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

Eva E. Borbas, Suzanne Wetzel Seemann, Robert O. Knuteson, Elisabeth Weisz, and Allen Huang

Space Science and Engineering Center
University of Wisconsin
Madison, WI, USA

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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

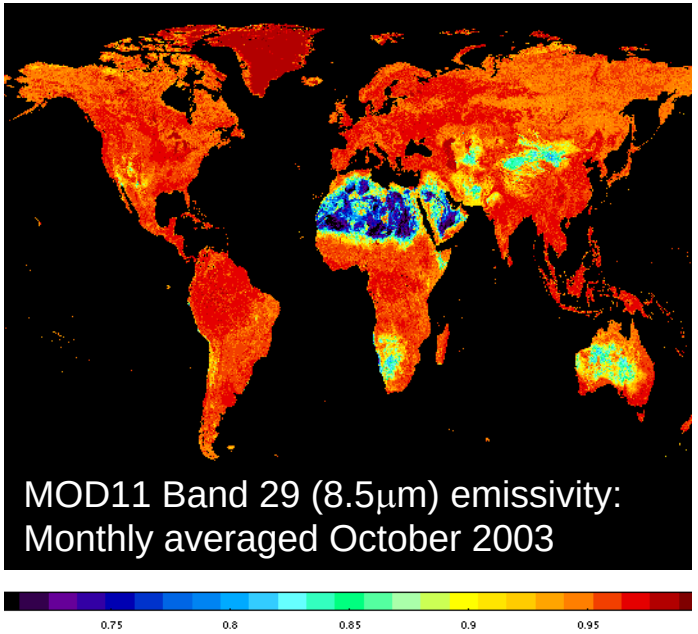
Motivation: Atmospheric retrieval algorithm such as (MOD07) requires a global set of profiles and corresponding surface data (Tskin, Psurf and surface emissivity).

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

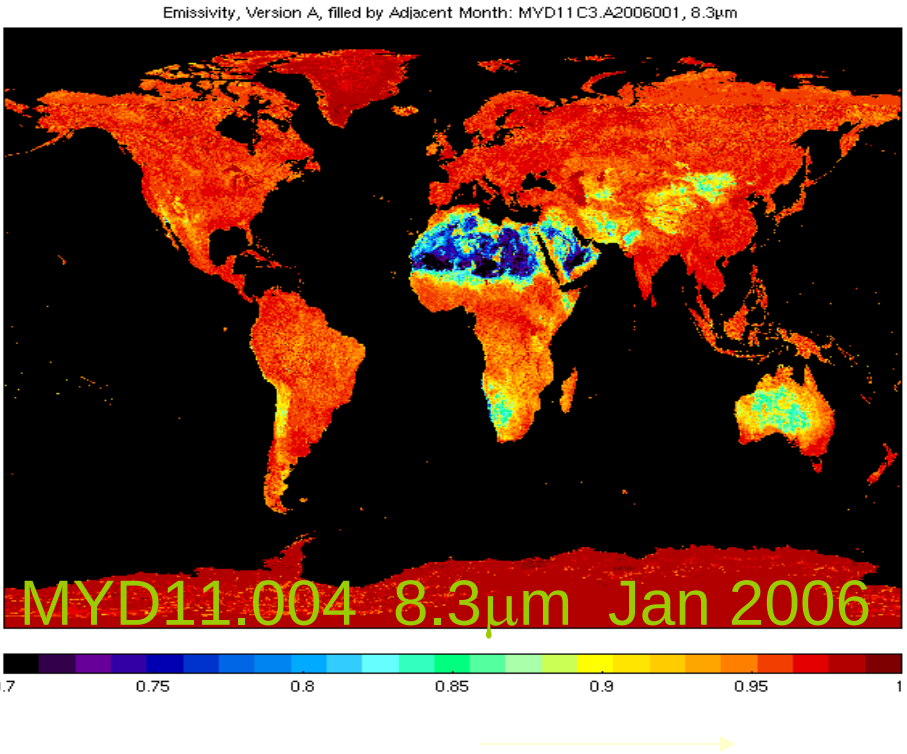
- **Result:** a monthly global emissivity database at 10 wavelengths with 0.05 degree spatial resolution.

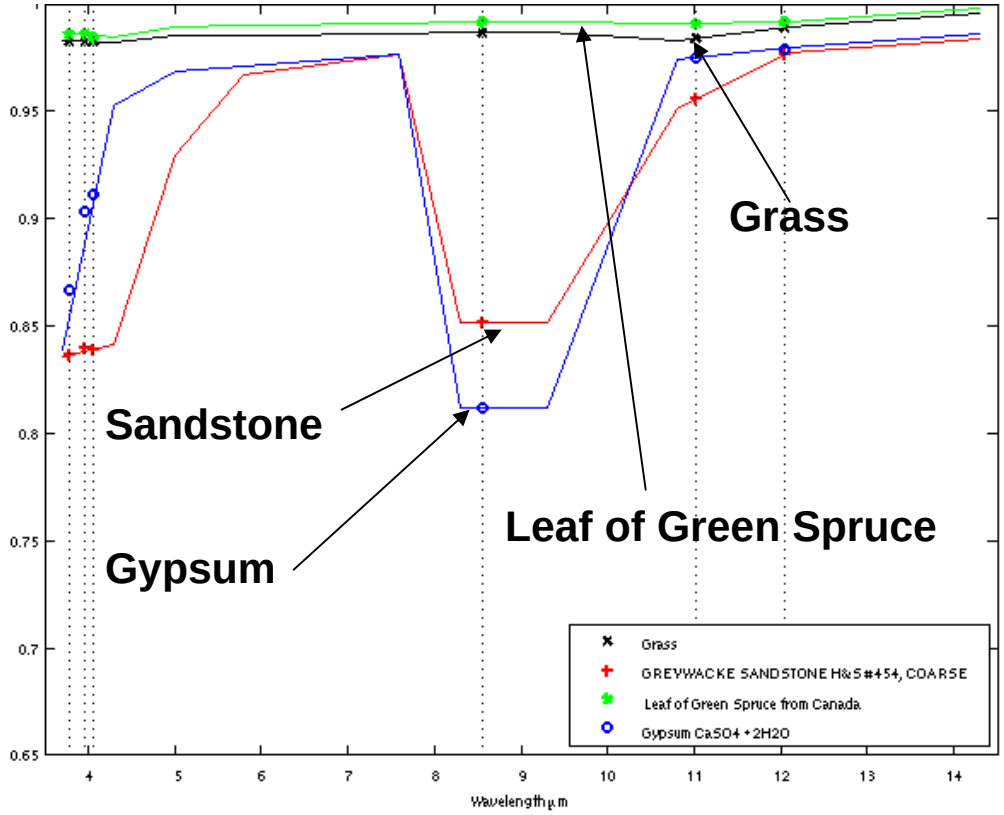
- **Reference:**

Suzanne W. Seemann et al., 2008: Development of a Global Infrared Land Surface Emissivity Database for Application to Clear Sky Sounding Retrievals from Multi-spectral Satellite Radiance Measurements. J. Appl. Meteor. Climatol., Vol. 47, 108-123.

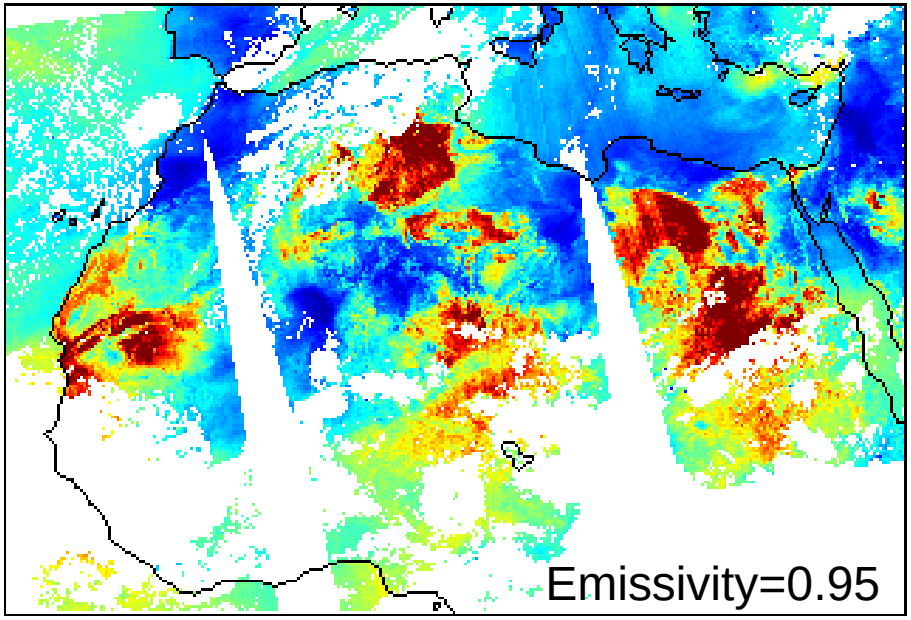
Moderate Spectral Resolution DB: Baseline Fit Approach (cont.)

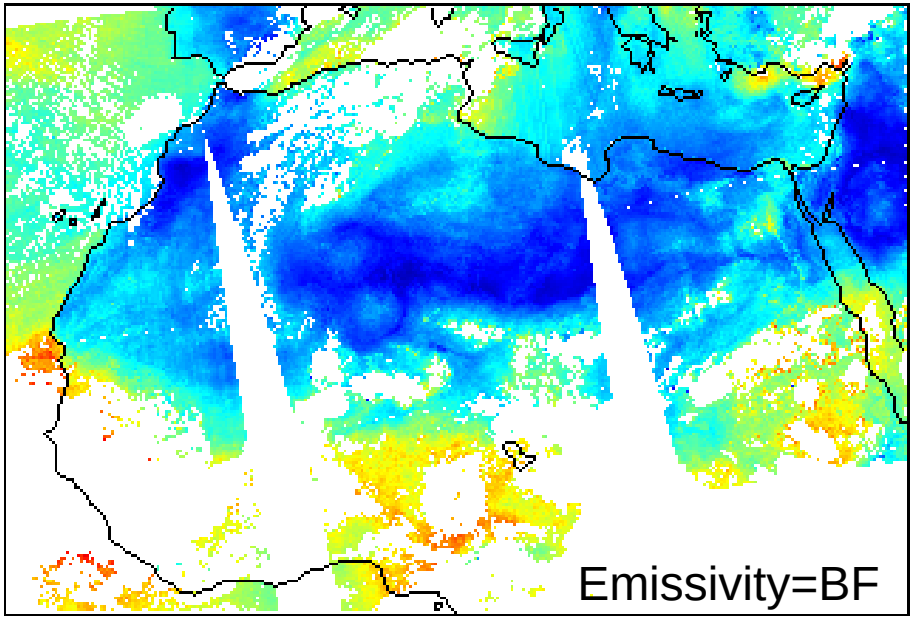
Examples of the application of the baseline fit method:

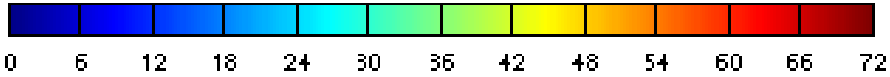


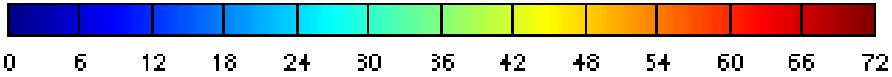


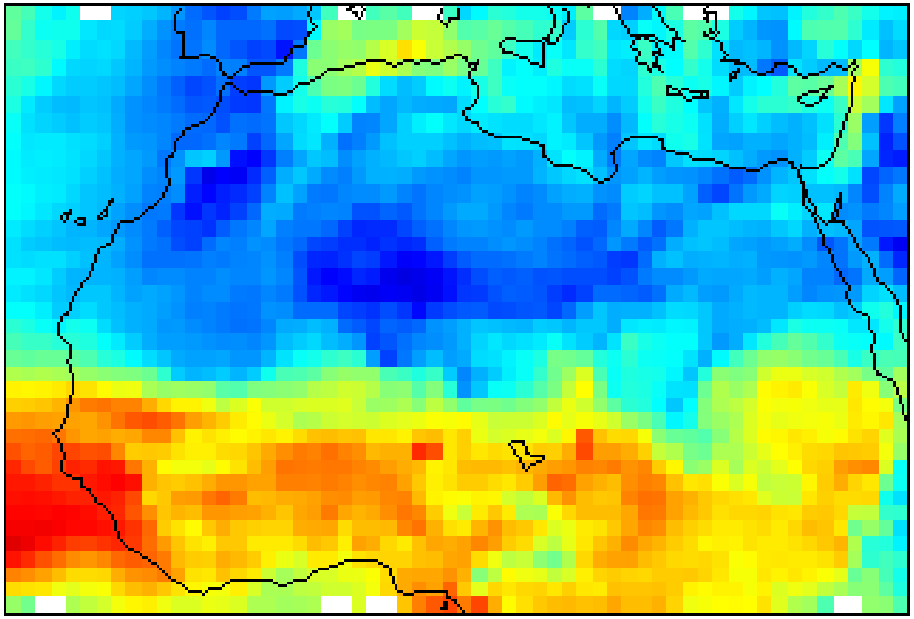
Application: MOD07 TPW on 1 Aug 2005 at 2000 - 2320 UTC



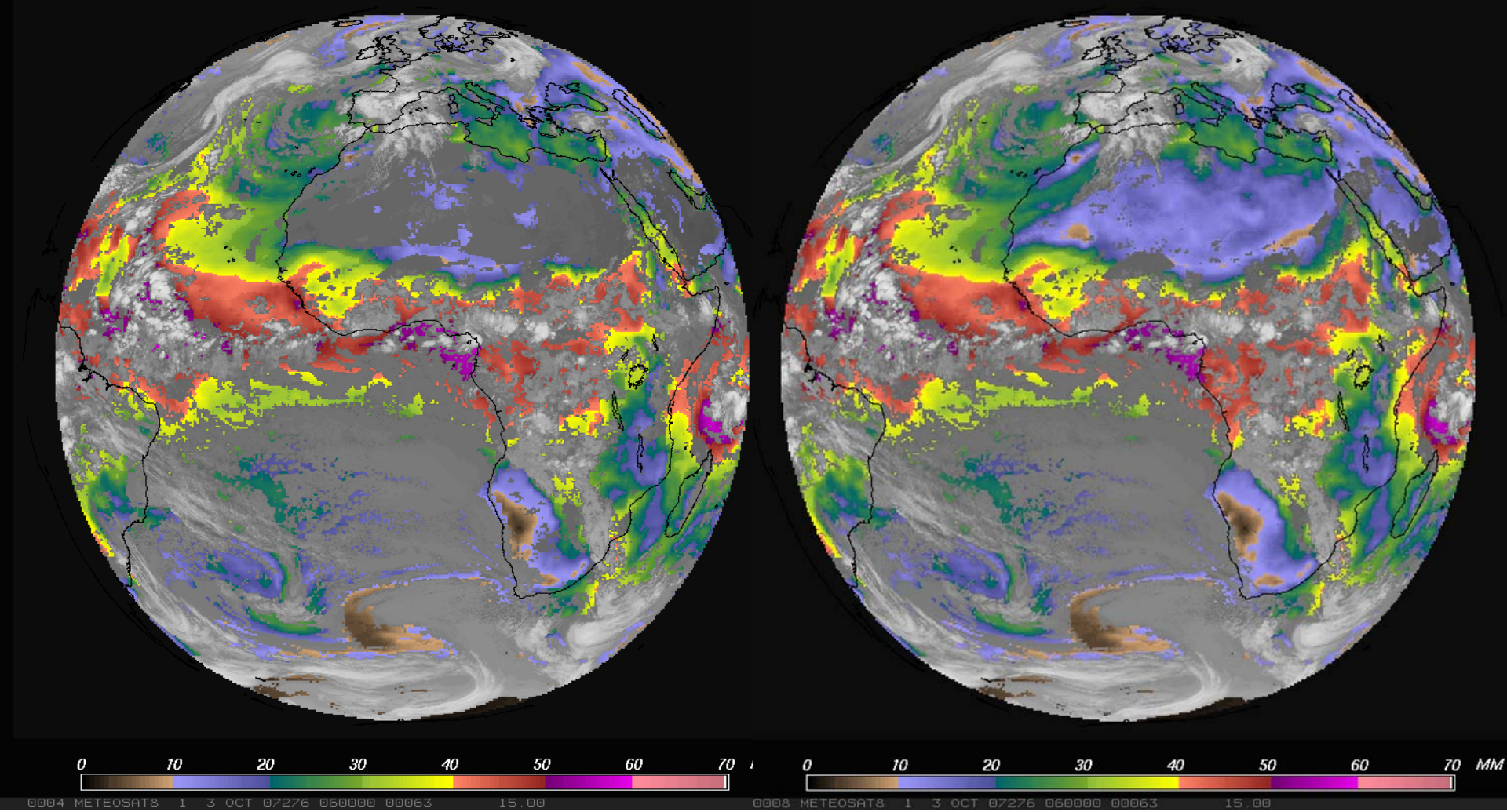








NCEP GDAS TPW,
2 Aug 2005, 00 UTC



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

$$\vec{\mathbf{e}} = \vec{\mathbf{c}}\mathbf{U}$$

$$\vec{\mathbf{c}} = \vec{\mathbf{e}} * \mathbf{U}^{\mathbf{T}}(\mathbf{U}\mathbf{U}^{\mathbf{T}})^{-1}$$

$\vec{\mathbf{e}}$ is the HSR emissivity spectra

$\vec{\mathbf{c}}$ is the PCA coefficient vector

$\mathbf{U}$ is the matrix of the first PCs of the lab emissivity spectra

- Most Important Idea (Bill Smith)

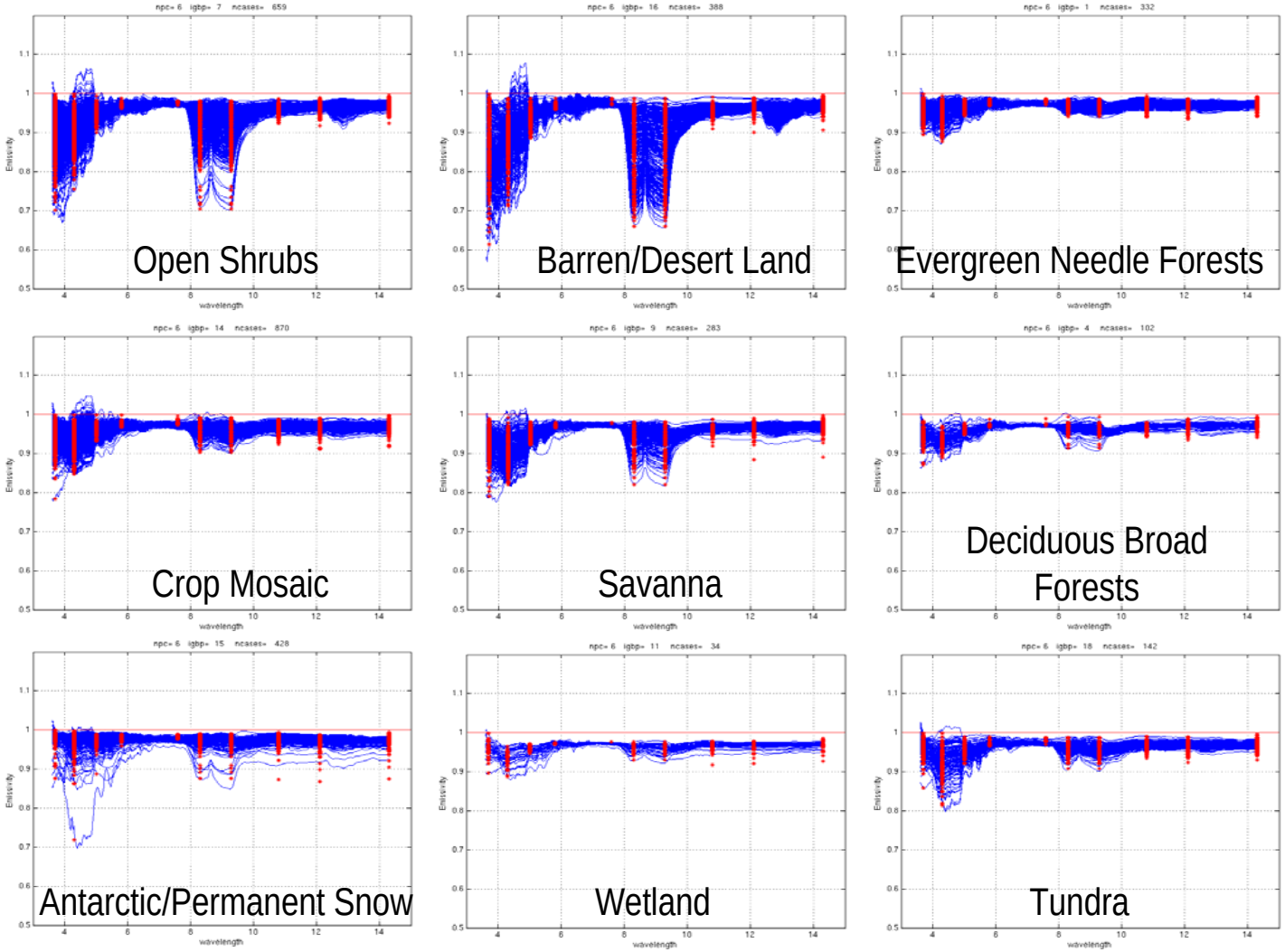
  Represent high spectral resolution infrared emissivity as a linear combination of a limited number (e.g. 6) of eigenfunctions of a set of laboratory spectra that covers 3.6 to 14.3μm.

- 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)

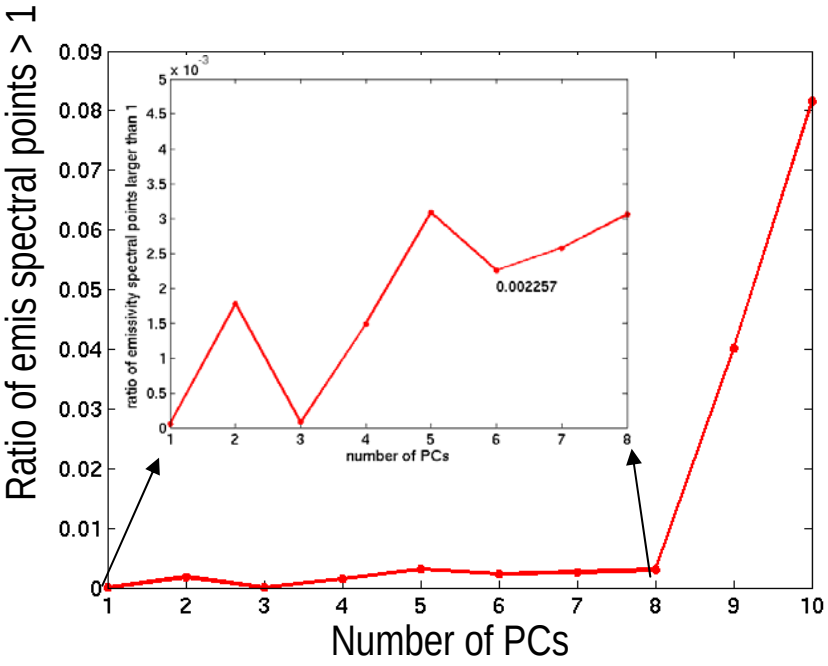
- Output: emissivity spectra with 416 spectral points between 3.6 and 14.3 μm
- What is available? A BF emissivity DB at 10 hinge points and a HSR algorithm

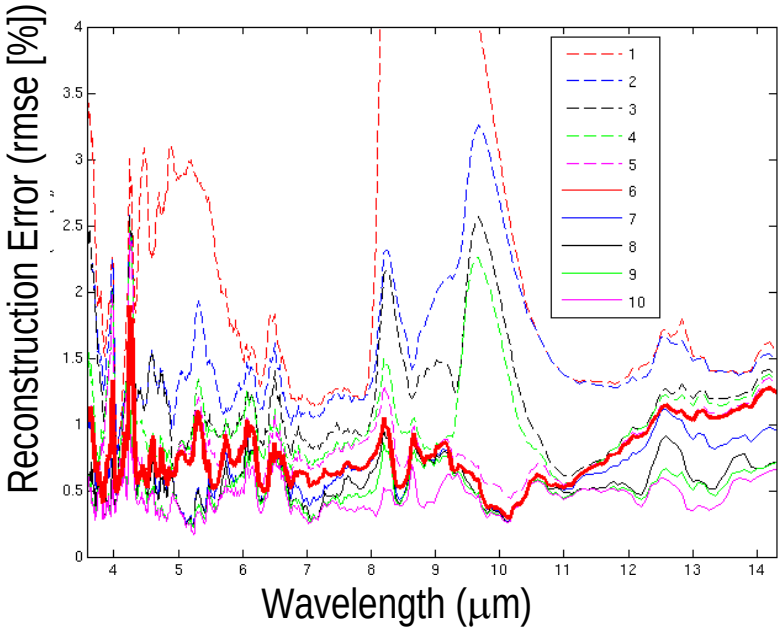
Application: HSR emissivity spectra for 5993 SeeBor training profiles separated by IGBP ecosystem types

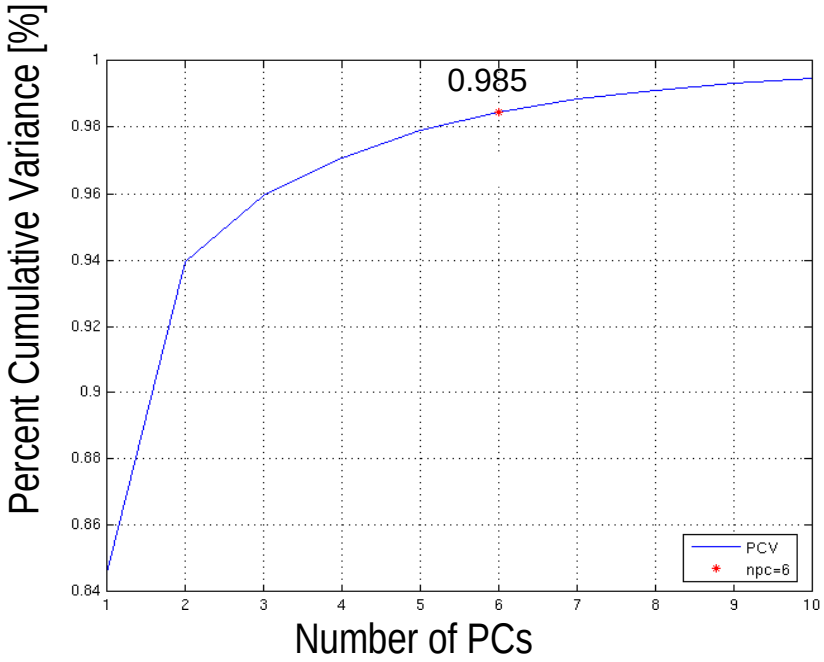
Red dots: the BF emissivity values; the first 6 PCs was used



How many PCs to use?

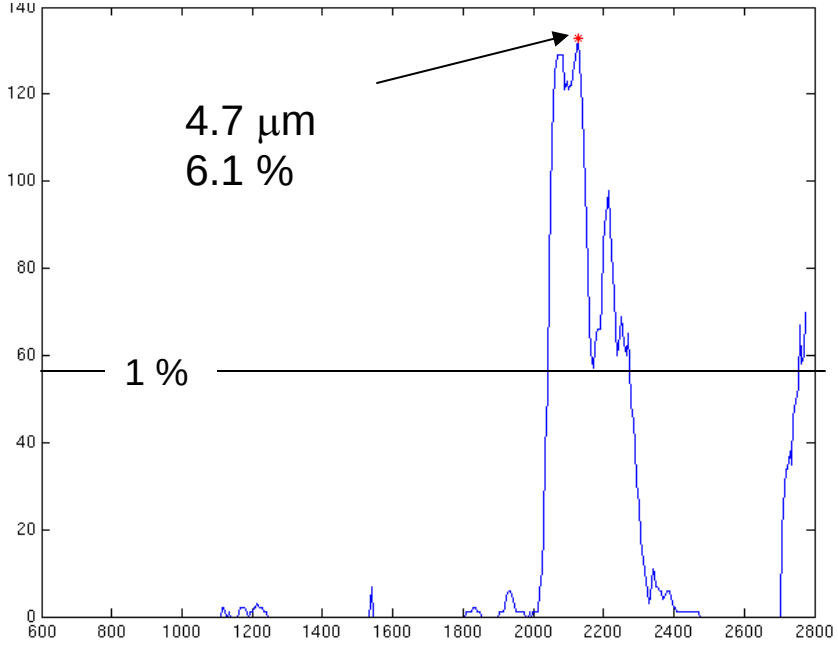




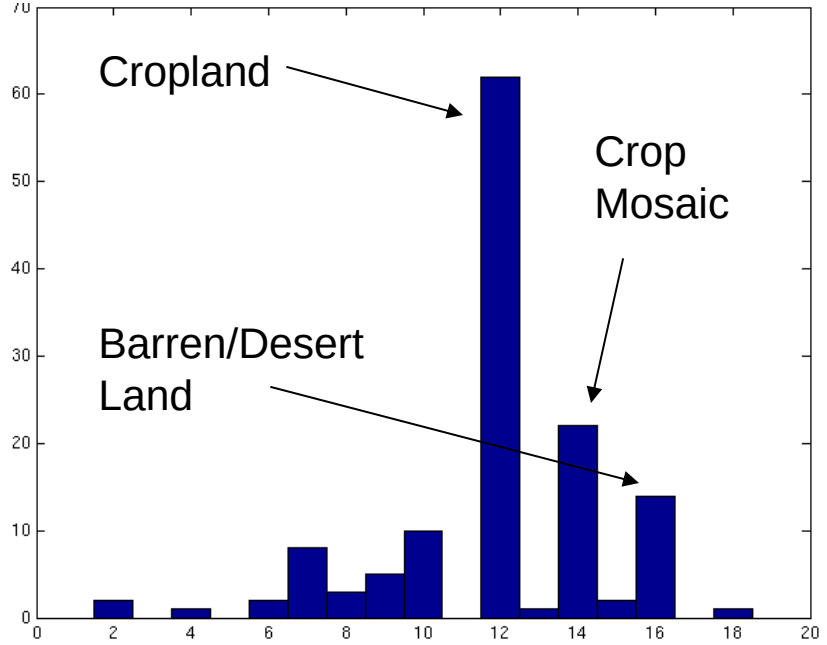


Location of instable cases in SeeBor training profiles

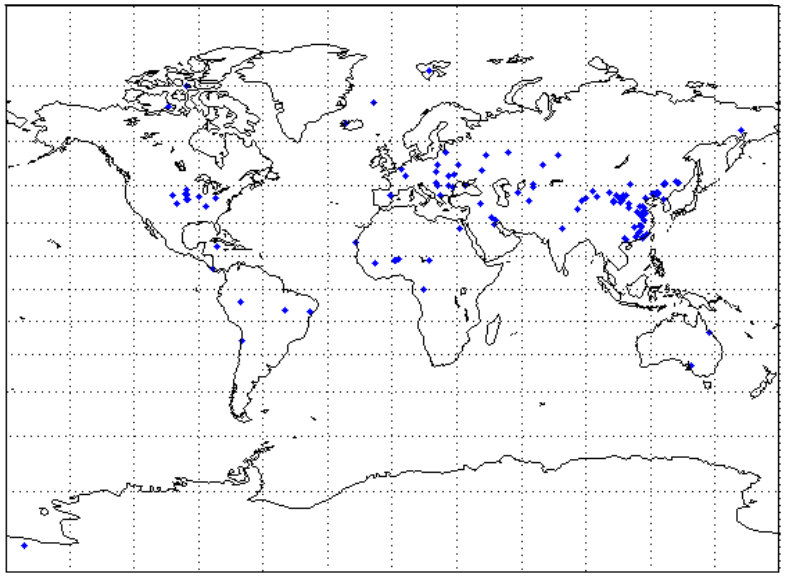
Histogram of HSR emissivity of SeeBor traning data > 1



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

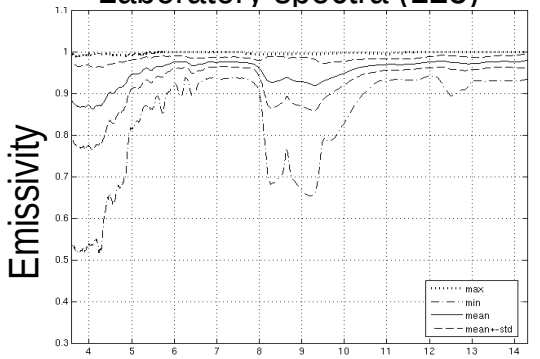


Location of cases >1 at 4.7 μm

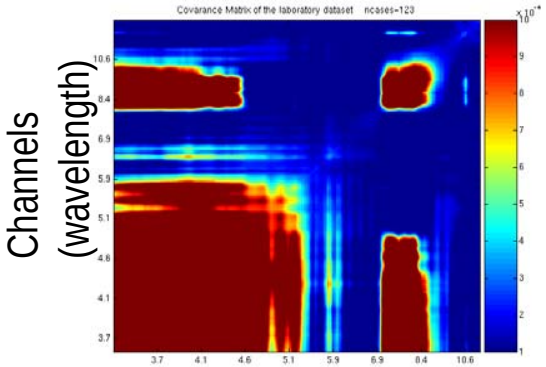


Application: HSR Emissivity Statistic and Covariance

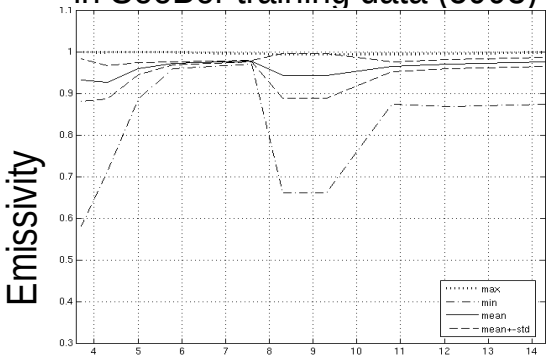
Laboratory spectra (123)



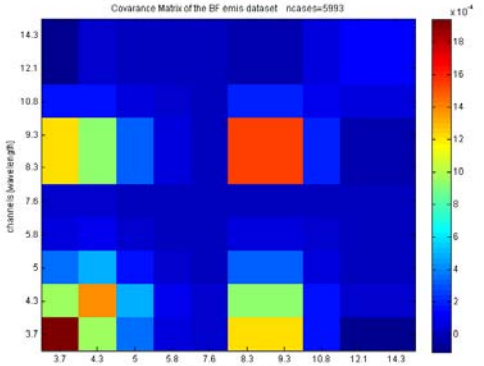
4 μm 14 μm



BF emissivity
in SeeBor training data (5993)

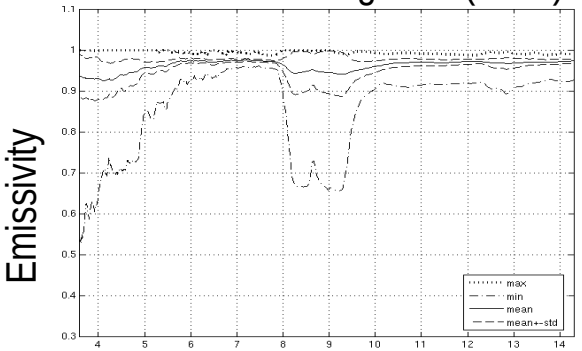


4 μm 14 μm

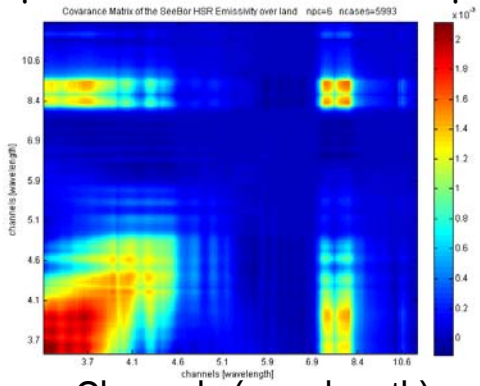


Channels (wavelength)

HSR emissivity
in SeeBor training data (5993)



4 μm 14 μm

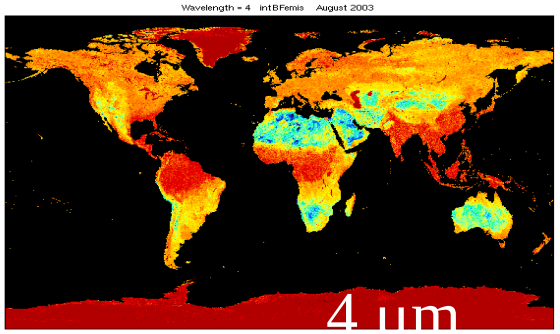


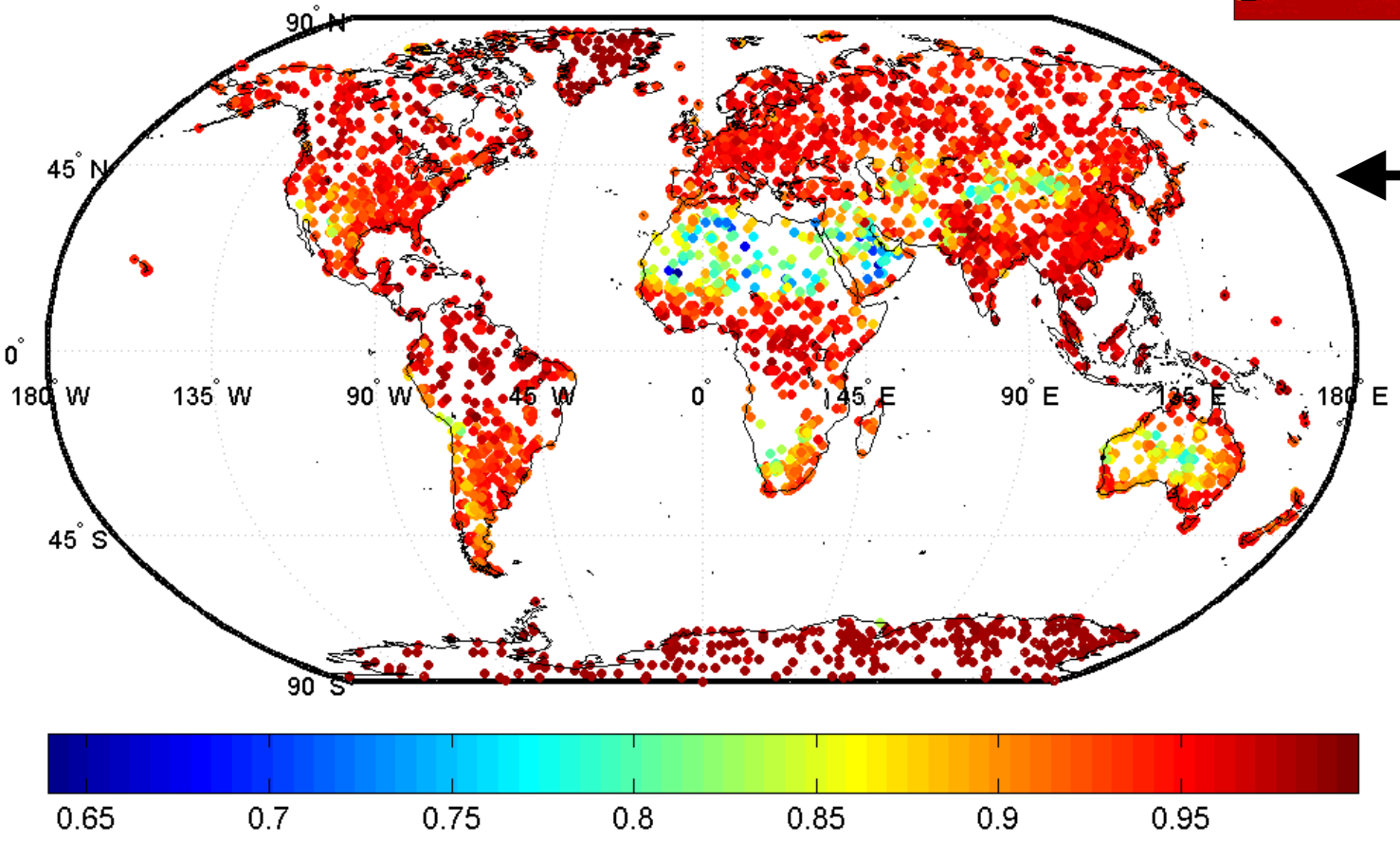
Channels (wavelength)

- 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





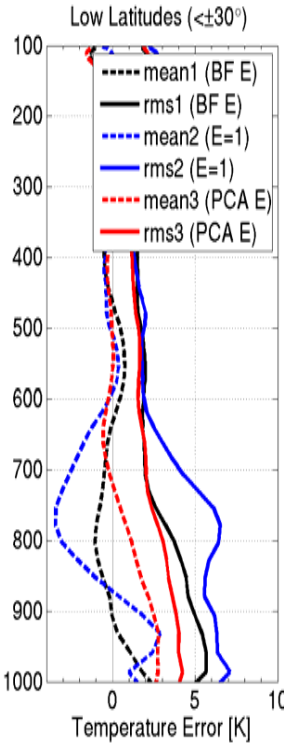
(reconstructed HSR at 4 micron)

SEEBOR training set contains 5993 HSR emissivity spectra located mainly at sonde launch sites

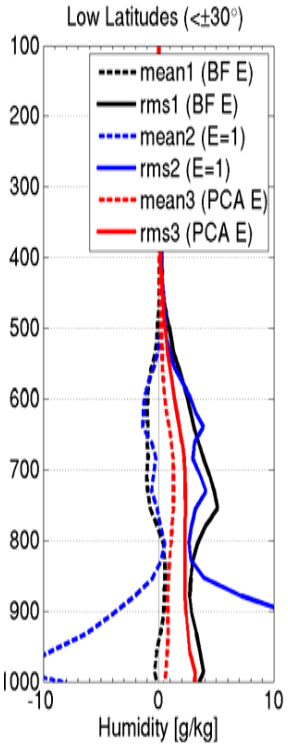
Application: IMAPP AIRS clear-sky retrievals

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.

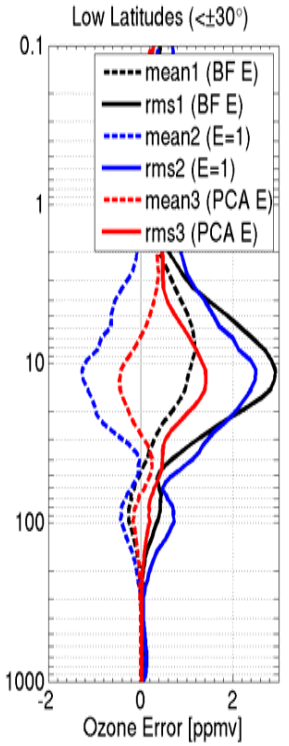
Temperature



Moisture (mixing ratio)

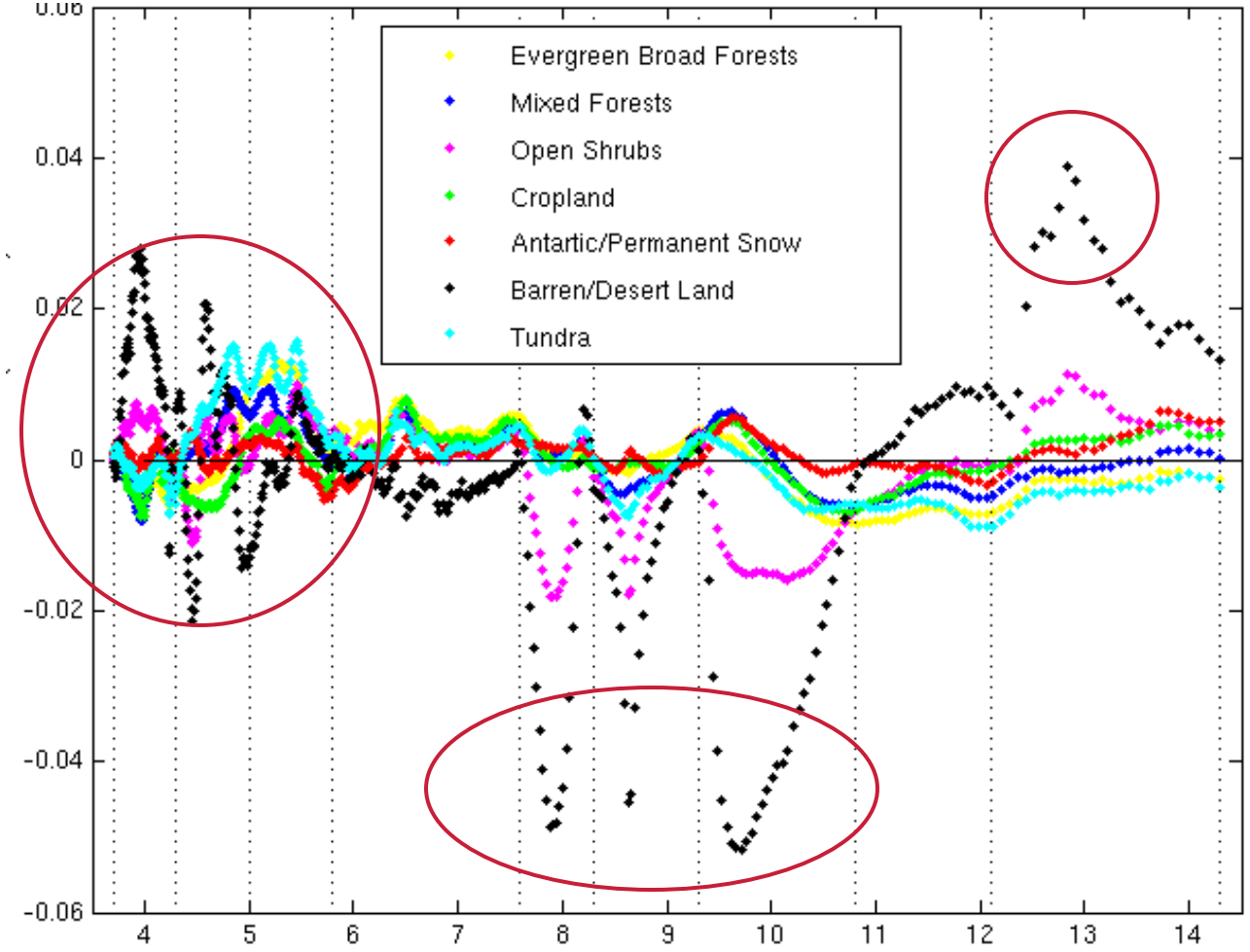


Ozone

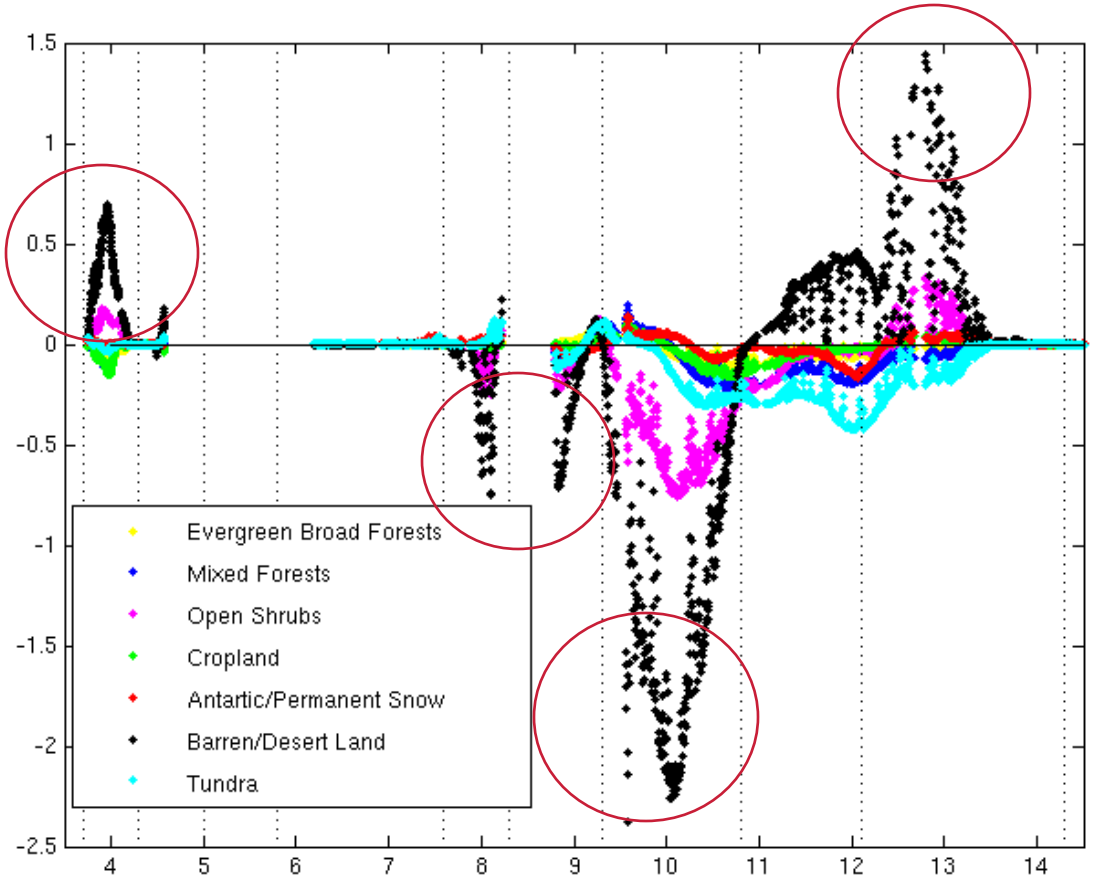


One day global statistics show improvement of AIRS retrieved temperature, moisture and particularly ozone profiles using the UW/CIMSS HSR emissivity algorithm over linear interpolation between the 10 hinge point of UW BF emissivity spectra.

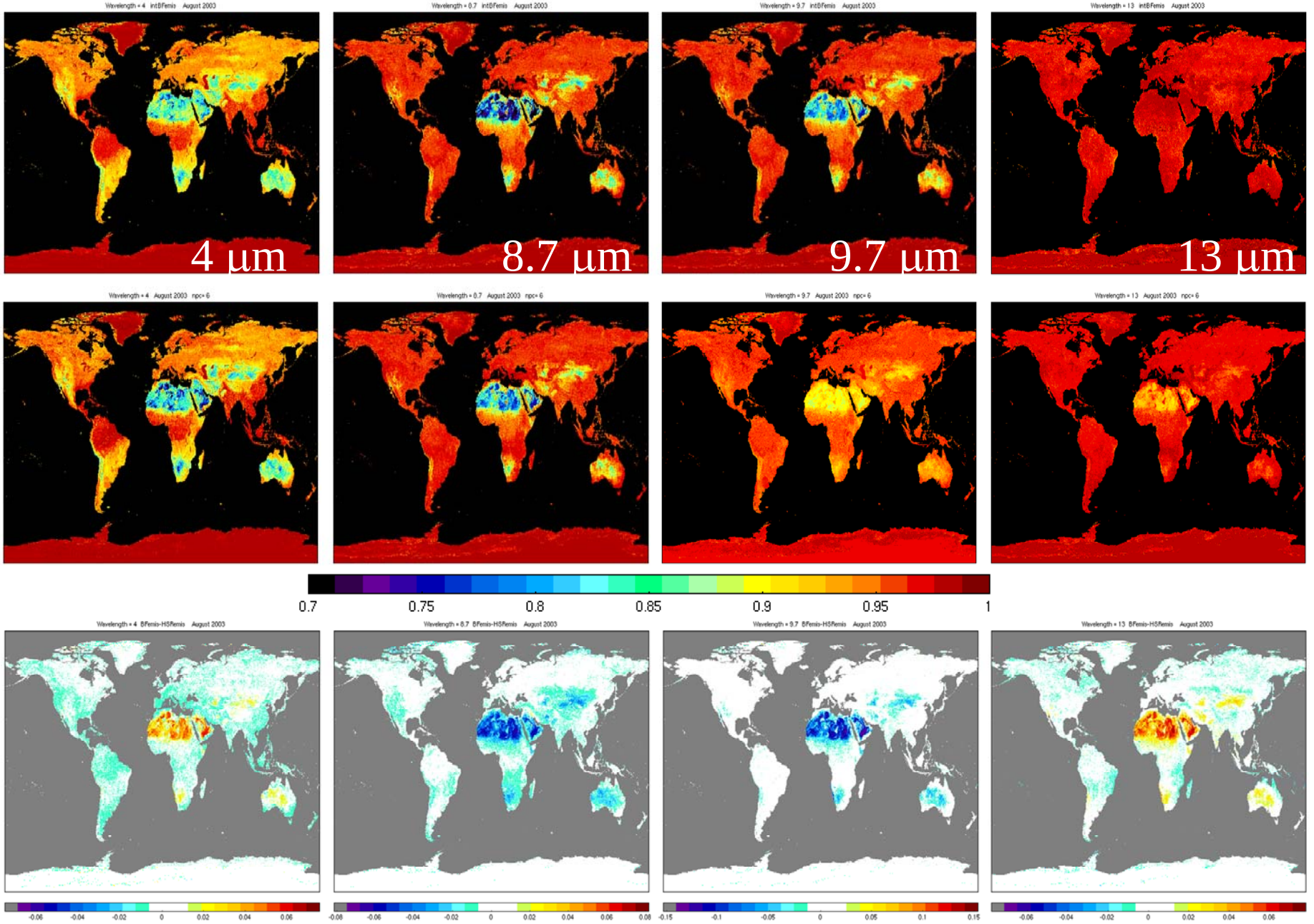
Averaged differences between BF and HSR emissivity spectra of 8583 land SeeBor profiles at 2378 AIRS channels By IGBP land classes



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)

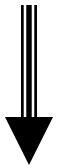


Emissivity comparison:

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

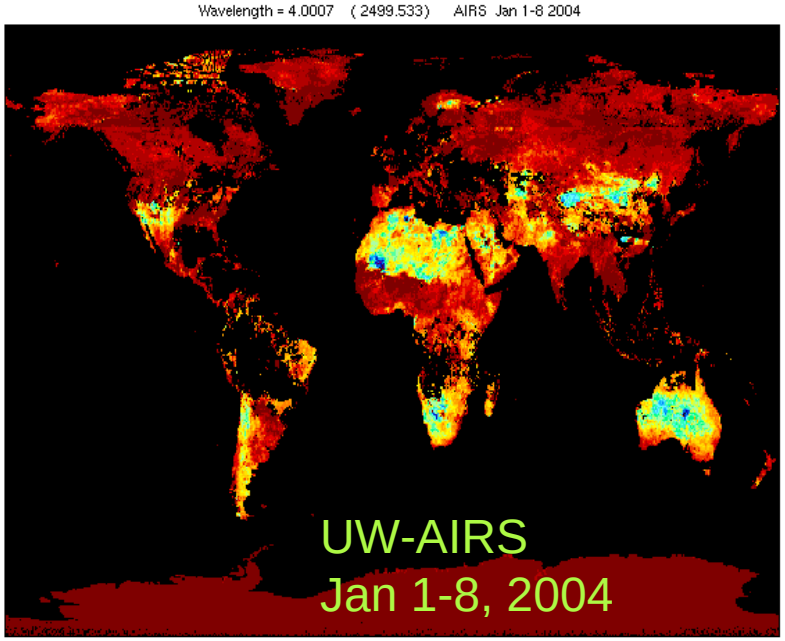
Because the UW HSR/BF emissivity data uses the MODIS MYD11 product as input, HSR/BF emissivity values will be affected by changes in the MYD11 algorithm.

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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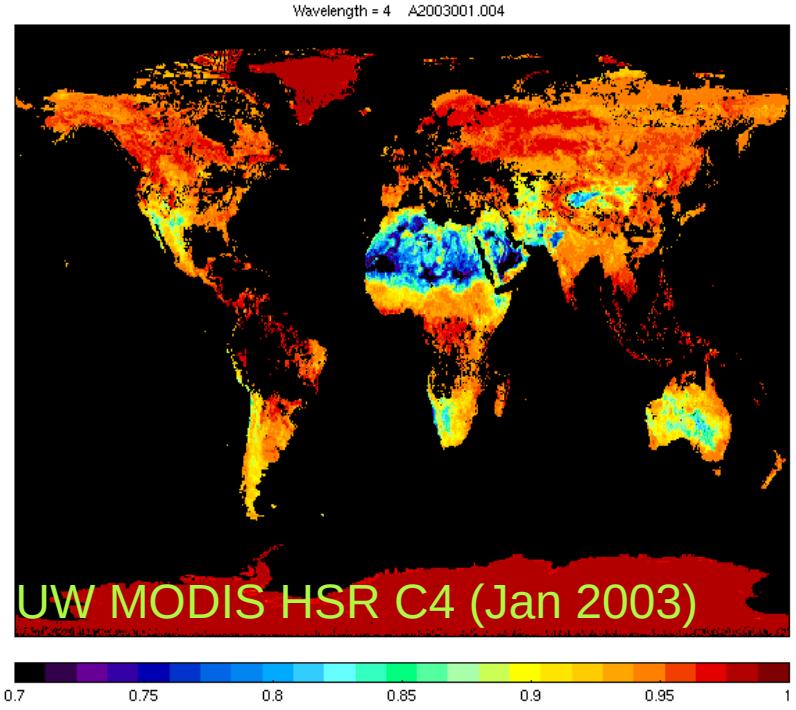
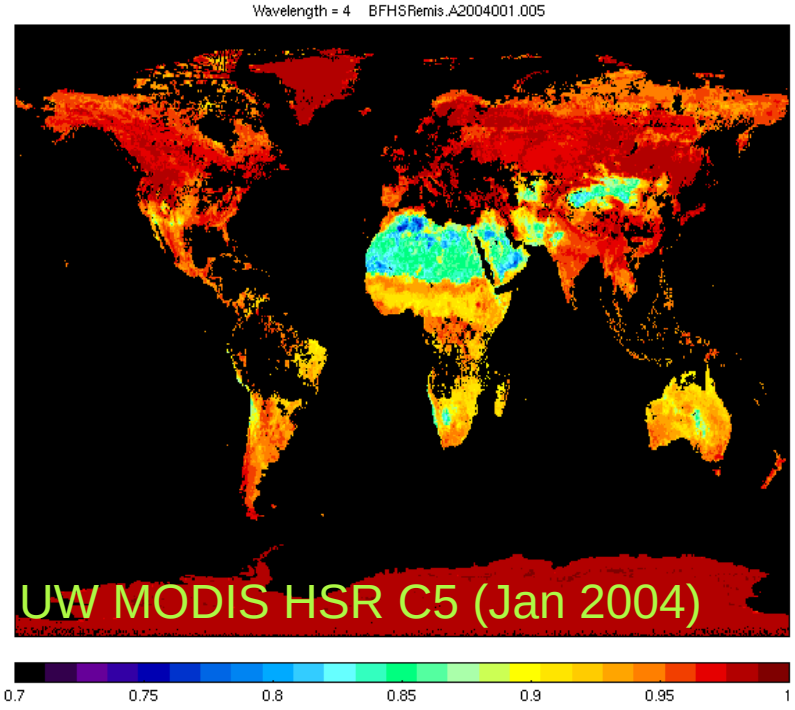
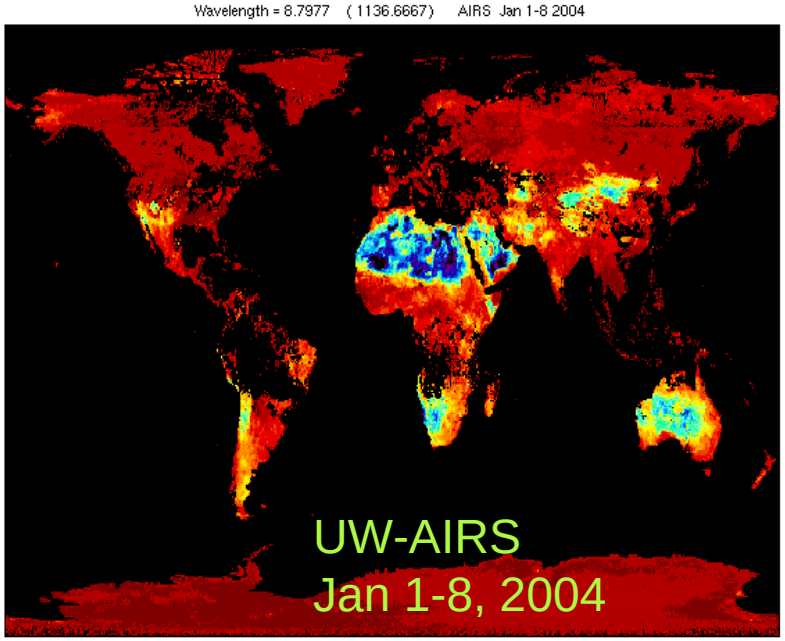
UW-AIRS
Jan 1-8, 2004


Wavelength = 4 A2003001.004
UW MODIS HSR C4 (Jan 2003)
0.7
0.75
0.8
0.85
0.9
0.95
1


Wavelength = 4 BFHSRemis.A2004001.005
UW MODIS HSR C5 (Jan 2004)
0.7
0.75
0.8
0.85
0.9
0.95
1

8.7 μm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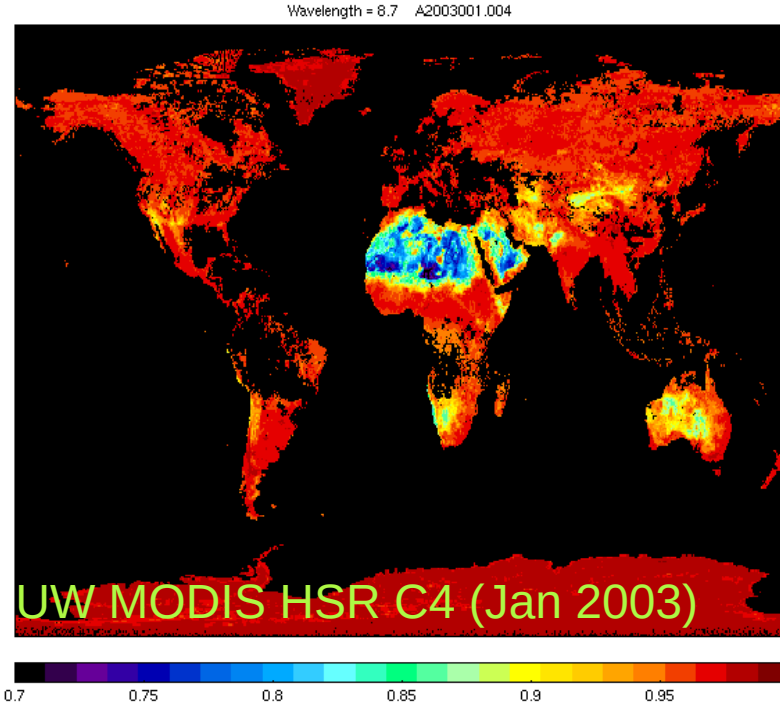
UW-AIRS
Jan 1-8, 2004


Wavelength = 8.7 A2003001.004
UW MODIS HSR C4 (Jan 2003)
0.7
0.75
0.8
0.85
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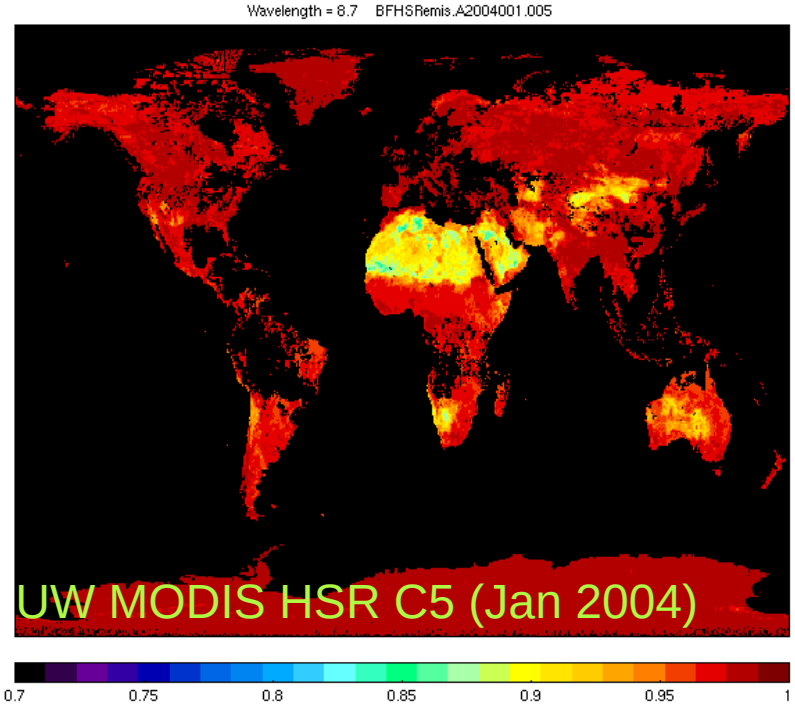
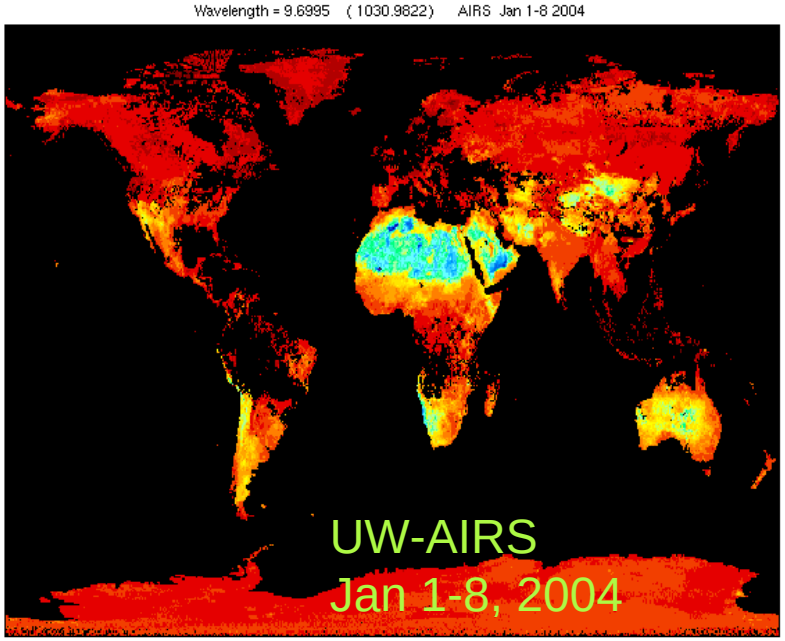
0.95


Wavelength = 8.7 BFHSRemis.A2004001.005
UW MODIS HSR C5 (Jan 2004)
0.7
0.75
0.8
0.85
0.9
0.95
1

9.7 μm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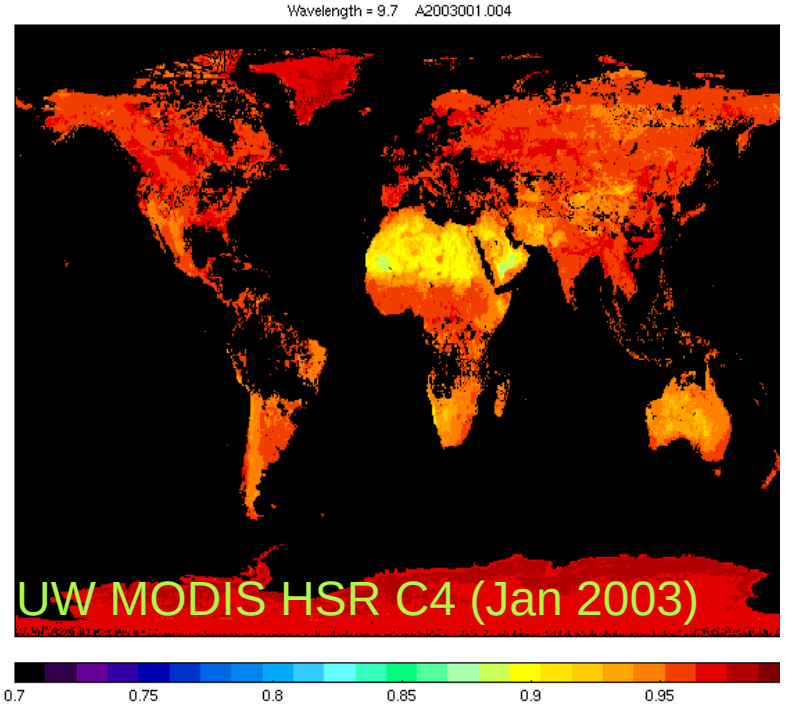
UW-AIRS
Jan 1-8, 2004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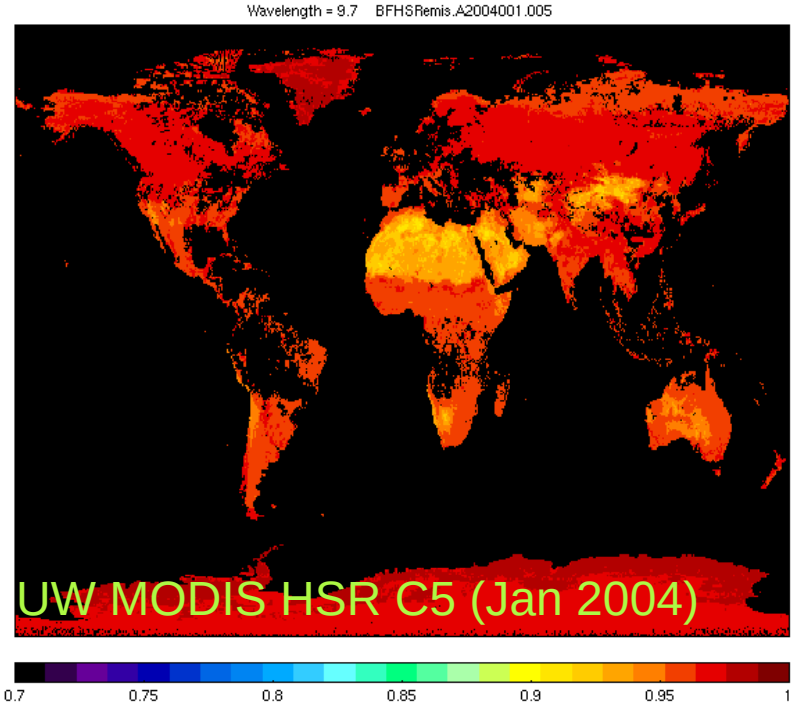
UW MODIS HSR C4 (Jan 2003)
0.7
0.75
0.8
0.85
0.9
0.95


Wavelength = 9.7 BFHSRemis.A2004001.005
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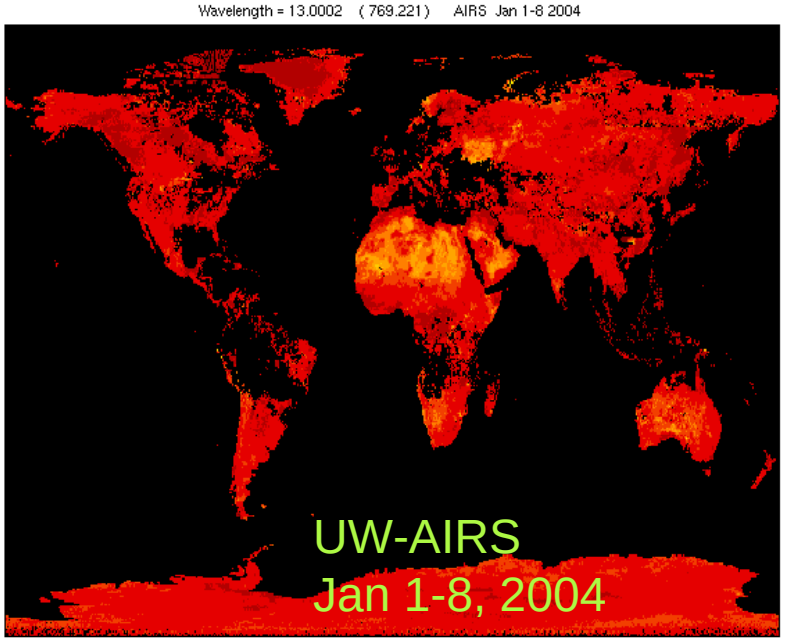
0.7
0.75
0.8
0.85
0.9
0.95
1

13 μm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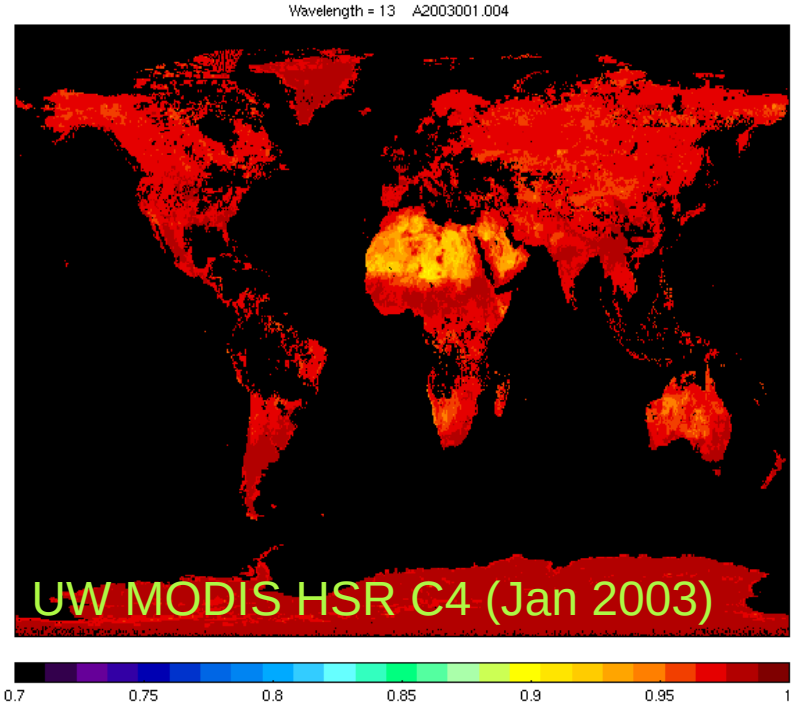
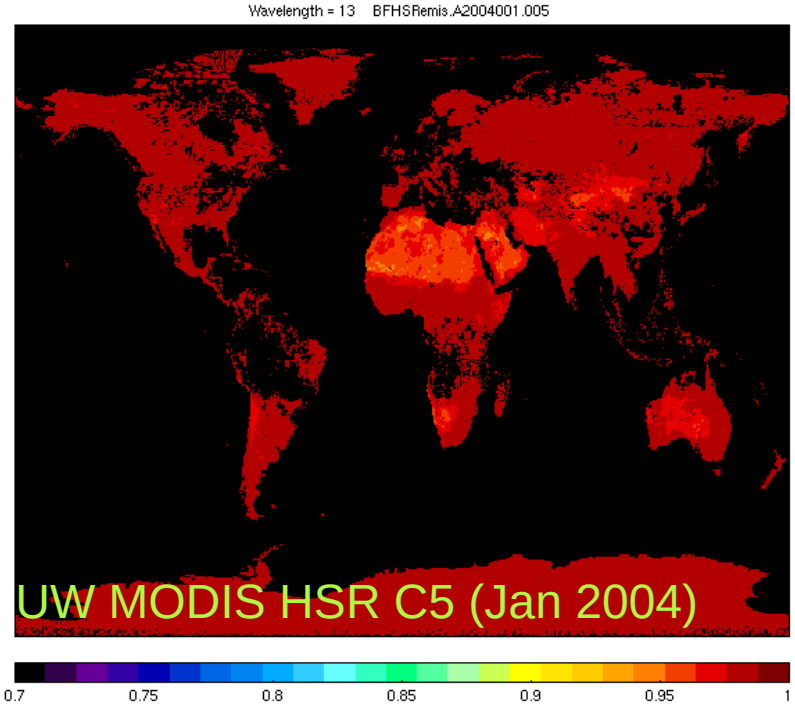
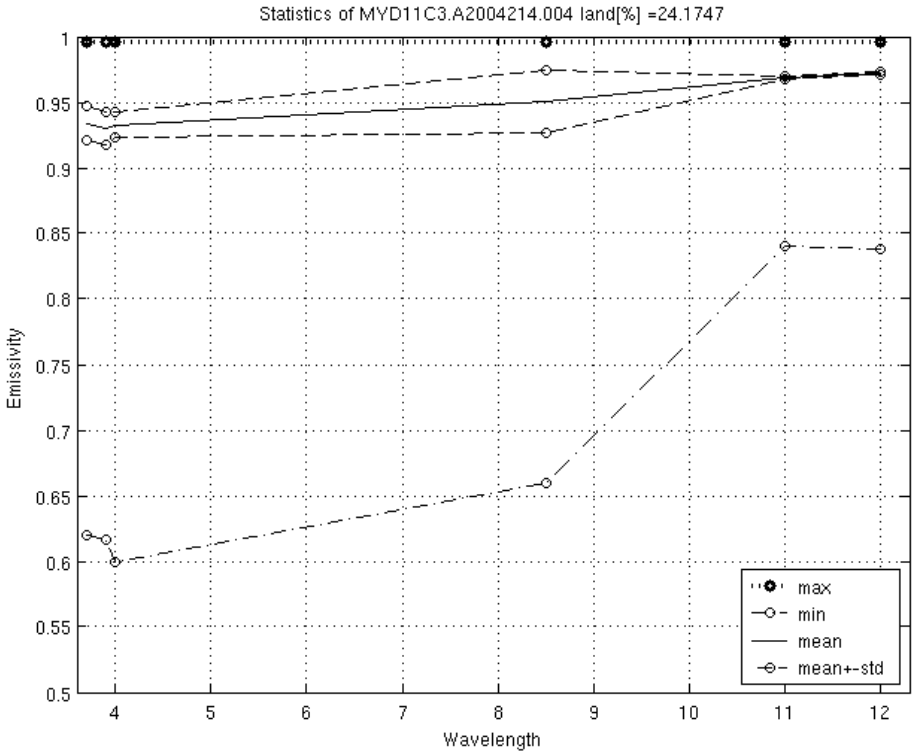
UW-AIRS
Jan 1-8, 2004


Wavelength = 13 A2003001.004
UW MODIS HSR C4 (Jan 2003)
0.7
0.75
0.8
0.85
0.9
0.95
1

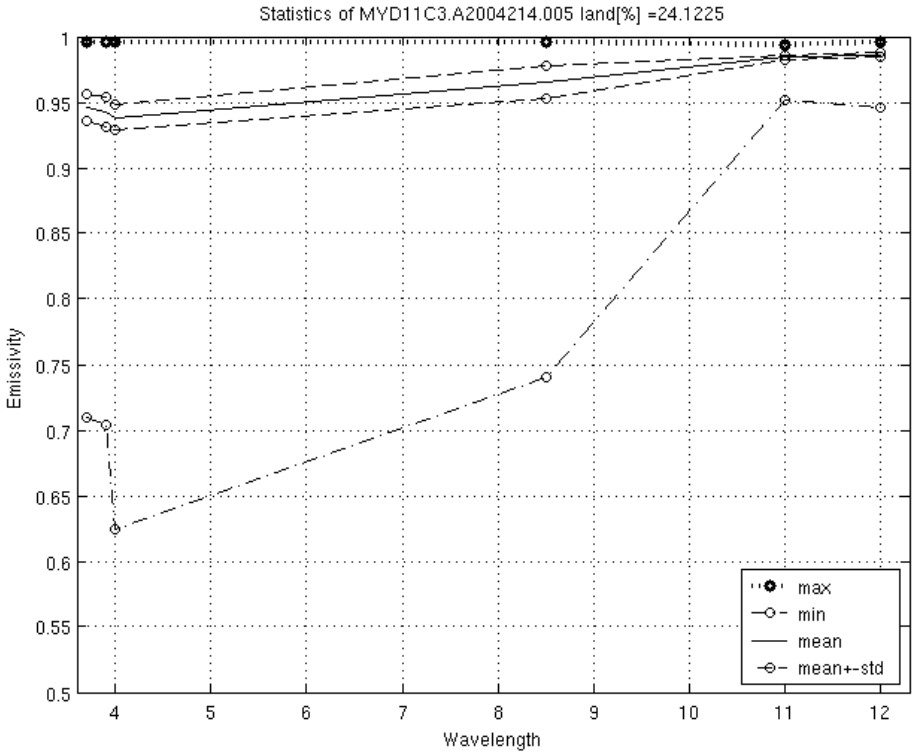

Wavelength = 13 BFHSRemis.A2004001.005
UW MODIS HSR C5 (Jan 2004)
0.7
0.75
0.8
0.85
0.9
0.95
1

Statistical differences between MODIS MYD11 collection 004 and 005 products

004 Aug 2004



005 Aug 2004

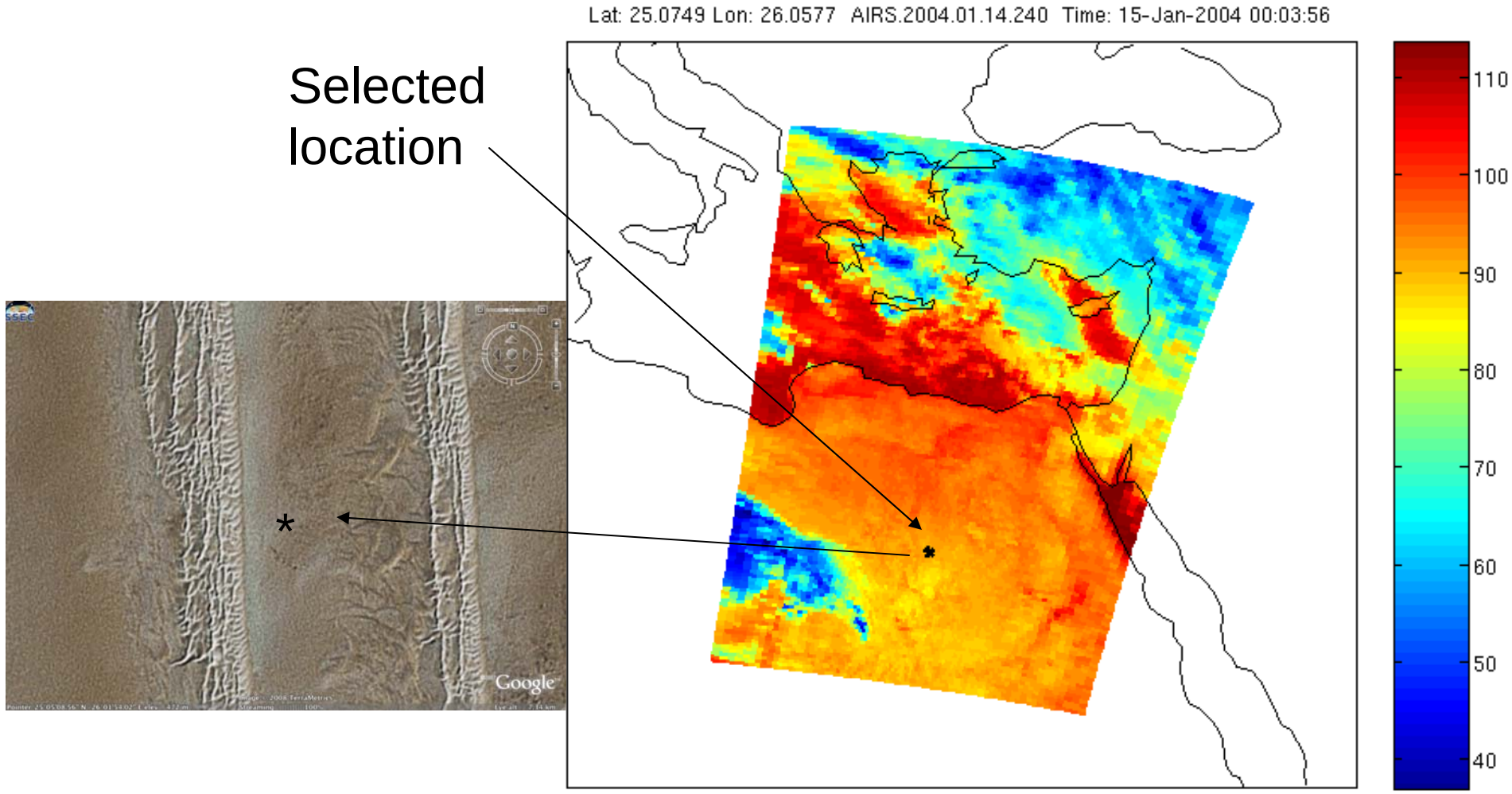


Significant differences:

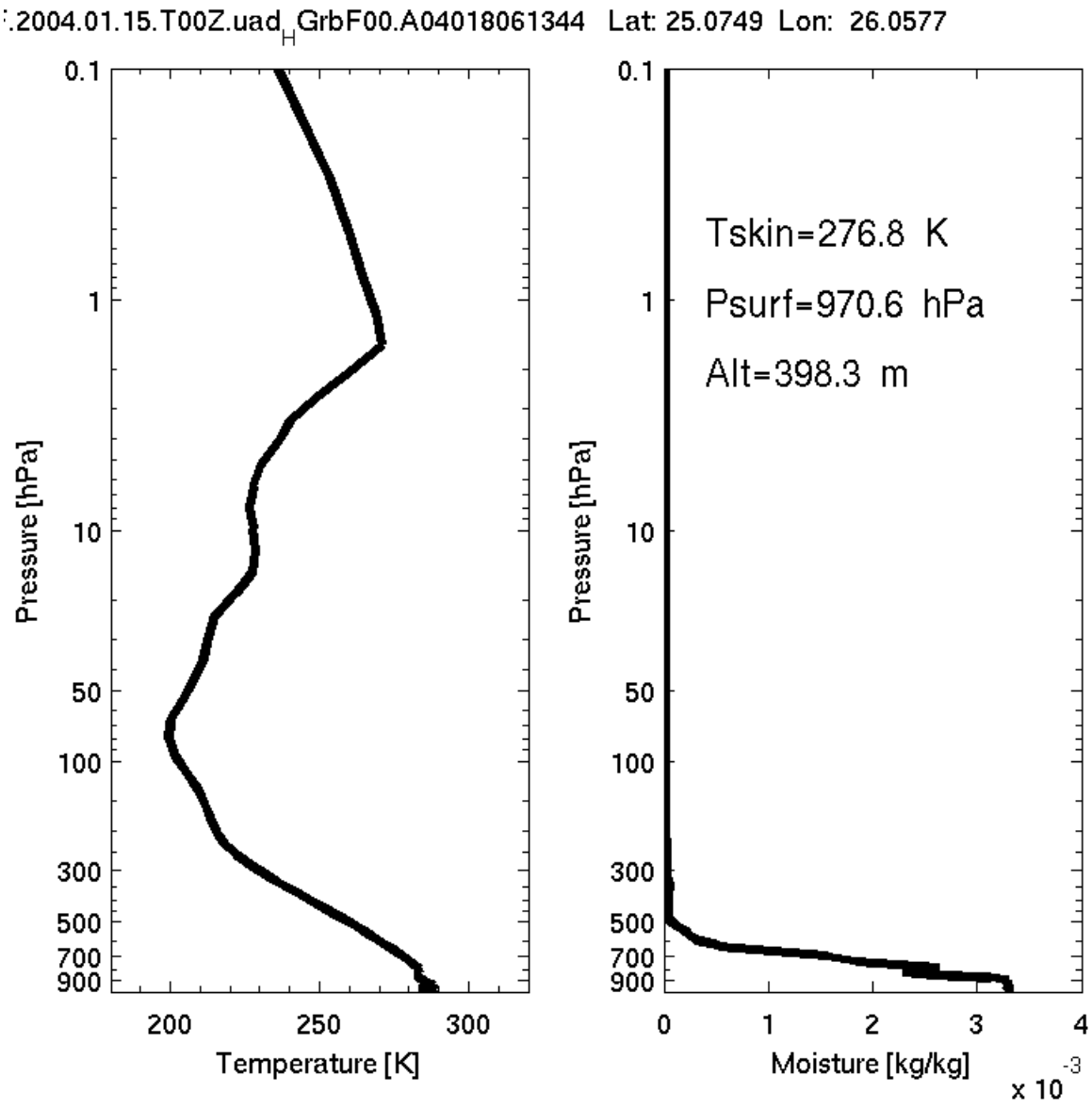
- loss of variability in band 31, 32 (11 and 12 μm)
- An increasing in minimum emissivity for band 20,22,23 and 29 (3.7, 3.9, 4.0 and 8.5 μm) by ~ 0.1

Emissivity Validation
A case study

AIRS granule January 15 2004 00:03 UTC, 12 μm radiances

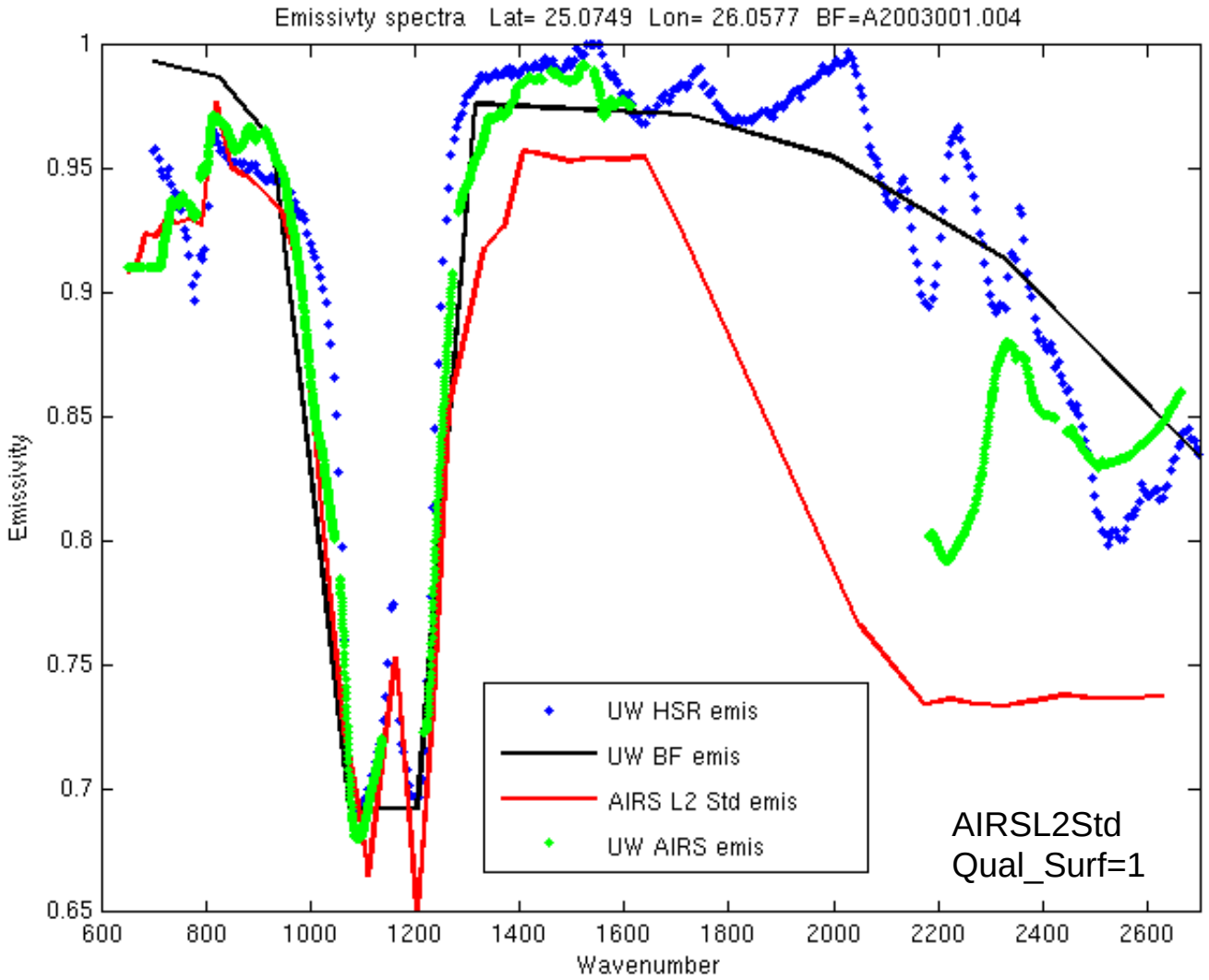


Atmospheric state from ECMWF analyses



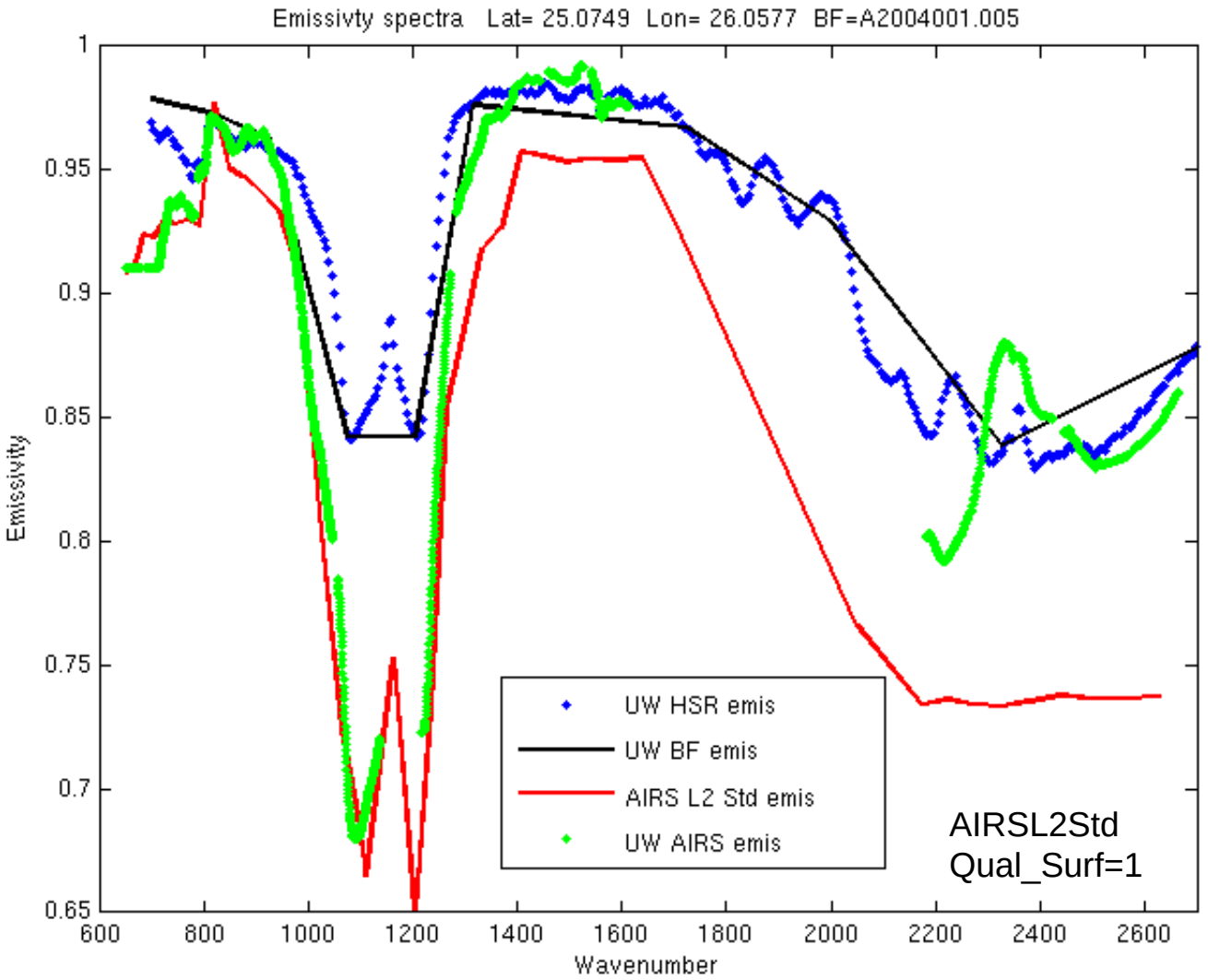
Emissivity

BF (black), HSR(blue) using MYD11 *collection 4*

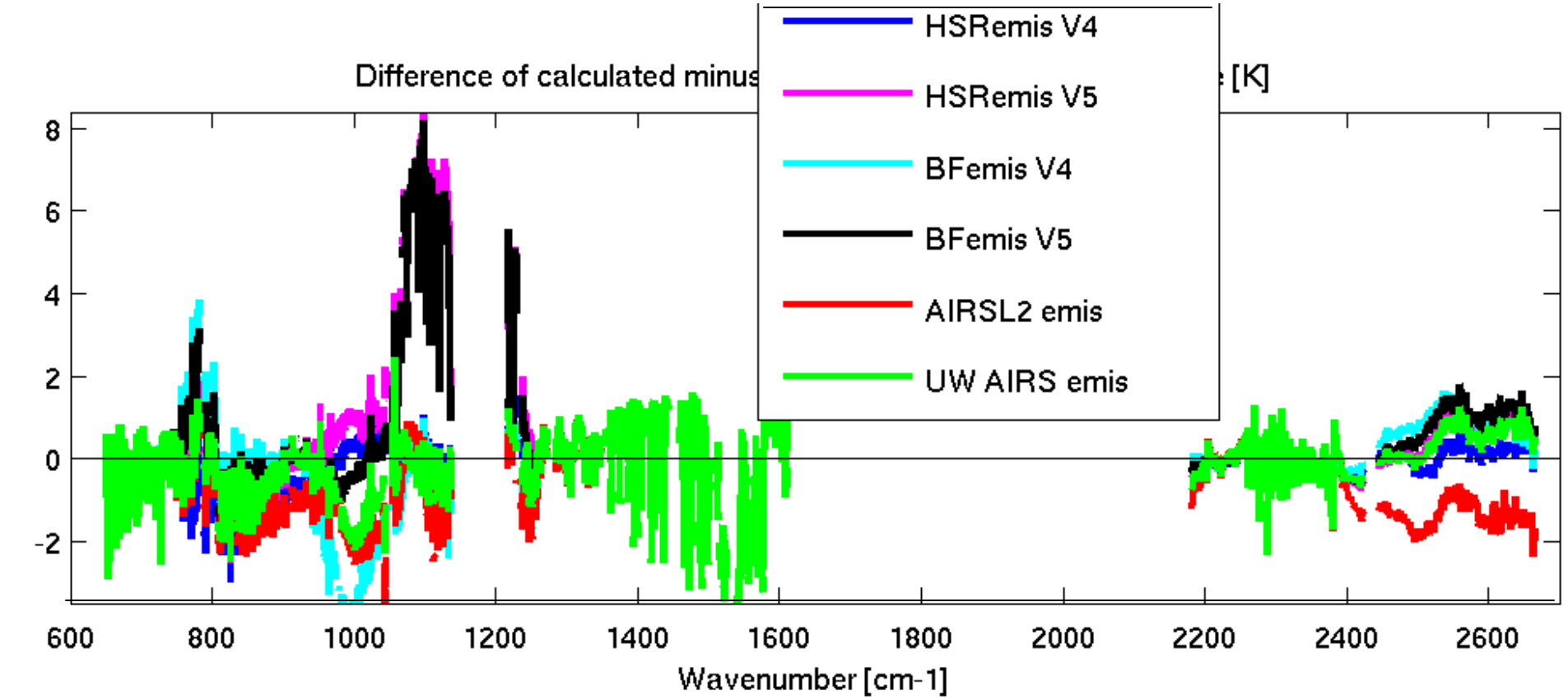


Emissivity

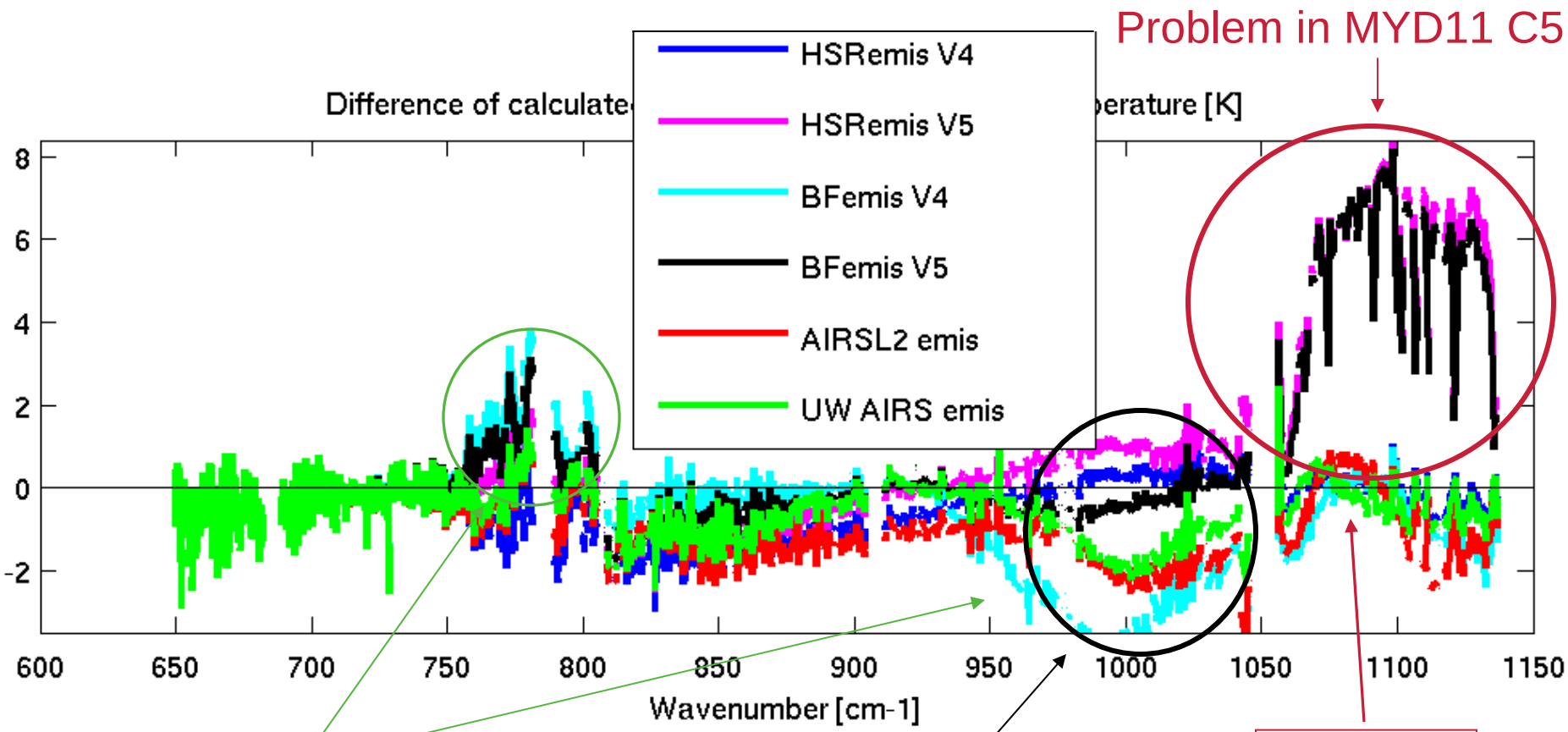
BF (black), HSR(blue) using MYD11 *collection 5*



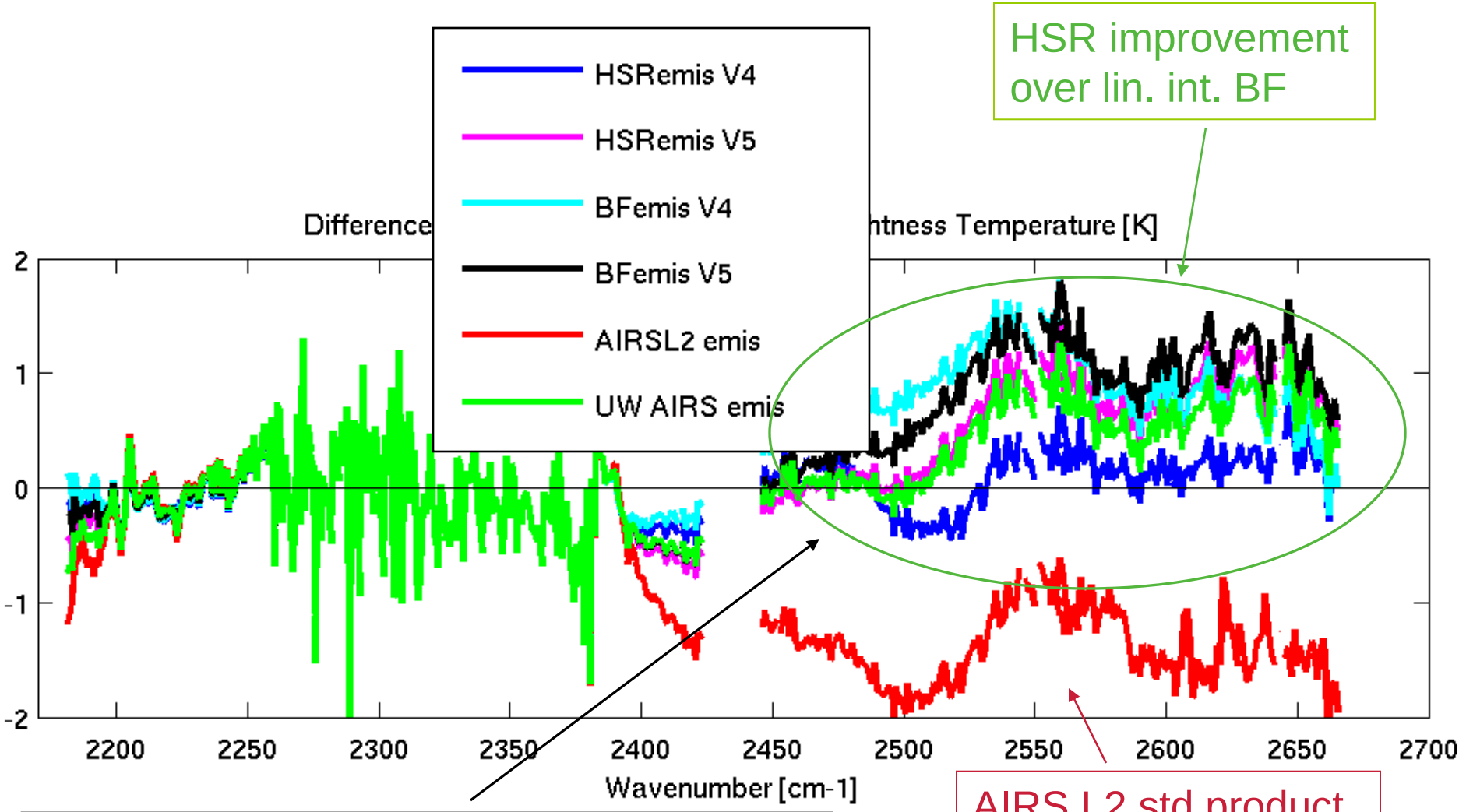
BT Residuals (Calc - Obs) (using Sarta V1.07)



BT Residuals (Calc - Obs) (LW)



BT Residuals (Calc - Obs) (SW)



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/***
- 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, 16th, 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.