Mapping Volcanic Plumes with AIRS, MODIS, and ASTER Data

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Focus of Presentation:

Development of a Common Set of Tools for the Analysis of Thermal Infrared (TIR) Data Acquired with AIRS, ASTER, and MODIS

Research Objectives:

(a) Monitor Volcanic Gas and Particle Emissions in an Effort to Detect Changes in the Rates of Emission Prior to an Eruption

(b) Study the Transport and Evolution of Plumes Generated by Explosive Eruptions

(c) Document the Fate of Volcanic Products in the Atmosphere Following an Eruptions

Approach:

Study the Record of AIRS, MODIS, and ASTER Data Spanning Recent Eruptions of Mount Etna

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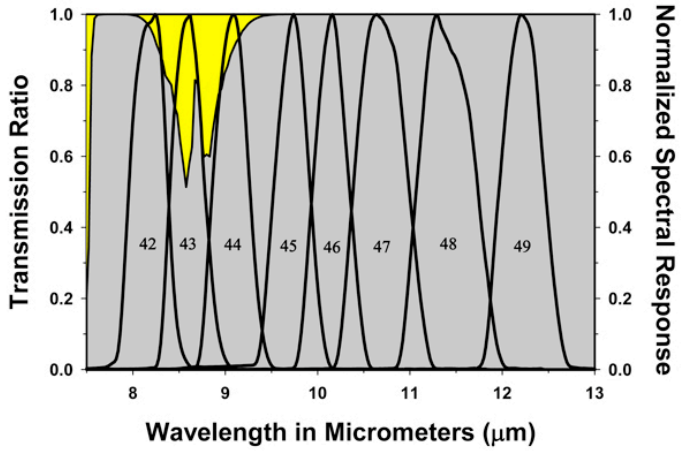
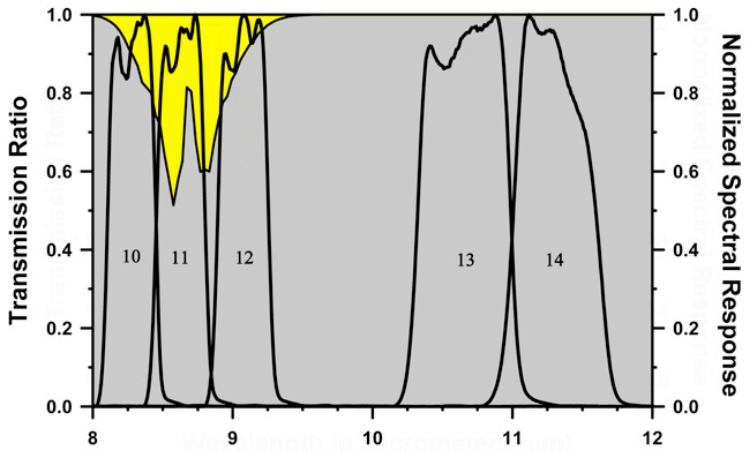
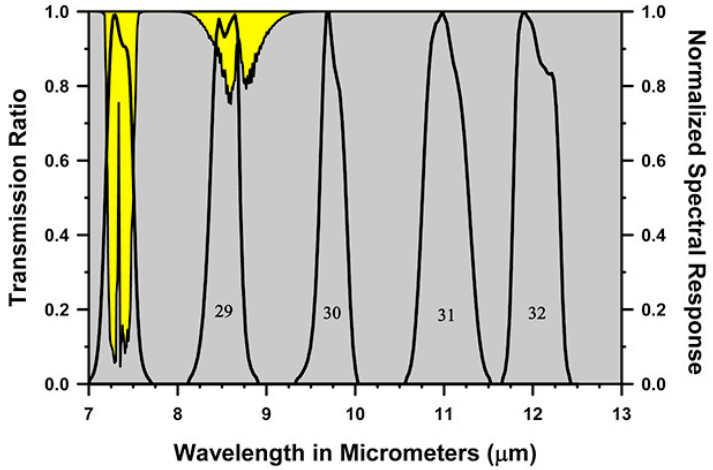
MASTER Calibration for Arenal 2003



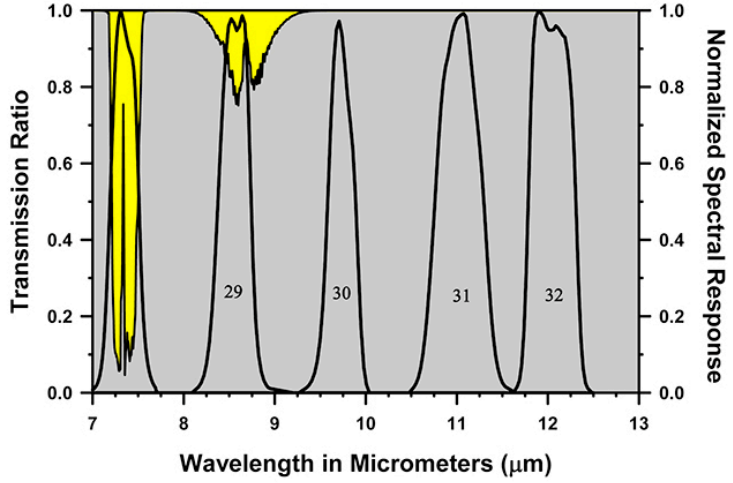
ASTER Response vs. SO_2 Transmission



MODIS-Terra Response vs. SO_2 Transmission



MODIS-Aqua Response vs. SO_2 Transmission



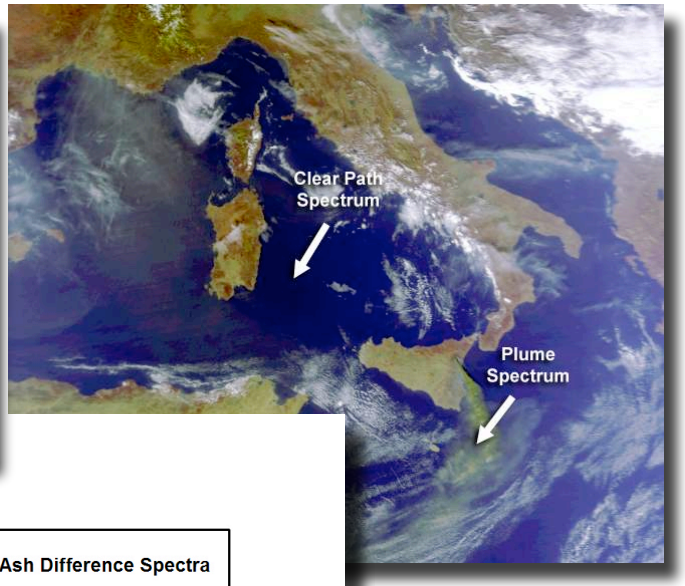
Comparison of the TIR Absorption Spectrum of SO_2 with the Spectral Response of ASTER and MODIS

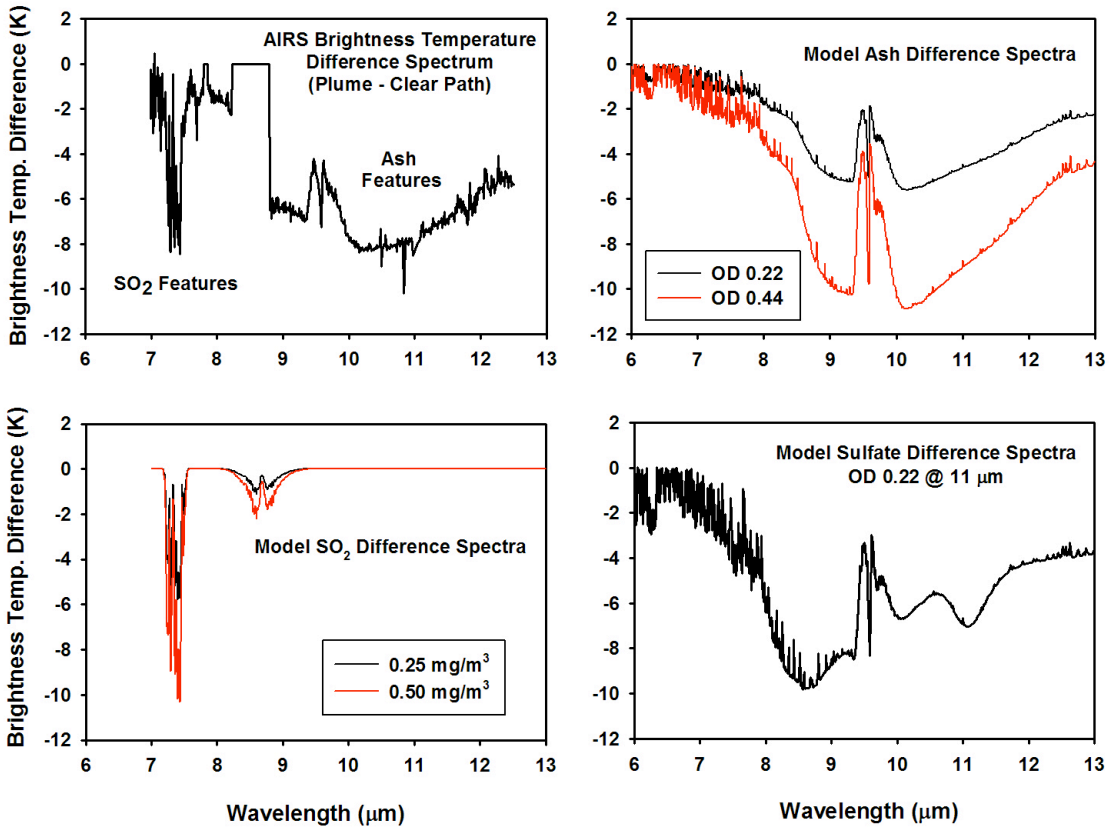
SO_2 Plumes Transparent at Wavelength > 10 μm

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

High Spectral Resolution (~ 2700 IR Channels) Permits Unambiguous Identification of SO_2, Silicate Ash, and Sulfate Aerosol

Eruption Plumes Have Few (if any) "Transparent" Windows – Motivation for Major Revision of SO_2 Retrieval Algorithm





Model Spectra Courtesy of B. Kahn and A. Eldering

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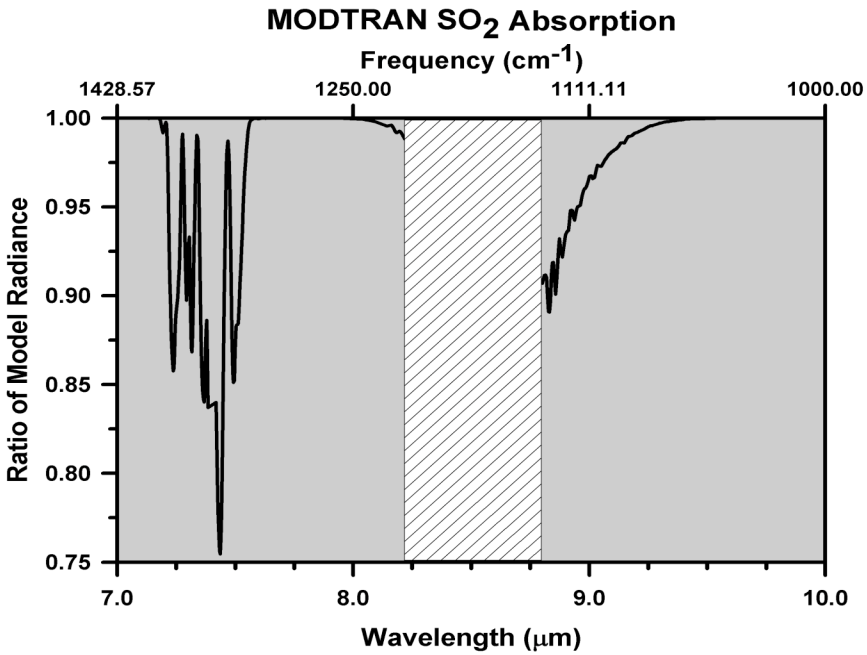
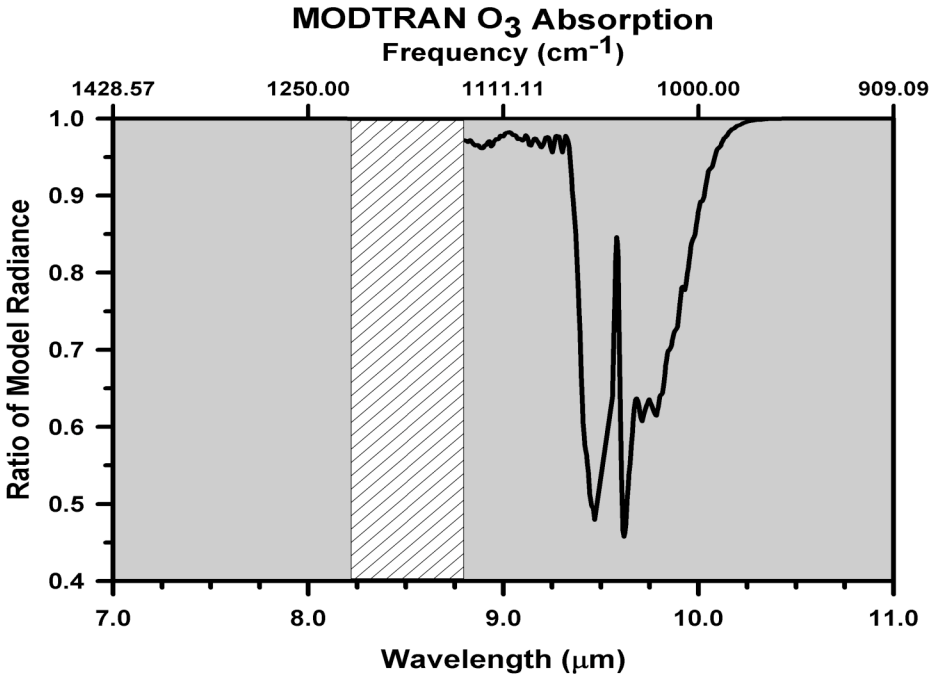
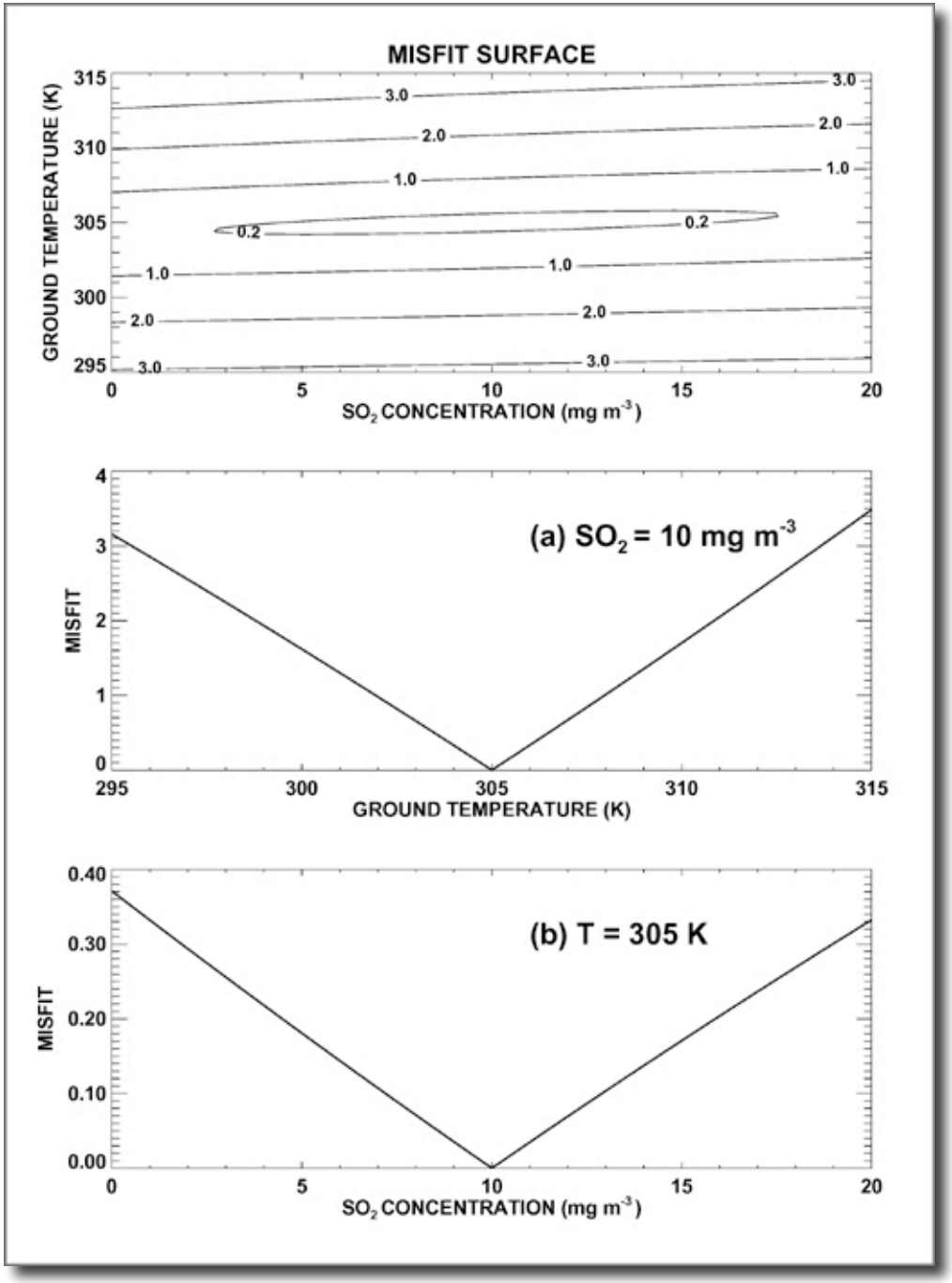
- Estimate SO_2 Concentration by Modeling Changes in Ground Radiance
- Retrievals Based on MODTRAN
- Characterize Local Atm Conditions with Profiles of Temp and Humidity
- Plume at Ambient Air Temperature







Surface Temperature vs. SO_2 Concentration

Can We Estimate Surface Temperature While Looking Through a Plume?

Ground Temperature has Stronger Influence on IRAD Than SO_2 Concentration

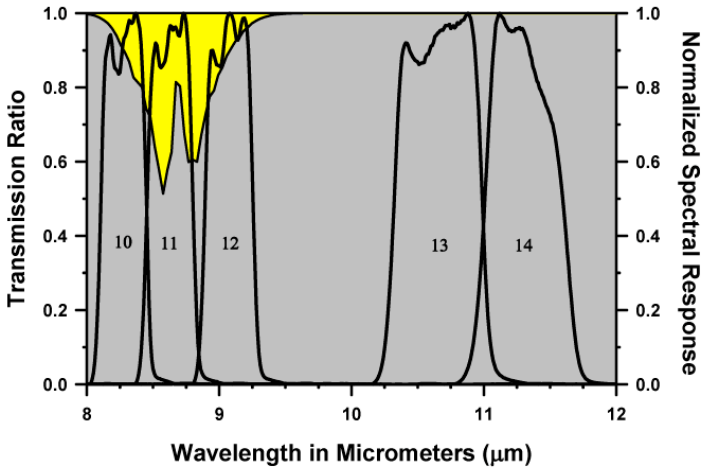
Simultaneous Retrieval of Temperature and SO_2 is Difficult; Cascading (Serial) Retrieval is a Better Option:

- **Evaluate Effect of Last SO_2 Estimate on Current Temperature Estimate**
- **Exit When $\Delta T <$ Threshold**

Define Initial Data Range for Minimum Misfit

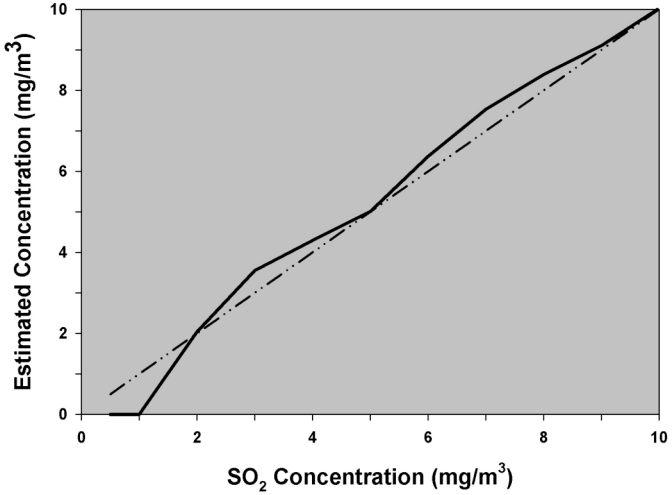
- **Subdivide Range on Second Pass**
- **Fit Parabola to Misfit**

ASTER Response vs. SO_2 Transmission



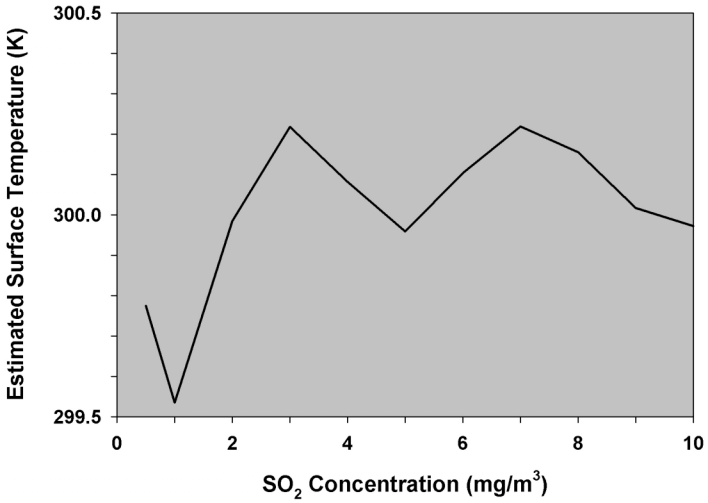
ASTER Simulation

(SO_2 Max = 25 mg/m^3)



ASTER Simulation

Temperature Estimate vs. SO_2 Concentration



Simulation of ASTER-Based SO_2 Retrievals

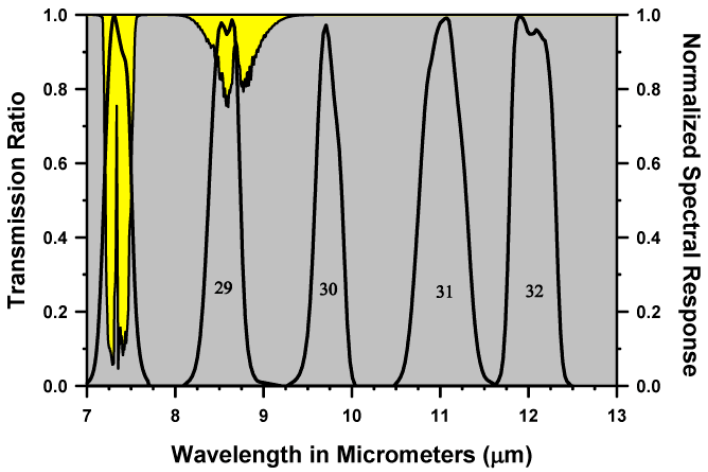
Plume Altitude: 6 km; Plume Thickness: 1 km

Sea Water Background at 300 K

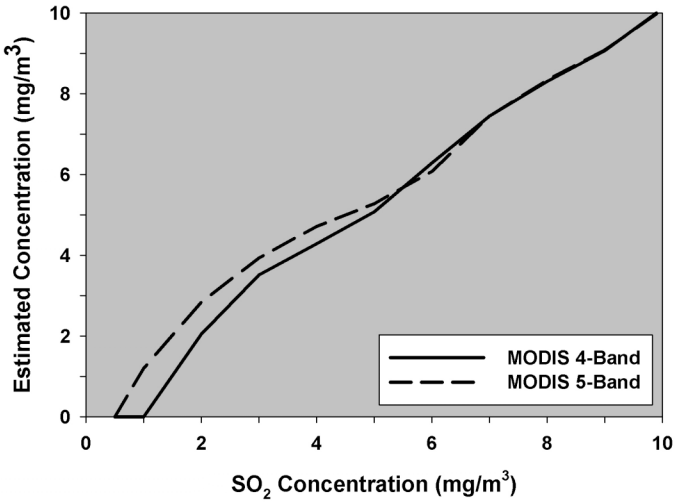
SO_2 Max = 25 mg/m^3

Lack of TIR Band(s) at 7.3 μm is Offset by High Spatial Resolution (90 m)

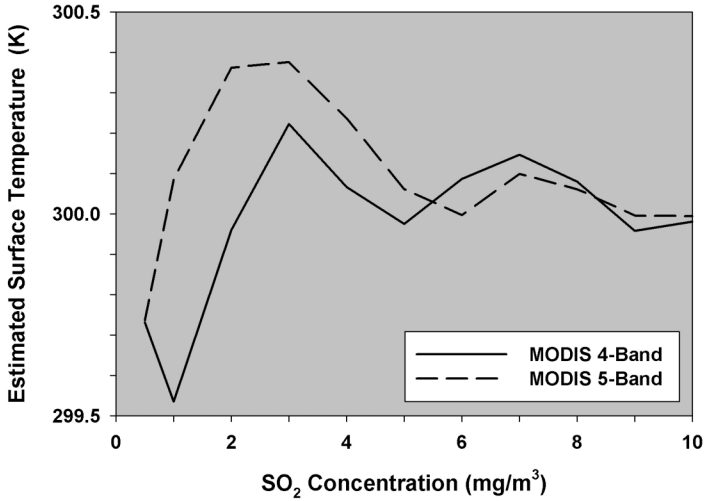
MODIS-Aqua Response vs. SO_2 Transmission



MODIS 4-Band vs. 5-Band SO_2 Retrievals



MODIS 4-Band vs. 5-Band Temperature Retrievals



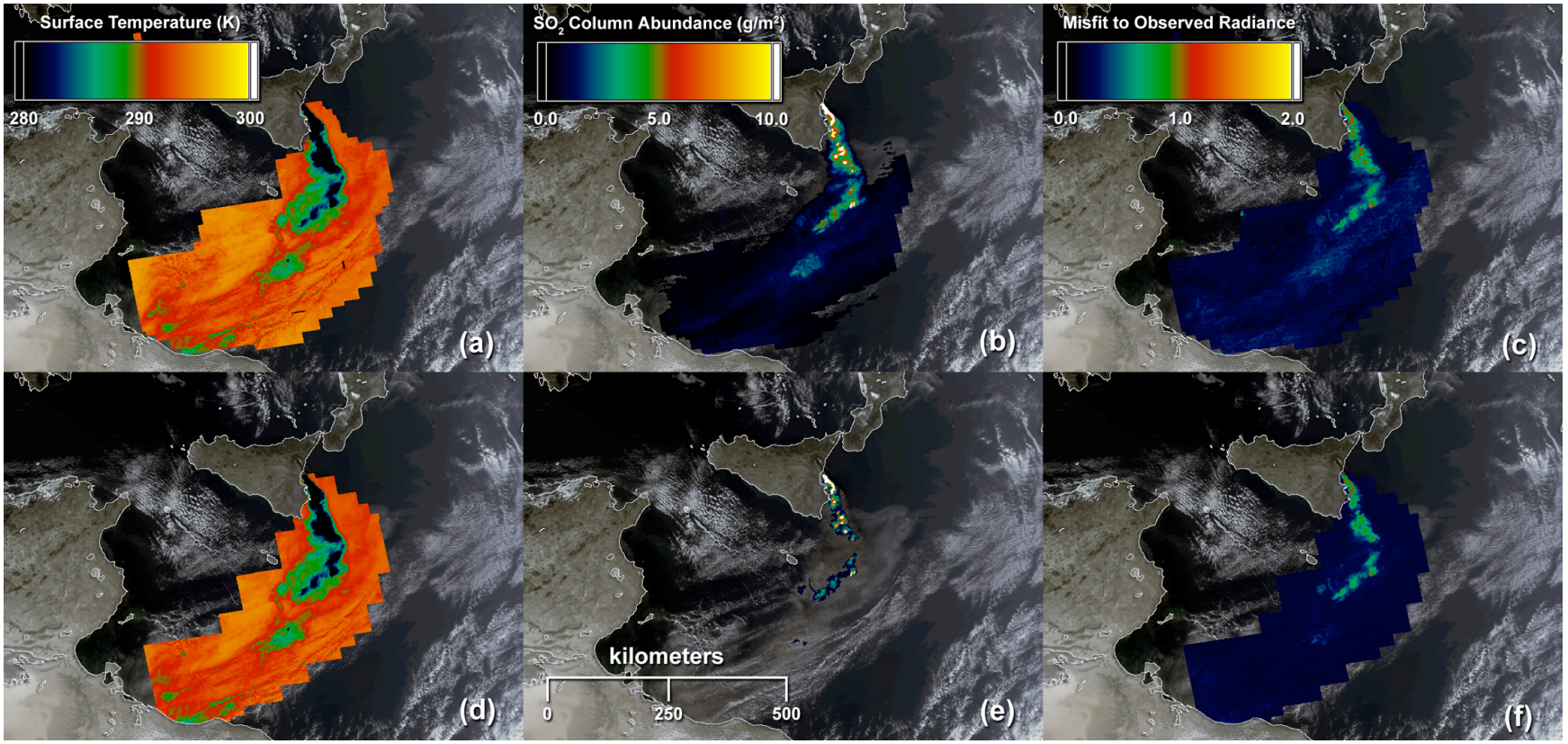
Simulation of MODIS-Based SO_2 Retrievals

Plume Altitude: 6 km; Plume Thickness: 1 km

Sea Water Background at 300 K

SO_2 Max = 25 mg/m^3

Use of Radiance from Band 28 (7.3 μm) Increases Sensitivity to Low Concentrations of SO_2

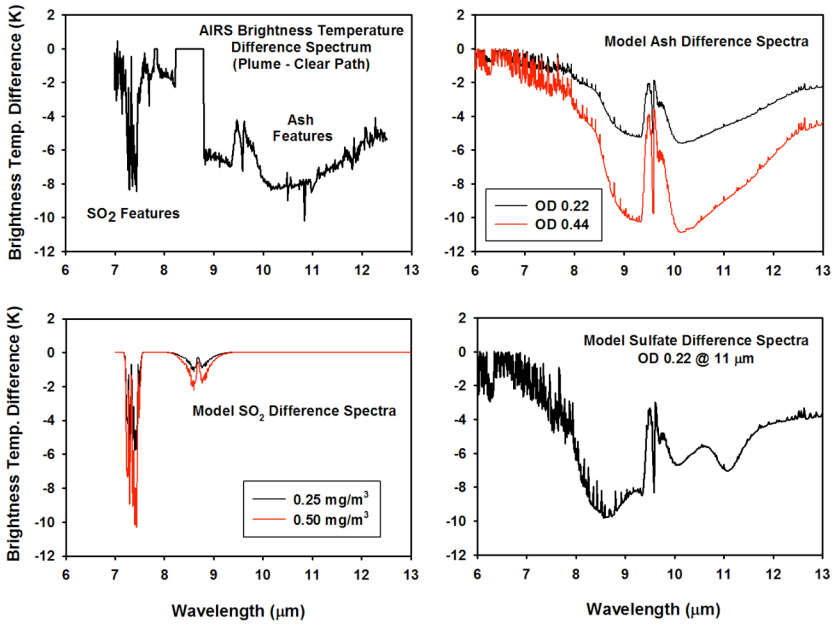


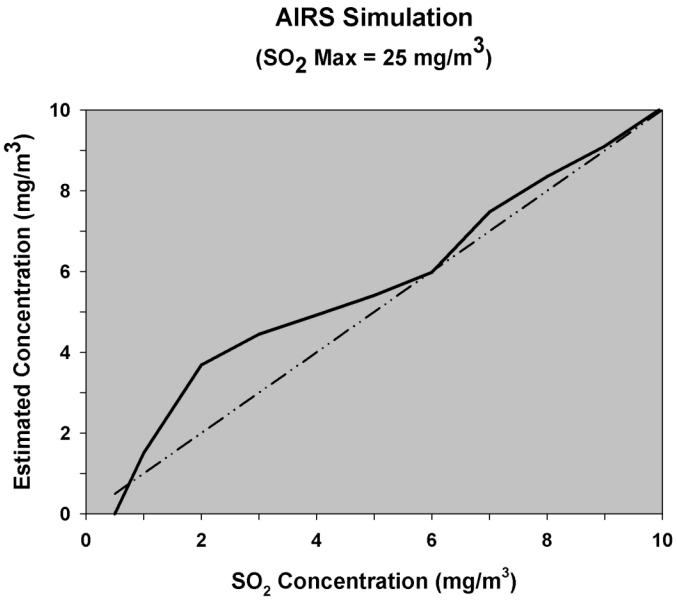
MODIS-Based SO_2 Retrievals: 28 October 2002

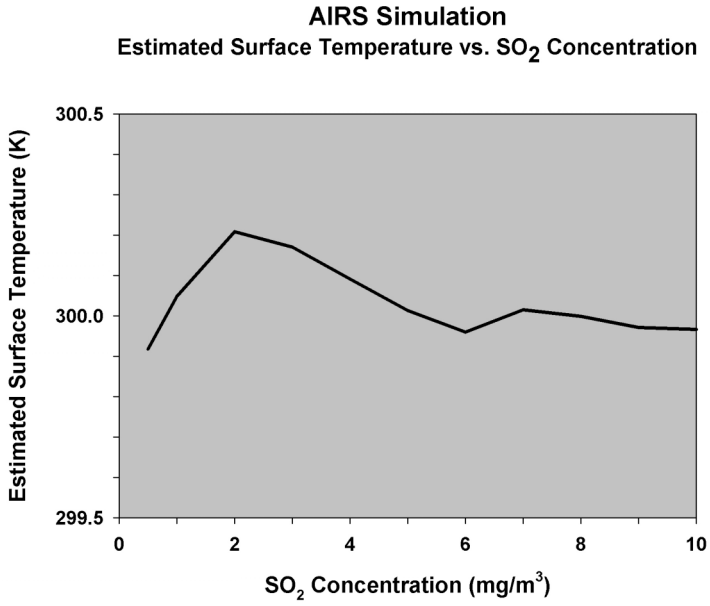
Comparison of Retrievals with 5-Band (Top Row) and 4-Band (Bottom Row) Surface Temperatures

Improved Sensitivity to Low Concentrations of SO_2

Increased Influence of Water Vapor on SO_2 Estimates – Requires Better Descriptions of Atm. Water Vapor (NCEP Reanalysis or AIRS L2?)







Simulation of AIRS-Based SO_2 Retrievals

Plume Altitude: 6 km; Plume Thickness: 1 km

Sea Water Background at 300 K

SO_2 Max = 25 mg/m^3

Iterative Estimation of Surface Temperature in the Presence of Absorbing (and Emitting) Species – No Clear View of Ground

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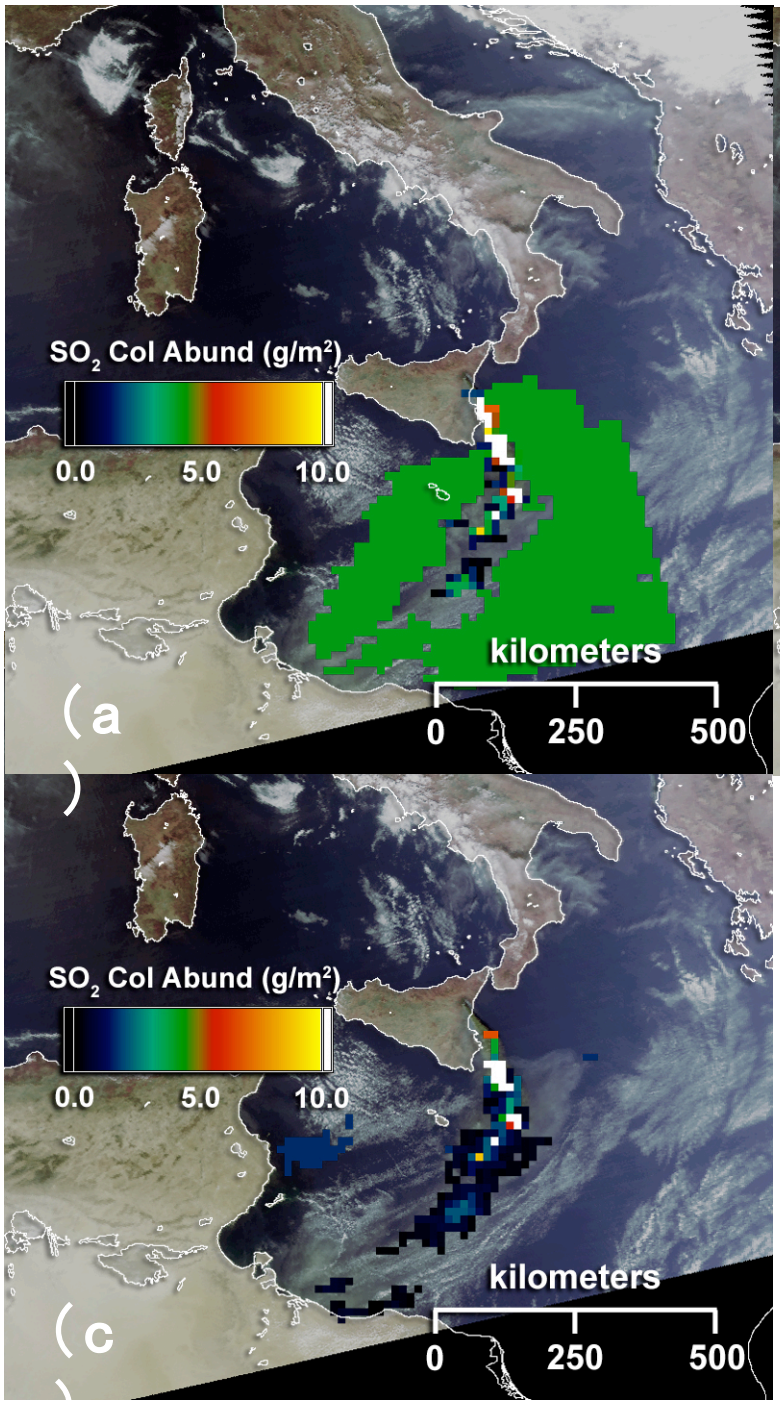

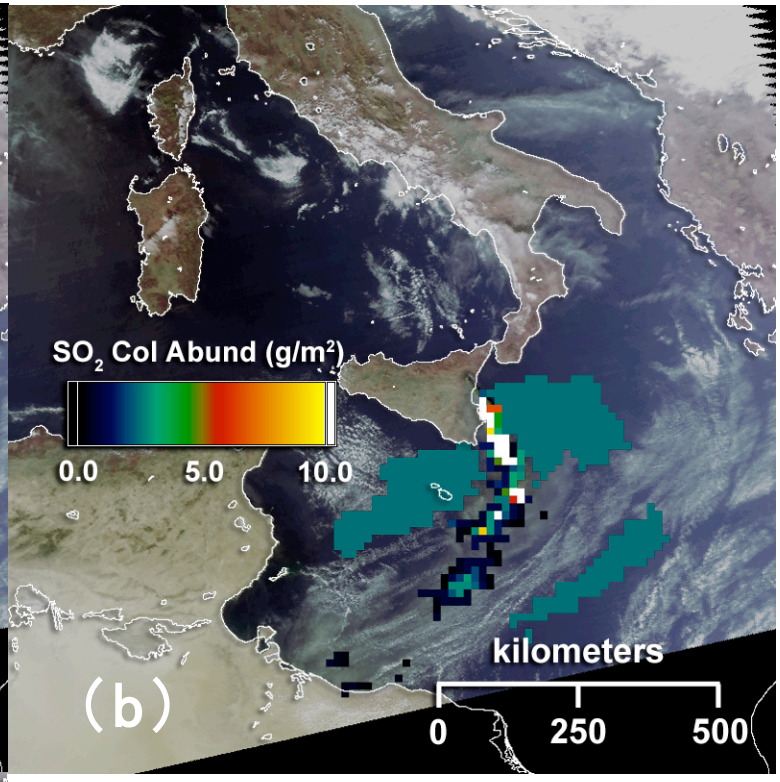

AIRS-Based SO_2 Retrievals

Mt. Etna, 28 October 2002

Comparison of Retrievals with Maximum SO_2 Concentrations of (a) 25, (b) 15, and (c)10 mg/m^3

Max. SO_2 Defines Range of Concentrations for First Pass in Retrieval Algorithm

Decrease in Max SO_2 Eliminates Bias in Retrievals and Increases Sensitivity to Low Concentrations of SO_2

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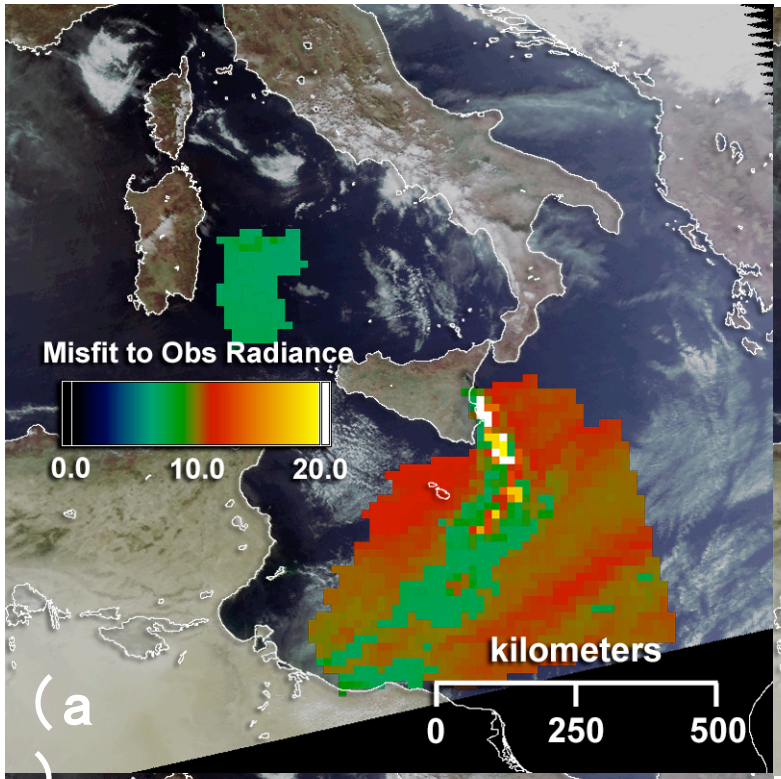

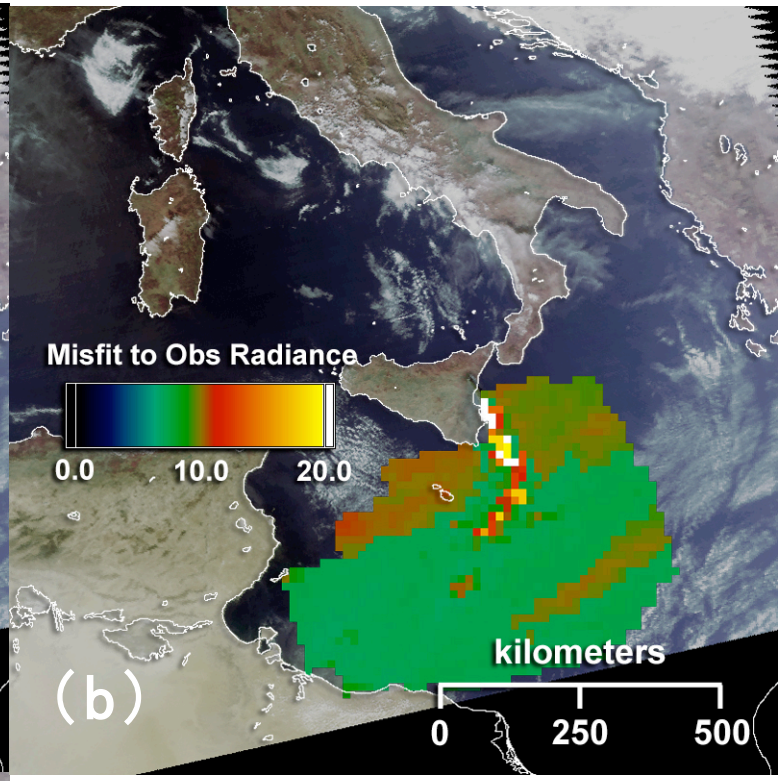

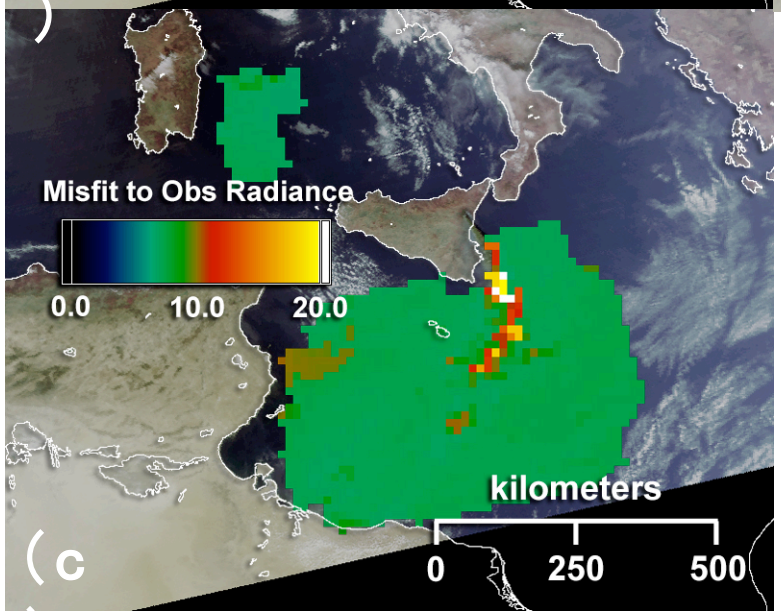

Comparison of Misfit with Maximum SO_2 Concentrations of (a) 25, (b) 15, and (c)10 mg/m^3

Misfit Improves with Decrease in Max. SO_2, but Does Not Fall To Zero Outside of Plume

MODTRAN Does Not Fit All H_2O Lines Observed by AIRS

Require Upgrade to MODTRAN and Better Descriptions of Atm. Water Vapor

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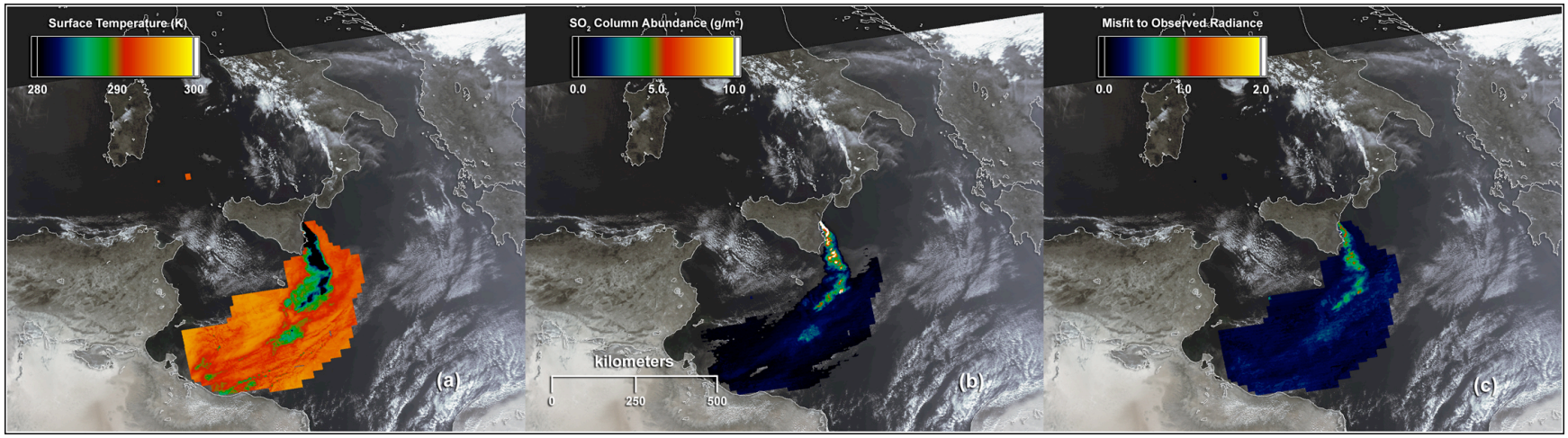

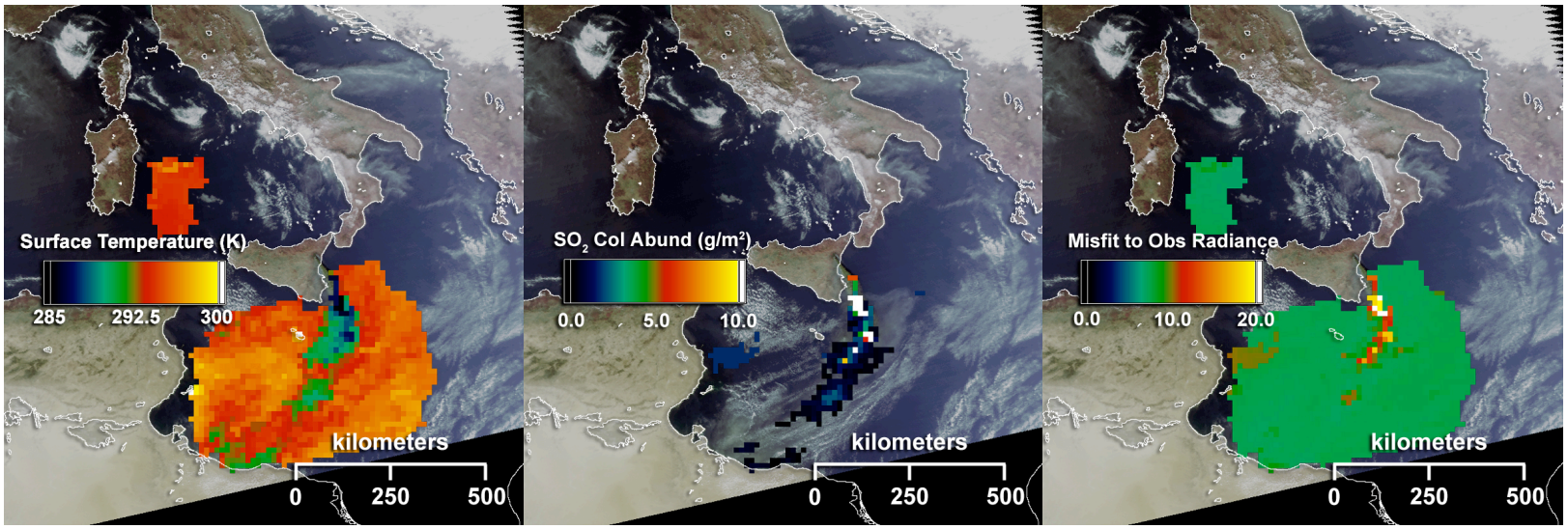

Comparison of Retrievals from MODIS-Aqua (Top Row) and AIRS (Bottom Row) Data

Spatial Resolution at Nadir: 1 km for MODIS vs. 17 km for AIRS

Excellent Agreement for Surface Temperature

Good Agreement for SO_2 Retrievals: Dependant on Uniformity of Plume

AIRS Misfit is 10X Higher Than MODIS Misfit: High Sensitivity to Water Vapor

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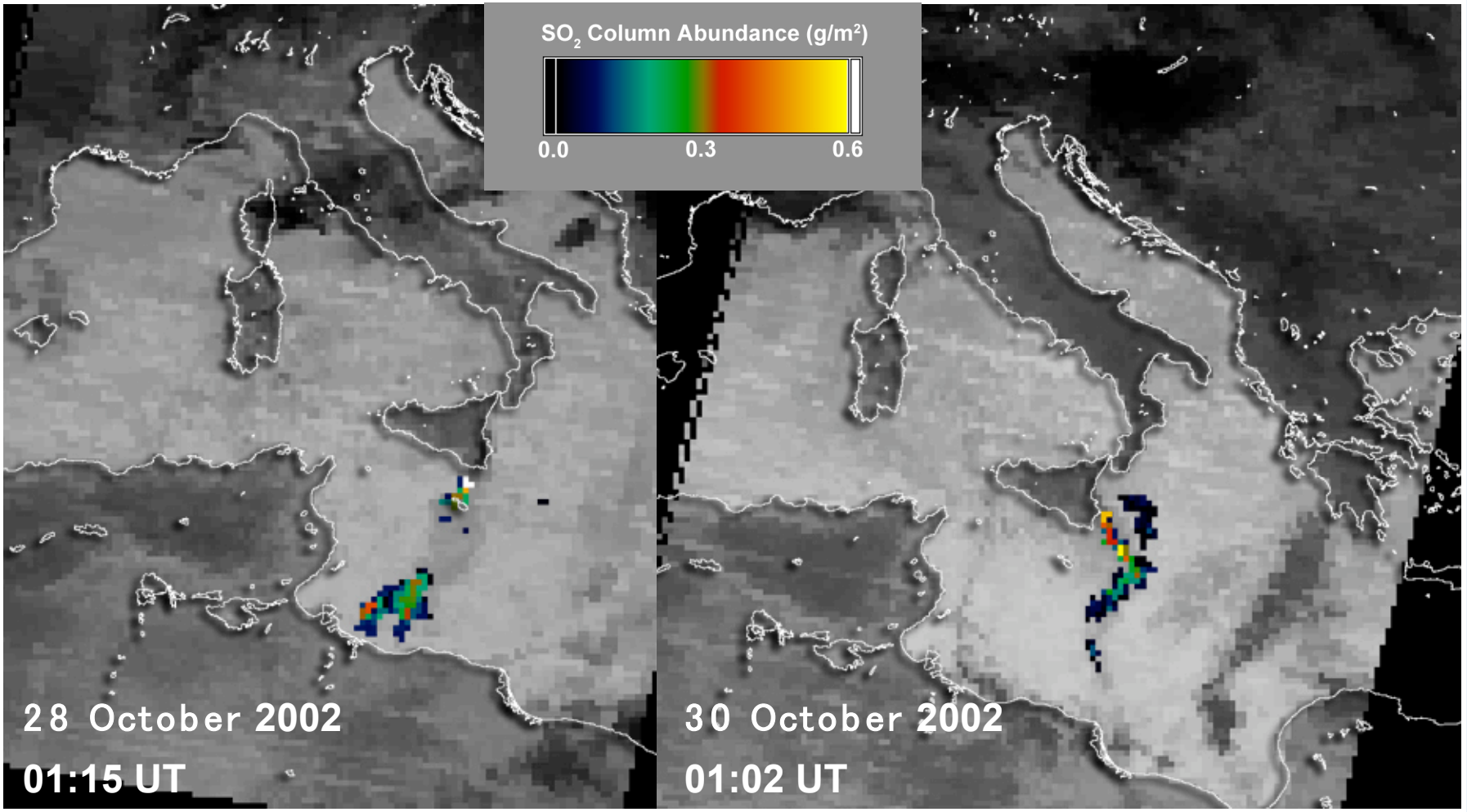

Pre-Dawn Retrievals for Mt. Etna

Plume Altitude 7 km; Plume Thickness 2 km; Max. SO_2 2.0 mg/m^3

Brightness Temperature of Ocean: 295 K (28 October); 290 K (30 October)

Plume Temperature (NCEP): 261 K (28 October); 259 K (30 October)

Temperature Delta: - 34 K (28 October); -31 K (30 October)

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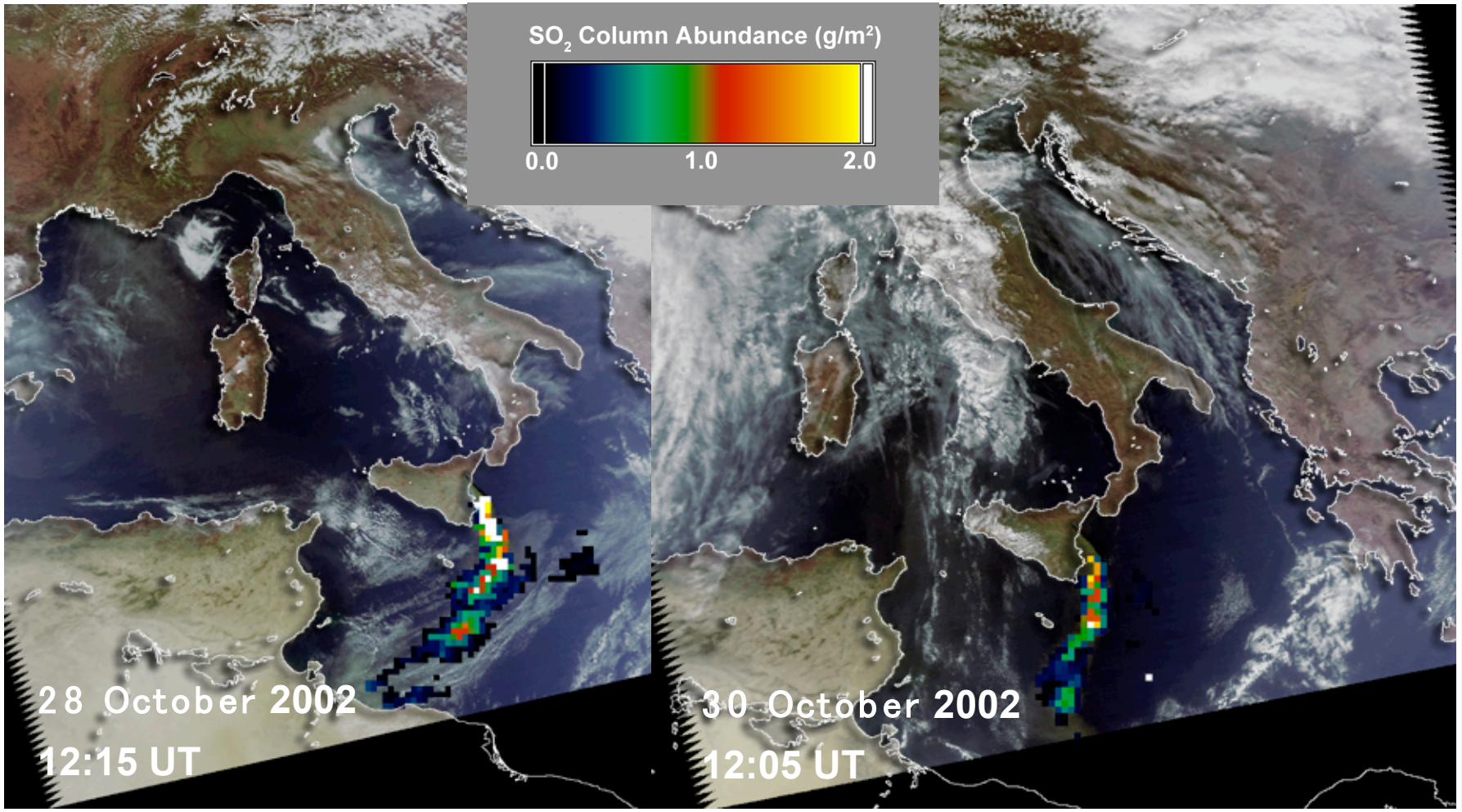

Mid-Day Retrievals for Mt. Etna

Plume Altitude 7 km; Plume Thickness 2 km; Max. SO_2 2.0 mg/m^3

Brightness Temperature of Ocean: 294 K (28 October); 294 K (30 October)

Plume Temperature (NCEP): 261 K (28 October); 260 K (30 October)

Temperature Delta: - 33 K (28 October); - 34 K (30 October)

3X Increase in SO2 Over Pre-Dawn Retrieval Not Due to Changes in Temperature Delta

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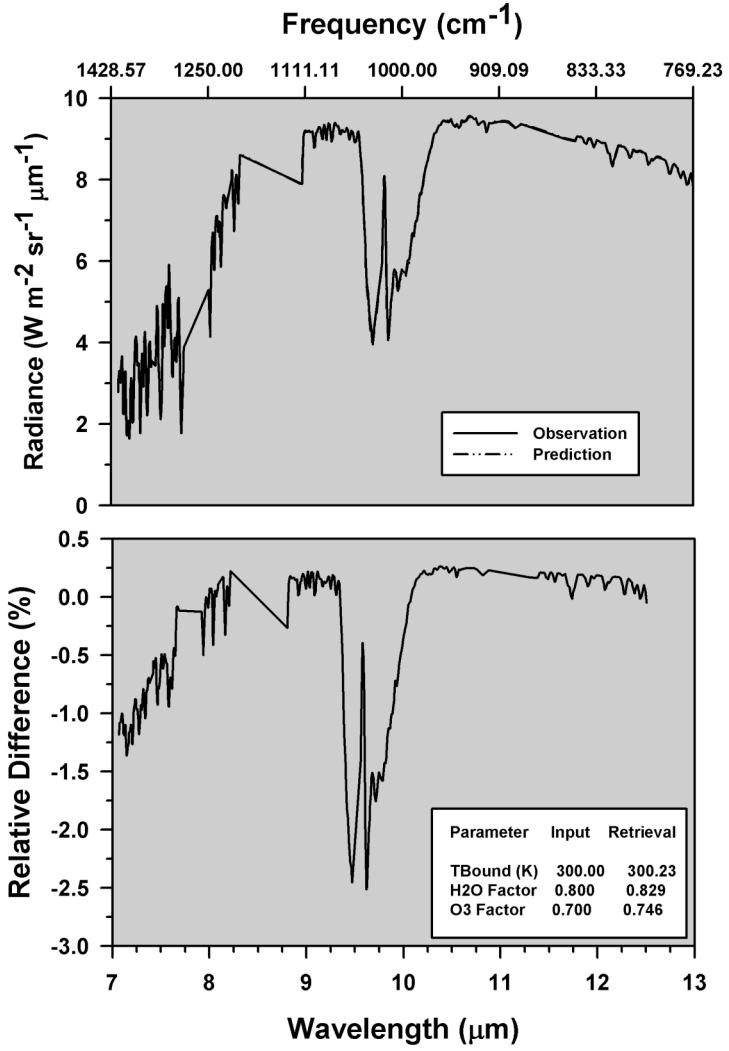

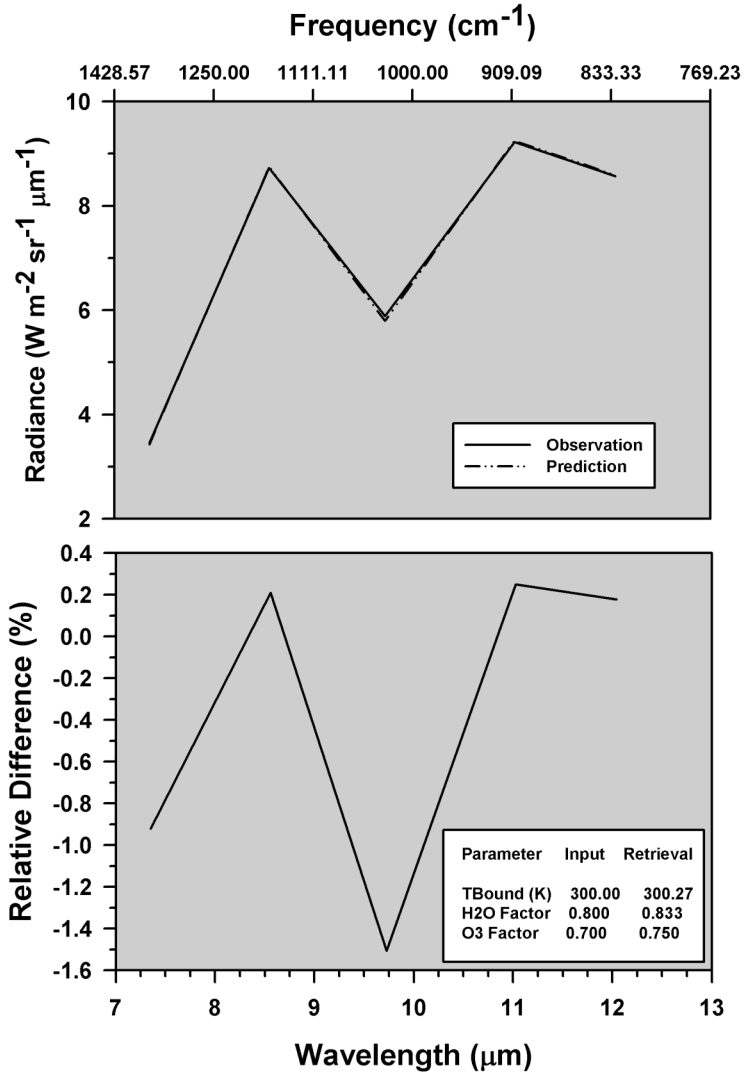

Retrieval of Atmospheric Factors: H_2O Vapor and O_3

Synthetic Radiance Spectra Generated with MODTRAN

Atmospheric Factors are Multiplicative Factors Applied to Entire Column – Preserves Relative Distribution of Species

Heritage in Processing of Data From Airborne Instruments – Short Atm Paths

Good Technique for H_2O; Bad Technique for O_3

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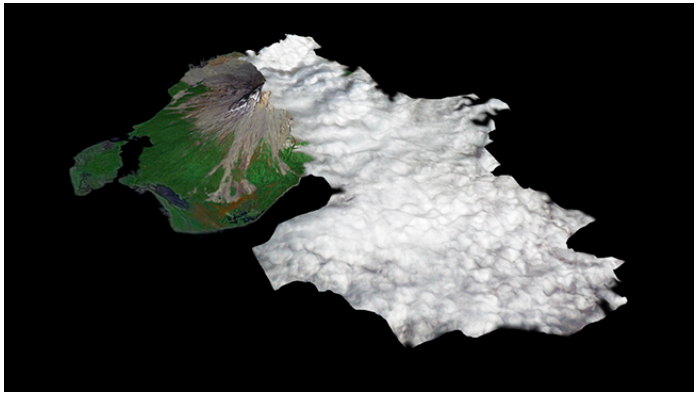
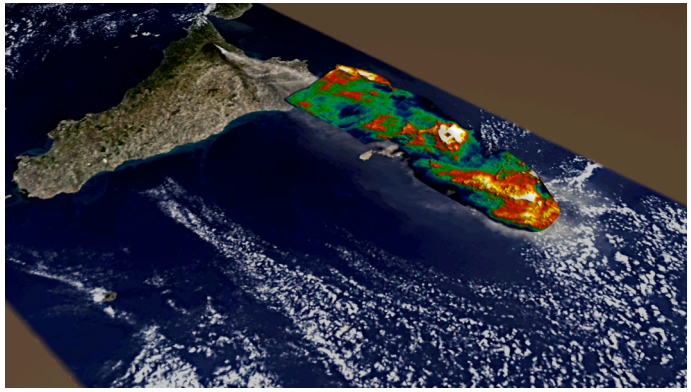
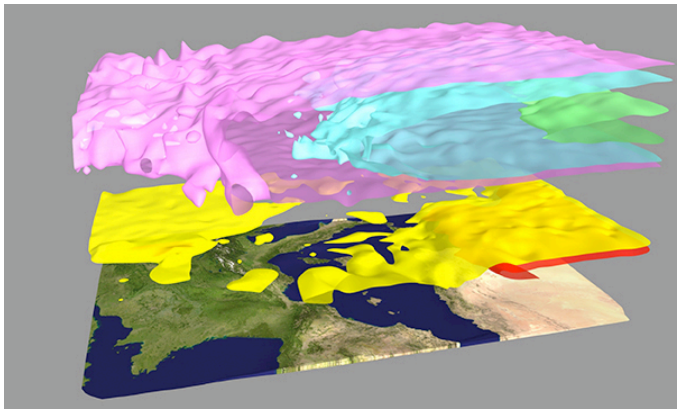






Future Directions

Upgrade MODTRAN

Expand Investigations to Volcanoes in the Arctic and Tropics – Wide Variety of Atmospheric Conditons

Continue Comparisons with SO_2 Retrievals From Different Techniques/Instruments

- **(1) AIRS**
  - **Jan 07 Public Release of SARTA (UMBC) Will Include SO_2 Forward Model (*Carn et al., 2005*)**
  - **Prata and Bernardo Technique**
- **(2) OMI**

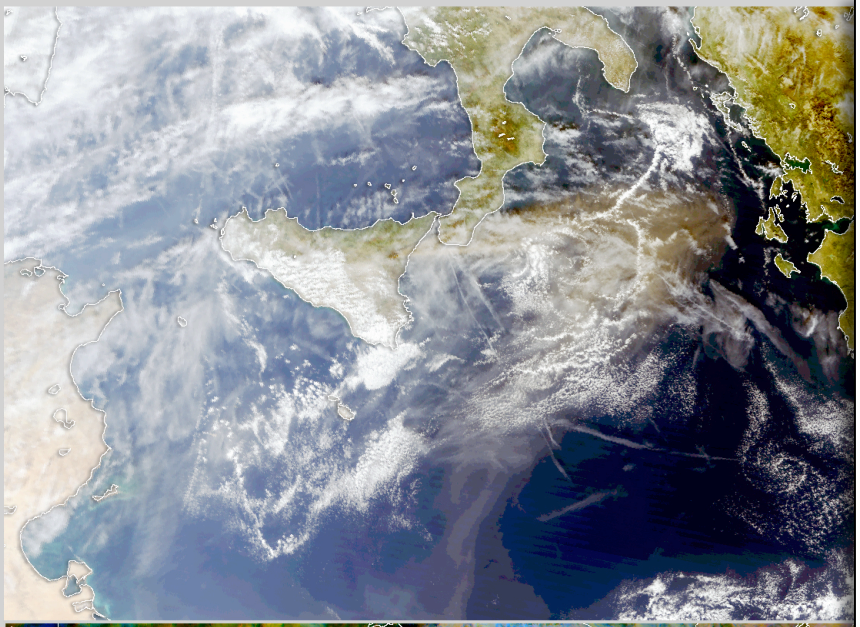
Accommodate Spatial Variations in Plume Morphology and Atmospheric Conditions

- **(1) Plume Altitude Maps Derived from MISR and ASTER**
- **(2) AIRS L2 Profiles of Atm Temperature and Humidity**

Mount Etna Eruption Plume

31 October 2002
09:35 UT

MODIS-Terra RGB Image (Bands 1, 3, 4)



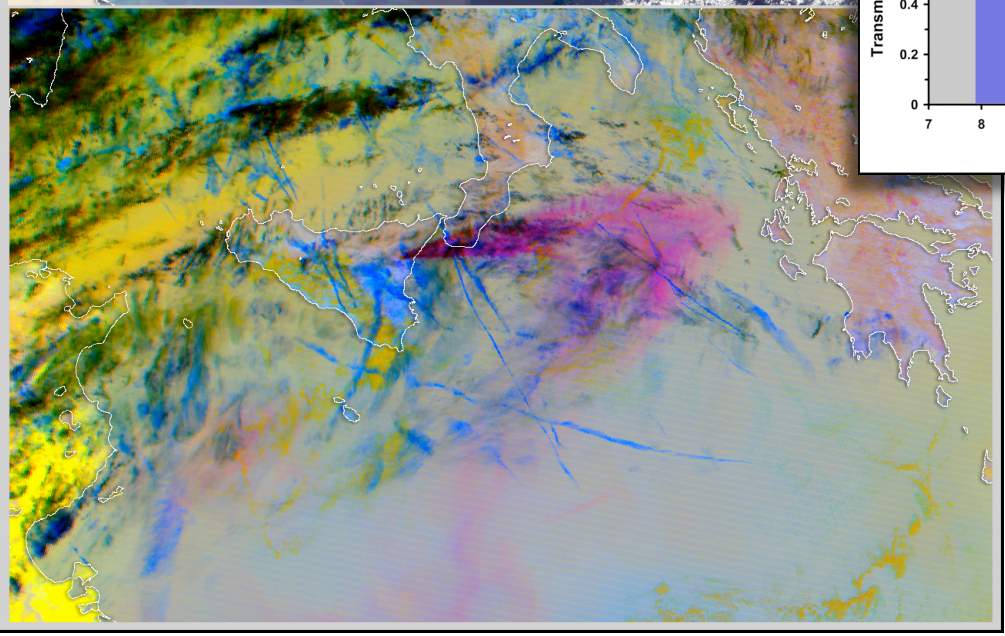
Color Composite of MODIS TIR Bands 29, 31, and 32

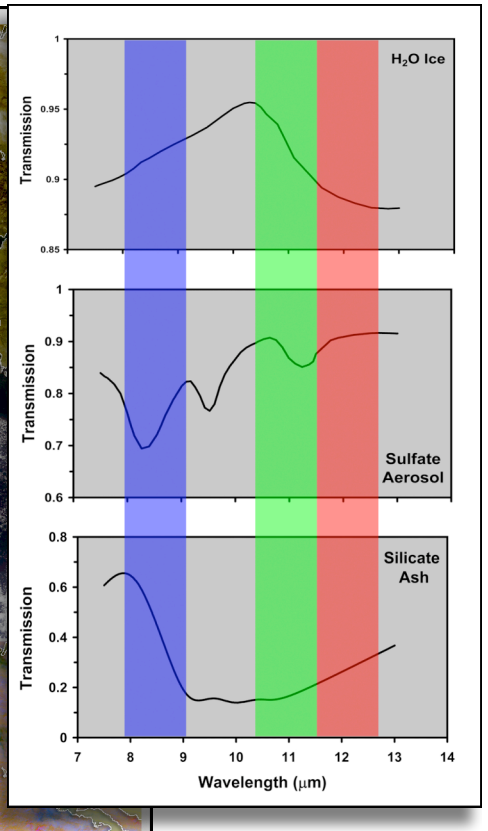
De-Correlation Stretch with Local Statistics

Volcanic Ash: Red to Magenta

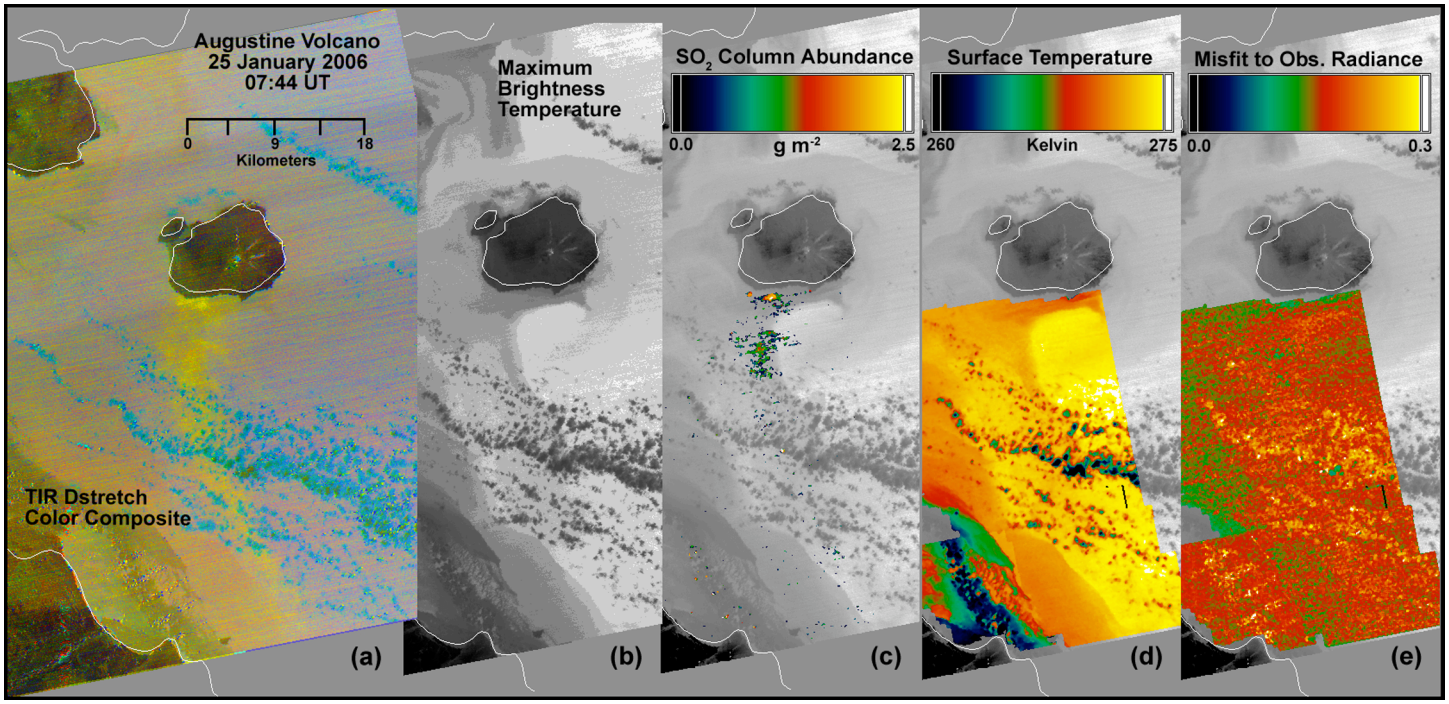
Jet Contrails: Blue

Sand (on surface and aloft), Ship Tracks, and SO_2: Yellow





Model Spectra Courtesy of I.M. Watson

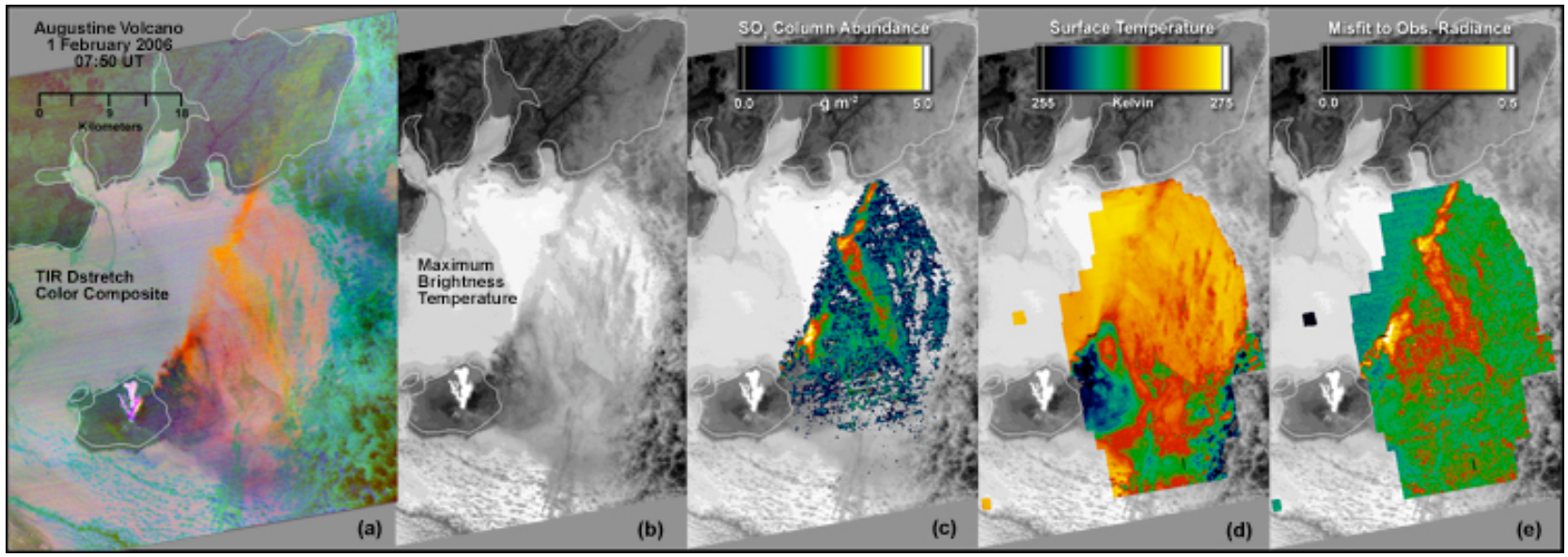


ASTER Detection of Augustine Plumes

Imagery Acquired at Night

Passive Emission of SO_2 Detected on 25 January 2006 During Pause Between Eruptions

February Plume (1 Feb 2006) Shows Evidence of Multiple Eruption Phases or Wind Shear



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