CENTRE NATIONAL D'ÉTUDES SPATIALES

HYPXIM STATUS 2015

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With the collaboration of:

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GeoHyper, 1-2 october 2015

- **HYPXIM, is a preliminary study (i.e. phase 0) which begun in 2009, lead and funded by CNES**
  - HYPXIM mission meets the needs of a wide national community of users who currently uses high-resolution hyperspectral images (airborne, UAV, etc.), for research or commercial applications .
  - To meet these requirements, two concepts (mini & micro class) were preliminary designed with industrial support from Airbus Defense & Space (ADS)+Thales Alenia Space (TAS) .

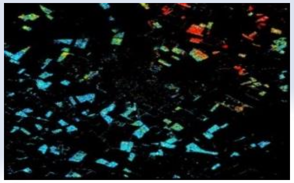
- **During the period 2011-2012 different activities have been conduced by CNES in collaboration with scientific labs, defence and industrial partners in order to evaluate the both different concepts in an experimental approach**

- **The HYPXIM phase A based on the most performant concept took place mid-2012, but was frozen in 2013 for economic reasons.**

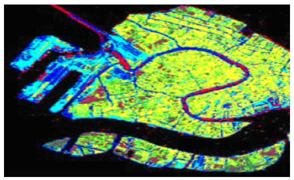
- **An alternative system was studied in 2014-2015 in order to evaluate low orbits (360km) for a performant hyperspectral demonstrator @ low cost**

ECOSYSTEMS ADAPTATION (CONTINENTAL & COASTS)
CRISIS EVENTS IMPACTS
DEFENSE & SECURITY

HYPXIM

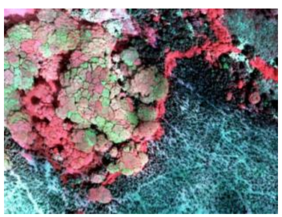


GEOSCIENCES:
Mineral Cartography,
Agriculture,
Soils degradation, Humidity ,

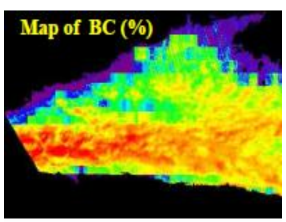


URBAN ENVIRONMENT
Materials maps and variability,
Urban planning
Urban climatology,

COAST
Bathymetry;
Reefs cartography and diagnostics
Intertidal sedimentology,
Inland water quality,



VEGETATION:
Forest Biodiversity,
Water leaf contents,
Biochemistry spectroscopy



ATMOSPHERE
Gases & Aerosols, Anthropic Polluti
Volcanology,
Fires

SECURITY & DEFENSE:
Traficability,
Target detections,
Landscape anomalies

Visible, Near-Infrared and Short Wave Infrared (VNIR/SWIR, 350-2500 nm) hyperspectral imaging spectroscopy, may provide accurate thematic cartographies and also estimated some ecosystems biogeochemical properties.

SCIENTIFIC & SOCIETAL QUESTIONS ?

- **OBSERVED IMPACTS: HOW CLIMATE AND HUMAN PRESURE AFFECT THE MOST VULNERABLE ECOSYSTEMS ? IS IT POSSIBLE TO QUALIFY & QUANTIFY THIS IMPACTS ?**
- **EFFECTIVE ADAPTATION : HOW CAN REDUCE THESE EFFECTS WITH AN APPROPRIATE RESPONSE ?**
- **RESILIENCE : HOW TO OBSERVE & MEASURE THESE BENEFITS?**

HYPXIM MAIN MISSION REQUIREMENTS (1/2)

HYPXIM

- Spectral continuum is required from VIS to SWIR optical domain
- Spectral resolution: goal=10 nm, threshold=15nm in VIS-NIR channel
- The panchromatic image can be combined with the hyperspectral image so as to enhance spatial resolution.

Domain	Spectrum (nm)	Spectral res. δλ (nm)	SNR
VIS	400-700	10	≥ 250:1
VNIR	700-1100	10	≥ 200:1
SWIR	1100-2500	10	≥ 100:1
PAN	400-800	400	≥ 90:1

SNR = Signal-to-Noise Ratio

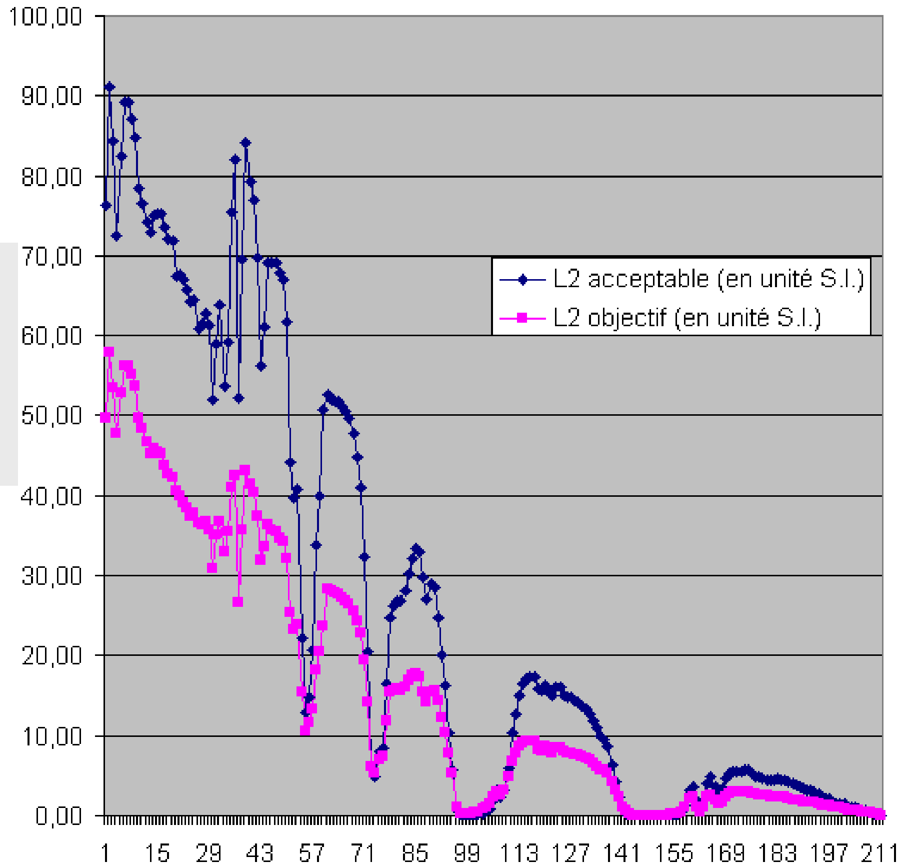
Spectral continuum was also required for TIR with a spectral resolution of 100 nm, but ***was not considered in phase A because less mature than the others needs***

- Ground Spatial Resolution (GSR) - 3 classes of needs are identified for VNIR-SWIR domain (0.4 - 2.5 µm) :
  - 20 meters and larger => covered by EnMAP and PRISMA missions.
  - 10 to 15 meters
  - 5 to 10 meters

  } => **HYPXIM's targets**.
- Swath :
  - Goal: up to 30km; Threshold: 15km, Minimum: 8km
- Satellite's revisit frequency is mostly critical
  - Daily revisit required for some applications (e.g. security & defence) but 3-day revisit period acceptable.
  - Non critical for many others applications (geosciences, urban environment).

2 levels of radiances requirements has been taken into account:

GOAL : Spectral L2 Radiances based on the 6 themes (with favorable atm. But SZA: 60°)



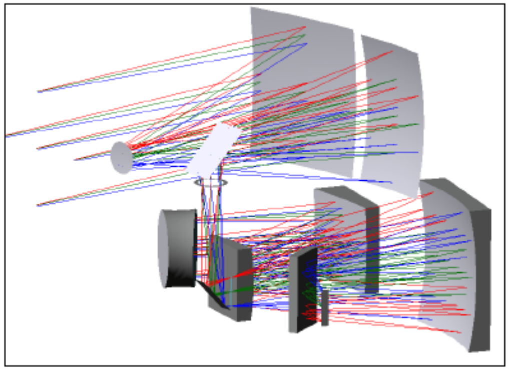
Threshold : Spectral L2 Radiances based on the 4 themes (with unfavorable atm. but SZA: 30°)

Atmospheric and Coastal topics are not included

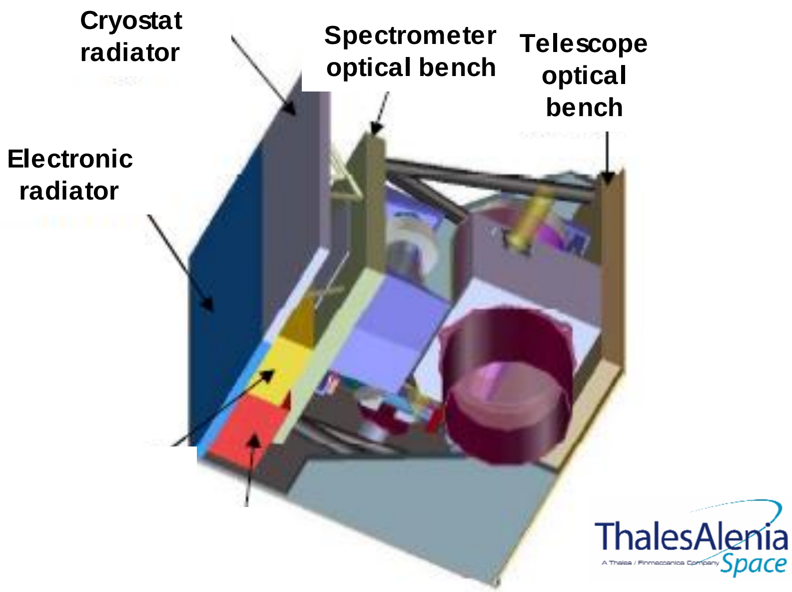
Outputs of the mission group analysis based on statistical analysis

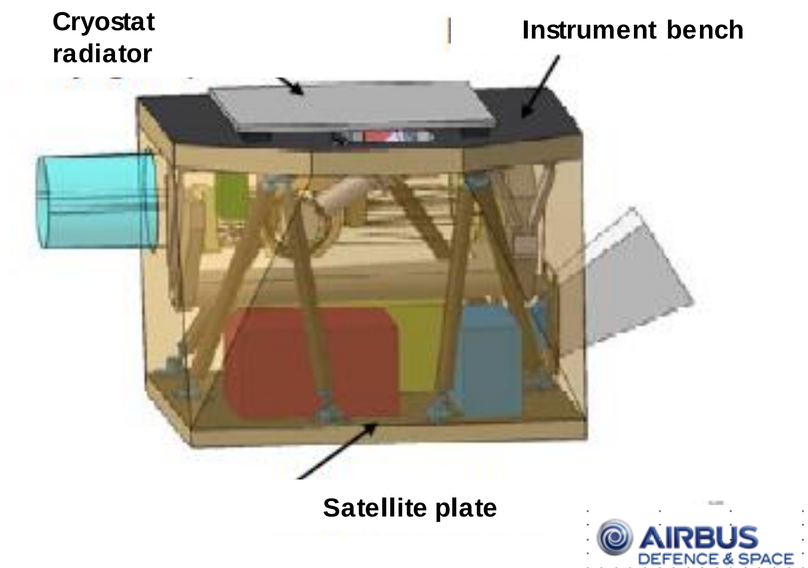
Some key technologies miniaturization has allowed to achieve a compact high-resolution hyperspectral instrument :

- An unique and mature compact design:
  - Forefront TMA (Three-Mirror Astigmatic) telescope
  - A very compact prism spectrometer (new concept)
  - Unique focal plane covering the whole range from 0.4 to 2.5 microns thanks HgCdTe detectors
  - focal plane cooled down to 150 K with Mini Pulse Tube Cooler



- PAN channel shares forefront telescope with the spectrometer
  - 12000 pixel, 6 µm linear detector at the focal plane, ambient T°
  - Low impact on instrument volume & mass

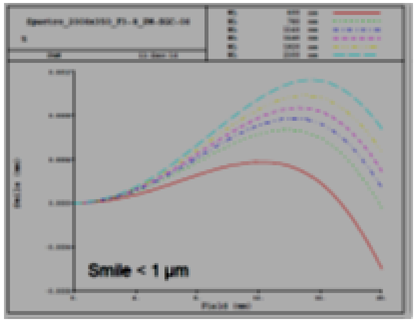




- Commits with all the performance requirements @ 8m

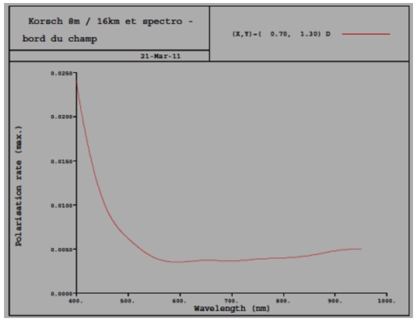
HYPXIM CONCEPT OVERVIEW (3/3)

- Smile < 1 µm



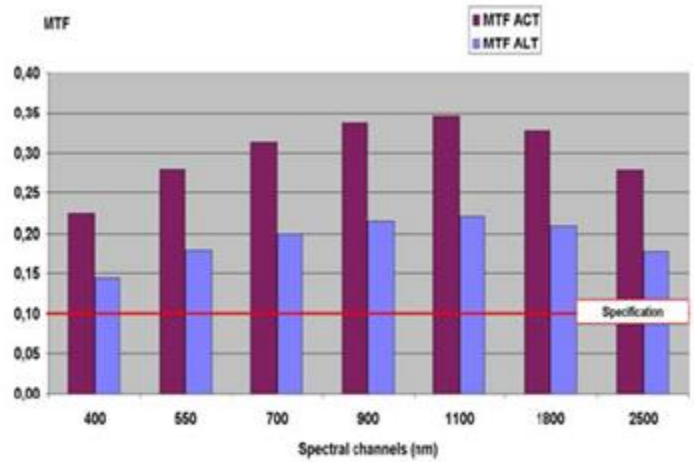
- Keystone < 5 µm

- Polarisation < 2,4%



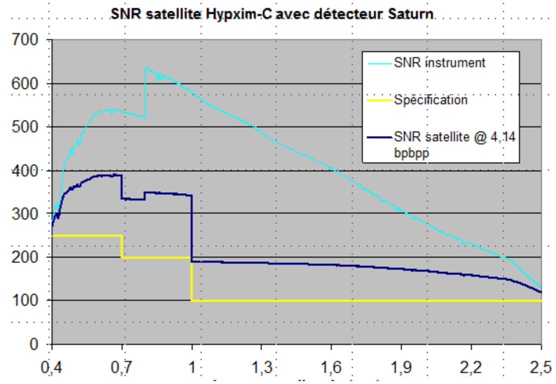
- MTF

Hyperspectral > 0,1 for all bands



PAN MTF: 0,09 (X) et 0,10 (Y)

- SNR (HYPXIM-C)



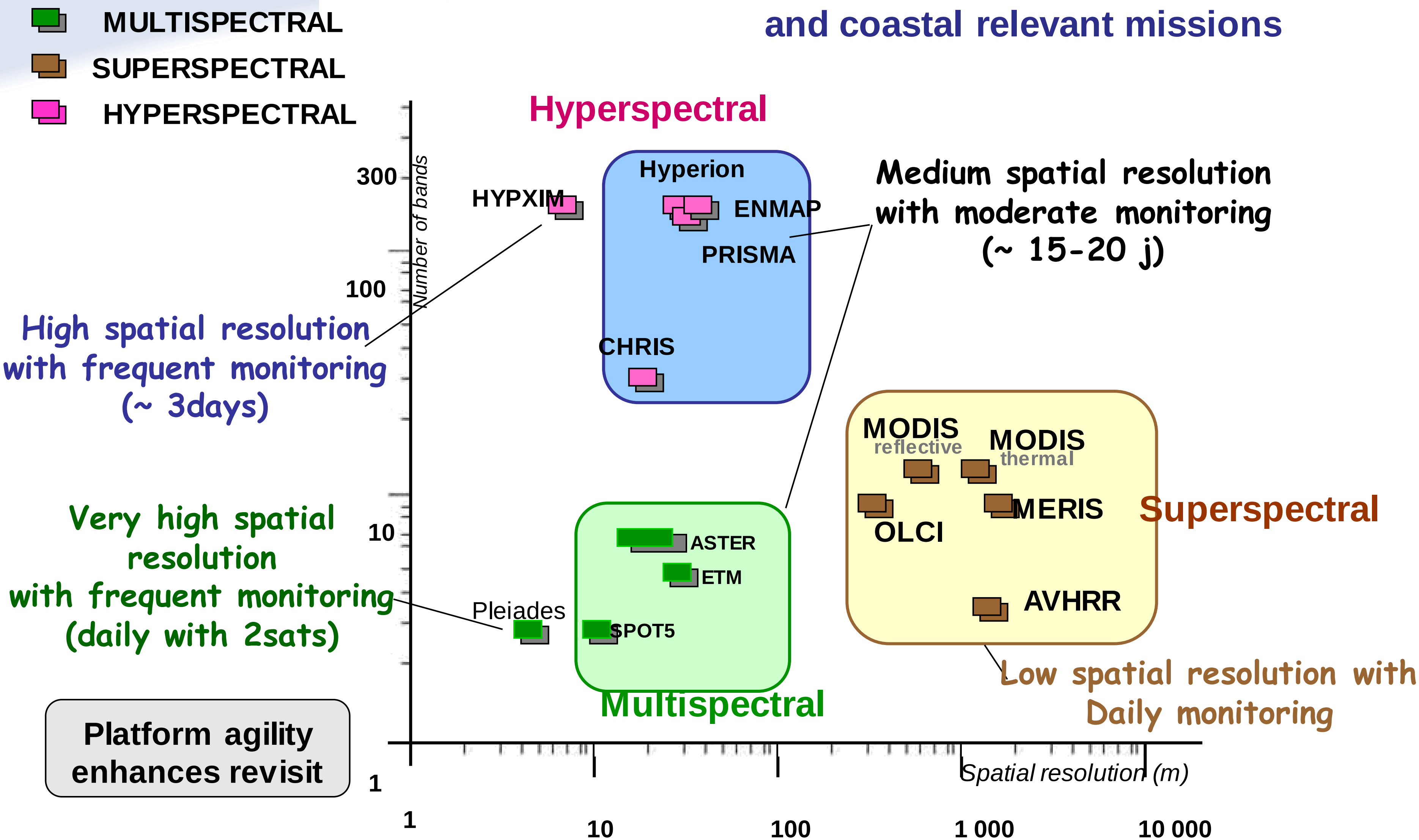
HYPXIM MISSION: 3 DESIGNS MEETS THE REQUIREMENTS

HYPXIM

	HX-Challenging	HX-Performance	HX-Demonstrator
Altitude	650 km	660 km	360 km
Payload	TMA telescope Φ150 mm	TMA or Korsch telescope Φ450 mm,	TMA telescope Φ150 mm
	Detector VNIR-SWIR 1000 x 256 pixels (off-the-shelf)	Detector HgCdTe 2000 x 360 pixels (to be developed)	Detector VNIR-SWIR 1000 x 256 pixels (off-the-shelf)
Resolution/Swath	15 m / 15 km	8 m / 16 km	8 m / 8 km
Panchromatic band	Resolution: 3.75m	Resolution: 1.85m	Resolution: 1.85m
Spectral bandwidth	400 – 2500 nm / < 14 nm	400 – 2500 nm / 10 nm	400 – 2500 nm / < 14 nm
Payload budget	Mass 70 kg	Mass ~115 kg	Mass 70- 90 kg (*)
	Power 110 W (imaging),	Power < 150 W (imaging)	Power 110 W (TBC)
Satellite	195 kg (at launch)	600 kg (at launch)	350 kg (with election propulsion) -500kg(if chemical propulsion)
Revisit period	+/-20° across-track imaging : 15 days	+/-20° across-track imaging : 15 days	+/-20° across-track imaging : 15 days
(+/-60° in latitude)	+/-35° across-track imaging: 3 days (2 satellites)	+/-35° across-track imaging: 3 days (1 satellite)	+/-35° across-track imaging: 3 days/*5 days* *with some coverage options* (1 satellite)
Imaging capacity (for one satellite)	~ 63 000km2 per day (280 images/day)	~100 000 km2 per day (270-450 images)	~7000 km2 per day (~110 images)
Link to Ground	X-band link at 160 Mbps (with ground or mobile stations)	X-band link at 620 Mbps (with ground or mobile stations)	X-band link at 160 Mbps (with ground or mobile stations)
Launcher compatib.	Soyuz, Vega, Ariane 5	Soyuz, Vega, Ariane 5	Vega
Expected lifetime	5 years (incl. end-of-life operations)	10 years (incl. end-of-life operations)	5 years (incl. end-of-life operations)

HYPXIM

Spatial & Spectral Scales of continental and coastal relevant missions



HYPXIM MISSION RECENT ACTIVITIES

- 2014: **CNES Scientific Prospective Seminary (SPS 2014),** confirmed a medium-term hyperspectral mission and recommended especially to focuses on Coastal zones, Urban Ecosystems and Forest Biodiversity
  - *Launch date expected (2023-2025)*

- 2014-2015: **Platform & System new Design studies** based on the same Hypxim instrument at low orbit (360km)
  - Based on the Microsat compact instrument but 8m GSD and high level of Image quality
  - Flexible demonstrative mission on low orbits covering a panel of test-sites (~100)
  - Capabilities to change the orbit (2 times by year) using electric propulsion

- 2015-2016: **Science and Defense engineering consolidation studies continue :**

  1- Cal/VAL and image processing research: **CNES R&T Program** (see next slide).

  2- Image Quality support and accompanying the demonstration projects of the Defense in the frame of **HYPEX Research Project** (slides 14-15)

  3- Consolidation of the Scientific mission in the frame of **TOSCA Program** (slides 16-40).

HYPXIM ACTIVITIES @ THE CNES R&T PROGRAM

- **MAIN OBJECTIVES:**

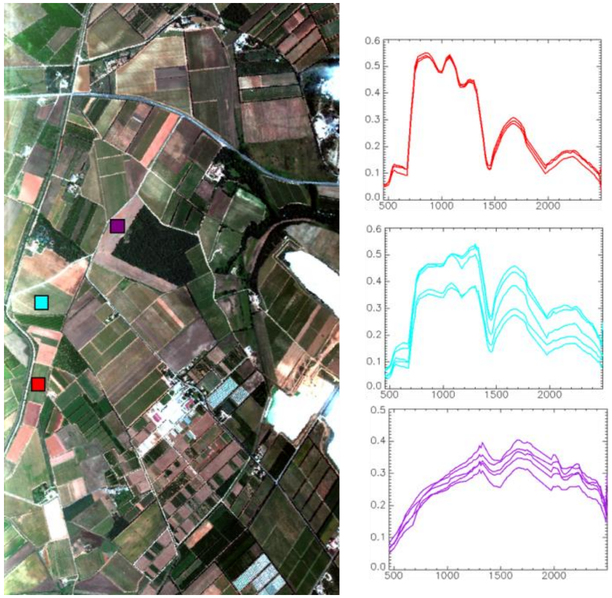
Panel of technical activities centered on the development of methods and algorithms (simulators for CAL/VAL studies, image processing) in order to increase the CNES expertise "from the physical signal to the final product".

- **Annual Program funded by the CNES**
  - **Radiometry (R&T 2014-2015):**
    - End-to-End « Surfaces+atmosphere » simulator for signal polarization analysis;
    - Coastal Ocean Color algorithms: Inversion methods for the water column parameters.
  - **Fusion Panchromatic/Hypespectral (R&T 2014) :**
    - Fusion algos state-of-art and benchmarking (R&T 2014);
    - Combination of Fusion and Unminxing approaches (R&T 2014)
  - **Classifications:**
    - Algorithms benchmarking : Hyper vs multi-spectral comparizons
    - Modélisation :Building a statistical model taking into account functional, spatial and temporal aspects.
  - **Modelisation by graphic image processing (R&T 2015):** Exploiting the properties of graphs in order to achieve significant differences like irregular sampling, change detection, anomaly detection, specific filtering, etc.

***R&T**: Research and Technology annual CNES programme*

HYPEX CONTRACT SUMMARY

- **MAIN OBJECTIVES:**
  - Demonstrate the contribution of Hyperspectral (HS) from airborne and spaceborne sensors for Defense themes;
  - Develop and evaluate processings and tools for the exploitation of HS data



- **Research Contract funded by the DGA**
  - Production: ONERA, CEA, CNES, BRGM

- **Agenda : 3 years (ending : may 2016)**

HYPXIM SCIENTIFIC CONSOLIDATION @TOSCA PROGRAM

- **MAIN OBJECTIVES:**
  6 projects covers the main topics which can help us to consolidate HYPXIM design. They are based on field studies, physical modeling and experimental airborne campaigns mainly to analyze GSD vs SNR needs.
- **TOSCA Scientific Annual Program funded by the CNES**

NAME	*TOPICS*	MAIN OBJECTIVES	LABORATORIES
HYPERTROPIK	*FOREST BIODIVERSITY*	Consolidation of Hypxim mission for the theme "Biodiversity of Tropical Forests' contribution of 3D radiative transfer model (DART).	CESBIO, CIRAD, AMAP/IRD, ECO&SOL/INRA, TETIS/Irstea et ESE/Paris Sud
SAMSAT2	*RIVER SEDIMENTOLOGY*	Bio-optical properties analysis of Amazona delta water from hyperspectral data, in order to modelize the signal of the matters in suspension (MES).	GET (Geoscience & Environment lab of Toulouse)
HUMPER	*SOILS DEGRADATION*	Spatial resolution needs for the study of soil texture. Setting up a complete simulation chain to compare with different hyperspectral cameras.	ONERA, LISAH/IRD, CESBIO
MiHySpecSol		Impact of Spectral resolution for perennial properties of Mediterranean soils mapping	LISAH/IRD, ITAP/IRSTEA
HYPERCORAL	*COASTAL BIOTOPES*	Physical environmental parameters extracted from airborne hyperspectral images for mapping and monitoring of fragil habitats reef (Coral reef area -Reunion Island)	LDO, IFREMER, LETG, LPG, SEAS-OI, ESPACE-DEV, ECOMAR
URBHYP	*URBAN PLANIFICATION*	Hypxim requirements, to provide relevant information with the complexity of the environment for urban development and planning	LIVE, ONERA, in coordination with ANR project HYEP

TOSCA scientific Committee - annual selection

SOIL STUDIES

URBAN

COAST

BIODIVERSITY

PREMIMINARY SCIENTIFIC PROGRAM RESULTS

SOIL STUDIES
URBAN
COAST
BIODIVERSITY

Sciences work program progress overview

	PHYSICAL MODEL	THEMATIC ALGOS	IN SITU DATA	AIRBORNE ACQUISITION	*SENSIBILITY TO ATMOS. CONDITIONS*	*SENSIBILITY TO GSD vs SNR*	*SENSIBILITY TO SPECTRAL RESOLUTION*
SOILS DEGRADATION (1)							
URBAN PLANIFICATION (2)							
COASTAL ENVIRONMENT (3)							
FOREST BIODIVERSITY (4)							

(1) HUMPER / MiHySpecSol

(2) URBHYP/ / HYEP

(3) HYPERCORAL

(4) HYPERTROPIK

VALIDATE
IN PROGRESS
TBD

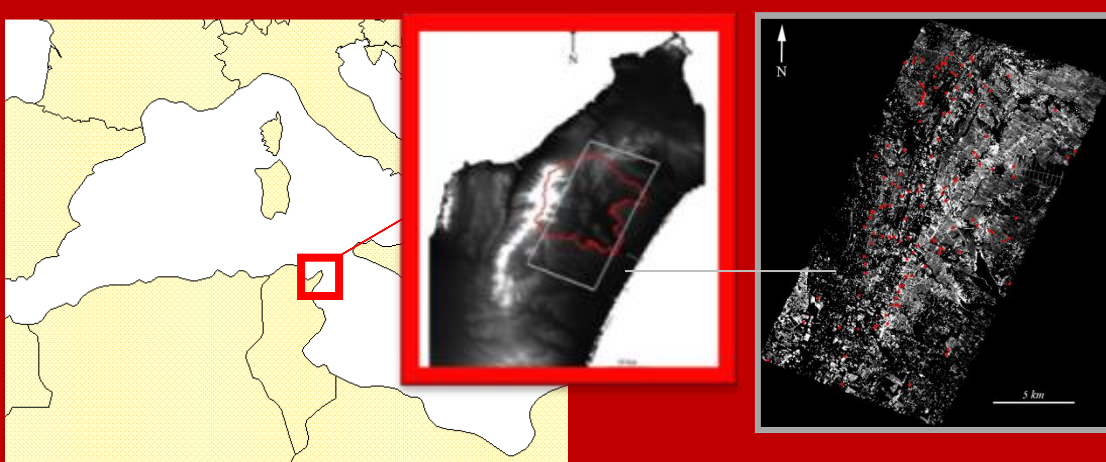
LISAH ONERA irstea CESBIO

WHAT CAN BE EXPECTED FROM HYPXIM FOR SOILS STUDIES ?

Sensitivity Analysis of soil property prediction to :

1- Atmospheric effects and **Spatial resolution**
(HUMPER Project 2013-2014)

2- Spectral resolution and **Signal Noise Ratio**
(MiHySpecSol Project 2014-2015)



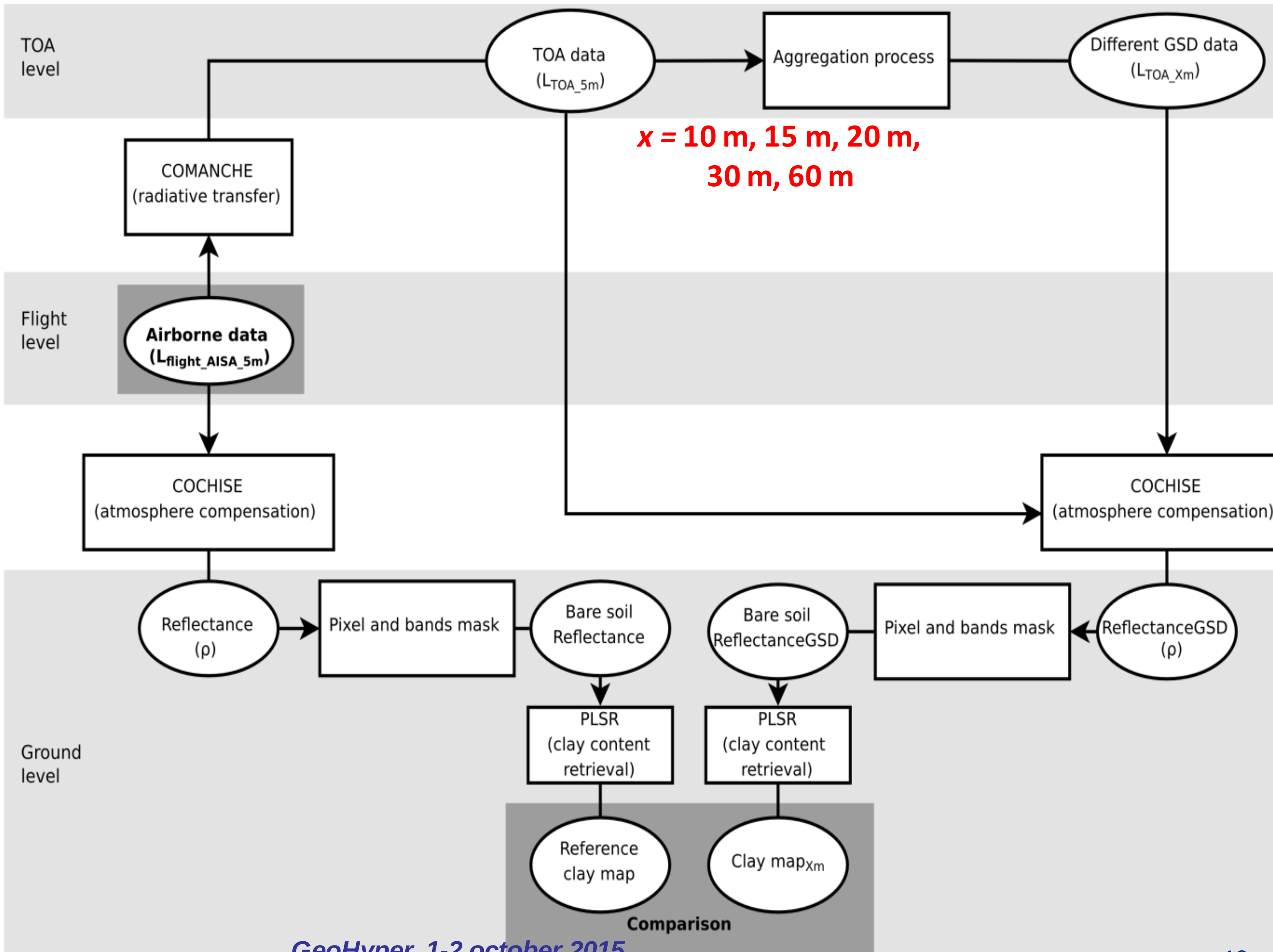
AISA-DUAL airborne data (300km²)

- Spectral domain: 400-2500 nm
- Number of Spectral Bands: 290
- Spatial resolution: 5 m
- Spectral resolution:
  - 4.67 nm between [400 - 960 nm]
  - 6.28 nm between [960 to 2450 nm]

METHODOLOGY

Sensitivity to Atmospheric effects and spatial resolution

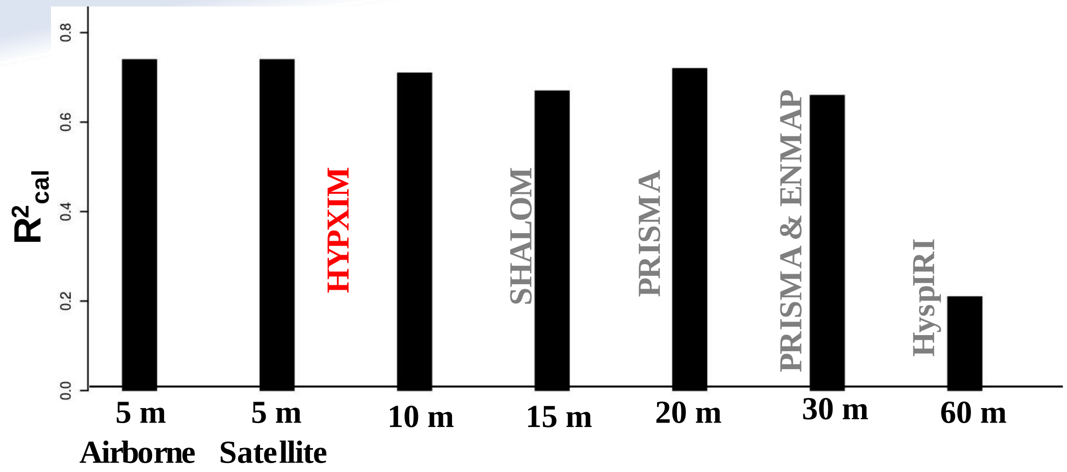
Gomez et al., 2015

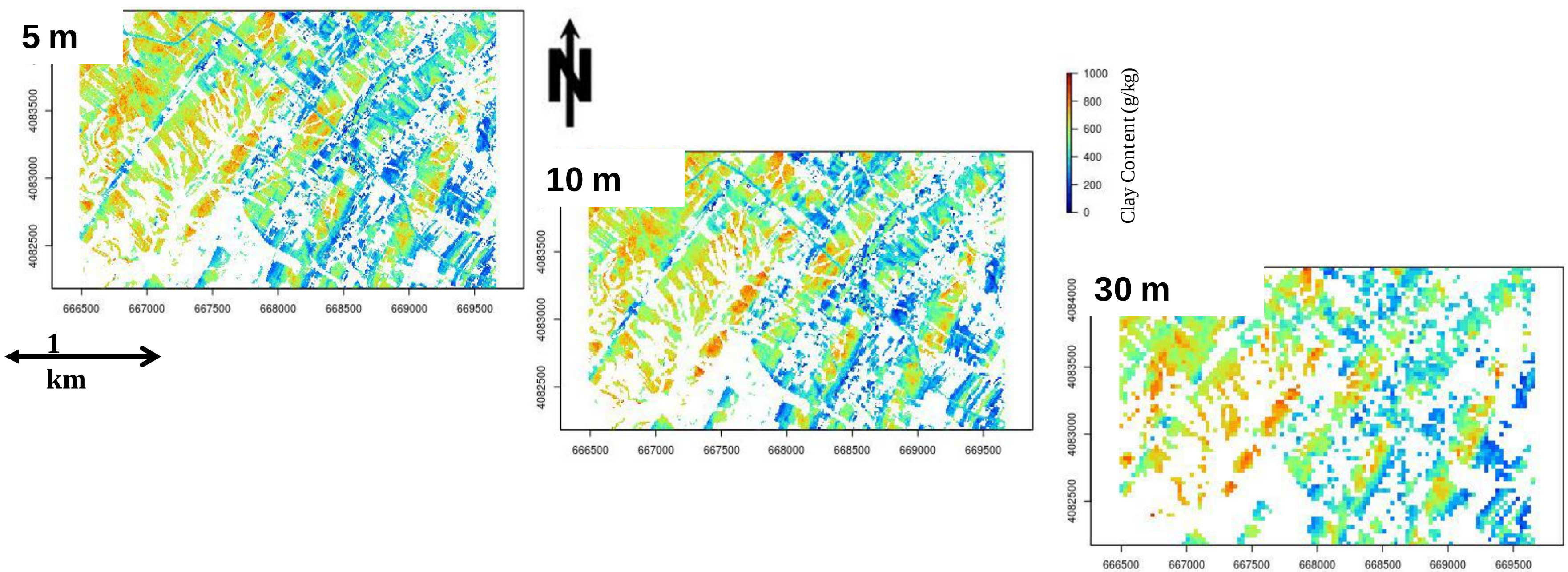


RESULTS

Sensitivity to Atmospheric effects and spatial resolution

Gomez et al., 2015

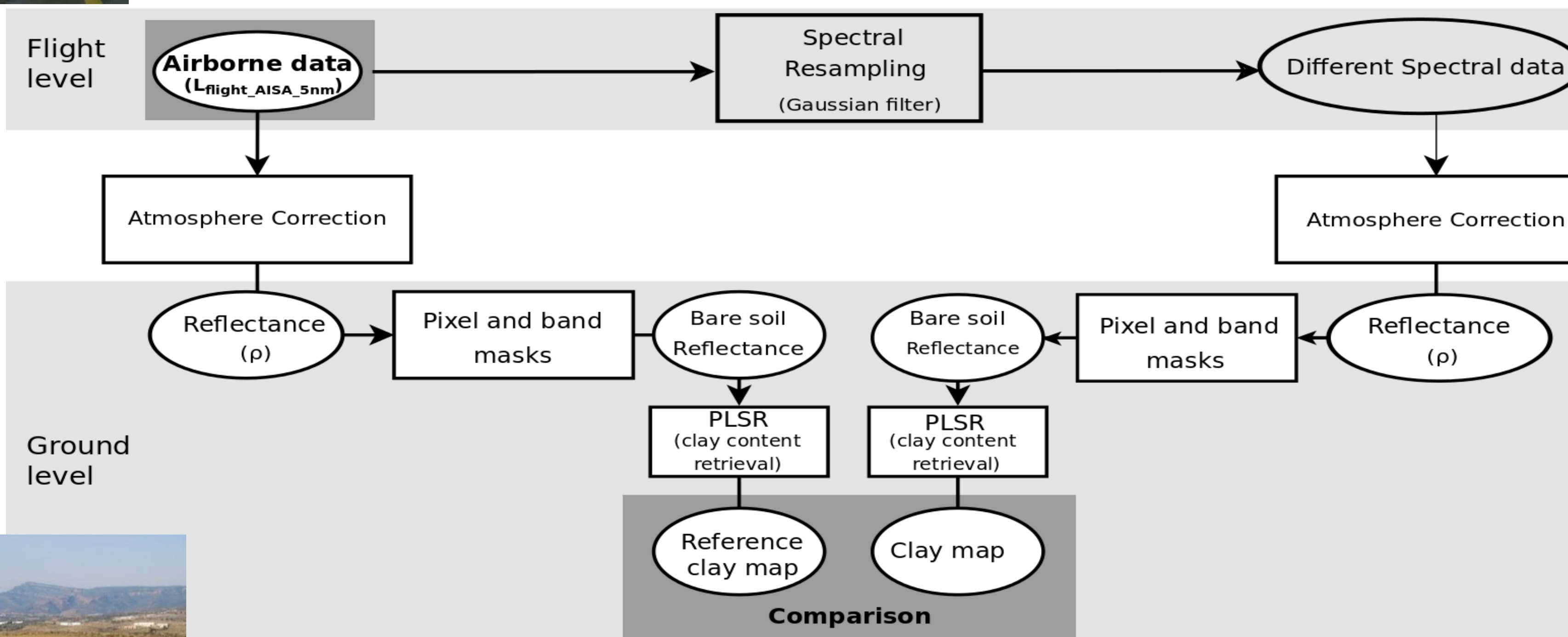




Sensitivity to spectral resolution

Gomez et al., 2015

~10 nm, ~37 nm, ~60 nm,
~100 nm, ~200 nm

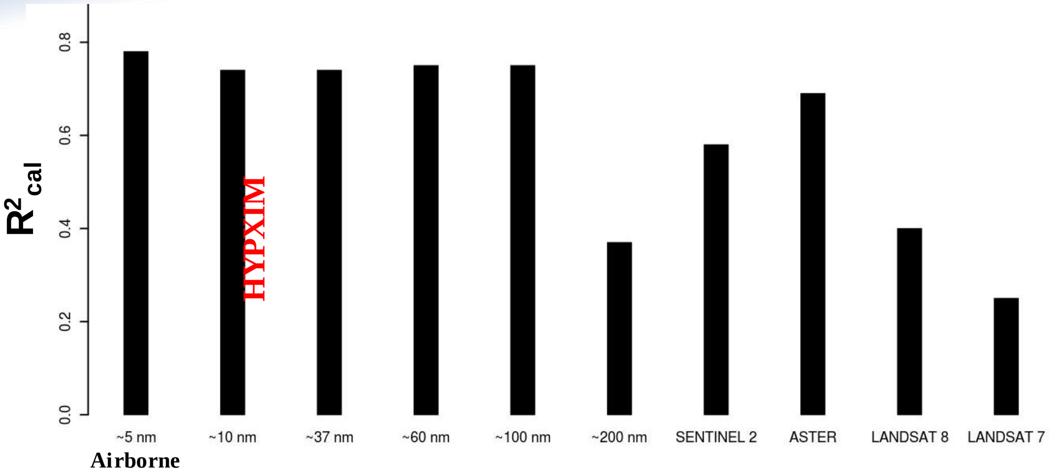


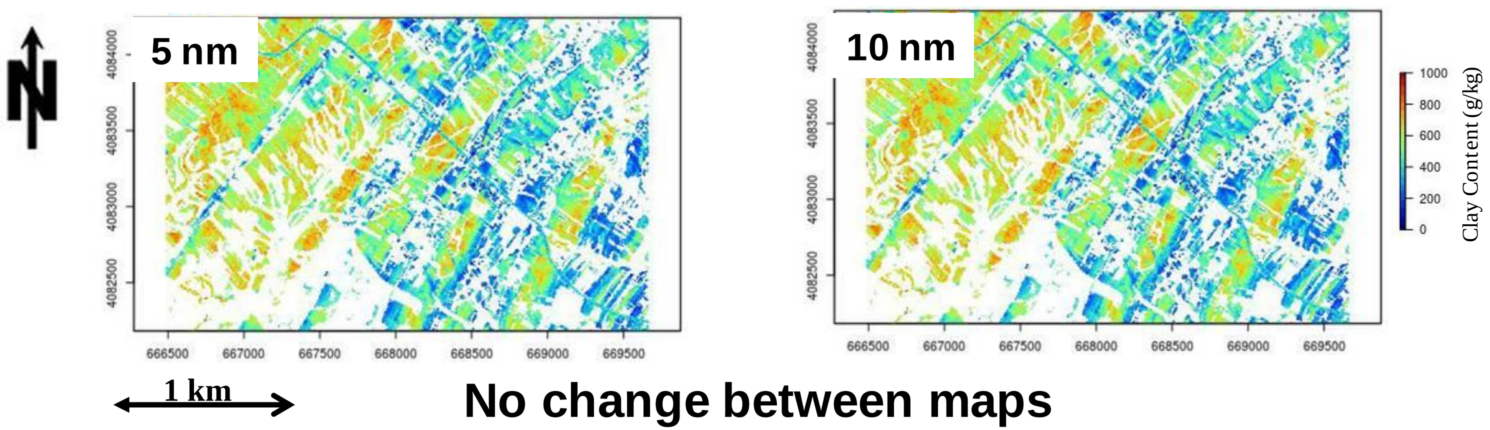
RESULTS

Sensitivity to spectral resolution

Adeline et al., in revision

Work still in progress





No change between maps

SOIL STUDIES
URBAN
COAST
BIODIVERSITY

WHAT CAN BE EXPECTED FROM HYPXIM FOR URBAN STUDIES ?

■ Atmosphere compensation

=> *Three different atmosphere correction tools are compared as a function of the spatial resolution*

■ Impact of spatial resolution vs spectral domain

=> *Classification performances comparison of existing sensors (Pleiades, Sentinel-2 and HYPXIM) in radiance unit*

■ Fusion algorithm

=> *HYPXIM : PAN/Hyperspectral products*

Authors:

- **Rosa Oltra-Carrio (ONERA)**
- **Guillaume Roussel (LIVE, ONERA)**
- **Briottet Xavier (ONERA)**
- **Laetitia Loncan (ONERA, GIPSA-Lab)**

HYEP

Atmospheric correction (1/2)

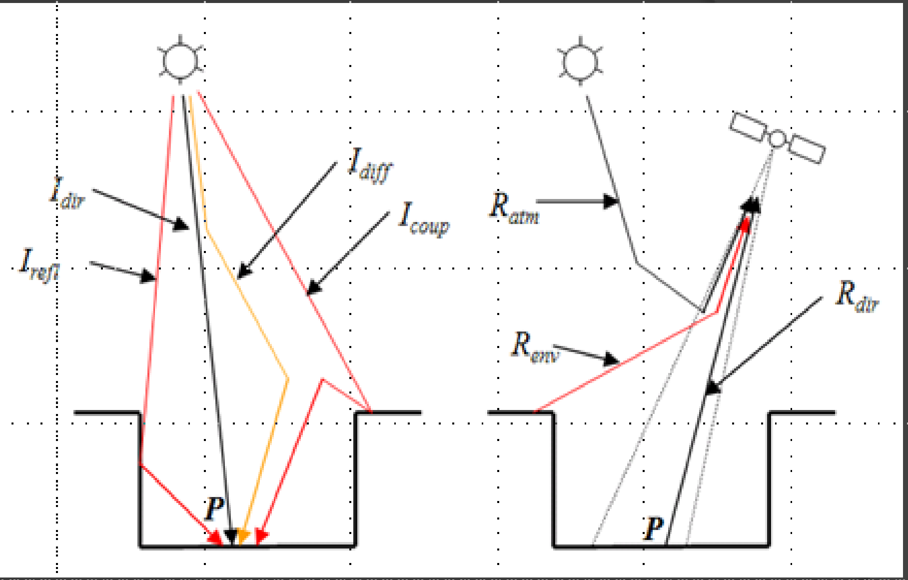
ONERA THE FRENCH AEROSPACE LAB
X. Briottet, X. Ceamanos, G. Roussel

- Urban environment issues : shadows, occultations, vertical facades
- Objective : from the sensor radiance, going back to the reflectance ρ

$$\rho = \frac{R_{tot} - R_{env} - R_{atm}}{\frac{1}{\pi} \times I_{tot} \times \tau_{up}}$$

$$I_{tot} = I_{dir} + I_{diff} + I_{coup} + I_{refl}$$

$$R_{tot} = R_{dir} + R_{env} + R_{atm}$$



- Comparison of three methods

- COCHISE[1]
  - Flat ground hypothesis :
    - I_{refl} neglected
    - I_{diff}, I_{coup}, and R_{env} processed without considering the relief
  - Limitation : no proper correction in shadowed areas

- Empirical method[2]
  - Fast algorithm correcting both shadows and relief effects without DEM
  - Suited to classification applications
  - Limitation : some radiative terms are roughly approximated, which prevent this method to be used for spectrum identification

- ICARE[3]
  - Efficient method suited to 3D environment (DEM known)
  - Suited to spectrum identification

[1] Miesch et al., « **Direct and inverse radiative transfer solutions for visible and near-infrared hyperspectral imagery** », *Geo and Remote Sensing*, 2005.
[2] Chen et al., « **Efficient empirical reflectance retrieval in urban environment** », *IEEE Journ. of sel. top. in applied earth obs. and remote sensing*, 2012.
[3] Lachérade et al., « **ICARE : a physically-based model to correct atmospheric and geometric effects from high spatial and spectral remote sensing**

HYEP

Atmospheric correction (2/2)

ONERA THE FRENCH AEROSPACE LAB
X. Briottet, X. Ceamanos, G. Roussel

Empirical method steps :

- A shadow mask is processed using the Nagao algorithm[4]
- I_{dir}, I_{diff}, R_{atm}, R_{env} and τ_{up} are processed using Comanche, a direct radiative transfert code
- I_{tot} is processed differently for sunlit and shadowed areas

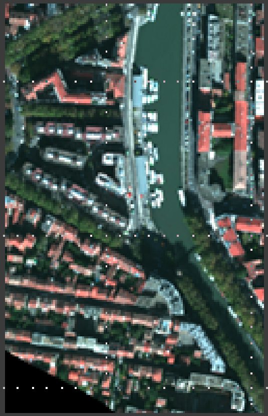
$$\rho = \frac{R_{tot} - R_{env} - R_{atm}}{\frac{1}{\pi} \times I_{tot} \times \tau_{up}}$$

$$\rho = \frac{R_{tot} - R_{env} - R_{atm}}{\frac{1}{\pi} \times (I_{dir} + I_{diff}) \times \tau_{up}}$$

Sunlit areas

$$\rho = \frac{R_{tot} - R_{env} - R_{atm}}{\frac{1}{\pi} \times (\alpha_{sky} \times I_{diff} + I_{refl}) \times \tau_{up}}$$

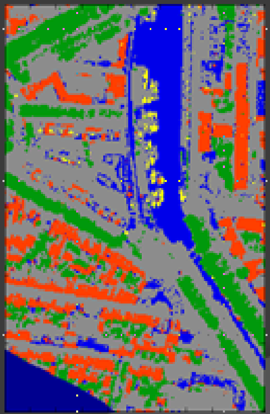
Shadowed areas



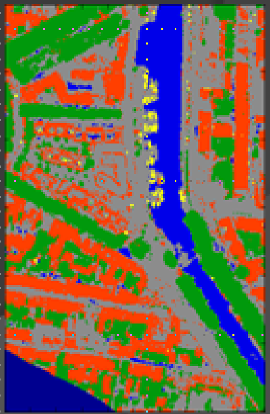
Colored composition

Shadow mask

Classification results comparison



COCHISE



Empirical method

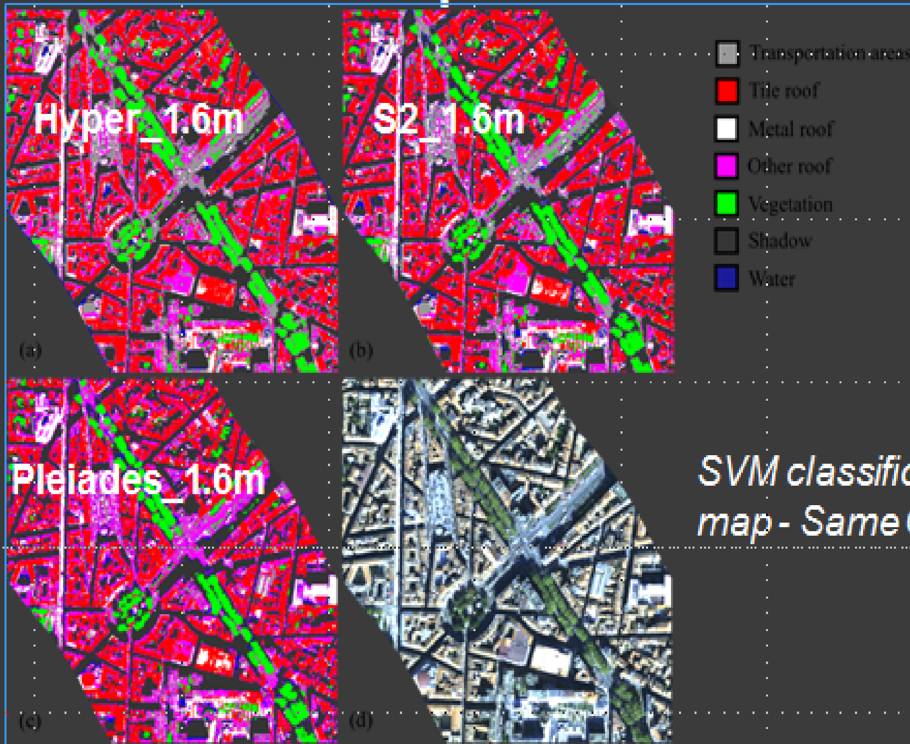
Perspectives :

- Improvements of the ICARE method (computing time, spectral resolution)
- Application of these 3 methods on images of several spatial resolutions

[4] Nagao et al., « Region extraction and shape analysis in aerial photographs », *Computer Graphics and Image Processing*, vol. 10, no. 3, pp. 195 – 223, 1979.

HYEP
Hyperspectral Imagery for Environmental urban Planning

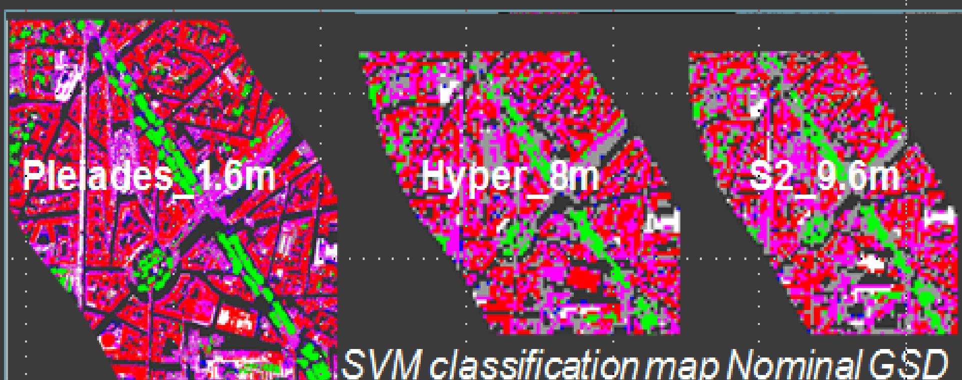
Applications : milieux urbains (33) – classification - Classification des surfaces urbaines : résolution spatiale vs domaine spectral



SVM classification map - Same GSD.

Results of a supervised classification (SVM) on the radiance image

Image	Kappa	Overall accuracy (%)
SENTINEL 2_1.6m	0,88	89,7
Hyper_1.6m	0,86	87,9
PLEIADES_1.6m	0,80	82,6
HYPER_8m	0,77	80,7
SENTINEL-2_9.6m	0,66	71,4



SVM classification map Nominal GSD

With a same GSD, SWIR band improves the good classification performances

With their nominal resolutions, Pléiades (2m) and HYPXIM (8m) have similar classification performances

Ongoing:

- Fusion Pan/hyper (Loncan, ONERA-Gipsa Lab)
- Improve the number of class
- Unmixing taking into account the intraclass variability (C. Revel, OMP-ONERA)

Etude ADEME Ilot de fraicheur urbain, R. Oltra Carrio, X. Briottet, 2014

SOIL STUDIES
URBAN
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BIODIVERSITY

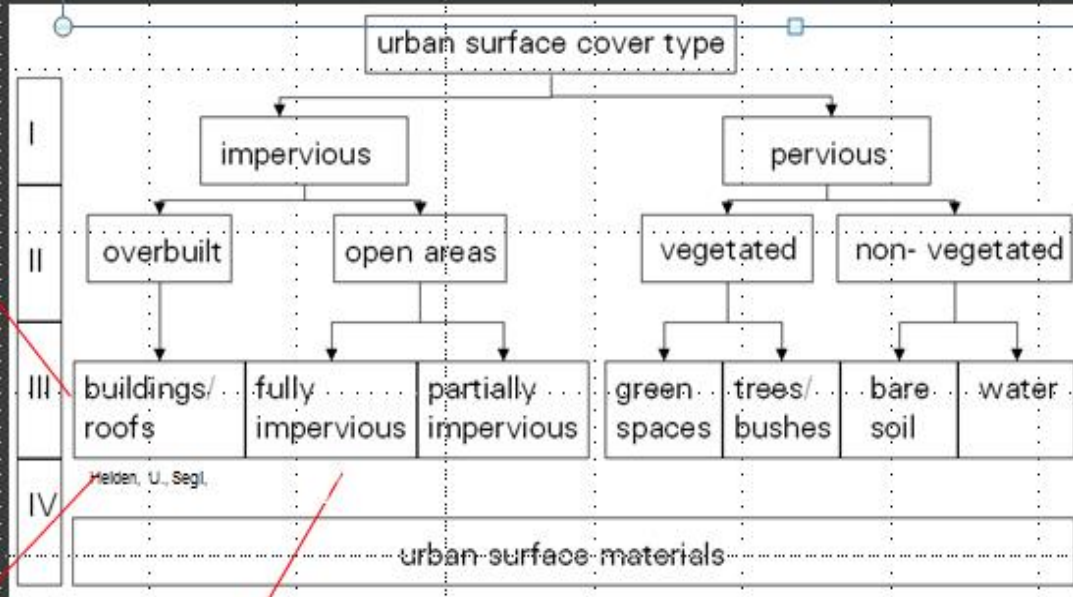
Pan / Hyperspectral Fusion (4 scale factor)

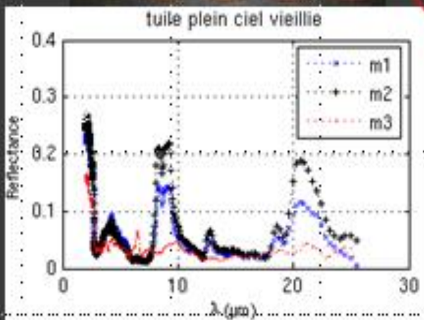
Pan Image

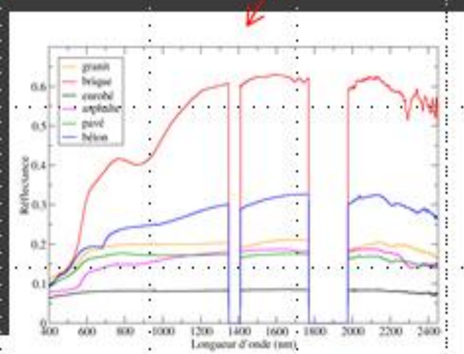
Hyperspectral Image

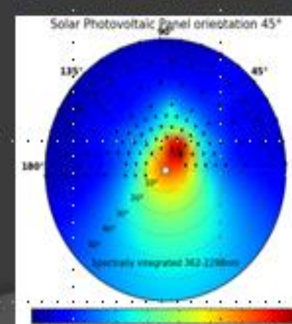
See Laétitia LONCAN presentation (DGA/ONERA PhD funding –GIPSA-Lab/ONERA collaboration)

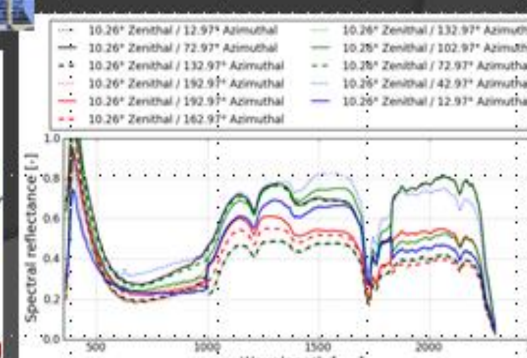
Taxonomy and data base

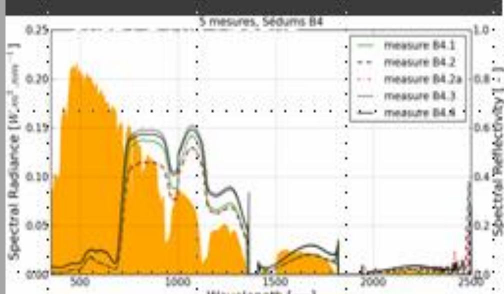












WHAT CAN BE EXPECTED FROM HYPXIM FOR COASTAL ENVIRONMENTS ?

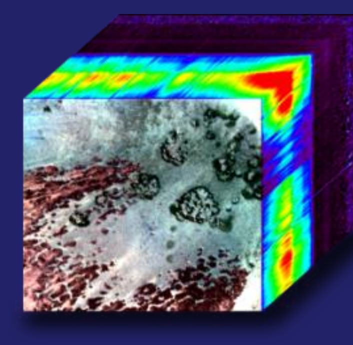
Hypercoral project Goal :

To assess the potential of hyperspectral imaging and spatial complementarity with existing optical satellites (including the Pleiades and SPOT 5) for extracting physical parameters of the environment (bathymetry, Backgrounds, Water Column), mapping and monitoring habitat reef area.

Approach:

- Development of a direct model , then inversion to extract the hyperspectral signal: bathymetry / background reflectance and optical properties of the water column

- Campaigns acquisitions multi platforms (satellite / aircraft / UAV) and multi sensors (multi and hyperspectral) at different spatial resolutions) and ground truth



Multiscale data

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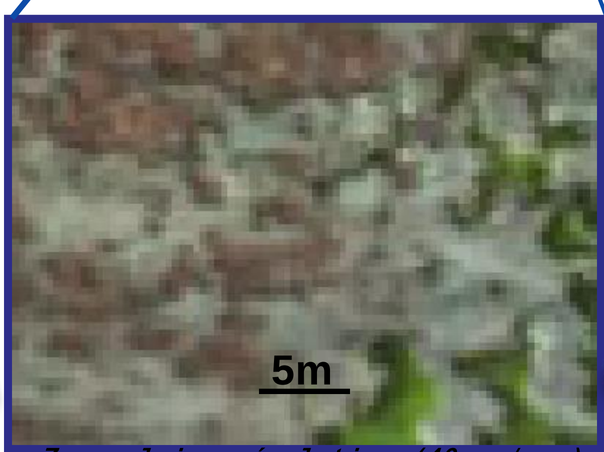
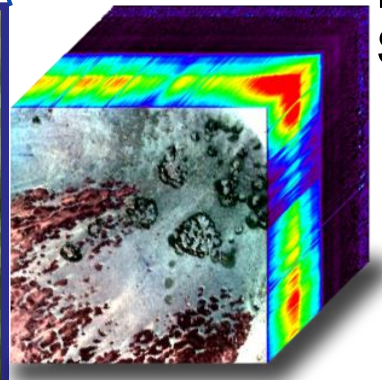
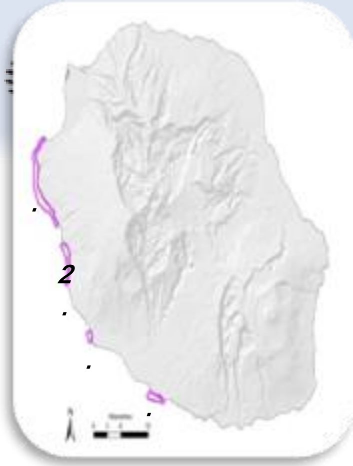
Airborne hyperspectralcampaign

Septembre 2014 et mai 2015



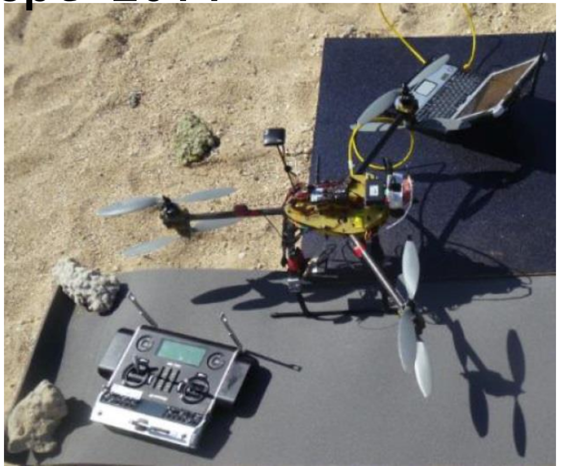
Zoom pleine résolution (40cm / px)





Pléiades – Mai 2015

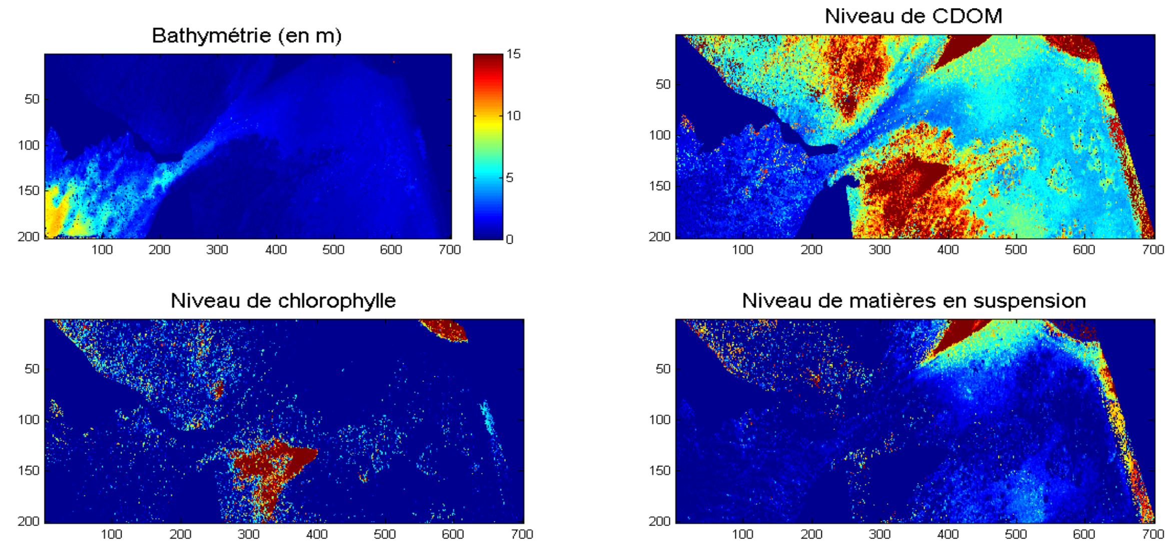
Drône multispectral Sept 2014



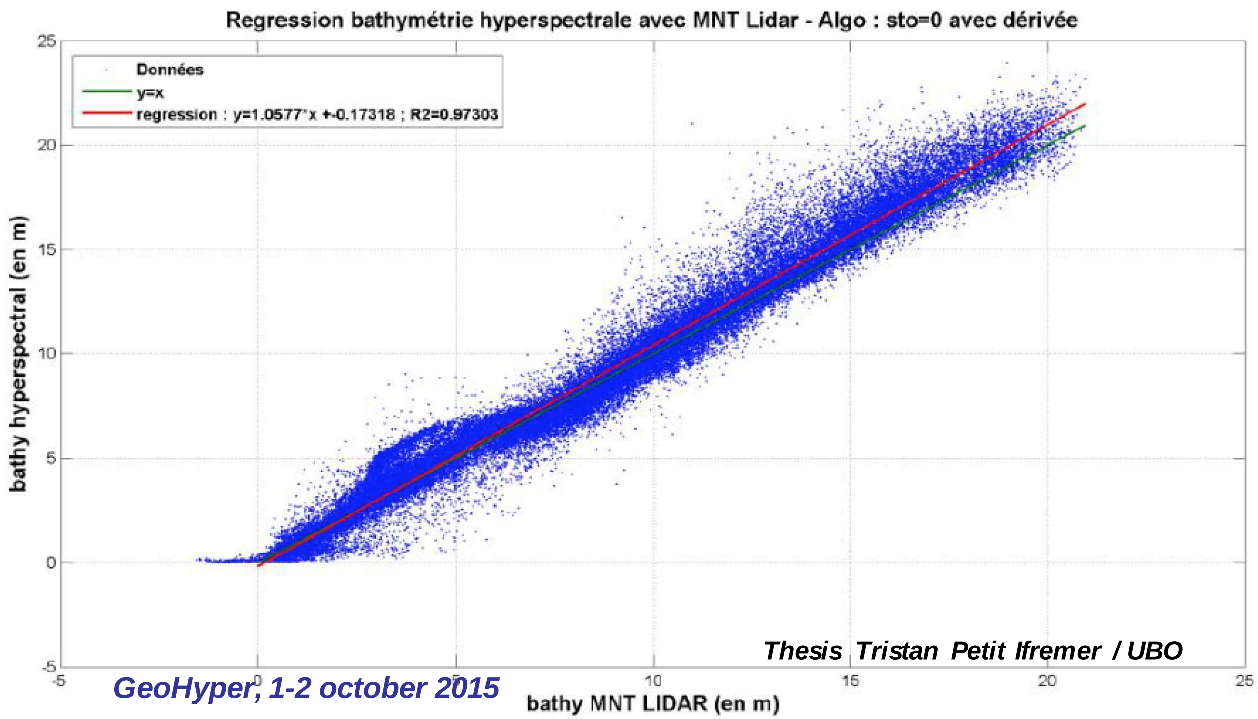
In Situ Campaign

- **Bathymetry**
- **Bedrock description:**
  - substrate identification
  - biological coverage
  - coral typology
  - reflectance Spectrum

Water Column characterization:
- amount of incident radiation, absorption, scattering,
- Fluorimetry (chla & CDOM),
- Sampling: mass and chemical measurements



**Preliminary results on the hyperspectral inversion signal, for bathymetry,
but also the water column content and the substratum**

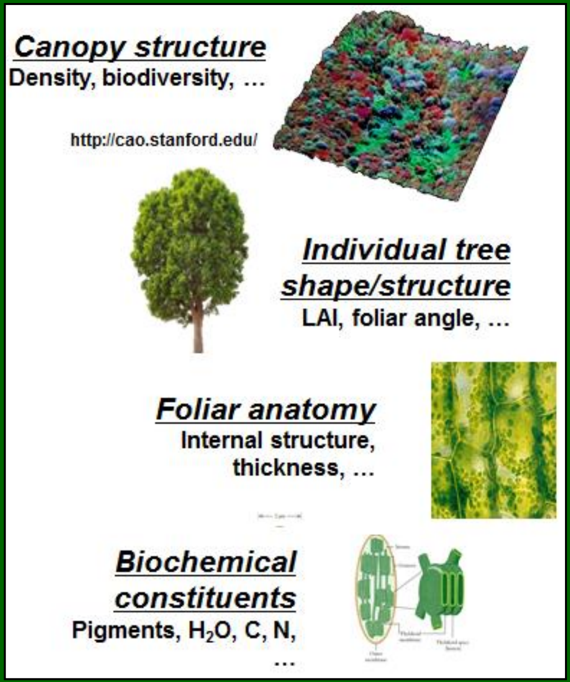


Thesis Tristan Petit Ifremer / UBO

WHAT CAN BE EXPECTED FROM HYPXIM FOR FOREST STUDIES ?

Airborne HR imaging spectroscopy has demonstrated its potential in tropical environments:

- Confirmation that trees structure combined with leaf biochemical properties influence the radiometric signal reflected by vegetation and contribute to the estimation of biodiversity (Carlson et al., 2007)
- Identification of tree species (Clark et al, 2005; Féret & Asner 2013)
- Mapping at fine scales as well local species diversity (α-diversity), than changes in forest species communities (β-diversity) (Féret & Asner 2014).



But what performance and limits for spaceborne measurements in this very complex environment ? We need to consolidate HYPXIM specifications for this topic, and in particular GSD vs SNR, =>high impact on the telescope size

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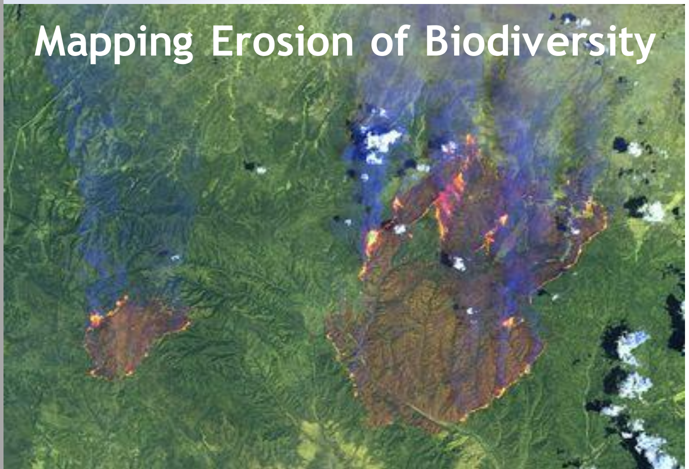
TROPICAL FOREST BIODIVERSITY STUDY: A GLOBAL INTEREST



Jesse Allen, data courtesy Landsat 7 Science Team,

Human activity (urbanization, deforestation, farming / agriculture, exploitation of geological resources) and climate change, globally affect ecosystems, causing accelerated erosion of biodiversity.

Tropical ecosystems are particularly affected by anthropogenic pressure. These regions host the most global biodiversity ('hot spots').

France is the home of 40% of the European flora (because numerous territories located in tropical region) and has a special interest for forest biodiversity research. But knowledge of these forests (species distribution, role in the carbon balance of the planet) is extremely low

Improved characterization of tropical biodiversity is a priority for forthcoming spatial missions programmed for the next decade, such as **HYPXIM**.

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HYPERTROPIK PROJECT SUMMARY

The project is structured into 4 steps:

- **First step (2014-2016)**, develop a simulator "**end to end"** based on DART code for an improved understanding of the hyperspectral signal at different scales

- **Then (2015-2016)** develop, adapt and validate **algorithms** focusing on vegetation parameters such as:
  - biological and structural diversity mapping,
  - quantification of biophysical parameters (LAI)
  - Quantification of biochemical parameters (pigments, H20)

- **Airborne Hyper and Lidar acquisitions (2015-2016)**, for validation of DART, and parametric studies at various conditions of acquisition (sun/view angle, atmospheric disturbance,...)

- **Parametric studies** based **on DART+ Airborne simulations (2016-2017)** for various conditions of acquisition (sun/view angle, atmospheric disturbance,...) and a range of spatial, spectral, and radiometric resolution, to establish a set of well-argued HYPXIM Mission requirements

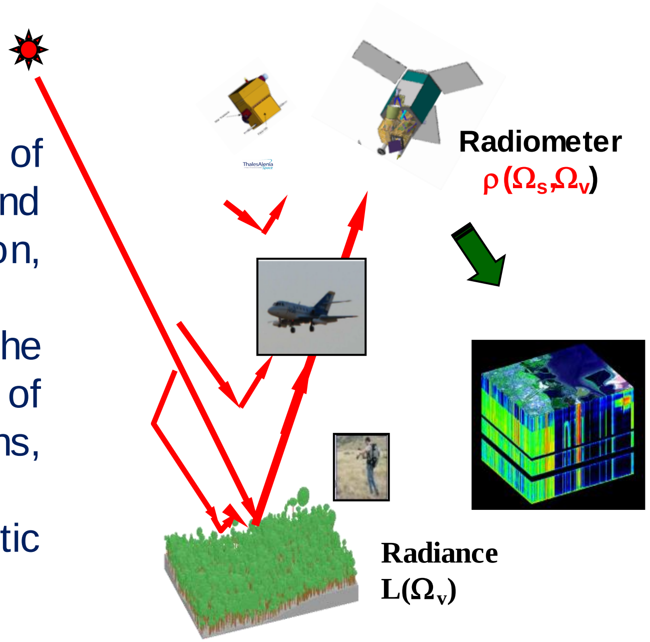
« END TO END » PHYSICAL MODELING & VALIDATION

- **DART model step: from a 3D Radiative transfer model to simulated hyperspectral images:**

DART is based on the 3D representation of various components of the scene (mock-up, atmosphere, MNT, solar direction) and instrumental characteristics (spectral domain, spatial resolution, view direction, ...).

The vegetation can be simulated as a medium constituted by the juxtaposition of turbid cells (LAI, LAD, …) and / or as a collection of triangles with translucent optical properties and specific orientations, etc.

DART generate hyperspectral images of radiance and realistic HYPXIM simulations

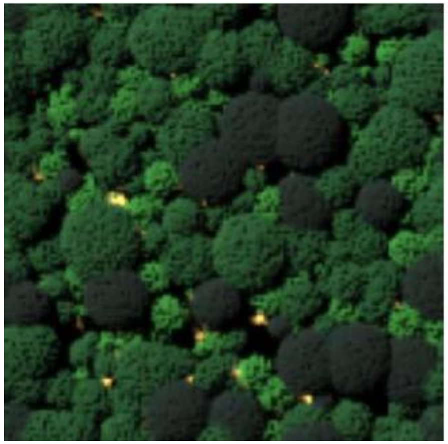


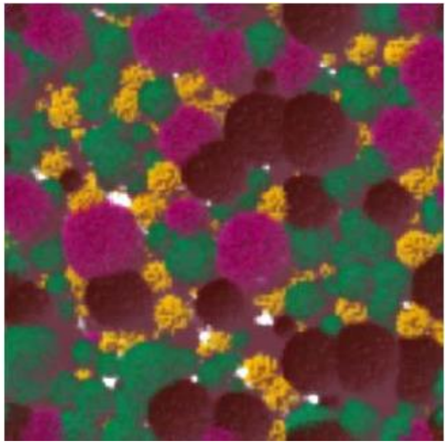
- Airborne validation Campaign :

Critical for the validation of DART simulations and preparation HYPXIM acquisitions.

The aim is to compare the images of radiance generated by DART with airborne/satellite hyperspectral images.

This data will be also used for a parametric study focusing on instrument requirements and conditions of acquisition.



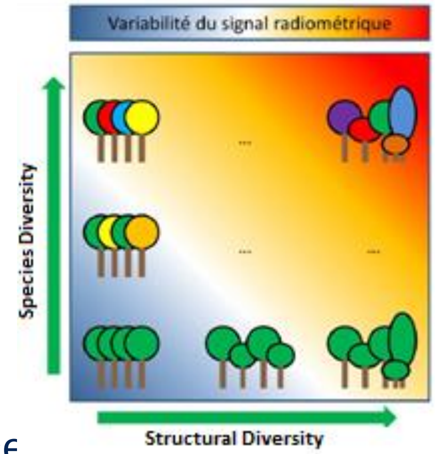


ALGORITHM STUDIES: PRELIMINARY RESULTS

For mapping biodiversity, how to distinguish the biochemical composition from the structural complexity ?

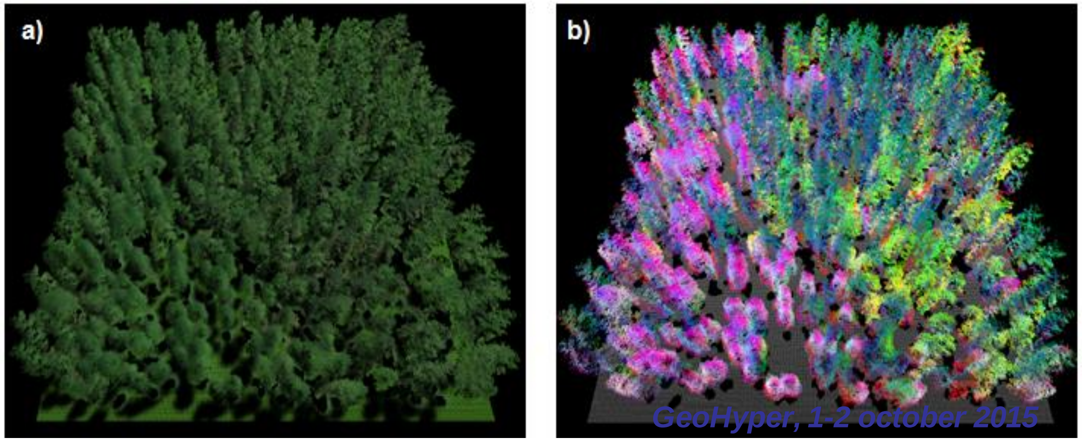
Spectral information allows accurate identification of tree species based on their chemical composition and their structure.

Spatial analysis based on size attributes, shape and texture, which also help describe the canopy, (for example: development stage for mangroves)



Our aim:

- to separate the signal of vegetation from other types of surfaces,
- to identify the tree species through their "specific spectral signature"
- to detect signals related to environmental factors or vegetation phenology inducing changes in the foliar optical properties



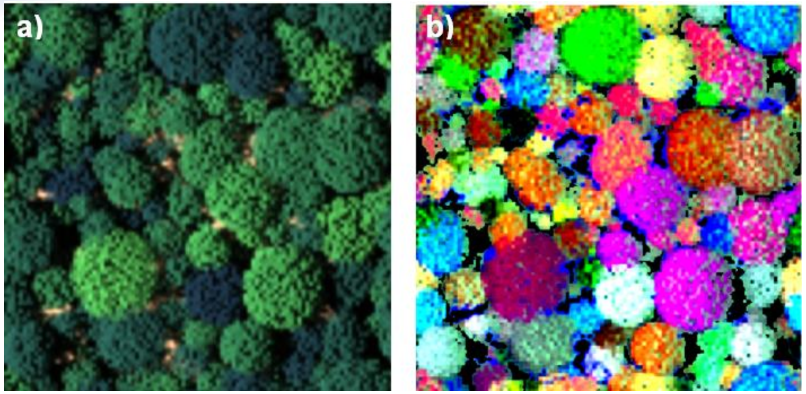
Example of Järvselja birch stand (Estonia):
(a) RGB 3D representation of a combination of Lidar and hyperspectral simulation by DART (RAMI-benchmark, JRC);

(b)Three components selected from a PCA hyperspectral DART simulation, highlighting species variability in function of their structure and foliar chemistry.

Ref.: Yin et al. (in preparation)

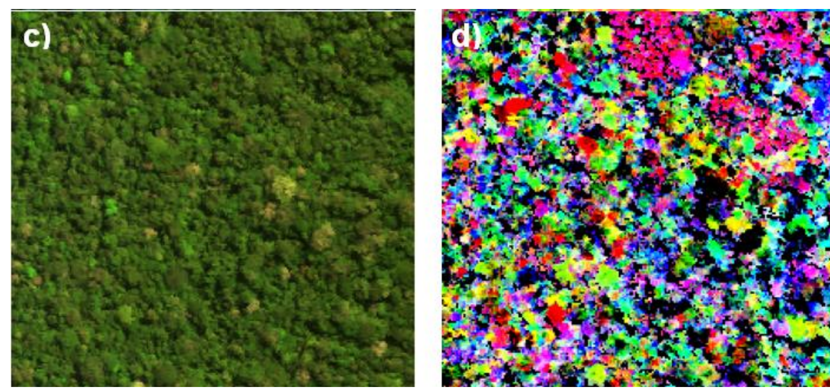
ALGORITHM STUDIES: PRELIMINARY RESULTS

Quantification of biophysical parameters (LAI) and biochemical (pigments, …)



DART simulation have been developed, integrating a variety of 20 distinct leaf optical properties distributed between the trees @ 50cm resolution.
Fig a): RGB presentation of an hyperspectral simulation
Fig b): combination of 3 components from the PCA, highlighting these leaf optical properties

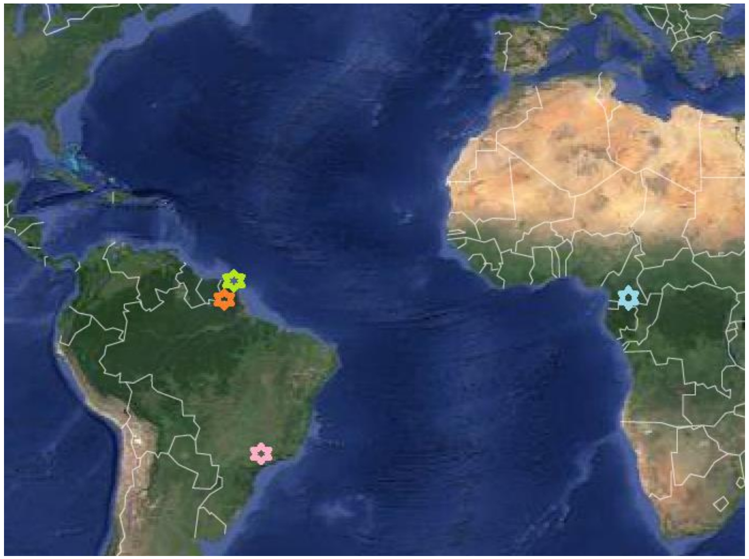
Carnegie Airborne Observatory (CAO)
Fig. c) Application of this approach using airborne hyperspectral imagery *(Site: CICRA, Peru; Féret & Asner, 2014).*
Fig d) Despite different spatial resolutions (2m vs 0.5 m), a similar PCA processing allows extraction of components corresponding to characteristics of individual trees/species, partly explained by variations in leaf optical properties.

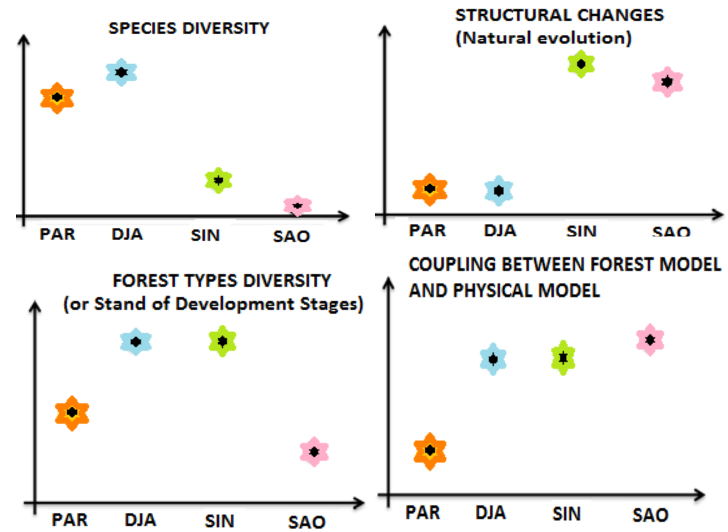


=> Quantitative comparison shows a greater variability in the simulations DART vs CAO data. In tropical environments, photosynthetic pigment content is generally very high, close to saturation in the visible domain and reduce the variability of the signal. So, the excessive variability in the DART simulation is probably due to under-estimated pigment content.

NEXT STEP

4 test-sites are selected as representing different stages of forest biodiversity





- **Dja test-site (Cameroon):** a dense and fragile rainforest characterized by a high diversity (species, architecture) and limited topographical variations.
- **Paracou / Nouragues test-sites (French Guiana):** a dense rainforest characterized by high species diversity, a structural variability TBD and a complex topography.
- **Sinnamary test-site (French Guiana):** mangrove consisting of only two dominant species, but, with a soil frequently flooded (tidal or rainy season), a high growth rate and fast changes.
- **São Paulo test-sites (Brazil):** eucalyptus plantations characterized by very low species diversity but with significant structural variability among clones and among growth stages

French Guyane: Hyperspectral /Lidar validation campaign (in preparation)

SYNTHESIS & PERSPECTIVES

THE PREPARATION OF THE INNOVATIVE HYPERSPECTRAL DUAL MISSION HYPXIM CONTINUES IN THE FOLLOWING DIRECTIONS:

1. THEMATIC PRIORITIES ARE CURRENTLY STUDIED WITH EXPERIMENTAL APPROACHES AND DEMONSTRATIONS

2. AN IMPORTANT EFFORT IS ALSO GIVEN TO THE ENHANCEMENT OF SIGNAL MODELIZATION AND TO ALGORITHM VALIDATIONS, IN ORDER TO PREPARE THE SCIENTISTS COMMUNITY AND THE DEFENSE USERS FOR THE USE OF NEW *HIGH SPECTRAL & HIGH SPATIAL RESOLUTION* SATELLITE DATA

3. THE HYPXIM REQUIREMENTS (RESOLUTION, SNR, BANDWITH, ..) ARE BEING CONSOLIDATED, FOCUSING ON A “JUST NEED” BASIS

4. A LOW COST MICROSAT DEMONSTRATOR COULD BE PROPOSED FROM 2017.

HYPXIM

Thanks for your attention