Session 2: Forthcoming EO capacities for monitoring soil parameters

Toward soil mapping and monitoring from imaging spectroscopy: Capacity of new generation hyperspectral satellite sensors

- On the example of EnMAP

Prof. Dr. Sabine Chabrillat and the soil group at GFZ remote sensing sectio

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Head hyperspectral remote sensing applications group, Potsdam
and
LUH- Leibniz University Hannover, Institute of soil science, Hannover,
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GFZ Helmholtz Centre Potsdam

Leibniz Universität Hannover

ESA Symposium on Earth Observation for Soil Protection and Restoration

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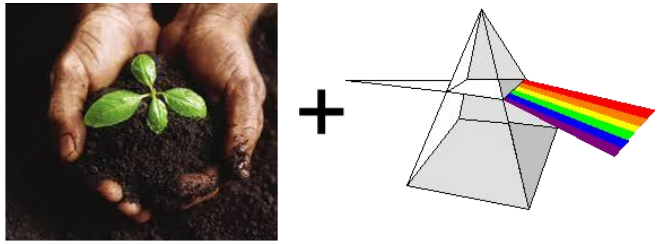
Monitoring of soil properties

- Hot topic right now
  - Soil as a provider of foods and services, role as carbon storage
  - European Soil Protection Directive
    - Mapping and monitoring of topsoil properties
    - Identification soil erosion/degradation hotspots
    - Soil fertility, Management agricultural practices
  - European green Deal (healthy soils, biodiversity)
  - The international "4 per 1000" Initiative (Soils for Food Security and Climate)
  - Policies for reducing greenhouse gases emissions



Soil mapping is one of the pillars to the challenge of sustainable development Jeffrey Sachs

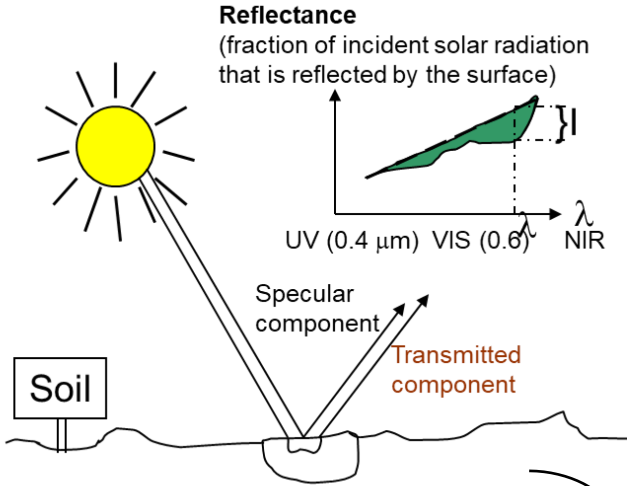
- Main issues
  - Need for accurate, up-to-date and spatially referenced soil information
  - Existing maps: static, large effort, not completely up-to-date
  - Soil Monitoring Law recommends research on monitoring of spatial and temporal changes of soils

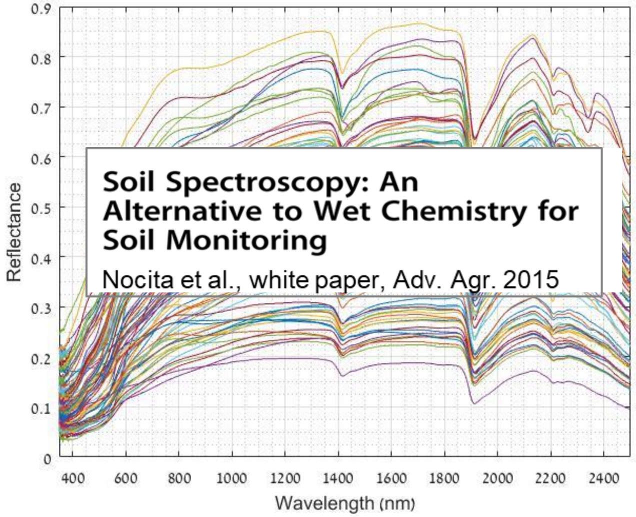
→ Global interest in soil spectroscopy and remote sensing of soils methods

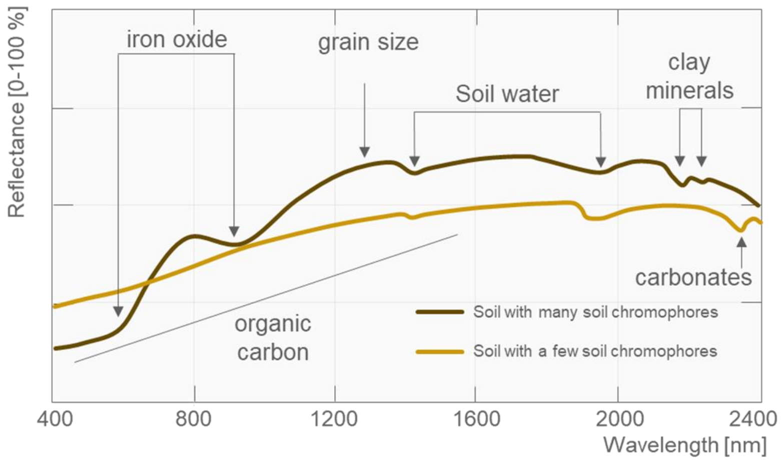
→ Potential applications

In the lab: Soil spectroscopy → Dry chemistry

- Interaction of solar radiation with soil
- Provides unique information about soil composition





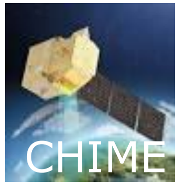


Soil attribute
pH_{Ca}
pH_w
pH_b
LR
OC
Clay
Silt
Sand
CEC
Ca
Al
NO_3–N
P_{Col}
K
EC

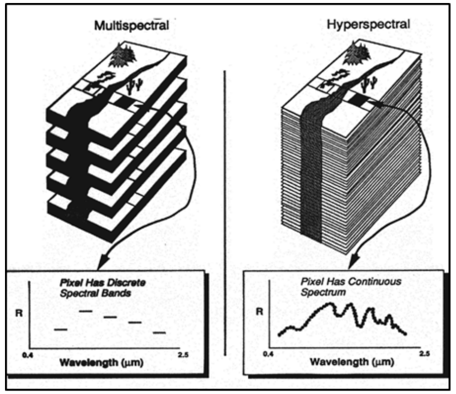
- Important soil chromophores in soil Vis-NIR reflectance
- Extraction of chemical and physical attributes with spectral modeling
- Endless potential applications – Agriculture, Environmental, Health…

Imaging spectroscopy or hyperspectral remote sensing

- Sensors that allow to acquire >100 narrow contiguous spectral channels
  - **Current operating missions** for soil mapping (selection): ASI PRISMA, DLR/GFZ EnMAP
    - Started ~2019-2022, *2nd generation* hyperspectral missions 400-2500 nm
    - Target missions: Global coverage but not global mapping missions. Data acquisition is on-demand
  - **Upcoming global IS mapping missions**: ESA Copernicus CHIME, NASA SBG
    - Planned end 2020s, *3d generation* hyperspectral missions 400-2500 nm
    - Operational global missions



- Hyperspectral (spectroscopy) vs. multispectral (Landsat/S-2, <~10-15 spectral bands)
  - Direct detection of soil constituents
  - Direct detection of bare dry soil pixels, PV/NPV, soil moisture, based on the soil spectroscopy signal



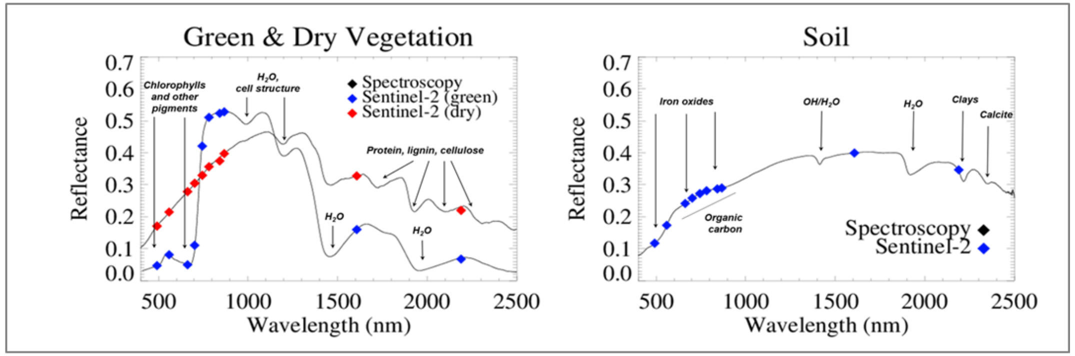
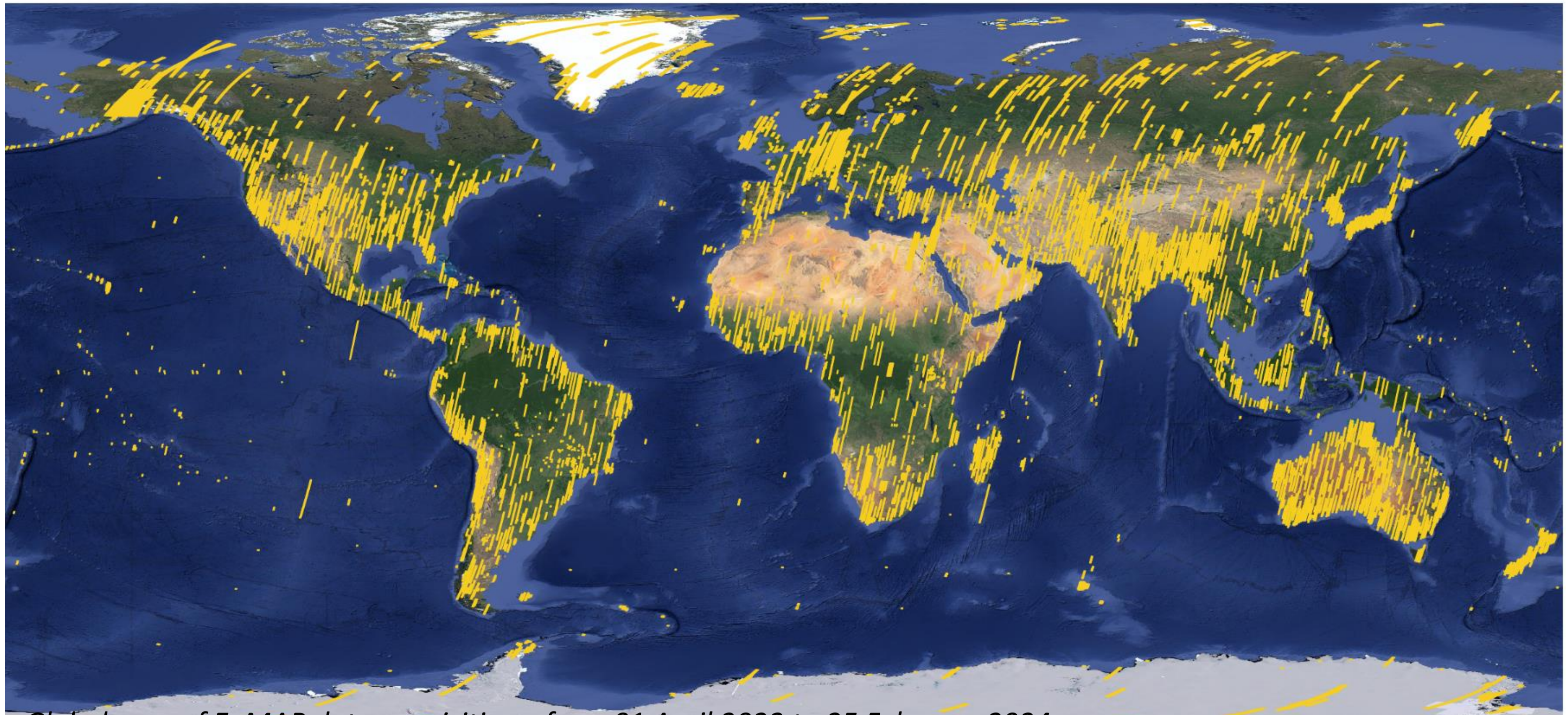


Fig. L. Guanter (Rast & Painter, 2019, Surv Geophy)

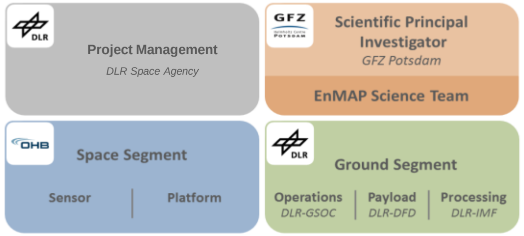
EnMAP: A new sensor for monitoring Earth's environment

- 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



Global map of EnMAP data acquisitions from 01 April 2022 to 25 February 2024

Mission consortium

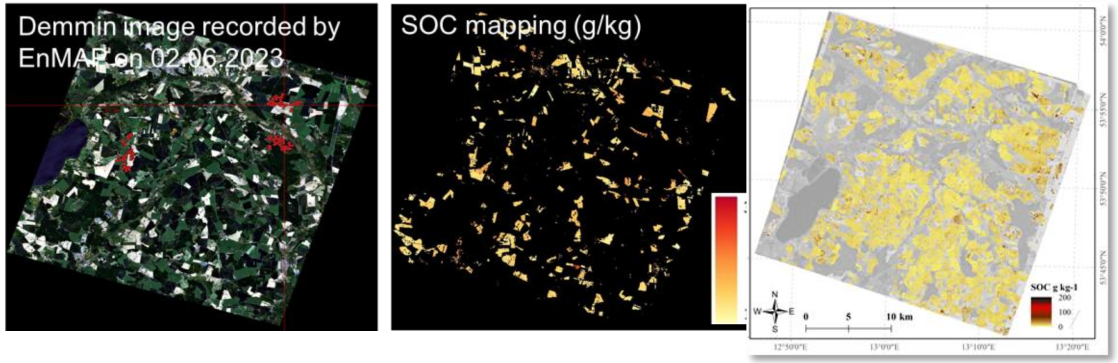


- DLR Space Agency in Bonn is responsible for the overall project management
- Core funding from the German Federal Ministry of Economic Affairs and Climate Actions (BMWK)
- GFZ science PI: Extensive Scientific Exploitation preparation program supported by EnSAG (EnMAP science advisory group) and EnMAP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

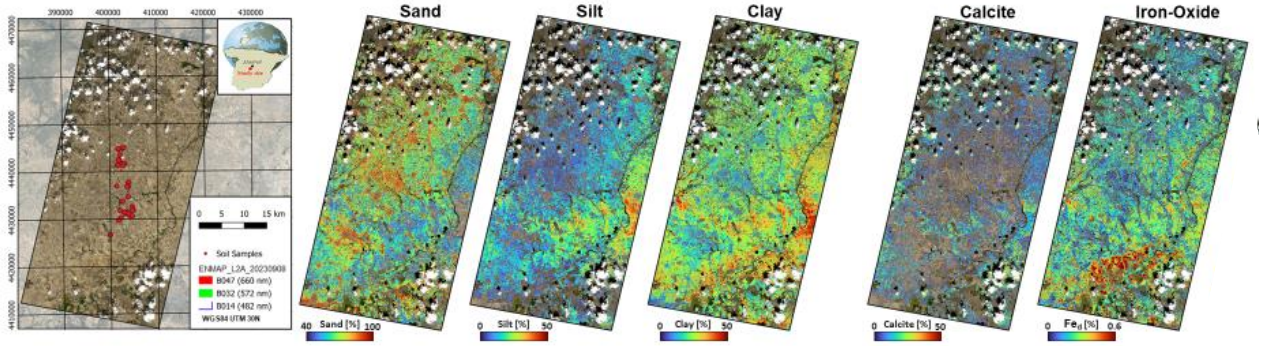
More information www.enmap.org

EnMAP soil mapping: selected examples

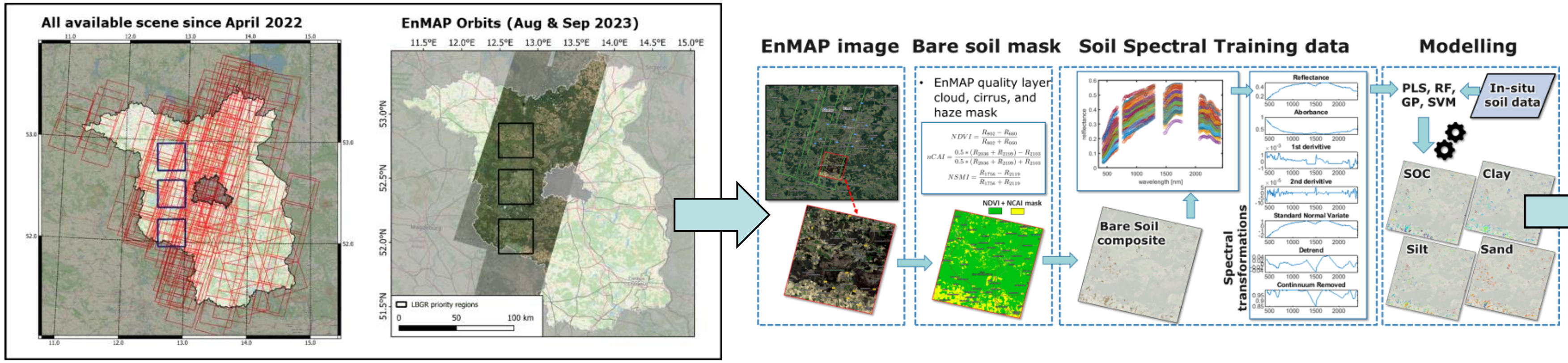
- From one scene

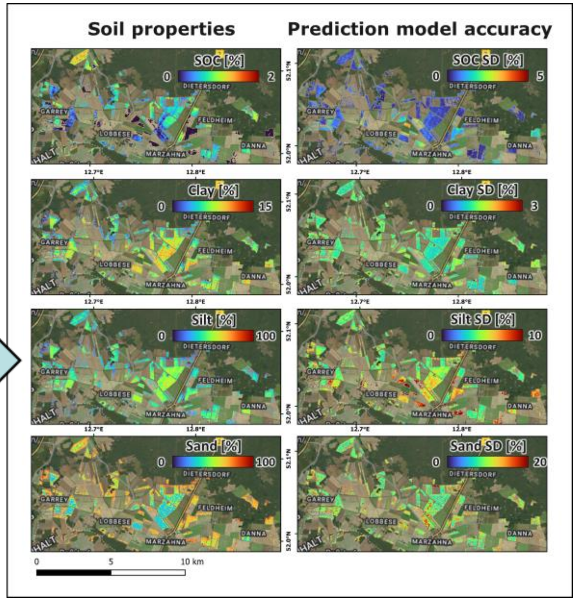


to multiple scenes and multiple key soil variables



- To regional mapping
  - Development of an automatic workflow from the images to the soil mapping

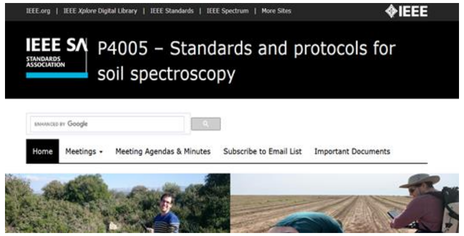




- To hyperspectral temporal composites

Summary and outlook

- Spaceborne hyperspectral sensors holds large potential for soil mapping and monitoring
- Focus on key soil health parameters where dry chemistry demonstrated highest determination capabilities
- Major advances in methodology and data availabilities were achieved
  - Integration of **operational algorithms** and **workflow**
  - Integration of **large soil spectral libraries** (e.g. LUCAS) as model calibration
  - **Machine Learning**/Deep learning/AI increasingly used
  - Global soil databases
    - Advances on **standards and protocols** for harmonized soil spectral libraries
    - **Large initiatives** (FAO Glosolan, SoilSpec4gg, BraSpecS, …)



- Nevertheless, challenges to be addressed
  - **Technical/Data challenges**: Surface disturbances, modeling accuracy, more global soil databases
  - PRISMA/EnMAP & upcoming spaceborne IS missions: **Synergies with other sensors** (S2 for higher multitemporality, S1 for soil moisture, LSTM for texture parameters such as sand) and contribution to Copernicus services
  - **Support timely delivery of soil products and integration into soil mission**
    - Developing future Copernicus GEO-services (e.g. upcoming CHIME high priority SOC products)
    - **Integration of Earth Observation soil maps into soil monitoring services**: where, when, how
    - Especially, EO could support **regular monitoring of spatial and temporal changes of soils**

Thank you for your attention !

We would like to acknowledge all our colleagues from the Worldsoils consortium and from EnMAP soil mapping and verification projects (MRV4SOC, WHEATWATCHER, LGRB..)

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