

12.812 END-OF-TERM EXAM

December 10, 2003

1. (20%) Hantel's results for the zonal mean heat balance in the Northern Hemisphere are shown below. Consider the balance in summer, in the vertical column between 49° and 90° . Make the (not implausible) assumption that *all* the error in the data is in the values of LH and SH. Using this assumption for the distribution of the errors, recalculate the values of W^E at 250, 500, and 750 mb, and the value of LH plus SH. Do these new values imply that each of the four boxes in the column is nearer or farther from "radiative-convective" equilibrium than Hantel's values implied? (For the lowest box treat SH plus LH as the "surface" value of W^E .)

2. (10%) Define verbally:

- (a) available potential energy
- (b) transformed Eulerian Mean Equations

3. (20%) At a particular time, level, and latitude, the meridional velocity, v , can be approximated as a function of the longitude, by

$$v = \begin{cases} +v_0, & \text{for } \lambda_0 - \frac{\pi}{3} < \lambda < \lambda_0, \\ -v_0, & \text{for } \lambda_0 < \lambda < \lambda_0 + \frac{\pi}{3}, \\ 0, & \text{for all other } \lambda \end{cases},$$

where v_0 and λ_0 are constants. Calculate the kinetic energy spectrum associated with this velocity field. At what wave number does the spectrum peak?

4. (25%) (In answering parts b and c you may make use of Figures 1 and 2.)

- (a) State the Eliassen-Palm Theorem for a quasi-geostrophic system with no moisture. Be sure to define the terms you use.
- (b) What *net* effect do atmospheric eddies have on the zonal mean zonal wind in January at the following locations?
 - i) 200 mb, 45N
 - ii) 500 mb, 50N
 - iii) 900 mb, 40N
- (c) Which eddy flux is primarily responsible for the forcing at each of these locations?

5. (25%) Discuss the energy cycle of the atmosphere above the Northern hemisphere as observed with radiosonde data by Oort and Peixoto for mean annual, winter, and summer conditions. Include in your discussion responses to the following questions:
- (a) What are the main physical mechanisms involved in the energy conversions?
 - (b) What are the main differences between the winter and summer cycles?
 - (c) What are the main driving mechanisms for the energy cycle in the annual mean and seasonally?
 - (d) What are the principal uncertainties and approximations in Oort and Peixoto's evaluation of the complete energy cycle?