ESE 101:

Homework 4 (due November 8):

1. Suppose a gas that absorbs solar radiation has a uniform mixing ratio of $1\,\mathrm{g\,kg^{-1}}$ and an absorption cross section of $5\,\mathrm{m^2\,kg^{-1}}$. Assume an isothermal atmosphere with $T = 260\,\mathrm{K}$, and a surface pressure of $10^5\,\mathrm{Pa}$.[1]

   (a) At what altitude is the rate of energy absorption per unit volume maximal when the sun is directly overhead?

   (b) At what altitude is the rate of energy absorption per unit volume maximal when the solar zenith angle is $45°$? What difference does the zenith angle make?

   (c) If the frequency range over which absorption takes place contains 5% of the total solar energy flux, what is the heating rate (K day^{-1}) at the level of maximum energy absorption? What is the heating rate one density scale height above and below the level of maximum absorption? (Use globally averaged insolation.)

2. **Muckhouse climate**. Suppose Earth's atmosphere had a large amount of scattering and absorbing aerosols in the stratosphere, such that most shortwave radiation is absorbed or reflected in the upper atmosphere and only a small fraction reaches the surface. (You can think of this as being the temporary result of a supervolcano eruption, or of an asteroid impact.)

   (a) Assume the aerosols are only scattering, not absorbing sunlight, and that 80% of the shortwave radiation incident at the top of the atmosphere is scattered back to space. An additional 10% is absorbed in the atmosphere, and the remaining 10% reach the surface, which has an albedo of 0.12. You can ignore the atmospheric scattering and absorption of the shortwave radiation that is reflected from the surface. Give a rough estimate of how the global-mean surface temperature will change from what it currently is, assuming the tropospheric temperature lapse rate and concentrations of longwave absorbers will not change. (The current Bond albedo of Earth is 0.3, and the total solar irradiance is $1362\ \mathrm{W\,m^{-2}}$.)

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[1] From Hartmann, *Global Physical Climatology*.

(b) Explain briefly and qualitatively (equations and numbers are not necessary) how feedbacks owing to changes in the concentration of water vapor will modify your estimate of the global-mean surface temperature change.

(c) Now suppose the aerosols are also absorbing sunlight, and that most sunlight is absorbed in the stratosphere, rather than being scattered back to space. Qualitatively, how would that change the tropospheric temperature structure?