Infrared continental surface emissivity spectra and skin temperature retrieved from IASI observation

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Introduction

Why Focusing on Ts and ε_s?

➢ To improve the determination of the tropospheric properties:

- ✓Thermodynamic properties (T, H2O, etc…)
- ✓ aerosols
- ✓Trace gases concentration

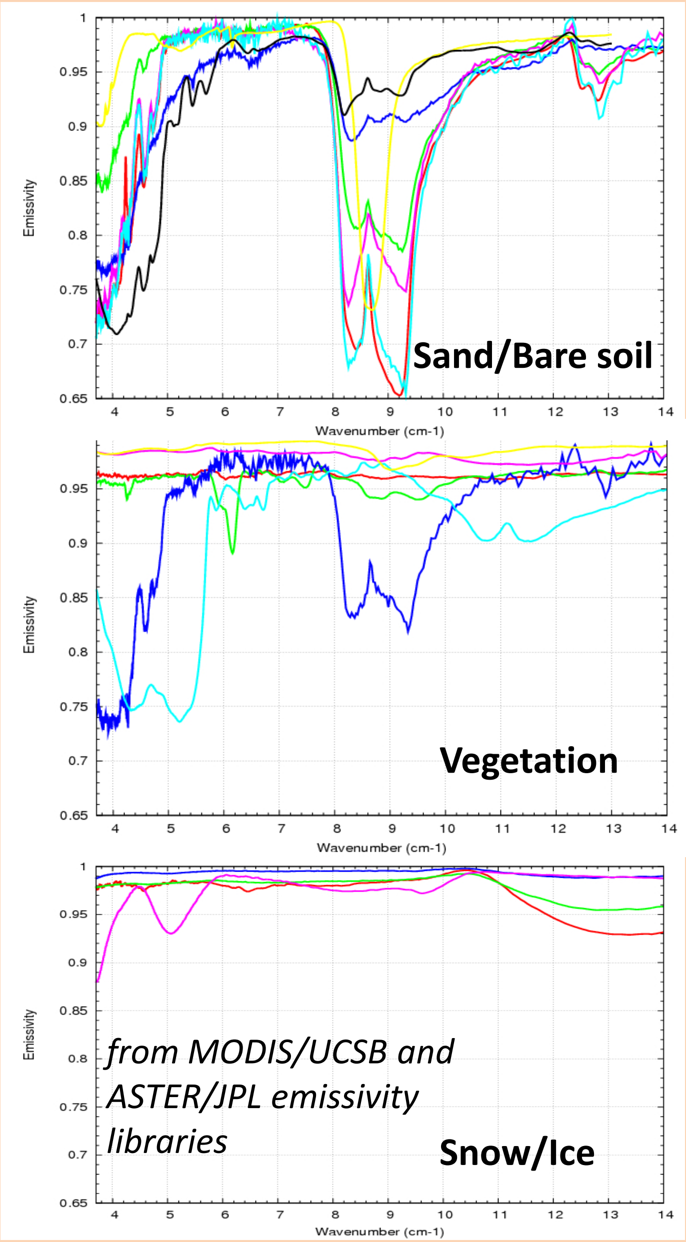
➢ Essential to estimate the radiative budget

➢ Necessary to have an accurate spectral estimation of emissivity (emissivity often considered as constant).

Advantage of using 2nd generation infrared sounders (AIRS, IASI) ?

➢ Can provide emissivity spectra at high resolution

➢ Global view and long-term monitoring of continental surfaces (e.g: Sahel evolution)



Infrared RTE
(lambertian surface, clear sky, night)

$$I(\lambda,\theta) = \varepsilon_s(\lambda)\tau_s(\lambda,\theta)B(\lambda,T_s)$$

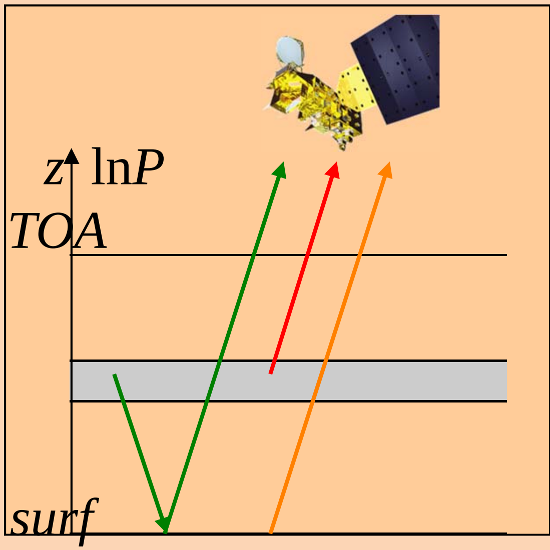
Surface Emission

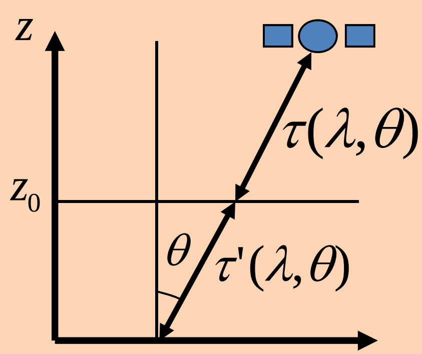
$$+\int_{\tau_s(\lambda,\theta)}^{1} B[\lambda,T]\,d\tau(\lambda,\theta)$$

Upwelling Atmosphere Emission

$$+(1-\varepsilon_s(\lambda))\tau_s(\lambda,\theta)\int_{\tau_s(\lambda,\theta)}^{1} B[\lambda,T]\,d\tau'(\lambda,\theta)$$

Reflected Downwelling Atmosphere Emission for a Lambertian surface



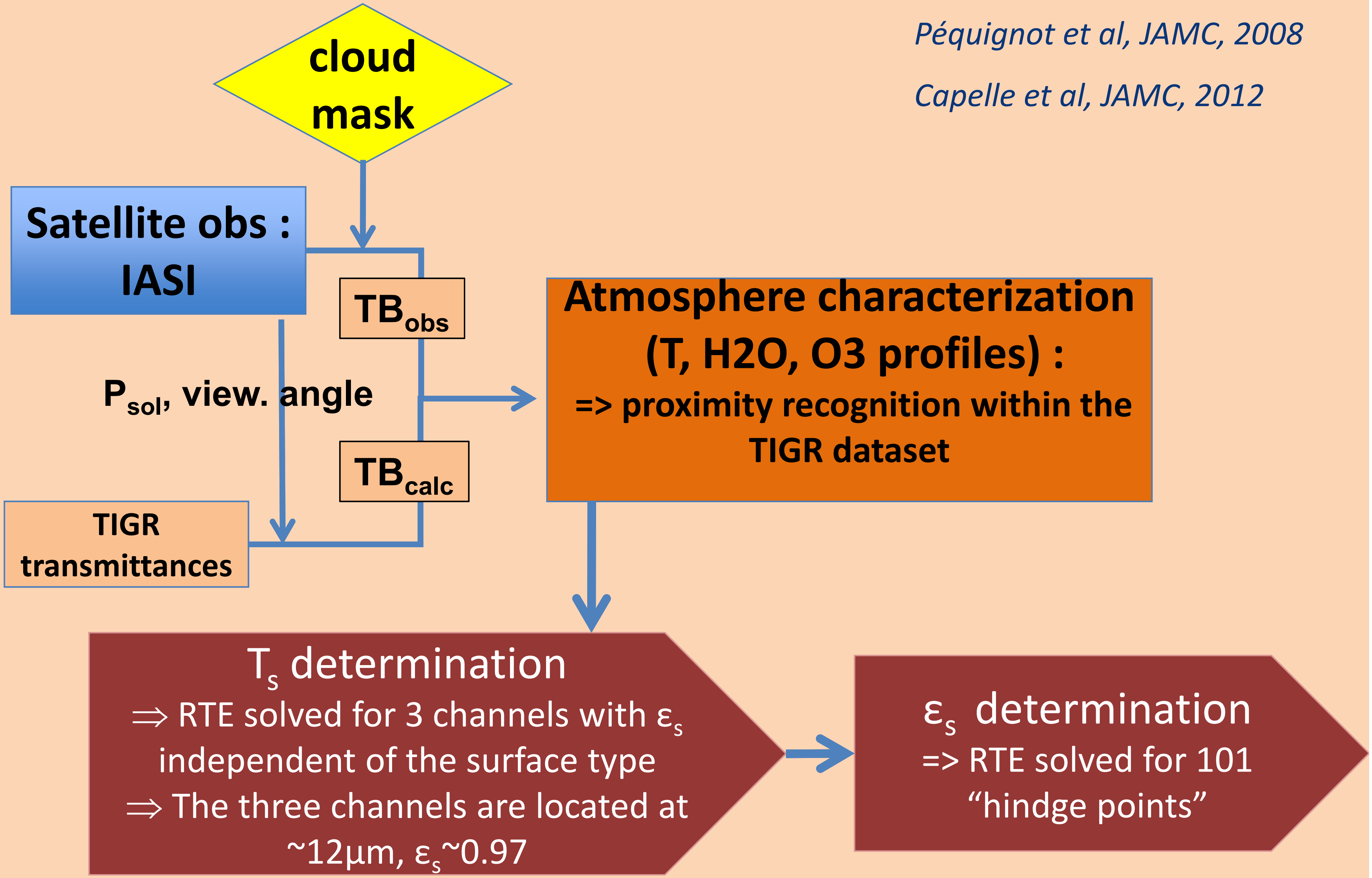


$$\tau'(\lambda,\theta)\tau(\lambda,\theta)=\tau_S(\lambda,\theta)$$

Multi Spectral Method (MSM)

Péquignot et al, JAMC, 2008

Capelle et al, JAMC, 2012



Determination of the continuous emissivity spectrum

→ ε calculated for **101 "hinge points"**

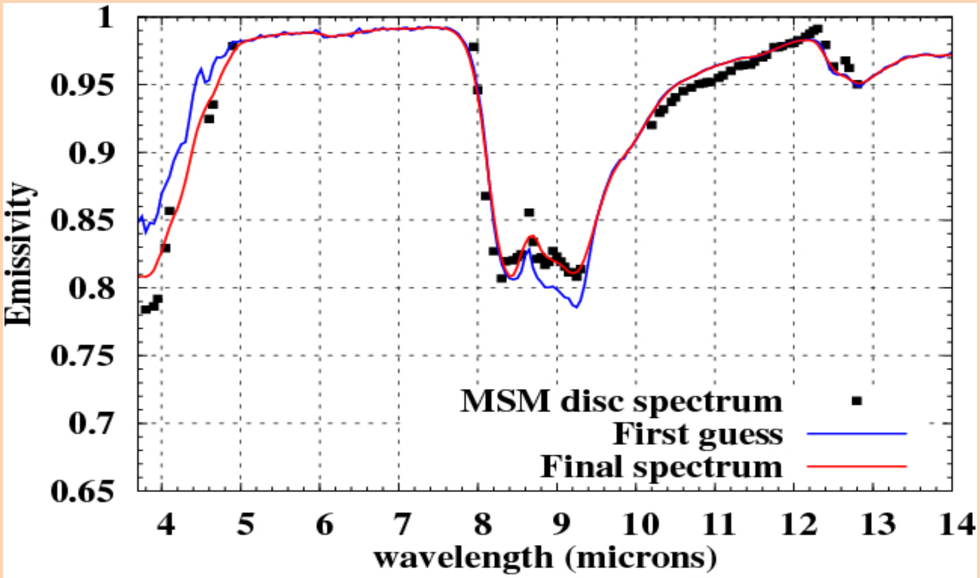
→→→ **Discontinuous spectrum with a demonstrated accuracy of less than 1.5% at 12 μm and ~4.5% at 4 μm.**

MSM emissivity database:

- 165 high spectral resolution emissivity laboratory measurements of different samples of typical Earth surfaces are selected from MODIS/UCSB and ASTER/JPL emissivity libraries.
- They are linearly interpolated at 0.05 μm resolution between 3.7 and 14.0 μm.

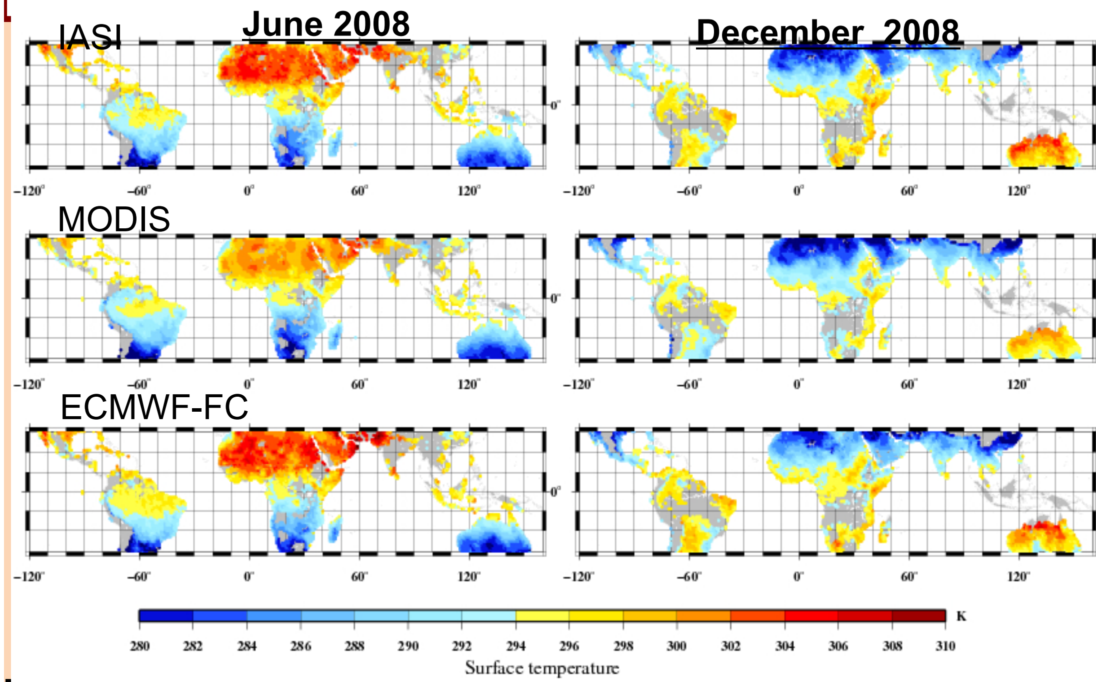
Proximity recognition + shape fit procedure

Emissivity continuous spectrum at 0.05 μm resolution between 3.7 and 14.0 μm



Results for surface temperature:

Comparison with MODIS and the ECMWF forecast data



	MODIS – IASI			ECMWF FC - IASI
June 2008	-1.32 ± 1.5K	N. Hem.	-1.93 ± 1.5K	0.45 ± 1.7 K
		S. Hem.	-0.70 ± 1.1K	
Dec. 2008	-1.19 ± 1.4K	N. Hem.	-0.88 ± 1.3K	0.24 ± 2.4K
		S. Hem.	-1.85 ± 1.3K	

⇒ Good agreement with MODIS surface temperature (std - dev of about 1.4 K) and ECMWF fcst (bias < 0.5K).

⇒ IASI/MSM results are in between MODIS and ECMWF fcst

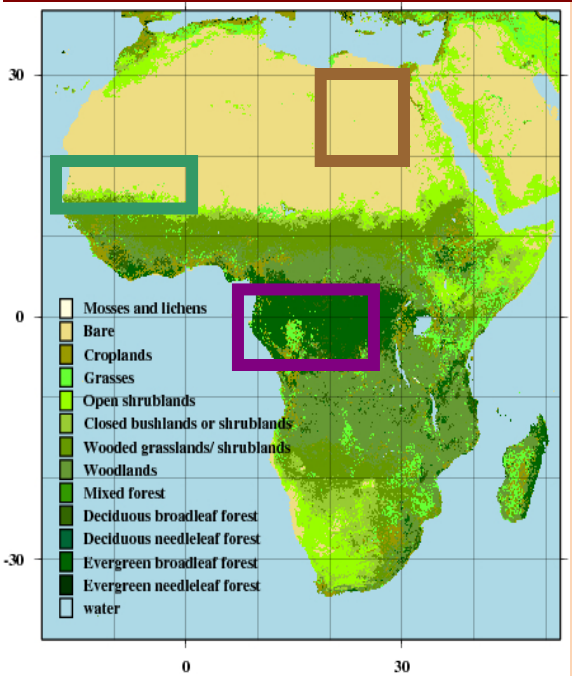
⇒ With ECMWF, small biases but with a large standard deviation in December (??)

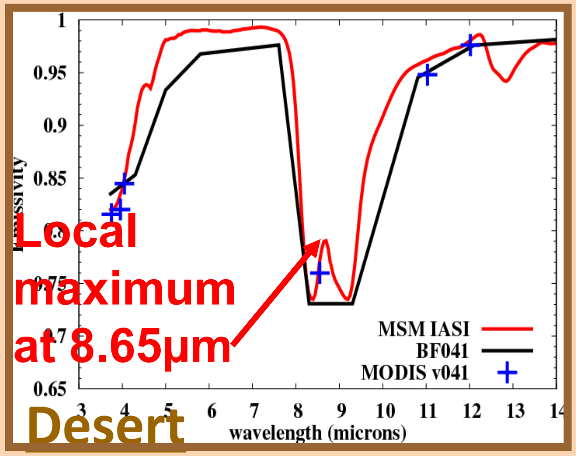
⇒ With MODIS, biases depend on the season: (-0.8K in winter and ~-1.9K in summer, with a std dev larger in summer)

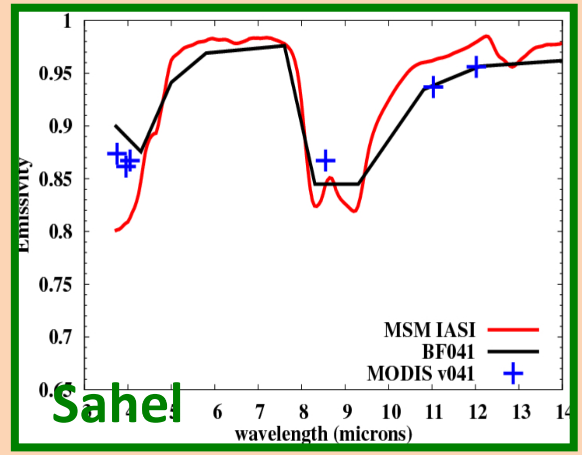
=> A part of this difference can be explained by the diurnal cycle impact due to the 1 hour time shift between IASI and TERRA (21h30 .vs. 22h30) -> see Capelle et al., 2012

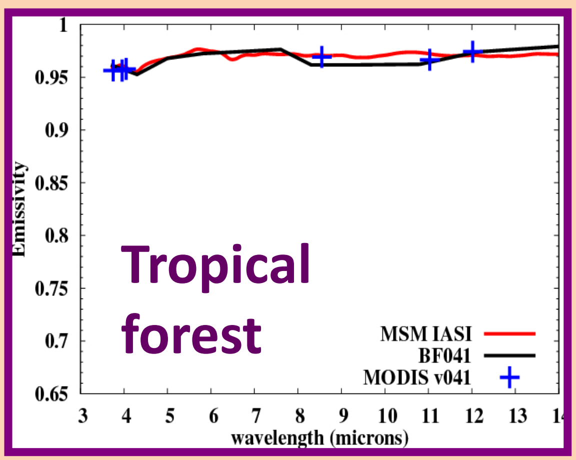
Results for the infrared surface emissivity spectrum:

comparison with MODIS





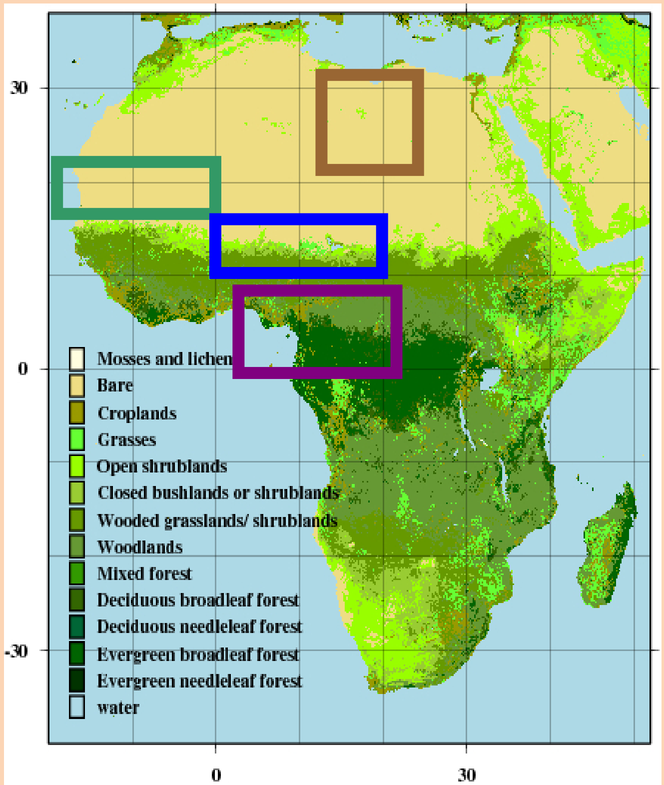


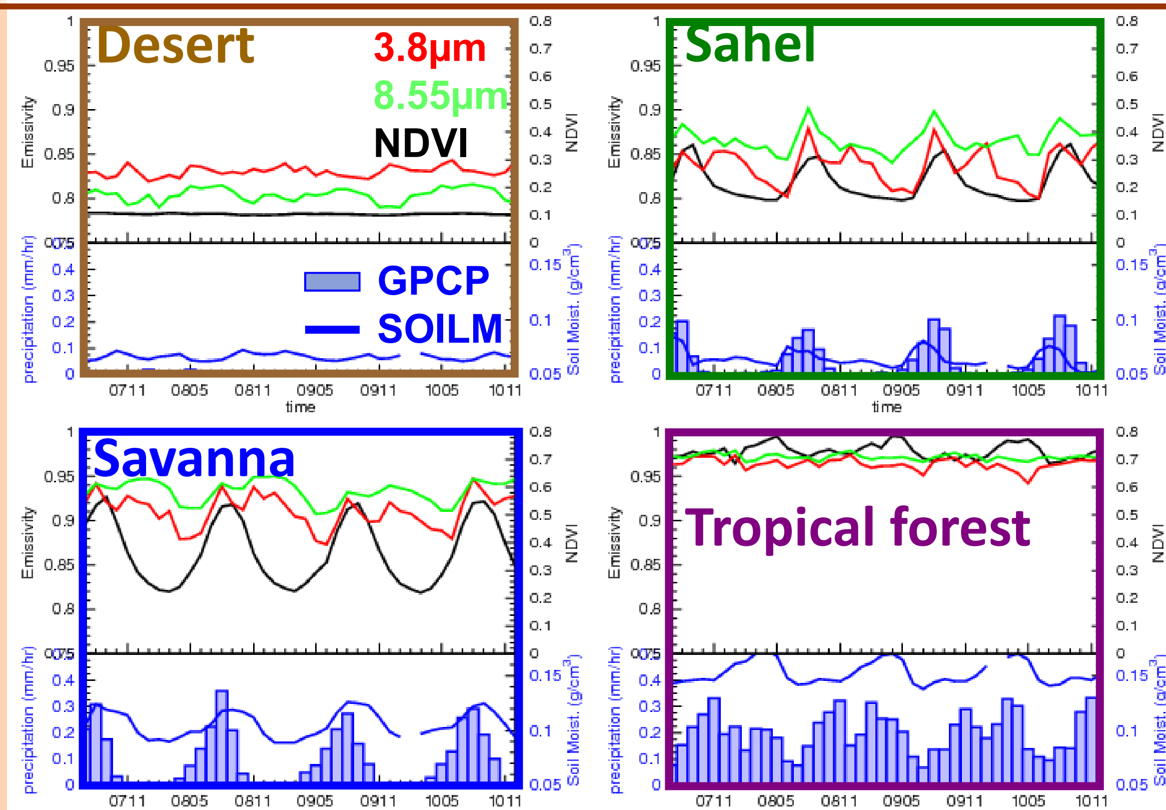


- The **accurate** shape of the spectrum characterizes the observed surface (high resolution in the quartz reststrahlen 8 µm band is important)
- In general, good agreement with MODIS low resolution emissivities
- The IASI/MSM method actually reproduces the local maximum of emissivity at 8.65 µm observed in the high spectral resolution laboratory spectra for sand soil.

Time series from July 2007 to December2011

Example of the reststrahlen bands at 3.8 and 8.55 µm





➢Variations (seasonal) strongly depend on the surface type: no variation over desert or tropical forest, strong variations over Sahel or Savanna.

➢The variations follow the NDVI / soil moisture / precips : emissivity increases with vegetation and/or the soil water content

➢**Opportunity of long-term monitoring of continental surfaces (Metop1, 2, 3, etc…) at global scale.**

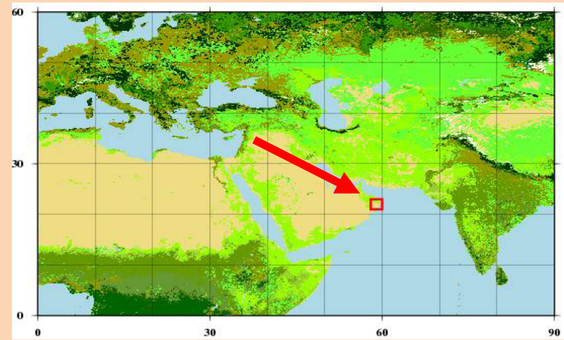
Application of the IASI-MSM at local scale:

Comparison with ARIES emissivity from the MEVEX Oman campaign, May 2009

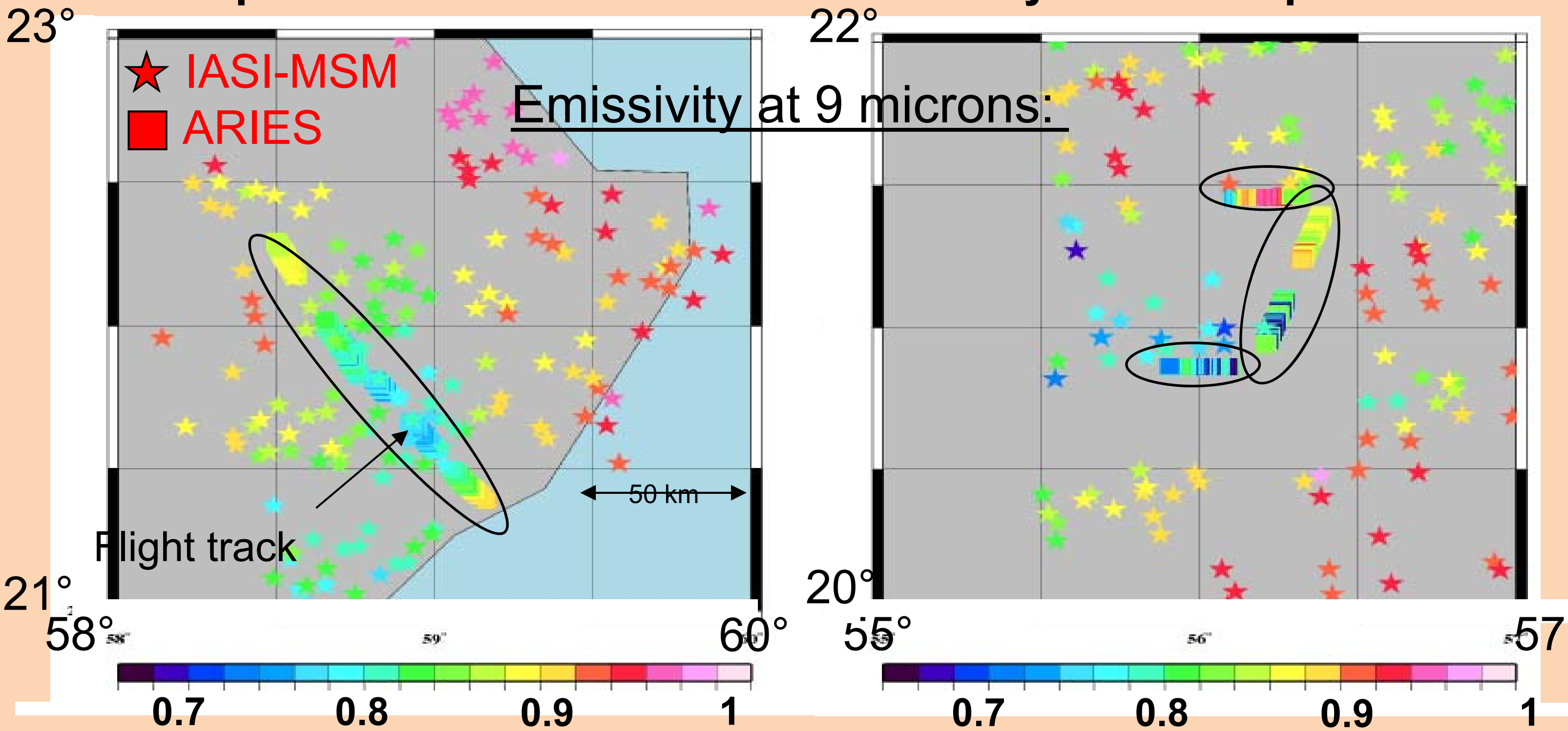
Emissivity measurement during the aircraft MEVEX campaign of the MetOffice:

IR radiance collected by ARIES interferometer on-board the FAAM BAe146-301 Atmospheric Research Aircraft

• During low-level flights, the surface emissivity can be derived directly from the hyperspectral data.



=> Two flights at low-level were selected as suitable for emissivity retrieval from ARIES and compared here with IASI-MSM emissivity for each spot.



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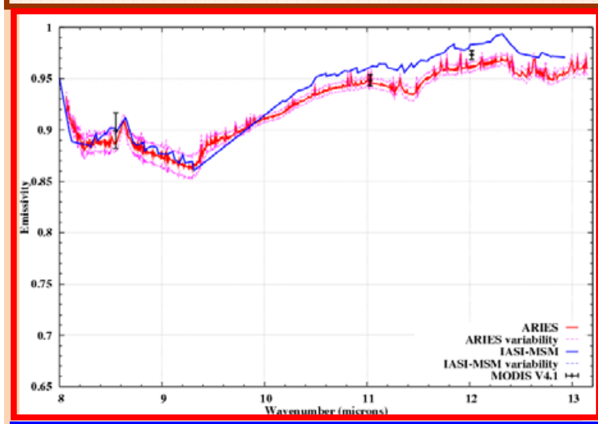
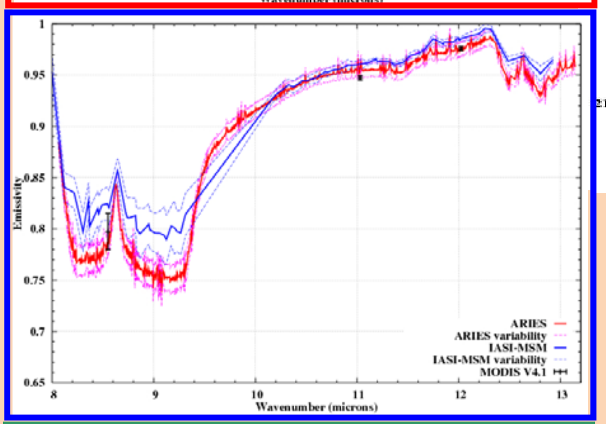
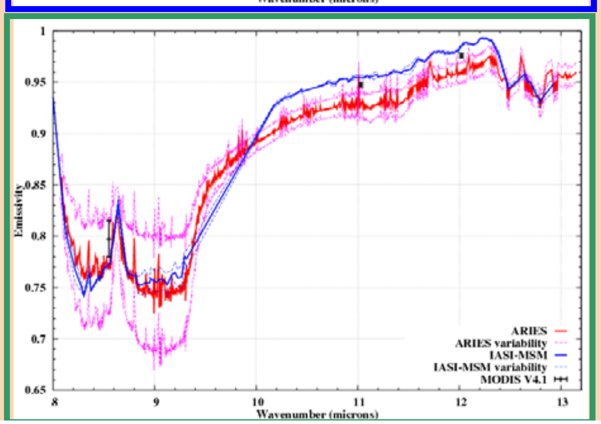
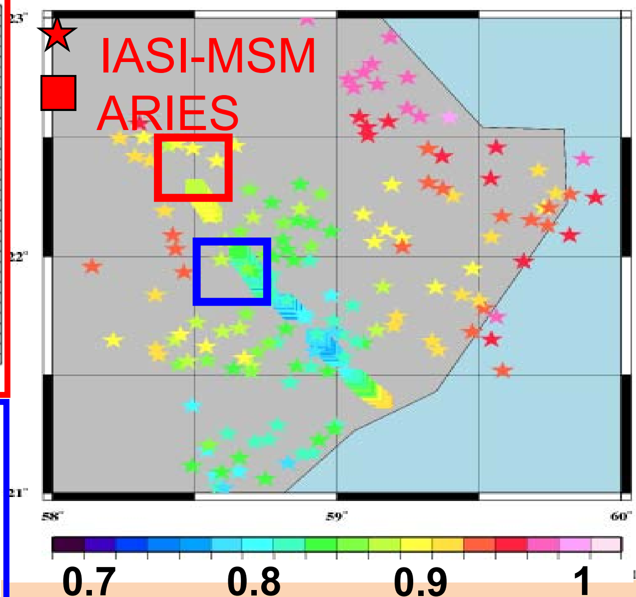
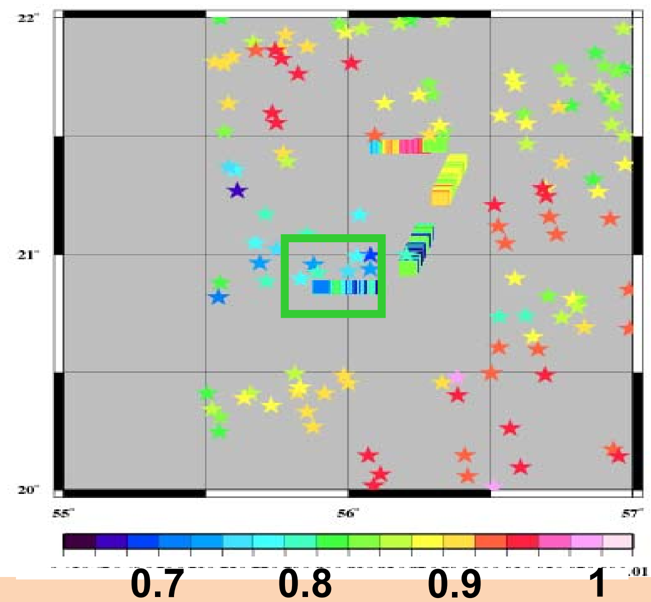










⇒ In general, good agreement IASI-MSM(local) with ARIES

⇒ Large spatial variations of emissivity at very local scales consistent between ARIES and IASI-MSM.

- Ex: 10% variation for an area < 0.5°

⇒ At 12µm, differences < 0.02, but IASI-MSM always greater than ARIES. MODIS in-between.

⇒ At 8 µm, in general, differences < 0.04. Largest differences might be due to our 0.25° box averaging given the large variations of emissivity at this wavelength.

Conclusions

• **Final product**: High spectral resolution continental surface emissivity spectra (0.05 µm from 3.7 to 14 µm), and surface temperature from July 2007 up to now.

• **Results at global scale :**

- Comparisons of T_s with MODIS and ECMWF fcst and of emissivity with MODIS have been performed with good results.
- The resulting emissivity spectra well reproduce small variations, such as the local maximum at 8.65 µm observed in the laboratory spectra from the 165-MOD-AST emissivity libraries for sand soil.

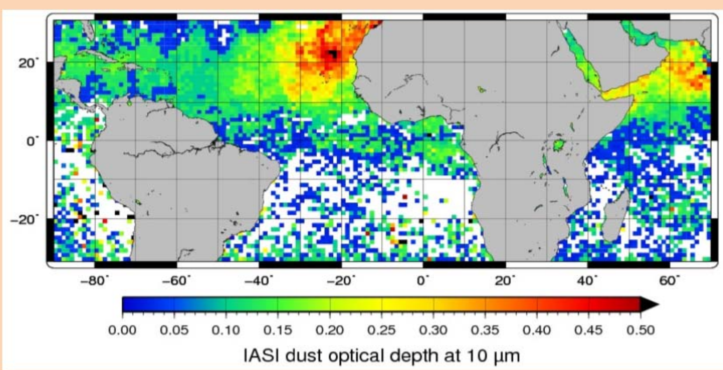
• **Results at local scale (=iasi spot):**

- Good agreement with “in-situ” measurements from ARIES
- IASI-MSM emissivity reproduces the large variations seen by ARIES over quite small areas.

Perspectives

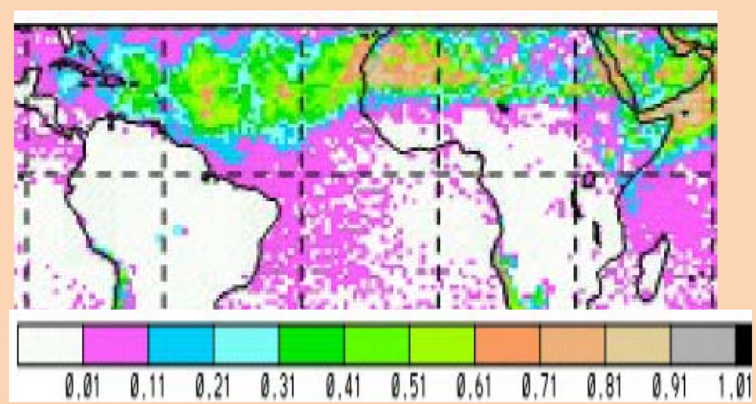
- **Improvement of the studies at local scale:**
  - ➢ Why IASI-MSM emissivity is in general greater (<0.02) than the ARIES one?
- **Monitoring of continental surfaces (vegetation cover, drought..):**
  - ➢ Using the strong correlation between soil properties (vegetation, moisture) and emissivity to follow the evolution of the surface properties
- **Retrieving aerosol properties above continents and particularly above deserts**
  - ➢ still difficult to achieve at solar wavelengths
  - ➢ requires knowledge of the surface properties such as T_s and ε

Aerosols retrieval over sea retrieved from IASI



Peyridieu et al., in prep.

Aerosols mask (July 2008)



Pernin et al., priv. comm"