JPL Developments in Retrieval Algorithms for Geostationary Observations – Applications to H_2CO

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Outline

1. who we are and what we do
2. tools available/developed at JPL for geostationary monitoring
3. planned developments
4. application: H_2CO from geostationary orbit, retrieval sensitivities
5. summary

JPL Atmospheric Science Expertise (non-exhaustive)

Atmospheric Observations from ground-based (CLARS, TCCON), aircraft (CARVE), and satellite (TES, MLS, OCO-2) instruments, covering the visible, near-IR, thermal IR and microwave spectral regions

Radiative Transfer Modeling for simulation of atmospheric radiances, full scattering and polarization; AMF computations

Atmospheric Retrievals from FTS and grating spectrometer sensors (TES, MLS, OCO-2, OMI) in the UV/VIS/near-IR/thermal IR

Assimilation/OSSE Models

… JPL also goes to Mars ….

Atmospheric Research Tools in place at JPL

Radiance simulation, based on full multiple scattering, polarized RT model (V)LIDORT; includes Jacobian computations.

Air Mass Factor tool for computing trace gas AMF used in UV/Vis total column retrievals; based on LIDORT RT model.

Inversion Tool to derive estimates of retrieval sensitivities for FTS and grating spectrometer instruments; includes instrument noise models and a linear inversion module.

Assimilation and OSSE models, for study of instrument hardware optimization and science studies (see next talk by Jessica Neu)

Atmospheric Research Tools Under Development

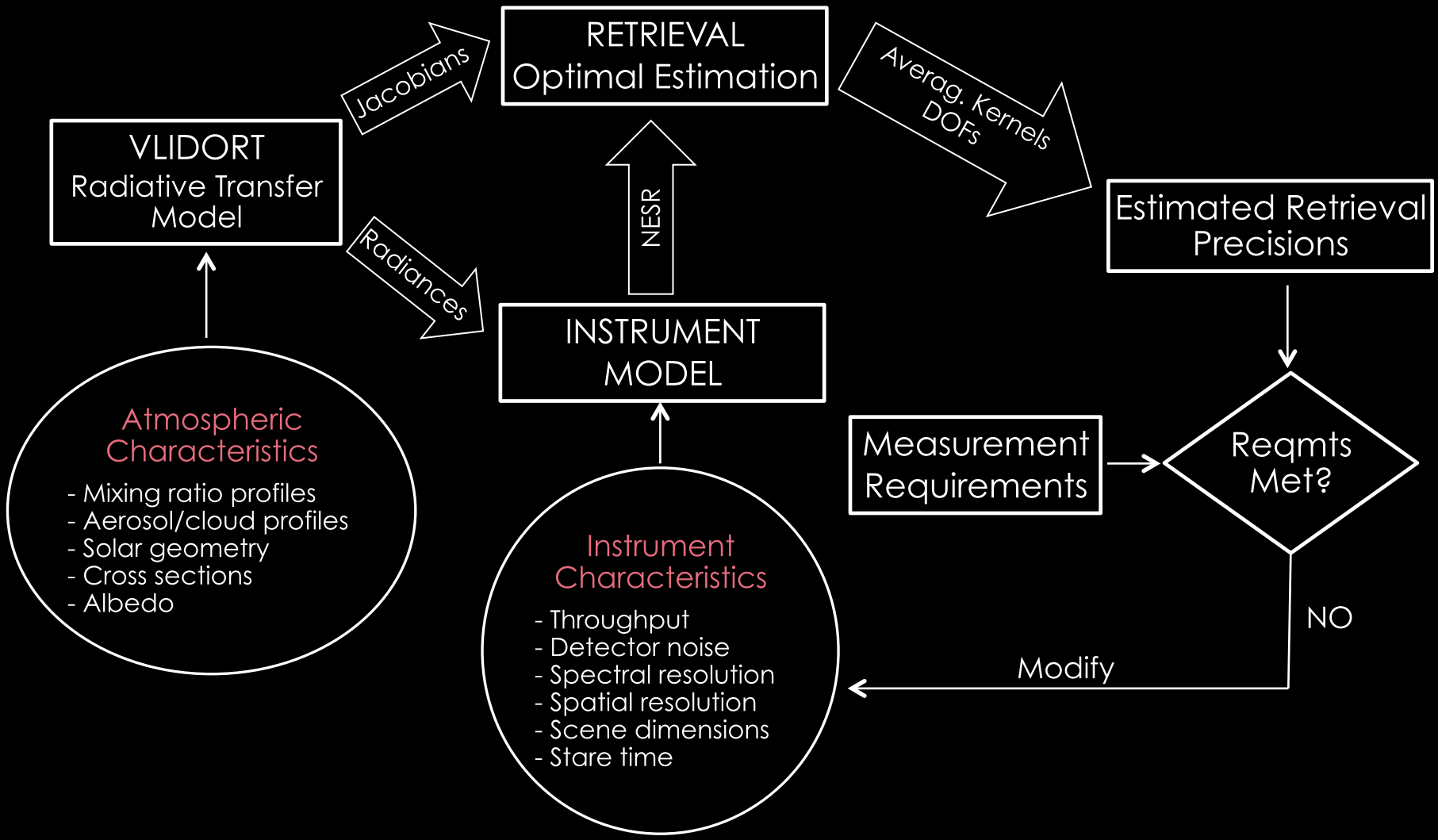
Integrated Retrieval Tool:

JPL-internal development for a retrieval algorithm to process ground-based, aircraft and satellite observations (LEO nadir/limb and GEO) in the UV/VIS/near-IR/thermal-IR, with a flexible user-interface for "turn-key" retrieval operations

Coupled Retrieval+Assimilation Tool:

Feed-forward improvements in atmospheric retrievals and chemical modeling by coupling retrievals and near-real-time assimilation – iterative initial guess/AMF climatologies from chemical models as part of the retrieval process. Obviously computer intensive

Overview of Instrument Modeling and Retrieval Flow



Sample Study:
Retrieval Sensitivities of H_2CO from Geostationary Orbit

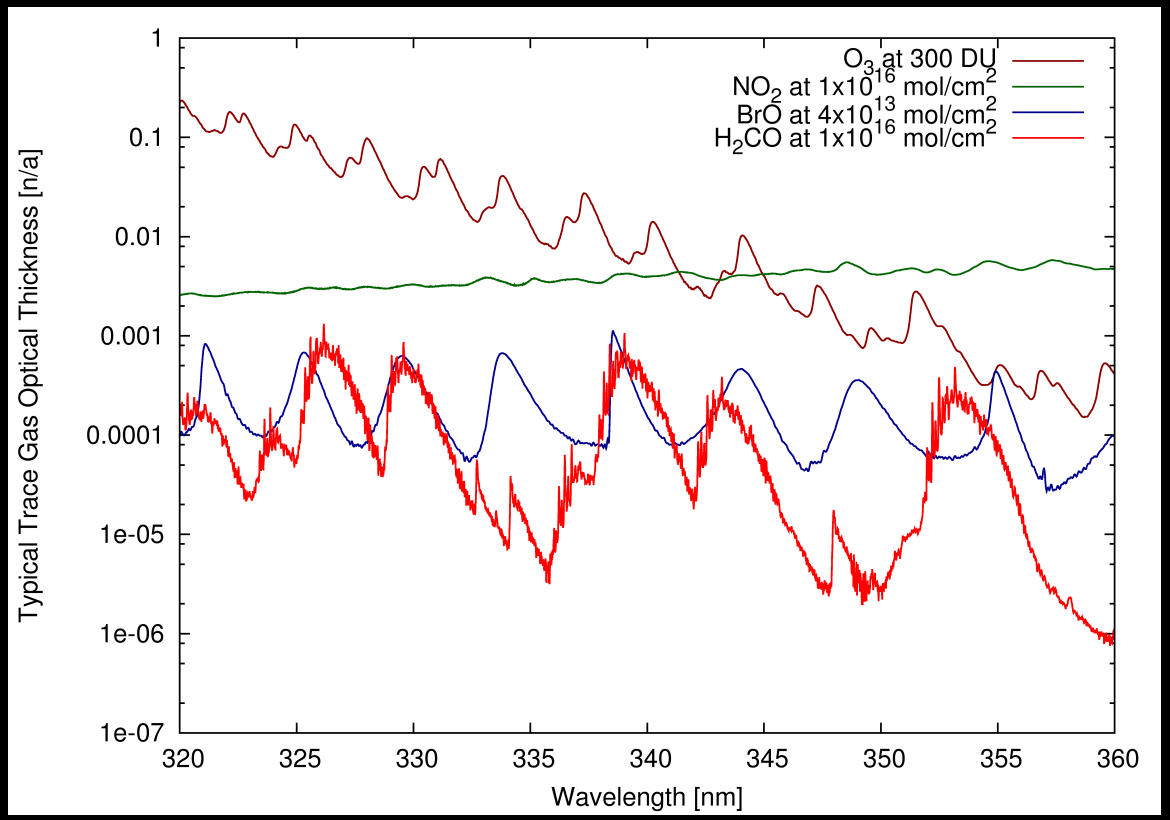
Question 1

What are the limits of H_2CO retrievals from GEO? E.g., are we able to detect background values at low solar elevation?

Question 2

What is the influence of instrument spectral resolution on H_2CO observability?

Typical Trace Gas Optical Thickness in the UV



Retrieval of H_2CO (lower troposphere) is difficult due to interfering strong O_3 and moderately strong NO_2 and BrO absorption in the stratosphere.

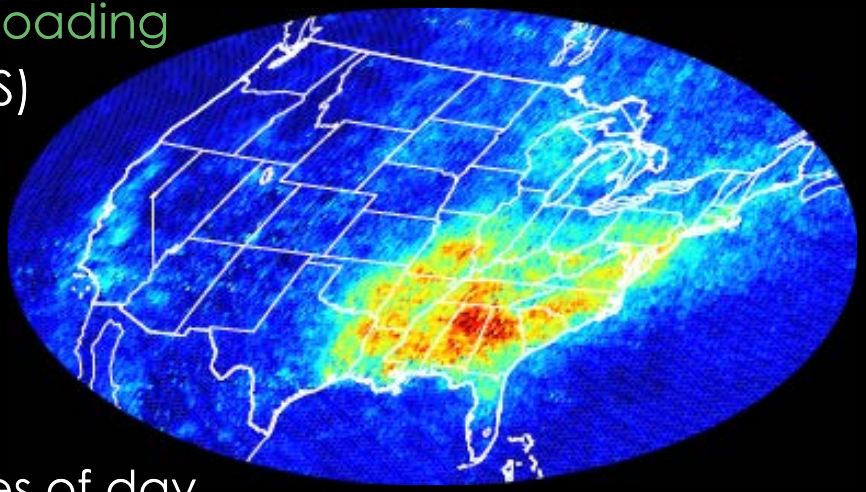
Spectral correlation of BrO and H_2CO absorption cross-sections adds complication

Approach

Use existing scenarios from PanFTS/Geo-CAPE sensitivity study (GEO satellite over the US) from 30 July 2006.

Select three scenarios of varying H_2CO loading

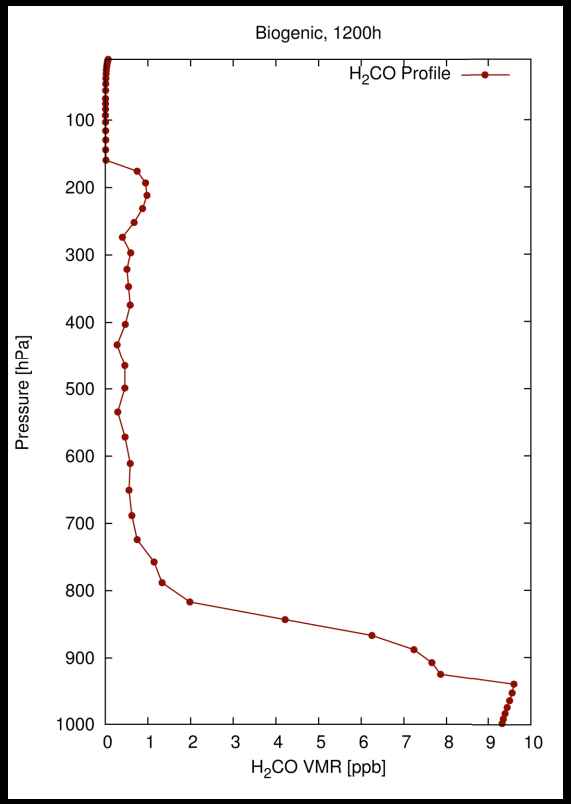
- strong biogenic (south-eastern US)
- moderate/strong anthropogenic (Los Angeles, downwind)
- background (Oregon)

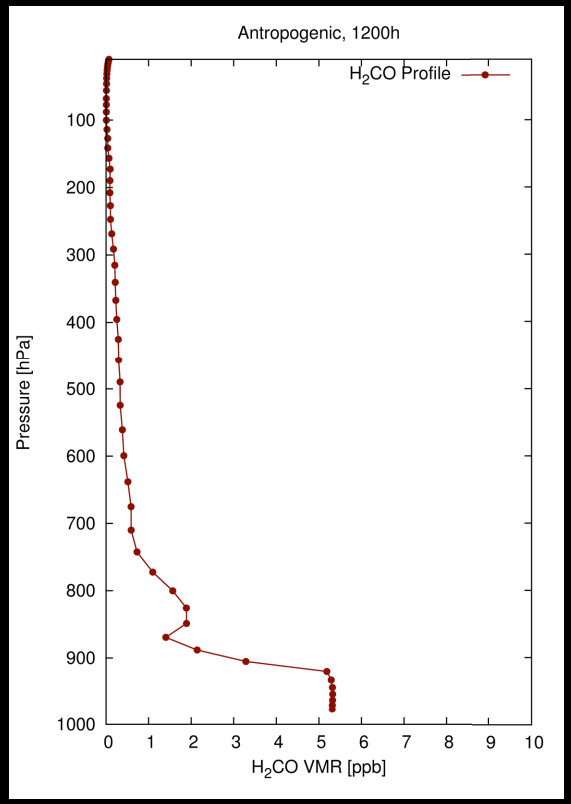


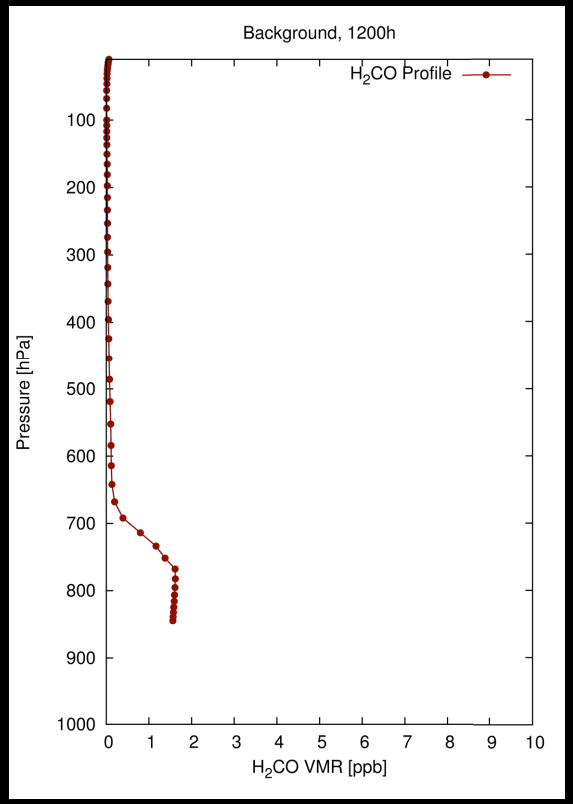
For each case, observe at different times of day for a range of solar zenith angles: 1200h, 1500h, 1800h.

Viewing zenith angles at the three locations are determined by the position of the GEO satellite.

H_2CO Volume Mixing Ratio Vertical Profiles







Three basic scenarios:

- Strong Biogenic (south-eastern United States)
- Moderate/Strong Anthropogenic (Los Angeles, downwind)
- Background (Oregon)

Radiance/Jacobian Simulations:

Fully scattering atmosphere
Spectral range 300-365 nm, spectral resolution 0.05 nm
Atmospheric constituents O_3, NO_2, SO_2, BrO, H_2CO, aerosols, but no clouds

Instrument Spectral Resolution:

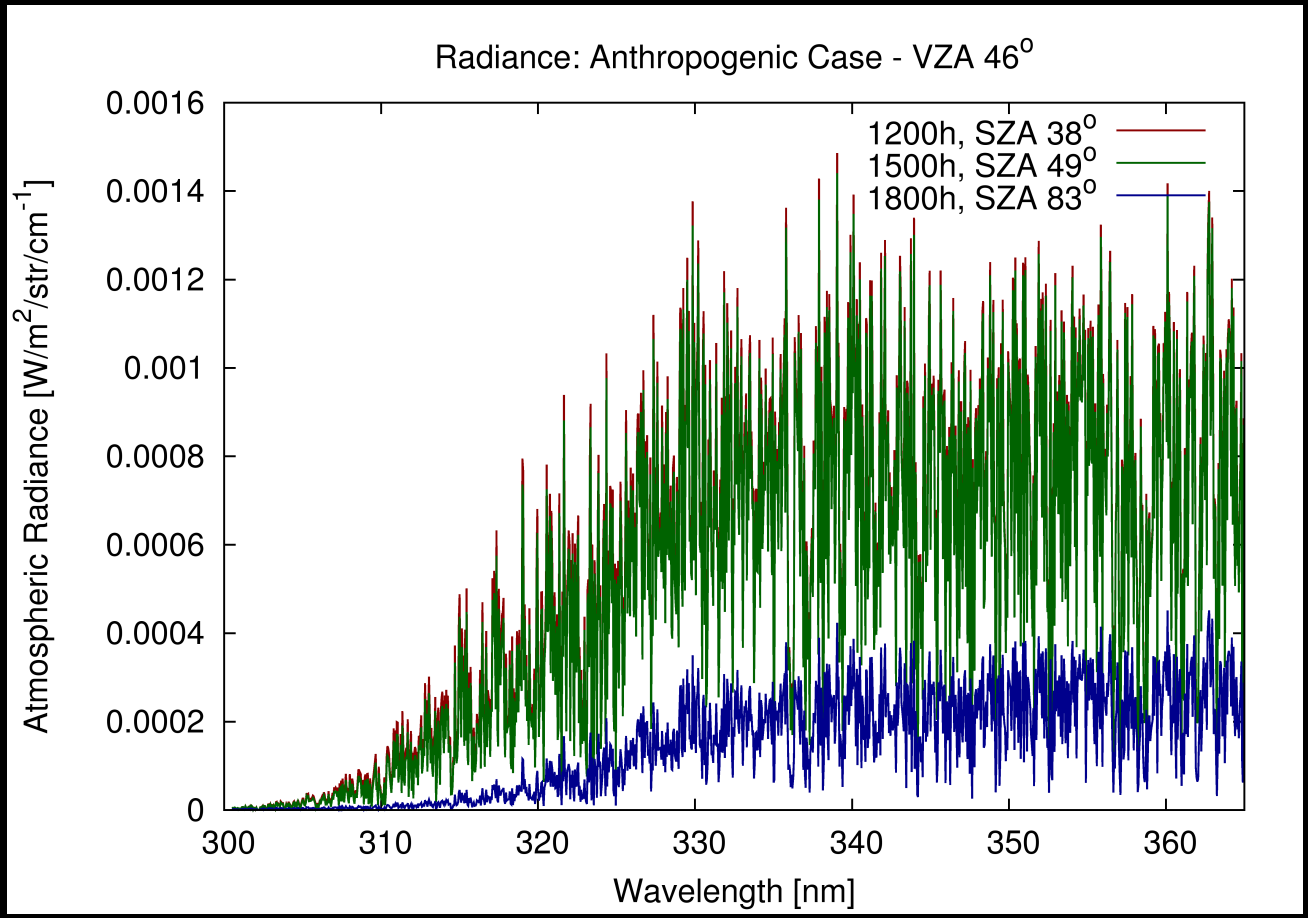
Instrument slit functions of 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0 nm FWHM
Convolve simulated radiances/Jacobians

Steps in the Processing Chain:

1. Simulate radiance
2. Convolve radiances with instrument slit function
3. Process convolved simulations with Inversion Tool to obtain Averaging Kernels, Degrees of Freedom, retrieval estimate, error estimate.

Note that the Inversion Tool does not perform iterative retrievals

Atmospheric Radiances (unconvolved)



Interlude:
Averaging Kernels and Degrees of Freedom

Averaging Kernels:

Characterizes the sensitivity of the retrieval estimate on the "true state"; vertically resolved, *i.e.*, measures information content as a function of altitude

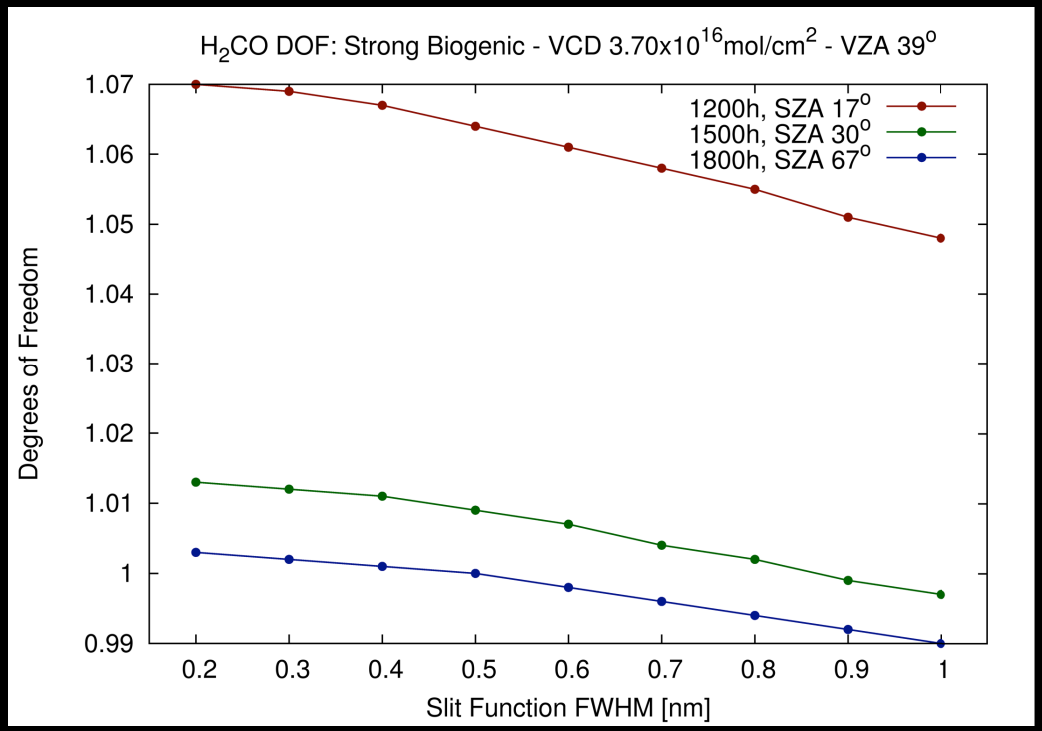
Degrees of Freedom (DOF):

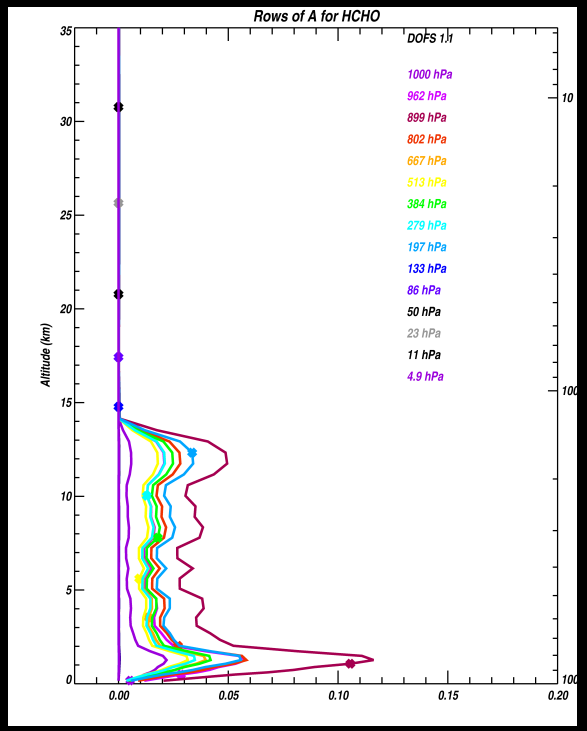
Derived as sum of the diagonal elements of the Averaging Kernel matrix; measures total information content in the observations on the target

DOF = 0	no information about the target
DOF = 1	sufficient information to retrieve the total column
DOF > 1	additional information on the target beyond total column, which may be exploited for vertical separation of Trop/Strat or PBL/Lower Trop/Upper Trop/Strat, *etc*.
DOF < 1	partial sensitivity to the full column

Results: H_2CO DOF as function of FWHM

Case 1: Strong Biogenic Source – south-eastern United States

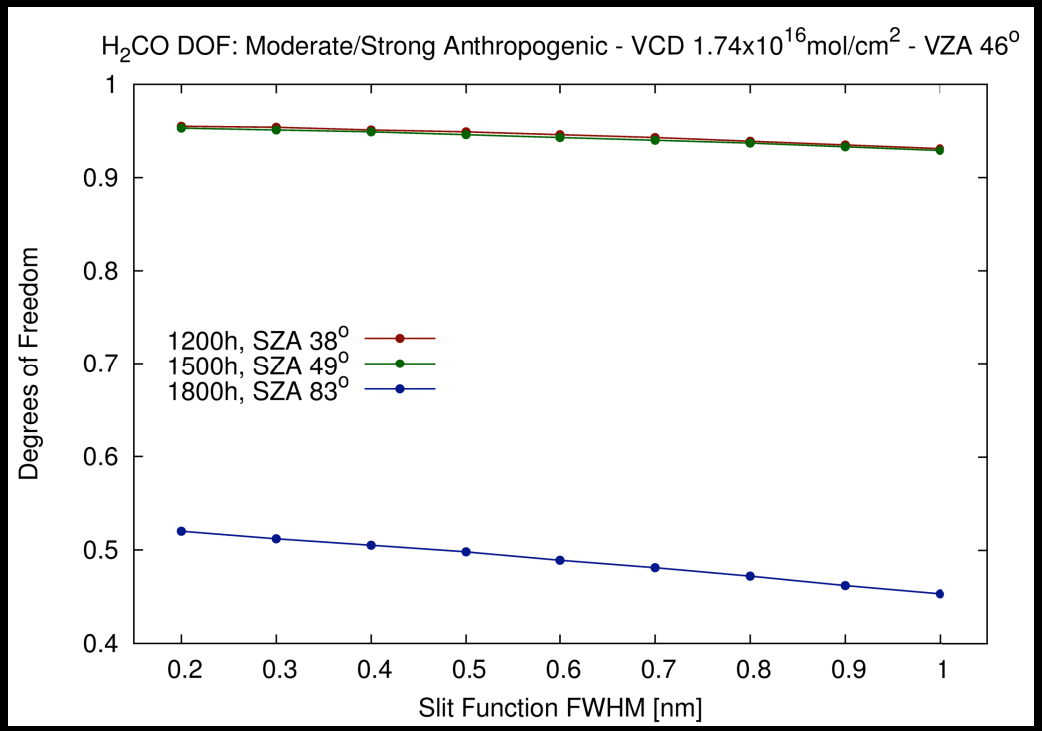


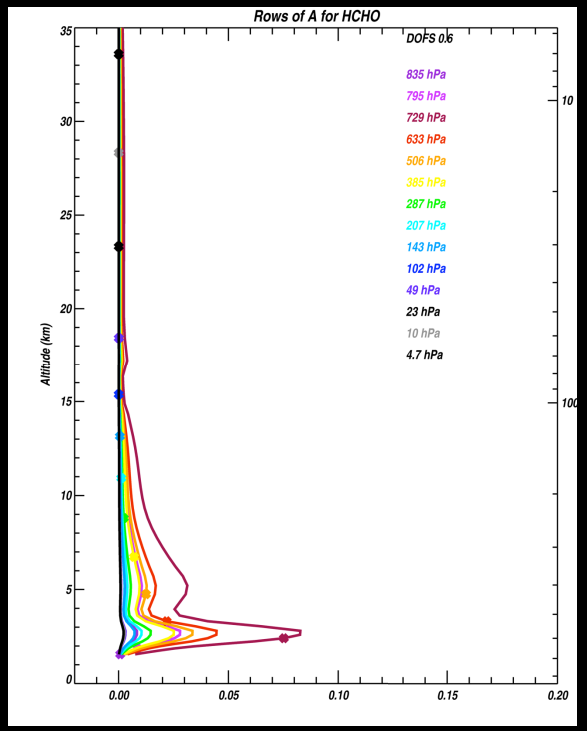


DOF~1 at all solar elevations, *i.e.*, full information on total column.

Results: H_2CO DOF as function of FWHM

Case 2: Moderate/Strong Anthropogenic – Los Angeles, downwind

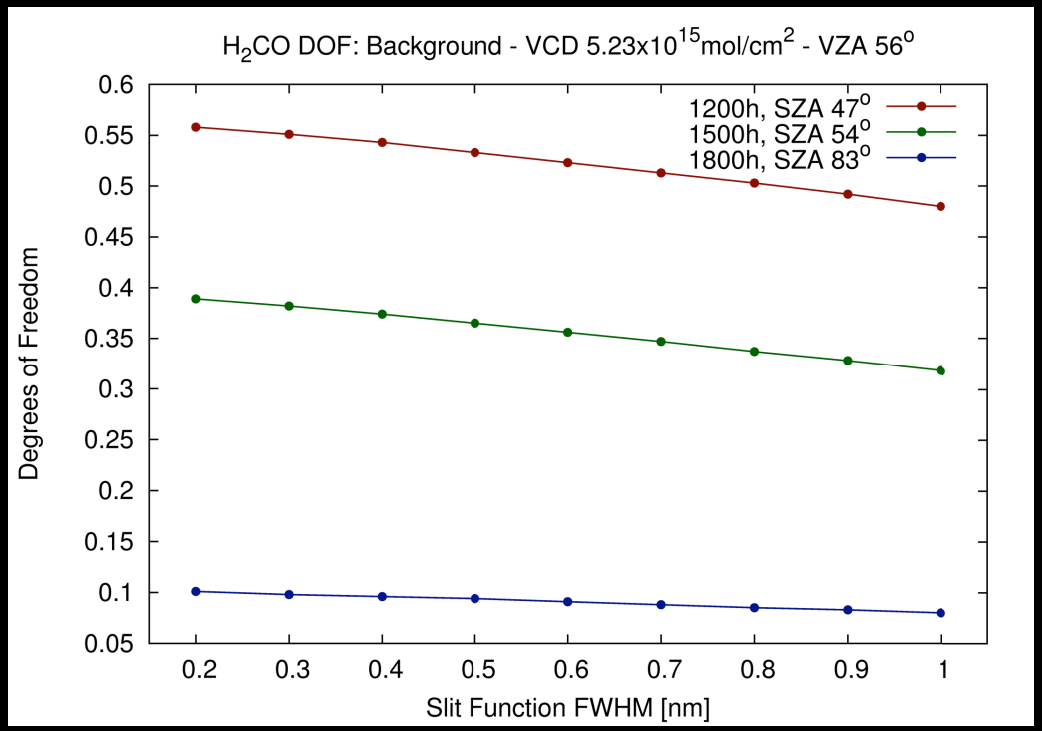


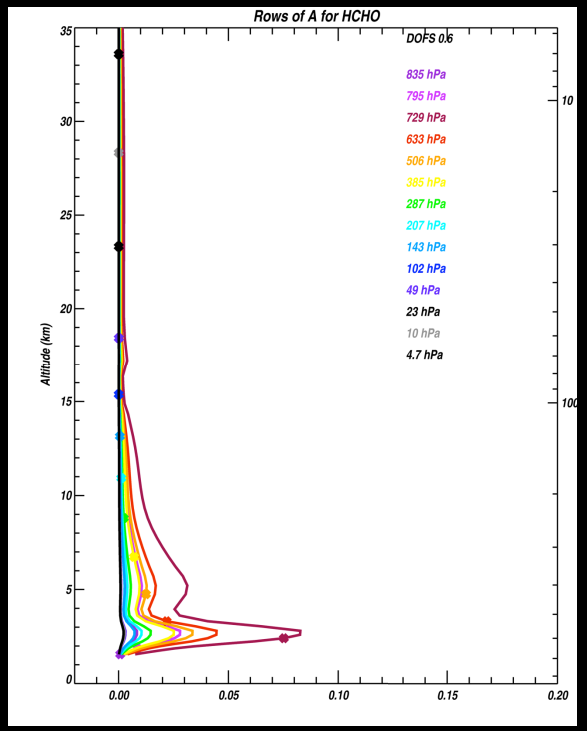


DOF~1 at high solar elevations, but <1 for low sun. This is partly an influence of aerosol loading in this scenario, but 83° sza is tough challenge for any retrieval

Results: H_2CO DOF as function of FWHM

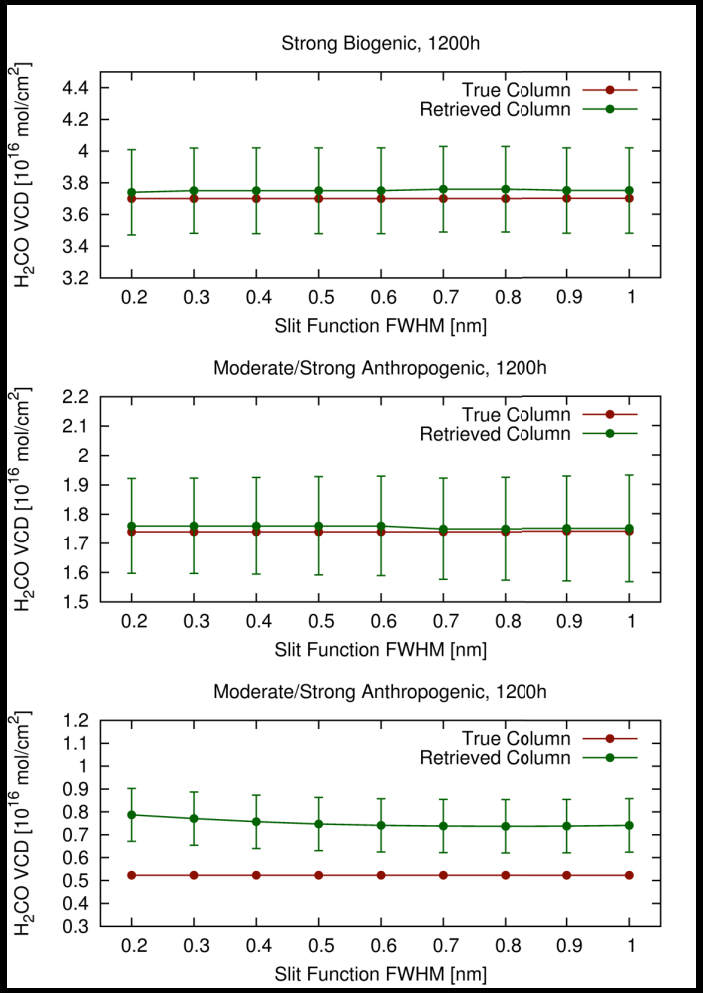
Case 3: Background – Oregon





DOF <0.6 at all solar elevations, and very low for moderate/large SZA. H_2CO retrieval at background level will be a challenge (GEMS is adopting co-adding approach)

Results: H_2CO Retrieved Columns and Error Estimate



Output from linear Inversion Tool

Error bars show measurement error.

Remember: no iterative retrieval was performed.

A proper total column or optimal estimation retrieval should reduce uncertainties and may alleviate part of the discrepancy between true and retrieved columns in the Background case.

Summary

JPL has strong expertise in atmospheric retrievals from UV through thermal IR, and a wide range of tools to apply to observations and instrument characterization. Radiative Transfer, AMF, Inversion, Fitting, Assimilation.

Tools were applied for a preliminary study of H_2CO sensitivities from GEO.

Results show promise for moderate/strong H_2CO lading but also that low background conditions will prove a challenge.

H_2CO DOF are not too strongly dependent on FWHM. GEMS choice of 0.6 nm FWHM(?) spectral resolution is adequate for H_2CO retrievals.

Case study can easily be adapted to GEMS observations/instrument model for more in-depth sensitivity characterization.

Leads right into Assimilation and OSSE studies … next talk by *Jessica Neu*