Dynamical Meteorology (NS-MO402m)
February 4, 2005

In this exam all symbols have their normal definitions.

Question 1

Explain how the drag exerted by the Earth' s surface on the atmosphere can lead to non-zero momentum loss of air at, for instance, 100 hPa and at the same time *zero* momentum loss of the layer of air in between, for instance, 800 hPa and 100 hPa.

Question 2

The horizontal components of the equation of motion in pressure coordinates and the equation of continuity are

$$\frac{\partial u}{\partial t} + u\left(\frac{\partial u}{\partial x}\right)_p + v\left(\frac{\partial u}{\partial y}\right)_p + \omega\left(\frac{\partial u}{\partial p}\right) = -\left(\frac{\partial \phi}{\partial x}\right)_p + fv$$

$$\frac{\partial v}{\partial t} + u\left(\frac{\partial v}{\partial x}\right)_p + v\left(\frac{\partial v}{\partial y}\right)_p + \omega\left(\frac{\partial v}{\partial p}\right) = -\left(\frac{\partial \phi}{\partial y}\right)_p - fu$$

$$\left(\frac{\partial u}{\partial x}\right)_p + \left(\frac{\partial v}{\partial y}\right)_p + \left(\frac{\partial \omega}{\partial p}\right) = 0$$

Apply the quasi-geostrophic approximation to these equations and derive the quasi-geostrophic vorticity equation. Express this equation in terms of the geopotential and the vertical velocity in pressure coordinates. The relative vorticity is defined as follows:

$$\zeta = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}$$

Question 3

Demonstrate that the geostrophic wind turns clockwise (veers) with increasing height if there is advection of relatively warm air. make use of the fact that the thermal wind vector is parallel to tthe isotherms as well as of the fact that, when looking in the direction of the thermal wind vector, the relatively cold air is located on the left hand side.

Question 4

Can you estimate the maximum vertical velocity of a parcel that is initially located near the Earth' s surface from the value of CAPE (convective available potential energy)? Will this give you an over-estimate or an under-estimate of the maximum vertical velocity? Why?

Question 5

a) Describe in words the implications of the invertibility principle for potential vorticity.

b) What is the dynamical significance of the Rossby deformation height,

$$\Delta z = \frac{\sqrt{f(f+\zeta)}}{N}$$