

## Dynamics II, Exercise 1, 23. April 2007

### 1) Basic questions about dynamics.

Q1: The Coriolis parameter  $f$  is defined as ...

Q2: Please clarify: On the Northern Hemisphere, particles tend to go to the right or left relative to the direction of motion due to the Coriolis force?

Q3: Please write down the equation of state for the ocean and atmosphere!

Q4: What are the dominant terms in the momentum balance for the large-scale dynamics at mid-latitudes?

Q5: What is the hydrostatic approximation in the momentum equations?

Q6: Please write down the thermal wind relation!

Q7: Please write down the mass conservation budget in 3 dimensions!

Q8: Please write down the Euler forward numerical scheme for  $\frac{d}{dt}x = f(x)$  !

Consider also the special case  $f(x) = x^2$ !

Q9: Please write down the barotropic potential vorticity equation for large-scale motion!

Q10: Please write down the dispersion relation for Rossby and gravity waves!

### 2) Ocean thermohaline circulation: Consider a geostrophic flow $(u, v)$

$$-fv = -\frac{1}{\rho_0} \frac{\partial p}{\partial x} \quad (1)$$

$$fu = -\frac{1}{\rho_0} \frac{\partial p}{\partial y} \quad (2)$$

with pressure  $p(x, y, z, t)$ .

Use the hydrostatic approximation

$$\frac{\partial p}{\partial z} = -g\rho \quad (3)$$

and equation (1) in order to derive the meridional overturning stream function  $\Phi(y, z)$  as a function of density  $\rho$  at the basin boundaries!  $\Phi$  is defined via

$$\Phi(y, z) = \int_0^z \frac{\partial \Phi}{\partial \tilde{z}} d\tilde{z} \quad (4)$$

$$\frac{\partial \Phi}{\partial \tilde{z}} = \int_{x_e}^{x_w} v(x, y, \tilde{z}) dx \quad (\text{zonally integrated transport}), \quad (5)$$

where  $x_e$  and  $x_w$  are the eastward and westward boundaries in the ocean basin (think e.g. of the Atlantic Ocean). Units of  $\Phi$  are  $m^3 s^{-1}$ . At the surface  $\Phi(y, 0) = 0$ .

Consider now a water planet with flat bottom (unlike the Earth). What is the meridional overturning stream function  $\Phi(y, z)$  in this ocean ?