Department of Physics and Astronomy, Faculty of Science, UU.
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In 2006/2007, the course NS-MO401M was given by J.T.F. Zimmerman.

Dynamical Oceanography (NS-MO401M)
28 August 2007

All exercises have equal weight. Use of books / PC not allowed.

Question 1

Give a qualitative description of the circumstances and mechanisms by means of which an equatorial counter-current (ECC) is established.

Question 2

In a frictionless, equivalent barotropic model, Rossby waves are governed by the following quasi-geostrophic potential vorticity equation

$$(-R_*^{-2}\zeta_0 + \Delta\zeta_0)_t + J(\zeta_0, \Delta\zeta_0) + \beta\zeta_{0x} = 0.$$

a) Interpret each of the terms (and parameters) physically.

b) Under what conditions is a plane monochromatic wave an exact solution of this equation?

c) Determine the velocity field associated with such a wave solution.

d) Why is this called a dispersive wave?

e) Set up an energy equation and interpret the expressions for energy and energy flux.

Question 3

a) What is an 'equivalent barotropic' model?

b) What does the rigid-lid approximation entail?

c) Why are streamfunction and surface elevation fields identical in (scaled) quasi-geostrophic theory?

Question 4

a) Why is ocean circulation governed by a vorticity equation?

b) Which equation is this (in general)?

c) Discuss the elements in the derivation that have given rise to this description?

Question 5

Consider an ocean, confined to the region $0 < x < L$, $0 < y < L\pi/3$, subject to a zonal 'Monsoon' wind

$$\tau = \mathrm{Re}\,[(-\cos(3y/L)\exp(\mathrm{i}\omega t), 0)]\,,$$

where $\mathrm{Re}\,[\ldots]$ signifies the real part of the expression inside brackets. Neglecting nonlinear and free-surface effects, the circulation the circulation is governed by the following QGPV equation:

$$\Delta\psi_{0t} + \beta\psi_{0x} + r\Delta\psi_0 = g \equiv W\hat{\mathbf{k}} \cdot \nabla \times \tau.$$

a) Where does the frictional term come from and what is the meaning of damping rate r?

b) Assuming that the damping rate, r, is of the same order of magnitude as the seasonal Monsoon frequency ω, nondimensionalize the equation.

c) By assuming that the Ekman number is small, determine a uniformly valid solution to this equation that satisfies appropriate boundary conditions.

d) Give an interpretation of your result.