Aerosol chemistry: general
ATMOSPHERIC AEROSOLS: ensembles of condensed-phase particles suspended in air

Typical aerosol size distribution

Aerosols are the visible part of the atmosphere:
California fire plumes
Pollution off U.S. east coast
Dust off West Africa
FINE AEROSOL COMPOSITION IN NORTH AMERICA

Annual mean PM$_{2.5}$ concentrations (NARSTO, 2004)

Current air quality standard is 15 $\mu$g m$^{-3}$
ORIGIN OF THE ATMOSPHERIC AEROSOL

Size range: 0.001 μm (molecular cluster) to 100 μm (small raindrop)
WHY CARE ABOUT ATMOSPHERIC AEROSOLS?

- Public health
- Chemistry
- Visibility
- Cloud formation
- Ocean fertilization
- Climate forcing
By scattering solar radiation, aerosols decrease visibility and increase the Earth's albedo.

Scattering efficiency is maximum when particle radius $= \lambda$.

Particles in 0.1-1 $\mu$m size range are efficient scatterers of solar radiation.

Fig. 8-3 Scattering of a radiation beam: processes of reflection (A), refraction (B), refraction and internal reflection (C), and diffraction (D).

Fig. 8-4 Scattering efficiency of green light ($\lambda = 0.5 \mu$m) by a liquid water sphere as a function of the diameter of the sphere. Scattering efficiencies can be larger than unity because of diffraction. Adapted from Jacobson, M. Z. Fundamentals of Atmospheric Modeling. Cambridge, England: Cambridge University Press, 1999.
EPA Regional Haze Rule requires that natural visibility be achieved in all US wilderness areas by 2064.

Park et al. [2006]
HOW TO OBSERVE AEROSOLS FROM SPACE?

**Solar occultation (SAGE, POAM…)**
- Pros: high S/N, vertical profiling
- Cons: sparse sampling, cloud interference, low horizontal resolution

**Active system (CALIOP…)**
- Pro: vertical profiling
- Con: sparse sampling, low S/N

**Solar back-scatter (MODIS, MISR…)**
- Pro: horiz. resolution
- Con: daytime only, no vertical resolution
Aerosol optical depths (AODs) measured from space

Jan 2001 – Oct 2002 operational data

MODIS (c004)
return time 2x/day;
nadir view
known positive bias over land

MISR
9-day return time;
multi-angle view
better but much sparser

van Donkelaar et al. [2006]
ANNUAL MEAN PM$_{2.5}$ CONCENTRATIONS (2002) derived from MODIS satellite instrument data
RAOULT’S LAW

$$P_{H_2O, SAT}^o$$

$$P_{H_2O, SAT} = x_{H_2O} P_{H_2O, SAT}^o$$

An atmosphere of relative humidity $RH$ can contain at equilibrium aqueous solution particles of water mixing ratio $x_{H_2O}$
HOWEVER, AEROSOL PARTICLES MUST ALSO SATISFY SOLUBILITY EQUILIBRIA

Consider an aqueous sea salt (NaCl) particle: it must satisfy

\[ x_{Na^+} + x_{Cl^-} \leq K_s \] (solubility equilibrium)

\[ x_{Na^+} = x_{Cl^-} \] (electroneutrality)

\[ x_{Na^+} + x_{Cl^-} + x_{H_2O} = 1 \] (closure)

This requires:

\[ RH \geq 100(1 - 2K_s^2) \] "deliquescence RH"

At lower RH, the particle is dry.
UPTAKE OF WATER BY AEROSOLS: HAZE

NaCl/H₂O

Deliquescence RH; depends on particle composition