Infrared continental surface emissivity spectra 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

from MODIS/UCSB and ASTER/JPL emissivity libraries

Bare soil: quartz
Quartz Reststrahlen bands

Bare soil: calcite

Bare soil: gypsum

Snow and Ice

Vegetation

ITSC XVI : Angra dos Reis - Brasil - 7-13 May 2008
Angular variation of emissivity in TIR

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

=> Lambertian assumption

Angular variation impact on TIR emissivity: effect $< 5\%$ for $\theta < 40^\circ$.

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

\[ \tau'(\lambda, \theta)\tau(\lambda, \theta) = \tau_s(\lambda, \theta) \]
In order to calculate $\varepsilon_s(\lambda)$ one needs:

1) identifying clear sky radiances $\rightarrow$ EUMETSAT IASI L2 cloud mask (based on AVHRR)

2) knowing the thermodynamic state of the atmosphere ($T$, $H_2O$, $O_3$ profiles) $\rightarrow$ EUMETSAT IASI L2 products

3) estimating the surface skin temperature

$\tau_s(\lambda, \theta) \neq 0$
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], $\lambda_0 = 12.17$ µm

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

The right hand side is 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

\[
\varepsilon_s(\lambda) = \frac{1(\lambda, \theta) - \int_0^{\infty} B[\lambda, T] \, d \tau(\lambda, \theta) - \tau_s(\lambda, \theta) \int_0^{\infty} B[\lambda, T] \, d \tau'(\lambda, \theta)}{\tau_s(\lambda, \theta) \left\{ B(\lambda, T_s) - \int_0^{\infty} B[\lambda, T] \, d \tau'(\lambda, \theta) \right\}}
\]

\(\varepsilon\) calculated for about 90 IASI channels selected for their high sensitivity to surface parameters

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.

Least square minimization + shape adjustment

Emissivity continuous spectrum between 3.7 and 14.0 µm
- Quartz reststrahlen bands are well observed and dominate the $\varepsilon$ spectra
- In quartz reststrahlen bands $\varepsilon$ 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 (1\textsuperscript{st}, 9\textsuperscript{th}, 25\textsuperscript{th}) : surface temperature over land

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

$\mu = -0.9$ K

$\sigma = 1$ 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 $T_{\text{lowest_level_TIGR}} + \text{Gaussian}(\mu=0\text{K}, \sigma=4\text{K})$

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]

Theoretical accuracy on ε : < 1.5%
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

Semi-Desert

Tropical forest

Multi-spectral Method
CIMSS-SSEC
EUMETSAT
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.