# Homework 5

due Oct. 4, 2017

[100 pts.]

## Problem 1: Vertical winds under geostrophy

Consider the momentum equations in Cartesian height-coordinates for geostrophic flow assuming that $\rho = \rho(z)$.

(a) What can you say about the vertical gradient of the vertical velocity ($w$) in the case of an f-plane approximation? Please provide the necessary derivation to support your conclusion.

(b) Looking at your derivation for (a), do you think you would have come to the same conclusion if you had made a $\beta$-plane approximation? Why? (You do not need to provide the full derivation), just a yes/no with an explanation will suffice.

*Hint: start with the horizontal momentum equations, then combined them to get an equation for the horizontal divergence of the flow and then apply the continuity equation.*

## Problem 2: Rossby number and Geostrophic balance

Use the data file from previous homeworks (ERA-interim_300hPa_2014-Jan1-8.nc), and the newly provided data file that provides partial time derivatives and advection terms for $u$ and $v$ (ERA-interim_uvtnds-300hPa_2014-Jan1-8.nc). For this problem, focus on the *zonal momentum equation* (i.e. $u$), however, you can look at $v$ as well if you would like.

(a) Choose a single time step of interest. Compute and plot the Rossby number fields on a world map by taking the ratio of the absolute magnitudes of (i) the local acceleration of $u$ and the Coriolis acceleration, (ii) the horizontal advection of $u$ and the Coriolis acceleration, and (iii) the vertical advection of $u$ and the Coriolis acceleration. Plot the corresponding $u$ wind field in another graph. You should have four plots at this point.

(b) Compare the Rossby numbers in the tropics and in the midlatitudes. What do you notice? What does this tell you about geostrophic balance in the upper-troposphere? Discuss the overall size and spatial structure of the Rossby numbers in relation to the zonal flow pattern.

(c) Average the individual terms used in (a) in time over the entire data record (8 days = 32 six-hourly time steps) and repeat the analysis and plots. For example, average the local acceleration of $u$ and the Coriolis acceleration over the requested number of days, and *then* calculate the Rossby number. Briefly discuss the differences between the results from a single time step versus over the full 8 days.

(d) Using your results from (c), zonally-average your two fields of Rossby numbers and plot them as a function of latitude. Since this will result in only 3 different lines, plot them all on the same figure and use color to denote the different Rossby terms. What do you notice about the behavior of the Rossby numbers and thus the validity of geostrophic balance as you move from the tropics to the poles?[1] Why is this?

[1] You might have an easier time visualizing the general pattern if you apply a moving average to each Rossby number curve before plotting it to smooth the wiggles a bit.