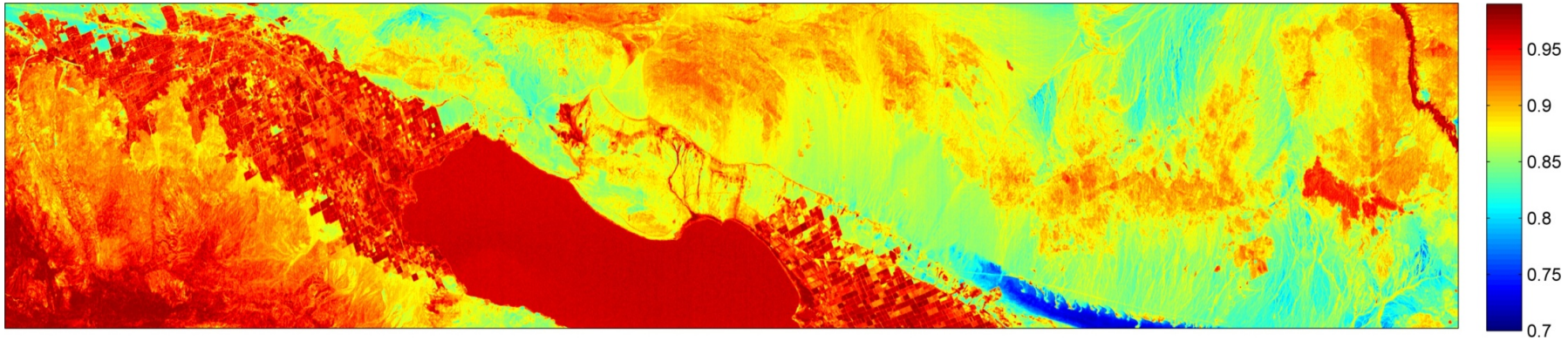
National Aeronautics and Space Administration

The HyspIRI Preparatory Airborne Campaign MASTER Level 2 Temperature and Emissivity Products



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2013 HyspIRI Science Workshop,15 - 17 October 2013, Pasadena, CA

Outline

- Relevance to HyspIRI TIR
- MASTER L2 online ordering tool
- MASTER TIR Retrieval Algorithm
- Example with improved Water Vapor Scaling (WVS) model
- AVIRIS-derived water vapor initial results
- Summary

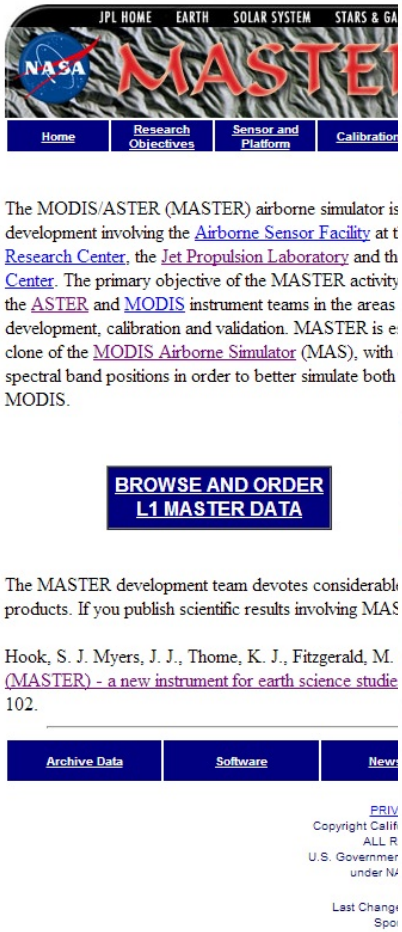
Relevance to HysplRI

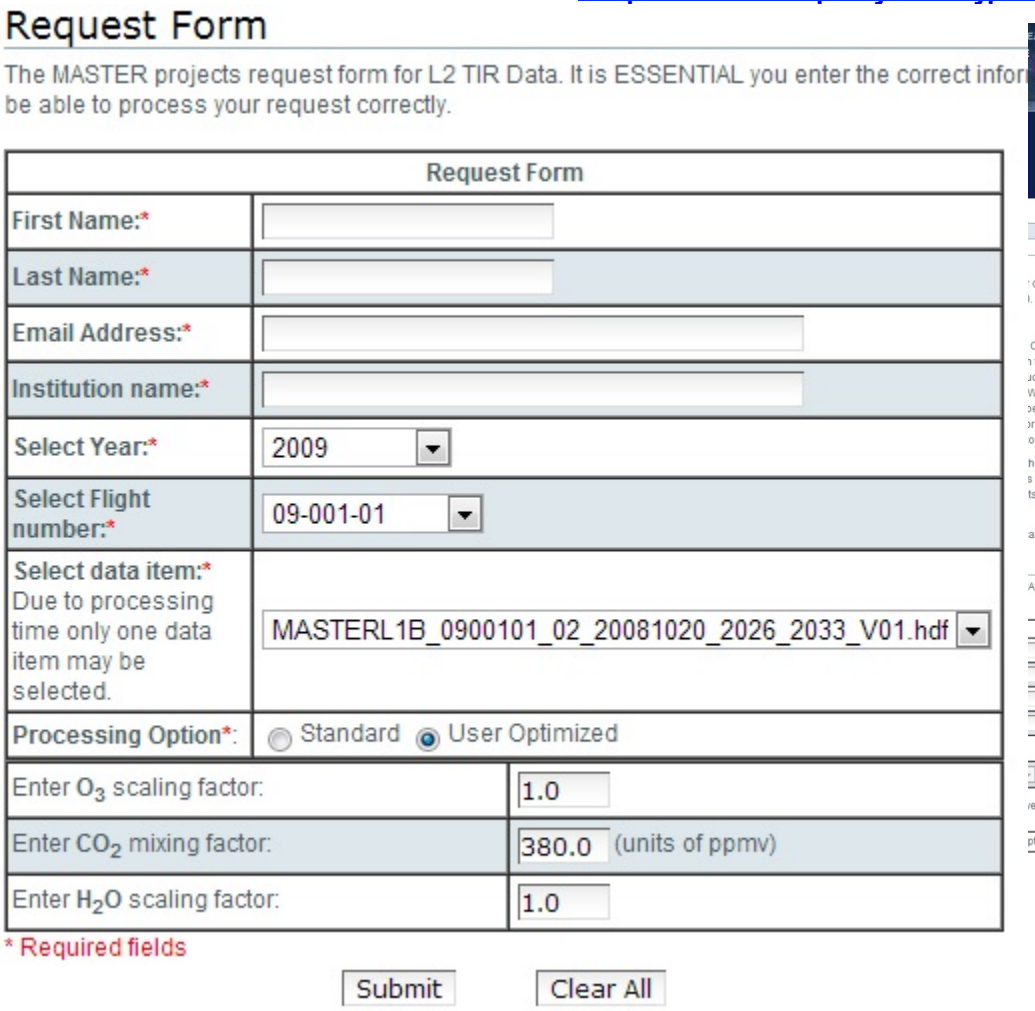
- MASTER TIR L2 online ordering tool:
  - Support for HysplRI prep. airborne activities research (FY13-15)
  - Available for all pre-existing MASTER data
- MASTER L2 TIR retrieval (PyMASTER)
  - TES + Water Vapor Scaling (WVS) method
  - Closer simulation of HysplRI-TIR L2 algorithms

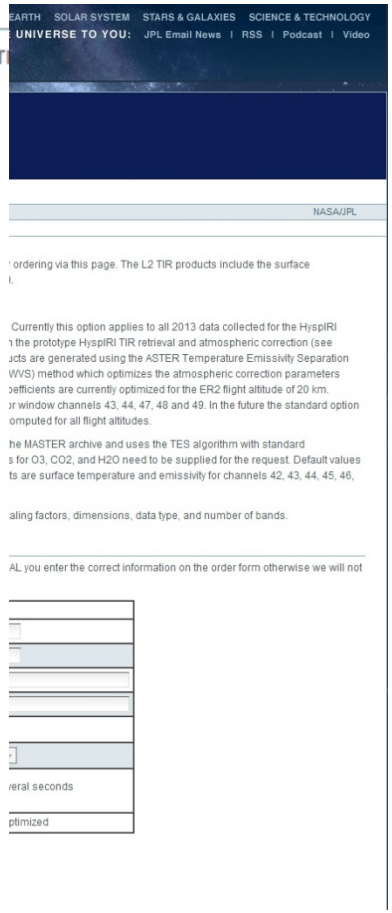
(e.g. ATBDs at http://hyspiri.jpl.nasa.gov/documents)

MASTER L2 TIR online ordering tool

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







1) Standard: All 2013 HyspIRI airborne data retrieved with TES+WVS
2) User-optimized: Pre-2013 data using TES, optimization necessary (H2O, O3)

Thermal Infrared Radiative Transfer

At-sensor Radiance

Surface Radiance

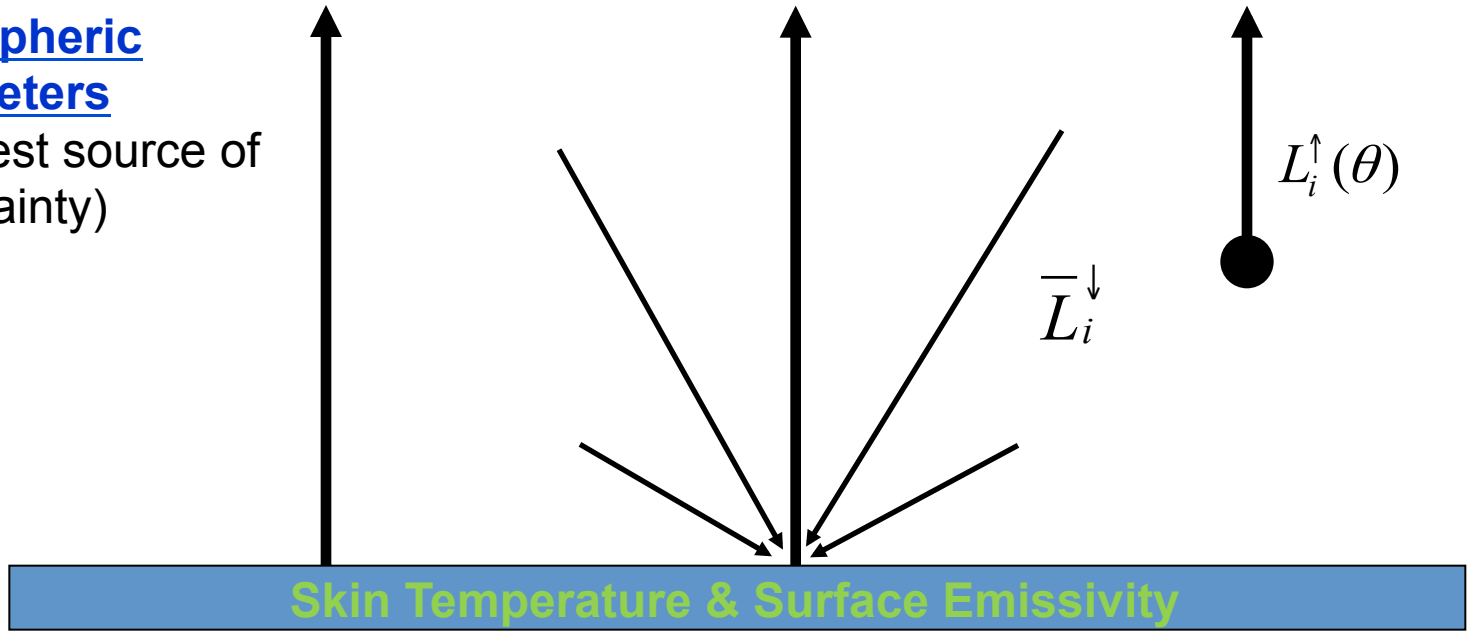
$$L_i(\theta) = \tau_i(\theta) \cdot e_i \cdot B_i(T_S) + \tau_i(\theta) \cdot (1 - e_i) \cdot \overline{L}_i^{\downarrow} + \int B_i(T(P)) d\tau_i$$

Surface Emission

Surface Reflection

Atmospheric Emission

Atmospheric Parameters
(Greatest source of Uncertainty)



Atmospheric Correction

Observed Radiance

Surface 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:** $\tau_i(\theta)$ $L_i^{\uparrow}(\theta)$ $L_i^{\downarrow}(\theta)$

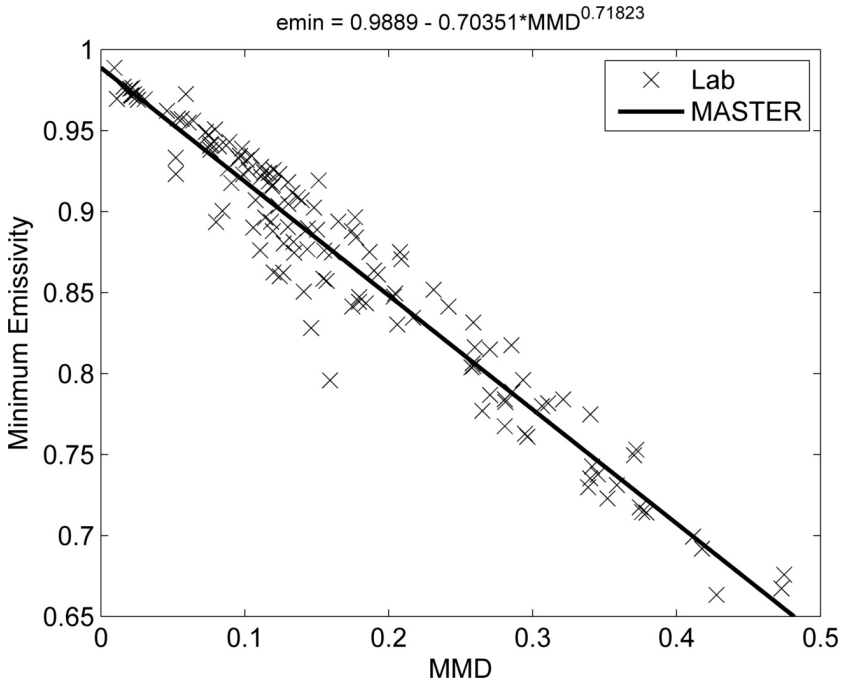
- Radiative transfer code – MODTRAN5.2
- Atmospheric profiles - NCEP (6-hourly, 1º spatial, 26 vertical levels)
- Digital Elevation data - ASTER GDEM v2

Band-dependent Temperature Emissivity Separation (TES) Calibration curves

TES algorithm can be run for MASTER TIR bands with constraints:

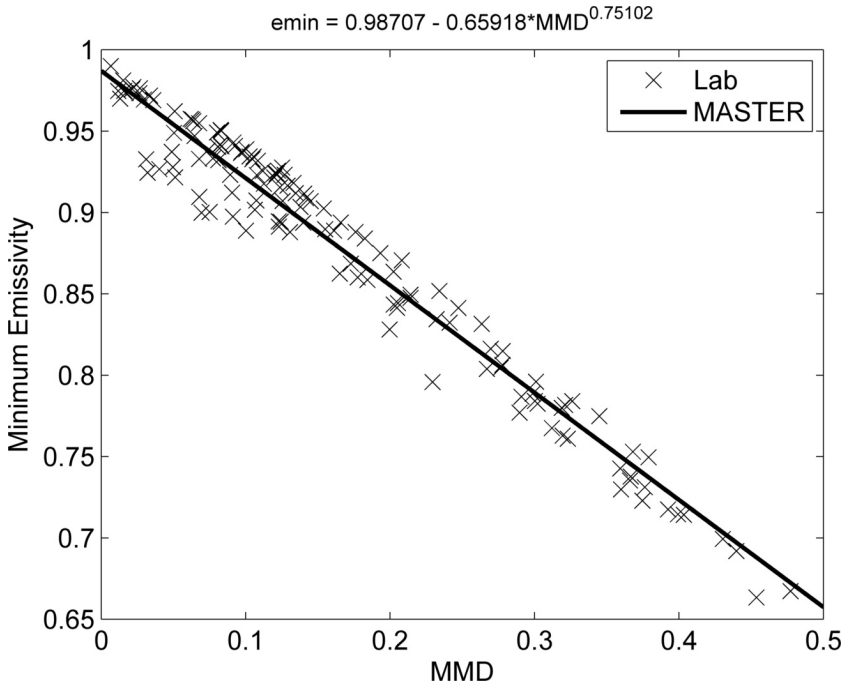
1. Minimum of 3 bands required
2. At least one band between 11-12 µm (48 or 49)
3. At least one band between 8 - 9.5 µm (43 or 44)

Bands 43, 44, 47, 48



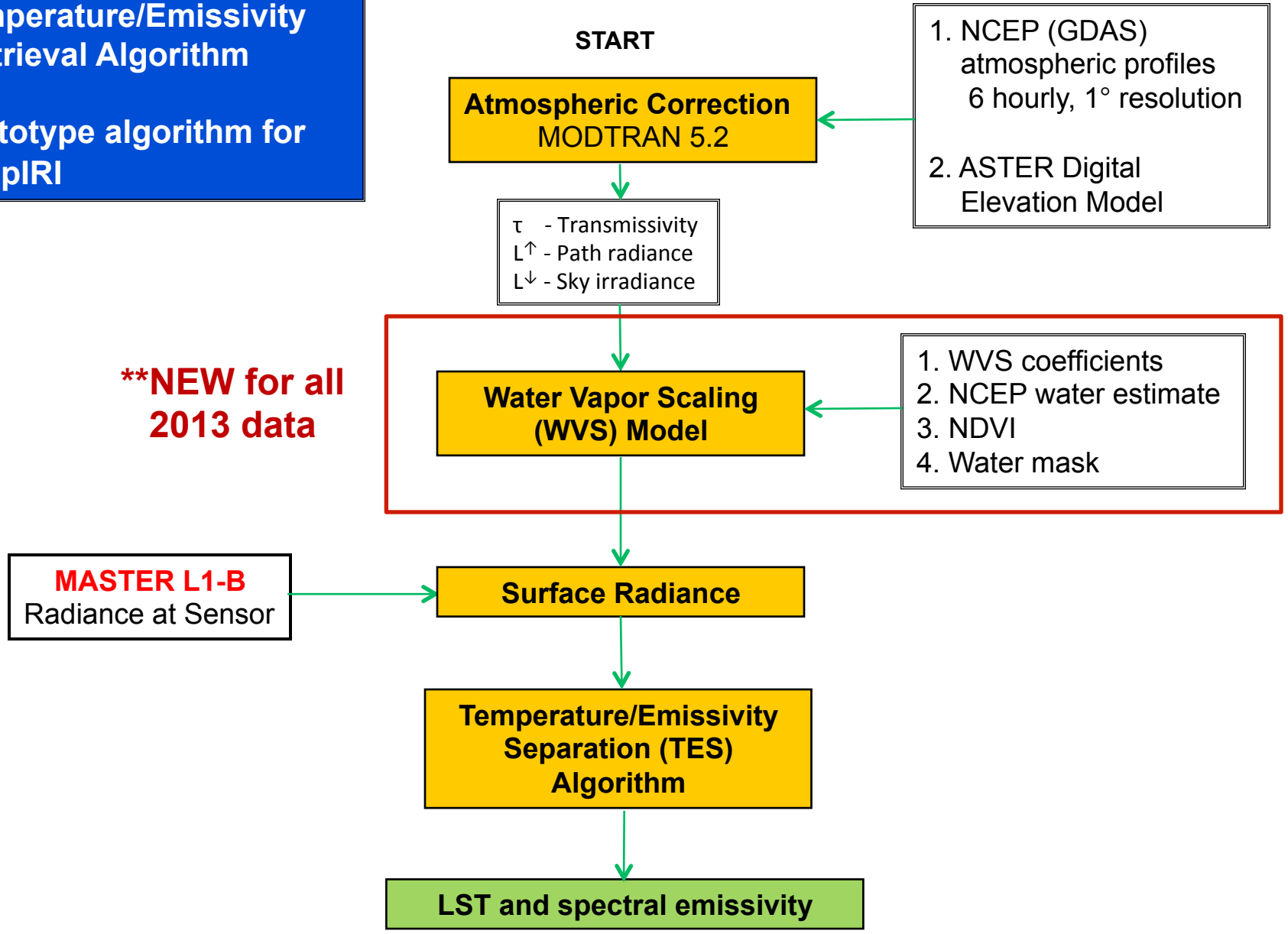
Min – Max Emissivity

Bands 43, 44, 49

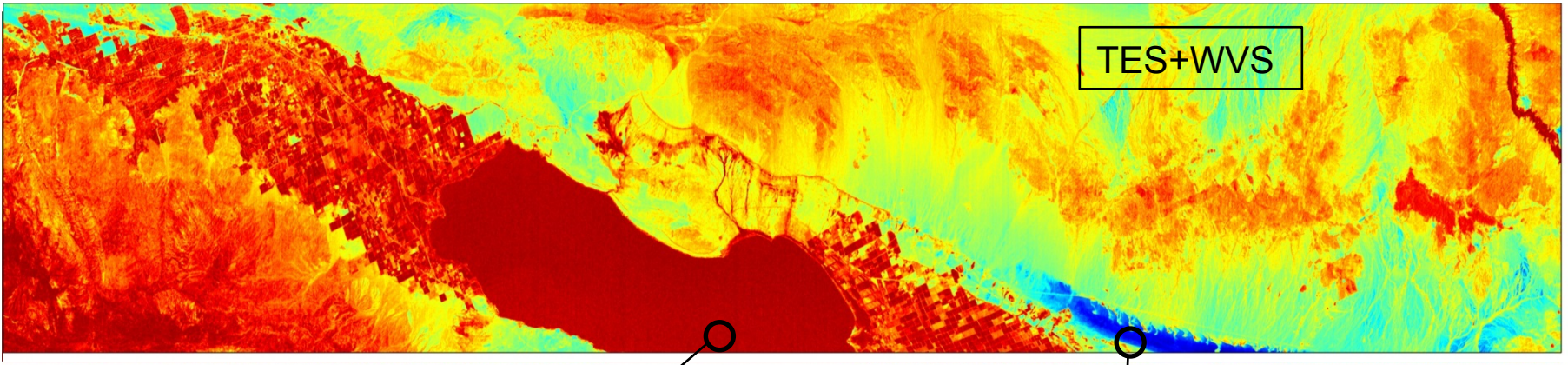


Min – Max Emissivity

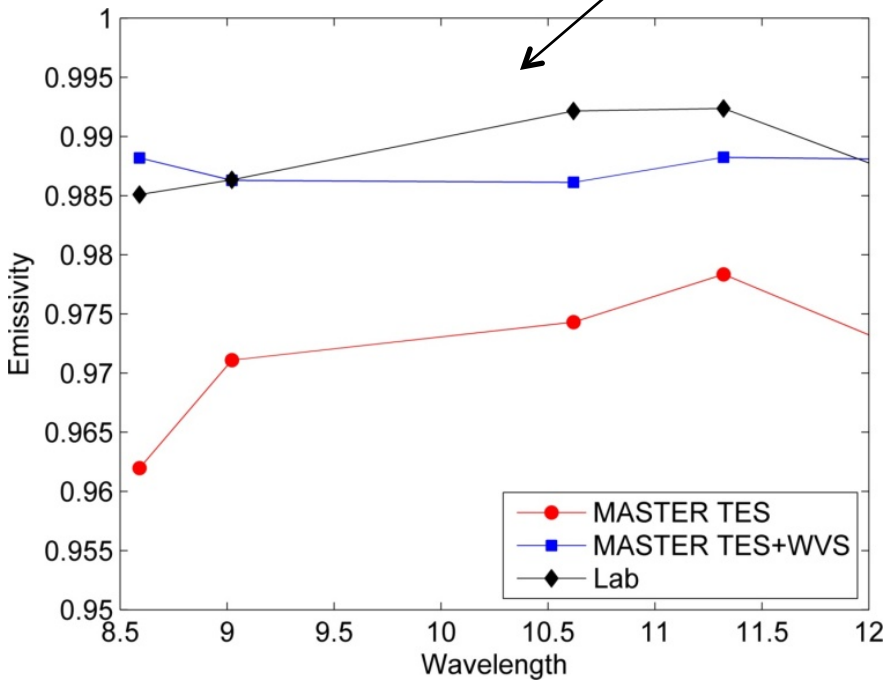
- **PyMASTER Land Surface Temperature/Emissivity Retrieval Algorithm**
- **Prototype algorithm for HysplRI**



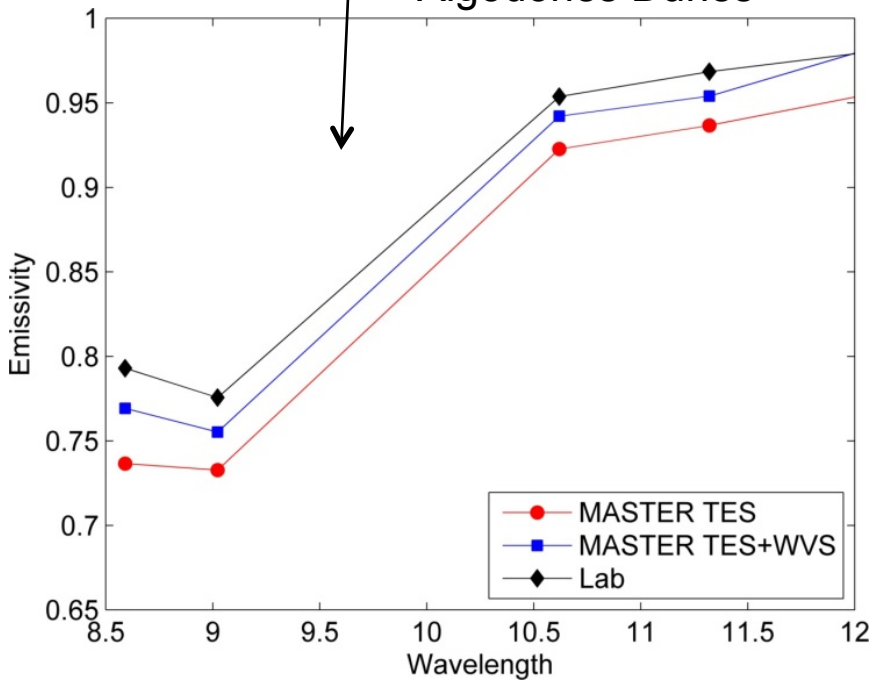
Emissivity band 44 (9 micron) - MASTERL1B_1394100_19_20130502_2141_2215_V01



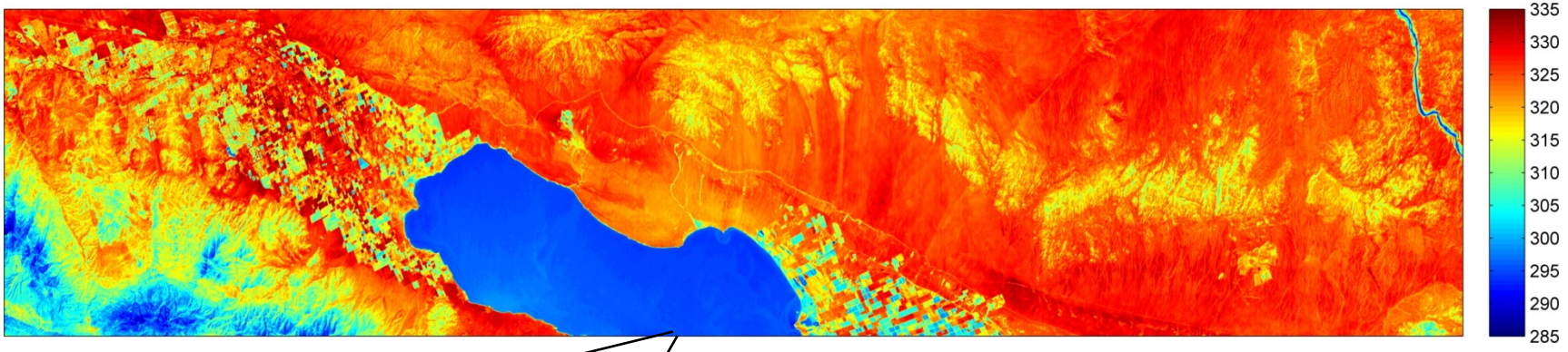
Salton Sea



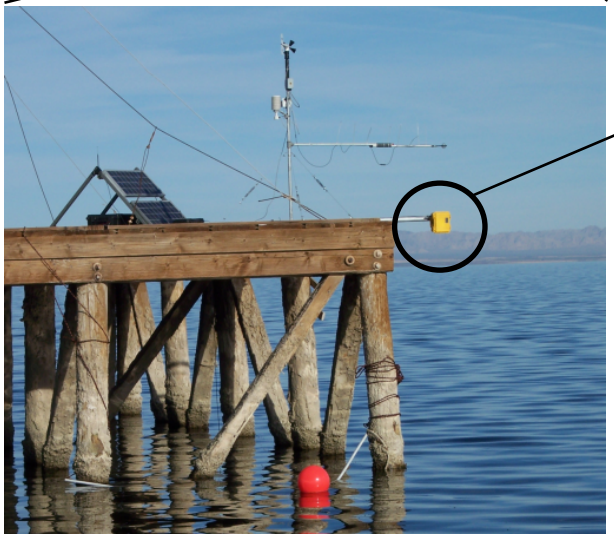
Algodones Dunes



Surface Temperature [K] - MASTERL1B_1394100_19_20130502_2141_2215_V01



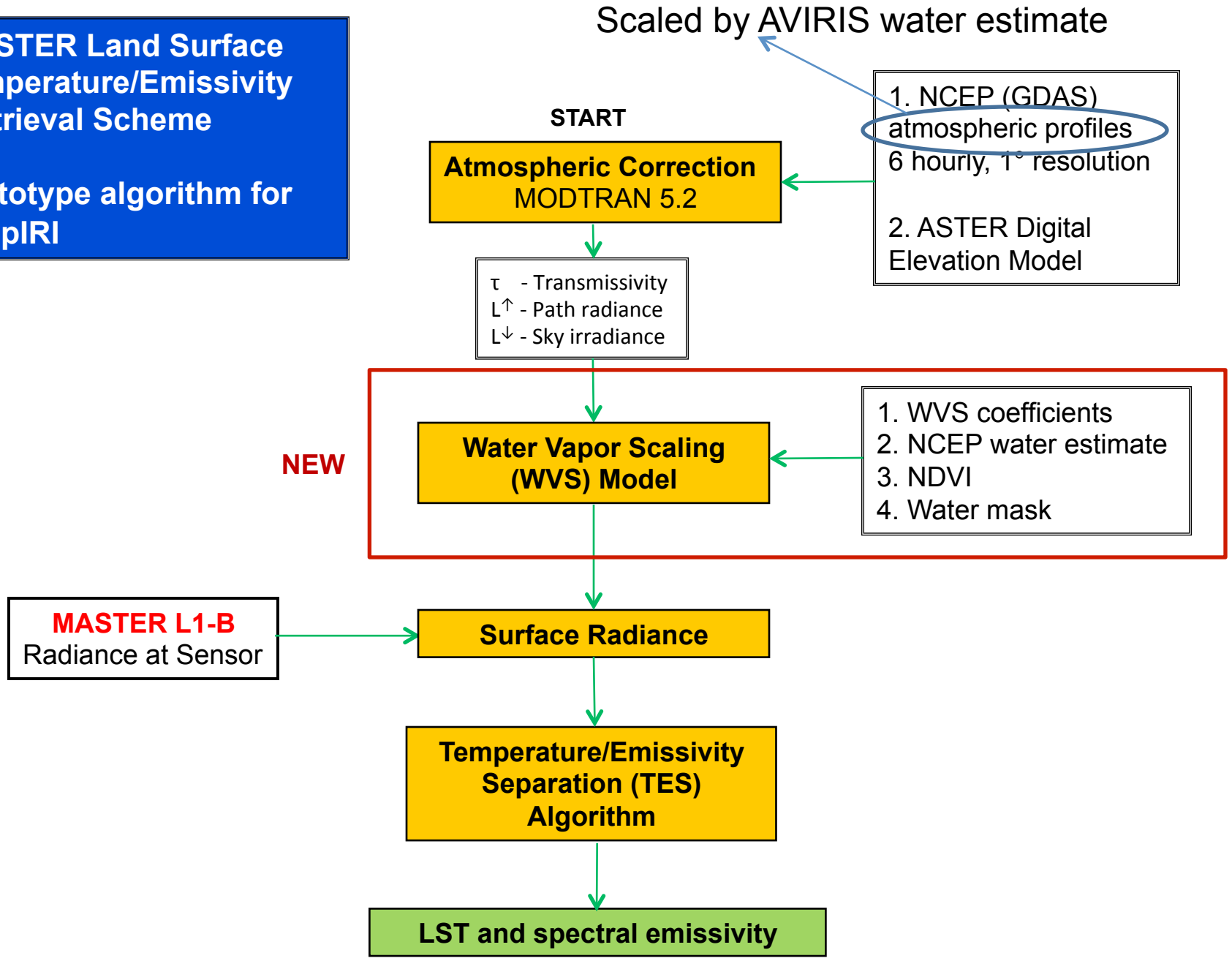
NCEP total water vapor = 0.56 cm

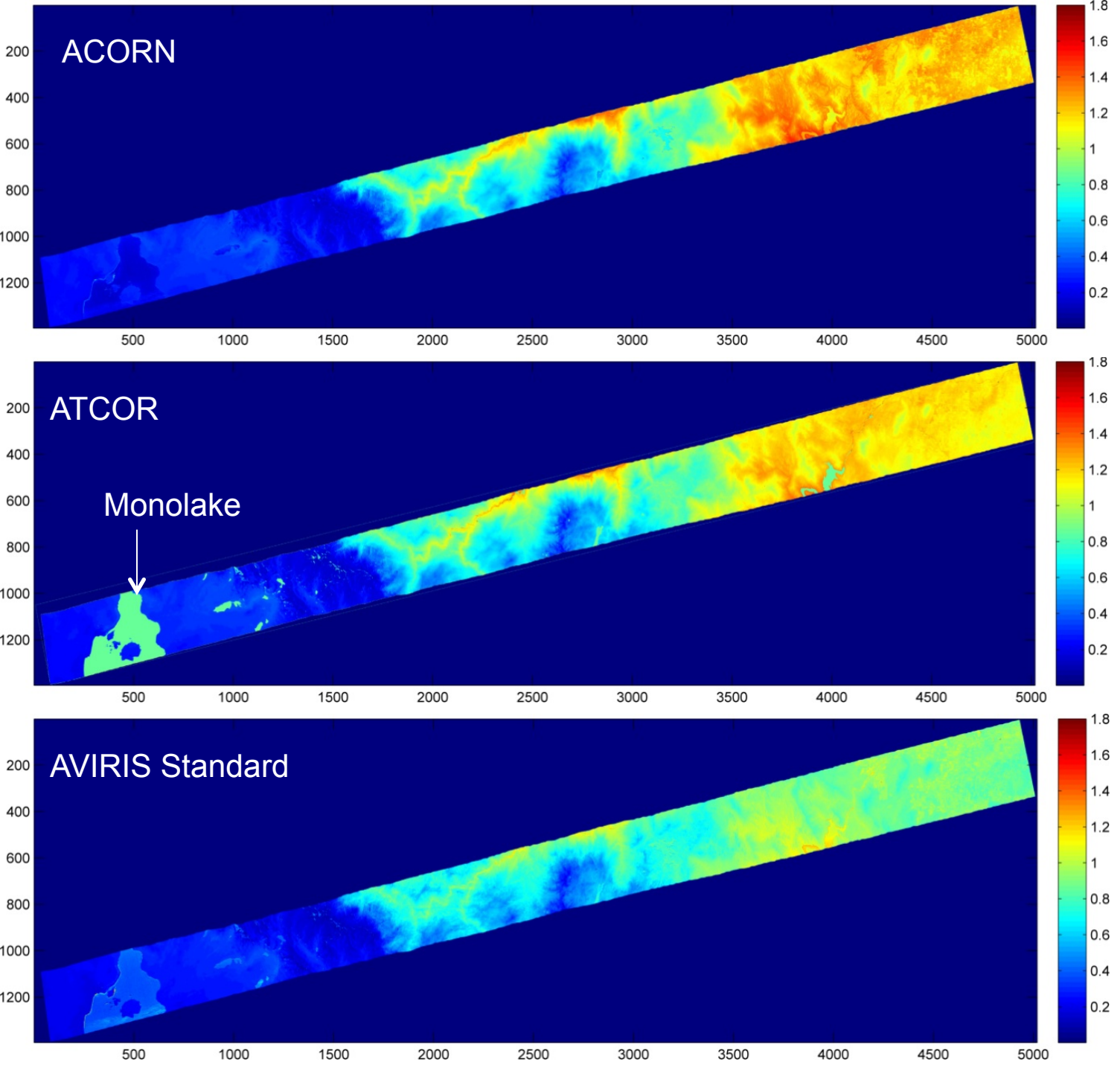


Radiometer Skin Temp	295.35 K
TES +WVS	295.52 K (0.17 K bias)
TES	296.04 K (0.69 K bias)

BUT: On more humid days (3-4 cm) Temperature errors can potentially rise to 3-5 K without WVS!!

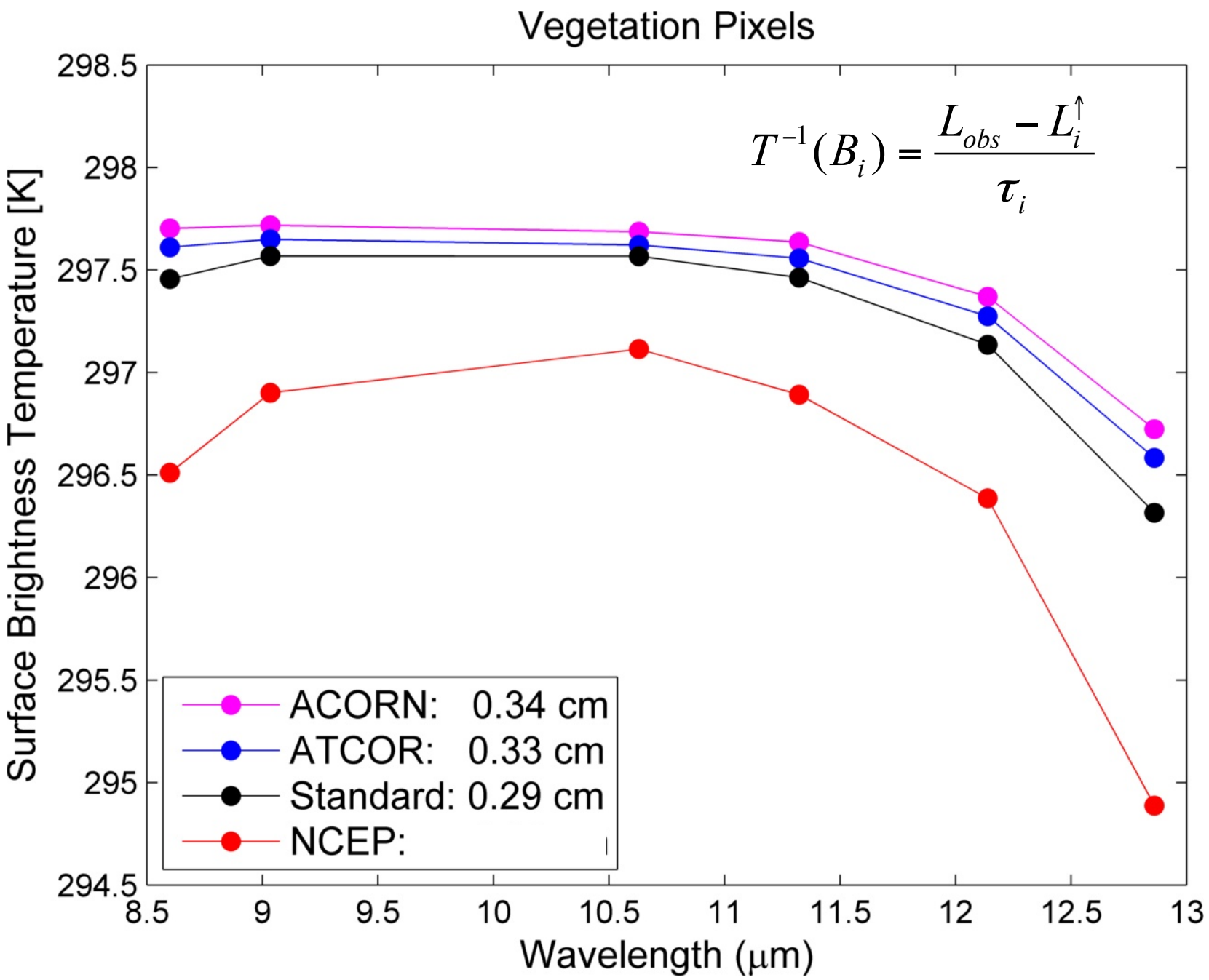
- **MASTER Land Surface Temperature/Emissivity Retrieval Scheme**
- **Prototype algorithm for HyspIRI**

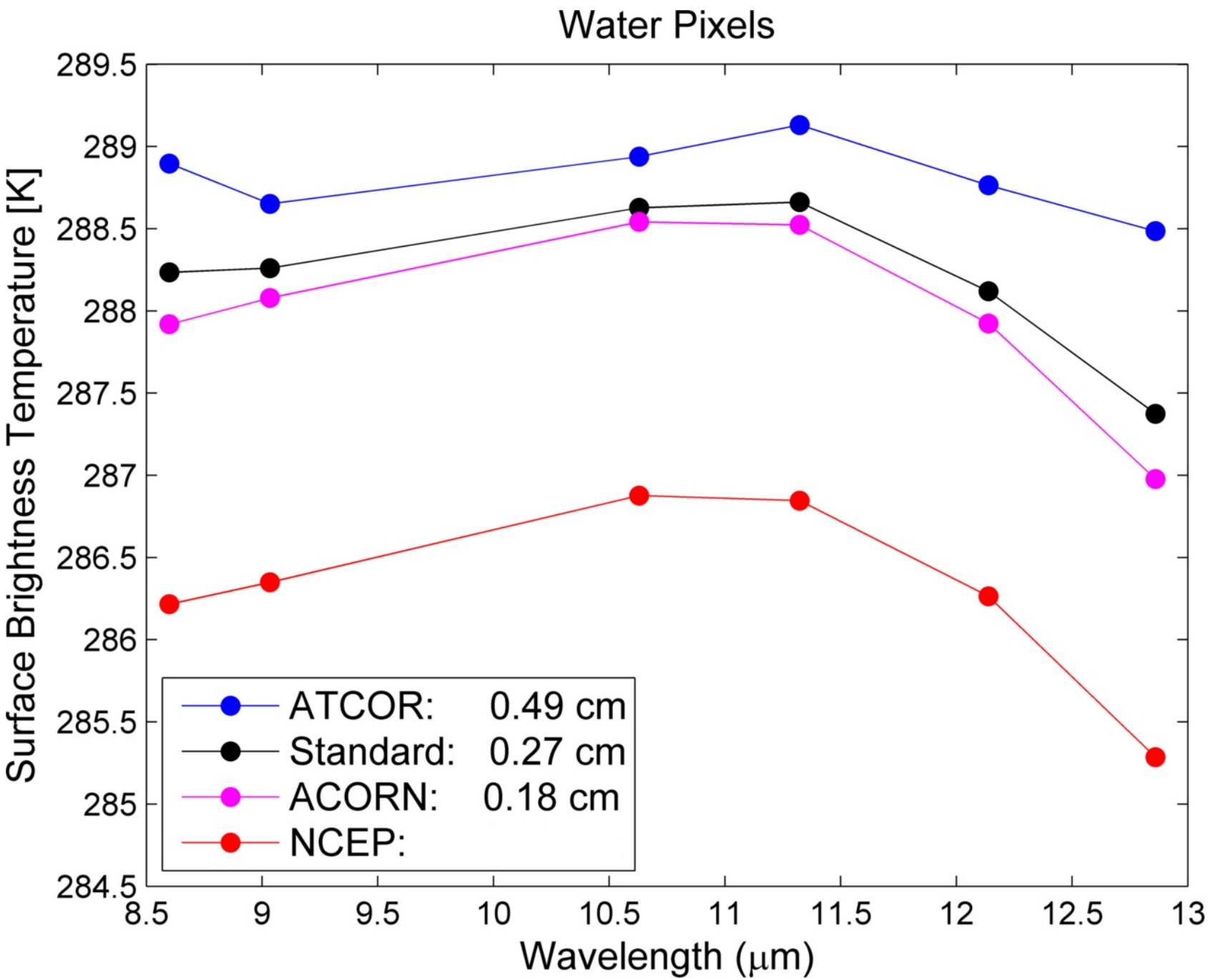




AVIRIS Run 23,
2 May, 2013

Total Water
Column (cm)


Vegetation Pixels
$T^{-1}(B_i) = \frac{L_{obs} - L_i^{\uparrow}}{\tau_i}$
Surface Brightness Temperature [K]
298.5
298
297.5
297
296.5
296
295.5
295
294.5
8.5
9
9.5
10
10.5
11
11.5
12
12.5
13
Wavelength (μm)
ACORN: 0.34 cm
ATCOR: 0.33 cm
Standard: 0.29 cm
NCEP:


Water Pixels
Surface Brightness Temperature [K]
289.5
289
288.5
288
287.5
287
286.5
286
285.5
285
284.5
8.5
9
9.5
10
10.5
11
11.5
12
12.5
13
Wavelength (μm)
ATCOR: 0.49 cm
Standard: 0.27 cm
ACORN: 0.18 cm
NCEP:

Summary

- Online ordering tool available for ordering MASTER L2 TIR data:
  - 'Standard': All 2013 HyspIRI data (with WVS)
  - 'User-optimized': All other data (old algorithm)
- Atmospheric correction method (WVS) implemented for MASTER 2013 HyspIRI airborne data (Improved emissivity spectra and more accurate temperatures)
- Initial AVIRIS derived water vapor results show improved atmospheric correction vs NCEP standard

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

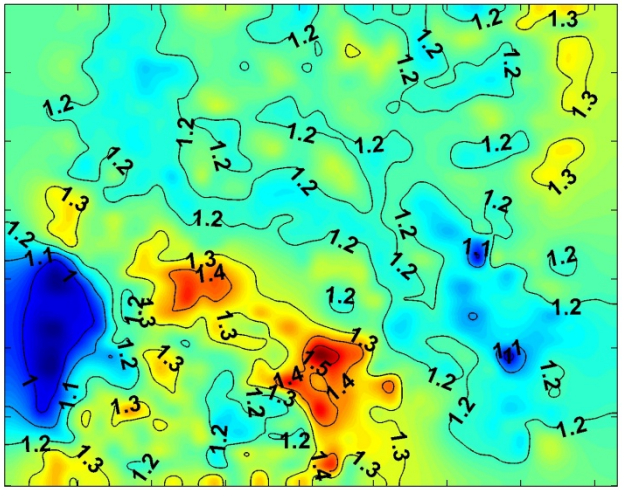
$$T_{g,i} = \alpha_{i,o} + \sum_{k=1}^{n} \alpha_{i,k} T_k$$

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

Scaling factor

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

WVS Scaling Factor, γ



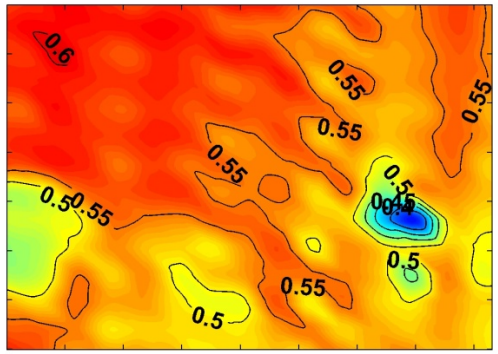
Before Scaling

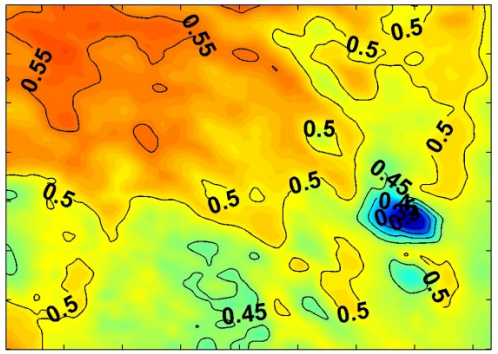
After Scaling

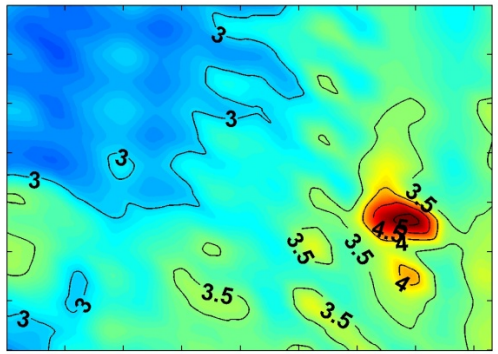
Transmittance

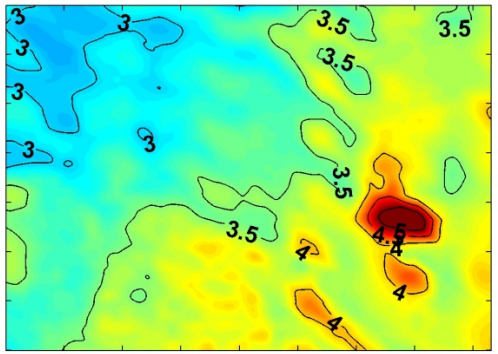
Path Radiance

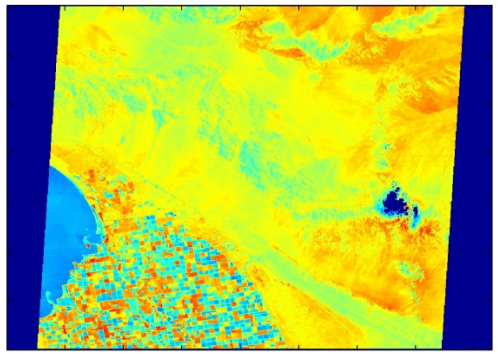
Surface Radiance

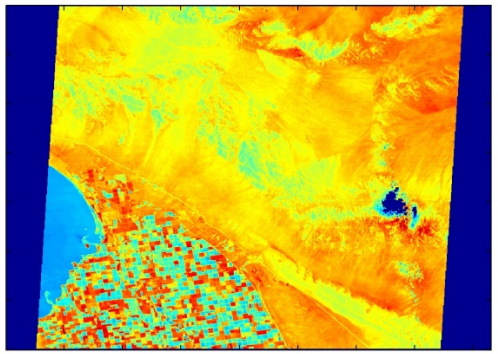


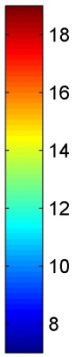












Water Vapor Scaling (WVS)

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

The End

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JPL 400-1278 7/06

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