

The French Hyperspectral EO mission HYPXIM

A second generation high spectral and spatial resolution imaging spectrometer

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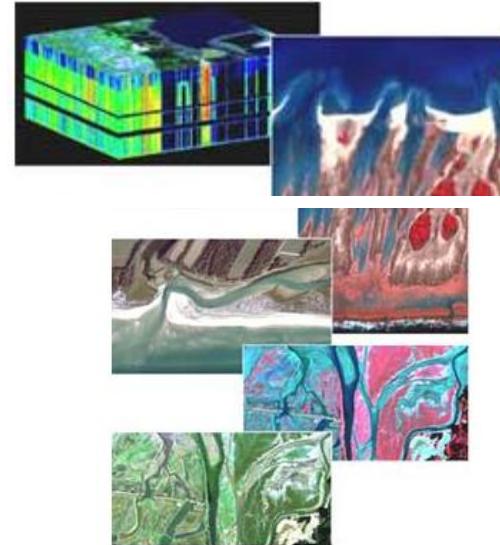
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HYPXIM: A NEW INSTRUMENT

SPATIAL RESOLUTION OF CURRENT
and FUTURE HYPERSPECTRAL
MISSIONS (EnMAP, PRISMA, HypIRI,
HISUI, etc.) ≥ 30 m
UNSUITED FOR SOME APPLICATIONS

HYPXIM COMBINES:

HIS: HIGH SPECTRAL RESOLUTION (10 nm) + HIGH SPATIAL RESOLUTION (< 8 m)
+
VERY HIGH SPATIAL RESOLUTION (PAN< 2m)
+
GLOBAL ACCESS
+
REGULAR REVISIT TIME
19 (nadir) to 3 days (pointing capabilities)



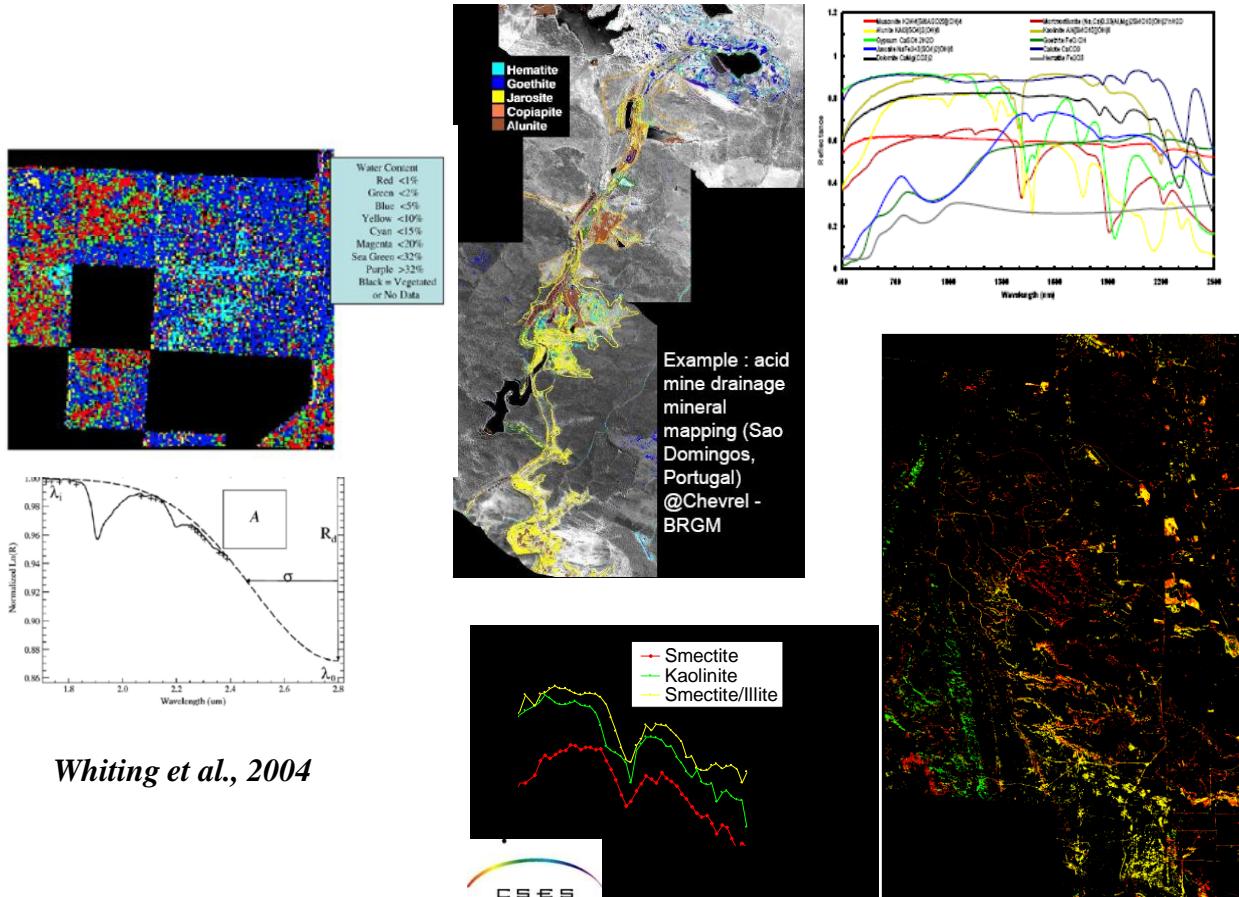
HYPXIM DATA CLOSE TO AIRBORNE AND IN SITU:

1- ACCESS TO NEW INFORMATION FROM SPACE

2- ACCURATE MEASUREMENTS OF PARAMETERS POORLY RETRIEVED AT LOWER RESOLUTION

3- BETTER APPRAISAL OF HUMAN IMPACT ON HIS ENVIRONMENT

HYPERSPECTRAL MAIN USER NEEDS: GEOSCIENCES



Objectives:

- Mineral mapping
- Environmental impact
- Naturals/Industrial Hazards
- Soil erosion/degradation
- Soil properties

⇒ Relevant scale = mining sites, river banks, geologic formation

Parameters:

- Mineral composition, concentration/quantity, C
- organic content, soil moisture content, grain size, clay content

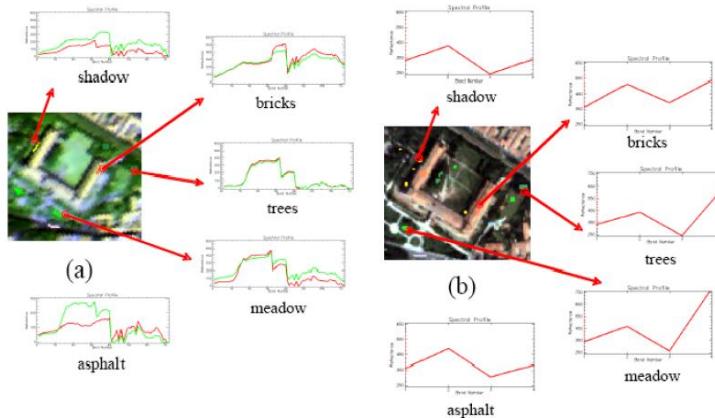
⇒ Requires taking into account intimate mixtures and alteration crusts

Spectral characteristics: 0.4-2.5 μm, resolution < 10nm in VNIR/SWIR - SNR >300:1 in VNIR, > 100:1 in SWIR

Geometric characteristics: GSD ~5-20 m

Temporal characteristics: less than monthly for certain environmental monitoring applications (10 days), can be critical during a crisis (3-5 days).

HYPERSPECTRAL MAIN USER NEEDS: URBAN ECOSYSTEMS



Spectra of some covers in DAIS data (a) and in Quickbird data (b), from Dell'Acqua et al., 2006.

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					

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.

Objectives:

Urban planning

Biodiversity: plant species, vegetation health

Cartography: urban material, impervious soil, vegetation species

Urban microclimatology: air quality, urban heat island, health

Hydrology: water quality

⇒ Relevant scale = small spatial scale

Parameters:

composition of urban materials (chemistry, permeability, moisture content, dangerous materials), temporal evolution, sanitary state, manmade/natural surfaces

⇒ Fusion Panchromatic + hyperspectral

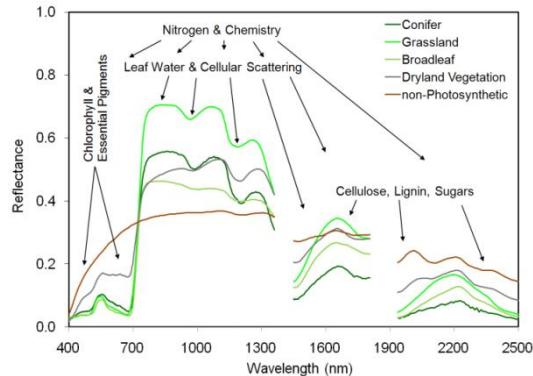
⇒ Requires taking into account intimate mixtures, shadows

Spectral characteristics: 0.4-2.5µm, resolution < 10nm VNIR/SWIR - SNR>250:1 VNIR, >100:1 in SWIR

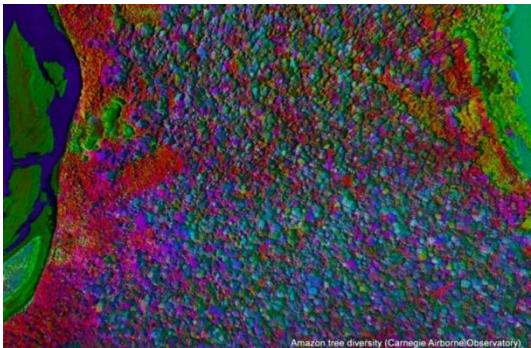
Geometric characteristics: GSD < 5m

Temporal characteristics: critical during the growing season and during a crisis (3-5 days).

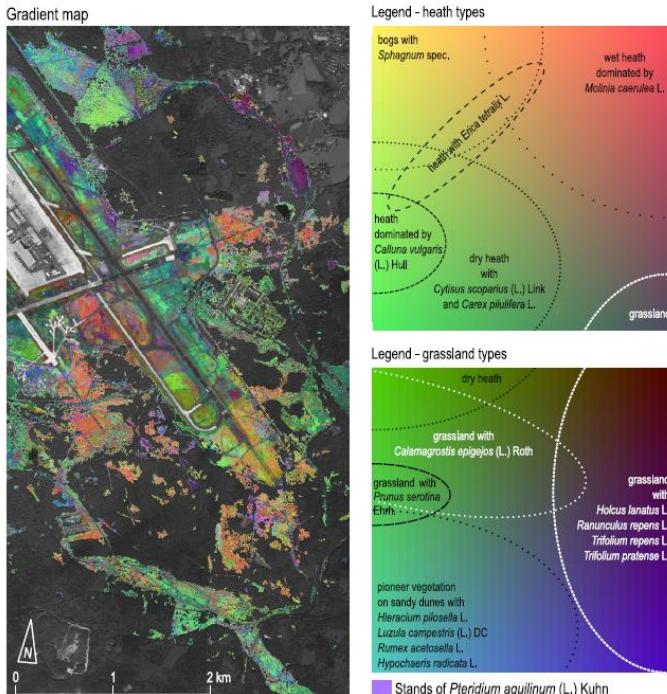
HYPERSPECTRAL MAIN USER NEEDS: PLANT BIODIVERSITY



"Global Terrestrial Ecosystem Observatory (GTEO)"



<http://cao.stanford.edu/>



Feilhauer et al., 2011

Objectives:

Biodiversity: taxonomic distribution of plants, chemical composition, texture, detection of invasive plants (e.g. meadow)

Precision agriculture: crop monitoring, weed detection, yield forecasting

Forestry: species, tree health, CO₂ fluxes, fire hazard assessment

Necessity of data at an intermediate scale between *in situ* and global

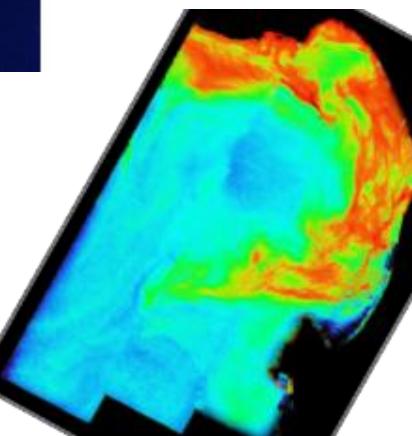
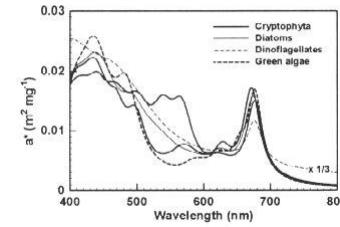
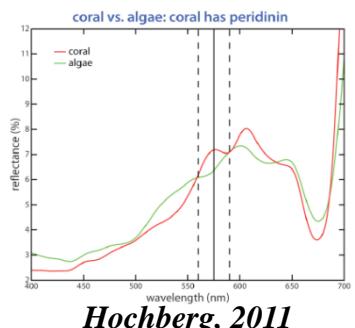
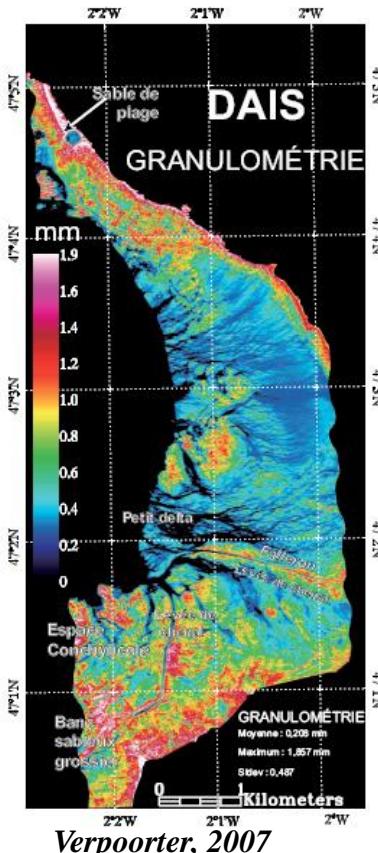
Parameters of interest: pigments, water and dry matter content, C:N, LAI, light-use efficiency

Spectral characteristics: 0.4-2.5μm, resolution < 10nm

Geometric characteristics: resolution ~5-10m is useful for some applications

Temporal characteristics: critical during the growing season (10 days)

HYPERSPECTRAL MAIN USER NEEDS: COASTAL ECOSYSTEMS



Objectives:

Algal blooms: impact on tourism, primary production and carbon cycle, coastal dynamics, fisheries

Eutrophization

River discharges: marine pollution

Bathymetry: military applications

Seabed mapping: sand, benthic species, corals...

Intertidal zone: interface with human activities, seashells, sediment dynamics

⇒ Relevant scale = small spatial scale

Parameters:

pigments, mineralogy, grain size, moisture content, species

⇒ Requires taking into account intimate mixtures

Spectral characteristics: 0.3-1µm for the majority of applications.

Extended to 2.5 µm for characterisation of sediments, resolution < 10nm.

SNR >400 in VNIR.

Geometric characteristics: GSD <10m

Temporal characteristics: Variable, strong constraints for certain applications (1 day)

HYPERSPECTRAL MAIN USER NEEDS: ATMOSPHERE

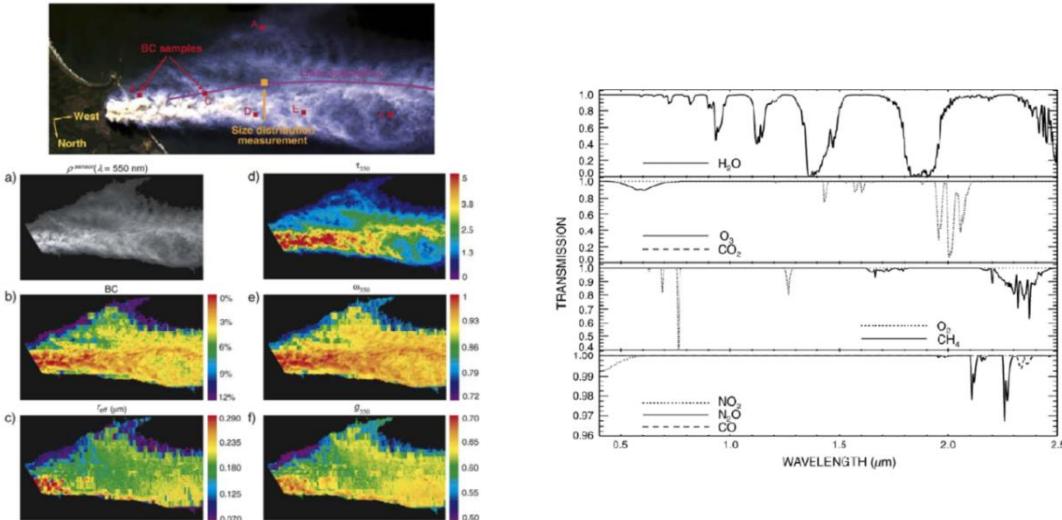
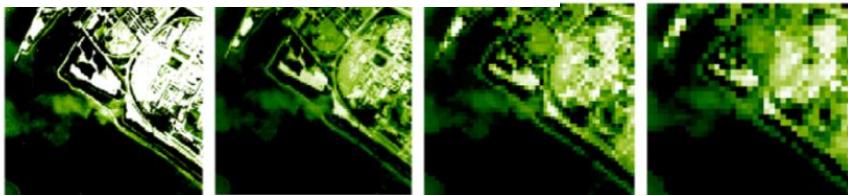


Figure 9: Quinault biomass burning aerosols plume analysis; a) image of p_{sensor} at 550 nm, b) map of BC (%), c) map of r_{eff} (μm), d) map of τ_{550} , e) map of ω_{550} and f) map of g_{550} . Scales are given in the right side of each image, from Alakian et al., 2009.



Effect of spatial resolution of plume detection; from left to right: 3.4 m; 10m; 20m; 30m (Courtesy R. Marion).

Spectral characteristics: 0.4-2.5 μm , resolution < 10nm

Geometric characteristics: GSD < 20 m

Swath: 10-50 km

SNR > 250:1 (VNIR), > 150:1 (SWIR)

Temporal characteristics: Can be critical during a crisis (3-5 days).

Objectives:

Plume characterization: air pollution, biomass burning, volcanic eruption

Air Traffic

⇒ Relevant scale = small spatial scale

Parameters:

Gases: type, abundance

Aerosols: type, abundance, particle size

HYPERSPECTRAL MAIN USERS NEEDS: CRYOSPHERE

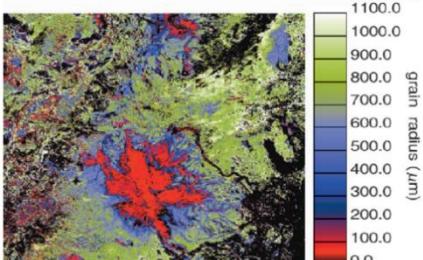
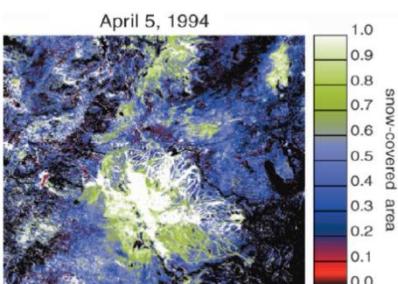


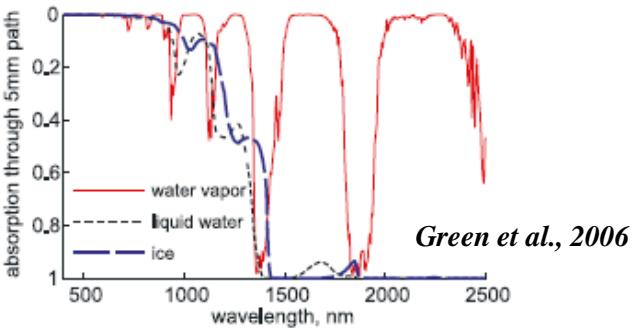
Fig. 8. MEMSCAG snow-covered area and grain size for the AVIRIS acquisition on April 5, 1994.

Painter et al., 2003

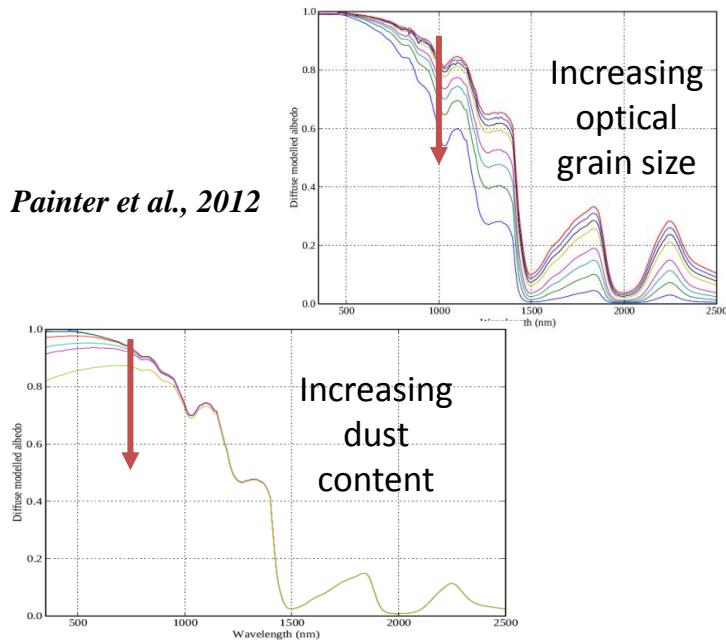
Spectral characteristics: $0.3\text{-}2.5\mu\text{m}$, resolution $< 10\text{nm}$

Geometric characteristics: GSD $\sim 5\text{-}10\text{m}$

Temporal characteristics: $< 5\text{ days}$



Painter et al., 2012



Objectives:

Climate: albedo (dust, algae), surface energy budget, climate change

Hydrology: snowmelt models, liquid water content, floods

⇒ Relevant scale = small spatial scale

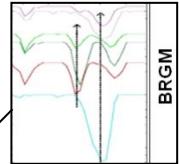
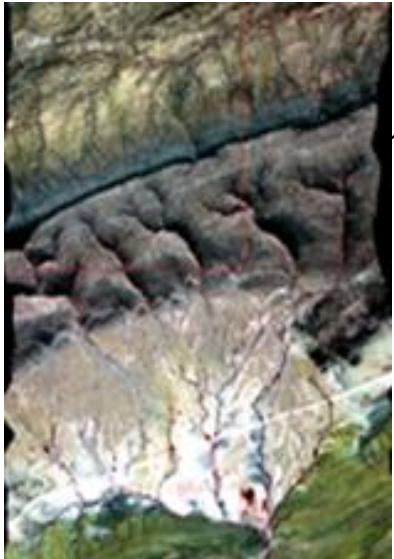
Parameters:

grain size, water liquid content, impurities type and content

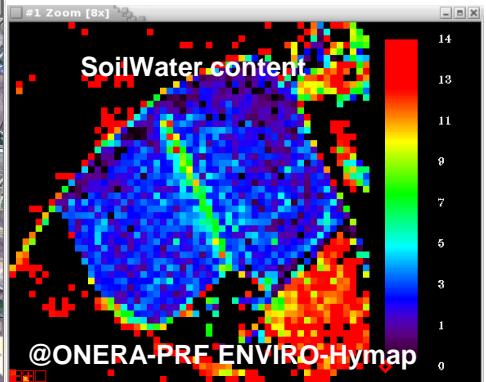
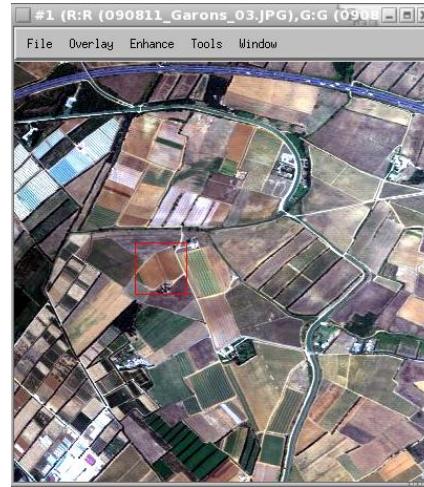
⇒ Requires taking into account intimate mixtures, topography

SNR $> 500:1$ in the VIS, $> 250:1$ elsewhere

HYPERSPECTRAL MAIN USER NEEDS: DEFENCE



Namibia HYPXIM simulated image
(CNES/BRGM)



Key applications identified.

Among these, three should be noted in particular :

- trafficability indices
- detection/characterisation of objects/anomalies
- characterisation of coastal zones (bathymetry)

Spectral characteristics: 0.4-2.5μm, resolution < 10nm in VNIR/SWIR

Geometric characteristics: GSD < 5 m (urban) and ~10 m (geosciences)

Temporal characteristics: short revisit period required.

SCIENCE REQUIREMENTS: SUMMARY

Sensor characteristics derived from science requirements

Domain	$\delta\lambda$ (nm)	GSD (m)	Swath (km)	Revisit Period	SNR
Geosciences	≤ 10	10	50 - 100	Non critical	>300:1 in VNIR >100:1 in SWIR
Coastal ecosystem	≤ 10	≤ 10	Variable	Critical for inter tidal monitoring	> 400:1 in VNIR
Vegetation biodiversity	≤ 10	≤ 10	Variable	Critical during growth period	TBC
Urban ecosystem	≤ 10	5	20 - 50	Critical during crisis	>250:1 in VNIR >100:1 in SWIR
Cryosphere	10	5-10	20- 50	< 5 days	>500:1 in VNIR >250:1 in SWIR
Atmosphere	≤ 10	20	10 - 50	Variable	>250:1 in VNIR >150:1 in SWIR

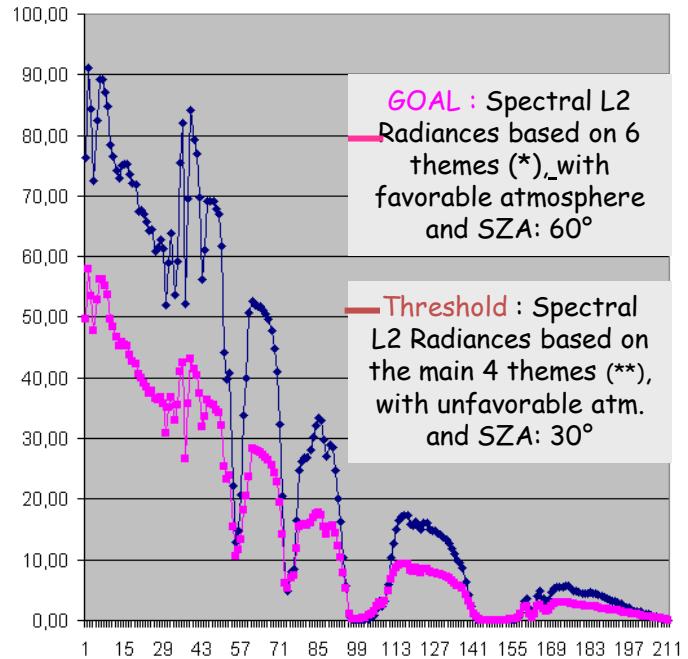
Summary table of mission requirements expressed by the six science user groups where $\delta\lambda$ is the spectral resolution, GSD the ground sample dimension and SNR the signal-to-noise ratio, the spectral range is [0.4, 2.5μm].

All these requirements have to be refined

HYPXIM: MAIN MISSION REQUIREMENTS

Domain	Spectrum (nm)	Spectral res. $\delta\lambda$ (nm)	SNR@L2
VIS	400-700	10	$\geq 250:1$
VNIR	700-1100	10	$\geq 200:1$
SWIR	1100-2500	10	$\geq 100:1$
PAN	400-800	400	$\geq 90:1$

- ⇒ Spectral continuum required from VIS to SWIR, spectral resolution of 10 nm,
- ⇒ Spectral SNR with 2 levels of L2 (goal and threshold)
- ⇒ GSD HIS < 8m, and a panchromatic channel (GSD < 2 m) will enhance the scene analysis
- ⇒ Swath : 15 km minimum
- ⇒ Revisit: daily revisit required for some applications , 3-5 days acceptable for Defence

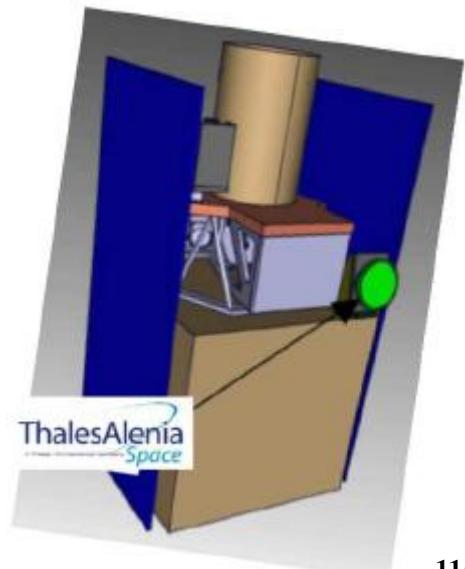
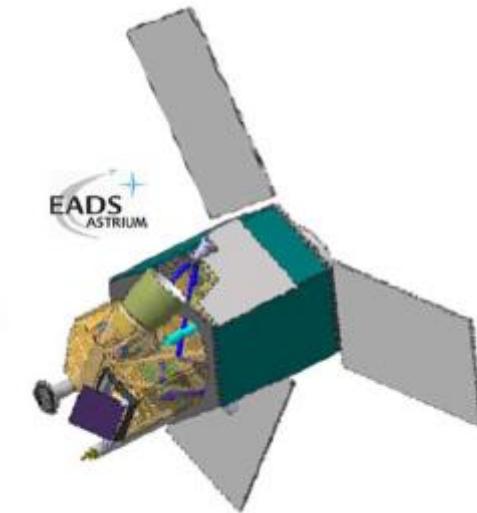


(*) Goal: Geosciences, Vegetation, Urban, Defence, Atmosphere and Coastal zones

(**) Threshold: Geosciences, Vegetation, Urban, Defence

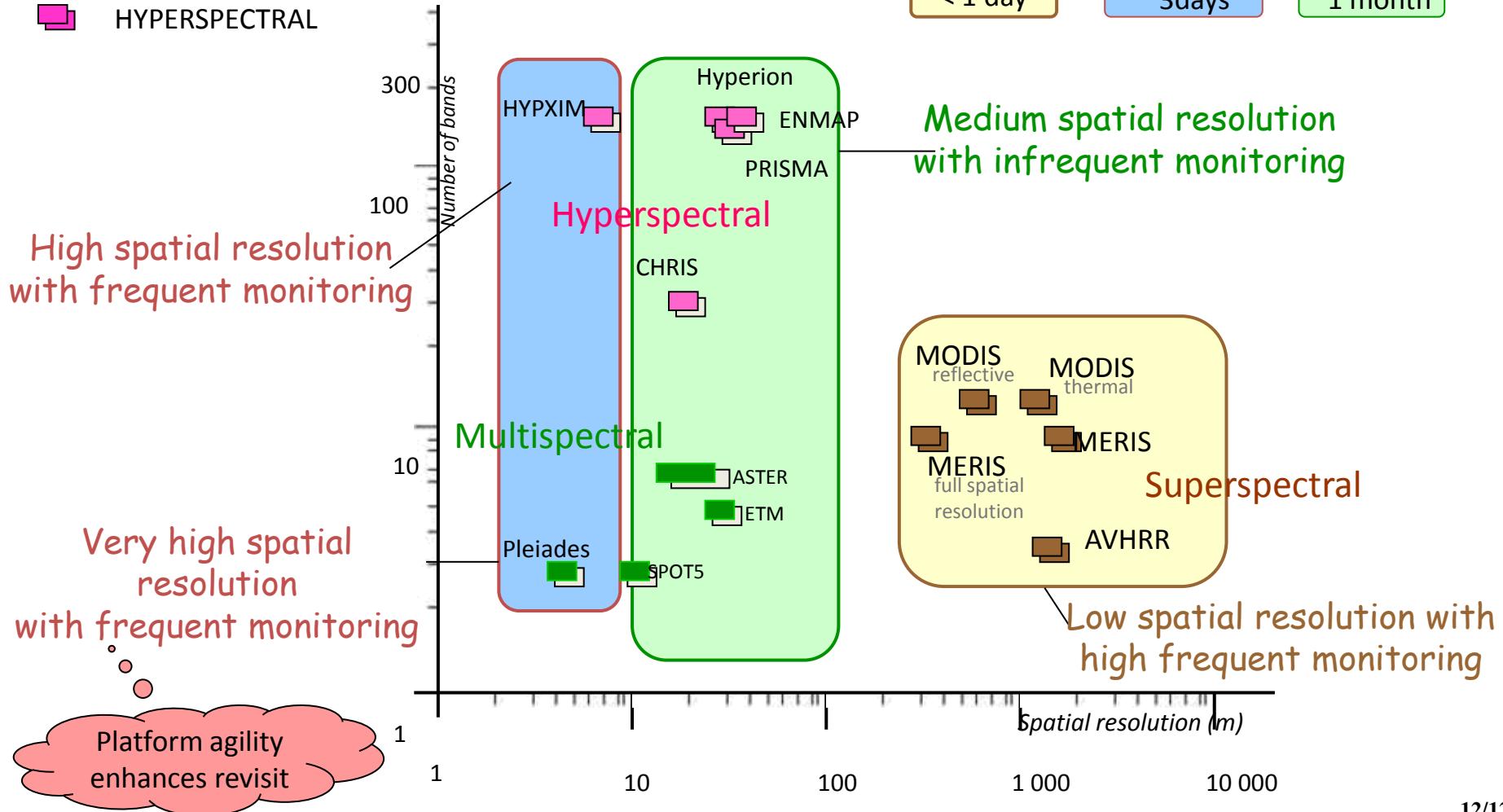
HYPXIM: SYSTEM DESCRIPTION (as per end of Phase 0)

ALTITUDE	660 km
PAYOUT	TMA or Korsch telescope, diameter: 450 mm, Prism-based spectrometer, Dedicated panchromatic channel, Detector VNIR-SWIR 2000 x 360 pixels
HYPERSPECTRAL RESOLUTION / SWATH	8 m / 16 km
PANCHROMATIC CHANNEL	1.85m /16km
SPECTRAL BANDWIDTH / RESOLUTION	400 – 2500 nm / 10 nm
PANCHROMATIC CHANNEL	1.85m/16km
PAYOUT BUDGET	Mass~115 kg, Power 150W (imaging)
SATELLITE	600 kg (at launch)
REVISIT PERIOD	With +/-20° across-track imaging: 15 days With +/-35° across-track imaging: 3 days
IMAGING CAPACITY	~100 000 km ² per day (270-450 images)
GROUND-TO-SPACE LINK	X-band link at 620 Mbps (with ground or mobile stations)
LAUNCHER COMPATIBILITY	Soyuz, Vega, Ariane 5
EXPECTED LIFETIME	10 years (incl. end-of-life operations)



HYPXIM: POSITION IN THE INTERNATIONAL CONTEXT

- █ MULTISPECTRAL
- █ SUPERSPECTRAL
- █ HYPERSPECTRAL



CONCLUSIONS

Seven scientific/defence domains have been identified by a group of science and defence users of imaging spectroscopy.

Scientific requirements have to be refined in Phase A to find a tradeoff with existing technology

A phase 0 study conducted by CNES from 2009 to 2012 proved the mission's feasibility. CNES decided then to pursue with a phase A study but it was put on hold, pending on budget.

Phase A may restart in 2014, the growing scientific community is pushing.

High resolution hyperspectral imagery from space is foreseen to be a powerful tool for numerous scientific applications in many different areas, thus serving a wide scientific community