Radiative Forcing Calculation: Spectroscopy and Lineshape Uncertainties

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Outline

- **Objective: Assess uncertainties in radiative forcing due to uncertainties in radiative transfer calculations**
- **Three sources of uncertainty/error:**
  - **Spectral line parameters**
  - **Line shape function**
  - **Approximate methods relative to LBL calculations in climate models**
- **Motivated by Prof. W. Happer, Princeton, who is claiming that climate models overestimate forcing by ~ 40% due to inappropriate use of Voigt line shape "to infinity"**
  - **Wings of CO_2 lines are known to be sub-Lorentzian**
- **Working with Collins, Feldman (LBL), Fahey (NOAA), and Anderson and Lawler (U. Wisconsin/Physics)**
- **Report today on progress and future plans**

Radiative Forcing: Definitions for this Study

- **Definition**
  - **Compute net flux at the tropopause in the sense of "down – up"**
  - **Compute change in net flux at the tropopause in going to 280 ppm CO2 from 560 ppm CO2 – this is the radiative forcing definition**
- **At present using mid-latitude summer standard atmosphere for both 280 ppm and 560 ppm cases**
  - **Have realistic profiles from Dan Feldman which we will use in time**
- **Compute up and down fluxes, spectrally and spectrally integrated at 13 km (minimum T in MLS profile)**
- **Compute forcing, sometimes called instantaneous forcing for this definition**
  - **Get 5 W/m_2, consistent with earlier results of *Collins et al*., 2006**

Basic Parameters

- **Radiative Transfer Codes**
  - **MRTA – Dave Kratz – Voigt lineshape**
  - **LBLRTM – Taumi Daniels – "Chi factor" lineshape to account for sub-lorentzian wings, in accordance with observed lineshape**
  - **Codes are complimentary and useful for validation of each other**
- **Spectral Range: 500 to 800 cm^{-1}**
- **All lines, all bands, all isotopes of CO_2, O_3, H_2O**
- **Spectral Resolution: 0.005 cm^{-1} MRTA; 0.002 LBLRTM**

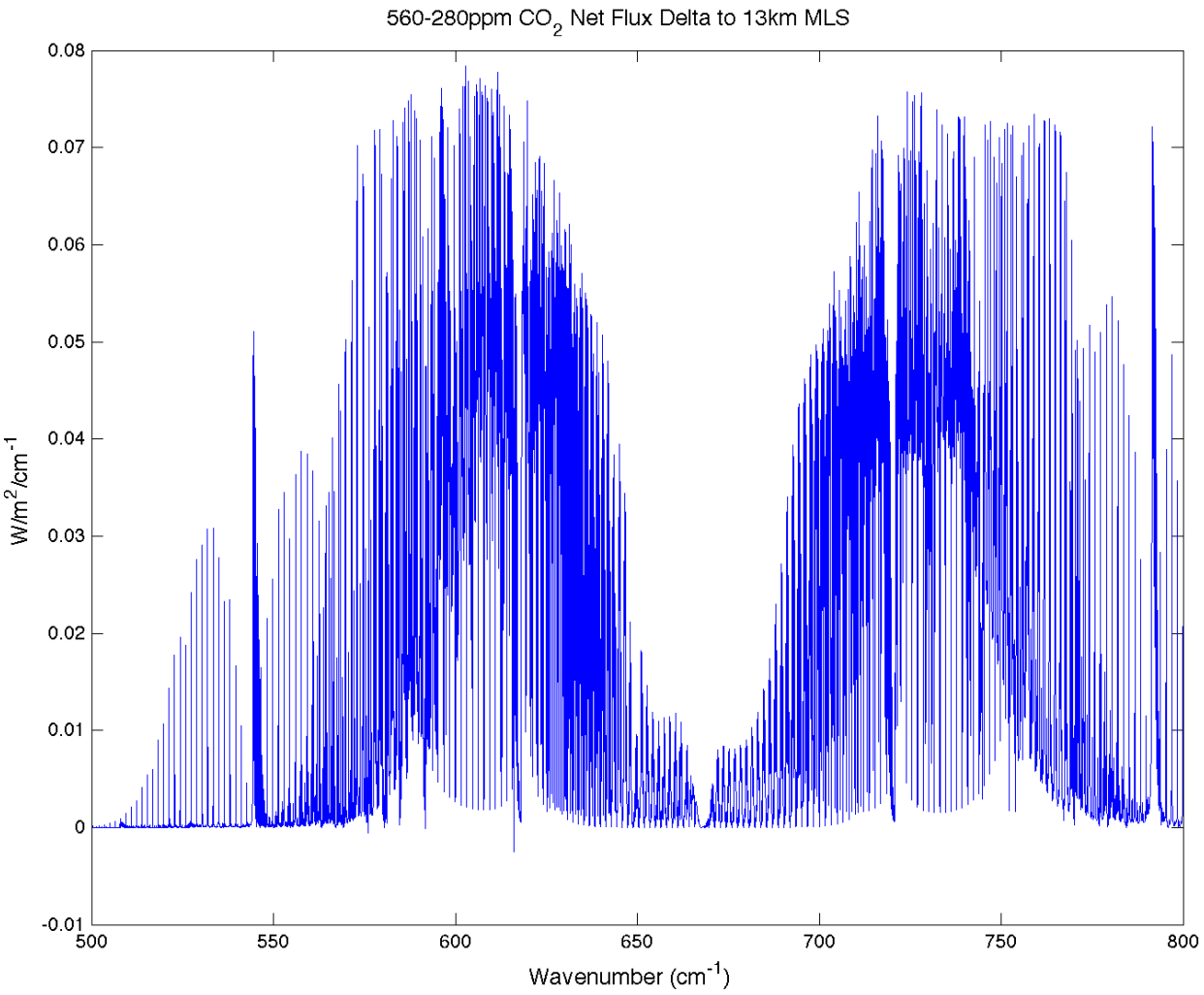
Studies to Date

- **The spectrum of radiative forcing**
- **Radiative forcing "Curve of Growth"**
- **Effect of line wing cut off**
- **Effect of line strength cut off**
- **Effect of width of spectral interval**

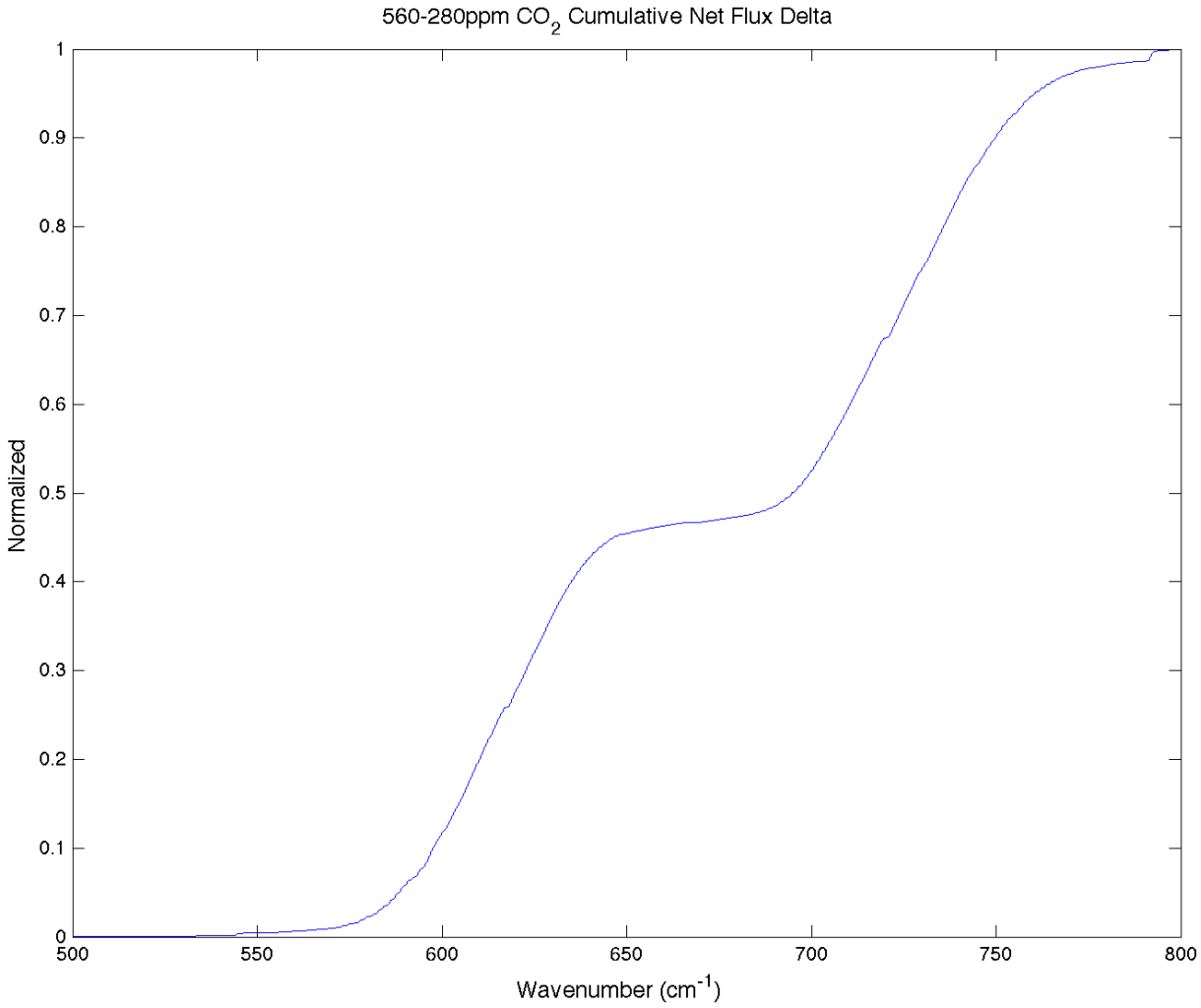
- Effect of perturbing the Voigt shape – started

- Effect of CO_2 line strength uncertainty – about to begin

The Spectrum of Radiative Forcing by CO_2

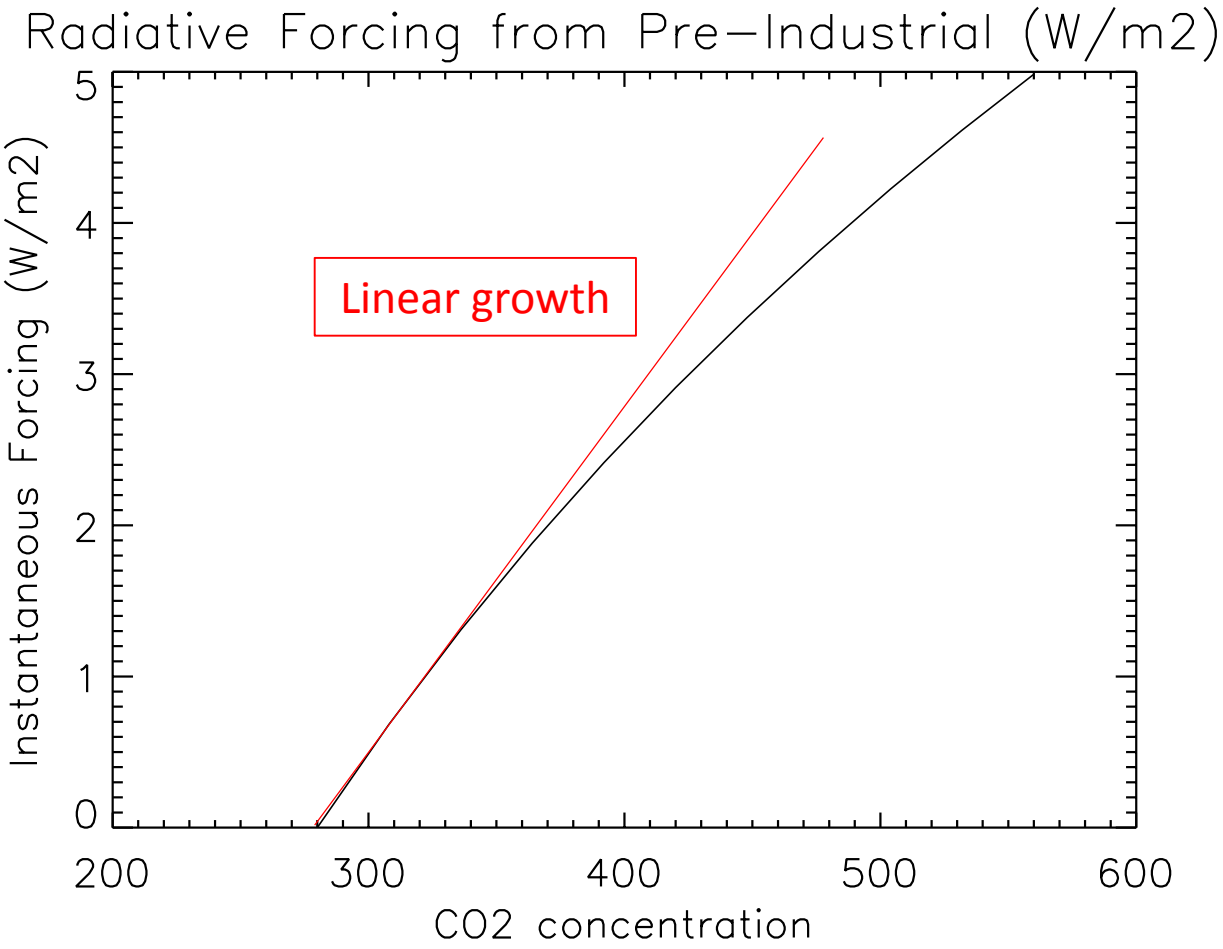


Cumulative Spectral Contribution to CO_2 Radiative Forcing



Radiative Forcing Curve of Growth

- Compute radiative forcing as a function of CO2 amount
- Start at 280 ppm, increase by 28 ppm, until doubled CO2 is reached (560 ppm)
- Plot results



Mid-latitude summer; voigt lineshape; 25 cm^{-1} out from line center
All CO_2 lines and bands from HITRAN 2012;

Effect of Line Wing Cutoff

- Compute forcing for standard case but extend Voigt wings out from line center
- Results: (MRTA, full Voigt)
  - 3 cm^{-1} 4.979 W/m2
  - 25 cm^{-1} 4.984 W/m2
  - 50 cm^{-1} 5.033 W/m2
  - 75 cm^{-1} 5.143 W/m2
  - 100 cm^{-1} 5.342 W/m2
  - 200 cm^{-1} 5.623 W/m2
  - 300 cm^{-1} 5.623 W/m2
- Baseline LBLRTM: 4.964 W/m^2 with Chi-Factor shape
- Conclusion
  - Voigt lines out to 3 cm^{-1} give same forcing as LBLRTM with sub-lorentizian wings
  - Going "to infinity" with Voigt lines only increases forcing by 13%, not 40%, but no one does this anyway

Effect of Line Strength Cut-Off

- Lots of really weak lines on the database – want to find out which ones are doing the forcing
- Begin to assess this by eliminating weak lines until forcing changes
- Results: LBLRTM. Baseline forcing is: 4.964
  - 1e-29 4.964
  - 1e-28 4.964
  - 1e-27 4.964
  - 1e-26 4.963
  - 1e-25 4.957 Cut off here – include all lines greater than 1e-25
  - 1e-24 4.928
  - 1e-23 4.752
  - 1e-22 4.257

Effect of Width of Spectral Interval

- Using MRTA code
- Baseline width: 500 to 800 cm^{-1}
  - Forcing: 4.984 W/m2
- Narrow width to 510 to 790 cm^{-1}
  - Forcing: 4.917 W/m2
- Change is larger than 1.3 % narrowing 20 cm^{-1}
- Make no change at this time to baseline interval

Effects of Uncertainty in Line Parameters (1)

- A major goal is to assess the uncertainty in radiative forcing due to uncertainty in spectral line parameters (S, halfwidth) and in line shape
- HITRAN and AER databases list uncertainties for each spectral line and for 6 of the parameters for that line (S, halfwidth, etc)
- Goal is to use the stated uncertainties in the line parameters to estimate the uncertainty in the forcing
- However, discovered that 2012 HITRAN listed all CO2 lines in 15 um region as having uncertianty > 20%.
- This was found to be a placeholder until updated line list is ready
- The updated line list is available – today! Iouli Gordon at Harvard SAO is sending MGM the update listing

Effects of Uncertainty in Line Parameters (2)

- We are ready to do the assessment of the uncertainty – expect the major parameter will be the line strength
- Line halfwidths may be known to 1% (need to verify reference)
- Will proceed by perturbing strengths and assessing forcing
- Likely will do a Monte Carlo study
- If uncertainty is too large (5%?) then will recommend required reductions in uncertainty of line parameters

Assessing Uncertainty in Line Shape

- We already know that LBLRTM with best-known lineshape gives same results on forcing as full Voigt to 25 cm^{-1}, and even at 3 cm^{-1} out is not substantially different
- Note all IR limb sensors (LIMS, HALOE, SABER) do fine with Voigt to 25 cm^{-1}.
- Need to determine where "action" in sub-lorentzian wing is – it may be – is it less than 3 cm^{-1}?
  - This should be available in literature (and Ken Jucks)
- We can readily perturb the voigt shape in MRTA
- Unlikely to perturb chi-factor in LBLRTM – would not trust our alterations of the code
- Still need to think this through, but it is last hurdle to be cleared in this study

Discussion

- Feedback (or forcing) and suggestions from the team?