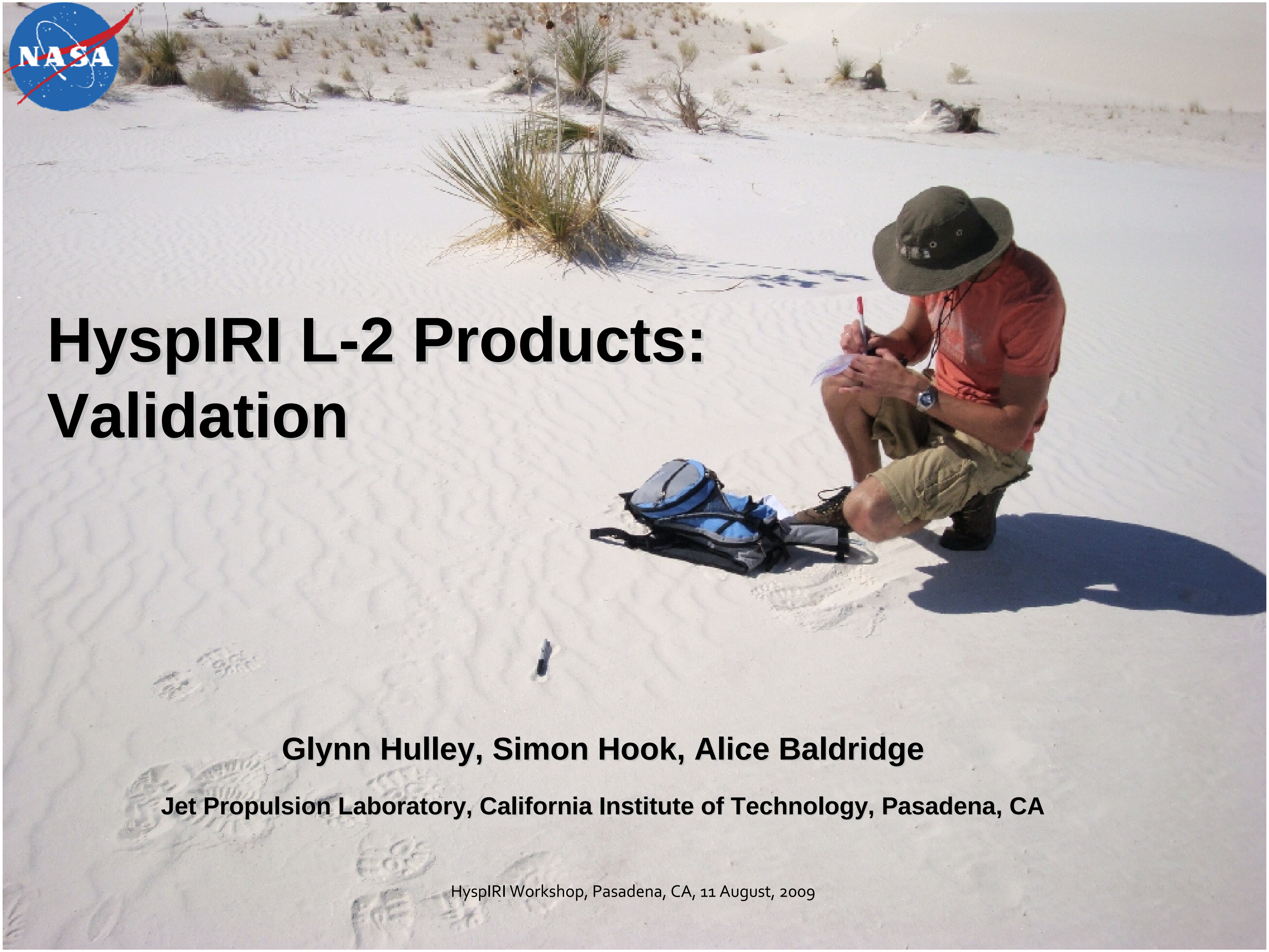


HyspIRI L-2 Products: Validation

Glynn Hulley, Simon Hook, Alice Baldridge

Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

HyspIRI Workshop, Pasadena, CA, 11 August, 2009

Outline

- Surface Radiance
  - Water Targets
  - Land Targets

- Land Surface Emissivity
  - Validation Criteria
  - Pseudo-invariant sand dune sites

- Land Surface Temperature (LST)
  - Validation Criteria
  - Example sites

1. Surface Radiance

➢ **Water Surface Targets:**

1. Lake Tahoe automatic Cal/Val facility (Cool, 0 - 25º C)
2. Salton Sea (Hot, >35º C!)

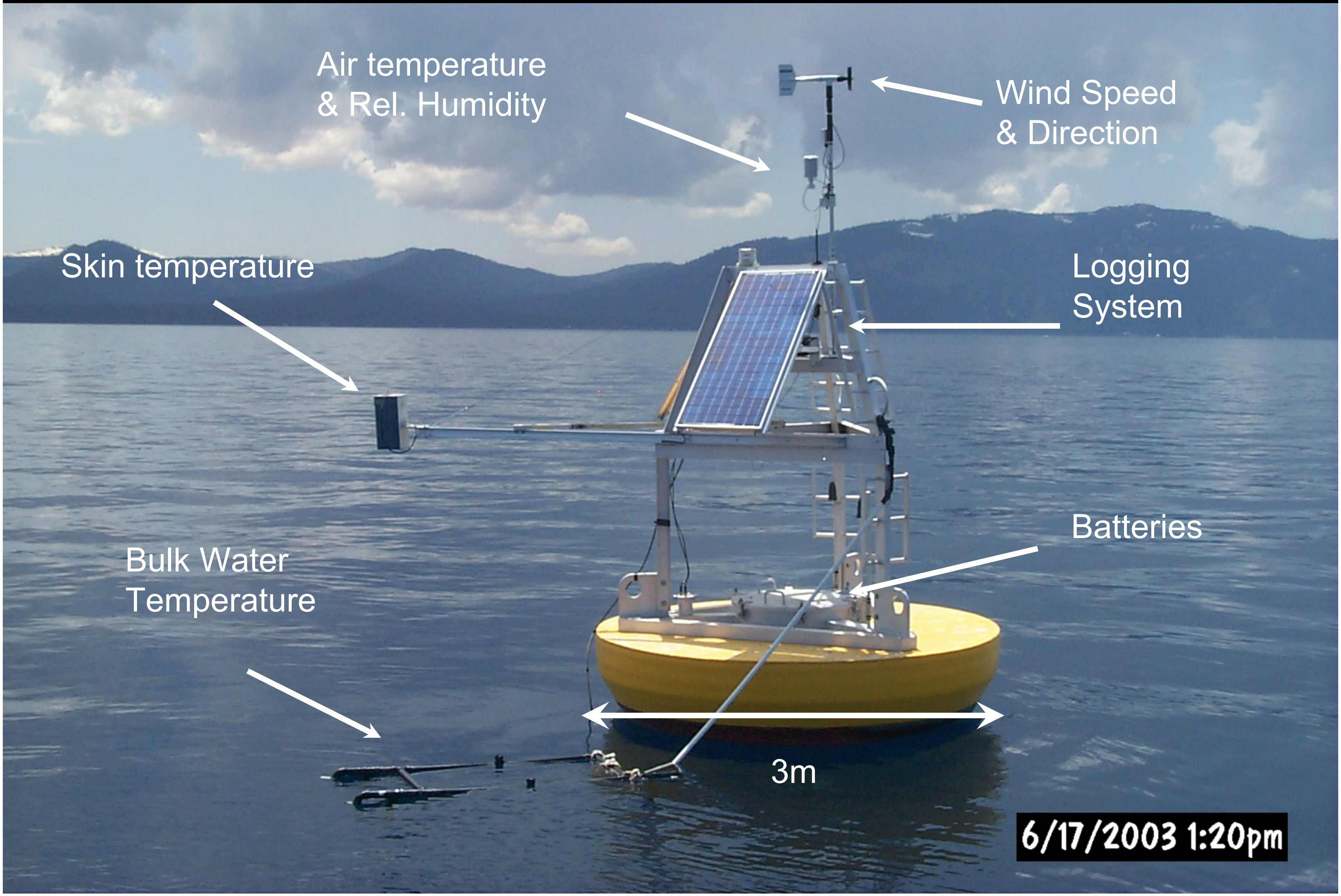
➢ **Land Surface Targets:**

1. DOME-Argus, Antarctica (high, and cold, <-60º C)
2. Valencia site (>30 km^2), homogenous rice fields (cool)
3. Sand dune sites in southwestern USA - pending (hot)
   - Emissivity measured and well characterized
   - Multiple balloon launches to control temperature and PWV
   - Sun photometer for aerosol optical depth and column water

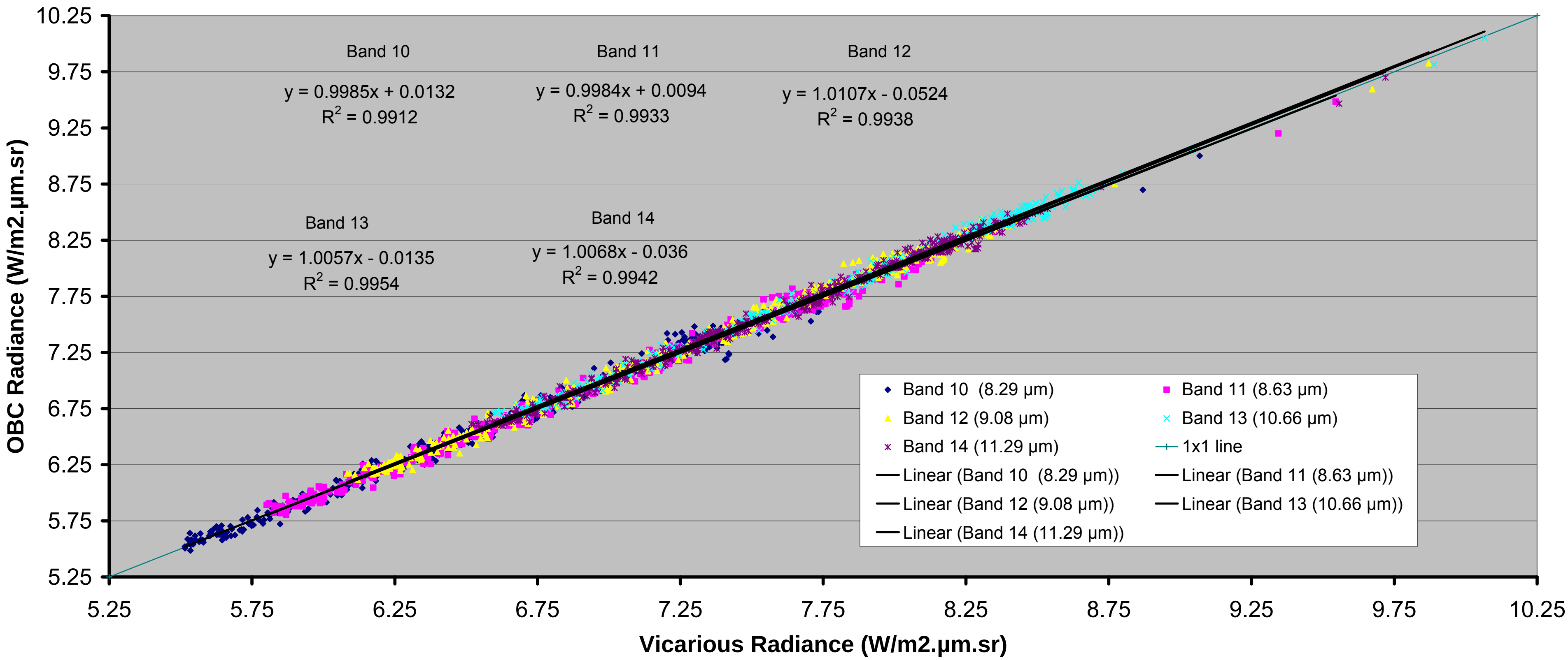
➢ **Airborne Instruments**

- HyTES, MASTER

TB3 Installed 11-04-2002



ASTER Vicarious and OBC Thermal Infrared Derived Radiances at Lake Tahoe and Salton Sea CY2000-2008, v3.0x



Excellent best fit lines obtained in all bands Rsquared is typically 0.99

Data clearly follow 1x1 line

2. Emissivity Validation

- **Sensor Intercomparisons**
  - North American ASTER Land Surface Emissivity Database (NAALSED)
  - Validated, at 100 m resolution

- **Ground Truth Measurements**
  - 9 pseudo-invariant sand dune sites covering broad range of emissivity in TIR (0.6 – 0.96)
  - Emissivity of samples measured in the laboratory using Nicolet spectrometer and integrating sphere (high accuracy – 0.02%)

- **Airborne Data**
  - HyTES (Hyperspectral Thermal Emission Spectrometer)
  - 256 TIR bands
  - Simulation and algorithm development for HyspIRI
  - Expected 2011 debut

Sensor Intercomparison

http://emissivity.jpl.nasa.gov

Jet Propulsion Laboratory
California Institute of Technology

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North American Land Surface Emissivity Project

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« June 2009 »

Mo	Tu	We	Th	Fr	Sa	Su
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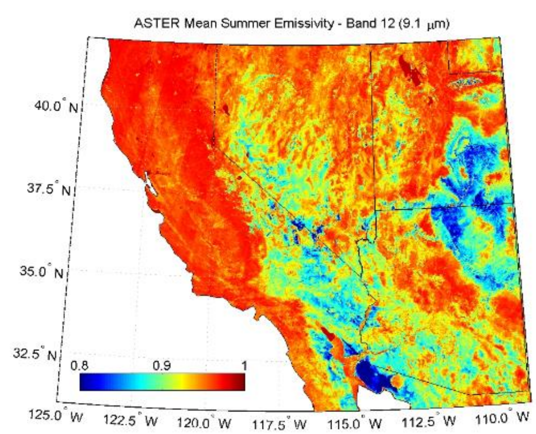
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

North American Land Surface Emissivity Project

Welcome to the website for the North American Land Surface Emissivity Project. The goal of the project is to create a seamless database of emissivity from standard ASTER emissivity products for use in climate research. The Earth emits energy at wavelengths we cannot normally see, that energy is a function of the temperature and the emissivity of the surface. The surface emissivity primarily depends on the composition of the surface. Thus as the surface composition changes through, for example, land cover land use change, so does the surface emissivity. The land surface emissivity is measured by several instruments mounted on satellites and aircraft. Some of the most well known satellite sensors are AIRS, ASTER and MODIS.

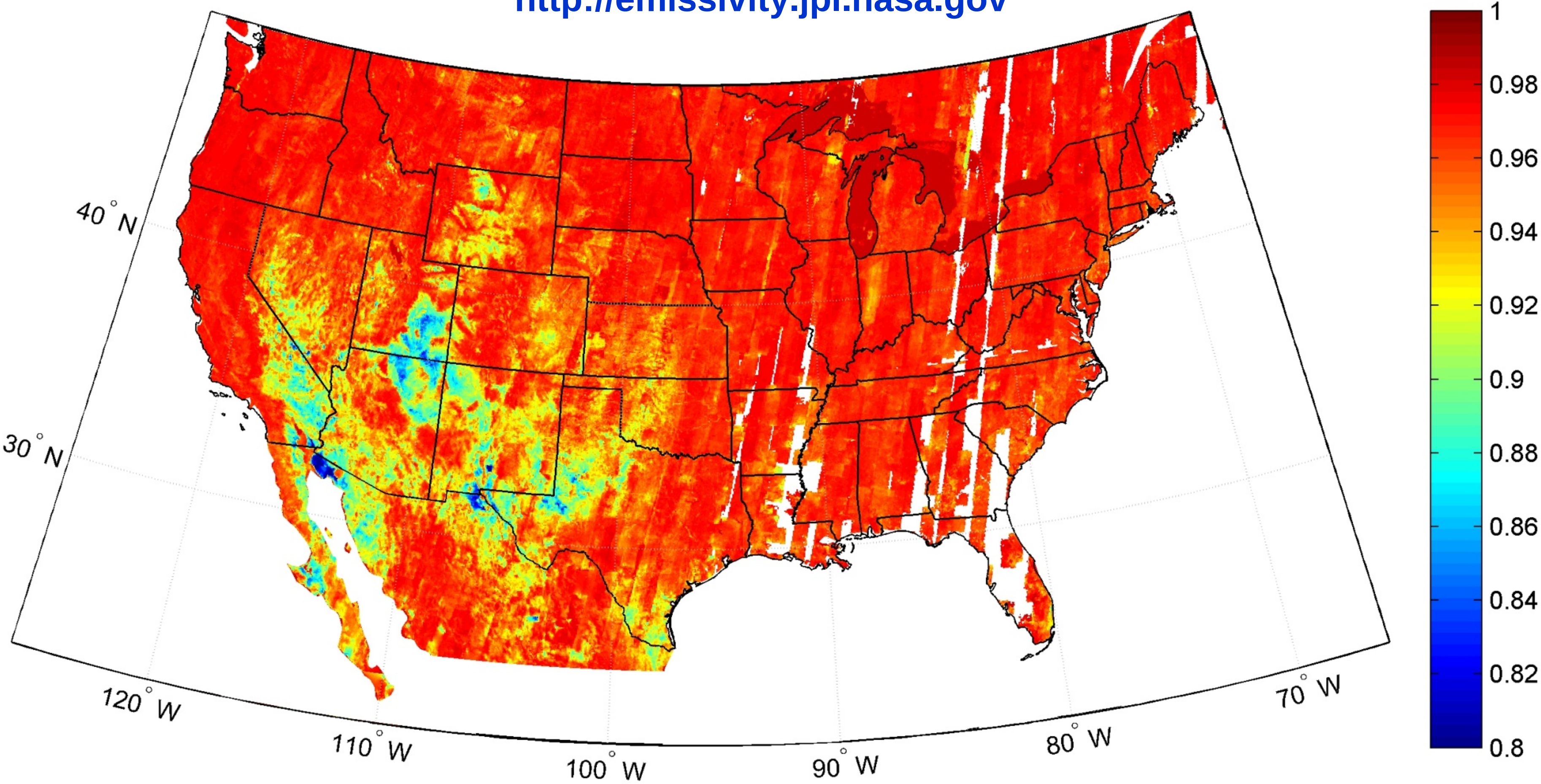
Of these three satellite sensors, ASTER provides the most detailed emissivtiy images with a pixel spatial resolution of 90m. The image below was created by merging together all the ASTER emissivity data ever acquired over California, Nevada, Arizona and Utah under clear skies from 2000-2008 for the months July, August and September.



In the image above areas of red correspond to areas with large amounts of vegetation cover which has a

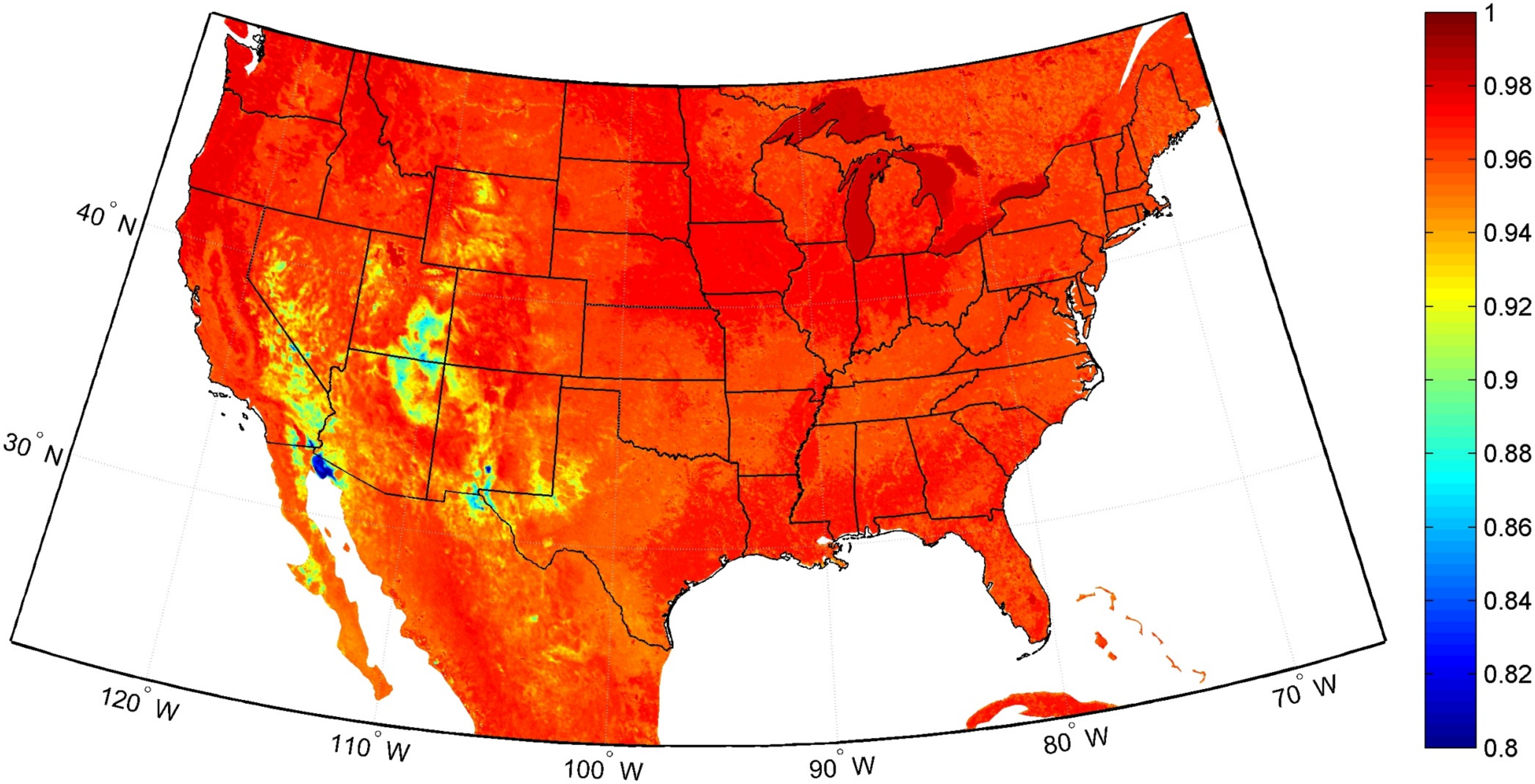
NAALSED Mean Summer (Jul-Sep) Emissivity:
Band 12 (8.6 µm): 2000-2008: 50,075 scenes

http://emissivity.jpl.nasa.gov

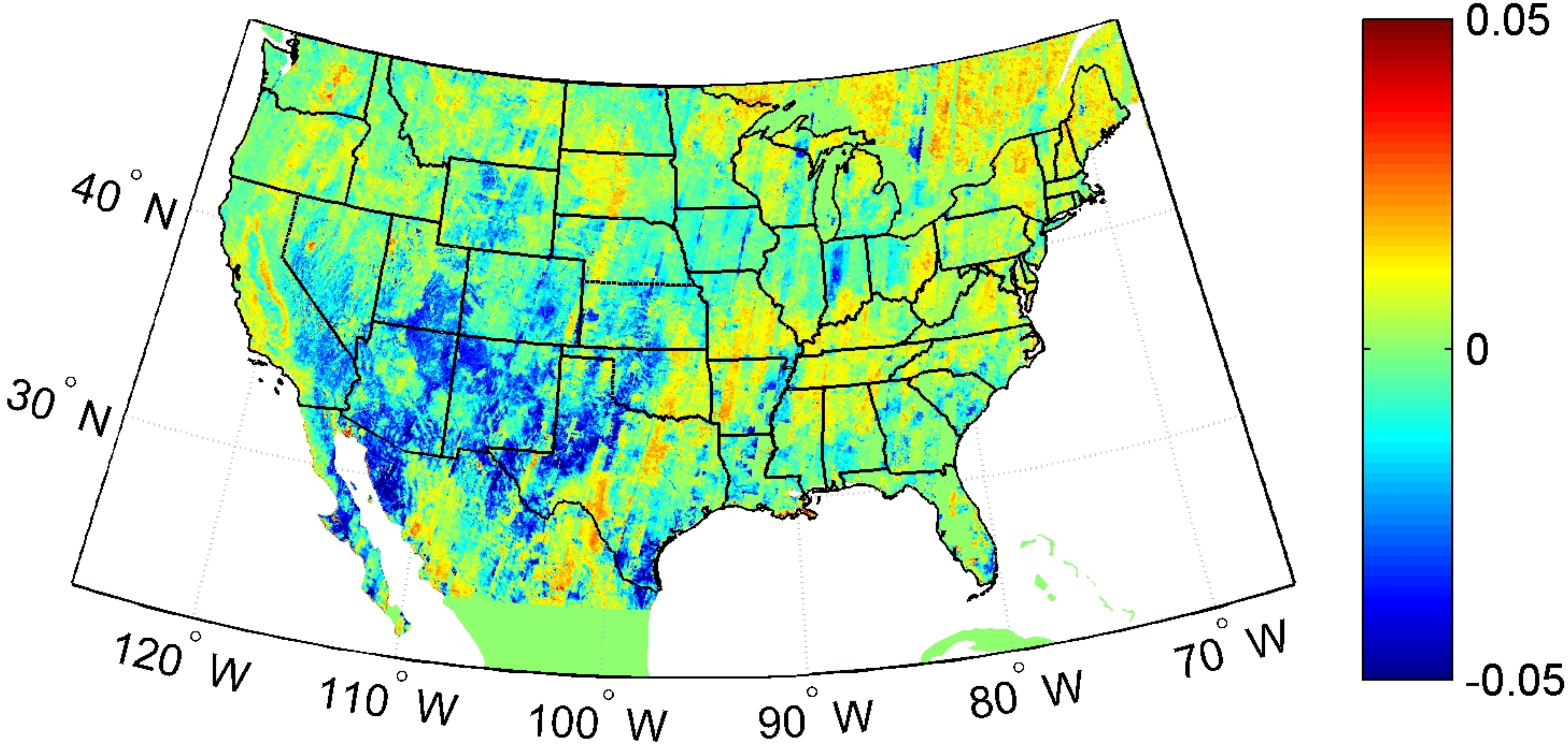


Hulley, G. C., & Hook, S. J., (2009),The North American ASTER Land Surface Emissivity Database (NAALSED) Version 2.0, *Remote Sensing of Environment*, doi:10.1016/j.rse.2009.05.005

MODIS V4 Mean Summer Emissivity: 8.55 μm: 5 km



ASTER minus MODIS V4 Emissivity: 8.6 µm: 5 km



Ground Truth: Emissivity Validation Criteria

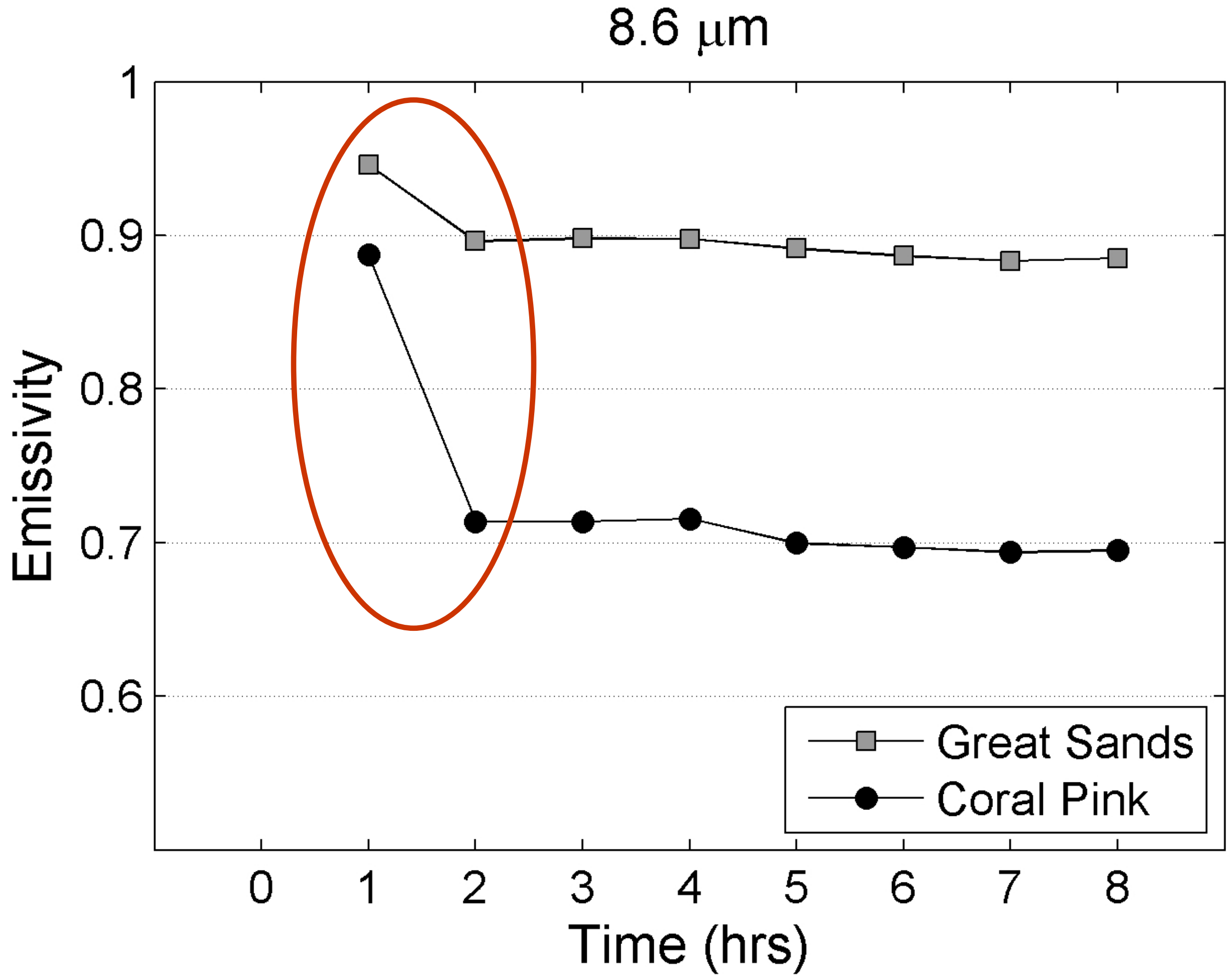
1. Homogenous in emissivity at scale of imagery
   - Coefficient of variation (CV)
2. Several pixels available for validation over site
   - eg. ASTER – 1 km^2, MODIS – 10 km^2
3. Known composition, particle size
   - X-Ray Diffraction (XRD), lab spectroscopy

Pseudo-Invariant Sand Dune Sites

- Consistent physical properties over long time periods
- Sparse vegetation cover
- Rapid infiltration and evaporation of soil moisture
- Known composition and particle size (XRD, lab)
- Advantage over playas, pans:
  - Do not collect water over long periods
  - Drying of surface does not lead to cracks, fissures which will raise emissivity due to cavity radiation effects

Sand Dune Sites: Soil Moisture

- Sand samples saturated with water and left outside to dry
- Emissivity variation related to well-known 3-Stage soil evaporation process



Emissivity decreases by up to 15% in less than 1 hr!!

Sand Dunes: Major Characteristics

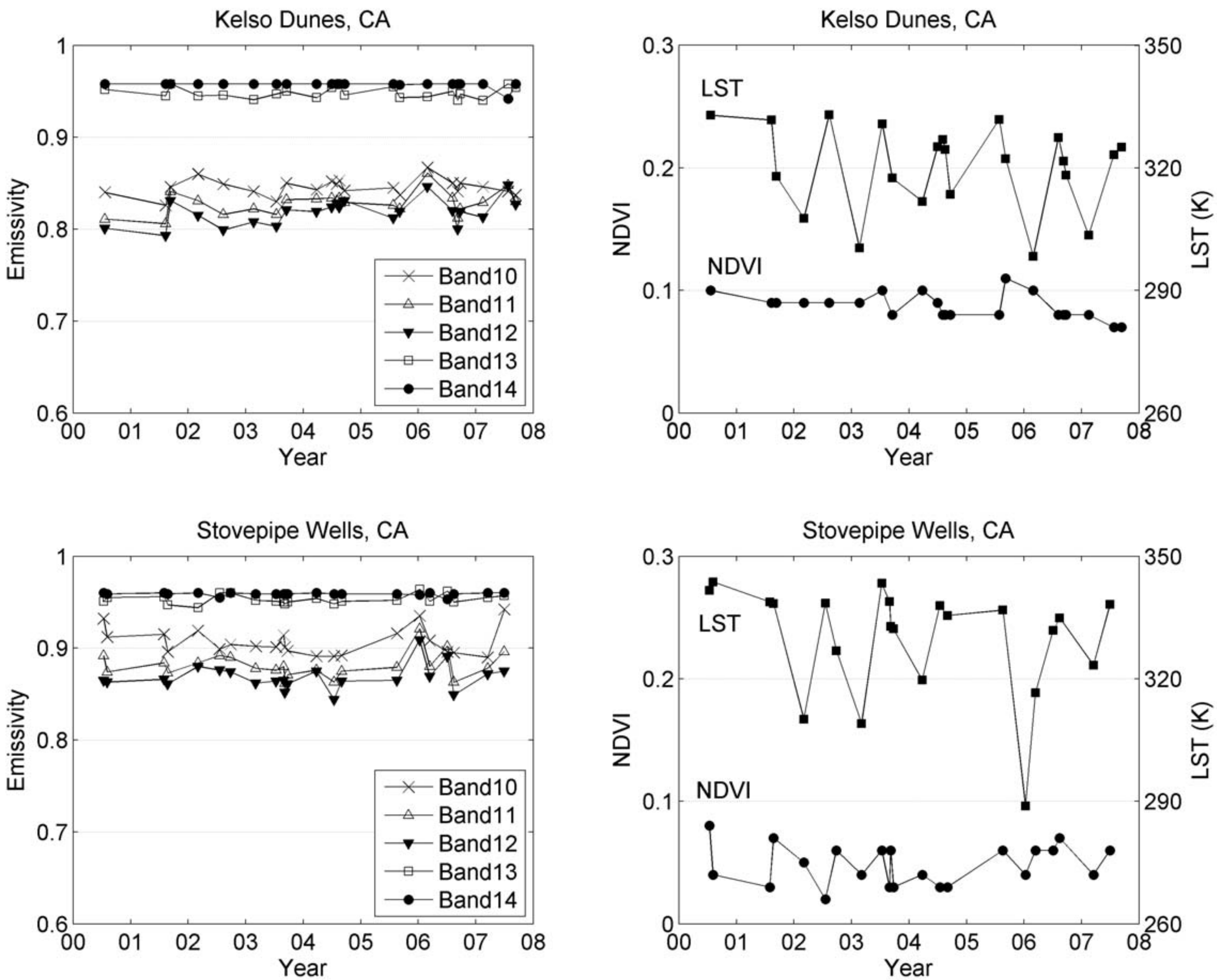
Table 1

Summary of the major characteristics of each dune site including locality, elevation, surface area, dune height, grain size, sand source and bulk mineralogy.

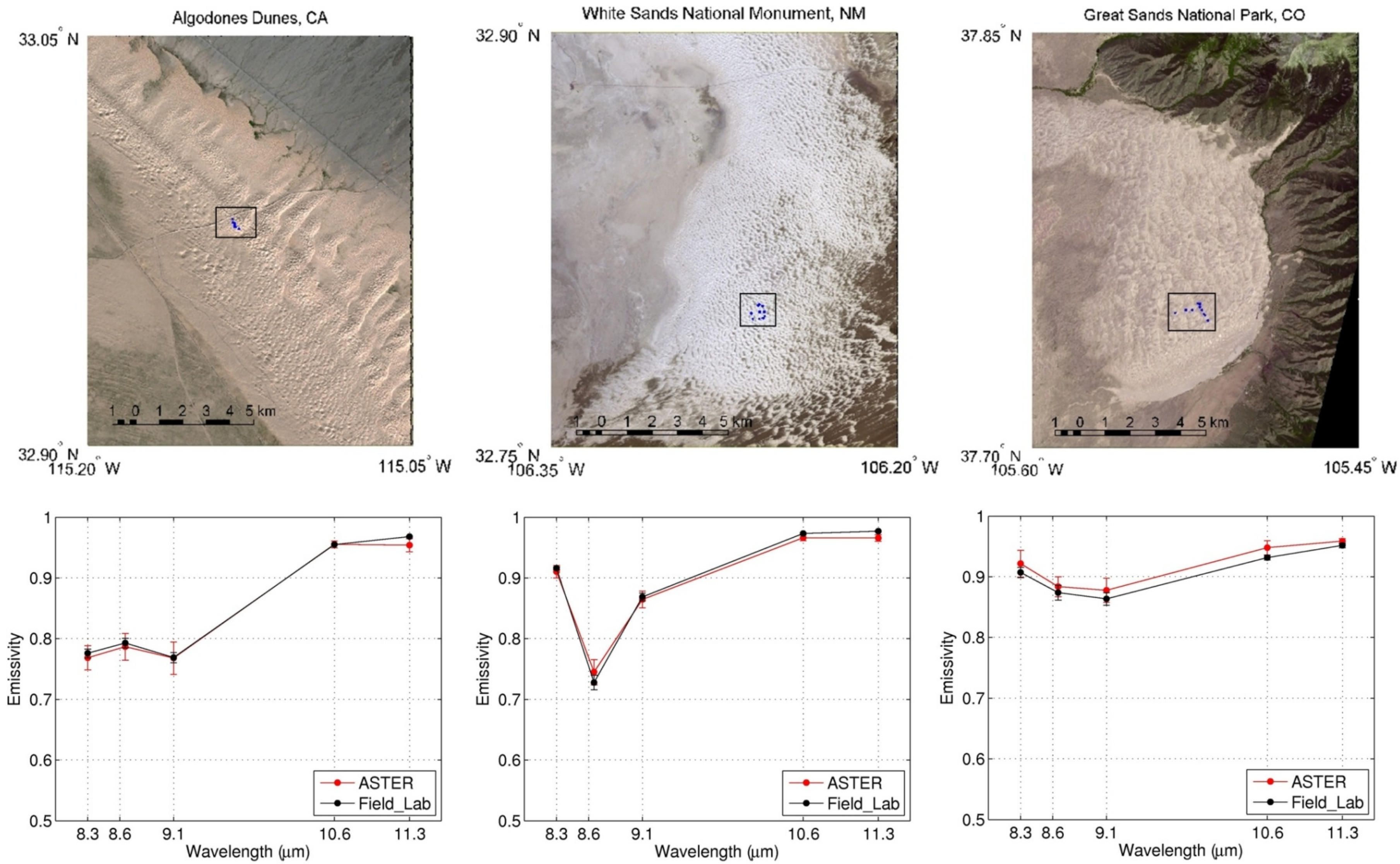
Dune site	Locality	Surface area (km^2)	Elevation/max dune height (m)	Grain size	Sand source	Mineralogy (XRD)
Algodones (32.95° N, 115.07° W)	Southeast CA, Eastern margin of the Salton Trough	720	94/80	Medium to coarse sand	Beach sand from Lake Cahuilla	Major: quartz
Coral Pink (37.04° N, 112.72° W)	Sand Valley, just north of UT–AZ border, west Kanab	13.6	1780/10	Medium sand	Navajo, Page and Estrada Jurassic sandstones of the Vermillion Cliffs	Major: quartz
Great Sands (37.77° N, 105.54° W)	San Luis Valley, CO, adjacent to Sangre de Cristo, NE of Alamosa	104	2560/230	Medium to coarse sand	Quartz and volcanic fragments derived from Santa Fe and Alamosa formations, recent fluvial (Rio Grande) deposits	Major: quartz Minor: potassium feldspar
Kelso (34.91° N 115.73° W)	Mojave Desert, CA, southeast of Baker	115	800/195	Medium sand	Derived from sedimentary, metamorphic, igneous terrains from Mojave River alluvial apron	Major: quartz Minor: potassium feldspar Trace: magnetite
Killpecker (41.98° N 109.10° W)	Southwest WY, from Eden across Rock Springs into Red Desert	550	2000/45	Medium sand	Sandstone and siltstone of the Laney member of the Green River Formation	Major: quartz Trace: magnetite Minor: plagioclase feldspar, epidote
Little Sahara/Lynndyl (39.7° N 112.39° W)	West-central UT, Sevier River drainage basin, west of Lynndyl	575	1560/200	Fine sand	Deltaic and shoreline sediments from the Provo shoreline of Lake Bonneville	Major: quartz Minor: plagioclase feldspar, pyroxene, carbonate, magnetite
Stovepipe Wells (36.62° N, 117.11° W)	Central Death Valley, CA, near Stovepipe Wells	7.7	−12/40	Medium sand	Mixed lithic fragments and quartz from Emigrant Pass to the west and Furnace Wash to the east	Major: quartz Minor: plagioclase feldspar, potassium feldspar
Moses Lake (47.05° N, 119.31° W)	Quincy Basin in central WA	40	345/18	Fine sand	Basaltic sand from the east bank of the Columbia River	Major: quartz, albite
White Sands (32.89° N, 106.33° W)	South-central NM, Tularosa Valley	704	1216/10	Fine sand	Paleo-lake Otero, present playa Lake Lucero to the southwest	Major: gypsum

Hulley, G. C., Hook, S. J., and A.M. Baldridge, (2009), Validation of the North American ASTER Land Surface Emissivity Database (NAALSED) Version 2.0, *Remote Sensing of Environment*, 113, 2224-2233

Sand Dune Site Stability



Validation of North American ASTER Emissivity Database (NAALSED)



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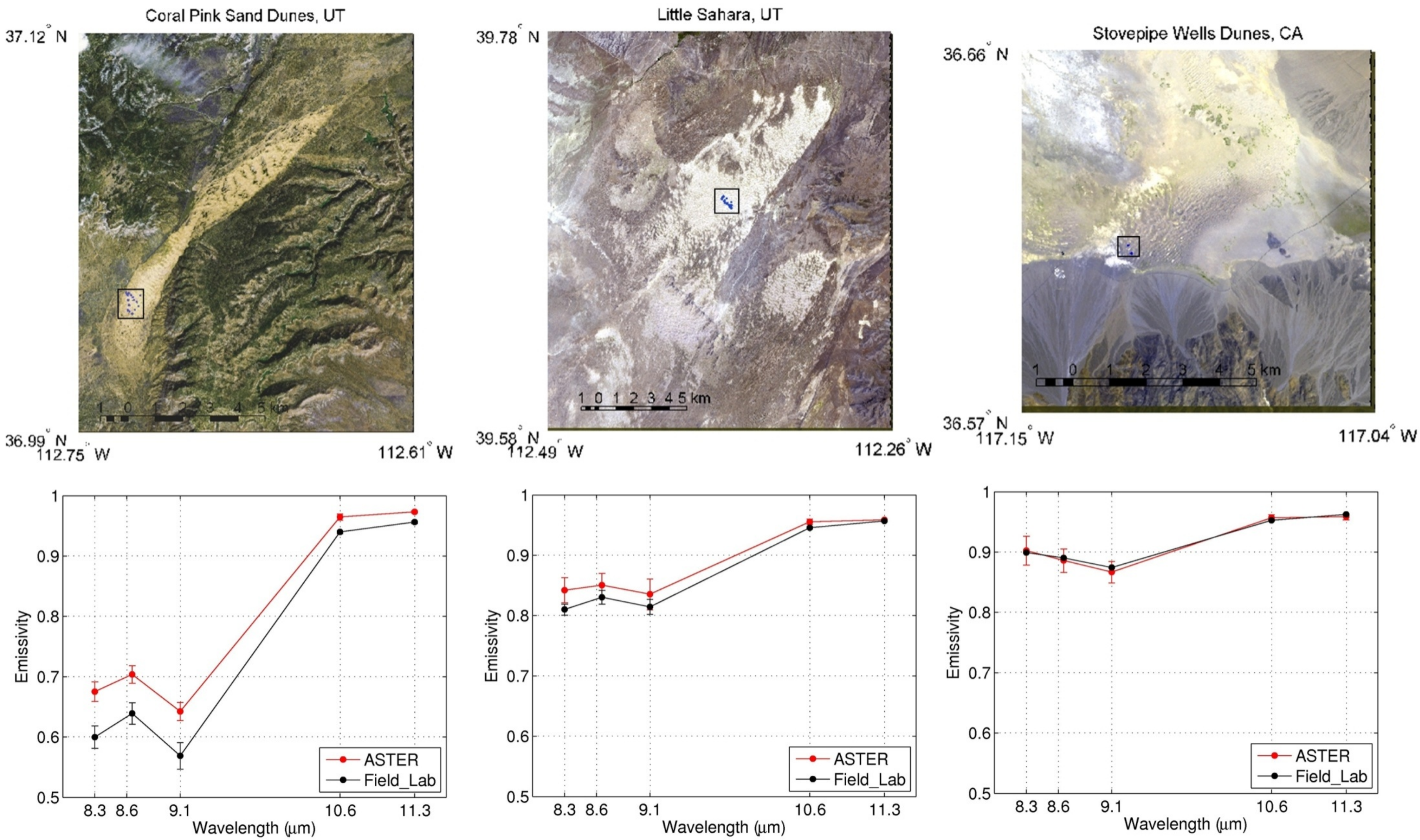

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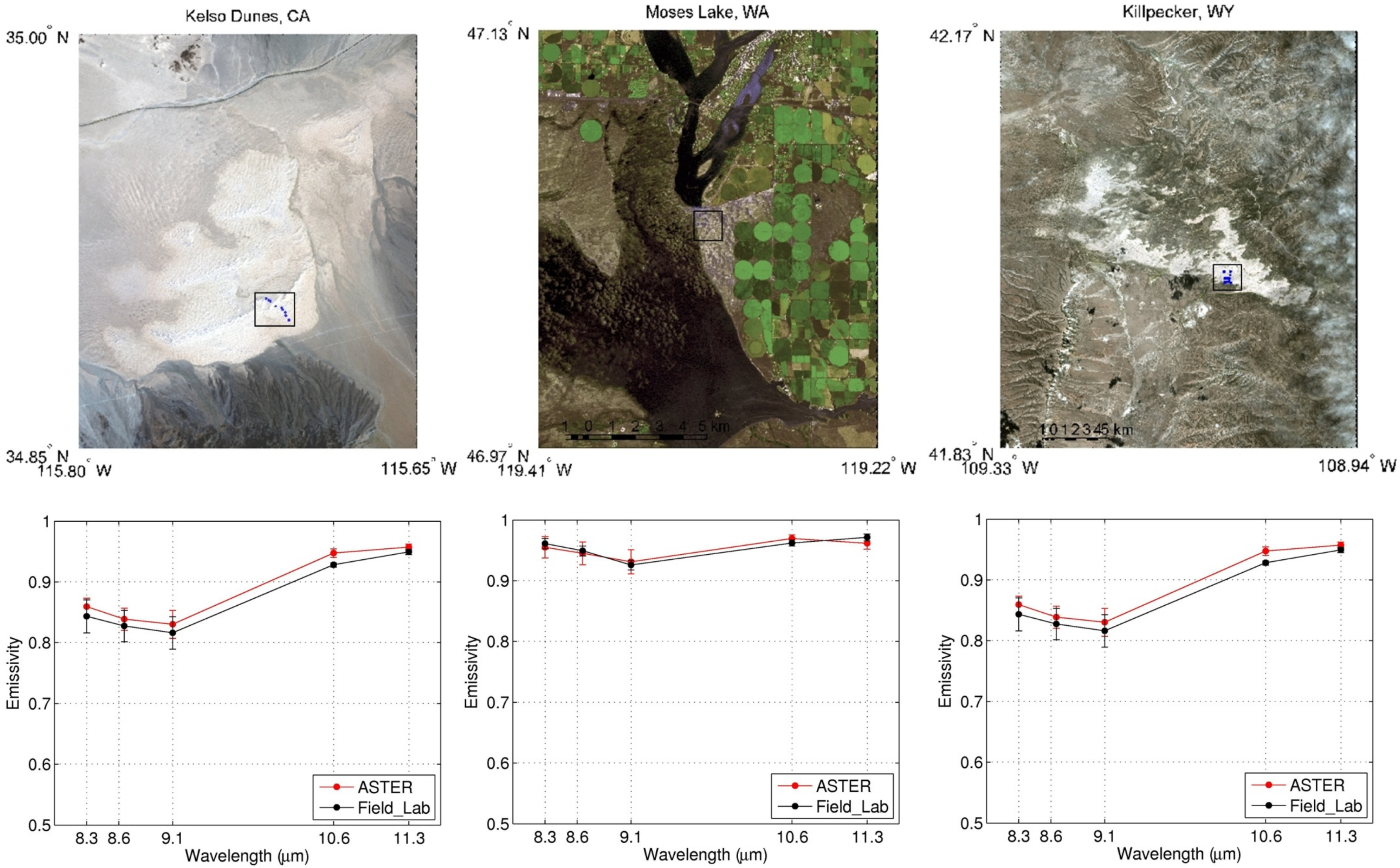
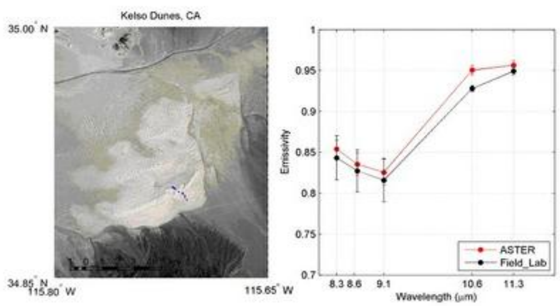


Hulley, G. C., Hook, S. J., and A.M. Baldridge, (2009), Validation of the North American ASTER Land Surface Emissivity Database (NAALSED) Version 2.0, *Remote Sensing of Environment*, 113, 2224-2233

North American Land Surface Emissivity Project

Kelso Dunes

The Kelso Dunes are located in the Mojave Desert National Preserved southeast of Baker, CA. Sand from the Mojave River alluvial apron is driven approximately 35 miles by predominantly westerly winds, piling up at the base of the Granite and Providence mountains, which flank the south and southeast sides of the dune field. The westerly winds are counterbalanced by strong winds from other directions that result in a result in a variety of dunes forms [*Sharp*, 1966]. The dune field covers an area of 115 km^2 and contains dunes that rise up to 195 m above the terrain. Large portions of the dunes have sparse vegetation cover that stabilizes areas of previously drifting sand. The dunes are composed predominately of quartz and feldspar eroded from granitics of San Bernardino Mountains to the south but also contain a large proportion of lithic fragments [*Edgett and Lancaster*, 1993] .



NAALSED validation with pseudo-invariant sand dune sites

	ASTER MINUS LAB EMISSIVITY (%)					
Dune site	**Band 10**	**Band 11**	**Band 12**	**Band 13**	**Band 14**	**Mean**
Algodones	0.68	0.60	0.13	0.02	1.40	**0.57**
Stovepipe Wells	0.17	0.77	1.02	0.34	0.37	**0.53**
White Sands	0.34	2.76	0.16	0.92	1.08	**1.05**
Kelso Dunes	1.57	1.04	1.33	1.91	0.81	**1.33**
Great Sands	1.44	0.97	1.42	1.64	0.69	**1.23**
Moses Lake	0.69	0.52	0.42	0.61	1.01	**0.65**
Sand Mountain	7.74	6.47	9.01	1.82	1.10	**5.23**
Coral Pink	7.48	6.44	7.32	2.50	1.70	**4.90**
Little Sahara	3.55	2.39	2.60	0.96	0.19	**1.94**
Killpecker	2.34	1.99	2.26	1.33	0.81	**1.75**

< 1.6% (1 K)

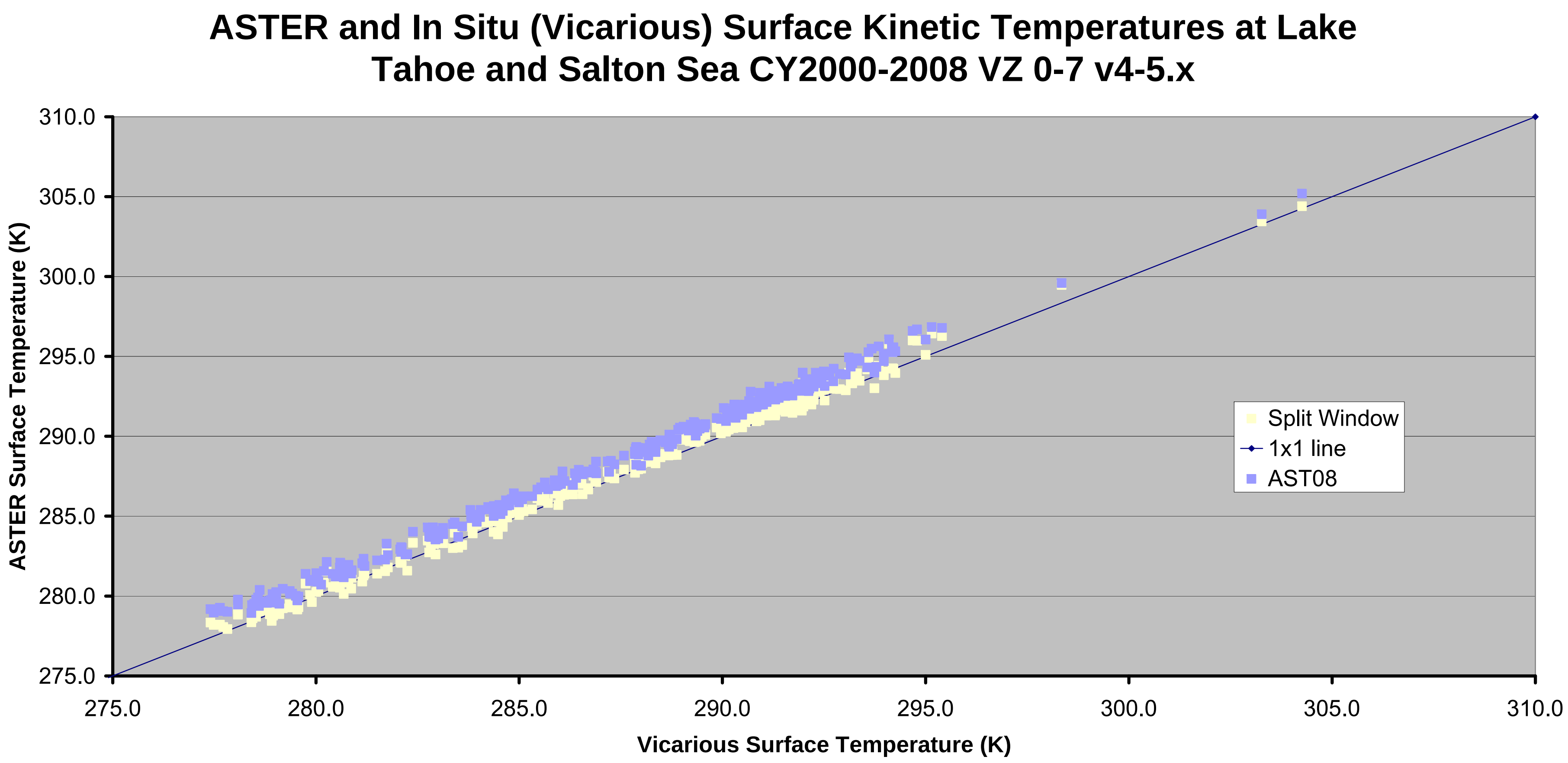
3. LST Validation

- **Notoriously difficult due to large spatial heterogeneity, and rapid temporal variations**

- **In-Situ ground measurements concurrent with overpass**
  - Lake Tahoe and Salton Sea automatic Cal/Val facility (since 2000)
  - Rice field validation site in Valencia, Spain (full cover)
  - MSG-SEVIRI validation sites over Africa
  - DOME-A site, Antarctica
  - NOAA Surfrad sites
  - Automated radiometer towers at sand dune sites?

- **Radiance-based LST validation (MODIS)**
  - Atmospheric profiles concurrent with overpass and an accurate measured emissivity are needed
  - TOA radiance estimated for two LST values close to retrieved value. 'True' LST is found by interpolating these values to observed radiance.

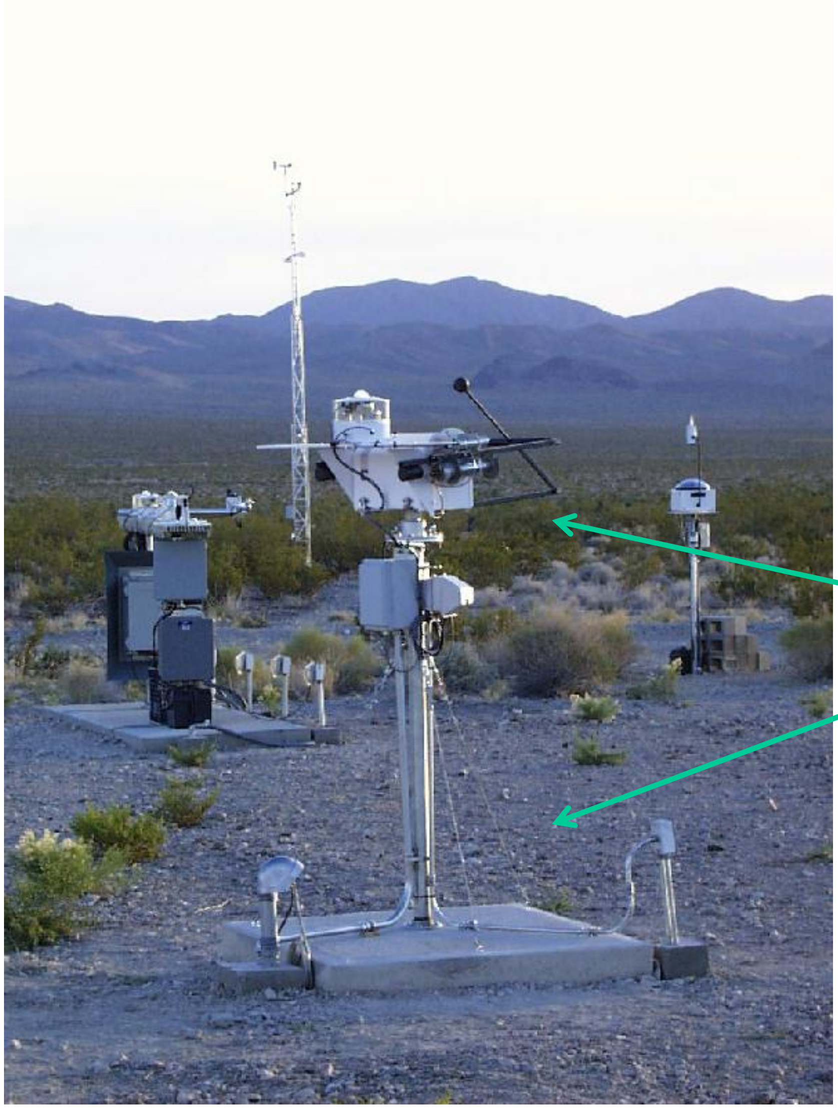
Lake Tahoe


ASTER and In Situ (Vicarious) Surface Kinetic Temperatures at Lake Tahoe and Salton Sea CY2000-2008 VZ 0-7 v4-5.x
ASTER Surface Temperature (K)
Vicarious Surface Temperature (K)
310.0
305.0
300.0
295.0
290.0
285.0
280.0
275.0
275.0
280.0
285.0
290.0
295.0
300.0
305.0
310.0
Split Window
1x1 line
AST08

NOAA Surface Radiation Budget Network (SURFRAD) sites

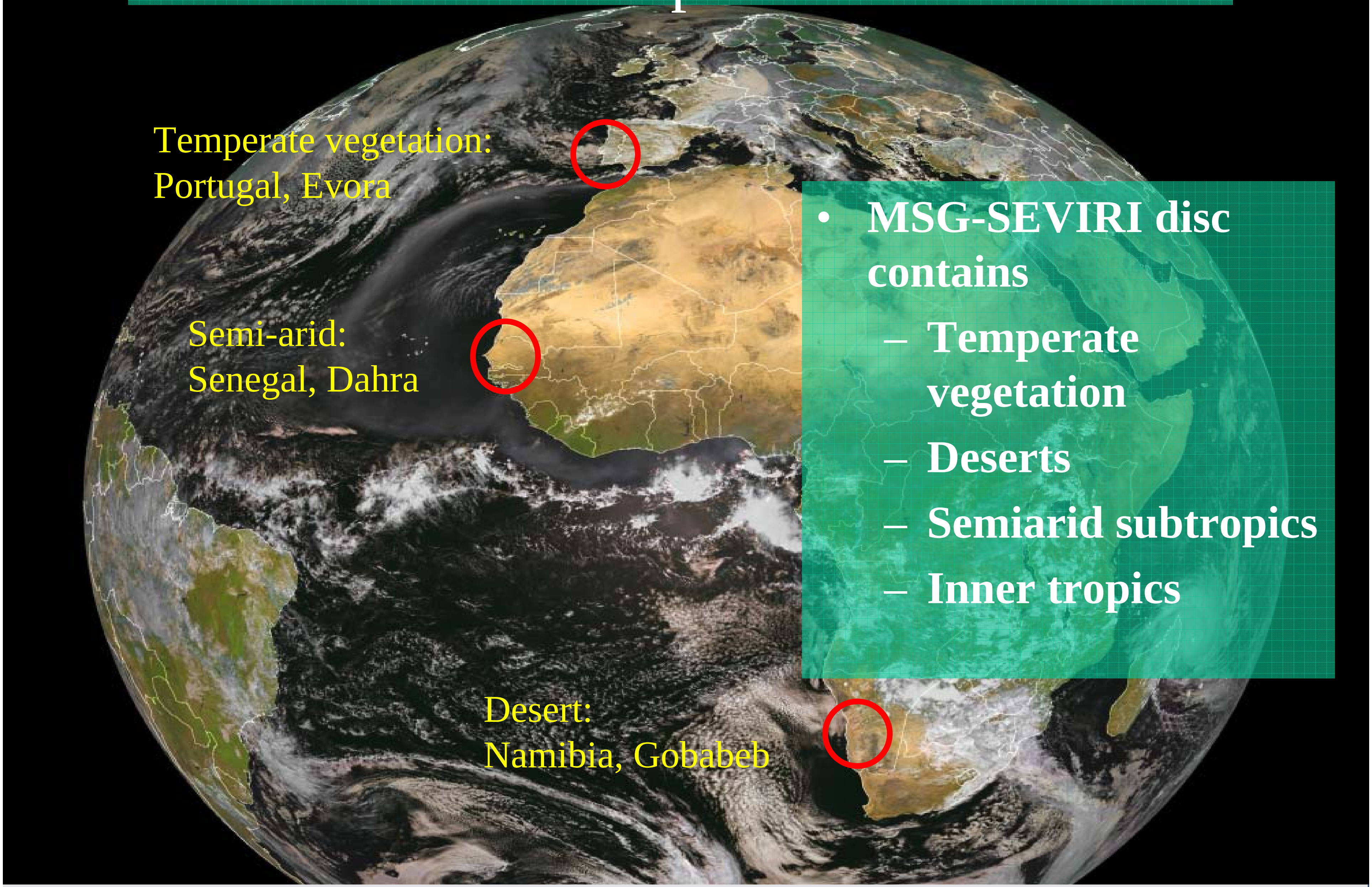
- Used for surface radiation measurements and future VIIRS (MODIS follow-on) LST validation
- 7 sites (flux towers) set up around USA
- **However**, NOT ideal for LST validation
  1. Most are situated over **heterogeneous** areas
  2. **Emissivity** is estimated from **land classification maps**
  3. **LST** is approximated using **Stefan-Boltzmann law** using an estimated broadband emissivity from 11-12 micron range
  4. **Currently** this approach does not meet <1 K requirement for HyspIRI LST product over semi-arid, arid regions

Desert Rock Surfrad site, Nevada



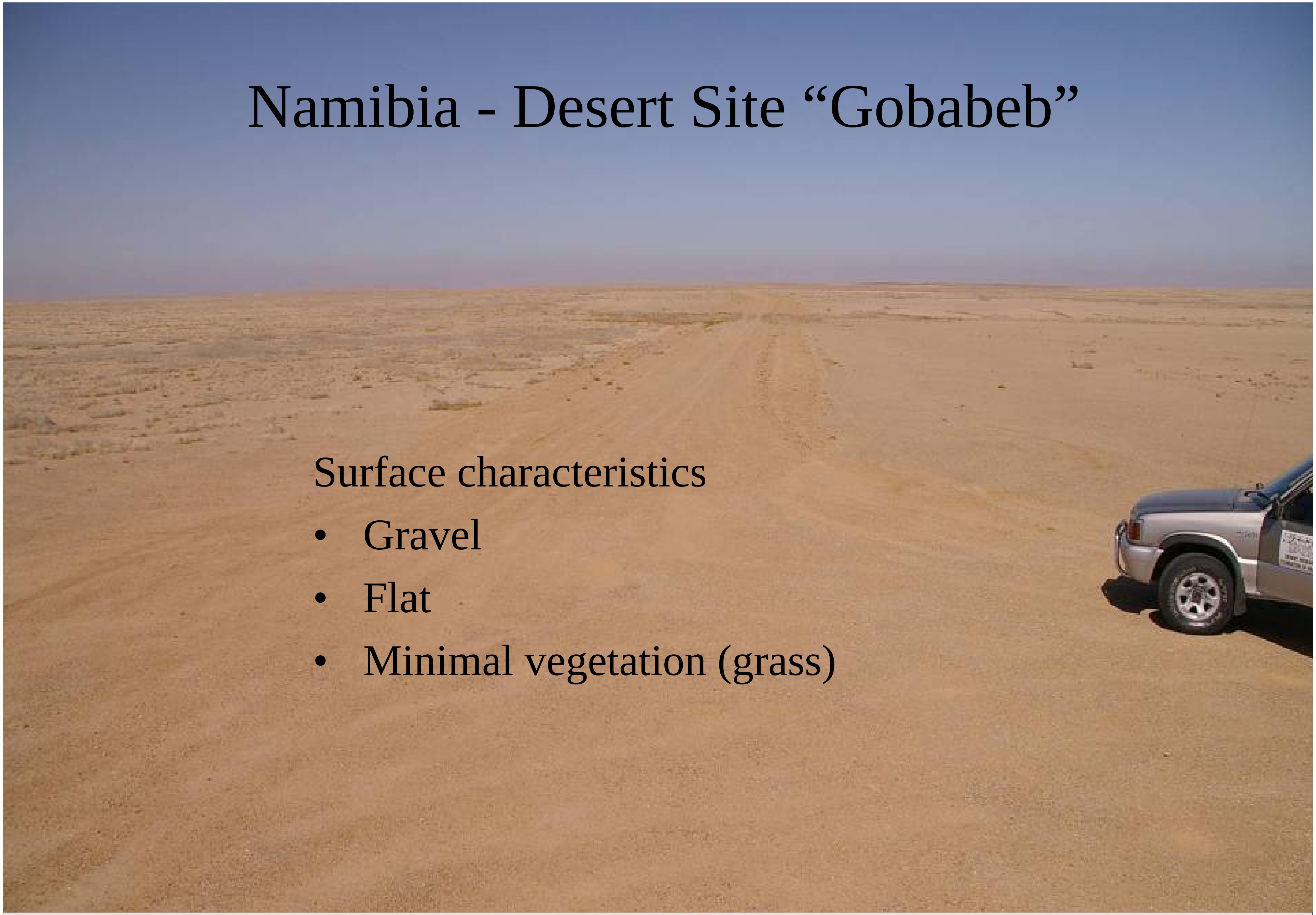
Mixed Scene type

Land Surface Temperature Validation



- **MSG-SEVIRI disc contains**
  - **Temperate vegetation**
  - **Deserts**
  - **Semiarid subtropics**
  - **Inner tropics**

Namibia - Desert Site "Gobabeb"



Surface characteristics

- Gravel
- Flat
- Minimal vegetation (grass)

Instruments at Gobabeb, Namibia

- 25 m level
  - 2 Heitronics KT15 radiometers
  - 1 Apogee IRR-PN radiometer
  - Wind speed & direction
  - Temperature & humidity
- 2.5 m level
  - 1 Heitronics KT15 radiometer (sky temp. at 52° zenith angle)
  - Energy balance (K&Z CNR1) SW & LW
  - Wind speed & direction
  - Temperature & humidity
  - Data-logger and radio-link
  - Energy supply solar panel

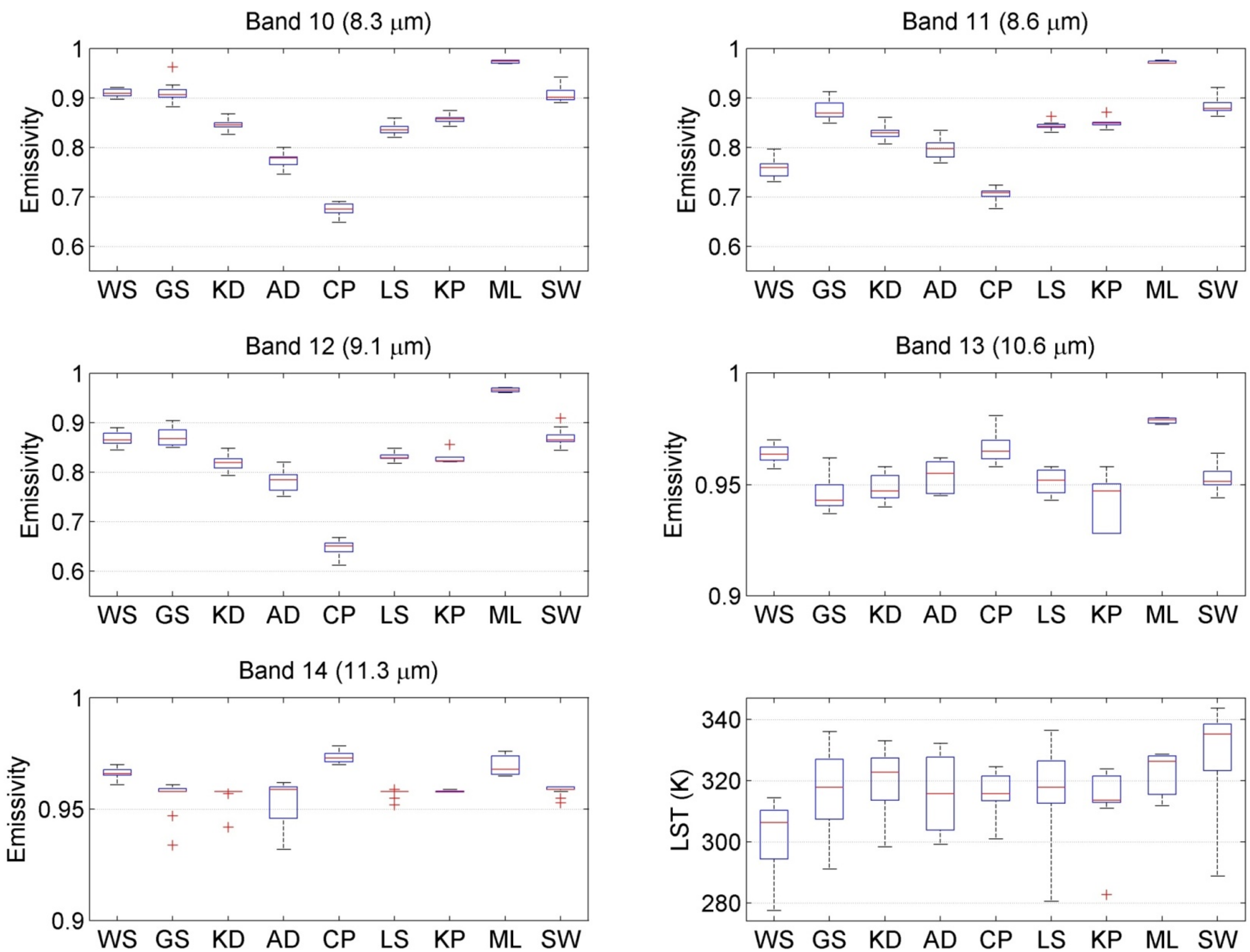
Conclusions

- **Identified Core L-2 Products**
  - Surface Radiance
  - Land Surface Temperature
  - Land Surface Emissivity

- **Established criteria for emissivity/LST validation**
  - Homogenous sites at scale of imagery
  - Several pixels covering site
  - Known composition

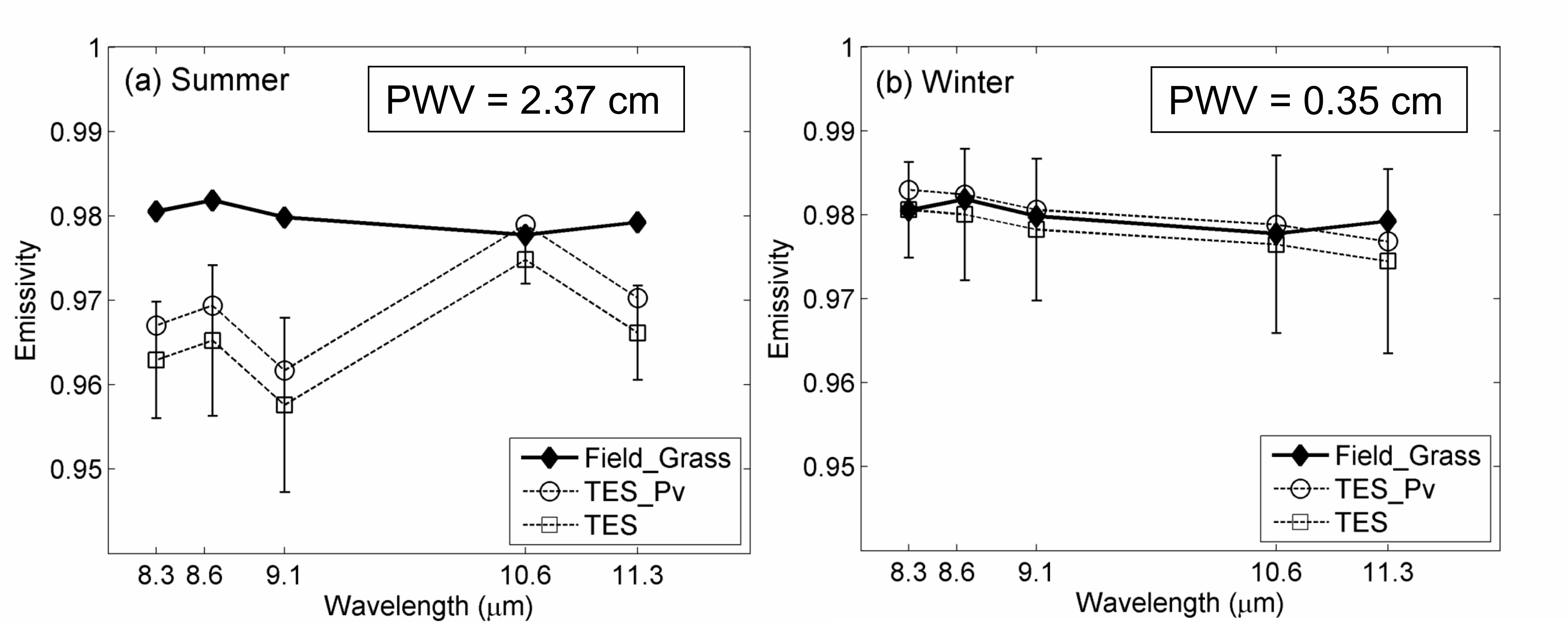
- **Proposed validation sites meeting above criteria:**
  - Lake Tahoe/Salton Sea automatic cal/val site (cool-warm)
  - Antarctica, DOME-A (cold)
  - Valencia rice fields (cool)
  - Pseudo-invariant sand dune sites (hot)

Sand Dune Site Stability



Vegetation Validation Results

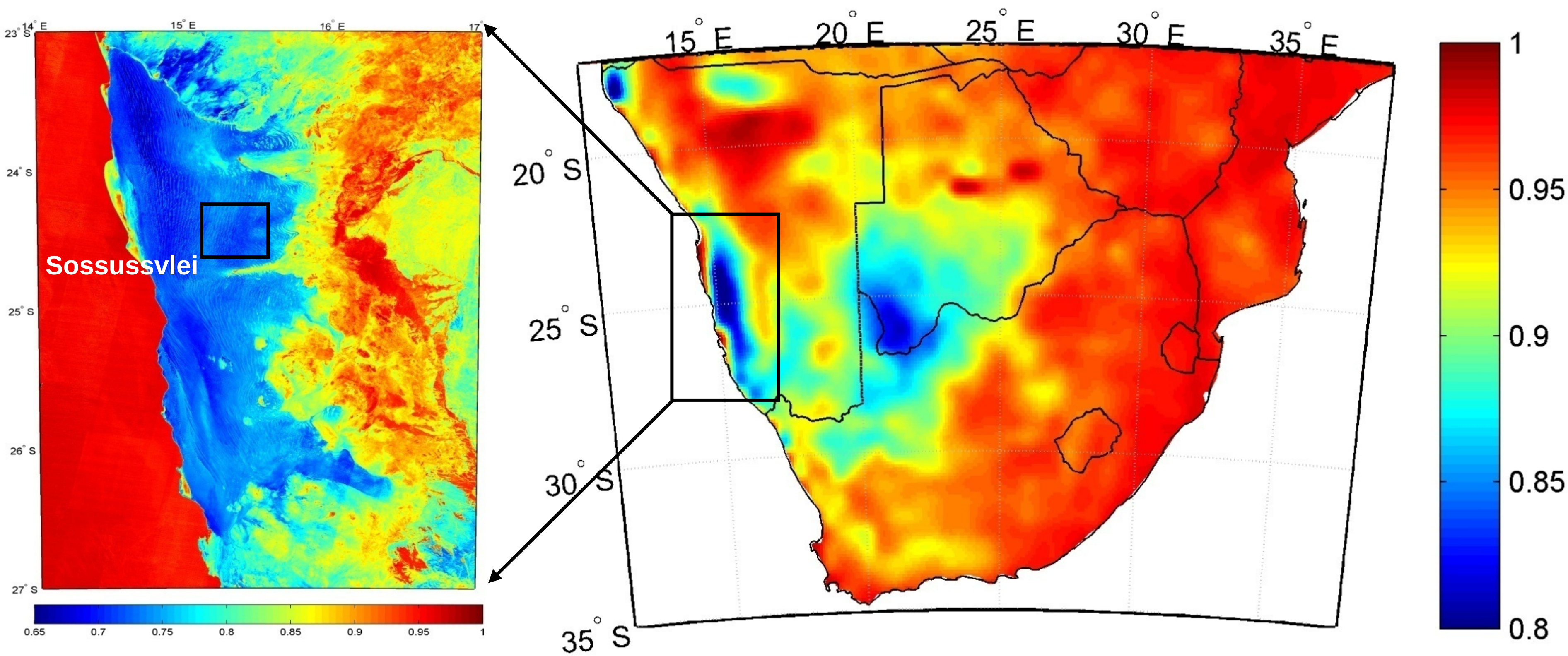
- 10x10 km Grassland in Northern Texas (~80% cover)
- In-situ measurements with TIR interferometric spectroradiometer by UCSB



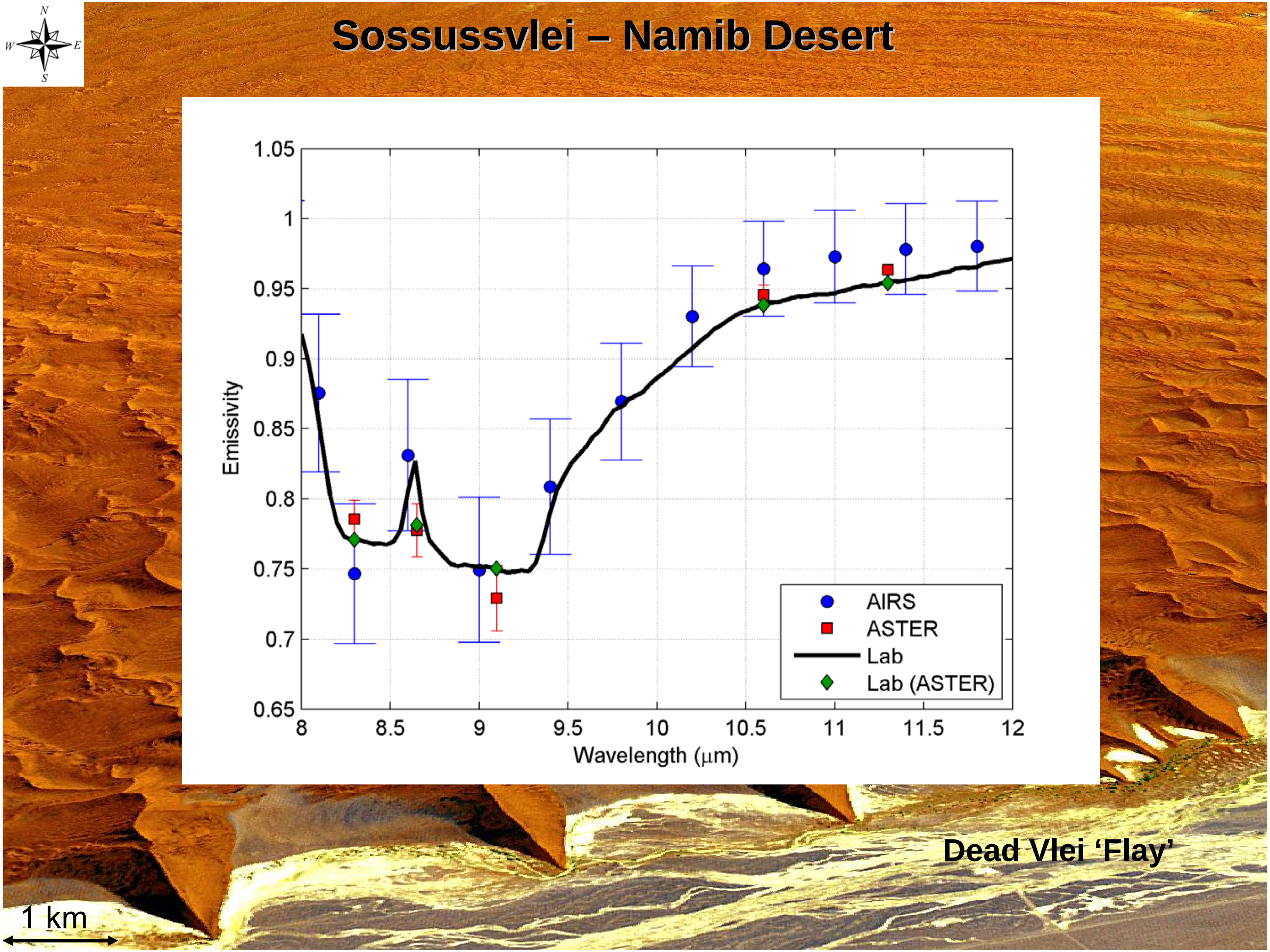
Emissivity Validation: Namib Desert, Namibia

ASTER Mean Emissivity
July-Sep,2000-2008,8.6 μm

AIRS Mean Emissivity, July 2002-2006, 8.6 μm



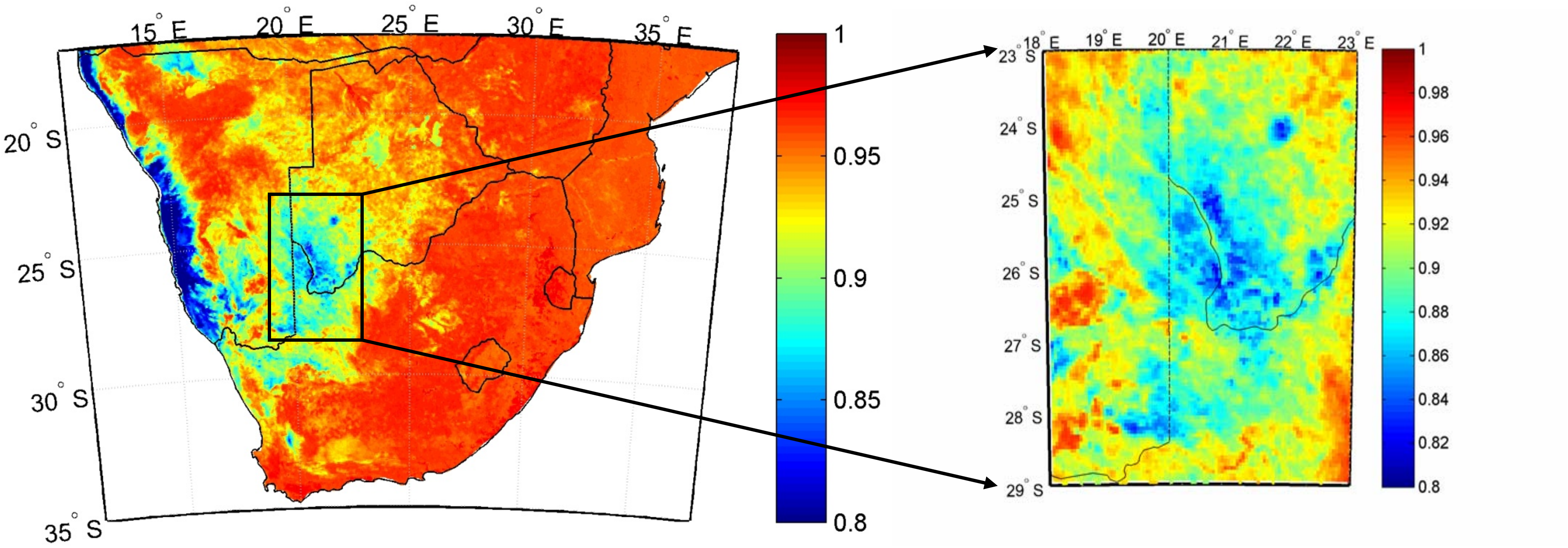
Sossussvlei – Namib Desert

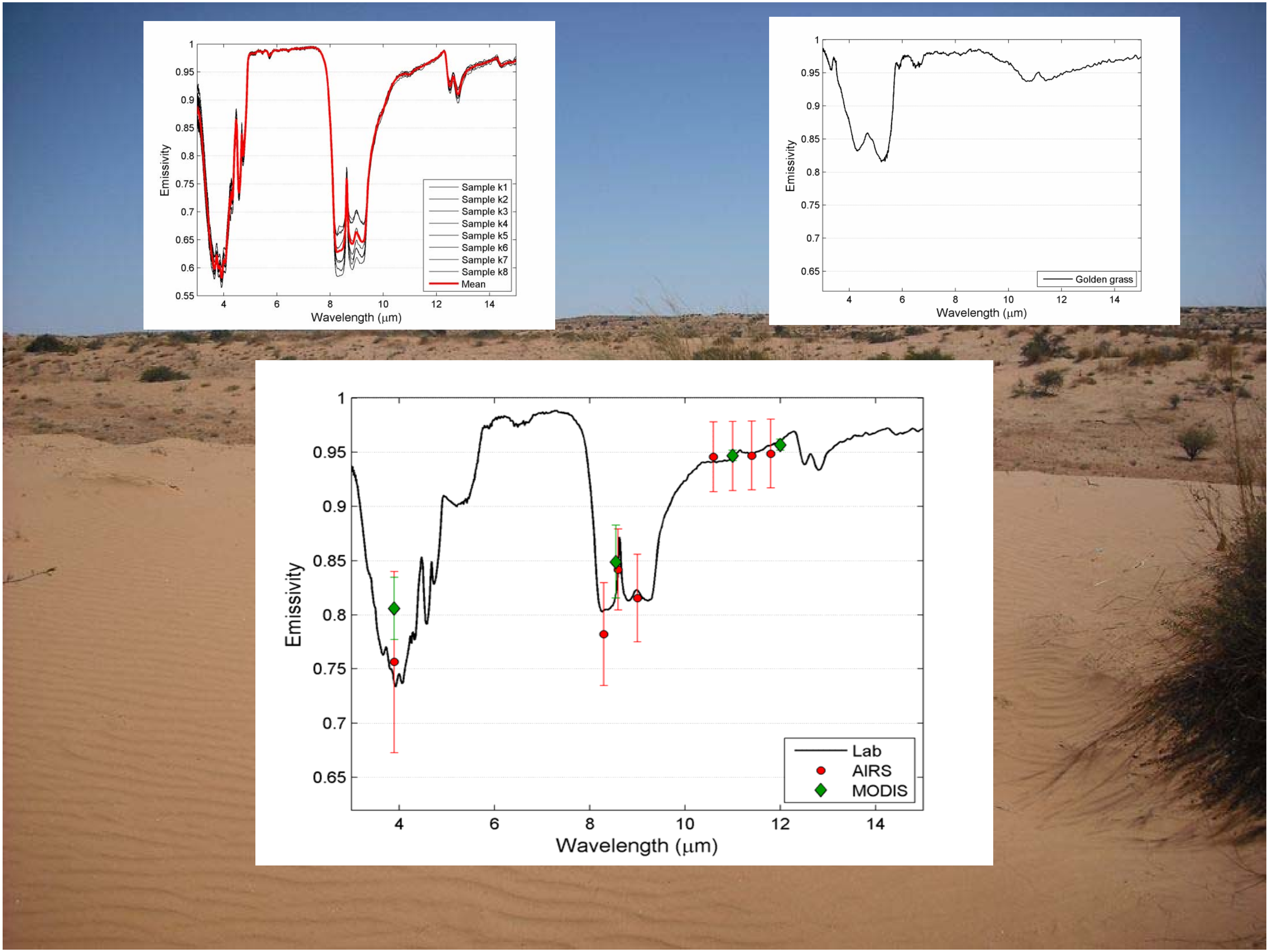


Emissivity Validation:

Kalahari Desert, South Africa

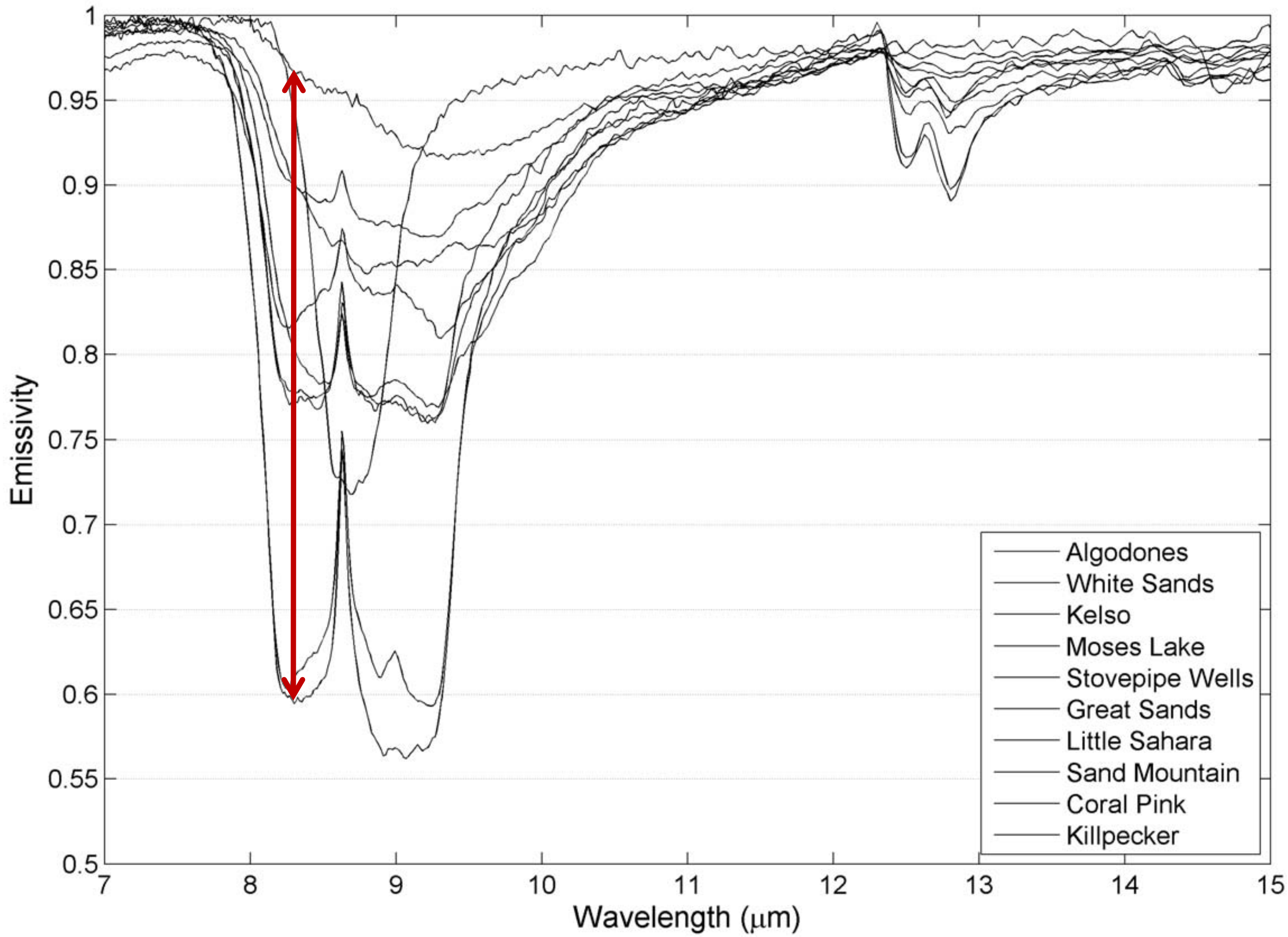
MODIS v4 Mean Emissivity, July 2002-2006, 8.6 μm





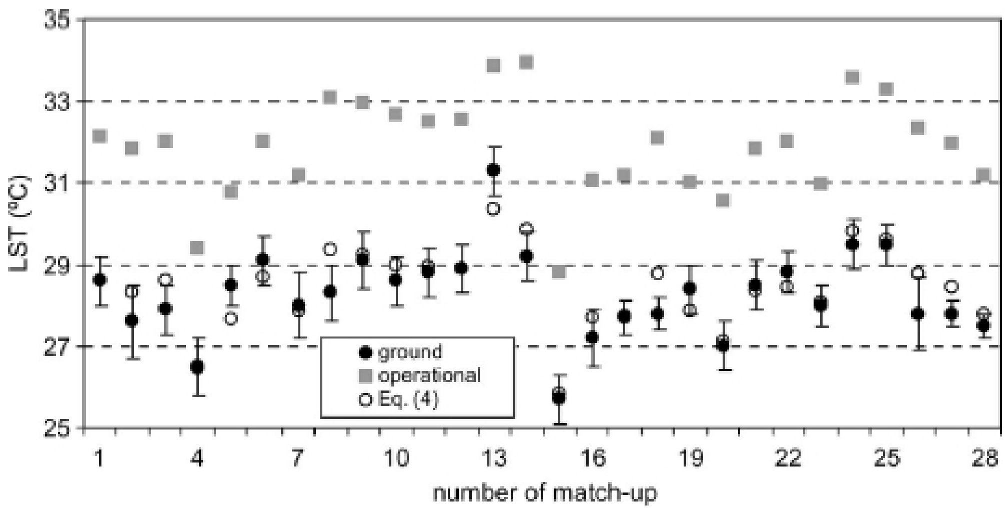
Emissivity
Wavelength (µm)
Sample k1
Sample k2
Sample k3
Sample k4
Sample k5
Sample k6
Sample k7
Sample k8
Mean
Emissivity
Wavelength (µm)
Golden grass
Emissivity
Wavelength (µm)
Lab
AIRS
MODIS

Sand Dunes: Emissivity Range



Valencia Rice Field Site

AATSR LST validation

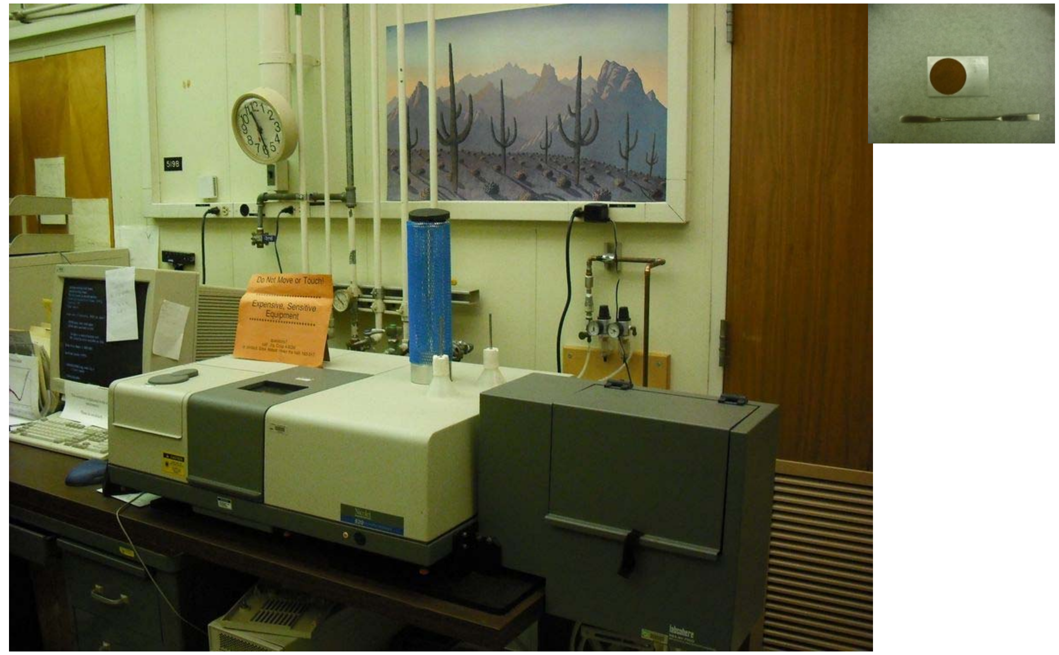


Coll et al., (2009)

When correct biome is classified (broadleaf shrub), AATSR LST show excellent agreement with in-situ measurements (<0.5°C)

Sand samples collected in field

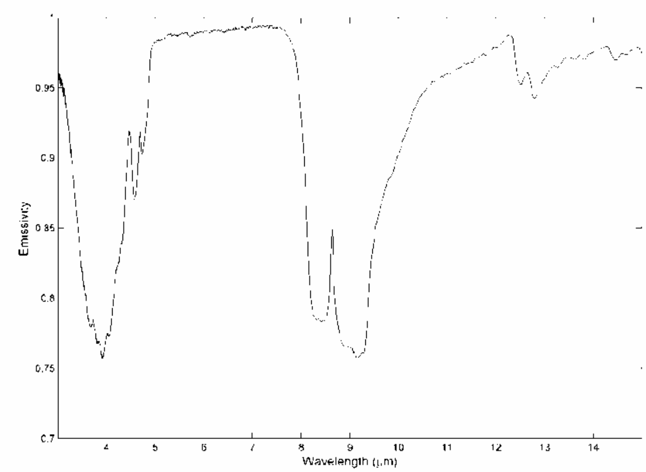
Reflectance measured using Nicolet 520 FTIR spectrometer



JPL

LAB MEASUREMENTS

$\varepsilon = 1 - r$



spectral range: 2.5 – 15 μm

spectral resolution: 4 cm^{-1}

1000 scans in 10 minutes