Estimation of Rangeland Changes & Evapotranspiration Using Multispectral Thermal Infrared Data

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DA
Agricultural Research Service

ARID-LAND AGRICULTURAL RESEARCH CENTER

NASA

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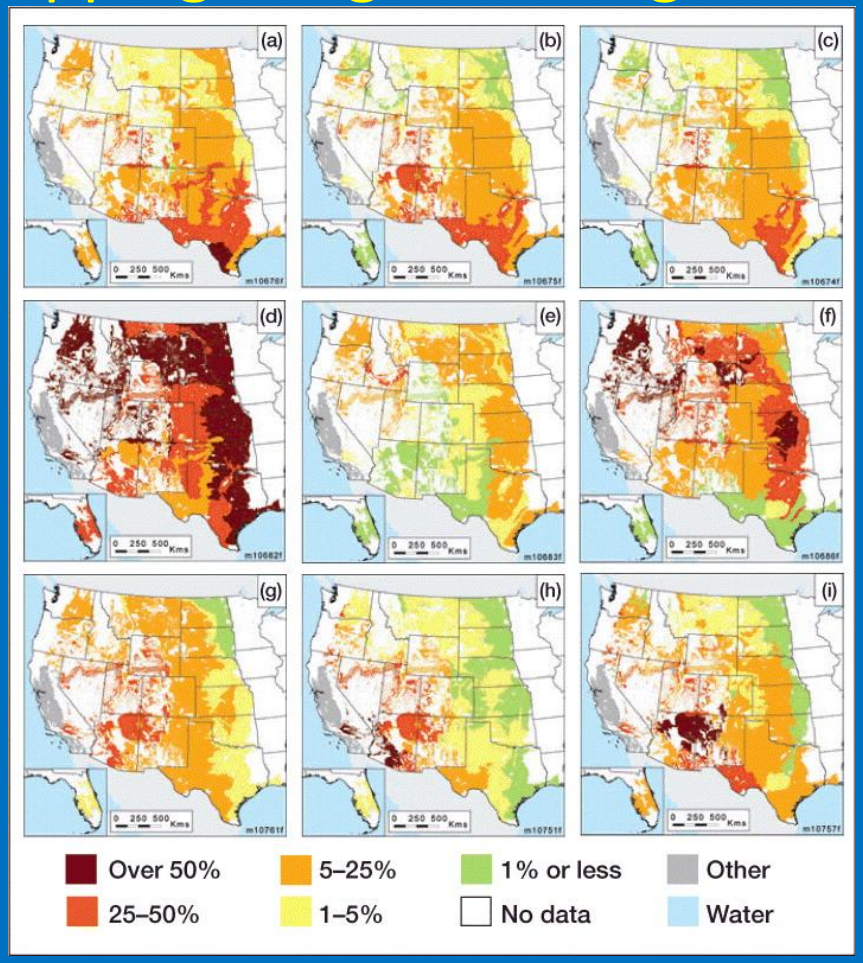
Outline

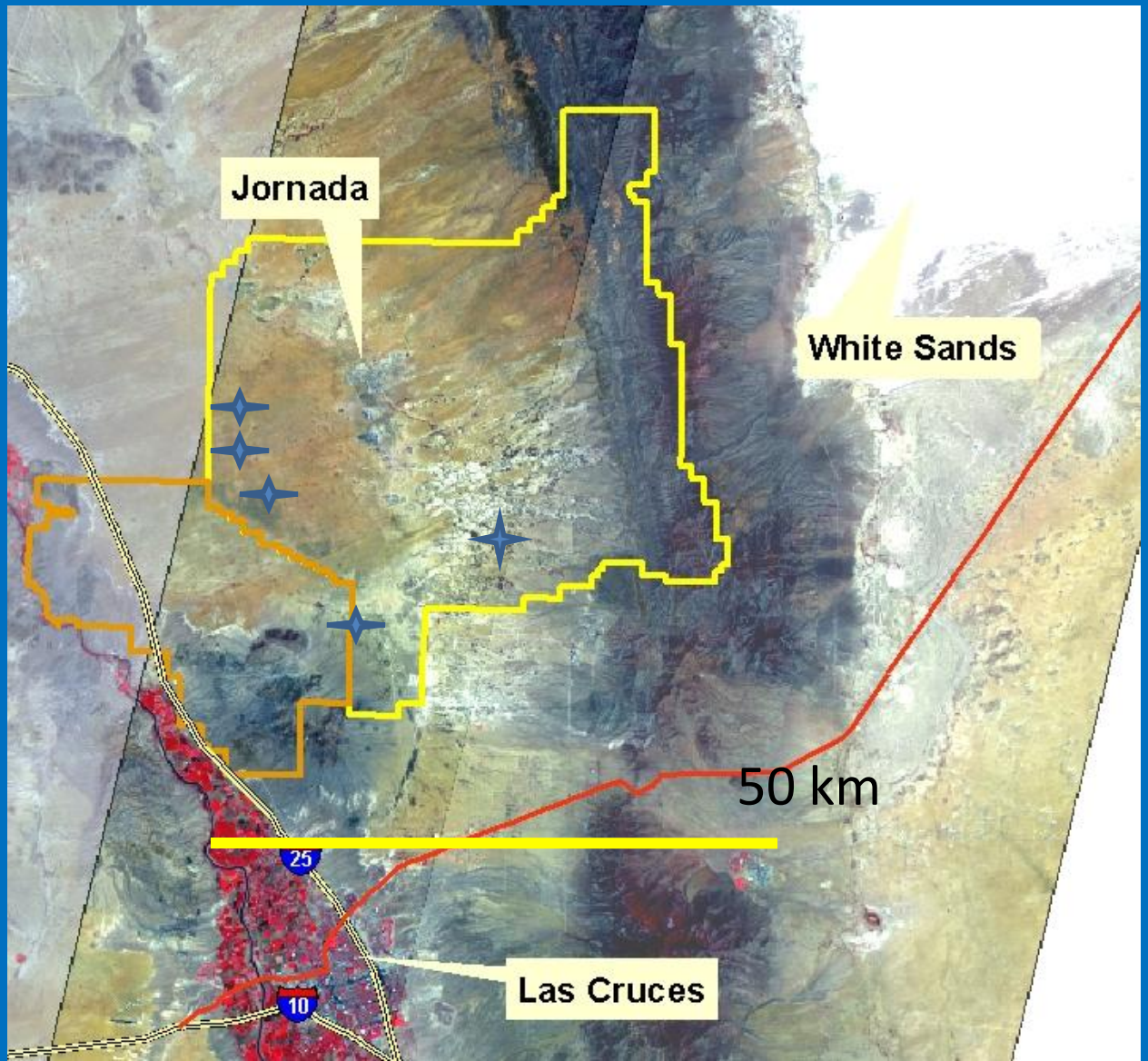
- Rangeland cover change using thermal infrared with ASTER & MASTER
- Effect of remote sensing resolution over Jornada
- Modeling surface energy fluxes using land surface temperatures and emissivities
- Objective: Highlight HyspIRI's multispectral TIR capability for rangeland science

Mapping Rangeland Degradation

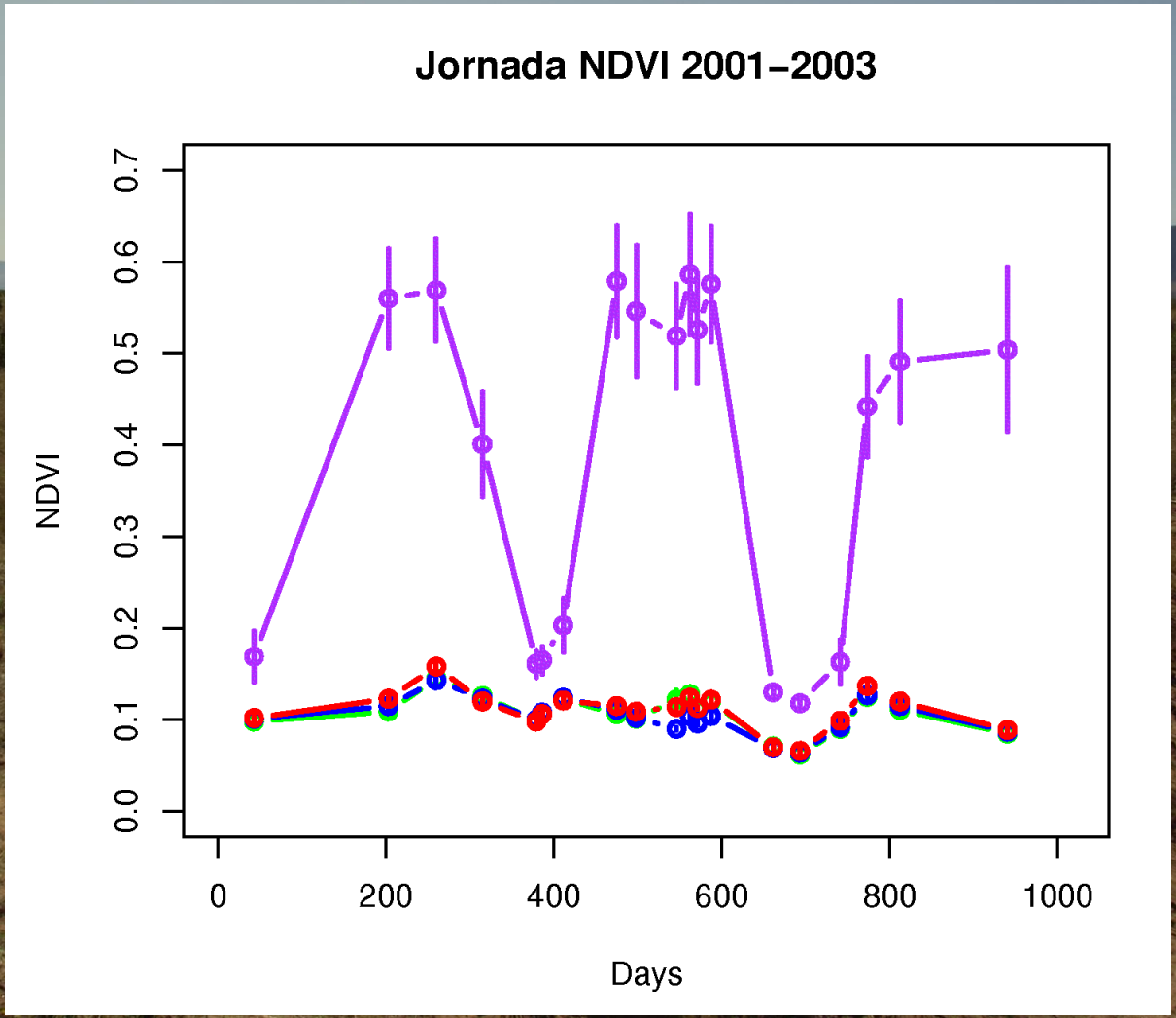


From: Jeffrey E Herrick, Veronica C Lessard, Kenneth E Spaeth, Patrick L Shaver, Robert S Dayton, David A Pyke, Leonard Jolley, and J Jeffery Goebel. 2010. National ecosystem assessments supported by scientific and local knowledge. *Frontiers in Ecology and the Environment* **8**: 403–408. "Copyright by the Ecological Society of America"

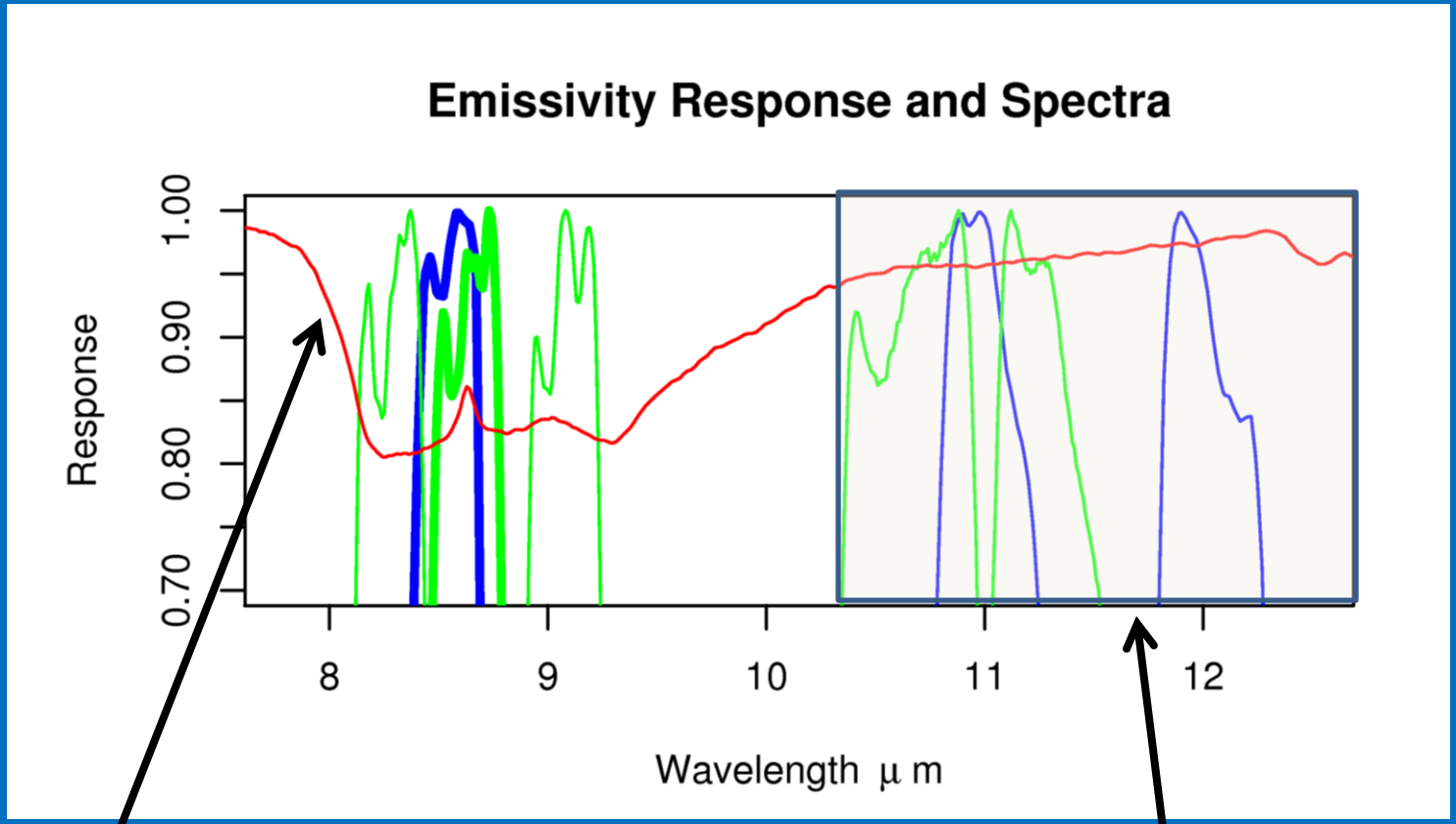
ASTER Composite over Jornada 2001-2003



Dynamic Range of Remotely Sensed Vegetation Indices over Rangeland is small



Thermal Band Emissivities Could Help Monitor Vegetation Cover Regardless of Greenness

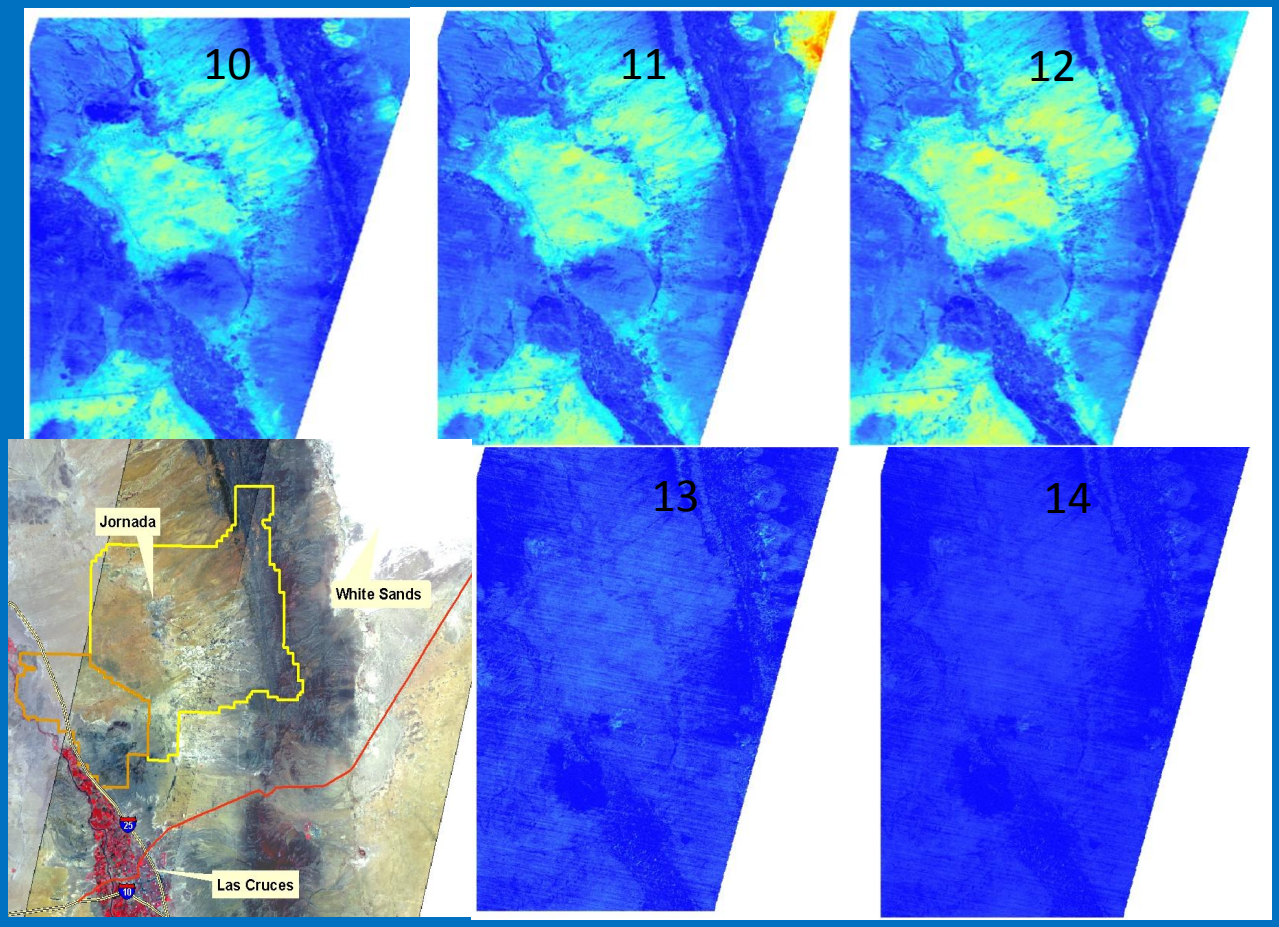


Siliceous Soil

Split-Window Region

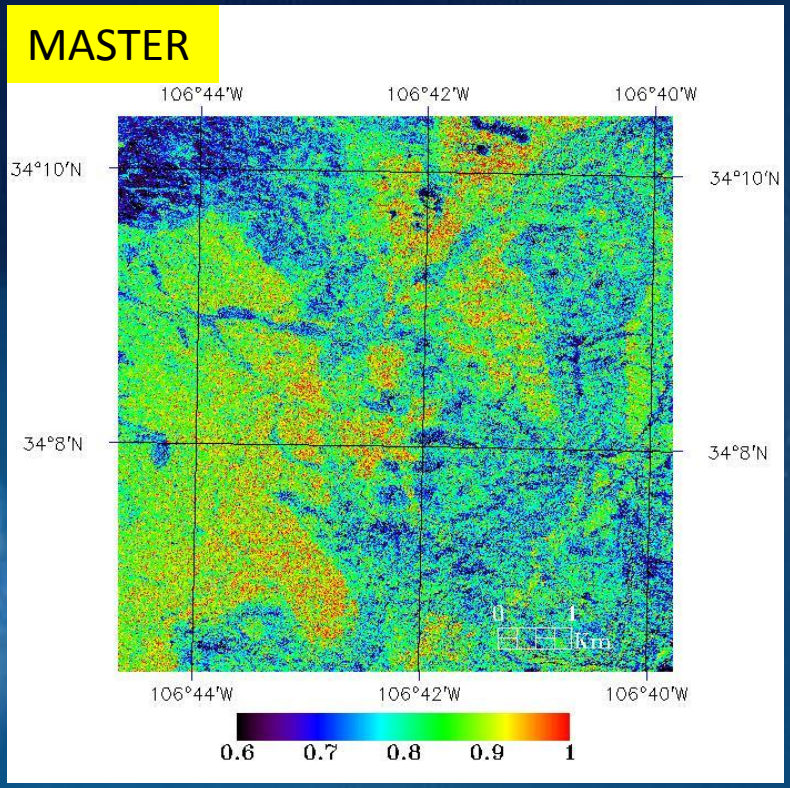
Spectral Variation of Brightness Temperature

- Strong soil signature
- Affected by surface moisture
- Vegetation masking of soil

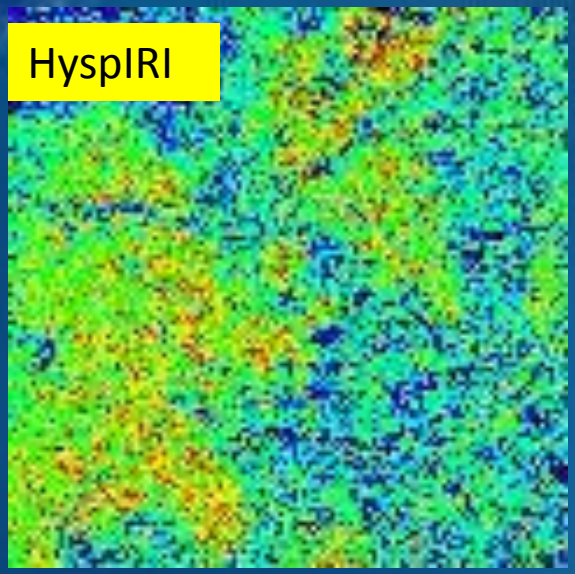


Emissivity λ=8.2µm

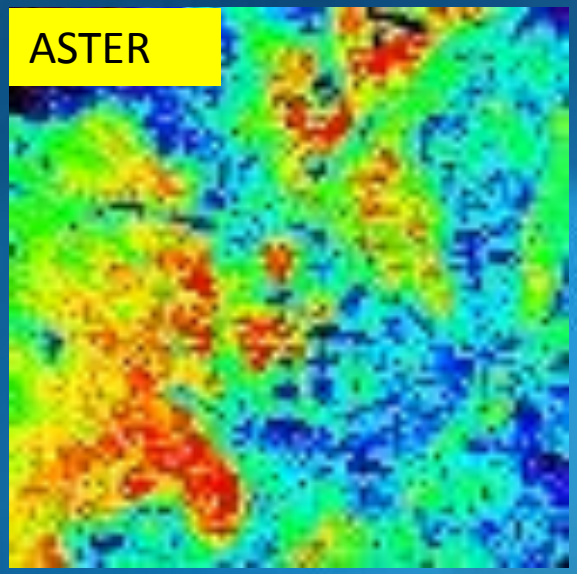
MASTER



HyspIRI

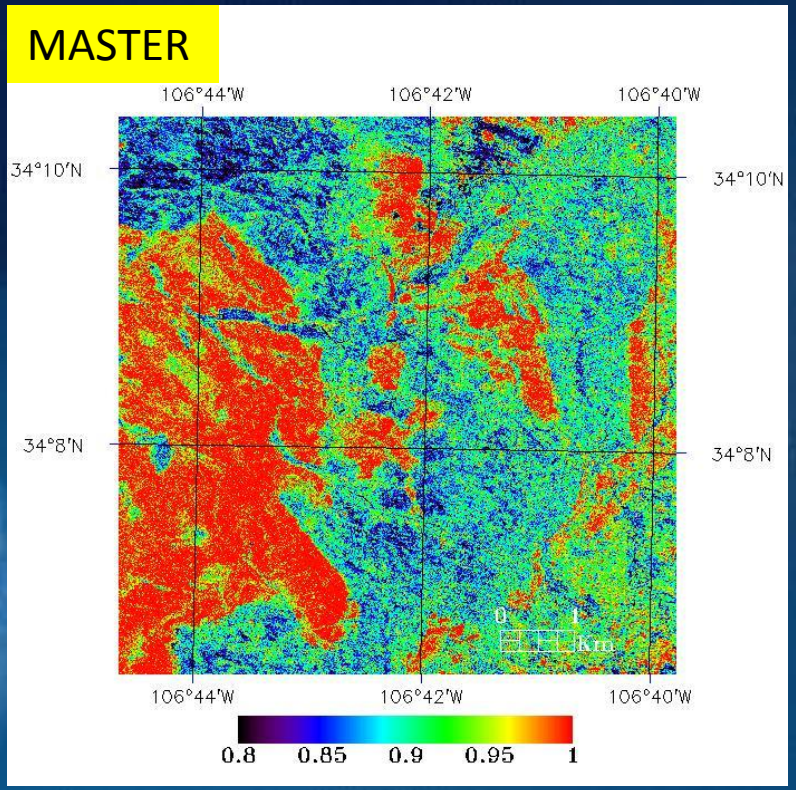


ASTER

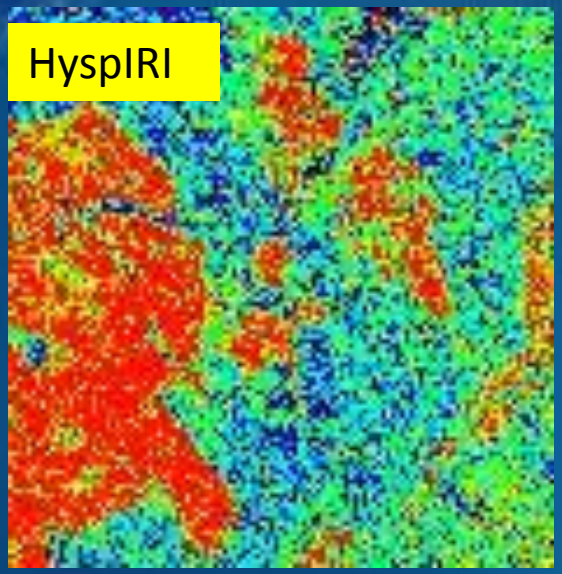


Emissivity λ=8.6μm

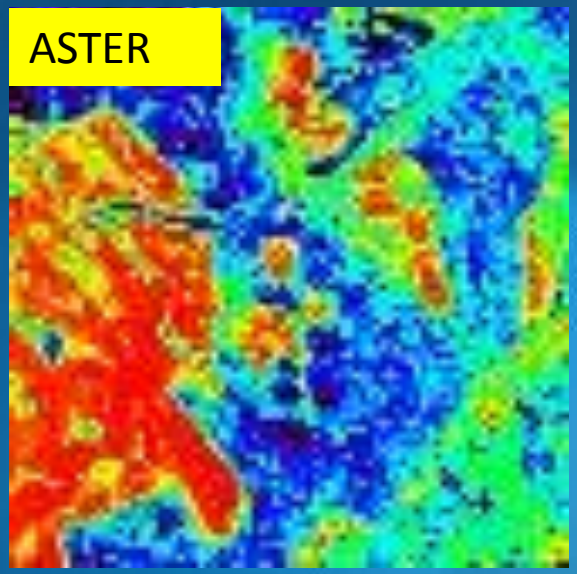
MASTER



HyspIRI

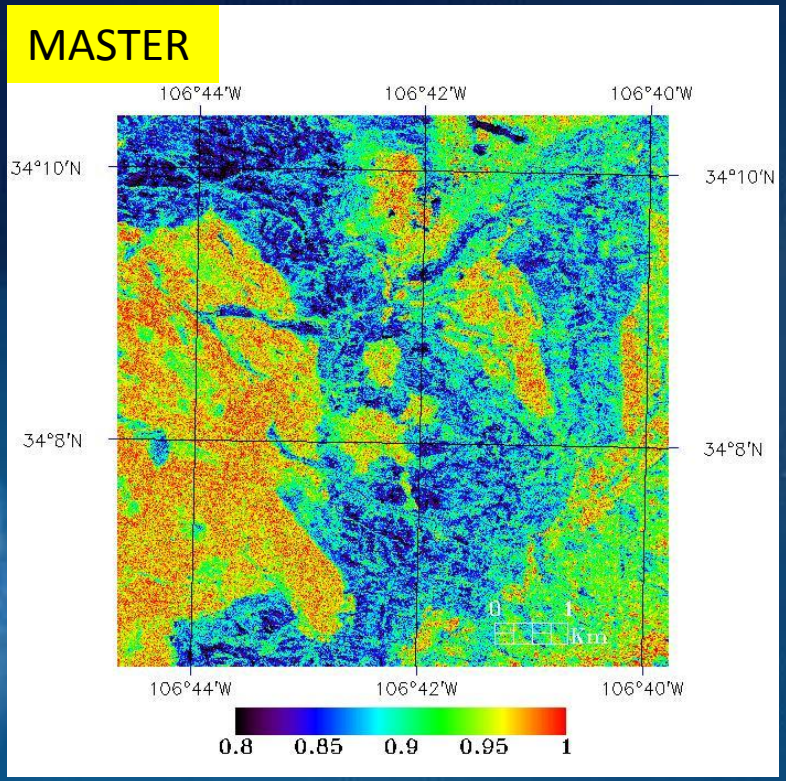


ASTER

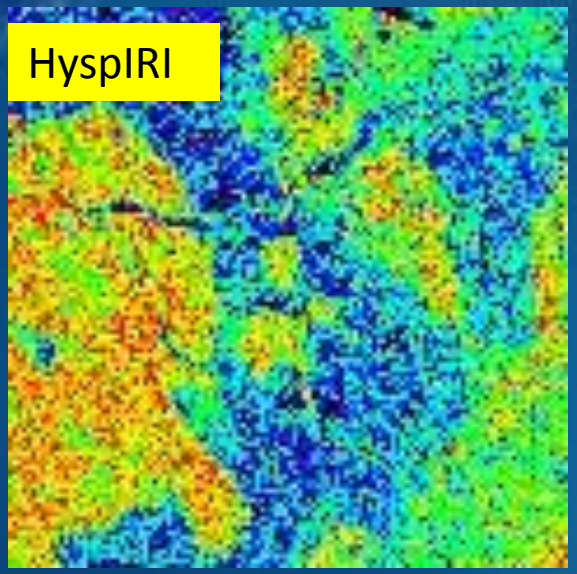


Emissivity λ=9.1µm

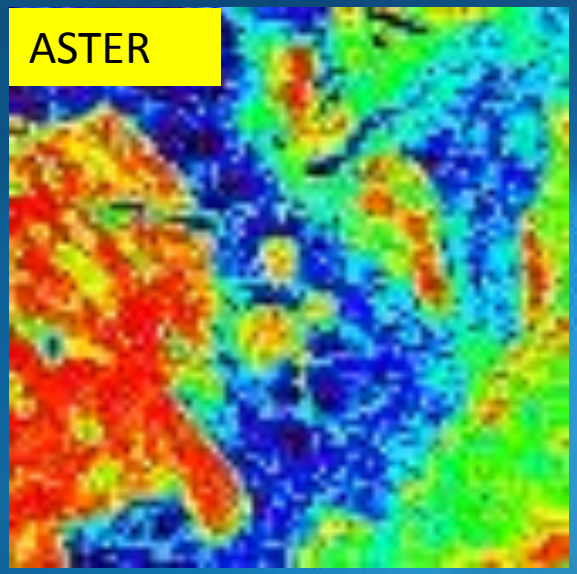
MASTER



HyspIRI

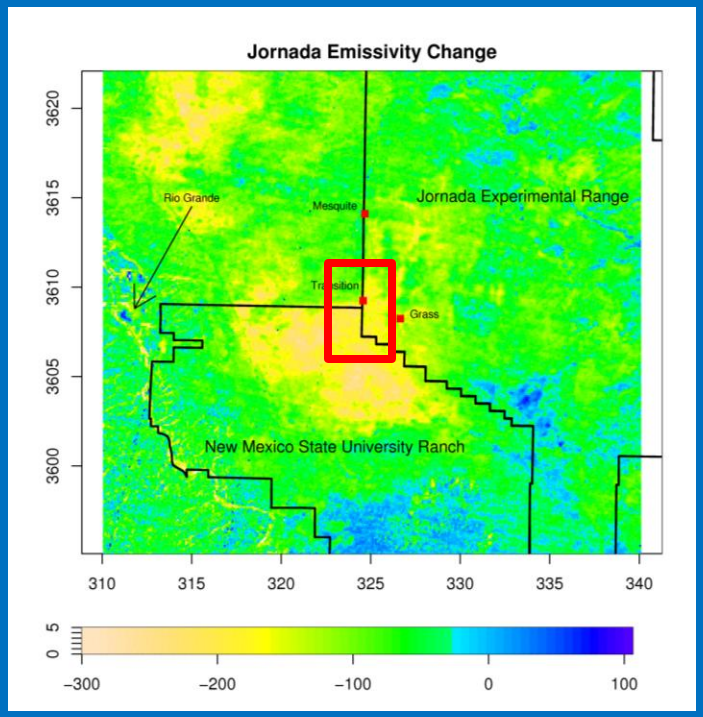


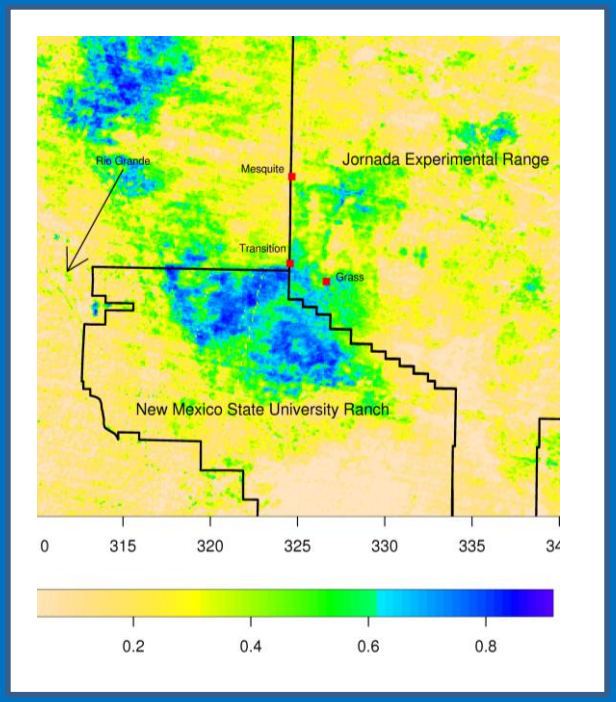
ASTER

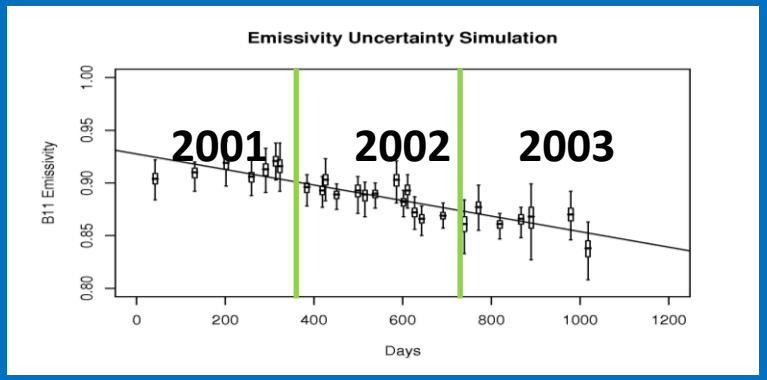


Linear Emissivity Trend
26 ASTER scenes, 2001-2003
Drop of 3% over three years

R^2

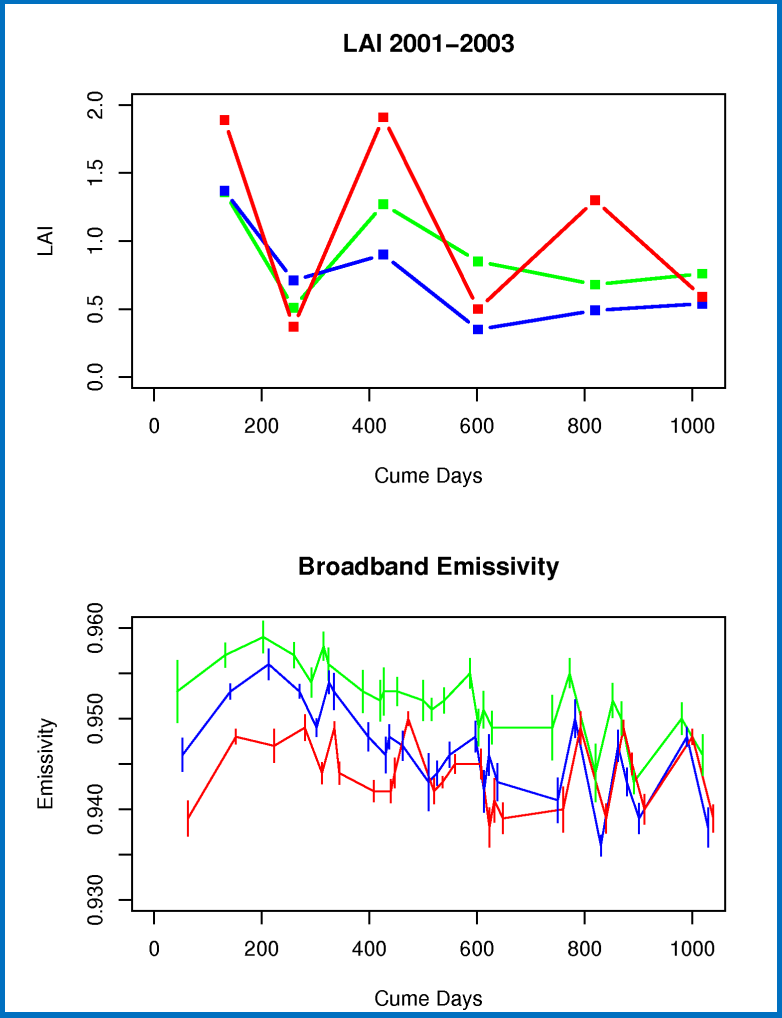




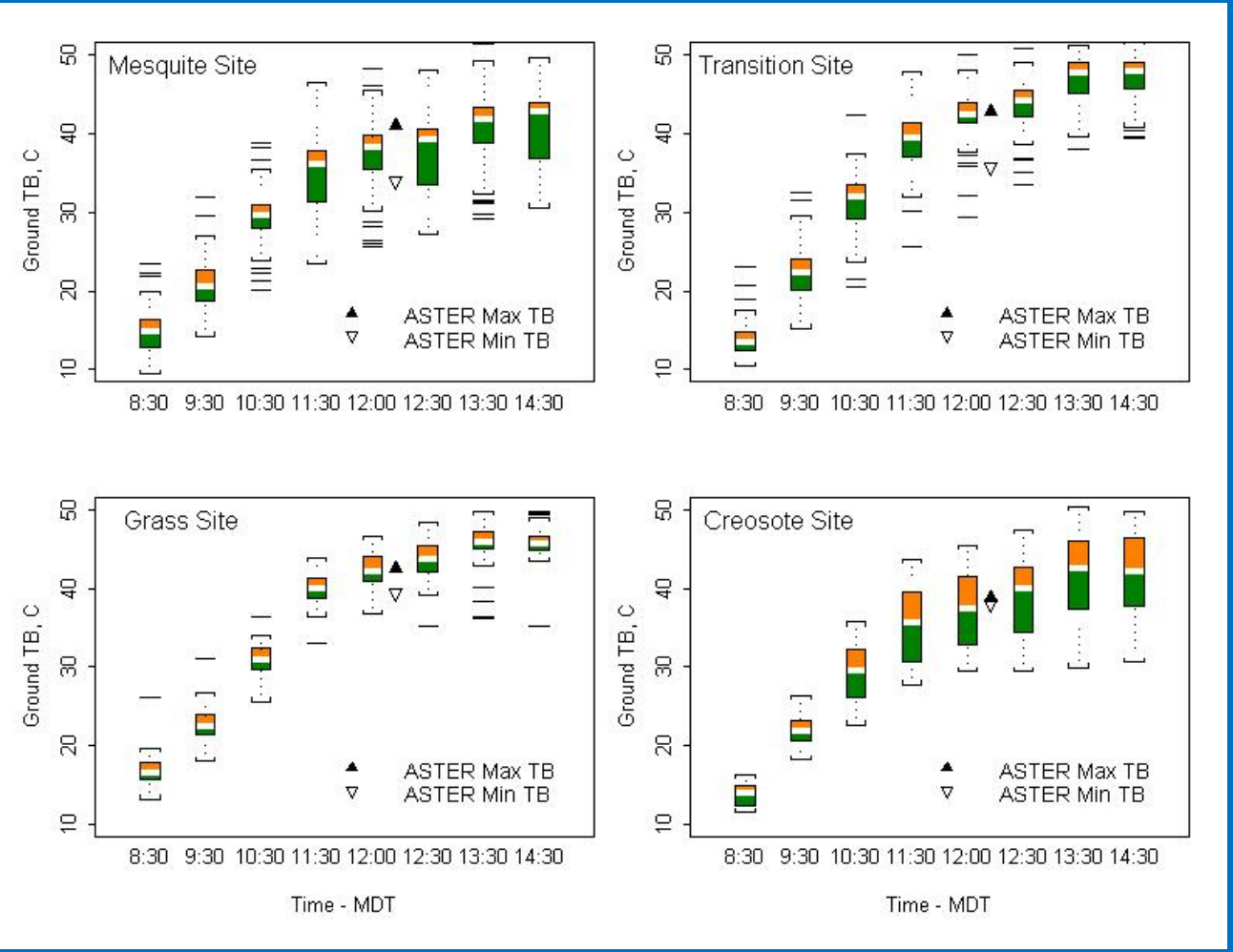


200 m extract

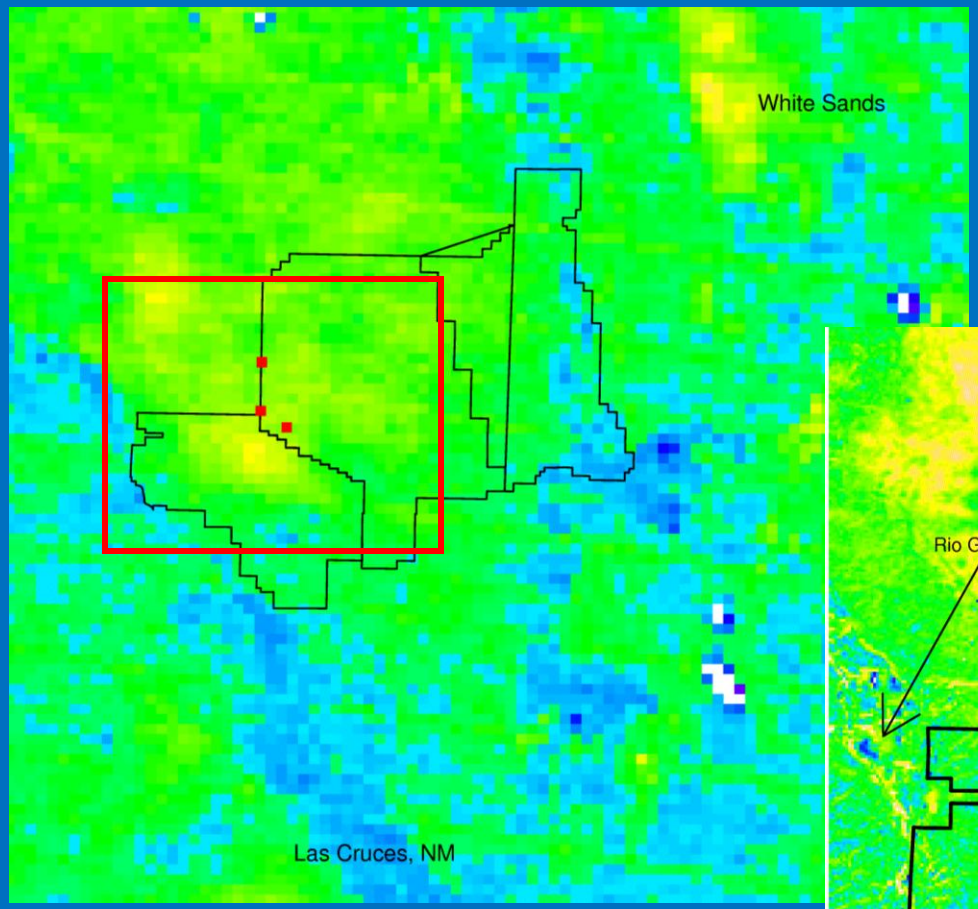
Emissivity Changes Appear to Correlate with Leaf Area Changes



Land Surface Temperature Validation of ASTER at Jornada, 2002

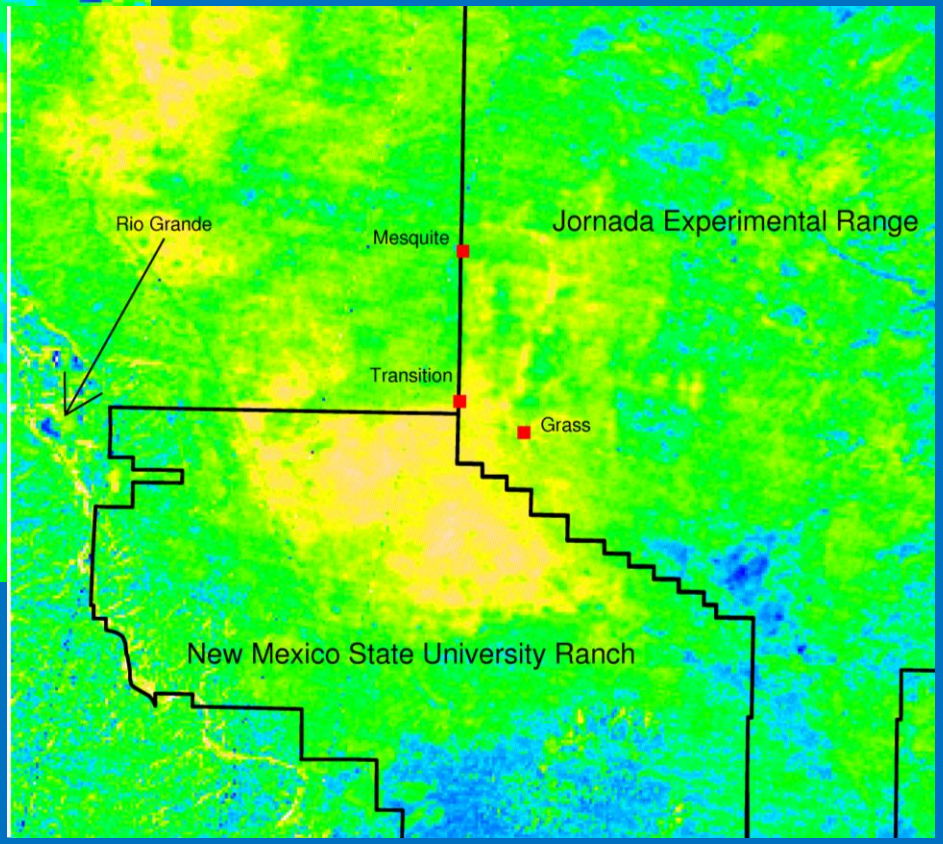


Emissivity Changes Observed by ASTER & MODIS

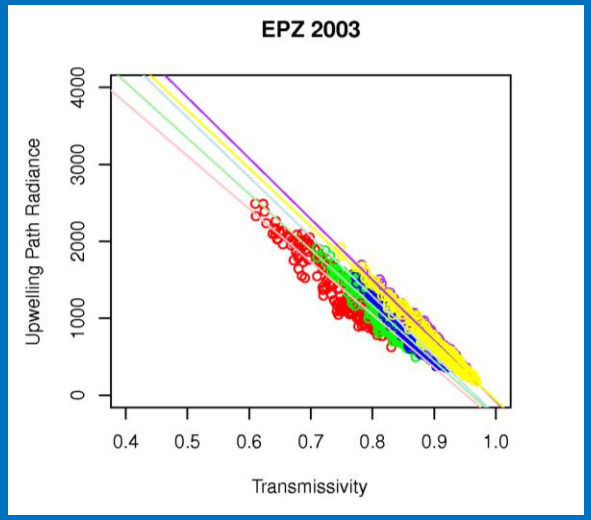


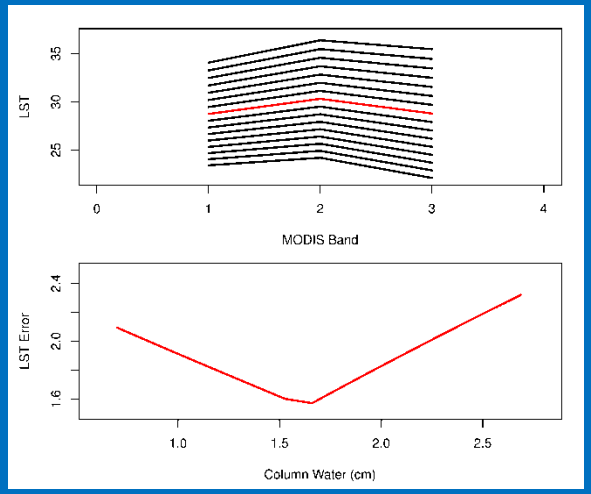
MODIS/Terra

ASTER

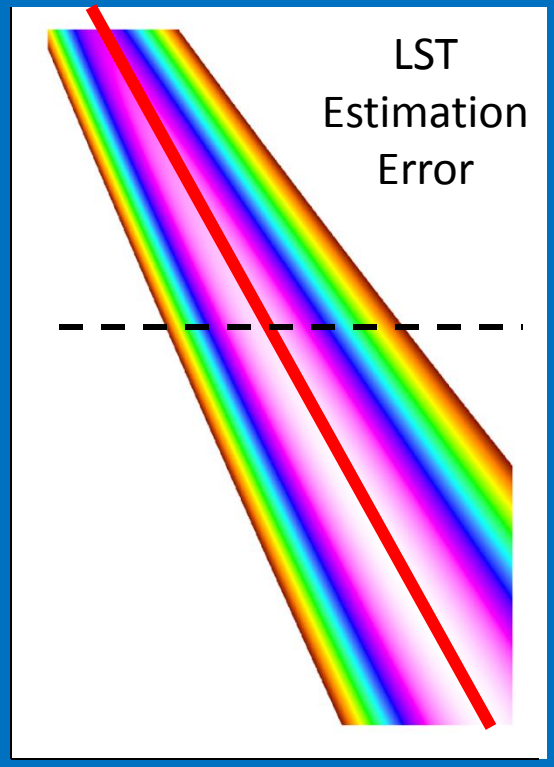


Multispectral TIR constrains atmospheric correction terms

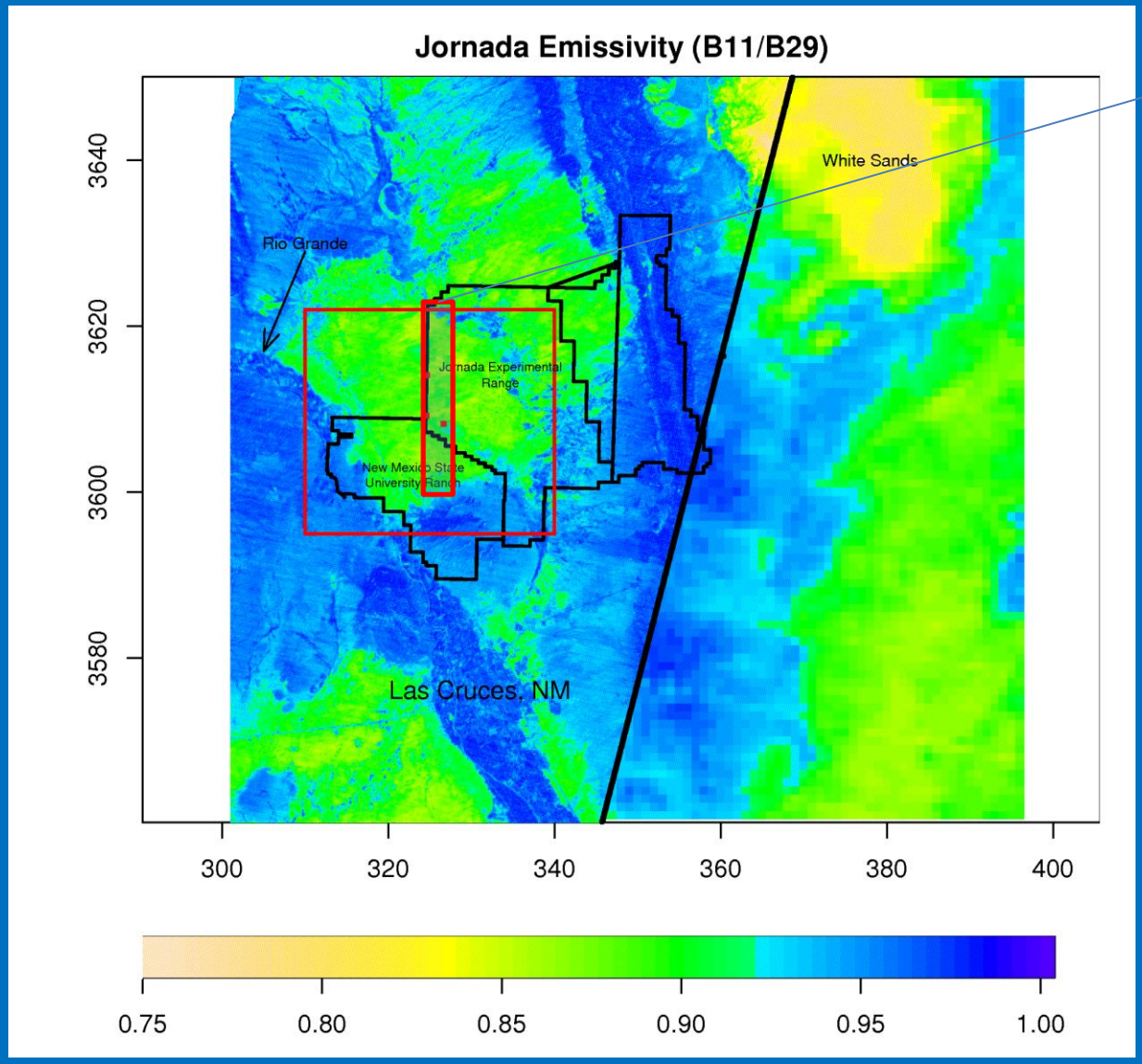


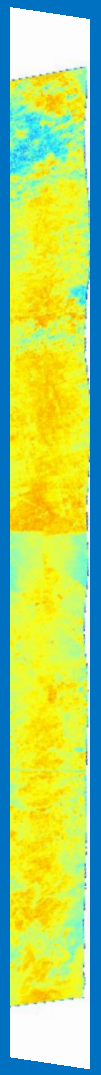


1. Atmospheric profile at site uncertain
2. Errors in correction will exaggerate spectral emissivity contrasts
3. Can constrain errors:
    1. Check LSTs after correction.
    2. Adjust atmospheric correction parameters using ‘known’ emissivity targets.



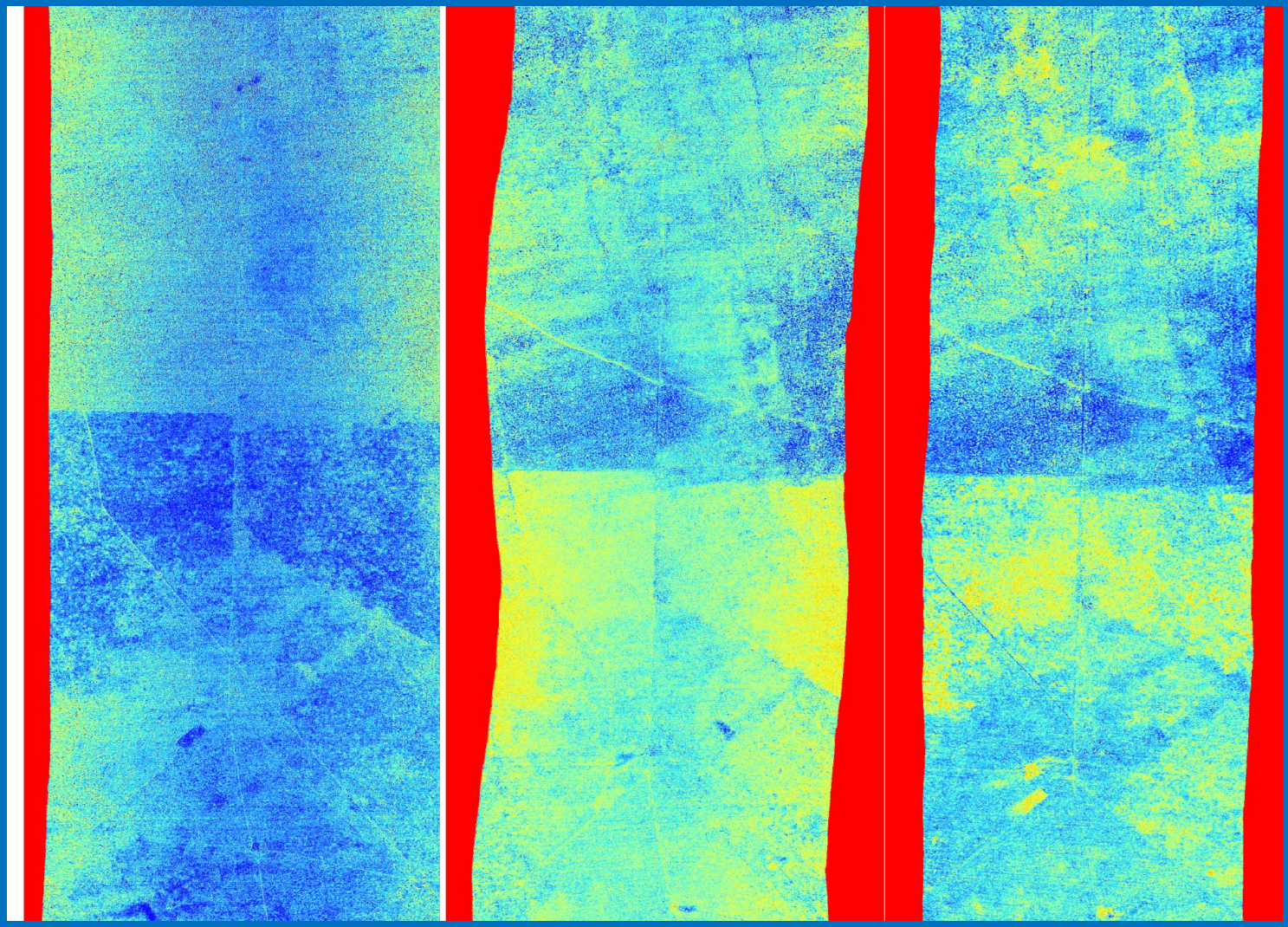
Short Wavelength Emissivities with ASTER/MODIS
Jornada 2003





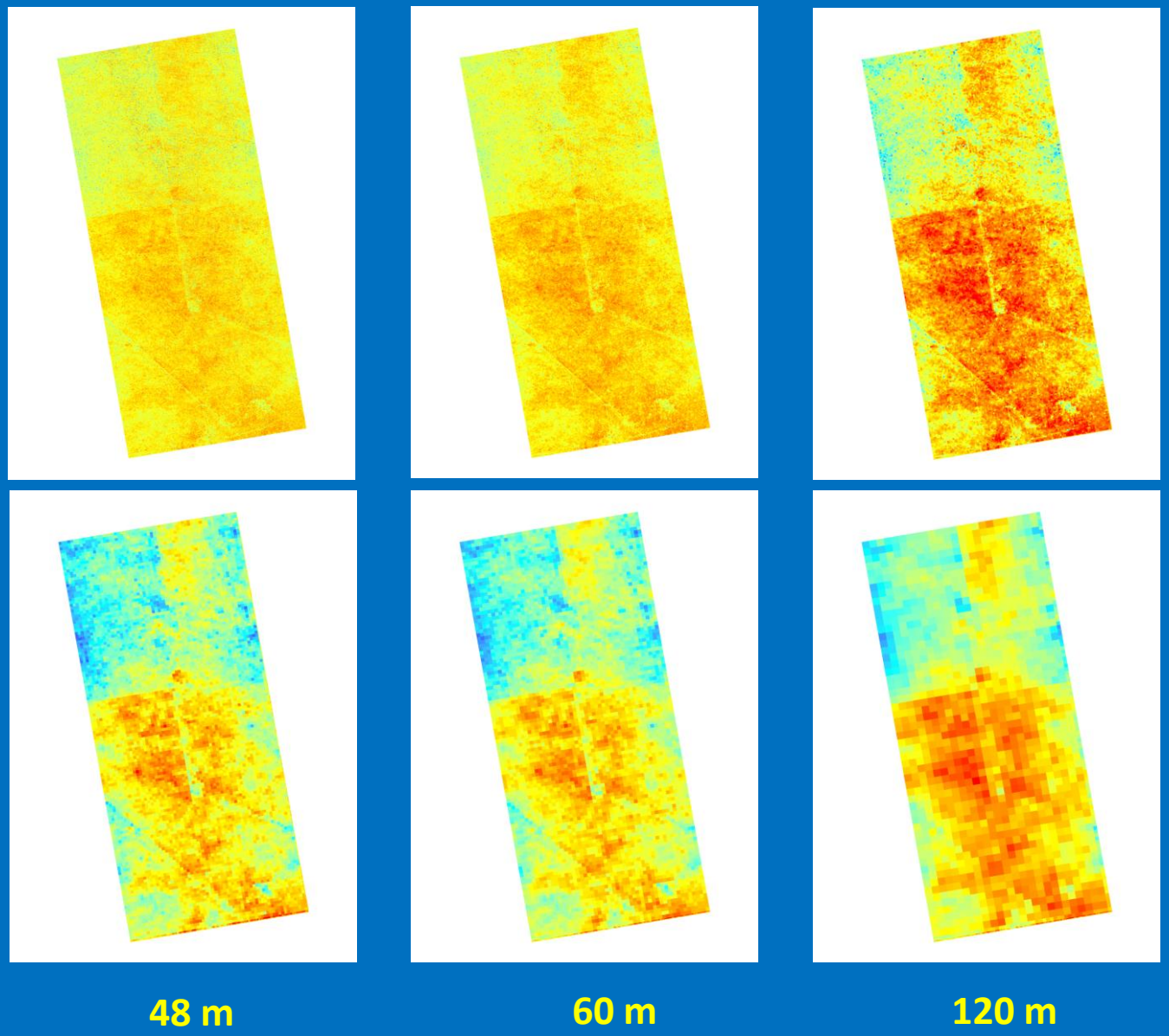
MASTER Band 43 Emissivity Changes May 2001/2002/2003

6-12 m resolution

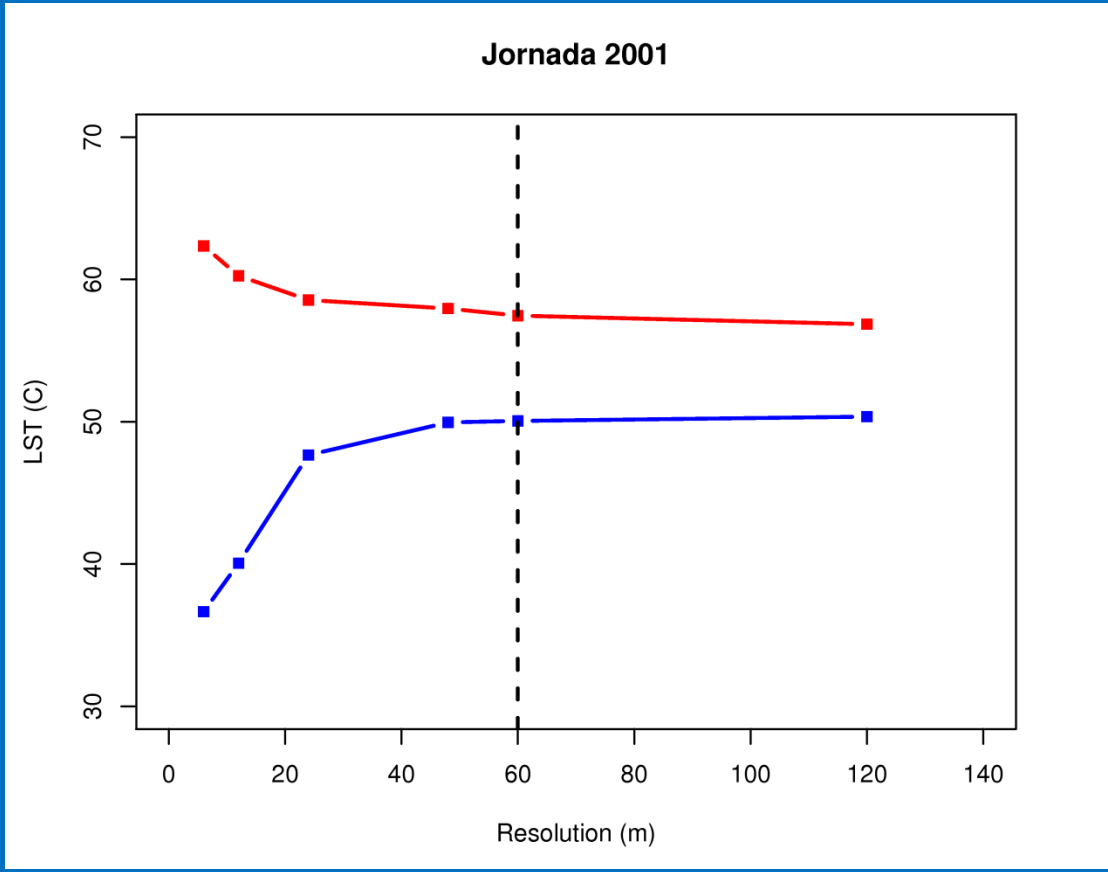


May 2001 May 2002 May 2003

Land Surface Temperature Scaling over Jornada Rangeland

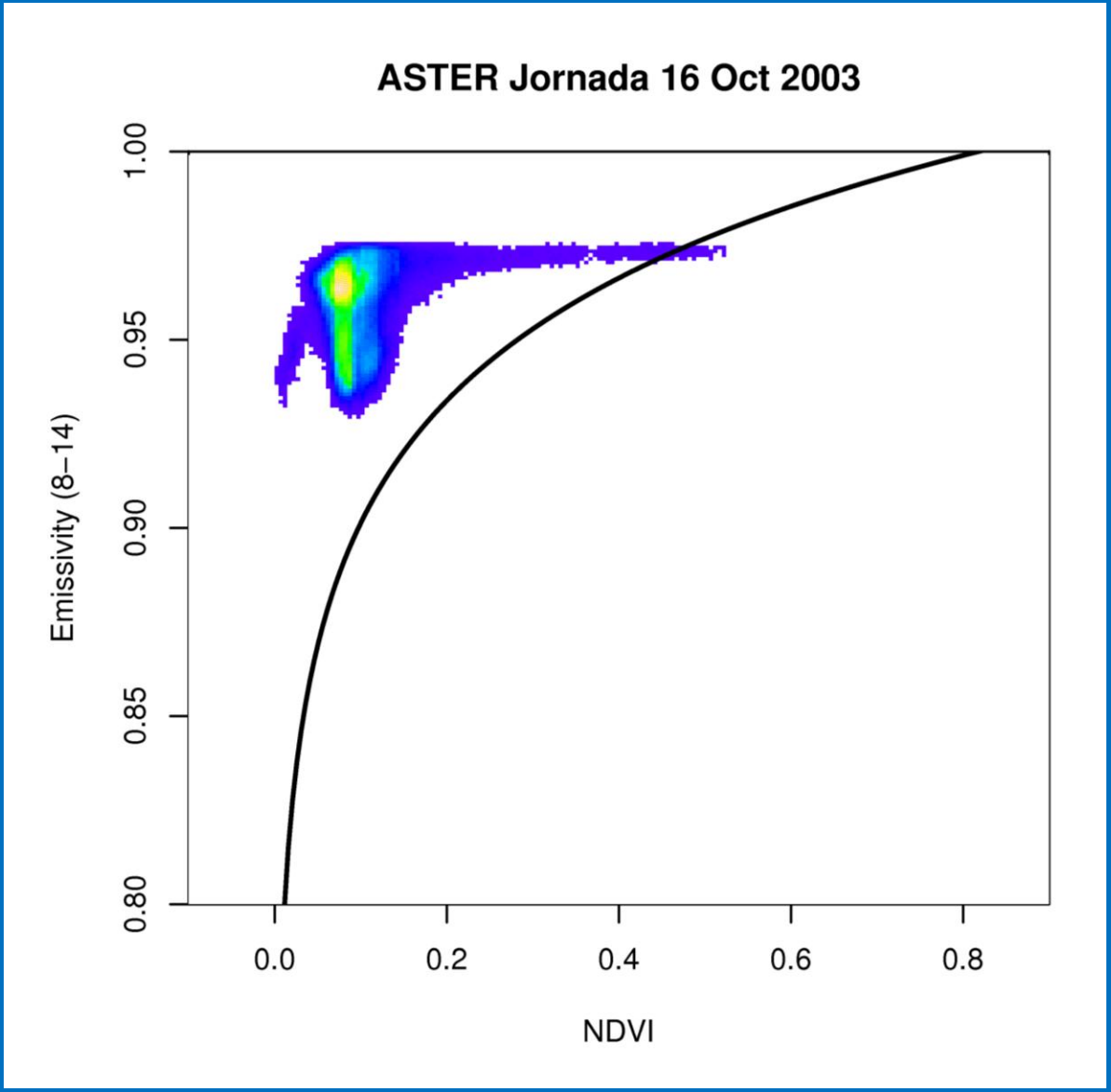


Scaling of Land Surface Temperatures Over Jornada Rangeland



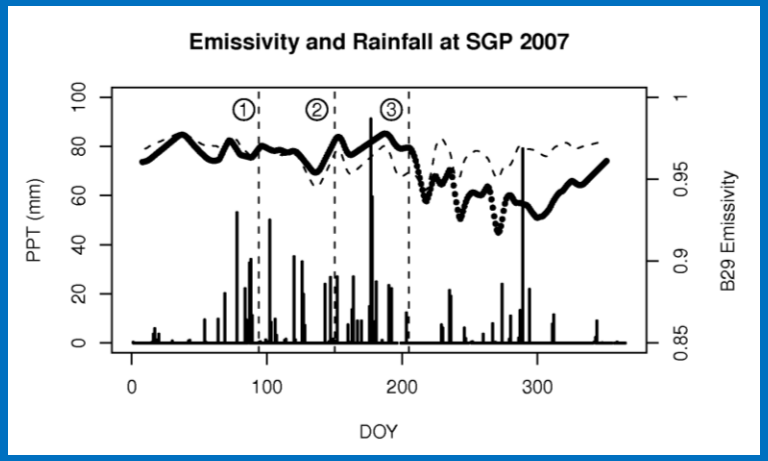
- Most of LST dynamic range lost ~50m
- LST contrast loss mainly over cooler surfaces
- HyspIRI resolution will discriminate land used changes, but not individual shrubs
- Loss of range needs to be considered when modeling surface energy fluxes

NDVI is not a satisfactory estimator for Emissivity

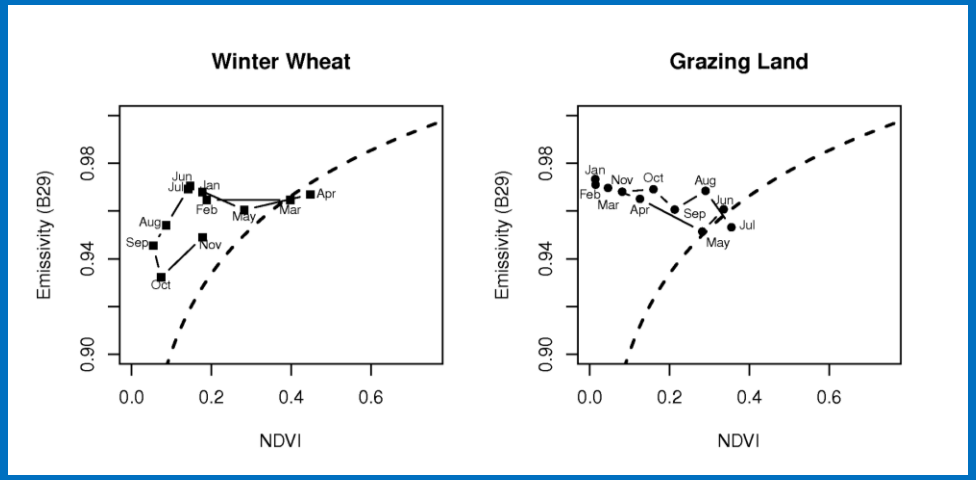


Land Surface Emissivity: Seasonal Variability Examples from Rangeland & Cropland

Emissivity responds to harvest not senescence



B29 Emissivity vs. NDVI



Surface Energy Balance Modeling: Incorporation of Emissivity Observations

Rn – G = H + LE

Rn: reassign soil fraction to senescent vegetation fraction, revise light extinction, revise emissivities for canopy & soil

G: affected by Rn_soil reduction

H: Increases importance of aerodynamic resistance term ra

LE: Affected by changes in Rn, G, H

$$\mathrm{LE} = \frac{\Delta}{\Delta+\gamma}\left[\mathrm{R_n} - \mathrm{G}\right] + \frac{\gamma}{\Delta+\gamma}\rho \mathrm{c_p}\left[\mathrm{e^\star} - \mathrm{e_a}\right]/\mathrm{r_a}$$

Penman (no TIR & no stress detection)

$$\mathrm{LE_C} = \mathrm{f_g}\alpha\left[\frac{\Delta}{\Delta+\gamma}\right]\mathrm{R_{n,C}}$$

Priestley-Taylor

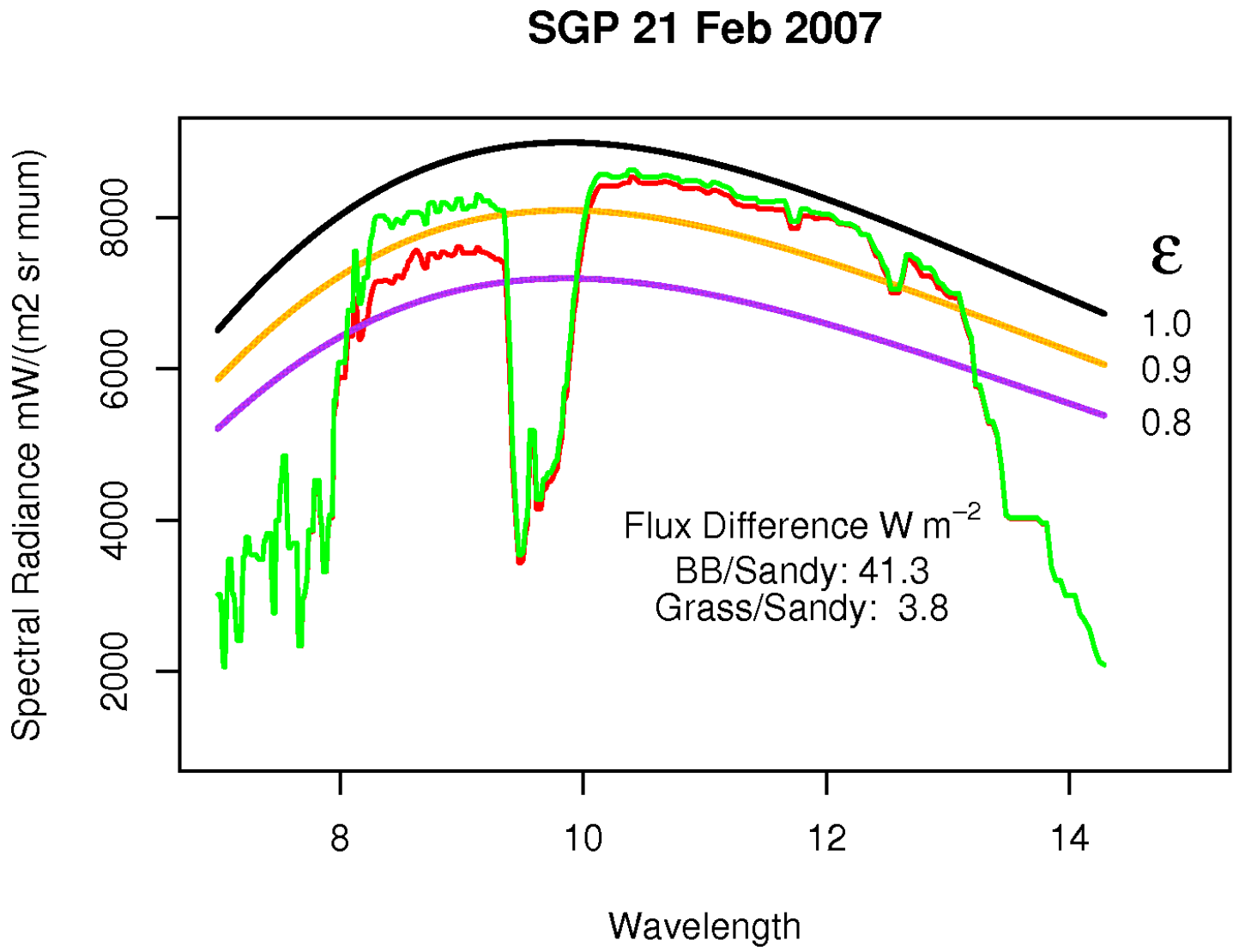
$$H \cong H_{soil}(\Delta T) + H_{canopy}(PT)$$

$$\mathrm{LE_S} = \mathrm{R_{n,S}} - \mathrm{G} - \rho \mathrm{c_p}\frac{\mathrm{T_s} - \mathrm{T_a}}{\mathrm{r_a} + \mathrm{r_s}}$$

Evaporation (soil, residual)

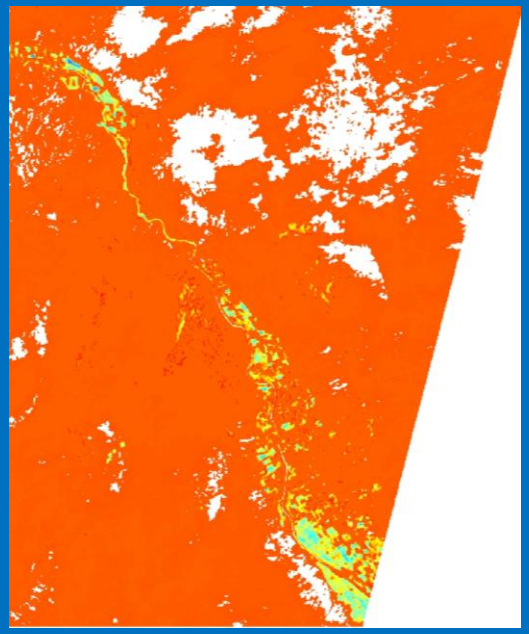
$$\mathrm{LE} = \mathrm{R_n} - \mathrm{G} - \rho \mathrm{c_p}\left[\frac{\Delta \mathrm{T}}{\mathrm{r_a}}\right]$$

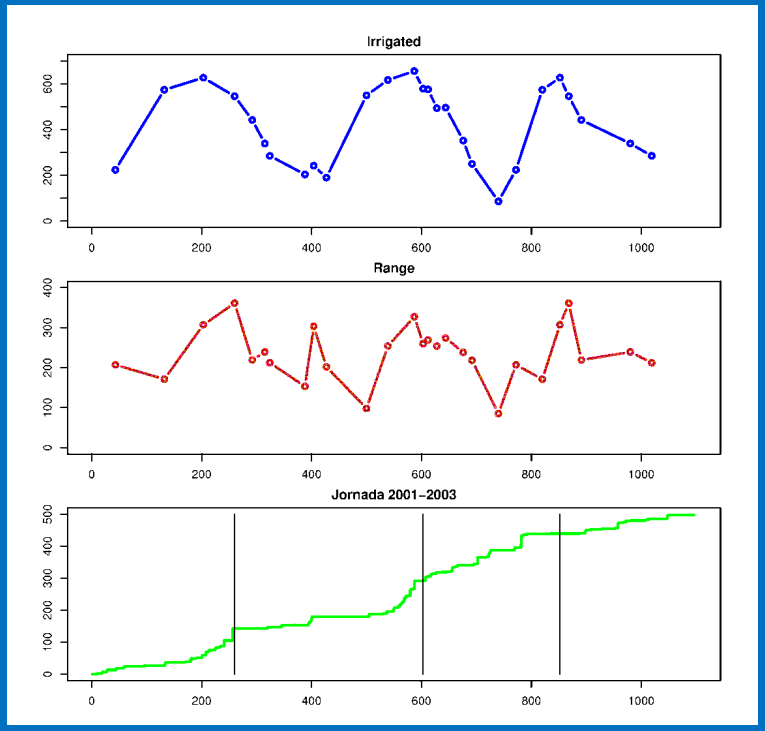
Emissivities Can Improve Net Radiation Estimation



ET Modeling with ASTER & MASTER at Jornada 2001-2003

Rangeland LE is small, but not zero
Modeling with MASTER will help answer what can be resolved at 60 m





Irrigated Lands

Rangeland

Precipitation

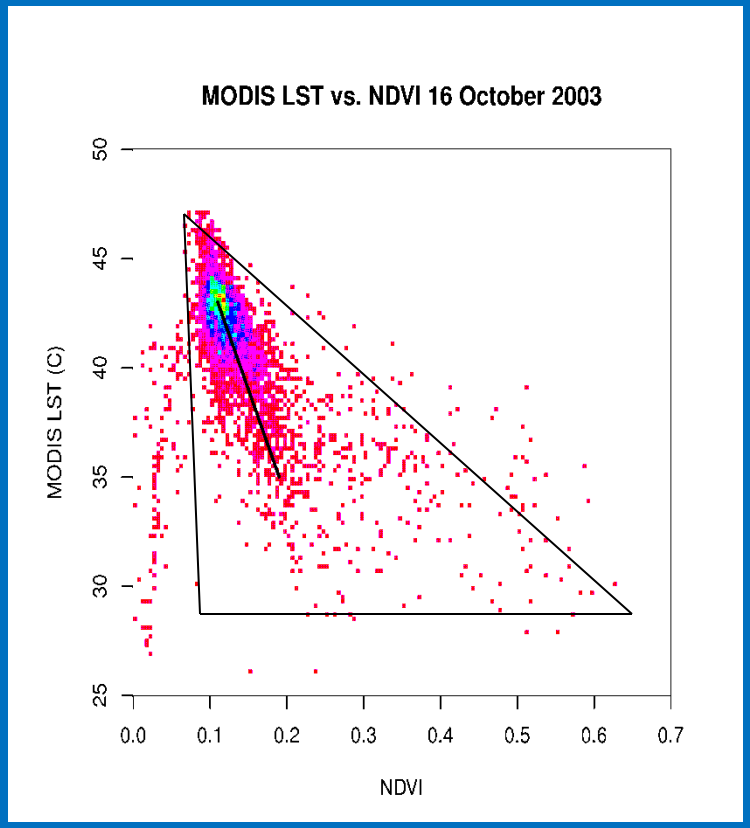
Conclusions

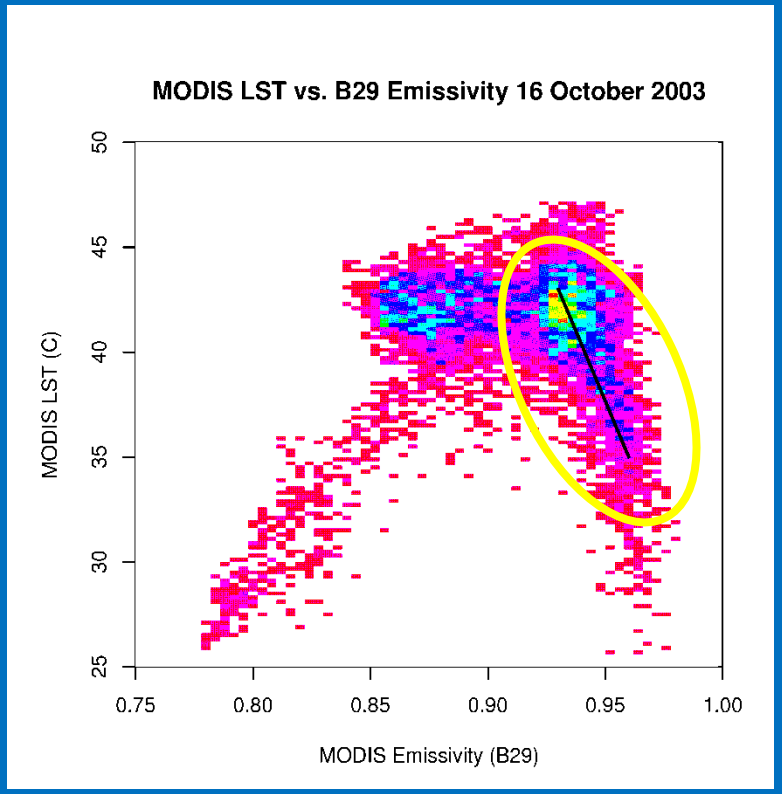
- Multispectral thermal infrared provides new information about rangeland vegetation cover
- This information can be used to improve discrimination of senescent vegetation & modeling of surface energy fluxes
- MASTER 6-12 m results show impact of resolution on observations over rangeland, modeling will help answer consequence for water flux estimation.

==========

- Implication for HyspIRI: Regional to Global scale data products should include time-continuous multispectral emissivities for detecting weekly-yearly+ changes.

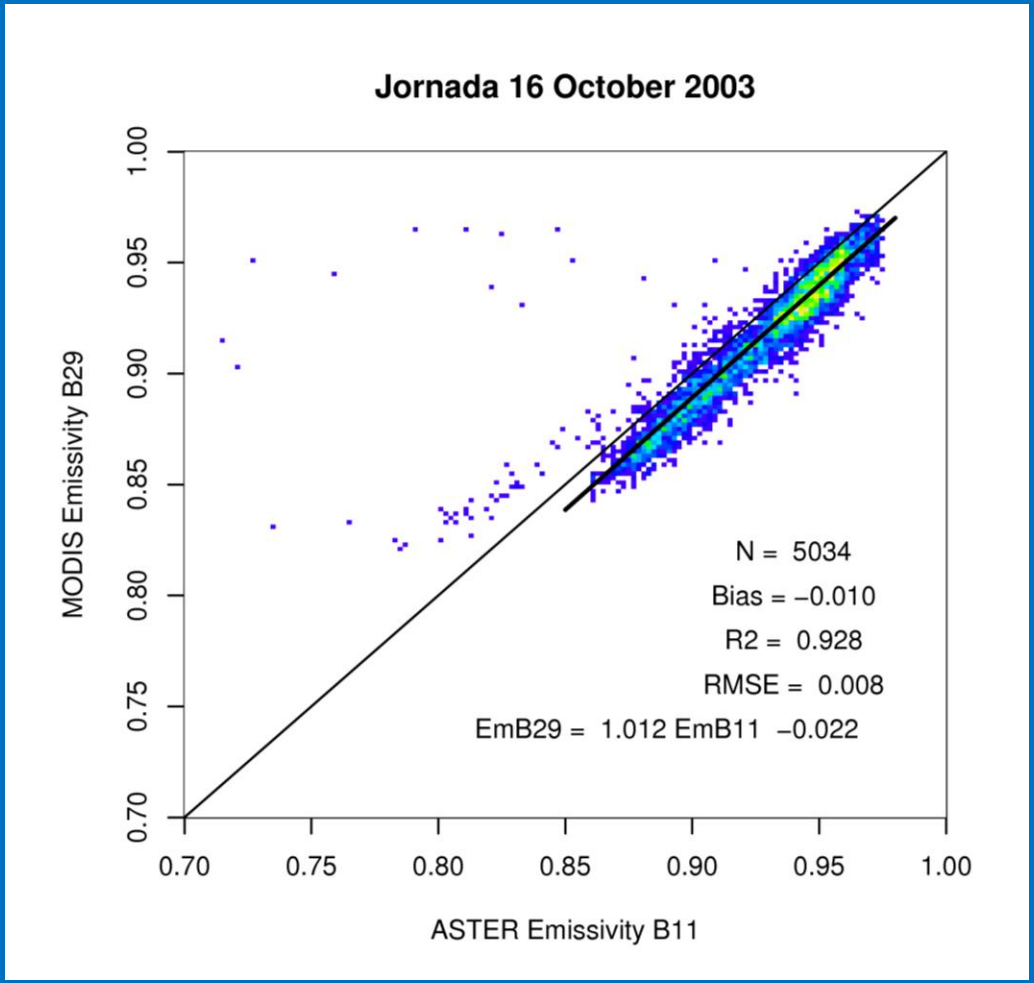
Emissivities May Help Disaggregation ('Sharpening')





$$LST = k\left[b_0 + b_1 NDVI\right] + (1-k)\left[c_0 + c_1 Emiss.\right]$$

Comparing Sensor Emissivities: MODIS B29 vs. ASTER B11



All Jornada Sites - Oct 6, 2002