Radiative Processes in Planetary Atmospheres — Homework 6
Due: December 12, 2001

Please show your work.

1. Compute the length of day and daily mean top-of-the-atmosphere solar insolation (W/m^2) at $65°$N on about July 21 for **today** and **130,000 years ago**. From Figure 6.2 in Liou (1992) the eccentricity then was about 0.038, the longitude of the perihelion from the vernal equinox was about $45°$, and obliquity was $24.0°$. Assume that the longitude of the earth and the true anomaly are linearly proportional to time. What is the relative size of the change in solar flux from 130,000 years ago to today is due to obliquity versus that due to the sun-earth distance?

2. a) Calculate the radiative forcing for a solar constant increase of 0.1% at sunspot maximum. Compare this with the *current* radiative forcing from the anthropogenic increase in trace gases.

   b) Derive the climate sensitivity parameter G_0 for surface temperature with no climate feedbacks using a current surface temperature of $288°$K. It is easiest to assume that the outgoing longwave flux is proportional to the emitted surface longwave flux, $F_{LW} = (1 - g)\sigma T_s^4$, where g is a normalized greenhouse factor. Why should g be constant for this calculation?

   c) What is the resulting no feedback global surface temperature change for the current radiative forcing from anthropogenic trace gases?

3. a) Suppose cloud cover of all types *decrease* by 5% (i.e. 0.03 for a cloud amount of 0.60) for each degree of surface temperature increase (and all other cloud properties stay constant). What is the feedback factor f_{cc} for this hypothetical cloud feedback? Use ERBE cloud radiative "forcing" results for the global mean net effect of clouds. Is this a positive or negative feedback?

   b) Climate models show that the water vapor feedback by itself increases the no feedback climate sensitivity by a factor of 1.6 (i.e. $G_{wv} = 1.6G_0$). What is the total climate sensitivity including the water vapor feedback and the cloud feedback in part a?

   c) It is unlikely that the change in cloud cover for all cloud types would be the same. Discuss how changing the cloud cover of i) low altitude stratus clouds over the ocean and ii) thin high altitude cirrus clouds over land would cause radiative effects of opposite signs.

4. a) Consider a more realistic version of the Eddington gray radiative equilibrium model. In this version there is a completely transparent atmospheric window occupying a fraction f (weighted by the blackbody spectrum) of the longwave spectrum. Assume f does not depend on temperature. For Earth's atmosphere, $f \sim 0.3$. The longwave spectrum outside of the atmospheric window is gray. Assume there is no shortwave absorption. Derive the following expression for the surface temperature in this model

$$T_s^4 = T_e^4 \, \frac{1 + \frac{3}{4}\tau^*}{1 + \frac{3}{4} f \tau^*}$$

where T_e is the effective blackbody temperature of the planet, and τ^* is the longwave optical depth outside the window. Hint: let I and B in the Eddington gray radiative equilibrium derivation refer to the nonwindow part of the spectrum and add in the window contribution where necessary.

b) Explain how having an atmospheric window prevents a runaway greenhouse effect in surface temperature as the longwave optical depth goes to infinity (as compared with the result for no window $f = 0$).

c) What is the radiative equilibrium surface temperature for a longwave optical depth $\tau^* = 15$ and window parameter $f = 0.3$? Show that the surface/atmosphere temperature discontinuity, $T_s - T(\tau^*)$, is reduced substantially with the window as compared to the model with no window and optical depth τ^* adjusted to get the same surface temperature.