SIO 40 Fall 2007 Homework 7 **Due Nov 30th**

This homework covers materials presented in lectures 20 and 21 as well as the accompanying reading assignments for those lectures (see syllabus). These are primarily short answer questions. In most cases, a few sentences should suffice. Please try to answer all questions in the space provided, use the back of the page if you have to. Be careful to answer each part of multi-part questions. **Note:** Homeworks will be graded on the basis of a *random subset* of these questions – so your best strategy will be to answer all the questions to the best of your ability.

1) Explain how human activities are "speeding up" the global carbon cycle.

Humans speed up the carbon cycle by extracting fossil fuels from the lithosphere and burning biomass, extracting carbon from these reservoirs and adding it as CO_2 to the atmosphere at rates that are greatly accelerated relative to natural processes. The consequences for climate are likely to involve global increases in surface temperatures and associated effects, because CO_2 is a greenhouse gas.

2) How does the amount of CO_2 produced by fossil fuel consumption compare to the natural flux of CO_2 in the carbon cycle?

The amount of CO_2 added to the atmosphere by fossil fuel combustion (about 6 Gigatons/yr) is only about $1/10^{th}$ the size of the annual natural flux of CO_2 between the atmosphere and the terrestrial biosphere, or between the atmosphere and the ocean (each 60-90 Gt/yr). However, the flux of CO_2 from fossil fuel burning has a disproportionately large effect on the atmosphere because this flux is not balanced by uptake of CO_2 into other reservoirs.

3) What are the major processes that can remove CO_2 from the atmosphere, and what are the approximate time scales for these processes to be effective?

CO_2 uptake processes that involve photosynthetic conversion of CO_2 into biomass include reforestation of the northern hemisphere and increased terrestrial biomass due to CO_2 and nitrogen fertilization – both of these processes are operable on decadal to century timescales. CO_2 can also dissolve into the upper ocean on a decadal timescale, but it will take more than 1,000 years to equilibrate with the deep ocean. Dissolution of carbonate sediments on the seafloor can also be a sink for CO_2, but only over thousands of years. Weathering continental rocks also removes CO_2 from the atmosphere, but this will take millions of years to affect atmospheric CO_2.

4) What is the net effect of anthropogenic aerosol production on climate (ie. heating or cooling?), and is this effect uniform over both hemispheres?

In the IPCC's 4^{th} Climate Assessment report, certainty about the effects of anthropogenic aerosols has improved. It is now virtually certain that anthropogenic aerosols have a net cooling influence on climate and that this effect is greatest in the northern hemisphere, where most sources of anthropogenic aerosols are located.

5) Why does the ocean have a limited capacity for CO_2 uptake?

The capacity of the ocean for taking up CO_2 is limited by several factors: 1) The carbonate ion, CO_3^{2-}, which reacts with CO_2 to result in conversion of both CO_2 and CO_3^{2-} to bicarbonate (HCO_3^-), can eventually be depleted by continued oceanic uptake of anthropogenic CO_2, which would reduce the ocean's buffering and uptake capacity. 2) The ocean is getting progressively warmer as a consequence of global warming. The increased temperature (of the surface ocean, in particular) both reduces the solubility of CO_2 and increases the stratification of ocean waters, making it more difficult to mix the surface and deep ocean. Both the solubility and mixing factors will tend to reduce the ocean's capacity for CO_2 uptake.

6) What greenhouse gases other than CO_2 have human activities added to the atmosphere? (name at least two, and discuss sources)

Methane (CH_4) – sources primarily agricultural, including ruminants and rice paddies.

Nitrous oxide (N+O) – source mostly from use of nitrogen-containing fertilizer, agricultural soil management and automobile emissions

CFC's – source a variety of industrial applications, including aerosol propellants, coolants, solvent cleaning, etc.

7) Why is sea level rising? (Name at least two contributing factors, and be as specific as you can.)

The two main factors in global sea level rise include the melting of continental ice sheets (eg. Greenland and Antarctica) as well as the thermal expansion of warming seawater. Differences in the regional rate of sea level rise may also be related to the rate and pattern of continental rebound from the most recent glaciation (eg. the northern part of the North American continent is still rising as it rebounds from the weight of the glaciers).

8) In what way(s) has the observed melting of ice shelves and glaciers in Antarctica and Greenland caught scientists by surprise?

The most surprising thing has been the speed with which some glaciers in Greenland and West Antarctica appear to be melting, which was not predicted by climate models. It seems that when floating ice shelves break off, the glaciers formerly behind the shelves begin to move (and melt) much faster. This may be due to poorly undersood factors such as the melt-water lubrication of the glacier/continent interface.

9) What terrestrial, coastal and oceanic ecosystems are thought to be most vulnerable to the effects of climate change?

Terrestrial systems in the high northern latitudes (tundra, boreal forest) are especially vulnerable to increasing temperatures, as are mountain ecosystems. Mediterranean climates may experience increased drought. Coastal ecosystems like mangroves and salt marshes are vulnerable to flooding. In the ocean, coral reefs are under threat from a variety of factors, and polar ecosystems that depend on sea ice are also vulnerable.

10) The polar regions and Africa are regions predicted to be especially vulnerable to the effects of climate change. Why is this?

In polar regions, particularly in the Northern hemisphere, the temperature increase due to global warming is predicted to be significantly greater than the global average. This will make climate change effects in those regions more severe. Africa faces problems particularly due to projected drought and higher temperatures, but also because the population is already poor with limited resources, so their capacity to adapt to climate change is limited.

11) How did the Kyoto Protocol create a market in carbon trading, and what is meant by the term "cap and trade" when applied to carbon emissions?

Kyoto created a market in carbon trading by adopting a cap and trade policy to reduce emissions. In this scheme, a cap or limit is place on the amount of carbon that can be emitted. Countries/industries that emit carbon are given credits or allowances to emit a specific amount. The total amount of credits cannot exceed the cap, limiting emissions to that level. Countries/industries that pollute beyond their allowances trade for credits from those who pollute less. Carbon trading is now a growing business, on the level of nations, corporations, and even individuals.

12) What are the main conclusions of the recent Review of the Economics of Climate Change by Sir Nicholas Stern?

Main points:

Doing nothing about climate change will cost between 5 and 20% of global GDP, depending on how bad the damages related to climate change will be. Acting now to reduce greenhouse gas emissions and curb global warming will cost as little as 1% GDP. Based on Stern's analysis, early action on climate change is warranted and worth the cost. The report also outlines a variety of specific suggestions to approach the problem.