Lectures 40-41. **Global change due to anthropogenic aerosols:**

Aerosol from biomass burning and mineral aerosols.

Objectives:

1. What are aerosols from biomass burning?
2. What is mineral aerosol?
3. Direct radiative forcing by aerosols from biomass burning and mineral aerosols.

Readings: Seinfeld and Pandis (1998): p. 1160-1169

1. What are aerosols from biomass burning?

Burning produces various gases and particulates. Particulates containing carbon are called **carbonaceous aerosols** (excluding carbonates).

Carbonaceous aerosols are divided into two classes:

1) **elemental carbon** (also called "black carbon" or "graphitic carbon" or "soot" or EC or BC);
2) **organic carbon** (OC)

Major difference in optical properties: carbonaceous particles comprised of organic carbon scatter but do not absorb solar radiation, while those made of black carbon strongly absorb solar radiation.

- Elemental carbon is principal light-absorbing species in the atmosphere.

Elemental carbon is emitted as a result of incomplete combustion of fossil and biomass fuels.

Organic carbon, the most abundant carbonaceous aerosol species, may be emitted directly into the atmosphere in the form of particles by combustion, or may be produced in the atmosphere as the result of gas-to-particle conversion of anthropogenic and biogenic hydrocarbons.

Example of human activities resulting in biomass burning:

- Agriculture activities: burning of agriculture wastes; burning of forests to extend agriculture land, etc.
- Cooking and heating.

- It is generally believed that the vast majority (>90%) of biomass burning is human initiated and that biomass burning has increased significantly over the last 100 years.

Table 40.1 Inventory of the yearly emissions of black carbon particles and organic matter.

Products, Tg/yr	OC, Tg mass/yr	BC, Tg C/yr
Biomass burning:		
Savannas	**15.5**	**2.17**
Tropical forests	**16.6**	**1.93**
Agriculture fires	**3.1**	**0.53**
Domestic fuels	**9.3**	**1.0**
Biomass burning total	**44.6**	**5.63**
Fossil fuel	**28.5**	**6.64**
Natural sources	**7.8**	**---**
TOTAL	**81**	**12.3**

Biomass Burning is a Driver of Global Change:

⇒ Biomass burning is a significant global source of:

- greenhouse gases, carbon dioxide and methane, that lead to global warming;
- chemically active gases, nitric oxide, carbon monoxide, and hydrocarbons, which lead to the photochemical production of tropospheric ozone and acid precipitation (nitric oxide);
- methyl bromide which leads to the photochemical destruction of stratospheric ozone;
- atmospheric aerosols which impact global climate

⇒ Other impacts of biomass burning:

- the biogeochemical cycling of nitrogen and carbon compounds from the soil to the atmosphere;
- the hydrological cycle, i.e., run off and evaporation;
- the reflectivity and emissivity of the land;
- the stability of ecosystems and ecosystem biodiversity;

Some Locations of Biomass Burning:

Tropical forests (Brazil, Indonesia, Colombia, Ivory Coast, Thailand, Laos, Nigeria, Philippines, Burma, Peru);

Temperate forests (U.S., Europe);

Boreal forests (Alaska, Canada, Siberia, China);

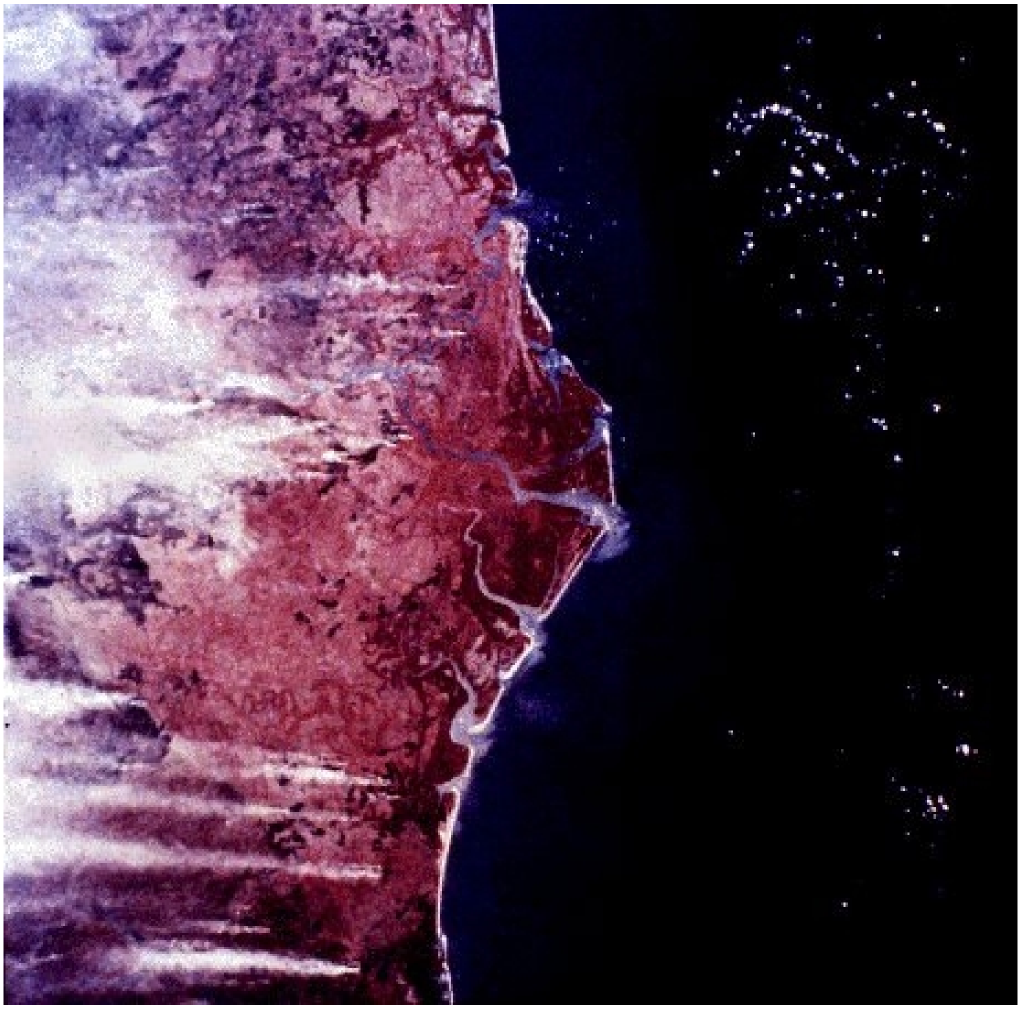
Savanna grasslands (Africa);

Agricultural wastes after the harvest (U.S., Europe, China, Africa).

- Biomass burning is a global process.

Figure 40.1 Space Shuttle photograph of burning in the tropical rainforest of Brazil. Estimates suggest that on the average, about 30 million acres of tropical rainforest in Brazil burn each year (NASA Photograph).

Figure 40.2 Space Shuttle photograph of fires in the east coast of Mozambique in southern Africa. The source of the burning in Africa is the savanna grass (NASA Photograph).



2. What is mineral aerosol?

General definition:

Mineral aerosols (or dust) mean any airborne crustal solid particles generated from any type of land surfaces.

Main definition:

Mineral aerosols (or dust) is a complex mixture of various minerals. Mineralogical composition of dust depends on dust origin, dust mobilization processes, and on dust chemical and physical transformation during transport in the atmosphere.

Major dust natural sources:

desert and semi-desert continental regions, which cover approximately 33% of the global land area

Example of human activities resulting in additional dust loading:

- various agricultural activities (such as over-cultivation of poor soils; inappropriate irrigation practices; etc.)
- deforestation;
- urbanization (e.g., building and road construction);
- mining and industry;
- off-road industry;
- tourism

UNEP (1992): Desertification rate = about 6×10^{24} km^2/yr

Importance for climate and climate change:

- Mineral aerosols can have a significant effect on the Earth's radiation budget: they are able to scatter and absorb both solar and thermal radiation.
- Mineral aerosols are important due to their global distributions and due to their large optical depth (or high column burden).
- Various human activities can result in additional dust loading (anthropogenic dust), increasing the direct radiative forcing of climate.

Importance for remote sensing applications:

- retrieval of dust radiative properties from remote sensing observations
- correct dust input in atmospheric correction algorithms

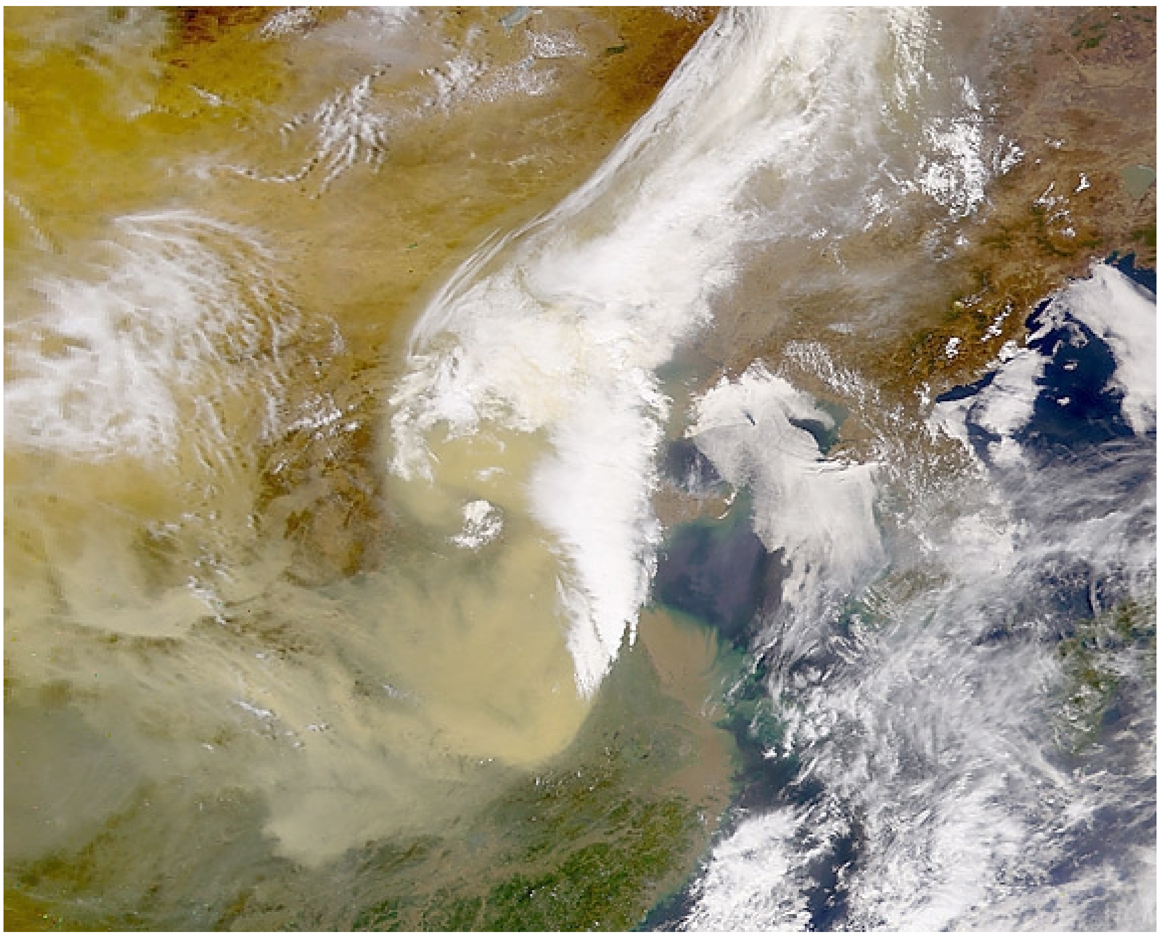
Importance for atmospheric chemistry:

- There is growing evidence that chemical reactions on airborne mineral aerosol surfaces play an important role in the tropospheric chemistry of SO_x, NO_y and O_3 [Dentener et al., JGR, 1996].

For instance, the removal of SO_2 and HNO_3 depends on the alkalinity of dust aerosols, therefore, the calcium content should be known. Hydrogen radicals like HO_2 and OH react on atmospheric particles through pathways involving redox reactions with iron, consequently the abundance of Fe^{3+} should be provided.

Need to know: size-resolved mineralogical composition of dust

Figure 40.3 SeaWiFS (Sea-viewing Wide Field-of-view Sensor) image show the development of a large dust storm in China and its interaction with a meteorological system that carried the dust far out into the Pacific Ocean. In the first image, from April 16, 1998, the bright yellowish-brown cloud near the coast is the center of the storm, being pushed by a frontal system. In the subsequent images from April 20-24, the atmospheric circulation around a low-pressure system entrains the dust from the storm and carries it over the north Pacific Ocean. On April 25, dust from this event reached the west coast of North America.



3. Direct radiative forcing by aerosols from biomass burning and mineral aerosols.

1991: Penner et al. demonstrated that smoke particles from biomass burning can cause global cooling comparable to the estimated contribution of sulfate aerosols.

1996: Sokolik and Toon, and Tegen et al. independently demonstrated that the global mean direct radiative forcing by anthropogenically generated mineral aerosol may be comparable to the forcing by sulfates and smoke from biomass burning. On a regional scale the forcing due to dust can greatly exceed that due to other anthropogenic aerosols.

Direct radiative forcings

by sulfates -> always negative (leading to cooling);

by aerosol from biomass burning -> negative
(if OC is major constituents)

by mineral dust -> negative or positive ?

- **Airborne mineral dust** has a significant effect on the Earth's radiation budget, as it can both scatter sunlight back to space (leading to negative radiative forcing or cooling), and absorb solar and infrared radiation (leading to positive forcing or warming).

Figure 40.4 Optical depth, direct radiative forcing and simulated surface air temperature change for three assumed anthropogenic aerosol distributions (Hansen et al., 1998)

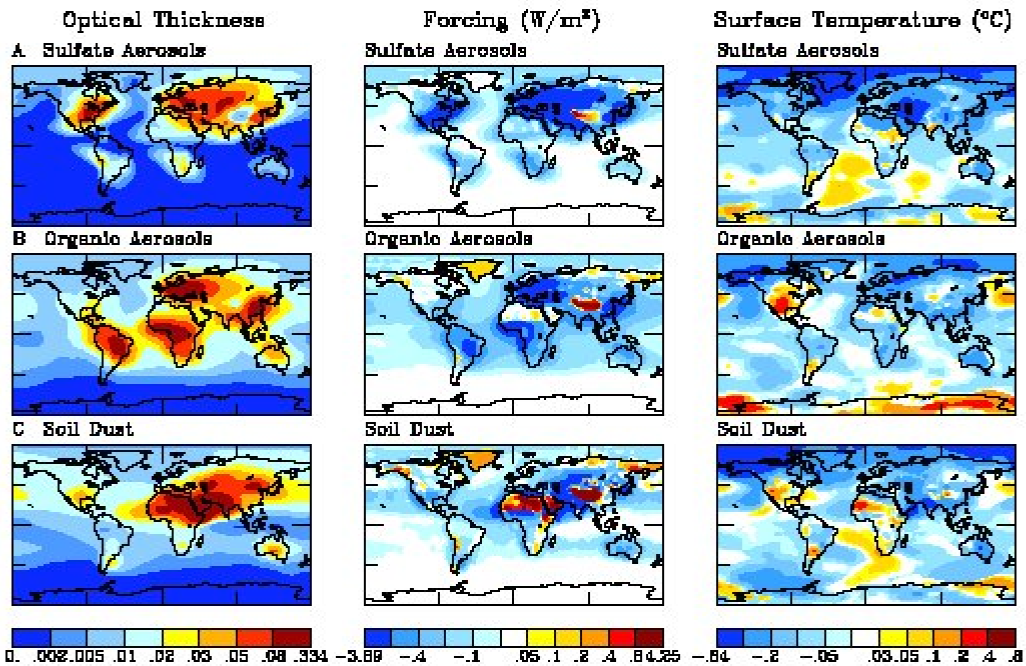


Figure 40.5 Estimated radiative forcing by various factors between 1850 and the present (Hansen et al., 1998).