ATM 240 – Fall 2008

Problem set #3 31 pts Due: 21 October 2008

1. Extend the single-layer "glass slab" model to include sensible and latent surface heat fluxes.
a. (5pts) draw a diagram showing the fluxes radiant and heat energy, similar to the hand out. Assume that $A_G = 1.0$ (and so it need not be written).
b. (3 pts) Use the Kiehl and Trenberth figure to combine the sensible plus latent heat fluxes (call that SLHF) and express SLHF as a fraction of E_s. Use the same figure to estimate a_A and A_A .
c. (5 pts)Write the 2 energy balance equations: atmosphere, surface. (Note that the TOA equation is the same as in the handout.) Use the combined sensible and latent fluxes that is expressed in terms of E_S in those equations.
d. (5 pts) Using fig. 3.7a one might assume 125 W/m^2 is absorbed in winter and 325 W/m^2 is absorbed in summer at 40N; use those estimates for E_s. From the information obtained in parts b and c, calculate the ground and atmospheric temperatures with the surface fluxes and if there were no surface fluxes in the ___________ season.

2. A simple linkage between the glass slab calculation, horizontal heat fluxes, and the motions of a "Hadley-type polar" cell. At 80 N, let $A_A = 0.85$, $A_G = 1.0$, $a_A = 0.3$. From figure 3.11a, b it may be assumed that $T_G = 250$ K in winter, 273 K in summer. Let $T_A = 225$ K in winter; 240 K in summer.
a. (4 pts) find the E_S needed for radiative balance in each season.
b. (2 pts) from figure 3.8a, one may estimate the observed solar radiation absorbed at 80 N; call that E^* In winter $E^*=0$, in summer let it = 171 W/m^2. The difference between E^* and E_S is the amount of heat flux energy needed per unit area. Call that Δ; and find that value for each season.
c. (4 pts) Δ is a loss of energy per second per square meter. What rate of heating in the column is needed to balance this loss of energy if the surface pressure is 1.013×10^5 Pa? Assume that the heating rate (dT/dt) is a constant in the vertical. Note that force equals mass times acceleration, and that pressure is a force per unit area. Find this heating rate for both seasons. Hint: recall the first law of thermodynamics equation: $C_P\, dT/dt = \alpha\, dP/dt + Q$ where Q is a diabatic heating rate per unit mass (W/kg units).
d. (3 pts) The dry adiabatic lapse rate is given by g/C_p where $g=9.8\ m/s^2$ and $C_p = 1004$ J/(K kg). If the column of air is warming by sinking, what value of vertical velocity must be present in winter and summer? For a bit of realism, assume that the air has lapse rate Γ = 6 K/km. Note that the sinking is providing the heating of the air. Also, ignore any horizontal heat transport.

NOTE: all homework is to be done by you as an INDIVIDUAL: no 'group' efforts, please. For written answers, please use a word processor, so that penmanship is not an issue. Equations and derivations can be *neatly* hand-written. Full credit requires proper units be included. Any plot must be completely and unambiguously labeled, including title and axes. Show ALL math steps.