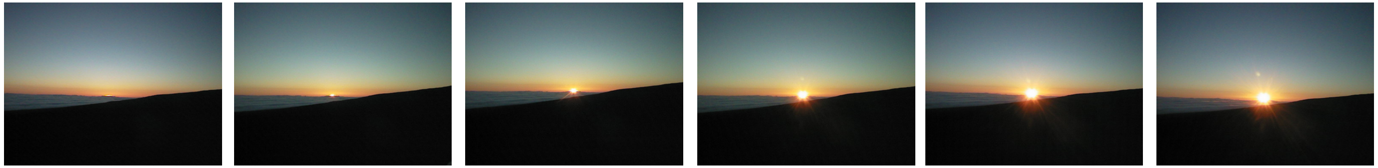


Variability of Aerosol Properties as Determined by Long-term Surface Observations

David Delene

For More Information See:

Delene, D. J., and J. A. Ogren, Variability of aerosol optical properties at four North American surface monitoring sites, Journal of Atmospheric Sciences, 59, 1135-1150, 2002. (Abstract, Manuscript, PDF)

[328 Citation – Google Scholar Page]

Definitions

Aerosols

Suspended solid or liquid matter, with a small settling velocity

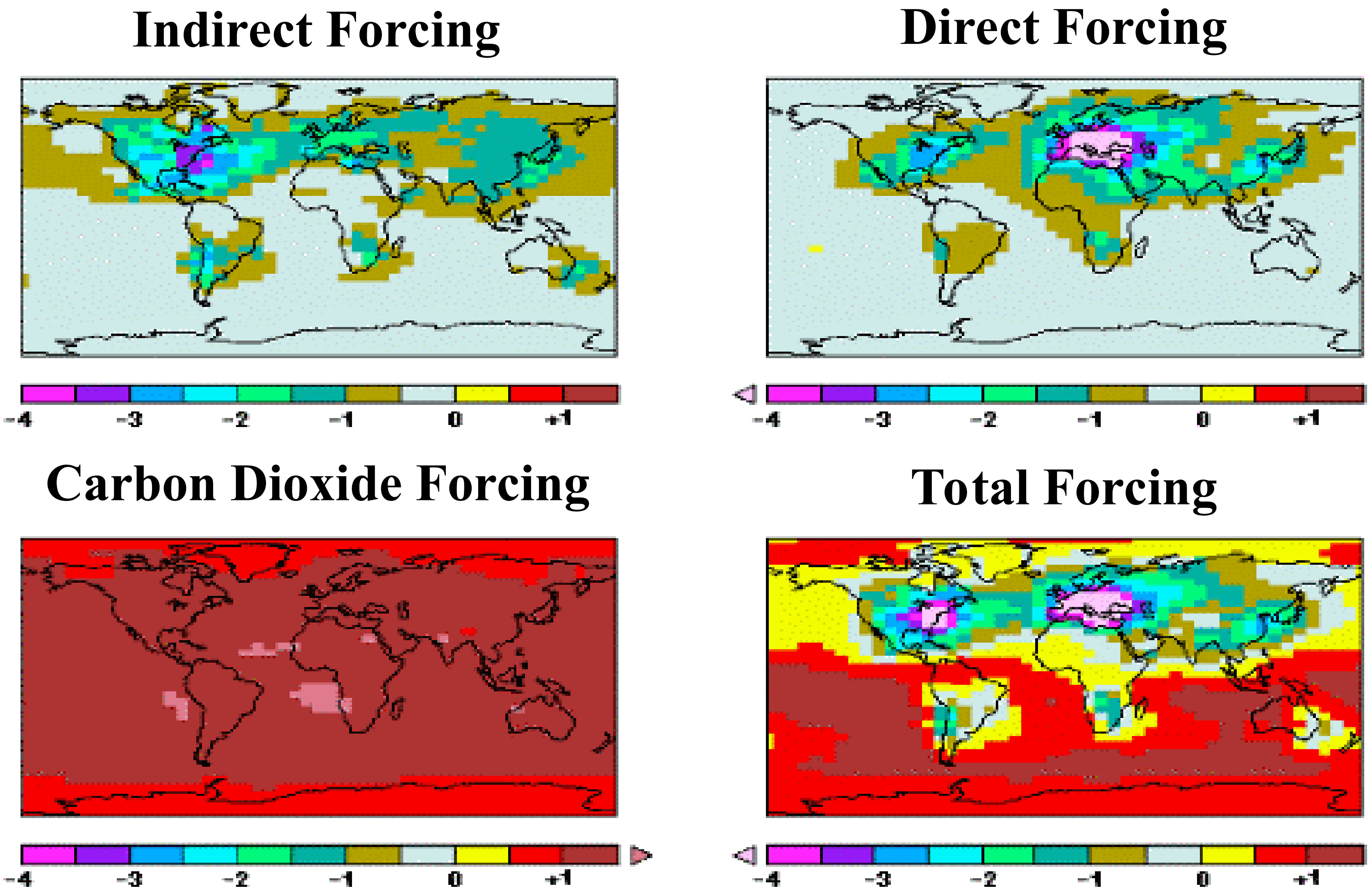
Atmospheric Aerosols

Suspended material in the Earth's atmosphere that have residence times of days, to a few weeks. Atmospheric Aerosols are sometimes referred to as "particles"

American Meteorological Society (AMS) Glossary

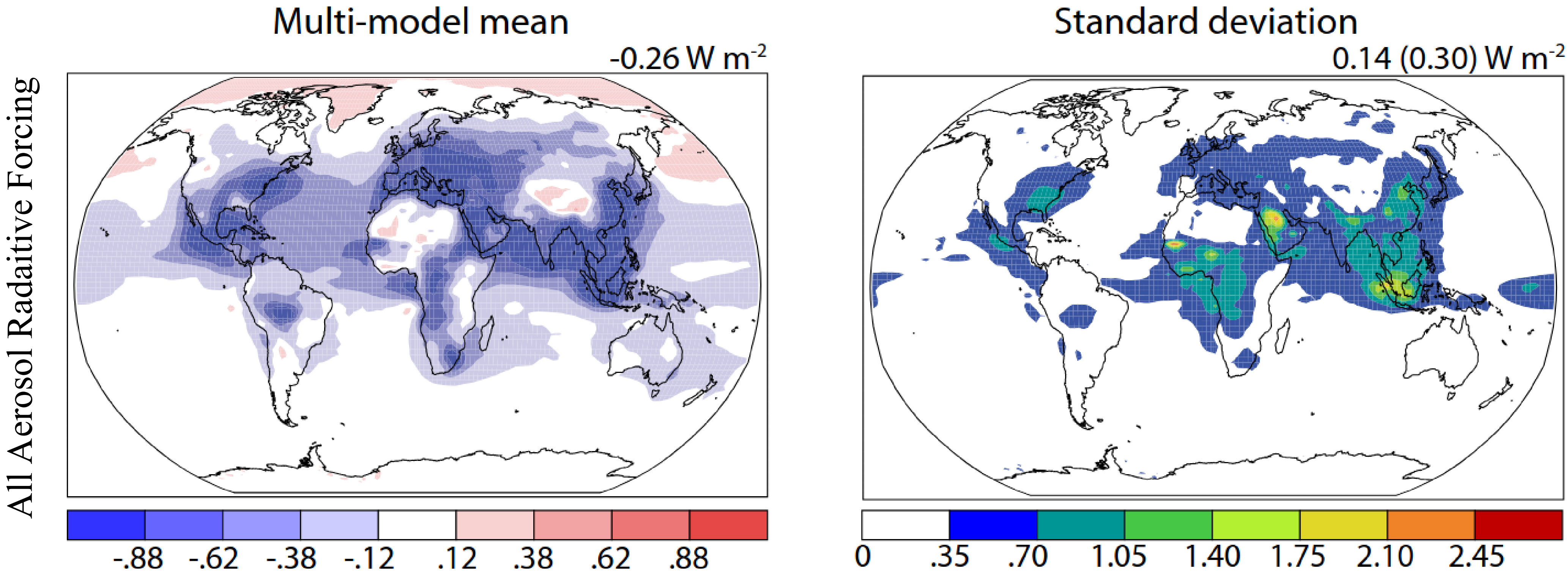
A colloidal system (heterogeneous, particle remain dispersed, not molecularly mixed) in which the dispersed phase is composed of either solid or liquid particles, and in which the dispersion medium is some gas, usually air (Reference).

What is the difference between a particle and an aerosol?



Climate forcing predicted by Lawrence Livermore National Laboratory Global Aerosol Model [Catherine C. Chuang & Joyce E. Penner].

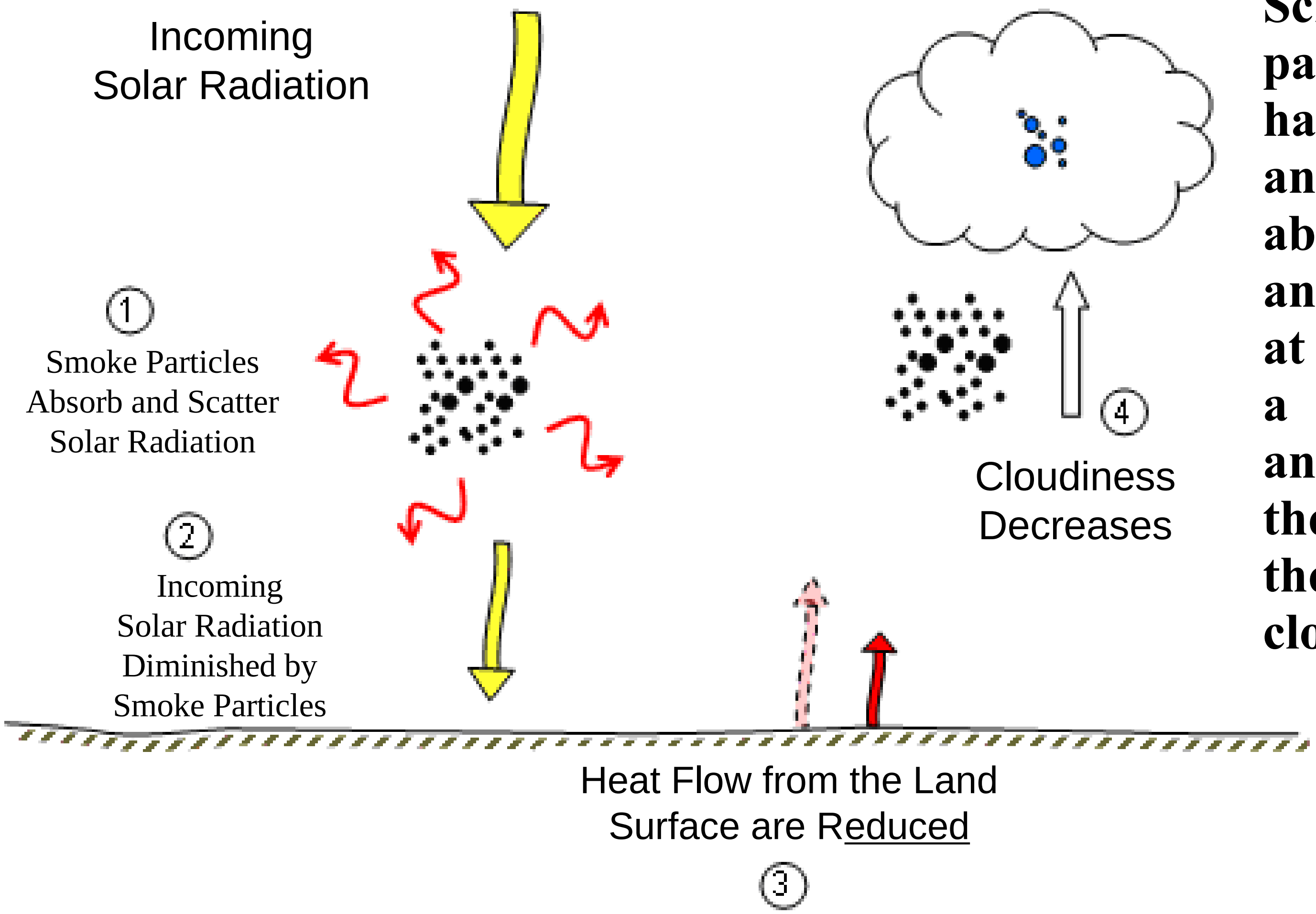
Preindustrial to Present-Day Forcig



Pattern of ACCMIP models 1850 to 2000 forcings, mean values (left) and standard deviation (right) for aerosols. Values above are the average of the area-weighted global means, with the area weighted mean of the standard deviation of models at each point provided in parenthesis.

Reference: https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf

Partially Absorbing Aerosols



Schematic of the role of partially absorbing particles have on the surface radiation and cloud formation. Aerosols absorb and scatter radiation (1) and diminish the net radiation at the surface (2). The results is a reduction in surface latent and sensible heat flows from the surface (3), which reduces the strength of convection and cloud formation.

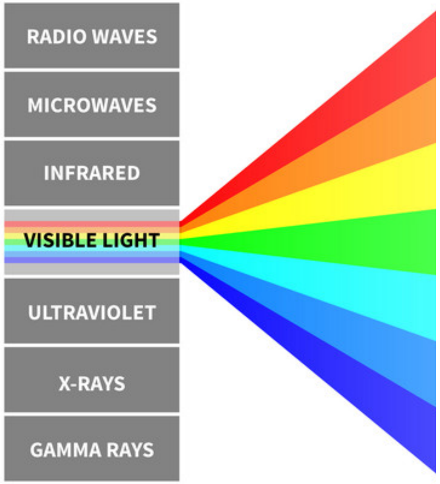
Image from NOAA Earth System Research Laboratory site, http://www.esrl.noaa.gov/research/themes/aerosols/

Atmospheric Aerosol Size Range

10^{-9}m to 10^{-5} m

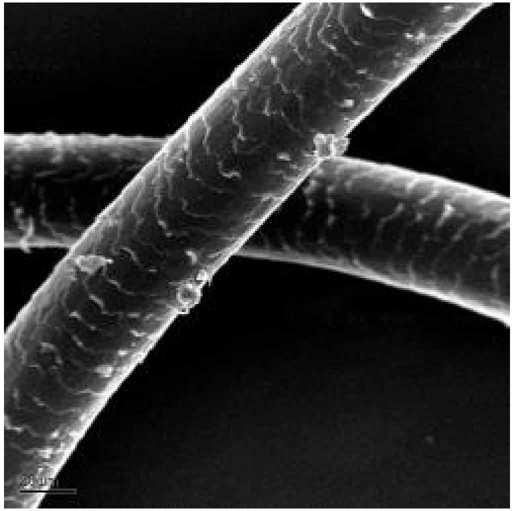
.001 µm to 10 µm

1 nm to 10,000 nm

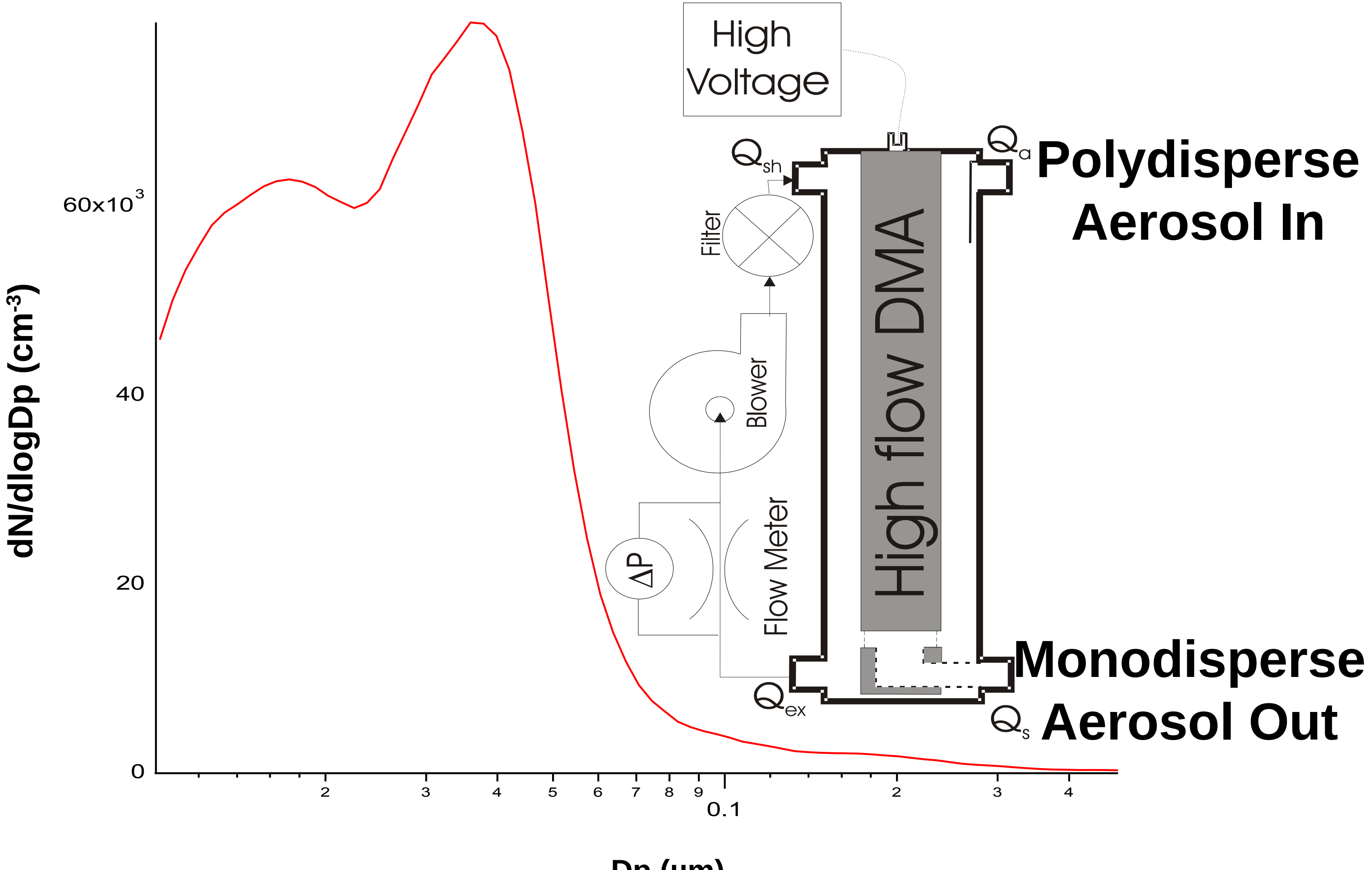


Wavelength of Visible Light?

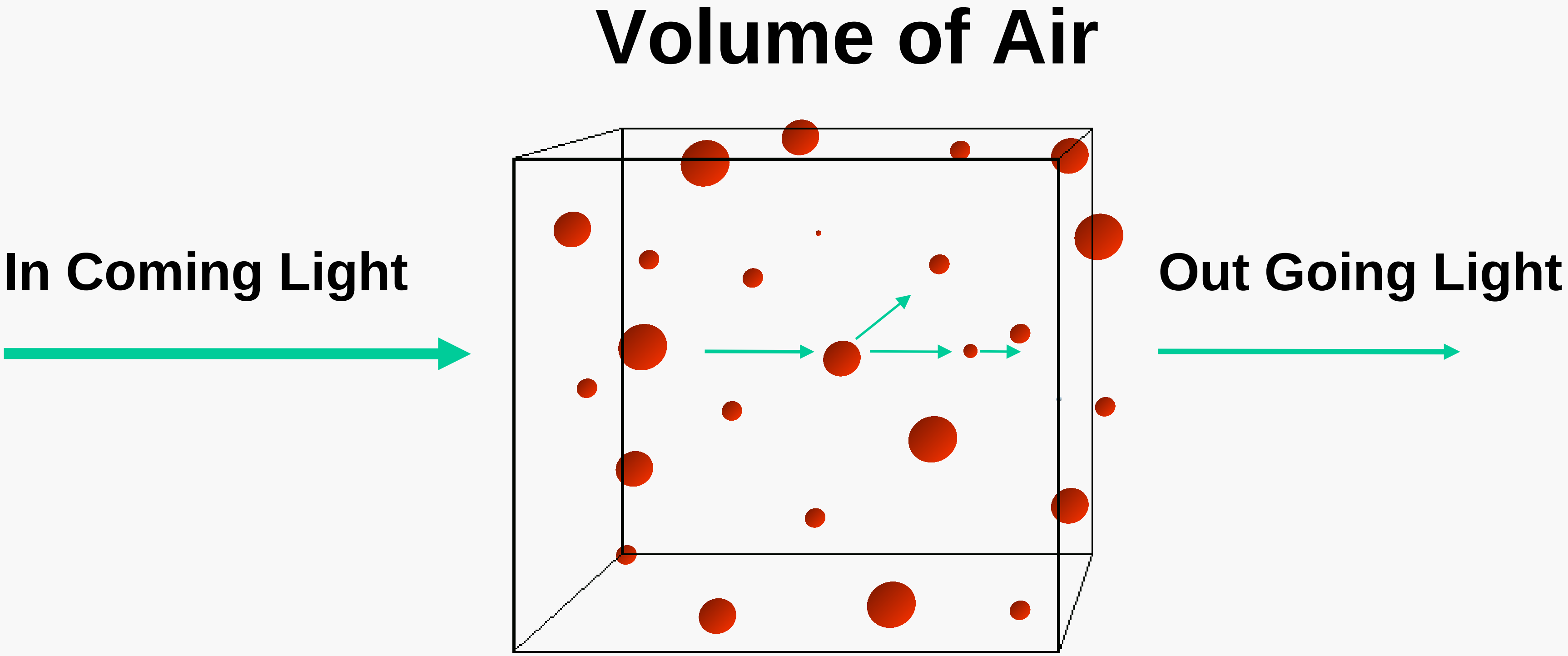
Size of a human hair?



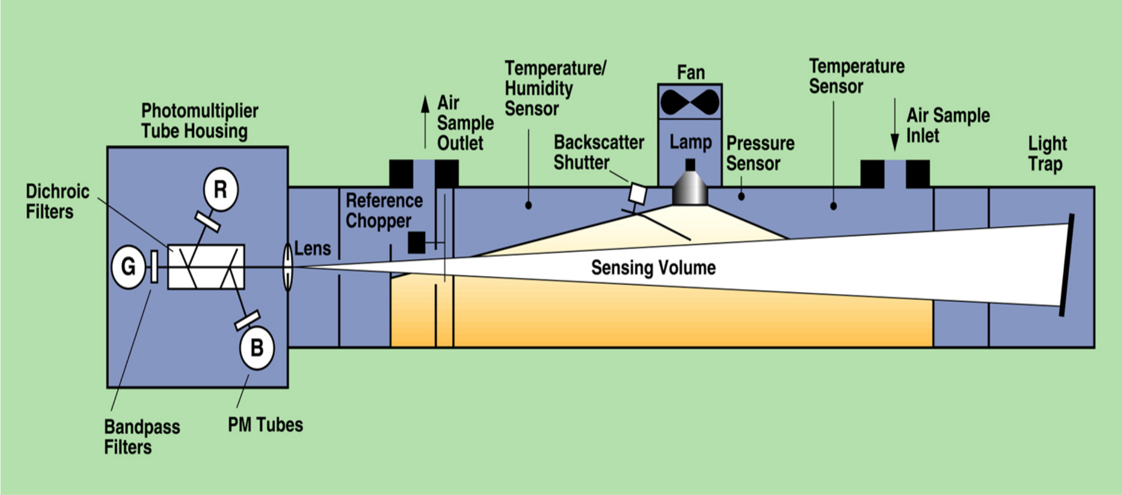
Aerosol Size Distribution



Light Scattering and Absorption by Aerosols



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

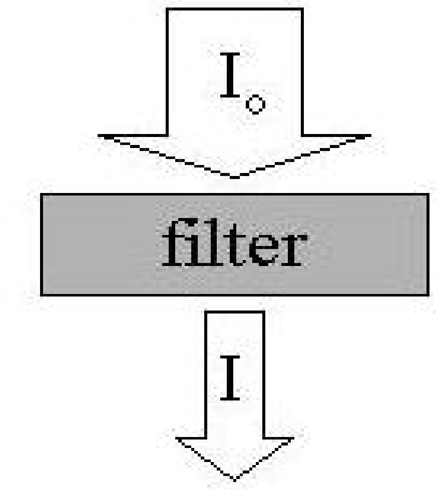
x = thickness of medium through which light passes

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

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

What is optical depth?

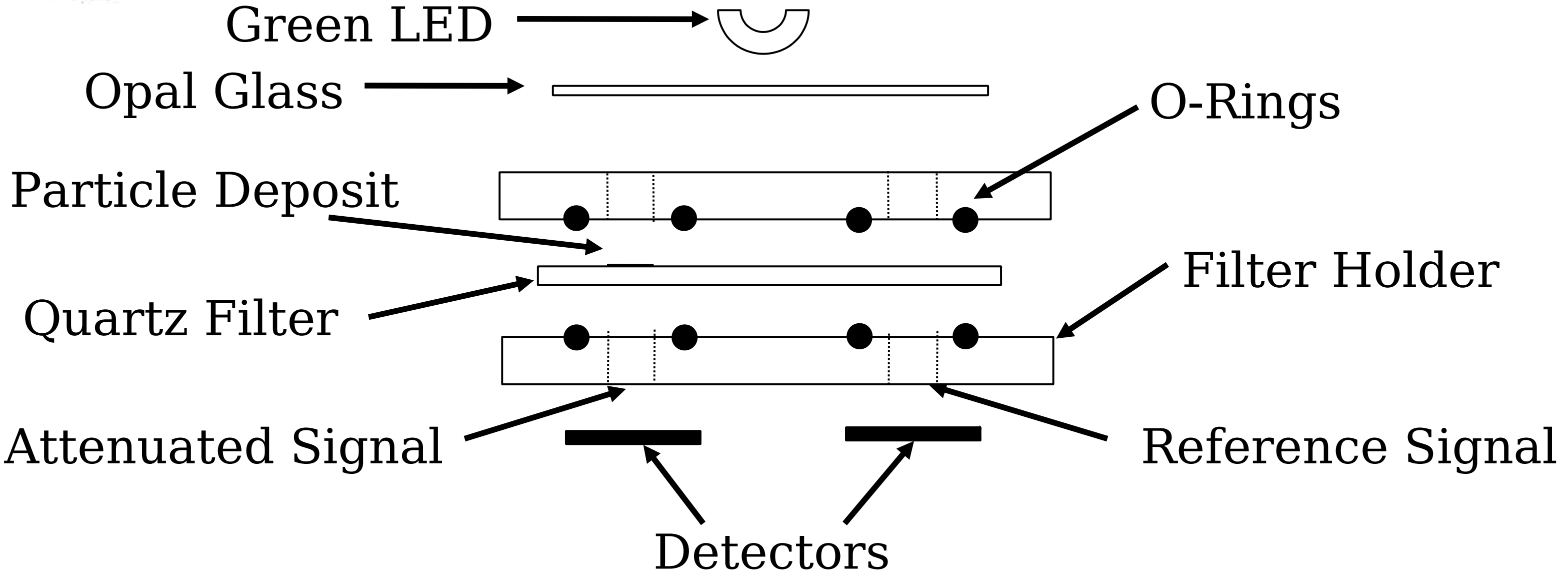
Particle Soot Absorption Photometer



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.



Aerosol Chemistry

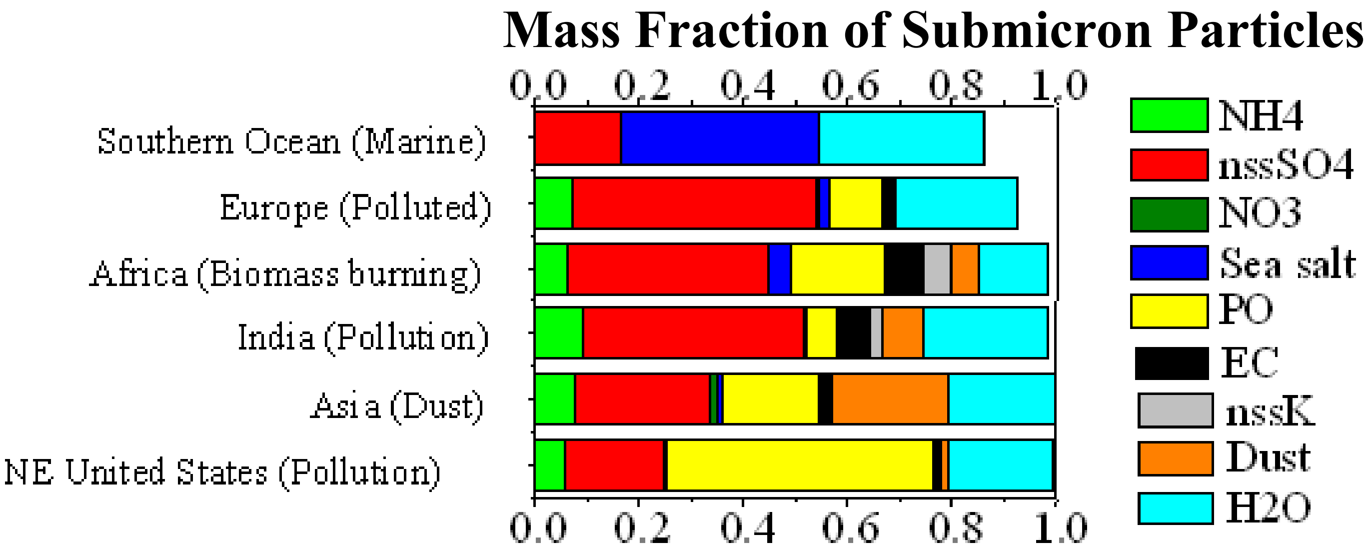
Primary

- Dust
- Sea salt
- Soot
- Primary Organics

Secondary

- SO_2 - Sulfate
- NOx - Nitrate
- VOC - Secondary Organics

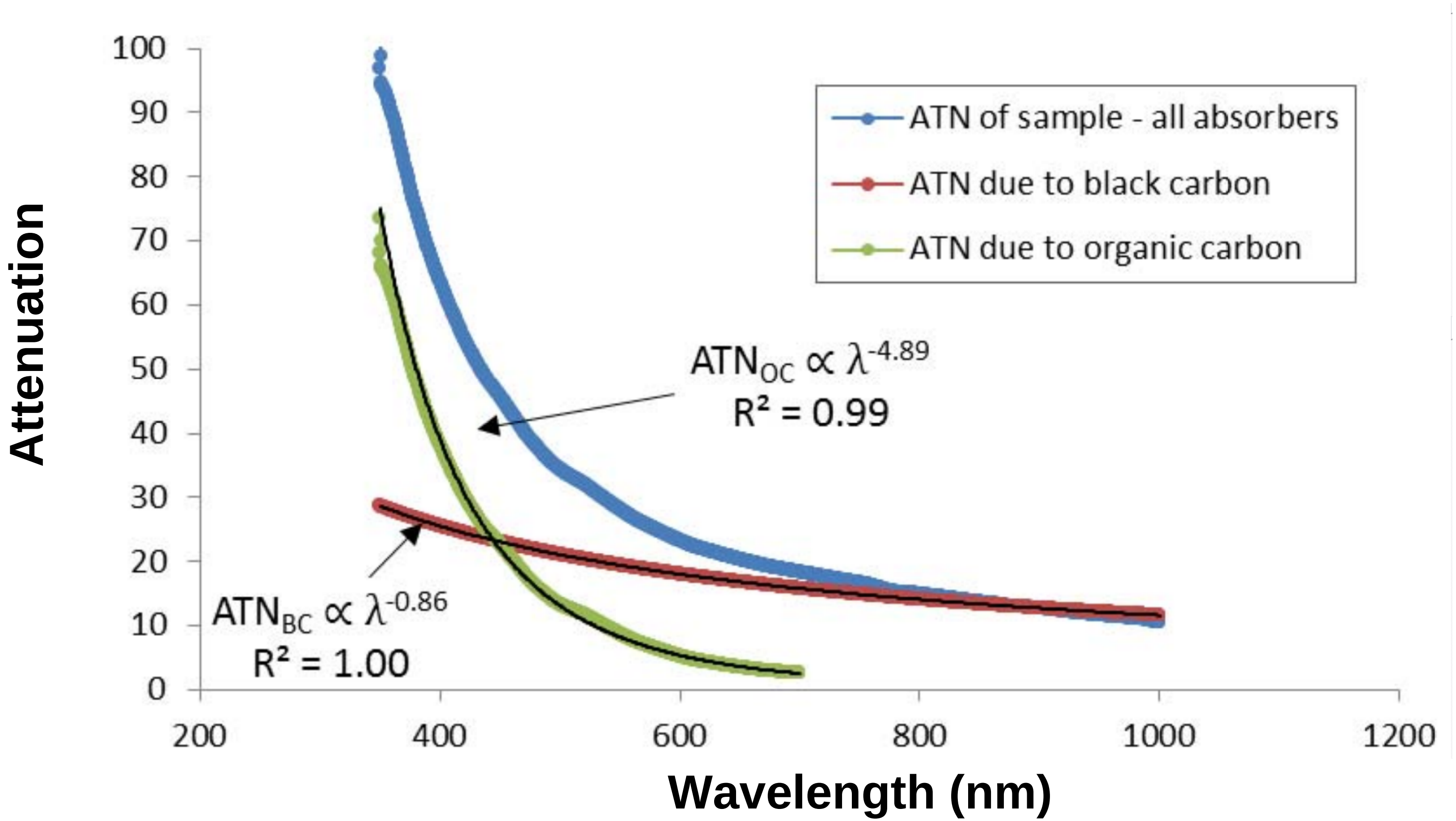
Mass Fraction of Submicron Particles from NOAA Shipboard Measurements



nssK - non-sea salt potassium

Image from NOAA Earth System Research Laboratory site, http://www.esrl.noaa.gov/research/themes/aerosols/

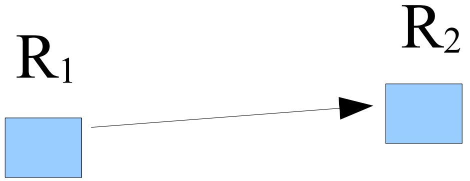
Smoke Aerosol Absorption



Estimated 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 Properties Can Have:

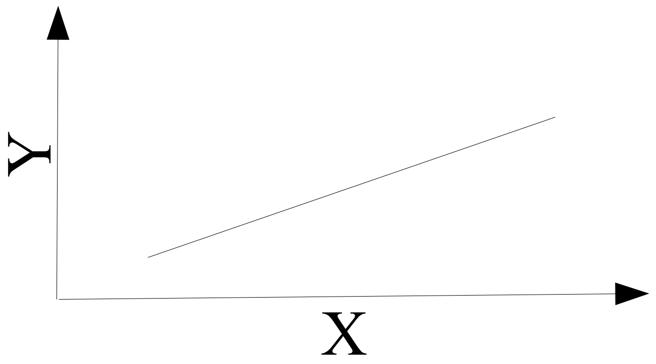
- **Regional Variability**



- **Vertical Variability**

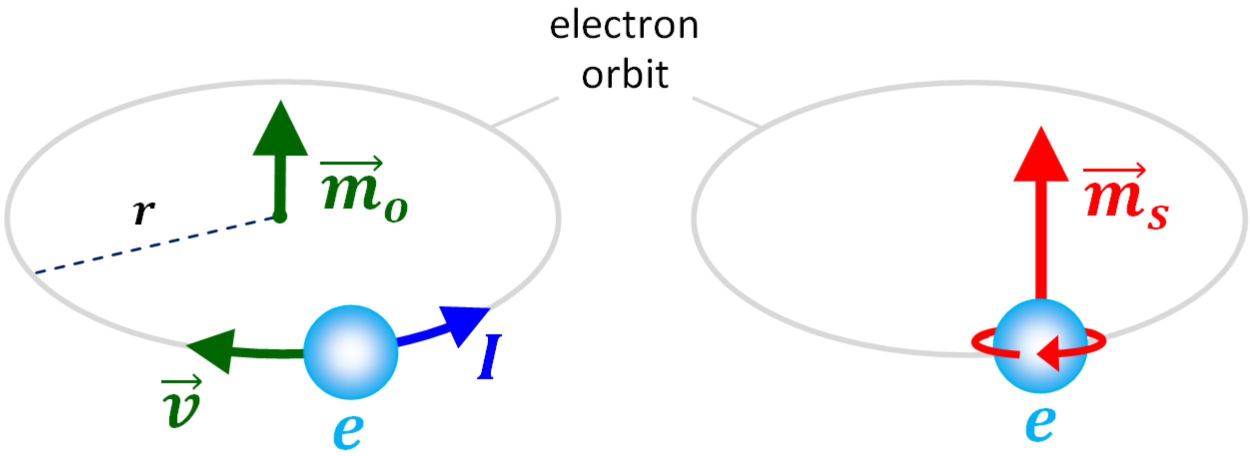
- **Temporal Variability**

- **Systematic Relationships**



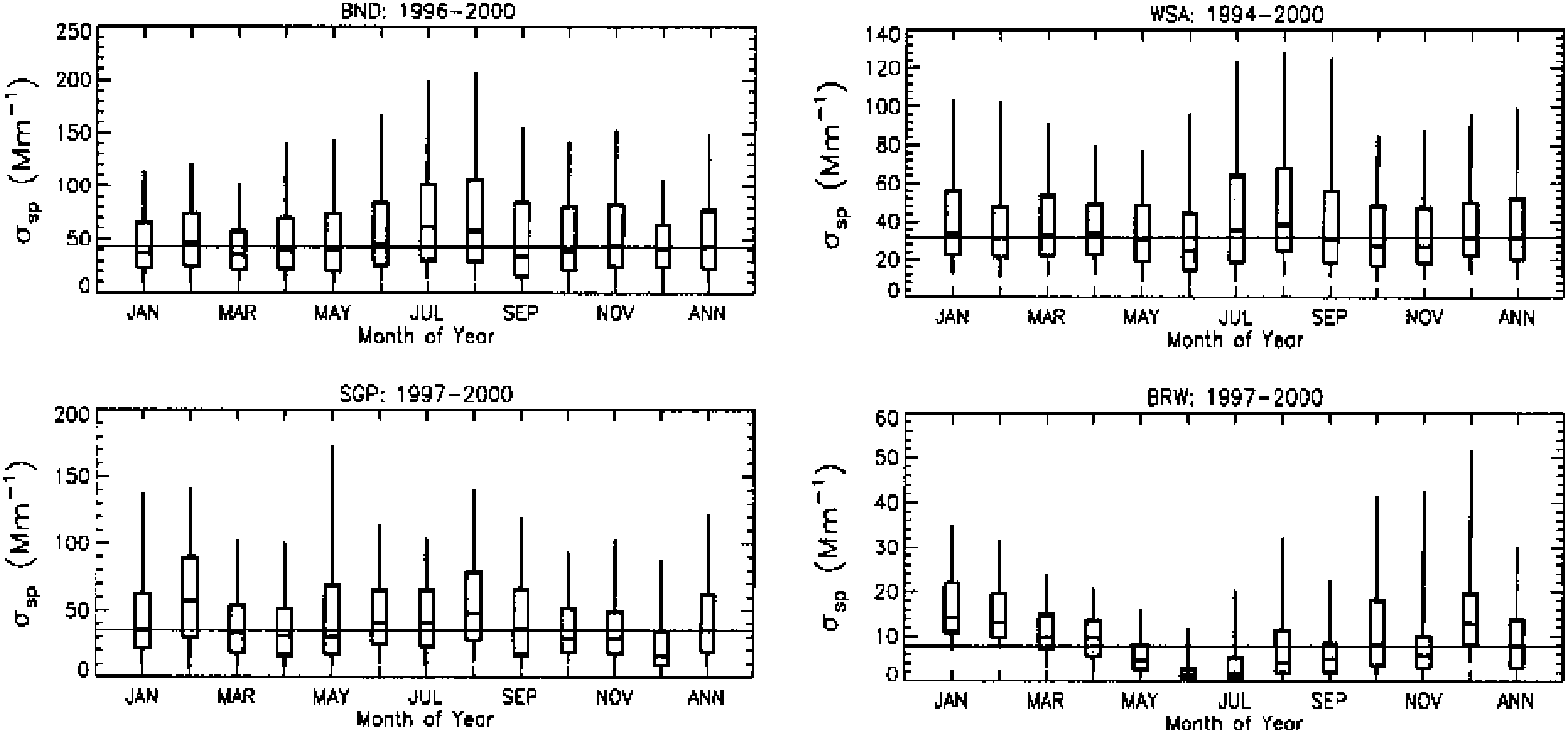
Aerosol Properties Can Be

- **Intrinsic**
  - **Intrinsic properties are inherent qualities of a thing.**
  - **Any property of any object or matter, such that occurs independently of other conditions**
- **Extrinsic**
  - **Extrinsic properties depend on the thing's relationship with other things.**
  - **How much.**



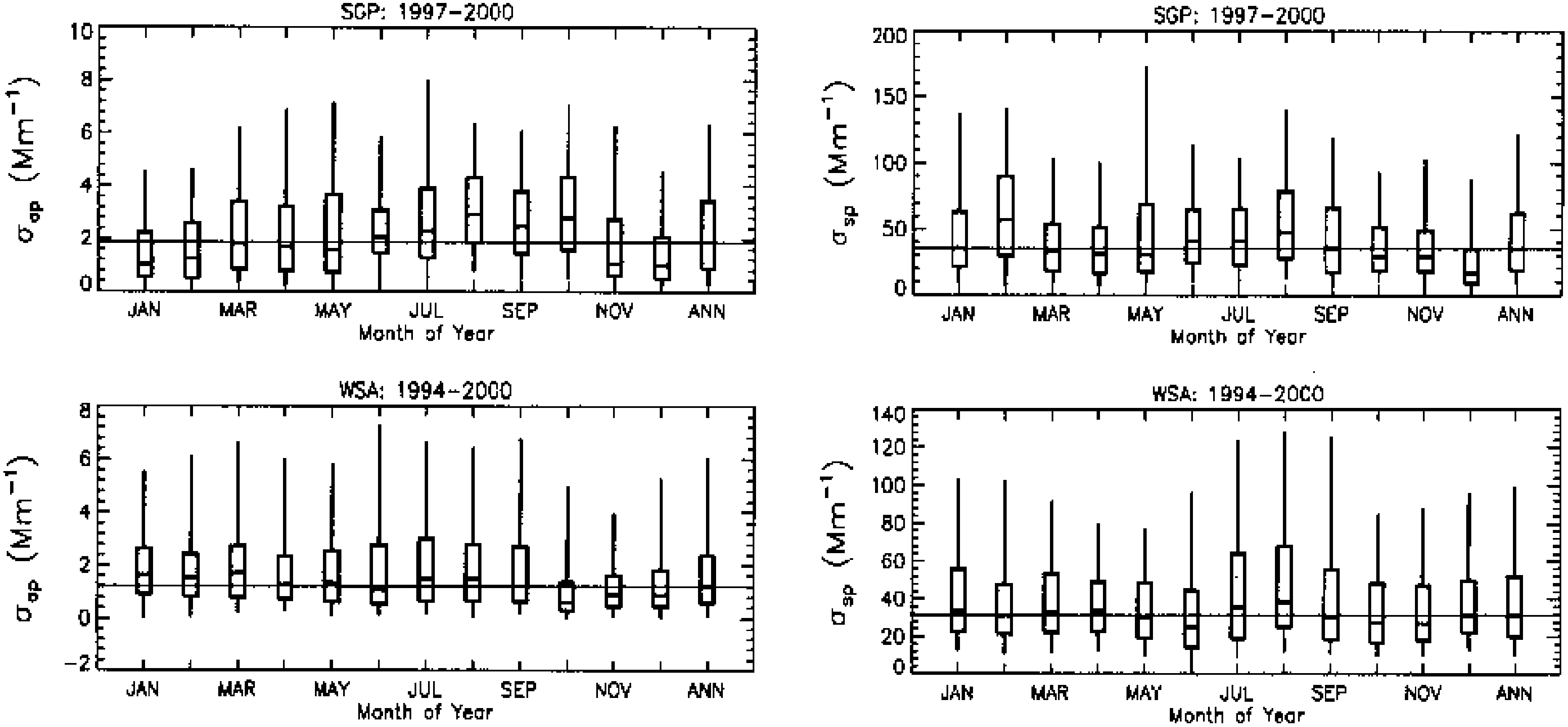
NOAA Aerosol Network

Seasonal and Regional Variability: Aerosol Scattering Coefficient



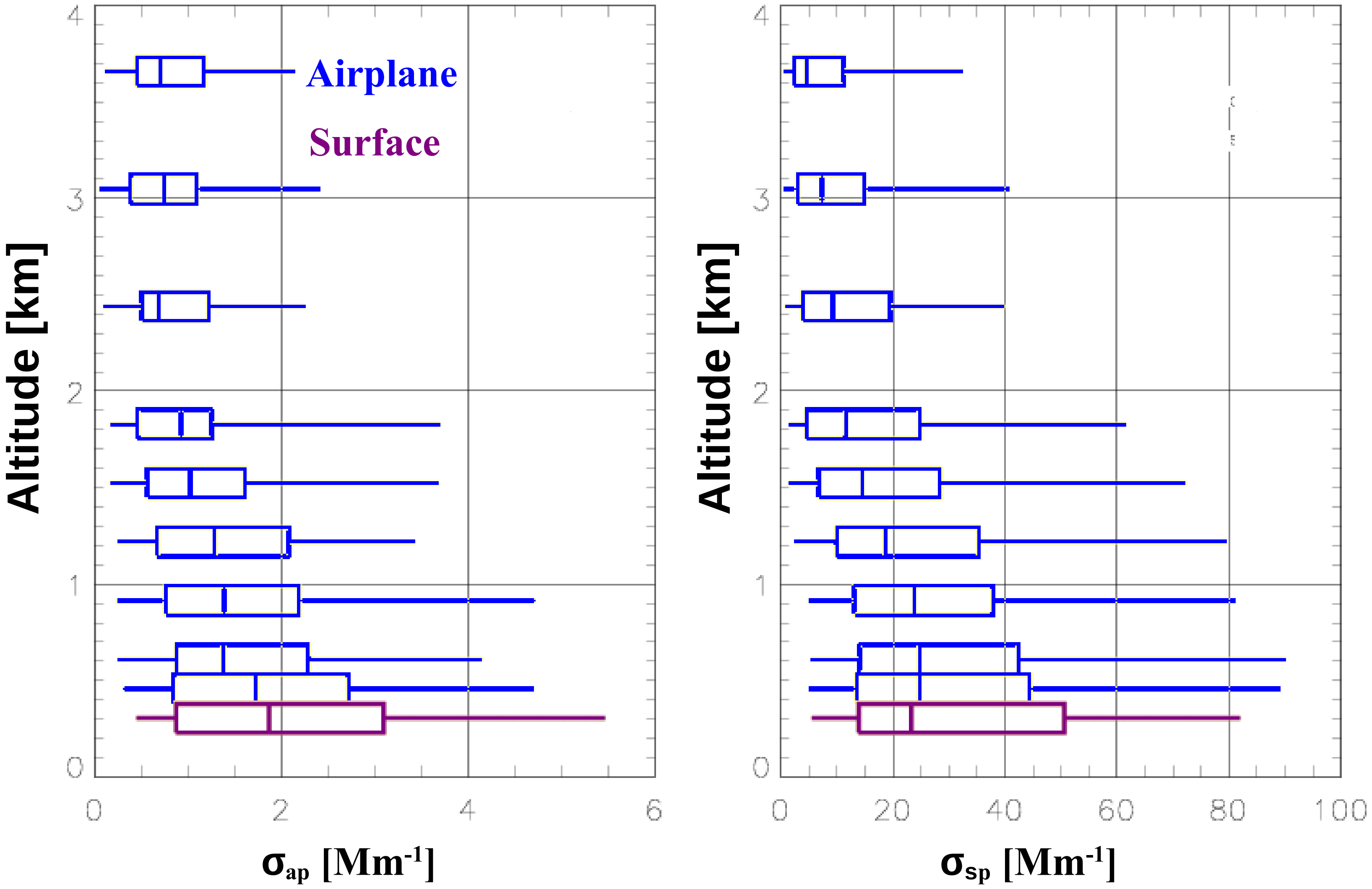
λ = 550 nm, D < 10 µm, RH < 40%

Seasonal and Regional Variability: Aerosol Absorption Coefficient

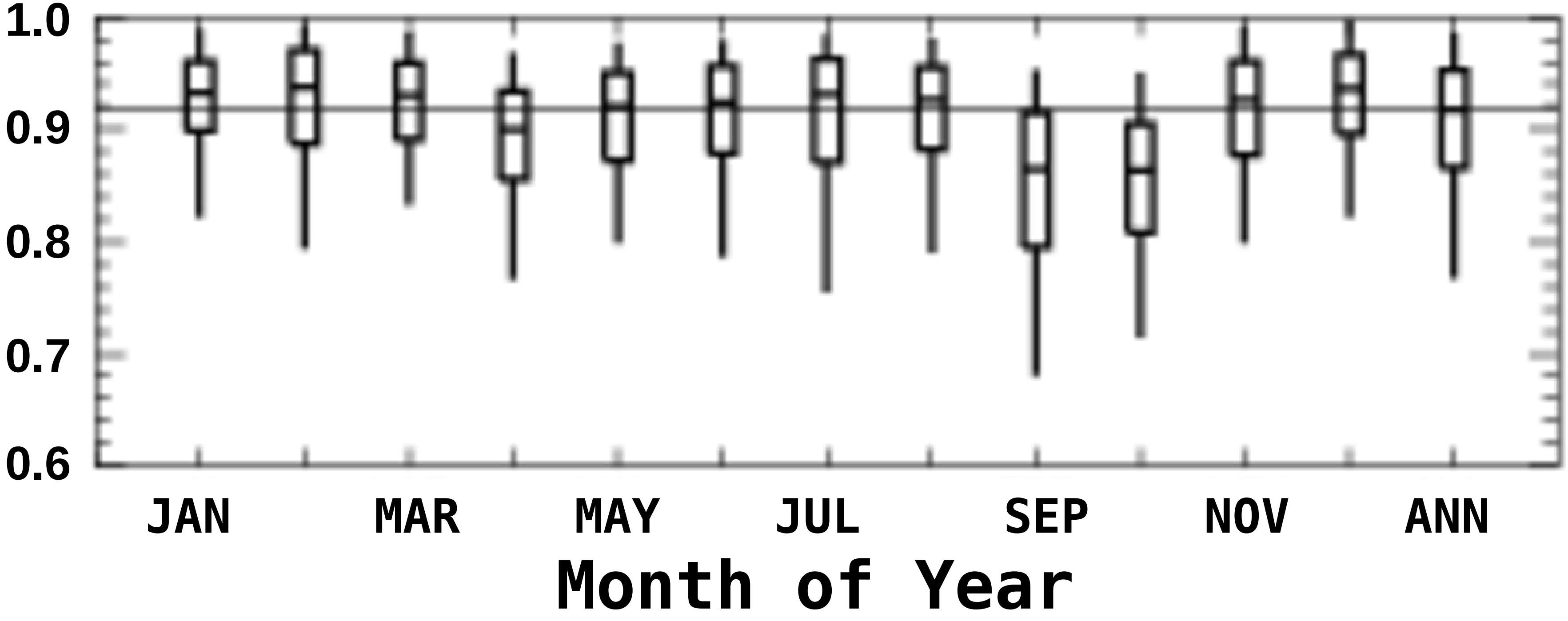


λ = 550 nm, D < 10 μm, RH < 40%

Values are adjusted to STP, λ = 550 nm, D < 1 µm, RH < 40%

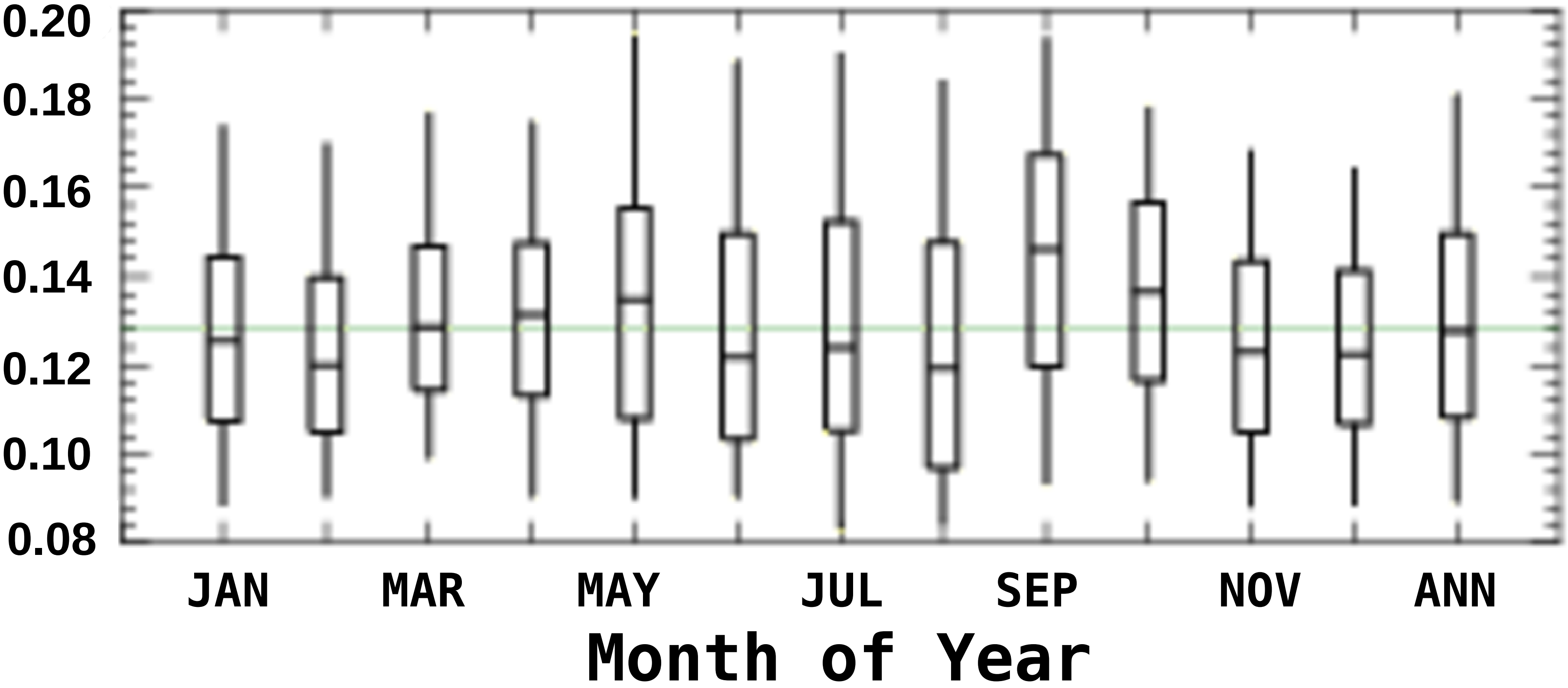


Annual Cycle of Single-scattering Albedo



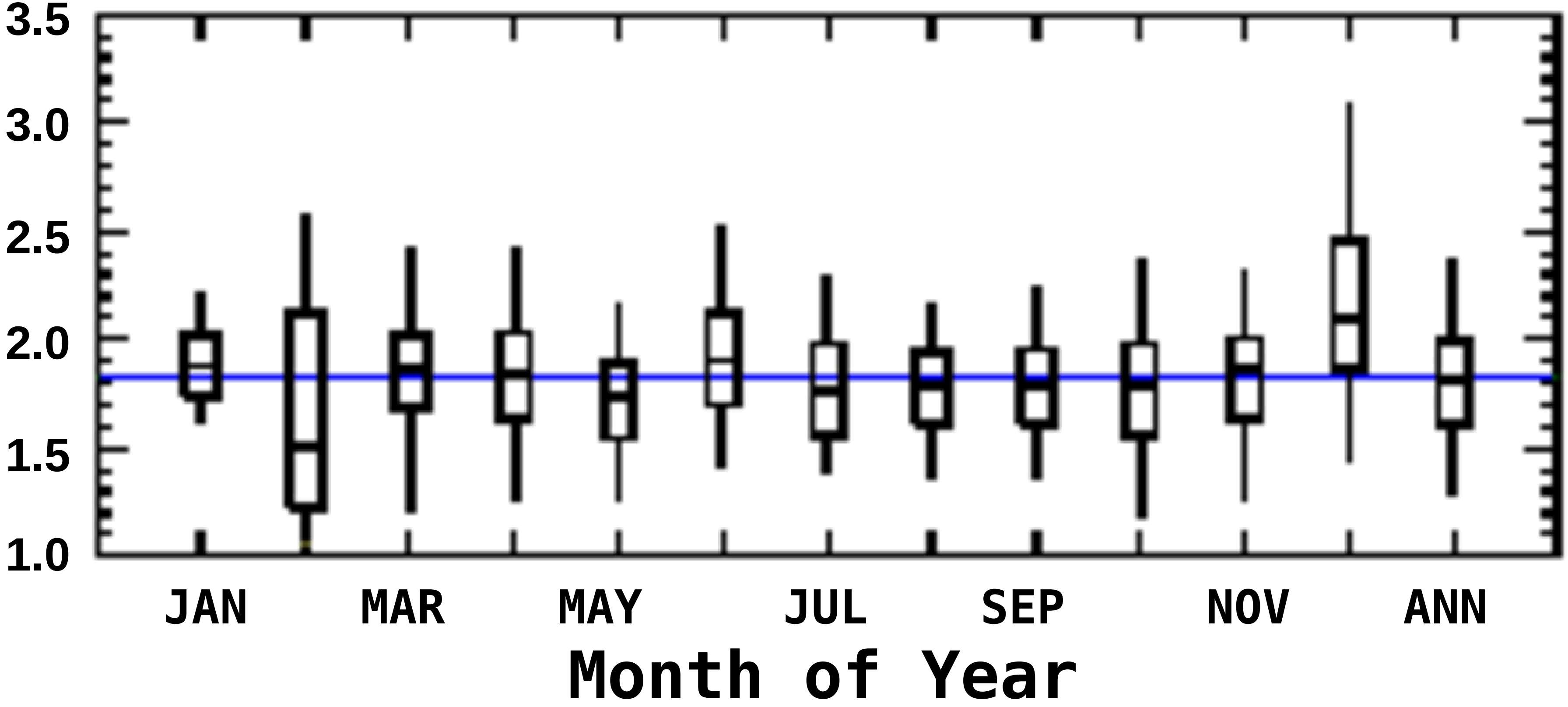
Bondville, Illinois (BND), 1996 – 2000 Hourly Averages
λ=550 nm, D<10 μm, RH<40%

Annual Cycle of Backscatter Fraction



Bondville, Illinois (BND), 1996 – 2000 Hourly Averages
λ=550 nm, D<10 μm, RH<40%

Annual Cycle of Hygroscopic Growth (f(RH)



DOE/ARM Southern Great Plains (SGP),

1999 Hourly Averages $f(RH)=\sigma_{sp}(85\%)/\ \sigma_{sp}(40\%)$

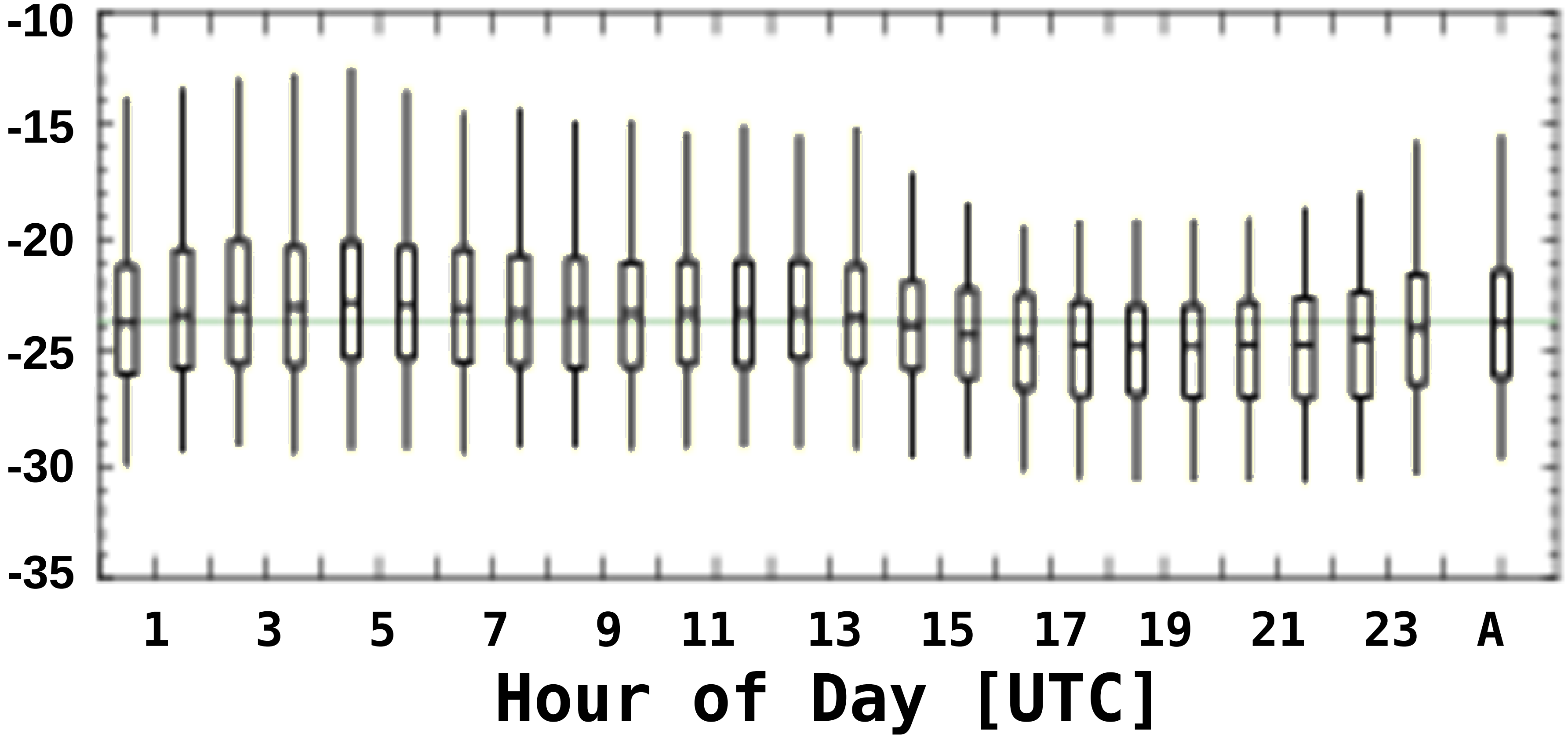
Direct Radiative Forcing Efficiency

$$\frac{\Delta F}{\Delta \delta} \approx - D S_0 T_{at}^2 (1 - A_c)(1 - R_s)^2 \tilde{\omega}_0 \bar{\beta} \left[1 - \frac{2R_s}{(1 - R_s)^2 \bar{\beta}} \left(\frac{1}{\tilde{\omega}_0} - 1 \right) \right]$$

ΔF	Aerosol Forcing	A_c	Cloud Fraction
δ	Aerosol Optical Depth	R_s	Surface Albedo
D	Daylight Fraction	$\tilde{\omega}_0$	Aerosol Single-Scattering Albedo
S_0	Solar Constant	$\bar{\beta}$	Average Aerosol Up-scatter Fraction
T_{at}	Atmospheric Transmission		

Haywood and Shine (1995)

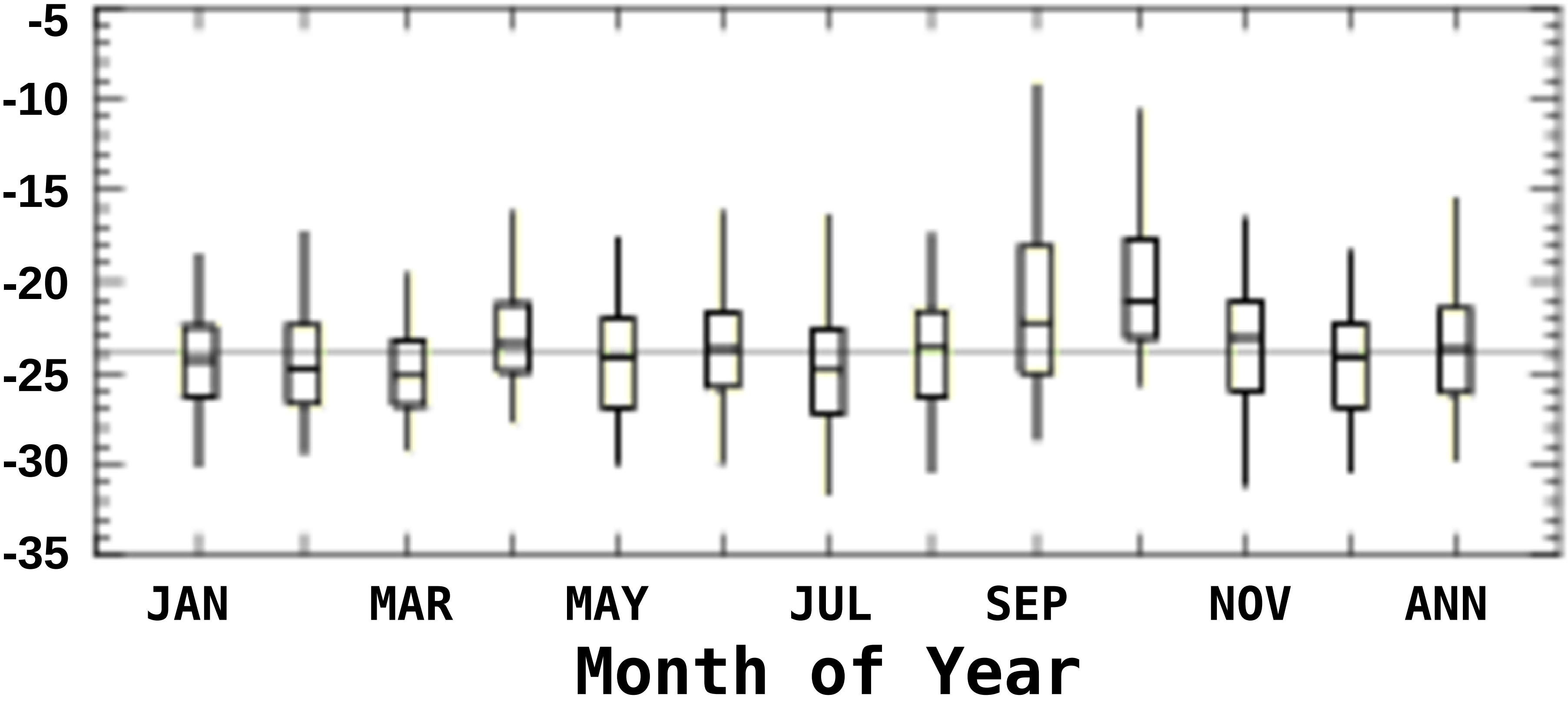
Daily Cycle of Forcing Efficiency



Bondville, Illinois (BND), 1996 – 2000 Hourly Averages

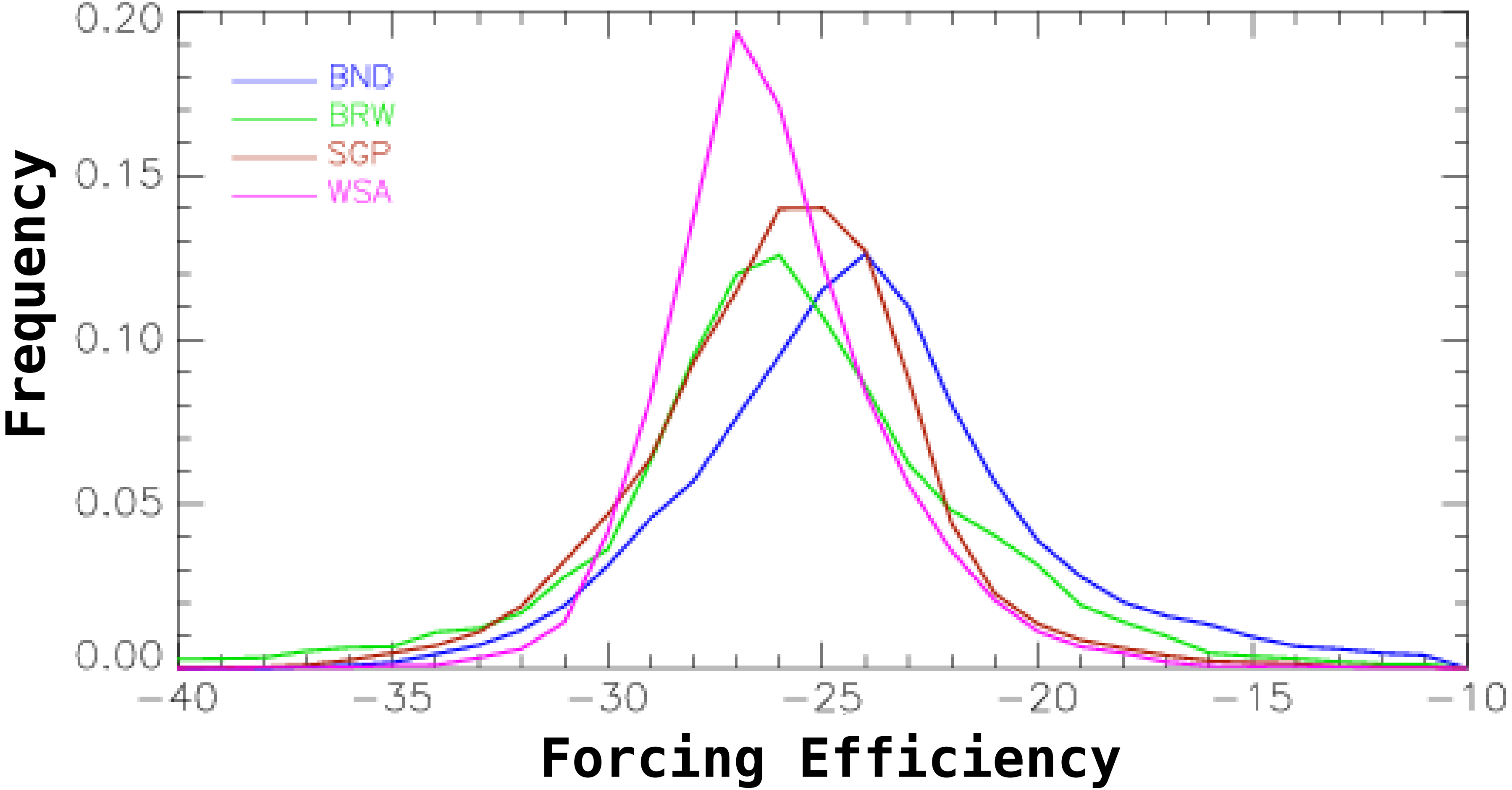
λ=550 nm, D<10 μm, RH<40%

Annual Cycle of Forcing Efficiency

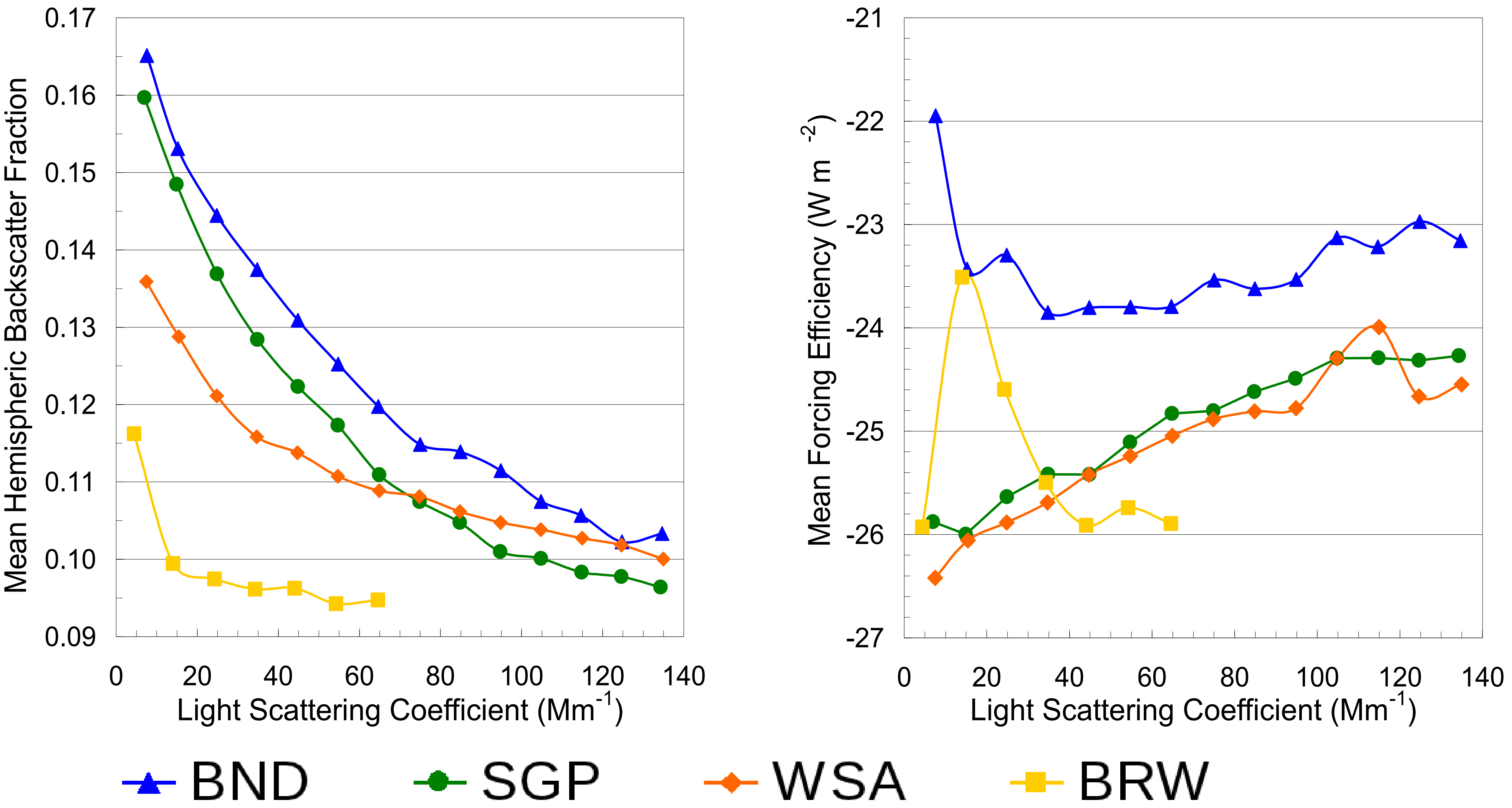


Bondville, Illinois (BND), 1996 – 2000 Hourly Averages
λ=550 nm, D<10 μm, RH<40%

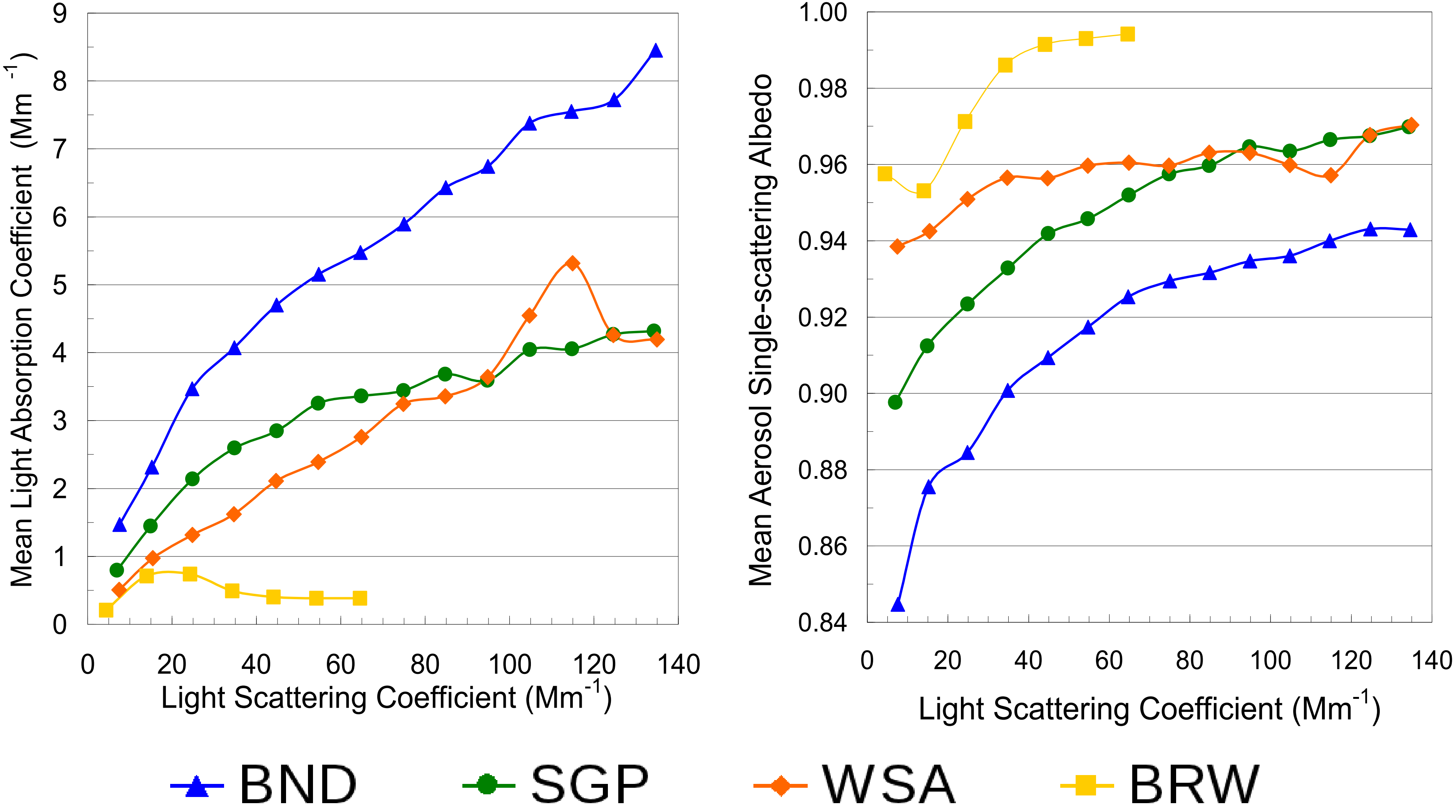
Radiative Forcing Efficiency Frequency



D_p < 10 μm, RH < 40% for one Arctic (BRW), one marine (WSA), and two continental (SGP, BND) sites.



λ=550 nm, D<10 μm, RH < 40%



λ=550 nm, D<10 μm, RH < 40%

Conclusions

- Average aerosol absorption is 10 times larger and average aerosol scattering is 5 times larger in Bondville, Illinois than in Barrow, Alaska.
- Variation in single-scattering albedo and hemispheric backscatter fraction combine to give $\pm 10\%$ variations in monthly median forcing efficiency and a $\pm 4\%$ variation among station median values.
- Regional and seasonal variations in aerosol properties and systematic relationships among aerosol properties can be important for applications that use “climatological” averages.