CzechGlobe GLOBAL CHANGE RESEARCH INSTITUTE CAS

Mapping of high, medium, or low-severity burned forest areas using airborne hyperspectral data

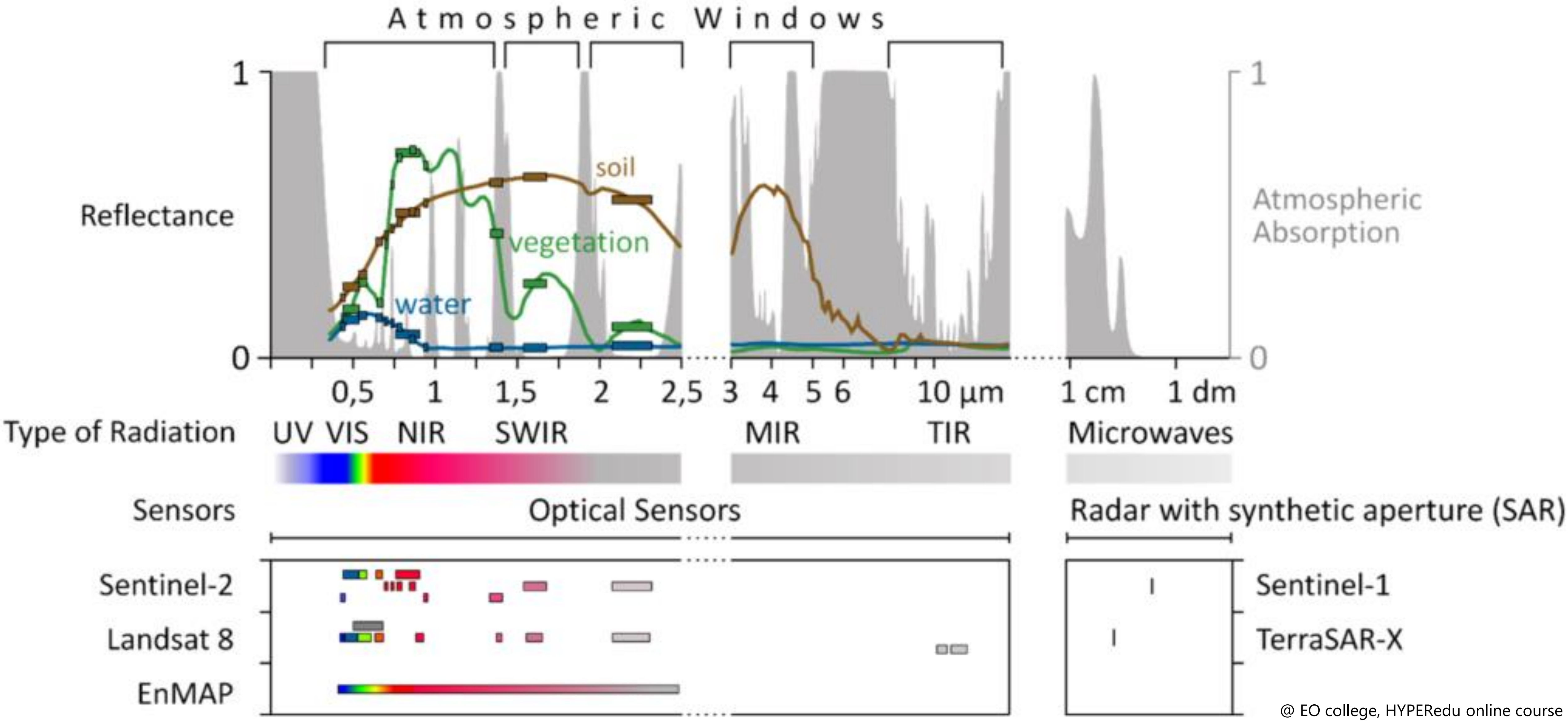
Olga Brovkina and colleagues

TAT July 2024 Chania, Greece

Overview

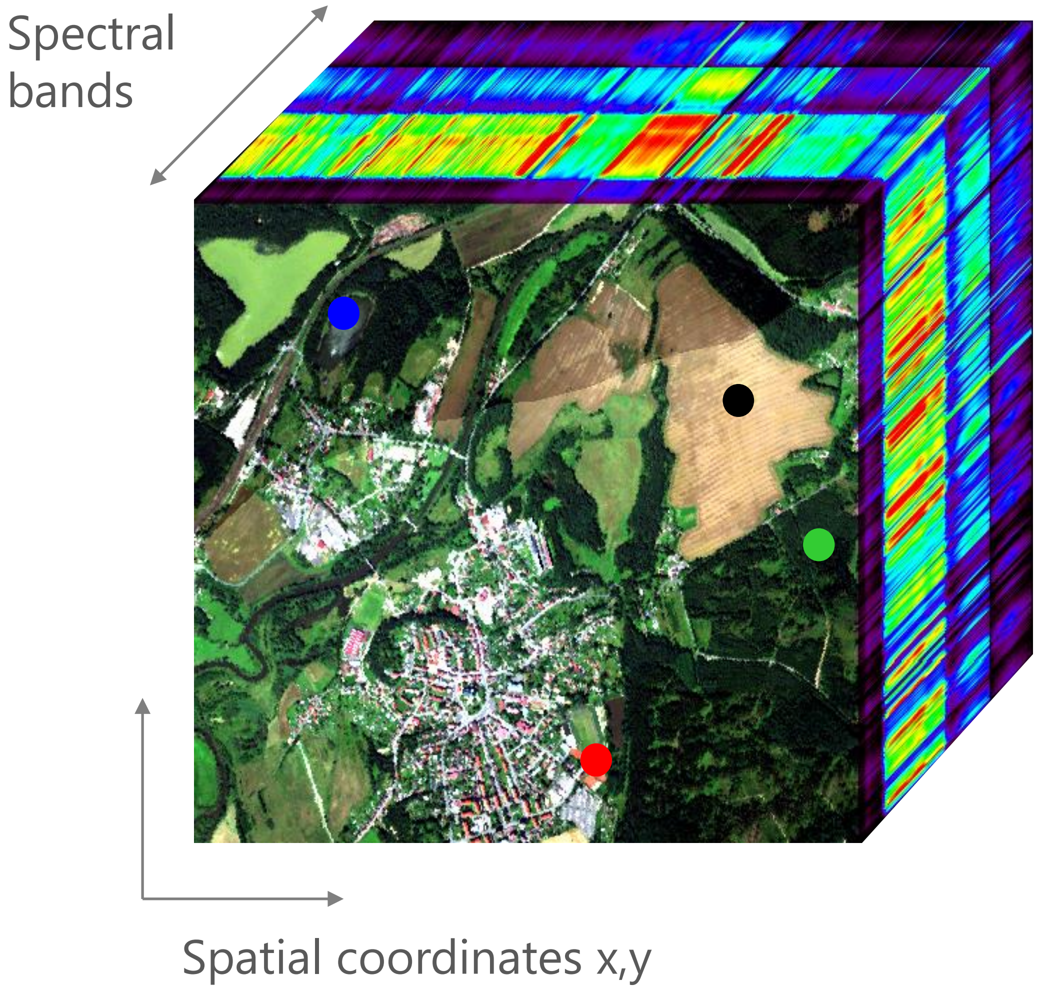
- Introduction to Hyperspectral Remote Sensing
- Airborne and Satellite Hyperspectral Sensors
- Hyperspectral Remote Sensing of Fire
- Mapping of high, medium, or low-severity burned forest areas using airborne hyperspectral data

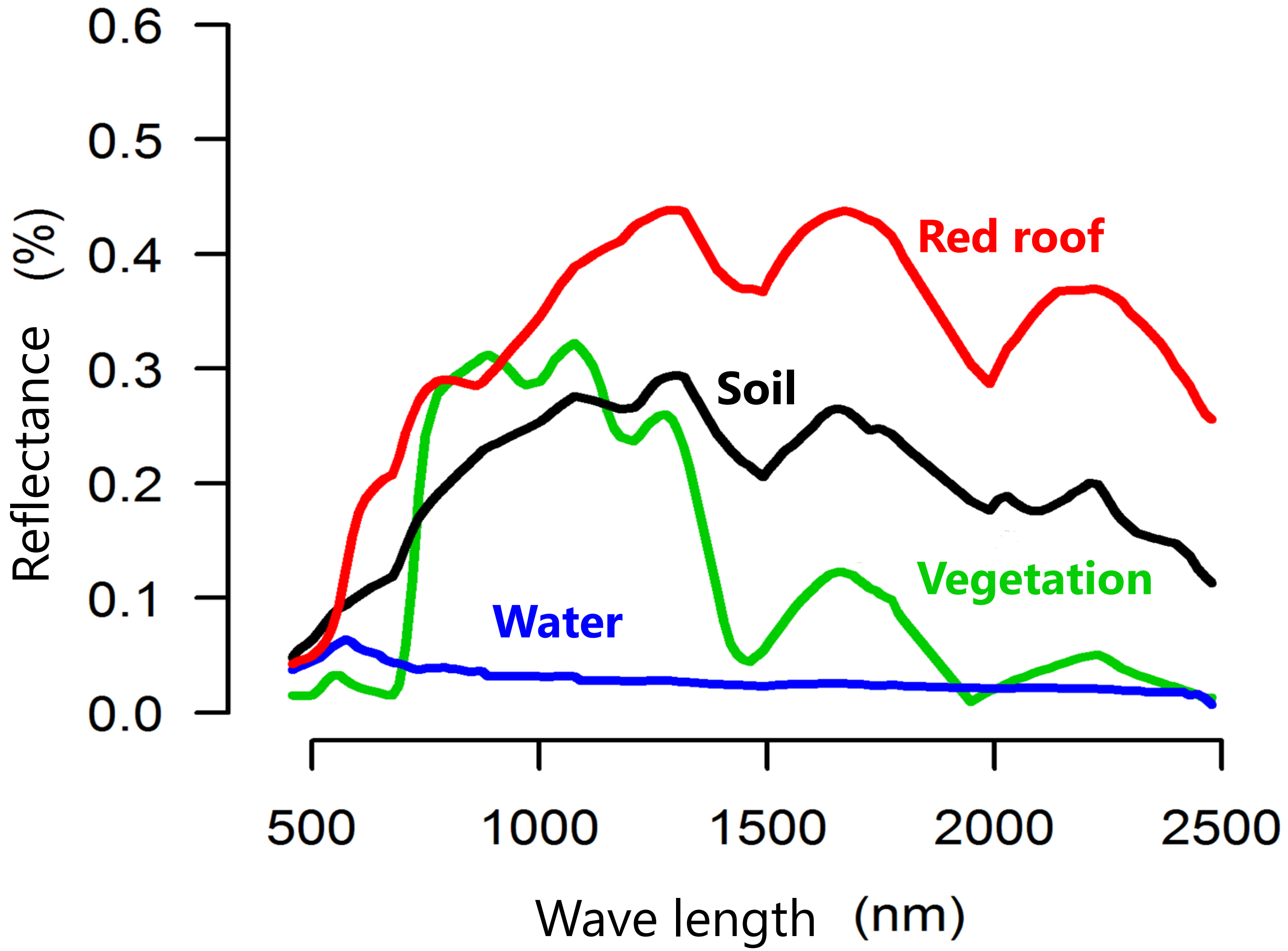
Hyperspectral vs. Multispectral



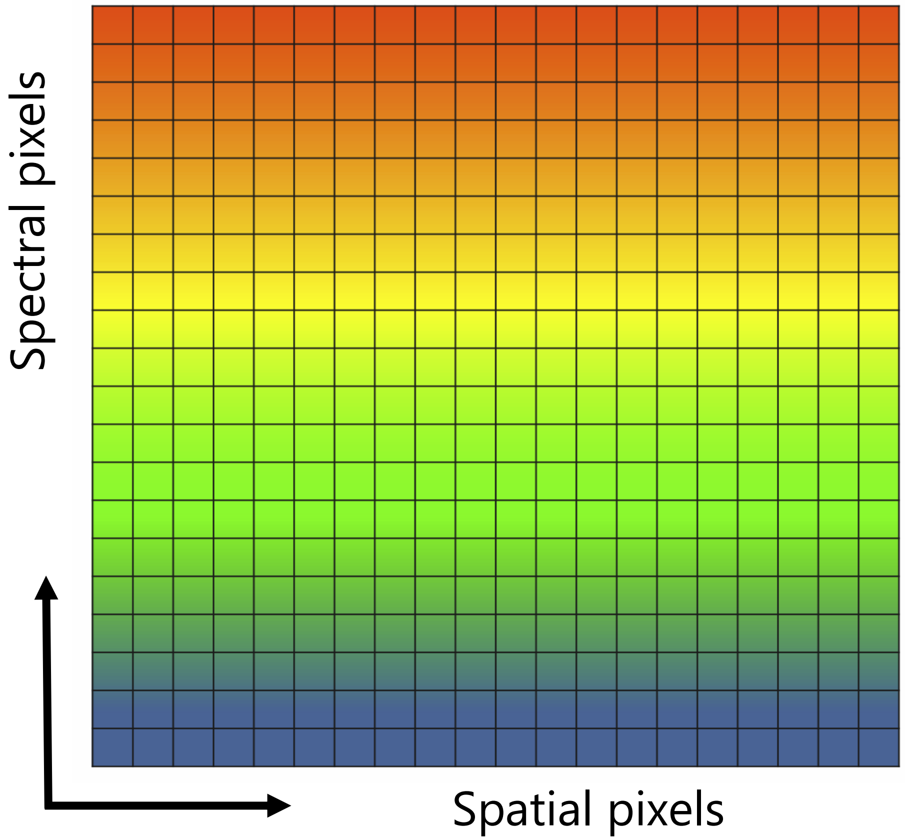
@ EO college, HYPERedu online course

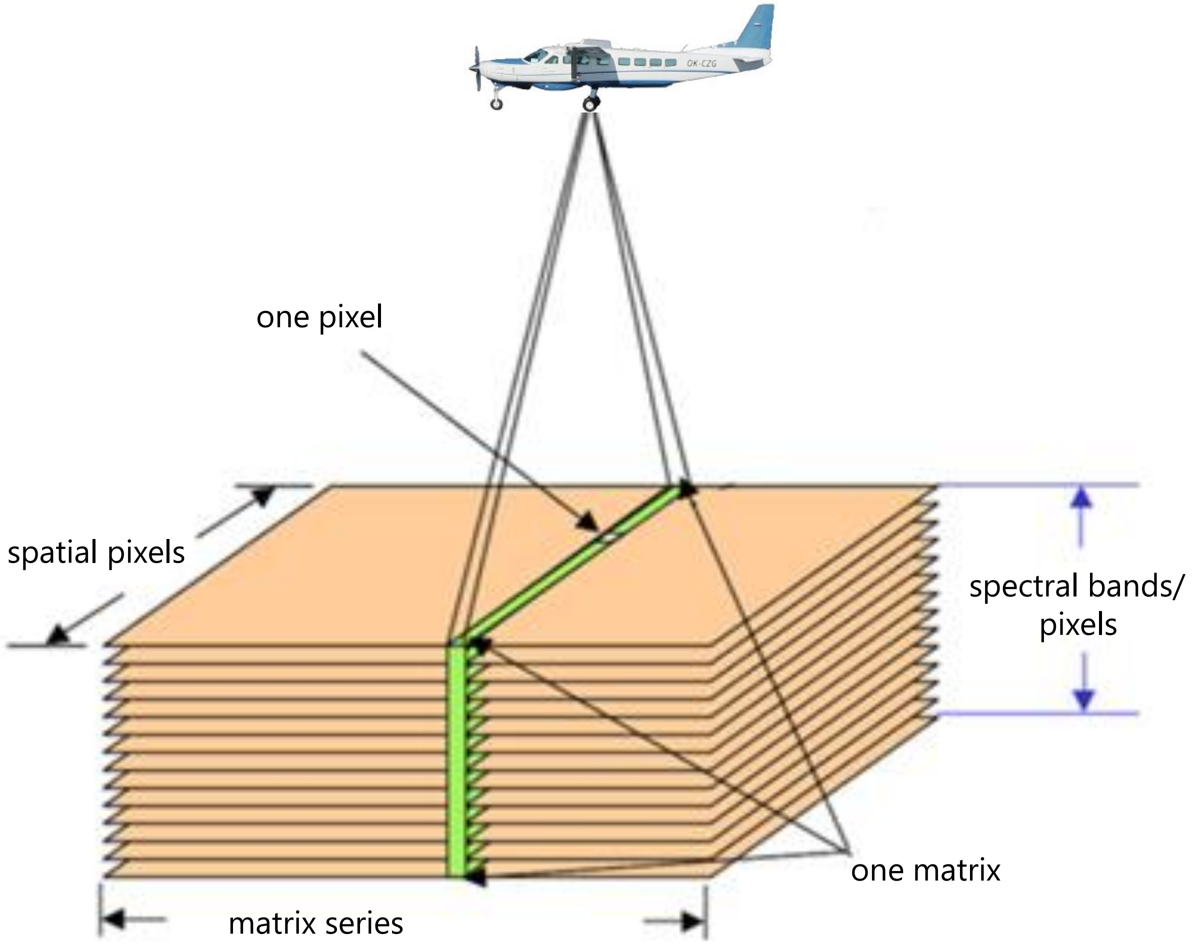
Hyperspectral „cube“



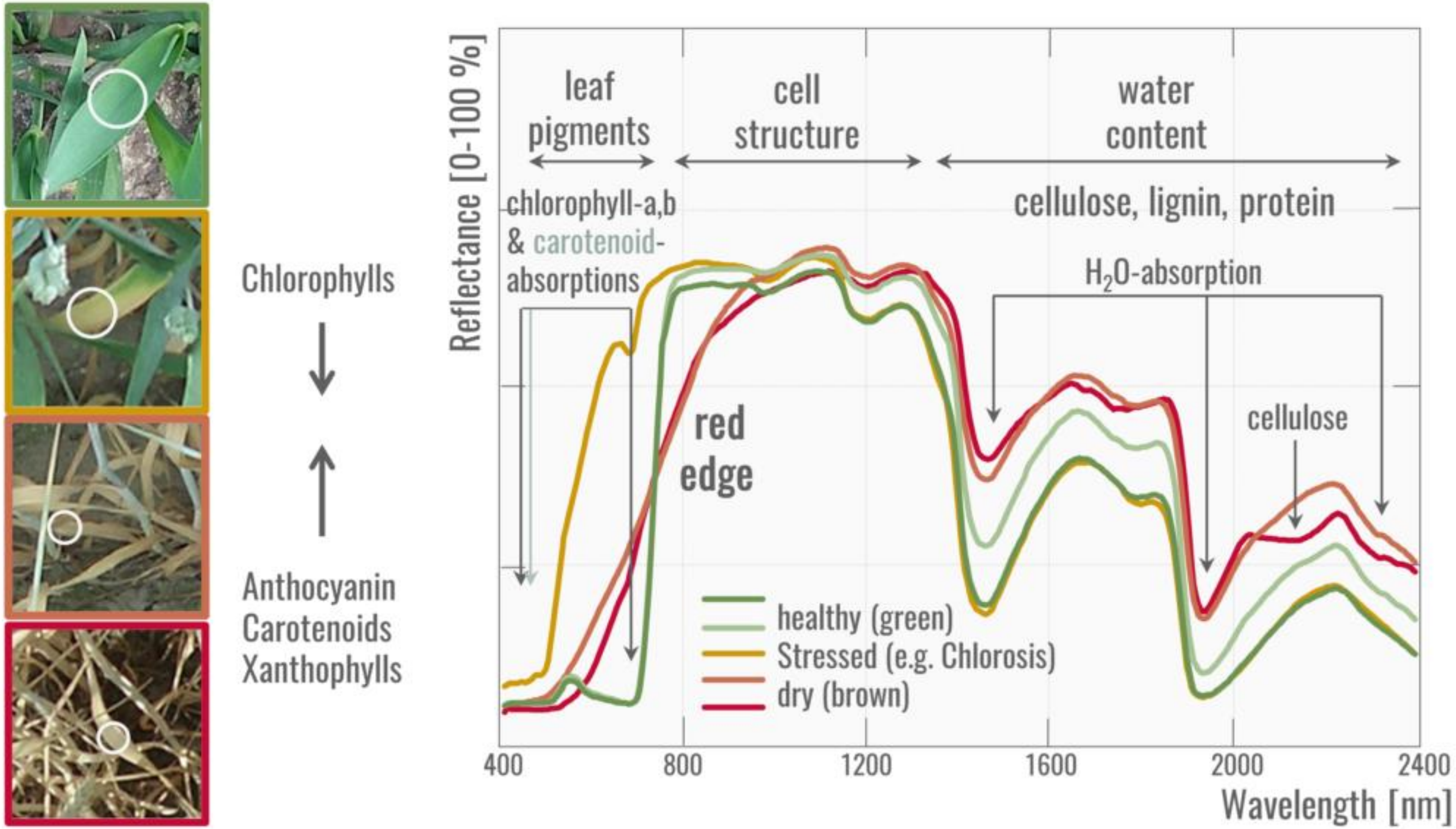


Principle of hyperspectral data acquisition

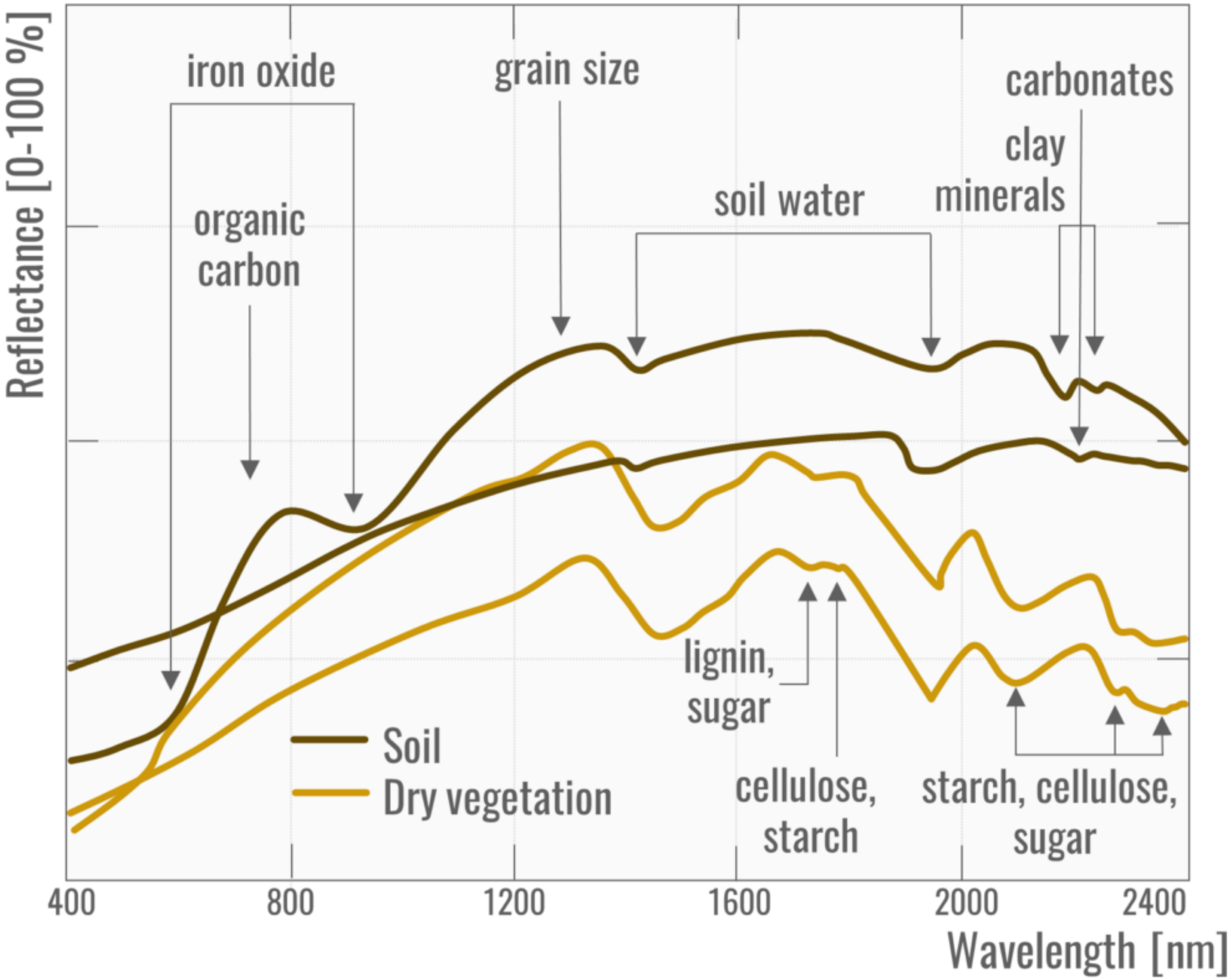




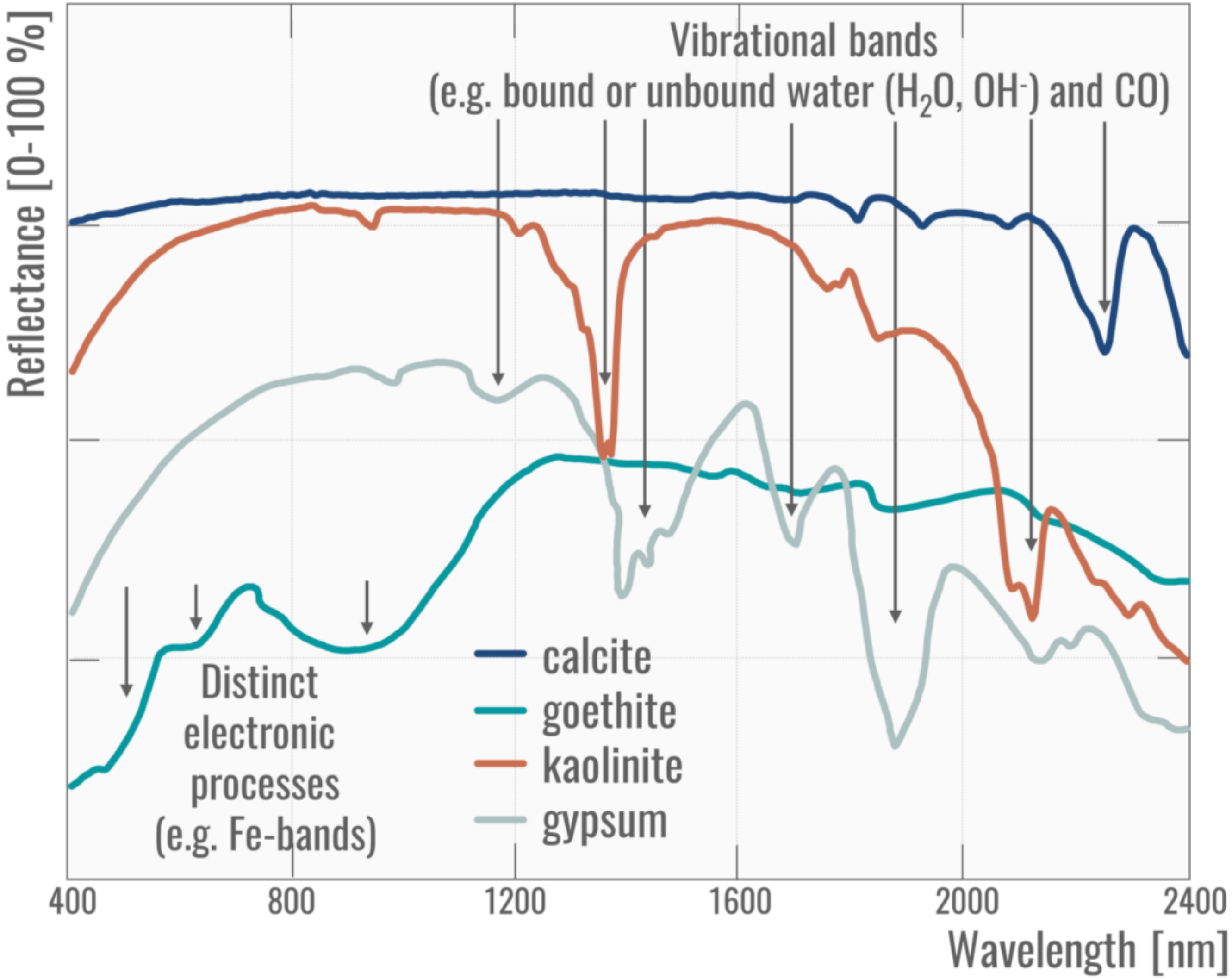
Vegetation spectra



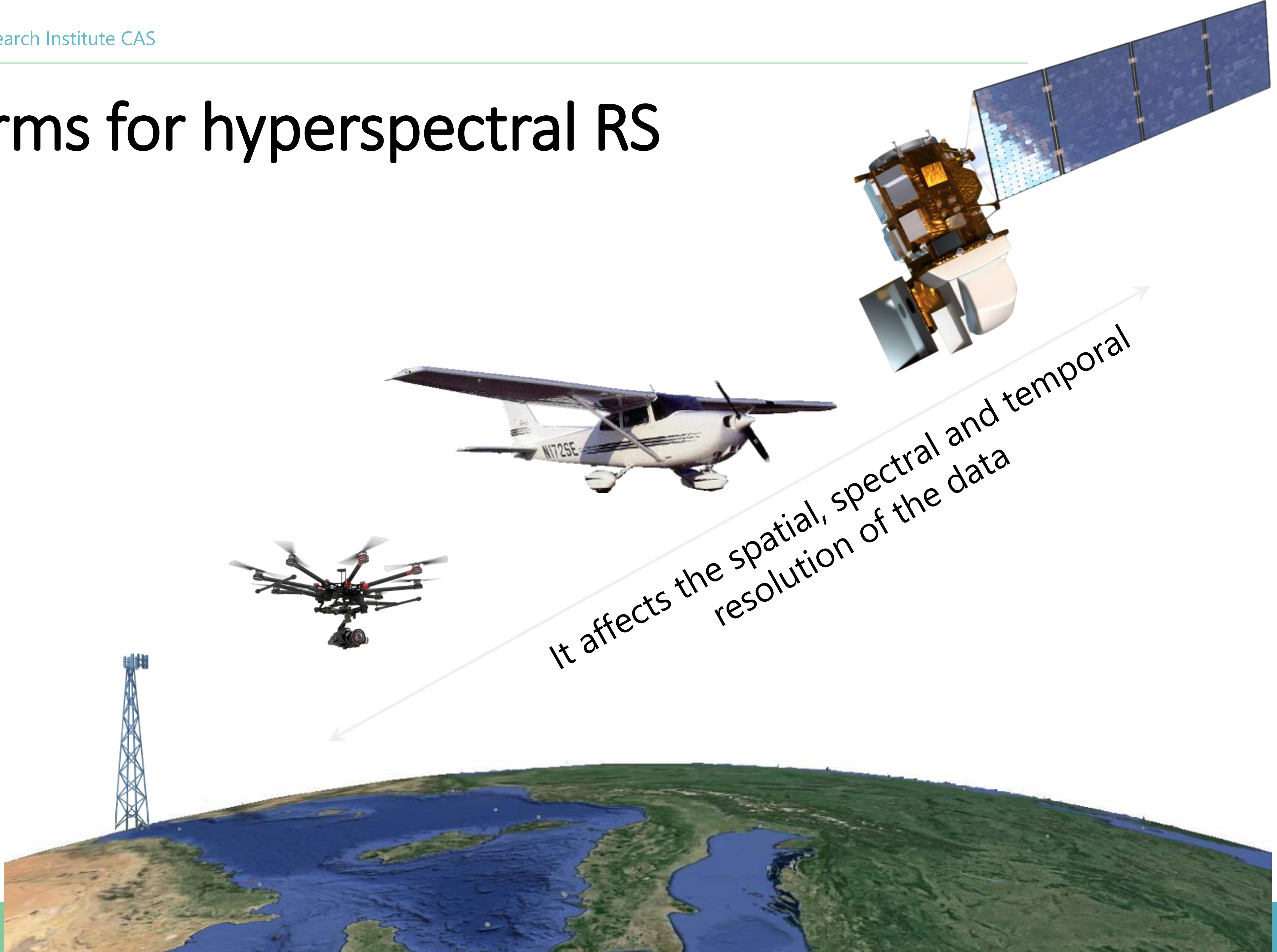
Soil spectra



Rocks spectra



Platforms for hyperspectral RS



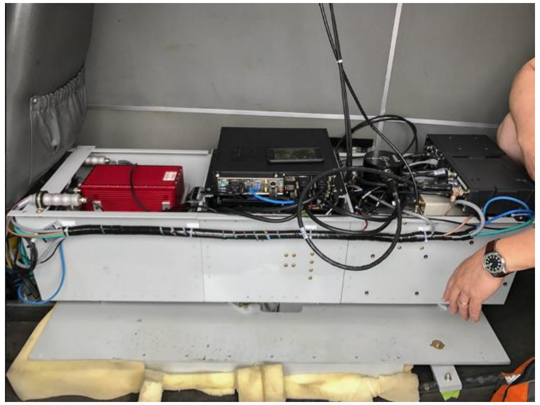
Airborne HS sensors

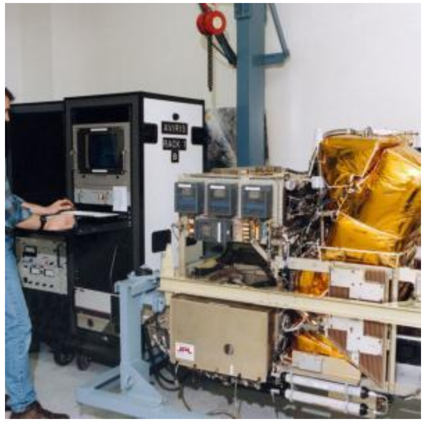
specim
SPECTRAL IMAGING

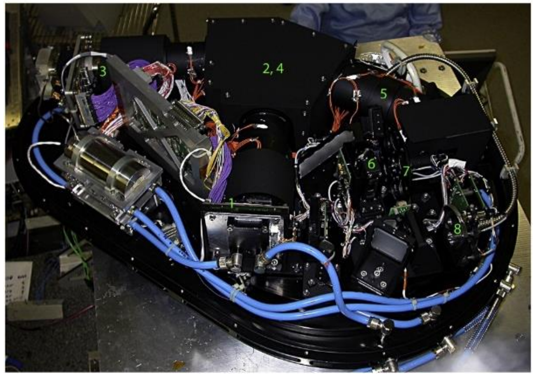
neo
NORSK ELEKTRO OPTIKK AS
HySpex

itres

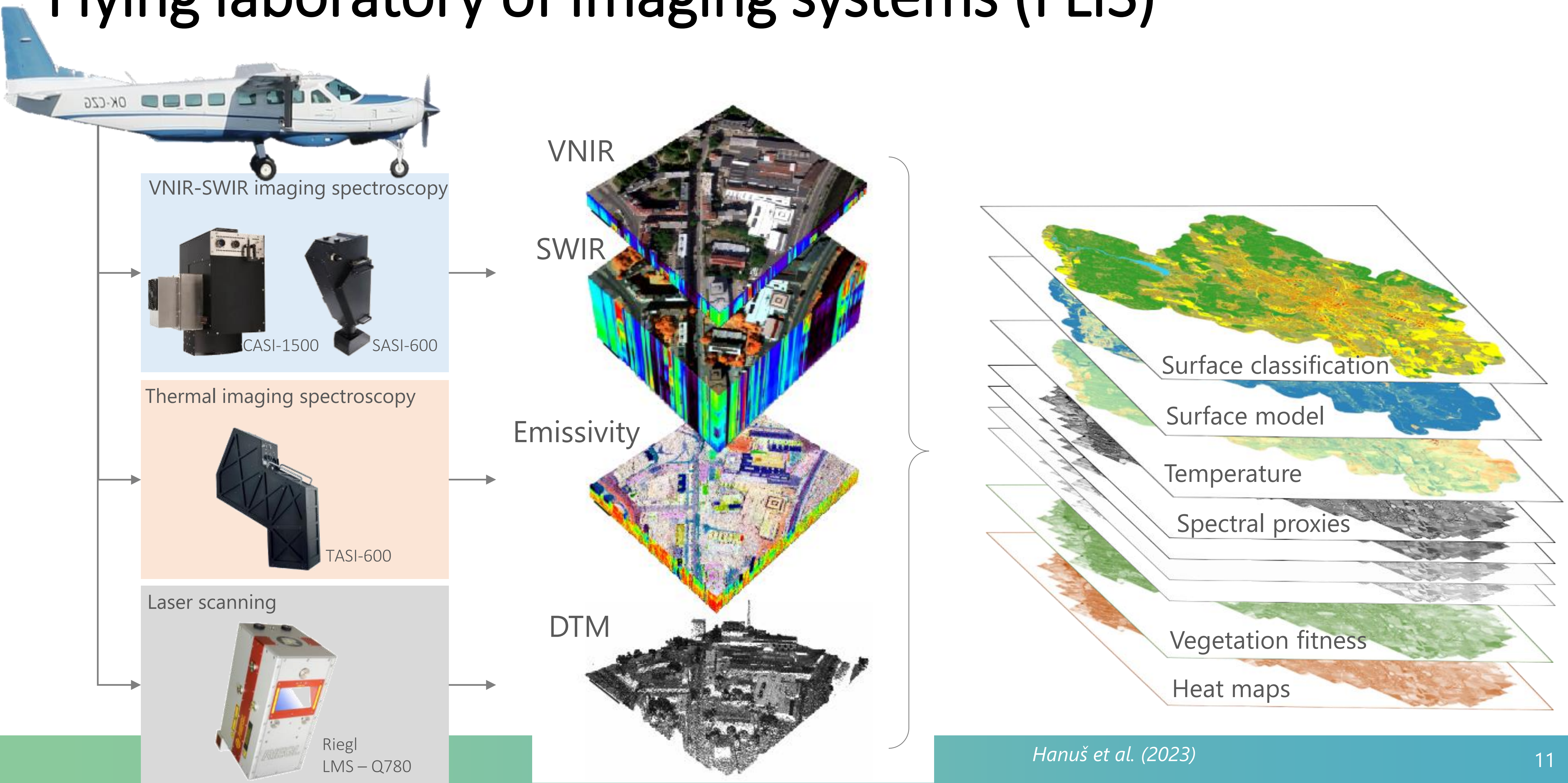
HyMap, operated by HyVista, Australia


G-LiHT, NASA GSFC custom-made frame with comercial sensors


AVIRIS-NG, NASA JPL


APEX, VITO Belgium + UZH Switzerland

Flying laboratory of imaging systems (FLIS)

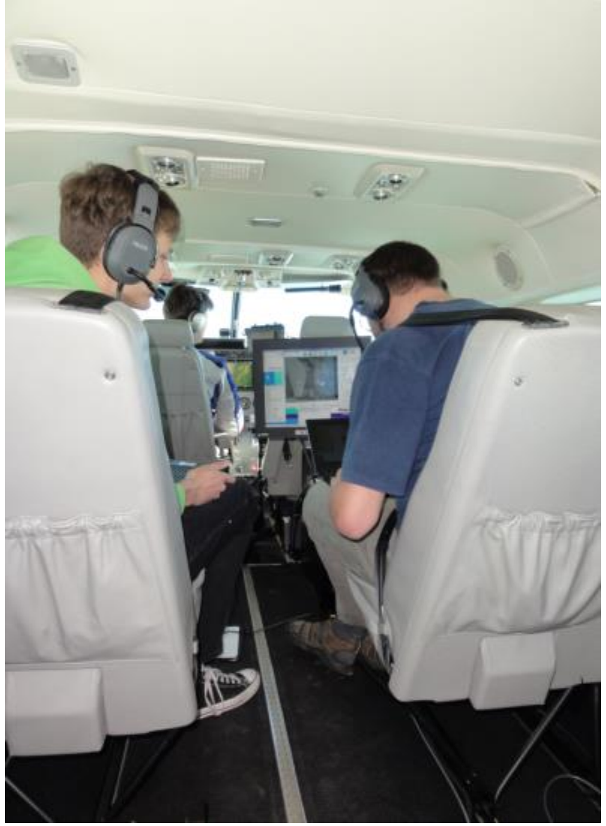


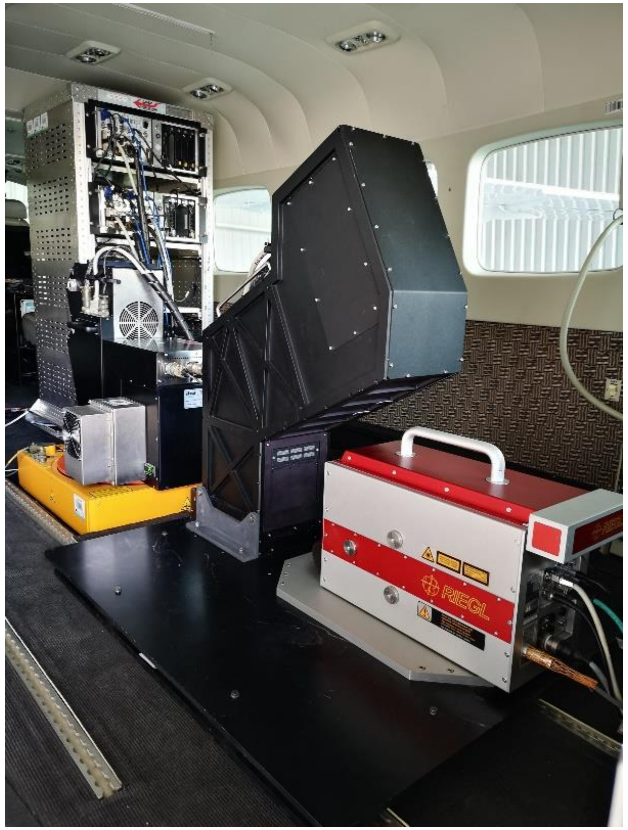
Hanuš et al. (2023)

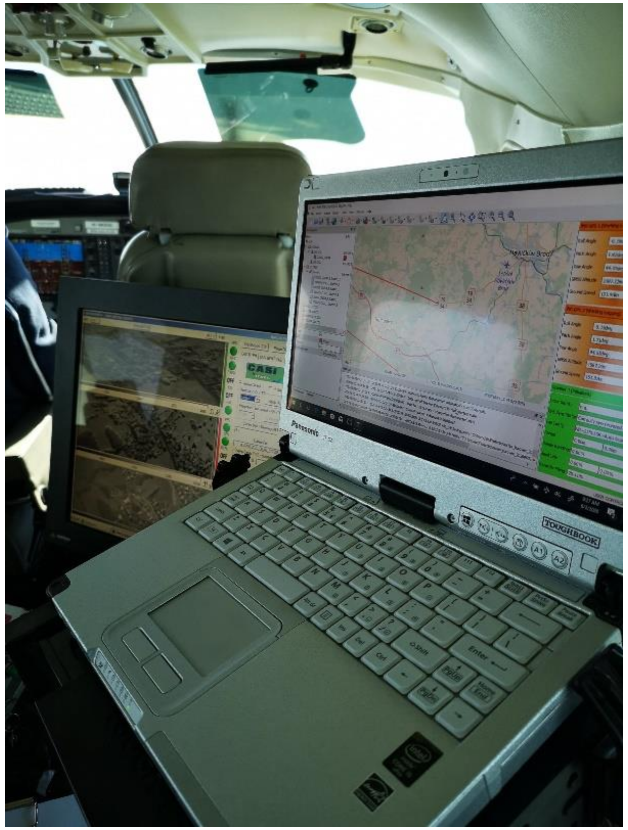
Flying laboratory of imaging systems (FLIS)

			
Sensor	**CASI-1500**	**SASI-600**	**TASI-600**
Band	VNIR	SWIR	LWIR
Spectral range [nm]	380-1050	950 – 2450	8 000 – 11 500
Number of pixels	1500	600	600
Max. spectral resolution [nm]	3.2	15	110
FOV [°]	40	40	40
Spatial resolution [m]	0.5 – 2.0	1.25 – 5.0	1.25 – 5.0

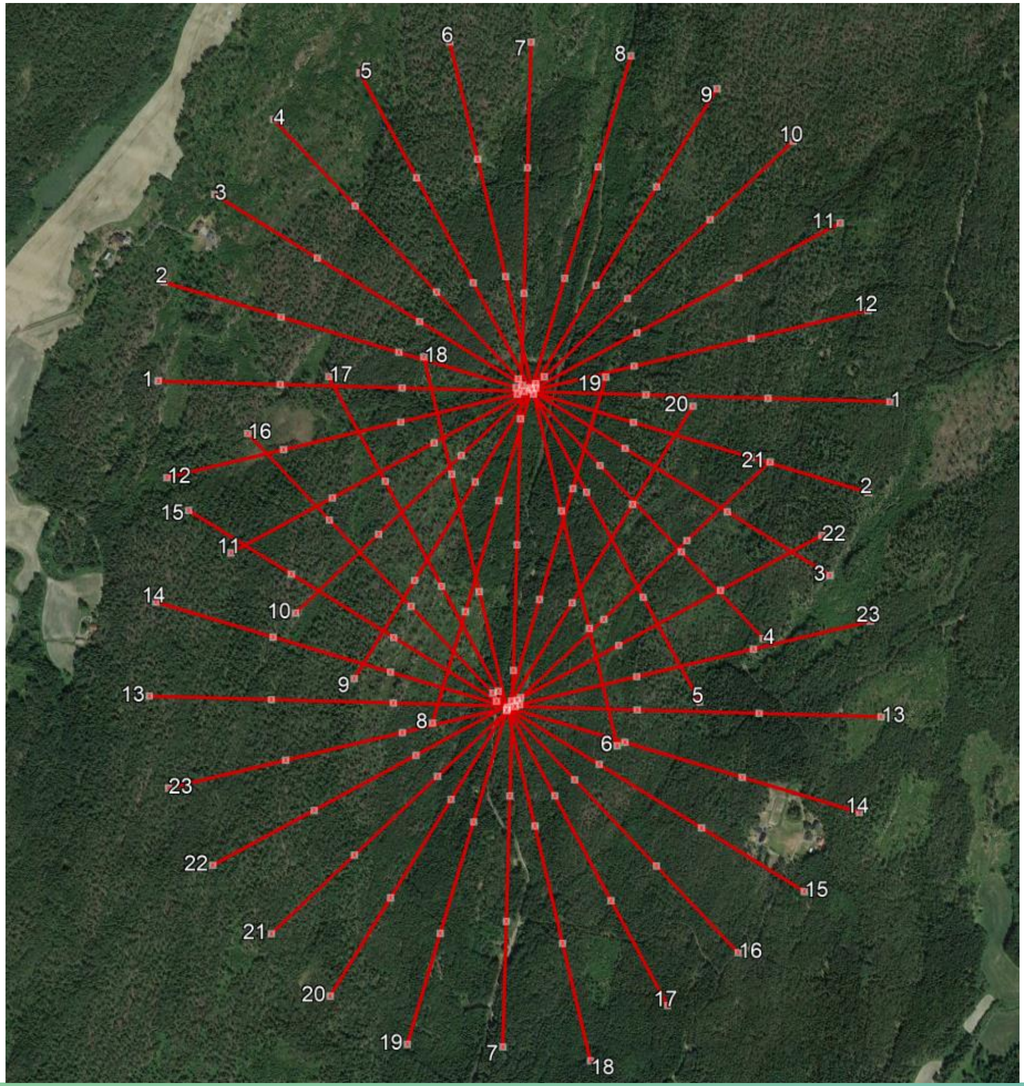
Sensors in airplane (3D view)



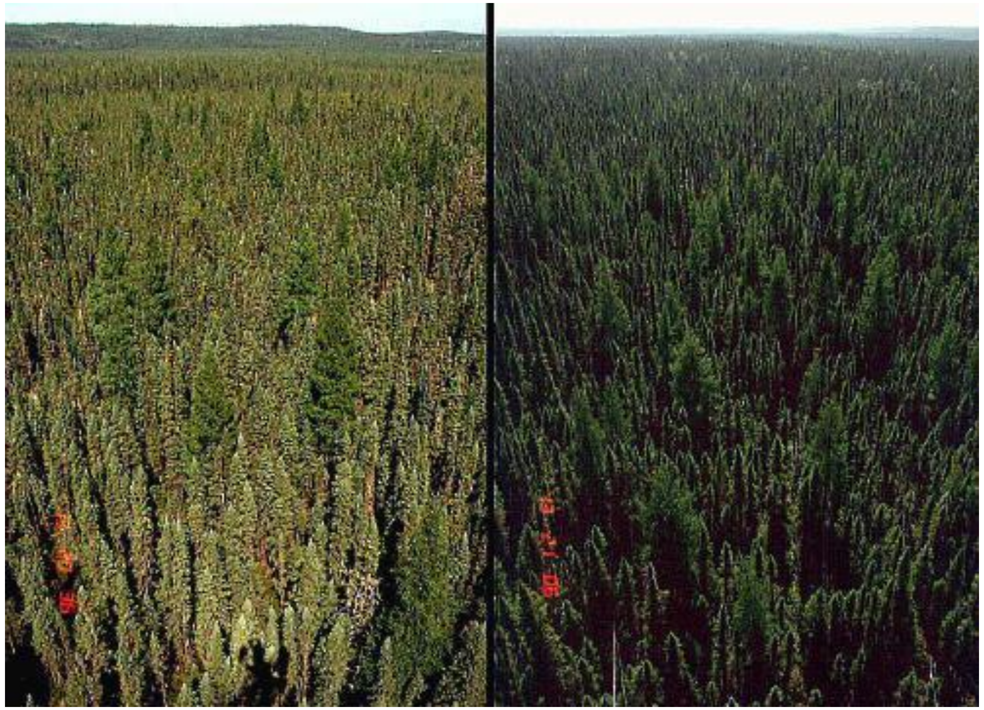




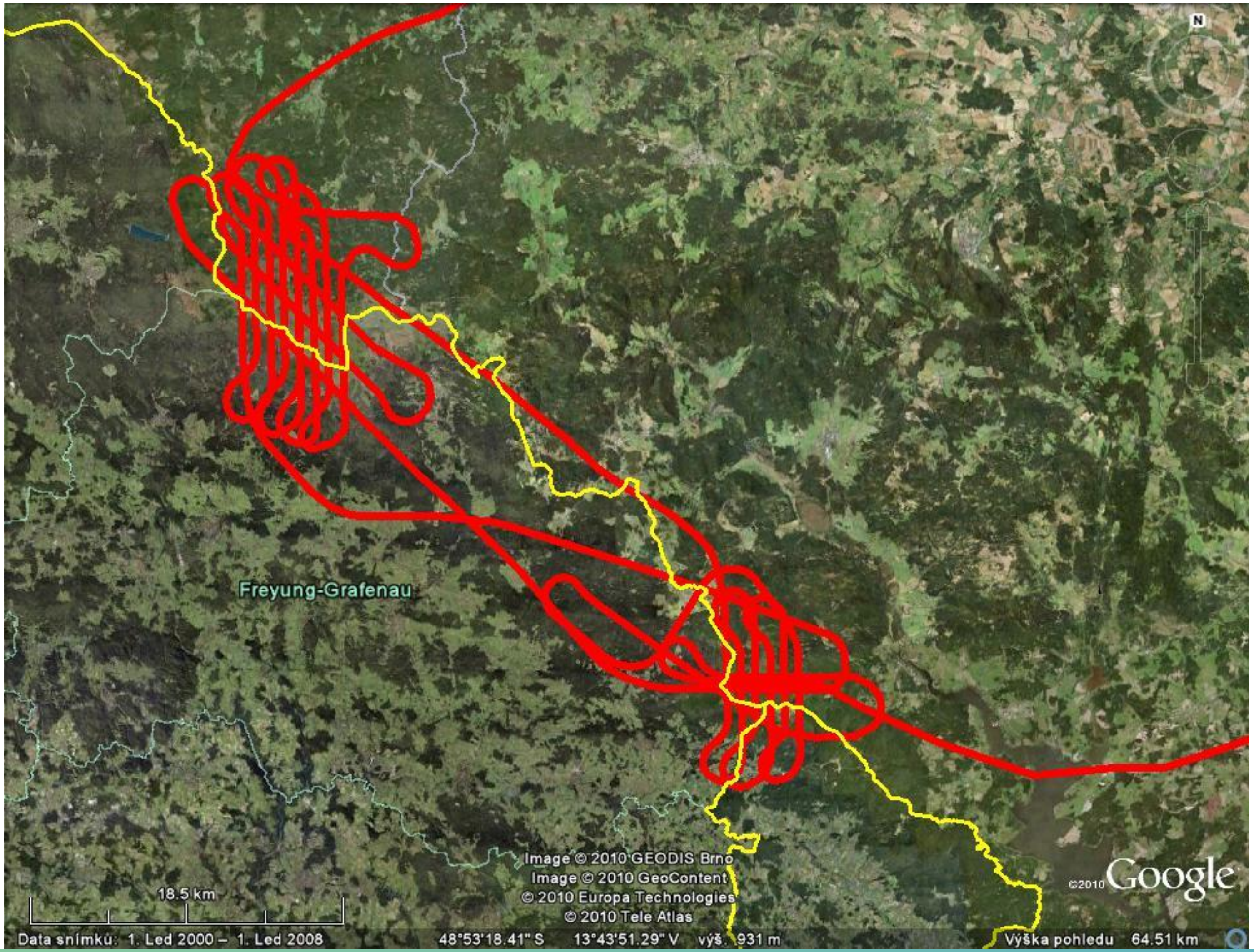
Planning of airborne campaign

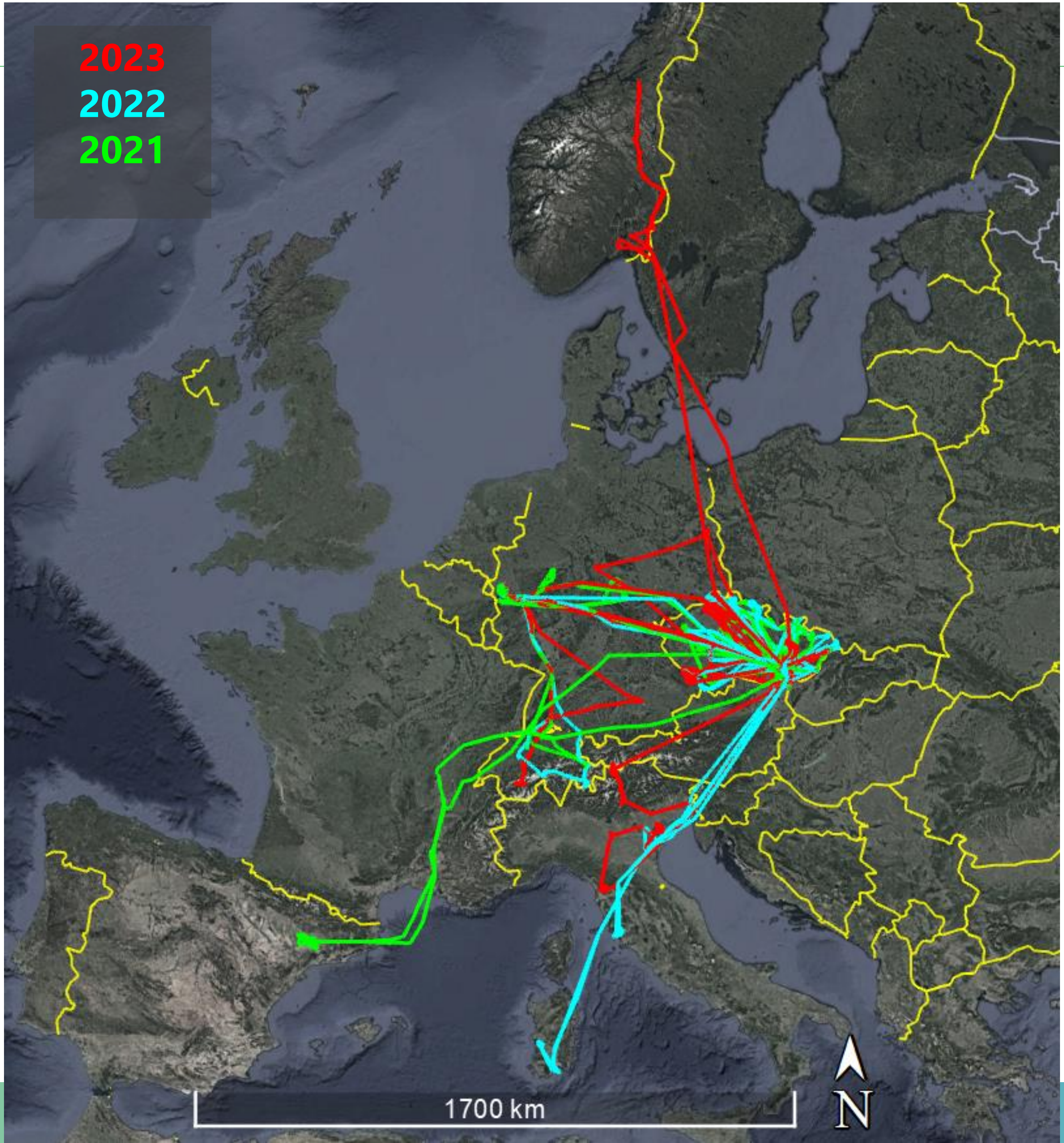


Dependence of lighting and viewing angles and directional reflectance of vegetation



Planning of airborne campaign

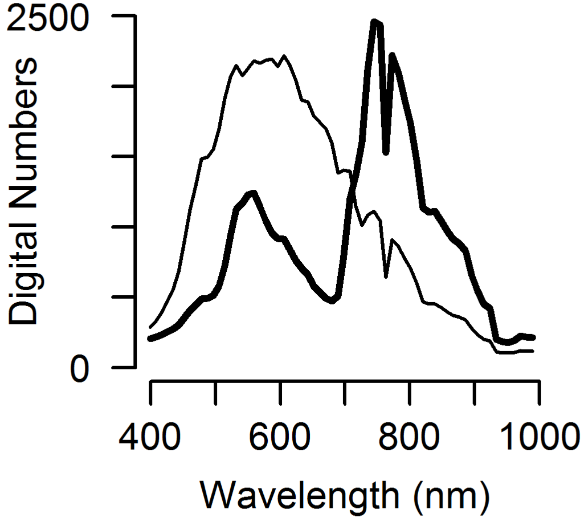


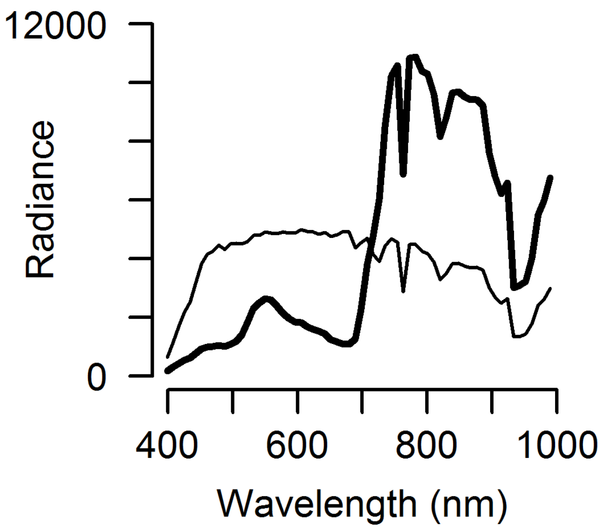

2023
2022
2021
1700 km
N

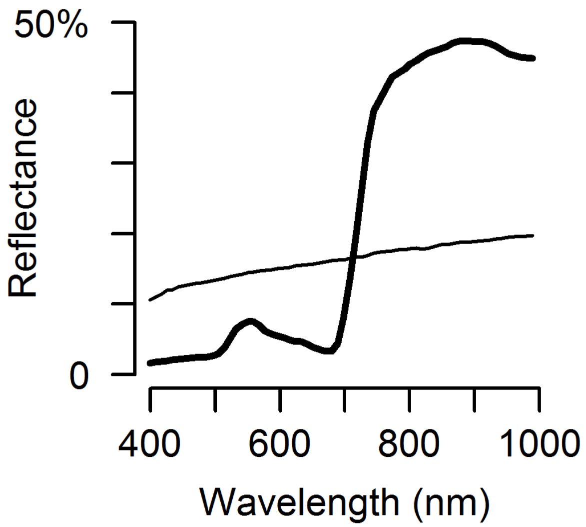
Radiometric and geometric corrections

Current state of the atmosphere
(amount of aerosols and water vapor)
Calibration surfaces

DN values → **Radiometric correction** → Radiance → **Atmospheric correction** → Reflectance

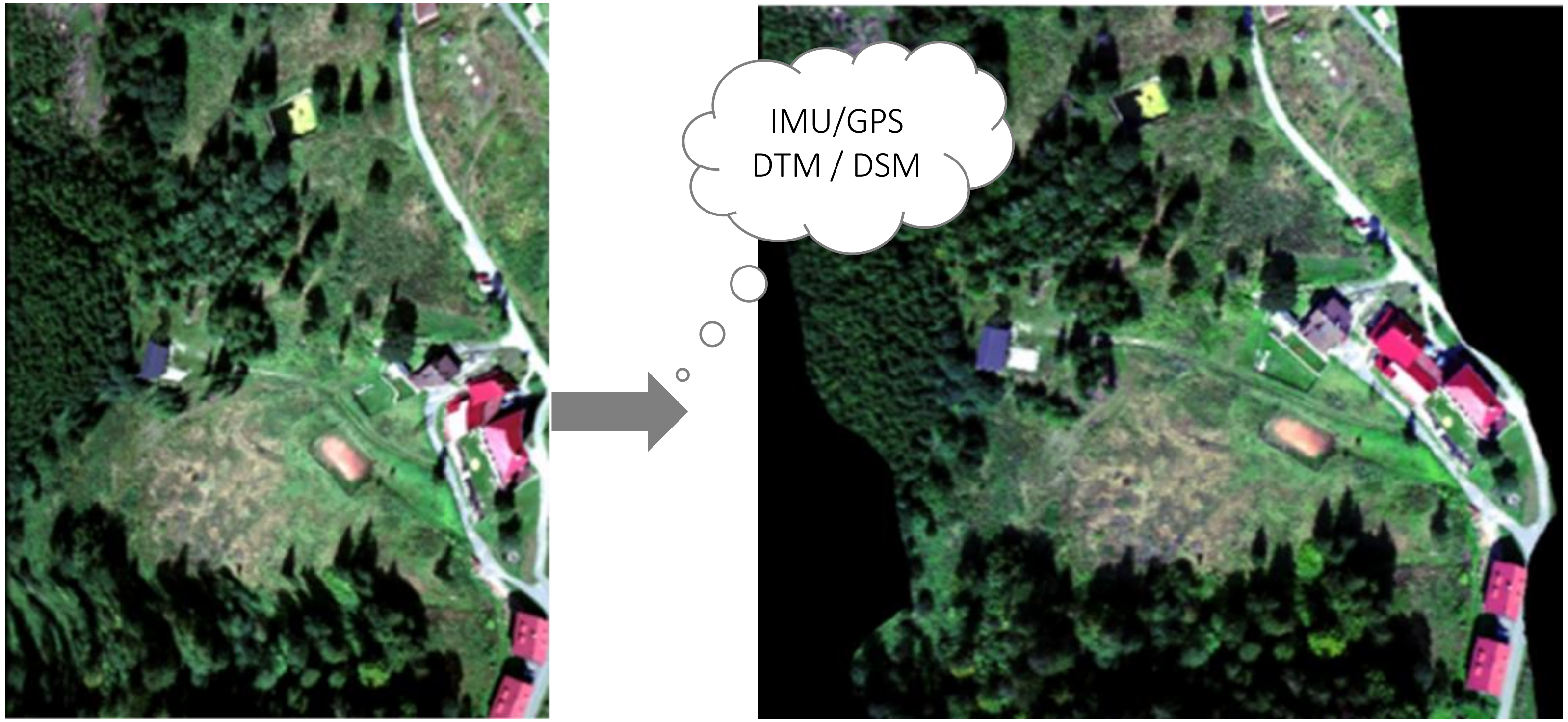






Georeferencing

- Geometric correction+ ortorectification

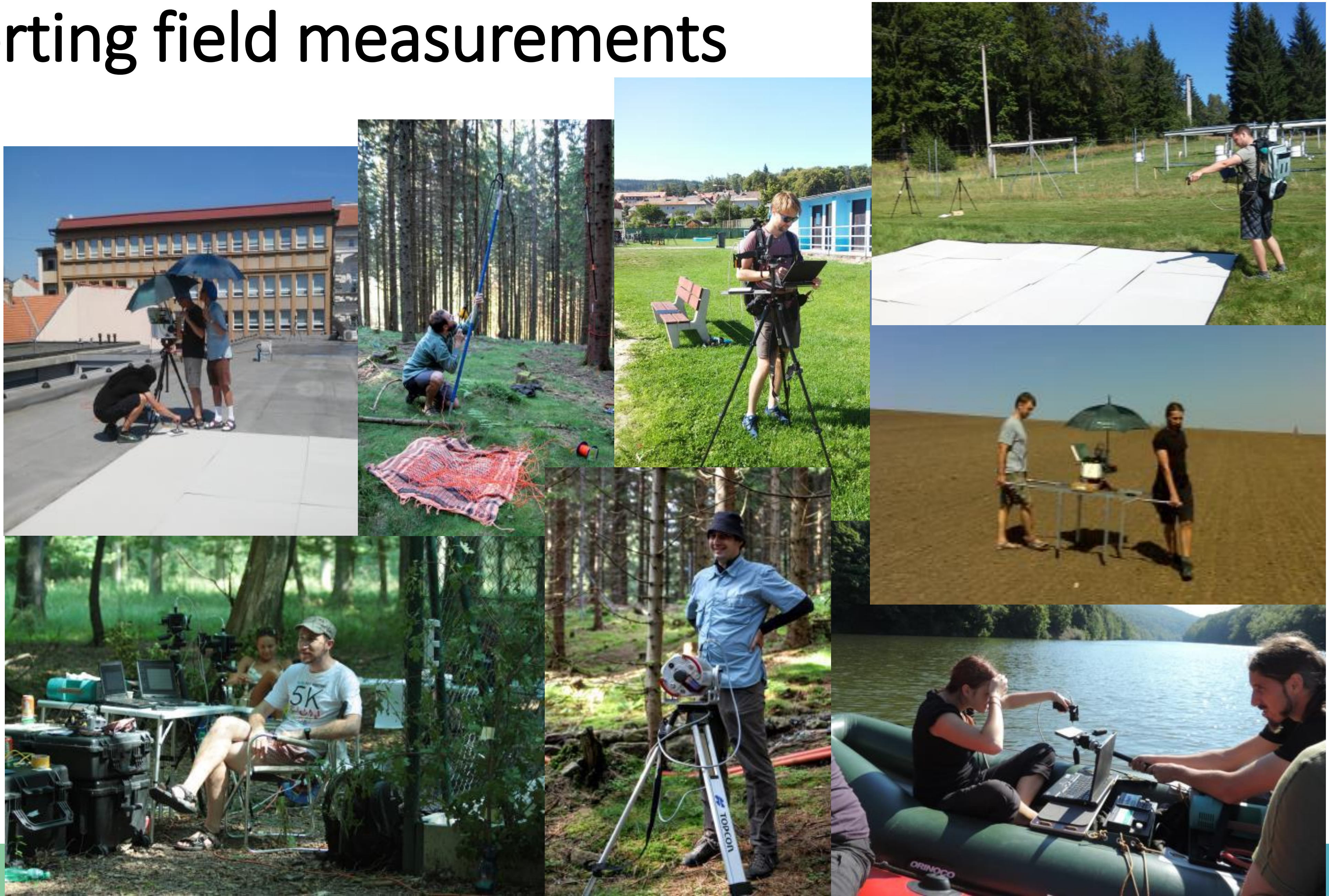


UTM 33N

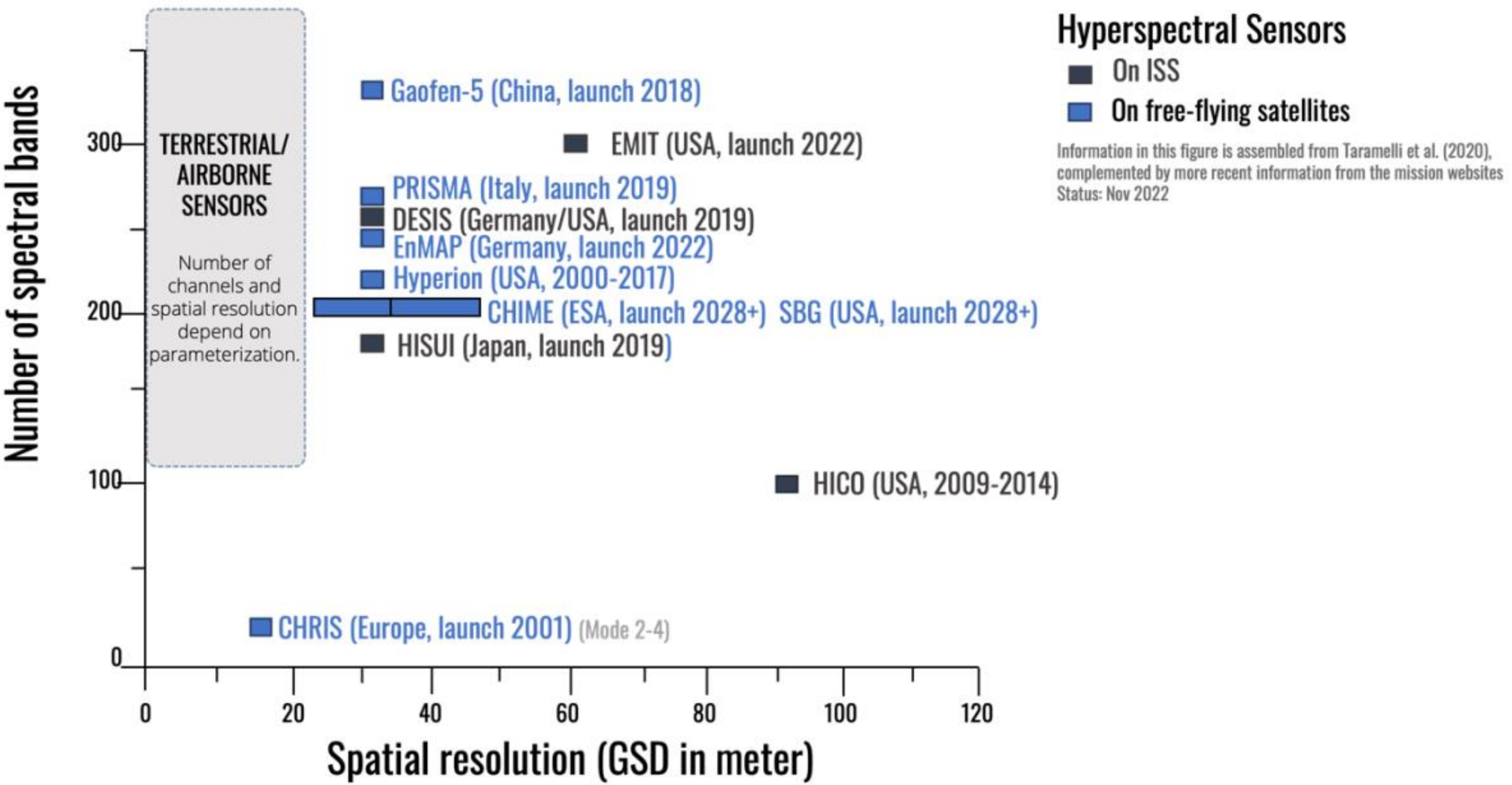
DTM

DSM

Supporting field measurements



Satellite hyperspectral systems



Satellite missions

Mission		Launch	Spec. range	Spec. sampl.	GSD / Swath
PRISMA	ASI, Italy	2019	400 – 1010 nm 920 – 2505 nm	14 nm	30 m / 30 km + PAN 5 m
DESIS (ISS)	DLR, Germany	2018 (until 2023)	400 – 1000 nm	2.5 nm	30 m
EnMAP	DLR, OHB, GFZ, Germany	2022	420 – 1000nm 900 – 2450nm	6.5 nm 10 nm	30 m / 30 km
EMIT (ISS)	NASA	2022 (until 2023)	3800 – 2500nm	7.4 nm	?/? desert areas
CHIME	ESA	<2030	400 – 2500 nm	< 10 nm	30 m / 130 km
SBG	NASA	<2030	400 – 2500 nm +TIR 3-5 & 8-12µm	< 10 nm	30-45m 40-60m
+ others HISUI, TianGong, HypXIM, GaoFen, TRISHNA,SHALOM					

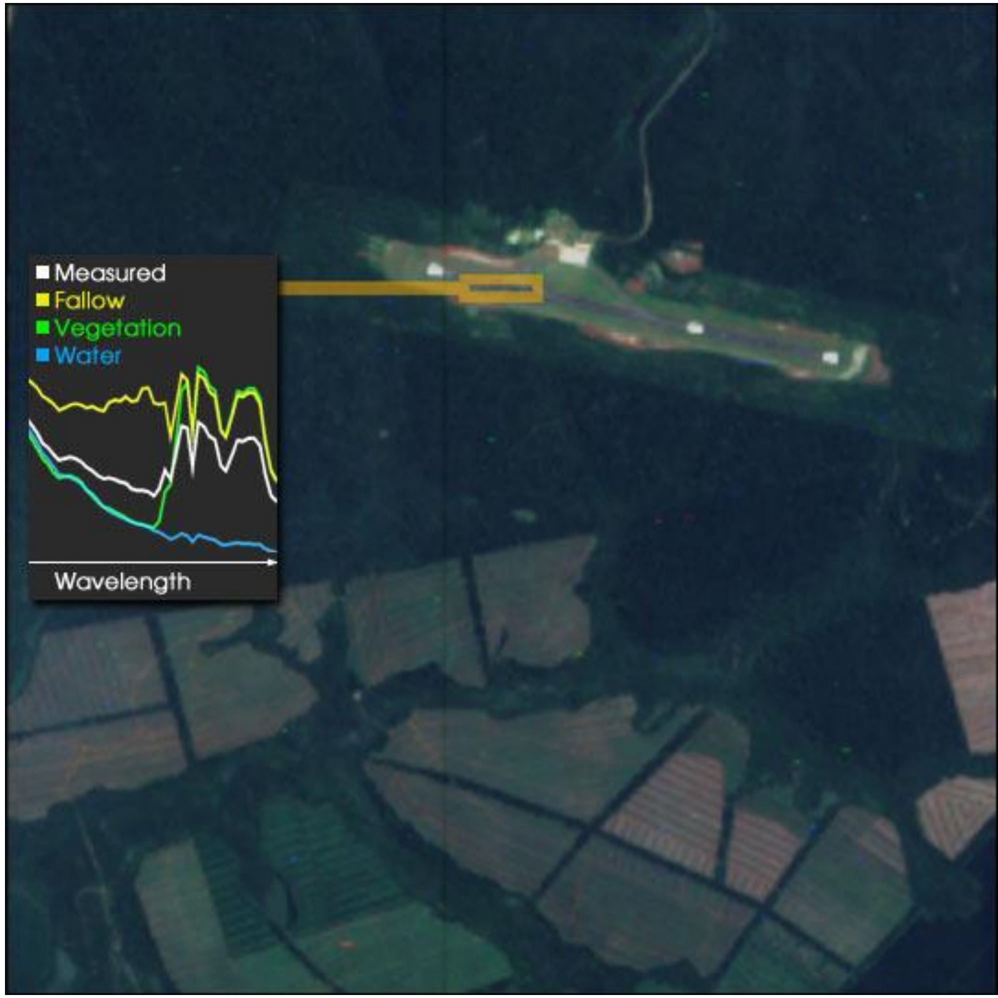
EO-1 Hyperion

Dataset availability 2001-2017

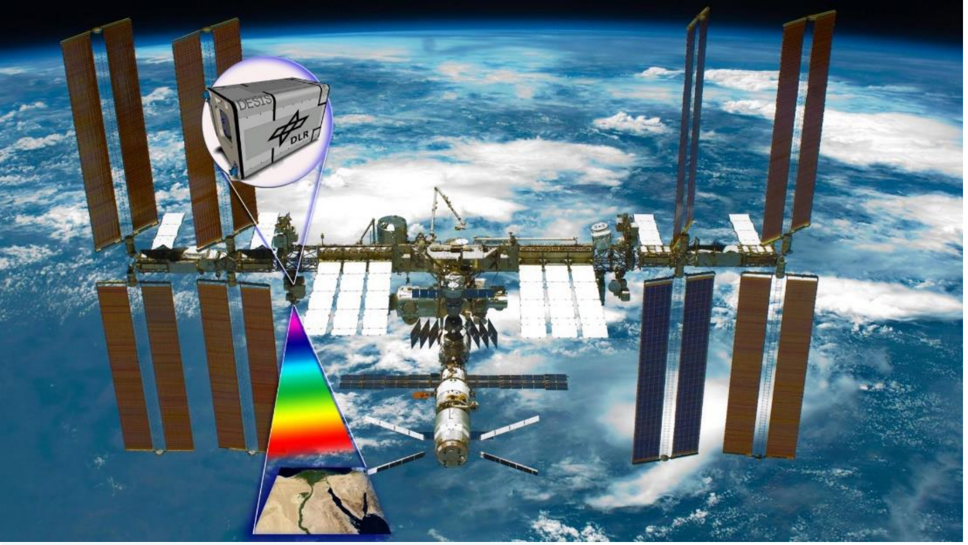
Revisit 16 days
30 m GDS
400 – 2500 nm (10 nm sampling)
220 bands
Swath width 7.5 km

Applications:

- Carbon cycle
- Vegetation
- Amazon rainforest
- Alaskan tundra
- Microbial life in the Arctic
- Volcanic activity



True-color Hyperion image of Argentina (composed of red, green, and blue channels)



DESIS

DLR Earth Sensing Imaging Spectrometer, Germany

Launched in 2018

Free for scientific purposes

Revisit 3 – 5 days
30 m GDS
400 – 1000 nm (2.5 nm sampling)
235 bands
Swath width is 60 km

Applications:

- Improving Earth observation in general and hyperspectral sensor systems in particular (precision farming, assessment of the situation after environmental disasters)
- Effects of the space environment on remote sensing instrument
- Contribute to hyperspectral remote sensing technologies for future satellite missions

GaoFen - 5

gao fen = high-resolution,
China National Space Administration (CNSA)

Revisit ?

30 m GDS

400 – 2500 nm
(5-10 nm sampling)

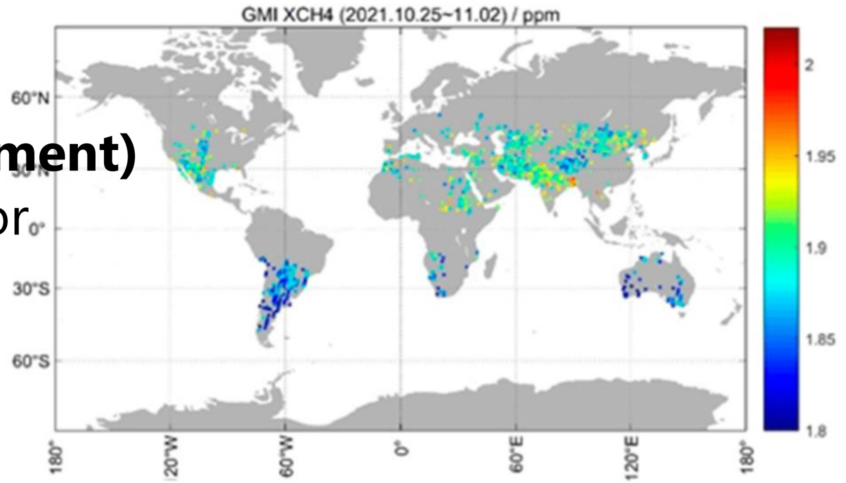
330 bands

Swath width 60 km

Launched in 2018

Six instruments onboard:

- VIS and SWIR HS camera (AHSI)
- Spectral imager
- **Greenhouse gas detector (GMI-II instrument)**
- Atmospheric environment infrared detector
- Differential absorption spectrometer for atmospheric trace gas
- Multi-angle polarization detector



Applications:

- Track air pollution and greenhouse gases in the atmosphere
- Variations in land cover
- Variations in water clarity

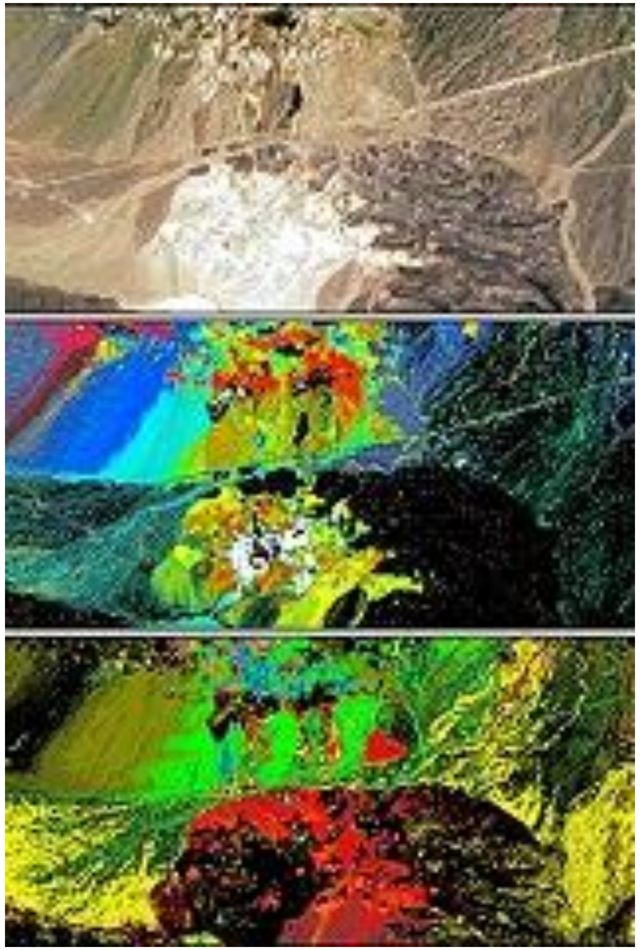
PRISMA

Repeat cycle 29 days
30 m GDS
400 – 2500 nm (12 nm sampling)
66 (VNIR), 171 (SWIR), 1 (PAN) band
Swath width 30 km

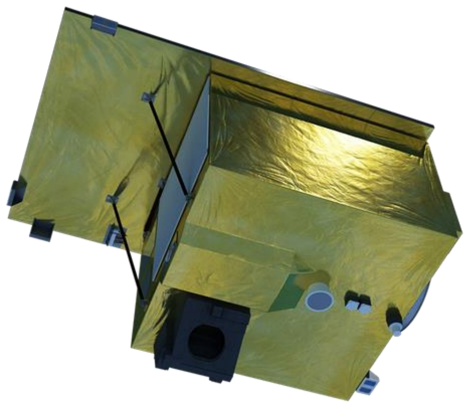
Launched in 2019, available for downloading

Applications (Europe and the Mediterranean region):

- Land cover and crop status
- Pollution quality of inland waters
- Status of coastal zones and the Mediterranean Sea
- Soil mixture and carbon cycle



https://prismauserregistration.asi.it/



EnMAP

Environmental Mapping and Analysis Program,
German Earth Observation Satellite

2022 – launch and early orbit phase

Target revisit is 4 days
30 m GDS
400 – 2500 nm (6 – 10 nm spacing)
Swath width 30 km

Main scientific goals:

- Study environmental changes
- Investigate ecosystem responses to human activities
- Monitor the management of natural resources

Applications:

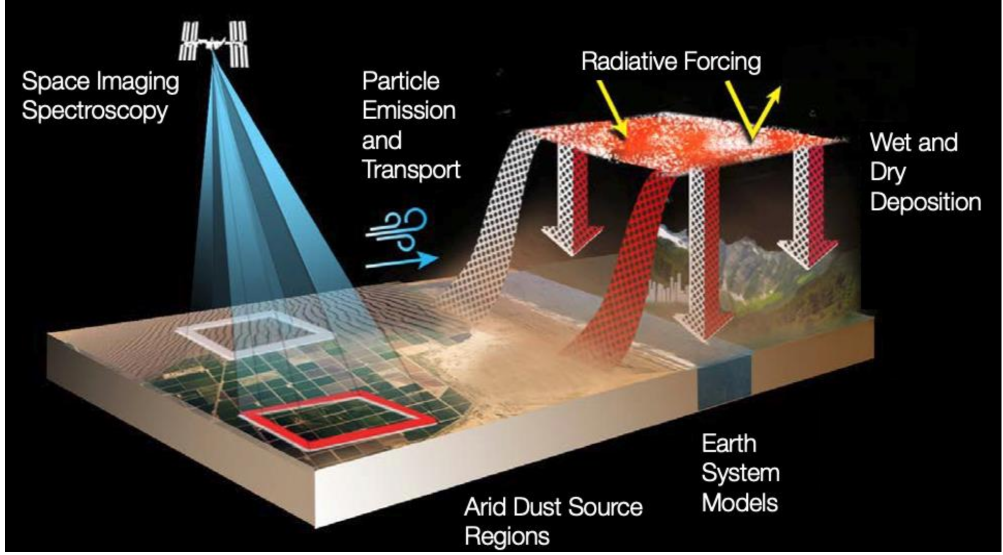
- Agriculture and forestry
- Geology and soils
- Urban areas
- Coastal and inland waters.

https://www.enmap.org/data_access/

EMIT

Earth Surface Mineral Dust Source Investigation

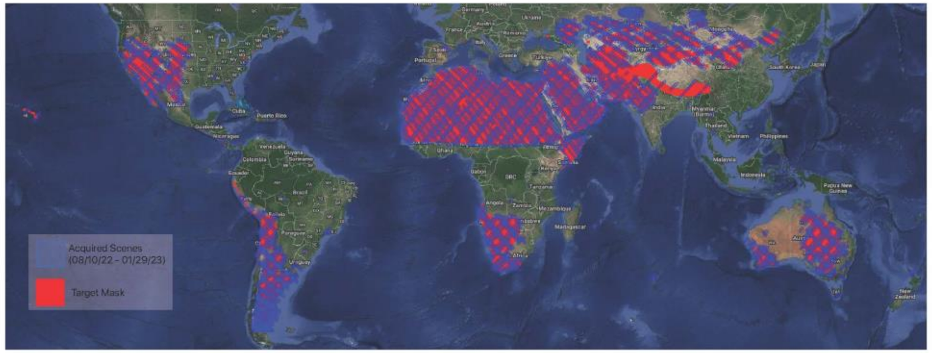
July 2022 on ISS
Operational for 1 year

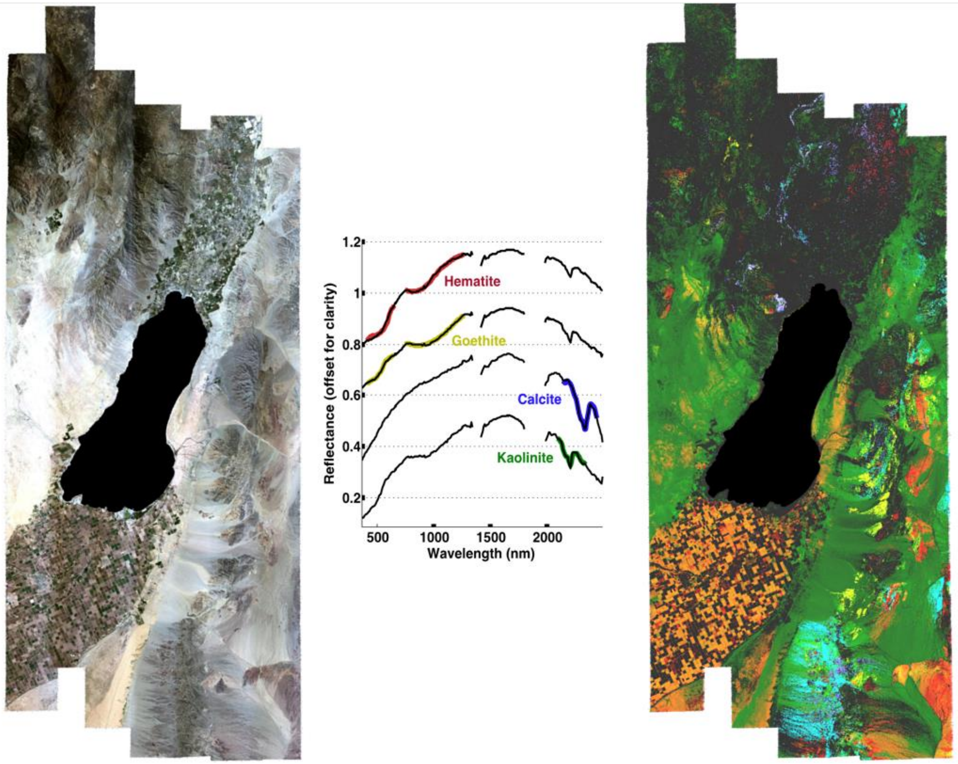


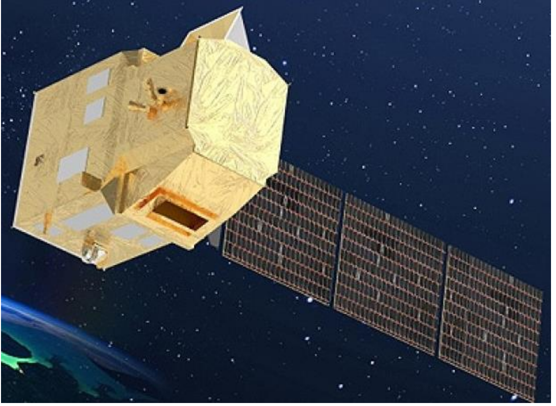
3 acquisitions in average
60 m GDS
380 – 2500 nm (~7.4 nm sampling)
285 bands
Swath width 75 km

Objectives:

- Measure mineral composition over arid lands
- Improve assessment of heating and cooling effects of mineral dust
- Predict changes in amount and type of dust due to climate change







CHIME

Copernicus Hyperspectral Imaging Mission for the Environment (Sentinel-10)

In preparation. Launch in 2028
Global, operational mission!

Revisit 11 days
30 m GDS
400 – 2500 nm (8.4 nm sampling)
Over 220 bands
Swath width 130 km

Target applications:

- agricultural management,
- biodiversity management,
- soil property characterization.

High priority L2B products

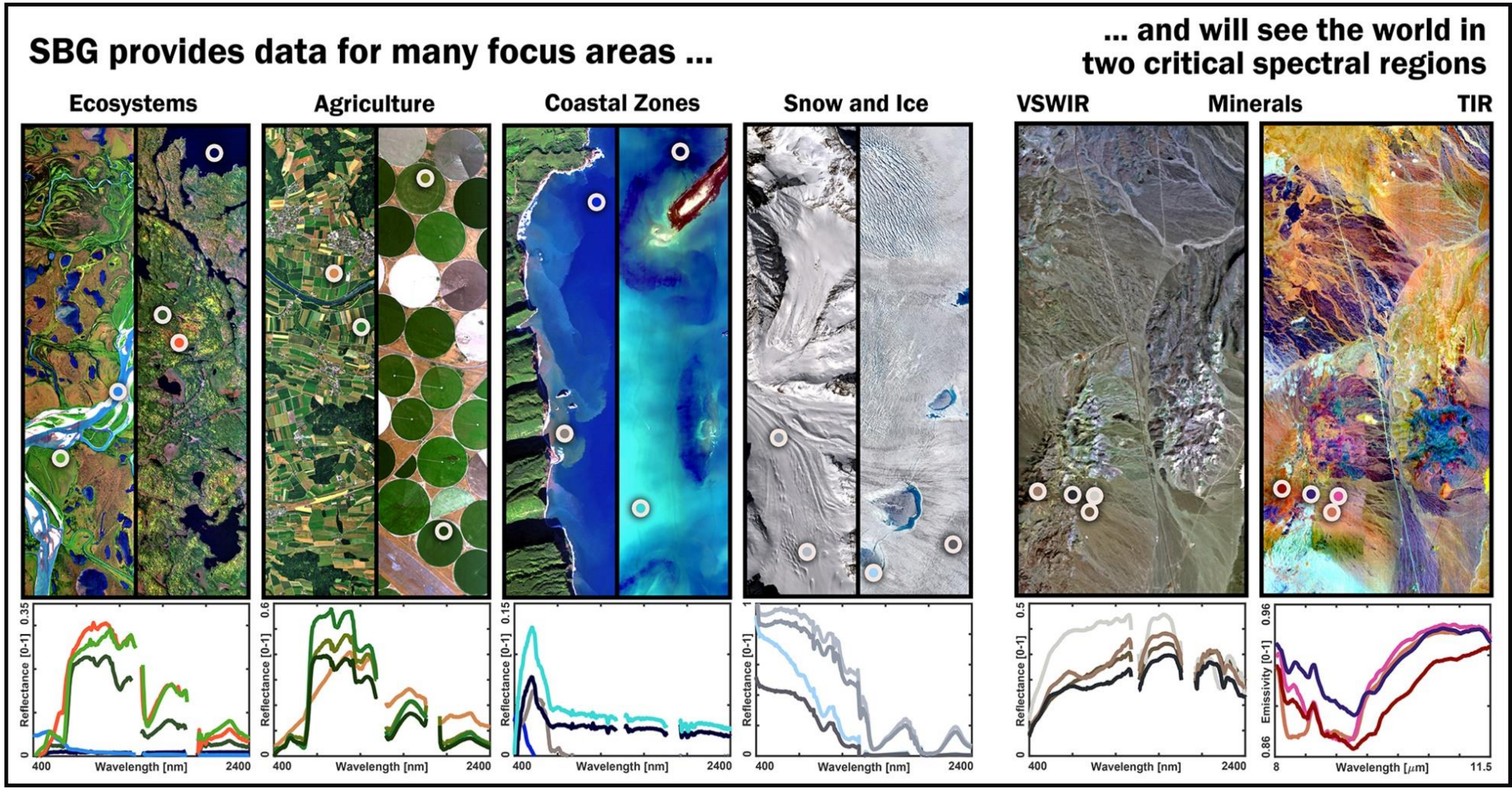
- Leaf / canopy nitrogen content
- Leaf / canopy water content
- Leaf mass per area
- Soil organic carbon content
- Kaolinite abundance

https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Going_hyperspectral_for_CHIME

SBG (Surface Biology and Geology) mission

In preparation. Launch in 2030

SBG Light (VNIR+SWIR)	SBG Heat (TIR)
Revisit 16 days	3 days
30 m GSD	60 m GSD (30 m for VNIR)
400 – 2500 nm (10 nm sampling)	4 – 12 µm
>200 bands	7 bands TIR 2 bands VNIR
Swath width 185 km	935 km



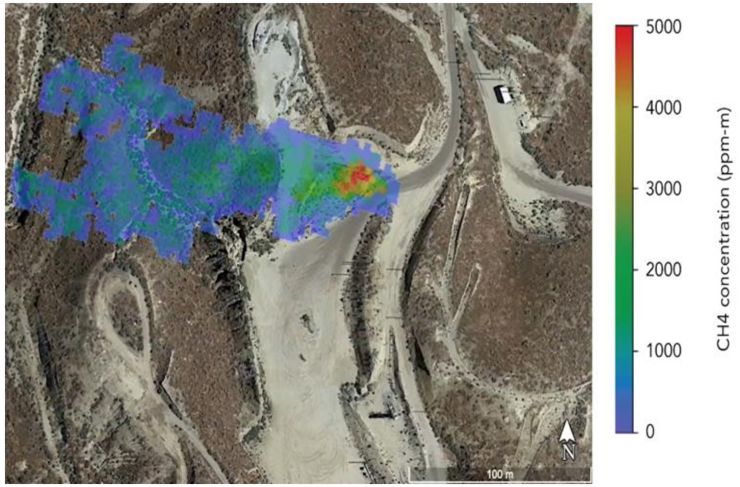
https://sbg.jpl.nasa.gov/

Carbon Mapper constellation

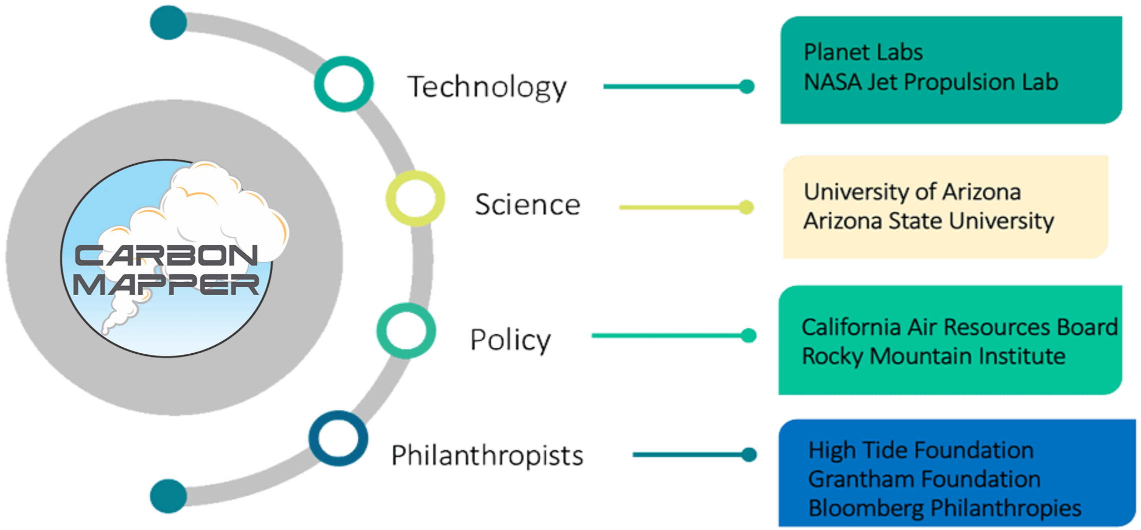
30-35 m GDS
400 – 2500 nm (5 nm spacing)
Scene width 18 km

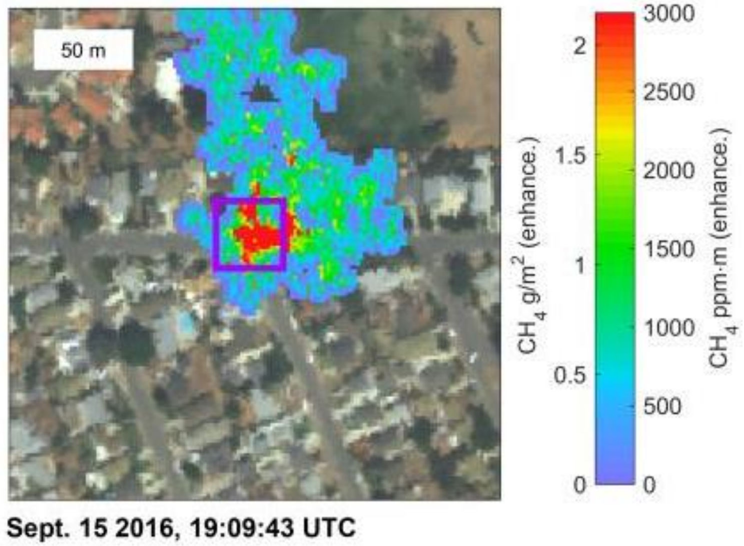
In preparation. Launch in 2024
Based on Planet's next generation SkySats

Target application:
pinpoint, quantify and track strong methane (CH_4) and carbon dioxide (CO_2) emissions at facility scale



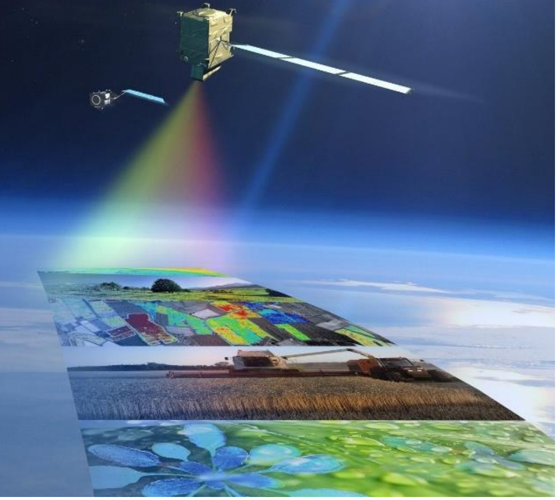
https://carbonmapper.org/case-studies/





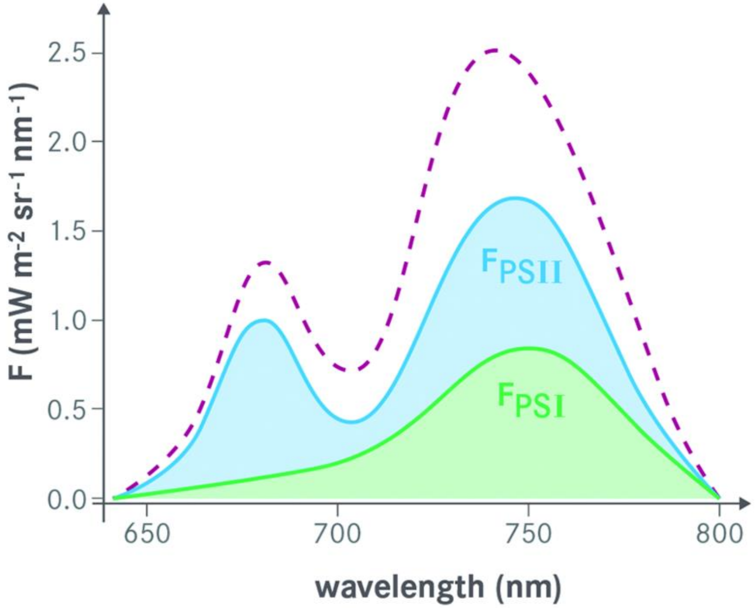
FLEX

FLuorescence EXplorer

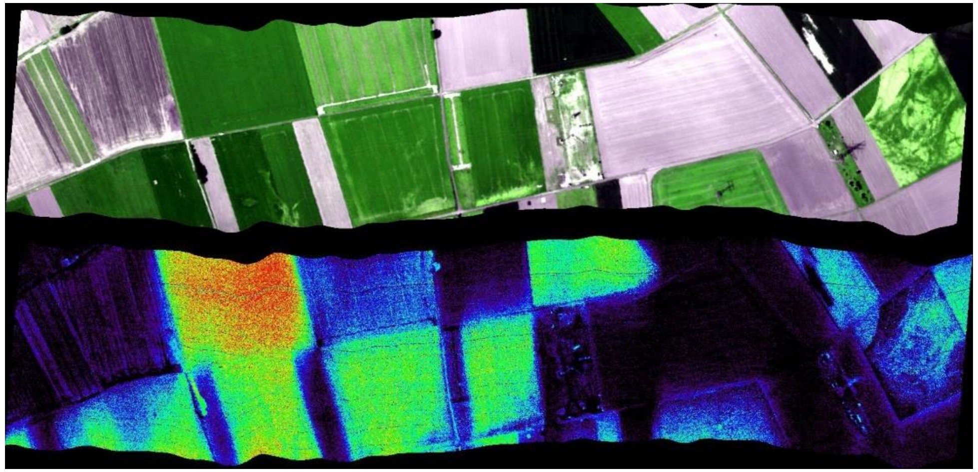


In preparation. Launch in 2025
In tandem (100 km ahead) with Sentinel-3

Sun-induced chlorophyll fluorescence
Subtle light emission signal directly related to photosynthetic activity



Revisit 27 days
300 m GDS
500 – 780 nm (sampling between 0.1 - 2 nm!)
Swath width 150 km

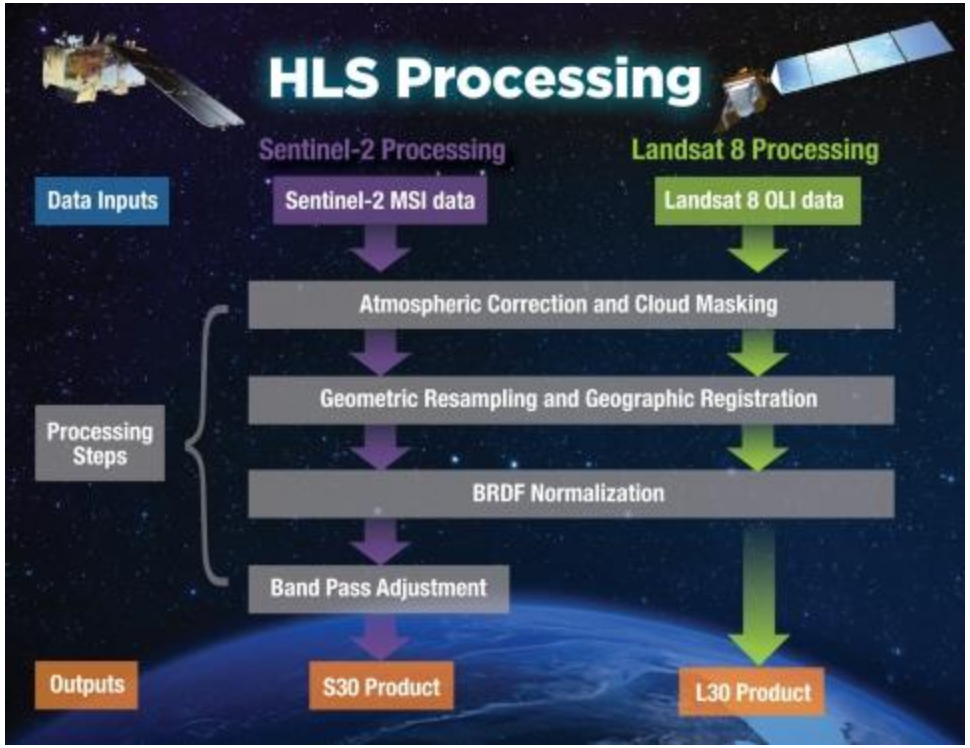


https://www.esa.int/Applications/Observing_the_Earth/FutureEO/FLEX

Synergies between

- Fussion of Landsat-8/-9 with Sentinel-2 into HLS product
- Fussion of future SBG and CHIME HS data
- Fussion of future SBG and LSTM (and CNES/ISRO TRISHNA) thermal data

- Seamless combination of different sensors into one product
- Increasing temporal resolution



Commercial (constallations) cubesats

SPECTRA

GHGSAT

CARBON MAPPER

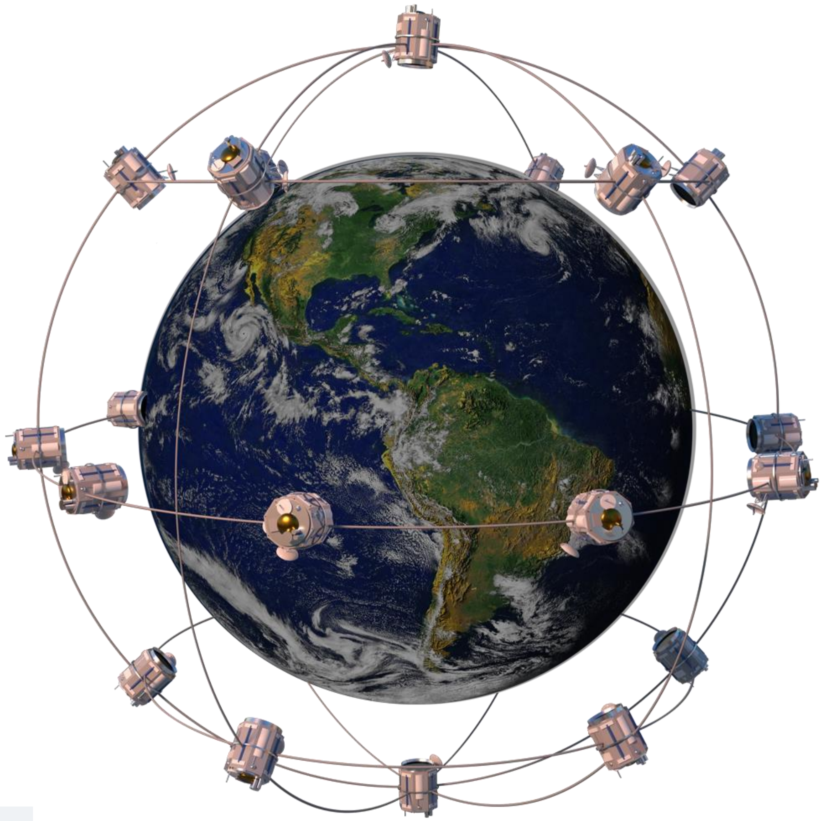
pixxel

planet.

OSK Orbital Sidekick

HySpecIQ

SCEPTER



… and many others

Some recommended sources to study….

- Online course Beyond the Visible – Introduction to Hyperspectral Remote Sensig
  - https://eo-college.org/courses/beyond-the-visible/

- NEON Science youtube chanell
  - Mapping the Invisible: Introduction to Spectral Remote Sensing https://youtu.be/3iaFzafWJQE

Hyperspectral Remote Sensing of Fire

Temporal phases in the fire disturbance continuum (after Jain et al., 2004)

Summary of RS hyperspectral **post-fire studies**

Reference	Application	Method
Qiu et al. (1998)	Recovery	SI
Riaño et al. (2002)	Recovery	SI and SMA
van Wagtendonk et al. (2004)	Severity	SI
Chuvieco et al. (2006)	Severity	SI and RTM
Jia et al. (2006b)	Severity	Classification
Kokaly et al. (2007)	Severity	Classification
Lewis et al. (2007)	Severity	SMA
Robichaud et al. (2007)	Severity	SMA
Lewis et al. (2008)	Severity	SMA
Mitri and Gitas (2010)	Recovery	Classification
Lewis et al. (2011)	Severity	SMA
Numata et al. (2011)	Recovery	SI
Huesca et al. (2013)	Severity and recovery	SI and SMA
Mitri and Gitas (2013)	Recovery	Classification
Schepers et al. (2014)	Severity	SI
Veraverbeke et al. (2014)	Severity	SMA
Somers et al. (2016)	Severity and recovery	SI and SMA
Chen (2017)	Severity	SI and SMA
Lewis et al. (2017)	Severity	SMA
Meng et al. (2018)	Recovery	Classification
Tane et al. (2018)	Severity	SMA

Advantages of Hyperspectral Data:

•**Detailed Spectral Information:** Hyperspectral data provides a large number of narrow spectral bands, allowing for a more detailed analysis of the land cover and changes over time.

•**Improved Discrimination:** Hyperspectral sensors can differentiate between subtle variations in spectral signatures, enabling better discrimination between burnt and unburnt areas.

•**Enhanced Vegetation Analysis:** Hyperspectral data allows for a more accurate assessment of vegetation health and stress, aiding in the determination of burn severity.

•**Targeted Indices:** Hyperspectral sensors can be designed to capture specific wavelengths relevant to burn severity assessment, allowing for the creation of targeted spectral indices.

•**Endmember Analysis:** The high spectral resolution of hyperspectral data facilitates the identification and analysis of endmembers, contributing to more accurate classification results.

Post-Fire Applications

Fire severity

refers to the intensity of the fire and the immediate effects of the fire on the environment during the actual burning

- **Measurements**: It is usually measured by factors such as flame length, fireline intensity, and the amount of energy released during the fire.
- **Indicators**: Indicators of fire severity include the heat produced, the speed of the fire spread, and the height of flames. These can affect the immediate combustion of vegetation and other organic materials.

Burn severity

represent the combined effect of the immediate fire impact and longer term recovery

- **Measurements**: It is often assessed by the degree of soil heating, vegetation mortality, and changes in soil properties and structure.
- **Indicators**: Indicators of burn severity include the depth of ash, changes in soil color, the degree of tree mortality, loss of organic matter, and changes in soil hydrophobicity.

Vegetation recovery

or regrowth, or regeneration refers to the process through which plant communities regenerate and re-establish themselves following a fire

- **Measurements**: fixed plots with detailed vegetation assessments -plant height, biomass, canopy cover, and so on.
- **Indicators**: presence of native vs. invasive species, changes in vertical and horizontal structure of plant communities, reduction in soil erosion as vegetation cover increases.

Post-Fire Applications

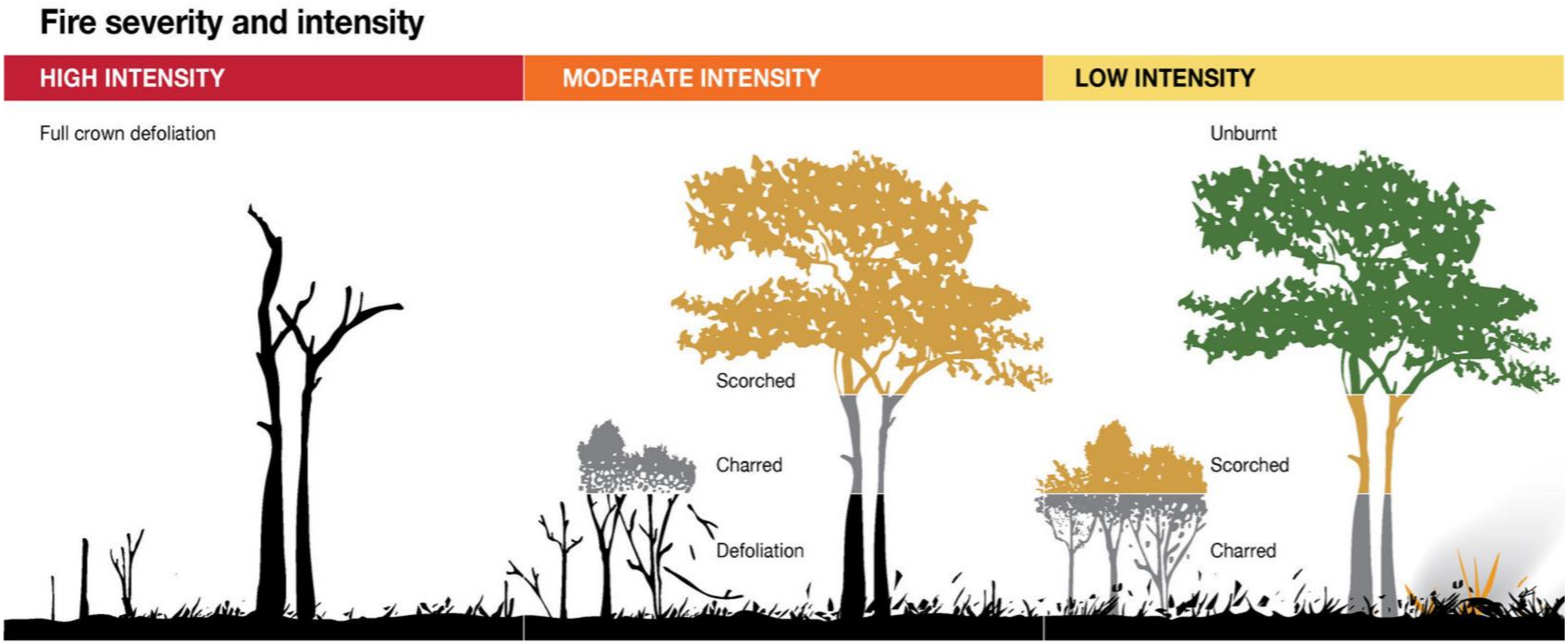
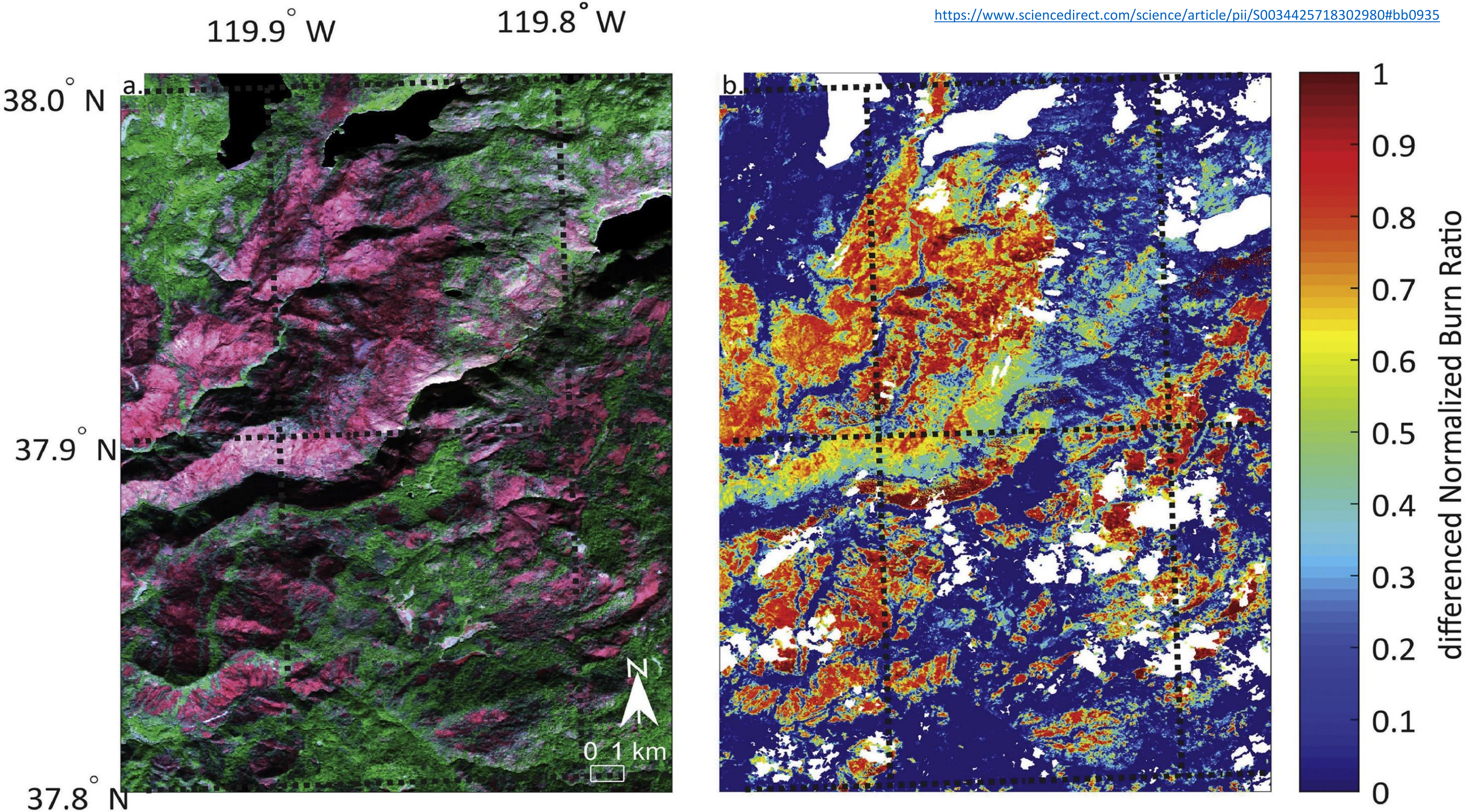
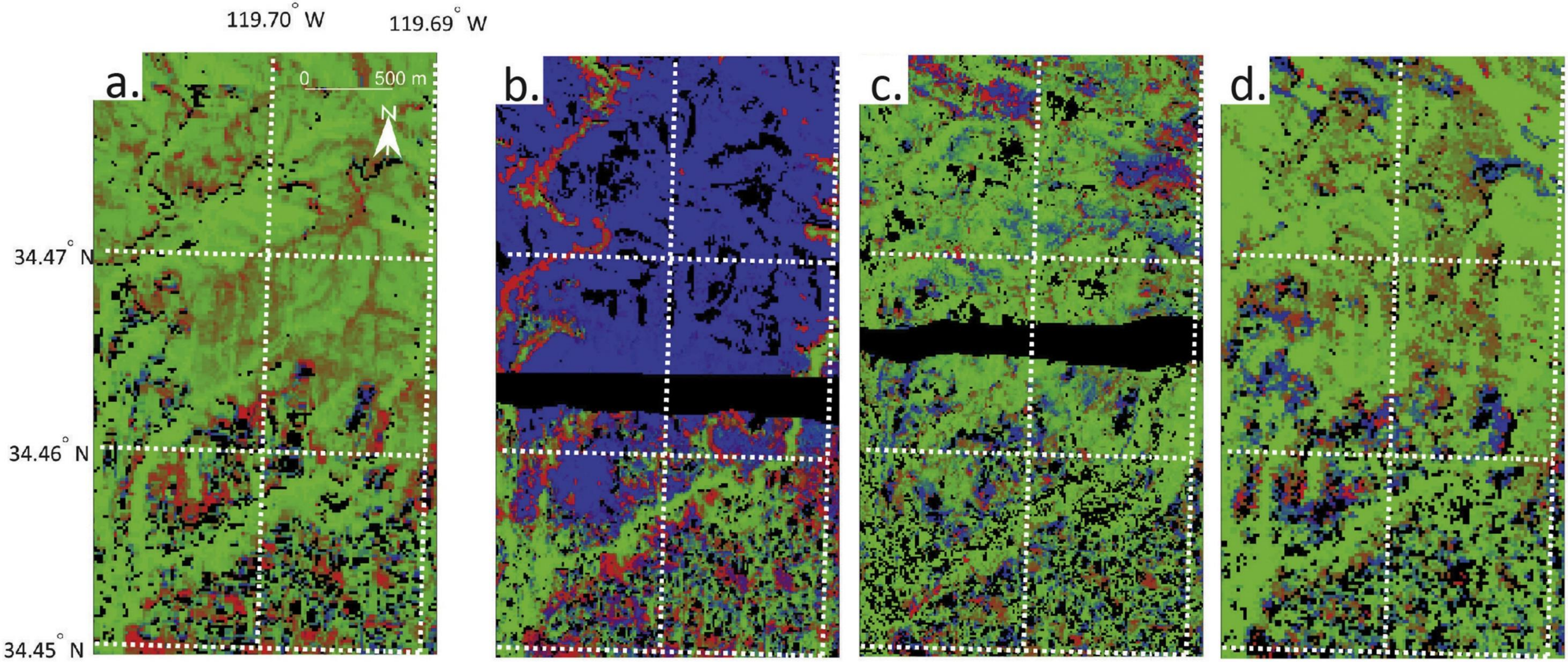


Illustration by Andrew Sullivan/CSIRO, 2021.


119.9° W
119.8° W
38.0° N
37.9° N
37.8° N
a.
b.
N
0 1 km
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
differenced Normalized Burn Ratio

Post-Fire Applications. Vegetation recovery



Time series of surface composition between 2004 and 2013 in the area of the 2009 Jesusita fire in California, USA, as derived from Airborne Visible/Infrared Imaging Spectrometer a) on August 6, 2004, b) just after the fire on August 26, 2009, c) on April 30, 2010, and d) on June 6, 2013.

Somers et al. 2016 https://www.sciencedirect.com/science/article/pii/S0034425718302980#bb0810

Post-Fire Applications. Burn severity

Main methods used

- change detection analysis by **comparing pre-fire and post-fire imagery**.
  This involves identifying differences in land cover, such as the loss of vegetation, changes in soil properties, and the emergence of burnt areas;

- infrared bands and indices like the **Normalized Burn Ratio (NBR)** can highlight the severity of the burn, indicating areas with varying degrees of damage;

- **supervised classification** algorithms to categorize land cover classes, distinguishing between burnt and unburnt areas. Training the classifier with known samples is needed.

Thank you for your attention!

https://olc.czechglobe.cz/en/home-en/

https://mapserver.czechglobe.cz/en/map

https://www.czechglobe.cz/en/

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