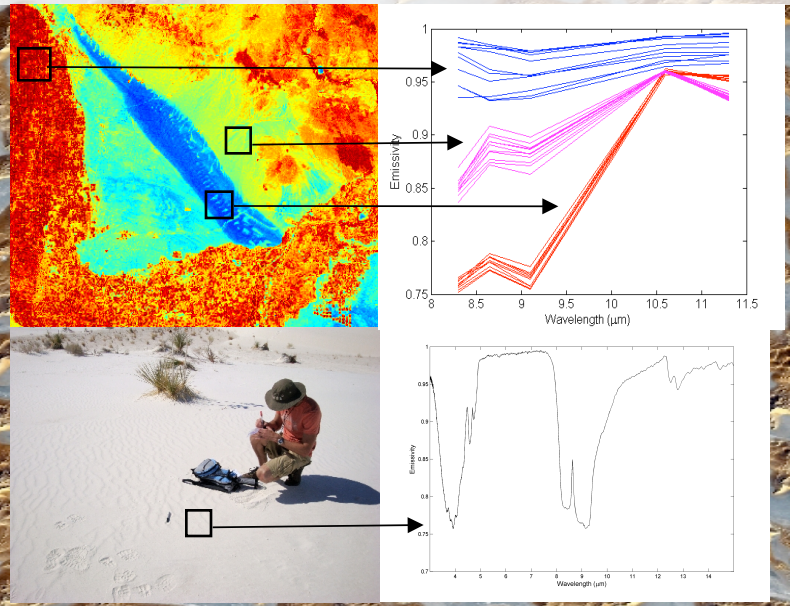
AIRS Land Surface Emissivity Validation Using ASTER and In-Situ Data



Glynn Hulley, Simon Hook

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

AIRS Science Team Meeting, Greenbelt, 2008

Jet Propulsion Laboratory
California Institute of Technology

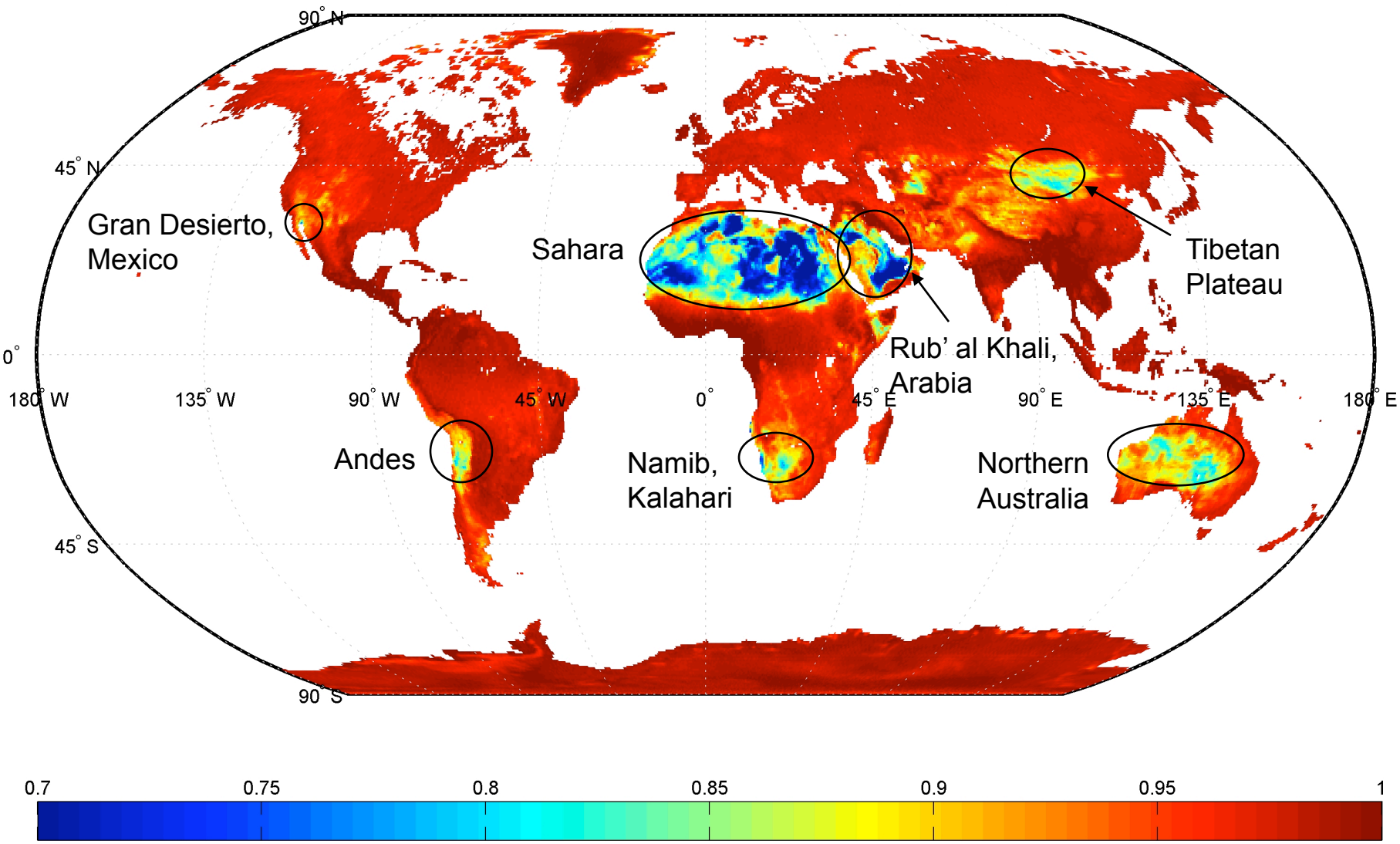
Outline

- Motivation
- AIRS global emissivity variation
- North American ASTER Emissivity Database
- AIRS emissivity validation over Namib Desert, Namibia
- Summary

Motivation

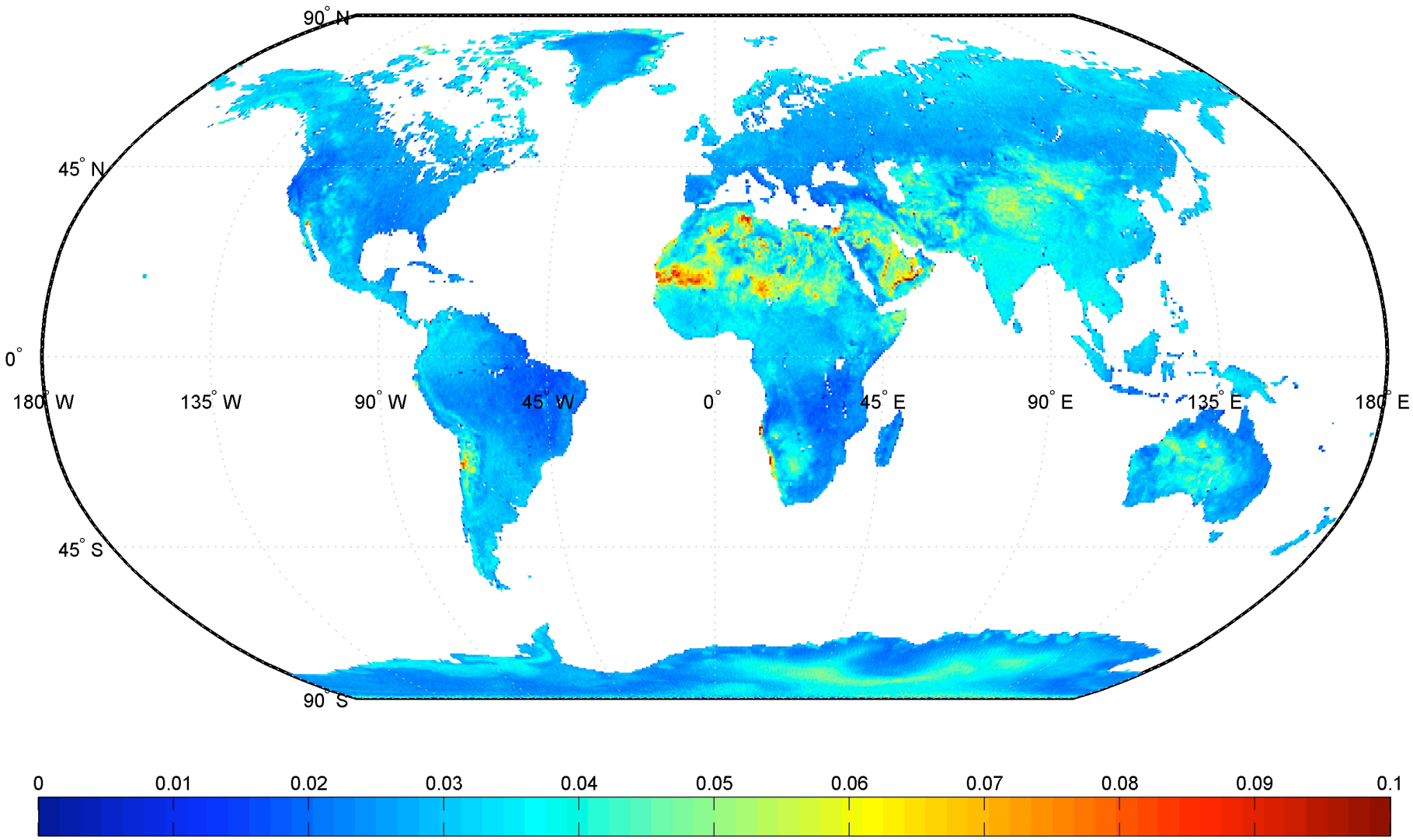
- Land Surface Temperature and Emissivity (LST&E) - NASA Earth System Data Records (ESDR's)
- LST&E products are key to global climate change studies
- Climate models used emissivity to estimate upward longwave radiation – 10% emissivity error = 7 Wm^2
- Emissivity key to retrieving accurate temperature profiles and total water vapor – AIRS
- ASTER and field data used for validating other emissivity products – eg. AIRS, MODIS, METEOSTAT-SEVIRI
- Emissivity critical in recovering Land Surface Temperature 1.5% emissivity error => 1 K LST error

AIRS V5 Emissivity Mean: July: 9.1 μm (1099 cm^{-1})



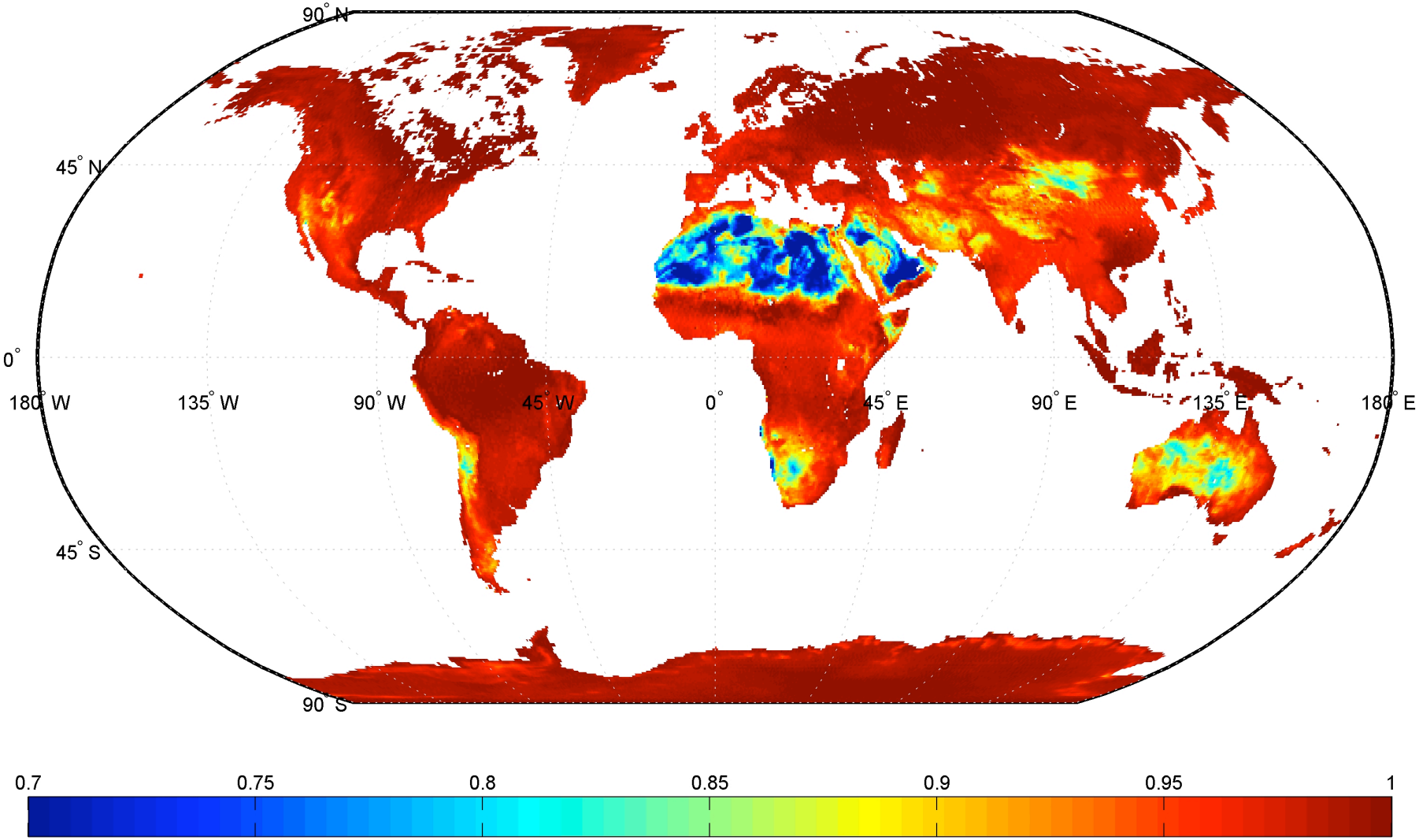
Most natural surfaces restricted to emissivities between 0.7-1.0

AIRS V5 Emissivity SDev: July: 9.1 μm (1099 cm^{-1})

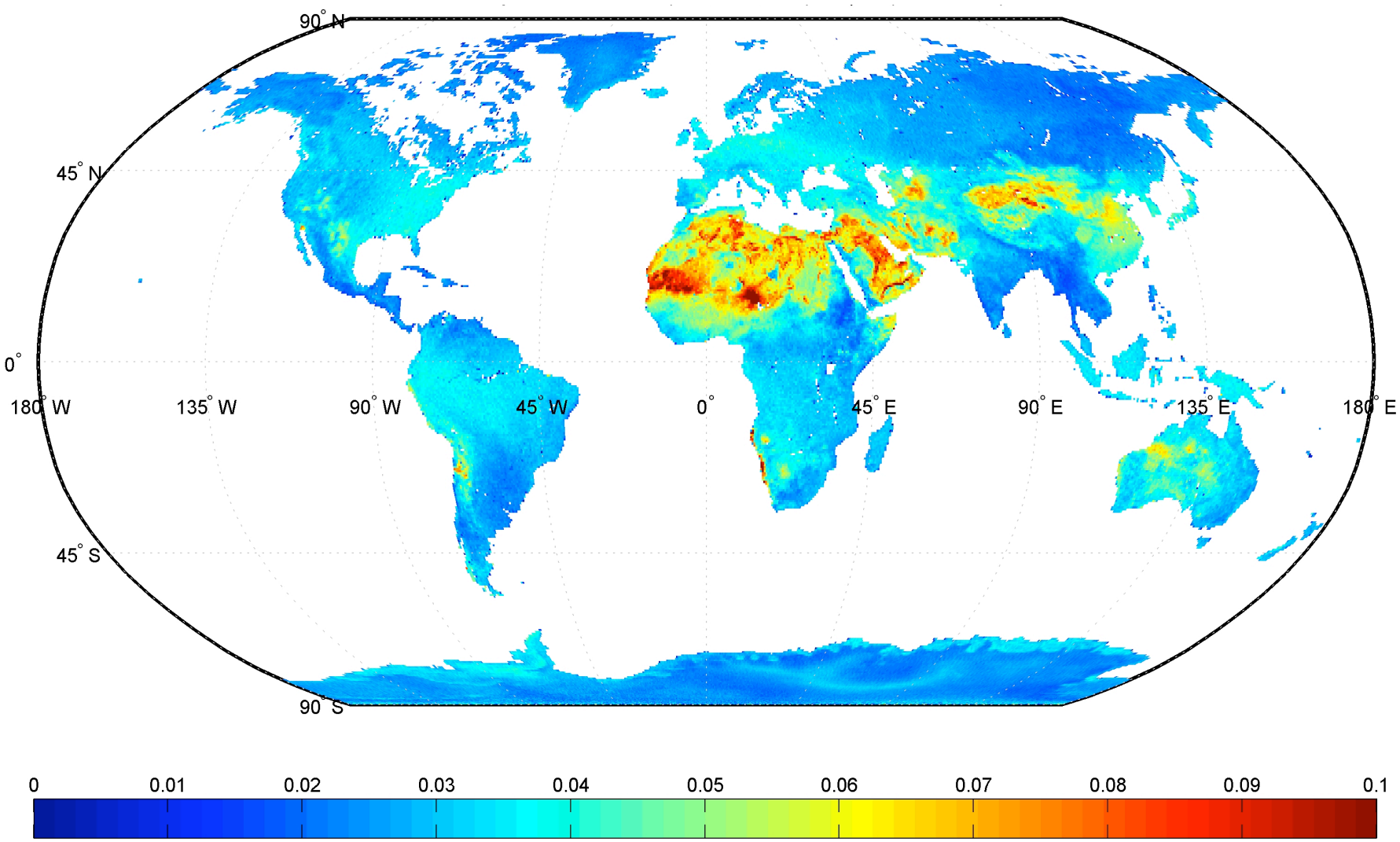


Large SDev related to large day/night emissivity differences over barren areas

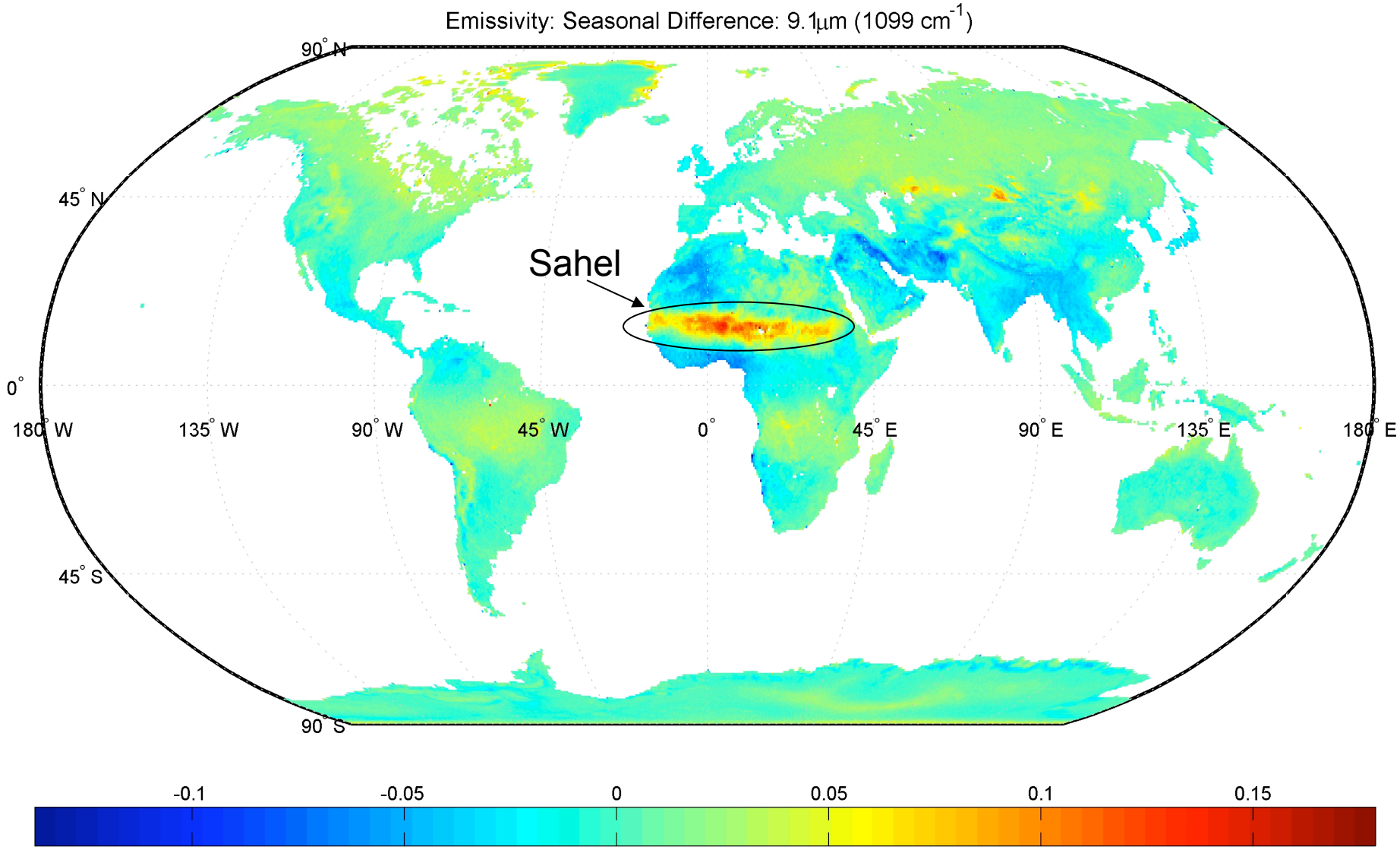
AIRS V5 Emissivity Mean: January: 9.1 μm (1099 cm^{-1})



AIRS V5 Emissivity SDev: January: 9.1 μm (1099 cm^{-1})



AIRS V5: July minus January



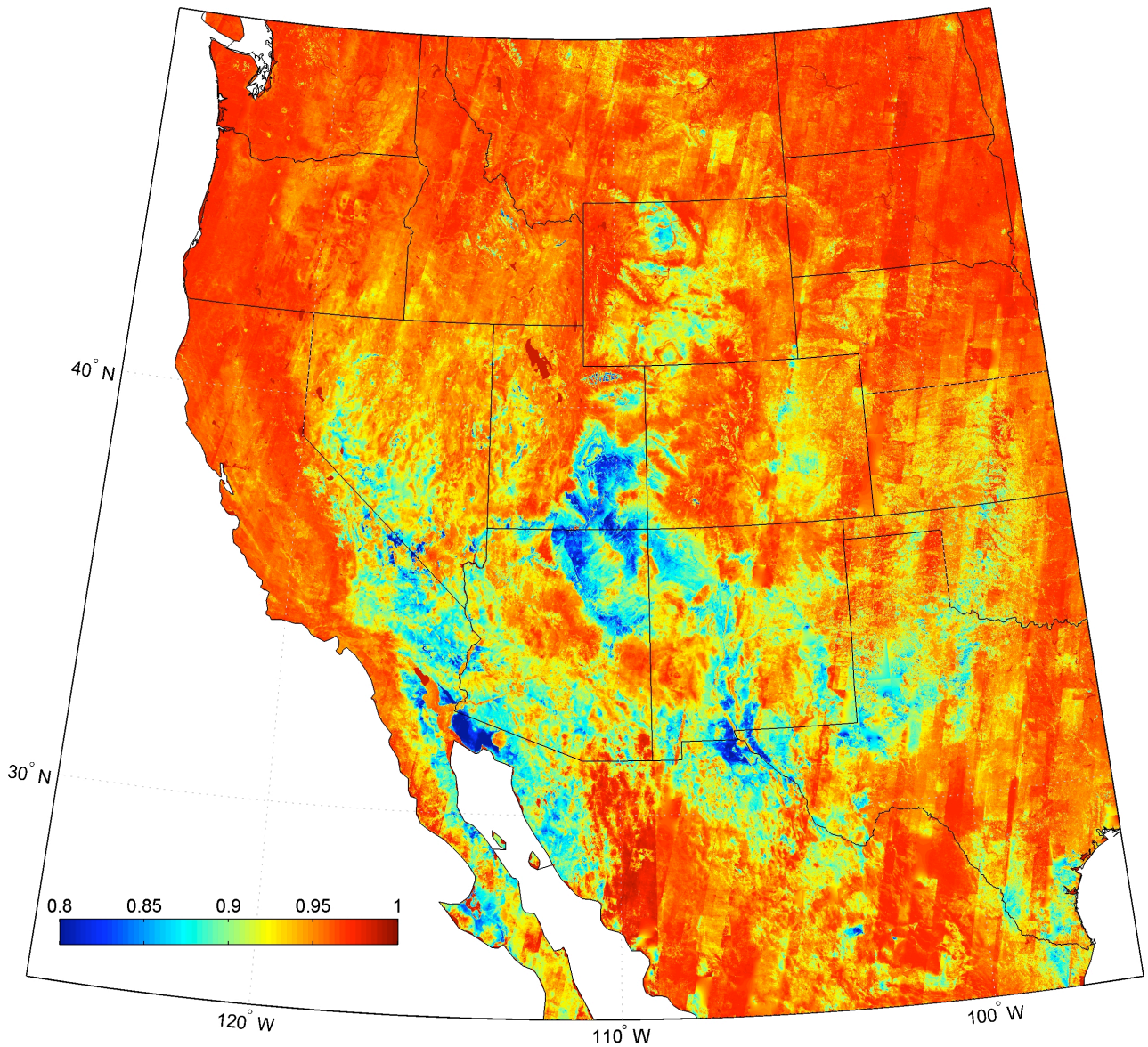
New ASTER Gridded Emissivity Product

- ASTER – Advanced Spaceborne Thermal Emission and Reflection Radiometer
- 90 m resolution at TIR bands: 8.3, 8.6, 9.1, 10.6 and 11.3 μm
- ASTER only available on-demand, and scene-by-scene basis
- Mean Summer (July-Aug-Sep) and Winter (Jan-Feb-Mar) emissivity (2000-2008)
- Determine all intersecting scenes on 1°x1° given grid – 'stacking' method
- Output mean and standard deviation for all clear observations on each pixel
- Products: Mean+Sdev Emissivity, Surface Temperature, NDVI, Counts

** **Hulley G.C., S.J. Hook, A.M. Baldridge,** 2008, The ASTER Land Surface Emissivity Database of California and Nevada, *Geophys. Res. Lett.*, L13401, doi:10.1029/2008GL034507

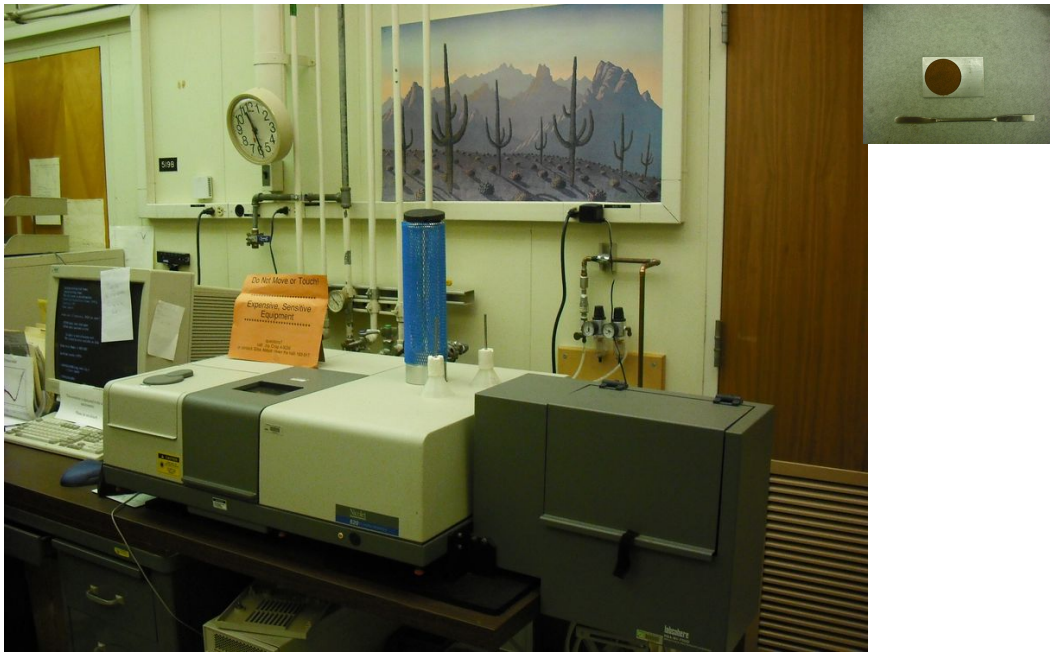
** **Hulley G.C., S.J. Hook,** 2008, A New Methodology for Cloud Detection and Classification with Advanced Spaceborne Thermal Emission and Reflection (ASTER) Data , *Geophys. Res. Lett.*, 35, L16812, doi:10.1029/2008GL034644

ASTER Mean Summer Emissivity: Band 12 (9.1 μm): 18,242 Scenes (2002-2008)



Sand samples collected in field

Reflectance measured using Nicolet 520 FTIR spectrometer



JPL

LAB MEASUREMENTS

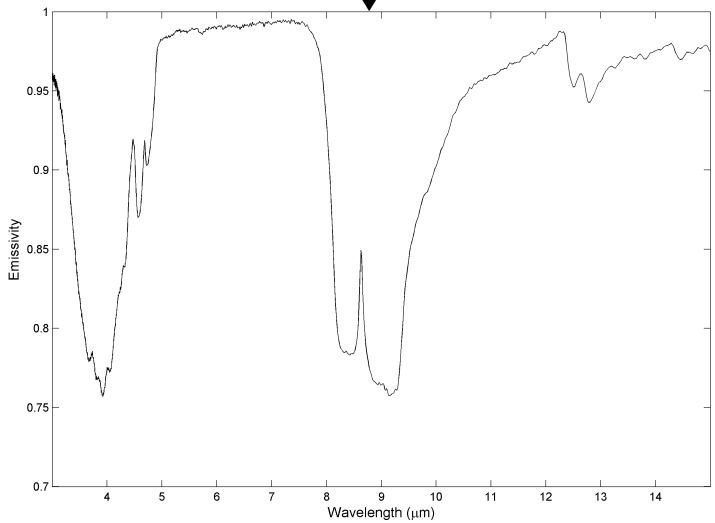
$\varepsilon = 1 - r$

spectral range: 2.5 – 15 μm

spectral resolution: 4 cm^{-1}

1000 scans in 10 minutes

Accuracy: 0.2%



CORAL PINK SANDS, UT

SAND MOUNTAIN, UT

ALGODONES DUNES, CA

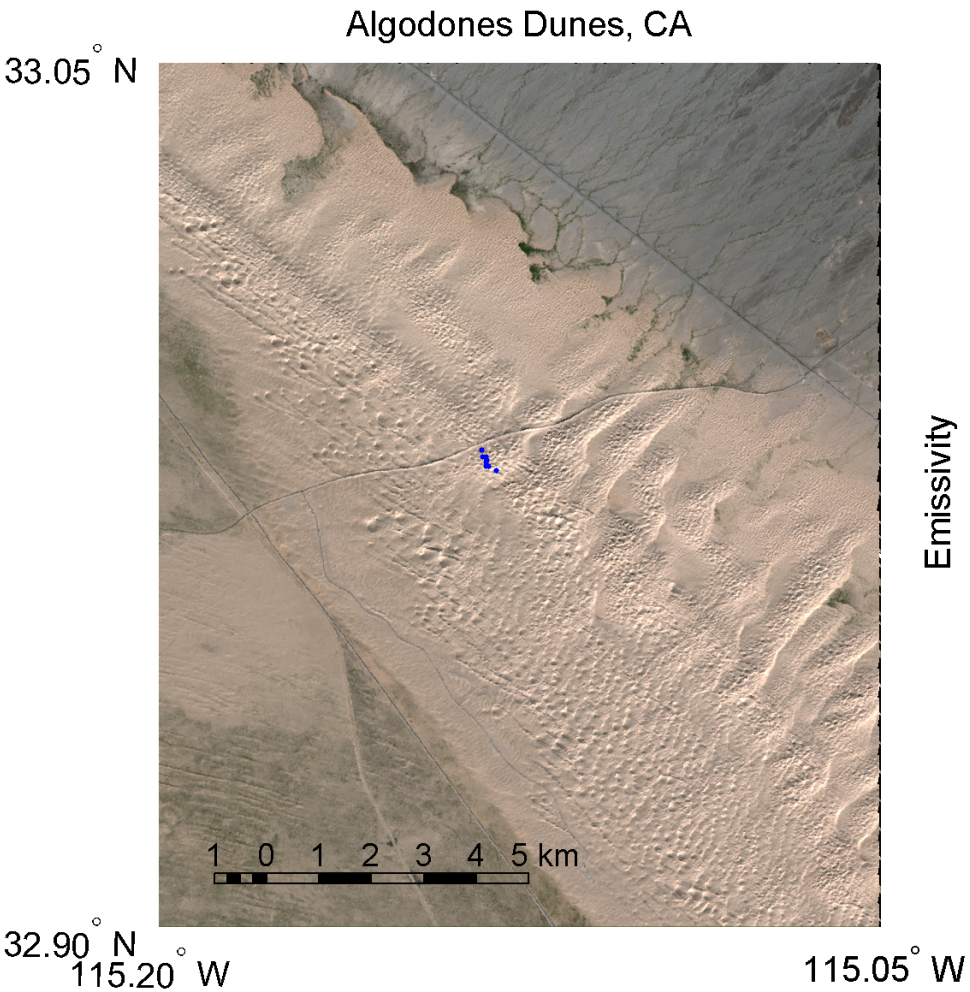
KILLPECKER, WY

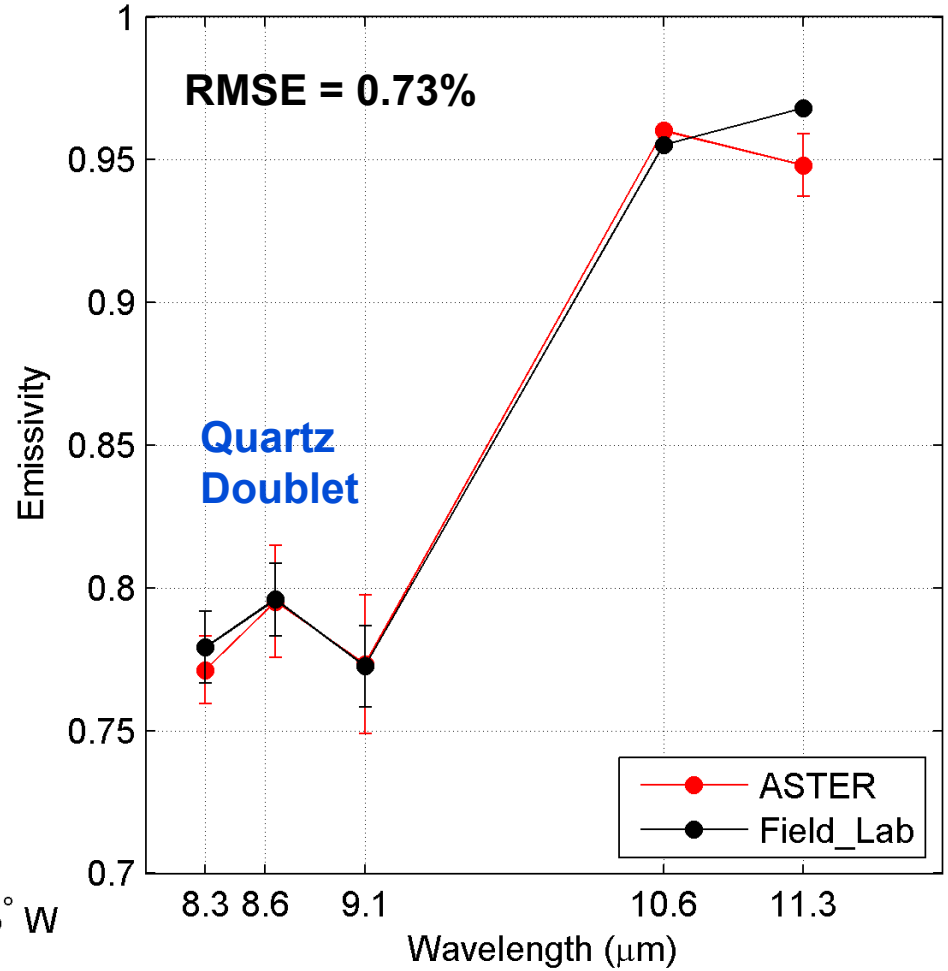
WHITE SANDS, NM

DEATH VALLEY, CA

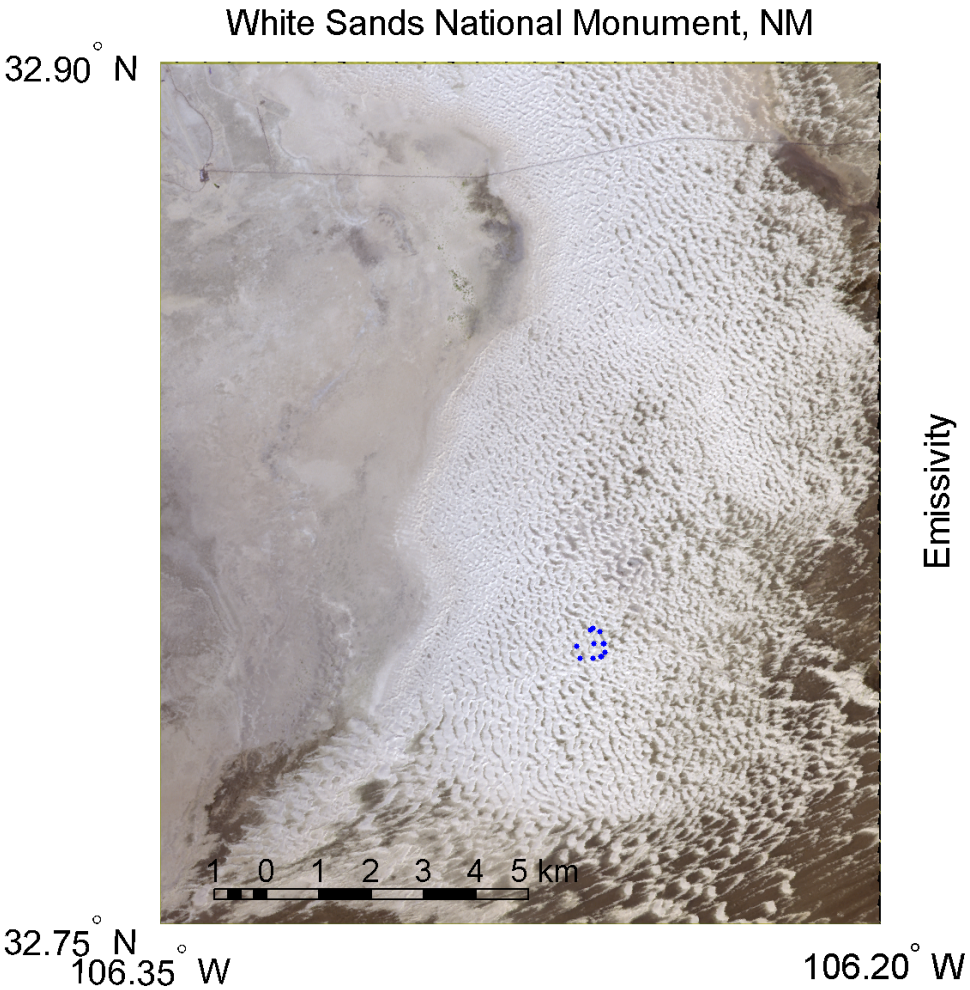
GREAT SANDS, CO

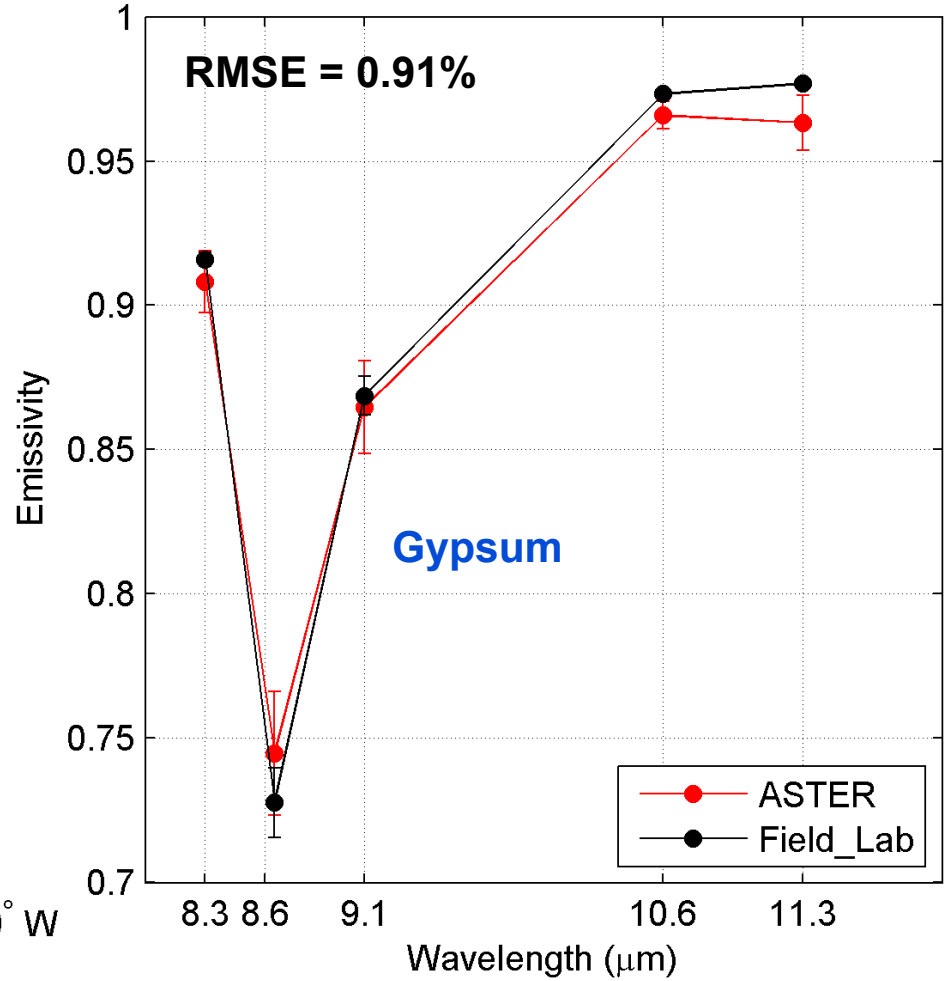
Algodones Dunes, El Centro, California





White Sands National Monument, New Mexico





ASTER Validation Over Sand Dune Fields in Western USA

	ASTER MINUS LAB EMISSIVITY (%)					
Dune site	**Band 10 8.3 µm**	**Band 11 8.6 µm**	**Band 12 9.1 µm**	**Band 13 10.6 µm**	**Band 14 11.3 µm**	**Mean**
Algodones	0.68	0.60	0.13	0.02	1.40	**0.57**
Stovepipe Wells	0.17	0.77	1.02	0.34	0.37	**0.53**
White Sands	0.34	2.76	0.16	0.92	1.08	**1.05**
Kelso Dunes	1.57	1.04	1.33	1.91	0.81	**1.33**
Great Sands	1.44	0.97	1.42	1.64	0.69	**1.23**
Moses Lake	0.69	0.52	0.42	0.61	1.01	**0.65**
Sand Mountain	7.74	6.47	9.01	1.82	1.10	**5.23**
Coral Pink	7.48	6.44	7.32	2.50	1.70	**4.90**
Little Sahara	3.55	2.39	2.60	0.96	0.19	**1.94**
Killpecker	2.34	1.99	2.26	1.33	0.81	**1.75**

< 2% (1.5 K)

http://emissivity.jpl.nasa.gov

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North American Land Surface Emissivity Project

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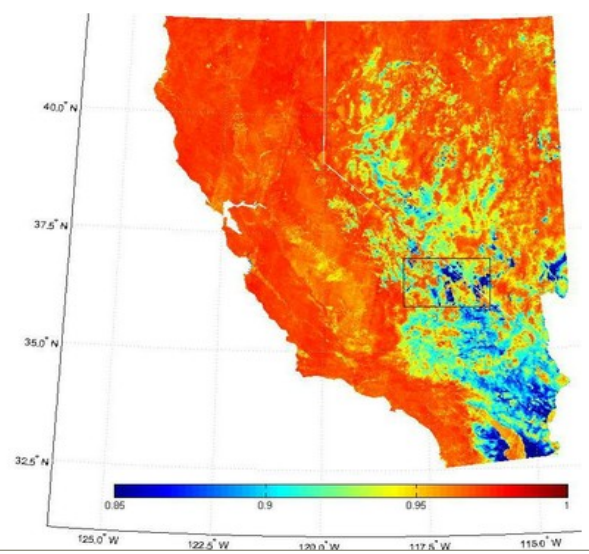
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

North American Land Surface Emissivity Project

Welcome to the website for the North American Land Surface Emissivity Project. The goal of the project is to create a seamless database of emissivity from standard ASTER emissivity products for use in climate research. The Earth emits energy at wavelengths we cannot normally see, that energy is a function of the temperature and the emissivity of the surface. The surface emissivity primarily depends on the composition of the surface. Thus as the surface composition changes through, for example, land cover land use change, so does the surface emissivity. The land surface emissivity is measured by several instruments mounted on satellites and aircraft. Some of the most well known satellite sensors are AIRS, ASTER and MODIS.

Of these three satellite sensors, ASTER provides the most detailed emissivtiy images with a pixel spatial resolution of 90m. The image below was created by merging together all the ASTER emissivity data ever acquired over California and Nevada under clear skies from 2000-2007 for the months July, August and September.



http://emissivity.jpl.nasa.gov

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20	21	22	23	24	25	26
27	28	29	30	31		

Emissivity Order

The goal of the North American Land Surface Emissivity Project is to produce a seamless database of land surface emissivity from ASTER data for climate research. The emissivity database produced from this work will be available for ordering via this page for so others can utilize this dataset. The data are arranged as tiles where each tile covers and area of 1 degree x 1 degree and the name of the tile corresponds to the top left corner of the tile e.g. 039120. Each tile consists of the 15 bands of data arranged in a sequential format. The first 5 bands are the mean emissivities at the 5 ASTER wavelengths, the next 5 bands are the standard deviations for the mean emissivities. The next 2 bands are the mean temperature and standard deviation of that temperature. The next band is the number of pixels used to calculate the means and the last 2 bands are the latitude and longitude.

The North American ASTER Land Surface Emissivity Database is available for FTP download at no charge by completing the order form below. It is ESSENTIAL you enter the correct information on the order form otherwise we will not be able to process your order correctly.

Order Form	
First Name: *	
Last Name: *	
Email Address: *	
Institution name: *	
Country: *	

* Required fields

Submit Order Clear All

Questions? Comments? Please contact Simon Hook.

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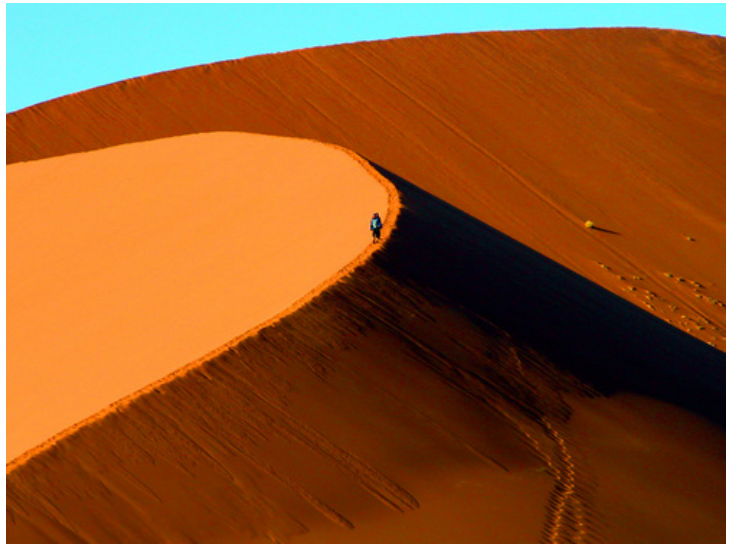
FIRSTGOV

Site Manager: Simon J Hook
Webmaster: Gerardo Rivera

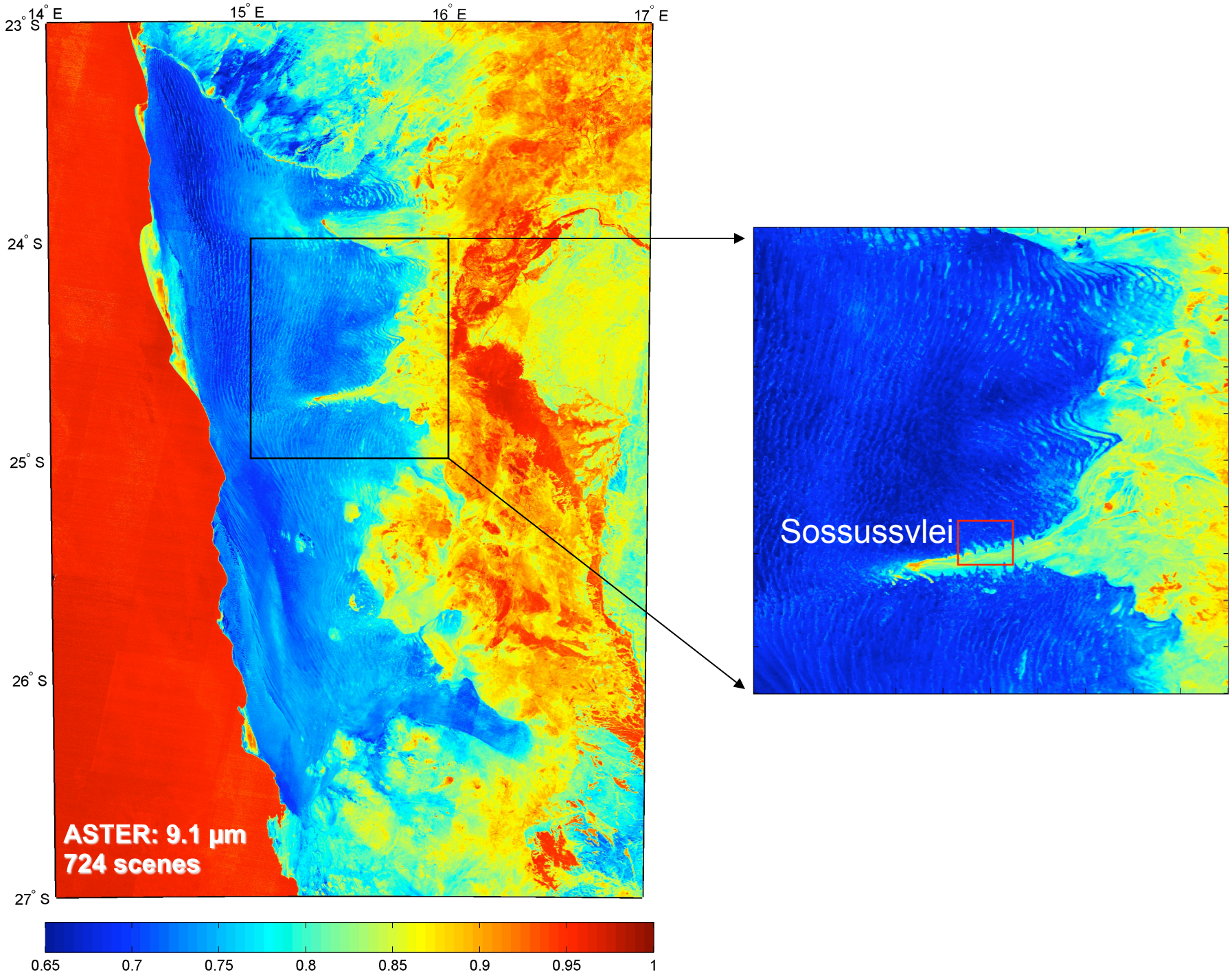
AIRS Emissivity Validation over the Namib Desert, Namibia



Namib Dunes, Namibia

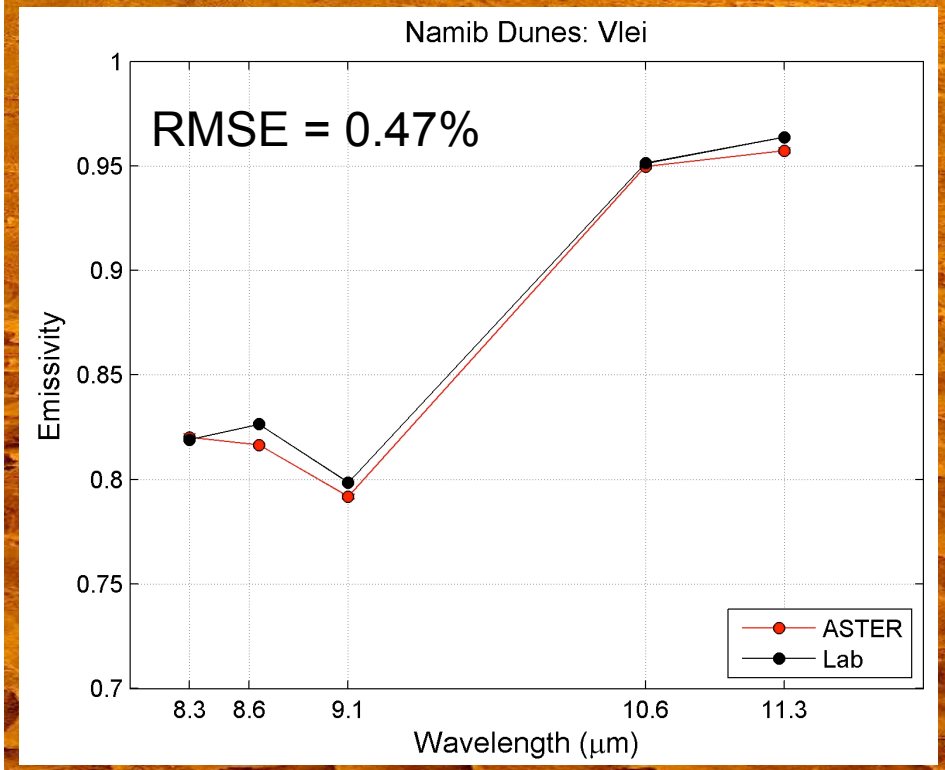
- Oldest (55 million years) and tallest (~300 m) dunes in the world
- Aridity caused by cool Hadley cell and cold Benguela current
- 10-85 mm annual rainfall and almost completely barren
- Occupies 80,900 km² (~1000 x 100 miles)
- Primarily quartz, with hematite (iron mineral)

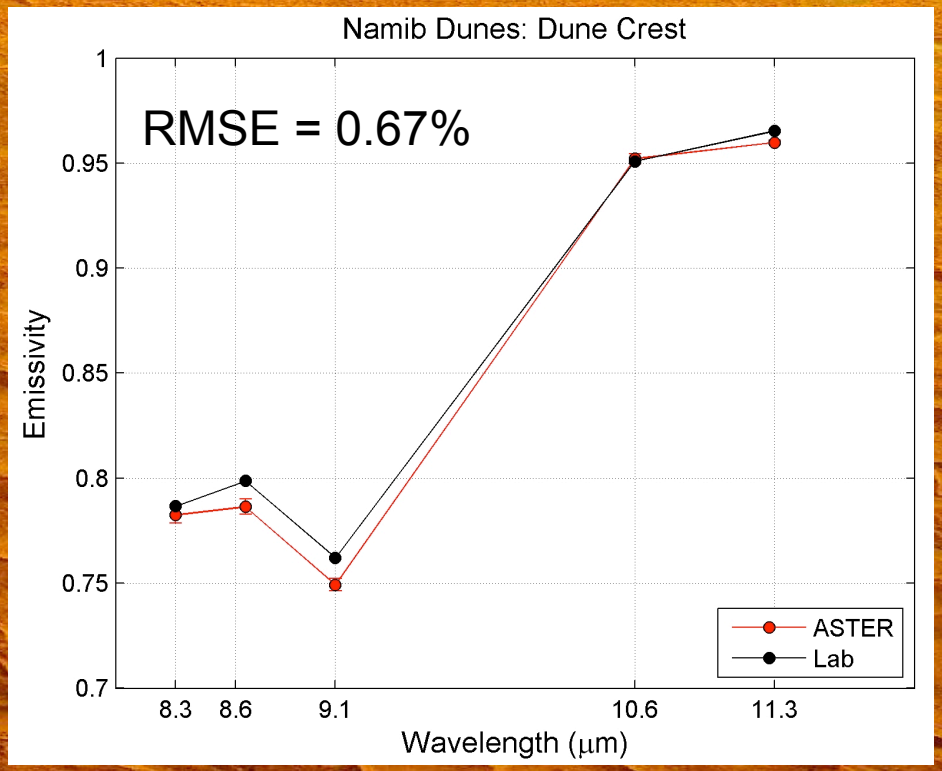
Expedia
ANGOLA
ZAMBIA
Lusaka
Choma
Monze
Katima Mulilo
Livingstone
VICTORIA FALLS
Harare
MALAWI
Tete
Shire
Quelimane
Oshakati
OWAMBO
OKAVANGO DELTA
Gwaai
Sabi
Chimoio
Bulawayo
ZIMBABWE
Beira
NAMIBIA
Windhoek
BOTSWANA
Limpopo
MOZAMBIQUE
Louis Trichardt
Tropic of Capricorn
KRUGER NATIONAL PARK
Pietersburg
Gaborone
Inhambane
Quissico
Fish
SOSSUSVLEI
KALAHARI
Pretoria
Nelspruit
Maputo
Mmabatho
JOHANNESBURG
Mbabane
Kuruman
Vaal
Vryheid
SOUTH AFRICA
Ulundi
Bloemfontein
ATLANTIC OCEAN
Maseru
Durban
INDIAN OCEAN
Moyni
Frere
Kokstad
Aliwal North
Umtata
Queenstown
Butterworth
Mdantsane
Cape Town
GARDEN ROUTE
Port Elizabeth
Namib Desert
© 2001 Microsoft Corp and/or its suppliers.
15°
20°
25°
30°
35°
20°
25°
30°
35°
40°

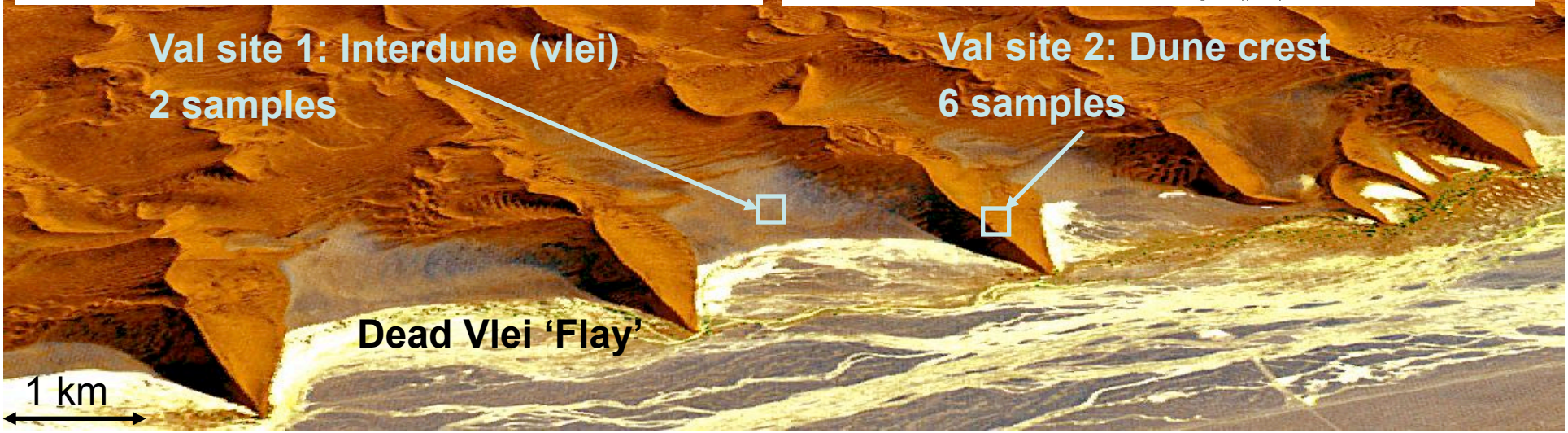

14° E
15° E
16° E
17° E
23° S
24° S
25° S
26° S
27° S
ASTER: 9.1 µm
724 scenes
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
Sossussvlei

Sossussvlei – Namib Naukluft Park

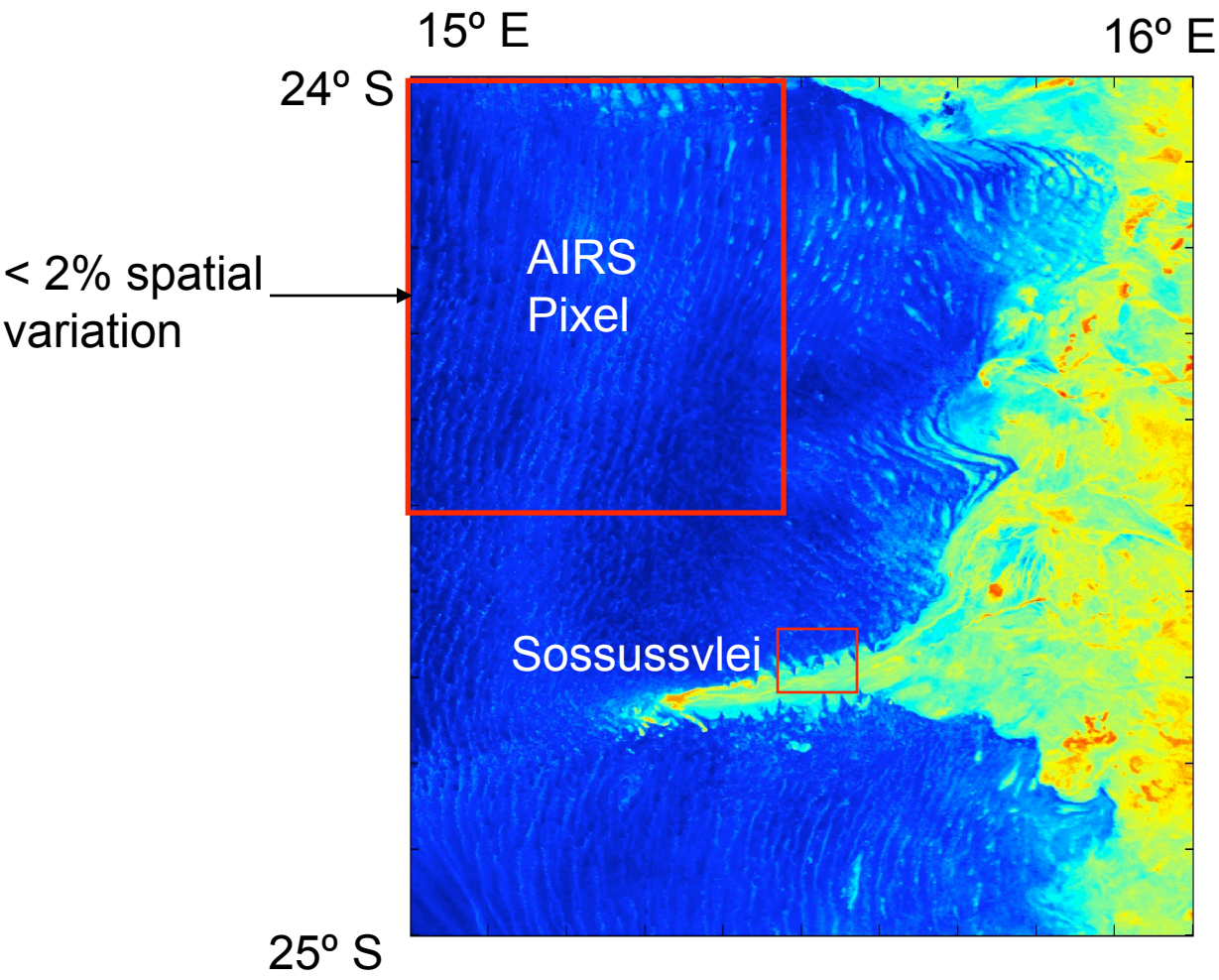
*Credit: ASTER Science Team



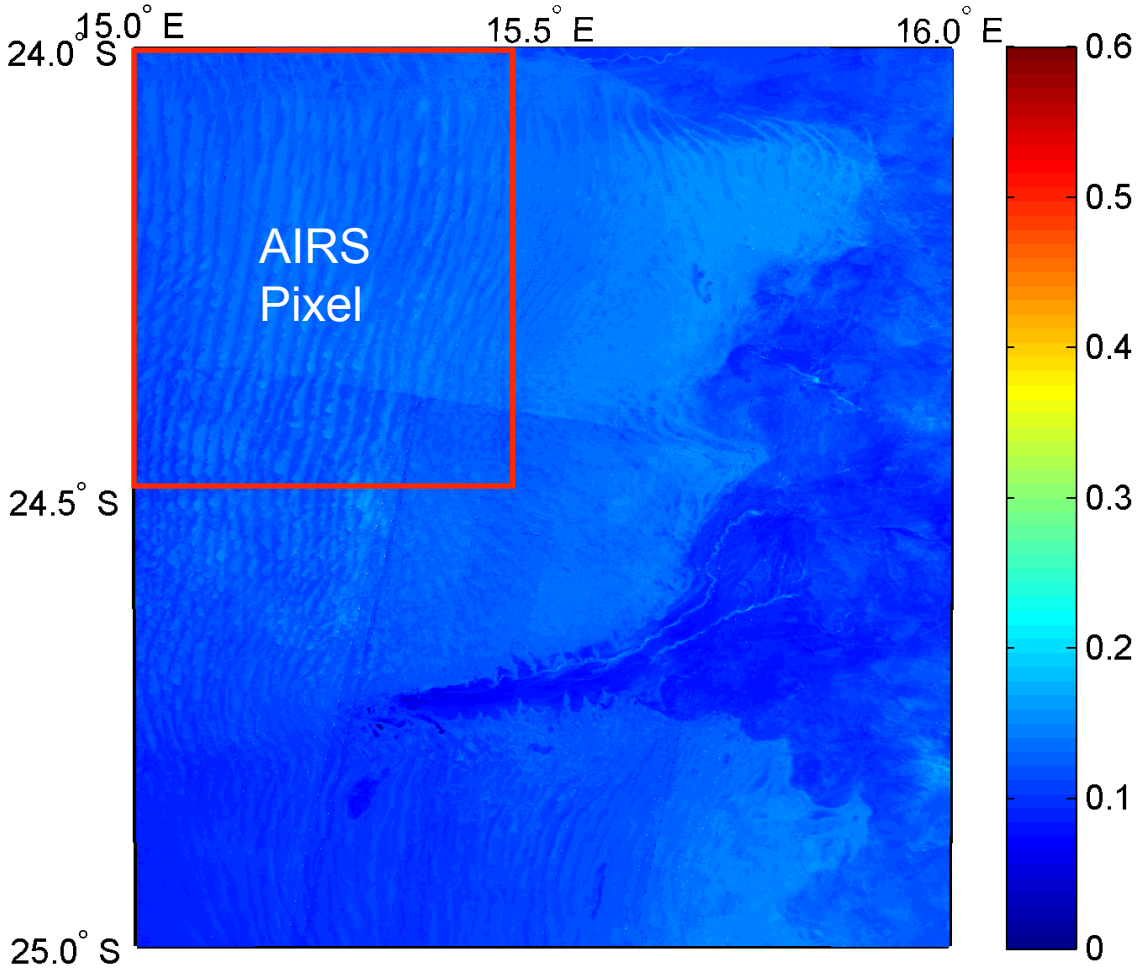


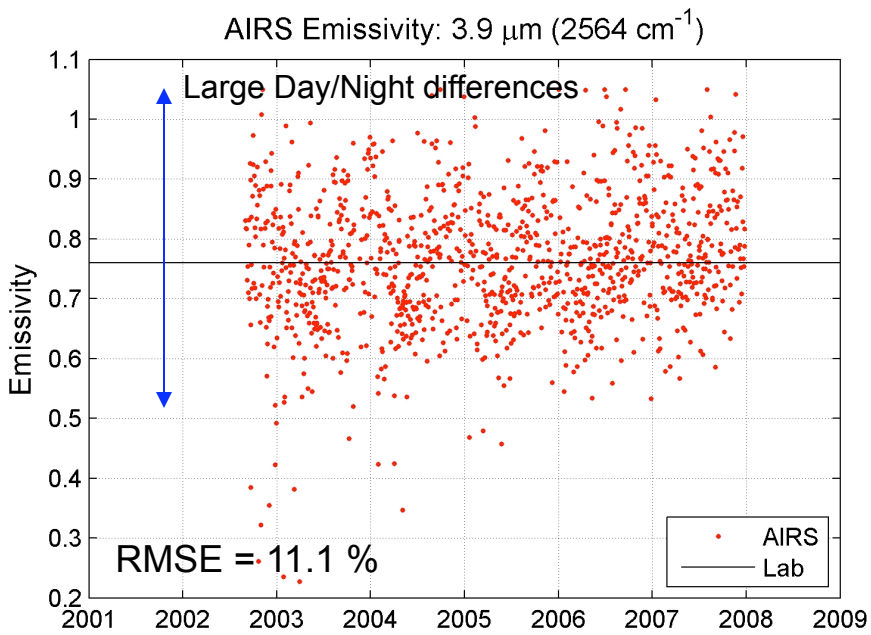


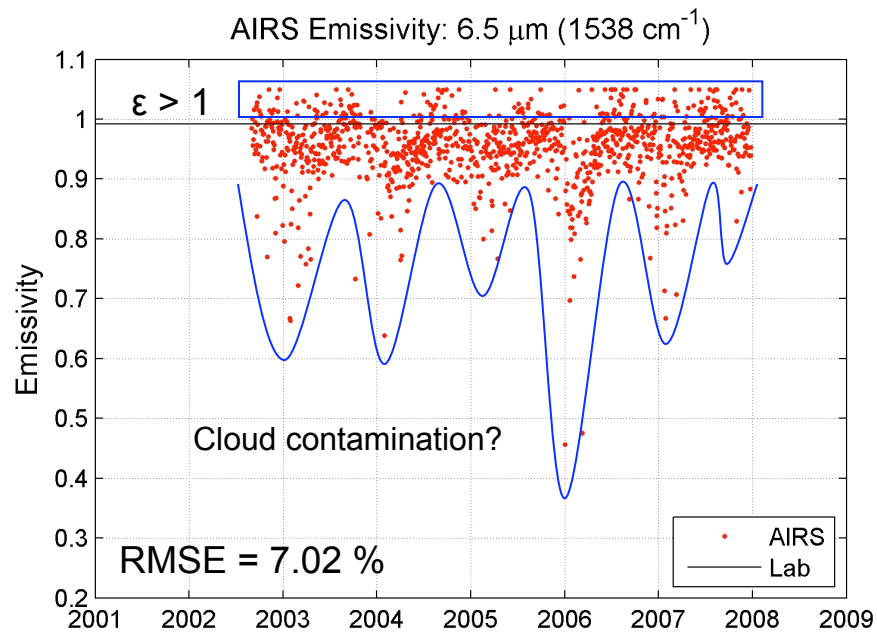
ASTER 9.1 μm Emissivity - Sossussvlei



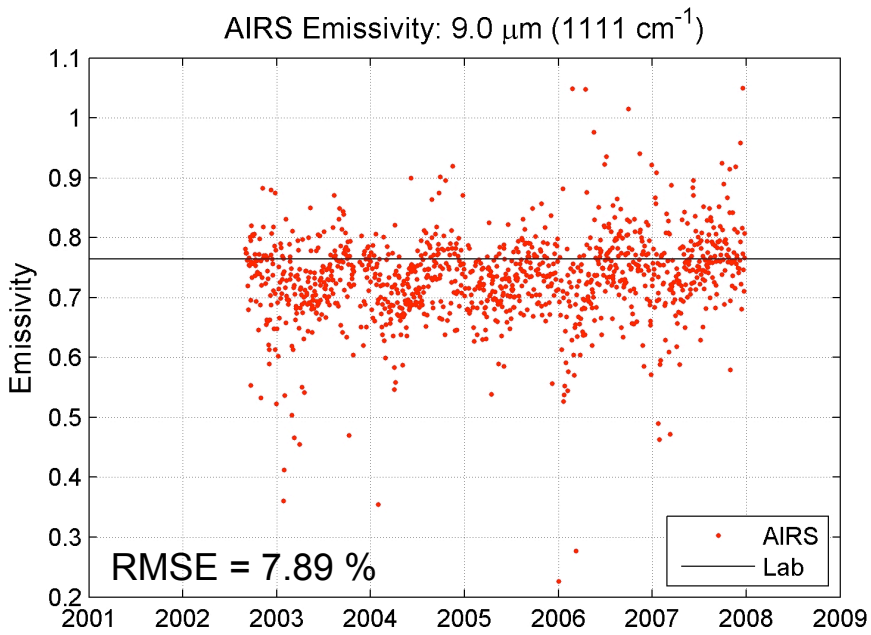
ASTER NDVI - Sossussvlei

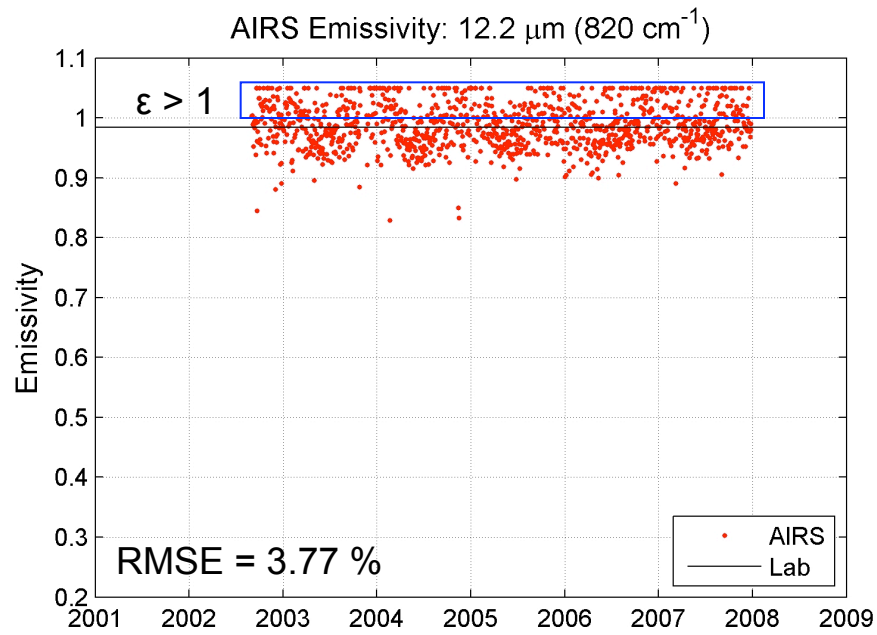


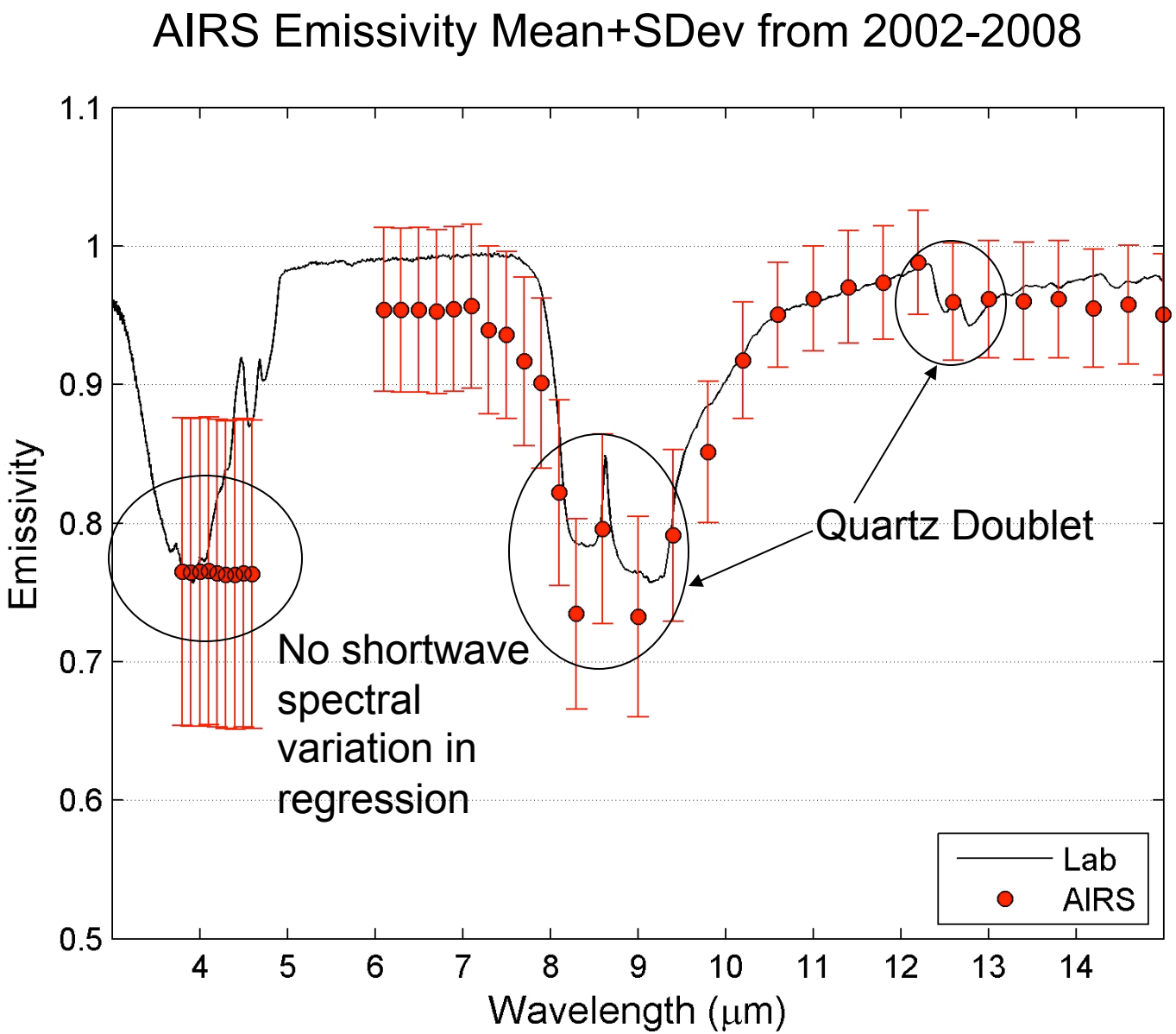


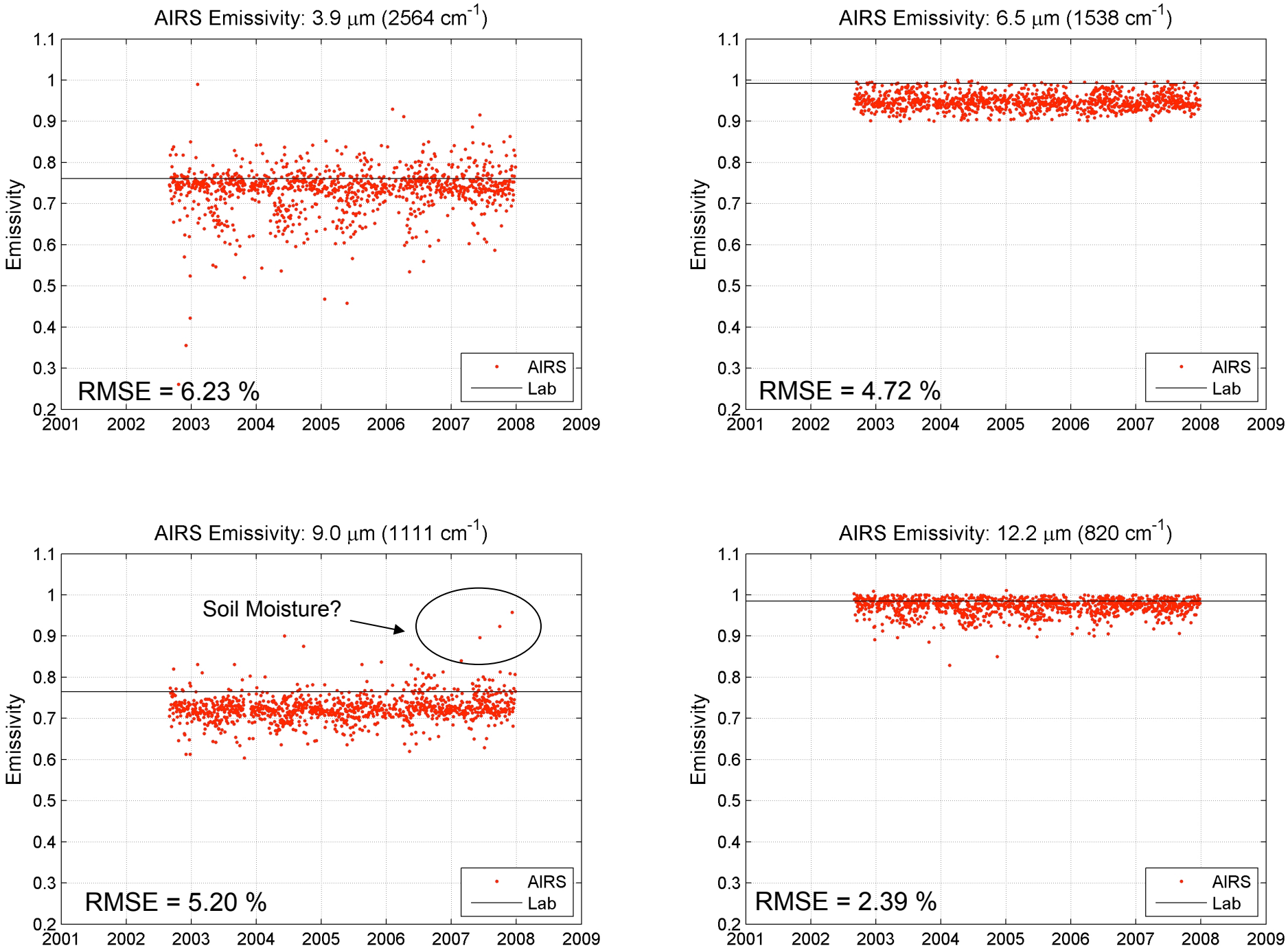


**Anomolously high rains during summer 2006 (102 mm, 6x annual rainfall) *Muller et al.,* 2008

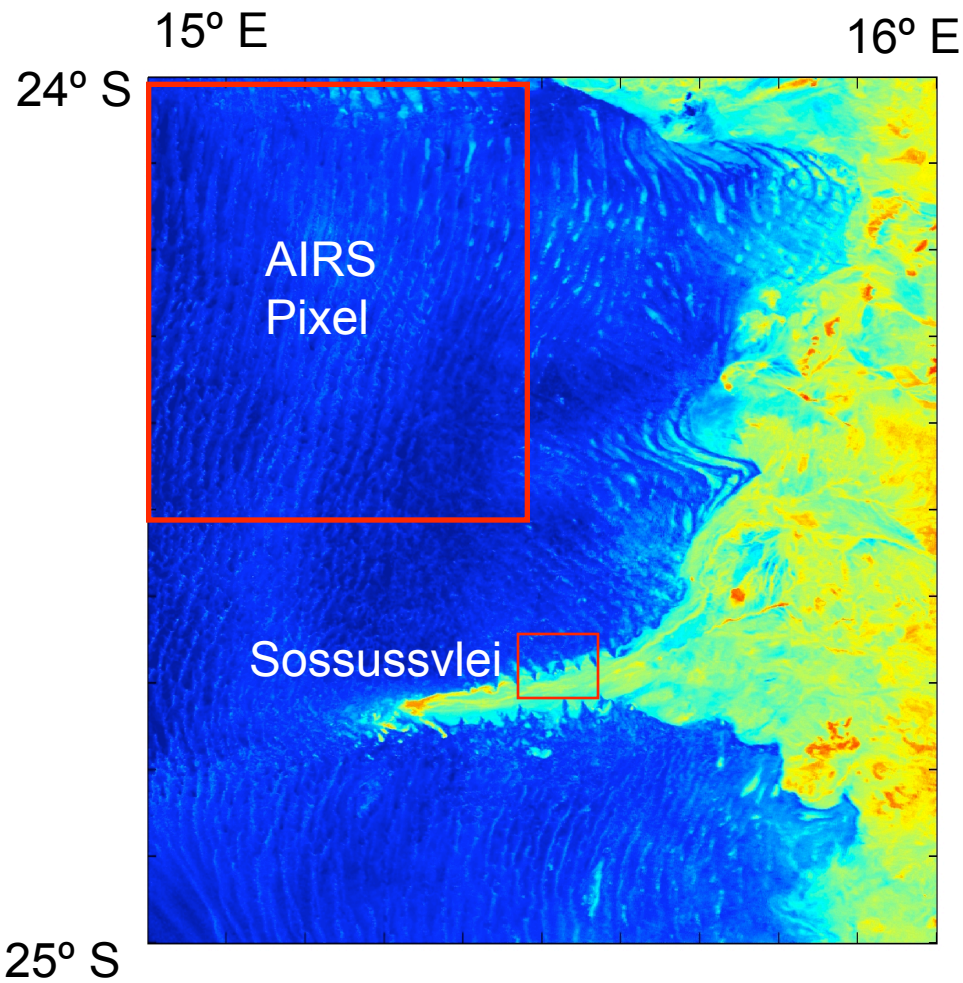


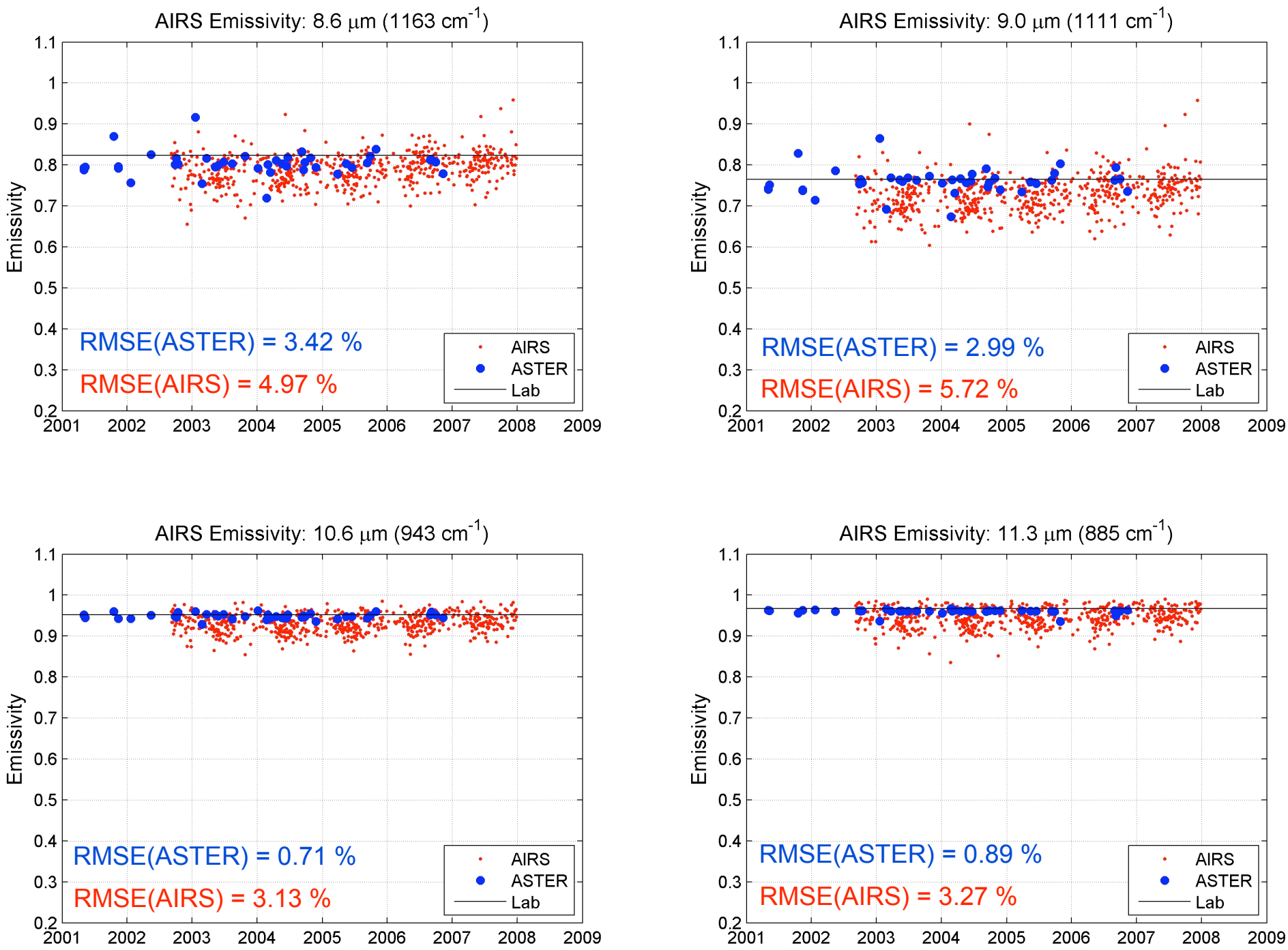


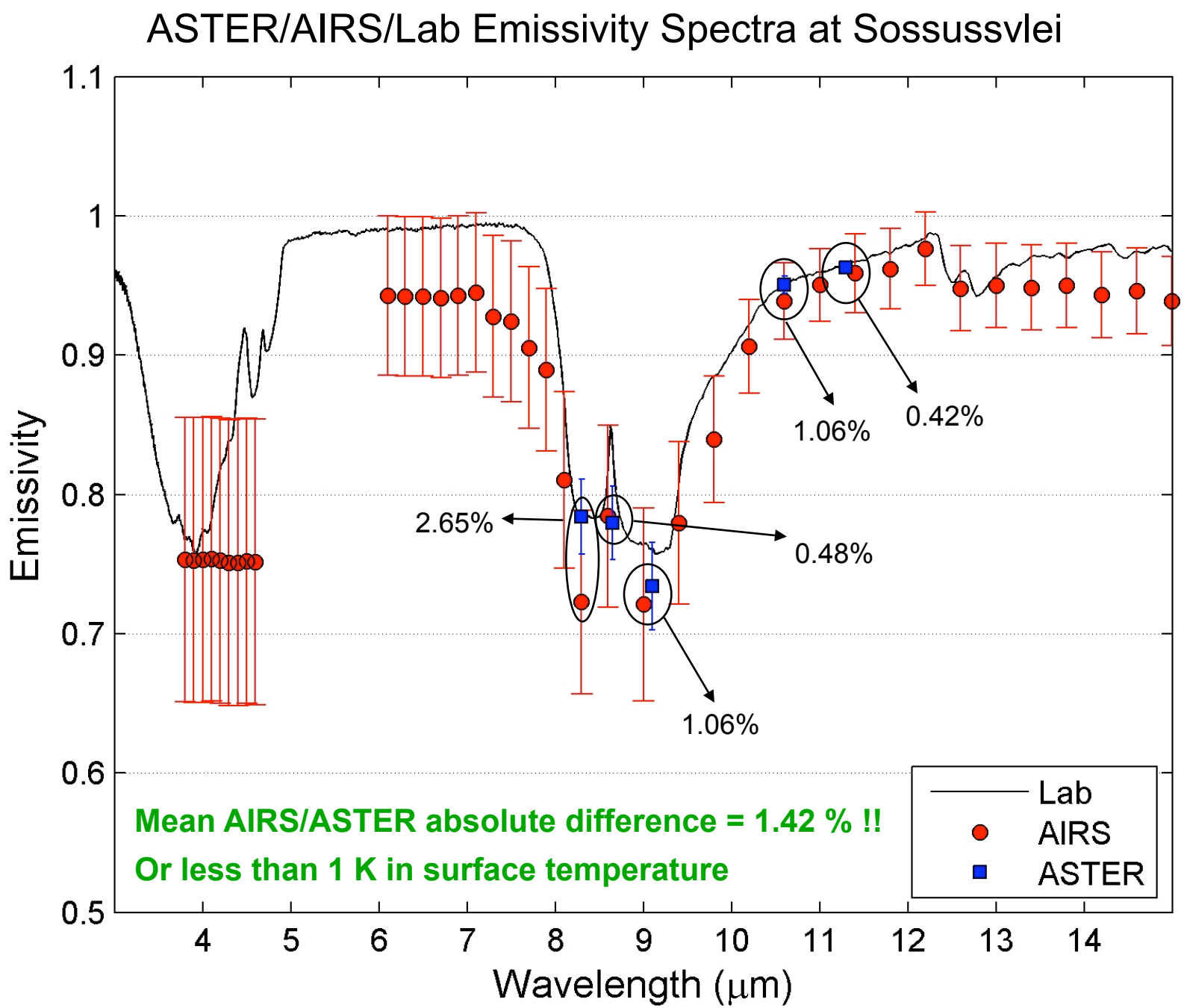

AIRS Emissivity Mean+SDev from 2002-2008
Emissivity
Wavelength (μm)
1.1
1
0.9
0.8
0.7
0.6
0.5
4
5
6
7
8
9
10
11
12
13
14
No shortwave spectral variation in regression
Quartz Doublet
Lab
AIRS


AIRS Emissivity: 3.9 μm (2564 cm-1)
AIRS Emissivity: 6.5 μm (1538 cm-1)
AIRS Emissivity: 9.0 μm (1111 cm-1)
AIRS Emissivity: 12.2 μm (820 cm-1)
Emissivity
RMSE = 6.23 %
RMSE = 4.72 %
RMSE = 5.20 %
RMSE = 2.39 %
Soil Moisture?
AIRS
Lab
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
2001
2002
2003
2004
2005
2006
2007
2008
2009

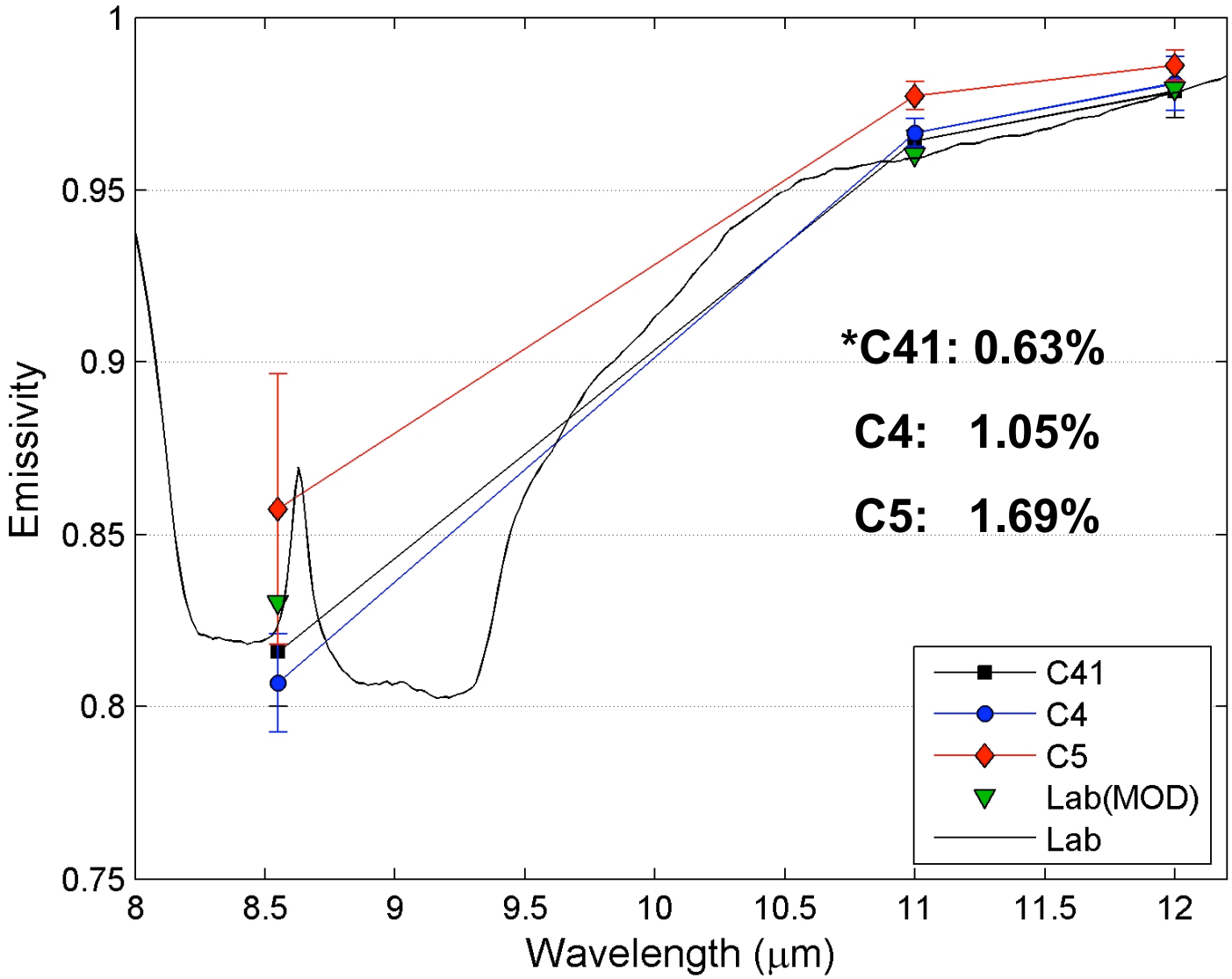
ASTER 9.1 μm Emissivity - Sossussvlei




AIRS Emissivity: 8.6 μm (1163 cm-1)
RMSE(ASTER) = 3.42 %
RMSE(AIRS) = 4.97 %
AIRS Emissivity: 9.0 μm (1111 cm-1)
RMSE(ASTER) = 2.99 %
RMSE(AIRS) = 5.72 %
AIRS Emissivity: 10.6 μm (943 cm-1)
RMSE(ASTER) = 0.71 %
RMSE(AIRS) = 3.13 %
AIRS Emissivity: 11.3 μm (885 cm-1)
RMSE(ASTER) = 0.89 %
RMSE(AIRS) = 3.27 %
Emissivity
AIRS
ASTER
Lab
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
2001
2002
2003
2004
2005
2006
2007
2008
2009


ASTER/AIRS/Lab Emissivity Spectra at Sossussvlei
Emissivity
Wavelength (μm)
1.1
1
0.9
0.8
0.7
0.6
0.5
4
5
6
7
8
9
10
11
12
13
14
2.65%
0.48%
1.06%
1.06%
0.42%
Mean AIRS/ASTER absolute difference = 1.42 % !!
Or less than 1 K in surface temperature
Lab
AIRS
ASTER

MOD11B1 daily product: July-Aug-Sep 2004: Sossussvlei, Namib



Summary

- North American ASTER Land Surface Emissivity Database (NAALSED) at JPL: http://emissivity.jpl.nasa.gov
- NAALSED validated over arid regions to within 1.5% (~1 K) and vegetated regions to within 1% (~0.67 K)
- AIRS/ASTER mean absolute differences agree to within 1.5% over Namib Desert from 8-12 μm
- However, AIRS variability is still large (~5%), particularly in shortwave, due to large day/night differences and e>1
- AIRS emissivity underestimated by ~5% from 6-8 μm (Cloud contamination?)
- Susskind group: V5+, includes new emissivity perturbation function, only shortwave channels used