Aerosols, CCN and fog, oh my!

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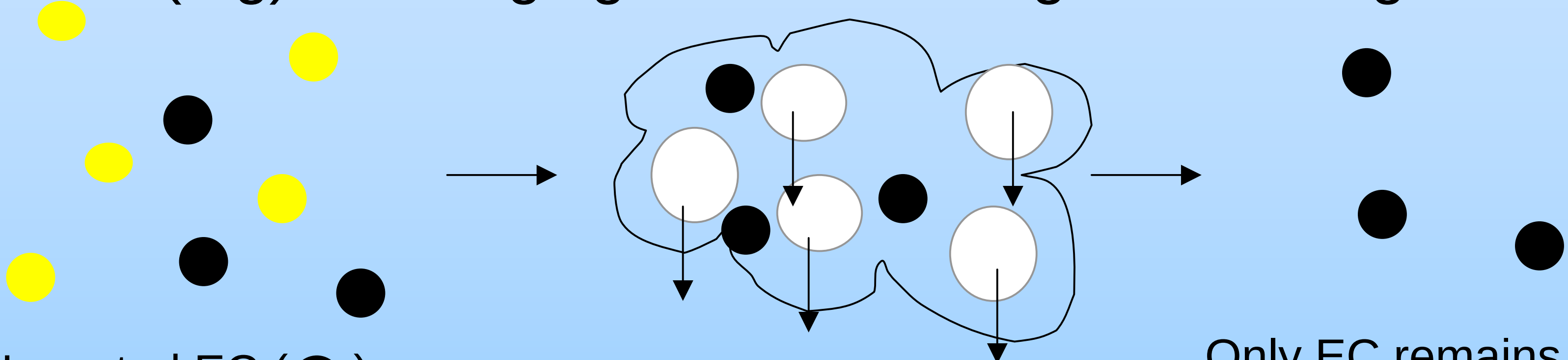
Hypotheses

Cloud (fog) scavenging decreases single scattering albedo.

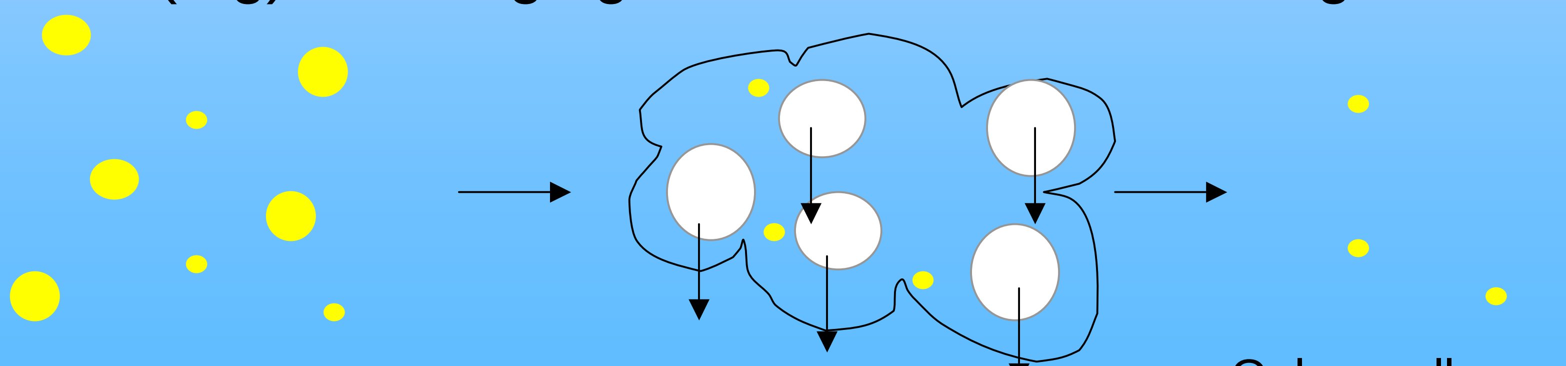


Uncoated EC (●)
Other aerosol (●)

EC not scavenged

Only EC remains

Cloud (fog) scavenging increases backscattering fraction.

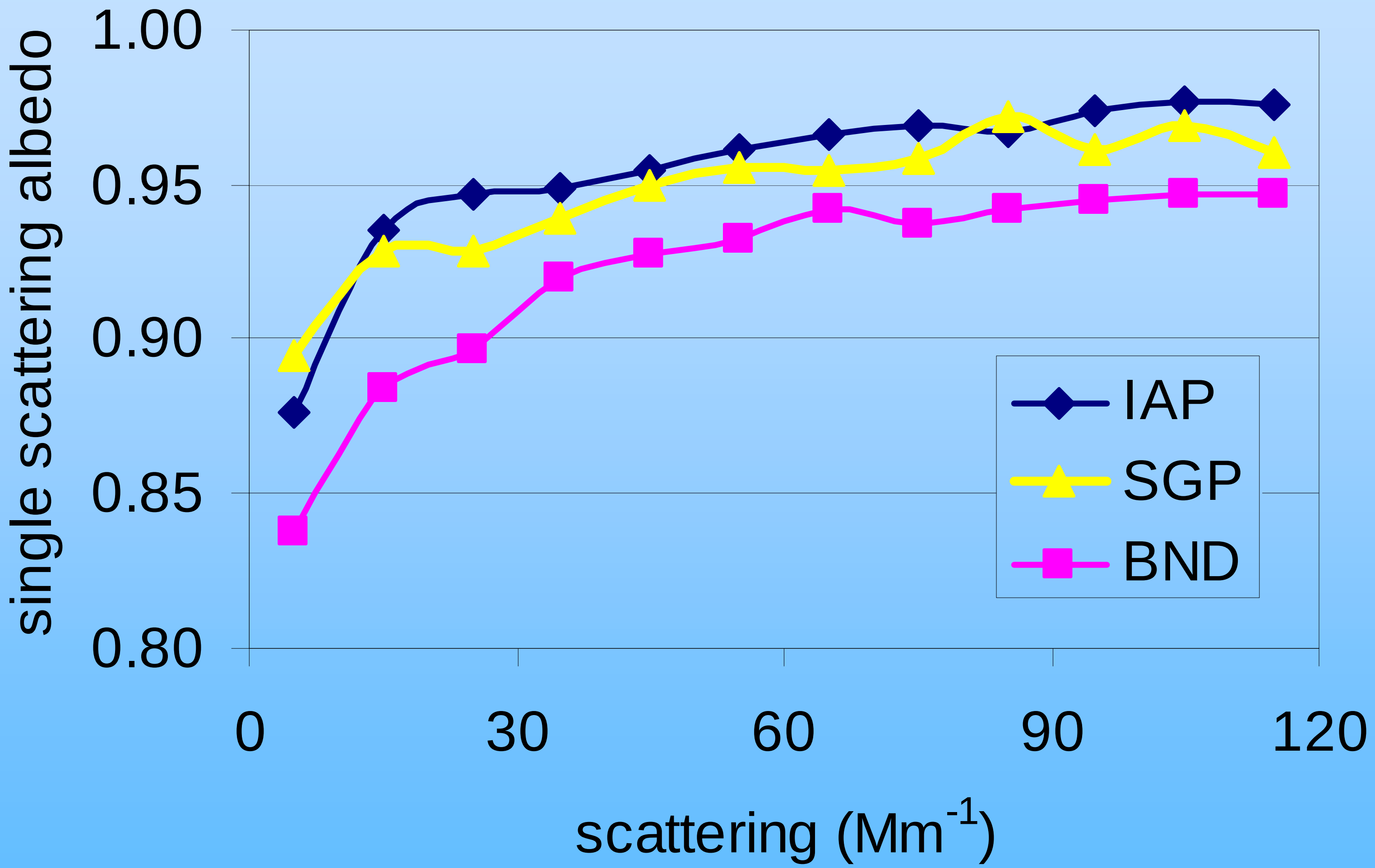


Small (•)
Big (●)

Big particles are scavenged

Only small particles remain

Single-scattering Albedo Increases as Pollution Increases



Notes: Binned, daily mean results for RH<40%, Dp<1μm, and λ=550nm.
BND=Bondville (IL), 1994-2003; SGP=Lamont (OK), 1996-2003;
IAP=Lamont (OK) vertical profiles, 2000-2004.

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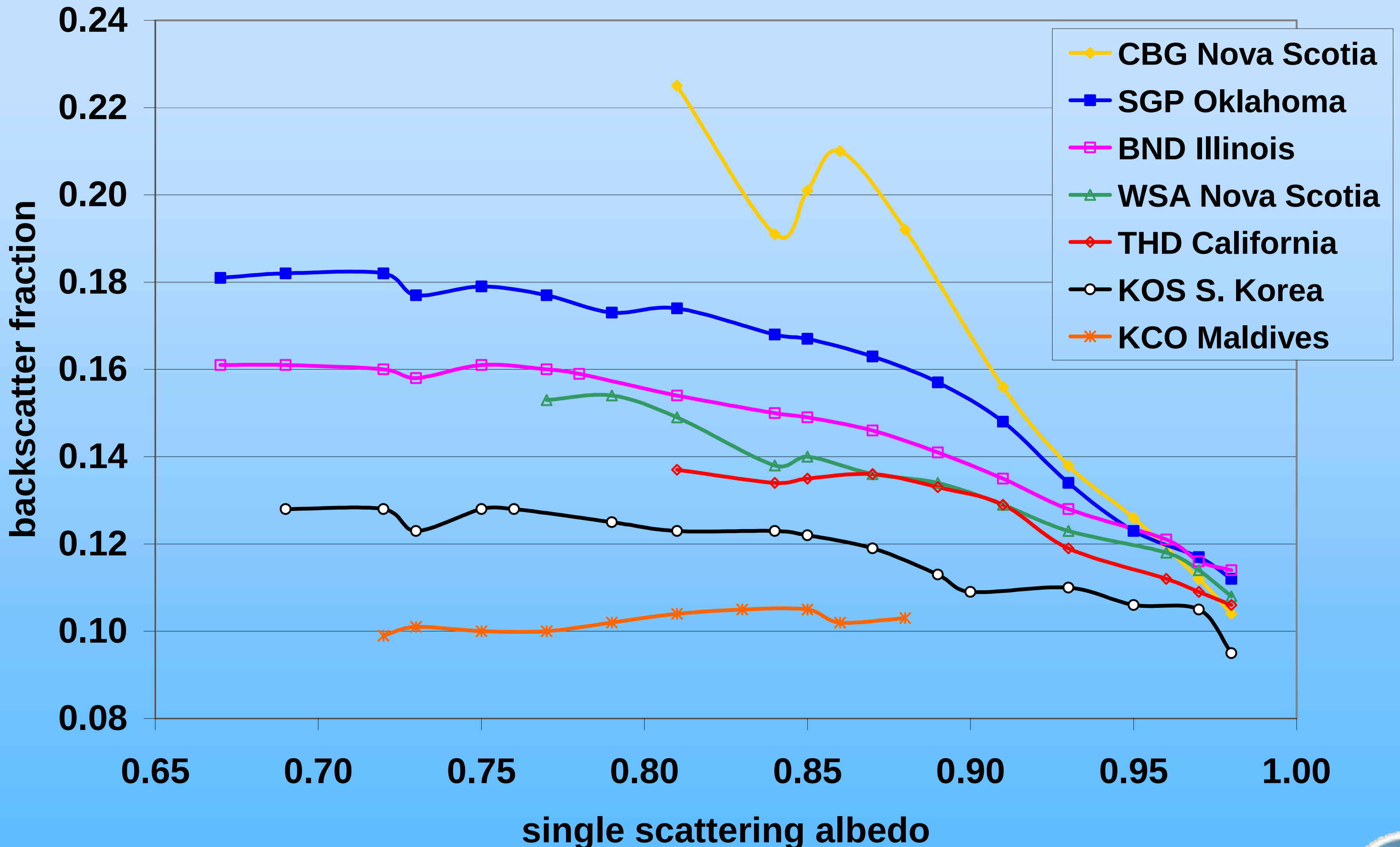
Co-variance of Aerosol Radiative Properties



Values measured at 550 nm wavelength, RH<40%, D_p<10μm

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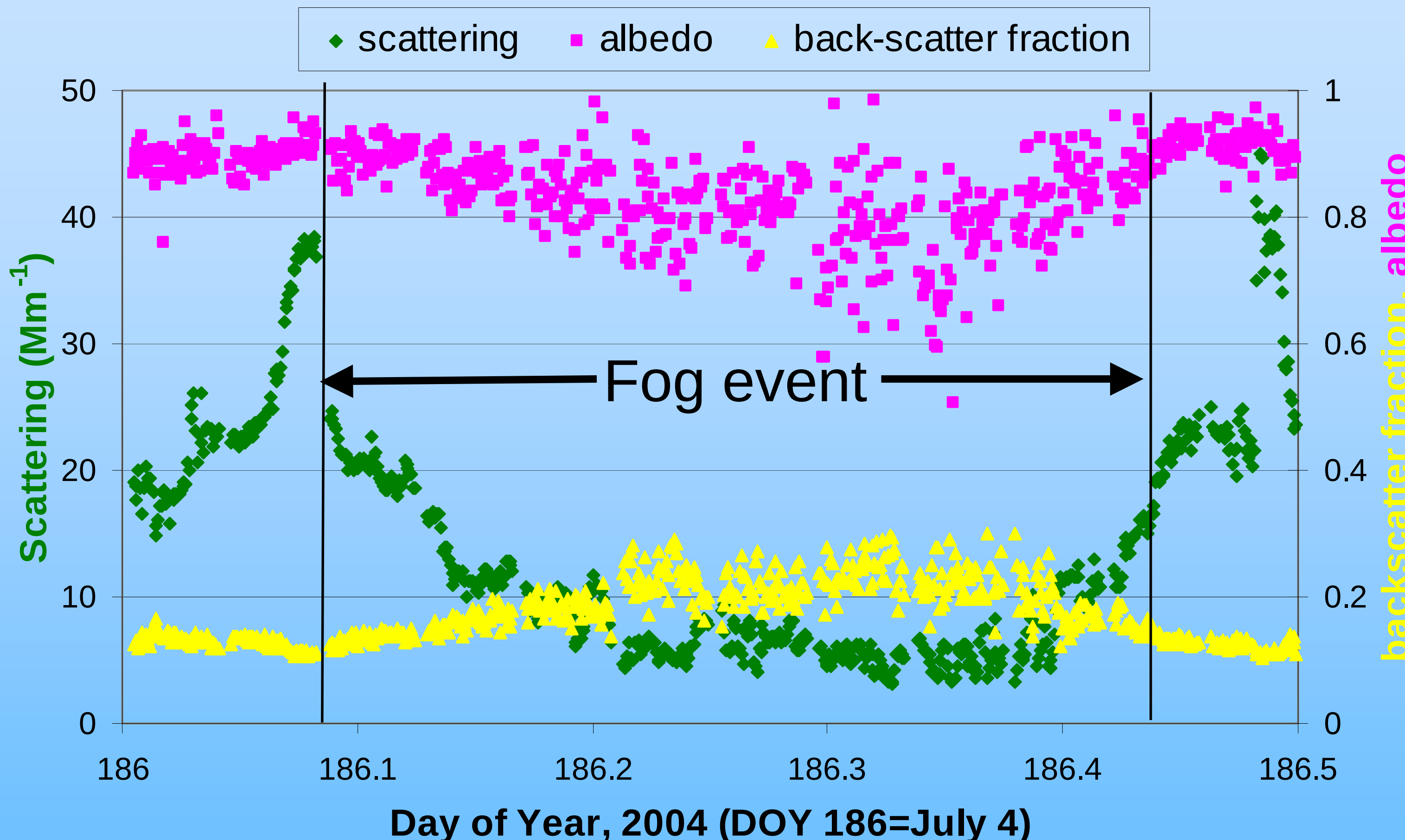
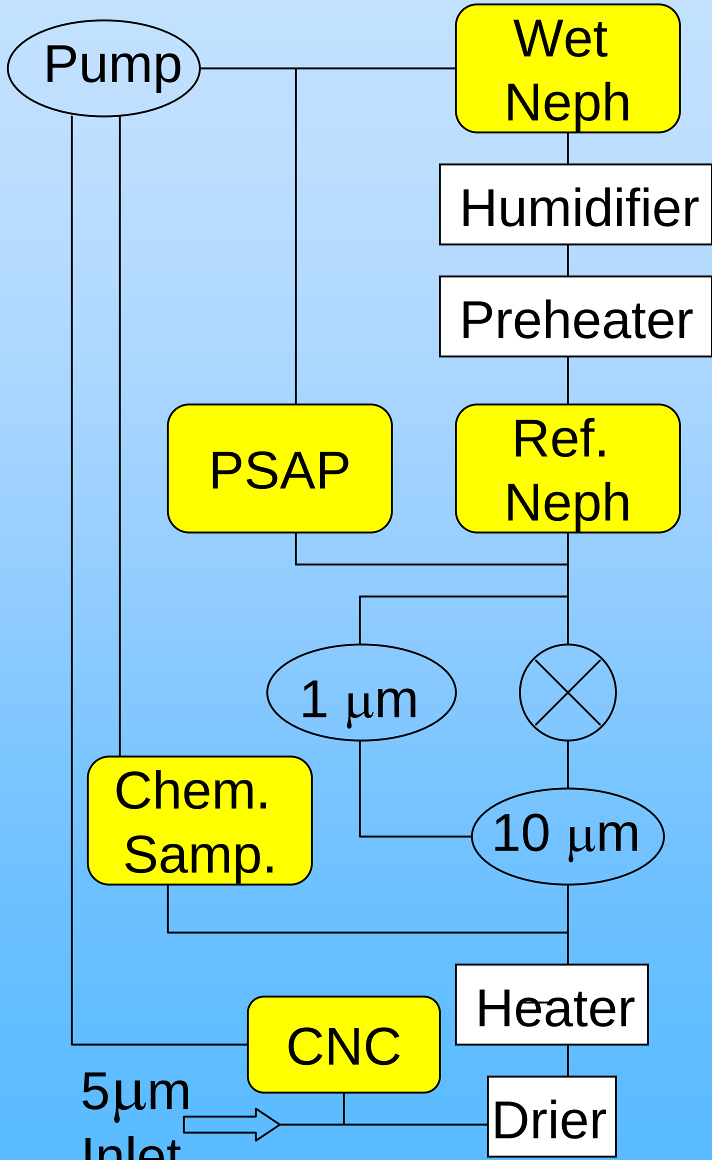
Effect of fog on aerosol optical properties

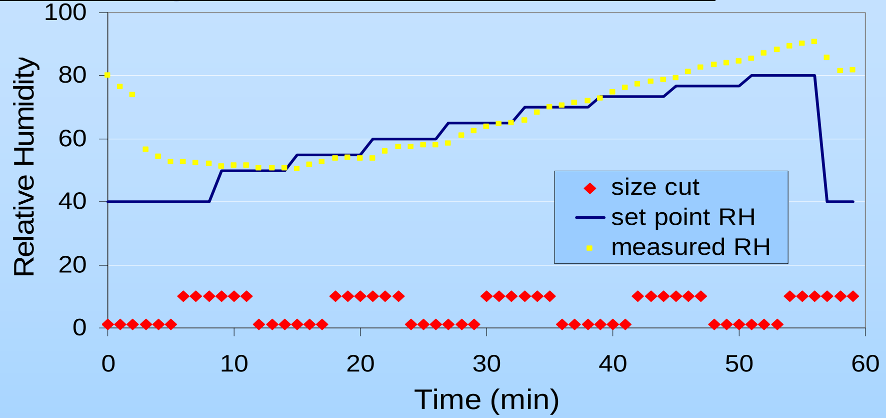


Onset of fog causes:

- •Decrease in light scattering,
- •Increase in back-scatter fraction,
- •Decrease in single scattering albedo

CMDL Humidograph System

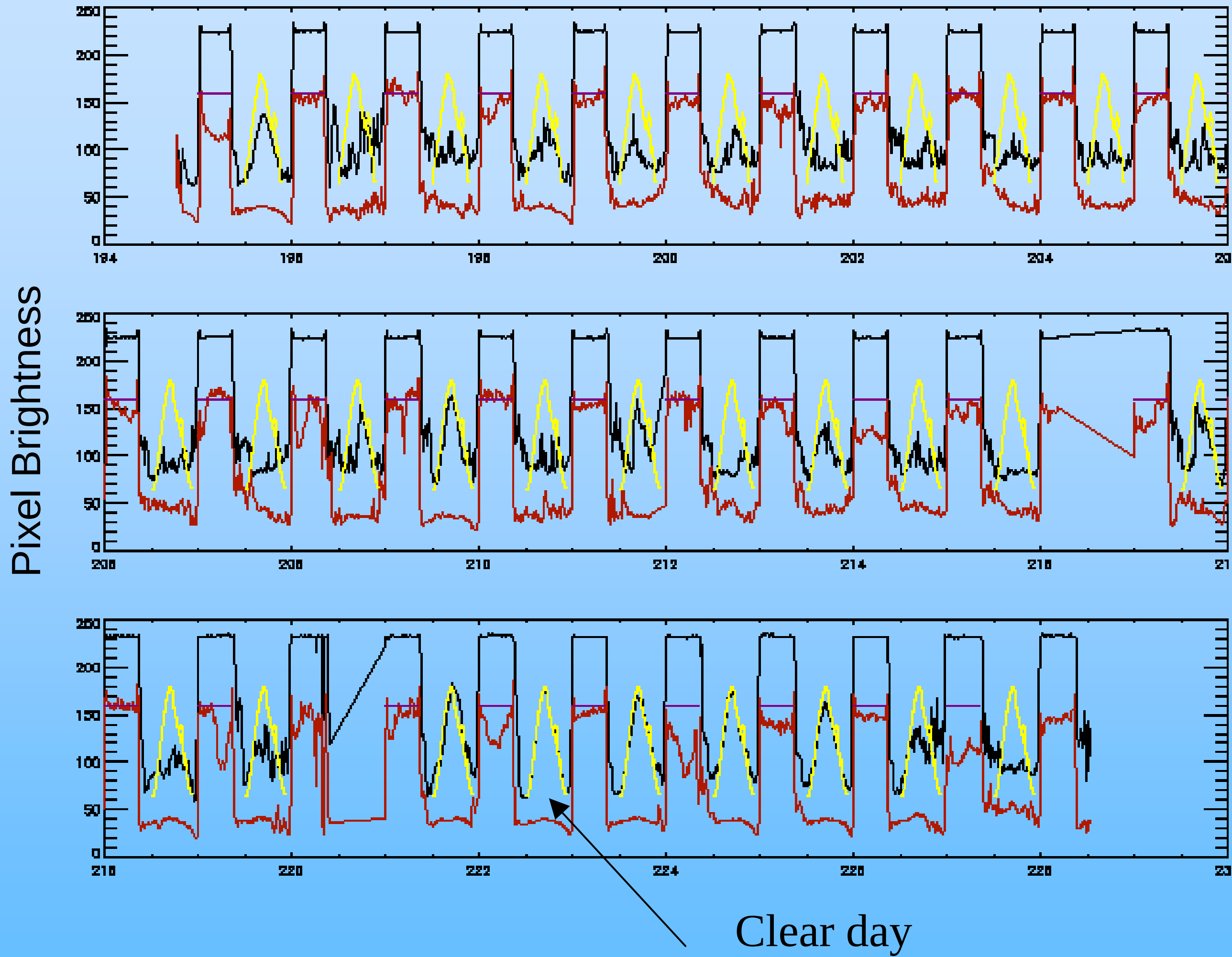




Plus…
→CCN
→SEMS
→FogCam

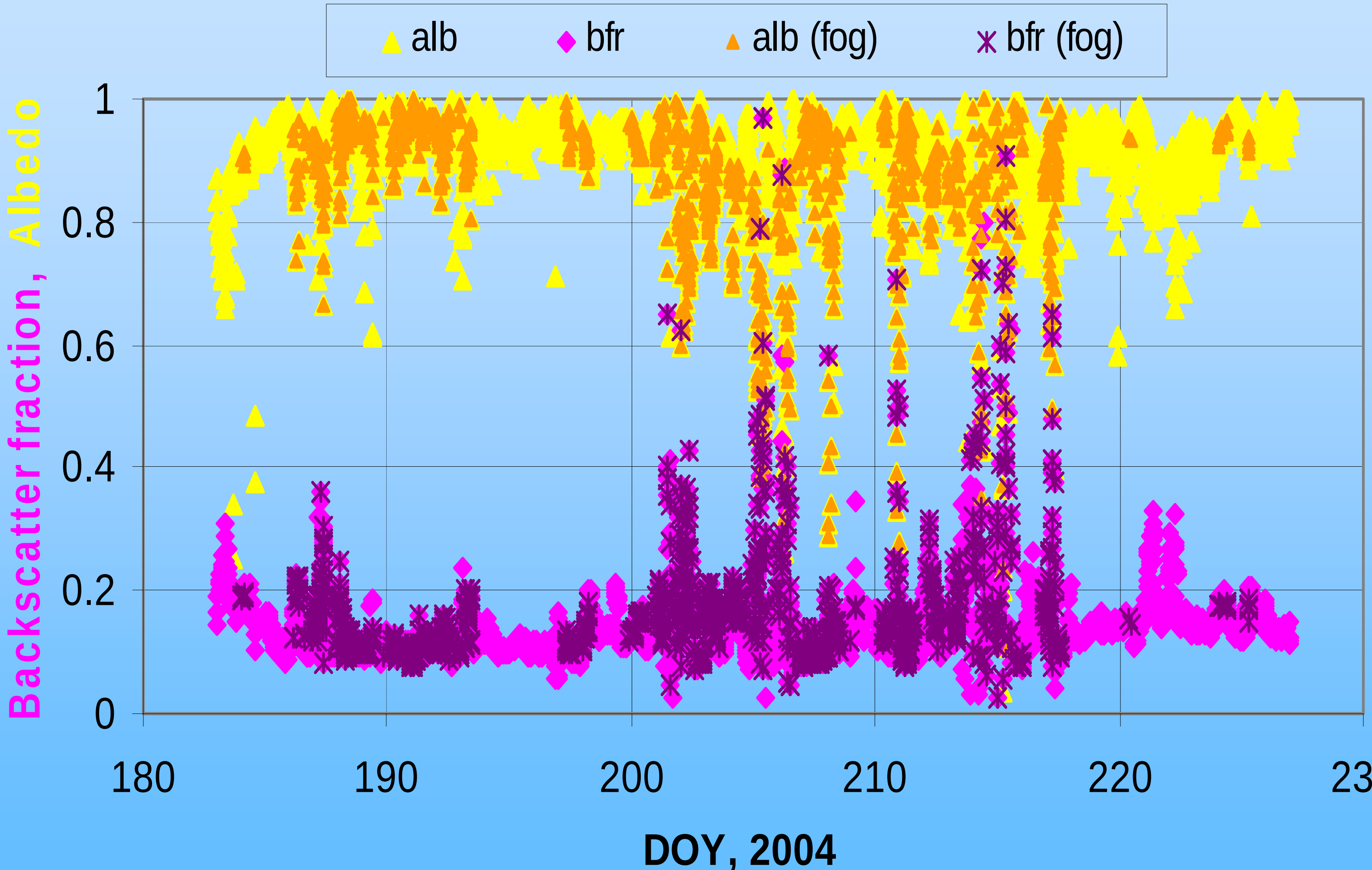
Fog at Chebogue point

Webcam –
2 black/white targets
1 picture/minute
Nighttime illumination

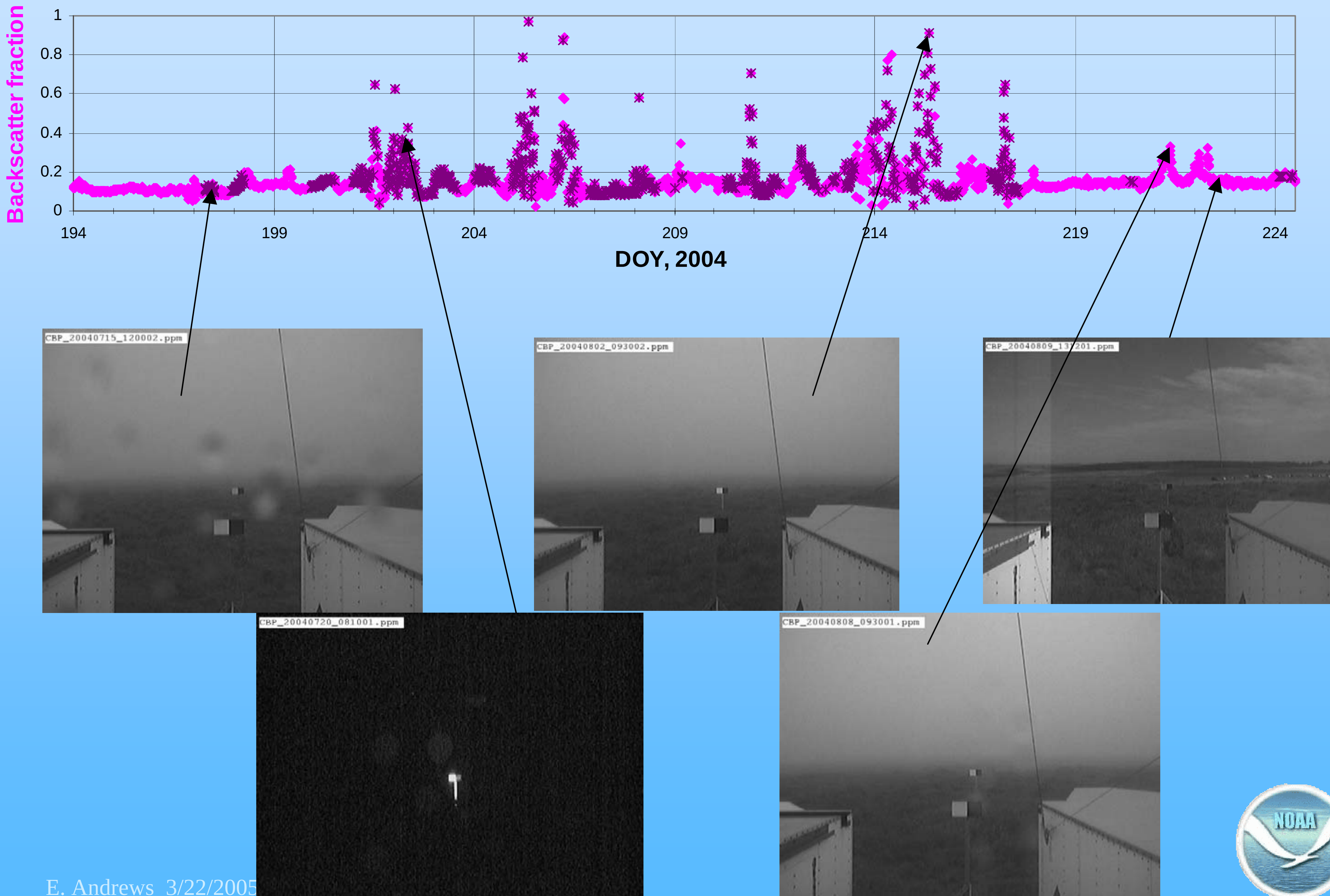


We will use Ells Dutton's fog identification based on IR fluxes instead of webcam.

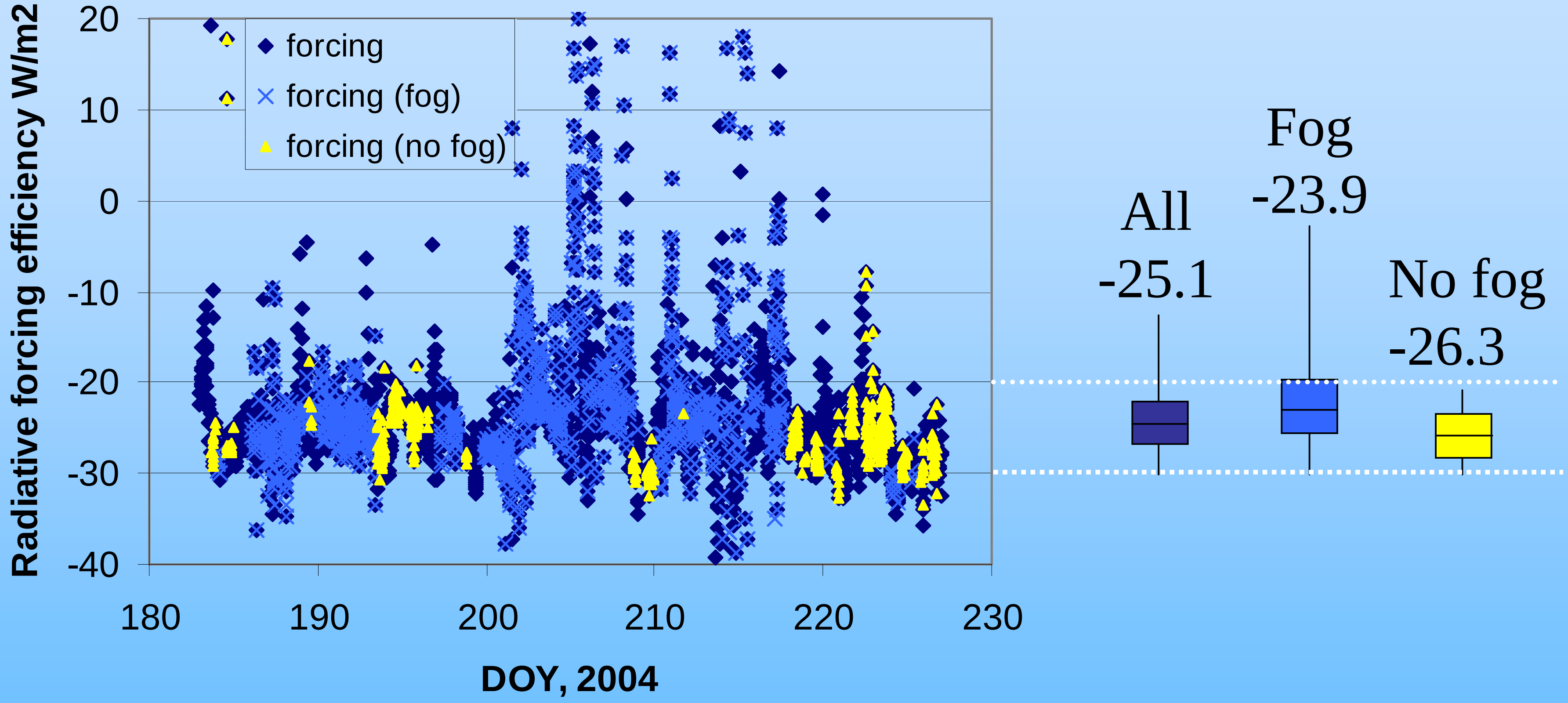
Effect of fog on aerosol optical properties



Webcam versus IR flux



Radiative Forcing at Chebogue Point



$$\Delta F \approx -DS_0 T_{at}^2 (1-A_c)(1-R_s)^2 \tilde{\omega}_0 \bar{\beta} \delta \left[1 - \frac{2R_s}{(1-R_s)^2} \left(\frac{1-\tilde{\omega}_0}{\tilde{\omega}_0 \bar{\beta}} \right) \right]$$

From Haywood and Shine, 1995

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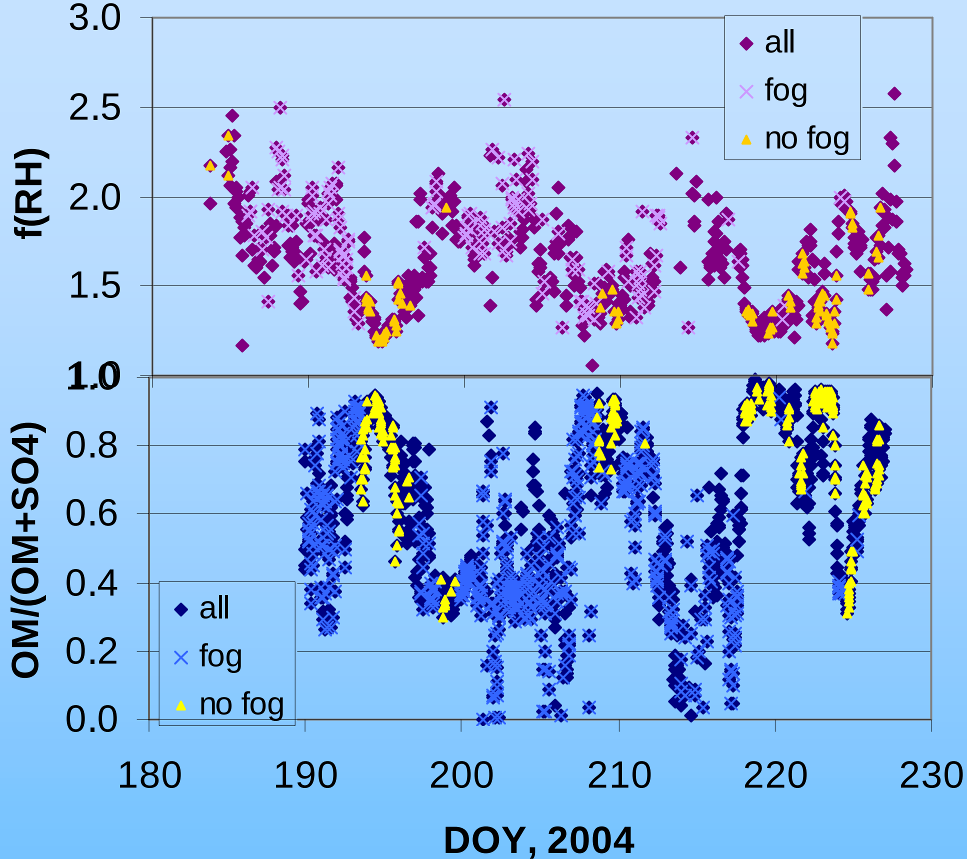
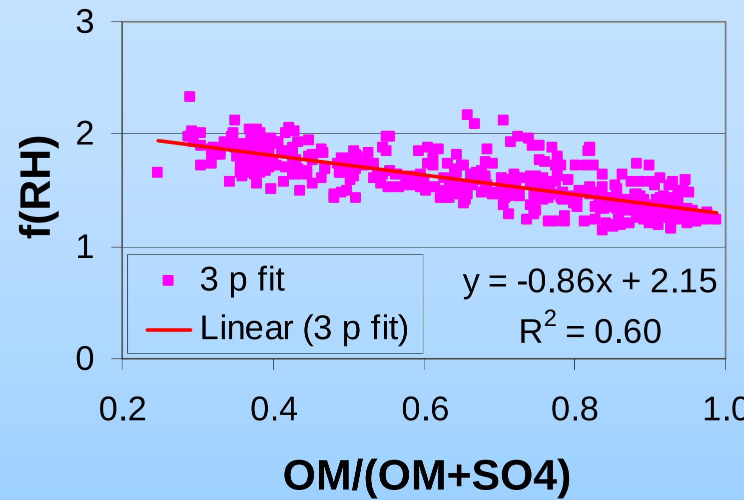
Fog, chemistry and hygroscopic growth



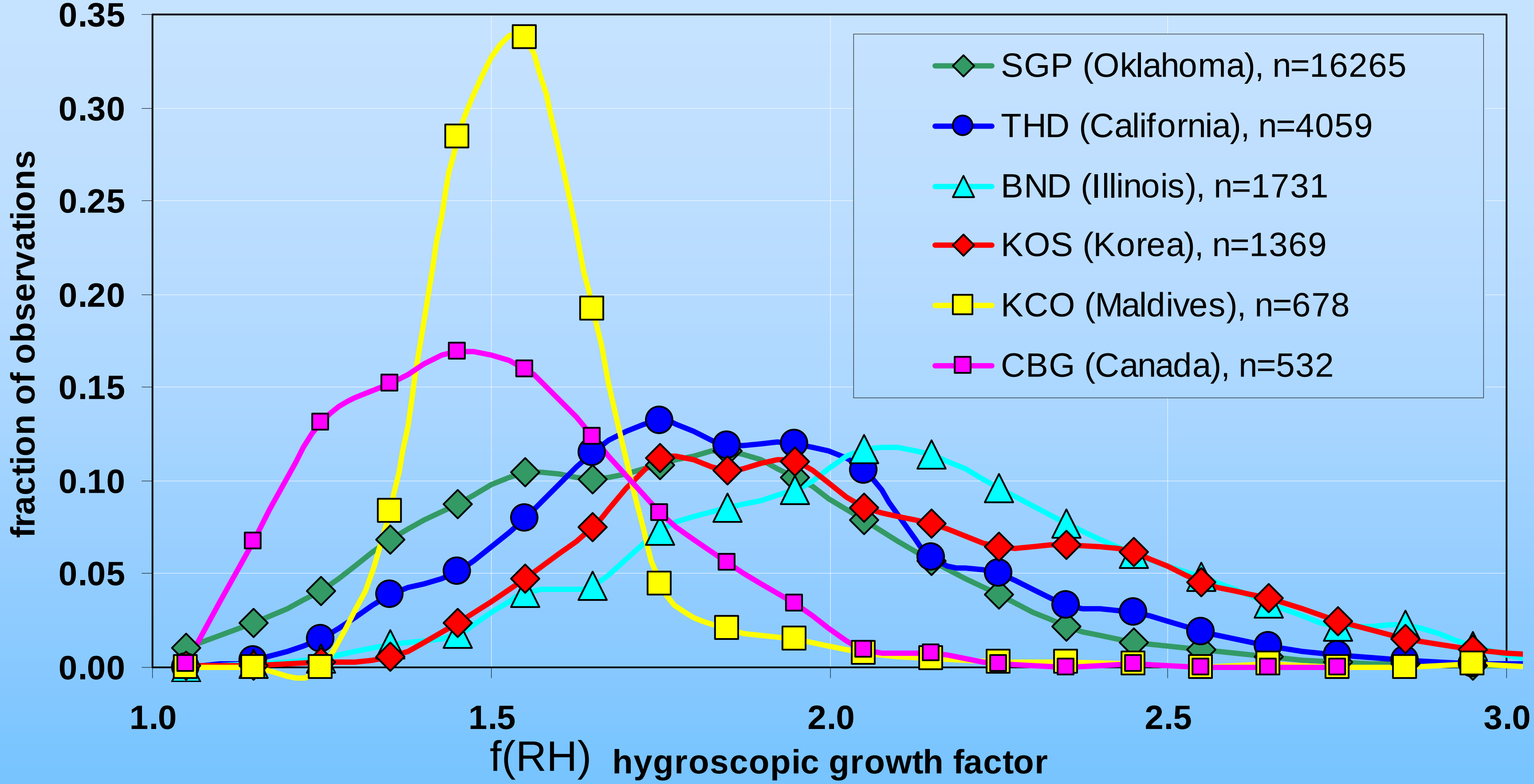


- f(RH) correlated with OM/(OM+SO_4) ratio
- Highest OM/(OM+SO_4) ratio during non-foggy periods
- f(RH) higher during foggy periods!

SO_4&OM data from Aerodyne/UMIST
[OM] > 0.25 ug/m^3, f(RH) for dp<1 um

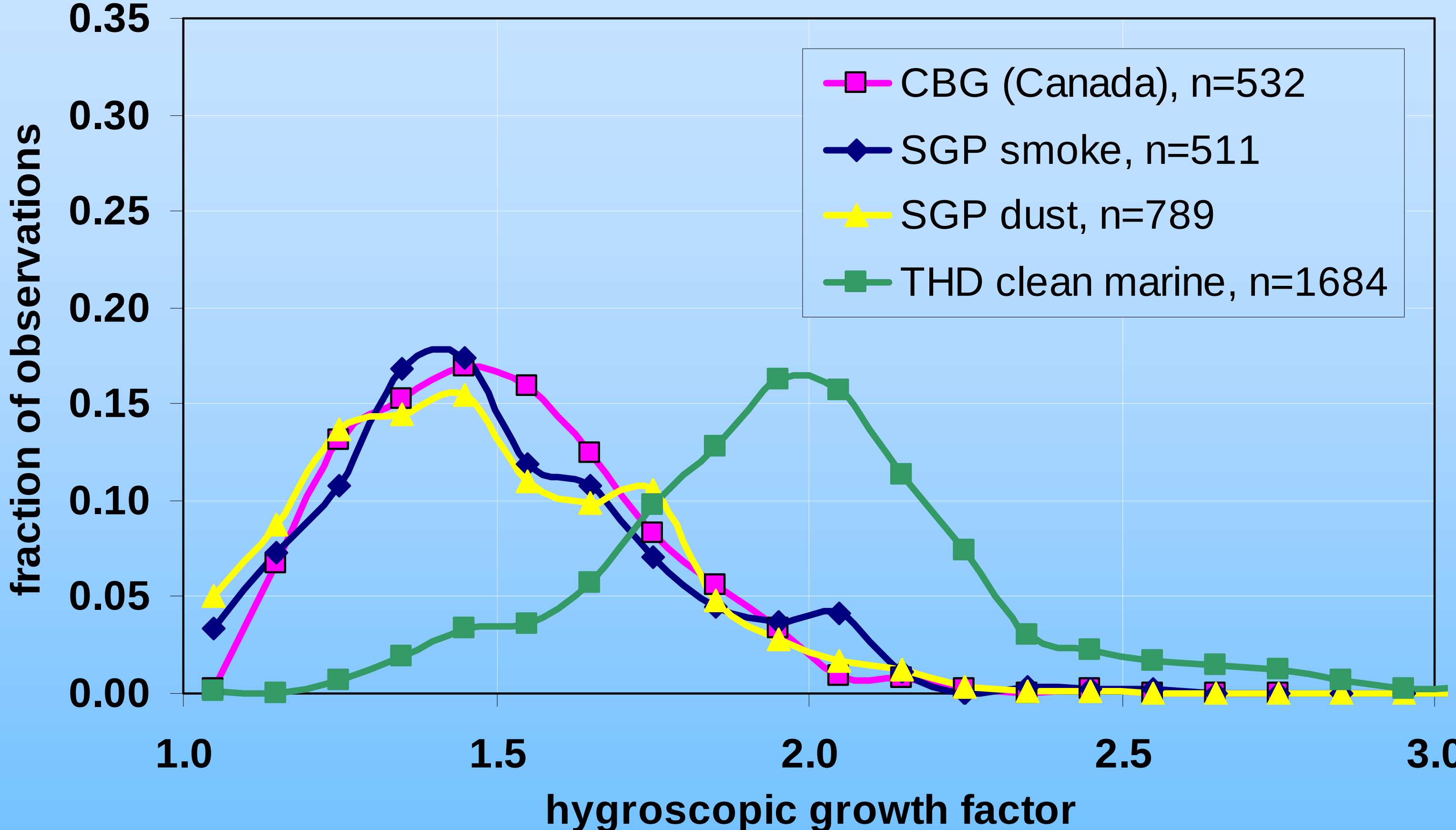
Another hypothesis – MSE curve?

Regional Differences in Hygroscopic Growth



Parameter plotted is σ_{sp}(85% RH)/σ_{sp}(40% RH), based on 2 parameter fit.
BND data courtesy of Prof. Mark Rood, Univ. of Illinois

Hygroscopicity as a function of aerosol type

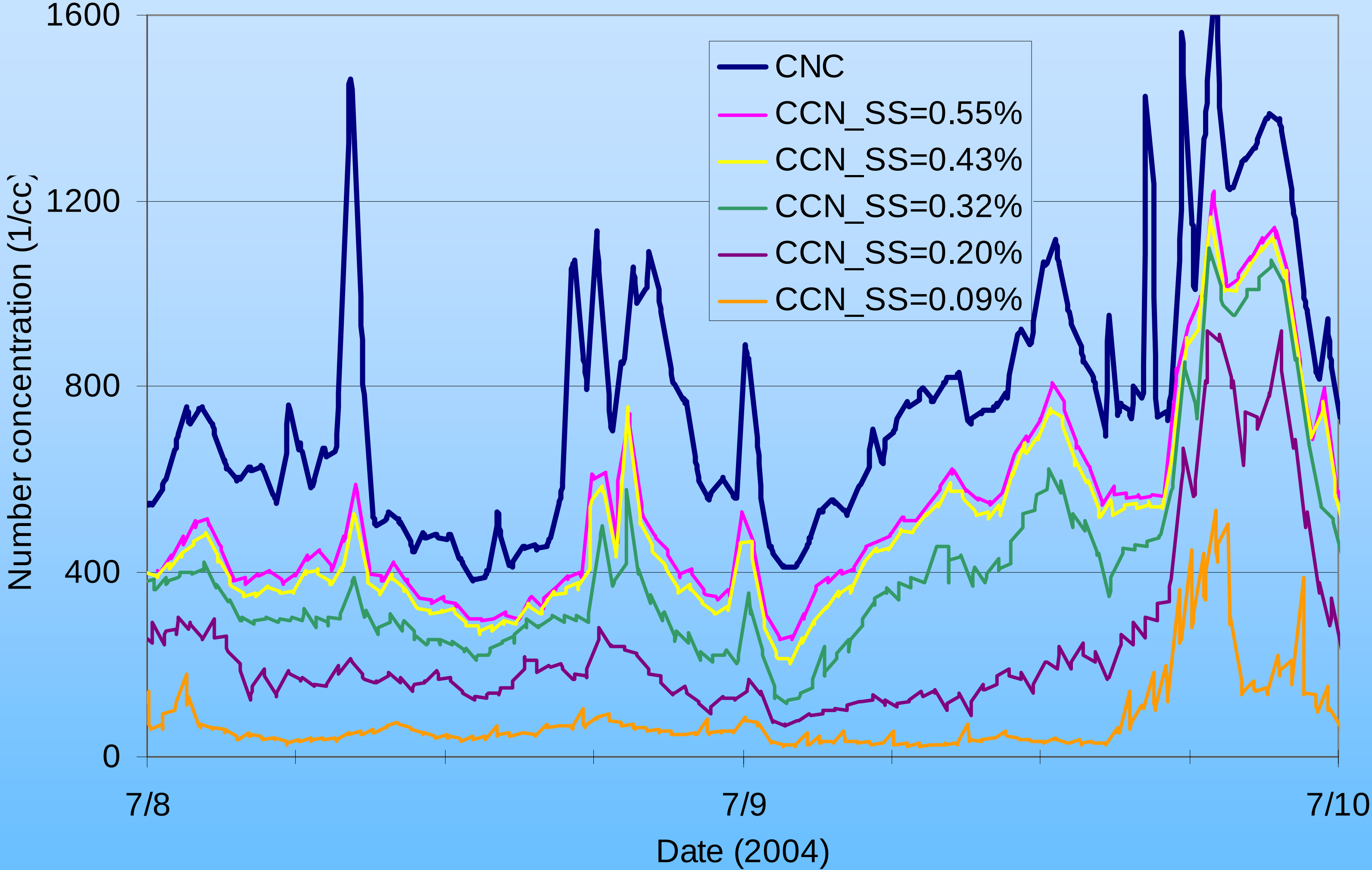


Smoke: single scattering albedo < 0.92

Dust: sub-micron scattering fraction < 0.65

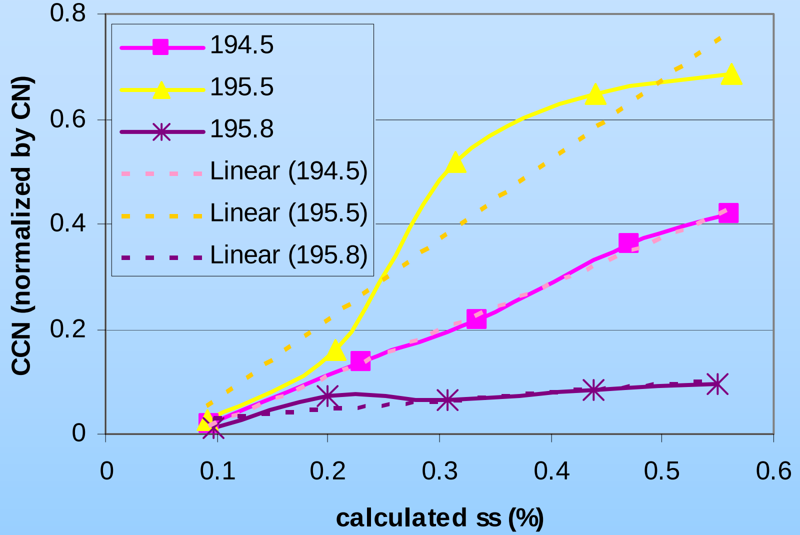
Clean marine: single scattering albedo > 0.96, sub-micron scattering fraction < 0.65

CN and CCN time series

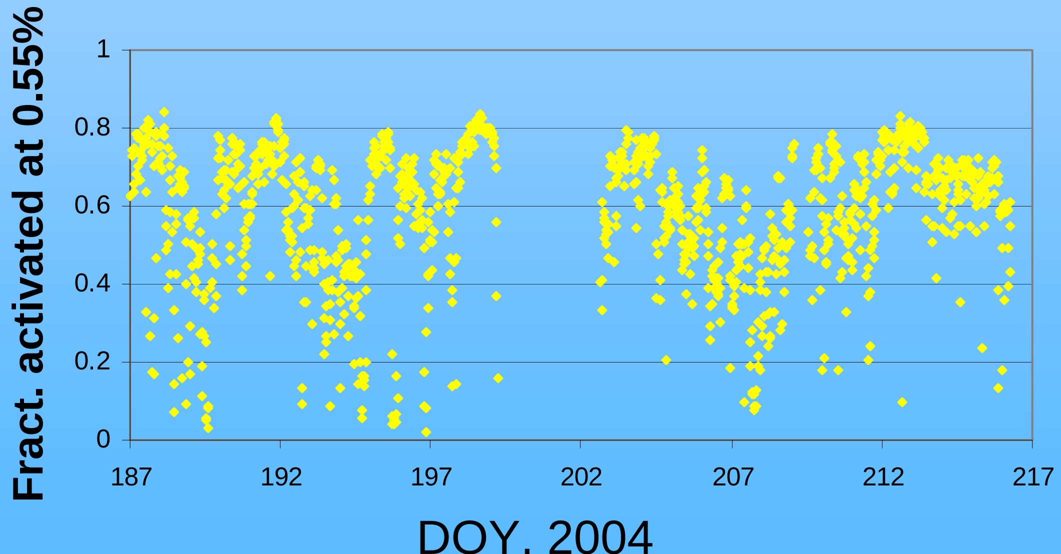


- Condensation nuclei concentration (CNC) provides upper envelope to CCN concentrations

CCN spectra at Chebogue Point

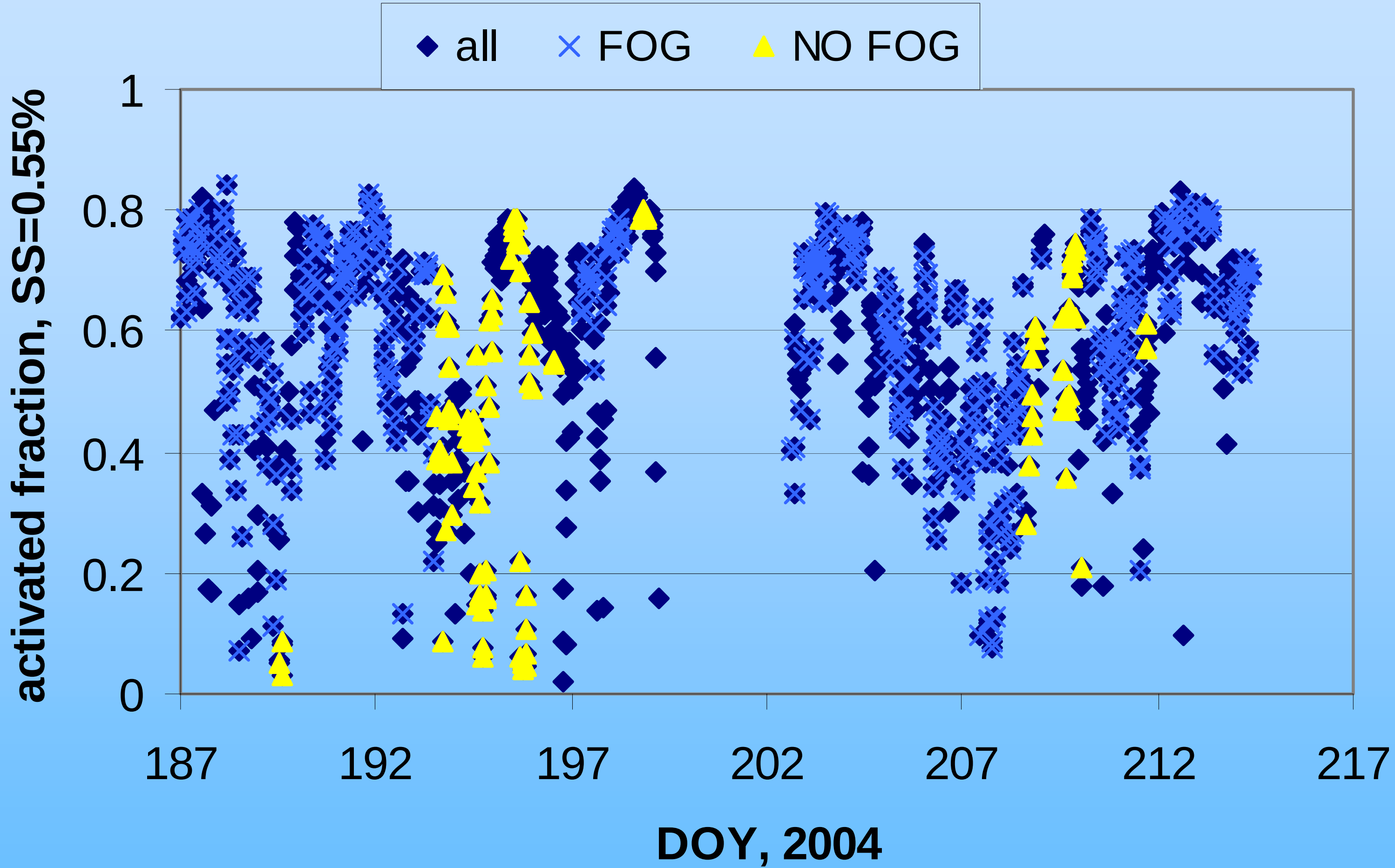


- Normalized CCN by CN
- Fit straight line as first approximation
- Lots of variation in slope



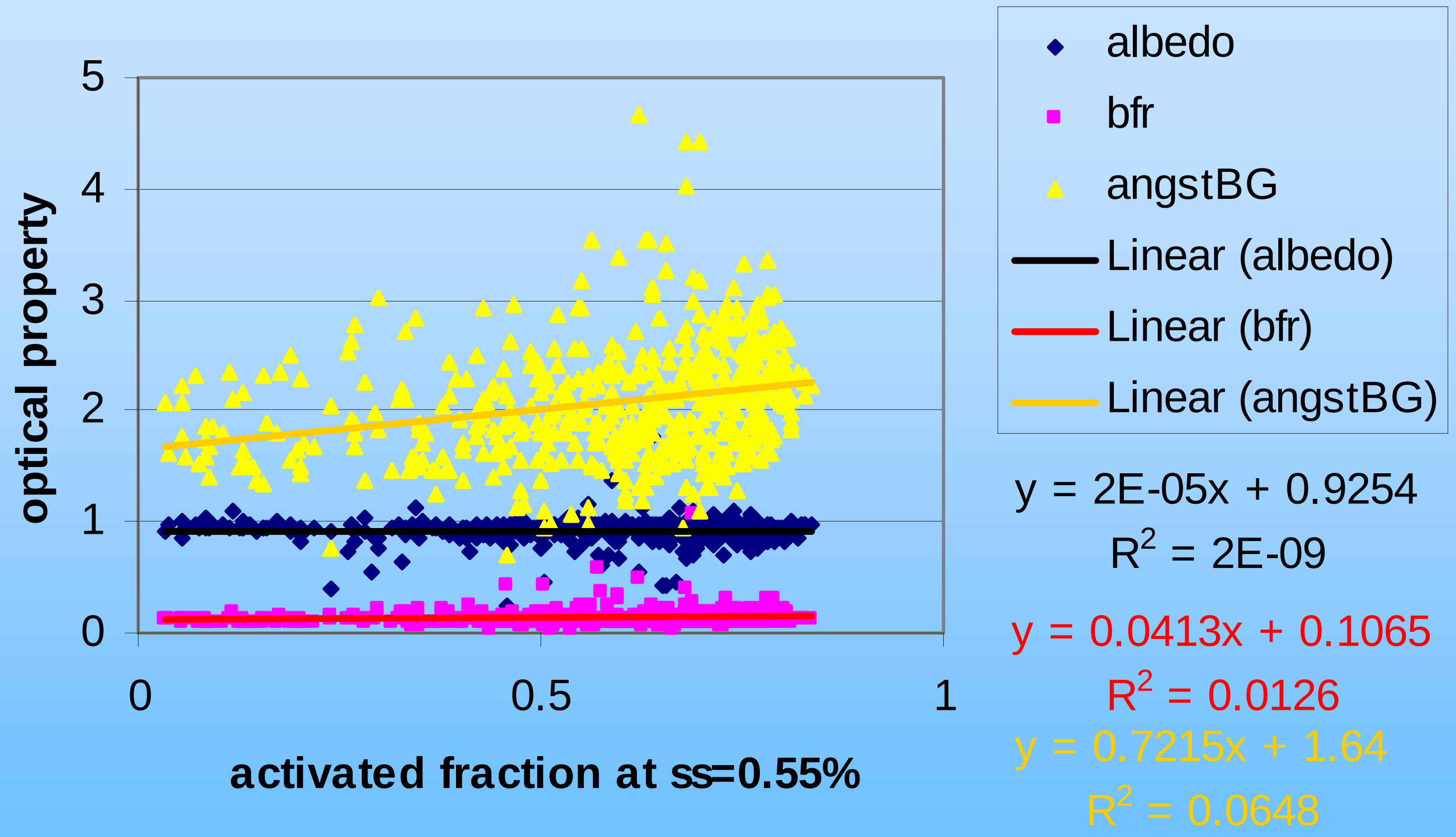
QUESTION:
How do spectra change during fog/aerosol events?

Activated fraction at SS=0.55% and fog



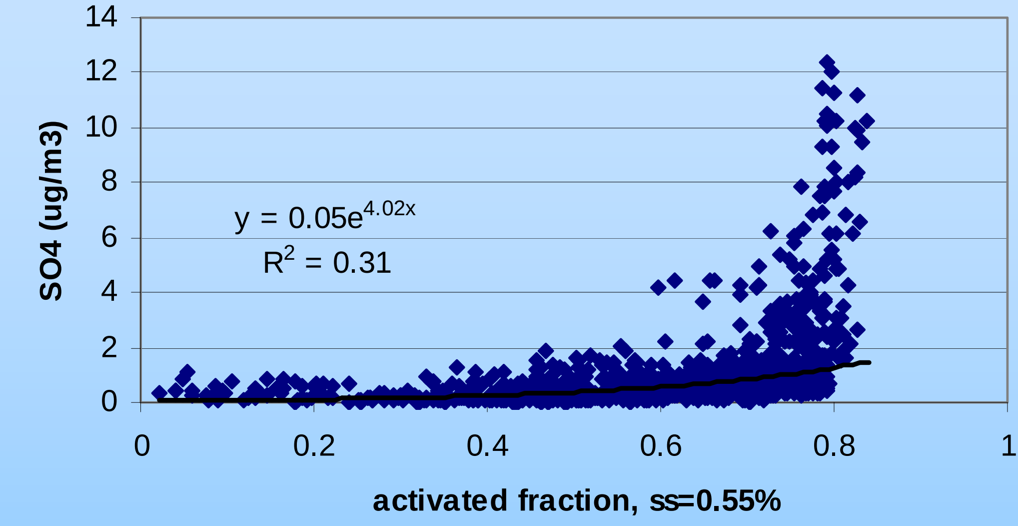
There doesn't appear to be a relationship between the fraction of CCN that activate at 0.55% super-saturation and the presence or absence of fog.

Activated fraction and aerosol optical properties

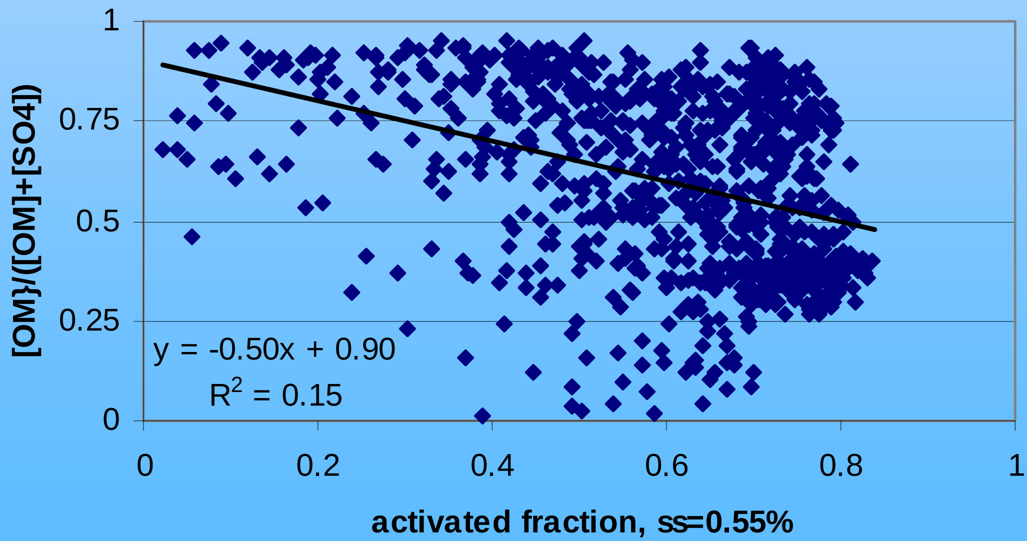


The Ångström exponent is inversely related to particle size. The activated fraction appears to increase slightly when the aerosol population is dominated by smaller particles.

Activated fraction and aerosol chemistry



More sulfate = More CCN



Higher $\frac{[OC]}{([OC]+[SO4])}$ = Less CCN

Summary

- Fog has a significant influence on aerosol optical properties
- Based on simplistic model, does not appear to strongly affect radiative forcing efficiency
- Hygroscopic growth is strongly correlated with aerosol composition – OM reduces hygroscopic growth
- CCN spectra are variable; but at this stage we're not sure what the sources of variability are, aside from general indications of size and chemistry effects – Jose Jimenez's group (CU) will be exploring this.


THANKS!

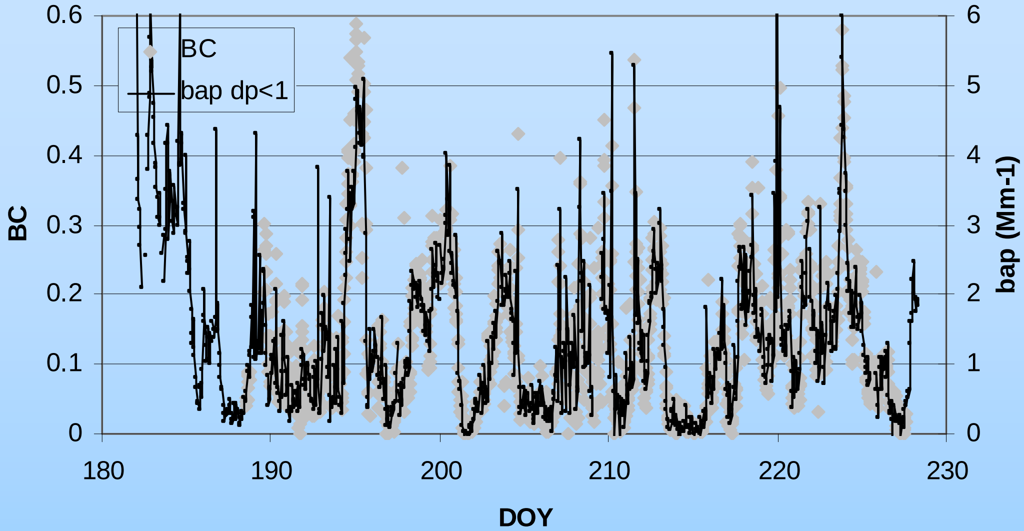
Cloud Scavenging Decreases Single-scattering Albedo

- **If the particles are externally mixed**
  - aerosol light scattering is dominated by particles that are readily-scavenged by clouds, such as sulfates and water-soluble organics
  - aerosol light absorption is dominated by less readily-scavenged particles, such as graphitic carbon (soot)
- **If the particles are internally-mixed**
  - larger particles are scavenged more efficiently than smaller particles
  - the scavenged particles have much higher single-scattering albedos than the smaller particles
- **Cloud droplets are therefore enriched in light scattering particles relative to light absorbing particles**
- **When precipitation falls, it removes more of the light scattering particles than the light absorbing ones**
- **Cloud scavenging therefore systematically decreases aerosol single-scattering albedo**

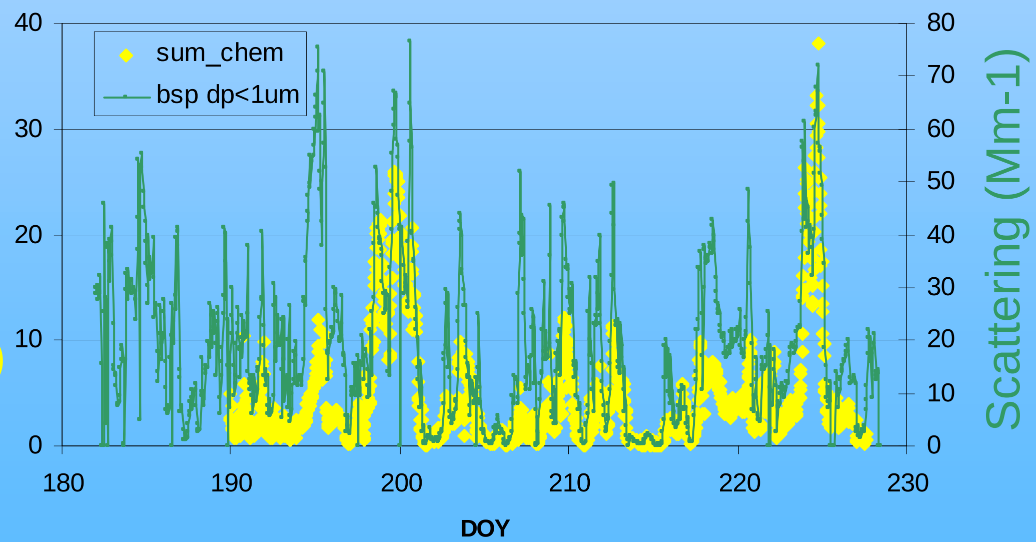
Cloud Scavenging Increases Backscatter Fraction

- **If the particles are externally or internally mixed**
  - light scattering efficiency shows a strong size-dependence in the transition region between scavenged and unscavenged particles
  - light backscattering scattering efficiency shows a weaker size-dependence in the transition region between scavenged and unscavenged particles
  - backscatter fraction shows a very strong size-dependence in the transition region between scavenged and unscavenged particles
- **Cloud droplets are therefore enriched in light scattering particles relative to light backscattering particles**
- **When precipitation falls, it removes more of the light scattering particles than the light backscattering ones**
- **Cloud scavenging therefore systematically increases aerosol hemispheric backscattering fraction**

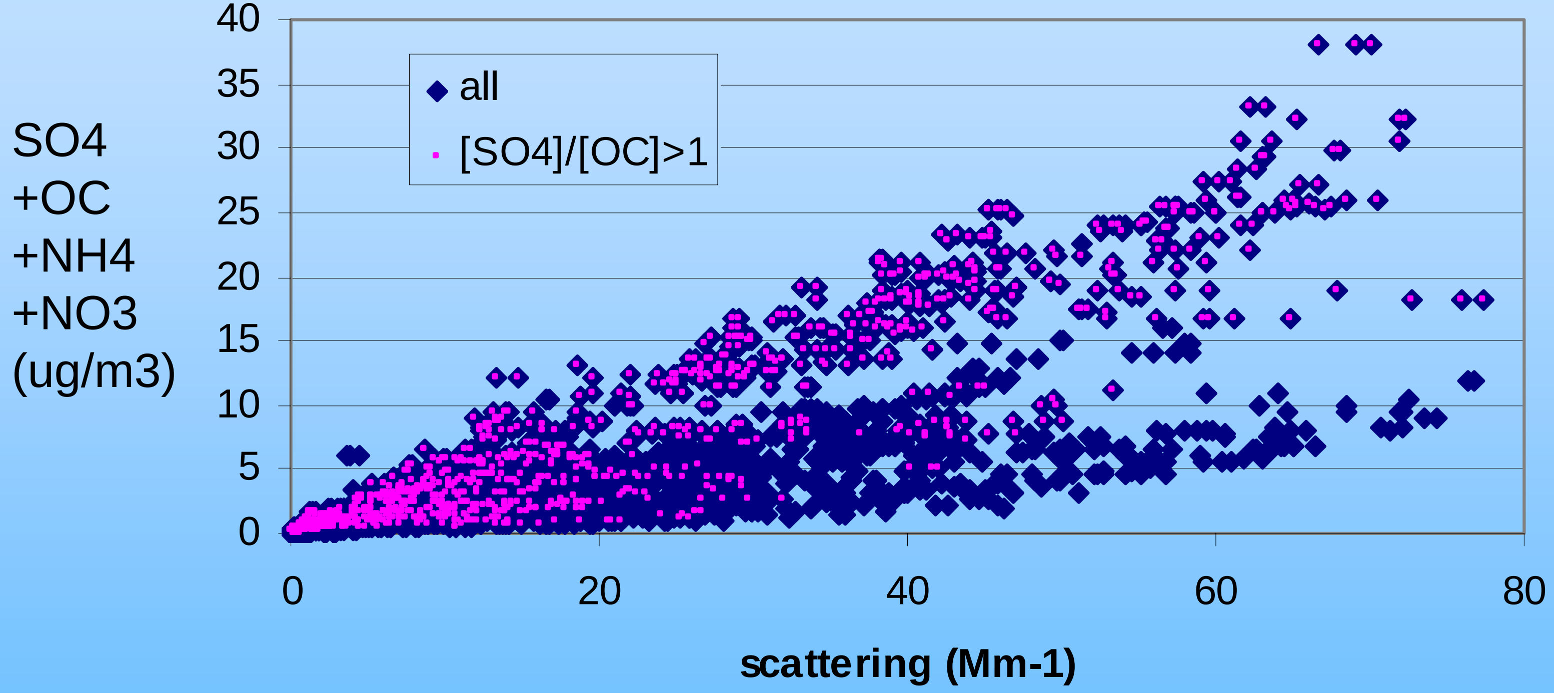
Optical properties and chemistry



SO4
+OC
+NH4
+NO3
(ug/m3)



Times when big difference between scattering and sum_chem are when SO4 > OC →Other ions? Water?



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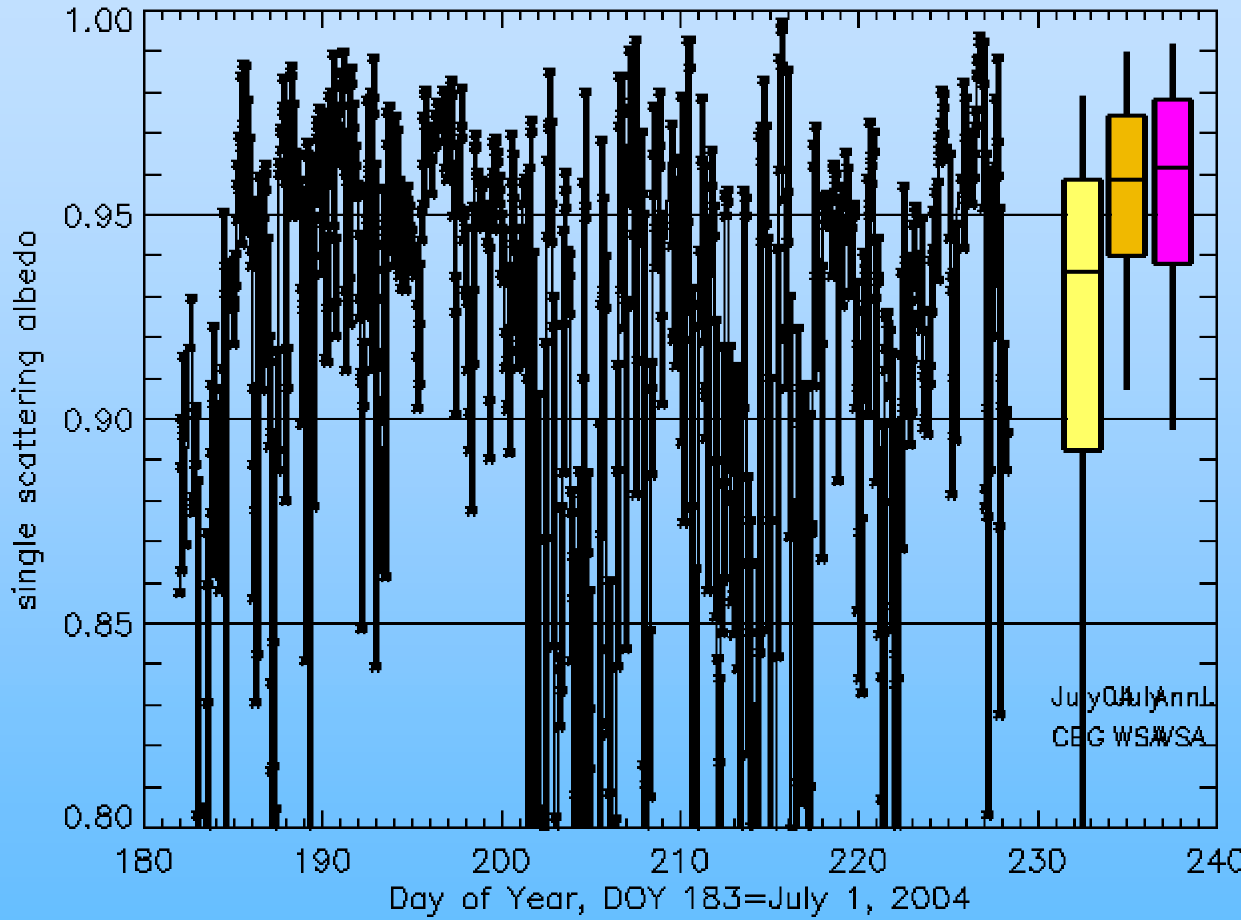
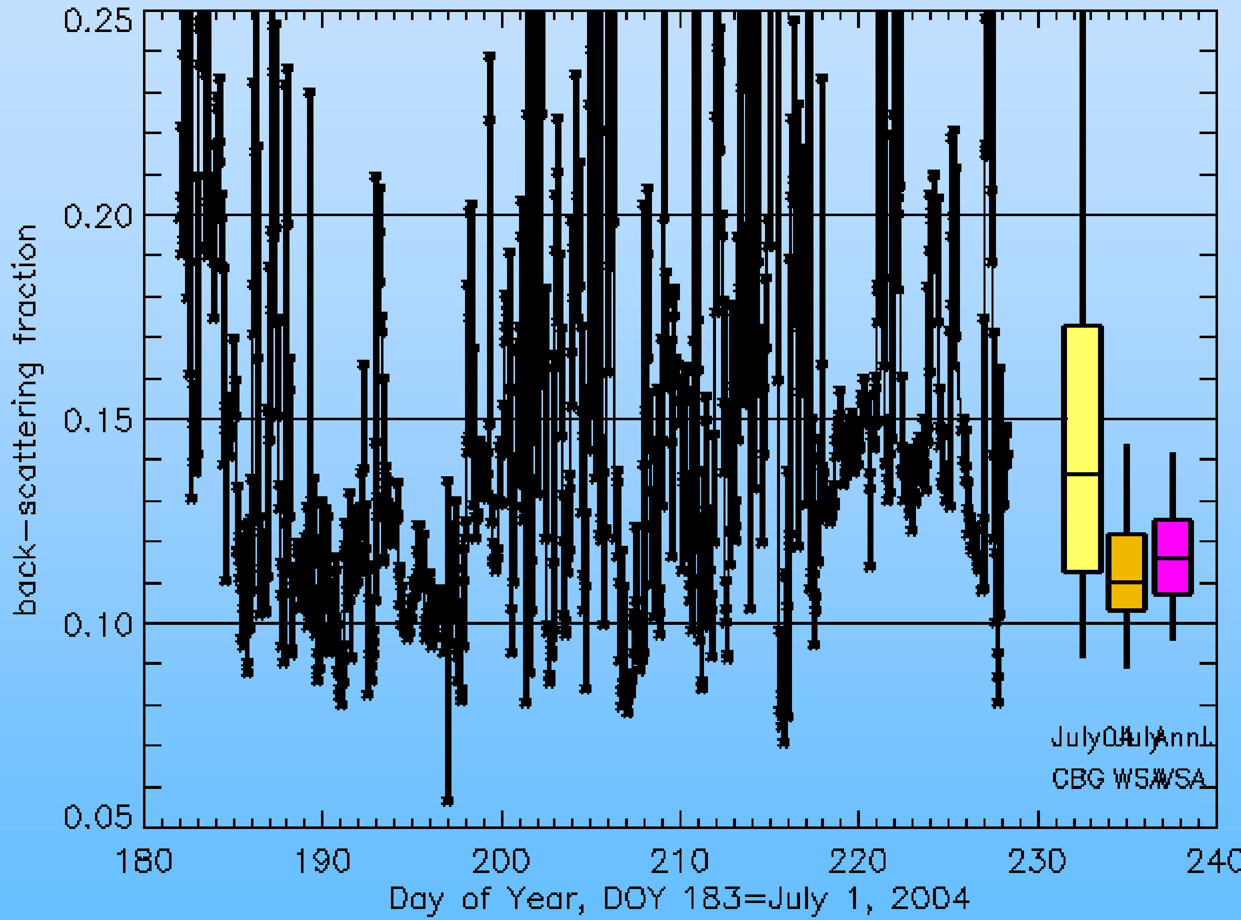
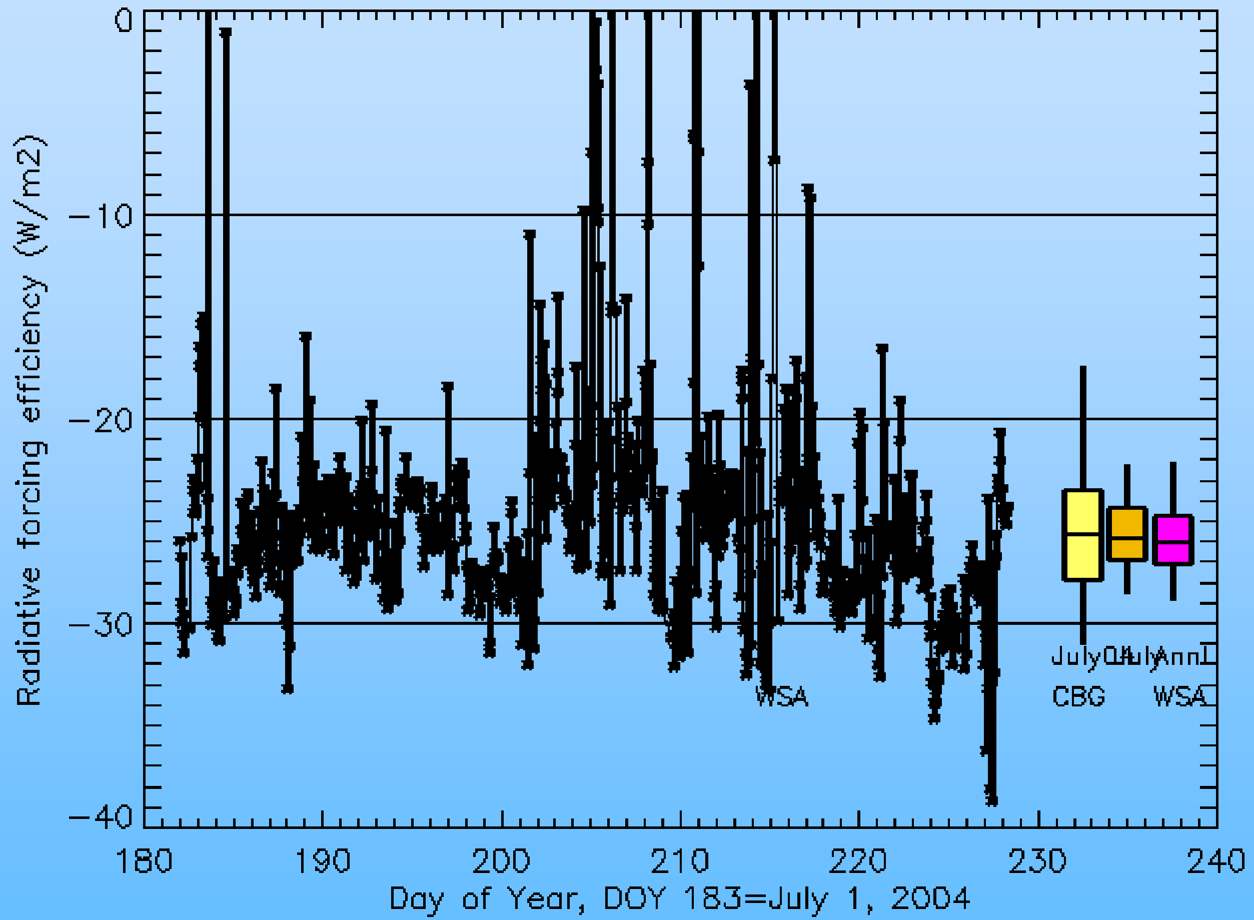
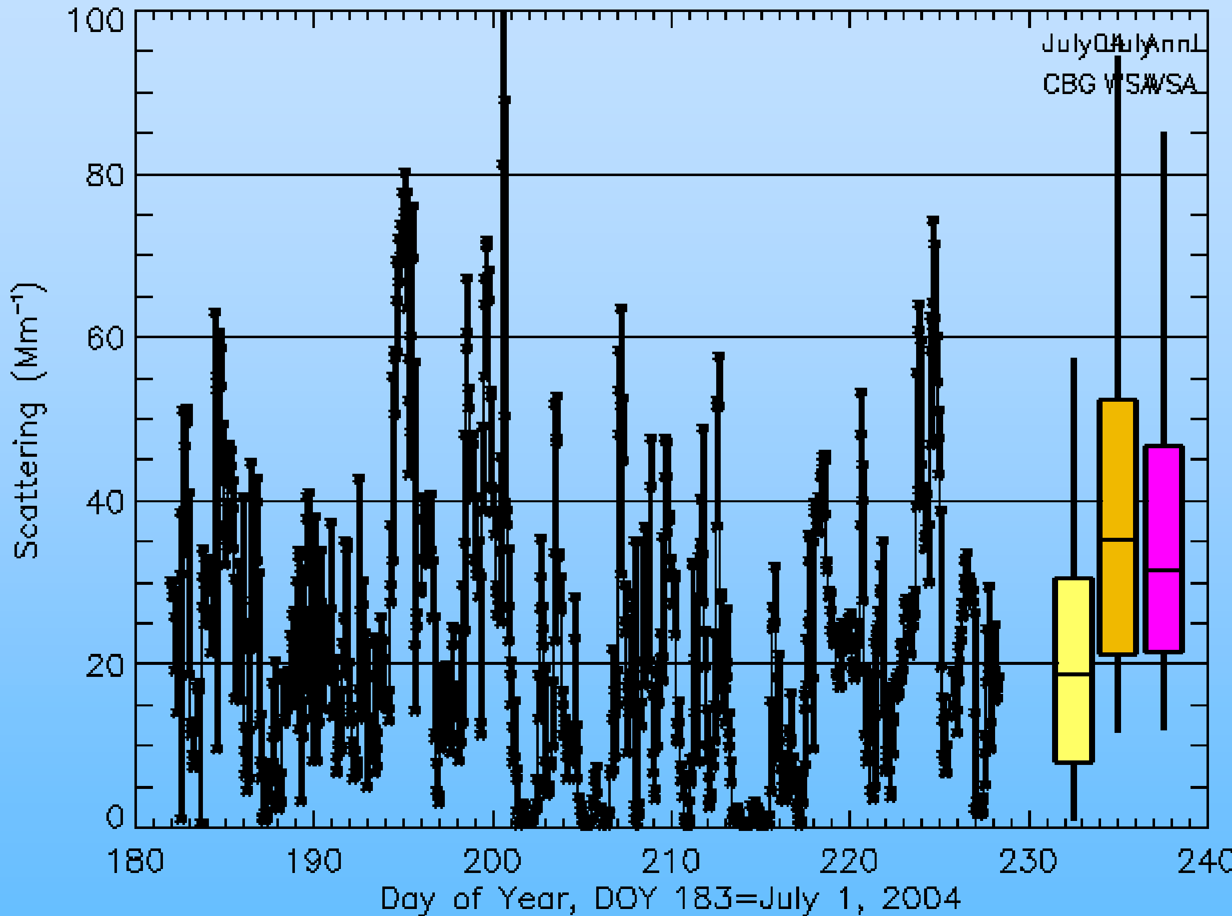


1.00
0.95
0.90
0.85
0.80
single scattering albedo
180
190
200
210
220
230
240
Day of Year, DOY 183=July 1, 2004


back-scattering fraction
0.25
0.20
0.15
0.10
0.05
180
190
200
210
220
230
240
Day of Year, DOY 183=July 1, 2004
July04 July Ann
CBG WSA WSA


0
−10
−20
−30
−40
Radiative forcing efficiency (W/m2)
180
190
200
210
220
230
240
Day of Year, DOY 183=July 1, 2004
WSA
JulyCBG
JulyWSA
Ann1
CBG
WSA


July04 July Ann
CBG WSA WSA
Scattering (Mm⁻¹)
0
20
40
60
80
100
180
190
200
210
220
230
240
Day of Year, DOY 183=July 1, 2004

Measurements and derived parameters

<u>MEASUREMENTS</u>

Light scattering (total) (450, 550, 700 nm)
Light scattering (back) (450, 550, 700 nm)
Light absorption (550 nm)
Particle number concentration
Cloud condensation nuclei number concentration at 5 supersaturation values
Ion concentrations and particle mass (PMEL)
Particle size distributions

<u>DERIVED PARAMETERS</u>

Back scatter fraction
Aerosol single scattering albedo
Ångström exponent