Status and Results of the EnMAP Mission – Introduction to Hyperspectral Earth Observation

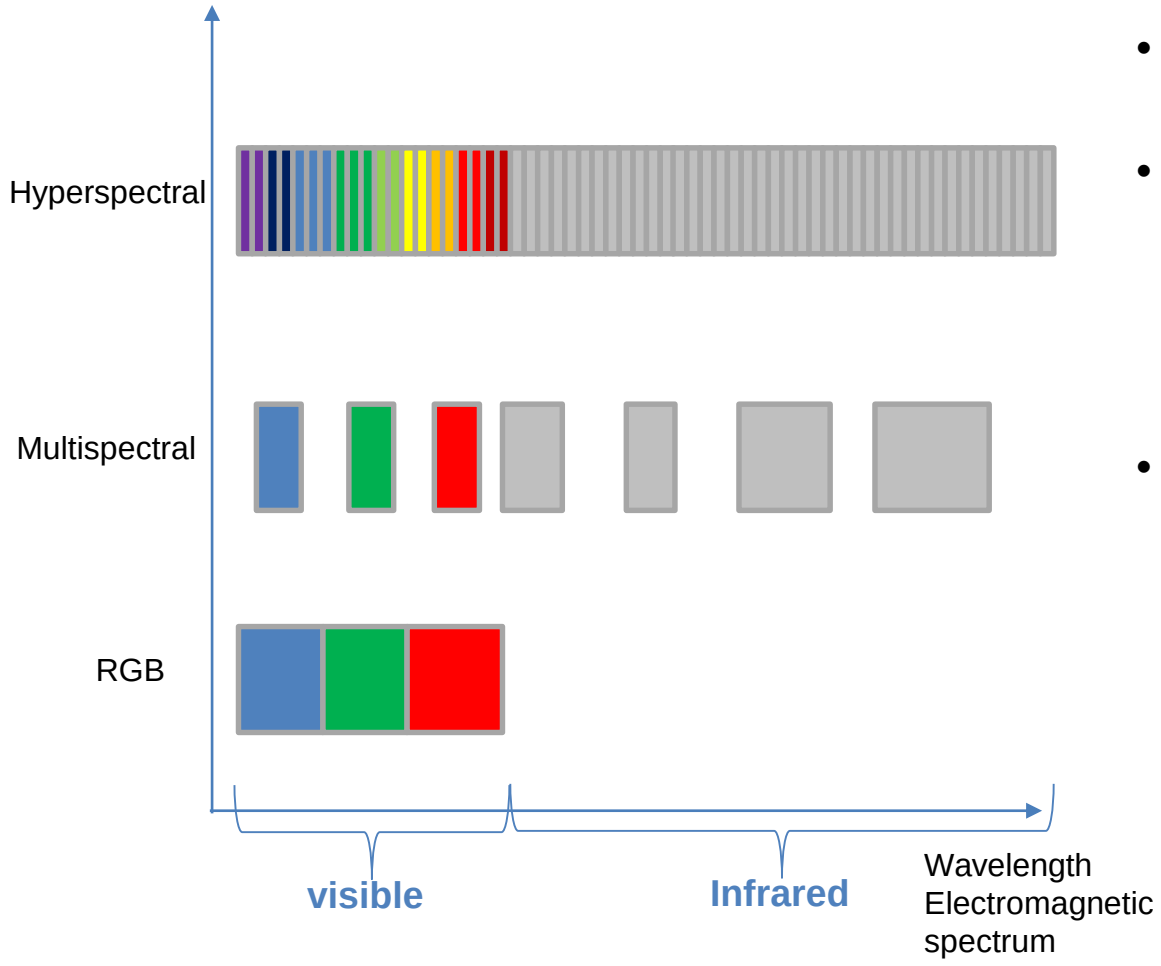
Emiliano Carmona, DLR/EOC-MF

4. July 2023

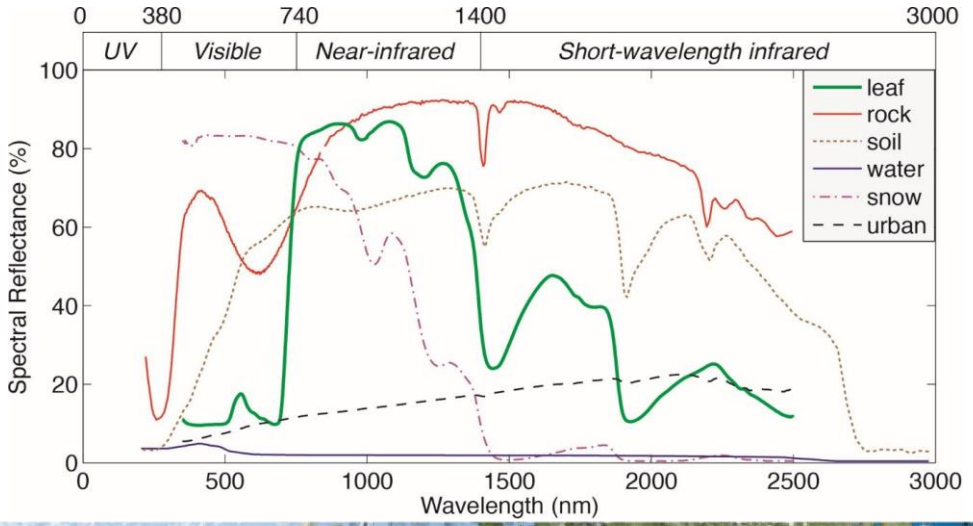
Imaging Spectroscopy

(Hyperspectral Imaging)

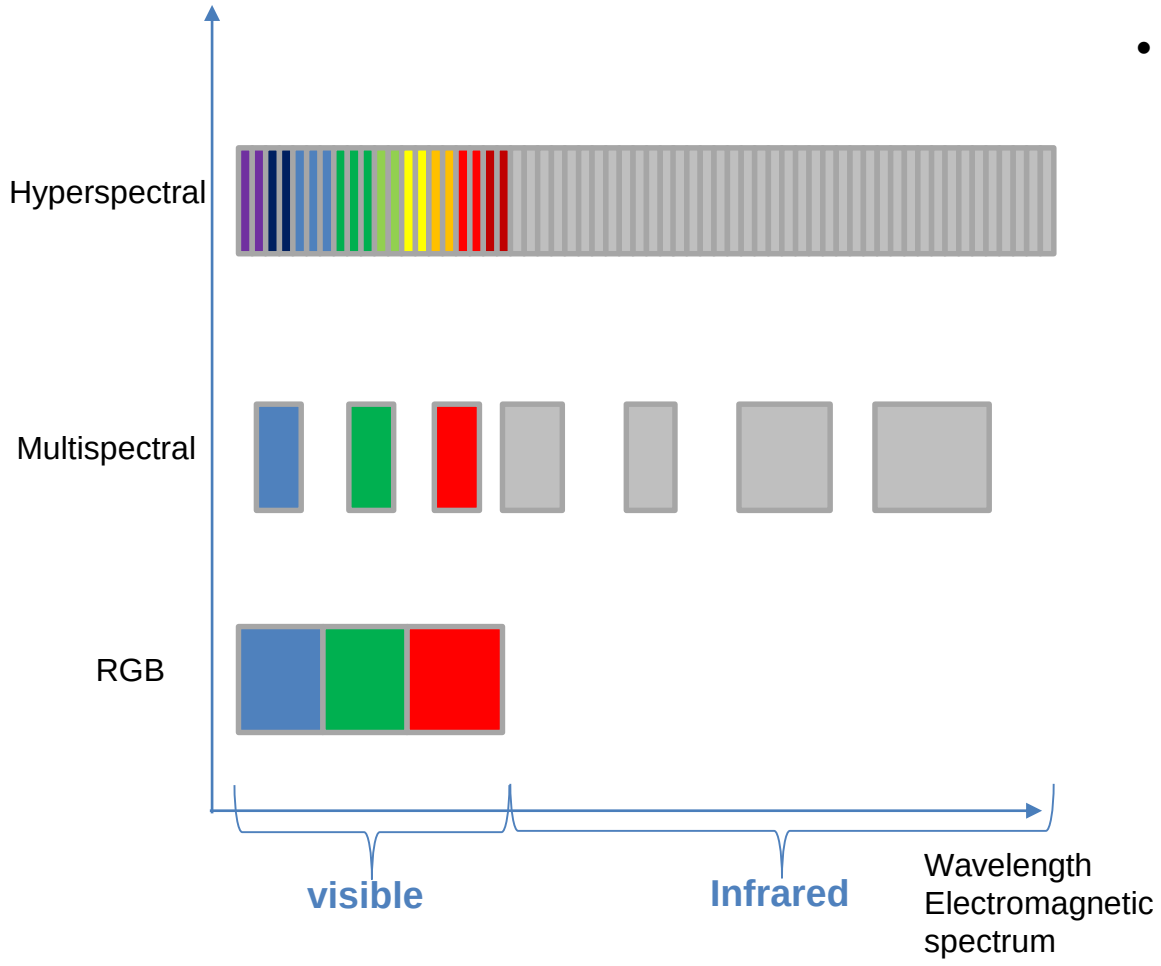
Imaging Spectroscopy



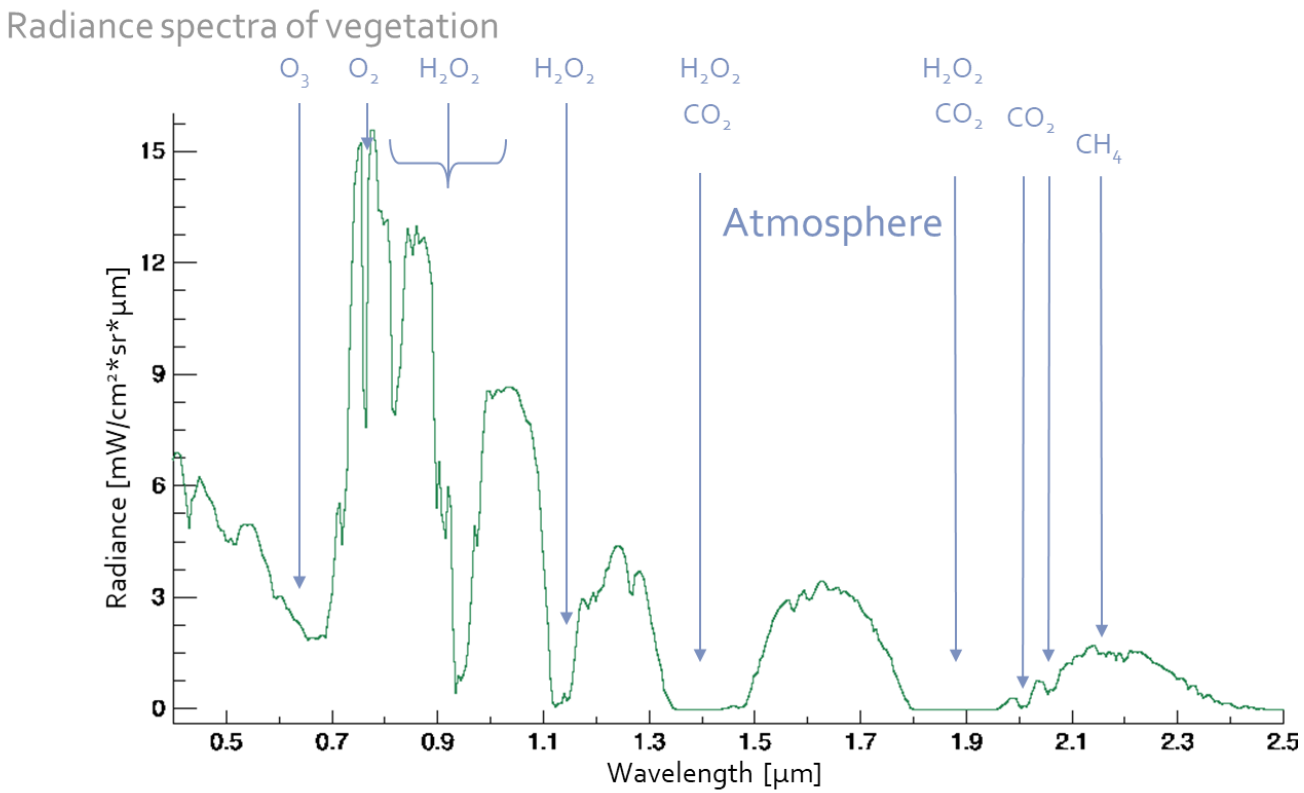
- Each spatial pixel in the image contains a spectrum of the light arriving at that sensor element
- Amount of data is significantly larger than in the case of normal RGB imaging or multispectral imaging (e.g. Sentinel 2 or Landsat)
  - Hyperspectral image typically contains > 100 spectral channels in one pixel
- More information about materials and physical processes



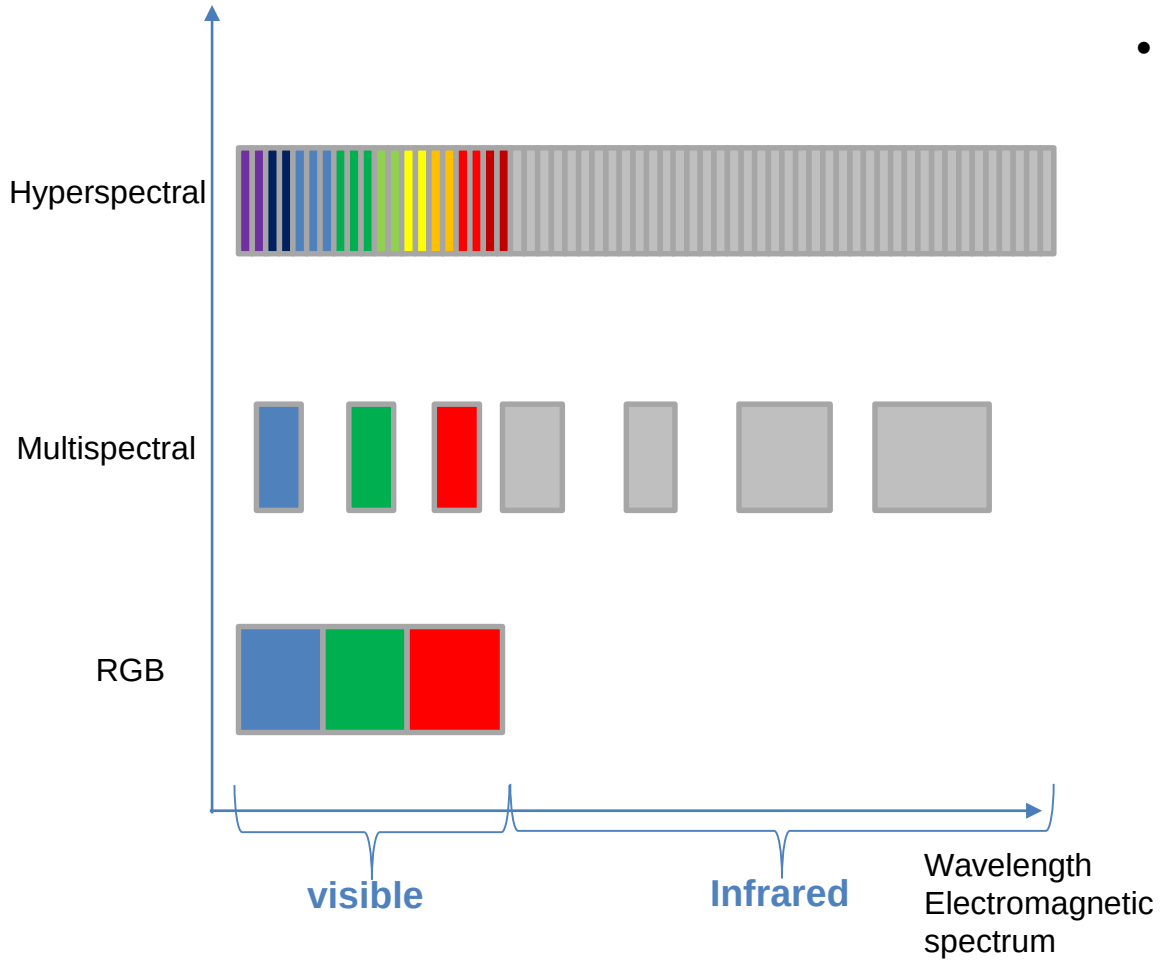
Imaging Spectroscopy



- Measured spectra affected by transmission through the atmosphere and reflectance of material being imaged



Imaging Spectroscopy



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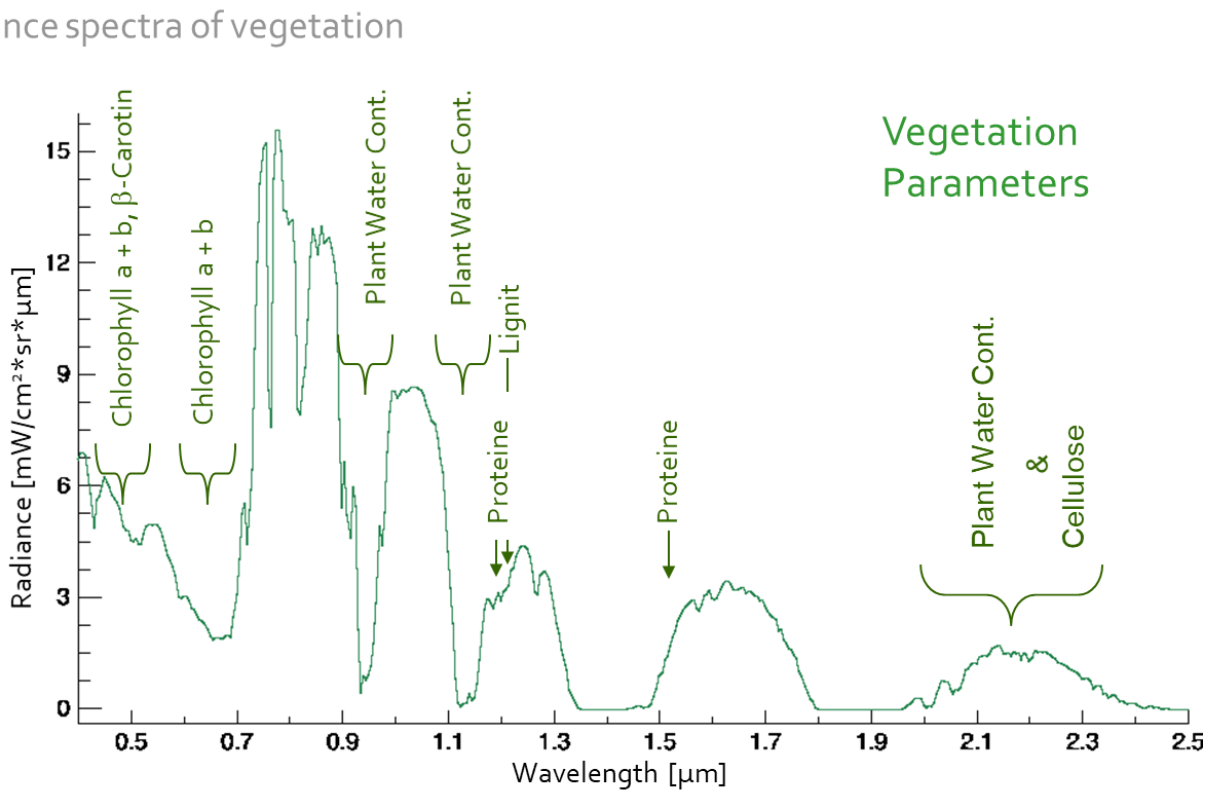
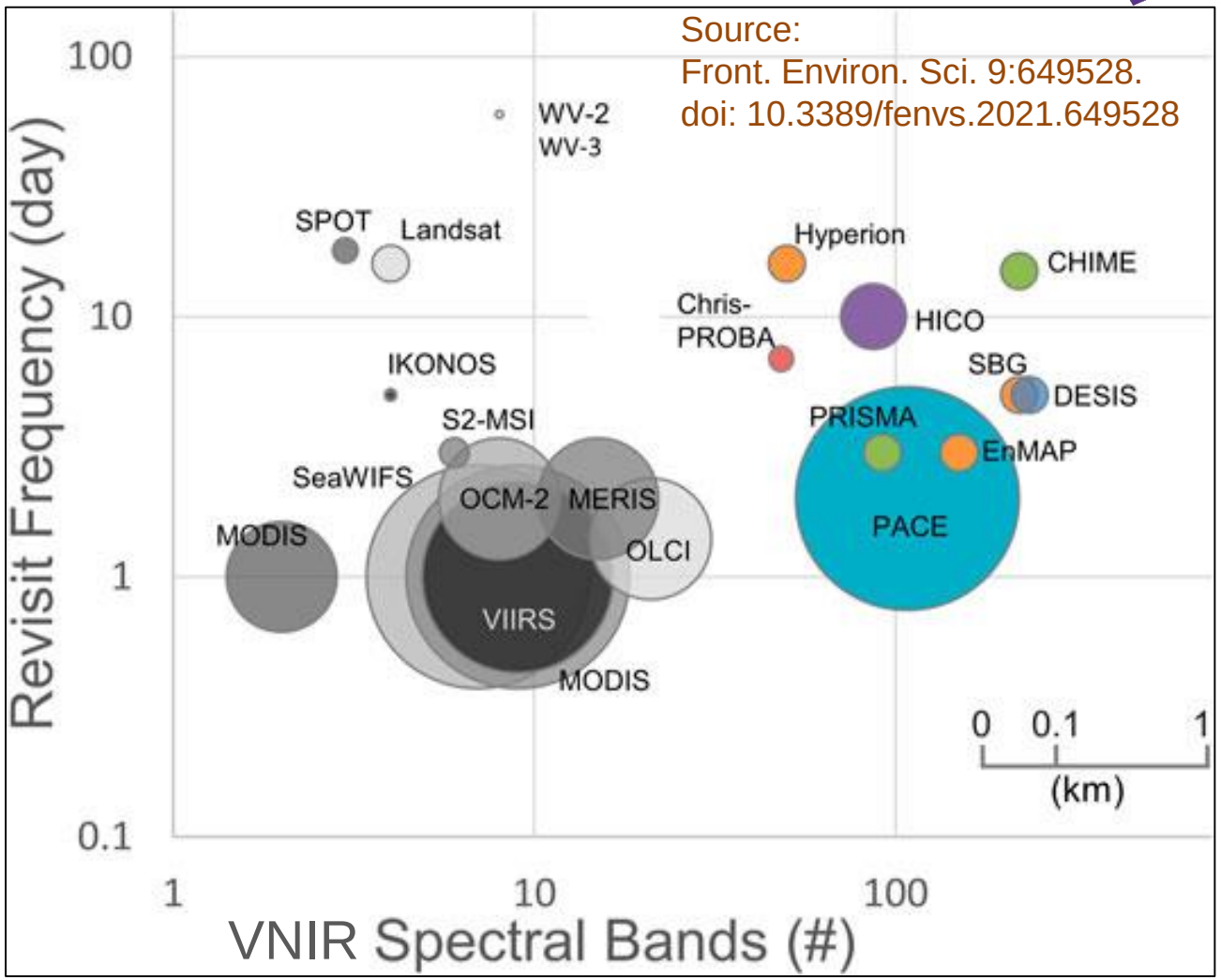


Imaging Spectroscopy Space Missions

- **HICO** (ONR), end of operations 2014, VNIR at ISS
- **HYPERION** (NASA), end of operations 2017
- **DESIS** (DLR+TBE), in operations since 2018 at ISS. VNIR only
- **PRISMA** (ASI), in operations since 2019
- **HISUI** (METI), in operations since end of 2019 at ISS
- **EnMAP** (DLR), in operations since 2022
- **EMIT** (NASA), in operations since 2022 at ISS

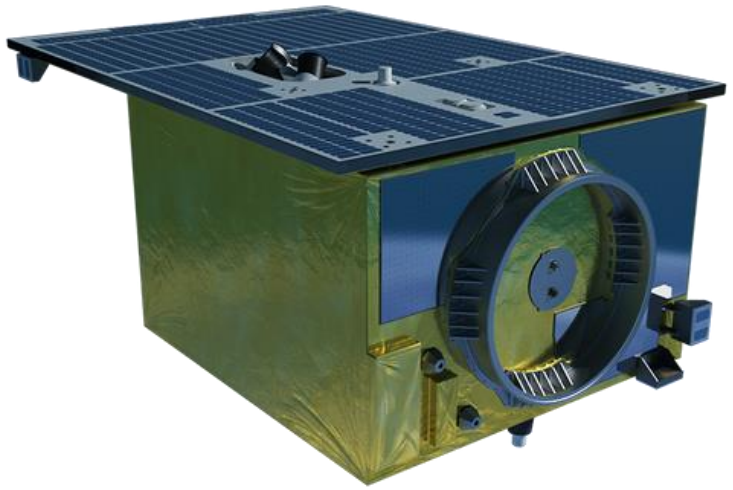
In future **SBG**, **PACE** (NASA) and **CHIME** (ESA)



Source:
Front. Environ. Sci. 9:649528.
doi: 10.3389/fenvs.2021.649528

EnMAP Mission

EnMAP Mission



- **EnMAP** (**En**vironmental **M**apping and **A**nalysis **P**rogram) is a spaceborne German hyperspectral satellite mission to monitor and characterize Earth's environment at a global scale.
- Main goal is to provide accurate information on the state and evolution of terrestrial and aquatic ecosystems for research in various fields like agriculture, geology, soils, urban areas, coastal and inland waters.
- **EnMAP** will provide scientific data for measuring climate change impact, analyze land cover change and surface processes, study biodiversity, study water availability and quality, analyze natural resources and provide hazard and risk assessments.

Project Management
DLR Space Administration

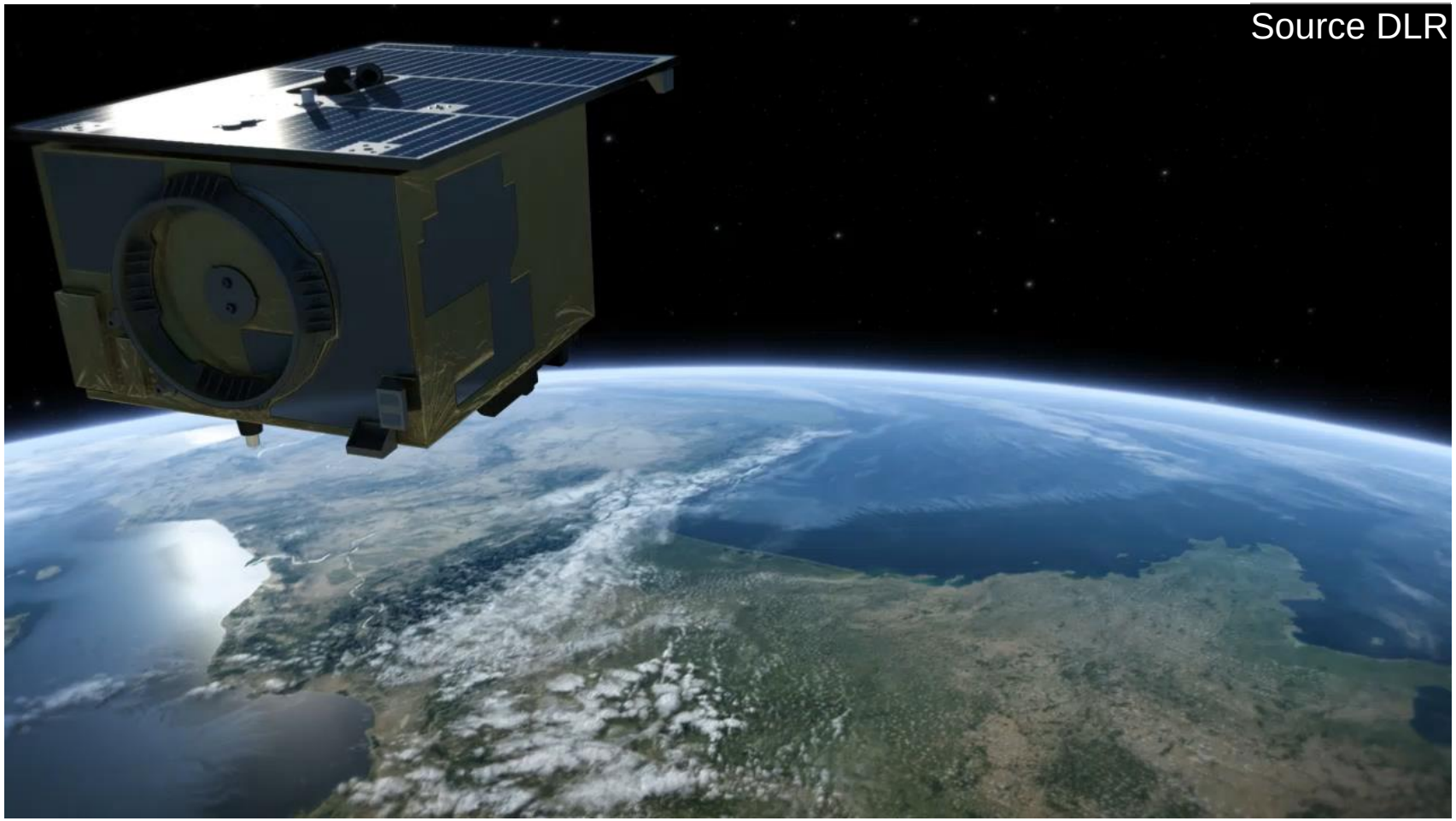
Scientific Principal Investigator
GFZ Potsdam

EnMAP Science Team

Space Segment
Sensor | Platform

Ground Segment
Operations *DLR-GSOC* | Payload *DLR-DFD* | Processing *DLR-IMF*

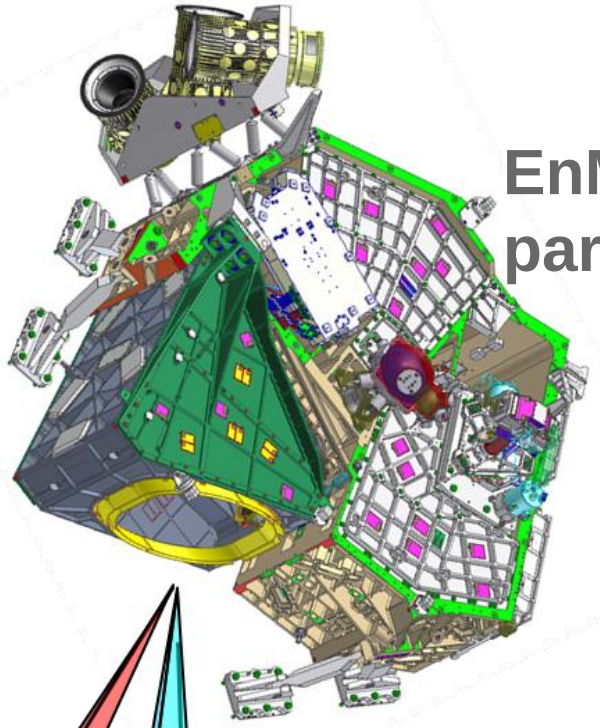
EnMAP Image Acquisition



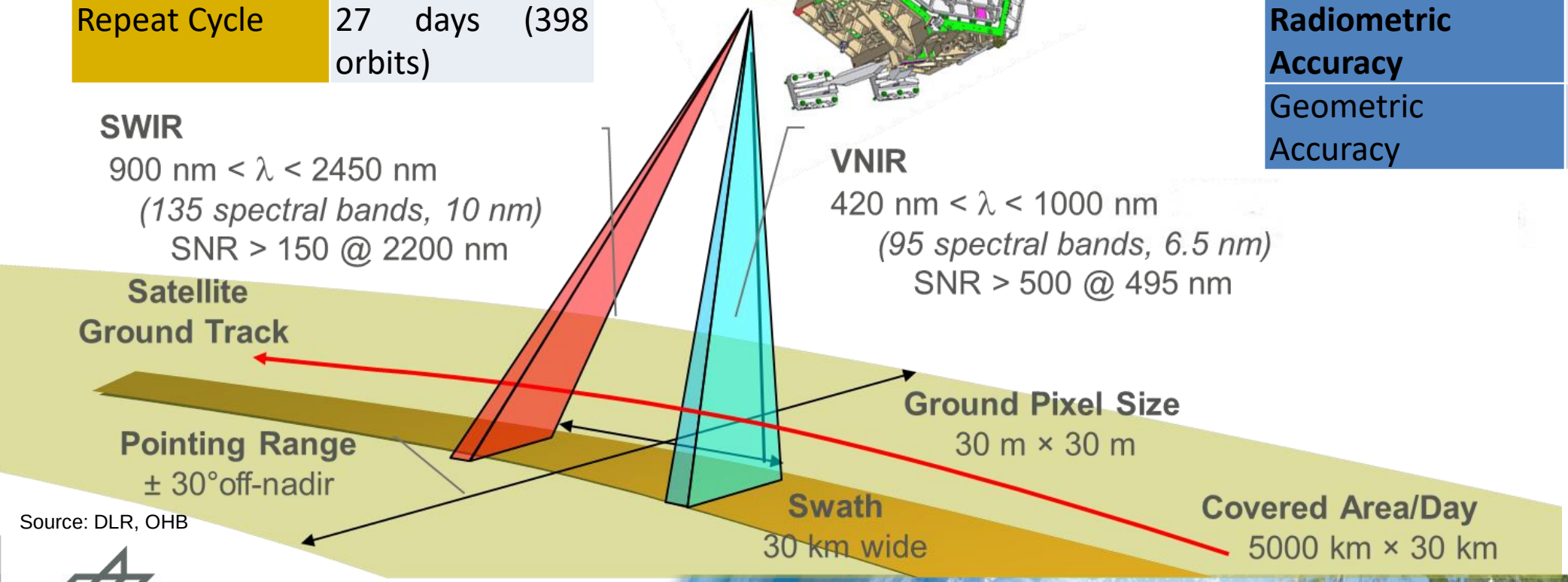
- Like most hyperspectral missions, EnMAP uses a **push-broom approach**, all 223 spectral bands are acquired simultaneously over an area of 30 Km × 30 m
- EnMAP products delivered as tiles of 30 Km × 30 Km
- EnMAP design to acquire 5000 Km (along-track) of data per day

EnMAP Satellite and Instrument parameters

Parameter	Value
Weight	916 Kg
Dimensions	1.7 × 2.0 × 3.1 m
Orbit type	Sun-syncrhronous
Orbit height	653 Km
Orbit Period	97 minutes
Repeat Cycle	27 days (398 orbits)

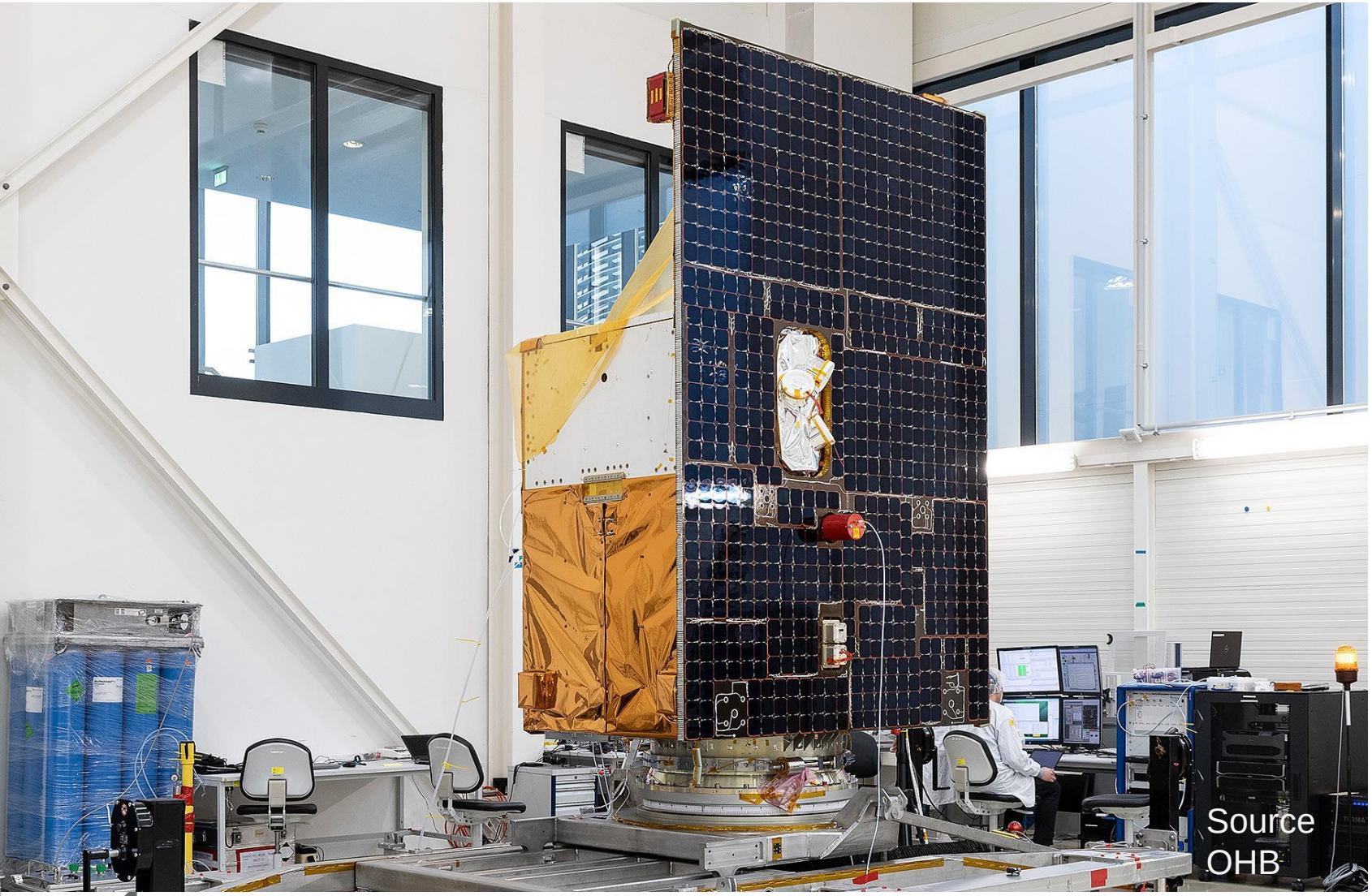


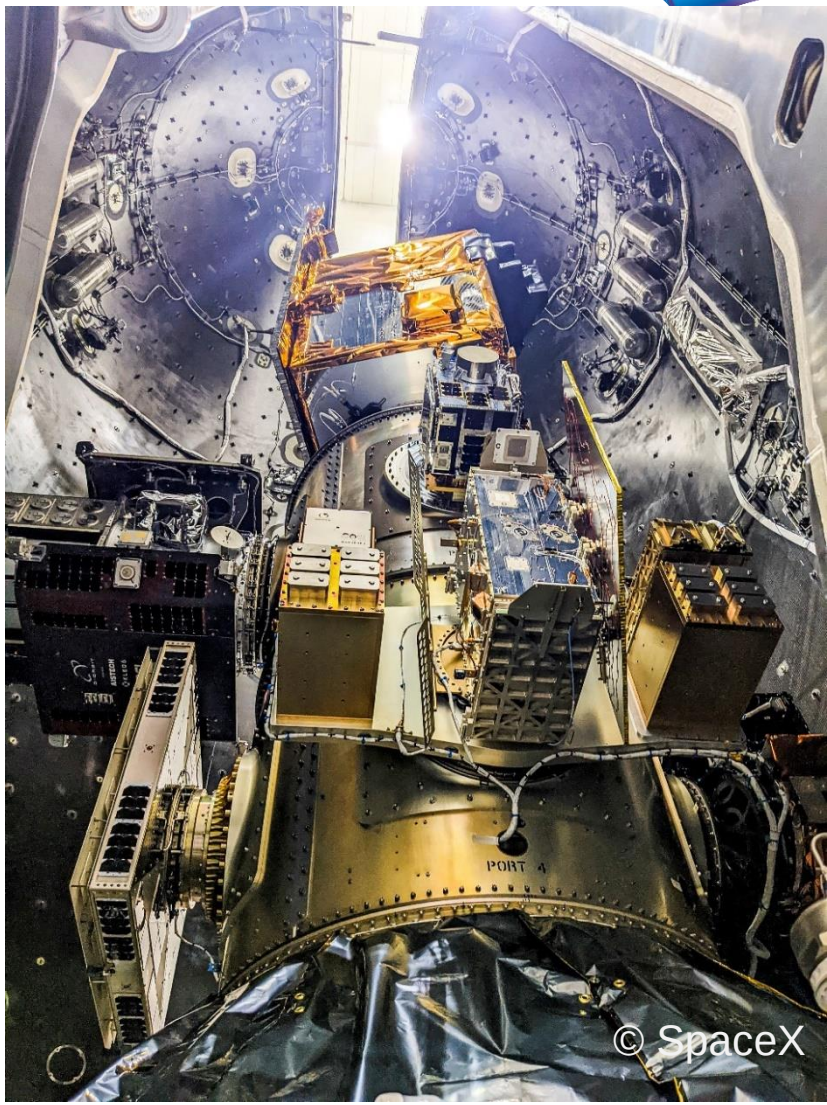
Instruments Parameters	Value
Spectral Accuracy	0.5 nm (VNIR); 1.0 nm (SWIR)
Radiometric Accuracy	**5.0% (absolute); 2.5% (relative)**
Geometric Accuracy	<30 m with GCPs (100 m without GCPs)



Source: DLR, OHB

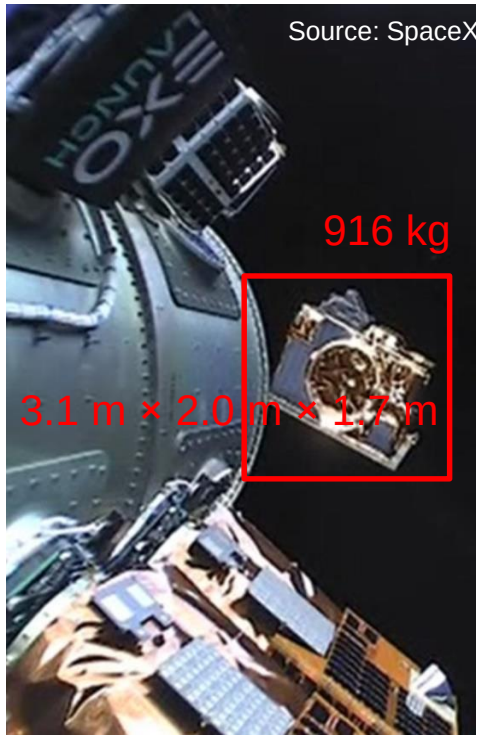
EnMAP Preparation



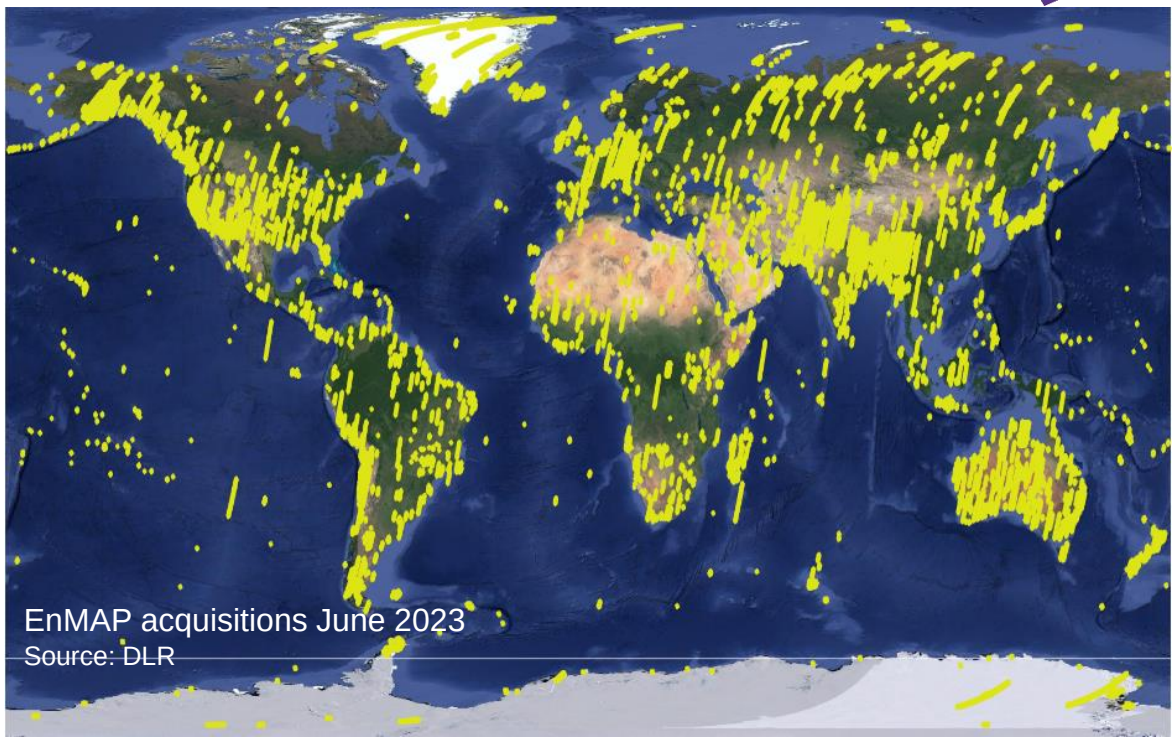


Source: SpaceX

Launch and start of operations

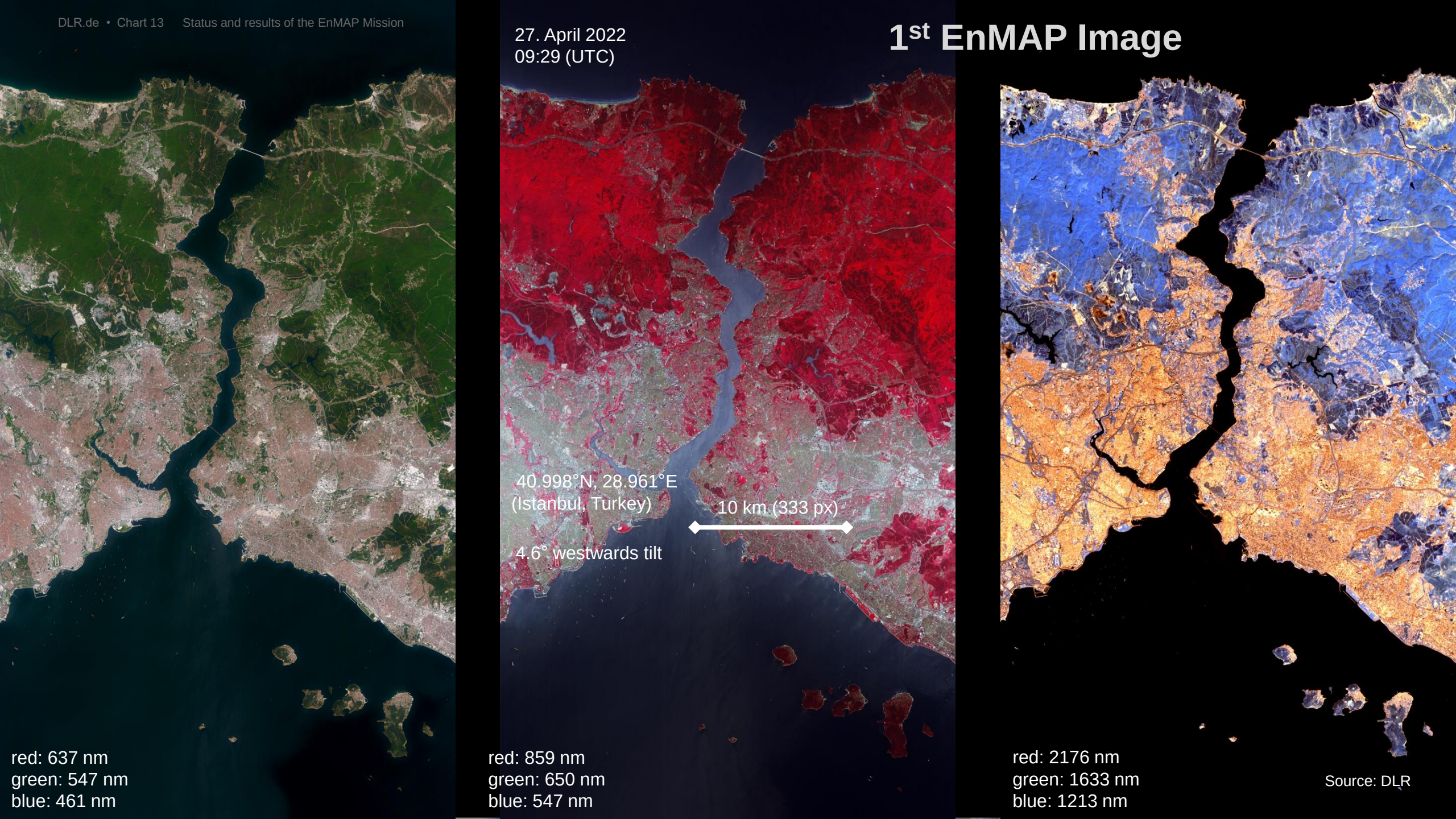


Source: SpaceX


EnMAP acquisitions June 2023
Source: DLR

- EnMAP launched on 1st April 2022 on a SpaceX Falcon 9 rocket from Cape Canaveral
- Commissioning Phase successfully closed. Start of routine operations November 2022
- Today ~30000 Products of 30×30 km archived and ready to download

1st EnMAP Image



red: 637 nm
green: 547 nm
blue: 461 nm

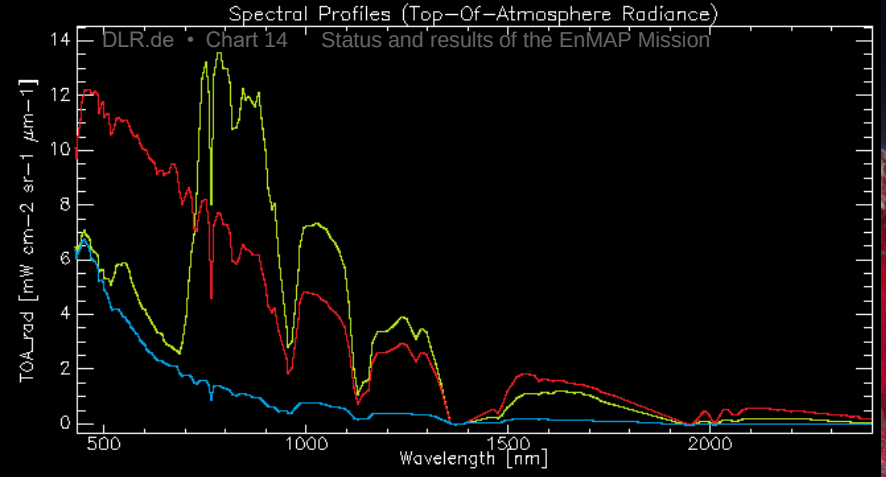
red: 859 nm
green: 650 nm
blue: 547 nm

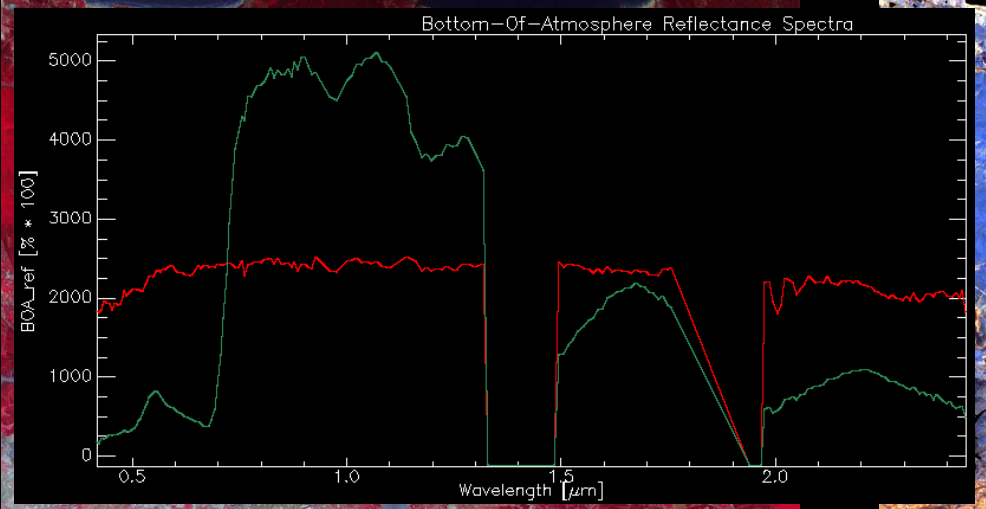
red: 2176 nm
green: 1633 nm
blue: 1213 nm

Source: DLR

1st EnMAP Image

27. April 2022
09:29 (UTC)





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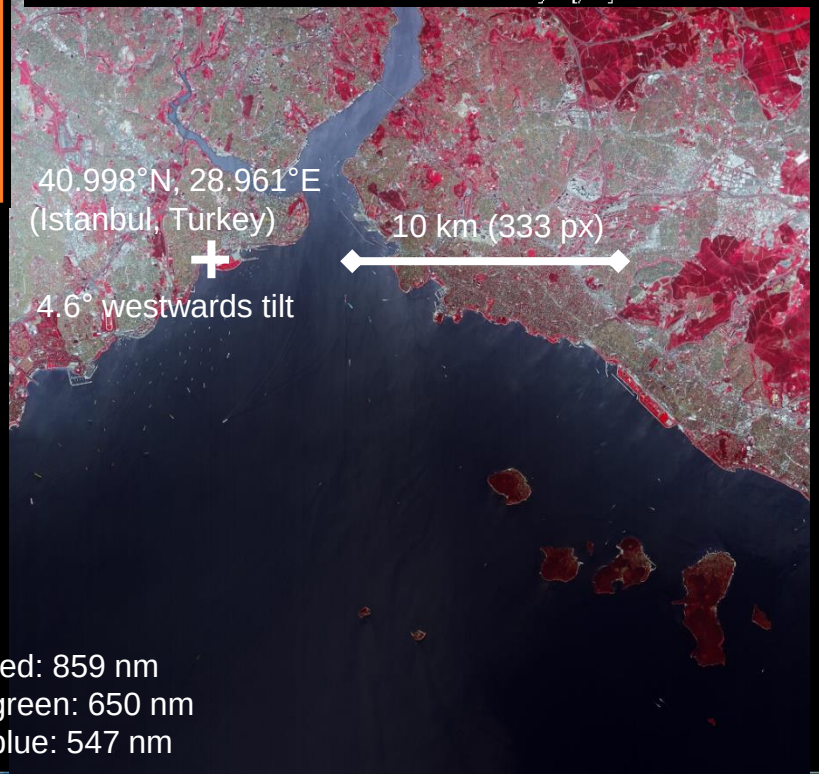

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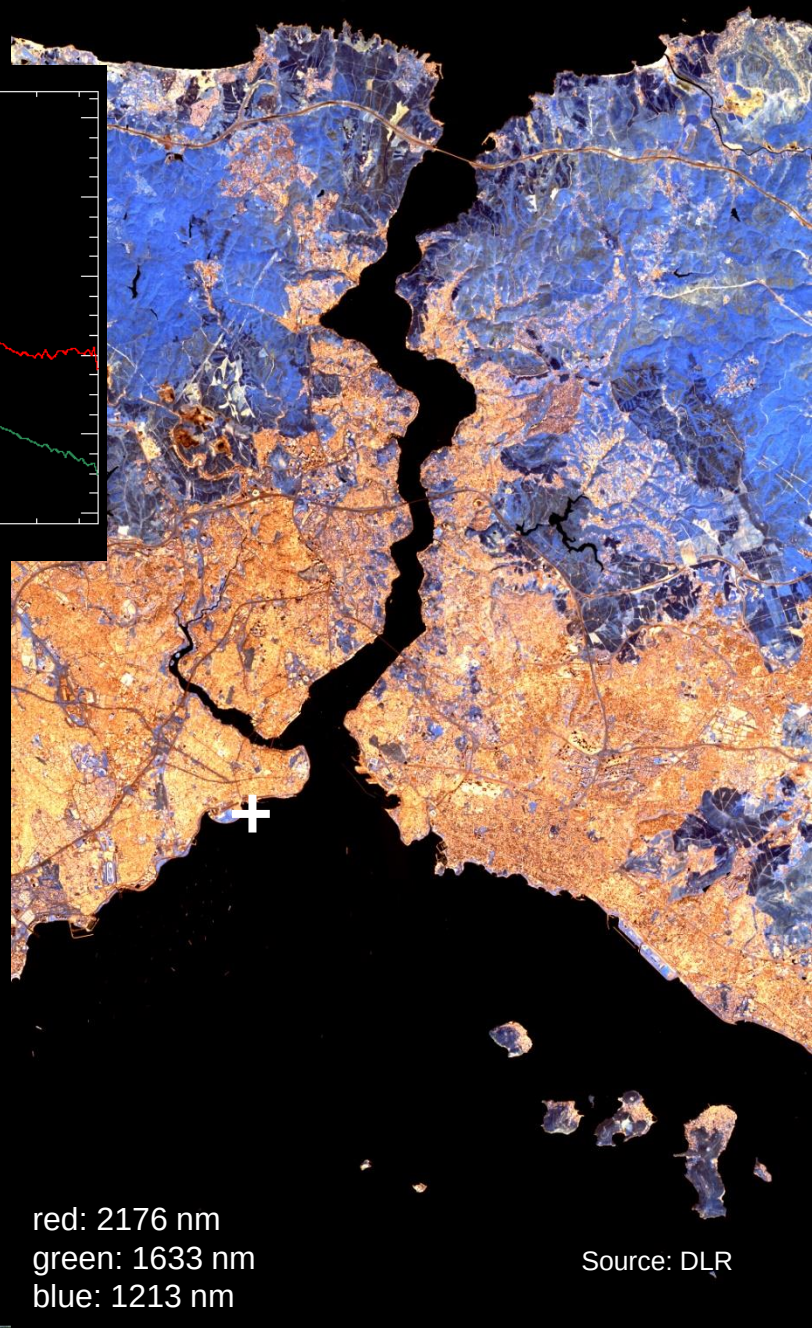


red: 2176 nm
green: 1633 nm
blue: 1213 nm

Source: DLR


Ambozaka (east coast of Madagascar)
01. April 2023


Lake Ballard (Australia)
08. April 2023

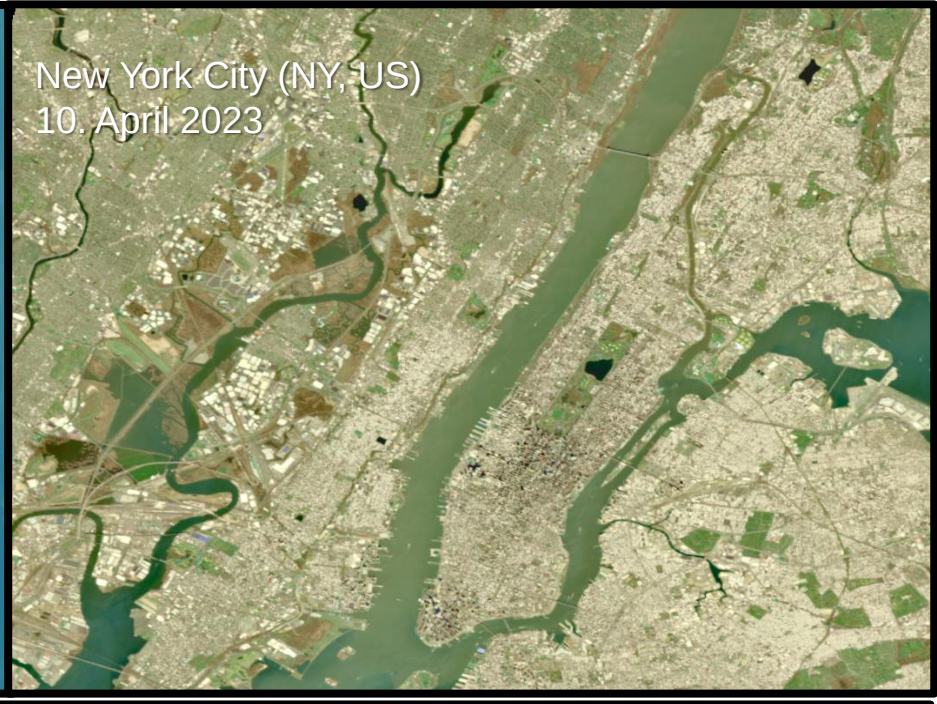

Fort Myers (FL, US)
07. October 2022

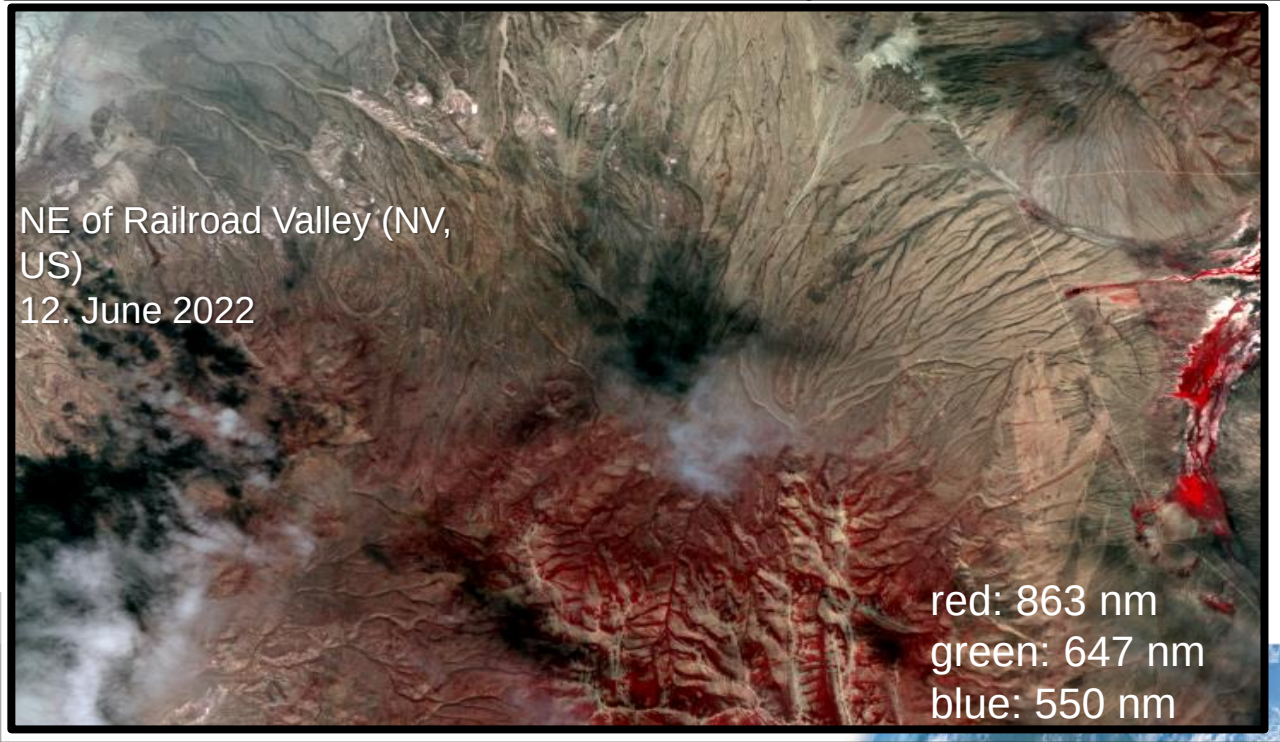

Teresa island (Patagonia, Chile)
18. September 2022

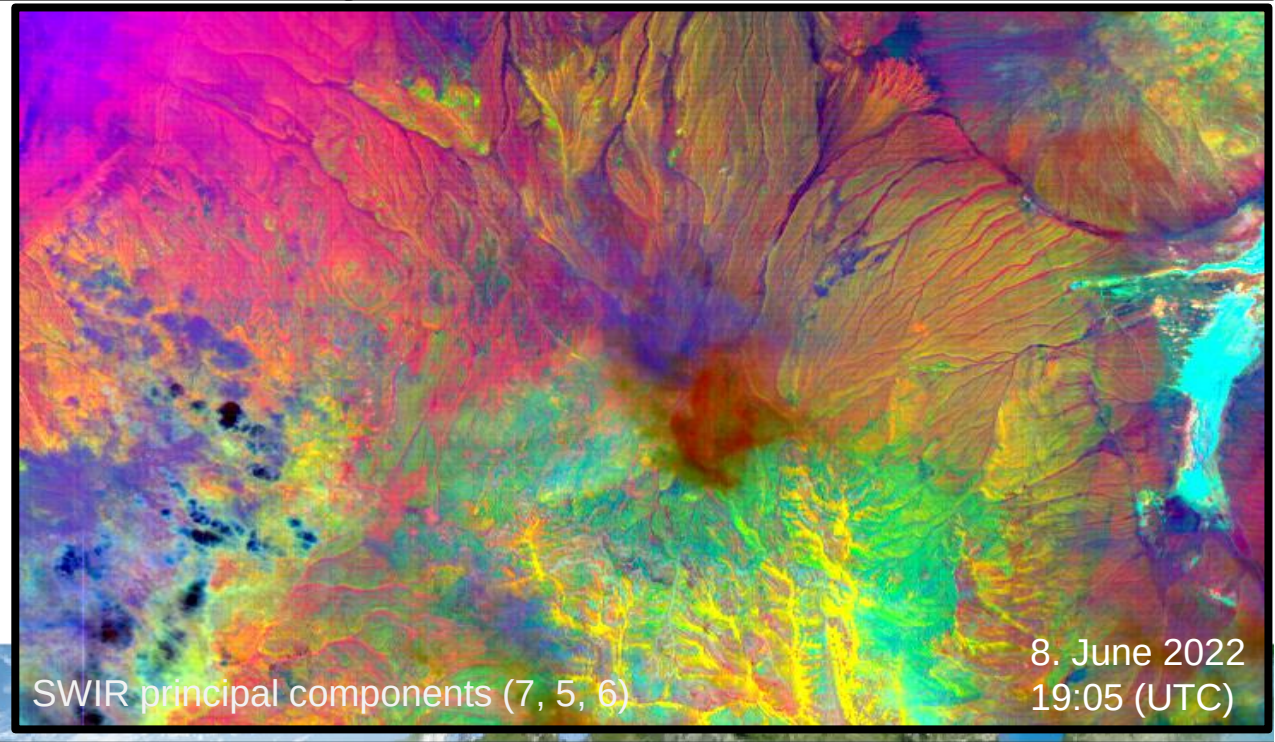

Port-Saint-Louis-du-Rhone (France)
02. August 2022


Ramree Island (Myanmar)
22. October 2022

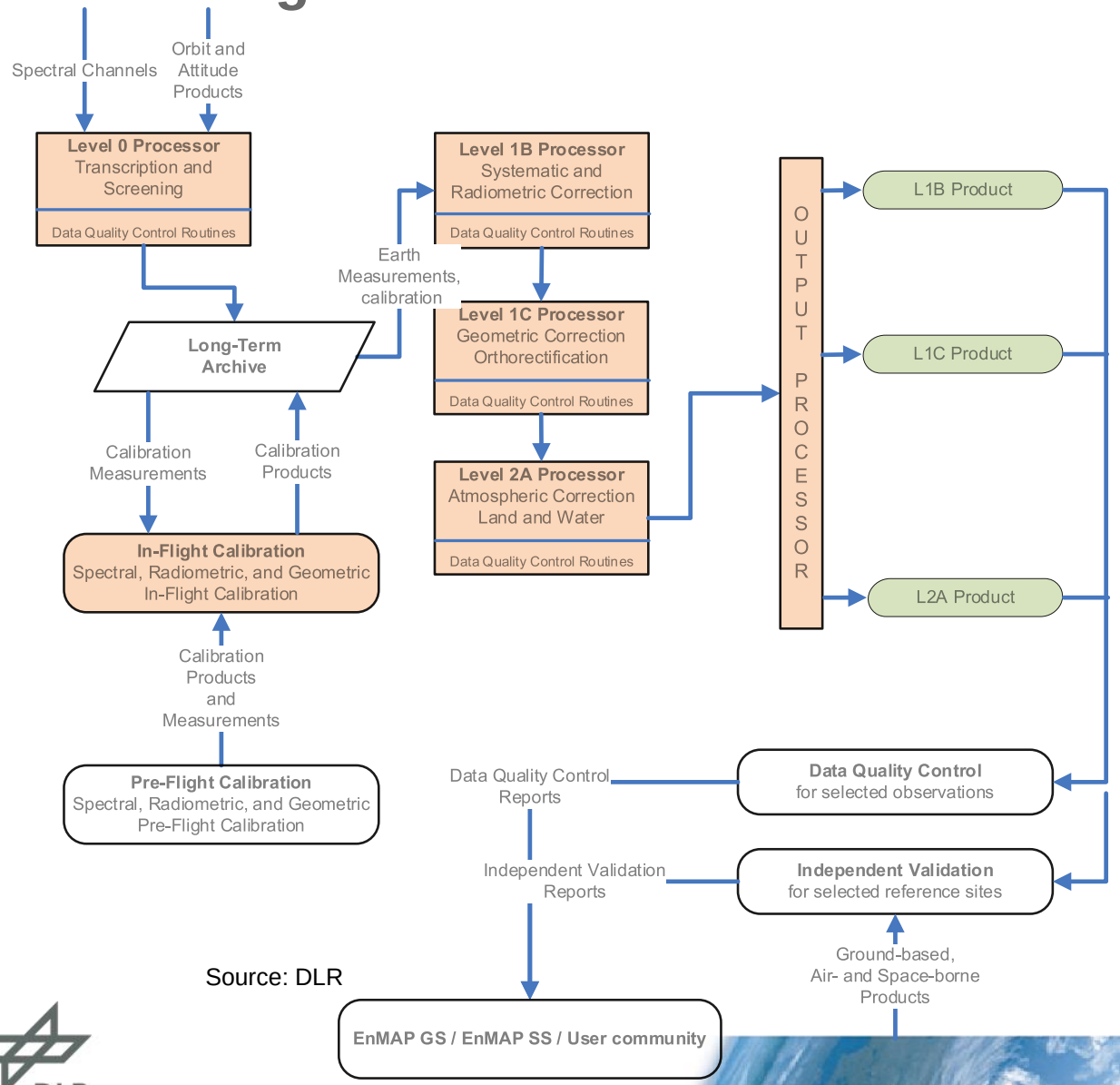

Mooroonga Island
(Australia)
02. September 2022


New York City (NY, US)
10. April 2023


NE of Railroad Valley (NV,
US)
12. June 2022
red: 863 nm
green: 647 nm
blue: 550 nm


SWIR principal components (7, 5, 6)
8. June 2022
19:05 (UTC)

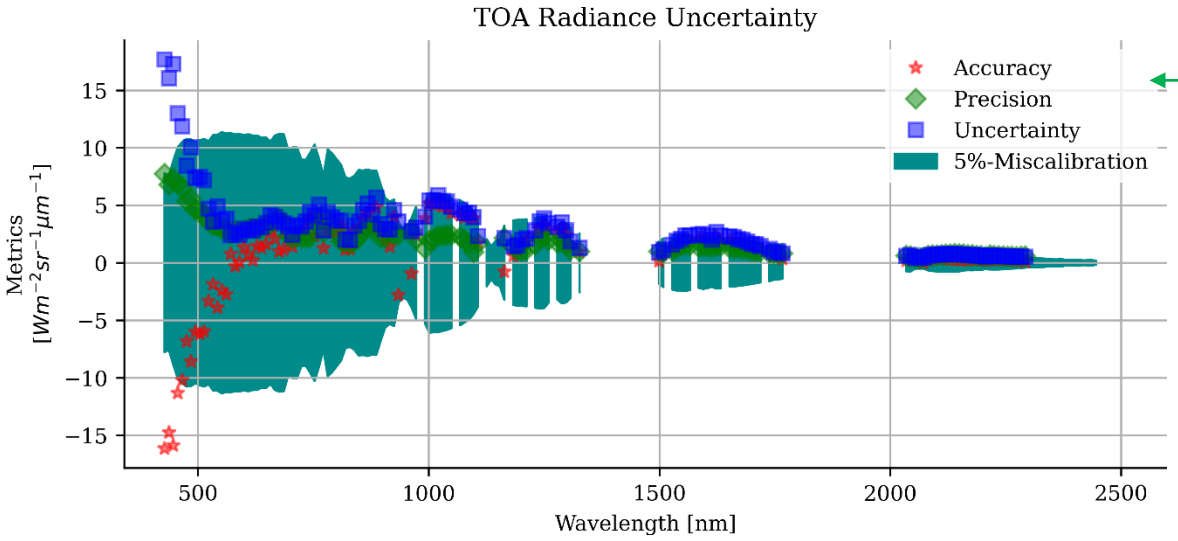
Processing chain and EnMAP Products



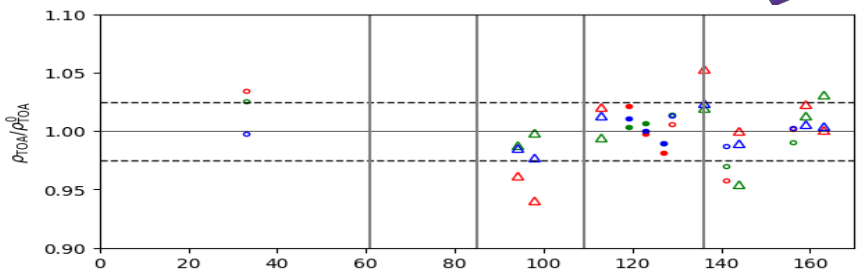
Source: DLR

- In-flight calibration observations are processed to generate updated calibration tables
- Three level of users products can be ordered (L1B / L1C / L2A) from Earth observations. Dedicated L2A water processor (2 types of water products)
- User products annotated with quality information (metadata) plus periodic quality and validation reports
- Quality Control (GS) and Independent Validation (GFZ) performed on user products
- EnMAP L2A data complaint with CEOS CARD4L at threshold specification

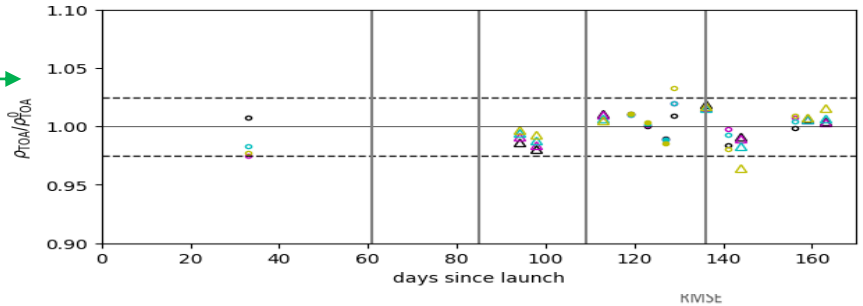
In-Orbit Validation

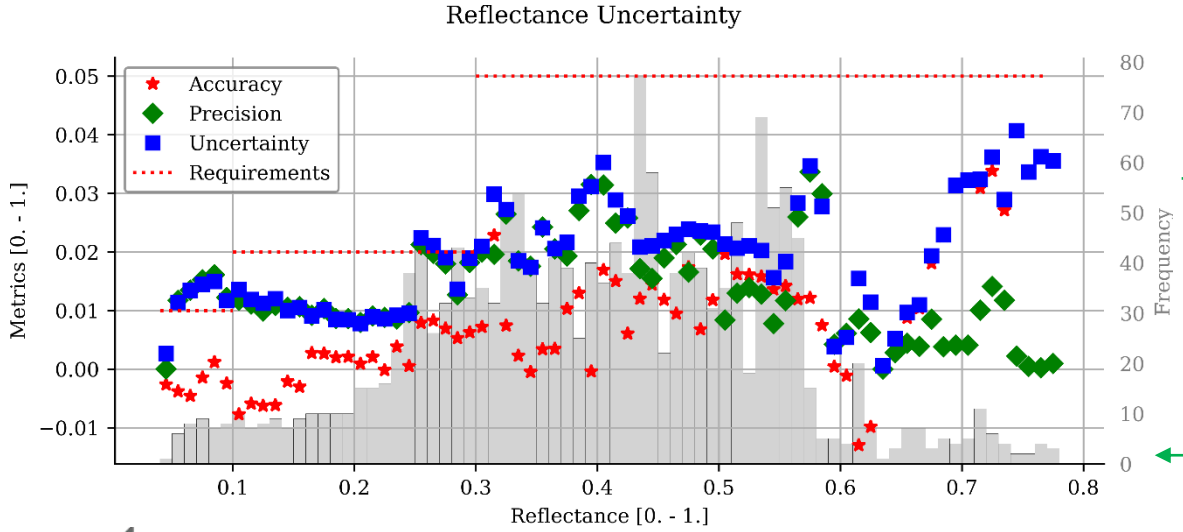


Radiometric Validation

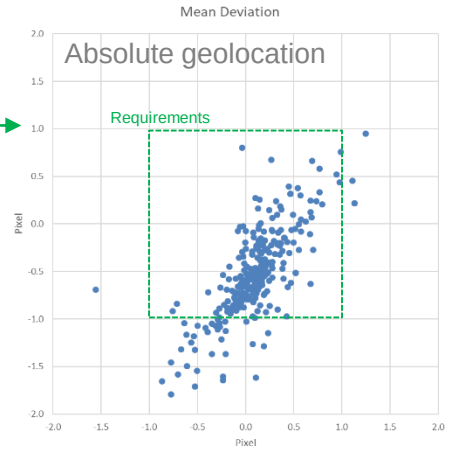


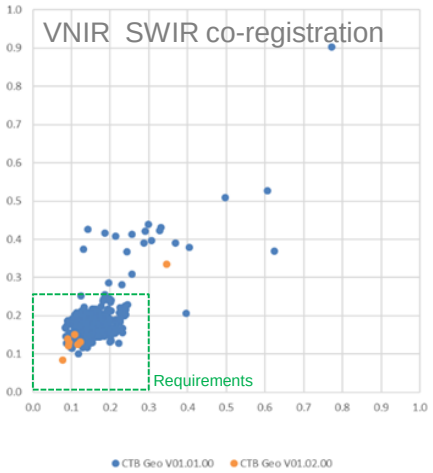
Radiometric Stability





Geometric Performance



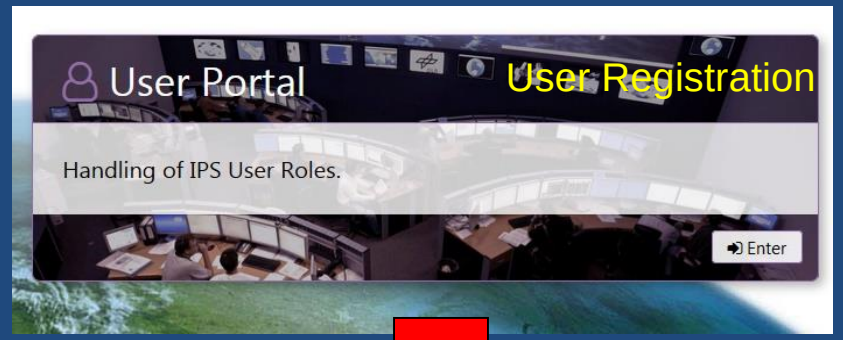


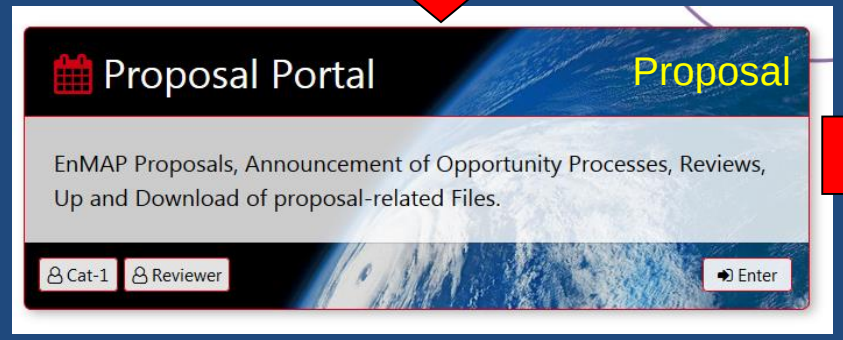
Reflectance Validation

How to get EnMAP Data

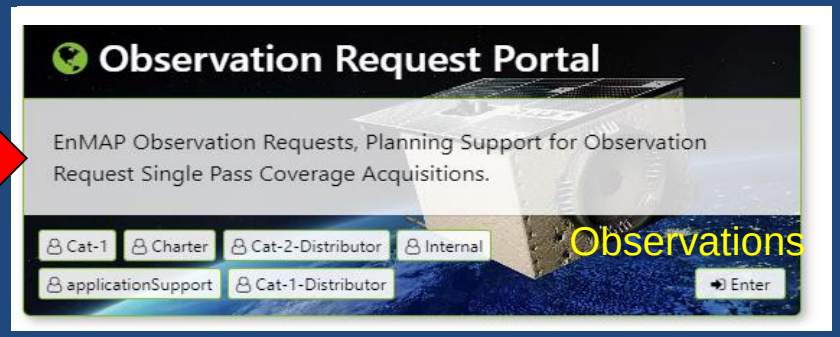
- EnMAP data access portal has two main entry points: new observations (**1**) and archived data (**2**)

1. EnMAP Instrument Planning Portal https://planning.enmap.org/



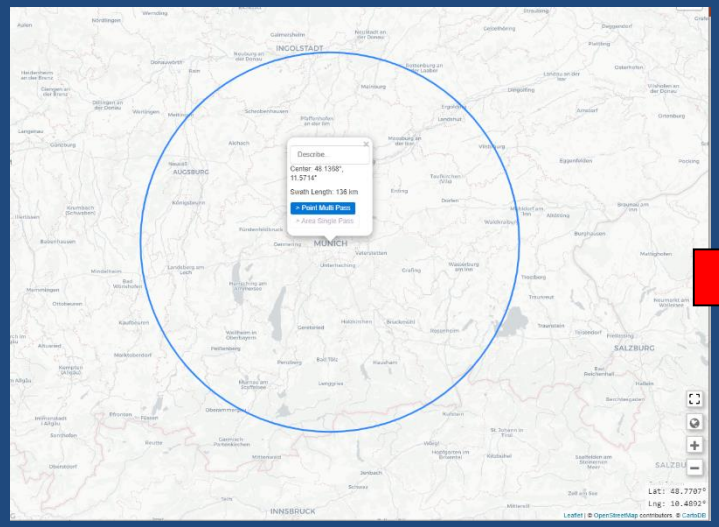


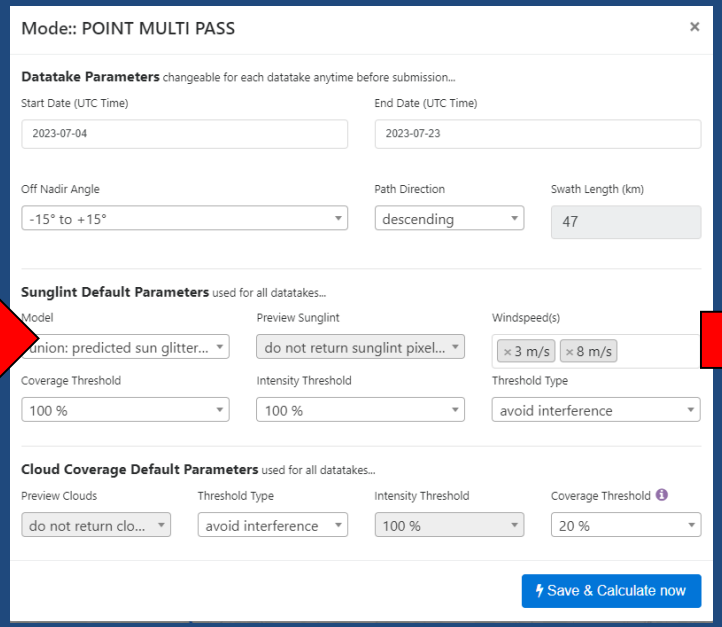
Where users can **register**, submit proposals (necessary to task the instrument) and request future EnMAP acquisitions

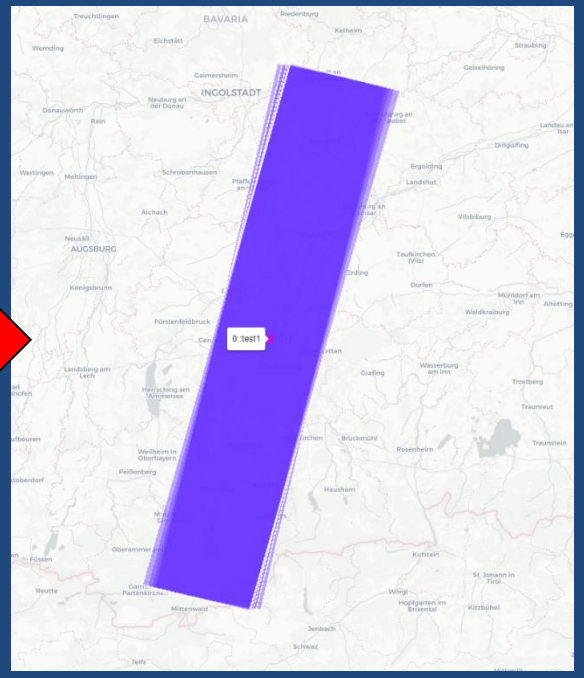


How to planned an EnMAP acquisition

1. EnMAP Instrument Planning Portal https://planning.enmap.org/







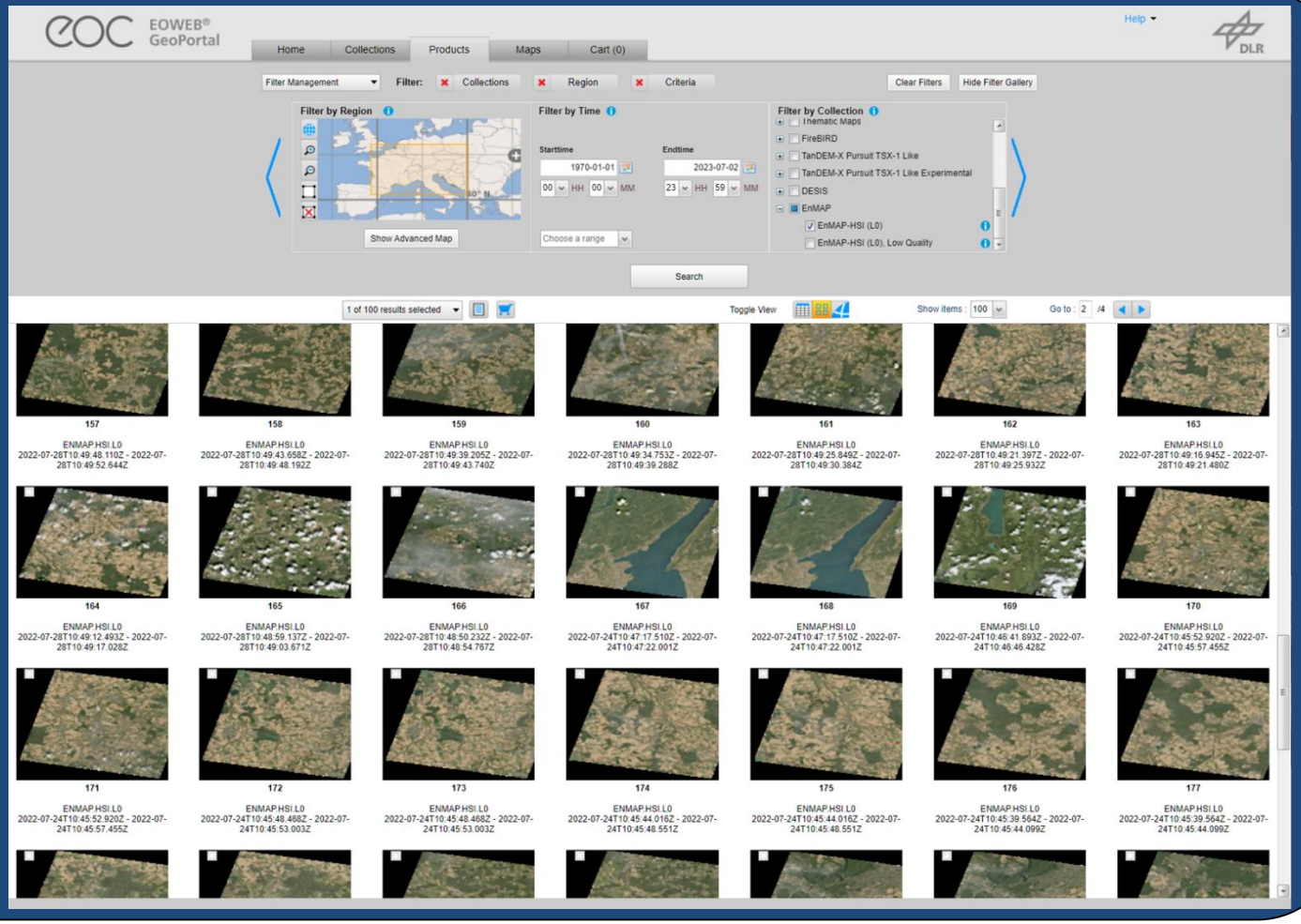
Satellite scheduling not guaranteed. Tasking decision depends on cloud statistics and forecast, satellite restrictions (e.g. maneuvers) and priority and quota assigned to the proposal

How to get archived EnMAP data

2. German Satellite Data Archive through EOWEB https://eoweb.dlr.de/egp/

Where users can browse the EnMAP catalogue and order the products. Products are processed on-demand, according to different processing options of their choice like:

- Processing level (L1B, L1C, L2A)
- Map projection
- Resampling options
- L2A processing mode (land, water, combined)
- Atmospheric correction parameters

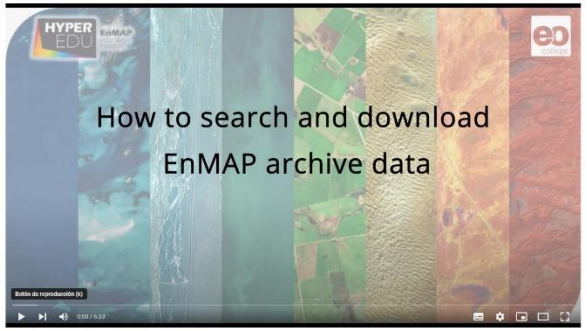


Introductory Videos (Screencasts)

Pre-processing 05 - Introduction to the EnMAP Data Access Portal

Pre-Processing 06 – The Proposal Portal

Pre-Processing 07 – The Observation Request Portal

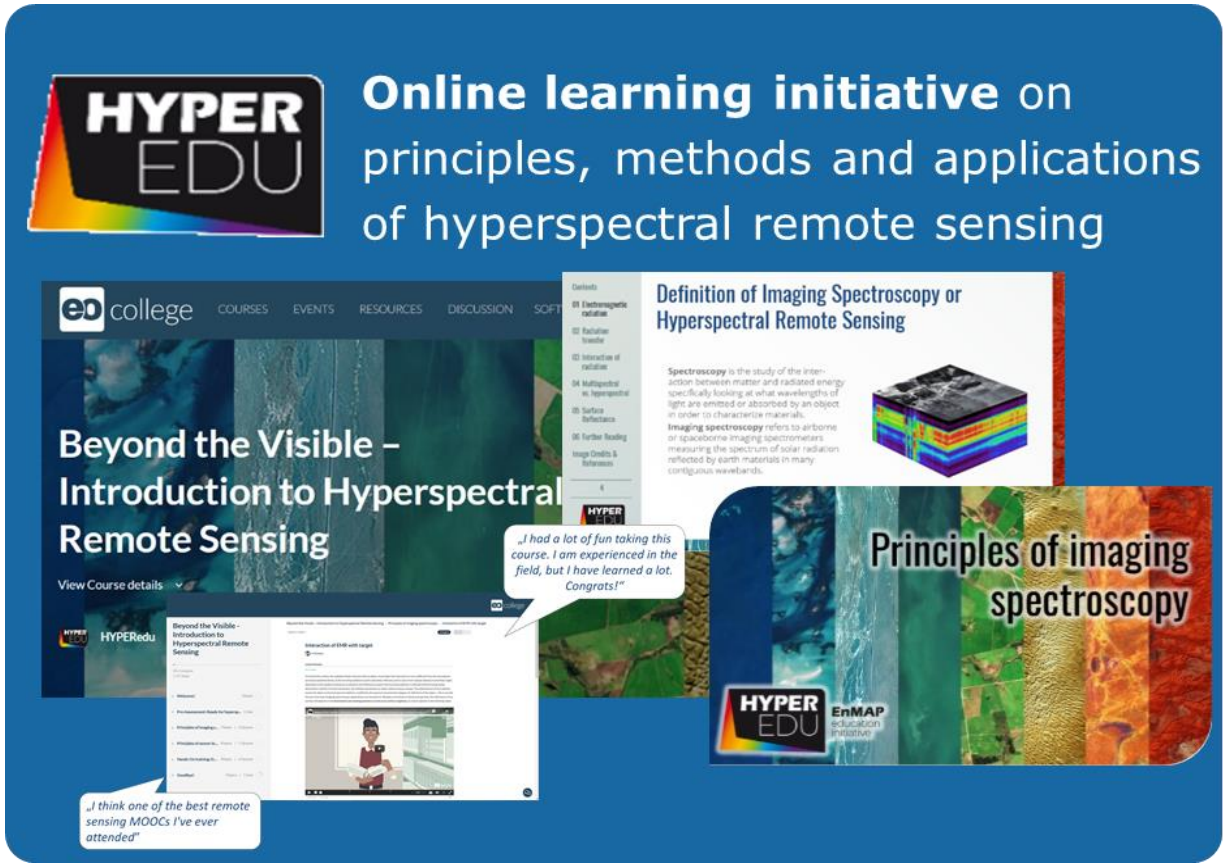


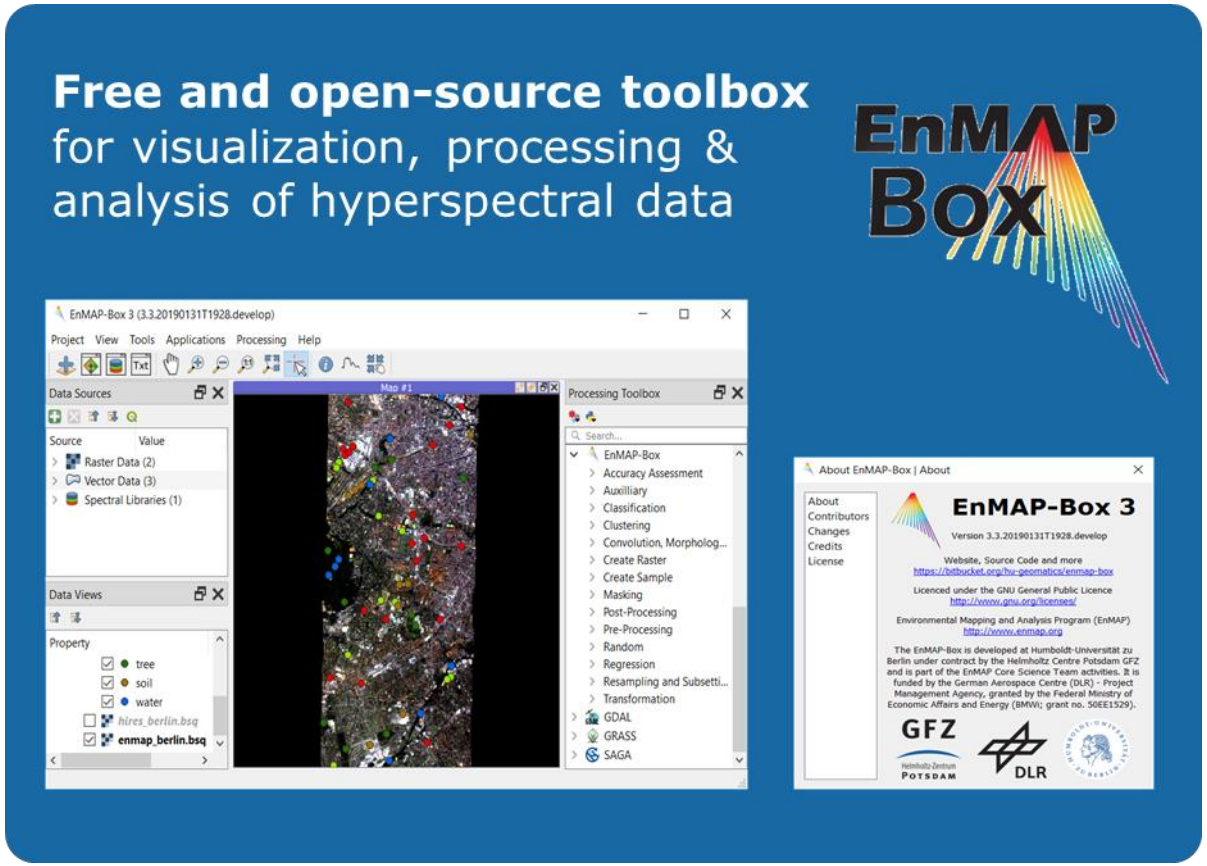
Pre-Processing 08 – The EOWEB GeoPortal (EGP)

- Introductory videos available at **HyperEDU** channel in YouTube can help you to register, submit a proposal, command new acquisitions or access the archived data
- Links available from https://www.enmap.org/data_access/

EnMAP science support activities for the exploitation of EnMAP data

Development of algorithm toolbox and education resources





https://www.enmap.org/events_education/hyperedu/

https://www.enmap.org/data_tools/enmapbox/

Applications of Hyperspectral Data

Archeological imaging spectroscopy

- Buried archeological structures become visible under certain conditions with indirect indicators
- Variations in vegetation, specially on arable land (cropmarks) can be used to identify buried structures. Hyperspectral data, containing more information about health and properties of the vegetation can be used to this end

Reference: Christopher Stewart 1, Georges Labrèche 1 and Daniel Lombraña González, Remote Sens. 2020, 12, 2795; doi:10.3390/rs12172795

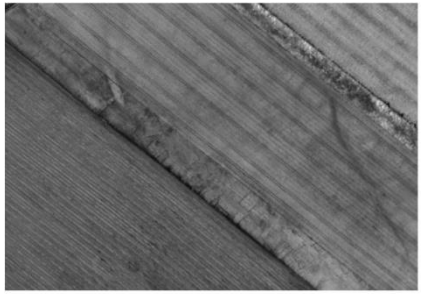
Figure 5. A diagram inserted in "Task Presenter" showing the physical mechanism of negative (left) and positive (right) cropmarks. The image is a modified version of the figure published by Stewart, 2017 [15].

Figure 1. An example of cropmarks in Google Earth in the case of the ancient Roman city of Ferentium. The image acquisition date is reported to be 7 August 2013. Courtesy of Google Earth Pro.

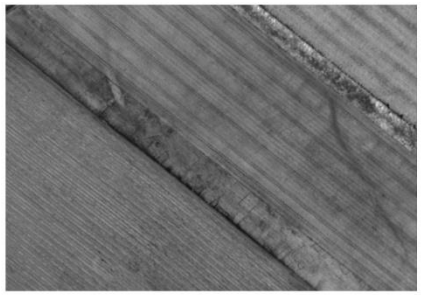
Crop Marks, best indices

- Spectral indices ranked according to mutual information

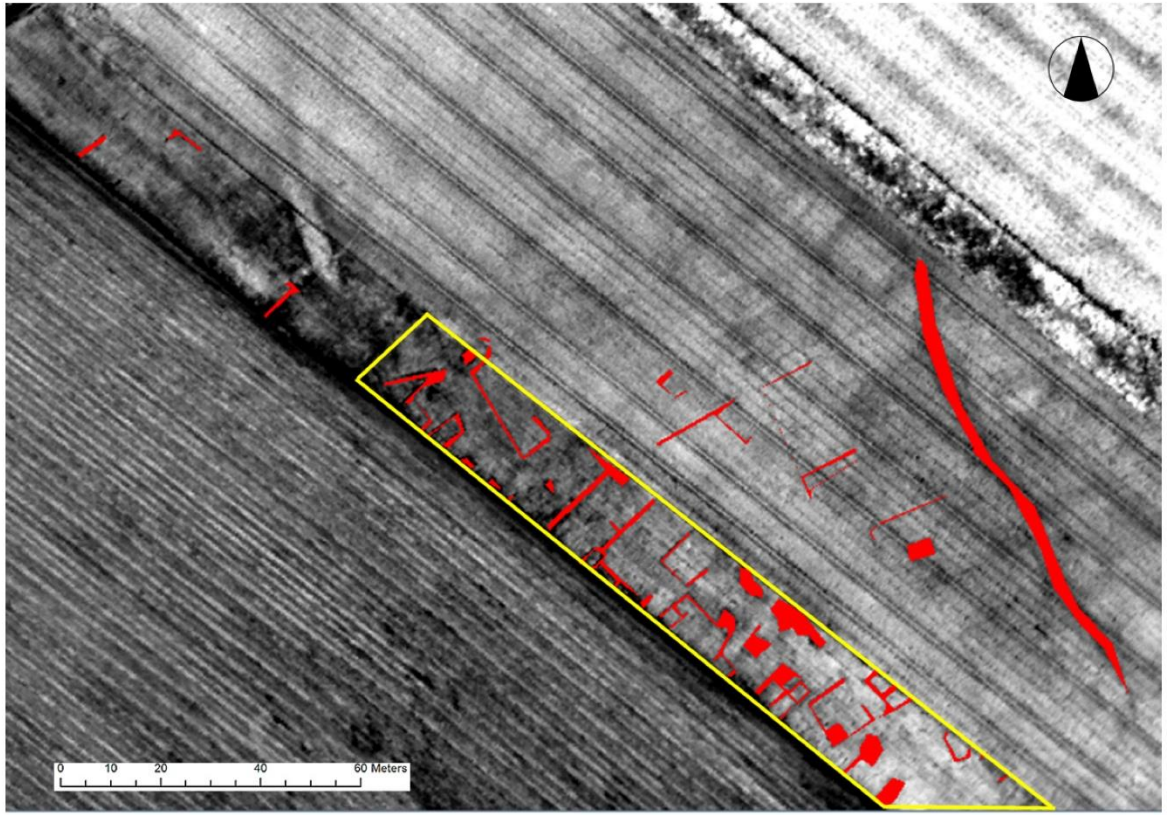
1 - True Color Combination



2 - NIR band at 787 nm

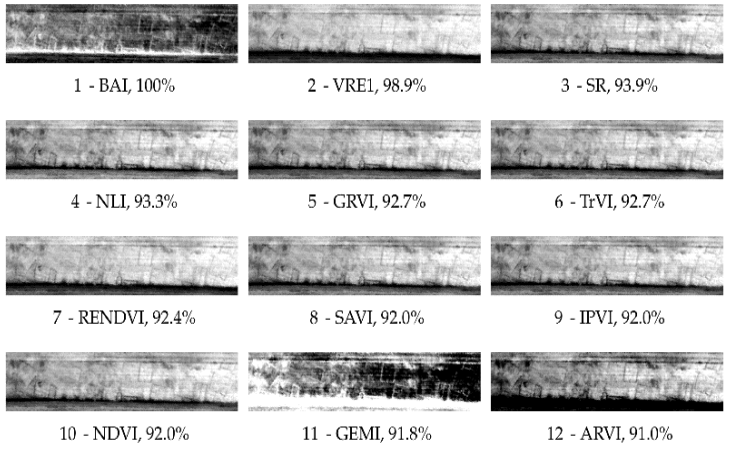


3 - PC 1

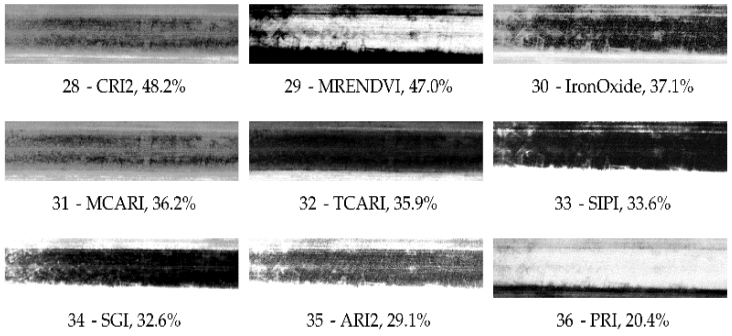


Cerra, D.; Agapiou, A.; Cavalli, R.M.; Sarris, A. An Objective Assessment of Hyperspectral Indicators for the Detection of Buried Archaeological Relics. Remote Sens. 2018, 10, 500. https://doi.org/10.3390/rs10040500

Best

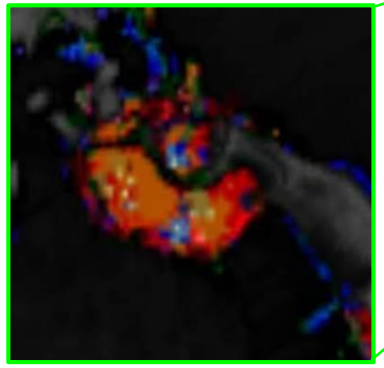


Worst

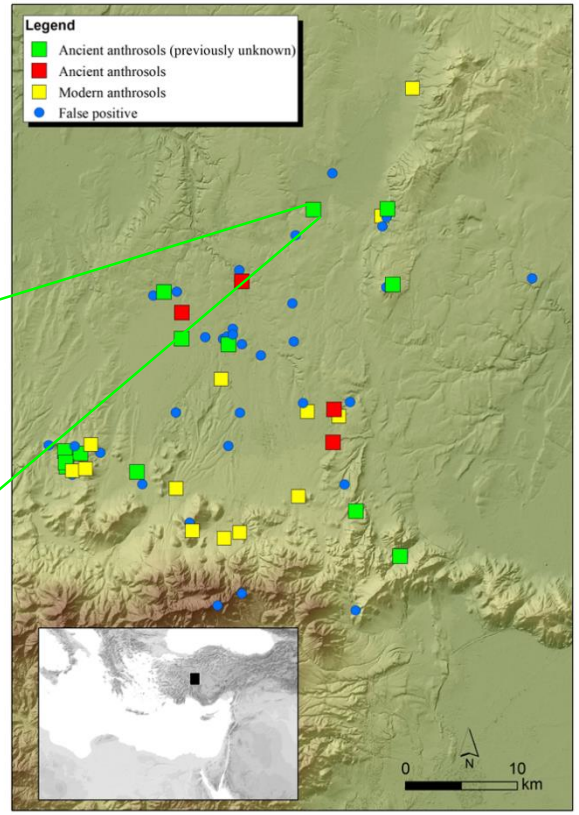


Landscape Archaeology with DESIS (Konya, Turkey)

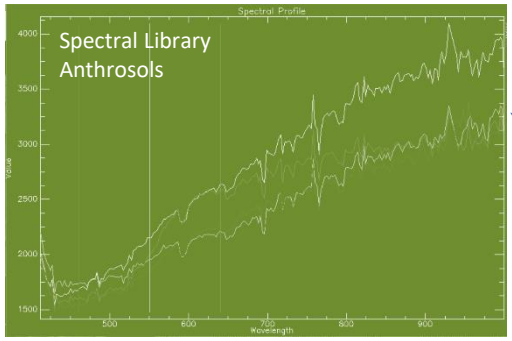
- **Anthrosols**: Anthropogenic soils characterized by a high level of organic content
- Result of dwelling for hundreds of years
- Several sites still unknown

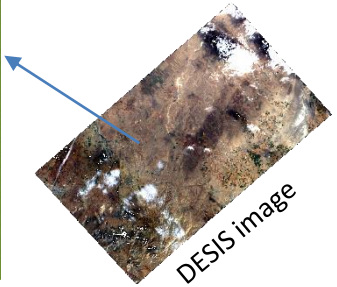


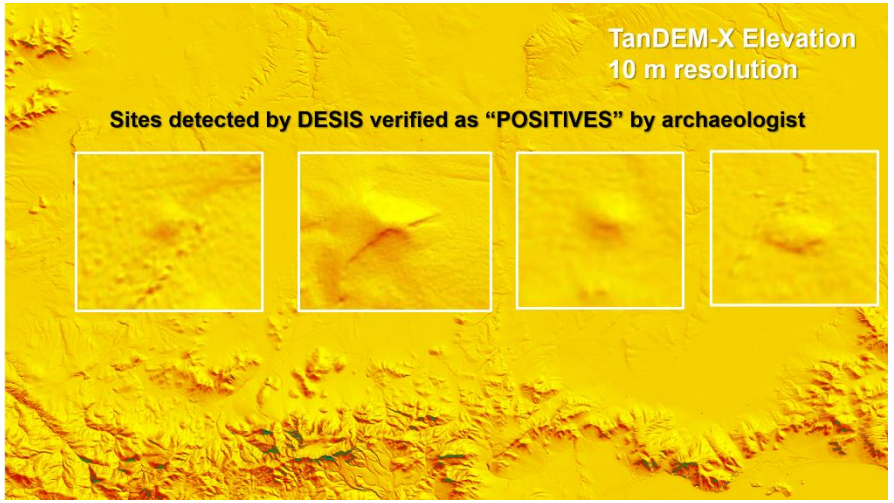
Probability of anthrosols



14 new discovered sites, Konya, Turkey
Verified by archaeologists (Univ. Chicago)







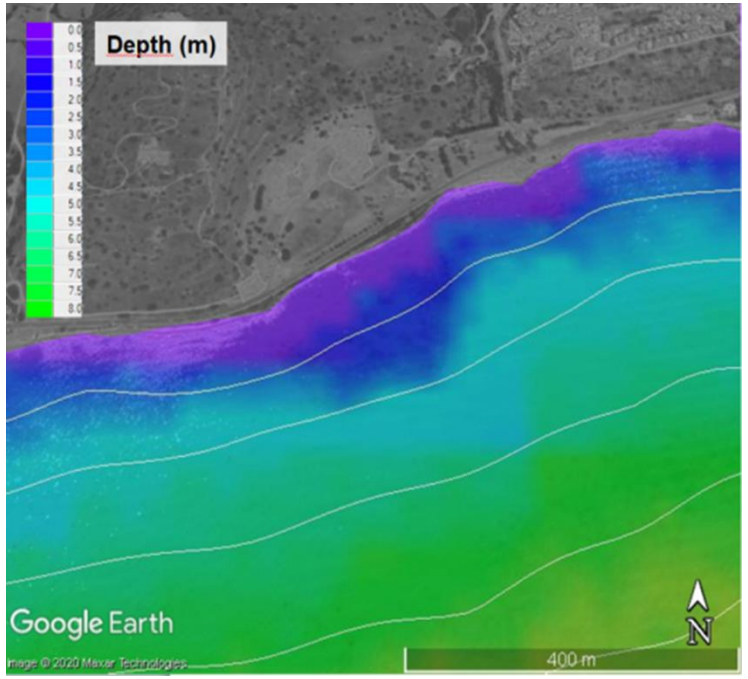
Additional Assessment using TanDEM-X

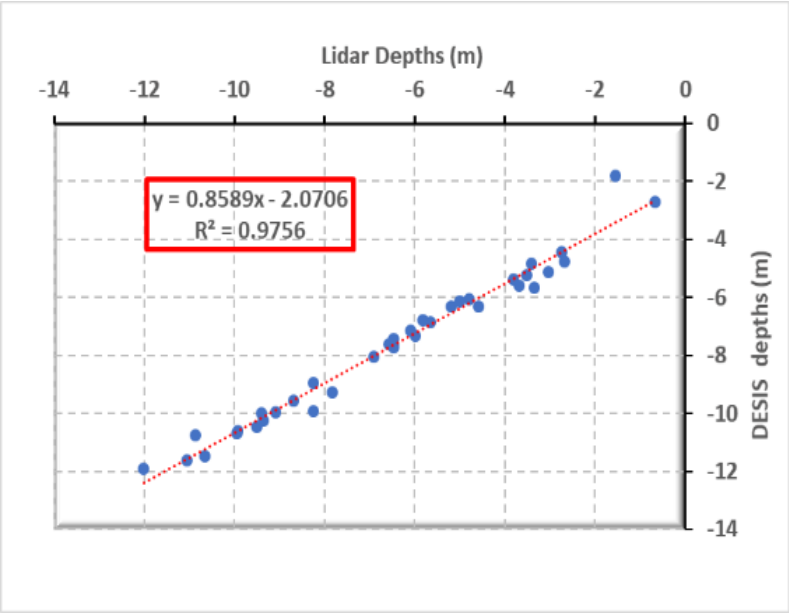
DESIS can provide an assessment of large areas for landscape archaeology by analyzing spectral signatures of soils

Cerra, D.; et al. Presented at 1st DESIS User Workshop, 2021

Coastal and Inland Waters

Bathymetrical map if submerged harbour of the ancient city Amathus (Cyprus)





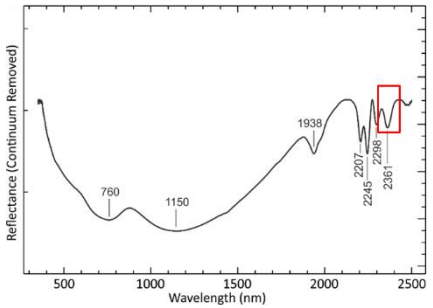
Comparison with ground truth (RMSE):

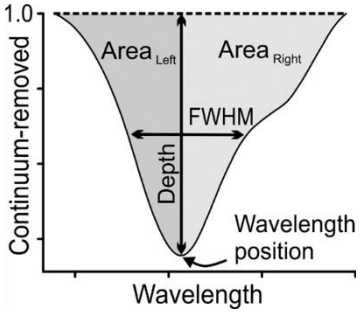
- S2: 0.72 m
- DESIS: 0.41 m

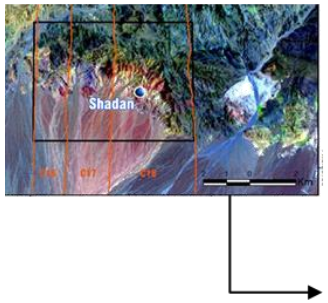
Reference: Cerra, D. und Gege, P. und Evagorou, E. und Agapiou, A. und de los Reyes, R. (2020) Monitoring Marine Areas from the International Space Station: the Case of the Submerged Harbor of Amathus. In: Digital Heritage - Euromed 2020, Seiten 1-11. Springer. EUROMED 2020, 2.-5. Nov. 2020, Paphos, Cyprus.

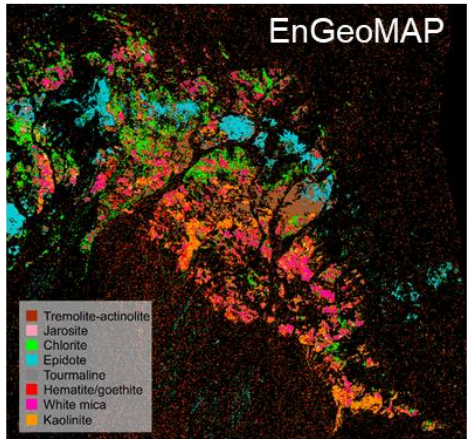
Geology and mineral exploration

Mineralogical footprint of a porphyry copper deposit (Shadan, Iran)

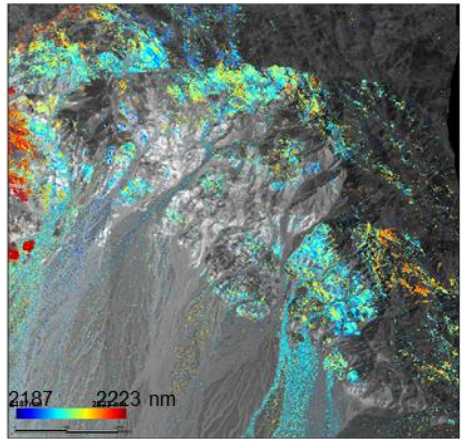


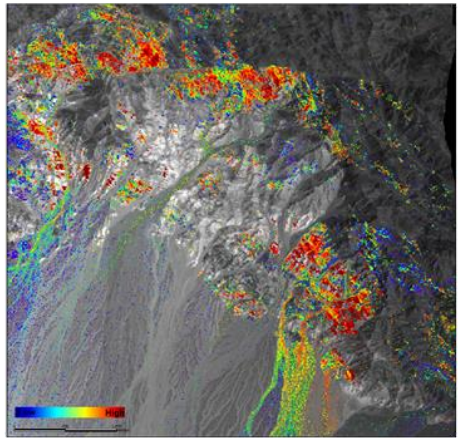




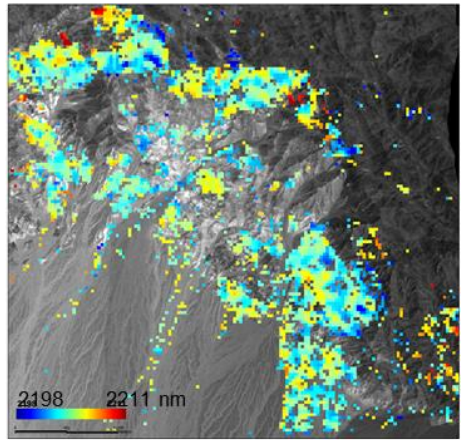


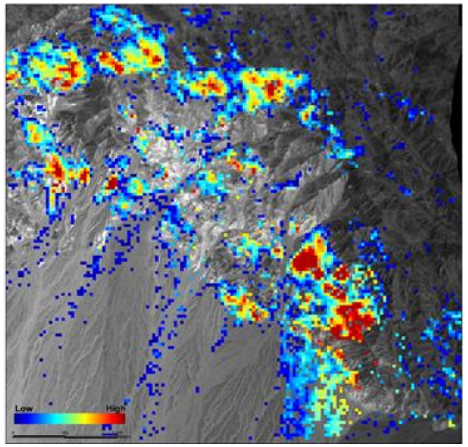
White mica composition **White mica Abundance**





HyMap
5 m



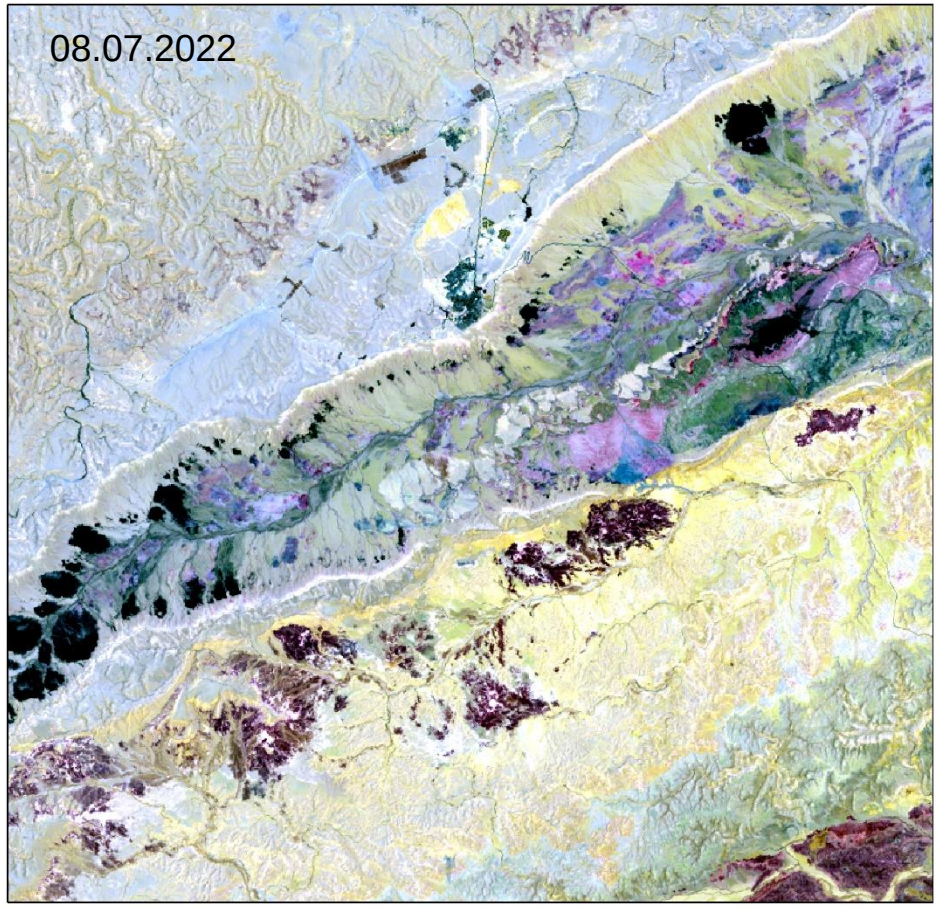


EnMAP
Simulation
30 m

Reference: Asadzadeh, S., et al. (2022), Targeting exploration drilling using airborne hyperspectral imagery: A case study from the Shadan Porphyry Copper Deposit, Iran, *Economic Geology*.

Geology and mineral exploration

Mineral variety and rock outcrops at huge eroded crater basin (Maktesh Ramon, Israel)



Enmap data@DLR [2022/2023]

RGB bands 2346 nm, 1390 nm, 458 nm

Courtesy: Asadzadeh, S. (GFZ), Chabrillat, S. (GFZ) , Ben-Dor, A. (Tel Aviv University)

Geology and mineral exploration

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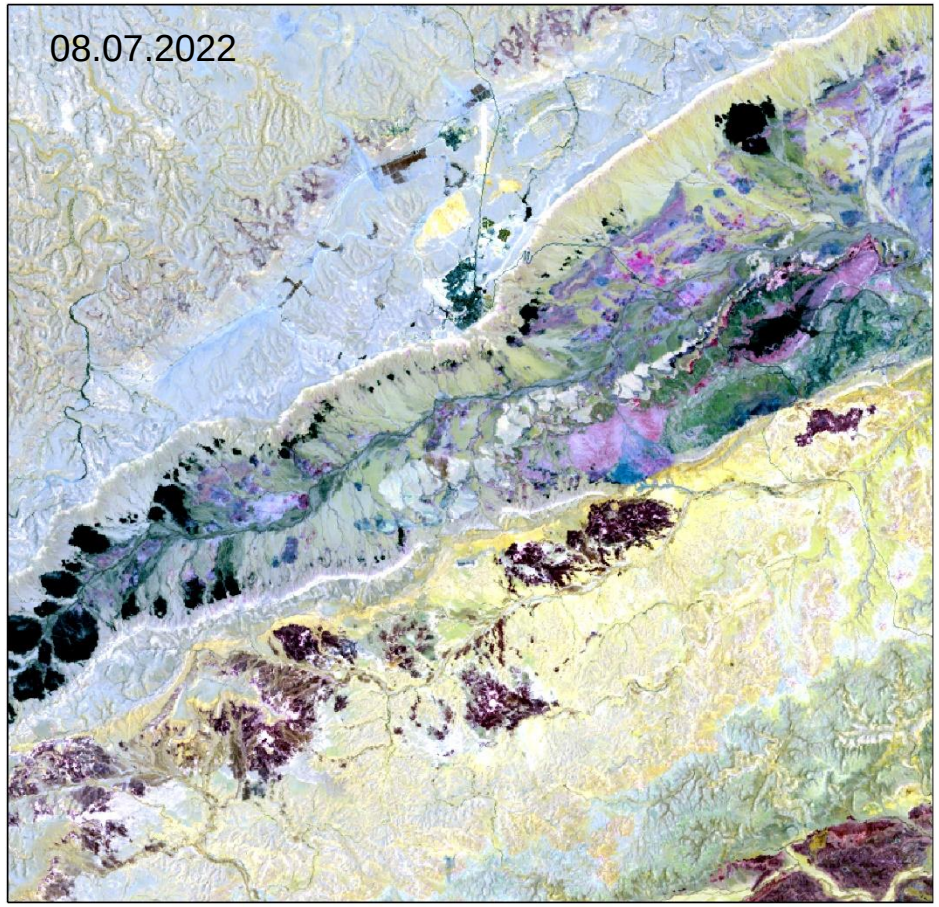

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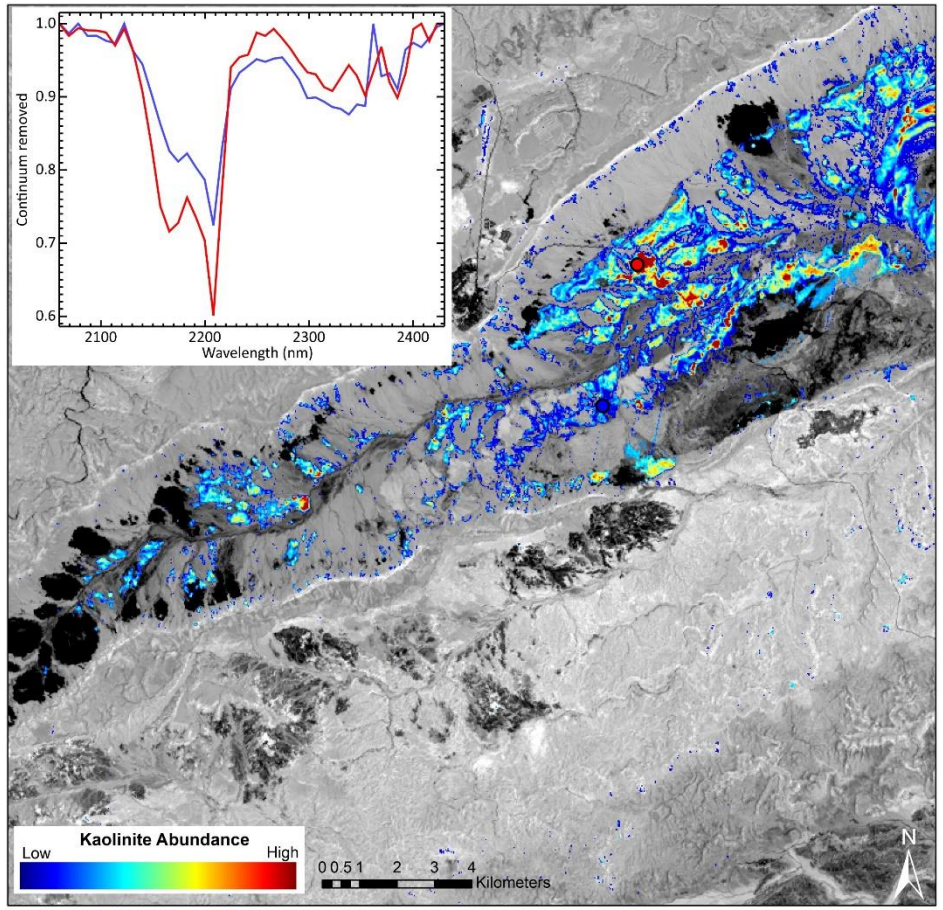
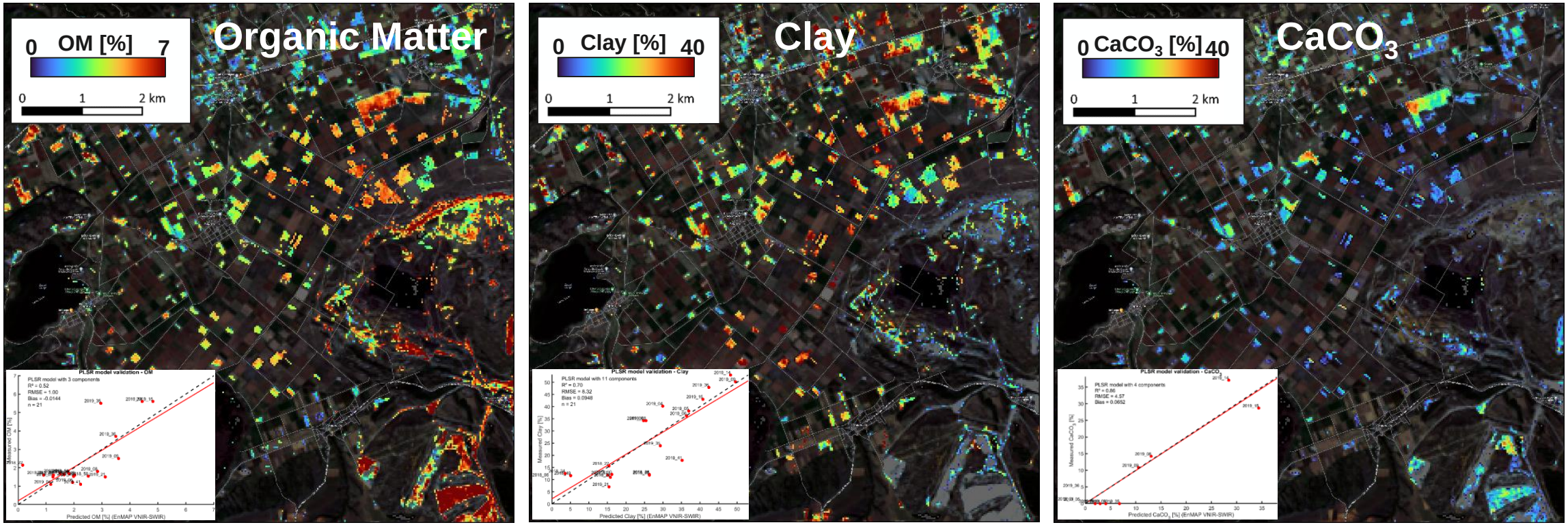


Courtesy: Asadzadeh, S. (GFZ), Chabrillat, S. (GFZ) , Ben-Dor, A. (Tel Aviv University)

Topsoil compositional mapping

Soil Organic Carbon maps, soil texture, soil moisture, soil carbonates, iron oxides content

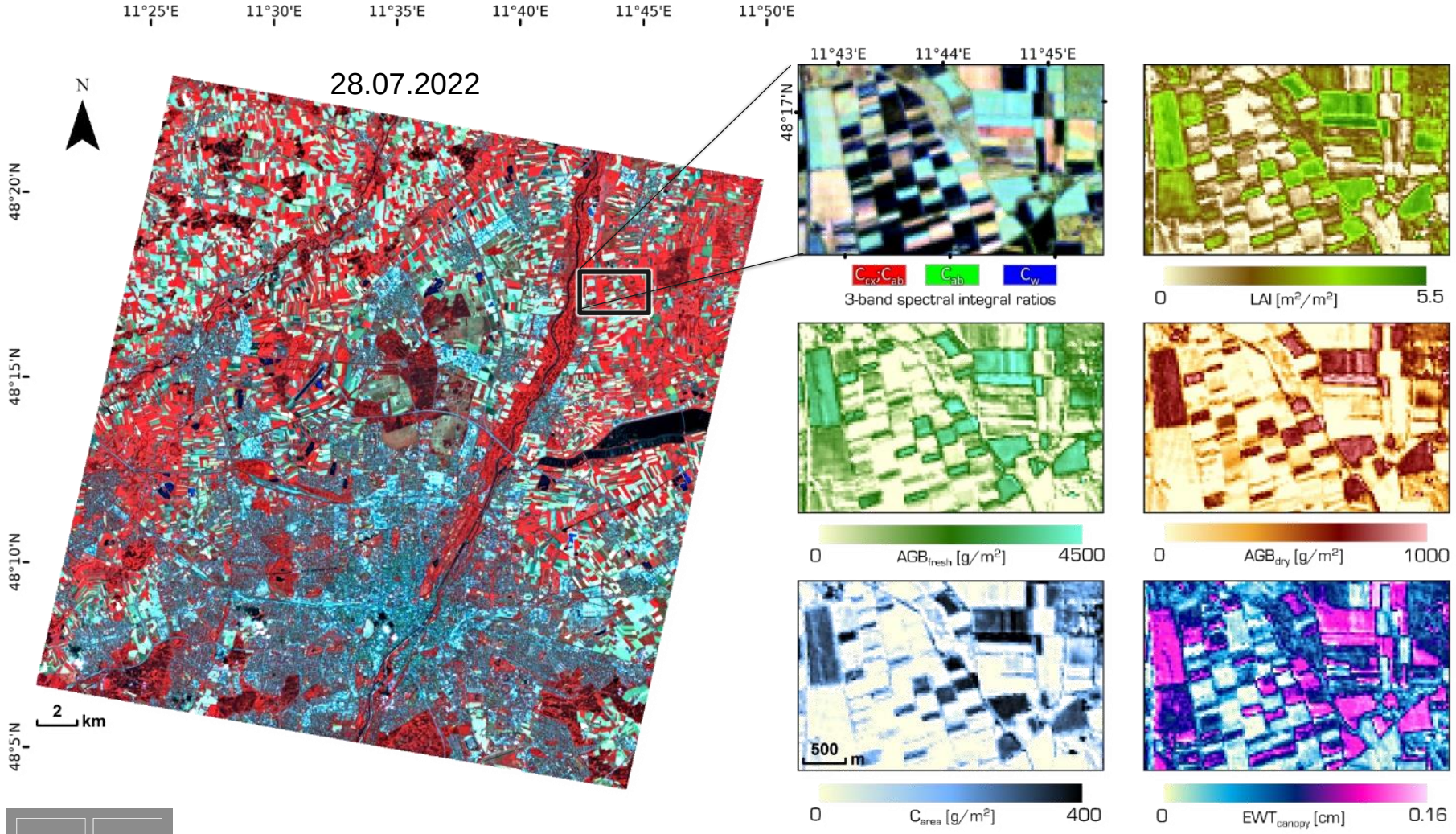


Enmap data@DLR [2022/2023]

Reference: R. Milewski et al., 2023

Precision Farming and Agricultural Monitoring

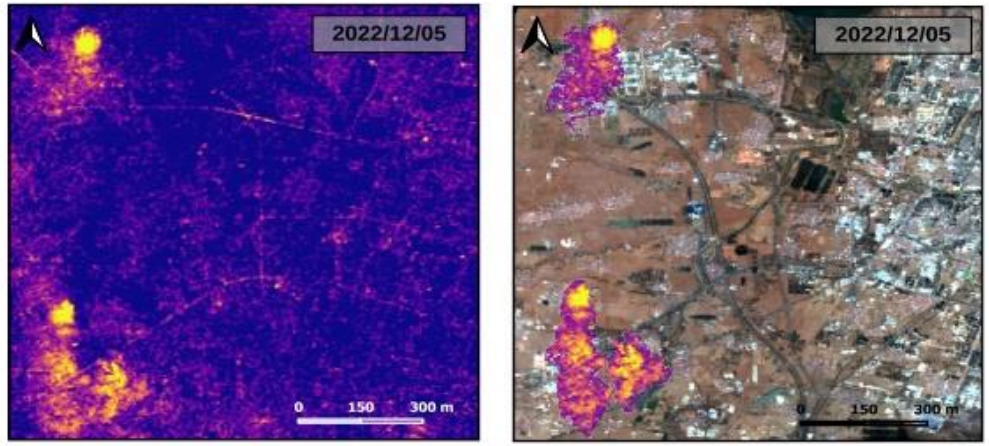
Mapping condition and crop health (Northern Munich (Germany)



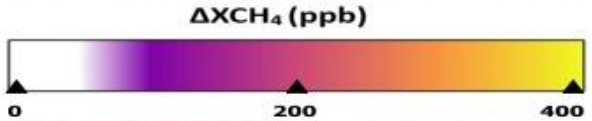
Enmap data@DLR [2022/2023]

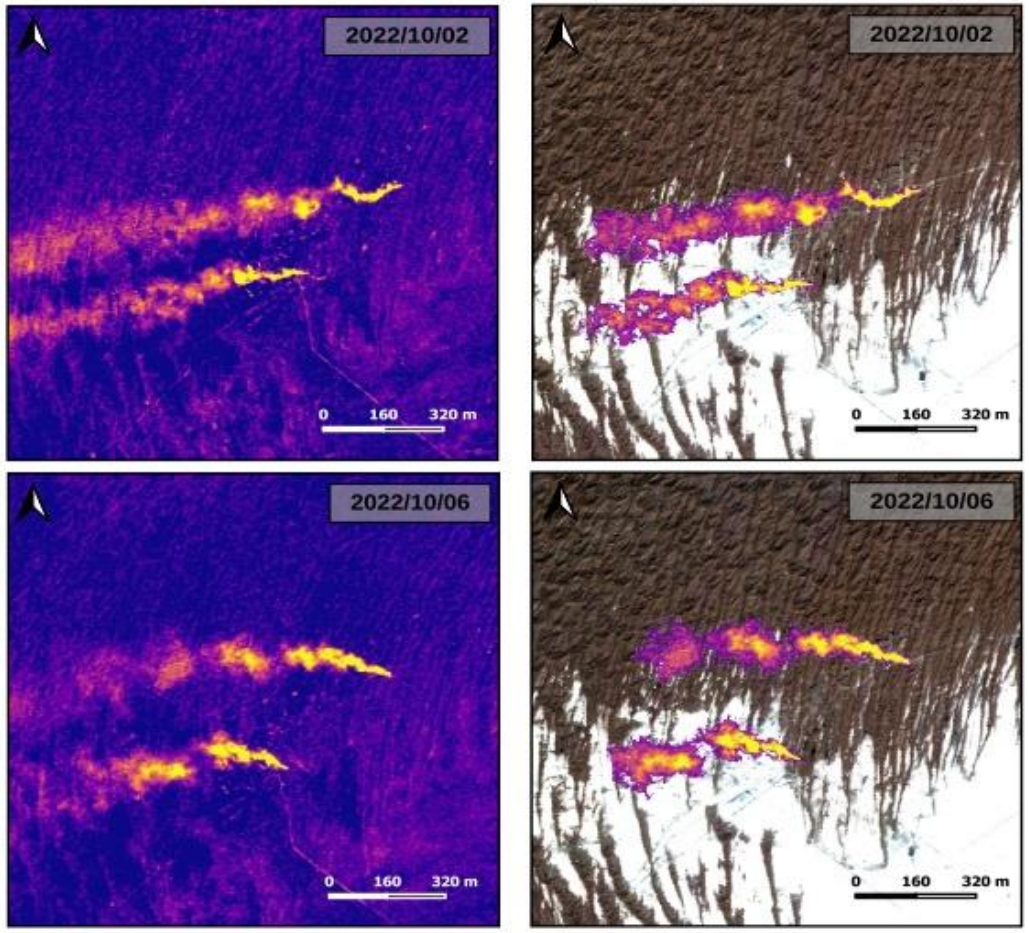
Reference:
Wocher, M. et al. (2022) Retrieval of carbon content and biomass from hyperspectral imagery over cultivated areas, ISPRS Journal or photogrammetry and Remote Sensing, 193, 104-114.

Methane detection (Reference: J. Roger et al., preprint at https://doi.org/10.31223/X5M65Z)

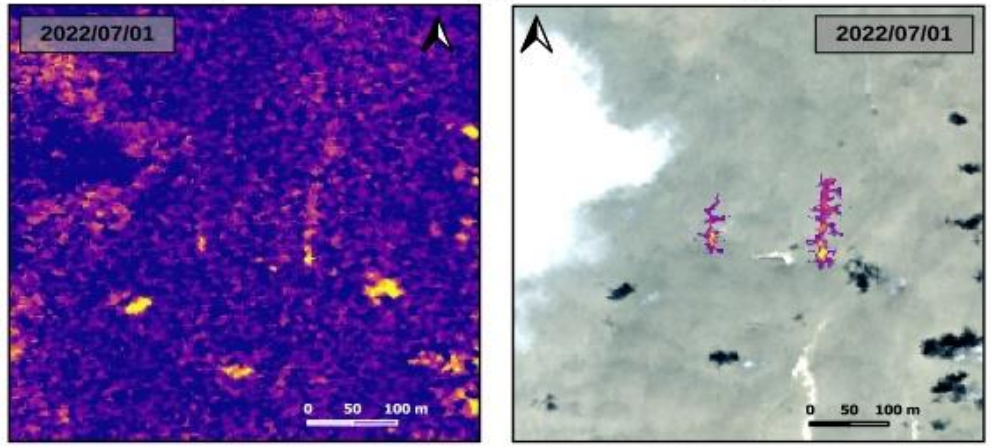


EnMAP Methane retrieval from coal mining area at Shanxi, China

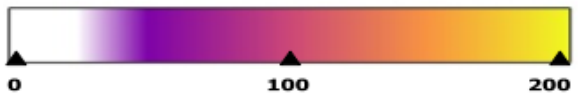




EnMAP Methane retrieval, oil & gas field at Turkmenistan

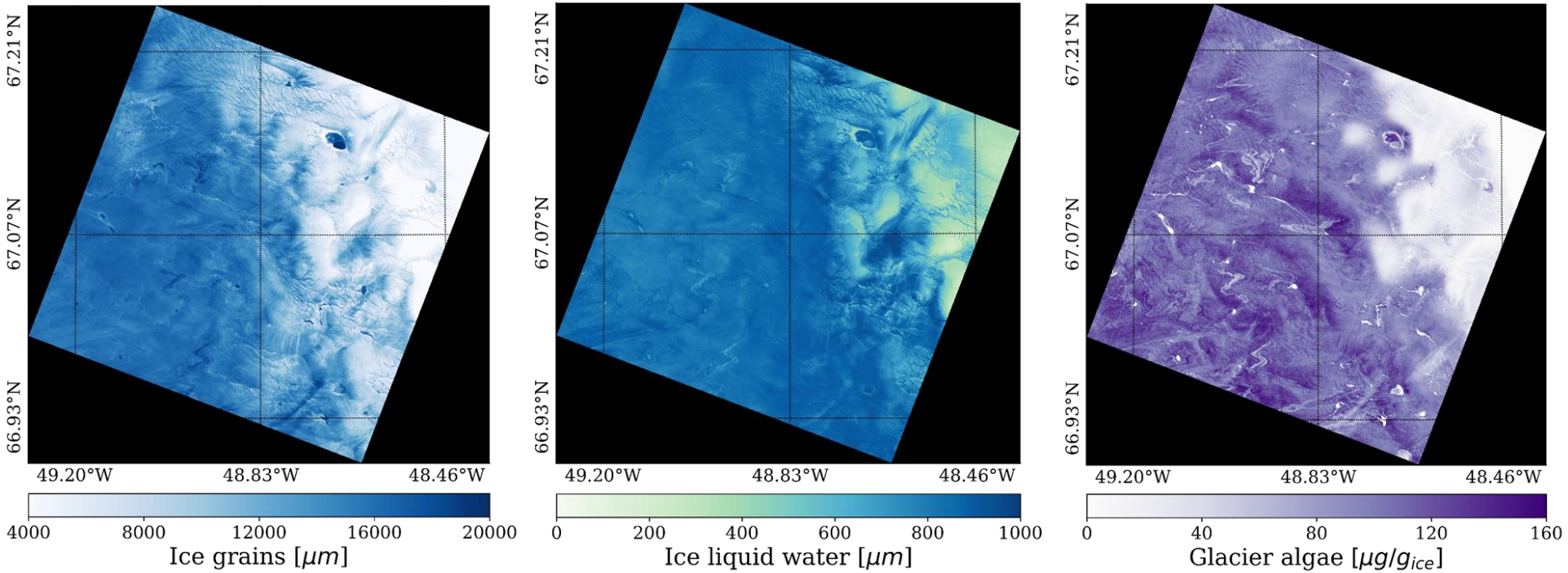


EnMAP Methane retrieval from offshore oil & gas field in the U.S. Gulf of Mexico



Snow & ice properties mapping

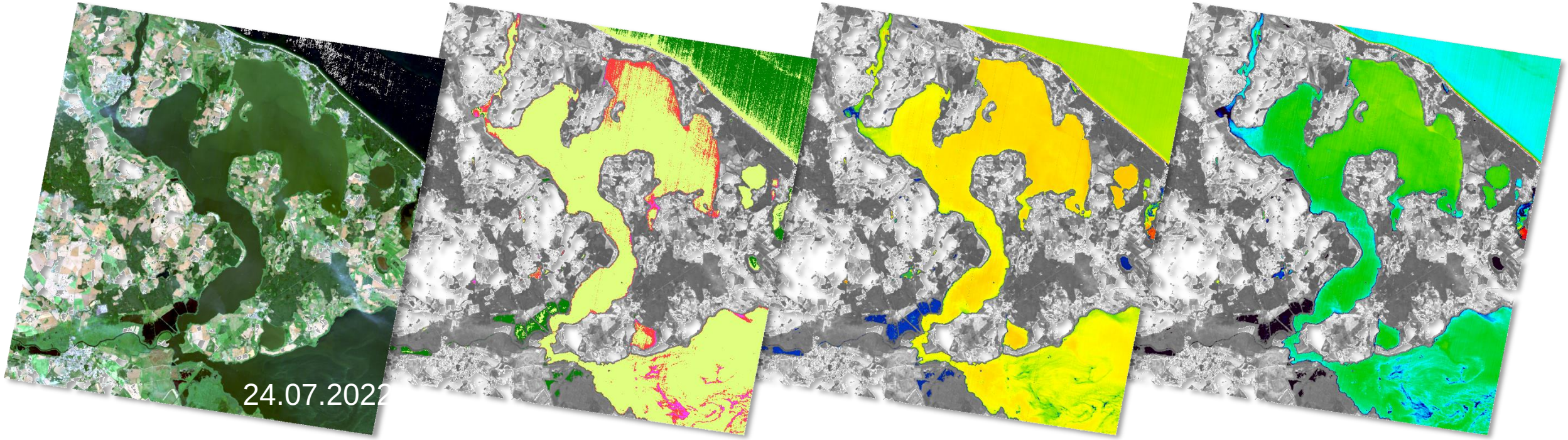
Novel combination of retrieval maps and uncertainties for grain size, liquid water, and algae concentration



Reference: Bohn, N., et al. (2022). Glacier ice surface properties in South-West Greenland Ice Sheet: First estimates from PRISMA imaging spectroscopy data. *J.G.R.: Biogeosc.*, 127

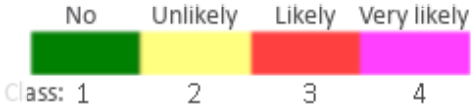
Water Quality Application

Water Quality parameter at Stettiner Haff (Oder), Germany



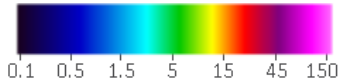
RGB (46/28/10)

Blue-green algae probability



Chlorophyll in µg/l

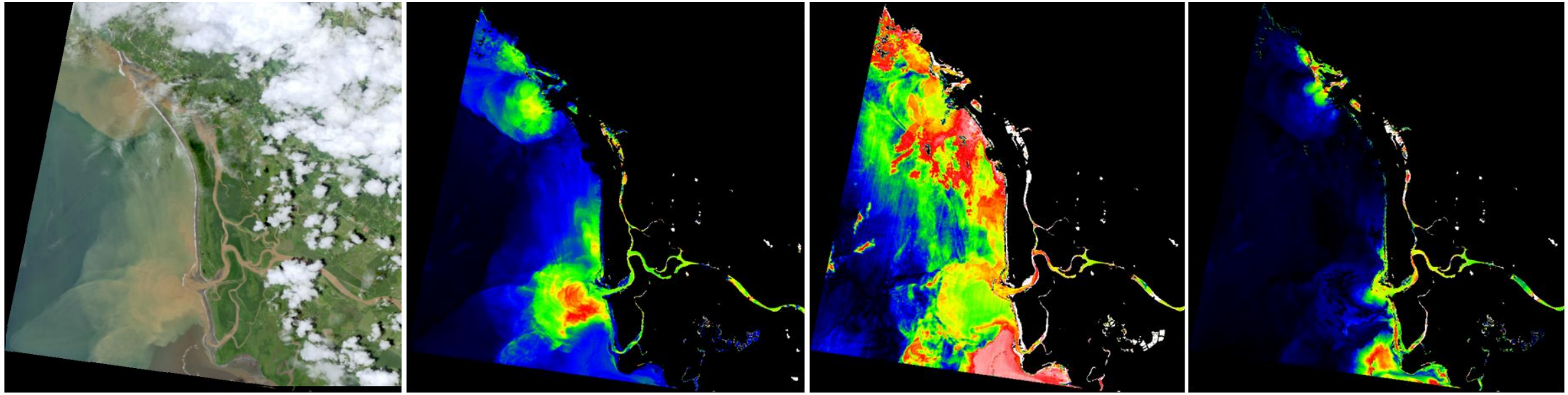
Turbidity in NTU



Coastal and Inland Waters

Water quality monitoring in Térraba Sièrpe Wetland (Costa Rica)

Enmap data@DLR [2022/2023]



RGB bands 5, 28, 46
440 nm, 556 nm, 664 nm

0 80
TSM [mg/l]

0 10
Chl concentration [µg/l]

0 5
CDOM absorption [m-1]

Coastal and Inland Waters

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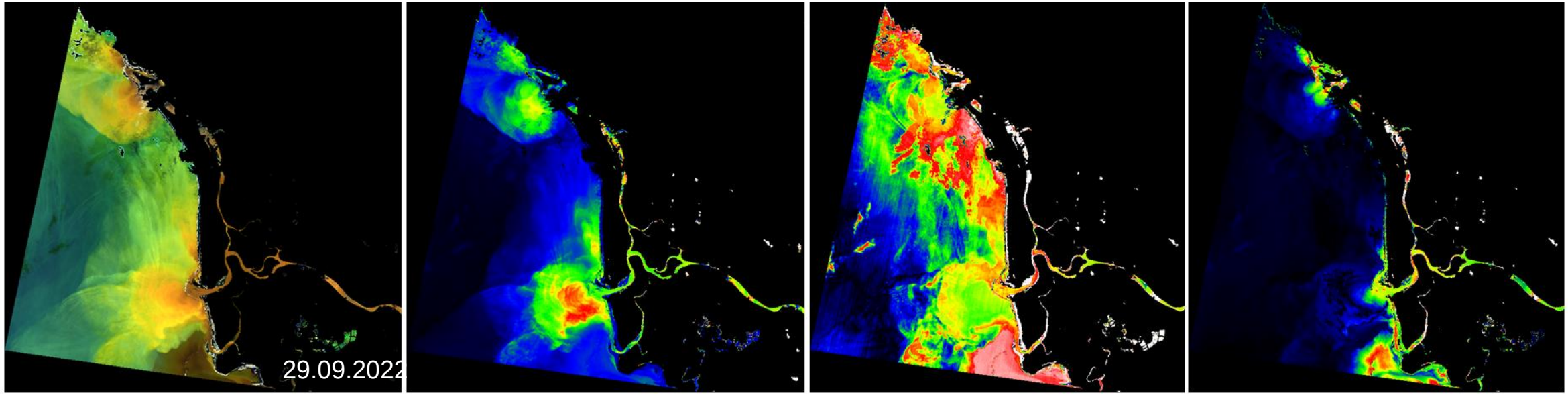

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Home | Mission | Science & Applications | Data & Tools | Events & Education

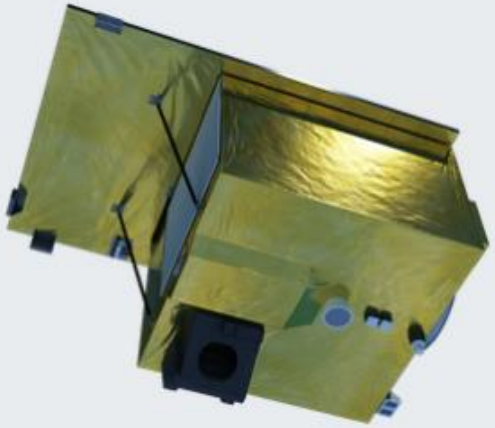
- Science Plan
- Brochure (english)
- Brochure (german)
- Flyer
- Video (german)

IMAGE GALLERY

Welcome to EnMAP

The German Spaceborne Imaging Spectrometer Mission

The Environmental Mapping and Analysis Program (EnMAP) is a German hyperspectral satellite mission that aims at monitoring and characterising Earth's environment on a global scale. EnMAP measures and models key dynamic processes of Earth's ecosystems by extracting geochemical, biochemical and biophysical parameters that provide information on the status and evolution of various terrestrial and aquatic ecosystems. For more information about the main objectives and the status have a look at the mission page.



Thank you !

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DLR OHB GFZ Helmholtz-Zentrum Potsdam