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Hyperspectral Imaging for Earth Observation in New Space

WHY using Hyperspectral imaging for Earth Observation ?

1- Hyperspectral Imaging Principle

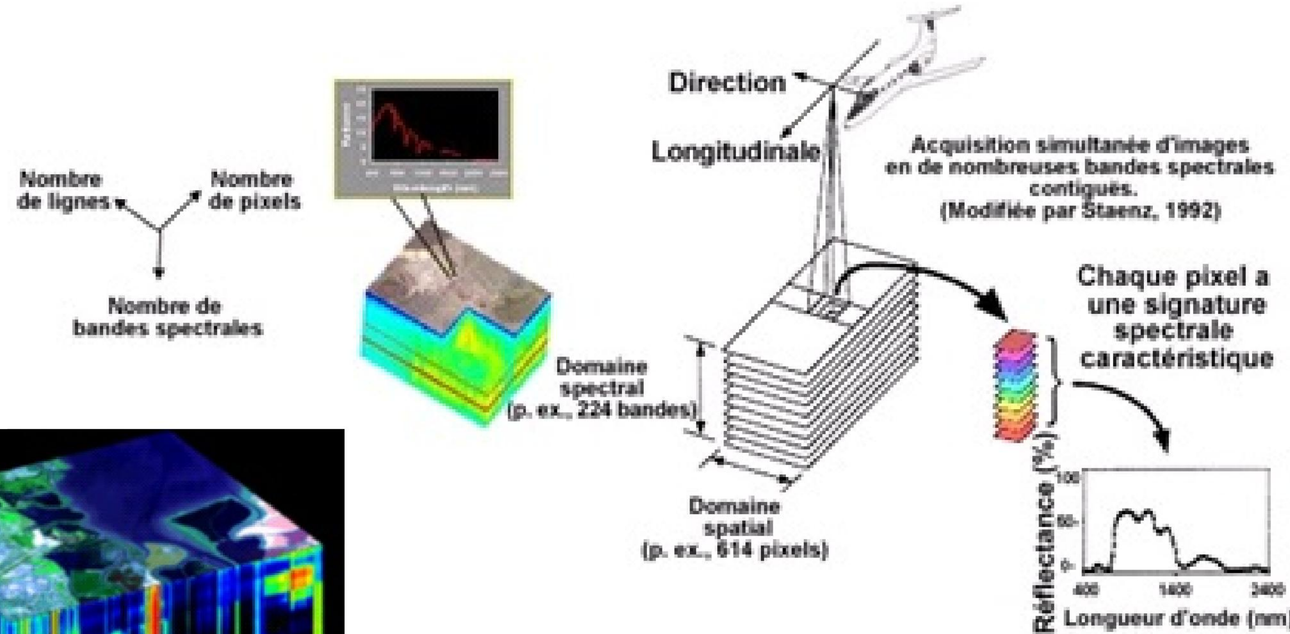

Figure 1: Principle

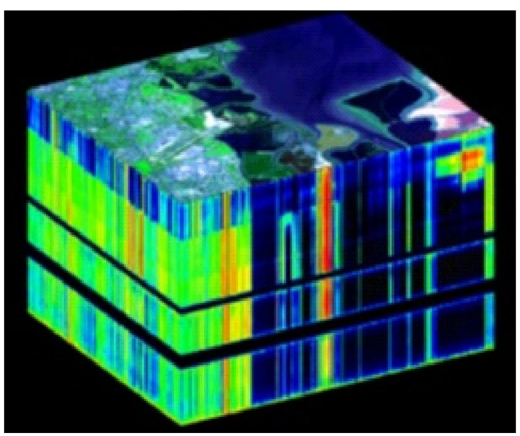

Figure 2: Figure 2 :Hyperspectral imaging of Moffett Field, CA (San Francisco Bay) by AVIRIS (NASA/JPL).

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WHY using Hyperspectral imaging for Earth Observation ?

1- Hyperspectral Imaging Principle (Figures 1 and 2)

This sensing technology allows a **very high spectral resolution**:

- very high number of spectral band: from 100 to 300
- narrow : < 10 nm
- contiguous

Thus continuous spectral acquisition from visible to SWIR (400 to 2500 nm), in the most used case (some instruments are available between 3 and 12 µm)

On each pixel, hyperspectral imaging measures the optical signature of its components. By hyperspectral techniques, it is possible to **identify** objects on complex surfaces or gas in atmosphere.

- Wavelength absorption peak allows components identification
- Amplitude gives concentration or quantity
- Shape gives physical properties of surfaces (granulometry, roughness, humidity,…)

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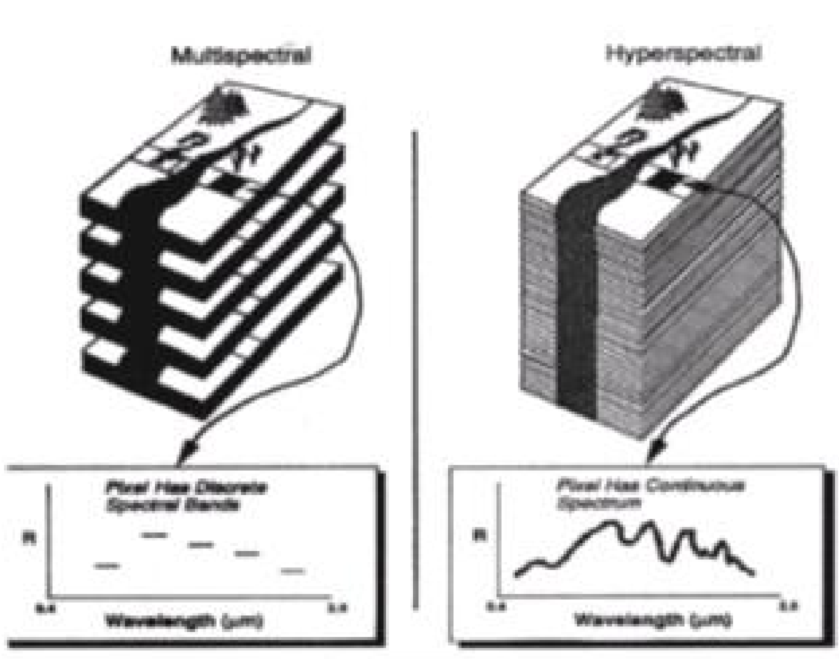
2- Comparison with Multispectral imaging



Much deeper analysis available from Hyperspectral imaging.

Important parameters:
SNR , sensitivity

Figure 3 : Comparison between information contained in one pixel for multispectral imaging and hyperspectral imaging.

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3- Applications for Earth Observation

- Geosciences (Minerals identification, cartography, erosion,…)
- Vegetation (biodiversity, water stress,…)
- Urban environment (urban planning, invasive plants,..)
- Coastal ecosystems
- Pollution: aerosols and gaz, water, ground,..
- Natural and anthropogenic hazards
- Defence : discrimination, intelligence, targeting, surveillance,…

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4 – Main evolution on spatial hyperspectral instruments

Most of the instruments launched from 2000 to 2015 have a limited spectral domain: from 0,4 to 1,0 µm, and limited spatial resolution: between 17 m for CHRIS (UK), 2001 to 506 m for HySi (India), 2008.

Last generations or projects show a strong evolution towards following trends:

- Larger spectral domain [0,4 -2,5 µm]:
  EnMAP (Germany, in Phase D, operational from 2020 to 2025)
  PRISMA (Italy)
  MSMI (South Africa)
  GAOFEN-5 (Chine), SHALOM (It, Is)

- Enhanced spatial resolution: 30 m for EnMAP, 30 m for PRISMA,
  8 m for HYPXIM/HYPEX/BIODIVERSITY
  (France/Singapour, Phase A)

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4 – Main evolution on spatial hyperspectral instruments

- Enhanced radiometric sensitivity: HyspIRI (US), 60 m spatial resolution, HISUI (Japan), 30 m

- Data fusion, combining panchromatic sensing (high spatial resolution, 2-4 m) and hyperspectral sensing (high spectral resolution 10 nm, 8 m).

This approach allows to combine wealth of informations from hyperspectral imaging with very high spatial resolution, enhancing thus data analysis.

- Algorithmes, signal processing, availability of optical properties databases are key. Maturation is on going, as hyperspectral data processing remains complex.

- Only 2 projects: HyspIRI/SBG, and GAOFEN 5 (launched in 2018), includes thermal IR spectral domain.

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5 – What is the interest for hyperspectral imaging in New Space?

New space is based on constellations of nanosatellites.

In term of hyperspectral imaging, the advantages could be:

- The possibility to split the spectral domain between several satellites.
  Each instrument could cover a different spectral domain.
  The advantage would be double:
    - reduce the cost,
    - combine several bands from 0,4 to 12 µm

- Use nanosatellites agility to make possible imaging at daily scale. Until now, revisit varies between 3 and 15 days.

This scale could allow a better surveillance of environmental parameters, like water stress, urban heast islands, and enhance military purposes.