Seasonal Climatology of Vertical Profiles of Aerosol Optical Properties at Two Rural Locations in the U.S.

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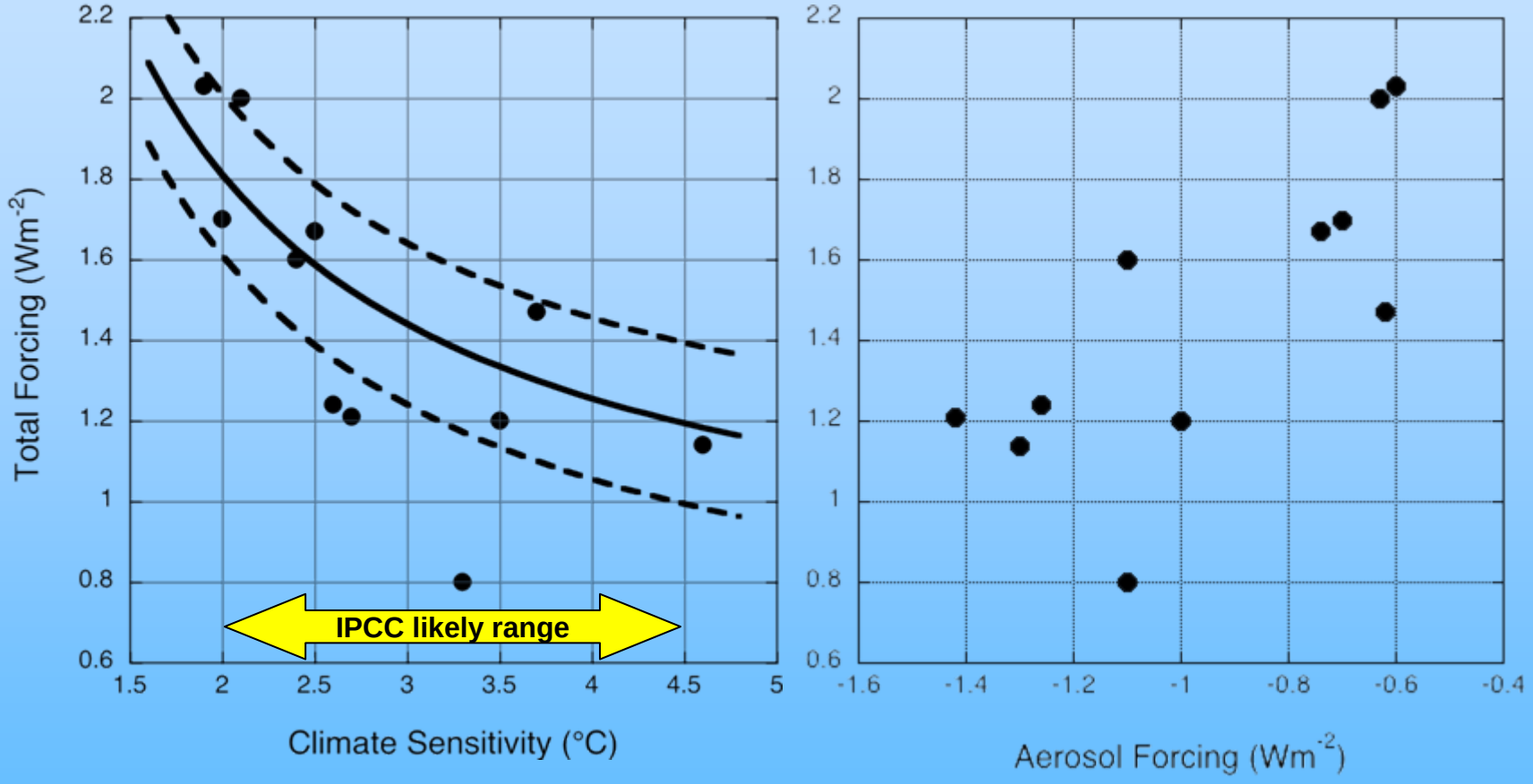
Reducing uncertainty of aerosol forcing will better constrain climate sensitivity



GCMs with lowest climate sensitivity have largest total forcing and least aerosol cooling. Source: Kiehl (GRL, 2007)

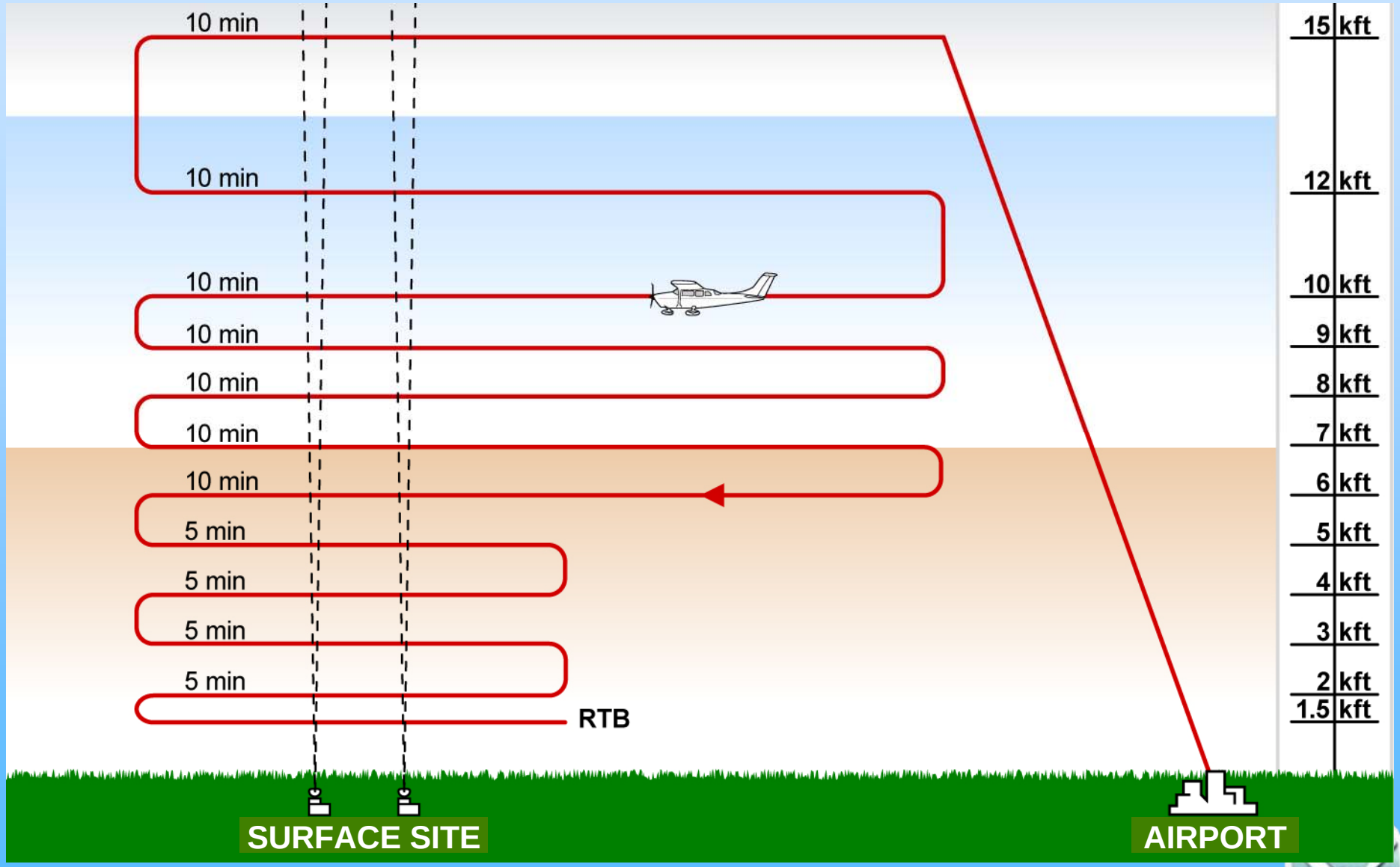
Airborne Aerosol Observatories

- Cessna Turbo 206
- Research velocity: 50 m sec^{-1}
- Ceiling ~5 km
- Instrument payload ~320 kg
- Flight duration: ~4.5 hours

- IAP (In-situ Aerosol Profiling)
- DOE/ARM Southern Great Plains (SGP) site in Oklahoma
- Cessna 206 operated Oct-2005 - Dec-2007; replaced Cessna 172XP (Mar-2000 – Oct-2005)
- 742 vertical profiles (both planes)
- Discontinuity in data set due to plane change. Cessna 172 data are for sub-micrometer particles only, Cessna 206 inlet system sampled particles up to ~7 μm diameter
- Funding from DOE/ARM Program

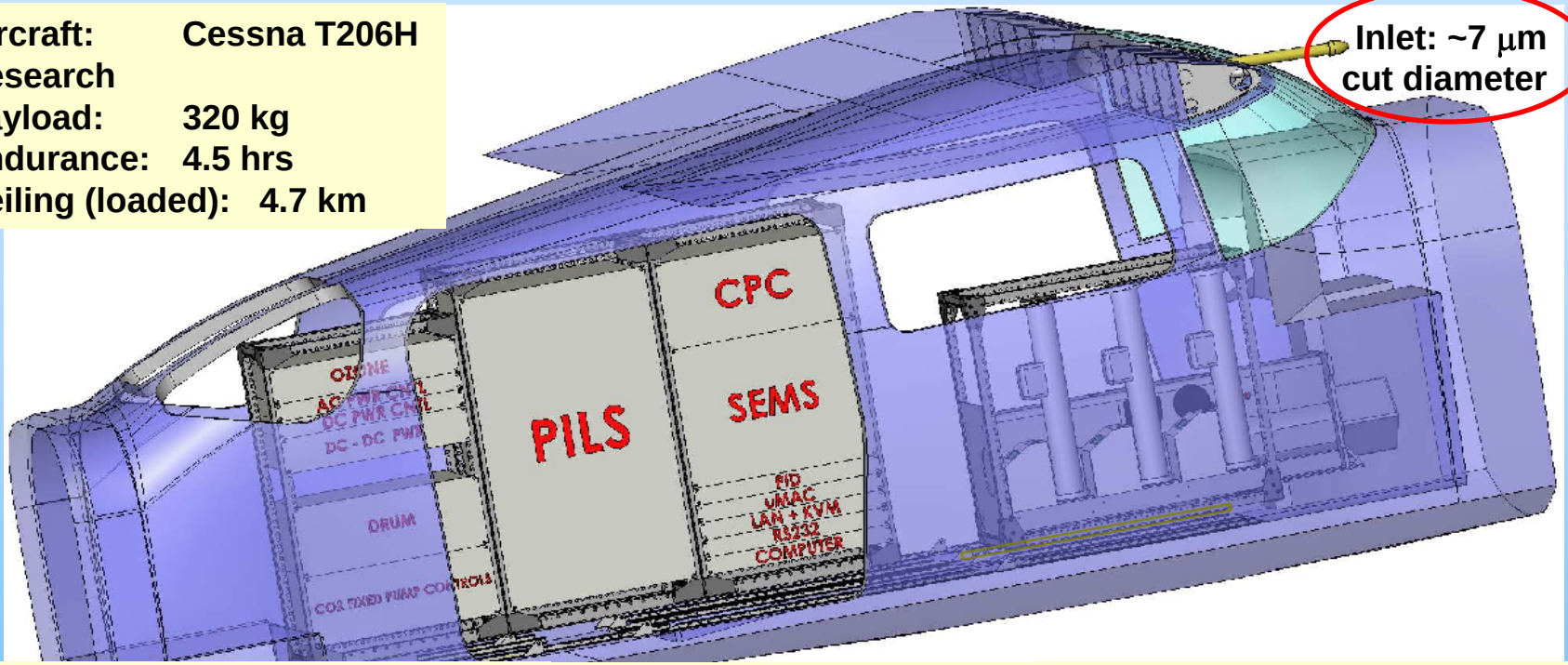
- AAO (Airborne Aerosol Observatory)
- Primary profile location near the Bondville (BND) surface station in east-central Illinois
- Jun-2006 - Sep-2009
- 401 vertical profiles
- 63 profiles were aligned with A-Train overflights, 41 aligned with Terra
- Funding from NOAA Climate Forcing Program

Flight Profile



NOAA "AAO" Instrument Package

Aircraft: Cessna T206H Research
Payload: 320 kg
Endurance: 4.5 hrs
Ceiling (loaded): 4.7 km



Chemical Properties

- **Major ions**
  - PILS sampler
  - analysis by IC
- **Gases (O_3, carbon-cycle flasks)**

Microphysical Properties

- **Number concentration**
  D > 10 nm
- **Size distribution**
  20 < D < 500 nm

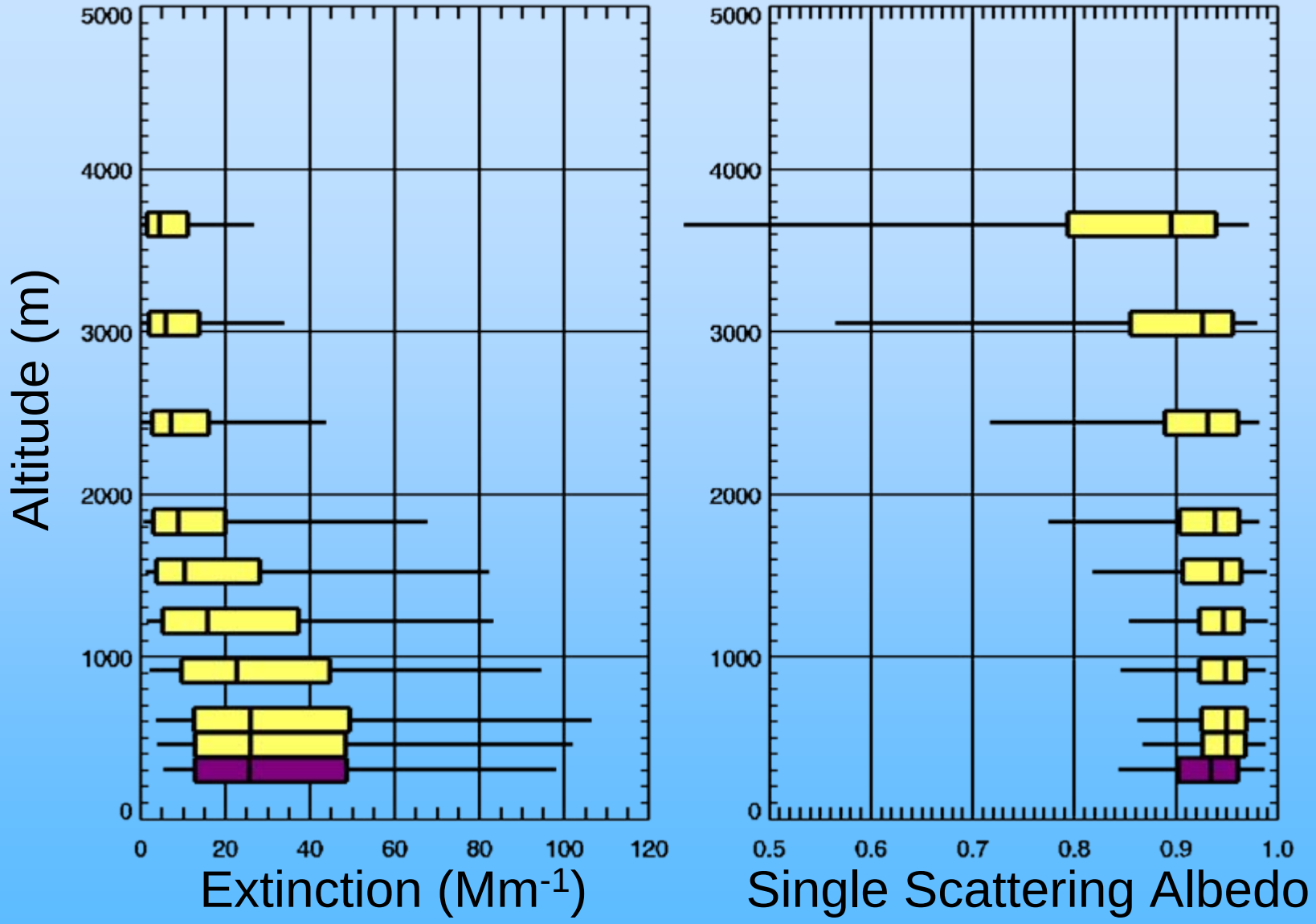
Radiative Properties

- **Light scattering, backscattering, and absorption**
  3 wavelengths,
  no size cut,
  <40% RH
- **Scattering vs. RH**
  1 wavelength,
  1 μm size cut,
  <40%, 65%, 85% RH

Sampling Program

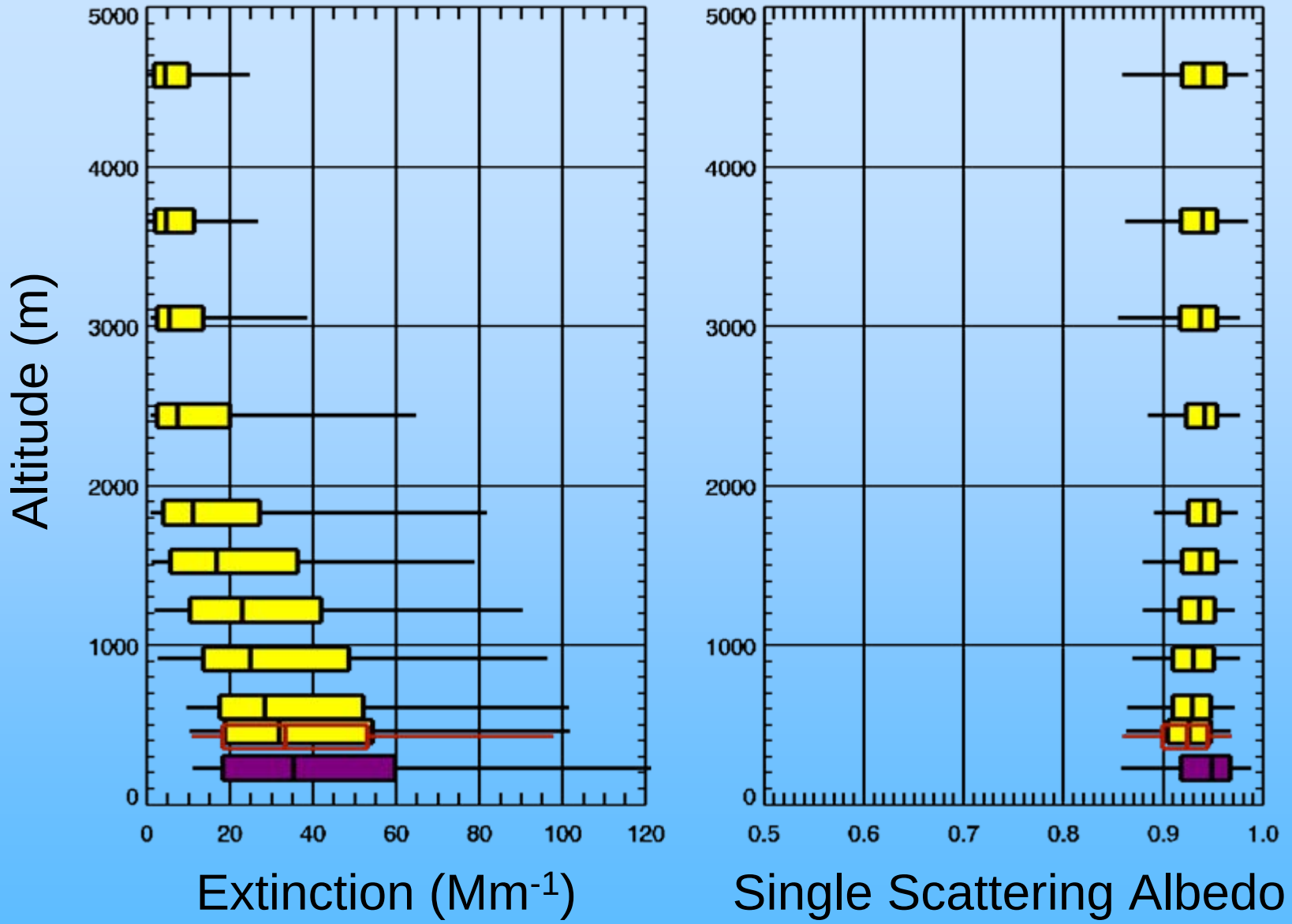
- **goal was 2-3 flights weekly, achieved 2.3 flights weekly 2006-06 to 2009-09**
- **vertical profiles to 4.6 km**
- **10 level legs spaced at 150 m to 600 m intervals**
- **attempt frequent matchups with Terra and A-Train satellites**
- **Flights near Bondville, IL surface monitoring site**

IAP - Surface vs. Aloft (1μm)

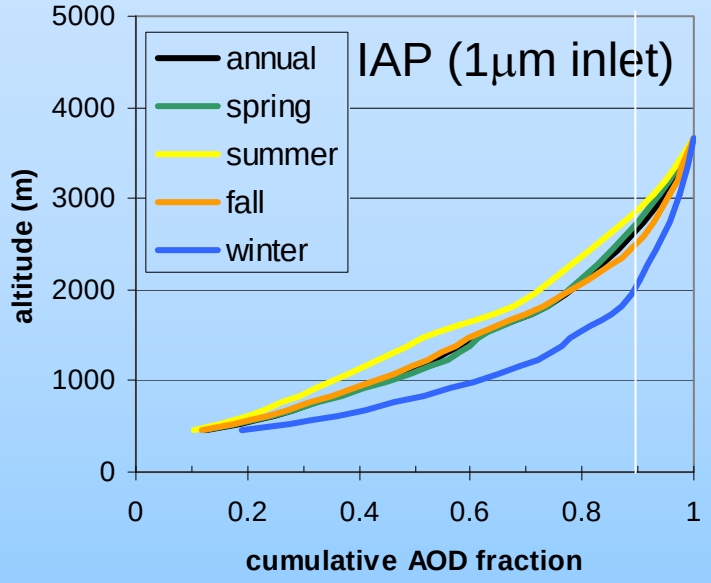


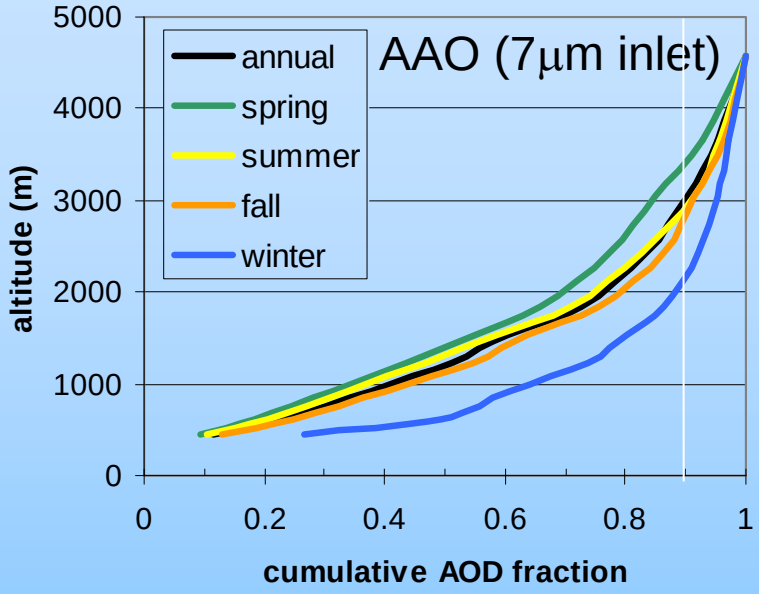
Data from 2000-2005 (old inlet, Cessna 172)

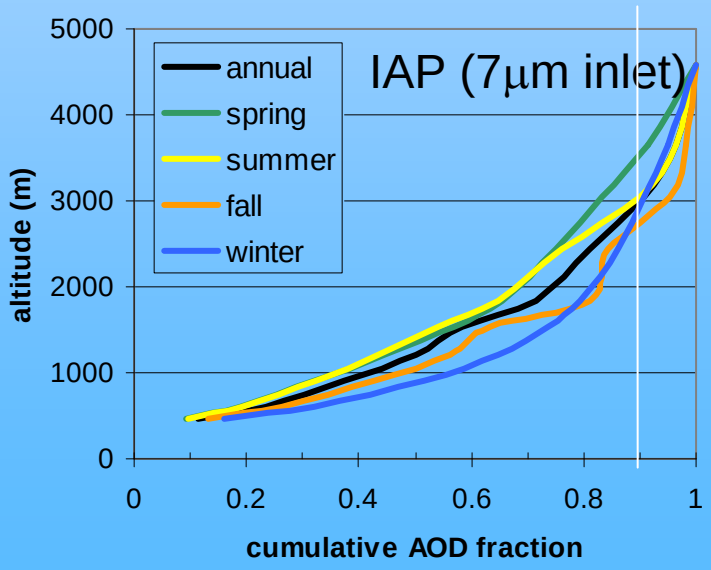
AAO - Surface vs. Aloft (7μm)



Cumulative AOD vs Altitude





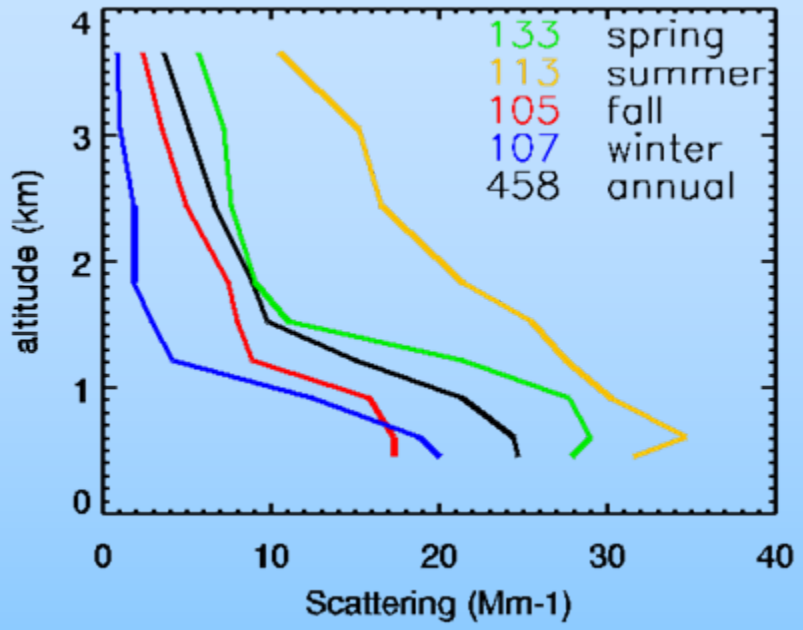


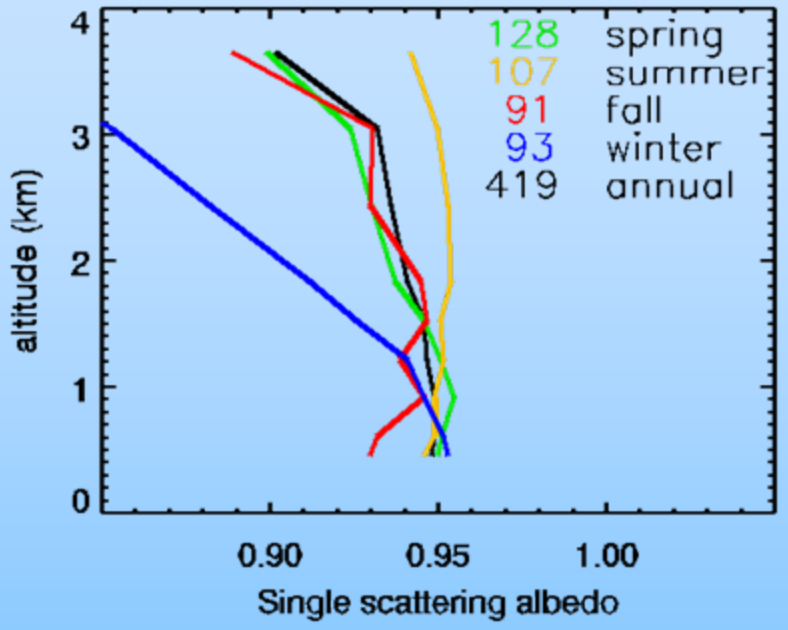
Annual – 90% AOD below 3000 m

Winter – most aerosol closer to surface
AAO (7um): 90% below 2000 m
IAP (1um): 90% below 2000 m
IAP (7um): 90% below 3000 m

 550 nm, dry conditions, ambient T&P, median values plotted

IAP - Seasonal Profiles (sub1μm inlet)



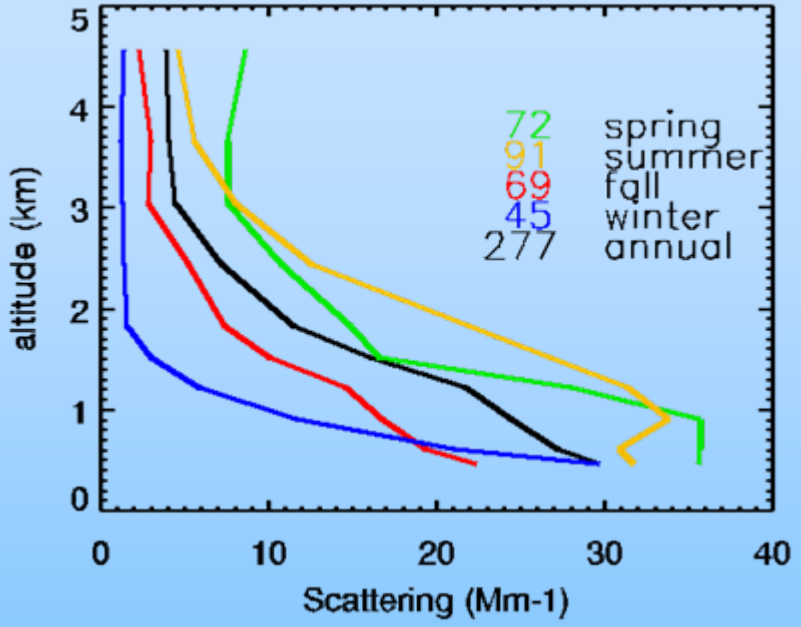


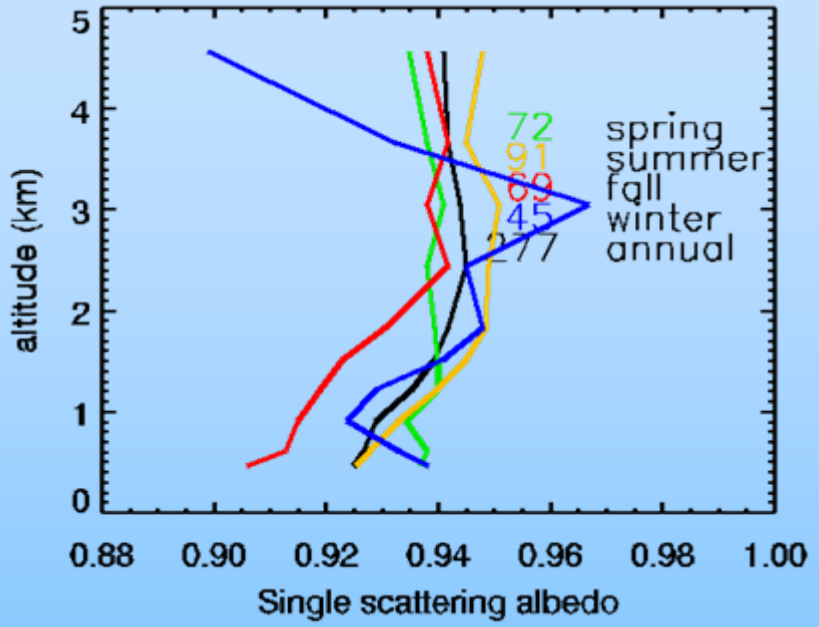
Scattering and SSA decreases with altitude

Spring/summer tend to have greater amounts of aerosol
Winter tends to have the least amount of aerosol

Fall/winter tend to have the lowest single-scattering albedo

AAO – Seasonal Profiles (sub7μm inlet)





Scattering decreases with altitude, SSA relatively constant

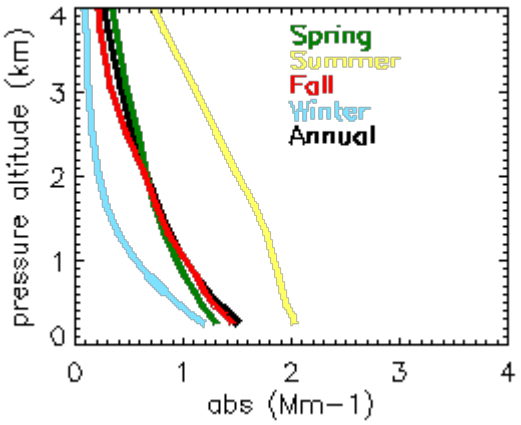
Spring/summer tend to have greatest amounts of aerosol
Winter tends to have the least amount of aerosol

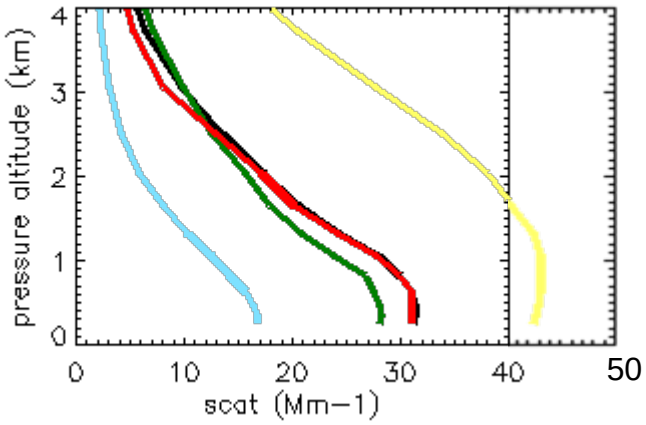
Fall tends to have the lowest single-scattering albedo

IAP Seasonal Profiles – model and measured

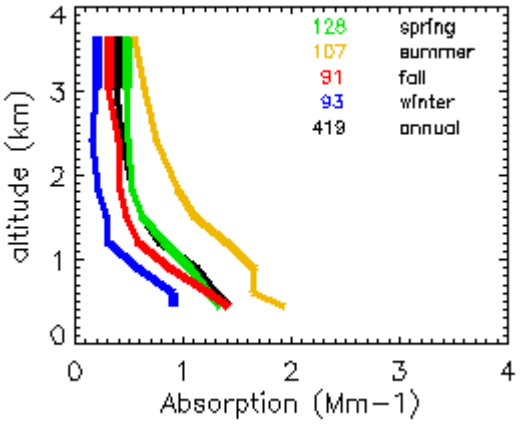
Plots show median value of 550 nm absorption and scattering (low RH, STP) for GFDL AM2 model and IAP measurements. Note: model plots are for all days of all years between 1994-2007 while measurement plots are for flight days only between 2000-2005.

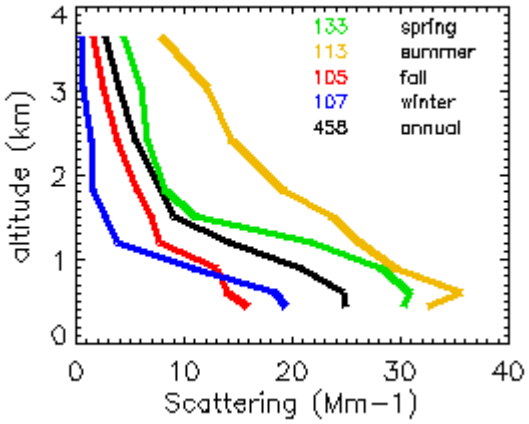
Model Results at STP





IAP Measurements (2000-2005) at STP

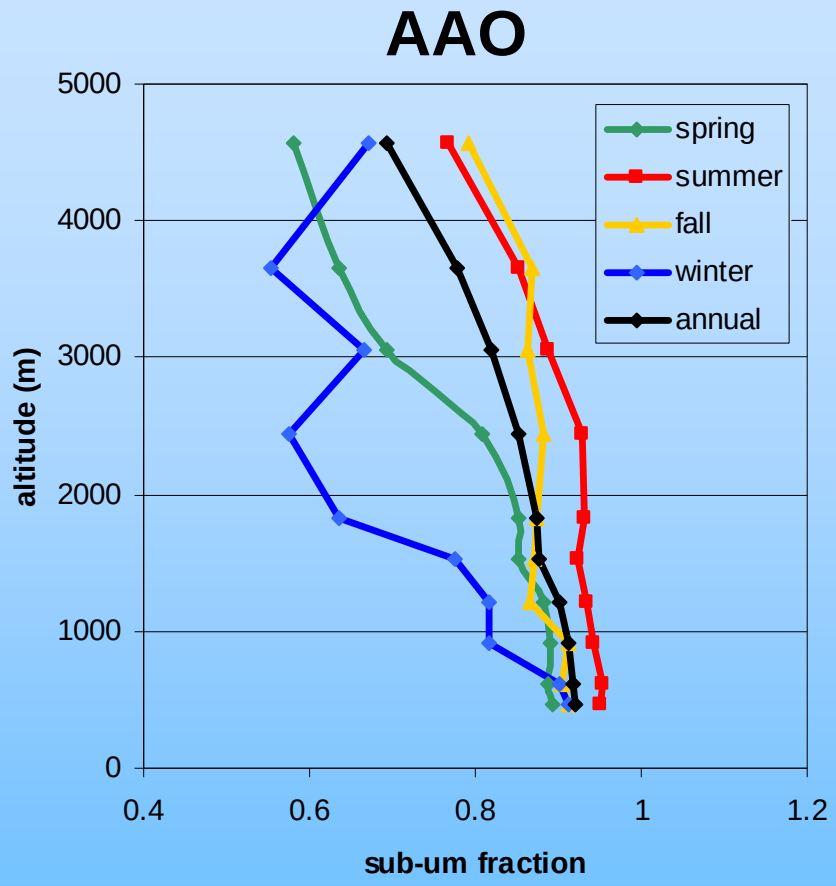


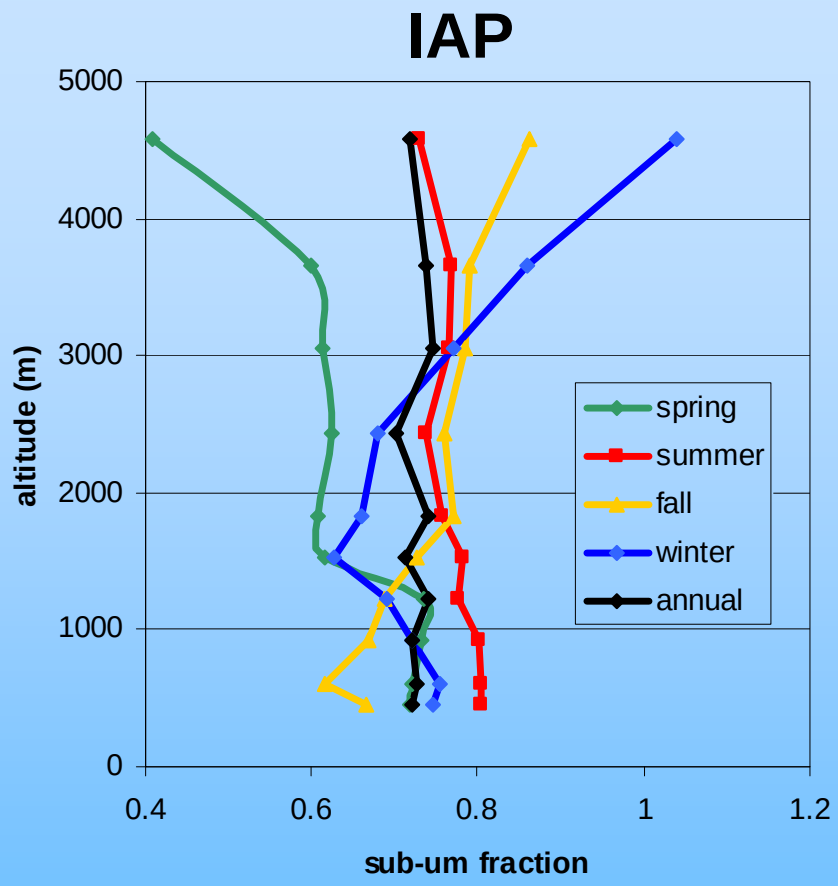


General seasonal trends are similar – winter lowest and summer highest.

Shapes of profiles are somewhat different – model doesn't have sharp step at 1-1.5 km seen in measurements.

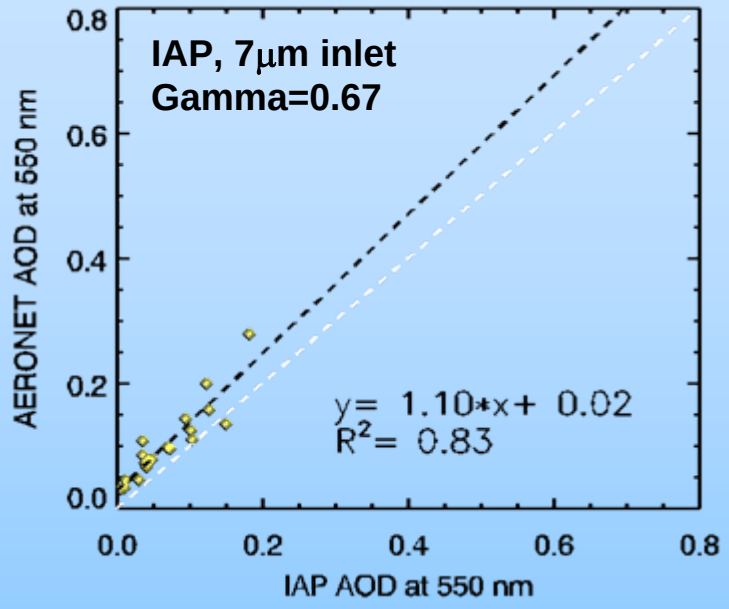
Sub-micron fraction profiles – seasonal

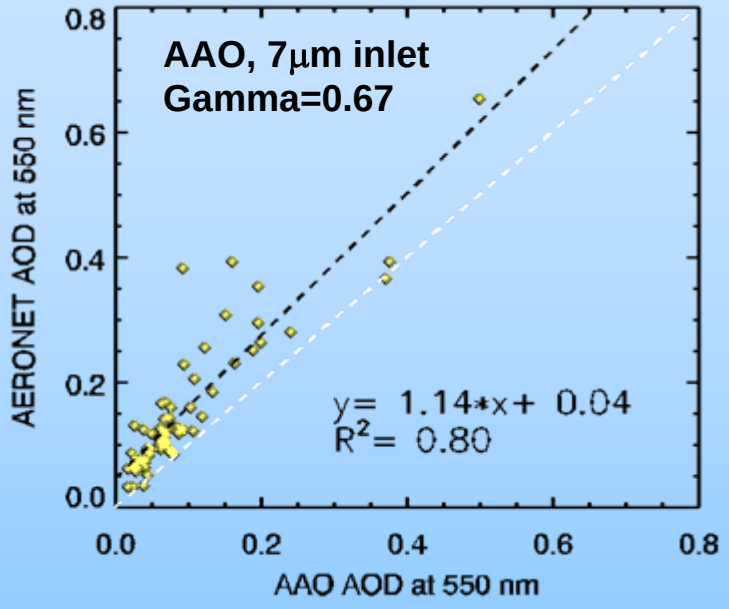


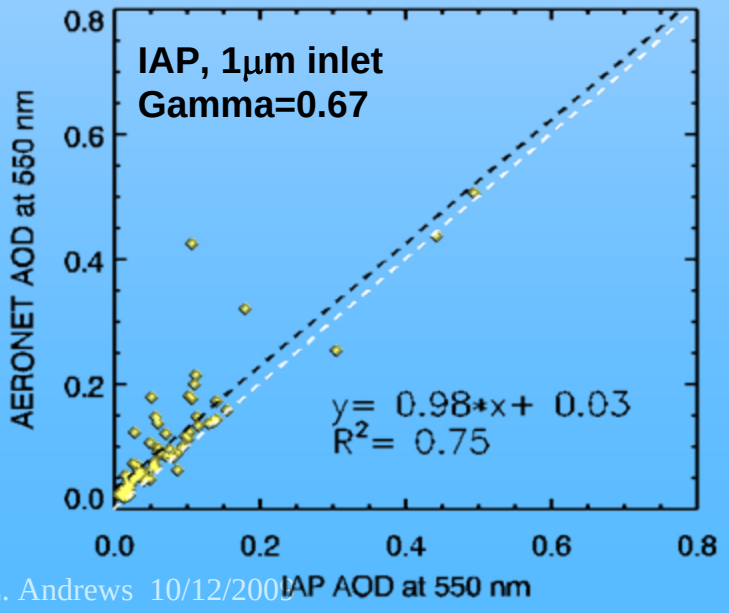


Summer tends to have most contribution from sub-micron aerosol
Winter and spring tend to have least contribution from sub-micron aerosol

In-situ vs. Aeronet Comparison - AOD





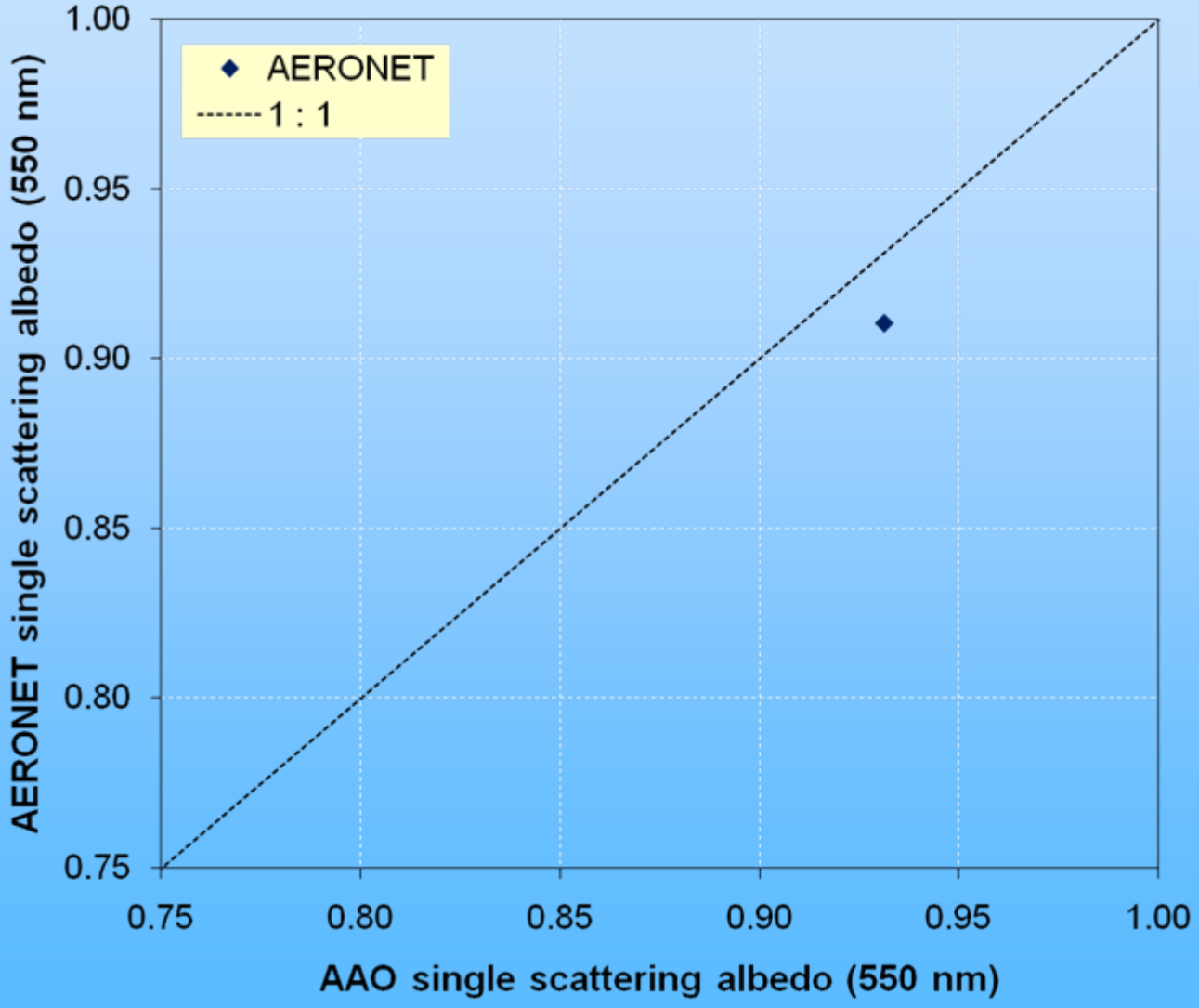


For purposes of comparison, used same f(RH) adjustment (gamma=0.67).

→similar 7 μm inlets on AAO and IAP give similar results

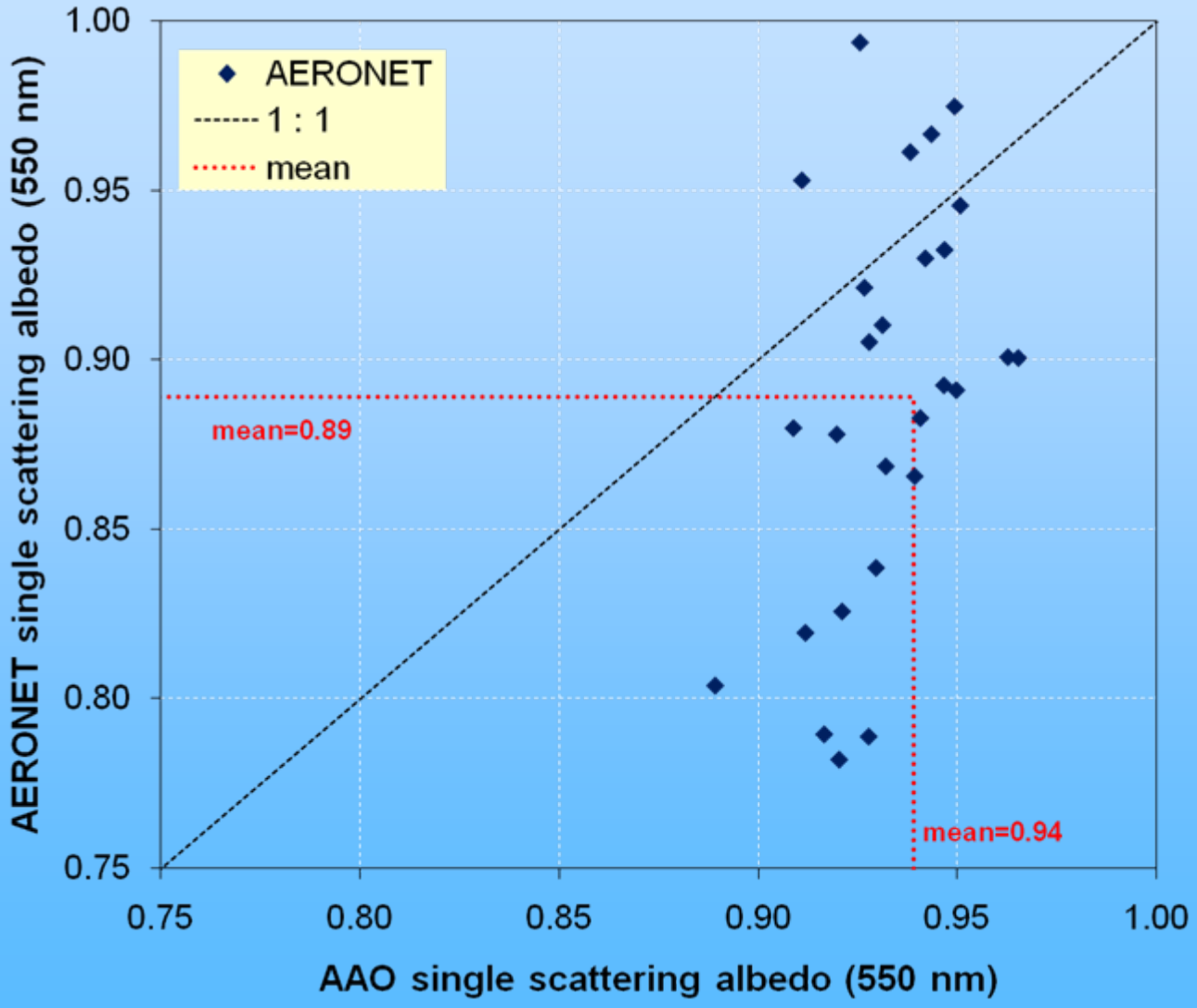
→1 μm inlet at IAP looks really great – sub-micron fraction adjustment and adjustment for aerosol above 12000' must be just right…☺

Single scattering albedo (Illinois)



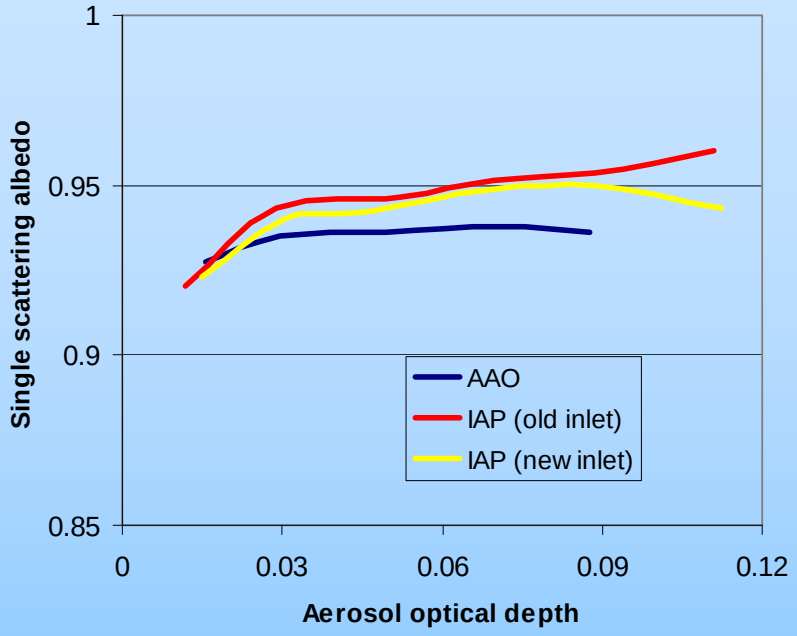
* Level 2.0

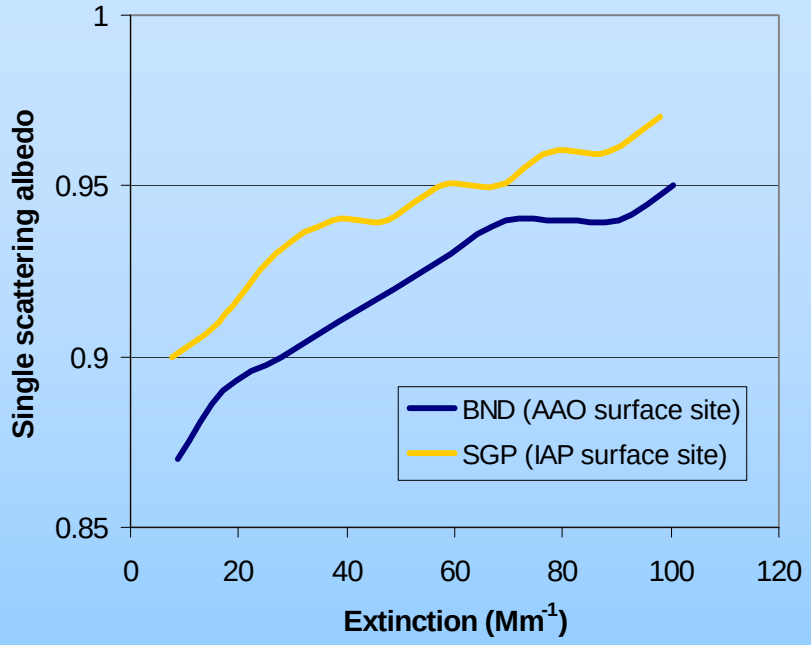
Single scattering albedo*

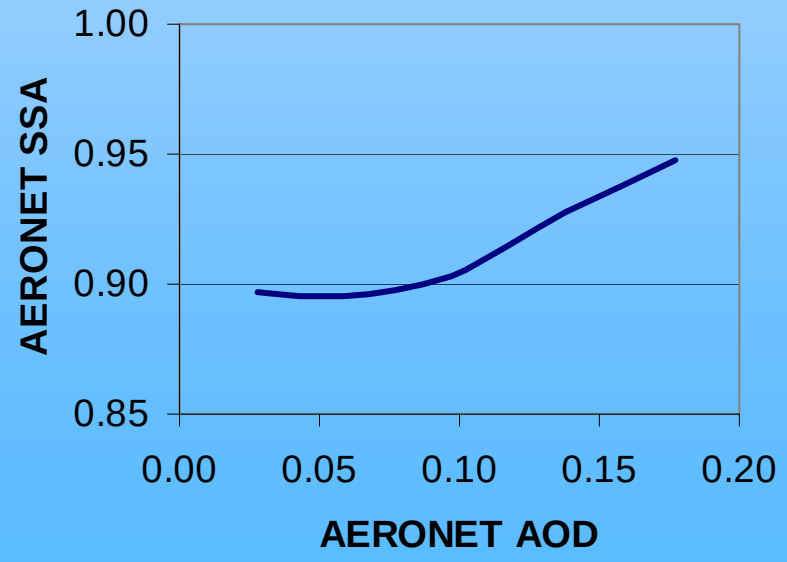


* Level 1.5

Systematic variation SSA vs AOD



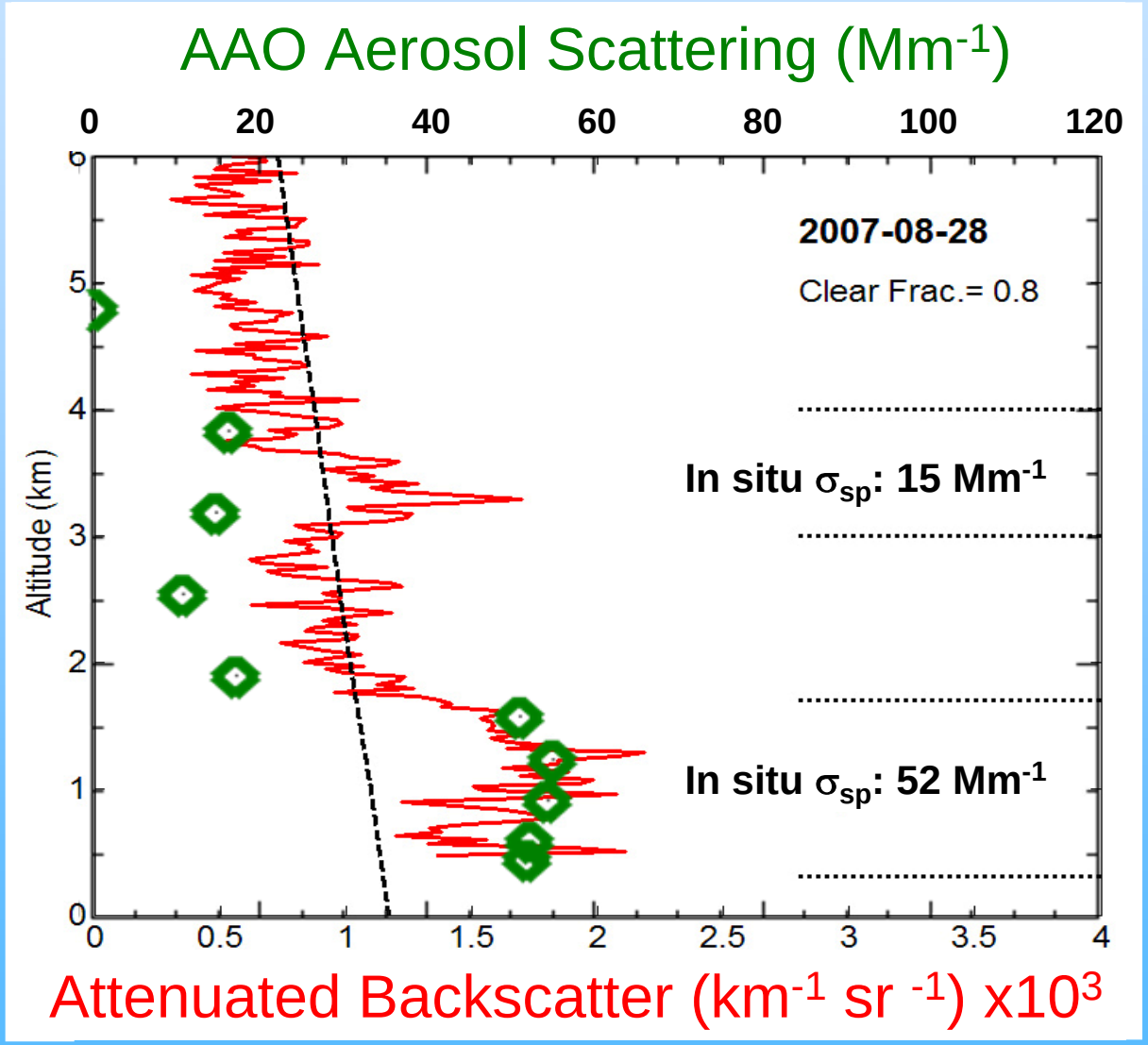




- Systematic variation not as strong for column as for surface
- IAP/SGP tends to have higher SSA than AAO/BND
- AERONET systematic variation (SGP, Level 1.5) is similar at higher AOD, but flat at lower AOD; AOD range is different

In-Situ: dry conditions
AERONET: ambient RH

AAO – CALIPSO comparison



Conclusions

- **Statistically-robust evaluations of model predictions of aerosol optical properties are possible with in-situ measurements**
  - over 1100 vertical profiles of aerosol light scattering, backscattering, and absorption
  - over 100 station-years of surface measurements of aerosol scattering, Ångström exponent, backscatter fraction, sub-micrometer scattering fraction (see Sheridan poster)
- **Discussion question...**
  - what is the utility of near-real time (< 6 hr) in-situ aerosol data for future models?