Lecture 9.

Does particulate air pollution cool or heat the climate system?

Outline:

1. Background materials.
2. *Paper for class discussion*:

Andreae M.O., C.D. Jones, and P.M. Cox, Strong present-day aerosol cooling implies a hot future, Nature, v.435, pp.1187-1190, 2005.

Background materials.

Air pollution: basic concepts

Air pollution may be defined as any atmospheric condition in which *substances* are present at concentrations high enough above their normal ambient levels to produce a *measurable effect* on man, animals, vegetation, or materials.

Substances mean any natural or anthropogenic (man-made) chemical compounds capable of being airborne. They may exist in the atmosphere as gases, liquid drops, solid or mixed phase particles.

Air pollution classification:

According to chemical composition:

1. Sulfur-containing compounds.
2. Nitrogen-containing compounds.
3. Carbon-containing compounds.
4. Halogen-containing compounds.
5. Toxic substances (any of about)
6. Radioactive compounds.

According to physical state:

1. Gaseous
2. Liquid (aqueous) ↕ Particulate matter (PM)
3. Solid

PM (particulate matter) refers to aerosol particles in the atmosphere.

PM10 refers to aerosol particles with diameter < 10 μm.

According to the manner in which they reach the atmosphere:

1. Primary pollutants (those emitted directly from the sources)
2. Secondary pollutants (those formed in the atmosphere by chemical interactions among primary pollutants and normal atmospheric conditions)

According to the space scales of their effects:

1. Local (or indoor)
2. Regional
3. Global

Criteria air pollutants are six major pollutants defined by EPA (Environmental Protection Agency) for which ambient air standards have been set to protect human health and welfare.

Criteria pollutants (defined by EPA):

1. Ozone, O_3.
2. Carbon monoxide, CO.
3. Sulfur dioxide, SO_2.
4. Nitrogen oxides, NO_x.
5. Lead, Pb.
6. Particulates, PM10 and PM2.5

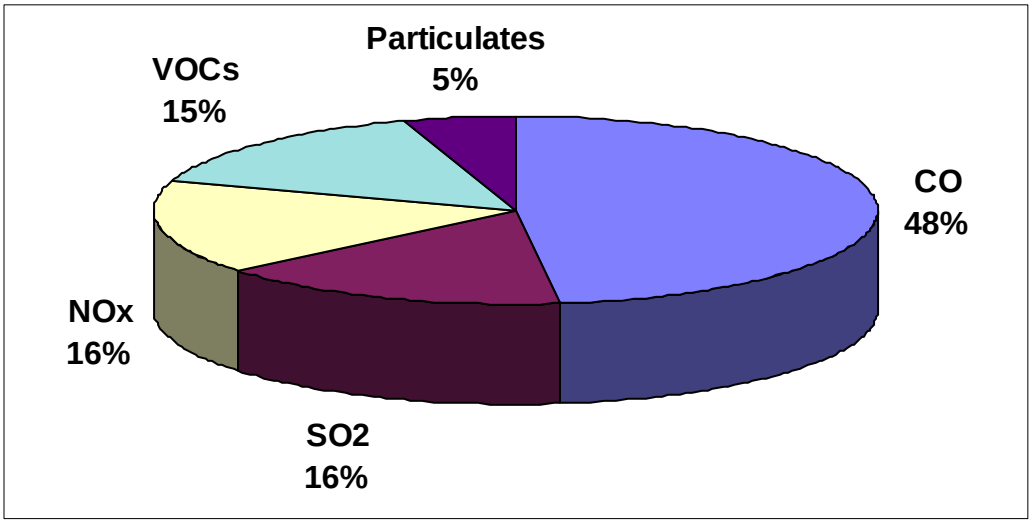

Figure 1. Primary pollutant emissions in the United States.

Major sulfur-containing compounds :

Sulfur dioxide, SO_2, is a colorless gas with a sharp odor, primary pollutant, has anthropogenic (man-made) and natural sources.

Anthropogenic sources: industries burning sulfur-containing fossil fuels, ore smelters, oil refineries.

- Sulfur is present in many fuels (e.g., coal, crude oils) over a wide range of concentrations. Combustion causes its oxidation to sulfur dioxide.

Natural sources: marine plankton, sea water, bacteria, plants, volcanic eruption

Major nitrogen-containing compounds

- Nitrogen, N_2, is a dominant gas of the atmosphere about 78% by volume
- NO_x stands for a mixture of nitric oxide, NO, and nitrogen dioxide, NO_2

Nitrogen oxides, NO_x, are formed mainly from N_2 and O_2 during high-temperature combustion of fuel in cars.

Anthropogenic sources: motor vehicles, biomass burning

Natural sources: bacteria, lightning, biomass burning

***Major carbon-containing compounds**:*

Carbon monoxide, CO, is a colorless odorless flammable gas, major pollutant of an urban air, produced from incomplete combustion.

Anthropogenic sources: petrol engined motor cars, cigarette smoke, biomass burning

Natural sources: biomass burning

NOTE: CO is also produced by atmospheric oxidation of methane gas and other hydrocarbons.

- CO is highly poisonous to humans and most animals: when inhaled, CO reduces the ability of blood hemoglobin to attach oxygen.

Carbon dioxide, CO_2, is a key greenhouse gas. Principal sources: fossil fuel combustion, deforestation, cement production.

Hydrocarbons and volatile organic carbons (VOCs):

organic gases are those that contain both hydrogen and carbon, but may also contain other atoms; **hydrocarbons (HCs)** are organic gases that contain only hydrogen and carbon**. Volatile organic compounds (VOCs)** are non-methane hydrocarbons (NMHC) and oxygenated hydrocarbons (which are hydrocarbons plus oxygenated functional groups).

Energy consumption dominated by coal, oil and natural gas =>

BURNING FOSSIL FUELS TO GENERATE ENERGY CREATES POLLUTION!!!

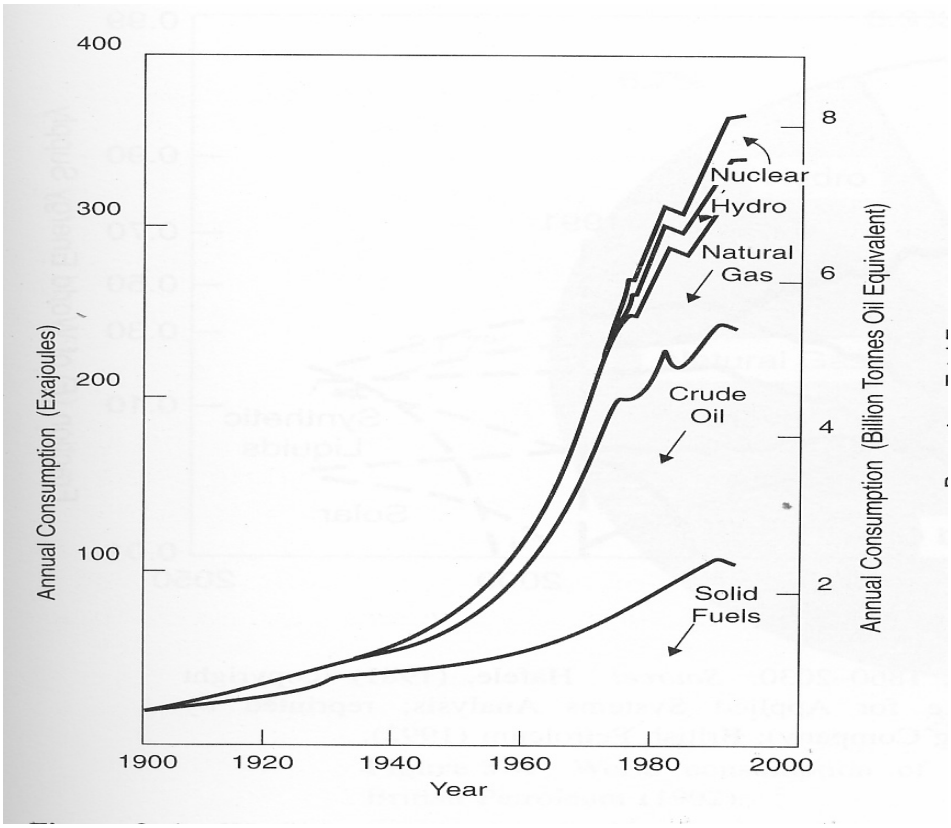

Figure 2. Worldwide energy consumption.

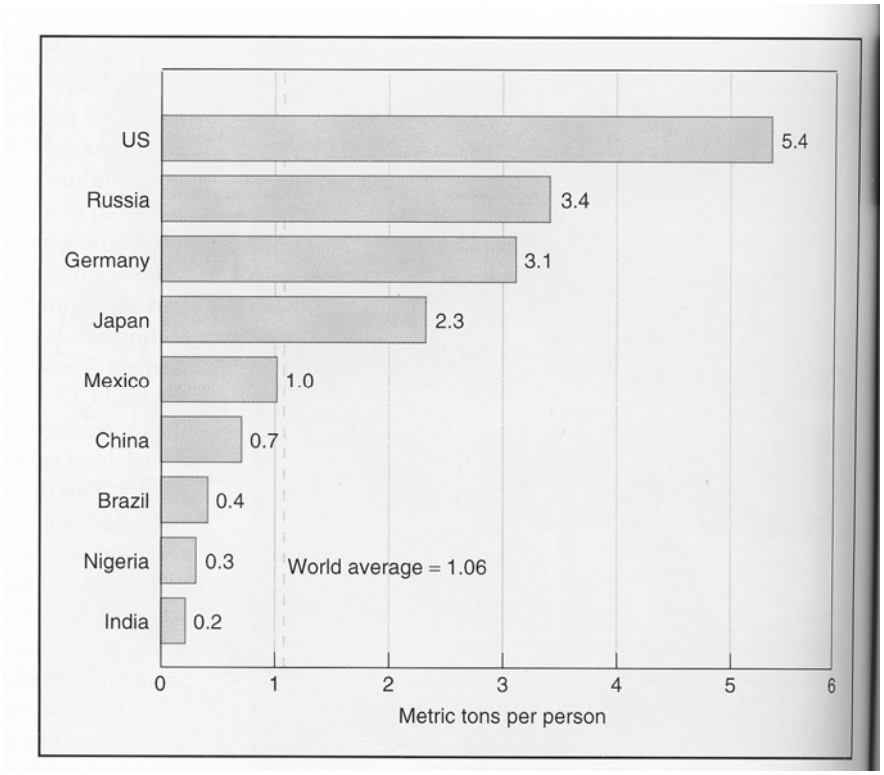

Figure 3. Per capita energy consumption.

SO2, NOX, and some VOCs are gaseous precursors of secondary aerosol particles (via gas-to-particle conversion processes) = > Controlling emission of these species affects the abundance of aerosol particles. In contrast to BC, sulfate- and nitrate-containing aerosols do not absorb light and therefore their direct radiative forcing is negative.

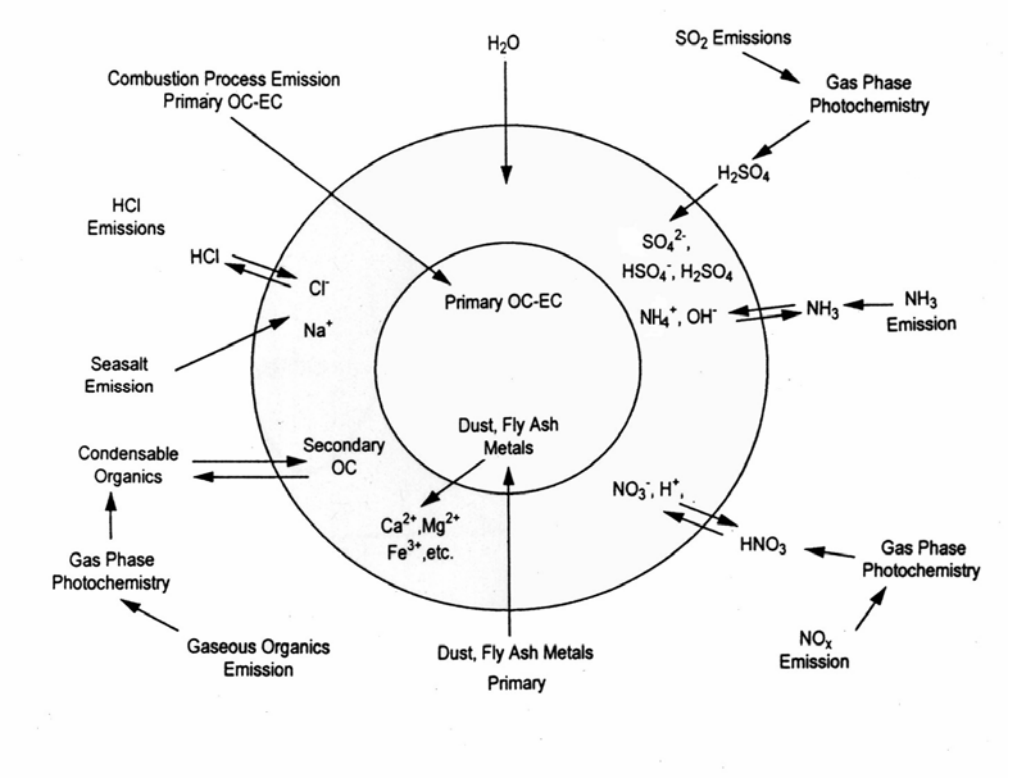

Figure 4. Schematic description of the main pathways for production of atmospheric aerosols and aerosol major chemical components. (NOTE: OC means organic carbon, EC means elemental (or black) carbon).

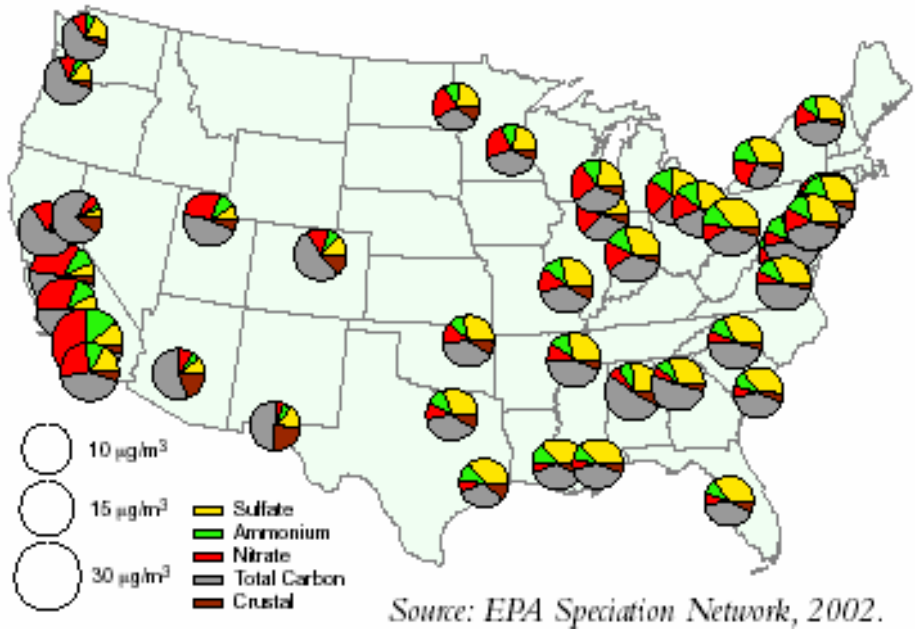

Figure 5. Annual average PM2.5 in urban areas in US, 2002.