Lecture 25

Direct and indirect climate radiative forcings.

Objectives:

1. Concept of radiative forcing.

2. Radiative forcing of aerosols and clouds vs. greenhouse gases.

Required reading:

Chapter 6 of IPCC report (be ready to discuss it in class on Dec.13)

1. Concept of radiative forcing.

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 CO_2 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 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)

$$DT_s = l\ DF$$

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

Direct radiative forcing of aerosols (or clouds) is defined as a difference between the net fluxes in 'clean' and perturbed atmospheric conditions.

$$\Delta F = F_{aer}(TOA) - F_{clean}(TOA) \qquad [25.1]$$

where

$F_{aer}(TOA)$ is the net total flux at the top of the atmosphere in the presence of aerosols (or clouds);

$F_{clean}(TOA)$ is the net total flux at the top of the 'clean' atmosphere.

Direct radiative forcing of aerosols (or clouds) can be expressed as

$$\Delta F = SWF + LWF \qquad [25.2]$$

where

SWF is the shortwave (solar) component of radiative forcing;

LWF is the longwave (thermal IR) component of radiative forcing;

$$SWF = F^{\uparrow}_{SW,clean}(TOA) - F^{\uparrow}_{SW,aer}(TOA) \qquad [25.3]$$

$$LWF = F^{\uparrow}_{LW,clean}(TOA) - F^{\uparrow}_{LW,aer}(TOA) \qquad [25.4]$$

Indirect aerosol radiative forcing of climate:

1) altering clouds:

aerosols serve as the cloud nuclei => modify the amount and properties of clouds => perturbed clouds affect the Earth's radiation balance;

2) changing atmospheric chemical composition:

aerosols affect the distribution and amount of radiatively active atmospheric gases=> affects the Earth's radiation balance

2.Radiative forcing of aerosols and clouds vs. greenhouse gases.

Key differences between aerosol forcing and GHG forcing:

- The two forcings (GHG and aerosol) have very different spatial and temporal distributions: GHG operates day and night, whether clear or cloudy, and is at a maximum in the hottest, driest places on Earth. In contrast, forcing by anthropogenic aerosols occurs mainly by day, direct aerosol forcing is strongest without clouds, and because of the relatively short residence time of aerosols, is concentrated near aerosol sources and downwind from the sources.

- Determination of GHG forcing is well-posed problem in radiative transfer (because IR absorption is well quantified for all GHG gases). Determination of direct and indirect aerosol forcings remains an unresolved problem (because of inadequacy of mathematical descriptions of aerosol and clouds).

Direct radiative forcing of aerosols:

sulfates -> always negative (leading to cooling);

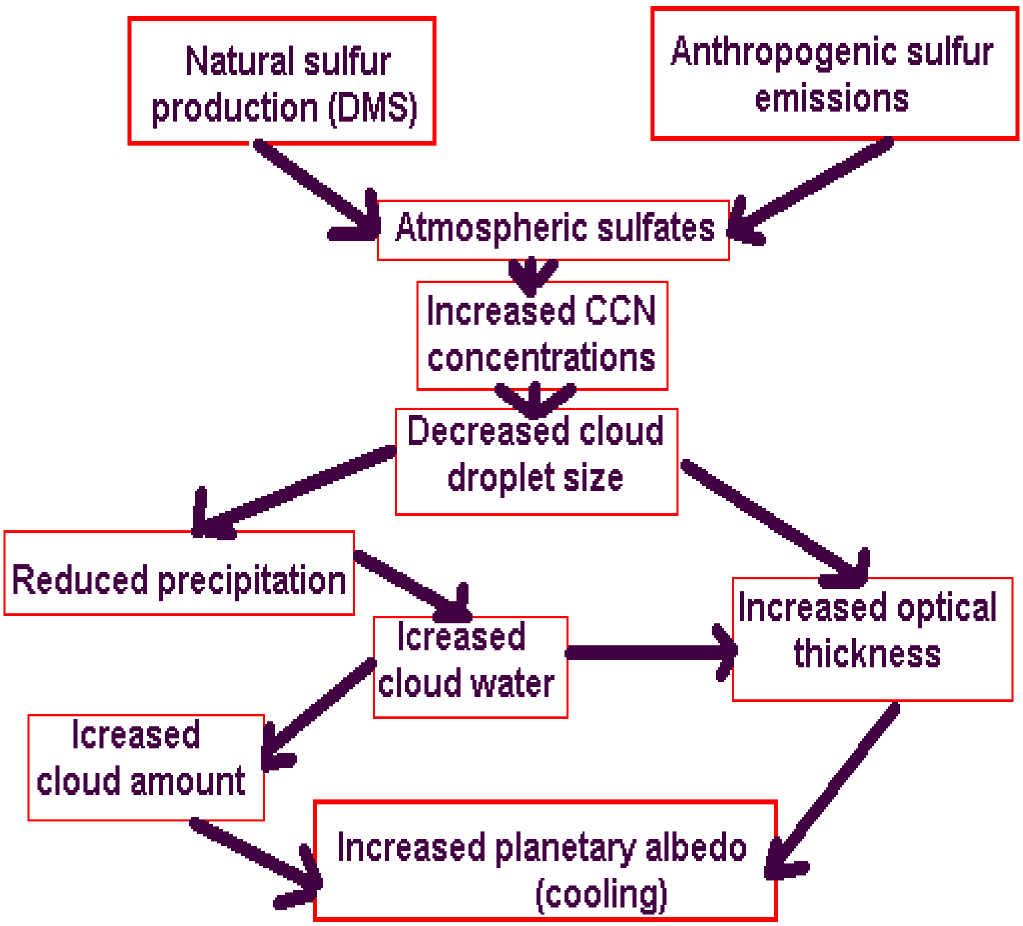
aerosol from biomass burning -> negative
(if OC is a dominant species)

mineral dust -> negative or positive ?
and carbonaceous aerosol
(if BC is a dominant species)

Indirect radiative forcing of aerosols:

via clouds -> negative

Figure 24.1 Schematic representation of the potential indirect forcing of anthropogenic and biogenic sulfur.



- Low clouds and high clouds, about 8 km above the surface have the dramatically different effects on the radiation field.

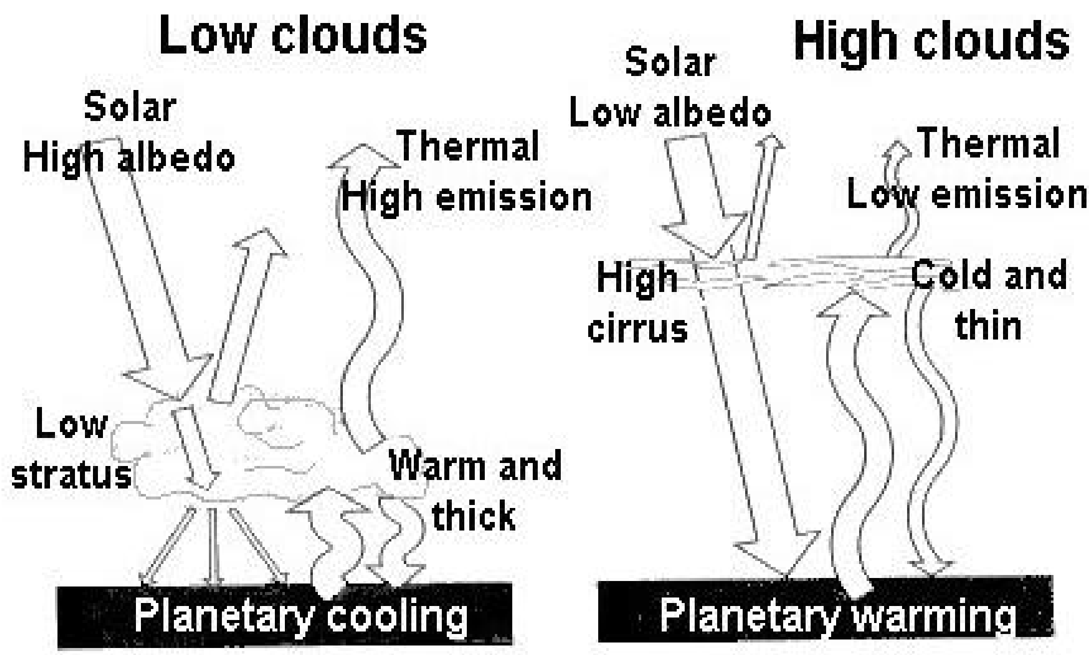


Figure 24.2 Estimated radiative forcing by various factors between 1850 and the present (Hansen et al., 1998).