SIO 210
Final Exam
December 10, 2003 11:30 – 2:30 NTV 330
No books, no notes. Calculators can be used.

There are three sections to the exam: multiple choice, short answer, and long problems. Points are given for correct answers.

Multiple choice or very short answer. (3 points for each question)

1. The Antarctic Circumpolar Current is composed of several different fronts. One of the fronts is the:

a) Subtropical Front
b) Subarctic Front
c) Polar Front

2. Water mass names are assigned to waters that have a very specific source or creation mechanism. What is the creation mechanism for Central Water?

a) Convection
b) Evaporation
c) Cabbelling
d) Subduction

3. The North Atlantic **subtropical** gyre has two separate named western boundary currents. One of them is the Gulf Stream. The other is located east of Newfoundland. What is its name?

a) Florida Current
b) North Atlantic Current
c) Azores Current
d) Labrador Current

4. What surface property in the 5 subtropical gyres is associated with the Subtropical Underwater? (that is, what property extremum identifies the STUW?)

a) Salinity
b) Temperature
c) Phosphate
d) C14

5. The flow through the many islands of the Indonesian archipelago goes **from** which ocean **to** which ocean? _____ to _____

6. Time scales. The time scale of glacial-interglacial changes in climate is set by
   a) Kelvin wave adjustment
   b) Variations in Earth's orbit
   c) Volcanoes
   d) Changes in equatorial wind systems

7. What does NOT contribute to formation of NADW?
   a) Entrainment
   b) Deep convection in the Labrador Sea
   c) Salty water flowing out of the Mediterranean
   d) Formation on the Greenland Shelf

8. Circle the correct answer (to complete the sentence):
Deep Western Boundary Currents
   a) only flow equatorwards
   b) are geostrophically balanced
   c) are inconsistent with the Stommel-Arons theory of abyssal circulation
   d) are typically the warmest waters in the abyssal ocean

9. In a region of downward Ekman velocity (Ekman pumping), what direction is the geostrophic general circulation beneath the Ekman layer? Assume the northern hemisphere: _____

10. Equatorial circulation is characterized by:
   a) Zonal jets
   b) Downwelling
   c) Geostrophic currents
   d) Weak variability

11. The Pacific Deep Water is NOT identified as
   a) An oxygen minimum
   b) A carbon 14 minimum
   c) A salinity minimum
   d) A silicate maximum

Short answer questions. Choose 5 of the 7 problems. (8 points for each question)

S1. We describe four different deep waters: North Atlantic Deep Water, Pacific Deep Water, Indian Deep Water and Circumpolar Deep Water.

Choose one of these deep waters to answer the following questions: _____(choice)

a) In what approximate depth range is your chosen deep water found?_____

b) In what ocean basin does your deep water originate? _____

c) List one identifying property (e.g. salinity, helium, phosphate, potential vorticity, whatever you want) that is easily used to identify your deep water, (most commonly as an extremum). _____

d) How is your deep water identified using this property?

e) What about the origination process or circulation of your deep water makes it possible for this property to be used to identify this water mass?

f) What are the source waters for this water mass?

g) What process or processes transforms these source waters into this water mass?

S2. ENSO is a coupled climate phenomenon in the tropical Pacific that has both regional and global impacts.

a) What two systems are coupled in ENSO?_____

b) One of the indicators of an impending El Nino event is a weakening of the trade winds.
Which direction do the trade winds blow? _____

c) What happens to the ocean when the trade winds weaken?

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d) How does this change in the ocean affect the atmosphere in turn?

e) During an El Nino event, the surface waters along the Peruvian coast become warmer. Why are the Peruvian surface waters usually cold?

S3. a) Name 2 regions of net evaporation

b) Name 2 regions of freshwater gain

c) Explain why regions of large freshwater loss are also regions of large heat loss

d) Explain how the ocean maintains a nearly steady salinity distribution given that there is net evaporation in some regions and net freshwater gain in other regions.

S4. Compare and contrast eastern and western boundary currents in subtropical gyres in terms of:
a) magnitude

b) direction

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c) forcing. For this portion, please explicitly but BRIEFLY describe the process that creates an eastern boundary current and the process that creates a western boundary current.

S5. a) What is the time scale of variability of ENSO? _____

b) What is a possible explanation for why it has this time scale (as opposed to say the shorter time scale for a similar variation in the tropical Atlantic)?

c) Draw a map of the Pacific SST anomalies associated with ENSO.

S6. During certain times, the earth, moon and sun are aligned to produce very high tides.
a) Sketch the alignment of the moon and sun relative to the earth at such a time.

b) What is the name given to this anomalously high tide?_____

c) What is the name given to the anomalously low tide?_____

d) What is the typical period for the anomalous high tide? (That is, what is the time between anomalously high tides?)

S7. On average, at the surface of the ocean, the tropics heat and the high latitudes are cooled.

a) Why does this require a net ocean heat transport?

b) Which ocean basin has equatorward net heat transport? _____

c) What is special about the circulation or processes in this ocean basin in regards to the equatorward heat transport?

Long problems. Choose 2 out of the 3 problems. (15 points for each question)

L1. The accompanying figure is a potential temperature section in the upper ocean from south to north in the subtropical North Pacific. (A small map showing its location is also shown.)

a) Why have we plotted potential temperature instead of temperature?

b) Assume that the potential density vertical section looks very much like this potential temperature section. Why would this be possible?

c) Assume that the circulation represented by this section is in geostrophic balance. Assume that the flow is very weak at the maximum depth of the section and increases upward.
Which direction is the flow in the bracketed regions labeled A and B?
(A) _____ and (B) _____

Indicate this direction on the plot.

d) Using your result from c), sketch a smoothed version of the sea surface height above the plot. Do this for the whole section.

e) Explain in words how the distribution of isotherms in bracketed area A can lead to a geostrophic velocity difference between the bottom of the section and the top of the section.

f) Label (Name) the current indicated by bracket A._____

g) Just to the left (south) of that current, there is a thickening of the isotherms. What is the name we give to this layer?_____

L2. A 100 meter deep freshwater lake is initially at 5°C. If the lake is cooled at an average rate of 1000 W/m^2, how much time is required before the first ice starts to form? (Assume that the lake is initially and always well mixed.)

L3. A geostrophic current in the ocean has a surface velocity of 1 m/s. The speed of the current linearly decreases with depth and equals zero at 1000 m. Calculate the horizontal density gradient perpendicular to the flow of the water. If the width of the current is 100 km, what is the difference in density on either side of the current? (Assume the latitude is 30°.)

Some useful (rounded) relations and constants (you might not need all of these):

1 Watt = 1 Joule/sec
seawater density: 1025 kg/m^3
freshwater density: 1000 kg/m^3
seawater specific heat: c_p = 4000 Joule/(kg °C)
$2\Omega = 1.458 \times 10^{-4}$ sec^{-1}
$f = 2\Omega \sin(\text{latitude})$