NAME: SOLUTIONS

December 15, 2006

EAS-4300 Oceanography FINAL Exam

There are 6 questions and you have up to 2 hours and 50 minutes.

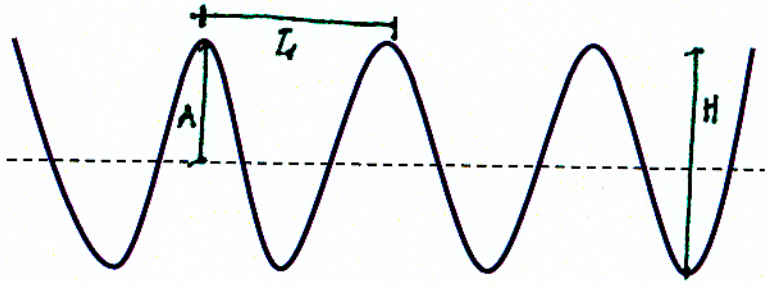
The questions may have more than one answer so it is important that you explain when asked to do so. However try to be brief and synthetic.

If you have questions during the exam, ask me.

You have about 30 minutes for each question.

Question # 1 — 18 pt. — OCEAN WAVES

a) Below is a diagram of an ocean gravity waves. The blue line represents the displacement of the sea surface height associated with a gravity wave propagation. Label with three segments the distance denoting the wave amplitude (A), wave height (H) and wave length (L).



3

b) Define and write down the general mathematical formula for the wave number (k), frequency (ω), steepness and phase speed (c). These formulas will be a function of wave height (H), and/or wave length (L) and/or wave period (T).

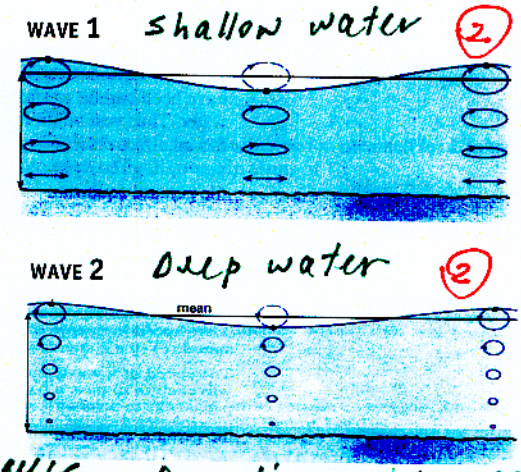
$k = \frac{2\pi}{L}$ (1) $\quad \omega = \frac{2\pi}{T}$ (1) $\quad c = \frac{\omega}{k}$ (1) $\quad \text{steepness} = \frac{H}{L}$ (1)

c) Label if WAVE 1 and 2 are DEEP WATER or SHALLOW WATER waves. How can you tell from the ellipses? Label with a capital D which of the two waves is dispersive? What does it mean for a wave to be dispersive? How can you tell if a wave is dispersive from the phase speeds c shown below?

(1)
- Ellipses become less oval and more stretched in shallow water

$c = \sqrt{gd}$

- Waves with different lengthscale L travel with different phase speed in deep water.



(2) (2)

$c = \sqrt{\frac{gL}{2\pi}}$

(1)
- dispersive because c depends on L

D = dispersive wave (2)

d) Swells originated in the Southern Ocean by strong storms take several weeks to arrive on the shores of the North Pacific, however tsunami waves take less than a day to go around the world's oceans. Can you explain why? Could you give a rough estimate of their phase speed?

Tsunami waves involve the entire water column and have a much longer wave lenght → travel like shallow water waves. $c = \sqrt{gH}$. Assuming $H = 4000$ m

$g = 10 \frac{m}{s^2}$

(2)

$c = 200 \frac{m}{s}$ ← (1)

13 pt.

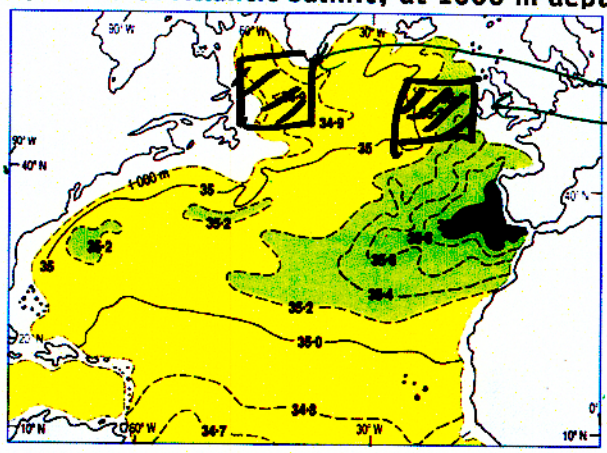
Question # 2 THERMOALINE CIRCULATION

a) Below is a map of salinity at 1000 m depth. Can you explain why there is a higher salinity in the green area? Also label the spatial location where you may find deep water formation (based on your knowledge of North Atlantic circulation).

• Mediterranean outflow. The Mediterranean is a basin where evaporation is stronger than precipitation → higher salinity.

(2)

Map of North Atlantic Salinity at 1000 m depth



(3) Deep water formation

b) Can you explain how the higher salinity water mass is important in the formation of deep waters in the North Atlantic? How is the formation of the North Atlantic Deep Water (NADW) different from Antarctic Bottom Water (AABW)? (Hint: remember the Polynyas?)

The high salinity water of the Med. is warm therefore its density is such that it does not sink to bottom. When it reaches the formation of deep water region it looses heat very fast but retains salinity → very dense and contributes to sinking / convection.

(2)

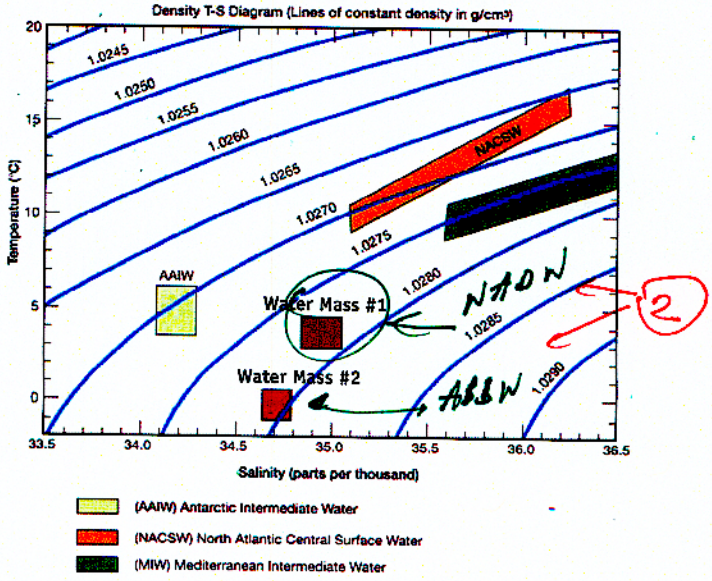
In the diagram below which water mass is more dense between Water Mass #1 and Water Mass #2? Which one corresponds to NADW and AABW? Is density a linear function of Temperature and Salinity in the diagram below (explain)?

(2)

• NADW more salty than AABW
NADW less warm than AABW

• No, density is a non linear function of TS and the iso-density lines on the diagram are curved.

(1)



(2)

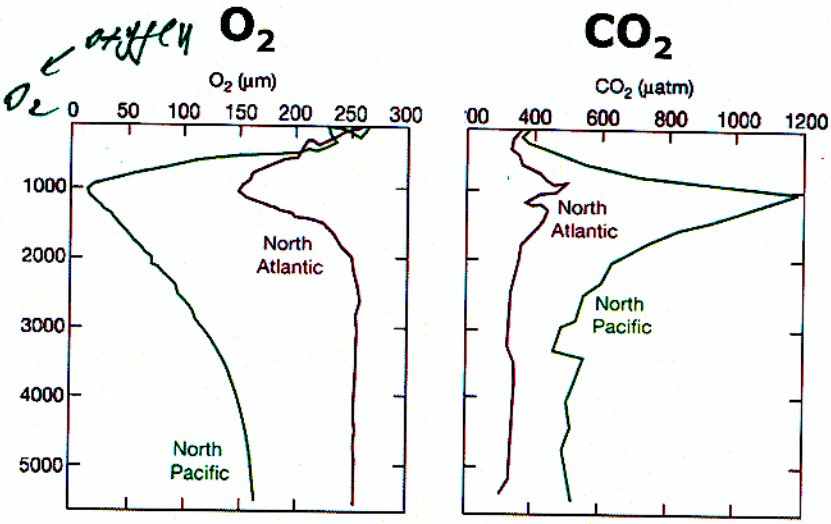
Question # 3 — 11 pt. — CHEMICAL OCEANOGRAPHY CARBON DIOXIDE

a) List the biological processes that are important in regulating the amount of Carbon Dioxide that goes from the Atmosphere into the ocean (briefly explain how).

- photosynthesis

$CO_2 + H_2O + light \rightarrow CH_2O + O_2$ (↑ organic matter; ↙ oxygen)

(3)



b) Several organism in the ocean build a hard shell around them either with Silica or Carbonate Calcium. Which of these two is likely to play a bigger role in the oceanic carbon budget and why?

Carbonate Calcium, they can incorporate carbon at the surface and when die and sink store carbon below the surface → removal of CO_2 from atmosphere (3)

c) Explain why the Oxygen curve in the graph above has a strong minima around 1000 m. Is the Carbon Dioxide maxima at 1000 m in the North Pacific related to the Oxygen minima?

- respiration uses O_2 and releases CO_2

(3)

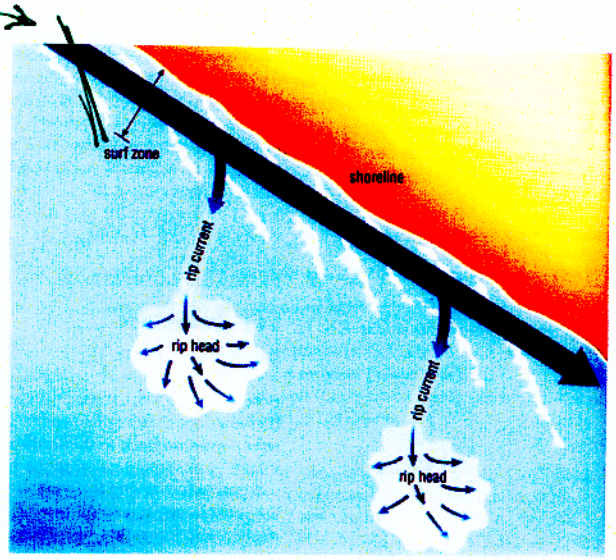
d) According to the graph above which deeper water masses are older, the ones in the North Pacific or North Atlantic? (Explain and remember that an old water mass is defined as one that has not seen the surface in a very long time).

North Pacific, low oxygen content → have not seen surface in a long time. (2)

No deep water formation in N. Pacific

Question # 4 — 14 pt. — COASTAL PROCESSES

a) The diagram below shows an alongshore current and rip currents. Explain how the alongshore current develops and who is driving it. Explain under which circumstances rip currents develop along the beach.



• Wave crest approaching the shore now parallel drive an alongshore pressure gradient force → current. (3)

• Rip current develop when there is a strong local convergence of mass (water) at a location along the beach. (2)

Figure 4 panel A and B show the same map of a beach. As a town counselor, you must vote on a proposal to allow a major hotel seaside resort expand its beach front by artificial replenishment (renourishment). The area of expansion is shown on Figure 4. The hotel proposes to dredge sand from the water offshore (labeled on the figure).

b) Draw the wave crests in proximity of Pt.1 and 2 (the red dots on the map) before the dredging on Panel A. On Panel B draw the crest after the dredging to show how they change. (3) (see diagram)

c) Discuss in which way the dredging will affect the Marina located east of the hotel.

probably increase the amount of sand advected by the alongshore current toward the entrance of the marina. (2)

d) Would there have been a better place to locate the entrance to the Marina? If so label it with a black X on Panel A. Explain your answer.

(2) (see diagram)

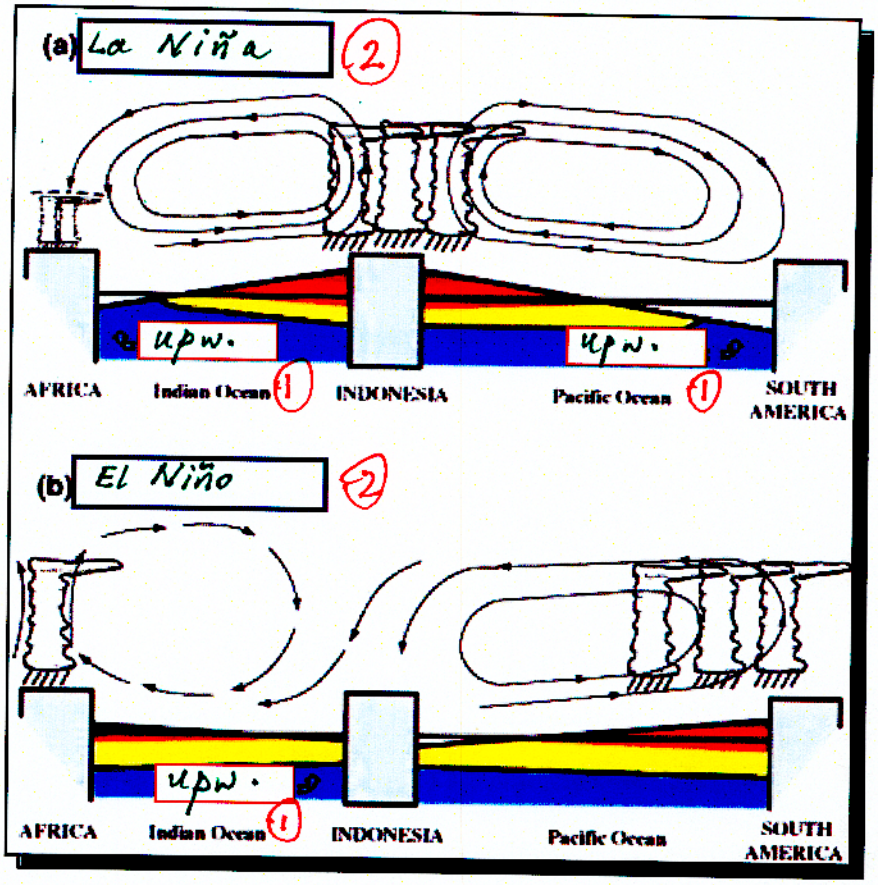
e) In the long term what will happen to the beach?

will be eroded away towards the west.

(2)

Question # 5 — 16 pt. — EL NINO and BIOLOGICAL PRODUCTION

a) The figure below shows an equatorial transect of sea level anomalies across the Pacific and Indian Ocean. The color red indicates that the water masses are warmer than usual and the blue colder than usual. Indicate which state corresponds to El Nino and which one to La Nina. Write the answer in the blue box. In the red box indicate if the arrow points to a region of upwelling or downwelling.



b) The black contours and arrow above the ocean correspond to the atmospheric circulation anomalies corresponding to El Nino and La Nina. How is this atmospheric circulation called? How is it linked to the ocean? Which of the two states corresponds to a weakening of the trade winds?

(1). The Walker circulation

(2). It is linked to the ocean by the warm/cold SST which can affect the center of deep convection during El Niño.

(2). El Niño = weaker trades

c) Based on the diagram above, how do La Nina anomalies affect the biological productivity at the following locations:

1) South America Coast: upw. (1)
2) African Coast: upw. (1)
3) Indonesian coasts (Pacific side): downwelling (1)
4) Indonesian coasts (Indian side): downwelling (1)

18 pt.

Figure 6, Panel A, shows a map of atmospheric pressure anomalies at the sea surface.

a) How is the North Atlantic Index defined? Based on the definition of the NAO is the SLP anomaly more consistent with the positive or negative phase?

• NAO = SLP_{Azores} − $SLP_{Iceland}$ • negative phase (2)

b) Based on this SLP map, draw the geostrophic atmospheric winds inside the BLUE BOX.

(see diagram) (3)

c) Figure 6, Panel B, shows two maps of SST anomalies during the cold and warm phase of the PDO. Which of the two SST anomaly maps is consistent with the SLP map? Explain why.

Negative phase because SLP map shows upwelling favorable conditions along North East Pacific → colder SST. (2)

Figure 7 shows a map of open ocean in the Southern Hemisphere. The red arrows indicate the direction of the wind stresses at the ocean surface. The black filled rectangles are islands.

d) In correspondence of each red arrow draw the direction of the Ekman Transport. Remember that you are in the Southern Hemisphere and the Coriolis force acts differently from the Northern Hemeshpere!

(see diagram) (3)

e) For each green dot on the map indicate if it is upwelling with a letter U and if it is downwelling with a letter D.

(3)

f) For each green dot draw an arrow indicating the direction of the surface Ekman Currents.

(3)

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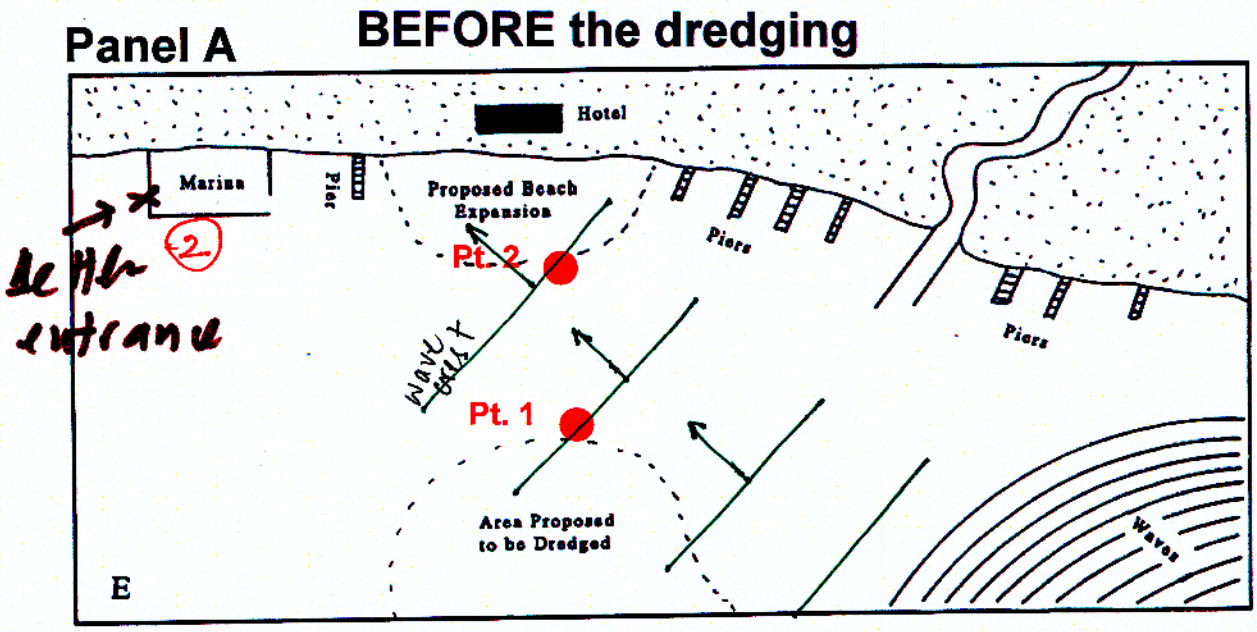
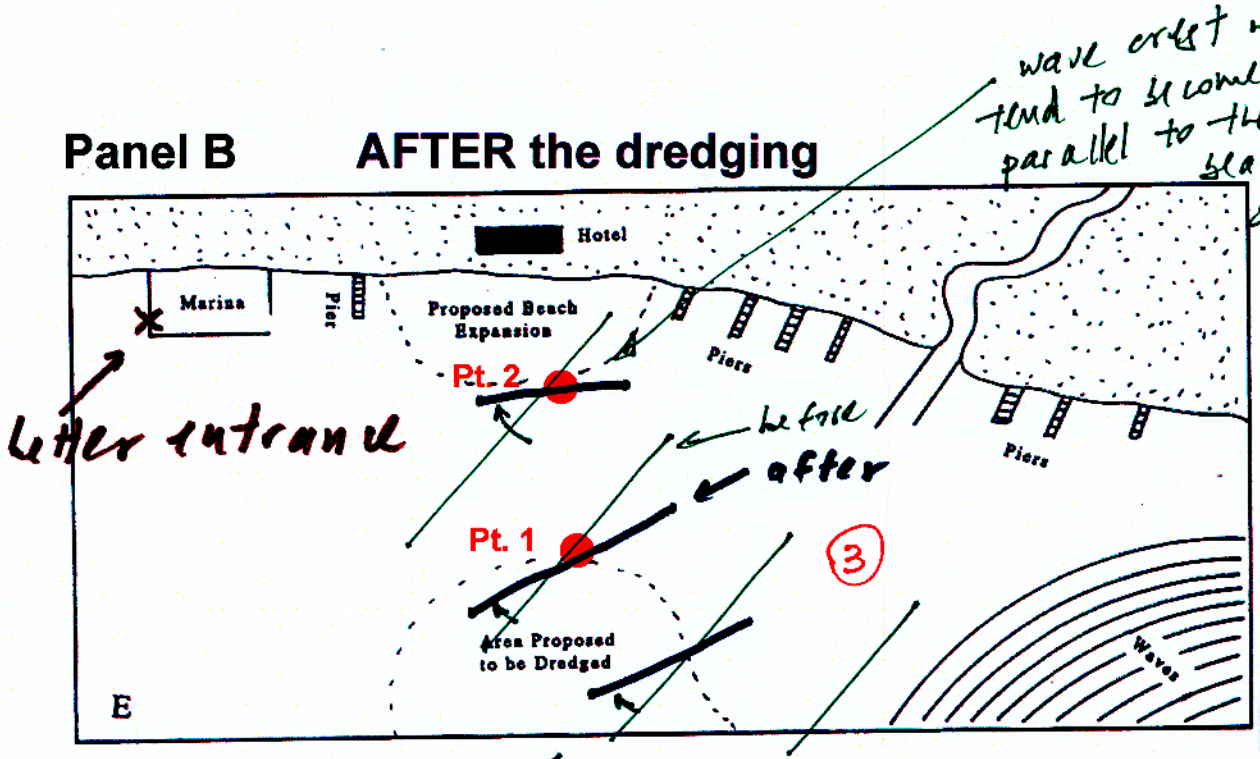
FIGURES

FIGURE 4





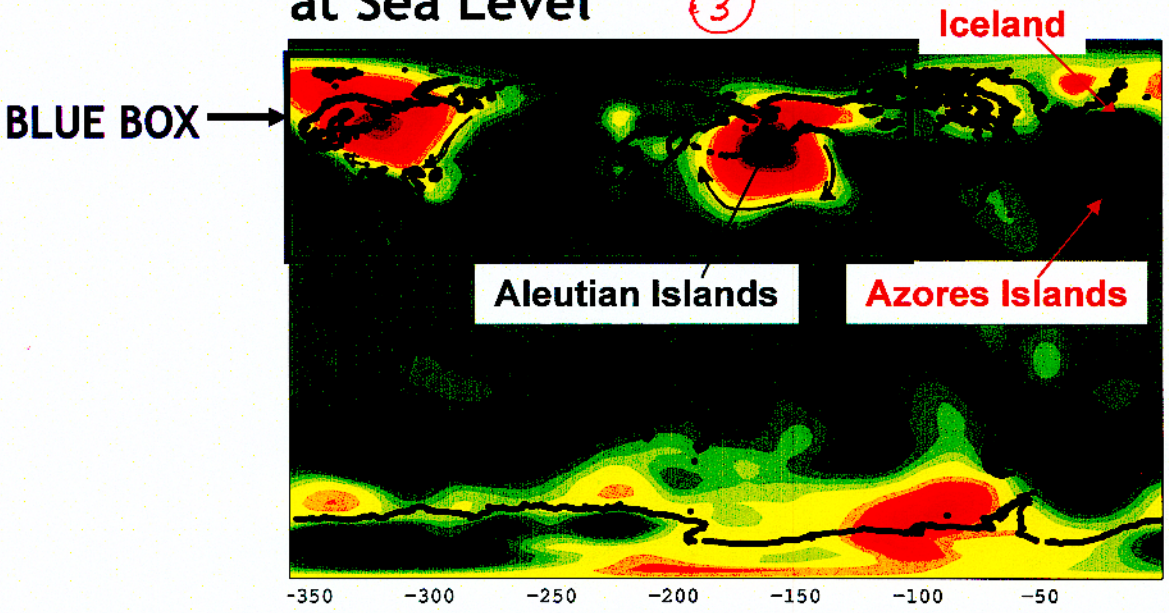
wave crest will tend to become more parallel to the new beach because shallow.

new wave crest tell the deeper water in the dredged area and are refracted.

Panel A

Atmospheric Pressure Anomaly at Sea Level

3



Panel B

upwelling conditions consistent with SST map

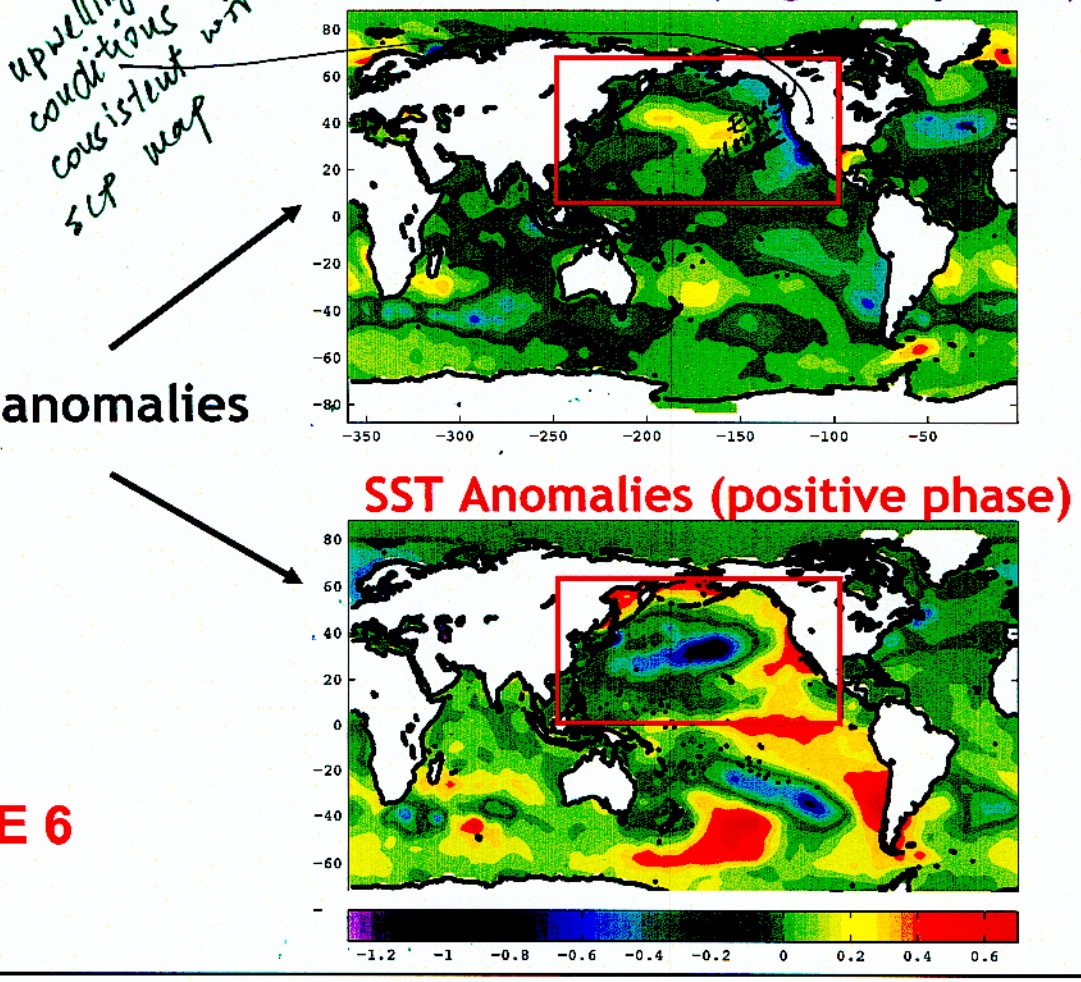
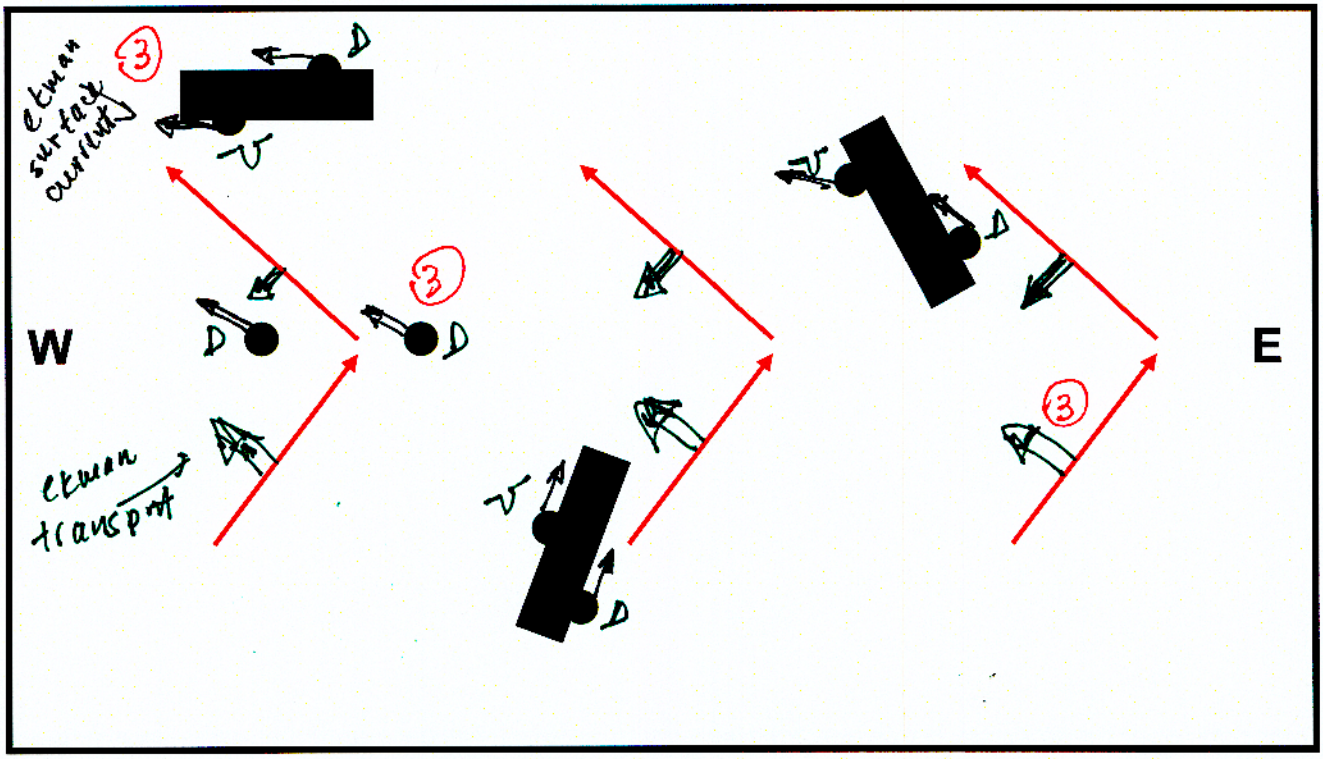


FIGURE 6

Red arrows on map are
Surface Wind Stresses

Open Ocean in Southern Hemisphere



Black rectangles are islands

FIGURE 7