

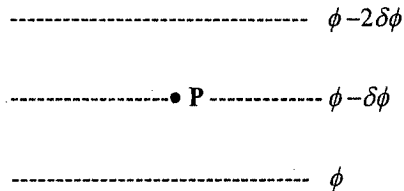
系所別:           水文科學研究所           科目:           大氣動力學          

1. In the rotating Earth coordinate, the equation of horizontal wind ( $V$ ) is written as

$$dV/dt = -\nabla\phi - f\mathbf{k} \times V + F_r, \tag{1}$$

where  $d/dt = \partial/\partial t + V \cdot \nabla + \omega \partial/\partial p$ ,  $\delta\phi = g\delta z$ ,  $f = 2\Omega \sin\phi$ , the earth angular velocity  $\Omega = 7.292 \times 10^{-5} \text{ s}^{-1}$ ,  $F_r$  is friction

- (a) what approximations have been made in deriving the above equation ? (5 %)
- (b) explain each of the forcing terms in (1), (10 %)
- (c)  $f\mathbf{k} \times V$  is an "apparent force", explain why? (5 %)
- (d) draw the steady state force balance expressed by equation (1) at point P in the following  $\phi$  field at an isobaric surface (10 %)



- (e) define geostrophic wind  $V_g$  (10 %)
- (f) derive  $\nabla \cdot V_g = -(v_g/f)(\partial f/\partial y)$ , (2)  
give a physical meaning of the result. (5 %)
- (g) compute the div of the geostrophic wind (2) at  $45^\circ\text{N}$  for  $v_g = 15 \text{ m s}^{-1}$  (5 %)



2. The concepts of geostrophic and gradient wind are valid for large-scale atmospheric motions. In mesoscale and convective-scale motions the force balance in the momentum equation is very different. For motion in the vertical ( $w$ ),

$$dw/dt = -(1/\rho)(\partial p/\partial z) - g + F_z,$$

where  $p$  is pressure,  $\rho$  density,  $F_z$  is friction, and Coriolis force neglected.

- (a) By letting  $\rho = \rho_o + \rho'$ ,  $p = p_o + p'$ , where basic state variables  $\rho_o$  and  $p_o$  are functions of  $z$  only and satisfy the hydrostatic balance.  
Show that  $(1/\rho)(\partial p/\partial z) + g = (1/\rho_o)(\partial p'/\partial z) + (\rho'/\rho_o)g$  (10 %)
- (b) From  $\theta = (p/\rho R)(p_s/p)^\kappa$ ,  $\theta = \theta_o + \theta'$ , where  $\theta$  is potential temperature,  $\kappa = -R/c_p$ ,  $p_s = 1000 \text{ mb}$ ,  
Show that  $\theta'/\theta_o \approx (1-\kappa)(p'/p_o) - \rho'/\rho_o$  (10 %)
- (c) From the above,  $dw/dt \approx -(1/\rho_o)(\partial p'/\partial z) - (\theta'/\theta_o)g + F_z$  (3)  
Explain the meaning of each term in (3) (10 %)

3. Explain the following

- (a) Thermally direct circulation transport sensible heat upward. (10 %)
- (b) The "Hadley circulation" does not extend from pole to equator in the earth's atmosphere. (10 %)