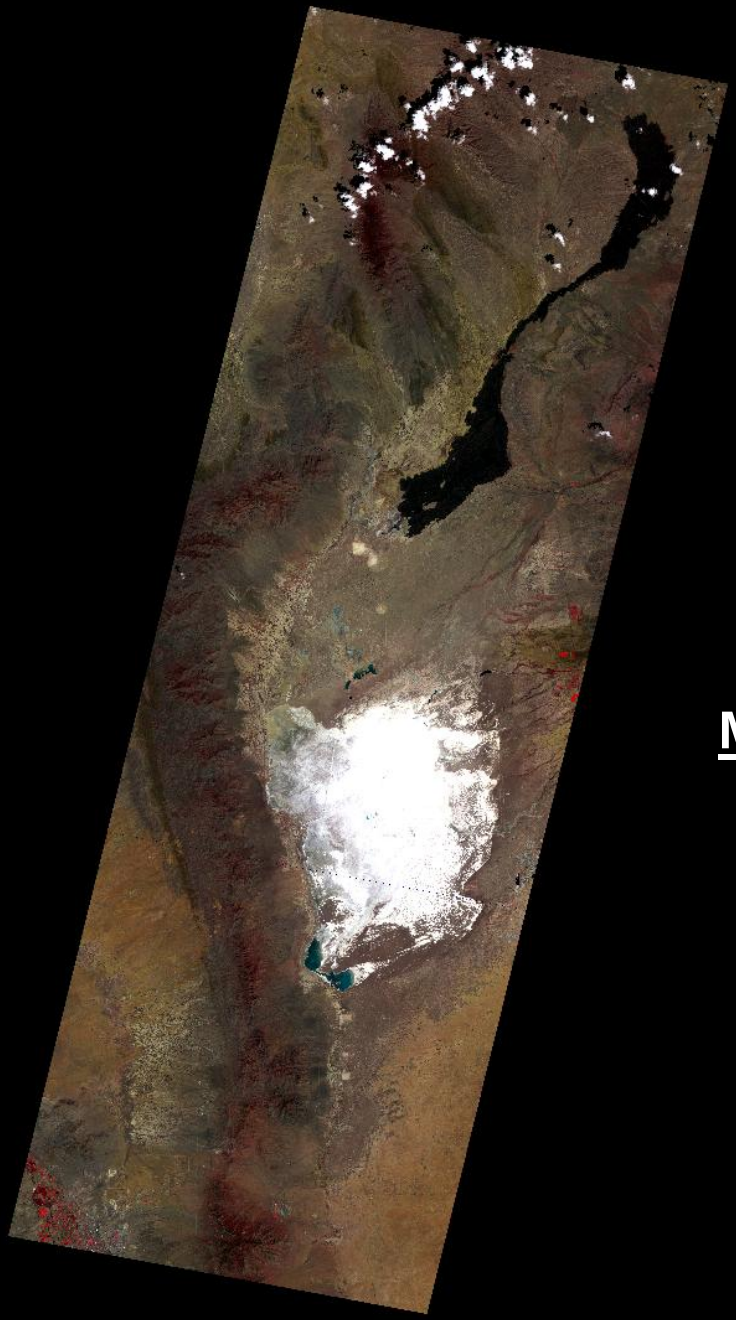
**2nd Workshop on Remote Sensing and Modeling of Surface Properties**
9-11 June 2009, Météo France, Toulouse, France



# Analysing Land Surface Emissivity with Multispectral Thermal Infrared Data

**Maria Mira, Thomas J. Schmugge*, Enric Valor, Vicente Caselles, and César Coll**

*(Maria.Mira@uv.es)*

*University of Valencia, Spain*
**New Mexico State University, NM (USA)*

# OUTLINE

- Emissivity Observations with ASTER

  HOW

  Multispectral Thermal Infrared from ASTER/TES:

  Temperature Emissivity Separation algorithm

  WHERE

  New Mexico: White Sands desert

- Quality of the ASTER emissivity product

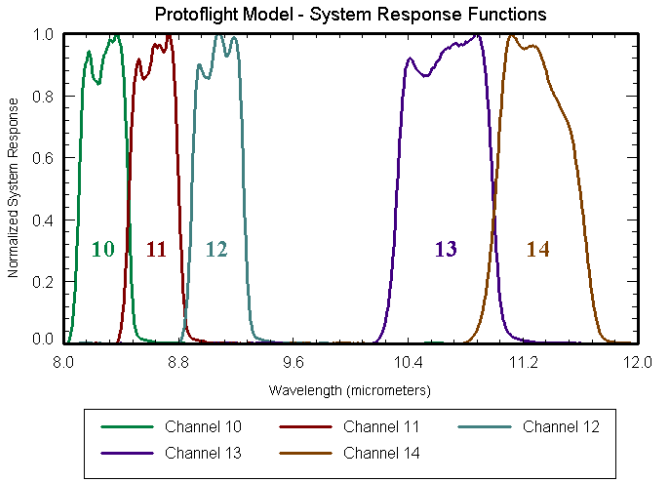
  (AST_05: ASTER L2 Surface Emissivity )

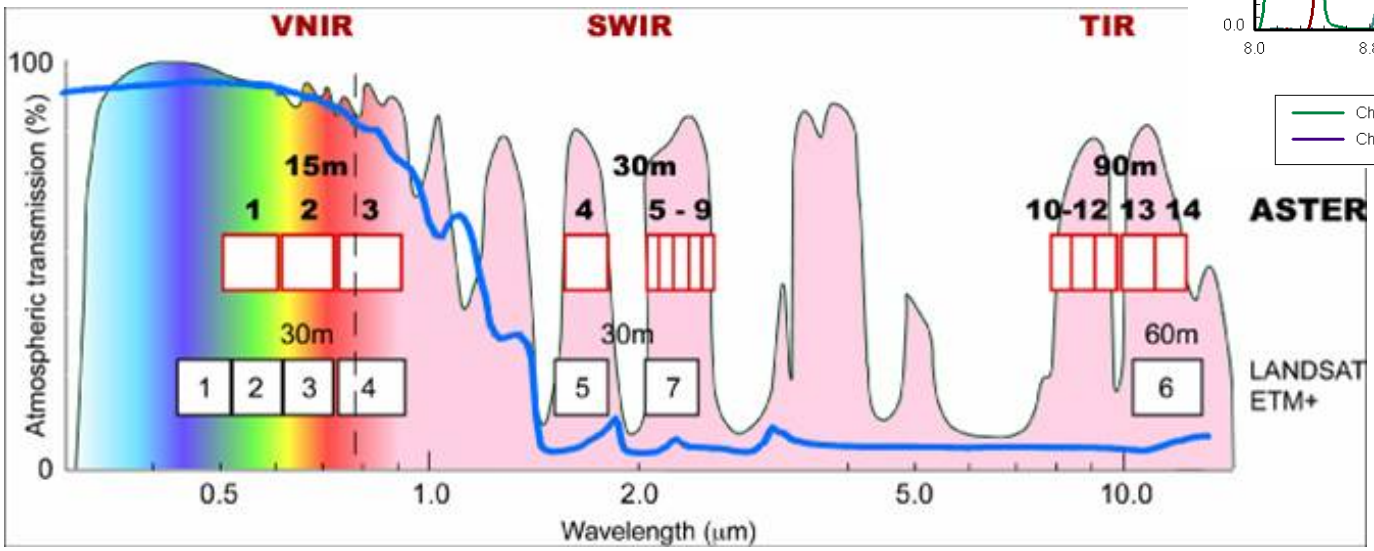
- Day/Night pairs with ASTER

- ASTER emissivities temporal variation

# Emissivity Observations with ASTER on NASA's Terra Satellite

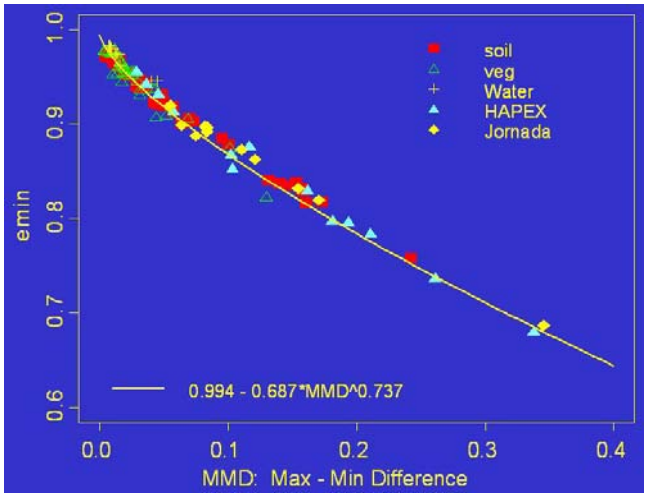
- SENSOR
  - Multispectral Thermal Infrared (TIR) data from the Advanced Spaceborne Thermal Emission & Reflection (ASTER) radiometer:
    - 5 bands in TIR, 90 m resolution, 60 km swath
- Terra satellite launched in December 1999



# TES
# Temperature Emissivity Separation

- Problem: 5 measurements & 6 unknowns
- Developed for use with ASTER TIR data
- Empirical relation between $\varepsilon_{min}$ and $\Delta\varepsilon$
- $\beta_i = \varepsilon_i / \langle\varepsilon_i\rangle$
- MMD = $\beta_{max} - \beta_{min}$
- $\beta_i$ can also be calculated from observed radiances
  - ✓ $\beta_i = ( L_i / \langle L_i \rangle)(\langle BB_i(T) \rangle / BB_i(T))$
- Doesn't work well for gray bodies




**We analyzed…**

➢ ASTER data acquired from 2006 to 2008, over White Sands area:

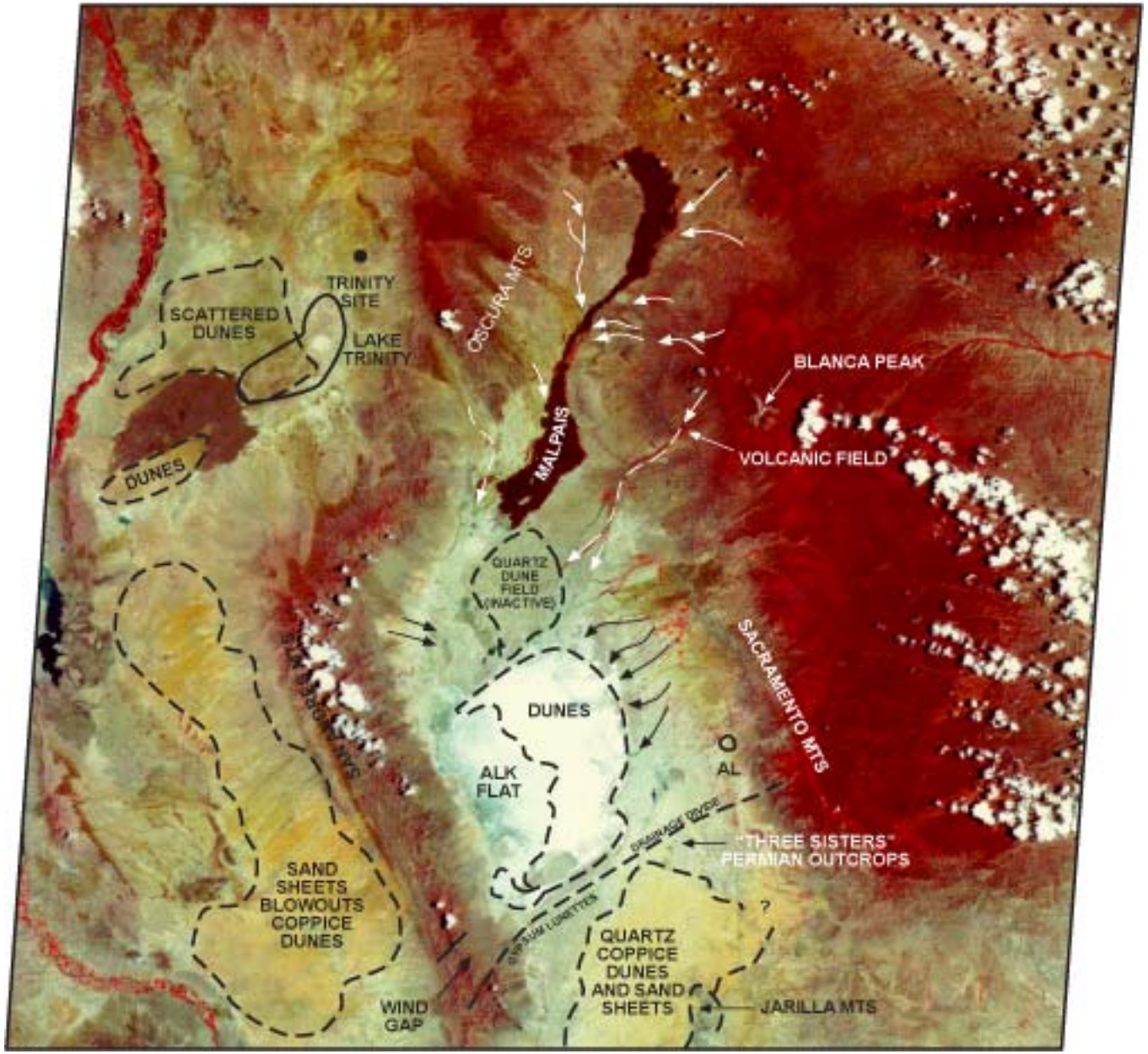
- 11 day observations and 4 night observations
- 3 day/night pairs

* Spatial resolution degraded from 90 m to 180 m to avoid the geolocation problem that ASTER has for high altitude locations.

➢ Gypsum dunes, such as White Sands desert in New Mexico, can be used as an excellent test case for low emissivity values.

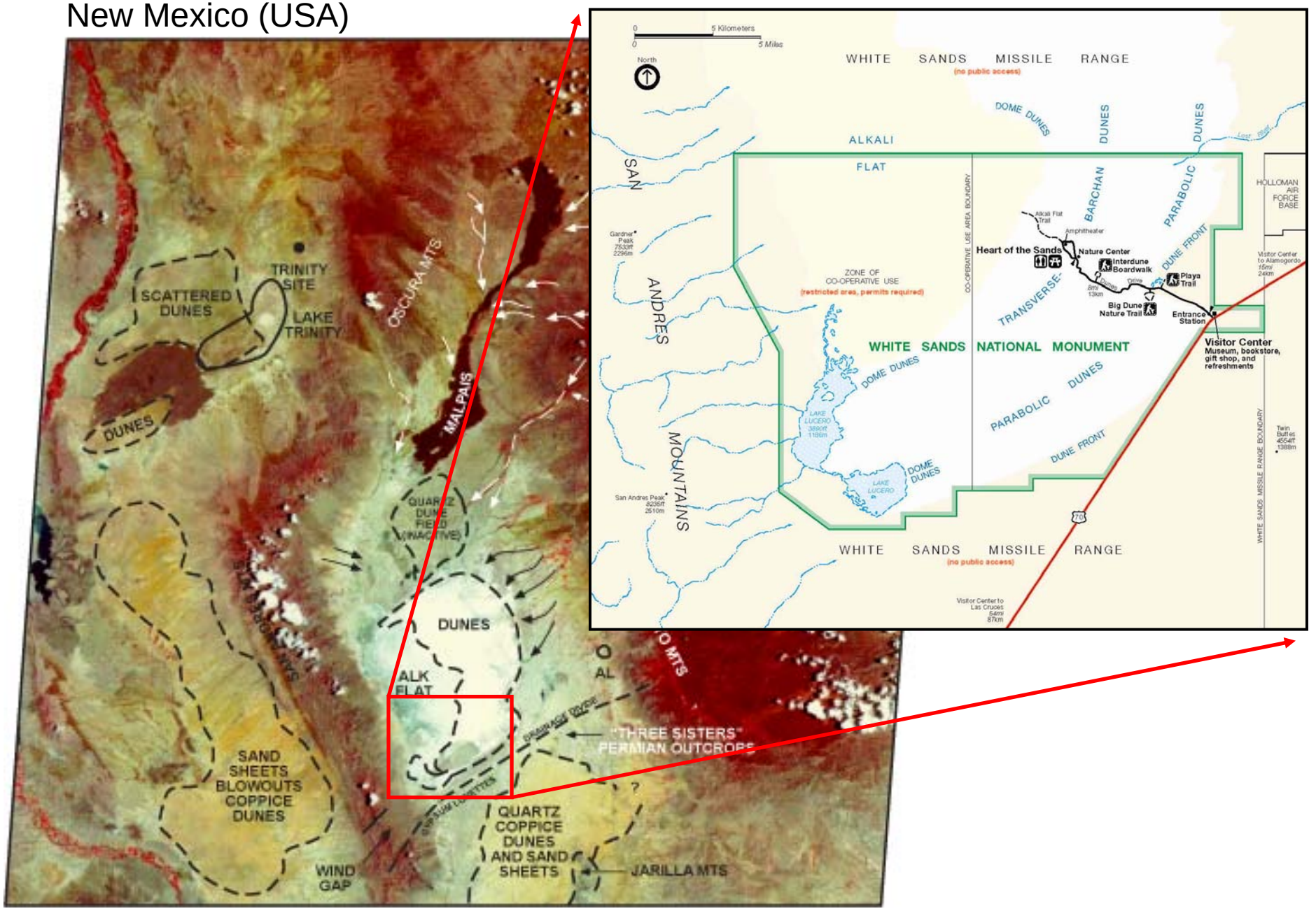
# Study Area

Landsat image of White Sands area,
New Mexico (USA)



Landsat image of White Sands area, New Mexico (USA)

# Study Area

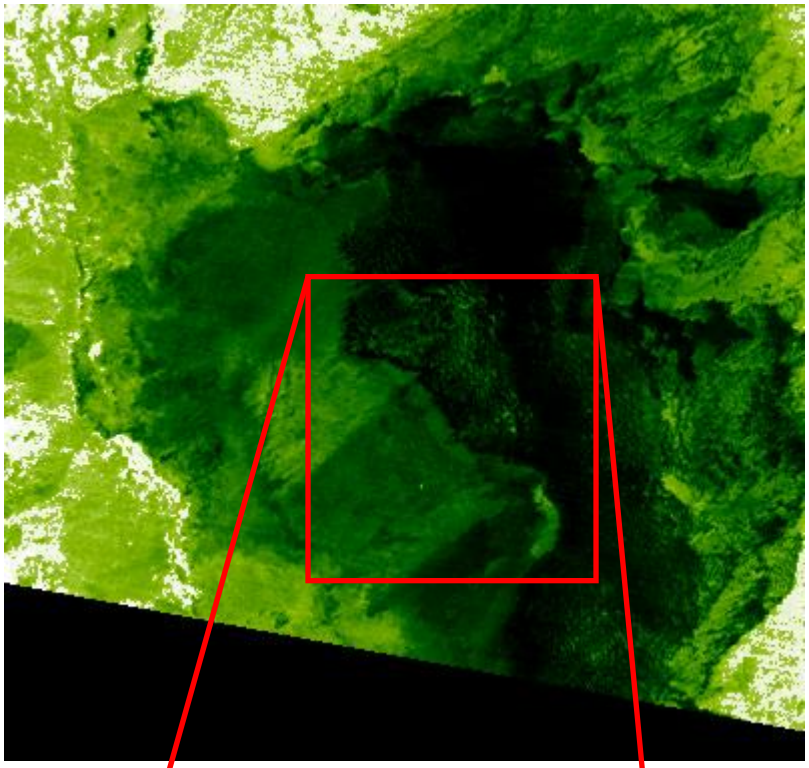


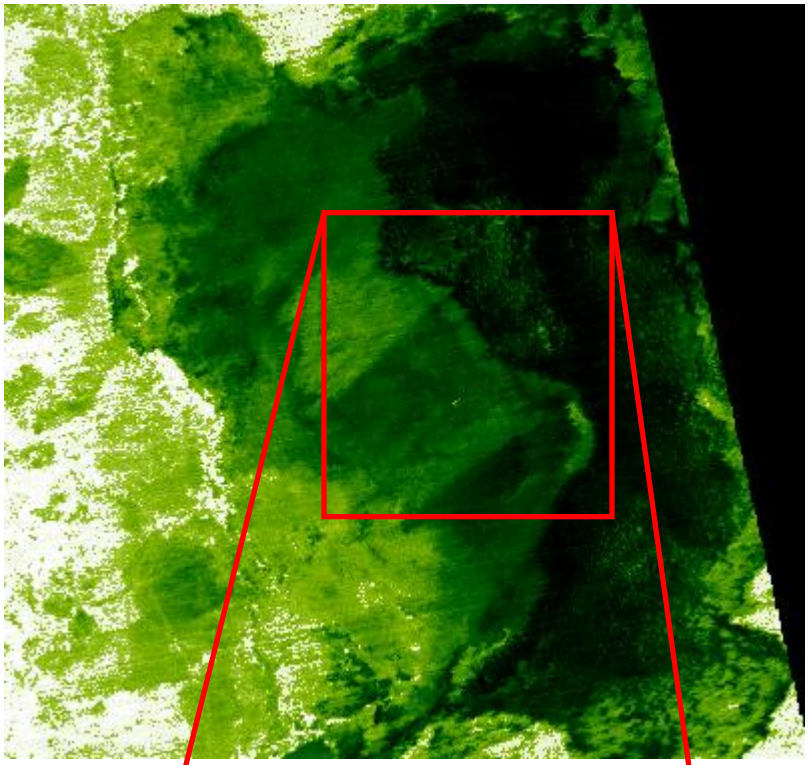
# Emissivities at Day and Night Observed Equally Well with ASTER/TES

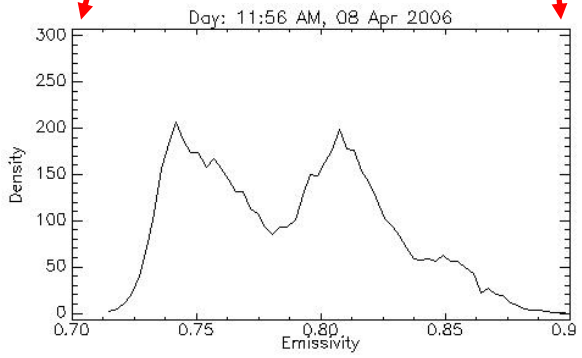
*Day: 11:56 AM*
*8 Apr 2006*

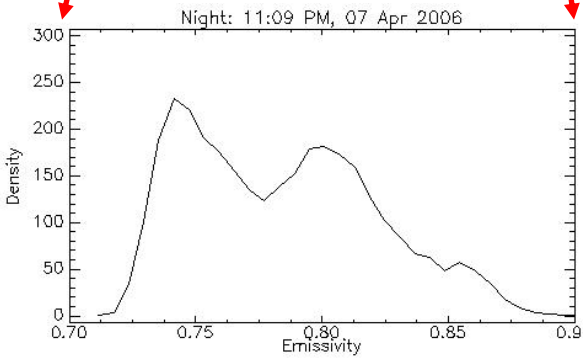
Band 11 (8.6 μm)

*Night: 11:09 PM*
*7 Apr 2006*



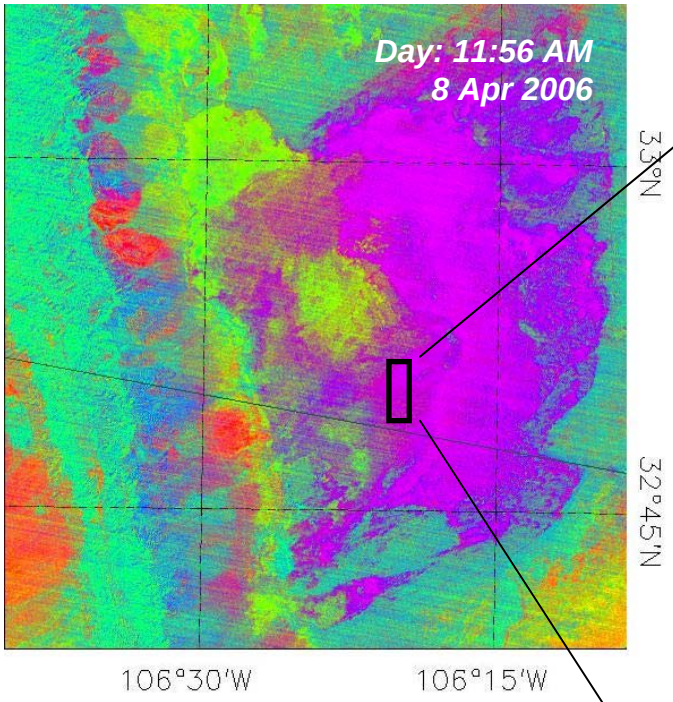


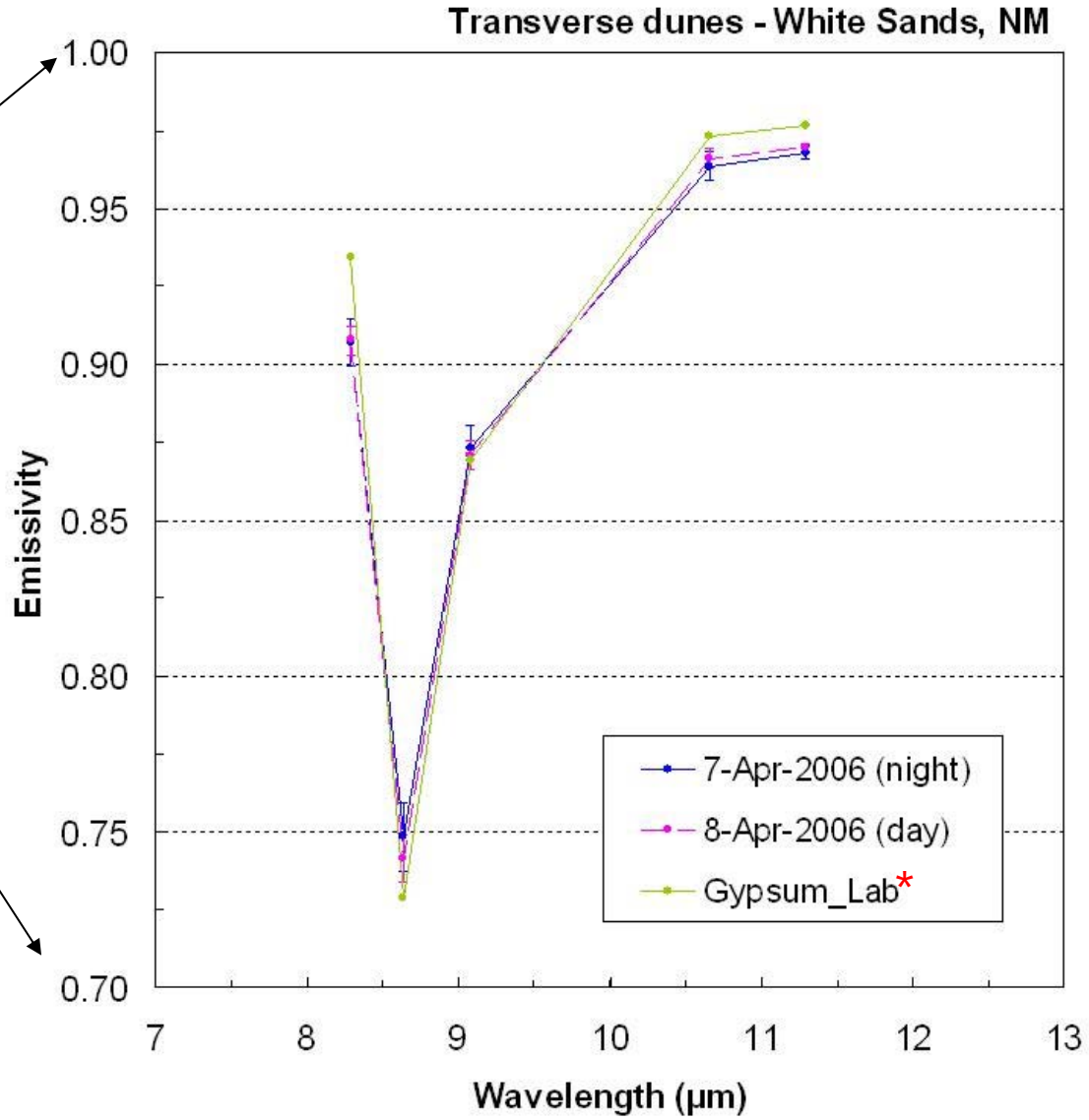


# Emissivities at Day and Night Observed Equally Well with ASTER/TES

Decorrelation Stretch
RGB (Band 14,12,10)



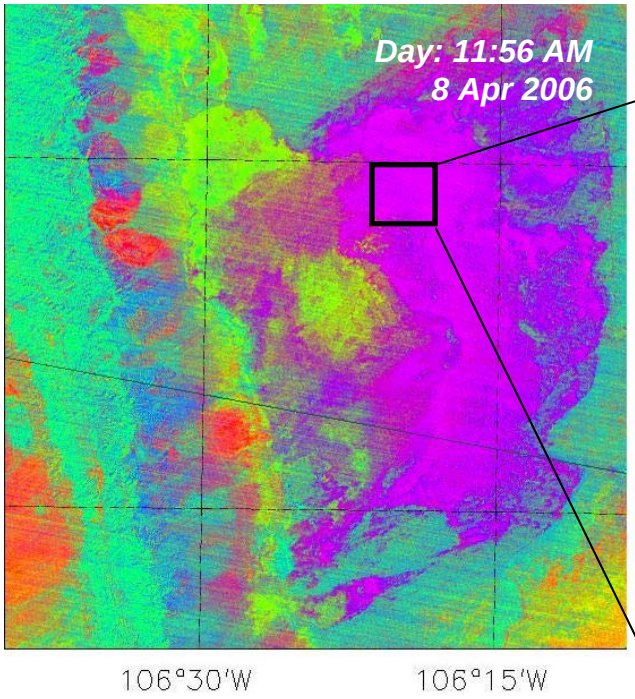




- Average emissivity value of 100 pixels of 180 m resolution.
- ASTER retrieves very well the low emissivity values of the gypsum spectrum.

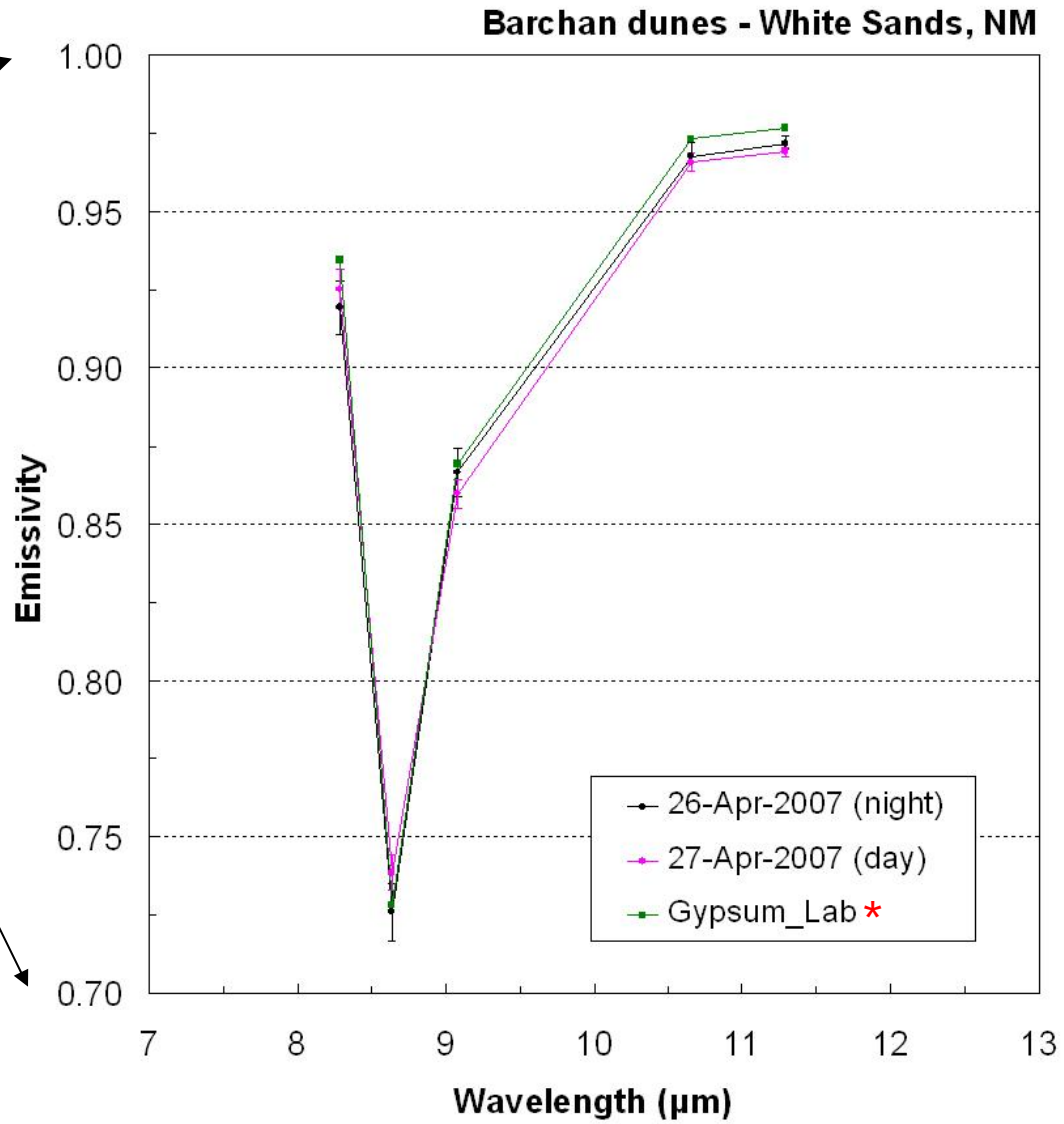
* Laboratory spectra from ASTER Spectral library at Jet Propulsion Laboratory

# Emissivities at Day and Night Observed Equally Well with ASTER/TES

Decorrelation Stretch
RGB (Band 14,12,10)

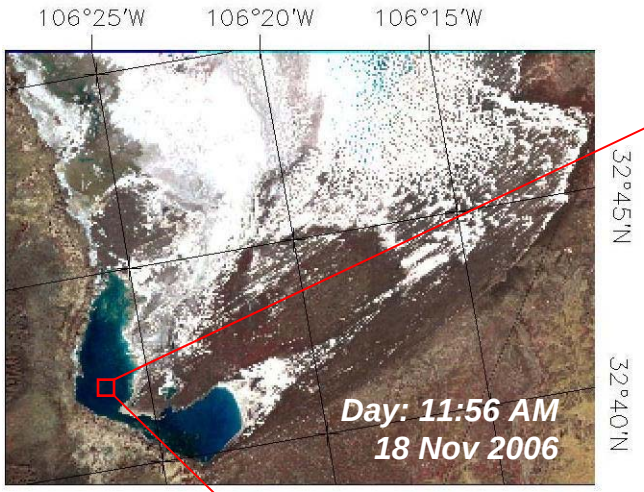



- Average emissivity value of 430 pixels of 180 m resolution.
- ASTER retrieves very well the low emissivity values of the gypsum spectrum.



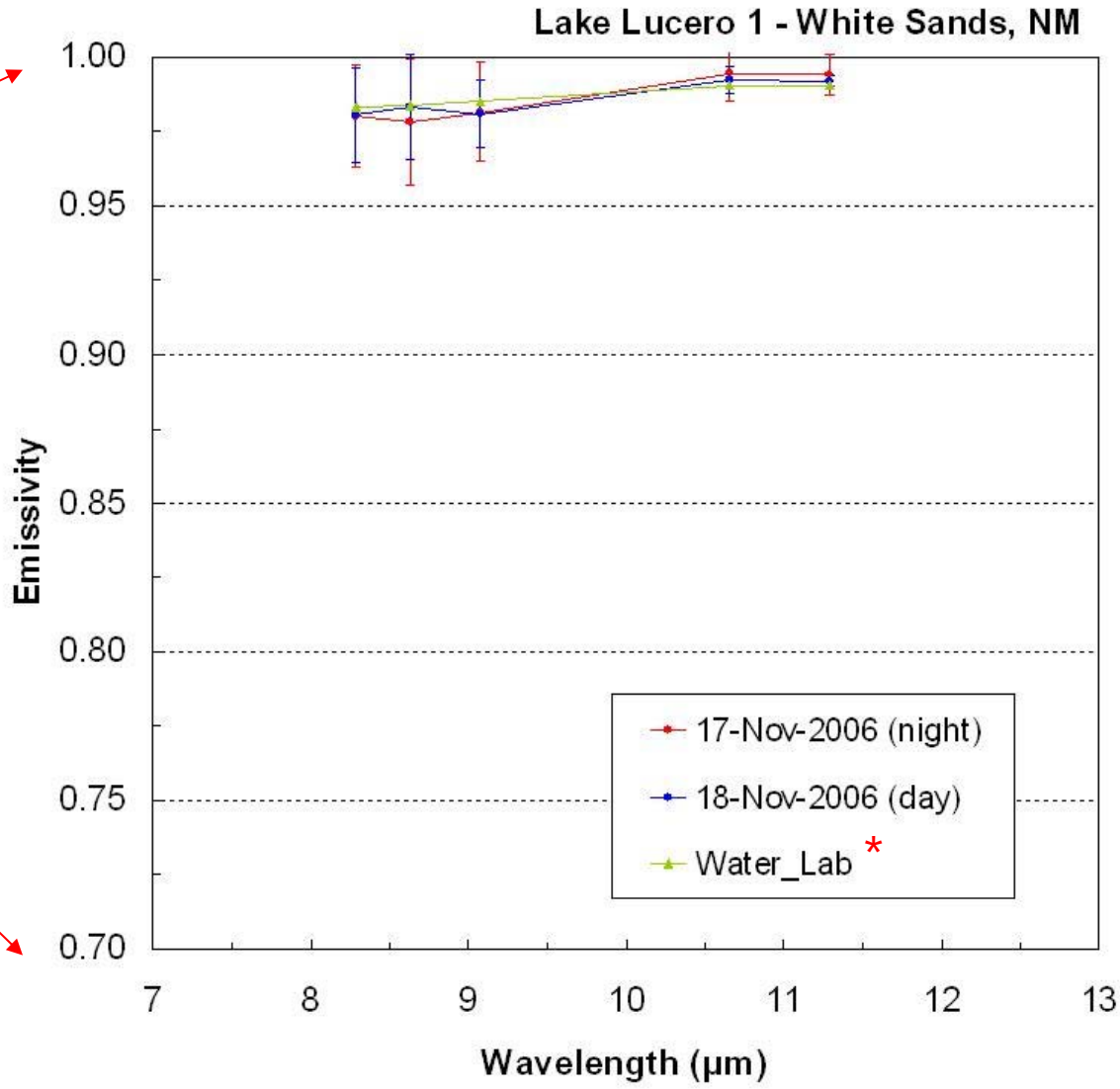

* Laboratory spectra from ASTER Spectral library at Jet Propulsion Laboratory

# Emissivities at Day and Night Observed Equally Well with ASTER/TES



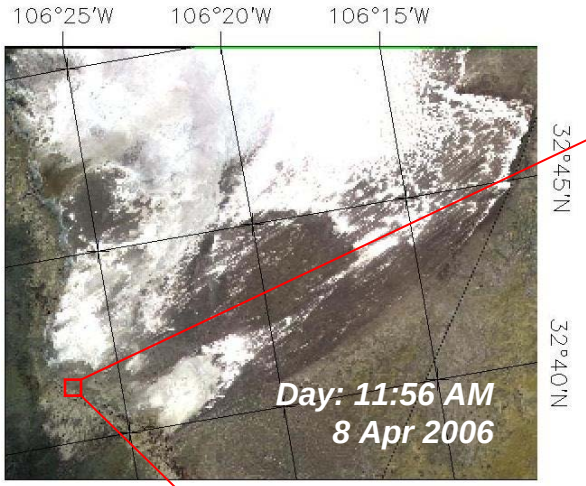

RGB (Bands 3N,2,1) from AST_07

- Average emissivity value of 80 pixels of 180 m resolution.
- ASTER retrieves very well the high emissivity values of the water spectrum.




* Laboratory spectra from ASTER Spectral library at Jet Propulsion Laboratory

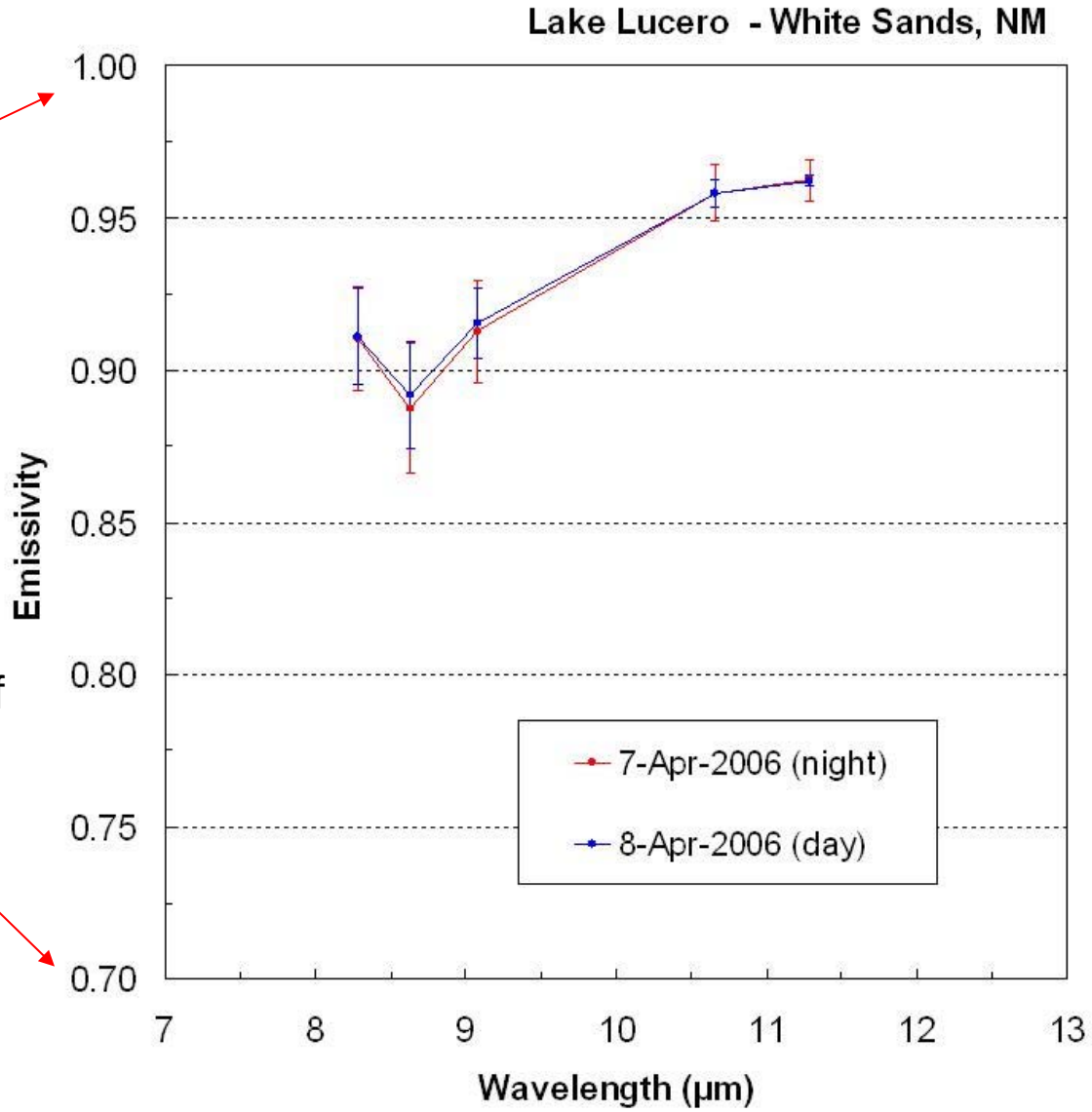
# Emissivities at Day and Night Observed Equally Well with ASTER/TES



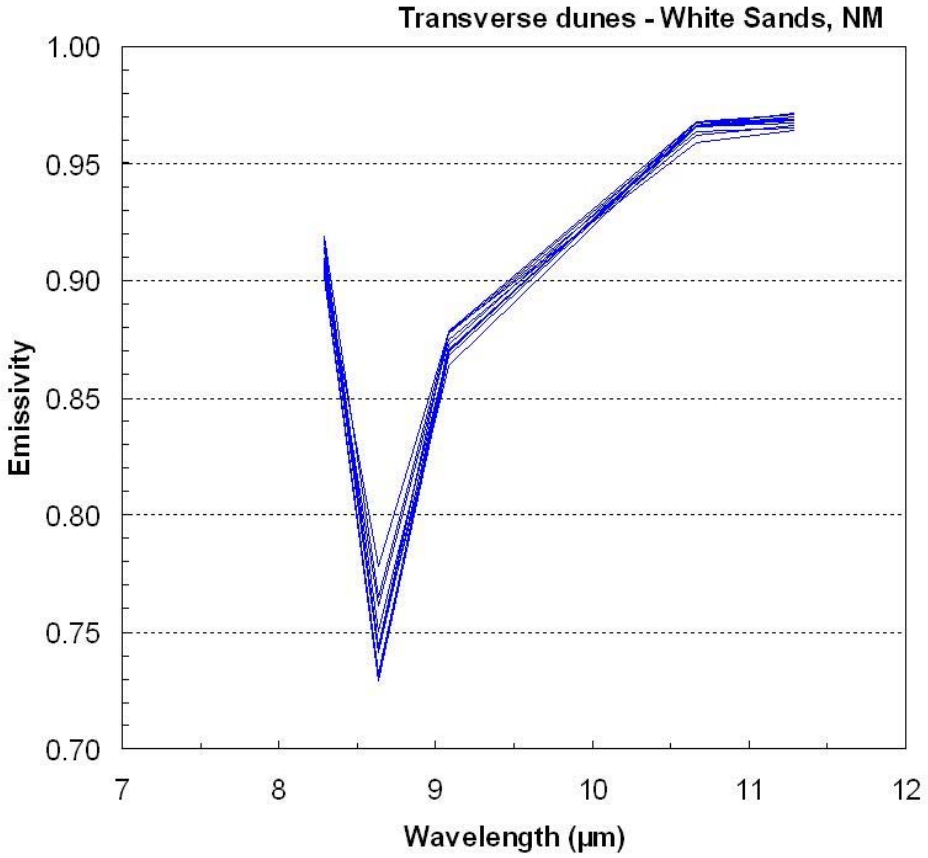

RGB (Bands 3N,2,1 ) from AST_07

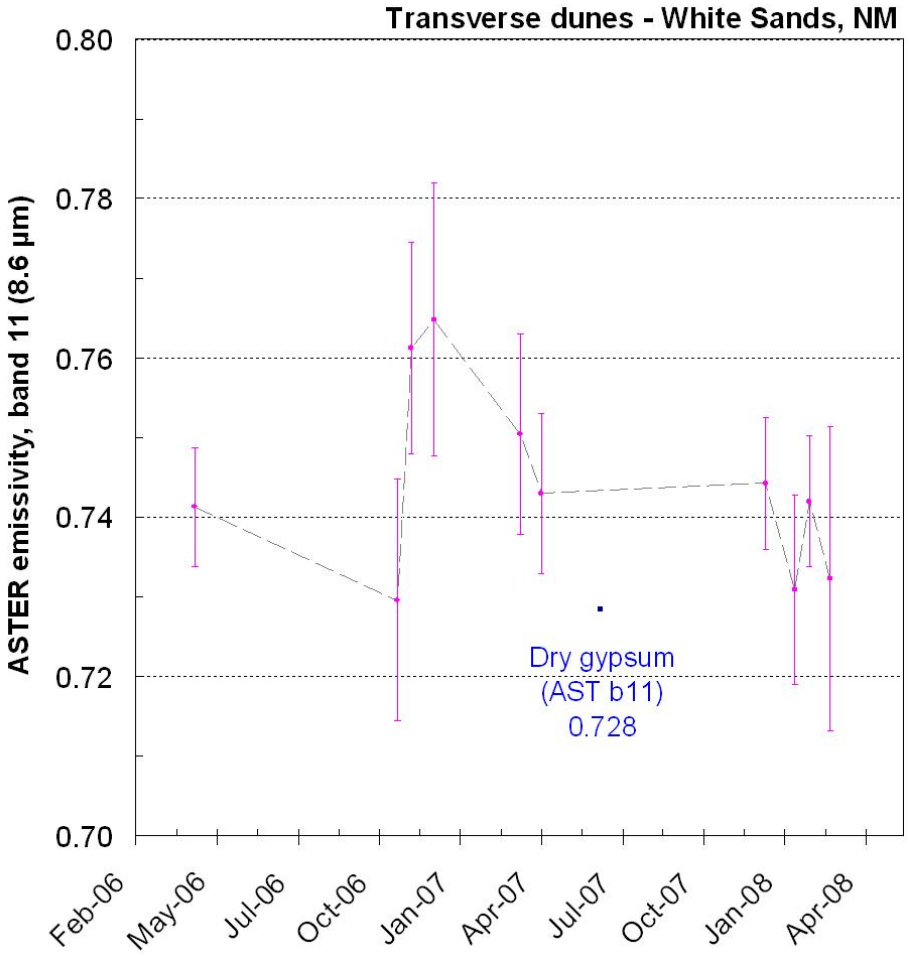
- Average emissivity value of 80 pixels of 180 m resolution.

Gypsum crystals

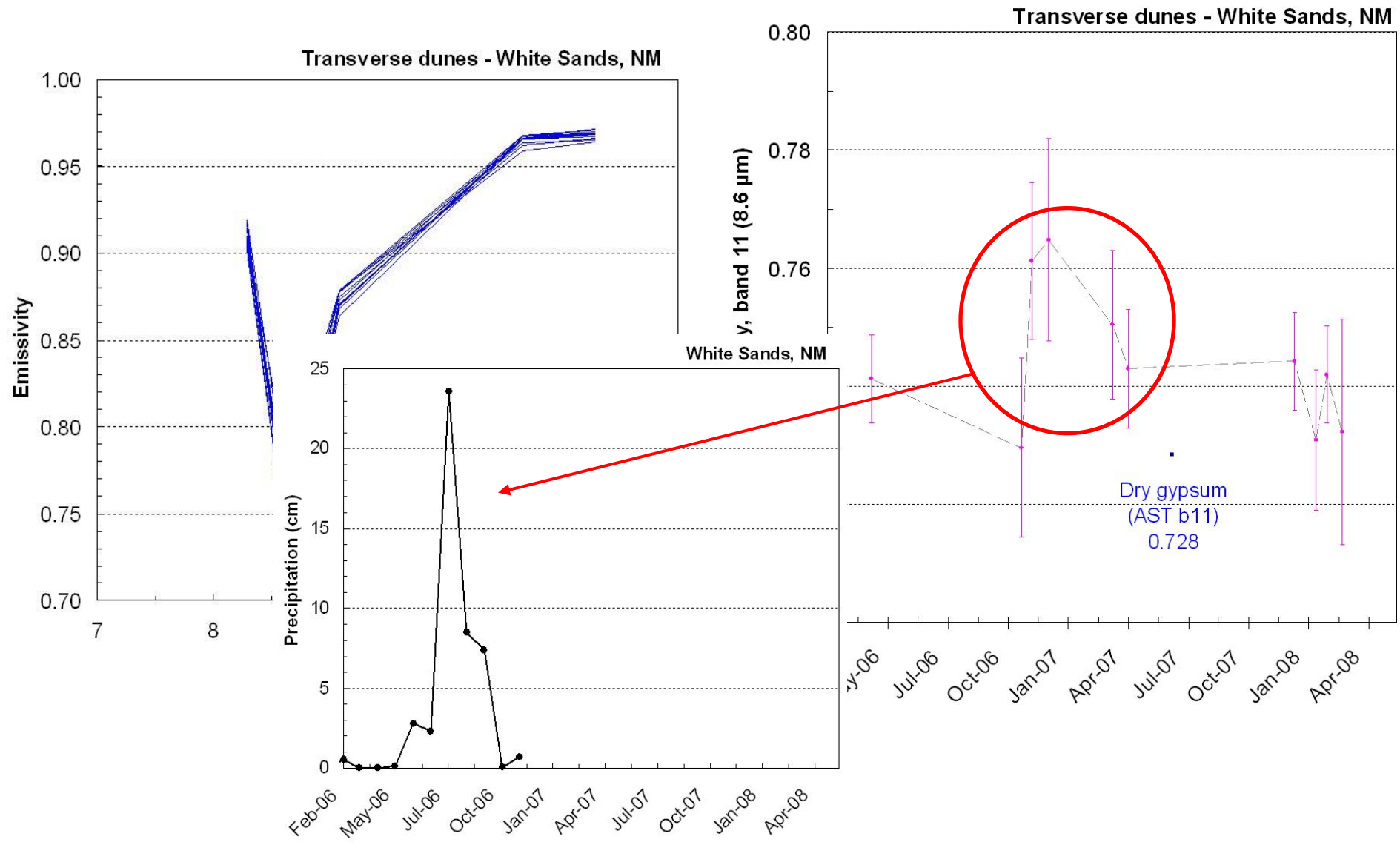


# ASTER emissivities temporal variation
# White Sands, NM

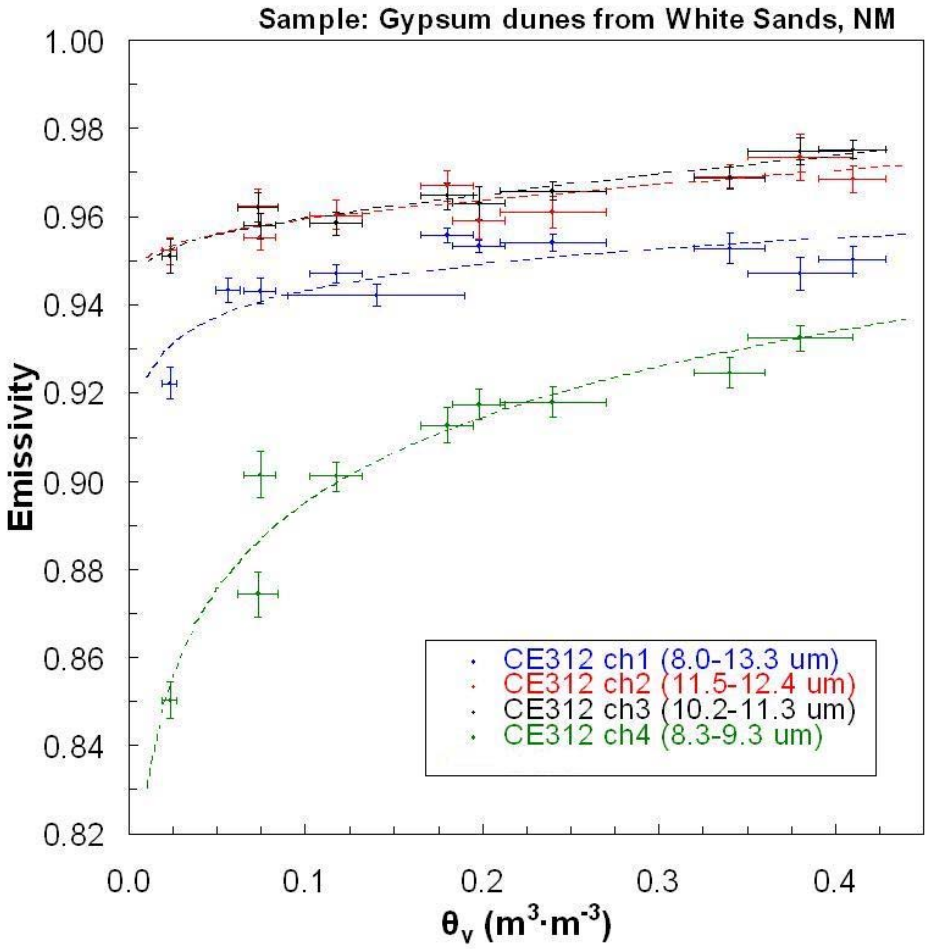


# ASTER emissivities temporal variation
# White Sands, NM



# Soil Moisture Effect on Thermal Infrared (8-13 μm) Emissivities




Mira et al. (IEEE-TGRS, under review)

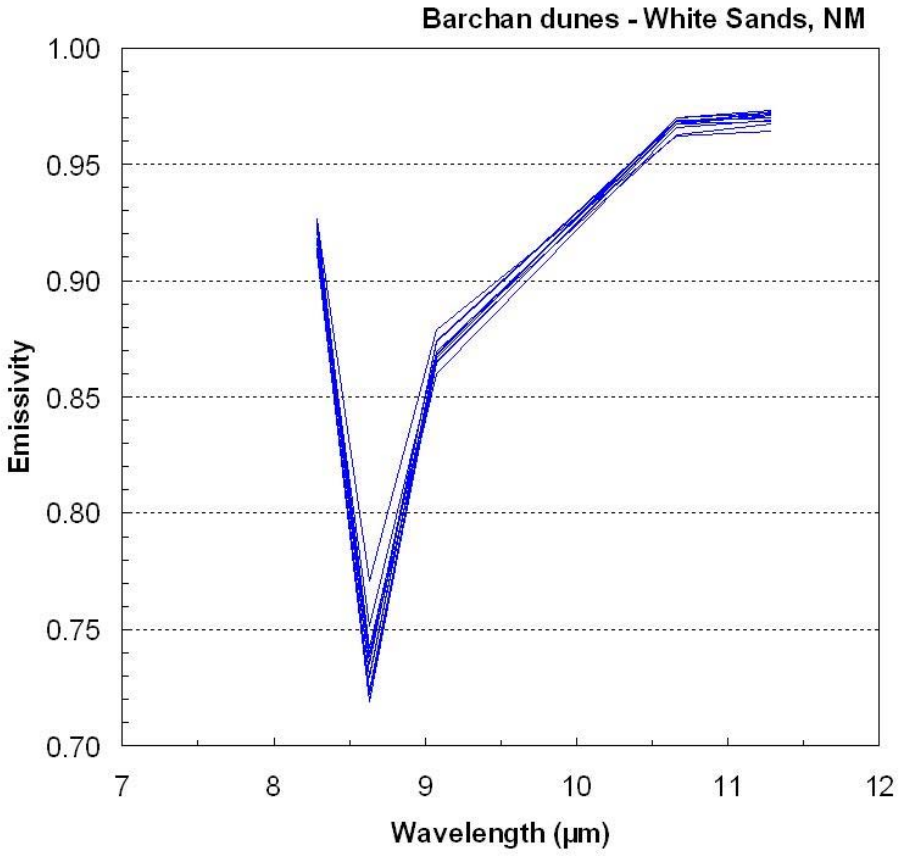
Lab measurements with a TIR Radiometer CIMEL Electronique CE312.

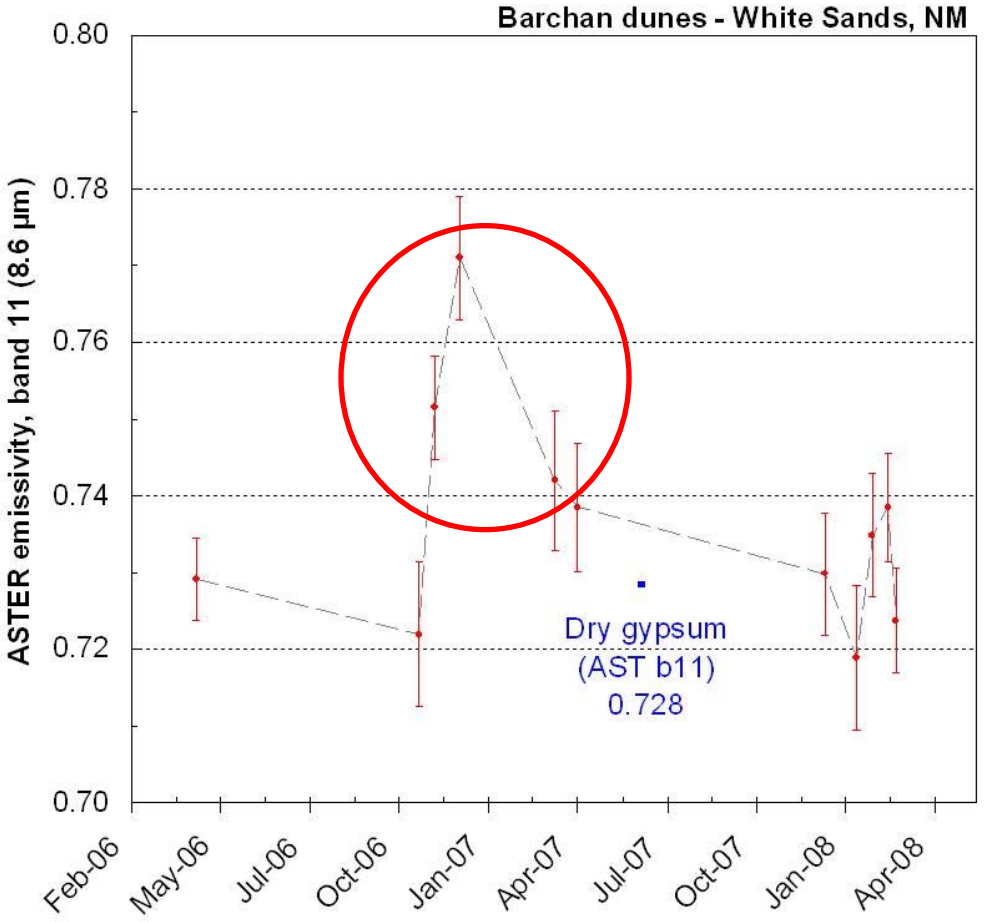
Emissivity measurements using the Box method (Rubio et al., 1997 & 2003).

Soil sample under controlled soil moisture.

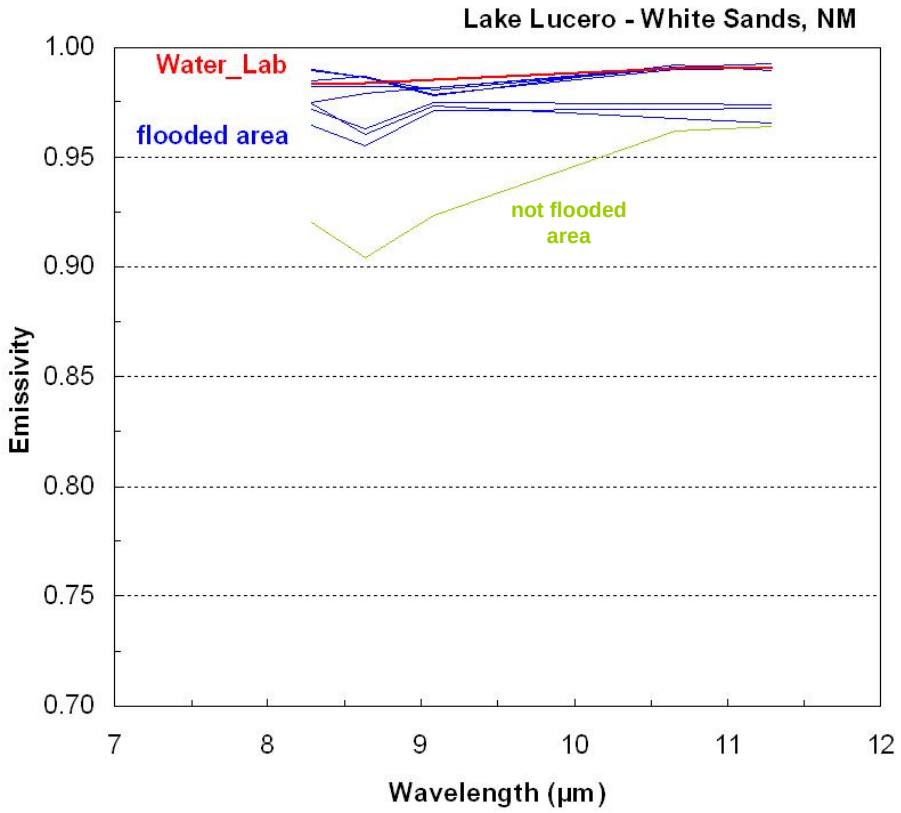
- TIR emissivities are sensitive to changes in soil moisture, mainly in the 8 to 9 μm domain.

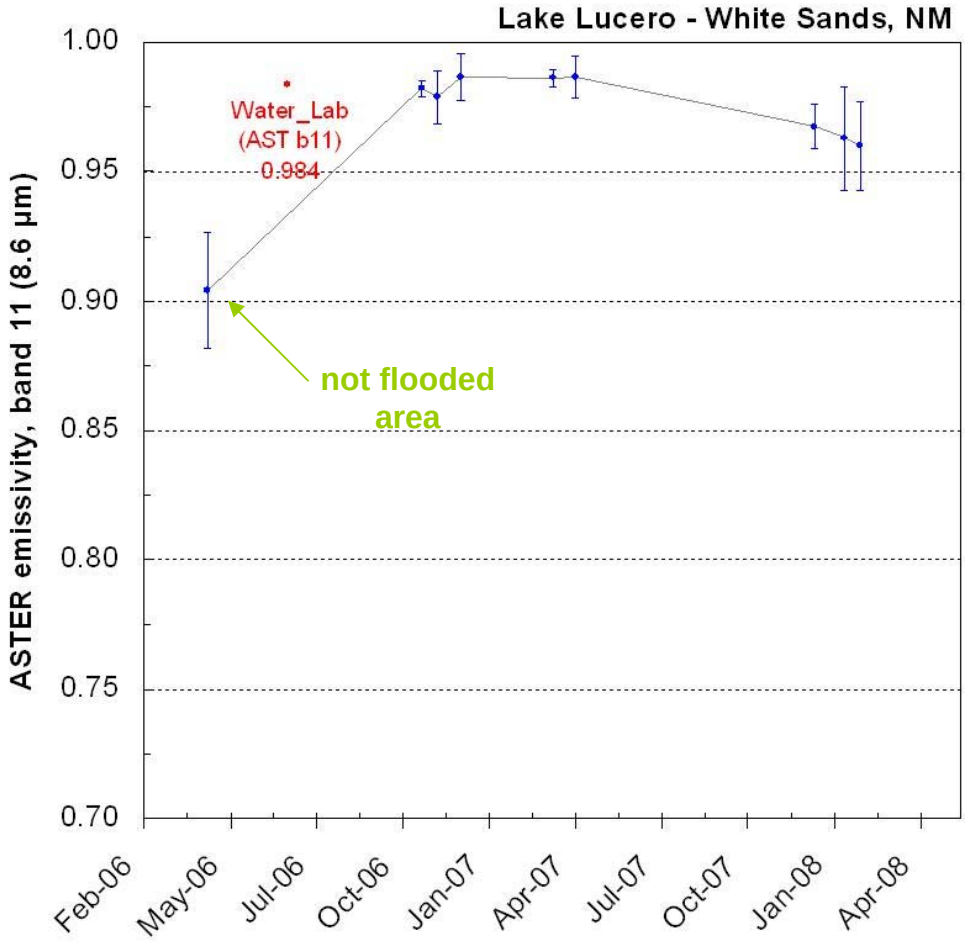
# ASTER emissivities temporal variation
# White Sands, NM



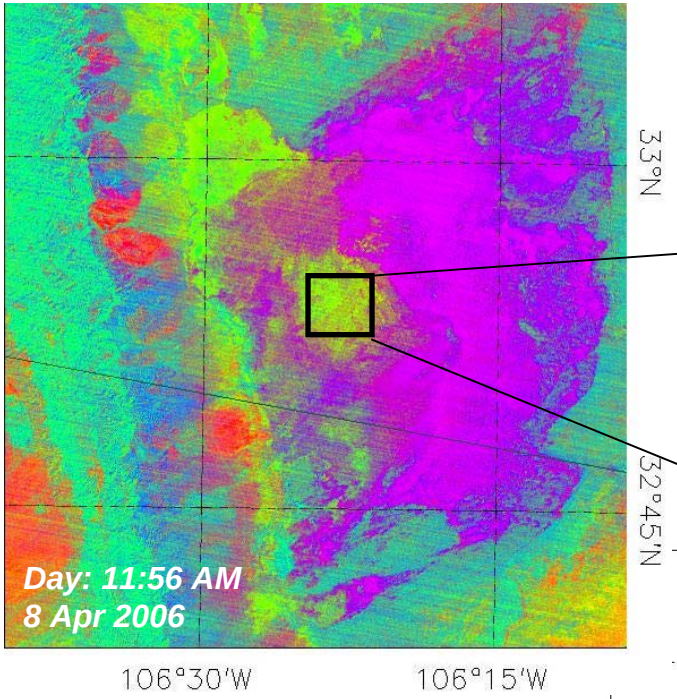
# ASTER emissivities temporal variation
# White Sands, NM

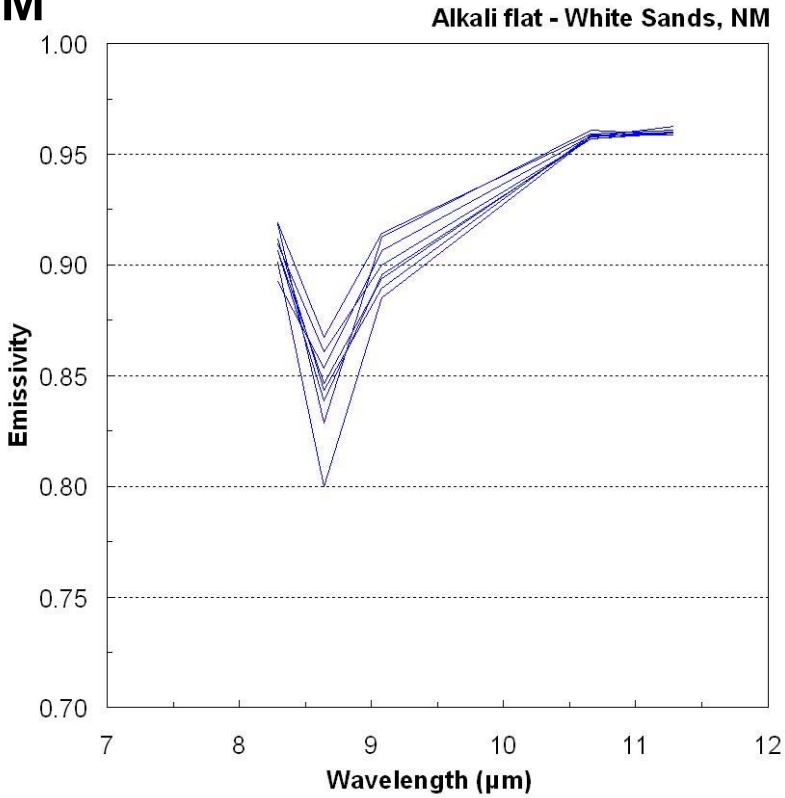


# ASTER emissivities temporal variation White Sands, NM

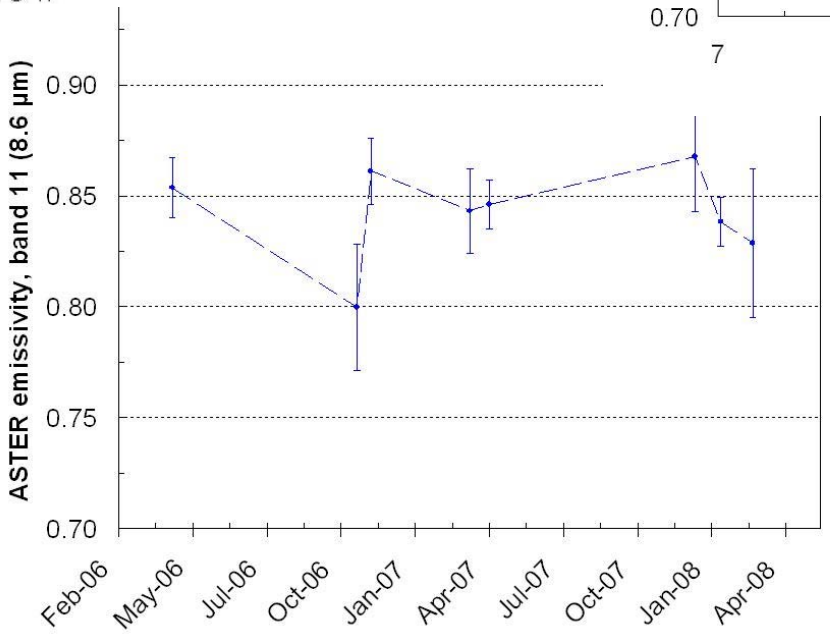
Decorrelation Stretch
RGB (Band 14,12,10)



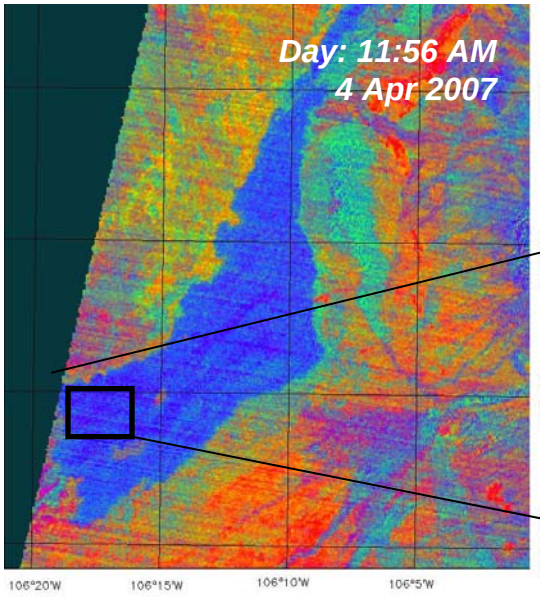

Alkali flat -

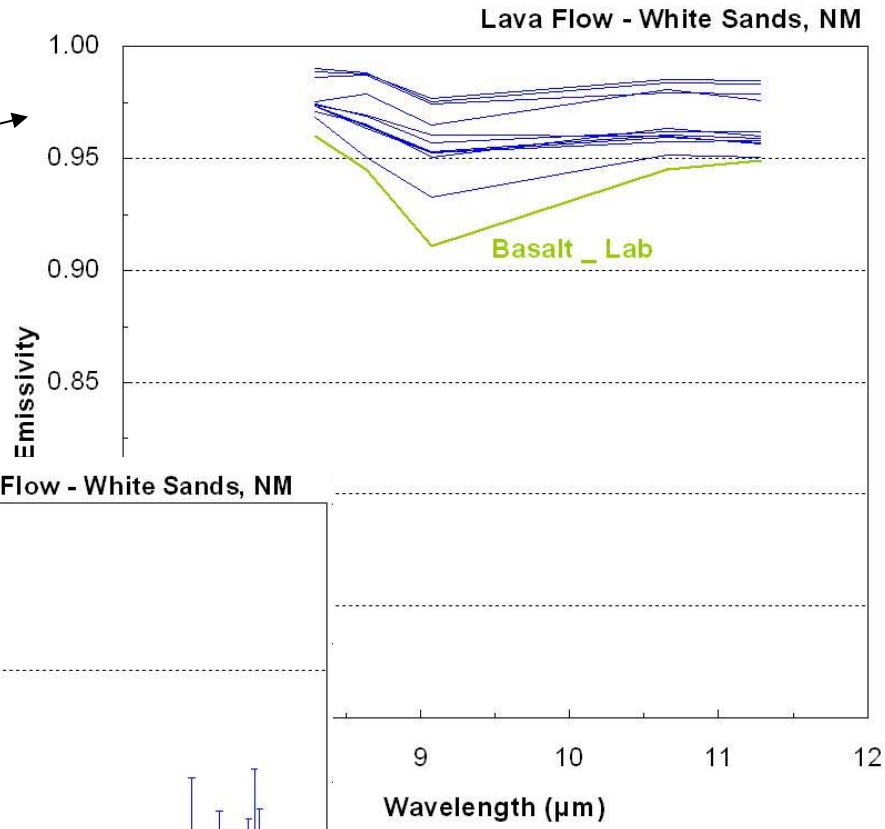
- Average emissivity value of 290 pixels of 180 m resolution.

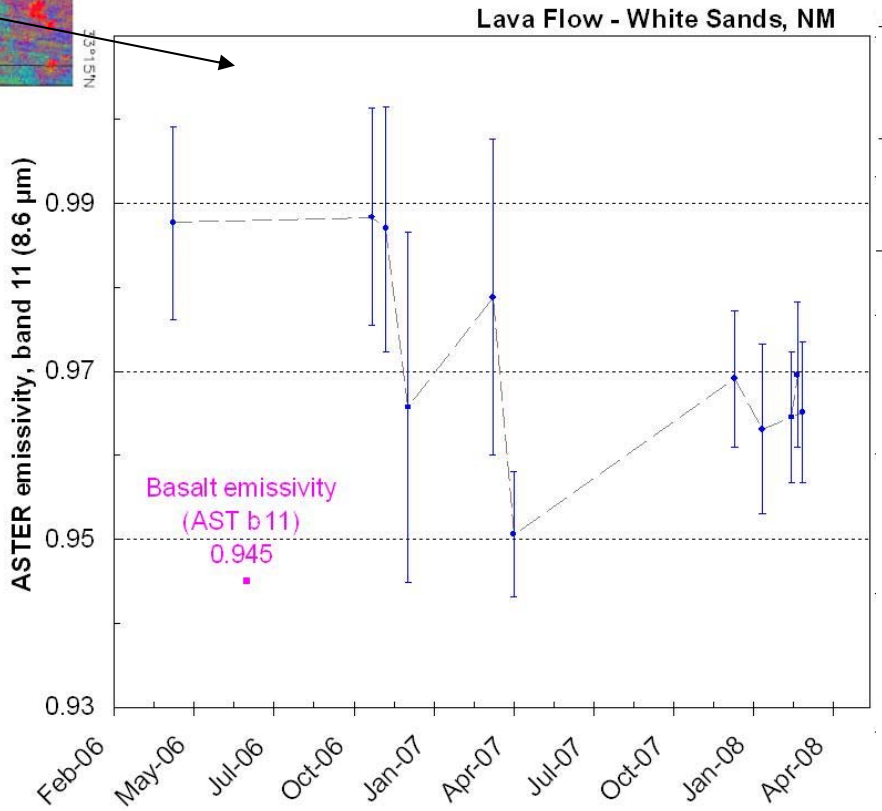


# ASTER emissivities temporal variation White Sands, NM

Decorrelation Stretch
RGB (Band 14,12,10)

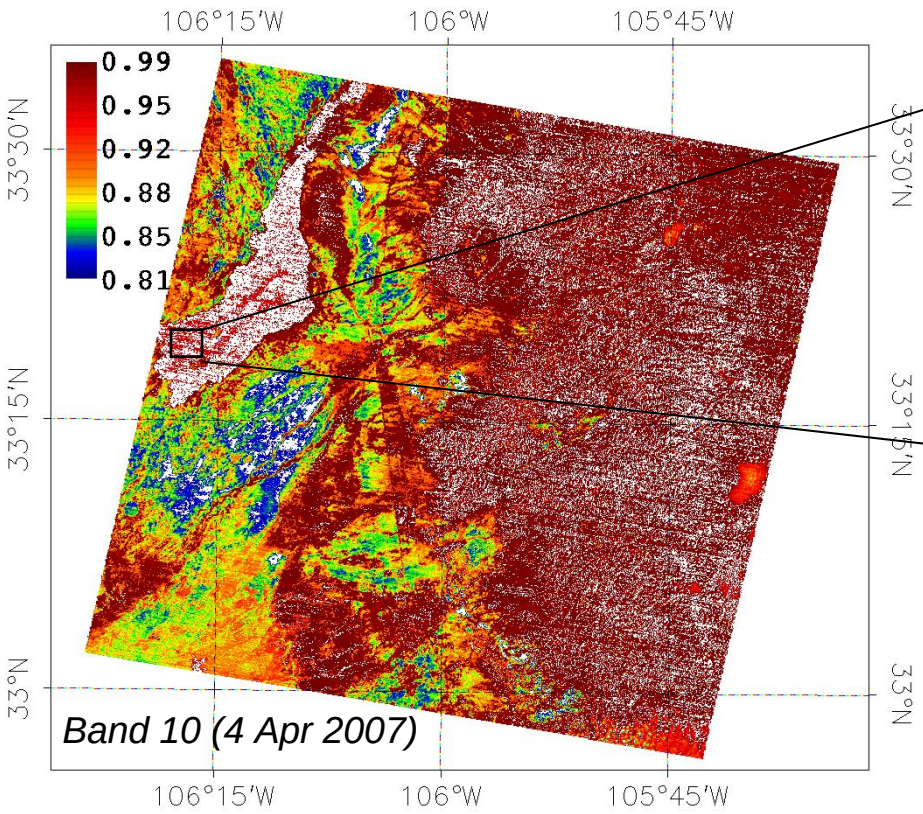


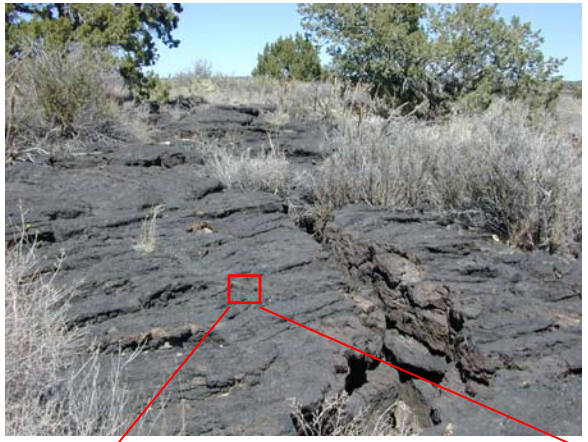



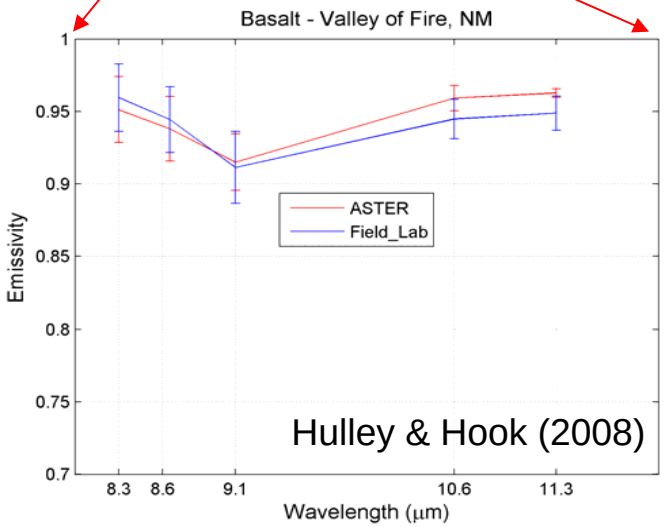

- Average emissivity value of 410 pixels of 180 m resolution.

# Unexplained Overestimated ASTER Emissivity Retrievals Band 10 (8.3 µm) and Band 13 (10.7 µm)




"Valley of Fire" north of White Sands, NM






- ε up to 1.018 are retrieved by ASTER/TES.

- Considering Lava Flow as a site with sparse vegetation, and using $\varepsilon = \varepsilon_{veg}P_v + \varepsilon_{basalt}(1-P_v)$ (Valor & Caselles, 1996) emissivities can be up to 0.97.

- Given ASTER/TES accuracy ~1.6% (Hulley & Hook, 2008), they are not justified.

# The North American ASTER Land Surface Emissivity Database (NAALSED)

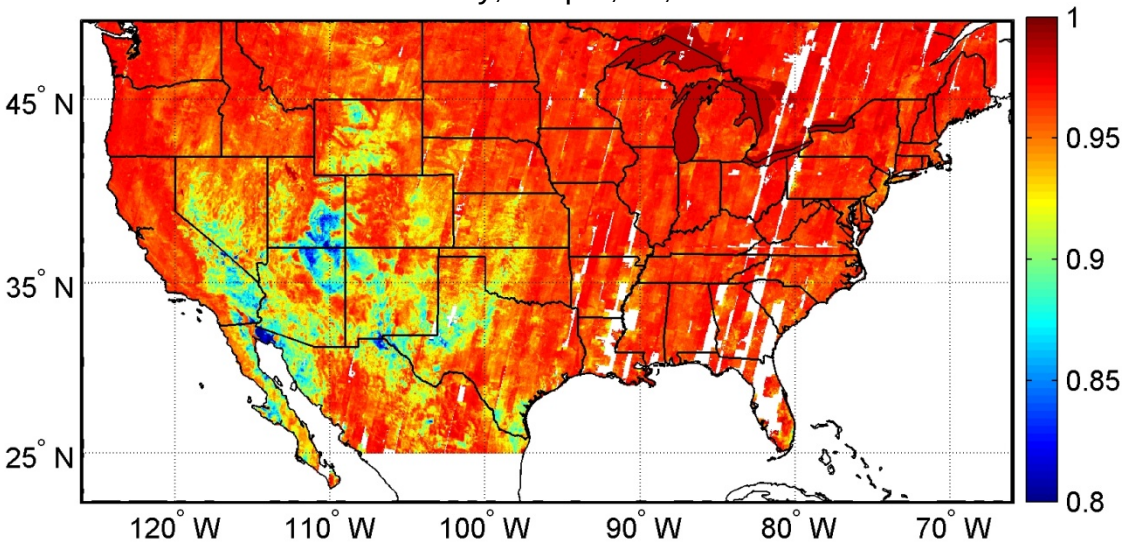
Jet Propulsion Laboratory
California Institute of Technology

http://emissivity.jpl.nasa.gov

Glynn Hulley, Simon Hook

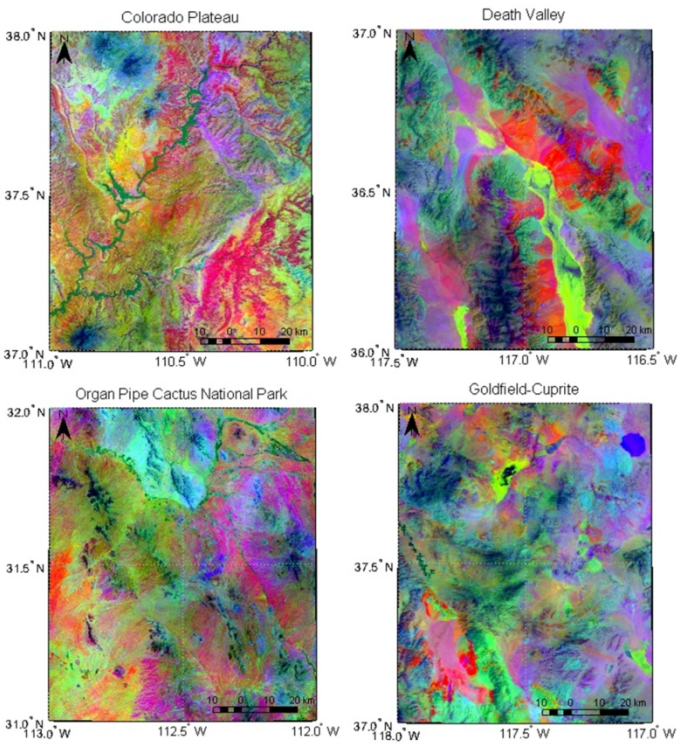
*Jet Propulsion Laboratory, Caltech, Pasadena, CA*

Mean Summer Emissivity, 8.6 µm, 70,075 ASTER scenes




** Gaps plan to be filled during Jul-Sep 2009 ASTER acquisition period

NAALSED Decorrelation Stretches




- Mean Summer (July, Aug, Sep) and Winter (Jan, Feb, Mar) emissivity from 2000-2008.
- 100 m spatial resolution in five TIR bands (8.3, 8.6, 9.1, 10.6, 11.3 µm).
- Data products: Mean and SDev Emissivity (TIR bands), Skin Temperature, NDVI, Land/Water map, Total Observations, Latitude, Longitude.

*Hulley and Hook, 2008 (GRL)*
*Hulley at al., 2008 (GRL)*
*Hulley and Hook, 2009 (RSE)*

Jet Propulsion Laboratory
California Institute of Technology

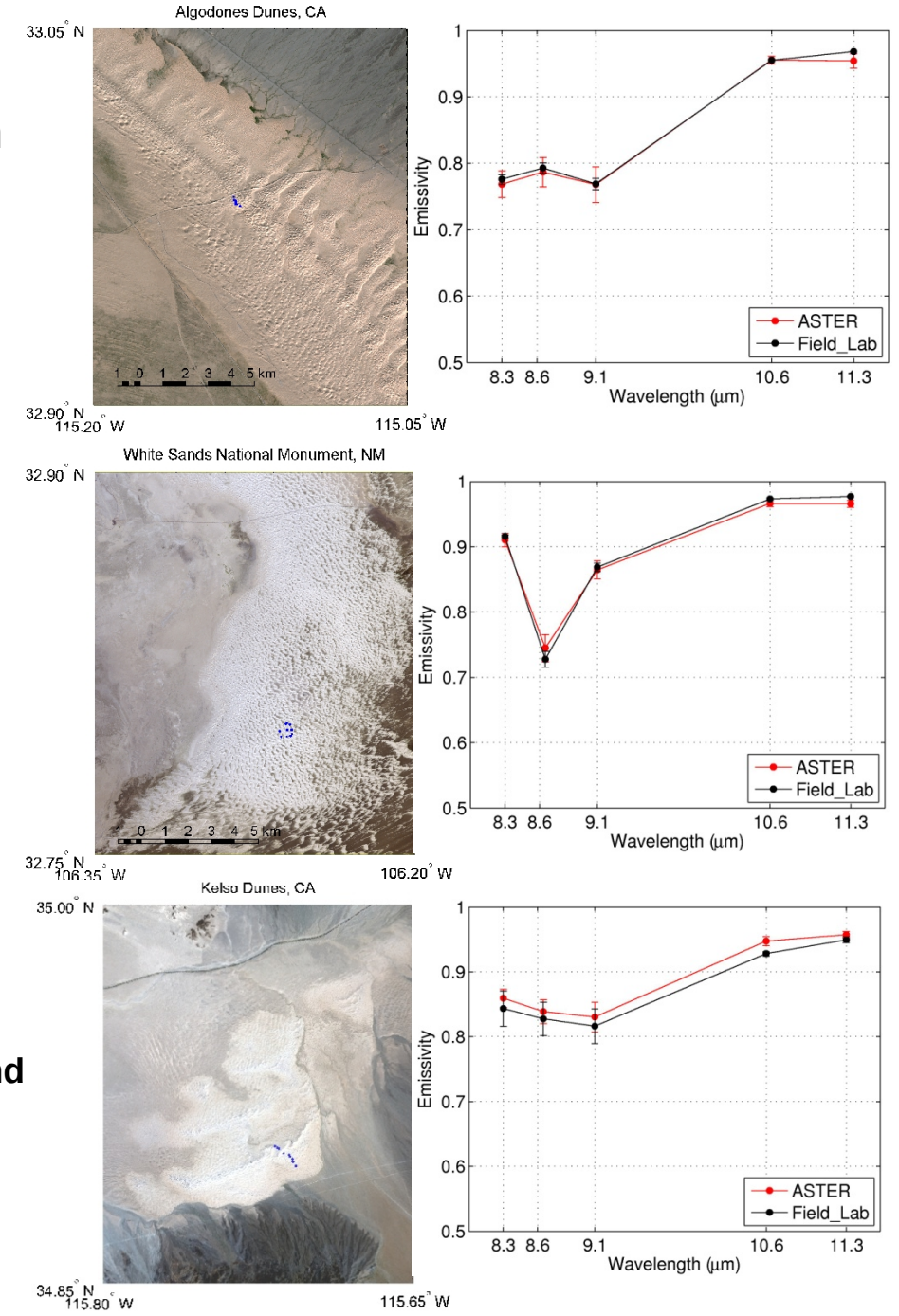
# The NAALSED

## ASTER Emissivity Database Validation

- Geologic Samples, collected on 1 km$^2$ grid, and measured in lab using JPL FT-IR spectrometer:
  1. Algodones dunes, CA
  2. White Sands National Monument, NM
  3. Kelso Dunes, CA
  4. Great Sand Dunes, CO
  5. Sand Mountain, UT
  6. Coral pink Sand Dunes State Park, UT
  7. Little Sahara Dunes, UT
  8. Killpecker Dunes, WY
  9. Stovepipe Wells dunes, Death Valley, CA
  10. Moses Lake Dunes, WA

- ASTER data extracted at sample coordinate position

- **Mean emissivity difference between NAALSED and the lab results is 1.6% (~1 K).**



# Conclusions

- ASTER and TES work reasonably well
  - Quantitative agreement (1–2%) with lab measures for emissivity
  - ASTER results are repetitive
    - Day / Night agreement (better than 1.2%)
  - Emissivity mapping on a regional scale

- ASTER/TES works best for targets with large spectral contrasts.

- ASTER provides good spatial and spectral resolution BUT infrequent coverage.
  - NAALSED provides 90 m emissivity map of USA.

- We observed unexplained overestimated ($\varepsilon>1$) ASTER emissivity retrievals, mainly at band 10 (8.3 μm) and band 13 (10.7 μm).

**Thank you for your attention**