Homework Assignment #4

ECE 597UU/697UU, Fall 2009

(Posted on the course website on Thu, 8 Oct; due in class on Thu, 15 Oct)

Problem 1 (6 pts.): Heating rate of the atmospheric boundary layer

The atmospheric boundary layer (ABL) is the region of the atmosphere that is directly affected by surface processes, such as solar heating during the day and nighttime cooling due to long-wave radiation. Suppose the daytime ABL thickness is $h$, the sensible surface heat flux is $H$, and the air density is $\rho$. Suppose that the ABL is well mixed, such that the heating is uniform in time and height. Suppose further that you can neglect the temporal change of $h$.

(a, 2 pts.) What is the heating rate, $dT/dt$ ($T$ is air temperature and $t$ is time), in terms of $h$, $H$, and $\rho$? (There is an additional material parameter of air that needs to be accounted for. Which one?)

(b, 2 pts.) Show explicitly that the expression on the right-hand side of your equation has the unit $K \cdot s^{-1}$.

(c, 2 pts.) What heating rate do you get for $h = 1$ km, $H = 300 \text{ W m}^{-2}$, and $\rho = \text{ kg m}^{-3}$? Is the result realistic? Too large, too small? Explain!

Problem 2 (6 pts.): Heating the oceans

(a, 2 pts.) Suppose the surface energy budget were not exactly balanced, such that there were a residual surface heat flux $\Delta S_0$ that heats the oceans uniformly. Suppose the globally averaged ocean depth is $D$. What would the ocean heating rate $dT/dt$ be?

(b, 2 pts.) Show explicitly that the expression on the right-hand side of your equation has the unit $K \cdot s^{-1}$.

(c, 2 pts.) Suppose that $\Delta S_0$ amounts to 0.1% of the solar constant. Assume $D = 4$ km. How long would it take until the ocean temperature were increased by 1 K? Compare your result with heating rates that are considered realistic in the context of global warming.

Problem 3 (4 pts.): Children heat the pool

Children play in a small swimming pool and cause turbulence with an r.m.s. velocity of 1 m s$^{-1}$. Suddenly, the children leave the pool, and the turbulent motion dissipates. Suppose that the turbulent kinetic energy is converted entirely into heat that increases the water temperature. By what amount does the water temperature increase? Justify your answer.

Problem 4 (4 pts.): Humidity in the desert

You are hiking in the desert, and the air temperature is 40 °C. You have a bottle filled with ice water, which you know has a temperature of 0 °C. There is no condensation on the outside of the bottle. What can you say about the relative humidity? Justify your answer.