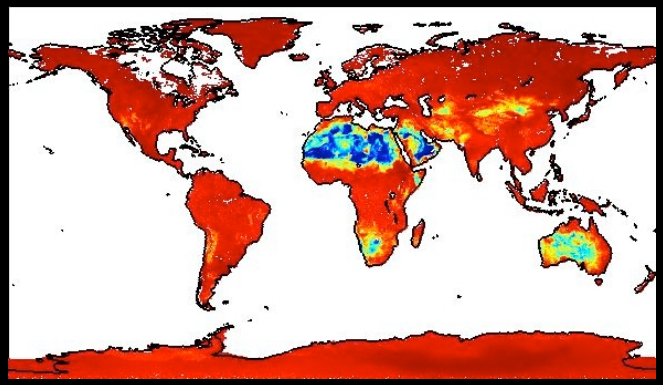
AIRS
Land Surface Emissivity



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NASA Sounder Science Meeting, Greenbelt, MD, Oct 2009

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Outline

- AIRS v5 validation summary
- AIRS v5.4.1 emissivity evaluation
  - Diurnal emissivity differences
  - Spectral analysis with lab measurements
- AIRS emissivity and soil moisture
- Summary

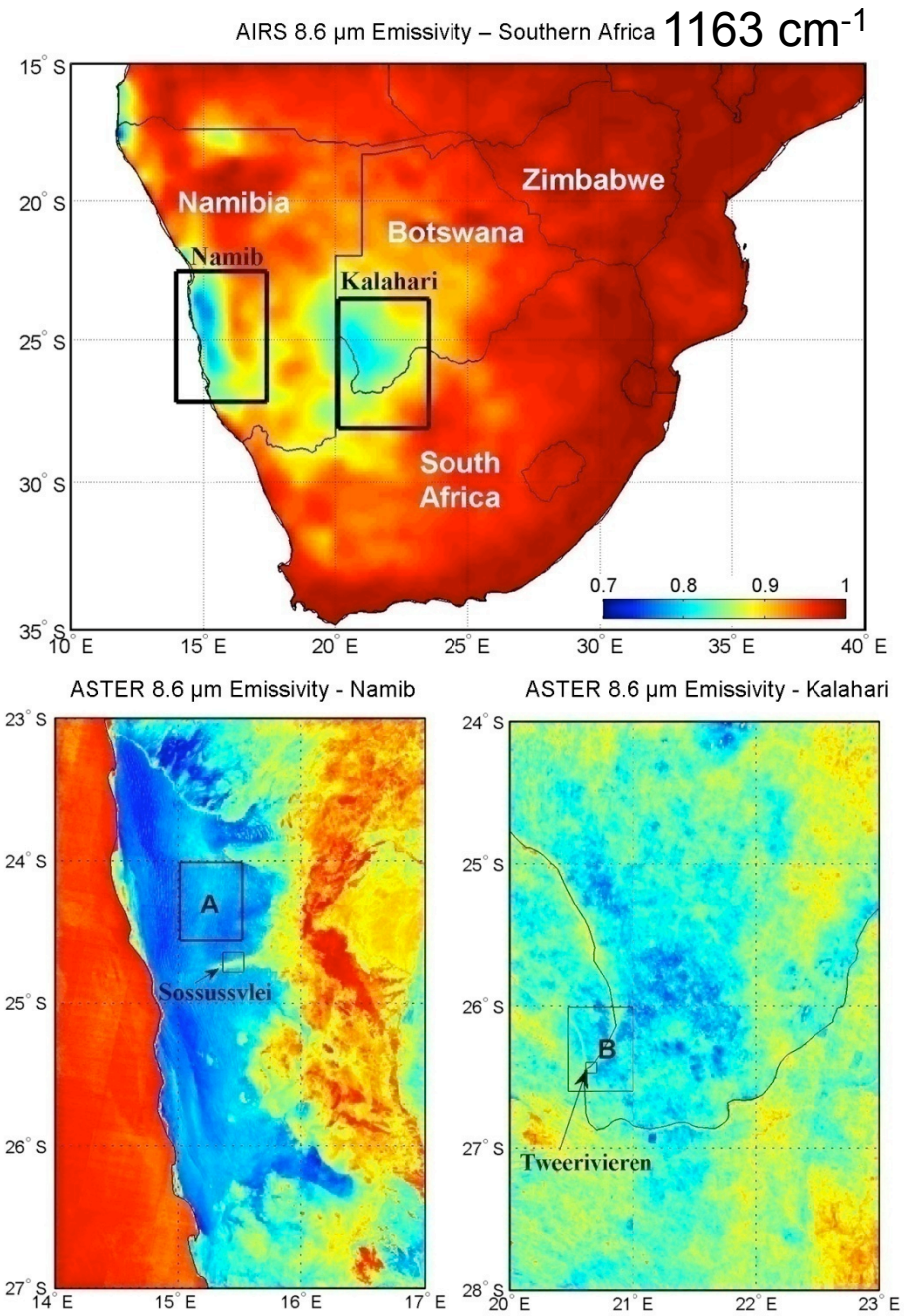
AIRS v5 Land Surface Emissivity Validation

Validation Targets:

- Namib Desert (desert)
- Kalahari Desert (semi-arid)

AIRS emissivity validation requires large, homogeneous sites with known composition.

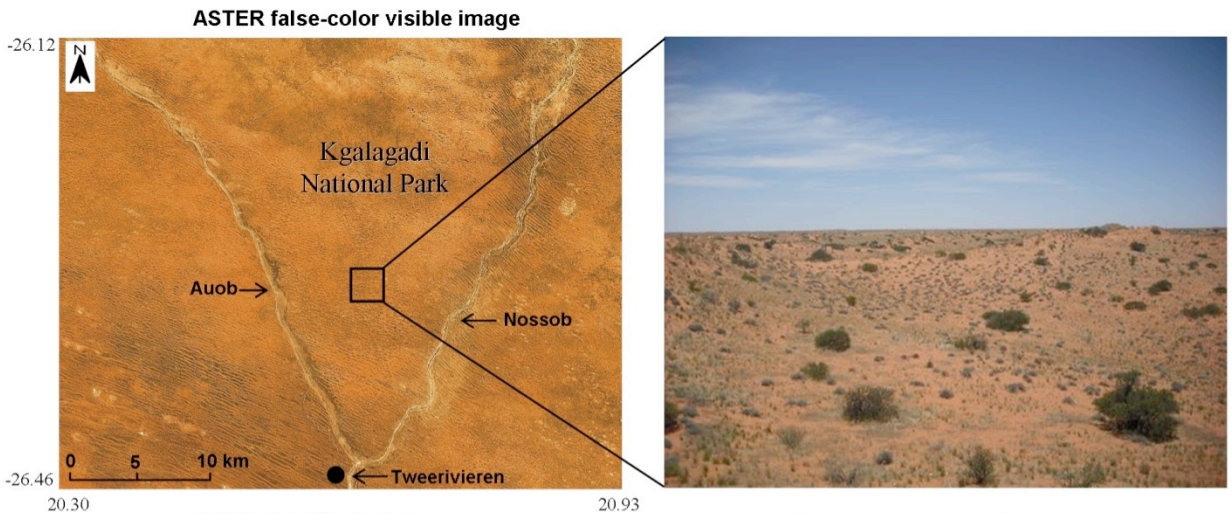
AIRS Emissivity was accurate to within **2.5%** at the two sites, using lab measurements of sand collected at both sites, combined with ASTER data (90 m).



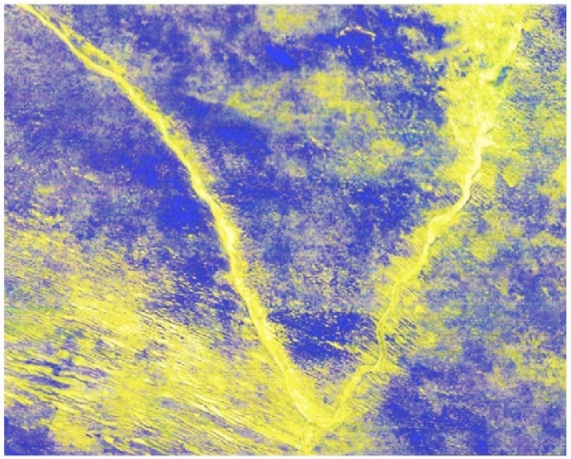
Hulley, G.C., S.J. Hook, E. Manning, S. Lee, E. Fetzer, 2009, Validation of the Atmospheric Infrared Sounder (AIRS) Version 5 Land Surface Emissivity Product over the Namib and Kalahari Desert, *Journal of Geophysical Research Atmospheres*, VOL. 114, D19104, doi:10.1029/2009JD012351

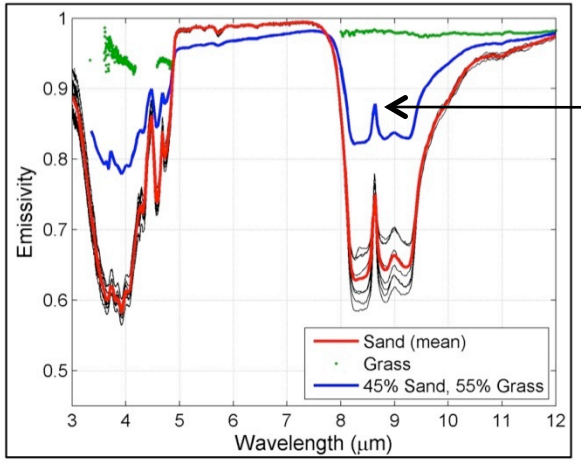
Kalahari Desert

- 20 sand samples collected at Kgalagadi National Park (17-21 November 2008)
- Sampling areas included dune crests, troughs, dry riverbeds



Major: Quartz
Minor: Hematite

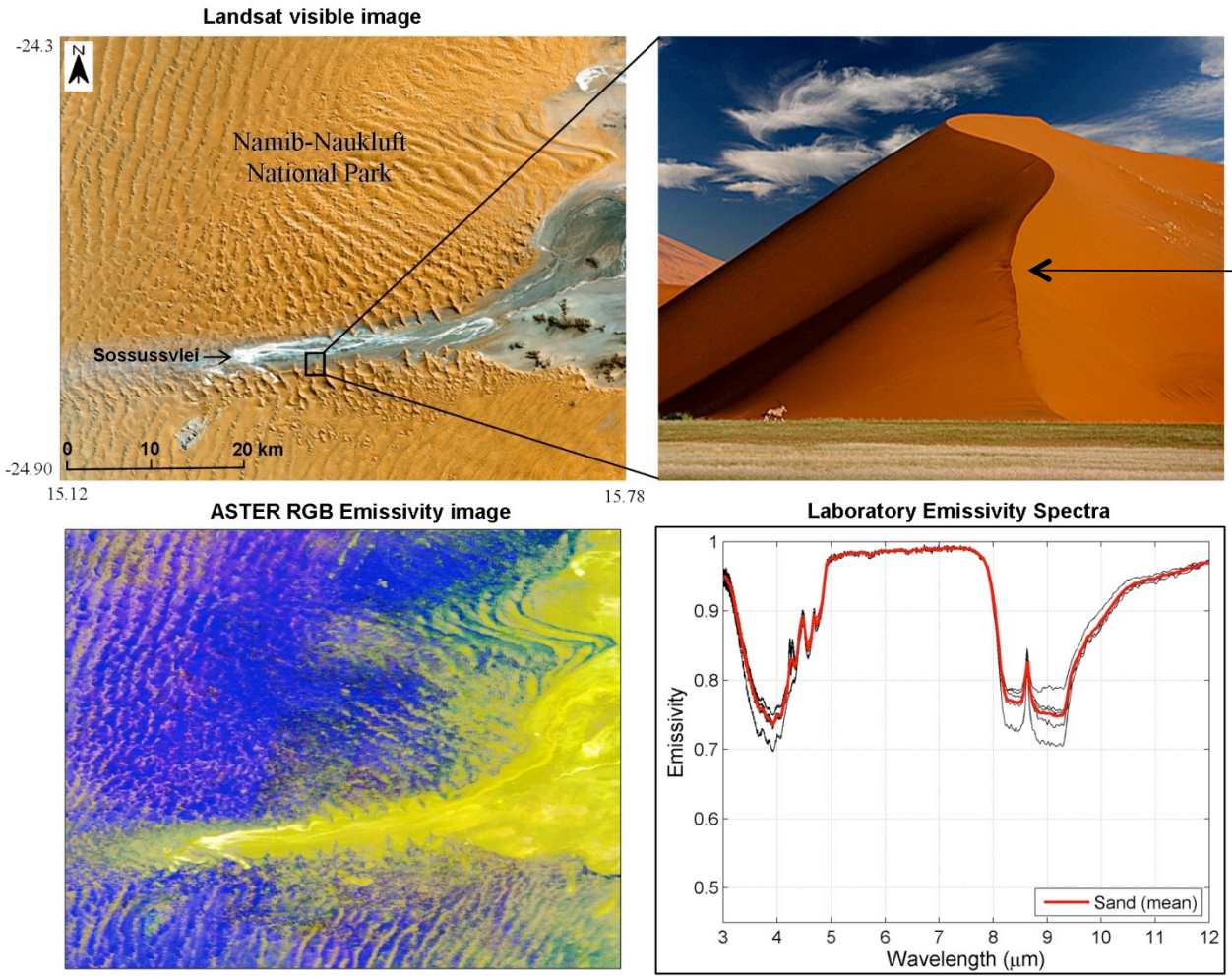




SAFARI 2000
Kalahari transects
- 55% Vegetation
- 45% Sand

Namib Desert

- Sand samples collected at Sossussvlei in Namib-Naukluft park
- 10 samples from a dune crest and interdune area



Major: Quartz
Minor: Feldspar, Magnetite

AIRS V5.4 Evaluation

- New Retrieval Methodology:

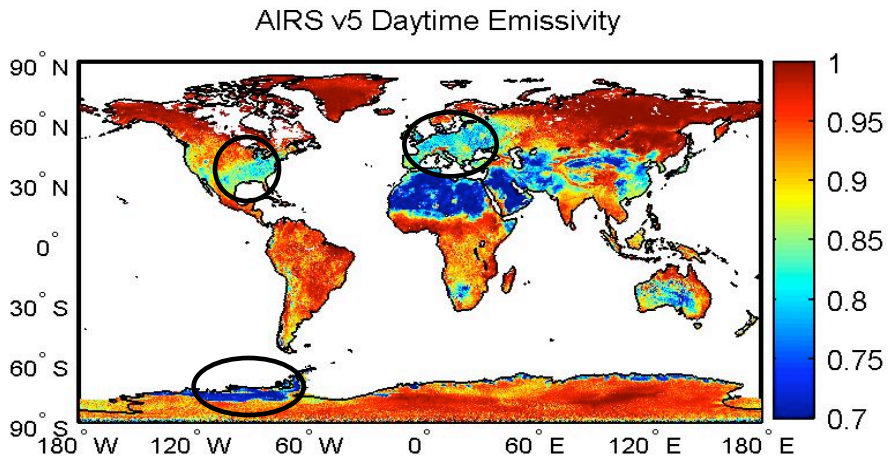
Susskind, J., and J. Blaisdell, (2008), Improved surface parameter retrievals using AIRS/AMSU 453 data, *Proc. SPIE, 6966*, DOI: 10.1117/1112.774759.

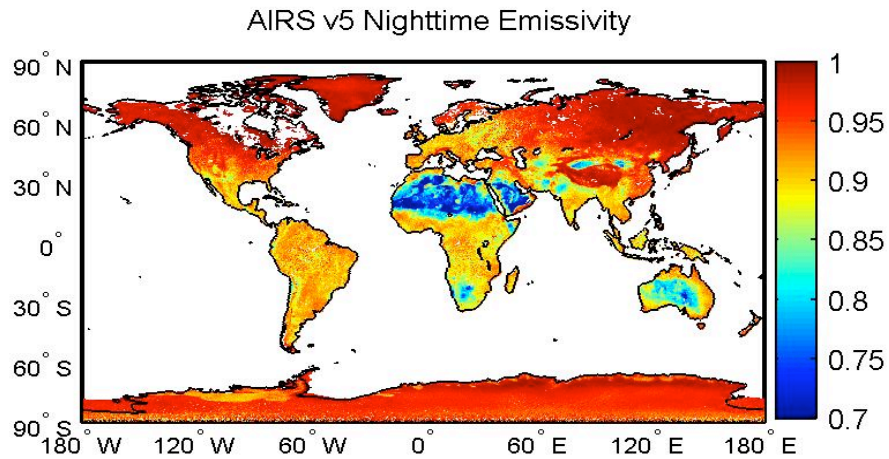
Following v5 emissivity issues are addressed (Hulley et al. 2009):

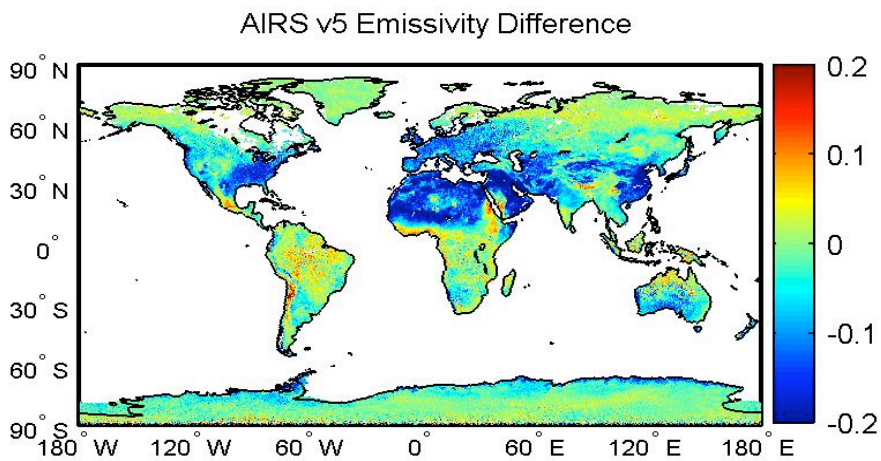
- Nonphysical values (e>1)
- Surface reflectance modeling errors
- Large Day/night discrepancies

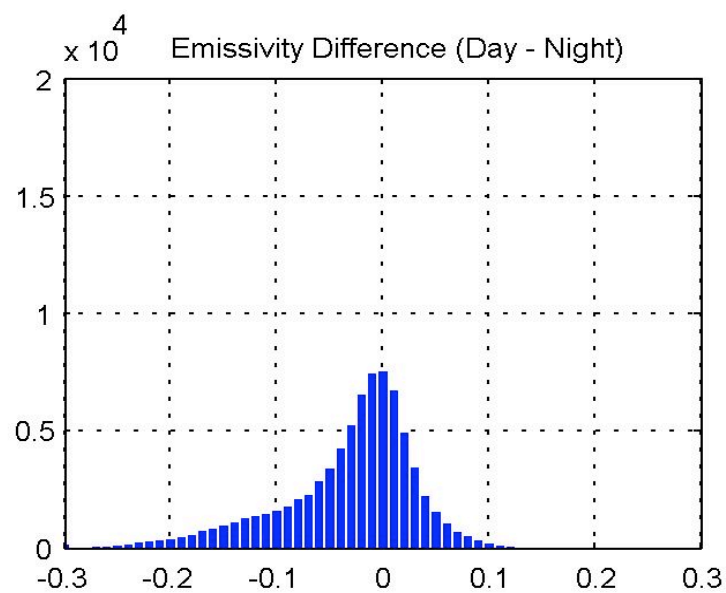
Two step retrieval: A set of shortwave channels used to retrieve LST, and then held constant in longwave emissivity retrieval.

AIRS **v5**: 3.9 μm (2631 cm^{-1}): December 2008

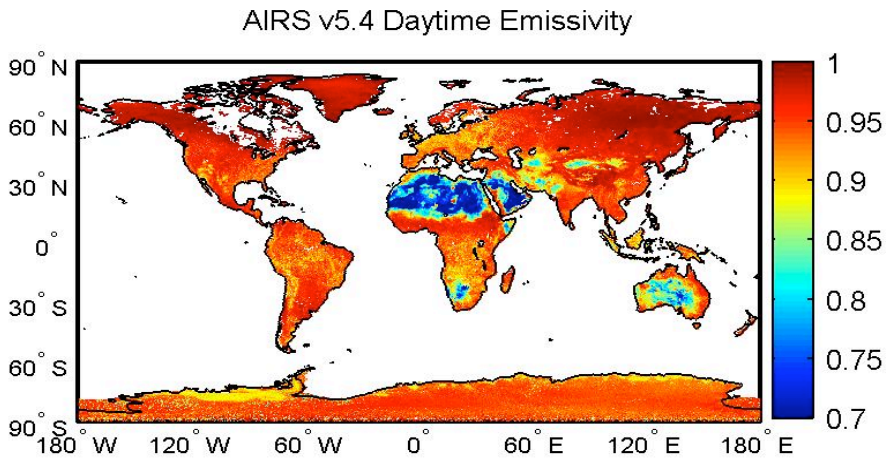


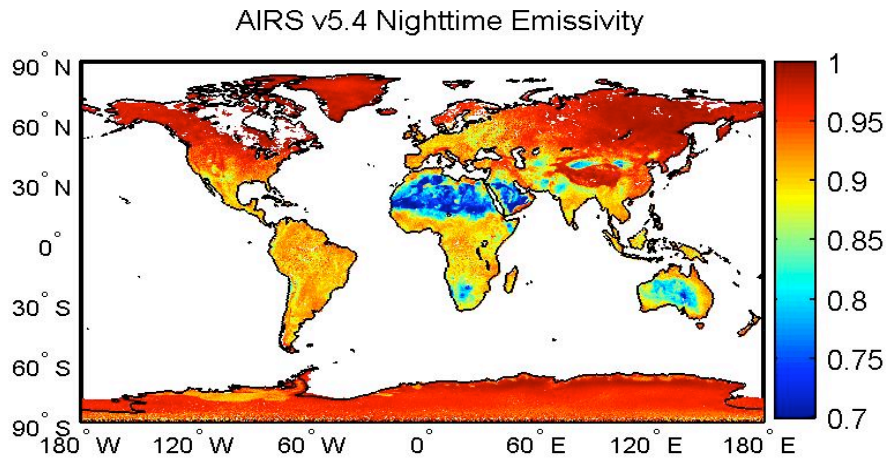


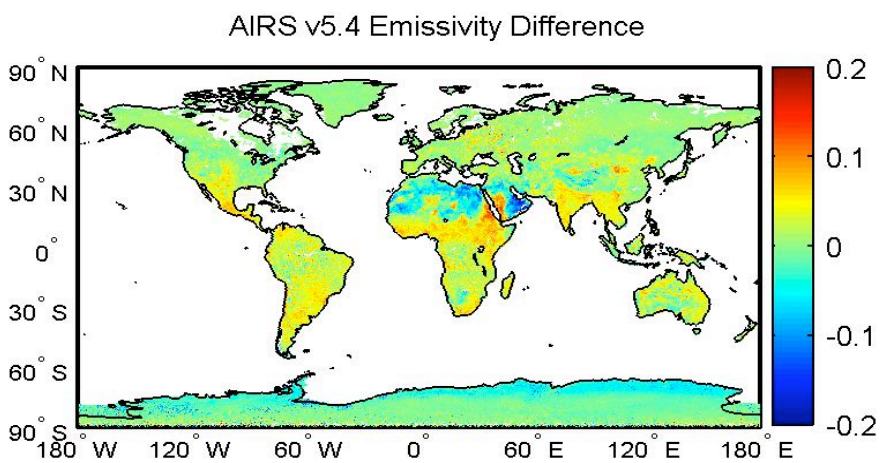


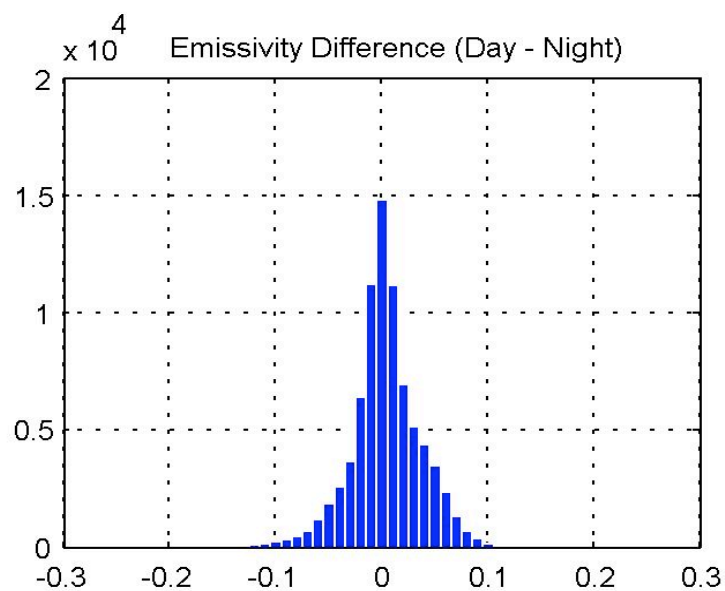


AIRS **v5.4.1**: 3.9 µm (2631 cm^{-1}): December 2008

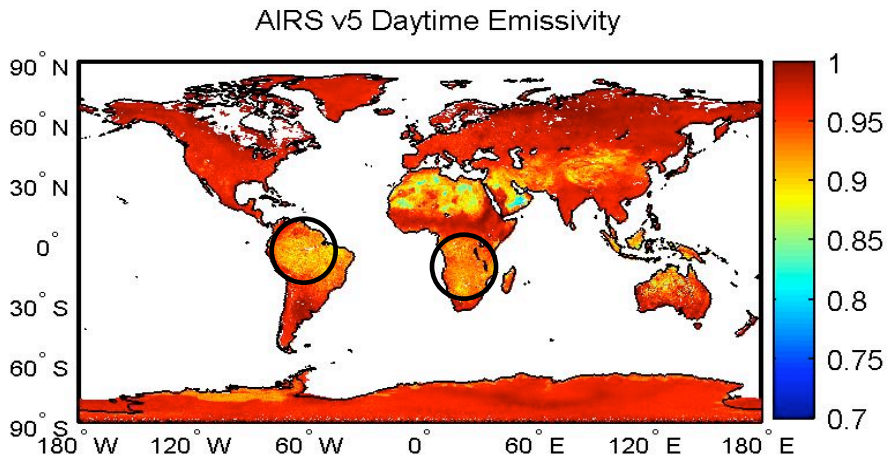


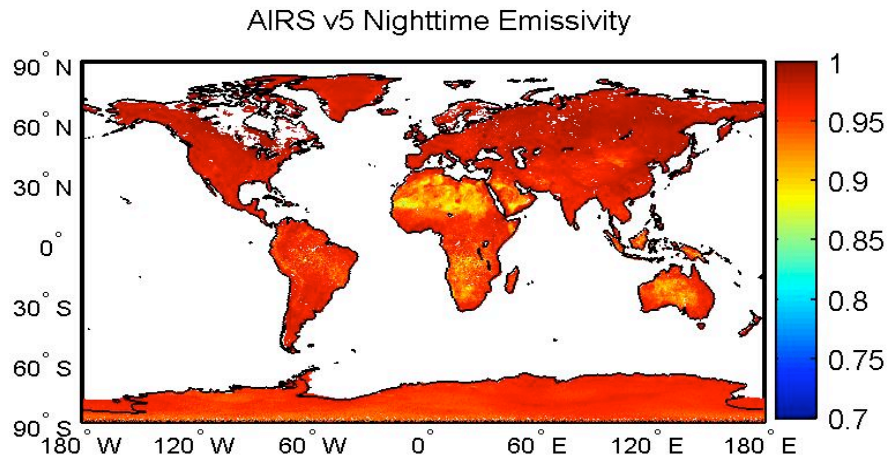


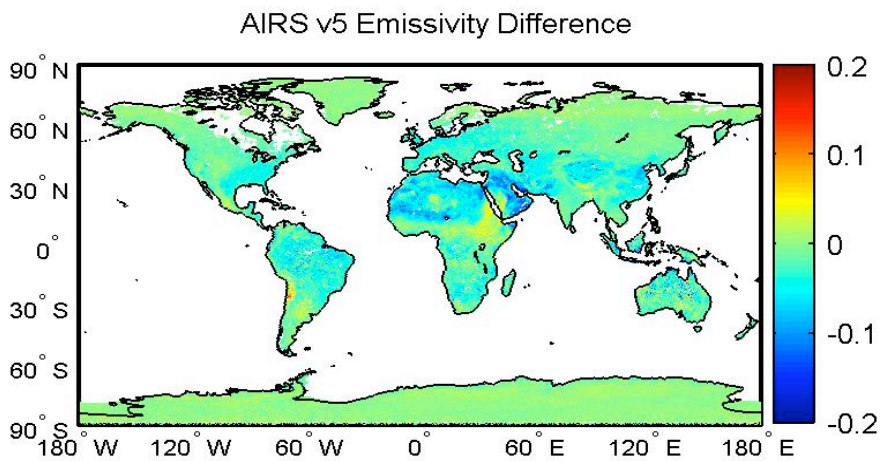


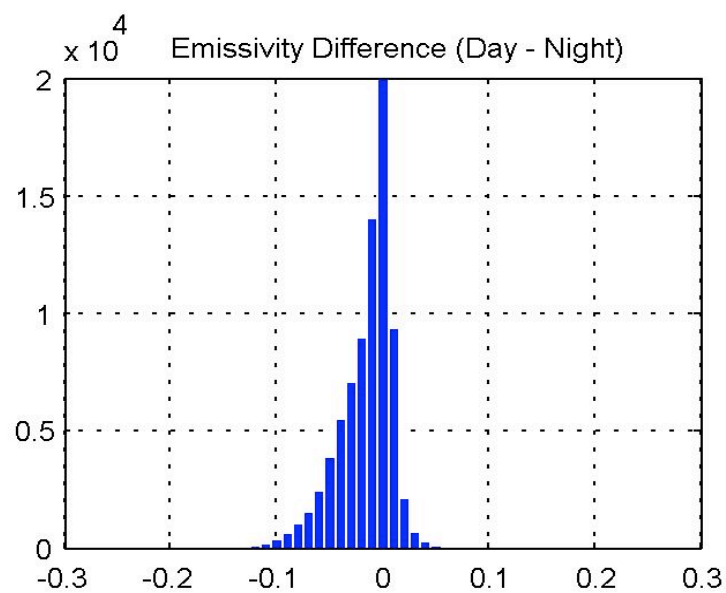


AIRS **v5**: 12 μm (833 cm^{-1}): December 2008

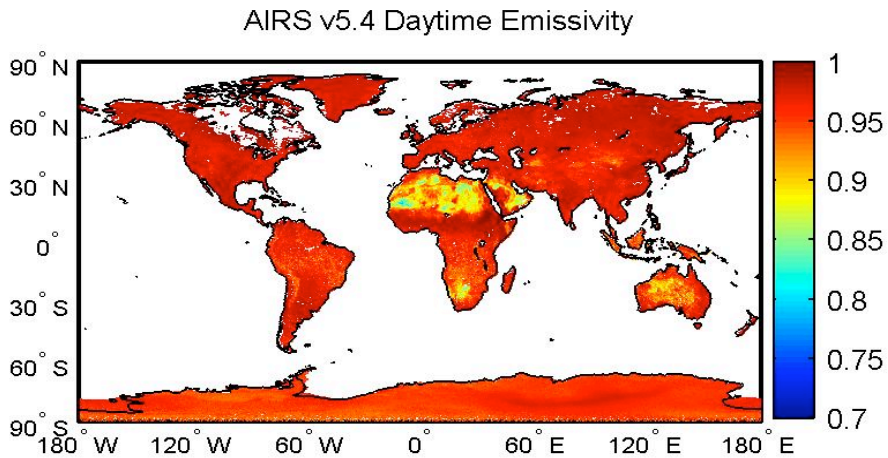


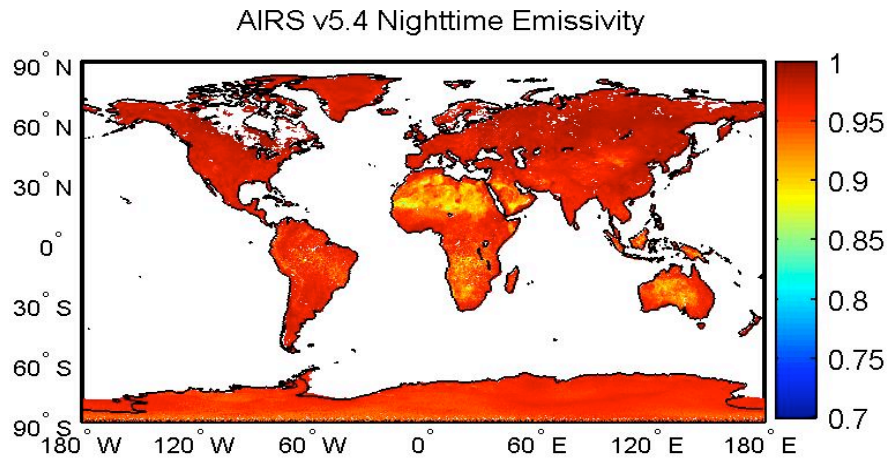


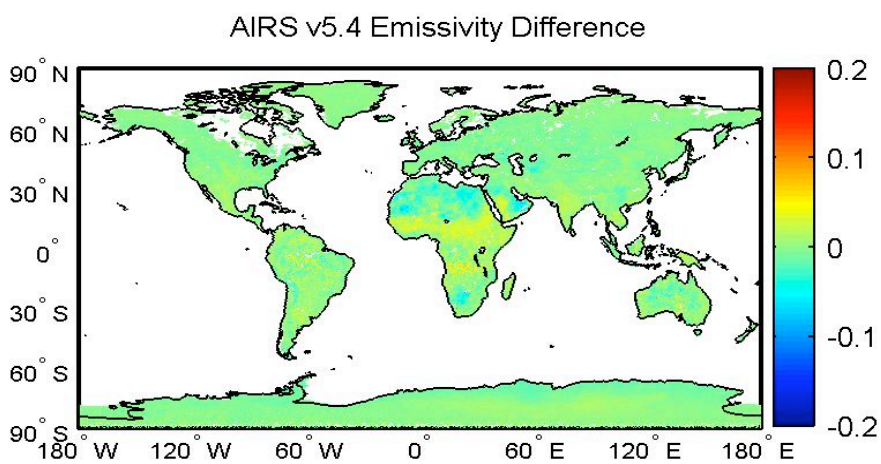


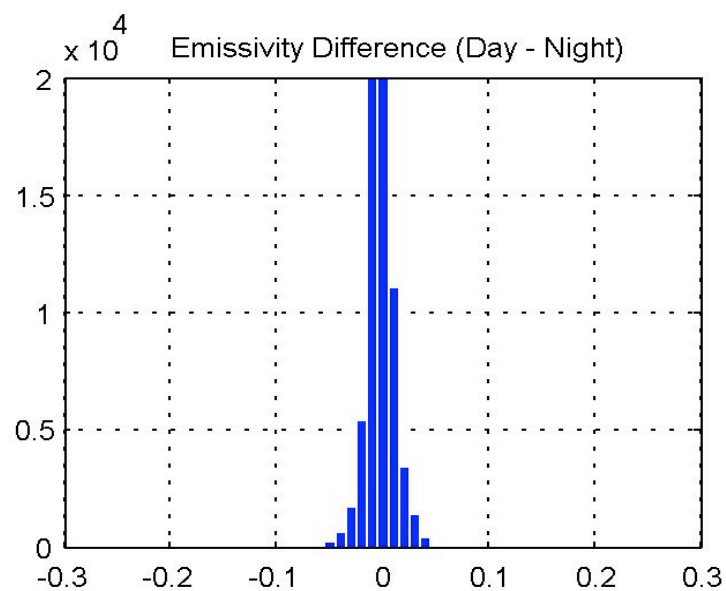


AIRS **v5.4.1**: 12 µm (833 cm^{-1}): December 2008



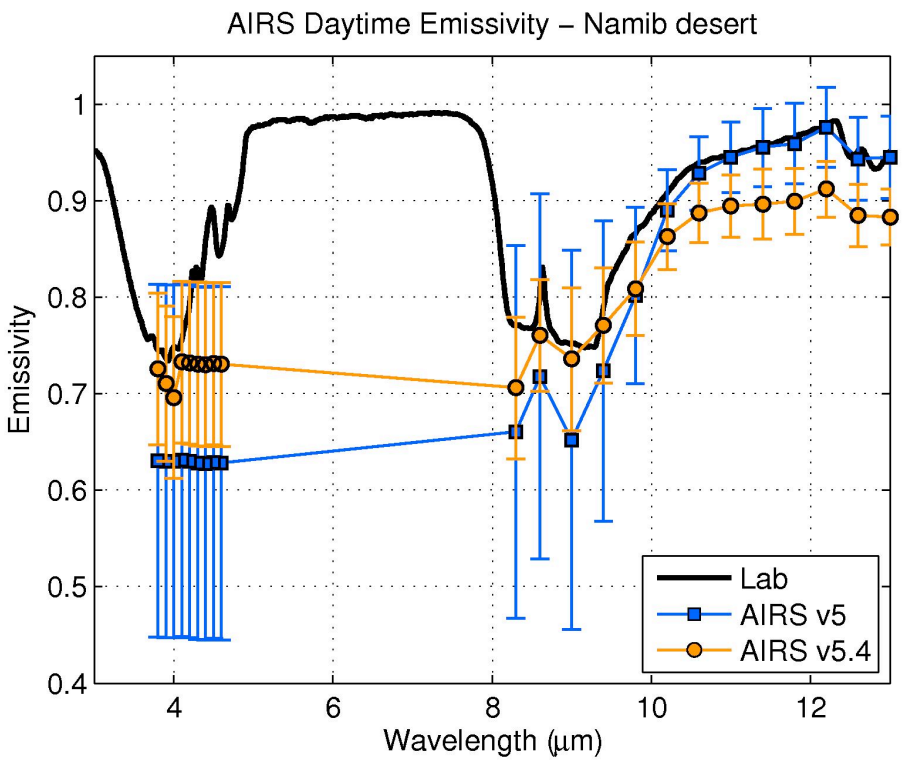




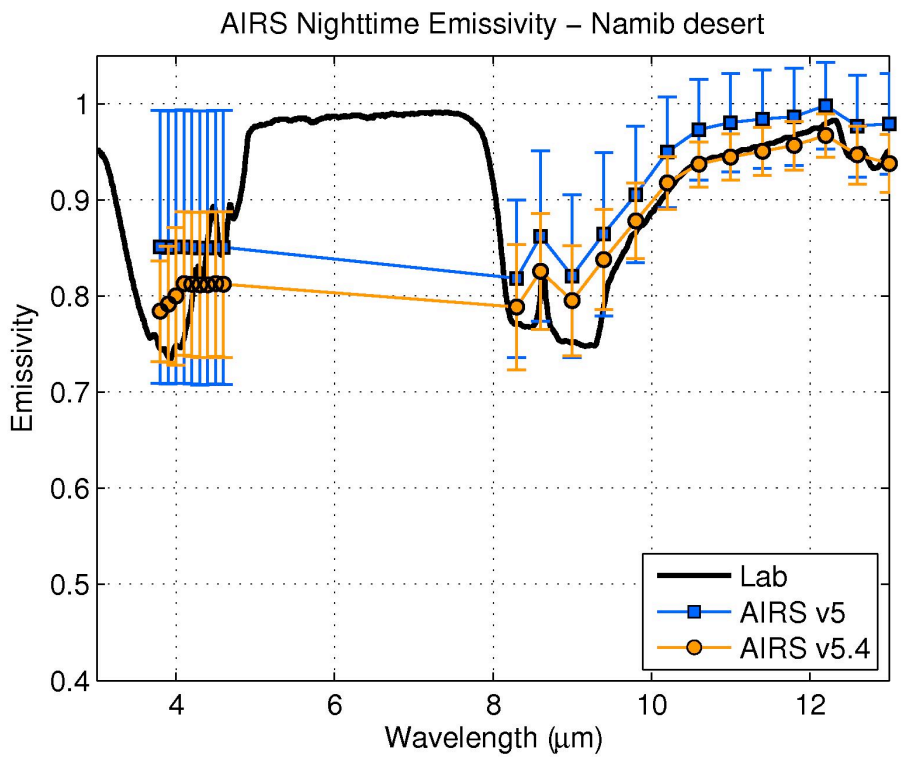


Namib desert: December 2008

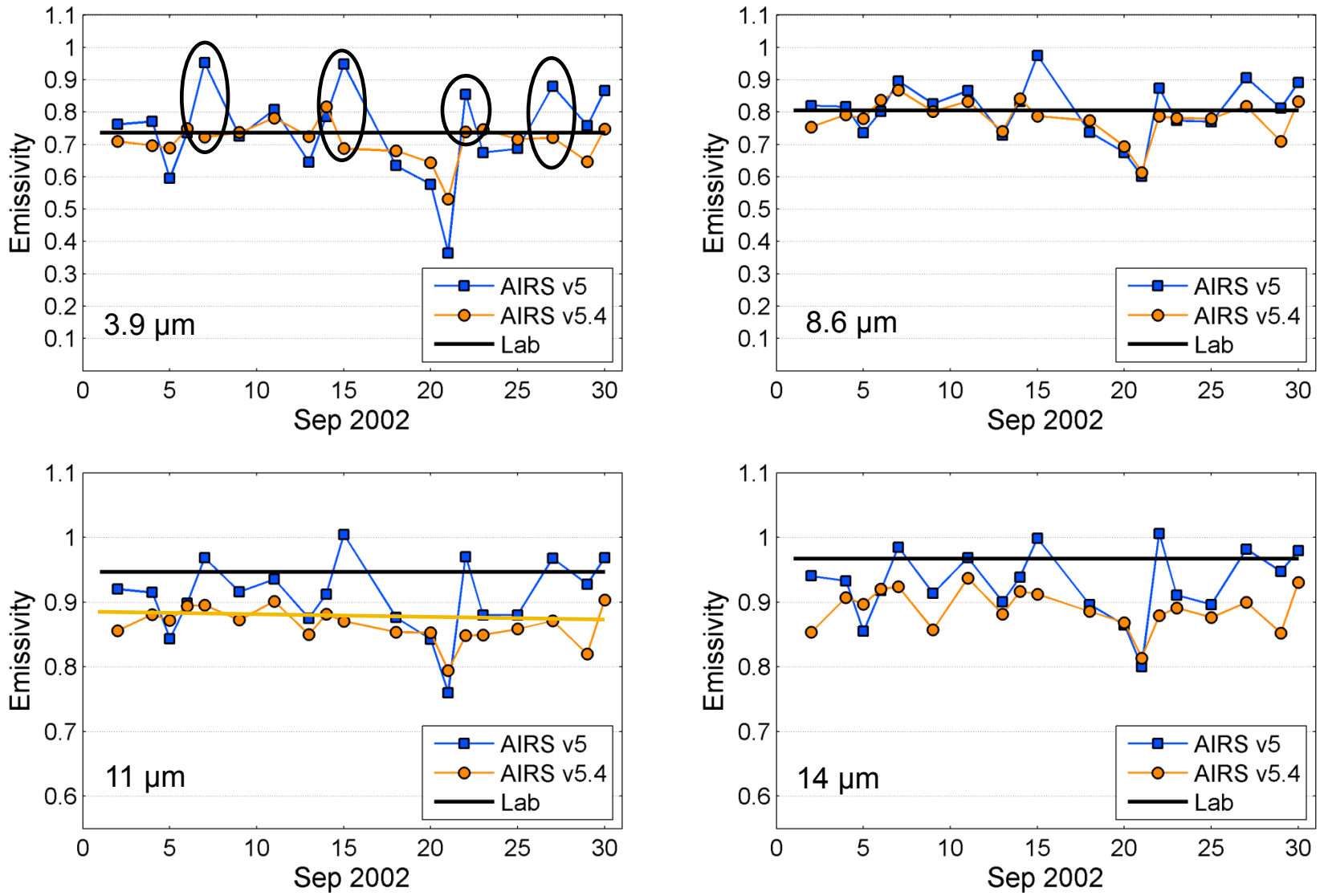
Day



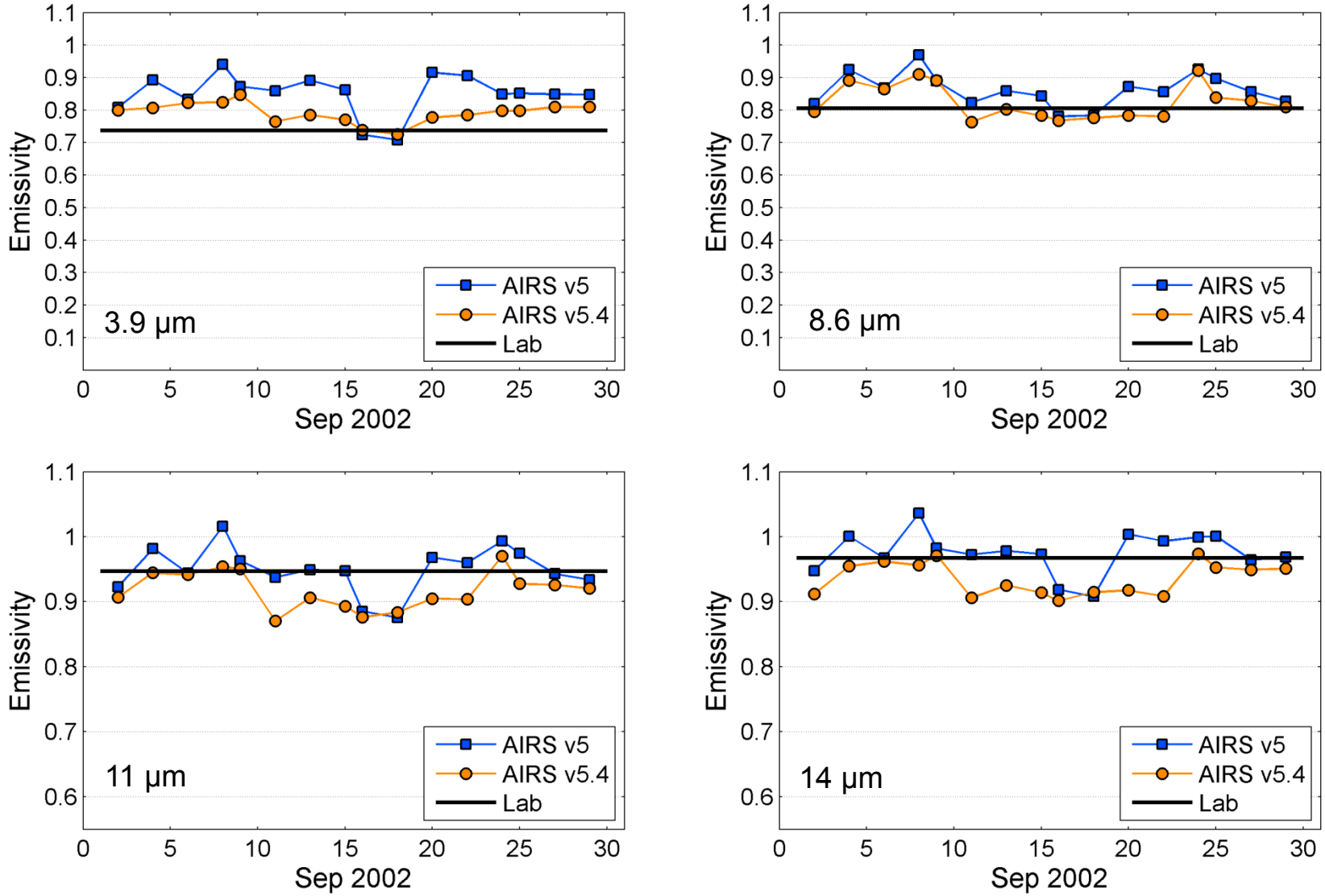
Night



Namib desert: Daytime temporal variations



Namib desert: Nighttime temporal variations

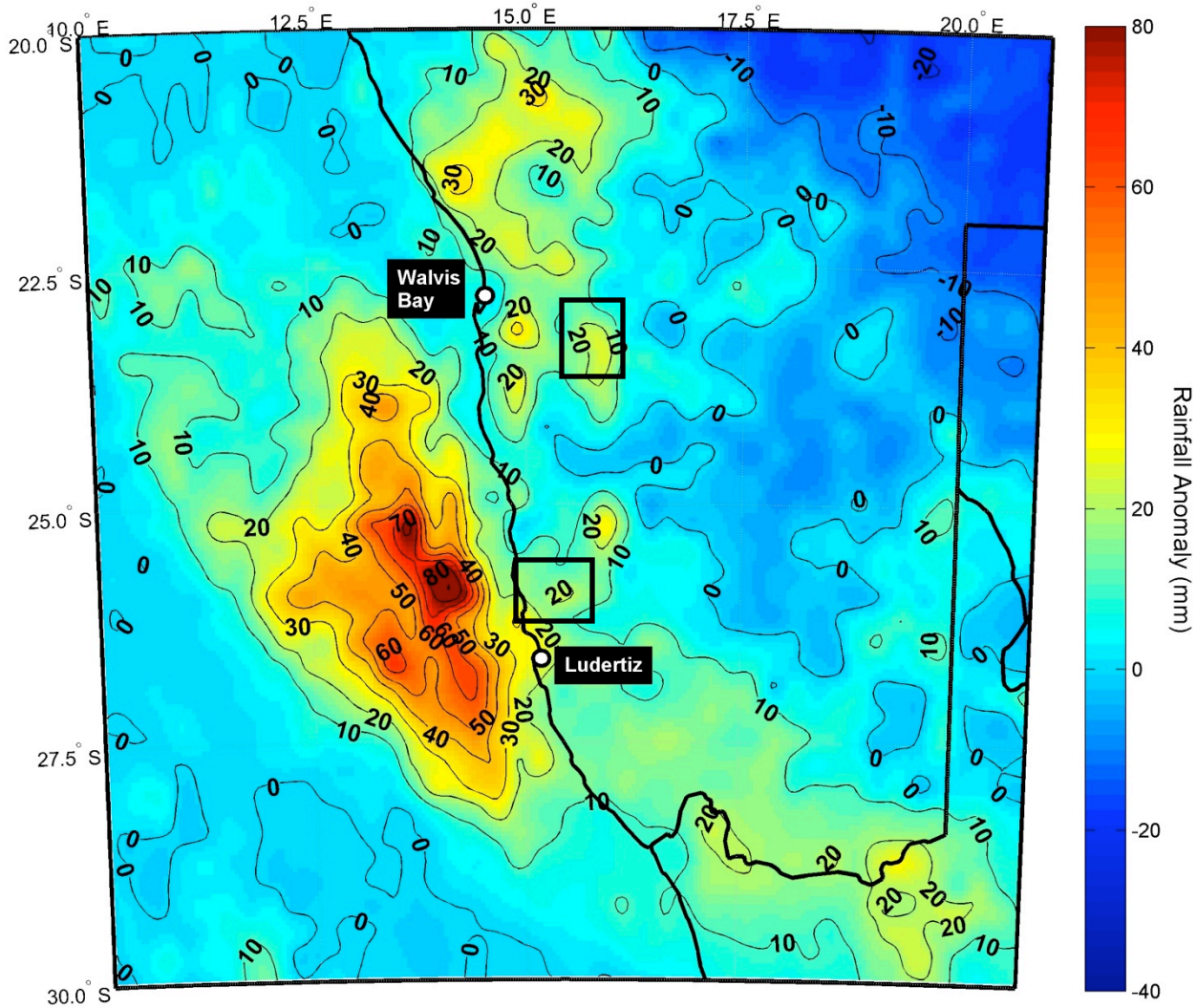


AIRS Emissivity and Surface Soil Moisture (SM)

SM is key variable:
- Agricultural land use
- Surface energy budget
- Drought monitoring
- Fire prediction

From 16-22 April 2006, almost **100 mm** rain was recorded at Luderitz – **6 times the long-term annual rainfall average!**

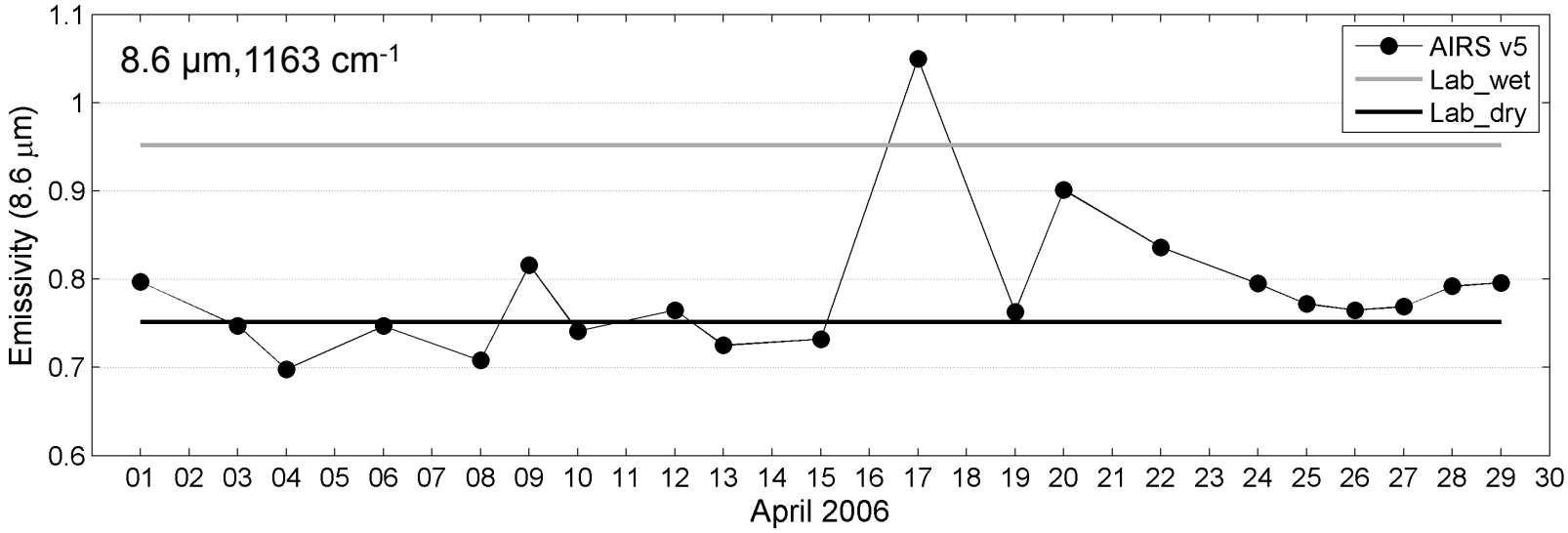
Tropical Rainfall Measuring Mission (TRMM) rainfall anomaly for April, 2006 (mm)

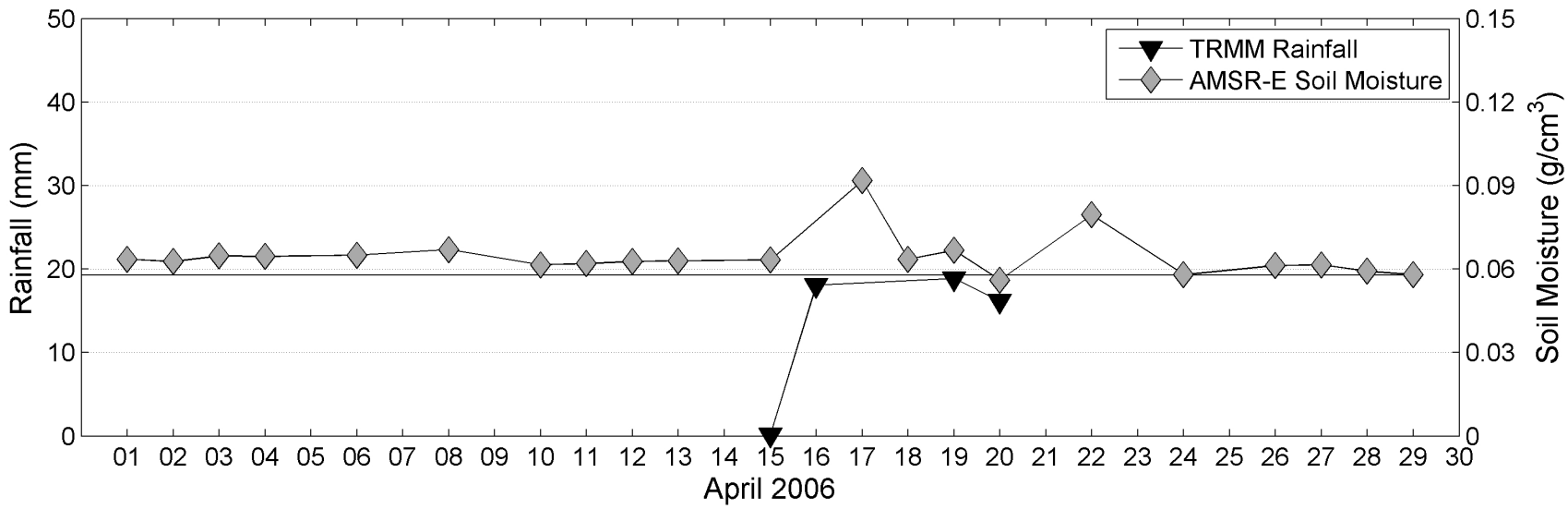


Hulley, G.C., S.J. Hook, 2009, Investigating the Effects of Soil Moisture on Thermal Infrared Land Surface Emissivity Retrievals from AIRS, MODIS and ASTER and Comparisons with Laboratory Measurements , *Remote Sensing of Environment*, *in review*

Quartz doublet (8-10 µm, 1250-1000 cm^{-1}) sensitive to soil moisture

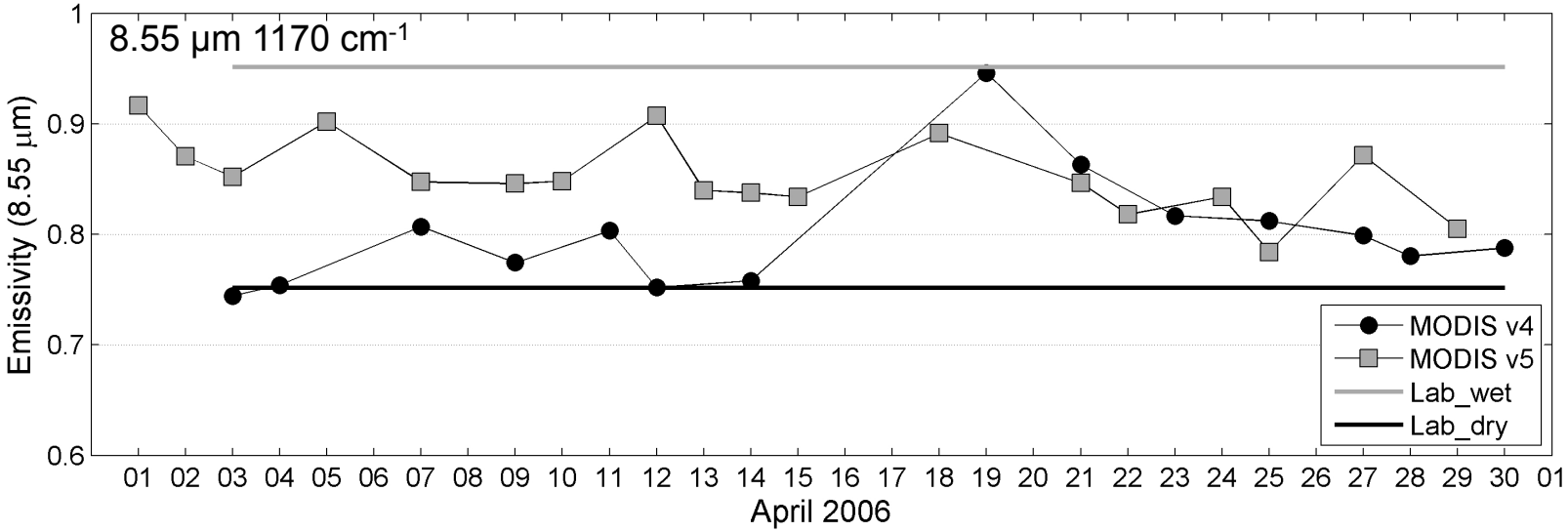
** AIRS is able to observe changes in soil moisture

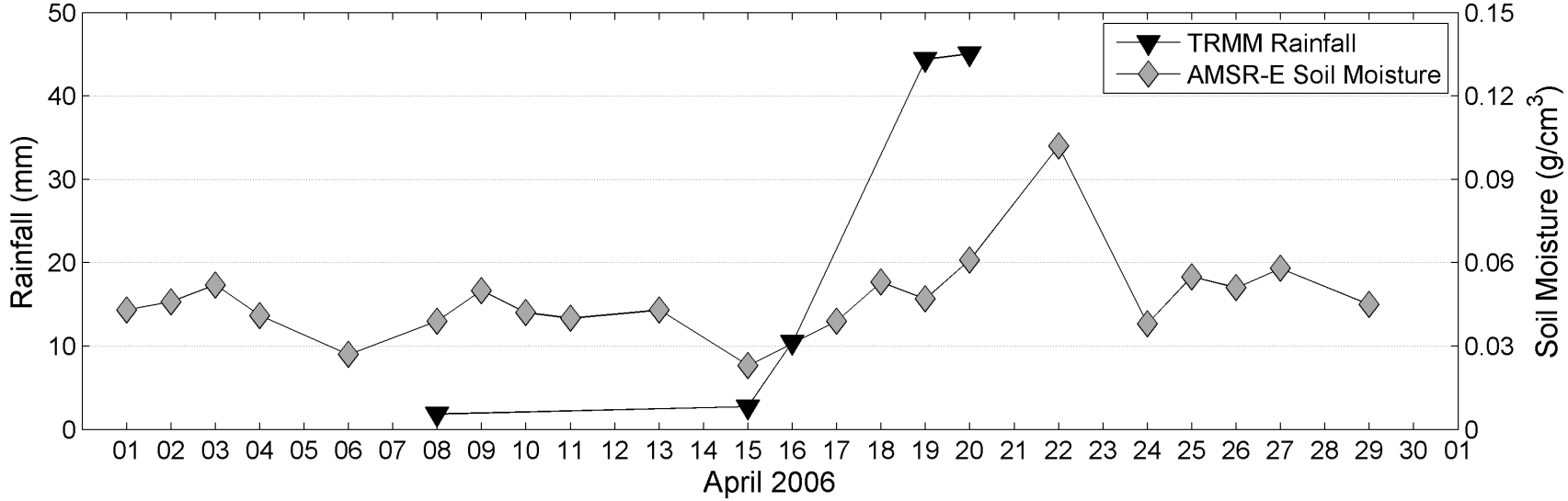




MODIS v4 emissivity (day/night, multi-spectral) **is sensitive to changes in soil moisture

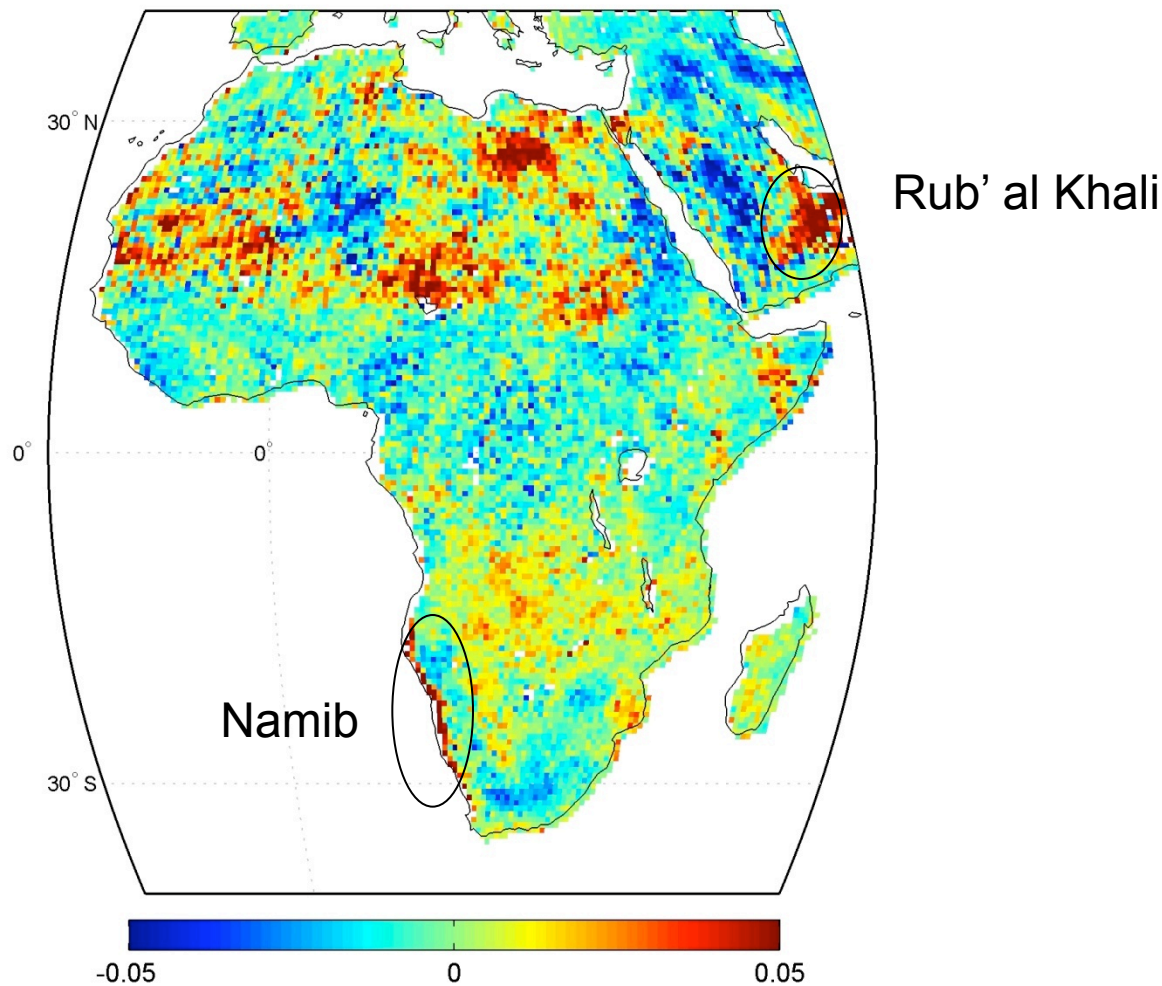
MODIS v5 emissivity (SW/land classification) **is not sensitive to changes in soil moisture

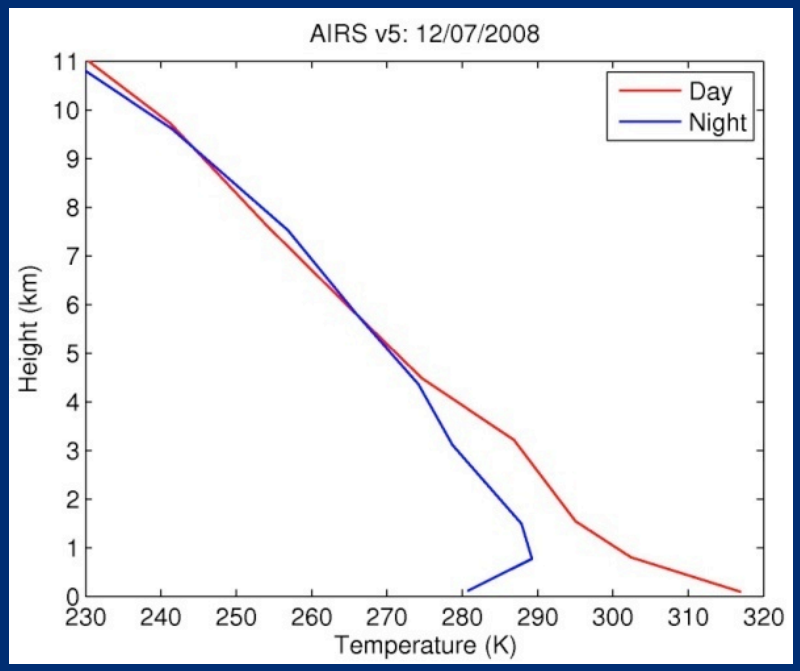




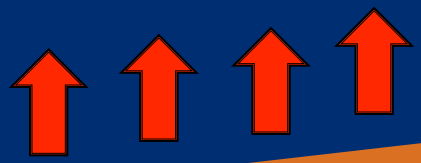
AIRS v5.4.1 Mean Diurnal Emissivity difference (night minus day), 8.6 μm, Sep 2002

Is AIRS v5.4 emissivity stable enough to distinguish real changes in land surface as a result of high frequency events, eg. surface soil moisture, vegetation cover (fires)?

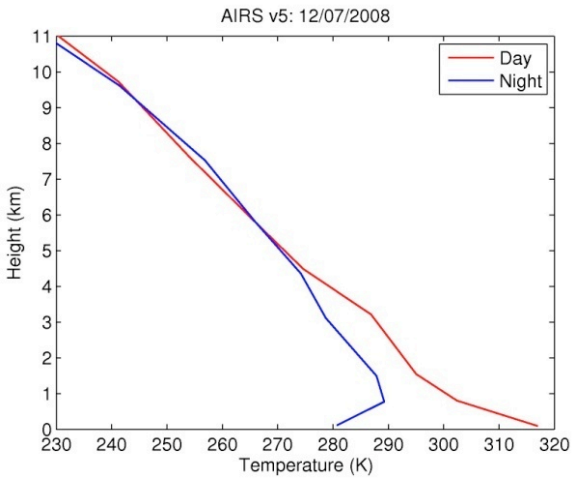


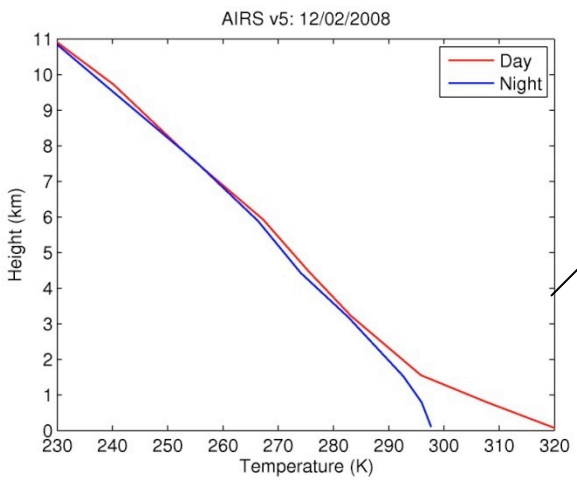


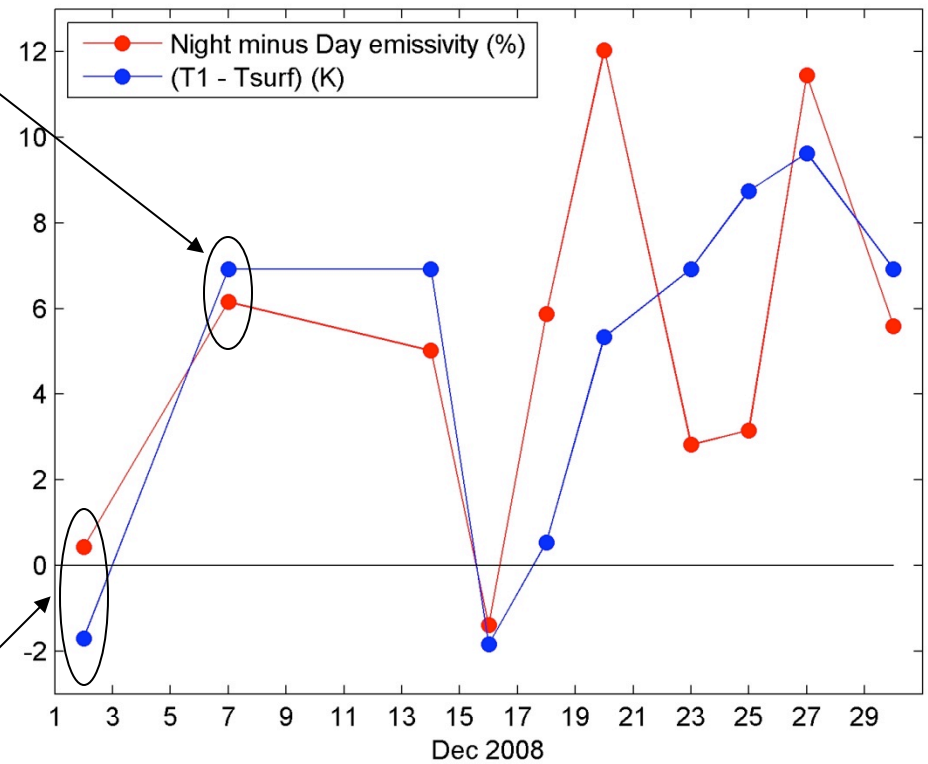
Radiative Cooling



Potential remote sensing of dew accumulation using v5.4.1







Strong correlation between temperature inversions and increased nighttime (~3 AM local) emissivity

Summary

- AIRS v5 validated to within 2.5% error over Namib and Kalahari deserts using ASTER/Lab Measurements
- AIRS v5.4.1 evaluation:
  - Smaller diurnal differences than v5 (up to a factor of 2)
  - Smaller daytime, shortwave temporal variation (more stable)
  - Spectral shape improved in shortwave and quartz band, but underestimates at longer wavelengths
- Potential for using AIRS IR emissivity to observe surface soil moisture changes, eg. due to rainfall, dew
- Developing a unified emissivity product using MODIS, ASTER:
  - Consistent retrieval methodology
  - New emissivity algorithm using ASTER TES with improved atmospheric correction (water vapor scaling method)
  - Testing at PEATE, for VIIRS

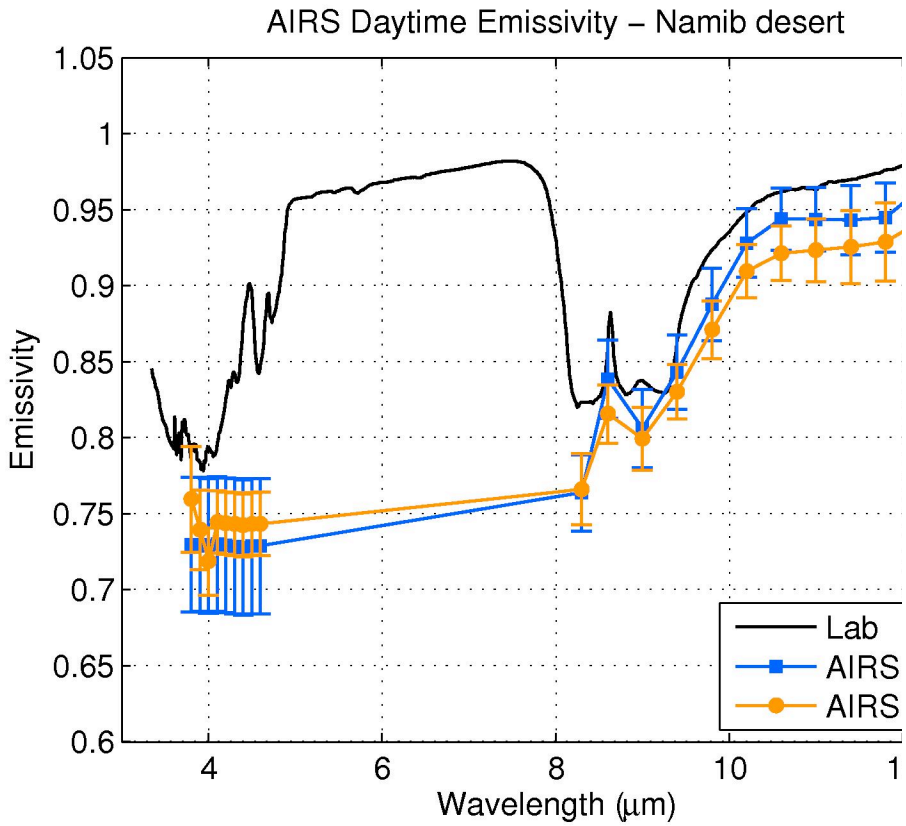
AIRS V5.4 Emissivity Retrieval

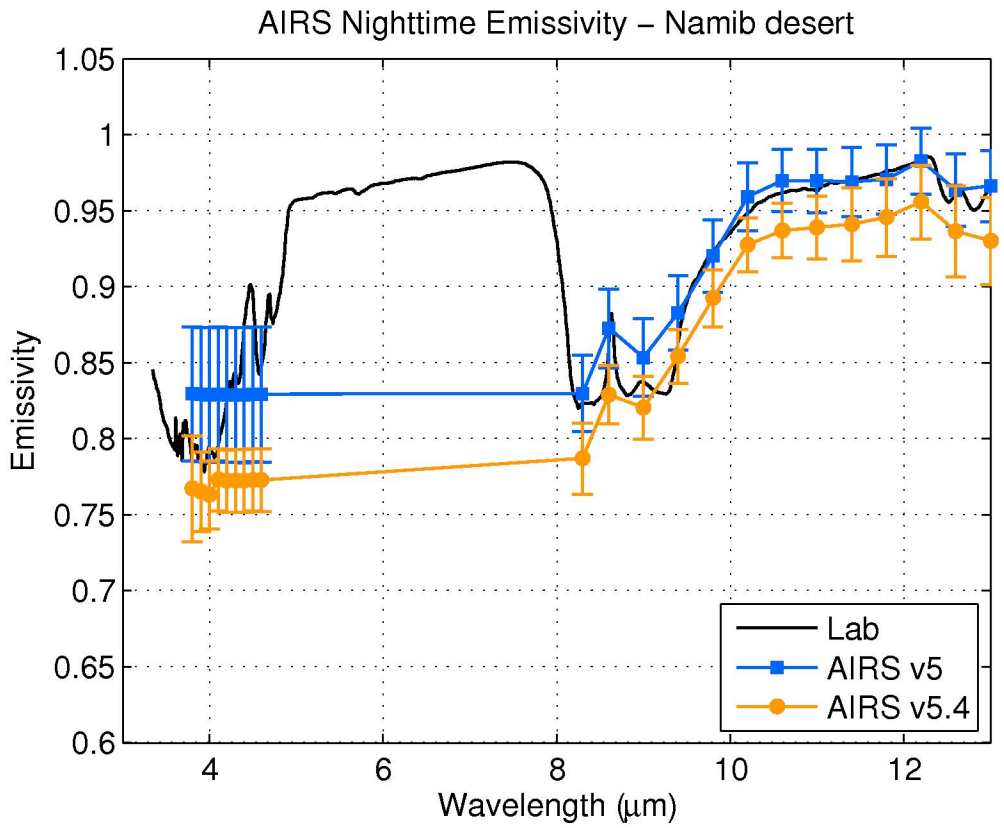
- AIRS Interim V5.4 Land Surface Emissivity produced at JPL for 6 September 2002 in preparation for v6
- New Retrieval Methodology:

  Susskind, J., and J. Blaisdell, (2008), Improved surface parameter retrievals using AIRS/AMSU 453 data, *Proc. SPIE, 6966,* DOI: 10.1117/1112.774759.

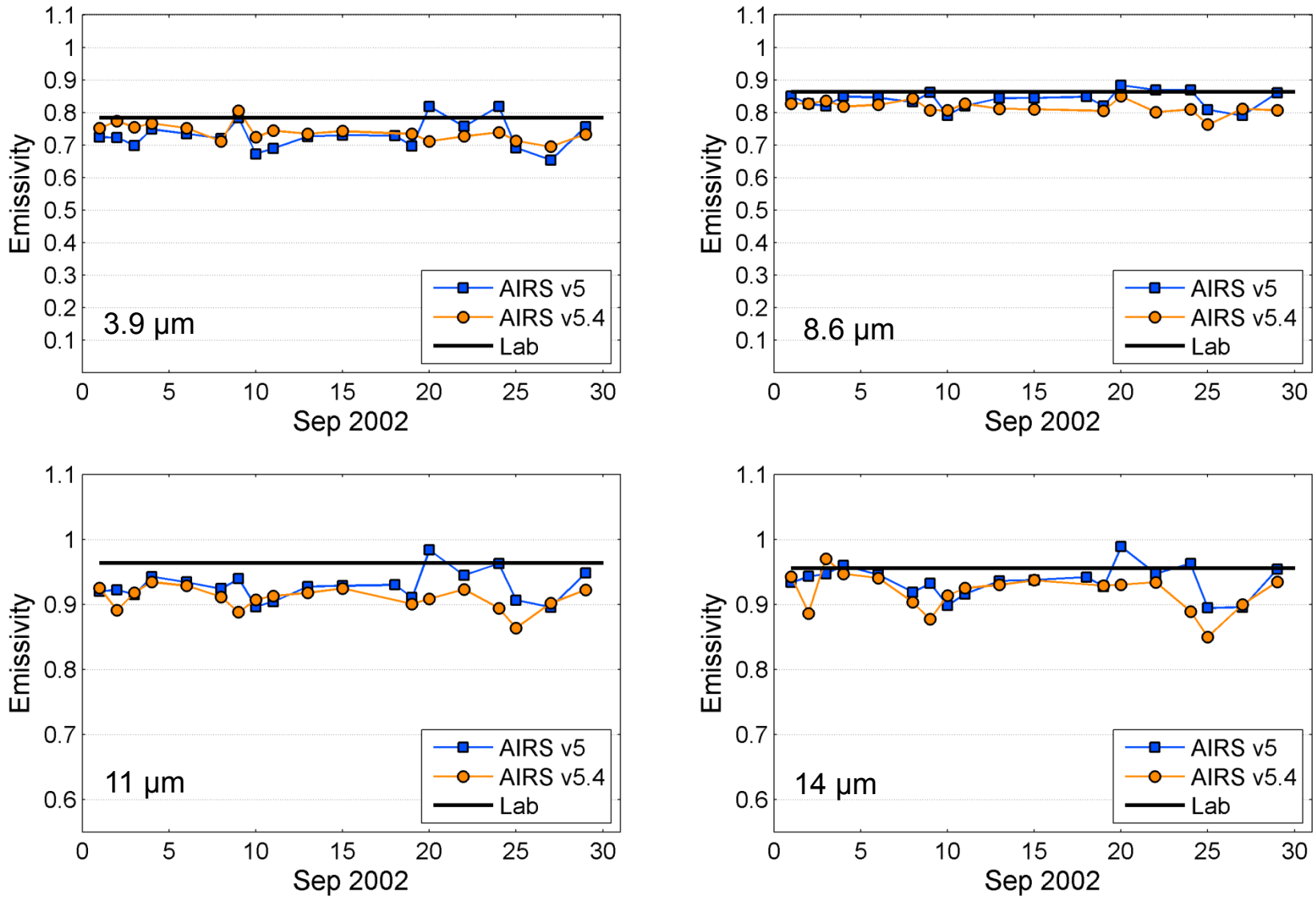
Differences with V5:

- V5: **Single step retrieval**
  - 15 longwave (758-1228 cm^{-1}) and 10 shortwave (2456-2658 cm^{-1}) channels
  - Ts determined along with A1, A2 longwave and A3 shortwave perturbation functions
- V5.4: **Two-step retrieval**
  - 57 shortwave (2396-2660 cm^{-1}) used to determine Ts along with A1s, A2s shortwave perturbation functions
  - 70 longwave (756-1234 cm^{-1}) channels used with **Ts, T(p), q(p) assumed known and held constant,** to retrieve 3 longwave perturbation functions

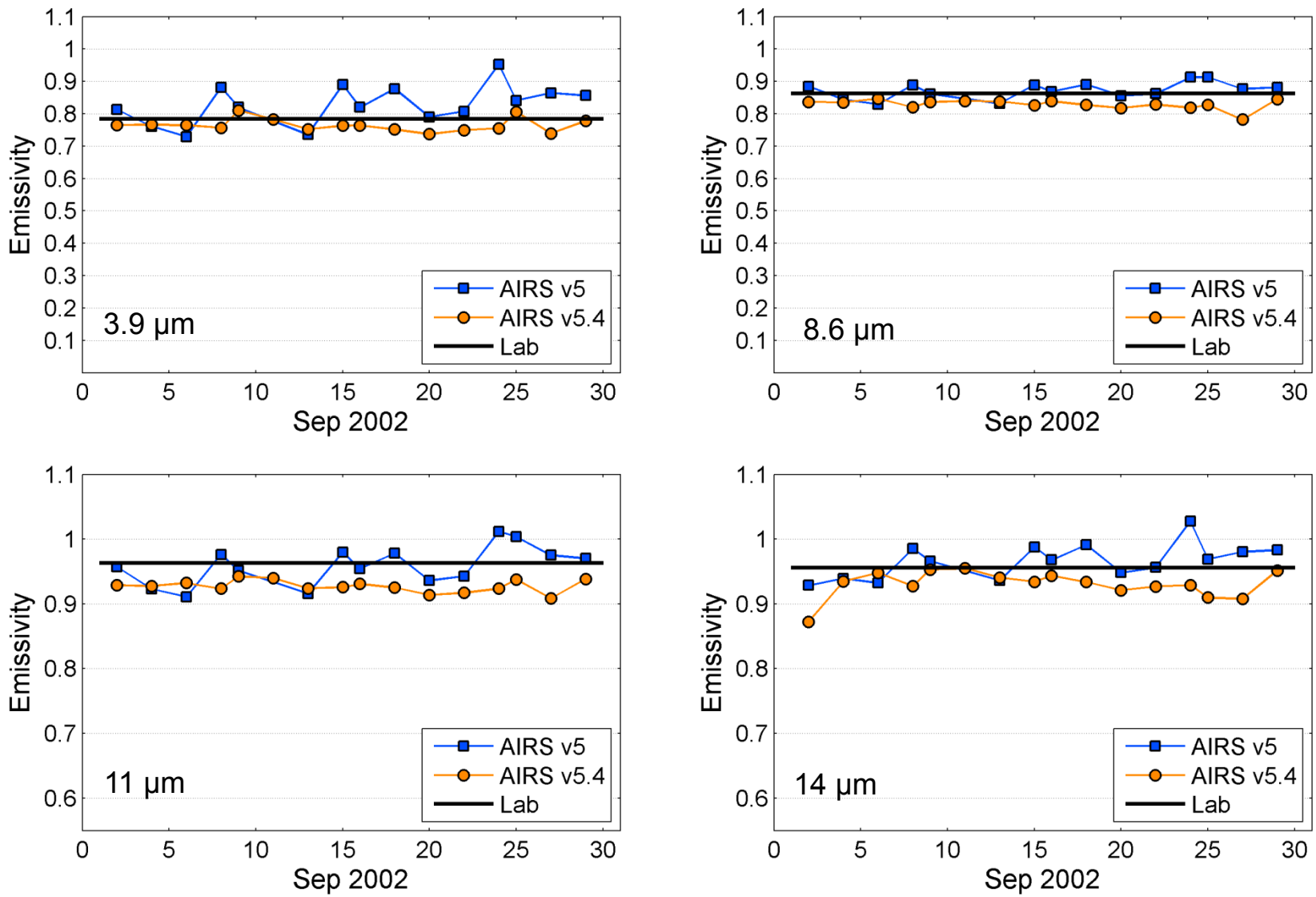

AIRS Daytime Emissivity – Namib desert
Emissivity
Wavelength (μm)
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
4
6
8
10
1
Lab
AIRS
AIRS


AIRS Nighttime Emissivity – Namib desert
Emissivity
Wavelength (μm)
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
4
6
8
10
12
Lab
AIRS v5
AIRS v5.4

Kalahari desert: Daytime temporal variations



Kalahari desert: Daytime temporal variations



V5 Validation Summary

- AIRS combined percent emissivity differences:
  - **Namib:** 2.32% (ASTER), and 2.26% (Lab data)
  - **Kalahari:** 2.26% (ASTER), and 0.68% (Lab data)
- Nonphysical emissivity values ($\varepsilon>1$) are observed on occasion.
- Longwave LSE's (>10 µm, 1000 cm^{-1}) are too closely correlated with 8-10 µm (1250-1000 cm^{-1}) LSE – reduced degree-of-freedom
- Characterization of bare surfaces in the emissivity regression with one mineral type (quartz) could potentially cause errors in spectral shape over rock/soil types with different mineralogy.
- Retrieved shortwave LSE's (3.5-5.5 µm, 2857-1818 cm^{-1}) are constant, as a result of being regressed from the longwave channels, with known poor skill.
- Consequently, diurnal LSE differences are significant and can be as large as 15% in the shortwave due to systematic errors caused by improper modeling of reflected solar radiation, eg. assumption of Lambertian surface.

Regression Solution Improvement for bare soil/sand spectra?

$$e = e_{soil} \cdot Fv + e_{veg} \cdot (1 - Fv)$$

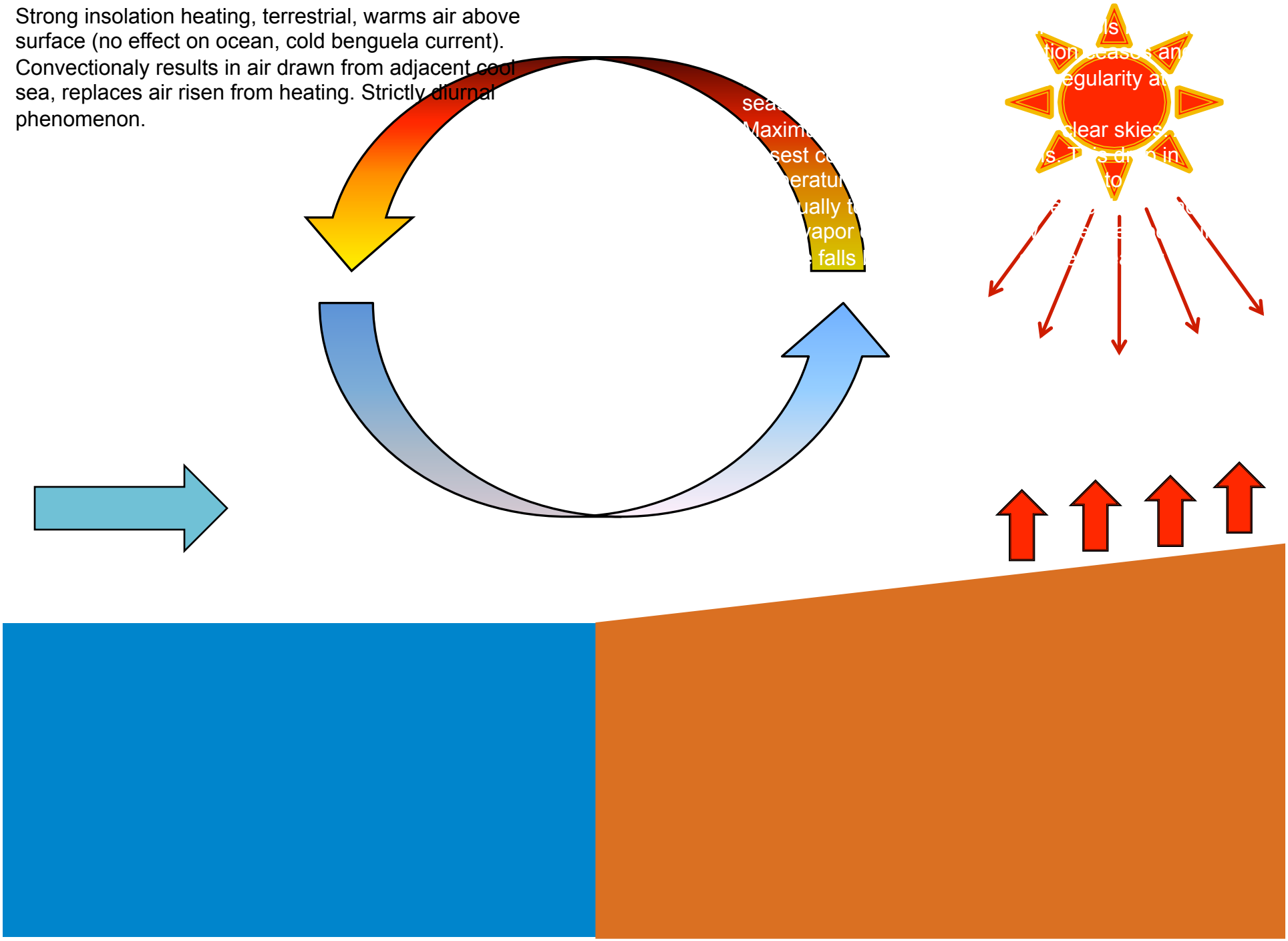
Fv = Vegetation fraction = (NDVI – NDVI_s)/(NDVI_v – NDVI_s)

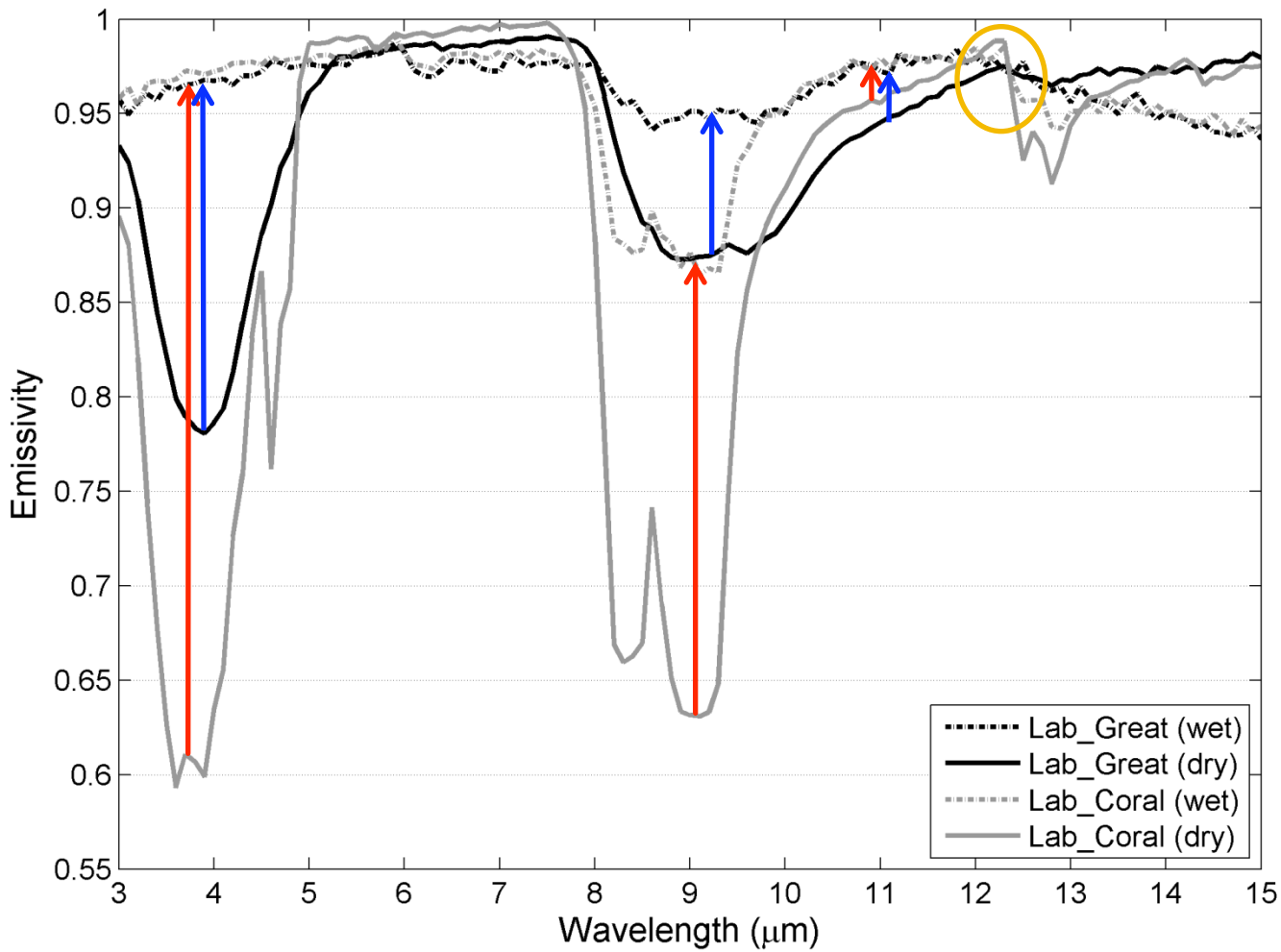
e_{soil} = quartz spectra (AIRS v5)

IGBP Class	Assignment
1, 2, 3, 4, 5 (Forests)	50% Alfisols + 50% Spodsols soils
6, 7, 8, 9, 10 (Shrublands, Grasslands)	Aridsols soil (dry environments)
12, 14 (Croplands)	Mollisols soil (rich, fertile)
13 (Urban)	50% concrete + 50% paving asphalts
16 (Bare)	25% rock + 50% quartz + 25% aridsols

**Use concurrent Aqua MODIS NDVI product instead of AVHRR?

Strong insolation heating, terrestrial, warms air above surface (no effect on ocean, cold benguela current). Convectionaly results in air drawn from adjacent cool sea, replaces air risen from heating. Strictly diurnal phenomenon.



Laboratory Measurements

- Reflectance of samples measured using Nicolet FT-IR spectrometer at JPL
- Converted to emissivity using Kirchhoff's law (e = 1 – r)
- Accuracy is 0.002 (0.2%)