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

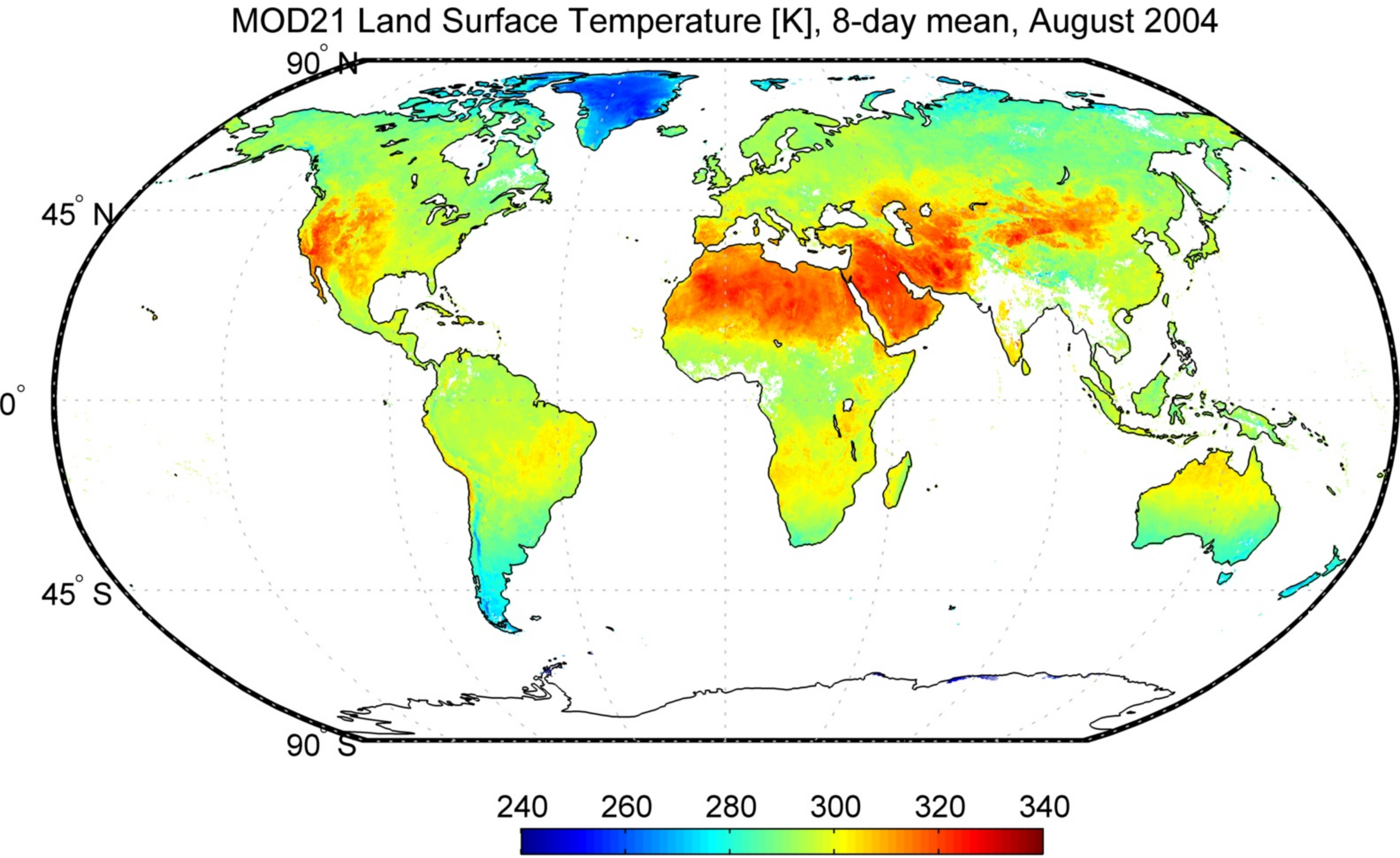
- The Problem
- The (not-so) Tough Choice
- The Right Answer
- Some Initial Results

THE PROBLEM

Primary MODIS LST&E Products

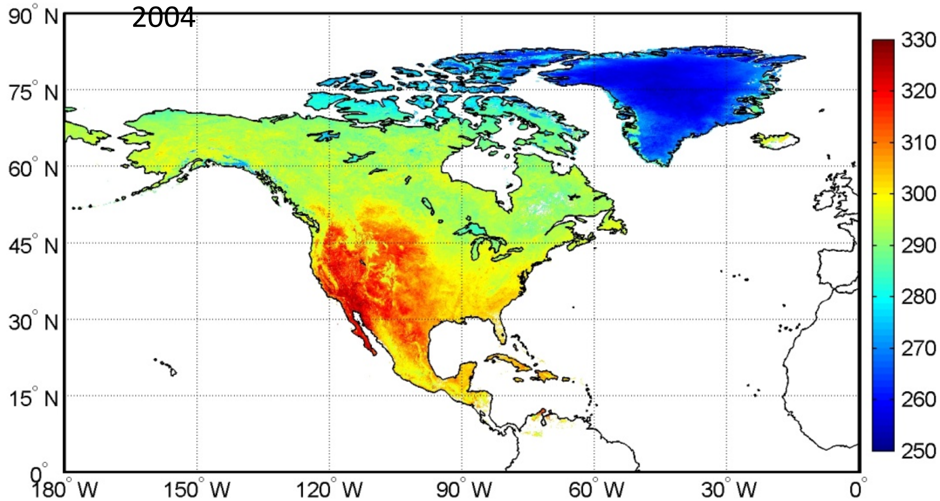
MODIS LST Products	ATBD Accuracy	Dimensions	Spatial Resolution	Temporal Resolution	Algorithm	Output Products
MOD11_L2	1 K	2030 lines 1354 pixels/line	1km at nadir	Swath 2x daily	Split-Window	- LST - Emissivity (bands 31, 32)
MOD11B1	1 K	200 rows 200 columns	~5 km (v4) ~6 km (v5)	Sinusoidal 2x daily	Day/Night	- LST - Emissivity (bands 20-23, 29, 31,32)
MOD11C3	1 K	360ºx180º Global	0.05º x 0.05º	Monthly	Day/Night + Split-Window	- LST - Emissivity (bands 20-23, 29, 31-32)
**MOD21	1 K	2030 lines 1354 pixels/line	1km at nadir	Swath 2x daily	Temperature Emissivity Separation (TES)	- LST - Emissivity (bands 29, 31, 32)

** New MODIS LST product developed at JPL

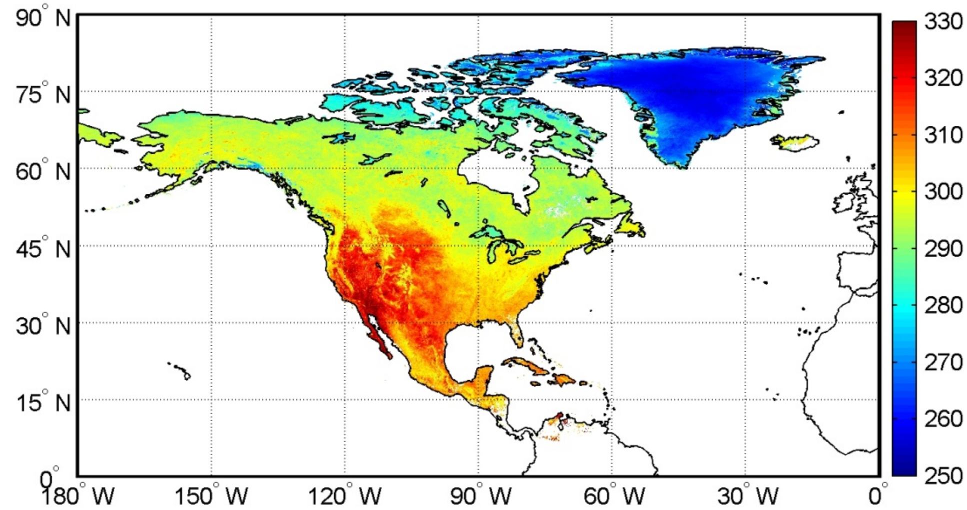

MOD21 Land Surface Temperature [K], 8-day mean, August 2004
90° N
45° N
0°
45° S
90° S
240
260
280
300
320
340

LST Comparisons

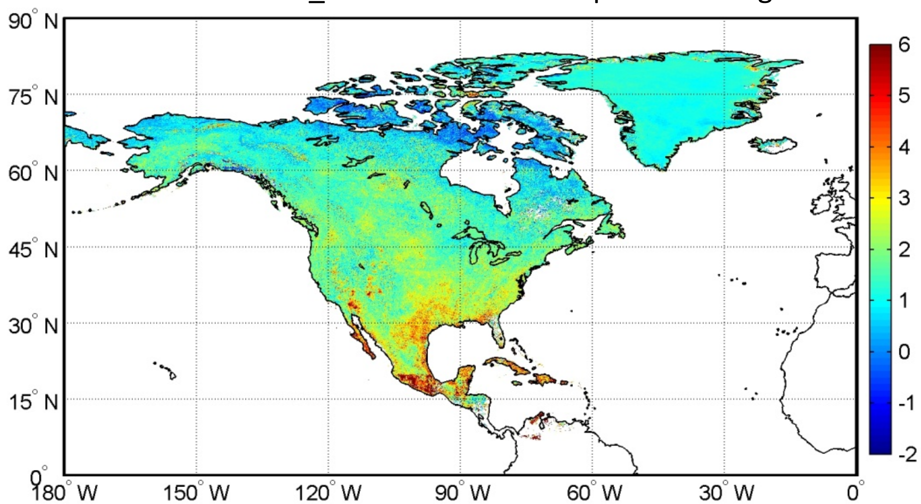
MOD11_L2 Land Surface Temperature: August 2004



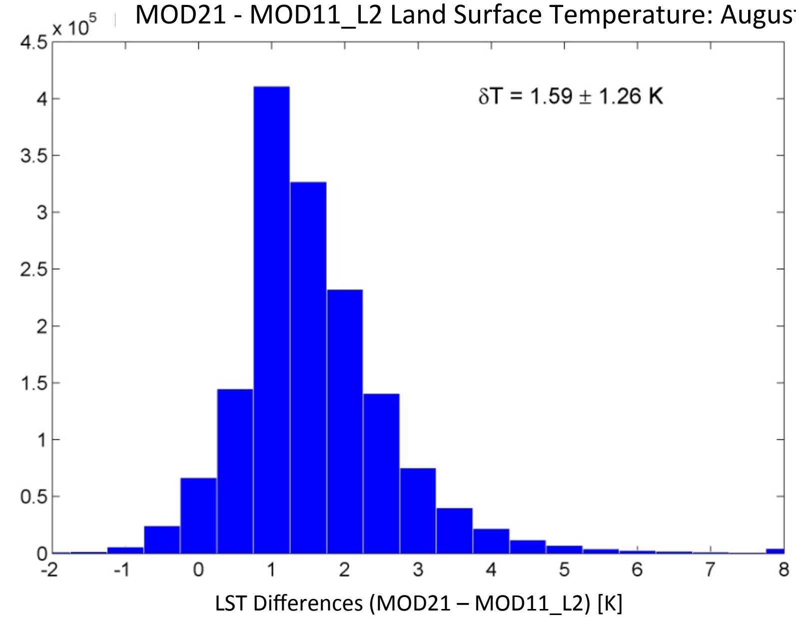
MOD21 Land Surface Temperature: August 2004



MOD21 - MOD11_L2 Land Surface Temperature: August 2004



MOD21 - MOD11_L2 Land Surface Temperature: August 2004



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

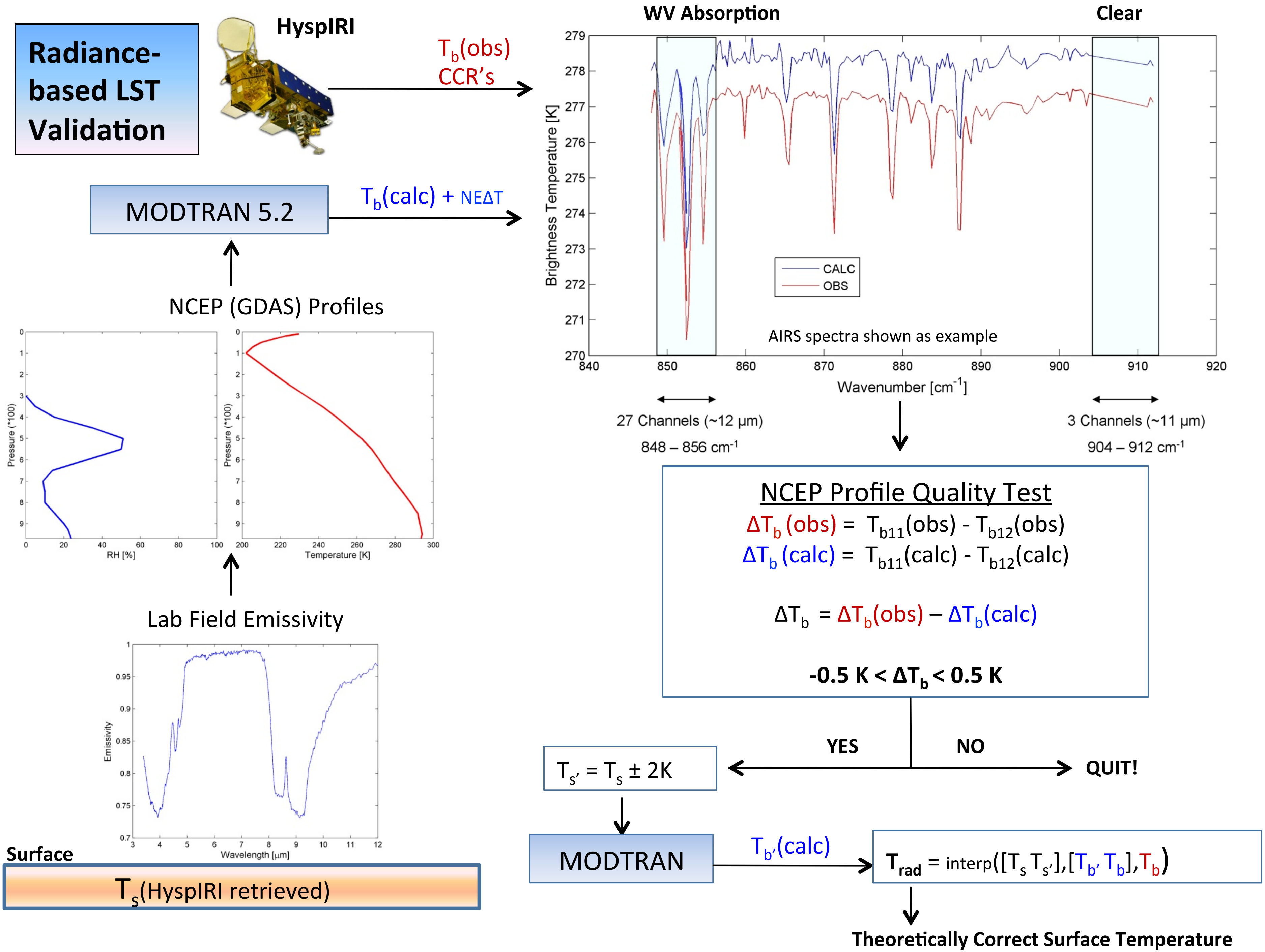
Image from tntmagazine.com

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

Image from wikimedia

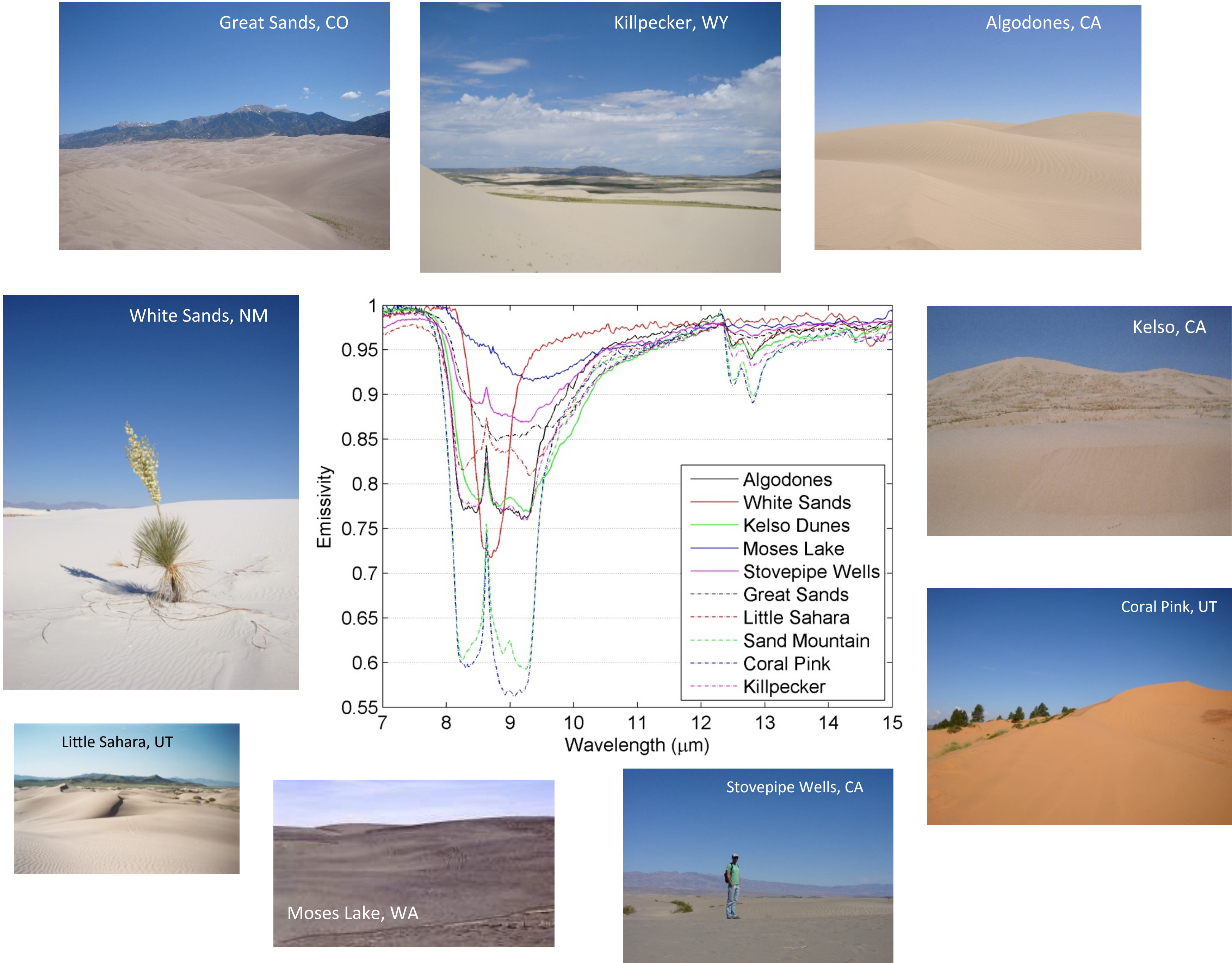

Radiance-based LST Validation
HyspIRI
Tb(obs) CCR's
MODTRAN 5.2
Tb(calc) + NEΔT
NCEP (GDAS) Profiles
Pressure (*100)
RH [%]
Temperature [K]
Lab Field Emissivity
Emissivity
Wavelength [µm]
Surface
Ts(HyspIRI retrieved)
WV Absorption
Clear
Brightness Temperature [K]
Wavenumber [cm-1]
CALC
OBS
AIRS spectra shown as example
27 Channels (~12 µm)
848 – 856 cm-1
3 Channels (~11 µm)
904 – 912 cm-1
NCEP Profile Quality Test
ΔTb (obs) = Tb11(obs) - Tb12(obs)
ΔTb (calc) = Tb11(calc) - Tb12(calc)
ΔTb = ΔTb(obs) – ΔTb(calc)
-0.5 K < ΔTb < 0.5 K
YES
NO
QUIT!
Ts' = Ts ± 2K
MODTRAN
Tb'(calc)
Trad = interp([Ts Ts'],[Tb' Tb],Tb)
Theoretically Correct Surface Temperature

Emissivity and LST validation plans for HyspIRI:
Pseudo-Invariant sand dune sites

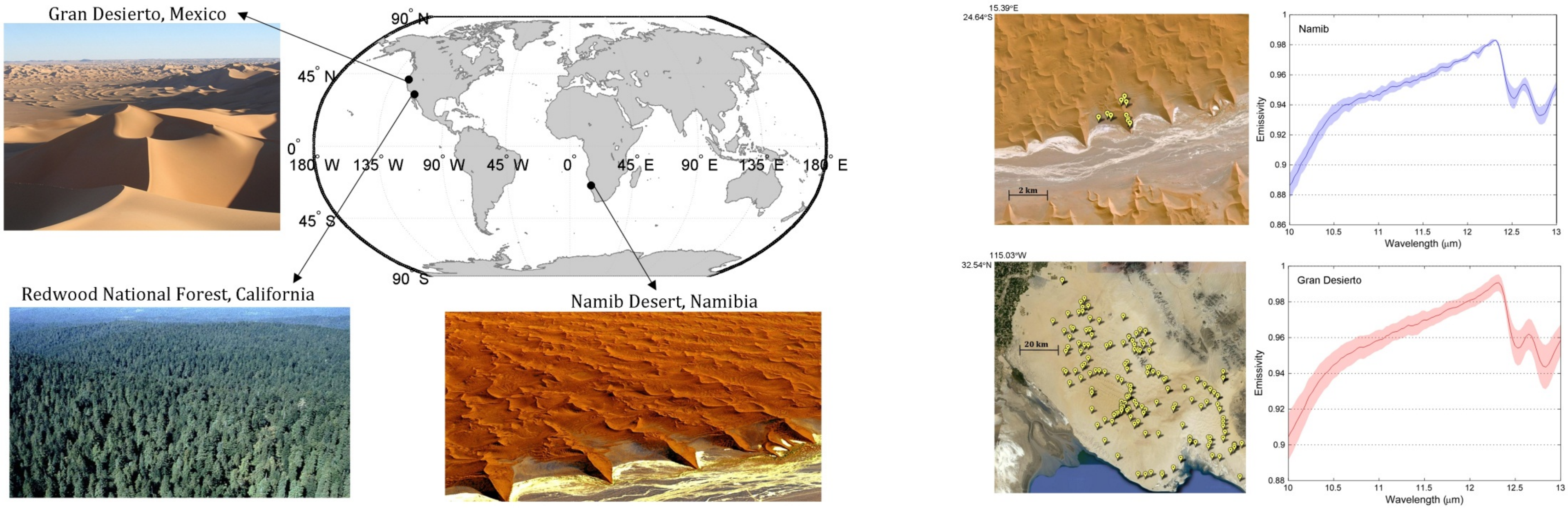
- Emissivity is notoriously difficult to validate. Typically large homogeneous areas with known composition are required (possible with HyspIRI – 60m)
- Sand-dune sites show consistent mineralogy and physical properties over long time periods
- Rapid infiltration after rains, and drying of surface does 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:**

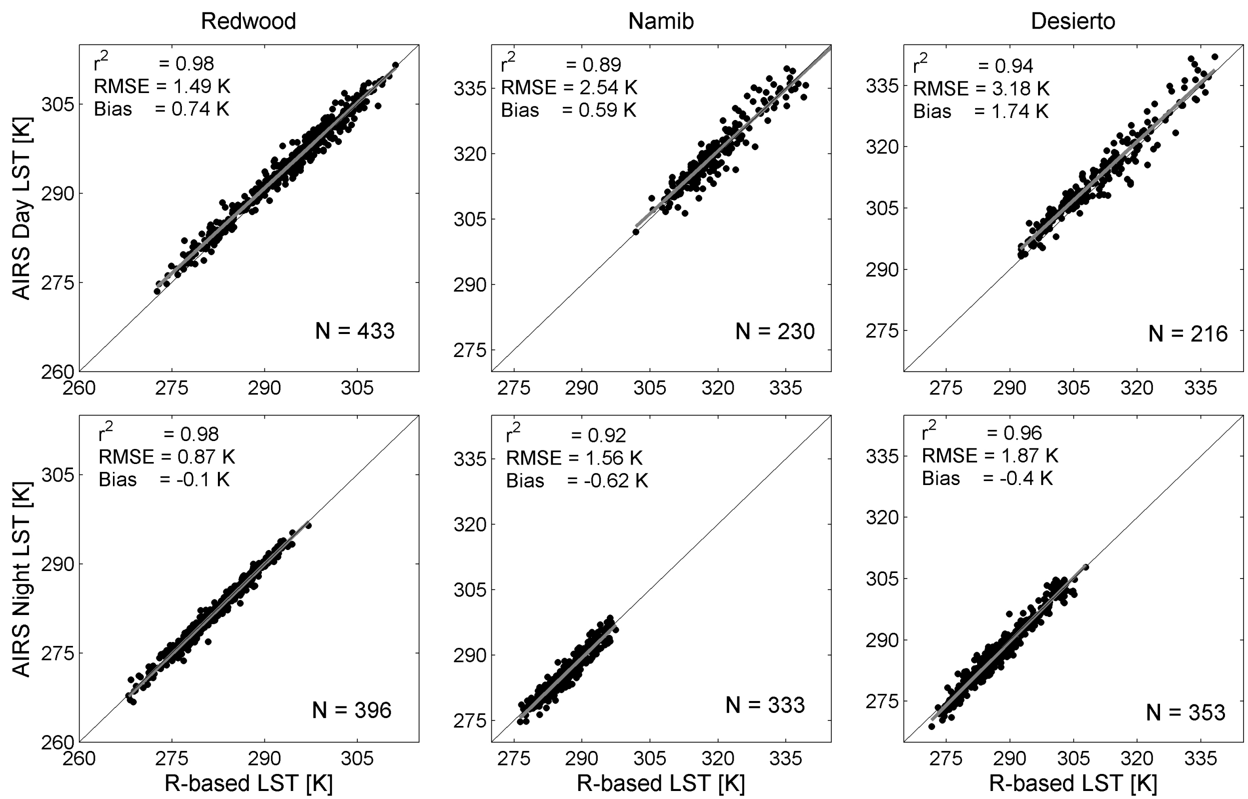
1. **Algodones Dunes, El Centro, California**
2. **Coral Pink Sand Dunes, Utah**
3. **Great Sands National Park, Colorado**
4. **Kelso Dunes, Mojave Desert, California**
5. **Killpecker Dunes, Wyoming**
6. **Little Sahara, Utah**
7. **Sand Hollow State Park, Utah**
8. **Stovepipe Wells Dunes, Death Valley, California**
9. **White Sands National Monument, New Mexico**


Great Sands, CO
Killpecker, WY
Algodones, CA
White Sands, NM
Kelso, CA
Coral Pink, UT
Little Sahara, UT
Moses Lake, WA
Stovepipe Wells, CA
Emissivity
Wavelength (μm)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
7
8
9
10
11
12
13
14
15
Algodones
White Sands
Kelso Dunes
Moses Lake
Stovepipe Wells
Great Sands
Little Sahara
Sand Mountain
Coral Pink
Killpecker

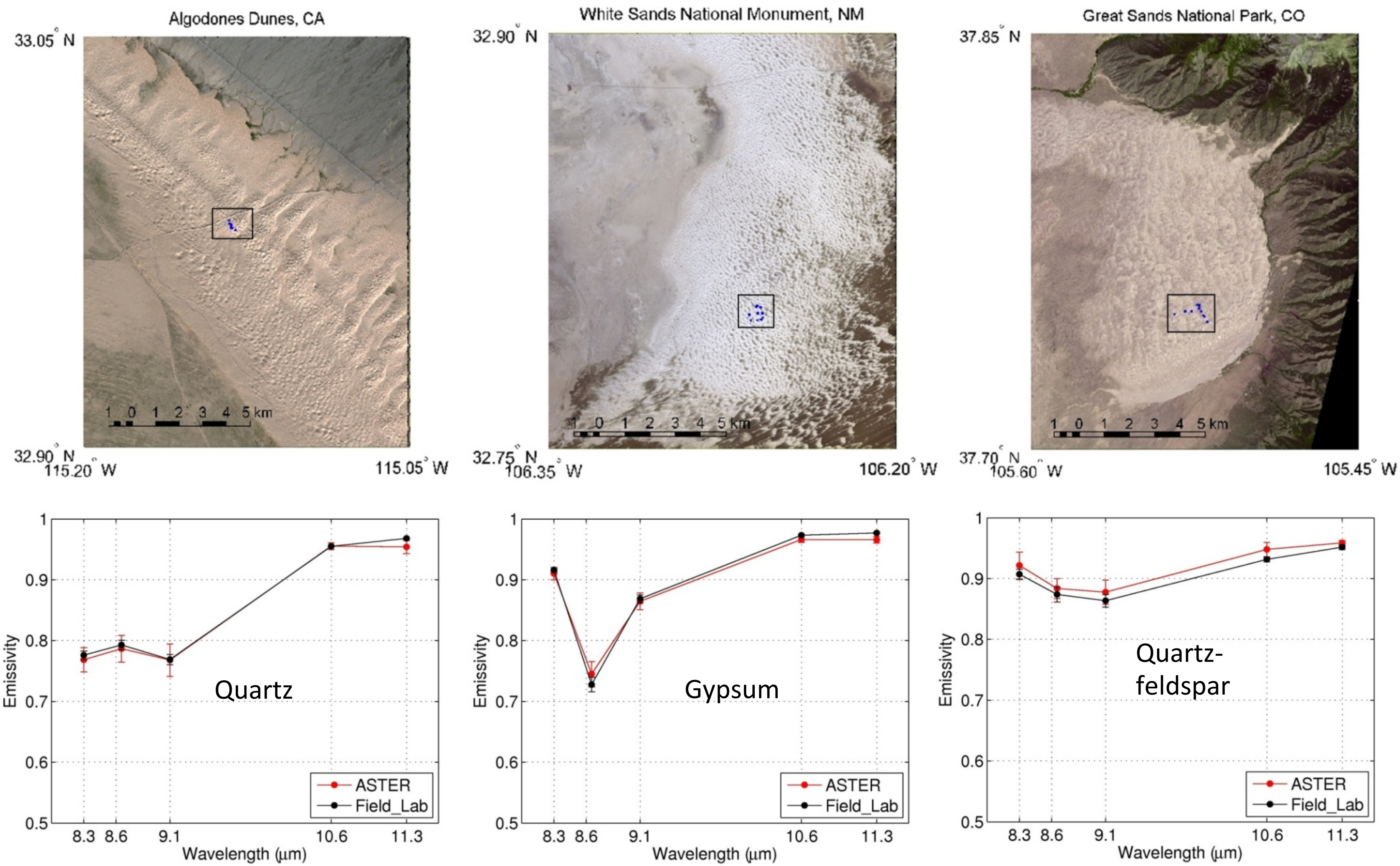
THE RESULTS (ON OTHER DATASETS)



AIRS validation

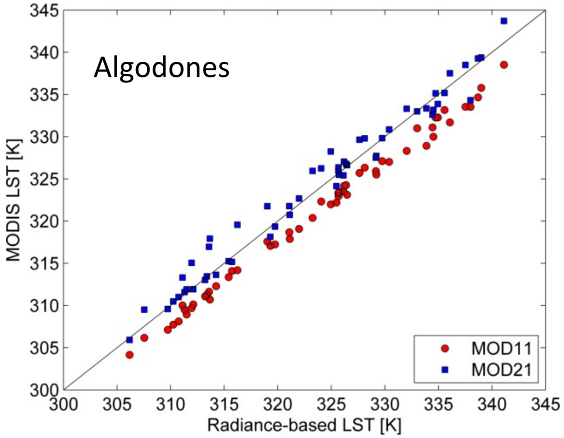


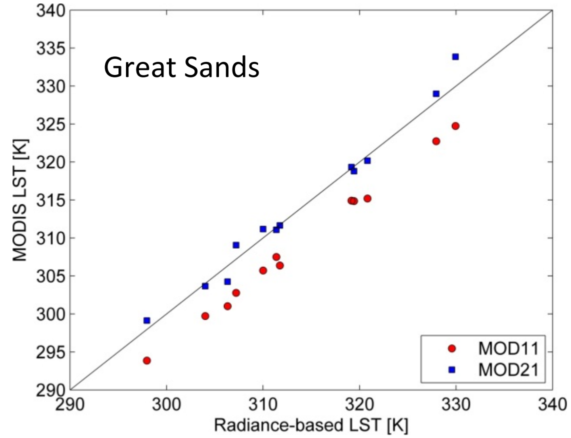
Example ASTER Sand Dune Emissivity Validation Results

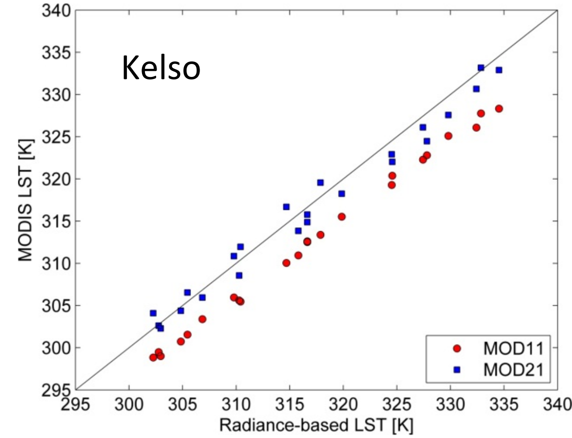


Hulley, G. C., Hook, S. J., and A.M. Baldridge, Validation of the North American ASTER Land Surface Emissivity Database (NAALSED) Version 2.0, *Remote Sensing of Environment* (2009), accepted

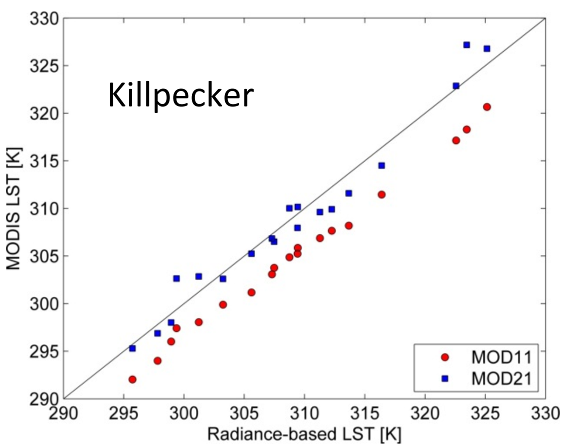
MODIS Validation

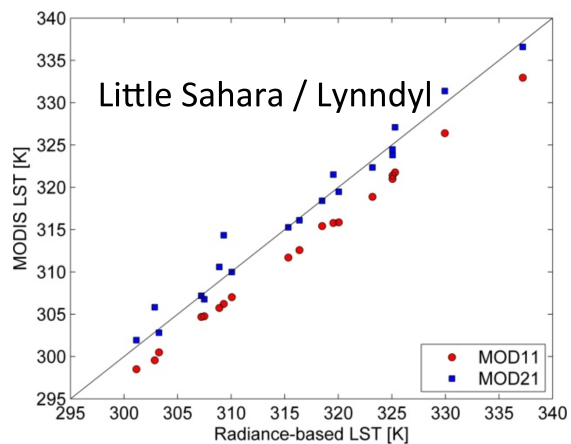


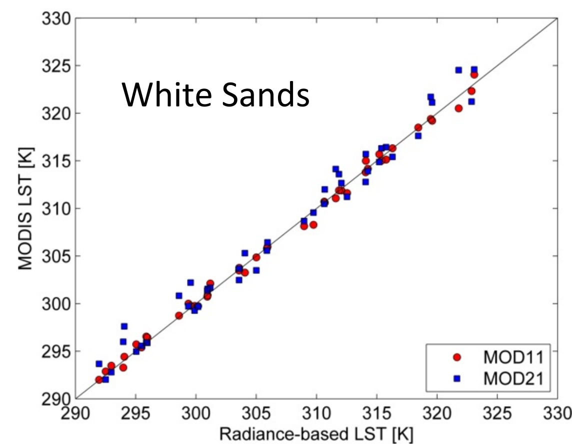




	MOD11 Bias	Mod 11 RMSE	MOD21 Bias	MOD21 RMSE
Algodones (197 scenes)	-2.6587	2.7871	0.5018	1.6004
Great Sands (123 Scenes)	-4.708	4.7417	0.4333	1.5237
Kelso (210 scenes)	-4.5234	4.5892	-0.6574	1.6494
Killpecker (147 scenes)	-4.072	4.1629	-0.0866	1.6845
Little Sahara (159 scenes)	-3.4255	3.468	0.5274	1.6335
White Sands (102 scenes)	-0.0583	0.5455	0.4843	1.3441







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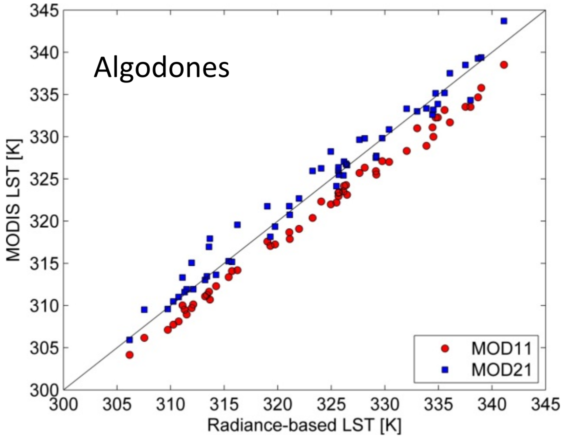

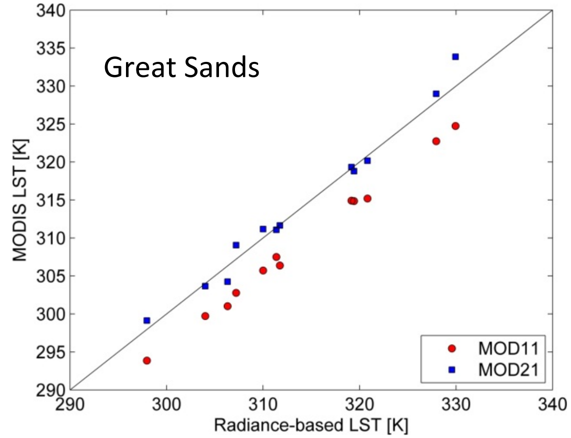

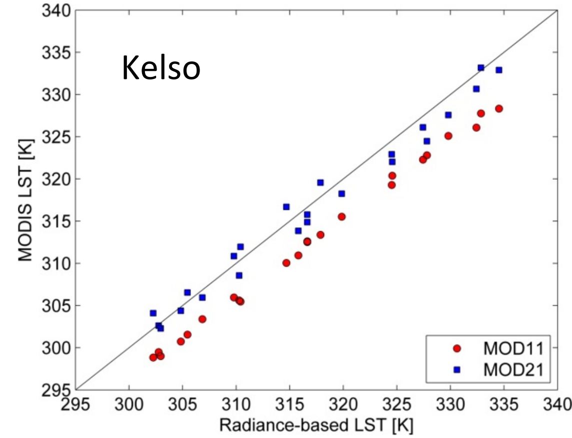

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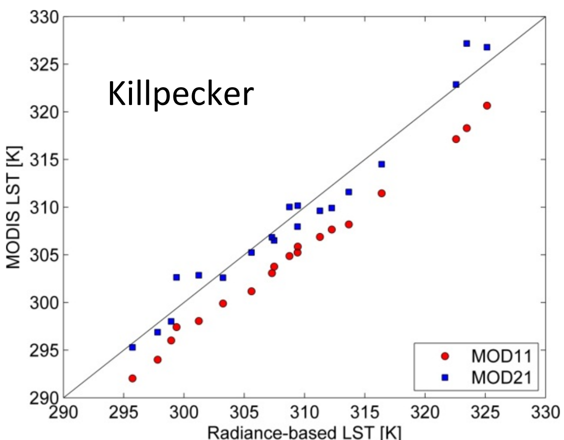

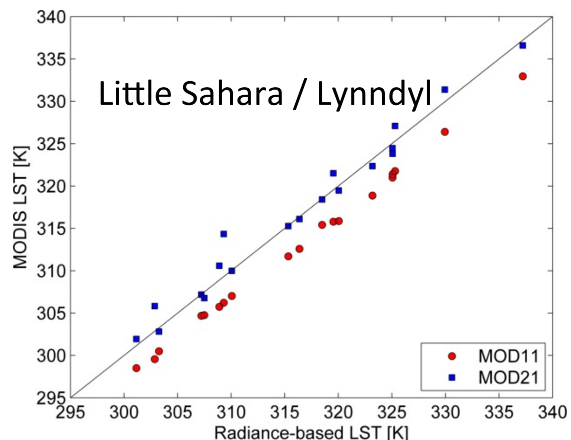

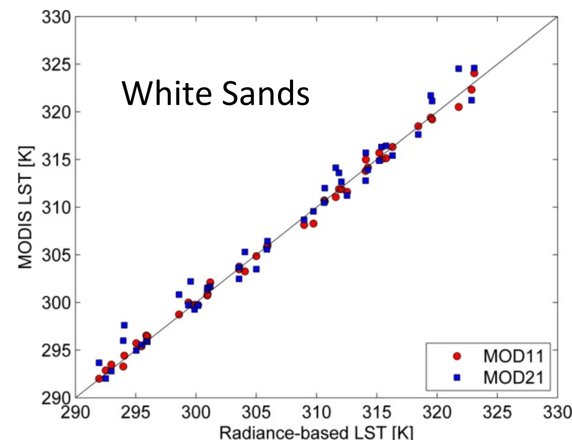

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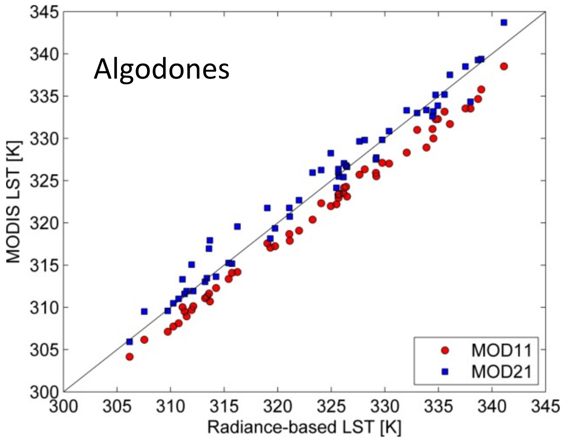

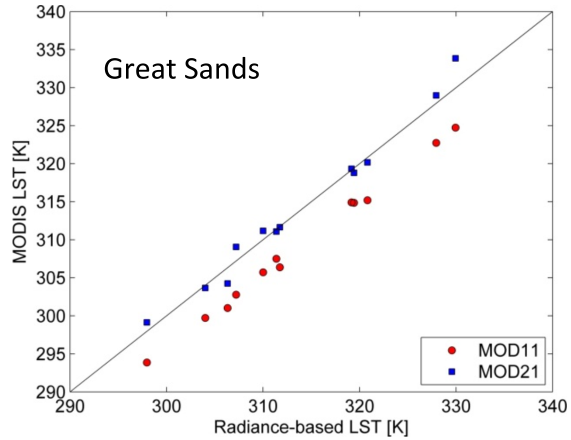

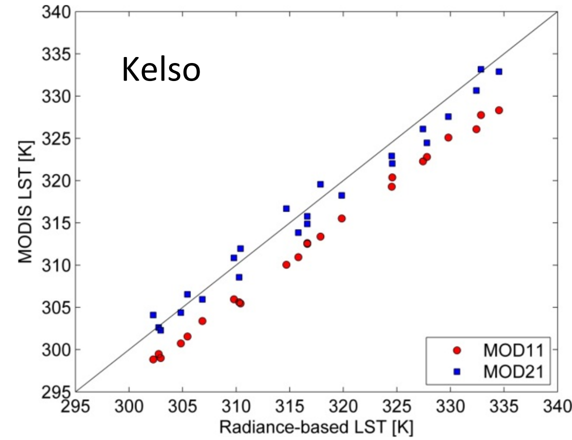

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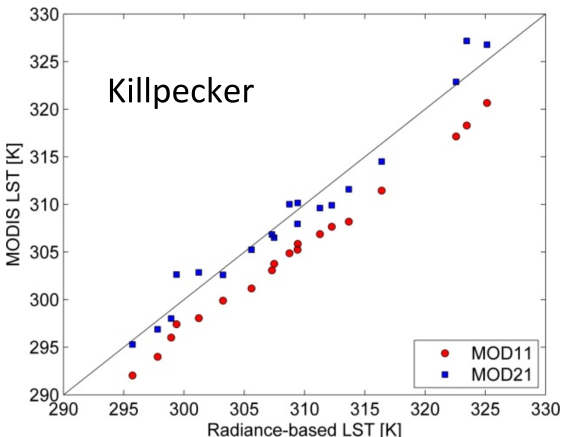
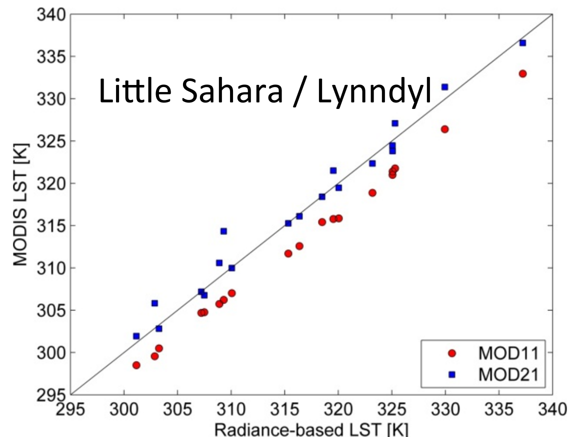
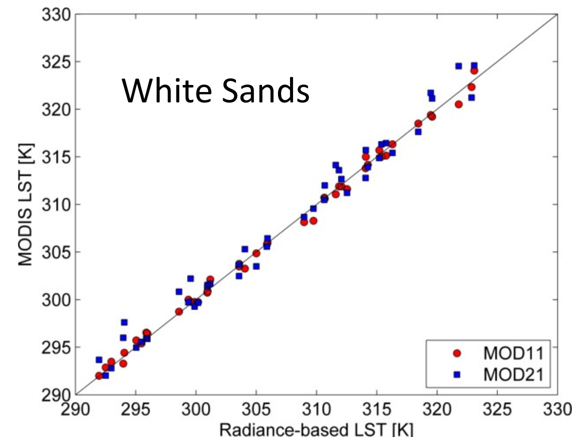
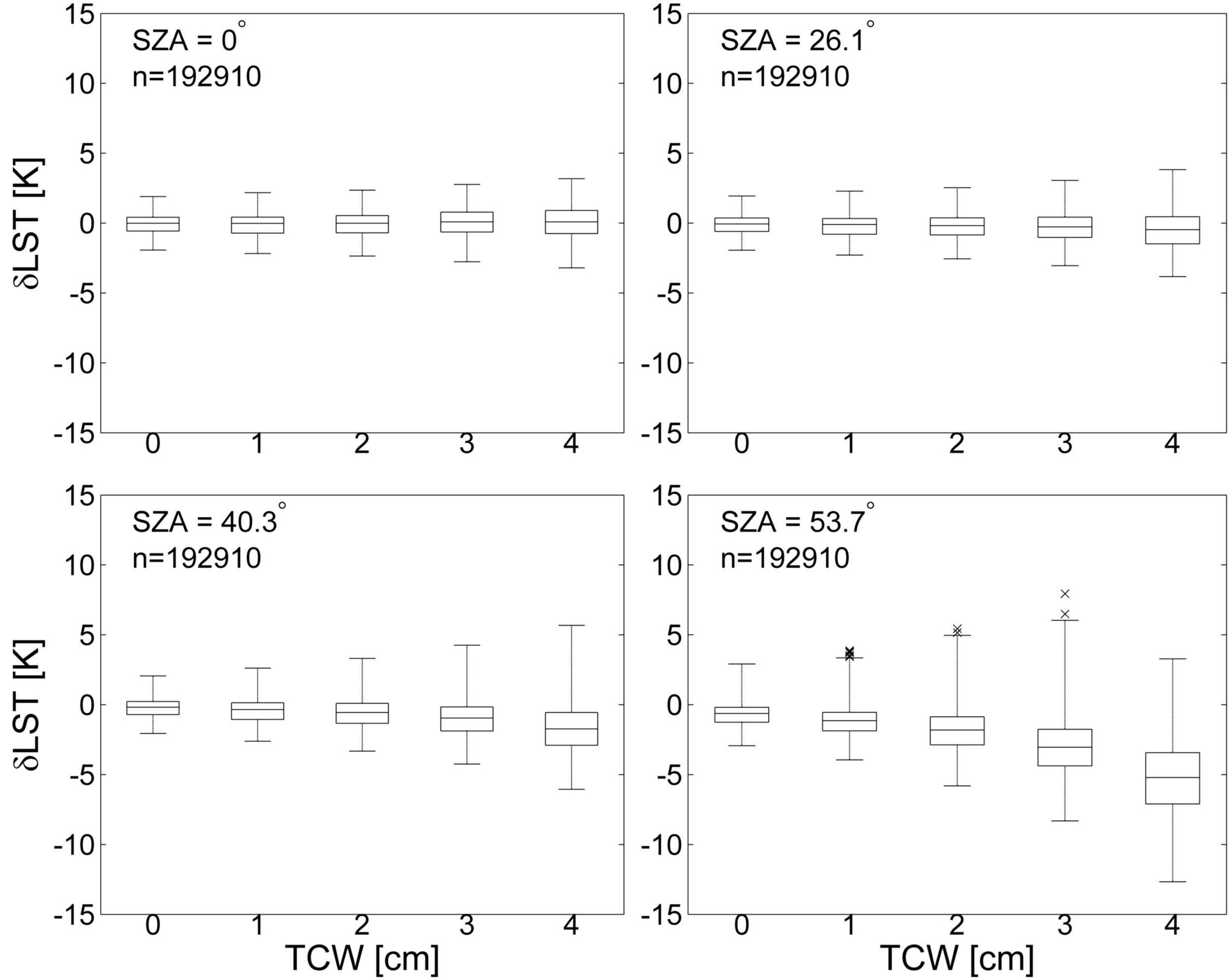






MOD21 LST Uncertainty



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

THANK YOU