Land surface temperature and emissivity uncertainty analysis of the HyspIRI instrument over nine pseudo-invariant sand dune sites in the US southwest

Or, “Wait, is that correct?”
Outline

• The Problem
• The (not-so) Tough Choice
• The Right Answer
• Some Initial Results
THE PROBLEM
## Primary MODIS LST&E Products

<table>
<thead>
<tr>
<th>MODIS LST Products</th>
<th>ATBD Accuracy</th>
<th>Dimensions</th>
<th>Spatial Resolution</th>
<th>Temporal Resolution</th>
<th>Algorithm</th>
<th>Output Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOD11_L2</td>
<td>1 K</td>
<td>2030 lines 1354 pixels/line</td>
<td>1km at nadir</td>
<td>Swath 2x daily</td>
<td>Split-Window</td>
<td>- LST - Emissivity (bands 31, 32)</td>
</tr>
<tr>
<td>MOD11B1</td>
<td>1 K</td>
<td>200 rows 200 columns</td>
<td>~5 km (v4) ~6 km (v5)</td>
<td>Sinusoidal 2x daily</td>
<td>Day/Night</td>
<td>- LST - Emissivity (bands 20-23, 29, 31,32)</td>
</tr>
<tr>
<td>MOD11C3</td>
<td>1 K</td>
<td>360°x180° Global</td>
<td>0.05° x 0.05°</td>
<td>Monthly</td>
<td>Day/Night + Split-Window</td>
<td>- LST - Emissivity (bands 20-23, 29, 31-32)</td>
</tr>
<tr>
<td><strong>MOD21</strong></td>
<td>1 K</td>
<td>2030 lines 1354 pixels/line</td>
<td>1km at nadir</td>
<td>Swath 2x daily</td>
<td>Temperature Emissivity Separation (TES)</td>
<td>- LST - Emissivity (bands 29, 31, 32)</td>
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** New MODIS LST product developed at JPL
MOD21 Land Surface Temperature [K], 8-day mean, August 2004
LST Comparisons

MOD11_L2 Land Surface Temperature: August 2004

MOD21 Land Surface Temperature: August 2004

MOD21 - MOD11_L2 Land Surface Temperature: August 2004

ΔT = 1.59 ± 1.26 K

LST Differences (MOD21 - MOD11_L2) [K]
The Big Question

How do we know what’s right?
Multiple Choice Answers

• Temperature Based Validation
• Radiance Based Validation
Temperature Based Validation

- LST can vary at very small scale within a pixel
- Complex validation – requires measuring the temperature at multiple points within the spatial area of a pixel (m’s to km’s) for validation
Temperature Based Validation
Radiance Based Validation

- Requires compositionally homogeneous pixel
- Easier validation – comparison of sample emissivity + LST to measured TOA radiance
  - LST is initially taken from LST&E product & then adjusted until calculated radiance matches measured radiance
Radiance-based LST Validation

HyspIIRI

T_b(obs) CCR’s

MODTRAN 5.2

T_b(calc) + NEΔT

NCEP (GDAS) Profiles

Lab Field Emissivity

Surface

T_s (HyspIIRI retrieved)

WV Absorption

Clear

AIRS spectra shown as example

27 Channels (~12 μm)
848 – 856 cm⁻¹

3 Channels (~11 μm)
904 – 912 cm⁻¹

NCEP Profile Quality Test

ΔT_b (obs) = T_b11(obs) - T_b12(obs)
ΔT_b (calc) = T_b11(calc) - T_b12(calc)

ΔT_b = ΔT_b(obs) - ΔT_b(calc)

-0.5 K < ΔT_b < 0.5 K

T_s′ = T_s ± 2K

YES

NO

QUIT!

T_rad = interp([T_s', T_b(calc)], [T_b', T_b, T_b])

Theoretically Correct Surface Temperature
Emissivity and LST validation plans for HyspIRI: Pseudo-Invariant sand dune sites

- Emissivity is notoriously difficult to validate. Typically large homogeneous areas with known composition are required (possible with HyspIRI – 60m)
- Sand-dune sites show consistent mineralogy and physical properties over long time periods
- Rapid infiltration after rains, and drying of surface does not lead to cracks
- Mineralogy and composition can be accurately determined using lab reflectance and X-ray diffraction measurements at JPL

**Sand-dune validation sites:**

1. Algodones Dunes, El Centro, California
2. Coral Pink Sand Dunes, Utah
3. Great Sands National Park, Colorado
4. Kelso Dunes, Mojave Desert, California
5. Killpecker Dunes, Wyoming
6. Little Sahara, Utah
7. Sand Hollow State Park, Utah
8. Stovepipe Wells Dunes, Death Valley, California
9. White Sands National Monument, New Mexico
THE RESULTS (ON OTHER DATASETS)
AIRS validation
Example ASTER Sand Dune Emissivity Validation Results

## MODIS Validation

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<tr>
<th>Location</th>
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<tbody>
<tr>
<td>Algodones (197 scenes)</td>
<td>-2.6587</td>
<td>2.7871</td>
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<tr>
<td>Great Sands (123 Scenes)</td>
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### Diagrams:
- Algodones
- Great Sands
- Kelso
- Killpecker
- Little Sahara / Lynndyl
- White Sands
MODIS Validation

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Killpecker

Little Sahara / Lynndyl

White Sands
MODIS Validation

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Uncertainties increase above ~2cm Total Column Water (TCW) and with Sensor zenith angle (SZA) due to residual errors in atmospheric correction.
THANK YOU