Infrared continental surface emissivity spectra retrieved from IASI observations

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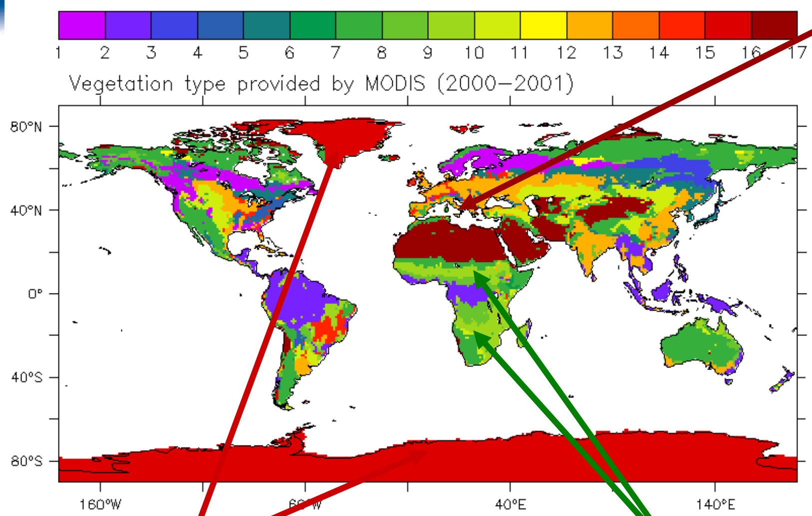
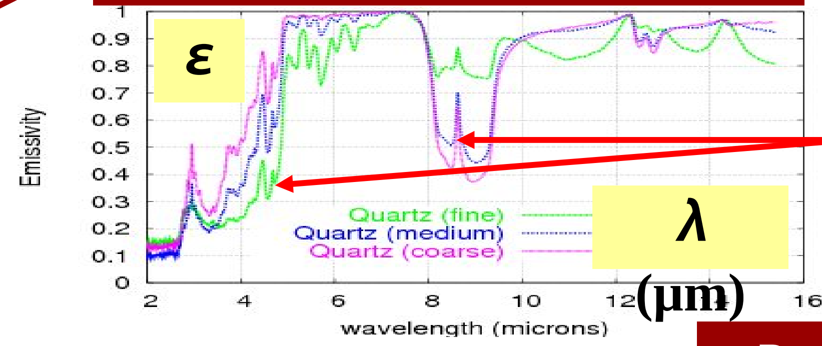
Spectral variation of emissivity in TIR



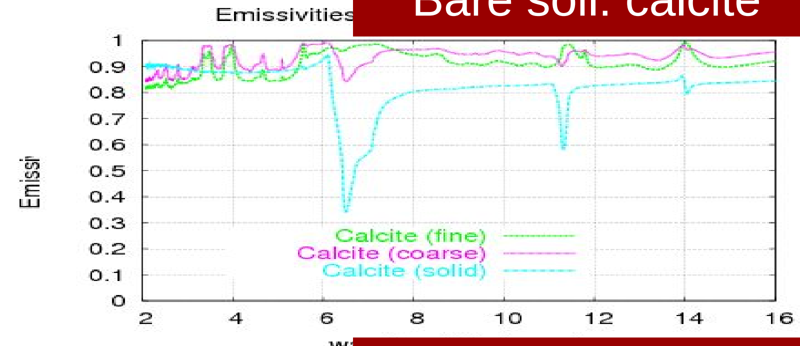
Bare soil: quartz



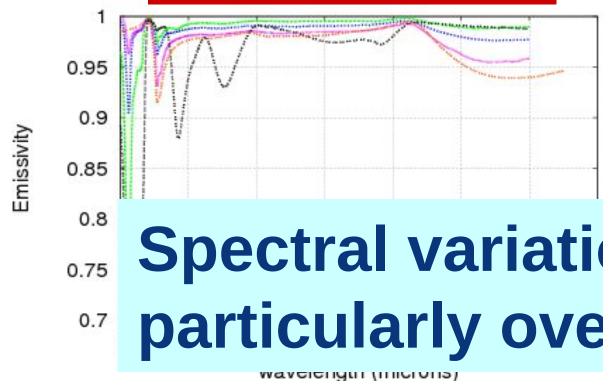
Quartz Reststrahlen bands

from MODIS/UCSB and ASTER/JPL emissivity libraries

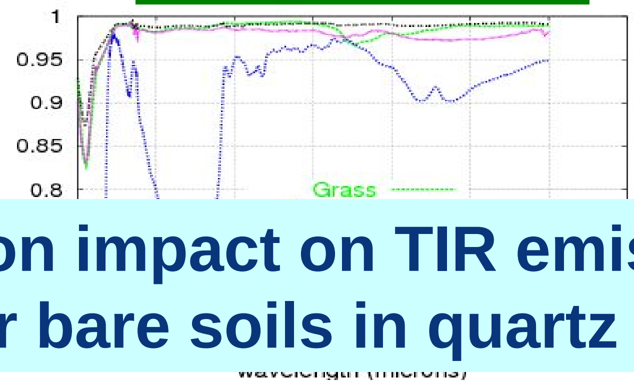
Bare soil: calcite



Snow and Ice



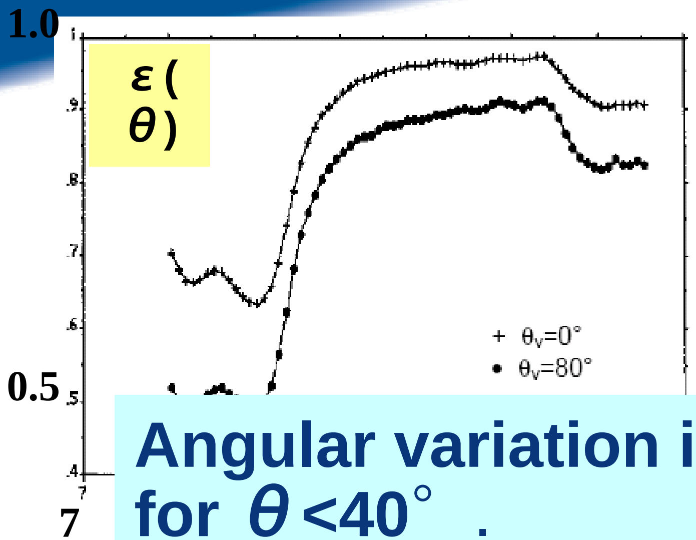
Vegetation

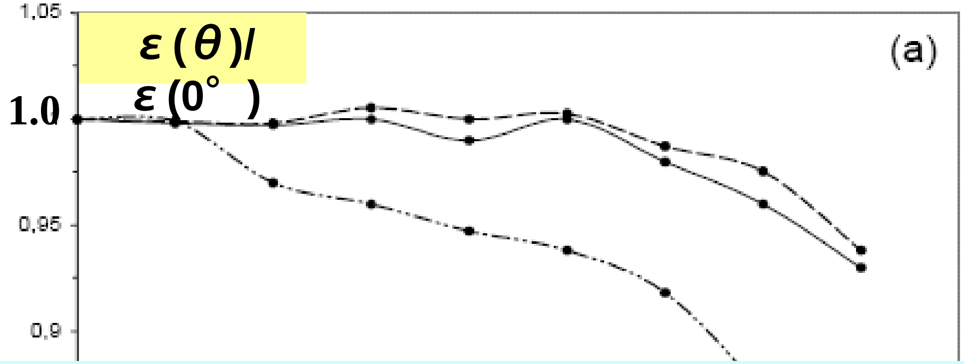


Bare soil: gypsum

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

Angular variation of emissivity in TIR





Angular variation impact on TIR emissivity: effect< 5% for θ<40°.

For IR sounders at 10km spatial resolution, this effect is even smaller (spatial averaging)

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Conclusion : For IR sounders, emissivity angular variation is a 2nd order effect in comparison to spectral variation for viewing angles lower than 40°.

=> Lambertian assumption

Infrared RTE (lambertian surface, clear sky, night)

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

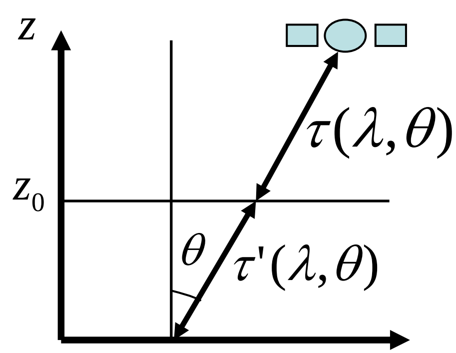
Surface Emission

$$+\int_{\tau_s(\lambda,\theta)}^{0} B[\lambda,T]\,\partial\tau(\lambda,\theta)$$

Upwelling Atmosphere Emission

$$+(1-\varepsilon_s(\lambda))\tau_s(\lambda,\theta)\int_{\tau_s(\lambda,\theta)}^{0} B[\lambda,T]\,\partial\tau'(\lambda,\theta)$$

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.

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

The formula holds only for **window channels** $\tau_s(\lambda,\theta) \neq 0$

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

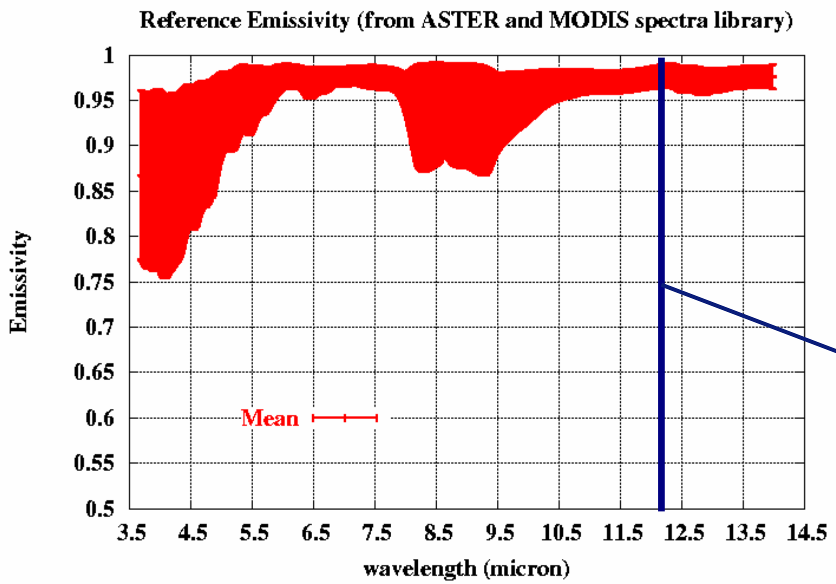
1) identifying clear sky radiances -> EUMETSAT IASI L2 cloud mask (based on AVHRR)

2) knowing the thermodynamic state of the atmosphere (T, H_2O, O_3 profiles) -> EUMETSAT IASI L2 products

3) estimating the surface skin temperature

Surface skin temperature :

semi-transparent spectral band [12.12 - 12.22 µm]



Emissivity variability ($\mu \pm \sigma$) of the 8461 IASI channels calculated from soil and vegetation emissivity spectra of MODIS/UCSB and ASTER/JPL libraries

Spectral band [12.12 - 12.22 µm], λ_0=12.17 µm

$\tau_S > 0.5$ and $\varepsilon \sim 0.97$

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

right hand side calculated from EUMETSAT L2 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

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

ε calculated for about 90 IASI channels selected for there high sensitivity to surface parameters

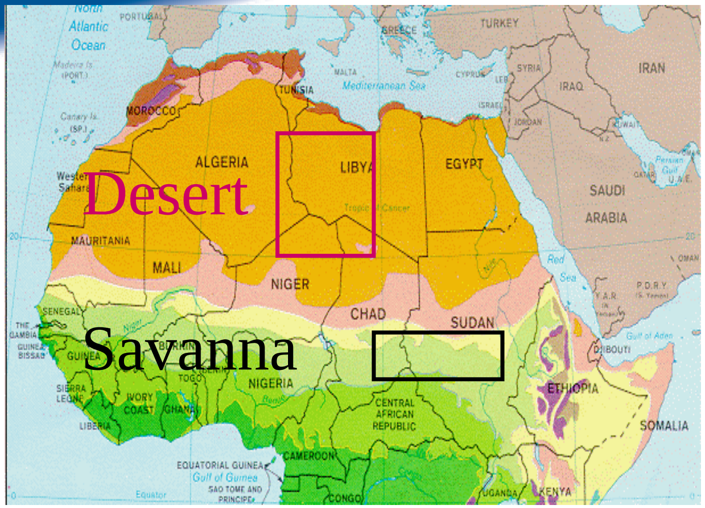
Least square minimization + shape adjustment

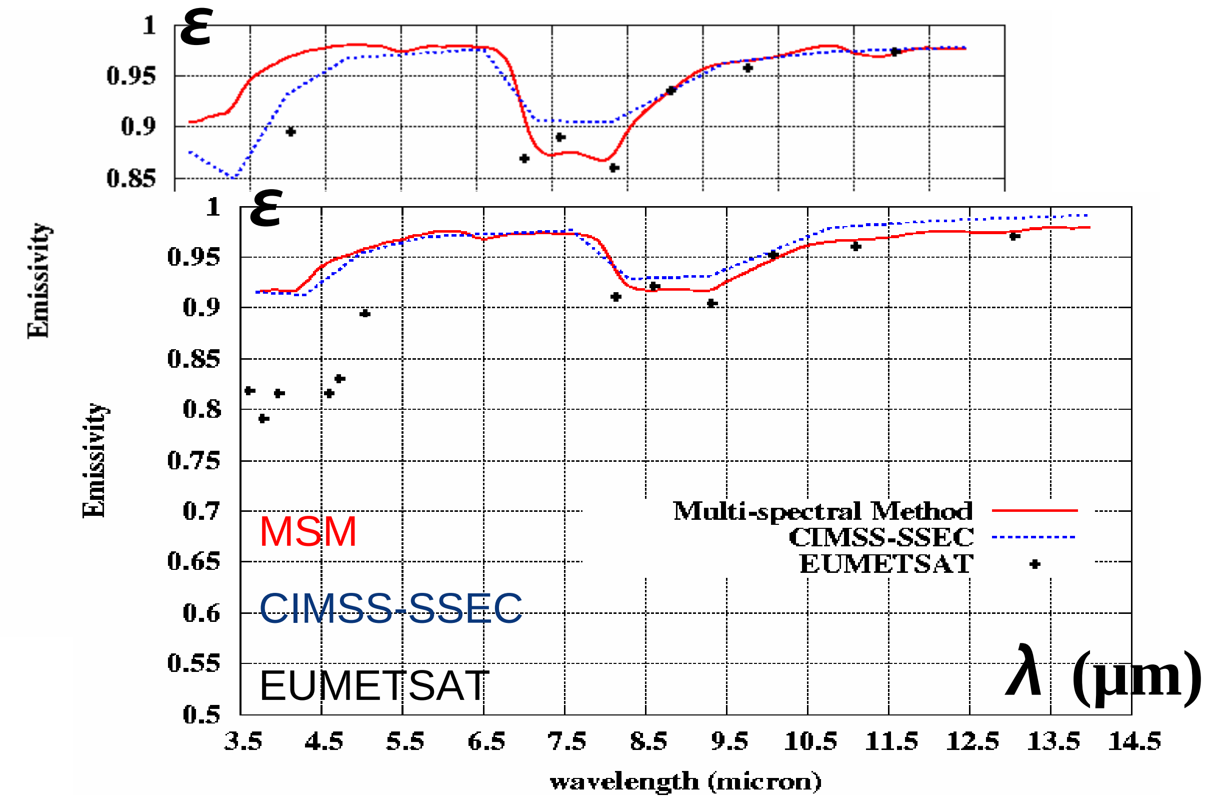
MSM Emissivity database :

- 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

Results for Jan 2008 (1st, 9th, 25th) : spectral variation (1)

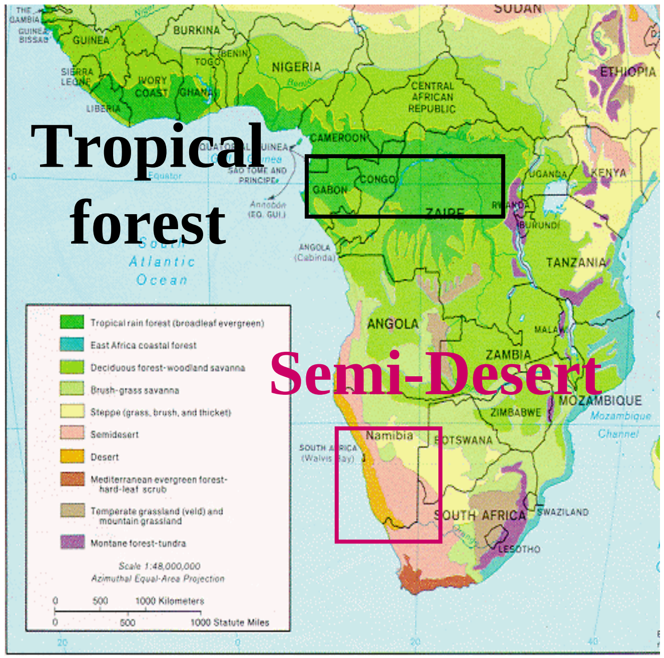


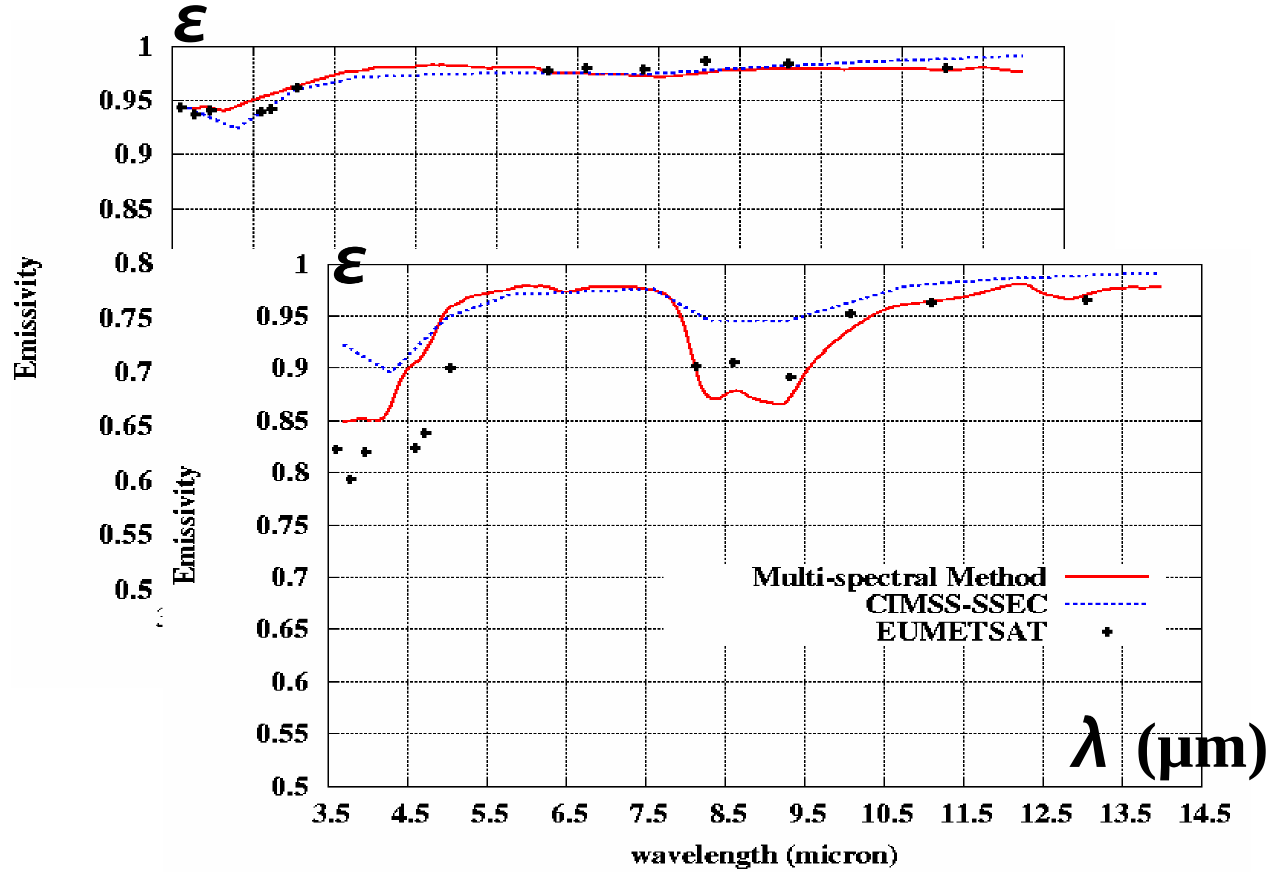


- Quartz reststrahlen bands are well observed and dominate the ε spectra

- In quartz reststrahlen bands ε increases with the % of vegetation (Example of Savannas)

Results for Jan 2008 (1st, 9th, 25th) : spectral variation (2)



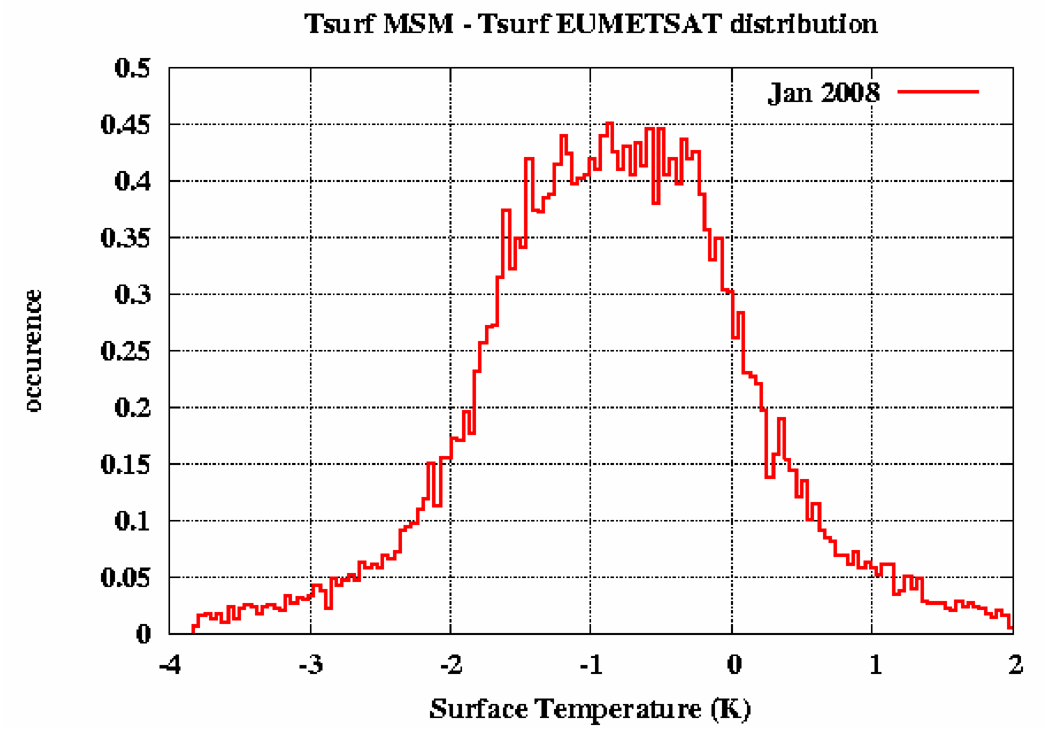


- Tropical forest emissivity close to 1 (as expected)

- For semi-desert areas emissivity still influenced by quartz reststrahlen bands

Results for Jan 2008 (1st, 9th, 25th) : surface temperature over land

Difference between T_{surf} calculated by MSM and T_{surf} provided by L2 - Eumetsat



μ = - 0.9 K

σ = 1 K

Values coherent with presently reported accuracies

Expected accuracy on emissivity calculated by the MSM

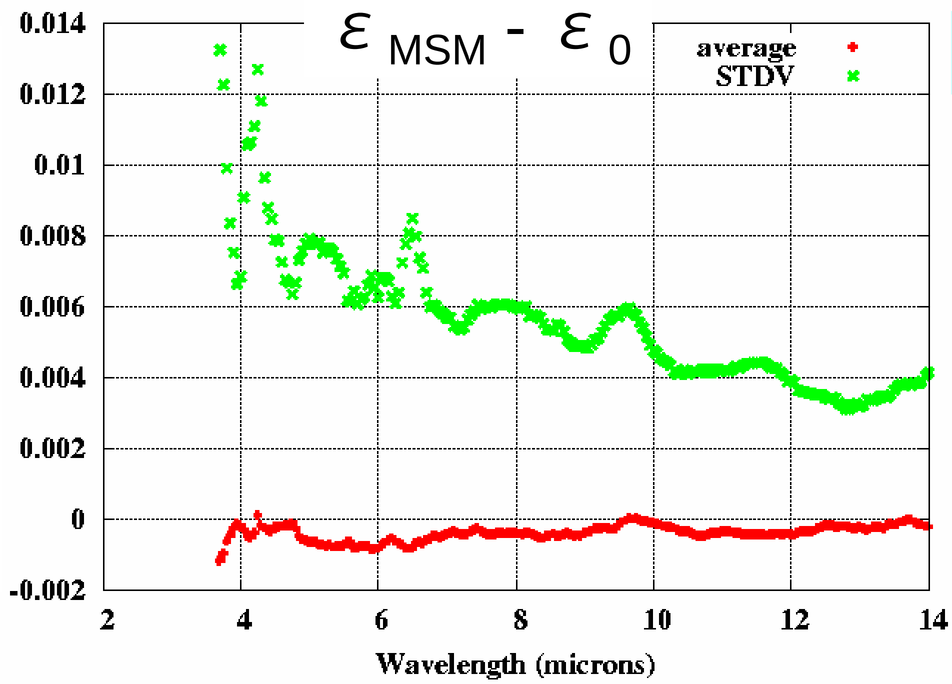
Statistics done on 10000 simulated cases :

For each simulation we have randomly chosen :

1/ an emissivity spectrum (MSM emissivity database)

2/ an atmospheric situation (TIGR dataset)

3/ a surface temperature defined as $T_{lowest\_level\_TIGR}$ + Gaussian(μ=0K, σ=4K)



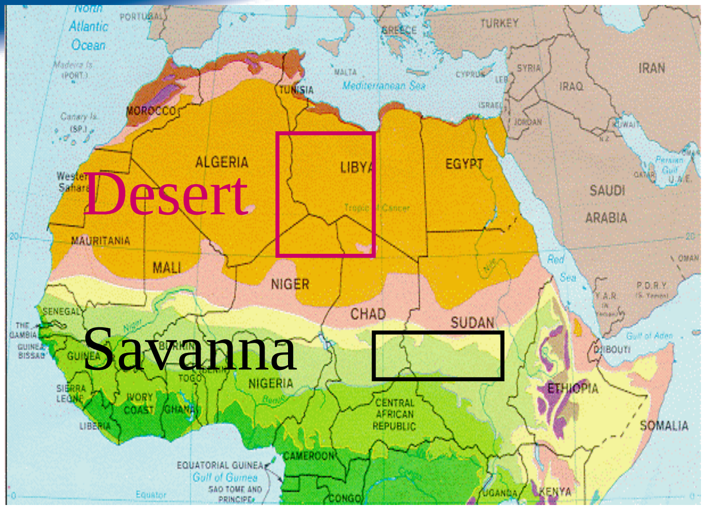
Theoretical accuracy on ε : < 1.5%

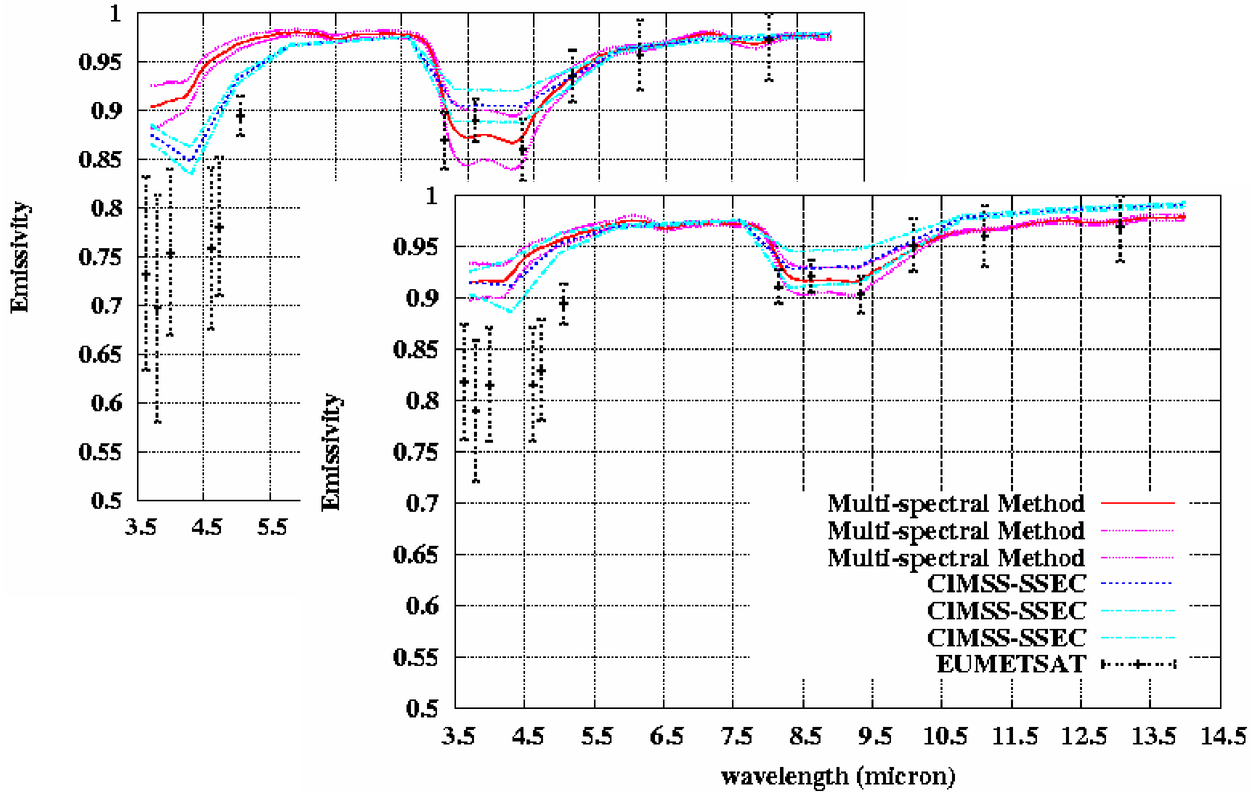
Other effect has to be considered for operational processing :

- Residual clouds
- Potential wavelength dependant bias between radiative transfer simulations and observations
- Angular variation of ε

Expected effect (from AIRS experience) : error increase of about 25-50 % *[Péquignot et al, 2008]*

Comparison with CIMSS and EUMETSAT L2

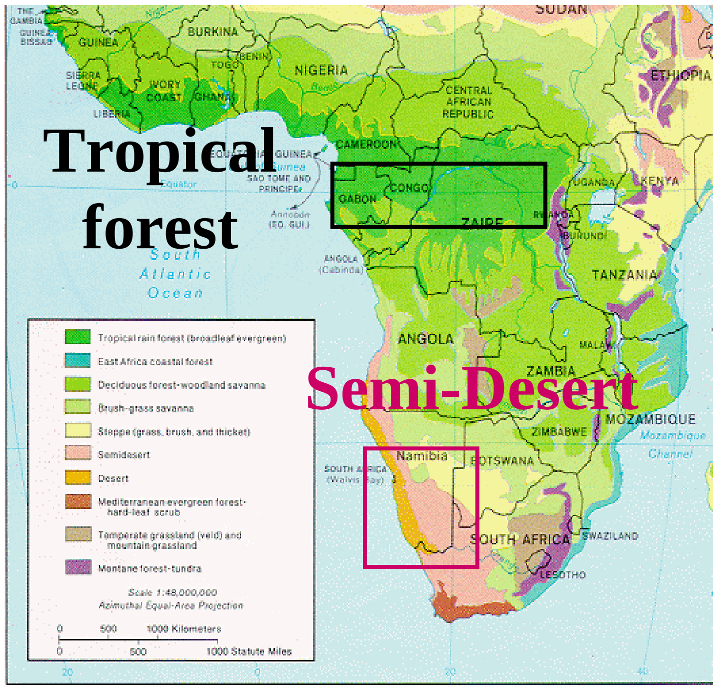


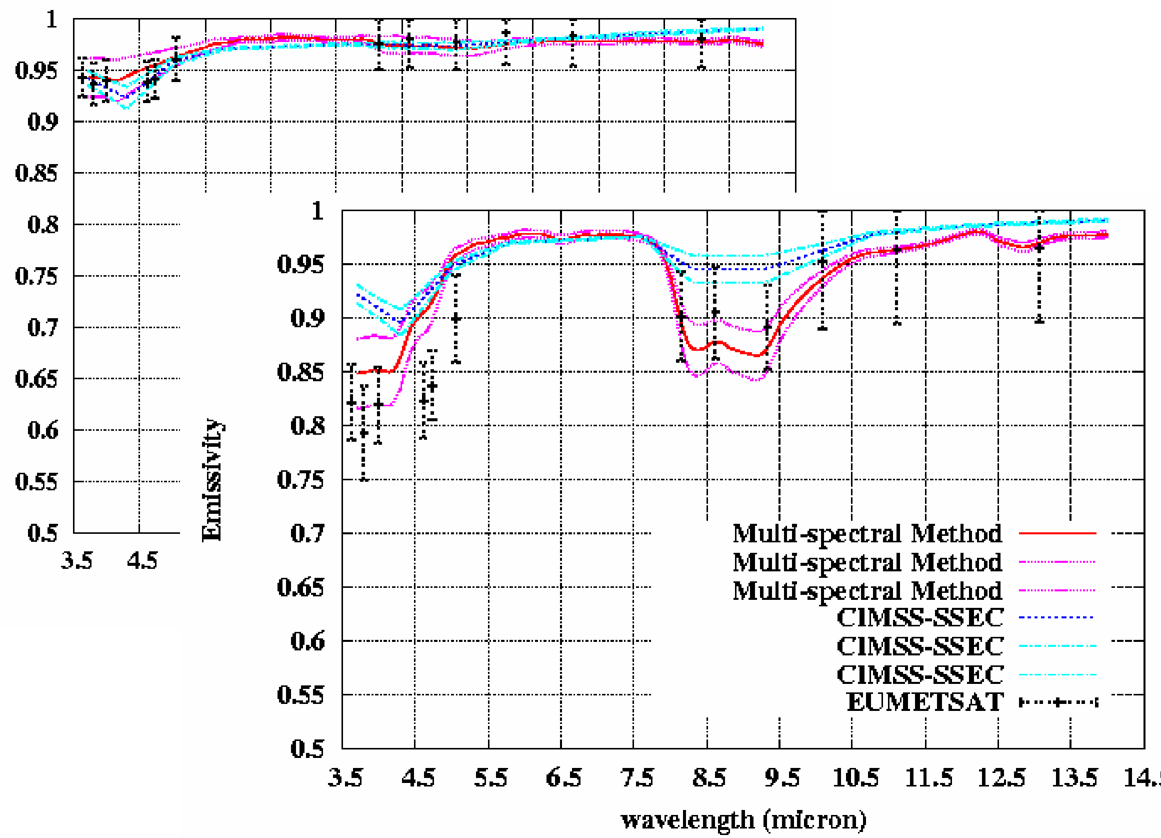


- Good agreement between MSM, CIMSS and EUMETSAT emissivities, except at 4 µm (signal lower in that spectral region, emissivity harder to estimate)

- Lower spatial dispersion for CMISS and MSM emissivity

Comparison with CIMSS and EUMETSAT L2





Conclusions

1) Emissivity Multi-Spectral Method (MSM) works well and is adapted to instruments with high spectral resolution.

2) We need to analyze more data to go further with comparisons and build a climatology of emissivity retrieved from IASI

3) Such 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.

4) Easy to implement the Multi-Spectral Method in Near Real Time inversion data processing.