Recent updates of the UW/CIMSS high spectral resolution global land surface infrared emissivity database

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Outline

• UW/CIMSS Global Land Surface Emissivity Database
  • Dataset available: http://cimss.ssec.wisc.edu/iremis/

  • UW/CIMSS MODIS-based (moderate spectral resolution) emissivity DB
derived by the Baseline Fit (BF) method
  • High Spectral Resolution (HSR) emissivity algorithm
    using PC statistical regression method

• Comparison on BF vs HSR emissivity data

• Comparison to other emissivity datasets

• Dependence on MODIS/MYD11 emissivity products: Collection 4 vs 5

• A case study as validation

• Summary

• Future Plans
Motivation: Atmospheric retrieval algorithm such as (MOD07) requires a global set of profiles and corresponding surface data (Tskin, Psurf and surface emissivity).

We need:
A gridded, global surface emissivity database at high spectral and high spatial resolution

We have:
• MODIS MOD11 emissivity, but only at 6 wavelengths (only 4 distinct wavelength regions): 3.7, 3.9, 4.0, 8.5, 11, 12 μm (monthly data on 0.05 degree grid (missing values))

• Laboratory measurements (UCSB, Dr. Wan, MODIS land team) of emissivity at high spectral resolution, but not necessarily representative of the emissivity of global ecosystems as viewed from space
Moderate Spectral Resolution DB: Baseline Fit Approach

• **Input data**: MODIS MYD11 - ACCURACY DEPENDANCE!!!
  • The baseline fit method based on a **conceptual model** developed from laboratory measurements of surface emissivity is applied to fill in the spectral gaps between the six emissivity wavelengths available from MYD11.
  • **10 hinge points** were chosen to capture as much of the shape of the higher-resolution spectra as possible between 3.6 and 14.3 μm:
    
    3.6, 4.3, 5.0, 5.8, 7.6, 8.3, 9.3, 10.8, 12.1 and 14.3 μm

• Adjust a laboratory-derived “baseline emissivity spectra” based on the MOD11 values for every global latitude/longitude pair.

• **Result**: a monthly global emissivity database at 10 wavelengths with 0.05 degree spatial resolution.

• **Reference**:
  
Moderate Spectral Resolution DB: Baseline Fit Approach (cont.)

Examples of the application of the baseline fit method:

- Grass
- Leaf of Green Spruce
- Sandstone
- Gypsum

MYD11.004 8.3μm Jan 2006
Application: MOD07 TPW on 1 Aug 2005 at 2000 - 2320 UTC

Emissivity=0.95

Emissivity=BF

NCEP GDAS TPW, 2 Aug 2005, 00 UTC
MSG SEVIRI retrieved TPW product coverage for a uniform spectral emissivity (=0.95 left) and for the spectral emissivities taken from the UW/CIMSS BF emissivity database (right). Note the bad coverage, i.e. non-successful retrievals, over the large desert areas. (03 October 2007, 0600 UTC, box size is 15 x 15 MSG pixels)

Marianne Koenig and Estelle de Coning: The MSG Global Instability Indices Product and its Use as a Nowcasting Tool. Submitted to “Weather and Forecasting”
High Spectral Resolution database:
UW BF emissivity DB + PC statistical regression algorithm

\[ \tilde{e} = \tilde{c}U \]
\[ \tilde{c} = \tilde{e} \ast U^T (UU^T)^{-1} \]

- \( \tilde{e} \) is the HSR emissivity spectra
- \( \tilde{c} \) is the PCA coefficient vector
- \( U \) is the matrix of the first PCs of the lab emissivity spectra

**Most Important Idea (Bill Smith)**
Represent high spectral resolution infrared emissivity as a linear combination of a limited number (e.g. 6) of eigenfunctions of a set of laboratory spectra that covers 3.6 to 14.3\( \mu \)m.

**Accuracy** depends on
- UW/CIMSS BF emissivity DB and MODIS MYD11 data
- Set of laboratory spectra (current version contains 123 selected lab spectra on 5 wavenumber [cm\(^{-1}\)] spectral resolution)

**Output:** emissivity spectra with 416 spectral points between 3.6 and 14.3 \( \mu \)m

**What is available?** A BF emissivity DB at 10 hinge points and a HSR algorithm
Application: HSR emissivity spectra for 5993 SeeBor training profiles separated by IGBP ecosystem types

Red dots: the BF emissivity values; the first 6 PCs was used
How many PCs to use?

Number of PCs vs. Percent Cumulative Variance [%]

Reconstruction Error (rmse [%]) vs. Number of PCs

Ratio of emis spectral points > 1 vs. Number of PCs

Reconstruction Error (rmse [%]) vs. Wavelength (μm)

Percent Cumulative Variance [%] vs. Number of PCs

Number of PCs: 0.985
Location of instable cases in SeeBor training profiles

Histogram of HSR emissivity of SeeBor training data > 1 at 4.7 μm by IGBP categories

4.7 μm
6.1 %

1 %

Location of cases >1 at 4.7 μm
Application: HSR Emissivity Statistic and Covariance

- IASI Physical Retrieval using Bayesian optimal estimation method (Antonelli’s talk; UWPHYSRET)

- As first guess in UW AIRS physical retrieval (Jun Li’s talk)

- 1DVAR application
Bootstrapping a HSR Global Climatology

Full UW HSR database contains
- 6000 spectra in every 50 km sq.
  over 60 months (5 years) of data.
- Total greater than 1,500,000,000 HSR spectra

SEEBOR training set contains 5993 HSR emissivity spectra located mainly at sonde launch sites.
Application: IMAPP AIRS clear-sky retrievals

Profiles statistics between ECMWF analyses and AIRS retrievals for 240 granules (Sept 2, 2003) calculated using emissivity=1, the UW/CIMSS BF emissivity and HSR (PCA) emissivity assigned to the training profiles over land only.

One day global statistics show improvement of AIRS retrieved temperature, moisture and particularly ozone profiles using the UW/CIMSS HSR emissivity algorithm over linear interpolation between the 10 hinge point of UW BF emissivity spectra.
Averaged differences between BF and HSR emissivity spectra of 8583 land SeeBor profiles at 2378 AIRS channels By IGBP land classes
Averaged differences of BT calculated with BF emissivity minus those calculated with HSR emissivity by IGBP land classes.
UW/CIMSS BF (top) and HSR emissivity (middle) and their differences (bottom)
Emissivity comparison:

UW-AIRS 8-day composite (by Jun Li) vs.
UW HSR monthly mean data
for Jan 2004

Because the UW HSR/BF emissivity data uses the MODIS MYD11 product as input, HSR/BF emissivity values will be affected by changes in the MYD11 algorithm.

Beginning with January 2007 the NASA LP DAAC began processing the MYD11 data with the new collection 5 algorithm.

Comparison on using MYD11 collection 4 vs 5 data
4 μm
8.7 μm
13 μm
Statistical differences between MODIS MYD11 collection 004 and 005 products

004 Aug 2004

005 Aug 2004

Significant differences:

• loss of variability in band 31, 32 (11 and 12 \( \mu m \))
• An increasing in minimum emissivity for band 20, 22, 23 and 29 (3.7, 3.9, 4.0 and 8.5 \( \mu m \)) by \( \sim 0.1 \)
Emissivity Validation
A case study
AIRS granule January 15 2004 00:03 UTC, 12 μm radiances
Atmospheric state from ECMWF analyses

\[ T_{\text{skin}} = 276.8 \text{ K} \]
\[ P_{\text{surf}} = 970.6 \text{ hPa} \]
\[ \text{Alt} = 398.3 \text{ m} \]
Emissivity
BF (black), HSR(blue) using MYD11 collection 4
Emissivity
BF (black), HSR(blue) using MYD11 collection 5
BT Residuals (Calc - Obs) (using Sarta V1.07)

Difference of calculated minus observed temperature [K]

Wavenumber [cm⁻¹]

-2 0 2 4 6 8

HSRemis V4
HSRemis V5
BFemis V4
BFemis V5
AIRSL2 emis
UW AIRS emis
Problem in MYD11 C5

HSR improvement over lin. int. BF

O$_3$ band
C5 improvement

8-9.5 $\mu$m
dBt > 6 K

BT Residuals (Calc - Obs) (LW)

Difference of calculated temperature [K]

Wavenumber [cm$^{-1}$]

HSRemis V4
HSRemis V5
BFemis V4
BFemis V5
AIRSL2 emis
UW AIRS emis
BT Residuals (Calc - Obs) (SW)

HSRemis V4
HSRemis V5
BFemis V4
BFemis V5
AIRSL2 emis
UW AIRS emis

HSR improvement over lin. int. BF

UW AIRS emissivity agrees very well with C5 HSRemis / C5 improvement vs C4

AIRS L2 std product underestimates emissivity in SW
Summary: UW/CIMSS Global Infrared Land Surface Emissivity Database

- Available: [http://cimss.ssec.wisc.edu/iremis/](http://cimss.ssec.wisc.edu/iremis/)
- Time coverage: Jan 2003 - Dec 2007 - 5 years
  - For request: Sept - Dec 2002 and Jan - March 2008
- Format: netcdf
- Size: ~40 Mb compressed / month
- Filling flag info included for MYD11 missing data
- Resolution: 0.05 degree ~ 5 km
- HSR emissivity algorithm has been beta-tested by
  - NRL-Monterey (Ben Ruston)
  - EUMETSAT (Phil Watts)
  - CIMSS (Leslie Moy, Kathy Strabala)
  - available for request
Summary (cont.)

• The comparison of the UW/CIMSS BF and UW/CIMSS HSR emissivities indicated that the largest differences occur around at 13, 10.2-9.7, 8.5, and 4 μm for arid and semi-arid regions; the HSR emissivity data can capture the quartz-reststrahlen band with the peak around 8.5 μm.

• UW/CIMSS BF emissivity data is continuously processed as a new data becomes available on the NASA LP DAAC server.
  - Recommendation due to MYD11 algorithm change (C4 vs. C5):
    - we do not recommend to use version 2 (based on MYD11 C4) and 3 (based on MYD11 C5) BF emissivity data as a continuous dataset
    - Only version 2 BF (MYD11 C4) emissivity data over dessert and non-vegetated area between 8 and 9.5 μm spectral range is recommended to use till the new MYD11 Collection 6 is available.
Future Plans

• Refine the PCA regression technique with using channels with different weights

• Test to apply PCA regression technique using AIRS retrieved emissivity spectra

• Demonstrate use of the UW Global Girded HSR dataset to create a climatology at 5 km spatial resolution by extracting the 5 year time variation by month

• Extend our validation for more cases, globally, for more months, more comparison with other available dataset

• Continue to evaluate the impacts of an improved surface emissivity value on retrieved MODIS and AIRS products
International TOVS Study Conference, 16\textsuperscript{th}, ITSC-16, Angra dos Reis, Brazil, 7-13 May 2008.
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,
Cooperative Institute for Meteorological Satellite Studies, 2008.