SIO 210 Problem Set 1
October 3, 2019
Due October 10, 2019 (1 week)

If you work together on these, please make sure that you understand the concepts and use your group discussion to help with the understanding.

1. (a) Explain briefly the usefulness of non-dimensional parameters.

For the following, using information from the introductory lecture slides and Chapter 1, give a typical height scale H, horizontal length scale L, and time scale T. Estimate two non-dimensional parameters: '*aspect ratio*' and '*Rossby number*'. For each one, briefly describe what you expect the ratio of vertical velocity to horizontal velocity to be.
(a) Gulf Stream (use width across the Gulf Stream for L rather than an along-stream lengthscale; also the Gulf Stream reaches to the bottom)
(b) El Niño/La Niña
(c) Global overturning circulation
(d) Internal wave

2. This potential temperature/salinity diagram shows contours of potential density. The large dot at lower temperature and salinity (cold,fresh) is the property of water flowing into the North Atlantic from the Nordic Seas, over the sill (deepest point) in Denmark Strait between Greenland and Iceland. The warm, salty dot is the water flowing into the North Atlantic from the Mediterranean, over the sill in the Strait of Gibraltar between Africa and Europe. (Although this does not matter for the problem, it is interesting to know that both sill depths are about the same: 500 m.)

(a) What is the potential density relative to the sea surface σ_θ of these two water parcels?_______________

(b) On the diagram, sketch in the contours of potential density σ_4 relative to 4000 dbar (that is, relative to a pressure higher than the sea surface pressure). This does not need to be exact, but please get the relative slope/angle of the contours.

Briefly explain why the σ_4 contours are rotated relative to the σ_θ contours.

(c) Relative to 4000 dbar, is the potential density σ_4 of the Mediterranean parcel **HIGHER** or **LOWER** than the potential density σ_4 of the Nordic Seas parcel? (circle one)

Again explain briefly.

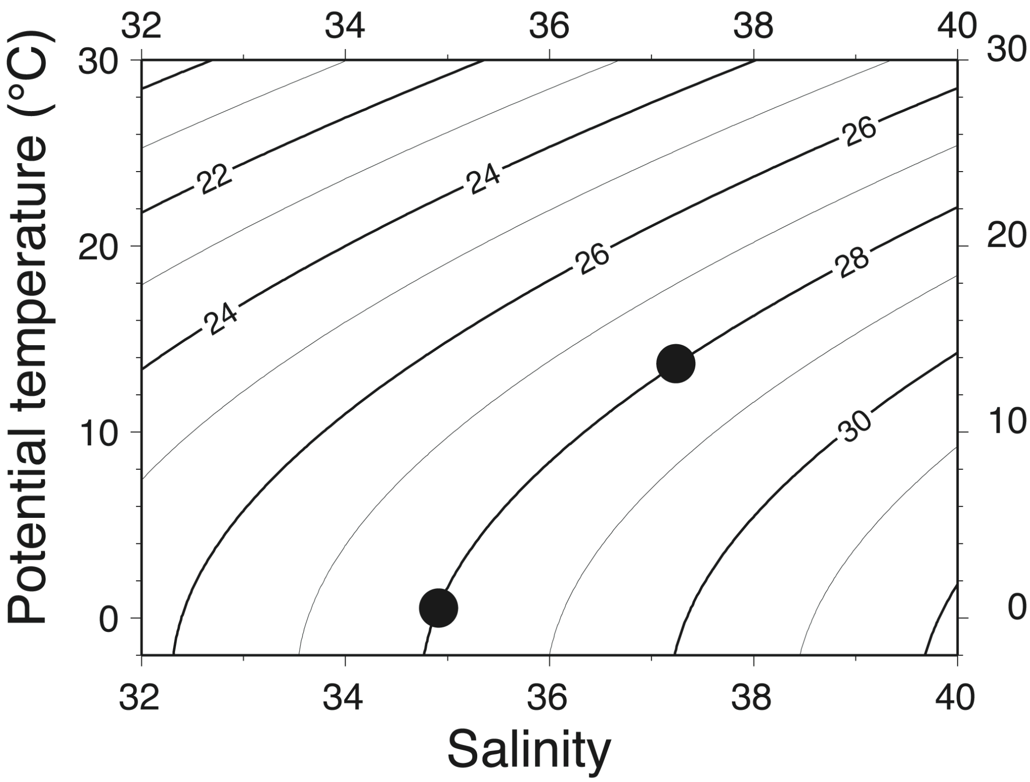
(d) The vertical axis is potential temperature referenced to the sea surface. This is not the same as the measured temperature. Is the *measured* temperature of both parcels

HIGHER (WARMER) or **LOWER (COLDER)**

than their potential temperature?

Explain this briefly.

e) Extra: is the potential temperature referenced to 4000 dbar of these parcels lower or higher than the potential temperature shown here (referenced to the sea surface)?



Postpone until Problem set 2. ~~3. (a) The California Current is a oceanic region along the west coast of North America. The upwelling region of the California Current is closest to the coast. This region is approximately 2000 km long along the coast and 100 km wide off the coast. Suppose that there is a net heating of this entire strip at a rate of 75 W/m^2 in the annual mean. If this heat is applied to the top 100 m of the ocean, calculate how much it will warm in one year. Assuming that the initial temperature is 10°C, what is the final temperature?~~

~~(b) Farther north along the coast, off Canada and Alaska in the Alaska Current, there is net precipitation. If there is net precipitation of 100 cm/yr in a strip the same size and depth as in~~

~~problem 3, calculate how much the water column will freshen in one year. Assume that the initial salinity is 33 psu. What is the final salinity?~~

4. (a) What forces balance each other in hydrostatic balance?

_____________ and _____________ (words)

b) Write these out in symbolic form (from lecture).

_____________ and _____________ (terms in equation)

c) The density of seawater is approximately 1025 kg/m^3. Using hydrostatic balance and this density, find the pressure at a depth of 4000 m. (Use gravity g = 9.8 m/sec^2. Ignore compressibility of seawater for this question.)

5. A potential density section from the Atlantic is shown. (from http://whp-atlas.ucsd.edu/atlantic/a16/sections/printatlas/printatlas.htm)
For the top 0-1000 m, the contoured property is potential density relative to the sea surface (0 dbar).
(a) What is the lowest potential density at the sea surface and where is it found (latitude)? (It will be easier to see if you go to the online section. You will find postage stamp plots of all of the properties – click on the potential density plot.)

(b) Using the vertical section, and the location of lowest potential density, what is the potential density at 150 m depth?

(c) Estimate the Brunt-Vaisala frequency N for this location and depth range, using values from (a) and (b).

(d) Do the same three steps for the density/N at 25°S.

e) Compare the results from (c) and (d). Which has higher frequency? Explain.

6. Using the same potential density section:
Note that in the lower panel there are three differently colored portions. The top is potential density relative to the sea surface (p=0) σ, the middle is relative to 2000 dbar (σ_2) and the bottom is relative to 4000 dbar (σ_4).

(a) Compare the ranges of densities in the three panels. Why is the actual range so different?

(b) Where are the highest σ_4 values found? Why is density so high here? What is the source of the dense water? (Tuesday Oct. 8 lecture)
Compare this high density with highest density in the other hemisphere (your first answer will be from either the southern or northern hemisphere - compare here with the other hemisphere). Why is there a difference between the two hemispheres?

σ $_{0,2,4}$ [kg/m^3] for A16 25° W