

1. Definition: climate is defined by the mean and variance of atmospheric condition over "long" periods (typically seasons, years, or longer).
2. Typical climate parameters: annual and monthly mean temperatures, diurnal temperature range, precipitation, humidity, winds, cloud cover, ice cover, vegetation cover, CO<sub>2</sub>.
3. Variations in climate in time and space are the result of the interaction of the energy, water, carbon cycles with the biosphere and lithosphere. The distribution of biomes and other life-forms reflect regional variations in climate.
4. Changes in climate in the past 200 years are deduced from the instrumental record. Paleo climates are deduced from "proxy" data, such as tree rings, corals, pollen, ocean sediments, ice cores. These chronologies are dated using radioactive and other dating methods.
5. There are natural quasi-regular cycles of climate variation which result from "internal" redistribution of energy and water by the atmospheric and oceanic circulations. The El-Nino-Southern Oscillation (ENSO) is a east-west see-saw in pressure, temperature, winds, convection which repeats every 2-7 year.
6. Other natural quasi-regular cycles of climate variation result from "external" forcing such as changes in solar input. Glacial-interglacial cycles have periods every 20,000 years, 40,000, and 100,000 years. The timing of these cycles is related to the changes in the earth's orbit around the sun. The energy, water and carbon cycles respond to the changes in insolation and may amplify the climate change.

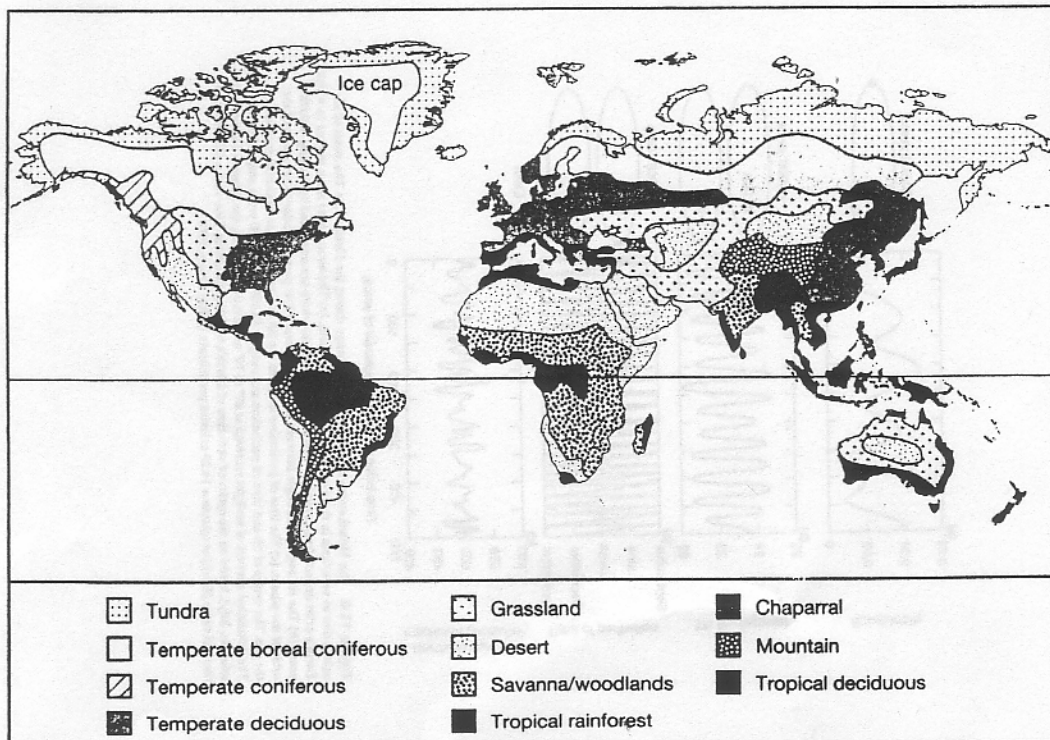


Figure 4.8 The major biomes of the terrestrial realm.

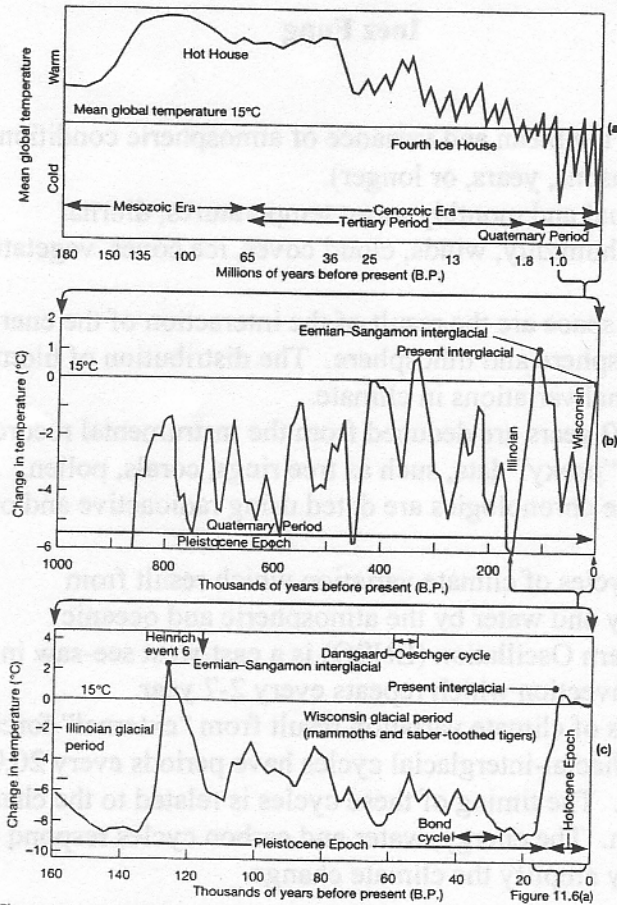


Figure 11.3 Changes in the temperature of Earth over time. (a) The temperature record of Earth during the past 180 million years; (b) an expanded representation of the last one million years; and (c) an expanded view of the last 160,000 years (After UCAR/OIES, 1991a.)

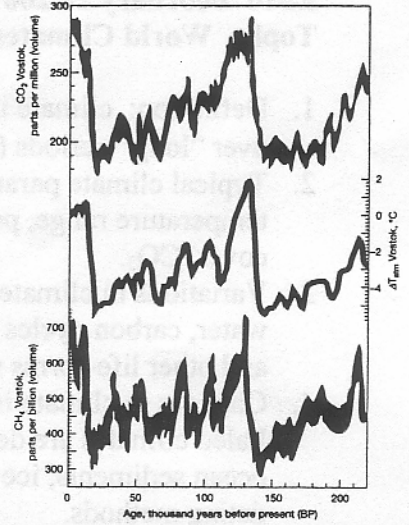


Figure 11.9 The trend of atmospheric CO<sub>2</sub>, CH<sub>4</sub>, and temperature as recorded in the Vostok, Antarctica, ice core. The atmospheric temperature at Vostok is plotted as a deviation from present-day mean temperature (ΔT<sub>atm</sub>). The different line widths represent the ranges in estimates. (After Jouzel et al., 1993.)

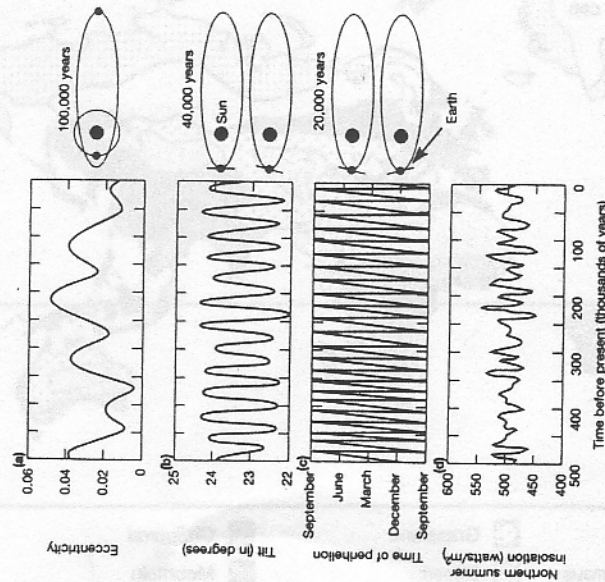


Figure 11.8 The Milankovitch theory of climatic change during the Pleistocene. The onset of ice ages is due to variations in three orbital parameters of Earth. (a) The eccentricity is the degree to which Earth's orbit departs from a circle. Times of maximum eccentricity are separated by roughly 100,000 years. (b) The tilt angle is the angle between Earth's axis and a line perpendicular to the plane of the orbit of the planet. (c) The time of perihelion involves the tilt of Earth's axis at its closest approach to the sun. The cycles of tilt and time of perihelion are roughly 40,000 and 20,000 years, respectively. (d) The calculated amount of sunlight received at 60° to 70° north latitude during the summer (summer insolation, July), based on the cycles of variation of Earth's orbital parameters. One watt = 0.0009 British thermal units (Btu) per minute = 14.28 calories per minute. (After Corey, 1964.)