Homework Sheet #5

ECE 697CC, Spring 2005

(Due in class on Thu, 15 April)

Problem 11 (total 40%): Wien's law

(a, 20%) Consider a black body radiating at a temperature T. Determine, on the basis of Planck's law for black-body radiation, the wavelength λ_m of maximum intensity.

(b, 10%) Solar light has the maximum intensity at $\lambda_m = 880\ \mu\text{m}$. Determine the black-body radiation temperature of the sun's surface.

(c, 10%) Assuming an average Earth surface temperature of 15 deg C, calculate λ_m for the terrestrial black-body radiation.

Problem 12 (total 30%): Simple climate model

Consider the following simple climate model, which does not account for the greenhouse effect: The horizontal diffusion of heat and the thermal inertia of the Earth's surface are so large that the Earth surface temperature is the same everywhere and does not vary with time. The albedo a (the fraction of the incoming short-wave radiation that is reflected back into space) is the same everywhere and does not change with time. The outgoing infrared, or long-wave, radiation (assume black-body radiation) balances the net incoming short-wave radiation.

(a, 15%) Show that the resulting surface temperature is

$$T_s = \left(\frac{(1-a)\, S_0}{4\sigma} \right)^{1/4}, \tag{1}$$

where $S_0 = 1367\ \text{W}\,\text{m}^{-2}$ is the solar constant and $\sigma = 5.67 \times 10^{-8}\ \text{W}\,\text{m}^{-2}\text{K}^{-4}$ is the Stefan-Boltzmann constant.

(b, 5%) Calculate T_s for $a = 30\%$ (the actual planetary albedo of Earth). Calculate the change of T_s that would result from an albedo increase from 30% to 31% (for example as a result of an increase of cloud coverage).

(c, 5%) What were T_s if the Earth surface were black and if there were no clouds.

(d, 5%) What were T_s if the Earth were covered with fresh snow ($a = 85\%$) and if there were no clouds.

Problem 13 (total 30%): Hydrological cycle

A substantial part of the incoming net solar radiation is used for the evaporation (from water surfaces or from wet soil) and transpiration (from plants and animals). Evaporation and transpiration are summarily referred to as evapotranspiration. The annual rate of evaporation over the oceans is 434×10^{15} kg; the annual rate of evapotranspiration over land is 71×10^{15} kg. The annual rate of precipitation over land is 107×10^{15} kg; the annual rate of precipation over the oceans is 398×10^{15} kg.

(a, 10%) Why is there an imbalance between precipitation and evaporation over the oceans, and an imbalance between precipitation and evapotranspiration over land? Why is the sum of these two imbalances equal to zero?

(b, 10%) What is the globally averaged, annual rate of precipitation (in mm)? (Assume a spherical Earth with a radius of 6371 km.)

(c, 10%) Calculate the globally averaged percentage of the incoming net solar energy that is used for evapotranspiration?