

ESYS10 Final examination

Thursday, March 18, 2004

3-6 PM

I. Fill in the blank (10 points each)

1. The measure "0.001 cm of pure ozone at 1 atm. pressure" is called a _____.
2. The international agreement that was signed in 1997 in Kyoto would limit _____ if ratified. (There several possible answers.)
3. When the wind blows over the ocean in the *northern* hemisphere, the uppermost layer of the ocean moves to the _____ of the wind. This frictional layer is called the _____ layer.
4. When carbon dioxide (CO₂) dissolves in water, it reacts with the water to form _____. (name or chemical symbol or both)
5. The reaction $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_2\text{O} + \text{O}_2$ is called _____ and takes place in _____.
6. Name at least one process or mechanism that can cause sea level to rise over climate time scales: _____ .
7. The approximate cycling time of the climate fluctuation known as El Niño or ENSO is _____ years.
8. The process in which a photon causes a molecule such as O₂ to break apart is called _____.

9. Name one of the locations where the deepest waters of the ocean (below about 2000 meters depth) are formed:_____.

10. In the absence of fossil fuel burning, the main *net* source of carbon dioxide to the atmosphere is _____.

II. Short answer

1. (20 points) (a) Explain why ozone depletion is an environmental hazard.

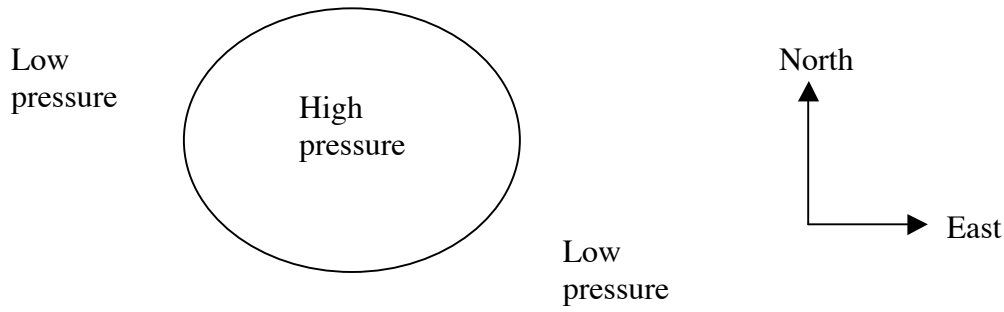
(b) Why has the ozone hole over Antarctica been much larger in the last several decades than ever before?

(c) Describe the stratospheric process that *produces* ozone.

(d) Describe the stratospheric process involving man-made chemicals that destroys ozone.

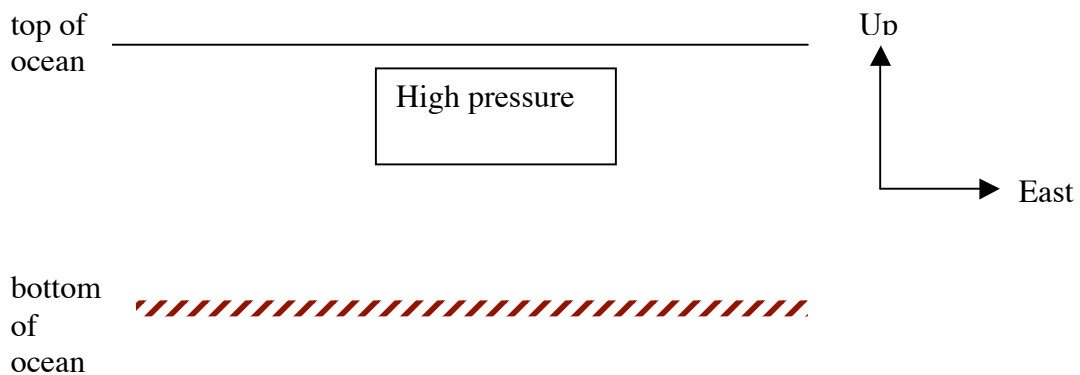
2. (10 points) The earth rotates once a day about its axis.

(a) Suppose you have a high pressure system in the atmosphere, in the northern hemisphere (sketched here). Draw the direction of the wind on the diagram, assuming that the earth's rotation has a strong impact on it.

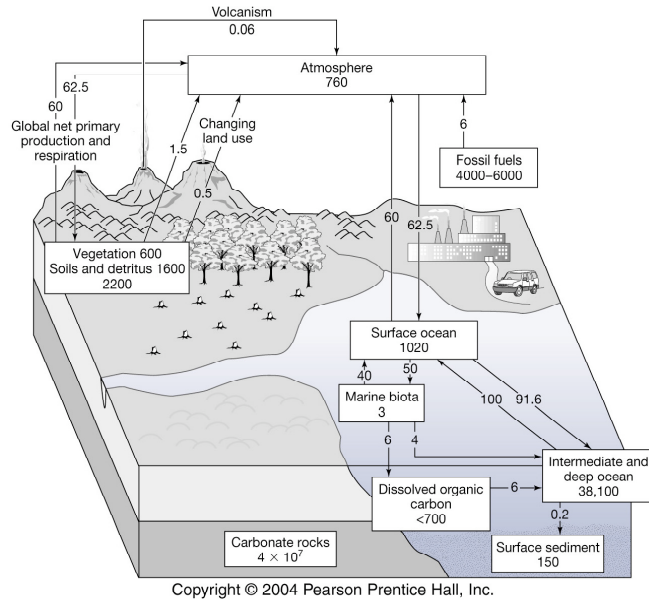


(b) What are the two forces that you must have considered in order to draw your answer in (a)?

(c) Now consider the ocean, and suppose that the high pressure system is associated with ocean currents (ignoring wind please!). Sketch the height of the sea surface across the high pressure system. (Use the straight line as a guide as a flat surface.)



3. (10 points) (a) On the accompanying diagram, circle the parts that belong to the "biological pump" described in the text and in class.



The units in the boxes are Gton(C).
The units on the arrows are Gton(C)/yr.

(b) How much carbon is in the intermediate and deep ocean reservoir? _____
Calculate the residence time of carbon in this reservoir. (You may do some simple rounding to avoid needing a calculator.)

(c) What physical process connects the intermediate and deep ocean carbon back up to the surface ocean?

4. (10 points) If the earth system were in equilibrium, the forests would be a very small sink for atmospheric CO₂.

(a) Explain how deforestation increases the amount of CO₂ in the atmosphere at a rate that is larger than this very small sink.

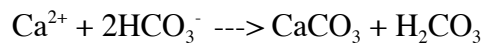
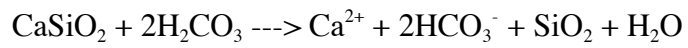
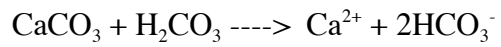
(b) As cleared land becomes forest again (as is happening in the eastern U. S., the growing forest is a larger sink for atmospheric CO₂ than is an equilibrium (old growth) forest. Why?

5. (20 points) Silicate and carbonate weathering have different impacts on the total amount of carbon in the atmosphere and liquid ocean (ignoring sediments).

(a) Explain how weathering removes CO₂ from the atmosphere in both cases.

(b) Explain how carbon is removed entirely from the ocean/atmosphere system.

(c) For these reactions, indicate *where* each one occurs and *what process* is involved:



(d) Why would carbonate weathering result in no net loss of carbon from the combined atmosphere/ocean, while silicate weathering causes a net loss?

III. Essay (40 points).

The following appeared in an editorial in the Philadelphia Inquirer on March 15, 2004. (Opinion paragraphs at start and finish are deleted.)

Make global warming an issue

Walter Cronkite

(material deleted)...First, the administration claimed that global warming was the work of liberal hysterics and had been discounted by "more sober scientists." Then, it admitted that it was happening but said there was no proof humans caused it, or could fix it.

Retreat No. 3 was the White House discovery that, yes, indeed, some of the warming was due to human activity, and we should take steps, say, to reduce emissions, but those steps should be voluntary on the part of industry.

There are two scientific theories that have been gaining credence in recent years that challenge the sanity of that kind of resistance to fact - and make no mistake about it, global warming is a fact.

Both theories begin with a phenomenon that is taking place right now. Scientists are beginning to understand climate as a complex interactive system that is affected by everything from the emission of greenhouse gases, to deforestation, to the condition of Arctic and Antarctic glaciers.

It is a system with a feedback mechanism. For example, higher temperatures lead to the melting of sea ice, which exposes more water to the sun. The water absorbs more solar energy, which accelerates global warming, and so on. Scientists fear that such feedbacks might produce a self-sustaining and accelerating warming that is beyond human control.

The second theory goes by the name of Abrupt Climate Change. It suggests that catastrophic results of global warming might not occur gradually, as most have expected, but quite suddenly - within a few years. This theory also starts with the melting of glaciers and sea ice, but involves the dilution of seawater's salinity - or salt content - that results. That salt content is a key element in an ocean current that takes heat from the tropics northward and cold water southward and in the process moderates temperatures in the Eastern United States and much of Europe.

The collapse of this so-called conveyor could, in the worst case, produce a new ice age. The best case would give us severe winters, increasingly violent storms, flooding, drought and high winds around the globe, disrupting food production and energy supplies and raising sea levels high enough to flood coastal cities and make them unlivable.

These are not predictions but real possibilities - far more possible today than scientists had previously believed. And while the politicians in the White House continue to stick their heads in the sand, some at the Pentagon have taken on the task of studying the national- security implications of Abrupt Climate Change.

What they came up with was a world whose "carrying capacity" - the number of people the globe can sustain - is being progressively lowered, a world where war becomes the rule, not the exception, and where wars are no longer fought for ideological, religious, or geopolitical reasons - but for resources and survival. This unclassified

Pentagon study, completed last fall, has been released to several news organizations and was highlighted in the Feb. 9 edition of Fortune magazine.".... (material deleted)

Write an essay analyzing Cronkite's arguments. Include in your essay at least the following:

- (1) a discussion of how greenhouse gas increases cause warming;
- (2) the evidence that climate is now changing in response to greenhouse gas changes;
- (3) a quantitative description of how much the planet is predicted to warm in response to current forcing, if the forcing continues unabated;
- (4) your interpretation of the second scenario (Abrupt Climate Change) that is listed in the editorial. Explain especially how the ocean is involved in this second scenario, based on your knowledge of the global thermohaline circulation. (We did not discuss this type of climate change in class. Cronkite's description here is of a world very different from the general global warming scenario that we did discuss, based on IPCC.)
- (5) What action on the part of the government is Cronkite probably urging? Why does it make a difference if the U.S. government responds?