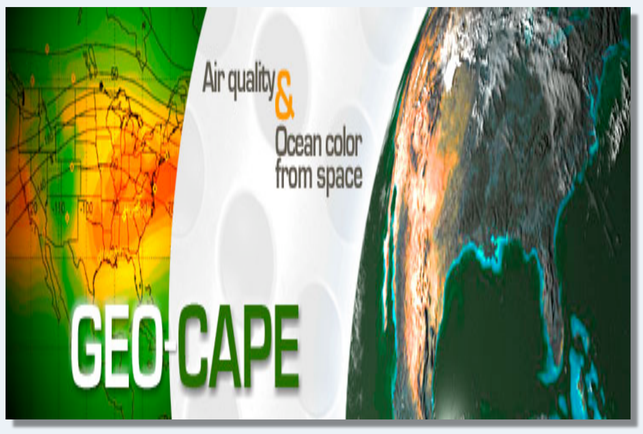
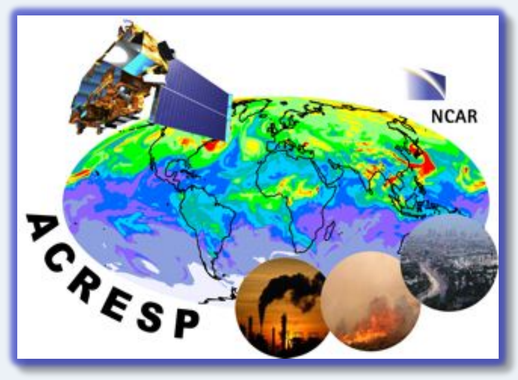


Detectability of O_3 and CO in the near-infrared: Implications for measurements from GEO-CAPE



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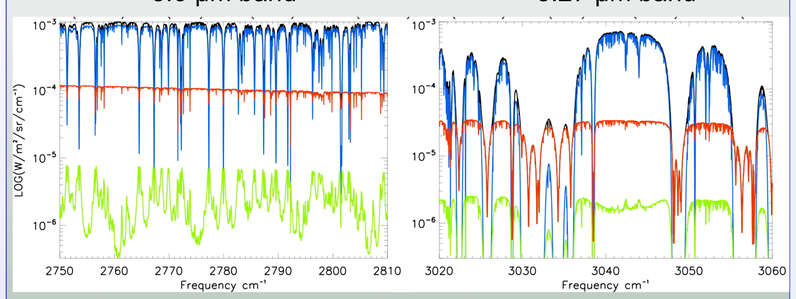
Assessing the feasibility of a near-IR O_3 & CO retrieval

- Determining the measurement sensitivity to lowermost troposphere (LMT) ozone (O_3) and carbon monoxide (CO) is important for the characterization of pollutant sources and a priority for GEO-CAPE
- For O_3, this is generally limited by Raleigh scattering in the UV and by lack of thermal contrast between the surface and atmosphere in the thermal-IR (TIR)
- In this study, we assess the feasibility of making a true total column ozone measurement with LMT sensitivity using solar backscatter in the near-IR (NIR)
- This is a particularly difficult region of the spectrum for nadir remote sensing as it falls at the weak-signal cross-over between the Earth thermal emission and solar backscatter
- Useful trace gas absorption signatures are also weak
- Here we perform a radiative transfer study for the NIR radiance sensitivity to tropospheric O_3 and CO and calculate radiance Jacobians (weighting functions) to investigate the impact of uncertain knowledge of the surface temperature and reflectivity and water vapor profile
- Demonstrating adequate weighting functions is an essential prerequisite for subsequent retrieval studies

O_3 Bands: Radiance Contributions

Case 1 – 'Dry' atmosphere, high albedo: 20% albedo, ΔT=0K at surface, T_surf=276.26 K, P_surf = 1000 hPa, lat = 45°, solar ZA = 30°, sat. ZA = 0°

3.6 μm band | 3.27 μm band



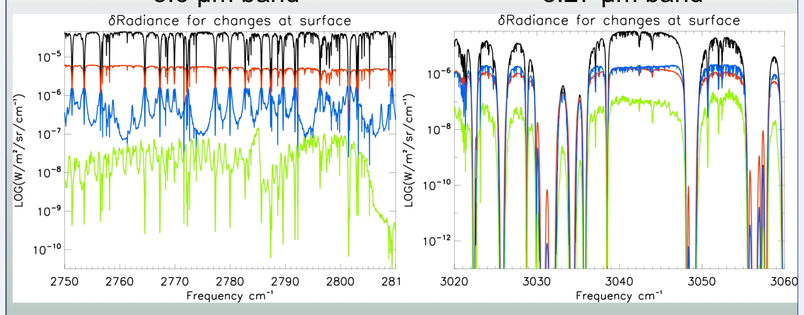
Total Radiance & Components:
Reflected solar
Thermal IR
Reflected downwelling IR

Although the solar irradiance is higher at 3.27 μm compared to 3.6 μm, stronger water vapor absorption (x100 in line strength) results in a smaller signal

O_3 Bands: ΔRadiance for surface terms

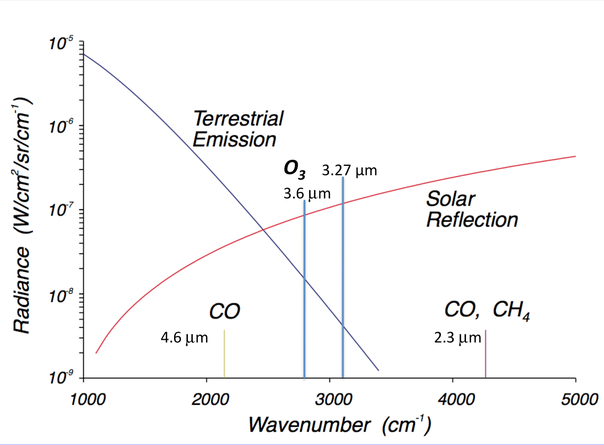
Case 1 – 'Dry' atmosphere, high albedo: 20% albedo, ΔT=0K at surface, T_surf=276.26 K, P_surf = 1000 hPa, lat = 45°, solar ZA = 30°, sat. ZA = 0°

3.6 μm band | 3.27 μm band



1% albedo increase	10% increase H_2O at 1000 hPa (ΔH_2O = 480 ppm)	10x increase O_3 at 1000 hPa to 198 ppb (ΔO_3 = 1.77 DU)
1K surface T increase		

Relative strengths of surface radiance source terms



Conclusions for surface term study

- Sensitivity to albedo dominates the TOA radiance, followed by the sensitivities to surface temperature and water vapor
- Retrieval over low albedo, high temperature surfaces will be particularly difficult because of the comparable contributions to total signal from thermal and reflected radiance
- This will require both albedo and surface temperature to be known to high accuracy to disentangle the signal components
- Surface heterogeneity for even slightly different FOVs will further complicate matters
- Radiance sensitivity to a 10× increase in surface ozone (i.e. a 200 ppbv pollution event!) is much smaller than the radiance change for a 10% increase in water vapor, which is lower than the expected error for a nadir water vapor retrieval
- The implications of this water vapor interference for ozone retrieval are studied below

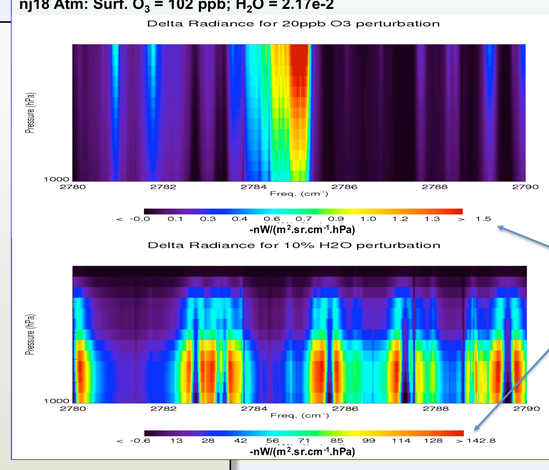
Comparison of O_3 & H_2O Jacobians

Setup:

- Assume perfect knowledge of albedo (20%) & surface temperature (276K)
- Because these are the leading terms determining reflected solar and thermal signal components, which may be of comparable magnitude, it will be a prerequisite for O_3 retrieval in this spectral region that both are known to high accuracy
- Calculations for NIR radiance are monochromatic (0.0025 cm^{-1} resolution) and assume no instrument line-shape or noise
- Assume the minimum requirement for a useful O_3 measurement sensitivity is 20 ppbv given that continental US surface values usually fall in the range 20–70 ppbv
- Also assume that the uncertainty in water vapor profile is 10% which is optimistic considering current sounding uncertainties (AIRS quotes 15%)
- Define "*Detectability*" as a figure of merit for detecting a 20 ppbv change in O_3 in the presence of water vapor with 10% profile uncertainty
- The Detectability radiance ratio for $\Delta R(\Delta O_3$ of 20 ppbv$)/\Delta R(\Delta H_2O$ of 10%) should be greater than unity for a useful O_3 measurement

Scaled Jacobians for polluted, wetter case

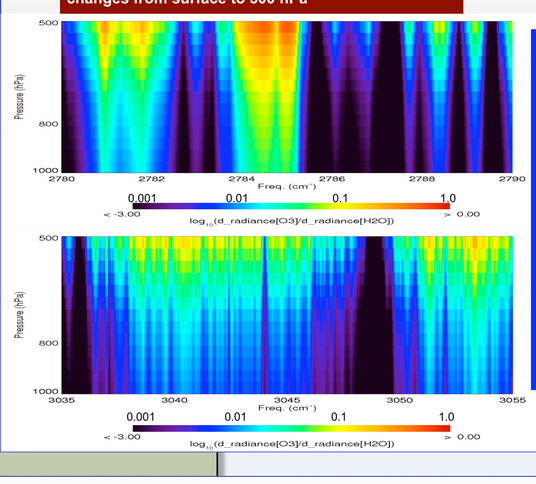
nj18 Atm: Surf. O_3 = 102 ppb; H_2O = 2.17e-2



To compare Jacobians for different absorbers, we need to scale to atmospheric conditions to see relative radiance sensitivities

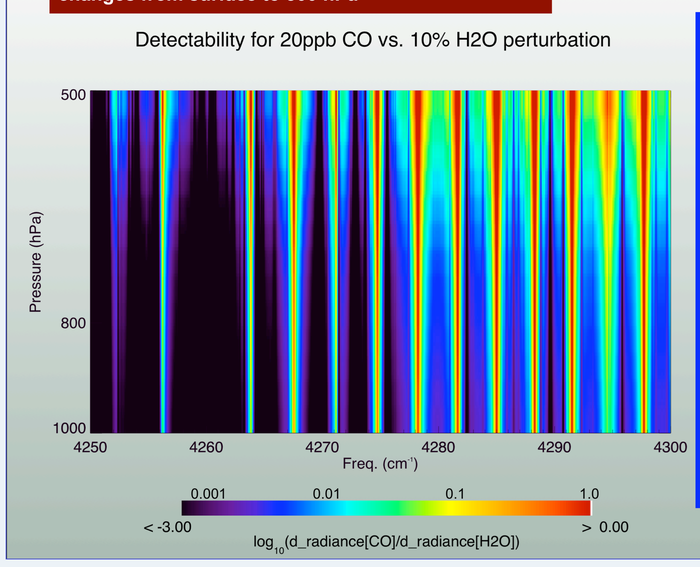
Note very different color scales

Best case 'Dry' atmosphere Detectability scenario: ΔR [for ΔO_3 of 20 ppbv] / ΔR [for ΔH_2O of 10%] changes from surface to 500 hPa



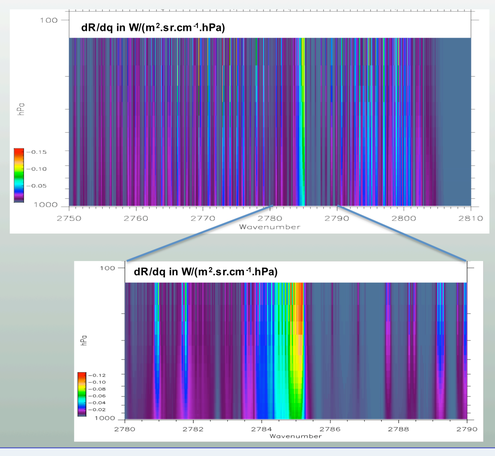
- The Detectability measure does not reach unity in either spectral region
- Ozone Jacobians & Detectability also both decrease toward the surface as a result of H_2O absorption
- Near-surface sensitivity is the main motivation for the NIR measurement

Carbon Monoxide Detectability : ΔR [for ΔCO of 20 ppbv] / ΔR [for ΔH_2O of 10%] changes from surface to 500 hPa



- Detectability measure reaches a value of 1.1 near the surface
- This is 20 times better than the corresponding NIR O_3 calculation
- Use of gas correlation in the case of MOPITT improves detectability to 2.5

Ozone Jacobian example

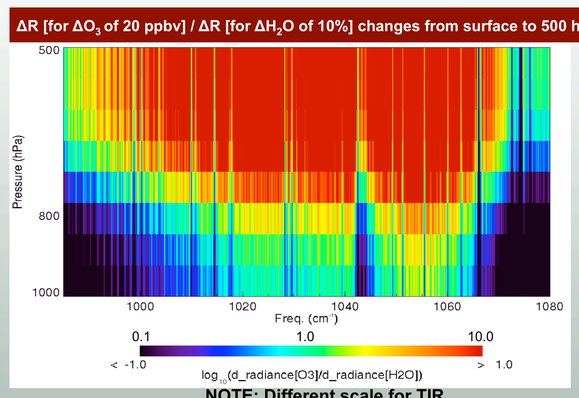


Ozone monochromatic Jacobians for "Dry" Case

The most promising ozone lines (for the 111-000 band) fall at about 2785 cm^{-1}

Compare with Detectability in the TIR

ΔR [for ΔO_3 of 20 ppbv] / ΔR [for ΔH_2O of 10%] changes from surface to 500 hPa



NOTE: Different scale for TIR

TIR O_3 and H_2O Jacobians are from TES with 0.1 cm^{-1} resolution, cloud-free case at 65°N, Aug 2006, surface T = 295 K, H2O vmr = 1.3E-2, thermal contrast = 8.7K

Conclusions for water vapor study

- Even in the "best case scenario" assuming a dry atmosphere and perfect knowledge of surface albedo and temperature, the uncertainty in the water vapor profile alone would most likely prevent the detection of changes in tropospheric O_3 in the NIR
- If the study were taken to the next stage with a retrieval analysis, the radiance error associated with a 10% water vapor uncertainty would form part of the 'forward model component error' in the MAP retrieval measurement error covariance matrix
- As demonstrated here, this radiance error would dominate any forward model radiance change associated with a change in tropospheric O_3
- The NIR 3.3 & 3.6 μm bands would not add significant information to tropospheric ozone retrievals using the UV and TIR bands
- Although it is still a difficult, the NIR CO measurement is much more promising (as demonstrated by SCIAMACHY & MOPITT) and detctability is 20 times better than the NIR O_3
- These conclusions do not depend on any proposed instrument description since they essentially assume a perfect instrument with zero noise and monochromatic spectral resolution

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