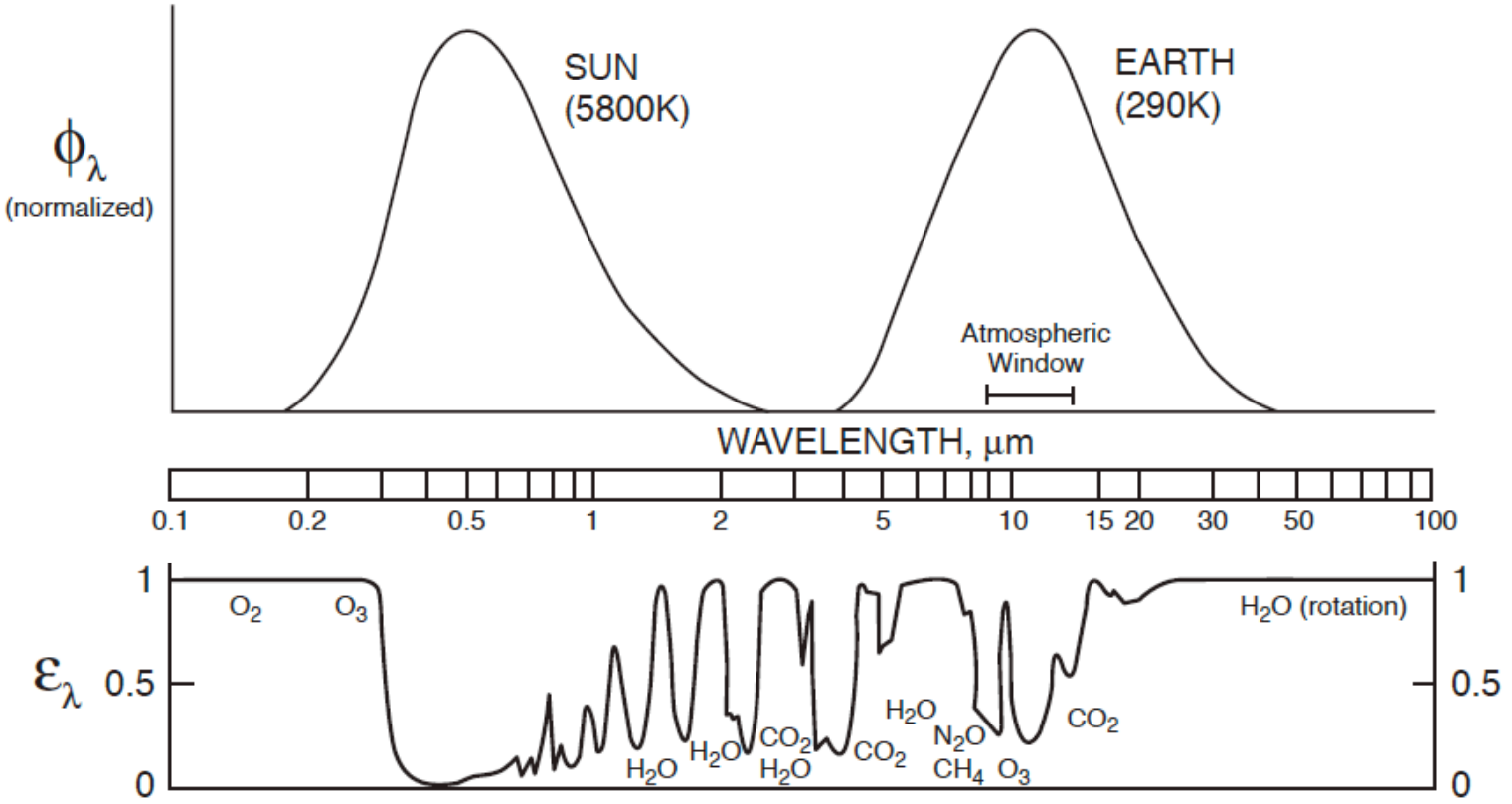
PHY392S
Physics of Climate

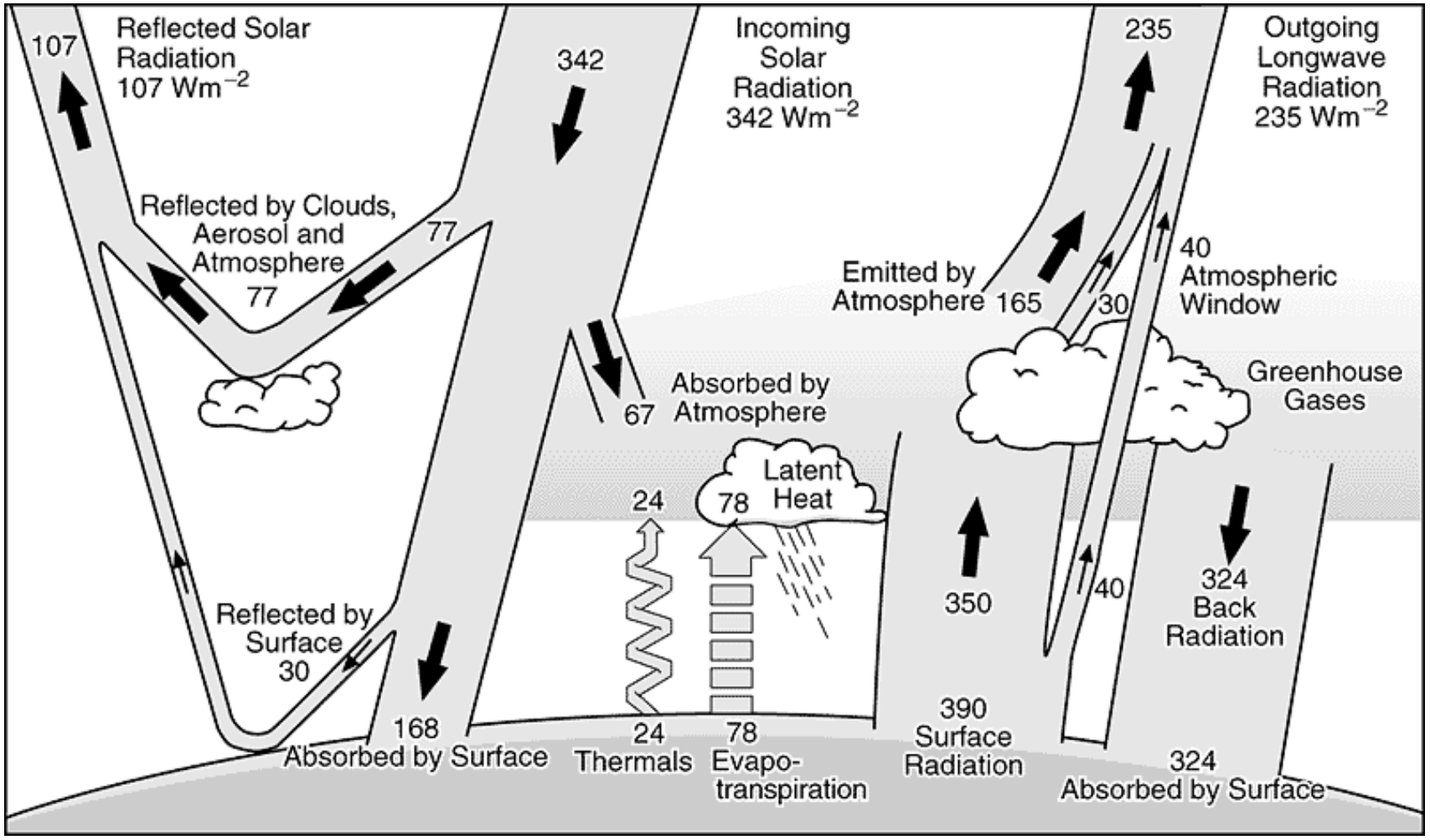
Lectures 8 and 9

Supplementary slides

GREENHOUSE EFFECT:
absorption of terrestrial radiation by the atmosphere



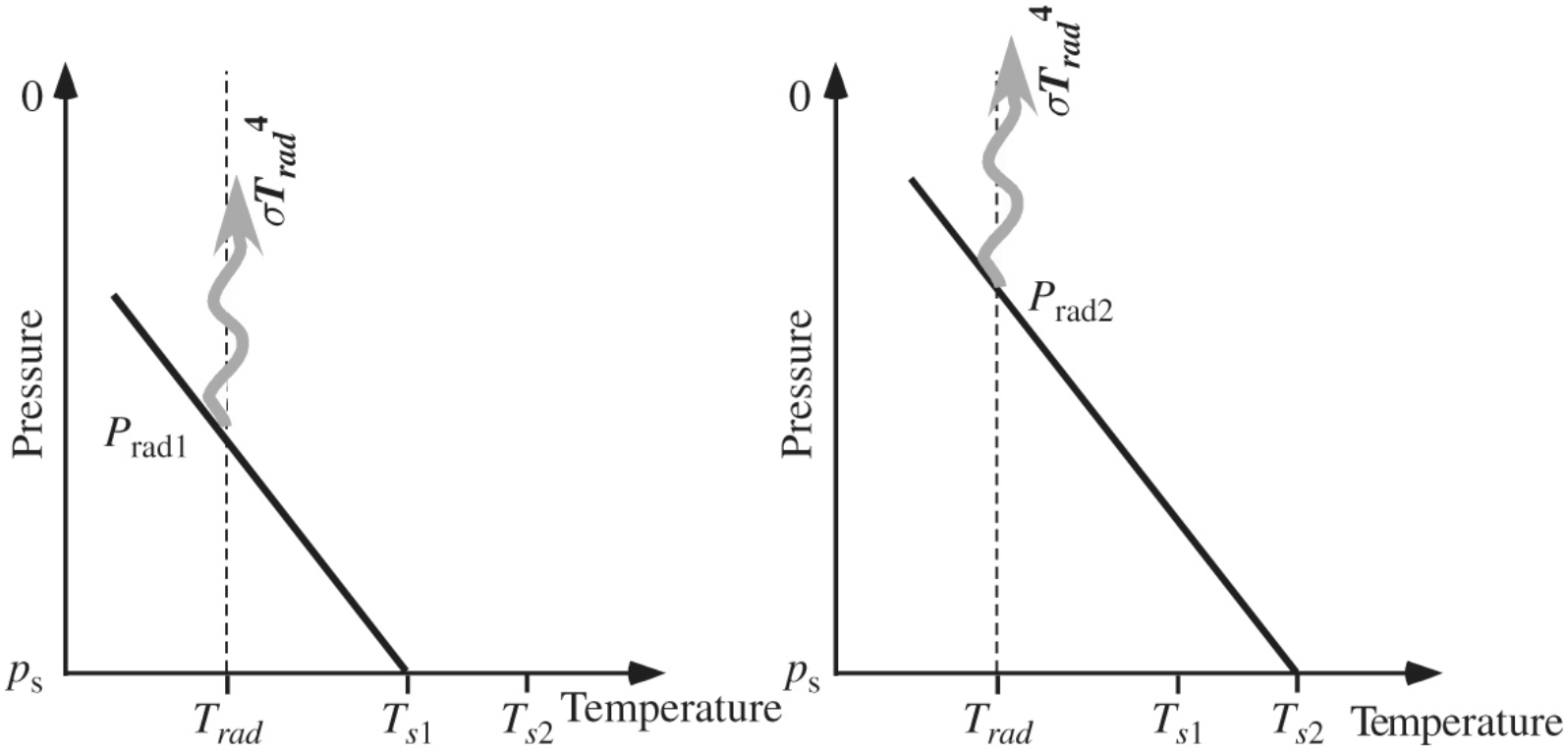
Earth's Energy Budget



Source: Kiehl and Trenberth: Earth's Annual Global Mean Energy Budget, Bull. Am. Met. Soc. 78, 197-208, 1997.

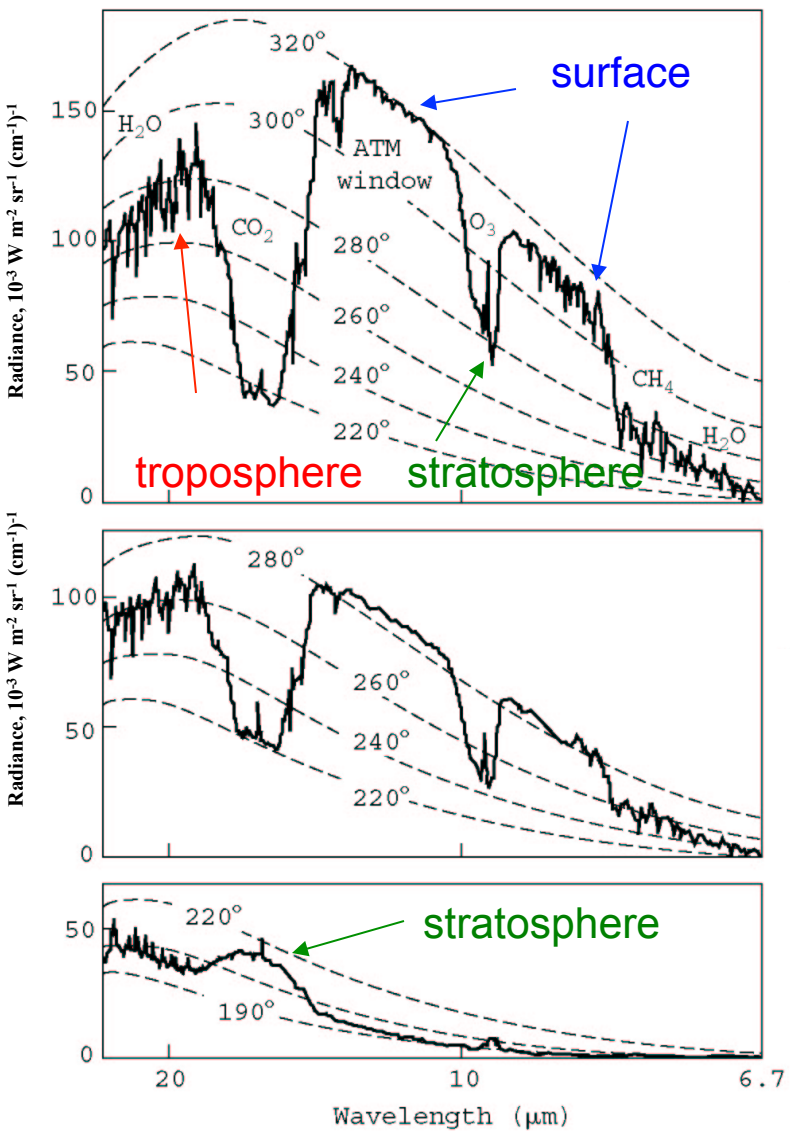
Impact of adding GHG

$$T_s = T_{rad}\left(\frac{P_s}{P_{rad}}\right)^{R/c_p}$$



Note: Pierrehumbert uses T_{rad}, whereas we use T_e

Terrestrial Radiation Spectrum From Space



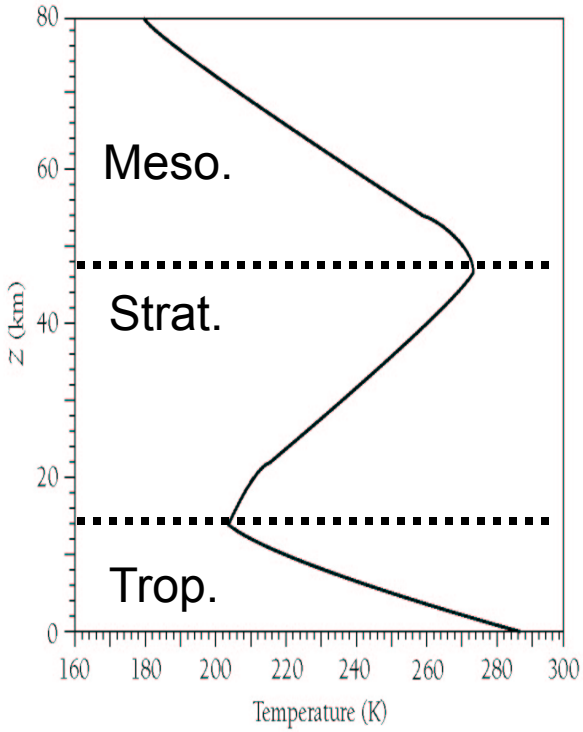
Composite of blackbody radiation spectra for different *T*

Sahara

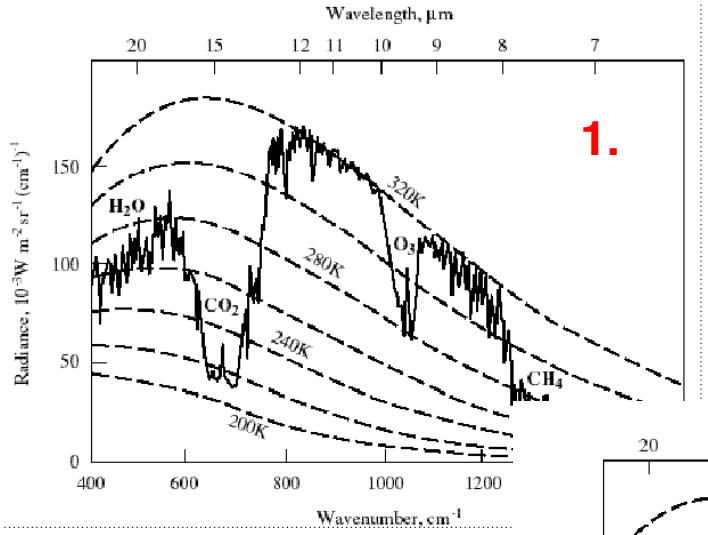
Mediterranean

Antarctica

Atmospheric T profile

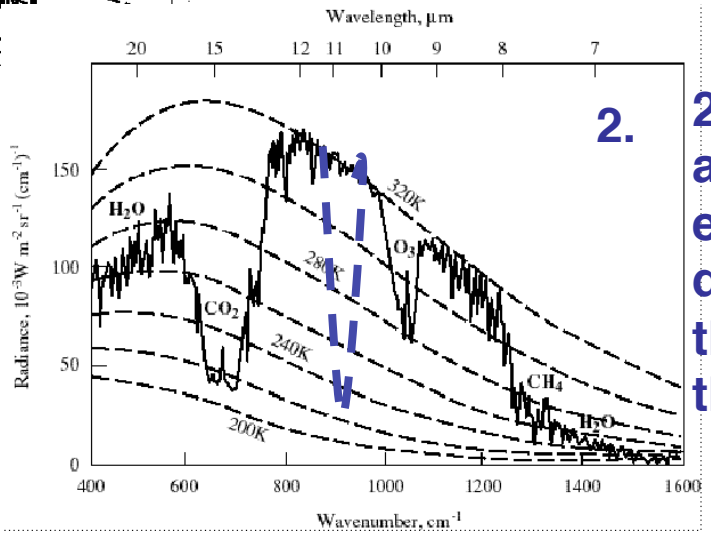


How Does Addition Of A Greenhouse Gas Warm The Earth?

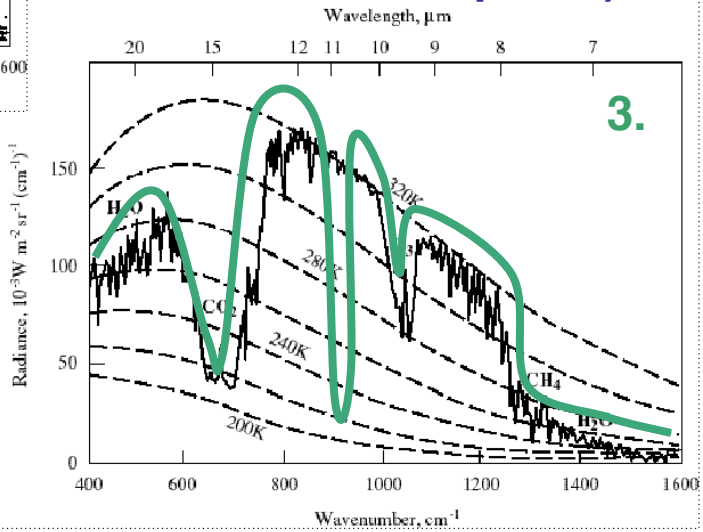


Example of a GHG absorbing at 11 μm

1. Initial state



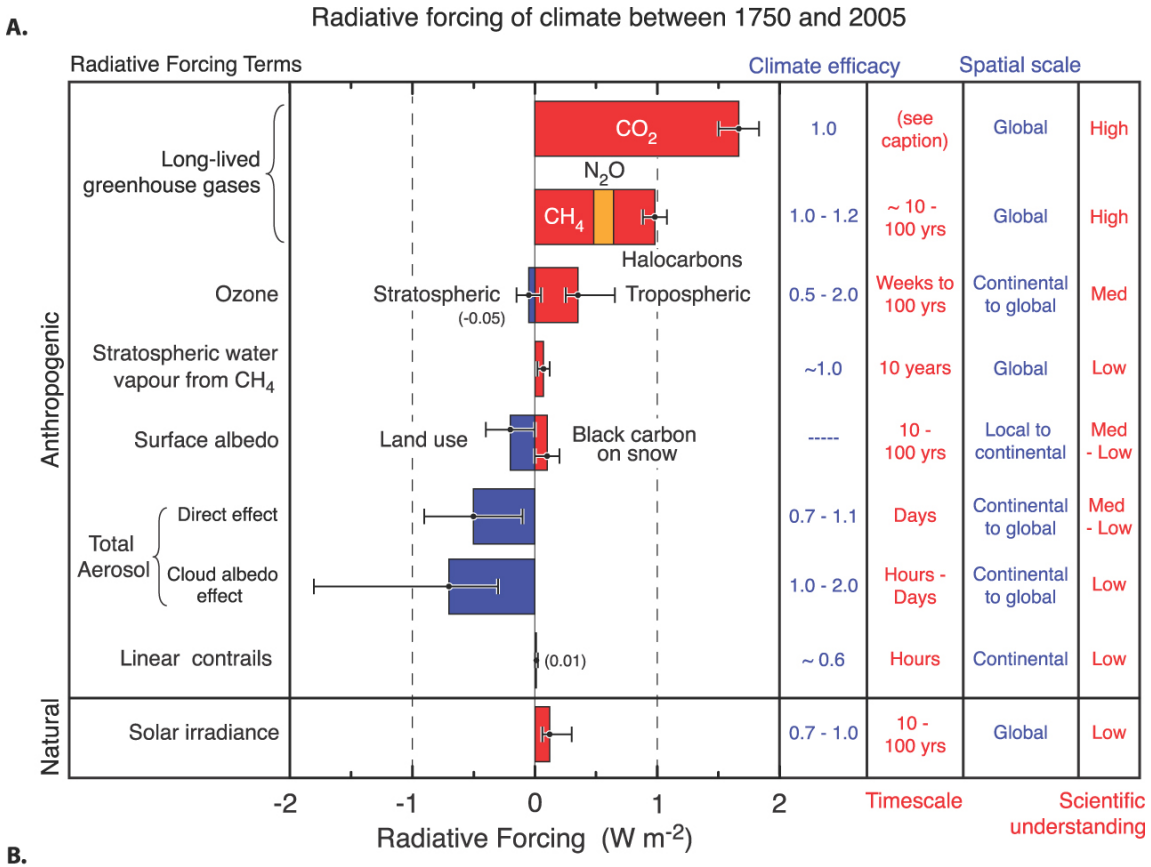
2. Add to atmosphere a GG absorbing at 11 μm; emission at 11 μm decreases (we don't see the surface anymore at that λ, but the atmosphere)

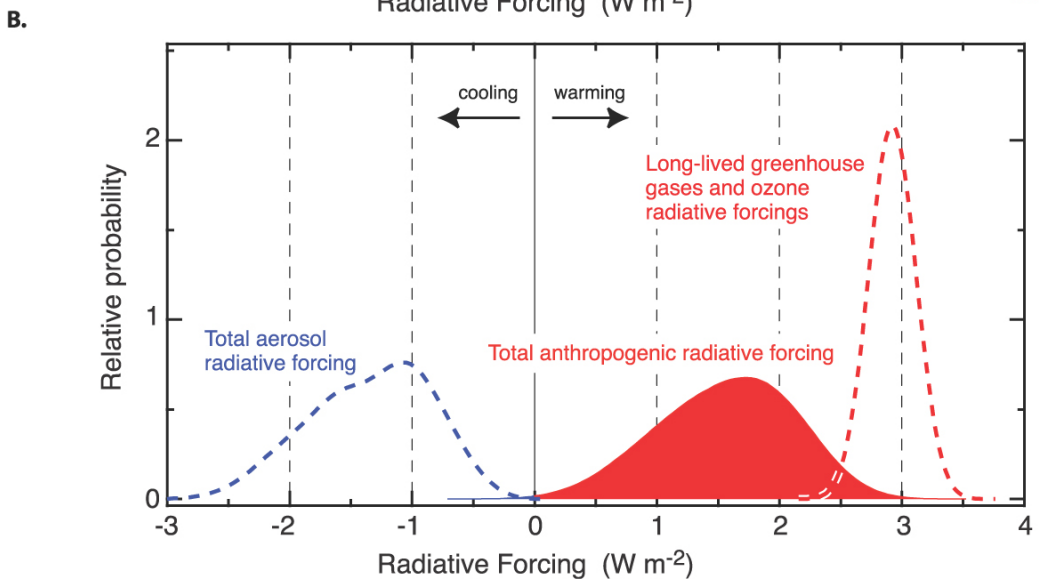


3. At new steady state, total emission integrated over all λ's must be conserved
⇨ Emission at other λ's must increase
⇨ The Earth must heat!

[courtesy D. Jacob]

Global Radiative Forcing of Climate, 1750-present





IPCC [2007]

It has been proposed that global warming due to increasing CO_2 could be countered by injections of SO_2 in the stratosphere to produce sulfate aerosols.

a) It is estimated that injecting one ton of sulfur as SO_2 in the stratosphere would increase the albedo A of the Earth by $\Delta A = 4 \times 10^{-8}$ for a duration of one year. Show that the corresponding radiative forcing ΔF for that 1-year period would be 1.4×10^{-5} W m^{-2}.

b) We would like to use these SO_2 injections to maintain the climate at its present state, canceling the effect of future growth of CO_2. The present-day CO_2 concentration is 380 ppm with a growth rate of 1.5 ppm/yr. The radiative forcing ΔF (W m^{-2}) from increasing the CO_2 mixing ratio from C_o to C can be approximated as $\Delta F = 6.3 \ln(C/C_o)$. Calculate the amount of sulfur that would need to be injected to the stratosphere in the first year of this program.

c) The business-as-usual scenario from IPCC projects a rise of CO_2 to 500 ppm by 2050. Calculate the amount of sulfur that will need to be injected to the stratosphere in 2050 to maintain climate at the condition we have today.