ESS 200b. Problem set 3

Due at beginning of class on Thursday, Dec 6th, 2007
Use SI units, state your assumptions, and show all your work.
Please begin each problem on a separate page.

1. *Effect of atmospheric solar absorption on lapse rate*
   Assume that the troposphere behaves like two blackbody layers in the infrared, as in Wallace and Hobbs, p.122, Figure 4.9. Assume that both atmospheric layers absorb $0.1\sigma T_E^4$ of the incoming solar radiation, and that the surface absorbs the remaining $0.8\sigma T_E^4$. (a) Calculate the new radiative equilibrium temperature profile. (b) How does it differ from the case where all the solar heating is applied to the surface? (c) Does the vertical distribution of heating influence the effective temperature? (d) Explain why solar energy absorbed at the surface heats the atmosphere more than solar energy absorbed in the atmosphere.

2. *Relative magnitude of convective and radiative fluxes*
   Place the two layers in the model of problem 1 at 2.5 and 5 km. Assume a fixed lapse rate of $\Gamma = 6.5$ K km^{-1} and a planetary effective temperature of 255 K. (a) Derive energy balance equations for each layer that, other than radiative fluxes (long and short wave), include an unknown convective energy flux C_{s2} [W m^{-2}] from the surface to the lower layer and C_{21} [W m^{-2}] from the lower layer to the upper layer. (b) Solve for the temperature profile in radiative-convective equilibrium and find the required convective energy fluxes from the surface and the lower layer. (c) Find the ratios of your surface radiative and convective fluxes to the values given in Wallace and Hobbs Figure 10.1 on p. 420. (d) What do this and problem 1 imply about the relative roles of atmospheric solar absorption, longwave cooling, and convective cooling in regulating Earth's surface temperature?

3. *Does orbital eccentricity explain seasonal temperature changes?*
   (a) Show that the changes in the Earth's equilibrium temperature T_E and the Earth-Sun distance r are related by $\delta T_E/T_E = -\delta r/2r$. The distance between the Earth and the Sun varied by about 3.3% annually, with a minimum and maximum on January 3 and July 5, respectively. (b) Compute the induced seasonal change in the Earth's equilibrium effective temperature ΔT_E [K] from January to July. (c) Discuss the relative role of zenith angle and eccentricity in determining Northern Hemisphere seasonal T changes (you might find useful Wallace and Hobbs figures 10.5, 10.7, or 10.8, in answering to this part of the problem)

4. *Distribution of solar heating by well-mixed absorbers*
   (a) What percentage of the incident monochromatic intensity with wavelength λ and zero zenith angle is absorbed in passing through the layer of the atmosphere extending from an optical depth $0.2 < \tau_\lambda < 4.0$? (b) What percentage of the outgoing monochromatic intensity to space with wavelength λ and zero zenith angle is emitted from the layer of the atmosphere extending from an optical depth $0.2 < \tau_\lambda < 4.0$? (c) In an isothermal atmosphere with temperature T_v, through how many scale heights ($H = R_d T_v / g_0$) would the layer in (a) and (b) extend?

5. *Global dimming and global warming*
   Read the attached letters, which appeared during the last year on EOS. Briefly summarize the on-going discussion, using the knowledge you have on radiative-convective balance. Describe the discussed changes in terms of changes to parameters that enter in a radiative-convective equilibrium calculation (e.g. changes in convective fluxes, lapse rates, short wave radiation absorption in the atmosphere, thickness of perfectly absorbing layers in the infrared...). Comment on the effects that you expect those changes have on the surface temperature.