Recent updates and validation of the UW/ CIMSS high spectral resolution global IR land surface emissivity database

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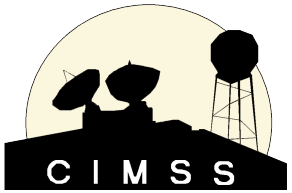
2nd Emissivity Workshop, Toulouse, France, Jun 9-11, 2009



Outline

1. UW/CIMSS Global IR Land Surface Emissivity Database (UWiremis database)

   - 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

2. Validation
   - Comparison to other emissivity datasets: NAALSED (ASTER), Jaivex ARIES

   - Comparison on the UWiremis BF vs Uwiremis HSR emissivity data
   - Dependence on MODIS/MYD11 emissivity products: Collection 4 vs 5

3. Conclusions, Recommendations

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

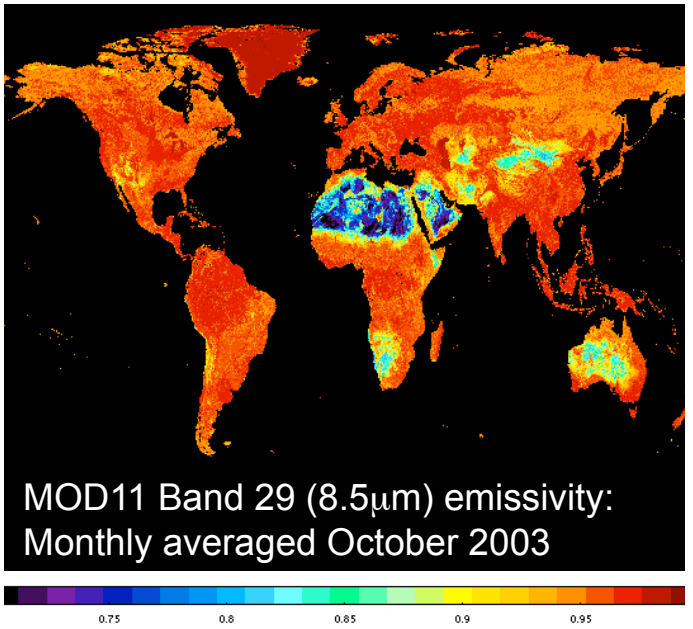
We need:

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 3.7 and 14.3 μm:

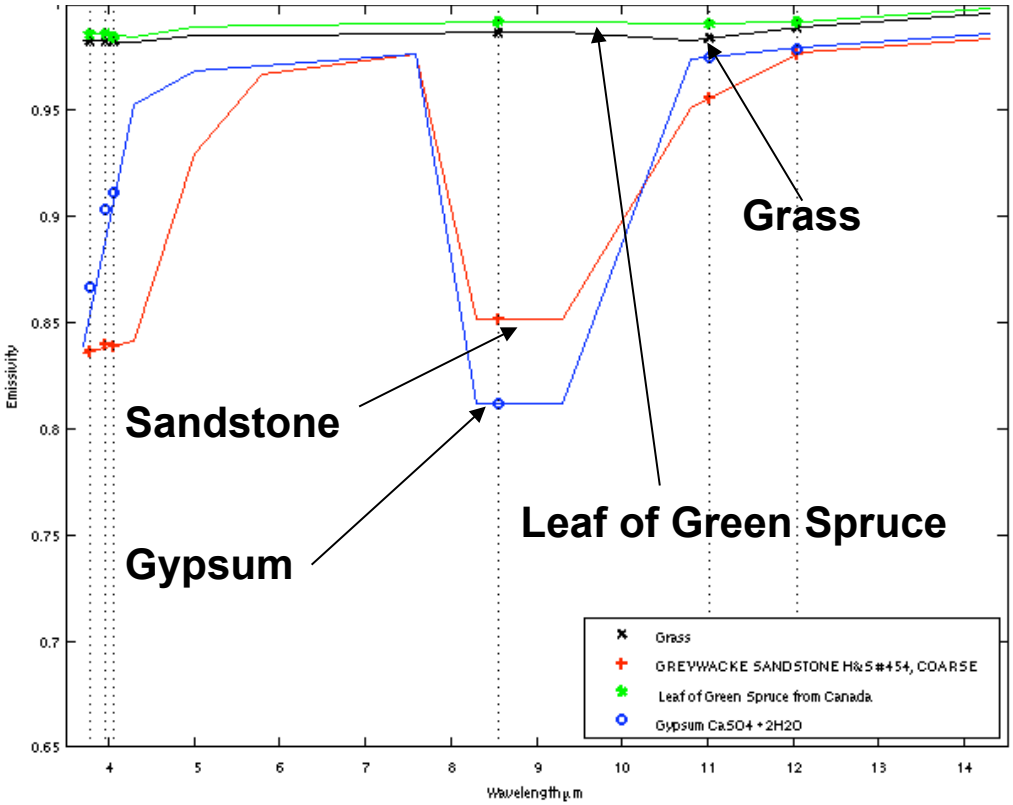
3.7, 4.3, 5.0, 5.8, 7.6, 8.3, 9.3, 10.8, 12.1 and 14.3 μm

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

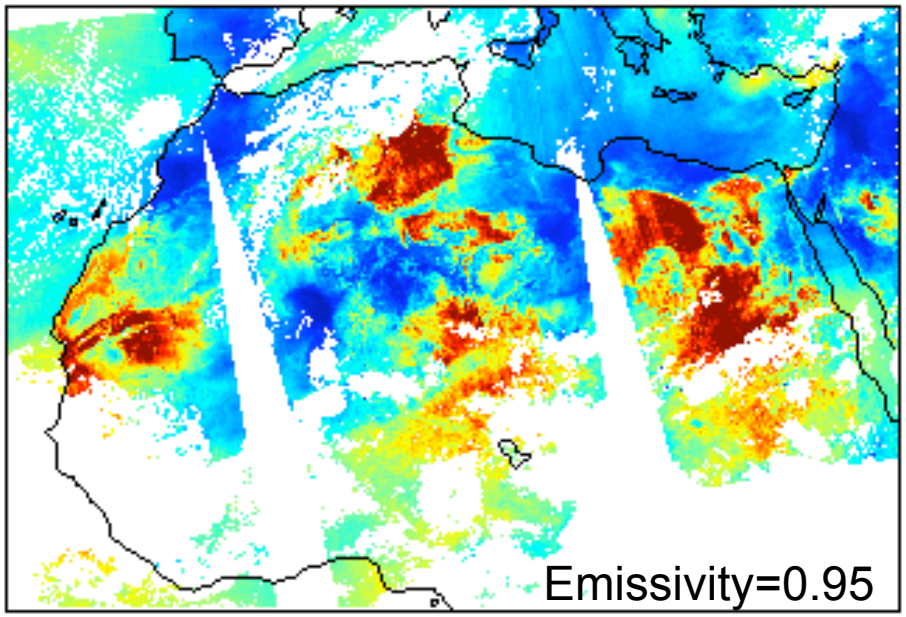
•**Result:** a monthly global emissivity
•database at 10 wavelengths with 0.05 degree spatial resolution.

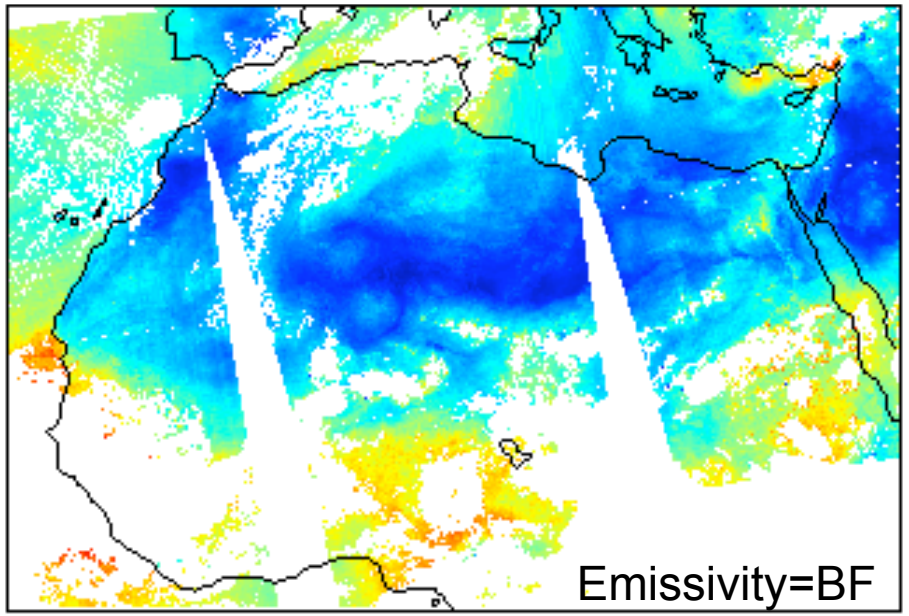
•**Reference:**

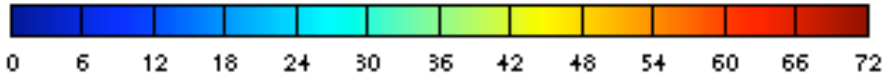
Suzanne W. Seemann et al., 2008: J. Appl. Meteor. Climatol., Vol. 47, 108-123.

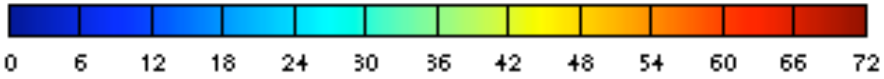


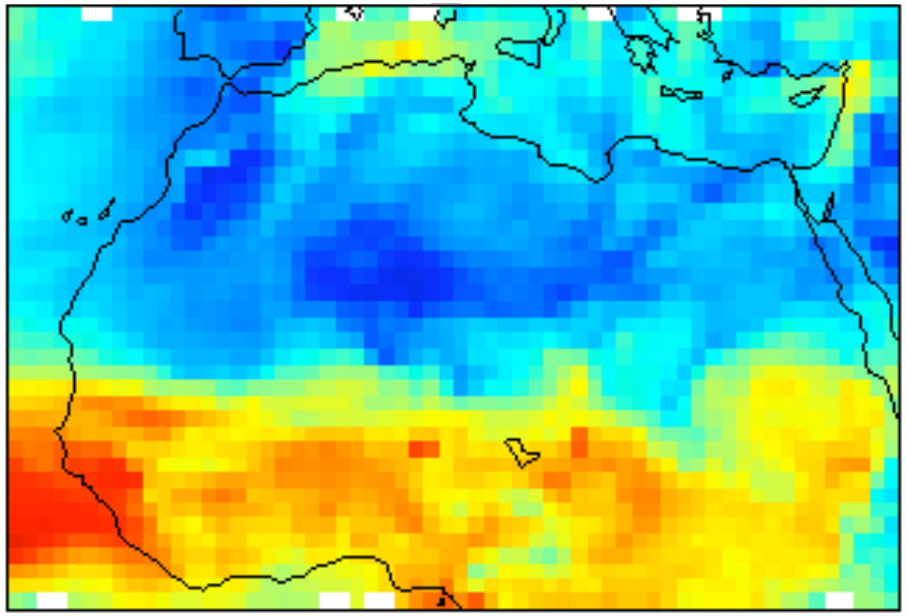
Application: MOD07 TPW on 1 Aug 2005 at 2000 - 2320 UTC



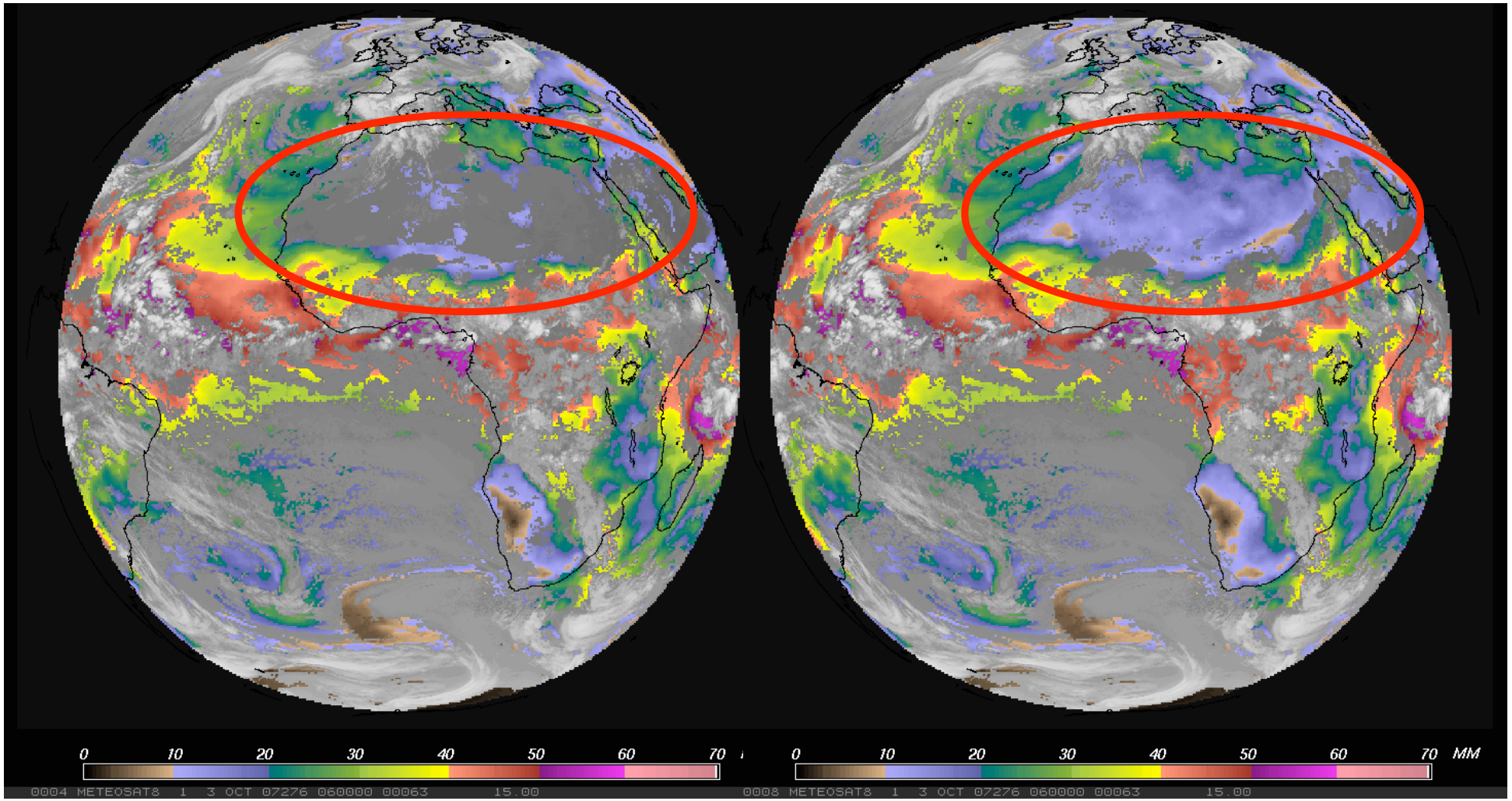








NCEP GDAS TPW,
2 Aug 2005, 00 UTC



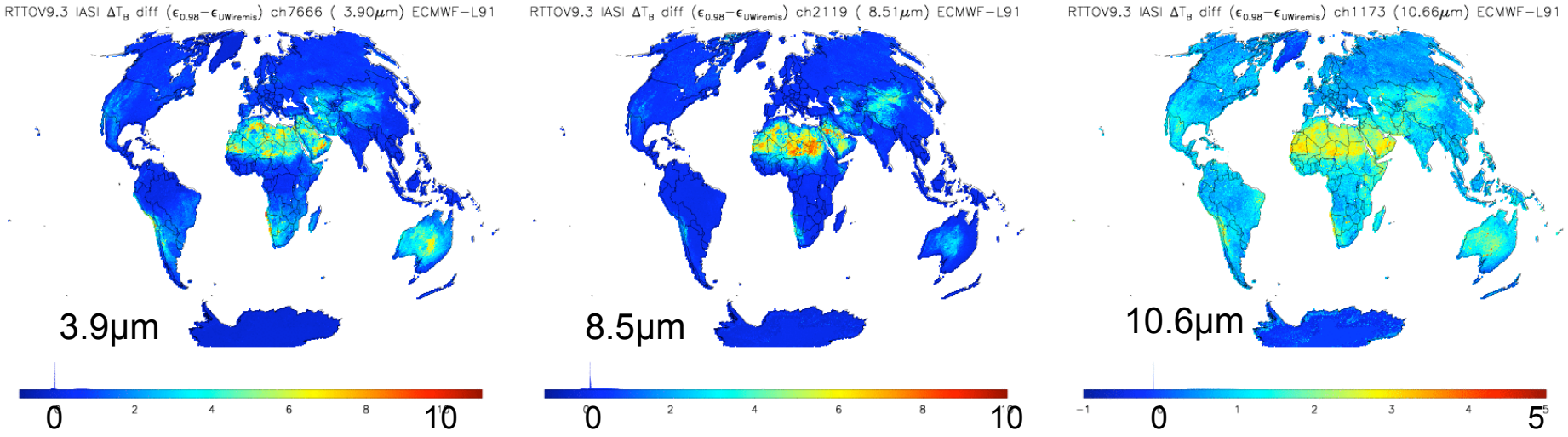
MSG SEVIRI retrieved TPW product coverage for a uniform spectral emissivity (=0.95 left) and for the spectral emissivities taken from the UW/CIMSS BF emissivity database (right). Note the bad coverage, i.e. non-successful retrievals, over the large desert areas. (03 October 2007, 0600 UTC, box size is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

EUMETSAT NWP-SAF: Associate Scientist mission

Title: Provision of RTTOV interface for land surface infrared emissivity

- **Objective**: To provide an improved estimate and associated error of land surface emissivity for infrared radiometers for input to RTTOV (v9 and later).
- **Participants**: Roger Saunders (UKMO), Benjamin Ruston (NRL), Eva Borbas (UW/CIMSS)
- **End of mission**: Fall 2009 , official release in RTTOV10

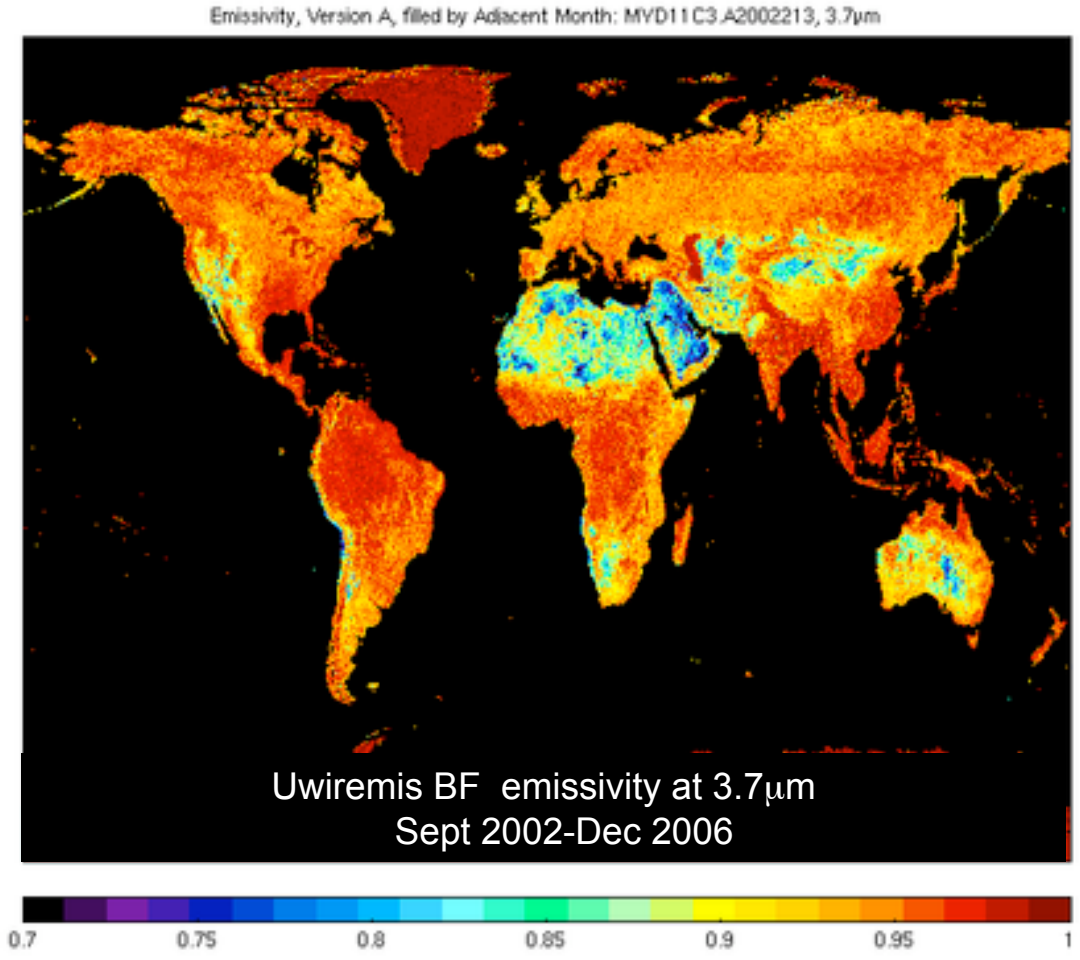


Calculated IASI brightness temperature differences at 3.9 (left), 8.5 (middle) and 10.6 μm (right) on Jan 15 2008. The simulation was made using the default land IR emissivity value of 0.98 and using the UWiremis values.

UW Global Infrared Land Surface Emissivity Database (Uwiremis Baseline Fit (BF) emissivity)

- Available: ***http:/cimss.ssec.wisc.edu/iremis*** *(over 100 registered users since Sept 2006)*
- Time coverage: Oct 2002 - Dec 2006 - 4 years (version 2)
- Oct 2002 –Oct 2008 - 6 years (version 3)
- Format: netcdf
- Size: ~40 Mb compressed / month
- Filling flag info
- Resolution: 0.05 degree ~ 5 km

Applications/Users :
MODIS Atmospheric Retrievals (UW,NASA)
IMAPP/AIRS retrievals (UW)
GEOCAT (NOAA/CIMSS)
Climate Monitoring SAF (EUMETSAT)
AIRS Retrieval of Dust Optical Depths (UMBC/ASL)
IASI-Metop Cal/Val (CNES, France)
IASI retrieval (EUMETSAT, UW, Neteo-France))
Retrieval of hot spot data from AATSR (ESA)
Energy balance from ASTER over glacier (Univ of Milan)
*AIRS trace gas retrieval (*Stellenbosch University, South-Africa, JCET-UMBC)
Education (Seoul National Univ.; NTA, Konstantin)
SEVIRI water vapor retrievals (UW, EOS)
SEVIRI aerosol retrieval (Univ Oxford)
SEVIRI cloud and ozone retrieval (EUMETSAT)
SEVIRI cloud phase, cloud top parameter retrievals (KNMI)
LST retrievals from GOES-R (NOAA NESDIS)
OSS calculations (AER)
AIRS NWP model assimilation (UKMO)



UWiremis High Spectral Resolution database: UWiremis BF emissivity DB + PC regression algorithm

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

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

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

$\vec{c}$ 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 3.7 to 14.3μm.

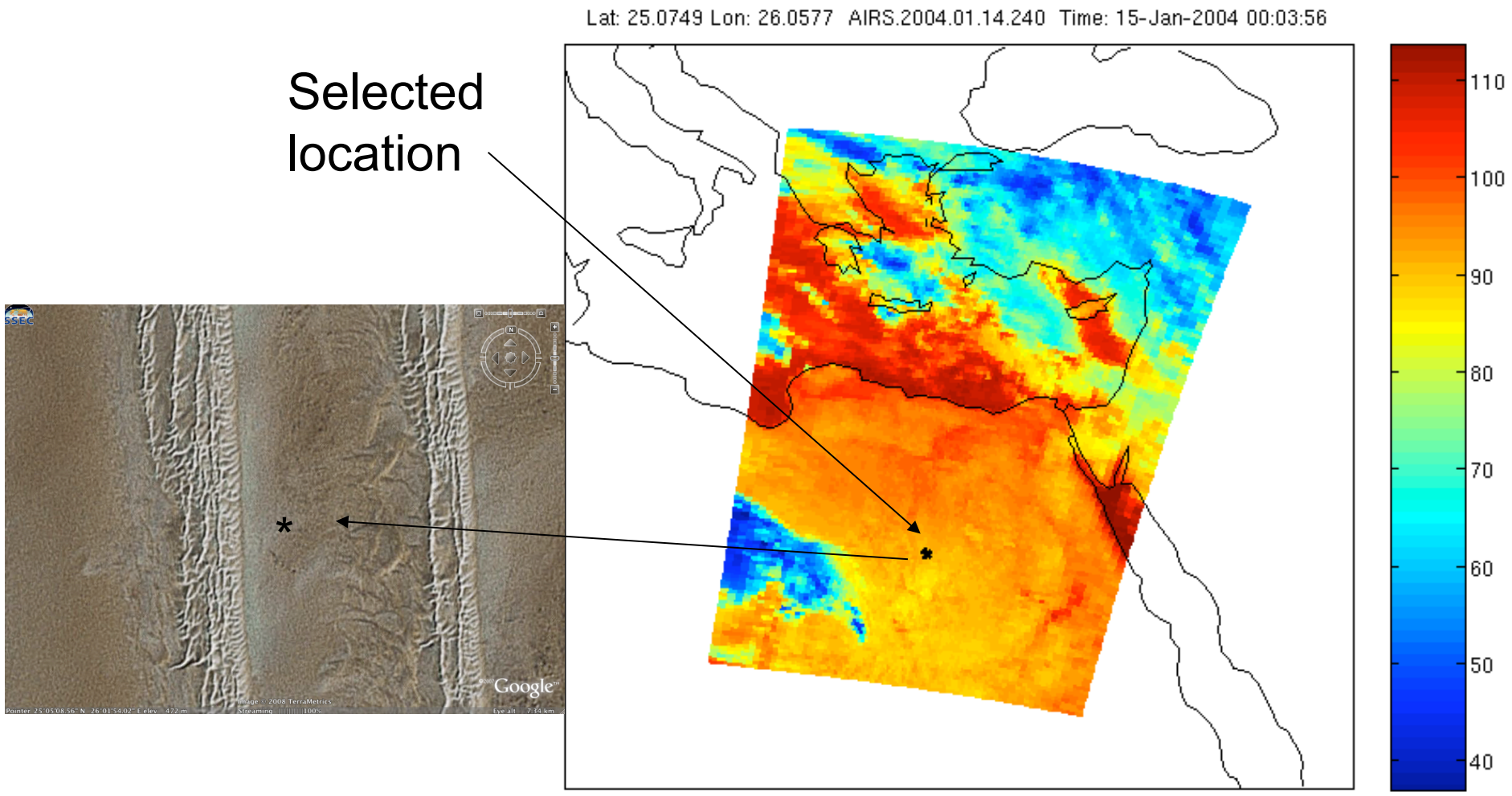
- Accuracy depends on
  - UWiremis BF emissivity DB and MODIS MYD11 data
  - Set of laboratory spectra (current version contains 123 selected lab spectra on 5 wavenumber [cm^{-1}] spectral resolution)

- Output: emissivity spectra with 416 spectral points between 3.7 and 14.3 μm

HSR emissivity algorithm (matlab, fortran90) includes Uwiremis BF DB reader, beta-tested by scientists from NRL-Monterey, EUMETSAT CIMSS, NASA

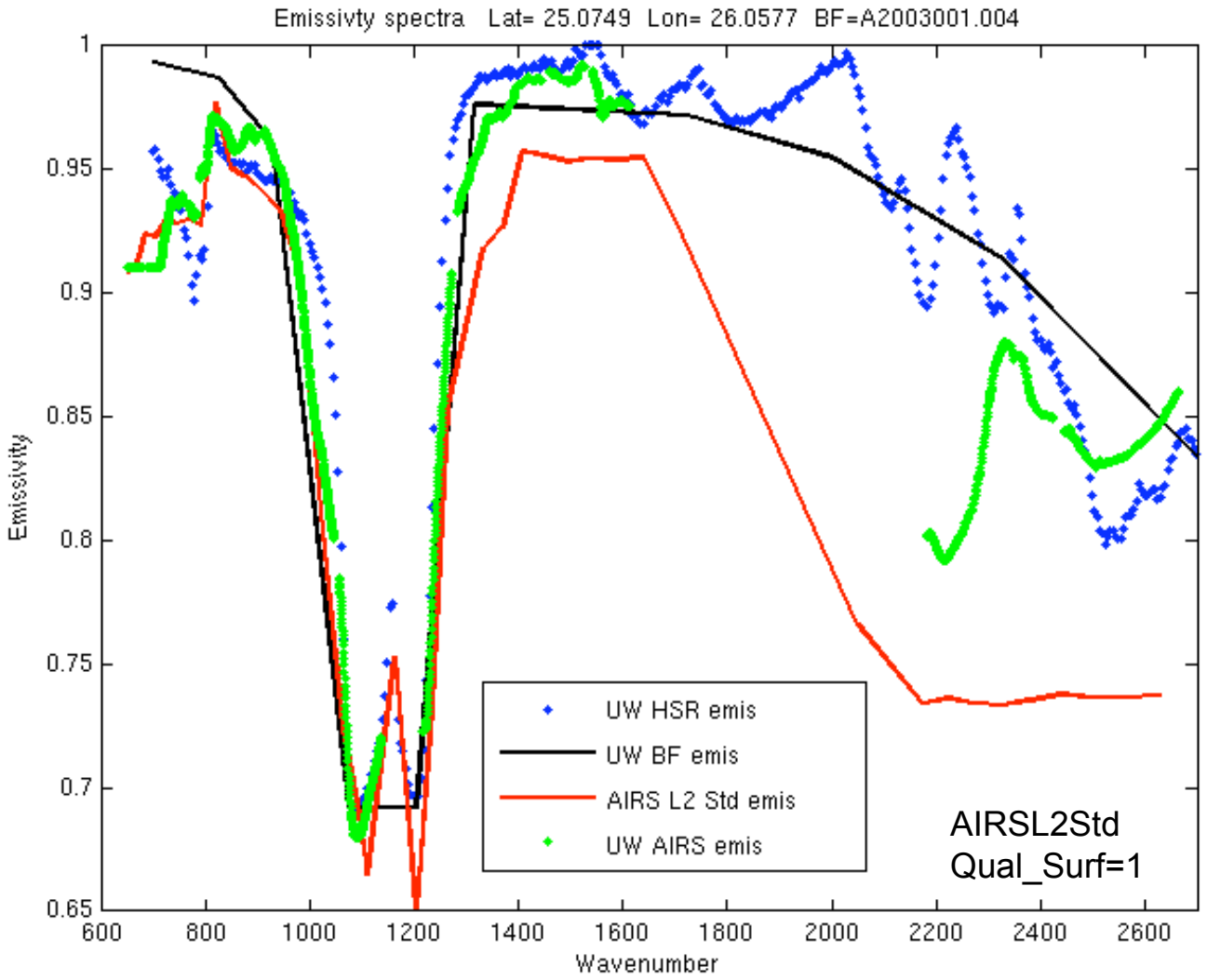
Emissivity Validation
A case study

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



Emissivity

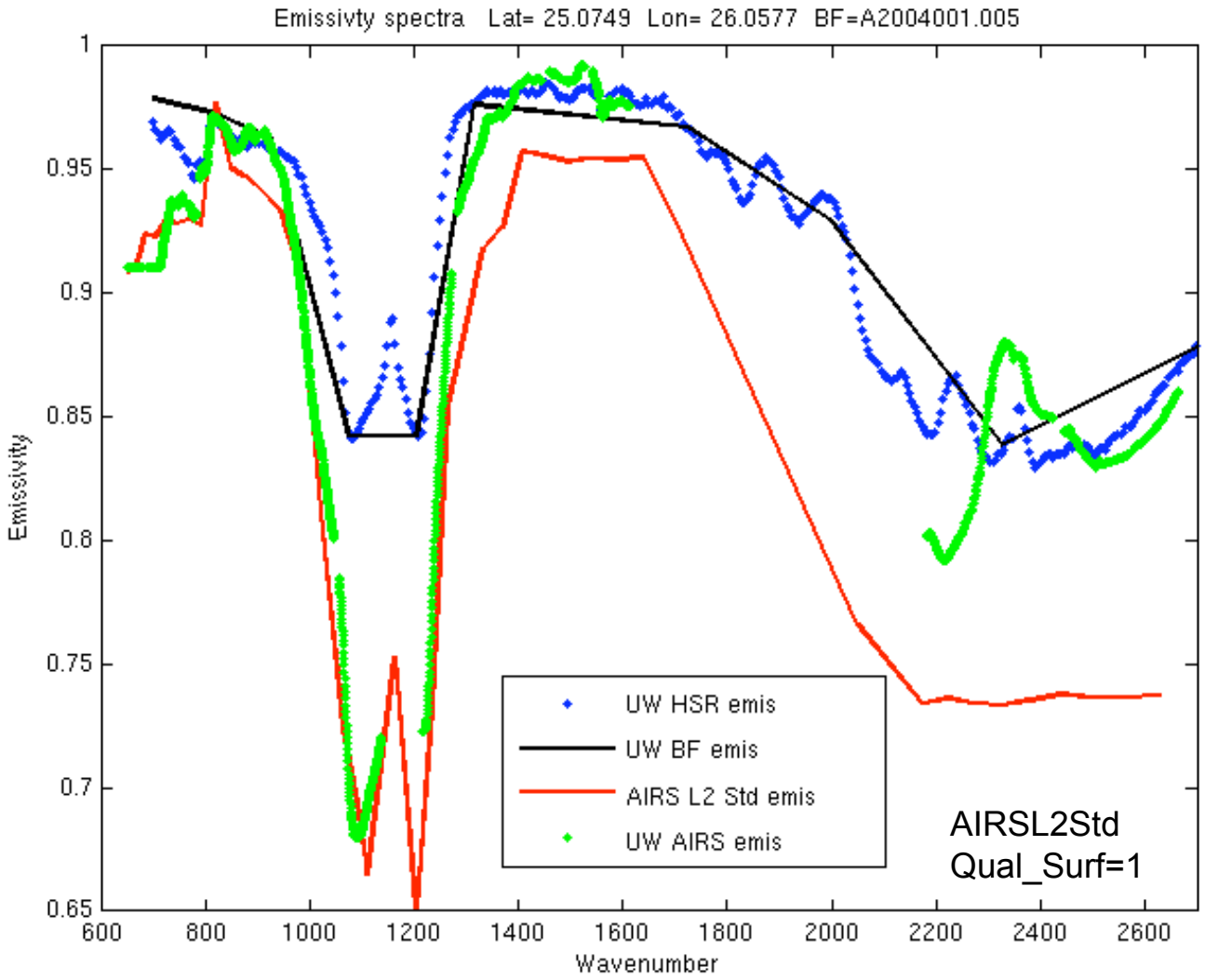
BF (black), HSR(blue) using MYD11 *collection 4*



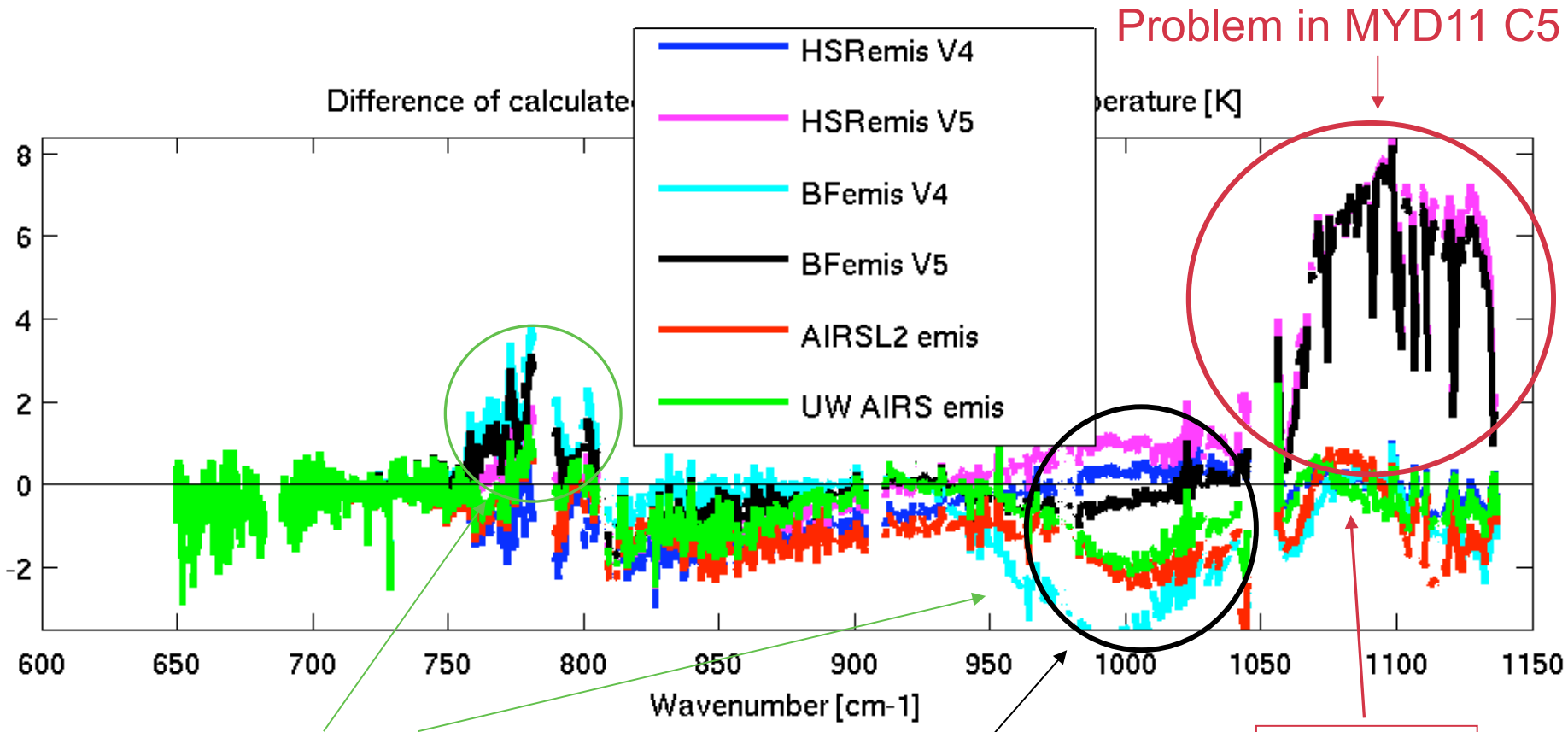
Jun Li's Poster

Emissivity

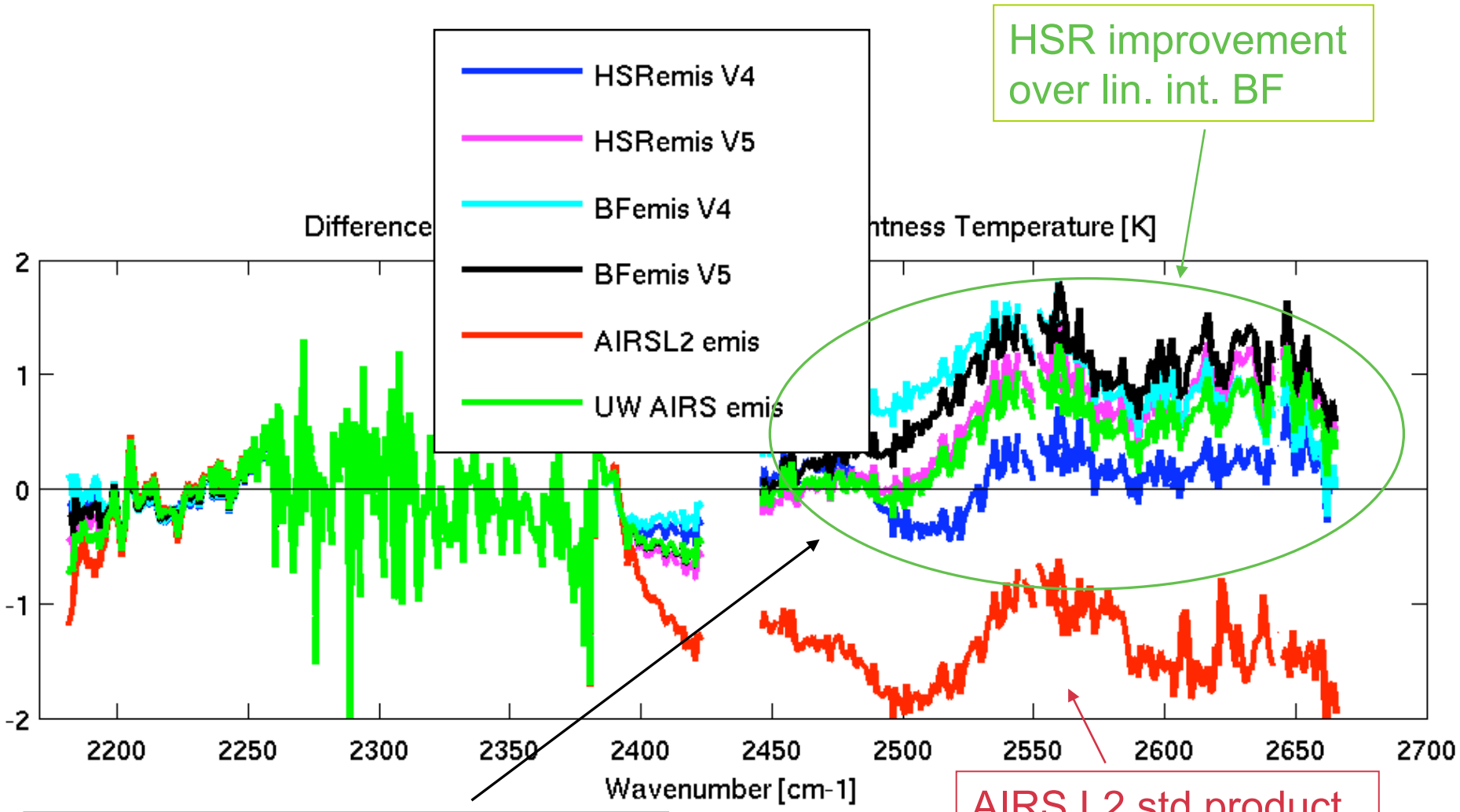
BF (black), HSR(blue) using MYD11 *collection 5*



BT Residuals (Calc - Obs) (LW)



BT Residuals (Calc - Obs) (SW)



HSR improvement over lin. int. BF

Some improvements of C5 vs C4

AIRS L2 std product underestimates emissivity in SW

Comparison of ASTER and UWiremis database

NAALSED (ASTER) DB: North-America

Mean and standard deviation of emissivity for

Winter (Jan-Feb-Mar) and Summer (Jul, Aug, Sep)

over 2000-2008 time period.

Band: 8.3, 8.6, 9.1, 10.6 and 11.3 μm

Spatial Resolution: 100m, 1km, 5km, 50km

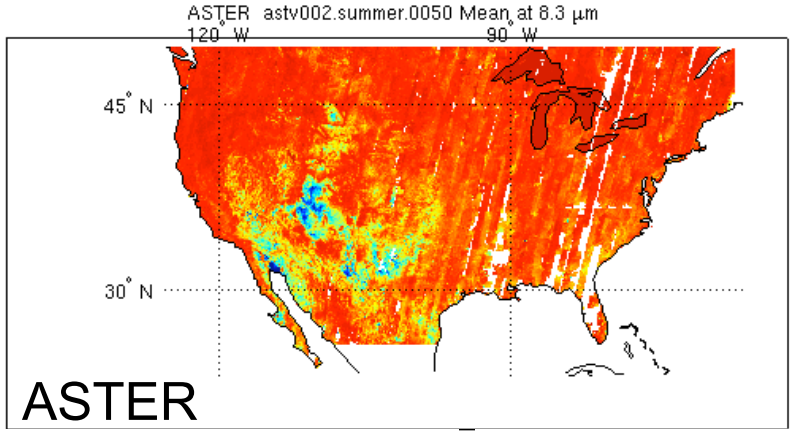
UWiremis MODIS-based DB: Global

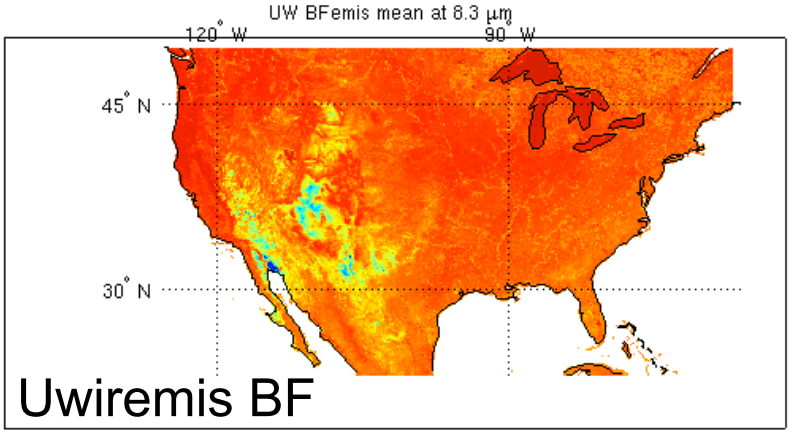
BF and HSR emissivites were interpolated into the ASTER bands and averaged for wintertime and summertime over the 2003- 2006 time period

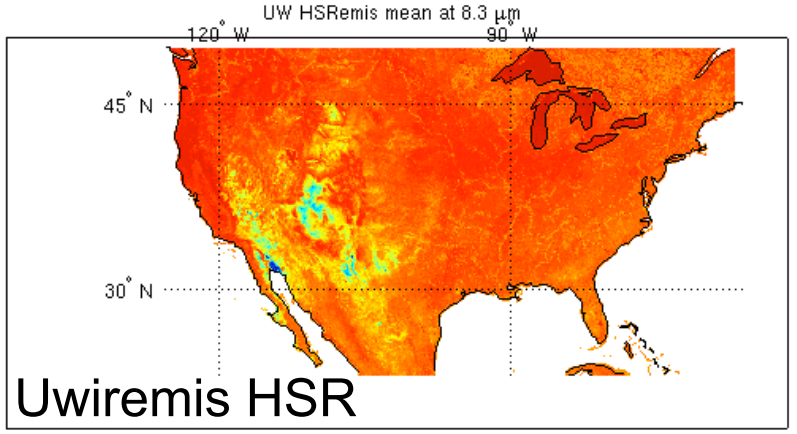
BF hinge points: 8.3, (9.3), 10.8, 12.1 μm

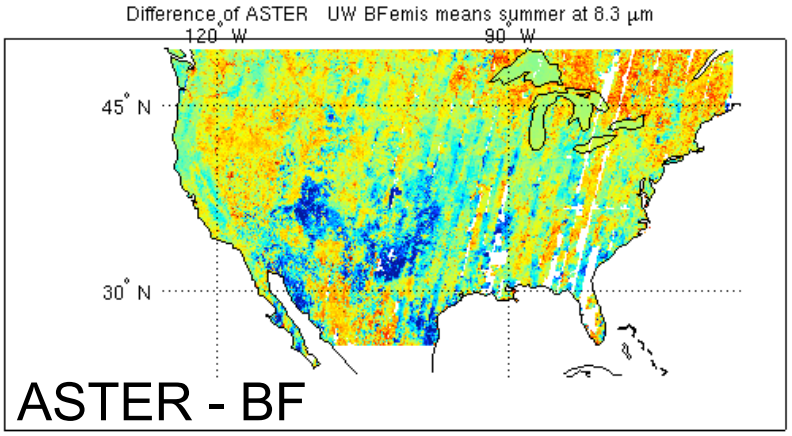
Spatial Resolution: 5km

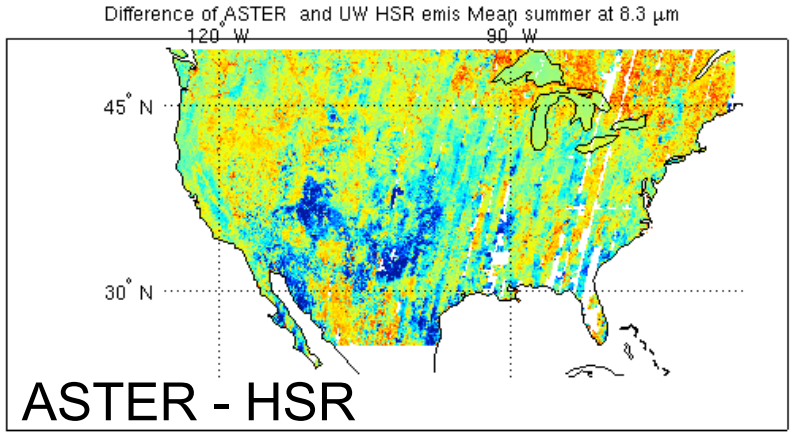
Summertime Mean Emissivity at 8.3 µm



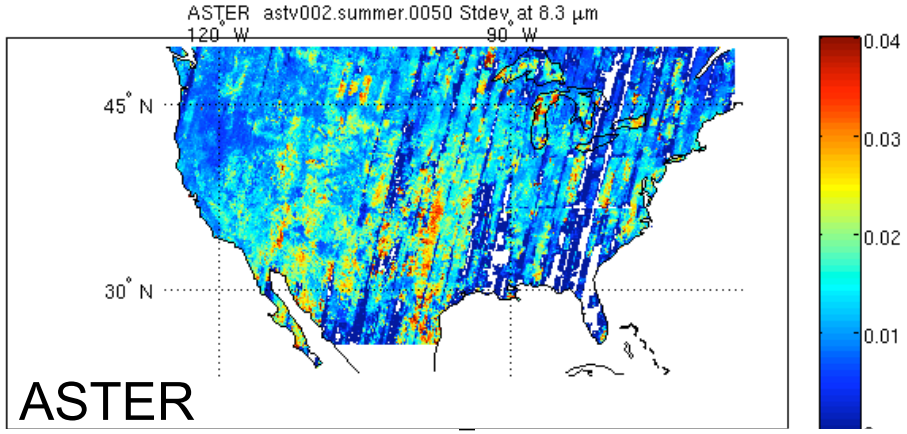


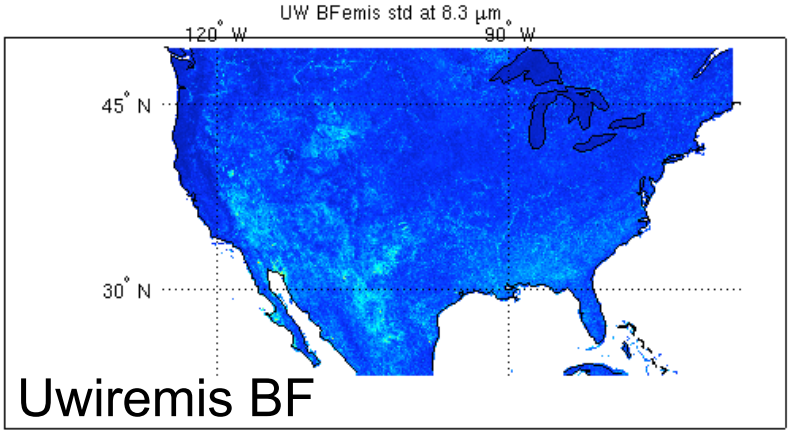


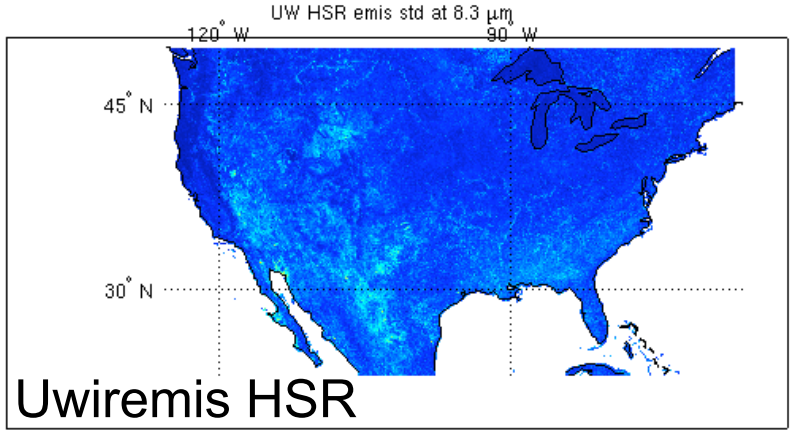


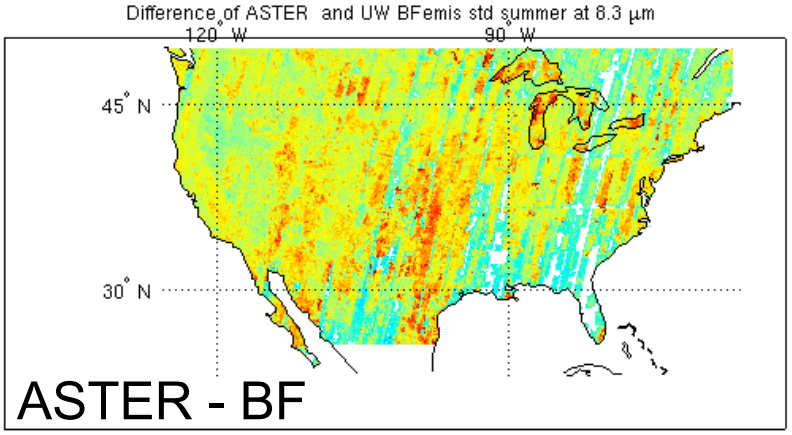


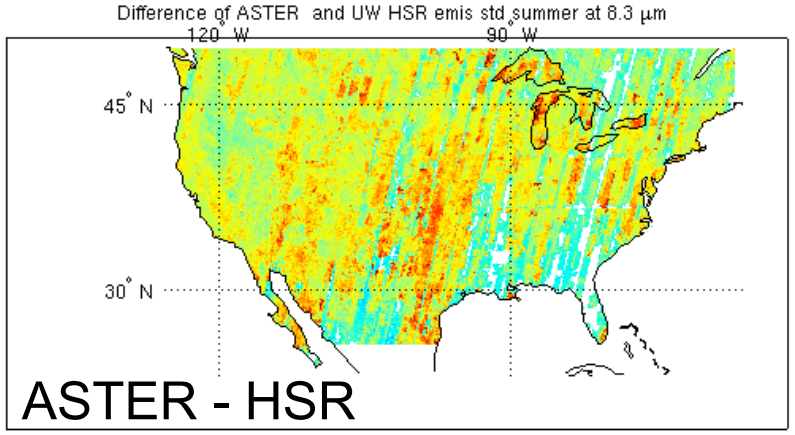
Summertime Stdev of Emissivity at 8.3 μm



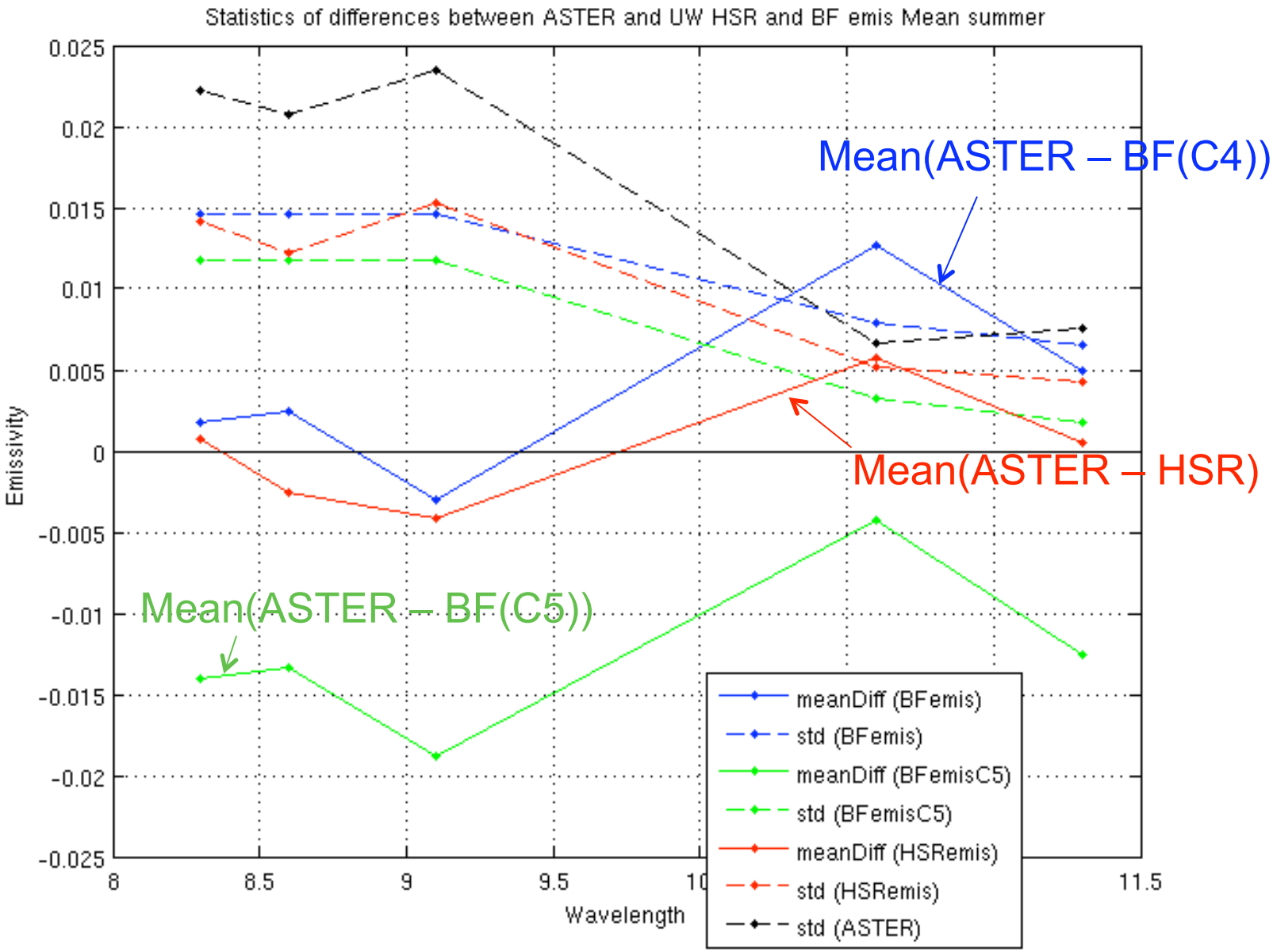




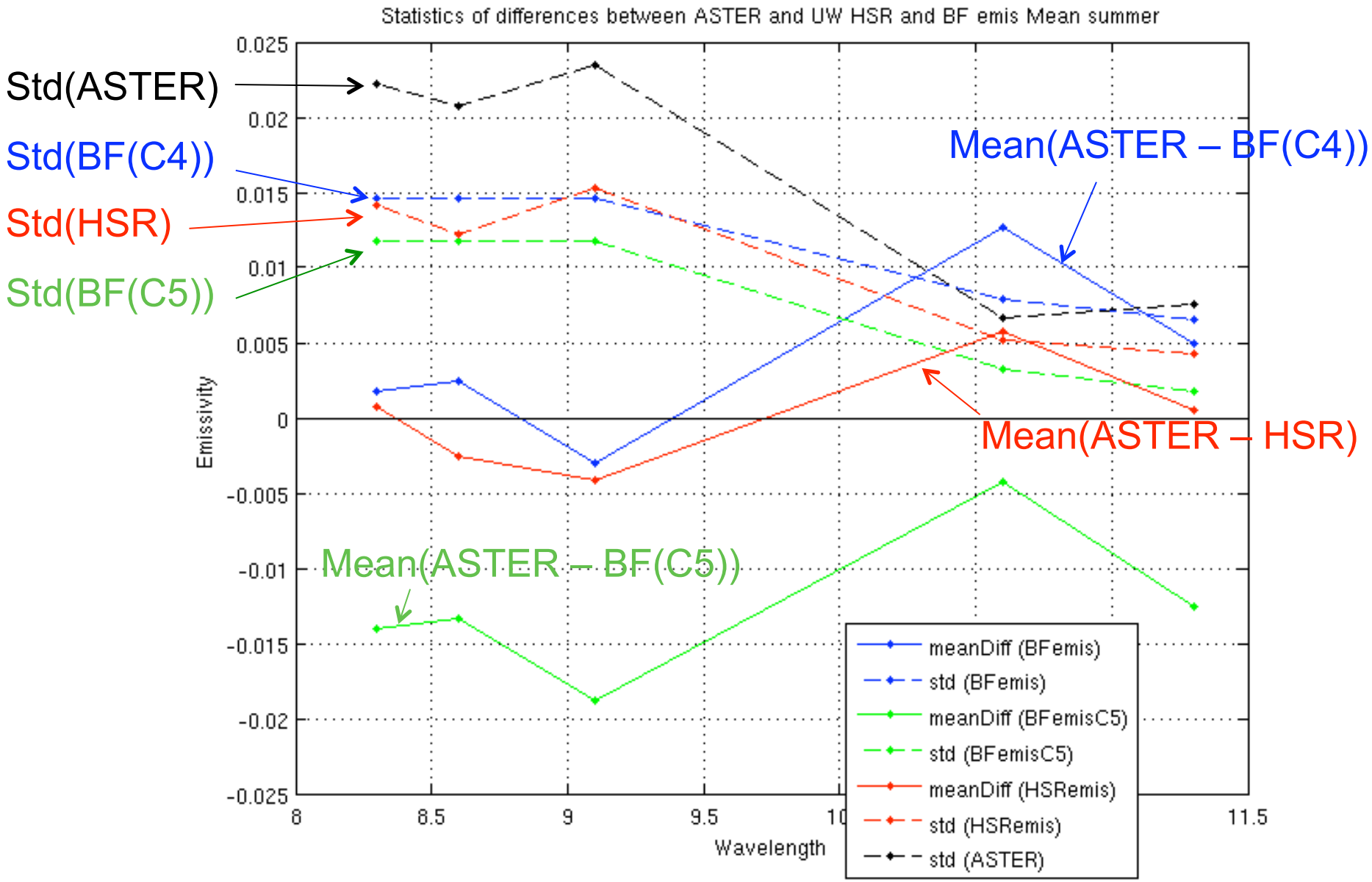


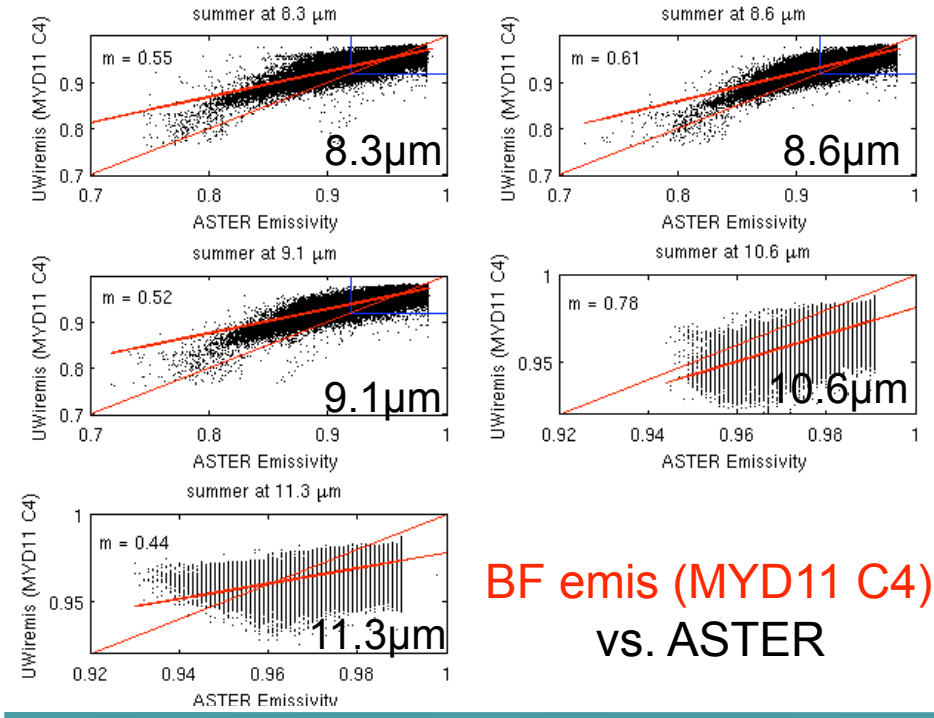


Differences between ASTER and Uwiremis means at summertime

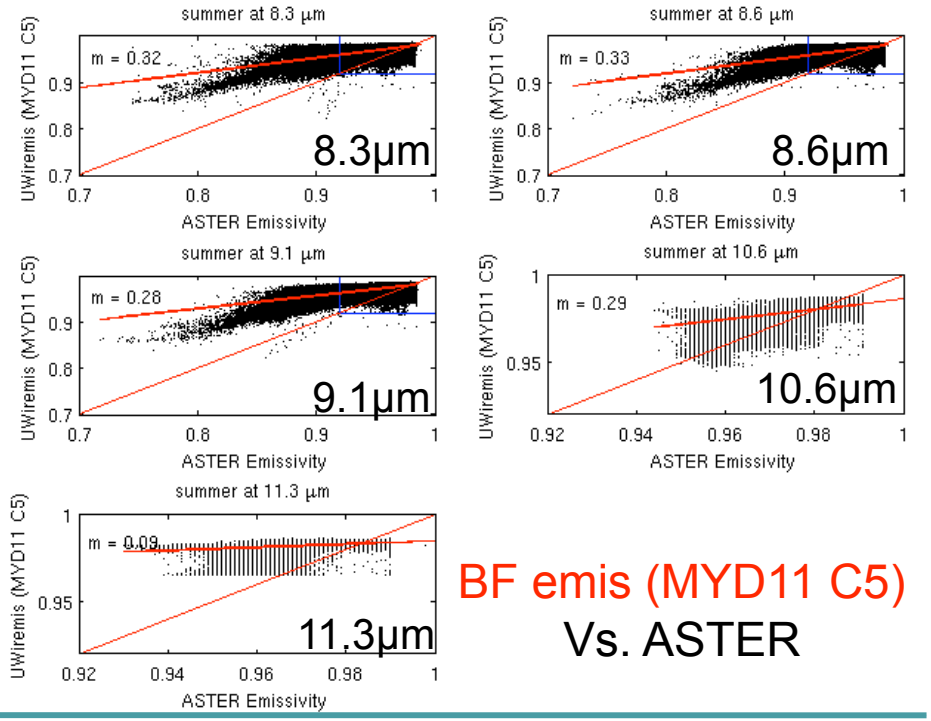


Differences between ASTER and Uwiremis means at summertime

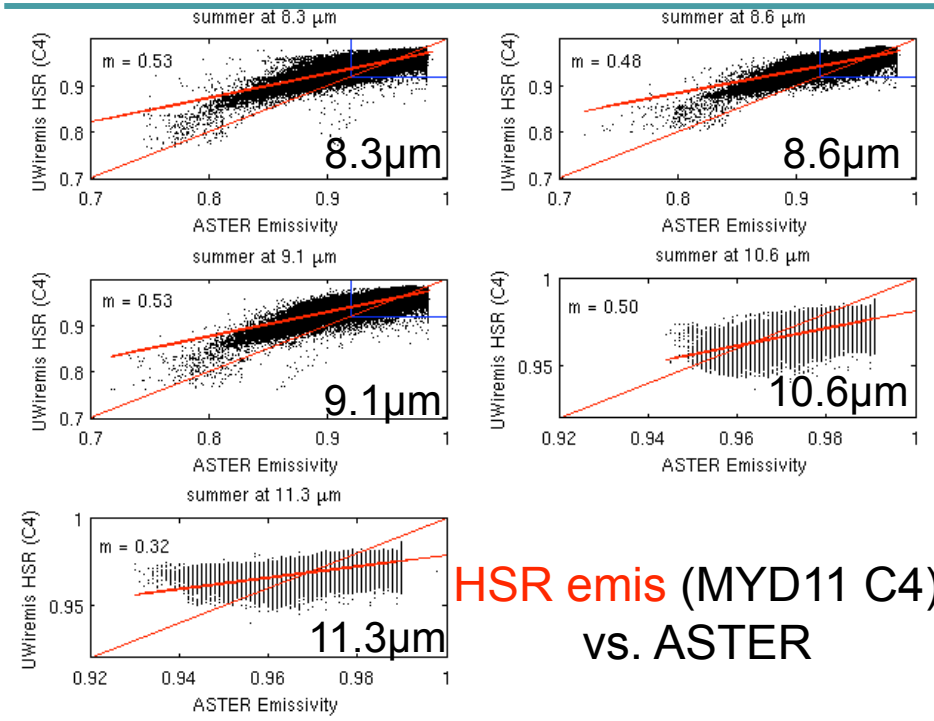




BF emis (MYD11 C4) vs. ASTER



BF emis (MYD11 C5) Vs. ASTER

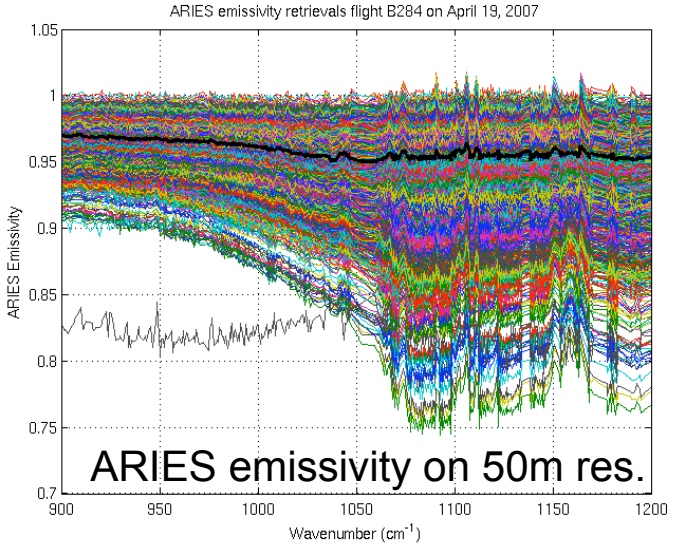


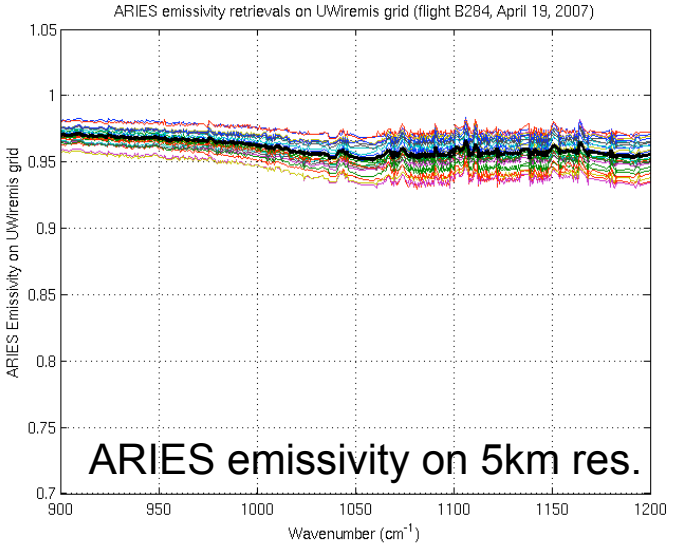
HSR emis (MYD11 C4) vs. ASTER

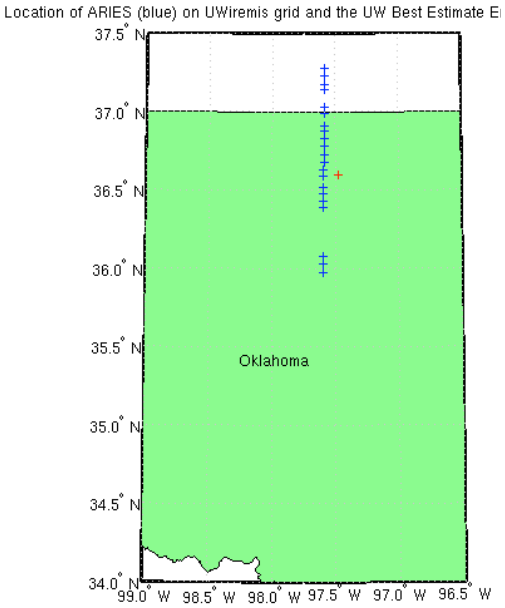
Scatter plots of Uwiremis vs ASTER mean emissivity at Summertime

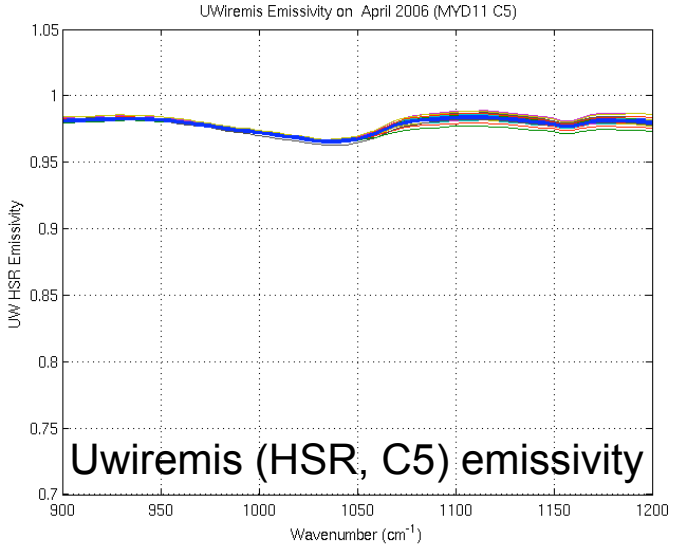
Validation with ARIES 'true' surface emissivity
Jaivex Case Study: 19 April 2007 Oklahoma

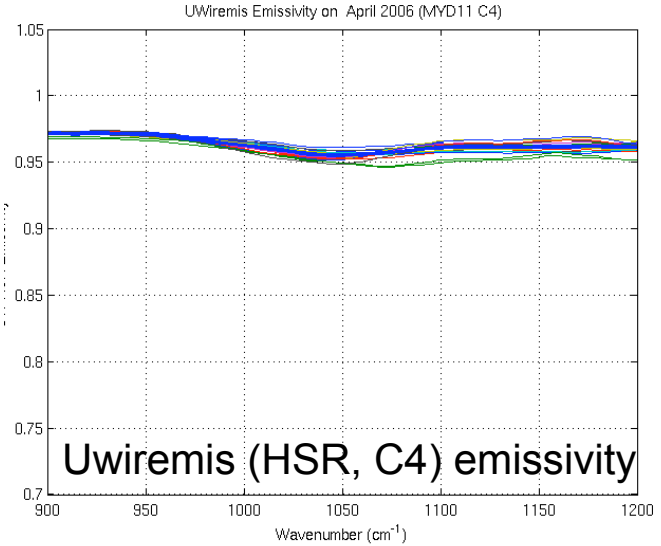
- Aircraft:B284
- Altitude: 3000foot
- Foot print: 50 m
- Spectral range:
- 8.3 and 11.1μm
- Night time clear-sky
- Provided by Stuart Newman (UKMO)



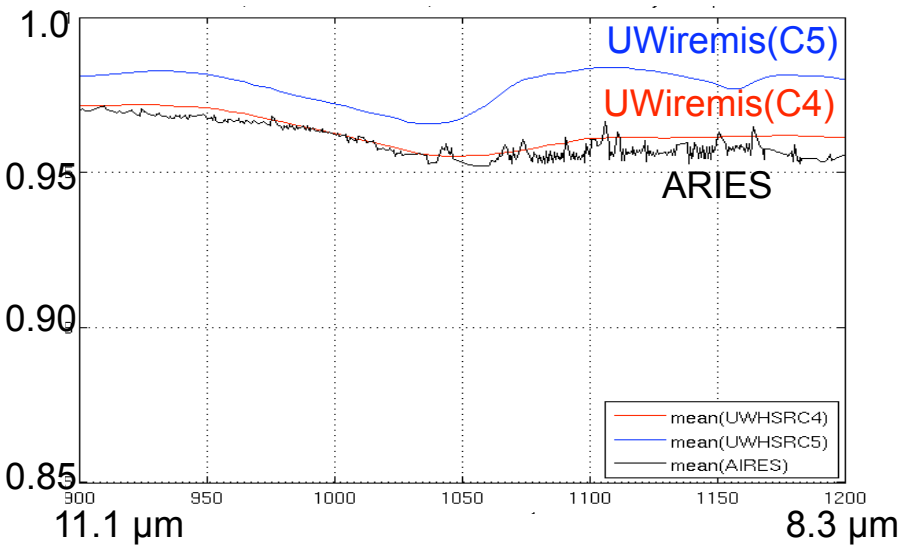




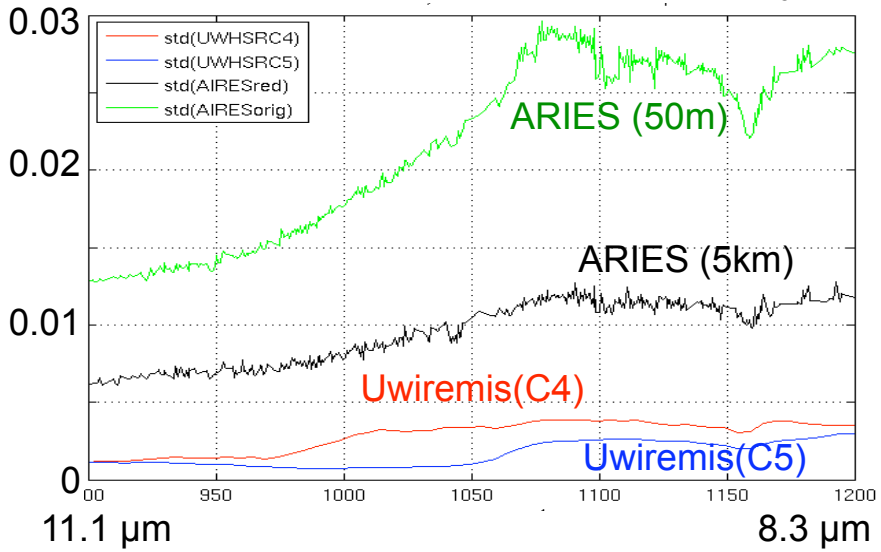




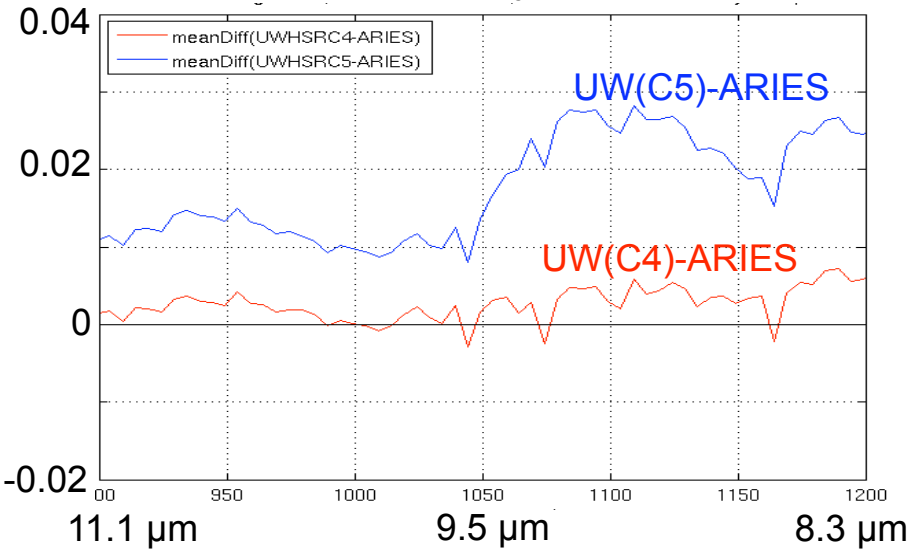
Mean of emissivity data



Standard deviation of emissivity data



Mean of emissivity differences



Conclusion

- The case study over the Sahara dessert indicated a problem at 8-9.6μm in MODIS MYD11 C5 input data. It caused about 6K brightness temperature error in the forward model calculation.

- ASTER and Uwiremis BF(C4) mean emissivities agree within 1%, and with Uwiremis HSR within 0.5 %.

- The C4 vs C5 comparison against the ASTER DB shows a 1.5 % bias and -0.3 % difference in standard deviation: BF(C5) values are higher with smaller standard deviation. (similar result with AIRES comparison)

- The scatter plots indicated that Uwiremis BF(C4) and HSR(C4) data fits better to the ASTER mean emissivities than using the MODIS MYD11 C5 products as input.

- Uwiremis (based on MODIS C4 data) agrees in 0.5% with the Jaivex ARIES aircraft measurements between 8.3 and 11 μm. The mean difference increasing to 1 (between 9.5-11μm) and 3 % (8.3-9.5μm) when using Uwiremis (C5) data in this comparison.

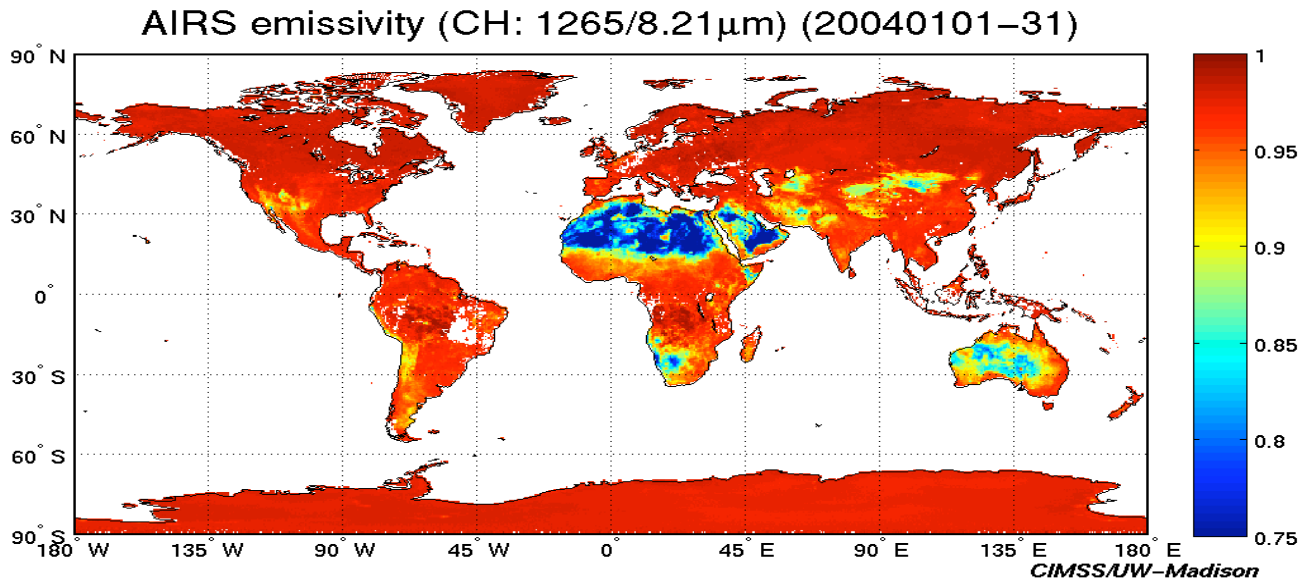
- The spatial interpolation of the ARIES measurements indicated that the ARIES data have a higher standard deviation due to the finer spatial resolution.

Recommendations

- UWiremis 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
  - version 2 BF (MYD11 C4) emissivity data is recommended to use specially over dessert and non vegetated area between 8 and 9.5 μm spectra till the new collection 6 MODIS MYD11 is available.

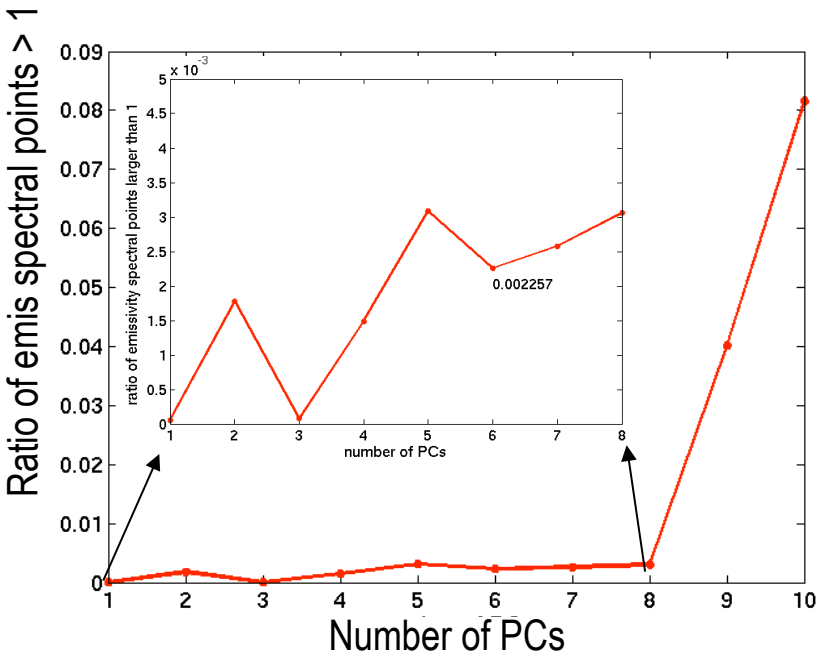
Global Hyperspectral Resolution Surface IR Emissivity Spectra Derived from advanced IR sounder radiance Measurements

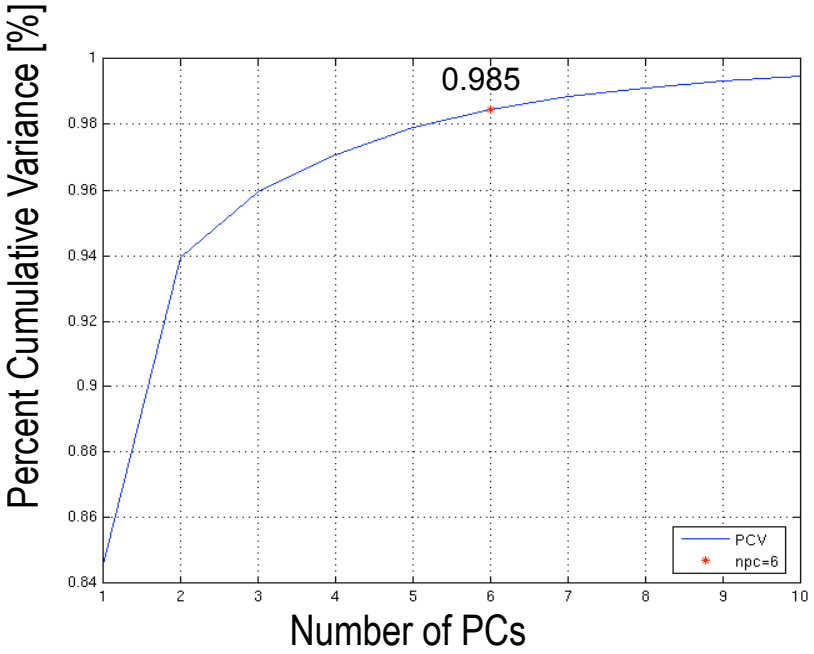
Jun Li, Jinlong Li, Elisabeth Weisz, Eva Borbas, Lihang Zhou, Mitchell Goldberg

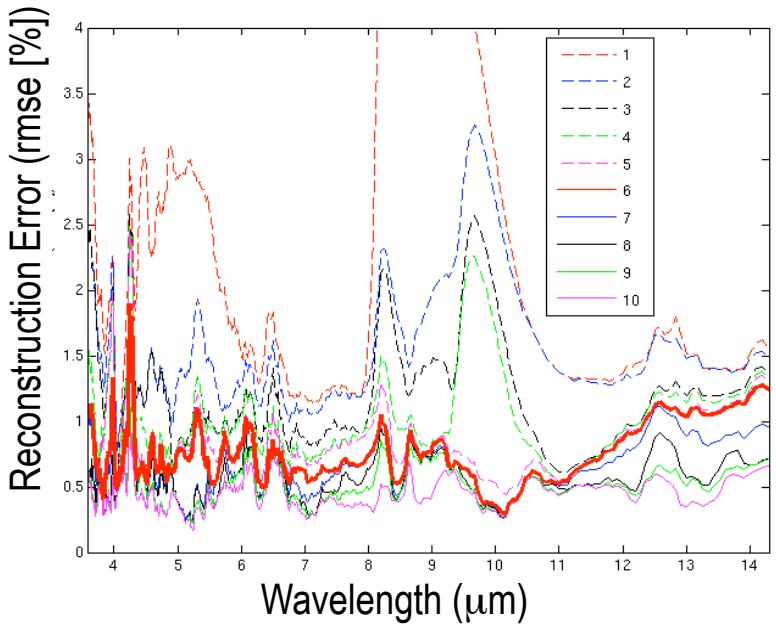


In this study, we have developed an algorithm (1DVAR) to retrieve hyperspectral IR emissivity spectrum simultaneously with the sounding by using the eigenvector (EV) representation of emissivity spectrum, the EVs are derived from laboratory hyperspectral emissivity measurements. This retrieval method has been applied to process one month's Atmospheric InfraRed Sounder (AIRS) radiance measurements, and the global high spectral resolution surface IR emissivity spectra have then been derived from the composite of clear sky single field-of-view (SFOV) retrievals. Our derived emissivity spectra agree with other emissivity products (MODIS etc), but provide a full spectral coverage.

How many PCs to use?







Location of instable cases in SeeBor training profiles