# P2.7 A GLOBAL INFRARED LAND SURFACE EMISSIVITY DATABASE AND ITS VALIDATION

Eva E. Borbas*, Leslie Moy, Suzanne W. Seemann, Robert O. Knuteson, Paolo Antonelli, Jun Li, Hung-Lung Huang,
Space Science and Engineering Center, University of Wisconsin-Madison, USA

Isabel Trigo, and
Instituo de Meteorologia, Lisbon, Portugal

Lihang Zhou
NOAA NESDIS ORA

## 1. INTRODUCTION

Two global infrared (IR) land surface emissivity databases with high spectral and high spatial resolution will be introduced in this paper. Both databases are derived from a combination of high spectral resolution laboratory measurements of selected materials, and MODIS observed land surface emissivities (MYD11) at 6 wavelengths. For a given month, a spectrum of emissivity from 3.7 to 14.3 µm is available for every latitude/longitude point globally at 0.05-degree spatial resolution.

The first method uses the baseline fit (BF) method (Seemann et al., 2006) to derive emissivity at 10 wavelengths which were chosen as inflection points to capture as much of the shape of the higher resolution emissivity spectra as possible between 3.6 and 14.3µm, so the emissivity values in between the inflection points can be derived by interpolation. For the second database, a regression method was used between the first 6 eigenvectors of the 332 laboratory spectra and MODIS emissivity observations to create a high spectra resolution emissivity dataset.

Both methods are compared with other satellite-based emissivity measurements including the land surface emissivity derived for use in land surface temperature retrievals from Meteosat Second Generation / Spinning Enhanced Visible and Infrared Imager (MSG/SEVIRI) and with the operational Atmospheric Infrared Sounder (AIRS) emissivity retrievals.

## 2. DATA

Both University of Wisconsin (UW) databases are derived from a combination of high spectral resolution laboratory measurements of selected materials (Salisbury et al. 1992, 1994, Korb et al. 1996), and MODIS MYD11 (Wan and Li, 1997, Wan 1999) observed land surface emissivities available at 3.7, 3.9, 4.0, 8.5, 11.0 and 12.0 µm. For a given month, a spectrum of emissivity from 3.7 to 14.3 µm is available for every latitude/longitude point globally at 0.05-degree resolution.

The baseline fit (BF) emissivity database is derived at moderate spectral resolution (10 values in the 3.7-14.3µm 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. (2006) is applied by adjusting the magnitude of the emissivity at each of the inflection point wavelengths based on the observed MODIS MYD11 emissivity values. The result of the BF adjustment is a spectrum of emissivity at ten inflection points for each month at each MYD11 latitude and longitude point (0.05 degree resolution) over land.

For the second UW database, principal component analysis (PCA) of 332 selected laboratory spectra (wavenumber resolution between 2-4cm$^{-1}$, at 413 wavenumbers) and the MODIS MYD11 emissivity observations were used to create a high spectra resolution emissivity dataset. Regression relationship between the first 6 principal components of the lab spectra and the 6 MODIS emissivity observations were used to determine the high spectra resolution emissivity spectra at each MYD11 latitude and longitude point over land.

Both datasets are compared with land surface emissivity derived from SEVIRI data on MSG1 and with the operational AIRS emissivity retrievals.

The Satellite Application Facility on Land Surface Analysis (LSA SAF) (http://landsaf.meteo.pt) generates maps for MSG1/SEVIRI channels 10.8 and 12.0 µm. The algorithm is based on the so-called vegetation cover method, and uses another LSA SAF product - the Fraction of Vegetation Cover. This methodology has been developed for the currently retrieved land surface emissivty (LSE) maps (10.8 and 12.0 µm), as well as for the remaining IR channels (3.9 and 8.7 µm), and for a broadband LSE (3-14 µm), necessary for the estimation of longwave surface fluxes.

The operational 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

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* *Corresponding author address*: Eva E. Borbas, Univ. of Wisconsin, Space Science and Engineering Center, 1226 W. Dayton St., Madison, WI, 53706; e-mail:eva.borbas@ssec.wisc.edu

for Medium-Range Weather Forecasts (ECMWF) forecast and a surface emissivity training dataset. The training dataset used for the AIRS v4.0 algorithm had a limited number of soil, ice, and snow types and very little emissivity variability in the training ensemble. An updated regression coefficient set has been generated using a number of published emissivity spectra (12 spectra for ice/snow, 14 for land) that were blended randomly together for land and ice respectively.

## 3. COMPARISON OF UW DATABASES

Figure 1 shows a comparison of August 2003 emissivity at 8.5 μm over the in the Eastern Sahara Desert region derived from the PCA regression technique (left) and that derived from the baseline fit method (right). Another comparison of emissivity spectra for 10 selected locations is shown in Figure 2. Note that the two methods agree fairly well in shape and magnitude, however the PCA regression technique has significantly more spectral detail, including the sub-peak at 8.5 μm present in the emissivity spectra of many sandy soils.

As a test of the two methods, a simulation study was performed. A set of 321 high spectral resolution laboratory measurements of emissivity for common surface materials was chosen. Emissivity values corresponding to the 6 MYD11 wavelengths were extracted from each of the laboratory spectra and these six values were input to both BF and PCA regression algorithms. This is intended to simulate the case where the algorithms only have MYD11 data as input, yet provide us with high spectral resolution spectra for validation. In the case of the baseline fit method, these 6 values were input into the new baseline fitting scheme and the result was an emissivity spectra at the 10 inflection point wavelengths for each laboratory spectra. The derived spectra were linearly interpolated between the 10 inflection points to arrive at a resolution of 5 wavenumbers for comparison with the laboratory-measured spectra subsampled at the same wavelengths. For the PCA regression technique, PCA regression coefficients were applied to the 6 emissivity values for each laboratory measurement. By extracting only the six MOD11 wavelengths, an evaluation can be made as to how well these two methods fills in the gaps in the spectral regions between MOD11 values.

Some examples of these comparisons for various materials are shown in Figure 3, and the combined results from all 321 spectra are presented as an absolute mean difference in Figure 4. Generally, the baseline fit emissivity agrees well with the laboratory in shape and magnitude, but lacks in detail. The high spectral resolution fluctuations in emissivity will not be captured by this approach. The PCA regression method compares very well the individual spectra especially in the 8-9 μm region where a sub-peak at 8.5 μm is present in the emissivity spectra of many sandy soils. It captures the high resolution fluctuations better than the BF method, but it also has some additional fluctuations like at the 5-6 μm region for leaf of oak that needs further investigation. Overall, the shape of the baseline fit emissivity, is captured sufficiently for applications of moderate spectral resolution such as the MOD07 atmospheric regression retrievals from MODIS (Li et al, 2000, Seemann et al. 2003). The mean absolute fitting errors over all 321 spectra (shown in Figure 4) are never greater than 0.03, and are considerably lower than those for a constant emissivity equal to 1 (black dashed line in Figure 4), a value still commonly used in many applications. For reference, the mean absolute fitting errors are also included in the Figure 4 (red dotted dashed line) for a simple linear interpolation between MYD11 wavelengths. Significant improvement by both methods is seen in the 4.5-8 μm region, and moderate improvements exist around 9.5 μm, and for wavelengths greater than 12.5 μm. The PCA regression method performs better than the BF method at 4.5 and 7.8 μm, were the BF method has an extra small hump in the difference plot. PCA regression method does somewhat worse in 9.5 μm and in the far IR wavelength (wavelength larger than 12.5 μm) PCA regression method is better again.

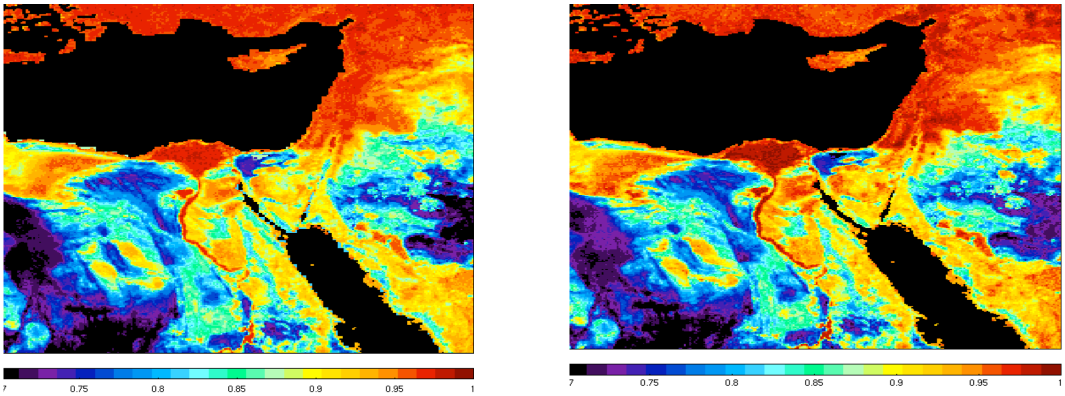

**Figure 1**: Global emissivity at 8.5 μm for August 2003 derived using the PCA/MOD11 regression method (left panel, high spectral resolution) and the baseline fit method (right panel, moderate spectral resolution) in the Eastern Sahara Desert region.

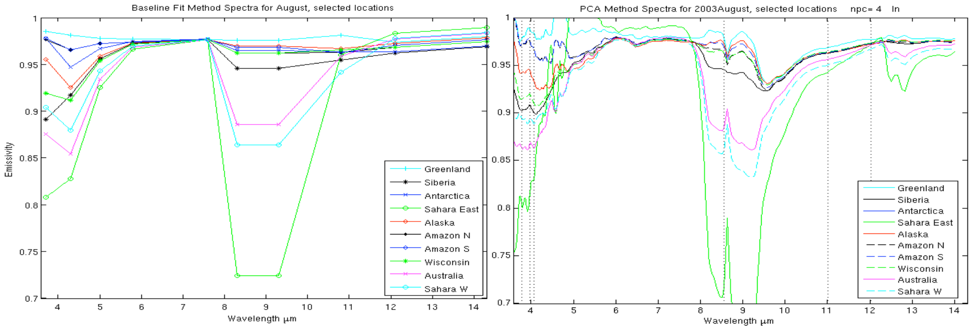

**Figure 2**: Emissivity spectra for August 2003 at 10 selected locations created by the baseline fit method (left) and PCA regression method (right).

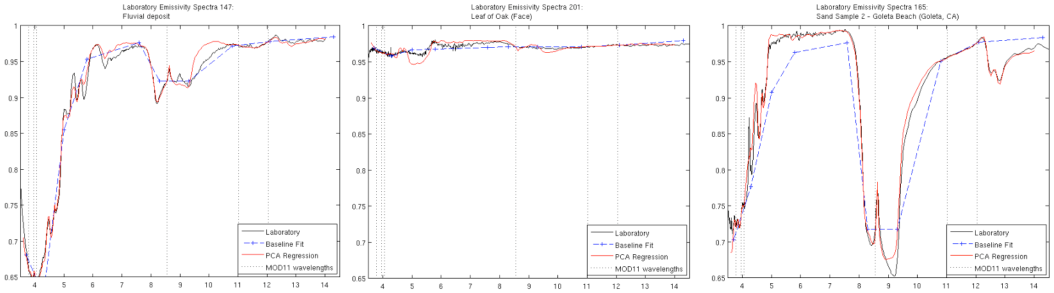

**Figure 3**: Comparison of original laboratory-measured emissivity spectra (black) with that derived by the baseline-fit approach (blue dashed) and PCA regression method (red solid) using only the emissivity values at the MOD11 wavelengths (identified by the black dotted vertical lines). Spectra are shown for three materials: Fluvial deposit (left), leaf of Oak (middle), and sand sample from Goleta Beach (Goleta, CA, right).

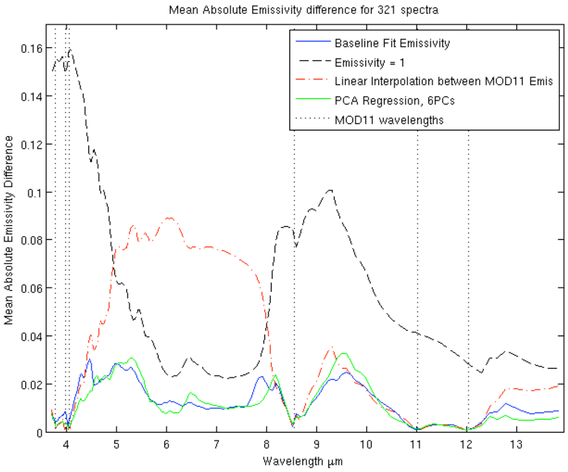

**Figure 4**: Mean absolute difference between the original high spectral laboratory data and the baseline fit-derived emissivity (blue solid line) and the PCA regression emissivity (green solid line) over all 321 spectra. This is compared with the mean absolute emissivity difference for a constant emissivity of 1 (black dashed), and the mean absolute emissivity difference for an emissivity linearly interpolated between the 6 MOD11 values (red dash-dot), where both are compared with the original high spectral laboratory emissivity. MOD11 wavelengths are shown as dotted lines. Results were computed at every 5 wavenumbers.

## 4. COMPARISON OF UW BF EMISSIVTY DATABASE WITH SEVIRI AND AIRS

The comparison of the BF database with the LSA SAF database was made for 2006 January in 4 regions of the world at 4 wavelengths (3.9, 8.7, 10.8, 12.0 μm, SAF spectral resolution). The SAF database grid was interpolated onto the BF database grid. The analysis of the comparison of these three databases is still ongoing, but selected example comparisons are shown below. Figure 5 shows the monthly mean differences between the SEVIRI and BF emissivities at 8.7 μm in South America for January 2006. Most of the differences are less than 5% with the exception of the western coastal desert.

The BF LSE database and the operational AIRS emissivity retrievals were compared at 42 wavelengths for July 2004. BF LSE database values that fell inside of the AIRS emissivity retrieval FOVs were averaged. Monthly mean differences, the ratio of the differences, and the histogram of the values were calculated. Figure 6 shows the differences between the AIRS and BF emissivities globally at 8.5μm. The differences are also less than 5% with the exception of deserts of North and South Africa and Australia.

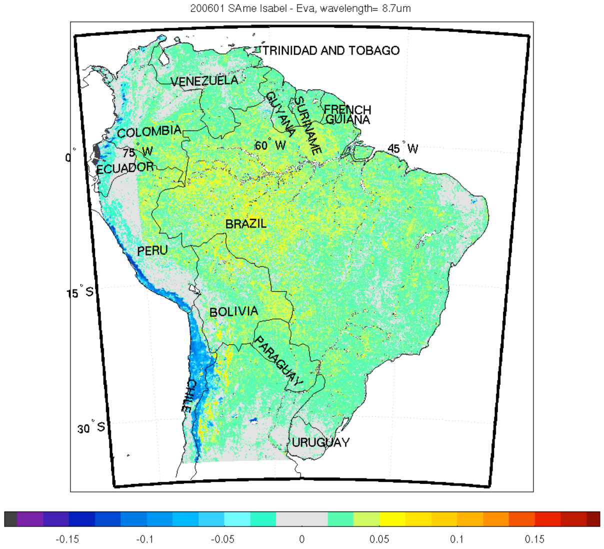

**Figure 5**: Monthly mean differences between the SEVIRI and BF emissivities at 8.7 µm in South America for January 2006.

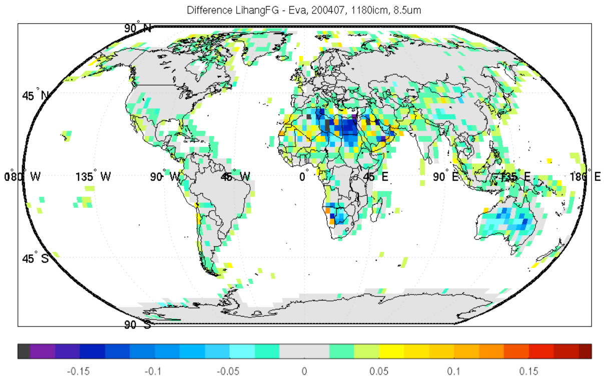

**Figure 6**: Monthly mean differences between the AIRS and the BF emissivities globally at 8.5 µm for July 2004.

## 5. CONCLUSION, FUTURE PLANS

Two UW emissivity databases were introduced. Both are derived from a combination of high spectral resolution laboratory measurements of selected materials, and MODIS observed land surface emissivities at 6 wavelengths. One uses the BF method producing an emissivity spectra at 10 infection points and the other uses a PCA regression technique resulting in high spectral resolution emissivity spectra with wavenumber resolution between 2-4cm$^{-1}$, with 413 wavenumbers. Both methods produce monthly global land surface maps on 0.05 degree (about 5 km) resolution. The two datasets/methods were compared to each other and to land surface emissivity retrievals derived from MSG1/SEVIRI and AIRS data. Generally, the two UW methods agree fairly well in shape and magnitude, however the PCA regression technique has significantly more spectral detail, including the sub-peak at 8.5 µm present in the emissivity spectra of many sandy soils.

SEVIRI and AIRS comparisons are preliminary and it is too early to draw conclusions regarding the validation of the BF database. However, the differences highlight regions for further investigations for both the SEVIRI and AIRS datasets. Refined comparisons will include the application of the AIRS quality flags and improvements in spatial matchups. SEVIRI comparisons will be extended to include northern hemisphere summer where clouds and snow are not as pervasive.

The UW Baseline Fit database is available from the authors from a public web site and is already being used in a number of science investigations. The new PCA method is still being evaluated and refinements are expected over the next year. The current status of these databases can be obtained by contacting the lead author.

In the future, for validation the datasets will be compared with other emissivity measurements from selected field experiments.

## 6. REFERENCES

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## 7. ACKNOLEDGEMENTS

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