CLIM 752 Ocean General Circulation, Problem Set 1

1. I've provided files with annual-average potential temperature θ, salinity, potential density (σ_θ) and meridional velocity v on longitude-depth sections in the Atlantic and Pacific basins of a GCM simulation. For each basin:

a) Use contour plots or other graphics to show the θ and v sections.

b) Calculate and plot the zonal integral of v, calculated along constant depths, as a function of z.

c) Calculate and plot the zonal integral of $v dz/d\theta$, calculated along constant potential temperature θ, as a function of θ. There are a number of ways to estimate this from the data. Here is a suggestion: assume that each gridpoint is a box which is Δx m wide and Δz m tall (Δz is different for each level in the model), and that θ and v are uniform within each box. Divide the temperature axis into small intervals (you decide how small), and sort the gridboxes into these intervals. In other words, the temperature of the box determines to which θ that particular box is contributing it's velocity.

Calculate and plot (d) z-coordinate and (e) θ-coordinate meridional overturning streamfunction as a function of z and θ, respectively, at this particular latitude.

f) How would you interpret the zonal average flow based on your z-coordinate integrals? How about based on your θ-coordinate intervals? Describe each in about 1–3 sentences for each ocean.

2. What instruments are most useful for deducing the distribution of ocean velocity (name as many as you like)?

3. What is the main source of error in constructing climatological estimates of the circulation?

4. The real ocean is bounded only by a sea-floor and by the sea surface, but ocean models often have side walls too. Is there any physical justification for this?

5. What is the justification for neglecting high-frequency variability (subseasonal and shorter timescales) in discussing the general circulation. What are the dangers of neglecting it? If ocean circulation is not constant in time, what do we mean when we discuss the "steady circulation?"

6. What kind of processes or phenomena can cause errors in numerical models at a given spatial resolution? How high resolution is high enough?

7. Why would rainfall or evaporation interfere with our ability to describe the circulation in the ocean with a horizontal streamfunction?

8. The governing equations for ocean velocity, temperature, and salinity, are given by (14) in Chapter I of Klinger and Haine. These equations are statements of how each quantity changes over time. Thus if there is a given surface forcing (wind stress and conditions on temperature and salinity) and a given initial condition, the equations can be integrated in time to find how each quantity evolves. However, in some theoretical or numerical models, $\partial/\partial t$ terms are removed from the momentum equations. How can velocity change over time in that case? Harder question (optional): What difference does removing those terms from the momentum equations make in the evolution of the flow?