EnMAP Hyperspectral Imager

GFZ Helmholtz Centre POTSDAM

EnMAP Imaging Spectroscopy Mission: Status and Science Perspectives

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G. Rossner, C. Chlebek, S. Fischer, B. Sang,
the EnMAP Science Advisory Group,
and many others…

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DLR

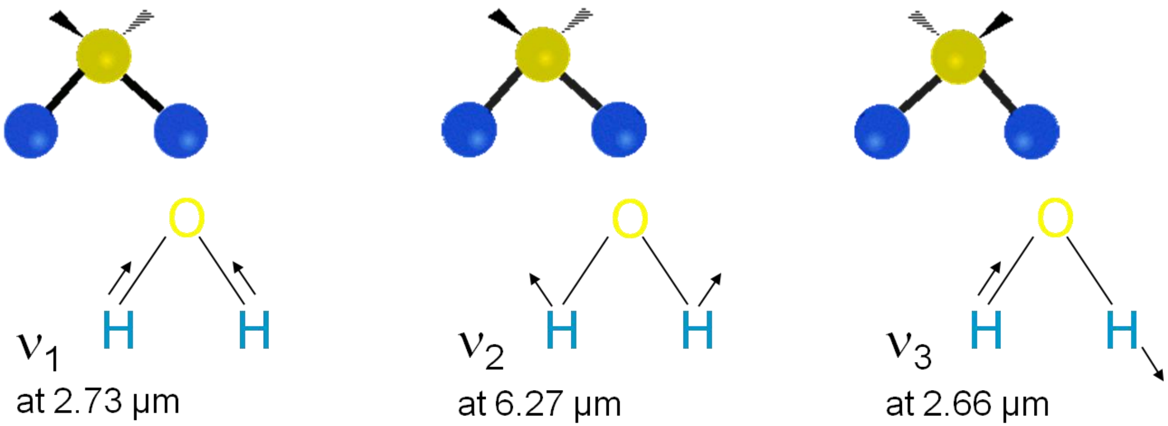
KAYSER-THREDE

OHB TECHNOLOGY

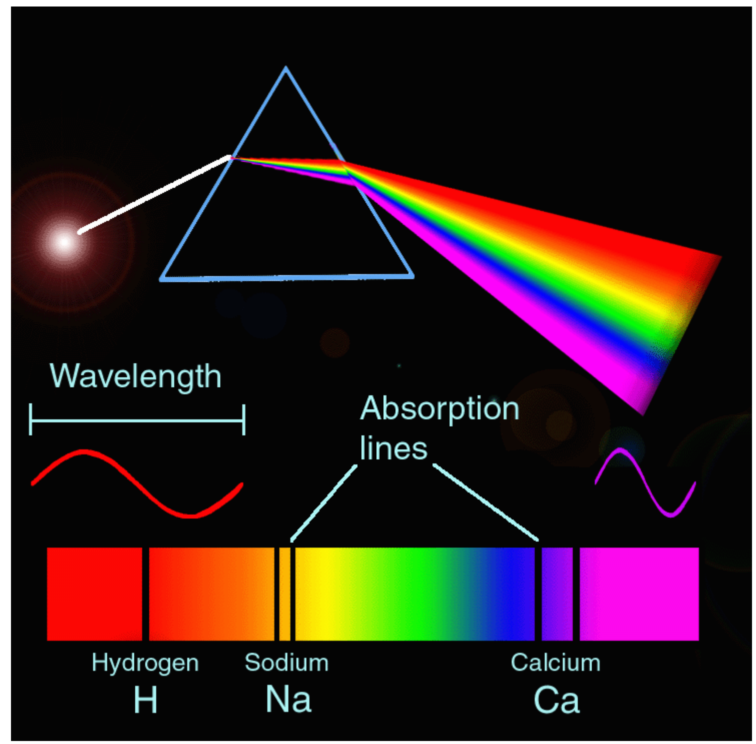
Quo Vadis imaging spectroscopy

- **Reflectance spectroscopy** → Reflectance spectroscopy is the study of light as a function of wavelength that has been reflected or scattered from a solid, liquid, or gas
- **Absorption bands** due to electronic, vibrational or rotational energy transitions in atoms and molecules that **characterize material**

Water molecule: 3 fundamental modes of vibration



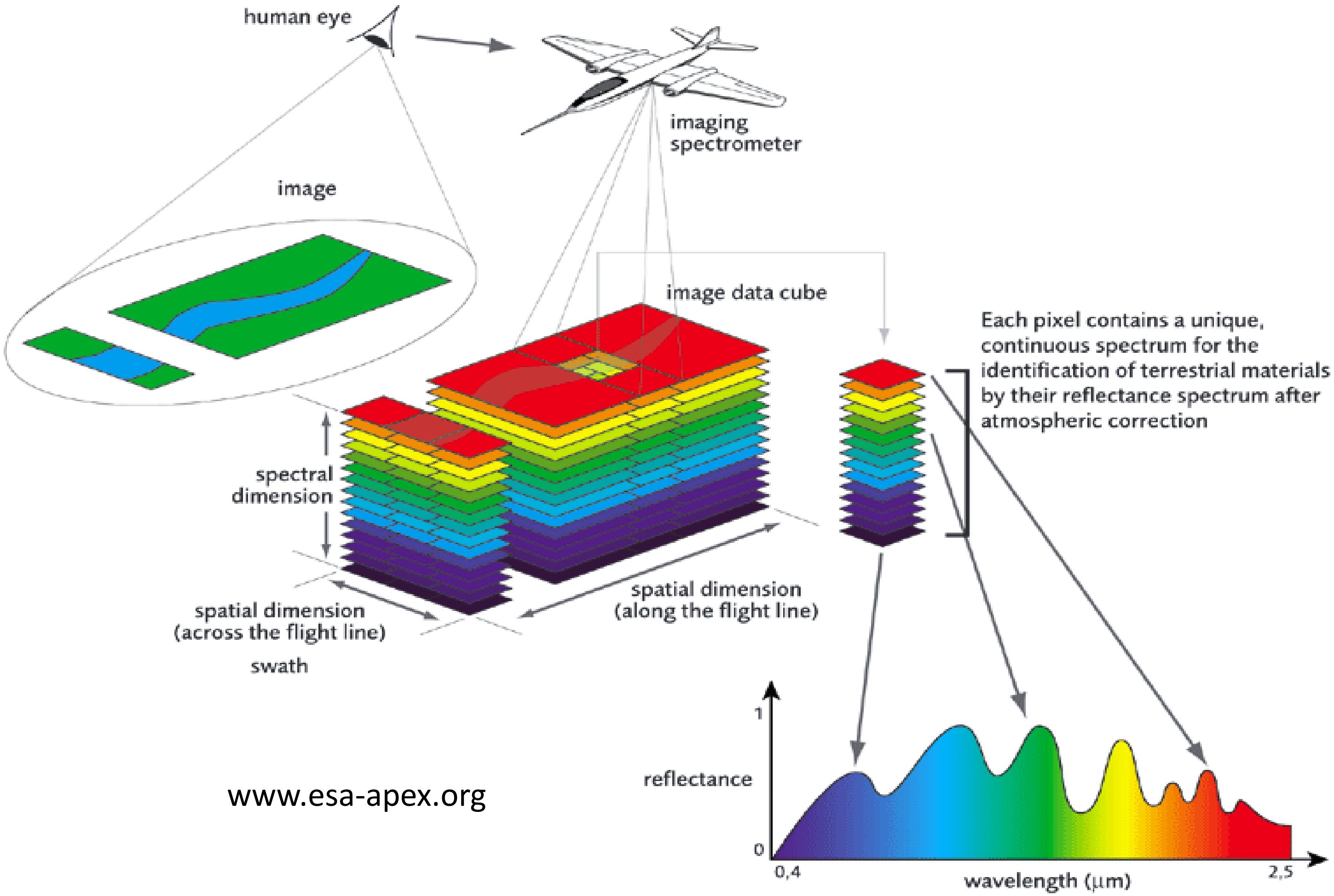
- **Imaging spectroscopy** → Study of solar electromagnetic radiation reflected by Earth materials in the spatial domain



Airborne or spaceborne Imaging Spectroscopy (IS)

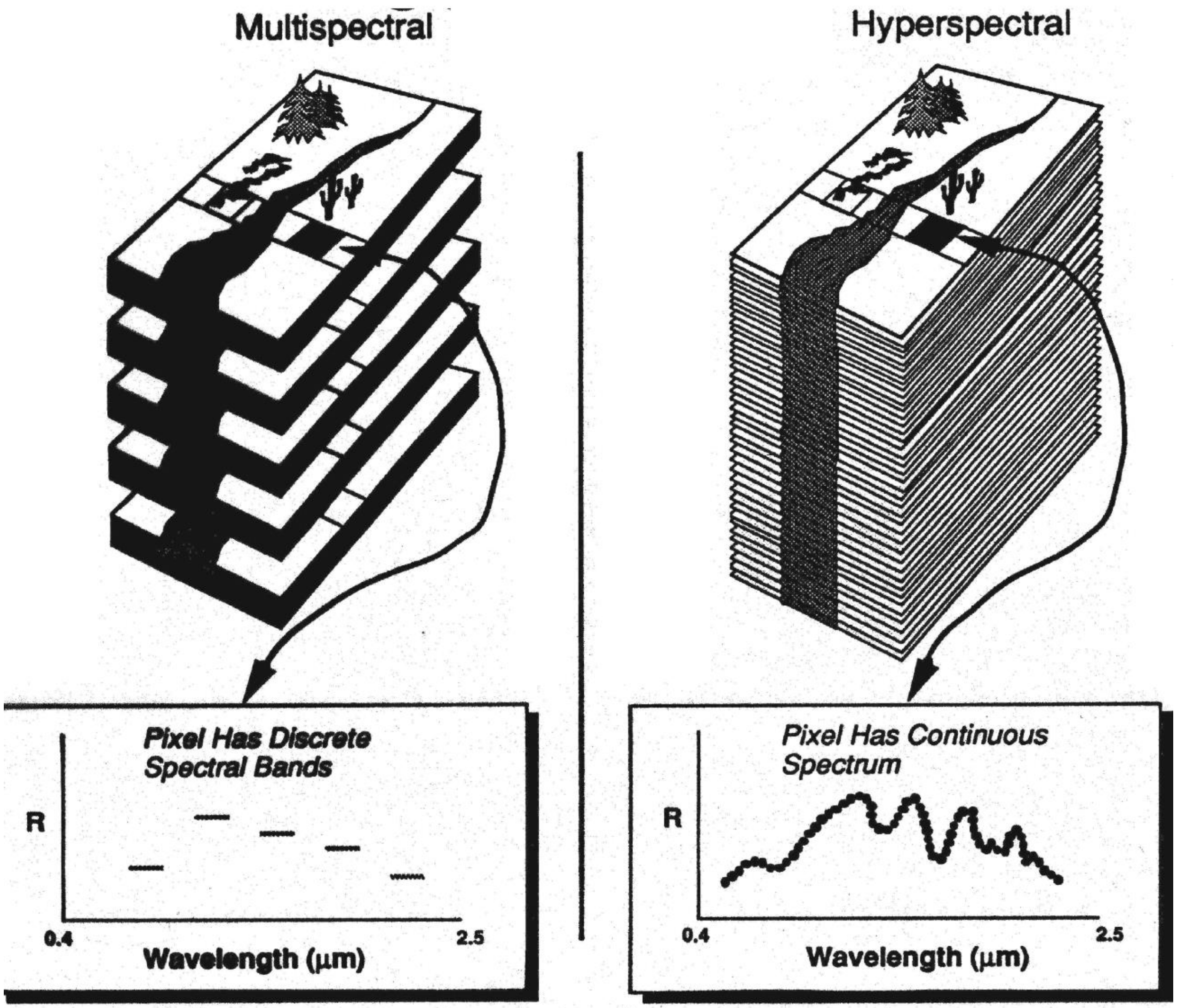
Also named: Hyperspectral Remote Sensing (HRS)

Each image is acquired in >~100 narrow contiguous spectral bands



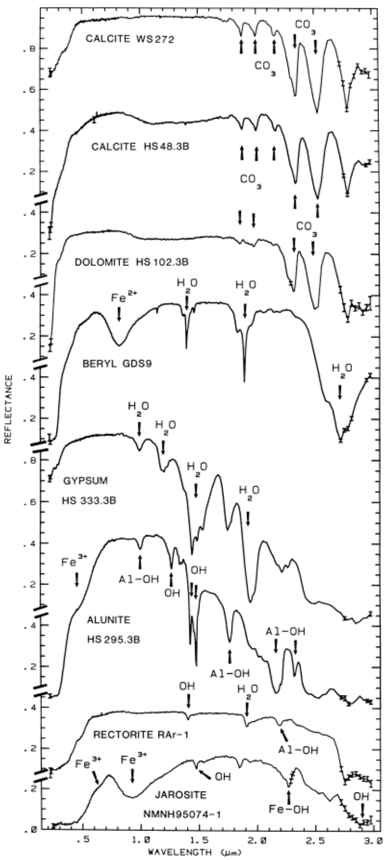
www.esa-apex.org

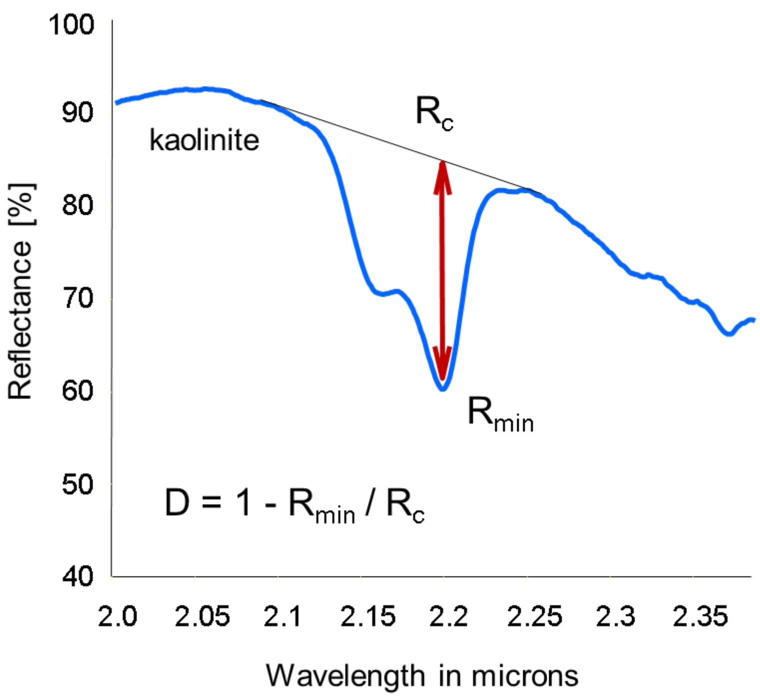
Comparison multispectral - hyperspectral



From absorption bands to material identification & quantification

Absorption bands → spectral features in the spectrum of reflected radiation





Each material on the Earth's surface has a unique spectral characteristic

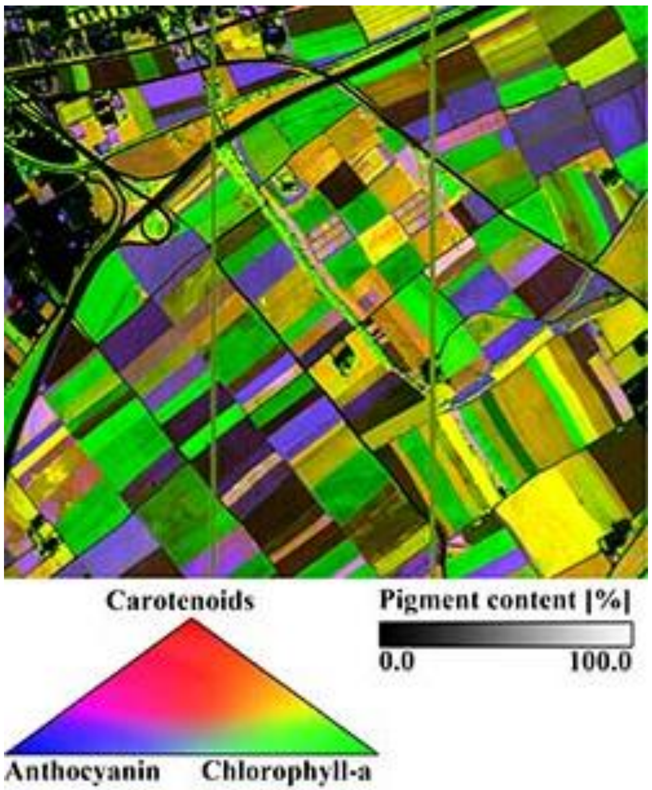
Pigments, Minerals, Man Made Objects

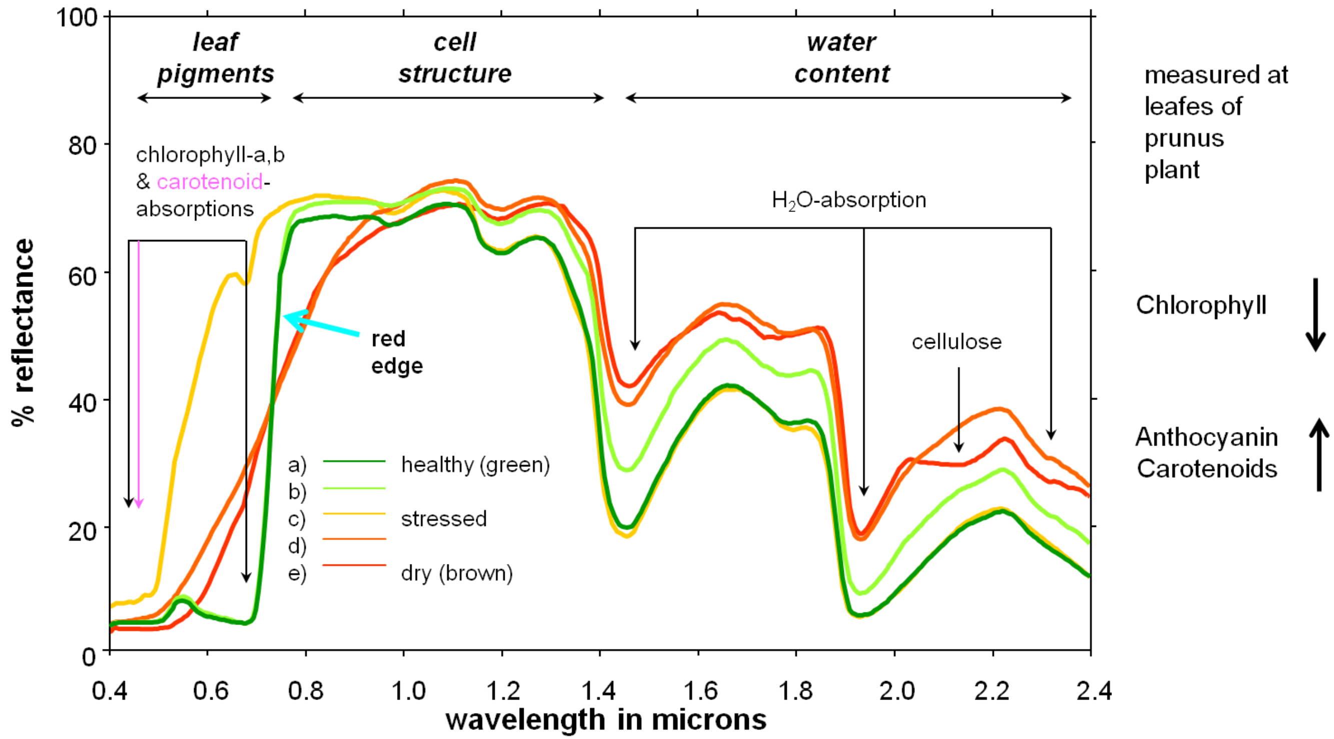
Shape
Position → Identification

Depth → Quantification

Vegetation: Mapping leaf pigments

Absorption features in the reflectance spectrum due to leaf pigments can be exploited to map vegetation condition and for early stress detection

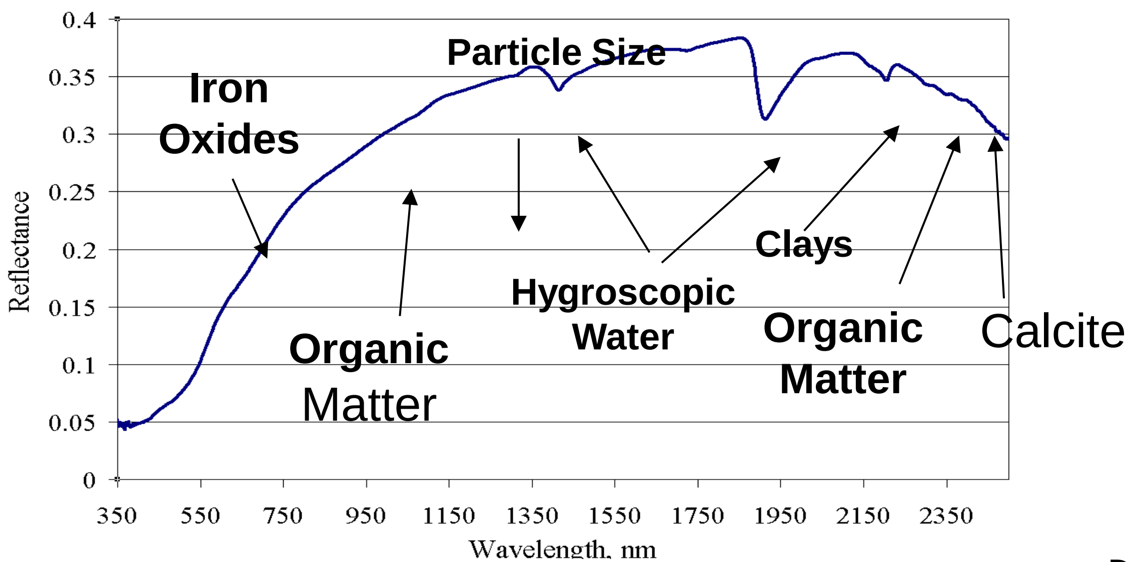




Damm et al.

Soil Mapping and Monitoring

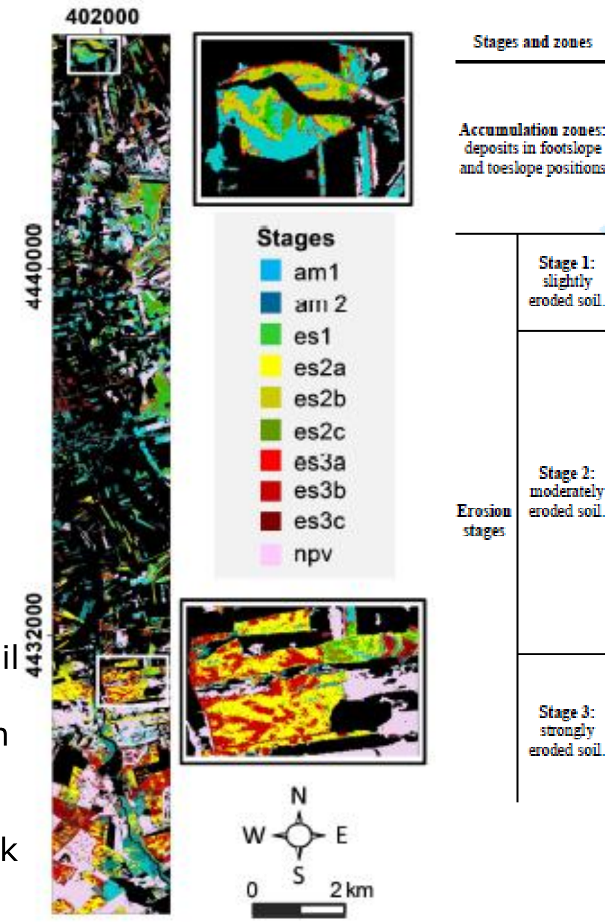
Absorption features in the reflectance spectrum due to mineral and water constituents can be exploited to map soil conditions and detect soil erosion/ degradation



Ben-Dor E., and A. Banin 1995b, Soil Science

7 Main Soil Chromophores

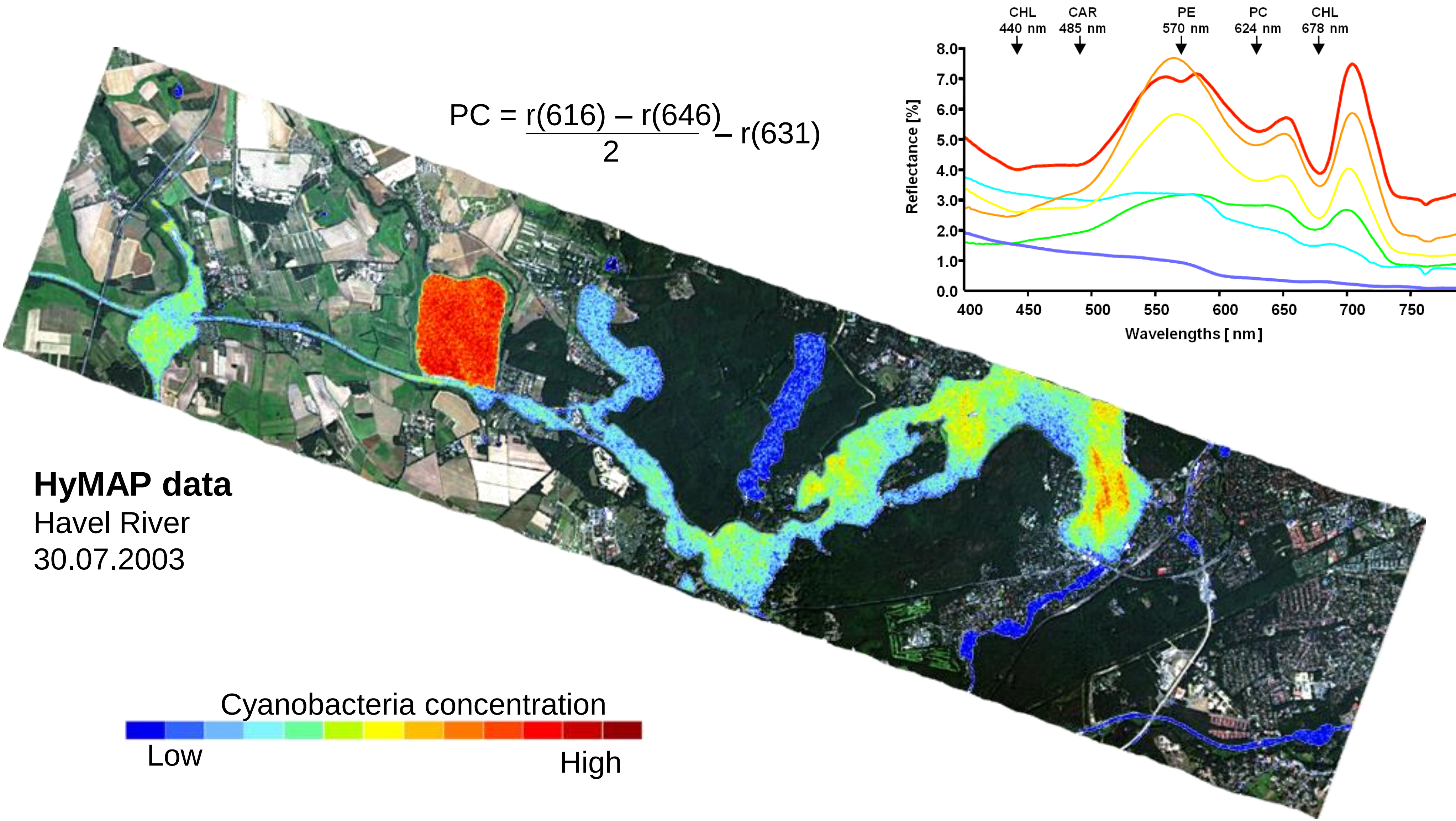
Distribution of soil erosion stages and accumulation zones using the SVM classifier, AISA Eagle/ Hawk data @3m



Schmid et al., 2015, JSTARS

Water quality: distribution of Cyanobacteria

$$PC = \frac{r(616) - r(646)}{2} - r(631)$$



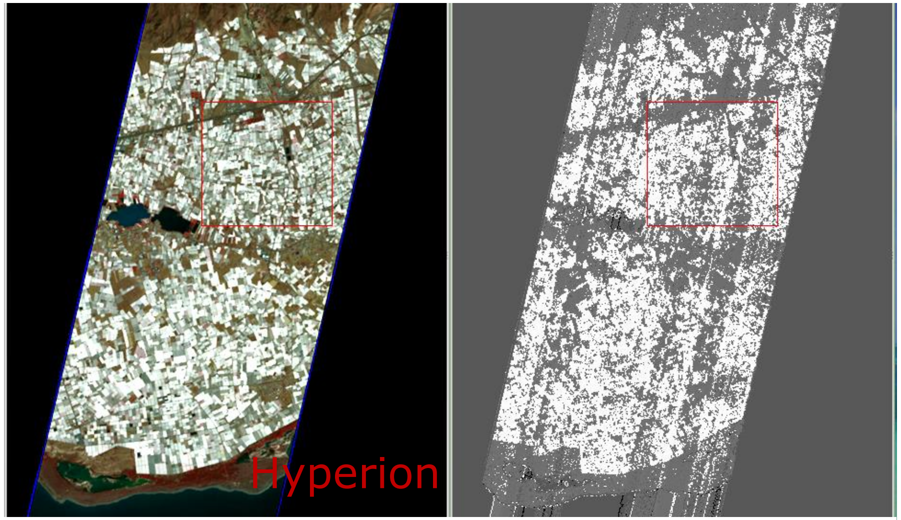
HyMAP data
Havel River
30.07.2003

Cyanobacteria concentration

Low High

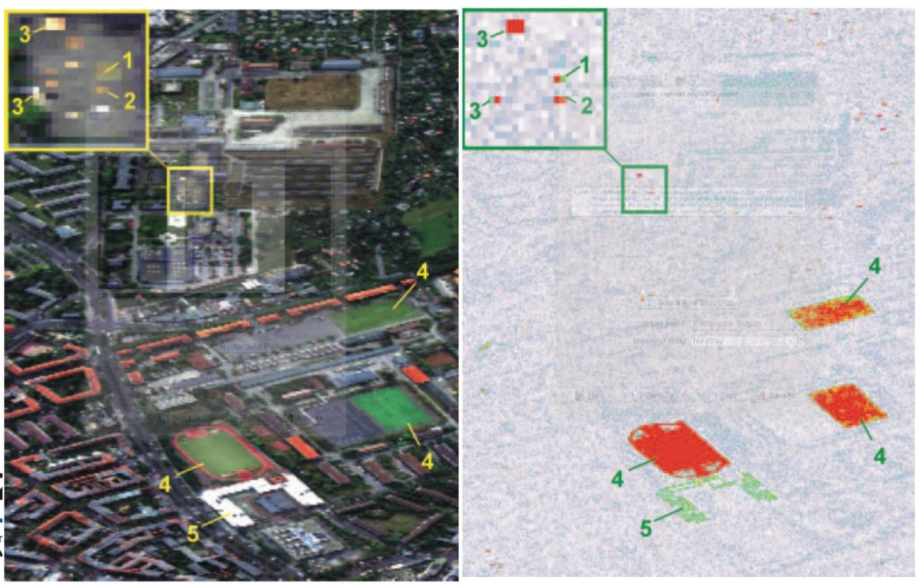
Monitoring hydrocarbons

Kuester et al

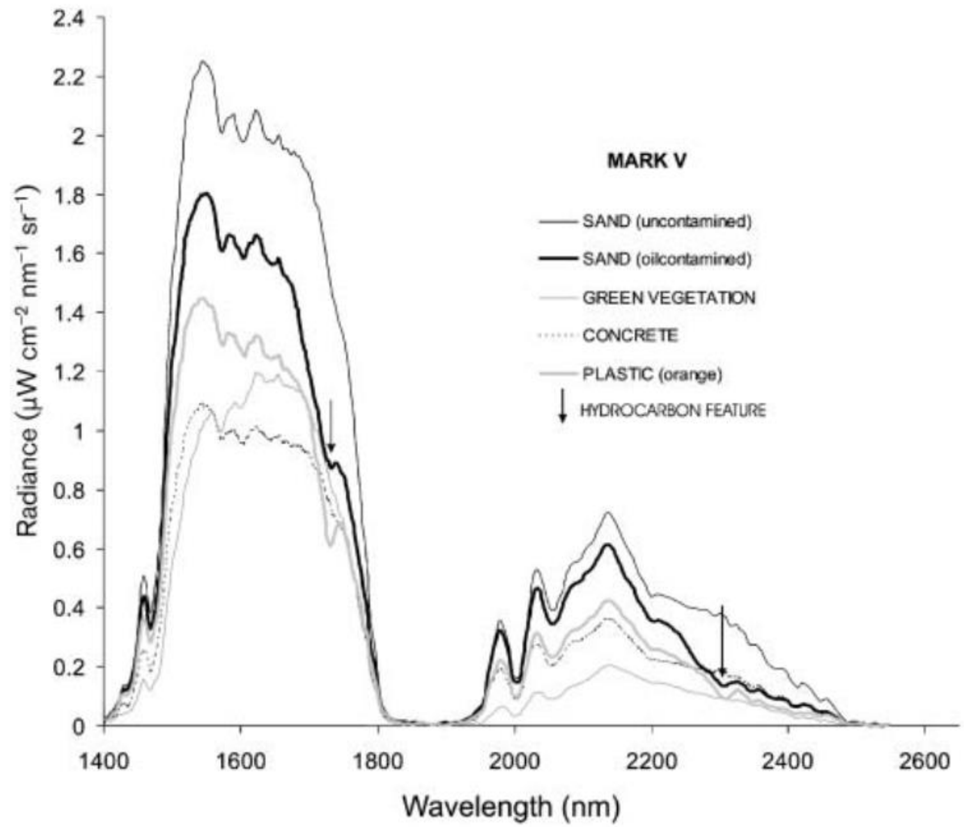


Almeria plastic foil greenhouses

Plastic in urban areas



3. HyMap RGB colour composite image in near-natural colours based on VIS bands 16/R, 10/G, and 3/B; the image is of the BGR premises with (1) and (2) oil-contaminated reference areas, (3) plastic sheets, (4) artificial grass and race track, (5) plastic roofs; insert above left: zoomed section.



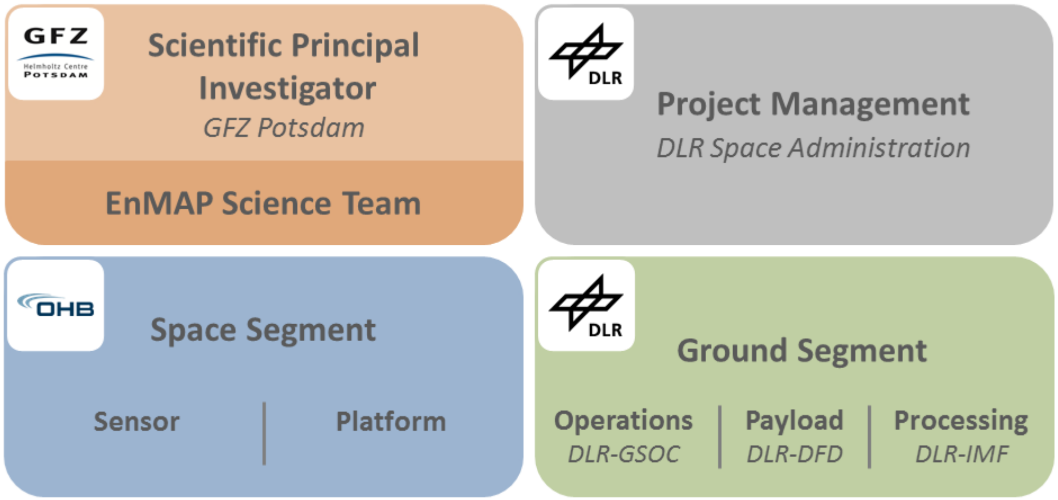
Kühn, F.; Oppermann, K.; Hörig, B. Hydrocarbon index—An algorithm for hyperspectral detection of hydrocarbons. Int. J. Remote Sens. 2004, 25, 2467-2473.

Toward EnMAP: Status of Spaceborne Imaging Spectroscopy

- **The long and sad history of spaceborne imaging spectroscopy:**
  - Current missions → So-called "technology demonstrators"
    - Low data quality and limited acquisition capability
    - Examples: Hyperion (USA NASA, 2000) & CHRIS/PROBA (UK/ESA, 2001), designed for a 1-year lifetime!
  - There are more imaging spectrometers looking at the Moon and Mars than at the Earth!
  - Most of imaging spectroscopy applications rely on airborne spectrometers → heritage from AVIRIS (NASA-JPL, since 1987)

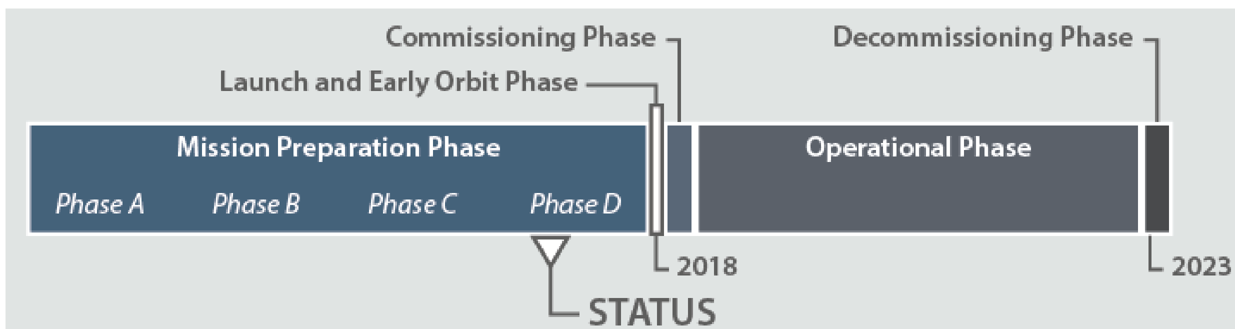
→ EnMAP expected to fill the gap in operational spaceborne imaging spectroscopy

- **Spaceborne missions under development:**
  - EnMAP (Germany, launch 2018)
  - HISUI (Japan, launch 2018?)
  - PRISMA (Italy, launch ???)
  - HyspIRI (NASA, launch >2023?) and more..

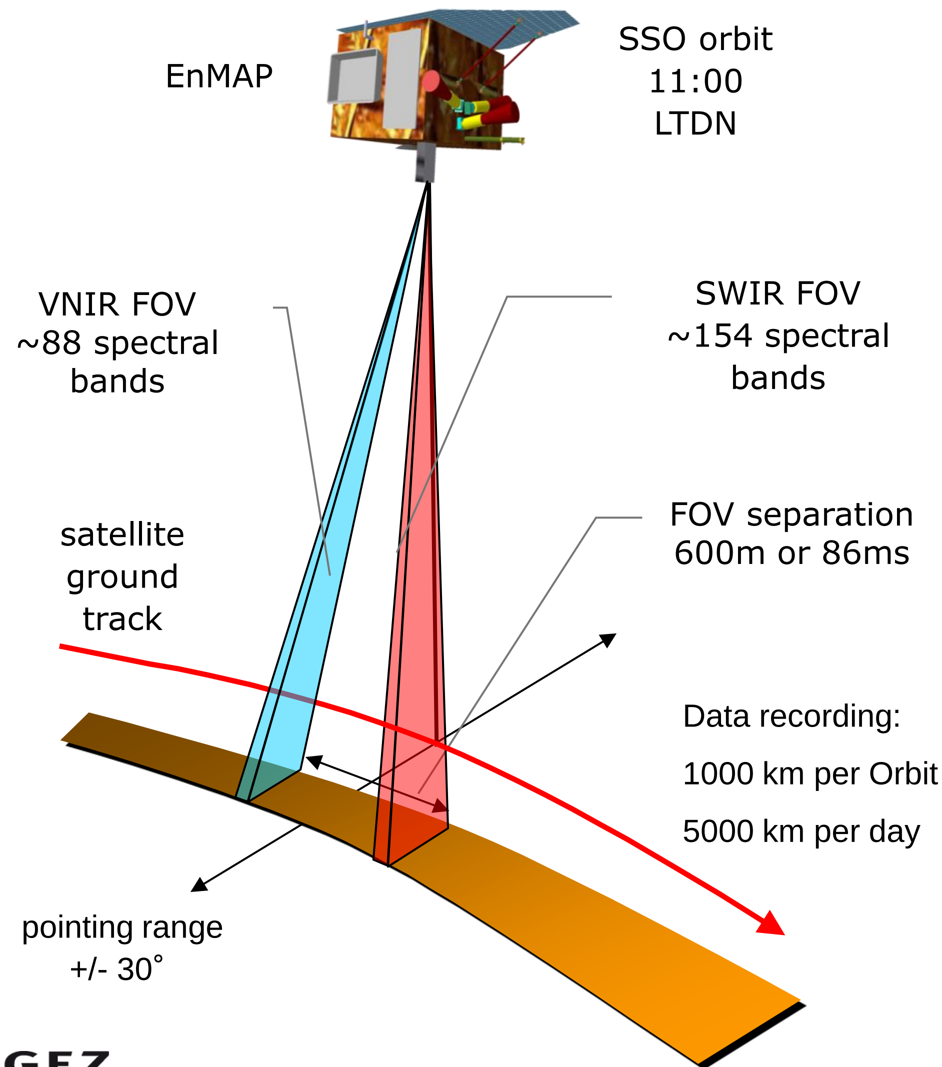


- EnMAP: Environmental Mapping and Analysis Program
- Conceived as an operational imaging spectroscopy mission for EO
- Good data quality & higher level products from ground segment
- Open data policy

- Core funding from the German Federal Ministry of Economics and Technology
- Currently under construction phase, launch ~mid 2018



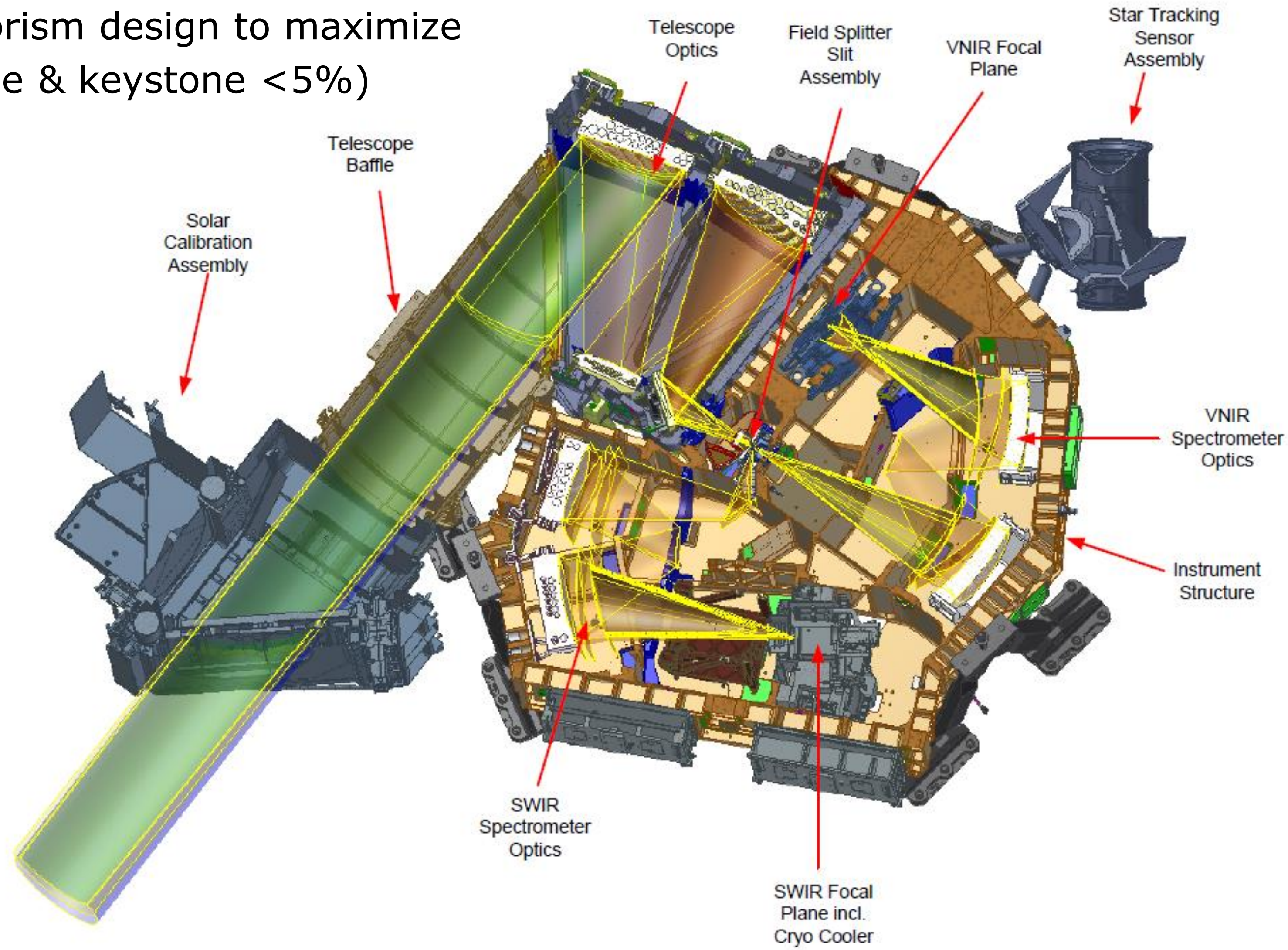
EnMAP – Main Mission Parameters



- Push-broom imaging spectrometer
- Spectral range
  - 420 nm to 1000 nm (VNIR)
  - 900 nm to 2450 nm (SWIR)
- Mean spectral sampling distance
  - VNIR ~6.5 nm
  - SWIR ~10 nm
- Signal-to-noise ratio (at Lref)
  - > 500 @ 495 nm
  - > 180 @ 2200 nm
- Swath width 30 km; length up to 1020 km
- Ground Sampling Distance 30 m
- Repeat rate
  - 27 days nadir
  - 4 days at ± 30° off-nadir pointing
- Mission lifetime ≥ 5 years

Dual-spectrometer instrument concept

- Independent VNIR & SWIR FPAs: field splitter & double entrance slit
- Curved Offner prism design to maximize uniformity (smile & keystone <5%)



Pre-processing: from raw data to surface reflectance spectra

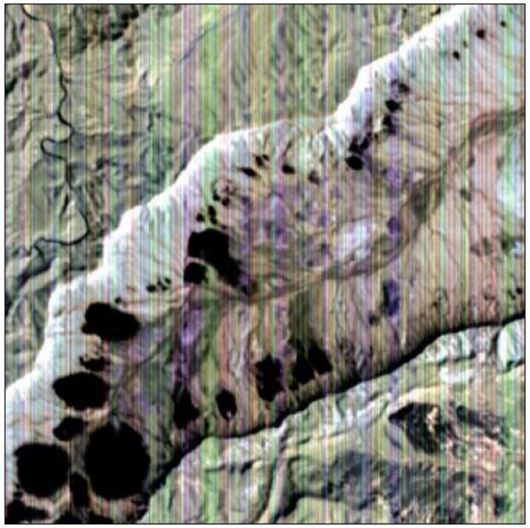
- **Data pre-processing in Remote Sensing:** series of operations with the image in order to convert the raw data acquired by the sensor into high quality reflectance data in a given map projection.
- **Name convention for remote sensing data products:**
  - Level 0 data - digital number data

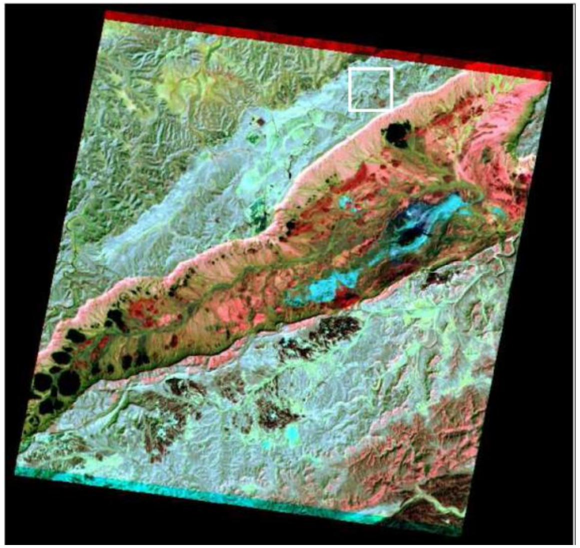
  → **Radiometric correction**
  - Level 1B data - radiometrically calibrated radiance data

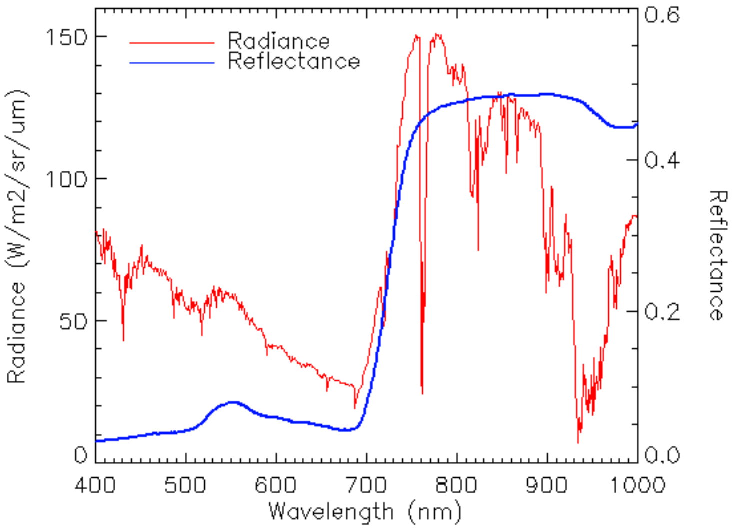
  → **Geometric correction**
  - Level 1C data - radiometrically calibrated radiance data in a map projection

  → **Atmospheric correction**
  - Level 2 data – Surface reflectance data in a map projection

“Raw data” (digital numbers) → Calibrated Radiance → Geographical projection → Surface reflectance







Data Products & Acquisition Priorities

User products: Level 1B, Level 1C, Level 2A

Product	Definition
Level 0	Time-tagged instrument raw data with auxiliary information (internal)
Level 1B	Radiometrically-corrected, spectrally- and geometrically-characterised radiance
Level 1C	Orthorectified level 1B
Level 2A	Atmospherically-corrected level 1C

Acquisitions:

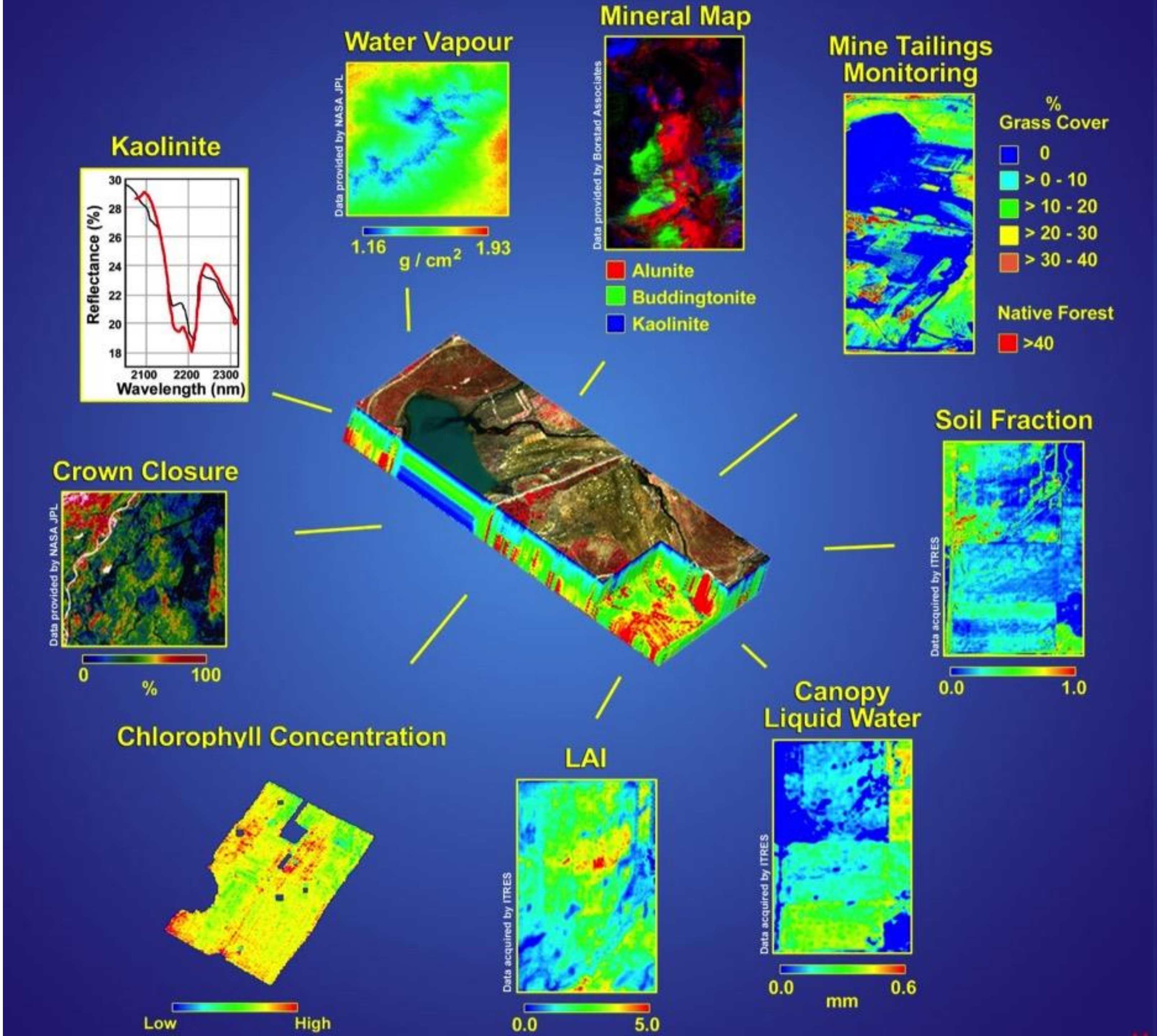
- Restricted to 1000 km/orbit, and 5000 km/day
- Daily acquisition plan (mostly) based on user requests and categories

Priority	Request
1	Internal user
2	Support for catastrophic events
3	Registered users (Cat.1) excellent proposals
4	Registered users (Cat.1)
5	Non-registered users (Cat.2)
6	Requests beyond fulfilled contingents
7	Background mission

Imaging Spectroscopy & Science

→Quantitative mapping for a wide range of research fields

→Great potential for new (and unexpected!) applications



EnMAP Science Plan

Content

- Research context and significance
- General mission framework
- EnMAP perspectives and impact
- Scientific exploitation strategy
- Defined by EnSAG

www.enmap.org

EnMAP Science Advisory Group (EnSAG)

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Tobias Hank


Matthias Locherer

Agriculture

Uni Trier


Joachim Hill


Henning Buddenbaum

Forests

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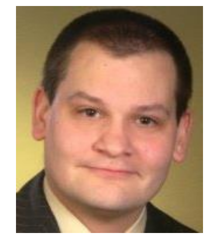
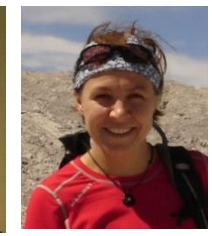

Tobias Storch


Uta Heiden

Ground segment + Urban

HU Berlin


Patrick Hostert


Pedro Leitão


Sebastian v. d. Linden


Andreas Rabe

Natural Ecosystems and Ecosystem Transitions

HZG Geesthacht


Hajo Krasemann


Roland Doerffer


Hong Yan Xi

Coastal and inland waters

ESA


Mike Rast

Uni Lethbridge

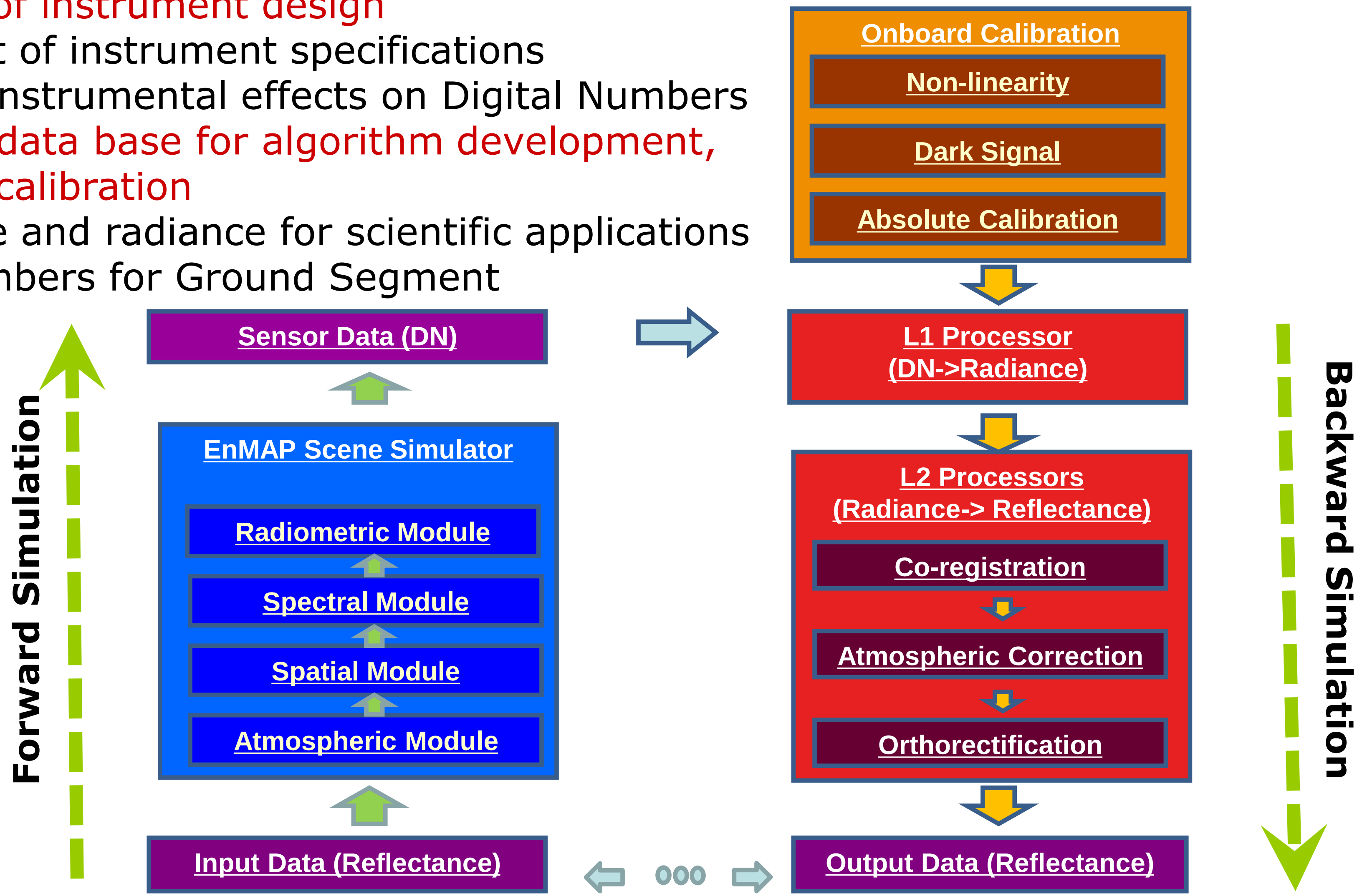

Karl Staenz

Scientific advisory

EnMAP end-to-end scene simulations

Objectives:

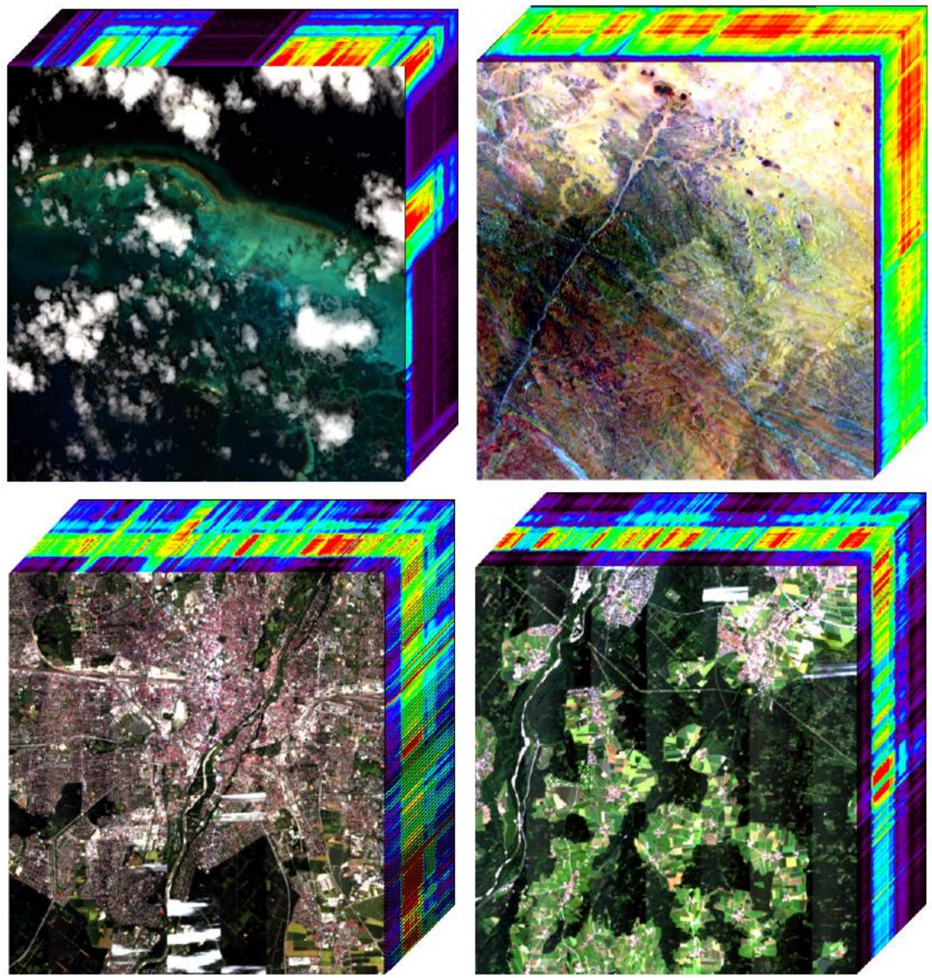
1) Optimization of instrument design
   - Refinement of instrument specifications
   - Impact of instrumental effects on Digital Numbers
2) Generating a data base for algorithm development, validation and calibration
   - Reflectance and radiance for scientific applications
   - Digital Numbers for Ground Segment



Segl et al., IEEE JSTARS, 2012

EnMAP end-to-end scene simulations

Simulation of (i) EnMAP-like TOA radiance images and (ii) L2 surface reflectance after pre-processing



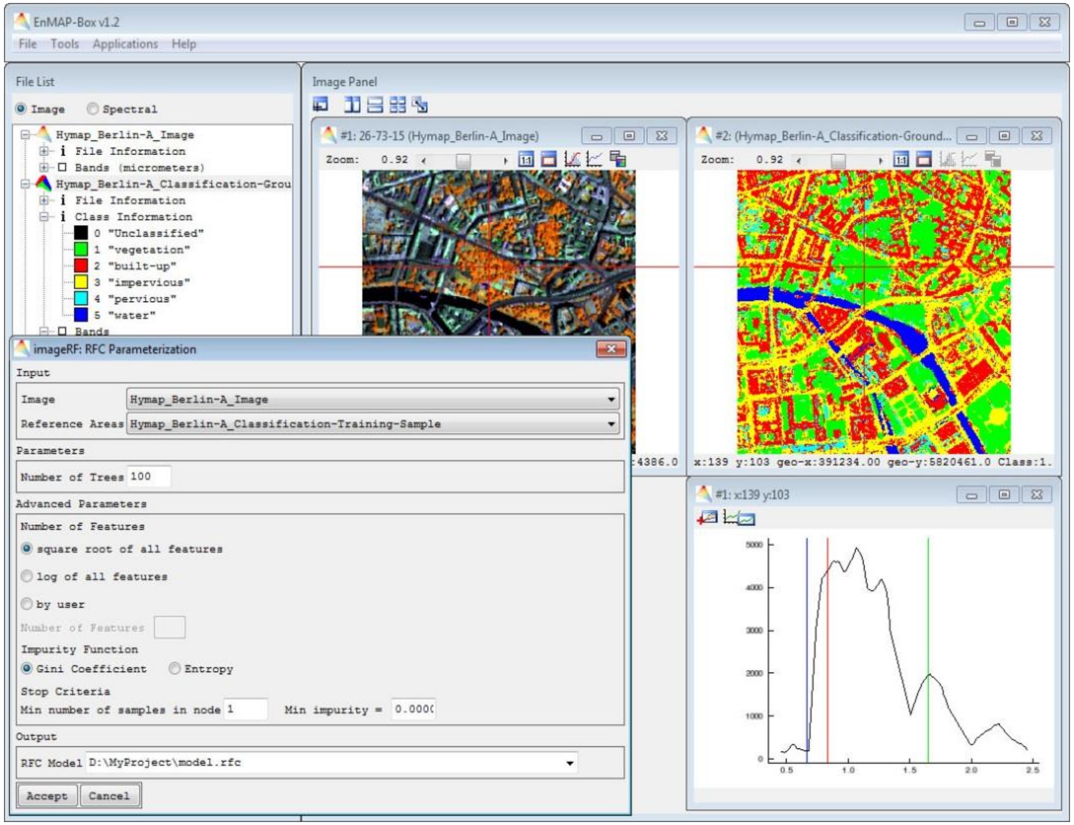
Many (>100) simulated EnMAP data sets already available

Contact Karl Segl at GFZ if you need simulations for your study site!

EnMAP-Box

Rabe, van der Linden et al. (HU Berlin)

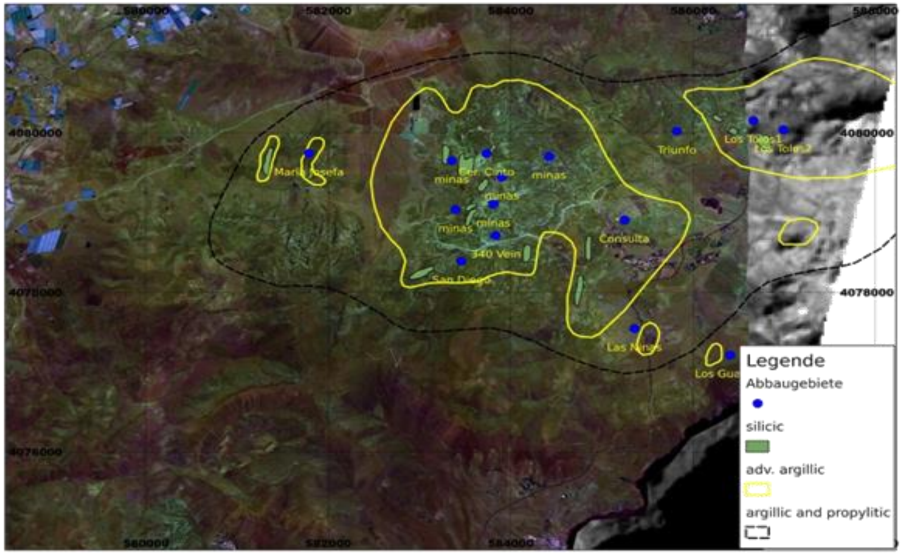
- Software for the pre-processing and scientific exploitation of EnMAP data
- Free, open source and platform independent
- Reference algorithms for different application fields being developed by EnSAG partners



Download from
www.enmap.org/?q=enmapbox

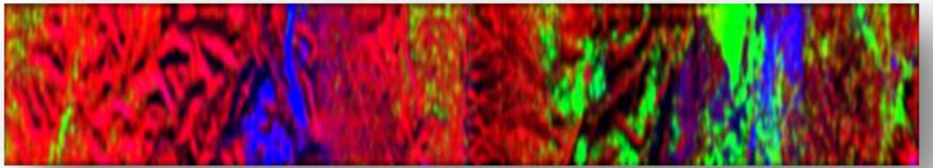
EnGeoMAP: Geological Mapping

- Expert system for geological mapping of resource deposits and monitoring of mine waste
- Full mineral identification and semi-quantification



Gold mining sites Rodalquilar Caldera; Spain; HyMAP, Hyperion; Geology after Arribas (1989)

Hyperspectral image



L3-Product: abundant minerals (red-carbonates, blue – epidotes, green-clays

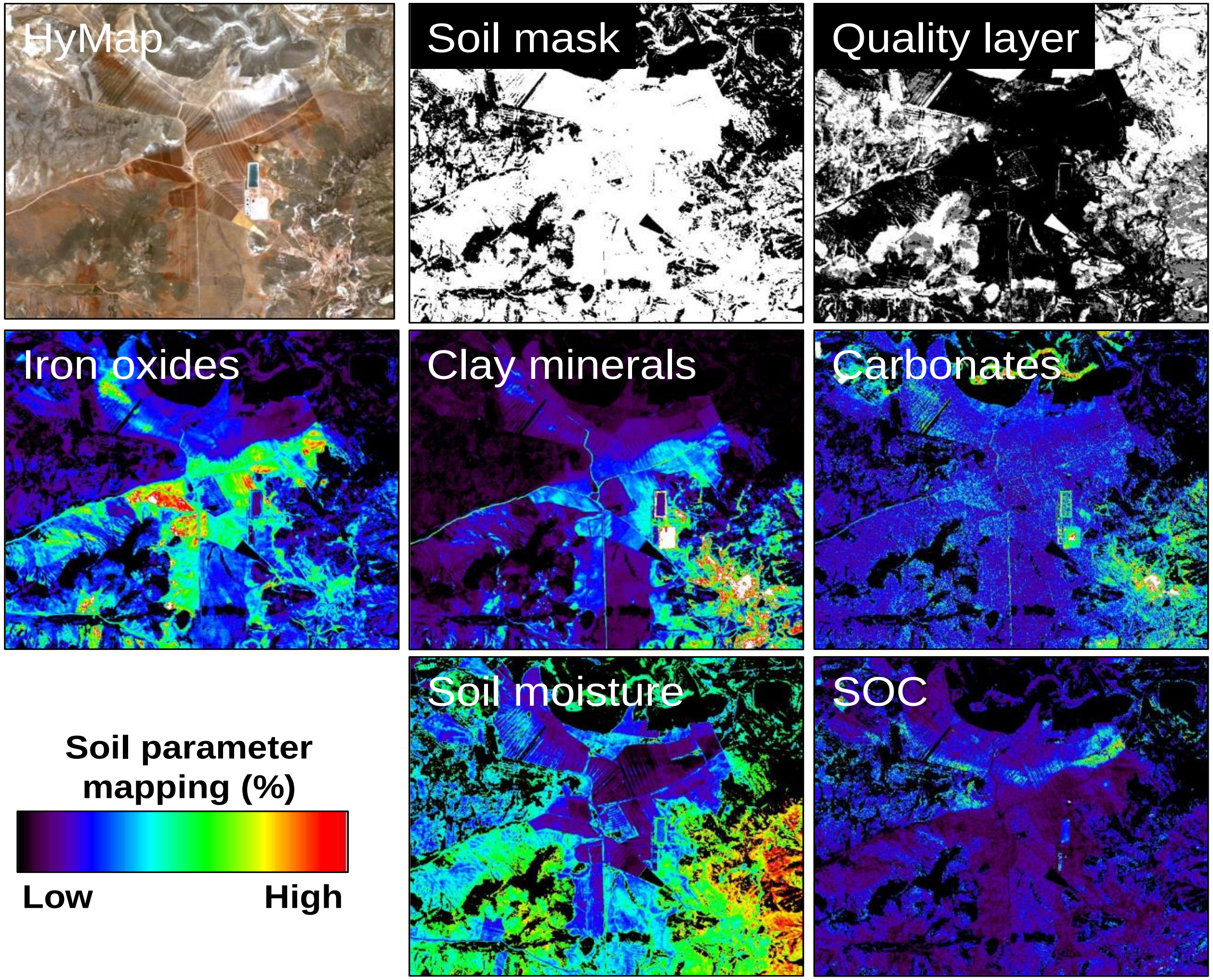
Rogass et al.

EnSoMAP: Digital Soil Mapping

- Expert system for soil mapping
- Automatic generation of semi-quantitative soil maps (soil moisture content, organic carbon, iron oxides, clays, carbonates content) + quality layer map
- User custom option for fully quantitative soil mapping
- Currently distributed for airborne users:

www.gfz-potsdam.de/hysoma

Chabrillat et al.



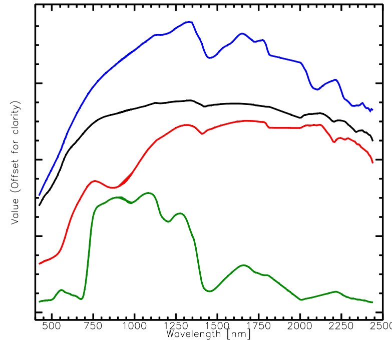
Example L3 soil products

Soil mapping: Potential from spaceborne platforms

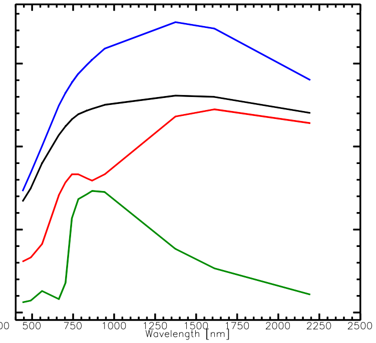
- **Upcoming high-quality imaging spectroscopy data expected from next generation orbiting sensors to be launched soon,** e.g. EnMap (2018), HISUI (2018), Shalom (2020), HyPXIM (>2023), HypSRI (>2023)

- **From local → regional → global scale**
  - Support to soil and agriculture related EU policies and different stakeholders
  - Global soil mapping and monitoring

- **Demonstration of potential of hyperspectral imagery for soil mapping applications from airborne to satellite scale over bare fields**
  - Simulation of satellite images based on existing datasets
  - Algorithm development
  - Feasibility and expected accuracy for delivery of soil products



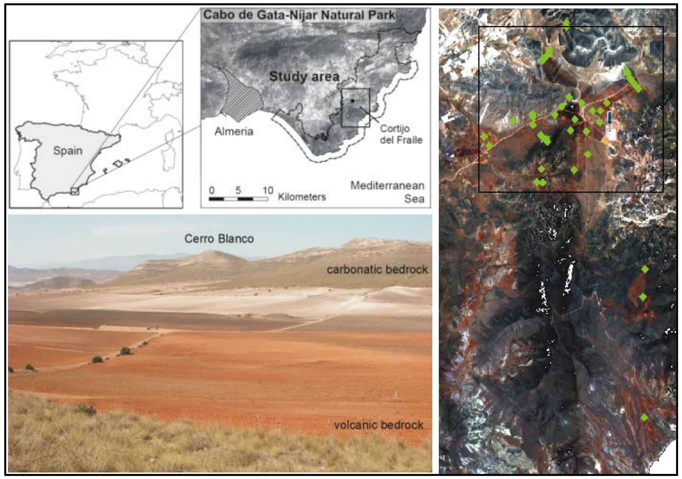
EnMAP simulation



S-2 simulation

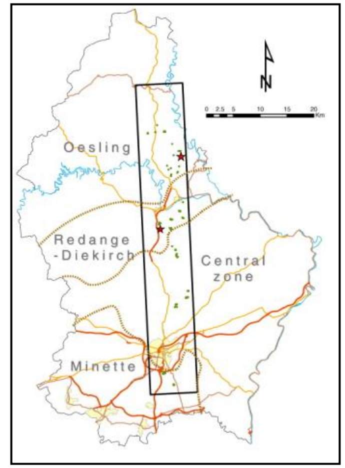
Case study: Soil properties mapping in bare crops

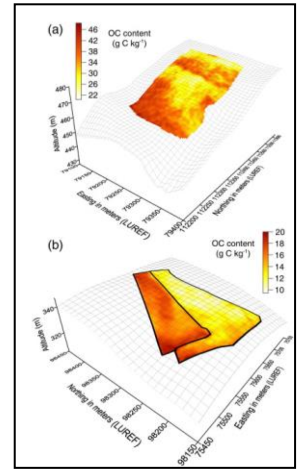
Semi-arid Mediterranean Spain



- Parameters of interest: Mineralogy (Clay, iron oxide, $CaCO_3$ content)
- In-situ validation dataset: 50 samples
- Airborne HyMap imagery: 126 sp. bands ~400-2450nm, SSD 12-17 nm. GSD 4.5m

Luxembourg

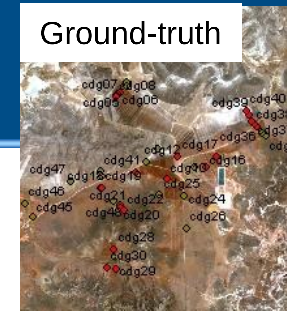




- Parameter of interest: Soil organic carbon (SOC) content
- In-situ validation dataset: 81 samples
- Airborne AHS-160 imagery: 20 sp. bands ~442-1019nm, SSD 27-30 nm. GSD 2.6m
- Collaboration UCL, Louvain, Belgium

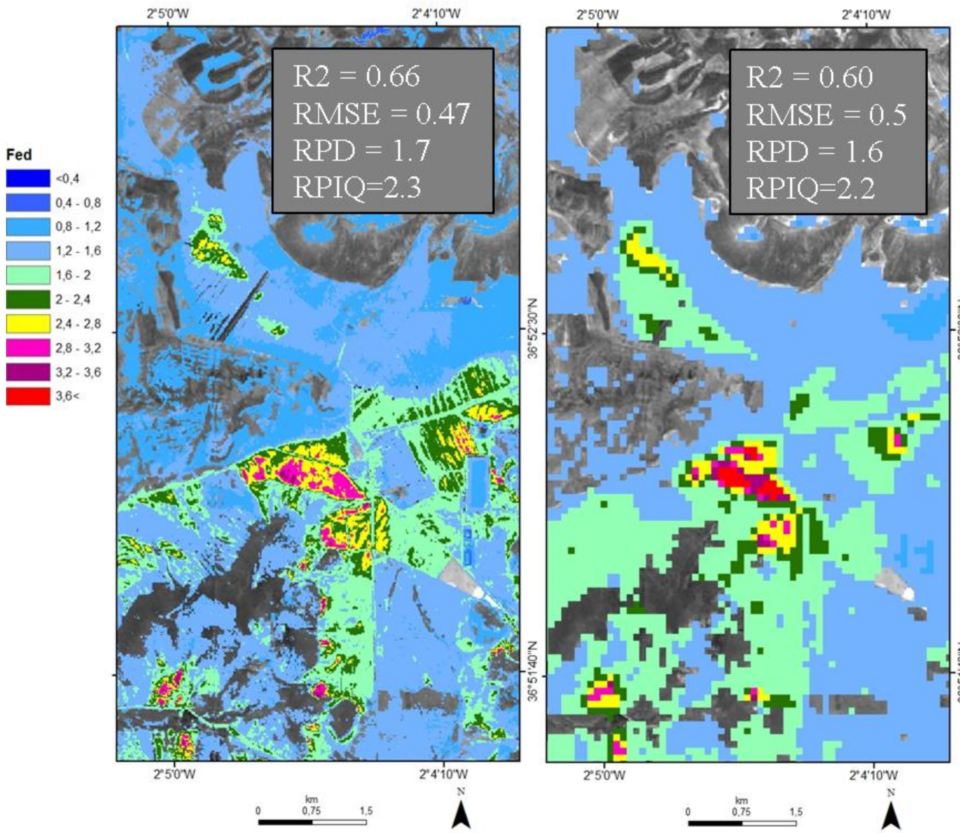
⇨ **EnMAP end-to-end scenes simulation** of (i) EnMAP-like TOA radiance images and (ii) L2 surface reflectance after pre-processing (Segl et al., 2012): 244 sp. bands ~450-2450 nm, SSD 6.5-10nm. GSD 30m

Potential spaceborne soil mineralogical mapping

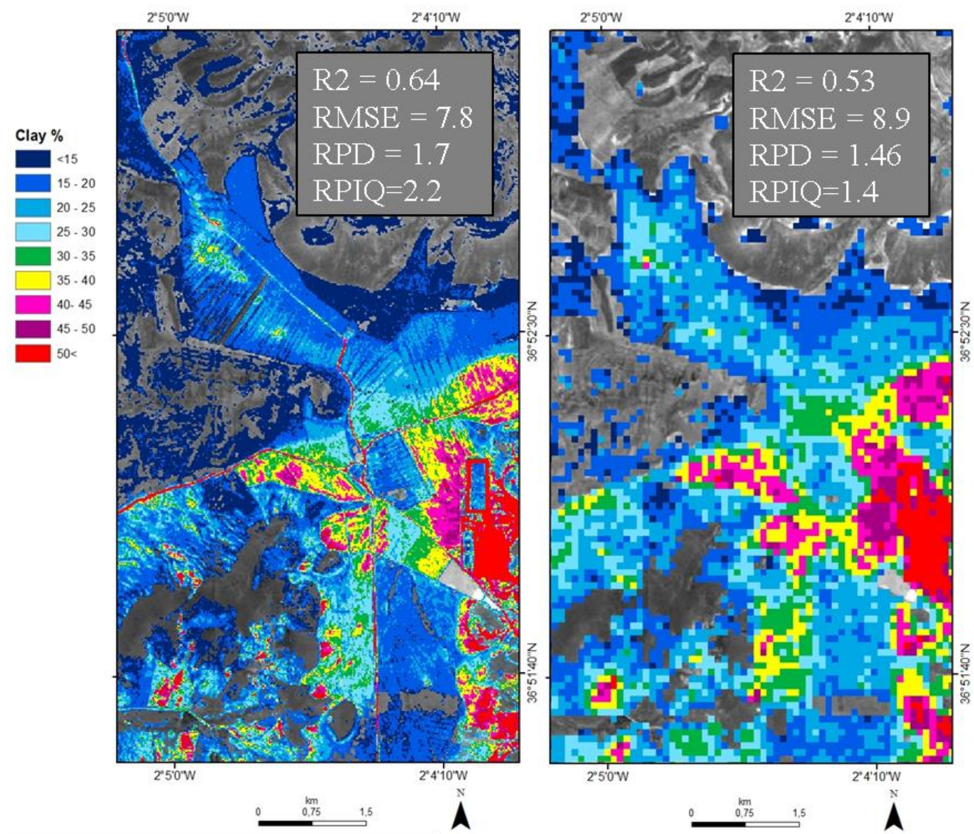


Retrieval of soil mineralogical content (AutoPLSR): Soil maps and prediction model performances vs. Ground-truth data

Airborne HyMap (4m) | Simulated EnMap (30m)



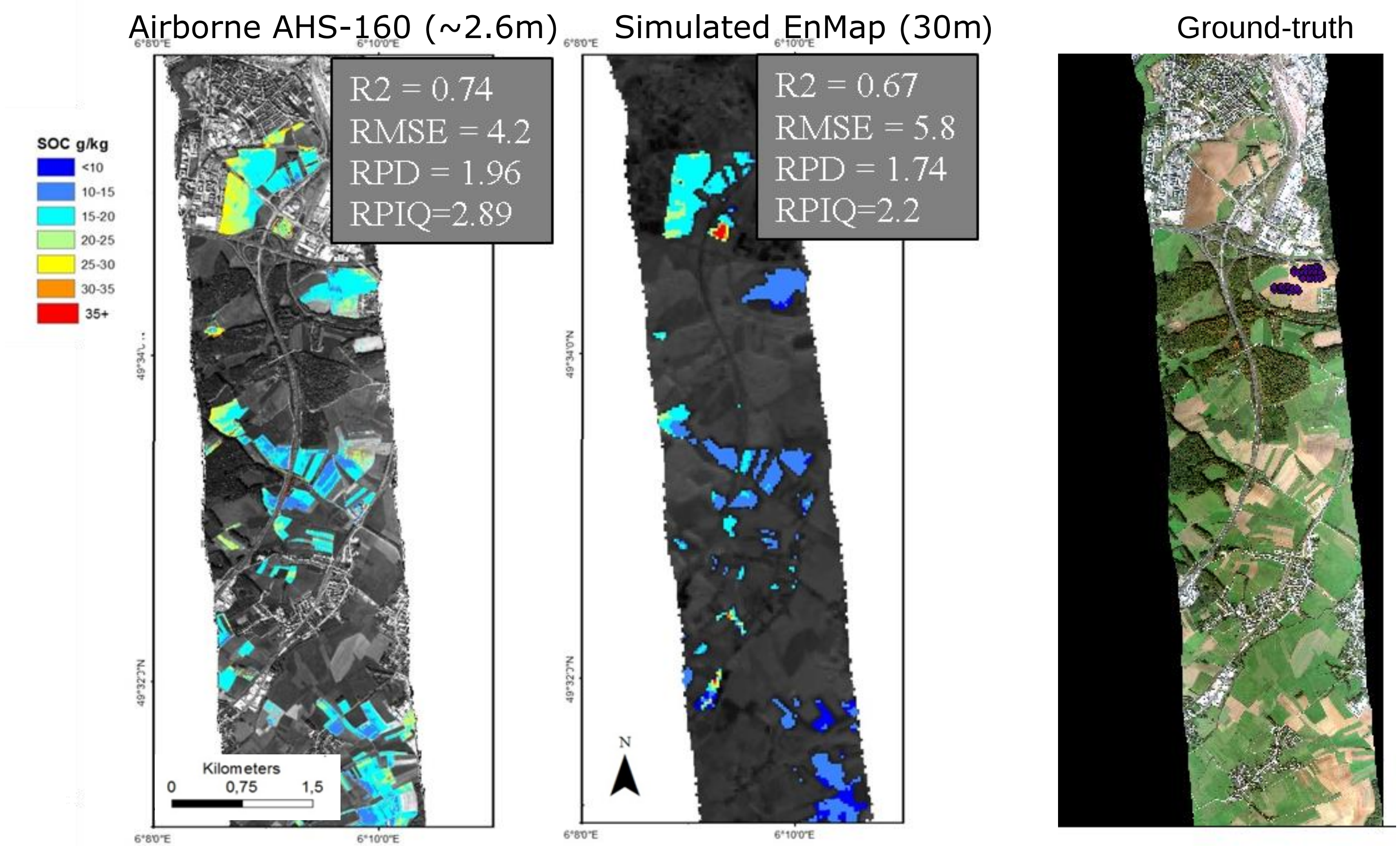
Airborne HyMap (4m) | Simulated EnMap (30m)



Steinberg et al., 2015,

Potential spaceborne soil organic carbon mapping

Retrieval of soil OC content (AutoPLSR): Soil maps and prediction model performances vs. Ground-truth data



Steinberg et al., 2015, Rem. Sens.

Overall agreement from airborne to spaceborne
Slighly reduced prediction accuracy at spaceborne level

EnMAP-flight campaigns

Airborne hyperspectral images and associated in-situ data

provided free of charge to science community under CC BY-SA Licence

Search **metadata portal** at www.enmap.org → data

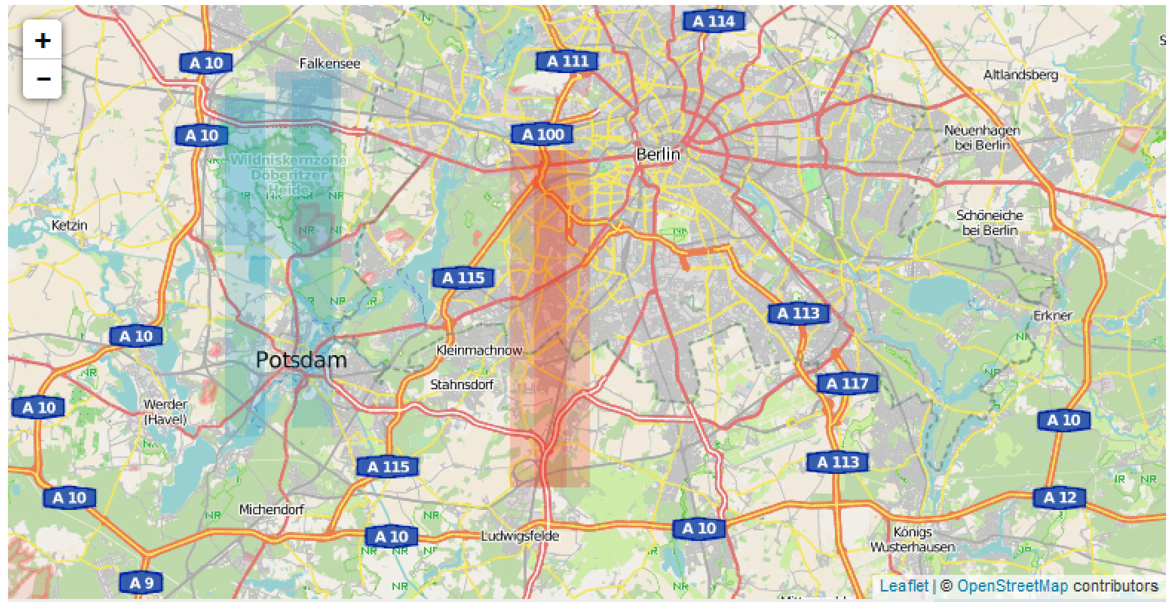
Datasets published as **data publications** (with DOI)

Technical Report will be provided with each dataset (documentation of data acquisition, processing, quality etc.)

http://www.enmap.org/?q=flightbeta

EnMAP - Flight campaigns

Several hyperspectral airborne flight surveys have been carried out in the frame of the EnMAP preparatory program to support method and application development in the prelaunch phase. The metadata base below provides details about the campaigns, information about recorded airborne hyperspectral data sets and other data associated to the respective campaigns like field and laboratory measurements. Further, it informs about the availability of simulated EnMAP and Sentinel-2 data. Contact details of the data owners are given for interested researchers regarding data exchange. The data listed in this metadata base is freely available for scientific purposes.

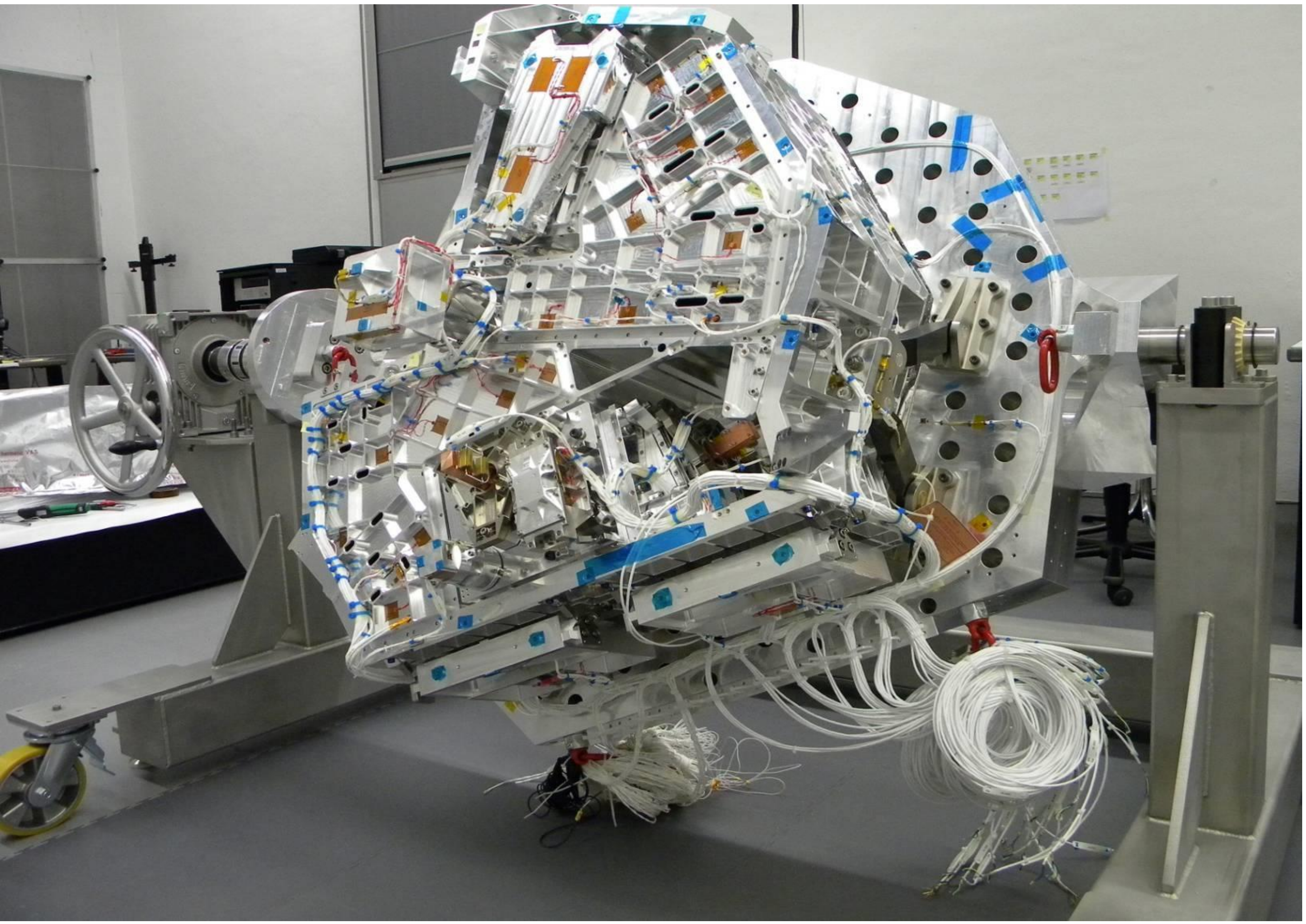


Name	Application	Sensor	Product-Level	Date
search				
Idarwald/Hochwald (DE)	Forest	HySpex VNIR-1600 HySpex SWIR320m-e	L1	Jun 9, 2014
Idarwald/Hochwald (DE)	Forest	HySpex VNIR-1600 HySpex SWIR320m-e	L1	May 5, 2014
Pfälzer Wald/Merzalben (DE)	Forest	HySpex VNIR-1600 HySpex SWIR320m-e	L1	Apr 16, 2014
Idarwald/Hochwald (DE)	Forest	HySpex VNIR-1600	L1	Apr 10, 2014

Support to young researchers

- **PhD Programme:** 15 PhD projects currently ongoing on different research areas and groups in Germany
- **YoungEnMAP:** International Summer Schools organised every year

EnMAP summer school participants (Lauenburg, March 2015)



Thank you for your attention!

Federal Ministry of Economics and Technology

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www.enmap.org