

Supported by:

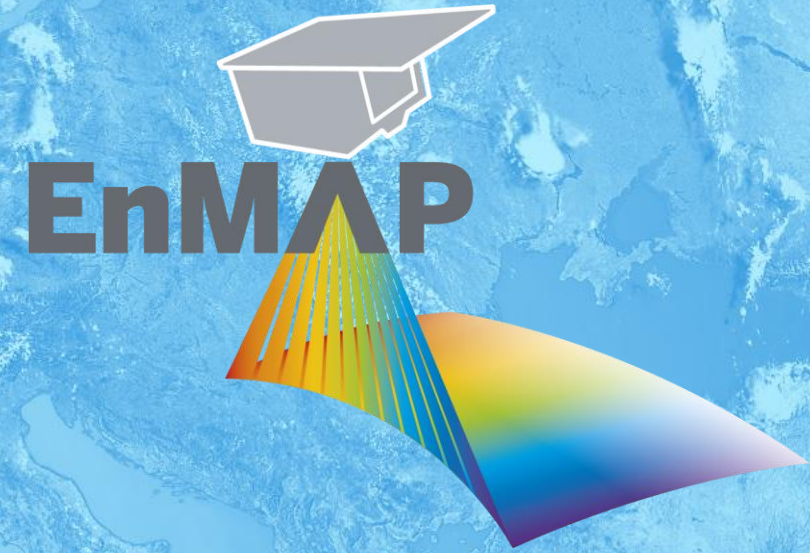


Bundesministerium
für Forschung, Technologie
und Raumfahrt

on the basis of a decision
by the German Bundestag



German
Space Agency
at DLR



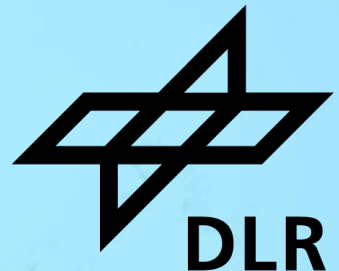
DIE ENMAP MISSION

Vera Krieger, Mission Science Coordinator

Im Namen des EnMAP Consortium

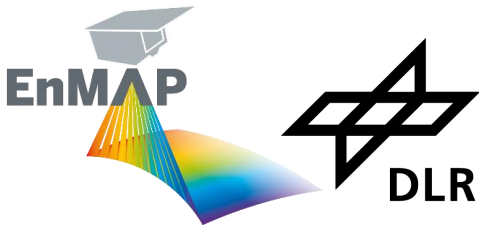
Geoforum 11. November 2025

Laura La Porta (Mission Manager) and Michael Bock (Data License)
D. Reintsema, R. Wernitz, K. Bagschik, M. Bock, S. Fischer
E. Carmona, D. Schulze, N. Pinnel, S. Baumann, M. Pato, S. Hartung,
M. Habermeyer, S. Engelbrecht, K. Wirth, ...
Science PI: S. Chabrillat, K. Segl, A. Okujeni, P. Reiners ...
R. Feckl, M. Betz, M.S. Guilherme ...

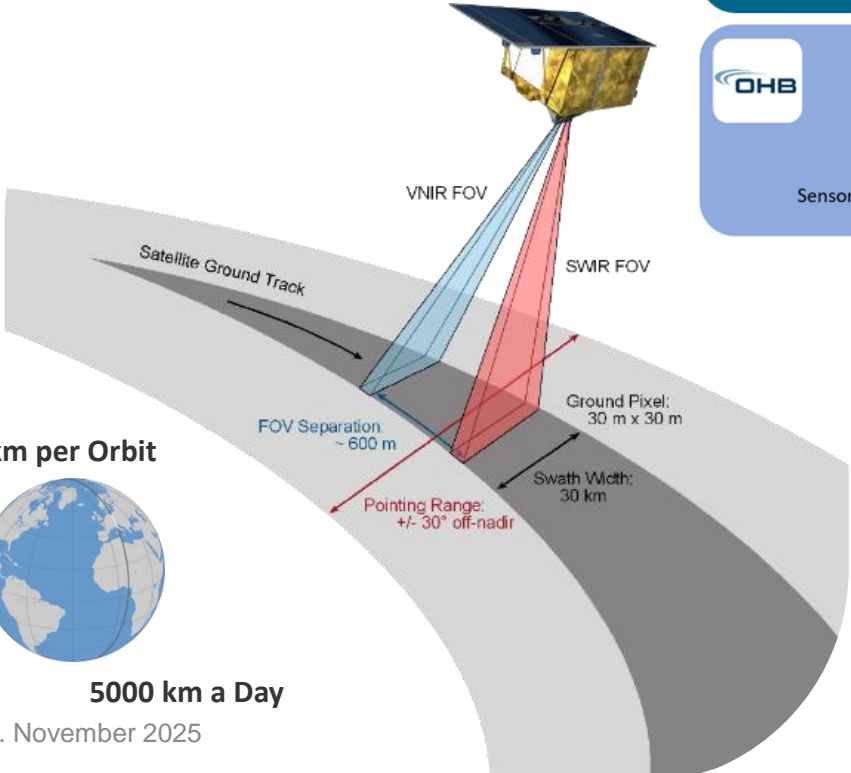


DLR

EnMAP – Mission and Sensor Charakteristik



Orbit characteristics		
Orbit / Inclination	sun-synchronous / 97.96°	
Target revisit time	27 days (VZA ≤ 5°) / 4 days (VZA ≤ 30°)	
Equator crossing time	11:00 h ± 18 min (local time)	
Instrument characteristics	VNIR	SWIR
Spectral range	420 - 1000 nm	900 - 2450 nm
Number of bands	91	134
Spectral sampling interval	6.5 nm	10 nm
Spectral bandwidth (FWHM)	8.1 ± 1.0 nm	12.5 ± 1.5 nm
Signal-to-noise ratio (SNR)	> 400:1 @ 495 nm	> 170:1 @ 2200 nm
Spectral calibration accuracy	0.5 nm	1 nm
Ground sampling distance	30 m (at nadir; sea level)	
Swath width	30 km (field-of-view = 2.63° across track)	
Acquisition length	1000 km/orbit - 5000 km/day	



1000 km per Orbit




5000 km a Day

 **Deutsche
Raumfahrtagentur**

Project Management

 **GFZ** Helmholtz-Zentrum
für Geoforschung

Science PI

 **OHB**

Space Segment

Sensor | Platform

 **DLR**

Ground Segment

Operations
DLR-GSOC | Payload
DLR-DFD | Processing
DLR-IMF

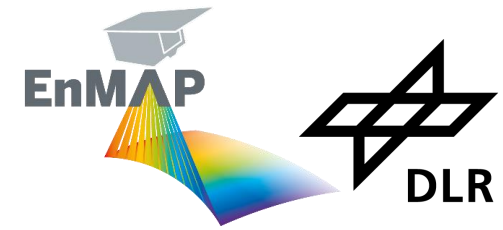
Supported by:



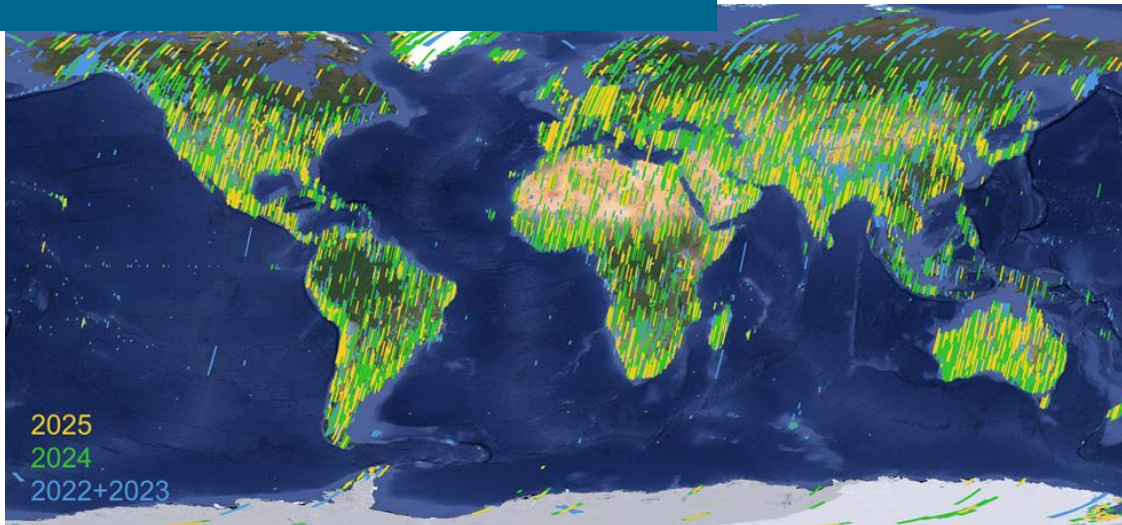
on the basis of a decision
by the German Bundestag

www.enmap.org

EnMAP – 3 Jahre operationell

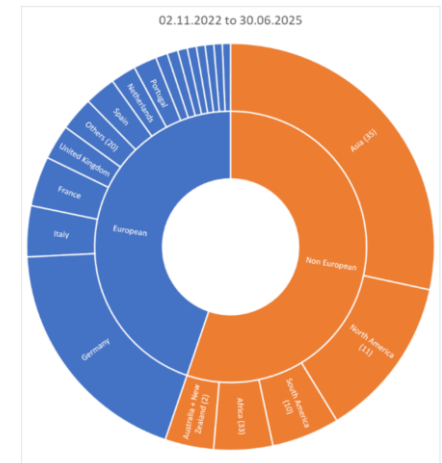


Wachsendes Archiv mit weltweiten Daten



Wachsende internationale Nutzergemeinschaft

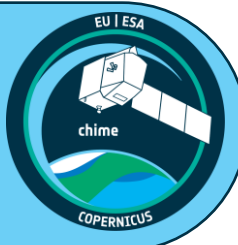
- > **5.100 registrierte Nutzer**, aus 130 unterschiedlichen Ländern, darunter 36 europäische Länder
- > **150.00 Produkte** im Archiv
- > **800 wissenschaftliche Proposals** sind eingegangen zur Datenaufnahme



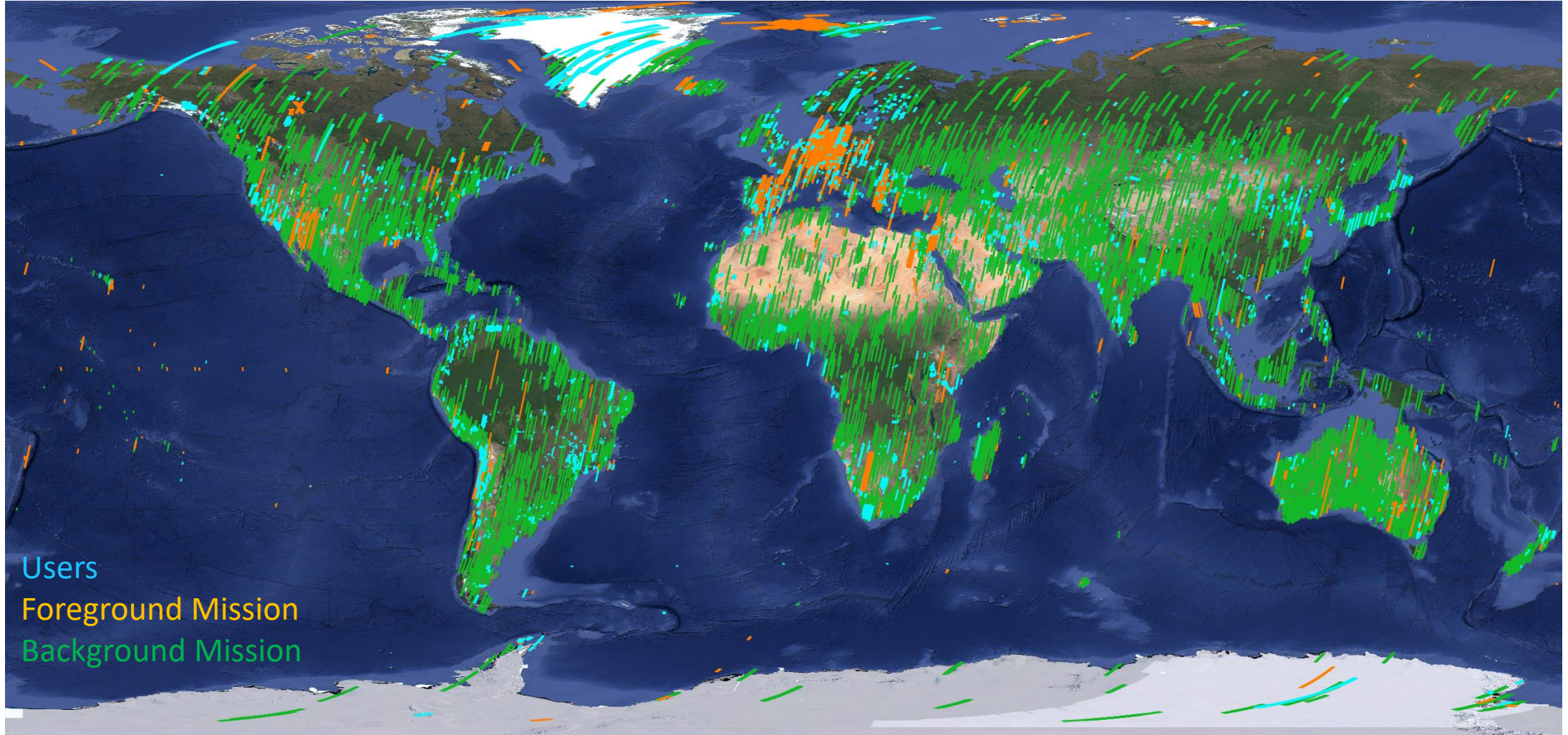
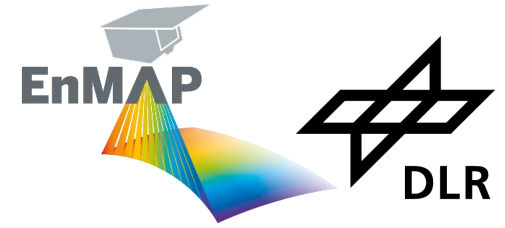
EnMAP hat sich von einer wissenschaftlichen Mission zu einer ausgereiften operativen Plattform entwickelt.

- **Anspruchsvolle Tasking mission**
- **Intensive Unterstützung der Nutzer, Internationaler Kampagnen-support**
- **Exzellente Datenqualität demonstriert durch starkes Wissenschaftsprogramm**

**Pathfinder for
ESA's CHIME
Mission**



User Tasking, Foreground und Background Mission

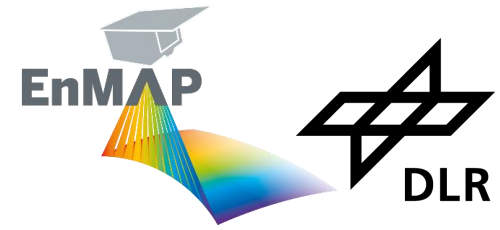


Courtesy of E. Carmona

Foreground Mission

Currently in ,winter mode‘

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



- Gestartet 03/2024
 - ~1000 km lange Streifen
 - Definiert durch Nutzerbedarfe (Workshops, Umfragen)
 - Aktualisierung während Laufzeit
 - Höchste Priorität
- ! Flexibel (**Kampagnen**, Wetter)

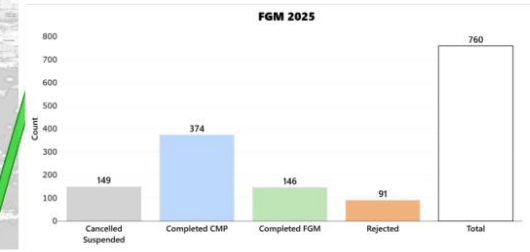
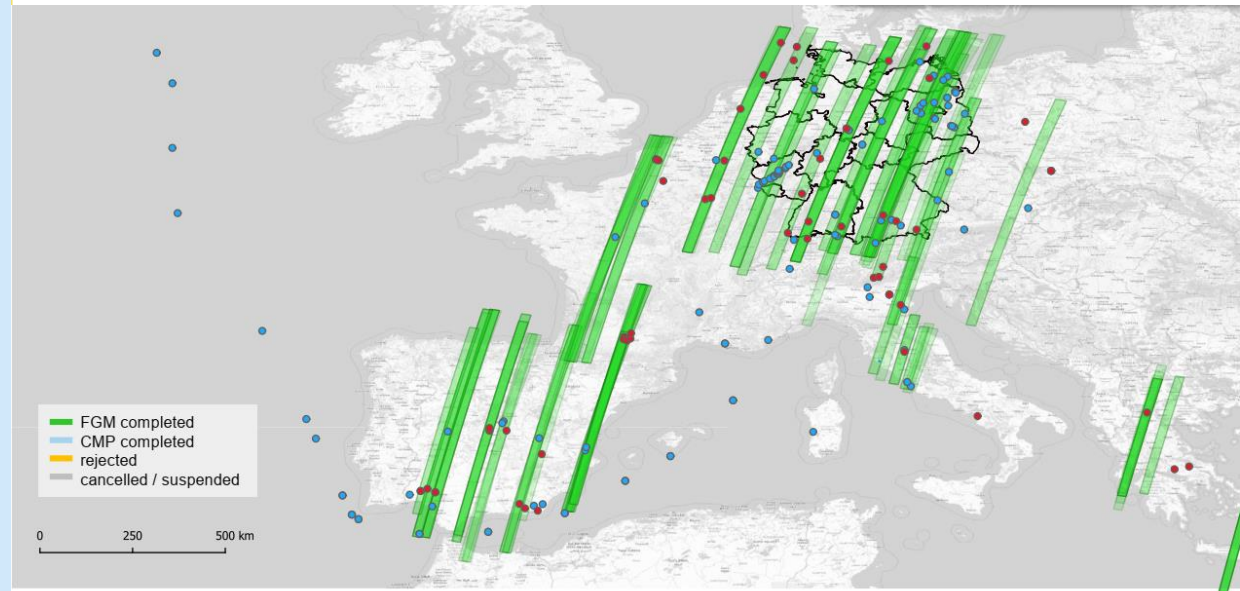
Ziel

- Optimierung der Aufnahme rate
- Zeitreihen über Europa

Unterstützte Kampagnen

- Methane Experiment (USGS)
- Greenland (GFZ)
- Artic (AWI)
- Soil Sites/Demmin (GFZ)
- Oil detection (Mexico) (NASA)
- Aquatic/Agriculture (Uni Valencia)
- Sardegna, Lago di Garda (CNR)
- Jolanda di Savoia (ITC, CNR)
- Namibia (HU Berlin, GFZ)
- Deception Island, Antarctica (GFZ)
- PUCH-Agri-Rose-L/CARMA campaign
- ESA Advanced Ocean Training Course 2025

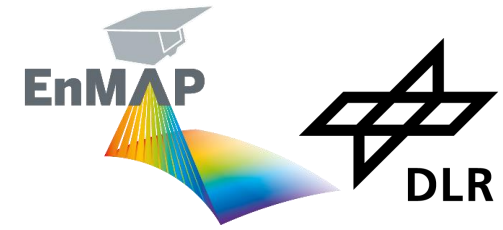
Koordination GFZ mit Ground Segment Application Support




Courtesy Nicole Pinnel

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

Kooperation mit dem USGS



EnMAP as a pathfinder for Landsat Next Science product development



EnMAP as a pathfinder for Landsat Next science product development in the Landsat Collection 3 era

April 2, 2025

Christopher J. Crawford¹, Saeed Arab², Pat Scaramuzza², Ben-Roberts Pierle³, Raymond Kokaly⁴, Nathan Roberts², Benjamin Page³, Shannon Franks², Calli Jenkerson², Danika Wellington¹

¹ U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD 57198, USA
² KBR, contractor to the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD 57198, USA
³ ESTS, contractor to the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD 57198, USA
⁴ U.S. Geological Survey (USGS) Geology, Geophysics, Geochemistry Science Center Spectroscopy Lab, Lakewood, CO 80225, USA

Work performed under USGS Contract [140G0121D0001]

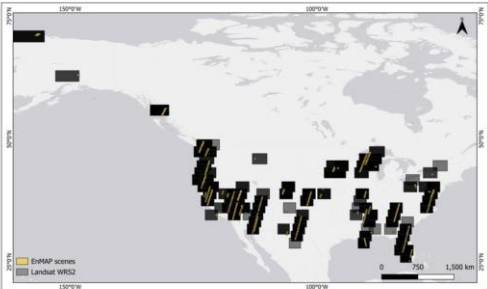
Corresponding Author: cjcrawford@usgs.gov

U.S. Department of the Interior
U.S. Geological Survey

2nd EnMAP User Workshop 2025: Munich, Germany, April 2-4, 2025

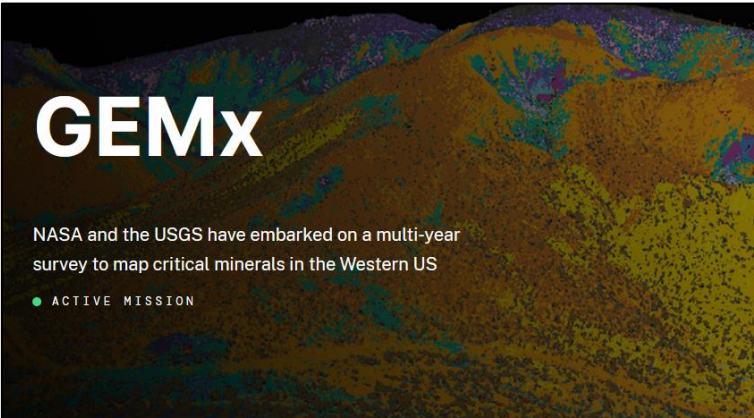
Coincident imaging Acquisition Tool (CAT)

- Coincident acquisition tool (CAT 2.0) finds past spatial/temporal coincidence for (same day within 24 hours):
 - Landsat 8/9
 - EnMAP
 - Sentinel-2
 - EMIT
- Future projections available for Landsat 8/9 and target instruments
 - Based on past acquisition times at ROI
- Built on top of STAC APIs
- Supports tasking requests for EnMAP and PRISMA



578 coincident (± 1 hour) acquisitions between Landsat 8/9 and EnMAP for January 2023 – August 2024

2nd EnMAP User Workshop 2025: Munich, Germany, April 2-4, 2025



GEMx

NASA and the USGS have embarked on a multi-year survey to map critical minerals in the Western US

● ACTIVE MISSION

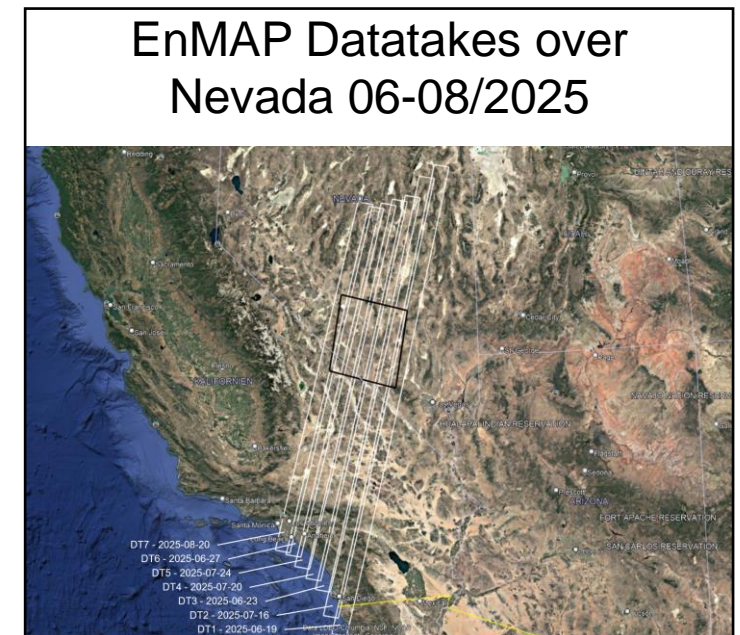
The Geological Earth Mapping Experiment (GEMx) is a joint effort between NASA and the U.S. Geological Survey (USGS) to advance our knowledge of critical mineral resources in the Western United States.

MISSION FOCUS AREA
Western United States

MISSION DATES
2023-2027

MISSION TYPE
Airborne hyperspectral and multispectral sensors covering visible to longwave infrared

OBJECTIVE
Map surface minerals using airborne remote sensing



Slides: Christopher J. Crawford, USGS – April 25

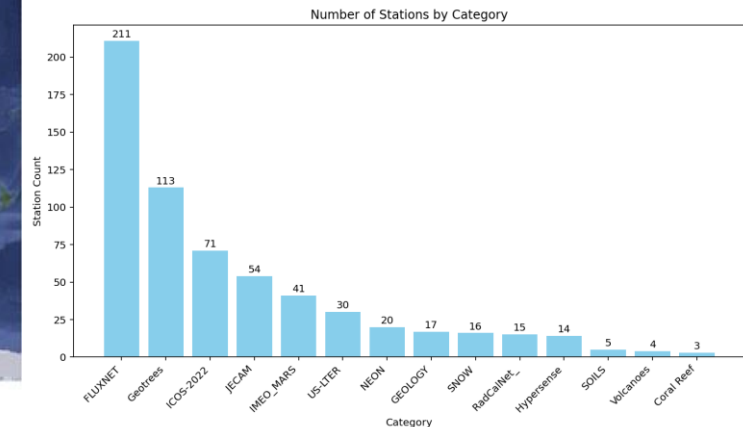
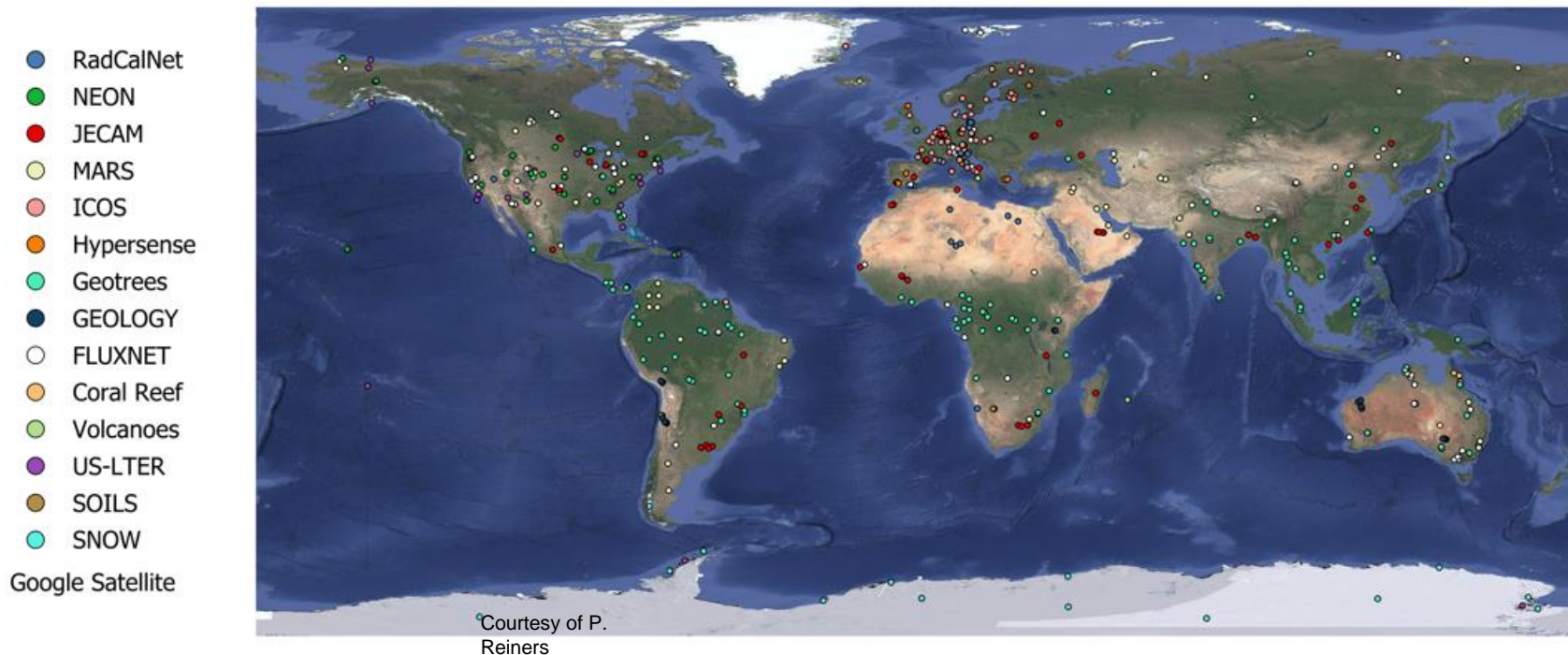
<https://impact.earthdata.nasa.gov/case/campaign/GEMx/>

Mehr als 600 Internationale Cal/Val sites in der Background Mission

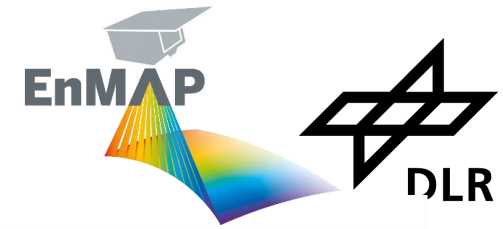
Ziel

- Fokus Zeitreihen
- Räumliche Abdeckung

Globale Liste der Ziele (Networking sites) (> 600 sites)

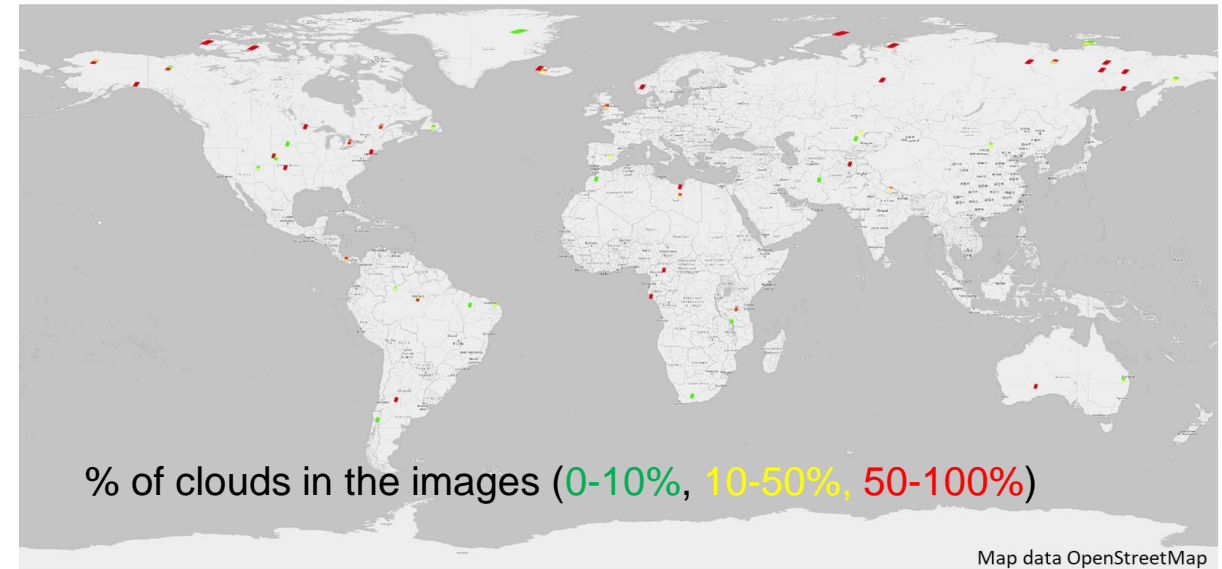


EnMAP & PRISMA match-ups



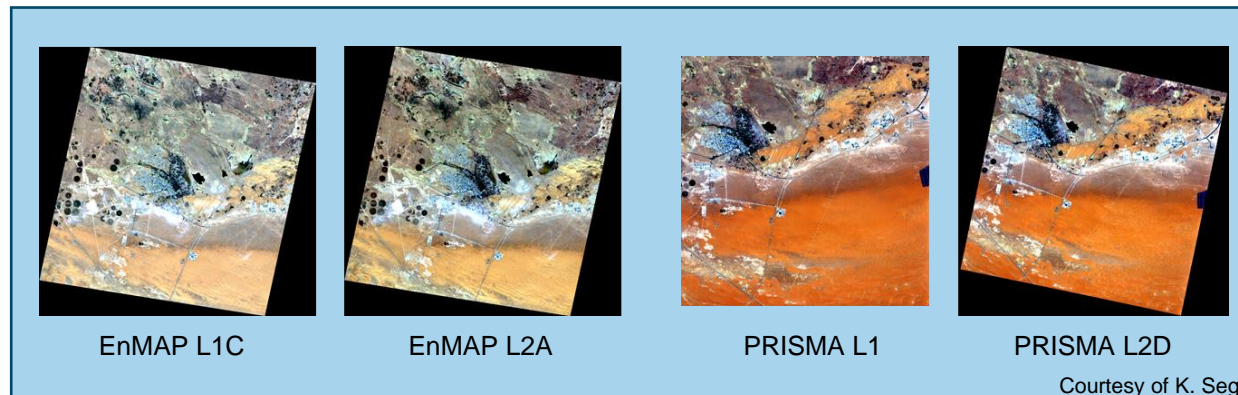
Ziel: Entwicklung von L1/L2-Transfer functions für Multi-Sensor-Zeitreihenanalysen und/oder Cross-Calibration exercises

- **> 165** gemeinsame Erfassungen weltweit verteilt (einschließlich Wissenschafts- oder Netzwerkstandorte im Rahmen von Cal/Val oder thematischen Kampagnen)
- Regelmäßige Treffen zur Identifizierung/Auswahl von Match-ups
- Zeitplan wird 1x monatlich erstellt



Courtesy of E. Carmona

Map data OpenStreetMap

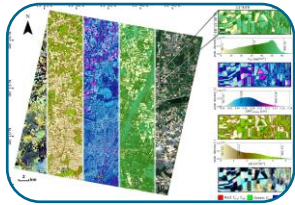


Courtesy of K. Segl

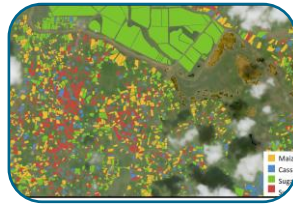
Erste Ergebnisse
zeigen gute
Übereinstimmungen

EnMAP – Anwendungsbeispiele

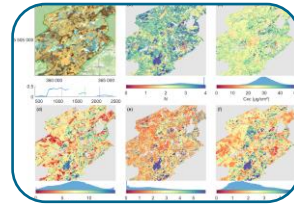
Von wissenschaftlicher Grundlagenforschung ...



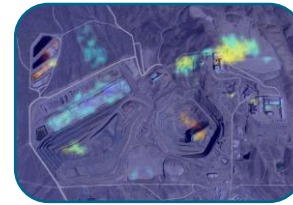
Landwirtschaftliche Praxis erleichtern und Erntevorhersagen



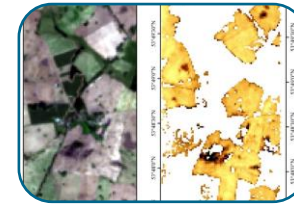
Feldfrucht-Erkennung in Kenia



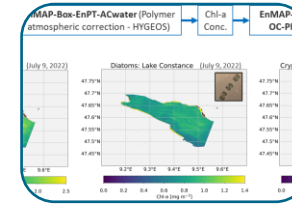
Waldmonitoring



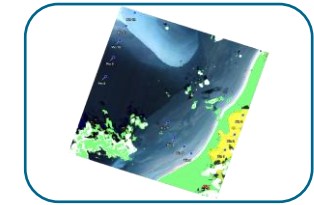
Detektion und Klassifizierung von Rohmaterialien



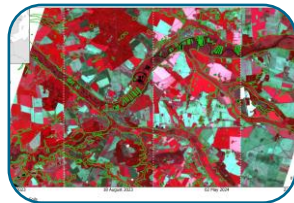
Bodengüte – Bodendegradation, Numerical Soil Organic Carbon Estimation



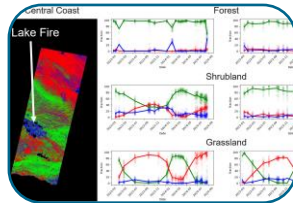
Gewässergüte



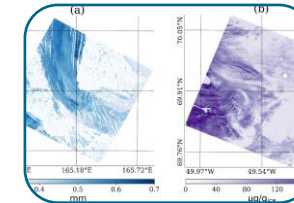
Klassifizierung von Algentypen



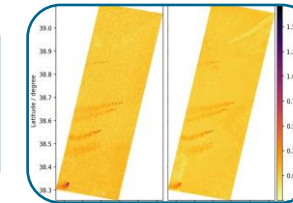
Moorökosysteme: Überwachen der Wiedervernässung



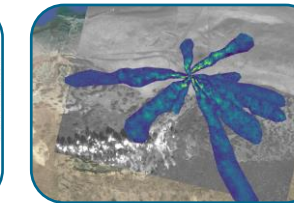
Feuerökosysteme: Brandrisikoeinschätzung, Brandfolgen, Regenerationsprozesse



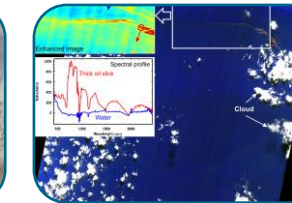
Schnee und Eiskarakterisierung, Gletschermonitoring



Überwachung von Treibhausgasemissionen



Methanleaks: Erkennung und Quantifizierung

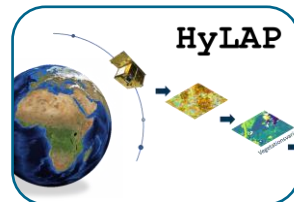


Erkennung eines Ölteppichs nach Schiffsunglück



Identifikation von illegalen Müllkippen

... bis hin zu Anwendungen als kommerzielle Services



Landwirtschaft – Managementempfehlungen



Blue Carbon Market – Mangroven



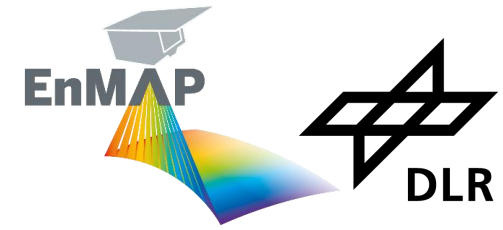
Seegrasmonitoring



Deutsche Firmen können seit Februar 2025 EnMAP Aufnahmen als **kommerzielle Nutzer** Aufnahmen tasken

EnMAP – Bodenqualität

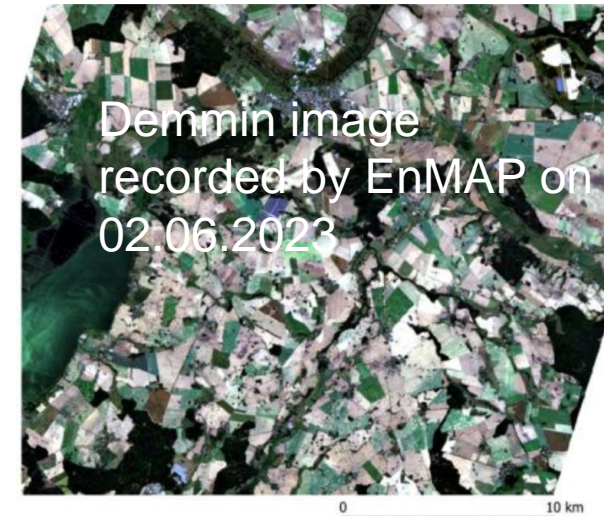
Boden ist der größte terrestrische Kohlenstoffspeicher



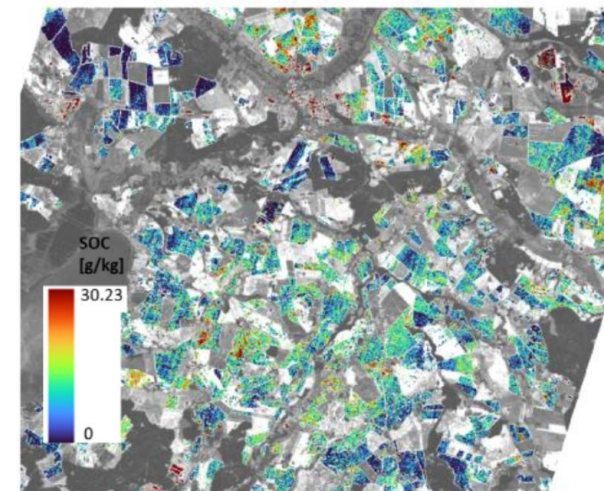
Bodendegradation ist Europa und weltweit ein ernstes Problem

- Auswirkungen auf Ernährungssicherheit und Klimawandel
 - z.B. Reduzierung des Gehalts an organischem Kohlenstoff (SOC) im Boden
 - Bodenkohlenstoff ist eine der wesentlichen Klimavariablen (ECVs) von GEOSS.
 - SOC wichtig für z.B. für Bodenfruchtbarkeit und Wasserspeicherung
- EU-Gesetz zur Bodenüberwachung: EU auf dem Weg zu gesunden Böden bis 2050 → Kohlenstoffwirtschaft
 - SDGs: SOC als relevanteste Bodeneigenschaft im Hinblick auf Klimaregulierungen, Überwachungsstatus sollte verbessert werden

EnMAP ermöglicht die Quantifizierung des Kohlenstoffgehalts im Oberboden → Kalibrierte Daten, hohe spektrale Auflösung und hoher SNR, auch im SWIR sind für die meisten Bodenanalysen entscheidend



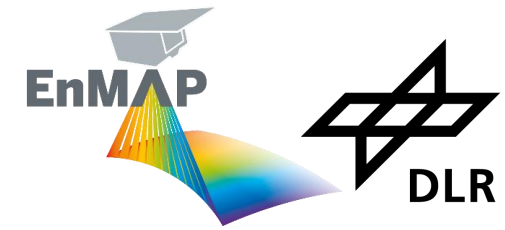
Data: EnMAP L2A
Demmin, Germany,
22.09.2024



Map of the soil
organic carbon
content (g/kg) based
on predominantly
bare soil pixels

Copernicus web page
EnMAP example
Courtesy K. Ward

Mineraliendetektion mit EnMAP



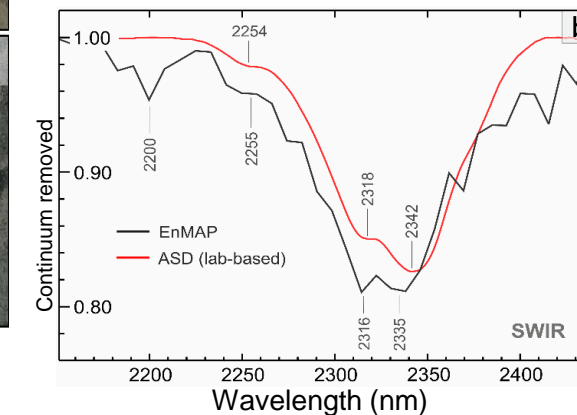
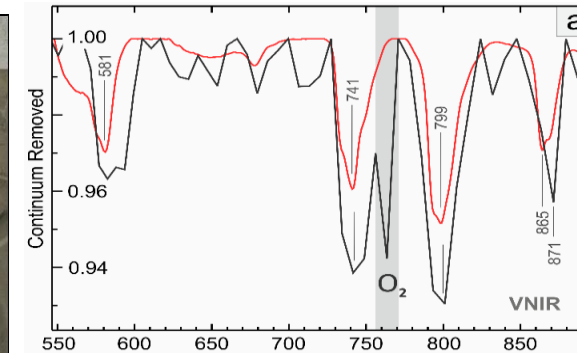
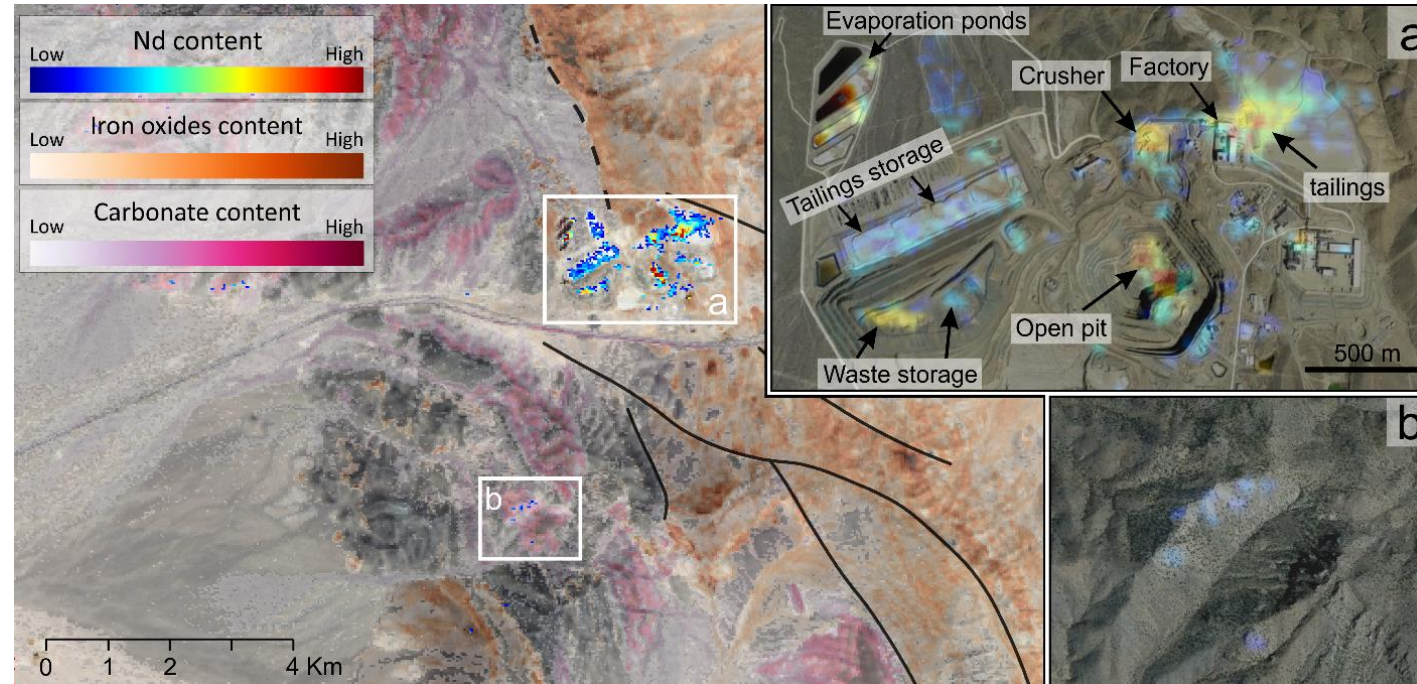
Deposit type	Metal endowment*
Porphyry Copper	Cu ± Mo ± Au ± Re ± Te ± Se
Iron Oxide-Copper-Gold (IOCG)	Cu ± Au ± U ± Co ± REE**
Volcanogenic massive sulfide (VMS)	Zn-Cu ± Pb ± Ag ± Au ± Se ± In
Epithermal gold (low/high S)	Au-Ag ± Sb ± Cu
Pegmatites	Li ± Be ± Sn ± W ± Ta
Carbonatites	P ± REE ± Nb ± Th
Orthomagmatic Ni-Cu-(PGE)	Ni-Cu ± PGE***
Skarns	Fe ± Cu ± W ± Zn ± Sn
Mississippi valley type (MVT)	Zn-Pb ± Cd ± Ge ± In ± Ga
Sedimentary exhalative (SEDEX)	Zn-Pb ± Ag ± Co
Bauxites	Al ± V
Lithium volcano-sedimentary	Li ± B

EnMAP deckt ein breites Spektrum an Mineralisierungssystemen und Minenstandorten ab:

- 250+ Ziele in 40+ Ländern auf 5 Kontinenten
- 10+ Lagerstättentypen.
- Viele wichtige Rohstoffe: Cu, Au, Mo, Al, Pb, Zn, Ni, Mn, Li, und REEs.

EnMAP: REE's - Seltene Erden

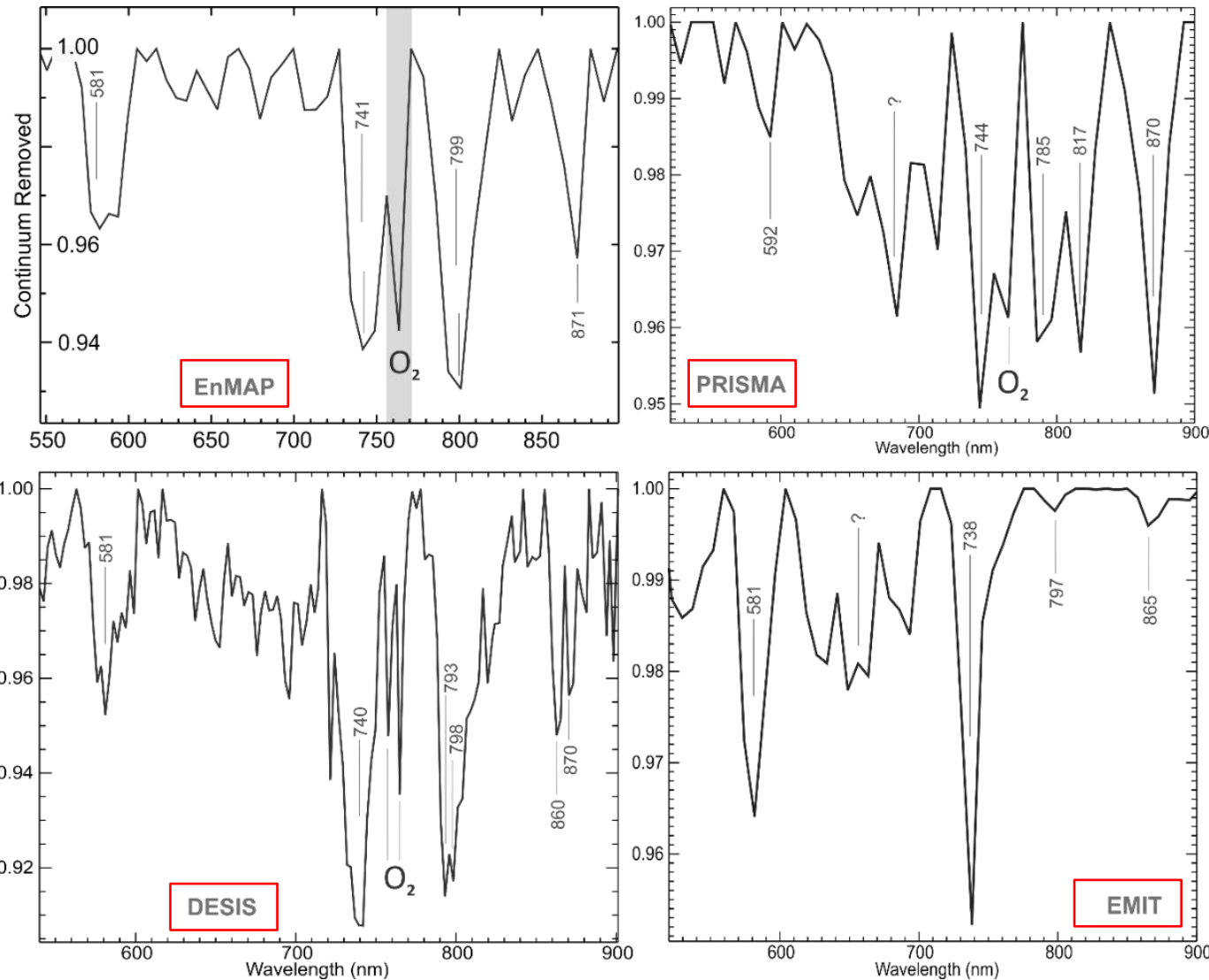
Ausläufer von Nd-haltigem Bastnaesit bei Mountain Pass wurden erfolgreich mit EnMAP entdeckt.



Source: Wikipedia

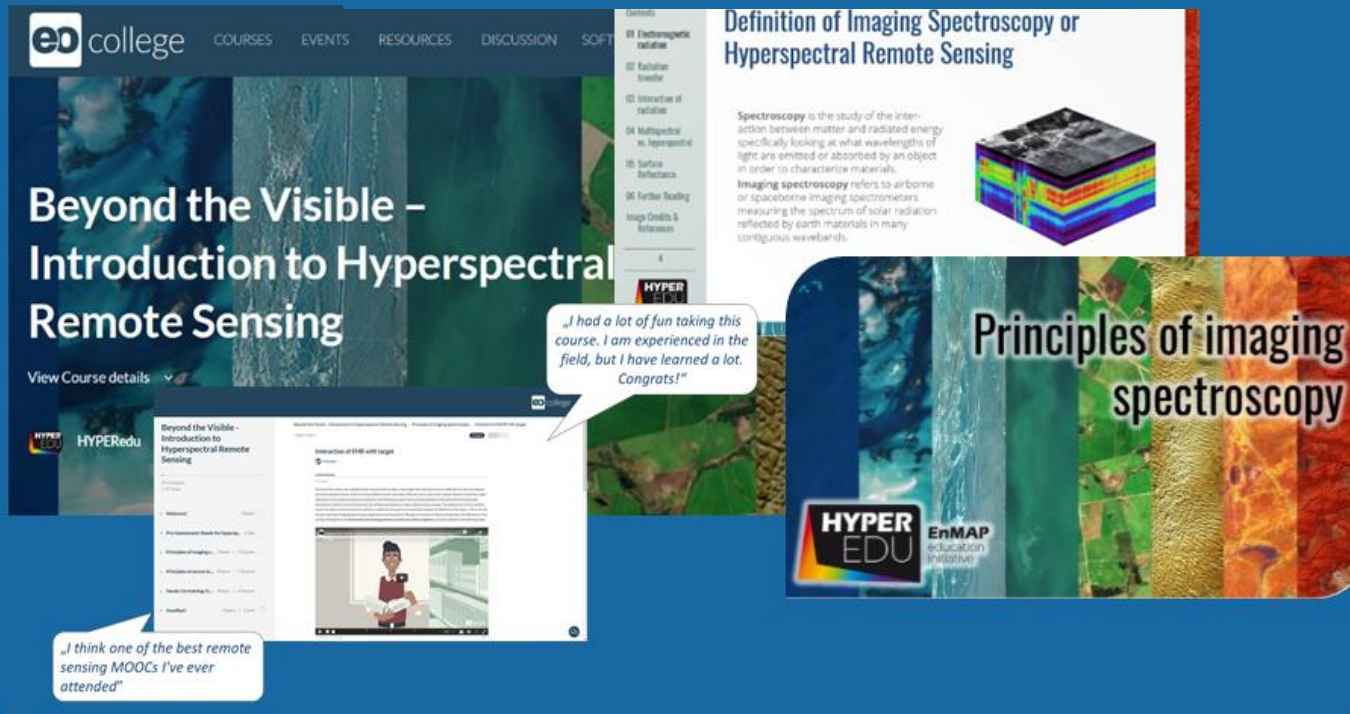
Asadzadeh et al.
Scientific Rep. 2024

Vergleich mit anderen Sensoren



- EnMAP liefert Ergebnisse, die mit denen des hochspektralen DESIS-Sensors vergleichbar sind.
- Die atmosphärische Korrektur von EMIT eliminiert die REE-Merkmale (ISOFIT-Bias).
- PRISMA zeigt die schlechteste Leistung bei der REE-Erkennung.
- Wasserdampf und O₂ bei 720 und 760 nm sind die größten Hindernisse für die REE-Fernerkundung.

Online-Lehrprogramm zu Prinzipien, Methoden und Anwendungen der hyperspektralen Fernerkundung



Definition of Imaging Spectroscopy or Hyperspectral Remote Sensing

Spectroscopy is the study of the interaction between matter and radiated energy specifically looking at what wavelengths of light are emitted or absorbed by an object in order to characterize materials.

Imaging spectroscopy refers to airborne or spaceborne imaging spectrometers measuring the spectrum of solar radiation reflected by earth materials in many contiguous wavebands.

Principles of imaging spectroscopy

HYPER EDU EnMAP education initiative

"I had a lot of fun taking this course. I am experienced in the field, but I have learned a lot. Congrats!"

"I think one of the best remote sensing MOOCs I've ever attended"

HYPERedu
YouTube



[youtube.com/@HYPERedu_GFZ](https://www.youtube.com/@HYPERedu_GFZ)

HYPERedu
MOOC "Beyond
the Visible"

>2000 Participants!

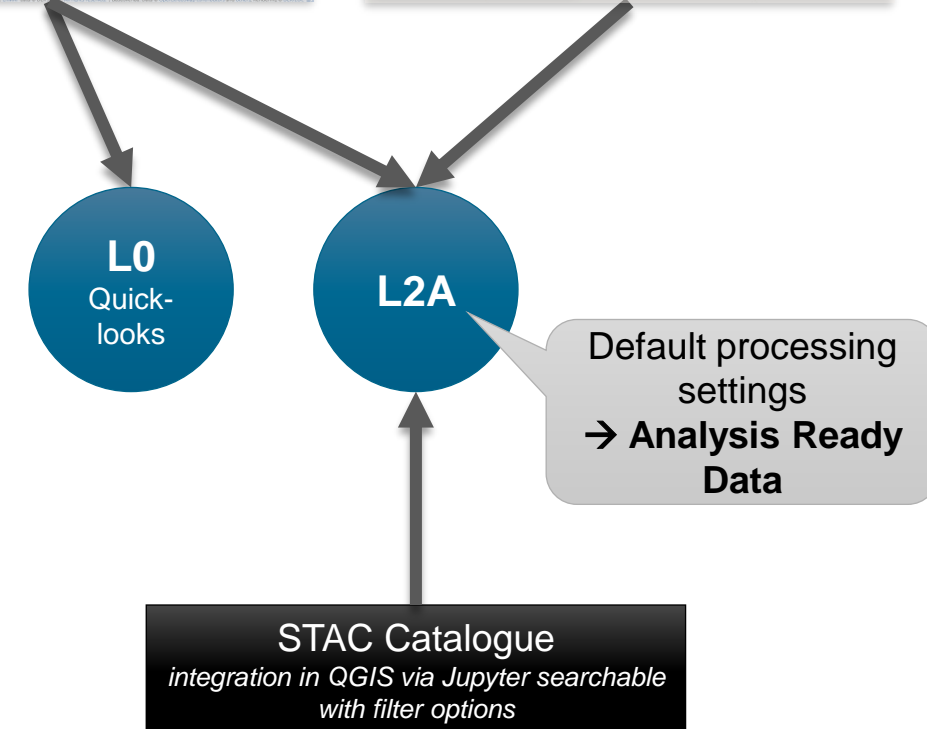
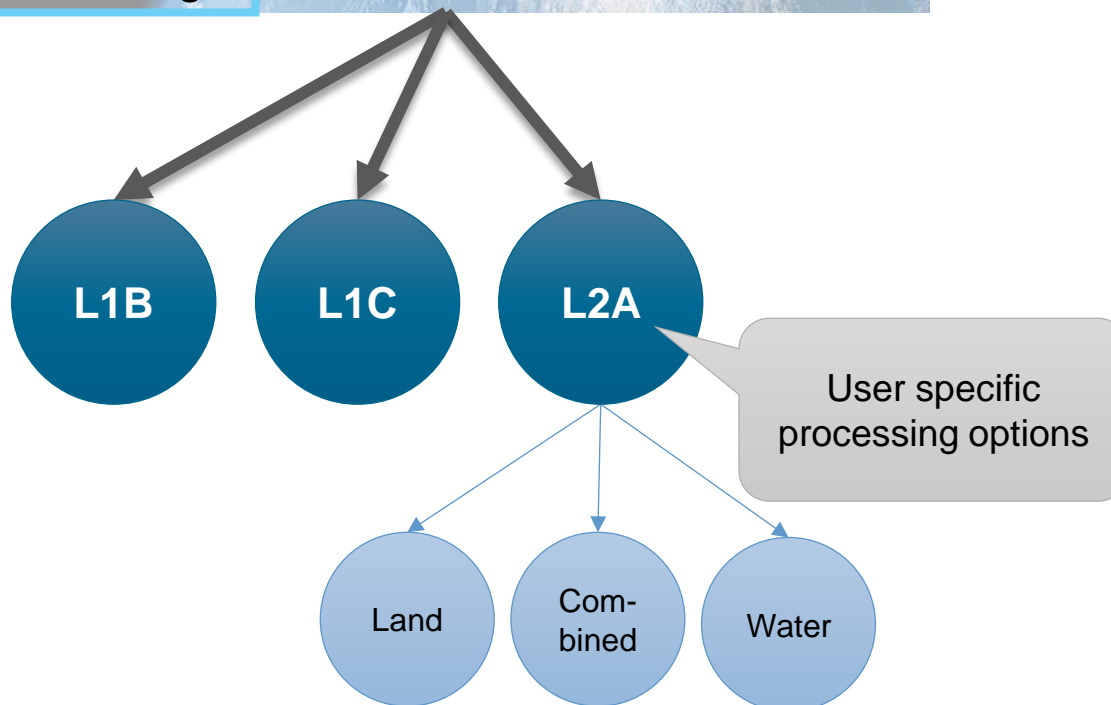
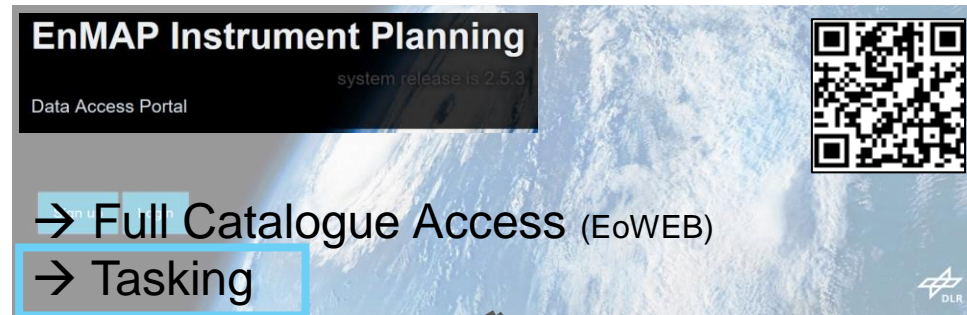
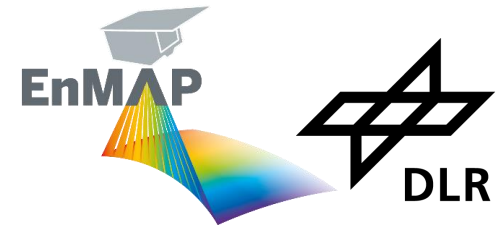


- from different countries and continents
- young (25-45 years)
- 30 % previous MOOC experience
- 60 % no contact with hyperspectral data before

<https://eo-college.org/courses/beyond-the-visible/>

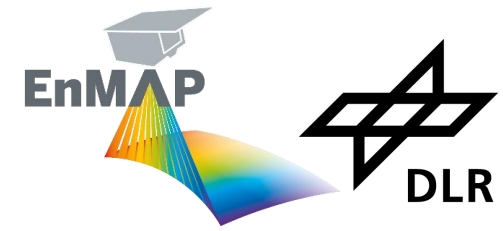
EnMAP Data Access points

Registration obligatory → EU sanction list check



EnMAP Tasking

EnMAP ist als nutzergesteuerte Mission und ist auf Ihren Beitrag angewiesen!



<https://planning.enmap.org/>

Instrument Planning Portal

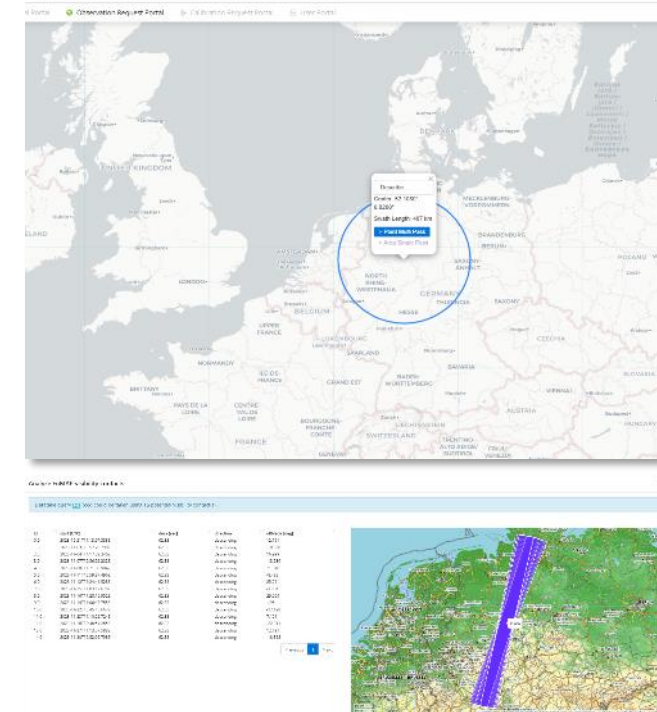


Source: DLR

Tasking future acquisitions

Accessing archived data

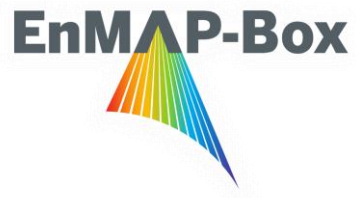
Ins. Planning Portal Observation Request



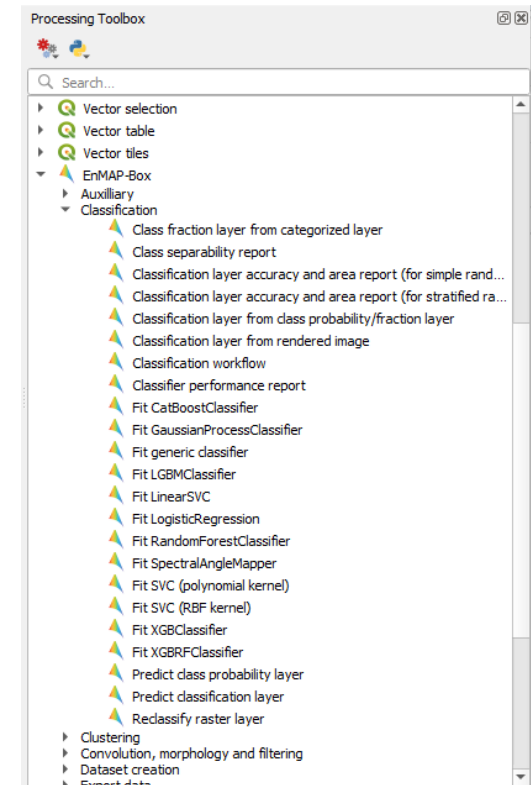
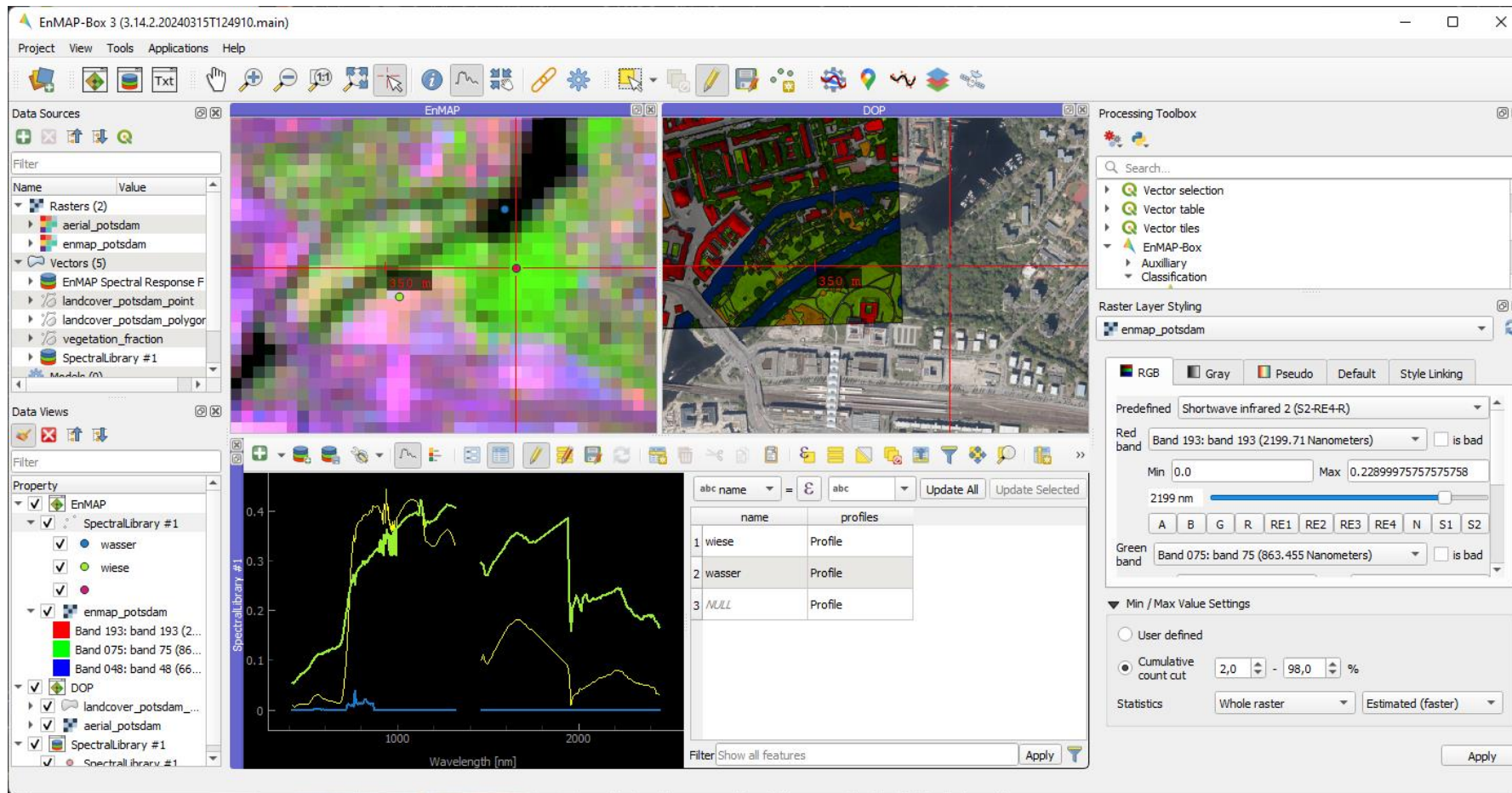
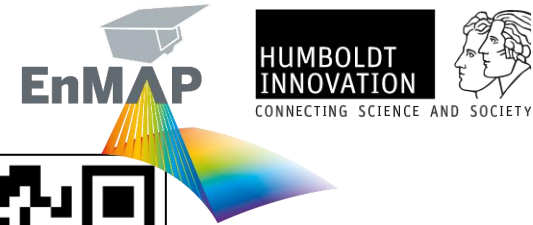
Source: DLR

Einstiegspunkt ist das **Instrument Planning Portal** (Selbstregistrierung):

1. Benutzerregistrierung
2. Einreichung von ‚Proposals‘ (Wissenschaft - Cat1/ Firmen - Cat2)
3. Tasken von zukünftigen EnMAP-Aufnahmen



EnMAP-Box

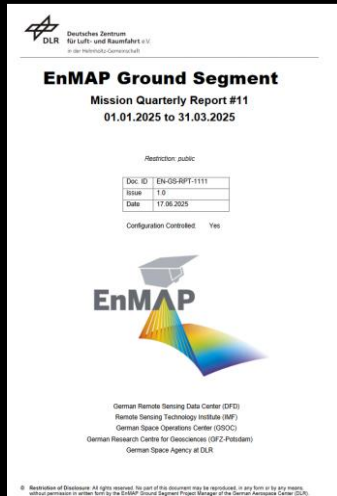


<https://enmap-box.readthedocs.io>

Jakimow, Janz, Thiel, Okujeni, Hostert, van der Linden, 2023. EnMAP-Box: Imaging spectroscopy in QGIS. SoftwareX 23, 101507.



www.enmap.org

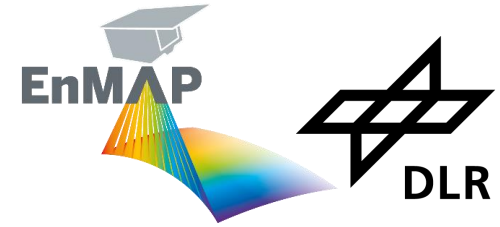


Danke für die Aufmerksamkeit

MOOC: Einführung
in die hyperspektral-
Fernerkundung



EnMAP als Wegbereiter für die ESA-CHIME Mission



CHIME - Copernicus Hyperspectral Imaging Mission

- EnMAP entscheidend für die Festlegung der CHIME-Missionsanforderungen in der frühen Phase
- EnMAP grundlegend für die CHIME Level-2 Prototyp Aktivitäten



CHIME Key Specifications



- Carpet-mapping observations of land and coastal areas
- $SZA < 84^\circ$
- Spectral range: 400 – 2500 nm
- FWHM ≈ 10 nm, SSI ≈ 8.4 nm
- Ground Resolution: 30 m
- Swath ≈ 130 km
- Revisit 11 days (w/ 2 satellites)
- High radiometric accuracy and SNR, low spectral/spatial mis-registration

User data products:

- Top-of-atmosphere (TOA) radiance in sensor geometry
- Ortho-rectified TOA reflectance
- Bottom-of-atmosphere (BOA) land surface and aquatic reflectance both in sensor and ortho-rectified geometry

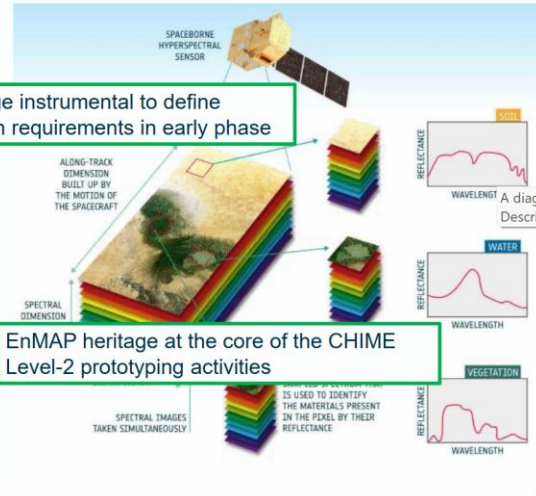
>> with associated uncertainties

Current baseline documentation:

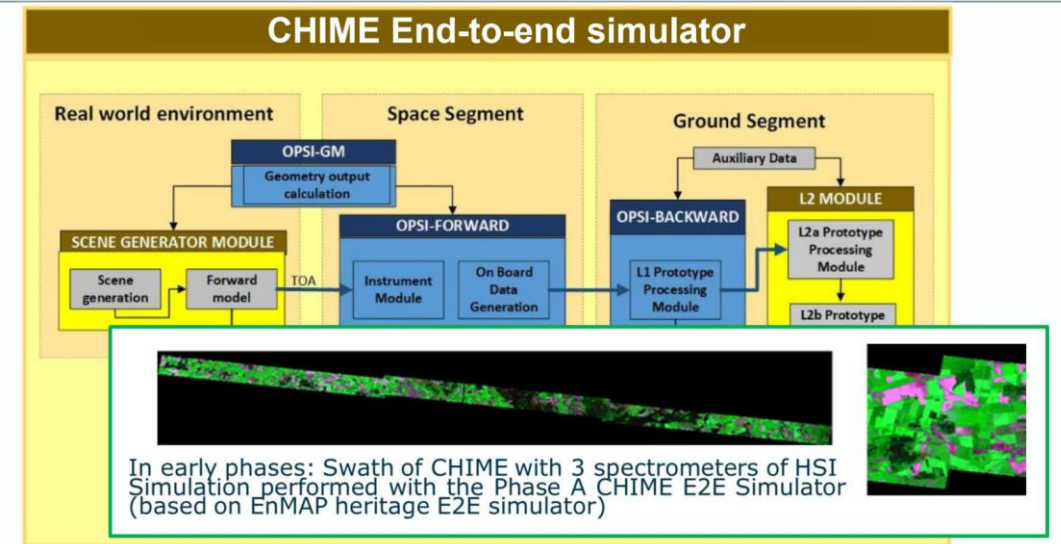
- MRD (ESA-EOPSM-CHIM-MRD-3216) version 3.0
- SSRD (CHIM-RS-ESA-PM-0002) version 2.1

EnMAP heritage instrumental to define CHIME mission requirements in early phase

EnMAP heritage at the core of the CHIME Level-2 prototyping activities



CHIME End-to-End Simulator



In early phases: Swath of CHIME with 3 spectrometers of HSI Simulation performed with the Phase A CHIME E2E Simulator (based on EnMAP heritage E2E simulator)

Slides: Marco Celesti, ESA

International campaign support

ESA Advanced Ocean Training Course 2025

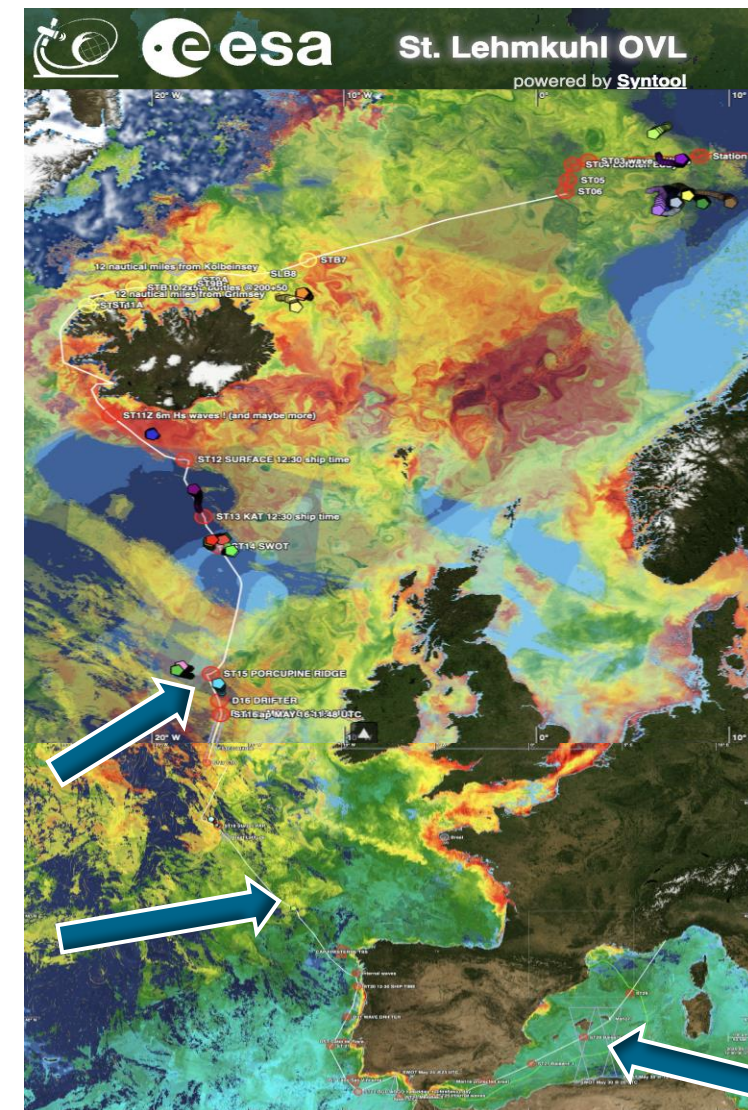
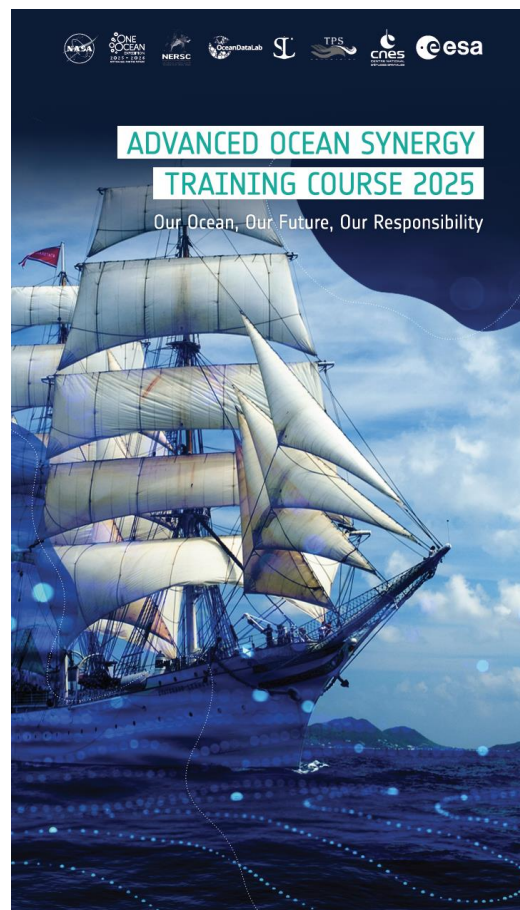
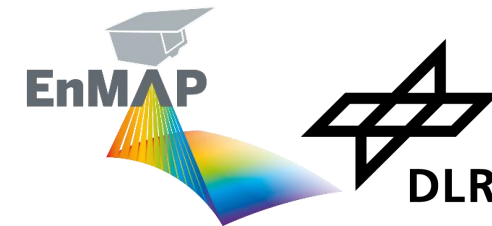
A unique co-located satellite and in situ data set

- 50 students, 21 lecturers, 22 countries
- ~4500 nautical miles
- 46 days at sea
- 1 marine heatwave, 1 marine cold spell
- Amazing biological succession/biodiversity
- 30 Oceanographic stations
- 63 CTD profiles
- 61 Phytoplankton nets
- 43 Zooplankton nets
- 157 ocean current drone flights
- 2 BGC-ARGO deployments
- 55 drifting buoys (35 wave drifters) deployed
- 38 lectures at sea
- Continuous sampling underway
- >15 Tb data acquired on the ship
- satellite imagery/data from Sentinel-1, -2, -3, -6,

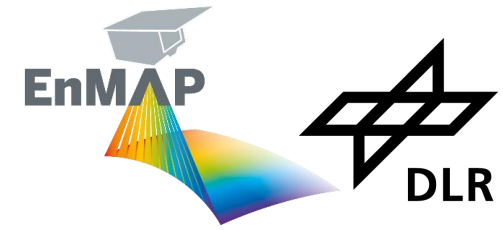
➔ EnMAP (16.05., 19.05. and 28.05.2025)

- First test of Sentinel-1C AIS with in-situ application
- >8 Journal articles in preparation

Slide courtesy: Craig Donlon and
Vannesa Keuck, ESA



International campaign support

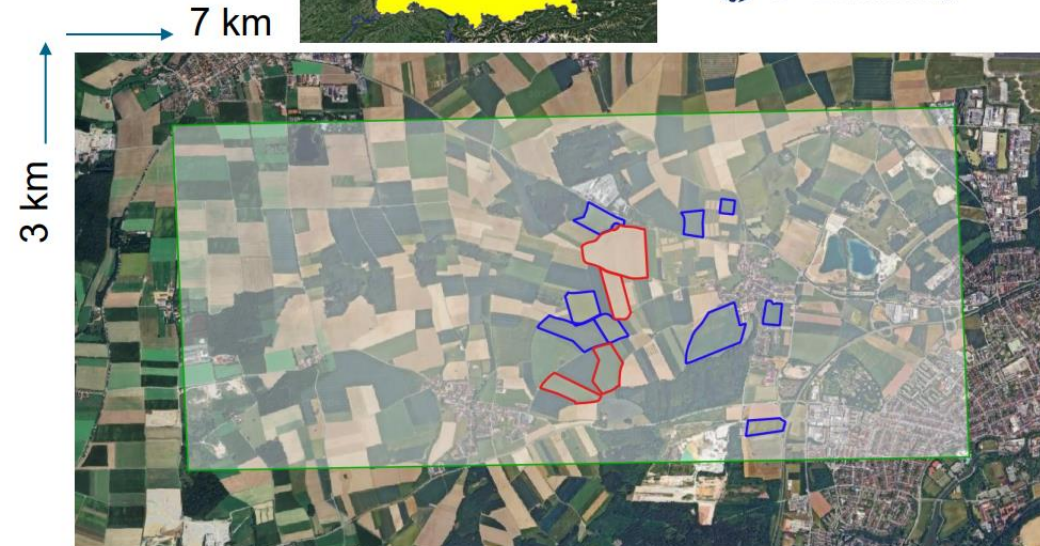


ESA AGRIROSE-L Campaign - Potential for matchups

- ESA campaign in support of ROSE-L and CHIME missions
- Agricultural area Northwest of Munich, Germany
- Observed between 22 April – 21 July 2025
- With several instrumentations:
 - Laboratory + Field (soil + vegetation traits)
 - UAV (fractional vegetation cover)
 - Airborne (F-SAR + HySPEX)
 - Spaceborne (DESIS, EnMAP, PRISMA)
 - (1) Time series
 - (2) Sensor matchups



Partner:



Contact: Tobias Hank (LMU)

Moon calibrations

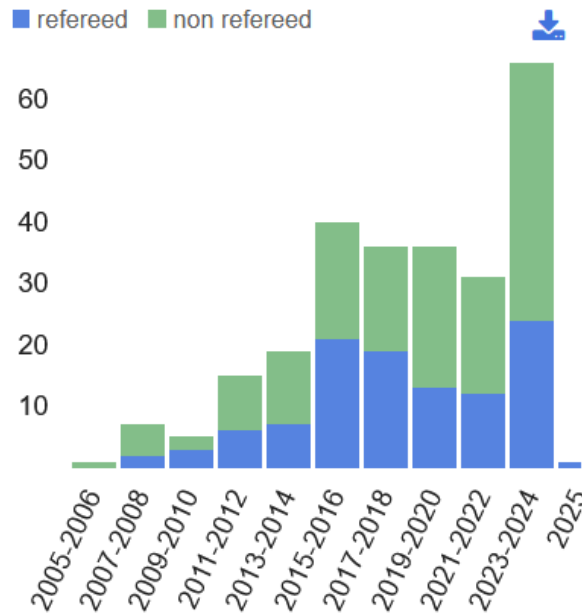
- Moon observations for calibration & cal/val studies
- Along-track scanning strategy
- 10 acquisitions since launch
- 2-monthly acquisitions, close in time to Sun calibrations
- Data not publicly available
- Collaborations with external partners for Moon data exploitation (e.g. CNES)



10.04.2025



Publications



Source: NASA ADS

Special Issue on RSE in preparation!
Submission of papers
end 2025/beginning 2026
Get ready!

Asadzadeh, S., Koellner, N., Chabrillat, S. (2024), **Detecting rare earth elements using EnMAP hyperspectral satellite data: a case study from Mountain Pass, California**. Scientific Reports, 14, 20766.

doi: [10.1038/s41598-024-71395-2](https://doi.org/10.1038/s41598-024-71395-2)



Full mission evaluation of EnMAP reflectance products using the correction processors

MARIANA A. SOPPA,¹ MAXIMILIAN BRELL,¹ SABINE CHABRILLAT,^{2,3} LEONARDO M. A. ALVARADO,^{1,4} PETER GEGE,⁵ STEFAN PLATTNER,⁵ IAN SOMLAI-SCHWEIGER,⁵ THOMAS SCHROEDER,⁵ FRANÇOIS STEINMETZ,⁷ DANIEL SCHEFFLER,² VITTORIO E. BRANDO,⁸ MARIANO BRESCIANI,⁹ CLAUDIA GIARDINO,⁹ SIMONE COLELLA,⁸ DIETER VANSTEENWEGEN,¹⁰ MAXIMILIAN LANGENBACH,¹¹ EMILIANO CARMONA,¹¹ MARTIN MIGUEL PATO,¹¹ SEBASTIAN FISCHER,¹¹ AND ASTRID BRACHER^{1,13,*}

Detecting methane emissions from palm oil mills with airborne and spaceborne imaging spectrometers

Adriana Valverde^{1,*}, Javier Roger¹, Javier Gorroño¹, Itziar Irakulis-Loitxate^{1,2} and Luis Guanter^{1,3}

Evaluation of EnMAP imagery for predictive modelling of soil salinity in highly saline soils

Francisco M. Canero¹, Diego Lopez-Nieto¹, and Victor Rodriguez-Galiano¹
University of Seville, Department of Physical Geography, Seville, Spain (fcanero@us.es)

Gaussian Process Regression Hybrid Models for the Top-of-Atmosphere Retrieval of Vegetation Traits Applied to PRISMA and EnMAP Imagery

by Ana B. Pascual-Ventoe^{1,*}, Jose L. Garcia¹, Katja Berger^{1,2}, José Estévez¹, Jorge Vicent^{1,3}, Adrián Pérez-Suay¹, Shari Van Wittenberghe¹ and Jochem Verrelst¹

Identification of a Potential Rare Earth Element Deposit at Ivanpah Dry Lake, California Through the Bastnäsite Indices

by Otto C. A. Gadea¹ and Shuhab D. Khan^{2,*}

Department of Earth and Atmospheric Sciences, University of Houston, Houston, TX 77204, USA

* Author to whom correspondence should be addressed.

Remote Sens. 2024, 16(23), 4540; <https://doi.org/10.3390/rs16234540>

Hajaj, S., Harti, A.E., Pour, A.B. et al. Recurrent-spectral convolutional neural networks (RecSpecCNN) architecture for hyperspectral lithological classification optimization. Earth Sci Inform 18, 125 (2025). <https://doi.org/10.1007/s12145-024-01534-w>