

## 12.812 END-OF-TERM EXAM

December 13, 2005

1. (10%) Assume that the zonal mean annual mean solar radiation incident at the top of the atmosphere is described by  $[\overline{Q}] = \frac{S_0}{4}(1 + S_2 P_2)$ , where  $P_2 = \frac{1}{2}(3x^2 - 1)$ ,  $x =$  sine of the latitude and  $S_0$  and  $S_2$  are constants. Also assume that the zonal mean annual mean planetary albedo is given by

$$[\overline{\alpha}] = \alpha_0(1 + \alpha_2 P_2),$$

where  $\alpha_0$  and  $\alpha_2$  are constants. Calculate the global mean annual mean planetary albedo.

2. (10%) Hantel (1976) concluded that, to first order, the atmosphere is in “radiative-convective equilibrium.” Explain what Hantel meant by this phrase.

3. (25%)

(a) Consider the following situation. The 850-mb level at latitude  $40^\circ\text{N}$  is crossed by two fronts, at longitudes  $90^\circ$  and  $270^\circ\text{E}$ . From  $90^\circ$  to  $270^\circ$  the air temperature is  $16^\circ$  and the winds are southward at 4 m/s. From  $270^\circ$  to  $90^\circ$  the air temperature is  $23^\circ\text{C}$  and the winds are northward at 6 m/s. How much kinetic energy per unit mass is there in planetary zonal wave number 1, 2, 3, and 4, at this level and latitude?

(b) What zonal wave numbers dominate the observed Northern Hemisphere mid-latitude spectrum of transient meridional eddy sensible heat flux in the lower troposphere? In the upper troposphere?

4. (25%)

(a) Define the following quantities:

(i) Eliassen-Palm Flux (for a dry atmosphere)

(ii) Residual mean meridional circulation (used in deriving the transformed Eulerian mean equations)

- (b) State the Non-Acceleration Theorem for a dry atmosphere.
  - (c) What physical interpretation does the residual mean circulation have?
5. (30%) The entire atmosphere above the northern hemisphere of a hypothetical, mountainless planet is observed to have the following properties:
- A. Solar heating is greater at the equator than at the pole.
  - B. At any level, the field of mean zonal temperature  $[\overline{T}]$  has its maximum at the pole and decreases from there equatorward.
  - C. Within eddies, at a given latitude and level, warm parcels of air are rising to lower pressures and cooling adiabatically, while cold parcels of air are sinking to higher pressures and heating adiabatically.
  - D. The eddy transport of sensible heat is poleward.
  - E. The eddy momentum transport is on average down the gradient of angular velocity.
  - F. The atmosphere's mean meridional circulation is dominated by a single cell whose upper branch is directed equatorward and whose lower branch is directed poleward.
  - G. Frictional dissipation is negligible.
  - H. More latent heat is released within the warm sectors of eddies around a latitude circle than in the cold sectors.

Do the following:

Construct as much of an energy cycle diagram for this planet's northern hemisphere as the above information allows. Indicate clearly the direction of all arrows involved in your diagram. Clearly *label* each arrow with the *letter* or *letters* corresponding to the specific observational fact(s) chosen from the list above used to justify each arrow.