

Hyperspectral satellite imaging

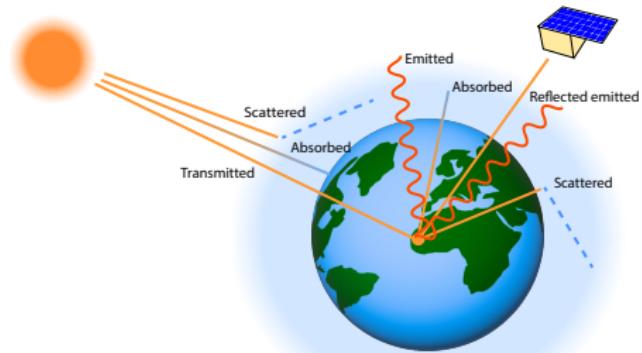
Digital imaging systems - 1MD130

Linus Falk

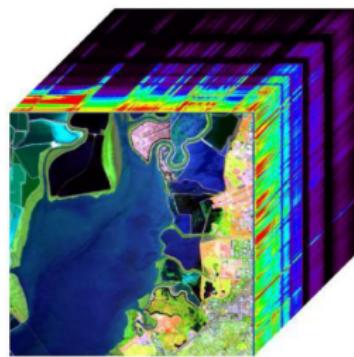
March 7, 2023

Introduction

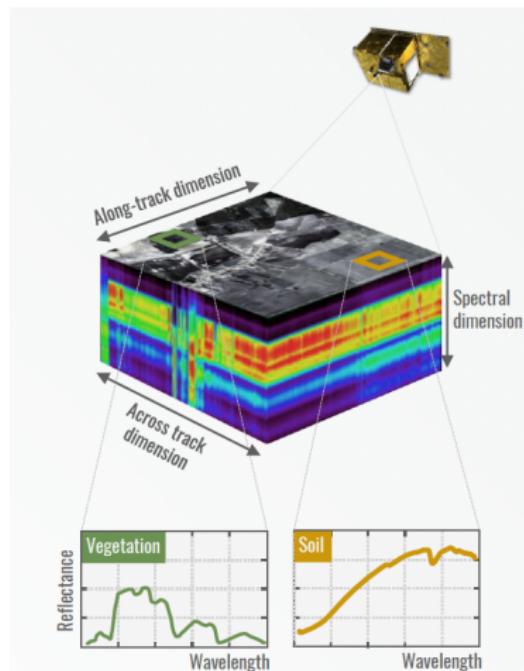
- Spectroscopy of reflected light from earth surface
 - Passive technique
 - Acquires images in many spectral bands so for each pixel a reflectance spectrum can be derived
 - Important absorption features occur in the 400-2500 nm band (reflected solar radiation dominates natural EMS)



Introduction



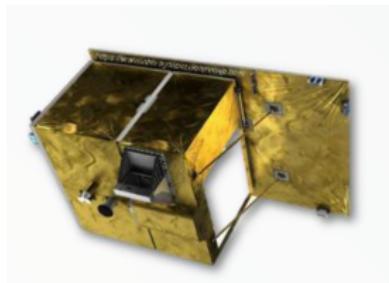
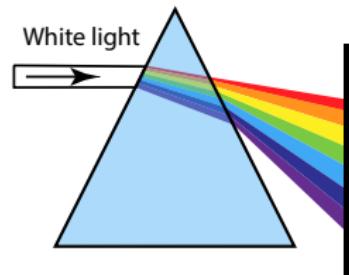
[1]



[2]

Brief History

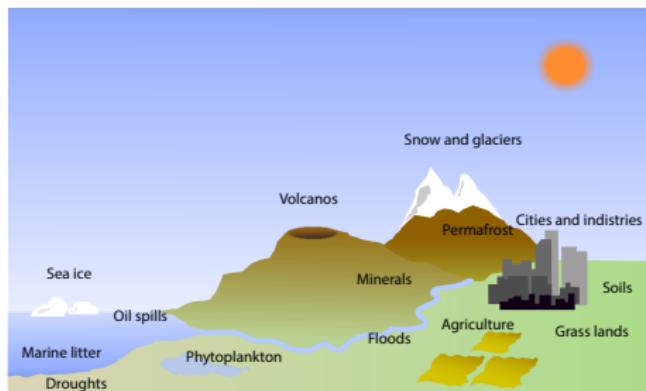
- **1660** Division of light - Sir Isaac Newton
- **1800-1820** Discovery of absorption bands - Joseph von Fraunhofer
- **1982** First imaging spectrometers - Jet propulsion lab (JPL)
- **2000** First spaceborne imaging spectrometers - NASA EO-1
- **2022** Launch of EnMAP - DLR



[2]

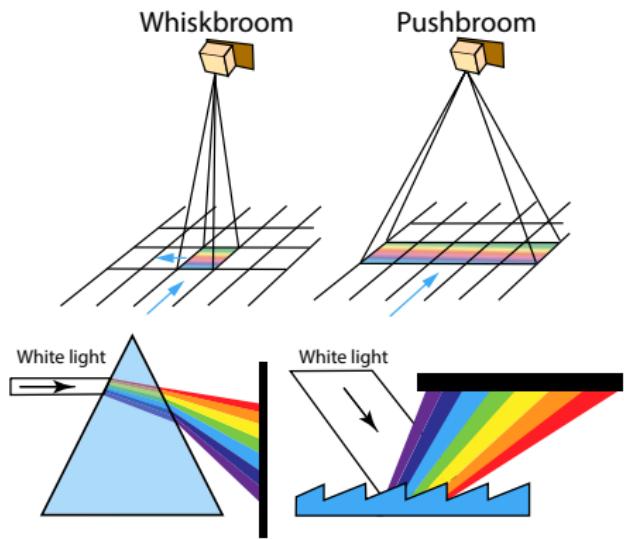
Use today & limiting factors

- Used in research
 - Ecosystem processes
 - Surface mineralogy
 - Water quality
 - Soil type and erosion,
 - vegetation type and more...
- Global/National scale
 - Limited use for private sector
- Defence/military

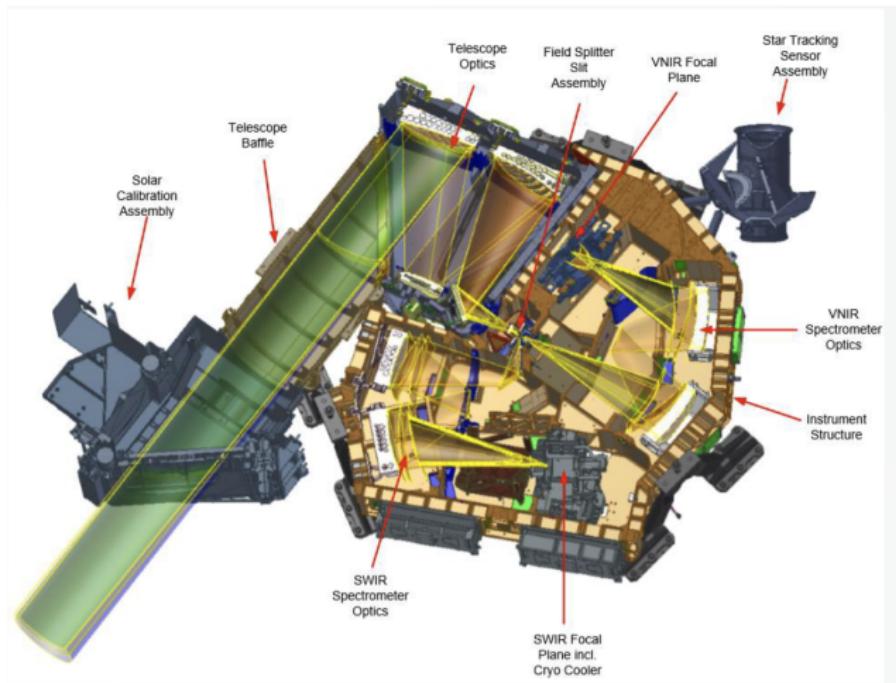


How is the image formed

- Scanning:
 - Push-broom
 - Whisk-broom
- Dispersive optics:
 - Diffraction Grating Spectrometers
 - Prism Spectrometers
- Sensor types :
 - CMOS & CCD - NVIR
 - MCT (Mercury Cadmium Telluride) - SWIR (Cooled)



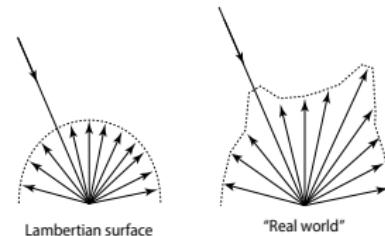
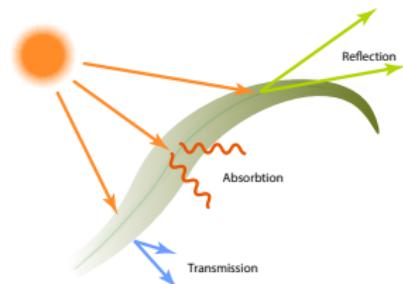
How is the image formed



[2]

What property of the sample is imaged?

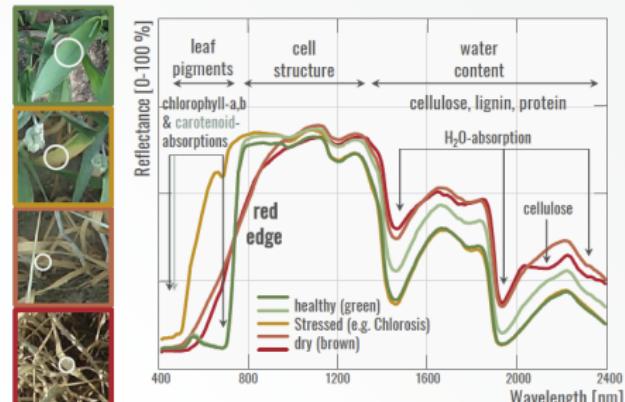
- Interaction radiation
 - **Absorption**
 - Reflection
 - Transmission
- Absorption processes
 - Electron transfer
 - Vibrational process
- Each material has a unique spectral characteristic



What property of the sample is imaged?



[3]



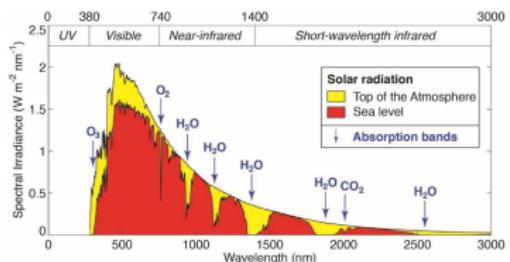
[1]

Atmospheric window

- At surface reflectance
- Top-of-atmosphere radiance
- Atmosphere absorption
 - Water vapor
 - Carbon dioxide
 - Ozone
- Atmospheric window largely transparent



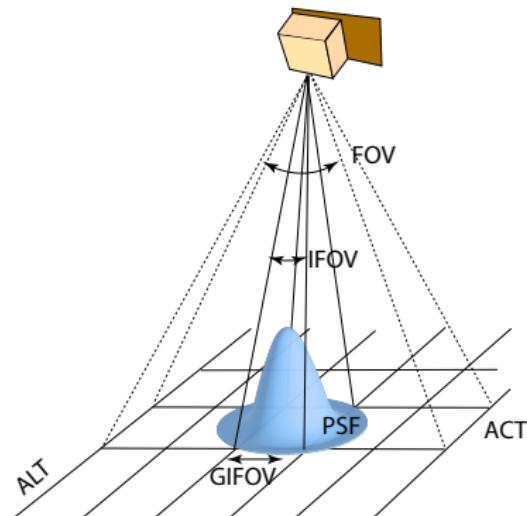
[4]



[5]

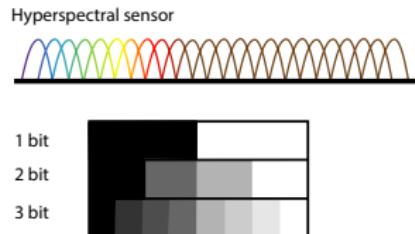
Resolution and sample size

- Spatial resolution
 - Field-of-view (**FOV**) and Instantaneous **FOV** (**IFOV**)
 - Ground-projected instantaneous-field-of-view (**GIFOV**)
 - depends on the satellite elevation and varies with the viewing angle
 - Across-track (ACT) and along-track (ALT) resolution
 - affected by integration time and smearing effects



Resolution and sample size

- Spectral resolution
 - Portion of the **EMS** to which an instrument is sensitive
 - Hyperspectral imaging - hundred of channels
- Radiometric resolution
 - Ability of the sensor to register differences in radiation
 - Typically 8 and 12 bit,
- Temporal resolution
 - Time between two acquisitions
 - Depends on satellite orbit
 - Vary greatly depending on cloud coverage



[4]

Resolution and sample size

	EnMAP
Imaging principle	Push-broom-prism
Groundsampling resolution	30m
Strip lengths	30 - 1000km
Spectral range	VNIR: 420 nm - 1000 nm SWIR: 900 nm - 2450 nm
Mean spectral sampling distance	VNIR: 6.5 nm SWIR: 10 nm
Radiometric resolution	14 bit

Table: EnMAP in numbers

Calibration Correction

- Radiometric correction
 - Sensor data to physical unit
 - Use of calibration data
 - Linear transform
- Geometric correction
 - Sensor geometry to Object/Map coordinates
- Atmospheric correction
 - Atmospheric scattering
 - Absorption effect, adjacency
 - Illumination effect (terrain & clouds)



[2]

Cost and limiting factors

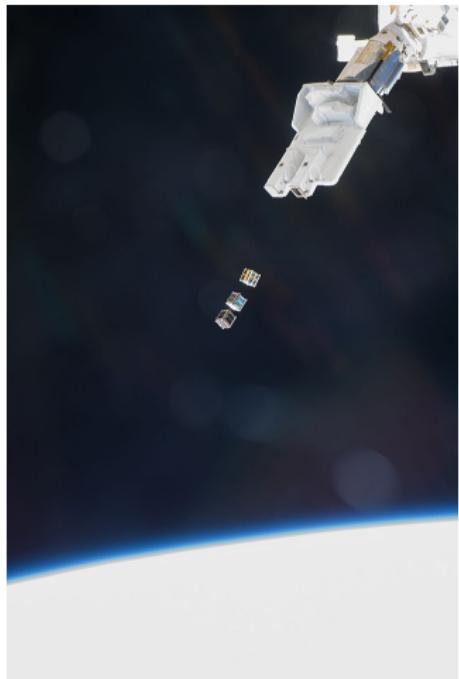
- Acquisition cost
 - EnMAP budget: 330 million euros
 - Five years of operations in orbit
- Data availability
 - Repeat interval
 - Historic and future data
- Open source project
 - EnMAPbox - QGIS
 - Visualizing and analyzing EnMAP data



[6]

Variants and future use

- CubeSats - constellation of miniaturized satellites
 - Better temporal resolution
- Agriculture
- Monitor hazard and risks



[7]

QGIS - EnMAPbox Demo

References I

- [1] S. Foerster H. Kaufmann K. Segl L. Guanter A. Brosinsky, T. Kuester.
Principles of imaging spectroscopy, slide collection.
PEnMAP education initiative, 2019.
- [2] S. Livens K. Segl T. Kuester H. Kaufmann L. Guanter S. Foerster
A. Brosinsky, M. Brell.
Imaging spectroscopy sensor technologies, slide collection.
PEnMAP education initiative, 2021.
- [3] Contributors to Wikimedia projects.
Starr-120504-5544-Kanaloa kahoolawensis-leaves showing
stress-nursery-Maui - Wikimedia Commons, May 2012.
[Online; accessed 7. Mar. 2023].

References II

- [4] Contributors to Wikimedia projects. ISS-40 Thunderheads near Borneo - Wikimedia Commons, August 2014. [Online; accessed 7. Mar. 2023].
- [5] Chabrillat, S.; Guanter, L.; Kaufmann, H.; Foerster, S. EnMAP Science Plan , October 2022. [Online; accessed 7. Mar. 2023].
- [6] Contributors to Wikimedia projects. SpaceX Falcon 9 rocket and Crew Dragon spacecraft lifts off from Launch Complex 39A - Wikimedia Commons, May 2020. [Online; accessed 7. Mar. 2023].

References III

[7] Contributors to Wikimedia projects.

ISS-38 Nanosatellites deployment (a) - Wikimedia Commons,
November 2013.

[Online; accessed 7. Mar. 2023].