Airborne VNIR-SWIR hyperspectral remote sensing for environmental urban mapping

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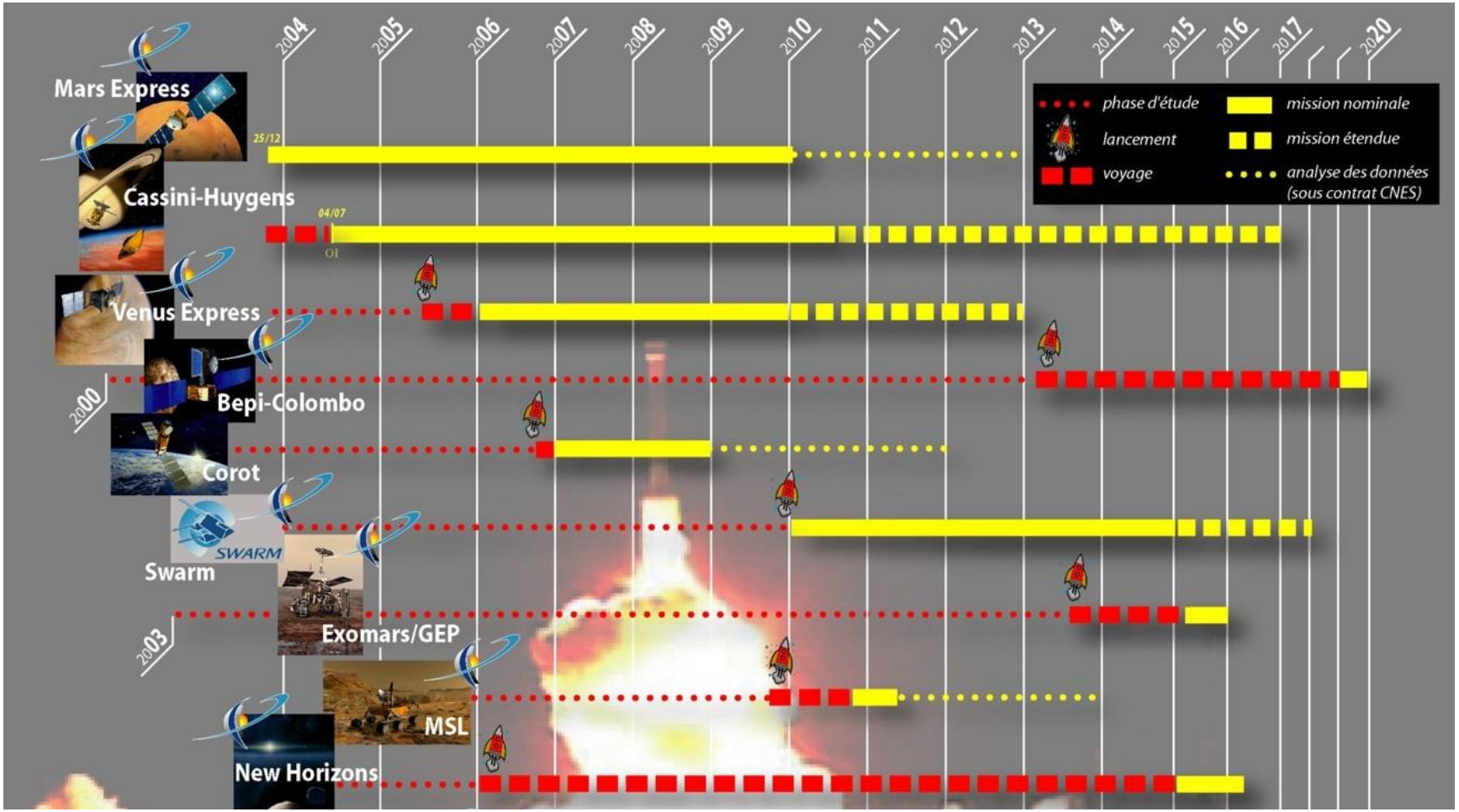
and collaborators

* VegDUD post-doc (ANR-09-VILL-0007-01)

Where does we come from?

Planetology !

Laboratoire de Planétologie et Géodynamique de Nantes UMR-CNRS 6112



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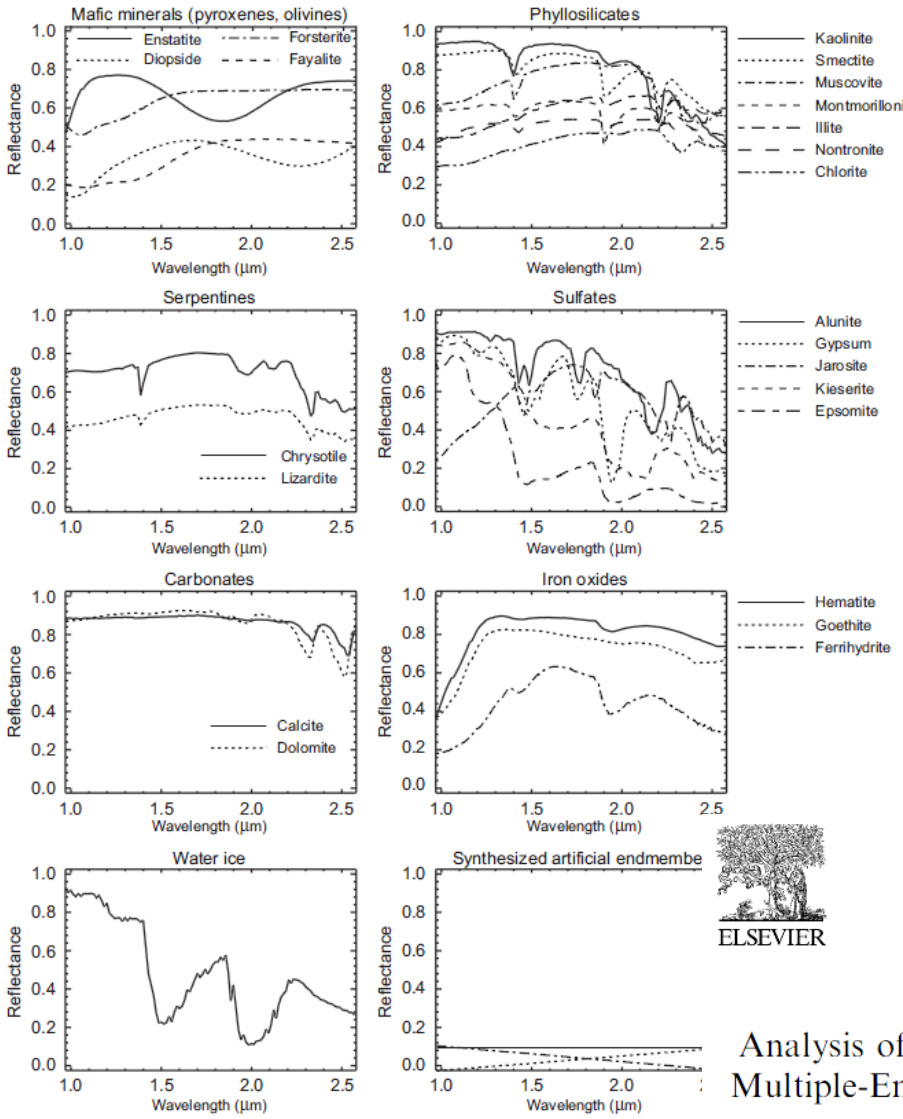

Fig. 1. Spectral library used as input for the linear unmixing. This library contains pyroxenes, olivines, phy serpentines, a water ice frost spectrum, and three straight line components.

Hyperspectral data are intensively used for mapping planetary surfaces

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Planetary and Space Science 56 (2008) 951–975
Planetary and Space Science
www.elsevier.com/locate/pss

Analysis of OMEGA/Mars Express data hyperspectral data using a Multiple-Endmember Linear Spectral Unmixing Model (MELSUM): Methodology and first results

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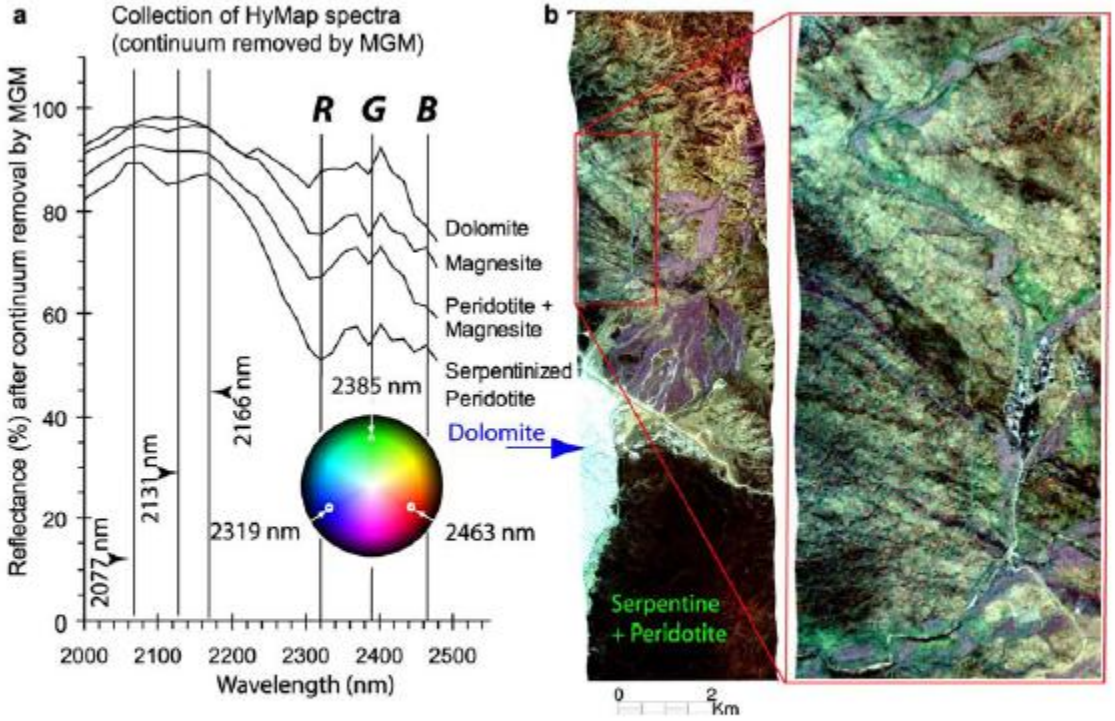

Figure 119. Spectra of carbonates and serpentinized minerals – a. Collected from the Hymap image – b. Alteration and magnesite mapping. Pure magnesite appears medium green along the wadi (bottom right). The dolomite (blue arrow) is carried from the Jabal al Akhdar massif on the North-West, invisible on the image.

HyMap airborne image
showing peridotite alteration in serpentine
and its weathering in carbonates

Hyperspectral data are intensively used for mapping planetary surfaces

and tested on Earth
in desert area

Geochemistry Geophysics Geosystems G3
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Geological mapping strategy using visible near-infrared–shortwave infrared hyperspectral remote sensing: Application to the Oman ophiolite (Sumail Massif)

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Faculté des Sciences, Département de Géologie, Université Abdelmalek Assaadi, BP 2121, Tétouan, Morocco

Why are we looking at urban environments?

AllEnvi

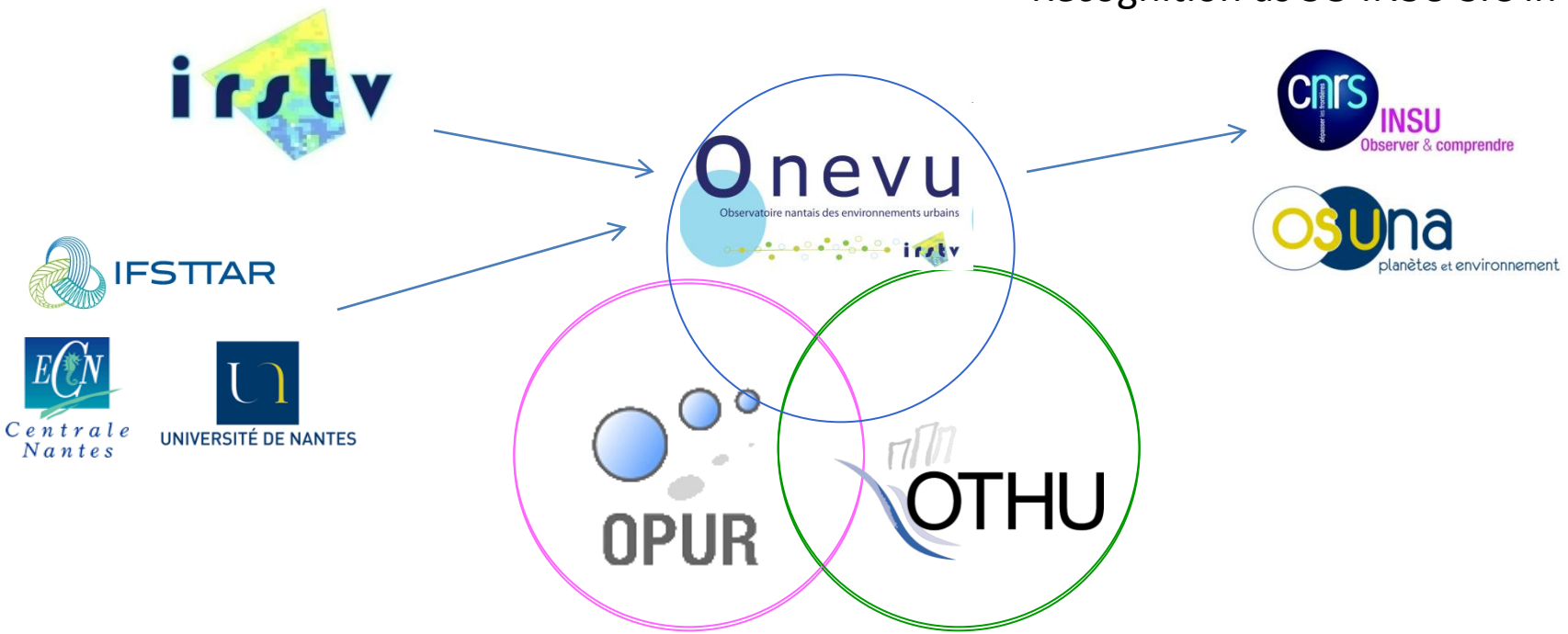
Alliance nationale de recherche pour l'Environnement

SOERE Environnement Urbain

Le système d'observation et d'expérimentation URBIS

A network of 3 observatories for urban environments in Nantes, Paris and Lyon

Recognition as SO INSU SIC in 2012



Onevu
Observatoire nantais des environnements urbains

irstv

OSUNA planètes et environnement

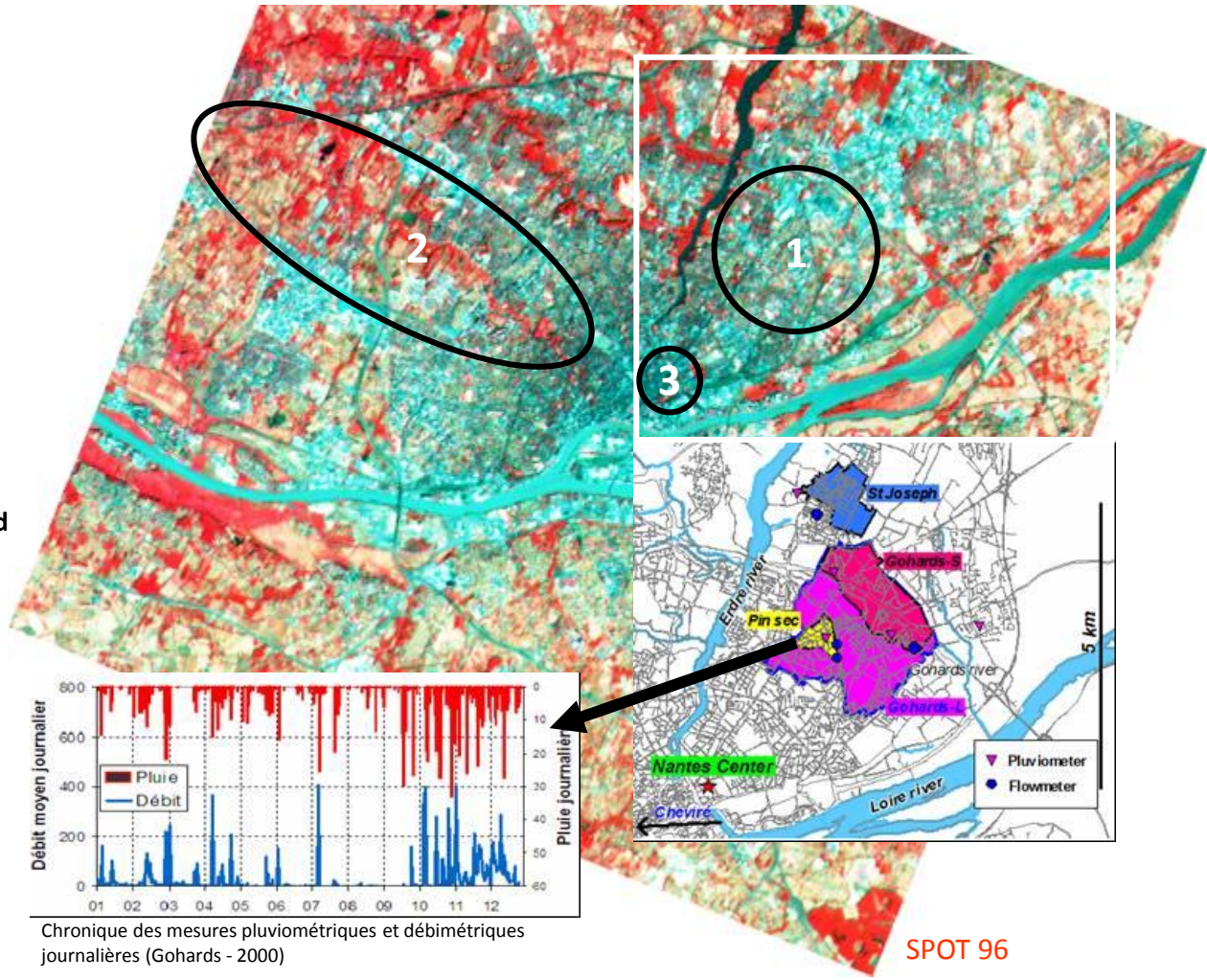
AllEnvi
Alliance nationale de recherche pour l'Environnement

cnrs INSU
Observer & comprendre

The observatory for urban environments in Nantes

I – Urban Hydrosystems

- 1 : Pin-Sec & Gohards watershed
- 2 : Chézine watershed
- 3 : Nantes-Centre (local water quality)



Chronique des mesures pluviométriques et débimétriques journalières (Gohards - 2000)

SPOT 96

Mainly supported by

FEDER = ERDF: European Regional Development Fund

l'Europe s'engage en Pays-de-la-Loire avec le FEDER

CPER 2007-2013 GÉNIE CIVIL, ENVIRONNEMENT ET GESTION DURABLE DE LA VILLE

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
PRÉFECTURE DE LA RÉGION PAYS DE LA LOIRE

Région PAYS DE LA LOIRE

Meigeville (regional fund)

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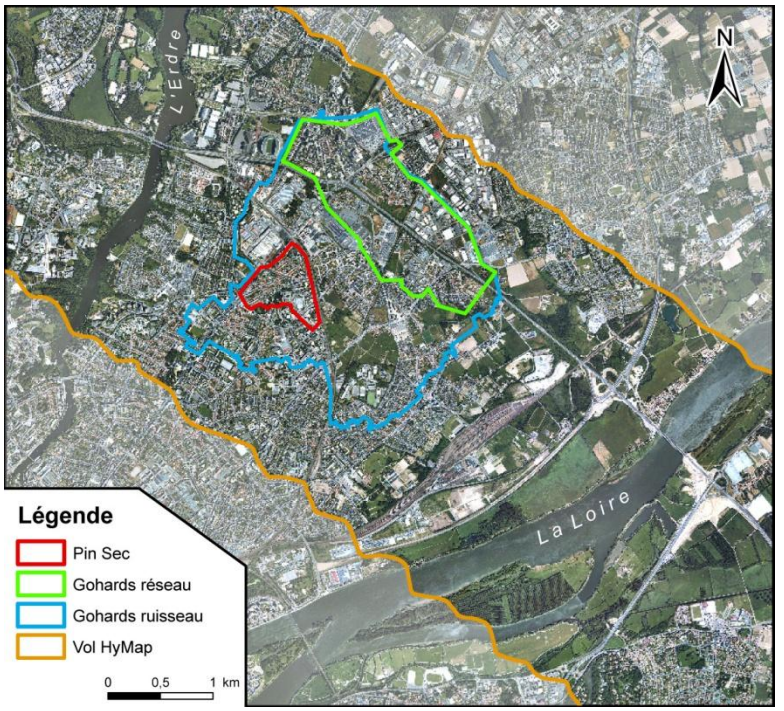
Observatoire nantais des environnements urbains

Région PAYS DE LA LOIRE

Meigeville



First airborne campaign in august 2008

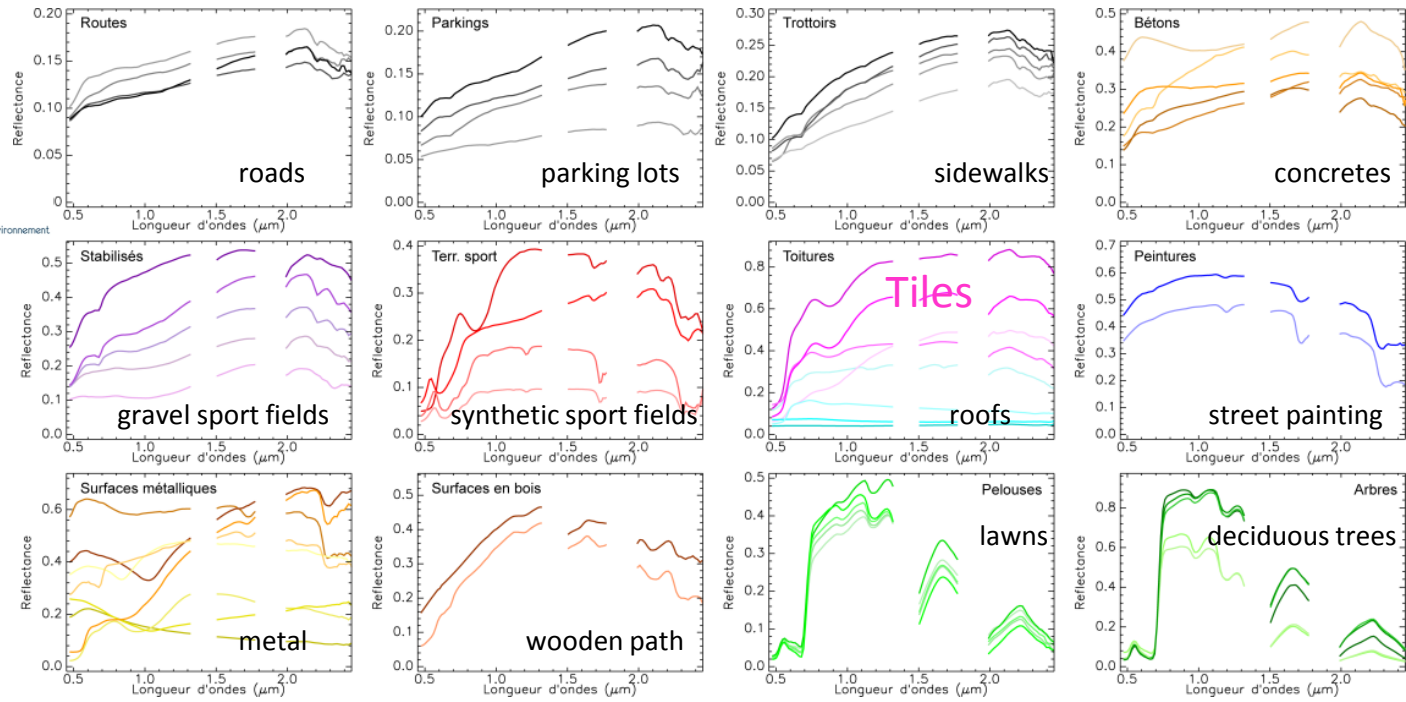
-DLR (German Aerospace Centre)
- 2008 July 22 at 10h00 UTM

-126 channels
- spectral range: 0.45 – 2.48 µm
- spectral resolution: 15 to 20 nm
- spatial resolution: 4 m
- atmospheric correction : Atcor 4

HyMap :
- Pin Sec : 152 km²
- Chézine : 184 km²

Onevu
Observatoire nantais des environnements urbains

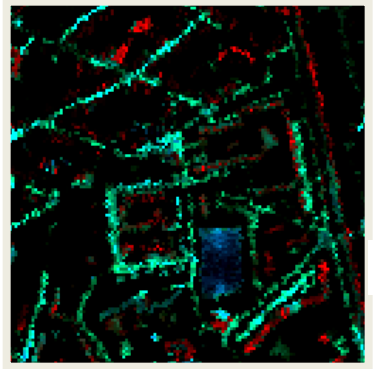
First constitution of a spectral library (2008)



Color composite image HyMap (4 m)

Cadastre

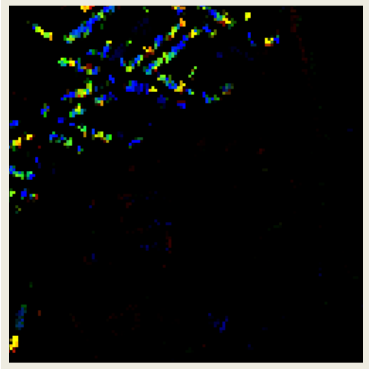
Spectral angle maping of urban materials



Parking lot asphalts

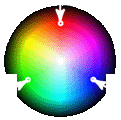
Gravel roofs

Road asphalts



New interlocking roof tiles

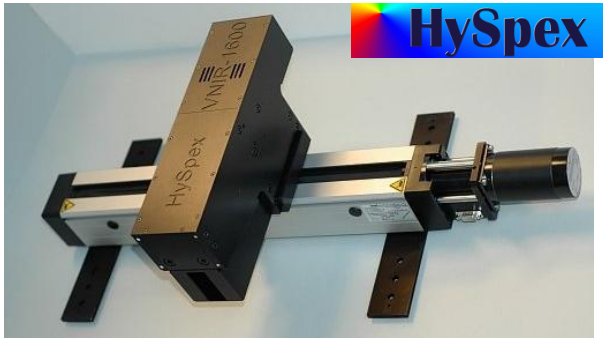
Barrel tiles



Old interlocking roof tiles

ASD FieldSpec 3

Régis Roy post-doc 2008



CPER 2007-2013 GÉNIE CIVIL, ENVIRONNEMENT ET GESTION DURABLE DE LA VILLE

Axe 3 : l'application de la télédétection au génie civil environnemental et à la gestion durable de la ville

	2008			2009	
Plateforme	**Laboratory**			**Field and airborne**	
	VNIR-1600	**SWIR-320i**	**SWIR-320m**	**VNIR-1600**	**SWIR-320m-e**
Detector	Si CCD 1600 x 1200	InGaAs 320 x 256	HgCdTe 320 x 256	Si CCD 1600 x 1200	HgCdTe 320 x 256
Spectral range	0.4 – 1.0 µm	0.9 – 1.7 µm	1.3 – 2.5 µm	0.4 – 1.0 µm	1.0 – 2.5 µm
Spatial pixels	1600	320	320	1600	320
FOV across track	17°	14°	14°	17°	14
Pixel FOV across/ along track	0.18 mrad/ 0.36 mrad	0.75 mrad/ 0.75 mrad	0.75 mrad/ 0.75 mrad	0.18 mrad/ 0.36 mrad	0.75 mrad/ 0.75 mrad
Spectral sampl.	**3.7 nm**	**5 nm**	**5 nm**	**3.7 nm**	**6.25 nm**
# of bands	160	145	256	160	256
Binning modes	2, 4, 8	-	-	2, 4, 8	-
Digitization	12 bit	12 bit	14 bit	12 bit	14 bit
Max frame rate	135 fps	350 fps	100 fps	135 fps	100 fps
Sensor head wgt.	4.6 kg	6.8 kg	7.0 kg	4.6 kg	7.5 kg
Sensor head dim. (lwh in mm)	315x84x138	320x140x152	360x140x152	315x84x138	360x140x152
Sensor head pwr. cons	~6 W	~30 W	~100 W	~6 W	~100 W
FPA cooling T	NA	~260 K	~195 K	NA	~195 K
Camera interface	Camera Link	USB 2.0 or Camera Link	Camera Link	Camera Link	Camera Link
Close-up lenses	30 cm 1 m 3 m	30 cm 1 m 3 m	30 cm 1 m 3 m	30 cm 1 m 3 m	
Additionnal lens				34° Field expander fore optics	
Computer	High performance rack computer with 5To (laboratory)			High performance rack computer (airborne, field)	
Stage	Translation stage with controller and aluminium frame for lab setup			Rotation stage with controller and tripod for field operations	
Light	Light source (400-2500nm) with 220V, 2.5A DC power supply				
Spectralon	30x5 cm at 20%, 50% and 99%				
				Touch screen for airborne operation	

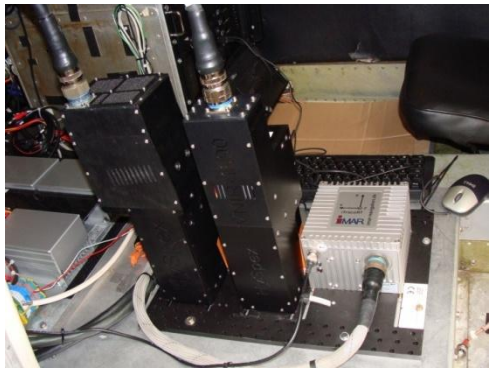
Airborne

Second and third airborne campaigns in 2010 and 2011

Operator :

- Actimar

Hyspex VNIR: 160 channels
spectral range: 400 - 1000 nm
spatial resolution: 0.6 m
spectral resolution: 4 nm
Hyspex SWIR: 256 channels
spectral range : 1000 nm - 2500 nm
spatial resolution : 1.2 m
spectral resolution : 6 nm
Atmospheric correction : Atcor 4 (Actimar)

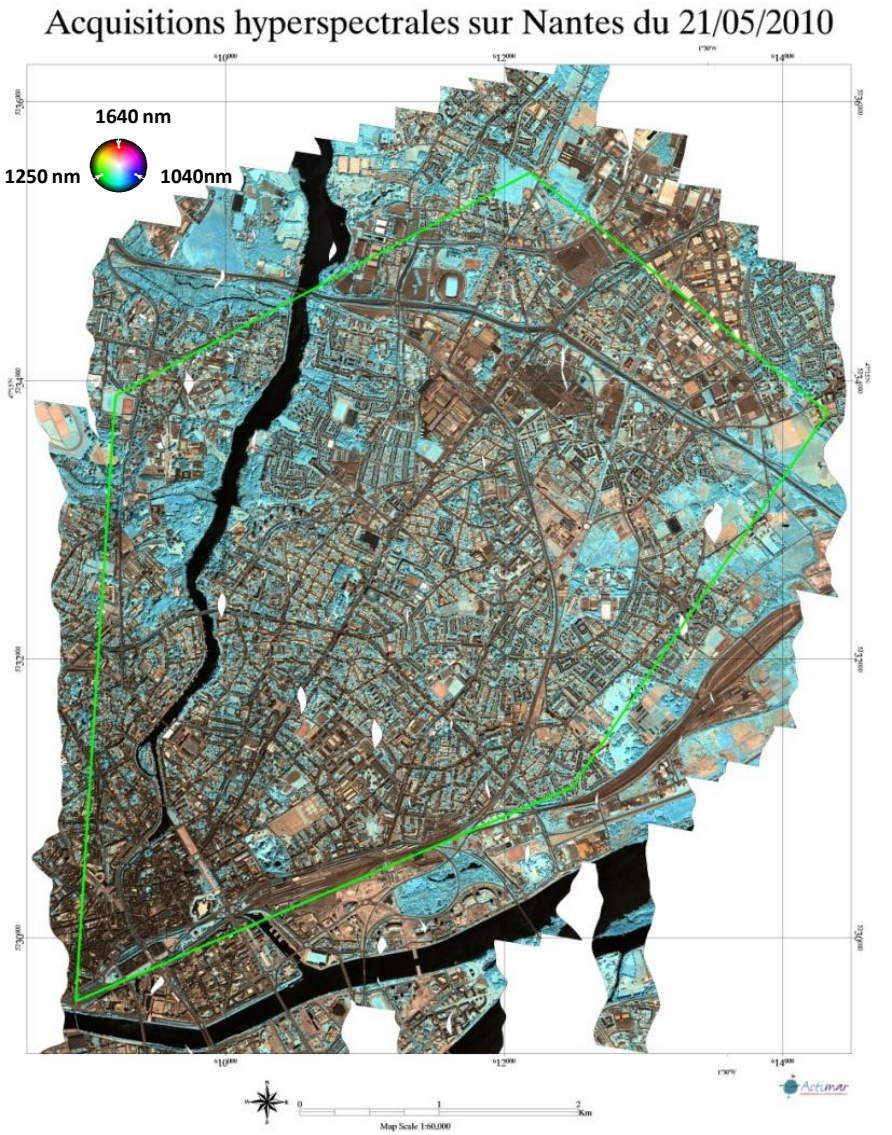


HySpex (LPGN)
Ans IMU(Actimar)

Campaign 1 (Meigeville program)
20 flight lines in 2010 May 21

Campaign 2 (ANR VegDUD)
2011 September 15,16 and 28
22 flight lines with difficult weather conditions

Example of 1 flight line



Mosaic of the 2010 flight lines

Data fusion at the lower spatial resolution

Image VNIR (0.4 – 1µm) (0.6m)

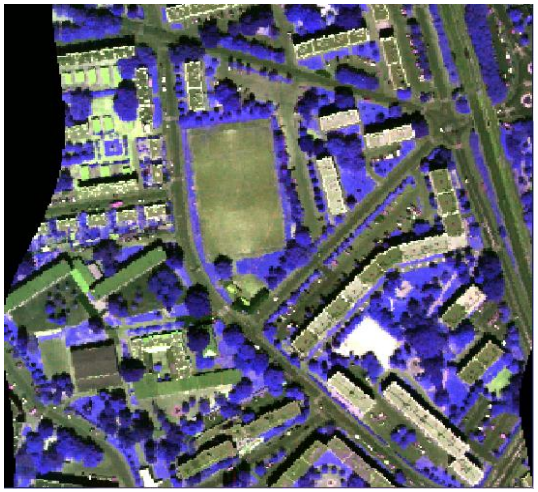
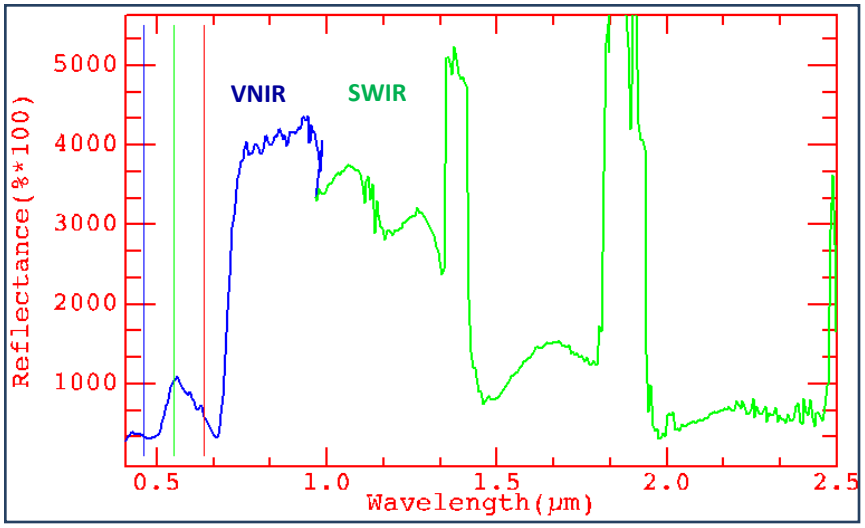
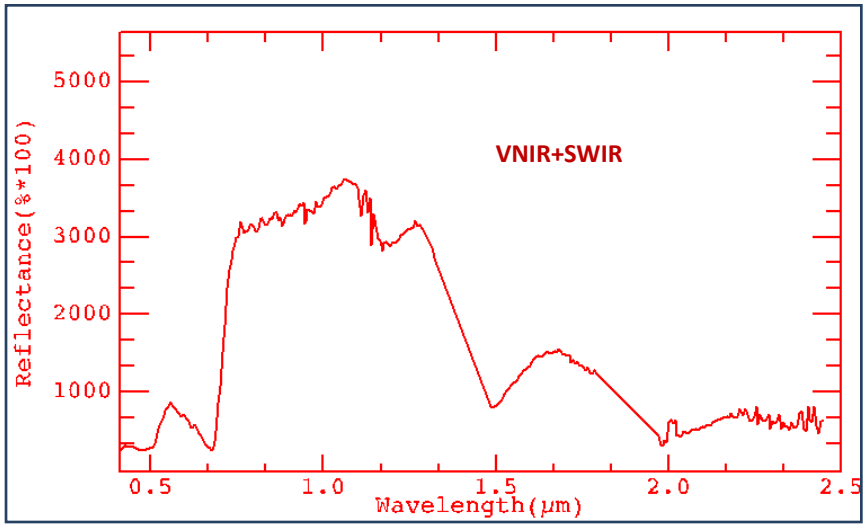


Image SWIR (1- 2.5 µm) (1.2m)

Image VNIR-SWIR (0.4- 2.5 µm) (1.2m)



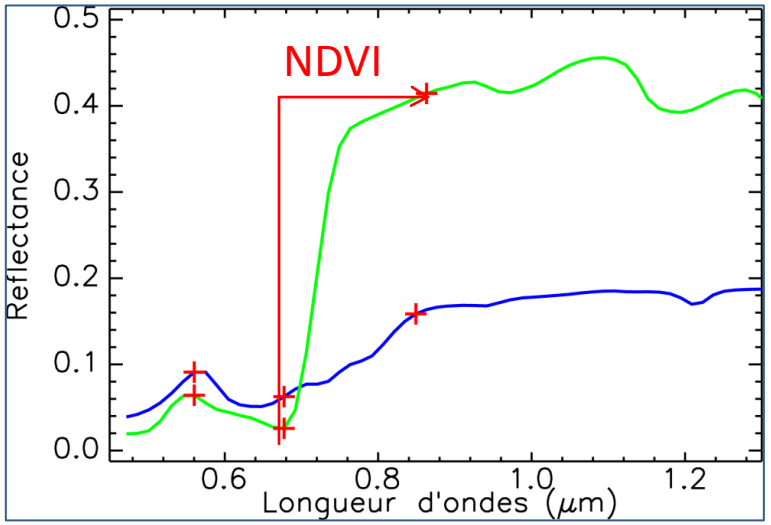


VegDUD

Focus the analysis on vegetation types

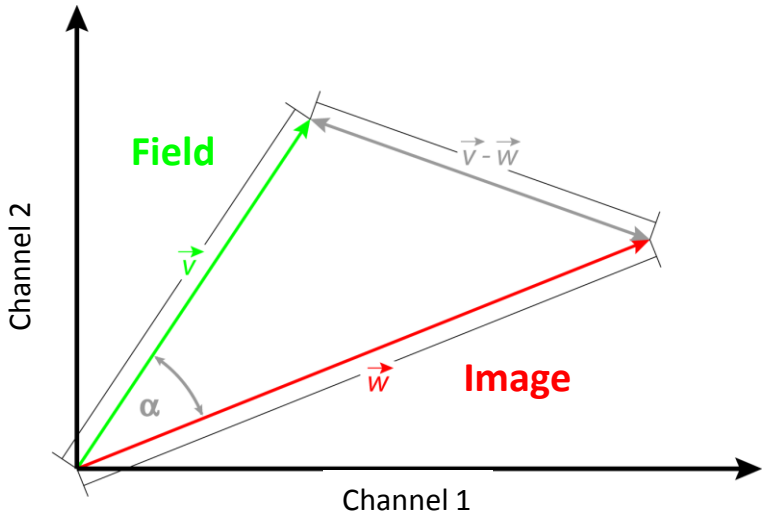
VegDUD Project (ANR-09-VILL-0007-01)

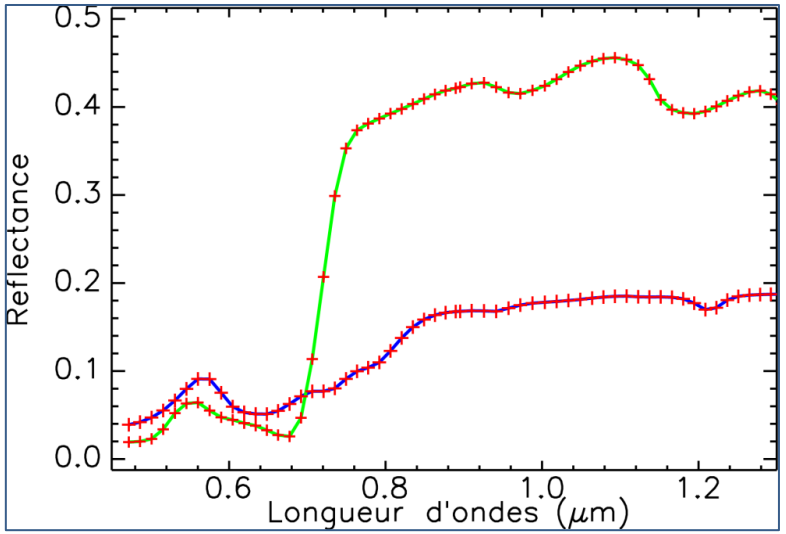
We can use indices (combination of 2 or 3 channels measuring a spectral curvature)



Or

We can use spectral angle mapping (measuring the angle between two vectors of 160 dimensions (HySpex channels))





VegDUD

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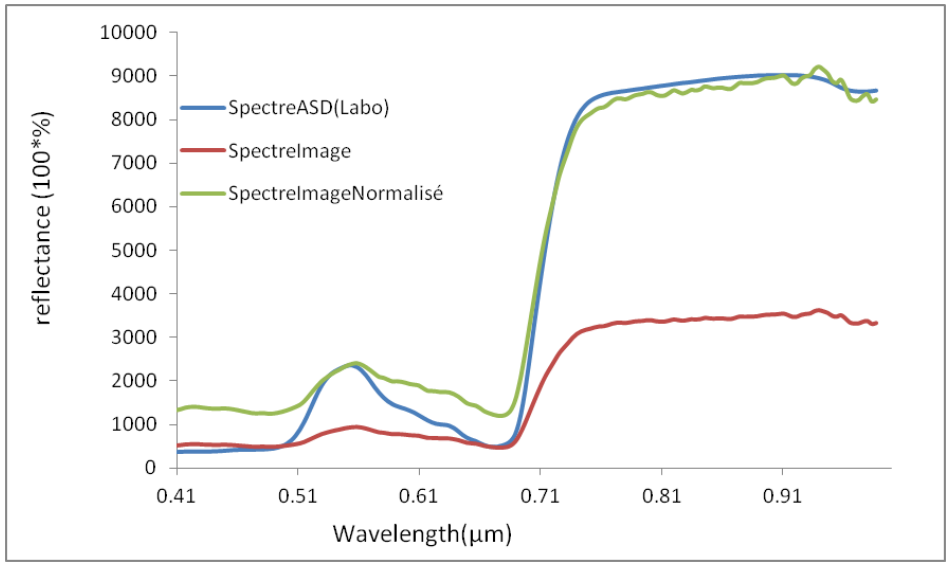


Bi-Directionnal Reflectance Distribution (BRDF) no direct comparison between lab and field data

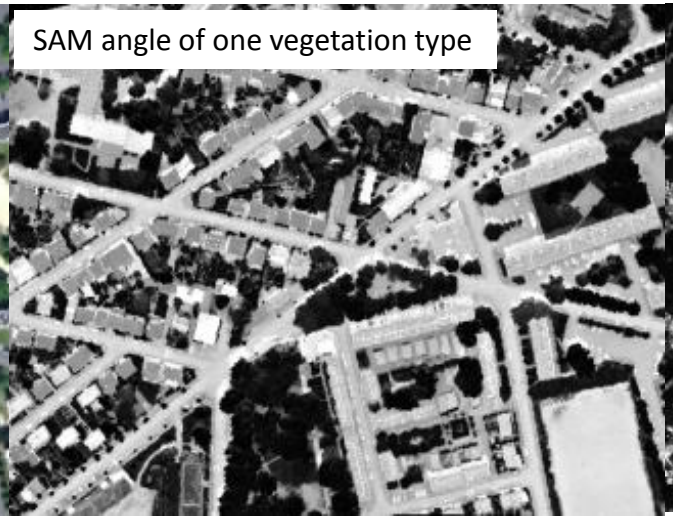
This can be avoided by:

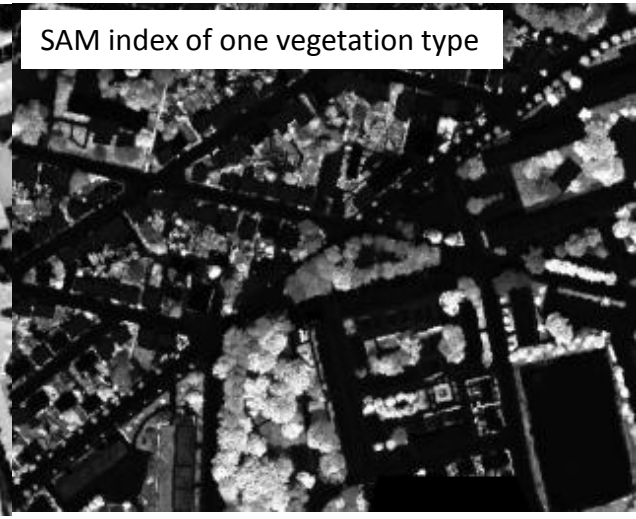
1) Using homogenous subsets of pixels constituting meaningful objects delineating trees or any vegetation patch

2) Sampling data in the image like for a remote sensing classical training

VegDUD

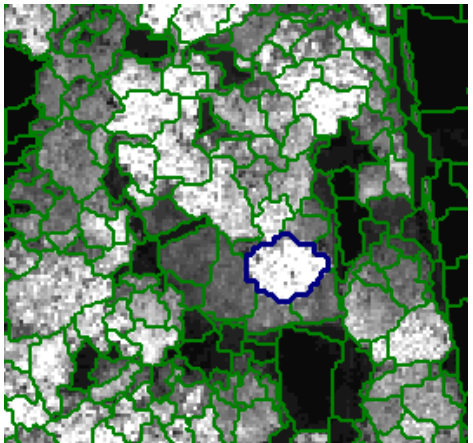
Image segmentation in objects

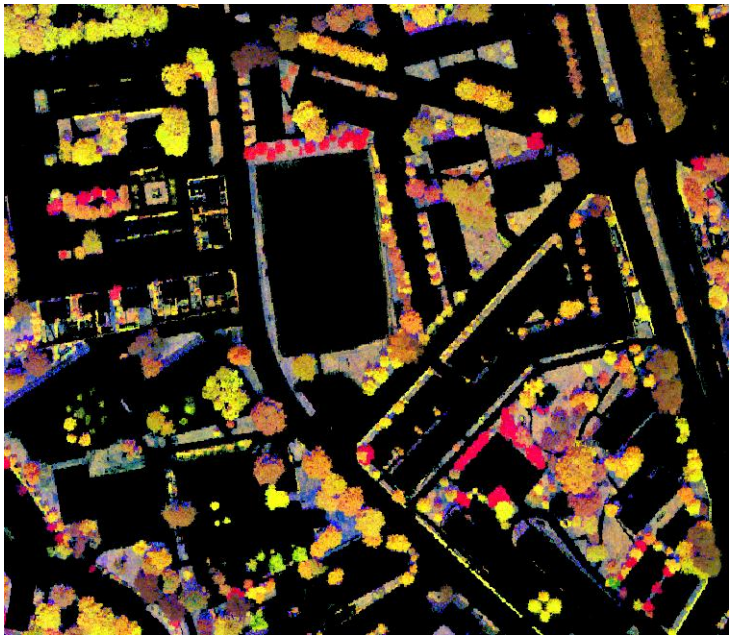




The segmentation of the image in objects is done with eCognition (Definiens software).

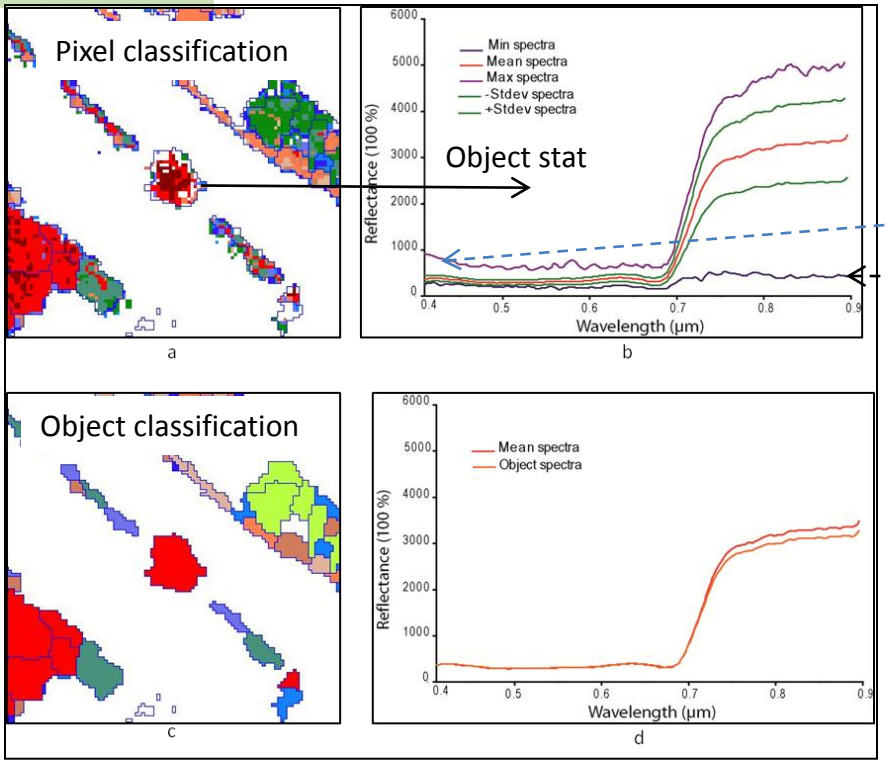
But instead of using directly the hyperspectral image, we use a compilation of indices and SAM results to feed the software and better delineates the tree borders.

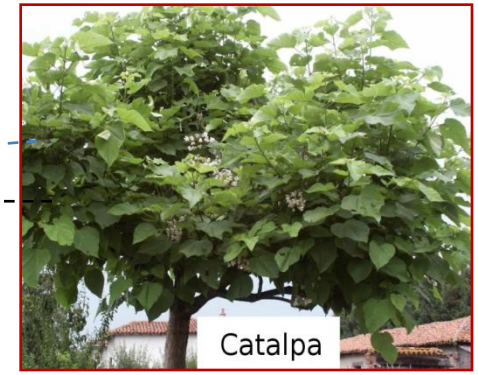




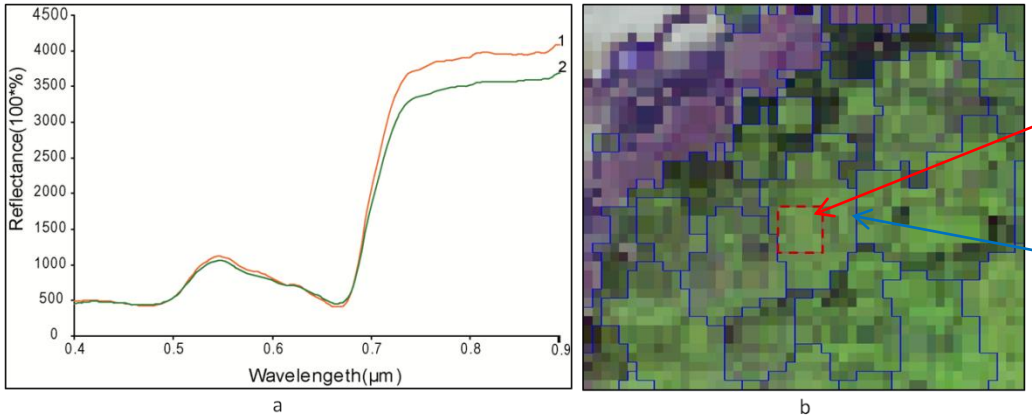
Color composite image of 3 SAM indices

Object statistics



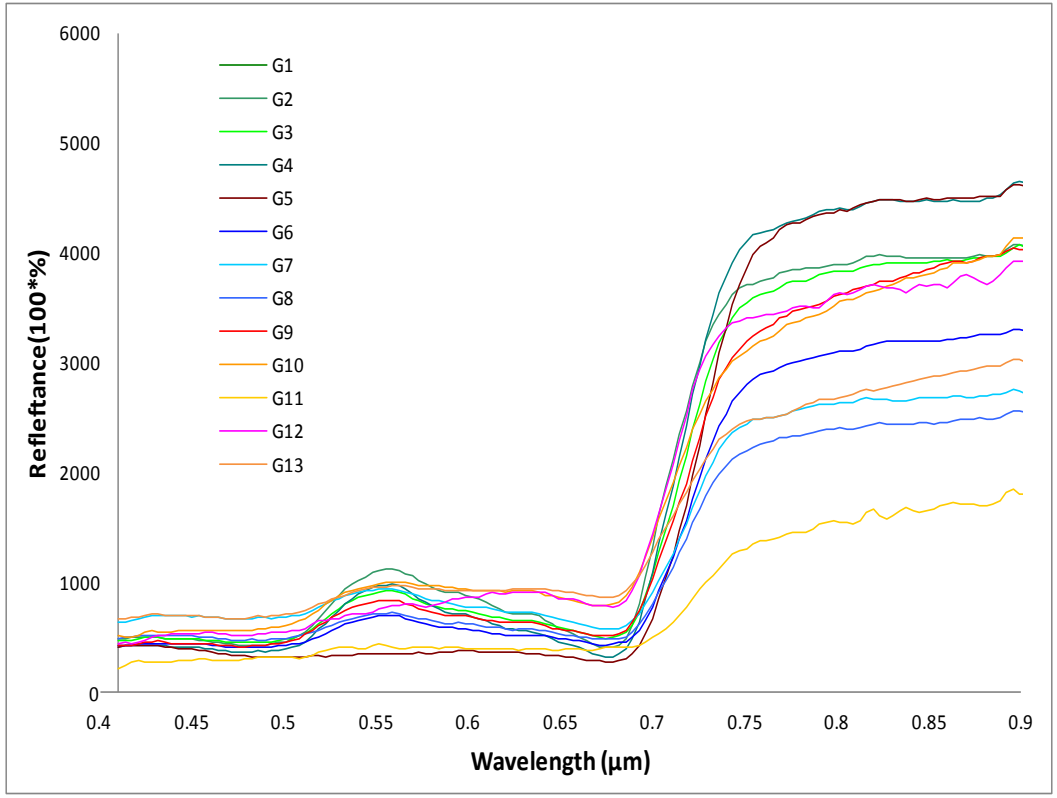


Example of G2 super-class (Quercus palustris, Acer negundo and Catalpa bignonoides)



Spectral training library for object classification

Training spectra of 13 vegetation super-classes
(group of vegetation spectrally identical)



Spectra of vegetation super-classes with species grouped according to their SAM index similarity.

G1: ***Fraxinus exelsior, Betula verrucosa, Quercus robur*****;**

G2: ***Quercus palustris, Acer negundo, Catalpa bignonoides*****;**

G3: ***Salix babylonica, Lonicera nitida, Platanus occidentalis*****;**

G4: ***Liquidambar styraciflua, Quercus coccinea*****;**

G5: ***Prunus cerasifera, Acer rubra*****;**

G6: ***Pinus radiate, Pinus pinea*****;**

G7: ***Cedrus atlantica*****;**

G8: ***Pinus sylvestris, Cupressus arizonica*****;**

G9: lawn;

G10: degraded lawn;

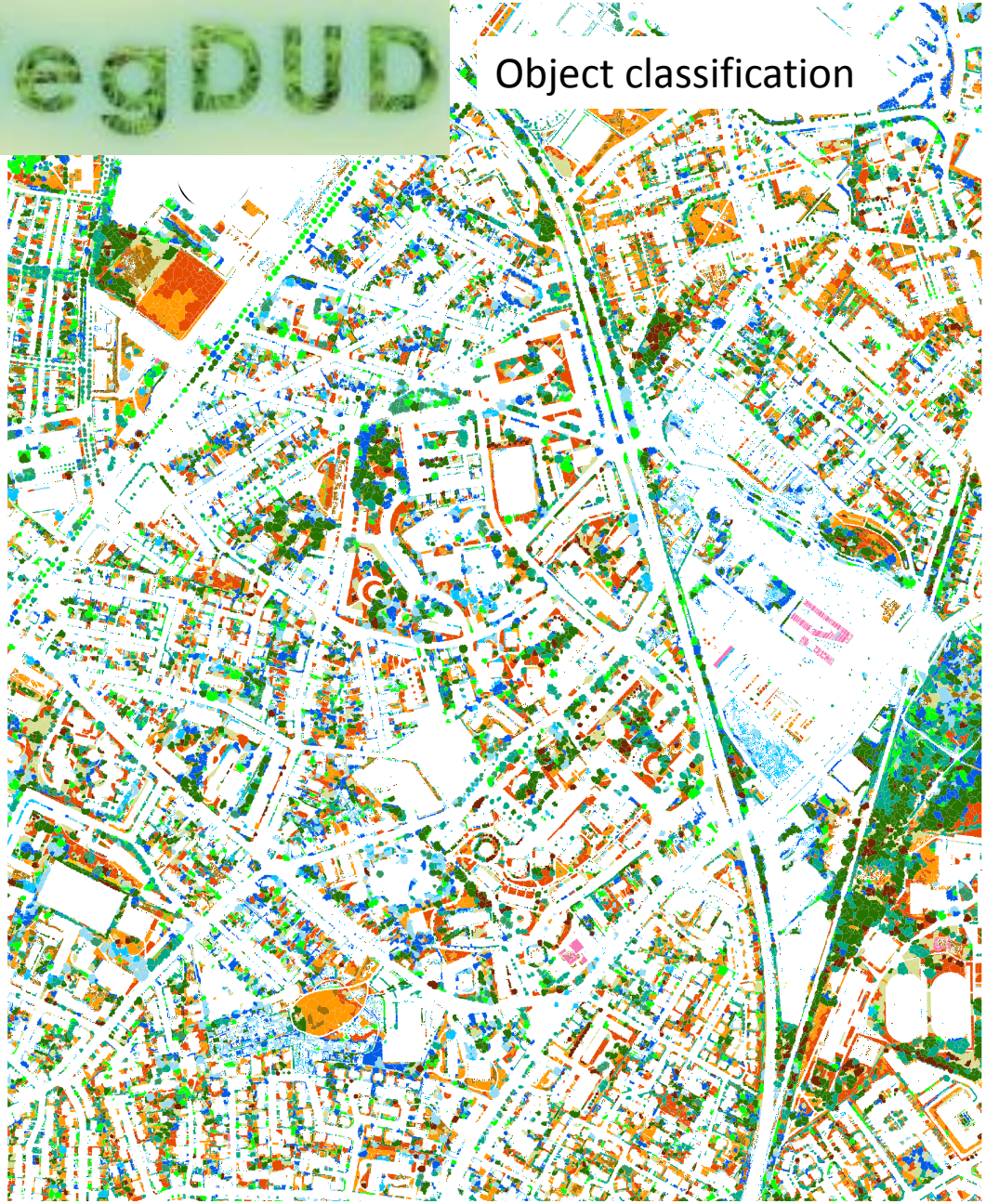
G11: shaded lawn;

G12: ***Sedum*****;**

G13-G14: other plants.

VegDUD

Object classification



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G3: *Salix babylonica, Lonicera nitida, Platanus occidentalis*;
G4: *Liquidambar styraciflua, Quercus coccinea*;
G5: *Prunus cerasifera, Acer rubra*;
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G8: *Pinus sylvestris, Cupressus arizonica*;
G9: lawn;
G10: degraded lawn;
G11: shaded lawn;
G12: *Sedum*;
G13-G14: other plants (unknown).

What about space-borne Earth hyperspectral observation?

CENTRE NATIONAL D'ÉTUDES SPATIALES

HYPXIM

HYPer Spectral IMagerie a Haute Resolution & Grand Champ

Véronique CARRERE (LPGNantes, Univ. de Nantes)

Coordinatrice du Groupe Mission Sciences (PI)

CONTEXTE de la Mission

- A l'étude depuis 2009 (Phase 0) – Passage en Phase A après Revue de Mission (11 Juin 2012) pour un lancement éventuel en 2018-2020 (?)

- Positionnement dans le contexte spatial français et international :

- Saut technologique / précurseurs : Hyperion, USA; HJ-1A/HSI, 2008, Chine; HySI/IMS-1, 2008, Inde;

et missions programmées : PRISMA, 2013?, Italie; EnMAP, 2015, Allemagne;

ou en pré-phase A : HyspIRI, USA; AToMS/NASA Venture Proposal, USA; HISUI, Japon;…

- Mission duale : doit satisfaire à la fois les besoins Défense et les besoins scientifiques civils (grande gamme d'applications)

- Participation de 2 industriels en parallèle durant la Phase 0 : T.A.S. et ASTRIUM

-> 2 projets d'instruments performants

SPECIFICATIONS

- Spécifications instrumentales retenues en fin de Phase 0 :

- Gamme spectrale = [400-2500 nm], couverture continue (+ capteur panchromatique)

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]].

+ Hydrosphère (neige, glace) à ajouter

- Plate forme « agile » (revisite) + ralenti pour meilleur SNR

- Capteur Infrarouge thermique envisagé pour une deuxième génération (?)