INFRARED CONTINENTAL SURFACE EMISSIVITY SPECTRA AND SKIN TEMPERATURE RETRIEVED FROM IASI OBSERVATIONS

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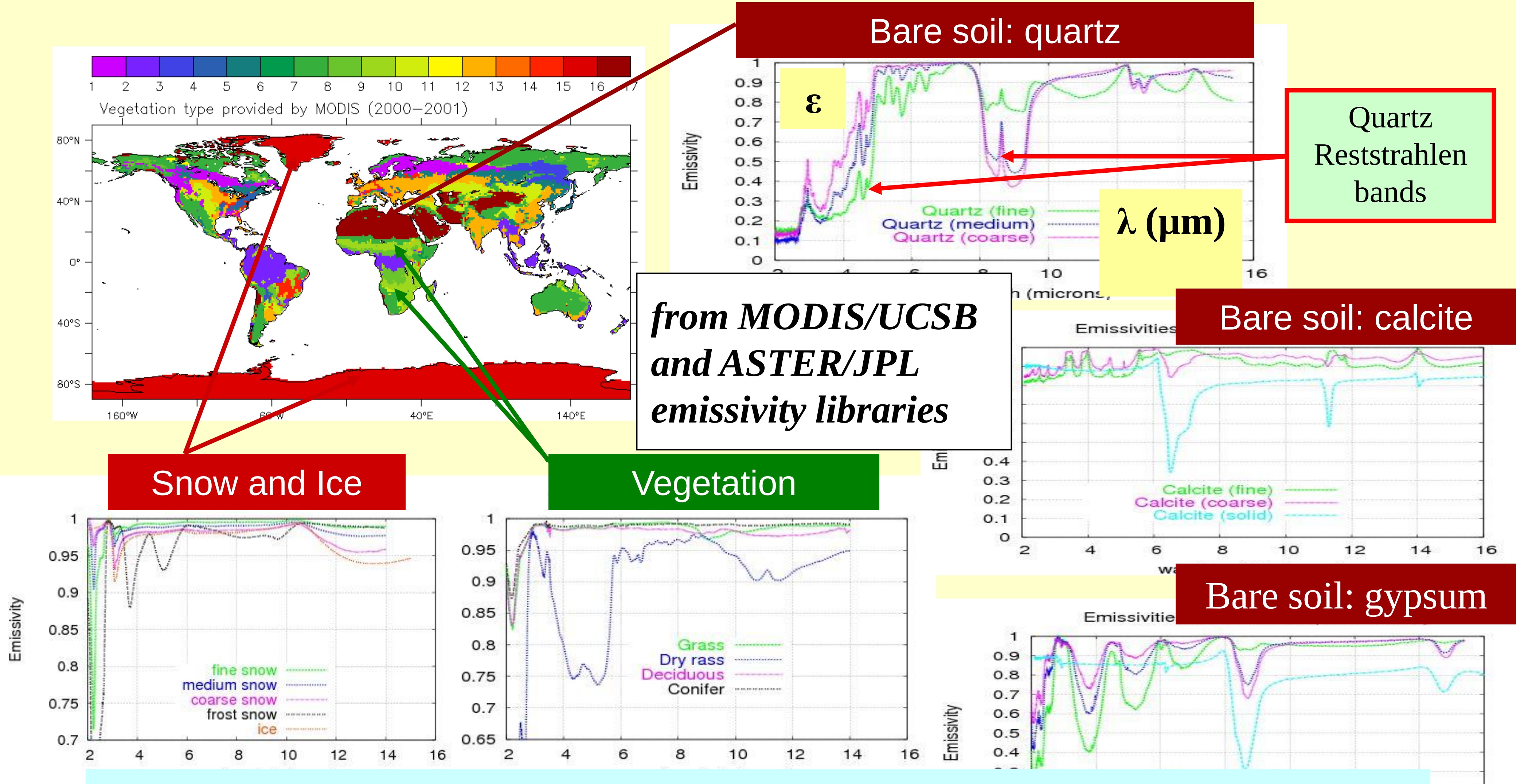
Spectral variation of emissivity in TIR



Spectral variation impact on TIR emissivity: up to 50%, particularly over bare soils in quartz Reststrahlen bands

Infrared RTE
(lambertian surface, clear sky, night)

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

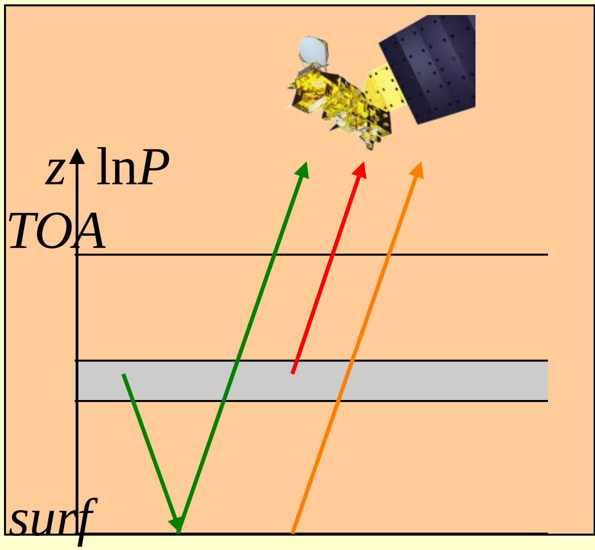
Surface Emission

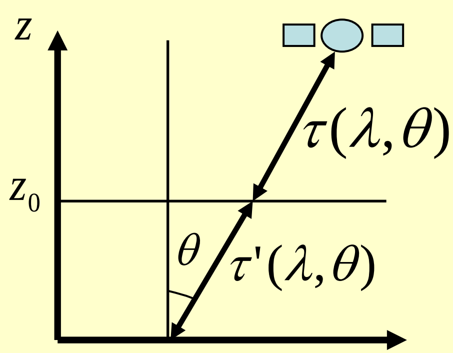
$$+\boxed{\int_{\tau_s(\lambda,\theta)}^{1} B[\lambda,T]\,d\tau(\lambda,\theta)}$$

Upwelling Atmosphere Emission

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

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. (2008), Infrared continental surface emissivity spectra retrieved from hyperspectral sensors. Application to AIRS. JAMC.

For **window channels $\varepsilon_s(\lambda)$ can be computed by :**

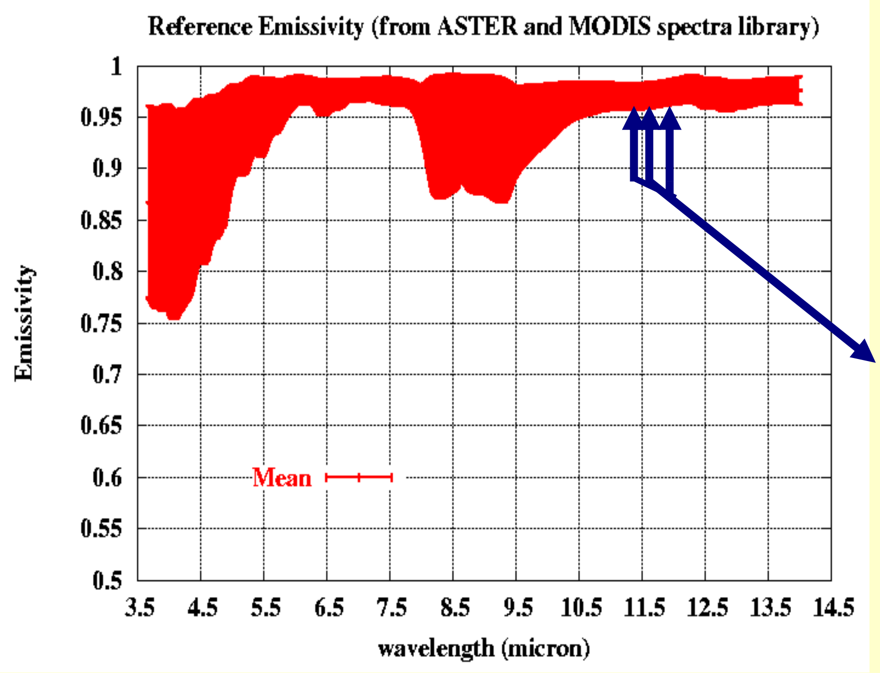
$$\varepsilon_s(\lambda) = \frac{\mathrm{I}(\lambda,\theta) - \int_{\tau_s(\lambda,\theta)}^{1} B[\lambda,T]\,\partial\tau(\lambda,\theta) - \tau_s(\lambda,\theta)\int_{\tau_s(\lambda,\theta)}^{1} B[\lambda,T]\,\partial\tau'(\lambda,\theta)}{\tau_s(\lambda,\theta)\left\{B(\lambda,T_s) - \int_{\tau_s(\lambda,\theta)}^{1} B[\lambda,T]\,\partial\tau'(\lambda,\theta)\right\}} \quad \text{with} \quad \tau_s(\lambda,\theta) \neq 0$$

<u>In order to calculate ε_s one needs:</u>

1) identifying clear sky radiances
2) knowing the thermodynamic state of the atmosphere (T, H2O, O3 profile)
   - Proximity recognition of radiance in the TIGR(*) climatological dataset
3) estimating the surface skin temperature
   - For channels presenting the double property of being atmospheric window and having an almost constant emissivity whatever the surface is, Ts remains the only unknown of the radiative transfer equation

(*) Chédin et al., 85; Chevallier et al., 98, Scott et al. 99)

Surface skin temperature :
semi-transparent spectral band [11 - 12 µm]



Emissivity variability (µ±σ) of the 8461 IASI channels calculated from soil and vegetation emissivity spectra of MODIS/UCSB and ASTER/JPL libraries

3 channels selected for their good transmittance (tau~ 0.6) and a small variability of the emissivity (σ ~0.01):

- **λ_1=11.429 µm**
- **λ_2=11.601 µm**
- **λ_3=12.001µm**

ε~ 0.97 is no more an unknown for these channels

$$T_s = B^{-1}\left(\frac{I_{sat}(\lambda_0,\theta) - \int_{\tau_s(\lambda_0,\theta)}^{1} B[\lambda_0, T(\tau(\lambda_0,\theta))]\,d\tau - (1-\varepsilon_s(\lambda_0))\,\tau_s(\lambda_0,\theta) \int_{\tau_s(\lambda_0,\theta)}^{1} B[\lambda_0, T(\tau'(\lambda_0,\theta))]\,d\tau'}{\varepsilon_s(\lambda_0)\,\tau_s(\lambda_0,\theta)} \right)$$

right hand side calculated with retrieved atmospheric profiles using a Fast Radiative Transfer Model based on 4A “line-by-line” code (4A : *[Scott and Chédin, 1981]*)

Infrared Emissivity Spectrum from 3.7 to 14 µm

$$\varepsilon_s(\lambda) = \frac{\mathrm{I}(\lambda,\theta) - \int_{\tau_s(\lambda,\theta)}^{1} B[\lambda,T]\,\partial\tau(\lambda,\theta) - \tau_s(\lambda,\theta)\int_{\tau_s(\lambda,\theta)}^{1} B[\lambda,T]\,\partial\tau'(\lambda,\theta)}{\tau_s(\lambda,\theta)\left\{B(\lambda,T_s) - \int_{\tau_s(\lambda,\theta)}^{1} B[\lambda,T]\,\partial\tau'(\lambda,\theta)\right\}}$$

→ ε calculated for **101 IASI** channels selected for their high sensitivity to surface parameters and low sensitivity to other contributions. These channels are distributed along the spectrum and are particularly located where the emissivity variability is highly dependant on the type of soil or vegetation in order to allow an accurate reconstruction of the entire spectrum.

→→→ Discontinuous spectrum with an expected accuracy on the retrieved emissivity of ~3% at 4 µm and less than 1% at 12 µm.

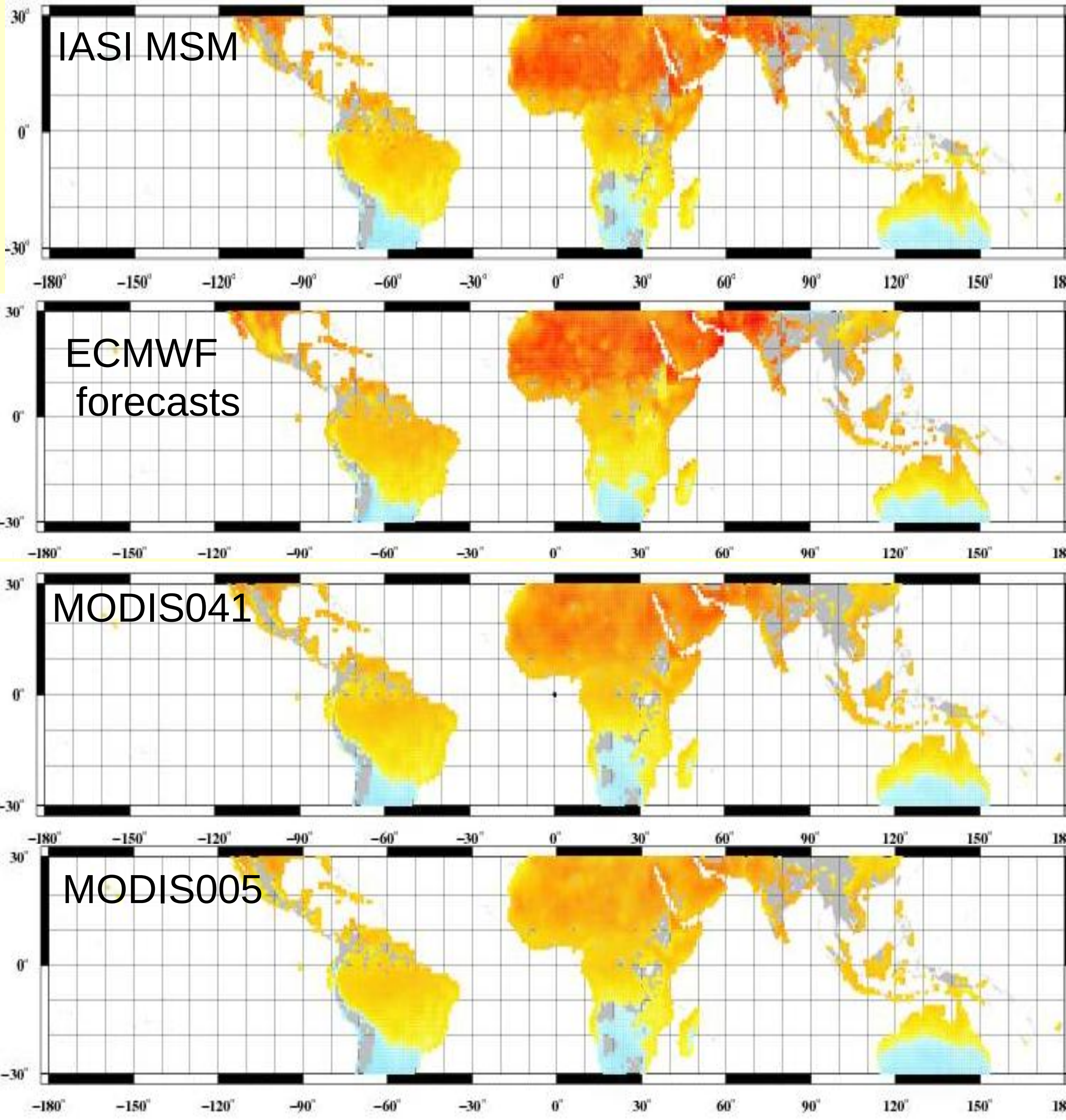
Least square minimization + shape adjustment

MSM Emissivity database :

- 165 spectra for various soil and vegetation types extracted from MODIS/UCSB and ASTER/JPL emissivity libraries.
- sampling : [3.70 - 14.0] µm at 0.05 µm resolution.

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

Estimation of T_S : comparison with MODIS and ECMWF

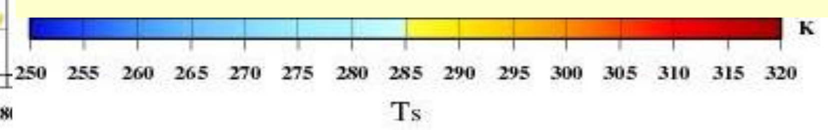


<u>For nighttime, June 2008</u>

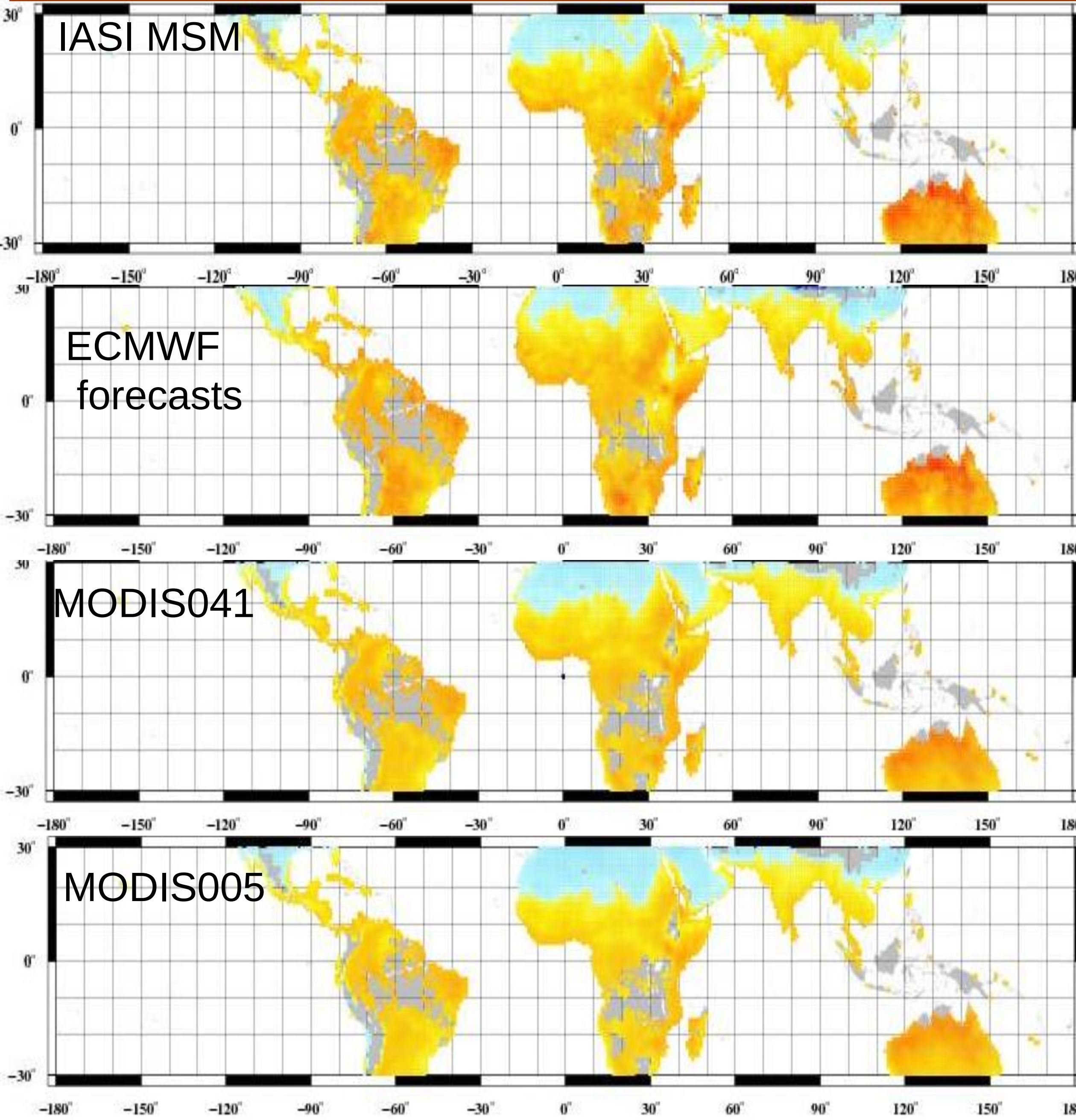
- **2 versions of MODIS data: v005 and v041**
- **T_s globally in agreement for the different products**
- **The largest discrepancies are located mainly on Sahara:**

-ΔTs ~ 2.5K (iasi – modis041)
-ΔTs ~ 5.5K (iasi – modis005)
-ΔTs ~ 0K (iasi – ECMWFfcs)

- **v041 more consistent with IASI results which lies between ERA-40 and MODIS**

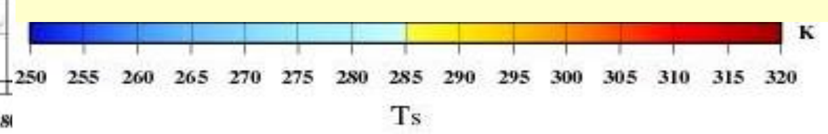


Estimation of T_S : comparison with MODIS and ECMWF

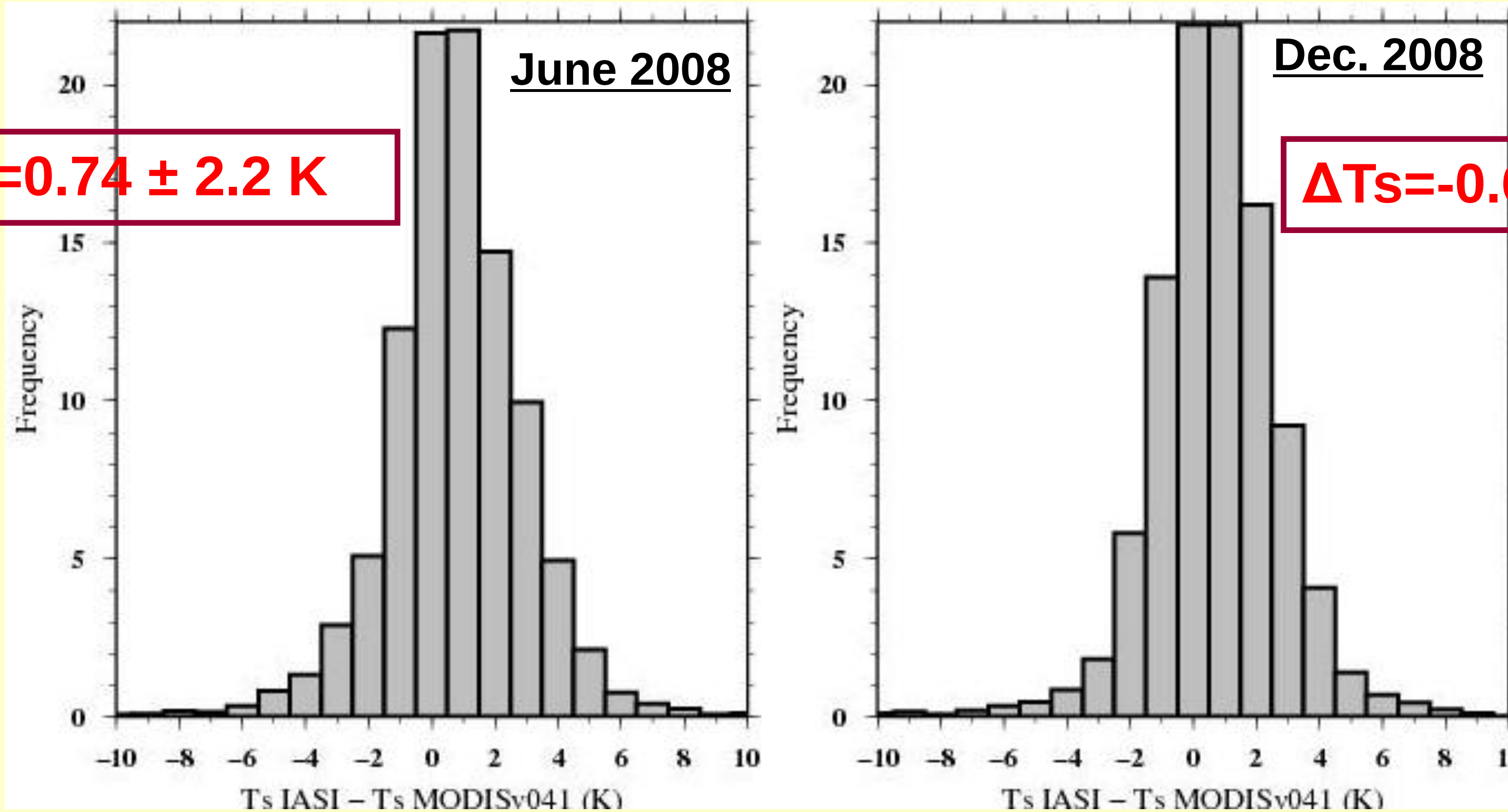


For nighttime, Dec. 2008

- In general, the two versions of MODIS colder than IASI MSM or ECMWF-fcs.
  - See Australia or South America
- On Sahara, ECMWF-fcs is the warmest, MODIS005 the coldest. IASI-MSM and MODIS041 similar.



Estimation of TS: comparison with MODIS

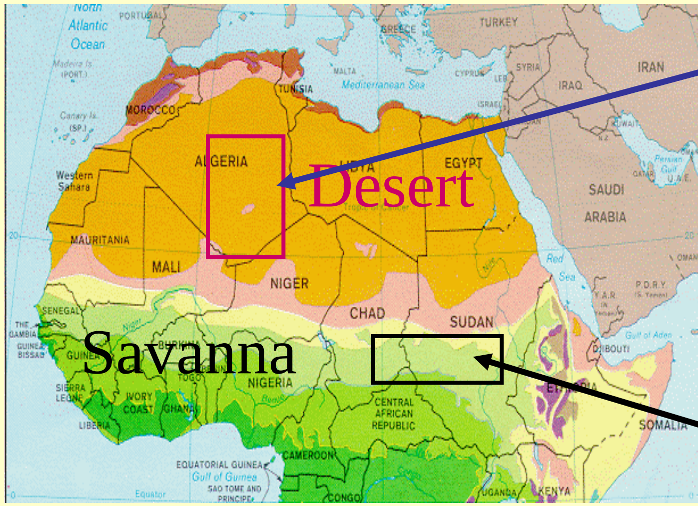


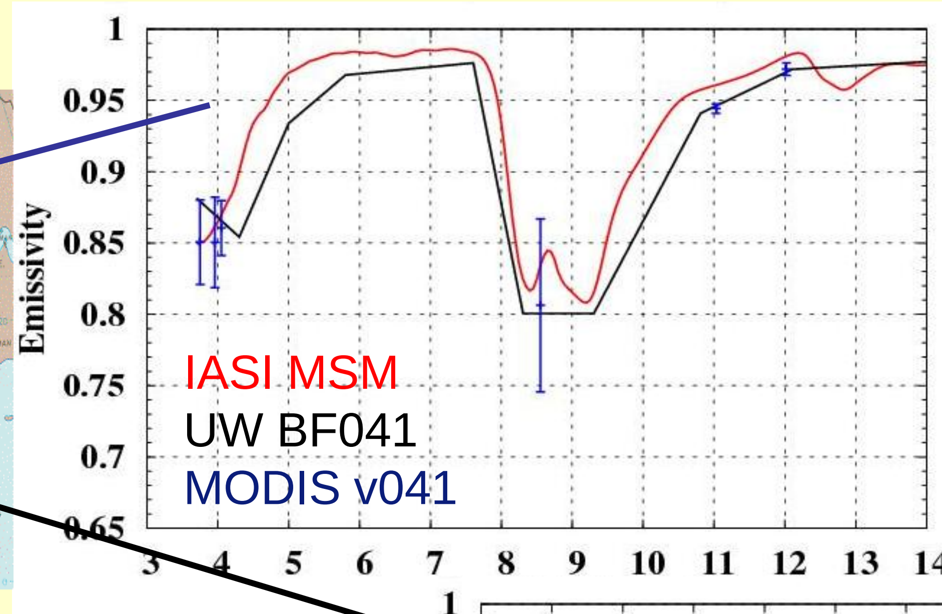
ΔTs=0.74 ± 2.2 K

ΔTs=-0.69 ± 2.1 K

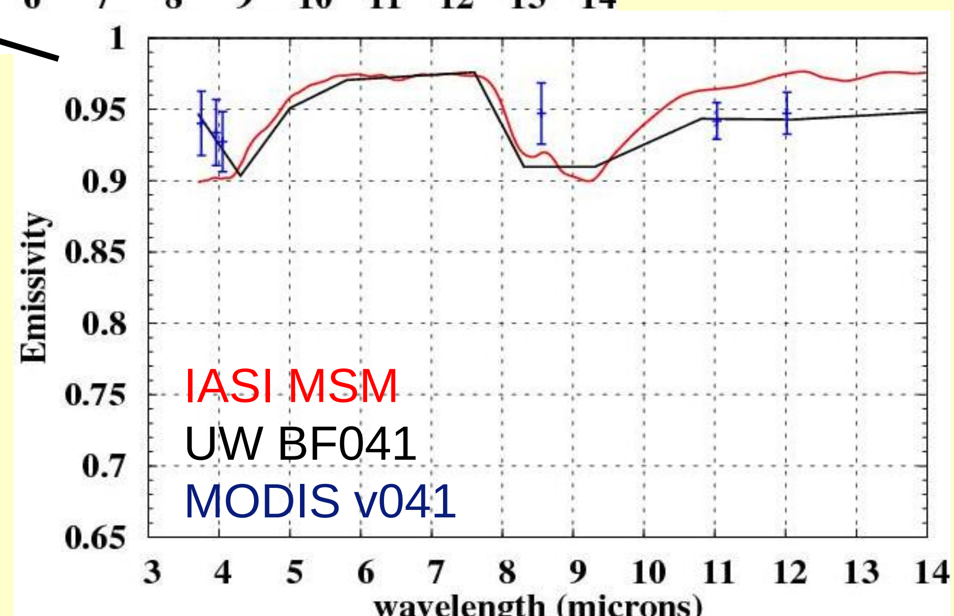
- Values consistent with reported errors on Ts found in the literature.
- Bias : keep in mind the 1 hour time shift between IASI and TERRA (21h30 .vs. 22h30).

Emissivity spectra :Comparison with MODIS datapoints and “continuous” spectra (1/2)



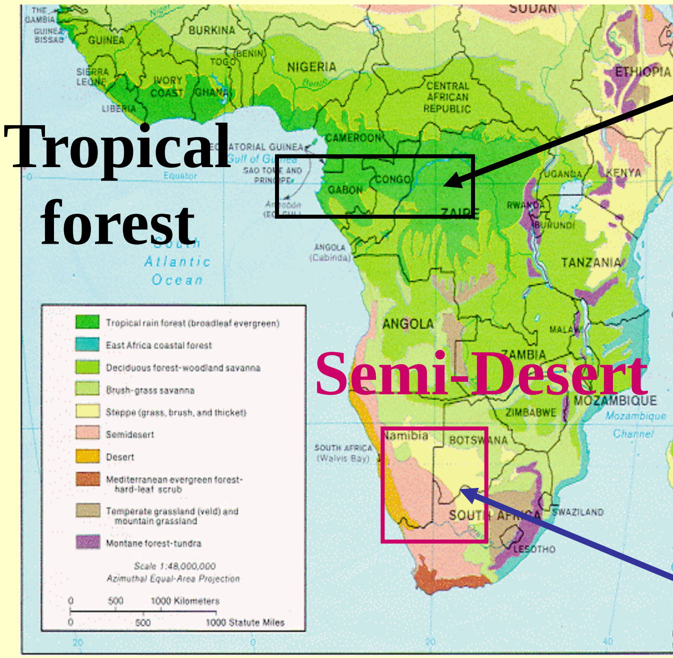


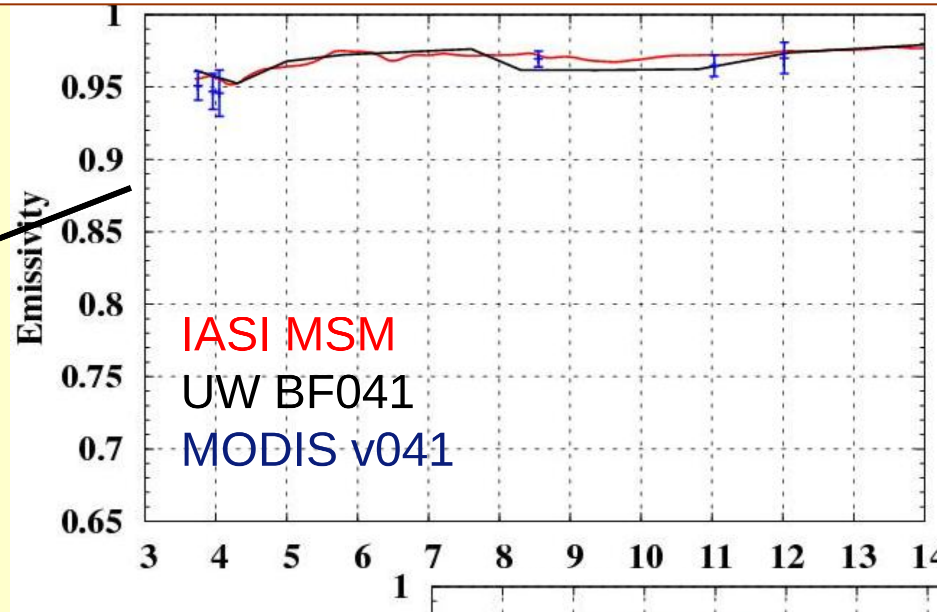
June 2008



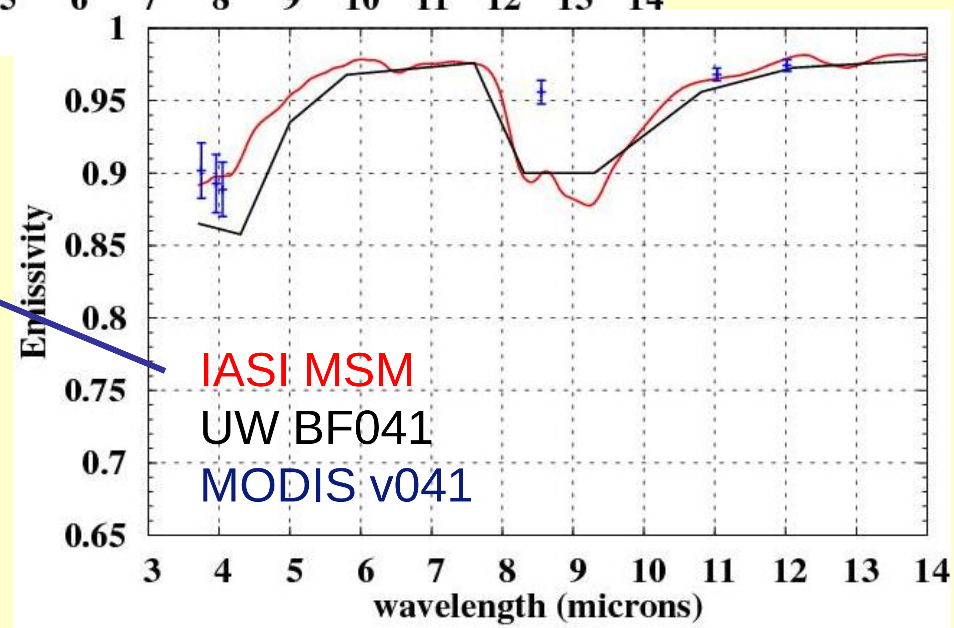
- **Emissivity strongly depends on the type of surface and its value increases with the vegetation.**
- **The Quartz Reststrahlen bands are well observed and dominate the spectra**
- **Good agreement between IASI MSM and MODIS emissivity**

Emissivity spectra :Comparison with MODIS datapoints and “continuous” spectra (2/2)



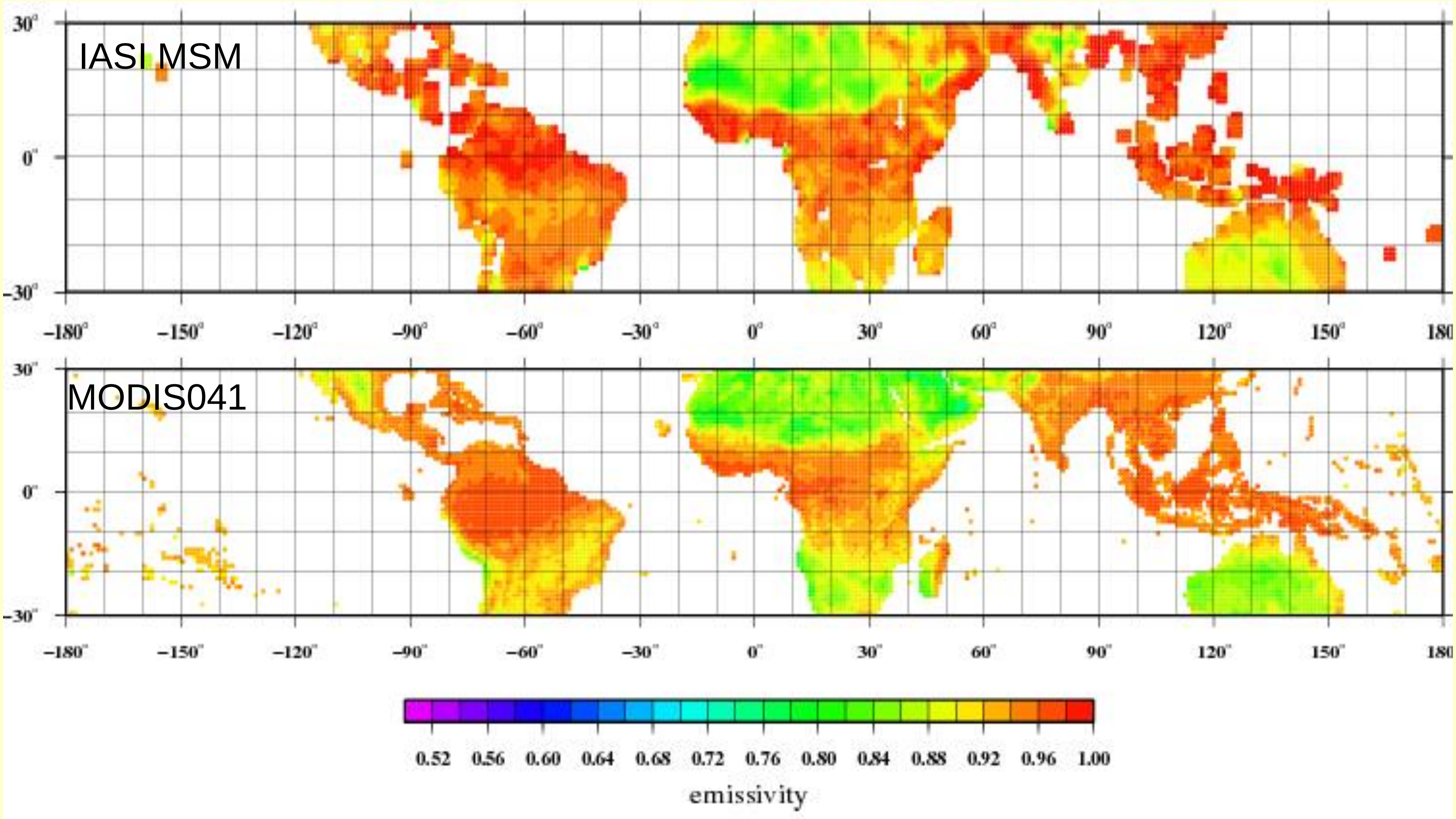


June 2008

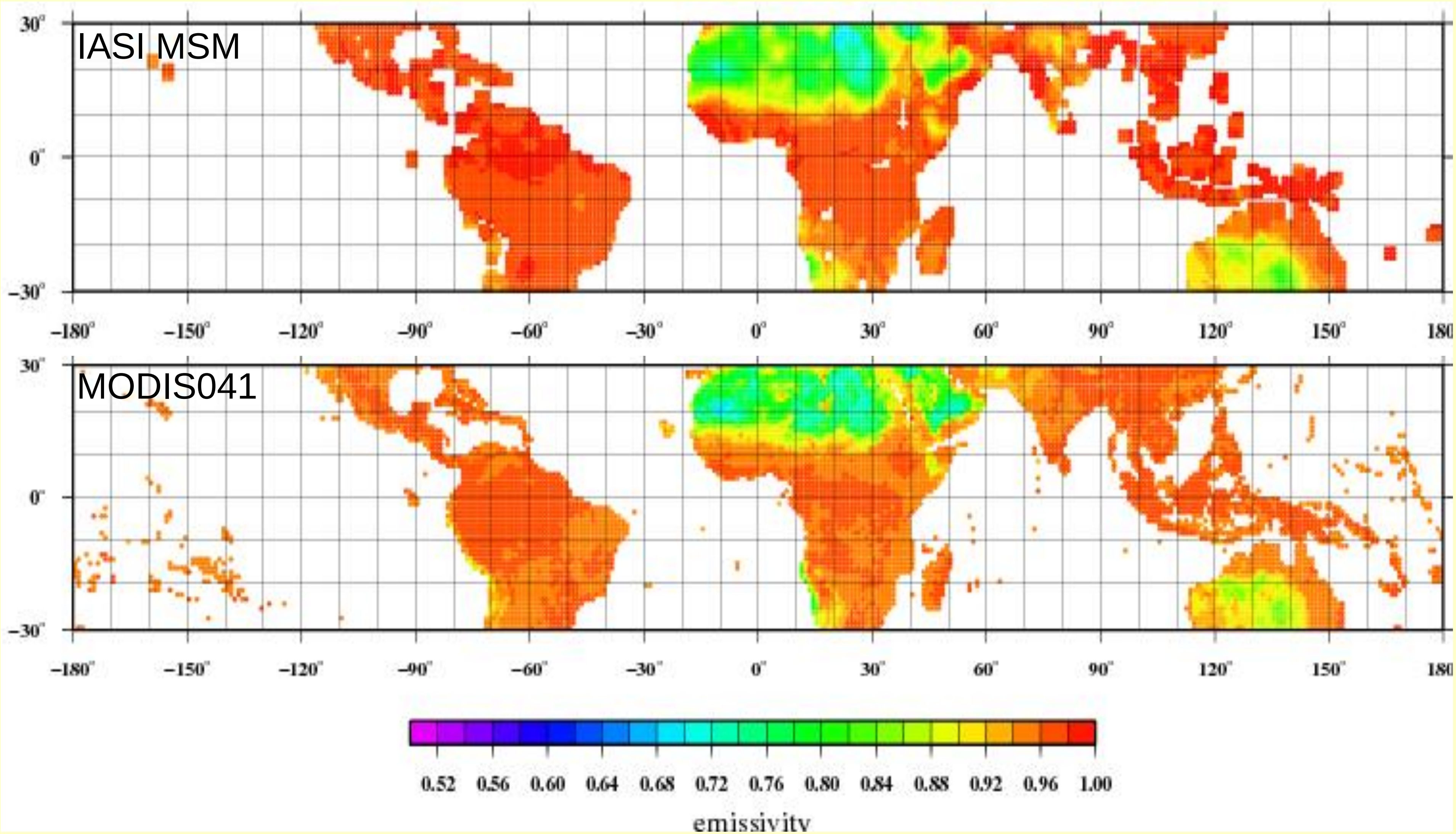


- **For tropical region the emissivity spectra is flat with a value close to 1.**
- **In semi-desert region, the quartz reststrahlen bands is also important**

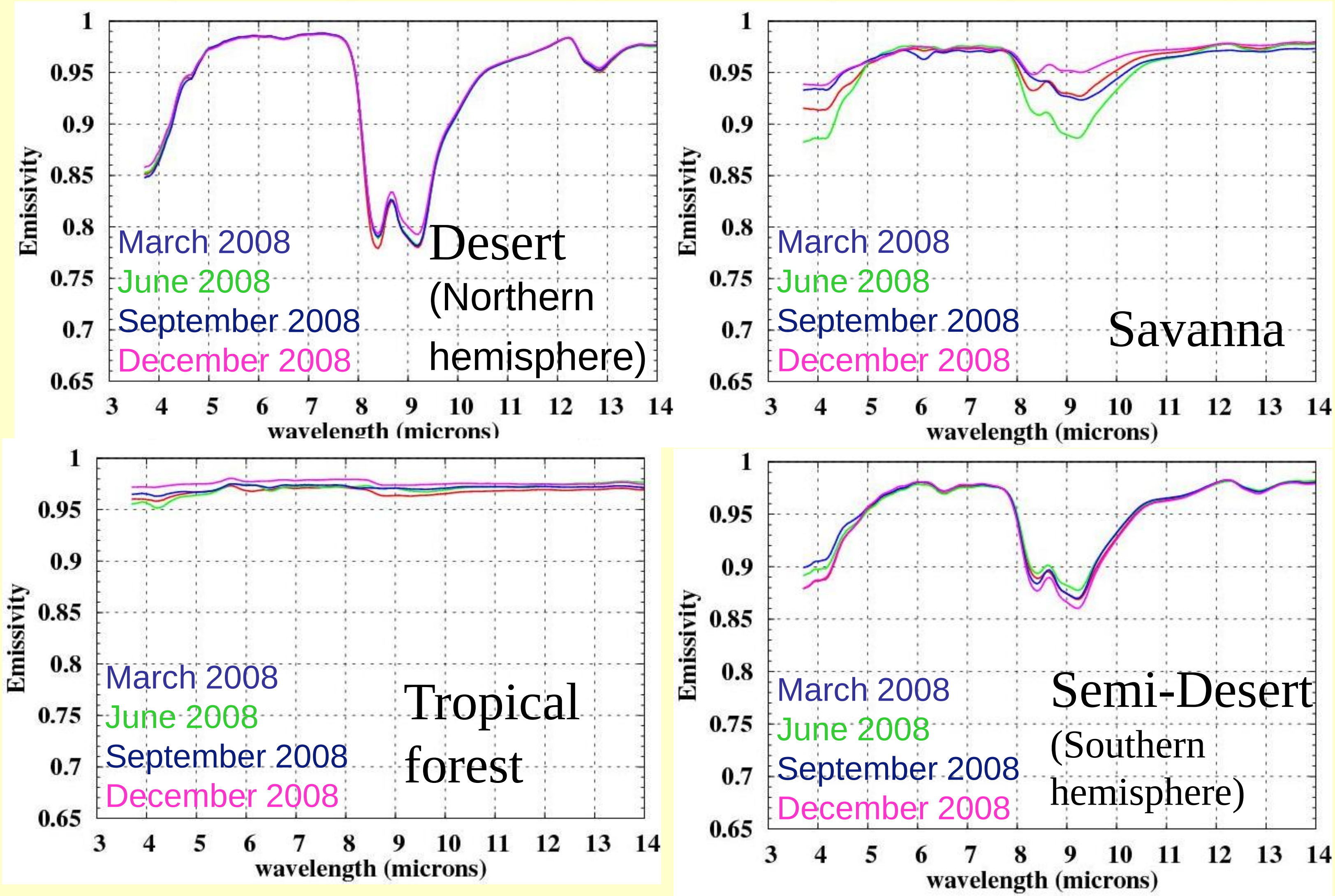
Map of emissivity at 4.05 microns for IASI and MODIS041 for June 2008



Map of emissivity at 8.55 microns for IASI and MODIS041 for June 2008



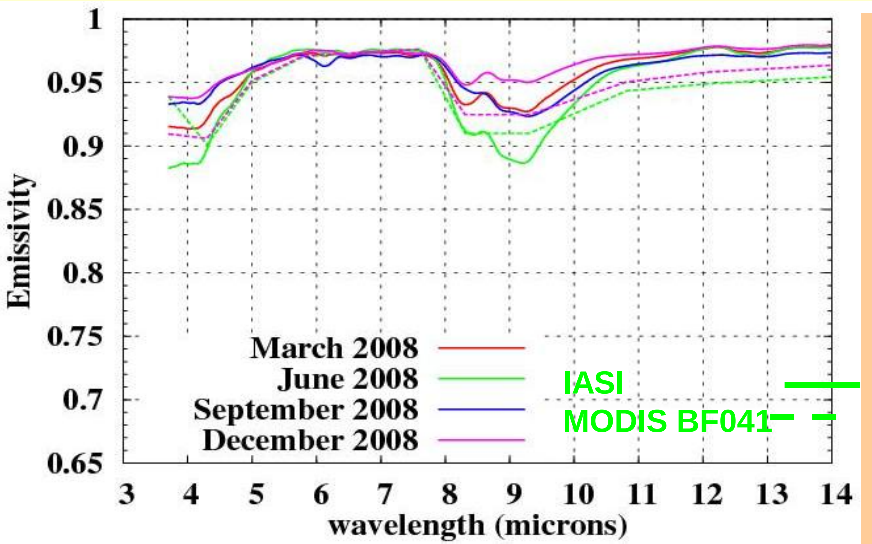
Seasonal variations of the emissivity



➢ **Seasonal variations are almost negligible in most regions except Savannas where the vegetation is more influenced by seasonal precipitations.**

Seasonal variations of the emissivity :

Case of Savannas

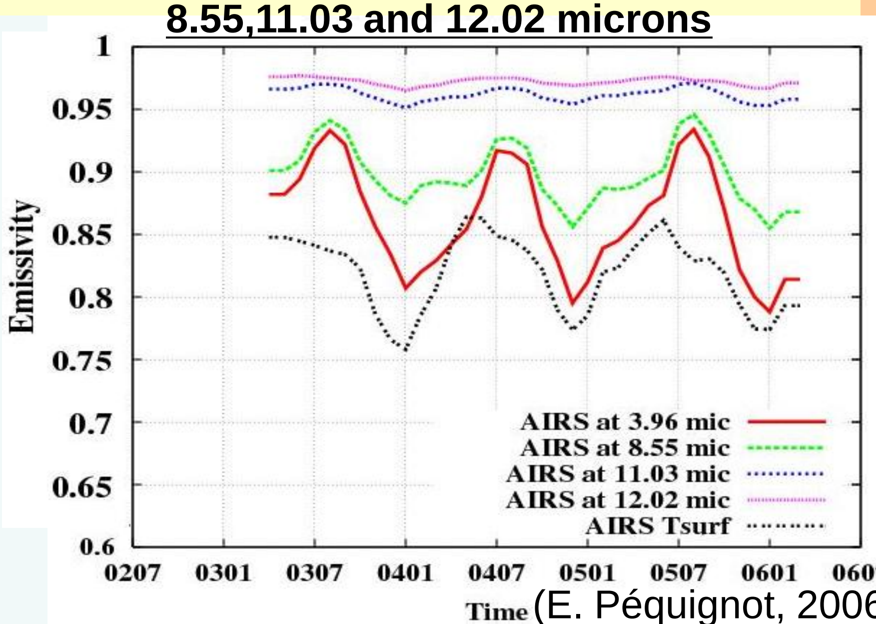


The seasonal variations are quite surprising:

- Emissivity in the reststrahlen band is higher in December (supposed to be the dry season) than in June (wet season).
- Disagree with previous results on AIRS (for the period 2003-2006).
- In agreement with MODIS BF results (even if the MODIS amplitude is smaller than the IASI one.

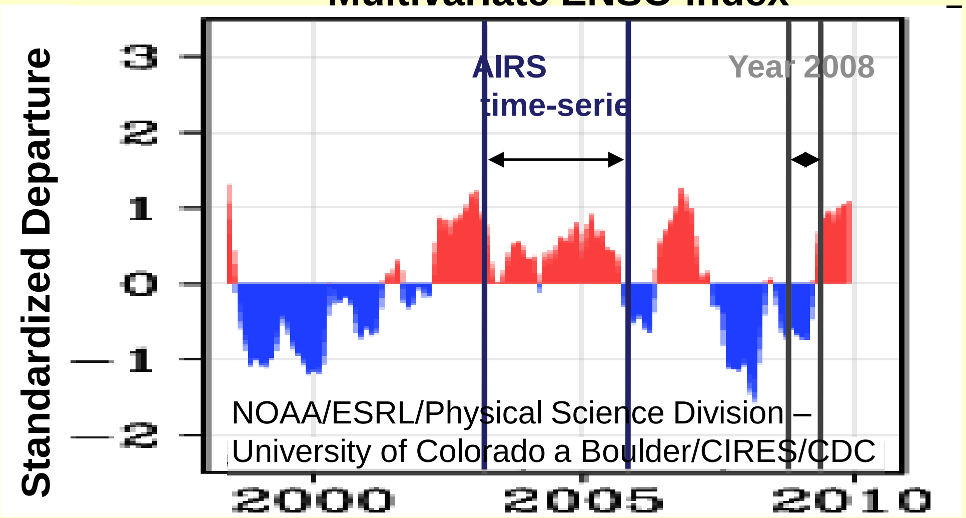
➢**But the 2 periods differ : El Nino/La Nina episodes → work in progress**

<u>**AIRS time-series for emissivity at 3.96, 8.55,11.03 and 12.02 microns**</u>



(E. Péquignot, 2006, thesis)

Multivariate ENSO index



Conclusions

1) Relatively good agreement between IASI MSM and MODIS continental emissivity and surface temperature for the regions considered (IASI-MSM Ts in between MODIS and ECMWF fcst). Some discrepancies can be partly explained by the diurnal cycle.

2) We will soon start to build a climatology of monthly continental surface emissivity as well as temperature retrieved from IASI. This climatology will be freely available through our website (as is currently available the climatology of emissivity retrieved from AIRS).

3) Preliminary results on seasonal variations ask the question of the validity of a climatology by month, averaged over years since it appears that the emissivity could be sensitive to non-cyclic phenomena such as El Nino/La Nina.

4) Such high resolution emissivity spectra and surface skin temperature should help improving models of the earth surface-atmosphere interaction and the retrieval of meteorological profiles from infrared vertical sounders.