Variability of Aerosol Optical Properties from Long-term Surface Monitoring Station Data

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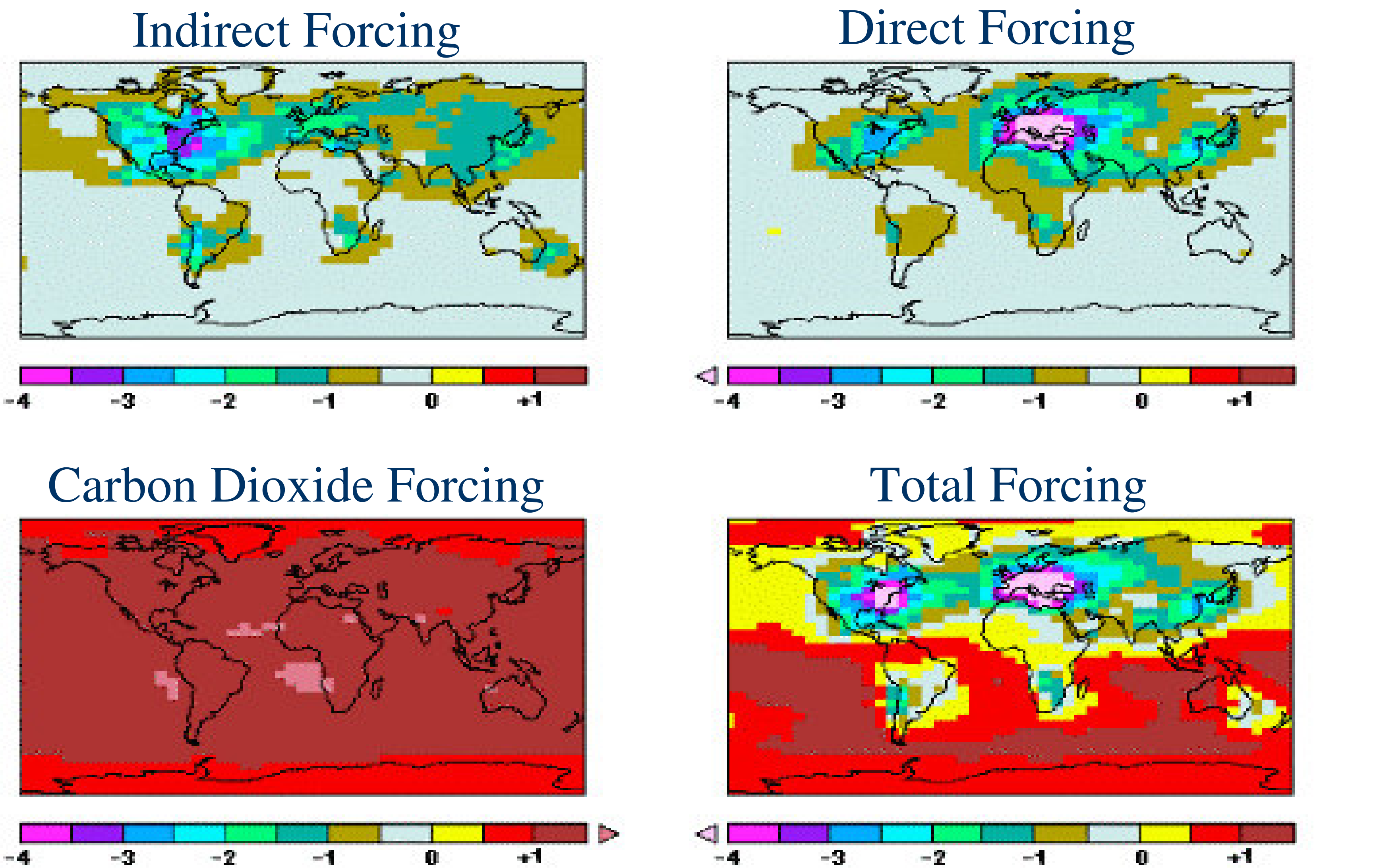
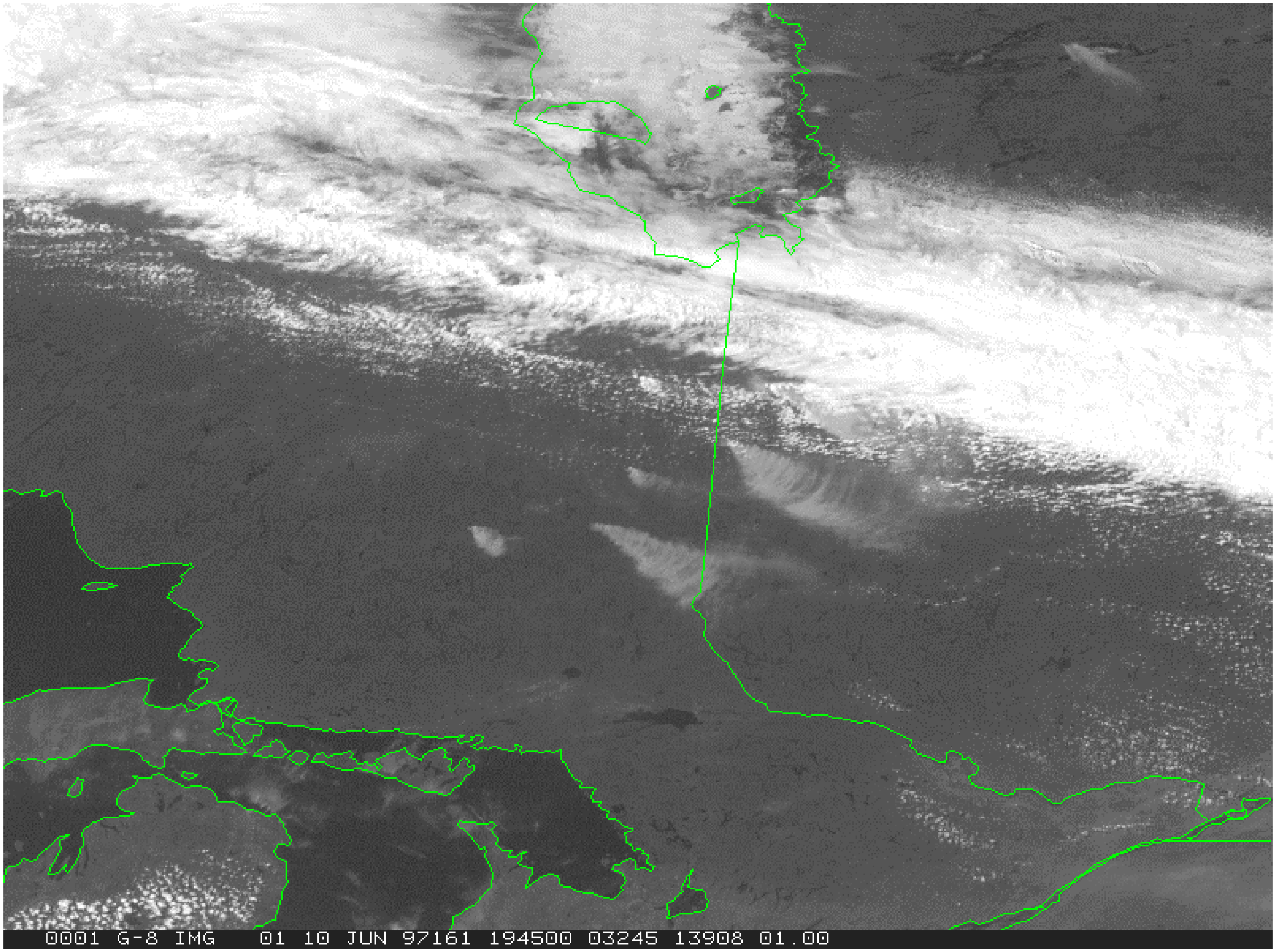
Importance of Aerosols



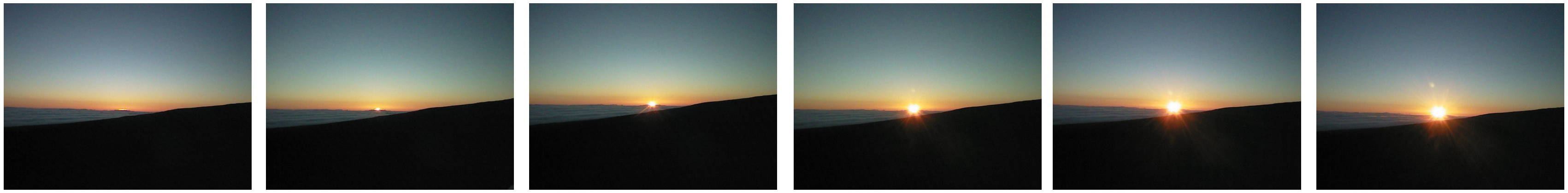
Climate forcing predicted from the Lawrence Livermore National Laboratory Global Aerosol Model [Catherine C. Chuang and Joyce E. Penner].

Direct Aerosol Forcing



Forest fires in Canada on June 10, 1997.

NOAA Aerosol Network



Mauna Loa Observatory (MLO) Aerosol System Upgrade

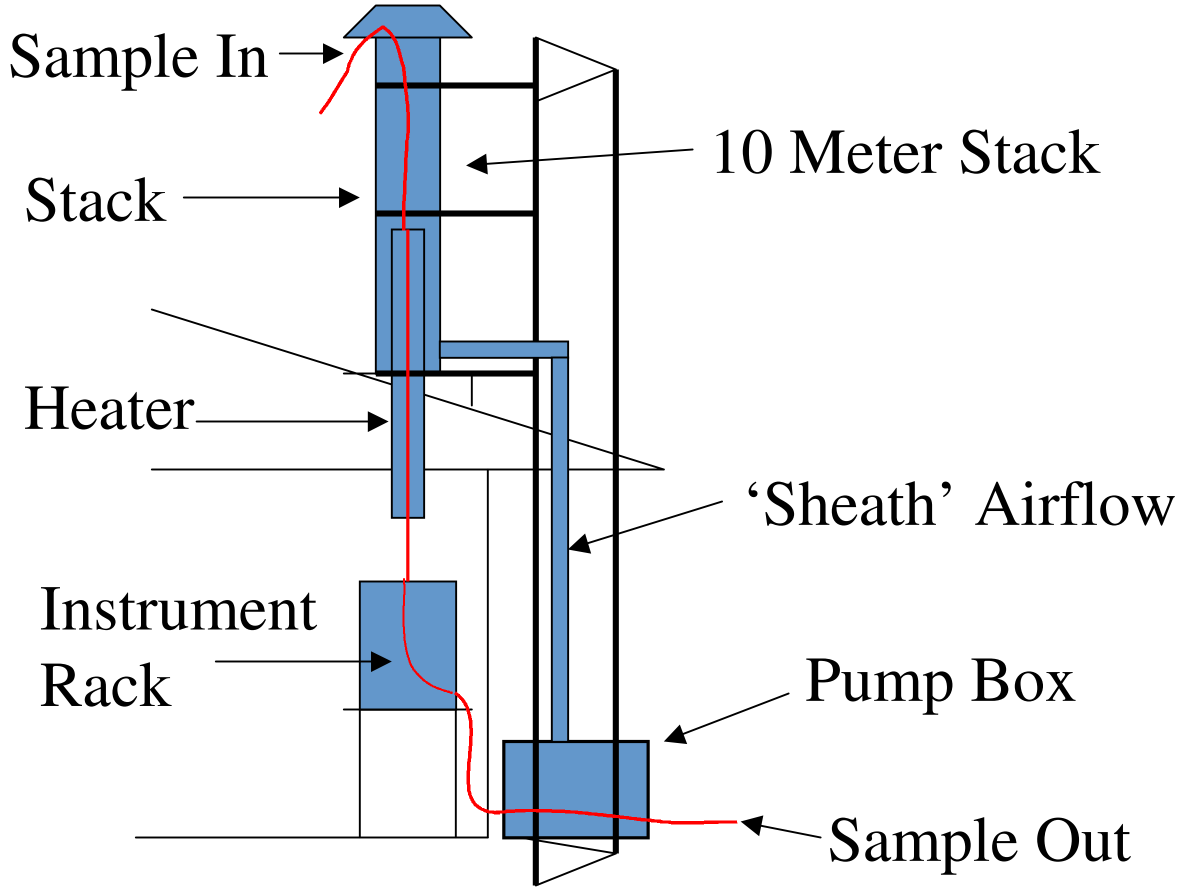
Motivation: New instrumentation that uses similar protocols as other NOAA stations

Bondville, Illinois

Lamont, Oklahoma

Barrow, Alaska

Aerosol Sampling System



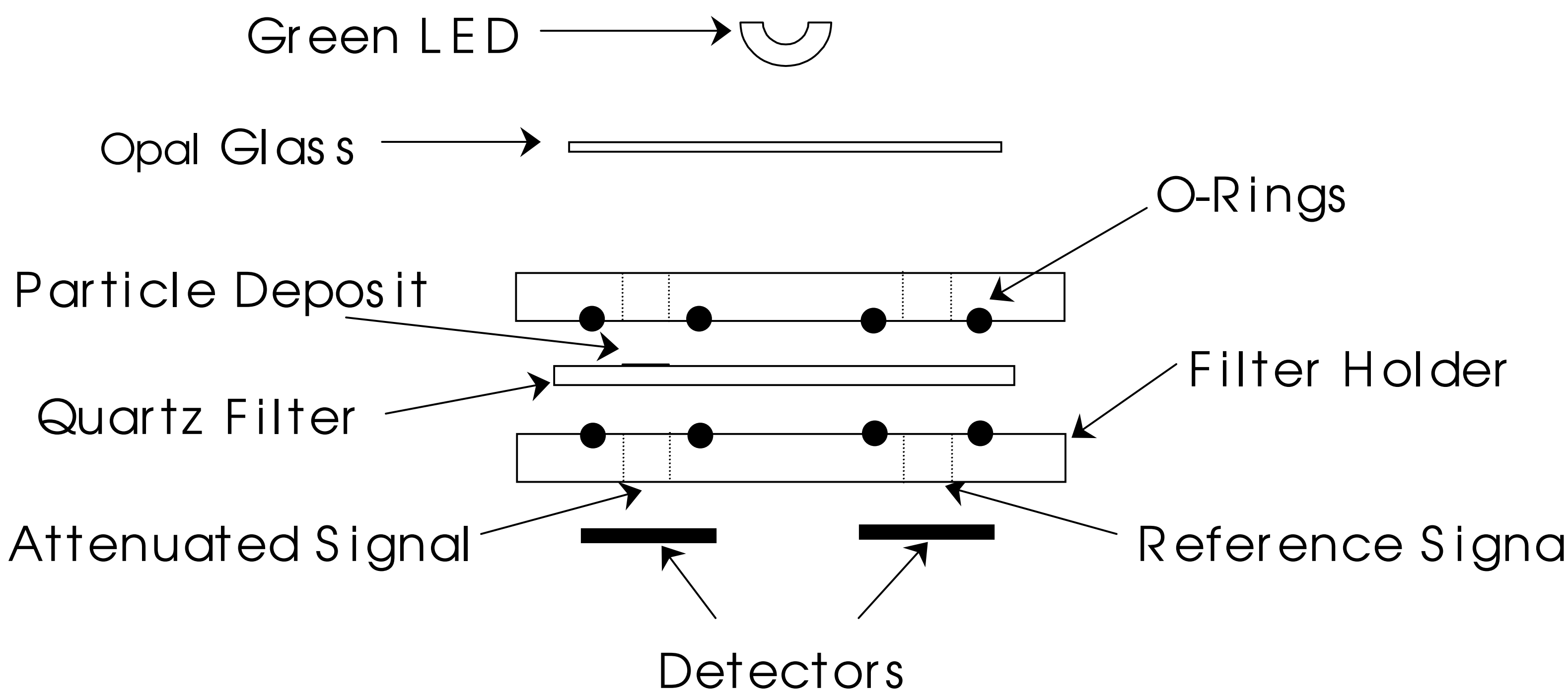
1 and 10 µm Size Cuts

Relative Humidity Control Less Than 40%

Aerosol Instrumentation

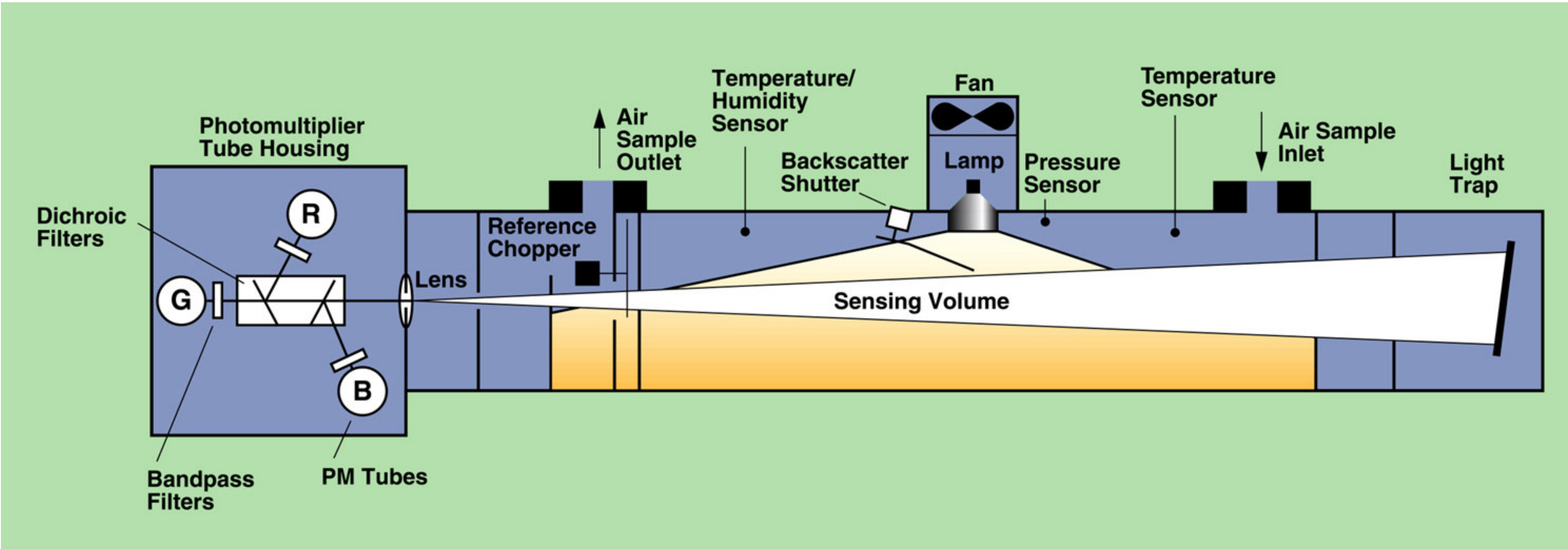
- Condensation Nucleus Counter – CN
- Particle Soot Absorption Photometer – σ_{bap}
- 3 Wavelength Nephelometer – σ_{bsp},σ_{bbsp}

Particle Soot Absorption Photometer



- Principle of operation is to measure the change in light transmission through a filter on which particles are collected.
- Calibration uses a reference absorption determined as the difference between light extinction and light scattering.
- Instrument exhibits a significant response to nonabsorbing aerosols and overestimates absorption due to suspended particles by about 20-30%.

Integrating Nephelometer



TSI 3563 Nephelometer schematic courtesy of TSI Incorporated

- The Nephelometer detects aerosol scattering by measuring total light scattered and subtracting light scattered by the air, the instrument walls and the detector background noise.
- Calibration is done by measuring two reference gases with know scattering values, typically air and CO_2.
- The nephelometer measures from 7-170^o scatting angles and the backsctter shutter allows blocking of angles from 7-90^o. Measurements are corrected to the 0-180^o and 0-90^o range.

Measured and Derived Parameters

Size and relative humidity (<40 %) controlled measurements:

σ_{sp} – Aerosol total light scattering coefficient at 450, 550, and 700 nm wavelengths

σ_{bsp} – Aerosol hemispheric back scattering coefficient at 450, 550, and 700 nm wavelengths

σ_{ap} – Aerosol light absorption coefficient at 550 nm wavelength

From these measurements, the following parameters are derived:

ω_o – Aerosol single-scattering albedo (ratio of total scattering to total extinction at 550 nm)

b – Hemispheric backscatter fraction (used in determining angular dependence of scattering)

å – Ångström exponent (describes the wavelength-dependence of light scattering)

ΔF/δ – Direct aerosol radiative forcing efficiency (assesses the importance of both ω_o and *b* on top of the atmosphere aerosol radiative forcing calculations)

Direct Radiative Forcing Efficiency

$$\frac{\ddot{A}F}{\ddot{A}\ddot{a}} \approx -DS_0T_{at}^2(1-A_c)(1-R_s)^2\tilde{\omega}_0\bar{\beta}\left[1-\frac{2R_s}{(1-R_s)^2\bar{\beta}}\left(\frac{1}{\tilde{\omega}_0}-1\right)\right]$$

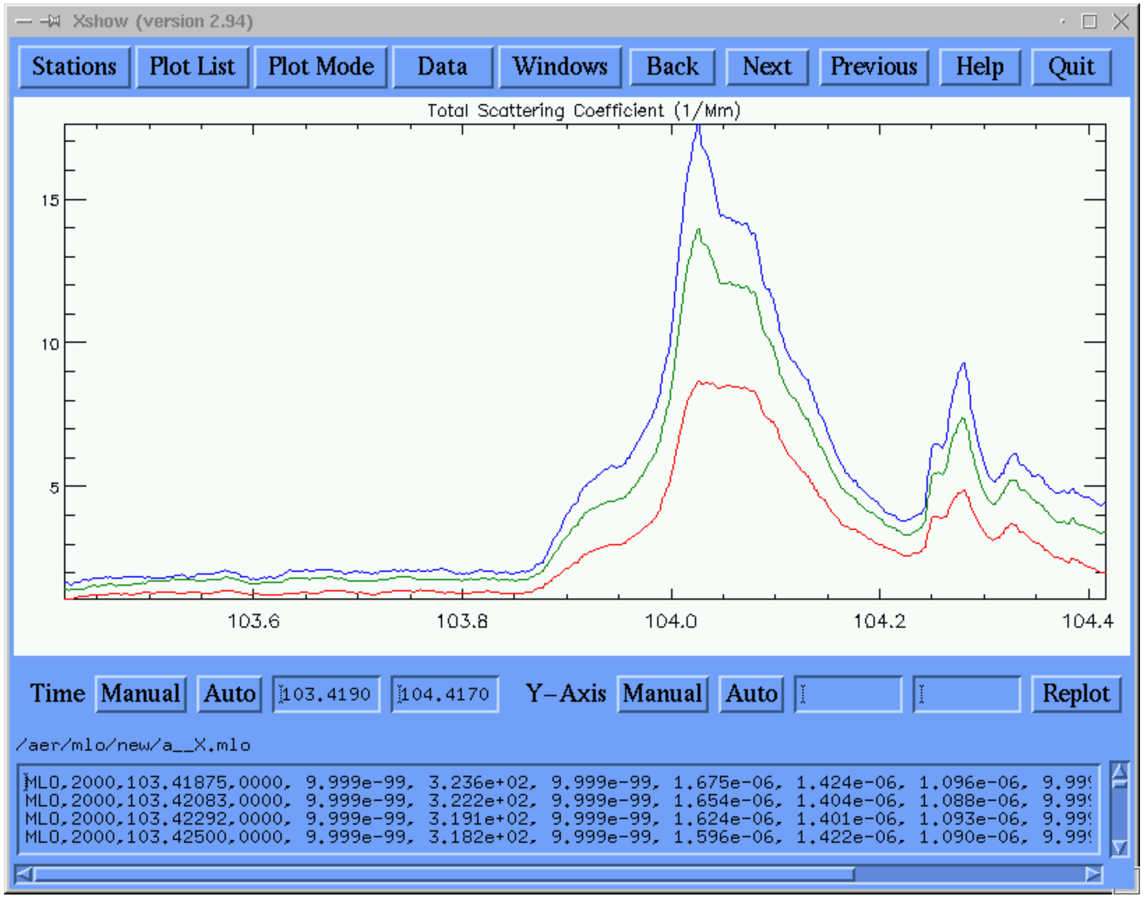
ΔF	Aerosol Forcing
δ	Aerosol Optical Depth
D	Daylight Fraction
S_0	Solar Constant
T_{at}	Atmospheric Transmission
A_c	Cloud Fraction
R_s	Surface Albedo
$\tilde{\omega}_0$	Aerosol Single-Scattering Albedo
$\bar{\beta}$	Average Aerosol Up-scatter Fraction

Source: Haywood and Shine (1995)

Aerosol Data Quality

- Daily automated generation and review of quality control plots
- Weekly editing of data by station scientist
- Yearly automated generation and review of quality assurance web pages

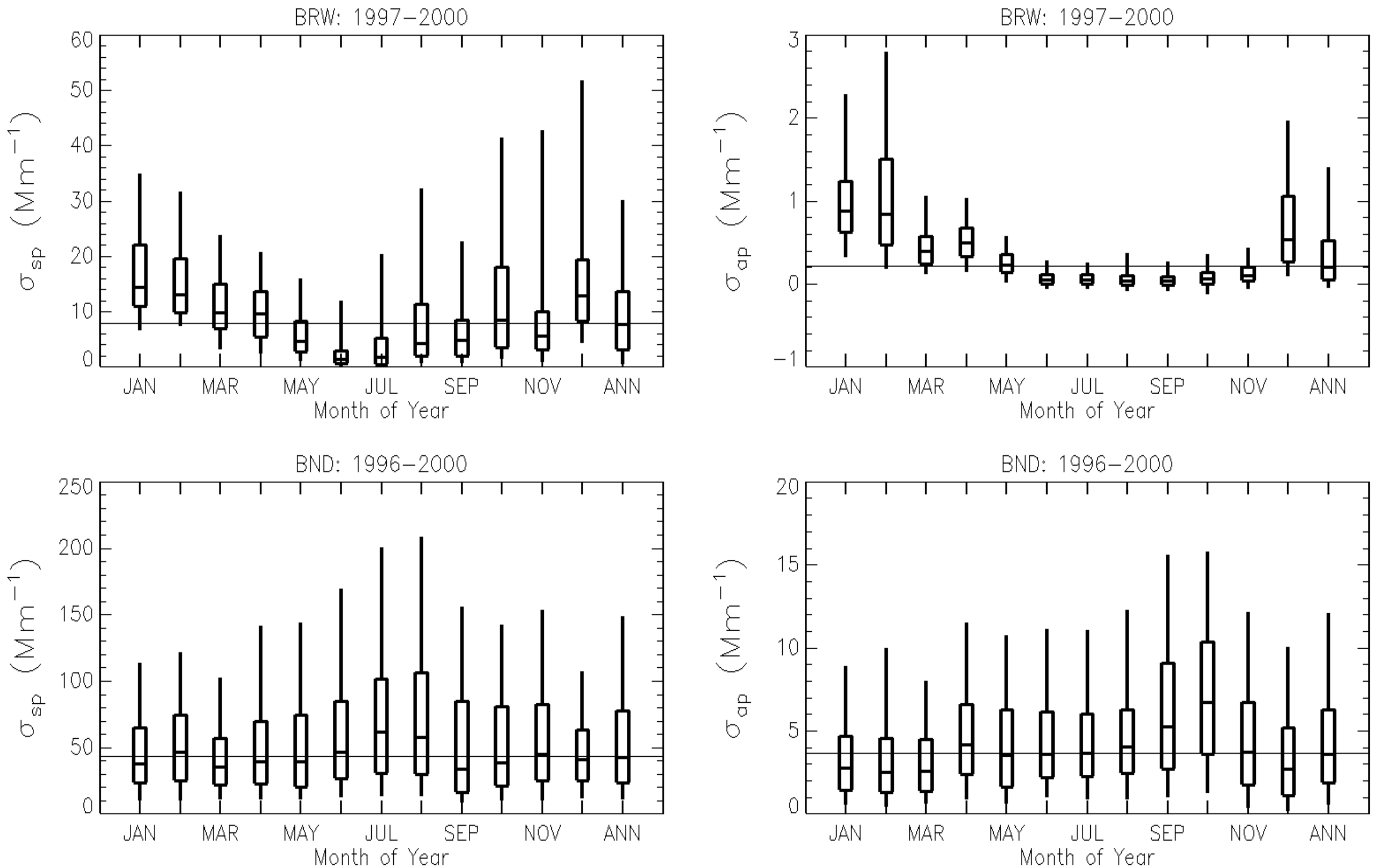
Custom Data Analysis Tool Written in IDL



Types of Aerosol Variability

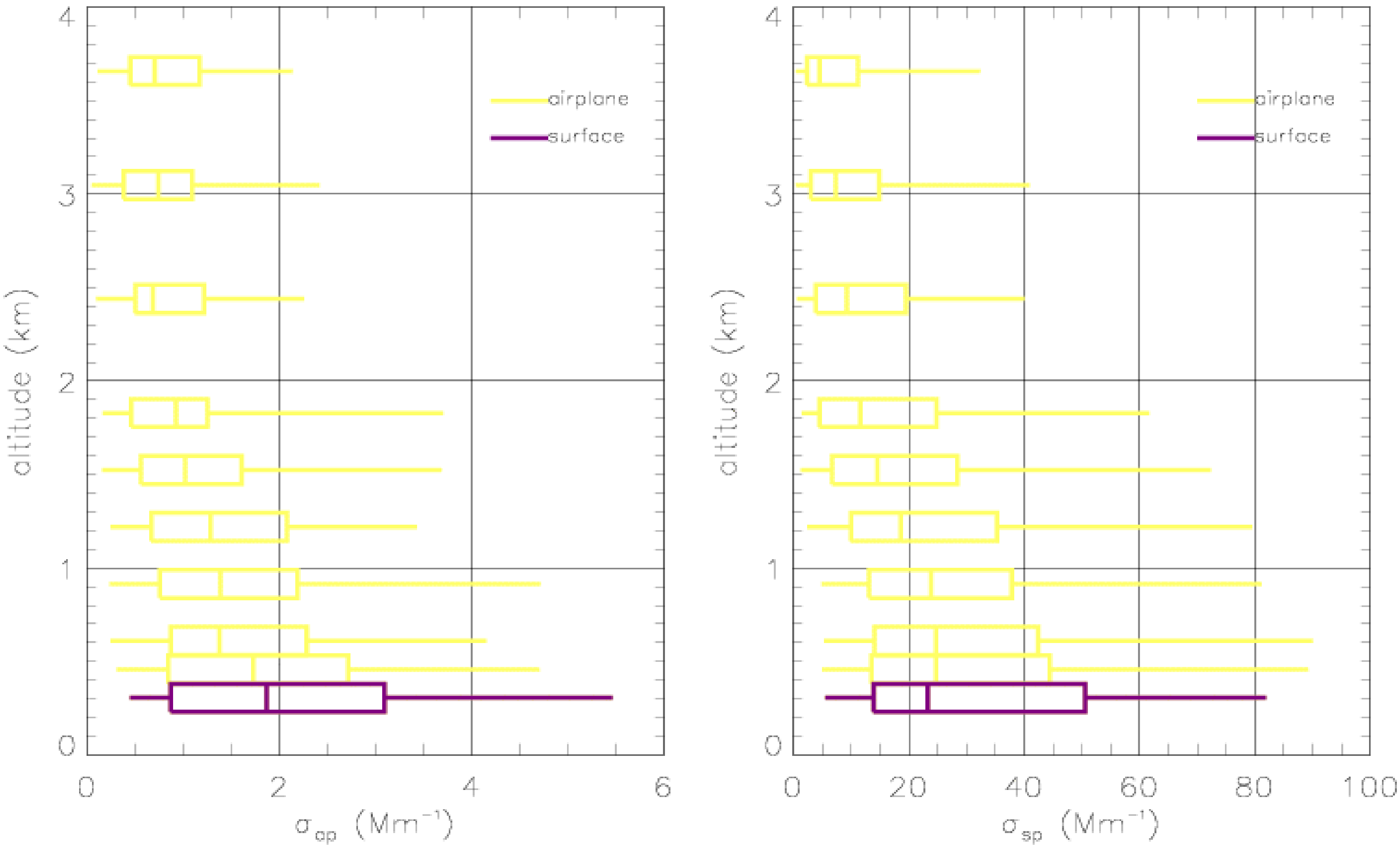
- Regional Variability
  - Changes from place to place on the earth
- Vertical Variability
  - Changes with height above the earth’s surface
- Temporal Variability
  - Systematic changes with the time of day or season
- Systematic Relationships
  - Changes with the concentration of particles

Seasonal and Regional Variability



Hourly Averages, λ=550 nm, D<10 μm, RH<40%

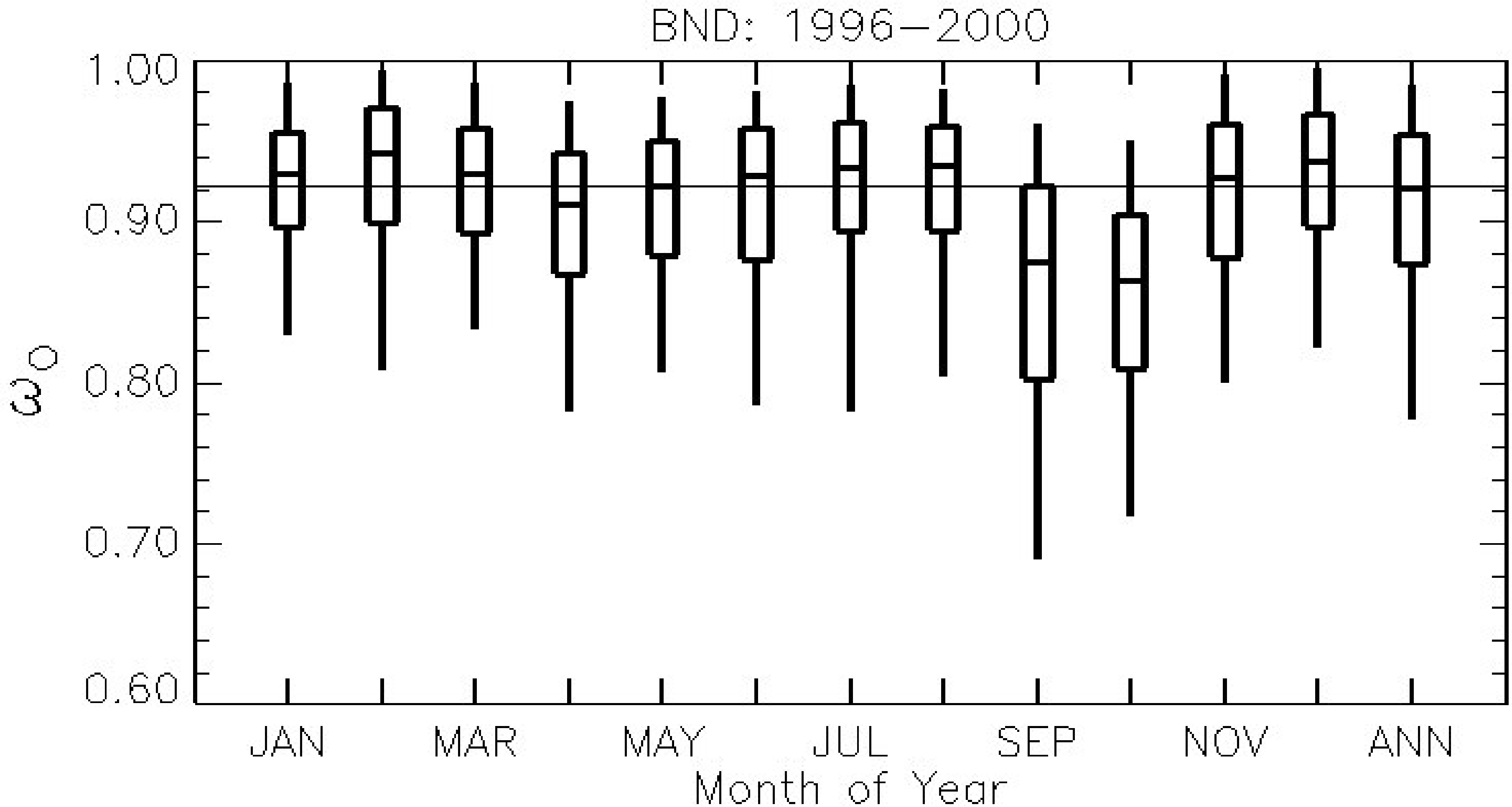
Vertical Variability



104 flights (March 25 – December 31, 2000)

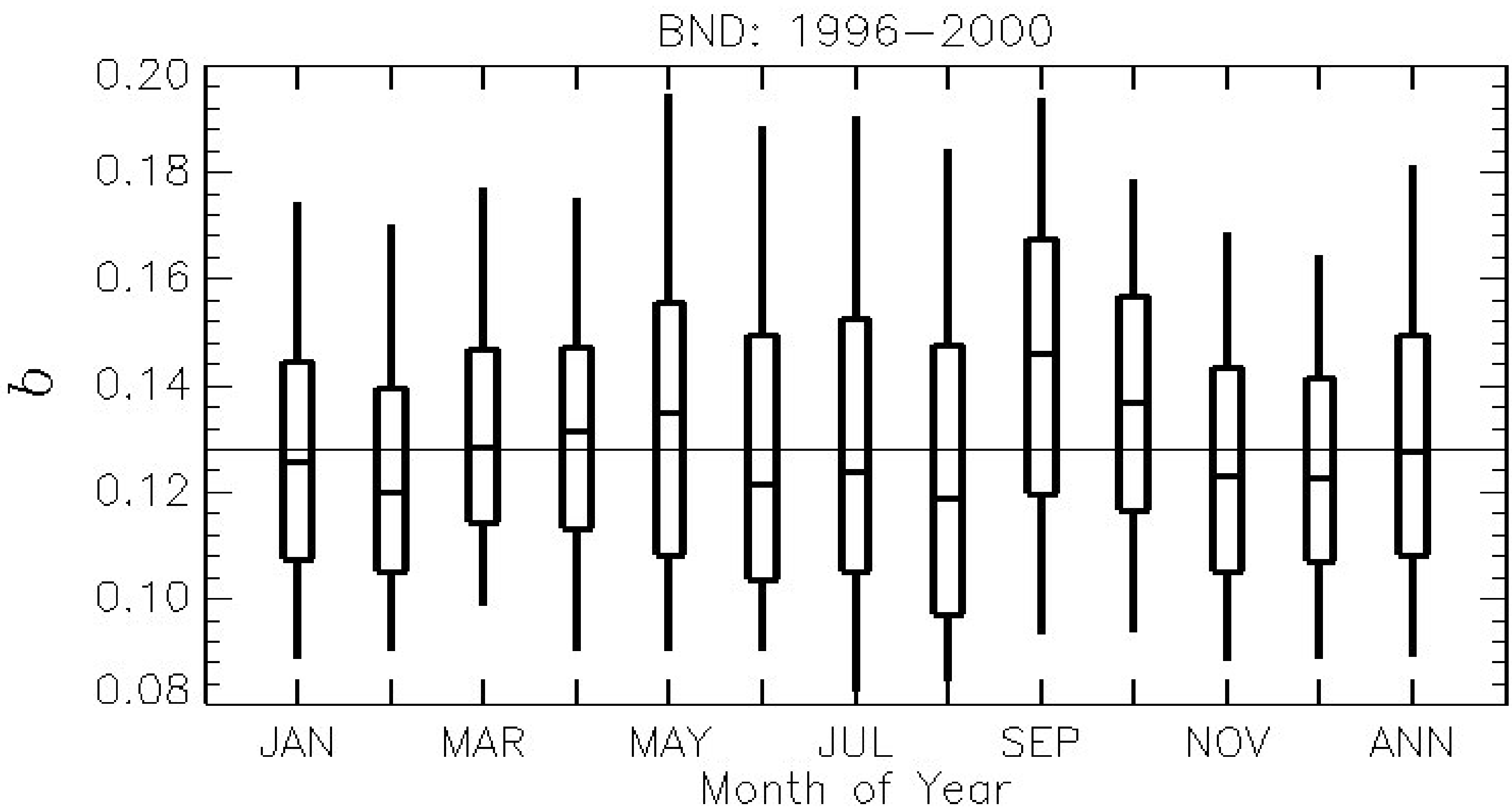
Values are adjusted to STP, λ = 550 nm, D < 1 µm, RH < 40%

Annual Cycle of Single-scattering Albedo at Bondville, Illinois



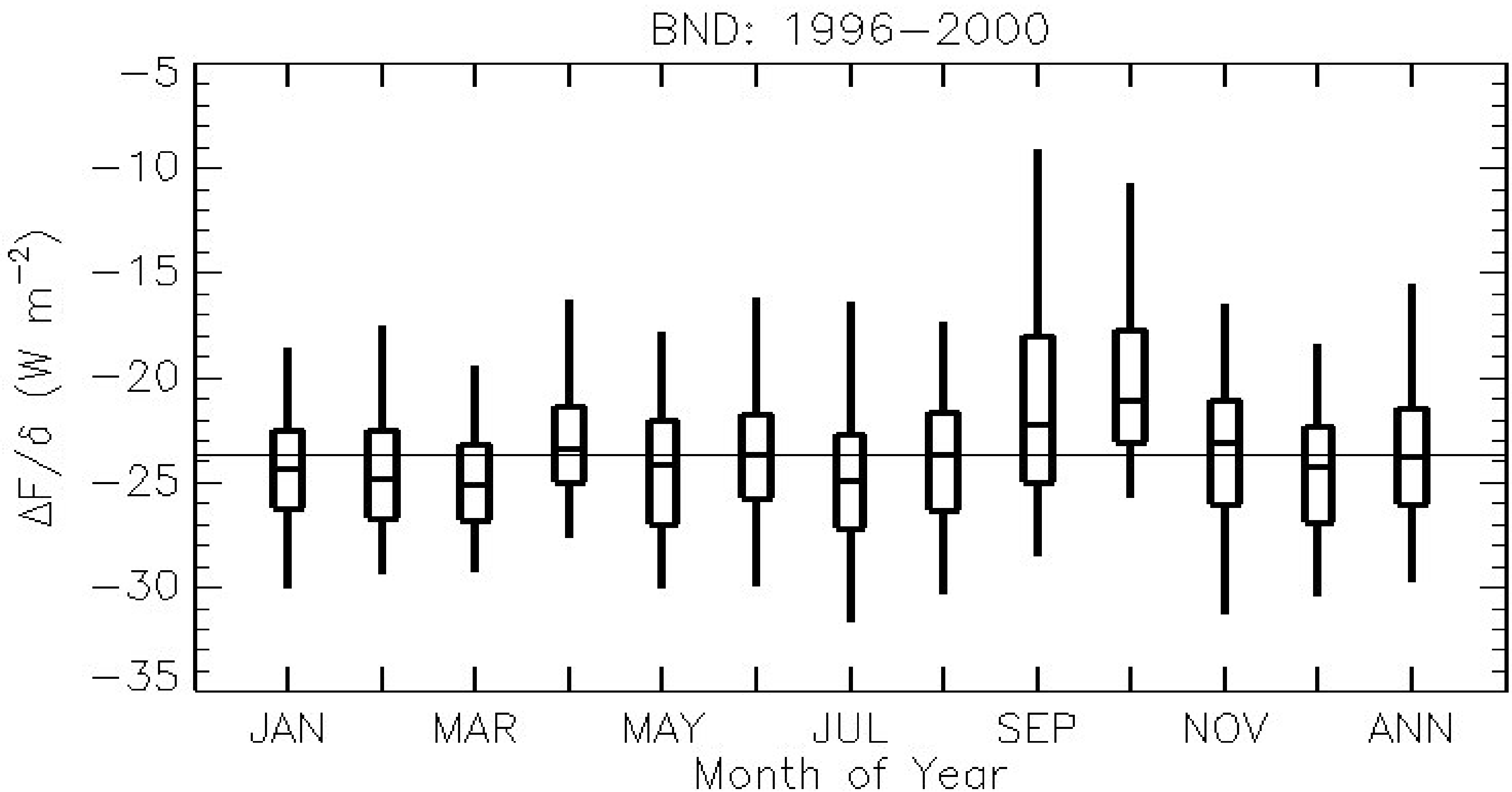
Hourly Averages, λ=550 nm, D<10 μm, RH<40%

Annual Cycle of Backscatter Fraction at Bondville, Illinois



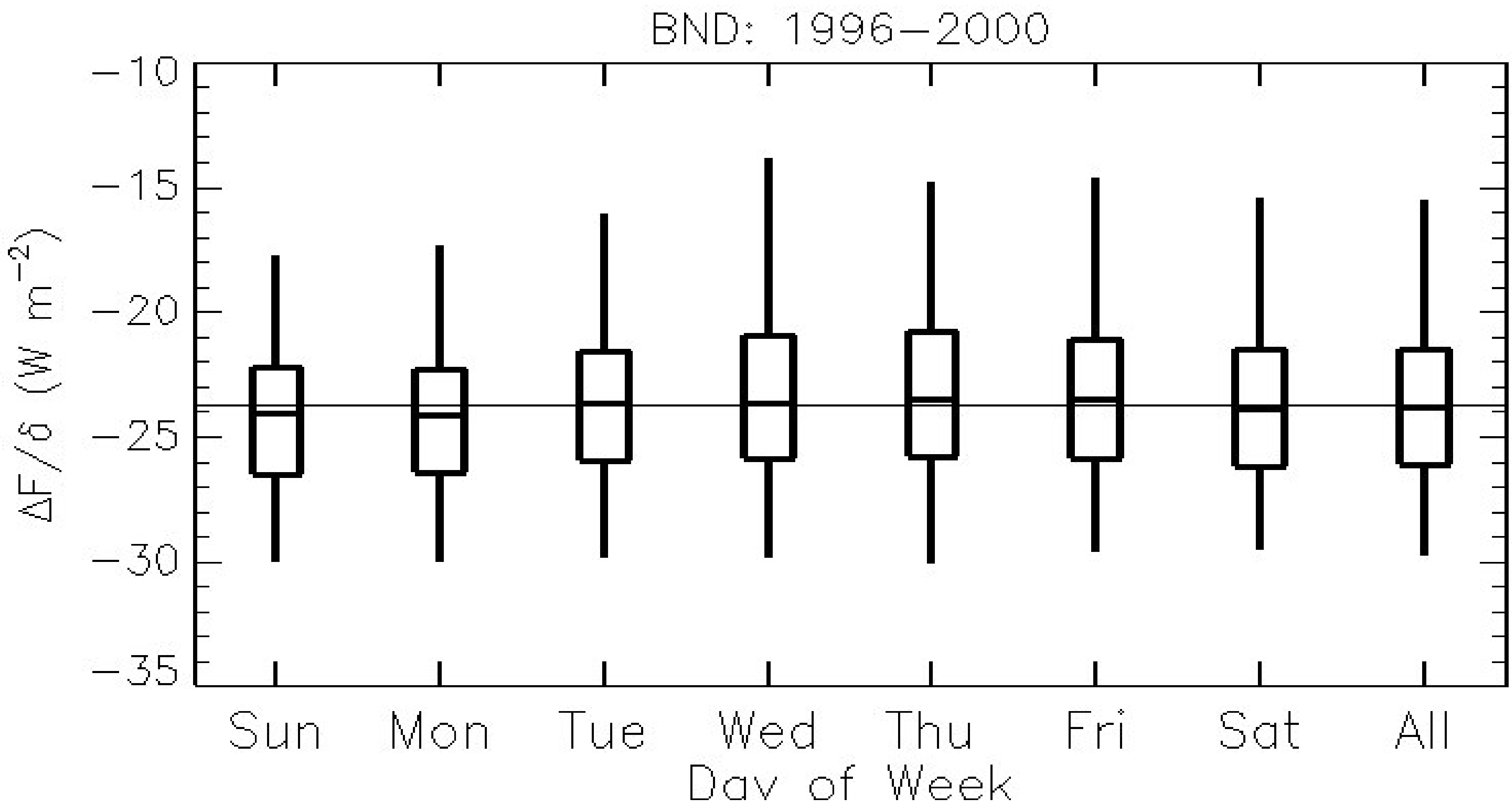
Hourly Averages, λ=550 nm, D<10 µm, RH<40%

Annual Cycle of Forcing Efficiency at Bondville, Illinois



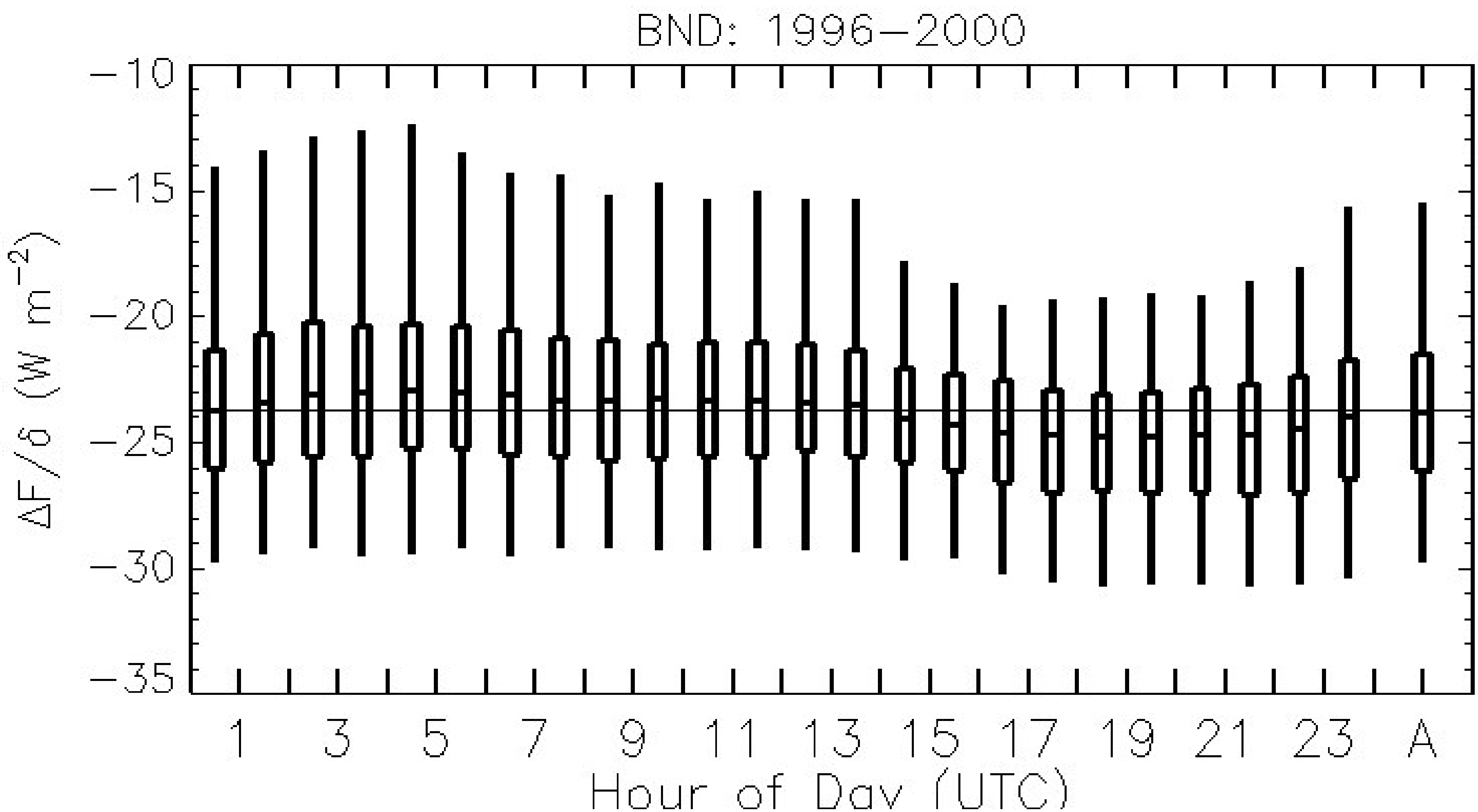
Hourly Averages, λ=550 nm, D<10 μm, RH<40%

Weekly Cycle of Forcing Efficiency at Bondville, Illinois



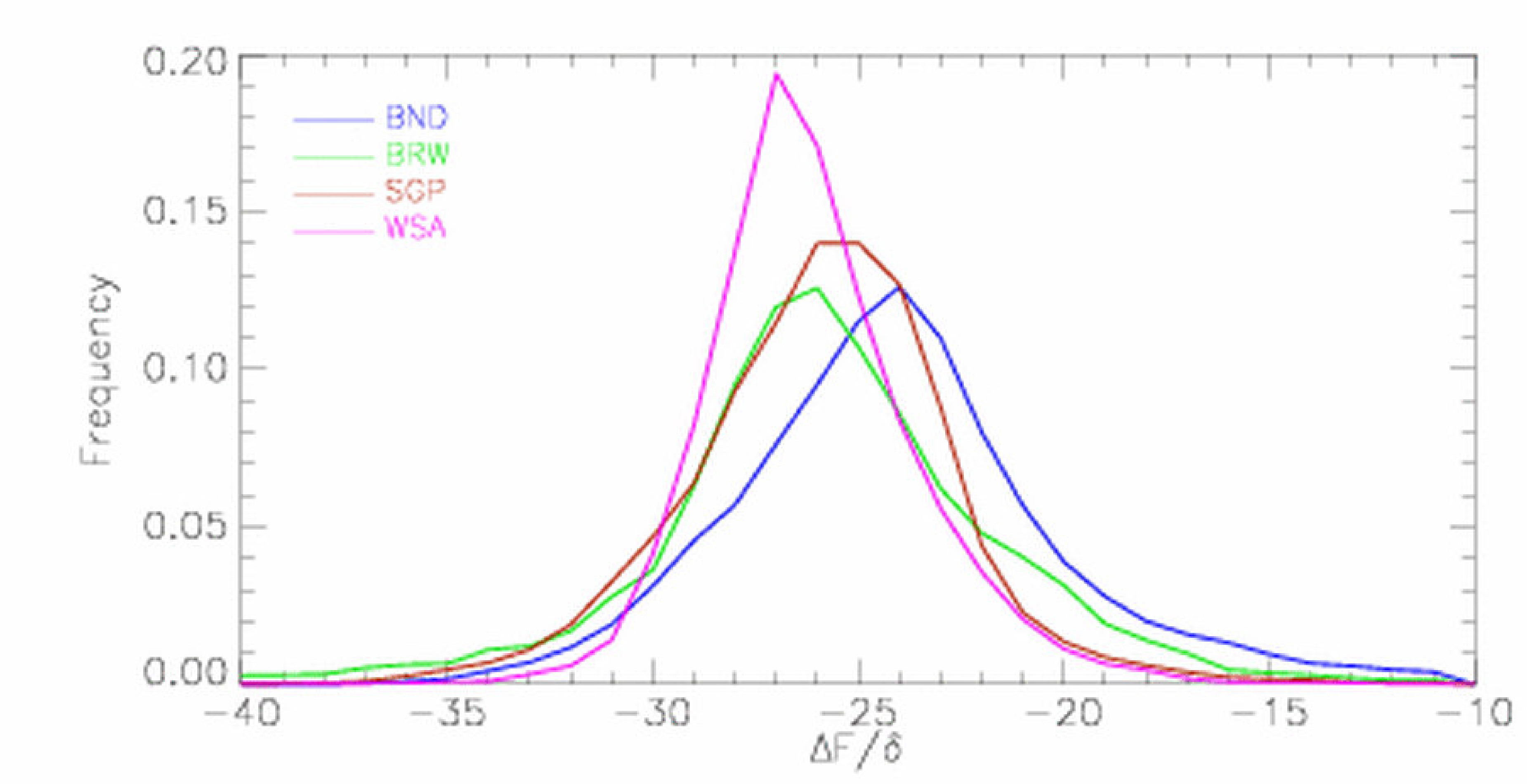
Hourly Averages, λ=550 nm, D<10 μm, RH<40%

Daily Cycle of Forcing Efficiency at Bondville, Illinois



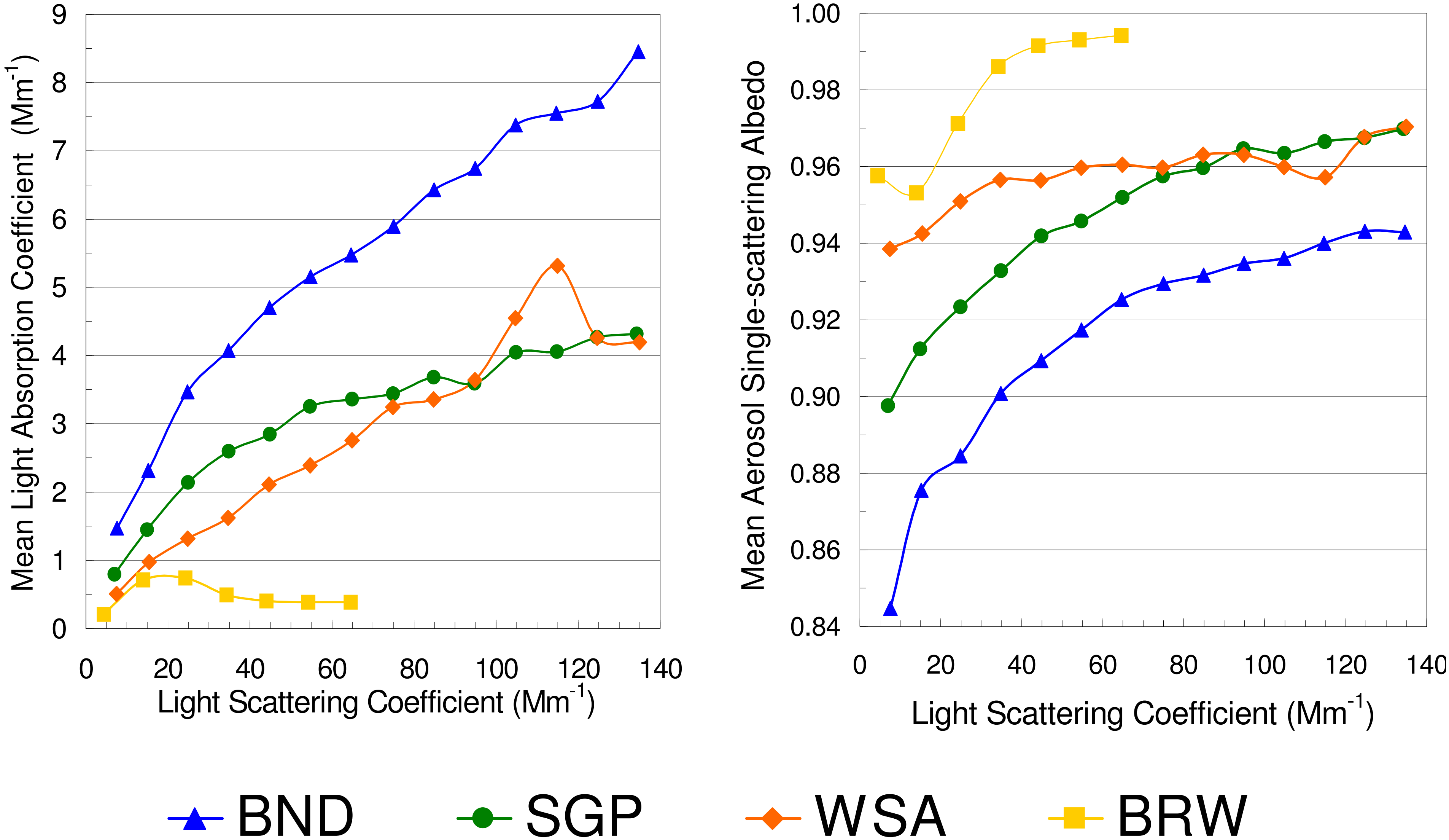
Hourly Averages, λ=550 nm, D<10 µm, RH<40%

Radiative Forcing Efficiency Frequency Distributions



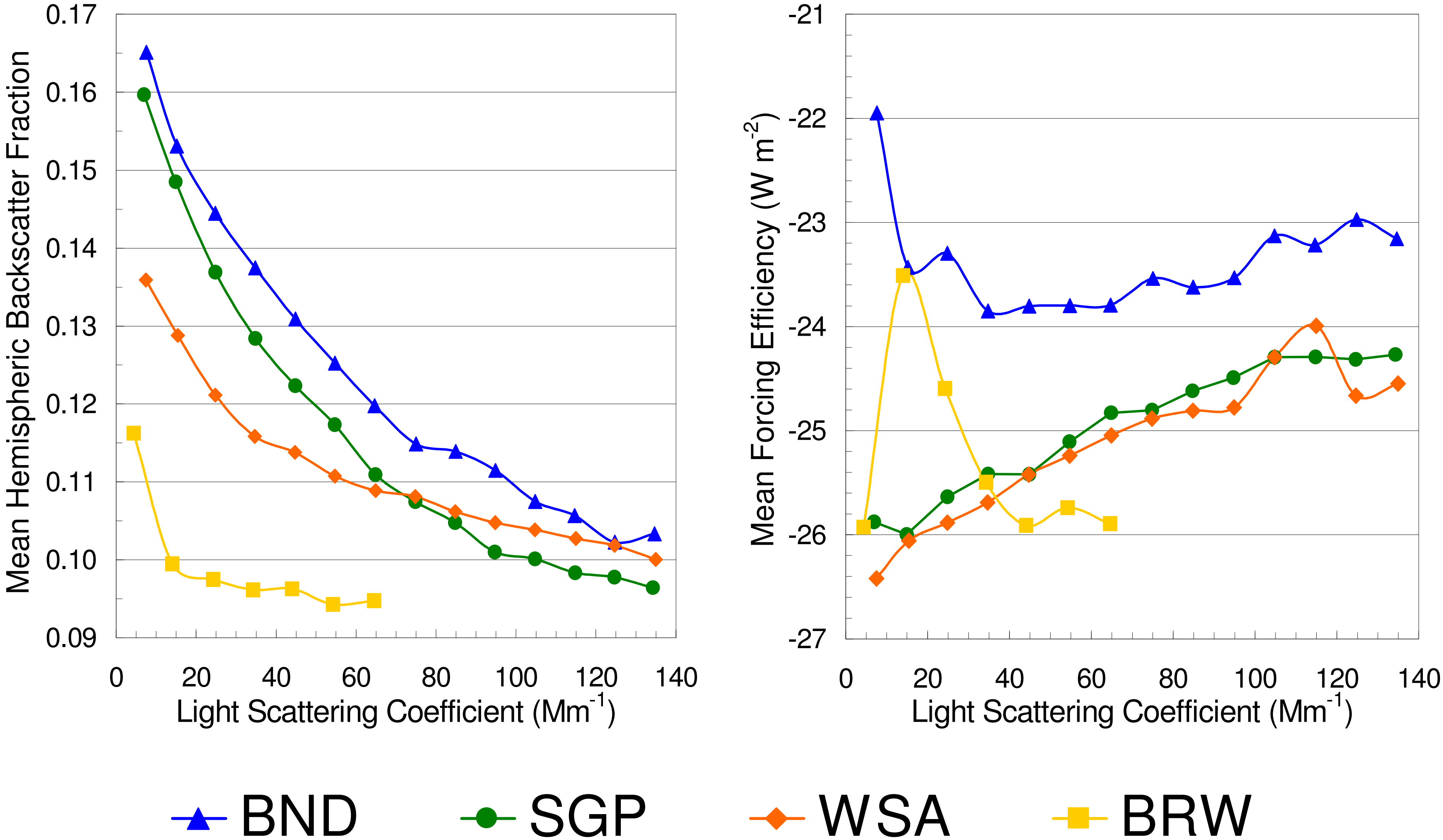
Results for $D_p < 10$ µm and RH < 40% for one Arctic (BRW), one marine (WSA), and two continental (SGP, BND) sites.

Systematic Relationships



λ=550 nm, D<10 μm, RH < 40%

Systematic Relationships



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 ±10% variations in monthly median forcing efficiency and a ±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.

Dust Event at Mauna Loa Observatory on April 18, 2000