Potential Contributions of HyspIRI to the Remote Sensing of Volcanic Plumes

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H_2O Vapor vs. SO_2 Absorption

H_2O Vapor Absorption Affects the Entire 8-12 μm Atmospheric Window:

> **Add Channel Sensitive to H_2O to Facilitate Atm. “Corrections”**

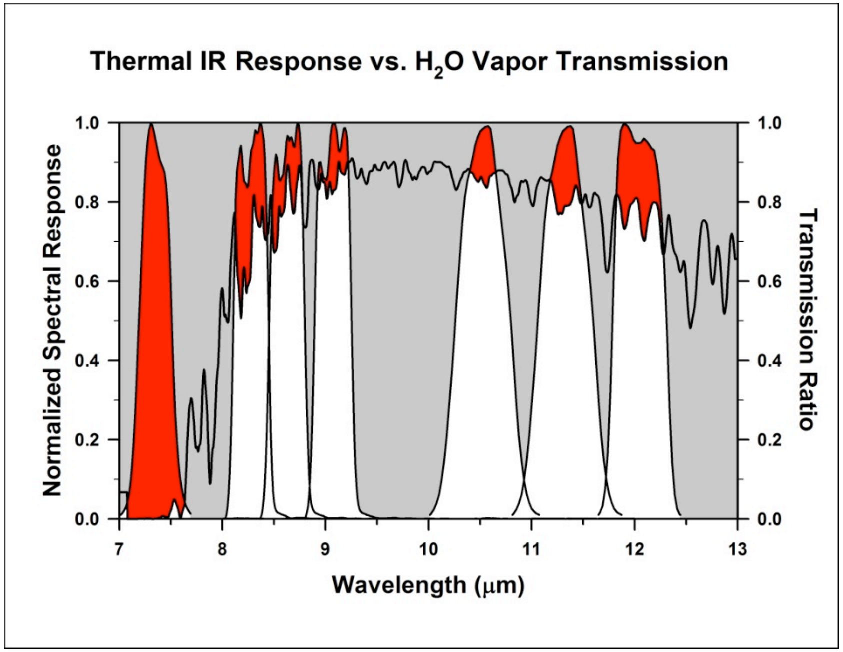
Considerable Variation in H_2O Within a Scene:

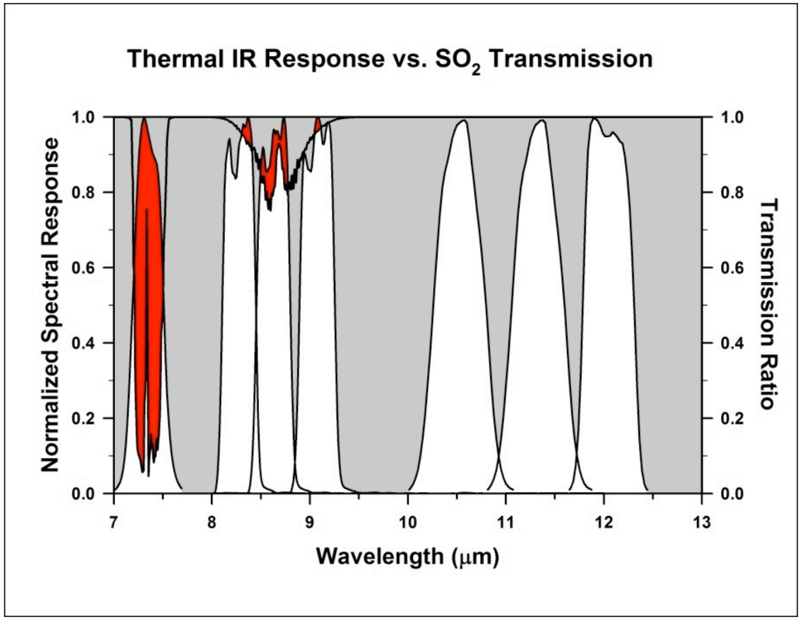
> **Can We Characterize These Variations?**

Very Strong H_2O Vapor and SO_2 Absorption in HyspIRI 7.3 μm Channel:

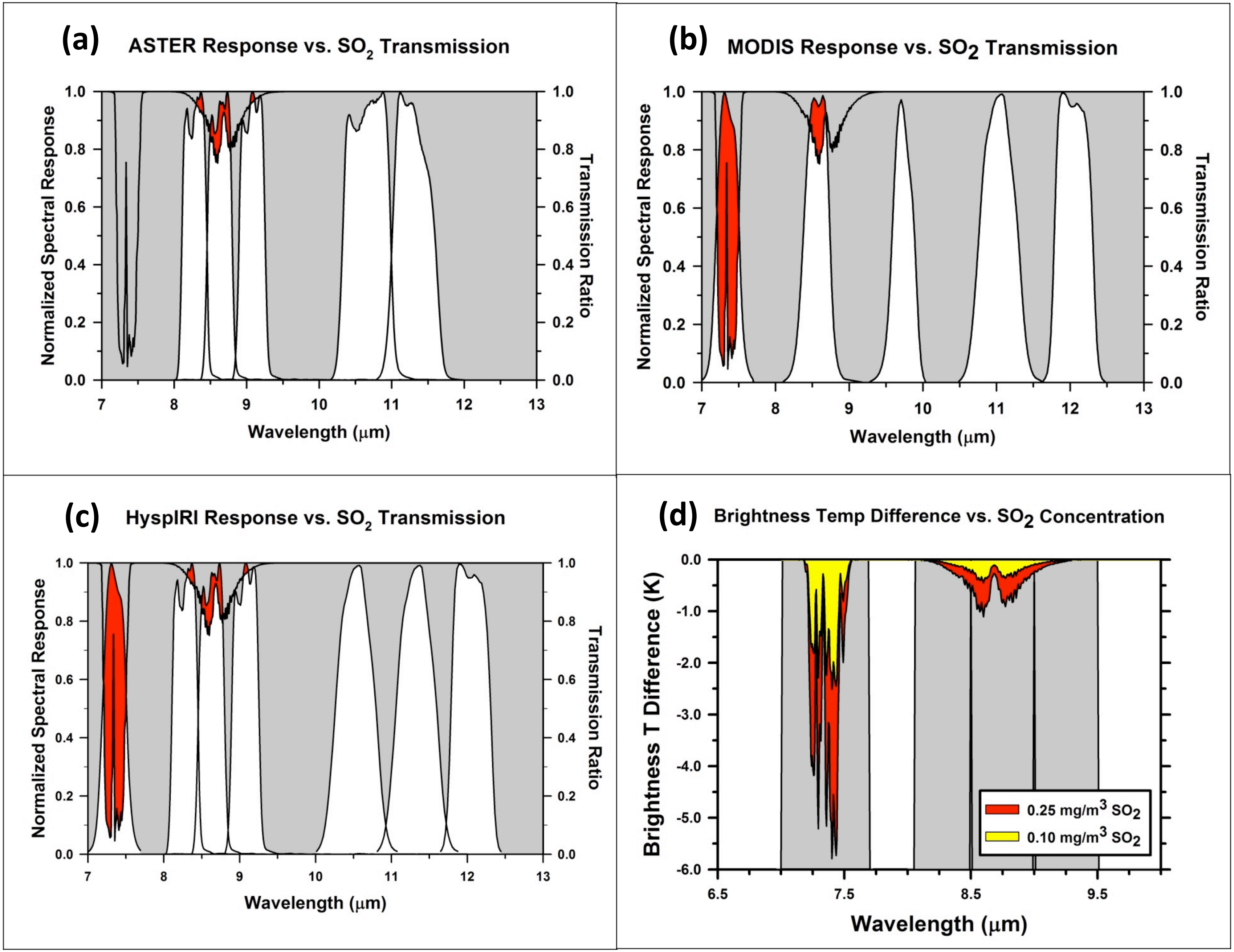
> **Can We Separate Effects of H_2O and SO_2?**

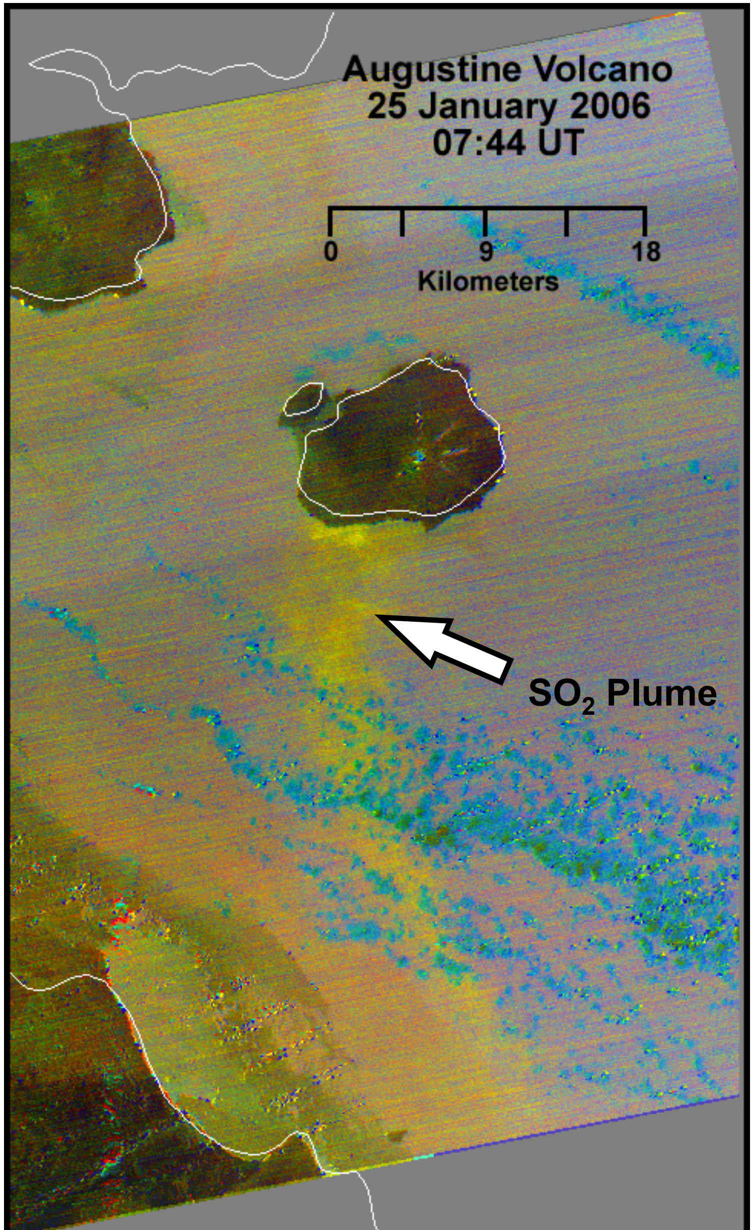
7.3 μm Not Suitable for Mapping Plumes Below 5 km? [Prata et al., 2003]



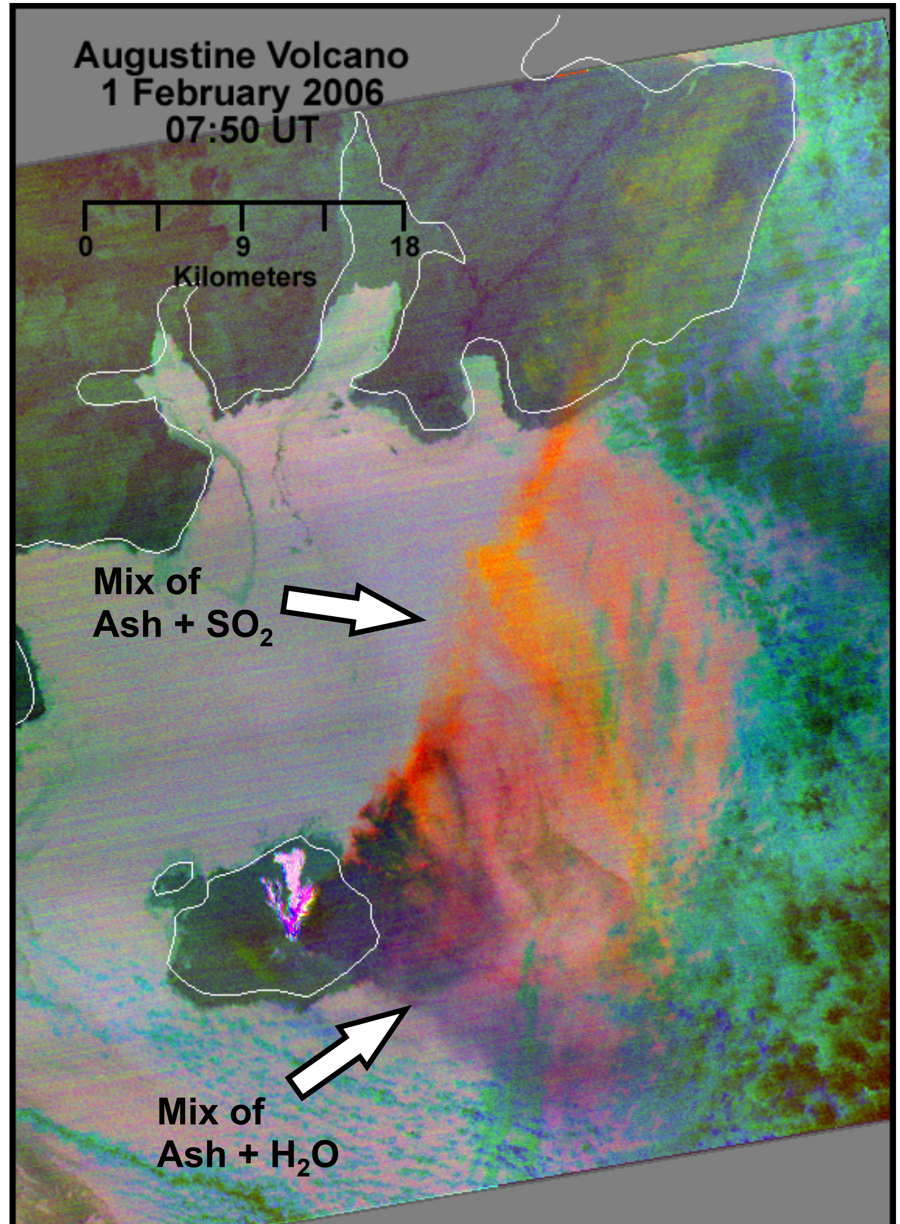


Heritage for HyspIRI Spectral Response

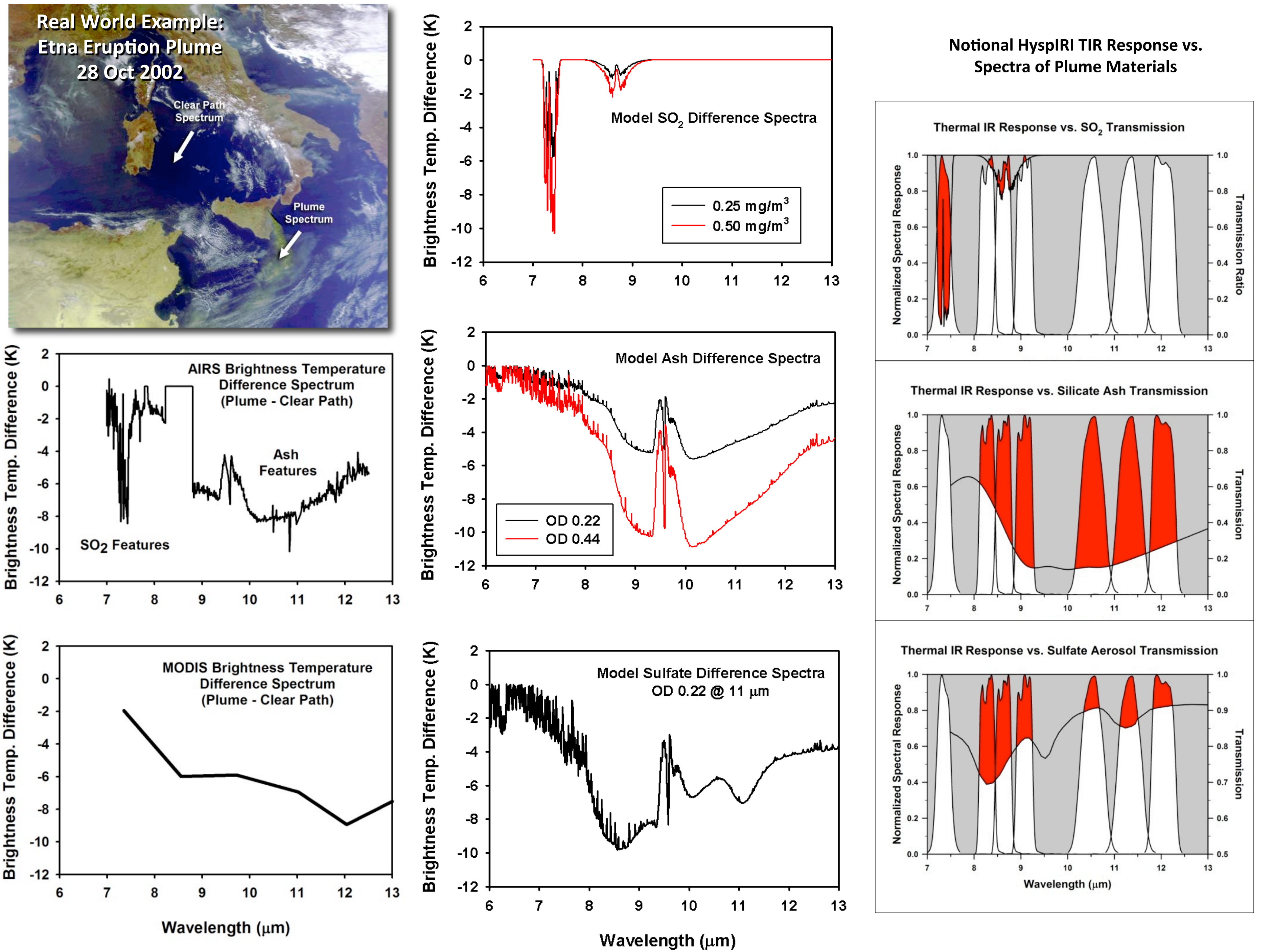




ASTER D-Stretch Depicting the Passive Emission of SO_2



ASTER D-Stretch Depicting Ash, water/ice, and SO_2 Released by Explosive Eruption


Real World Example:
Etna Eruption Plume
28 Oct 2002
Clear Path Spectrum
Plume Spectrum
Model SO2 Difference Spectra
0.25 mg/m3
0.50 mg/m3
Brightness Temp. Difference (K)
Notional HyspIRI TIR Response vs. Spectra of Plume Materials
Thermal IR Response vs. SO2 Transmission
Normalized Spectral Response
Transmission Ratio
AIRS Brightness Temperature Difference Spectrum (Plume - Clear Path)
Ash Features
SO2 Features
Brightness Temp. Difference (K)
Model Ash Difference Spectra
OD 0.22
OD 0.44
Brightness Temp. Difference (K)
Thermal IR Response vs. Silicate Ash Transmission
Normalized Spectral Response
Transmission
MODIS Brightness Temperature Difference Spectrum (Plume - Clear Path)
Brightness Temp. Difference (K)
Wavelength (µm)
Model Sulfate Difference Spectra
OD 0.22 @ 11 µm
Brightness Temp. Difference (K)
Wavelength (µm)
Thermal IR Response vs. Sulfate Aerosol Transmission
Normalized Spectral Response
Transmission
Wavelength (µm)

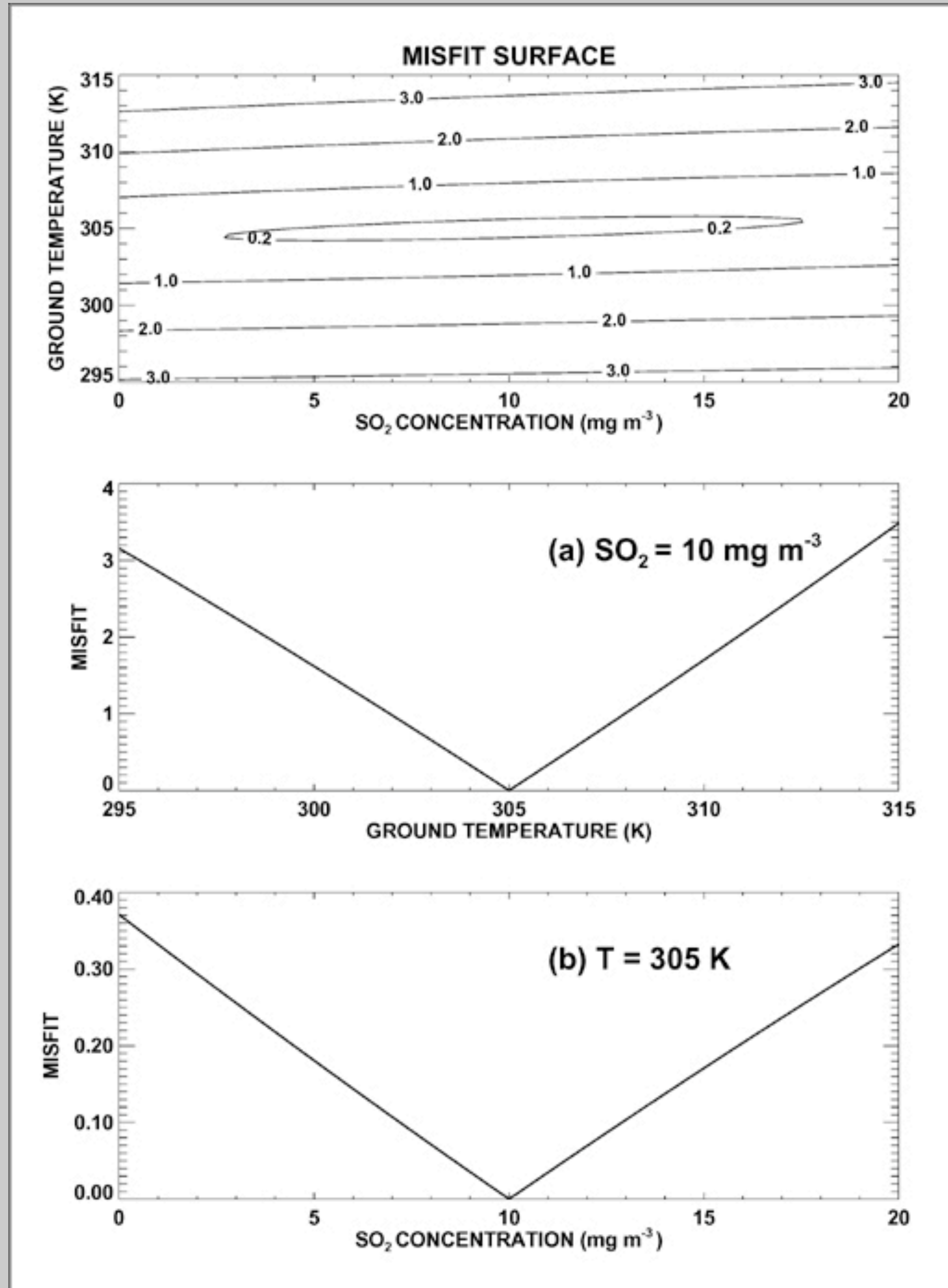
Retrieval of Surface Temperature and SO_2 Concentration

Ground Temperature has Stronger Influence on Perceived Radiance Than the SO_2 Concentration

Simultaneous Retrieval of Temperature and SO_2 is Difficult; Temperature is Well-Constrained but SO_2 is Poorly-Constrained

Cascading (Serial) Retrieval is a Better Option:

- **Estimate Surface Temperature**
- ***(Estimate H_2O Vapor Factor)***
- **Estimate SO_2 Concentration**
- **Repeat Temperature Estimation w/ Prior H_2O and/ or SO_2 Estimates**
- **Repeat H_2O and/or SO_2 Estimation with New Temperature**
- **Exit When ΔT < Threshold**



Retrieval Procedure Requires Profiles of Atm. Temp, H_2O, and O_3 as Input

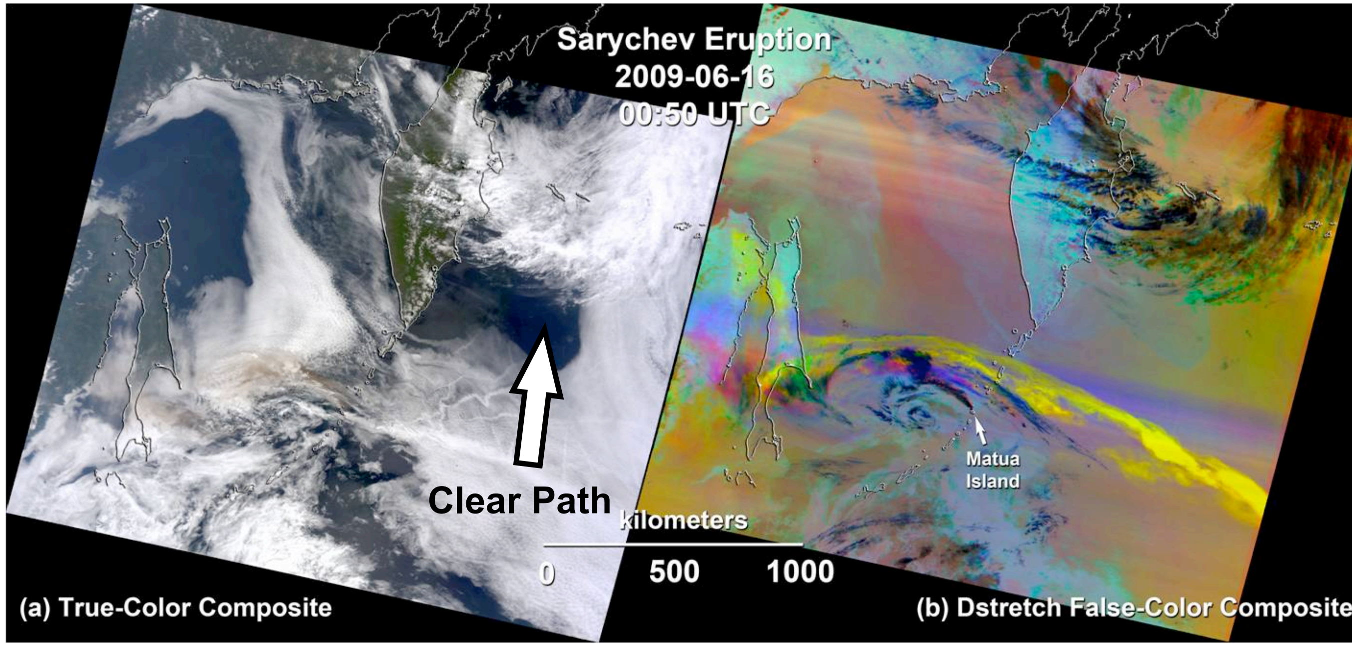
Radiance Spectra from Clear Path (Plume-Free) Regions are used to “Tune” the H_2O and O_3 Profiles

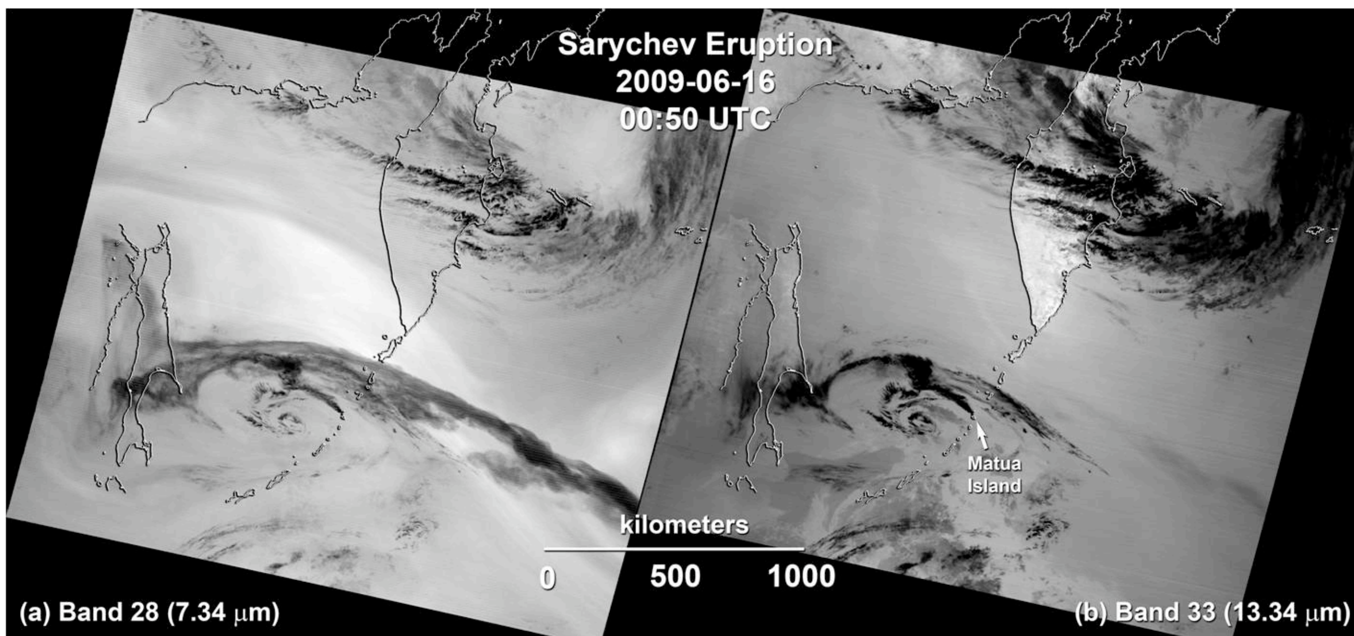
Tuning is a Time-Consuming Process: Retrieval of H_2O is More Efficient and a Better Characterization of Variations in H_2O

Two Candidates for H_2O Channel:
MODIS 28 (7.3 μm) and MODIS 33 (13.3 μm)

Strong H_2O Absorption in MODIS 28 Obscures the Surface

Moderate H_2O Absorption in MODIS 33 Does Not Obscure the Surface



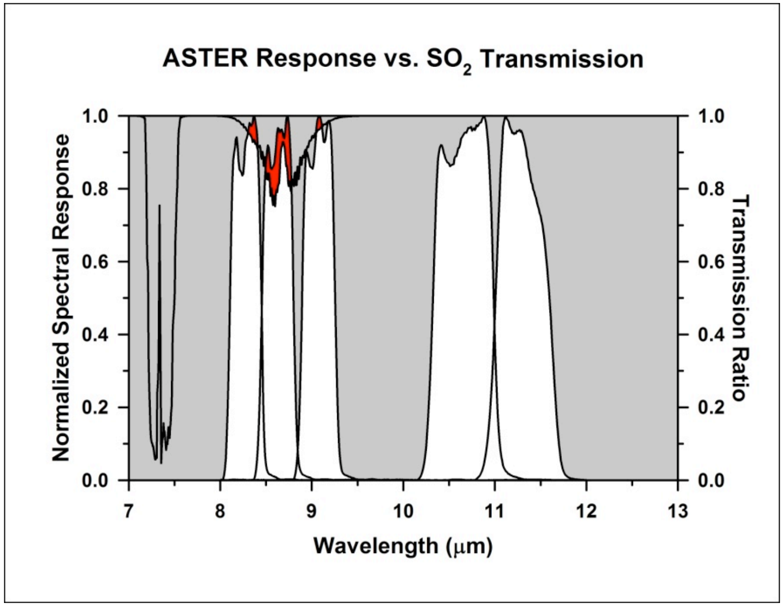


Simulated Retrievals of H_2O and SO_2

Evaluate Five Configurations of Channels
- ASTER, HyspIRI, MODIS 29-32, MODIS 28-32, and MODIS 29-33

Synthetic Radiance Spectra as "Observations"
- Surface Temp = 275 K, SO_2 Conc = 2.5 mg/m^3, H_2O Factor = 0.75
- Plume Altitude = 15 km, Sea Surface Background, Sarychev Atm. Profiles

Three Retrieval Modes/Configuration
- Temperature: Assume SO_2 = 0, H_2O = 0.75 (Tuning Mode)
- H_2O Factor: Assume SO_2 = 0 (Potential New Tuning Mode)
- H_2O + SO_2: Potential New Retrieval Mode



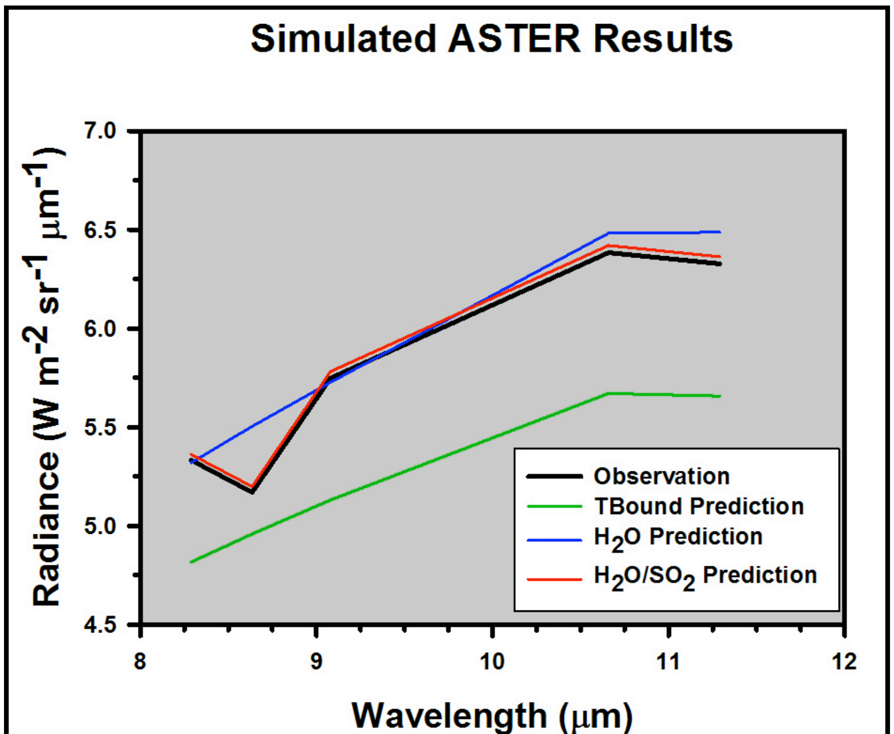
ASTER Simulation Results

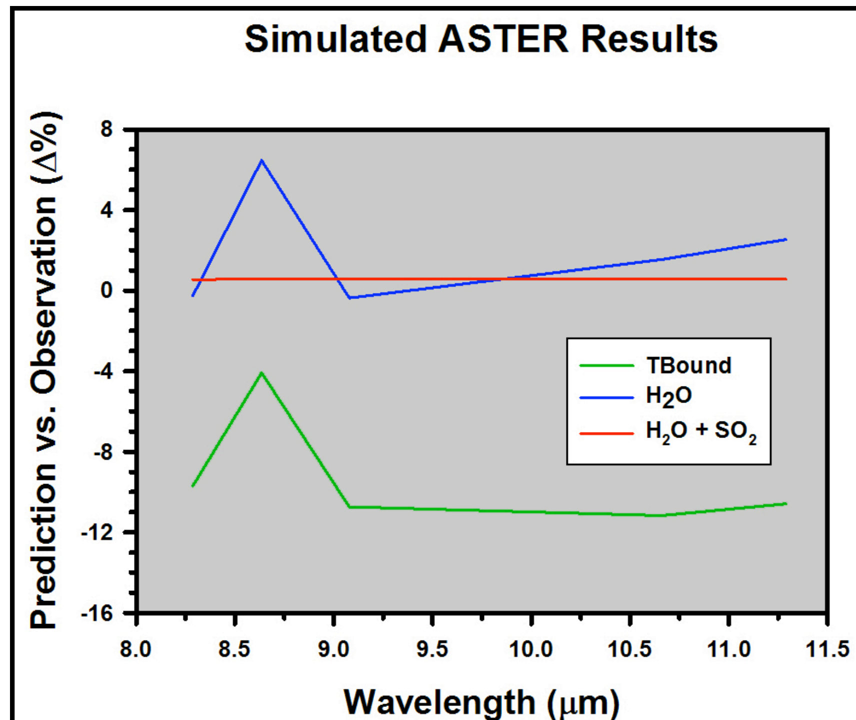
Temperature Under-Estimated, Misfit Spectrum 4 – 10%

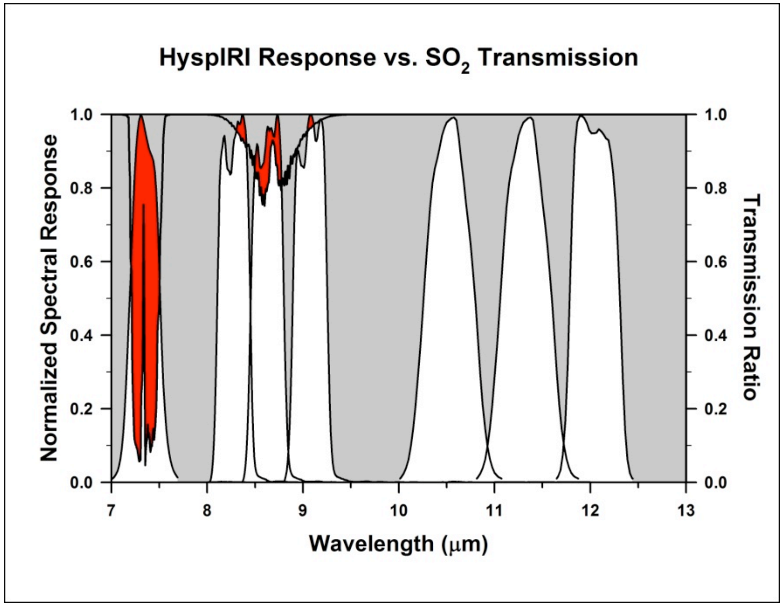
H_2O: Misfit Spectrum < 6%

$H_2O + SO_2$: Misfit Spectrum < 2%

Δ% Axis Range = 24%







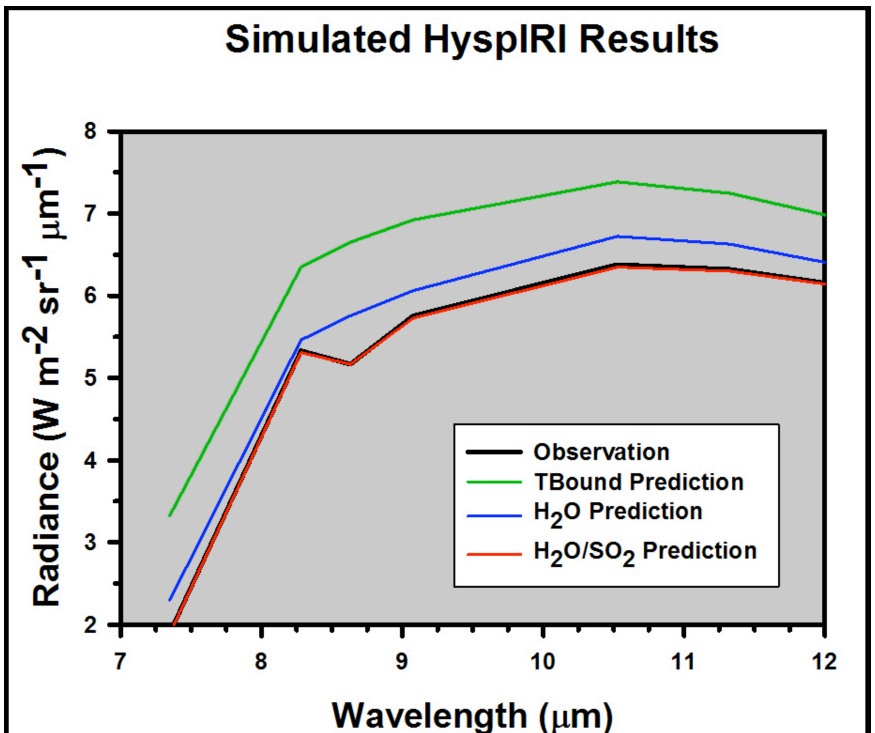
HyspIRI Simulation Results

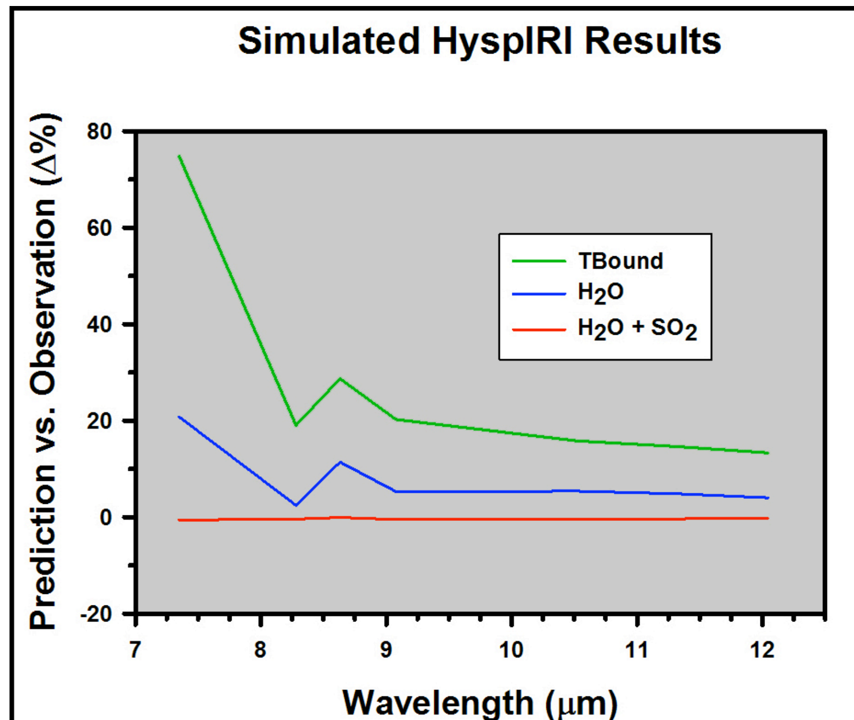
Temperature Over-Estimated, Misfit Spectrum ~75% at 7.3 μm

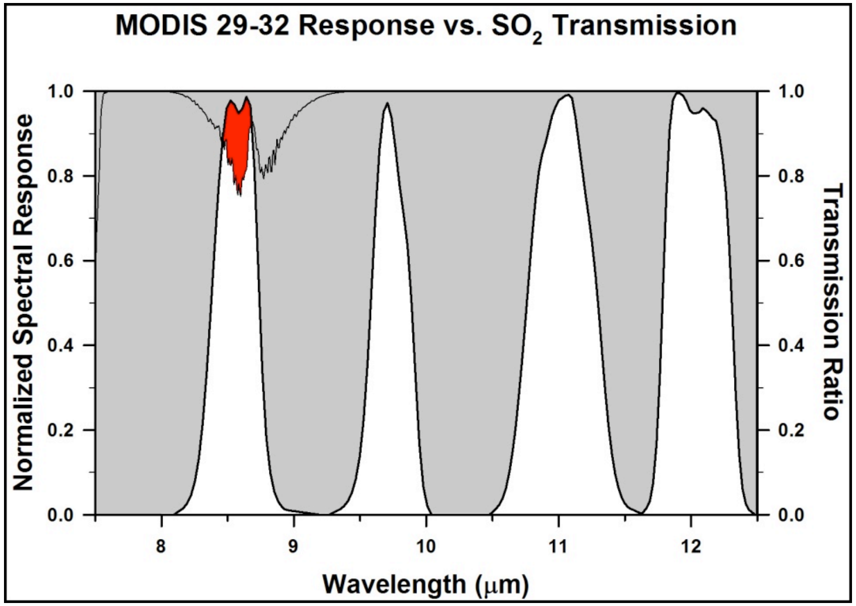
H_2O: Misfit ~20% at 7.3 μm

$H_2O + SO_2$: Misfit Spectrum < 2%

Δ% Axis Range = 100%







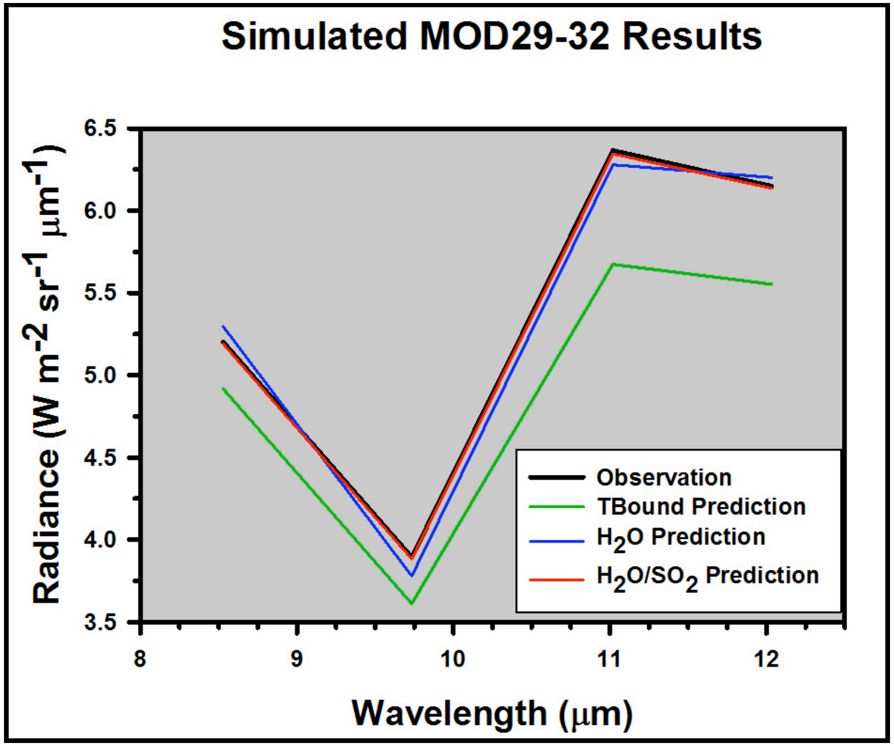
MODIS 29-32 Simulation Results

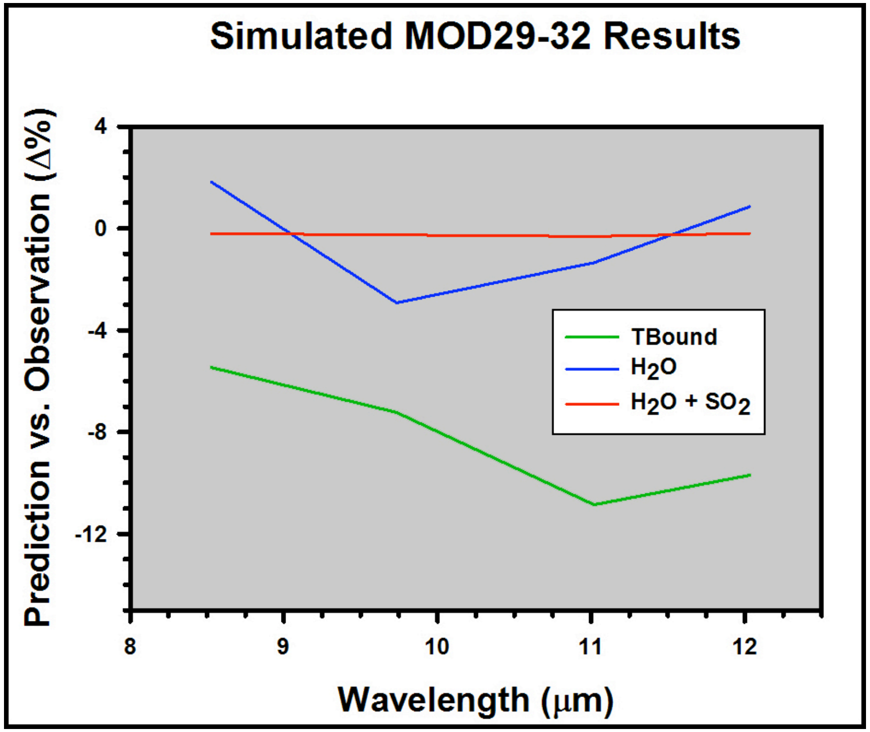
Temperature Under-Estimated, Misfit Spectrum Between 5 – 11%

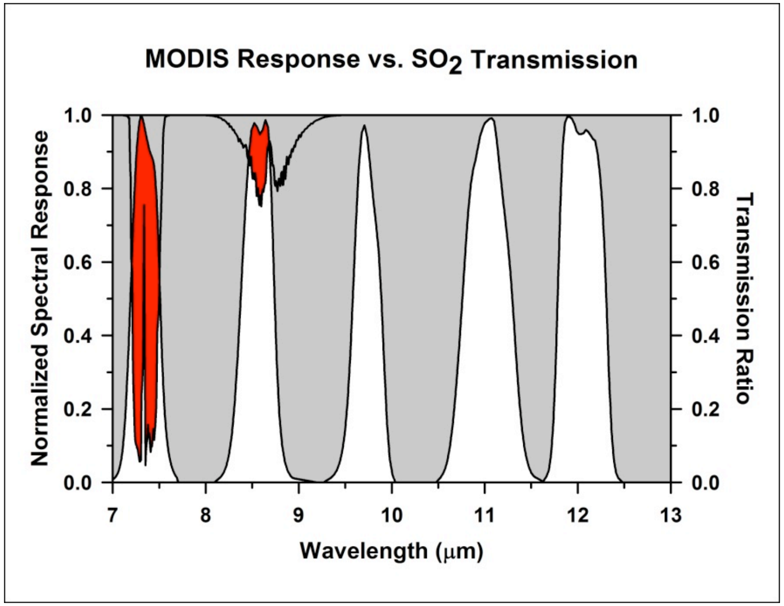
H_2O: Misfit Within ±3%

$H_2O + SO_2$: Misfit Spectrum < 1%

Δ% Axis Range = 19%







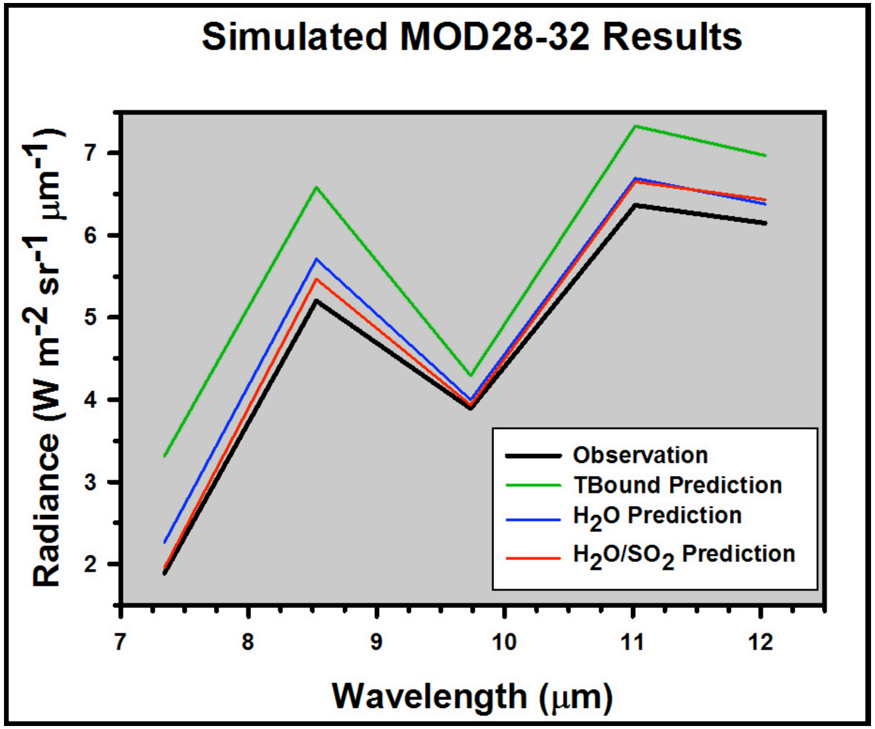
MODIS 28-32 Simulation Results

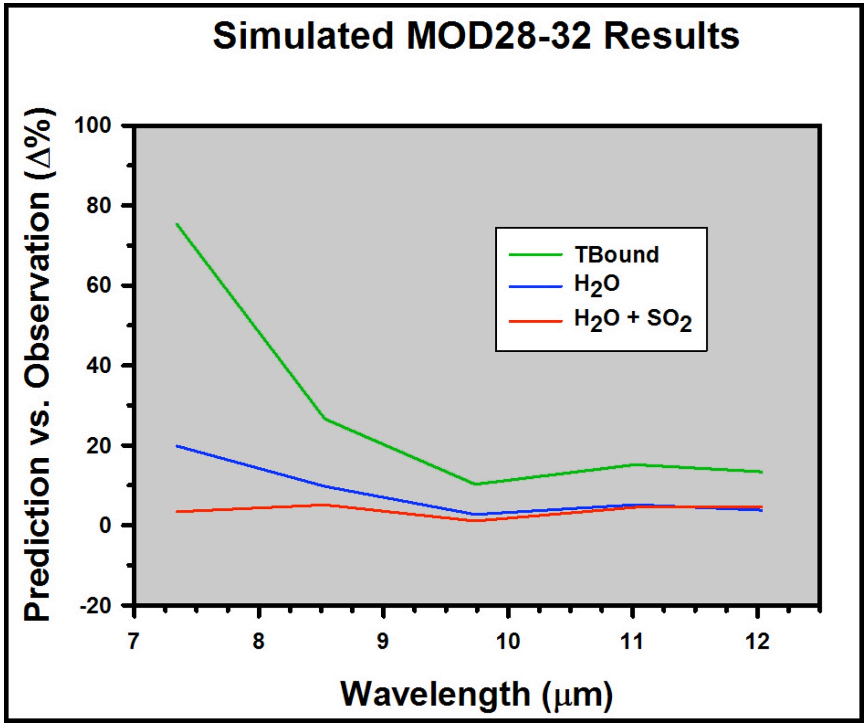
Temperature Over-Estimated, Misfit Spectrum ~80% at 7.3 μm

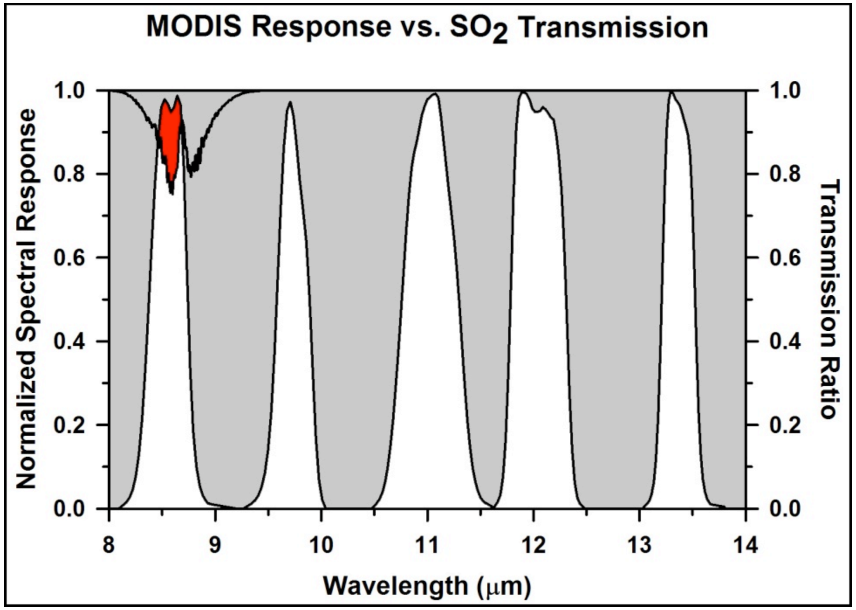
H_2O: Misfit ~20% at 7.3 μm

H_2O + SO_2: Misfit Spectrum < 10%

Δ% Axis Range = 120% (Worst Misfit)







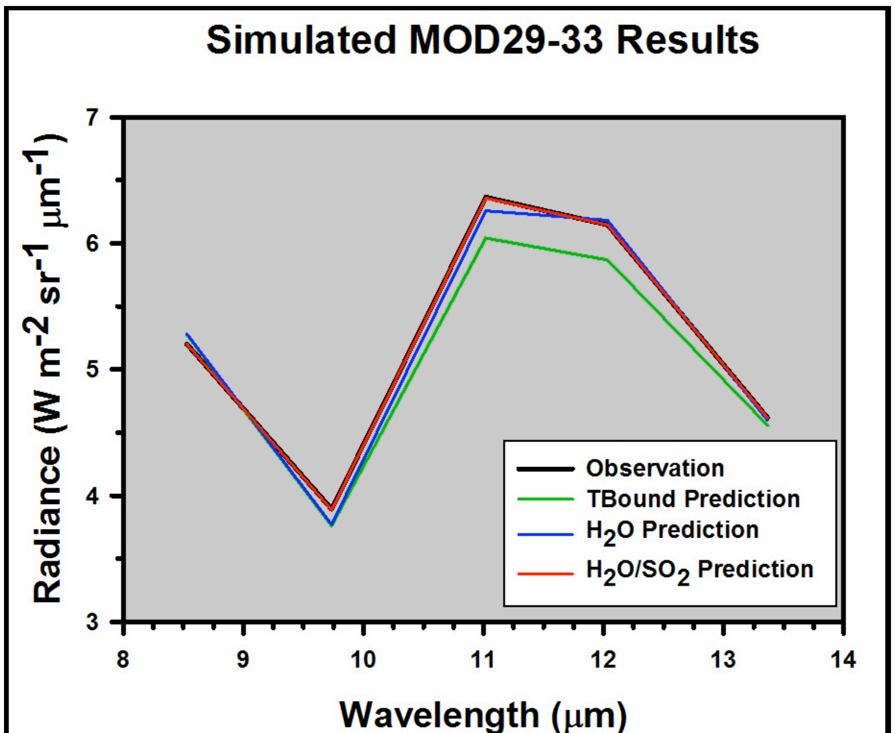
MODIS 29-33 Simulation Results

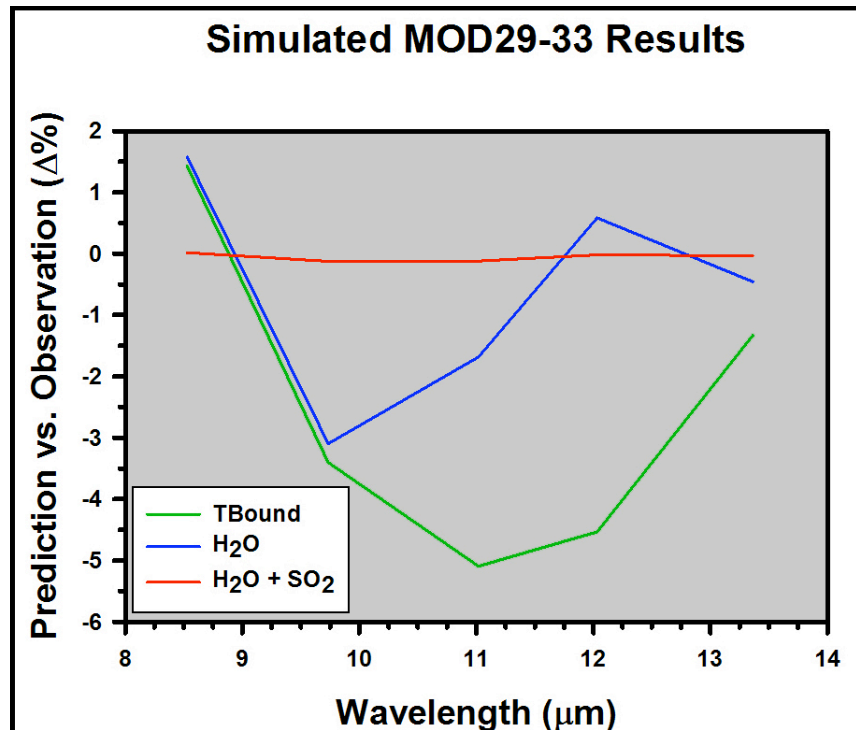
Temperature Under-Estimated, Misfit Spectrum < 6%

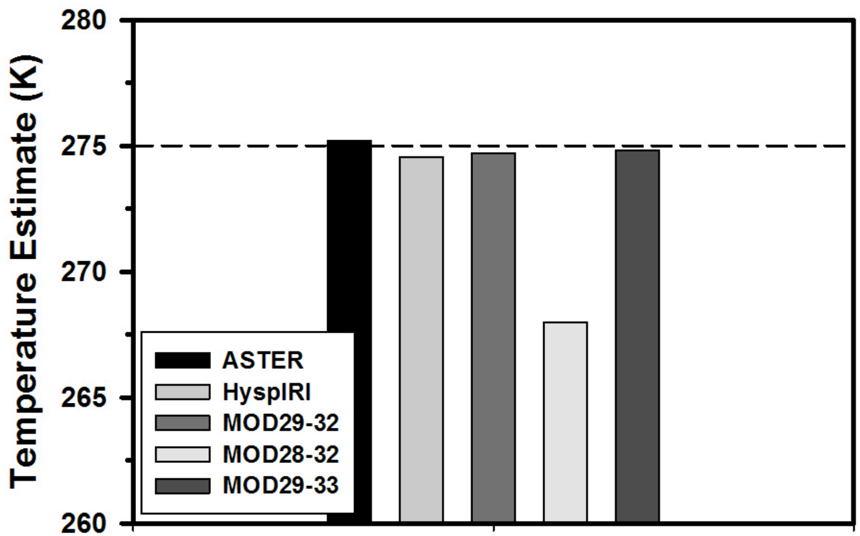
H_2O: Misfit < 3%

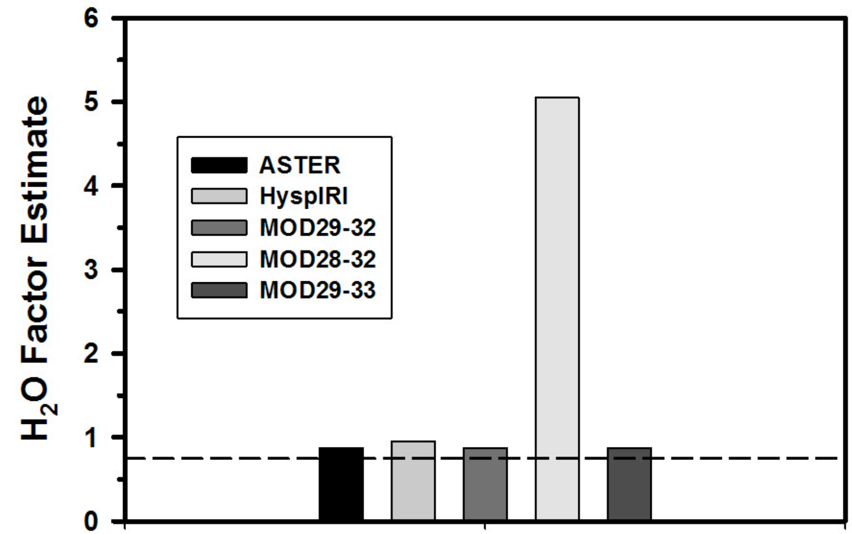
$H_2O + SO_2$: Misfit Spectrum < 1%

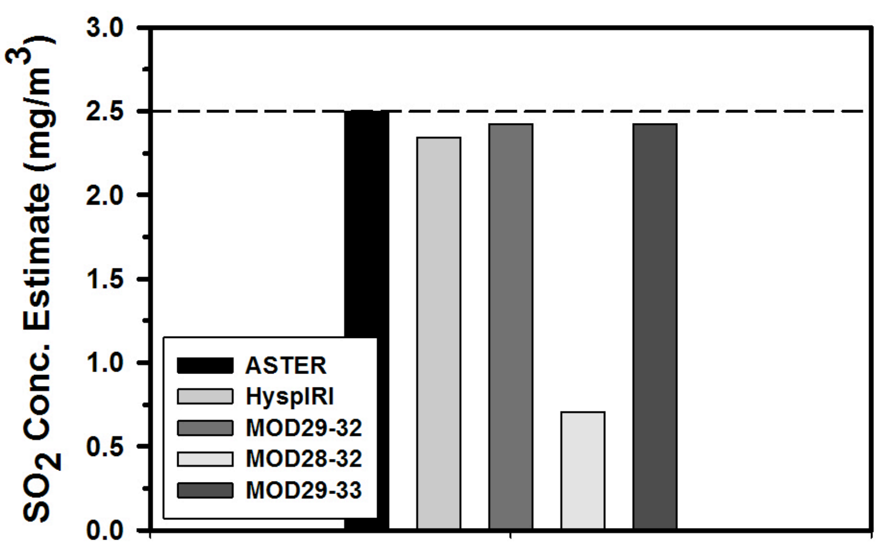
Δ% Axis Range = 8% (Best Misfit)











Retrieval Accuracy

ASTER: Best Overall Performance

MODIS 28-32: Worst Overall Performance

MODIS 29-32/MODIS 29-33: Roughly Equal Performance; Slightly Better Than HyspIRI

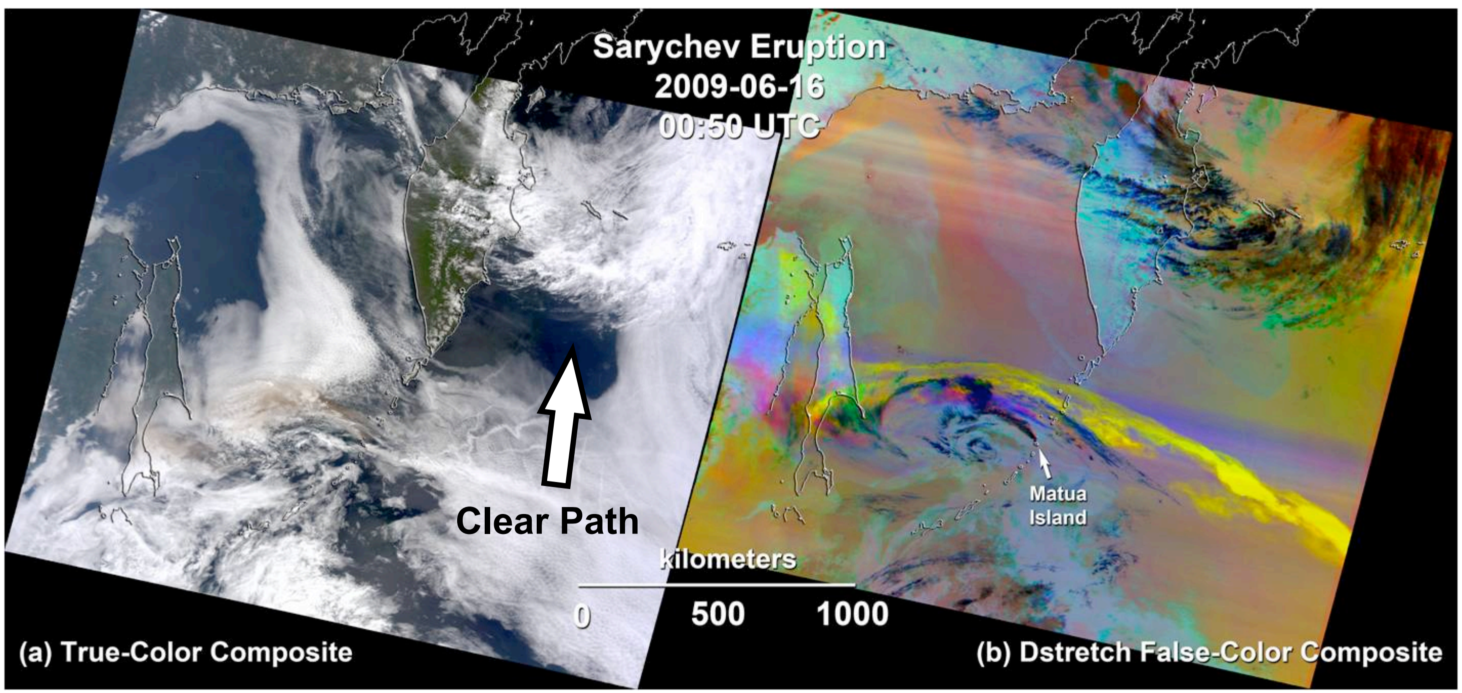
Presence of 7.3 μm Channel Degrades Performance

Note: All Configurations Produced Exact Retrievals in Traditional (TBound + SO_2) Mode

MODIS-Based Retrievals of H_2O and SO_2

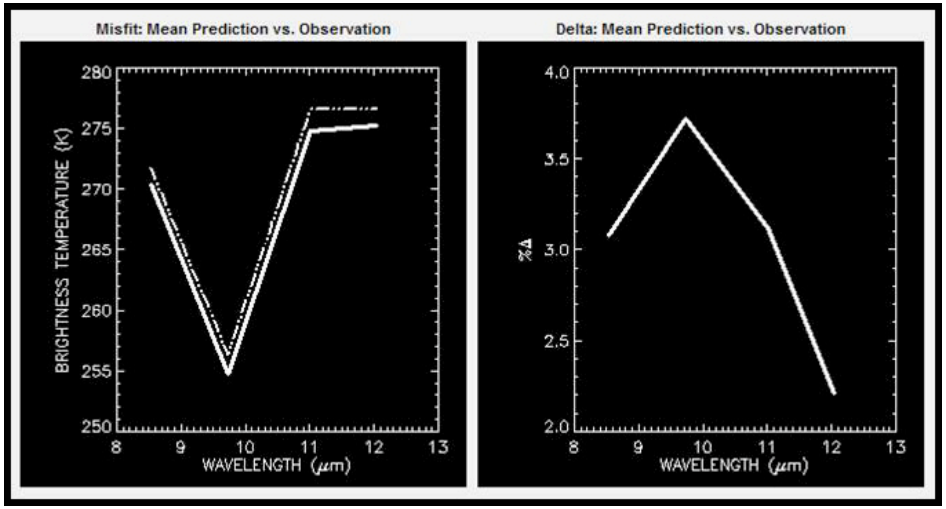
Evaluate Three Configurations of Channels
- **MODIS 29-32, MODIS 28-32, and MODIS 29-33**

Compare Temperature and SO_2 Retrievals with Fixed and Free H_2O Factors
- **Region-of-Interest Included SO_2, Ash, and Clear-Path Pixels**

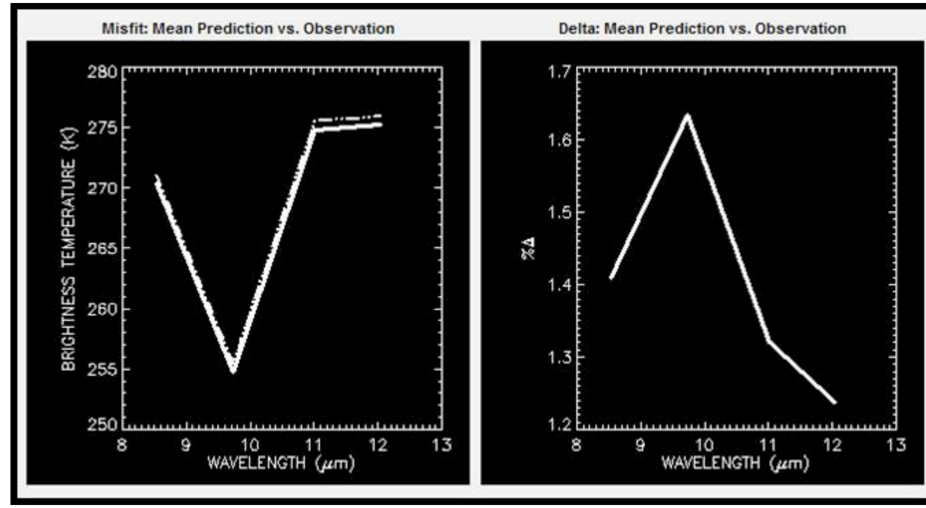


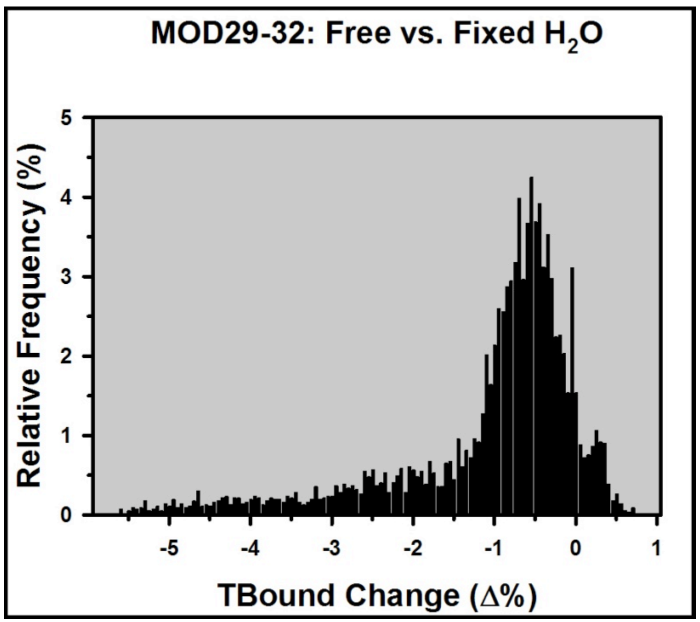
MODIS 29 – 32 Results

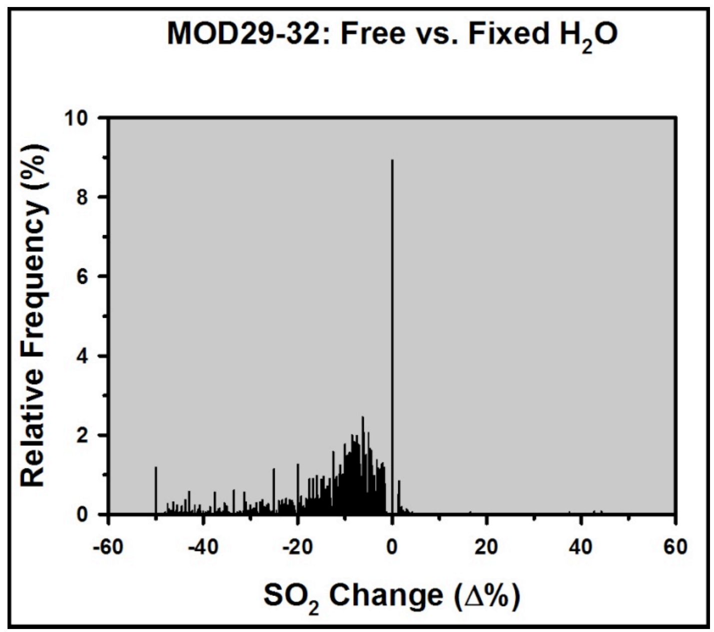
Fixed H_2O Factor



Free H_2O Factor







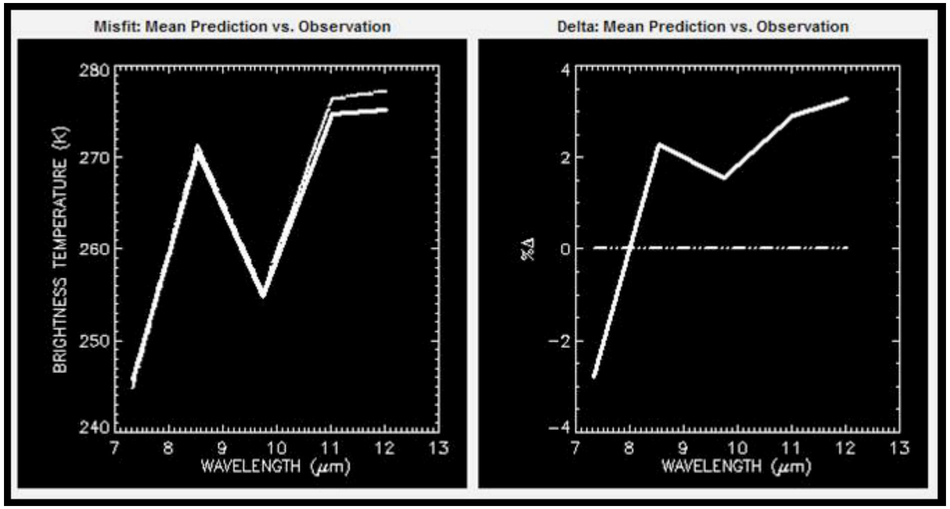
Improved Fit: Δ% Range Reduced from 2% to 0.5%

TBound Estimates Decreased ~0.5%

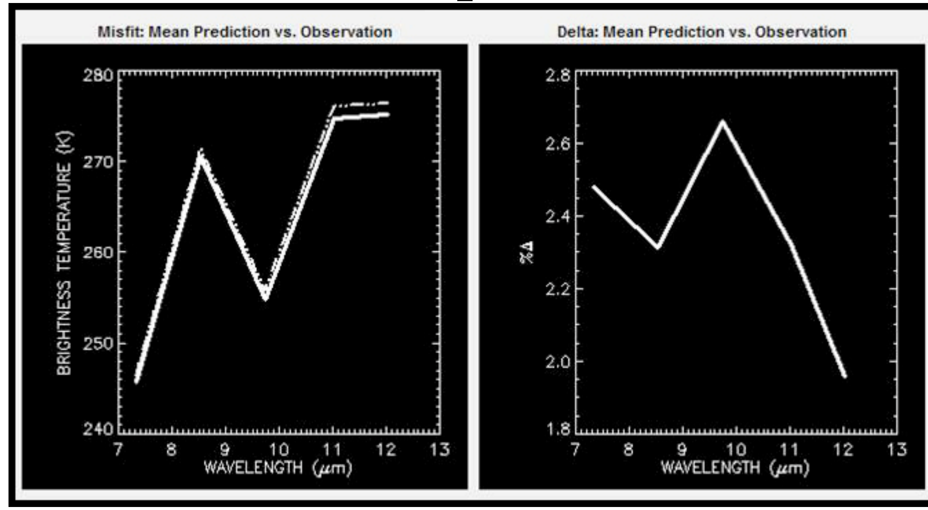
SO_2 Estimates Decreased 5 – 10%

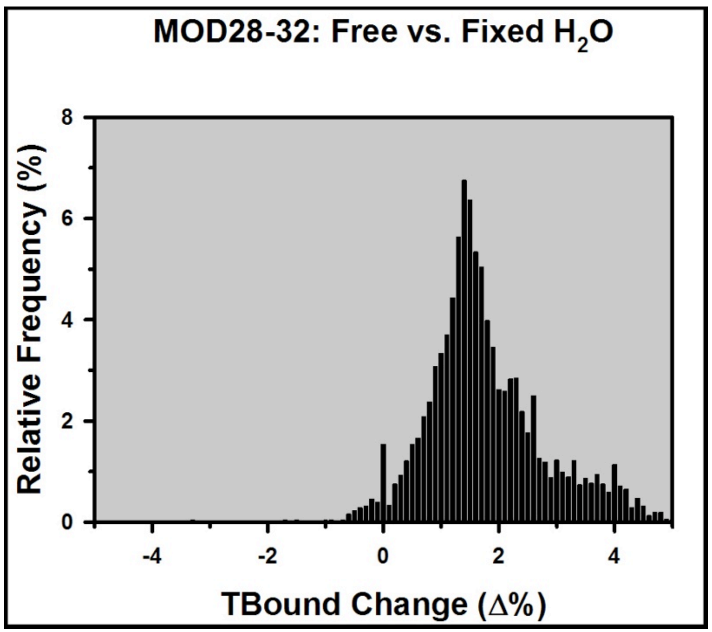
MODIS 28 – 32 Results

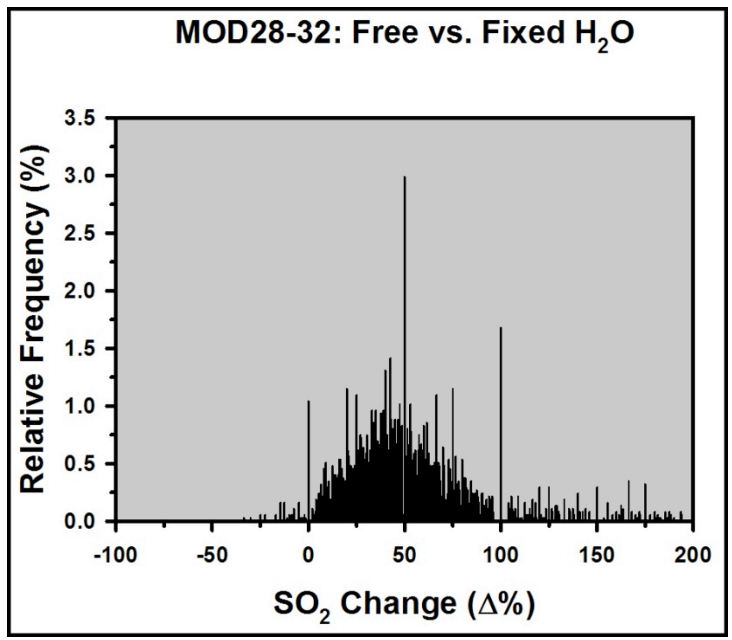
Fixed H_2O Factor



Free H_2O Factor







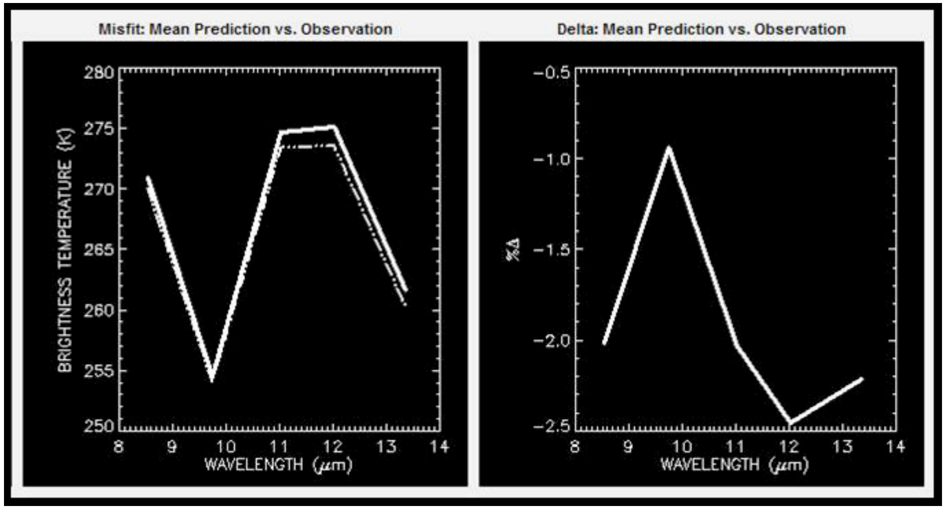
Improved Fit: Δ% Range Reduced from 8% to 1%

TBound Estimates Increased ~1.5%

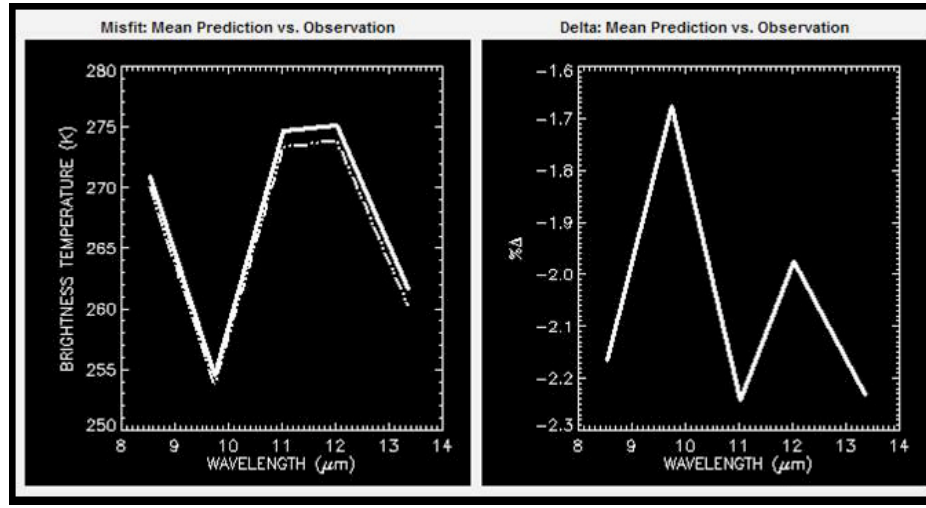
SO_2 Estimates Increased ~ 50%

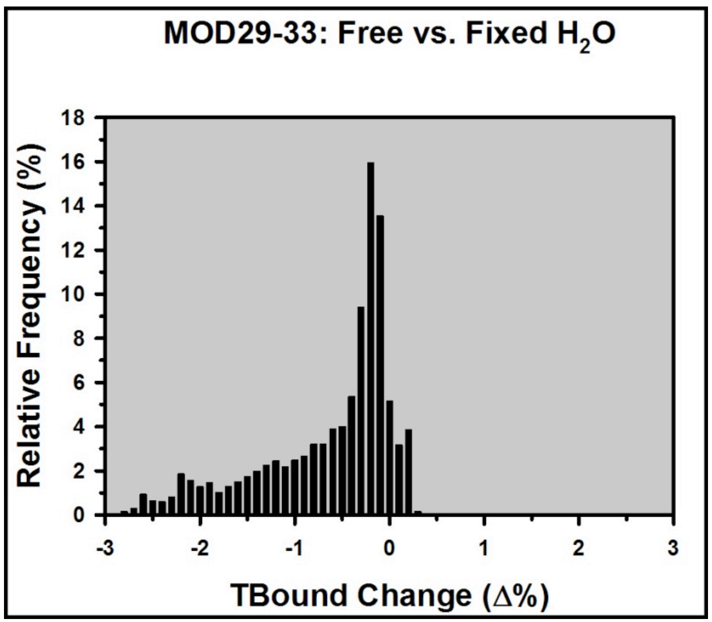
MODIS 29 – 33 Results

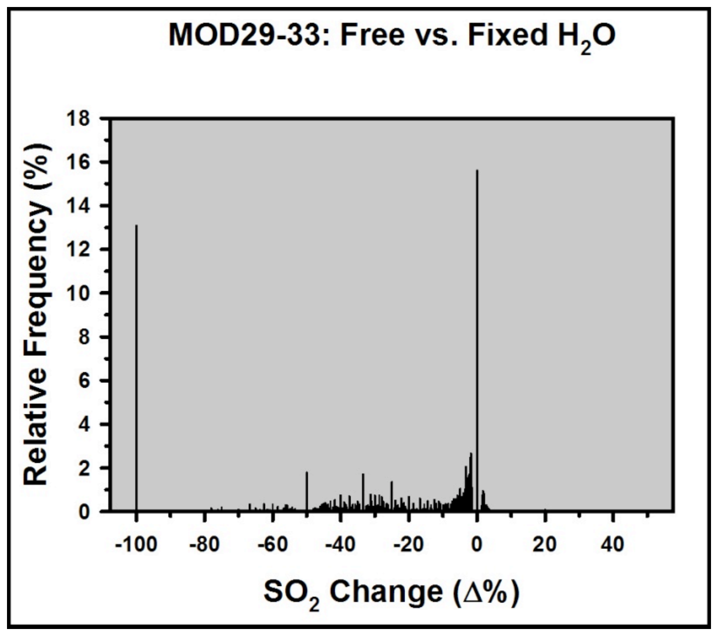
Fixed H_2O Factor



Free H_2O Factor







Improved Fit: Δ% Range Reduced from 3% to 0.7%

TBound Estimates Decreased < 0.5%

Problematic Interpretation of SO_2 Results:

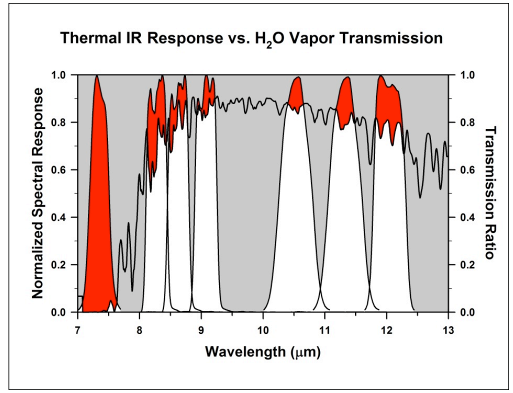
Reduction in Estimates < 10% ?

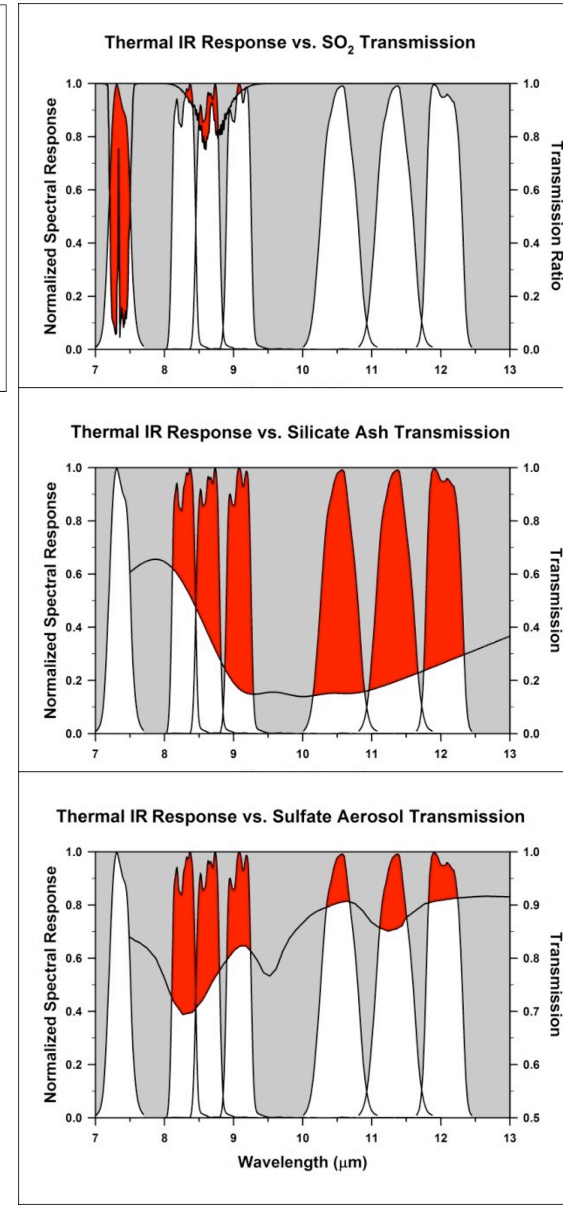
Spike @ -100% is Significant!

Spike @ 0 Change Significant?

Notional HyspIRI TIR Response vs.
Spectra of Plume Materials

Summary Remarks





Single Channel @ 7.3 μm Does Not Provide Sufficient Resolution to Separate the Effects of H_2O and SO_2

Characterizing Spatial Variations in H_2O Has Broader Science Impact than SO_2 Detection:

- **Shift Channel to Longer Wavelength (~ 8.0 μm)**
- **Definitive Solution to Channel Position Requires HyTES Data**

Adopting 13.3 μm Channel (MOD 33) for MODIS-Based Plume Mapping

- **Not Necessary for HyspIRI Due to High Spectral Resolution Between 8 and 9 μm**

Food For Thought: HyspIRI Channel Between 9.5 and 10 μm Would Help Discriminate Sulfate Aerosols from SO_2 or Ash