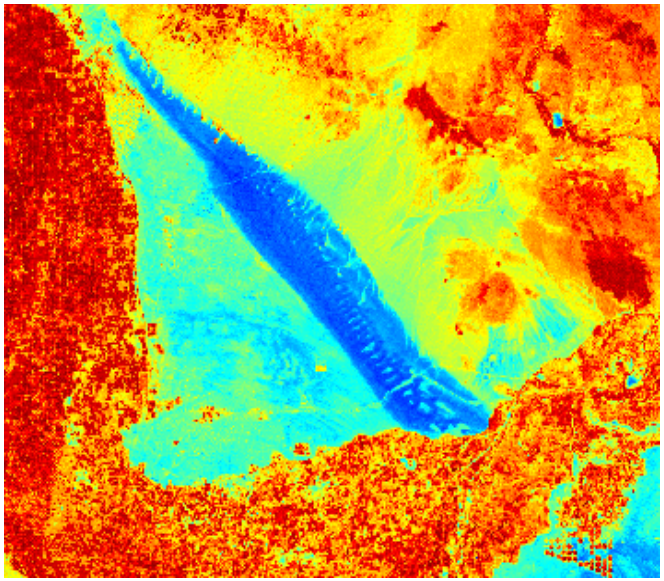
HyspIRI Level-2 Thermal Infrared Preparatory Activities



Glynn Hulley, Simon Hook

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Introduction

- **Land Surface Emissivity:** ratio between actual emitted radiation, and radiation emitted by a blackbody at the same temperature (typically varies from 0.6 – 0.99)

$$\epsilon_\lambda = \frac{L_\lambda}{L_\lambda(BB)}$$

- **Land Surface Temperature (LST):**

  how 'hot' the skin surface of the Earth feels at any given time

Brightness temperautre (radiometric) $T_b = B_\lambda^{-1}(L_\lambda)$

Kinetic temperature (LST) $L_\lambda = \varepsilon_\lambda \cdot B_\lambda(T_s)$

- LST and emissivity closely coupled variables, BUT are independent measurements!
  - Emissivity is intrinsic property of the Earth's surface
  - LST varies with local atmospheric conditions and irradiance history
  - Emissivity error of 0.015 = 1 K LST error

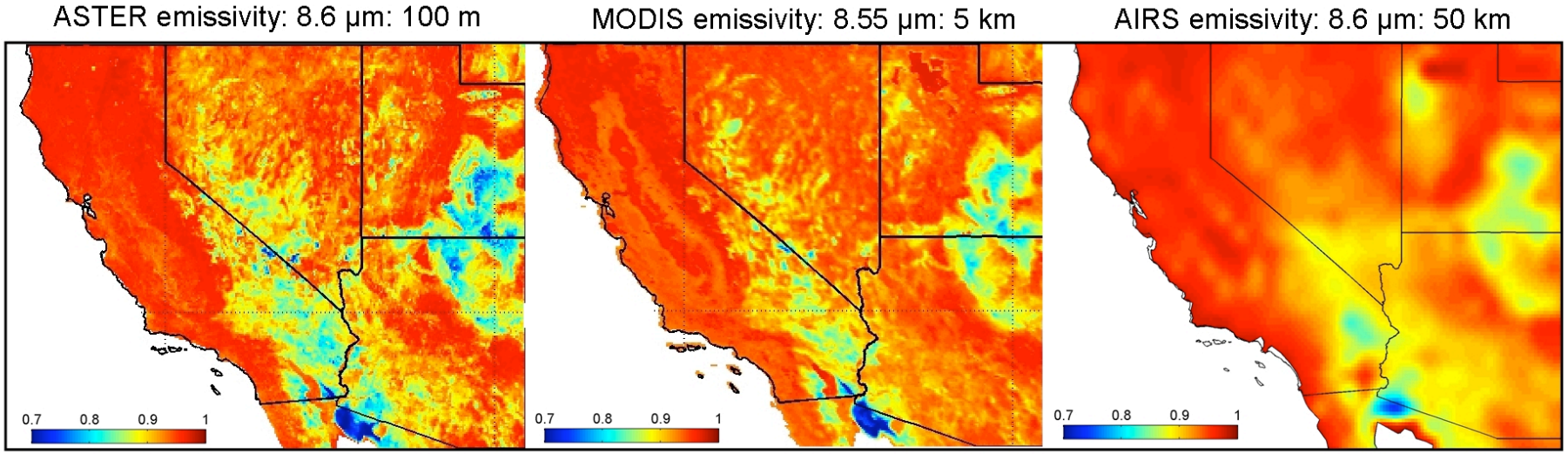
- Basic concepts, but large uncertainties between different sensors (e.g. MODIS, ASTER, AIRS)

HyspIRI Land Surface Temperature (LST) and Emissivity Relevance

- Temperature/emissivity => key components for HyspIRI:
  - Fire research (Randerson, Dennison, Giglio, Veraverbeke)
  - Evapotranspiration modeling (Anderson, Kustas, French, Ustin)
  - Urban studies (Luvall, Roberts, Quattrochi)
  - Volcano monitoring, thermal anomalies (Abrams, Realmuto, Vaughan, Wright, Pieri, Ramsey)
  - Surface composition (Ramsey, Mars, Kruse)

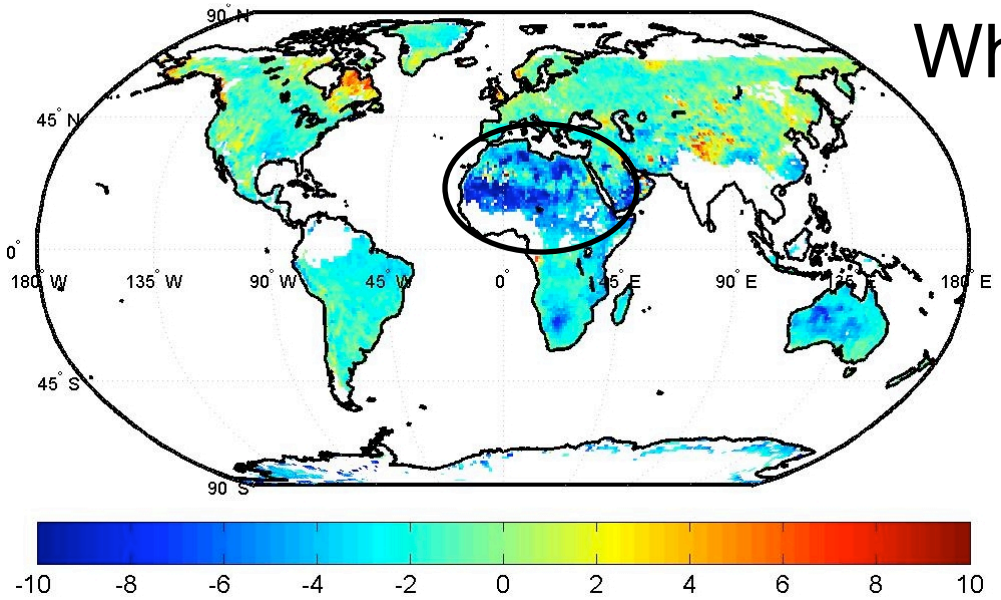
Broader Context: Uncertainty Analysis

Emissivity



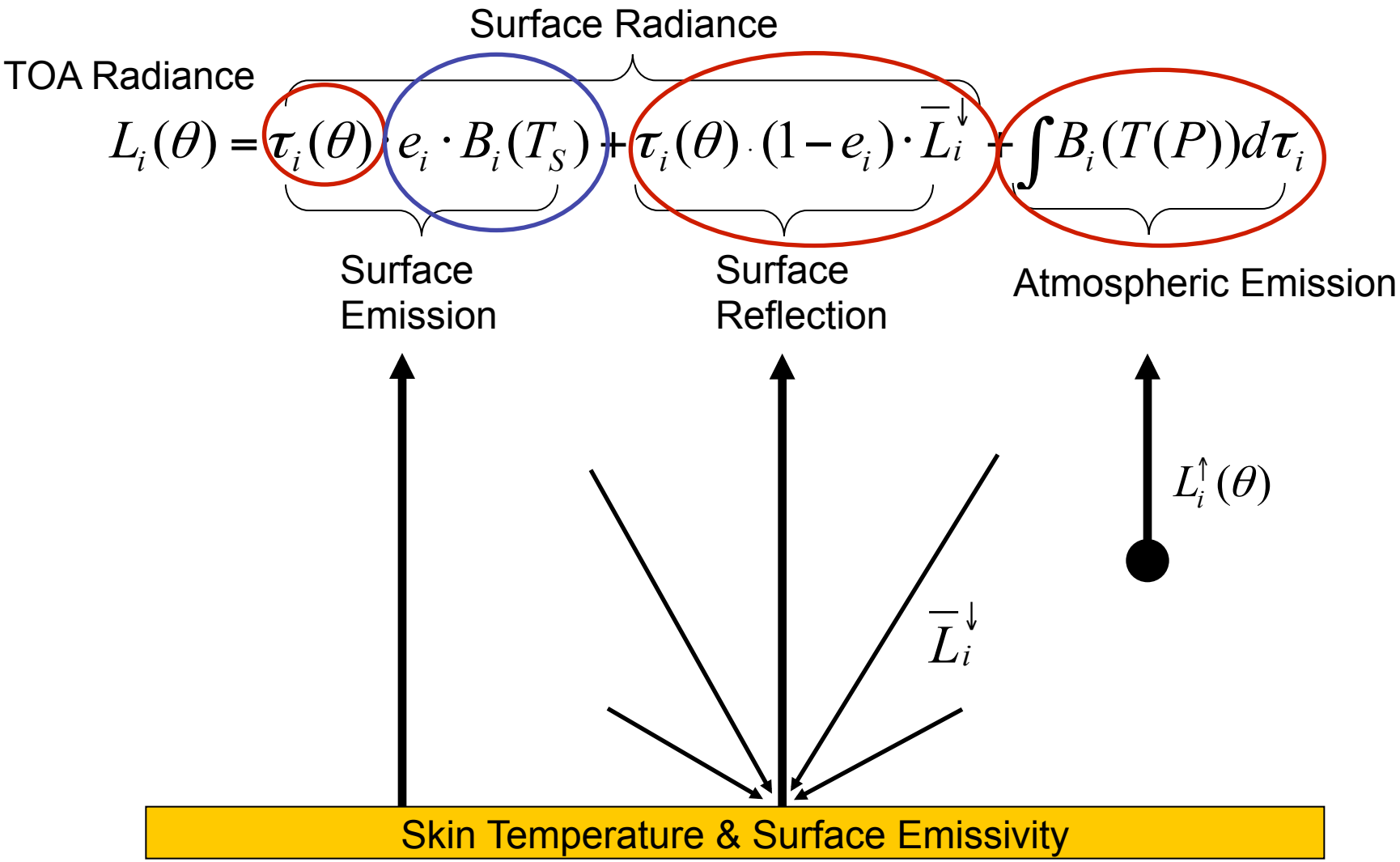
Land Surface Temperature (LST)

MODIS – AIRS daytime LST (K)



Who is Correct?

Thermal Infrared Radiative Transfer



	ASTER Simulated Data	HysplRI
Characteristics	90m, 16-day, 5 bands	60m, 5-day, 8 bands
Level-2 Core Products	1. Emissivity (5 bands) 2. Surface Temperature	1. Emissivity in 8 bands 2. Surface Temperature
Cloud Mask	v3.2 (Landsat, ASTER, MODIS heritage)	Development in progress….
Atmospheric Profiles	Terra MODIS (MOD07) - Coincident - 5 km - MOD07 ozone	Contingent upon data available at launch. NPP/NPOESS (JPSS) Back up: NWP models
Atmospheric Correction	Water Vapor Scaling (WVS) (Tonooka, 2005) MODTRAN™5.2 (Berk et al. 2005)	WVS (new model coefficients required) MODTRAN**
Temperature **E**missivity **S**eparation (TES) algorithm	Standard TES (Gillespie et al. 1998)	Standard TES (Gillespie et al. 1998) New Calibration curve

Water Vapor Scaling (WVS) Method

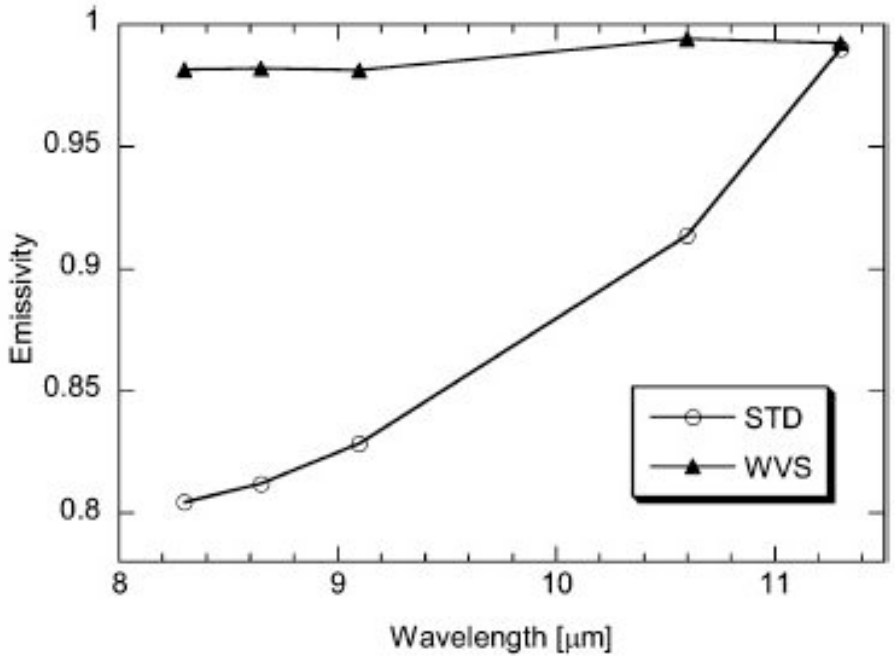


Fig. 9. Water surface emissivity spectra retrieved by the standard algorithm and by the WVS method, obtained from Lake Volta, Ghana, on October 1, 2003.

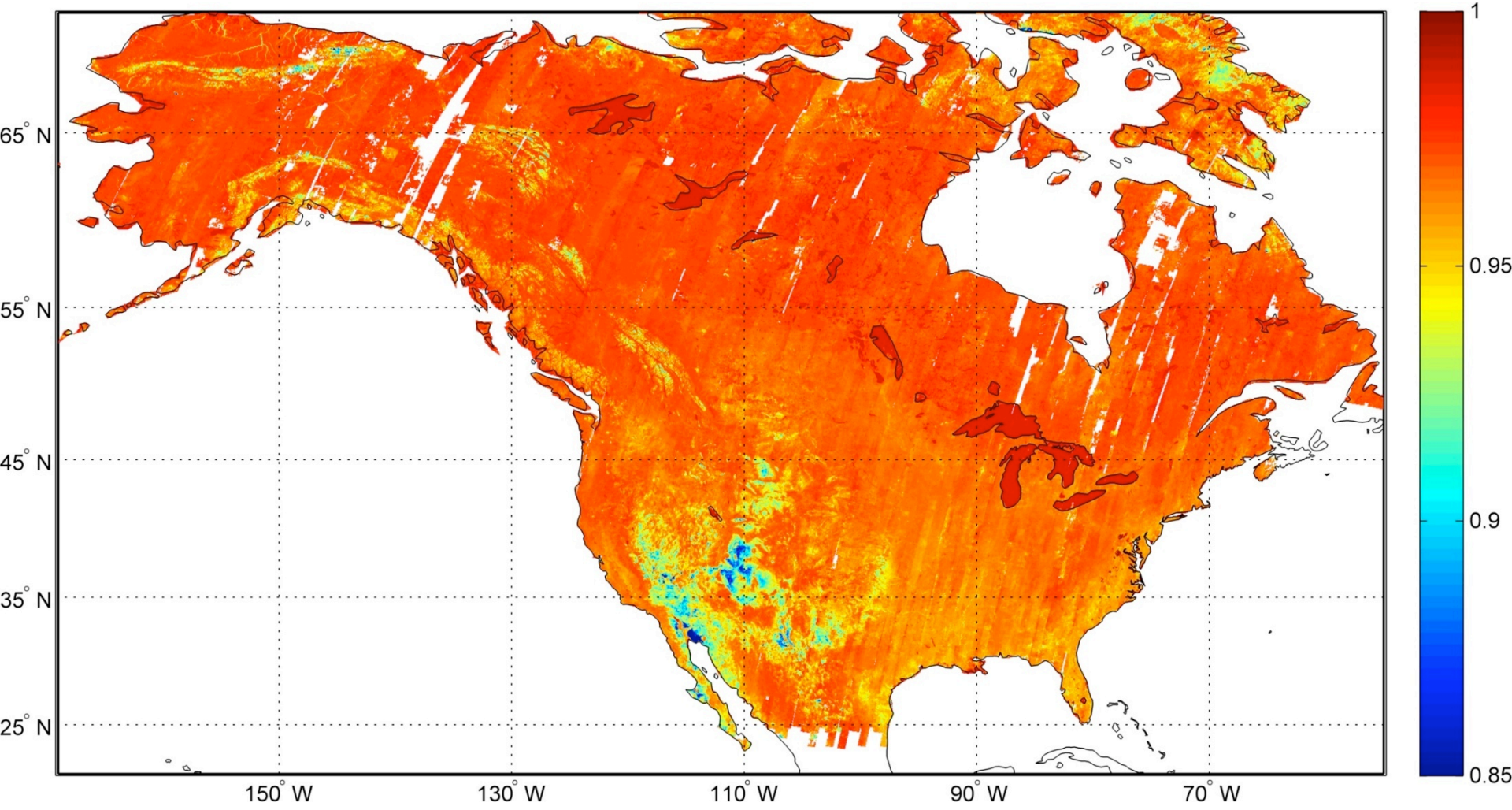
TABLE IV
LAKE SURFACE TEMPERATURE (CELSIUS) ON LAKE VOLTA, GHANA, RETRIEVED BY THE STANDARD ALGORITHM (STD) AND BY THE WVS METHOD, DERIVED FROM THE MODIS SST PRODUCT, AND GIVEN BY THE CLIMATIC REPORT

STD	WVS	MODIS	Climate
37.4	29.2	29.0	29.4

**Tonooka, 2005

North American ASTER Land Surface Emissivity Database (NAALSED)

Mean Summer Emissivity (Jul-Aug-Sep 2000-2010), Band 12 (9.1 μm)



http://emissivity.jpl.nasa.gov

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North American Land Surface Emissivity Project

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« June 2010 »

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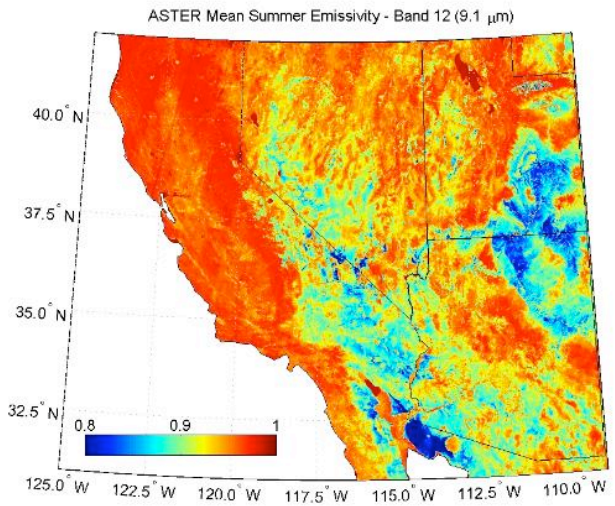
North American Land Surface Emissivity Project

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.



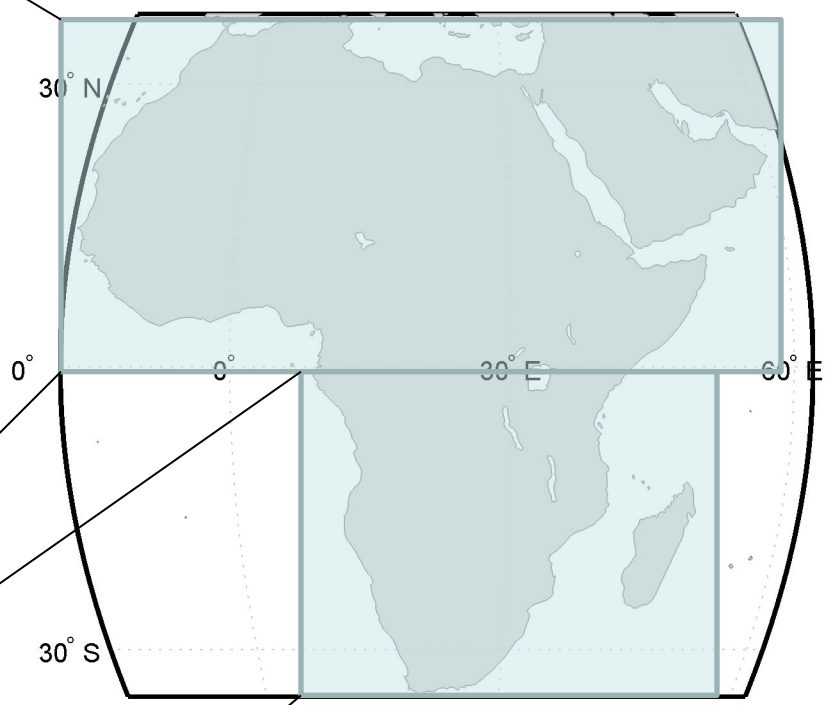
African ASTER Land Surface Emissivity Database (AALSED)

North Africa/Arabian Peninsula
- 134,662 ASTER scenes
- 49,977 MOD07 scenes

Progress:
- ✓ Data delivered from EROS
- ✓ Cloud masking completed
- ✓ TES completed
- ✓ Gridding in progress..

Southern Africa
- ~70,000 ASTER scenes
- 24,821 MOD07 scenes

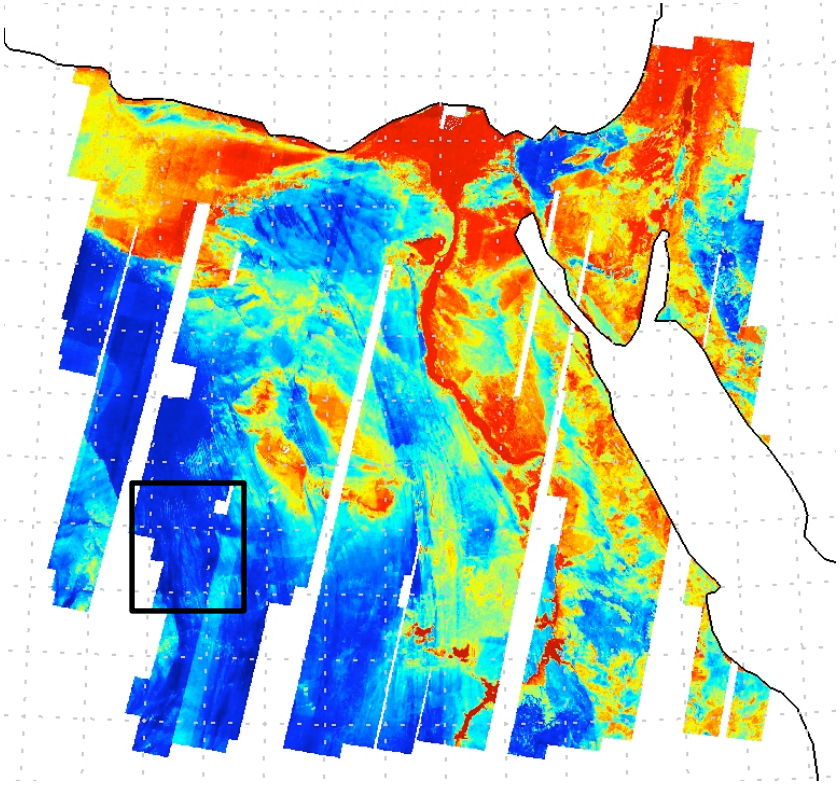
Progress:
- ✓ Data delivered from EROS
- ✓ Cloud masking in progress



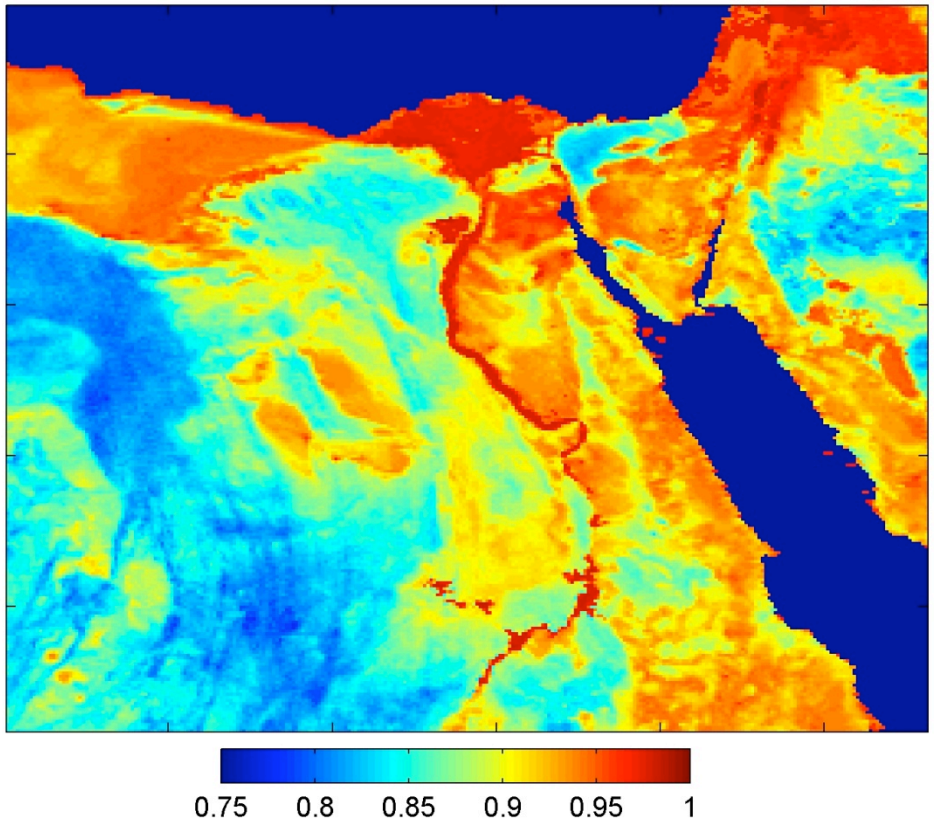
Algorithm Updates
- Updated WVS coefficients for MODTRAN5.2
- Included dust/smoke mask
- Improved no-SWIR cloud (post-2008) detection over desert

Egypt Test Area

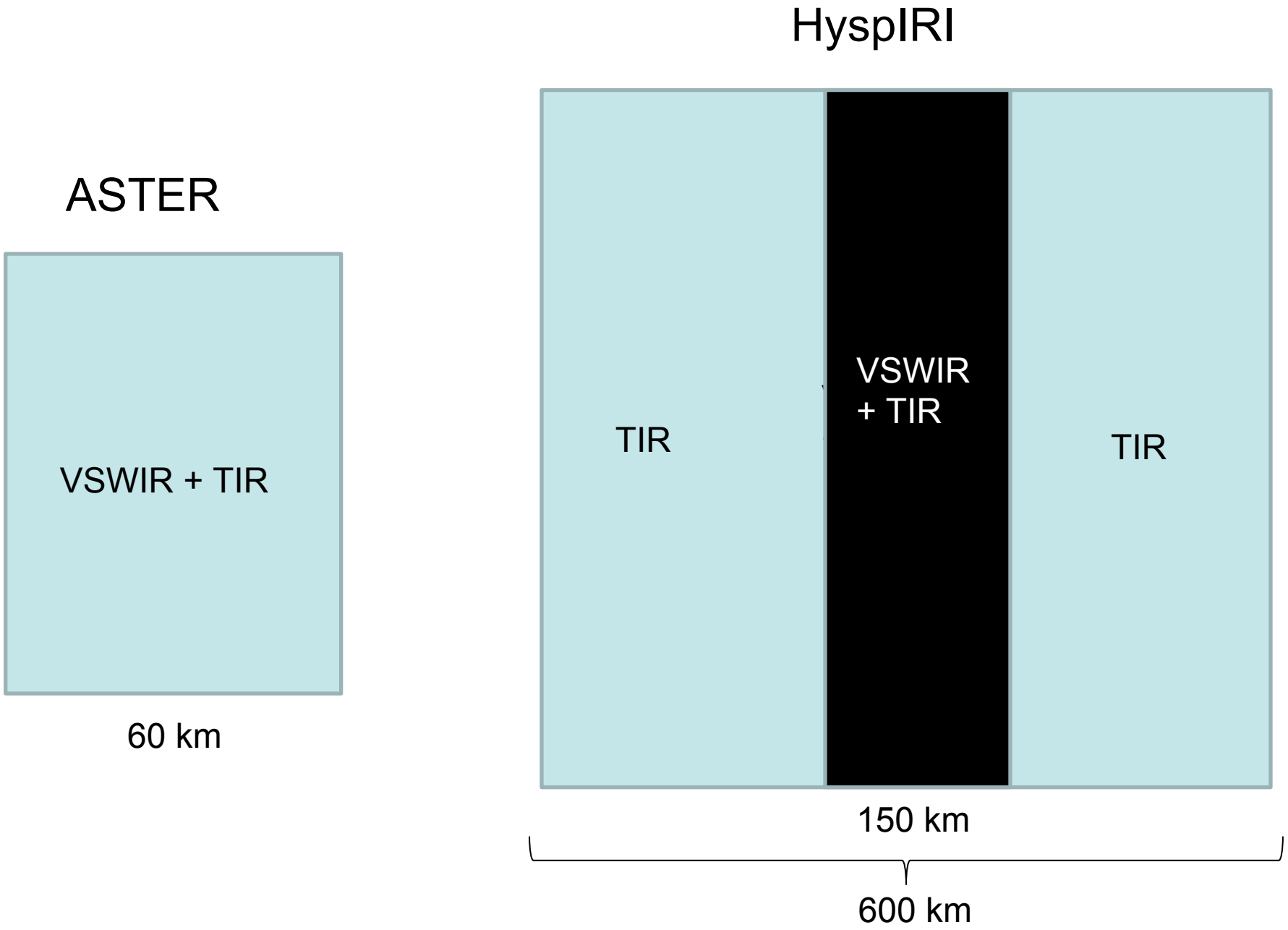
ASTER Band 11 (8.6 μm), 2000-2009 (4,888 scenes)



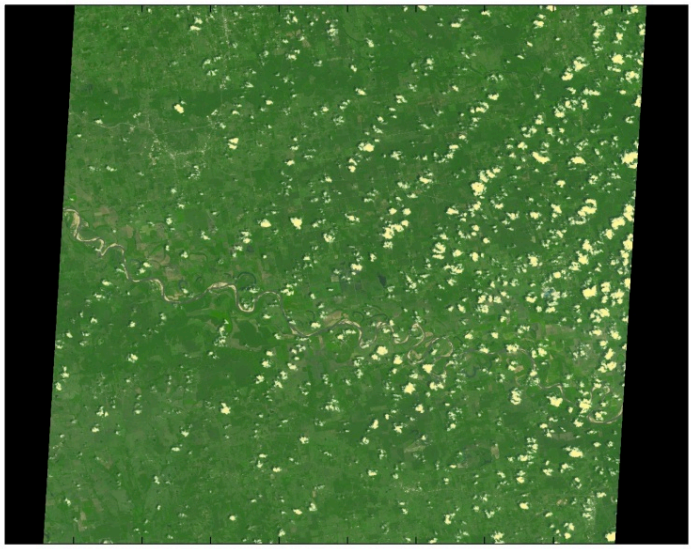
MODIS Band 29 (8.55 μm), MOD11C3, 5km



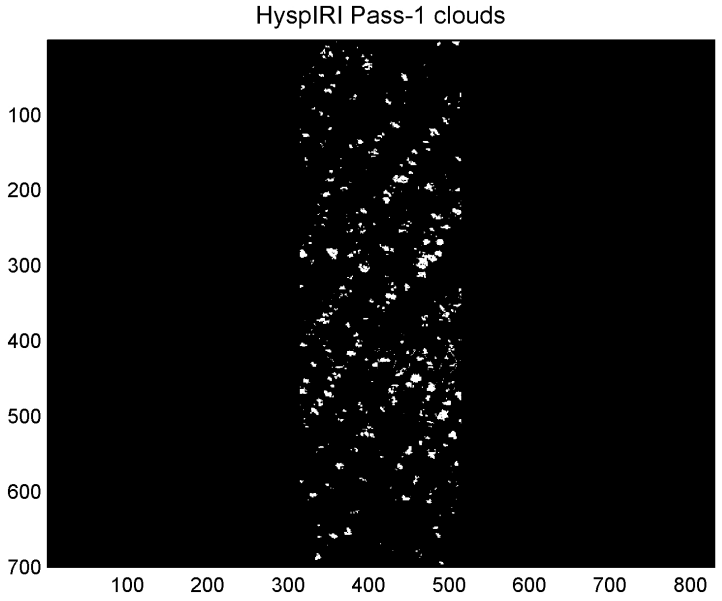
Cloud Detection?



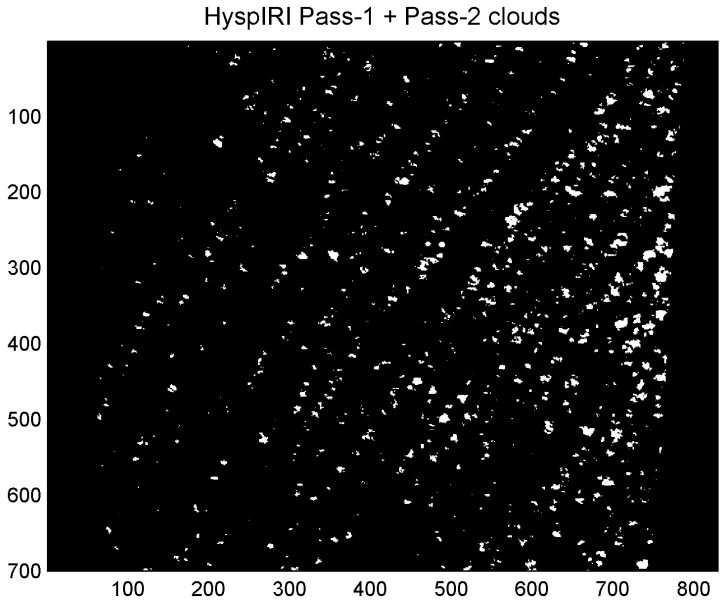
ASTER visible RGB



HyspIRI Simulated Pass-1



HyspIRI Simulated Pass-2



VSWIR + TIR Data

↓

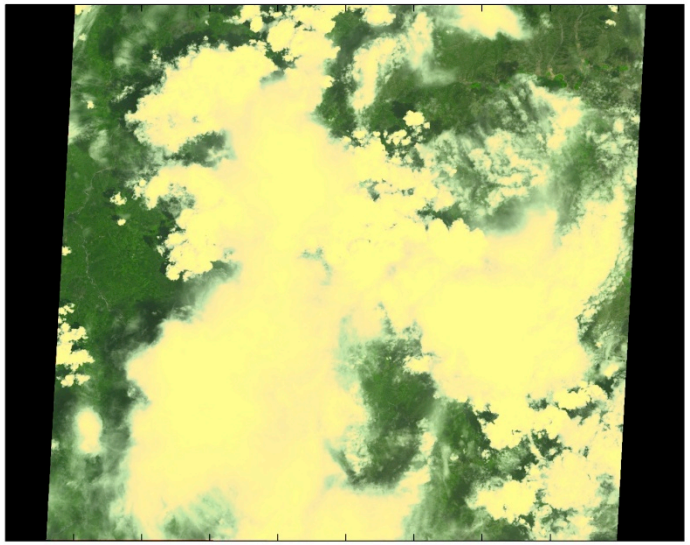
Mean Temperature: 292.22 K
Max Temperature: 299.96 K
Min Temperature: 287.89 K
Standard Deviation: 2.2 K
Skewness: 0.848

↓

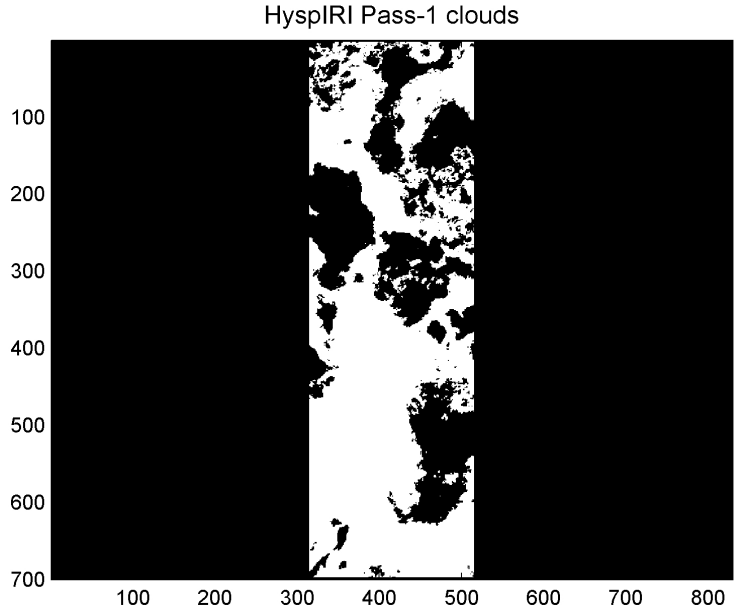
Statistical + TIR Data

←

ASTER visible RGB

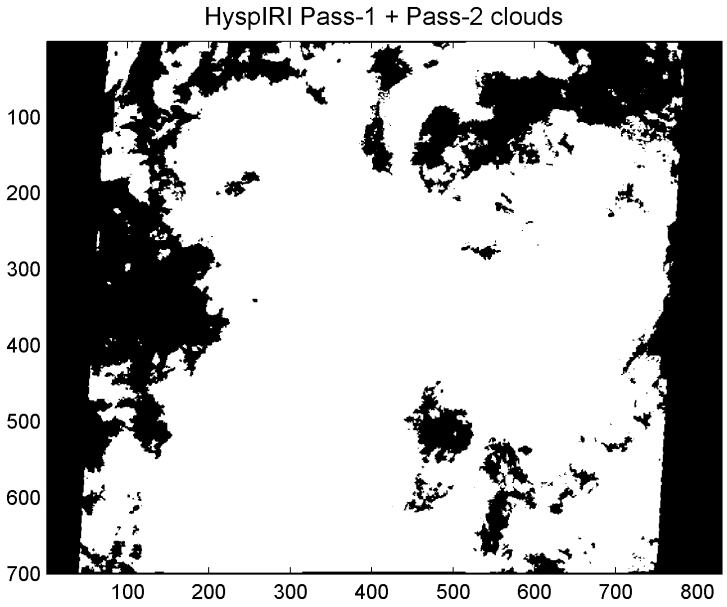


HyspIRI Simulated Pass-1



VSWIR + TIR Data

HyspIRI Simulated Pass-2



Mean Temperature: 252.42 K
Max Temperature: 299.88 K
Min Temperature: 231.52 K
Standard Deviation: 10.7 K
Skewness: 0.357

Statistical + TIR Data

HyspIRI ATBD's

2. JPL Publication XX-XX

HyspIRI Level-2 TIR Surface Radiance Algorithm Theoretical Basis Document, Version 1.0

HyspIRI Group

Prepared for National Aeronautics and Space Administration

By G. C. Hulley, S. J. Hook

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Jan 2010

Cleared and Released

2. JPL Publication XX-XX

HyspIRI Level-2 TIR Land Surface Temperature and Emissivity Algorithm Theoretical Basis Document, Version 1.0

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Jan 2010

In review: release imminent

- Oldest
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- Primaril

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Africa's Super Park

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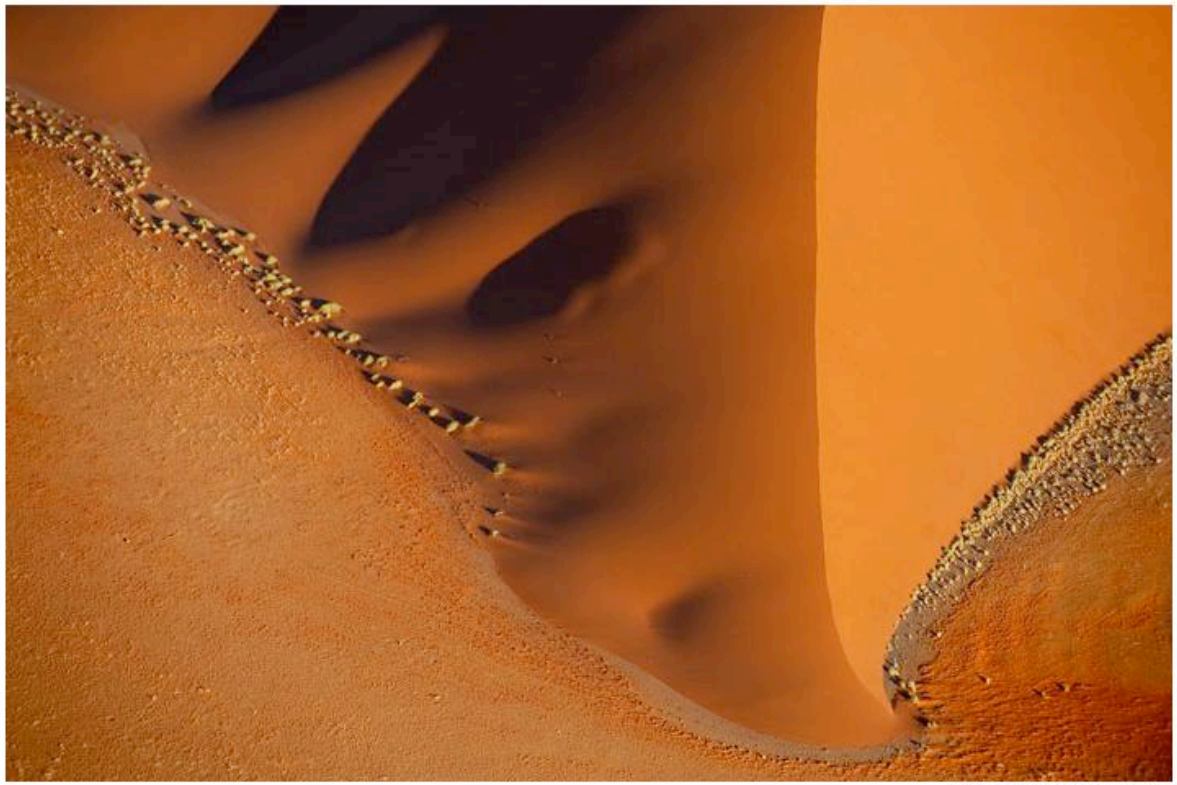
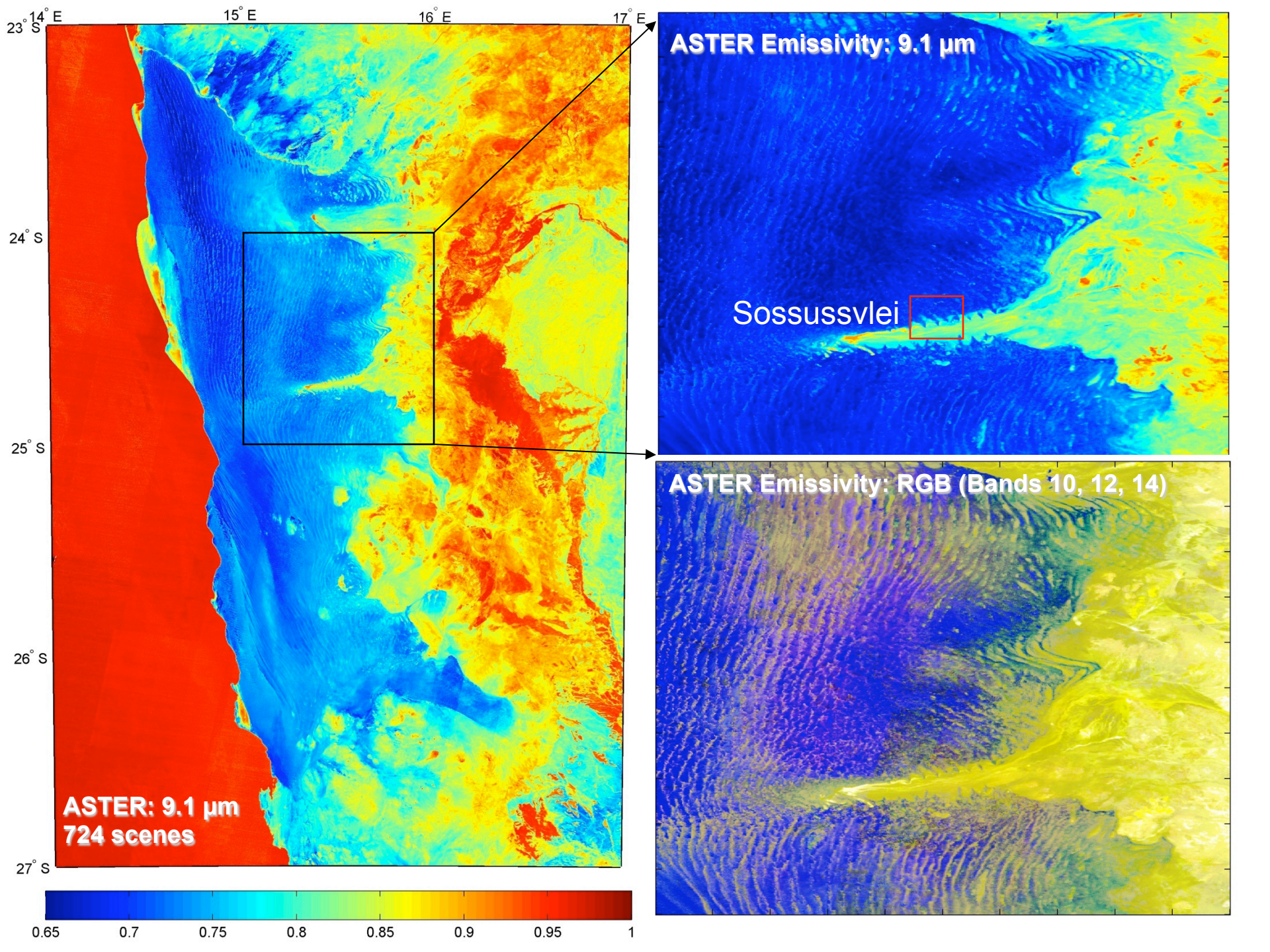
In 1990 the new nation of Namibia wrote wilderness protection into its constitution. Today nearly half of its land is set aside.

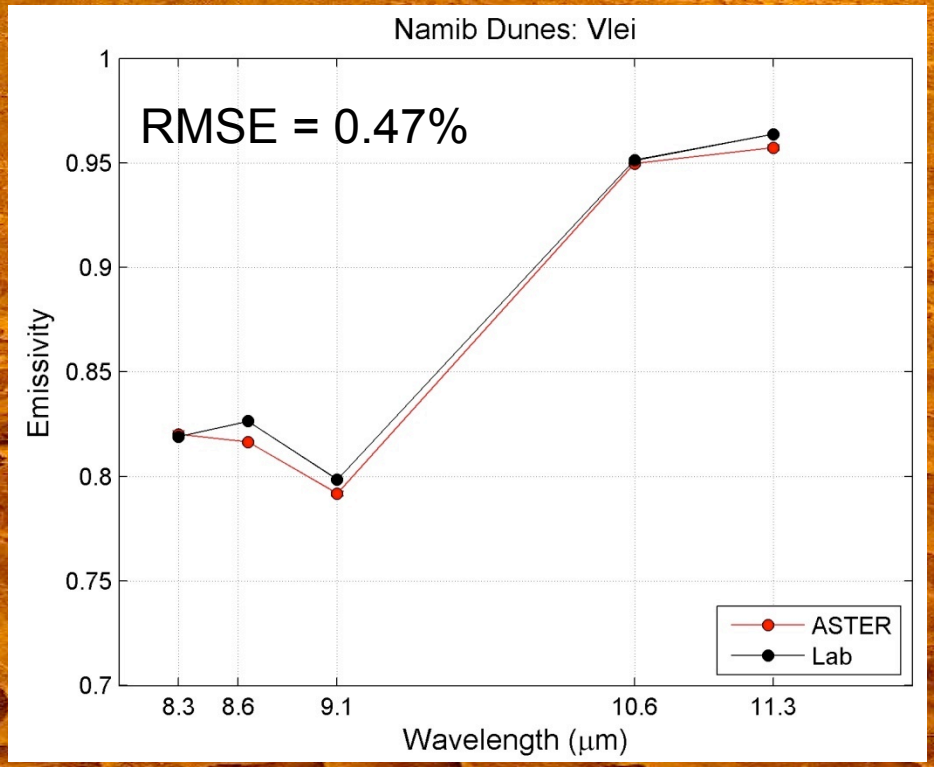


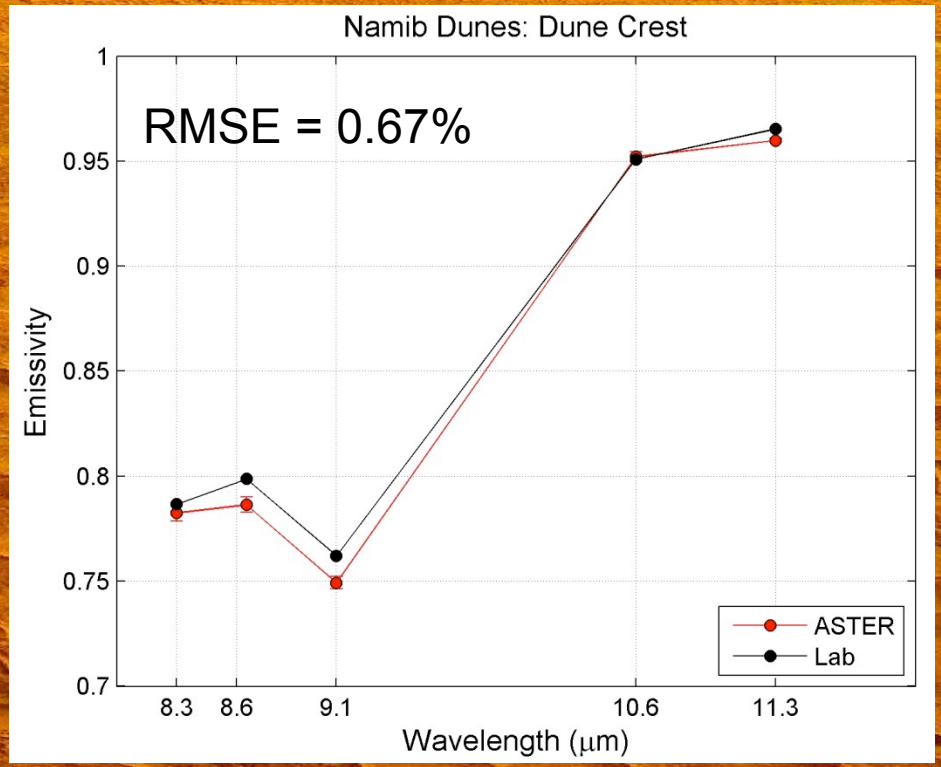
Photograph by Frans Lanting


14° E
15° E
16° E
17° E
23° S
24° S
25° S
26° S
27° S
ASTER: 9.1 µm
724 scenes
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1
ASTER Emissivity: 9.1 µm
Sossussvlei
ASTER Emissivity: RGB (Bands 10, 12, 14)

Sossussvlei – Namib Naukluft Park

*Credit: ASTER Science Team





Val site 1: Interdune (vlei)
2 samples

Val site 2: Dune crest
6 samples

Dead Vlei
'Riverved'

1 km

Summary and Future Work

- Simulated emissivity database being generated for HyspIRI TIR products
- Algorithm theoretical basis documents and procedures continue to be developed for generating HyspIRI Level-2 products (Cloud Mask, Surface Radiance, Temperature and Emissivity)

- Complete and release HyspIRI Cloud Mask ATBD
- Complete Africa and Australia ASTER Emissivity maps
- Validate emissivity using sand samples from large dune sites
- Validate temperature using in-situ and radiance-based methods

The End

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

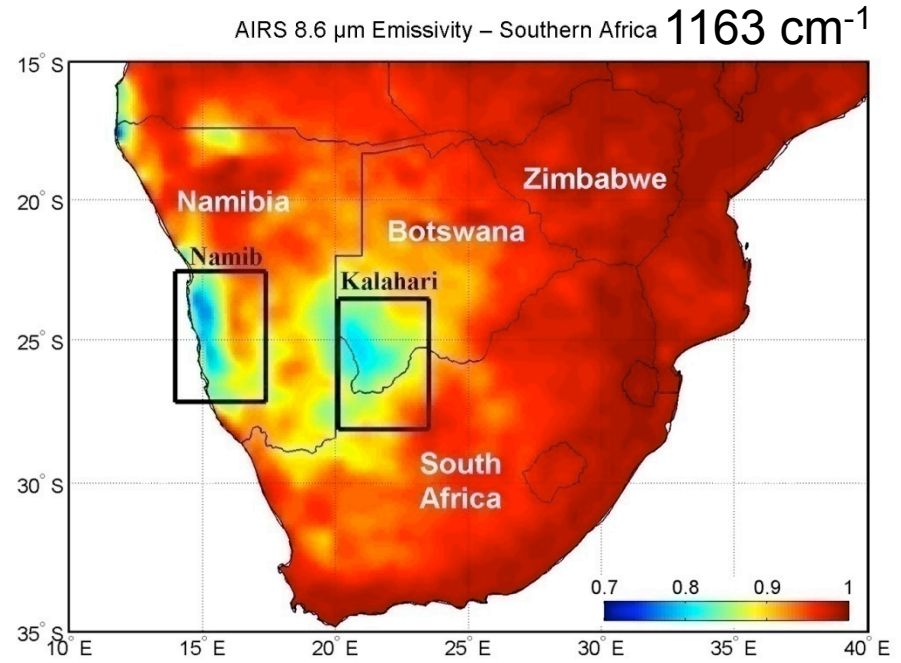
JPL 400-1278 7/06

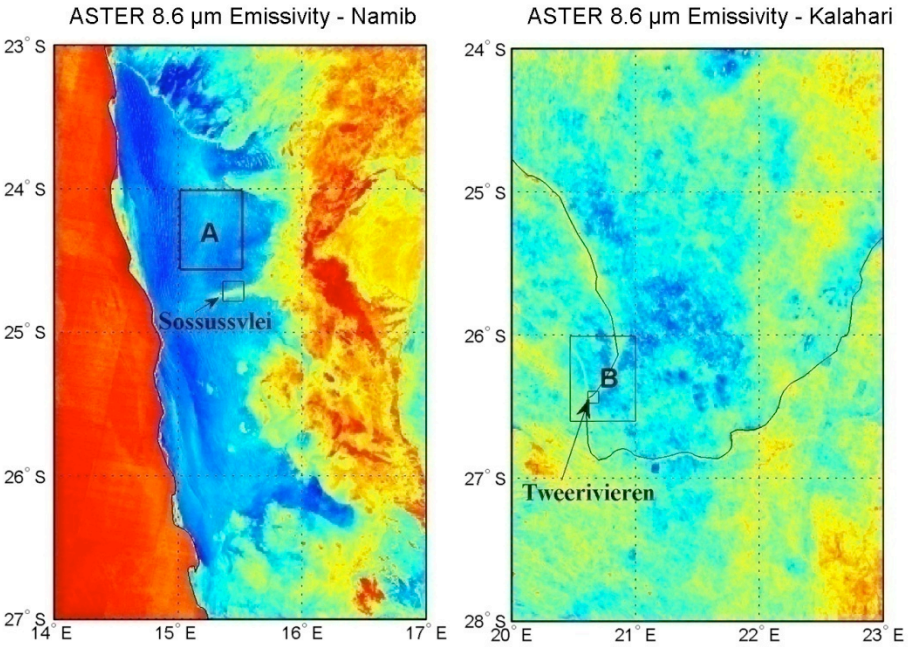
Atmospheric Infrared Sounder (AIRS, Aqua) v5 Land Surface Emissivity Validation

Validation Targets:

- Namib Desert (desert)
- Kalahari Desert (semi-arid)

AIRS emissivity validation requires large, homogeneous sites with known composition.

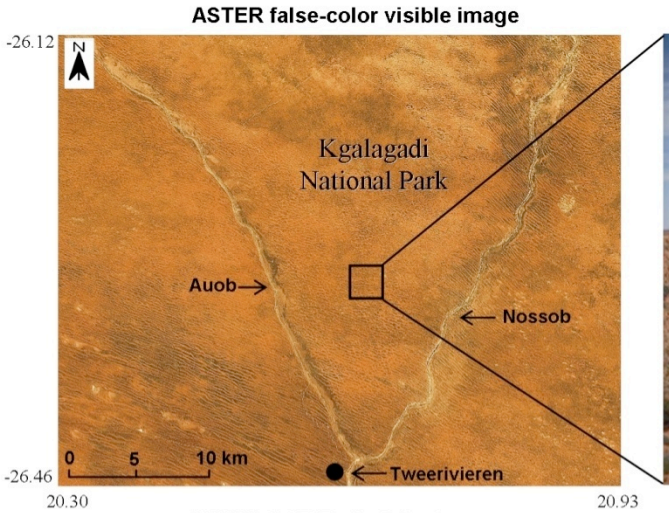




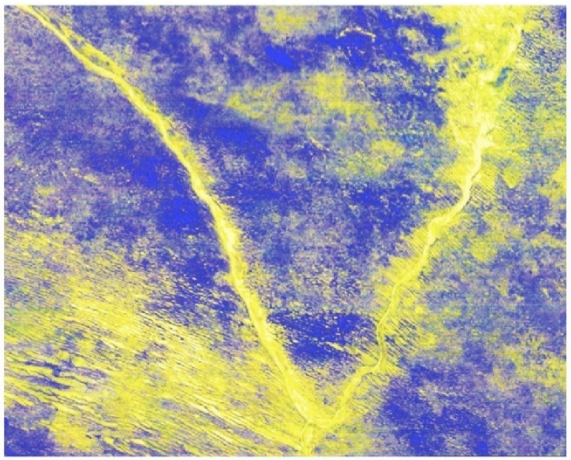
Hulley, G.C., S.J. Hook, E. Manning, S. Lee, E. Fetzer, 2009, Validation of the Atmospheric Infrared Sounder (AIRS) Version 5 Land Surface Emissivity Product over the Namib and Kalahari Desert, *Journal of Geophysical Research Atmospheres*, VOL. 114, D19104, doi:10.1029/2009JD012351

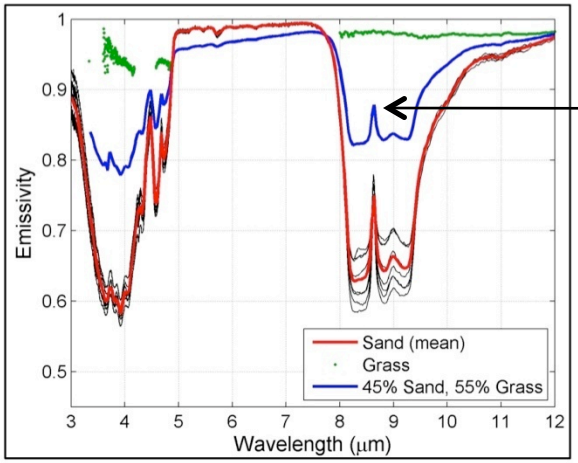
Kalahari Desert

- 20 sand samples collected at Kgalagadi National Park (17-21 November 2008)
- Sampling areas included dune crests, troughs, dry riverbeds



Major: Quartz
Minor: Hematite

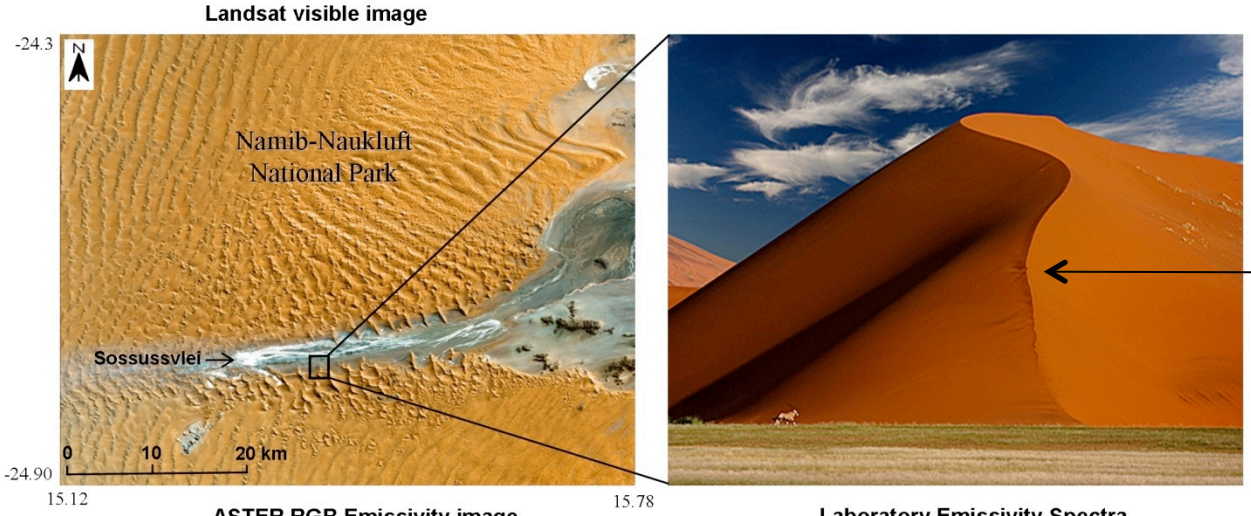




SAFARI 2000
Kalahari transects
- 55% Vegetation
- 45% Sand

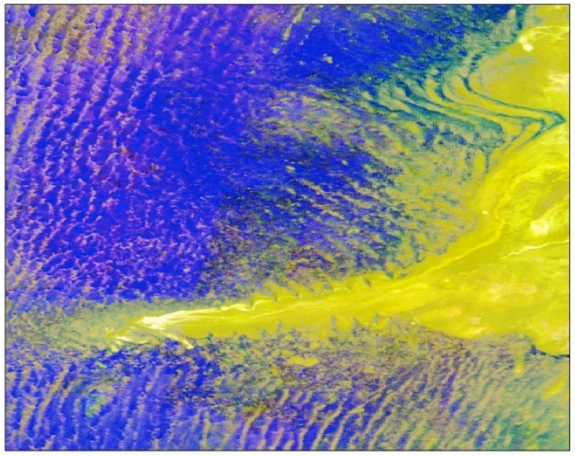
Namib Desert

- Sand samples collected at Sossussvlei in Namib-Naukluft park
- 10 samples from a dune crest and interdune area

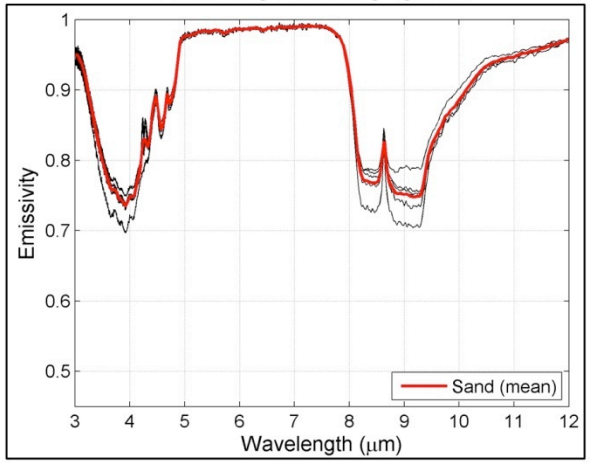


Major: Quartz
Minor: Feldspar, Magnetite

ASTER RGB Emissivity image



Laboratory Emissivity Spectra



NAALSED overlays in Google Earth - Colorado Plateau
Useful for geological mapping, resource exploration
Each color represents different rock types (eg. Red = quartz)