Comparison of LAND SURFACE EMISSIVITY from MODIS, AIRS, and SEVIRI

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Objective

An accurate infrared land surface emissivity product is critical for deriving accurate land surface temperatures, needed in many studies including surface energy and water balance research. An emissivity product is also useful for mapping geologic and land-cover features. Three emissivity products have been developed from MODIS, AIRS, and SEVIRI satellites, each with their own methodologies and associated strengths and weaknesses. Calculations of brightness temperatures using the different emissivity products will be compared to observed SEVIRI channels.

Methodology

The observed top of atmosphere radiation is the sum of atmospheric, surface, and reflected contributions. Using an RTM to make calculations for each part we can easily evaluate the TOA radiation assuming any given surface emissivity. Then we can compare these calculated radiances to observed SEVIRI radiances - for an objective evaluation of the different emissivity products.

The atmospheric state is described by ECMWF model runs for August 18, 2006 at 00UTC. The radiative transfer model (LBLRTM by AERS Inc.) was used to calculate the TOA radiation given by the atmosphere, the surface, and reflected terms in a 1x1 degree grid over North Africa. The calculations were then interpolated onto the finer SEVIRI grid, and convolved to the SEVIRI spectral resolution. We assumed the surface temperatures used by LSA SAF, and the surface emissivities given by: LSA SAF, UW MODIS BF, and NASA L2 AIRS. The LSA SAF emissivities are daily averages for August 18, 2006, the UW MODIS BF emissivities are monthly averages, and the AIRS Level 2 emissivities are for August 16, 00UTC values (August 18th was not available).

Observations

SEVIRI

The Spinning Enhanced Visible and Infrared Imager (SEVIRI) onboard the European MSG satellite became operational February 2004. Its coverage includes the whole of Europe and Africa and parts of South America every 15 minutes. It has a 3km resolution, and 12 spectral channels (8 channels in the IR ranging from 3.9 um to 13.9um). The greater volume and quality of data offers among other things, improved measurement of the Earth surface and cloud top temperatures; features we will exploit to evaluate different emissivity products.

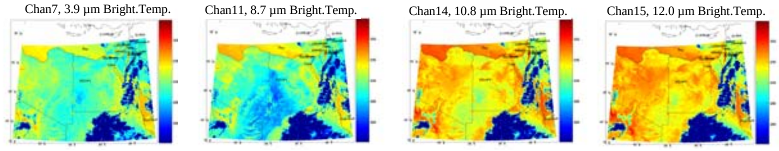
Emissivity is estimated from the SEVIRI observations using the equation:

$$R_{obs} = R_{atm} + B(T_s) * Tran * e$$

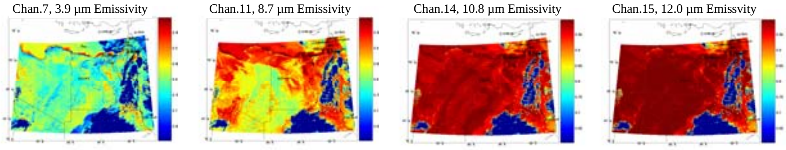
where R_{obs} is the observed radiance TOA, R_{atm} is the radiance from the atmosphere, $B(T_s)$ is the Planck radiance for the surface temperature T_s, Tran is the transmission through the atmosphere TOA, and e is the surface emissivity. Solving for e. The reflected contribution is ignored.

SEVIRI observed bright. Temp. and estimated Emissivity, Aug. 18, 2006 00UTC

Chan7, 3.9 µm Bright.Temp. | Chan11, 8.7 µm Bright.Temp. | Chan14, 10.8 µm Bright.Temp. | Chan15, 12.0 µm Bright.Temp.



Chan.7, 3.9 µm Emissivity | Chan.11, 8.7 µm Emissivity | Chan.14, 10.8 µm Emissivity | Chan.15, 12.0 µm Emissvity



Database Descriptions

UW MODIS BF

The University of Wisconsin's MODIS Baseline Fit (UW MODIS BF) global infrared land surface emissivity database is derived from a combination of high spectral resolution laboratory measurements of selected materials, and MODIS MYD11 observed land surface emissivities available at 3.7, 3.9, 4.0, 8.5, 11.0 and 12.0 µm.

The UW MODIS BF emissivity database is derived at moderate spectral resolution (10 values in the 3.7-14.3 micron range), with wavelengths chosen as the inflection points that best characterize the shape of each relevant laboratory emissivity spectra. The BF method described in detail in Seemann et al.[4] is applied by adjusting the magnitude of the emissivity at each of the inflection point wavelengths based on the observed MODIS MYD11 emissivity values. A spectrum of emissivity at the ten inflection points is given for each month at each MYD11 latitude and longitude point (0.05 degree resolution) over land. Seemann, S.W., et al., 2007: Development of a Global Infrared Land Surface Emissivity Database for Application to Clear Sky Sounding Retrievals from Multi-spectral Satellite Radiance Measurements. J. Appl Meteorol & Clim, accepted April 2007. http://cimss.ssec.wisc.edu/iremis/

LSA SAF

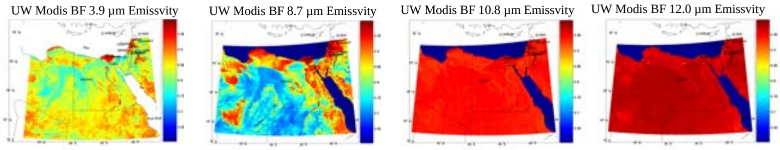
The land surface emissivity are derived for use in land surface temperature retrievals from Meteosat Second Generation / Spinning Enhanced Visible and Infrared Imager (MSG/SEVIRI). The Satellite Application Facility on Land Surface Analysis (LSA SAF) (http://landsaf.meteo.pt) generates maps for MSG1/SEVIRI channels IR 10.8 µm and IR 12.0 µm. The algorithm is based on the so-called vegetation cover method (VCM), and uses another LSA SAF product - the Fraction of Vegetation Cover (FVC). This methodology has been developed for the currently retrieved LSE maps (IR10.8 µm and IR 12.0 µm), as well as for the remaining IR channels (IR3.9 and IR8.7), and for a broadband LSE (3-14 µm), necessary for the estimation of longwave surface fluxes. The SEVIRI data will be reprocessed by EUMETSAT in January, 2008 to include several calibration corrections.

AIRS L2

The operational Atmospheric Infrared Sounder (AIRS) emissivity retrieval uses a NOAA regression emissivity product (Goldberg et al., 2003) as a first guess over land. The NOAA approach is based on clear radiances simulated from the European Centre for Medium-Range Weather Forecasts (ECMWF) forecast and a surface emissivity training dataset. The training dataset used for the AIRS v4.5 algorithm had a limited number of soil, ice, and snow types and very little emissivity variability in the training ensemble. (ATBD AIRS-Team Retrieval for Core Products and Geophysical Parameters Level 2, JPL D-17006, M.T. Chahine et al).

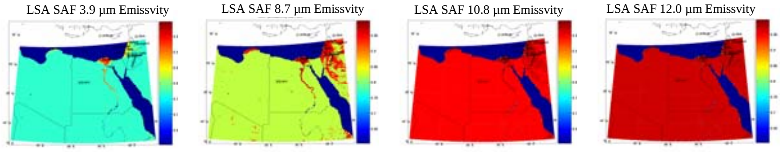
Emissivity from UW Modis BF, monthly average Aug. 2006

UW Modis BF 3.9 µm Emissvity | UW Modis BF 8.7 µm Emissvity | UW Modis BF 10.8 µm Emissvity | UW Modis BF 12.0 µm Emissvity



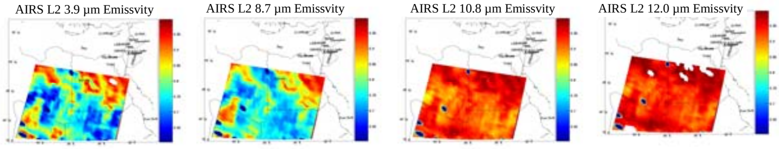
Emissivity from LSA SAF, Aug. 18, 2006 00UTC

LSA SAF 3.9 µm Emissvity | LSA SAF 8.7 µm Emissvity | LSA SAF 10.8 µm Emissvity | LSA SAF 12.0 µm Emissvity

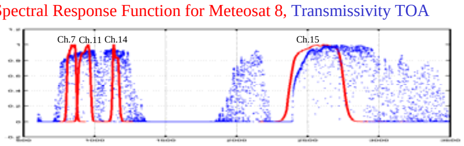


Emissivity from AIRS L2, Aug. 16, 2006 00UTC

AIRS L2 3.9 µm Emissvity | AIRS L2 8.7 µm Emissvity | AIRS L2 10.8 µm Emissvity | AIRS L2 12.0 µm Emissvity



Spectral Response Function for Meteosat 8, Transmissivity TOA



Spectral analysis at a desert site in Egypt

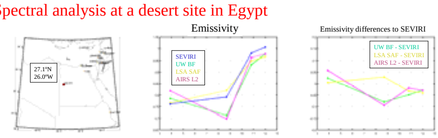
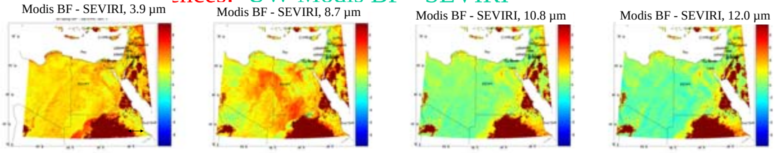


Table of Statistics for Brightness Temperature Differences

	Chan.7, 3.9um		Chan.11, 8.7 um		Chan.14, 10.8 um		Chan.15, 12.0um		
	Mean	StdDev	Mean	StdDev	Mean	StdDev	Mean	StdDev	No. Points
UW Modis BF	2.93	0.93	2.99	1.62	0.41	1.35	0.09	1.40	205000
LSA SAF	2.29	1.09	3.33	2.05	0.60	1.23	0.05	1.38	227000
AIRS Level2	2.55	1.16	3.30	1.66	-0.02	1.28	-0.41	1.30	137000

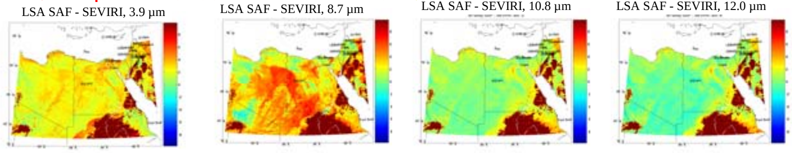
B.Temp differences: UW Modis BF - SEVIRI

Modis BF - SEVIRI, 3.9 µm | Modis BF - SEVIRI, 8.7 µm | Modis BF - SEVIRI, 10.8 µm | Modis BF - SEVIRI, 12.0 µm



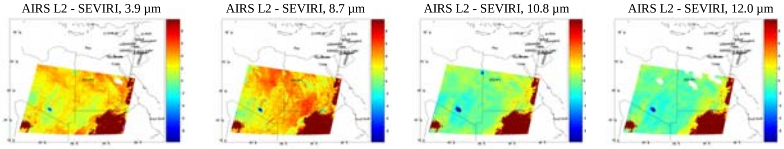
B.Temp differences: LSA SAF - SEVIRI

LSA SAF - SEVIRI, 3.9 µm | LSA SAF - SEVIRI, 8.7 µm | LSA SAF - SEVIRI, 10.8 µm | LSA SAF - SEVIRI, 12.0 µm



B.Temp differences: AIRS L2 - SEVIRI

AIRS L2 - SEVIRI, 3.9 µm | AIRS L2 - SEVIRI, 8.7 µm | AIRS L2 - SEVIRI, 10.8 µm | AIRS L2 - SEVIRI, 12.0 µm



Conclusions

The calculated brightness temperature using the three different emissivity products is in good agreement with SEVIRI observations at 12.0 µm; about +0.1 K, +0.1 K and -0.4 K respectively for UW Modis BF, LSA SAF, and AIRS Level 2. At 10.8 µm the agreement is good also; approximately +0.4, +0.6, and -0.02 K resp. However all the emissiviity models lead to a disagreement with SEVIRI observations of about +3 K at 8.7 µm, and between +2.3 to +2.9 K at 3.9 µm.

The use of 12.0 and 10.8 µm for the determination of land surface temperature appears to be valid. UW Modis BF and AIRS L2 emissivities are in generally good agreement with each other while the LSA SAF emissivity is limited by its lack of spatial detail.

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