

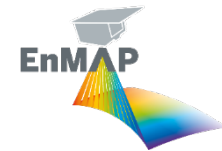
Science preparation exploitation and support of the EnMAP mission

Prof. Sabine Chabrillat

And the whole EnMAP science team

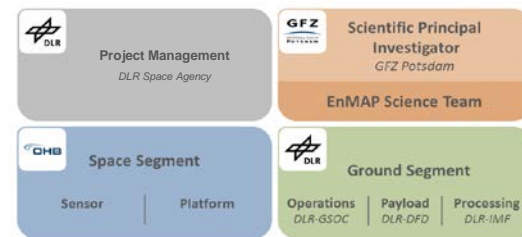
GFZ - Helmholtz Center Potsdam German Research Center for Geosciences, Section remote sensing and geoinformatics, Potsdam and
LUH- Leibniz University Hannover, Institute of soil science, Hannover, Germany

EnMAP: A new sensor for monitoring Earth's environment



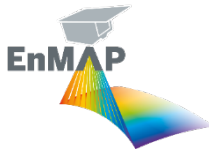
- Hyperspectral spaceborne mission “Environmental Mapping and Analysis Program”
- **Core themes:** Environmental changes, ecosystem responses to human activities, management of natural resources
- **Core parameters:** Global coverage, 30m pixel size, 242 spectral channels, revisit 27 days nadir, 4 days with off-nadir tilting, max 5000 km acquisitions/day
 - **Scientific mission**
 - Measurements of **key biophysical and geochemical parameters**
 - **Highly calibrated** imaging spectroscopy data
 - **Co-existence** with Sentinel-2 & Landsat-8
 - Data acquisition **on demand**

Mission consortium



- DLR Space Agency in Bonn is responsible for the overall project management
- Core funding from the German Federal Ministry of Economic Affairs and Climate Actions (BMWK)
- GFZ science PI: Extensive Scientific Exploitation preparation program supported by EnSAG (EnMAP science advisory group) and EnMAP science team

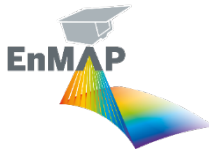
EnMAP scientific preparatory activities: Science and education program



- **More than 40 PhD students and post docs** funded as part of the EnMAP science program since 2010
- **Application & algorithm development** in various fields, incl. agriculture, forestry, natural ecosystems, geology and soil, urban areas, coastal and inland waters
- **Regular EnMAP summer schools**



EnMAP scientific preparation and exploitation activities: Current program



Phase 2020-2023: pre-launch, launch, commissioning and 1st year into operation

Work packages:

- WP1 - Sensor simulation, validation/data quality activities
- WP2 - EnMAP Box, algorithm consolidation and validation
- WP3 - Training and workshops, HYPERedu platform, outreach
- WP4 - International collaboration, coordination

Partners:

Lead GFZ Potsdam (soil, minerals) with HU Berlin/Univ. Greifswald (EnMAP Box), LMU München (agriculture), AWI Bremerhaven (water)

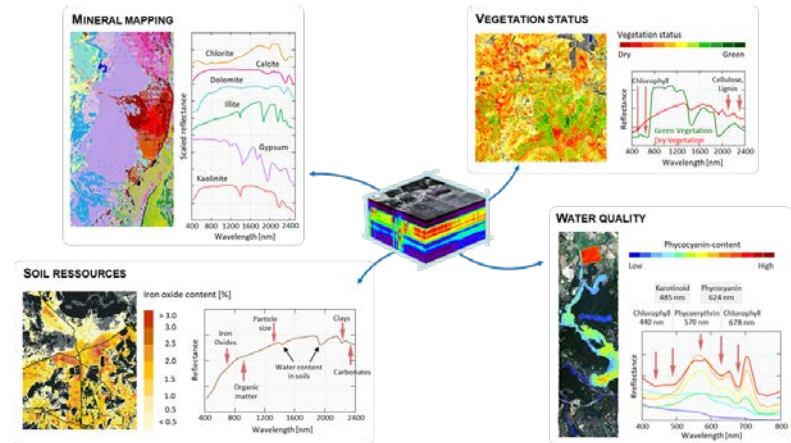
Funding:

DLR Space Agency with resources from the BMWK

GFZ/EnSAG science support activities: Current focus

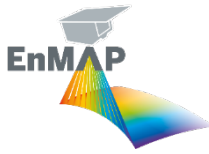
- **External Validation (data quality monitoring):** EnMAP product validation, coordination and campaigns 2023
- **Science & Application development:** Demonstration of science potential of EnMAP, user training/software incl. EnMAP workshop and EnMAP courses
- **Mission support:** Science/Technical recommendations to the mission board (data quality, acquisitions, wavelength extension), review of users proposals, announcement of opportunities, background and foreground mission

Next project phase in preparation



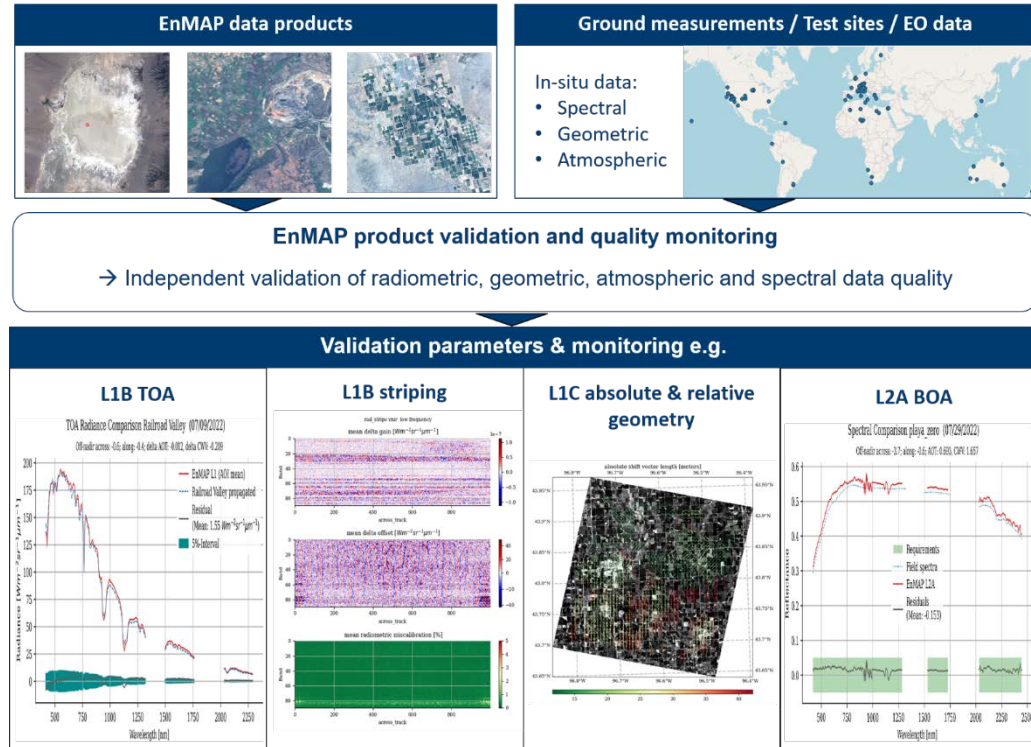
External Validation of data products

Data quality monitoring: Concept



- **Validation activities during commissioning and nominal phase**
 - **Independent validation effort** in addition to Q/C from the ground segment
 - **Estimation of quantitative error** and potential error sources, report non-compliance or recommendation for improvement
 - **Based on EnMAP products L1B / L1C / L2A and reference data, airborne & spaceborne data**
 - **Collaboration with the science international community**
 - **Cross-validation with other missions**
 - **Support for preparation upcoming CHIME**

- **Development of the EnVAL processor:**
Field-, image-, model-based validation



Brell, M., et al. (2021): The EnMAP Satellite – Data Product Validation Activities. *WHISPERS 2021*

External validation of EnMAP products (GFZ): Results

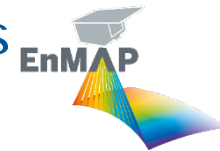


Image based



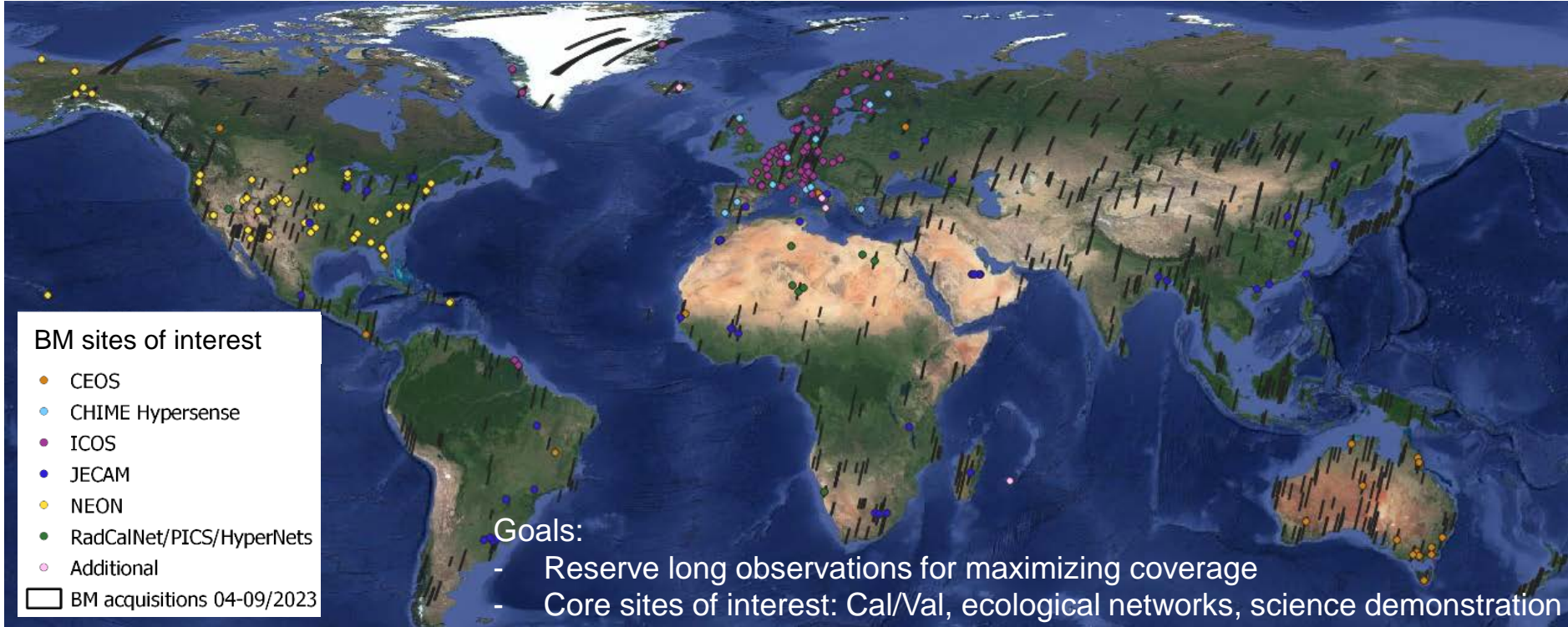
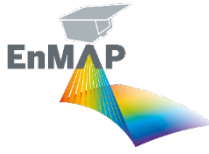
Field based

In-situ/
Reference data

Data product	Field-, Image-, Model based validation			
	Radiance	Reflectance	Geometry	Quality
L1B	<p>Validation efforts were very successful!</p> <ul style="list-style-type: none"> – Top-of-Atmosphere radiance (L1B) – Geometric accuracy. Co-registration (L1C) – Bottom-of-Atmosphere reflectance (L2A) – Smile and keystone <2% – Across-track destriping implemented 3/2023 (algorithm GFZ) <p>→ Data quality exceeding all requirements!</p> <p>→ Important decision-making basis for the Flight Qualification Review (10/2022) and continuous quality improvement efforts (EnMAP processor)</p> <p>→ Validation is continuing: Please contact Max Brell@GFZ if you like to contribute</p>			
L1C				
L2A				



Background mission (BM) and foreground mission(Europe) acquisitions



BM sites of interest

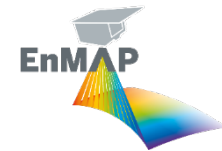
- CEOS
- CHIME Hypersense
- ICOS
- JECAM
- NEON
- RadCalNet/PICS/HyperNets
- Additional

□ BM acquisitions 04-09/2023

Goals:

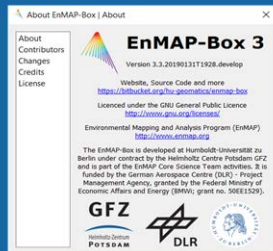
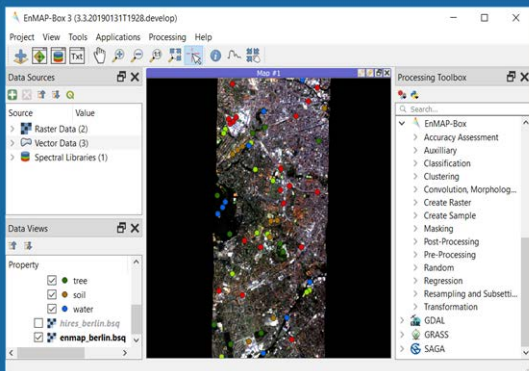
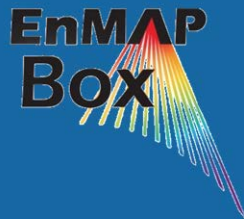
- Reserve long observations for maximizing coverage
- Core sites of interest: Cal/Val, ecological networks, science demonstration

Algorithm toolbox and education resources: Status

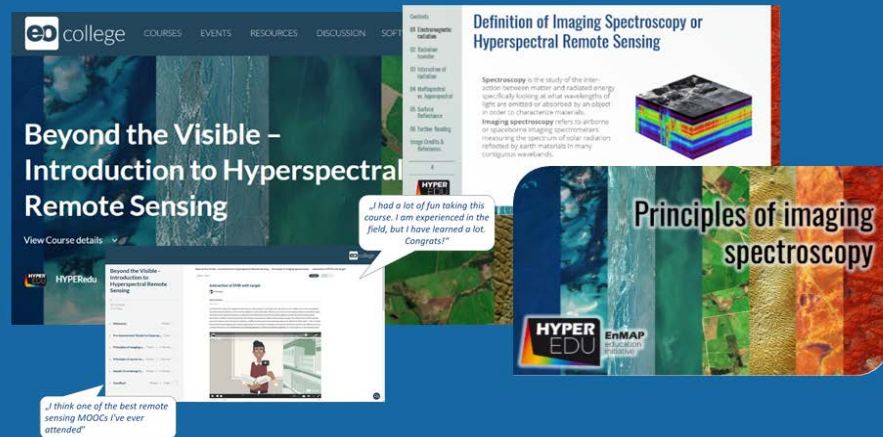


Activities maintained and will further develop

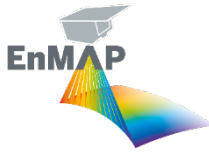
Free and open-source toolbox
for visualization, processing &
analysis of hyperspectral data



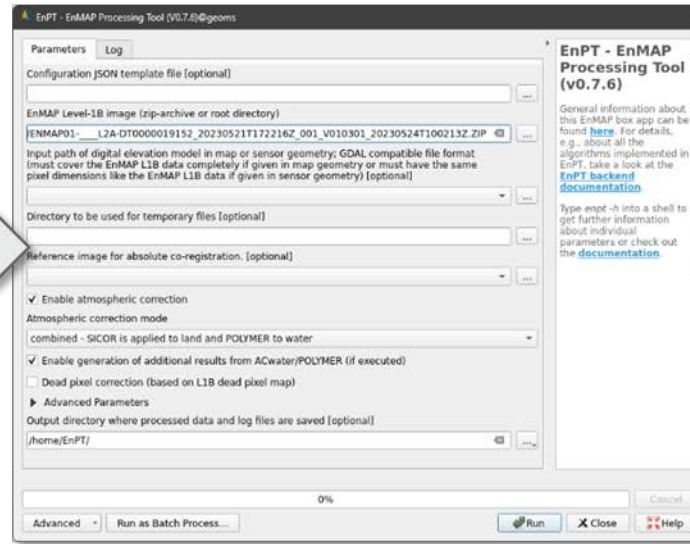
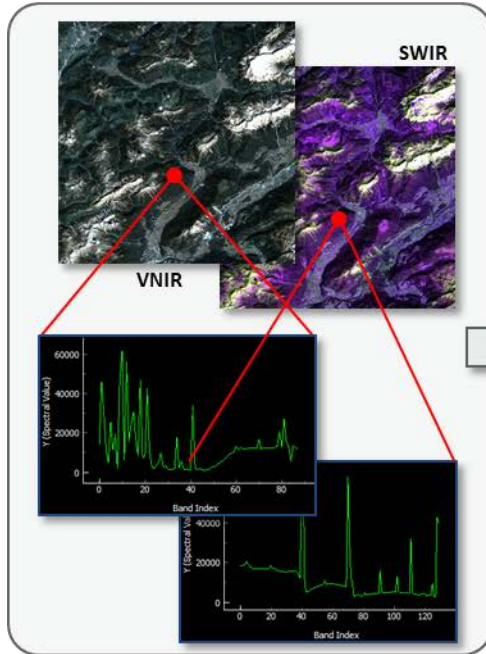
Online learning initiative on
principles, methods and applications
of hyperspectral remote sensing



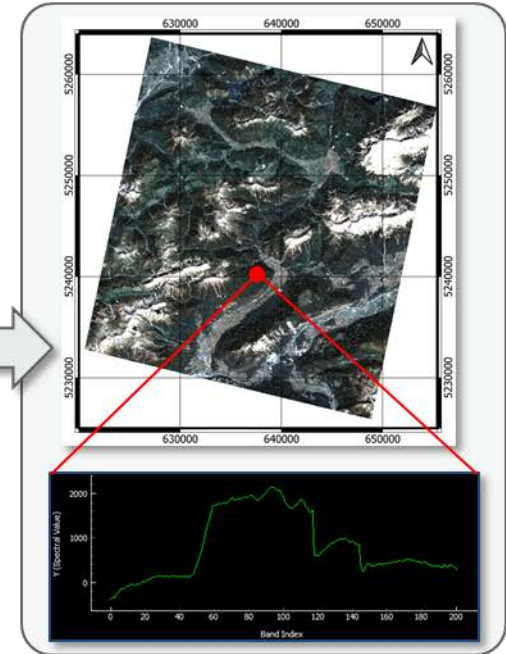
Software toolboxes: EnMAP Preprocessing Tool (EnPT) Alternative “do-it-yourself”



Level 1B



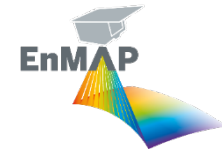
Level 2A



Scheffler D., Bohn N., Guillaso S., Segl K. (2021). EnPT - EnMAP Processing Tool (Version v0.18.2). Zenodo. <http://doi.org/10.5281/zenodo.4977250>

Bohn, N., Scheffler, D., Brell, M., Segl, K. (2022). SICOR - Sensor Independent Atmospheric Correction, Zenodo. <http://doi.org/10.5281/zenodo.5973187>

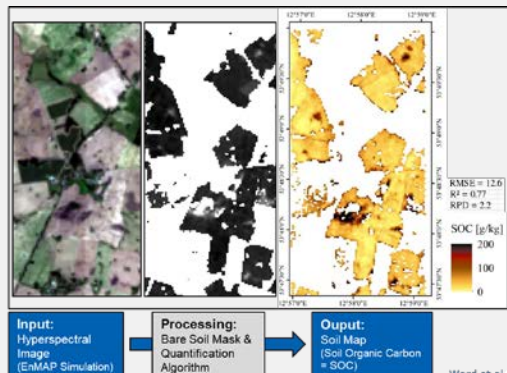
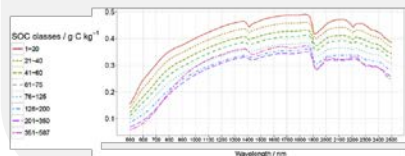
Retrieval of bare Earth surface properties



- Science and methodological developments for several applications; Research focus on
 - **Demonstration of EnMAP potential** for new EO products
 - **Development of software toolboxes** for the user community implemented in QGIS/ EnMAP-Box (**EnSoMap**, **EnGeoMap**, **EnSnowMap**)

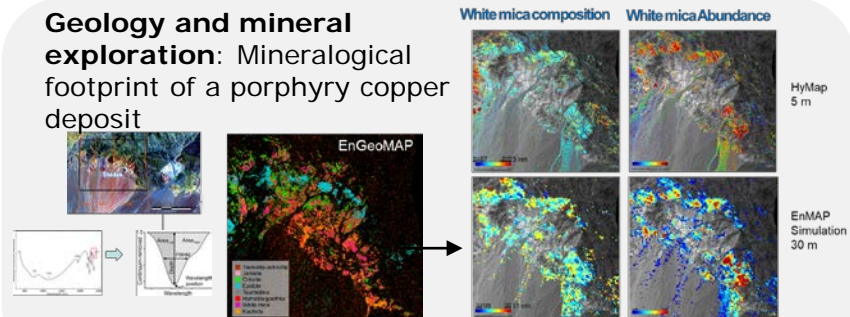
Topsoil compositional mapping: Soil Organic Carbon maps, soil texture, soil moisture, soil carbonates, iron oxides content

- Food security and climate change
- Visible range important
- Higher SOC → lower albedo
- Multivariate modelling



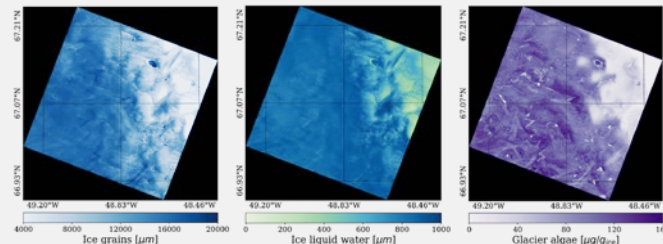
EnMAP simulation Ward et al. (2020)

Geology and mineral exploration: Mineralogical footprint of a porphyry copper deposit



Asadzadeh, S., et al. (2023), Targeting exploration drilling using airborne hyperspectral imagery: A case study from the Shadan Porphyry Copper Deposit, Iran, *Economic Geology*.

Snow & ice properties mapping: Novel combination of retrieval maps and uncertainties for grain size, liquid water, and algae concentration



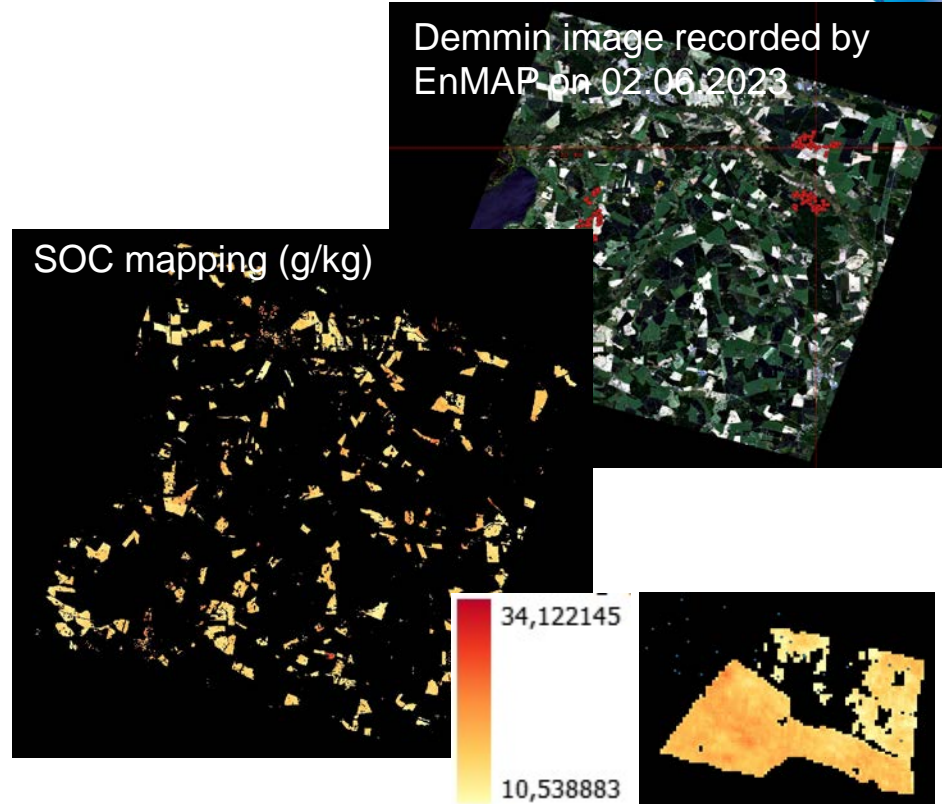
Bohn, N., et al. (2022). Glacier ice surface properties in South-West Greenland Ice Sheet: First estimates from PRISMA imaging spectroscopy data. *J.G.R.: Biogeosc.*, 127

Soil carbon



- Soil degradation is a serious concern in Europe and worldwide
 - Implications for food security and climate change
 - e.g. reduction of soil organic carbon (SOC) content
 - Soil Carbon is one of GEOSS Essential Climate Variables (ECVs)
 - SOC important for e.g. soil fertility and water retention
- Soil is largest terrestrial carbon storage
- SDGs: SOC as most relevant soil property regarding climate regulations → monitoring status should be improved
- EnMAP allows to quantify top-soils carbon content

Demmin image recorded by EnMAP on 02.06.2023



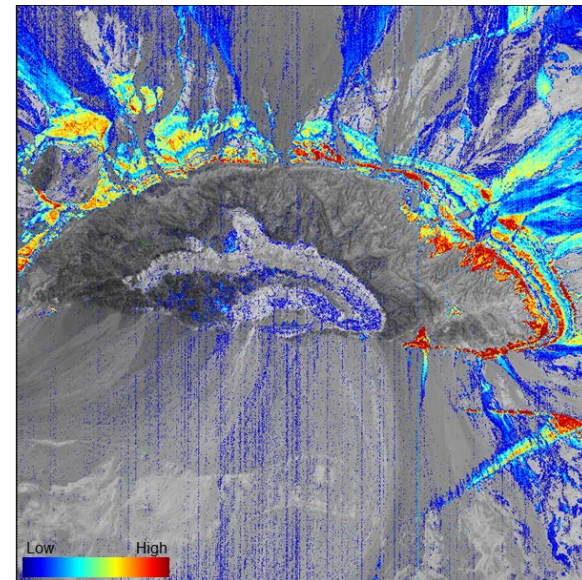
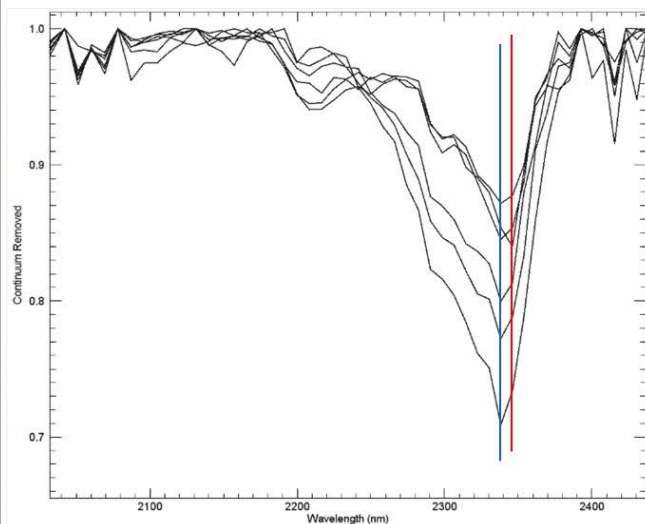
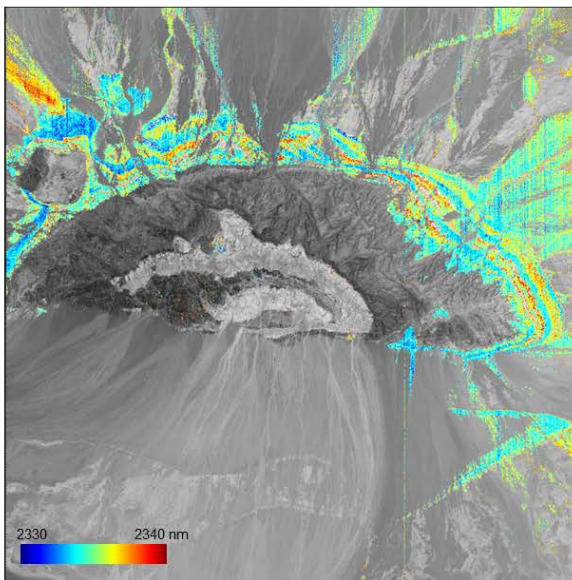
Raw material applications: EnMAP potential



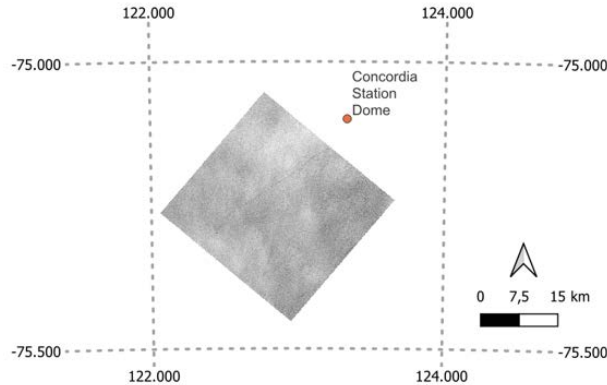
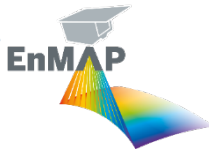
- Application areas: Mineral exploration and resource discovery, waste materials, lithologic mapping, rock unit characterization, metamorphism studies, Energy resource exploration: geothermal sources and oil & gas

Siah-Kuh: Carbonate mapping

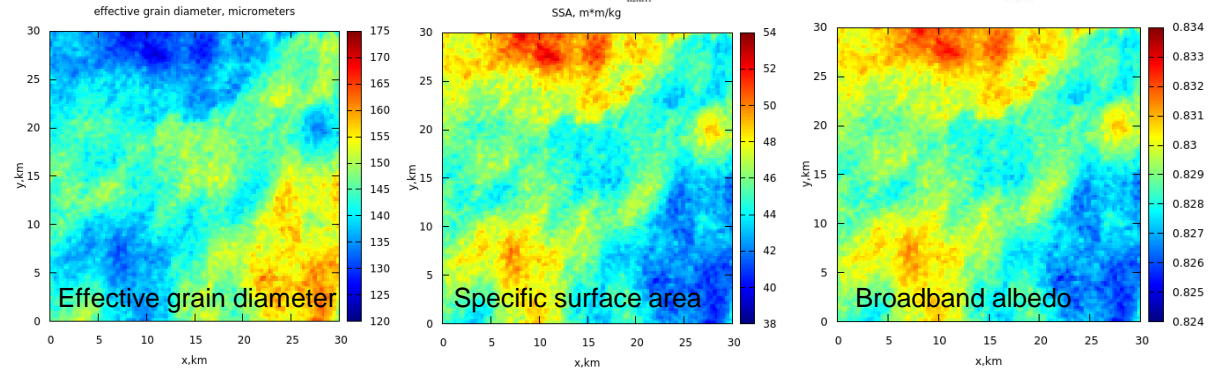
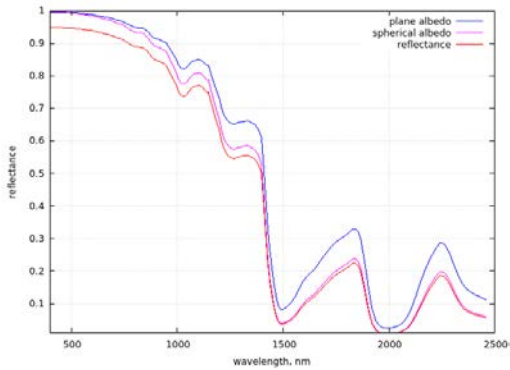
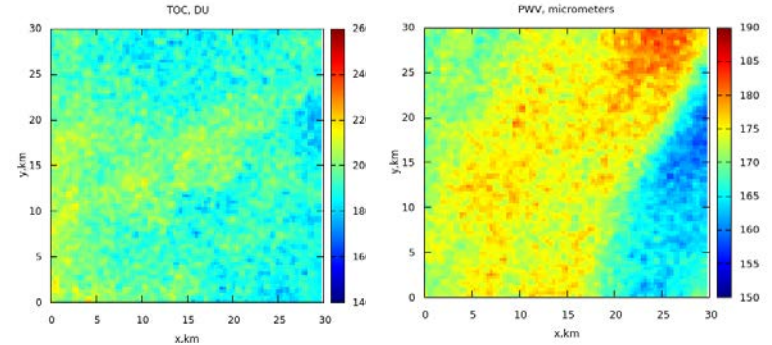
EnMAP data can depict <10 nm shifts in the minimum wavelength of carbonate minerals.



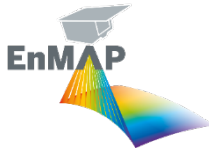
First retrievals of surface and atmospheric properties using EnMAP measurements over Antarctica



Total ozone and precipitable water vapor



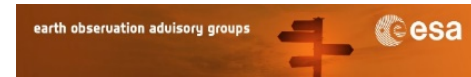
Outlook



- EnMAP after 12M in operational phase
 - Data quality exceeds requirements
 - Very strong user demand >1,400 users, > 300 user proposals
 - Optimise coverage with implementation background and foreground mission

- Extensive scientific exploitation program

- EnMAP mission science support
- Preparation for next operational hyperspectral missions (CHIME, SBG)
- Collaboration with current hyperspectral missions
 - Calval, supersites, reference datasets, standards and protocols



- EnMAP: Contribution to science fields and Copernicus services

- **Scientific exploitation in various GEO- and BIO-fields** such as key Green Deal challenges (climate neutrality [soil/vegetation carbon], disturbances/land degradation, sustainable development goals, food security, sustainable metal sourcing)
- **Combined data exploitation with current missions:** Global and rapid land monitoring and tracking critical Earth System processes (e.g. with S2, PRISMA, EMIT, HISUI, Geofen-5..)
- **Developing future Copernicus GEO-services** (e.g. upcoming hyperspectral mission)

