HYPXIM: A NEW HYPERSPECTRAL SENSOR COMBINING SCIENCE/DEFENCE APPLICATIONS

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Introduction

Imaging spectroscopy has proven to be a very efficient remote sensing technique to improve the understanding of Earth's functioning. Present space borne sensors like Hyperion have opened the way for new studies of surface diversity and chemistry. Furthermore, future programs like EnMAP, Prisma and HyspIRI prove that the scientific community is highly motivated to extend the range of applications using such techniques (cf. A. Held presentation).

In France, an ad hoc group of science and defence users of hyperspectral imagery named GSH (Groupe de Synthèse sur l'Hyperspectral) has been set up on CNES initiative to address several objectives:

- To establish an up-to-date view of all possible applications and specify the technical characteristics required for the user community
- To identify current and future systems that are likely to answer them,
- To deliver recommendations.

Following GSH report recommendations (2008), CNES has decided to proceed with a phase 0 mission study of a space borne hyperspectral sensor.

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Science requirements: Vegetation

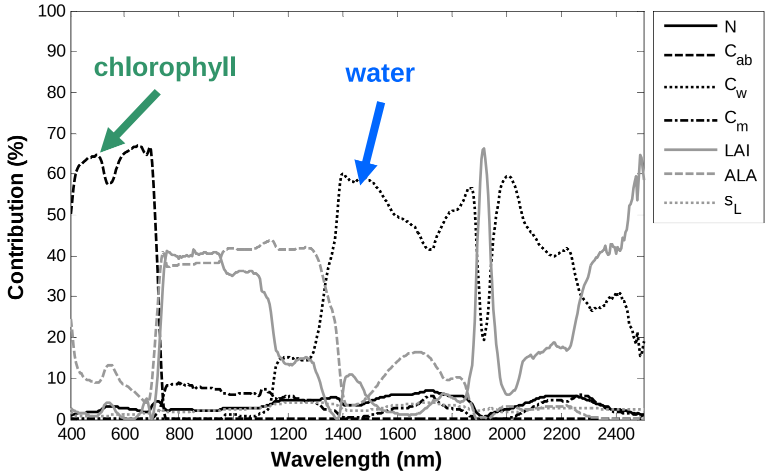
Vegetation provides foundations for life on Earth through ecological functions: regulation of climate and water, habitat for animals, supply of food and goods. The assessment of plant health, both at local and regional scales, using biological indicators such as leaf pigment and water content, may provide useful information for environmental applications such as:

Biodiversity: origin and taxonomic distribution of plant species based on their chemical composition, texture, detection of invasive plants

Ex: Species classification

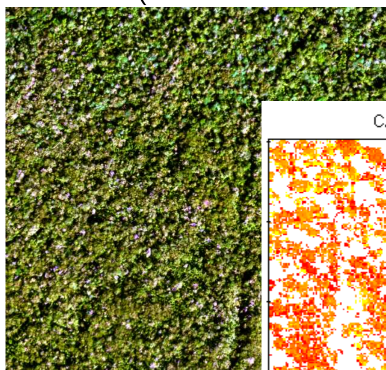
Precision agriculture: plant health (photosynthetic pigments, nitrogen, water content, leaf mass per area), drought, yields

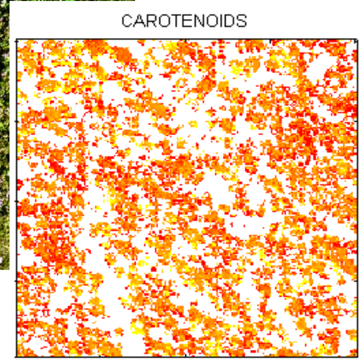
Jacquemoud, 2009



Forestry: tree health, CO_2 fluxes, fire risk assessment

Ex: Cartography of pigment content, tropical forest (Hawaii Volcanoes National Park)





Feret et al., 2008

1. S. Jacquemoud, W. Verhoef, F. Baret, C. Bacour, P.J. Zarco-Tejada, G.P. Asner, C. François & S.L. Ustin (2009), PROSPECT + SAIL: A review of use for vegetation characterization, *Remote Sensing of Environment*, 113:S56-S66.

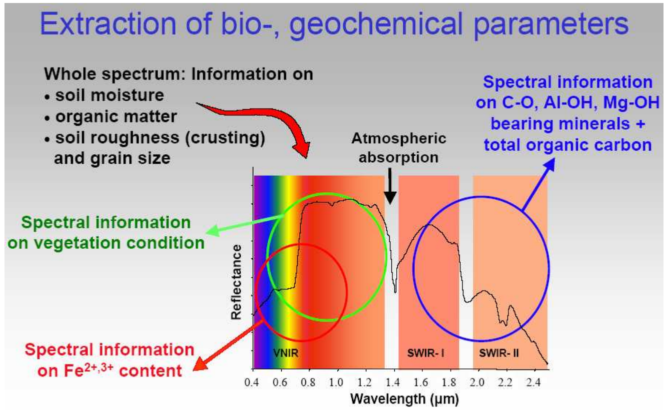
2. J.B. Féret, G.P. Asner, S. Jacquemoud & C. François (2008), Improved retrieval of chlorophyll and carotenoid contents at the canopy scale using hyperspectral CAO data and PROSAIL model, AGU Fall meeting, San Francisco (CA), 15-19 December 2008.

Science requirements: Geoscience / solid Earth science

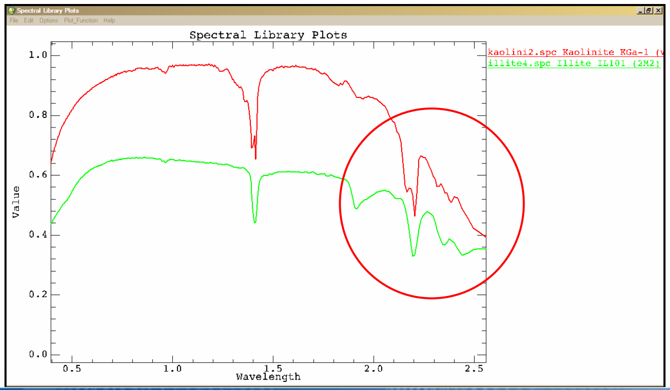
Hyperspectral sensors provide direct access to the mineral composition (identification and quantification) of exposed rocks and soils. This unique capacity constitutes a powerful tool for:

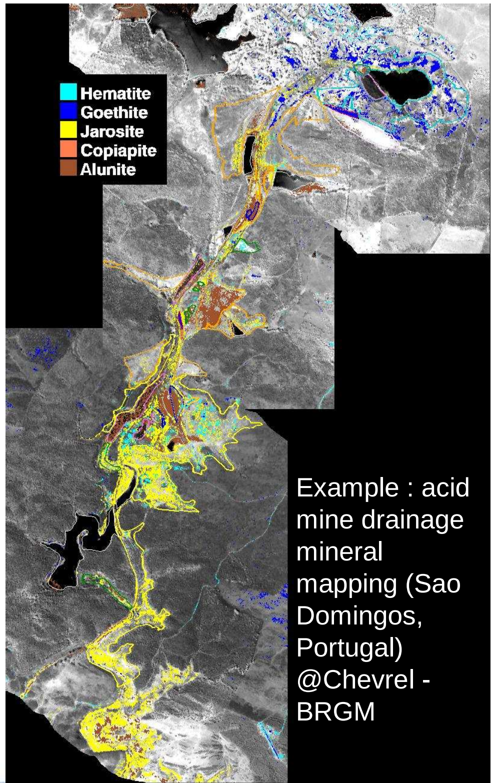
- mining and oil companies for prospecting, rehabilitation of abandoned mine sites (EU directive 2006/21/EC), recently extended to industrial sites.
- monitoring of land degradation/desertification, soil quality monitoring, soil status (water and carbon storage), mapping of environmental hazards related to swelling-shrinking clays, oil spills, etc.

Extraction of bio-geochemical parameters = interest of the entire reflective range



Absorption features of Kaolinite (at 2165 nm and 2205 nm) and illite (at 2195 nm) = interest of very narrow bands (<10 nm) (source USGS spectral library)





Example : acid mine drainage mineral mapping (Sao Domingos, Portugal) @Chevrel - BRGM

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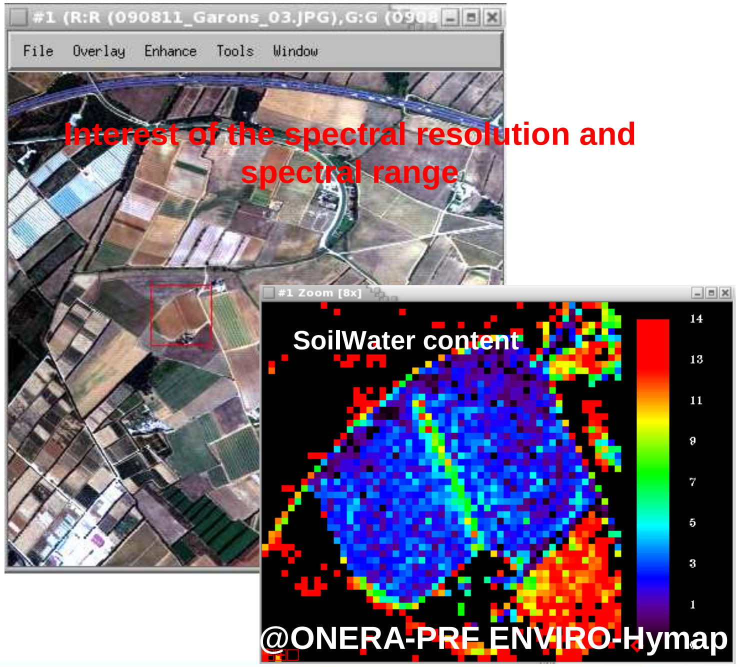
Science requirements: Defence

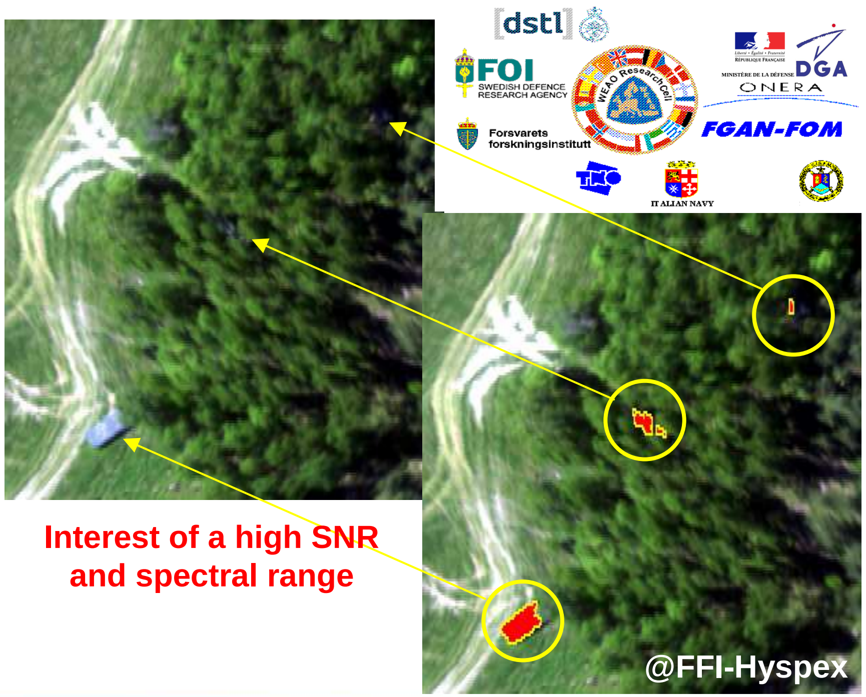
The defence fields of interest described by the GSH report mainly derive from a hyperspectral working group in the French Defence Sector.

A number of **key applications** have been identified and hyperspectral sensor requirements have been derived for space based applications like detection and characterization of objects of interest, or

Contribution to traficability analysis



Anomaly detection



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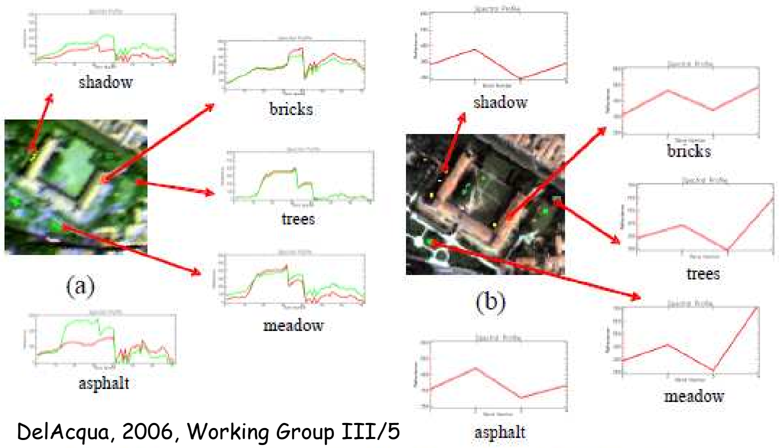
Science requirements: Urban area

As more than **half of the world's people live in cities**, scientists took an interest in urban areas to improve our knowledge of such a medium for applications in human health (air pollution, urban heat island), urban growth management, biodiversity, cartographie (urban material, impervious soil, vegetation species), or hydrology.

Specificity of such medium: strong surface heterogeneity explained by the presence of various materials in a small surface area.

The size of most of these patterns of interest is less than 5 m, which justifies an instrument like HYPXIM that combines a high spatial resolution imaging spectrometer with a panchromatic sensor. It will permit the analysis of very fine structures and open the way to a new range of applications.



DelAcqua, 2006, Working Group III/5

Figure 2: Spectra of some covers in DAIS data (a), and in Quickbird data (b).

Interest of the spectral resolution and spectral range

Class	*30 m*	*10 m*	*5 m*	*2.5 m*	*1 m*
Trees	*Group*				
Grass					
Park					
Dense buildings					
High buildings					
Road	Except motorway				
Railways			area		
Water	river				
Shadow					

Interest of the high spatial resolution

Puissant A., Hirsch J., 2004, Télédétection urbaine et résolution spatiale optimale : intérêt pour les utilisateurs et aide pour les classifications, *Revue Internationale de Géomatique*, 14(3-4), 403-415.

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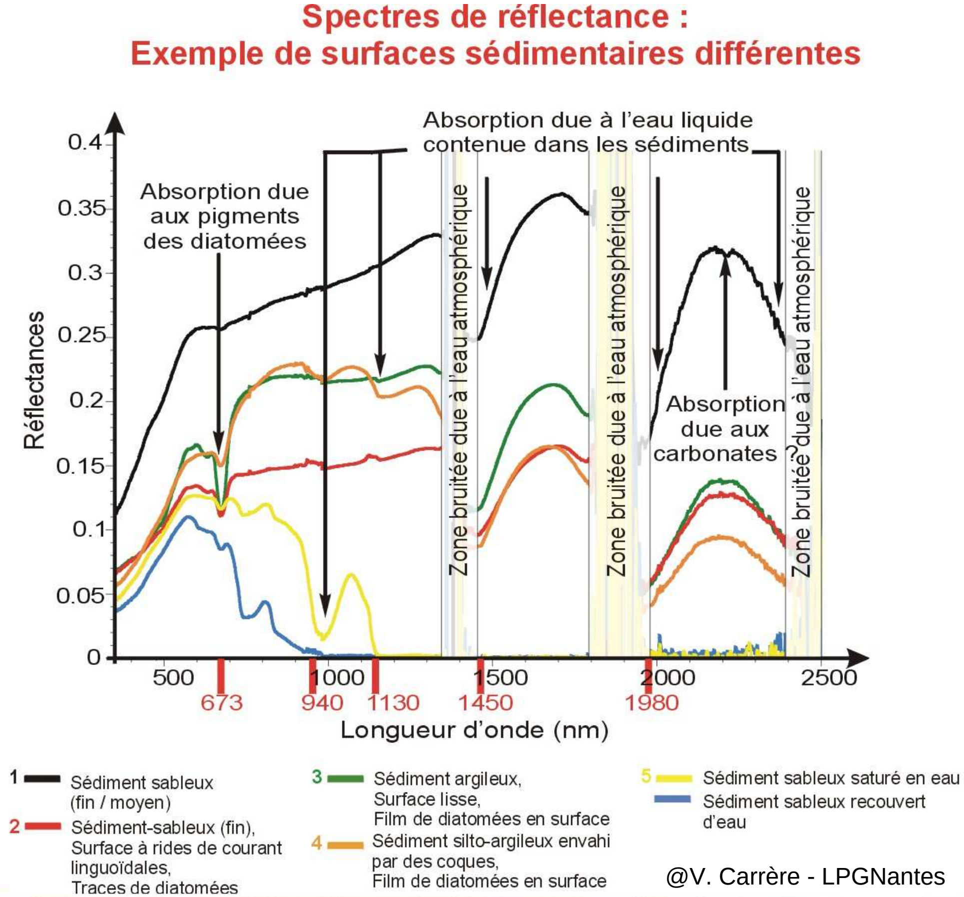
Science requirements: Coastal and inland waters

Today, more than 50% of the world´s population lives already within a 60km coastal belt. The increasing utilisation of coastal zones results in major problems, due to the impact of an increasing population. Coastal environment also constitutes the interface between land and ocean.



Biodiversity: algal blooms, benthic organisms (intertidal zone), macro-algae, eutrophisation by green algal blooms (coast and inland), etc

Sediment dynamics: grain size and mineral composition of suspended and deposited sediments, moisture content…

Bathymetry: in non turbid coastal zone

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Science requirements: Summary

From these different science and Defense requirements, the sensor characteristics are summarized as follow:

Domain	δλ (nm)	GSD (m)	Swath (km)	Revisit Period	SNR
Geosciences / solid Earth science	≤ 10	10	50 - 100	Non critical	>100:1 in SWIR
Inland and coastal waters	≤ 10	≤10	Variable	Critical for inter tidal monitoring	< 400:1
Vegetation	≤ 10	≤10	Variable	Critical during the growing season	> 1000:1
Urban area	≤ 10	5-10	20 - 50	Critical during crisis	>250:1 in VNIR >100:1 in SWIR
Atmosphere	≤ 10	20	10 - 50	Variable	>250:1 in VNIR >150:1 in SWIR
Defence	≤ 10	5-10	20	24 – 60 hours	>250:1 in VNIR >100:1 in SWIR

Summary table of mission requirements expressed by the five science user groups and defence users where δλ is the spectral resolution, GSD the ground sample dimension, RP the revisit period and SNR the signal-to-noise ratio, the spectral range is [0.4, 2.5µm]].

AT-SENSOR RADIANCES SPECIFICATIONS AS DEFINED BY THE SCIENTIFIC / DEFENCE GROUP

Several observable spectral radiances are defined:

- General conditions of simulation: no cloud, nadir viewing angle, target at sea level.
- Spectra:
  - Science: campaigns, ASTER-JPL, MEMOIRES-ONERA.
  - Defense: campaigns, MEMOIRES-ONERA
- L2: two mean radiances are estimated
  - **favorable case**: mid-latitude winter atmosphere, 60° solar zenith angle
  - **unfavorable case**: mid-latitude summer atmosphere, 30° solar zenith angle
  - A mean radiance is estimated by averaging all the radiances for the most favourable and most unfavourable cases.
- L4: maximum observable radiance without saturation.
  - flat Lambertian scene with the input variables.
  - Sub-artic winter atmosphere, aerosol (rural, V=50km)
  - + ,real images acquired over several types of plumes
- L1 and L3: not presented (restricted by Defence)

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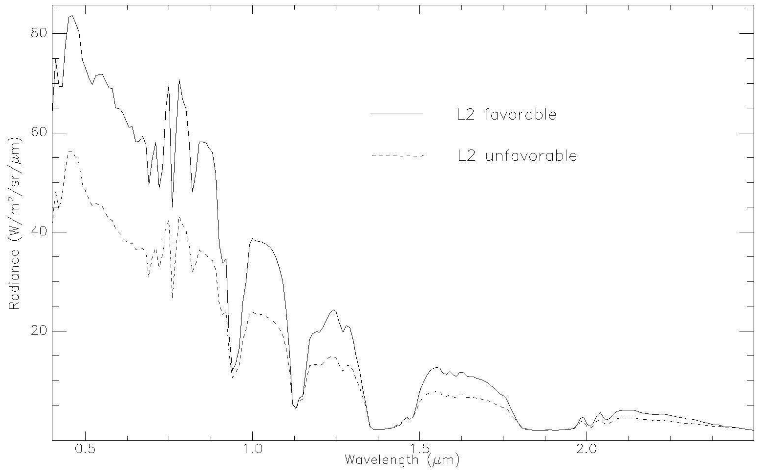
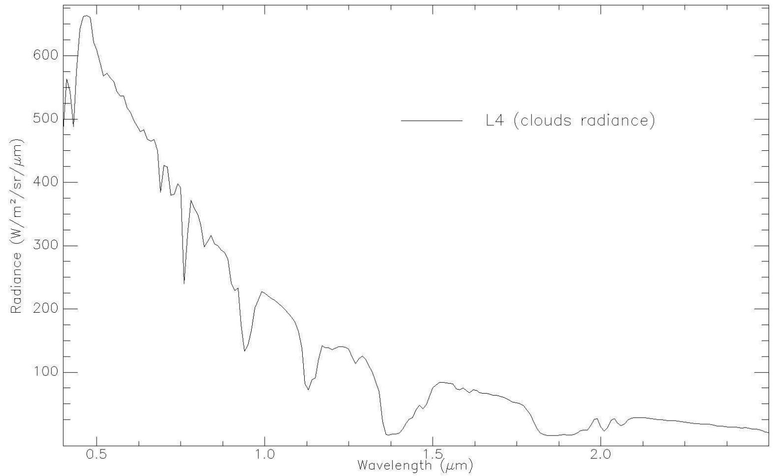
AT-SENSOR RADIANCES SPECIFICATIONS AS DEFINED BY THE SCIENTIFIC / DEFENCE GROUP

L2: favorable and unfavorable



L4



L2 radiances are lower than the corresponding specified radiances of Prisma or EnMAP for several reasons:

- two solar zenith angles (30°, 60°),
- the mean reflectance levels is much lower than 0.3
- its level varies with the wavelength.

Conclusion

Six scientific/defence domains have been identified after the work conducted during 18 months by a group of science and defence users of imaging spectroscopy.

On the basis of the summary note and recommendations, CNES is working on a Phase 0 study which should be completed in the middle of 2011 (cf S. Michel poster).

These radiances and the spatial scale required for these applications are very challenging and will define a very ambitious and innovative sensor.

Note:

- Large range of observable radiances
- High spatial resolution sensor and LWIR range will improve the identifed applications.

A phase A mission study is planned to start by the end of 2011.

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