Engenharia do Ambiente

Física da Atmosfera e dos Oceanos

2º Exame, 5 de Fevereiro de 2011 **Duração 3 horas.** **Página 1/2**

(Perguntas teóricas)

1. For a geostrophic flow:
    a) Explain the restrictions to be imposed in the Rossby number and in the Ekman number. Describe the Rossby number and the Ekman number.
    b) Show that relative vorticity is neglectable relative to planetary vorticity;

2. The existence of high pressure centres and low pressure centres at the surface of the Earth is associated to the vertical motion of air masses that influence the weather and to convection cells. Illustrate this phenomenon. In the illustration consider a cyclone and an anti-cyclone in the Northern hemisphere.

3. In a barotropic flow, describe Taylor-Proudman columns.

4. Illustrate an event of equatorial upwelling and of coastal upwelling. Describe each case using the concept of Ekman transport.

5. The barotropic North-Atlantic ocean circulation considers the Coriolis force in equilibrium with the barotropic force and with the wind stress in the momentum equations, in the beta plane approximation.
    a) Which extra term appears in the Stommel Ocean solution and why?
    b) Which alternative term was proposed by Munk? How does this affect the meridional transport compared with the Stommel solution?
    c) Consider adding the baroclinic term and no friction to the momentum balance and explain the JEBAR. How does it change the general circulation streamlines? Explain why JEBAR is more interesting than Stommel's or Munk's hypotheses.

6. Explain the western boundary current intensification.

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(Perguntas práticas)

1. The geostrophic balance equations are

$$\rho f u = -dp/dy$$
$$\rho f v = dp/dx$$

Do a scale analysis where $\partial\rho/\partial x \sim O(\delta\rho\ /\ L)$ and ($\delta\rho/\rho \ll 1$). Show that variations in ρ can be neglected in deriving Sverdrup's relation.

2 The wind stress induced by a mesoscale cyclone is given by por $(\tau_{0x}, \tau_{0y}) = \left(-A\ y\ e^{-\frac{r^2}{\lambda^2}}, -A\ x\ e^{-\frac{r^2}{\lambda^2}}\right)$, where $r^2 = x^2 + y^2$, and A λ are constants. Consider a flat-bottom, barotropic Ocean in geostrophic equilibrium below the Ekman layer with the beta plane approximation.

a) Calculate the Ekman transport.

b) Calculate the vertical velocity, below the Ekman layer.

c) Using the Sverdrup relation, calculate the meridional componente of velocity, $v(x, y, z)$, below the Ekman layer.

3 In the Ocean, two homogeneous bodies of water flow geostrophically in the same direction with velocities of 35 cm/s and 22 cm/s respectively. The slower water has density of 1033 kg/m^3. Find the angle of the interface between the bodies. *Suggestion: use the Witte-Margules relation.*

4 Consider a two layer fluid defined by following density distribution (note: each layer is homogeneous):

$$\rho(z) = \begin{cases} \rho_0 + \delta\rho, & -h(x) < z < \eta(x) \\ \rho_0, & -H < z < -h(x) \end{cases}$$

$$h(x) = h_0\left(1 - e^{-x/\lambda}\right)$$

a) Calculate $\phi(x)$ defined by $\phi(x) = -\int_{-H}^{0} z\ g\ \frac{\rho-\rho_0}{\rho_0} dz$.

b) Assuming that $H = H(y)$, obtain an expression for the zonal and meridional componentes of vertically integrated horizontal transport, M_x e M_y. Considere only JEBAR and stipulate zero wind stress.