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"

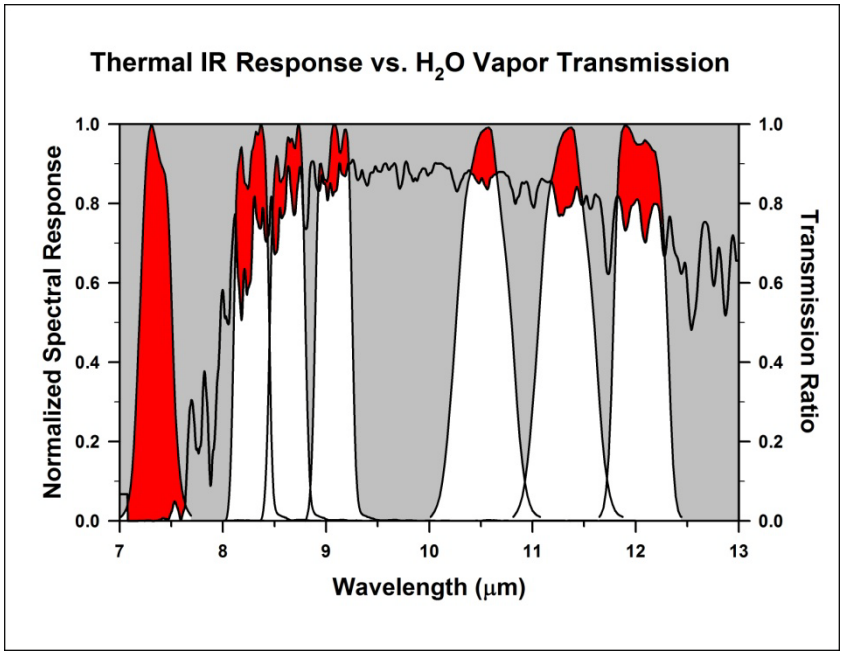
Considerable Variation in H_2O Within a Scene:

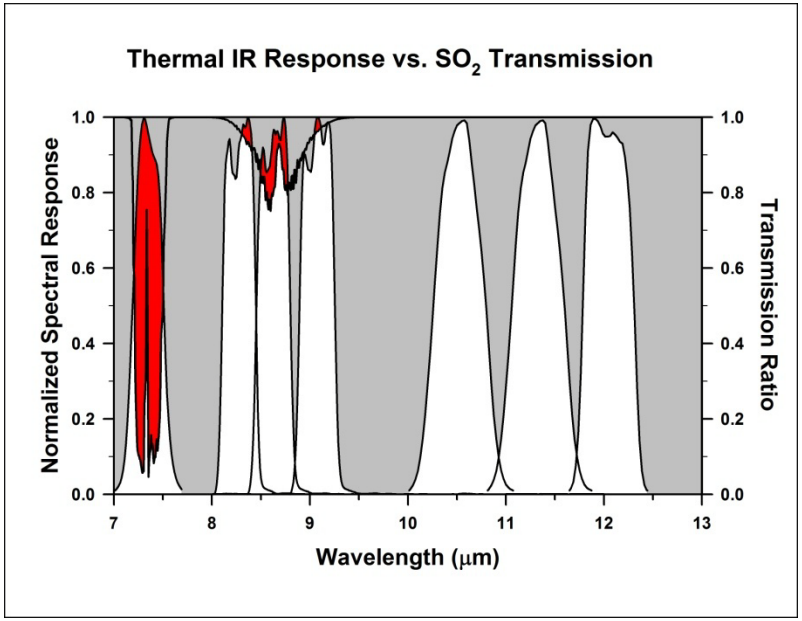
Can We Characterize These Variations?

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

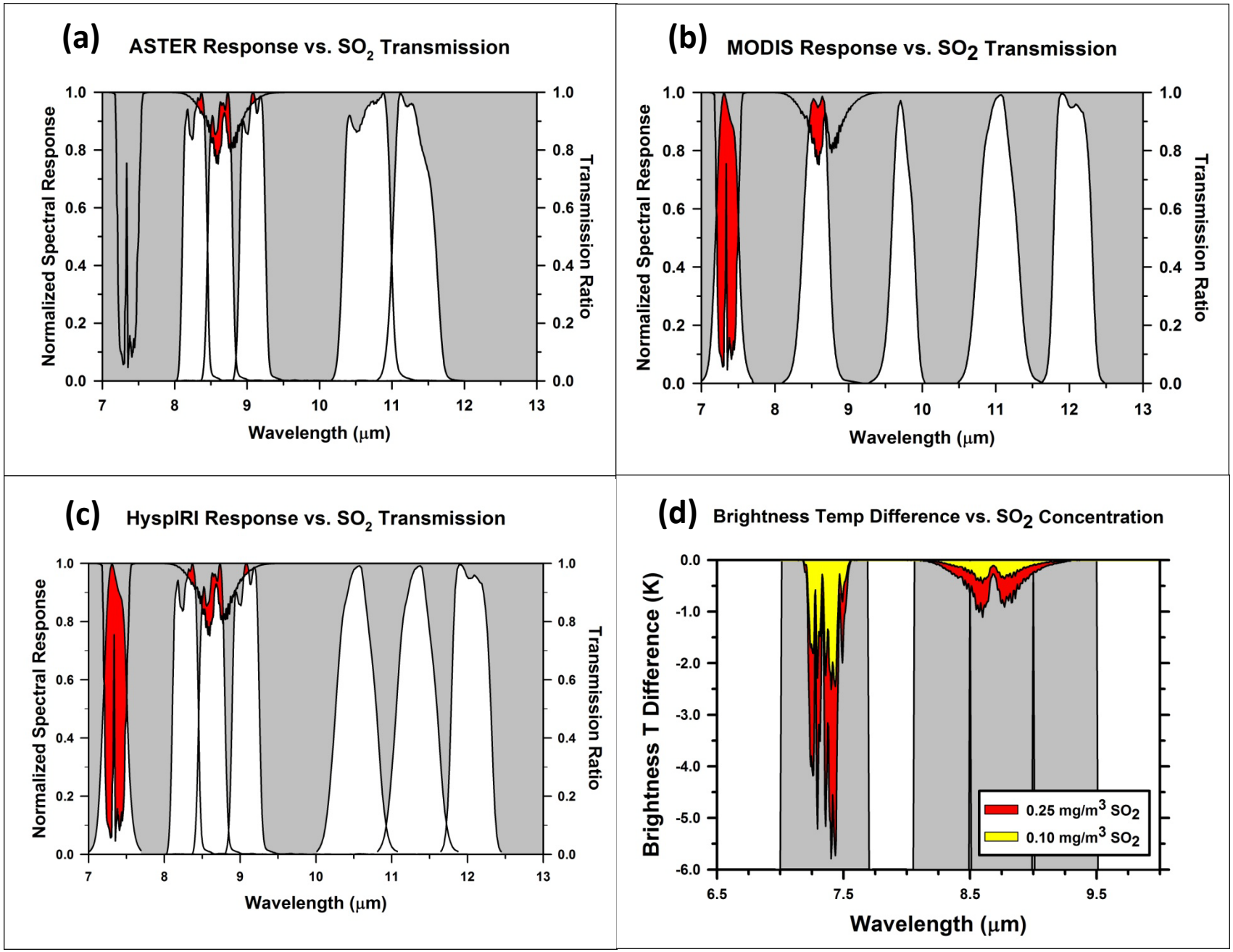
Can We Separate Effects of H_2O and SO_2?

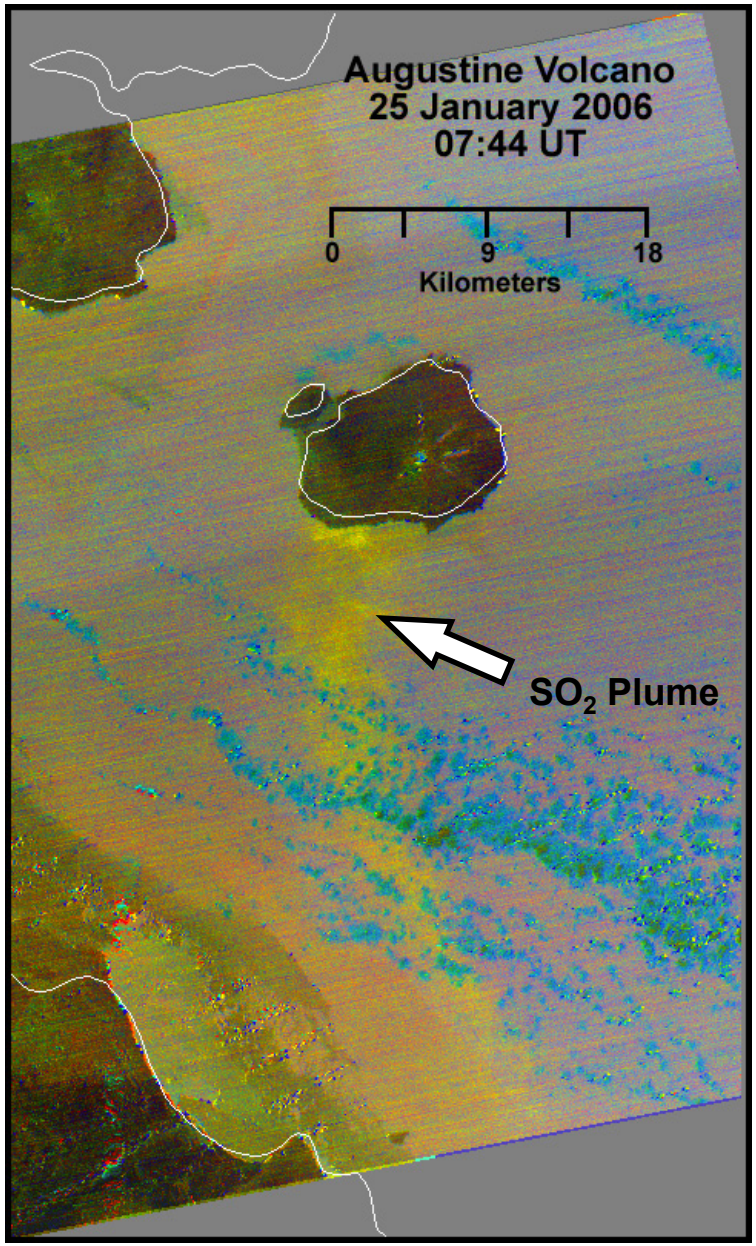
7.3 μm Not Suitable for Mapping Plumes Below 5 km? [Prata et al., 2003]



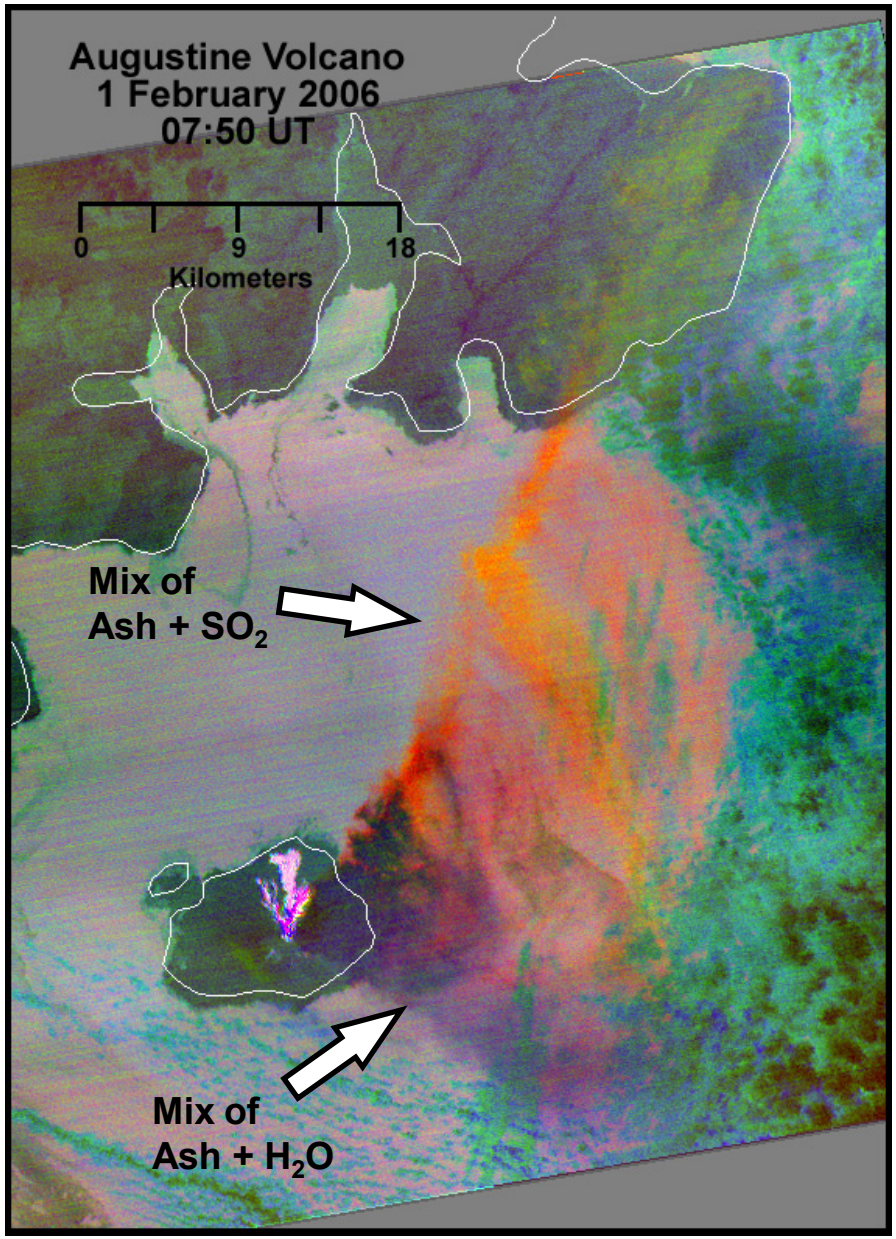


Heritage for HyspIRI Spectral Response

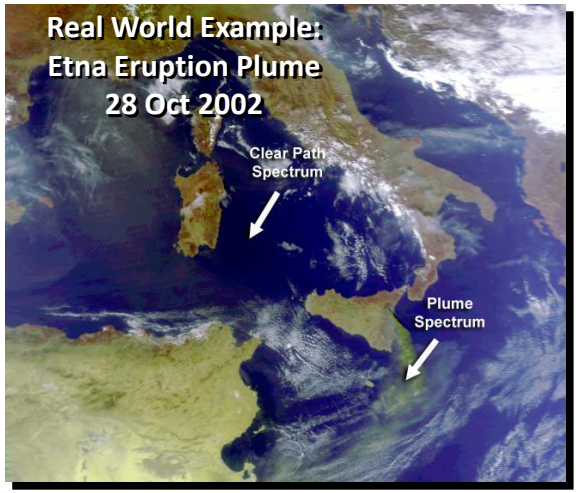


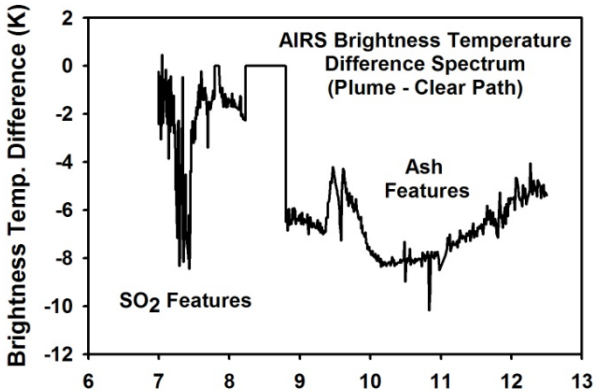


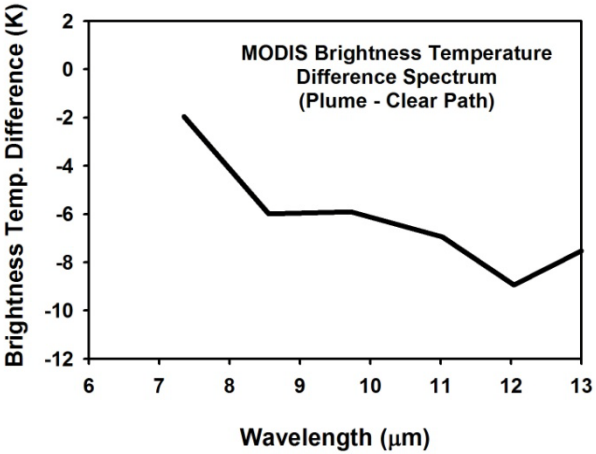
ASTER D-Stretch Depicting the Passive Emission of SO_2

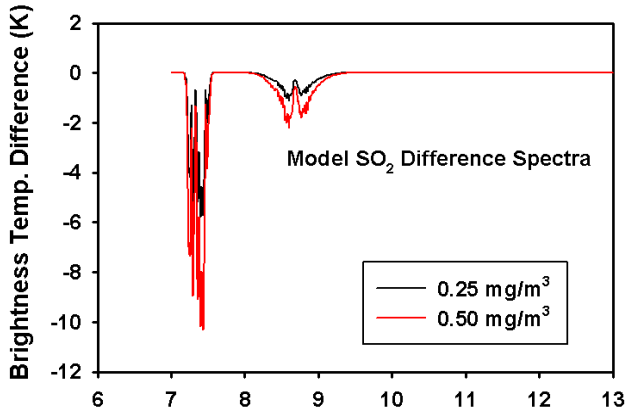


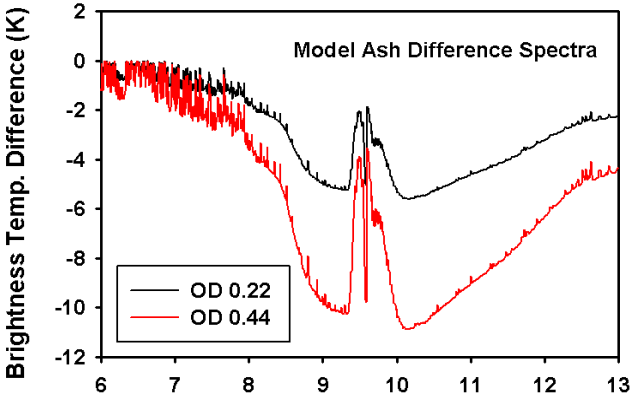
ASTER D-Stretch Depicting Ash, water/ice, and SO_2 Released by Explosive Eruption

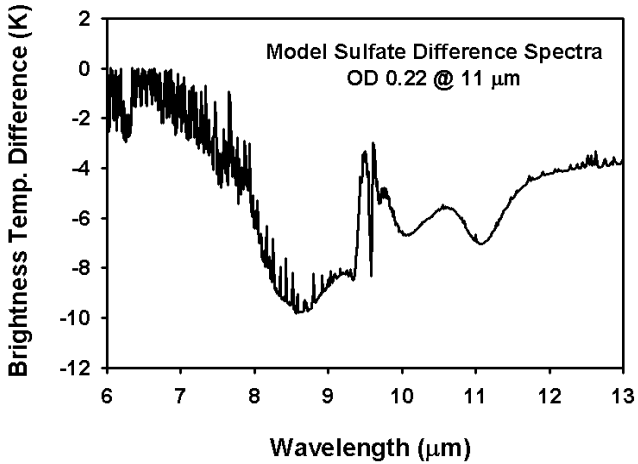




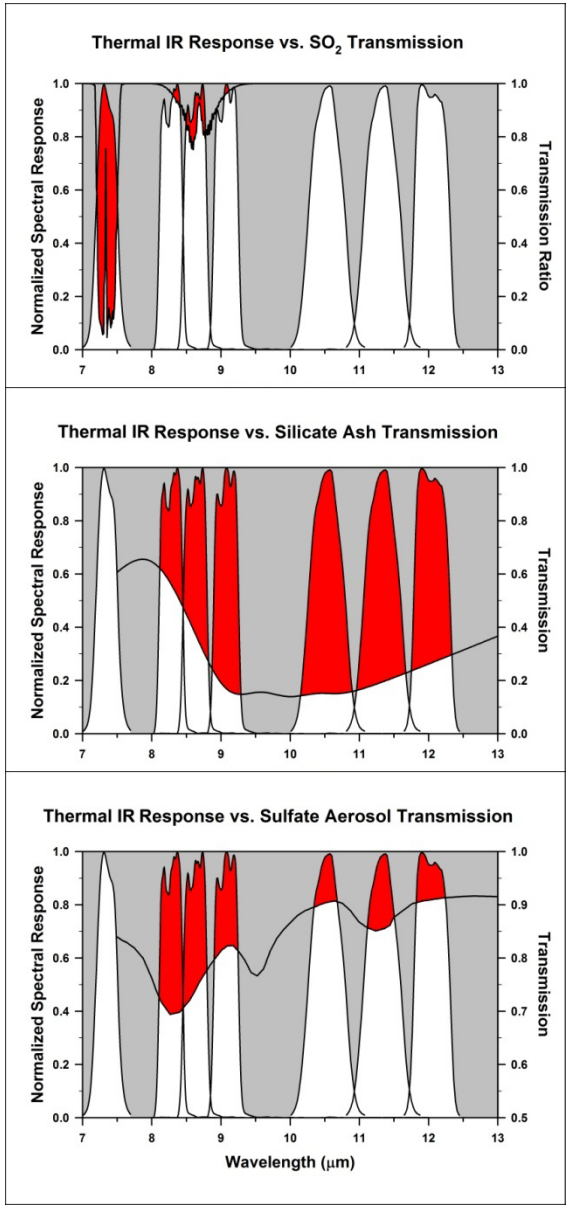








Notional HyspIRI TIR Response vs. Spectra of Plume Materials



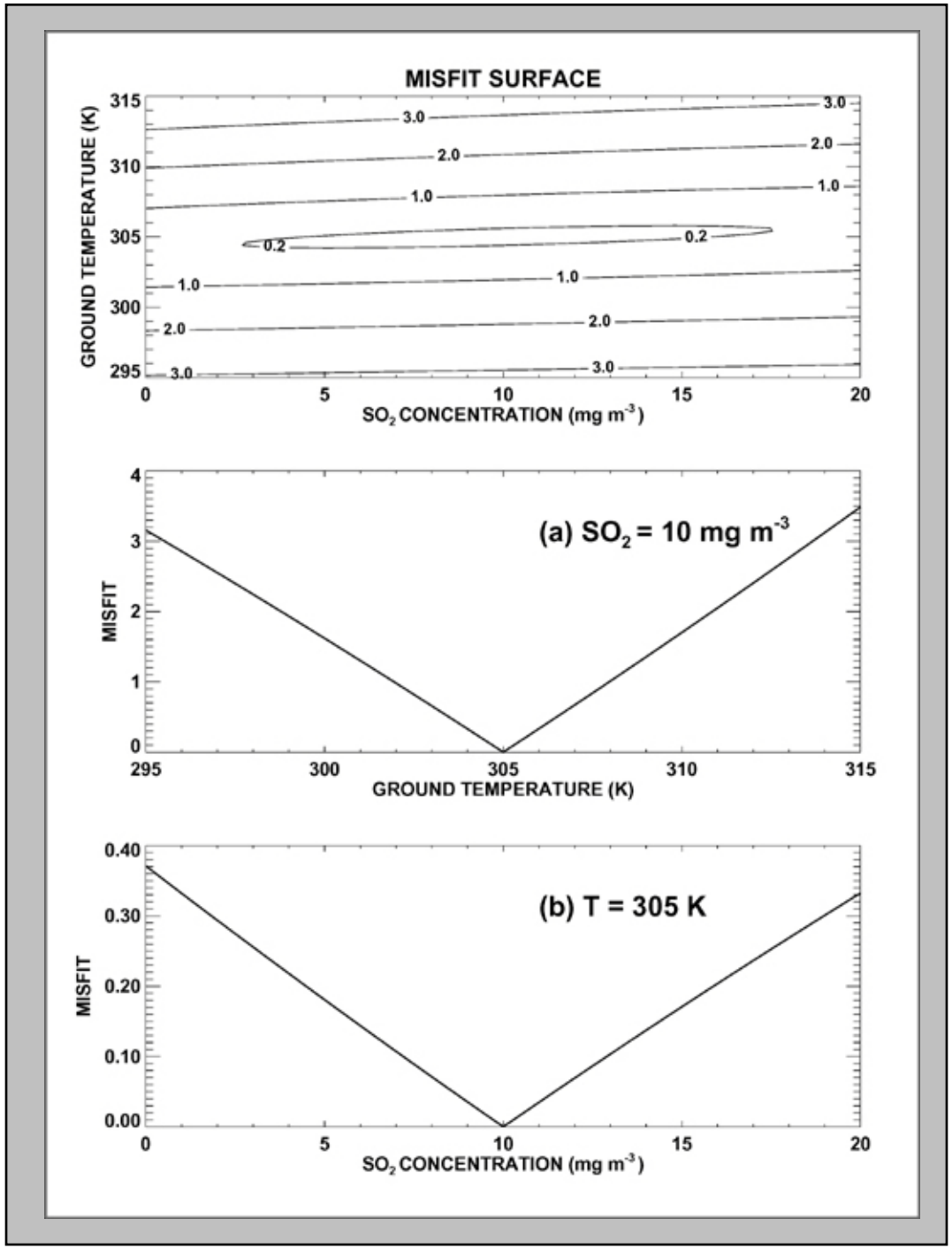
Retrieval of Surface Temperature and SO_2 Concentration

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

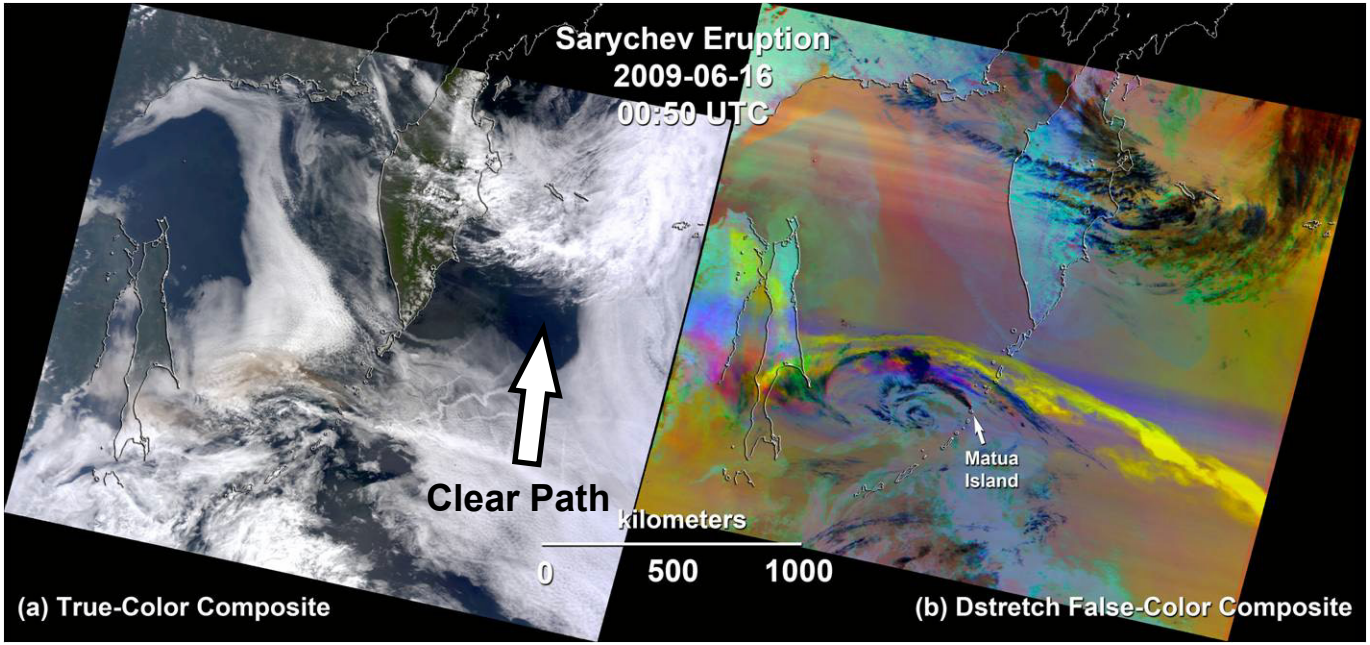
Radiance Spectra from Clear Path (Plume-Free) Regions are used to "Tune" the H_2O and O_3 Profiles

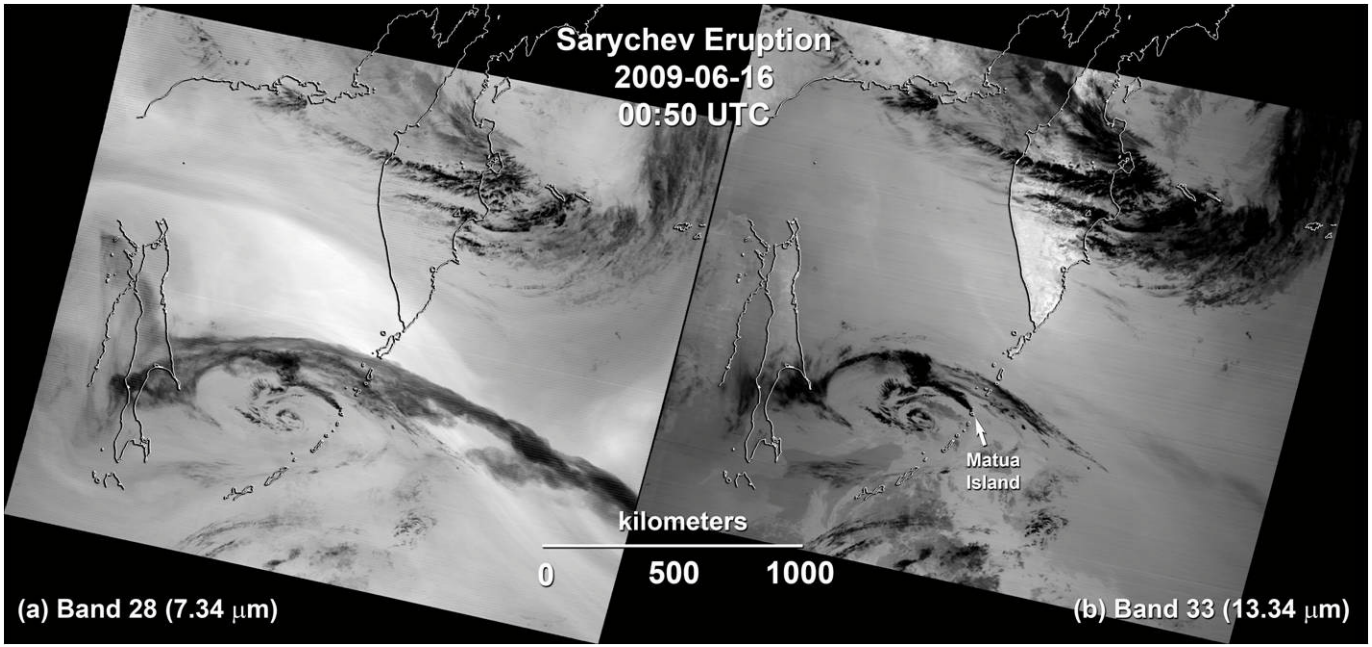
Tuning is a Time-Consuming Process: Retrieval of H_2O is More Efficient and a Better Characterization of Variations in H_2O

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

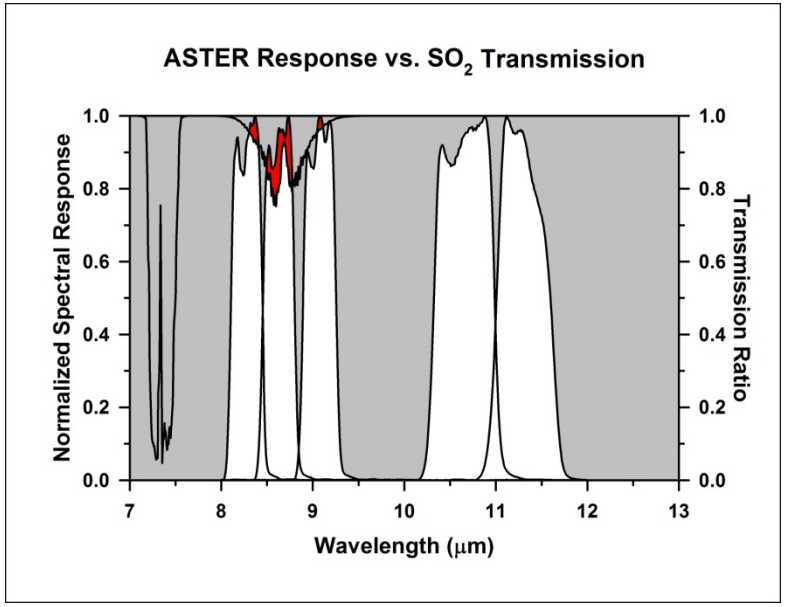
- ASTER, HyspIRI, MODIS 29-32, MODIS 28-32, and MODIS 29-33

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



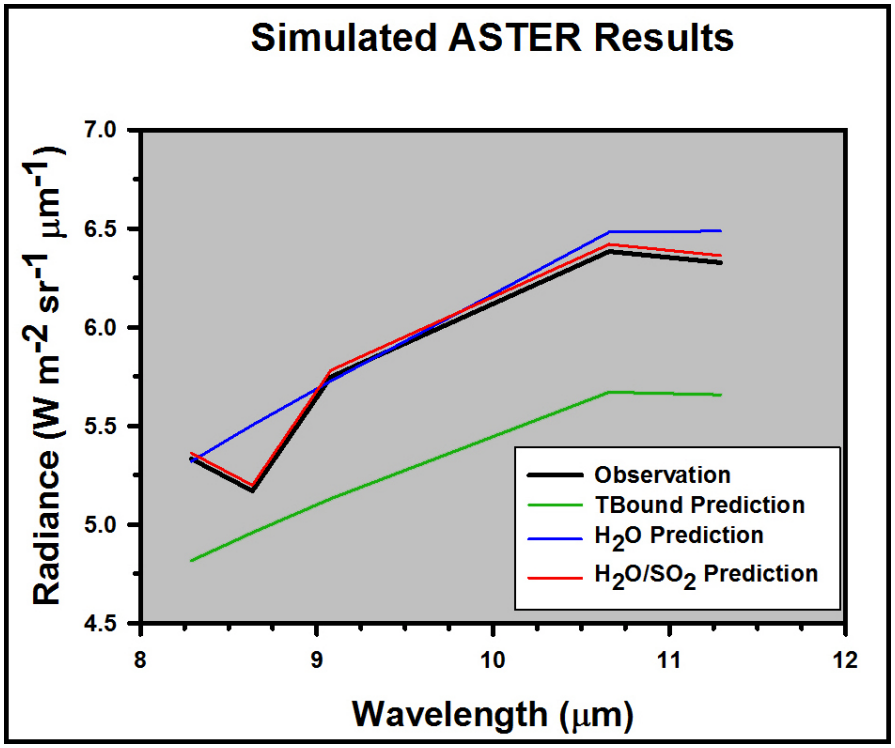
ASTER Simulation Results

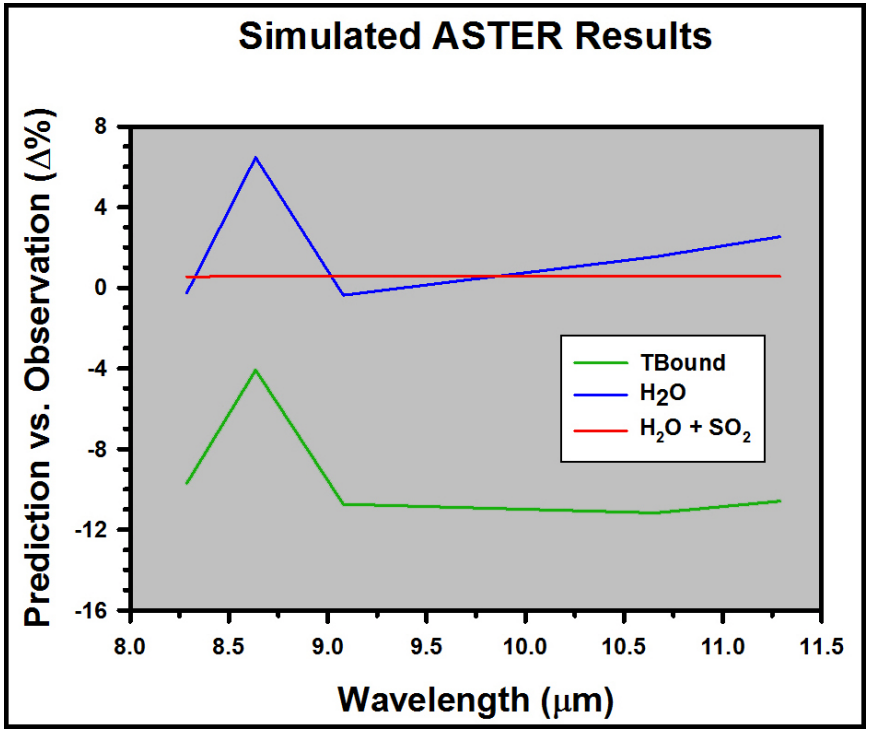
Temperature Under-Estimated, Misfit Spectrum 4 – 10%

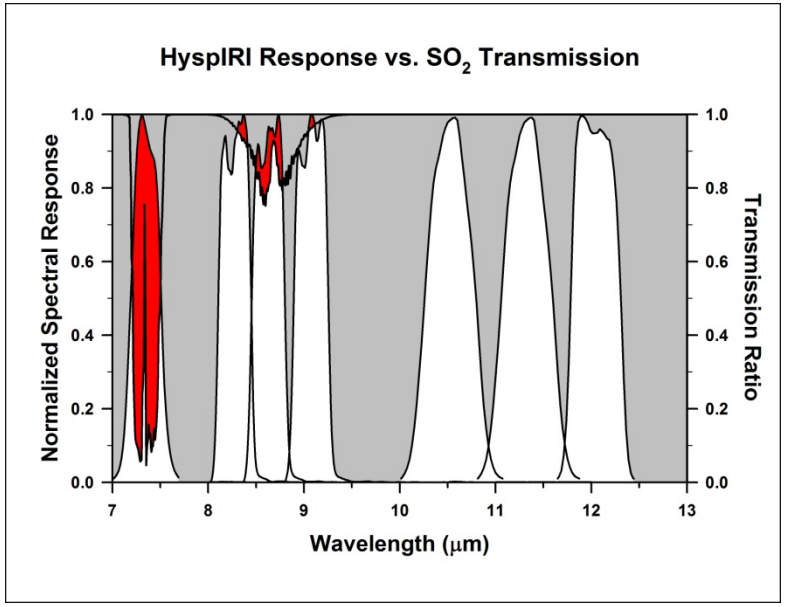
H_2O: Misfit Spectrum < 6%

$H_2O + SO_2$: Misfit Spectrum < 2%

Δ% Axis Range = 24%







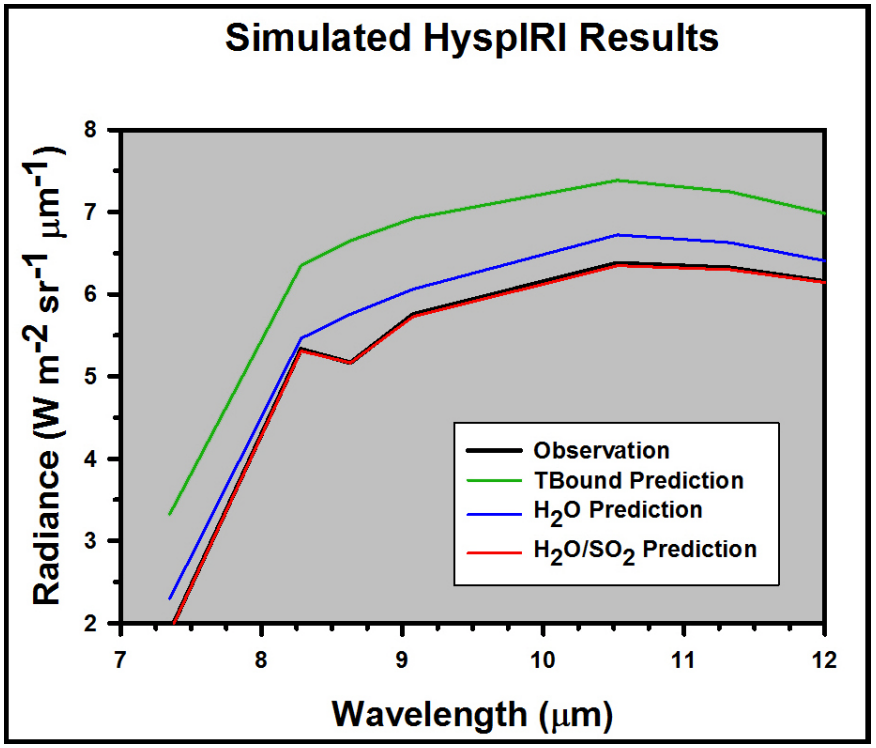
HyspIRI Simulation Results

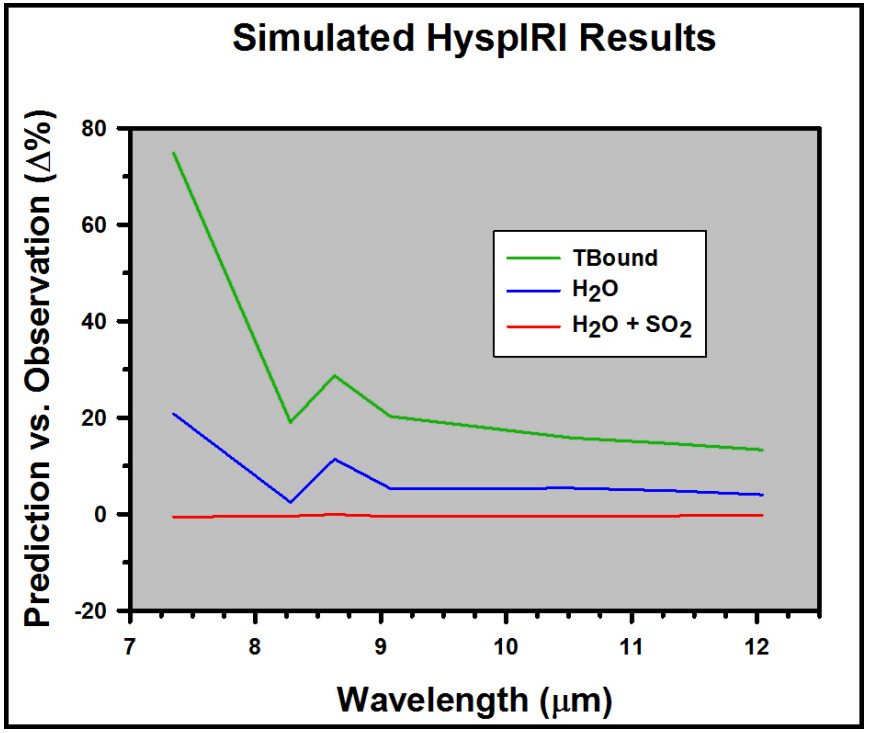
Temperature Over-Estimated, Misfit Spectrum ~75% at 7.3 μm

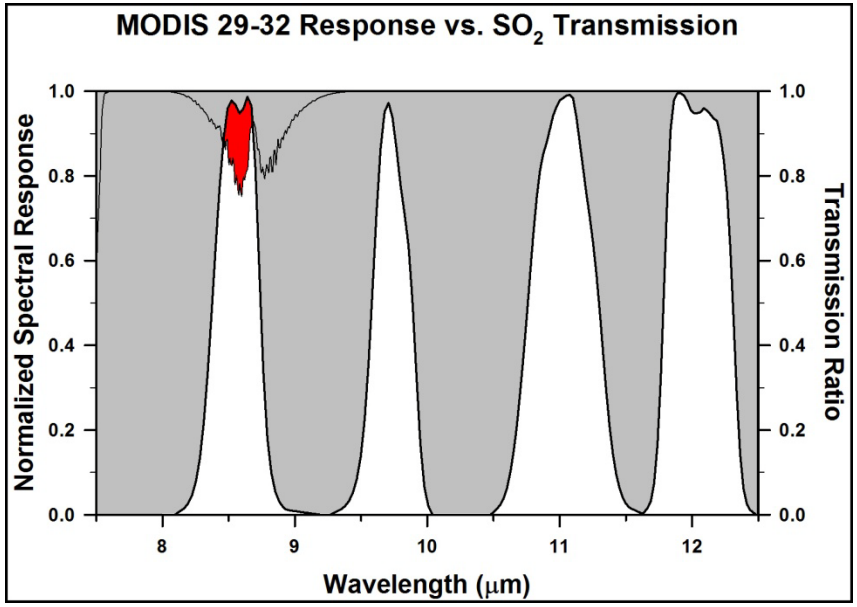
H_2O: Misfit ~20% at 7.3 μm

$H_2O + SO_2$: Misfit Spectrum < 2%

Δ% Axis Range = 100%







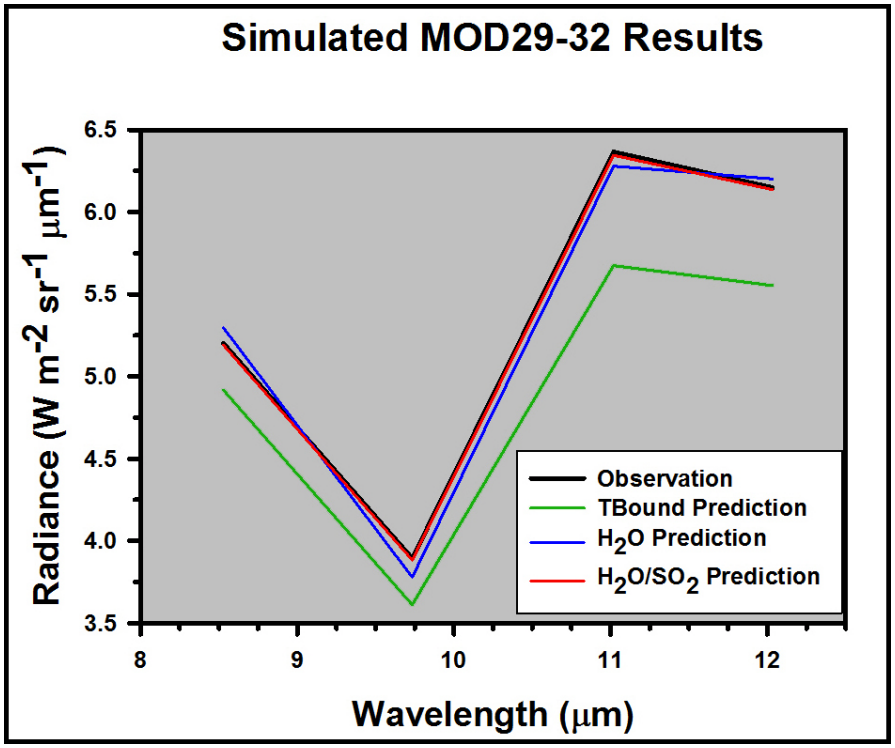
MODIS 29-32 Simulation Results

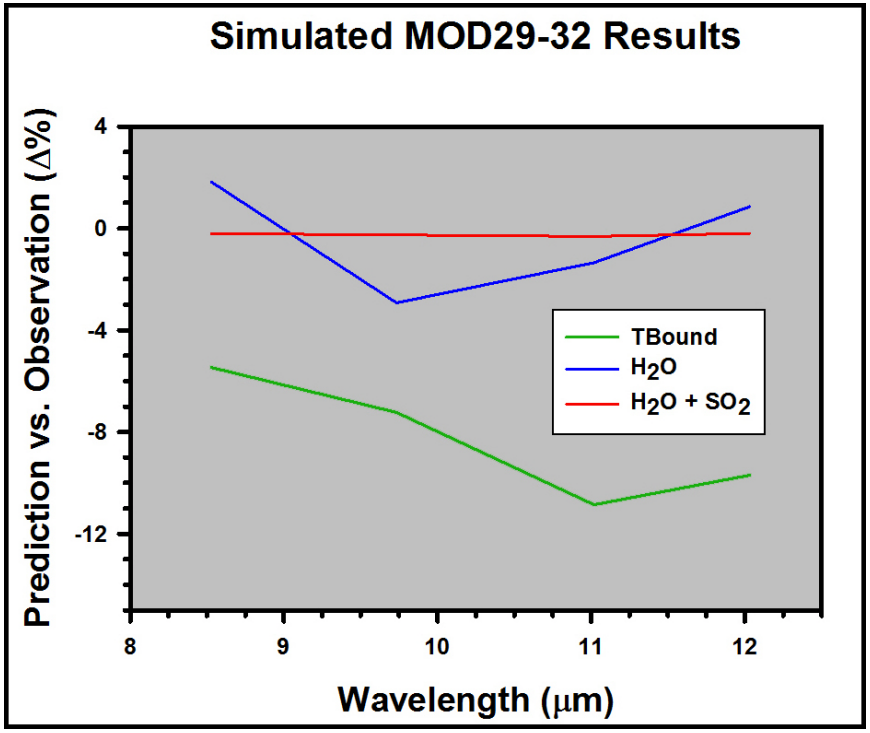
Temperature Under-Estimated, Misfit Spectrum Between 5 – 11%

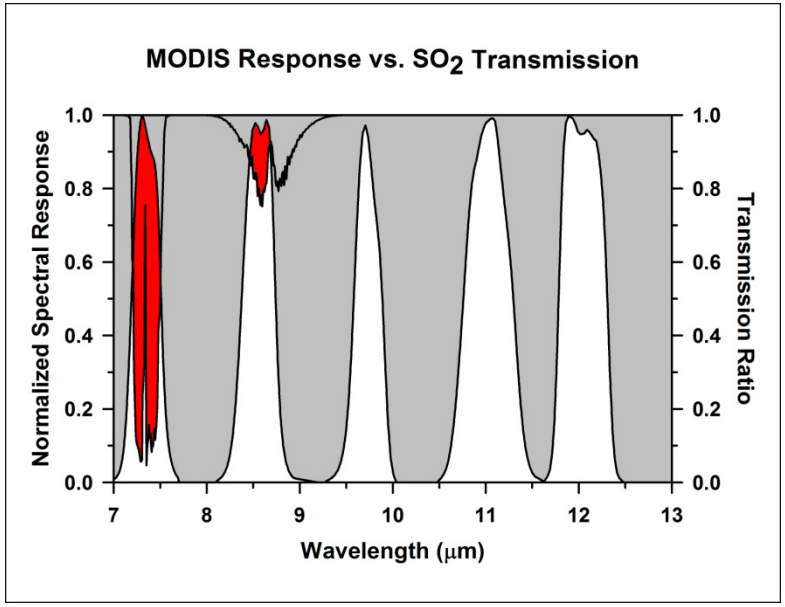
H_2O: Misfit Within ±3%

$H_2O + SO_2$: Misfit Spectrum < 1%

Δ% Axis Range = 19%







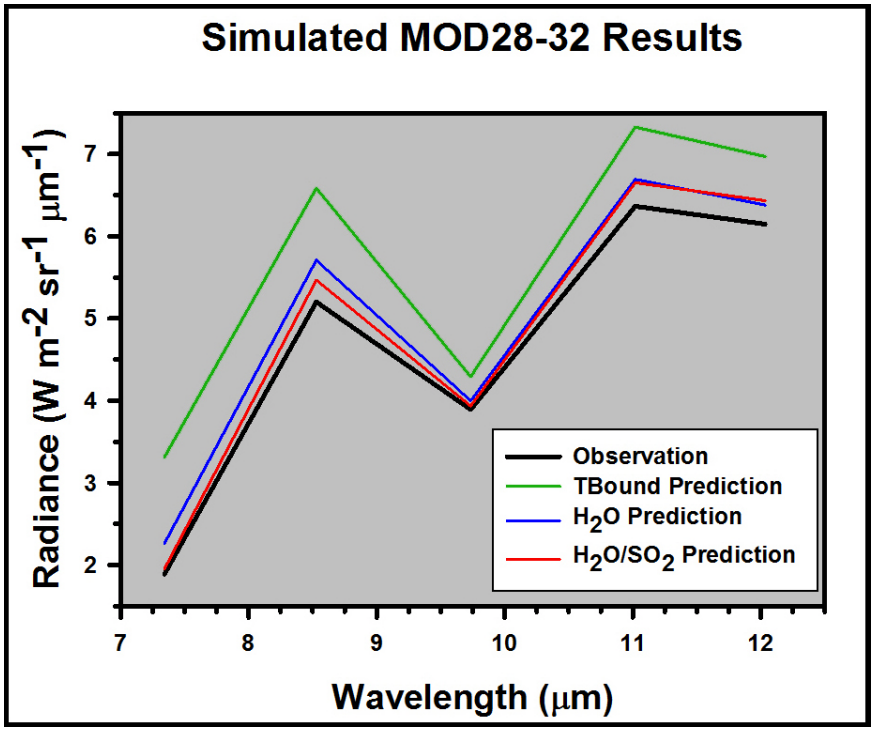
MODIS 28-32 Simulation Results

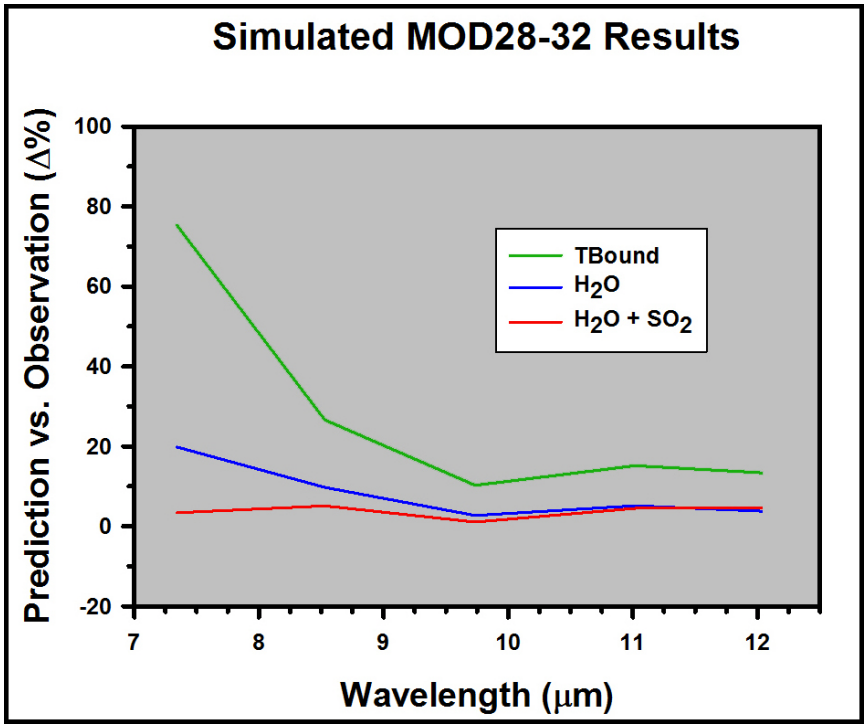
Temperature Over-Estimated, Misfit Spectrum ~80% at 7.3 μm

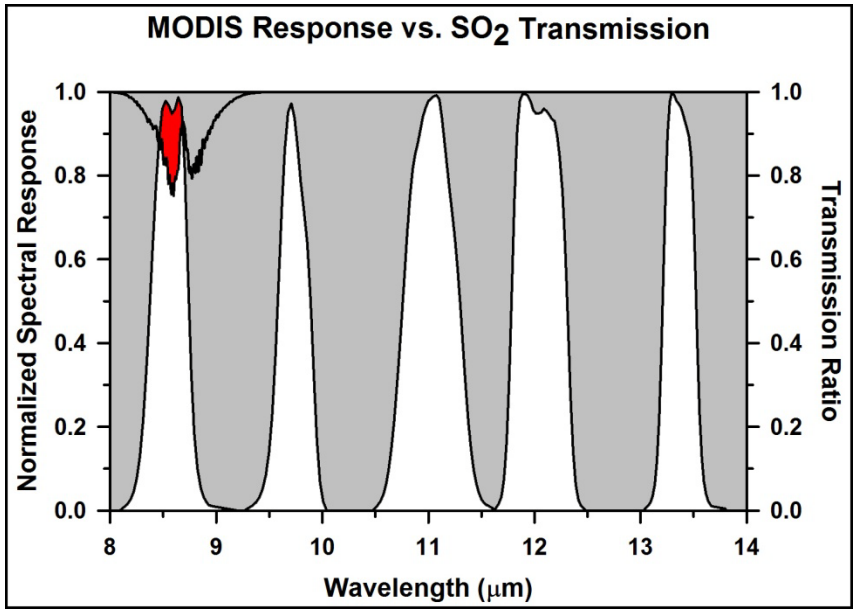
H_2O: Misfit ~20% at 7.3 μm

H_2O + SO_2: Misfit Spectrum < 10%

Δ% Axis Range = 120% (Worst Misfit)







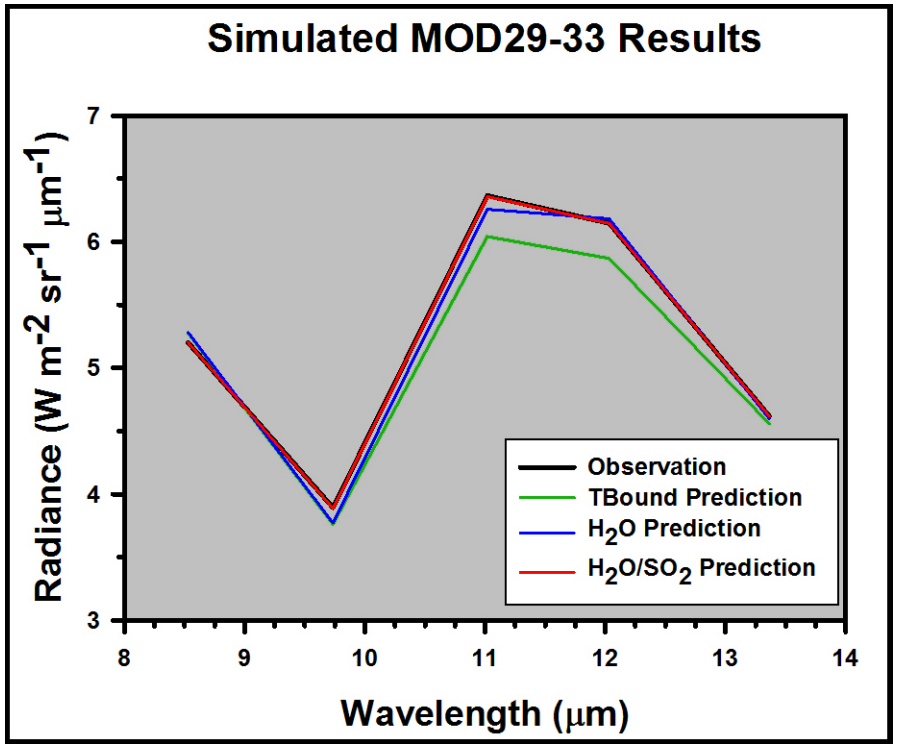
MODIS 29-33 Simulation Results

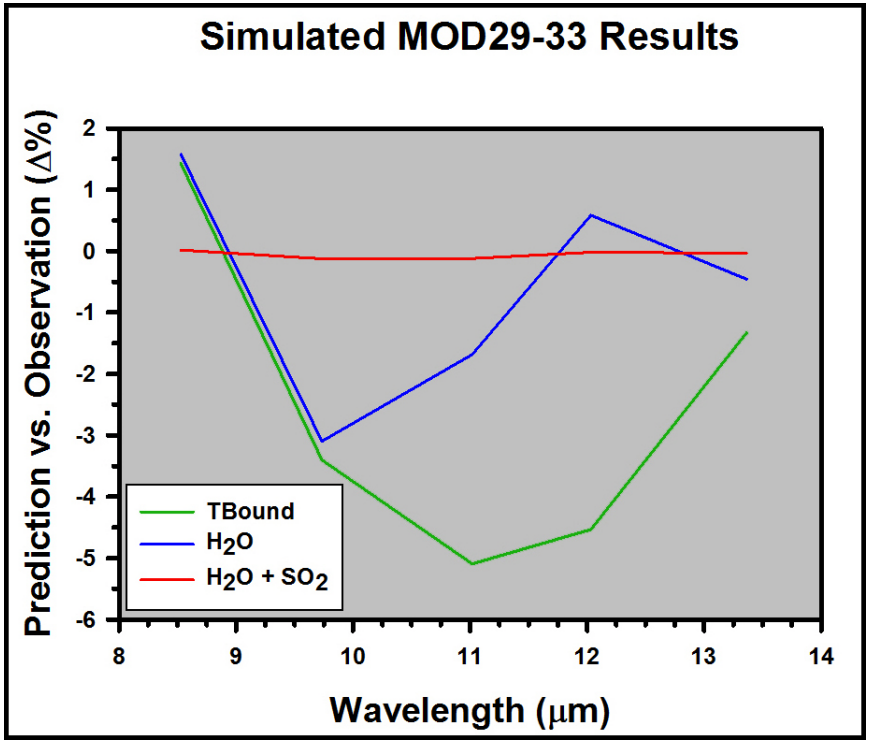
Temperature Under-Estimated, Misfit Spectrum < 6%

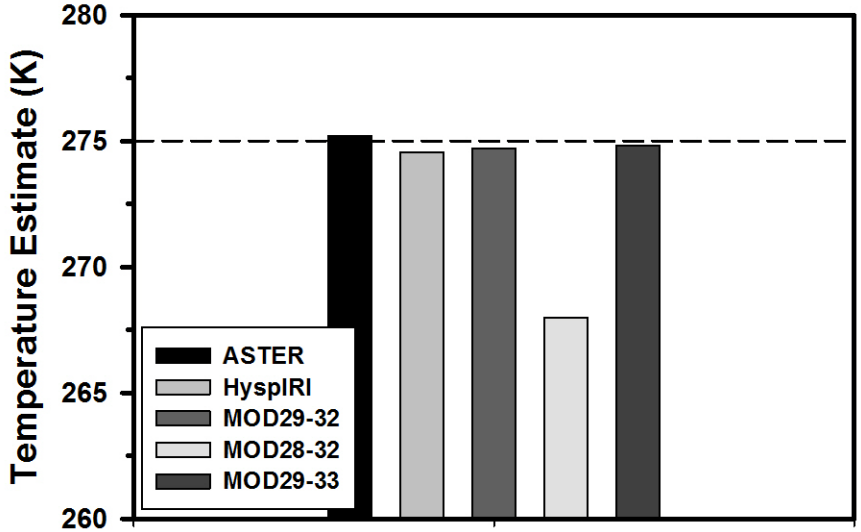
H_2O: Misfit < 3%

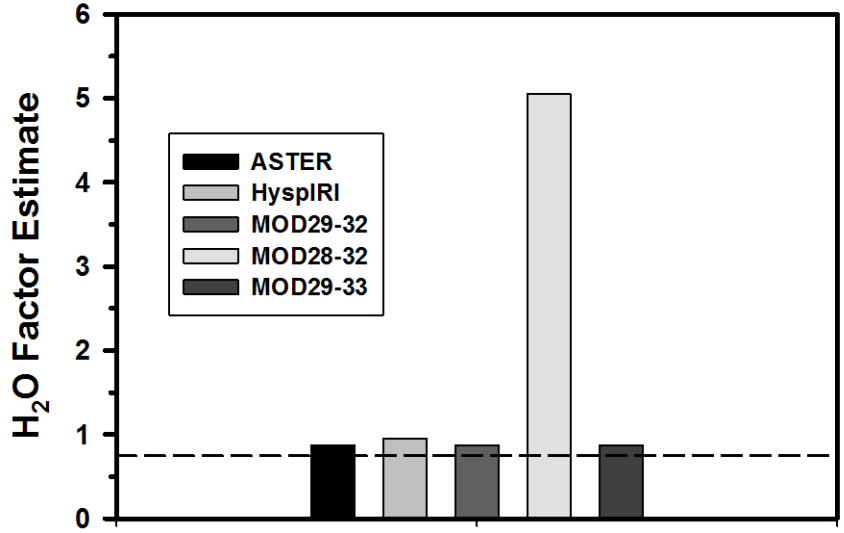
$H_2O + SO_2$: Misfit Spectrum < 1%

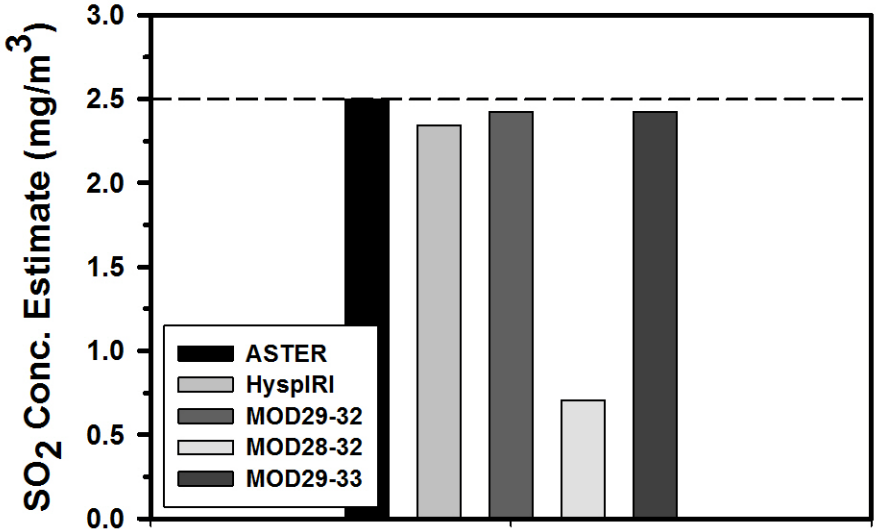
Δ% Axis Range = 8% (Best Misfit)











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

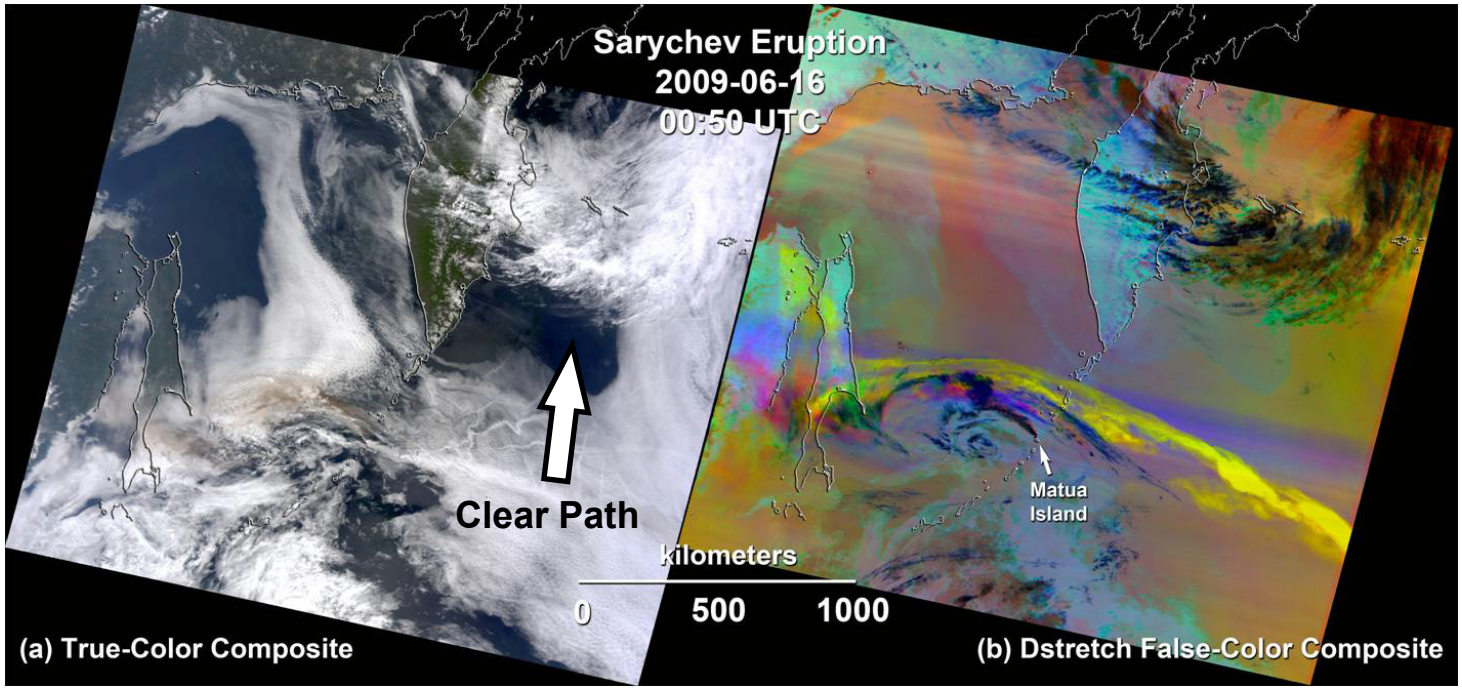
MODIS-Based Retrievals of H_2O and SO_2

Evaluate Three Configurations of Channels

MODIS 29-32, MODIS 28-32, and MODIS 29-33

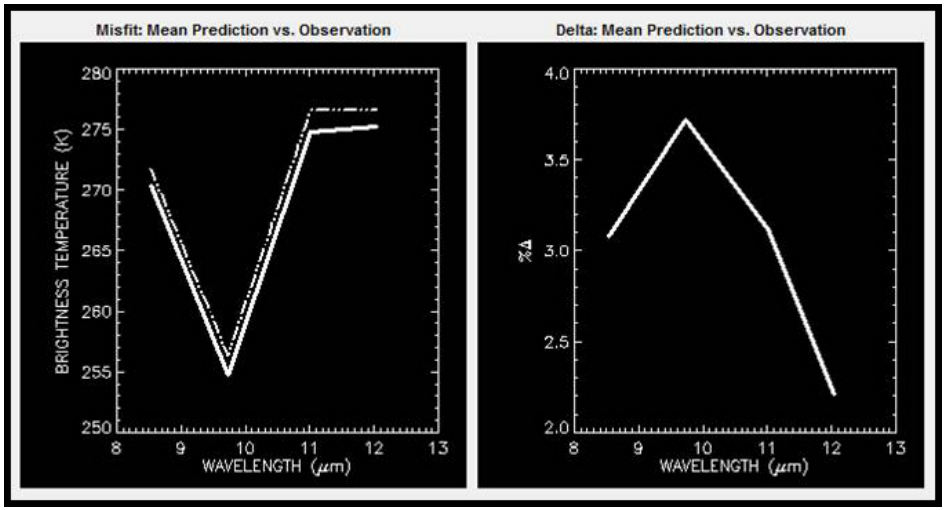
Compare Temperature and SO_2 Retrievals with Fixed and Free H_2O Factors

Region-of-Interest Included SO_2, Ash, and Clear-Path Pixels

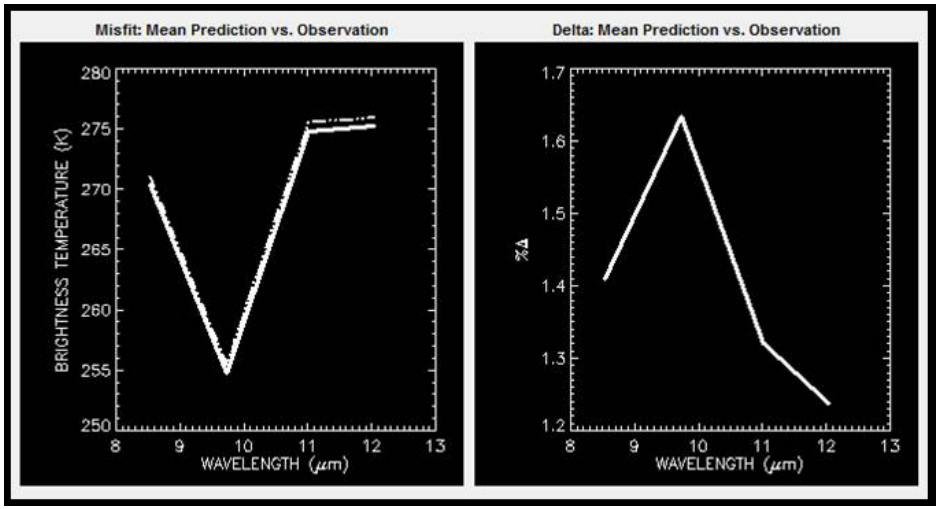


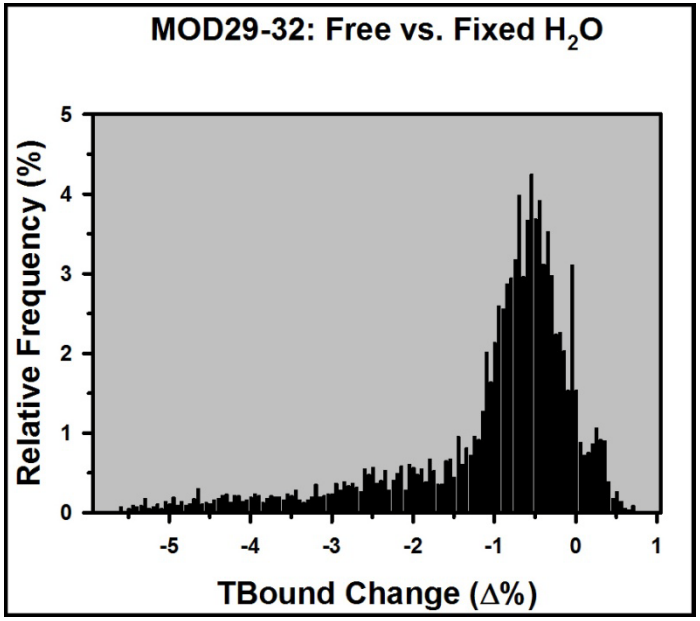
MODIS 29 – 32 Results

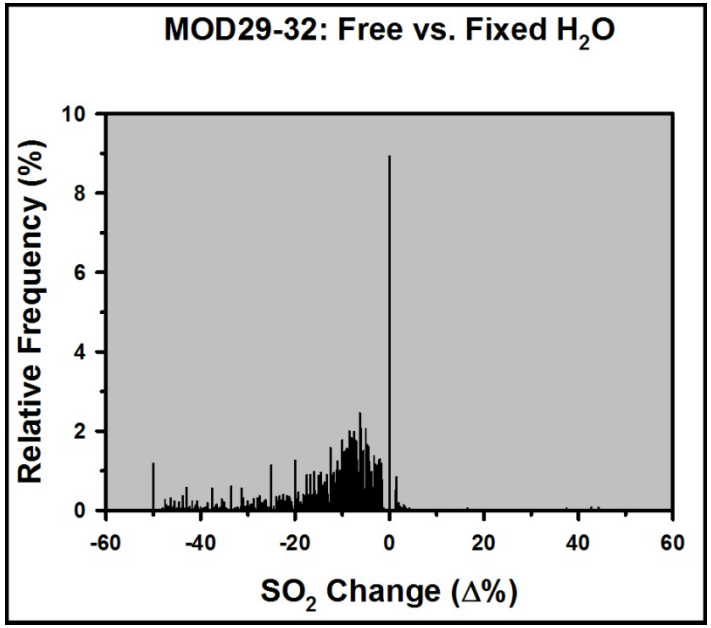
Fixed H_2O Factor



Free H_2O Factor







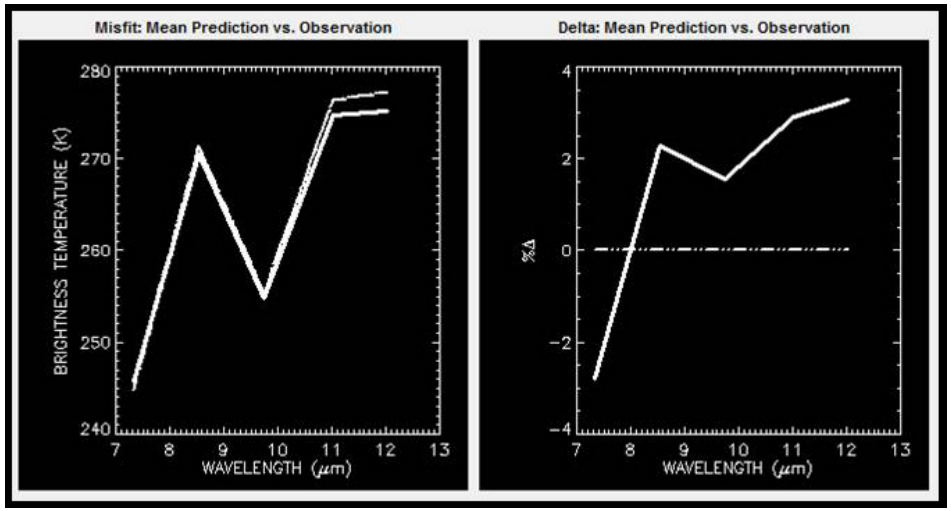
Improved Fit: Δ% Range Reduced from 2% to 0.5%

TBound Estimates Decreased ~0.5%

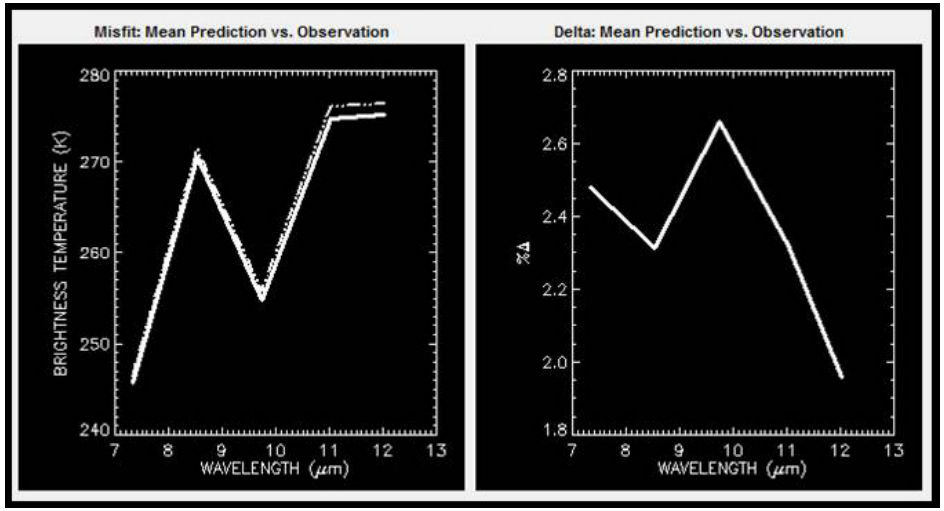
SO_2 Estimates Decreased 5 – 10%

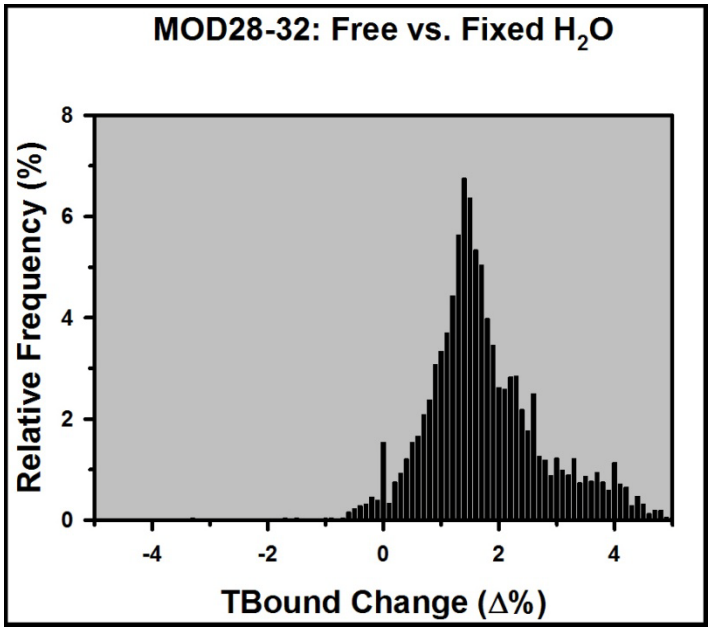
MODIS 28 – 32 Results

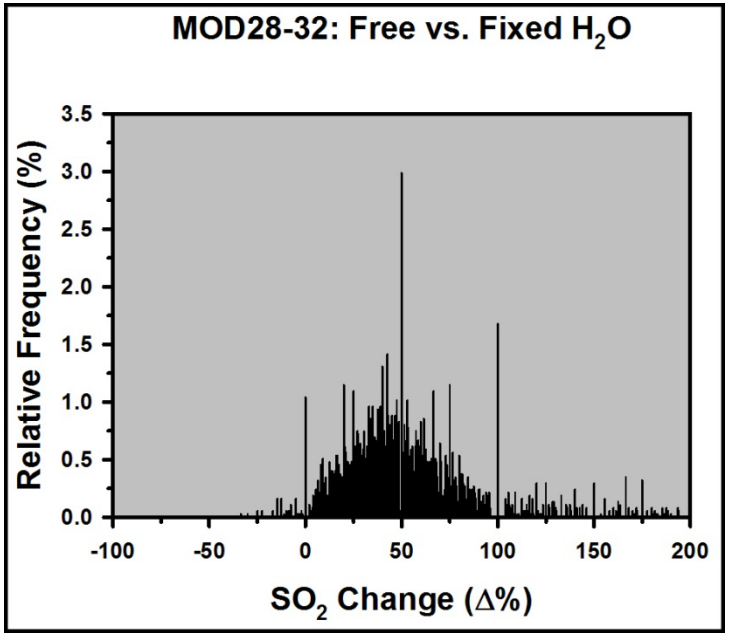
Fixed H_2O Factor



Free H_2O Factor







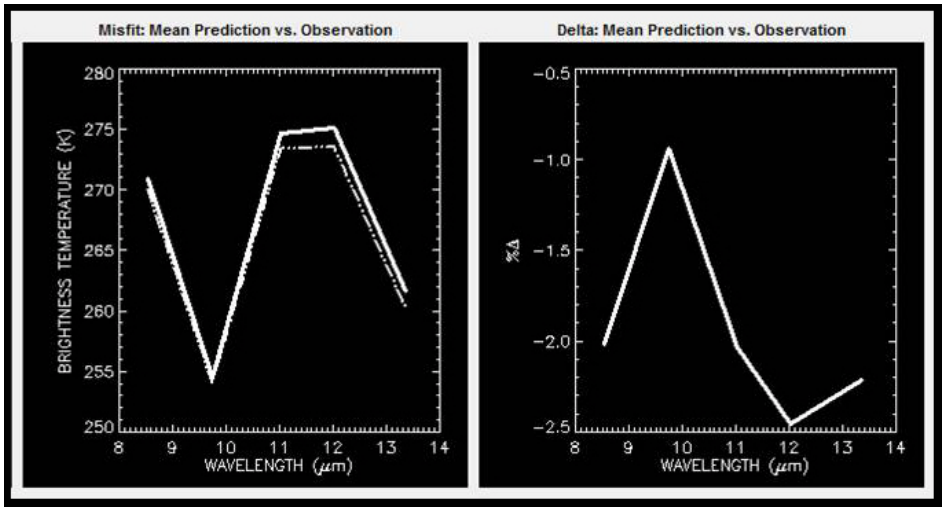
Improved Fit: Δ% Range Reduced from 8% to 1%

TBound Estimates Increased ~1.5%

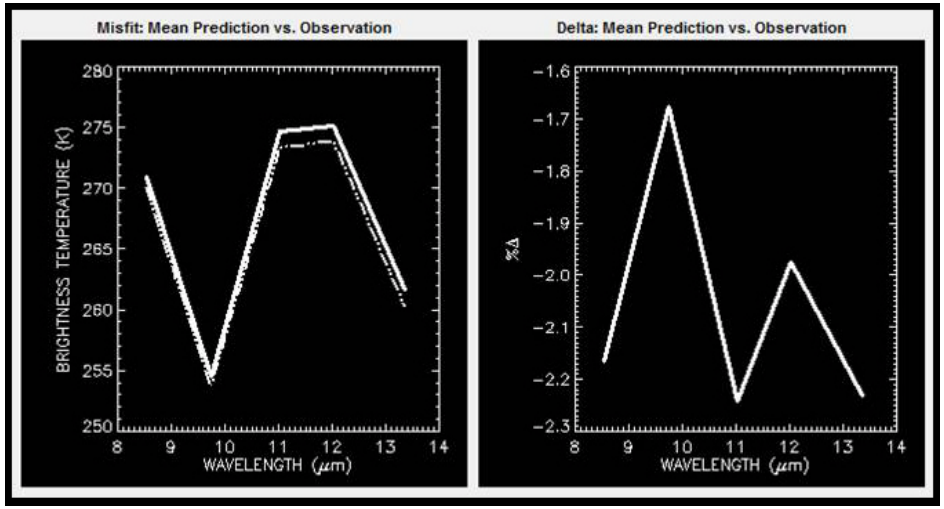
SO_2 Estimates Increased ~ 50%

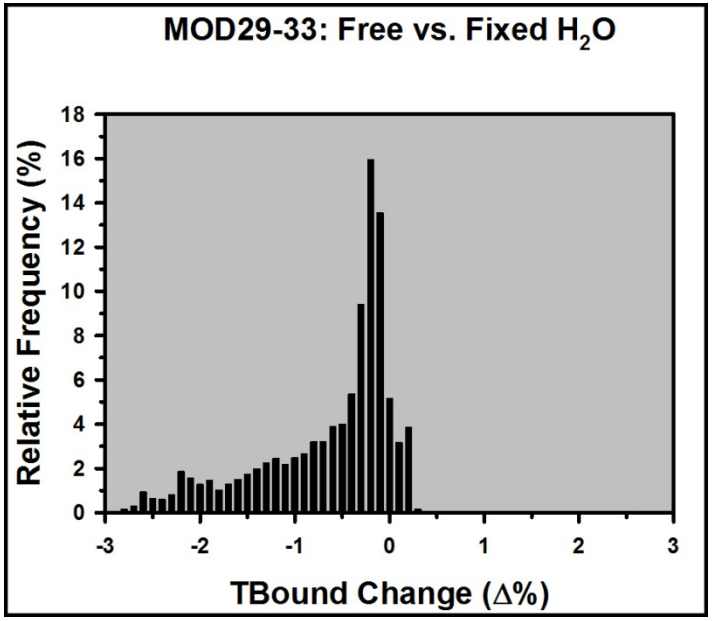
MODIS 29 – 33 Results

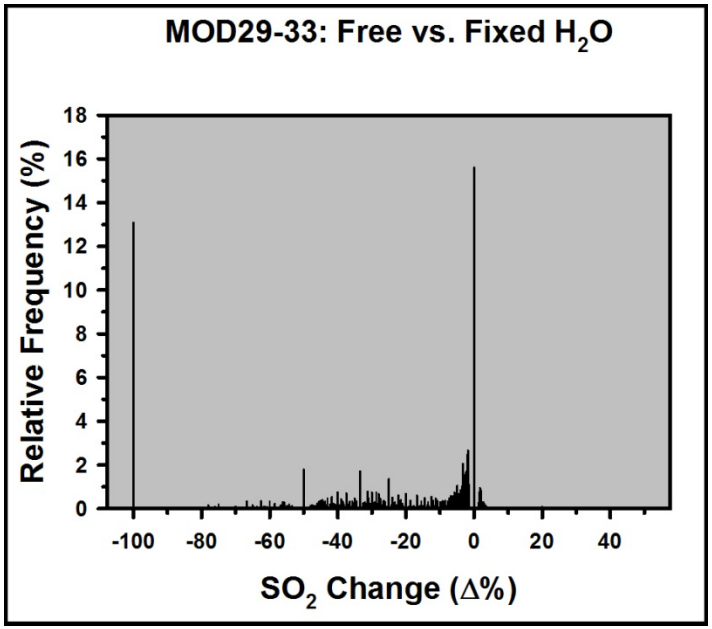
Fixed H_2O Factor



Free H_2O Factor







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

TBound Estimates Decreased < 0.5%

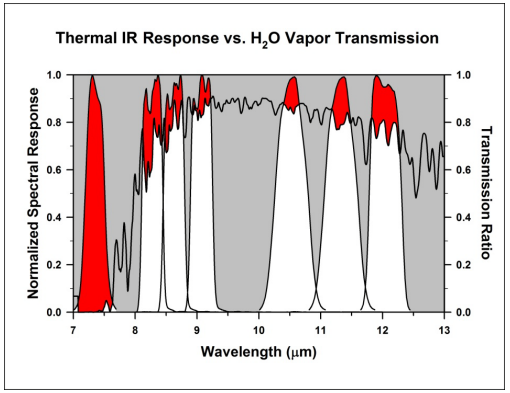
Problematic Interpretation of SO_2 Results:

Reduction in Estimates < 10% ?

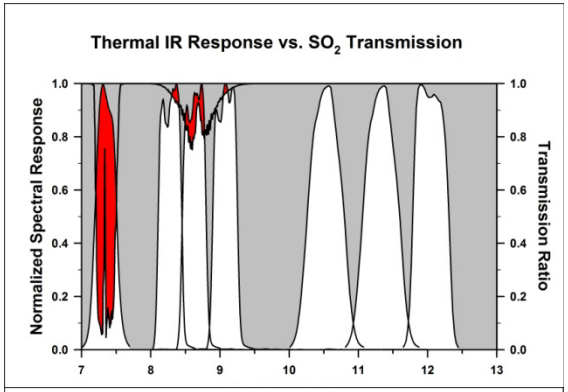
Spike @ -100% is Significant!

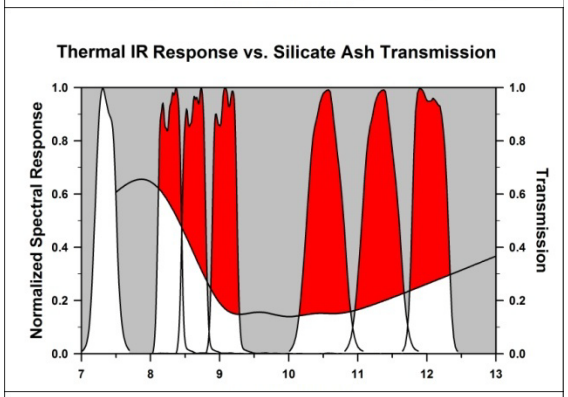
Spike @ 0 Change Significant?

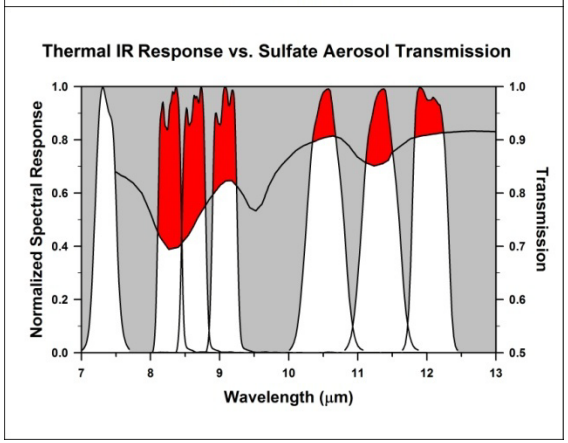
Summary Remarks



Notional HyspIRI TIR Response vs. Spectra of Plume Materials







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