Answers to the Third Exam

1. [10] Assuming that the Gulf Stream is in geostrophic balance, answer the following. If the Gulf Stream at 35N latitude is 50km wide, 1km deep and has a pressure difference across it of 4000 Pascal, compute the volumetric flow rate in the current. Express your answer in Sverdrups (i.e. 1SV= one million cubic meters per second)

   The geostrophic law applies to the Gulf Stream, so the current speed will be

$$U_{GEOS} = \frac{PG}{2\rho\Omega\sin(\phi)} = \frac{4000/50{,}000}{2\times1025\times7.27\times10^{-5}(\sin 35)} = 0.9m/s$$

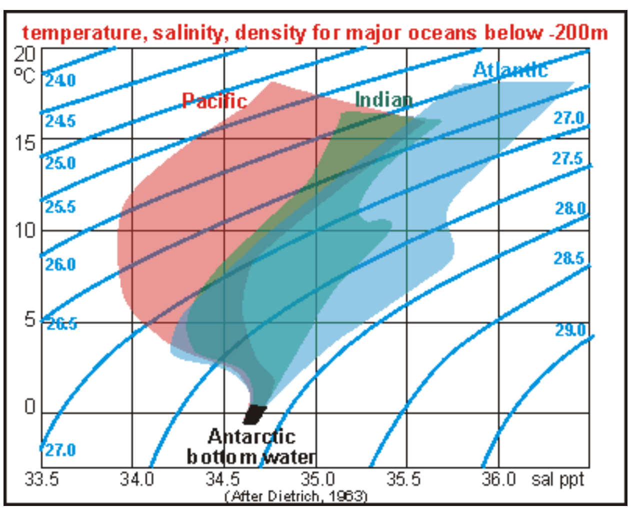
The depth and breadth of the current are 1000m by 50,000m so the volumetric flow rate is $FR = U * A = (.9)(1000)(50{,}000) = 45\times\frac{10^6 m3}{s} = 45\ Sverdrups$

2. [10] Consider two water masses (A and B) found near each other in the Atlantic Ocean. Mass A has S=36.0ppt and T=16C while Mass B has 35.5 and T=9C.
   a. Determine the density of each water mass

      Using the density plot below, the density of Mass A is 1025.5kg/m3 while for Mass B the density is 1027.5kg/m3

   b. Which water mass will be found higher in the water column?

      Water A is less dense than B so it will be found higher in the water column. Otherwise the water column would be unstable.



3. [10] Consider a region of the tropical Atlantic with S=35ppt. A heavy rain adds a half meter of freshwater on the ocean surface and it mixes down to 50 meters. What is the new salinity of the surface waters?

As the rain water mixes into the surface layer of the ocean, it will dilute the salt and decrease the salinity. The change in salinity is

$$\Delta S = S_0\left(\frac{-d}{D+d}\right) = 35\left(\frac{.5}{50+.5}\right) = -0.346ppt$$

The new salinity is $S=S_0+\Delta S=34.65$ppt

4. [10] In El Nino, the conditions in the eastern tropical Pacific Ocean are:
   a. SST **high** or low?
   b. Air pressure high or **low**?
   c. Precipitation **high** or low?
   d. Biological productivity high or **low**?
   e. Explain the physical connection between (a) and (d)

   When the SST is high, the water column is stable and vertical mixing is suppressed. Nutrient rich deep water is unable to reach the euphotic zone and primary productivity (i.e. phytoplankton) is reduced.

5. [10] During the last glacial maximum the conditions were
   a. CO_2 in the atmosphere high or **low**?
   b. Isotopes in fresh snow on Greenland heavy or **light**?
   c. Oxygen isotopes in new deep sea sediments **heavy** or light?
   d. Sea level high or **low**?
   e. Explain the relationship between (c) and (d).

   During a glacial period, large additional ice sheets exist on the continents (e.g. Laurentide and Scandinavian). This storage of water on land causes sea level to drop. Related to this is the shift in isotope ratio in the oceans. The light water isotopes evaporate preferentially and are stored in the ice sheets. The remaining water in the oceans is isotopically heavy.

6. [10] In recent centuries, we have the perihelion in January. Explain how the climate would be different if, due to precession, perihelion occurred in June.

   With perihelion (i.e. earth close to the sun) in January, the northern hemisphere winters are slightly warmer than they would otherwise be (i.e. compared to a *circular orbit) and the southern hemisphere summer is slightly warmer too. If the perihelion occurred in June, this pattern would reverse. The northern hemisphere seasons would be stronger and the southern hemisphere seasons would be weaker.*

7. [10] Explain the difference between sea ice and icebergs emphasizing their origin, thickness and salinity.
Sea ice is frozen sea water while icebergs are broken off chunks of glacier ice from compacted snow on land. Icebergs are freshwater (S=0) while sea ice has some salt, but less than full sea water (e.g. S~15ppt instead of S=35ppt). Icebergs come in a variety of shapes and sizes while sea ice is a thin layer of ice or crumpled ice from 1 to 5 meters thick.

8. [10] Compare recent trends in sea ice extent in the Arctic and Southern oceans. Be specific. In what months are they best compared?

Because of their different geography and geometry, we track sea ice differently in the two hemispheres. In the north, the Arctic basin is filled with sea ice in winter and spring, so we monitor the minimum sea ice in Fall, i.e. October. In the south, the sea ice mostly vanishes in Fall so we monitor the maximum sea ice in Spring, i.e. October. In recent years, Arctic sea ice in October has been decreasing rapidly while Antarctic sea ice is holding steady or even increasing slightly.

9. [10] Estimate the mass of salt in the world ocean (in kg)

We first estimate the mass of water in the ocean and then use an average salinity of 35ppt to compute the total salt. If the ocean were of uniform thickness D=5km around the globe, its volume would be $Vol = 4\pi R^2 D = 2.5\times10^{18} m3$. *With water density* $\rho = 1025 kg/m3$ *and salinity S=35ppt the salt mess is* $9\times10^{19} kg$. *To correct for the continents, take 2/3 of this value to obtain* $6\times10^{19} kg$

10. [10] Define
   a. Antarctic Bottom Water

   Antarctic Bottom Water (AABW) is very cold water found at the bottom of the ocean in the southern hemisphere. It is formed along the coast of

Antarctica and sinks to the bottom because of its high density.

b. Terminal moraine

A terminal moraine is a pile of rock and soil pushed to the end (i.e. the terminus) of a moving glacier.

c. Equatorial upwelling

Equatorial upwelling occurs along the equator because of the change in direction of the Coriolis Force. The Ekman drift in both hemispheres is away from the equator, so water must be brought up from depth to compensate. The upwelling nutrients usually cause high biological productivity there.

d. Mid-ocean ridge

The mid-ocean ridge is a thickening of the ocean crust where new crust is being generated from rising magmas. On the two sides of the ridge, the ocean crust moves away.

e. Ekman layer

The Ekman Layer is the shallow upper layer of the ocean that feels the wind stress directly. Due to the Coriolis Force, the water moves at right angles to the applied wind stress.