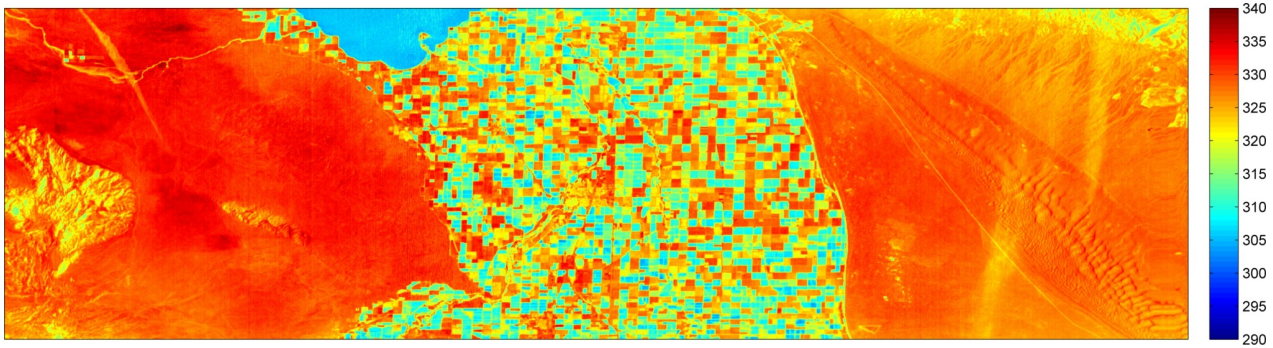
Improved Atmospheric Correction Techniques for MASTER and HyspIRI Thermal Infrared (TIR) Data



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Outline

- Relevance to HyspIRI
- MASTER online ordering tool
- Atmospheric correction
- Water Vapor Scaling (WVS) method
- Examples

Relevance to HyspIRI

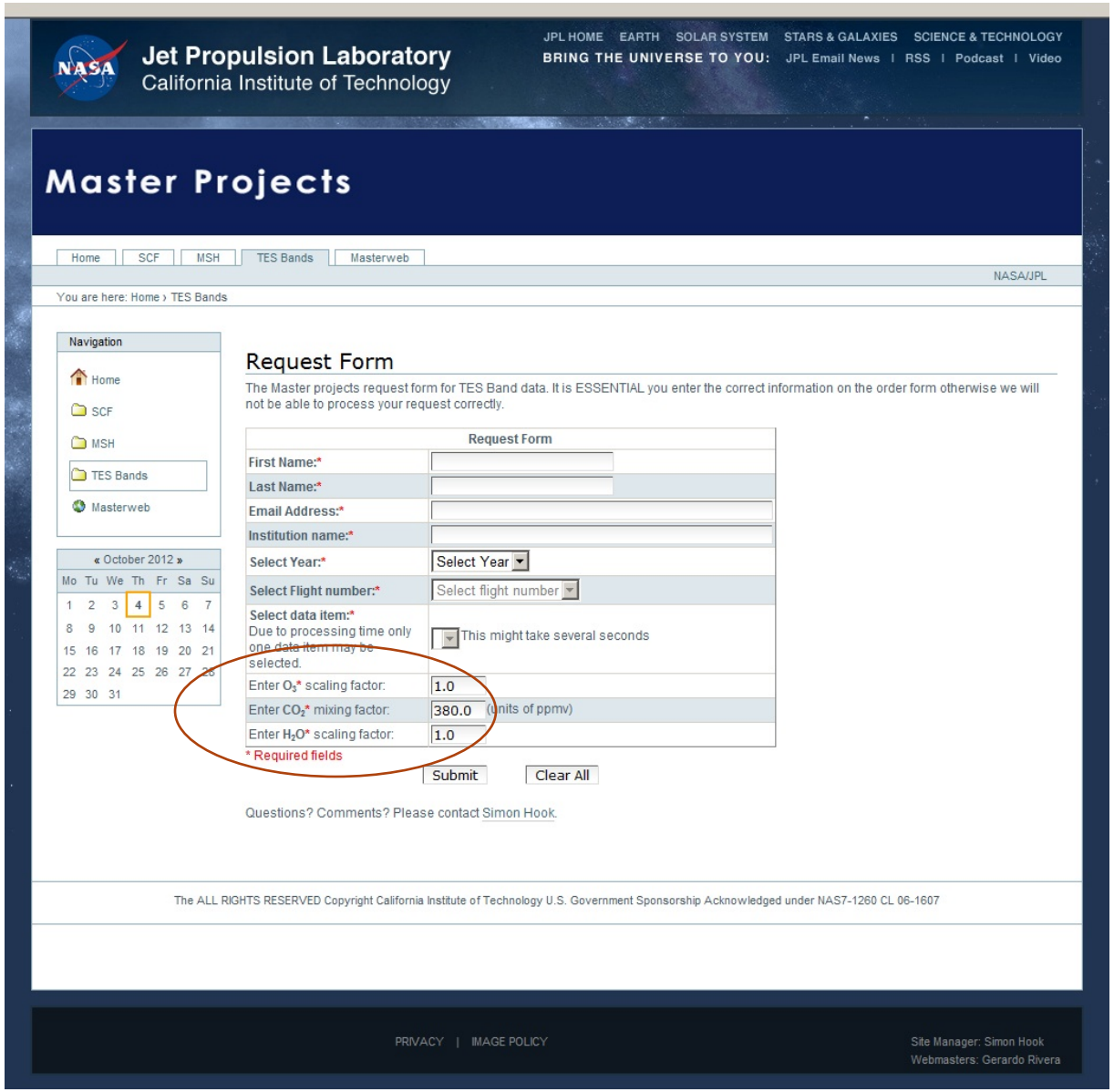
- MASTER TIR online ordering tool:
  - Support for HyspIRI prep. airborne activities research (FY13-15)
  - Prototype for distribution of HyTES-TIR data

- MASTER improved atmospheric correction
  - TES + Water Vapor Scaling (WVS) method
  - Closer simulation of HyspIRI-TIR L2 algorithms

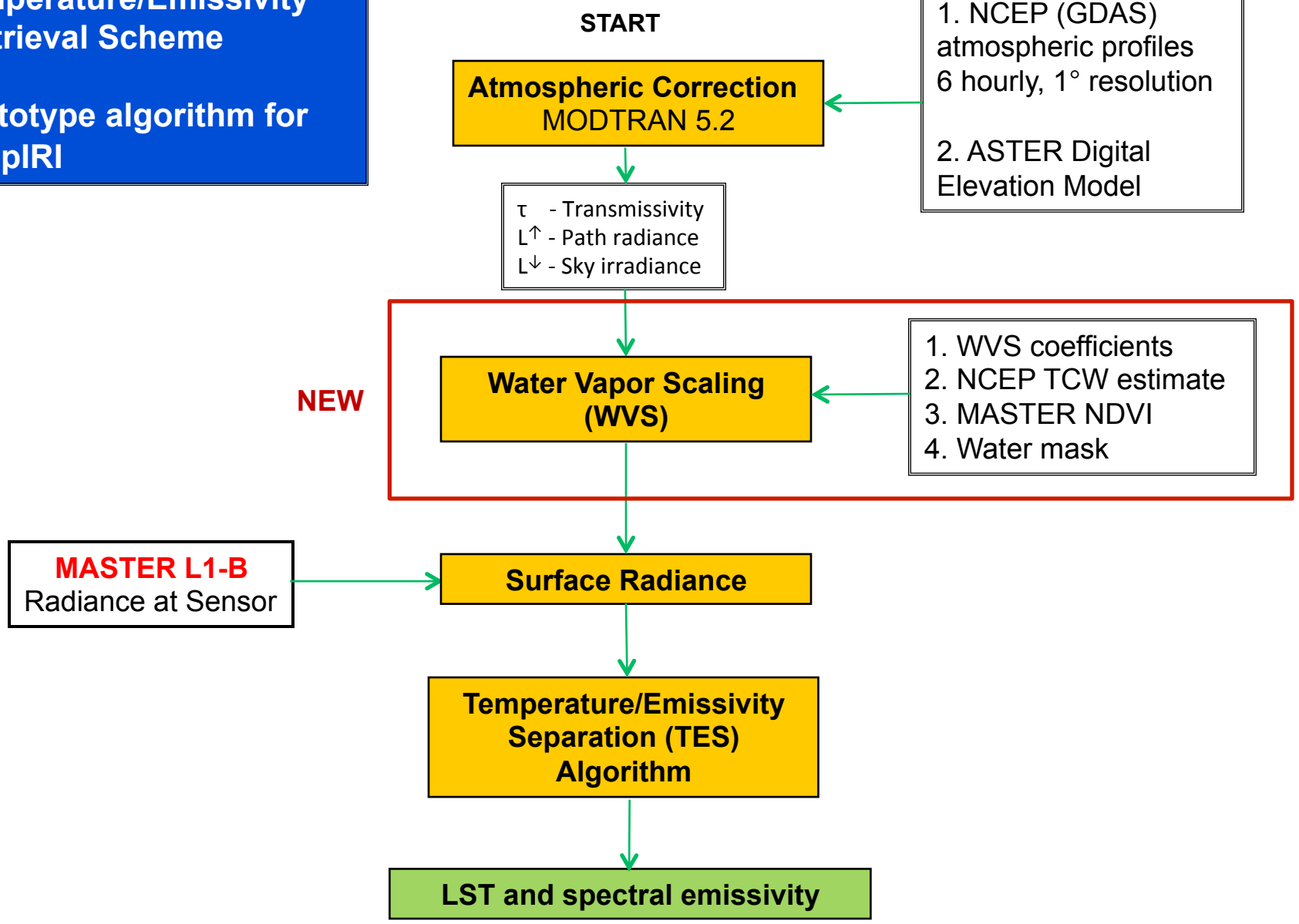
  (e.g. ATBDs at http://hyspiri.jpl.nasa.gov/documents)

MASTER online ordering tool

http://masterprojects.jpl.nasa.gov/tes-bands



- **MASTER Land Surface Temperature/Emissivity Retrieval Scheme**
- **Prototype algorithm for HyspIRI**

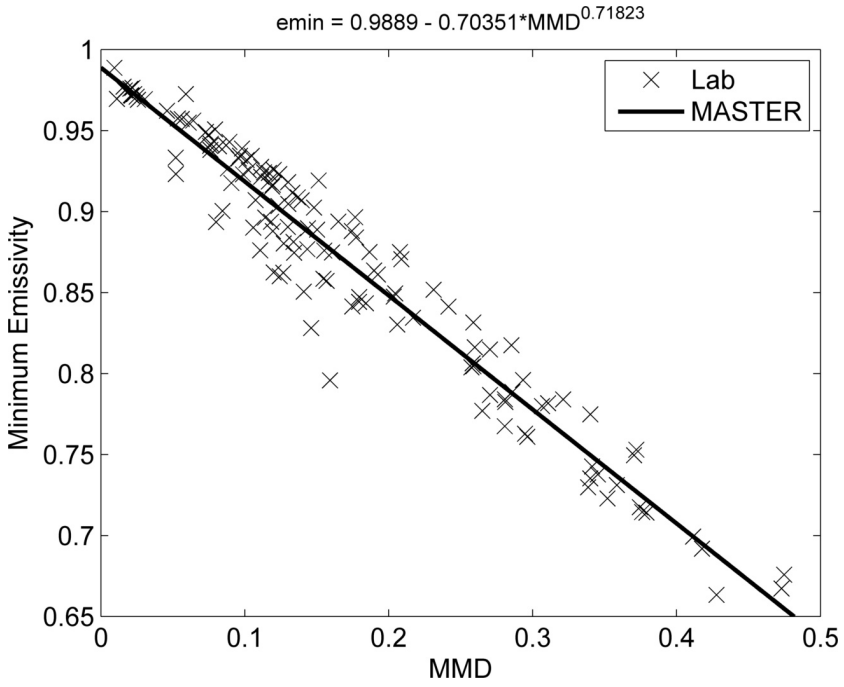


Band-dependent TES Calibration curves

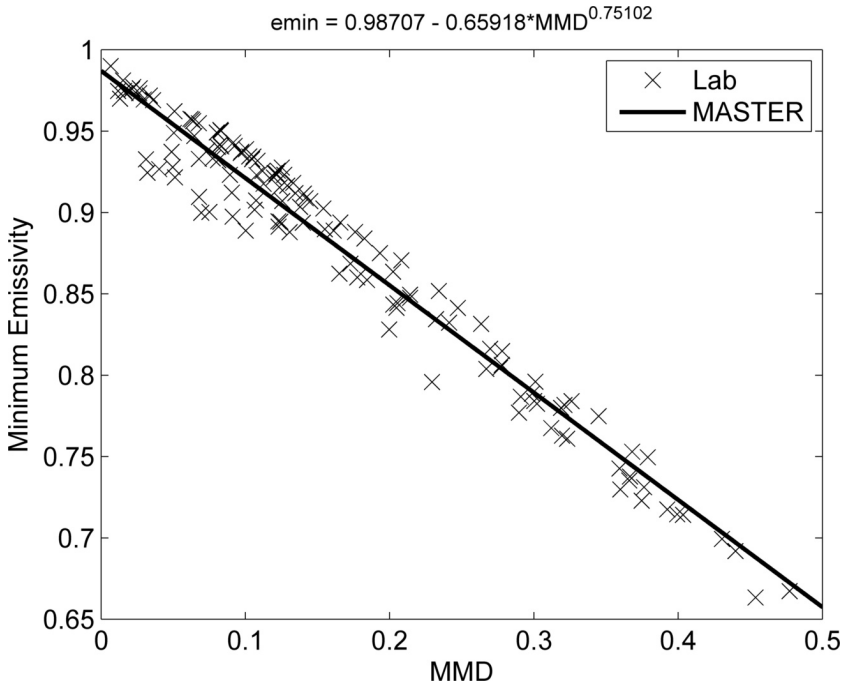
TES algorithm can be run for a combination of MASTER TIR bands:

- Minimum of 3 bands required
- At least one band between 11-12 µm (48 or 49)
- At least one band between 8 - 9.5 µm (43 or 44)

Bands 43, 44, 47, 48



Bands 43, 44, 49



Thermal Infrared Radiative Transfer

At-sensor Radiance

Surface Radiance

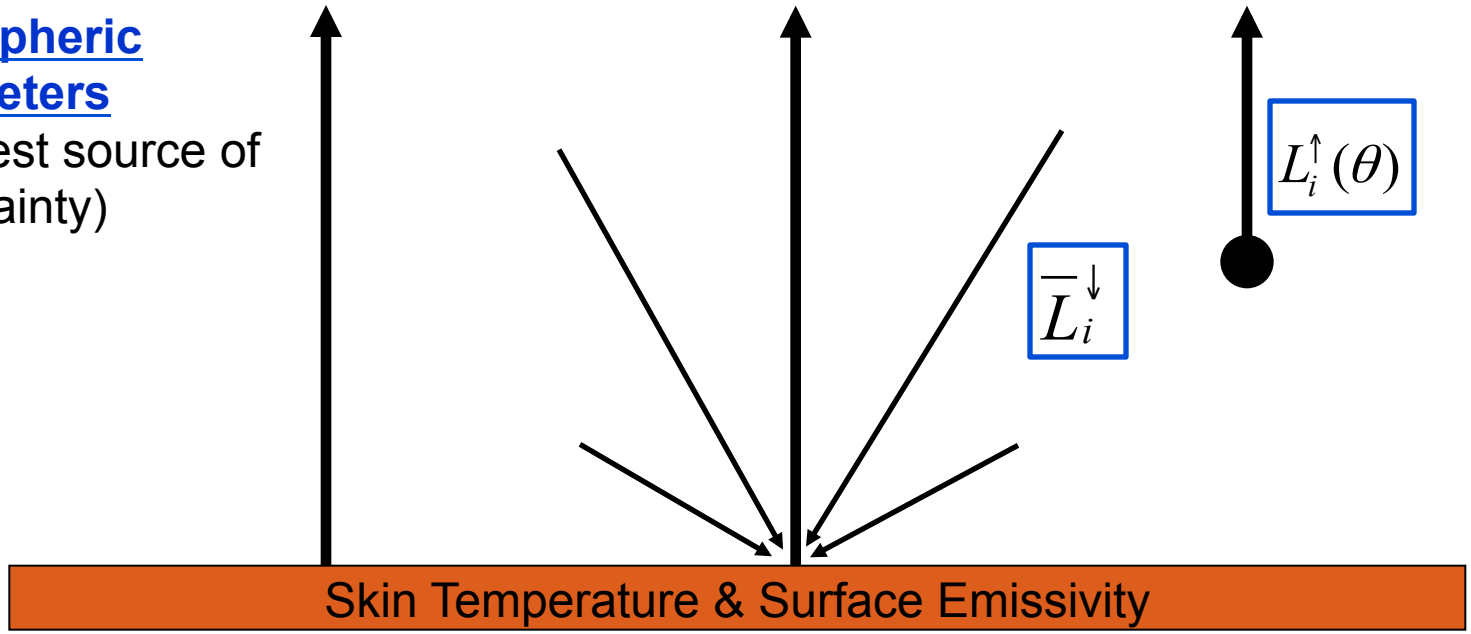
$$L_i(\theta) = \tau_i(\theta) \cdot e_i \cdot B_i(T_S) + \tau_i(\theta) \cdot (1 - e_i) \cdot \overline{L}_i^{\downarrow} + \int B_i(T(P)) d\tau_i$$

Surface Emission

Surface Reflection

Atmospheric Emission

Atmospheric Parameters
(Greatest source of Uncertainty)



Water Vapor Scaling (WVS) method

Tonooka, H., (2005), Accurate Atmospheric Correction of ASTER Thermal Infrared Imagery Using the WVS Method, IEEE Trans. Geos. Remote Sens., 43 (12)

Surface brightness temperature

Observed brightness temperature

Total column water estimate

EMC/WVD equation

$$T_{g,i} = \alpha_{i,o} + \sum_{k=1}^{n} \alpha_{i,k} T_k$$

$$\alpha_{i,k} = p_{i,k} + q_{i,k} W + r_{i,k} W^2 \quad (k = 0,1,..,n)$$

Scaling factor

$$\gamma^{a_i} = \frac{\ln\left[\frac{\tau_i(\gamma_2)^{\gamma_1^{a_i}}}{\tau_i(\gamma_1)^{\gamma_2^{a_i}}} \cdot \left(\frac{B_i(T_{g,i}) - L_i^{\uparrow}(\gamma_1)/(1-\tau_i(\gamma_1))}{L_i - L_i^{\uparrow}(\gamma_1)/(1-\tau_i(\gamma_1))}\right)^{\gamma_1^{a_i} - \gamma_2^{a_i}}\right]}{\ln\left(\frac{\tau_i(\gamma_2)}{\tau_i(\gamma_1)}\right)}$$

Water Vapor Scaling (WVS)

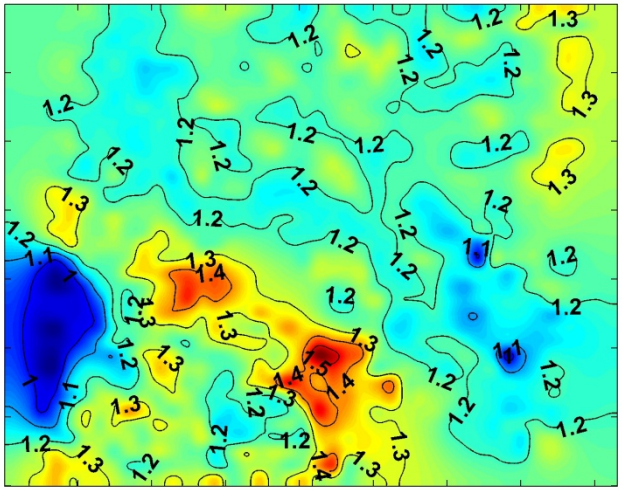
γ is used to modify and improve atmospheric correction terms:

Transmittance: $$\tau_i(\gamma) = \tau_i(\gamma_1)^{(\gamma^{a_i} - \gamma_2^{a_i} / \gamma_1^{a_i} - \gamma_2^{a_i})} \cdot \tau_i(\gamma_2)^{(\gamma_1^{a_i} - \gamma^{a_i} / \gamma_1^{a_i} - \gamma_2^{a_i})}$$

Path Radiance: $$L_i^{\uparrow}(\gamma) = L_i^{\uparrow}(\gamma_1) \cdot \frac{1 - \tau_i(\gamma)}{1 - \tau_i(\gamma_1)}$$

Sky Radiance: $$L_i^{\downarrow}(\gamma) = a_i + b_i \cdot L_i^{\uparrow}(\gamma) + c_i \cdot L_i^{\uparrow}(\gamma)^2$$

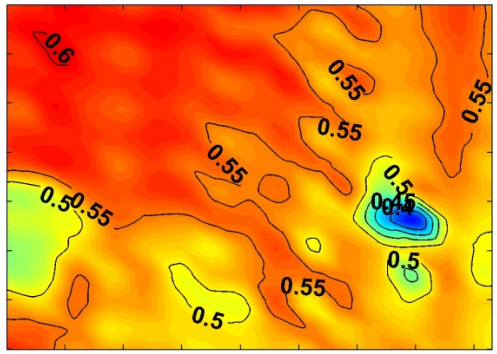
WVS Scaling Factor, γ

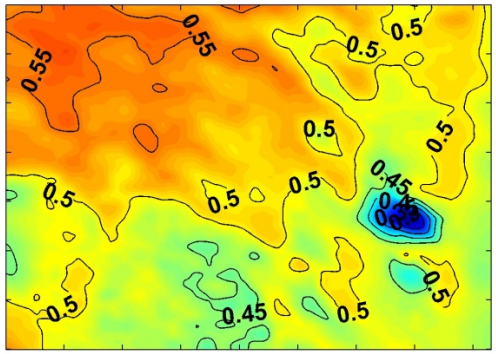


Before Scaling

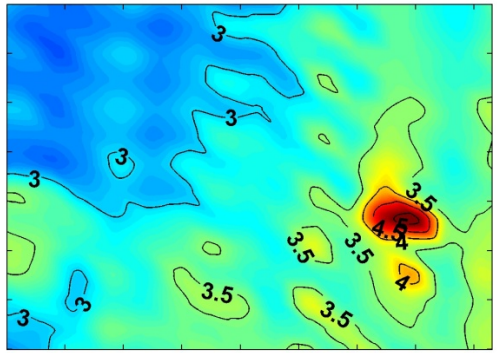
After Scaling

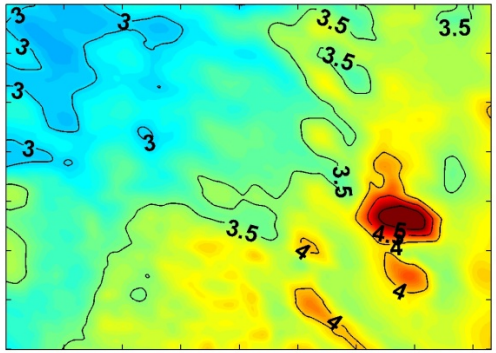
Transmittance



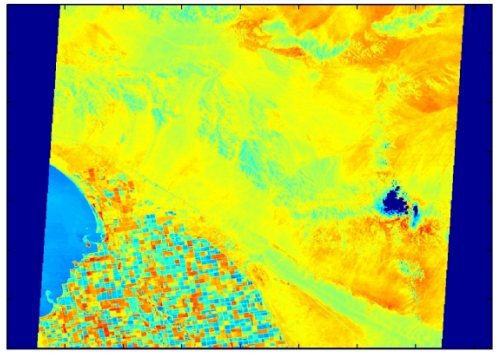


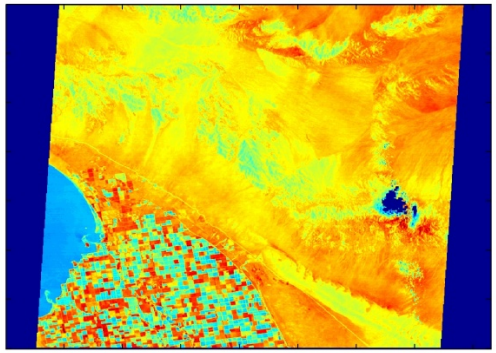
Path Radiance

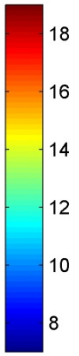




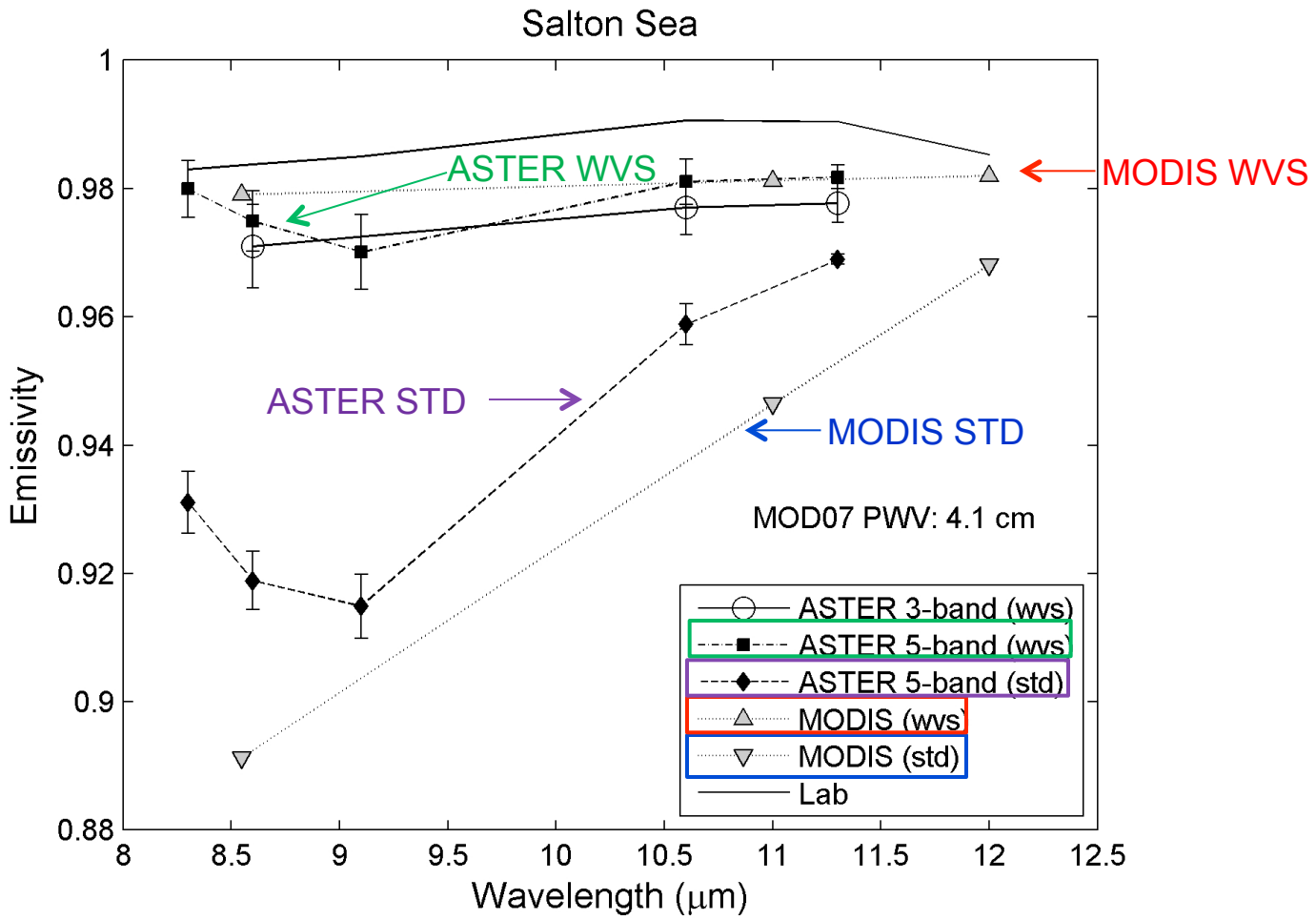
Surface Radiance



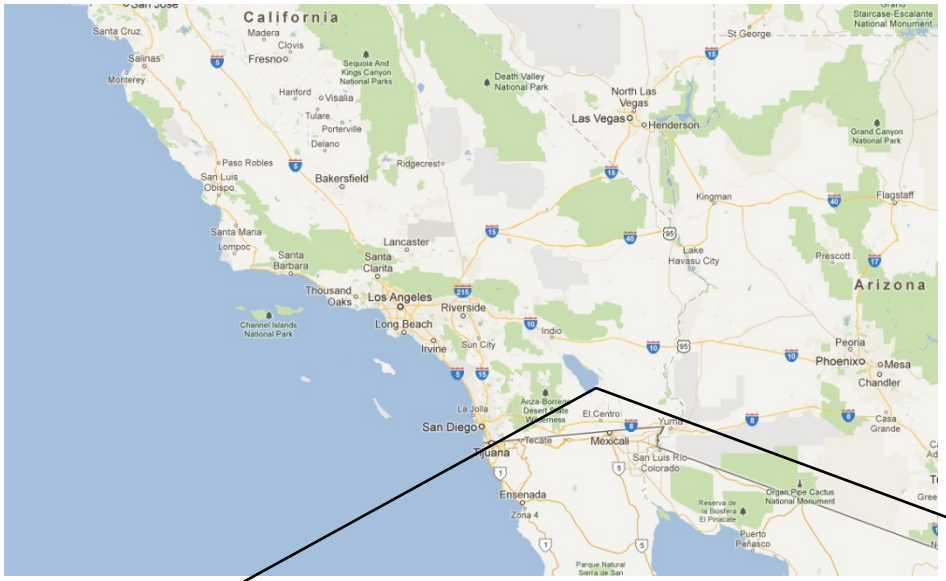




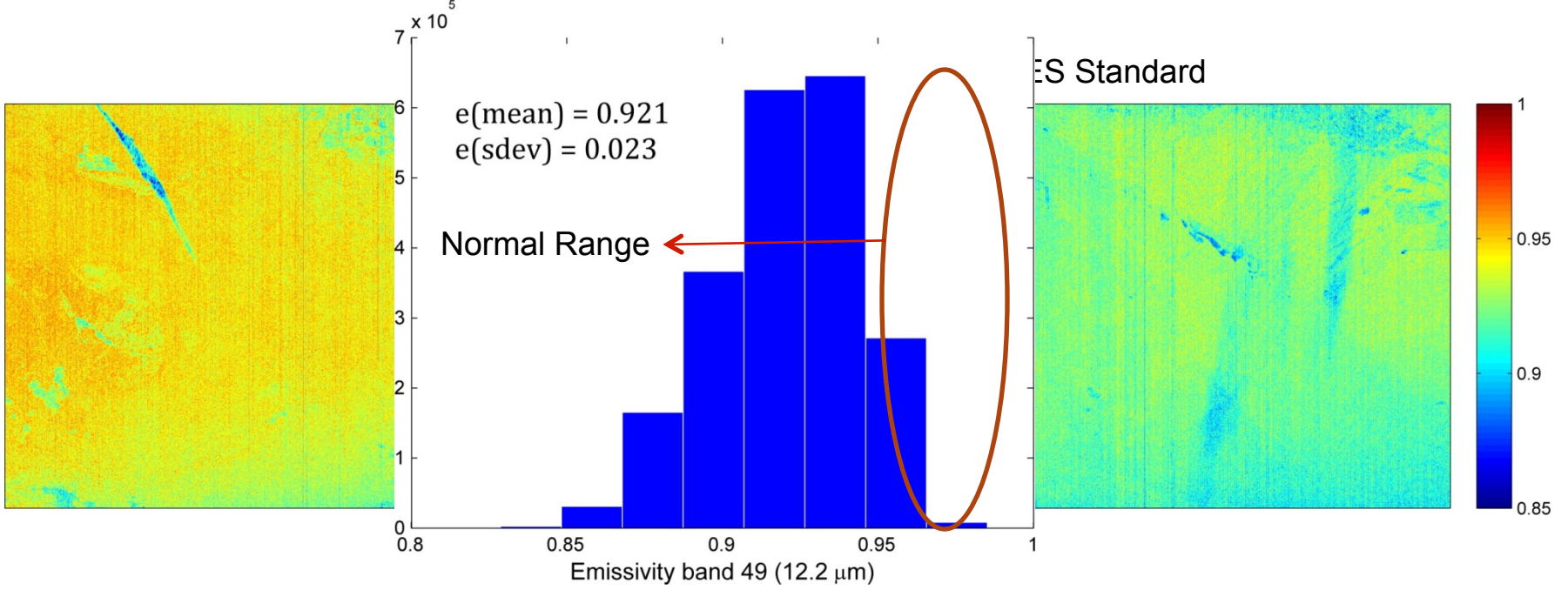
ASTER & MODIS Emissivity spectra for the Salton Sea showing effects of water vapor scaling (wvs)

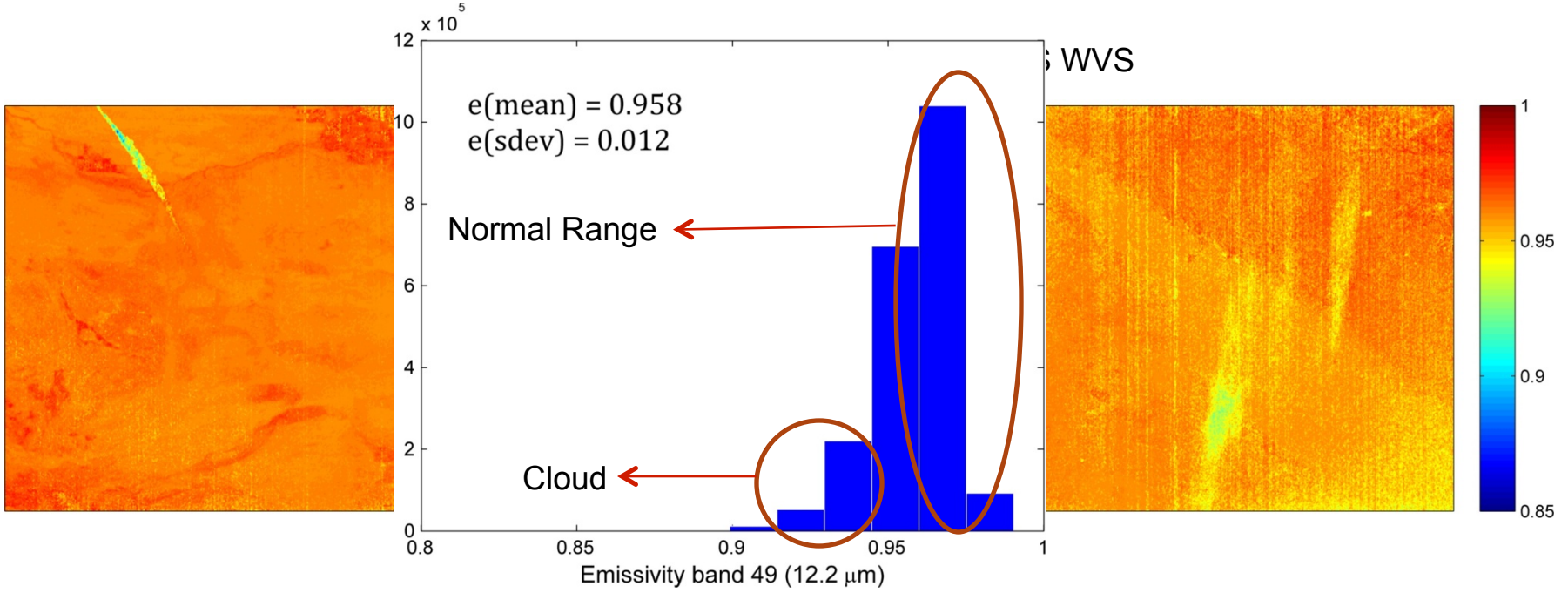


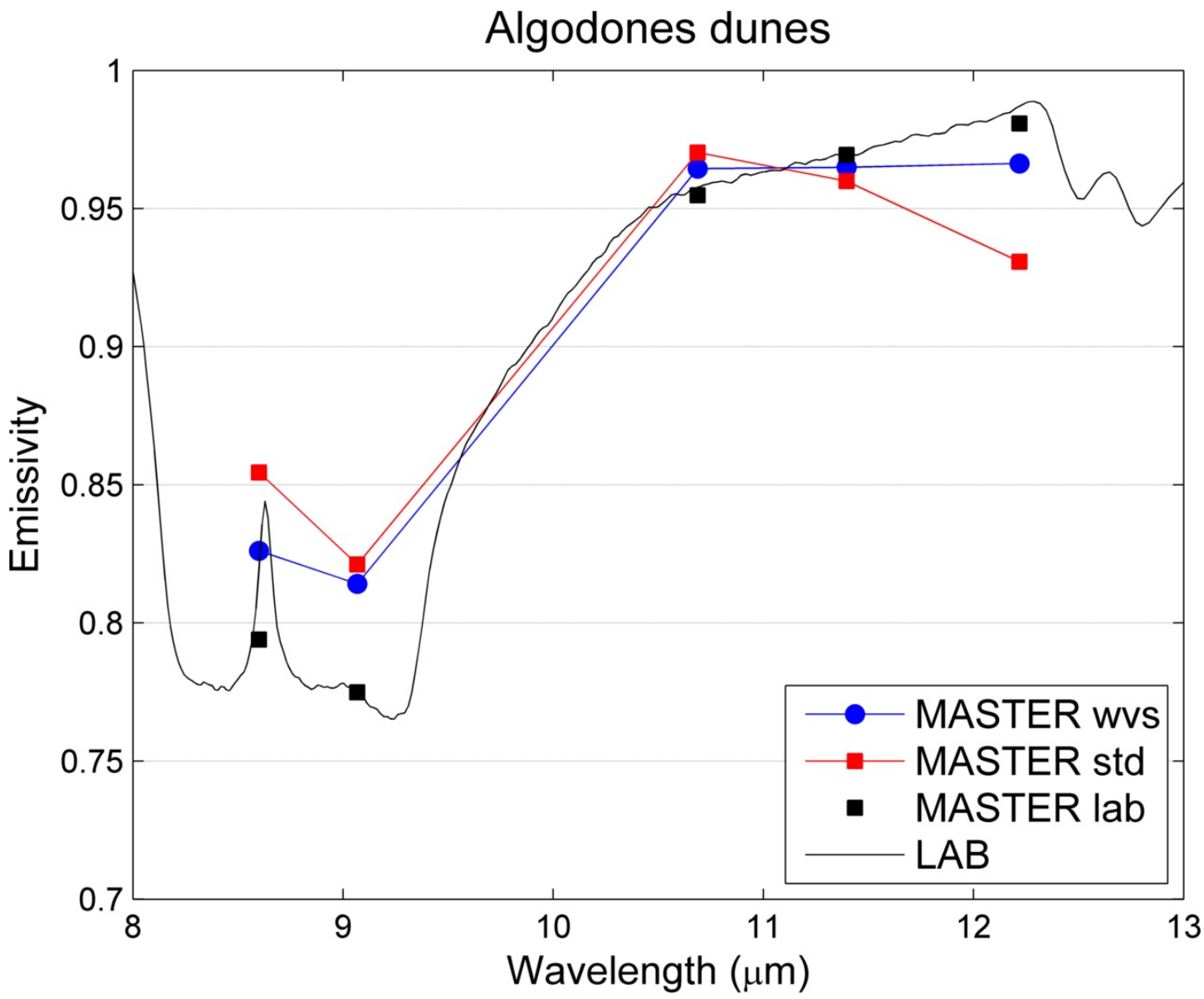
MASTER WVS test



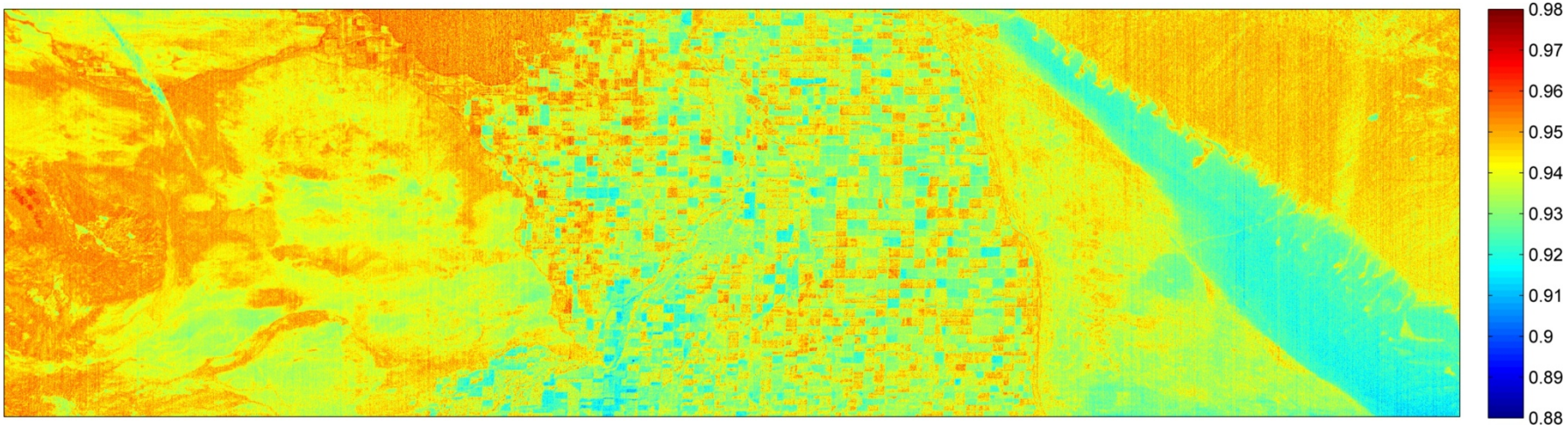
MASTERL1B_0395000_03_20030805_1745_1753_V02


ES Standard
x 10^5
e(mean) = 0.921
e(sdev) = 0.023
Normal Range
Emissivity band 49 (12.2 μm)
1
0.95
0.9
0.85

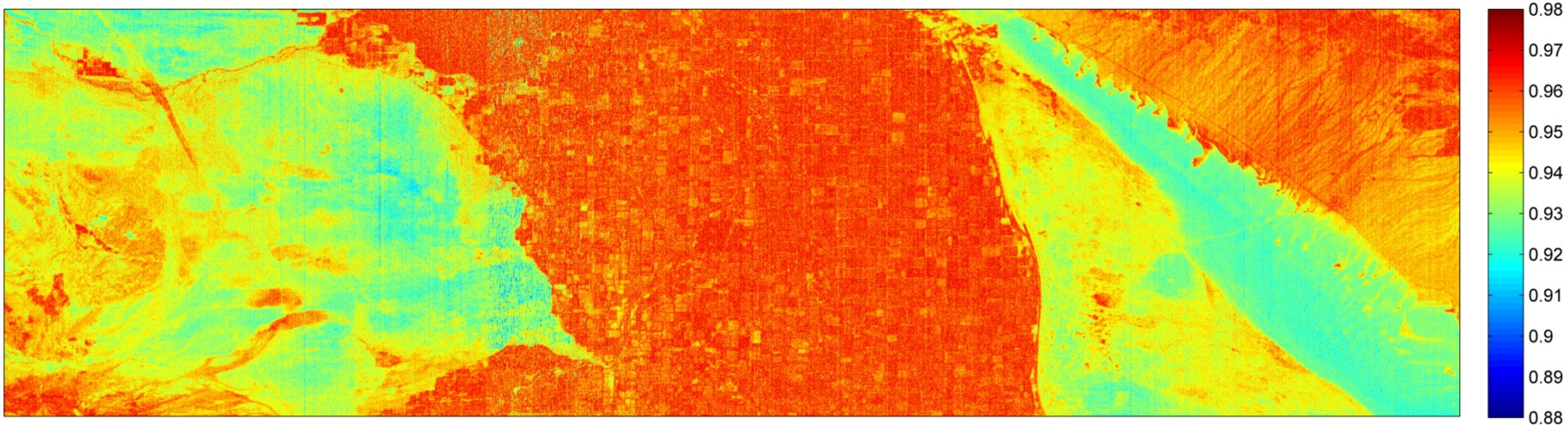

S WVS
x 10^5
e(mean) = 0.958
e(sdev) = 0.012
Normal Range
Cloud
Emissivity band 49 (12.2 μm)
1
0.95
0.9
0.85


Algodones dunes
Emissivity
Wavelength (μm)
1
0.95
0.9
0.85
0.8
0.75
0.7
8
9
10
11
12
13
MASTER wvs
MASTER std
MASTER lab
LAB

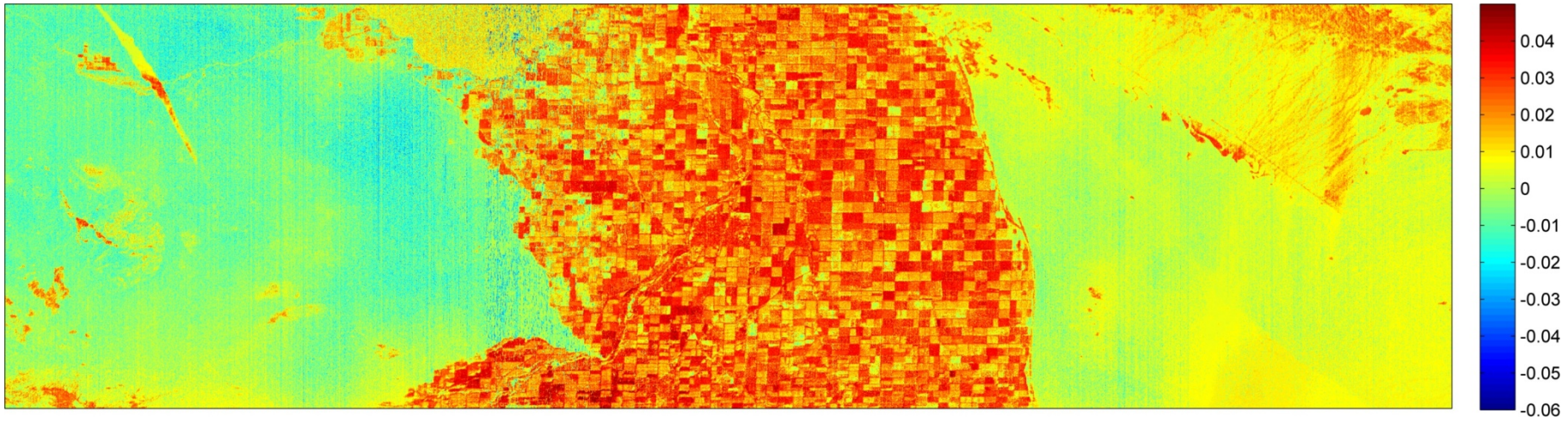
MASTER broadband emissivity (8-12 μm) -- TES Standard



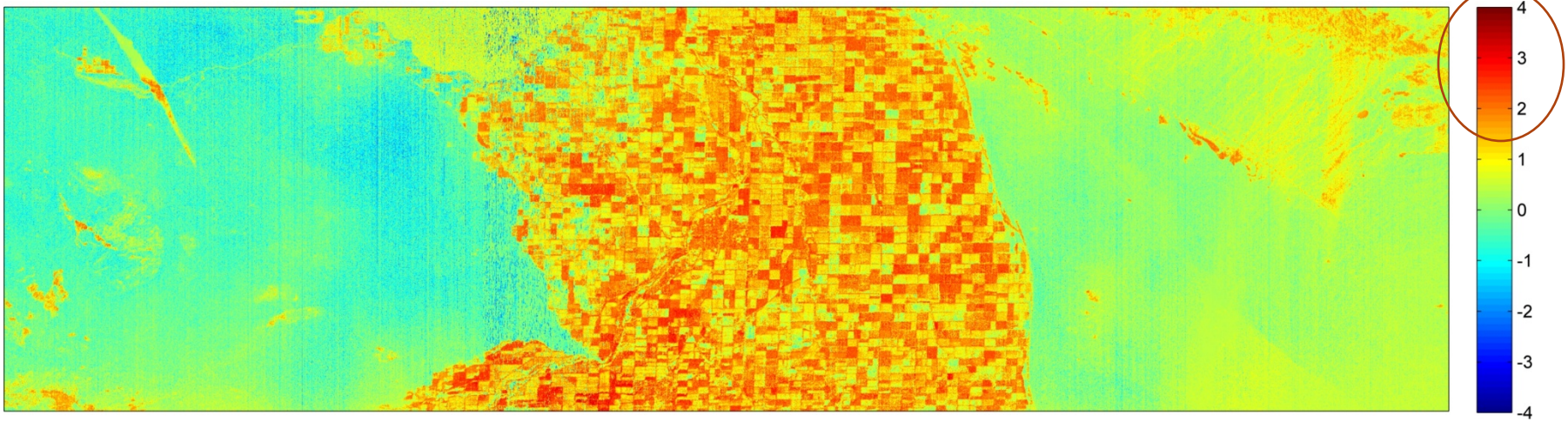
MASTER broadband emissivity (8-12 μm) -- TES WVS



Broadband emissivity difference (WVS – Standard)

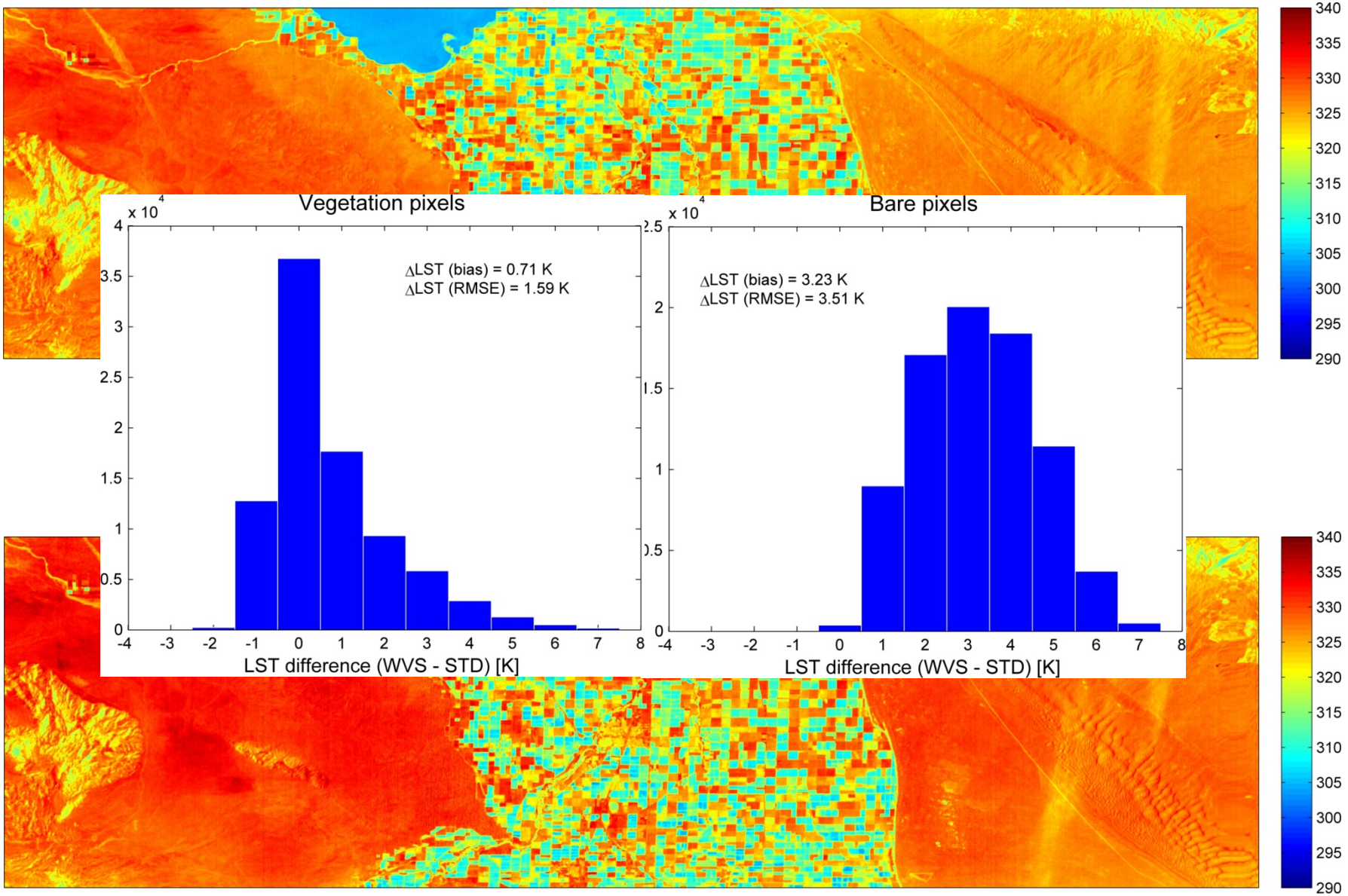


Change in Net Longwave Radiation (Wm-2)**



**Zhou et al. (2003)

MASTER Land Surface Temperature -- TES Standard



Summary

- Online ordering tool developed for MASTER TIR data
- Improved atmospheric correction method (WVS) implemented for MASTER TIR data
- Both will benefit future HyTES/HyspIRI TIR data

The End

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MASTER online ordering tool

- Automated MASTER online ordering and distribution tool implemented for L2 temperature/emissivity products
- ASTER-TES algorithm and atmospheric correction (MODTRAN5.2) implemented with Python code
- Prototype tool for distribution of future HyTES temperature/emissivity products
- Future enhancements include improvement of atmospheric correction using Water Vapor Scaling (WVS) method

Atmospheric Correction

Surface Radiance:

Observed Radiance

$$L_{surf,i} = e_i \cdot B_i(T_S) + (1 - e_i) \cdot \overline{L_i}^{\downarrow} = \frac{L_i(\theta) - L_i^{\uparrow}(\theta)}{\tau_i(\theta)}$$

- **Atmospheric Parameters:** $\tau_i(\theta)$, $L_i^{\uparrow}(\theta)$, $L_i^{\downarrow}(\theta)$

Estimated using radiative transfer code such as MODTRAN with Atmospheric profiles and elevation data

NCEP data (6-hourly, 1° spatial resolution, 26 levels)