NAME: SOLUTION TO FINAL EXAM

December 14, 2005

EAS-4300 Oceanography FINAL Exam

There are 6 questions and you have up to 2 hours and 50 minutes. However you should be done earlier!

Remember: this exam is not to test your ability to memorize things. Use the concepts you learned in the class to give answers and reasonable explanations to the questions. The questions may have more than one answer so it is important that you explain when asked to do so.

If you have questions during the exam, ask me.

You have about 30 minutes for each question.

Figure 1 shows vertical sections of dissolved oxygen in the Atlantic and Pacific Ocean.

a) Based on your knowledge of the thermohaline circulation, what can you say about the relationship between the age of the water masses and their dissolved oxygen content?

The older the water mass the more depleted is the oxygen concentration.
The age of a water mass is defined as the last time it was last in contact with the atmosphere. The major source of dissolved oxygen is the ocean surface through exchanges with the atmosphere and photosynthesis. At depth oxygen is rapidly consumed by the respiration process due to marine organisms.

5 pt

b) Mark the Atlantic and Pacific section.
Mark one location at the surface where deep waters are formed with a 'D'.
Mark one location at the surface where intermediate waters are formed with an 'I'.

See figure
3 pt

c) If you wanted to solve the global warming problem by removing Carbon Dioxide from the atmosphere and you could put it into the ocean in any point of sections A or B, what would be the best location? Explain your answer.

I would inject the CO2 at the location of the red dot in section A (Pacific Ocean). Those water masses are extremely old and will not see the ocean surface for a long time therefore the CO2 will not be released in the atmosphere anytime soon.
5 pt

d) Mark (if you can) the approximate location of the formation region for the Antarctic Bottom Waters (AABW) and the North Atlantic Deep Water. Briefly explain how each of these deep water are formed and discuss their temperature and salinity characteristic (e.g. which one is colder/warmer and fresher/saltier and why).

5 pt
See figure

NADW: are formed by deep convection in the North Atlantic. Cold and dry winds over the North Atlantic make surface water denser and initiate the convection events. The convection of deep water is more efficient due to the contribution of high salinity and relatively warm waters from the Mediterranean outflow that are advected in the formation region of the NADW. **NADW = cold, very salty**

AABW: are formed below the ice and the Polynya by cooling of the water mass by latent heat release and brine rejection, which makes the waters denser. The AABW are SALTY and the COLDEST water mass. **AABW = very cold, salty**

NADW saltier than AABW
AABW colder than NADW
AABW denser than NADW

Figure 2 shows a map of precipitation and water vapor.

a) Label the Trade winds and Westerlies.

See figure in book. 2 pt

b) Label the ascend and descent locations of the Hadley Cell and Polar Cell (AH = Ascending Hadley, DH = Descending Hadley, AP=Ascending Polar, DP=Descending Polar). Also indicate if these location correspond to low surface pressure of high surface pressure. 5 pt

See figure in book.

c) Where are the winds expected to be stronger and why?

2 pt

Over the southern ocean, the lack of continents allows the winds to reach higher speeds.

d) Where do you expect convection to be the strongest on the map? Would this be a region of low level convergence or divergence?

2 pt

According to the water vapor content map, the strongest convection is occurring at the location of the tropical storm in the Pacific.

e) Isolate a mid-latitude cyclone and it correspondent cold front.

See figure 2 pt

f) Identify the location of a tropical cyclone. What are the conditions needed for formation of a tropical cyclone?

Very warm SST, high humidity, strong convection 2 pt

c) Why do most mid-latitude areas only rarely experience a hurricane?

They lack very warm SST and high humidity 2 pt

d) Why are there no hurricanes at the Equator?

Because the Coriolis force is null at the equator, therefore there cannot balance between the pressure force and Coriolis force to maintain the circular cyclonic motion

2 pt

e) Draw the ocean circulation on panel C of figure 2 for the Pacific, Atlantic and Southern ocean. Make sure to include the gyres and label the major upwelling systems with a circle.

5 pt

See figure in book.

Figure 3 shows a map of Sea Surface Temperature Anomalies (SSTa).

a) What is the North Atlantic Oscillation and how is it defined?

The NAO is defined as a sea level atmospheric pressure oscillation between the Iceland low and the Azores high

NAO Index = SLP(Azores High) – SLP(Iceland Low)

3 pt

b) Label in figure 3, which of the two patterns corresponds to the positive phase of the NAO (hint: during the NAO the Gulf Stream is stronger and the storm track intensifies and shift norhtward bringing wet climate over northern Europe). 3 pt

c) Briefly explain which physical processes force the SST anomalies at location A and B (in the figure) during the NAO positive and negative phase. 4 pt

During NAO positive phase:

SST higher at location A because Stronger Gulf Stream == advection of warmer water from the tropics

SST cooler at location B because Stronger storm tracks == increases cooling of ocean surface, more evaporation leads to moist air and wet conditions over northern Europe

d) The ecosystem response to the NAO is classified into direct, indirect or integrated. For each type of response state briefly what it means and give at least one example. 6 pt

We have seen three type of ecosystem response:
1) DIRECT: A direct ecological response to one of the environmental parameters synchronised with the NAO.

Temperature Mediated Response
Length of active growing season, Individual growth (size), growth rate, eggs variability, timing of reproduction, spawning, time of food availability, larval growth and mortality

2) INDIRECT: The indirect effects of the NAO are non-trivial mechanisms that either involve several physical or biological intermediary steps between the NAO and the ecological trait and/or have no direct impact on the biology of the population.

Physically induced by changes in oceanic transport
Changes in spatial distribution of phytoplankton and larvae, alteration in competition between different levels of the trophic chain → alteration in food web
Effects on Predator-Prey
Through changes/alteration in the food

3) INTEGRATED: The integrated effects of the NAO involve simple ecological responses that can occur during and after the year of an NAO extreme. This is the case when a population has to be repeatedly affected by a particular environmental situation before the ecological change can be perceived (biological inertia) or when the environmental parameter affecting the population is itself modulated over a number of years (physical inertia)

a) On Figure 4a, draw a schematic of nitrogen cycling in the biological system and sediment in the ocean. In the arrows you will draw indicate if the transfer of mass is associated with organic or inorganic matter.

See figures 6 pt

b) With a different color insert in the diagram where nitrogen fixation and denitrification occur.

See figures 2 pt

c) Discuss briefly the role of bacteria in nutrient cycling.

Convert Dead Organic Matter into Nutrient Inorganic matter.
They are fundamental to the marine ecosystem ….see chapter 10 Bacteria as Decomposers.
2 pt

d) Also what special property makes bacteria vital in hydrothermal vents?

They are autotrophs can use chemical energy from oxidation of inorganic compounds (this process is called chemosynthesis), producing food. Because of this ability they represent the first trophic level to support life in hydothermal vents which exist deep in the ocean in anaerobic environments. These bacteria can also resit very high temperatures!

4 pt

e) Briefly sketch/describe how changes in availability of nutrients and sunlight in the regions listed in Figure 4b affect the primary productivity. **Please write your answer on the figure in the appropriate space.** 6 pt

a) It has been argued during the GW debate that burning fossil fuel and emitting more CO2 is beneficial to the planet because it increases plant growth as estimated in figure 5a. More plant growth equals more photosynthesis and therefore more storage of carbon in the vegetation. How would you argue against this theory?

The PRO group showed the results from the *Nature* Article published in 2004 (Mack et. al) that suggests that global warming actually decreases net ecosystem carbon. Nitrogen and Carbon in the deeper levels of the soil were **lost to the atmosphere at levels unaccounted for by plant productivity**, therefore creating a positive feedback for global warming

5 pt

b) Figure 5b shows the globally averaged temperature over the last 140 years. The anti-global warming group have argued that although CO2 has increased throughout the century the global temperature has had a negative trend between 1940-1980. During this period there is not positive correlation between temperature and CO2. How would you argue against this statement?

Although CO2 is increasing in the atmosphere the climate system undergoes natural oscillation on decadal timescales (e.g. the PDO and NAO). These oscillations are superimposed on the global warming trend and lead to period of apparent negative trends in the temperature timeseries.

3 pt

c) You are the president of the United States and you are concern about increase in sea level over the next century. What decision would you make about emissions of Carbon Dioxide in the atmosphere? Justify your choice (to the voters) by indicating the advantages/disadvantages of your choice.

To help you with your decision world wide scientist have presented you the following diagram.

If I was concerned with temperatures in the next century 2000-2100, it is clear from the graph that the constant emissions scenario will lead to lower global temperatures than the "fix the concentration" scenario. Even though in the "fix the concentration" scenario the emissions are significantly reduce by 2100, the temperature will stay warmer because they are more close to their equilibrium temperature for a given concentration of CO2. On the other hand the constant emission scenario is also not very good in the long run because eventually the temperatures will be very high in order to equilibrate to the higher CO2 concentrations in the atmosphere. In fact by 2200 the constant emission scenario show much higher CO2 atmospheric concentration than the "fix the concentration". Ultimately it seems that the best strategy is to reduce emissions right away.

6 pt

Look at figure 6. As a coastal engineer, you have been hired to prepare a plan for the area shown on the coastal chart. The main goals are to protect the town on Mitchell Point and the harbor facilities in Herman Bay. The land area consists of easily eroded sediment, mainly sand and silt. A study of wave and wind records for the past ten years indicates that from October through May the wind and waves are primarily from the southwest. From June through September they are from the Southeast.

a) Draw in red the longshore currents during the summer. Draw in blue (or dashed line) the longshore currents during winter. Remember to allow the refraction around headlands.

4 pt

b) In figure 6, locate where you expect the formation of rip currents with the label RP and a circle. Do rip currents occupy the same location year round or do they change location with season?

4 pt

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FIGURES

Dissolved Oxygen ml/l Figure 1

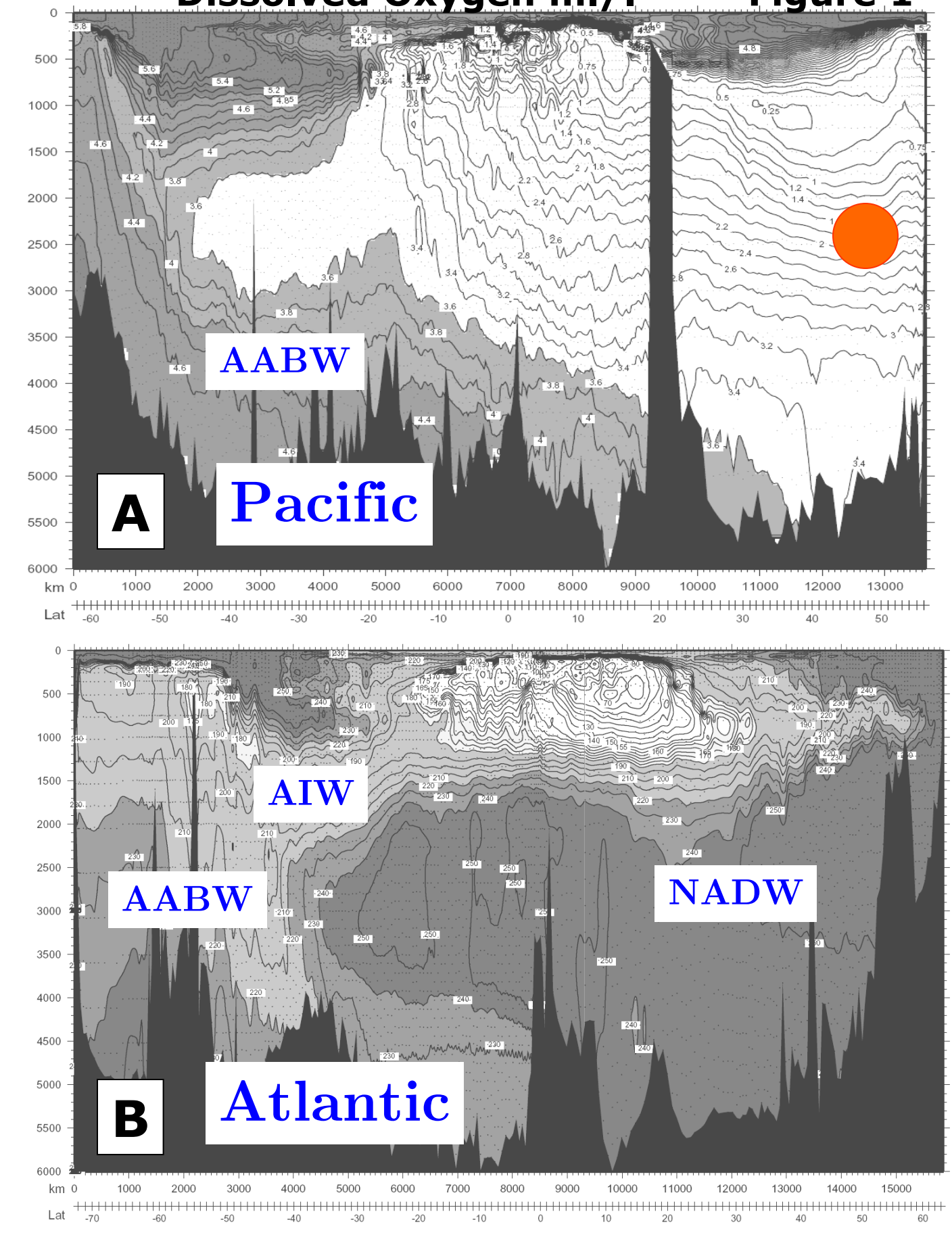
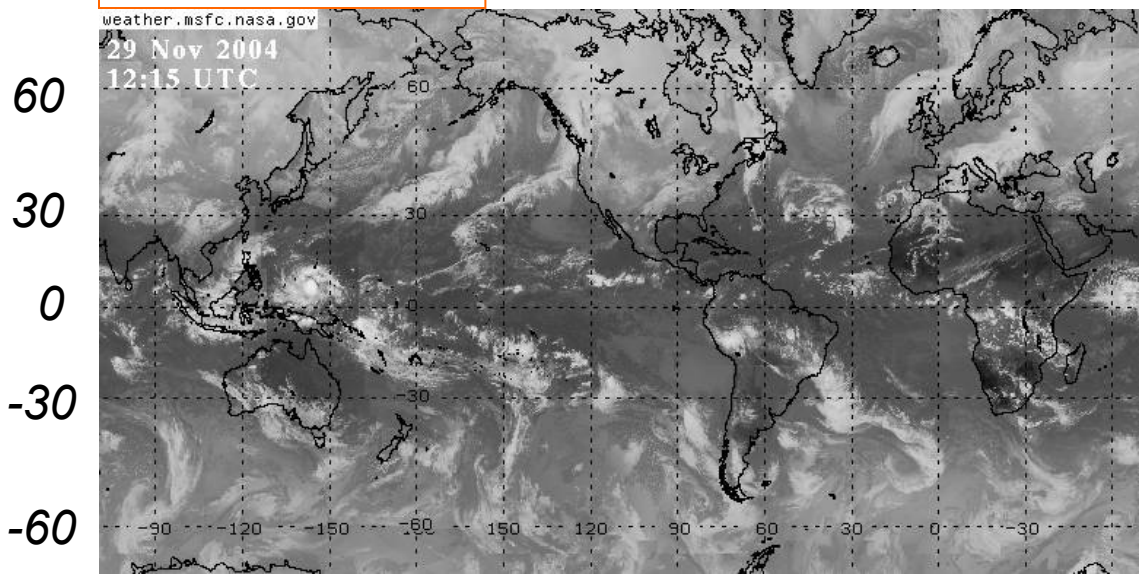


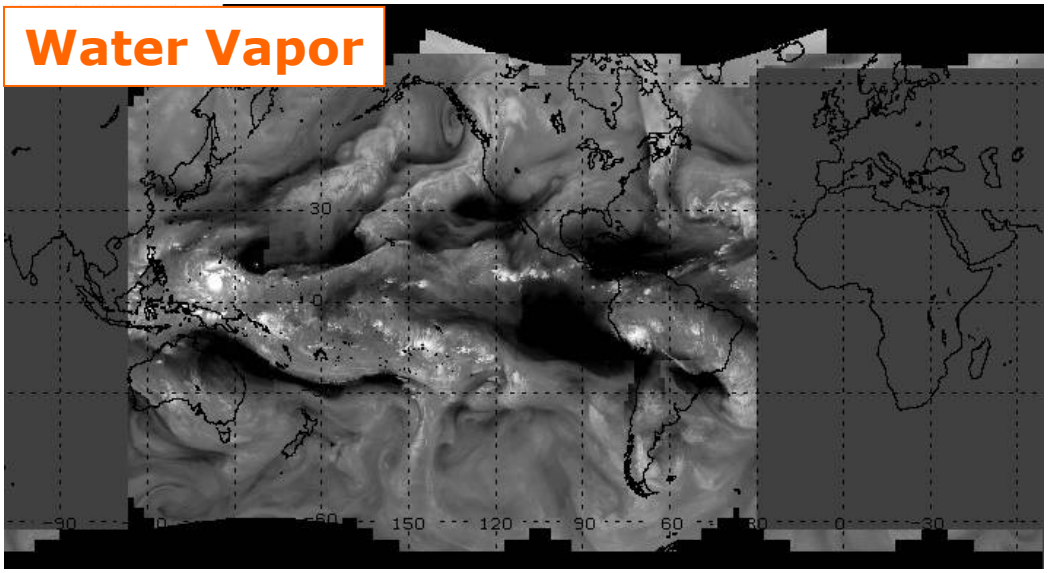
Figure 2

Precipitation

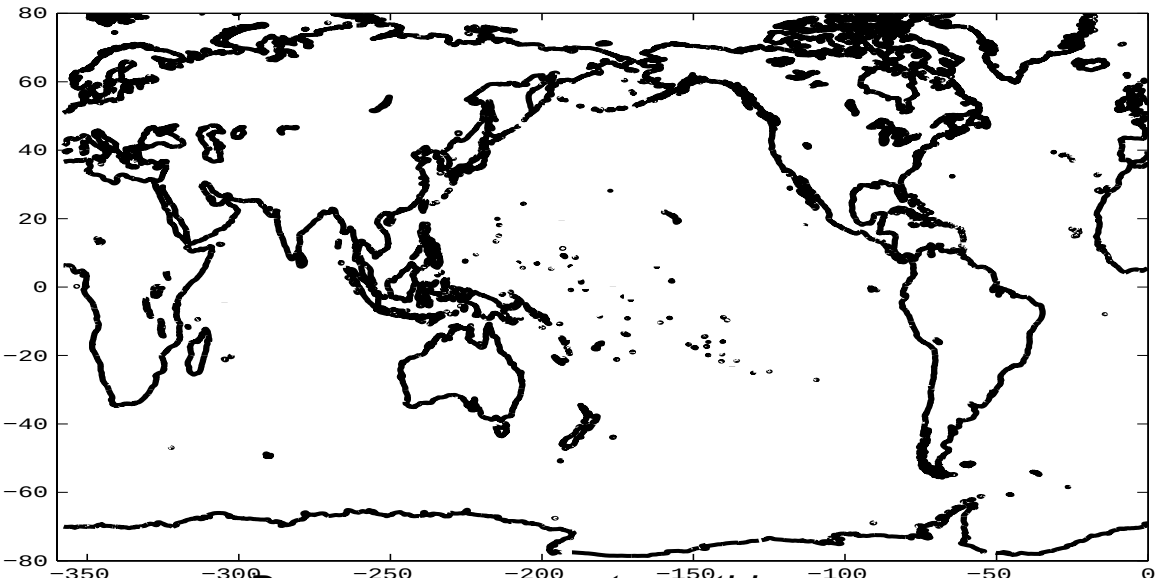


A

Water Vapor



B



C

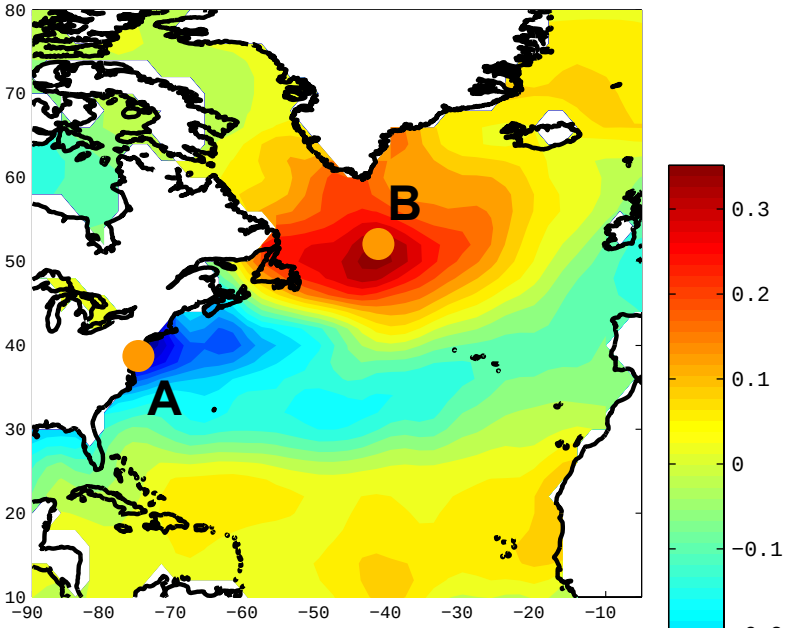
Draw ocean currents on this map

Figure 3

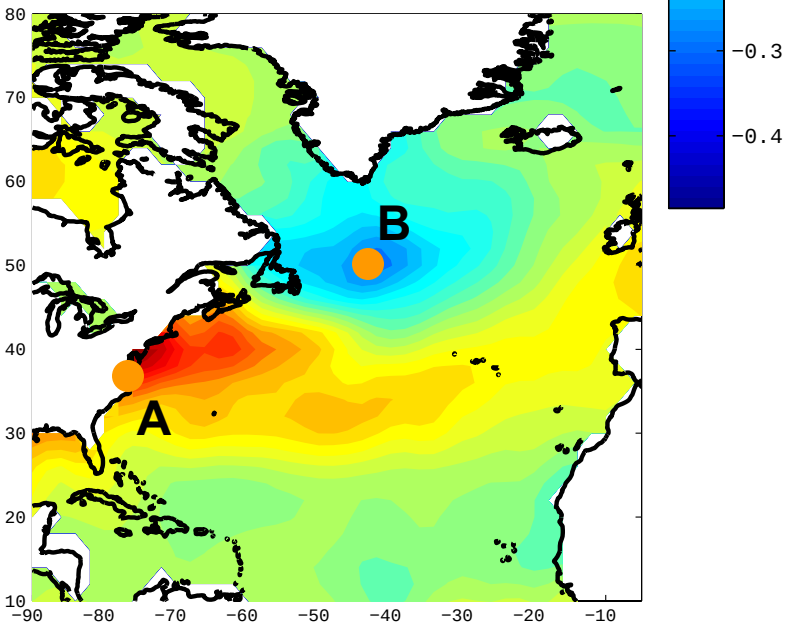
NAO

SST Anomalies [C]

Negative Phase

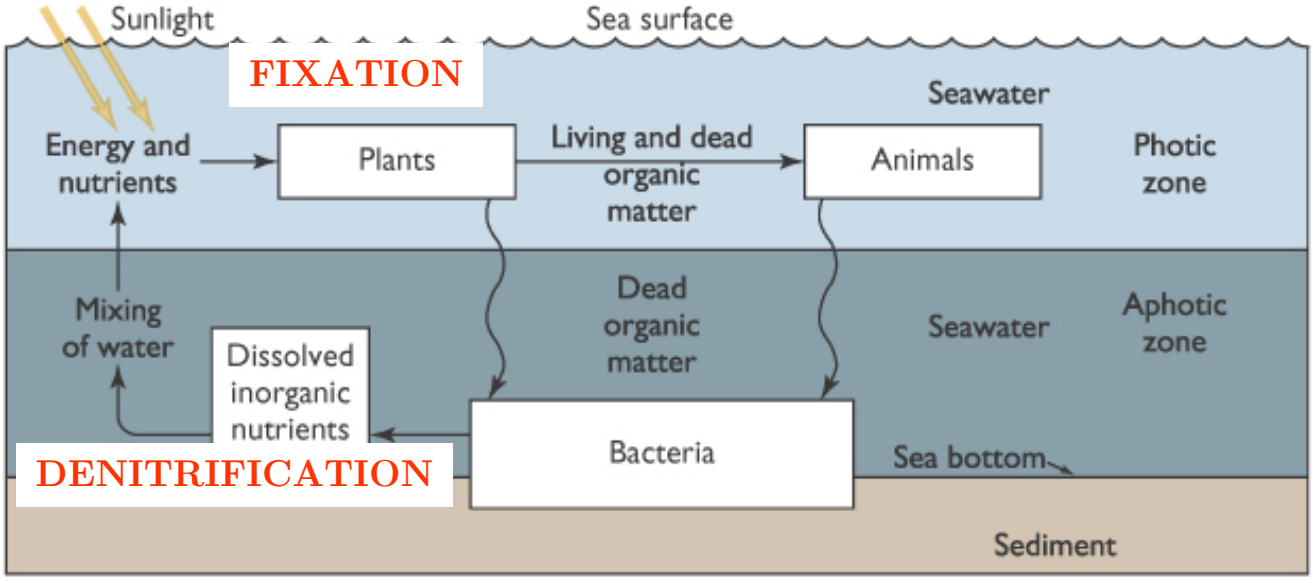


Positive Phase



Draw Nutrient Cycling Diagram

Figure 4a



(a) NUTRIENT CYCLING

Tropics and Subtropics

Sunlight is abundant, but it generates a strong thermocline that restricts upwelling of nutrients and results in lower productivity

High productivity locally can occur in areas of coastal upwelling, in the tropical waters between the gyres and at coral reefs.

Temperate regions

In temperate regions productivity is distinctly seasonal

In winter, the water column is isothermal and mixes easily, nutrients are abundant at the surface, but limited sunlight restricts productivity

In spring, sunlight becomes more abundant and there is a diatom bloom.

By summer, productivity declines as:
1.A thermocline develops and prevents vertical mixing and re-supply of nutrients.
2.Usage depletes the nutrients in the surface water.
3.Grazing by herbivores greatly reduces the population of phytoplankton.

In the fall, productivity initially increases as the water becomes isothermal and nutrients again become abundant, but then declines because the amount of sunlight decreases.

Polar regions

Polar waters are nutrient-rich all year but productivity is only high in the summer when light is abundant.

Figure 4b

CO_2 & Plant Growth

Figure 5a

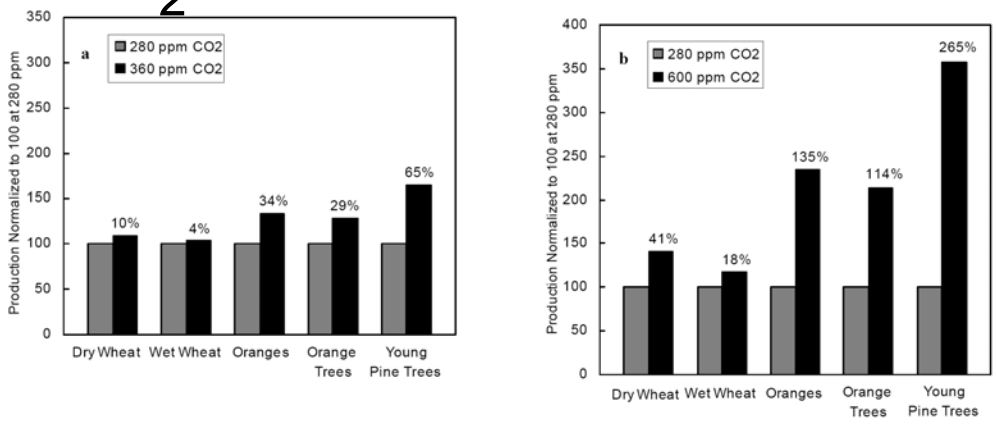


Figure 5b

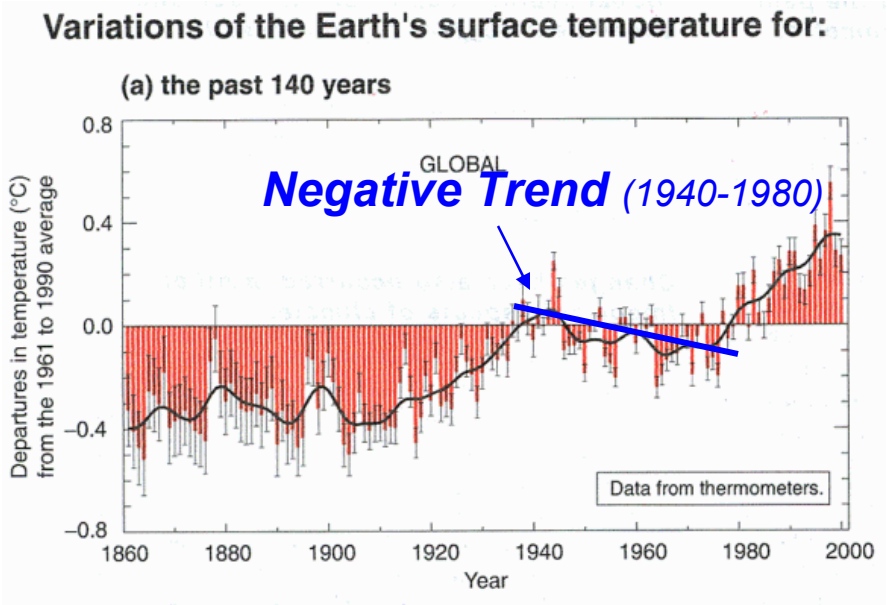


Figure 5c

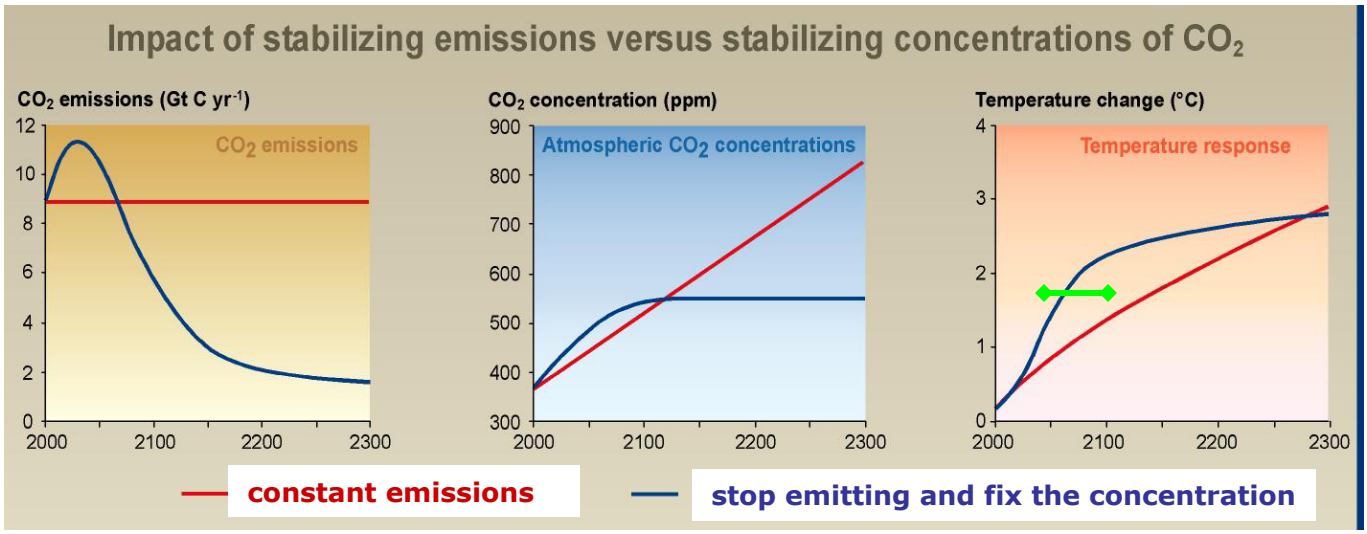
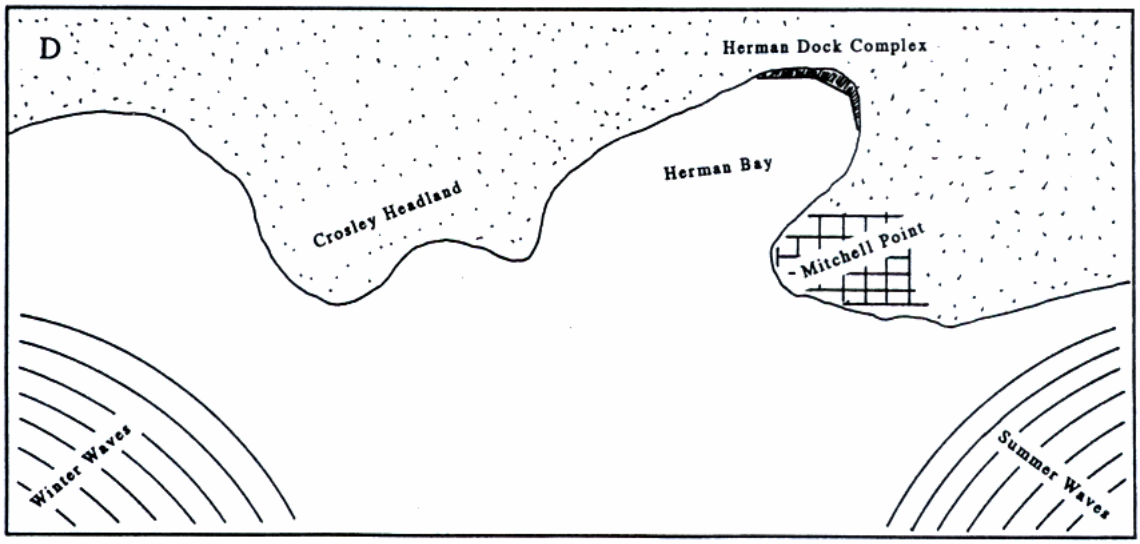


Figure 6


D
Herman Dock Complex
Herman Bay
Crosley Headland
Mitchell Point
Winter Waves
Summer Waves