EPS200: Atmospheric Chemistry and Physics

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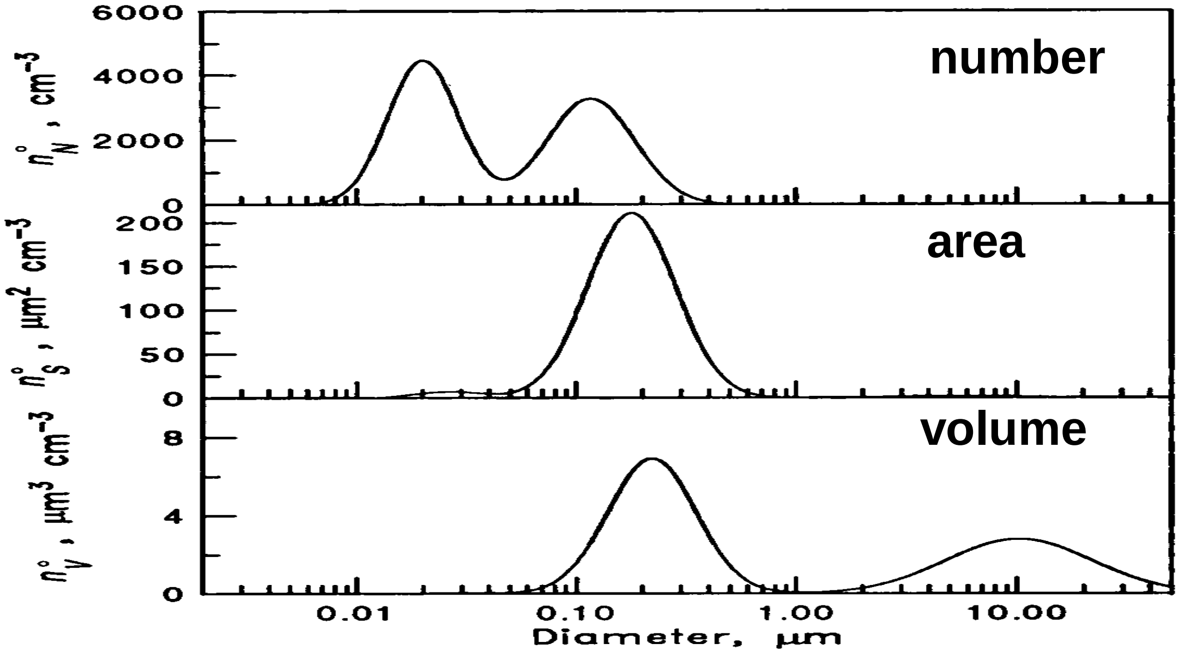
Aerosol chemistry: general

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

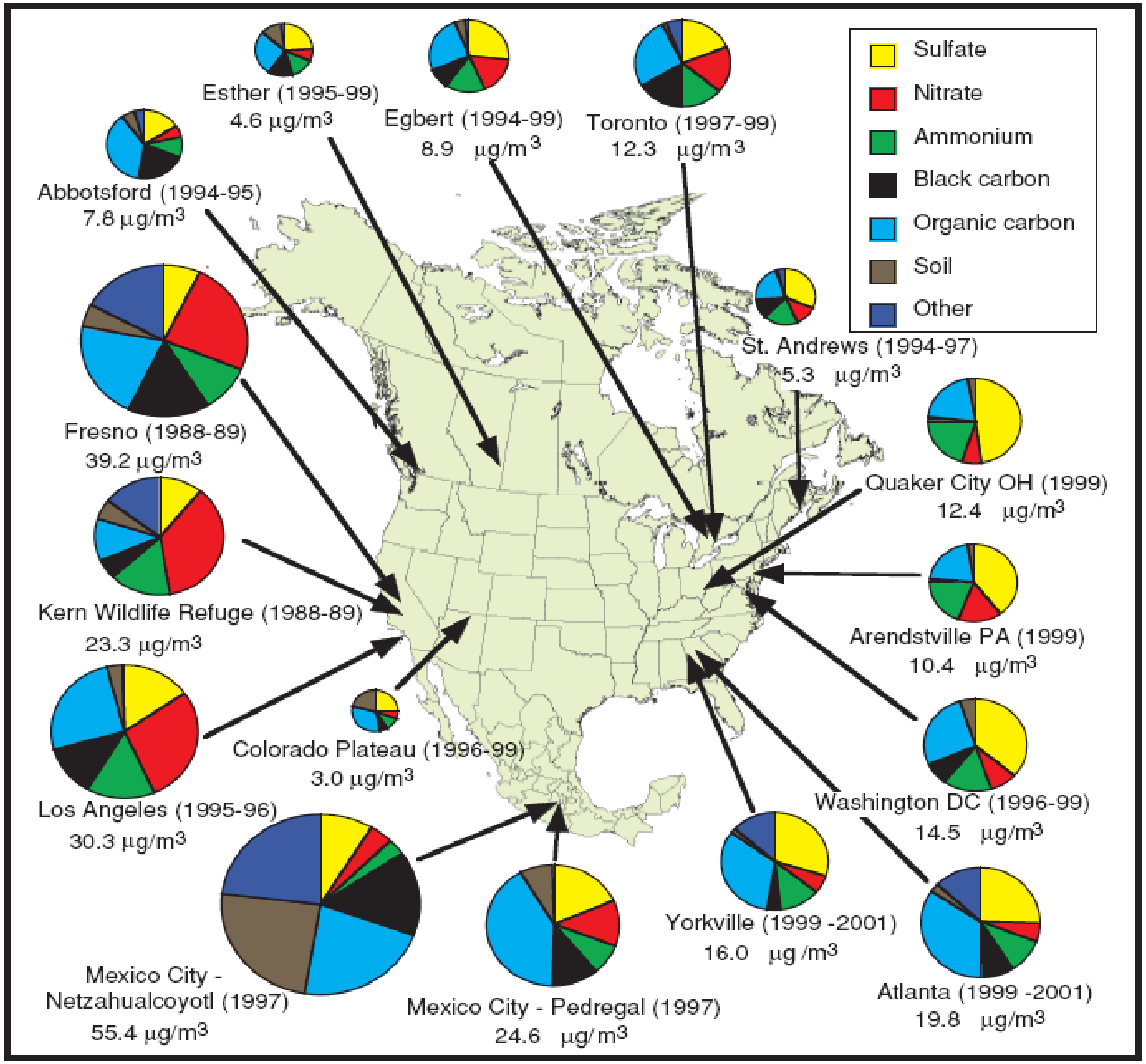
Pollution off U.S. east coast

Dust off West Africa

FINE AEROSOL COMPOSITION IN NORTH AMERICA

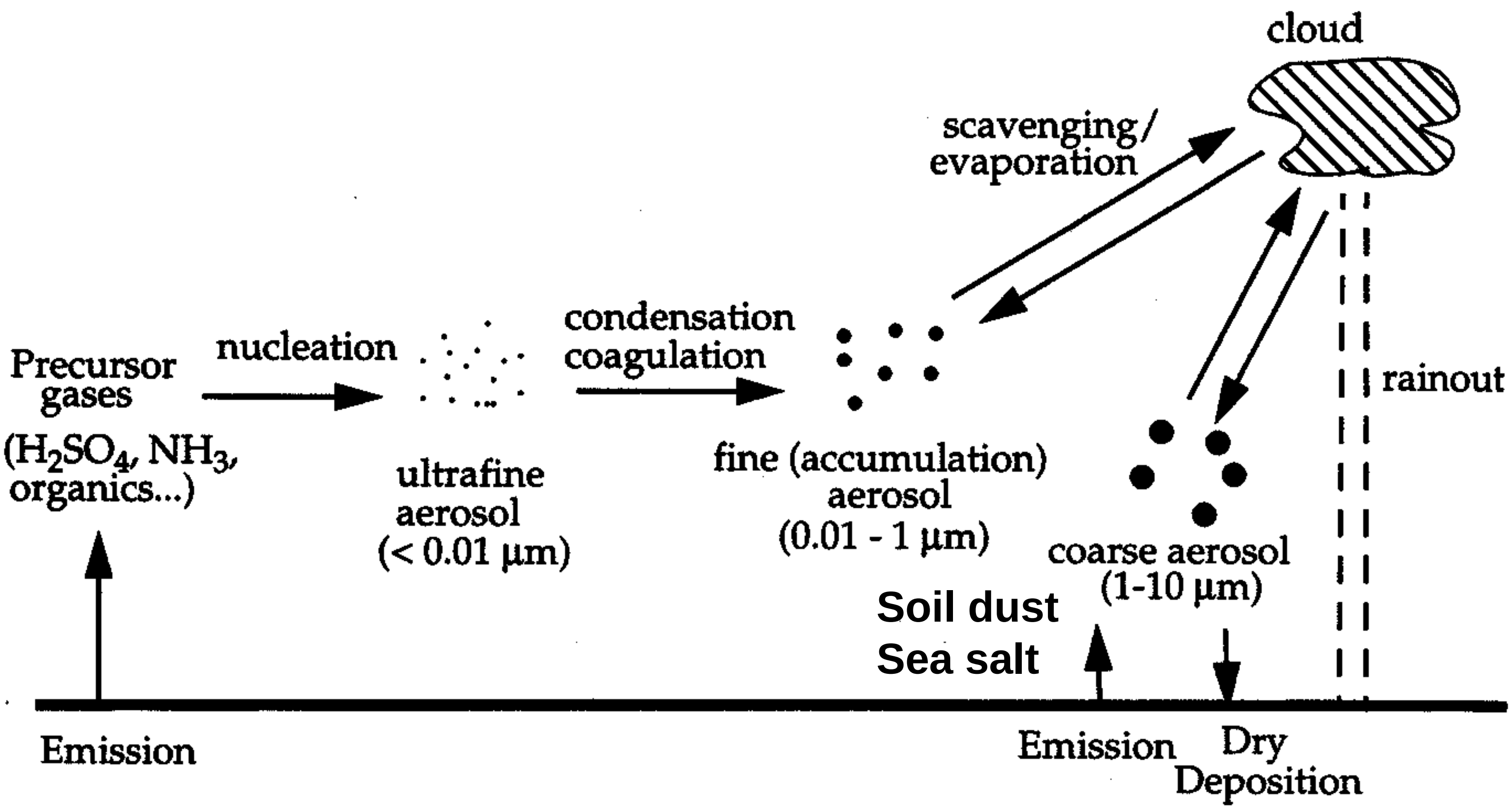
Annual mean $PM_{2.5}$ concentrations (NARSTO, 2004)

Current air quality standard is 15 $\mu g\ m^{-3}$

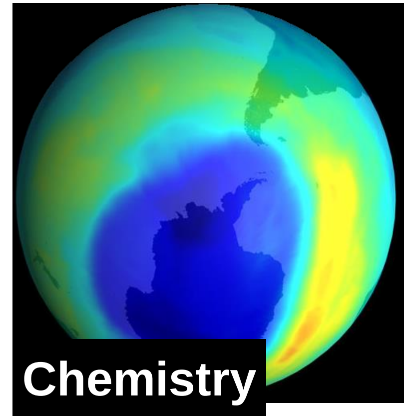


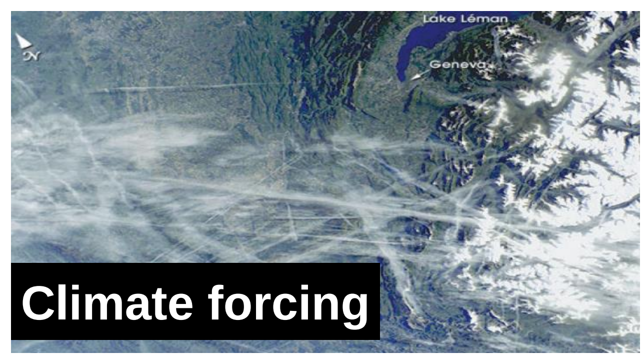
ORIGIN OF THE ATMOSPHERIC AEROSOL

Size range: 0.001 μm (molecular cluster) to 100 μm (small raindrop)



WHY CARE ABOUT ATMOSPHERIC AEROSOLS?





SCATTERING OF RADIATION BY AEROSOLS

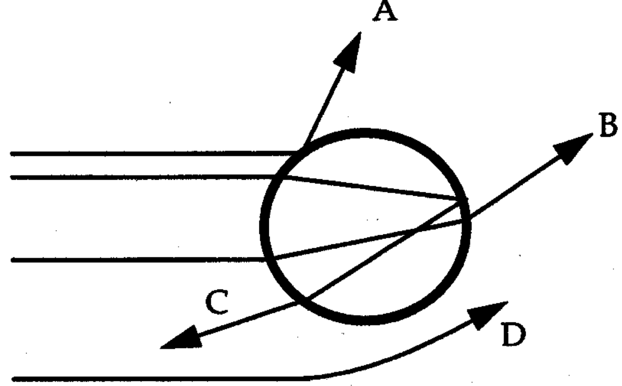


Fig. 8-3 Scattering of a radiation beam: processes of reflection (A), refraction (B), refraction and internal reflection (C), and diffraction (D).

By scattering solar radiation, aerosols decrease visibility and increase the Earth's albedo

Scattering efficiency is maximum when particle radius = λ
⇨particles in 0.1-1 μm size range are efficient scatterers of solar radiation

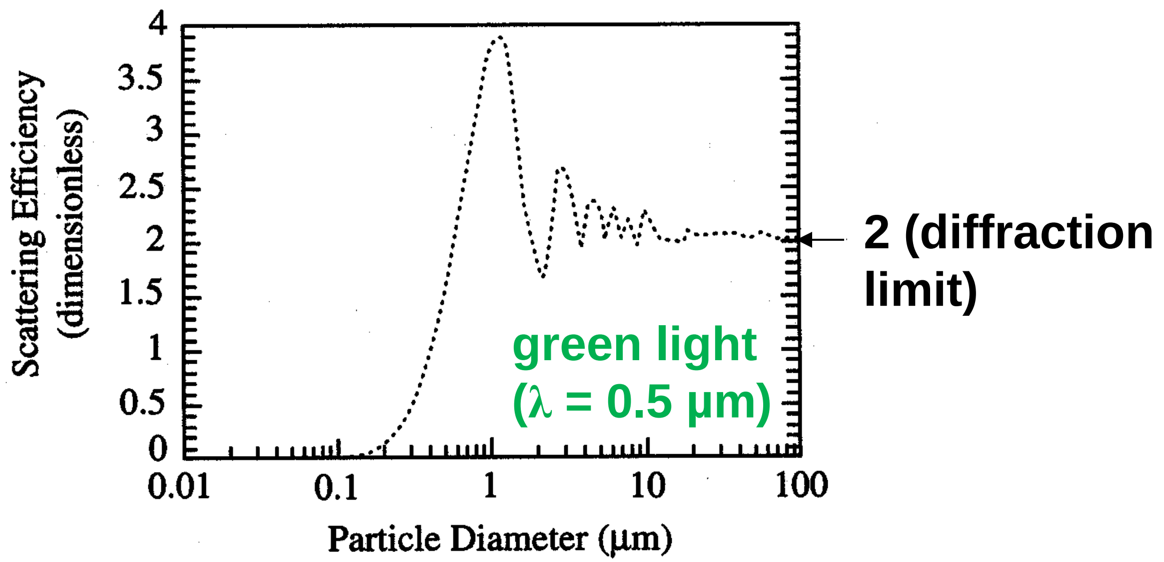
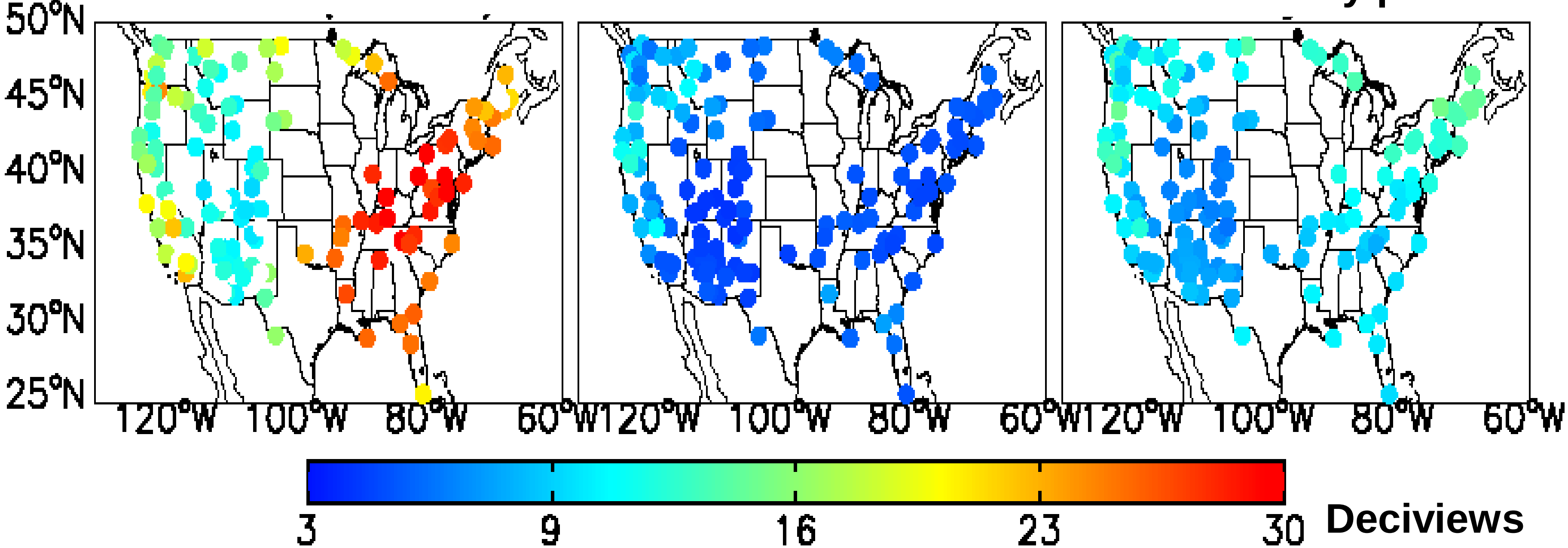


Fig. 8-4 Scattering efficiency of green light (λ = 0.5 μm) by a liquid water sphere as a function of the diameter of the sphere. Scattering efficiencies can be larger than unity because of diffraction. Adapted from Jacobson, M. Z. *Fundamentals of Atmospheric Modeling*. Cambridge, England: Cambridge University Press, 1999.

VISIBILITY IN U.S. WILDERNESS AREAS

EPA Regional Haze Rule requires that natural visibility be achieved in all US wilderness areas by 2064

2001 observations | **Natural** | **Background; includes transboundary pollution**

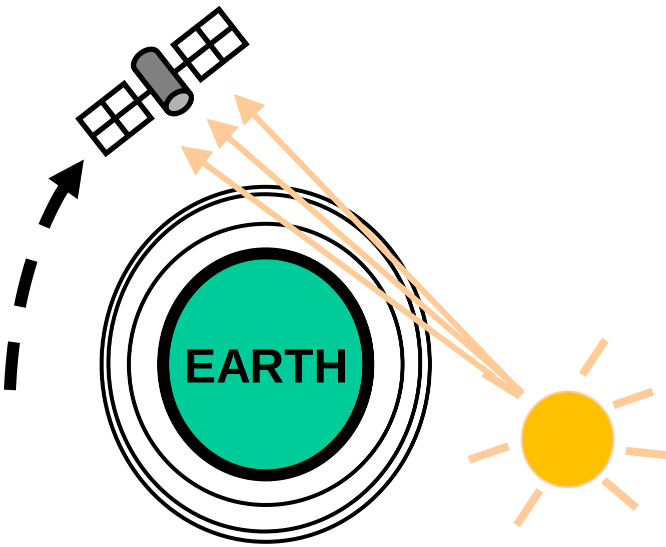


300 150 80 40 20 Visual range (km)

Park et al. [2006]

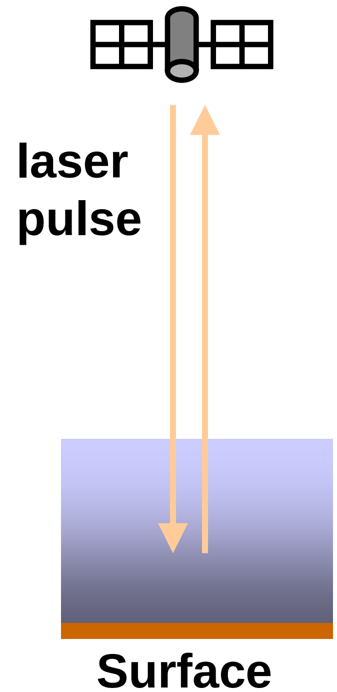
HOW TO OBSERVE AEROSOLS FROM SPACE?

Solar occultation
(SAGE, POAM…)



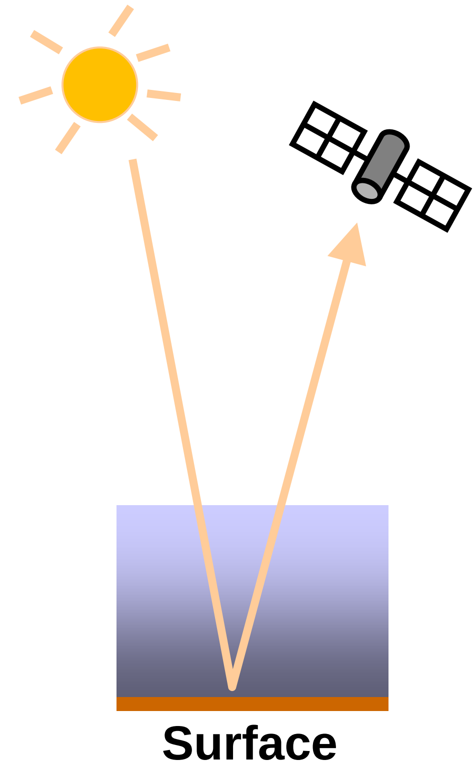
Pros: high S/N, vertical profiling
Cons: sparse sampling,
cloud interference,
low horizontal resolution

Active system
(CALIOP…)



Pro: vertical profiling
Con: sparse sampling,
low S/N

Solar back-scatter
(MODIS, MISR…)

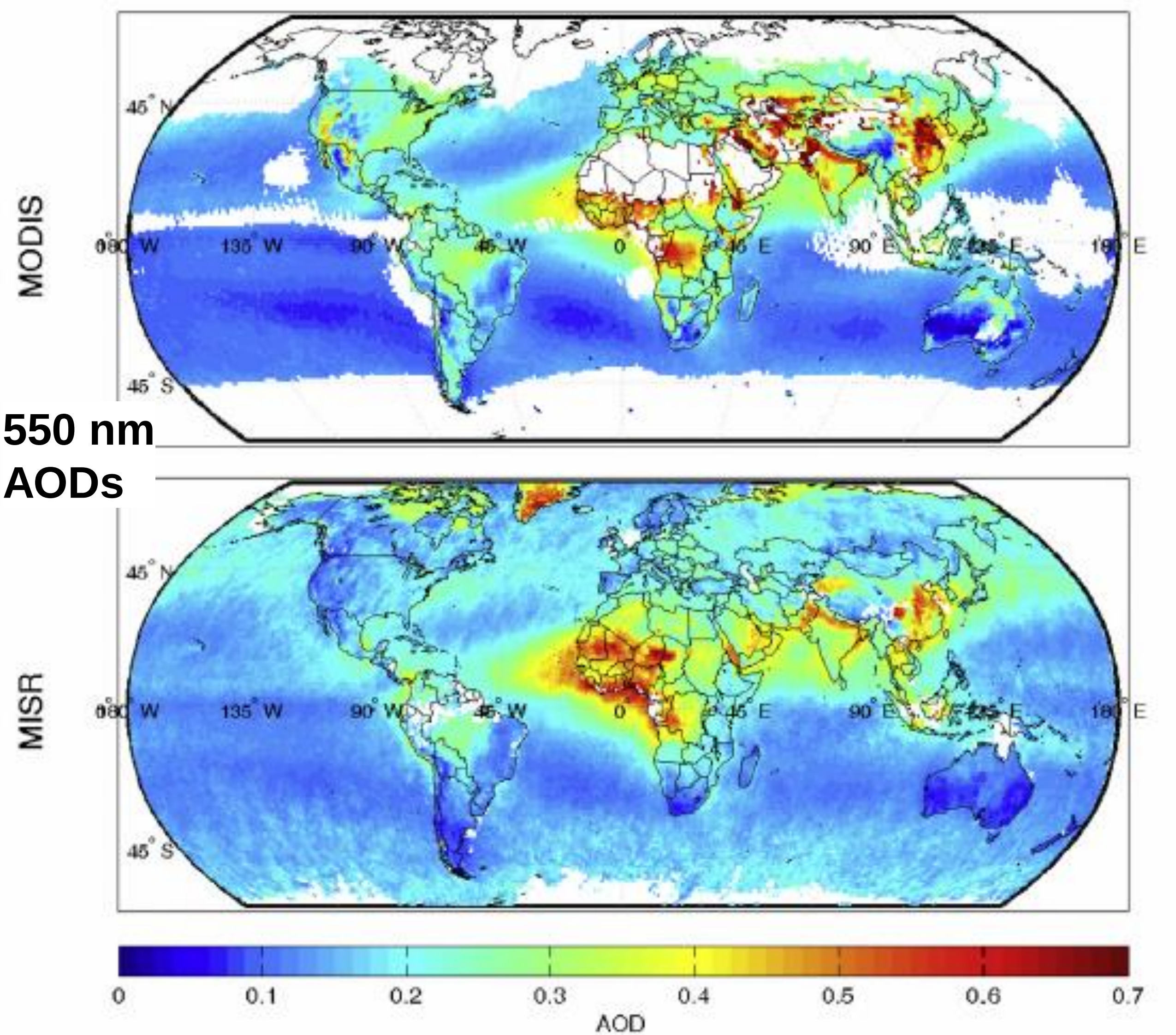


Pro: horiz. resolution
Con: daytime only,
no vertical resolution

Aerosol optical depths (AODs) measured from space

Jan 2001 – Oct 2002 operational data

550 nm AODs



MODIS (c004)

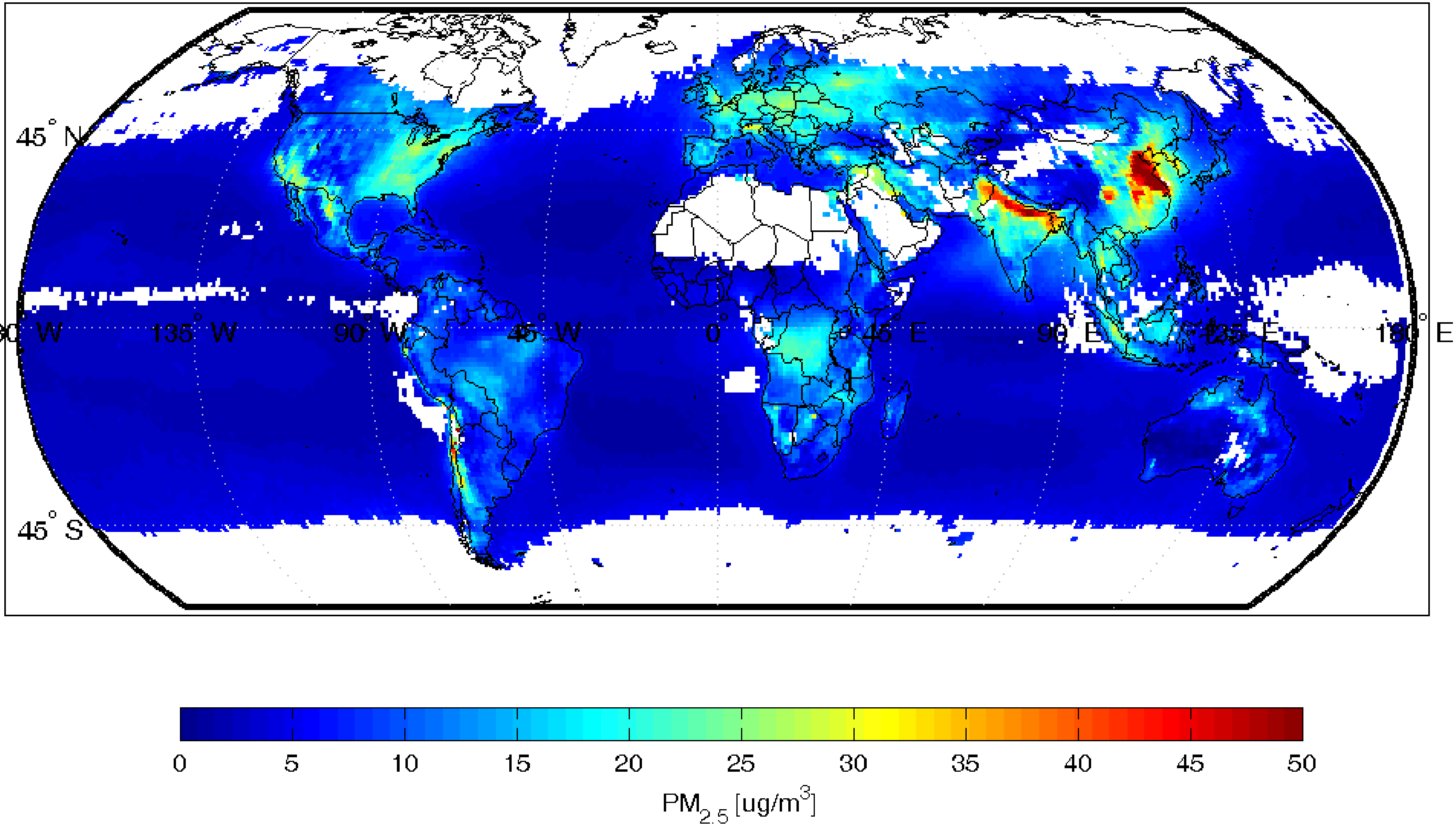
return time 2x/day;
nadir view
known positive bias over land

MISR

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

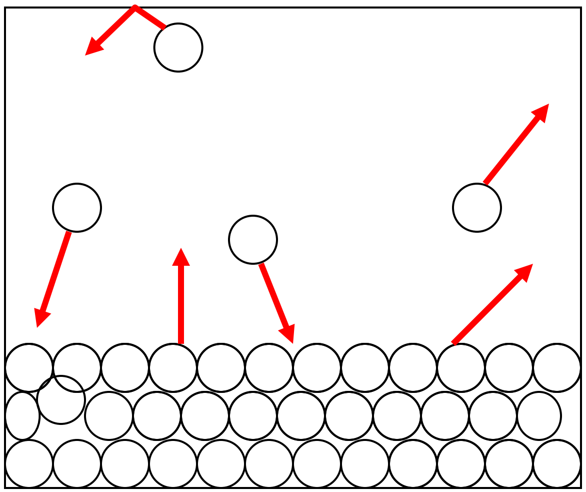
van Donkelaar et al. [2006]

ANNUAL MEAN $PM_{2.5}$ CONCENTRATIONS (2002) derived from MODIS satellite instrument data



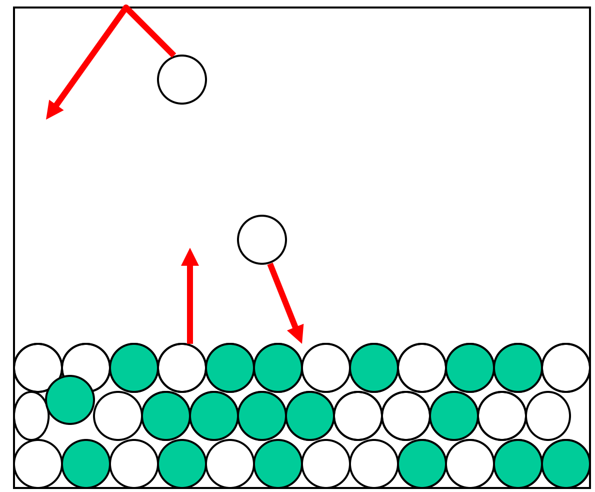
RAOULT'S LAW

$$P^{o}_{H2O,SAT}$$



water saturation vapor pressure over pure liquid water surface

$$P_{H2O,SAT} = x_{H2O} P^{o}_{H2O,SAT}$$



solute molecules in green

water saturation vapor pressure over aqueous solution of water mixing ratio x_{H2O}

An atmosphere of relative humidity *RH* can contain at equilibrium aqueous solution particles of water mixing ratio

$$x_{H2O} = \frac{P_{H2O,SAT}}{P^{o}_{H2O,SAT}} = \frac{RH}{100}$$

HOWEVER, AEROSOL PARTICLES MUST ALSO SATISFY SOLUBILITY EQUILIBRIA

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

$$x_{Na+}x_{Cl-} \leq K_s \text{ (solubility equilibrium)}$$

$$x_{Na+} = x_{Cl-} \text{ (electroneutrality)}$$

$$x_{Na+} + x_{Cl-} + x_{H2O} = 1 \text{ (closure)}$$

This requires:

$$RH \geq 100(1-2K_s^{\frac{1}{2}}) \text{ "deliquescence RH"}$$

At lower RH, the particle is dry.

UPTAKE OF WATER BY AEROSOLS: HAZE