SIO 210 Introduction to Physical Oceanography
Final Examination, Fall, 2005

December 7, 2005 9-12
This is a closed book exam - no notes, no books. You may use a calculator.

Overall grade in course: 10% book review, 10% instrument paper, 50% midterm, 50% final.

**Multiple Choice** (circle one answer for each) (2 points each)

1) Which is TRUE about the Equatorial Undercurrent (EUC) in the Pacific

A) The EUC provides a circuitous path for the transport of water from the south Pacific to the North Pacific.

B) The currently reverses directions seasonally

C) The Thickness of EUC is about 1000 meters

D) Maximum velocity at the core of the EUC is about 5 cm/s

2) If 'age' refers to total time since last resident in the mixed layer, which of the following water masses has the oldest age?

A) Central Water

B) Eighteen Degree Mode water

C) North Atlantic Deep Water

D) Pacific Deep Water

3) Which physical property of the ocean is NOT well measured by orbiting satellites?

A) Temperature

B) Salinity

D) Sea Ice coverage

E) Wave Height

4) Estimating ocean currents by the geostrophic method fails

A) in the Kuroshio Extension

B) at the equator

C) in cold abyssal waters

D) in the Antarctic Circumpolar Current

5) Which of the following is NOT TRUE about ENSO (El Nino/Southern Oscillation)

A) Characteristic period is 3-7 years

B) Decreases the sea surface temperature of the Eastern Tropical Pacific

C) Is associated with decreases in fisheries catches in the along the western coast of South America

D Alters the zonal structure of the tropical oceanic heat flux to the atmosphere

6) Which factor is most associated with large net heat loss by the ocean surface mixed layer?

A) low wind speed
B) low relative humidity of overlying air
C) low incident solar radiation
D) low salinity

7) Which of the following currents flows predominantly to the west?

A) Antarctic Circumpolar Current
C) Equatorial Undercurrent
D) South Equatorial Current
E) Florida Current

8) Mode waters are ...

A) Weakly Stratified
B) Poorly Oxygenated
C) Mostly confined to the Atlantic Ocean
D) None of the above

9) Which process is NOT involved in the Stommel-Arons model of abyssal circulation?

A) Geostrophic flow
B) Isolated sources of deep water
C) Vorticity increase related to downwelling
D) Western boundary current

10) Which of these regions produces high salinity dense (intermediate) water for the global ocean?

A) Red Sea
B) Dead Sea
C) Caspian Sea
D) Labrador Sea

11) Sverdrup balance is simplified way to describe flow in

A) the abyssal Pacific
B) the equatorial Atlantic
C) interior of the Brazil Current gyre
D) the frictional, wind-driven surface layer

12) Which of the following is NOT true for the Antarctic Circumpolar Current?

A) It is geostrophic
B) It reaches to the ocean bottom
C) It is modeled using Sverdrup balance
D) It has several fronts

13) Potential density

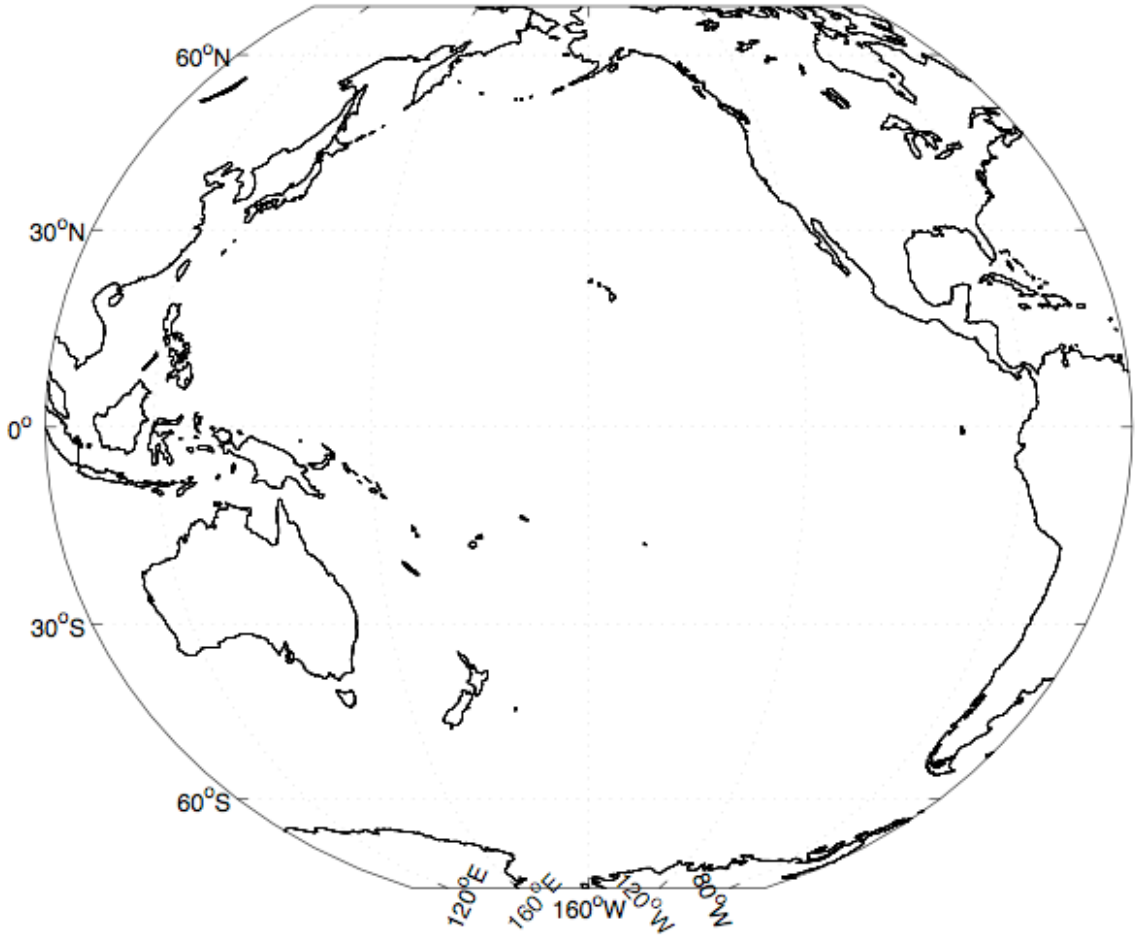
A) has pressure effects removed from temperature only
B) is always in the range of 1020 to 1028 kg/m3
C) decreases with increasing pressure
D) has smaller variation in the vertical than in situ density

14) Which of the following is NOT a decadal climate mode?

A) North Atlantic Oscillation
B) El Nino/Southern Oscillation
C) Southern Annular Mode
D) Pacific Decadal Oscillation

**Short answer questions (6 points each)**

S1. Sketch and label the primary wind-driven currents of the Pacific Ocean.



S2. Compare and contrast the rates and location of deep water production in the North Atlantic and North Pacific oceans. List three water properties which are helpful to distinguish North Atlantic Deep Water and Pacific Deep water. For each property identify if the concentration is high or low in each deep water mass (NADW, PDW).

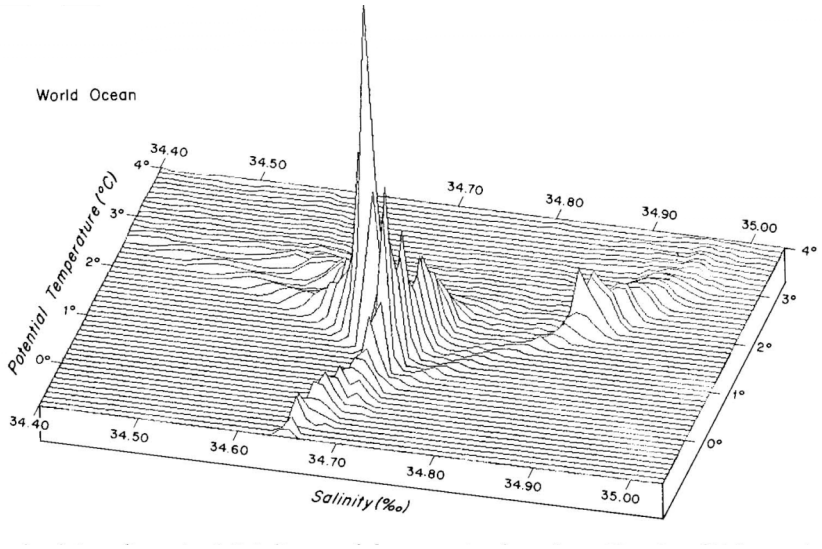
S3. Give an example of an ocean measurement currently conducted by an autonomous instrument. If the goal of this instrument deployment is to measure mesoscale variability, what would be an an optimal sampling rate for this instrument. [Assume you can neglect problems which might arise from aliasing of higher frequency phenomena.] What would be an appropriate sampling rate if the goal was to observe internal wave variability? Justify your choice of sampling rates. Be sure to phrase your answers in units of observations per time (e.g. hour/day/week/year).

S4. The accompanying plot is a volumetric potential temperature/salinity diagram for the world ocean from Worthington (1982).

(a) What is a volumetric potential temperature/salinity diagram?

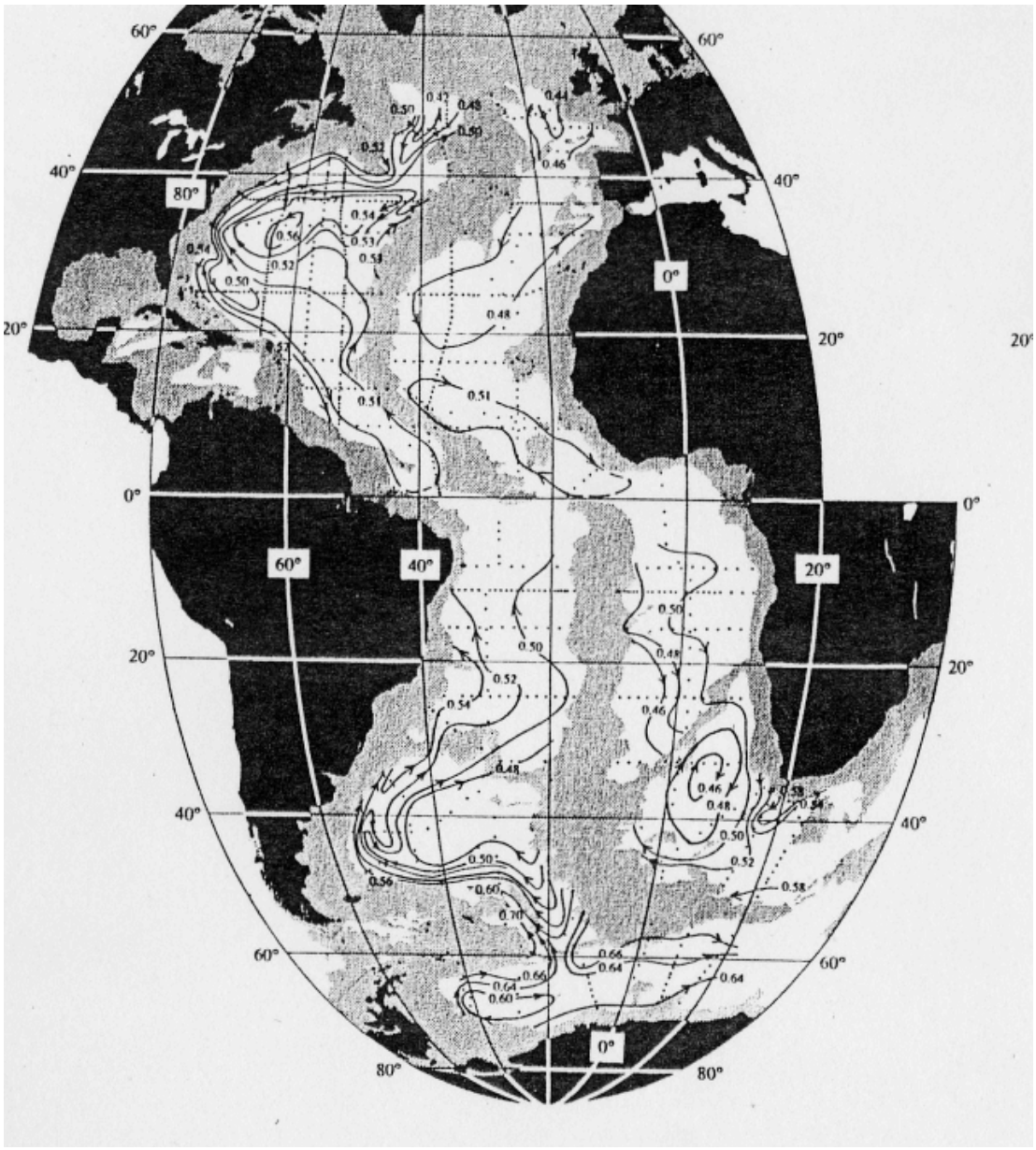
(b) Label the North Atlantic portion of the plot.

(c) What water does the largest peak in the diagram correspond to?




S5. The meridional heat transport in the subtropical South Atlantic Ocean is northward, even though the Brazil Current carries warm water southward and returns cooler water northward. Explain this apparent contradiction. That is, what causes northward heat transport in this ocean, and what parts of the circulation are involved in the heat transport?

S6. The figure shows steric height (dynamic height) at 4000 dbar (from Reid).




(a) Mark the Deep Western Boundary Current in the South Atlantic. (DRAW on figure.)

(b) Indicate where high and low pressure are relative to this current and the direction of the pressure gradient force that drives this current. (DRAW on the figure.)

(c) Which water mass is this current carrying?

**Long Answer/calculation (12 points each)**

L1. In a misguided effort to avert global warming, a North American oil cartel launches a massive engineering process to lower the albedo of the Northern Hemisphere. To accomplish this, the engineers remove all the water (and salt!) from the Arctic ocean and dam the connecting passageways between the Arctic and North Atlantic Oceans. (We don't know how they do this but we can be assured that Halliburton receives the bulk of the contracts.) After a strong backlash by environmentalists and ringed seals, it is decided to allow the Arctic basin fill again with water.

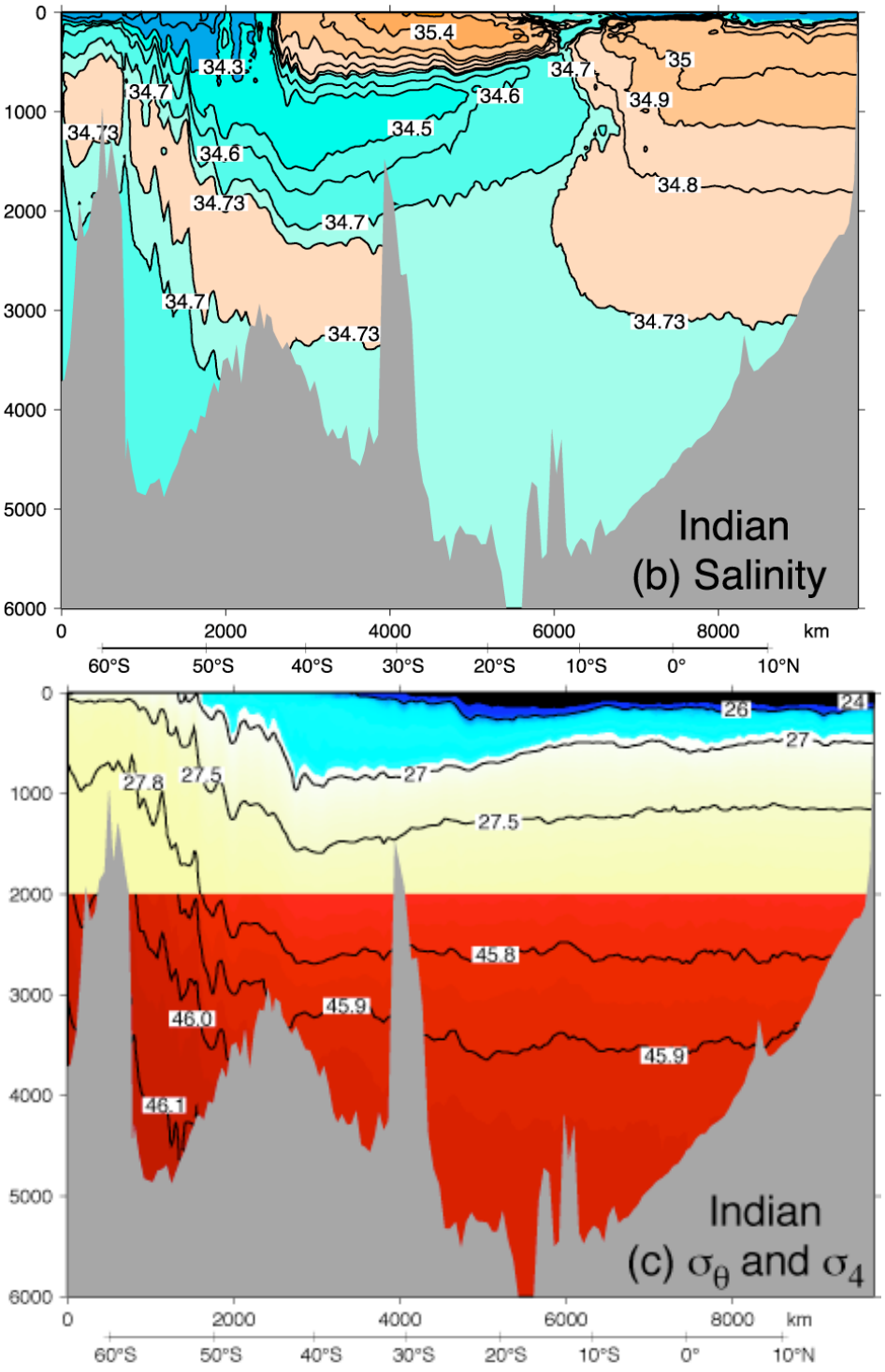
The primary inflows of water to the Arctic are the Bering Straits (1 Sv) and river runoff (0.2 Sv).

(a) How long would it take these sources to fill the Arctic basin up again?
[The area of the arctic basin is 14 million $km^2$. Average depth is 1200 m. 1 Sv = $10^6$ $m^3/s$]

(b) Consider how the filling rate changes if you add a factor for precipitation (both rainfall and snowfall) to the calculation. If the net precipitation over the Arctic is 10 cm/year, what is the change in the net time to fill the basin?

(c) If the mean salinity of the Bering Strait water is 32.5, what is the final salinity of the filled basin?

L2. The figures show salinity and potential density in the Indian Ocean along approximately 95°E.



(a) Label these water masses:

(i) Antarctic Intermediate Water

(ii) Red Sea Water

(iii) Circumpolar Deep Water

(iv) Subtropical Underwater

(v) Lower Circumpolar Deep Water or Antarctic Bottom Water

(vi) Indonesian Throughflow Water

(b) On either plot, label the Antarctic Circumpolar Current. Indicate which direction it is flowing.

(c) The Antarctic Circumpolar Current (ACC) is in geostrophic balance. Indicate where the low pressure and high pressure are relative to the ACC.

(d) Label the Subantarctic Front. Explain how you decided on its location. Also indicate approximately how wide it is in kilometers.

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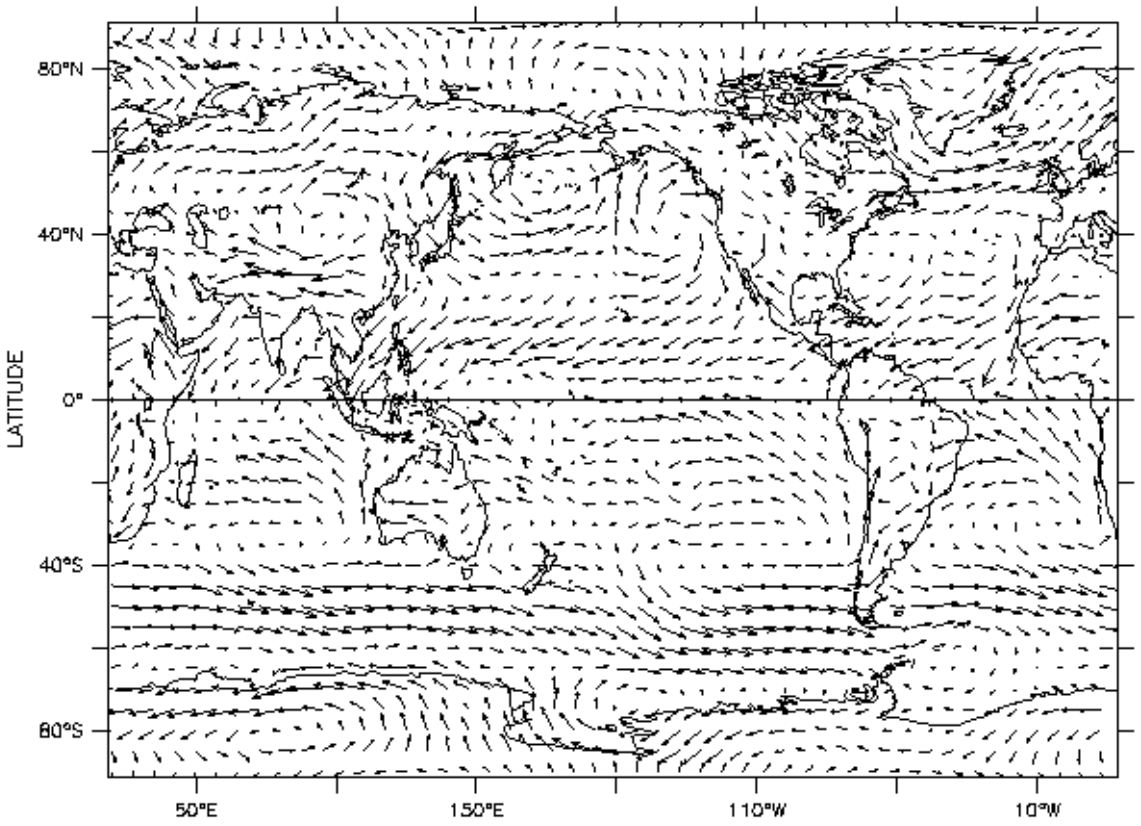
(e) Compute the approximate transport of the Subantarctic Front, assuming that its mean speed from top to bottom is 10 cm/sec. Assume the bottom depth is about 4000 m (ignore the topography in the plots).

L3. The mean winds are shown in the plot.




(a) Indicate where the trade winds are. (DRAW on figure.)

(b) Indicate where the westerlies are. (DRAW on figure.)

(c) Pick one of the *subtropical* ocean regions. Draw the direction of mean Ekman transport relative to the trade winds and westerlies in that basin. (Don't worry about the details of the wind – assume it is strictly zonal.) (DRAW on figure.)

(d) Is the Ekman transport convergent or divergent in the region you chose?_____

(e) Is there Ekman pumping or suction in the region you chose? _____

(f) Is the Sverdrup transport northwards or southwards in the region you chose?_____

(g) Show direction and location of the western boundary current in the region you chose. (DRAW on figure.)

(h) Explain how you would calculate the western boundary current transport from the winds. (If you know the formulas, great. If you do not, then explain it in words, deduced from the answers to the above questions.)