

SIO 210 Final examination
Wednesday, December 12, 2007
3-6 PM

Name: _____

This is a closed book exam. You may use a calculator.
Please mark initials or name on each page.

Check which you prefer regarding the return of this exam and other graded materials

_____ I will pick up the exam in Nierenberg Hall 310 (after Dec. 17)

_____ Return the exam etc to me via campus mail

Mailcode _____

There are two parts: Talley (weighted 70% of exam) and Hendershott (weighted 30% of exam)

Talley portion: 70 points

[1-5] Multiple choice 3 points each _____/15

[6-10] Short answer 5 points each _____/25

[11-12] Long answer 15 points each _____/30

Multiple choice (circle the single best answer for each) (3 points each)

1) The wind-driven subtropical gyres

(a) Shrink towards the pole with depth

(b) Extend in their entirety to the ocean bottom

(c) Have equal strength eastern and western boundary currents

(d) Are driven by Ekman transport divergence

2) Potential density computed relative to 4000 dbar

(a) depends on pressure, temperature and salinity

(b) has a range of values for the ocean between 22.0 and 28.0

(c) has flatter contours in the potential temperature-salinity plane than does potential density relative to 0 dbar

(d) has large inversions in the vertical in the deep (> 2000 m) South Atlantic

3) The monsoonal winds in the northern Indian Ocean

(a) blow from the Himalayan plateau towards the ocean during summer

(b) cause the western boundary current, the Somali Current, to reverse

(c) drive upwelling along the southeast coast of the Arabian peninsula in winter

(d) drive a permanent equatorial undercurrent along the equator

4) The Kuroshio

- (a) differs from other subtropical western boundary currents by including a so-called large meander before it separates from the coast
- (b) has a transport on the order of 10 Sv
- (c) is the western boundary current of the South Pacific
- (d) carries subpolar water to the coast of Japan

5) Deep Western Boundary Currents

- (a) are found only in the bottom 100 meters of the ocean
- (b) are not geostrophic
- (c) flow in the opposite direction of the interior Stommel-Arons flow
- (d) carry Lower Circumpolar Deep Water northward in the Pacific Ocean

Short answers. (5 points each)

6) Subduction is a process found in the upper ocean in the subtropical gyres.

- (a) Name one of the water masses that is associated with subduction
- (b) Describe how the water mass is detected

7) An Equatorial Undercurrent (EUC) is found in the Pacific and Atlantic Oceans.

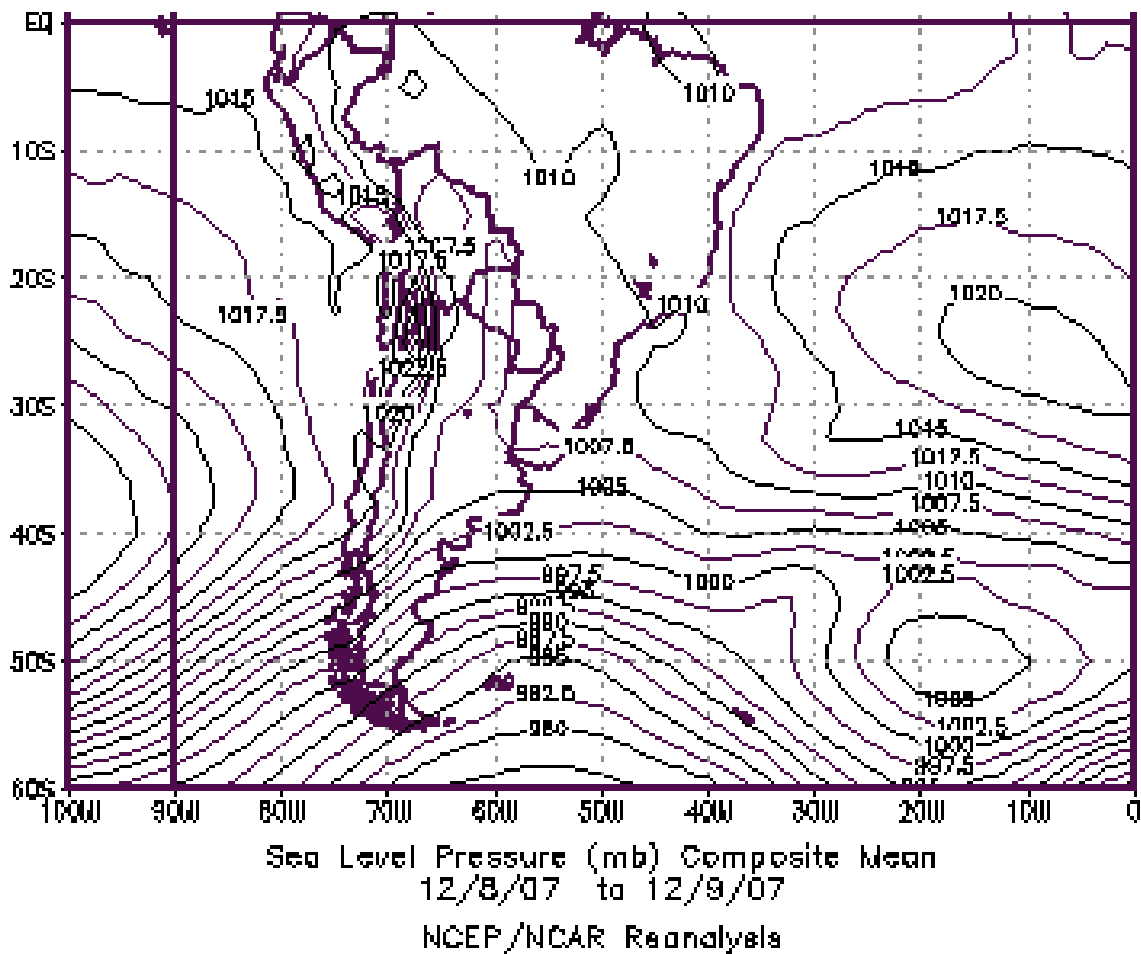
- (a) At approximately what depth is the EUC found in the Pacific?
- (b) Describe (3 sentences or less) what drives the EUC.

8) On the map provided, there are some high pressure centers. Be careful about what hemisphere this is from as you answer the following.

- (a) Choose ONE of the high pressure centers and indicate (on the map) the direction of the pressure gradient force relative to the high pressure.

(b) Indicate (on the map) the direction of the Coriolis force relative to the high pressure.

(c) Indicate (on the map) the direction of the geostrophic wind relative to the high pressure.



9) What are the units (in the mks system) of the following? (1 point each)

- (a) Mass transport
- (b) Freshwater transport
- (c) Heat transport
- (d) Oxygen transport
- (e) Volume transport

10) The trade winds blow from east to west throughout the tropics. Assume that the winds are steady and that they are exactly east-west (no north-south component) as you answer the following.

(a) What is the name of the frictional layer at the surface that is driven directly by the winds (everywhere except on the equator)?

(b) In the northern hemisphere, what is the direction of the ocean mass transport in this layer?

(c) In the southern hemisphere, what is the direction of the mass transport in this layer?

(d) What is the direction of transport in this layer exactly on the equator?

Long answer or calculation (15 points each)

11) The California Current flows southward along the west coast of the U.S. It is caused by the wind. For this question, consider it as a separate phenomenon from the subtropical gyre.

The California Current is driven by a southward alongshore wind. The wind causes an offshore Ekman transport.

Assume that the total Ekman transport is 1 Sv. ($1 \text{ Sv} = 1 \times 10^6 \text{ m}^3/\text{sec}.$)

(a) Explain how the California Current itself arises from this forcing. (short answer)

(c) Along the coast, there is upwelling in a strip that is about 10 km wide. Assume that it occurs over a 1000 km length of the coast. Make a reasonable assumption for the thickness of the upwelling layer based on what is causing the upwelling. _____m

Assuming that the Ekman transport of 1 Sv occurs out of this box, calculate the offshore Ekman velocity (using the transport and dimensions of the box).

(d) Calculate the upwelling velocity into the box (using the transport and dimensions of the box).

(e) The upwelled water is around 8°C. This water must become 13°C to join with the offshore waters. The expression for heat in terms of temperature is

$$Q = \rho c_p T$$

Assume that the seawater density is 1020 kg/m³ and the specific heat is 4000 J kg⁻¹ K⁻¹

What are the units of heat?

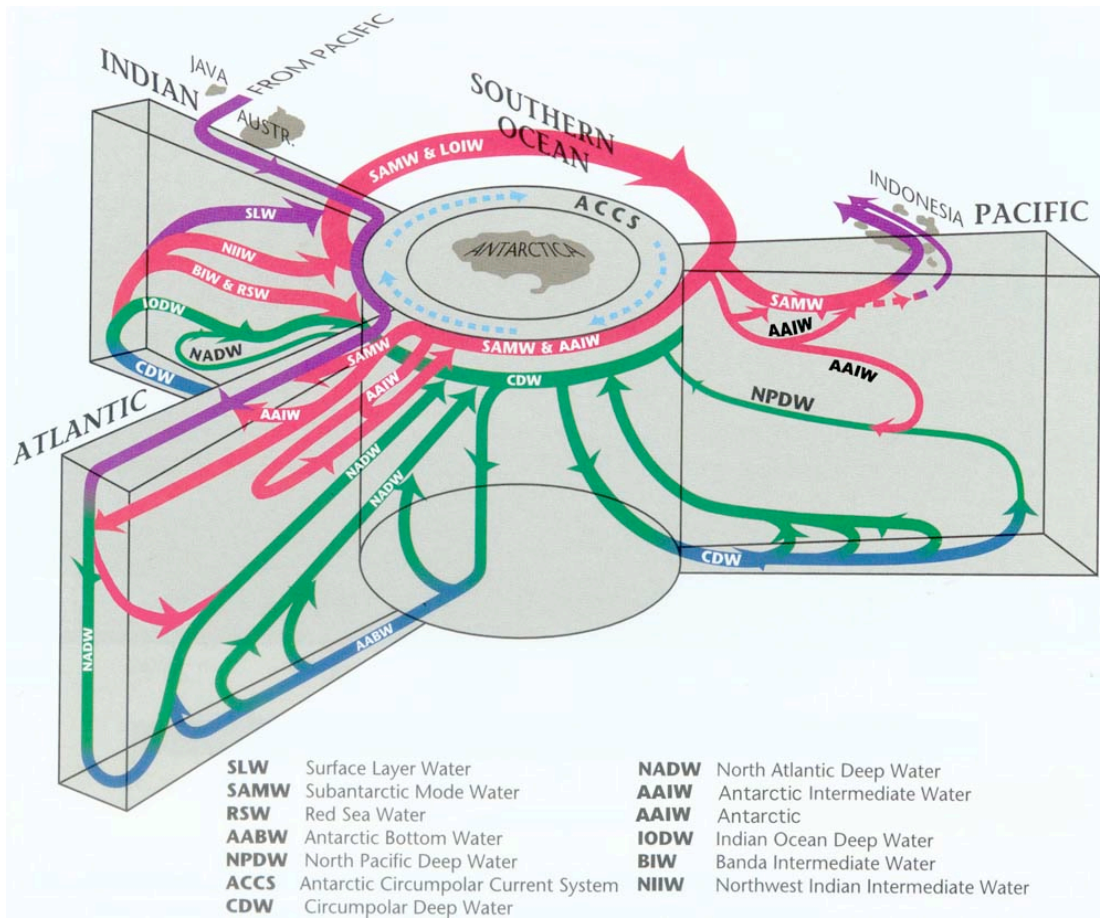
What is the heat transport into the box from the upwelling?

(f) What is the heat transport out of the box at the higher temperature?

(g) What is the net air-sea heat flux that must occur within the box to create this heating?

Calculate the air-sea heat flux for the box (upwelling strip) for conversion of the 8°C water to 13°C water.

12) This is an overturning schematic for the global ocean.



(a) On the diagram, there is a purple path at the top. Describe the significance of this pathway in terms of the global overturning circulation. (Describe what waters are involved and what their role is in the overturn.)

(b) On the diagram, there are many pathways labeled with water mass names. In class we did not necessarily talk about all of these, or use exactly the same terms (particularly in the Indian Ocean).

Nevertheless, pick one water mass. _____

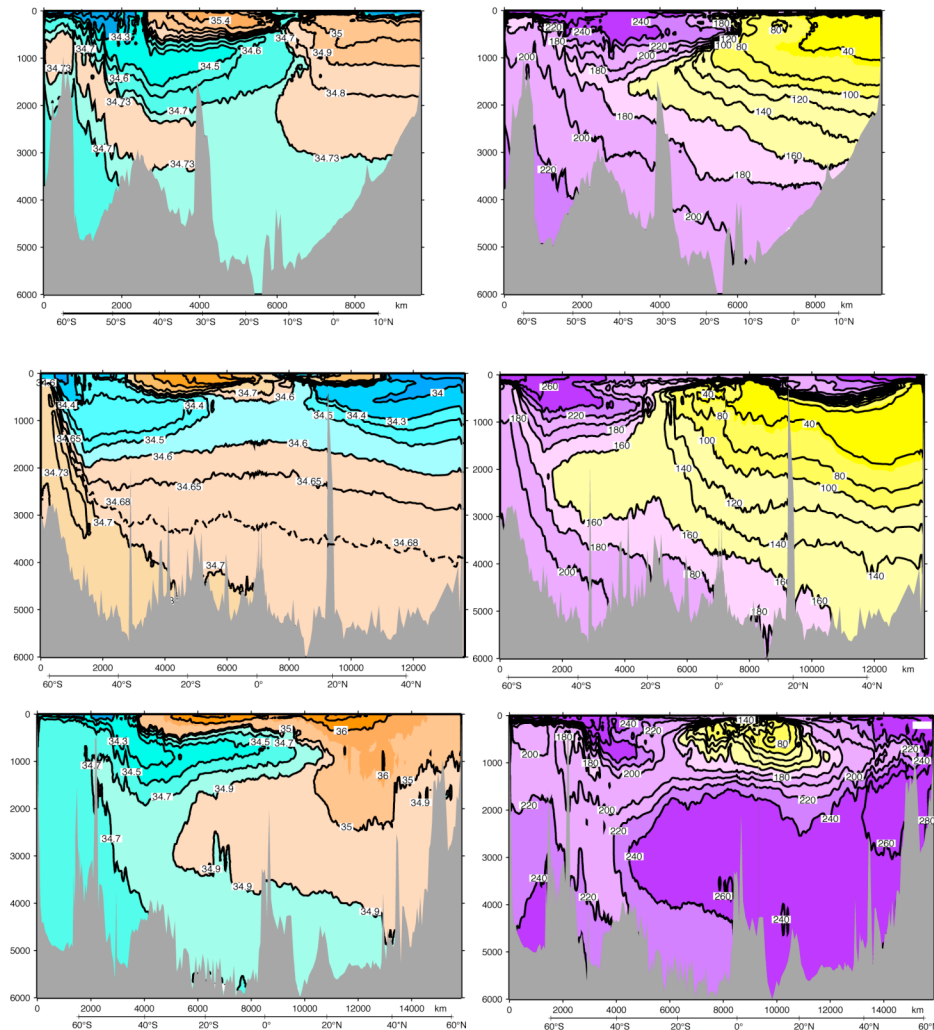
Describe how this water mass is recognized (what tracer or tracers are used to identify it).

(c) How is your chosen water mass formed?

(d) What about the formation process for your water mass produces the identifier that you gave in (b)?

(e) To assist with your description, here are oxygen and salinity sections from the Atlantic, Pacific and Indian Oceans.

Label the Pacific, Atlantic and Indian sections.
Label which are oxygen and which are salinity.



(f) On the sections, MARK where your water mass occurs. If it occurs in all three oceans, then label it in all three. Your water mass might not be identified by salinity or oxygen. If that is the case, then indicate generally where your water mass occurs relative to the oxygen and salinity features.

(g) Using the schematic at the top of the question and the sections, describe the evolution of either salinity or oxygen along the pathway of the water mass. Does it become fresher or saltier? How does its oxygen change?

_____KEY_____

1. Short answer questions about waves, for each mark or give the most nearly correct answer

- a. Waves generated by large mid-ocean storms cross the ocean at a speed of about
 - a. several Km/sec,
 - b. 1500 m/sec,
 - c. 200 m/sec,
 - *d. 10 to 30 m/sec.

- b. The first ocean waves of a tsunami cross the open ocean at a speed of about
 - a. several Km/sec,
 - b. 1500 m/sec,
 - *c. 200 m/sec,
 - d. 10 to 30 m/sec.

- c. Seismic waves, upon which our ability to issue a tsunami warning relies, travel at about
 - *a. several Km/sec,
 - b. 1500 m/sec,
 - c. 200 m/sec,
 - d. 10 to 30 m/sec.

- d. The mid-ocean stable platform FLIP scarcely moves up & down as ocean swell pass by, but as the waves of a tsunami pass by
 - *a. FLIP moves vertically with the tsunami waves,
 - b. FLIP moves vertically with a much smaller amplitude than the tsunami waves,
 - c. FLIP moves vertically with a much larger amplitude than the tsunami waves.

- e. At the coast, the vertical motion of the sea surface associated with a major tsunami is generally
 - *a. much greater than,
 - b. much smaller than,
 - c. about the same as that associated with wind generated waves.

- f. In the open ocean, the vertical motion of the sea surface associated with a major tsunami is generally
 - a. much greater than,
 - *b. much smaller than,
 - c. about the same as that associated with wind generated waves.

- g. A typical tsunami at a port consists of
 - a. An initial rise in sealevel followed by no further unusual sealevel variability.

- b. An initial fall in sealevel followed by no further unusual sealevel variability.
 - c. Either an initial rise or an initial fall in sealevel followed by no further unusual sealevel variability.
 - d. Either an initial rise or an initial fall in sealevel followed by unusual sealevel variability lasting for weeks.
 - *e. Either an initial rise or an initial fall in sealevel followed by unusual sealevel variability lasting for many hours.
- h. The seismic wave based tsunami warning system can accurately predict
- a. the initial arrival time and the initial amplitude of a tsunami,
 - *b. the initial arrival time but not the initial amplitude of a tsunami,
 - c. the initial amplitude but not the initial arrival time of a tsunami,
 - d. the entire sealevel history of the tsunami.
- i. The leading crest of the Sumatra tsunami of 2004 advanced into the Indian Ocean (mean depth $D_{\text{Indian}} \sim 2000$ m) and into the Strait of Mallaca (mean depth $D_{\text{Mallaca}} \sim 100$ m). What is the ratio of speed of advance in the Indian ocean to that in the Strait of Mallaca, $c_{\text{Indian}}/c_{\text{Mallaca}}$? Answer both with a formula and a number.
- $$c_{\text{Indian}}/c_{\text{Mallaca}} = \sqrt{D_{\text{Indian}}/D_{\text{Mallaca}}} = \sqrt{20} \sim 4.5$$
- j. If a tsunami alert is issued for La Jolla, you should
- a. go to the shore to watch the big waves come in,
 - *b. go to the top of Mt. Soledad,
 - c. pay no attention.

2. Short answer questions about tides, for each mark the most nearly correct answer.

- a. Spring tides (times of large semidiurnal tidal range) occur twice a month
 - a. when the moon is in the earth's equatorial plane,
 - b. when the moon is out of the earth's equatorial plane,
 - *c. at full or new moon,
 - d. at the quarter moons,
 - e. at lunar perigee.
- b. The daily inequality (elevation difference between a high tide and its immediate successor) vanishes for lunar tides

- *a. when the moon is in the earth's equatorial plane,
 - b. when the moon is out of the earth's equatorial plane,
 - c. at full or new moon,
 - d. at the quarter moons,
 - e. at lunar perigee.
- c. Above you thought about the daily inequality for lunar tides. There is also a daily inequality associated with solar tides. When is it greatest?
- *a. At the solstices (when the difference between the length of daytime and the length of nighttime is greatest)
 - b. at the equinoxes (when day and night are nearly the same length)
- d. The tidal range at times when lunar perigee and full/new moon occur together
- *a. is unusually large,
 - b. is unusually small,
 - c. is nothing special.
- e. Spring tides
- *a. may occur near the times of an eclipse of the sun or of the moon,
 - b. never occur near the times of an eclipse,
 - c. ONLY occur at the times of an eclipse.
- f. Neap tides
- a. occur near the times of an eclipse of the sun or of the moon,
 - *b. never occur near the times of an eclipse,
 - c. ONLY occur at the times of an eclipse.
- g. The earth rotates on its axis once every 24 hours, and the strongest tides are semidiurnal (one high water about every 12 hrs). If the earth rotated on its axis once every 36 hours but the orbital motions of earth and moon were not changed, then at most locations there would be one high water about every
- a. 6 hrs, b. 9 hrs, c. 12 hrs,
 - *d. 18 hrs, e. 36 hrs

3. Quantitative question about waves. Very long swells generated by a distant storm are observed in the open ocean. Their period is T seconds. What is their wavelength L ? Hint; this requires you to remember the formula $c = \sqrt{gL/(2\pi)}$ for wavespeed c and the general relationship $c = L/T$ to get a formula for wavelength in terms of wave period. Write that formula

$$L = \frac{g(T^2)}{2\pi} \quad \text{formula}$$

and approximately evaluate the result numerically assuming $T=20$ s and $g=10$ m/s².

$$L = 2000/\pi \text{ meters} \quad \text{numerical result (may be in terms of } \pi \text{)}$$

What is the numerical speed of these waves?

$$c = 100/\pi \text{ meters/sec} \quad \text{numerical result (may be in terms of } \pi \text{)}$$

As these waves pass by, water parcels at the surface carry out circular orbits (forward at the crest, then downward, backward at the trough, then upward). If the waveheight (from crest to trough) of these waves is H , what is the diameter D of the orbit?

$$D = H \quad \text{formula}$$

What is the average speed s with which water particles traverse the orbit?

$$s = \pi H/T \quad \text{formula}$$

Numerically evaluate the result for waves of period $T=20$ s and height $H=10$ m

$$s = \pi/2 \text{ meters/sec} \quad \text{numerical result (may be in terms of } \pi \text{)}$$

4. A More difficult question about tides. Question 2g above, envisages a situation in which the earth rotates about its axis once every 36 h rather than once every 24 but otherwise no detail of the astronomy or of the shape of the ocean floor or of the coasts is changed. Question 2a asks if the dominant period of the tide would change and, if so, what would it be. Now think more deeply about this situation and answer the following questions.

a. Would the spatial distribution and/or amplitude of the tide generating force change? Explain your answer in a short paragraph on page at end of exam.

Spatial distribution/amplitude of tide generating forces do not depend on earth's rate of rotation, they will not change. Simple way to think about

this is that, since orbit of moon and of center of earth does not change, then centrifugal force at center of earth does not change, lunar gravity does not change,

b. Would the spatial distribution and/or amplitude of actual the ocean tide and/or of ocean tidal currents change? To answer fully, you may need to think back in the course about dynamical matters that were discussed in connection with ocean currents. Explain your answer in a short paragraph on page at end of exam. I am looking as much for clearly expressed thought as I am for a single correct answer, so please think before you write. Partial credit allowed.

Important ideas.

Tide generating forces do not change shape, just period,
so maybe no change in ocean tide except period

Coriolis force is smaller, so expect change.

But time variation is also smaller, by exactly same amount,
so maybe no change after all.

Time for gravity waves to cross basin largely unchanged
(except for Coriolis effects), but period is different,
so may expect different shape of response.