Impact of Linewidth Narrowing on Climate Sensitivity

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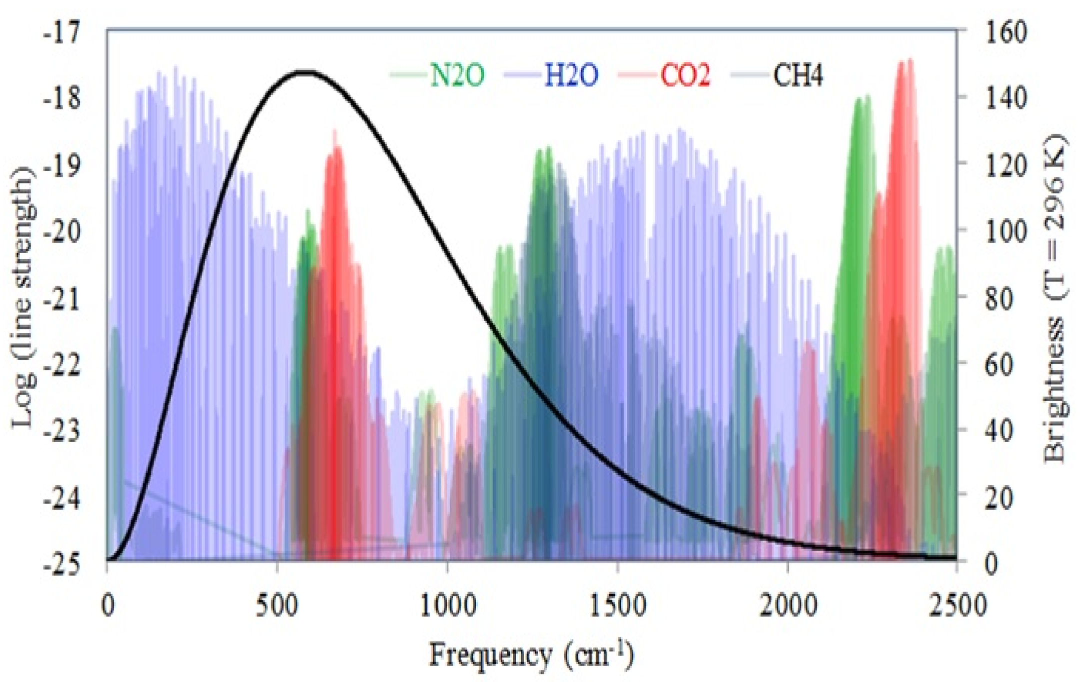
Overview

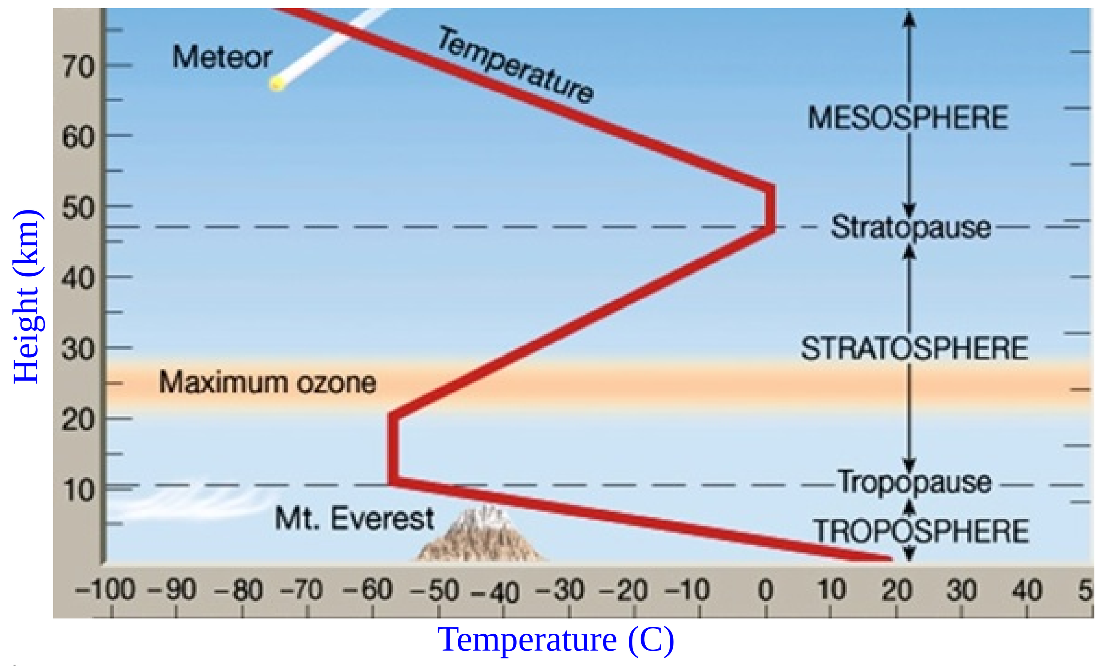
Increasing greenhouse gas concentrations affect the far-wing lineshape of molecular transitions. The finite time of molecular collisions & Dicke narrowing reduce the absorption cross section. This is critical when fitting atmospheric observations of infrared radiance to determine radiative forcing.

Procedure

A line by line computation of infrared radiative flux was performed. Linestrengths were downloaded from Hitran database for >100,000 lines for various greenhouse gas isotopomers.



Fast numerical routines developed to solve Schwarzschild equation for infrared flux through atmosphere. Calculations use standard atmospheric temperature profile & take into account observed altitudinal greenhouse gas concentrations.



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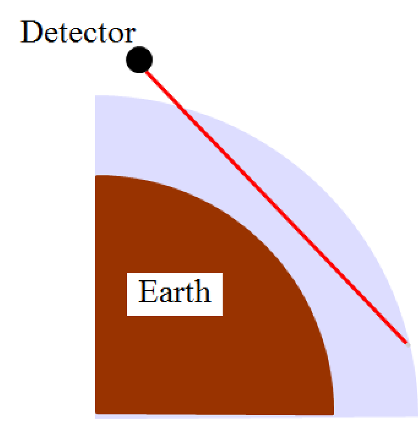
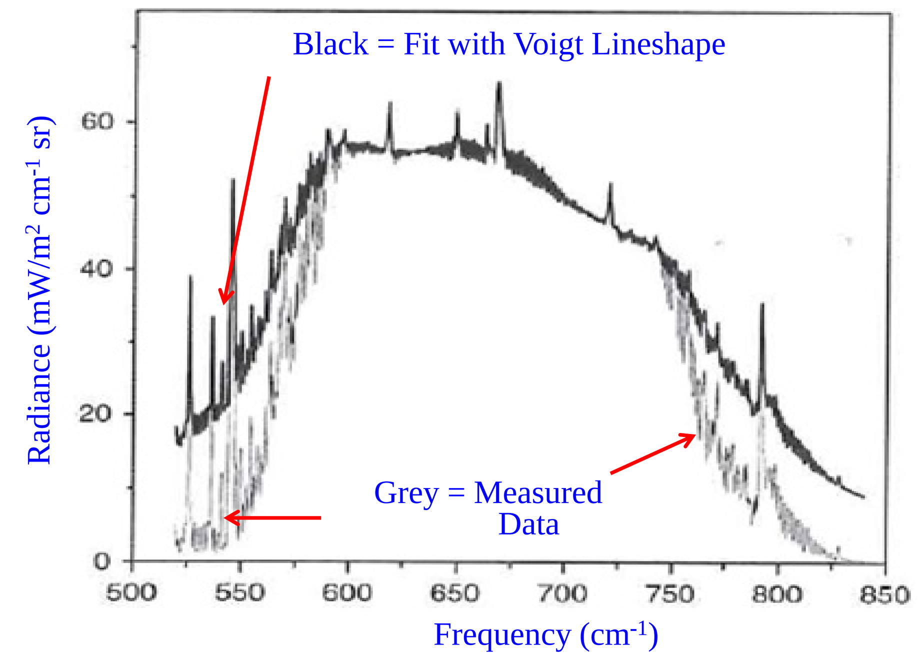
Voigt Lineshape **Fails** in Far Wings!

This is shown by balloon borne radiance detector at 40 km. (J. Hartmann et al, Coll. Effects on Molecular Spectra, Elsevier (2008)

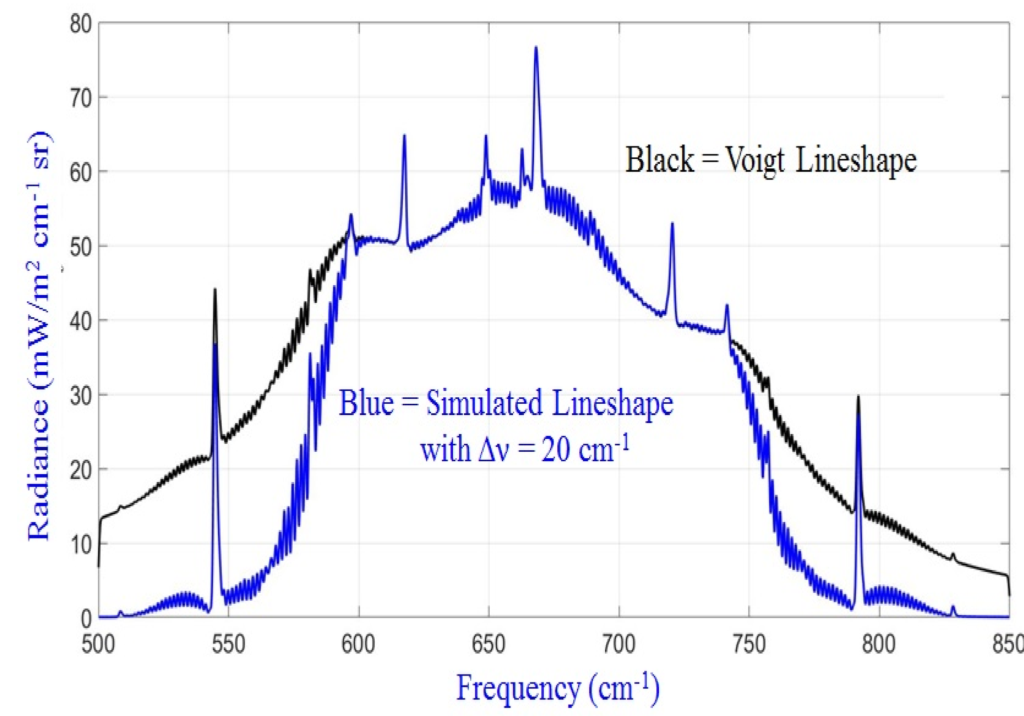




Data modelled by multiplying Voigt profile for each line by antipedestal function.

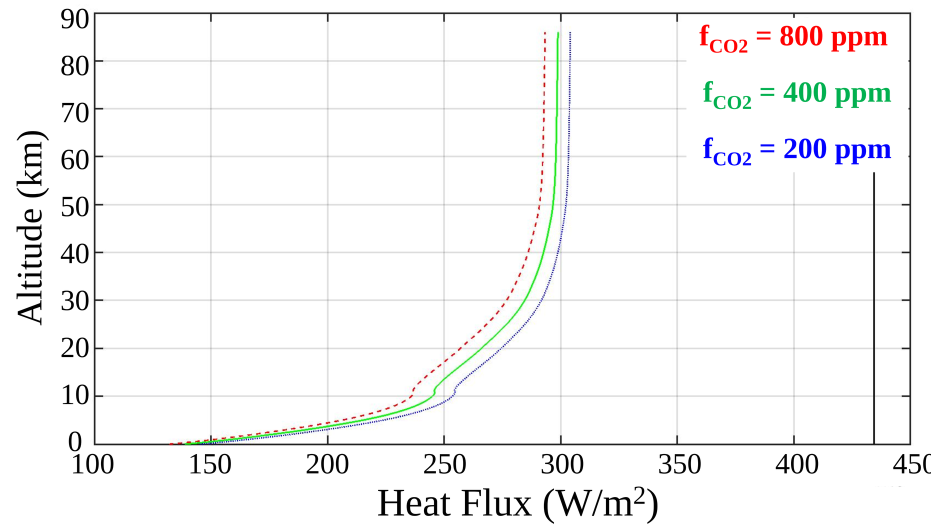
$$G(\nu) = G_{VOIGT}(\nu)\ \mathrm{sech}^2(\nu/\Delta\nu)$$

Good agreement with observed data found for width $\Delta\nu$ <50 cm^{-1} and <u>no adjustable parameters</u>.



Radiative Forcing due to CO_2 Doubling

Heat flux integrated over all frequencies.

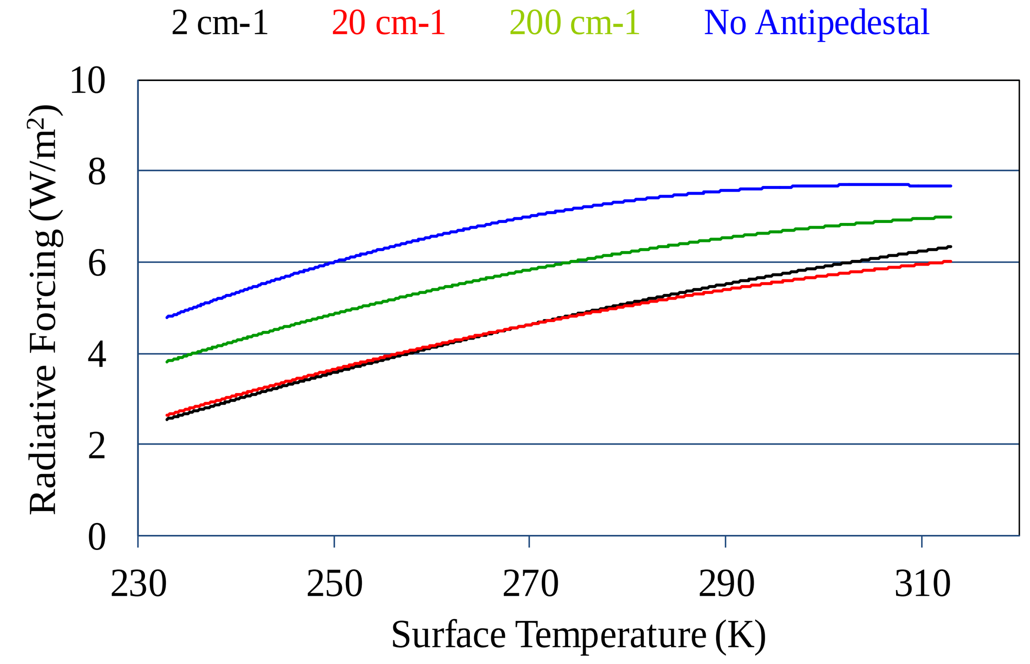


Radiative Forcing ΔJ

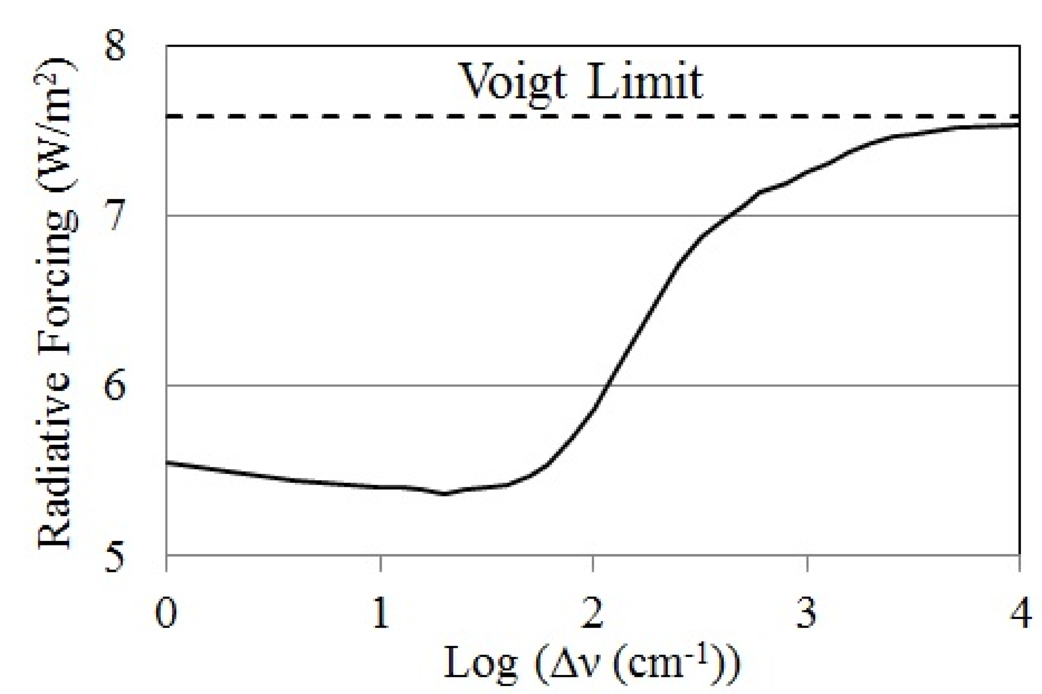
$= \text{Heat flux}_{400} - \text{Heat flux}_{800}$

Surface Temperature Dependence on Radiative Forcing

Radiative Forcing is plotted at top of atmosphere (TOA) for doubling CO_2, CH_4, N_2O & constant relative humidity.



Effect of Antipedestal Width on TOA Radiative Forcing



TOA Radiative Forcings

This was found for standard atmosphere & mean surface temperature of 288.7 K. A 6% H_2O increase assumes constant relative humidity. Analysis of 60 years of North American data shows assumption fails in dry areas where relative humidity decreases as temperature rises. (V. Isaac & WvW, *J. Clim.* **25**, 3599 (2012)

Greenhouse Gas	Concentration Change	Radiative Forcing (W/m^2)
H_2O	+6% at 70% Rel. Humidity	0.9
CO_2	400 → 800 ppm	4.0
CH_4	1.8 → 3.6 ppm	1.5
N_2O	0.32 → 0.64 ppm	2.2
Total	All of above	5.5
Plus	H_2O Dimers, Clouds, Aerosols	????

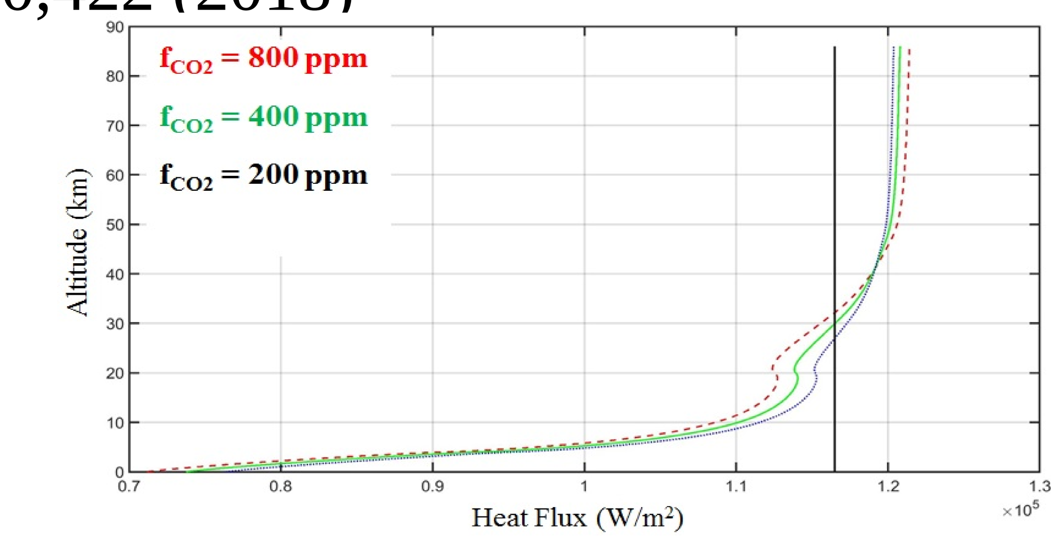
$$\Delta T = T\,\frac{\Delta J}{4J} = 1.4\ ^oC$$

$$\mathbf{\Delta T = S \log_2 C_2/C_1 \Rightarrow S \sim 1.5}$$

IPPC 2014: S = 1.5 – 4.5

Antarctic Winter Temp. Profile

Antarctic surface 25 ^oC colder than air 1-2 km higher results in negative radiative forcing. This agrees with H. Schmithüsen et al, *GRL* **42**, 10,422 (2018)



Conclusion

Voigt lineshape overestimates radiative forcing by tens of percent. Earth's surface temp. increases by ~1.4 ^oC due to doubling CO_2, CH_4, N_2O & assuming constant relative humidity. Future work should include clouds which can warm or cool. Warmer surface may increase convection enhancing heat transport from Earth's surface & is a negative forcing.