Synergistic Use of Datasets from Multiple Instruments for Earth Science Research

Ivan A. Csiszar, University of Maryland : Hazards

Simon J. Hook, Jet Propulsion Lab. : Hydrology - Presenter

Vince J. Realmuto, Jet Propulsion Lab : Hazards

Thomas Schmugge, New Mexico State University: Ecology

Outline

- Hazards
  - Mapping volcanic plumes (V. Realmuto)
  - Active Fire monitoring (I. Csiszar)
- Ecology
  - Calculating broadband emissivities for climate models (T. Schmugge)
- Hydrology
  - Measuring nutrient distribution in large lakes (S. Hook)
- Critical factors limiting use of multi-instrument data
- Wrap-up and ways to increase multi-instrument studies

OBJECTIVES OF PLUME MAPPING

Track Changes in SO_2 Emission Rate

Detect Passive Emissions Before an Eruption Occurs

Eruptions May be Preceded by Changes in Emission Rate

Few Volcanoes are Monitored with Necessary Frequency to Establish Baseline Emission Rates

Satellite Remote Sensing –> Facilitate Monitoring

Study the Fate of SO_2 in Atmosphere

Conversion to Sulfate Aerosols

Local/Regional Hazard to Respiratory Health

Regional/Global Climate Forcing

Nucleation Sites for Polar Stratospheric Clouds -> Catalysts for Ozone Depletion

Mapping Passive SO_2 Emissions from Space

Pu'u O'o Plume Map Derived from ASTER 90m TIR Data

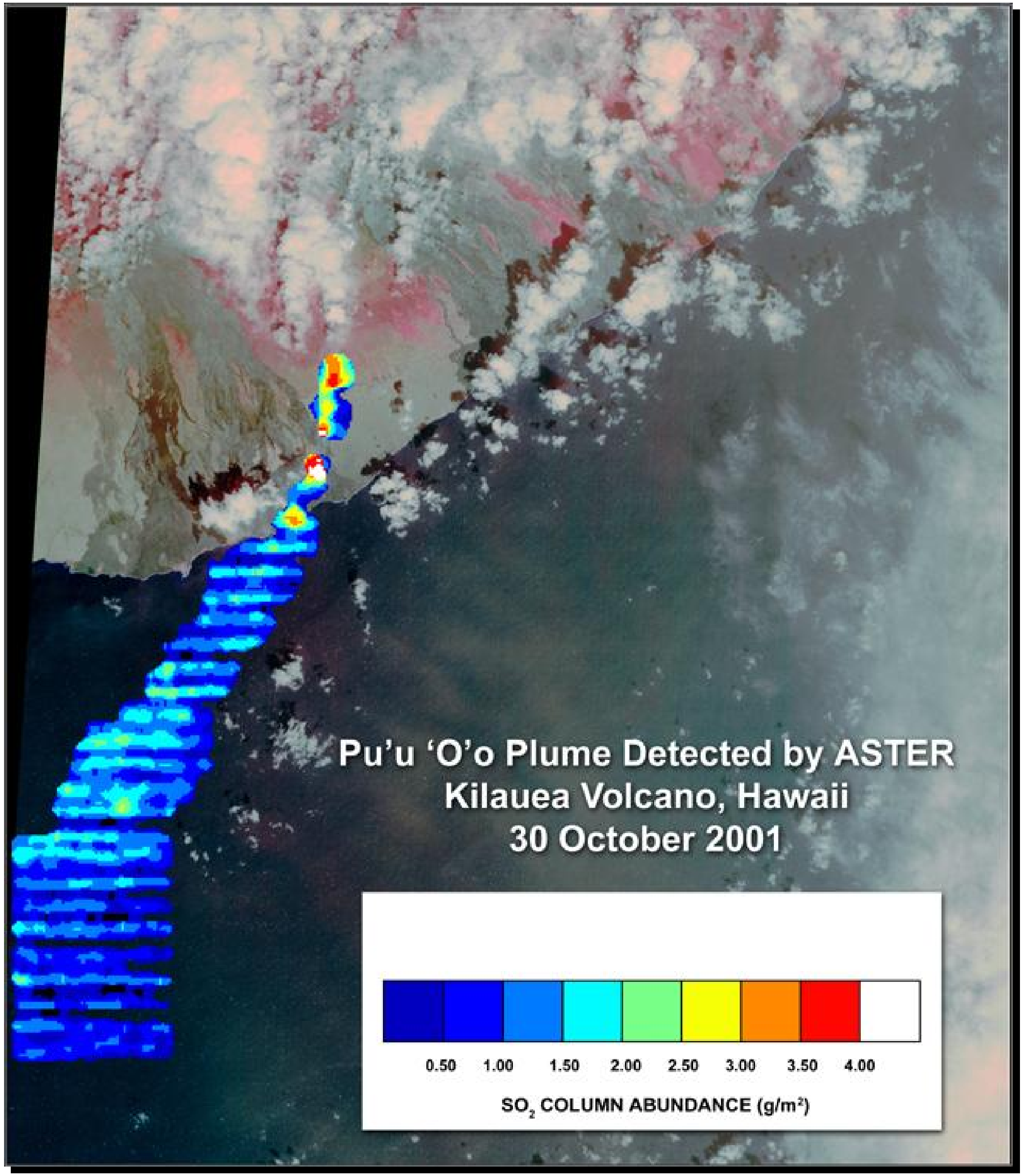
High Spatial Resolution (90 m) => High Sensitivity to Presence of SO_2

Mitigating Factors

Small Plume: typically 1 km in thickness and width

Low Altitude (typically 1.5 km asl): Low Temperature Contrast

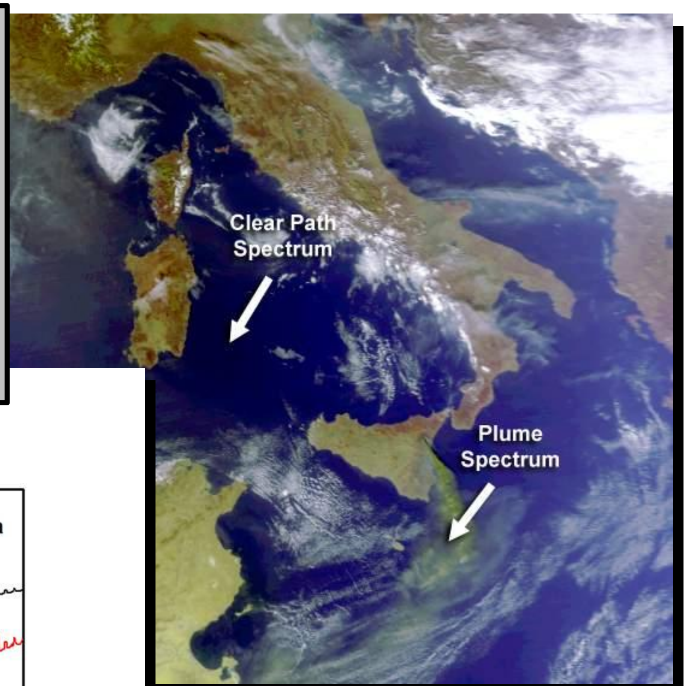
Warm, Humid Tropical Atmosphere: Decreased Temperature Contrast, Increased Atmospheric Absorption and Emission

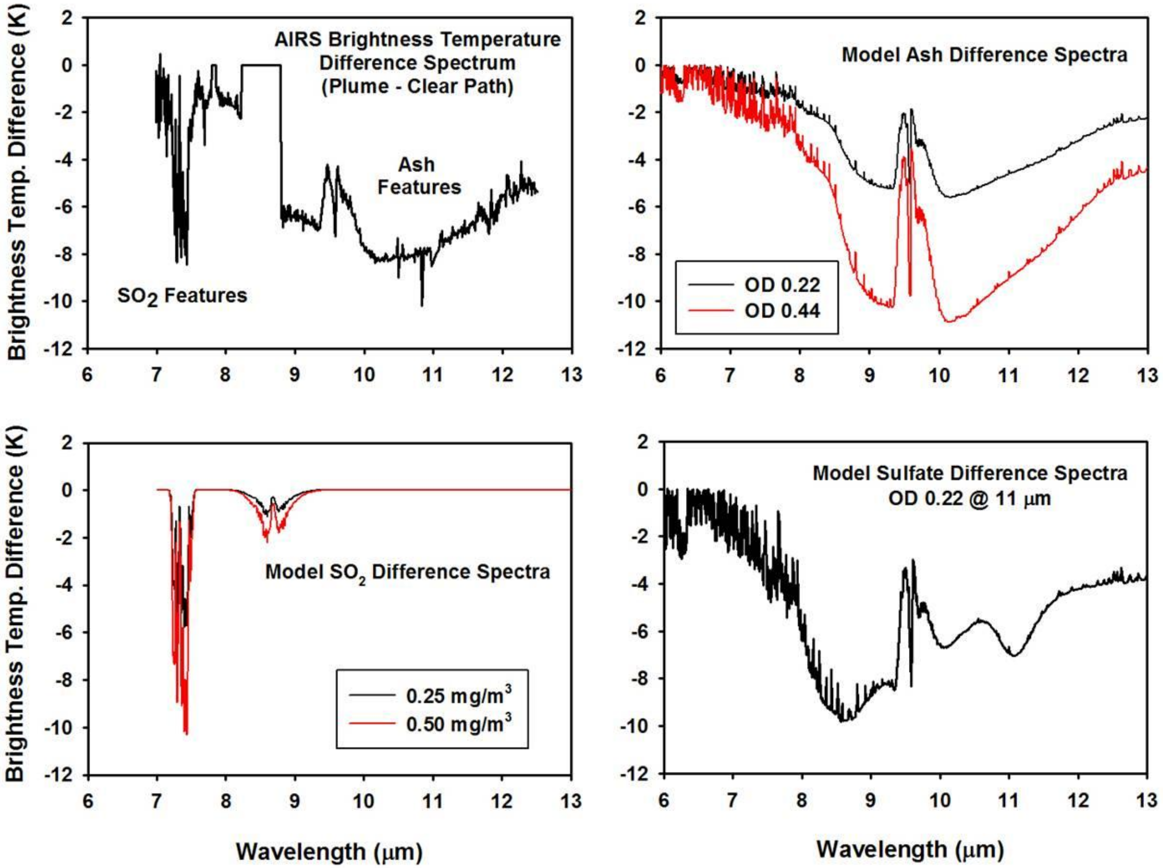


AIRS Data Acquired over Mount Etna Eruption Plume: 28 October 2002

Constituents of Volcanic Plumes Amenable to Satellite Remote Sensing: SO_2, Silicate Ash, Sulfate Aerosol

Rare in "Normal" Atmosphere - Relatively Low Concentrations Can Be Detected in the Thermal IR (TIR)



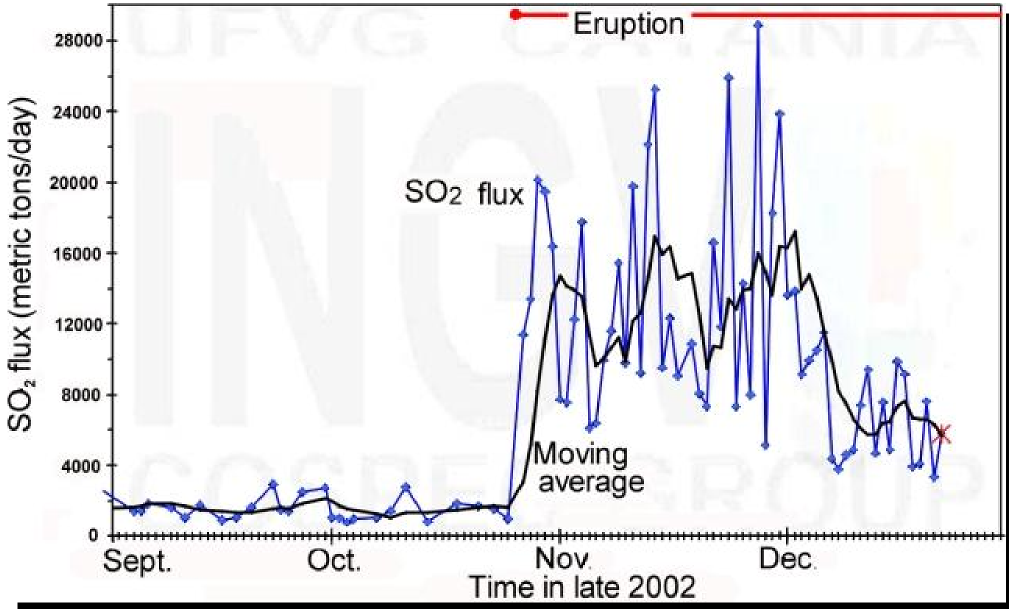


Forward Modeling Results

MODTRAN, CHARTS, LBLTran run at 1 cm^{-1} resolution

SO_2 concentrations between 0.25 – 0.50 mg/m^3

Silicate Ash Loading >> Sulfate Aerosol Loading



2002-2003 Eruption Of Mount Etna

27 Oct 2002 – 29 Jan 2003

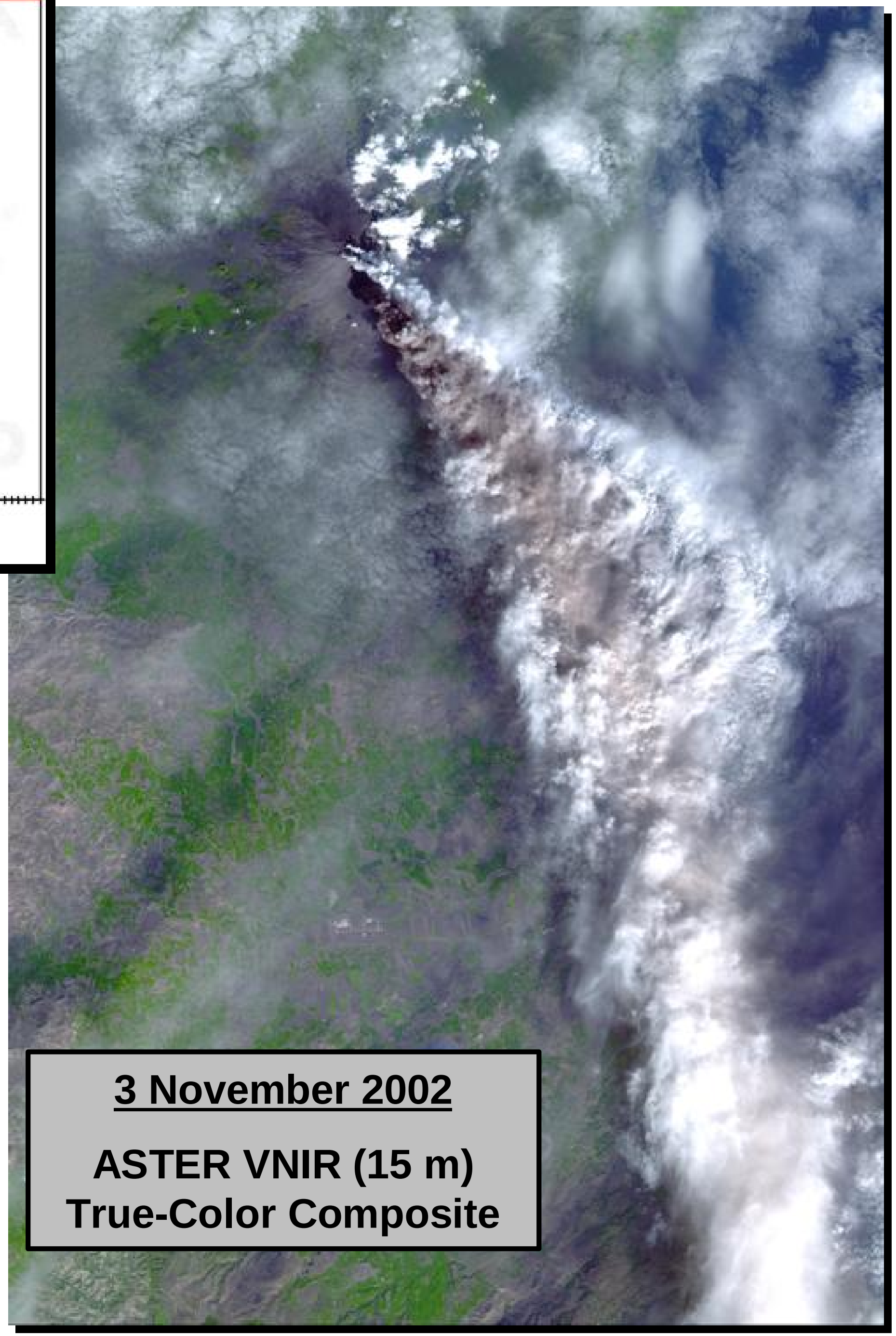
Terra/Aqua Record:

At least one daytime MODIS overpass per day

At least one daytime AIRS overpass every 2 days

Two MISR overpasses (one day apart) every 16 days

90 ASTER acquisitions between June and December 2002



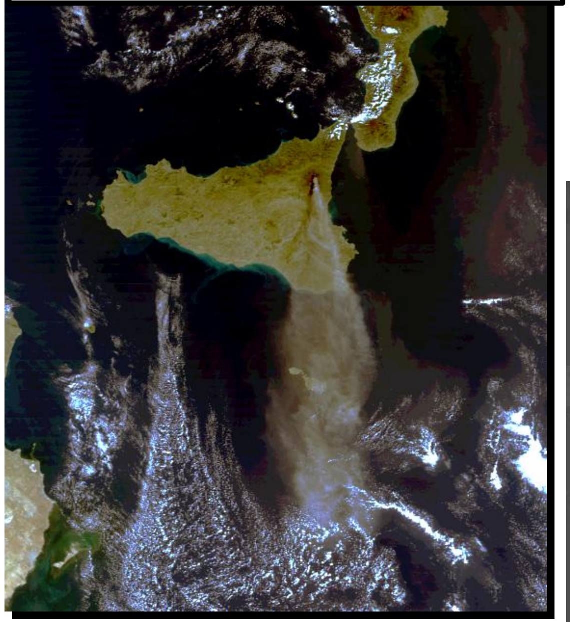
3 November 2002

ASTER VNIR (15 m) True-Color Composite

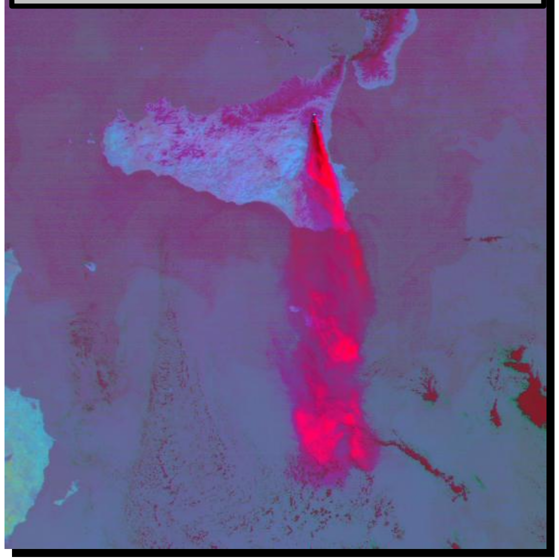
MODIS-Terra

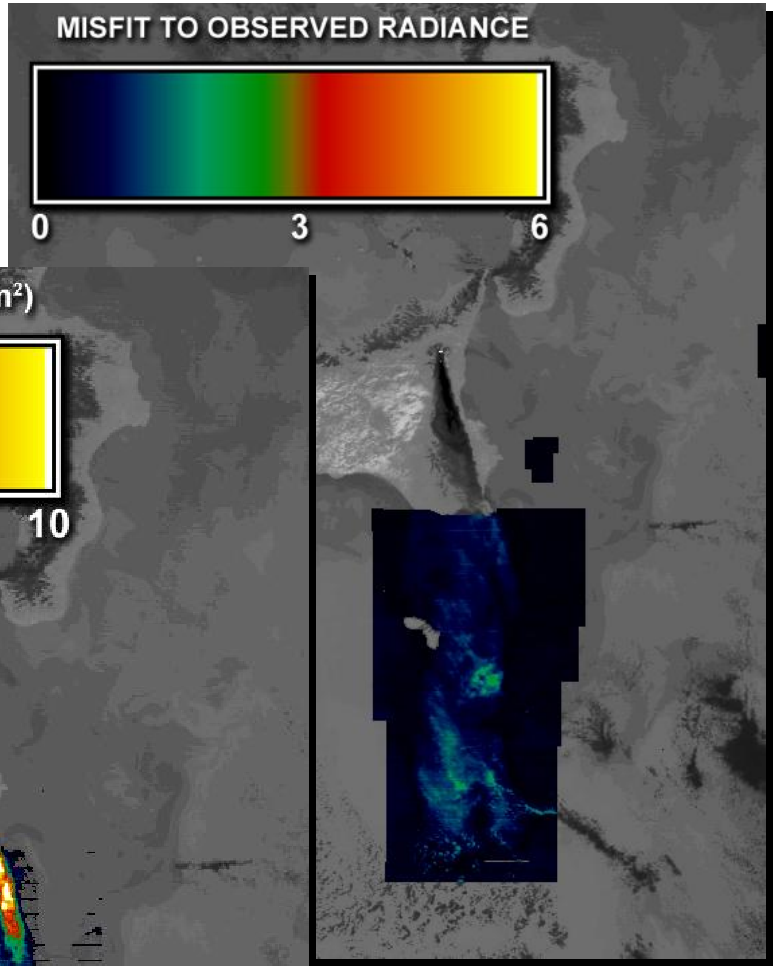
27 October 2002
10:02 UTC

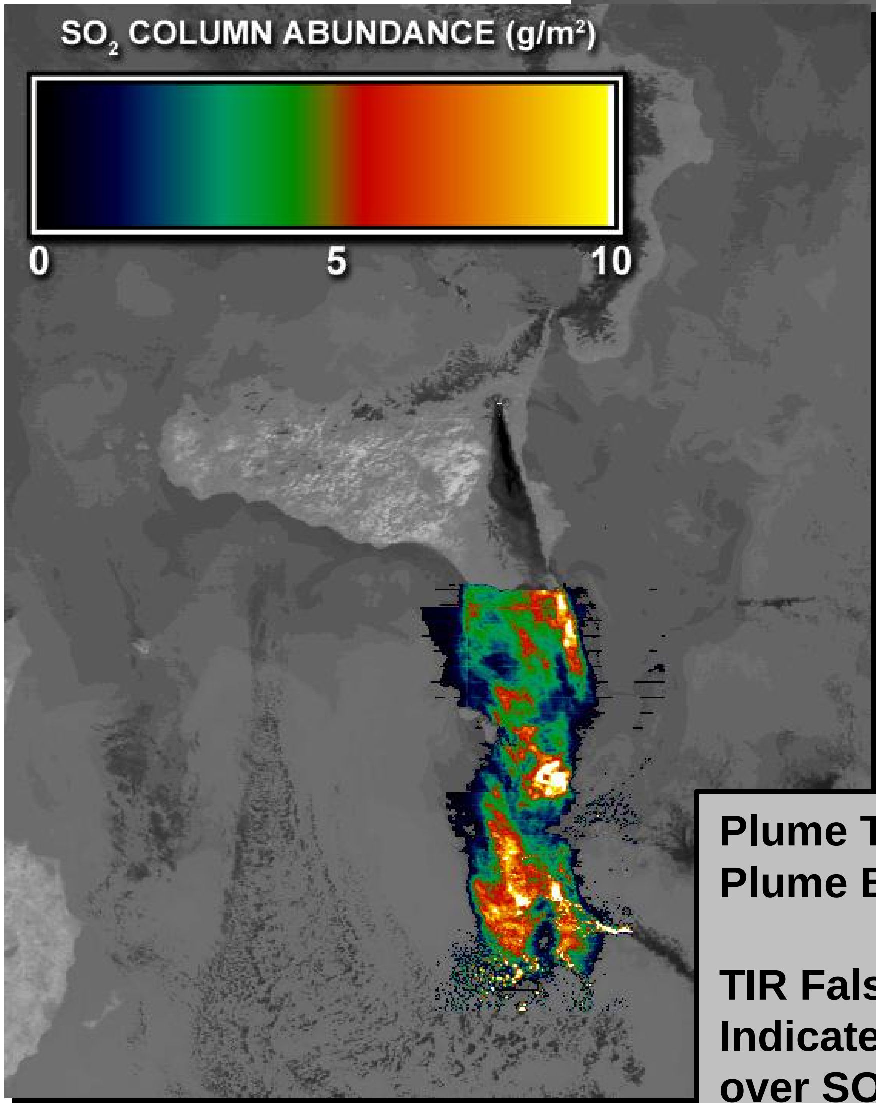
True-Color Composite



TIR False-Color Composite

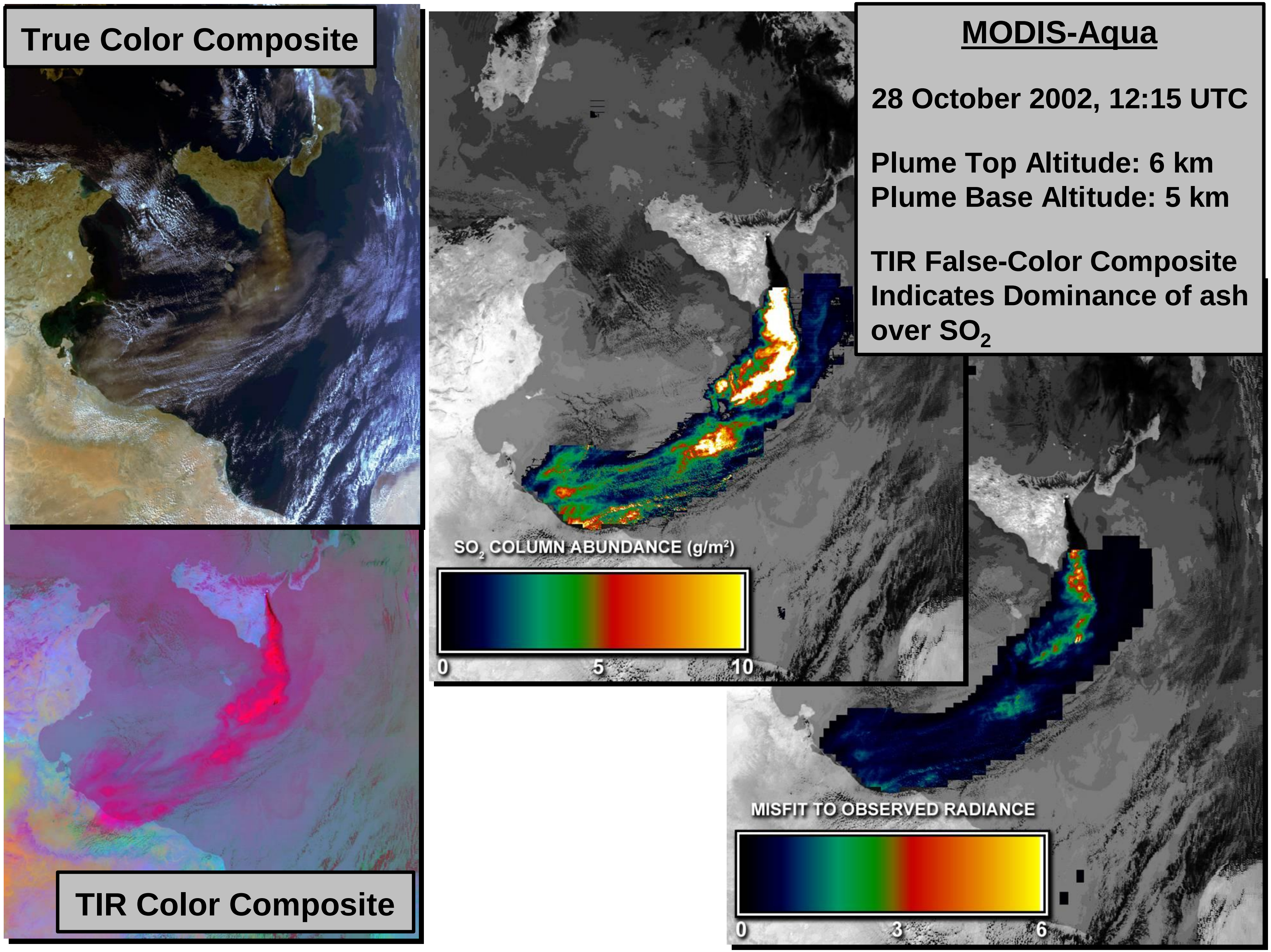




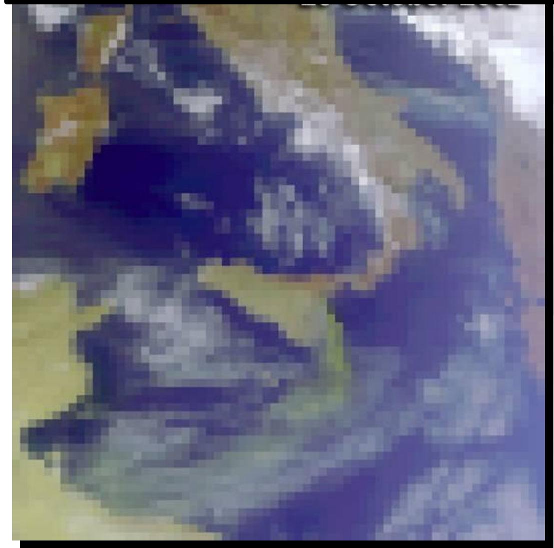


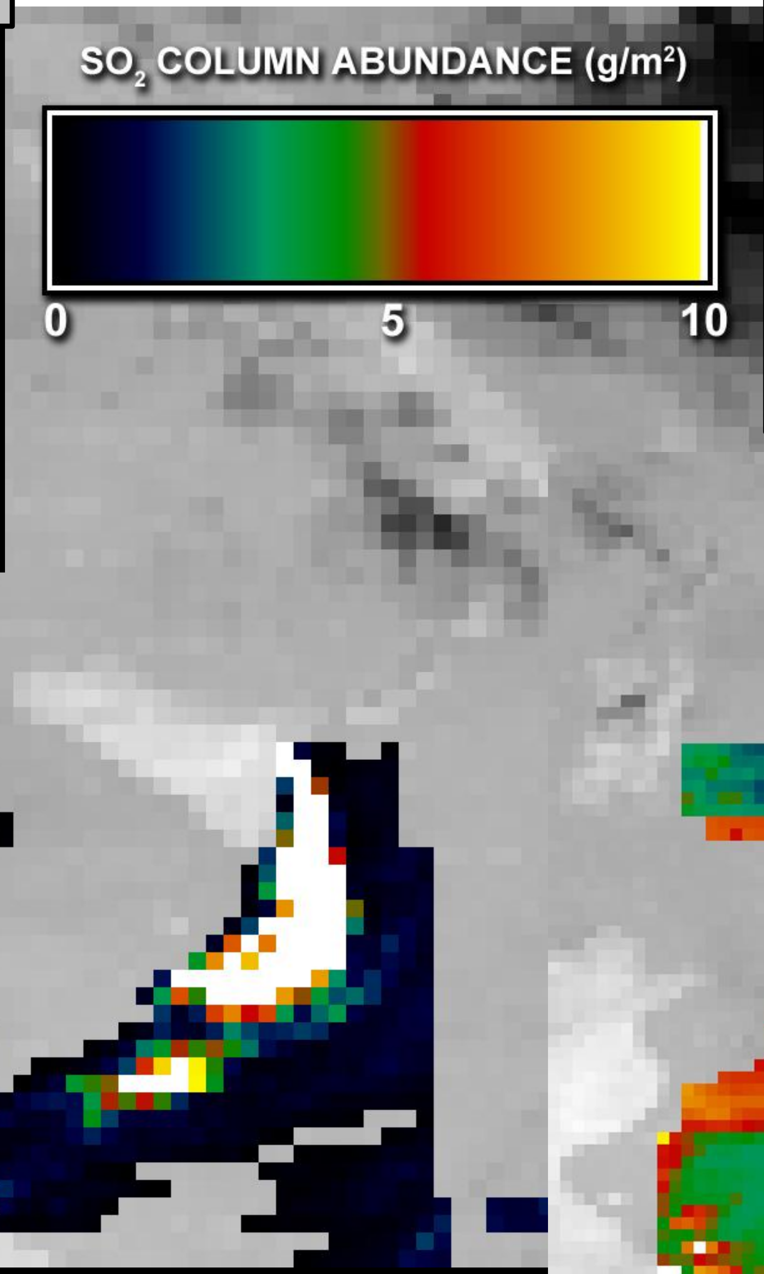
Plume Top Altitude: 6 km
Plume Base Altitude: 5 km

TIR False-Color Composite Indicates Dominance of ash over SO_2


True Color Composite
MODIS-Aqua
28 October 2002, 12:15 UTC
Plume Top Altitude: 6 km
Plume Base Altitude: 5 km
TIR False-Color Composite Indicates Dominance of ash over SO_2
SO_2 COLUMN ABUNDANCE (g/m^2)
0
5
10
MISFIT TO OBSERVED RADIANCE
0
3
6
TIR Color Composite

True Color Composite





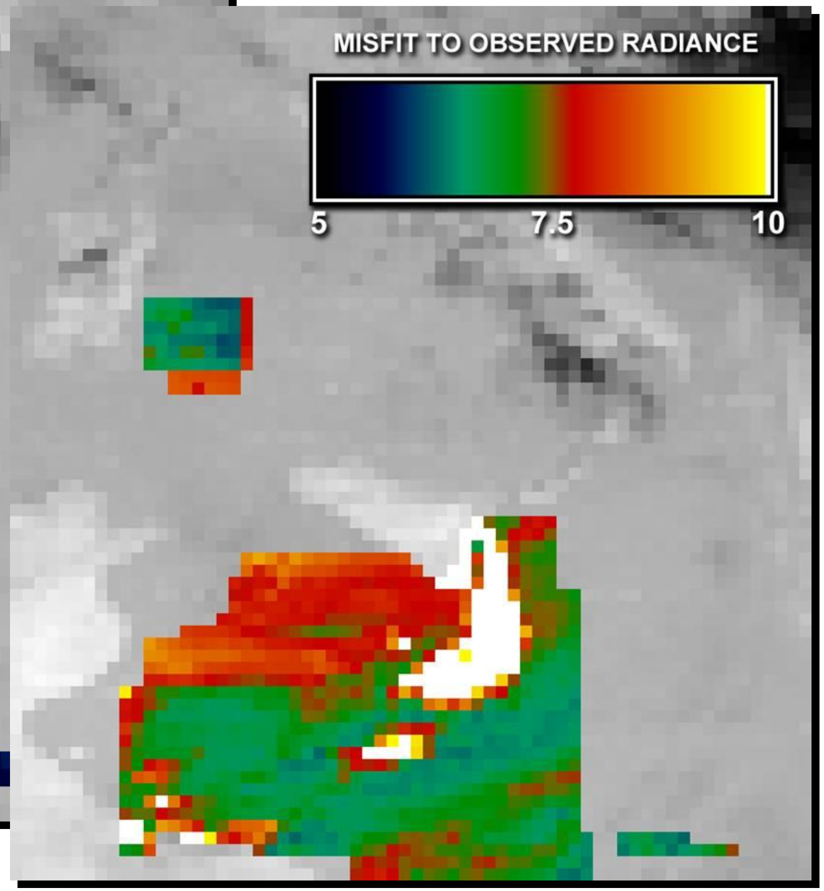
AIRS

28 October 2002

Plume Top Altitude: 6 km
Plume Base Altitude: 5 km

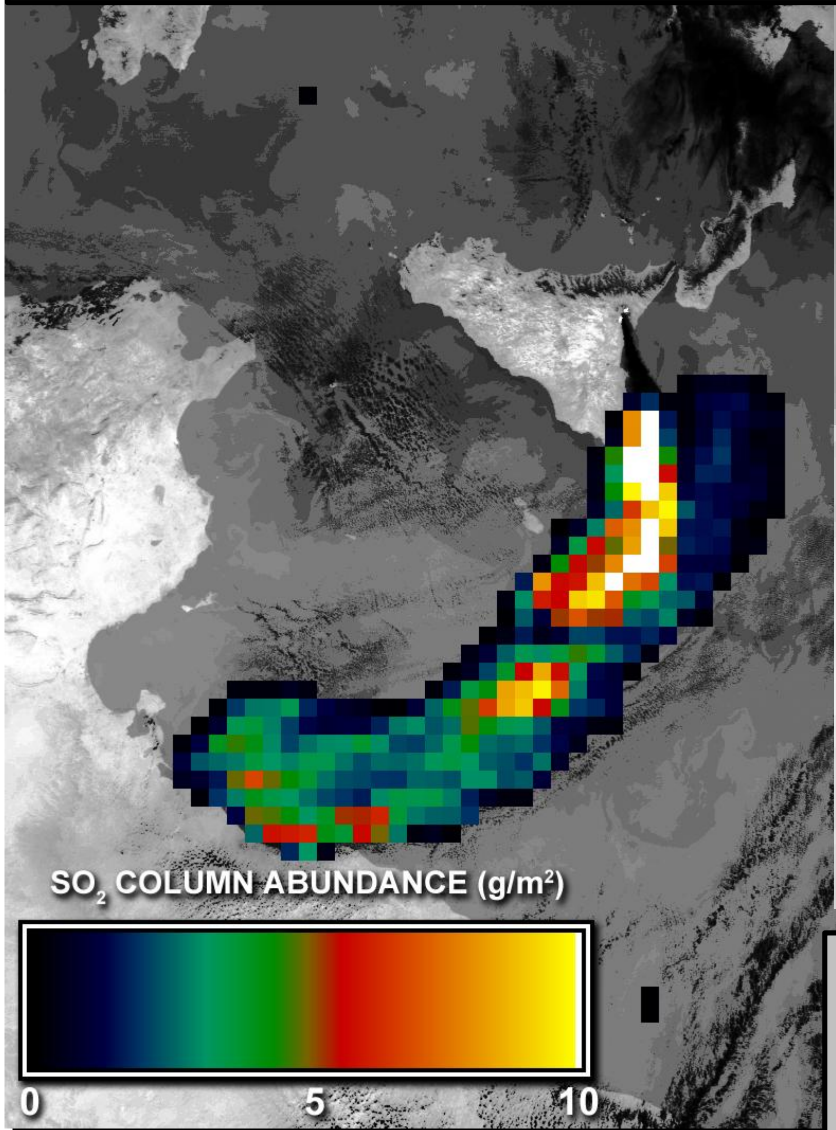
AIRS Misfit to Data is ~ 2X That of MODIS

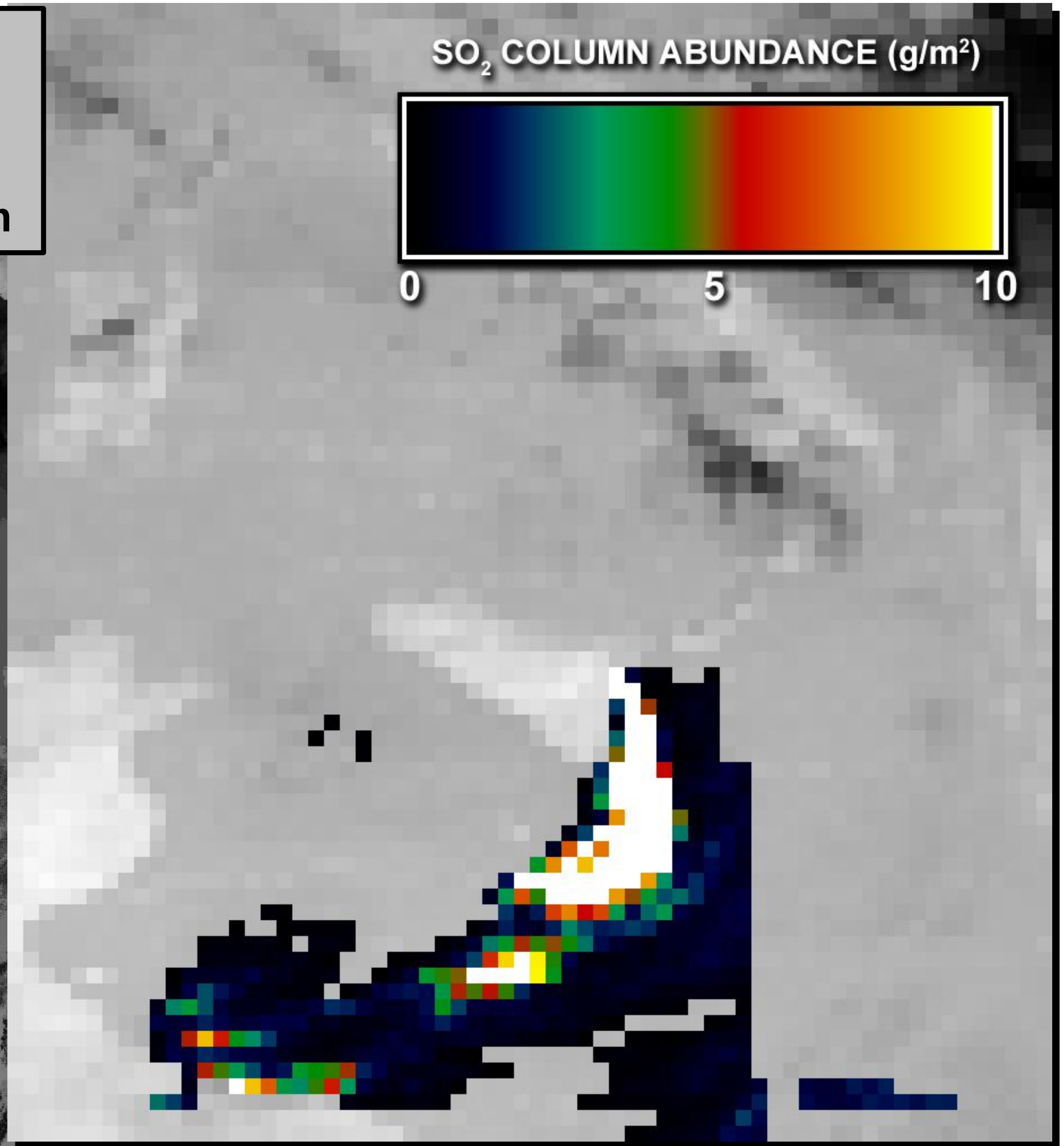
Need to Upgrade Version of MODTRAN Used in MAP_SO2



MODIS-Aqua vs. AIRS
28 October 2002

MODIS SO_2 Map Re-Sampled to ~ 17 km

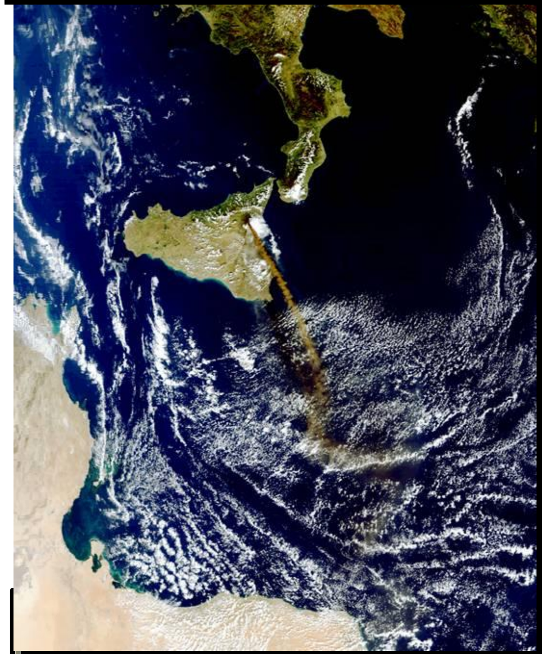




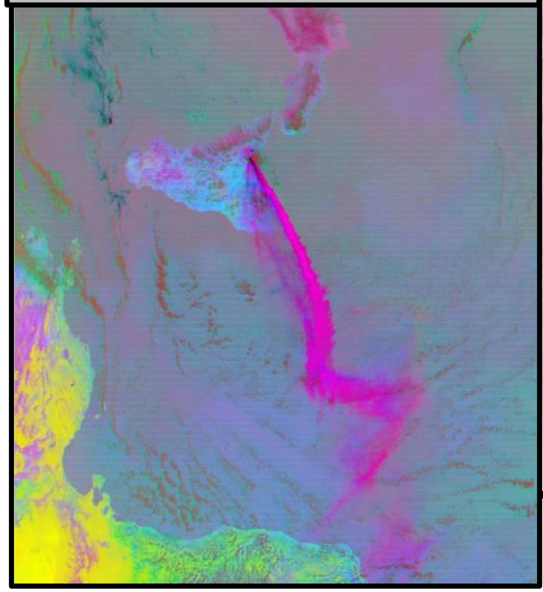
Lower Spatial Resolution of AIRS Results in Less Sensitivity to Small (~ 3 g/m^2) Changes in SO_2 Burden

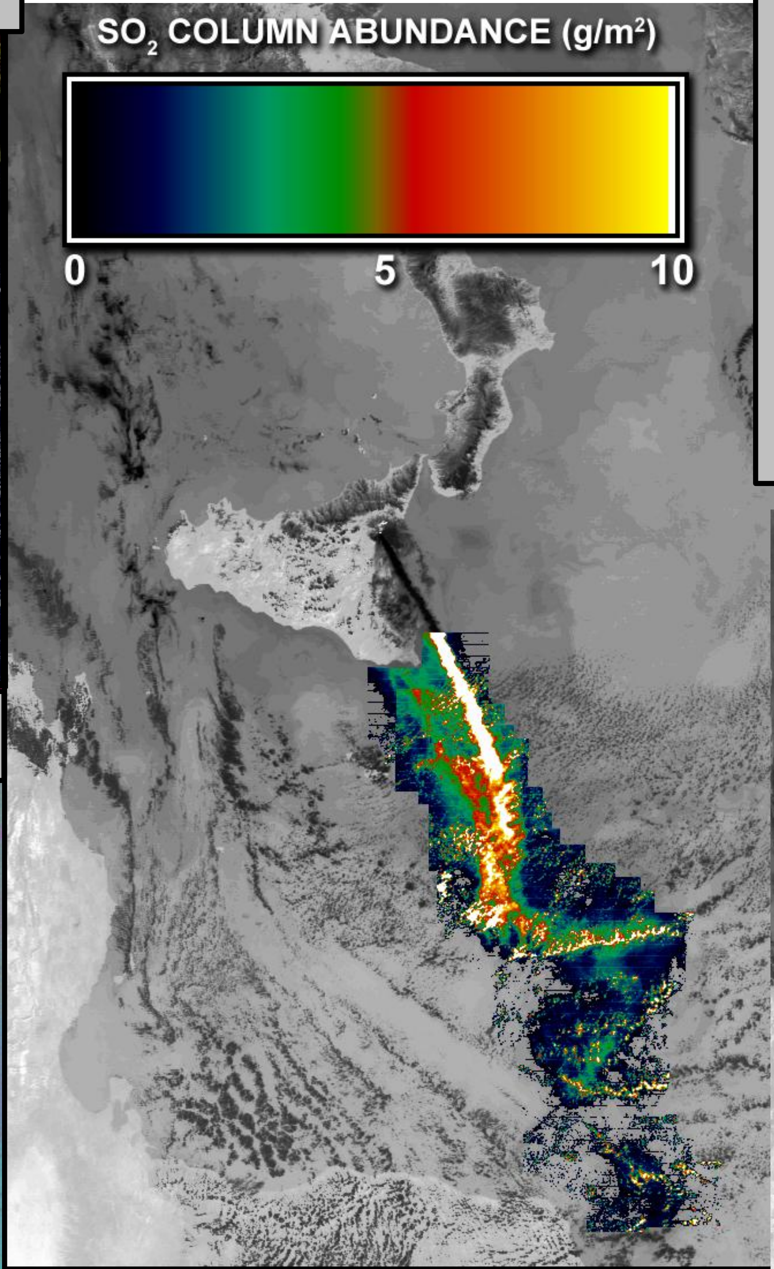
MODTRAN Upgrade will Improve the Sensitivity of AIRS-Based SO_2 Retrievals

True Color Composite



TIR Color Composite



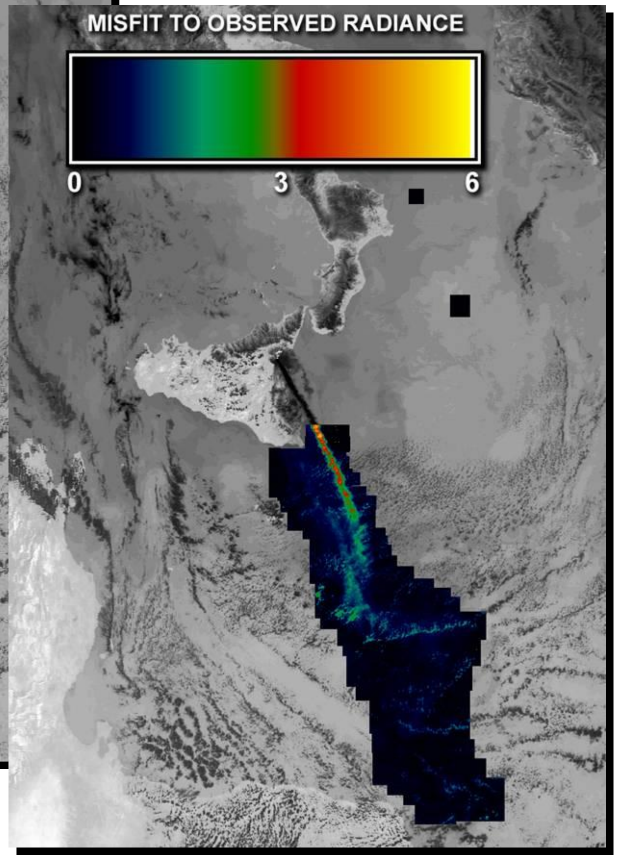


MODIS-Terra

29 October 2002, 09:45 UTC

Plume Top Altitude: 6 km
Plume Base Altitude: 5 km

TIR False-Color Composite Indicates Dominance of Ash over SO_2



SUMMARY REMARKS…

Retrievals Appear to be Consistent

Three Days of Activity; Three Instruments

MAP_SO2 Does Not Introduce Systematic Bias

AIRS-Based Retrievals in General Agreement with MODIS- Based Retrievals

Future Efforts

Focus on Days with Terra and Aqua Overpasses (eg. 27 Oct 2002)

Begin ASTER Processing (30 December 2002)

Incorporation of MISR-Based Plume Geometry

MODTRAN Upgrade

Incorporation of AIRS-Based Atmospheric Profiles

Using ASTER data to validate the MODIS active fire product

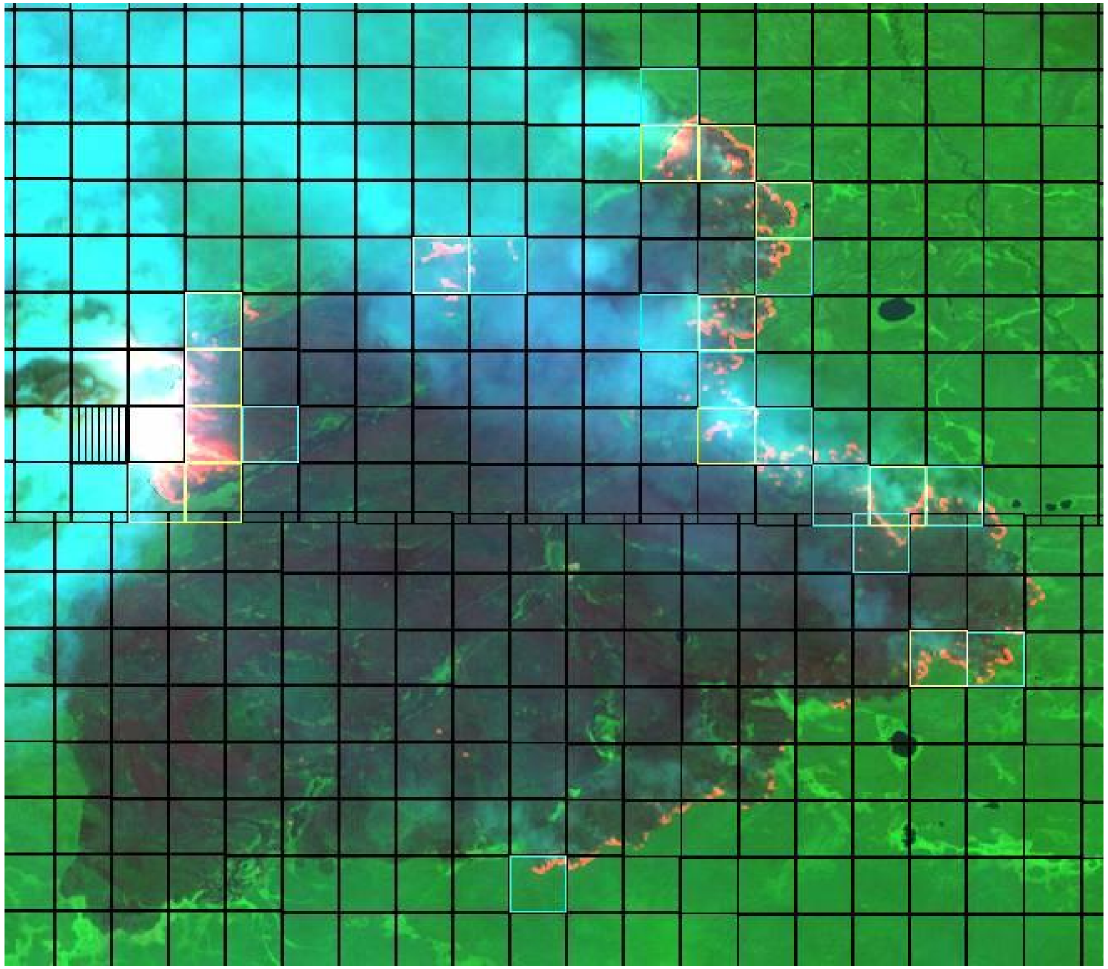
Ivan Csiszar

icsiszar@hermes.geog.umd.edu

Key Benefits

- ASTER can be used for detecting active fires that are much smaller than the lower MODIS detection limit
- ASTER and MODIS on same platform (perfect temporal coincidence)
- Disadvantages: ASTER has limited angular range, saturates (partly addressed with multiple gain settings) and limited availability

Coincident MODIS and ASTER active fire observations



ASTER, 8-3-1 RGB (30m) + 1km MODIS grid:
MODIS detections in color

MODIS v4 detection:

Yellow gridcells:
"fire", high confidence

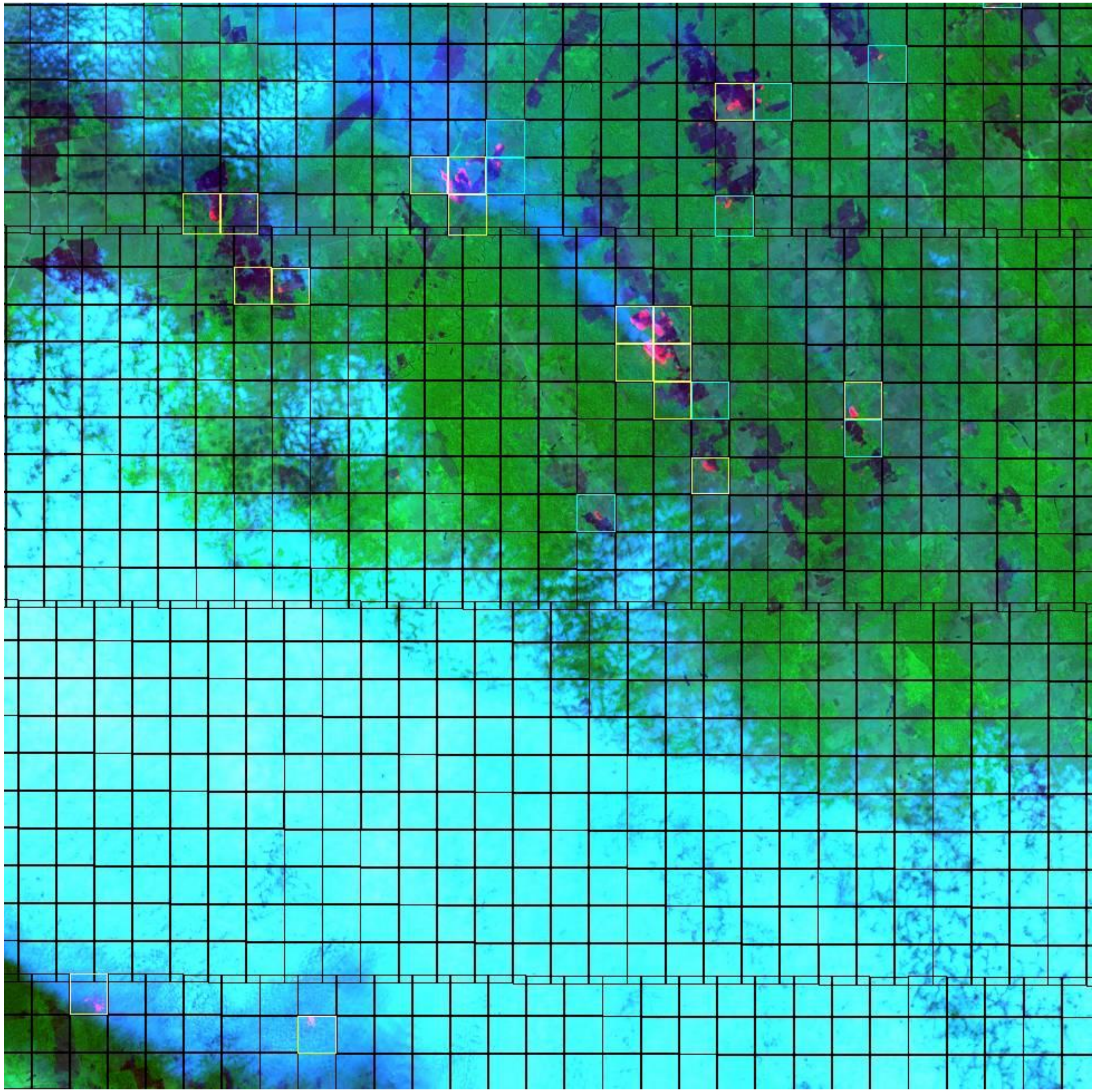
Blue gridcells:
"fire" nominal confidence

Gridcell with vertical shading:
"cloud"

Black gridcells:
"clear land"

July 23 2002 03:18 UTC
62.57N 125.72E (Siberia)

Csiszar et al., submitted

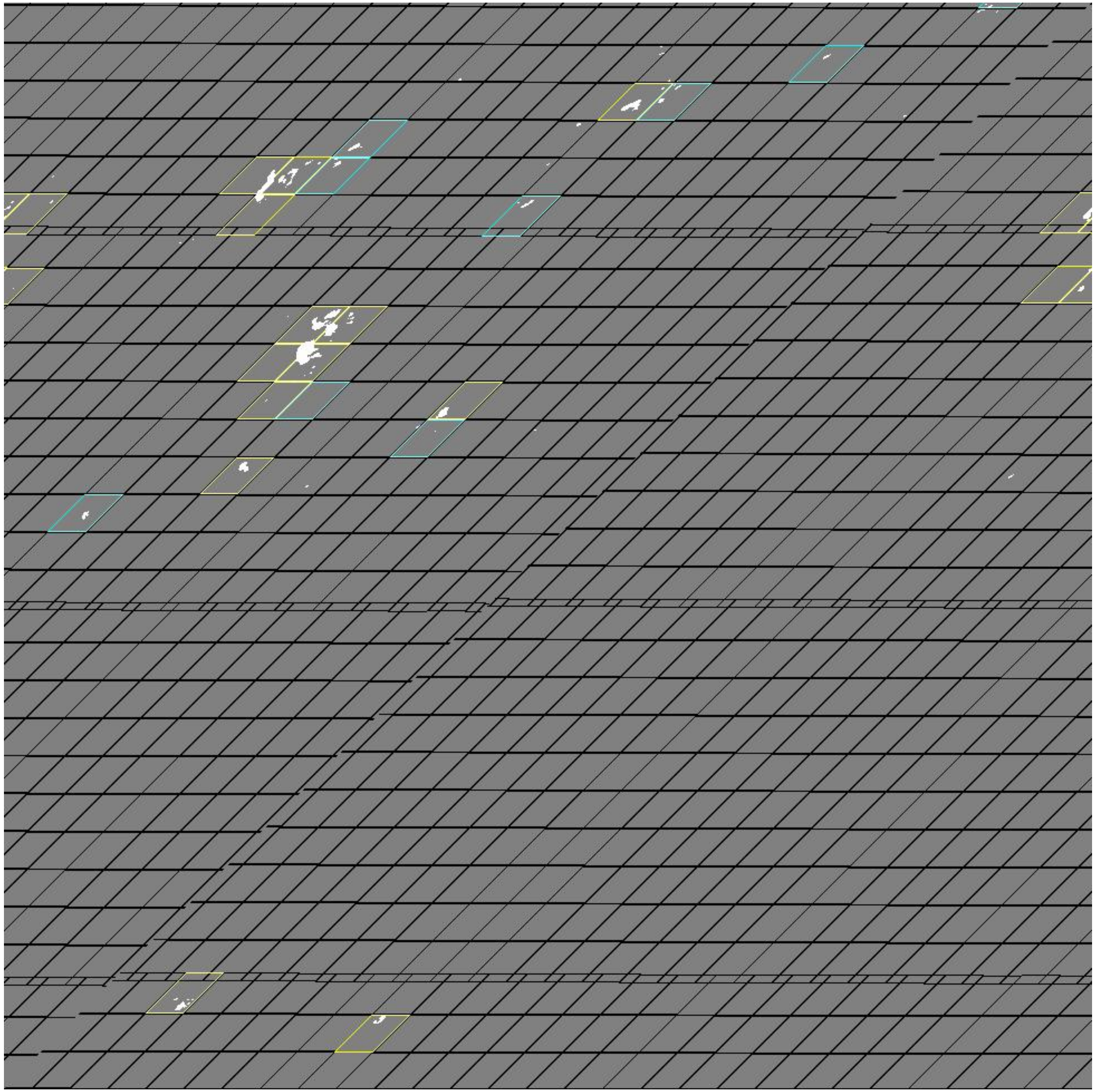


ASTER image and MODIS grid of Brazilian ACRE file

Note: fires visible through clouds in lower left corner. No standard ASTER fire products

Aug 29 2003 14:56 UTC
9.71S 67.15W (Brazil)

Morisette et al., in press



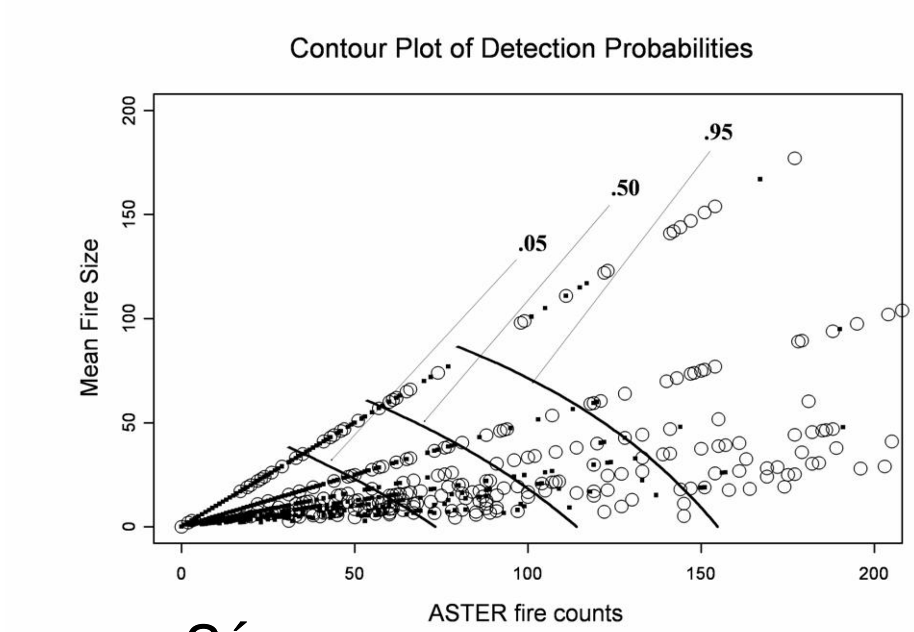
ASTER fire mask and MODIS grid

ASTER fire detection algorithm developed by Louis Giglio

Aug 29 2003 14:56 UTC
9.71S 67.15W (Brazil)

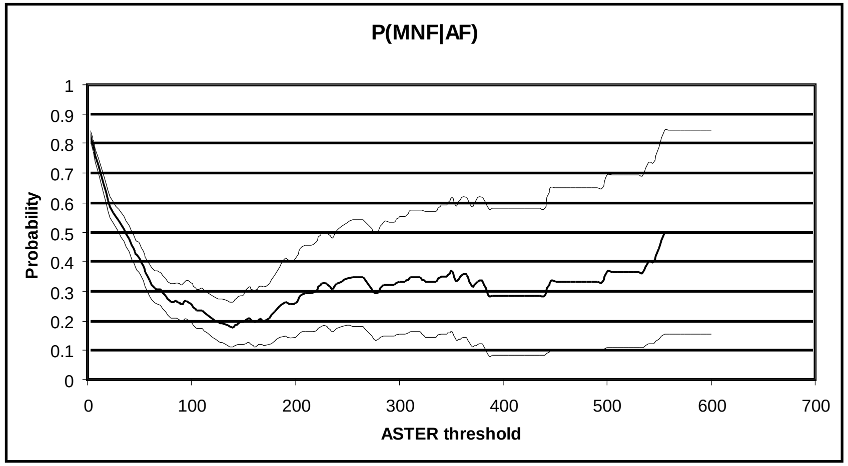
Morisette et al., in press

Comparison with coincident high-resolution satellite observations



?áMODIS “fire”; ?:MODIS “no fire”

Probabilities of detection as a function of ASTER fire pixels within MODIS pixel



Pixel-based accuracy assessment curve with 95% exact confidence intervals: omission error rate

NPOESS/VIIRS/LANDSAT active fire validation!

Csiszar et al., submitted

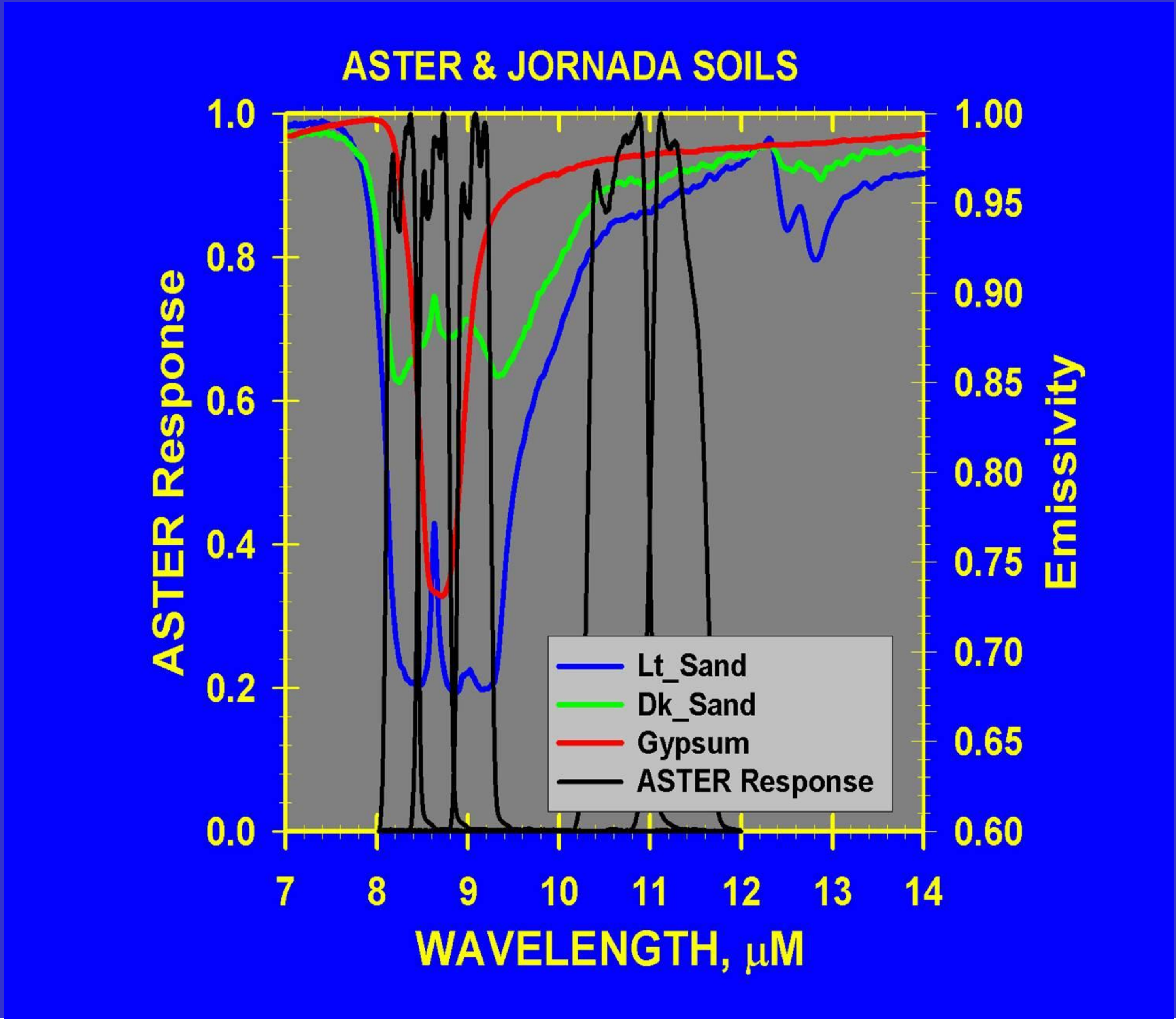
Calculating Broadband Emissivities for Climate Models

Tom Schmugge

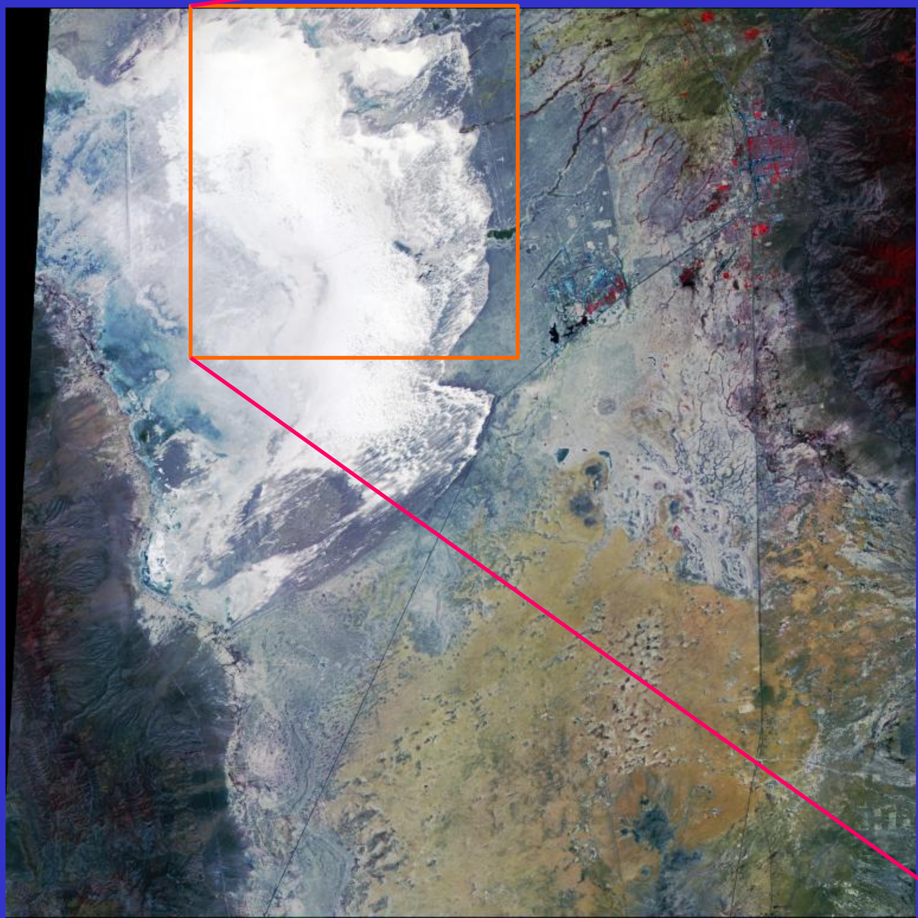
New Mexico State University

Approach: Extend from small to large target, from ASTER to MODIS

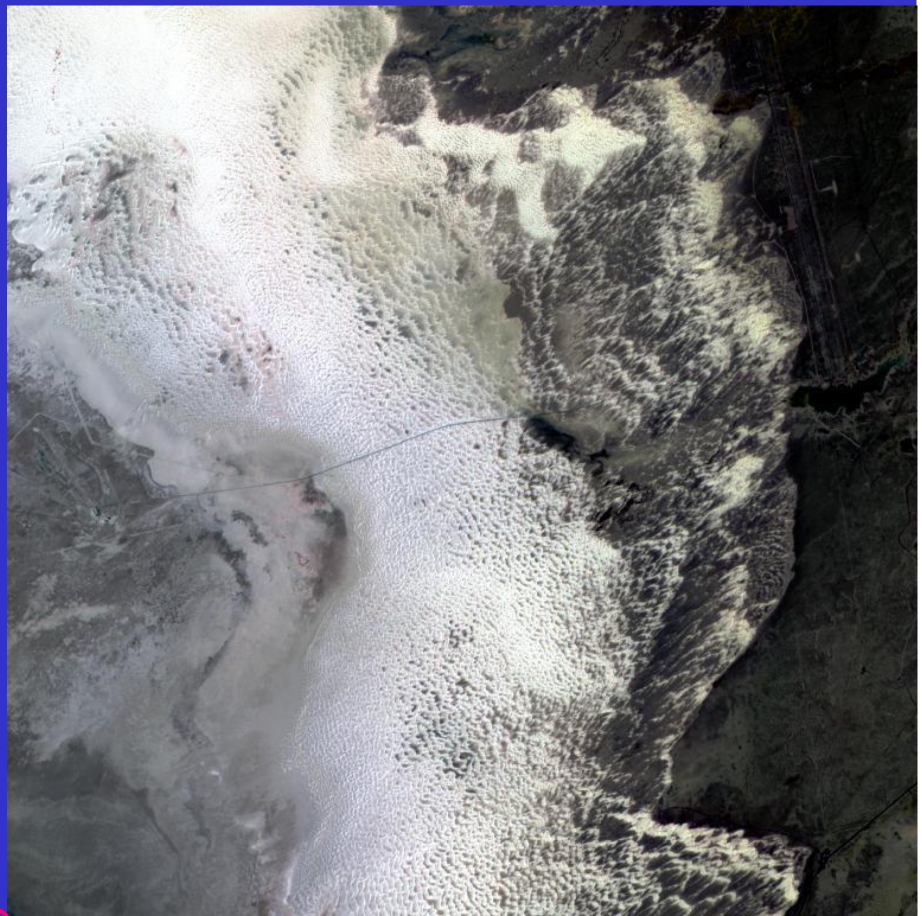
ASTER TIR Response



ASTER VNIR White Sands May 21, 2001



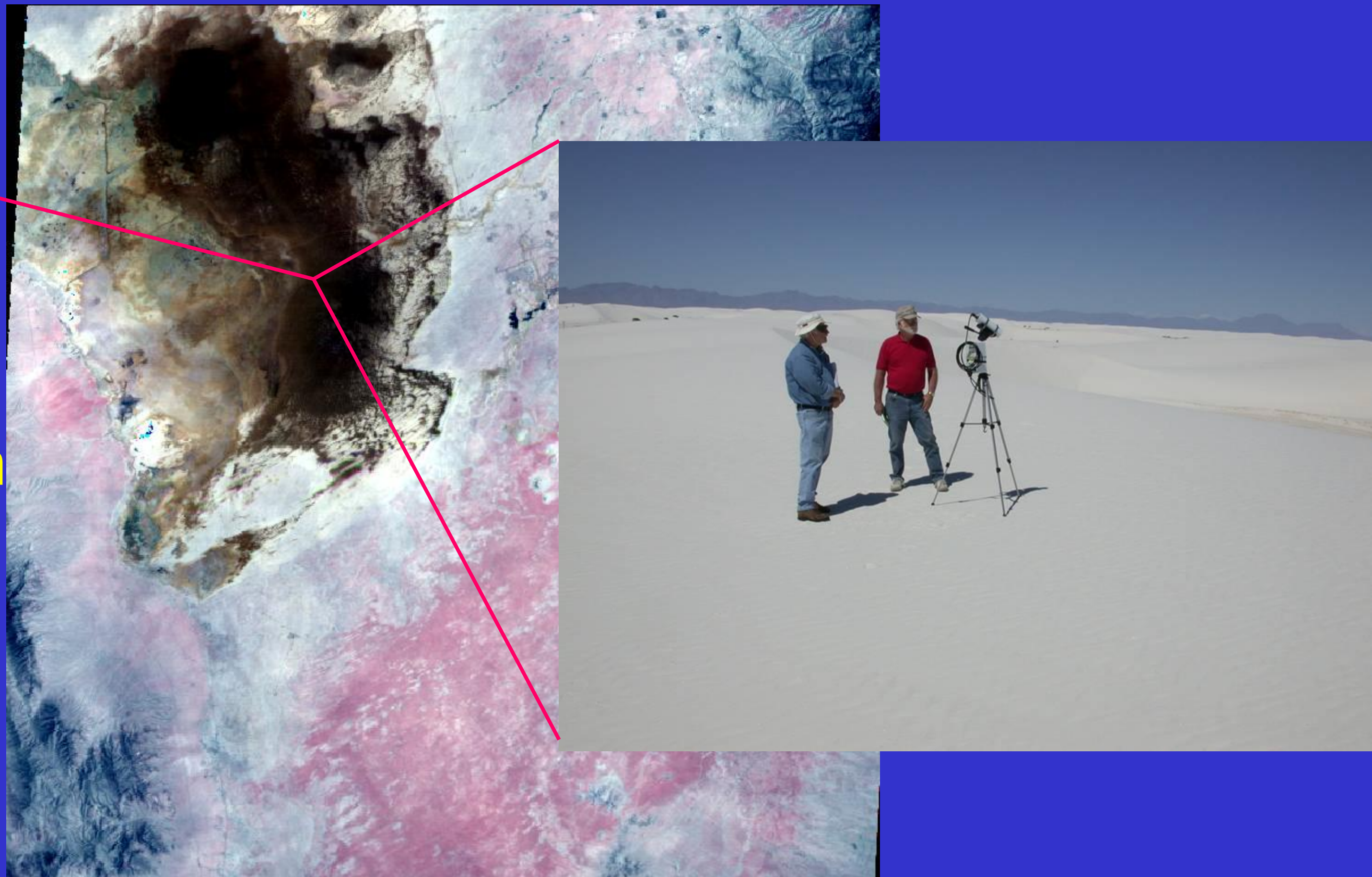
63 X 63 km



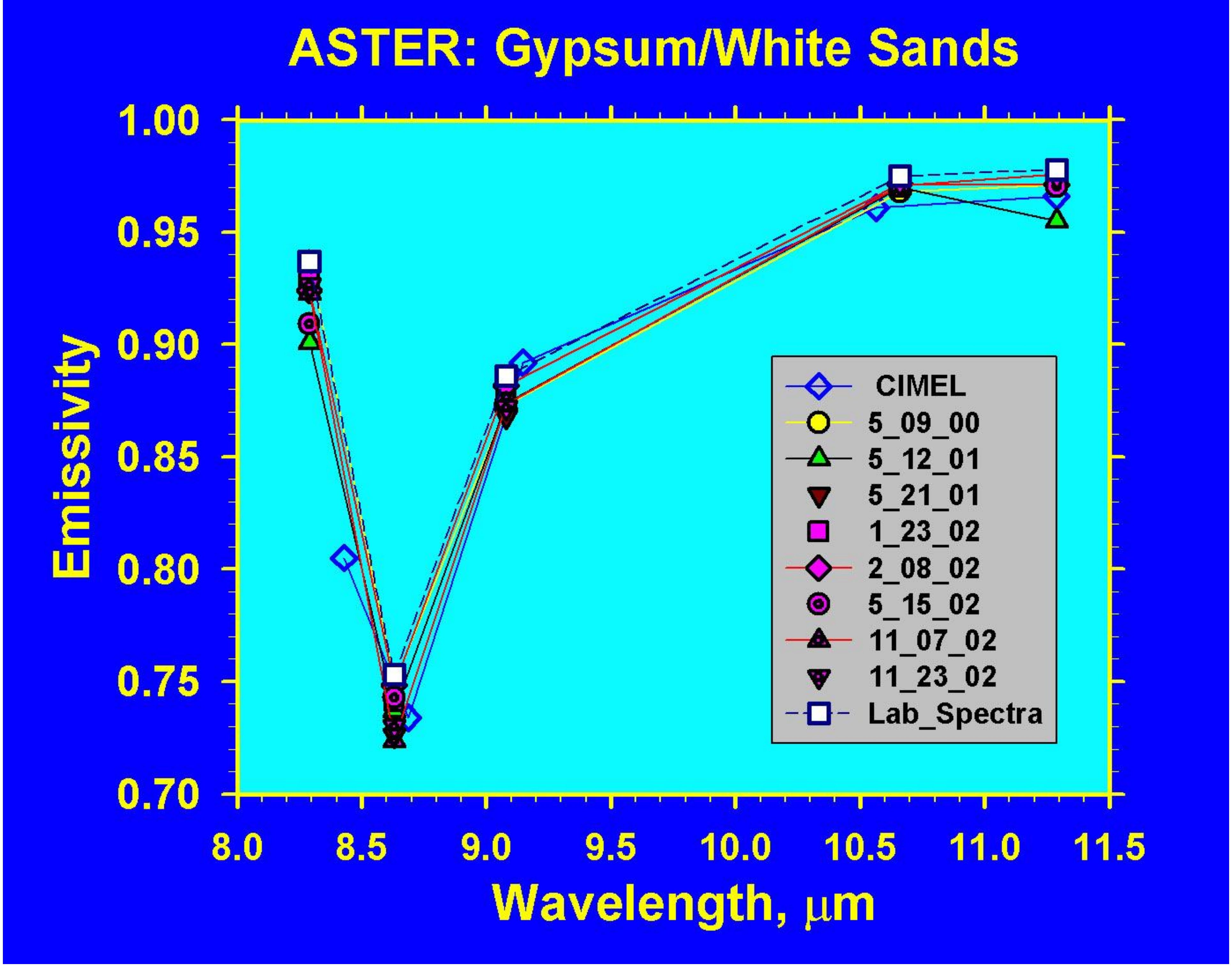
22 X 22 km

ASTER TIR White Sands May 21, 2001

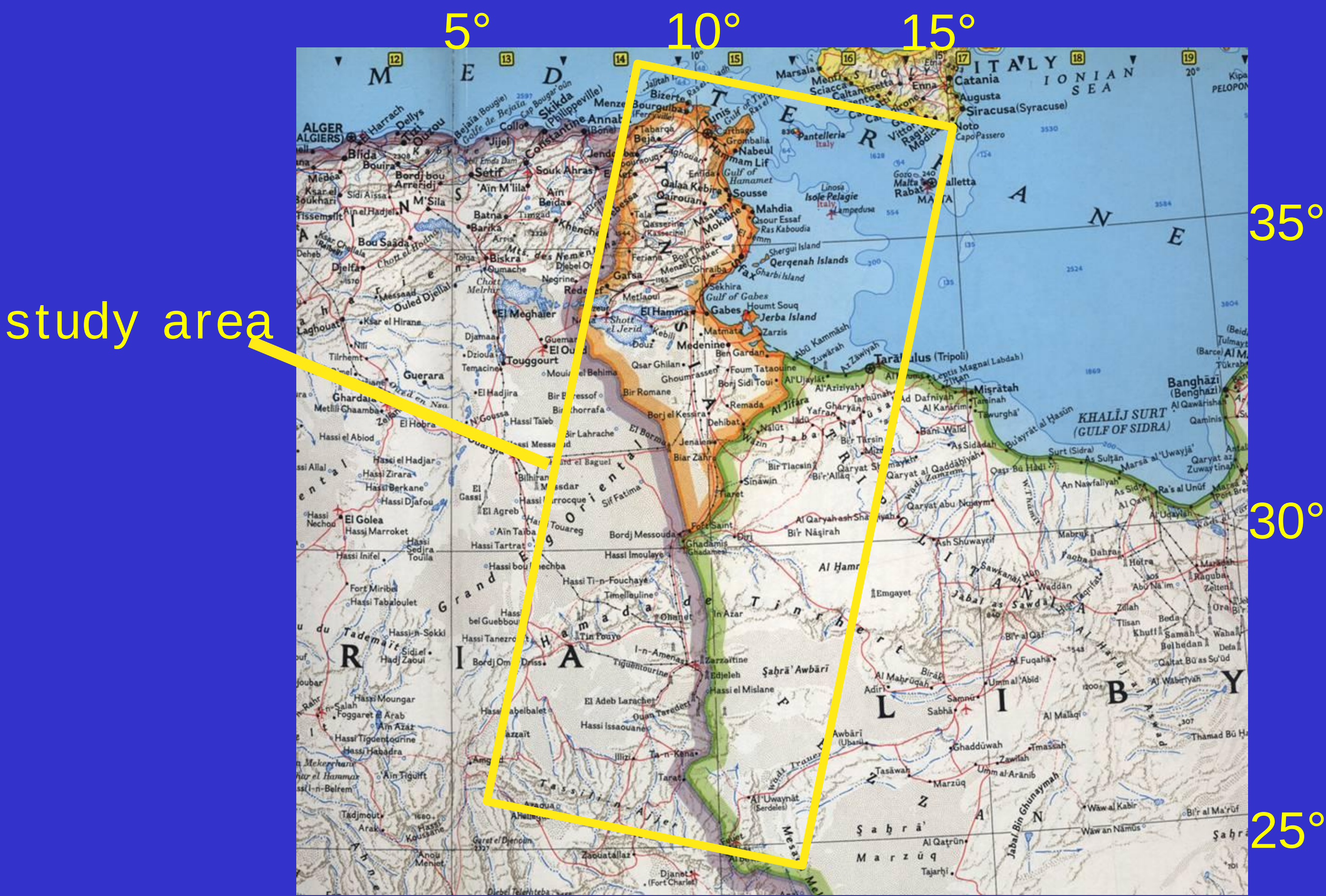
Ground Measure-ment Site



Red > 10.7 um
Grn > 9.1 um
Blu > 8.6 um

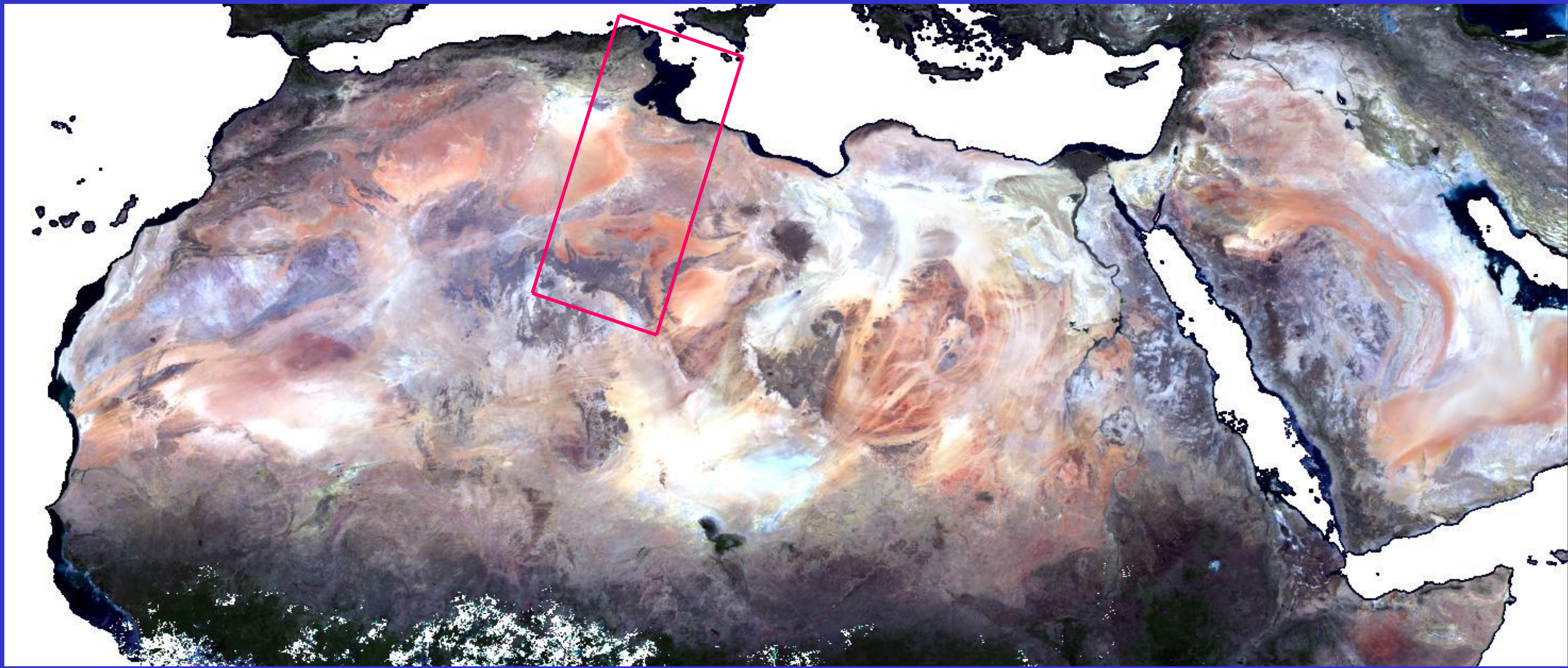

ASTER: Gypsum/White Sands
Emissivity
1.00
0.95
0.90
0.85
0.80
0.75
0.70
8.0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Wavelength, μm
CIMEL
5_09_00
5_12_01
5_21_01
1_23_02
2_08_02
5_15_02
11_07_02
11_23_02
Lab_Spectra

Study area: Sahara Desert in North Africa

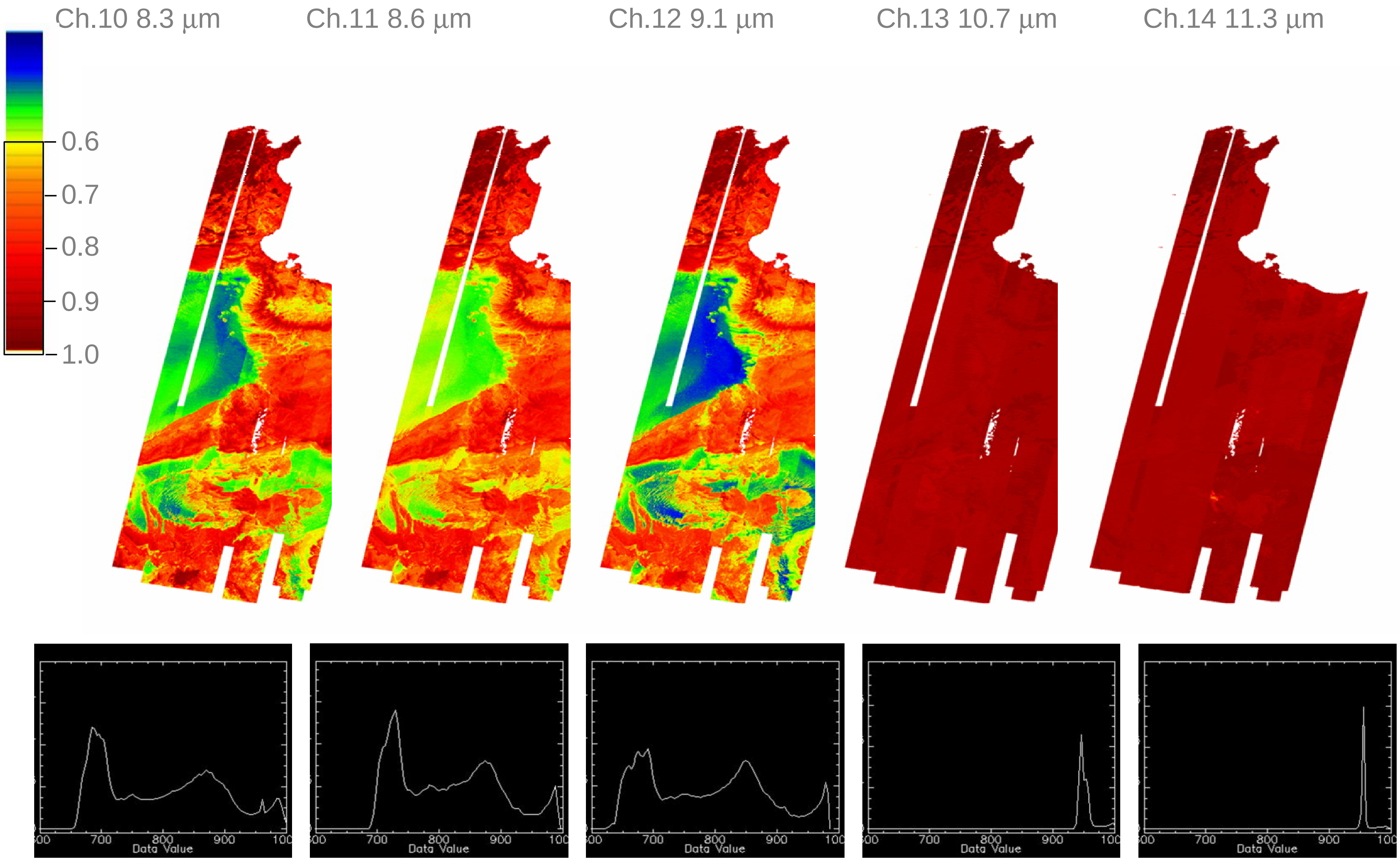


- 200 scenes of ASTER data acquired from 2000 to 2002
- Size of area 400 x 1500 km

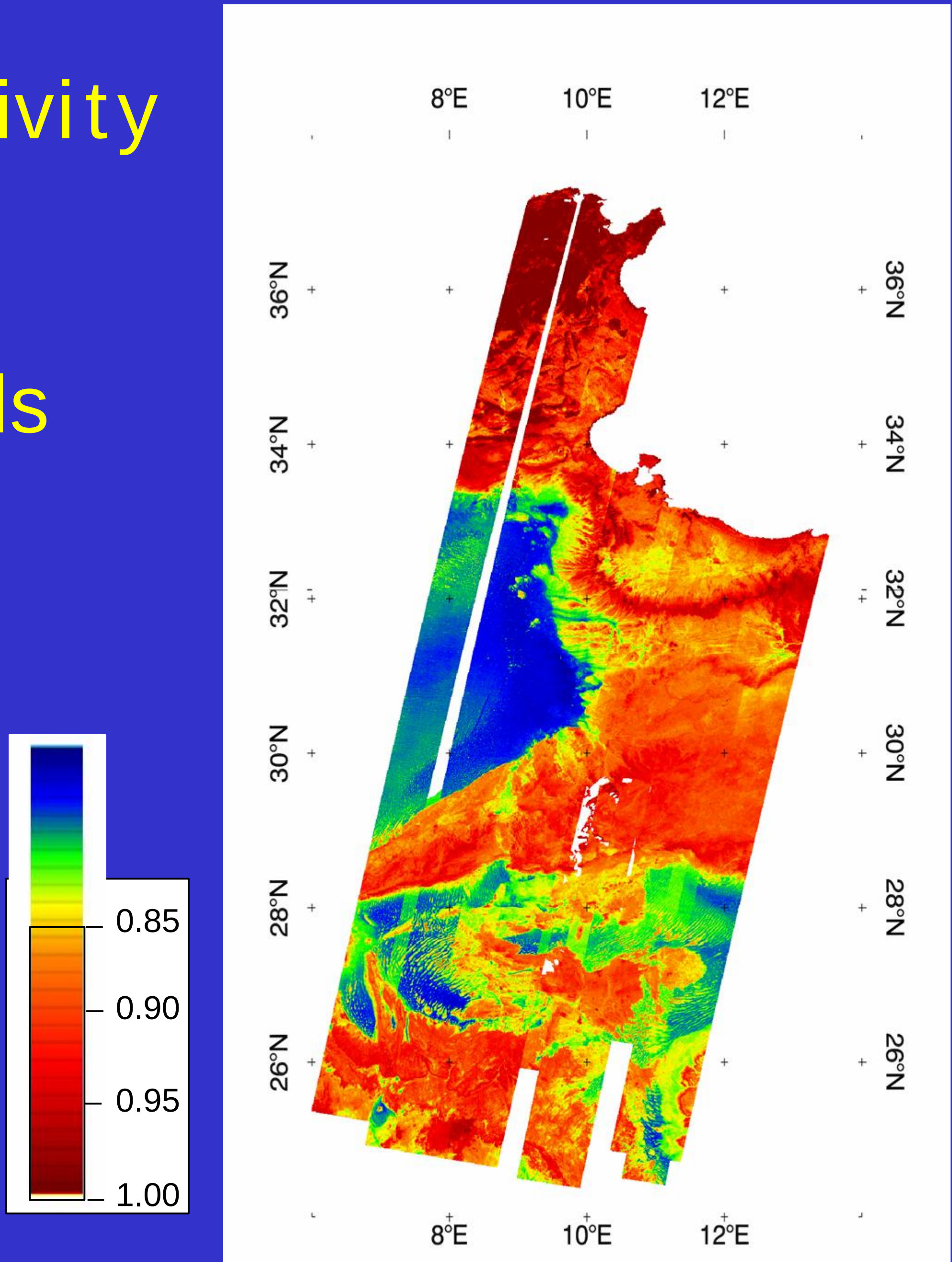
MODIS Nadir Adjusted Reflectivity Monthly Composite – 0.05



Emissivity of ASTER channels

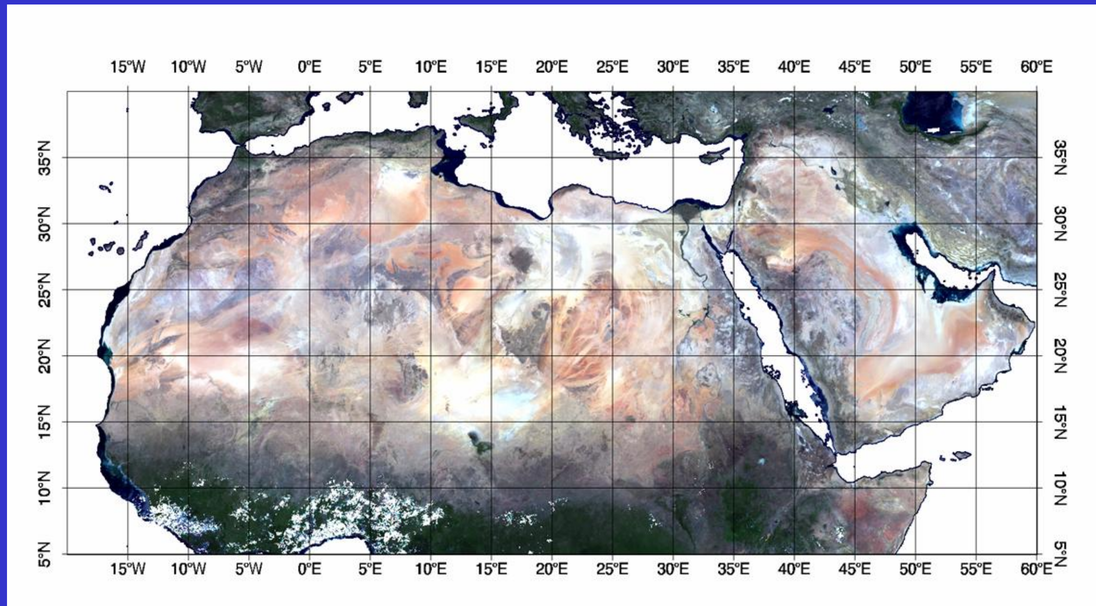


Broad band Emissivity Derived From Regression of 5 ASTER Bands

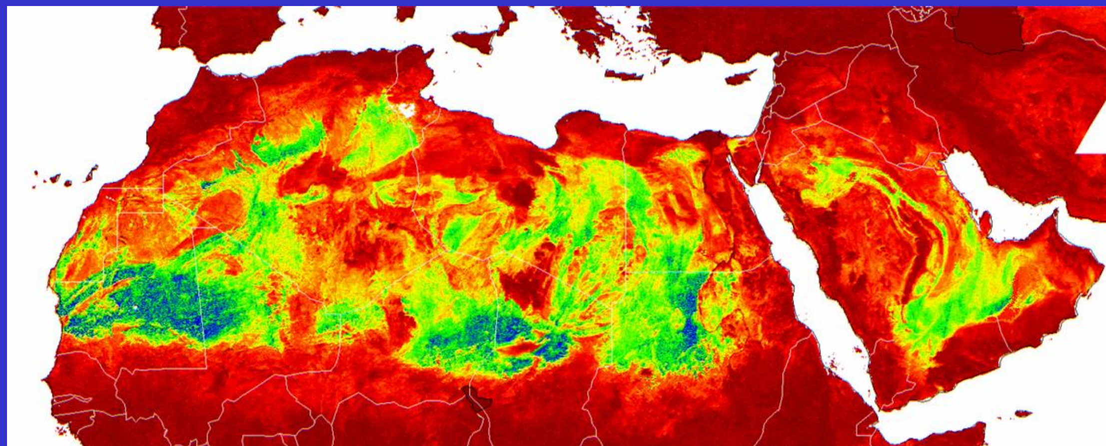


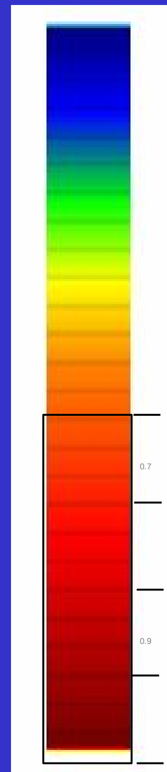
MODIS Products

Reflectivity



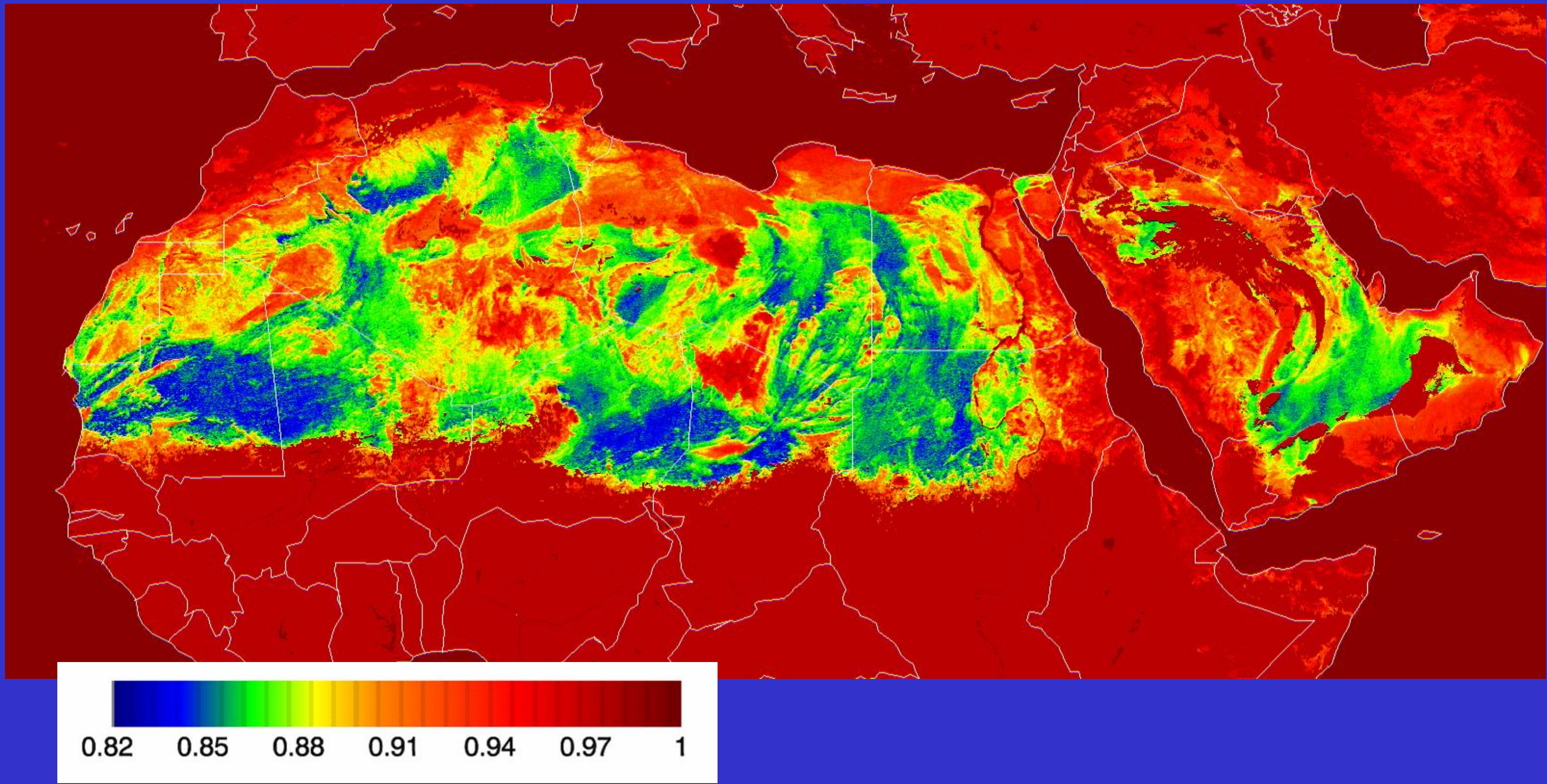
Emissivity
8.6 μm





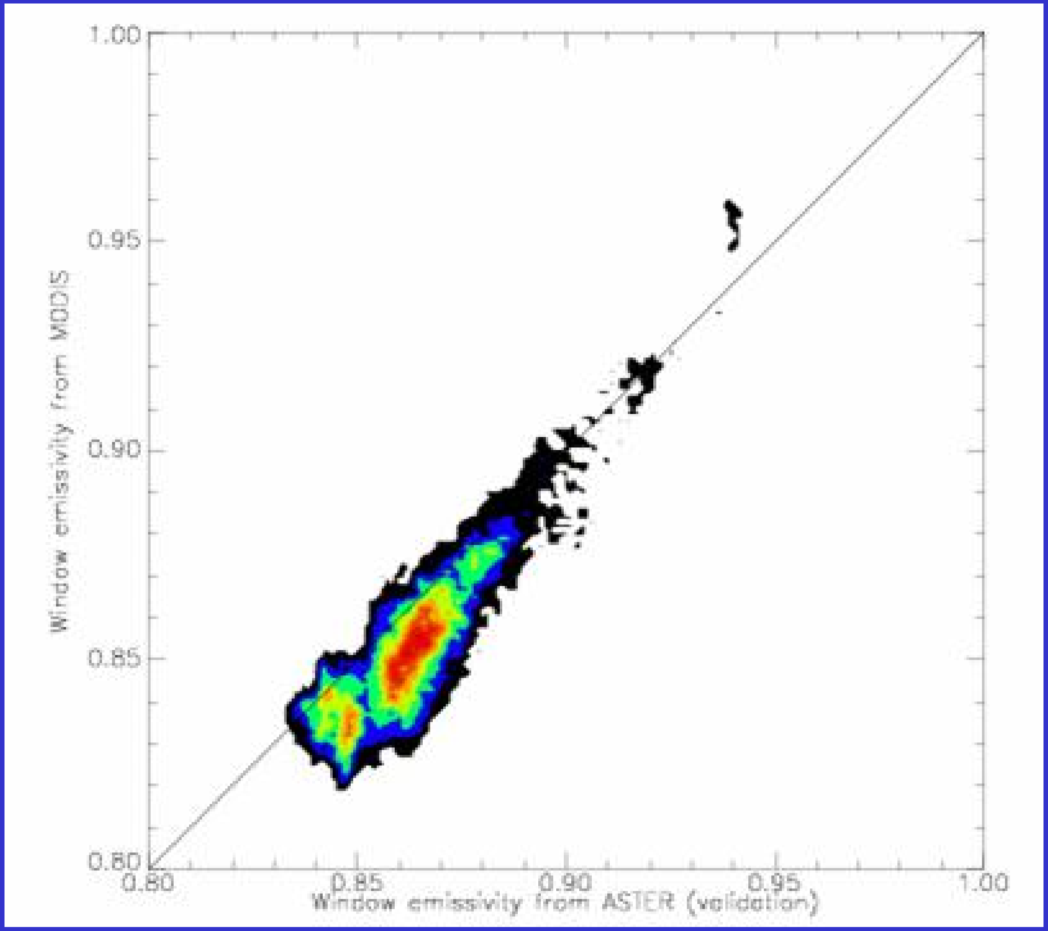
Window Emissivity

ε_{8-12} = 0.987 – –
0.08316 $_{7}$



Comparison: MODIS Estimated vs ASTER Observed

MODIS



Bias = -0.0083
RMSE = 0.0181

ASTER

Conclusions

- ASTER and TES work very well
  - Quantitative agreement (1 – 2%) with lab and field measures at White Sands
  - ASTER Results are repetitive
  - Emissivity mapping on a regional scale
  - Extend to Global scale with MODIS

Mapping Nutrient Transport in Lakes

Simon J. Hook

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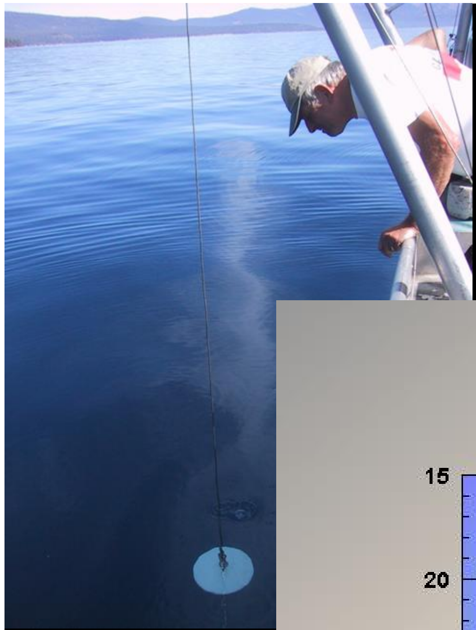
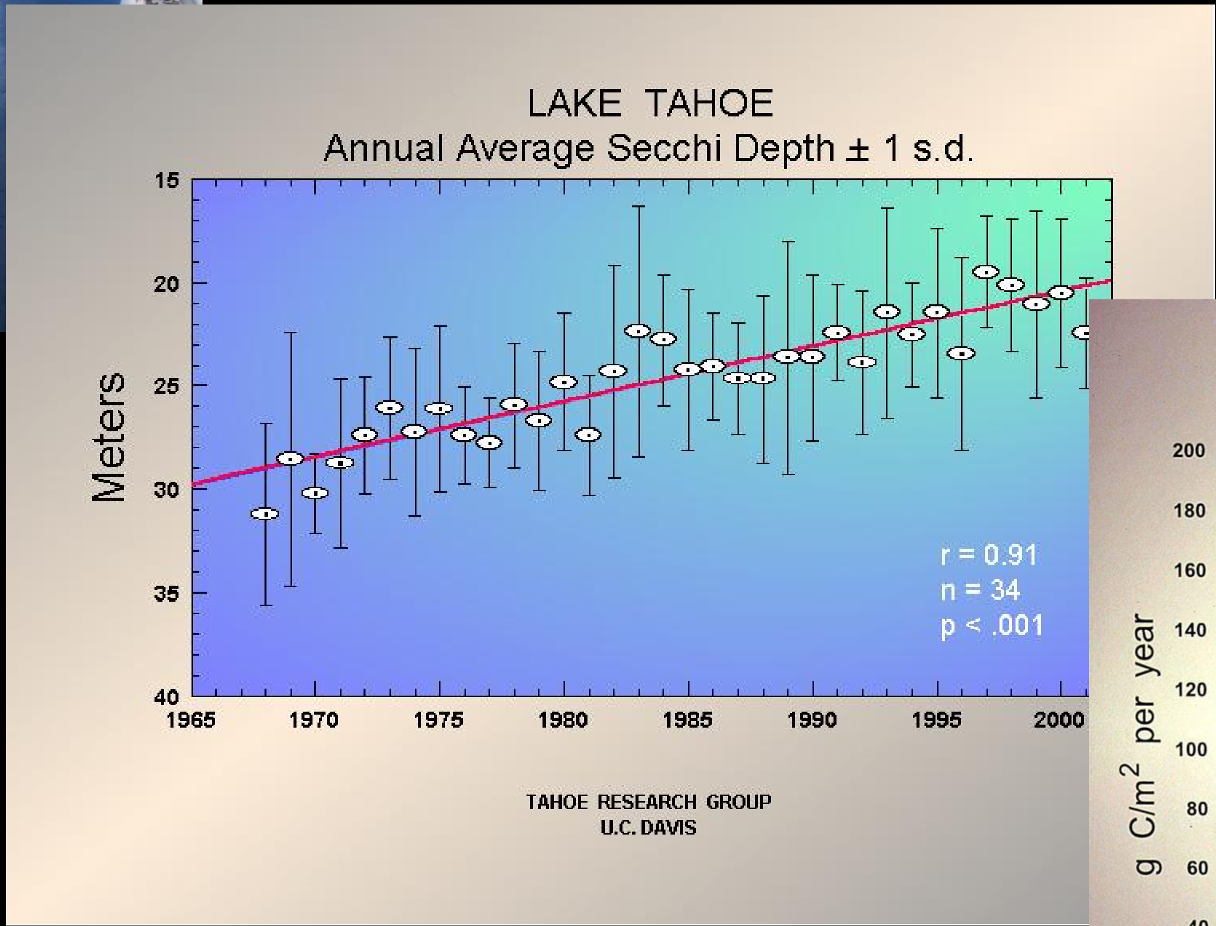
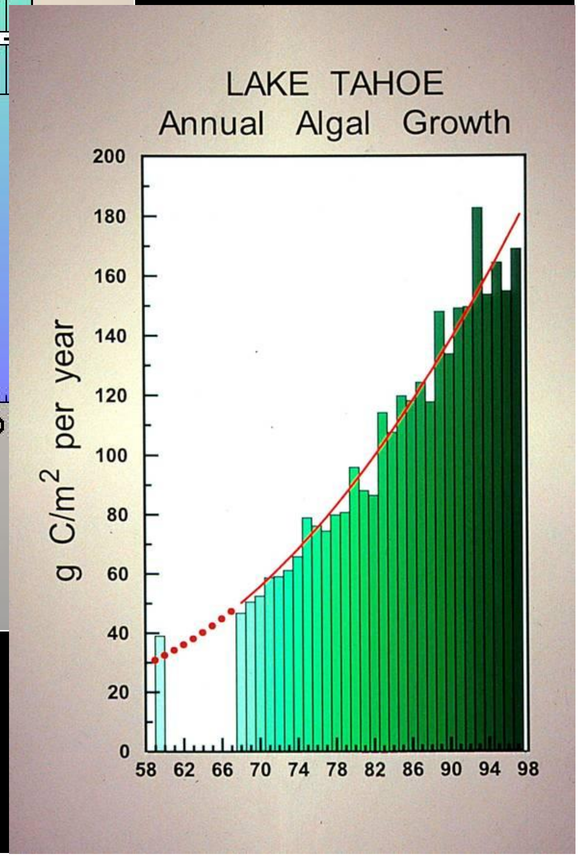
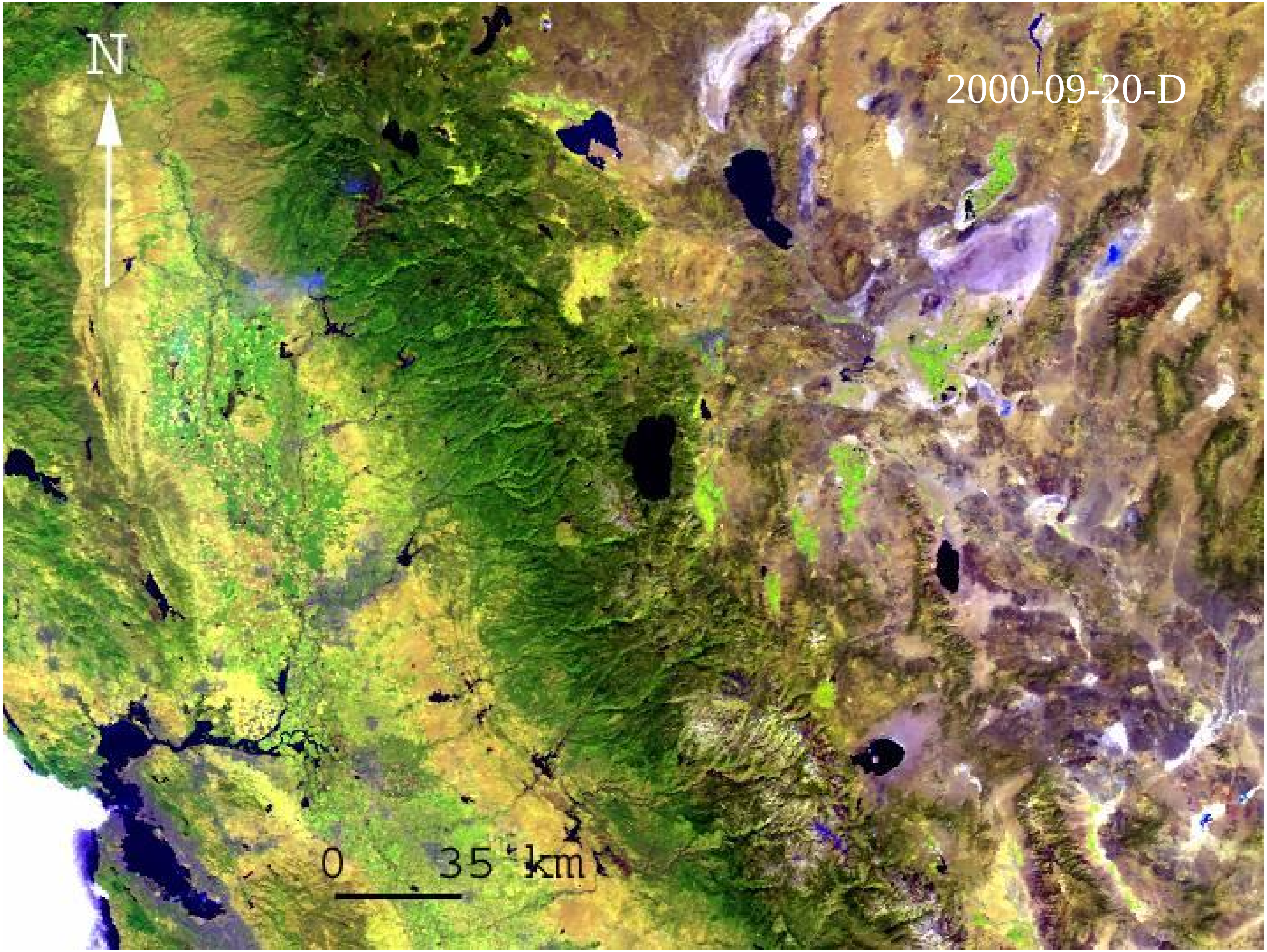
Measuring Nutrient Transport In Lakes





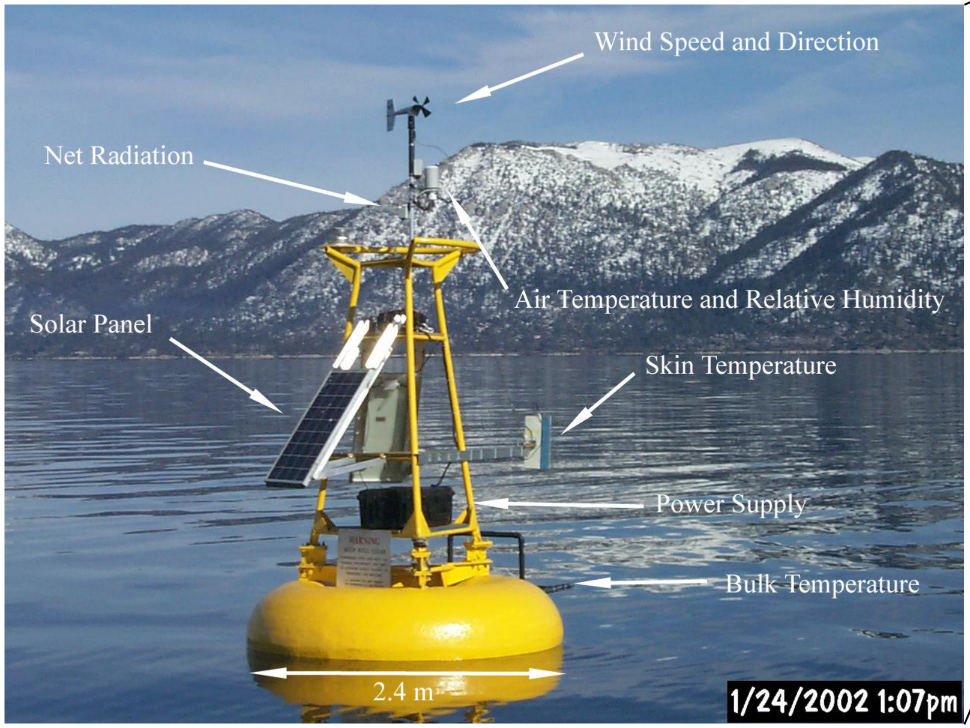


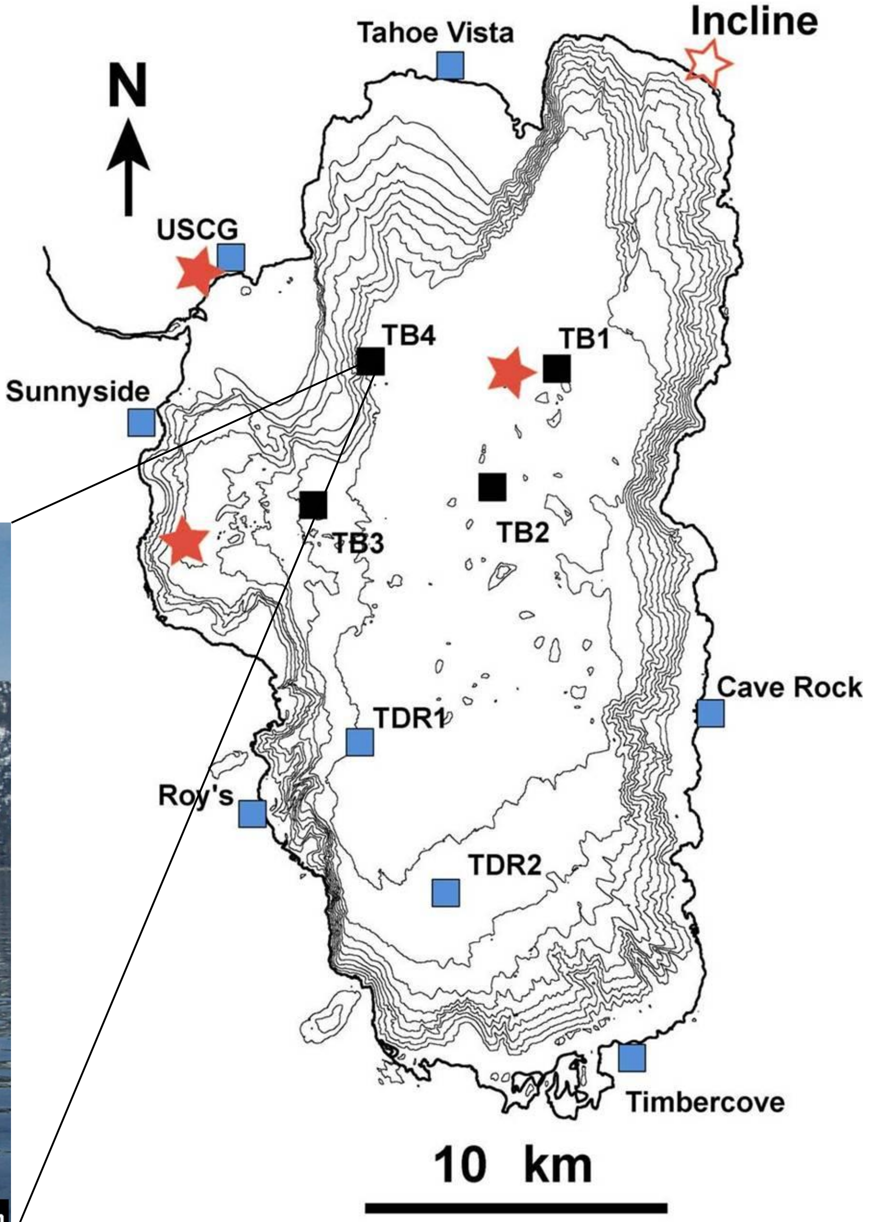
Simon J. Hook
Simon.j.hook@jpl.nasa.gov


N
2000-09-20-D
0 35 km

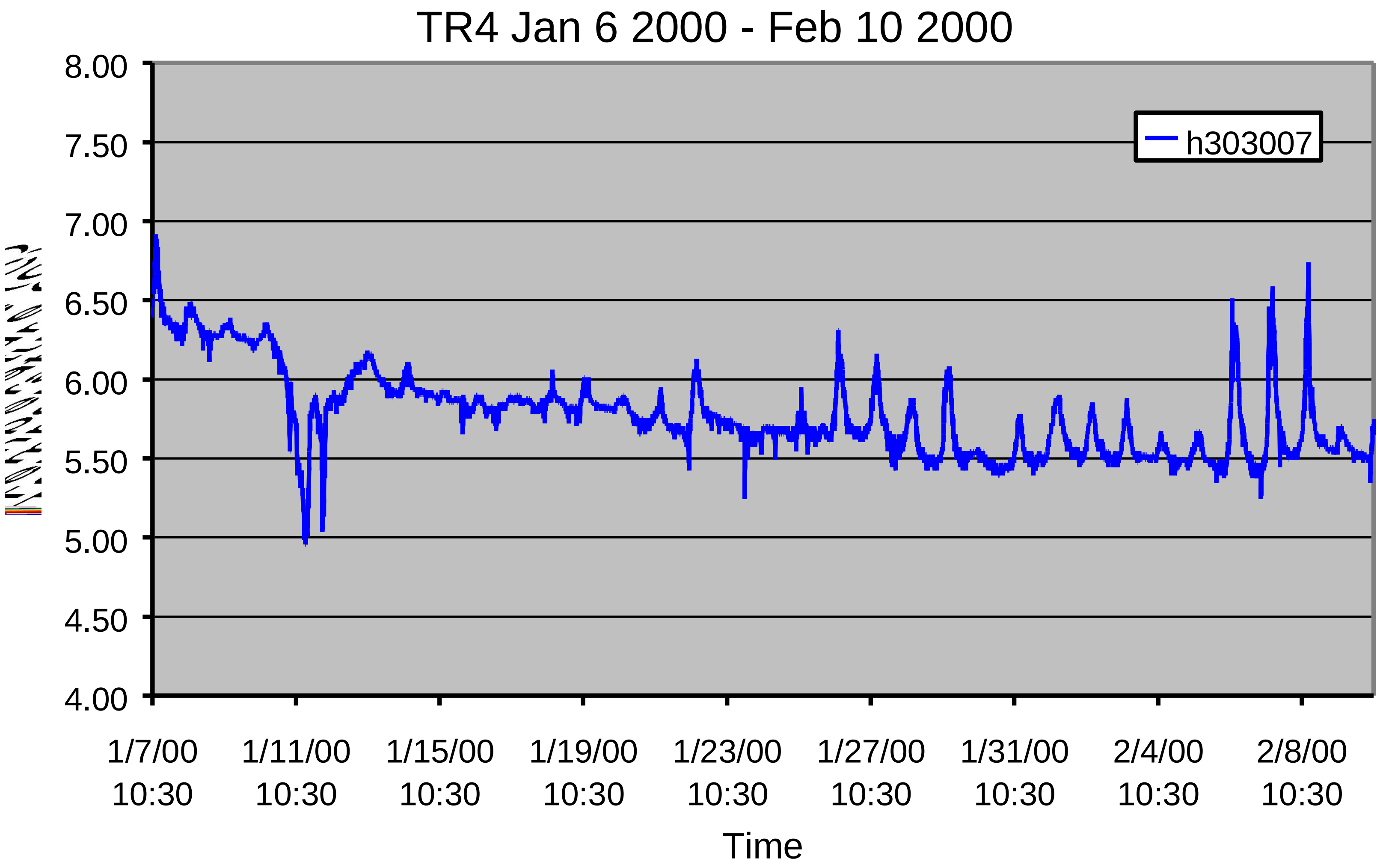
Infrastructure:

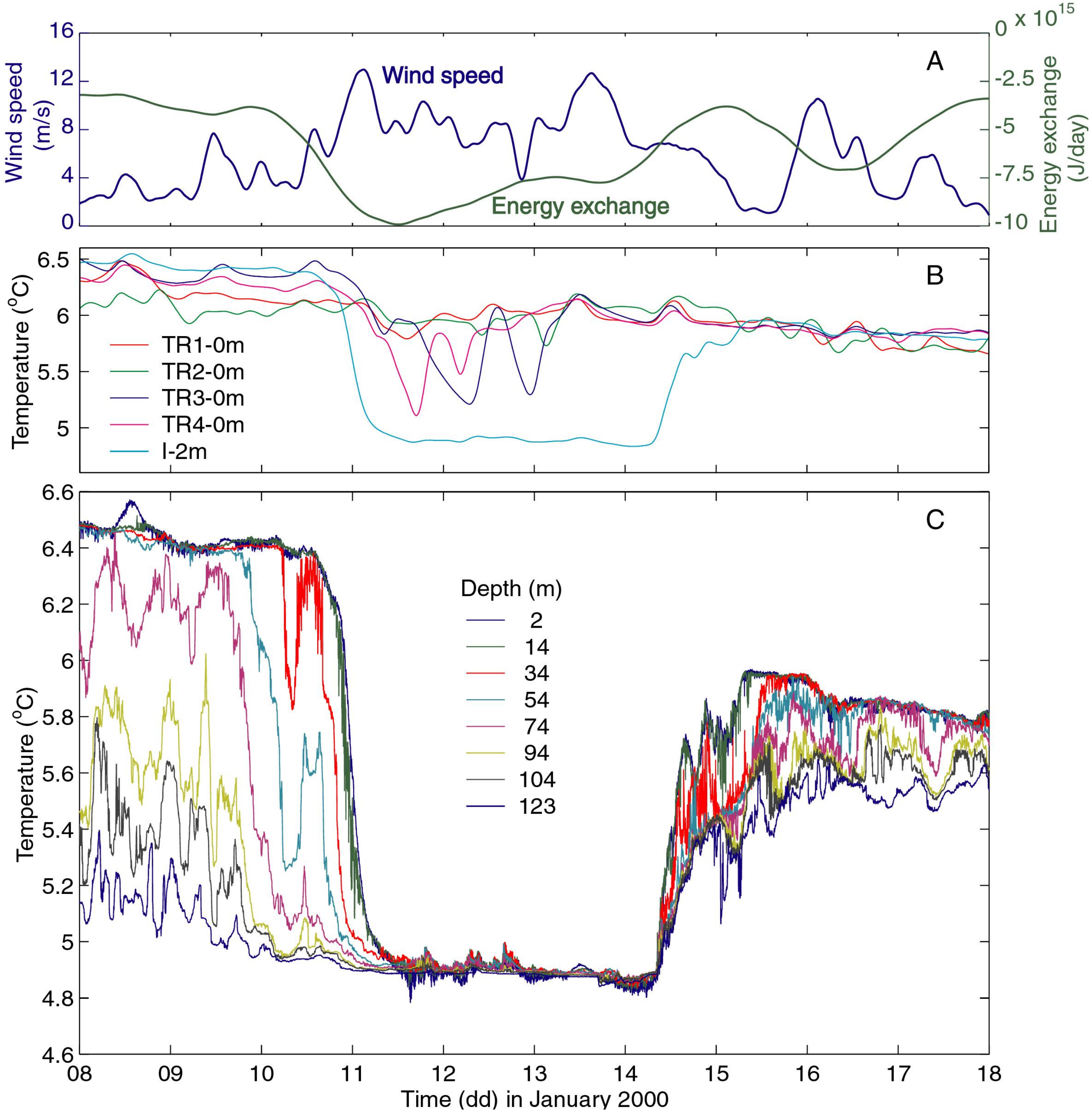
- Four NASA buoys
- Two UCD buoys
- Multiple meteorological stations around lake



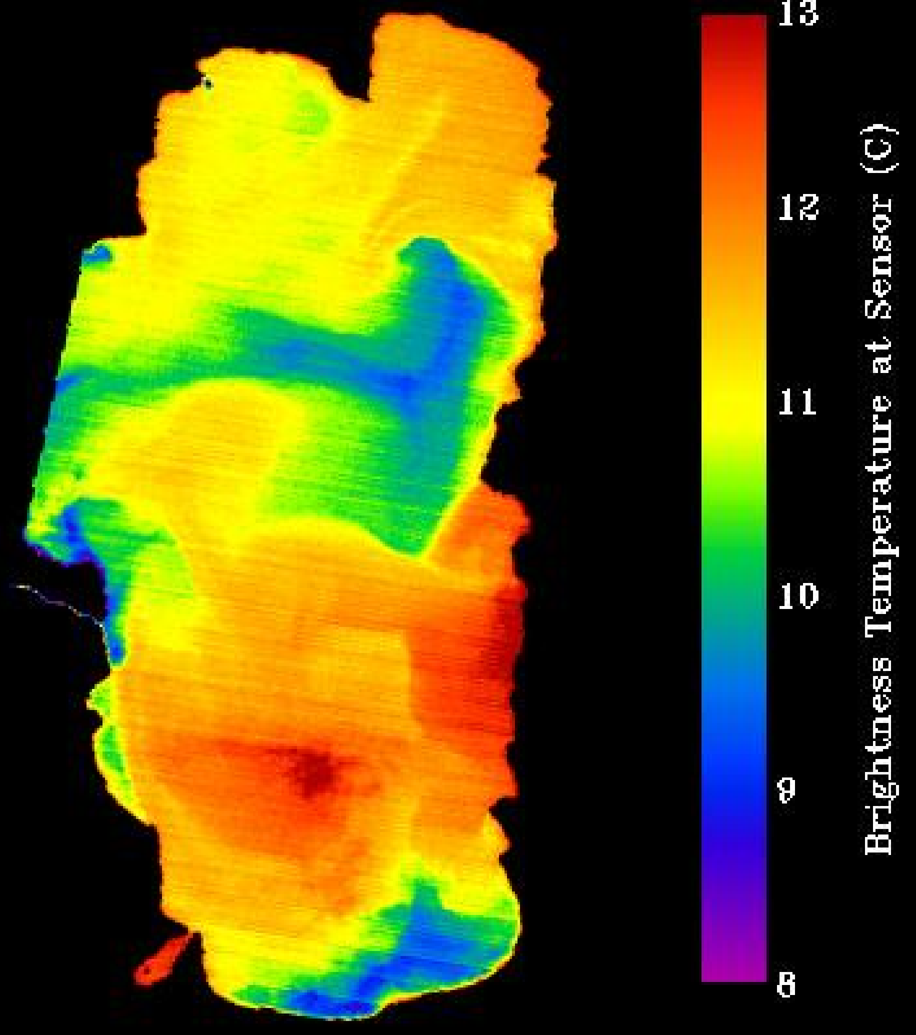


Temperature Trace from TR4 for January of 2000

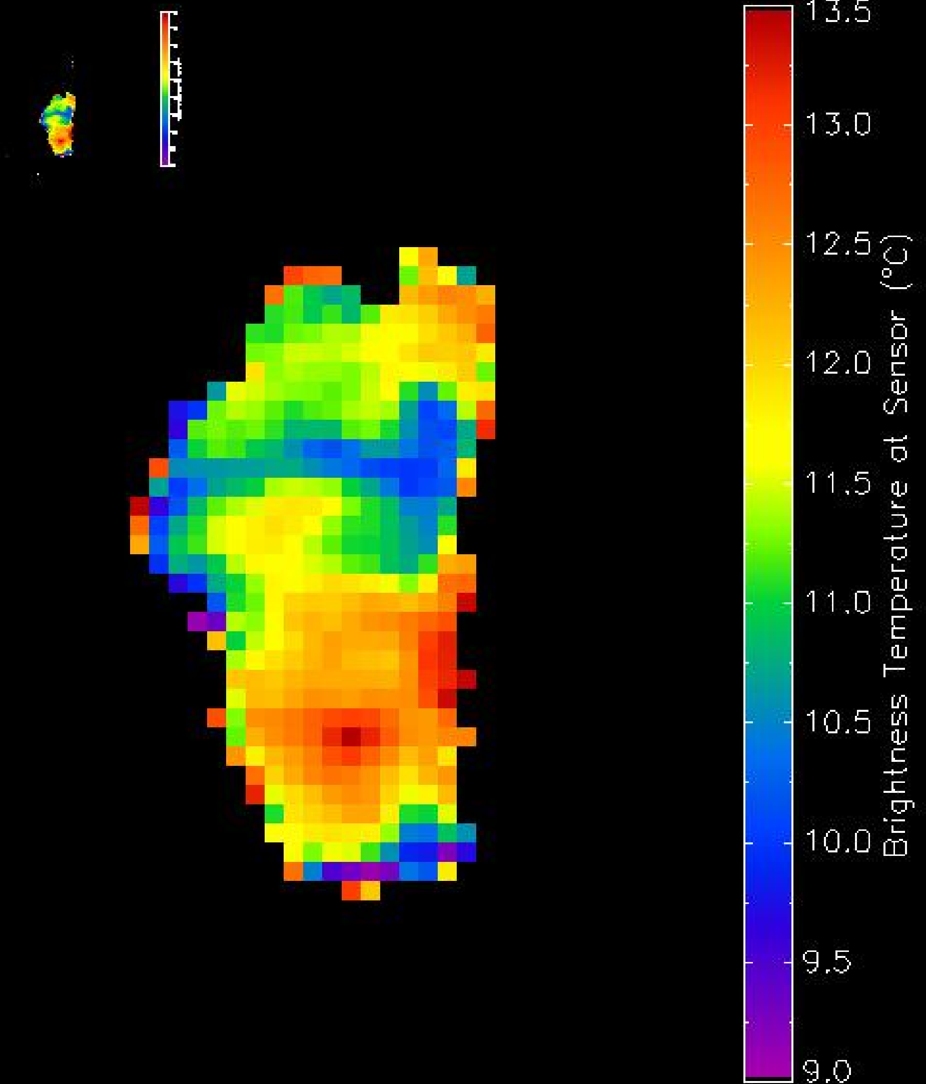




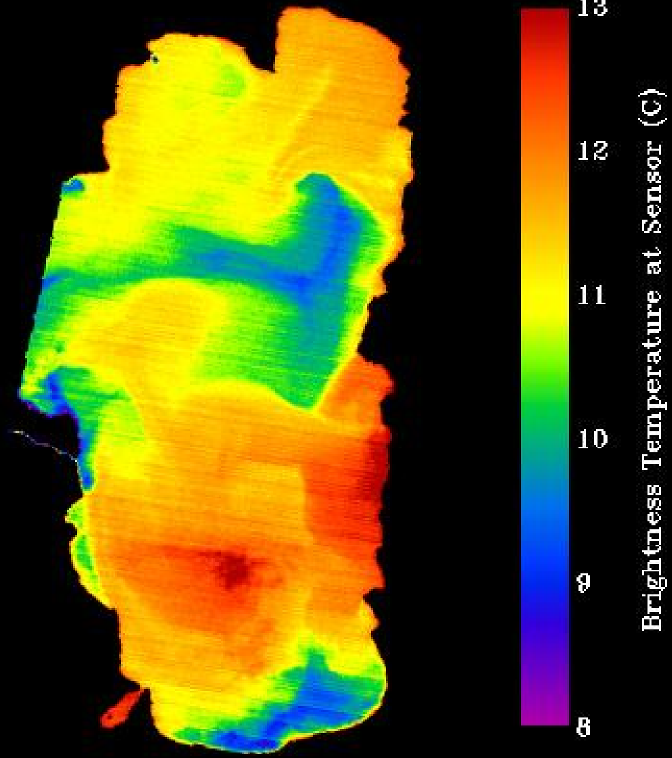
A
Wind speed
Energy exchange
Wind speed (m/s)
Energy exchange (J/day)
x 10^15
B
Temperature (°C)
TR1-0m
TR2-0m
TR3-0m
TR4-0m
I-2m
C
Depth (m)
2
14
34
54
74
94
104
123
Time (dd) in January 2000



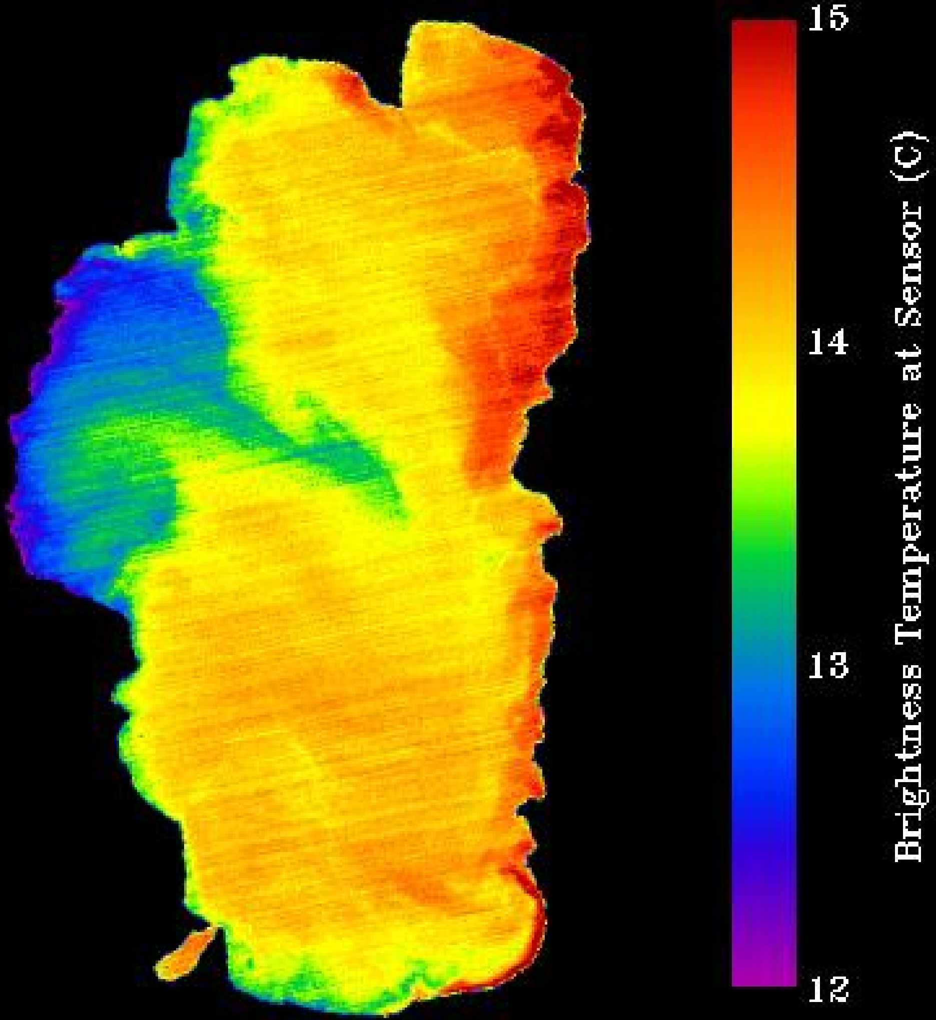
ASTER 6/03/2001



MODIS 6/03/2001

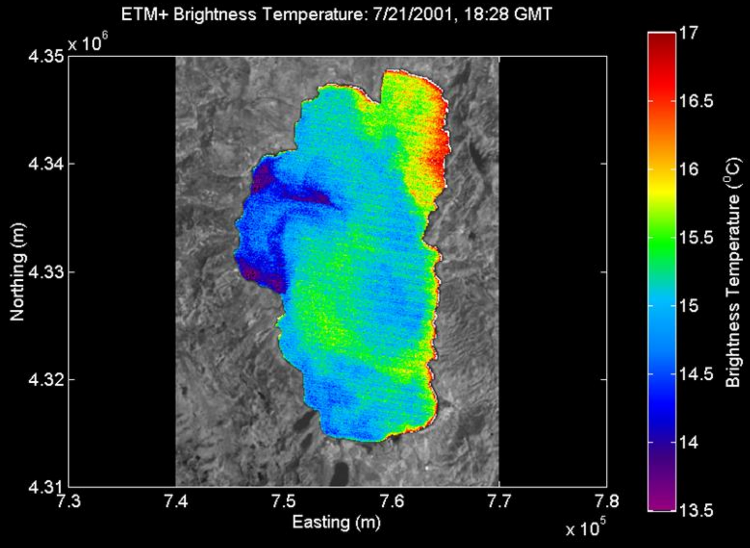


ASTER 6/03/2001

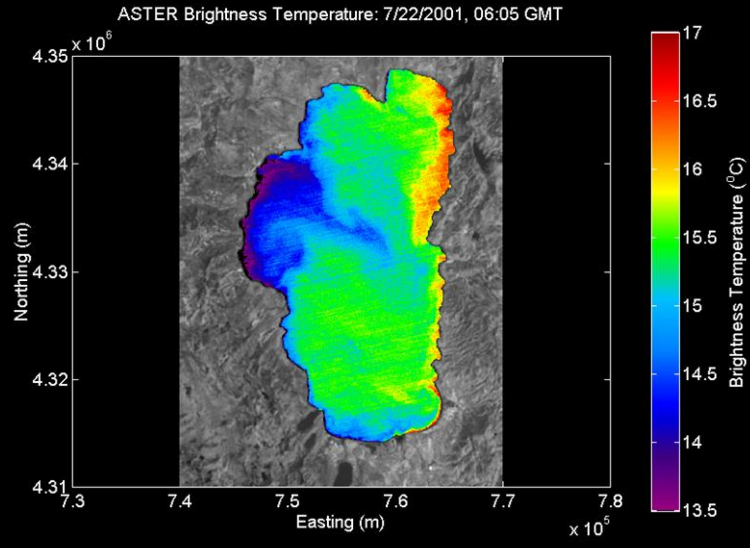


ASTER 7/22/2001

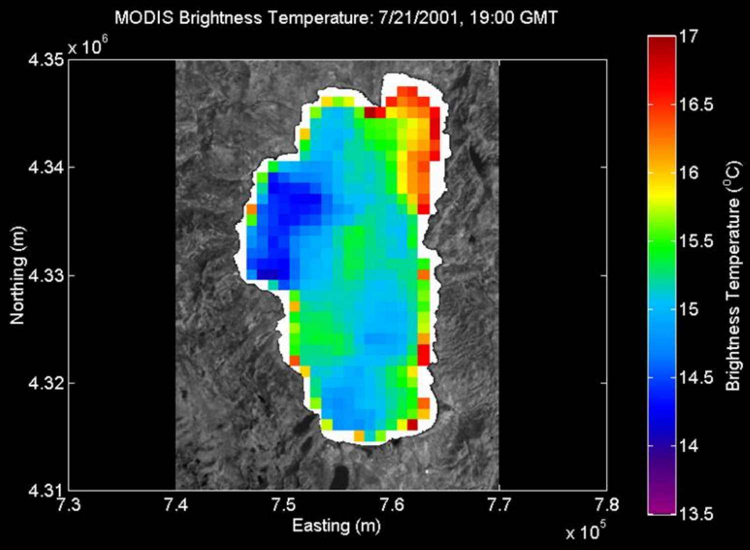
ETM+ 7/21/2001, 18:28 GMT



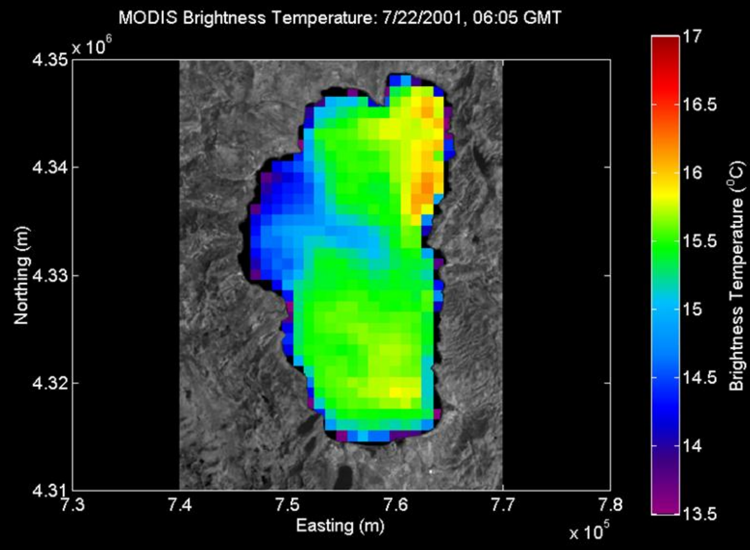
ASTER 7/22/2001, 06:05 GMT

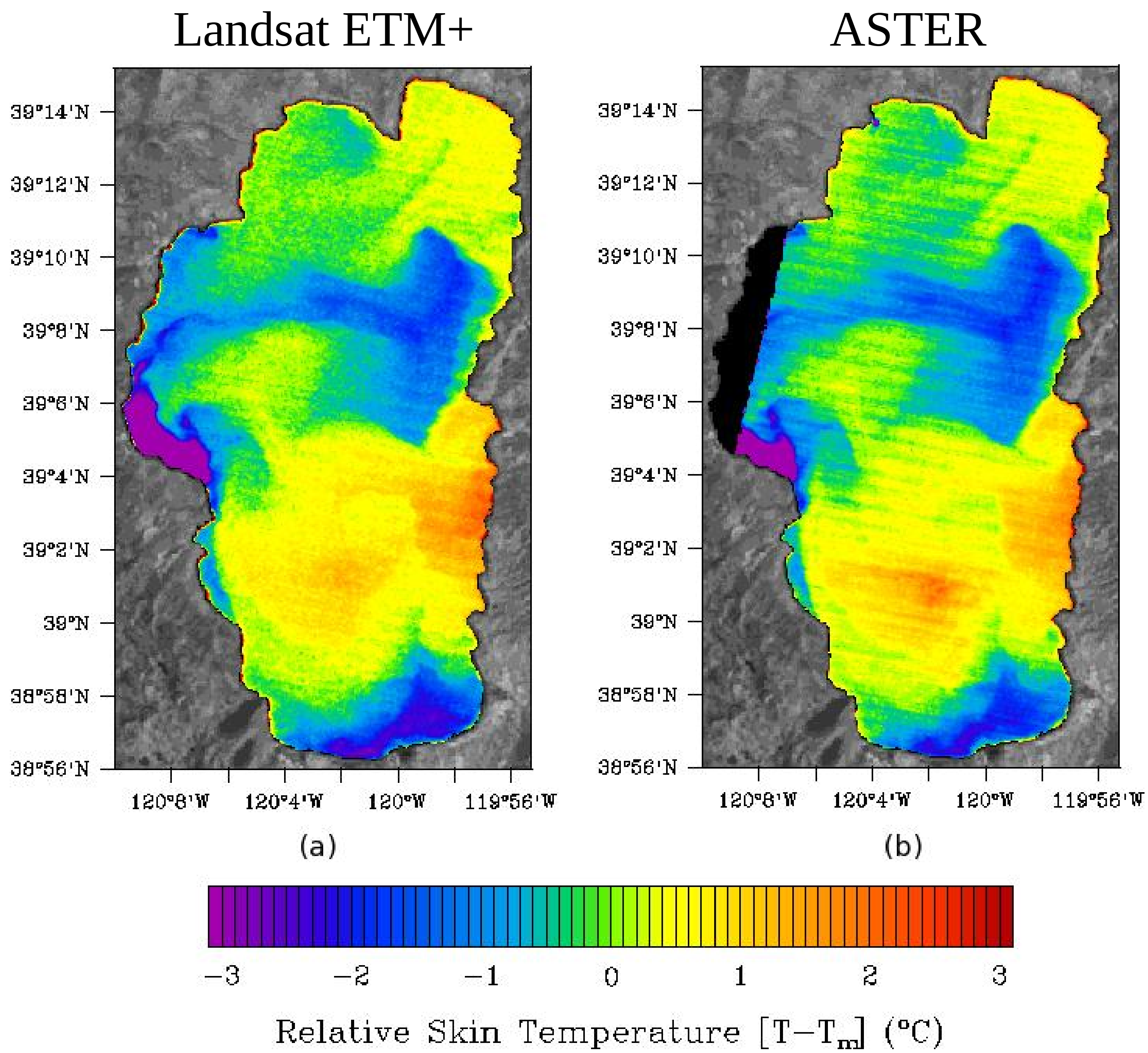


MODIS 7/21/2001, 19:00 GMT

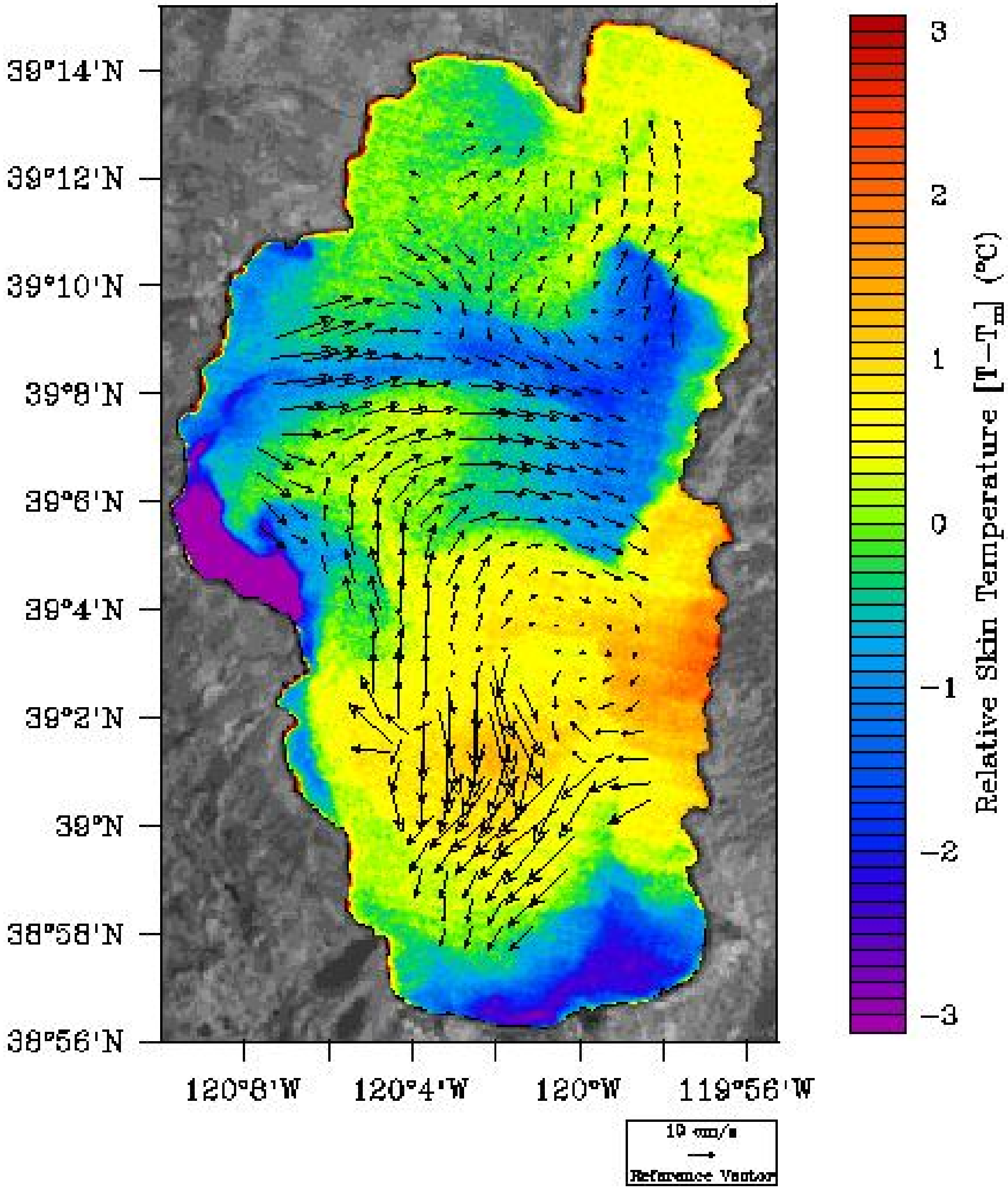


MODIS 7/22/2001, 06:05 GMT




Landsat ETM+
ASTER
39°14'N
39°12'N
39°10'N
39°8'N
39°6'N
39°4'N
39°2'N
39°N
38°58'N
38°56'N
120°8'W
120°4'W
120°W
119°56'W
(a)
(b)
−3
−2
−1
0
1
2
3
Relative Skin Temperature [T−Tm] (°C)

Current Tracking with Landsat ETM+ and ASTER Data using Maximum Correlation Method



Critical Factors Limiting Use of Multi-Instrument Data

- Interoperability/Protocols/Standards
- Information Assurance and Security
- Hardware/Software
- Infrastructure/Bandwidth
- Human and Institutional Capacity

From: Strategic Plan for the U.S. Integrated Earth Observation System

Critical Factors – Real World

- Geospatial data but cannot be accessed geospatially
  - Need to subset down to pixel level when order!
- Every pixel needs a latitude and longitude
  - No subset lattices or corner points – use double precision.
- Data stored in multiple projections
  - Need default, common projection
- Data ordering should not require a human in the loop
  - Implement SIMPLE subscription service
- Software lacks scripting
  - More toolkits with scripting support e.g. Python and PIL
- Open access
  - Allow users to FTP for free small subsets e.g. USGS NED approach

Wrap-Up

- Need Leadership from the top input with input from the bottom.
- Need clearly articulated vision for where we want to go and why.
- Need a system which can be used by the individual without requiring large institutional infrastructure
- Need clear milestones with tangible results
  - Roadmaps, Data Fusion working group?

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