Chapter 16: Climate Change

The Earth's Changing Climate
Possible Causes of Climate Change
Global Warming
The Recent Warming
Future Warming

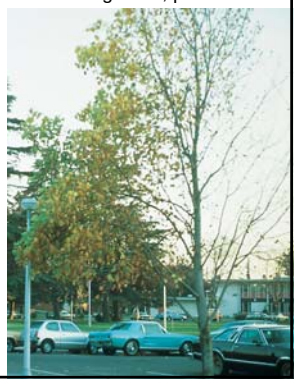
Climate and averaging

- Climate: average weather
- National Weather Service climatological "normals": average over most recent 3 decades; currently 1971-2000. See http://lwf.ncdc.noaa.gov/oa/climate/normals/usnormals.html
- Averaging period is arbitrary, though.
- For various studies, averaging period can be as short as a few weeks or as long as hundreds of years
- No matter what the averaging period, climate is always changing with time.

Scales of Changing Climate

- Not only does climate change on all time scales.
- Climate changes can be due to very local effects such as street light in fig. 16.1 and urbanization in general, to continental scale (continental drift), and planetary (orbital fluctuations).
- More on each of these later.

Fig. 16.1, p. 432



Determining past climate

- Recent climate: direct measurements (over 100 years for major cities in US, nearly 200 years for Europe).
- For historical era: written reports of freeze dates, floods, etc. Chinese records go back several thousand years.
- Supplemented by: tree rings, identification of plants from seeds and pollen found in various layers
- Oxygen isotope ratios in coral, etc.
- Geological record (dry lake beds, fossils, etc.)
- Climate simulation programs can check consistency of observations and estimate climate in places where observations are sparse.

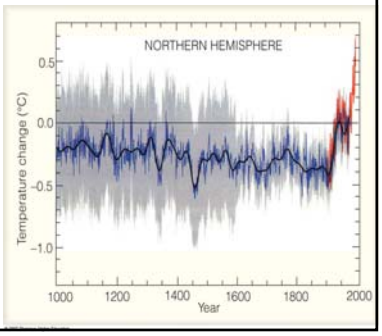
Ice Ages (pp. 432-433, 435)

- Ice age: glaciers cover significant area of Earth.
- We are currently in a minor ice age, with glaciers covering about 10% of Earth's surface. If all glaciers were to melt, sea level would rise by about 200 feet.
- Warming a few degrees C: sea levels up by ~1/2 m
- Sea level rising in some places (ice melting) and dropping in others (land rebounding from weight of past ice now gone that compressed it)
- Most recent major ice age: ~18,000 years ago, when sea level may have been ~400 feet lower, opening Bering land bridge between Asia and North America
- Precise no. of earlier ice ages is hard to say. Advance of new glaciers "erases" evidence of earlier glaciers.

Climate During Past 1000 years (p. 437)

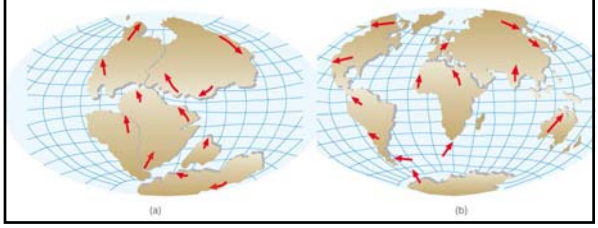
- Moderate during 1000-1400 AD
- Cooler between ~1400 and 1900 AD (Viking colony in Greenland perished)
- Definite warming since 1900

Fig. 16.6, p. 437: N Hem temp



Causes of Climate Change: Plate Tectonics (p. 439-441)

- Continental drift proposed by Alfred Wegener, who also proposed ice crystal process (p. 171)
- Fig. 16.8 (p. 440) shows estimated land distribution 180 million years ago and now



Orbital Fluctuations

- Serbian geophysicist Milutin Milankovitch (1879-1958) developed earlier ideas from self-educated Scotsman James Croll (1821-1890) that variations in the Earth's orbit could explain climate fluctuations.
- Orbital variations include:
  - Orbital eccentricity (how round the orbit is)
  - Wobbling of the Earth's axis
  - Changes in tilt of the Earth's axis
- These explain many fluctuations on time scales of 10s to 100s of thousands of years.

Particles in the Air (pp. 443-446)

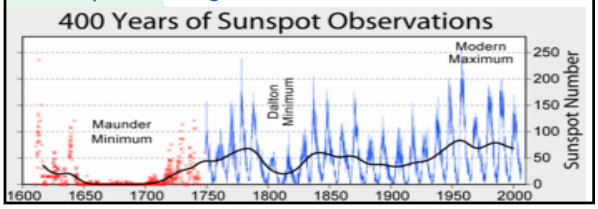
- Particles from wind-blown dust, fires, chemical reactions, etc. get in tropospheric air
- Dust from volcanic eruptions & asteroid impact can enter stratosphere
- These particles affect Earth's radiation budget (how much visible light is reflected or absorbed & how much infrared from surface is absorbed)
- Volcanoes & asteroid impact are the 2 leading contenders for what killed dinosaurs (& 70% of all species on Earth at the same time)

Particles in the Air (continued)

- Volcanic dust from major 19th & 20th century eruptions has been tied to cooling of up to ½°C for 1-3 years after eruption.
- 1816, "Year without a summer," followed huge eruption of Mt. Tambora in Indonesia in 1815.
- June 1991 eruption of Mt. Pinatubo in Philippines cooled global temperature by 1°C in 1 yr
- Large nuclear war would probably put great amount of dust into the air, causing "nuclear winter," killing millions or more (p. 444).

Variation in Solar Output (p. 446)

- Satellite measurement of solar output only since 1980's, but sun spots counted since Galileo observed them in 1612.
- Number of sunspots goes up and down with an 11-year cycle. Sunspot cycle does not repeat exactly. Numbers vary over time. E.g., few sunspots during 1650-1700: Maunder minimum



Variation in Solar Output (continued)

- At time of sunspot maximum, sun emits about 0.1% more energy, which is so small that it was undetectable before satellite measurements.
- Variation in solar output may account for some climate fluctuations on time scales of decades to centuries.
- See http://en.wikipedia.org/wiki/Solar_variation which is the source for the sunspot graph on the preceding slide.

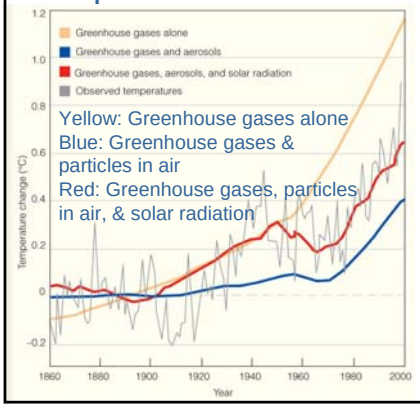
Global Warming (pp. 447-456)

- In last 100 years, global surface temperature is up by 0.6°C (about 1°F).
- How much of this is natural variability, and how much is caused by people? Most likely impact from adding greenhouse gases like CO_2.
- Computer climate models of the atmosphere and oceans are main tools for assessing impacts of concentration of greenhouse gases.
- As a starting point, models are checked by seeing how well they reproduce the present climate.

Carbon Dioxide & Other Greenhouse Gases (pp. 451-452)

- Half of CO_2 added to atmosphere stays there, with other half going into ocean
- From 1958 to 2006, CO_2 concentration in atmos has risen from 315 ppm to 380 ppm, a 20% increase. See fig. 1.5, p. 6.
- Methane increased by 150% in last 250 years, so 2.5 times as much now.
- Other greenhouse gases have also increased.

Example of model Validation: Fig. 16.17

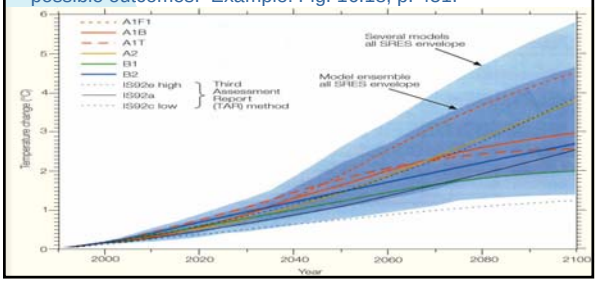


Computer simulation of surface air temperature considering various fluctuating factors

Gray line: observed temperature

Estimation of Future Climate: Ensemble Methods (pp. 451-452)

- Simulations are done with various models that include various effects based on estimates of greenhouse gas emissions. Model intercomparison suggests range of possible outcomes. Example: Fig. 16.18, p. 451.



Estimated Consequences of Global Warming (pp. 452-456)

- Probability of higher temperatures would increase; probability of lower temperatures would decrease.
- Biggest impacts over land and at high latitudes
  - Warming would melt snow, reducing reflected light
  - Increased plant growth would darken surface (increasing absorption of sunlight) & increase emission of CO_2 from the new plants.
- Last two examples are *positive feedbacks* that make an impact even greater.
- Negative feedback: response that would lessen impact. Example: Global warming could increase evaporation, which could increase clouds, which could increase amount of light reflected back to space

Estimated Consequences of Global Warming (continued)

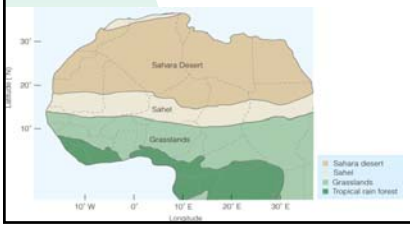
- Rise in sea level as ice on land melts
- Impacts on plants uncertain because of complexities
  - With warmer temperatures, a longer growing season, & more CO2, plants may grow faster
  - Faster growth may not as nutritious per pound
  - Uncertain how insects that eat plants will respond

Read Summary of IPCC Report (p. 454)

- IPCC = Intergovernmental Panel on Climate Change See http://www.ipcc.ch from Switzerland
- Third Assessment Report issued in 2001
- Most of warming in last 50 years due to human activities
- From 1990 to 2100, surface temperature expected to rise by 1.4 to 5.8°C.
- Amount of sea ice is decreasing
- Hurricane activity may be affected. (Research in the last couple years indicates that the overall number of hurricanes is not increasing as much as the number of category 4 and 5 hurricanes. See, for example: http://www.gatech.edu/news-room/release.php?id=898)

Drought in Sahel (p. 455)

- Sahel: strip of dry land several 100 km wide south of Saharan Desert
- Drought: started in 1968. At peak in 1973, rainfall at ½. Half of livestock and ~100,000 people died.
- Drought has persisted since then.



Global Warming, El Nino, & Australia (not in book)

- El Nino is taking place now
- Australia is going through its 3rd driest August-November on record (i.e., since 1900) and warmest spring since 1950.
- Australian wheat, barley, canola crops down 60-70%. Cattle prices down as much as 40%, sheep 80%.
- Concern: drought may be worse because of global warming. See graph of El Nino activity on p. 277.
- For example, see
  http://www.abc.net.au/worldtoday/content/2006/s1804742.htm
  http://www.iht.com/articles/2006/11/07/news/drought.php

Duration of El Niño (fig. 10.22, p. 277): ½ to 2 years long, recurring every few years