Tuesday, November 6th….

Announcements….
• Homework 7 - due today
• Homework 8 - paper 2 topics, questions and sources due Tuesday, Nov. 13
• Midterm Paper 2 - due Tuesday, Nov. 20
For next week…Homework 8

- Choose a paper topic (if it is not from the list, please check with me first)

- List 3 questions you plan to address.

- State at least one example that you will focus on (e.g. a lake that has been affected by acid rain, a carbon sequestration demonstration project, a particular carbon tax proposal, a further judgement that has cited Mass. vs. EPA, or how Japan plans to meet its Kyoto obligations)

- List 5 sources for your paper. For a website this should include (in addition to the URL) what the site is and what sort of information is found there.
10) **Carbon Tax:** What is a carbon tax? How is one implemented? What is the political history of carbon tax proposals in the U.S.? Are there currently supporters of a carbon tax? What are its advantages/disadvantages relative to a "cap and trade" system?

11) **Kyoto Protocol:** What is it? What nations are participating? What mechanisms does it mandate for reducing CO$_2$ and other greenhouse gases? Why doesn’t the U.S. participate? Why have other industrialized nations chosen to participate? What happens next?

12) **Energy/Climate Change and the 2008 elections:** What are the positions of the candidates? Which candidates seem to take the issues most seriously and have the most realistic positions from your point of view? What are their records to date? Why do some candidates choose to talk about climate change while others don’t? Has this topic come up in the debates to date? (This topic runs the risk of too many vague statements. Give examples?)
In class assignment…..

1. Which topic do you find most interesting or important and why?

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Earth’s temperature is rising…

According to the IPCC, the Earth has warmed by approximately 0.74°C = 1.3°F over the past century.

Figure produced by Global Warming Art
www.globalwarmingart.com
In El Nino events, energy flows from the Pacific ocean into the atmosphere, leading to a net warming. In La Nina events this energy flow is reversed, leading to a net cooling.
Receding glaciers provide a dramatic view of the effects of global warming.

This picture shows Boulder Glacier on Mount Baker in the North Cascades of Washington State in August 2003.

Photograph and outline by Mauri S. Pelto, Director of the North Cascade Glacier Climate Project [http://www.nichols.edu/departments/glacier/](http://www.nichols.edu/departments/glacier/)
We are asking the question, what anthropogenic and natural causes are driving global warming and other aspects of climate change……

The IPCC summarizes the effects of both anthropogenic and natural causes of global warming in terms of **radiative forcing** (RF for short).

Radiative forcing indicates how a given phenomena effects the energy balance between incoming and outgoing radiation.

RF’s can be positive or negative.

We can think of a positive RF as being like extra sunlight shining down on the Earth surface. In order to keep its energy balance, the Earth heats up.

A negative RF tends to cool Earth’s surface.

RF numbers allow us to compare the relative strengths of different man-made and natural causes.
There are many contributions to consider...

In the upper atmosphere, Ozone absorbs UV radiation from the Sun providing a negative radiative forcing. In the lower atmosphere it acts as a greenhouse gas, absorbing outgoing IR radiation.

Various anthropogenic effects on Earth’s albedo yield both positive and negative radiative forcings.

Changes in the Sun’s radiance
Greenhouse gas radiative forcing (IPCC)….

- CO₂ is the most important anthropogenic greenhouse gas.
- Atmospheric CO₂ has increased from 280 ppm in pre-industrial times to 379 ppm today.
- From ice cores, it is determined that over the past 650,000 years CO₂ levels have varied over the range 180 to 300 ppm.
- Burning fossil fuels is the main source of CO₂ increase, with changing land use (i.e. deforestation) making a significant, but smaller contribution.
- Fossil fuel emissions were 7.2 GtC/year over the period 2000-2005.

The 2007 IPCC report states, “Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture.”

1 GtC/year = 10⁹ tons of carbon emitted per year. Using the factor 44/12 = 3.67, this corresponds to 3.67 GtCO₂/year.
The “Keeling Curve” is named for Charles David Keeling of the Scripps Institution of Oceanography, who was the first person to make frequent regular measurements of the atmospheric carbon dioxide (CO₂) concentration, taking readings atop Mauna Loa in Hawaii from 1958 onwards. (wikipedia)

Hawaii was chosen as a site because it is far from major point sources of CO₂.
The annual fluctuation in carbon dioxide is caused by seasonal variations in carbon dioxide uptake by land plants. Since many more forests are concentrated in the Northern Hemisphere than the Southern Hemisphere, more carbon dioxide is removed from the atmosphere during Northern Hemisphere summer than during Southern Hemisphere summer. This cycle is sometimes referred to as the "breathing" of the Earth. (wikipedia)
This figure shows the variations in concentration of carbon dioxide (CO₂) in the atmosphere during the last 400 thousand years as measured from ice cores. Throughout most of the record, the large changes can be related to glacial/interglacial cycles within the current ice age.
The ice age cycles are believed to come from a number of oscillating factors in Earth’s orbit:

- eccentricity (how elliptic, 100,000yr)
- tilt (41,000yr)
- precession (23,000-19,000yr)

These are known as Milankovitch cycles.
Milankovitch cycles determine the character of the seasons, which depends on the relative distribution of sunlight between the hemispheres over the year.

New ice forms when summers are cooler and winters are less severe.

This can happen, e.g.

- if the tilt of Earth’s axis gets smaller
- if Earth is furthest from the sun in the summer (for a given hemisphere)

The basic reason for the seasons is the tilt of Earth’s axis. The direction of the tilt stays (almost fixed) over the year.

When Earth’s axis points towards the Sun, the Northern Hemisphere gets more than 1/2 the sunlight and it is summer in the north (& winter in the South).