NS-M0402M. per 1+2

prio 1.+

Exam: Dynamical Meteorology
Date: February, 1, 2008

In this exam all symbols have their normal definitions.

Problem 1

Weather systems

(a) Explain in words what is meant by the "Hadley circulation".

(b) Explain in words what is meant by the "Walker circulation".

Problem 2

Quasi-geostrophic approximation

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:

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

Problem 3

Thermal wind

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 the 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.

Problem 4

Invertibility principle

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

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

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

(N is the Brunt-Väisälä frequency)?

Problem 5

Structure of cyclones

Figure 2a and 2b show the distributions of absolute vorticity and potential temperature as a function of height and longitude at the same constant latitude through the centre of two different cyclones in the northern hemisphere. The isentropes are indicated by thin black lines (labeled in K; contour-interval is 5 K). Thick lines are isopleths of absolute vorticity (labeled in units of 10^{-4} s^{-1}; contour-interval is 0.5×10^{-4} s^{-1}).

(a) Is one of these cyclones a tropical cyclone? Why?

(b) In how far can you use quasi-geostrophic theory to describe the dynamics of these cyclones? Why?

(c) Which of these cyclones is most probabaly the result of baroclinic instability? Why?

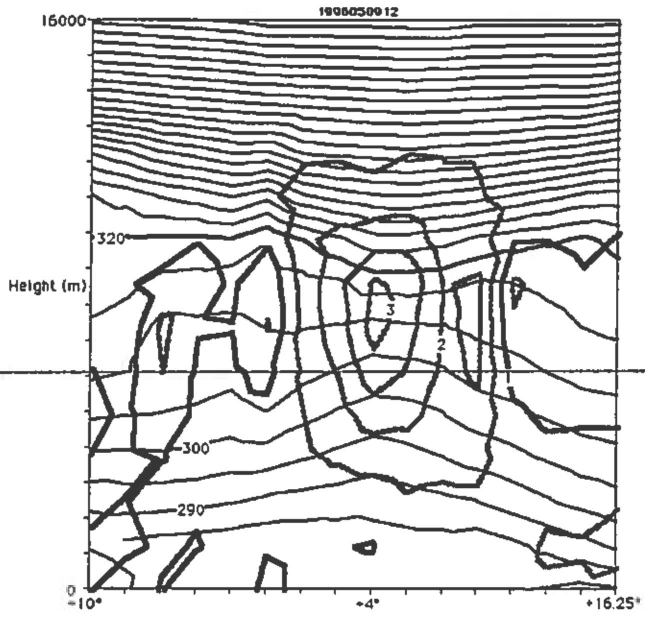

Figure 2a

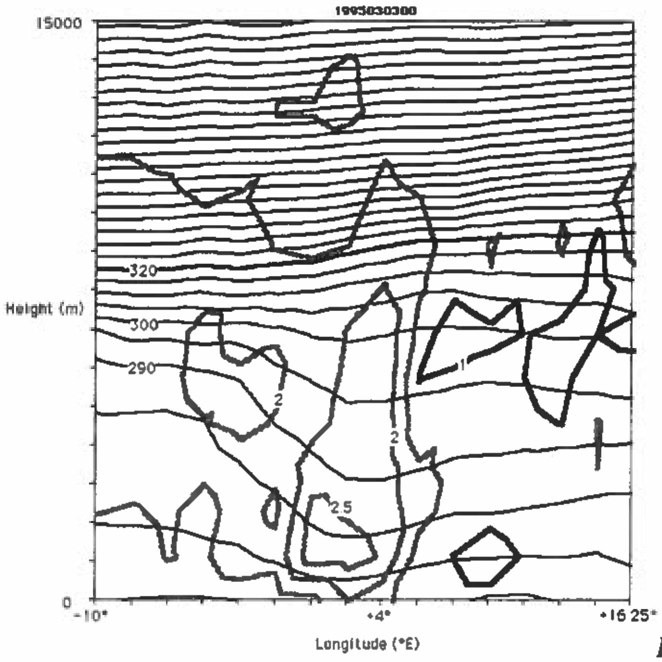

Figure 2b