Characterization of Dust, Particles, Fog and Snow

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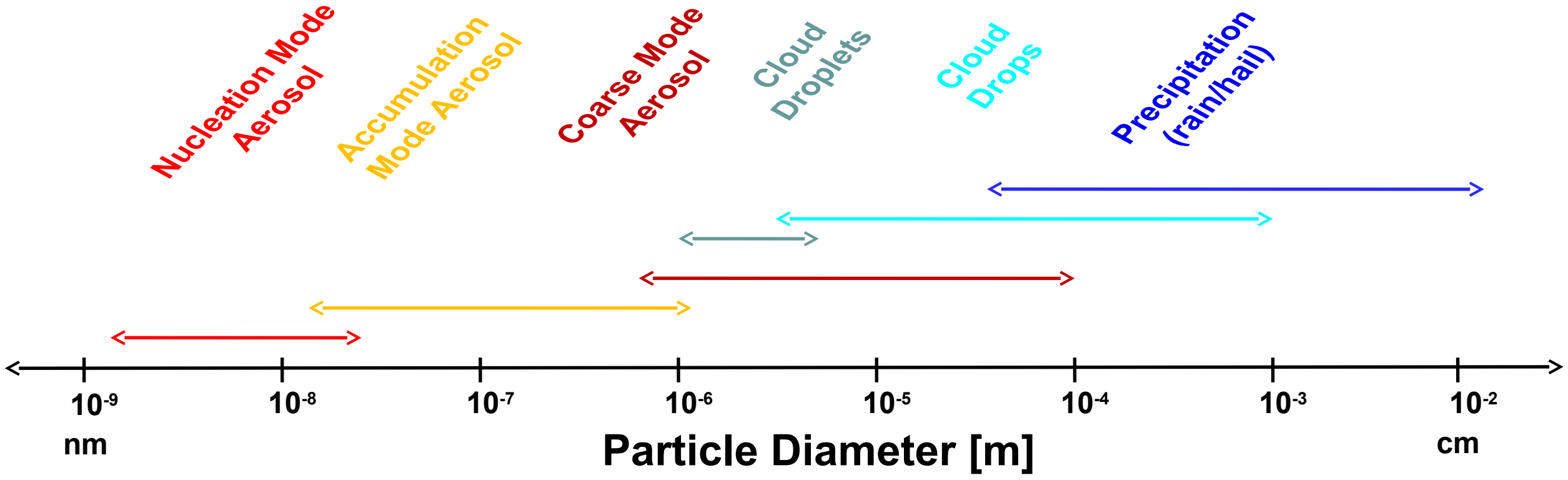
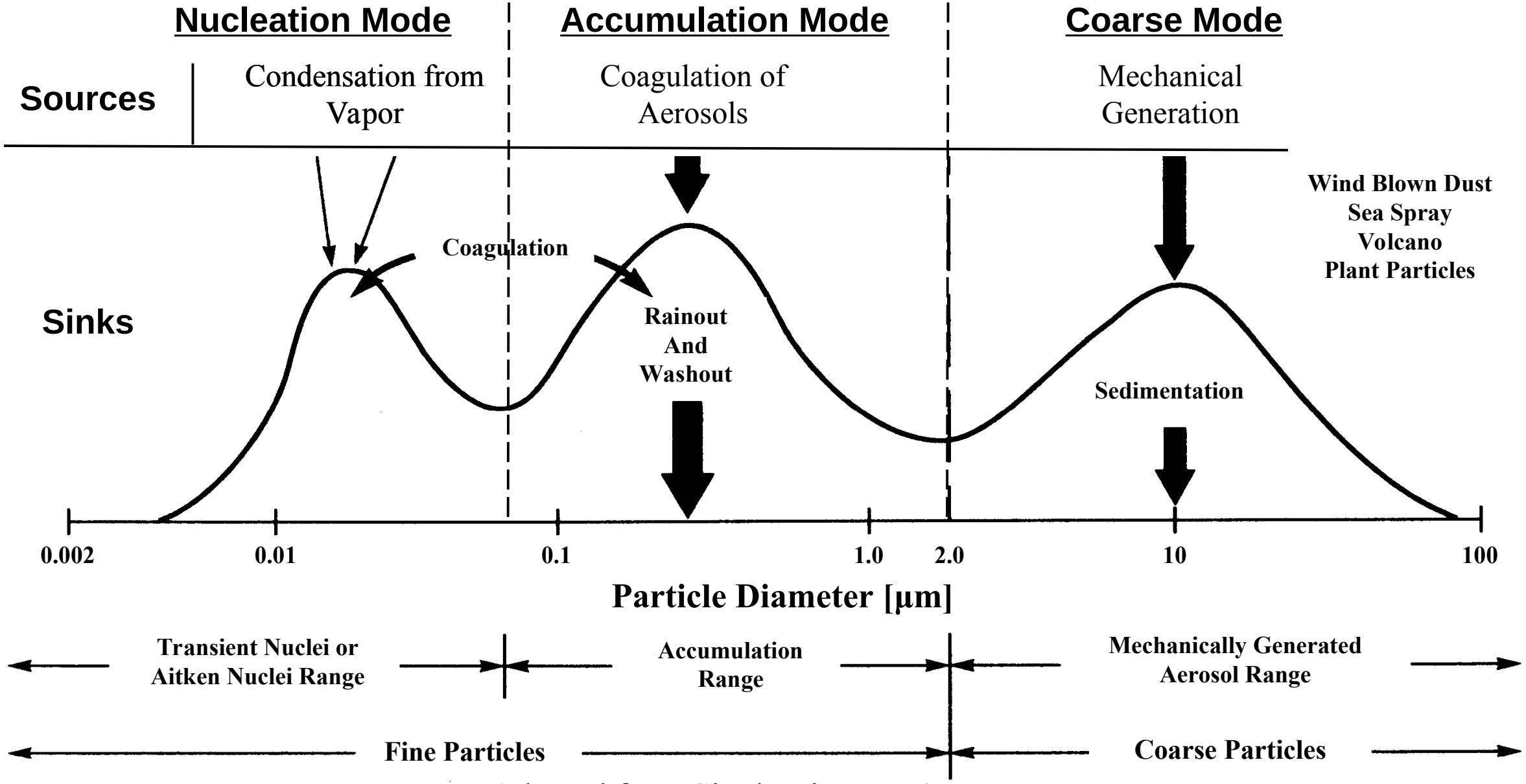
Overview of Atmospheric Particle

Atmosphere contains particles of all sizes.

- Suspended particles (aerosols) move with the average flow of gas molecules (atmospheric wind).
- Large particles (dust/drops/rain) have sufficient inertia to move independently of the wind.



Atmospheric Aerosol (Particles) Modes

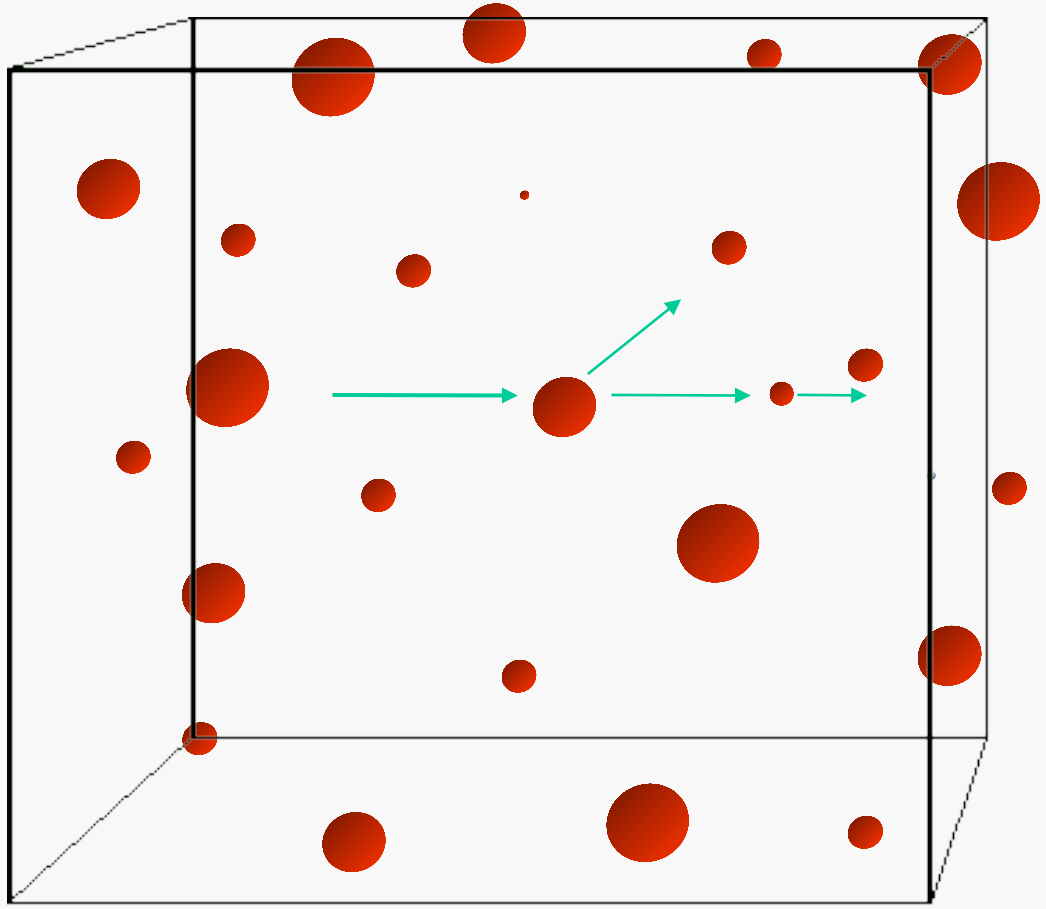


Adapted from Singh: Figure 5.4

Light Scattering and Absorption by Aerosols

Volume of Air

In Coming Light



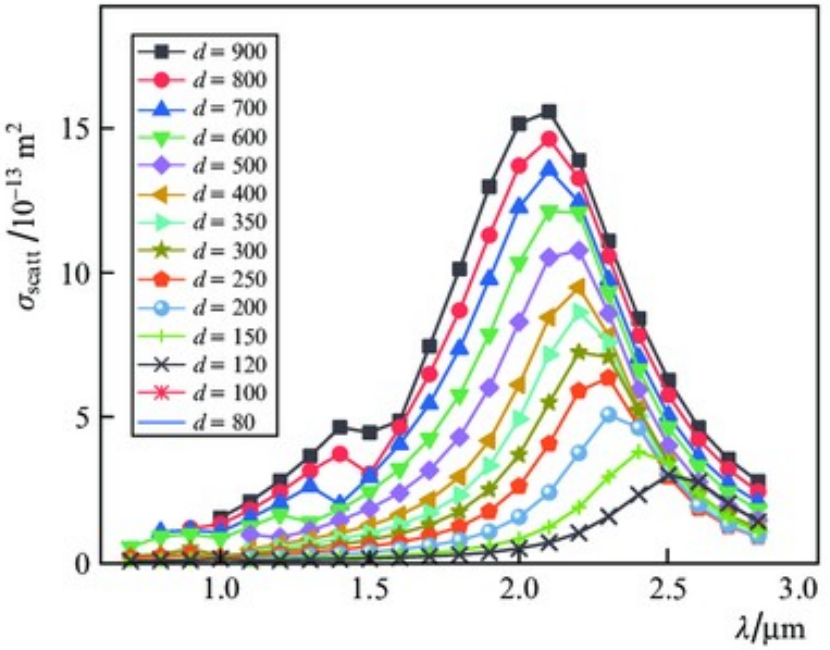
Out Going Light

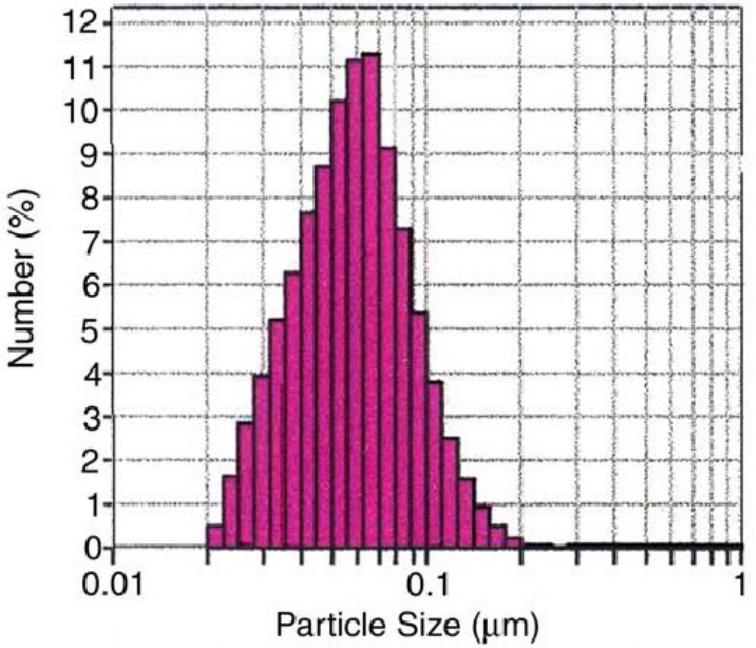
Atmospheric Aerosol Scattering

Volume Scattering Coefficient

$$\beta_{sca} = \int_0^{\infty} \sigma_{sca}(r)\, n(r)\, dr$$

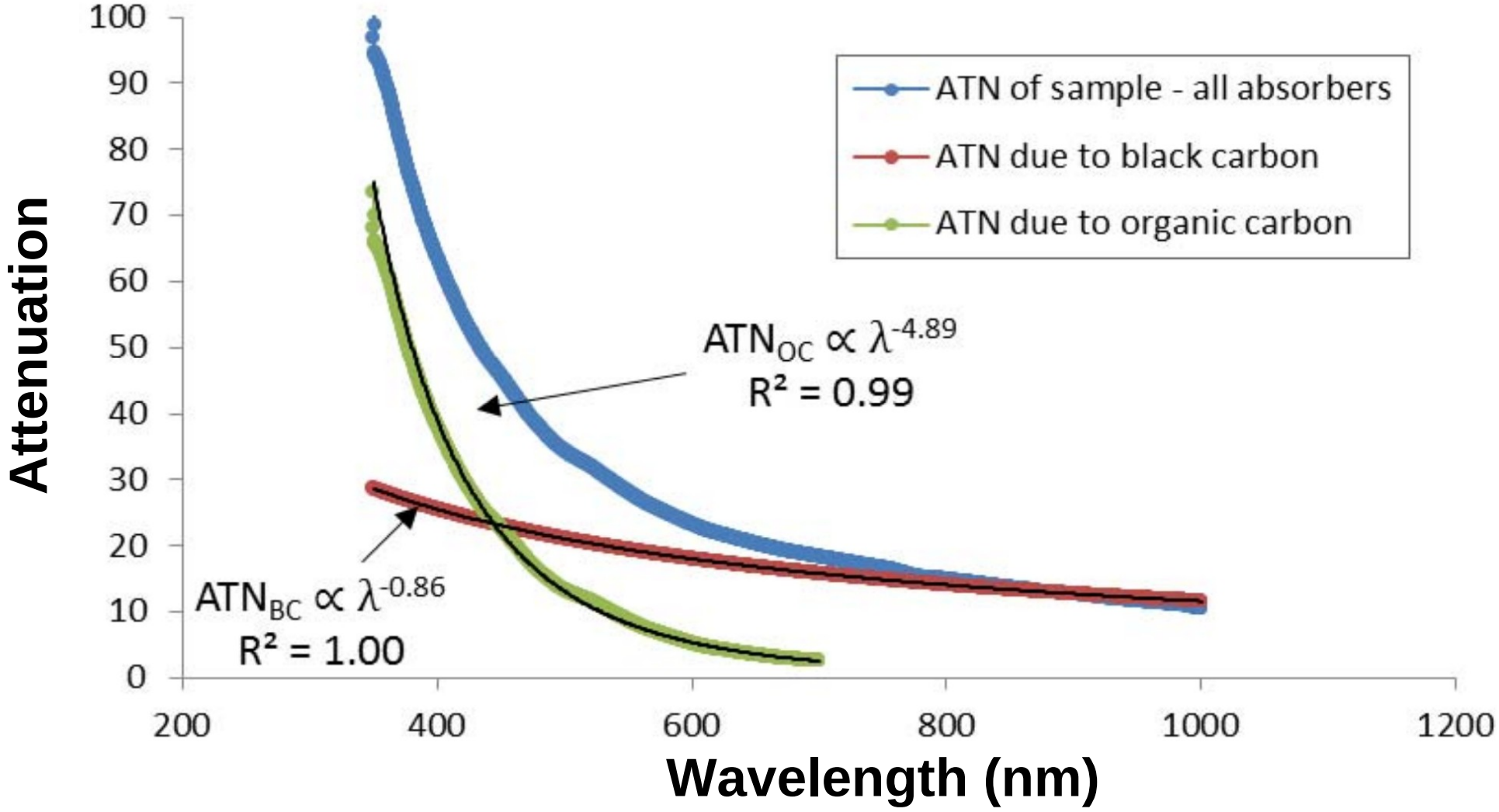
Scattering Cross-section — **Particle Number Concentration**





Take-away: Larger particles scatter more; however, the atmosphere typically contains less larger particles.

Smoke Aerosol Absorption



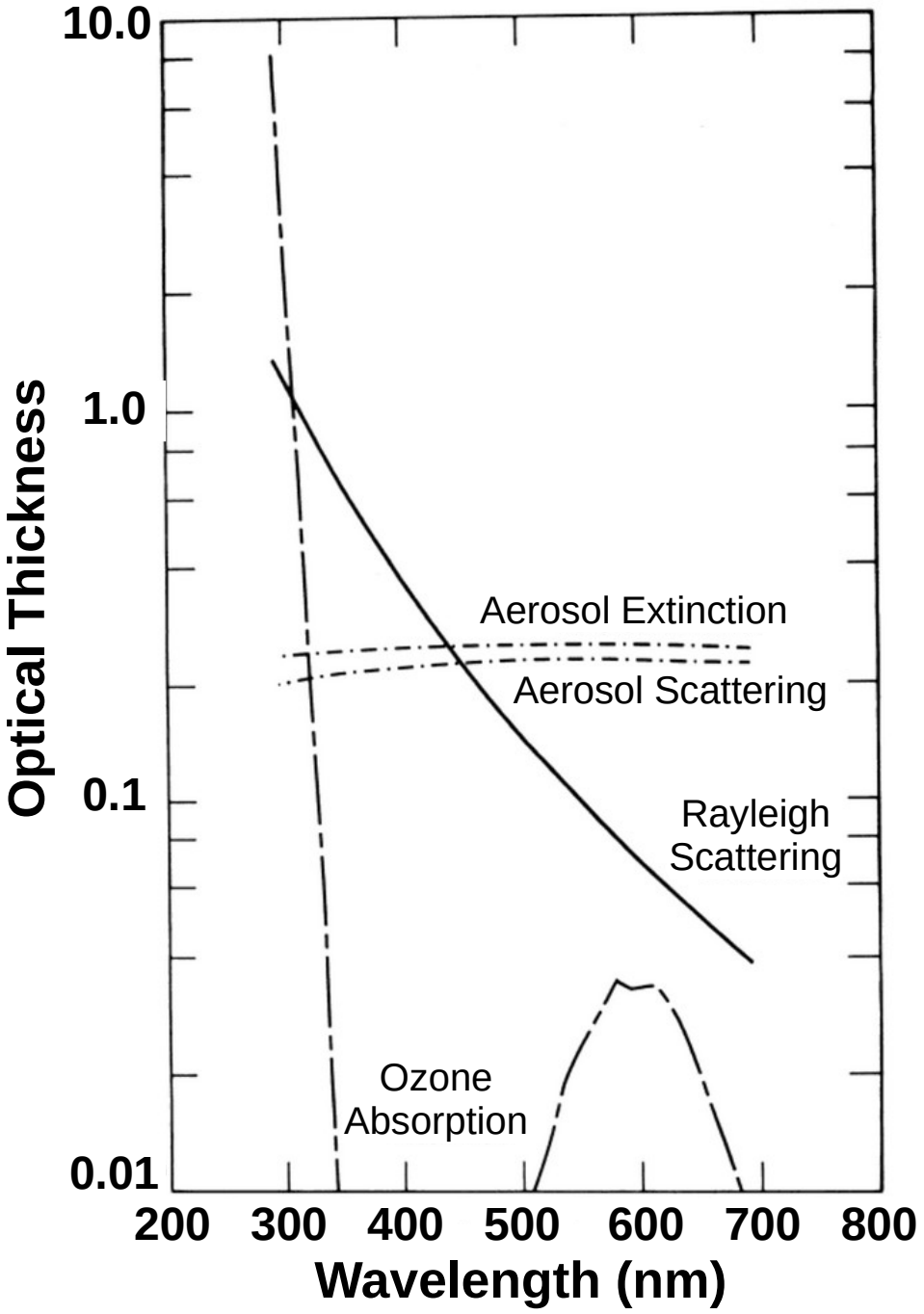
Contributions of black and organic carbon to the spectral attenuation of a residential wood smoke particulate matter sample. The exponents of the power law trend lines, 0.86 and 4.89, are the absorption Ångström exponents of the black and organic carbon, respectively, for this sample. ***Image from Kirchstetter and Thatcher, 2012.***

Aerosol Extinction Comparison

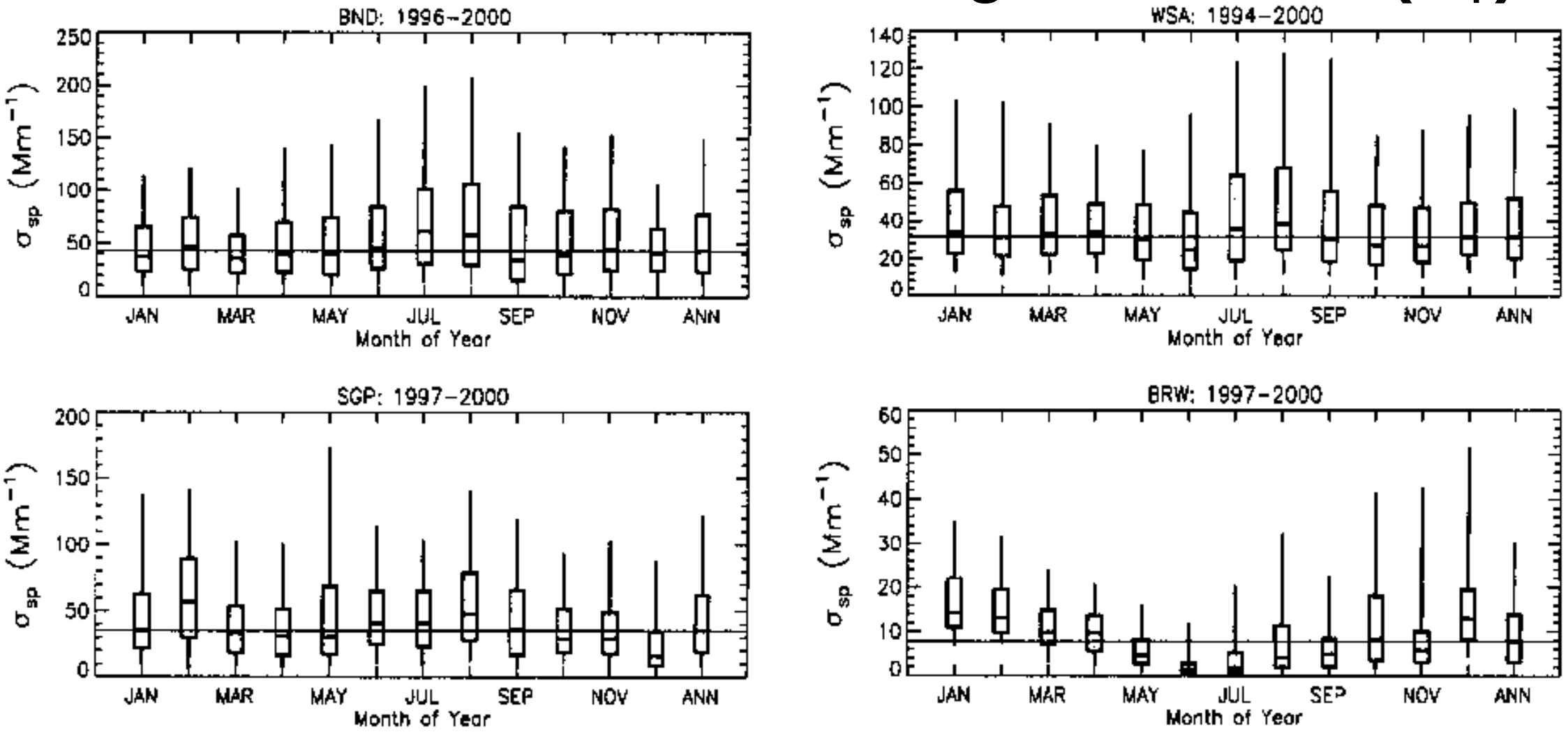
- Over visibility wavelength, aerosol scattering and extinction does not change very much, unlike Rayleigh scattering and ozone absorption.

Normal optical thickness as a function of wavelength (nm) for aerosols scattering and extinction, Rayleigh scattering, and Ozone absorption used as input for the actinic flux calculations.

Reproduced from Figure 2 of “Calculated Actinic Fluxes (290-700 nm) Air Pollution Photochemistry Applications” by James T. Peterson



Aerosol Volume Scattering Coefficient (σ_{sp})



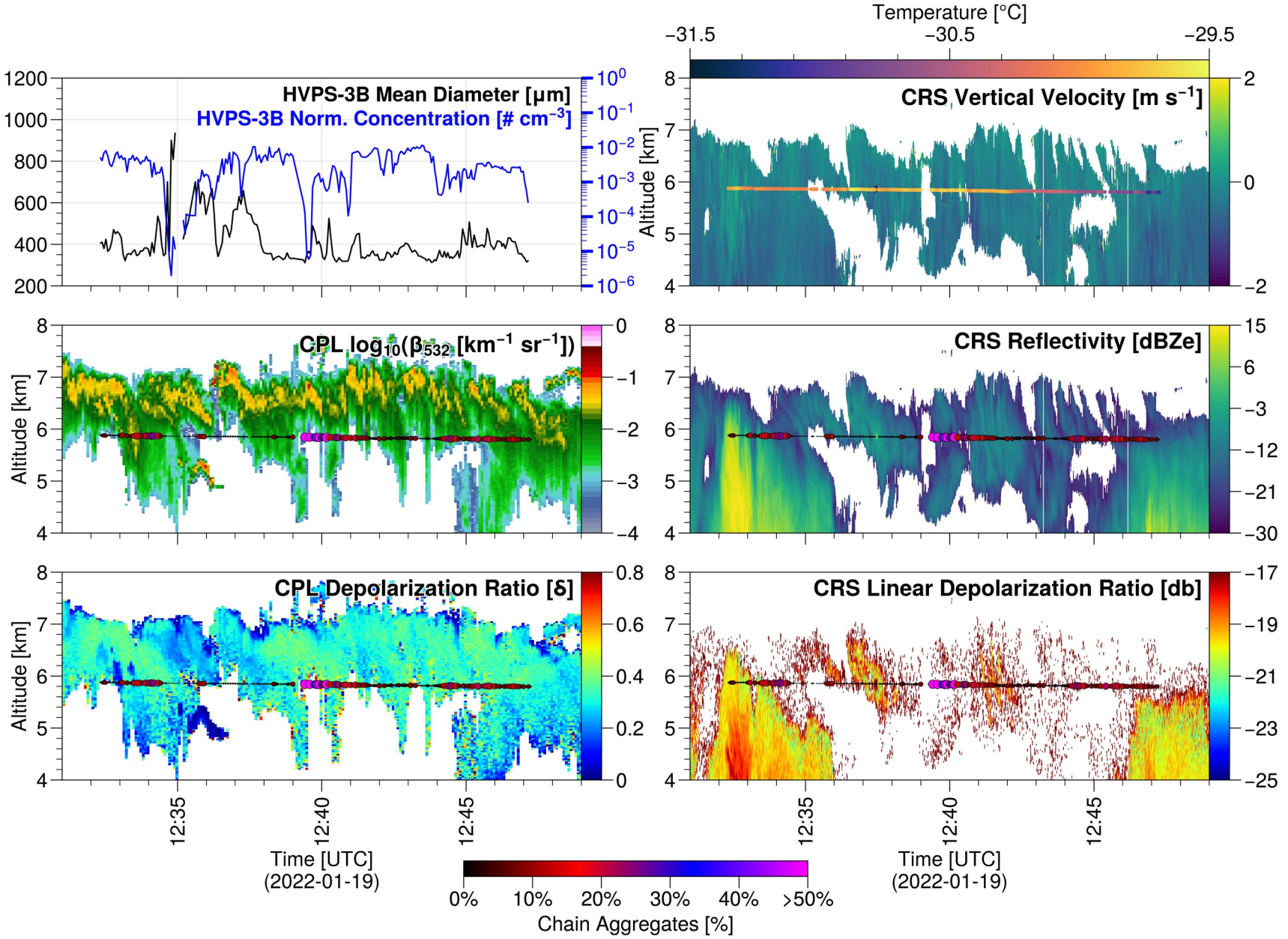
$\lambda = 550$ nm, $D < 10$ μm, $RH < 40\%$

Delene, D. J., and J. A. Ogren, 2002: Variability of aerosol optical properties at four North American surface monitoring sites, Journal of Atmospheric Sciences, 59, 1135-1150, https://doi.org/10.1175/1520-0469(2002)059<1135:VOAOPA>2.0.CO;2.

Crop Harvest Aerosols

- Illinois measurements indicated that the radiative properties of sub-micrometer aerosols change substantially during an approximate 6-week long period each year, which coincides with regional harvesting activities
  - Wrote proposal NSF proposal in 2007, which was rejected.
  - Wrote Notice of Intent for NASA Farm Flux Science Team, 2024 A.62 Call, not interested in measurements methodology proposed.

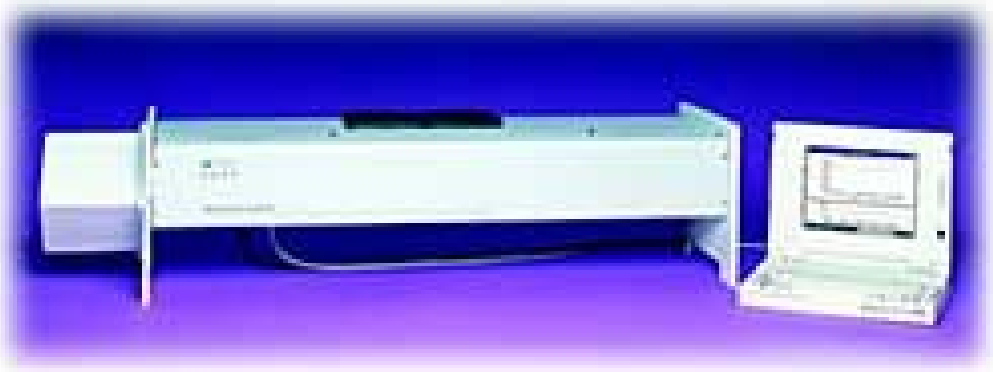
Remote Sensing (Lidar and Radar)

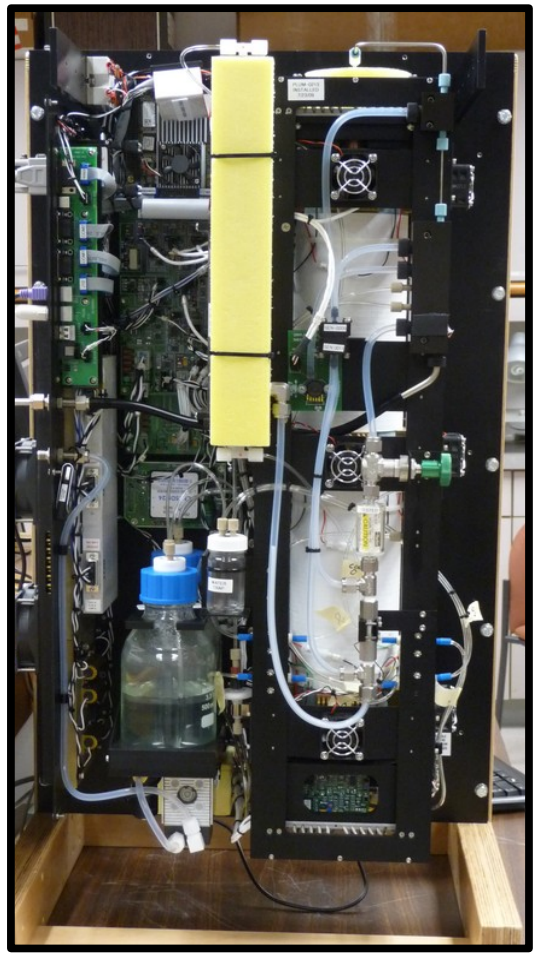


Nairy, Christian M., David J. Delene, Joseph A. Finlon, John E. Yorks, Emma Järvinen, Martin Schnaiter, Andrew J. Heymsfield, Andrew G. Detwiler, Lynn A. McMurdie, Unveiling In-situ Observations of Ice Crystal Chain Aggregates in Winter Storms. Journal of Geophysical Research Letter, In Preparation, 2025.

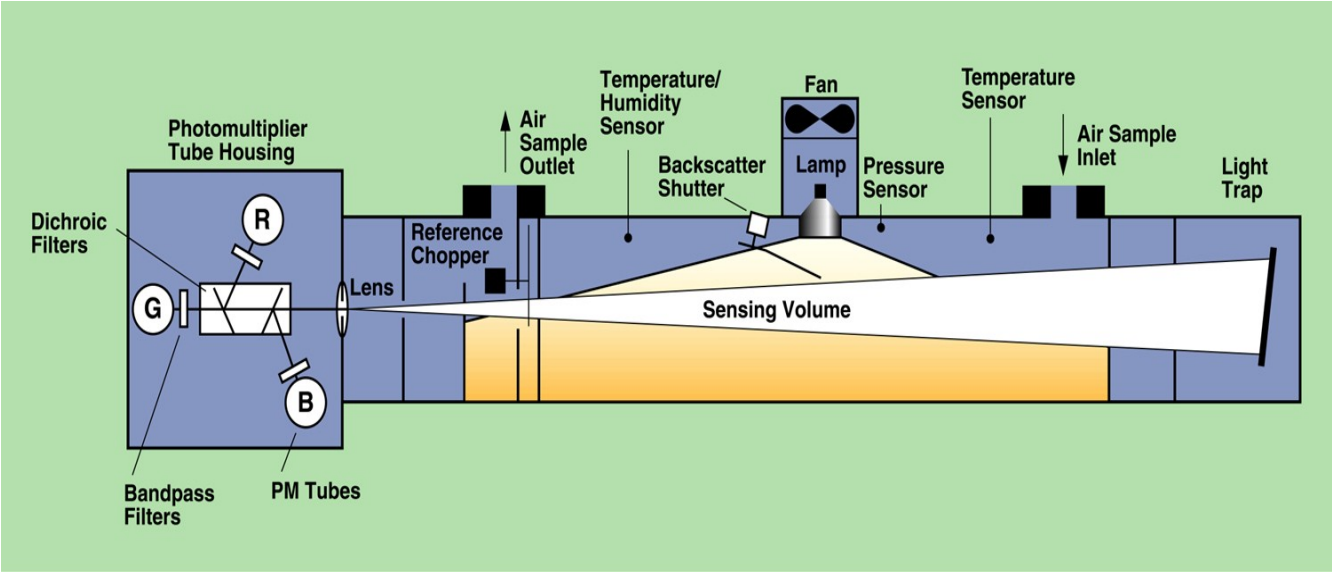
Questions and Discussion

Particle Sampling Instrumentation





Integrating Nephelometer



TSI 3563 Nephelometer schematic courtesy of TSI Incorporated

Beer-Lambert Law

$$I / I_o = e^{(- \tilde{A} x)}$$

I_o intensity of light source =

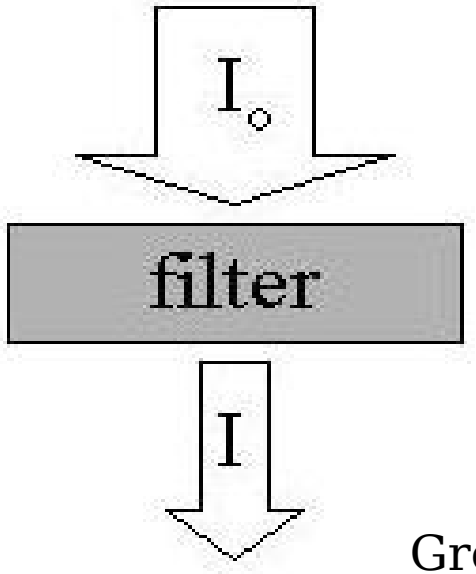
I = intensity of light after passing through atmospheric path

x = thickness of medium through which light passes

$\tilde{A}$ = total **extinction coefficient** (scattering + absorption)

$\tau = \tilde{A} x$ = Optical Thickness

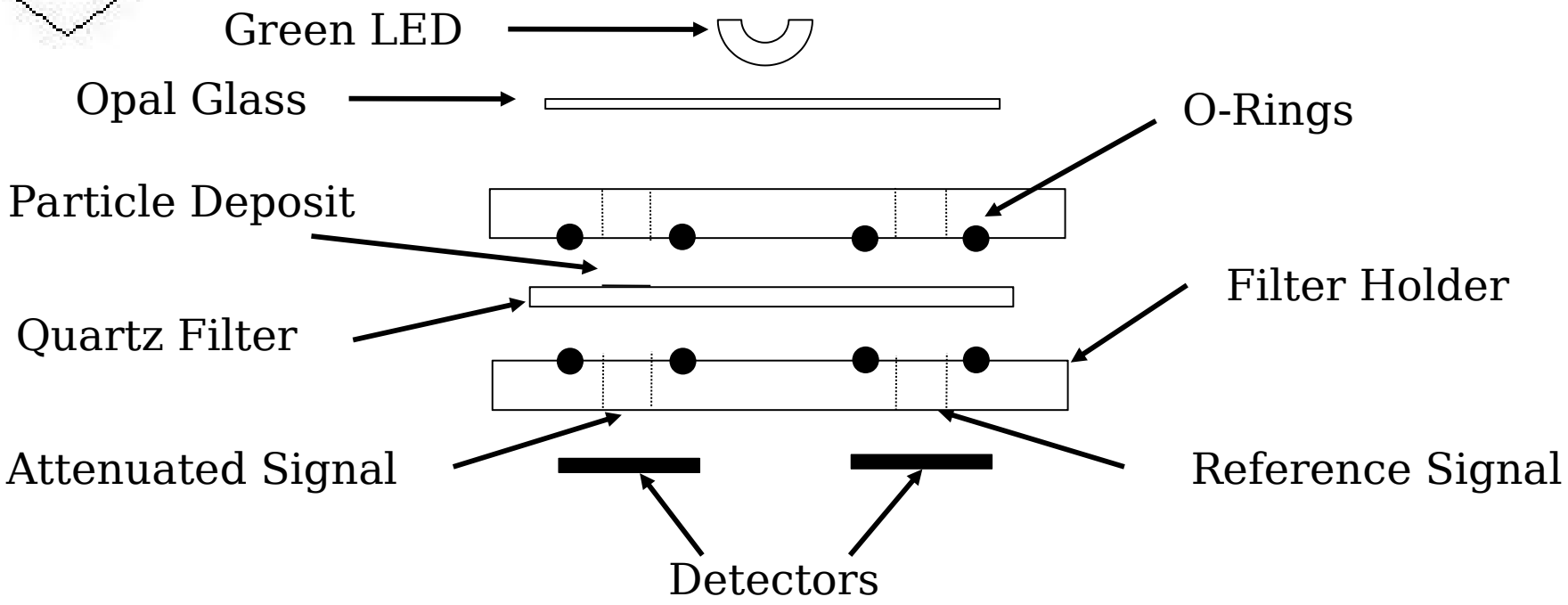
Particle Soot Absorption Photometer



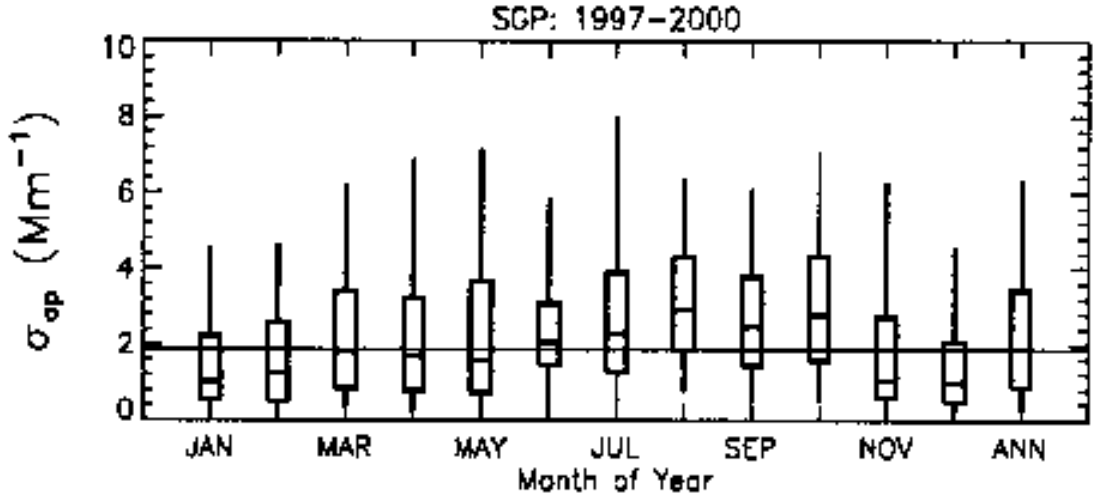
Beers Law

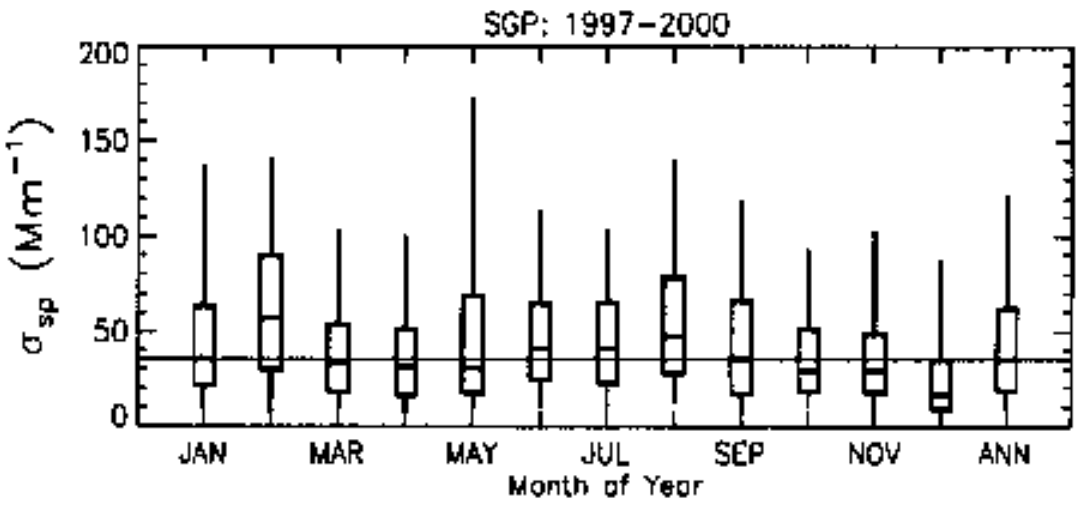
$$A = \ln(I_O / I)$$

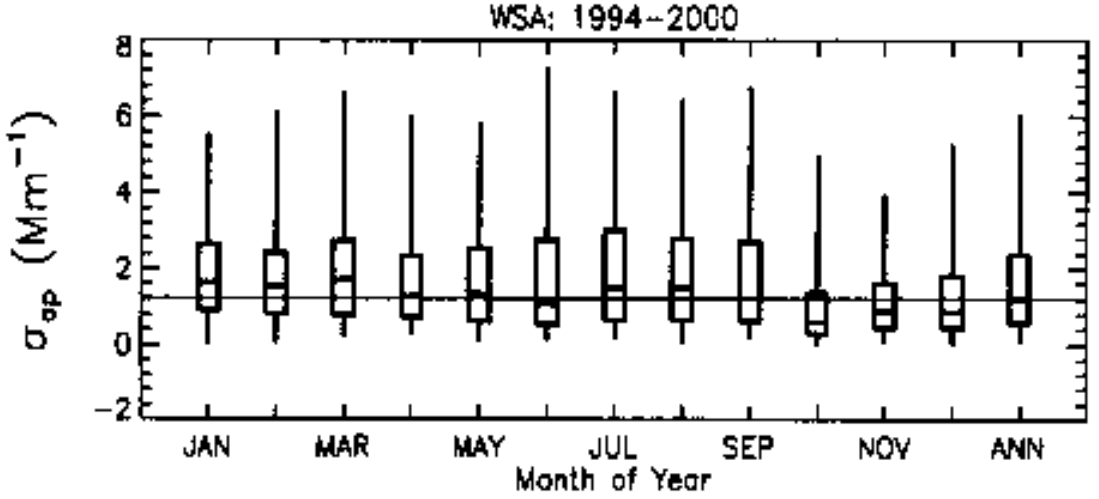
A is the absorbance
I is the intensity of light transmitted
$\mathbf{I_o}$ is the light intensity before passing through the filter.

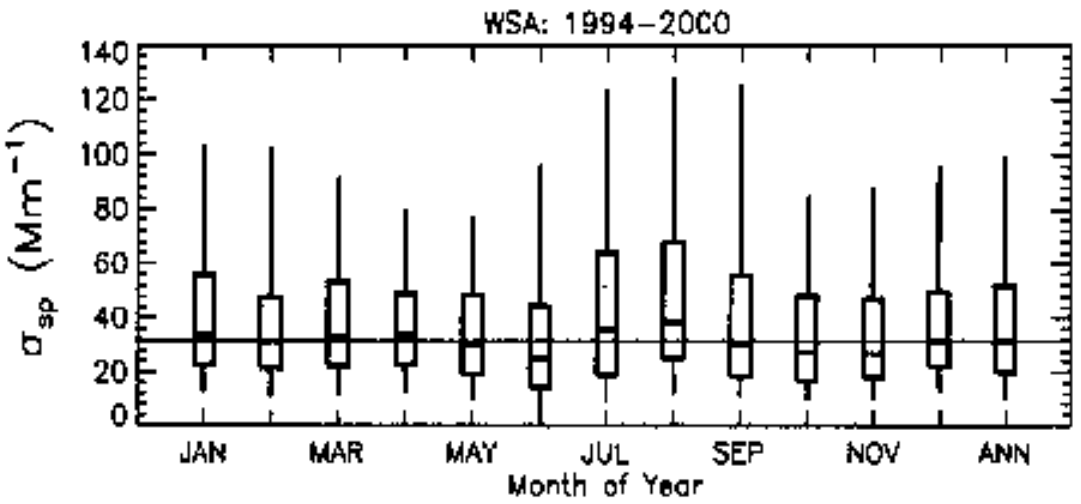


Seasonal and Regional Variability: Aerosol Absorption Coefficient



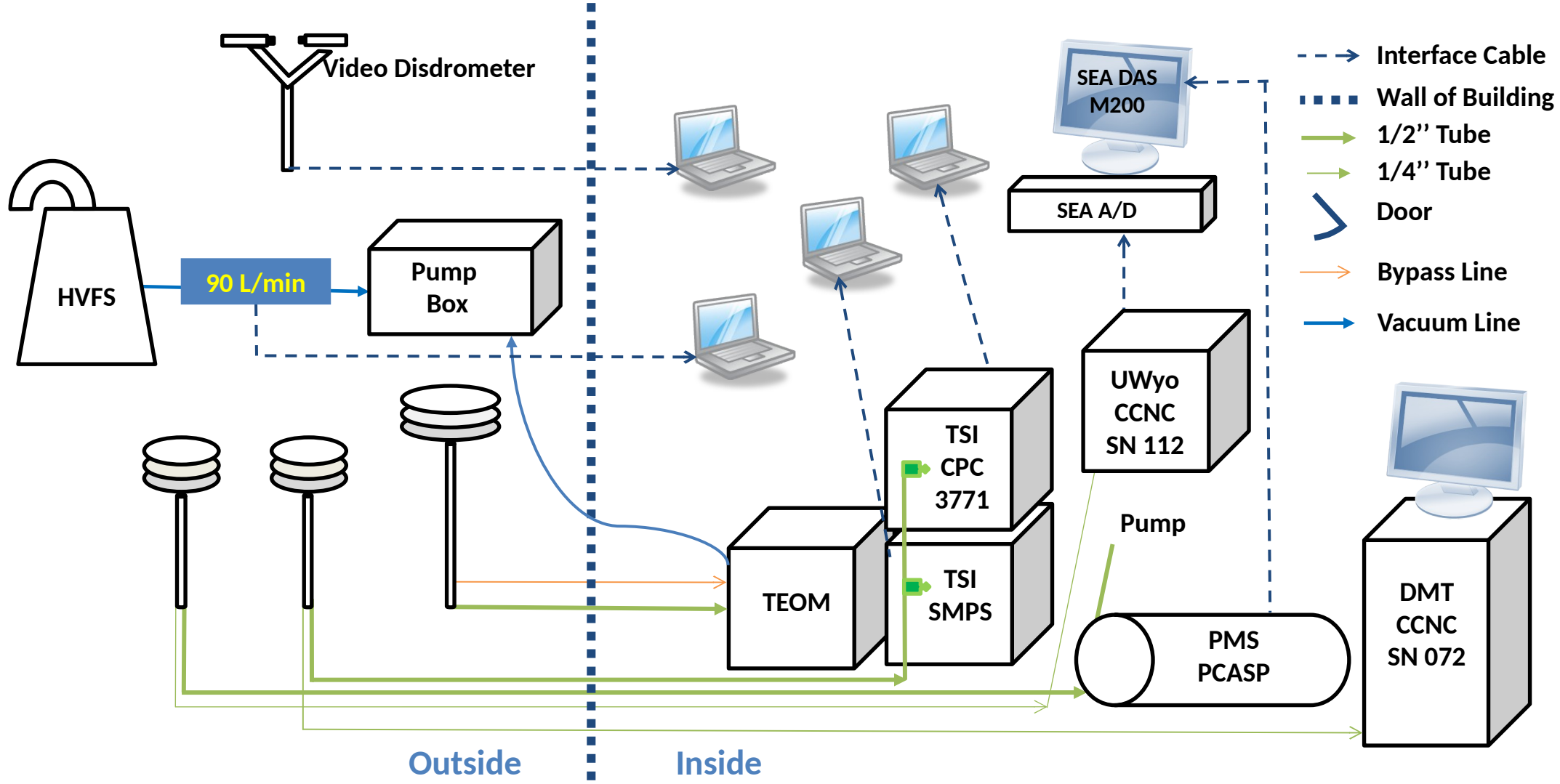






λ = 550 nm, D < 10 μm, RH < 40%

POLCAST Clifford Hall Aerosol Rooftop Sampling

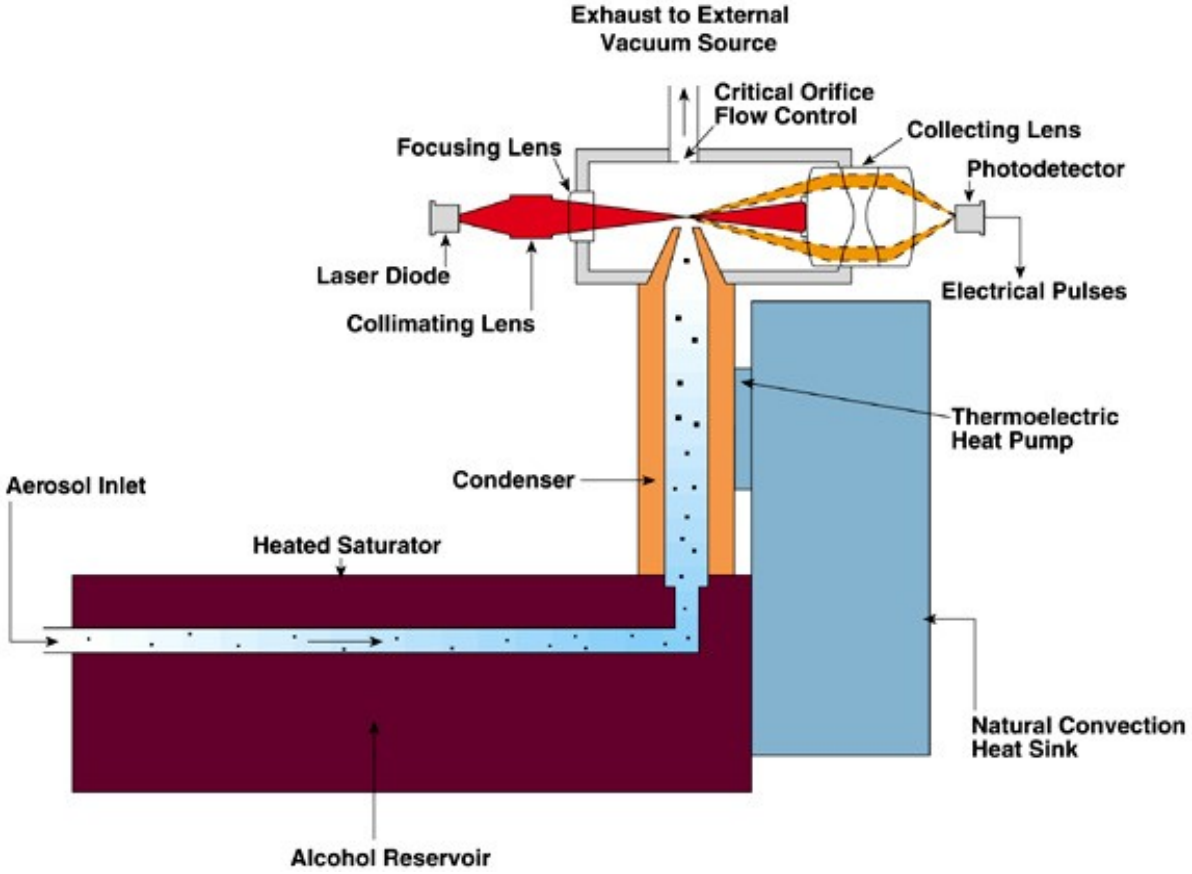


HVFS - High Volume Filter Sampler
PCASP - Passive Cavity Spectrometer Probe
SMPS - Scanning Mobility Particle Sizer
TEOM - Tapered Element Oscillating Microbalance

A/D - Analog to Digital Board
CPC - Cloud Particle Concentration
CCNC - Condensation Nuclei Counter
DAS - Data Acquisition System

DMT - Droplet Measurement Technology
PMS – Particle Measurement Systems
SEA - Science Engineering Associates
TSI - TSI Inc.

Condensation Particle Counter (CPC)



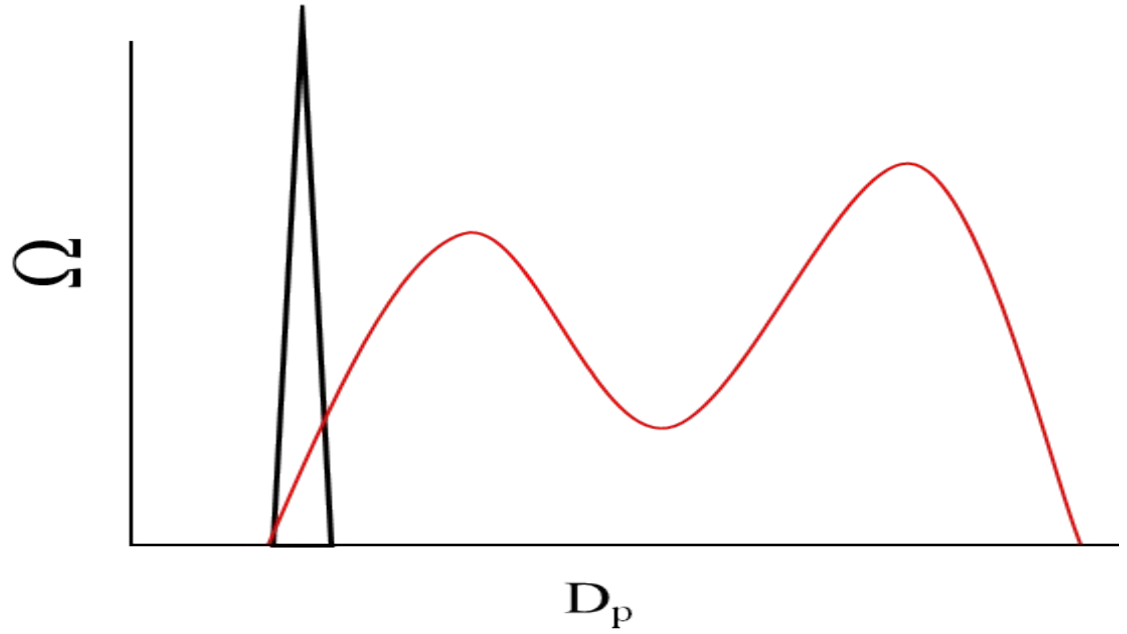
CPC Model 3772

CPC Model 3775

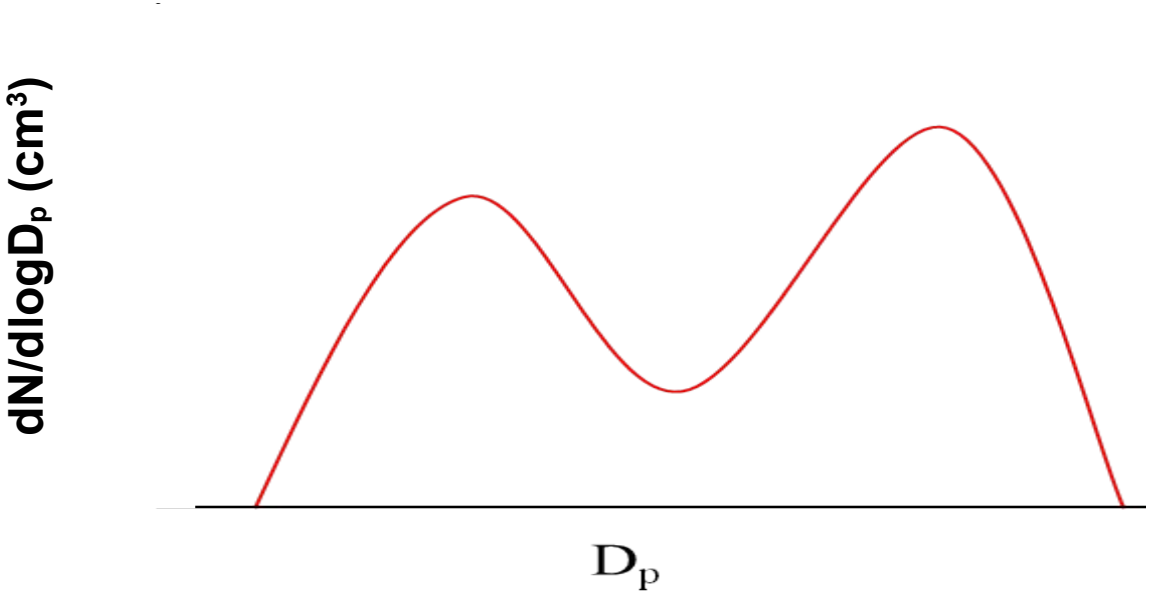
Alcohol vapor condenses onto particles which create particles large enough to be detected by an optical particle counter. Upon entering the instrument, the air sample passes through a saturation block where alcohol evaporates saturating the flow. The air sample next enters a condenser tube which cools the air sample. Cooling of the air sample creates a supersaturated environment and the alcohol condenses onto particles, regardless of particle composition.

Differential Mobility Analyzer (DMA)

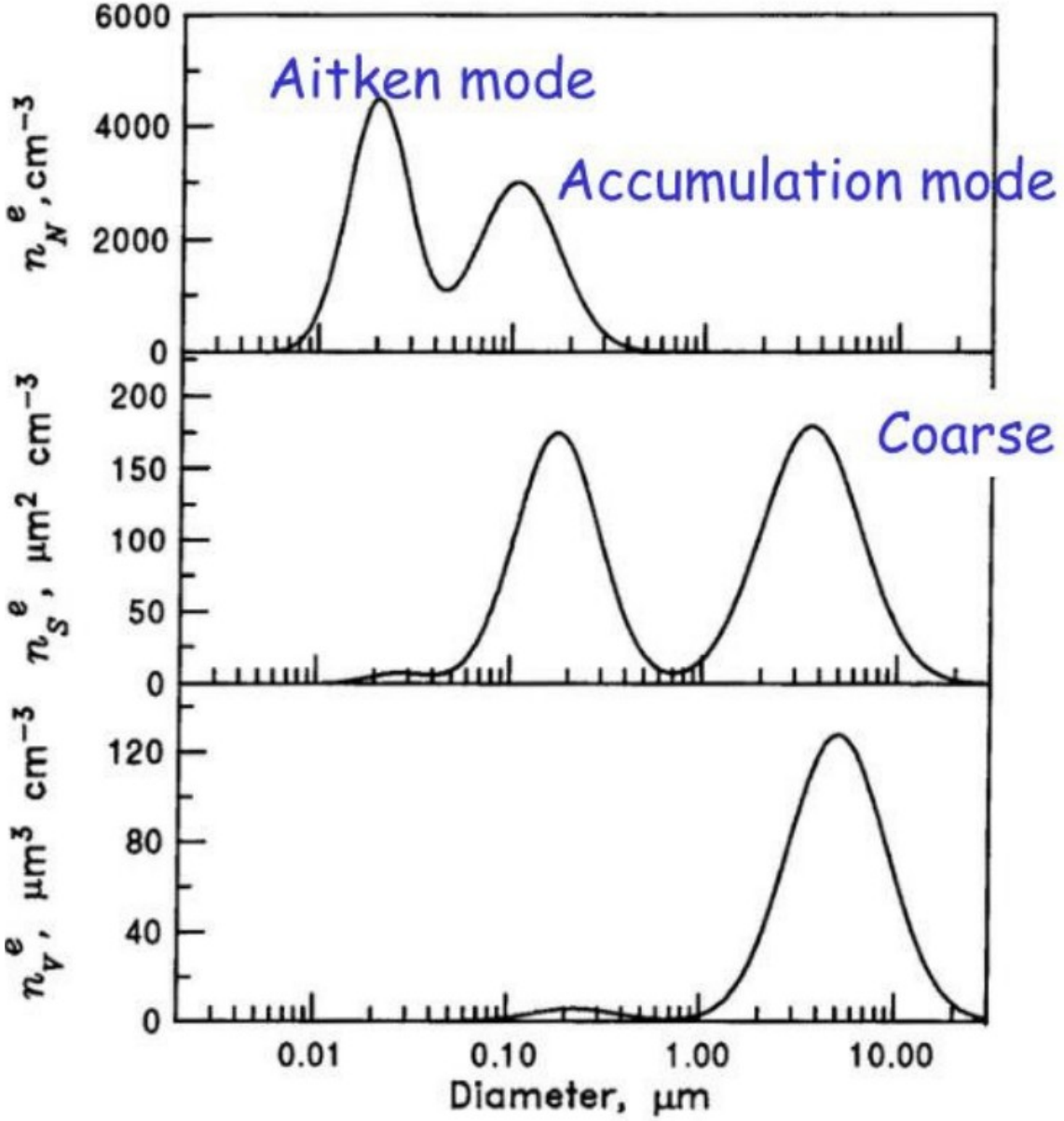
Polydisperse Aerosol In



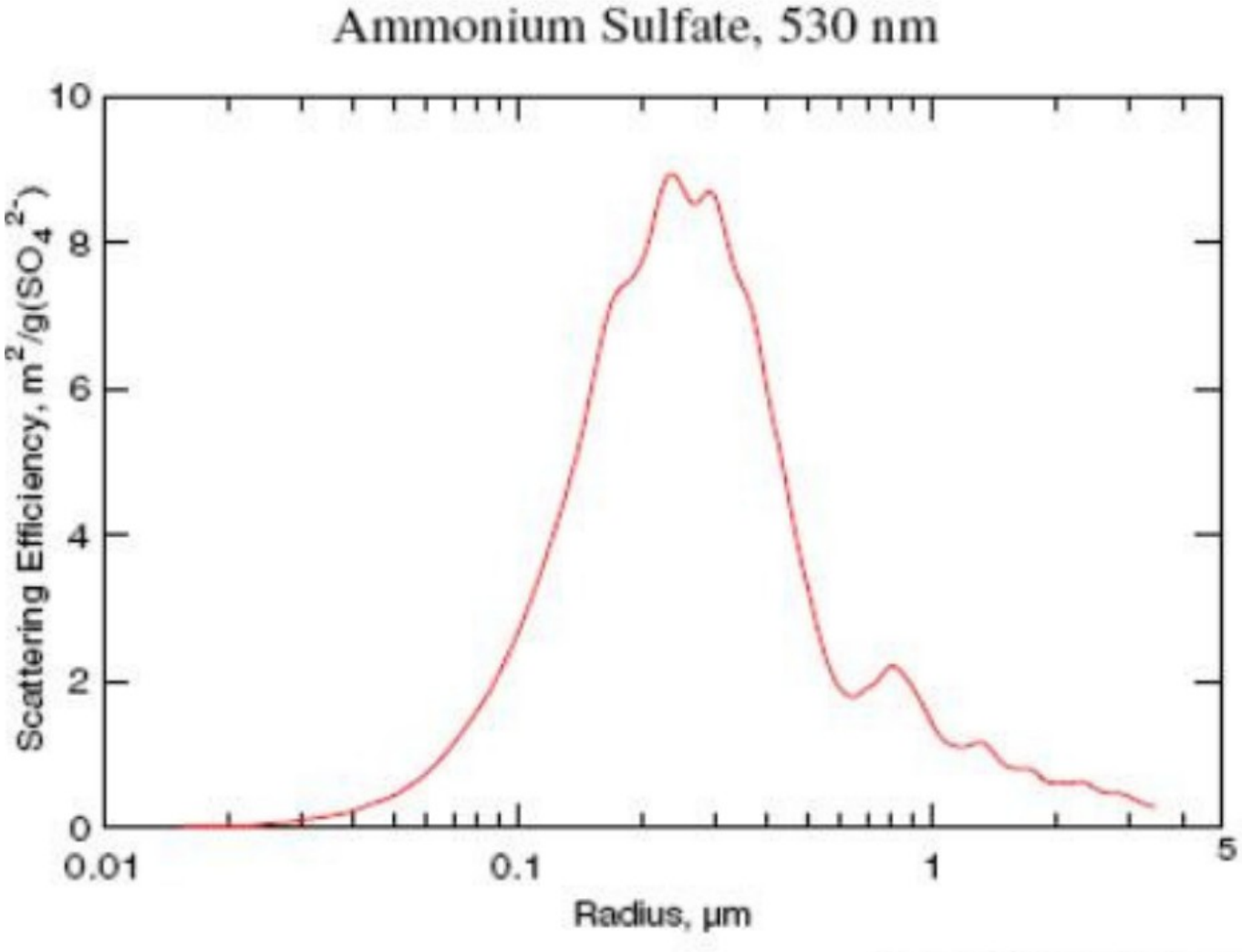
Monodisperse Aerosol Out



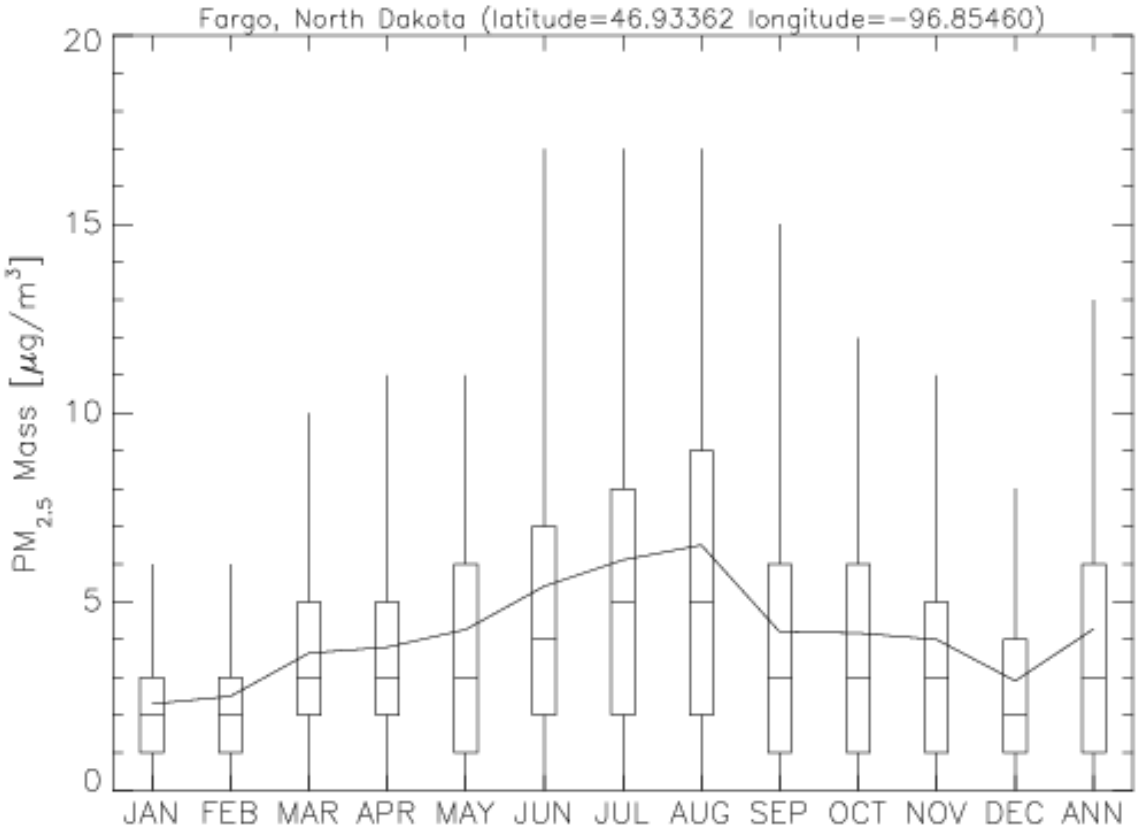
Log-normal Distributions



Scattering Cross-section



Aerosols Filter / Mass Sampling



Yearly cycle of 2.5 µm particulate matter at Fargo, North Dakota. The box and whiskers give the 5, 25, 50, 75, and 95 percentiles. The solid line represents the monthly mean. The x axis denotes the month of the year, with the last box-and-whisker denoting the percentile for the whole period. The statistics are based on all valid, hourly averaged data from June 2000 through December 2003.