Lecture 32. Introduction to climate and climate change. Part 2.

Objectives:
1. Natural climate variability and the anthropogenic climate change.
2. The global temperature record.
3. Invited talk: Prof. Brian Toon, LASP, University of Colorado.

Readings: Turco: p. 349-363.

1. Natural climate variability and the anthropogenic climate change.

Climate stability is the long-term reliability of the climate.

Climate variability is the noise in the climate system. It is the change in climate from the average or mean over a time interval of interest.

- The climate is measured by the average surface temperature of the Earth.

Factors important in natural climate variability:

(i) the distance of the sun from the Earth;

(ii) variations in the Earth's orbit;

(iii) solar constant (radiative flux from sun);

(iv) chaos.

Chaos is a term applied to describe the random behavior exhibited by a physical system such as climate system. Chaos is generated by the interactions among different elements of a coupled physical system.

- The climate system containing many variables (elements) and transformation (processes) has the enormous number of potential stable and unstable climatic states. However, in reality there are only a small number of stable climatic states known from the history of the Earth. It is not fully understood why climate system shows this high stability.

Some terminology used in the climate change studies:

Climate forcing is a change imposed on the climate system that has the potential to alter global temperature.

Examples: a change in solar radiation incident on the Earth is a natural climate forcing; change in atmospheric CO2 abundance due to fossil fuel burning is an anthropogenic forcing.

Climate response is the meteorological result of climate forcings, such as global temperature change, precipitation changes, or sea level changes.

Climate sensitivity, $\Delta T/\Delta F$, is the mean change in global temperature that occurs in response to a specified forcing.

- Climate model calculations predict an approximately linear relationship between global-mean radiative forcing, ΔF (W m^{-2}), and the equilibrium global-mean surface temperature change, ΔT_s(K)

$$\Delta T_s = \lambda \Delta F$$

where λ is the a climate sensitivity parameter (K (W m^{-2})$^{-1}$), ranging from 0.3 to 1.4 predicted by GCMs.

Feedback is a relationship between two or more components of the climate system whereby changes in one component cause changes in the other(s), which in turn affect further change in the first component. This relationship may be positive or negative.

Examples: positive feedback: snow and ice have high albedo reflecting solar radiation away from the Earth's surface, thereby cooling the surface temperature, and, hence, the reduced temperatures tend to result in more snow and ice. Negative feedback is a case when changes in the original component are damped out by its effect on the other components.

Solar variability (natural climate forcing):

Causes:

1) **solar sunspot cycle** (the number of sunspots has a cycle with a period of slightly longer than 11 years: the more sunspots there are, the greater the solar activity and the more intense the output of the sun will be);
2) **luminosity of the sun** (because the sun is a star, its luminosity experienced a long evolution);
3) **orbital perturbations of the Earth** (which cause changes in the distance from the sun; in the tilt of the axis of rotation, and in the precession of the equinoxes. The repetition periods of these characteristics are about 100000, 41000, and 22000 years, respectively (known as Milankovitch Cycles)

Volcanic eruptions (natural climate forcing):

introduce material into the stratosphere (stratospheric volcanic aerosol) that can remain in suspension for one to three years. Volcanic aerosol can reduce solar input by reflecting sunlight back to space, possibly leading to a fall in temperature.

Some anthropogenic climate forcings and their consequences:

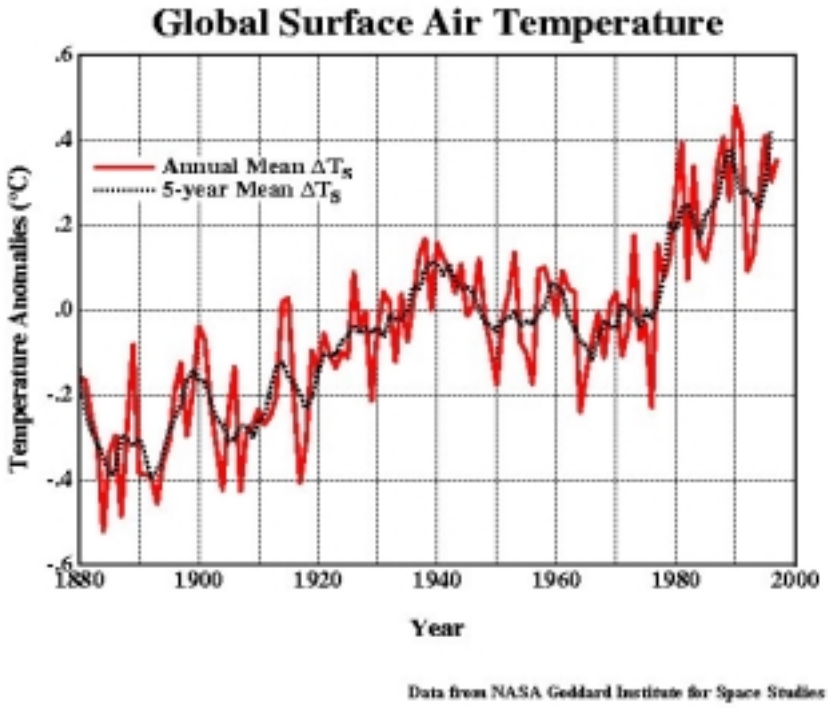
- anthropogenic greenhouse gases and global warming (discussed in Lectures 33-34);
- CFCs and ozone depletion (discussed in Lectures 35-38);
- anthropogenic aerosols and potential revival of global warming due to greenhouse gases (discussed in Lectures 39-41).

2. The global temperature record.

- Meteorological instrument records survive from as early as the 17th century, but it was not until about 1850 that the number of well-calibrated instrumental records of temperature and precipitation was adequate for statistical analysis.

Annual temperature anomaly is a term used to indicate the difference between the observed average temperature over a given year and the average temperature for some selected period (i.e., a large number of years).

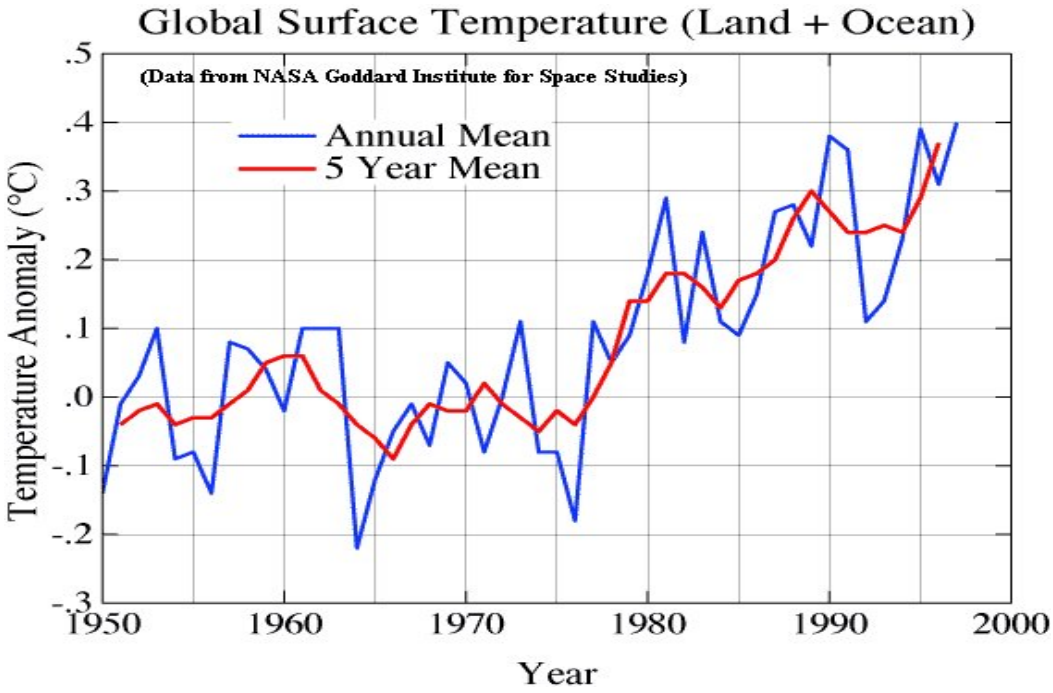
Figure 32.1 The global surface temperatures are anomalies in degrees Celsius relative to 1951 to 1980 mean.



NOTE: the record of surface temperature from 1880, reveals a warming since the late 19th century.

Figure 32.2 The temperatures are anomalies for a period 1950 to 1997.

(Anomalies from the 1951-1980 mean).



NOTE: the warmest surface temperature was in 1997!

Major focus of climate change studies:

Explain the existing warming trend in the global mean temperature.