SCOPE OF ONERA ATMOSPHERIC COMPENSATION TOOLS TO RETRIEVE THE OPTICAL PROPERTIES OVER DIFFERENT TYPE OF LANDSCAPE FROM HYPERSPECTRAL AIRBORNE ACQUISITIONS IN THE [0.4 - 2.5 µm] DOMAIN.

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ONERA

THE FRENCH AEROSPACE LAB

retour sur innovation

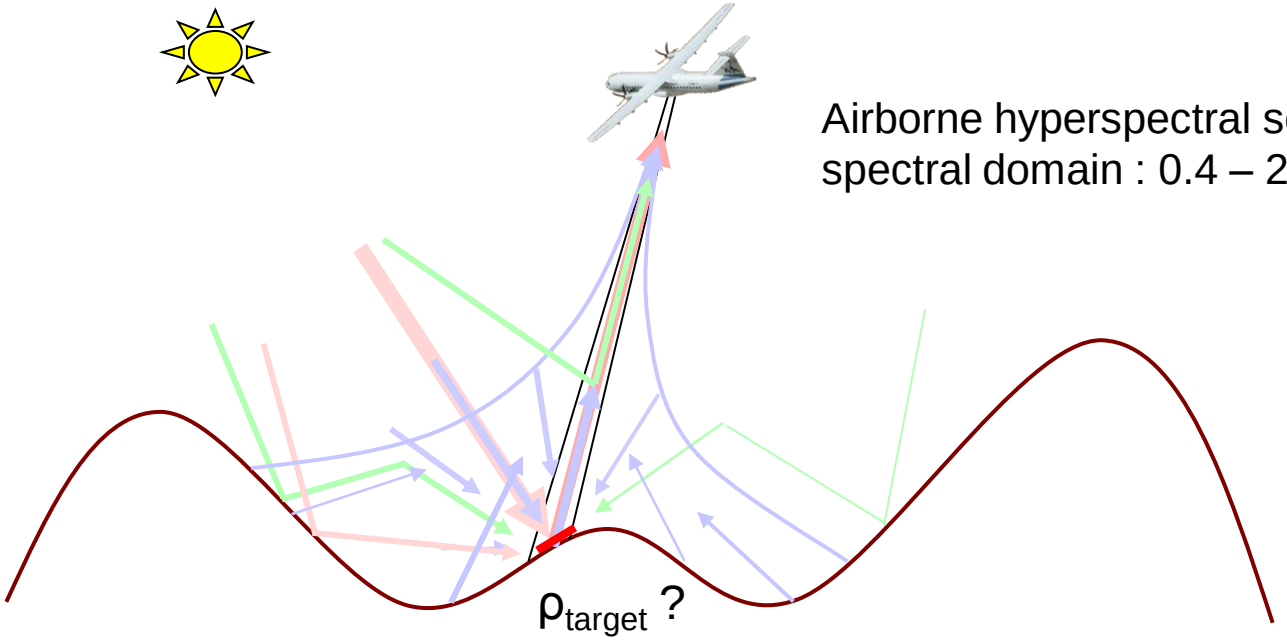
DOTA

Purpose of atmospheric compensation

→ To Extract spectral reflectance hypercube
from radiance hypercube

Atmosphere ⇨ absorption, scattering

Atmospheric scattering ⇨ neighborhood effects :
« convolution » of the image by environmental function



Airborne hyperspectral sensor
spectral domain : 0.4 – 2.5 µm

Outline

- Flat heterogeneous ground : Cochise (atmospheric COrrection Code for hyperspectral Images of remote SEnsing sensors)
  - Inversion scheme
  - Validation with Amartis simulations
  - Application to Aviris data
- Mountainous landscape : Sierra (Spectral reflectance Image Extraction from Radiance with Relief a Atmospheric correction)
  - Inversion scheme
  - Validation with Amartis simulations
  - Application to Hymap data
- Urban scene : ICARE (Inversion Code for urban Areas Reflectance Extraction)
  - Inversion scheme
  - Application to PELICAN images
- Conclusions

COCHISE

- Water-vapor retrieval
  - absorption band at 0.94 µm or 1.13 µm
  - LIRR (linear regression ratio) technique ; 2D LUT

- Reflectance retrieval

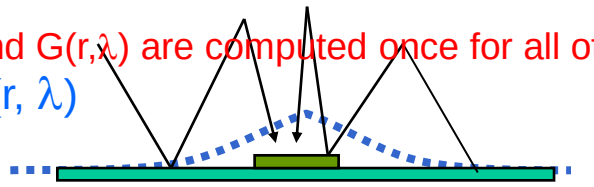
- iterative : $$R_{sensor}(x,y) = R_{atm} + \frac{I_{tot}}{\pi\left(1 - \rho^{env}(x,y).S\right)}\left[t_{dif}.\rho^{dif}(x,y) + t_{dir}.\rho(x,y)\right]$$

  - 1st solution homogeneous scene ($\rho = \rho_{env} = \rho_{dif}$) ⇨ **$\rho_1(x,y)$**

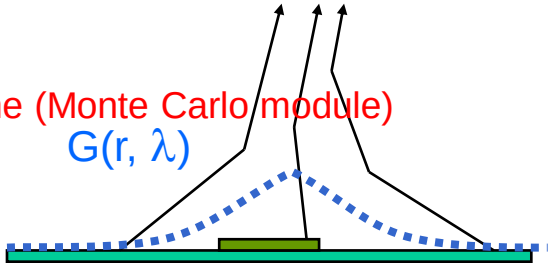
  - convolution with environmental functions ⇨ $\rho_1^{env}(x,y)\,;\,\rho_1^{dif}(x,y)$

F(r,λ) and G(r,λ) are computed once for all off-line (Monte Carlo module)

F(r, λ)



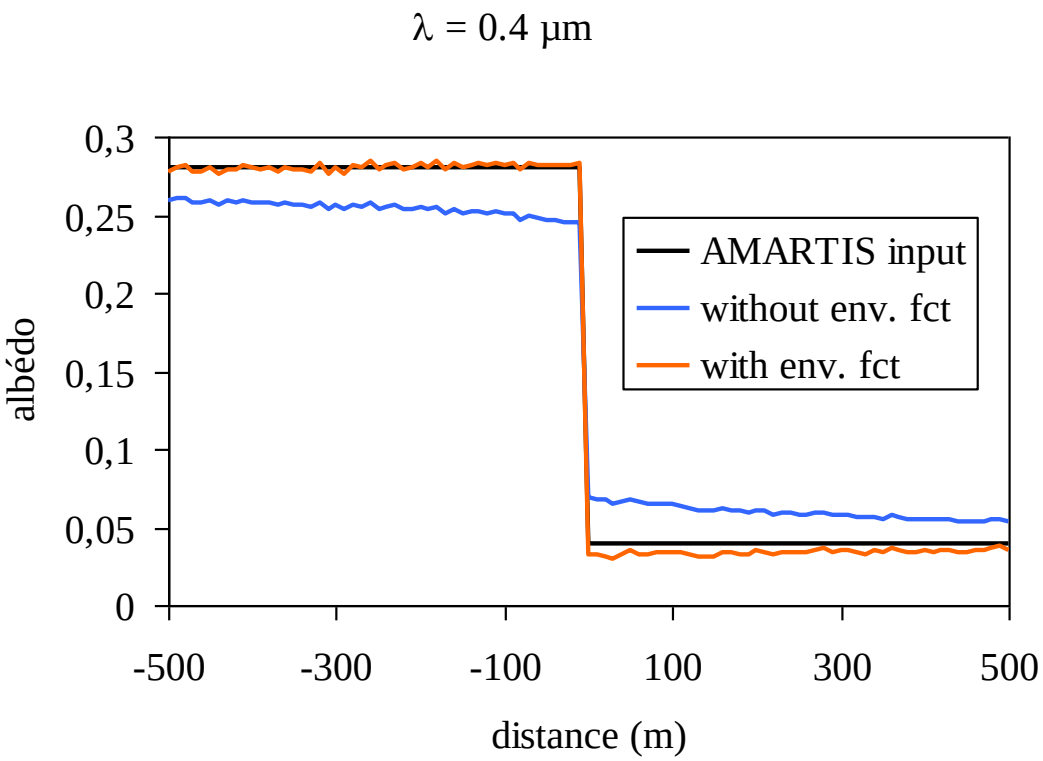
G(r, λ)



  - 2nd solution ⇨ **$\rho_2(x,y)$**

COCHISE - Validation

Validation of COCHISE with AMARTIS* simulations

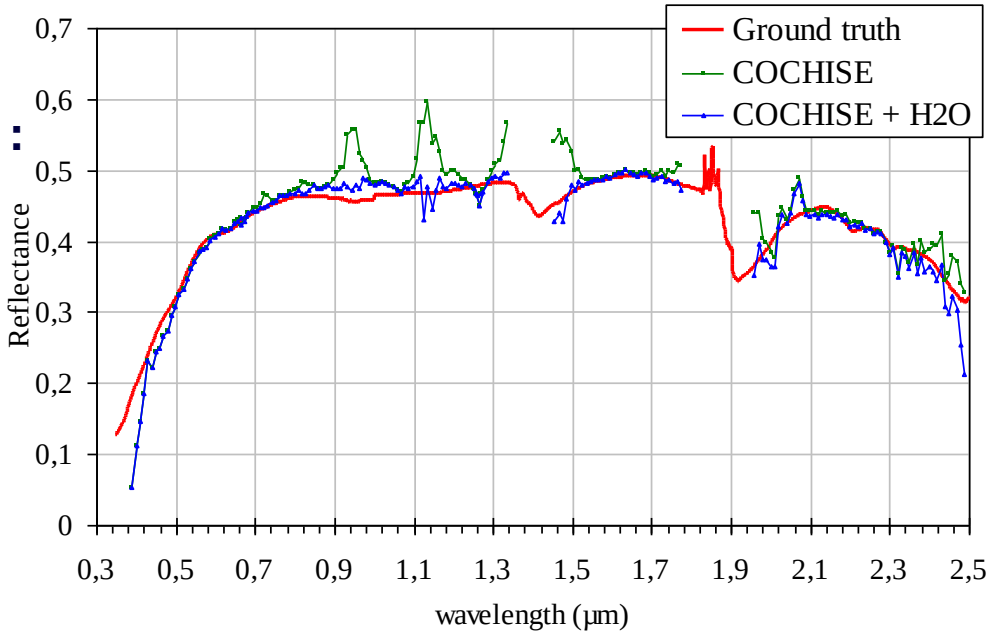


*Miesch C., Briottet X., Kerr Y.H., Cabot F. (2000), A radiative transfer solution for rugged and heterogeneous scene observations, *Applied Optics*, Vol. 39, p 6830-6846.

COCHISE – Application to AVIRIS data

- AVIRIS dataset over Rail Road Valley (17/06/1998)
  hypercube + ground reflectance + O_3 + H_2O + aerosols

- **Reflectance retrieval with COCHISE :**
- **In-situ measurements H_2O : 1.3 g/cm²**
- **- Retrieved H_2O : ~1.0 g/cm²**
- **(±5% over a 100x100 image)**
- **same results with *FLAASH**

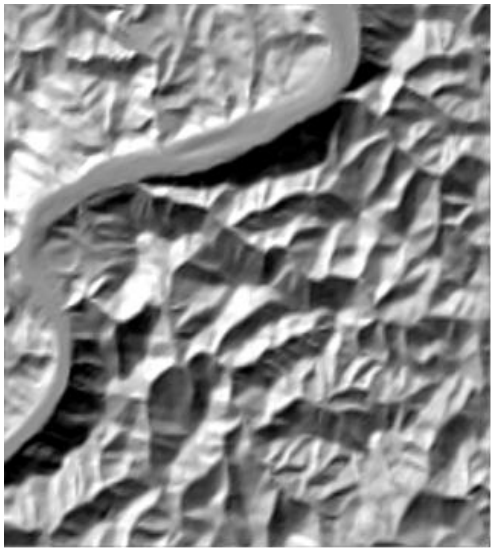


*Anderson G.P, Felde G.W., Hoke M.L., Ratkowski A.J., Cooley T., Chetwind J.H., Gardner J.A., Adler-Golden S.M., Matthew, M.W., Berk A., Bernstein L.S., Acharya P.K., Miller D., Lewis P. (2002), MODTRAN4-based atmospheric correction algorithm: FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes), *SPIE proceedings*, Vol. 4725, p 65-71.

Purpose of SIERRA - A new atmospheric and topographic corrections algorithm

Relief ⇨ slope/altitude variations :

- radiance variations with solar incidence/emergence angles on the slope
- reflections on neighborhood



← ***shaded relief***

HyMap radiance image 1665 nm

→

Purpose of SIERRA - A new atmospheric and topographic corrections algorithm

Purpose of SIERRA :

Extract from the radiance hypercube, a bi-hemispherical albedo hypercube
⇨ Corrected from neighborhood effects
⇨ Independent of solar incidence, viewing angles on the slope

-The forward model of SIERRA is based on

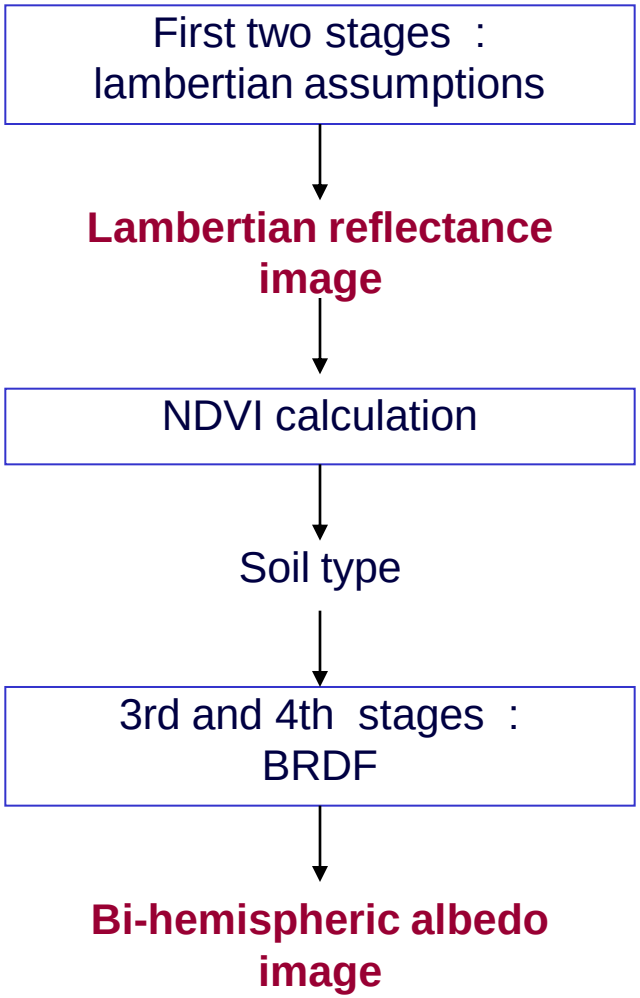
-"State of the Art models" adapted to the context, for the computation of irradiances/ at-sensor radiance terms,

- New model for diffuse irradiance

- BRDF model derived from Rahman's one*

*Rahman H., Pinty B., Verstraete M.M. (1993), Coupled surface-atmosphere reflectance (CSAR) model, 2, semi-empirical surface model usable with NOAA advanced very high resolution radiometer data, *Journal of Geophysical Research*, Vol. 98, p 790-801

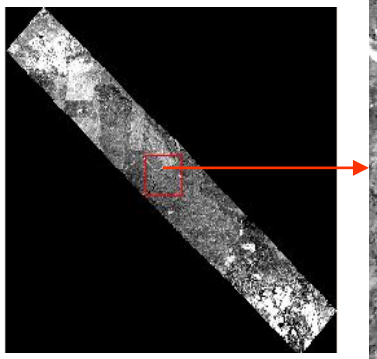
SIERRA - Inversion scheme : A 4 stages process



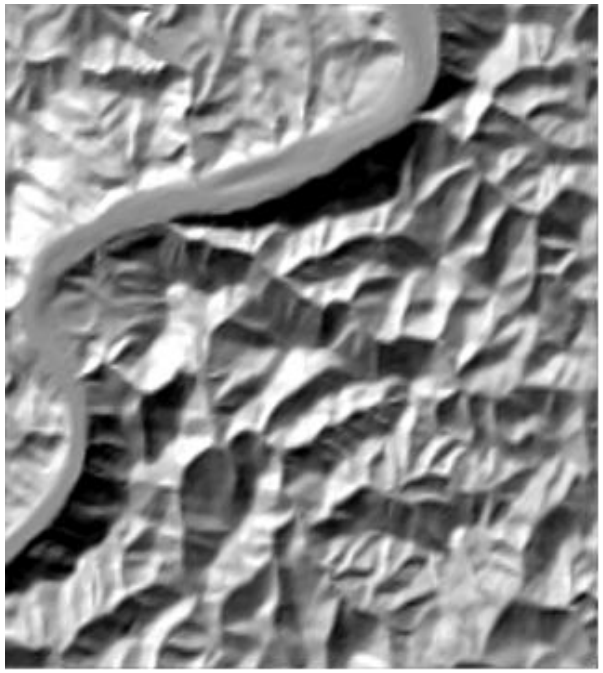
SIERRA - Application to HyMap data

HyMap hypercube :

- 128 bands – [0.4, 2.5 µm]
- over Calanas area, South of Spain
- altitude of the scene : 35-160 m
- Odiel river, scattered vegetation and trees plantations



radiance at 1665 nm

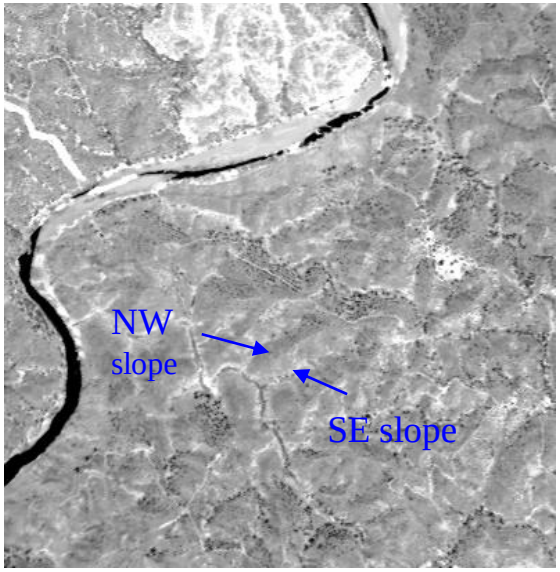


shaded relief

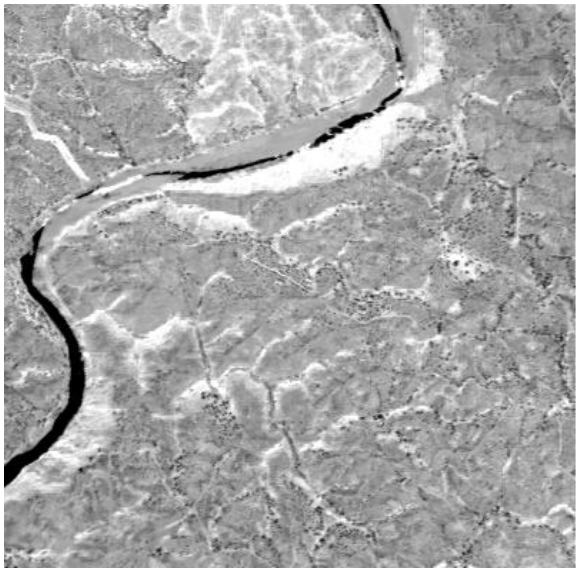
SIERRA - Application to HyMap data

Reflectance images at 1665 nm obtained with :

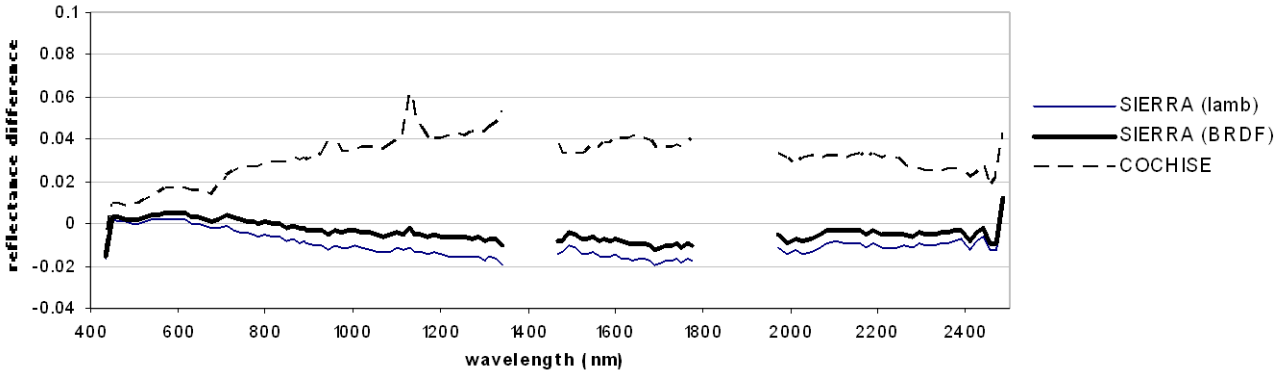
COCHISE (flat ground assumption)



SIERRA



Reflectance difference between SE and NW slopes



Similar performances than with ATCOR4

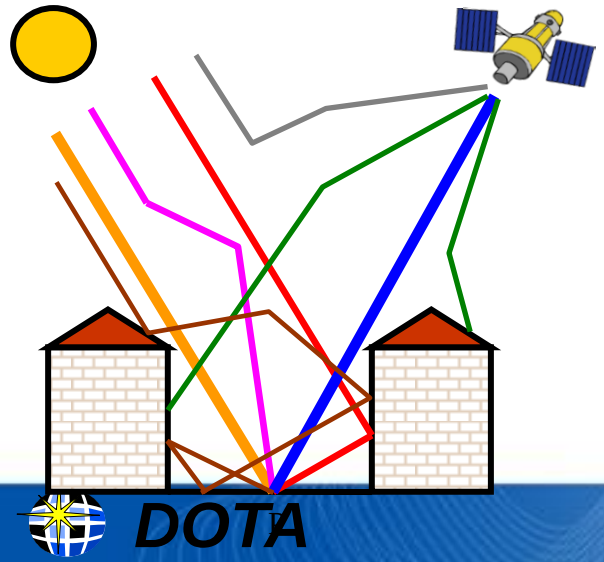
ICARE : Purpose

ICARE extract spectral reflectance over urban scene.

Main characteristics of urban areas:

- occultations
- shadows
- canyon roads (environmental effects)
- high spatial variability

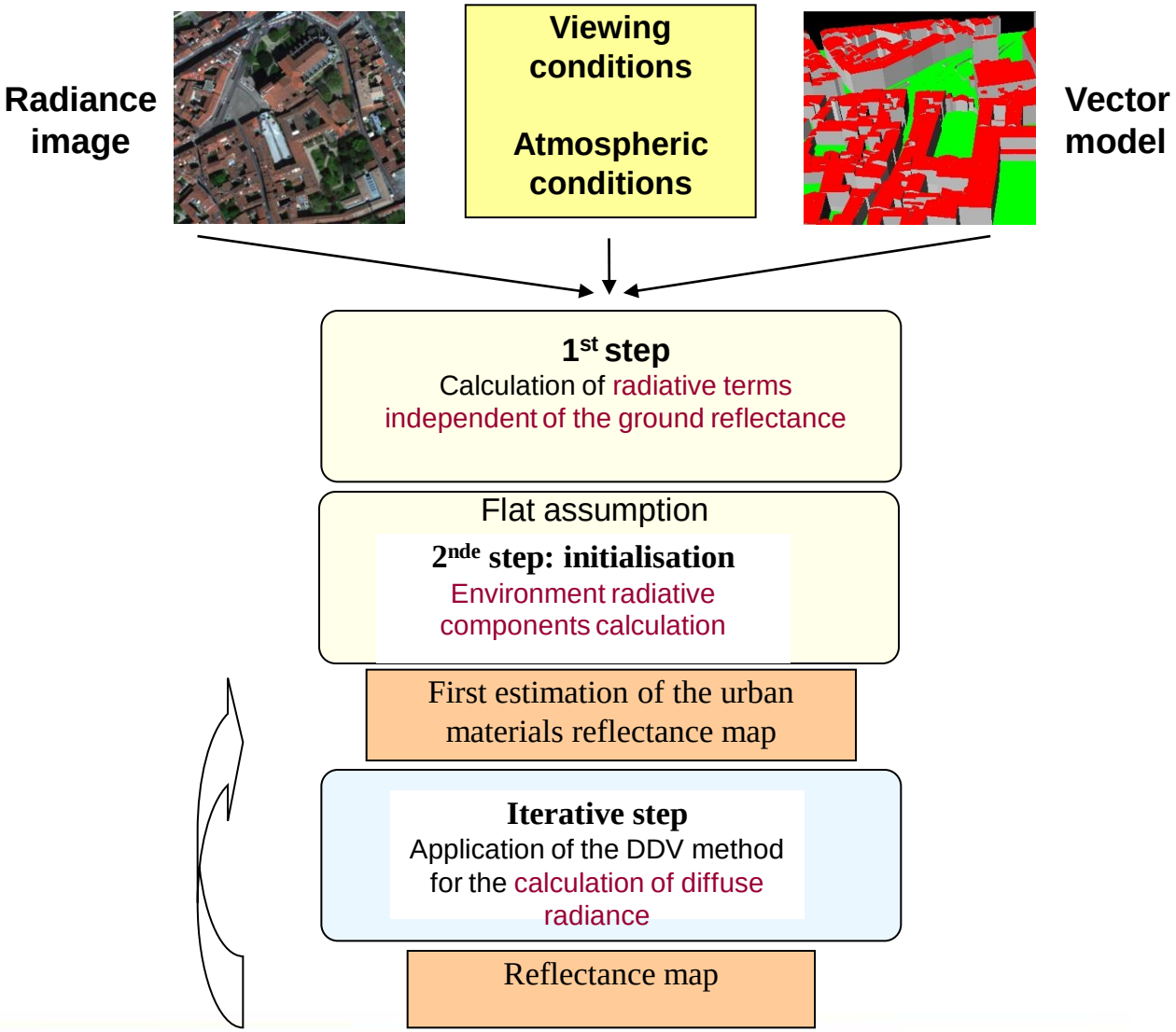
Radiances mainly depend on the conditions of illumination.



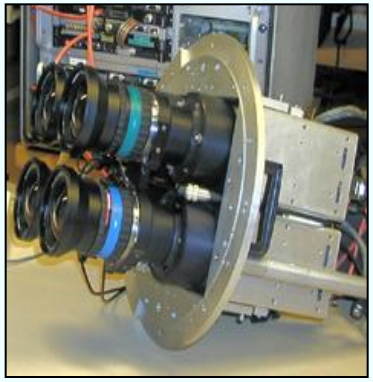
Eclairements (W/m²/µm)
- direct
- diffus
- réfléchi
- couplage

Luminances (W/m²/µm/sr)
- directe
- diffuse montante
- atmosphérique

ICARE - Inversion scheme

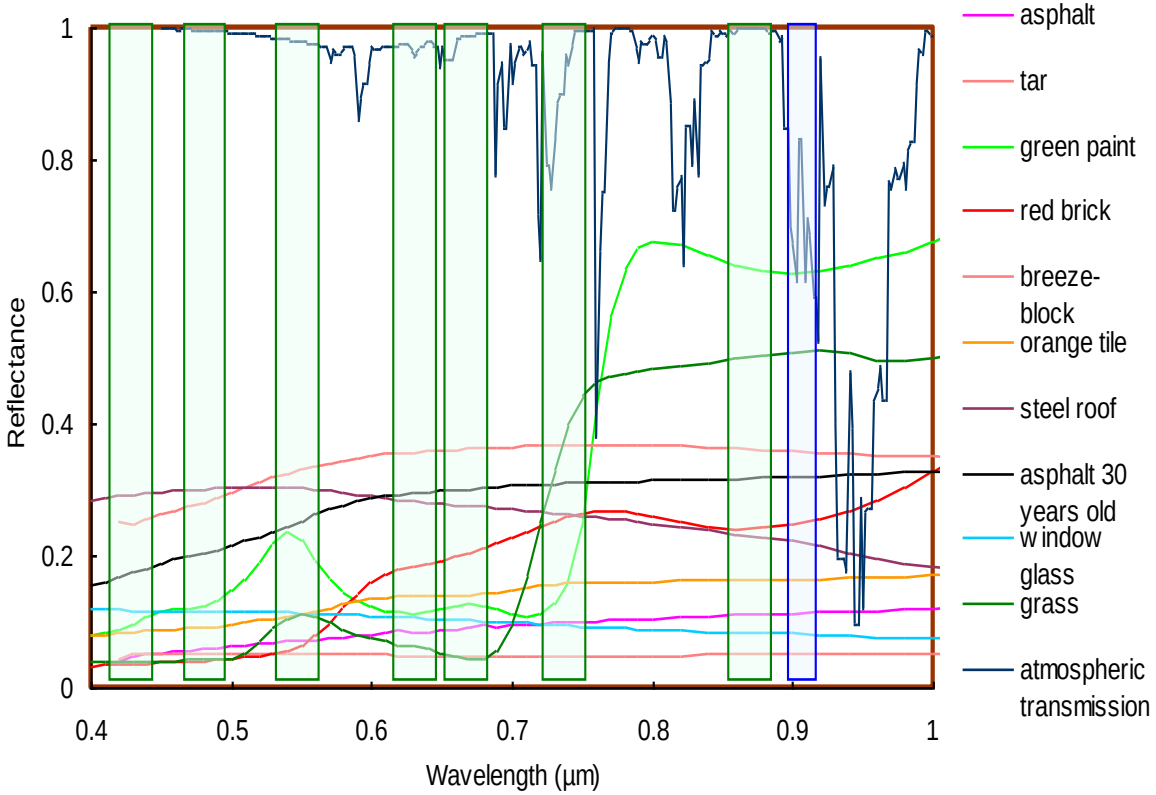


ICARE - Experimental validation



2 PELICAN systems
→ 8 spectral bands

•Airborne camera



Location of the eight narrow filters

TEST site :

administrative building in Toulouse

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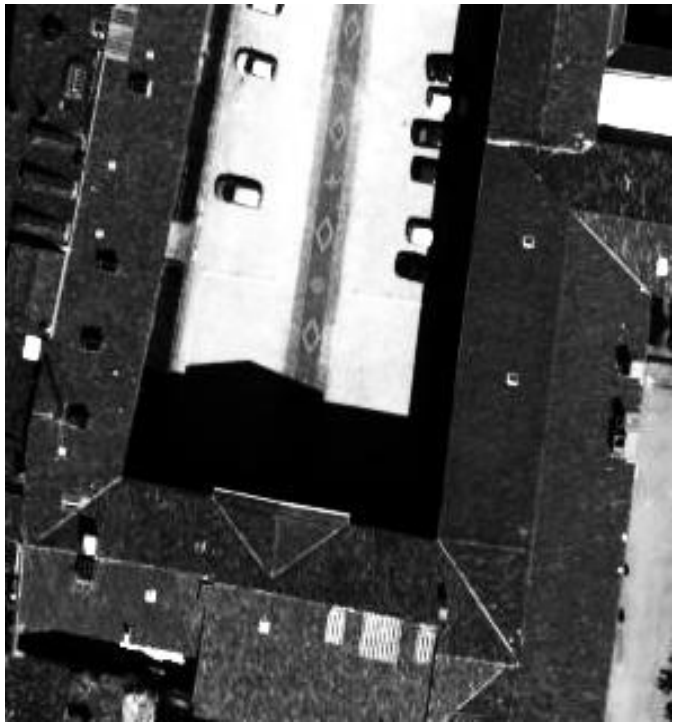
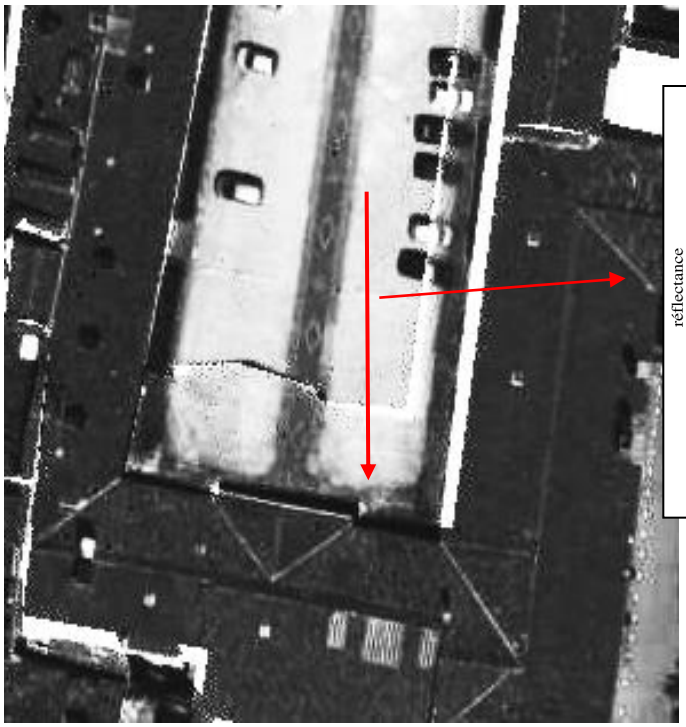
ICARE - Experimental validation

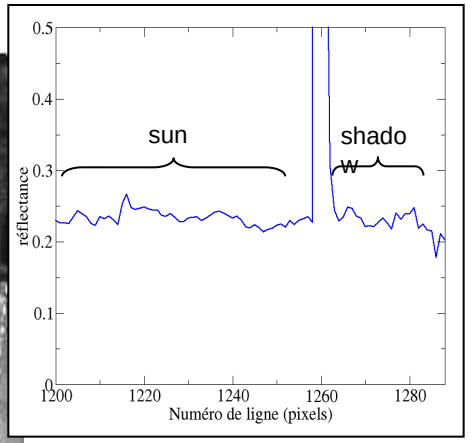
- Inversion results at 485 nm in the building area



Radiance Image



Reflectance Image



Very good continuity for ground materials located in shadows and sunny areas.

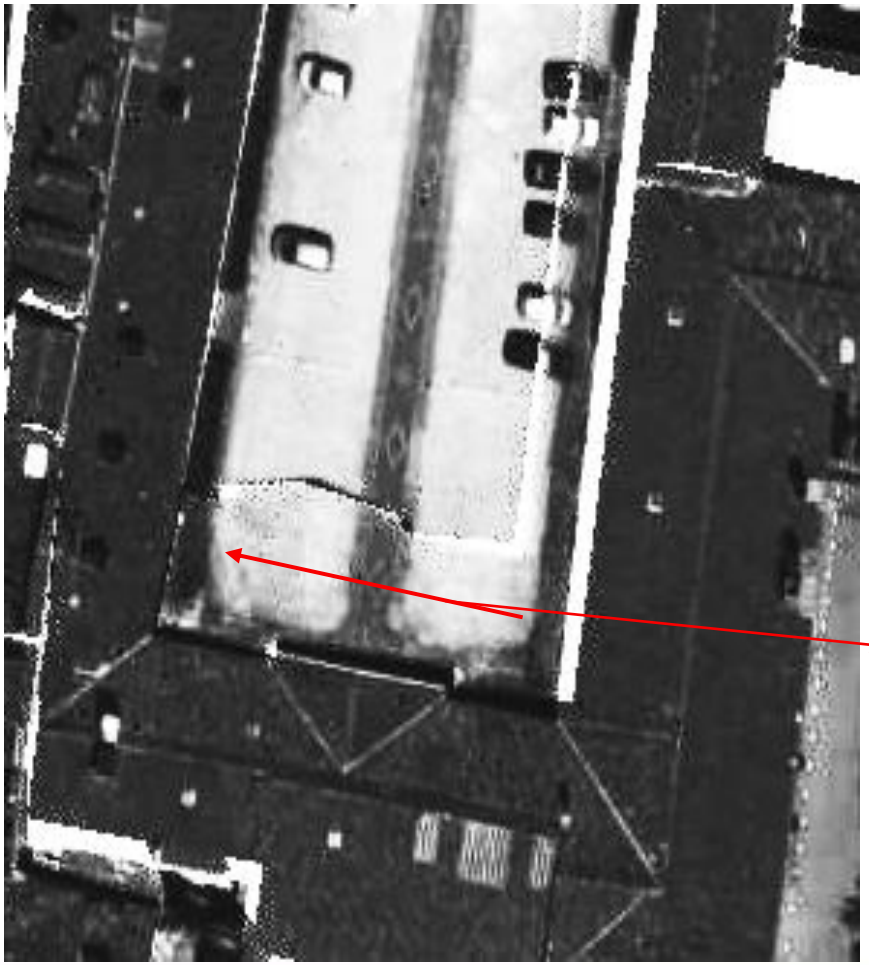
⇒ It means that the environment effects are correctly modeled.

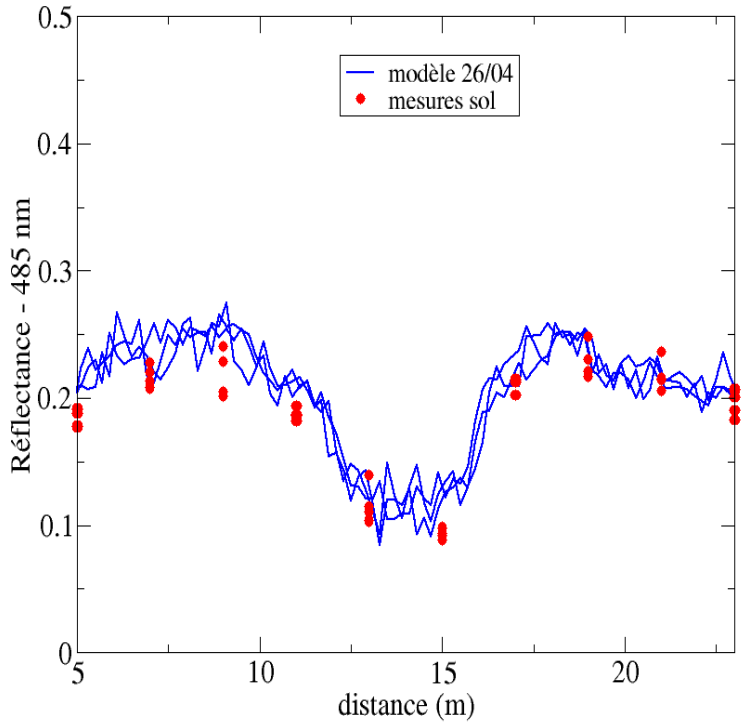
Origin of the main errors of ICARE : 3D vector model

White areas in the reflectance image correspond to geometric errors in the digital vector model. The quality of the reflectance image depends entirely on the quality of the vector model of the scene.

ICARE- Experimental validation

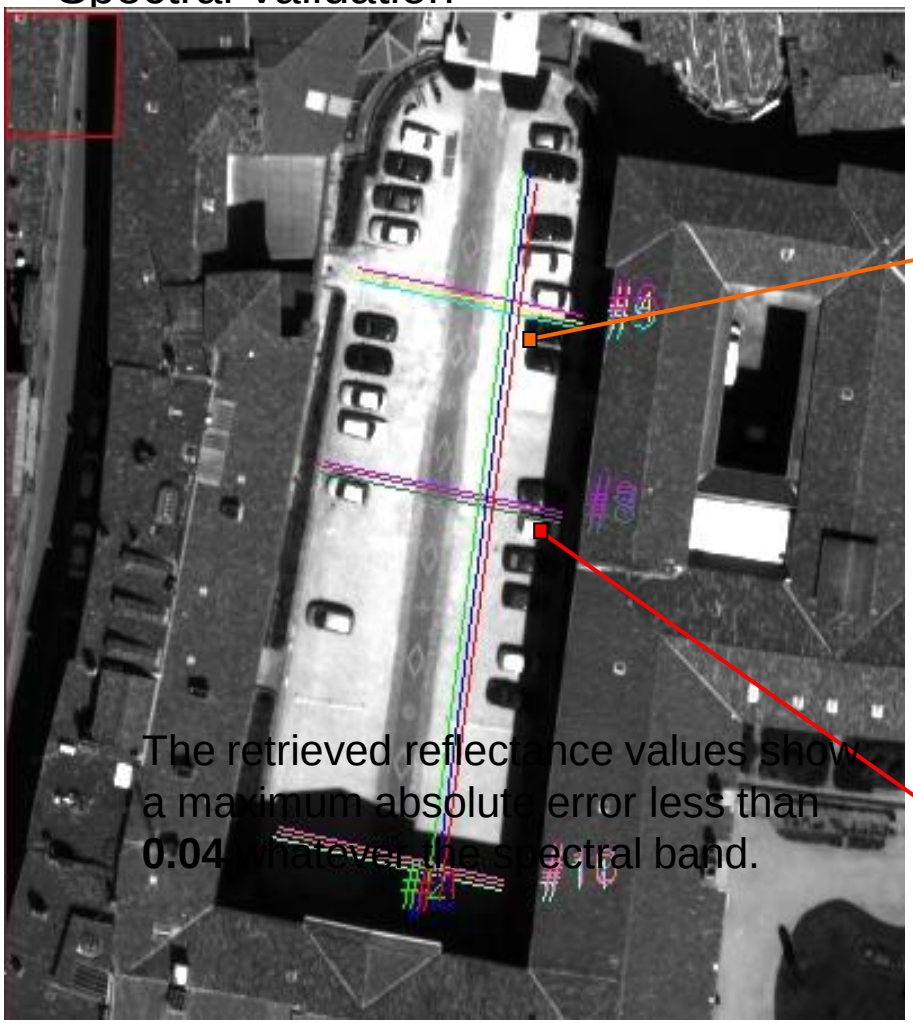
- **Comparison at 485 nm of reflectances retrieved by ICARE and ground measurements**

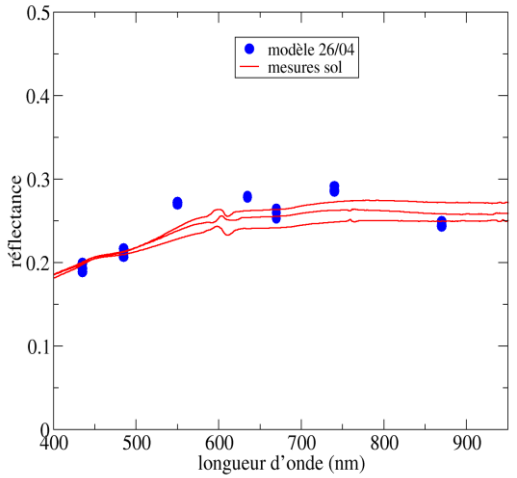


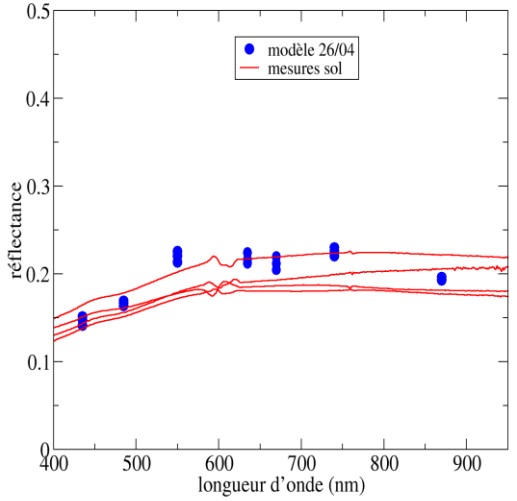


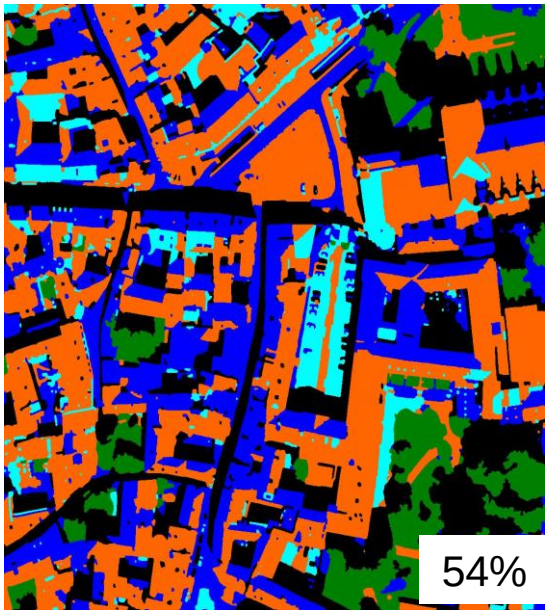
ICARE - Experimental validation

- Spectral Validation



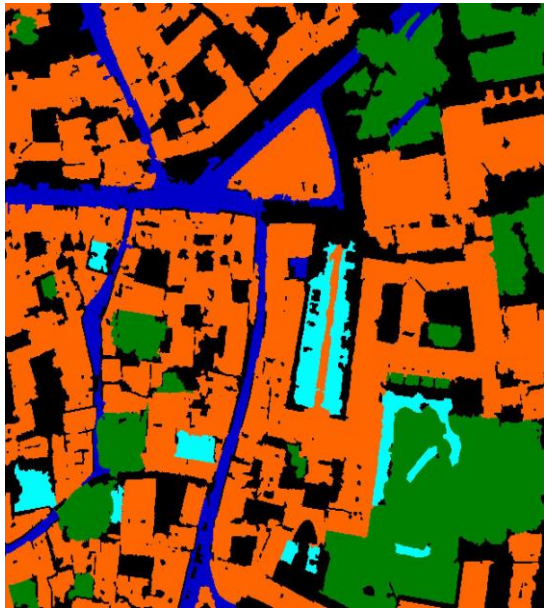






Radiance image Classification

Reflectance image Classification



Reference Classification

- tar
- granit + tile
- vegetation
- gravier
- Others (non referenced Pixels)

Improvement of the classification results of 20 points

Conclusion, perspectives

Three codes to extract reflectance image in the 0,4-2,5 µm, dedicated to three kinds of scene:

Flat landscape : *COCHISE

- Environment effect are taken into account very accurately

Montaineous landscape : **SIERRA

- The forward model of SIERRA is based on “state of the Art models”, that have been some time adapted to the context, for the computation of some irradiances/ at-sensor radiance terms, and on new model for diffuse irradiance.

- Inversion scheme is made up of four stages that go further in phenomena complexity. The first two inversion stages assume lambertian reflectance, while BRDF is taken into account in the last two stages.

- Validation on images simulated with AMARTIS at 450, 850, 1600 nm:

⇨ the ground reflectance is derived with a 5% relative error. Application to HyMap image clearly demonstrates the benefit of relief and BRDF corrections

•C. Miesch ; L. Poutier; V. Achard ; X. Briottet ; X. Lenot ; Y. Boucher, Direct and inverse radiative transfer solutions for visible an near-infrared hyperspectral imagery, IEEE Trans. Geosc. Remote Sensing, Vol 43, n°7, July 2005

**X. Lenot, V. Achard, L. Poutier, SIERRA: A new approach to atmospheric and topographic corrections for hyperspectral imagery Remote Sensing of Environment, Vol. 113, n° 8, August 2009, pp 1664-1677

Conclusion, perspectives

Urban area : *ICARE

- A physical inversion scheme, ICARE, is proposed which aims to retrieve the surface reflectance (lambertian assumption) from super or hyperspectral nadir acquisitions.

- Validation / Capitoul experiment: performances <0.04 in reflectance, main source of error: misregistration between the vector model and the radiometric image.

- **V2 Upgrade (2010, PhD S. Doz)**: validate improvements of ICARE (v2) considering multiangular viewings to also retrieve the surface reflectance of walls (MUSARDE trial, April 2009), integration of vegetation and its shadow
- **Ongoing** (new PhD K. Adeline with IGN, INRA) : reflectance retrieval in the shadows due to the vegetation

*"*ICARE: A physically-based model to correct atmospheric and geometric effects from high spatial and spectral remote sensing images over 3D urban areas*", S. Lachérade, C. Miesch, D. Boldo (IGN), X. Briottet, C. Valorge (CNES), H. Le Men (IGN), Volume 102, Numbers 3-4 / December, 2008, Special Issue on CAPITOUL Experiment (Special Editors: L. Gimeno, V. Masson and A. J. Arnfield), Meteorology and Atmospheric Physics Publisher Springer Wien, pp 209-222

Thank for your attention !