ESE 101:

Homework 6 (due November 30):

(Problems 1–3 adapted from Hartmann, ch. 5)

1. Use the bulk aerodynamic formula to calculate the evaporation rate from the ocean, assuming a transfer coefficient for evaporation $C_d = 10^{-3}$, a surface wind speed $U = 5\,\mathrm{m\,s^{-1}}$, and that the reference-level air temperature is 2 K less than the sea surface temperature. Calculate the evaporation rate for (a) surface temperature $T_s = 0°\mathrm{C}$, saturation specific humidity at the surface $q_s^* = 3.75 \times 10^{-3}$, relative humidity $\mathcal{H} = 70\%$; (b) $T_s = 0°\mathrm{C}$, $q_s^* = 3.75 \times 10^{-3}$, $\mathcal{H} = 100\%$; (c) $T_s = 30°\mathrm{C}$, $q_s^* = 27 \times 10^{-3}$, $\mathcal{H} = 70\%$; (d) $T_s = 30°\mathrm{C}$, $q_s^* = 27 \times 10^{-3}$, $\mathcal{H} = 100\%$. Assume a fixed air density of $1.2\,\mathrm{kg\,m^{-3}}$. How would you evaluate the importance of relative humidity versus the importance of surface temperature for determining the evaporation rate?

2. Calculate the Bowen ratio using the bulk aerodynamic formulas for surface temperatures of 0, 15, and 30°C, if the relative humidity of the air at the reference level is 85% and the air–sea temperature difference is 2 K. (Assume equal transfer coefficients for sensible and latent heat.)

3. Use the results of problem 2 to explain why high-latitude land areas often have high surface moisture content.

4. **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 $1362\ \mathrm{W\,m^{-2}}$.)

(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?