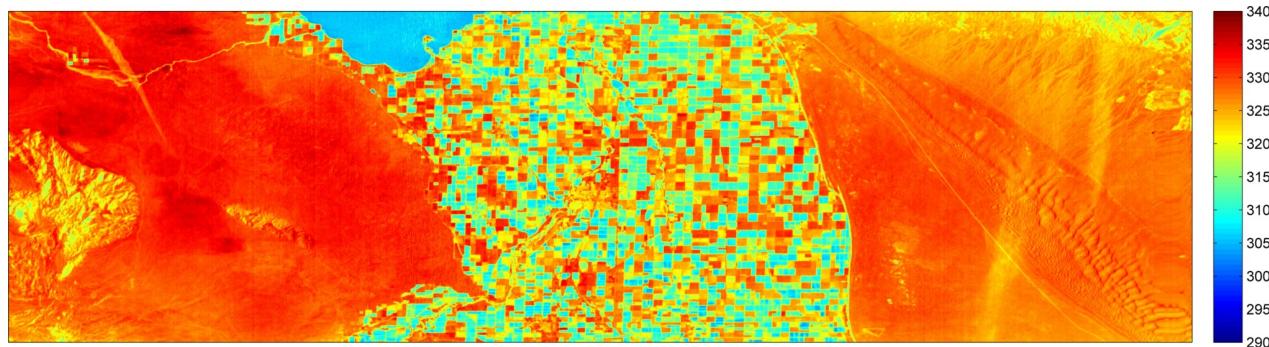




Improved Atmospheric Correction Techniques for MASTER and HyspIRI Thermal Infrared (TIR) Data



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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>

The screenshot shows the JPL Master Projects website with a blue header featuring the NASA logo and "Jet Propulsion Laboratory California Institute of Technology". The top navigation bar includes links for JPL HOME, EARTH, SOLAR SYSTEM, STARS & GALAXIES, SCIENCE & TECHNOLOGY, and options to BRING THE UNIVERSE TO YOU: JPL Email News, RSS, Podcast, and Video.

The main content area has a dark blue header "Master Projects". Below it is a navigation bar with links: Home, SCF, MSH, TES Bands (which is highlighted), and Masterweb. A "You are here: Home > TES Bands" breadcrumb trail is also present.

A left sidebar contains a "Navigation" menu with links to Home, SCF, MSH, TES Bands (highlighted), and Masterweb. Below the menu is a calendar for October 2012, with the 4th highlighted in yellow. A red oval is drawn around the date input field in the request form.

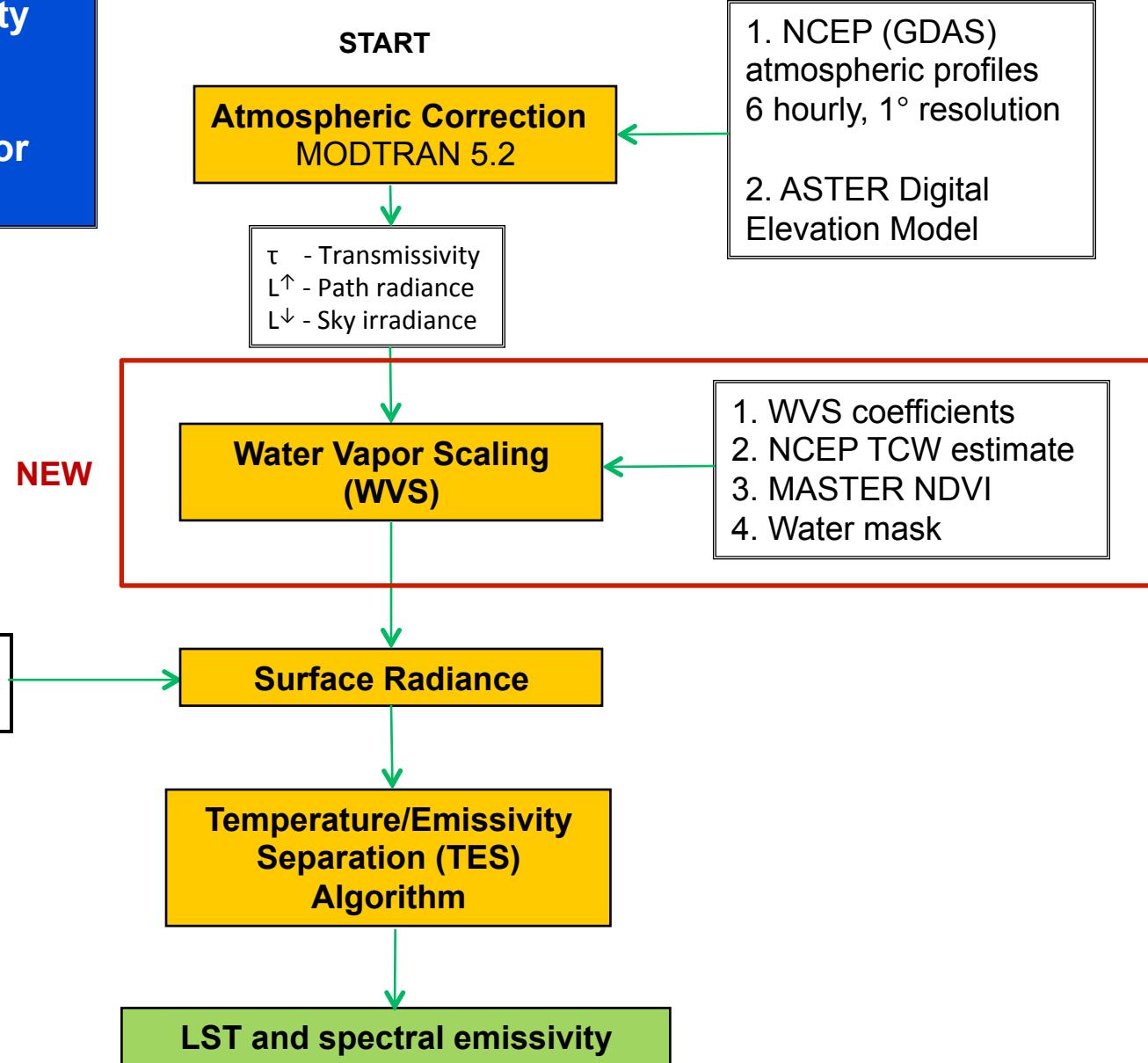
The central "Request Form" section has a title "Request Form" and a sub-instruction: "The Master projects request form for TES Band data. It is ESSENTIAL you enter the correct information on the order form otherwise we will not be able to process your request correctly." The form fields include:

- First Name:*
- Last Name:*
- Email Address:*
- Institution name:*
- Select Year:*
- Select Flight number:*
- Select data item:*
- Enter O₃* scaling factor: 1.0
- Enter CO₂* mixing factor: 380.0 (units of ppmv)
- Enter H₂O* scaling factor: 1.0

At the bottom of the form are buttons for "Submit" and "Clear All". A note below the "Select data item" field states: "Due to processing time only one data item may be selected. This might take several seconds".

At the very bottom of the page, there is a footer with copyright information: "The ALL RIGHTS RESERVED Copyright California Institute of Technology U.S. Government Sponsorship Acknowledged under NAS7-1260 CL 06-1607". The footer also includes links for PRIVACY and IMAGE POLICY, and credits the Site Manager: Simon Hook and Webmasters: Gerardo Rivera.

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

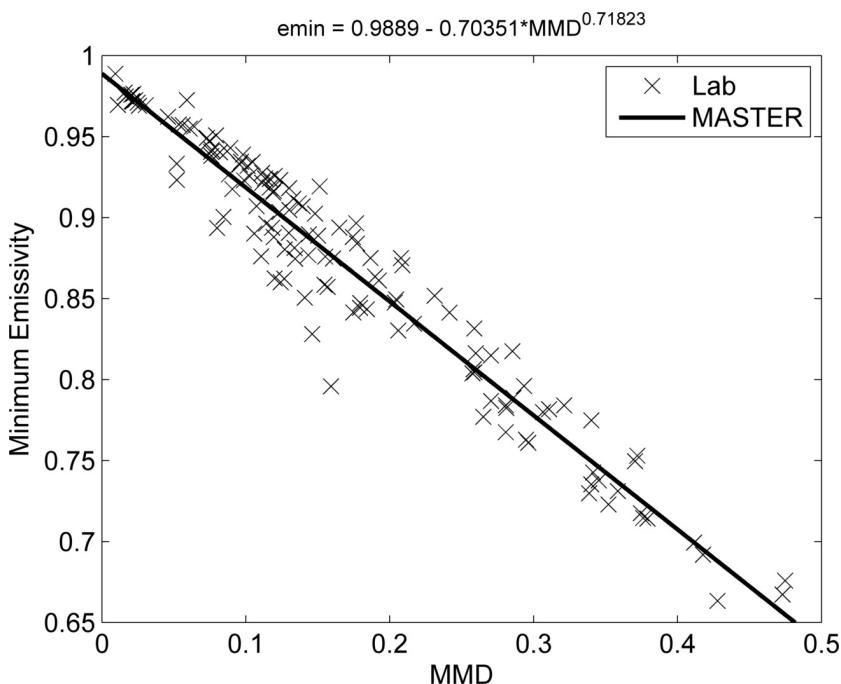


Band-dependent TES Calibration curves

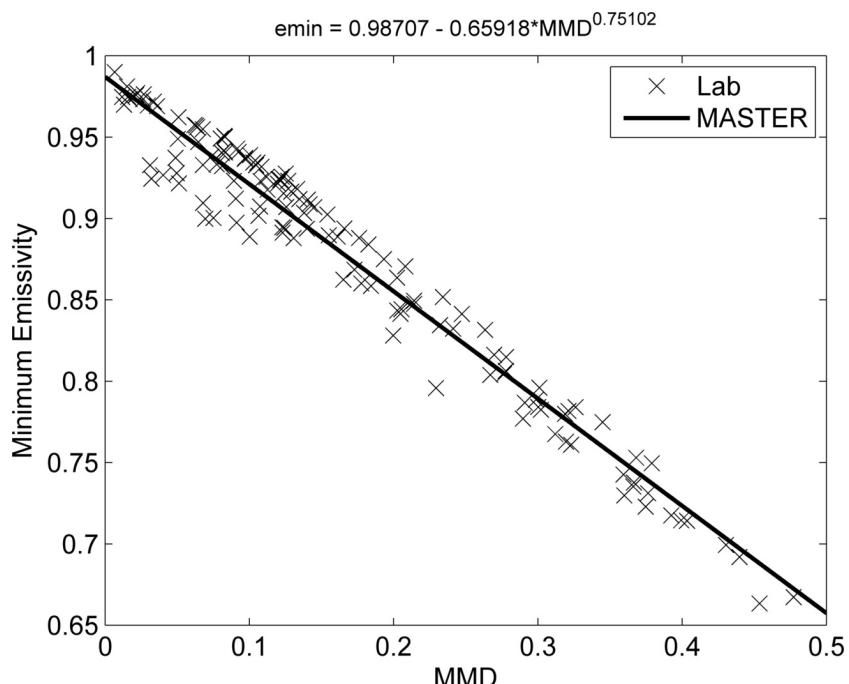
TES algorithm can be run for a combination of MASTER TIR bands:

- 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

$$L_i(\theta) = \underbrace{\tau_i(\theta) \cdot e_i \cdot B_i(T_S)}_{\text{Surface Emission}} + \underbrace{\tau_i(\theta) \cdot (1 - e_i) \cdot \bar{L}_i^{\downarrow}}_{\text{Surface Reflection}} + \underbrace{\int B_i(T(P)) d\tau_i}_{\text{Atmospheric Emission}}$$

Atmospheric
Parameters

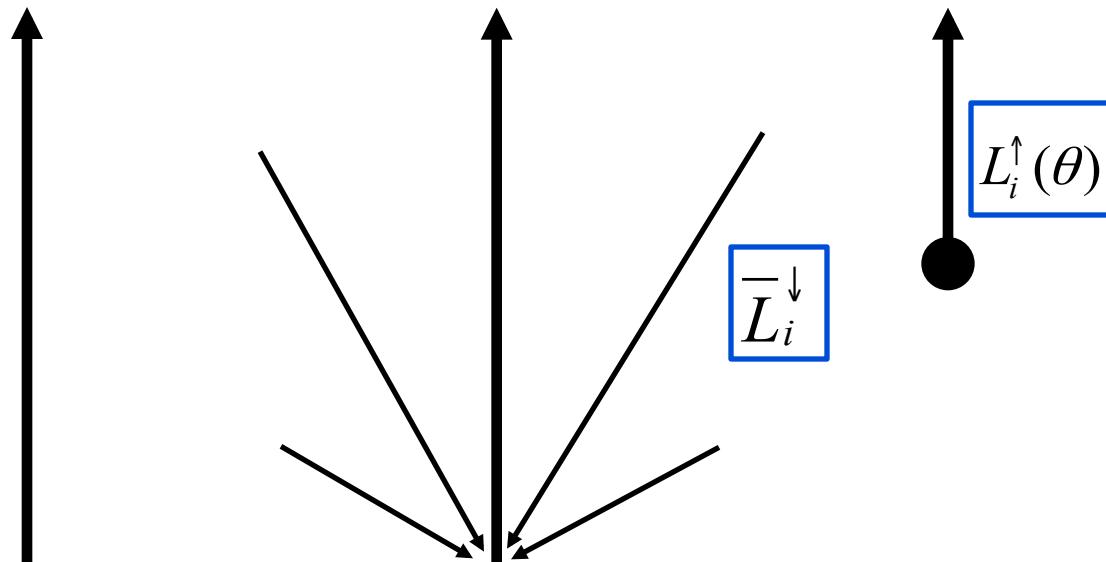
(Greatest source of
Uncertainty)

Surface
Emission

Surface
Reflection

Atmospheric Emission

Skin Temperature & Surface Emissivity



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

EMC/WVD equation

$$T_{g,i} = \alpha_{i,o} + \sum_{k=1}^n \alpha_{i,k} T_k$$
$$\alpha_{i,k} = P_{i,k} + q_{i,k} W + r_{i,k} W^2 \quad (k = 0, 1, \dots, n)$$

Observed brightness temperature

Total column water estimate

Scaling factor

$$\gamma^{a_i} = \frac{\ln \left[\frac{\tau_i(\gamma_2)^{r_1^{a_i}}}{\tau_i(\gamma_1)^{r_2^{a_i}}} \cdot \left(\frac{B_i(T_{g,i}) - L_i^\uparrow(\gamma_1)/(1-\tau_i(\gamma_1))}{L_i - L_i^\uparrow(\gamma_1)/(1-\tau_i(\gamma_1))} \right)^{\gamma_1^{a_i} - \gamma_2^{a_i}} \right]}{\ln \left(\frac{\tau_i(\gamma_2)}{\tau_i(\gamma_1)} \right)}$$

Water Vapor Scaling (WVS)

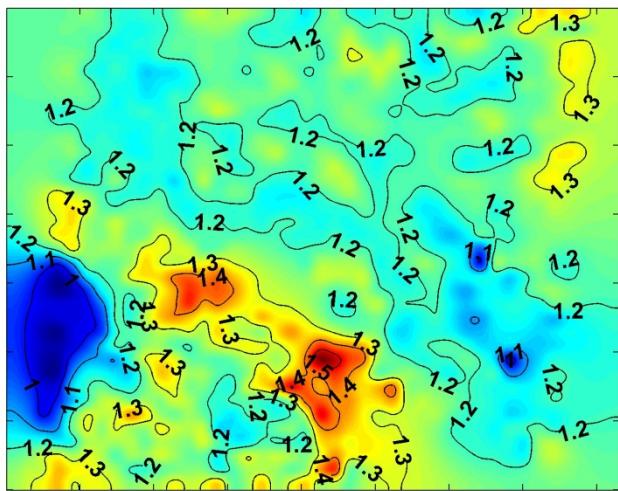
γ is used to modify and improve atmospheric correction terms:

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

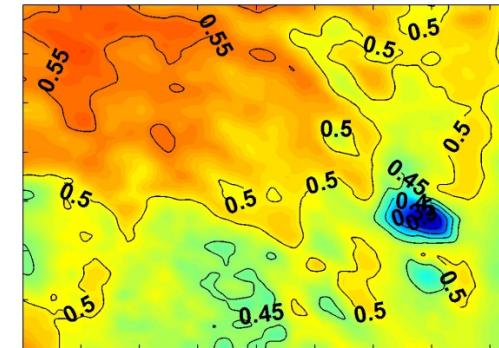
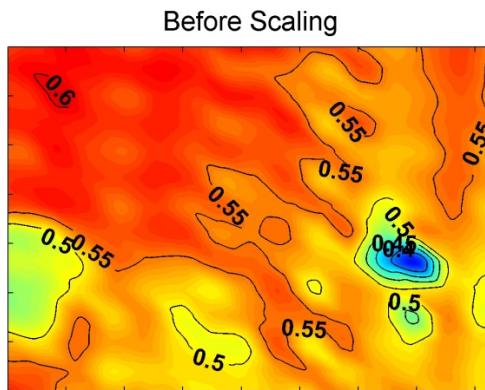
Path Radiance: $L_i^{\uparrow}(\gamma) = L_i^{\uparrow}(\gamma_1) \cdot \frac{1 - \tau_i(\gamma)}{1 - \tau_i(\gamma_1)}$

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

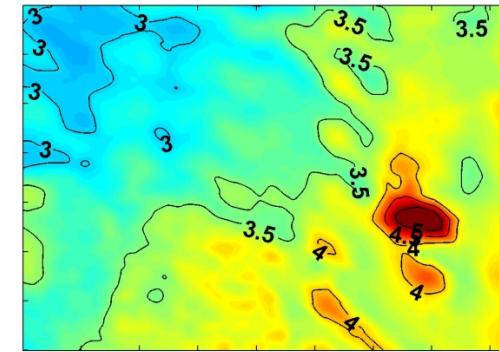
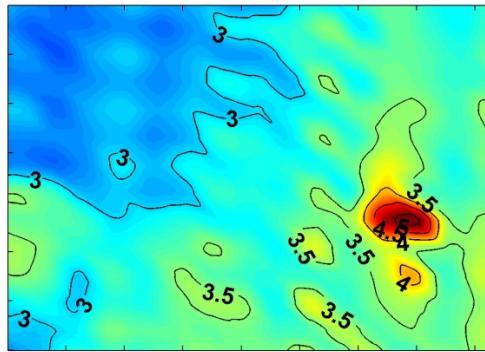
WVS Scaling Factor, γ



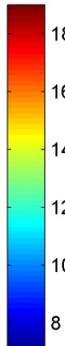
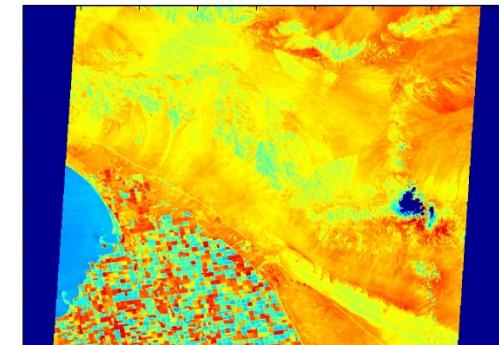
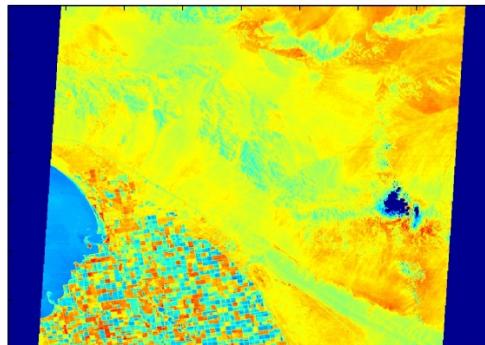
Transmittance



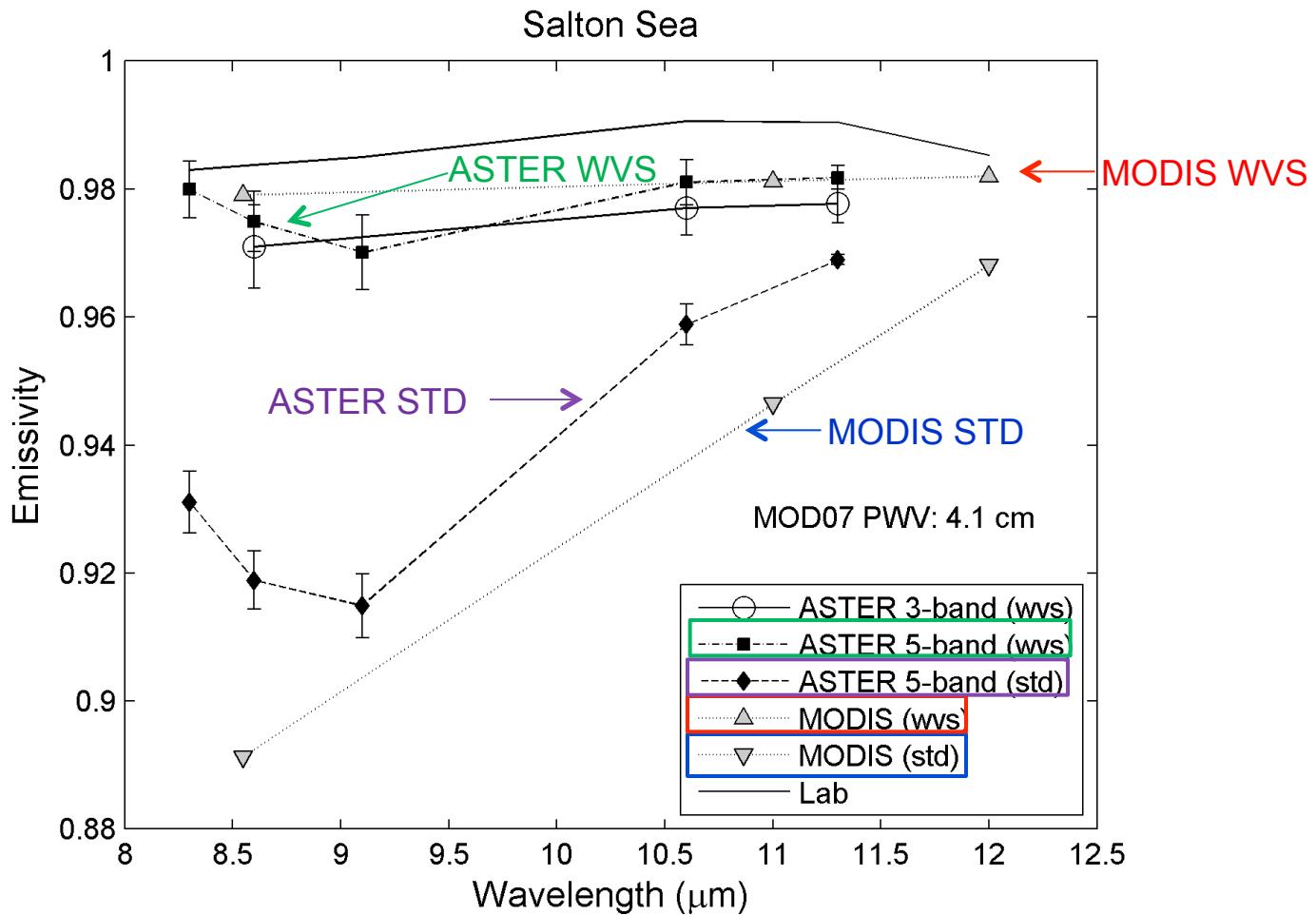
Path Radiance

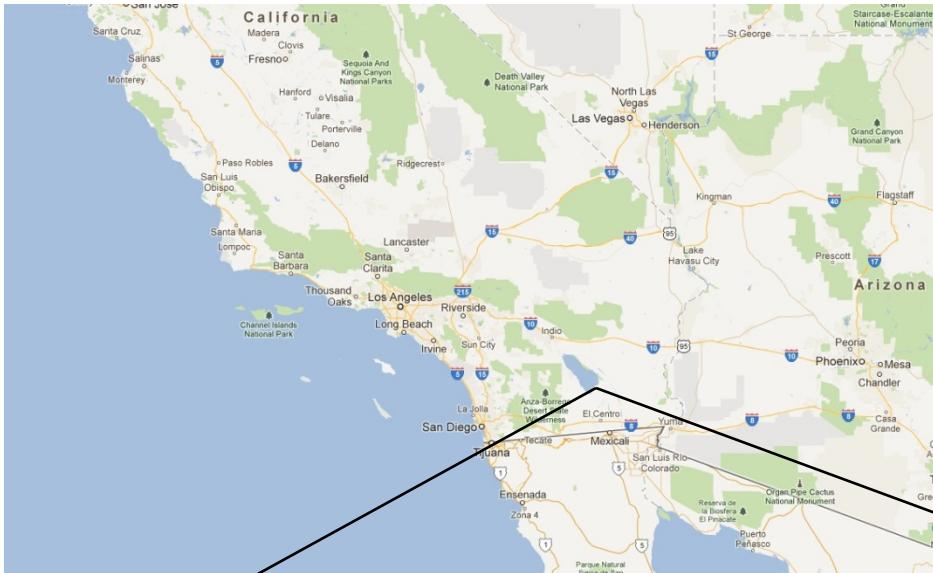


Surface Radiance



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

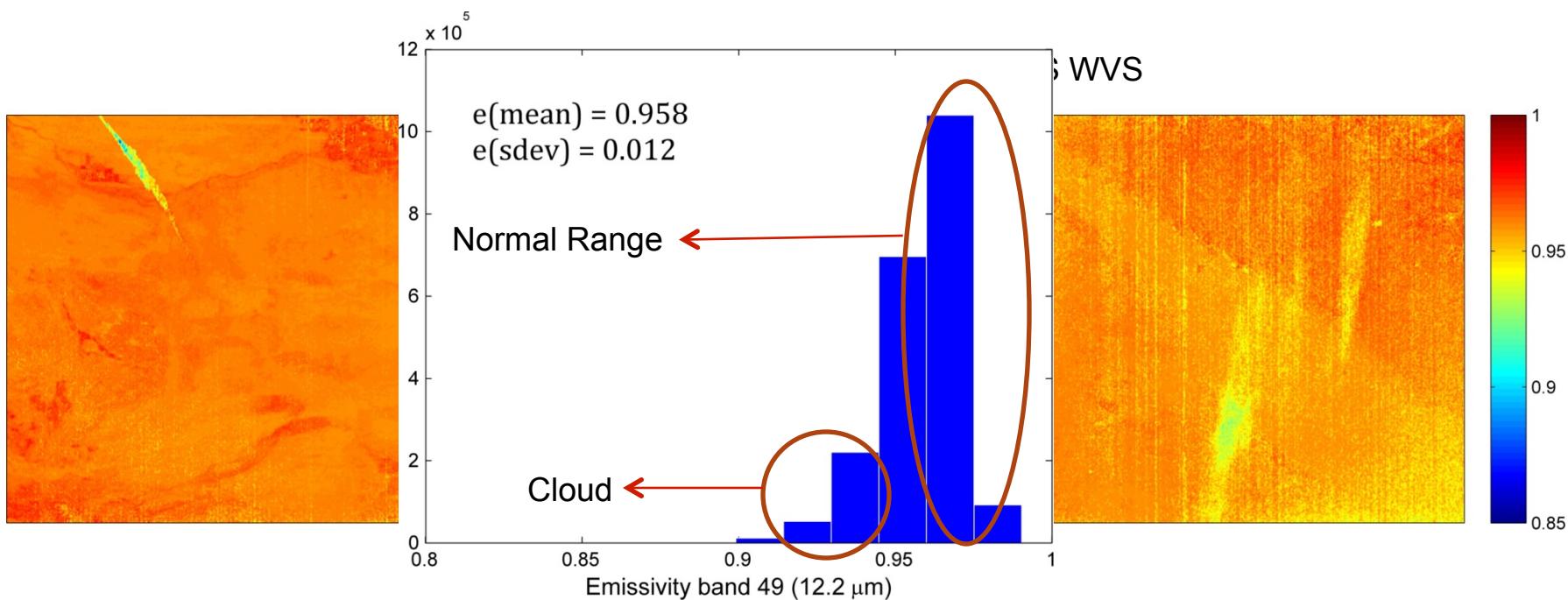
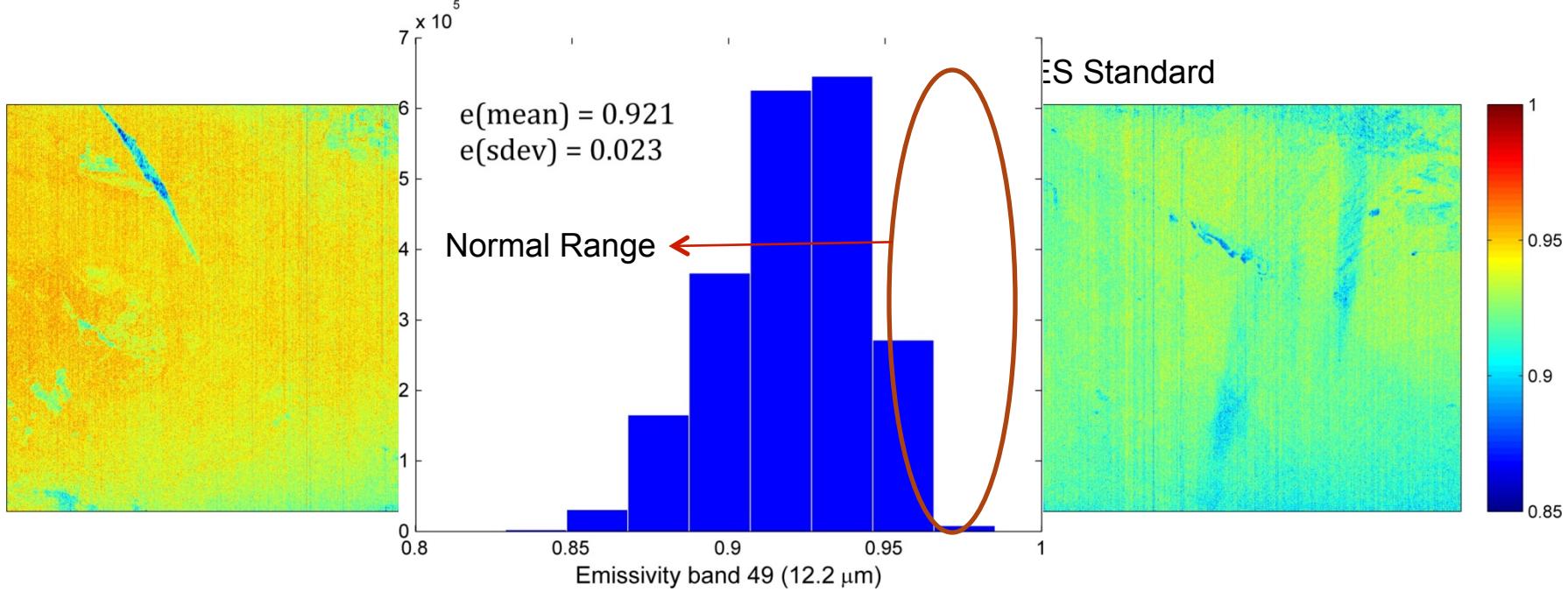




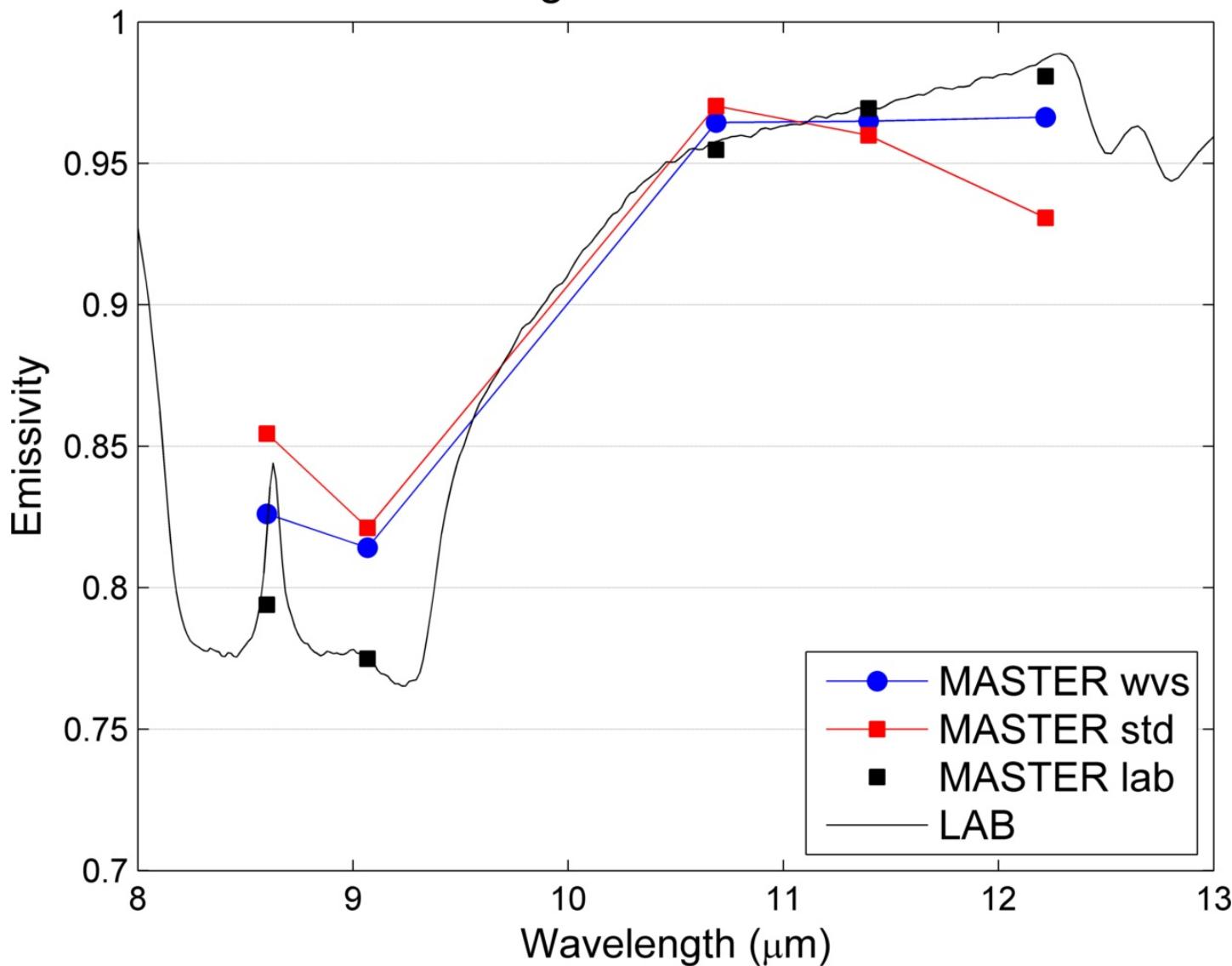
MASTER WVS test

MASTERL1B_0395000_03_20030805_1745_1753_V02

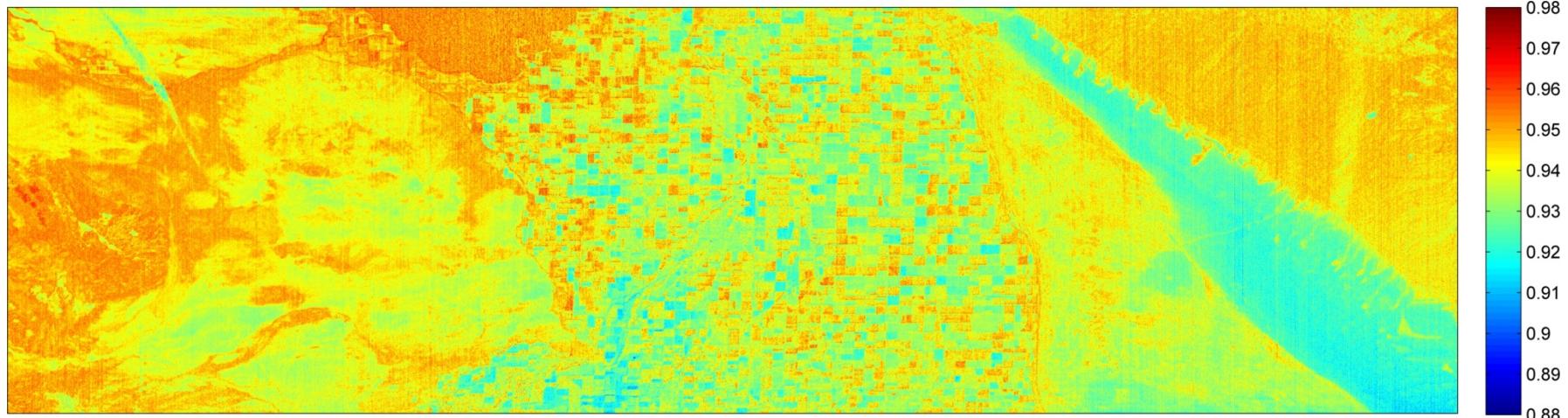




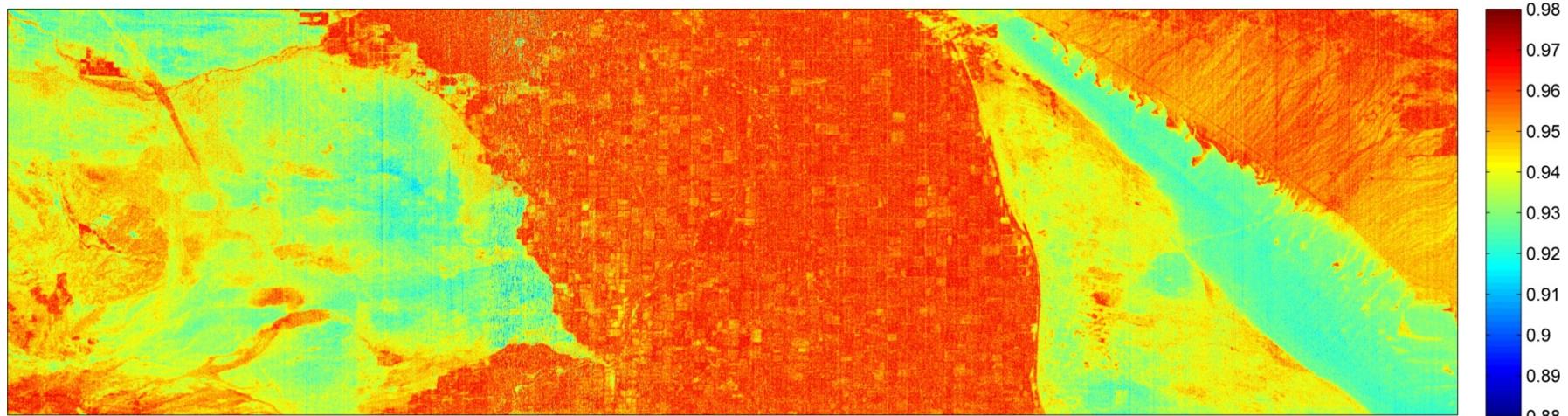
Algodones dunes



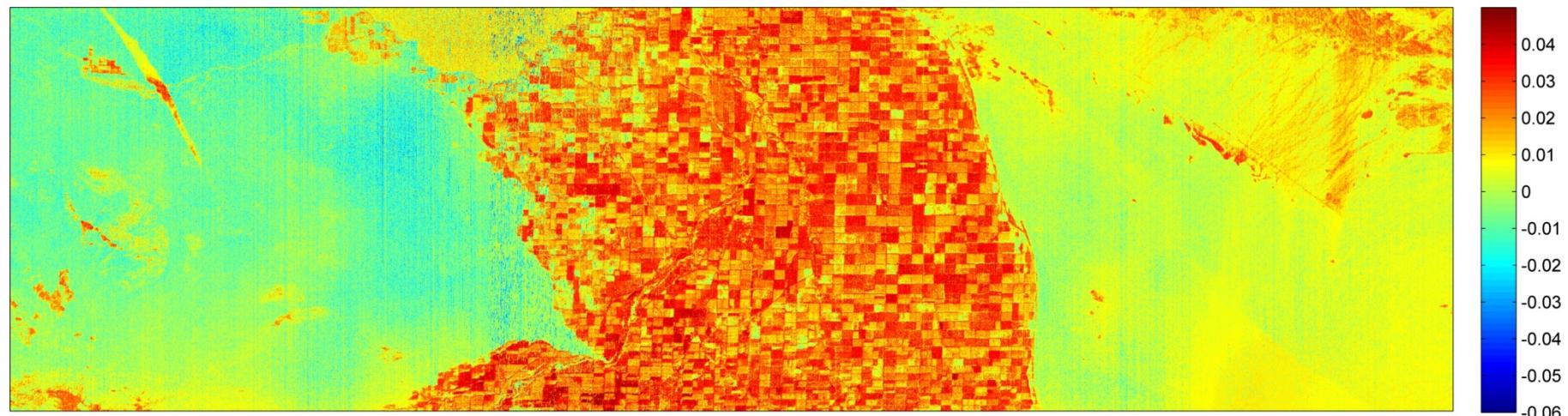
MASTER broadband emissivity (8-12 μm) -- TES Standard



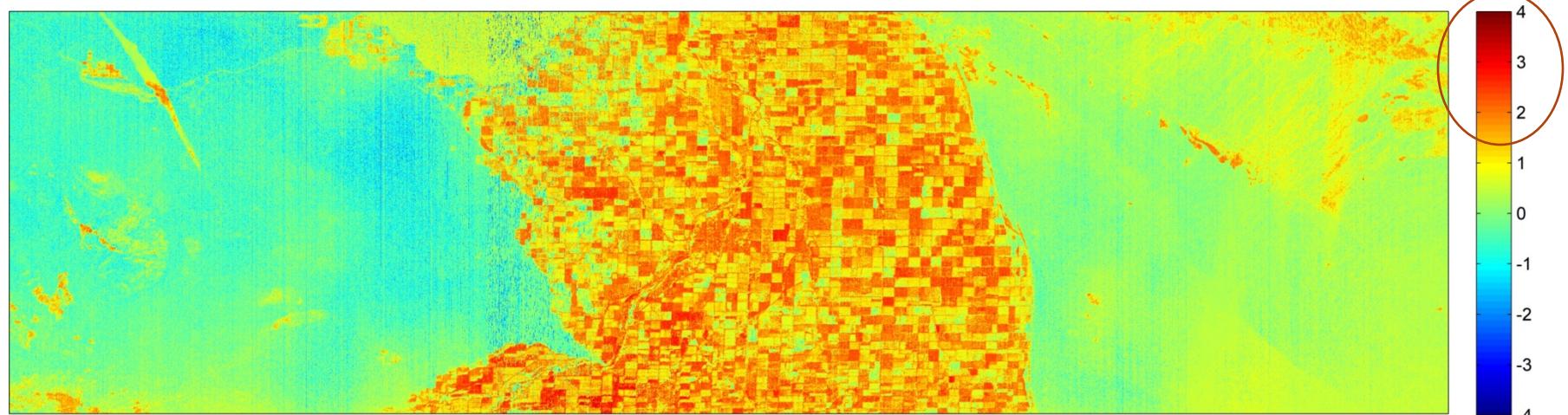
MASTER broadband emissivity (8-12 μm) -- TES WVS



Broadband emissivity difference (WVS – Standard)

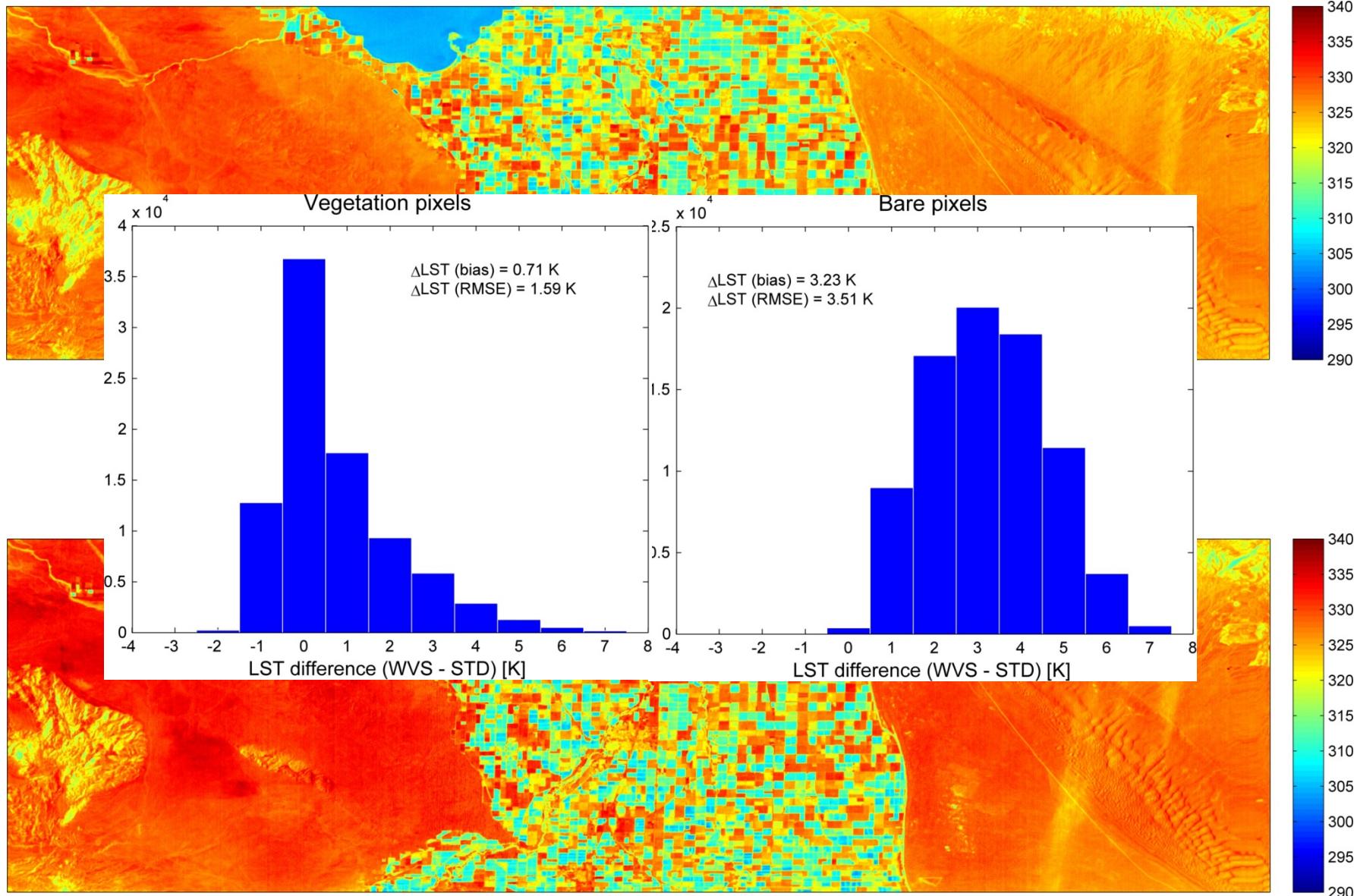


Change in Net Longwave Radiation (Wm^{-2})**



**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:

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

Observed Radiance

➤ **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)