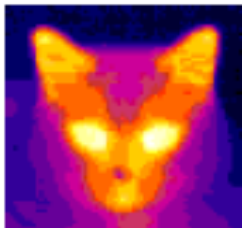

Specifications of a mission combining high spatial resolution and revisit in the thermal infrared : the CNES MISTIGRI project

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and the MISTIGRI mission group :

M. Bach [1], G. Boulet [2], X. Briottet [3], S. Cherchali [1], I. Dadou [4], G. Dedieu [5], O. Hagolle [5], F. Jacob [6], F. Nerry [7], A. Olioso [8], C. Ottlé [9], J.-L. Roujean [10], J. A. Sobrino [11]

[1] CNES, [2] IRD-CESBIO, [3] ONERA-DOTA, [4] LEGOS, [5] CESBIO, [6] IRD-INRA, [7] LSIIT/TRIO, [8] INRA, [9] LSCE, [10] Météo-France, [11] Univ.Valencia (Spain)

Main features of the mission

MISTIGRI = **Mi**cro**S**atellite for **T**hermal **I**nfraRed **Gr**ound Surface **I**maging

- **TIR**
- **High spatial resolution (~50 m)**
- **High revisit frequency (1 or 2 days)**

- **Mission developped in cooperation between France (CNES) and Spain (Univ. Valencia, CDTI)**

Present status:

- **Selected at CNES prospective seminar (2009)**
- **Phase A MISTIGRI (sept 2009→ end 2011) : consolidation of mission specifications**

http://www.cesbio.ups-tlse.fr/fr/indexmistigri.html

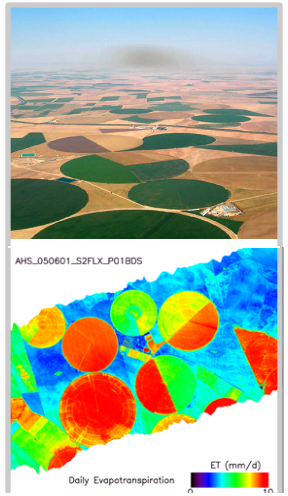
Scientific objectives

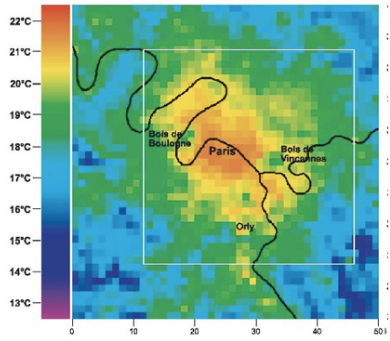
3 main scientific objectives :

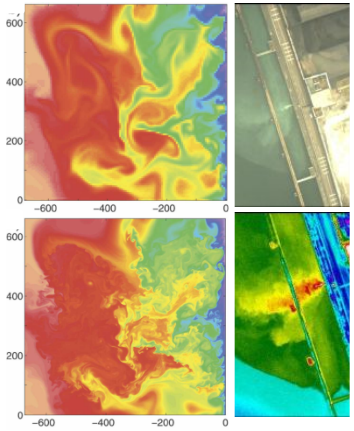
- **Monitoring of energy and water budgets of the continental biosphere** *[Agriculture/forestry, Water stress Irrigation, Biogeochimical cycles / carbon budgets, Agricultural practices vs Climate change, Hydrology, Ecology]*

- **Monitoring of the urban environment** *[urban EB, Anthropogenic fluxes, Urban climatology urban and heat waves, Urban and peri-urban hydrology, Urban vegetation, Urban meteorology and dispersion of pollutants]*

- **Monitoring of coastal and continental waters** *[Air-sea fluxes, Submesoscale activity in coastal and open ocean, Estuaries, Deltas, Biological activity and productvity]*





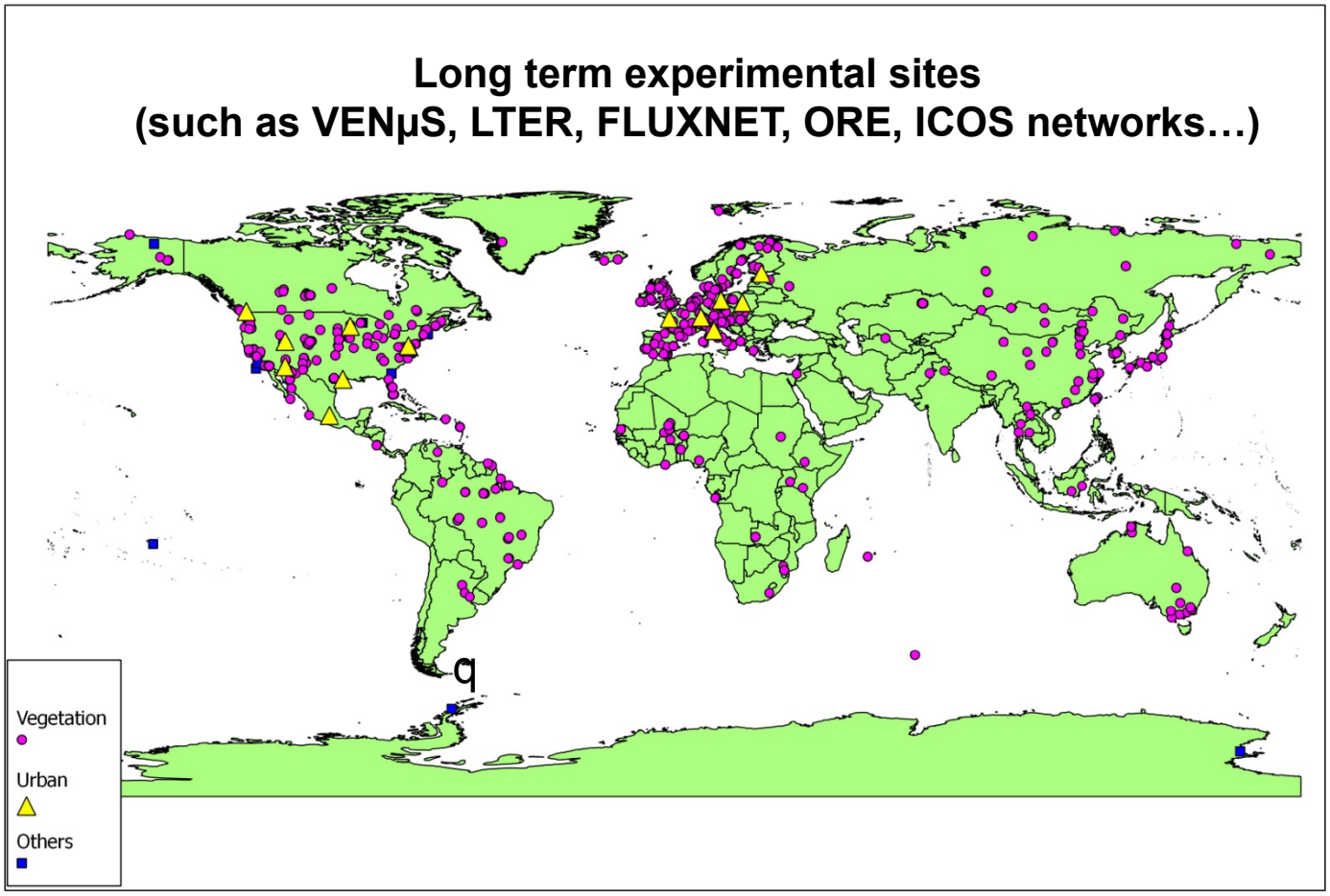


…and a large range of additional applications :

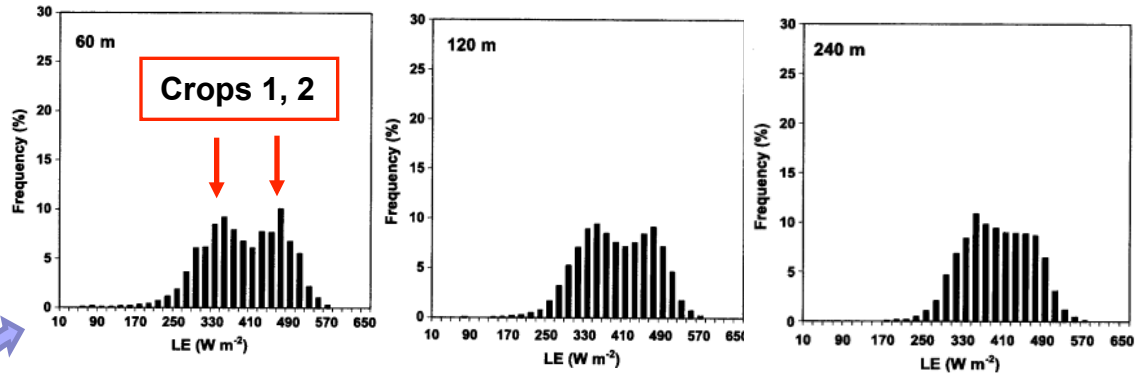
- **vulcanology, • geology, • pedology, • peat fires,**
- **diseases, etc…**

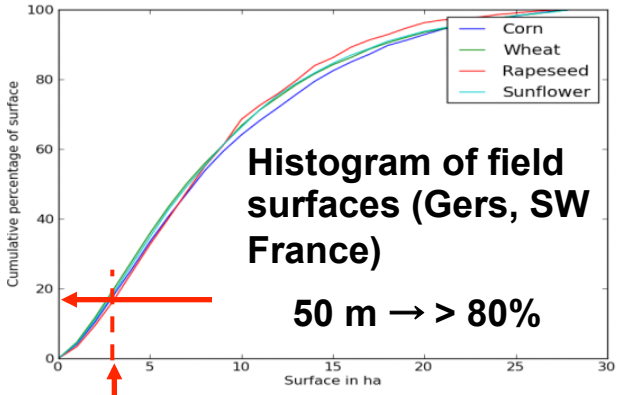
Lagouarde et al., 2012. IJRS, in press

Experimental mission based on the monitoring of a network of sites associated to scientific teams (similarity with VENµS stategy) – No global coverage



What spatial resolution ? (1/2)





Resolution must cope with the **mean size of fields**: **< ~100m required**

Kustas et al., 2004, Garrigues et al., 2006, Agam et al., 2007, LDCM…

Resolution must also cope with **turbulence** impacts

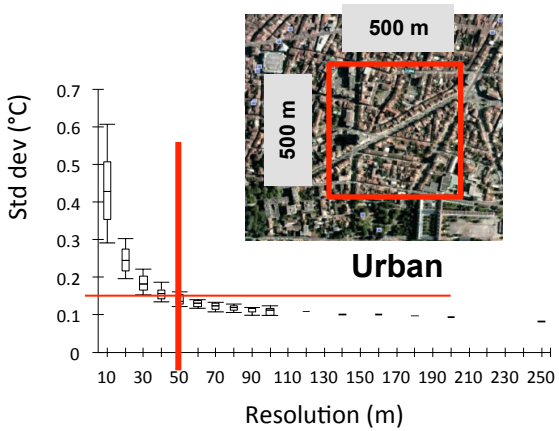
- Ts affected by atmospheric turbulence
- High frequency Surface Boundary Layer (SBL) turbulence smoothed by spatial integration on the pixel
- Low frequency Planetary Boundary Layer (PBL) turbulence (~ 1 km scale) affect the measurements whatever the pixel size. It contributes to the uncertainty on Ts

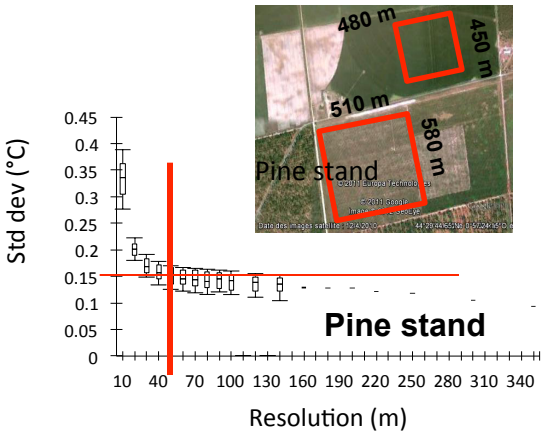
→ Analysis of the relation pixel size *vs* temporal stability of Ts (ergodicity ?)

What spatial resolution (analysis of turbulence) ? (1/2)

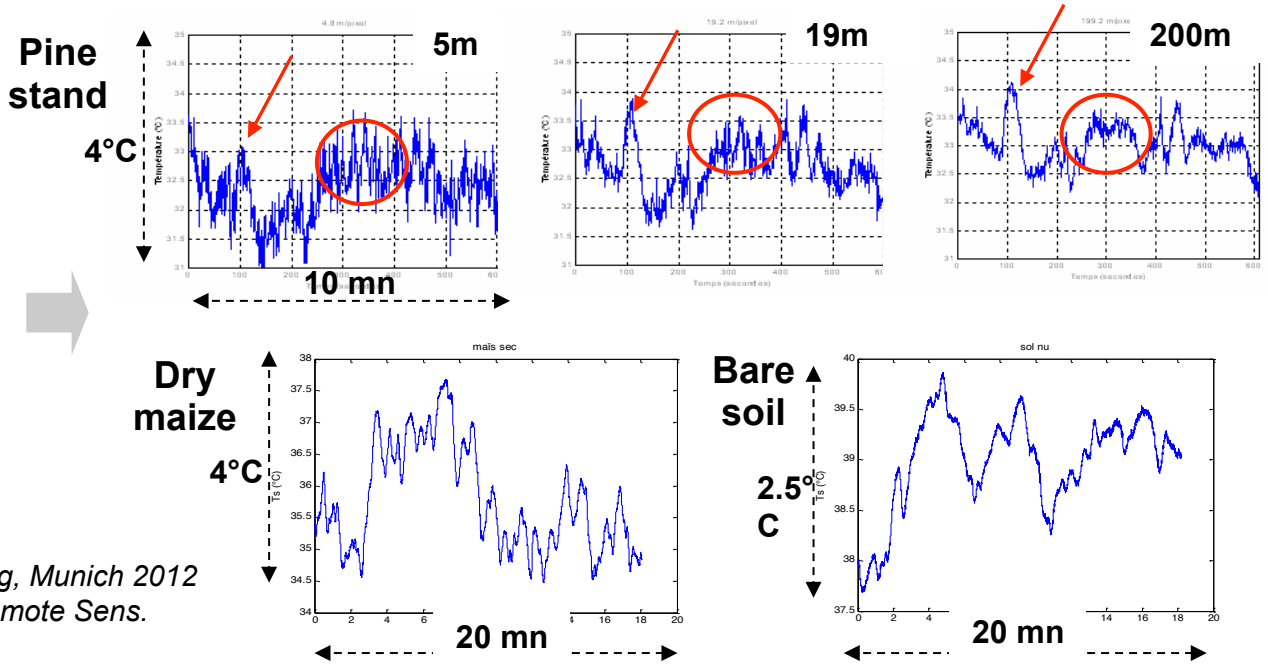
Experimental approaches using TIR helicopter borne and/or ground based measurements

SBL turbulence induced Ts fluctuations attenuated at 50 m resolution…





…but PBL turbulence contribute to uncertainty on Ts measurements (INRA studies)



Commandoire et al., IGARSS meeting, Munich 2012
Commandoire et al., Submitted to Remote Sens. Environ.

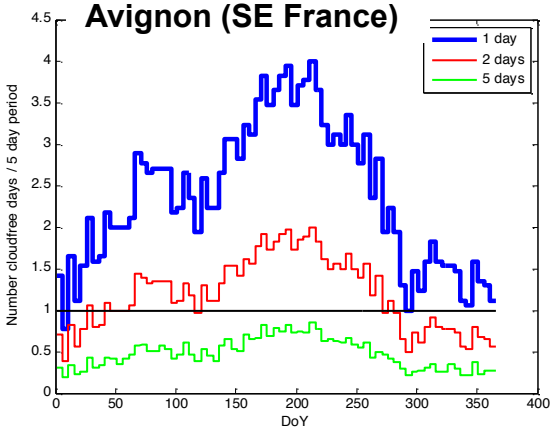
Revisit specification

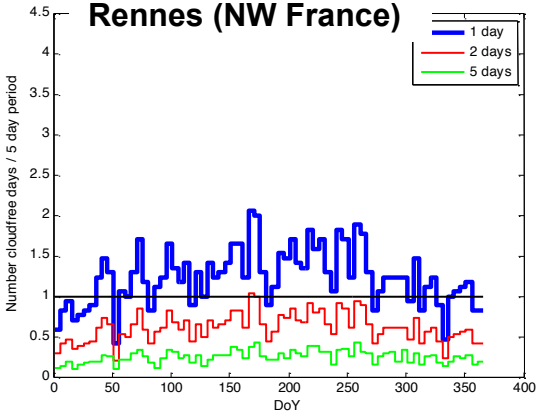
Revisit imposed by 2 combined constraints:

- **minimum availability of data** ⇒ analysis of cloudiness

- **sufficient accuracy on derived products** ⇒ sensitivity tests of retrieved fluxes to input TIR data frequency (from model or experimental datasets analysis)

Revisit specification (1/2) : analysis of cloudiness

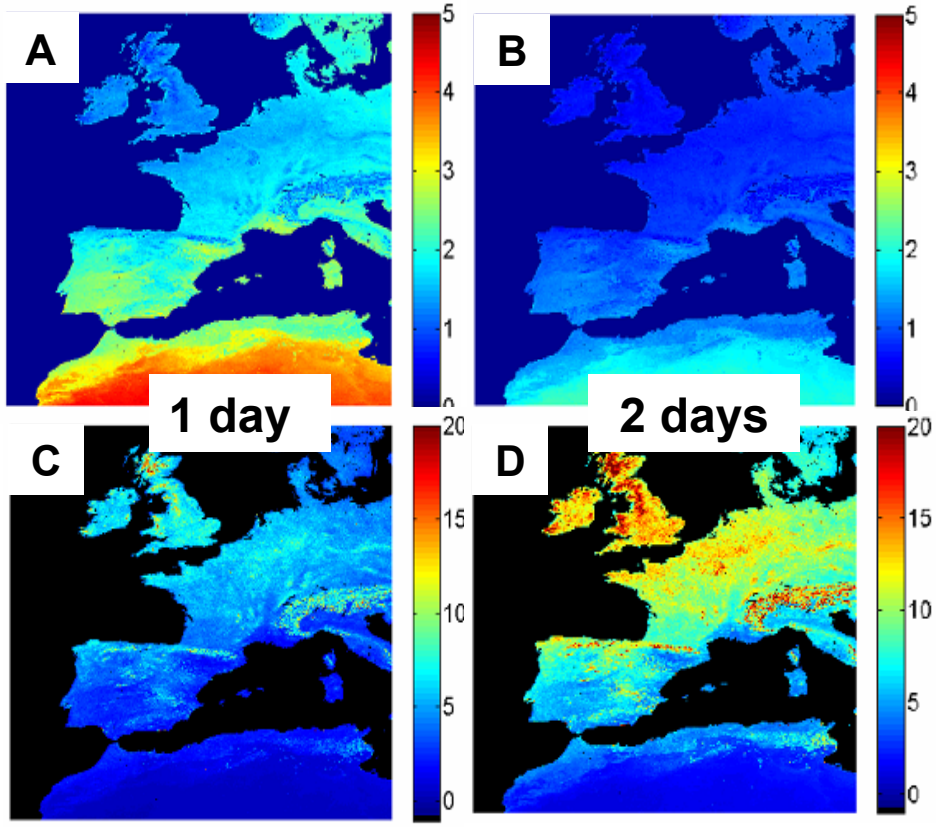




Statistical analysis of a hourly solar radiation dataset (1993-2009, INRA AGROCLIM)

Analysis of MODIS cloud masks (2000-2009)

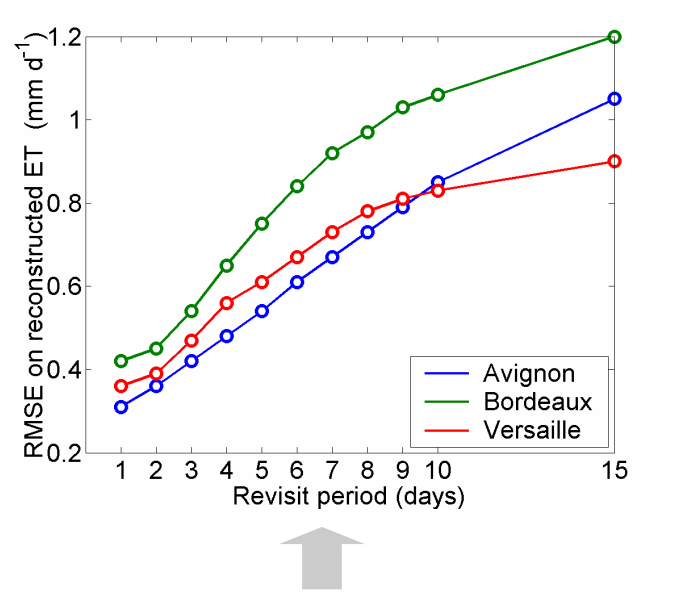
(March 1st – May 31st)



Number of cloudfree days per 5 day periods over Europe for 1day (A) and 2 day (B) revisits. Average number of days between cloudfree data for 1day (C) and 2 day (D) revisits.

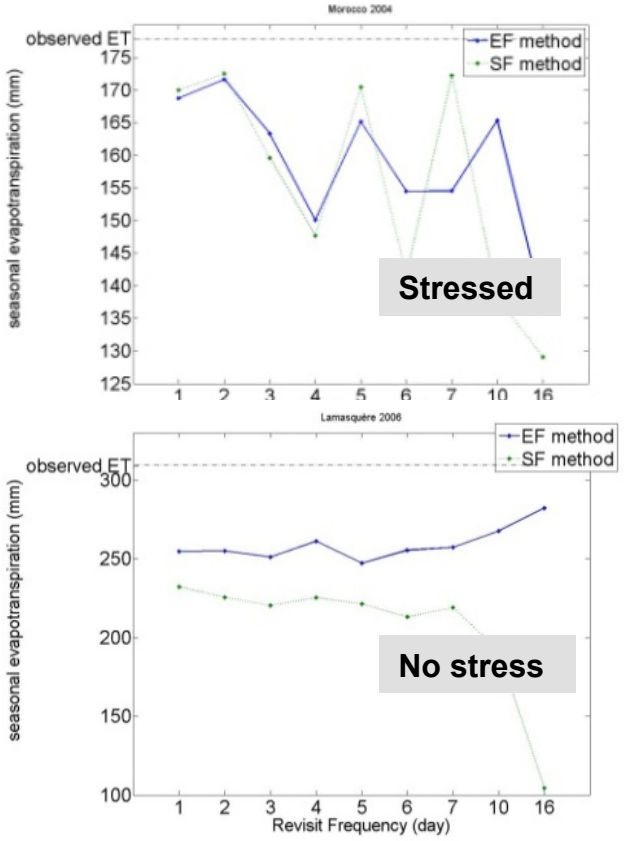
Availability of 1 data / 5day or per stress period → 1 or 2 days revisit

Revisit specification (2/2) : sensitivity of ETR accuracy to revisit



Analysis based on ISBA-AGs simulated ETR between 1950 and 2100 (IPCC scenario A1B)

Efficiency of seasonal ETR reconstruction for different revisits (analysis based on experimental data)

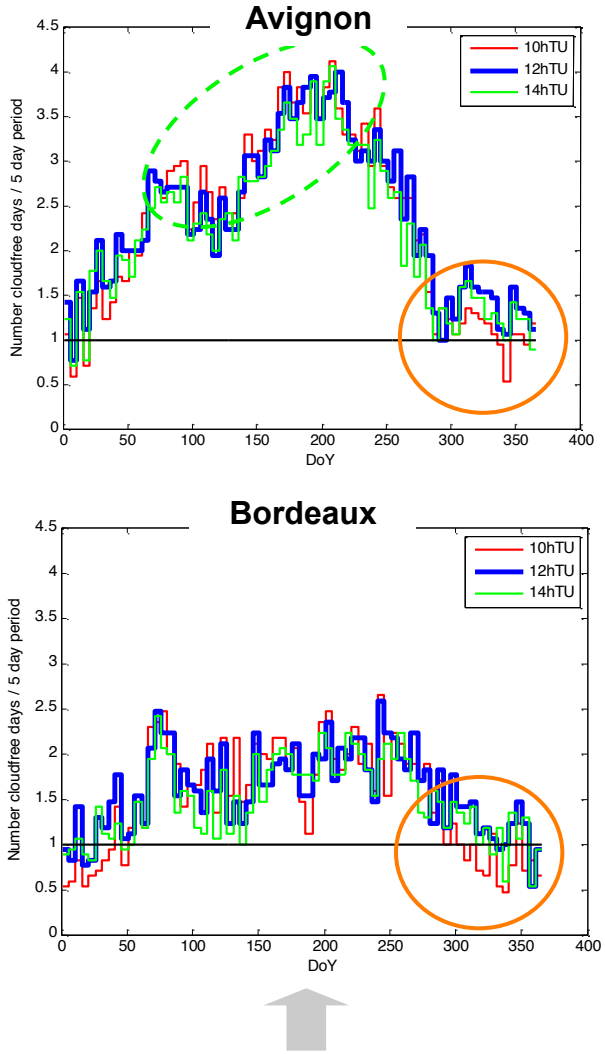


High revisit frequency necessary for stressed sites →1 or 2 days revisit recommended

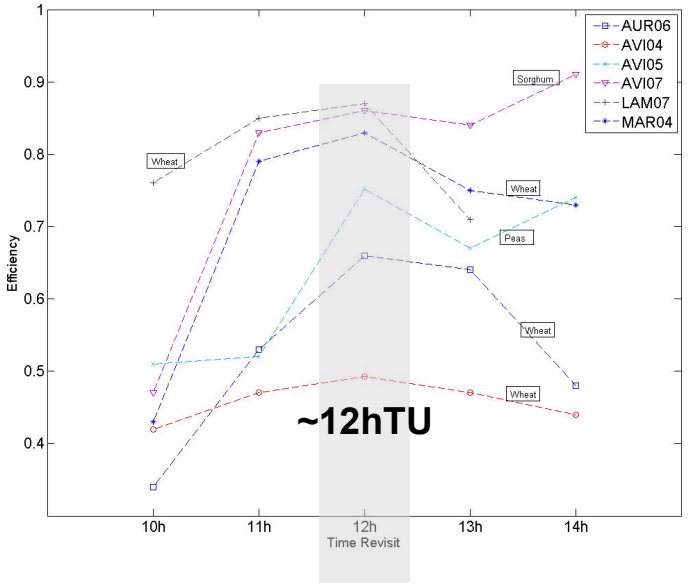
Lagouarde et al., RAQRS III meeting, Valencia, 2010

Delogu et al., Hydrol. Earth Syst. Sci., 2012

Overpass time specification



Evolution of the Nash efficiency for the extrapolation of LE according to time of satellite overpass from 10AM to 2PM.



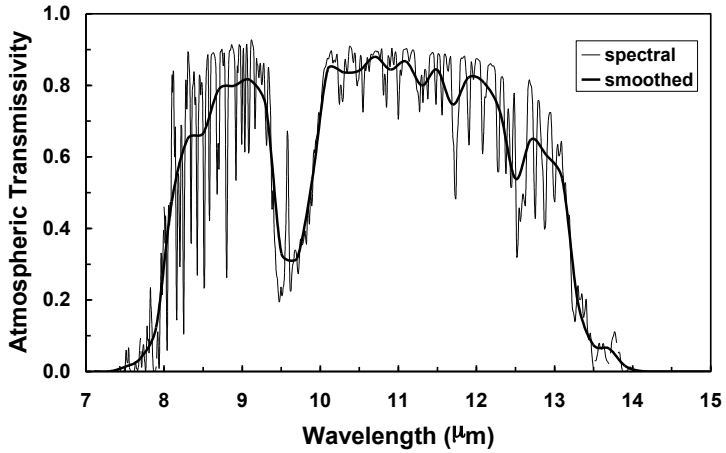
~11:00 - 13:00 UTC overpass time best suited

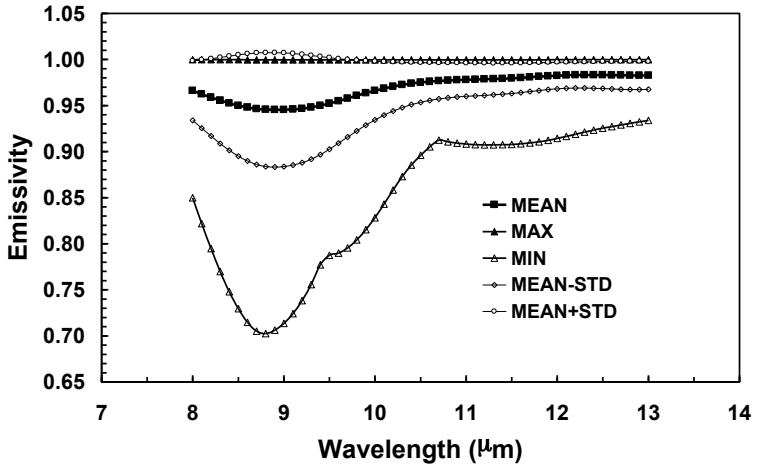
Data availability reduced by:

- ***morning fog and haze (winter)***
- ***afternoon convective cloud (summer)***

Selection of spectral bands

The choice of TIR bands must cope with atmosphere transmissivity and spectral variations of emissivity





A simulator has been built in A phase

Band	Central wavelength (μm)
TIR-3	10.3
TIR-4	11.5
TIR-1	8.6
TIR-2	9.1

NeDT <0.2-0.3K at 290K required (for NeDTs~1K)

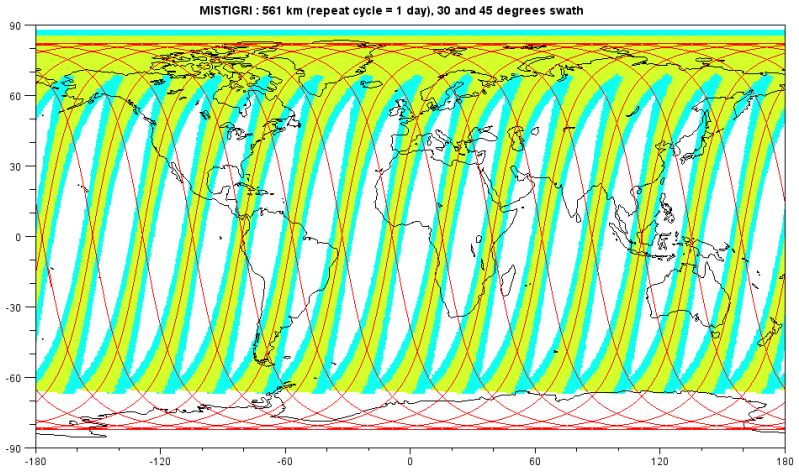
Absolute calib. 1K

Split Window, TES

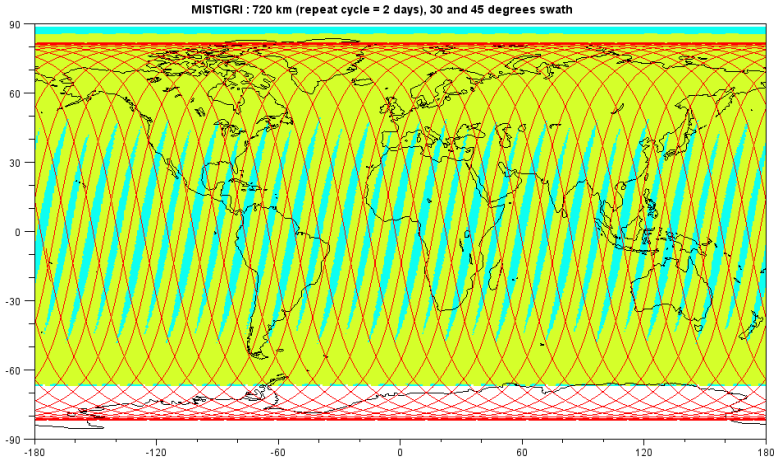
- **Merging TIR-1 & 2 would be possible with TES for reducing noise**
- **TIR 1&2 useful for retrieving emissivity over bare soils, partial vegetation, urban areas…**

Impact de la fréquence de revisite sur le choix de l'orbite

561 km / 1 day



720 km / 2 days



Choices of orbit and corresponding ground accessibility (assuming 30 and 45° depointing capacities)

Accessibility to ground sites obtained by rotating the platform, across (roll rotation) or along track (pitch rotation)

Note 1: 860 km (1 day) not compatible for a microsat mission

Note 2: nearly global accessibility at 1 day revisit possible by combining 2 satellites at 720 km (TIREX project submitted to ESA / not selected, Sobrino et al., 2010, RAQRS III, Valencia)

Viewing configuration of sites

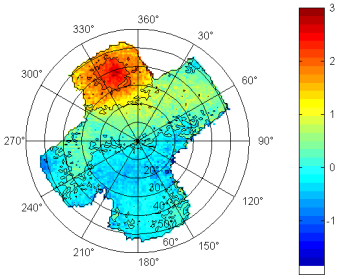
MISTIGRI viewing configurations required TIR anisotropy be experimentally studied and modelled

SAFIRE PA23 aircraft

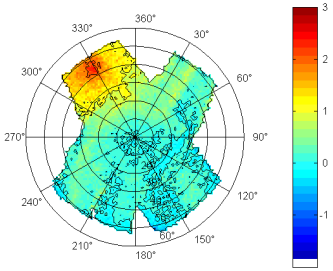
Sites seen in constant viewing configuration (720 km orbit example)

Directional anisotropy : experimental results

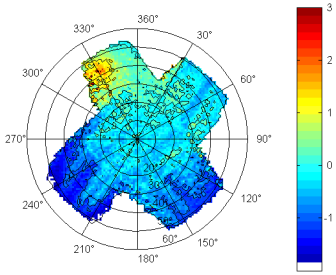
Experimental characterization of TIR **'hot spot' effects** ampaigns above different canopies (forest, urban…) in diurnal conditions revealed significant in directional anisotropy…



15 years stand

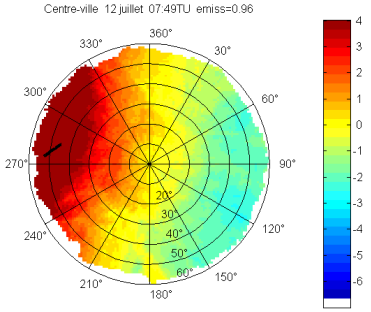


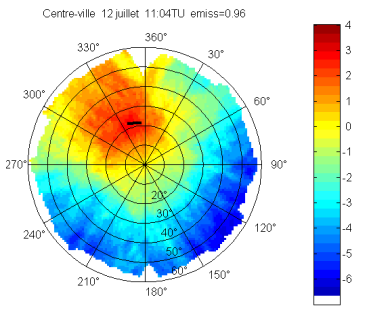
6 years stand : small trees, dense

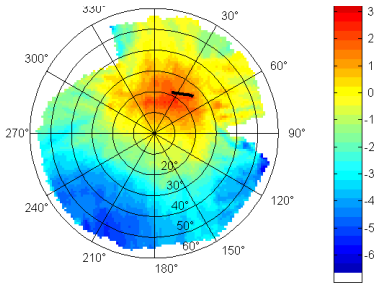


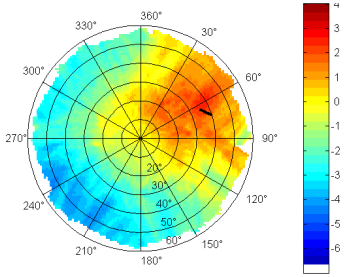
48 years stand : tall widely spaced trees

Impact of time of day on the hot spot position on a a urban canopy (Marseille) *(Lagouarde et al., Rem. Sens. Environ. 2004)*

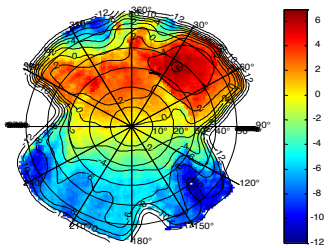




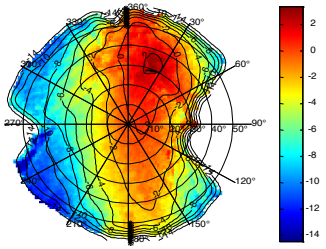




Impact of the stand structure on the hot spot size on a Maritime Pine stand *(Lagouarde et al., Rem. Sens. Environ. 2000)*



E - W rows

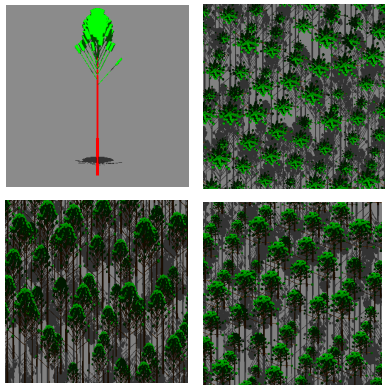


N - S rows

Impact of the orientation of rows on the TIR directional anisotropy of wineyards *(Lagouarde et al., 2012, IEEE-GRSL, subm.)*

Modelling directional anisotropy

Modelling approach based on the combination of 3D models and surface models

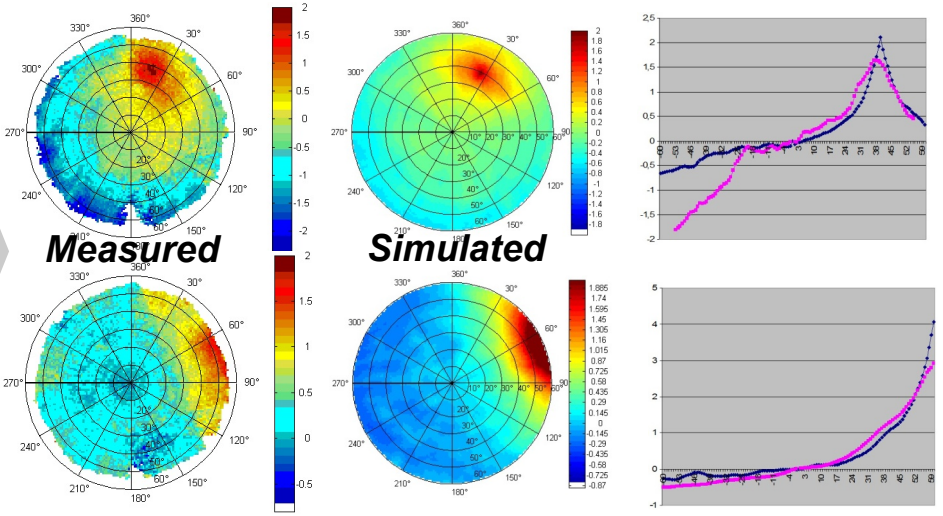


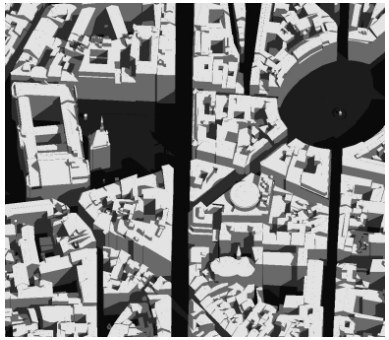
3D Pine stand

(Mira et al., RAQRS III; Kurz, PhD thesis)

+

SVAT MUSICA model



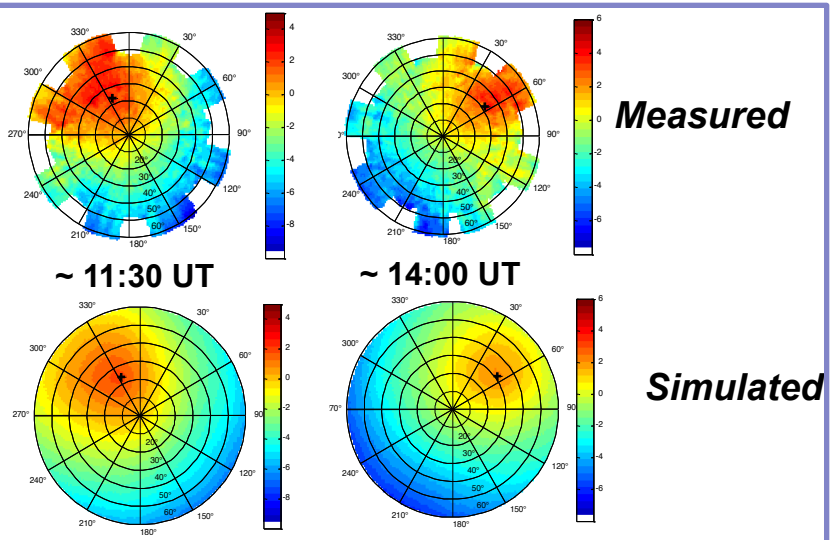


3D Toulouse city

(Lagouarde et al., RSE 2010 & RSE 2012; Kurz, PhD thesis)

+

SOLENE urban surface EB model (CERMA, Nantes)



CAPITOUL, Toulouse city July 15th, 2004

Summary of consolidated MISTIGRI specifications (A phase)

Spatial resolution : **~ 50 m (TIR) ~20 m (VNIR)**

Revisit : **1 – 2 days**

Sensors : **TIR** *Uncooled microbolometers ULIS 640x480 (25µm)*
VNIR *(1D CCD array)*

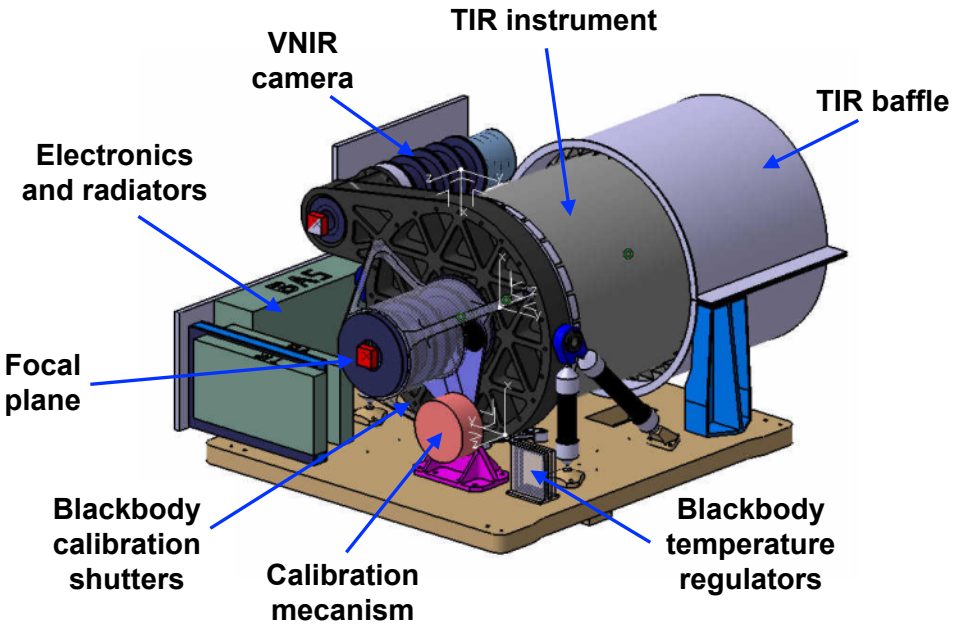
Spectral bands : **4 bands VNIR (0.45 0.67 0.865 0.910 µm)**
TIR registration, cloud detection, land use vegetation indices, first ε guess for TES, TIR disaggregation…

4 bands TIR (8.6 9.1 10.3 11.5 µm)
(possibly reduced to 3)
NeDT 0.2 to 0.5K at 290K required (for NeDTs~1K)
Absolute calib. 1K

Overpass time : **11 - 13 UTC**

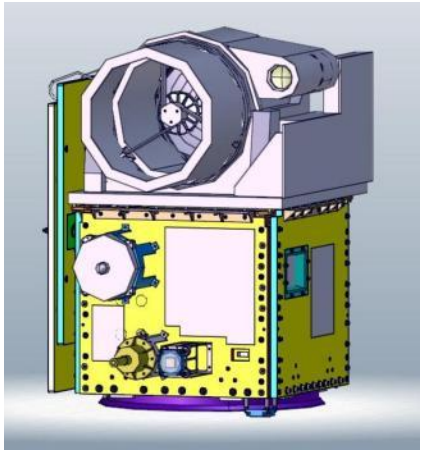
Swath : **32 km** (**reached with a 640x480 ULIS µbolometers array)**

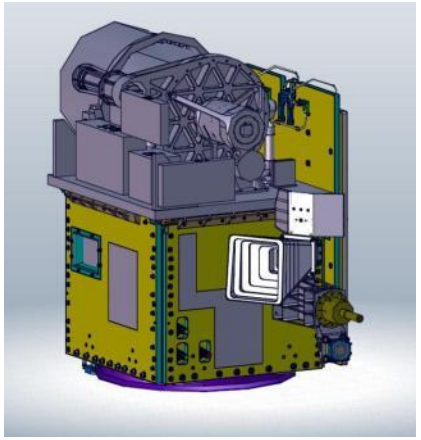
Instrumental design



An instrument and a mission architecture have been proposed in A phase (CNES and Thales Alenia Space)

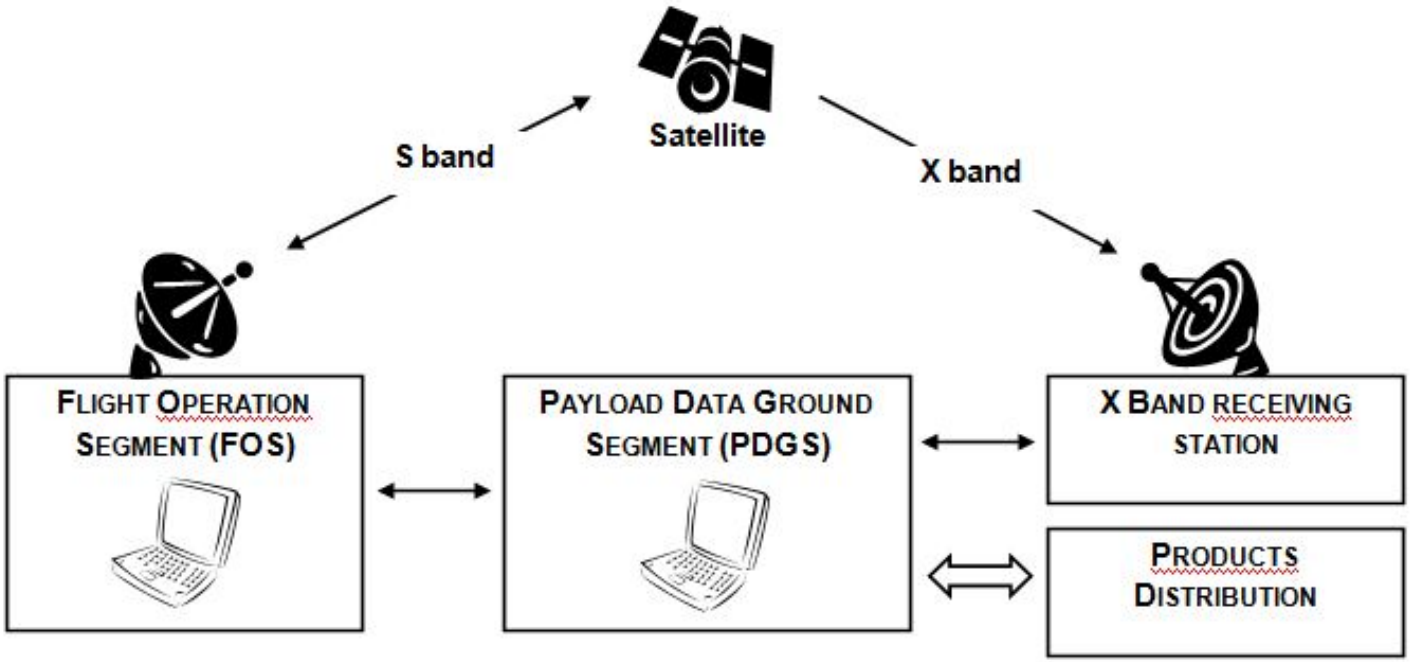
MISTIGRI satellite with the VNIR-TIR instrument installed on the MYRIADE platform (in yellow)





Payload and instrumental concept described in *Lagouarde et al., IJRS 2012*

Ground segment design



Based on :

- existing knowhow
- well-tried technologies
- Venμs developments

Perspectives

Phase A…

→ **Potentialities of high temporal high resolution TIR data : many applications in various fields clearly identified**

→ **Need of such data strongly expressed by the scientific community**

→ **Tools have been developed : data correction methodologies, surface models, inversion and assimilation techniques…**

→ **Maturity for TIR projects : MISTIGRI, HyspIRI…**

→ **Feasibility of MISTIGRI demonstrated**

At present…

- **MISTIGRI waiting for international partnership**
- **Possibility of conducting a joint complementary A phase**
- **2013 CNES prospective seminar**
- **Research on mission going on with CNES (TOSCA) funding**