AVIRIS and HyspIRI VSWIR Sensitivity to Atmospheric Carbon Dioxide Plumes

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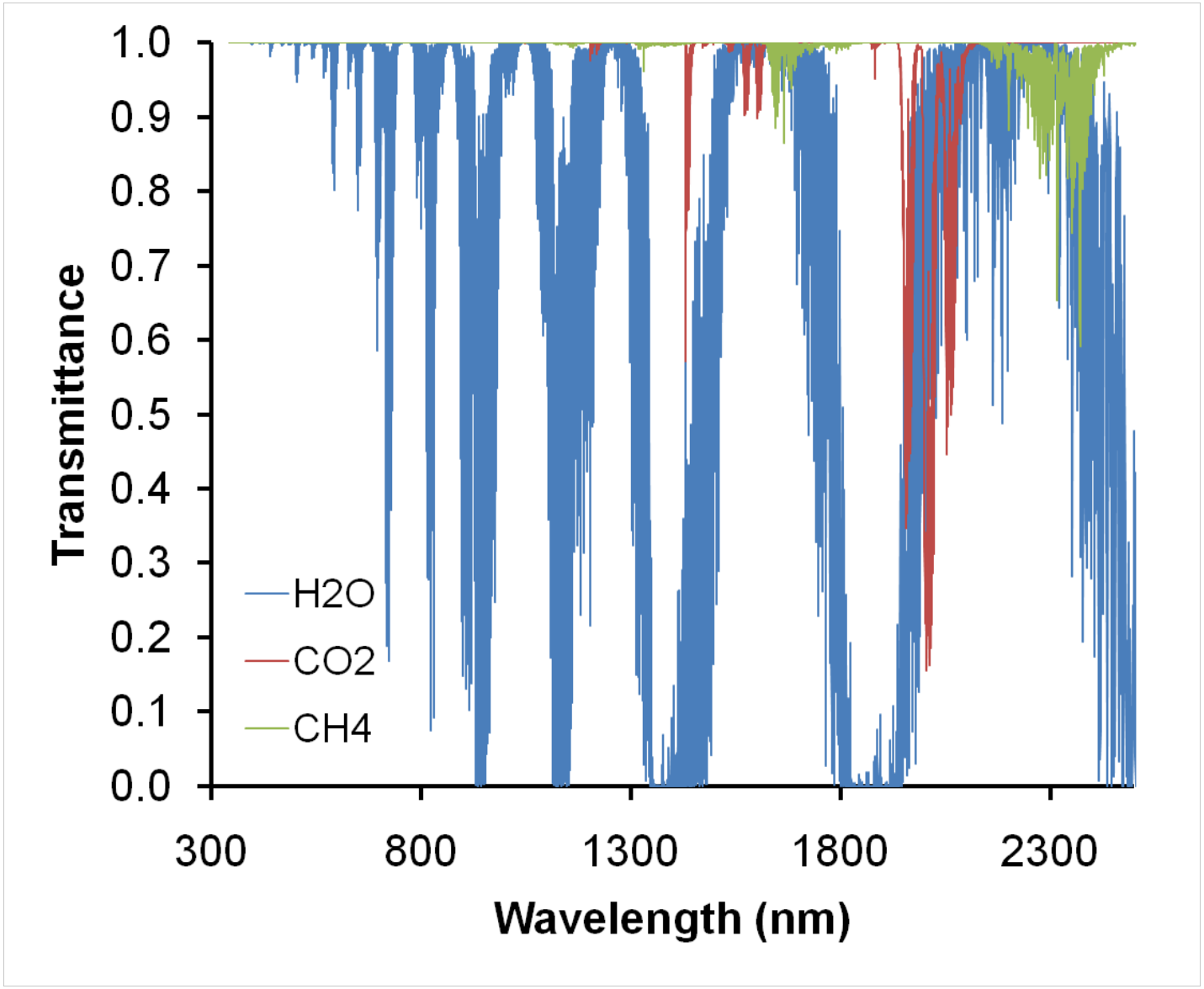
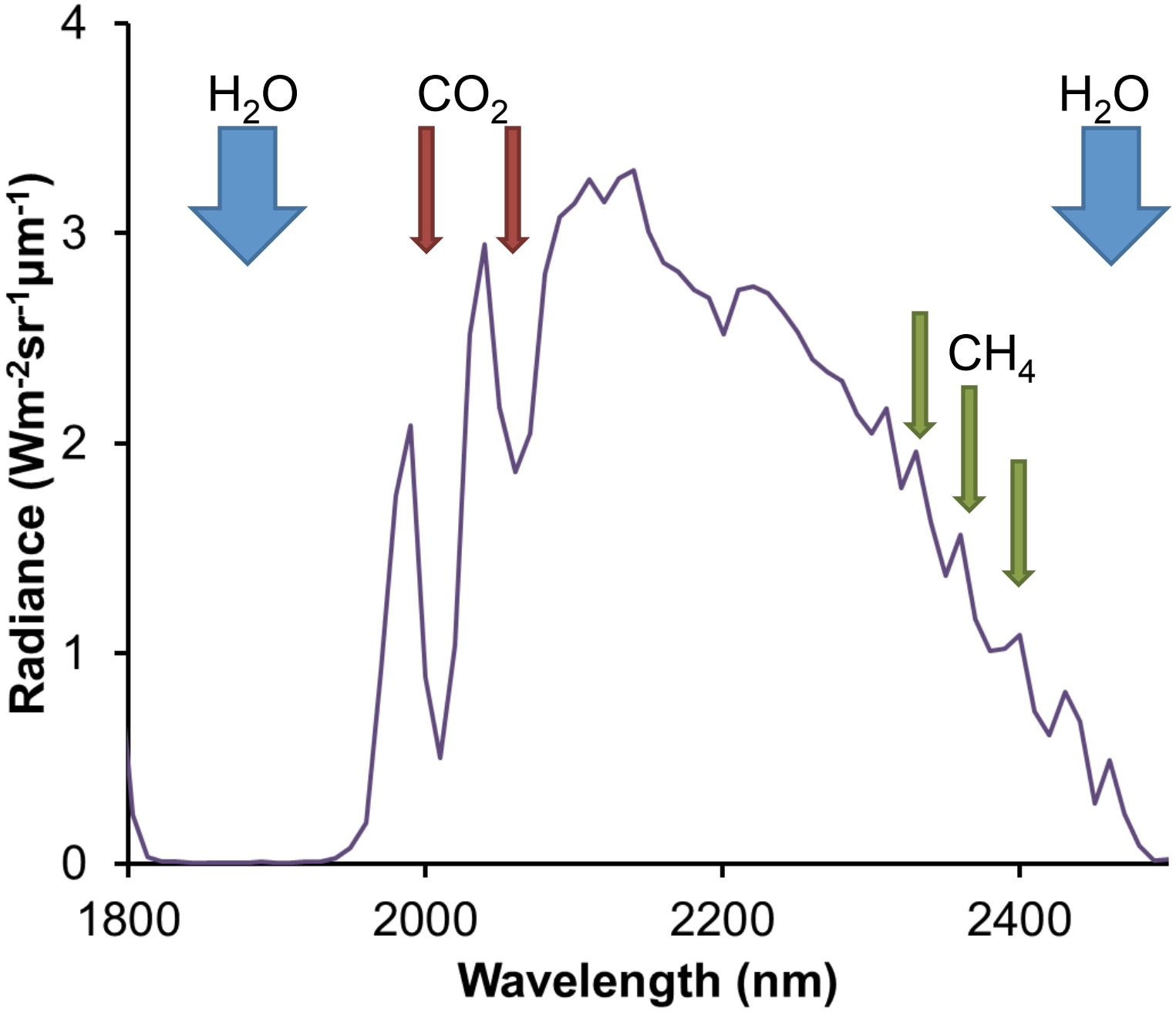
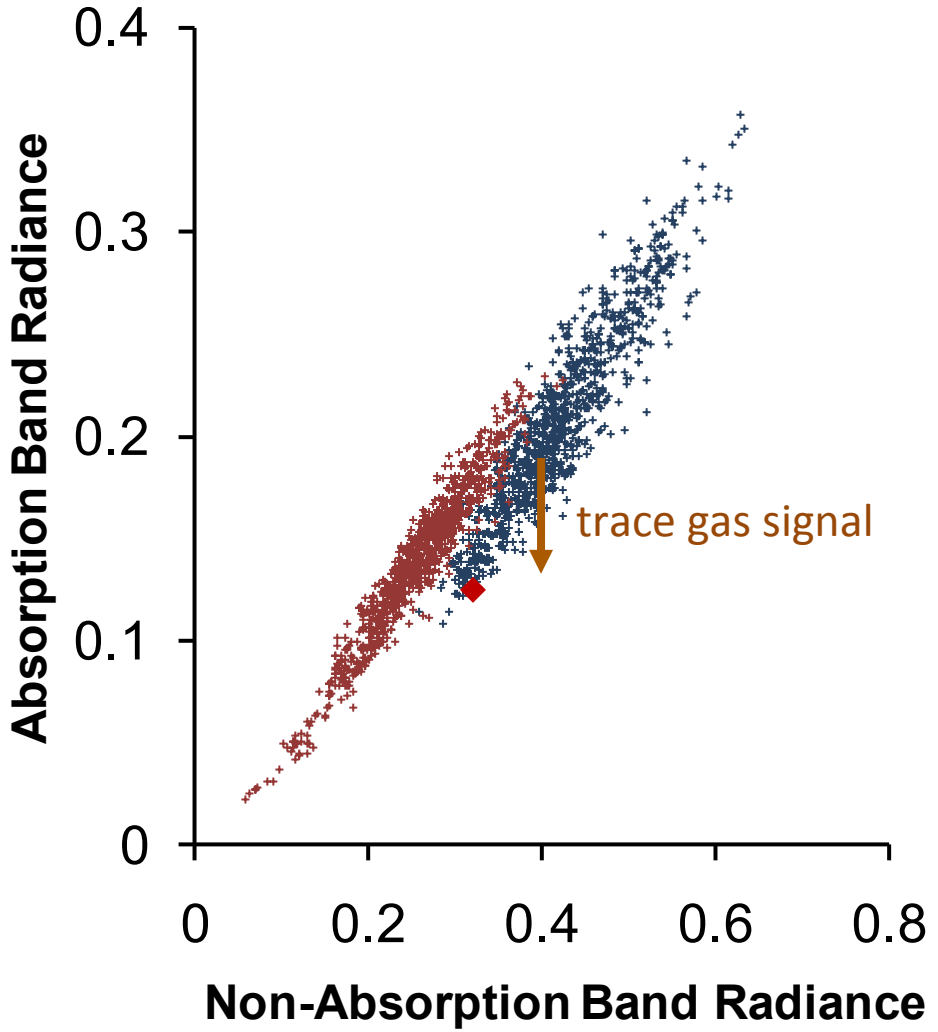
Trace Gas Absorption




H2O
CO2
H2O
CH4
Radiance (Wm-2sr-1µm-1)
0
1
2
3
4
1800
2000
2200
2400
Wavelength (nm)

Cluster-Tuned Matched Filter

- Applied to radiance data
- Uses k-means clustering to partition an image into multiple spectrally similar classes
- A matched filter is applied separately to each cluster to find outlier spectra matching the trace gas absorption spectrum

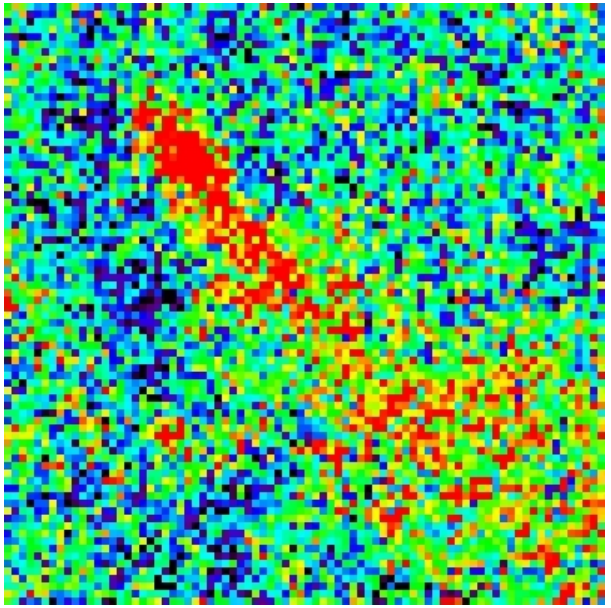


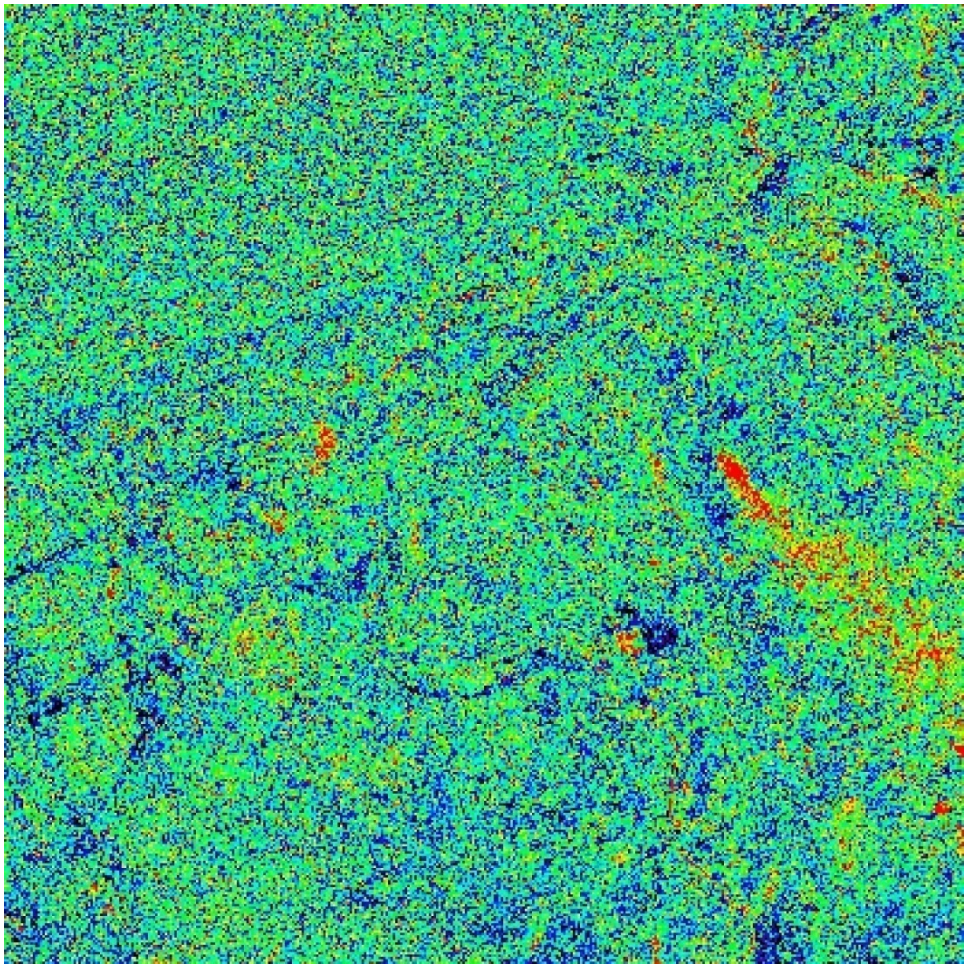
AVIRIS True Color Composite

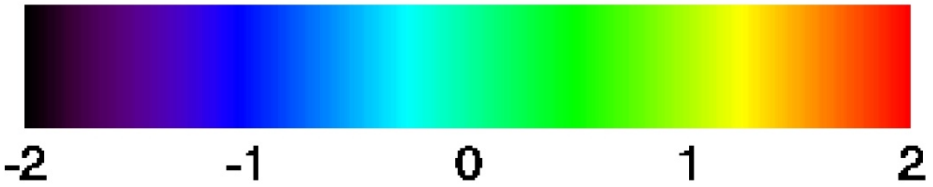
19 Jul 2011
7.4 m

Matched Filter Score

3.6
m/s

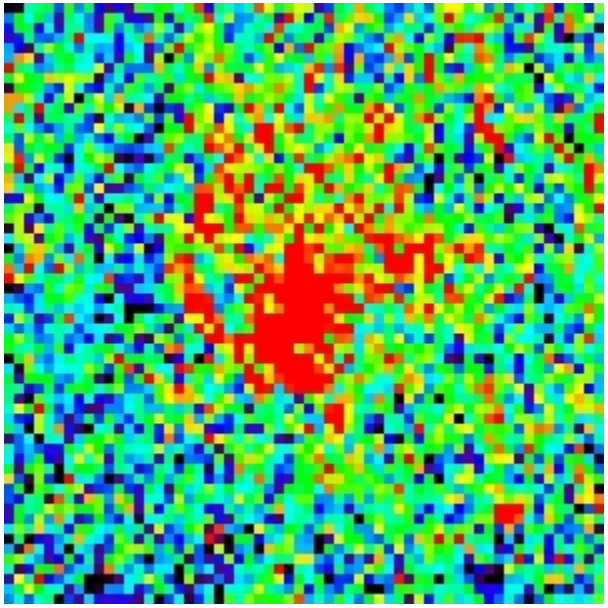




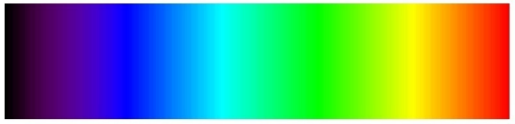


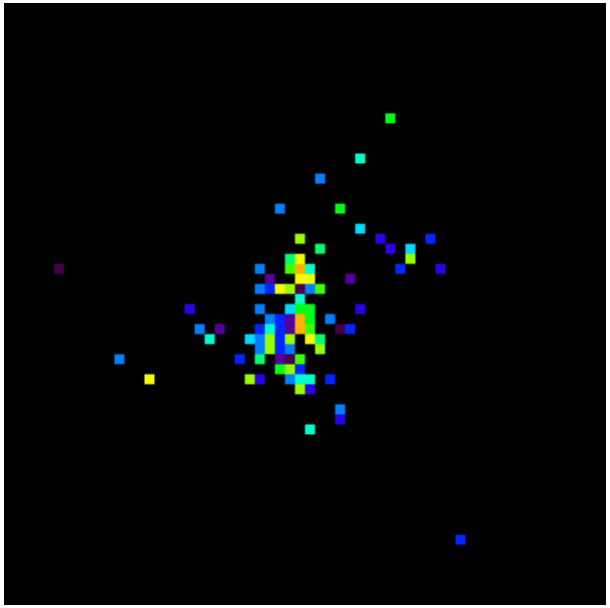
Nine Mile Point, New Orleans

AVIRIS Image

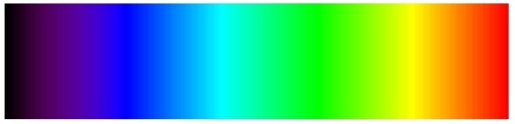


Matched Filter Score

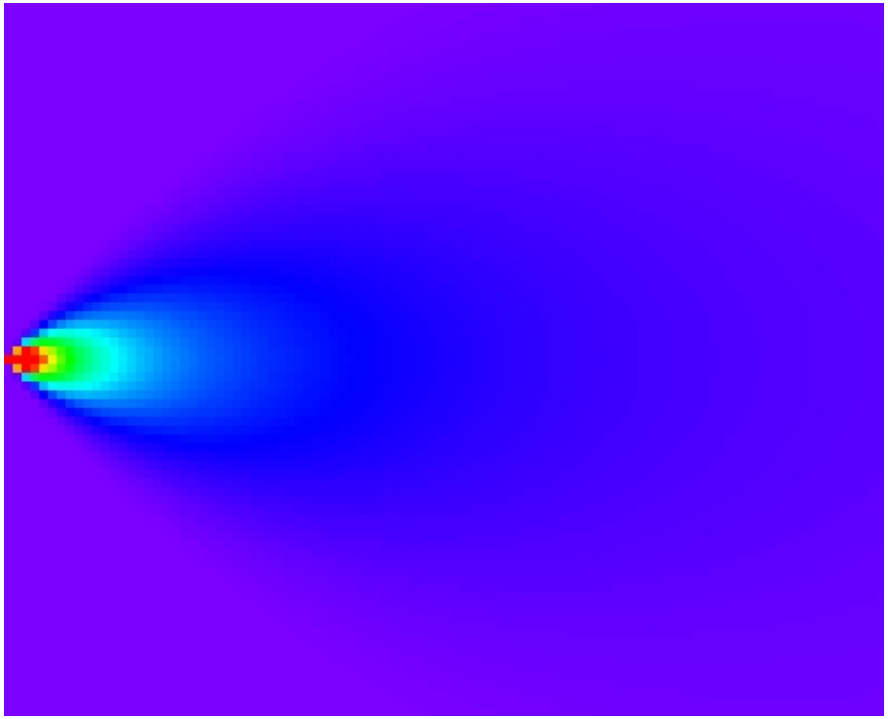


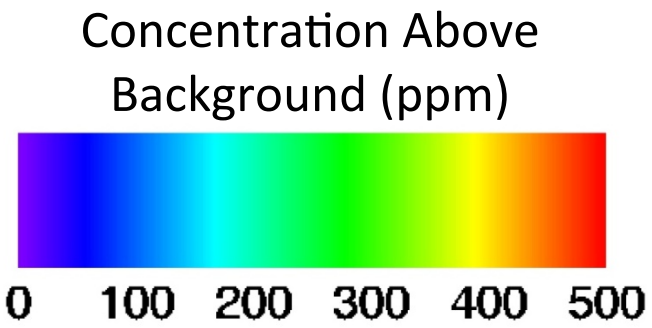


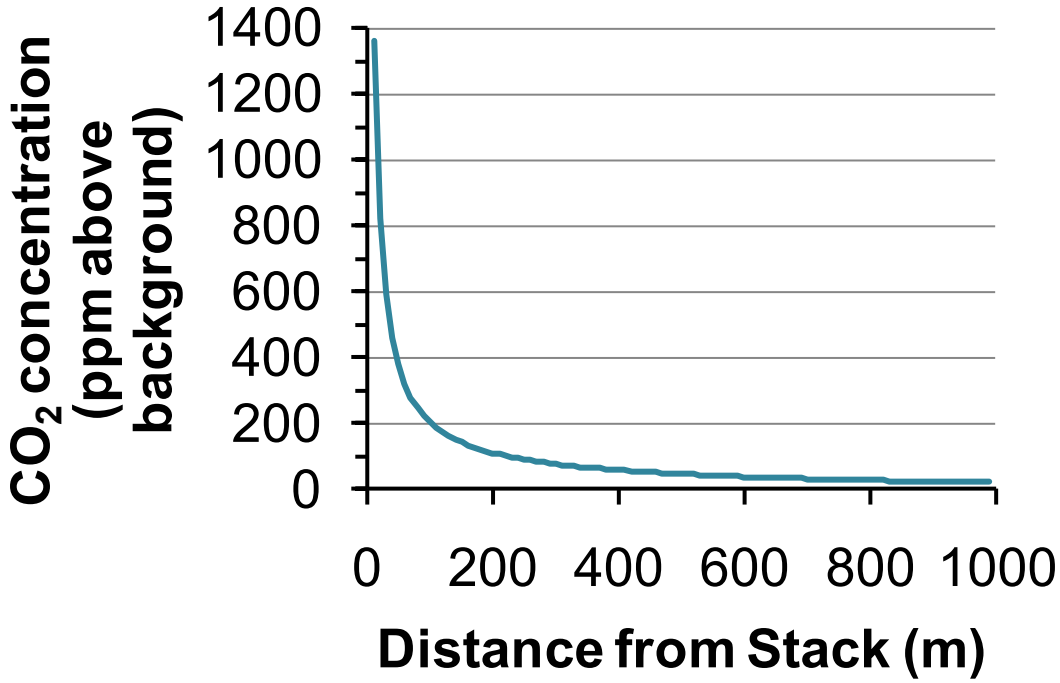
Modeled Concentration



Plume Dispersion Model
Mean Column CO_2 (500 m)

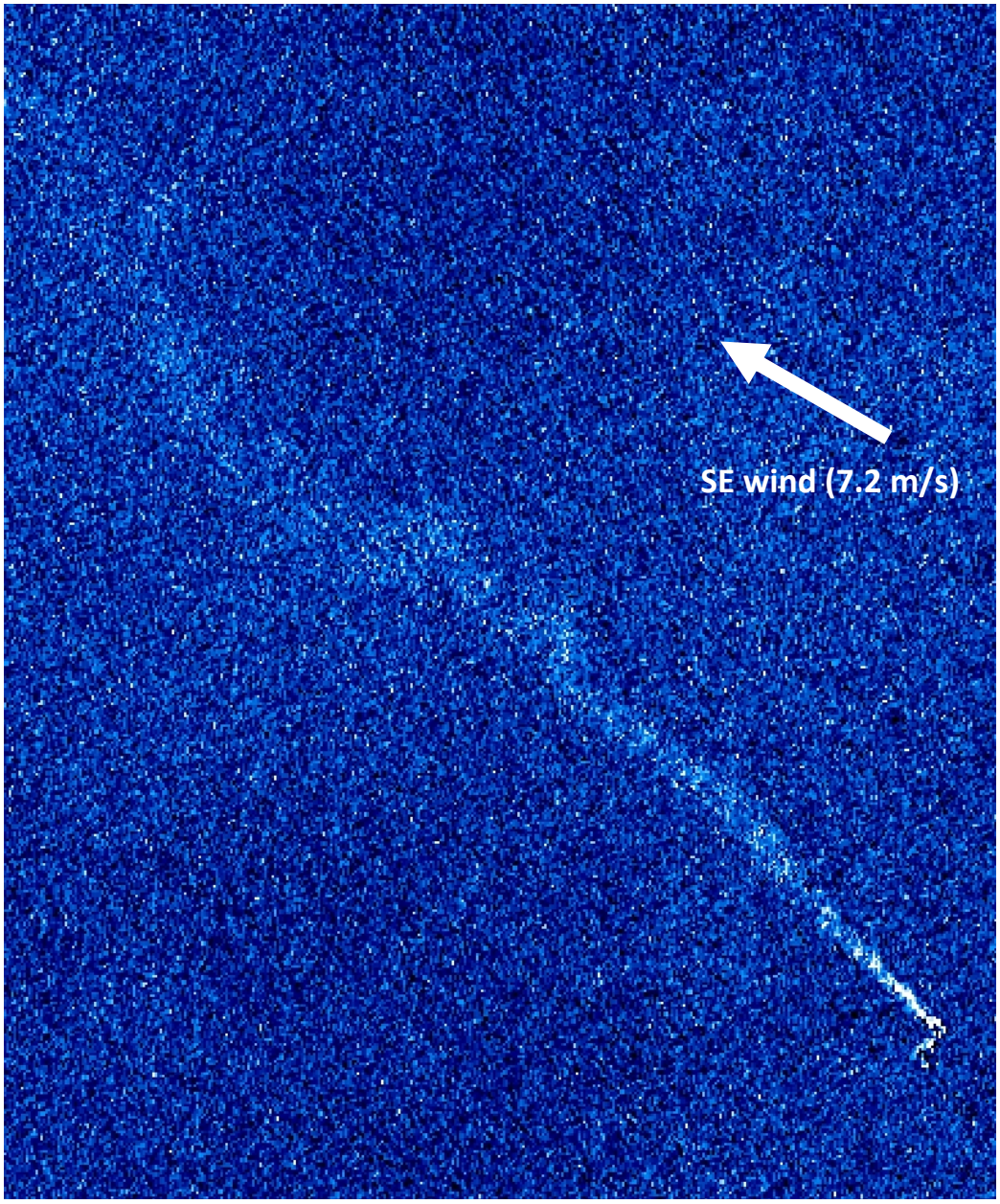






Methane

- Thorpe et al. applied cluster-tuned matched filters to methane plumes
- Marine
  - Natural seeps, platform
- Terrestrial
  - La Brea tarpits, Inglewood oil field

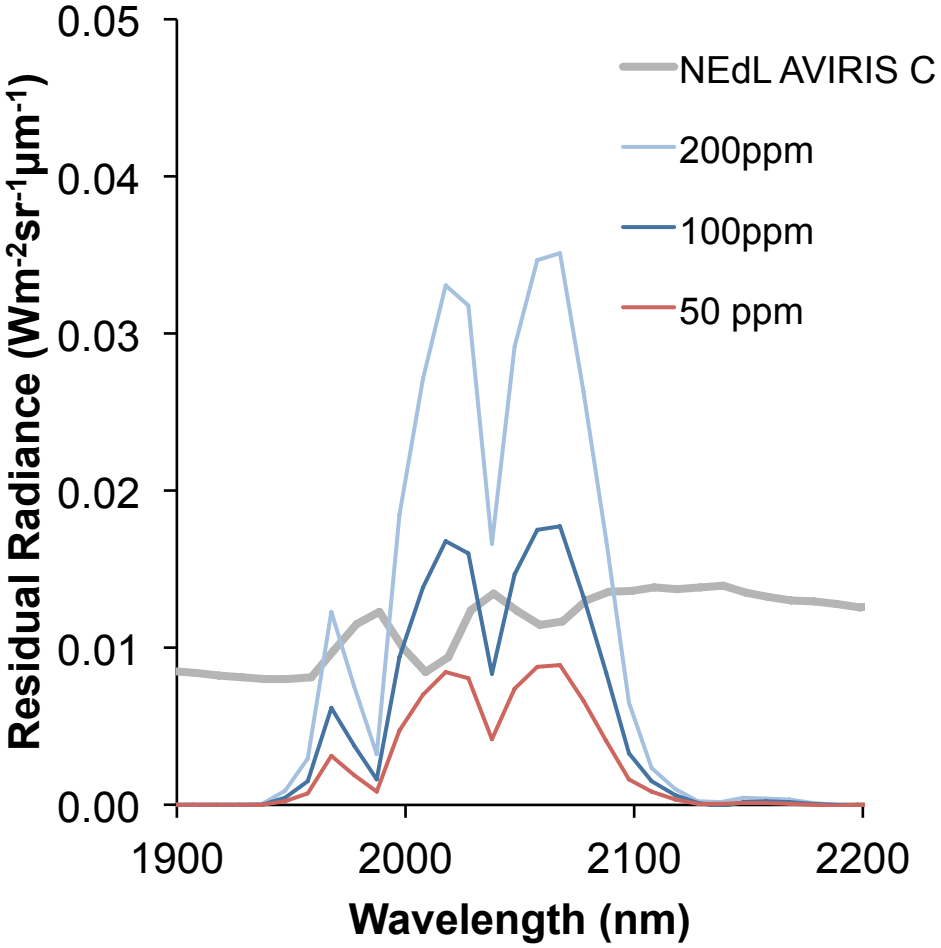


Objective

- Determine the sensitivity of SWIR imaging spectrometer data to elevated concentrations of carbon dioxide
- What is the minimum detectable increase in concentration above background?
  - AVIRIS Classic (HyspIRI VSWIR), AVIRIS Next Generation
  - Varying reflectance, water vapor, solar zenith angle, platform height

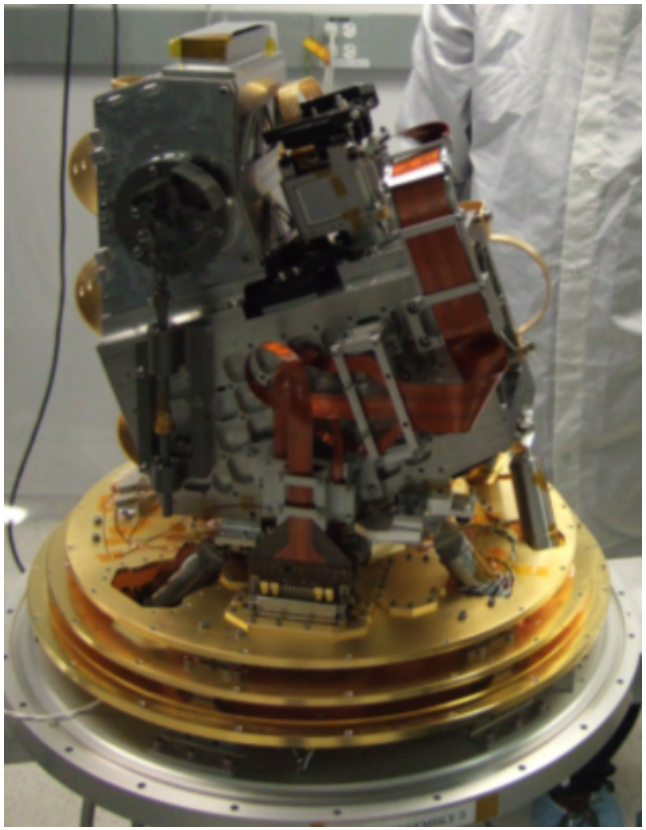
Methods

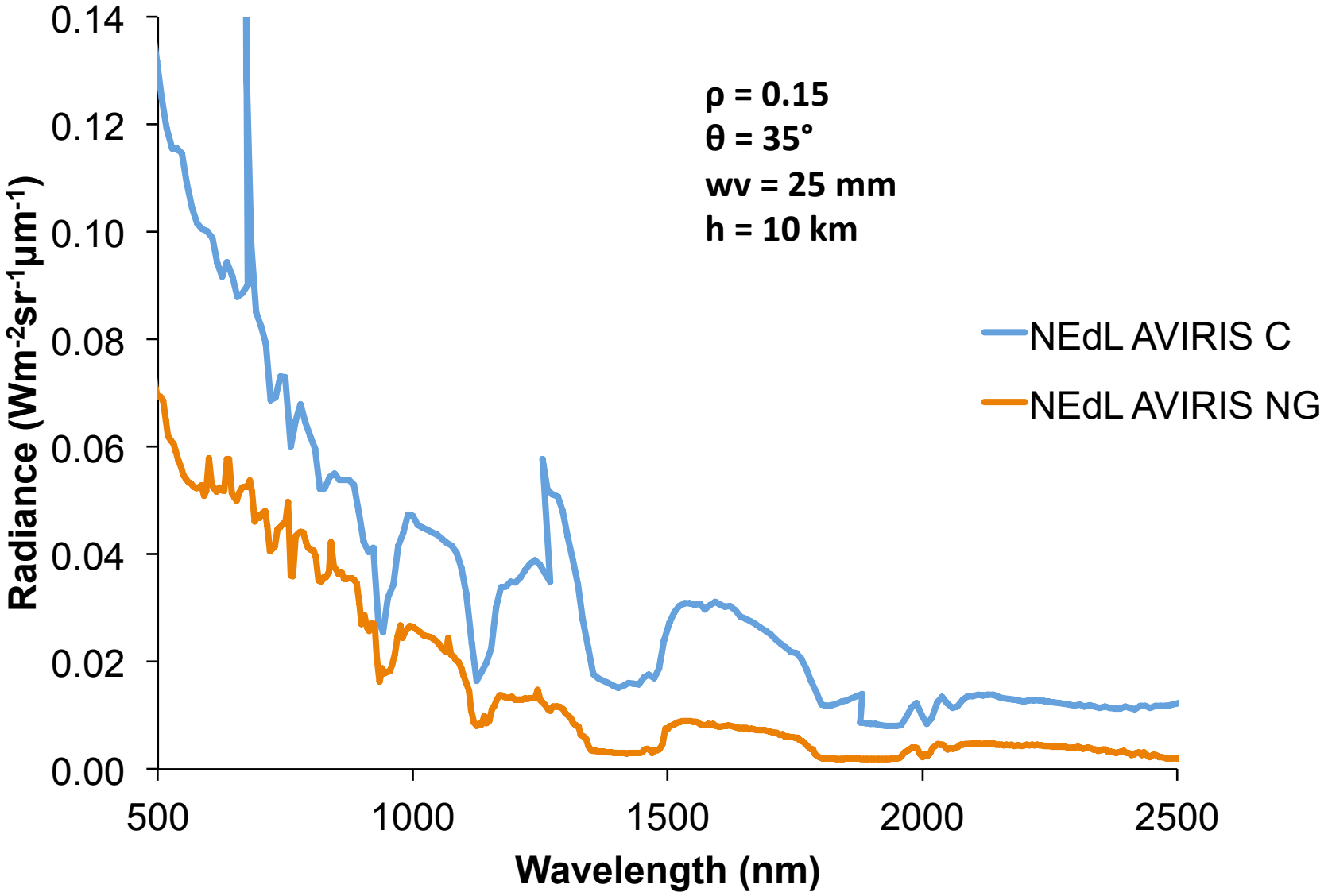
1. Determine noise equivalent delta radiance (NEdL) function for AVIRIS-C and AVIRIS-NG
2. Model residual radiance produced by increased CO_2 concentration using MODTRAN



Noise Equivalent Delta Radiance

- Minimum change in radiance distinguishable from noise
- AVIRIS-C and AVIRIS-NG radiometric models (JPL)
  - Photon noise
    - "Shot noise", includes dark current
    - Scales with square root of radiance
  - Read noise
    - Constant
- **NEdL is dependent on both wavelength and radiance**

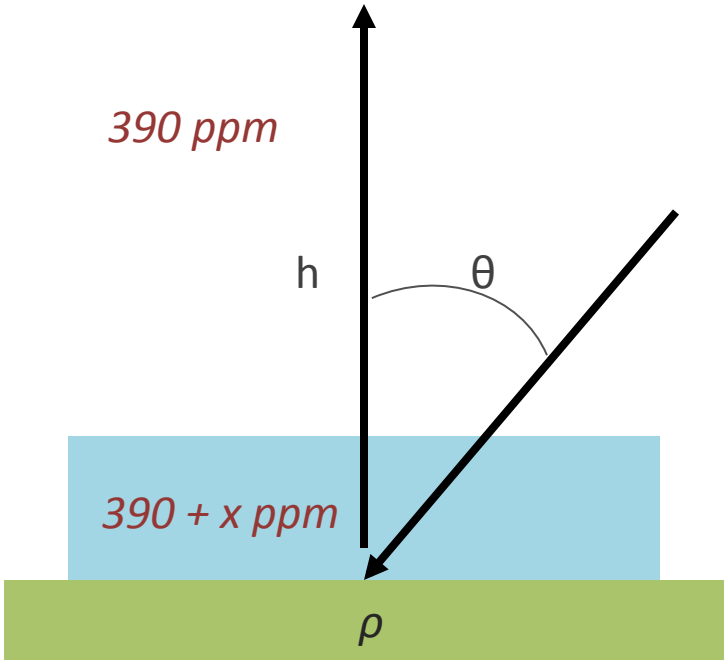



ρ = 0.15
θ = 35°
wv = 25 mm
h = 10 km
NEdL AVIRIS C
NEdL AVIRIS NG
Radiance (Wm-2sr-1µm-1)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
500
1000
1500
2000
2500
Wavelength (nm)

Radiance Modeling

- At-sensor radiance modeled using MODTRAN
- 390 ppm background CO_2 concentration
- Vertically uniform CO_2 layer
  - 0 to 500 m
  - 390 ppm + anomaly
- Assumptions
  - Two-way transmittance through enhanced CO_2 layer
  - Spectrally flat surface
- Residual radiance

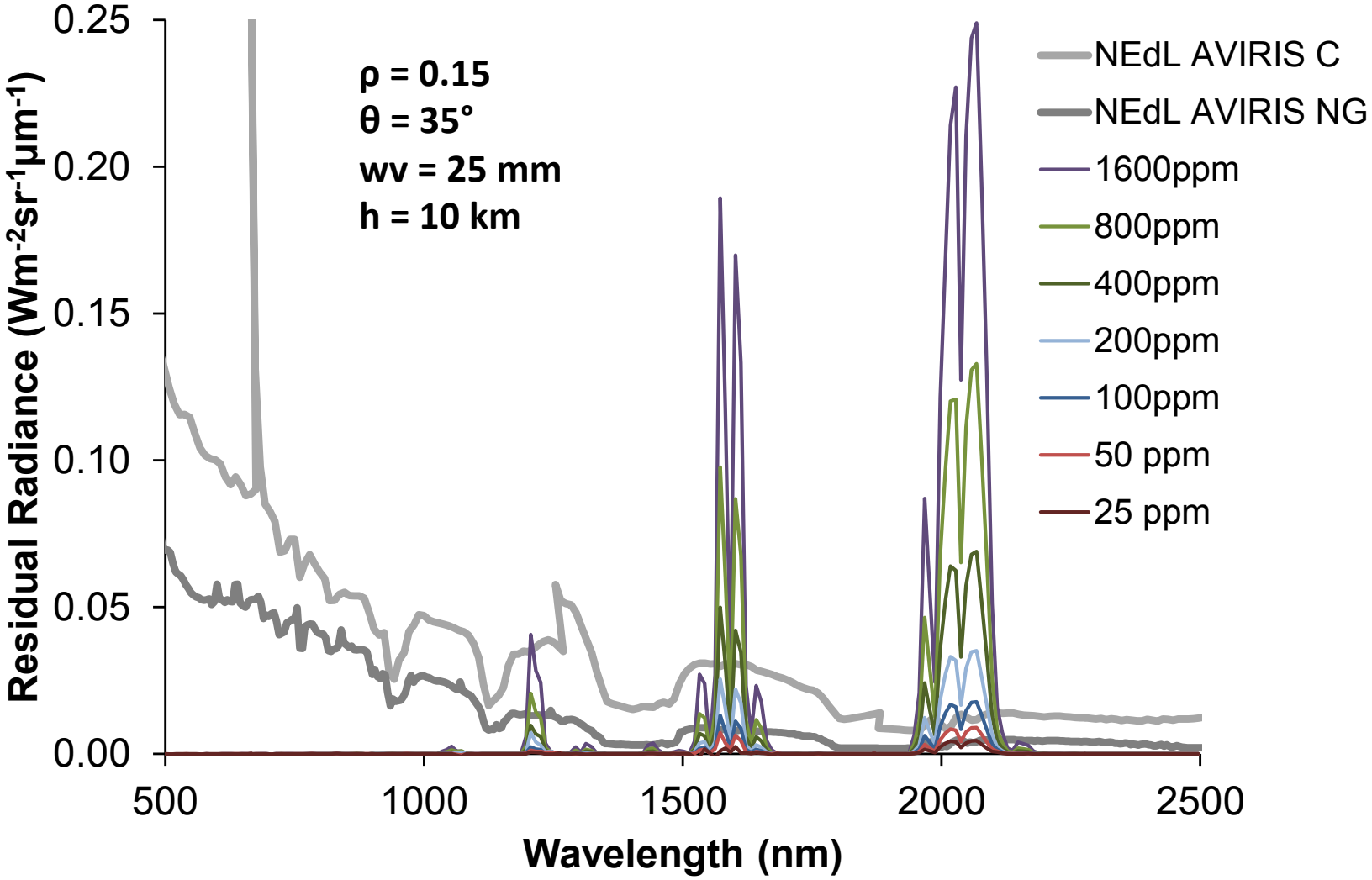
  $L_\lambda(390\ ppm) - L_\lambda(390 + x\ ppm)$



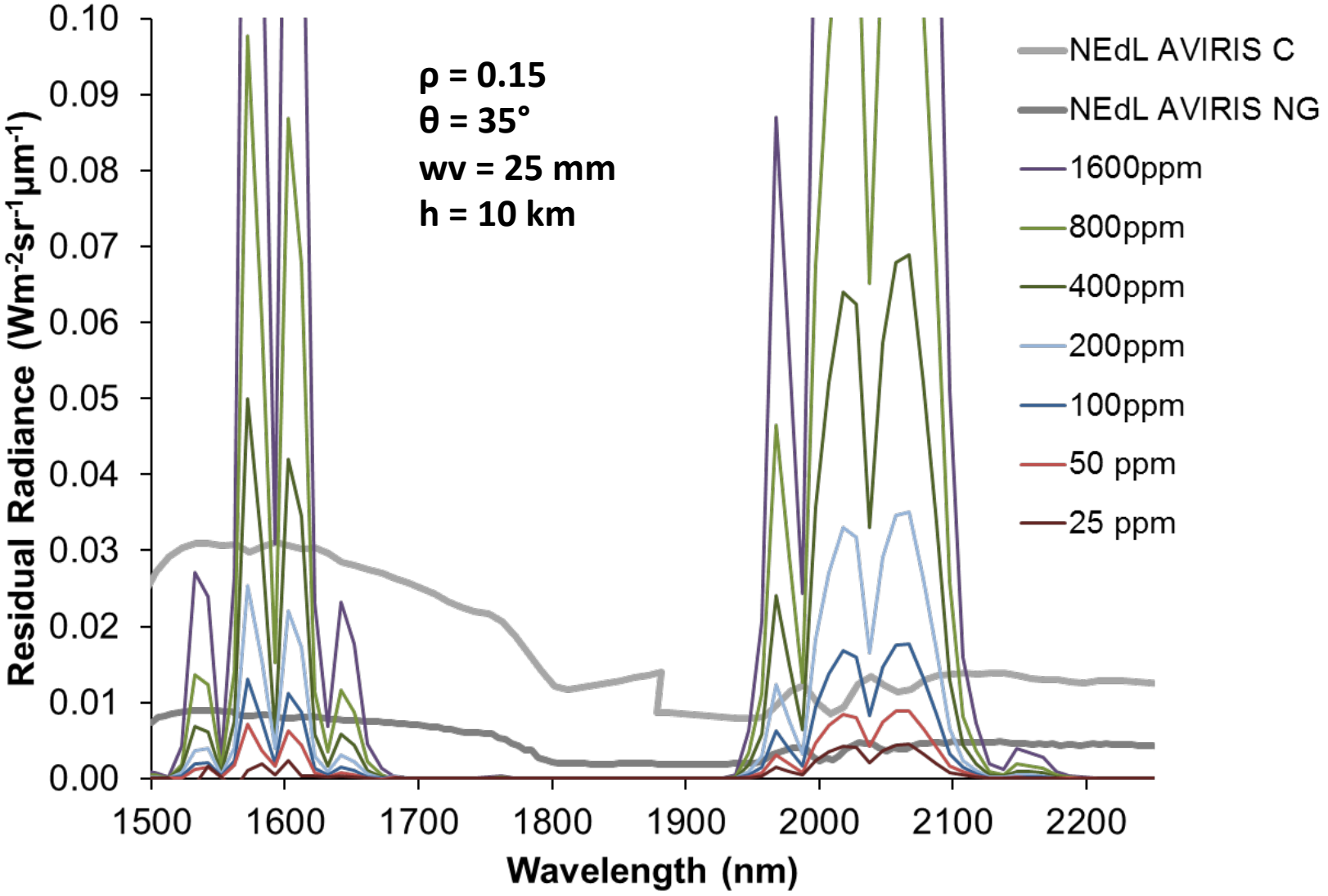
Simulation set	CO_2 anomaly (ppm above background)	Reflectance	Water vapor (mm)	Solar zenith angle (°)	Sensor height (km)
Baseline	0, 25, 50, 100, 200, 400, 800, 1600	0.15	25	35	10
Reflectance	0, 25, 50, 100, 200, 400, 800, 1600	0.025-0.50	25	35	10
Water vapor	0, 25, 50, 100, 200, 400, 800, 1600	0.15	10-40	35	10
Solar zenith angle	0, 25, 50, 100, 200, 400, 800, 1600	0.15	25	0-70	10
Height	0, 25, 50, 100, 200, 400, 800, 1600	0.15	25	35	0.5-100

Results

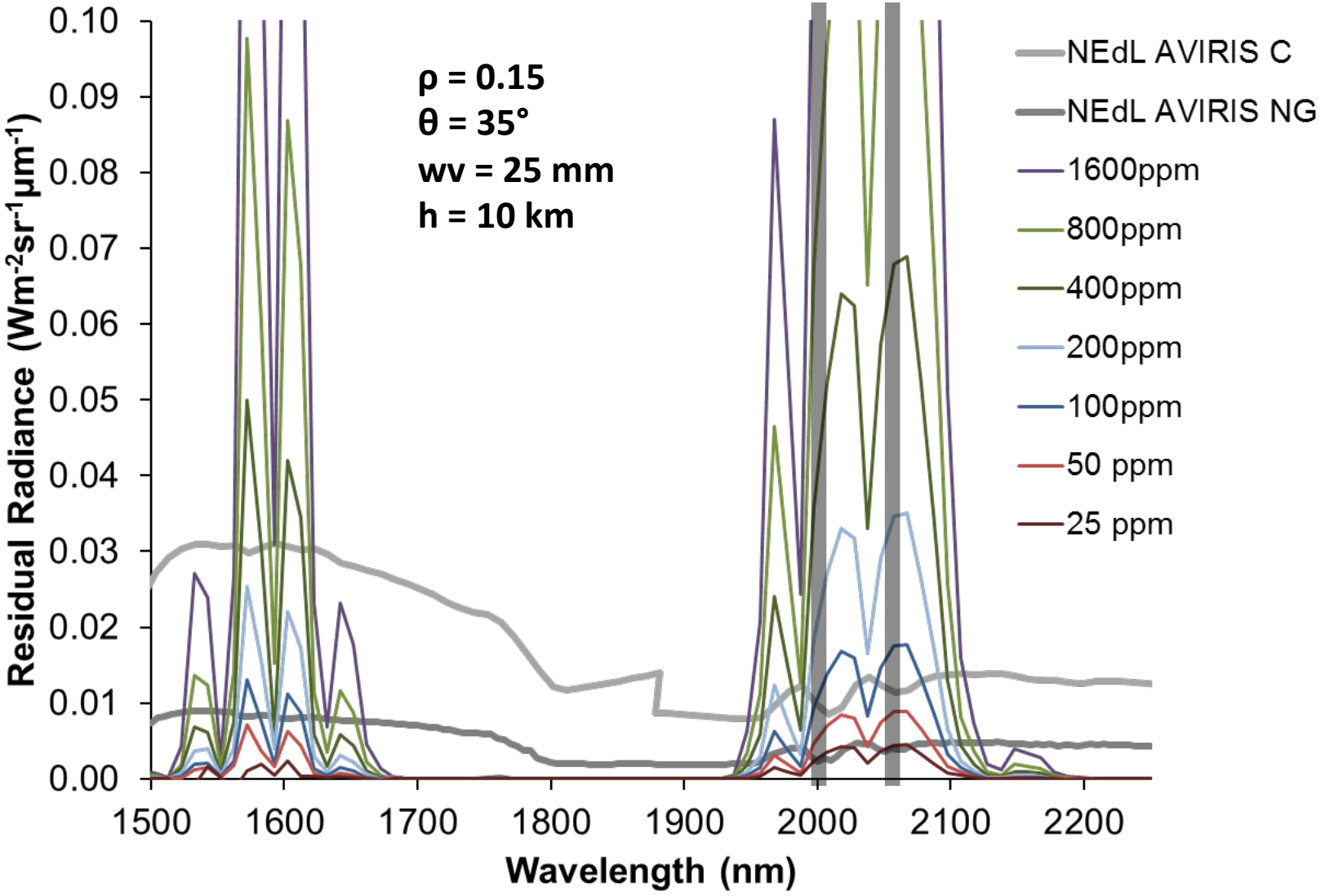
Baseline Scenario



Baseline Scenario

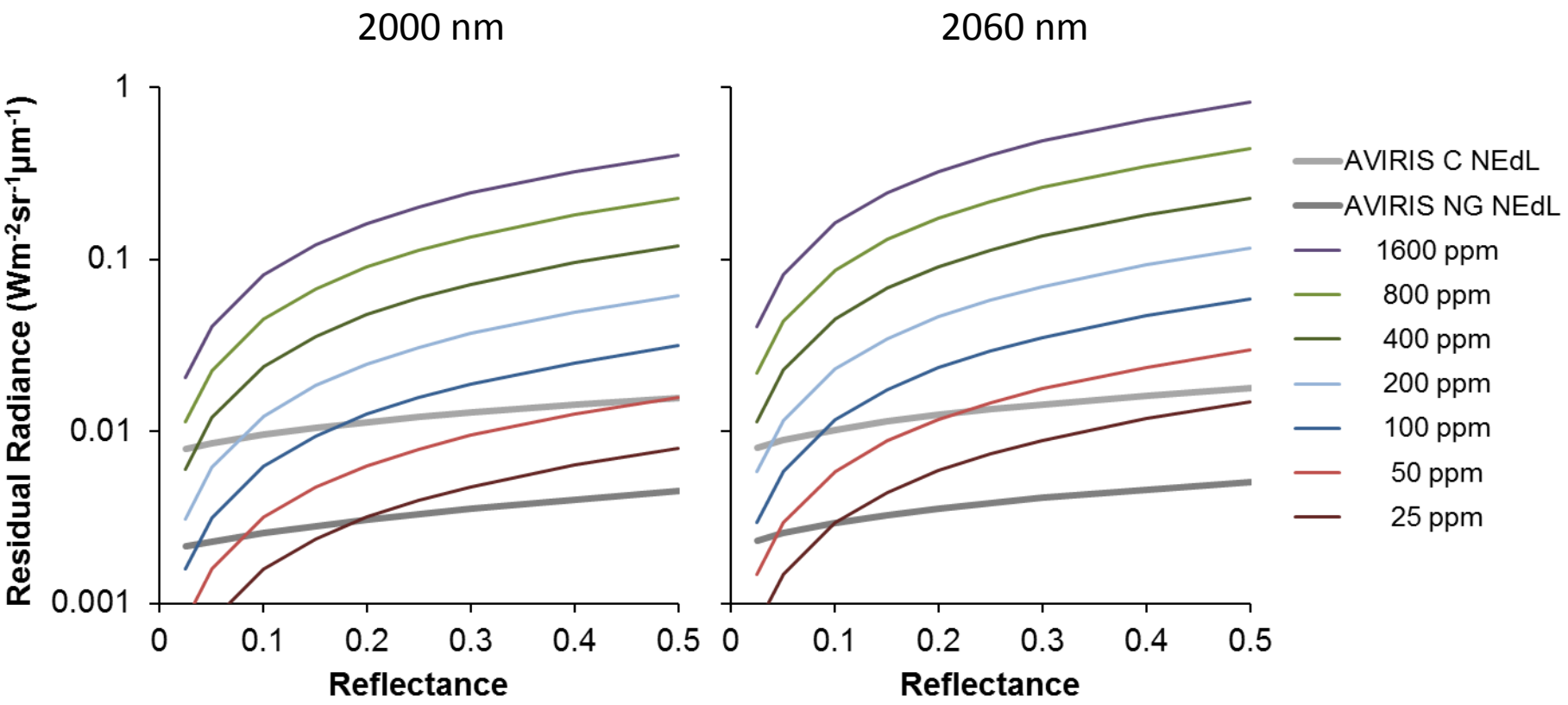


Baseline Scenario



Reflectance Sensitivity

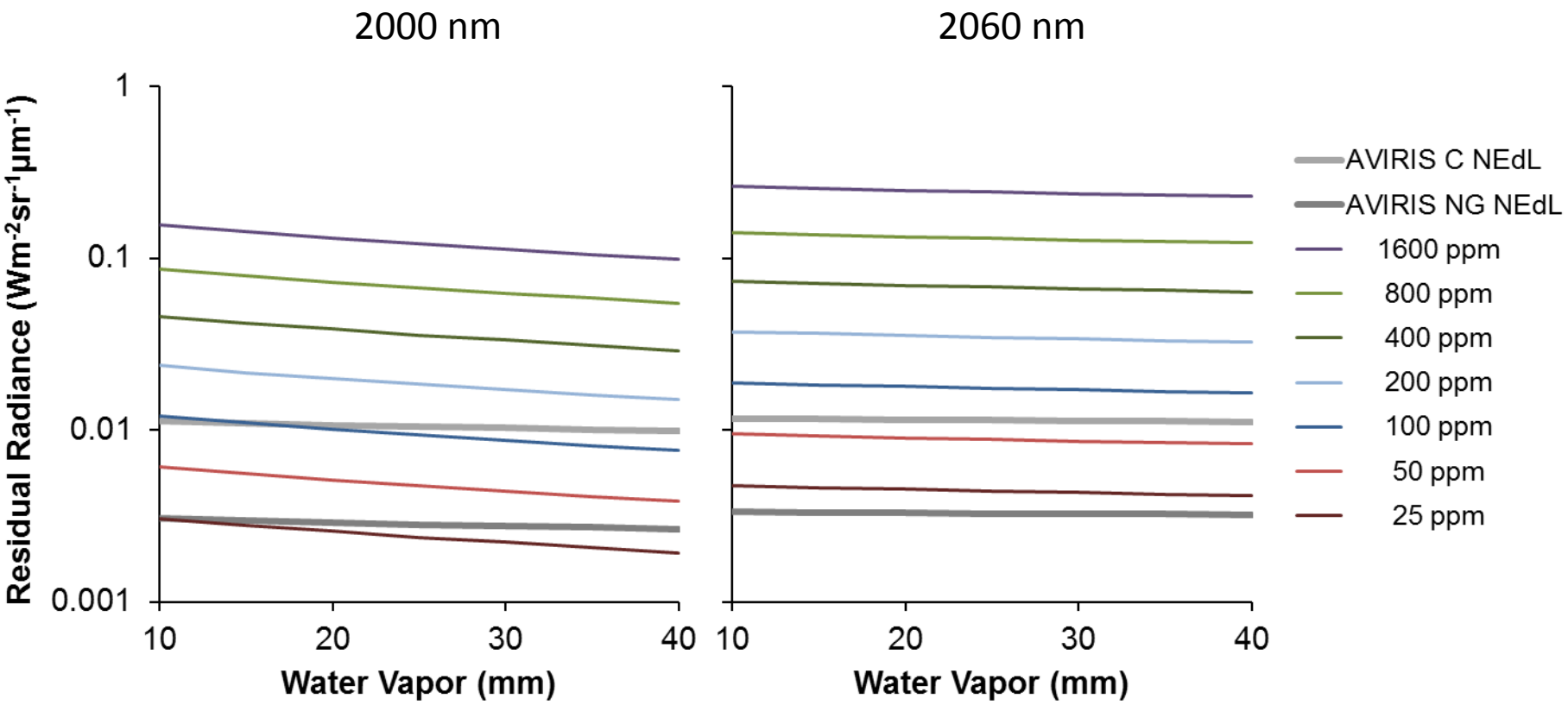
θ = 35°, wv = 25 mm, h = 10 km



- Sensitivity increases as surface reflectance increases

Water Vapor Sensitivity

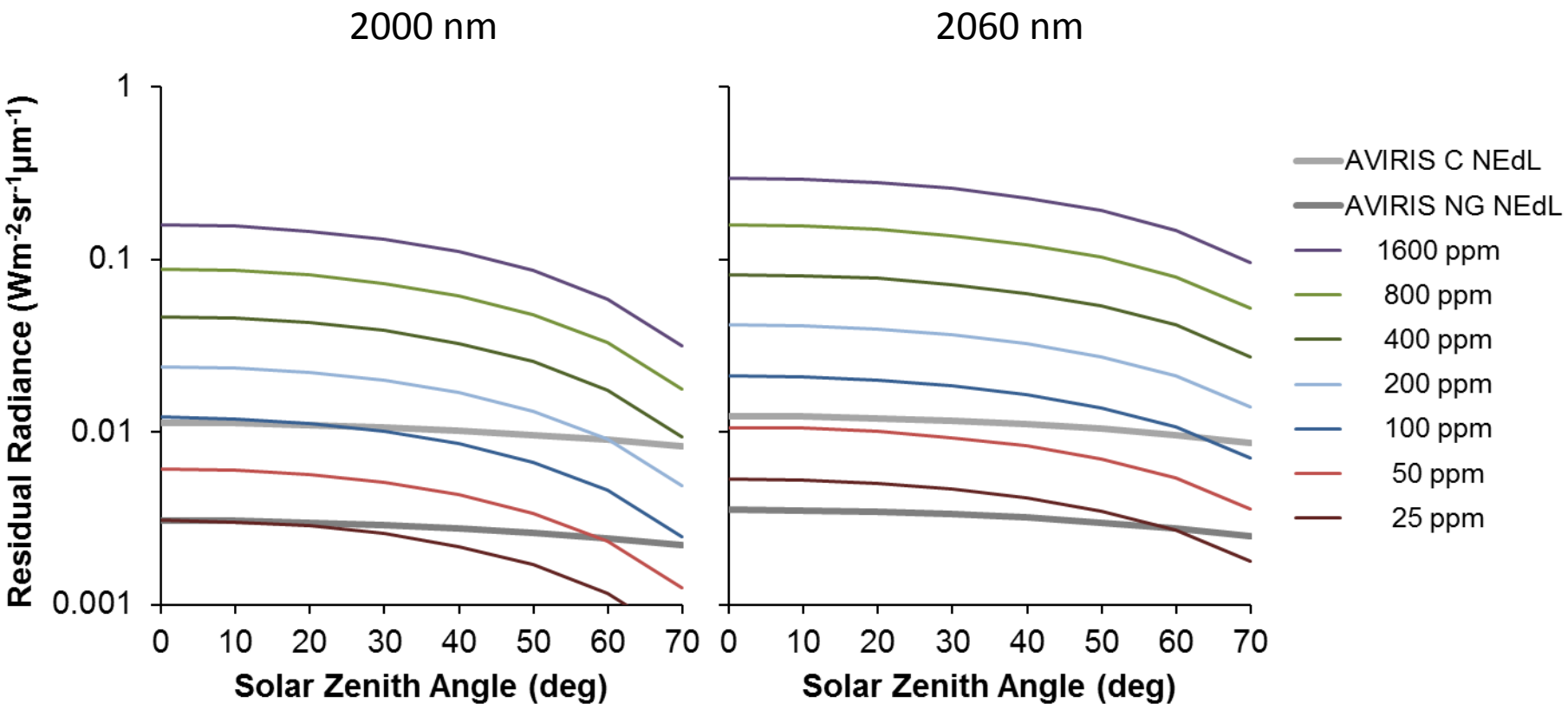
ρ = 0.15, θ = 35°, h = 10 km



- Sensitivity decreases as water vapor increases

Solar Zenith Angle Sensitivity

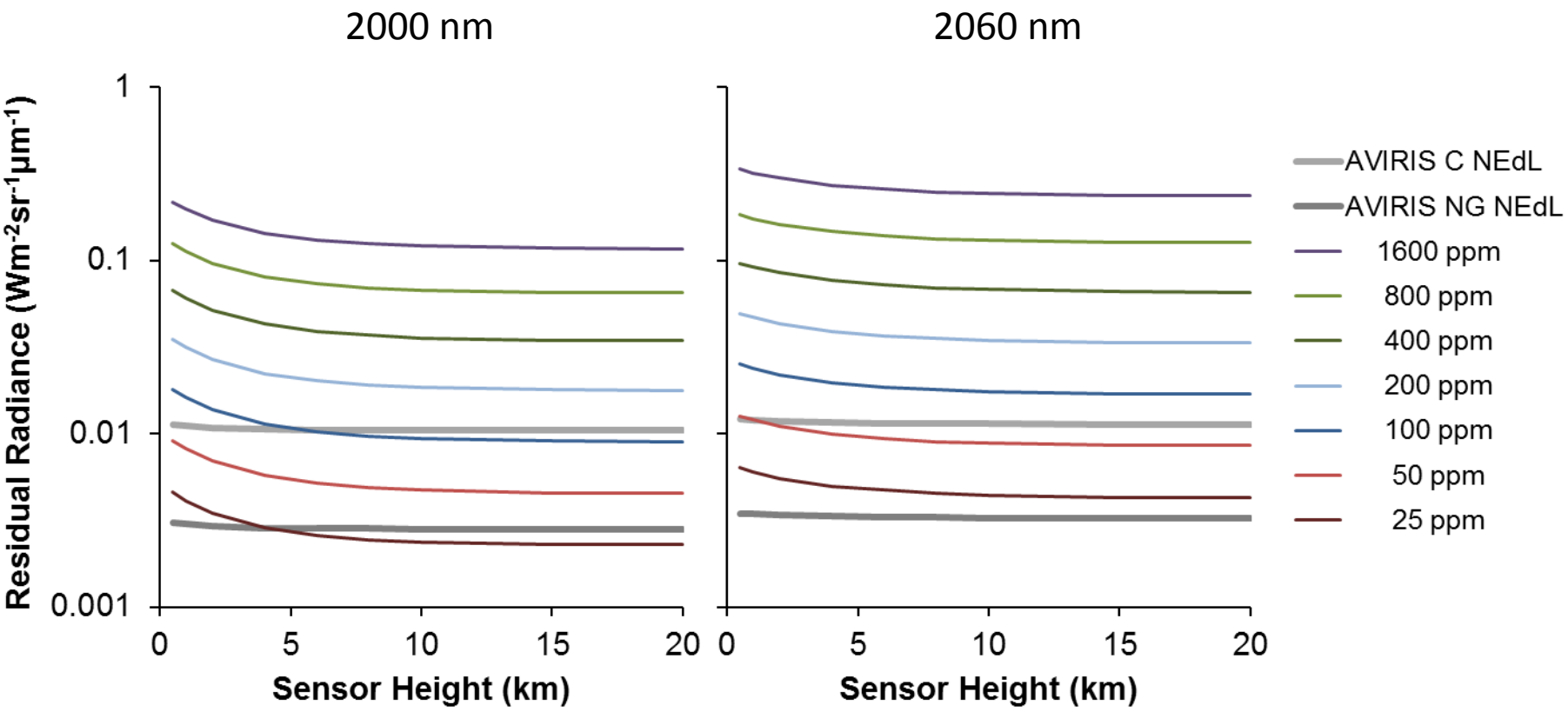
ρ = 0.15, θ = 35°, h = 10 km



- Sensitivity decreases as solar zenith angle increases

Platform Height Sensitivity

ρ = 0.15, θ = 35°, wv = 25 mm



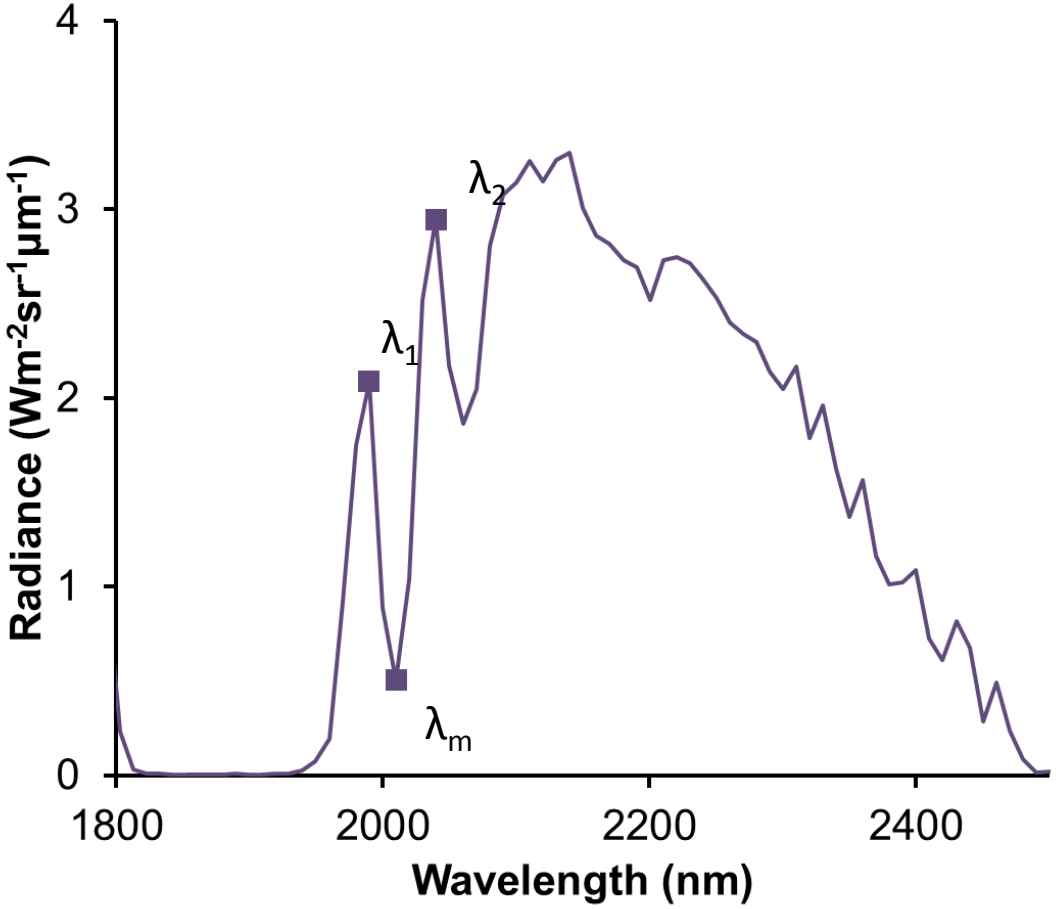
- Sensitivity higher at lower altitude, but is stable above 10 km

Summary

- Sensitivity to increased CO_2 is highly dependent on surface reflectance
- Sensitivity is highest at:
  - High surface reflectance
  - Low water vapor
  - Low solar zenith angle
  - Low platform height
- HyspIRI VSWIR sensitivity to increased CO_2 should not differ significantly from airborne above 10 km

Spinetti et al. (2008) CO_2 Continuum Interpolated Band Ratio (CIBR)

$$L\downarrow\lambda\downarrow m \ /0.4L\downarrow \lambda\downarrow 1 \ +0.6L\downarrow\lambda\downarrow 2$$



CIBR-Inverted CO_2 Concentration

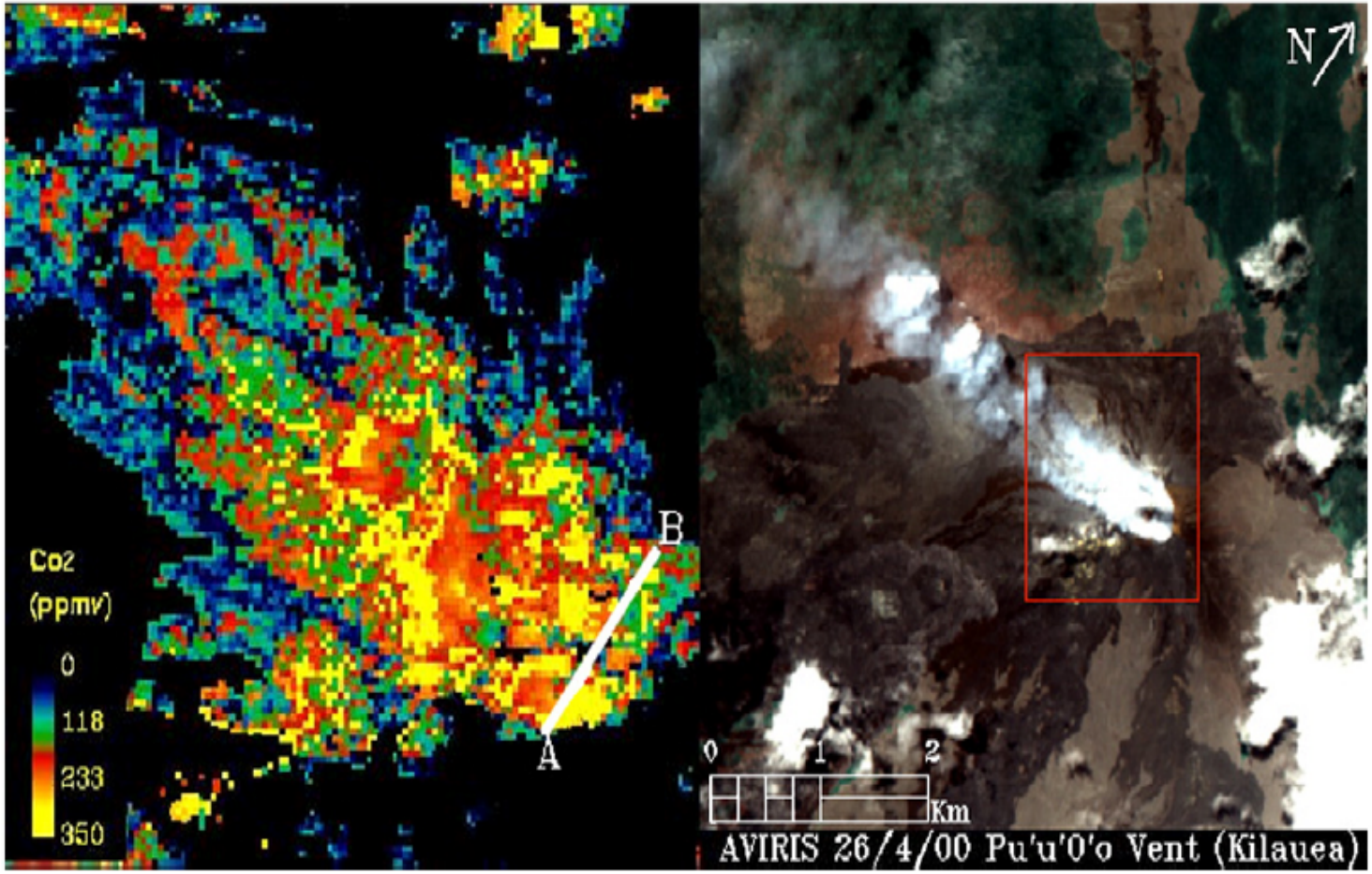
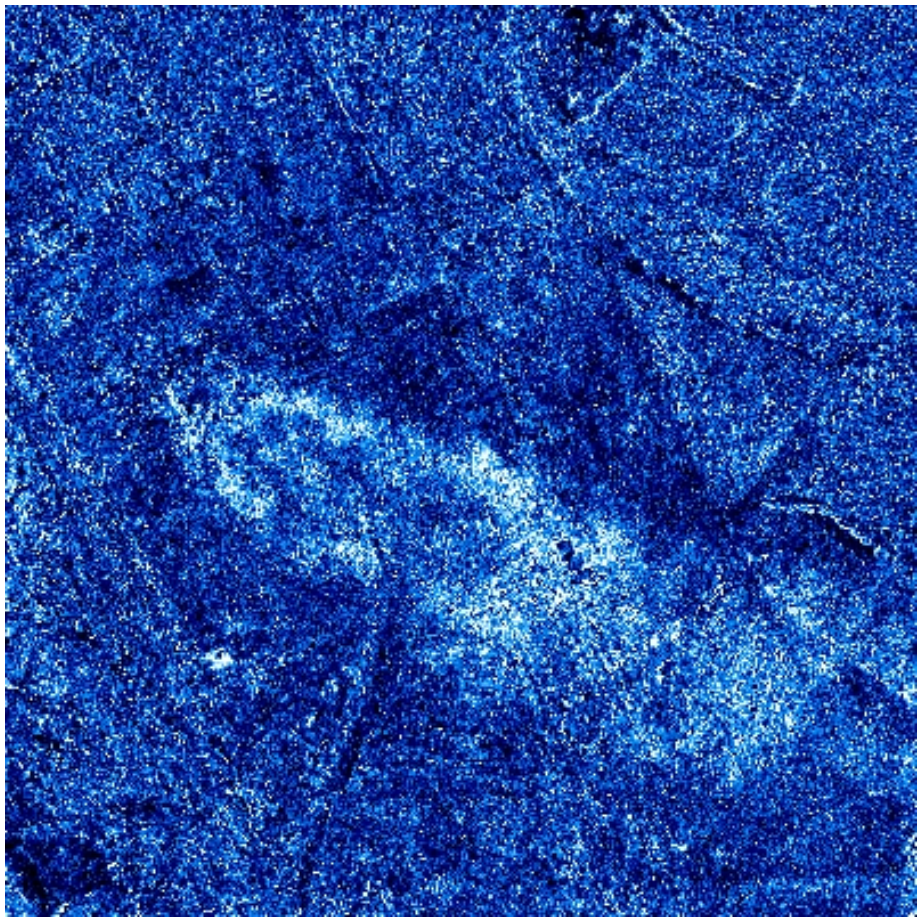


Fig. 5. Map of volcanic plume carbon dioxide on the left-hand side and AVIRIS image of Pu`u `O`o Vent plume acquired on 26th April 2000 in RGB composition on the right-hand side.

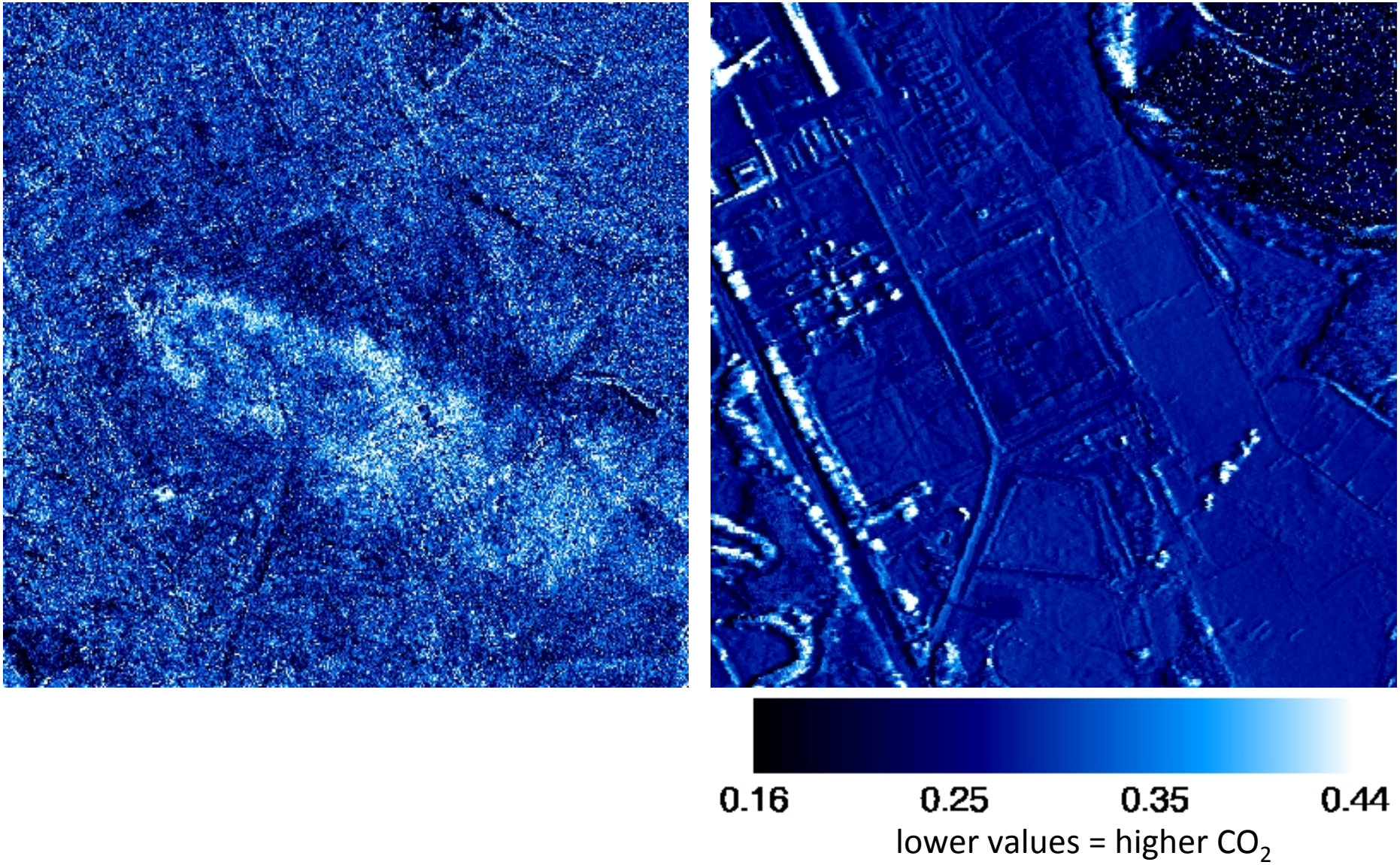
Spinetti et al., 2008

Matched Filter

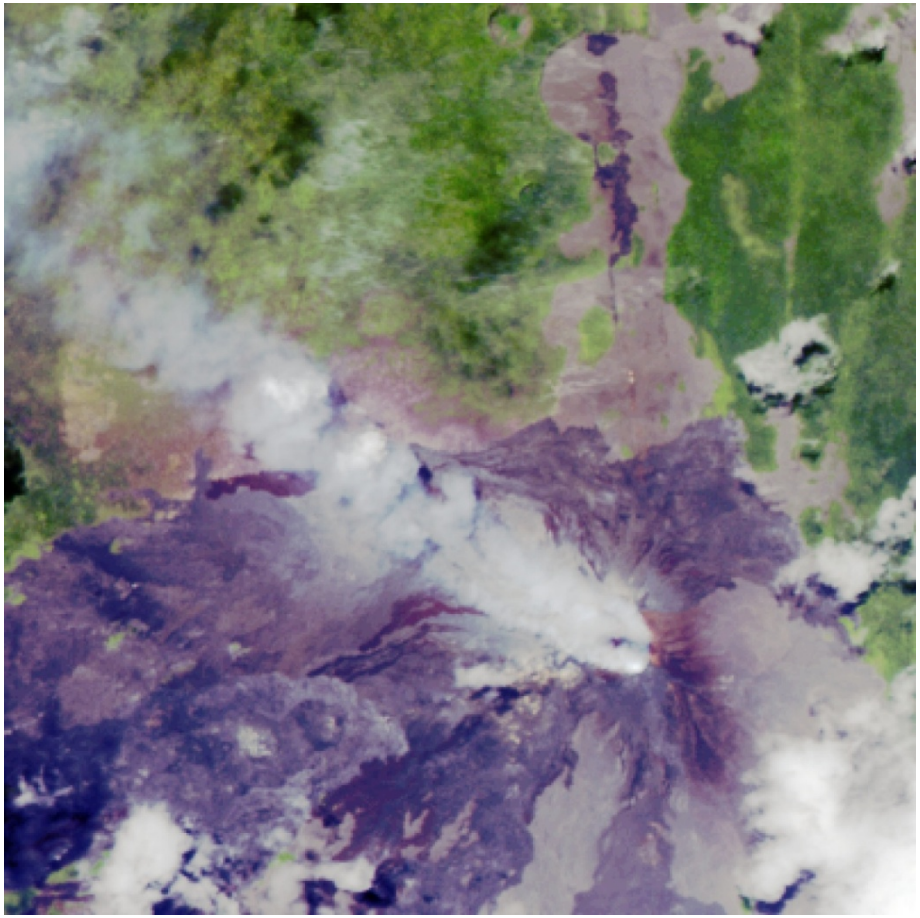
2.7 m

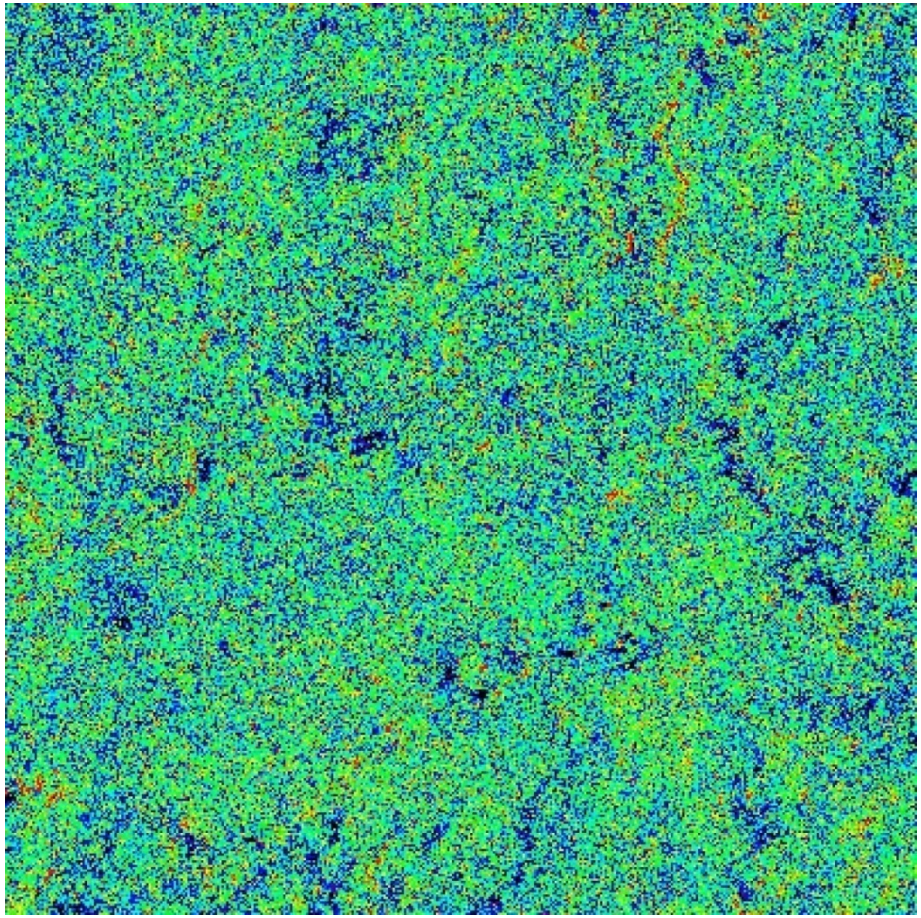


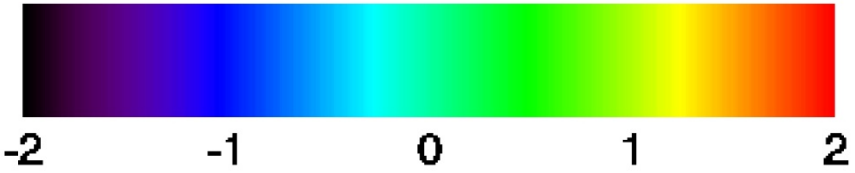
Spinetti et al. (2008) CIBR



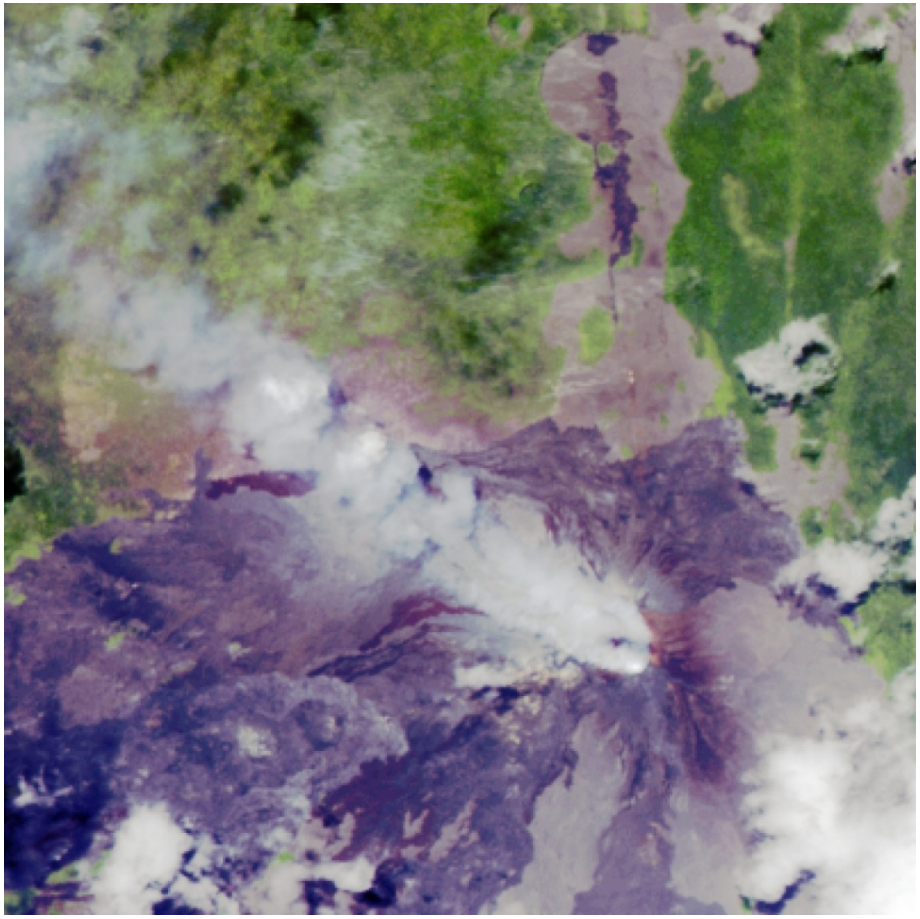
Cluster-Tuned Matched Filter

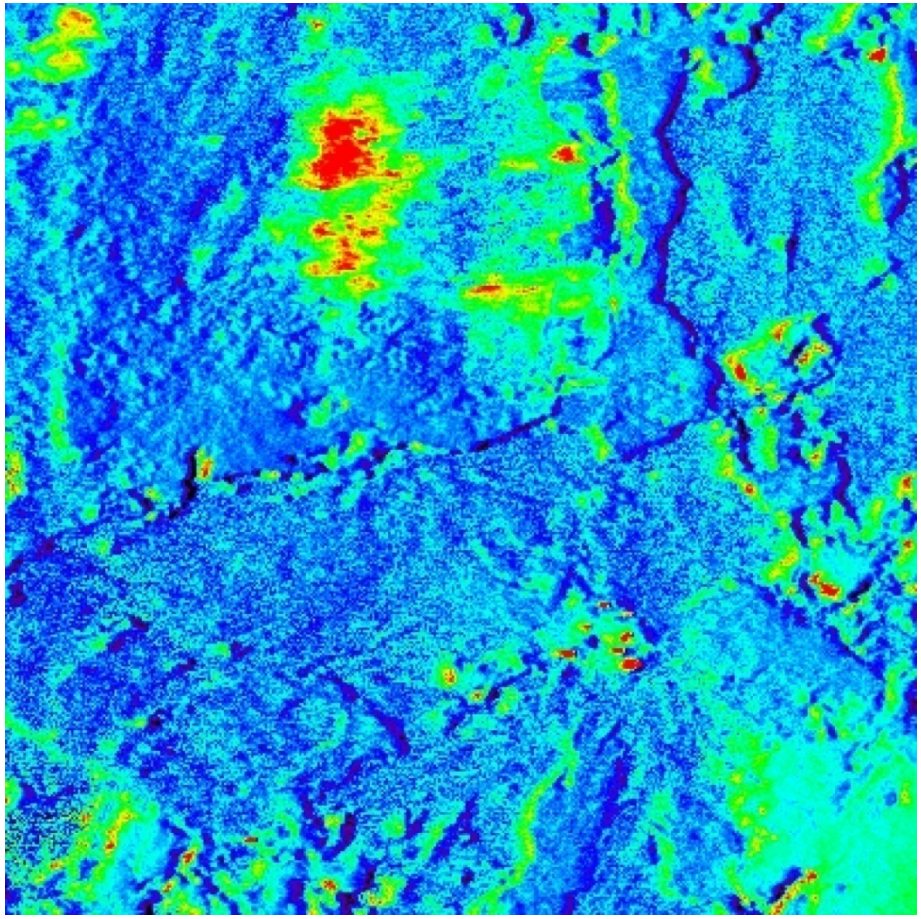


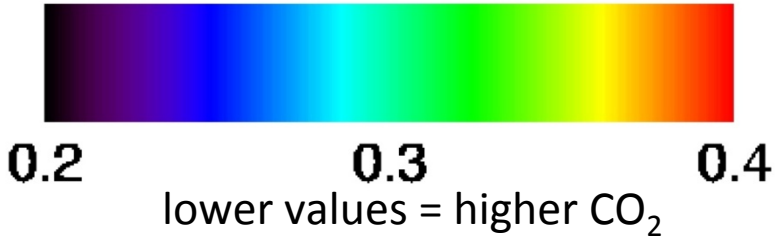




Spinetti et al. (2008) CIBR







Conclusions

- Residual radiance from elevated CO_2 concentrations is highly dependent on surface reflectance
  - Spectrally variable reflectance → poor results for CIBR
  - Matched filter uses clustering to remove background reflectance signal, provides detection ability
- Based on AVIRIS-C sensitivity, HyspIRI VSWIR will be sensitive to concentrations as low as 100-200 ppm above background (500 m plume depth)
- AVIRIS-NG sensitivity should be in the 25-50 ppm above background range
- Next step: AVIRIS/HyspIRI VSWIR sensitivity to water vapor

Questions?

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