Hyperspectral satellite imaging

Digital imaging systems - 1MD130

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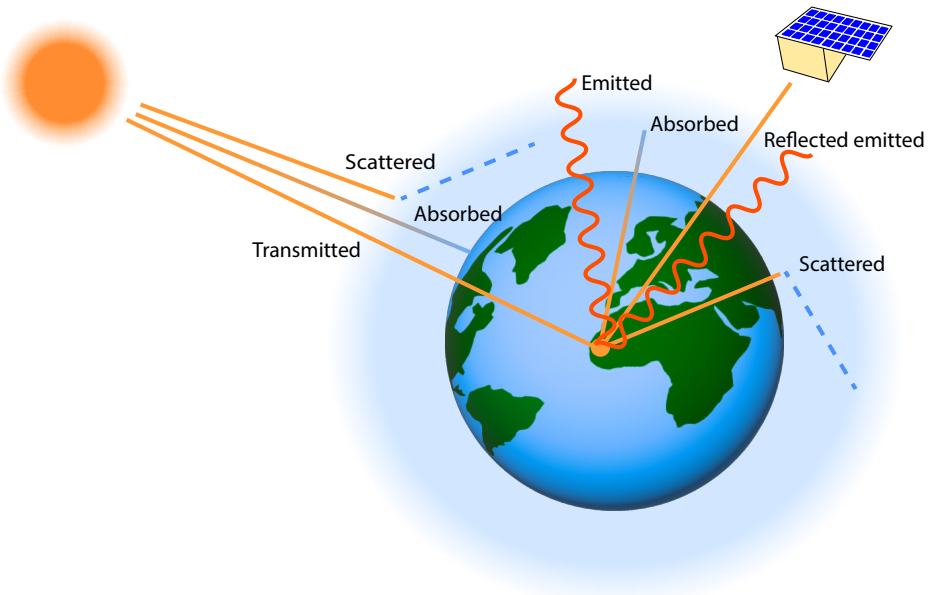
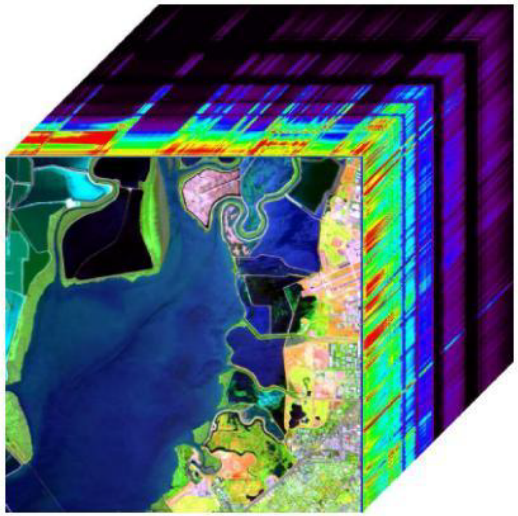
Introduction

- 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



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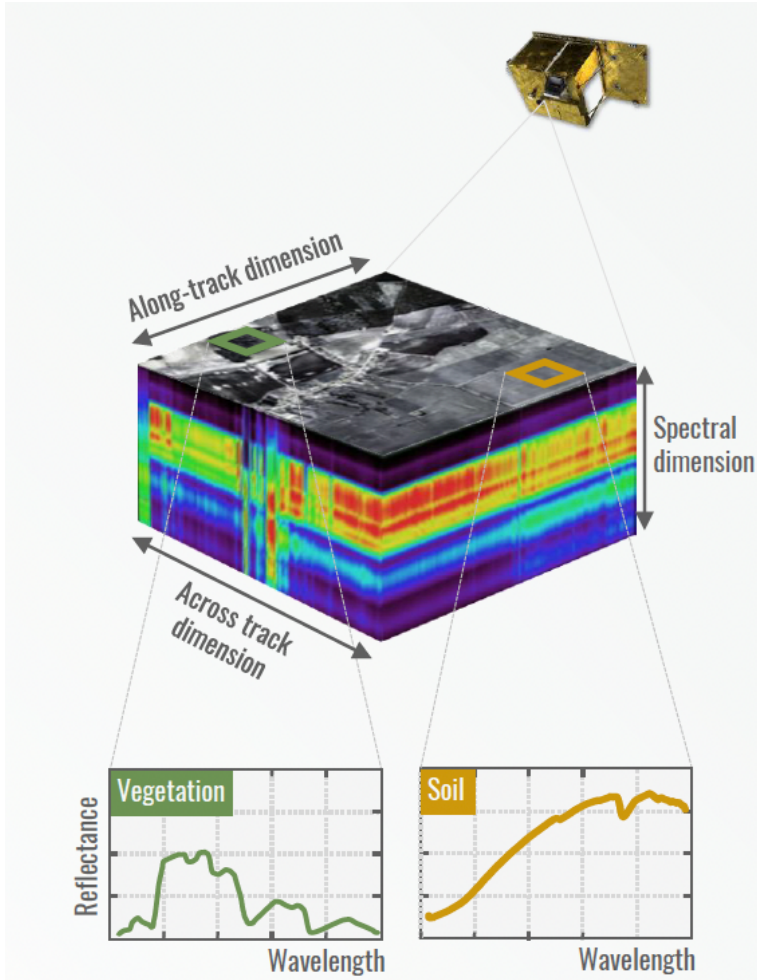

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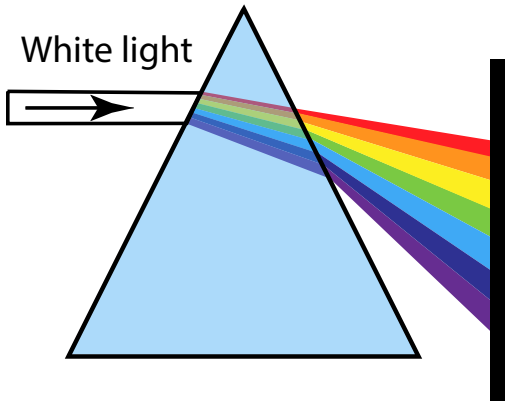
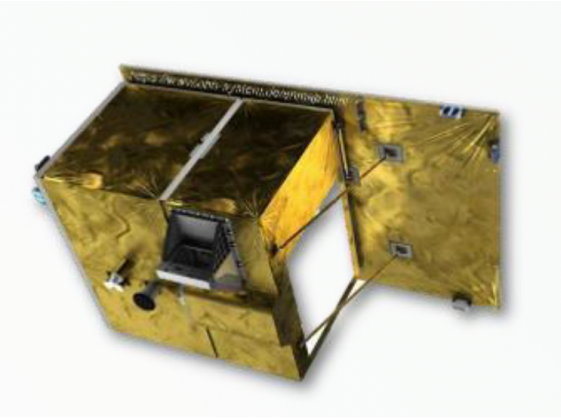
Brief History

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





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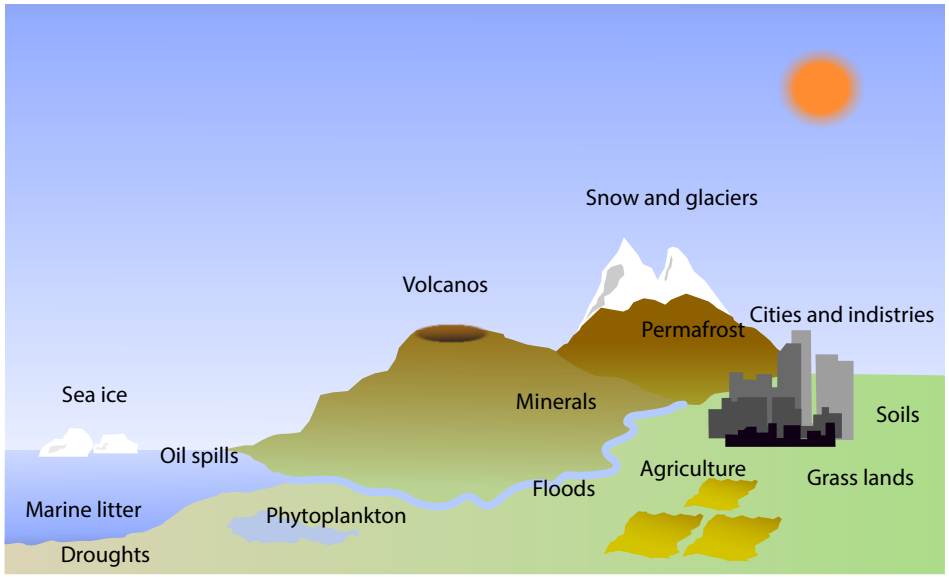
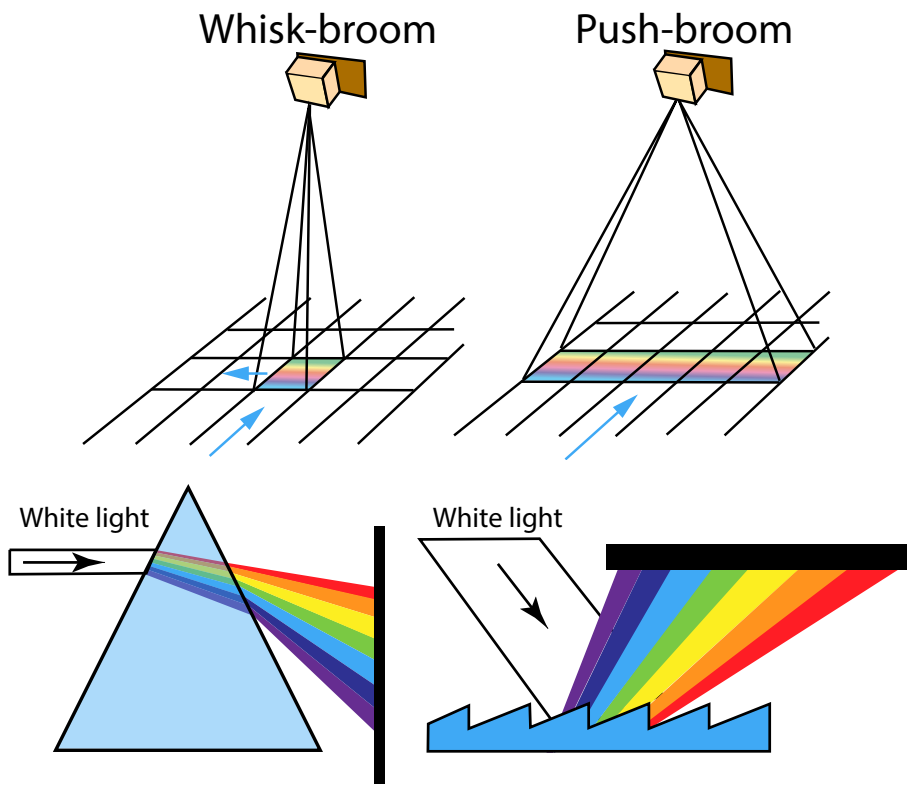
Use today & limiting factors

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



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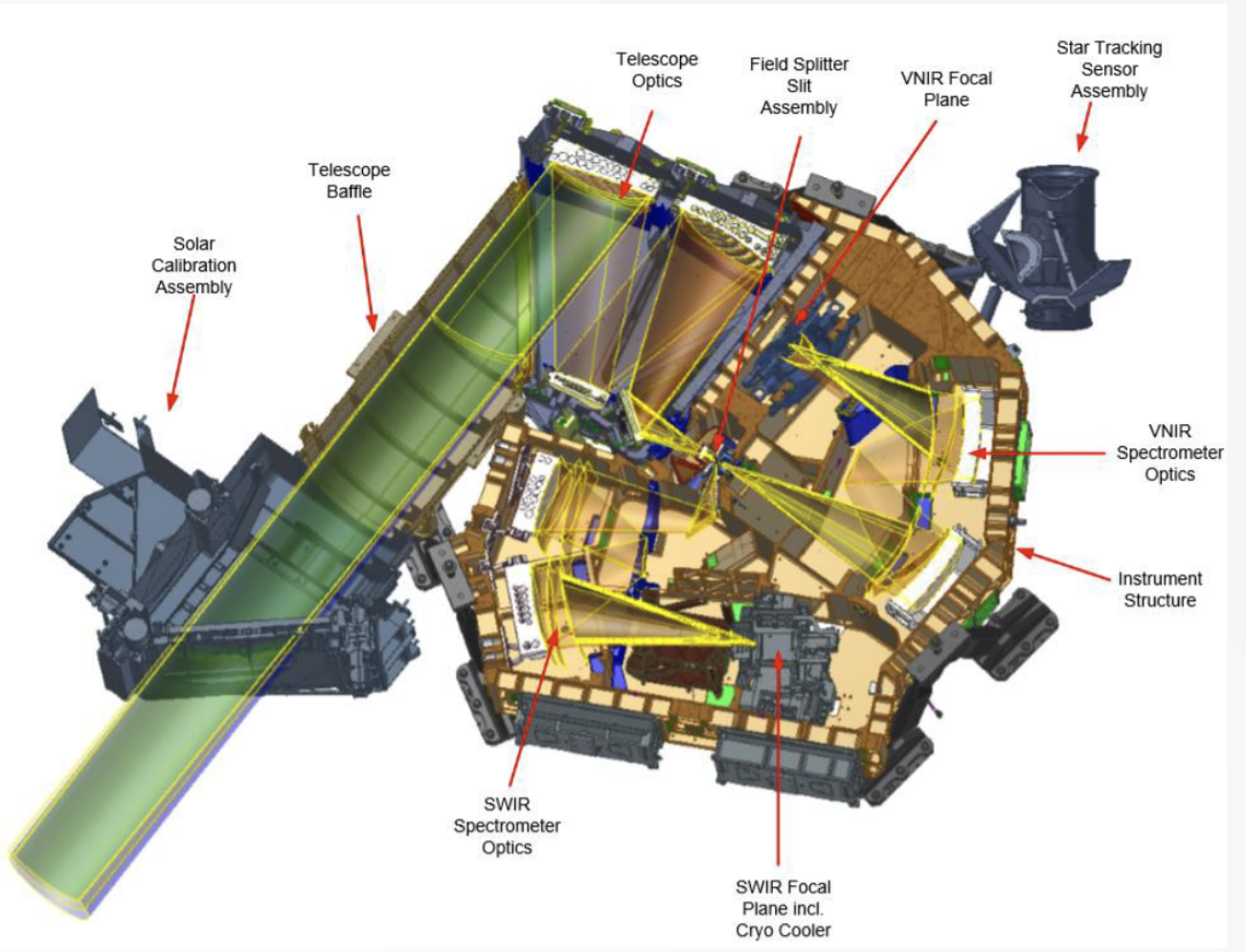

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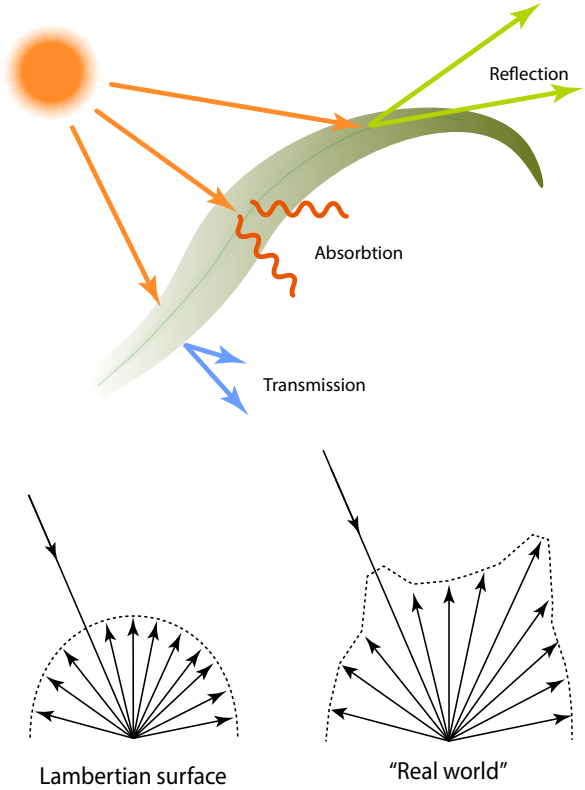
What property of the sample is imaged?

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



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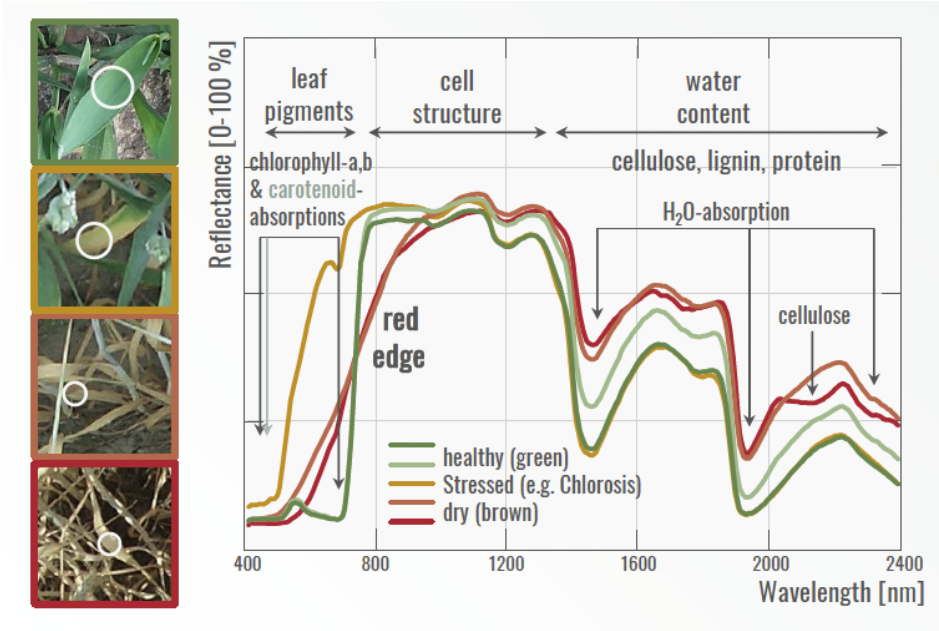
[3]



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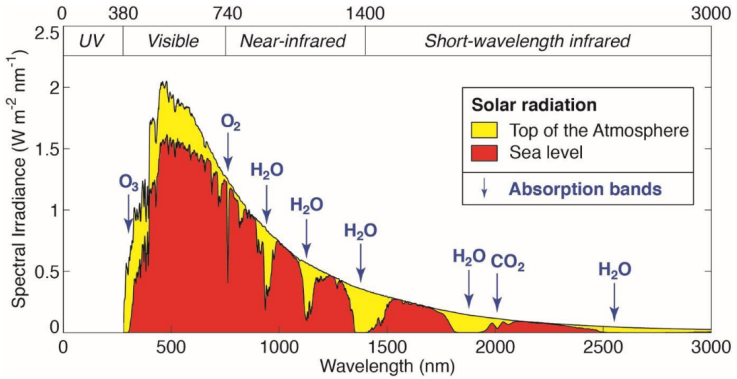
Atmospheric window

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

[4]



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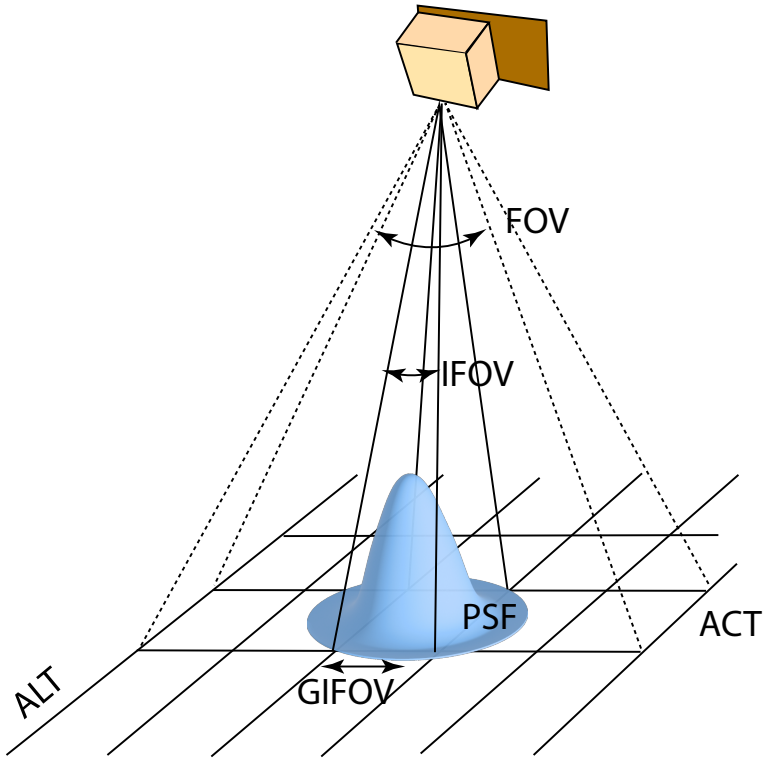
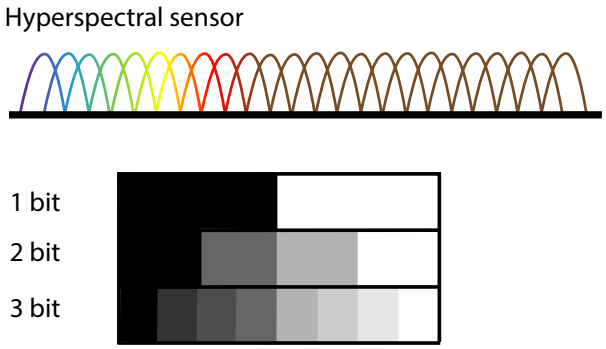
Resolution and sample size

- 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



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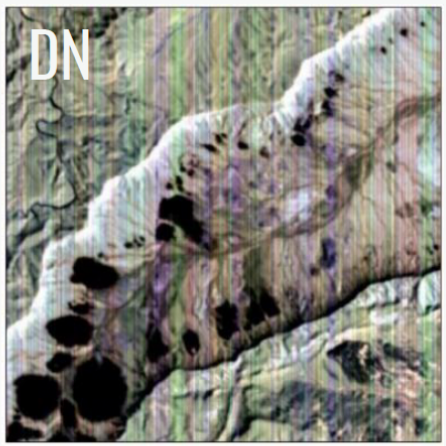
Resolution and sample size

	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	VNIR: 6.5 nm
distance	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)



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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

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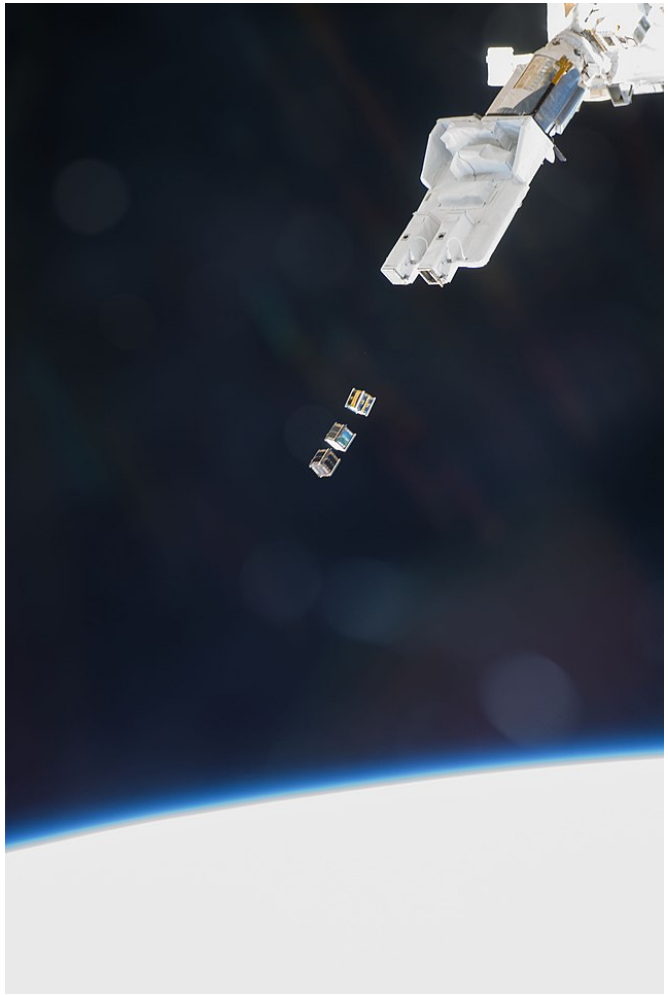
Variants and future use

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



[7]

QGIS - EnMAPbox Demo

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