ASTER Observations Near the Source Vents of Volcanic Plumes: Analogues for the HyspIRI TIR Mission

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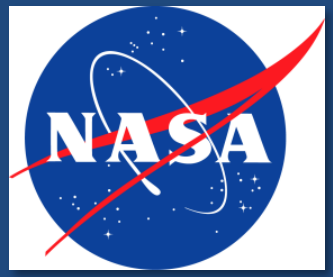


Volcanic Plumes Have Characteristic Spectral Features in the Thermal Infrared (TIR)

Plume Tracker: Map Volcanic Emissions with Interactive Radiative Transfer Modeling

Graphic User Interface

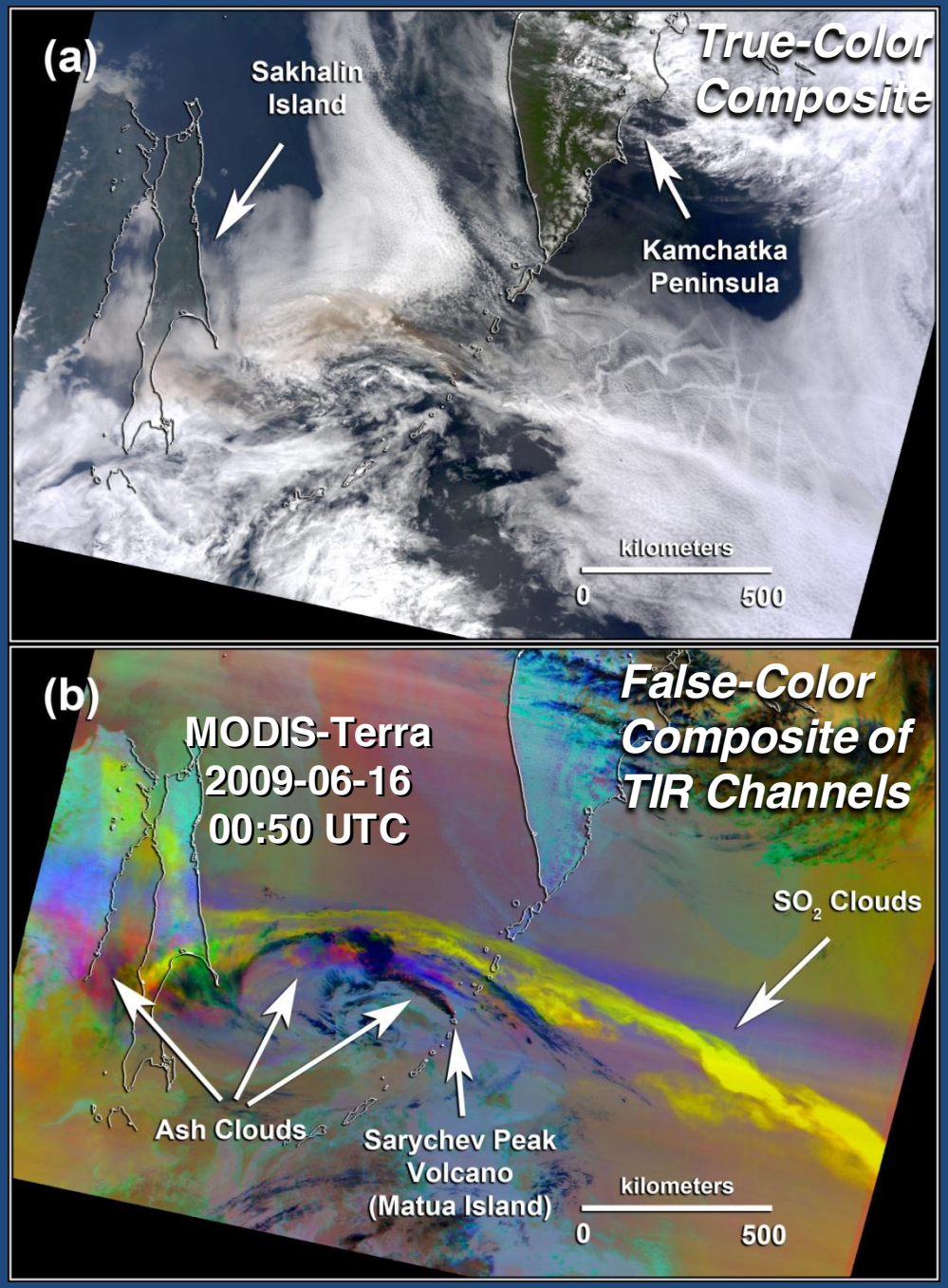
- Import Image and Ancillary Data
- Specify Parameters for RT Modeling
- Visualize Input Data and Retrieval Results

Radiative Transfer Model Based on MODTRAN 3.5

- Optimized for TIR Modeling
- Employs Hash Table to Minimize Calculations
- Portable Component Architecture

Retrieval Procedures

- Surface Temperature and Emissivity
- Total Column SO_2, H_2O Vapor, and O_3
- Optimized for 2-Component Retrievals



The High Spatial Resolution of HysplRI-TIR Will Provide a Unique Perspective on the Source Vents of Volcanic Plumes

Studies of ASTER Data Have Demonstrated the Challenges to Plume Mapping

- Variations in Surface Emissivity and Temperature
- Heterogeneous Plume Composition (e.g. SO_2 + Ash)

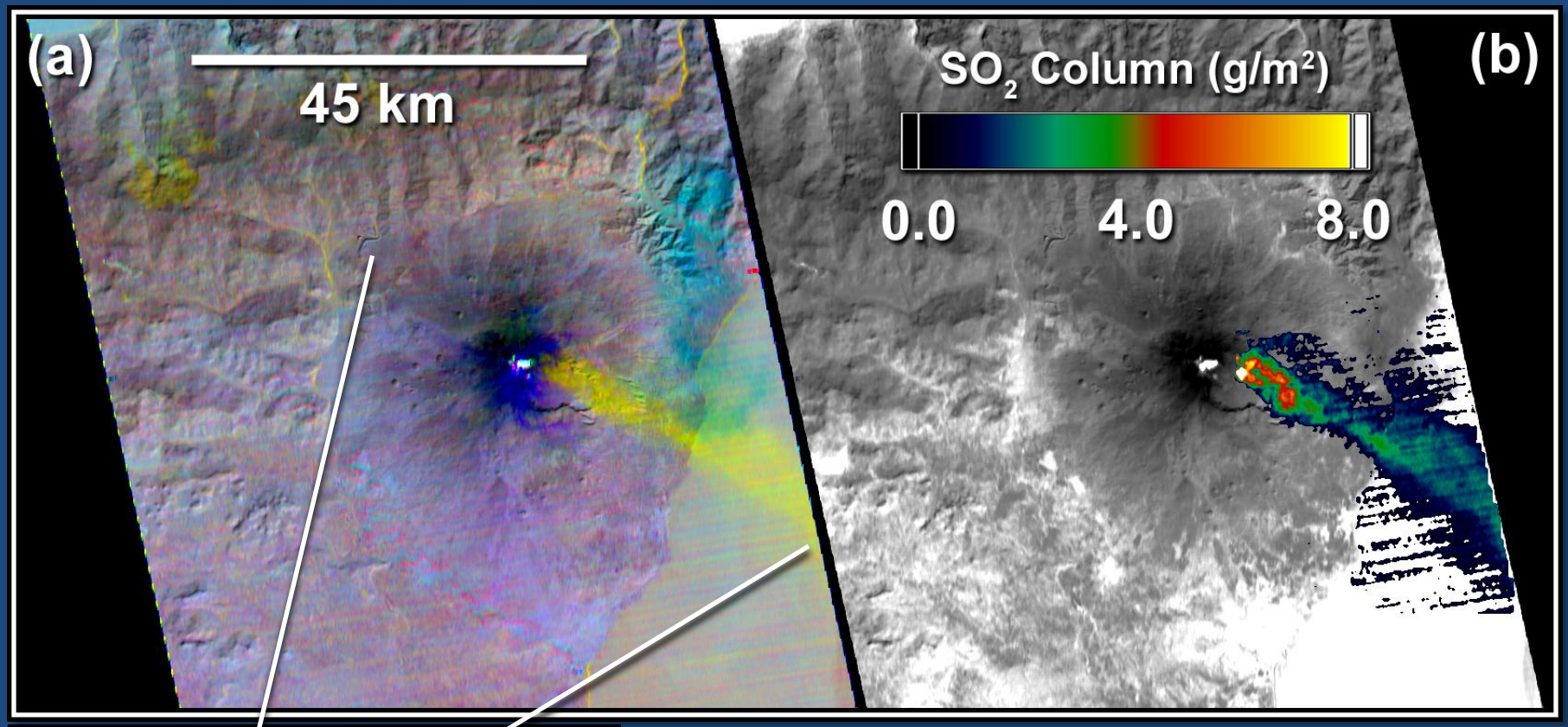
Comparisons of ASTER and Corresponding MODIS–Terra Observations

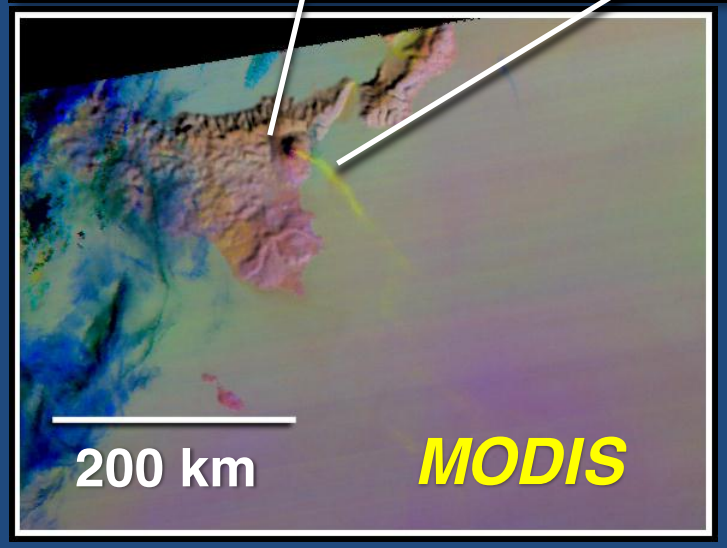
Note Non-Uniform Surfaces Beneath Plumes

- Difficult to Characterize with a Reference Spectrum or Look-Up Table

Note Heterogeneous Nature of Plumes Near Source Vents

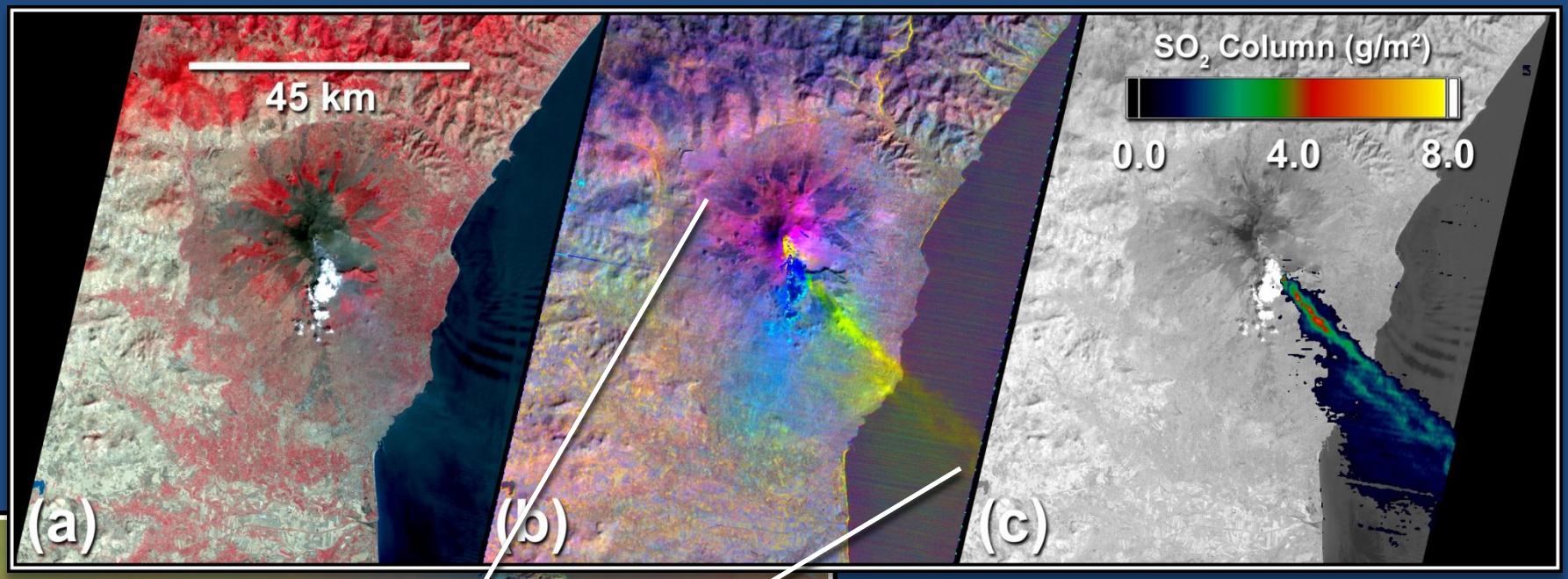
- Difficult to Separate the Effects of SO_2 and Ash
- Separation Necessary for Accurate Quantitative Estimates

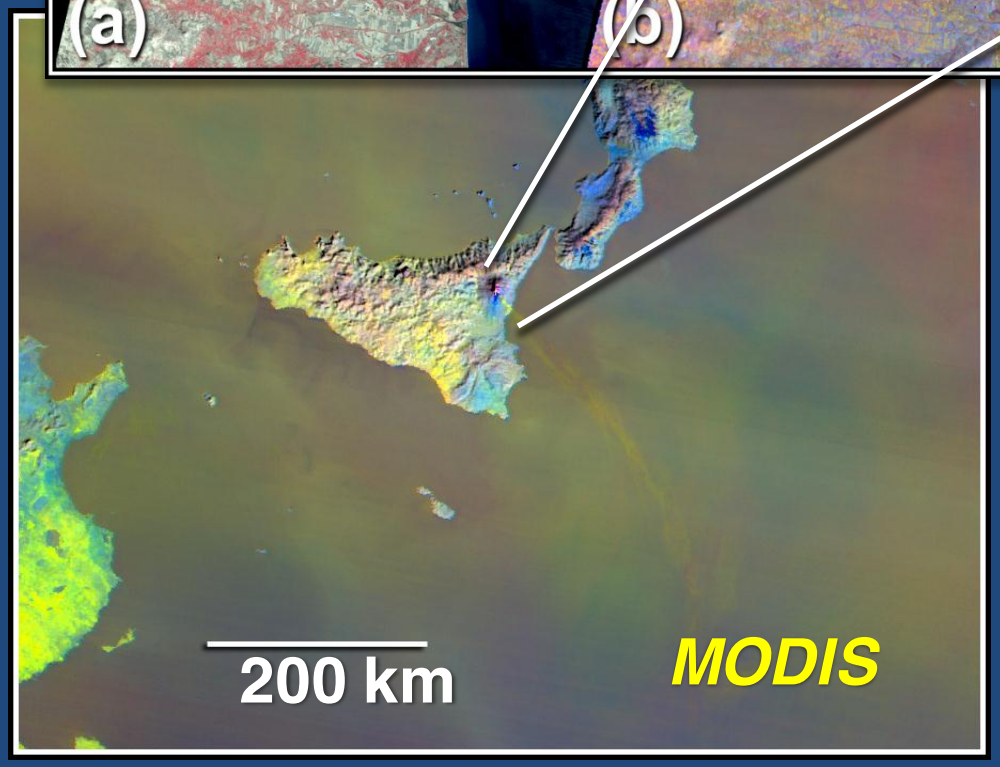




Mount Etna: 6 June 2000

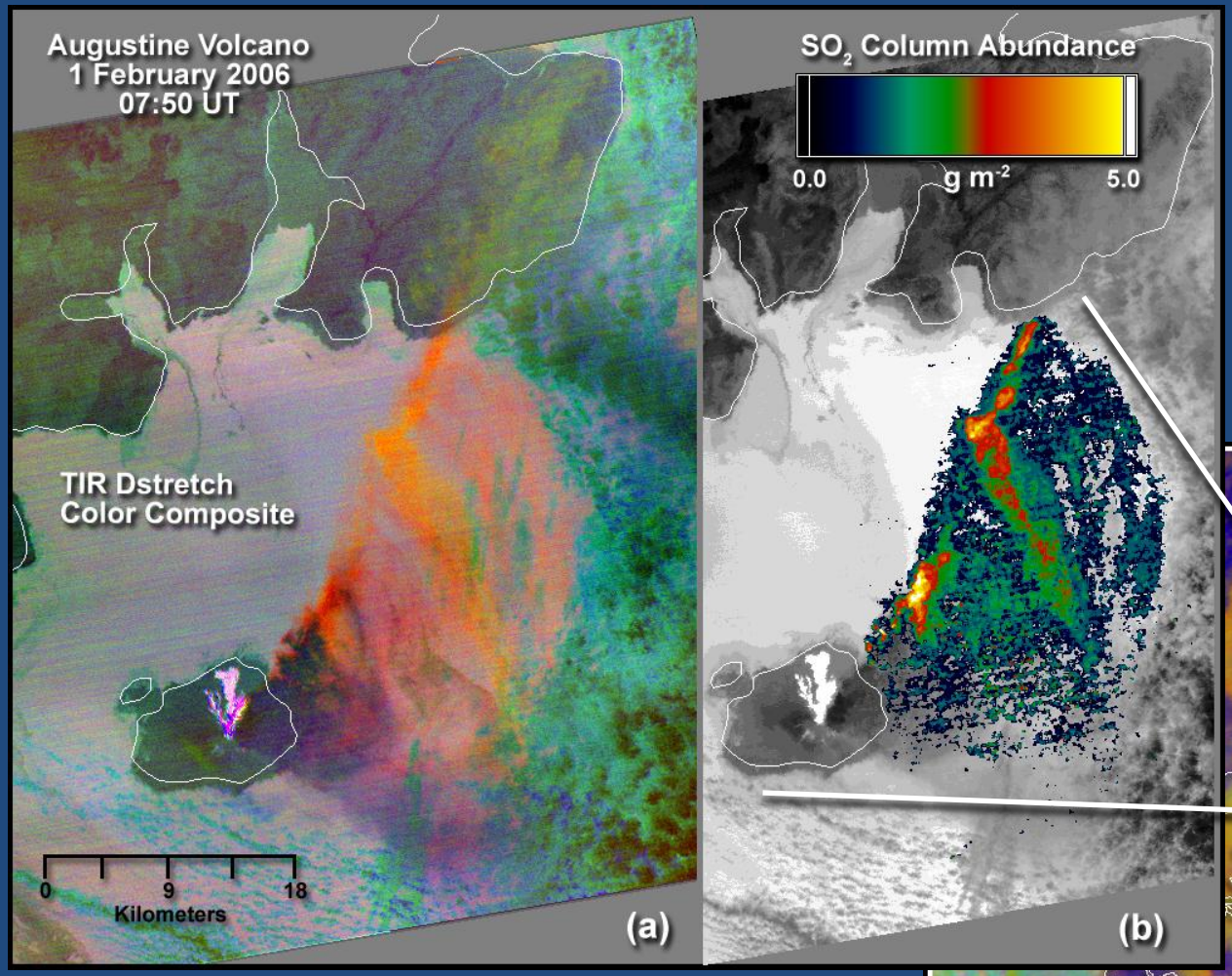
- Night-Time ASTER Data Acquisition (21:25 UTC)
- Near Conclusion of Long-Lived Eruption Episode: 26 Jan – 24 June
- Lava-Fountaining Event on 5 June 2000: Strong Gas Emissions





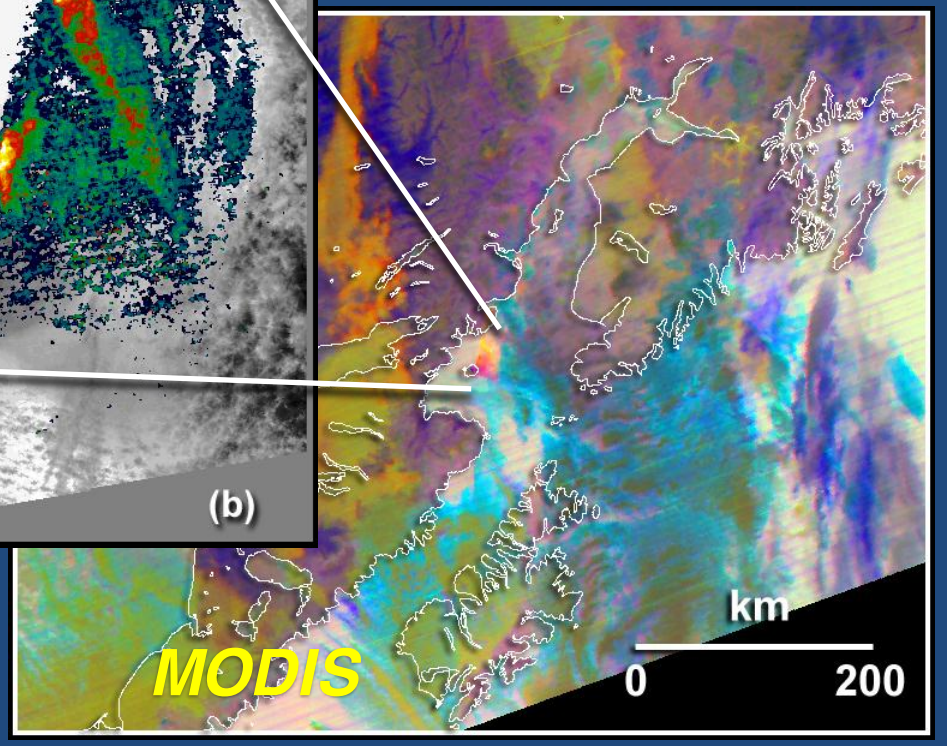
Mount Etna: 29 July 2001

- Daytime ASTER Data Acquisition (10:01 UTC)
- Fissure Eruption started on 17 July 2001
- On-going Strombolian Explosions at Time of Overpass
- Shearing of the Plume at Coast by On-Shore Winds



Augustine Eruption 1 February 2006

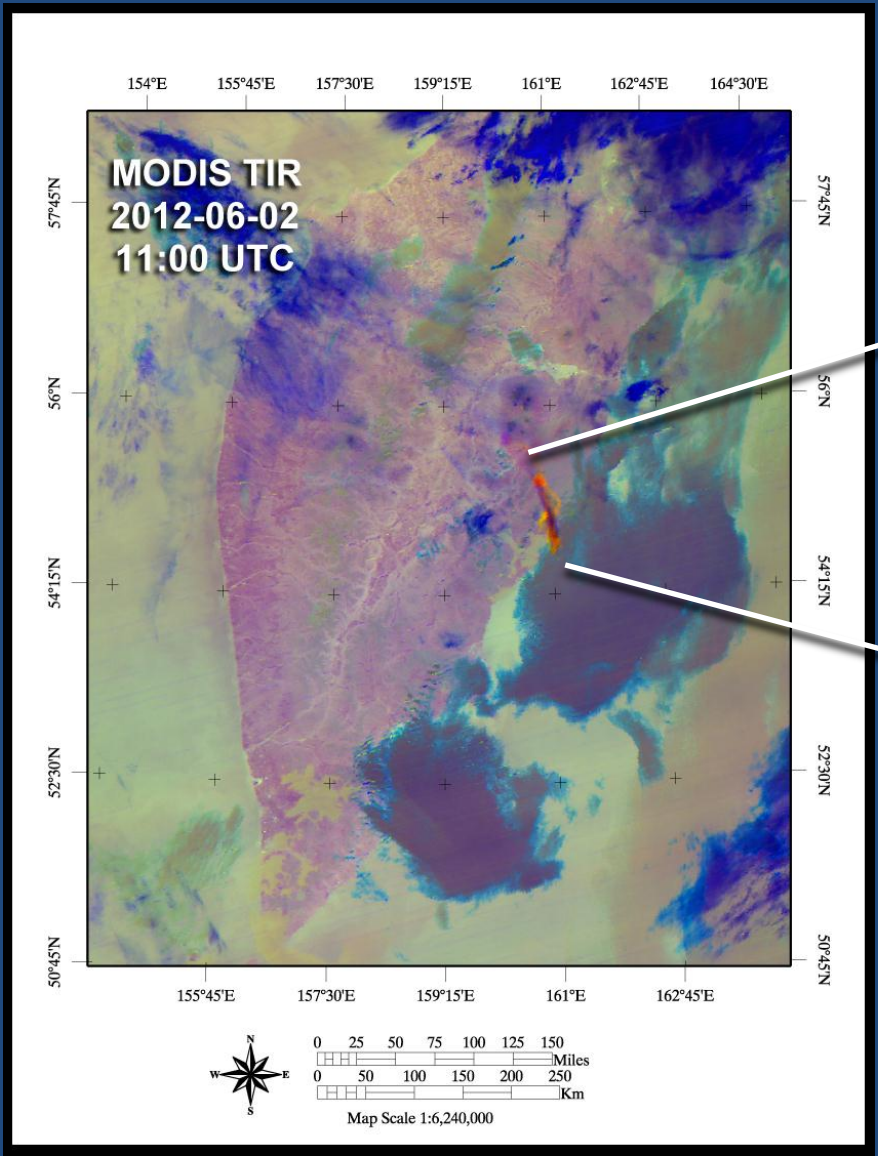
Night-time Data Acquisition

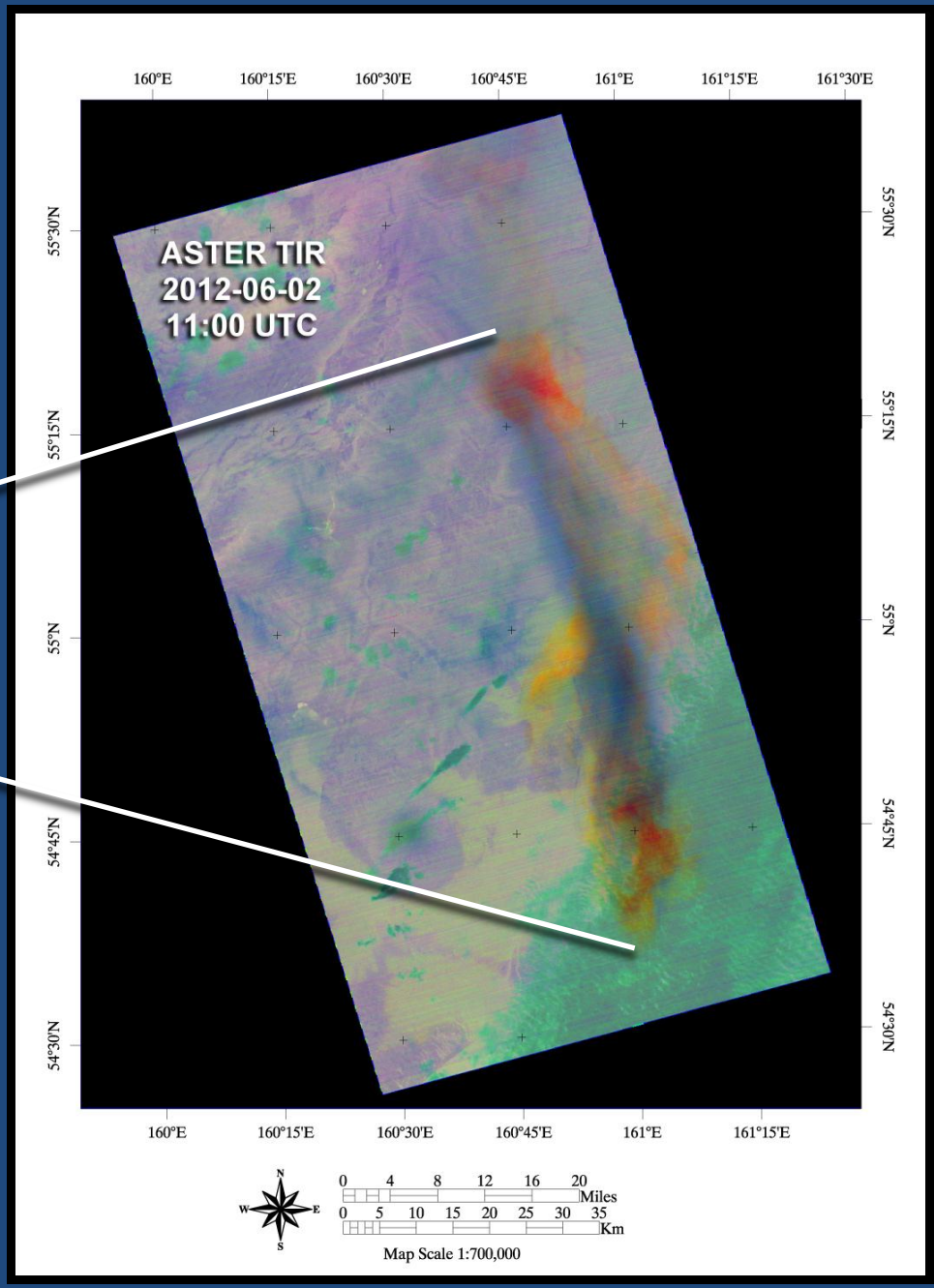


Explosive Eruption :

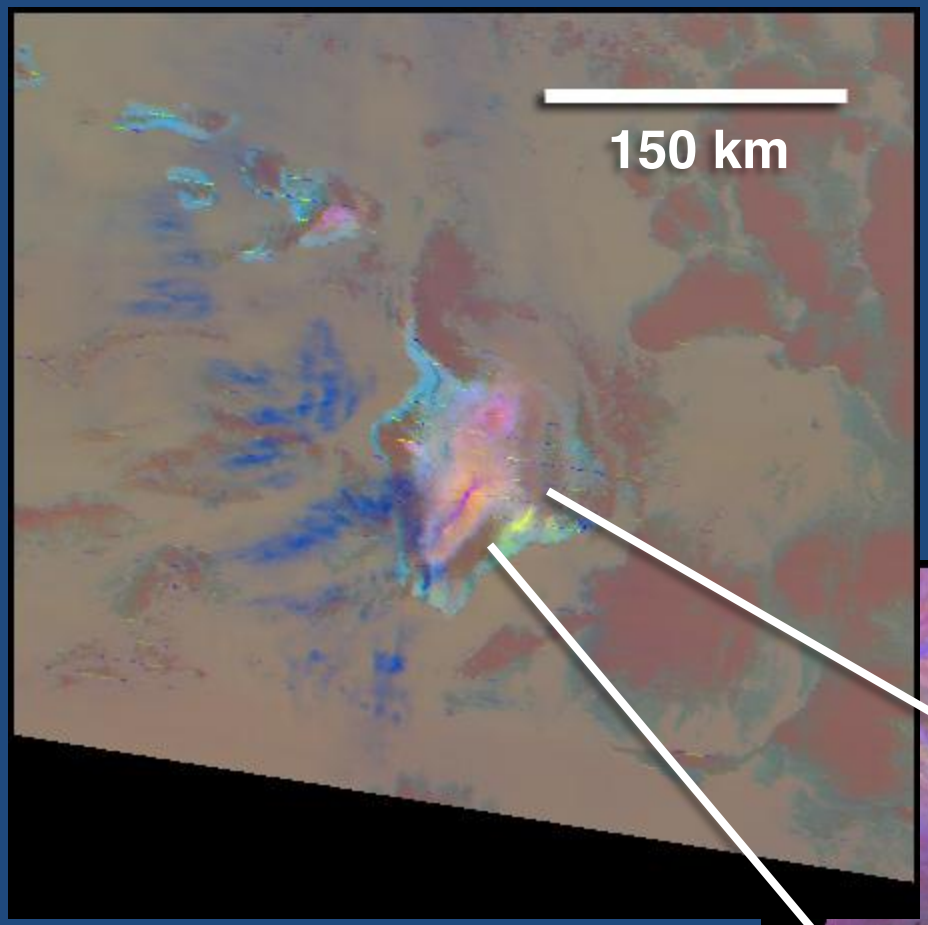
- Heterogeneous Plumes
- Plume Records Explosive Episodes
- High Opacity to TIR Radiance

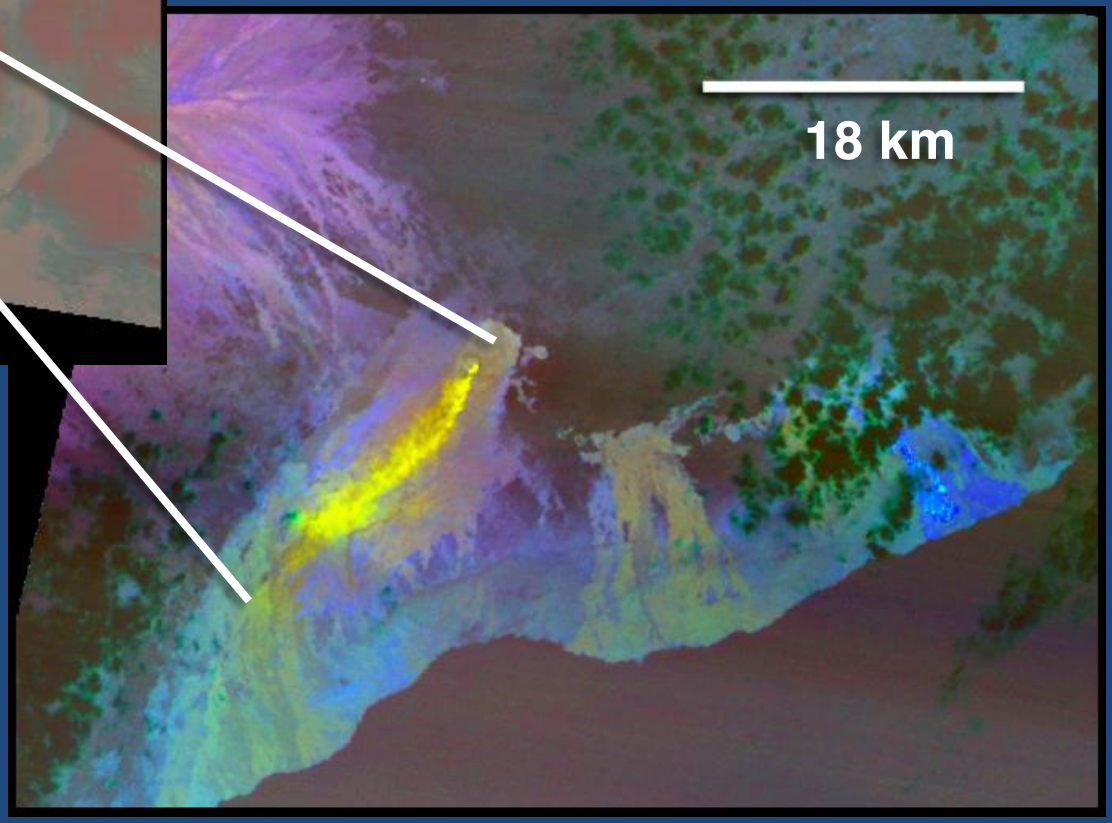
Sheveluch Eruption Clouds: Ash and SO_2 Components Separated by Wind Sheer?





Halemaumau Crater
Kilauea Volcano, Hawaii
21 May 2012



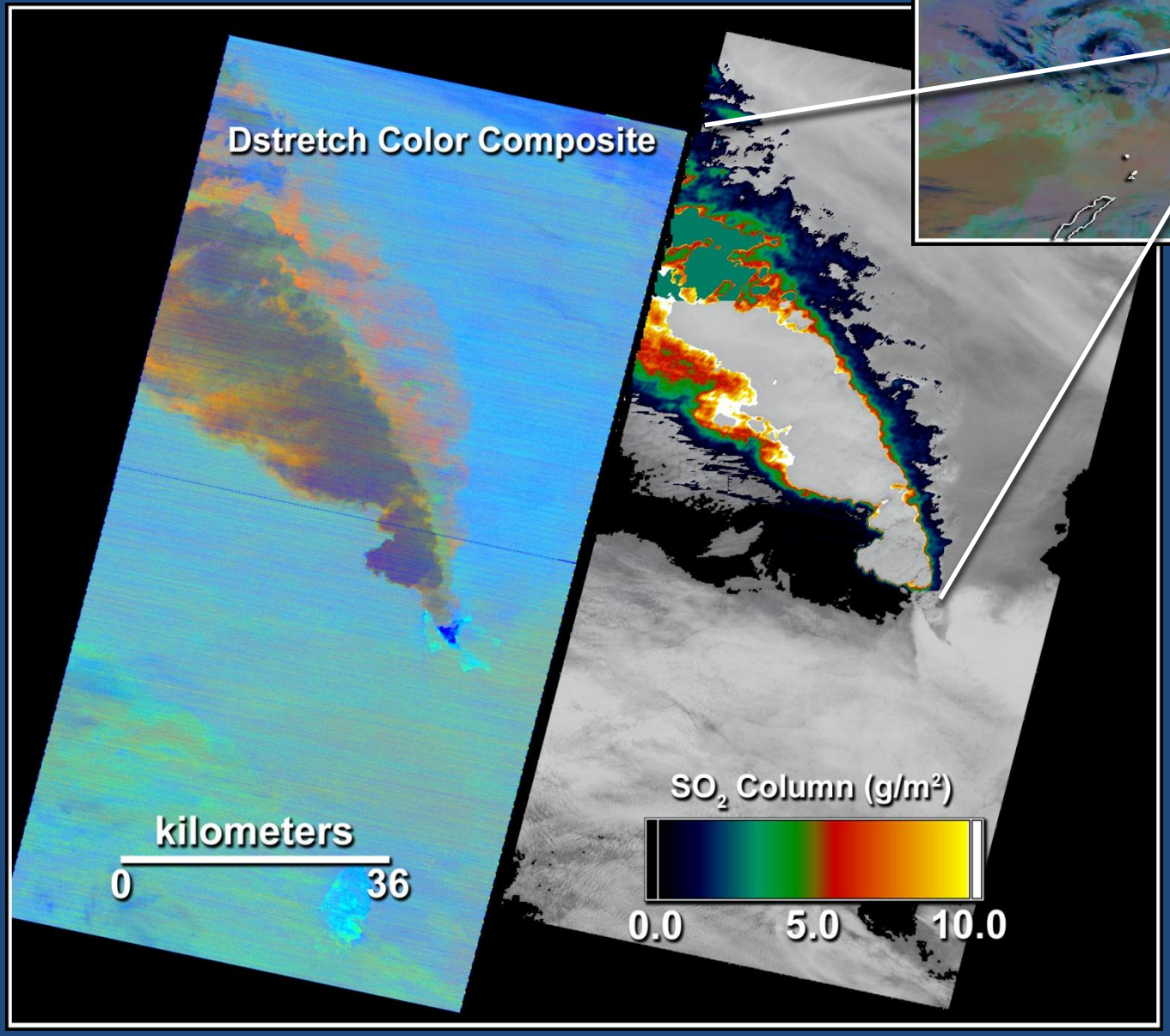


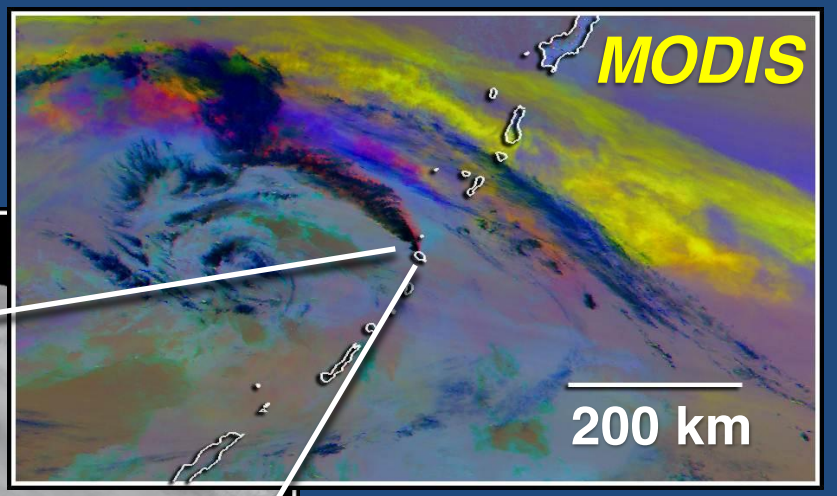
Primary Source of Gas Emissions at Kilauea Since Eruption in March 2008

Active Lava Pond with Cyclic Changes in Pond Height

Frequent Non-Magmatic Explosions due to Rockfalls from Crater Rim

Sarychev Peak Eruption
16 June 2009 00:50 UTC





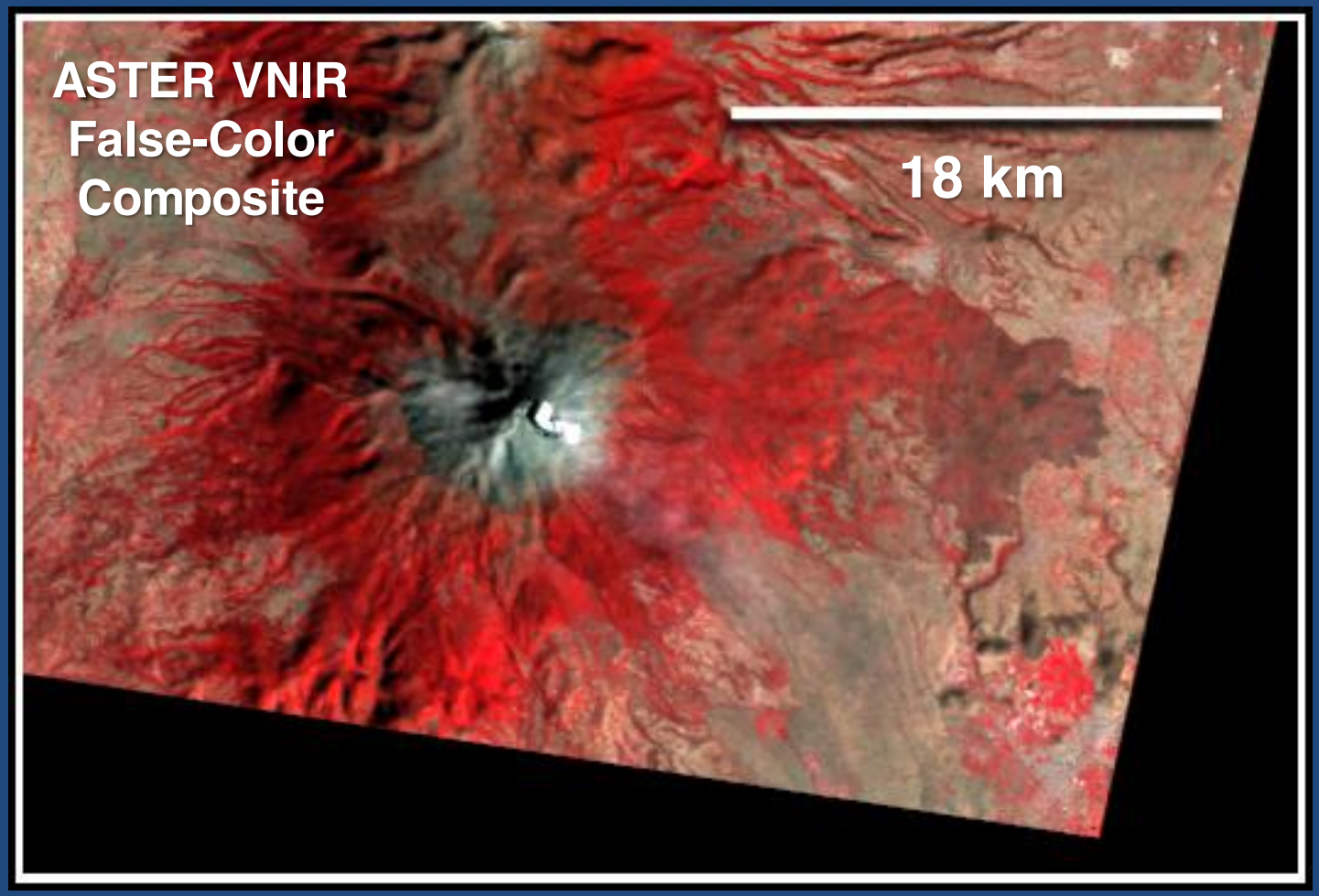
Continuous Emission of Ash

- Center of Plume Opaque in the TIR
- Map SO_2 in the Margins of Plume

SO_2 Concentrations in Plume Margin Similar to Those in Body of Stratospheric Cloud Bands

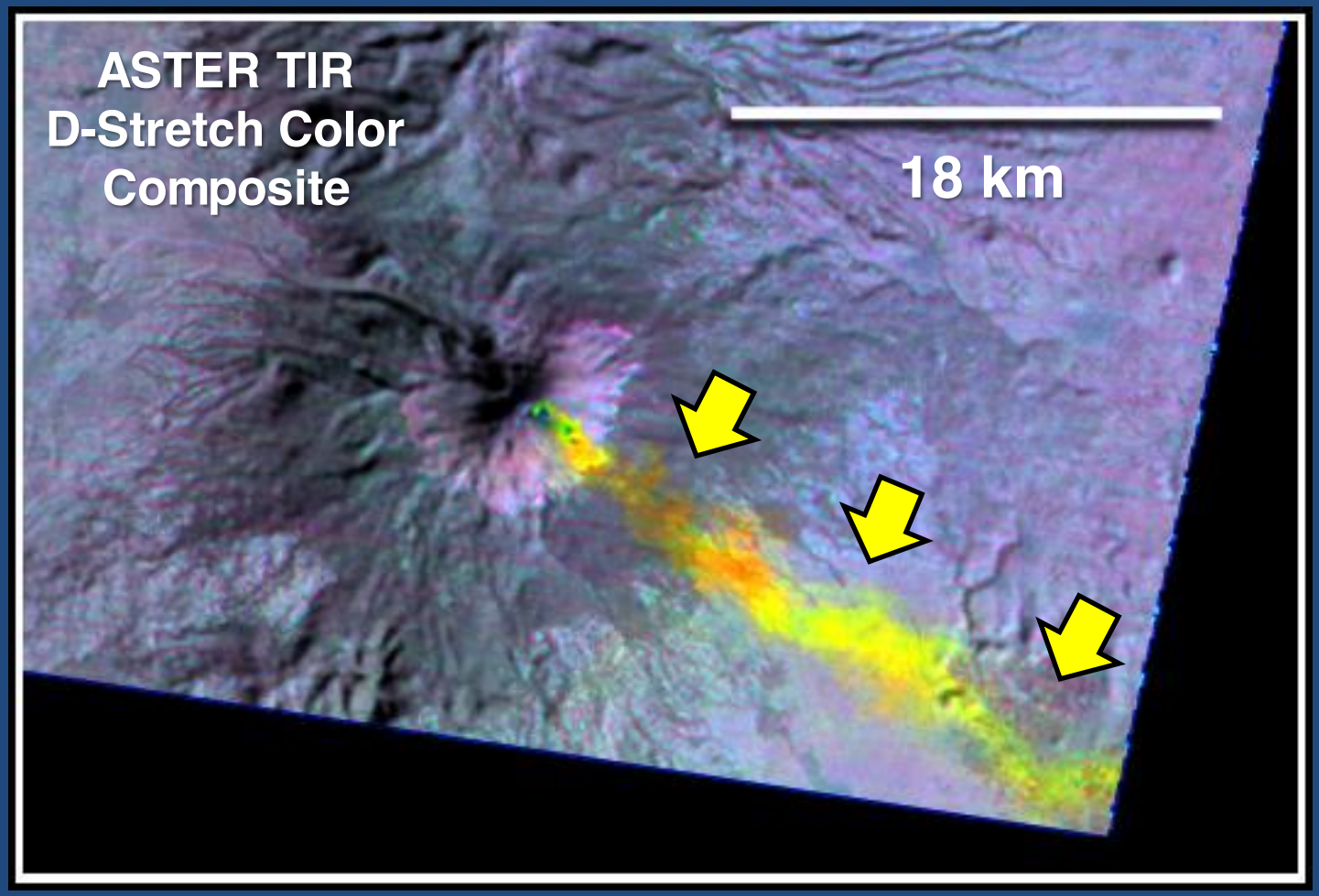
Analysis of an SO_2 Plume from Popocatepetl Volcano (Mexico)

23 April 2012



Popocatepetl Volcano
23 April 2012
17:17 UTC

CENEPRED (Centro Nacional de Prevencion de Desastres) Reports:
April 21-23: Gas, steam, and ash emissions drifting to the SE, E, and SW; Increase in seismicity
April 23: Ash plume generated, drifts to the NE; Incandescent fragments ejected to the W.

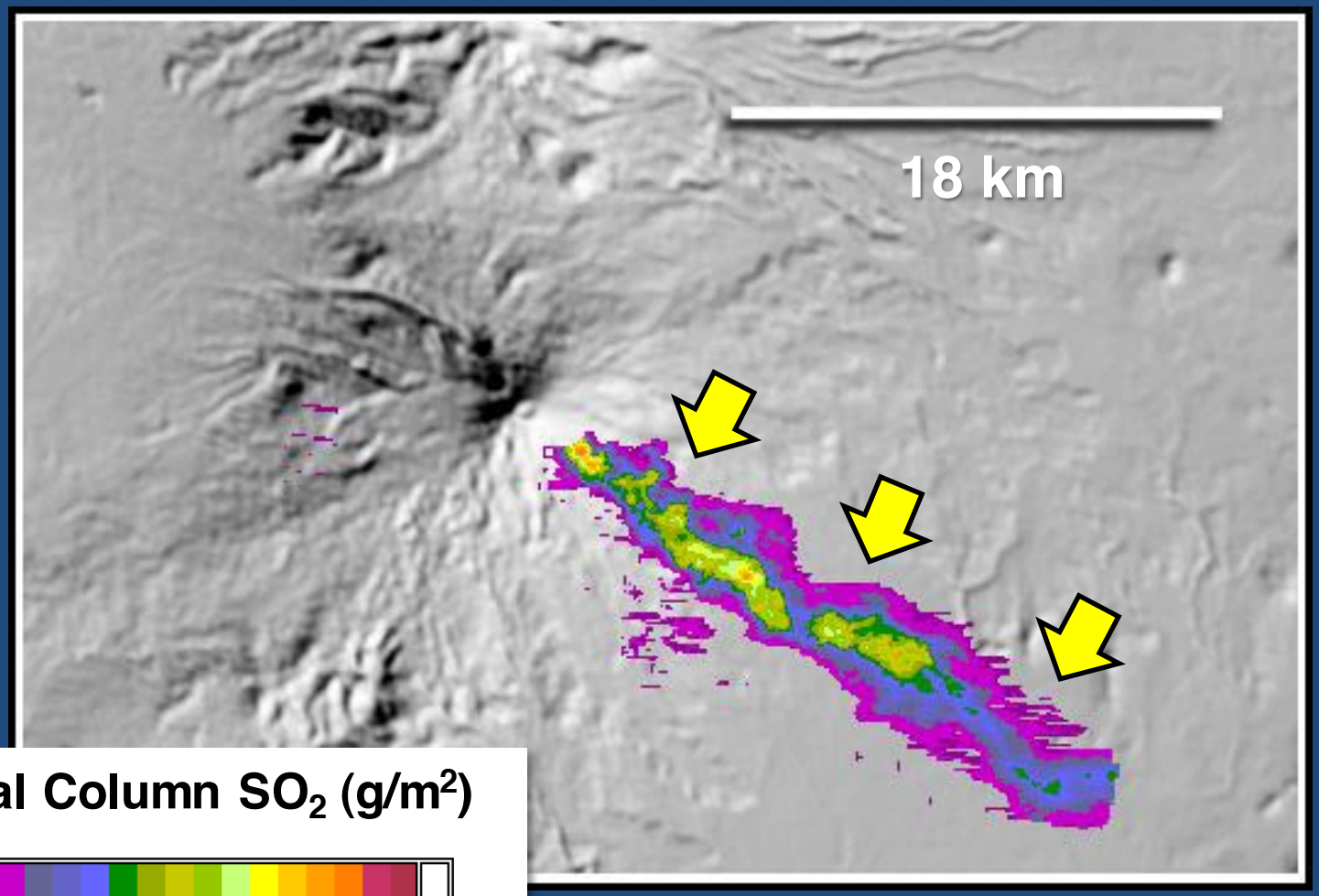


Popocatepetl Volcano
23 April 2012
17:17 UTC

D-Stretch Indicates that the SO_2 Plume Contained Little Ash

Changes in Surface Emissivity and Temperature Result in Changes in Display Color

Color Changes = Changes in Plume Composition?



Total Column SO_2 (g/m^2)

0 7.5 15

No Discontinuities in SO_2 Concentration with Changes in Surface Emissivity/Temperature!

Must Assign Emissivity to Every Pixel

Must Estimate Surface Temperature at Every Pixel

Analysis of a Heterogeneous (Ash + SO_2) Plume from Popocatepetl Volcano

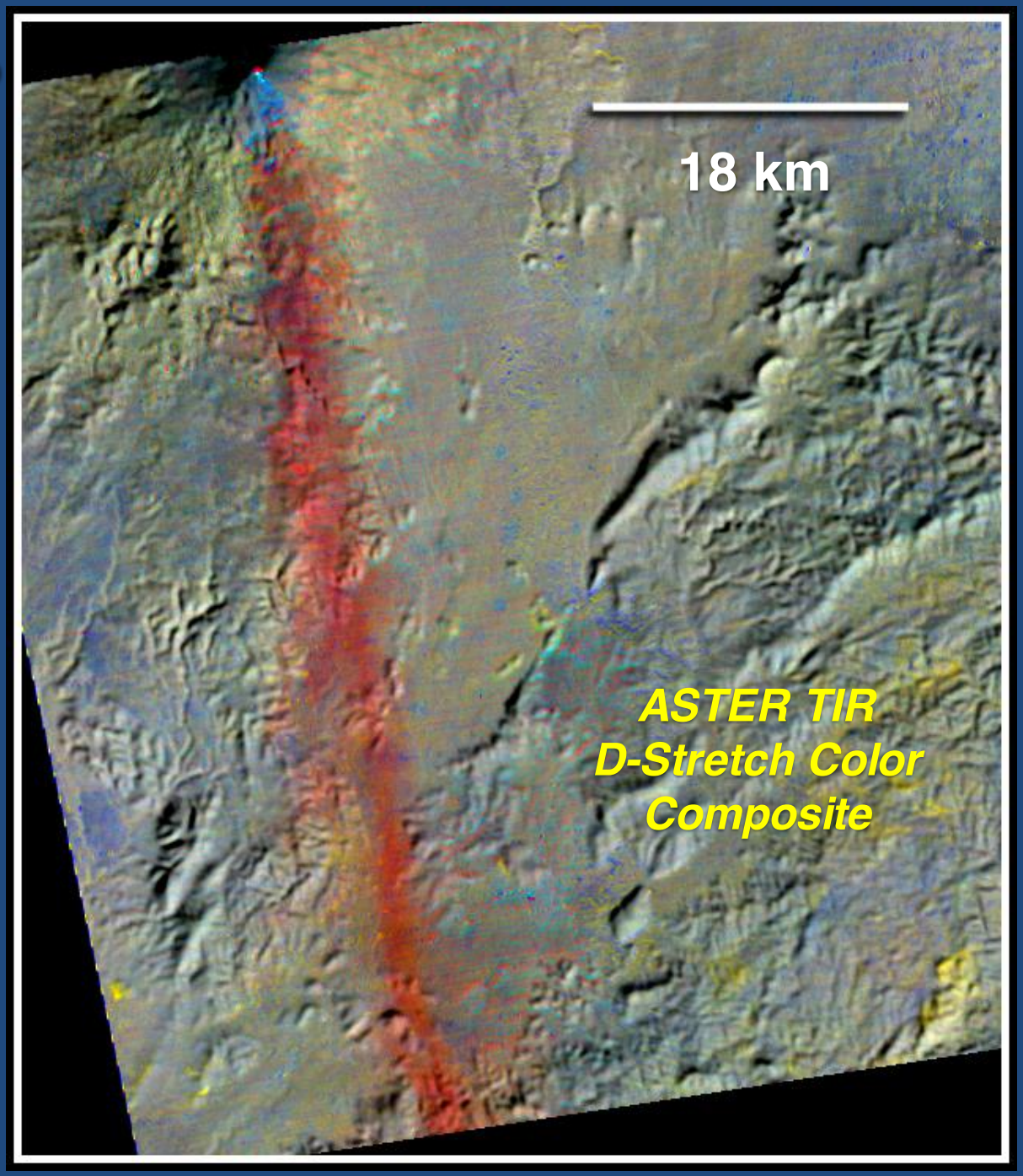
25 April 2012

Popocatepetl Volcano
25 April 2012
04:54 UTC

CENEPRED Reports:
April 25 & 27: Gas and ash plumes rising 1.5 km above summit crater

April 28: Incandescent ejects falling on E flank of volcano

D-Stretch Indicative of Ash-Rich Plume



Popocatepetl Volcano
25 April 2012
04:54 UTC

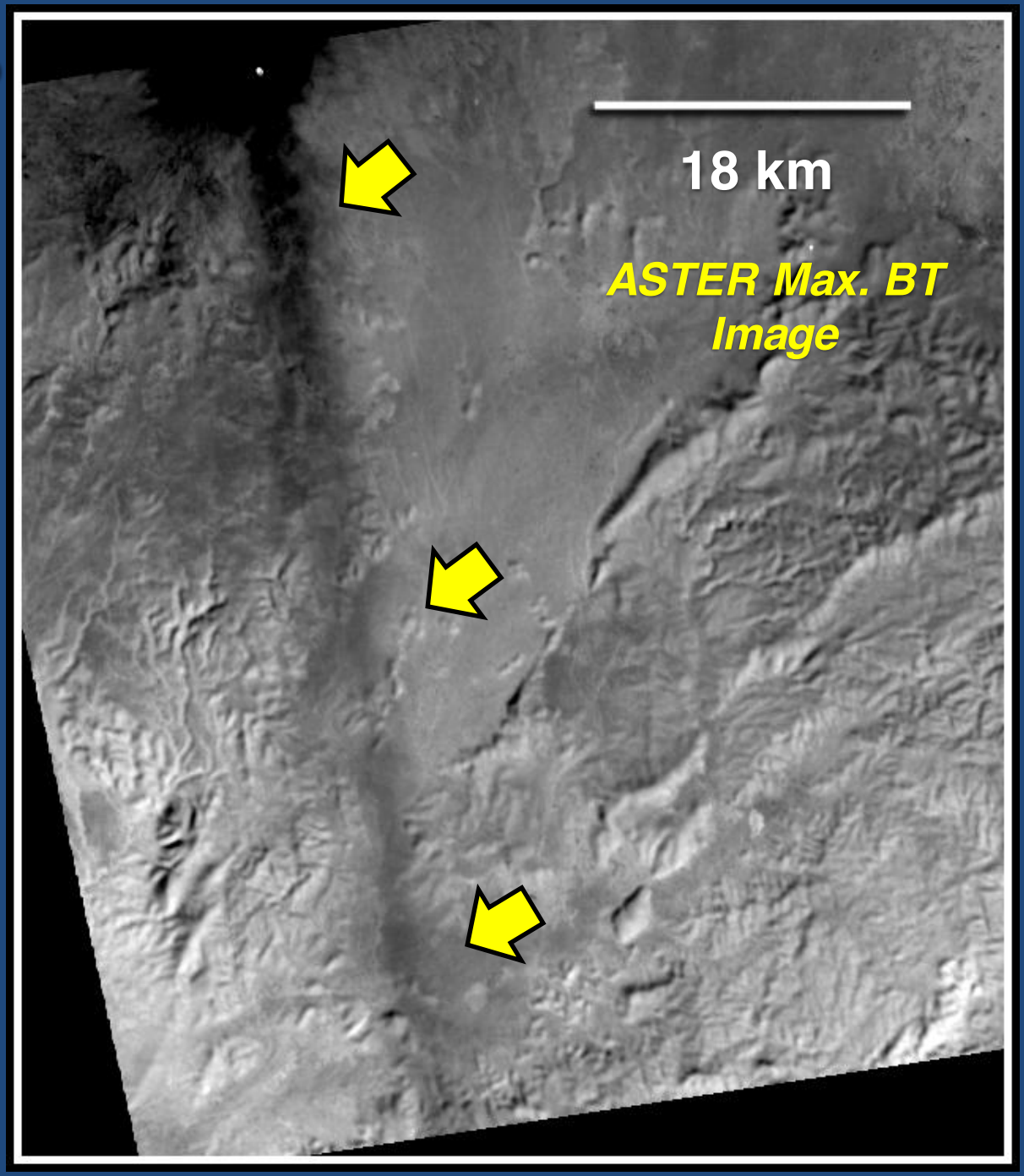
Maximum Brightness Temperature Image:
- Find the Max. BT Over all Five ASTER Bands
- Dark = Low Temperature

Proxy for Plume Opacity:
- Low Temperature = High Opacity

No Portion of Plume was Transparent in the TIR
- Common for Ash-Rich Plumes

Challenge for Temperature Estimation:
- Must Estimate Temps via Iteration

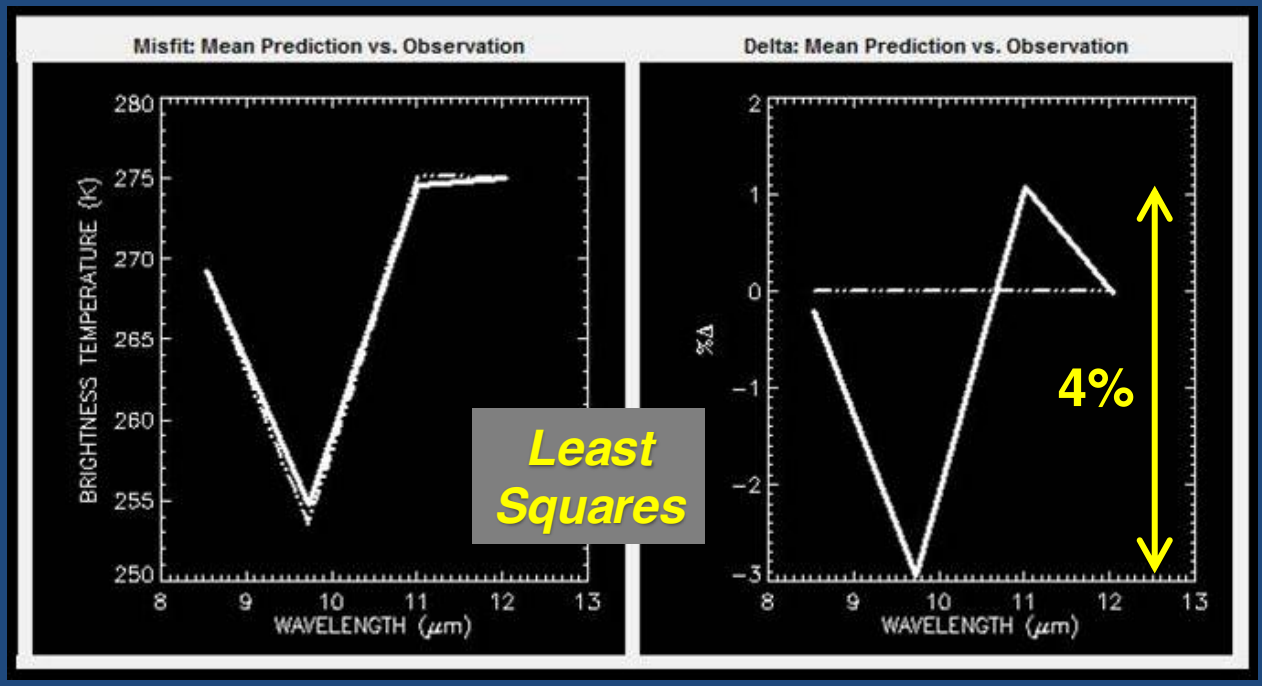
Challenge for Least Square Minimization:
- LS Solution Not Ideal For Radiometry



Misfit Calculation: Vector Projection vs. Least Squares

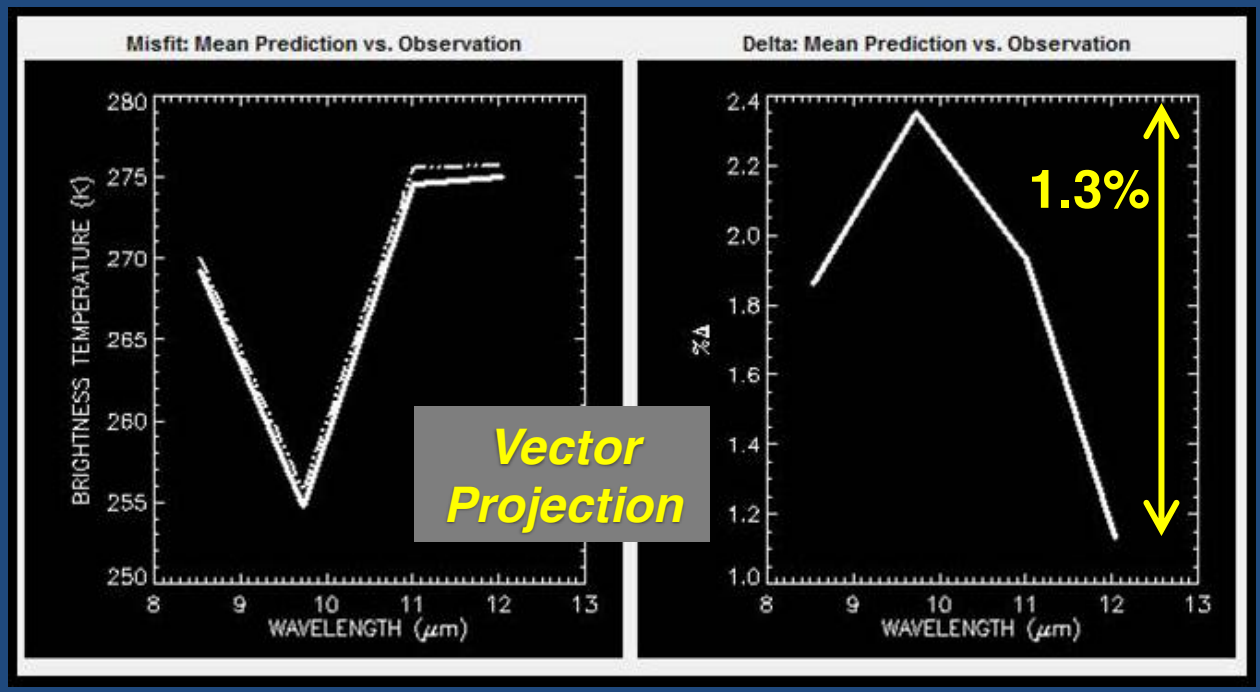
Least Squares:

- Optimal Fit to Noisy Data
- Equal Weight to all Outliers
- No "Consideration" of Shape of Spectra



Vector Projection:

- *Spectral Angle Mapping*: Dot Product between Two n-Dimensional Unit Vectors
- Minimize Angle Between Vectors
- Predicted Spectra Parallel to Obs. Spectra (in Vector Space)

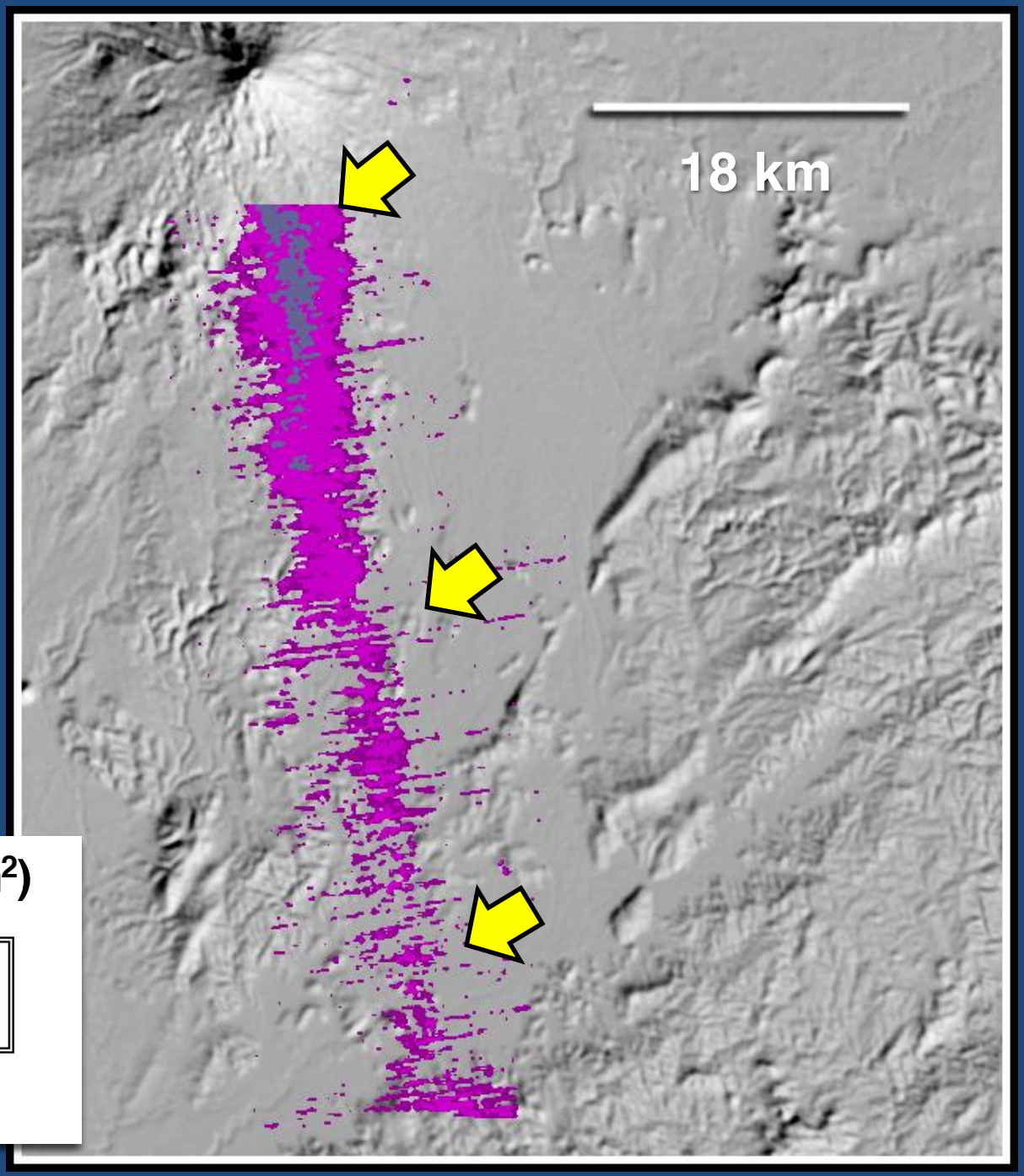


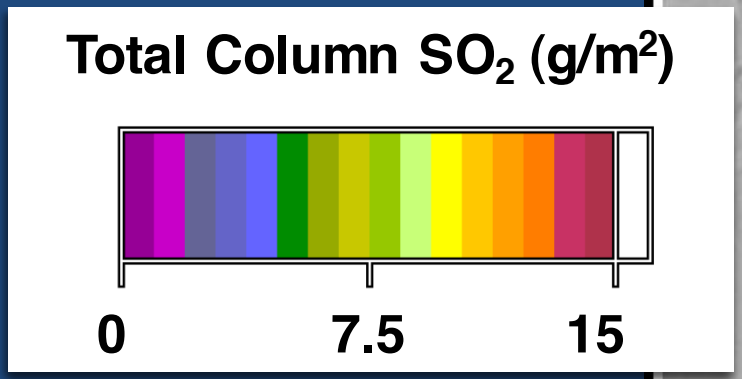
ASTER-Based SO_2 Map

SO_2 Concentrations on 25 April << 23 April

Surface Temp "Anomalies" Not Mapped to SO_2 Estimates

Separation of SO_2 and Ash Absorption Effects



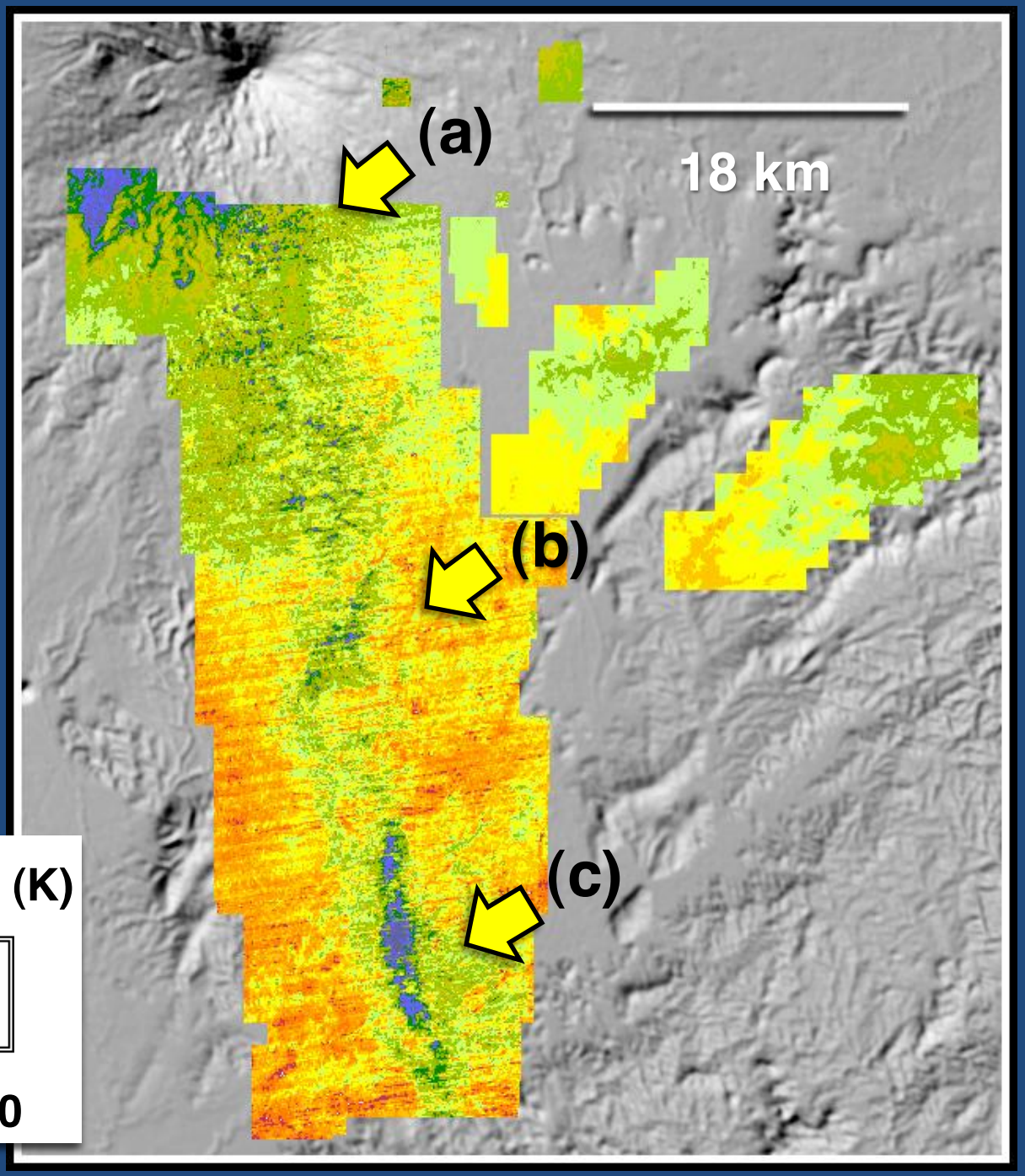


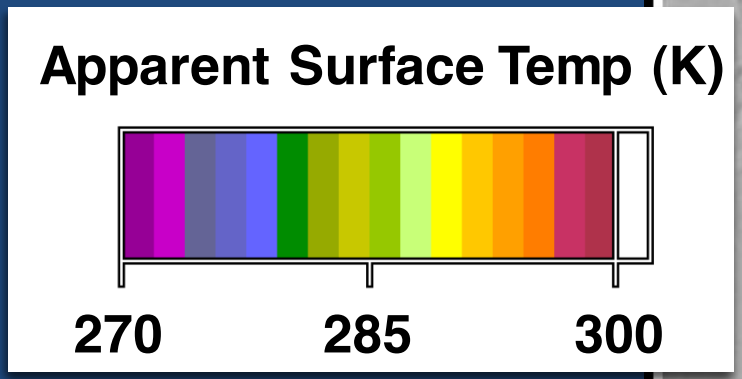
Map of Apparent Surface Temperature

Iterative Estimation of Surface Temperature

Anomalies (a) and (b) Minimized by Iterative Estimation

Anomaly (c) Remains: Impact on SO_2 Estimates Minimized





Plume Tracker Allows Users to Specify Surface Emissivity

Two Options: Input Reference Spectrum or Estimate of Surface Emissivity

Regardless of T/E Separation Technique, User Must Account for Atmospheric Effects

- Biggest Challenge is the Reflected Component of Downwelling Sky Radiance
- Intimate Relationship Between Emissivity Estimation and Atmospheric Correction

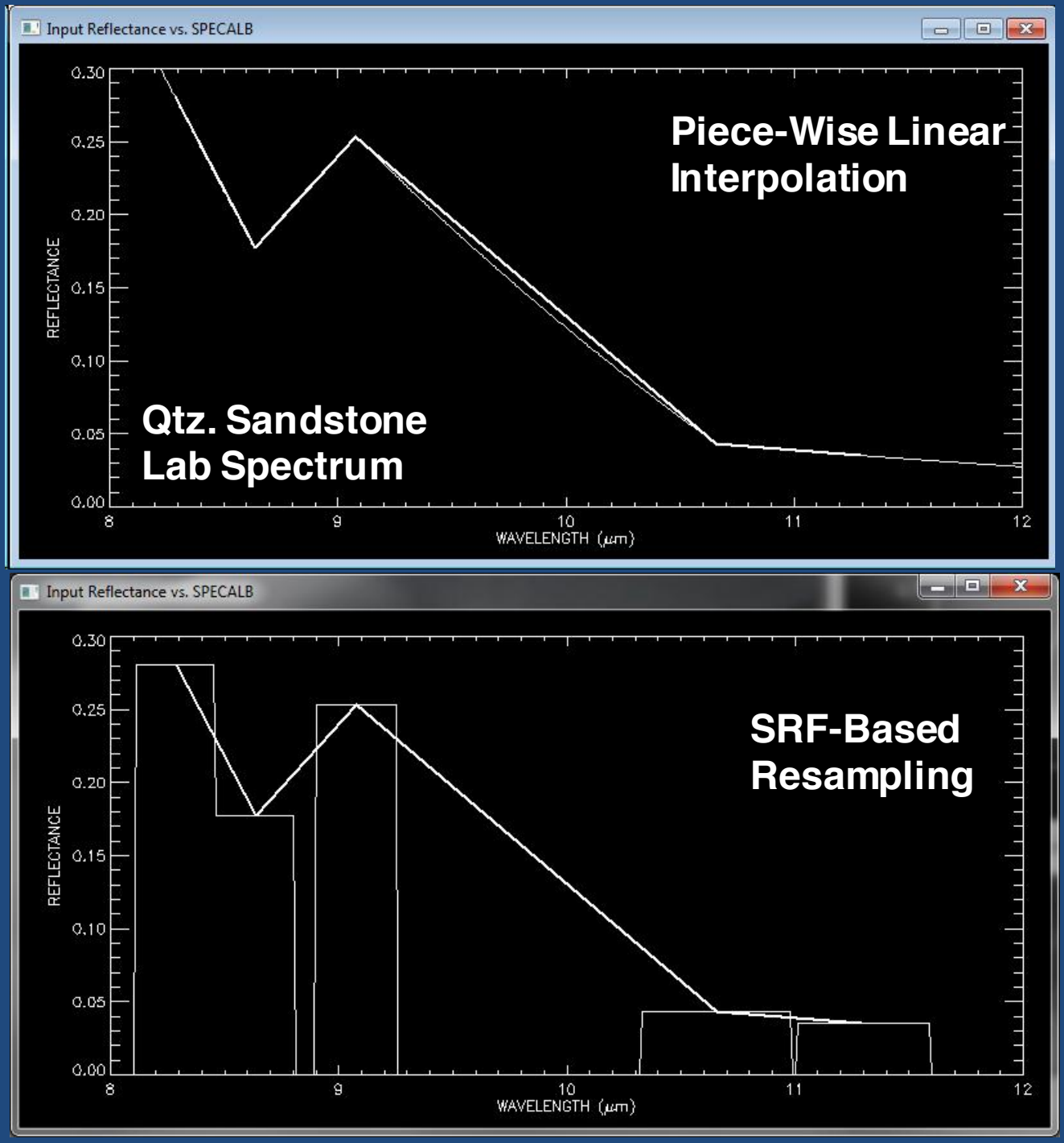
Interpolation of Reflectance Spectra

ASTER Resolution to MODTRAN Resolution

Linear Interpolation Results in Spectral Variation within Response Functions of Indiv. Channels

Resampling Based on SRF Ensures Uniform Reflectance w/in a Channel

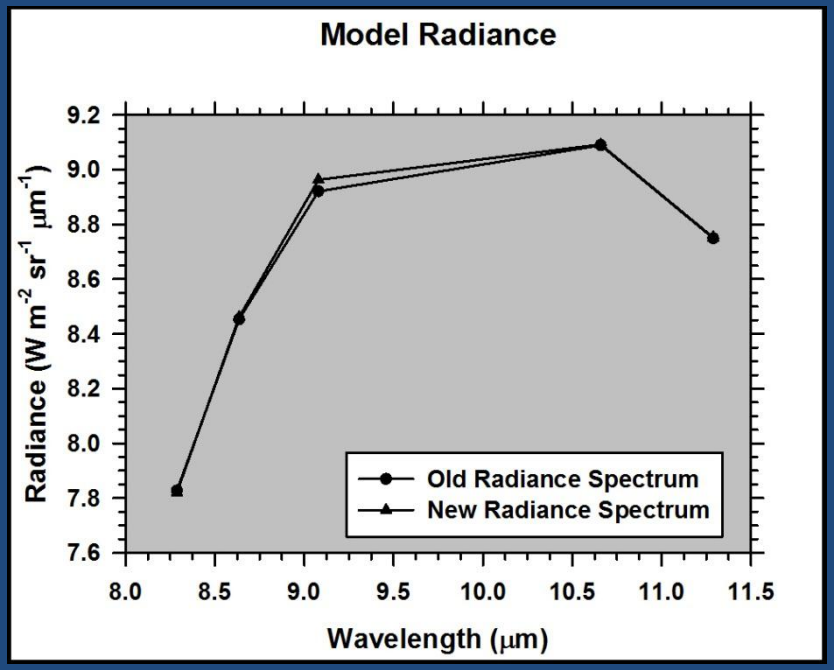
Regions Cover Normalized Response > 50%

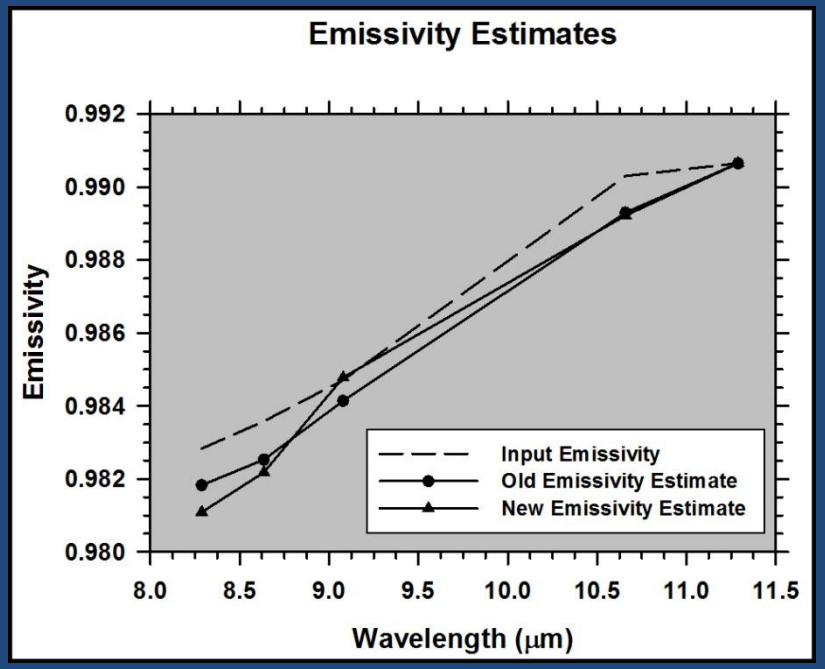


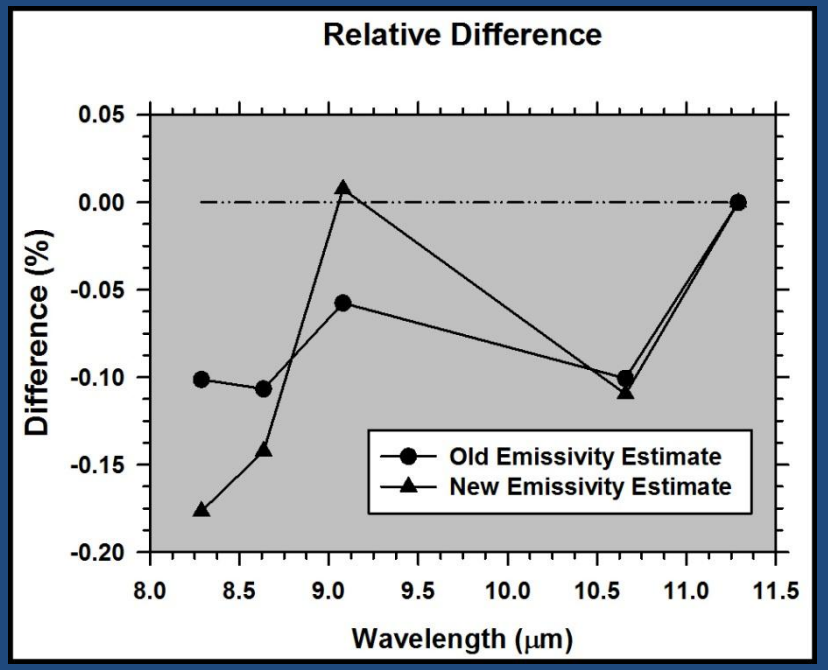
Simulations with Seawater Lab Spectrum

SRF-Based Resampling has Minimal Impact on the Estimated Emissivity (Normalized Emissivity Technique)

Expect Similar Performance with Other Low-Contrast Materials (e.g. Vegetation Canopies or Snow)





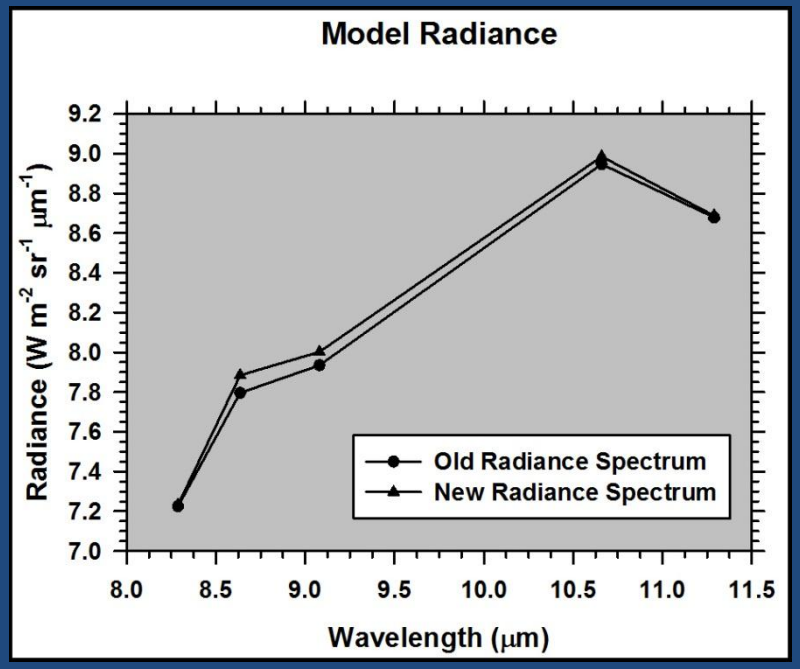


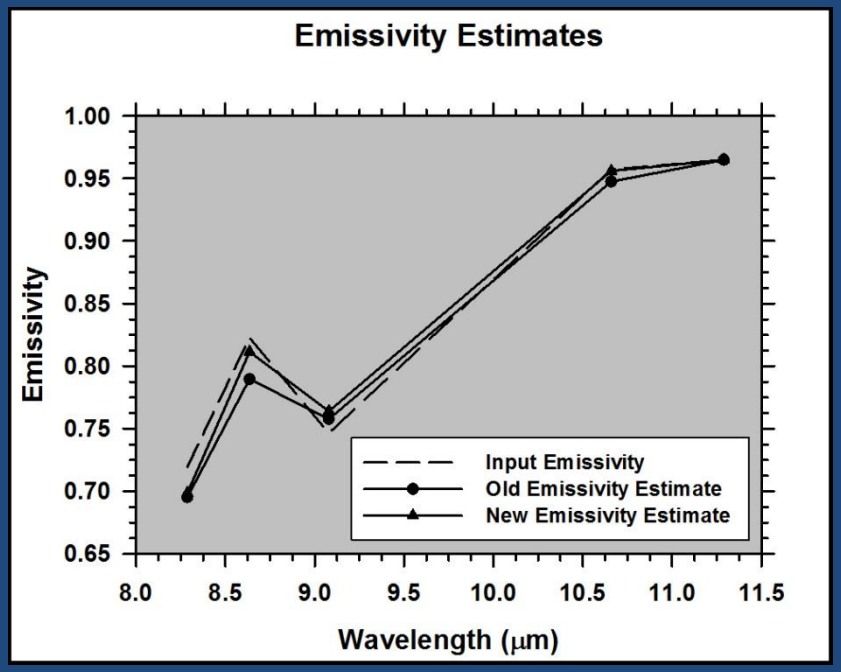
Simulations with Quartz Sandstone Lab Spectrum

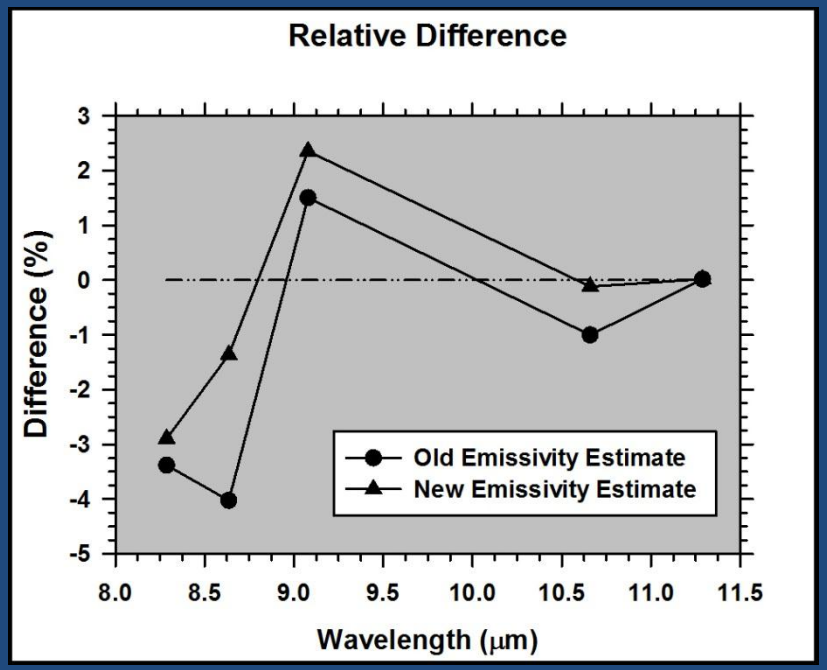
SRF-Based Resampling has Significant Impact on the Estimated Emissivity

Improved Estimates at 4 of 5 ASTER Channels

- Edge Effect at 9 μm (Channel 12)?
- May Need to Broaden Resampling Range (i.e. 40%)







Summary Comments

Knowledge of Surface Emissivity Essential for Retrievals Near Source Vents

SRF-Based Resampling of Input Emissivity Promising; Application to Satellite Data Forthcoming…

Evaluate Alternate Sources of Emissivity Spectra

- ASTER L2 Surface Emissivity (AST-05)
- ASTER Global Emissivity Map (GEM)
- "Double" Application of Atmosphere Correction

Re-Evaluate Treatment of Downwelling Sky Radiance