Notes About Climate Change

Reliable web resources concerning climate change

- Global Climate Change, NASA's Eyes on the Earth: http://climate.nasa.gov
- NASA's list of key websites: http://climate.nasa.gov/keyWebsites/
- NOAA climate research website: http://www.research.noaa.gov/climate/
- NOAA National Climatic Data Center: http://www.ncdc.noaa.gov/monitoring-references/faq/
- Intergovernmental Panel on Climate Change: http://www.ipcc.ch

Climate questions

- What is climate, and how is it different from weather?
  - The difference is the time scale of observation. Weather involves a short time scale, and climate involves a long time scale.

What are the components of Earth's systems that are important to climate? Some important components include:

- Atmospheric chemistry
- Ocean circulation (conveyor belt)
- Interactions of the atmosphere with solar radiation
- Interactions between the atmosphere and energy radiated from Earth
- Fires on Earth
- Variation in snow cover
- Volcanoes
- Variation in permafrost coverage
- Agriculture
- Deforestation
- Interactions between ocean and atmosphere
- Interactions between land and atmosphere
- Changes in Earth albedo
- Burning of fossil fuels
- Temperature of the oceans
- Variation in cloud cover
- Aerosols in the atmosphere
- Distribution of continents and oceans
- Greenhouse gas concentrations in the atmosphere

Composition of the atmosphere

- 78.084% nitrogen
- 20.946% oxygen
- 0.934% argon
- 0.0395% carbon dioxide
- 0.036% everything else: neon, helium, methane, krypton, hydrogen

Greenhouse gasses include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)

The atmosphere is transparent to sunlight in the visible range. Some of the solar radiation that reaches Earth's surface is re-radiated back at longer (infrared) wavelengths, and the atmosphere is less transparent to those wavelengths

Some of the longer-wavelength radiation emitted by Earth is absorbed by greenhouse gasses, trapping heat in the atmosphere and making Earth's surface warmer than it would otherwise be, by ~33°C

Astronomical causes of climate variation, pioneered by John Kroll and Milutin Milanković

- 22,000 year cycle, precession of the equinoxes -- Earth's elliptical orbit rotates slowly, such that Earth is closest to the Sun around December 21 today but on June 21 in 11,000 years.
- 100,000 year cycle, eccentricity (variation in shape) of Earth's elliptical orbit
- 41,000 year cycle, variation in the tilt of Earth's spin axis
- 22,000 year cycle, variation in the Sun's radiant output
- 11 year cycle, sunspots
- Possible variation in circulation of Earth's liquid iron outer core, leading to variations in the radiation belts that help protect Earth from solar radiation

Some records of climate change

- Crop records, including harvest dates
- Records of disease and famine
- Ship logs of temperature: sea surface, air
- Oxygen isotope ratios from datable shells
- Extent of mountain glaciers
- Extent of sea ice around Iceland
- Tree-ring data
- Ice records of harbors, lakes, rivers
- Microfossils from ocean sediment cores
- Ice cores from glaciers and ice sheets
- Extent of sea ice at north pole
- Pollen, dust, ash, gas (CO_2, CH_4, etc.) and oxygen-isotope data from ice cores

Small changes in sea level can result in large changes in the coastline. Sea level was about 120 m lower at the height of the Neogene ice age (within the last ~3 Myr) than it is today. Sea level can rise by ~80 m if it becomes warm enough so that all of the ice on continental crust melts. Sea level rises as water temperature increases, due to thermal expansion. Sea level rises of just a few feet can lead to serious problems for many coastal cities worldwide. See http://www.geosociety.org/news/pr/12-82.htm and http://www.ecu.edu/renci/Focus/SeaLevelRise.html

Ice and sea-sediment cores detail four cycles of slow cooling followed by very rapid warming (total range ~10°C) during the past ~400,000 years. The oldest *Homo sapiens* fossils are ~200,000 years old, so these cycles are not human-driven.

The time series showing variations in temperature, CO_2 concentration, CH_4 concentration and oxygen isotope ratios show that all of these factors have a very similar (correlated) pattern of variation. When greenhouse gasses CO_2, CH_4 and N_2O increase, temperature increases.

Increase in temperature results in lower O^{18}/O^{16} isotopic ratios; cooling results in higher ratios. We can measure oxygen isotope ratios preserved in several types of datable materials, and so we can get a good feel for the variation in temperature over time.

Temperature/climate variation over time is an intrinsic part of Earth's systems.

Humans' ability to potentially moderate the climate began with the onset of agriculture, on the order of 10,000 years ago. Animals were domesticated, forests were cut, crops were planted, surface drainage was changed for irrigation, fire was controlled and used extensively for a variety of purposes, static communities were built.

Since the industrial revolution in the mid-1800s, industrial air pollution has increased over previous levels. This is evident in the increasing level of CO_2 in the atmosphere. The current level of CO_2 in the atmosphere is greater than the level at any time in the last 650,000 years. Air samples collected at the Mauna Loa Observatory on Hawaii since the mid-1950s and at the South Pole since the 1970s document a steady rise in CO_2 in the atmosphere. Methane and nitrous oxide in the atmosphere have also increased since the mid-1800s.

Mean global temperature has increased since the late 1800s, and the rate of increase has also increased over that time interval.

Mean global sea level has increased by about a quarter of a meter since the mid-1800s, and the rate of increase has also increased over that time interval to a current rate of just under 1/3 meter per century.

With knowledge, we have the power to take reasonable, responsible and effective steps to mitigate human-induced global warming. We also have a moral responsibility to work toward leaving a healthy world for our children's grandchildren to inhabit.