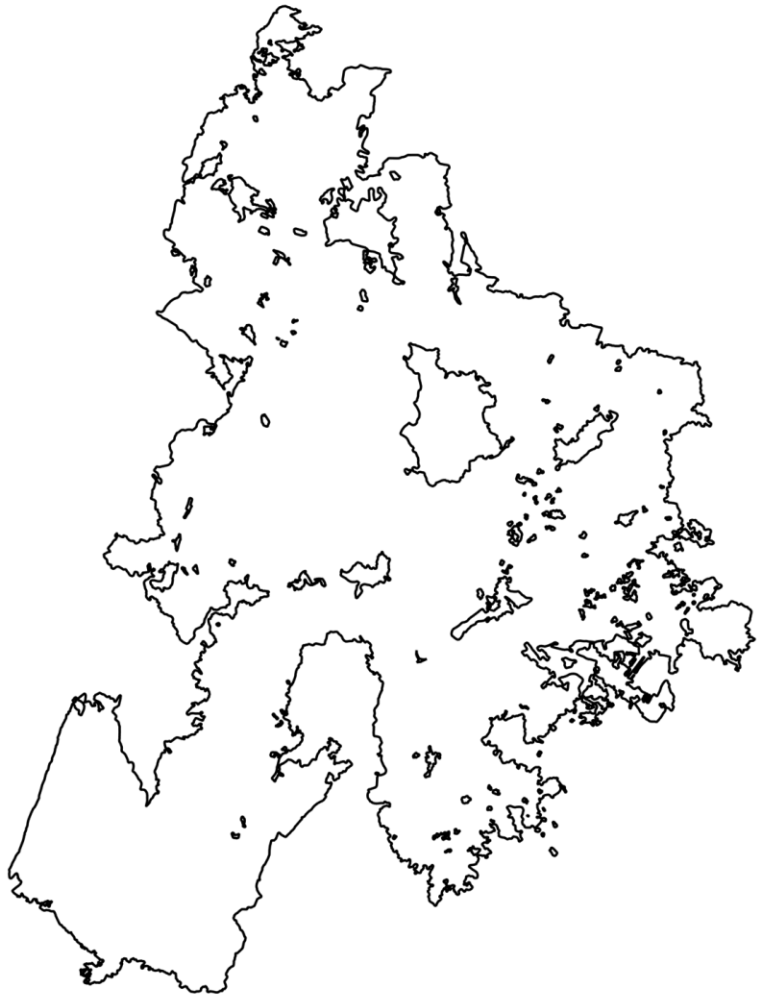
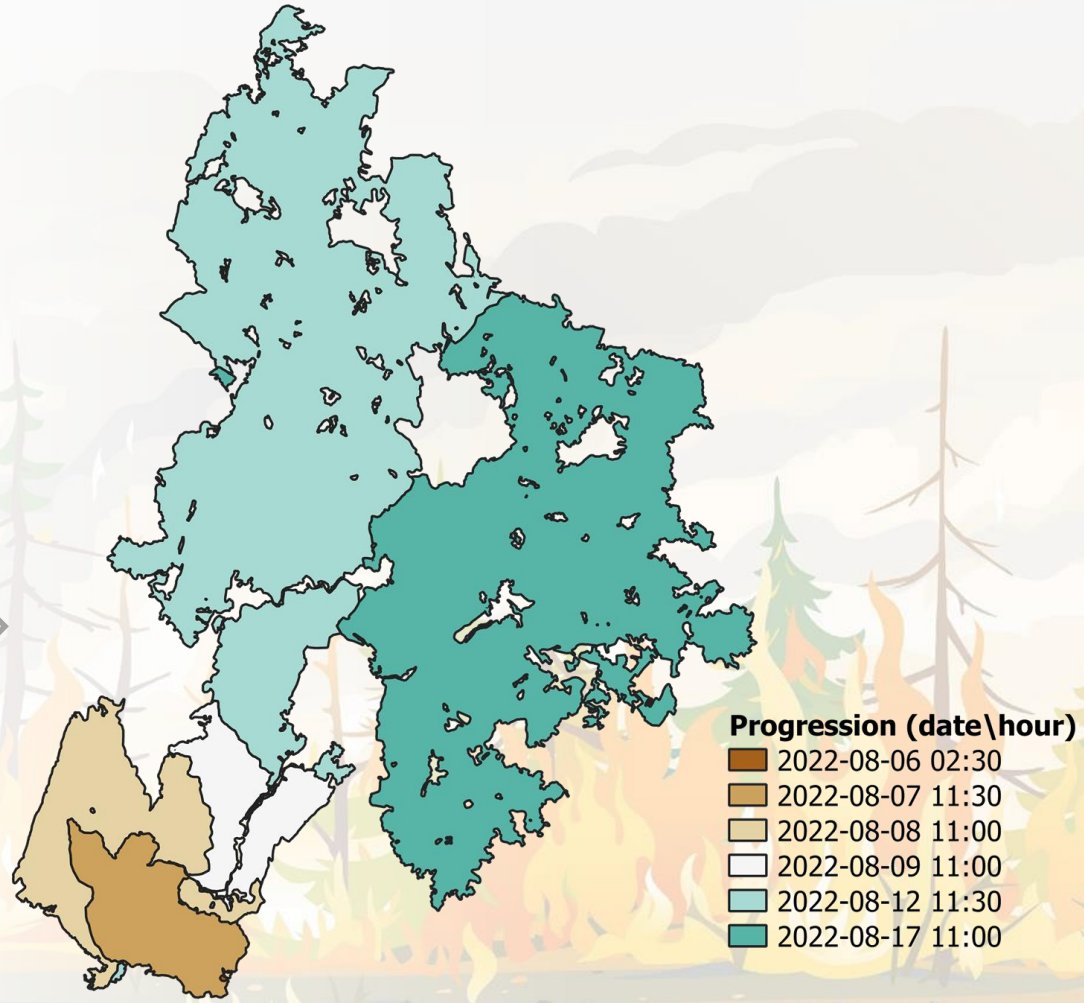


Create a “date_hour” field and fill it with the satellite imagery acquisition date/hour



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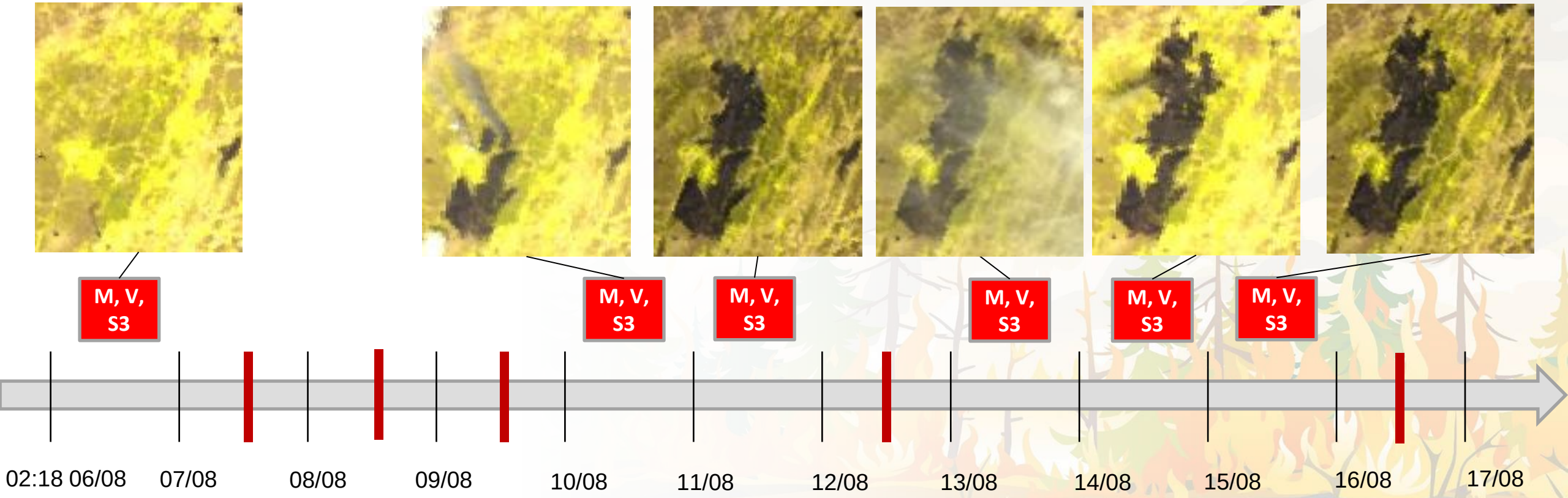
Reconstruction of wildfire spread using satellite data

Step #5. Break the final perimeter in intermediate perimeters using **moderate-res imagery**

Sentinel 3 -> Sentinel EO Browser (See Annex 5)
MODIS\VIIRS -> Wordview



source: Sentinel-2

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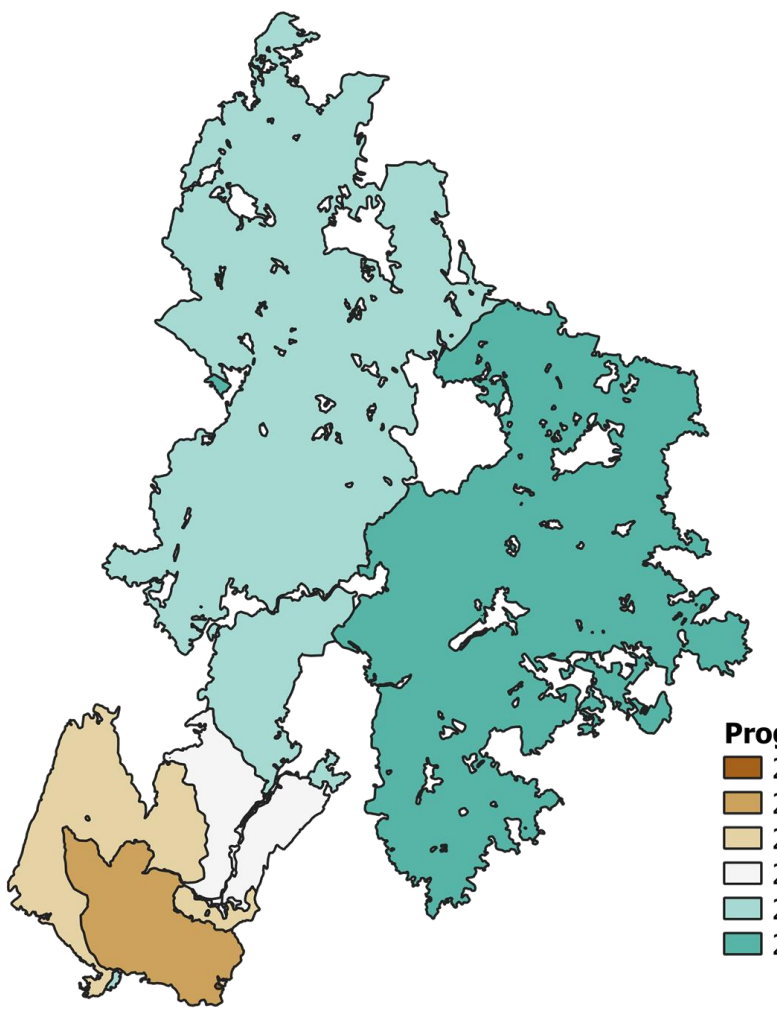
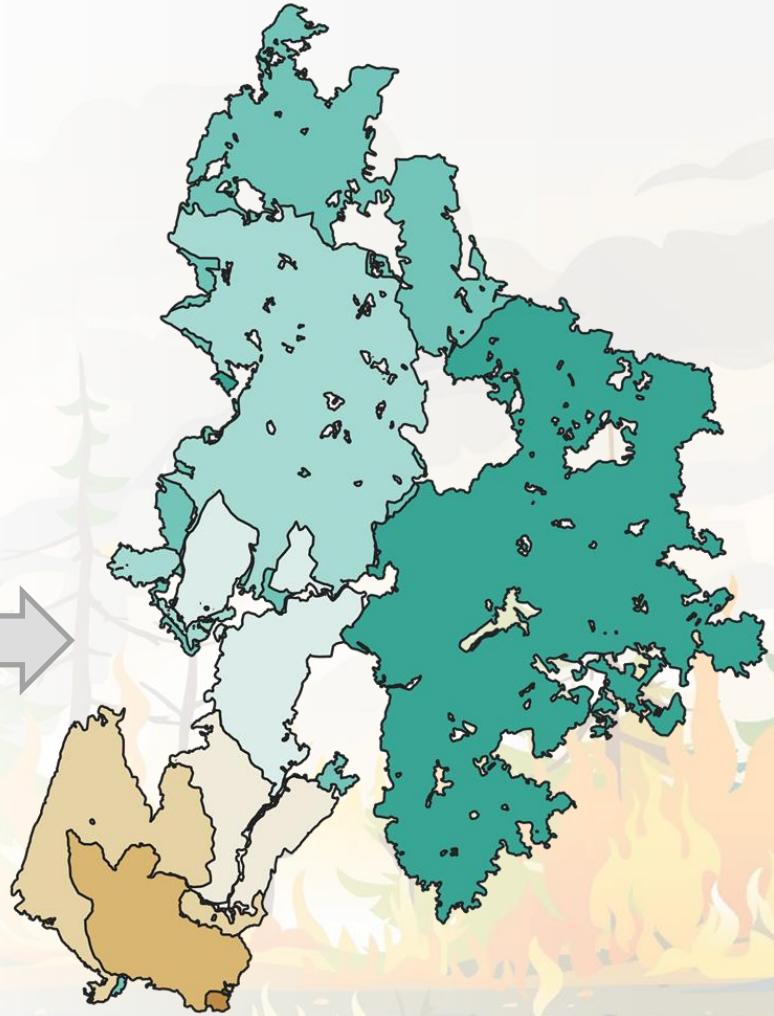
Reconstruction of wildfire spread using satellite data

Step #5. Break the final perimeter in intermediate perimeters using **moderate-res imagery**



Progression (date\hour)
- 2022-08-06 02:30
- 2022-08-07 11:30
- 2022-08-08 11:00
- 2022-08-09 11:00
- 2022-08-12 11:30
- 2022-08-17 11:00

Wildfire divided in daily progressions



Progression (date\hour)
- 2022-08-06 02:30
- 2022-08-06 11:30
- 2022-08-07 11:30
- 2022-08-08 11:00
- 2022-08-09 11:00
- 2022-08-10 11:30
- 2022-08-11 11:30
- 2022-08-12 11:30
- 2022-08-17 11:00

source: Sentinel-2

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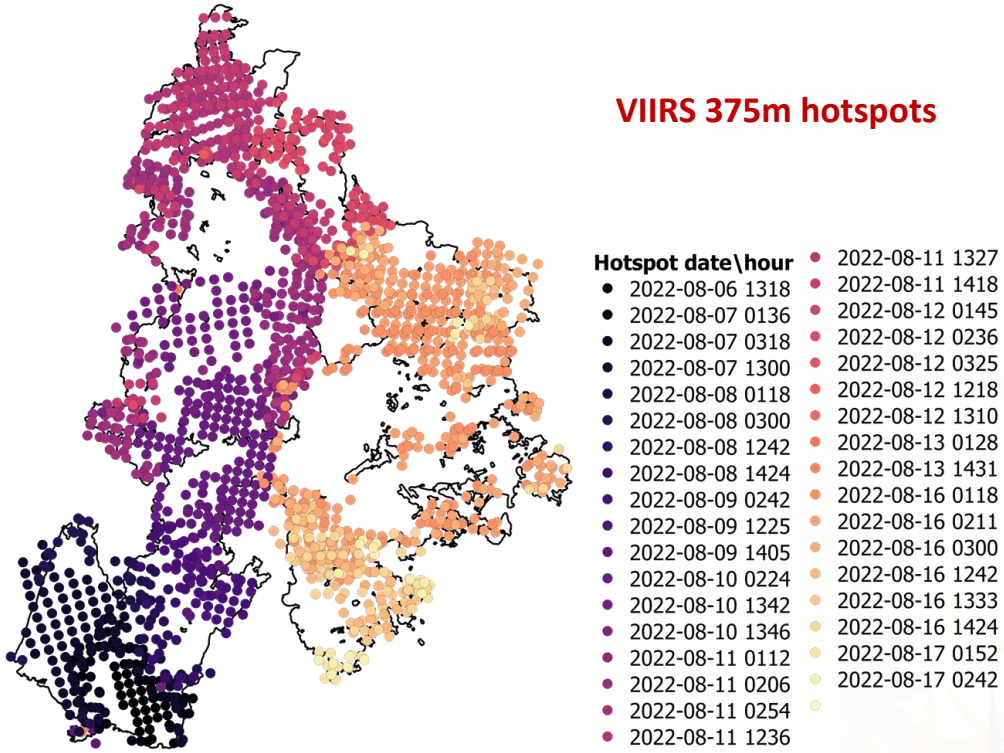
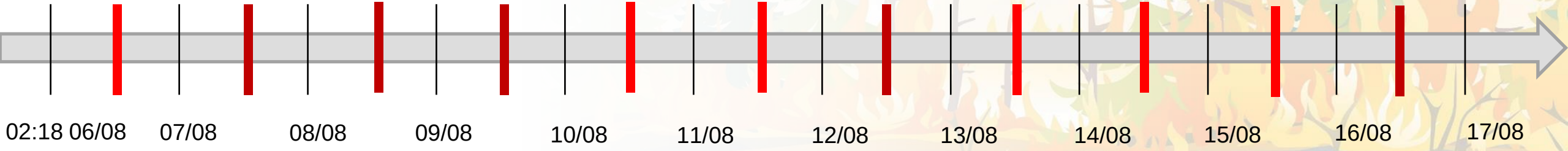
Reconstruction of wildfire spread using satellite data

Step #6. Break the final perimeter in intermediate perimeters using **thermal hotpots**



- Be careful with resolution (e.g. hotspots outside the burned area)
- Integrate the hotspots according to the previous progression & final perimeter
- Use only relevant observations that have significant fire spread;
- If applicable, advance the date\time of a previous progressions.



source: Sentinel-2

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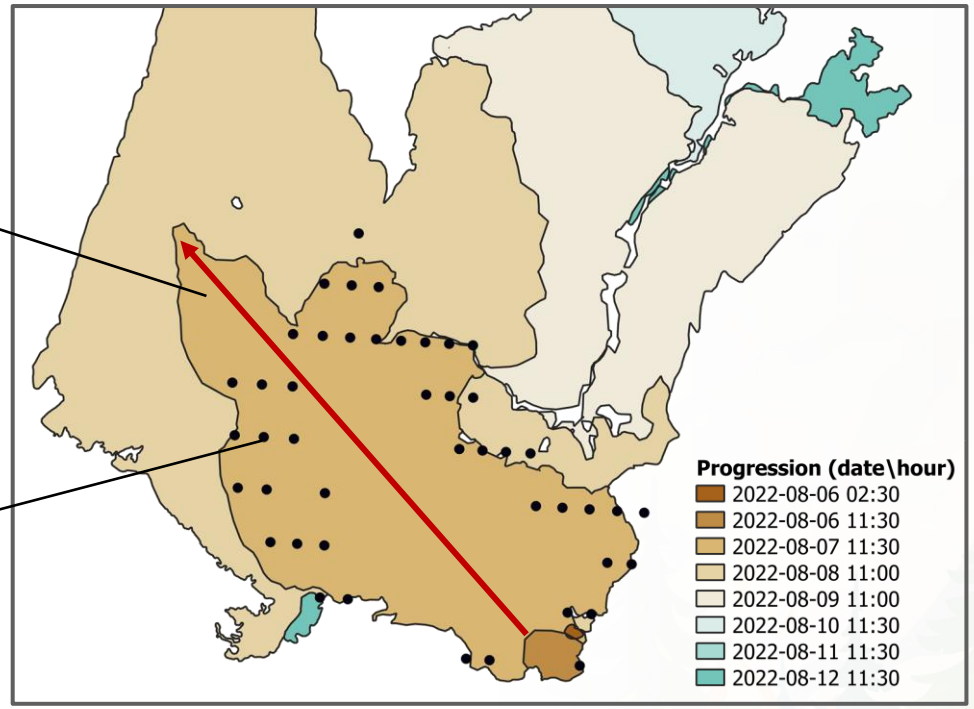
Reconstruction of wildfire spread using satellite data

Step #6. Break the final perimeter in intermediate perimeters using **thermal hotpots**

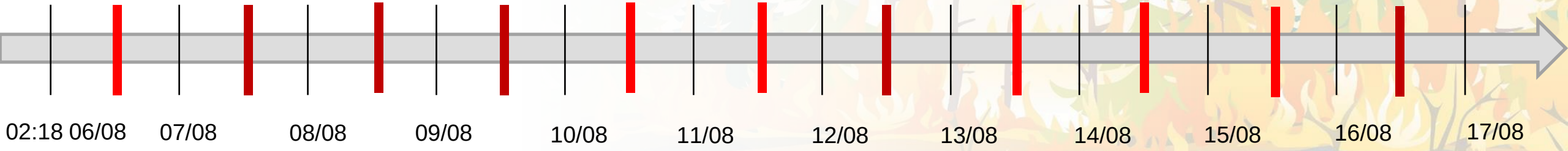
07/08
11:30

10h difference!

07/08
01:30



- Be careful with resolution (e.g. hotspots outside the burned area)
- Integrate the hotspots according to the previous progression & final perimeter
- Use only relevant observations that have significant fire spread;
- If applicable, advance the date\time of a previous progressions.



source: Sentinel-2

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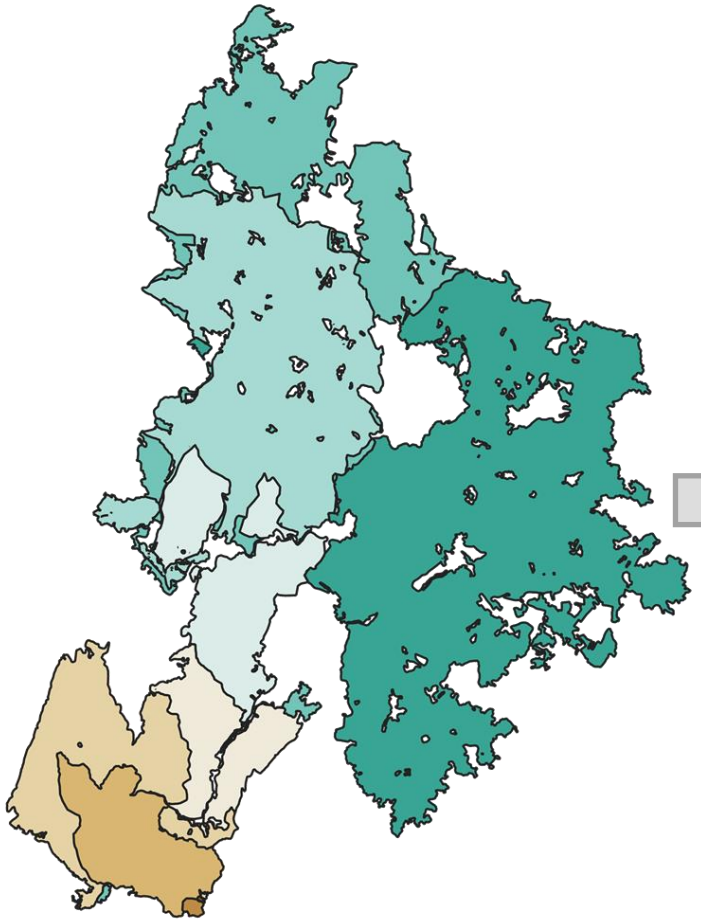
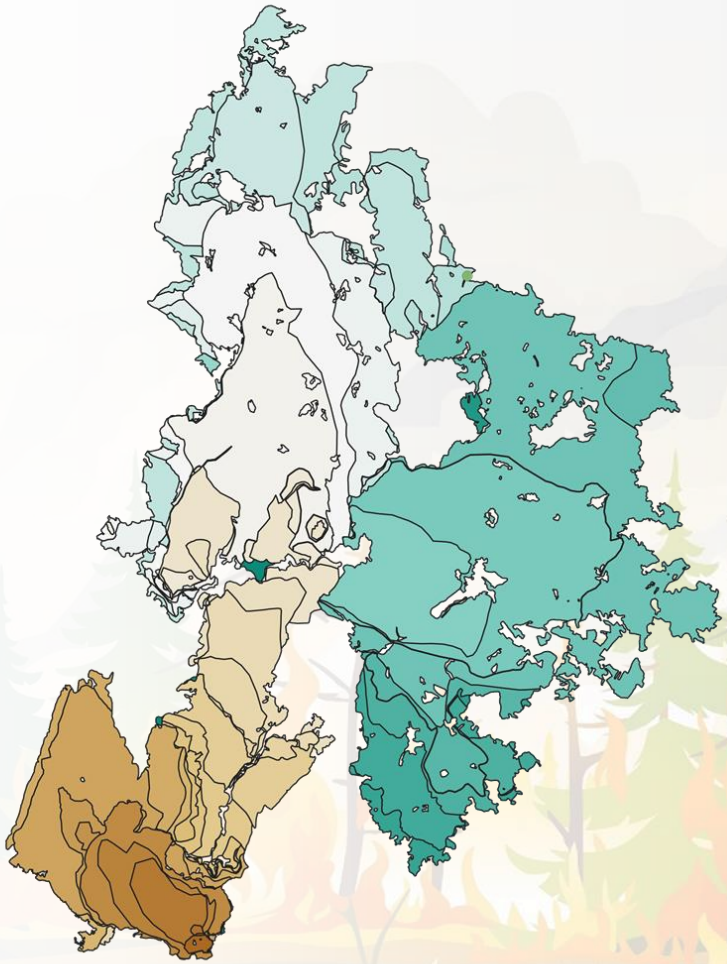
Reconstruction of wildfire spread using satellite data

Step #6. Break the final perimeter in intermediate perimeters using **thermal hotspots**



Progression (date\hour)
- 2022-08-06 02:30
- 2022-08-06 11:30
- 2022-08-07 11:30
- 2022-08-08 11:00
- 2022-08-09 11:00
- 2022-08-10 11:30
- 2022-08-11 11:30
- 2022-08-12 11:30
- 2022-08-17 11:00

Combine with other data sources



Progression (date\hour)
- 2022-08-06 03:30
- 2022-08-06 10:00
- 2022-08-06 11:30
- 2022-08-06 15:30
- 2022-08-06 19:30
- 2022-08-07 02:30
- 2022-08-07 10:30
- 2022-08-07 12:30
- 2022-08-07 17:30
- 2022-08-08 04:00
- 2022-08-08 10:00
- 2022-08-08 12:00
- 2022-08-08 16:30
- 2022-08-08 19:30
- 2022-08-09 03:30
- 2022-08-09 12:00
- 2022-08-09 15:00
- 2022-08-09 18:00
- 2022-08-09 19:00
- 2022-08-10 10:00
- 2022-08-10 12:30
- 2022-08-10 15:30
- 2022-08-10 17:30
- 2022-08-10 19:30
- 2022-08-11 03:00
- 2022-08-11 11:30
- 2022-08-11 12:00
- 2022-08-11 14:30
- 2022-08-11 19:30
- 2022-08-12 02:30
- 2022-08-12 12:30
- 2022-08-12 14:00
- 2022-08-12 19:30
- 2022-08-15 15:30
- 2022-08-15 17:30
- 2022-08-15 19:30
- 2022-08-16 03:00
- 2022-08-16 06:30
- 2022-08-16 12:00
- 2022-08-16 15:00
- 2022-08-16 18:30
- 2022-08-17 01:00
- 2022-08-17 03:00
- 2022-08-19 00:00
- 2022-08-24 00:00
- uncertain

source: Sentinel-2

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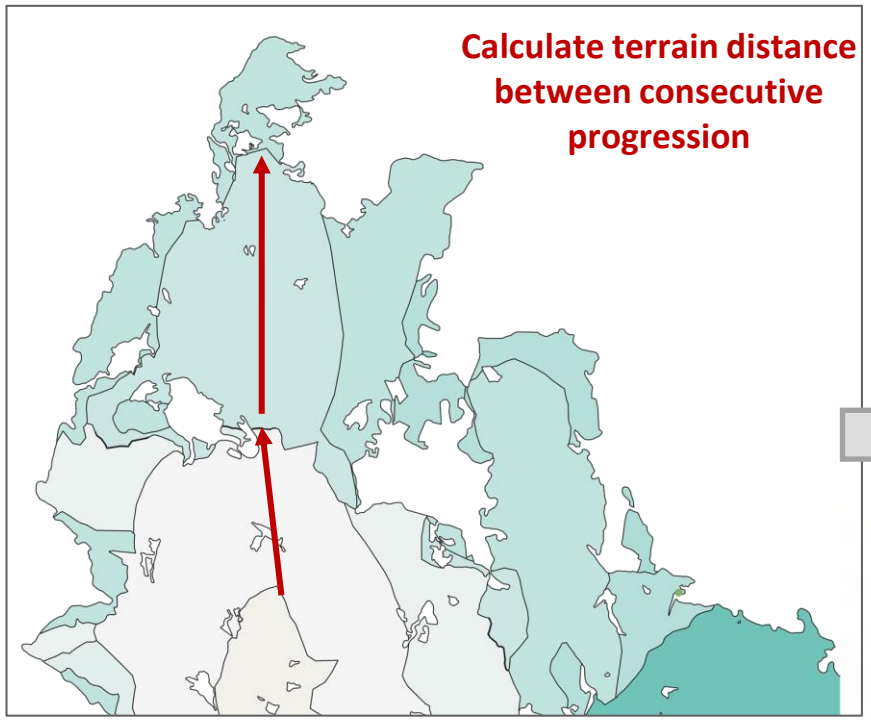
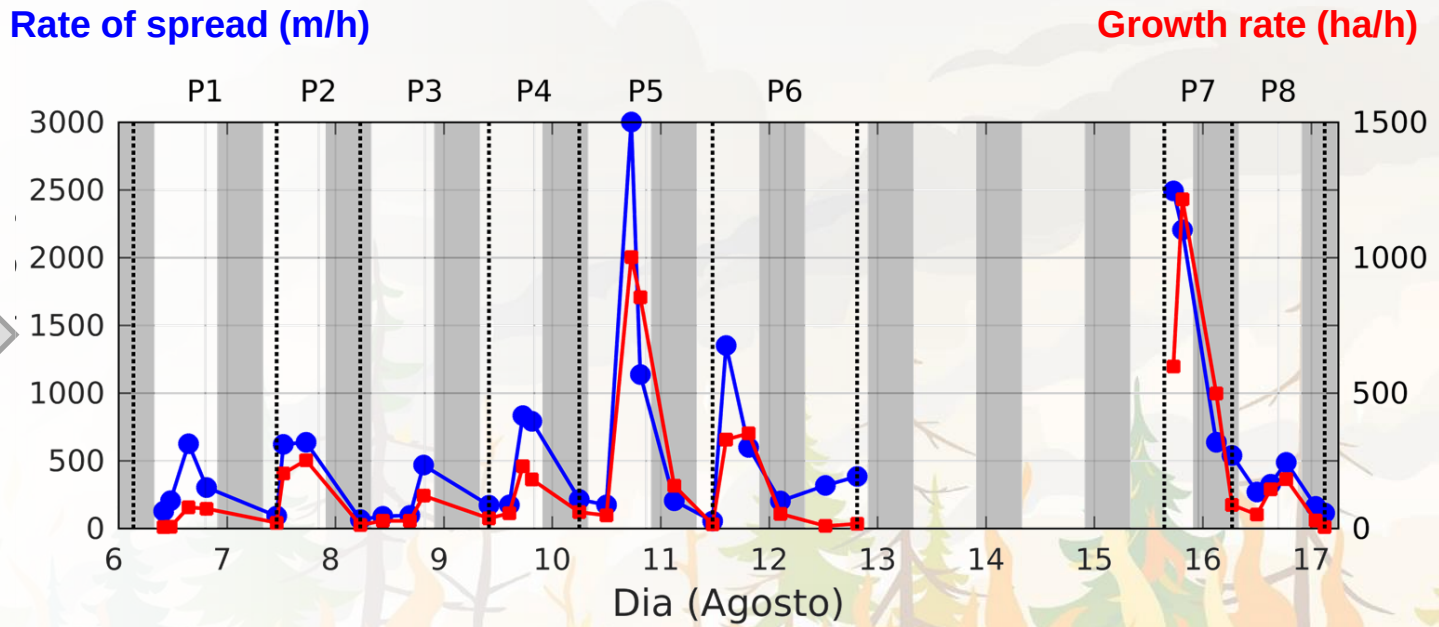
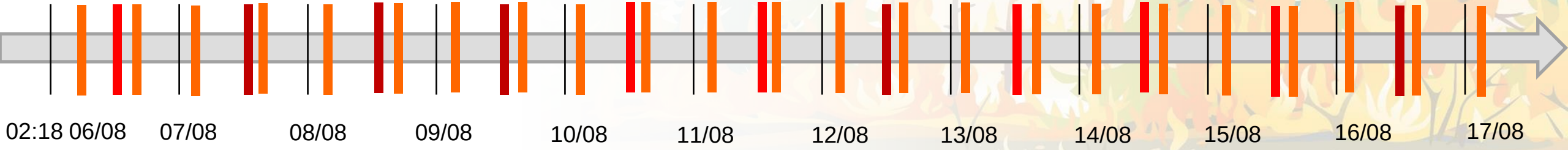
Reconstruction of wildfire spread using satellite data

Step #7. Estimate fire **behavior descriptors**







source: Sentinel-2

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Reconstruction of wildfire spread using satellite data

Take home messages

Fire spread can be reconstructed using freely available and easy-to-use satellite data

The approach presented can be applied in **any part of the globe**

Converge multiple sources of evidence

Be **cautious** with satellite data\products limitations (cloud cover, smoke, resolution)

Pay **especial attention** to the start and end of the progression to avoid major fire behavior underestimation

source: Sentinel-2

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Reconstruction of wildfire spread using satellite data

If you want to know more…

More **workshops** scheduled (advanced):

- Germany (November 2024 – TBC)
- Lisbon (Winter 2025)

Profit from the **Short Term Scientific Missions (STSM)** and visit us at Lisbon to learn more on wildfire reconstruction!

Visit https://nero-network.eu/grants for detailed information on how to **apply for a grant**!

Contact Akli Benali (aklibenali@gmail.com) for more **information**

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source: Sentinel-2

Reconstruction of wildfire spread using satellite data

Questions?

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(3) The NERO fire collection app

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Thank you!

NERO – european **N**etwork on **E**xtreme fi**R**e behavi**O**r (CA22164)
https://nero-network.eu

Annex 1. Satellite Bands

Sentinel 2

Sentinel-2 bands	Central wavelength (µm)	Resolution (m)
Band 1 – Coastal aerosol	0.443	60
Band 2 – Blue	0.490	10
Band 3 – Green	0.560	10
Band 4 – Red	0.665	10
Band 5 – Vegetation red edge	0.705	20
Band 6 – Vegetation red edge	0.740	20
Band 7 – Vegetation red edge	0.783	20
Band 8 – NIR	0.842	10
Band 8A – Vegetation red edge	0.865	20
Band 9 – Water vapour	0.945	60
Band 10 – SWIR – Cirrius	1.375	60
Band 11 – SWIR	1.610	20
Band 12 – SWIR	2.190	20

Landsat 8

Band	Wavelength range (nanometers)	Spatial Resolution (m)
Band 1 - Coastal aerosol	430 - 450	30
Band 2 - Blue	450 - 510	30
Band 3 - Green	530 - 590	30
Band 4 - Red	640 - 670	30
Band 5 - Near Infrared (NIR)	850 - 880	30
Band 6 - SWIR 1	1570 - 1650	30
Band 7 - SWIR 2	2110 - 2290	30
Band 8 - Panchromatic	500 - 680	15
Band 9 - Cirrus	1360 - 1380	30

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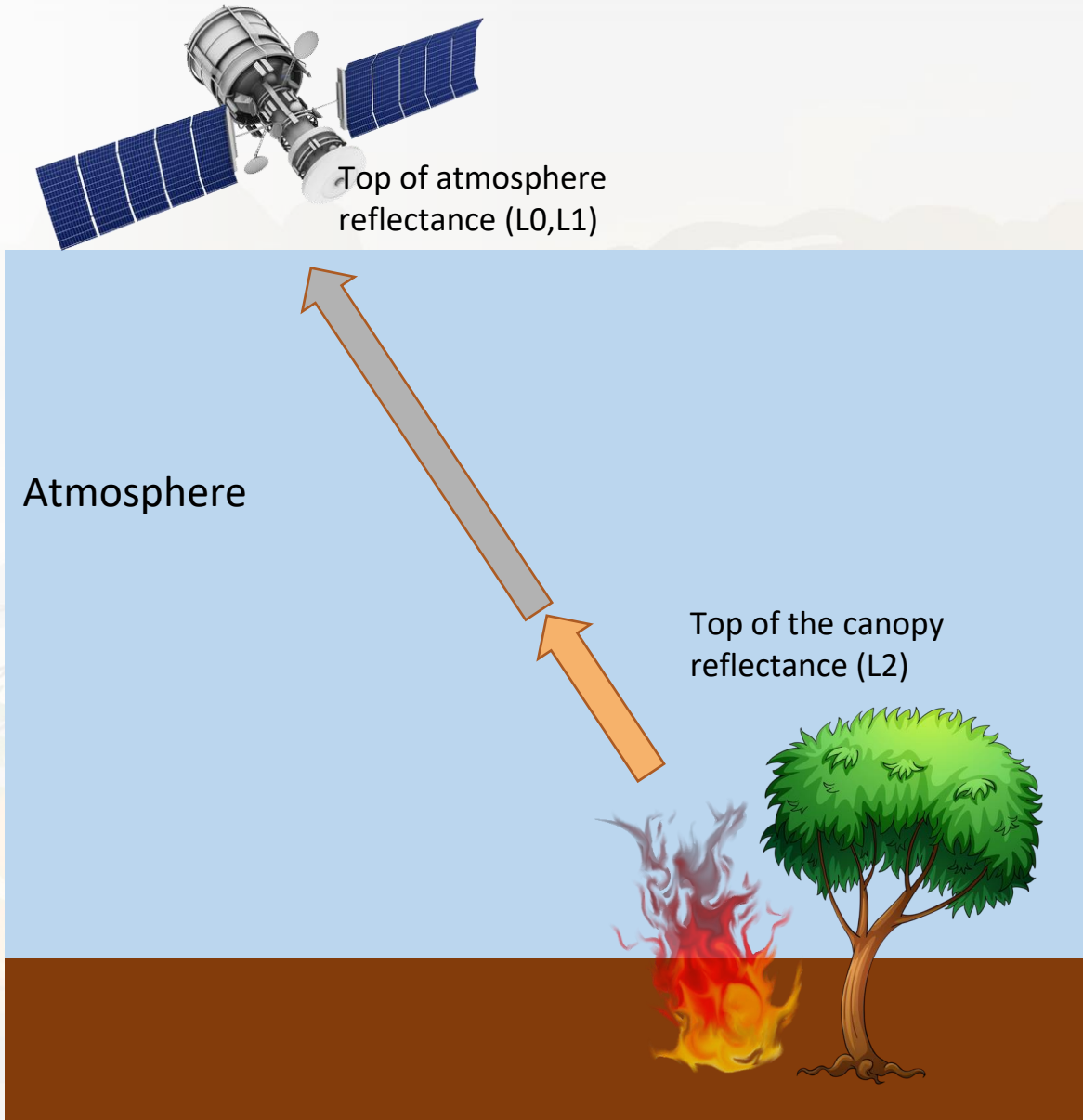
Annex 2. Atmospheric correction

- The atmosphere contaminates the signal acquired by satellites.
- This effect is usually removed to obtain the reflectance on the top of Earth's surface ("clean signal")
- The corrected reflectances are usually called top-of-the-canopy reflectances and labeled as Level 2 instead of L1 or L0 (example: Sentinel2)



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the European Union

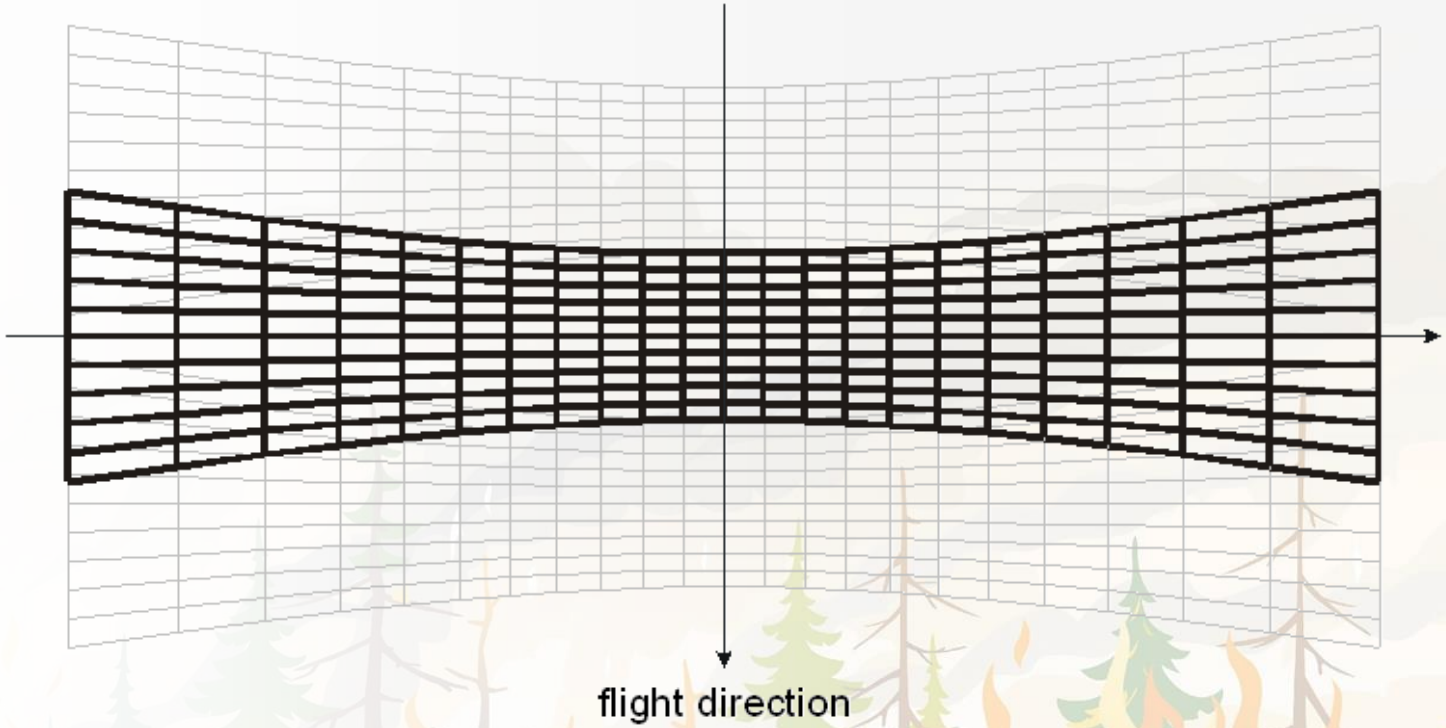
Annex 3. Pixel size deformation

At nadir (oblique angle immediately below the sensor), the resolution is maximum (nadir resolution).

The pixel size increases with increasing oblique viewing angles.

Some satellites have resampling procedures to attenuate pixel deformation (e.g. VIIRS)

In some products this information is provided to the user (e.g. VIIRS\MODIS hotspots)



Source: NASA

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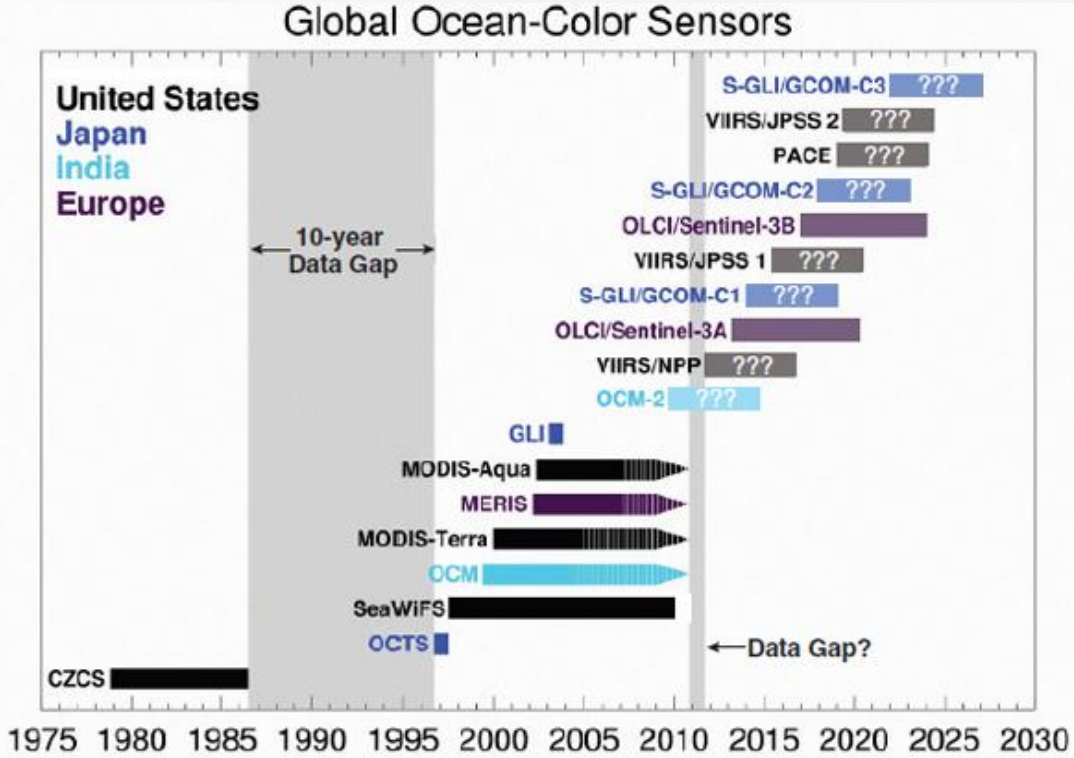
Annex 4. Satellite time span



Sources: USGS, EarthData, National Academic Press

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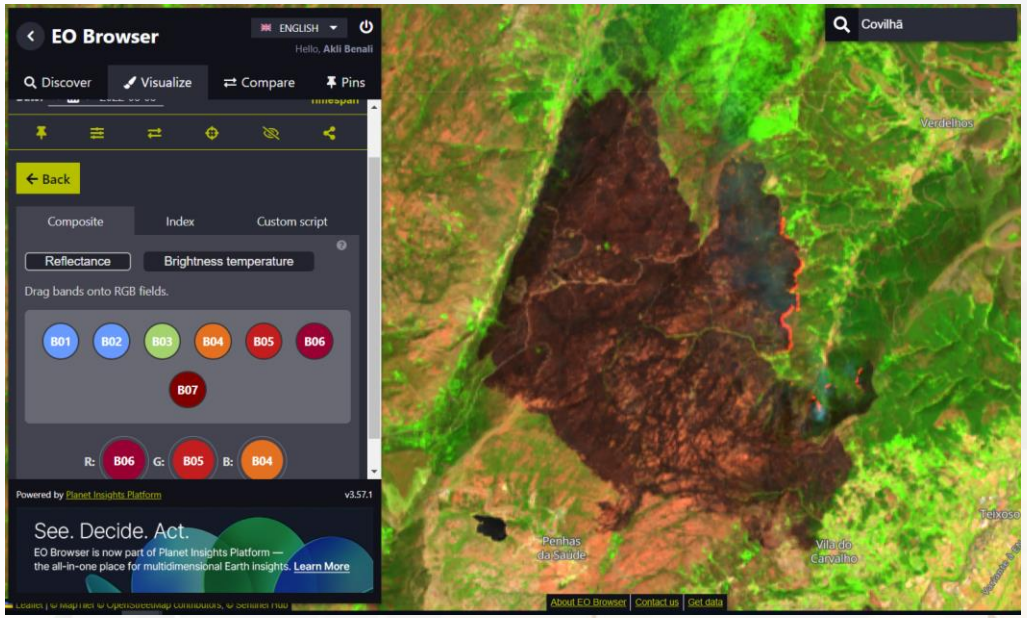
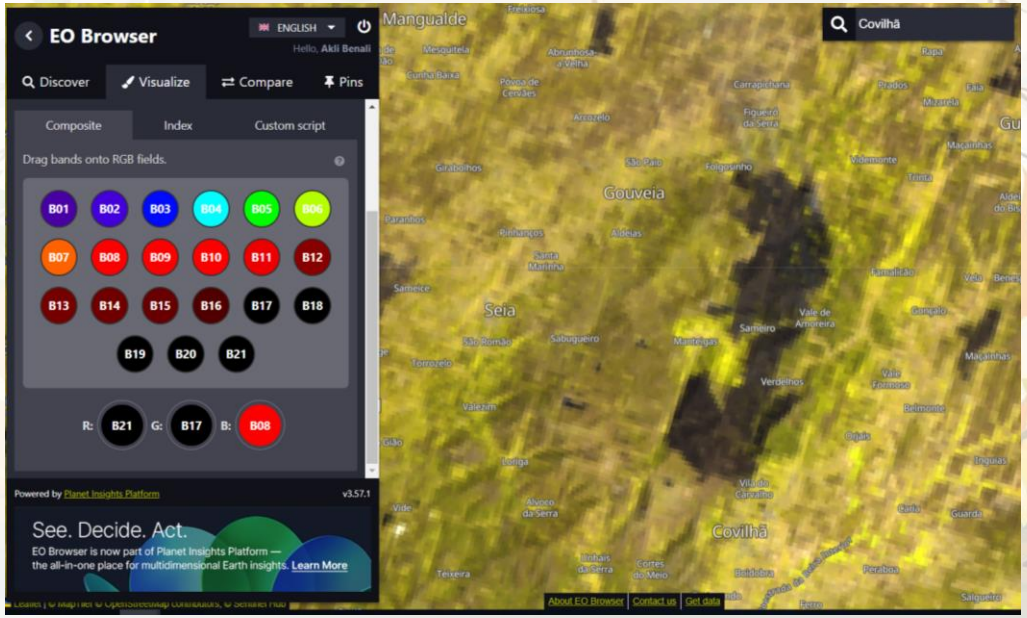
Annex 5. Working with data from Sentinel EO browser

1. Go to Sentinel EO Browser
2. Move to Region of Interest (“Go to Place”)
3. Select Sensors (left panel)
   prioritize L2 over L1 data
4. Define Time Range -> Search
5. Select satellite image (“Visualize”)

- **Sentinel 2**: SWIR composite
- **Landsat 8-9**, create your custom composite
  Custom -> R: Band 6; G: Band 5; B: Band 4
- **Sentinel 3 OLCI**: create your custom composite
  Custom -> R: Band 6; G: Band 5; B: Band 4





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Annex 6. Downloading VIIRS hotspots from FIRMS

1. Go to FIRMS archive download: https://firms.modaps.eosdis.nasa.gov/download/
2. Create New Request
3. Select Region, VIIRS (all satellites), Date start\end
4. Provide email address, Submit
5. Download data
6. Merge the 3 shapefiles (one for each satellite) in a single shapefile
7. Concatenate the ACQ_DATE and ACQ_TIME, fiels to get a “date_hour” string
   e.g. 2022-08-06 and 1318 -> 2022-08-06 1318
8. Remove all points significantly outside of the final burned perimeter (maximum buffer of 500m)

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