The “Ice Ages” and Global Climate

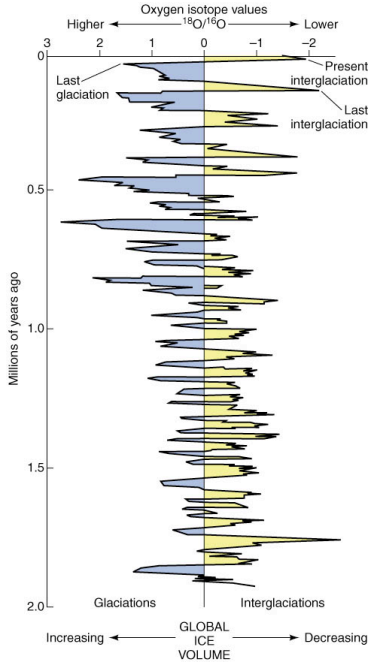
- A probable 0.6°C increase in average global temperature since the mid -nineteenth century very likely represents the initial part of this warming. The rate of warming is likely to reach 0.3°C per decade and may lead to a "super interglaciation," making Earth warmer than at any time in human history.
- Potential physical and biological consequences of global warming include global changes in precipitation and vegetation patterns; increased storminess; melting of glaciers, sea ice, and frozen ground; worldwide rise of sea level; local and regional changes in the hydrologic cycle; and increased rates of organic decomposition in soils.
- Evidence of past intervals of rapid environmental change in the geologic record and reconstructions of past warmer intervals can provide insights into physical and biological responses to global warming. Such reconstructions also permit evaluation of general circulation models.
- Viewed from the geologic perspective, the enhanced-greenhouse interval will be a brief perturbation in Earth’s climate history. On a human time scale, however, negative climate impacts can be expected to persist for many generations.
- Synthetic chlorofluorocarbon (CFC) gases entering the upper atmosphere break down and release chlorine, which destroys the protective ozone layer. Discovery of a vast and recurring ozone hole over Antarctica has led to international efforts to eliminate CFC production by the end of the century.

Summary

- Earth’s climate system involves the atmosphere, hydrosphere, lithosphere, and biosphere. Changes affecting it operate on time scales ranging from decades to millions of years.
- Using information from the geologic record, geologists can measure the magnitude and geographic extent of past climatic changes, determine the range of climate variability on different time scales, and test the accuracy of computer models that simulate past climatic conditions.
- The carbon cycle is among the most important of Earth’s biogeochemical cycles. Carbon resides in the atmosphere, the biosphere, the hydrosphere, and in the crust and cycles through these reservoirs at different rates.
- The anthropogenic extraction and burning of fossil fuels perturb the natural carbon cycle and have led to an increase in atmospheric CO_2 since the start of the Industrial Revolution.
- The increase in atmospheric trace gases (CO_2, CH_4, O_3, N_2O, and the CFCs) due to human activities is projected to warm the lower atmosphere by 2° to 4°C by the end of the next century.The greenhouse effect, caused by the trapping of long-wave infrared radiation by water vapor and trace gases in the atmosphere, makes Earth a habitable planet.

Cenozoic Glacial Age

- Over ten millions of years, the climate slowly grew cooler as Earth moved into a late Cenozoic glacial era.
- During the last few million years, the planet has experienced numerous glacial-interglacial cycles superimposed on the long term cooling trend.



- World sea level fell at least 100 m,
  - large expanses of the shallow continental shelves emerged as dry land.
    - Atlantic coast of the United States south of New York lay as much as 150 km east of its present position
    - North America and Asia formed a continuous landmass across what is now the Bering Strait
- Weight of the massive ice sheets caused Earth to subside by as much as 1 km
  - The Hudson Bay region is still rising as the lithosphere and asthenosphere adjust to the removal of this ice load

Little Ice Age

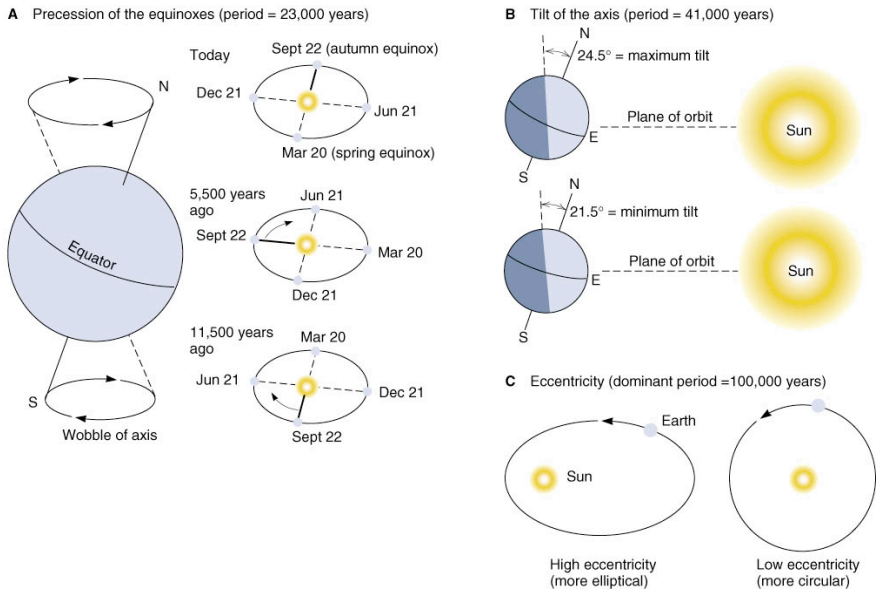
- Short-term fluctuations in average temperature can occur.
- The “Little Ice Age” was an interval of generally cool climate starting in the mid-thirteenth century and lasting until the mid-nineteenth century

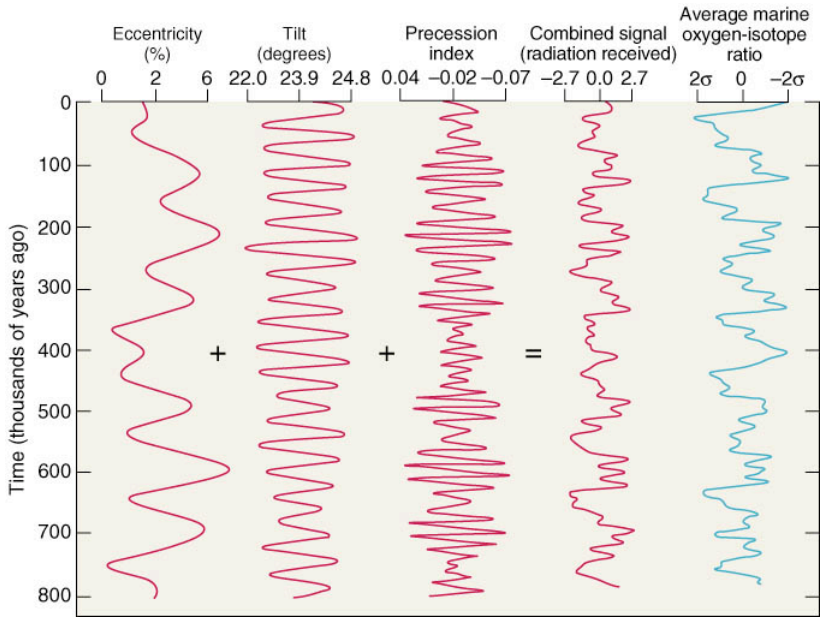
What Causes Glacial Ages?

- Shifting continents
  - The large scale uplift of continental crust where continents collide.
    - Change global atmospheric circulation
    - Change CO_2 due to change in weathering & volcanism
  - The opening or closing of ocean basins and seaways between moving landmasses.
    - Change global ocean circulation
- Astronomical changes
  - Minor variations in Earth' orbit around the sun, and in the tilt of the earth's axis, cause slight variations in the amount of radiant energy reaching any given latitude on the planet's surface.

Milutin Milankovitch's Theory

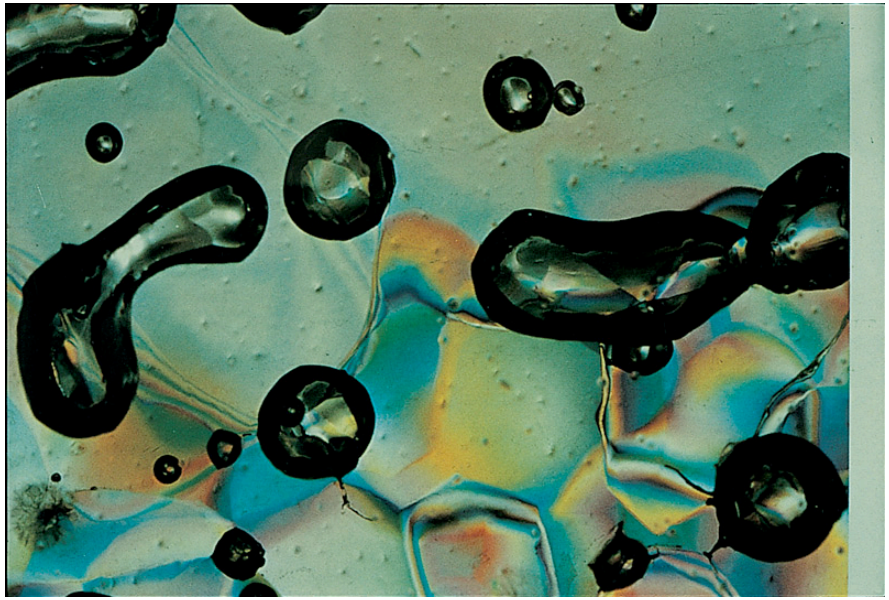
- Procession of Equinox
  - 23,000-26,000 year cycle
- Tilt of Earth's rotation axis changes
  - 41,000 year cycle
  - From 24.5^0 to 21.5° (Current 23.5° and decreasing)
- Eccentricity of the orbit changes
  - 100,000 year cycle
  - From 0 to 6% (current 3.4%)

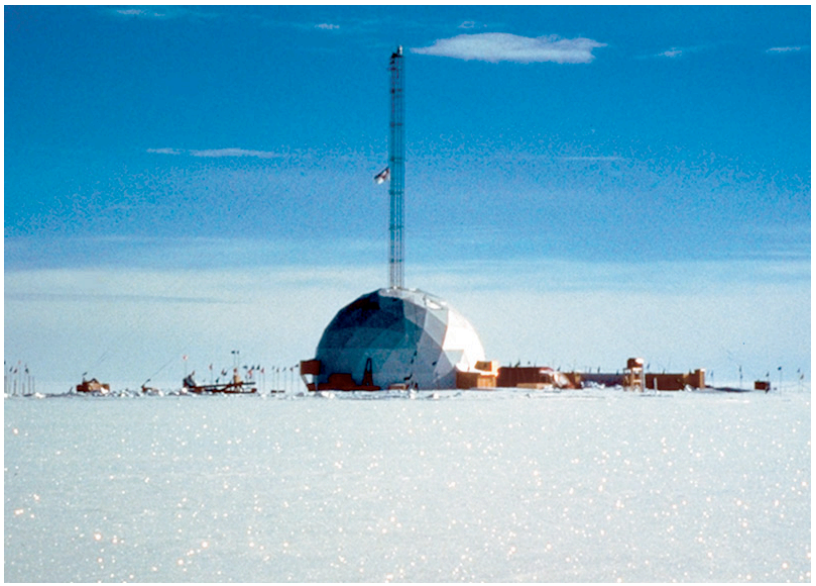


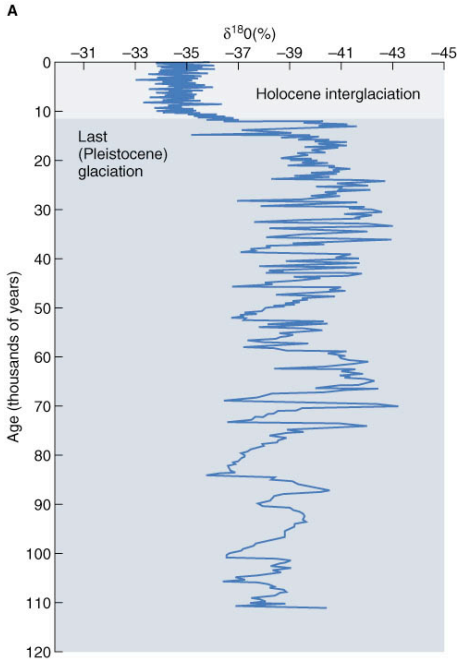


Ice Cores - Record of Past Climate

- Annual layers of snow - compacted into ice
- Layered stratigraphic section -
  - oldest at bottom, youngest at top
- Each layer with trapped air from the atmosphere at that time
  - Measure variations in CO_2 and methane
  - Measure $^{18}O/^{16}O$ ratio to determine temperature
    - Colder -> more ^{16}O in snow







What Causes Glacial Periods?

- Orbital factors
  - explain the timing of the glacial-interglacial cycles
  - The “Pacemaker”
  - BUT!! Variations in solar radiation reaching Earth’s surface are too small to explain 4-10^{0}C change
- Other possible factors:
  - Changes in atmospheric chemical composition.
  - Dustiness of the atmosphere.
  - Changes in the reflectivity of Earth’s surface.
  - Changes in ocean circulation patterns