The MEASURES High Spectral Resolution MODIS/ASTER Emissivity Database and its evaluation with RTTOV

E. Eva Borbas, Robert Knuteson and Michelle Feltz
UW-Madison/SSEC/CIMSS

Glynn Hulley and Simon Hook
NASA/JPL

NASA MEaSUREs
(Making Earth Science Data Records for Use in Research Environments)

MEaSUREs Land Surface Temperature (LST) and Emissivity (LSE) Data Products

Goal: Generate a Unified and coherent long-term, and well characterized Earth System Data Records (ESDRs) that are consistent across different platforms/sensors

Products	Input Datasets	Spatial Resolution	Temporal Resolution	Bands Used	Algorithm(s)
LEO LST	MODIS (Aqua/ Terra)	• 1-km • 0.05° (Global)	• 10:30 am/pm • 01:30 am/pm • Monthly	3 TIR (8-12 µm)	MERRA2/ RTTOV TES
GEO LST	GOES (8-12)	5-km (Americas)	Every 30 min	1 TIR (11 µm)	MERRA2/ RTTOV Single-Channel
LEO Emissivity: CAMEL	ASTER GED UW MODIS BF Laboratory measurements	0.05° (Global)	Monthly	13 and 417 (3.6-14.3 µm)	TES, Day/Night

The new official name of the database:

CAMEL = **C**ombined
ASTER and
MODIS
Emissivity over
Land

Also see as MEASUREs Emissivity
MODAST Emissivity

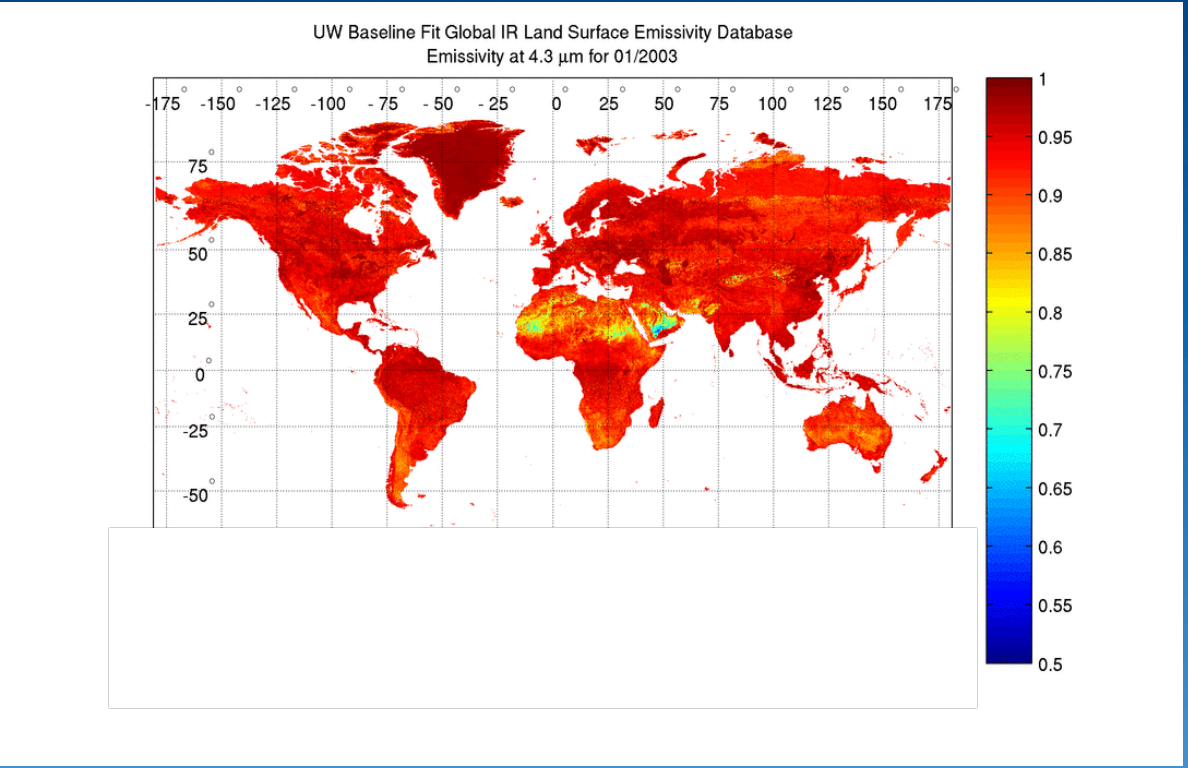
Outline

- MODIS Baseline Fit Emissivity DB (UWIREMIS)
- ASTER Global Emissivity Dataset (GED)
- Combined ASTER – MODIS Emissivity Dataset
- Validation/Evaluation
- Broad Band Emissivity
- Next steps

UW Global IR Land Surface Emissivity Database

- Based on the MO/YD11 – 6 bands of monthly mean emissivity
- Time coverage: Monthly: Terra: April 2000 – Dec 2013 / Aqua Sept 2002 – Dec 2015
- Spatial Resolution: 0.05 degree ~ 5 km;
- Spectral Resolution: 10 hinge points (3.6 and 14.3 μm)
- Available: http:/cimss.ssec.wisc.edu/iremis
- Method: Baseline Fit and Principal Component Regression

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)



The UW Global IR Land Surface Emissivity Database: Baseline Fit Method

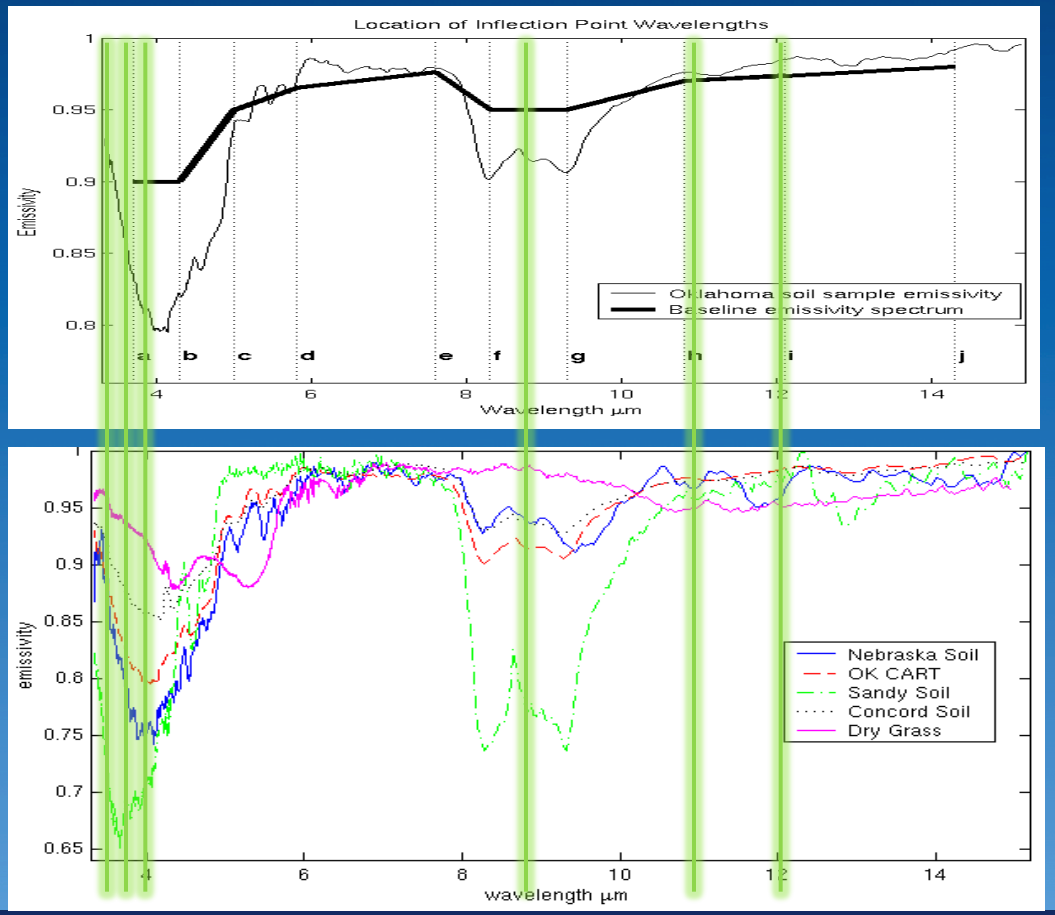
•Based on a **conceptual model** developed from **laboratory measurements** (UCSB) of surface emissivity is applied to fill in the spectral gaps between the six emissivity wavelengths available from **MYD11**

•**10 hinge points** were chosen between 3.7 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:
Seemann et al., 2008:
JAMC, 47, 108-123.



ASTER Global Emissivity Dataset (GED)

- *ASTER Quick Facts:*
  - VIS/SWIR/TIR sensor on Terra Spacecraft (launch Dec 1999)
  - 90 m spatial resolution (60 x 60 km swath)
  - 5 TIR bands (8 – 12 micron)
  - 16 day repeat (on demand imaging)
  - Temperature Emissivity Separation Algorithm (TES, (Gillespie et al. 1998))

Products	Spectral	Spatial	Temporal	Estimated Uncertainty	Availability
GEDv3	5 Bands (8-12 µm)	~100 m	Climatology (2000-2008)	~1.5-2%	*LPDAAC
GEDv4	5 Bands (8-12 µm)	~0.05°	ᵠMonthly (2000-2015)	~1.5-2%	*LPDAAC (Early 2016) **UW-Madison/CIMSS

ᵠ GEDv4 uses MODIS NDVI/snow cover to adjust GEDv3 emissivity on monthly steps

* https://lpdaac.usgs.gov/dataset_discovery/community/community_products_table

** http://cimss.ssec.wisc.edu/iremis/

Hulley, G. C., Hook, S.J., E. Abbott, N. Malakar, T. Islam, M. Abrams, 2015, The ASTER Global Emissivity Dataset (ASTER GED): Mapping Earth's emissivity at 100 meter spatial scale, Geophysical Research Letters, 42, doi:10.1002/2015GL065564.

Combined Emissivity ESDR:
Why we need this new dataset?

UWIREMIS database:

Advantages: its moderate spatial resolution (5km), uniform temporal coverage (monthly), and emissivities span the entire IR region (3.6-12 μm)

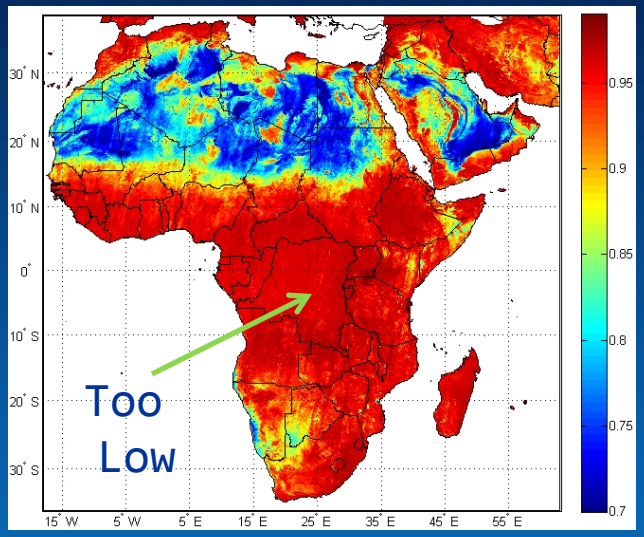
Limitation: emissivity in the TIR region (8-12 μm) is not well defined because MODIS only has 3 bands in this region (bands 29, 31, 32). This results in imperfect TIR spectral shape in the two quartz doublet regions at 8.5 and 12 μm.

ASTER-GED:

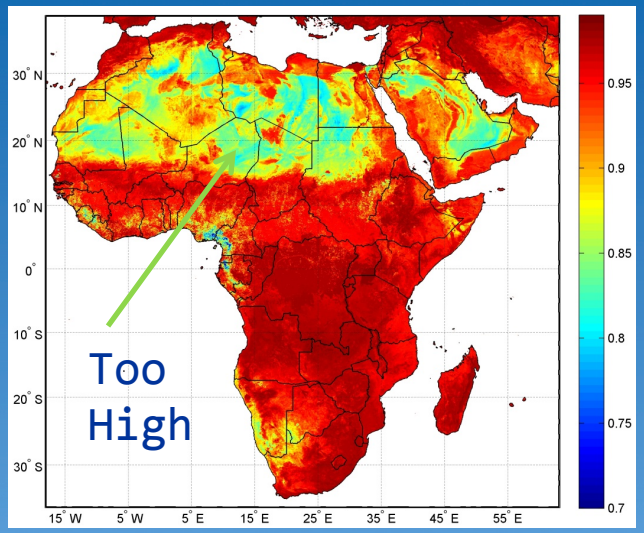
Advantages: its high spatial resolution (~100m) and high accuracy over arid regions.

Limitation: although there are more bands to more accurately define the spectral shape in the TIR region (5 bands, 8-12 μm), there are no bands in the mid-wave Infrared (MIR) region around 3.8-4.1 μm, which limits its use in models and other atmospheric retrieval schemes.

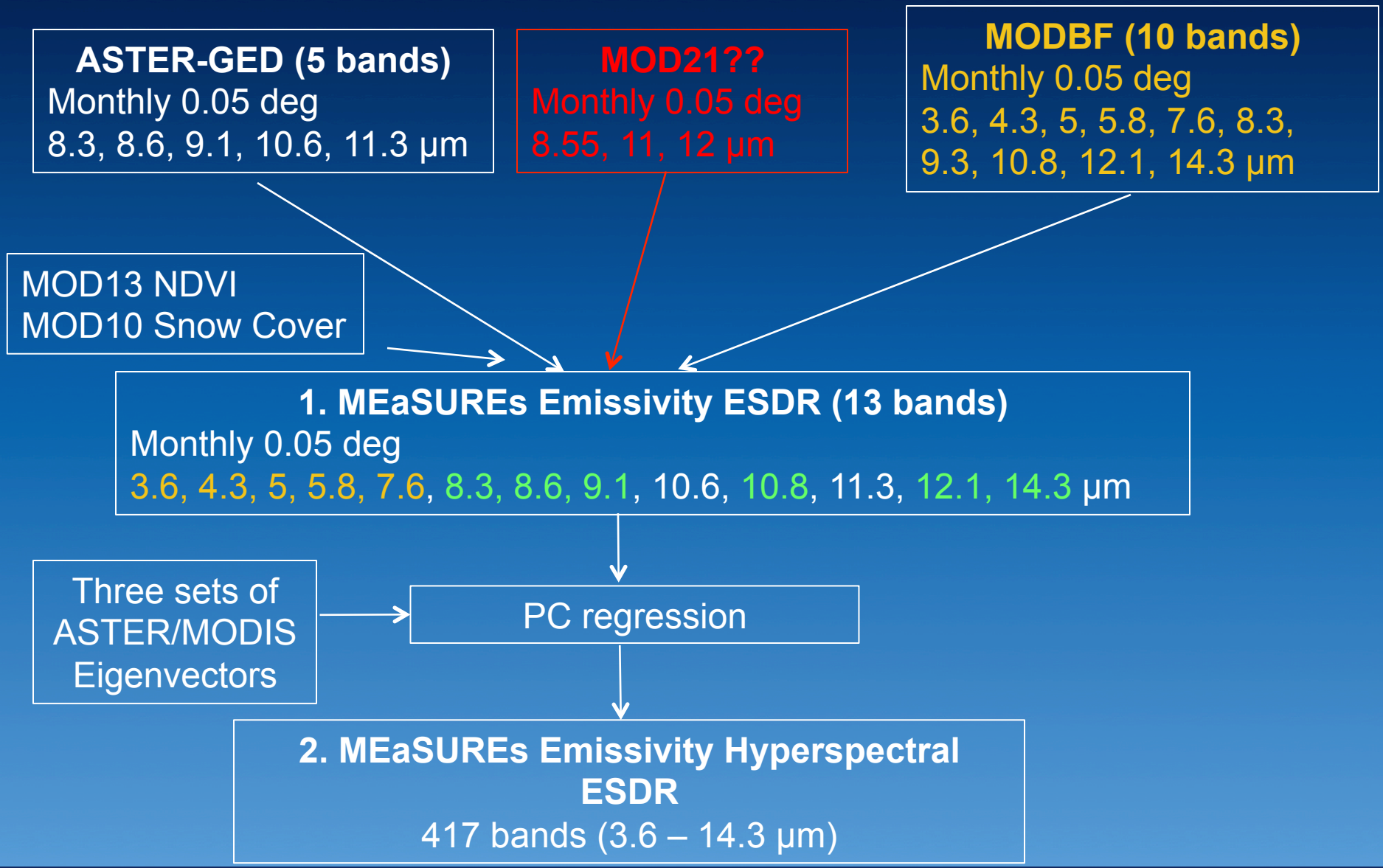
ASTER-GED (9.1 μm)



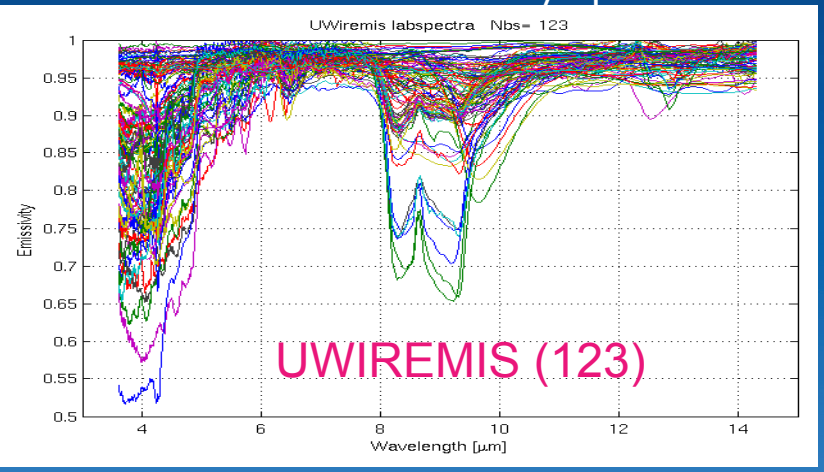
MODIS UWIREMIS (9.3 μm)



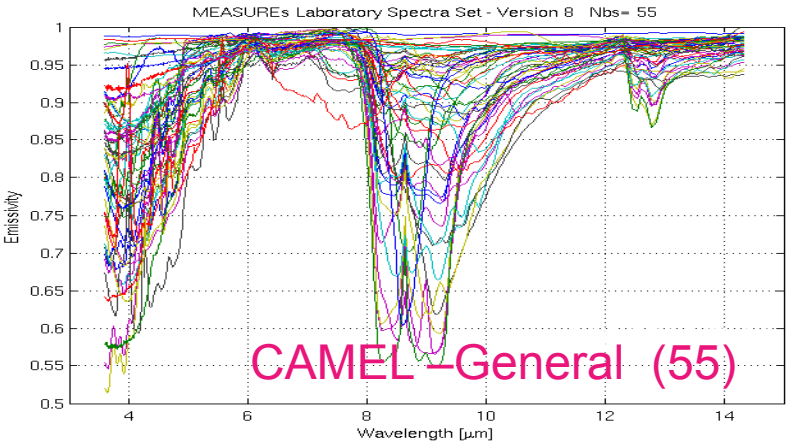
MEaSUREs MODAST Emissivity ESDR



UW BF selected Laboratory spectra

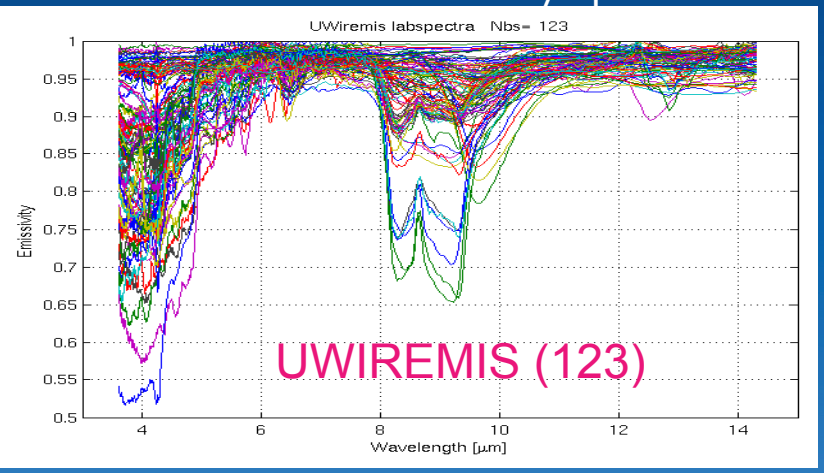


MEASUREs selected Laboratory spectra

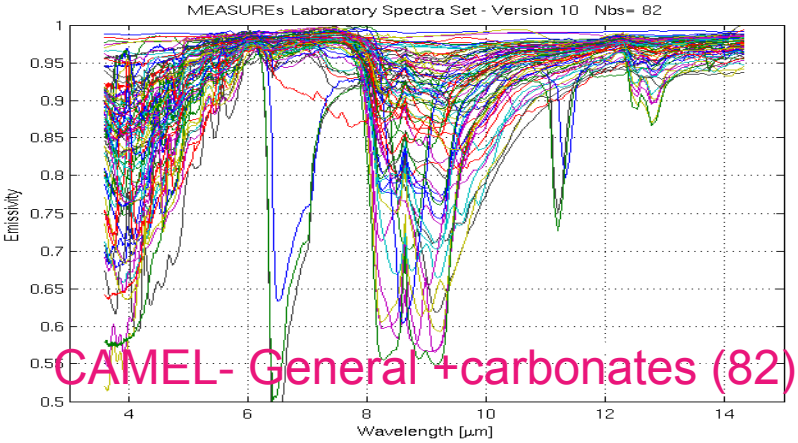


Rock,
soils,
sands,
veg,
ice,
water

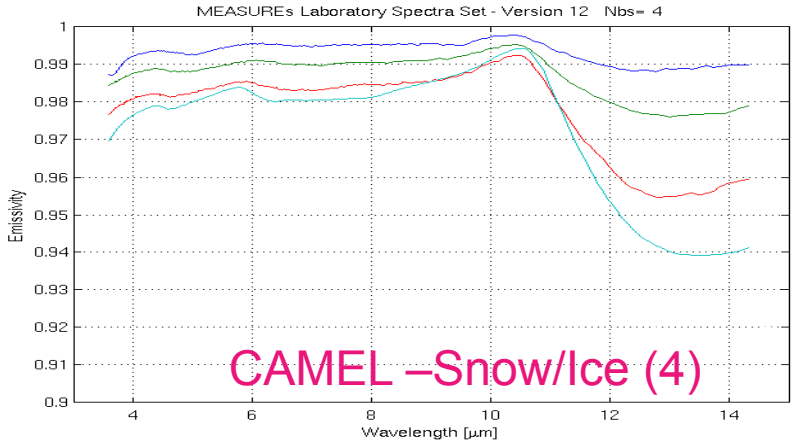
UW BF selected Laboratory spectra



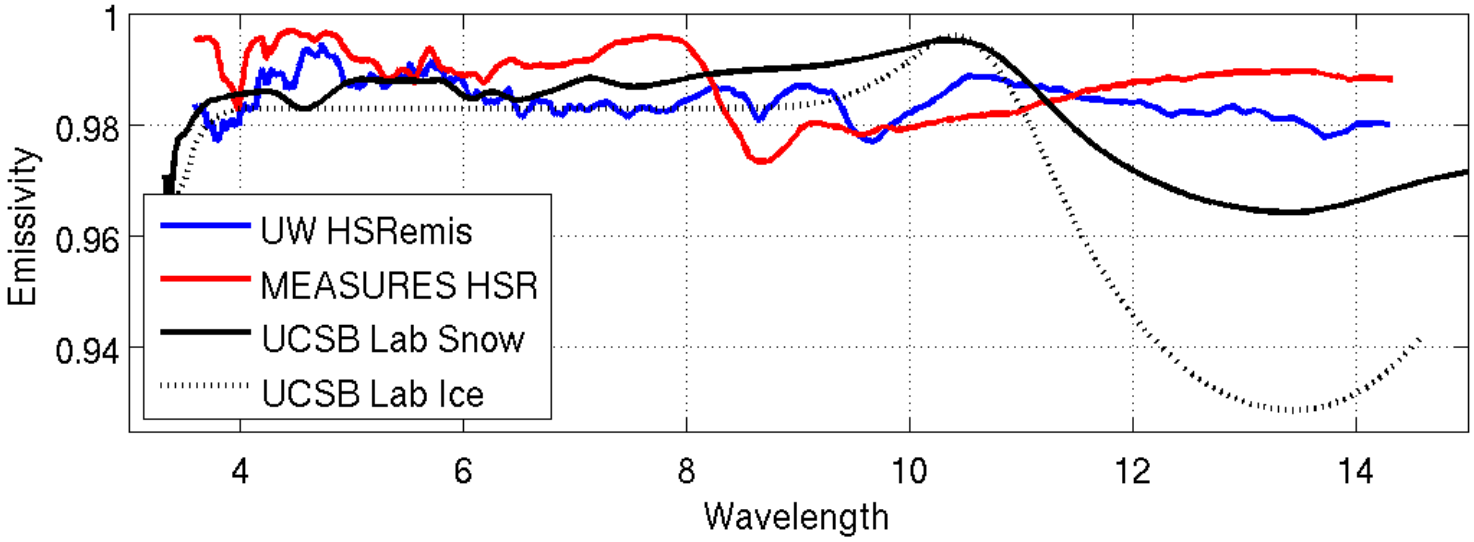
Rock,
soils, sands,
veg,
ice,
water
Carbonates



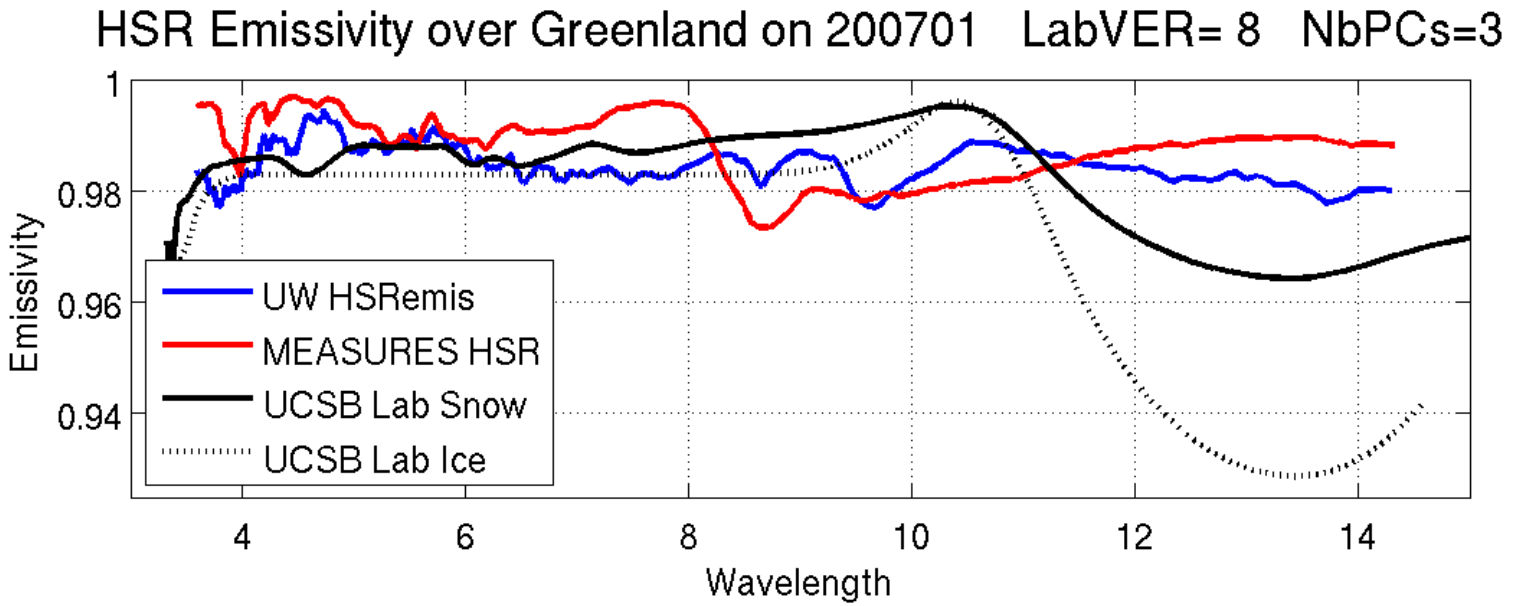
Fine snow
Med snow
Coarse snow
Ice

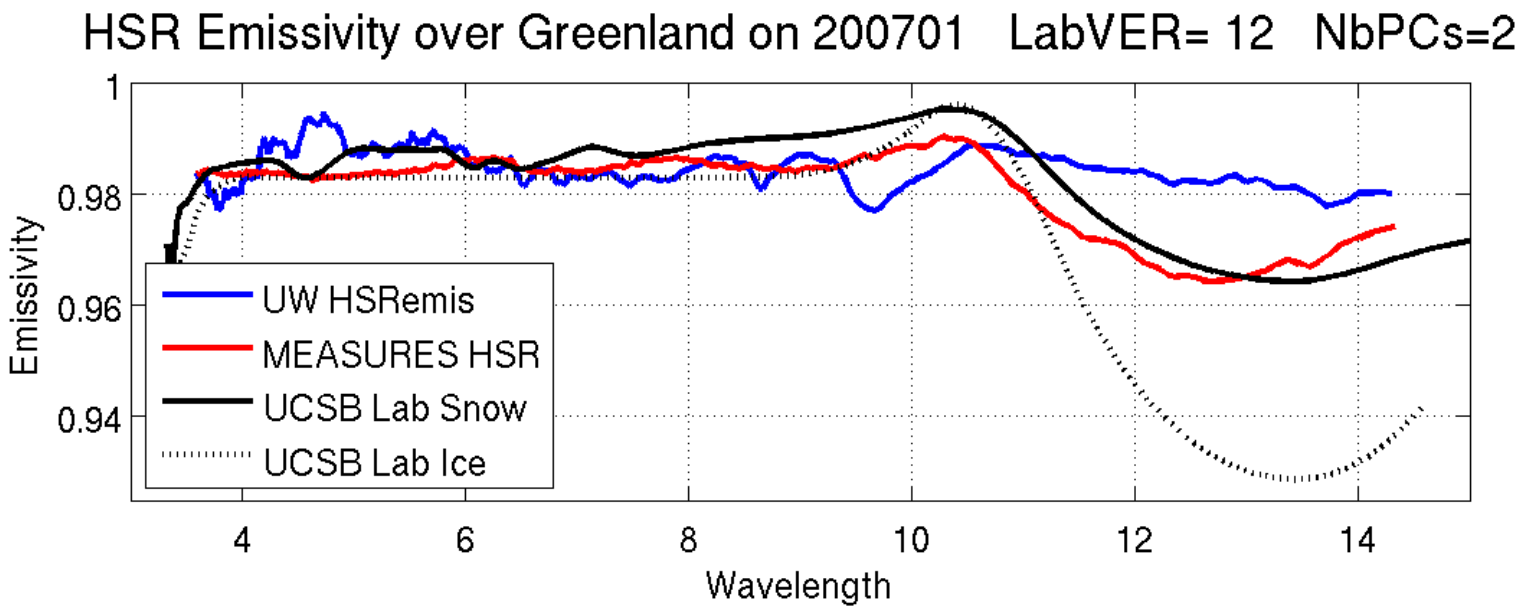


Greenland Case Study



Greenland Case Study





Comparison of UWIRMES and the MEASURES CAMEL DB

	UWIREMIS	MEASUREs CAMEL
Inputs:	MODIS MYD11 MODIS-ASTER Lab	UWIREMIS BF (10) ASTER-GEM (5) MODIS-ASTER Lab
Method:	Baseline Fit Conceptual model PCA Regression	Conceptual model PCA Regression
Laboratory data:	123 selected MODIS-ASTER	55 general lab set 82 general+carbonates 4 ice/snow labset
Number of PCs	6	2,3, 6, 9, Varies, by surface types based on the 8.6 µm ASTER emis and NDVI, or Snow Fraction
Outputs:	Emissivity spectra on 10 BF hinge point and 417 HSR points (3.6-14.3)	13 hinge point and HSR emissivity NDVI, Snow Fraction

Validation/Evaluation

1. Assess seasonal changes in vegetation phenology
   - Dahra, LSA-SAF Validation site
2. Check spectral invariance over graybodies
   - Vegetation
   - Large inland water bodies
3. Check spectral shape over geologic surfaces:
   - Namib desert (quartz and hematite sand)
   - Yemen (carbonate)
   - Mauna Loa Caldera (basalts)
   - Gran Desierto (feldspars/quartz)
   - Rub Al Khali (quartz)
   - Kalahari Desert (quartz/hematite)

*Credit: ASTER Science T

Namib Desert – Sossussvlei, Namibia

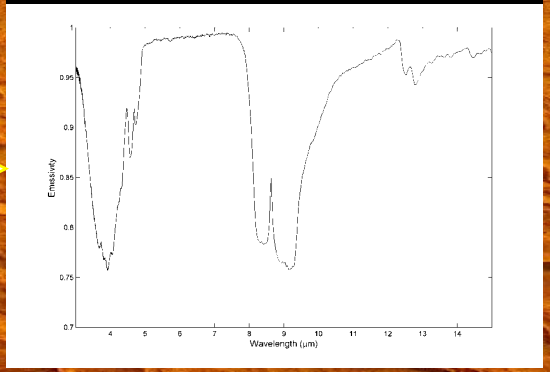
Collect Samples

Nicolet 520 FTIR spectrometer

Range: 2.5 – 15 μm

Resolution: 4 cm^{-1}

Estimated accuracy (0.02 K)

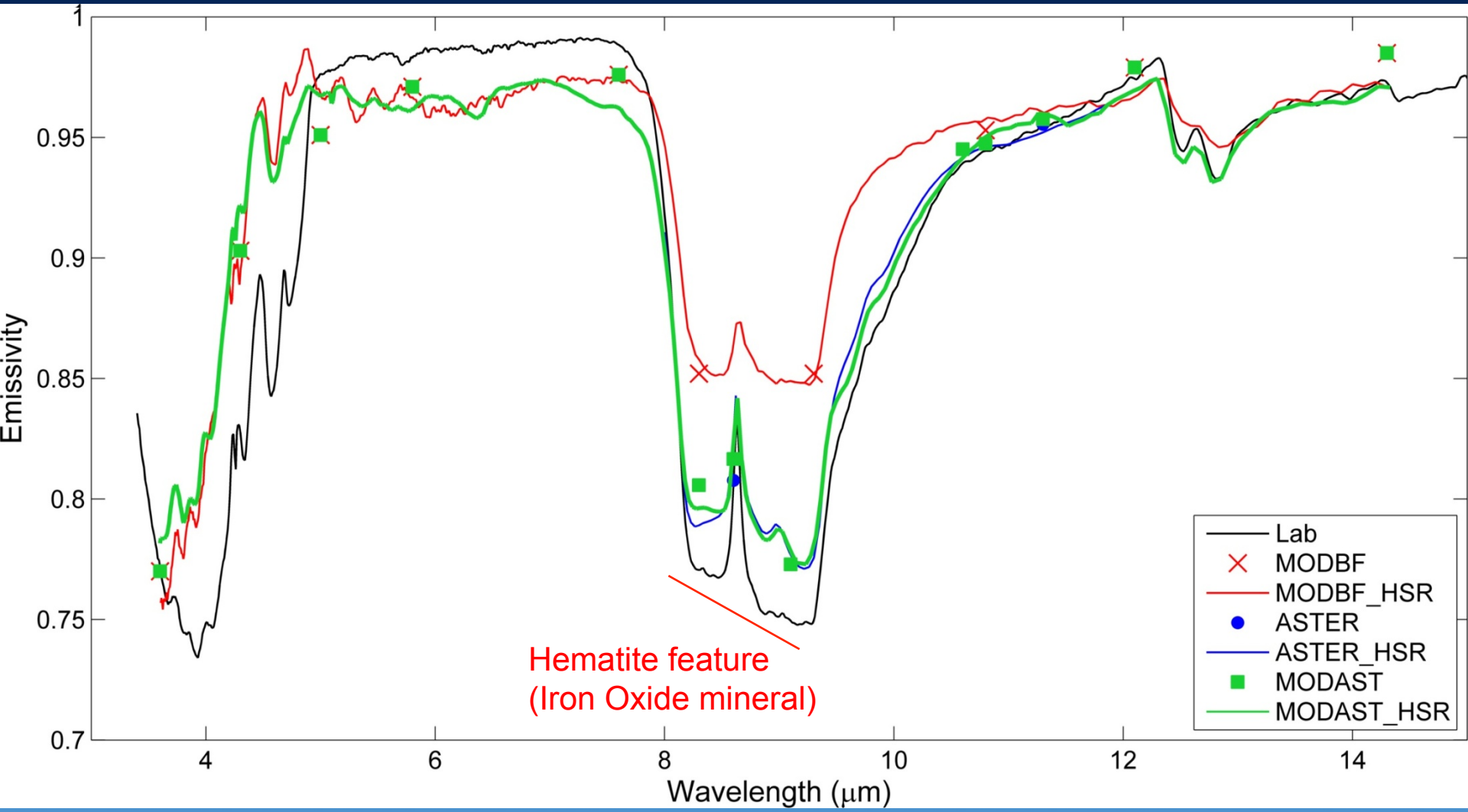


Site 1: Interdune (vlei)
2 samples

Site 2: Dune crest
6 samples

Dead Vlei 'Flay'

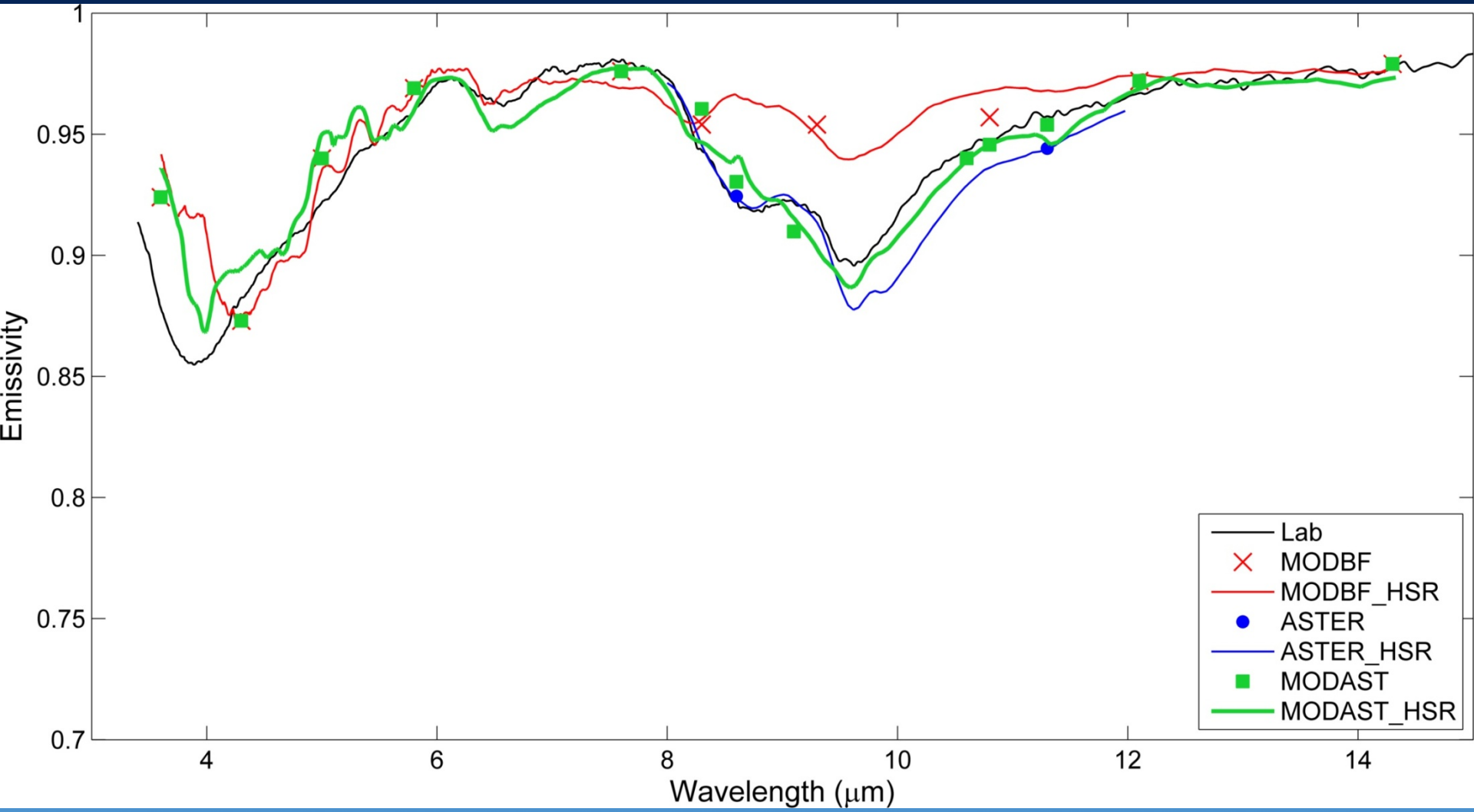
Namib Desert (Quartz)



Mauna Loa Caldera, Hawaii
Maffic lava flow – Basalt rock

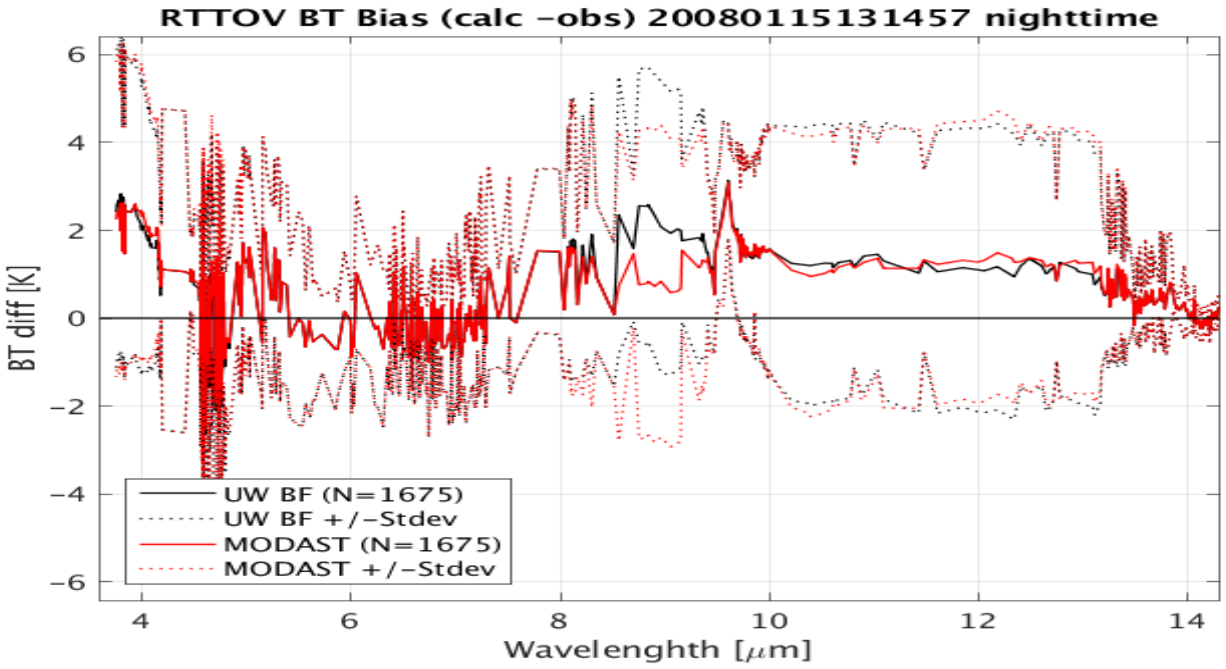
Sampled numerous times by ASTER science team at JPL since 1990's

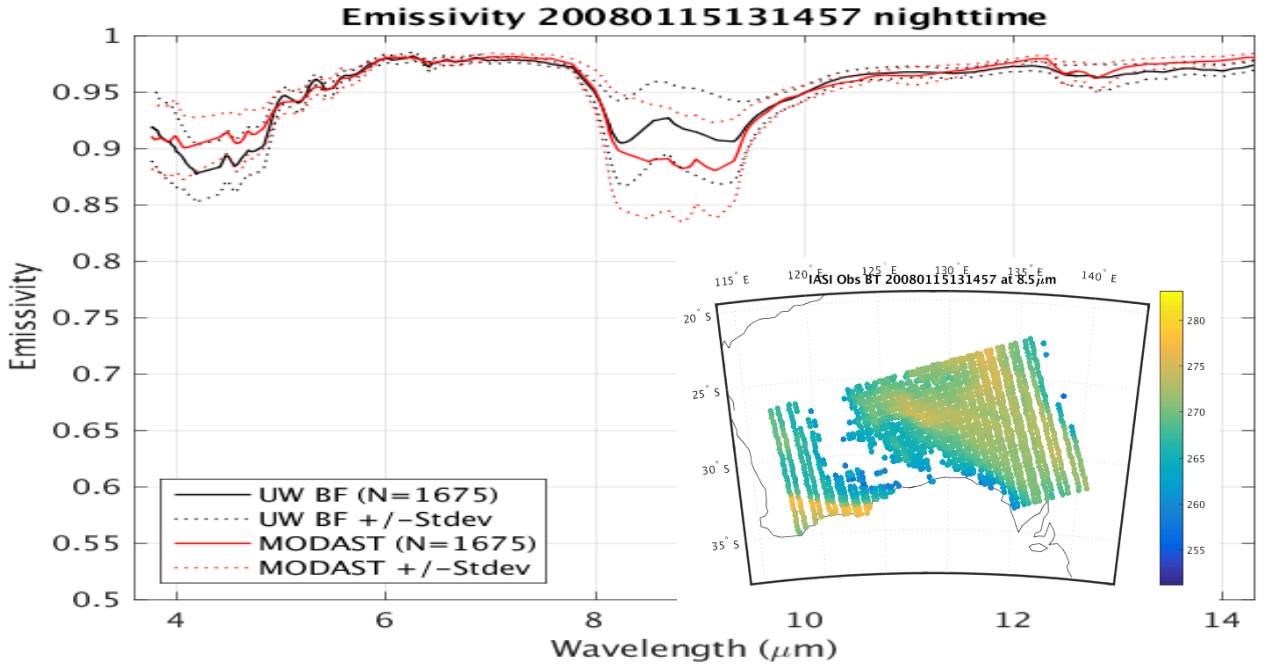
Mauna Loa Basalt Rock

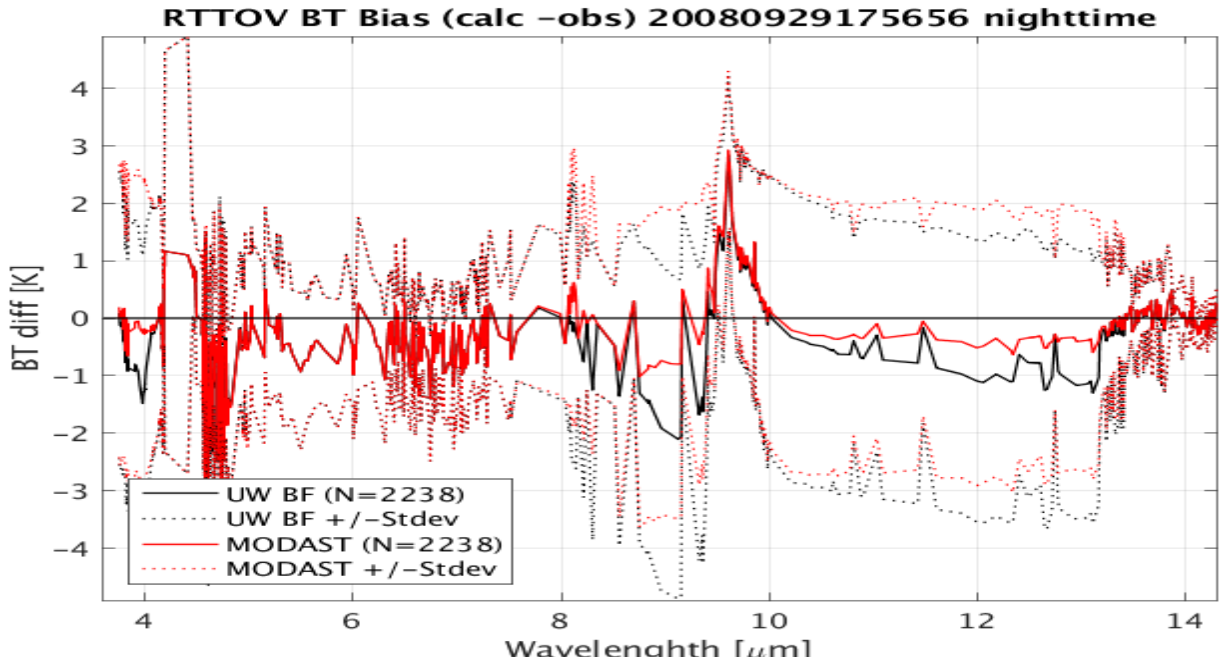


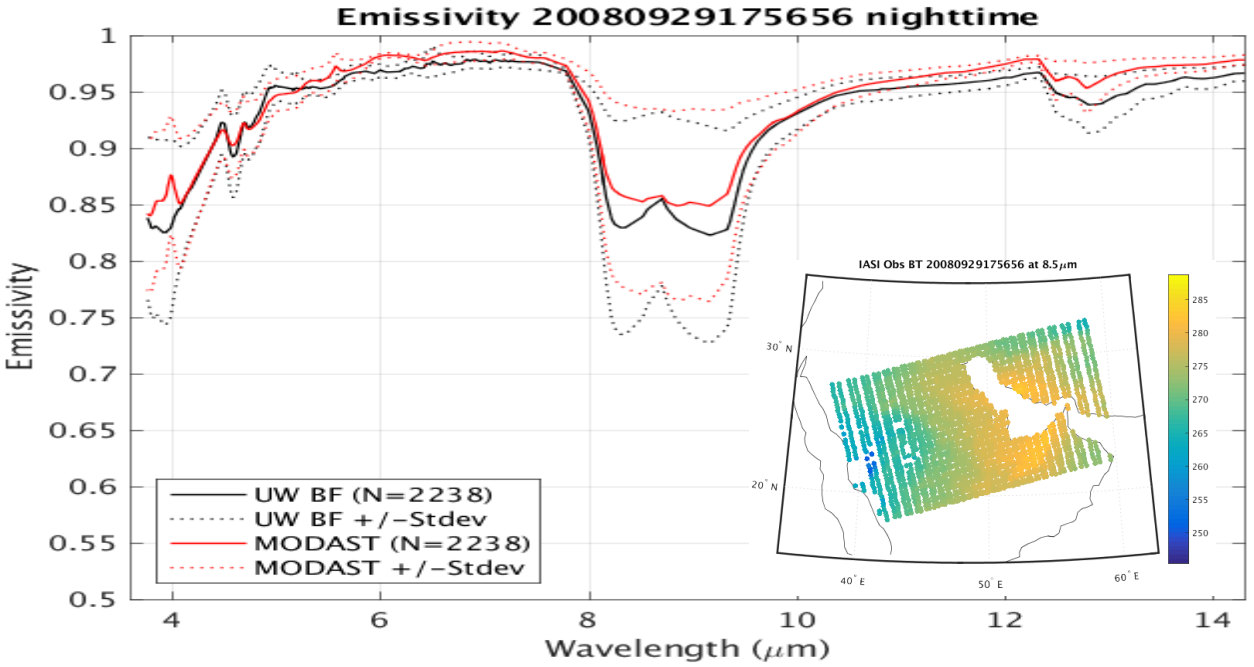
RTTOV IASI simulation results

- 4 days were selected (representing the 4 seasons):
  - January 15, April 14, July 15, Sept 29 2008
- ECMWF analyses was used for the forward calculation at 00, 06, 12, 18 and 24 UTC time on 0.5 degree resolution
- IASI granules were selected
  - only over land (no coast lines)
  - under clear (95%>) condition (MAIA cloud mask was used)
  - Between 2 hour (for nighttime) and 30 minutes (for daytime) time gap from ECMWF analysis
- Calculated brightness temperatures at 616 selected channels were compared to the observation.
- Snow fraction was not added to this study (set to 0).
- Day/night separation by solar azimuth angle (threshold=90)


RTTOV BT Bias (calc −obs) 20080115131457 nighttime
BT diff [K]
Wavelenghth [μm]
UW BF (N=1675)
UW BF +/−Stdev
MODAST (N=1675)
MODAST +/−Stdev


Emissivity 20080115131457 nighttime
Emissivity
Wavelength (μm)
UW BF (N=1675)
UW BF +/−Stdev
MODAST (N=1675)
MODAST +/−Stdev
IASI Obs BT 20080115131457 at 8.5μm


RTTOV BT Bias (calc −obs) 20080929175656 nighttime
BT diff [K]
Wavelenghth [μm]
UW BF (N=2238)
UW BF +/−Stdev
MODAST (N=2238)
MODAST +/−Stdev


Emissivity 20080929175656 nighttime
Emissivity
Wavelength (μm)
UW BF (N=2238)
UW BF +/−Stdev
MODAST (N=2238)
MODAST +/−Stdev
IASI Obs BT 20080929175656 at 8.5μm

Broad Band Emissivity

- ITSC20 RTSP WG recommendation (see also Luis Garand's talk at ITSC20) **addition of broadband emissivities to the available databases where appropriate or possible**.

- Previous studies: Wang et al. 2005; tang et al. 2010; Ogawa et al 2002, 2008; Huazhong et al 2013, Cheng et al 2012, 2015; - regression methods

- BBE definition:

$$\varepsilon_{BB} = \frac{\int_{\lambda 1}^{\lambda 2} e_l B_\lambda(T_S)\, d\lambda}{\int_{\lambda 1}^{\lambda 2} B_\lambda(T_S)\, d\lambda}$$

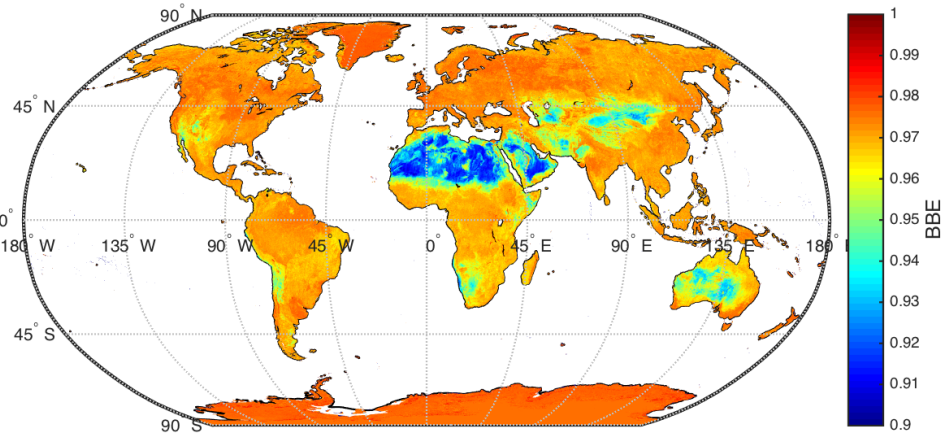
where T_s *is the mean of the monthly mean day and night MOD11 Skin Temp*

- CAMEL BBE products:
  - BBE over the 3.6 -14.3 μm - full available CAMEL spectrum
  - BBE over the 8.0 – 13.5 μm - optimal range for computing the most representative all wavelength, longwave net radiation (Ogawa and Schmugge 2003; Cheng et al, 2013).

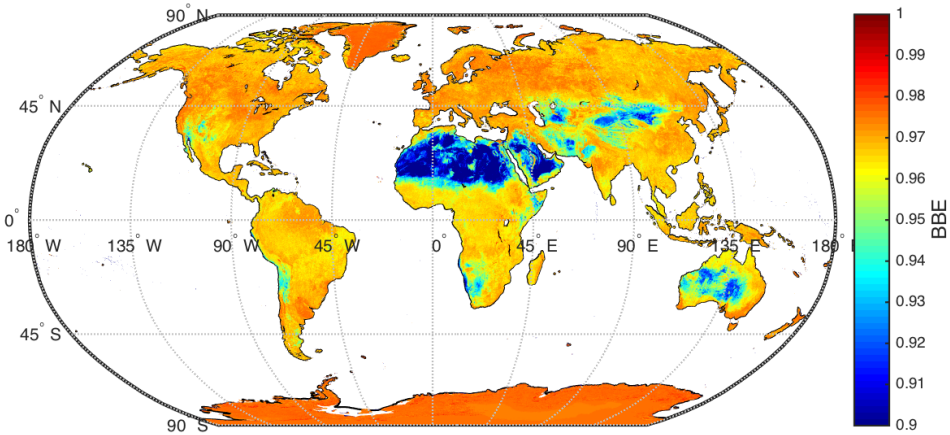
- Advantages:
  - no regression scheme are needed – integration over the full spectrum
  - Provides consistency with the IREMIS atlas used in Forward Model calculation

Broad band Emissivity for Sept 2012

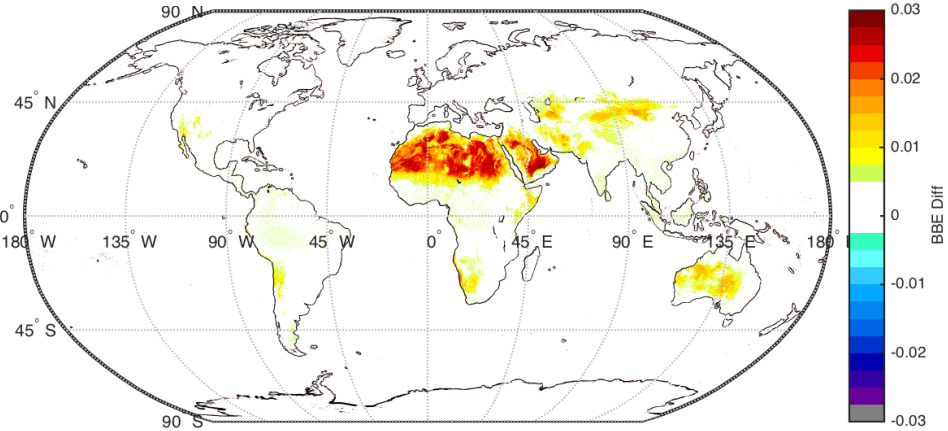
BBE 3.6-14.3 µm



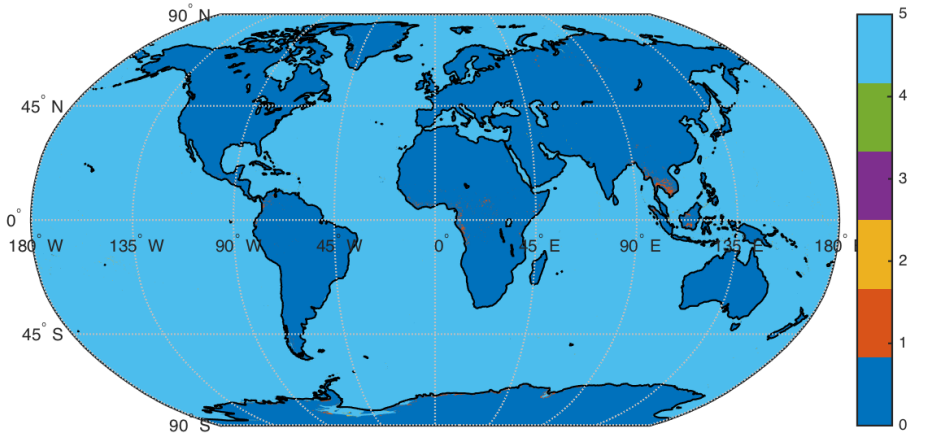
BBE 8-13.5 µm



BBE 3.6-14.3 µm – BBE 8-13.5 µm

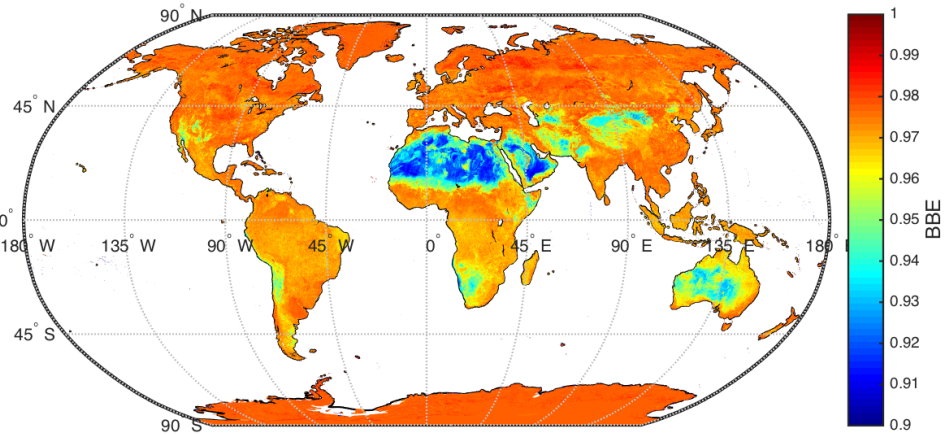


BBE QFLAG

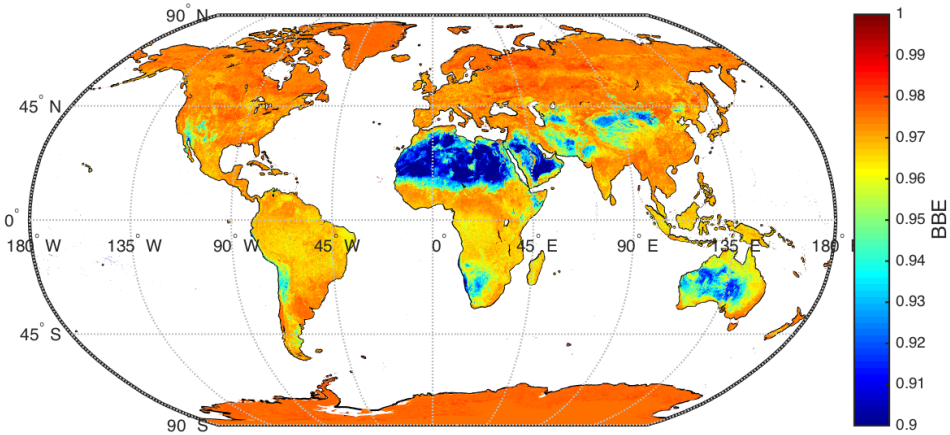


Broad band Emissivity for Jan 2013

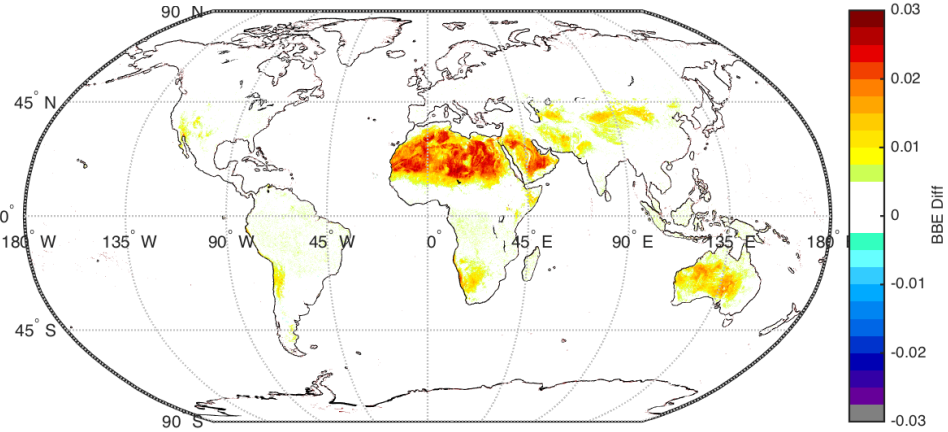
BBE 3.6-14.3 µm



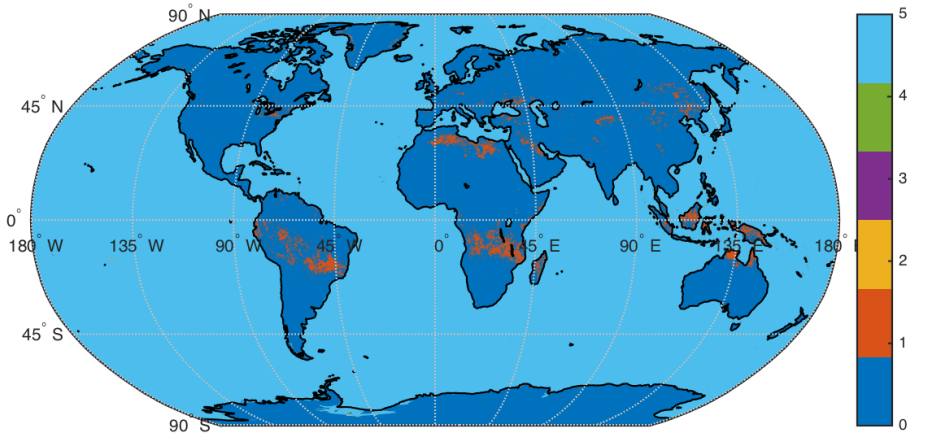
BBE 8-13.5 µm



BBE 3.6-14.3 µm – BBE 8-13.5 µm

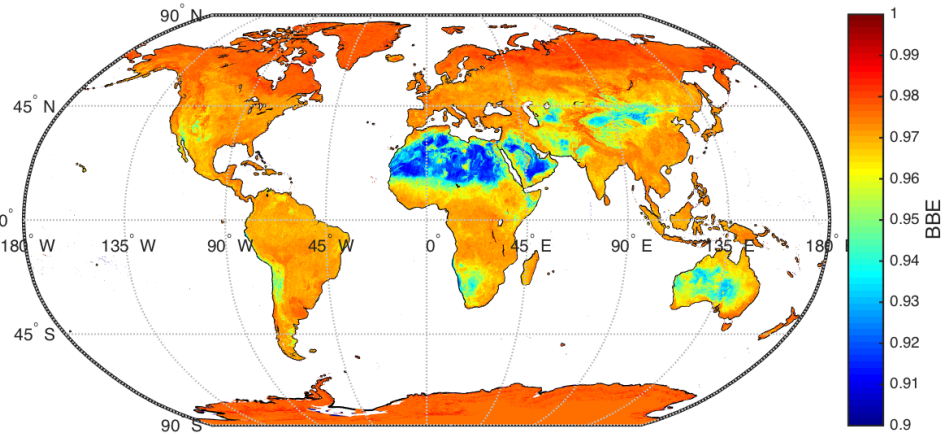


BBE QFLAG

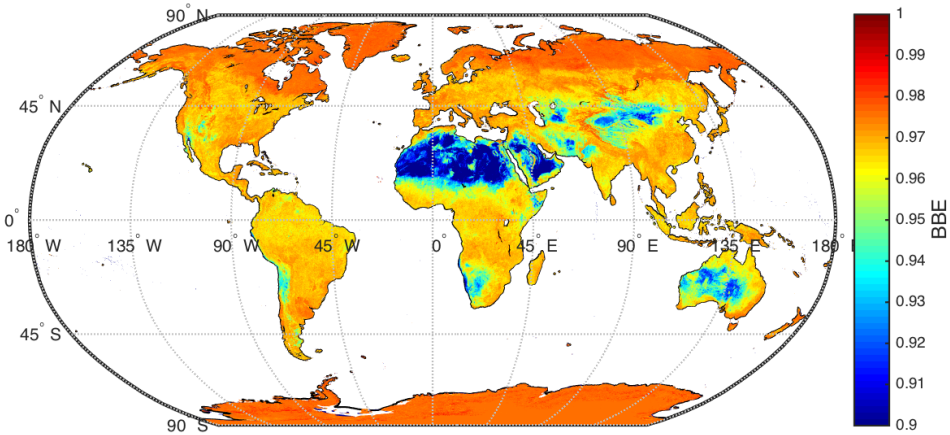


Broad band Emissivity for April 2013

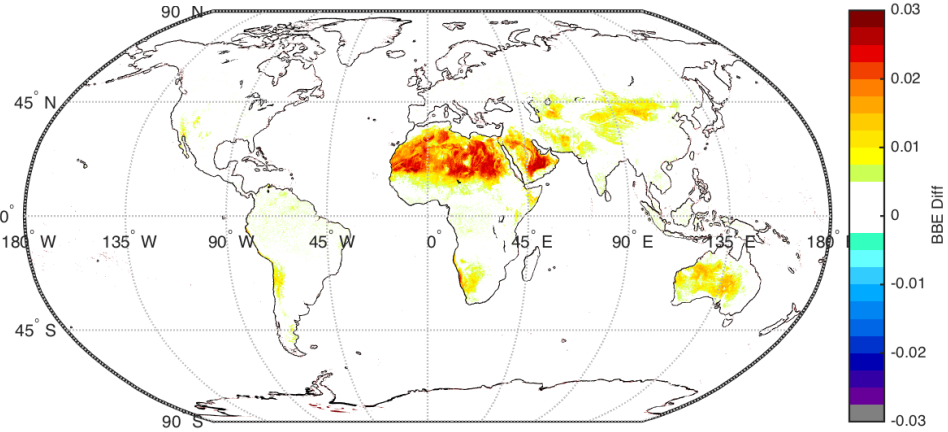
BBE 3.6-14.3 µm



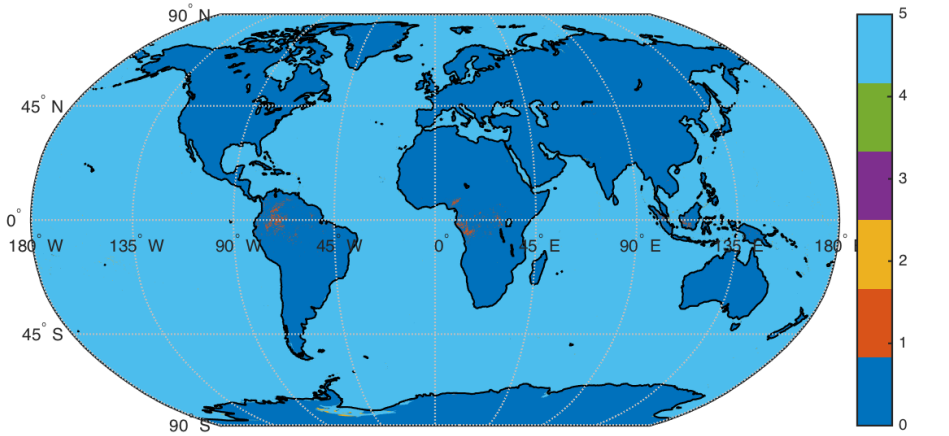
BBE 8-13.5 µm



BBE 3.6-14.3 µm – BBE 8-13.5 µm

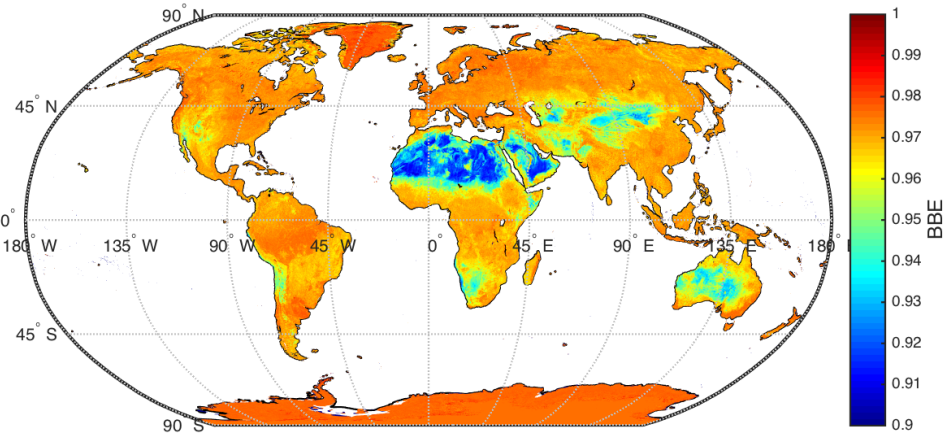


BBE QFLAG

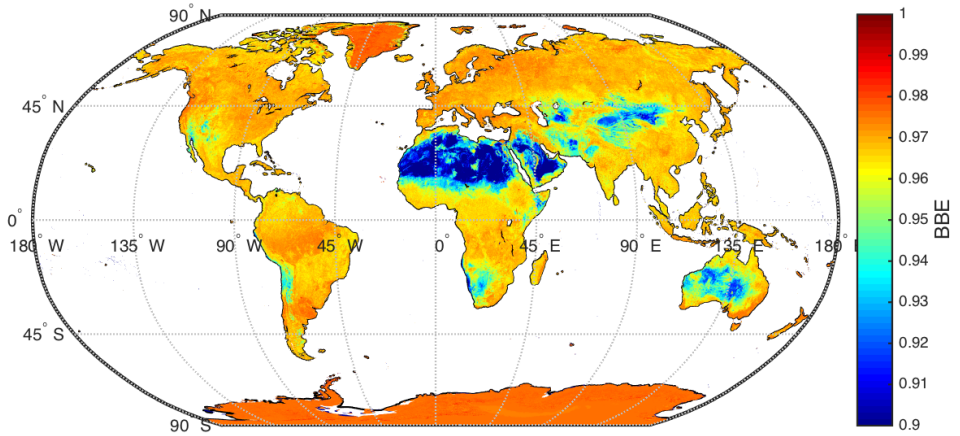


Broad band Emissivity for July 2013

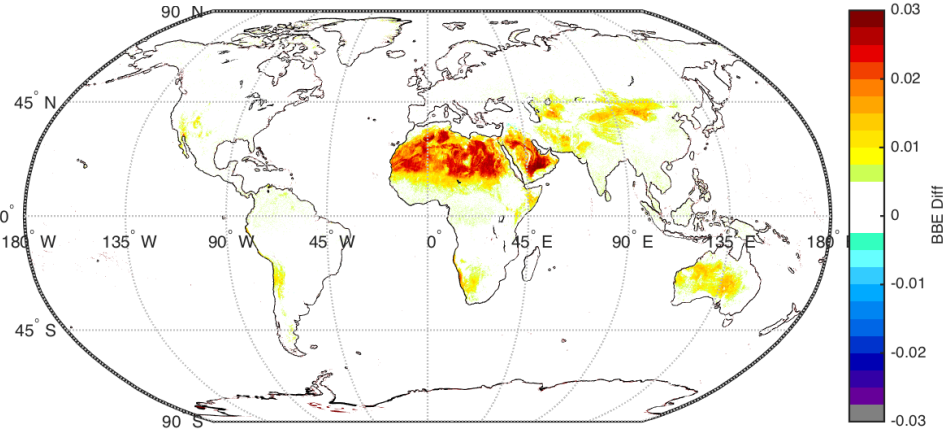
BBE 3.6-14.3 µm



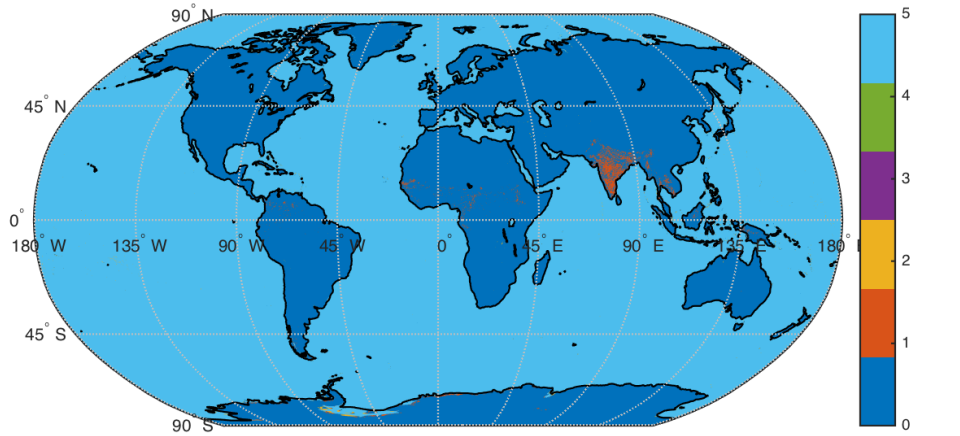
BBE 8-13.5 µm



BBE 3.6-14.3 µm – BBE 8-13.5 µm

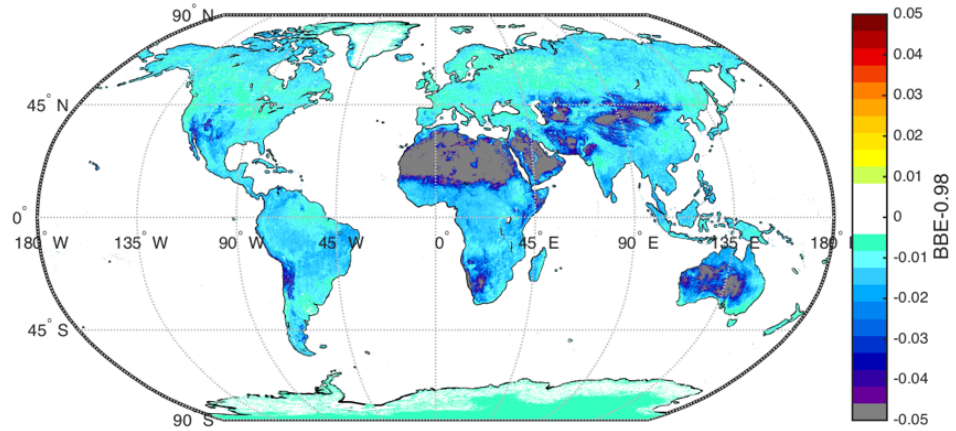


BBE QFLAG

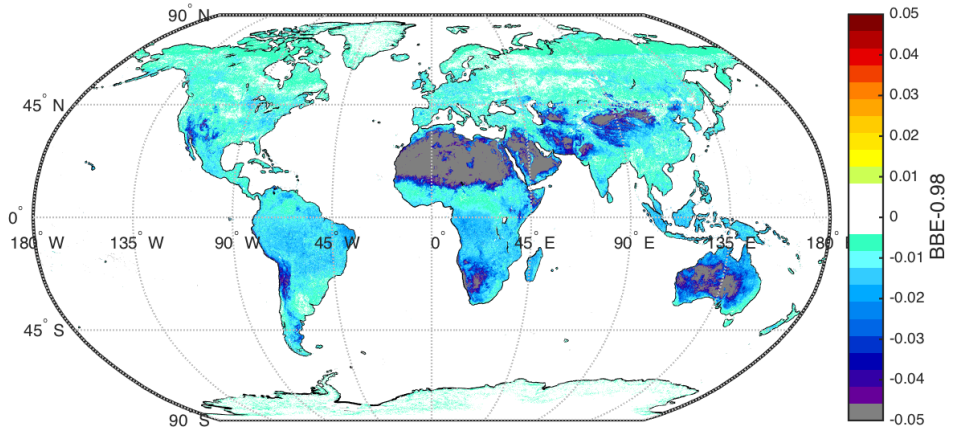


BBE – 0.980 for 8.0-13.5μm

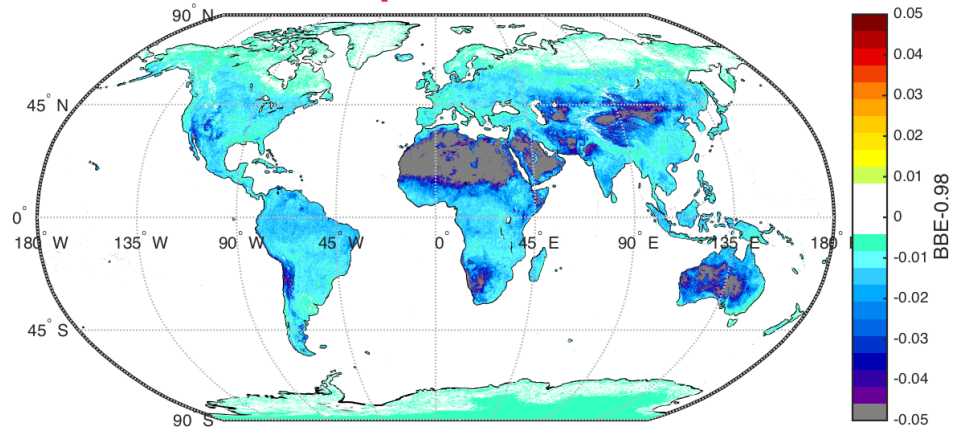
Sept 2002



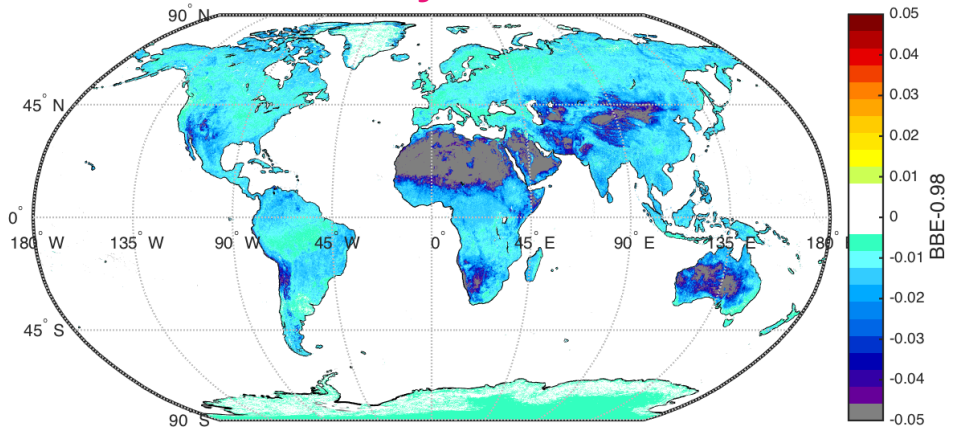
Jan 2003



Apr 2003

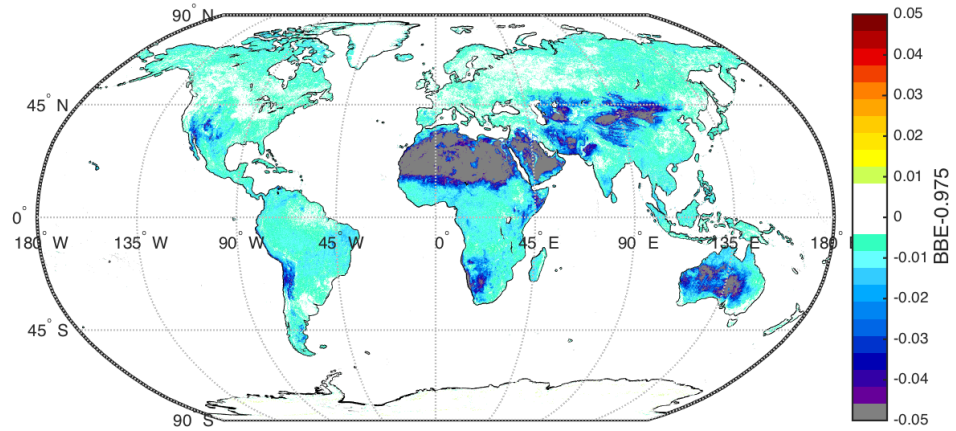


July 2003



BBE – 0.975 for 8.0-13.5μm

Sept 2002



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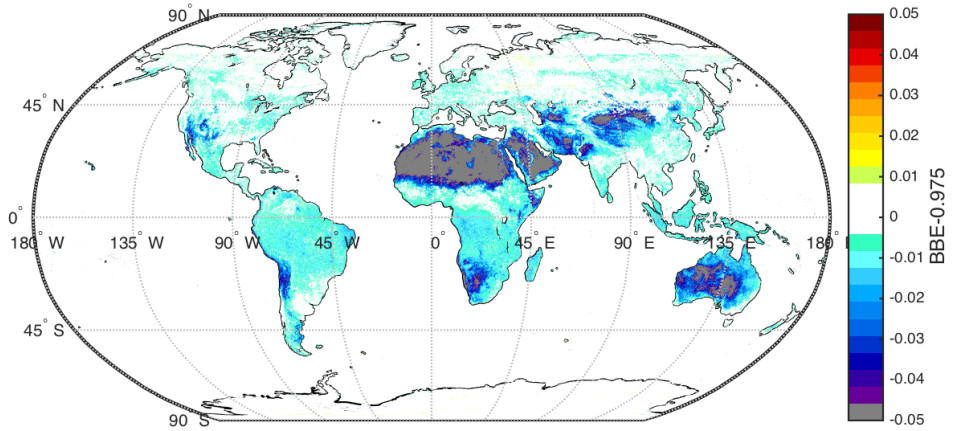

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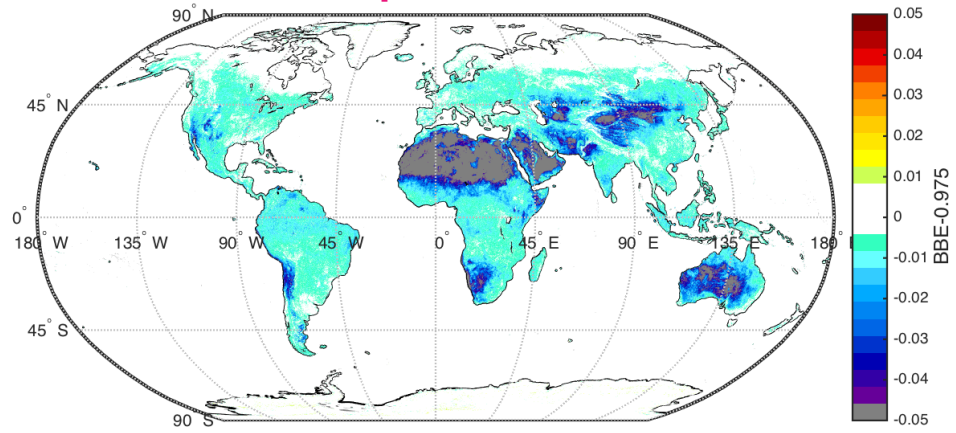
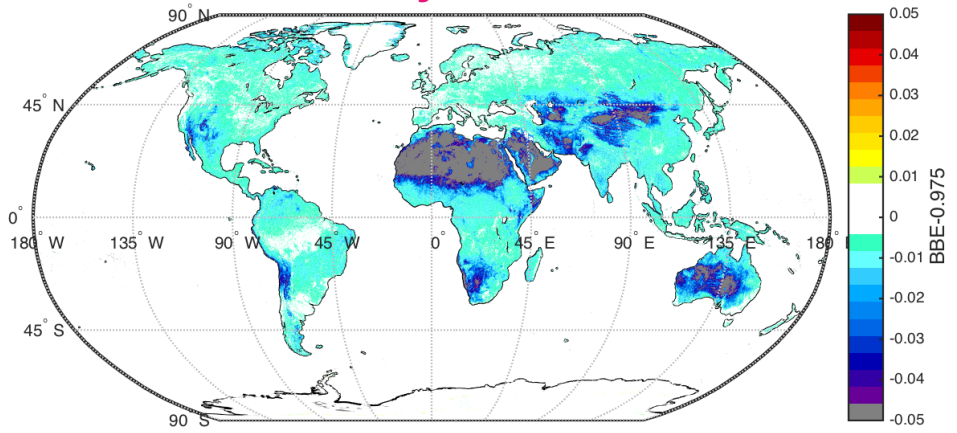
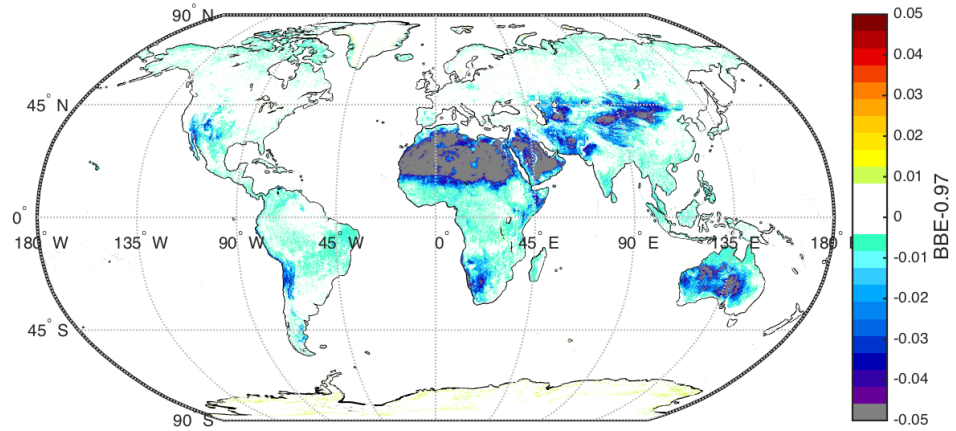


July 2003



BBE – 0.970 for 8.0-13.5μm

Sept 2002



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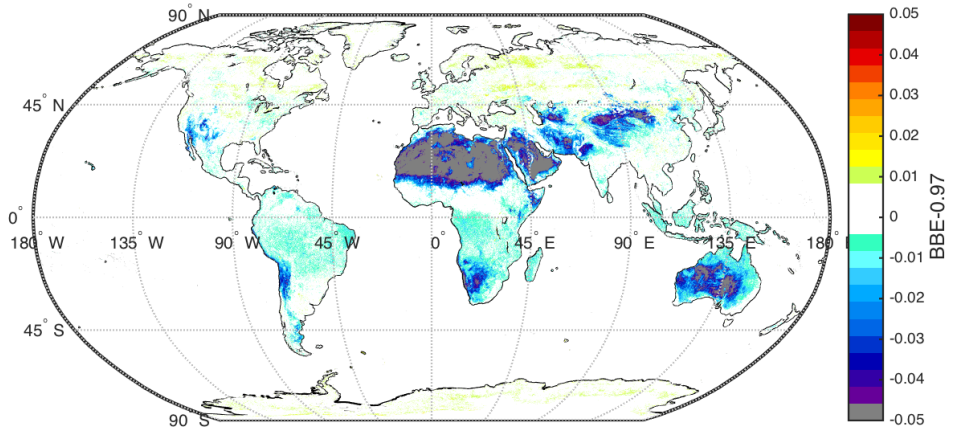

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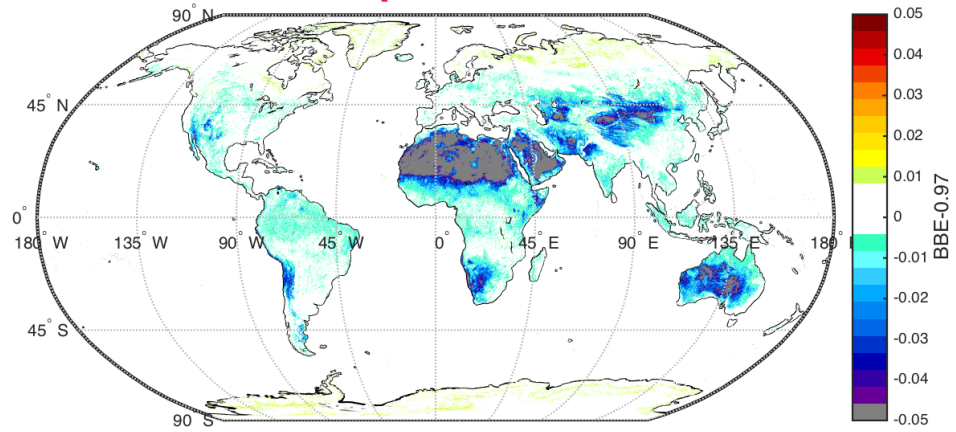

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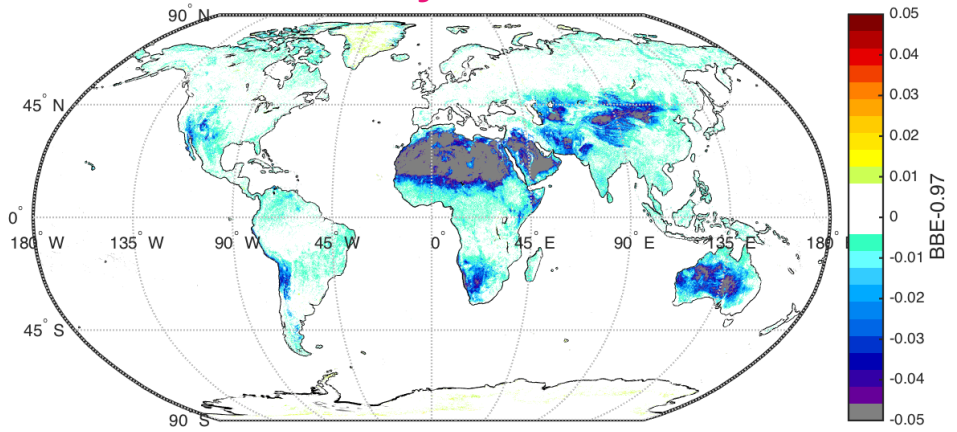
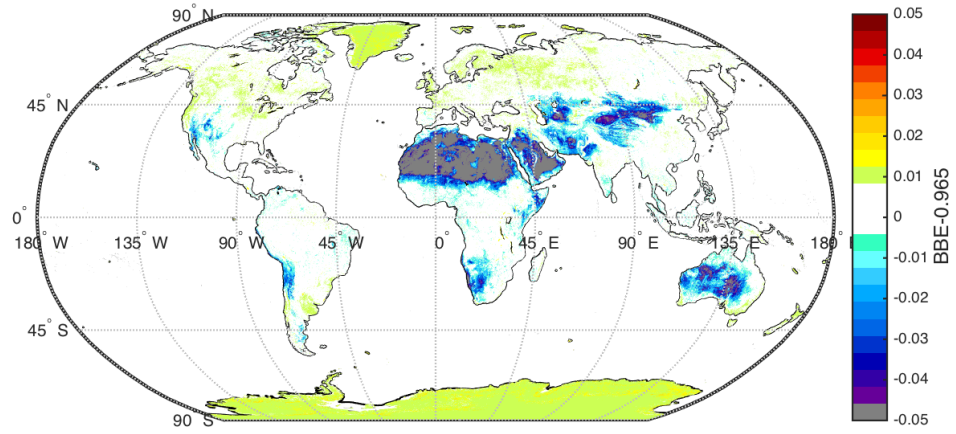


BBE – 0.965 for 8.0-13.5μm

Sept 2002



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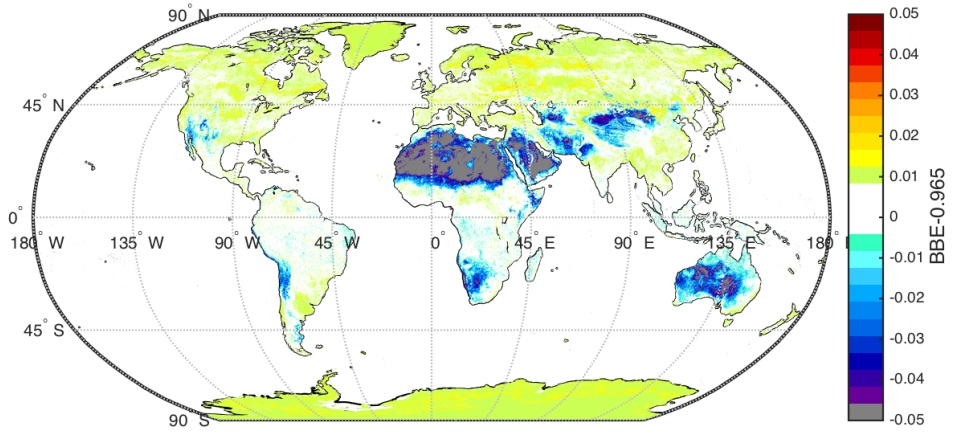

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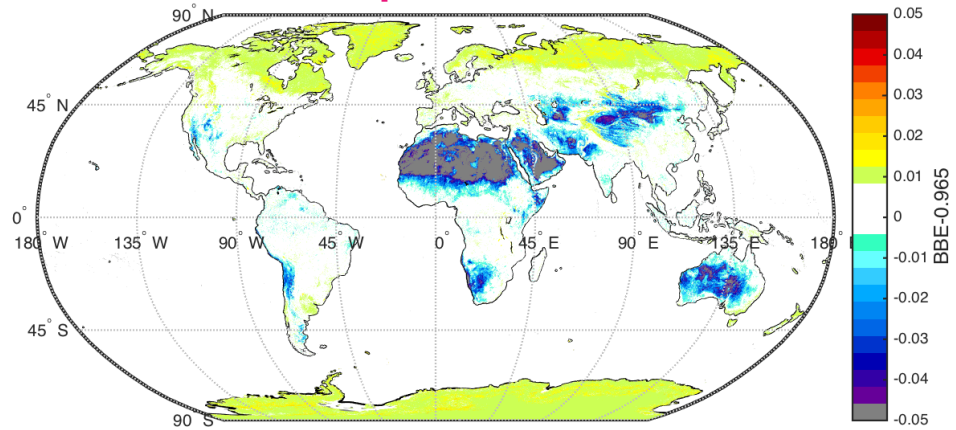
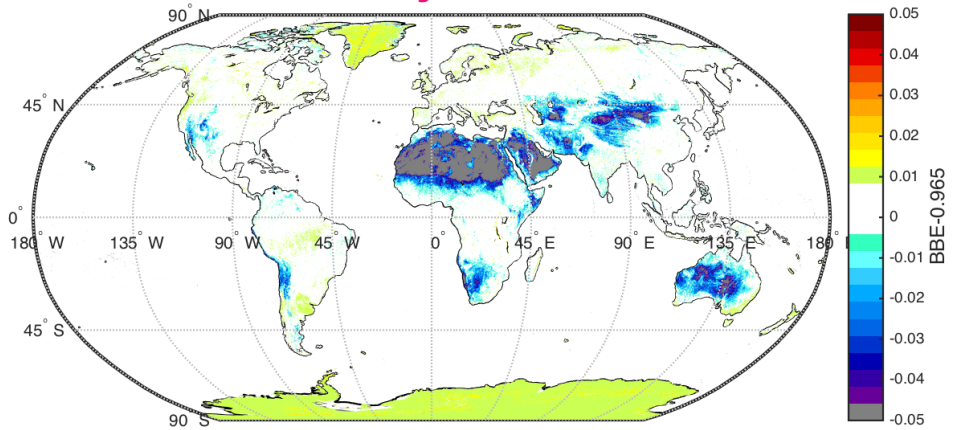
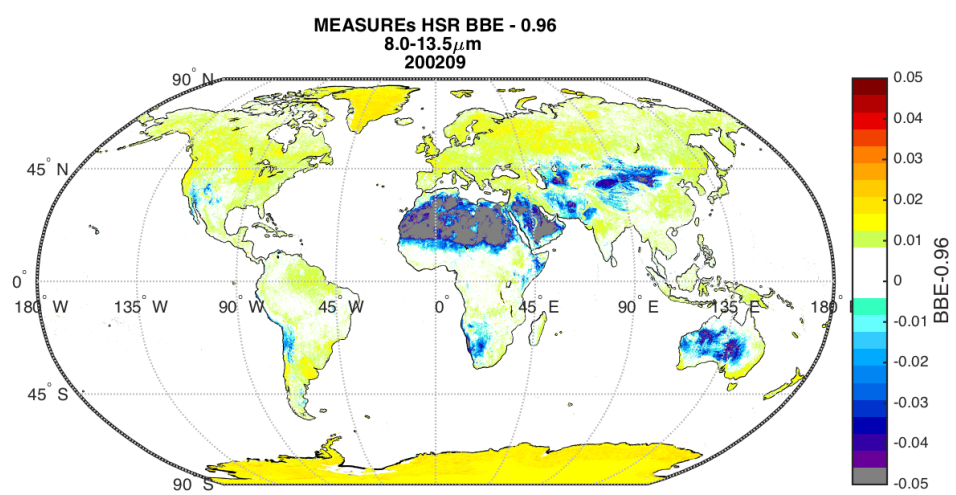
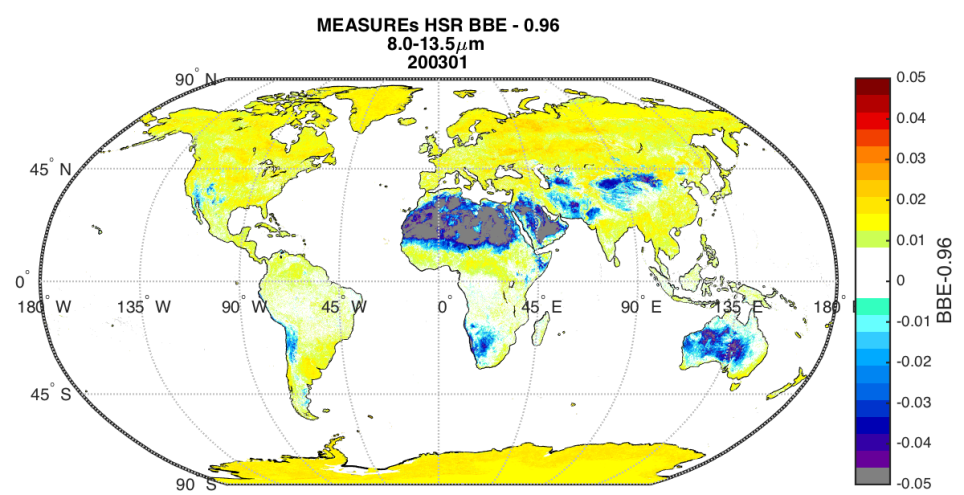


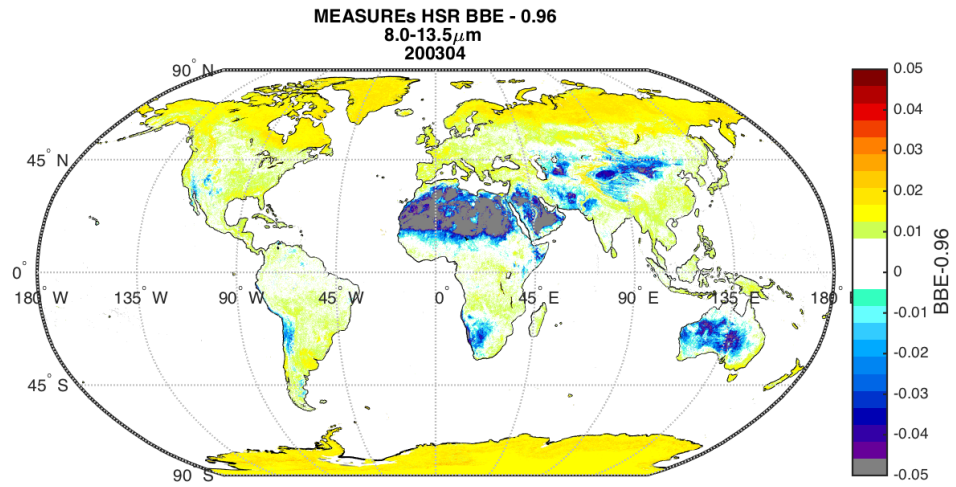
July 2003

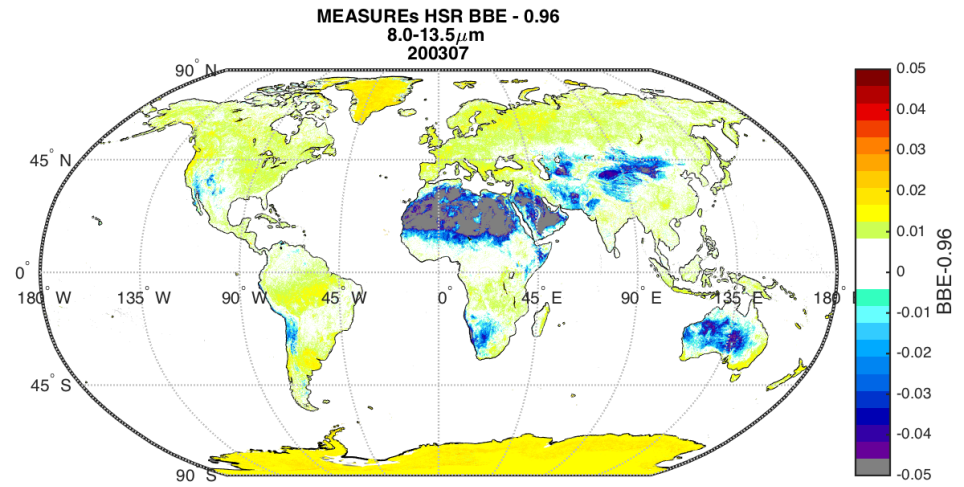


BBE – 0.960 for 8.0-13.5μm









Next Steps …

- Uncertainty determination (time, spatial and algorithm variabilities, total error)
- Continue to run RTTOV forward simulations with IASI to compare BT differences
- Continue evaluation with ground truth
- Compare with D. Zhou IASI product

Deliverables:

- Deliver first set of data to LPDAAC (Aug. 2016)
- 'Beta' product and algorithm currently available for testing and evaluation
  - Contact Eva.Borbas@ssec.wisc.edu for data access
  - 13 HP Emissivity, PCA coefficients and BBE monthly mean data file for 2002-2014 at 0.05 degree
  - HSR PCA algorithm (Fortran90, matlab)

Broad Band Emissivity (cont.)

BBE Quality Flag:

0= good data, bbe between 0.8-1

1= good data, but MOD11 SkinT was not available (cloudy); default value 290K was used

2= bbe outside of the 0.8-1 range

3= bbe calc failed

4= no bbe calc - no CAMEL coefs available

5= no bbe calc - Sea or inland water
based on CAMEL qflag