SIO 210 Introduction to Physical Oceanography
Final Examination, Fall, 2000

December 7,2000
8-11 AM
This is a 3-hour closed book exam - no notes, no books. You may use a calculator. I will have a calculator at the exam if you need to borrow one.

The final grade will be an average from the Hendershott mid-term and this final.
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1. The attached figure shows two zonal (west-to-east) vertical sections of potential temperature and salinity from the southern hemisphere. West is on the left and east is on the right.

(a) Identify one major difference between the two sets of sections that will enable you to identify which is the Pacific and which the Atlantic.

(b) Which is the Pacific and which the Atlantic?

(c) Both oceans have a salinity minimum at about 1000 dbar. What is this salinity minimum called?

This salinity minimum comes from the NORTH or SOUTH. (*circle one*).

(d) One of the potential temperature sections has inversions of potential temperature. Circle them on the section.

How is a potential temperature inversion possible given that density depends on temperature?

(e) Circle the western boundary currents on both sections.

Which direction do the western boundary currents flow, at least near the sea surface?

What evidence did you use to tell you which way the western boundary currents flow?

Label the western boundary currents (names).

(f) Above the potential temperature sections, sketch the shape of the sea surface, assuming that the current is strongest at the sea surface. Do not worry too much about eddies, but please make sure that the width of the major features is correct based on the given sections.

Explain here why you drew this shape.

(g) Indicate where the deep water layer is in both sections.

In the Atlantic, what is the origin of this deep water layer?

Explain why the Atlantic deep water layer has the particular characteristics that helped you identify it.

2. The South Pacific subtropical gyre has an eastern boundary current, the Peru Current.

(a) Which direction does the Peru Current flow? NORTHWARD or SOUTHWARD (*circle one*).

(b) Which direction does the wind blow to create the Peru Current? NORTHWARD or SOUTHWARD (*circle one*).

(c) At the coast of South America, there is a very productive fishery. Explain why the fish like this region.

(d) There is an undercurrent beneath the Peru Current, called the Peru-Chile Undercurrent, which is a classical undercurrent associated with an eastern boundary current. Which way does the undercurrent flow? NORTHWARD or SOUTHWARD (*circle one*)

(e) How deep is the Peru-Chile Undercurrent when the Peru Current/Peru-Chile Undercurrent system is fully established, based on what you know about such undercurrents? 10 m or 300 m or 1000 m (circle one)

(f) There are sea surface height variations associated with the Peru Current and Peru-Chile Undercurrent. Indicate very schematically in the following where the sea surface is HIGH and where it is LOW.

Explain at least one aspect of what you just drew. (i.e. you will have drawn a paired High-Low - explain *what* this pair has to do with the current system.)

(g) During an El Nino (which we did not study), the fish catch off Peru drops. What is a possible reason for this drop? (speculate based on the various things that you know about eastern boundary currents)

3. (a) Along the equator in the Pacific (and Atlantic) Ocean, the prevailing winds are easterlies (trades). This means that the winds blow from
EAST-to-WEST or from WEST-to-EAST (*circle one).*

(b) Is the sea surface in the western Pacific HIGH or LOW compared with the sea surface in the eastern Pacific? (*circle one*)

Explain.

(c) Is the sea surface in the western Pacific WARM or COLD compared with the sea surface in the eastern Pacific? (*circle one*)

Explain.

(d) How might this distribution of sea surface temperature from west to east in the Pacific help to sustain the winds of part 3(a)? (This is called the Walker circulation.)

(e) During an El Nino (which we did not study), the Walker circulation weakens. What would this do to the ocean circulation at the equator? (There will be several correct answers - just show good thinking and come up with at least one idea.)

(f) For the idea you came up with in (e), what would be the effect on sea surface temperature at the equator? (again, just show good thinking)

(g) What might happen to the winds at the equator, given what you think happens to sea surface temperature, from part (f)?

4. The attached figure shows surface drifter tracks in the Gulf Stream region.

(a) What does a surface drifter look like? (Describe the most basic features of its design.)

(b) How wide is the Gulf Stream (at a given moment, or "synoptically") after it separates from the North American coast?

(c) How wide is the envelope of drifter tracks in the attached figure, at a longitude of 50°W?

(d) If you average together all of the drifter tracks at each point on the map to get an average picture of the Gulf Stream, how wide would your average Gulf Stream be (at say 50°W)?

(e) Would your average Gulf Stream be STRONGER or WEAKER than the synoptic (actual, at a given moment) Gulf Stream? (circle one)

Explain.

5. The attached color figures show salinity in the Indian Ocean (labeled I09) and in the Atlantic Ocean (labeled A16).

(a) In the northern Indian Ocean, high salinity is found in the deep water. What is the main source of this high salinity? _____

(b) In the Atlantic Ocean, high salinity is found in the northern hemisphere between 1000 and 2000 m, and then within a thick layer in the South Atlantic. What is the main source of the high salinity?_____

(c) In both cases (Atlantic and Indian) the total formation rate of the mid-depth highest salinity water is on the order of: (1 Sv 15 Sv 100 Sv) (*circle one*)

(d) What are the units of a Sverdrup? (in the mks system)

(e) What water mass does the Atlantic's high salinity become a part of?
_____

(f) High salinity water in the deep Indian Ocean is found only in the Indian Ocean, while the high salinity from the North Atlantic is found throughout most of the world ocean. Why is the Atlantic water so widespread and the Indian water so limited in extent, given (c) above?

(g) On both sections, label the Antarctic Intermediate Water.

(h) On both sections, label the Lower Circumpolar Deep Water (or Antarctic Bottom Water).

6. Very briefly indicate (a) an identifying characteristic of each of the following water masses, and (b) an important water mass formation (or transformation) process for each:

Labrador Sea Water

(a)_____

(b)_____

Weddell Sea Bottom Water

(a)_____

(b)_____

North Atlantic Deep Water

(a)_____

(b)_____

Subtropical. Underwater

(a)_____

(b)_____

Pacific Deep Water

(a)_____

(b)_____

Subtropical Mode Water

(a)_____

(b)_____

7. The attached figure is a potential temperature (θ) - salinity profile from a single CTD station in the central South Atlantic Ocean.

(a) Label the salinity extrema.

(b) Superimposed on the plot are the potential density (σ_θ) contours, with potential density computed relative to the sea surface. Explain briefly what potential density is:

(c) The potential densities in the plot are not labeled - indicate on the plot where the density is HIGH and where it is LOW.

(d) Sketch schematically the contours of potential density computed relative to 4000 dbar (σ_4). (Just make sure the sense of the contours is correct relative to the σ_θ contours.)

(e) In terms of σ_θ, the very deepest water appears to be slightly statically unstable. What does this mean and how do you see it on the plot?

Explain how this is possible in a steady state ocean (which it basically is for this situation).

(f) There is also a potential temperature inversion in the figure. Explain how this is possible in a steady state ocean.

(g) On the blank plot, draw the potential temperature (θ) from this CTD profile as a function of pressure. (Just get the essential elements right - you do not have enough information to exactly reproduce this profile.)

(h) On the same sketch, draw the *temperature* profile.

8. The attached figure shows potential temperature on an isopycnal surface in the Okhotsk Sea (northwestern Pacific Ocean). Note the temperature scale at the bottom of the plot.

Indicate on the map where the coldest water is.

Indicate on the map where the saltiest water is, and where the freshest water is.

Considering the temperature scale, what is likely to be occurring to create the coldest water found on this map? (various answers accepted)

9. Suppose that the net mass transport involved in the deep overturn of the North Atlantic is 20×10^9 kg/sec.

(a) Assume that the inflow is all at one temperature T_{in} and that the outflow is all at one temperature T_{out} . If the net heat transport associated with the overturning is 1 Petawatt = 1×10^{15} W (W = Watt), what is the temperature difference (T_{in} - T_{out})?
(1 Watt = 1 Joule/sec; the specific heat of seawater is c_p = 4000 Joule/kg°K.)

(b) If we now think of another ocean, and assume that the heat transport is the same (1 Petawatt northward), but that the temperature difference (T_{in} - T_{out}) is only 3°C, then what is the mass transport associated with the overturning?