

Retrieval of size distributions from in situ particle counter measurements



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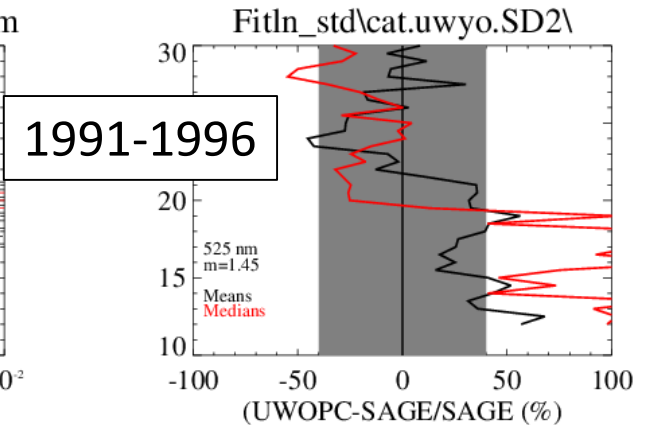
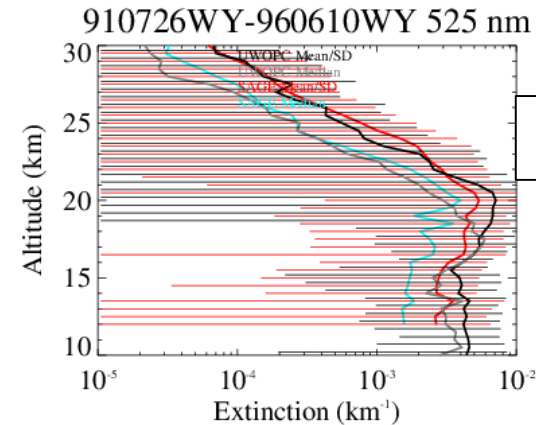
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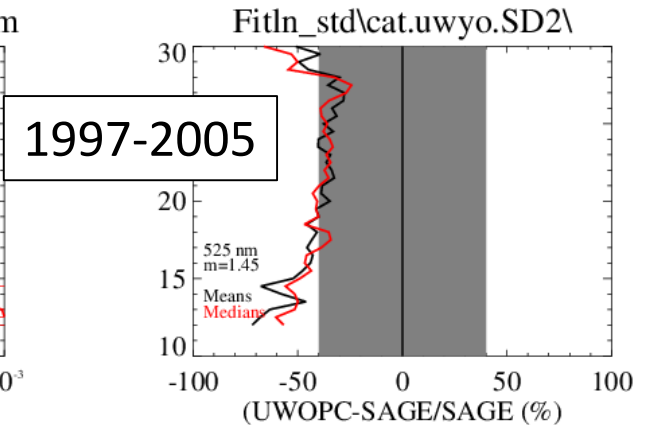
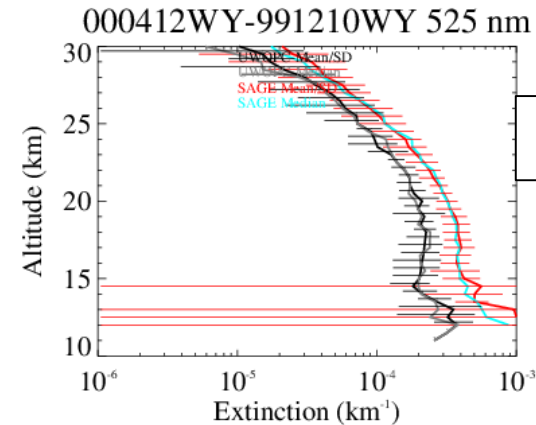
The problem

- During volcanic periods aerosol extinction derived from in situ measurements was in reasonable agreement with SAGE at multiple wavelengths
- During non-volcanic periods aerosol extinction derived from in situ measurements uniformly under estimated SAGE extinction at multiple wavelengths

No Profiles
SAGE 80
OPC 34



No Profiles
SAGE 22
OPC 12



Coincidence criteria: 15 degree longitude band, 6 degree latitude band, 168 hours

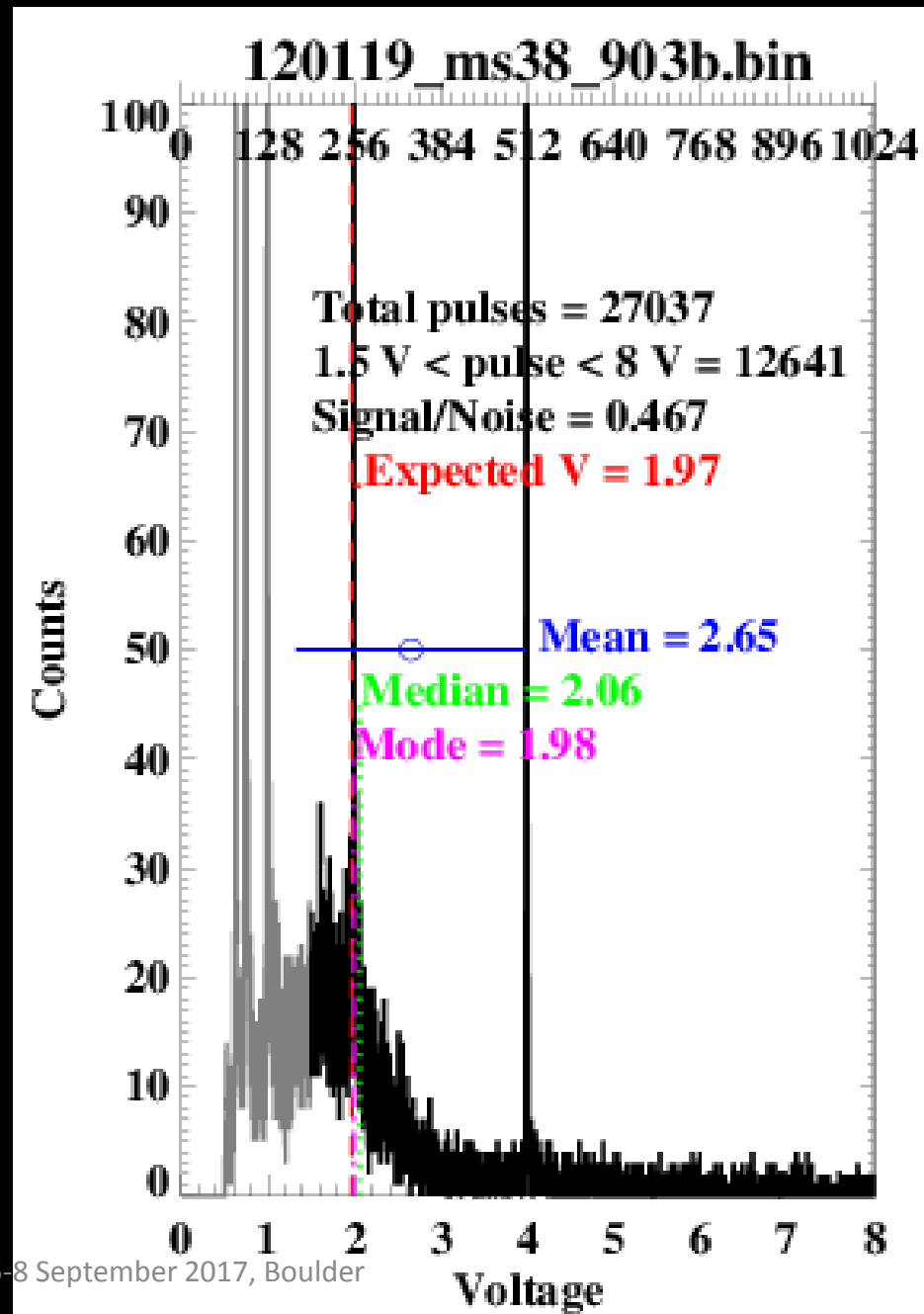
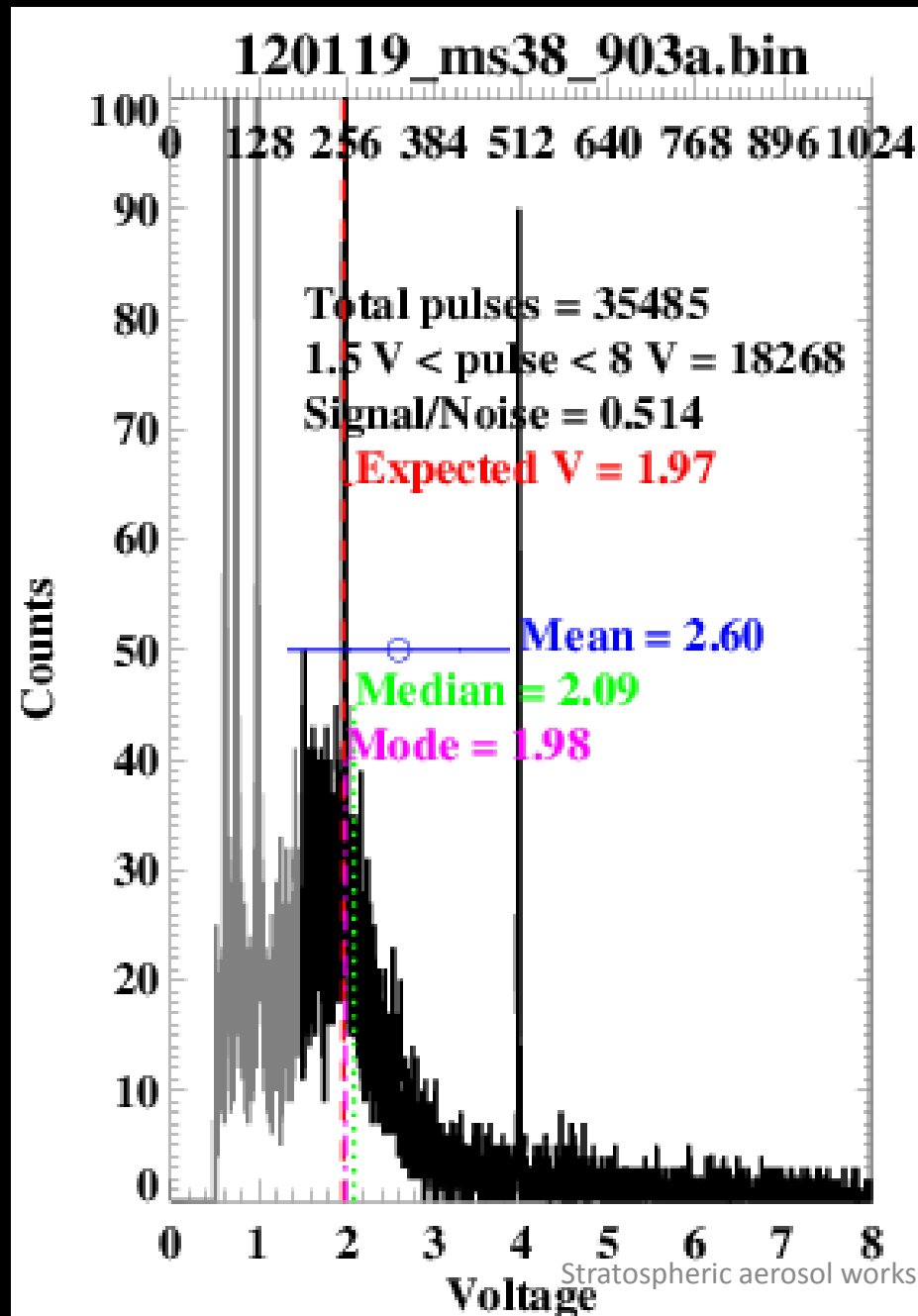
Possible source of problem

- Inlet sampling problem
- Particle evaporation in the inlet
- Counting efficiency
- Kovilakam and Deshler, JGR, 2015

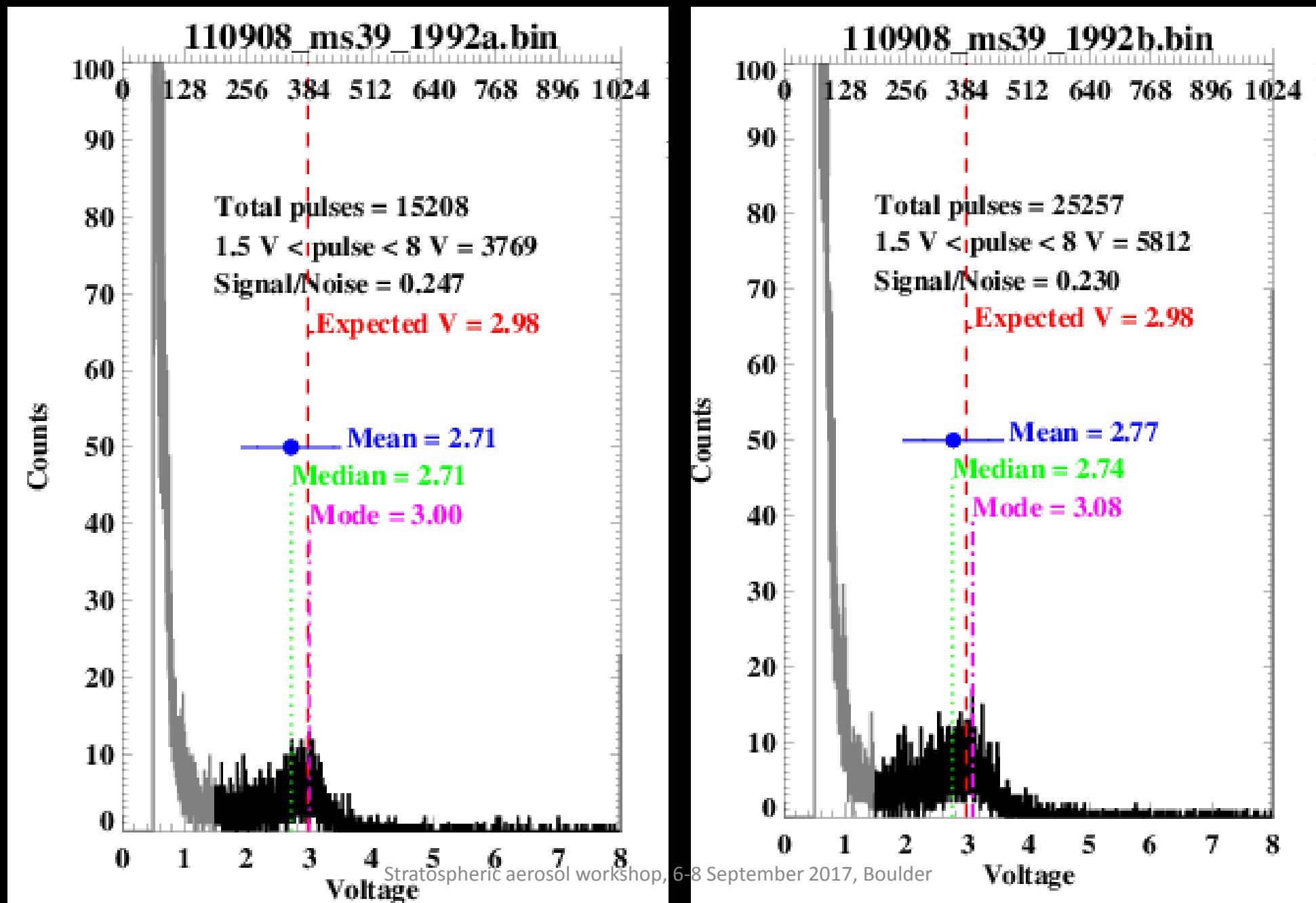
Possible source of problem

- Inlet sampling problem
- Particle evaporation in the inlet
- Counting efficiency (calibration problem)
- Arose from convergence of new investigator, new calibration system, and newly revised instrument.

Pulse height distributions from digital PHA, high gain board



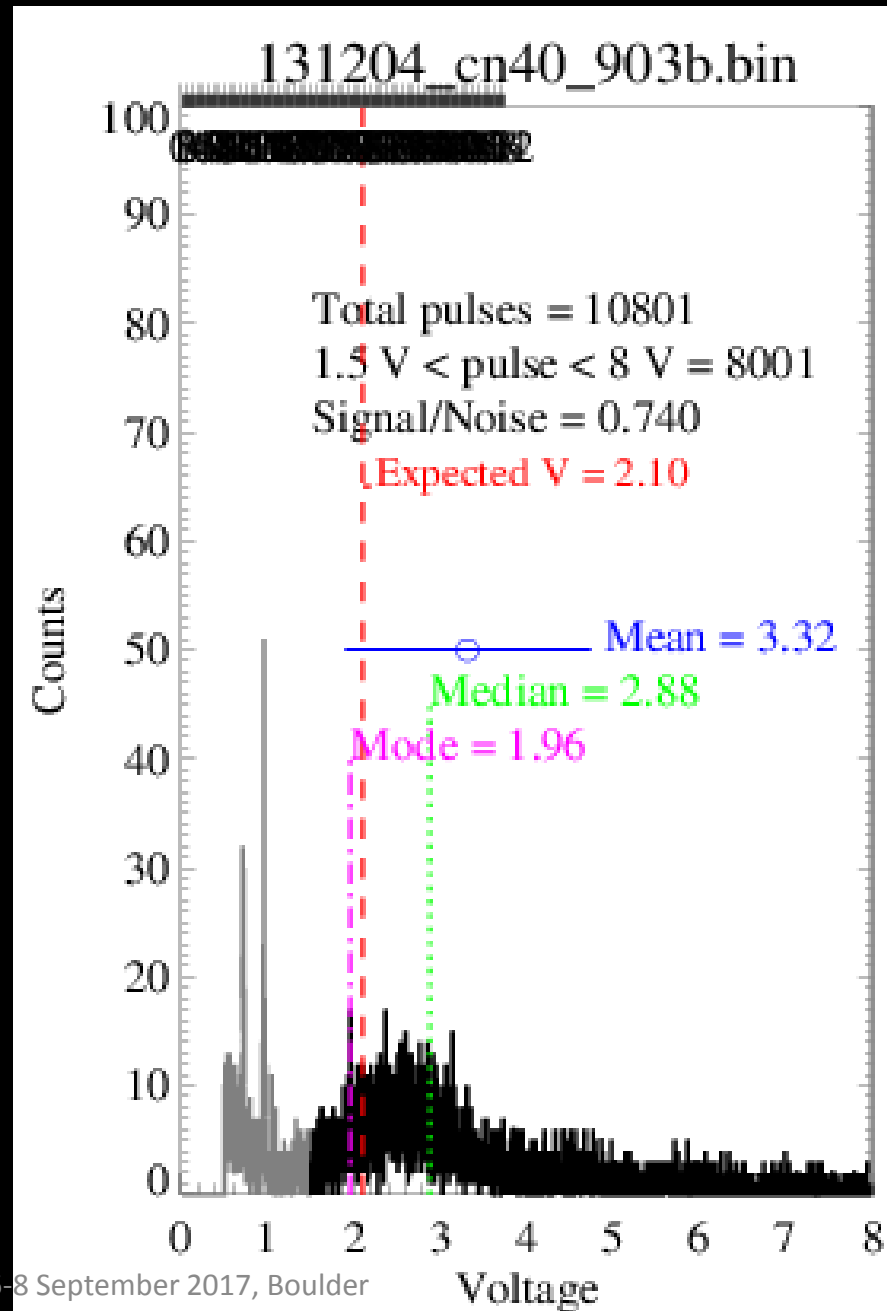
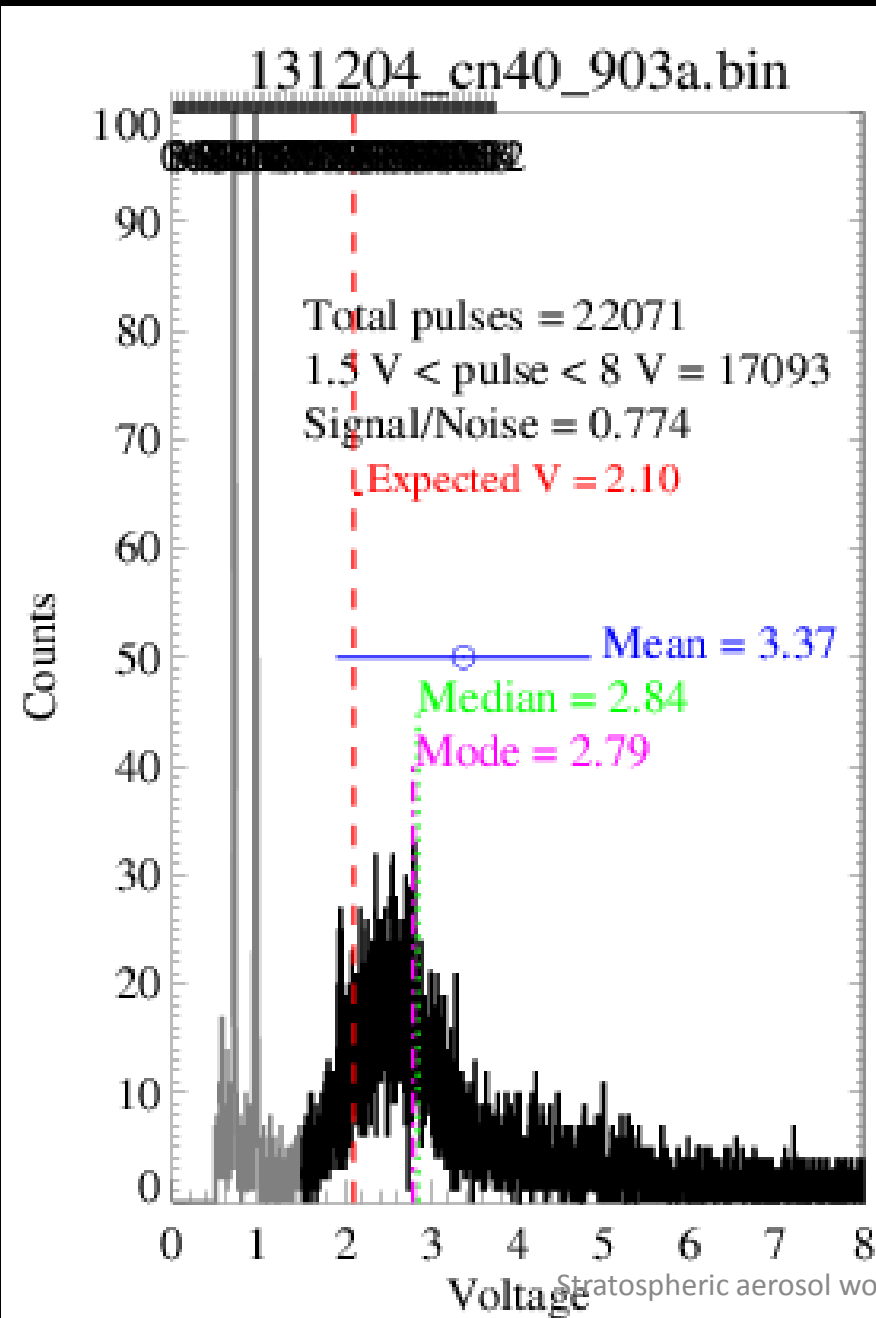
Pulse height distributions from digital PHA, low gain board



Lessons in statistics

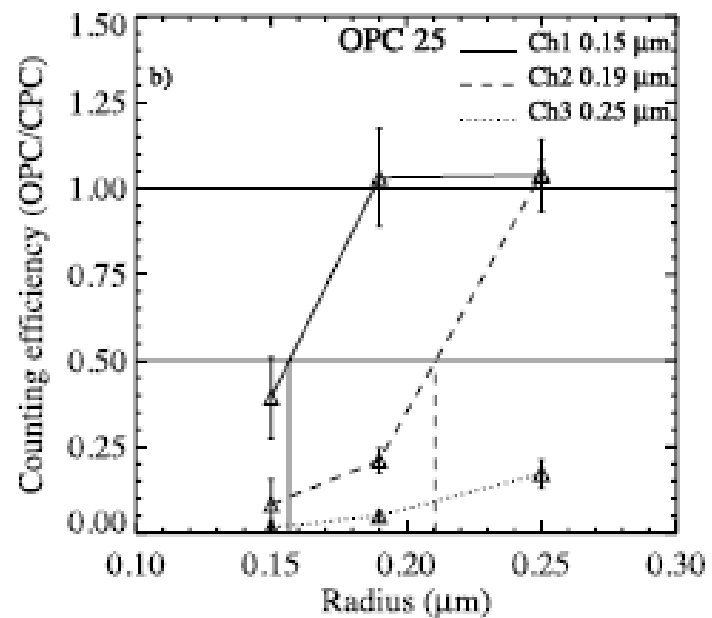
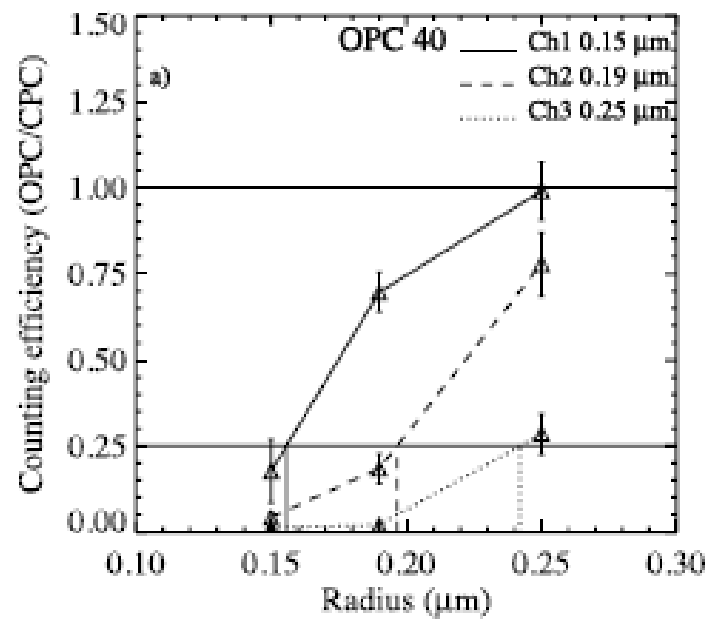
- Bin boundaries set at the middle of the Gaussian distribution from each PMT.
- Thus each pulse from a particle on the bin boundary has a 50% chance of being detected above the bin boundary
- Two PMTs
- What is the chance of seeing a pulse from both PMTs?
- Where should the bin boundary be to have 50% counting efficiency?

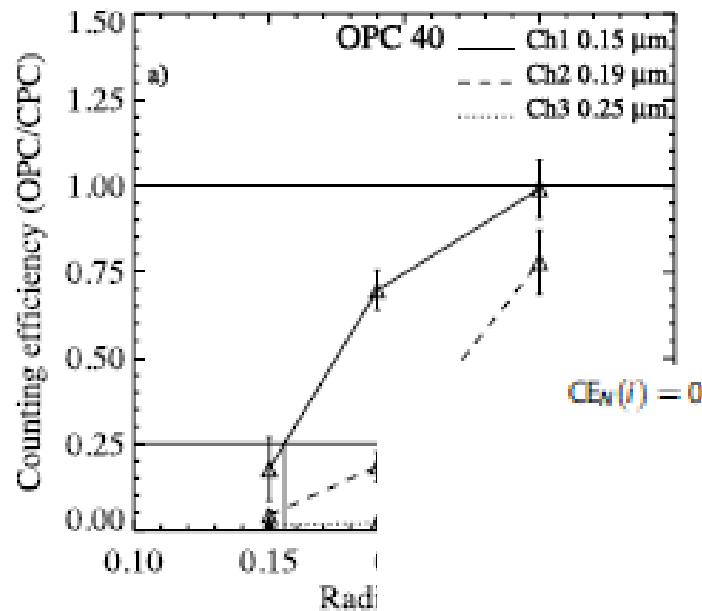
Pulse height distributions resulting from calibration using the old analog system



How to account for the reduction in counting efficiency from the expected 50%.

- Correct the number concentration of each bin (Kovilakam and Deshler, 2015)
- **Correct the size of each bin (Lars)**
- Don't correct the data, but fold the counting efficiency into the size distribution retrieval (Tom and Beiping)

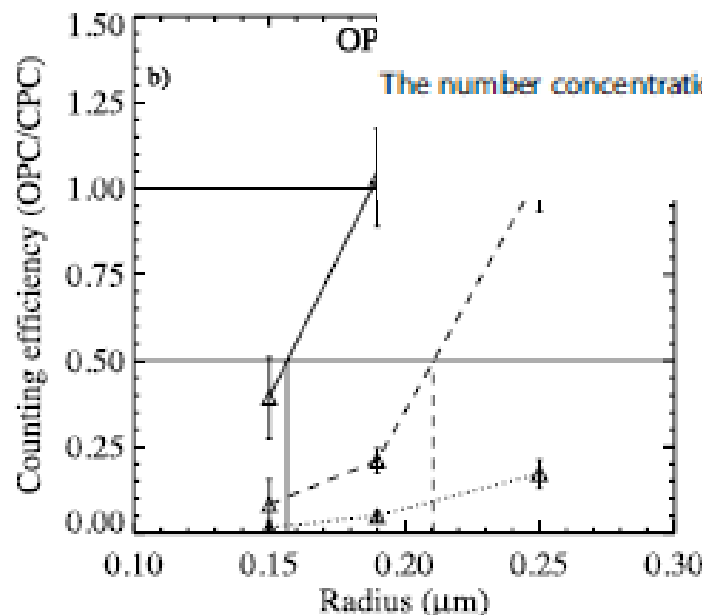




$$CE_N(i) = 0.5 + (CE_M - 0.5)A_i, \quad (i = \text{channel number}; i = 1, 2, \dots, 12)$$

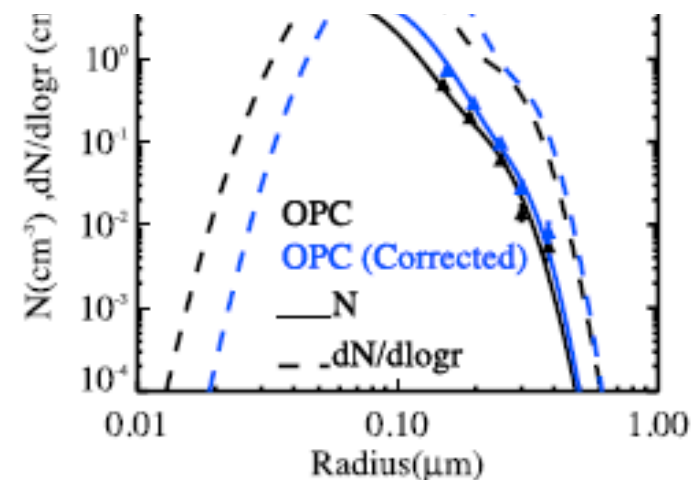
$$A_i = \begin{cases} f_{dn}(i)/f_{dn_{ref}} & f_{dn}(i) < f_{dn_{ref}} \\ 1 & f_{dn}(i) > f_{dn_{ref}} \end{cases} \quad \text{and} \quad (5)$$

$$f_{dn}(i) = \frac{\ln(N_i/N_{ref})}{\ln(r_{i+1}/r_i)} \quad (6)$$

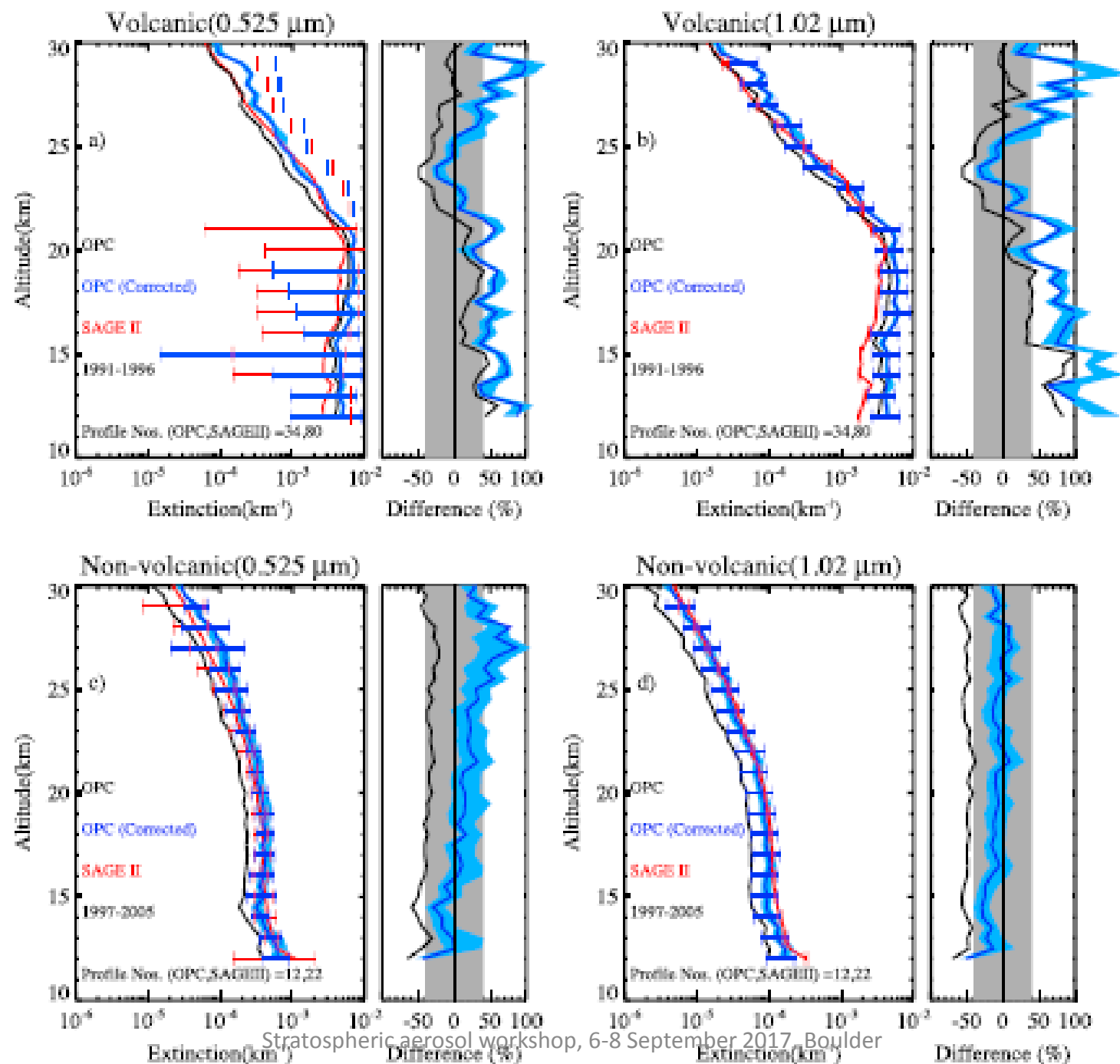


The number concentration correction factor, C_c is then given by

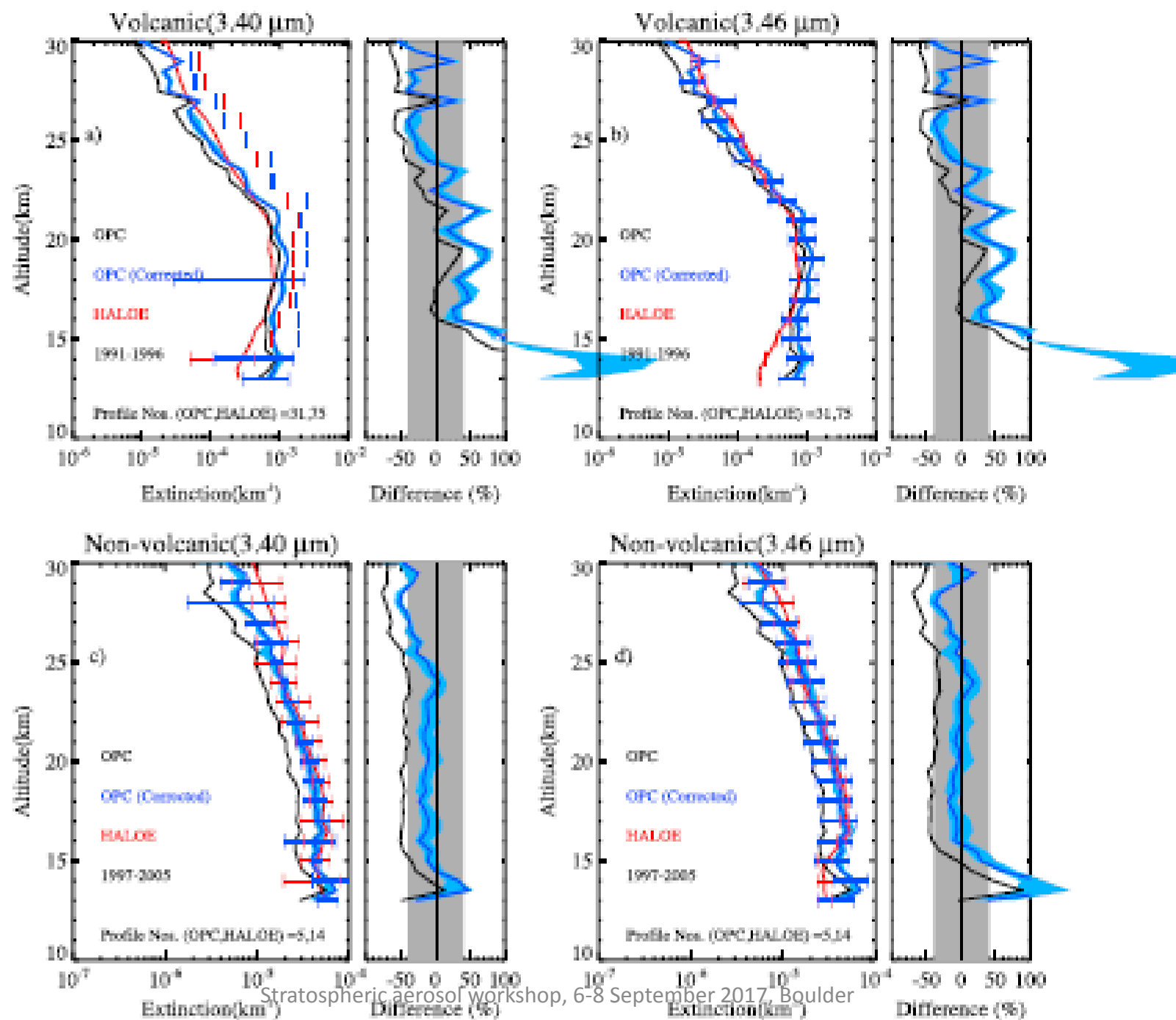
$$C_c(i) = 0.5 / c_{k_0} \quad \text{and} \quad N_c(i) = C_c(i) \times N(i), \quad (7)$$



Kovilakam and Deshler,
J Geophys Res, 2015



Kovilakam and
Deshler, *J Geophys
Res*, 2015



Don't correct the data, but fold the counting efficiency into the size distribution retrieval (Tom and Beiping)

$$N(> r_i) = \int_0^{\infty} CDF(r_i) \bullet dn / da(N, r_g, s_g) \bullet da$$

- Steps in this process

1. Fit the laboratory data to a cumulative distribution function (CDF).
2. Revise the fitting algorithm to use a parameter space search.
3. Apply the new fitting algorithm and compare with satellite extinction measurements.
4. Compare satellite and in situ derived surface area density (SAD)

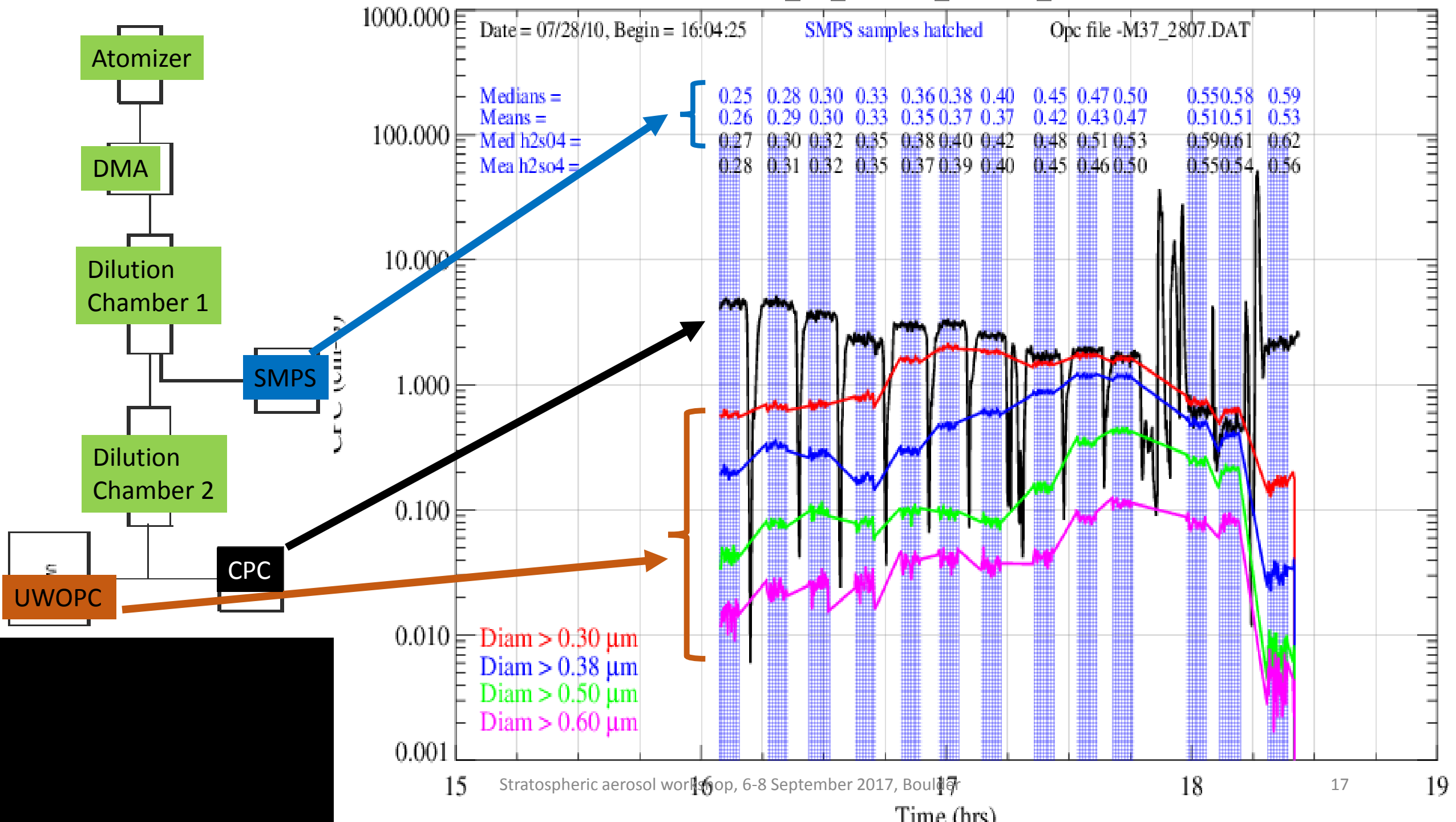
Don't correct the data, but fold the counting efficiency into the size distribution retrieval (Tom and Beiping)

$$N(r > a_i) = \int_{\infty}^{a_i} CDF(r, a_i) \bullet dn / dr \bullet dr$$

- This required revising the algorithm to determine aerosol size distributions from straight forward routines easily tied to the data to searches of the parameter space to identify the lognormal fitting coefficients to solve the equation. Where CDF is the cumulative distribution function, and $N(r > a_i)$ is the observation for each channel i

Fit the laboratory data to a cumulative distribution function (CDF).

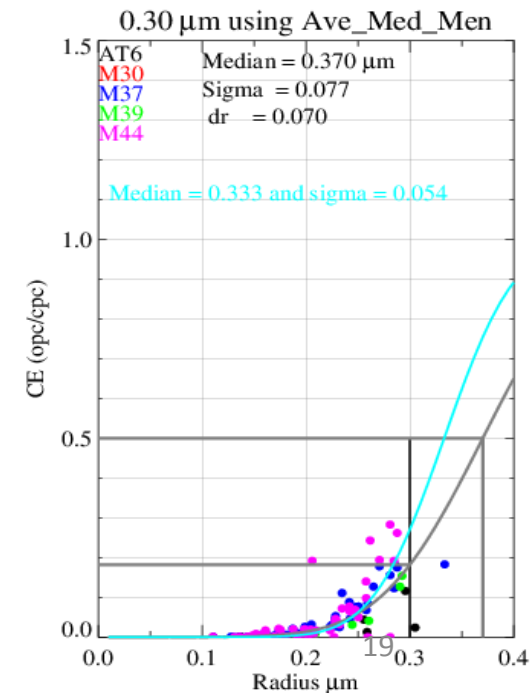
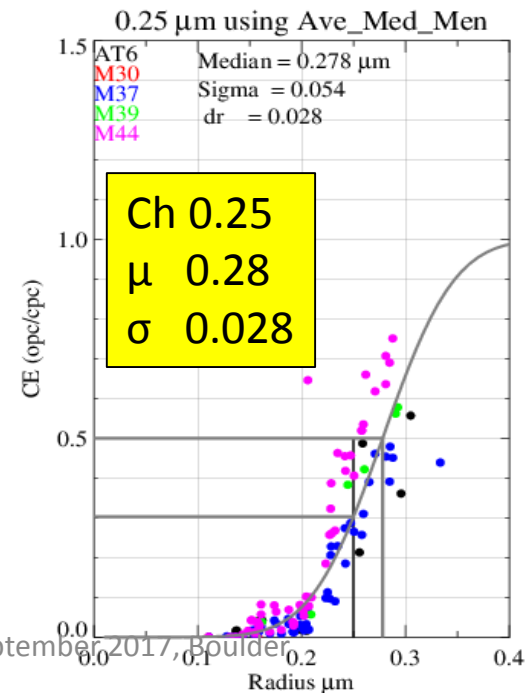
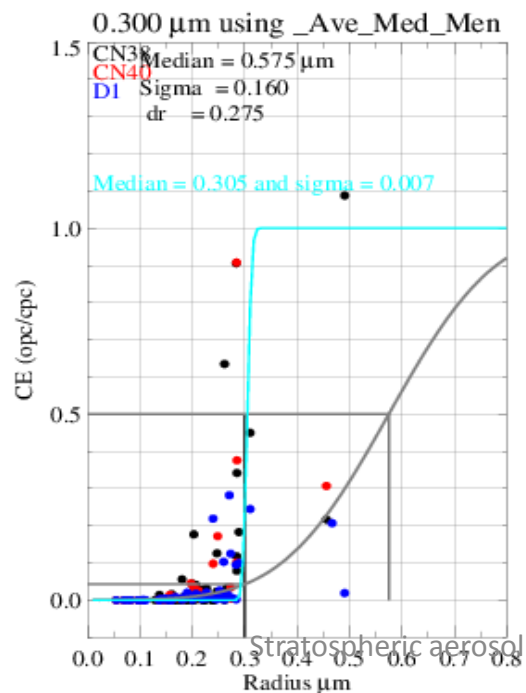
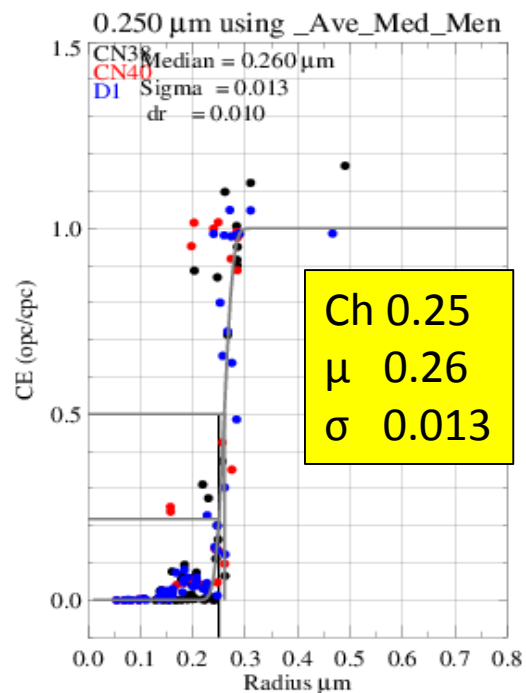
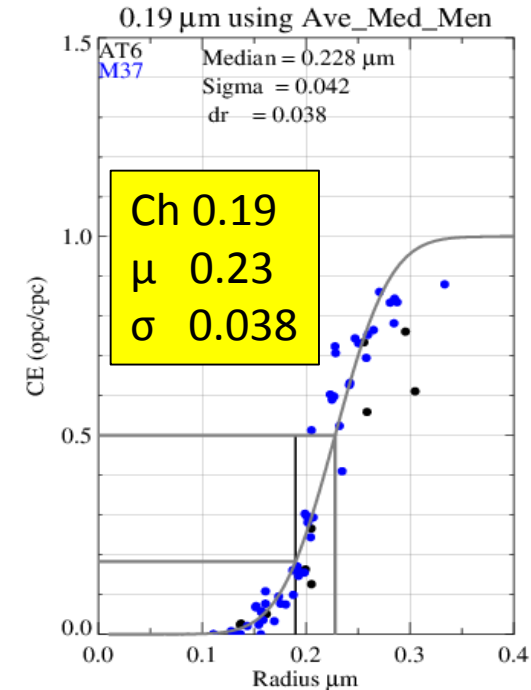
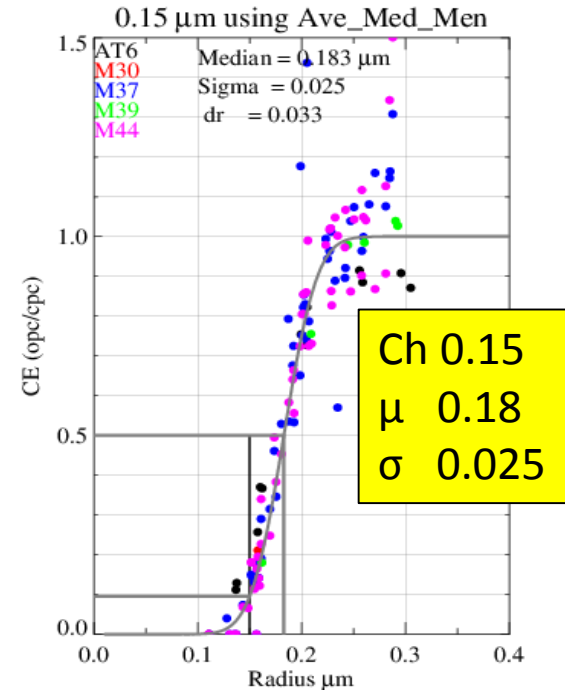
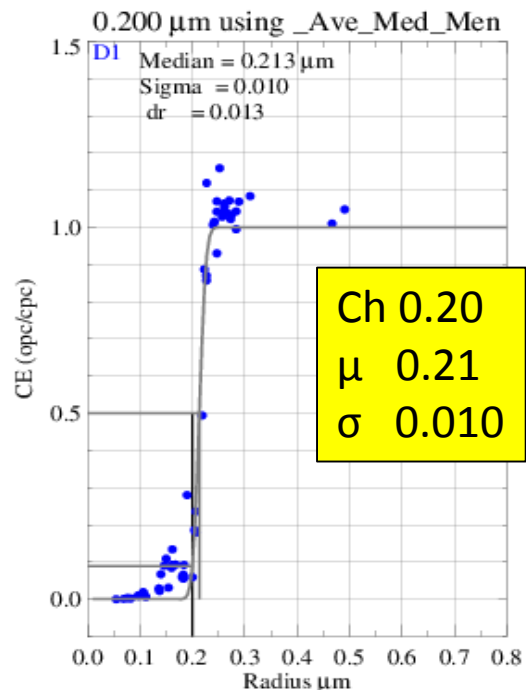
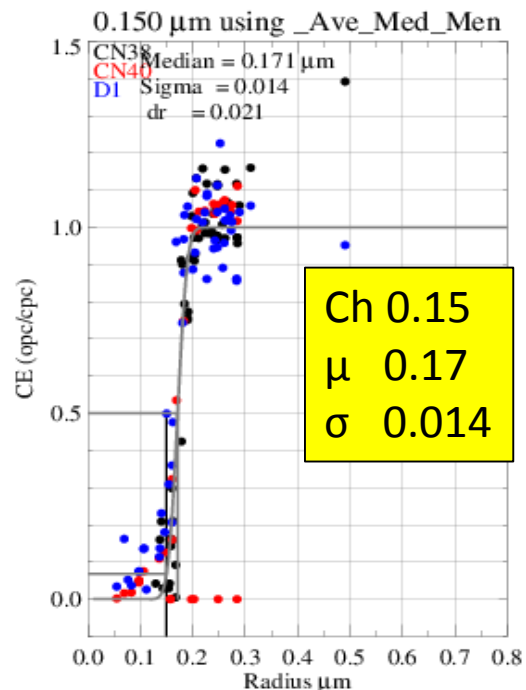
- Revisit all the laboratory data.
- Composite the measurements and derive a CDF for each channel subject to laboratory measurements
- Extrapolate the parameters of the CDF for those channels measured to sizes not amenable to laboratory measurement.



Cumulative distribution function (CDF) at any size, r , is given by the error function (erf).

$$CDF(r) = \frac{1}{2} \left[1 + \operatorname{erf} \left[\frac{r - \mu}{\sqrt{2} \sigma} \right] \right], \quad \text{where } \operatorname{erf}(z) = \frac{2}{\sqrt{\pi}} \int_0^z \exp(-t^2) dt.$$

The median, μ , and distribution width, σ , of the CDF are determined using a least squares fit of the laboratory measurements with this function at each channel size

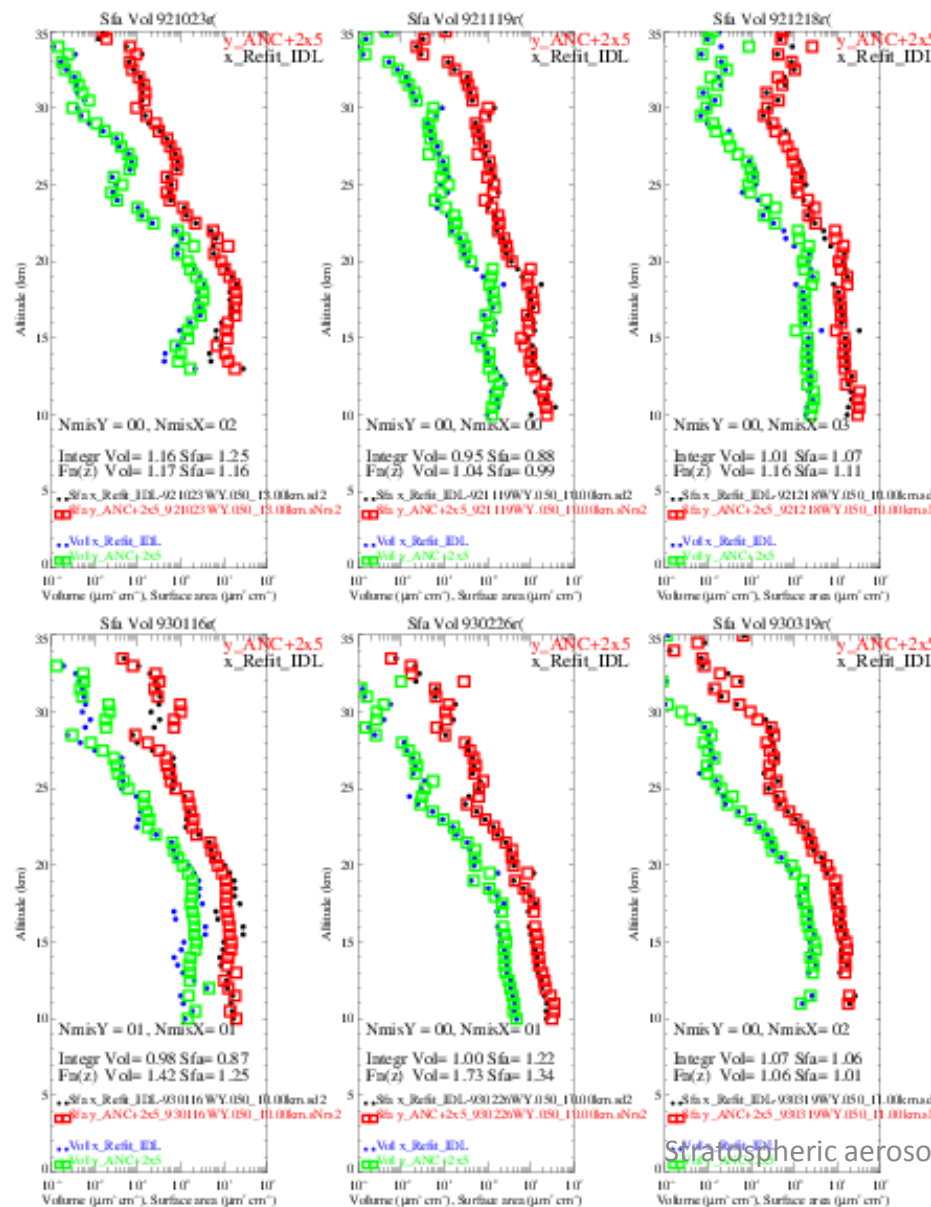


Revise the fitting algorithm to use a parameter space search.

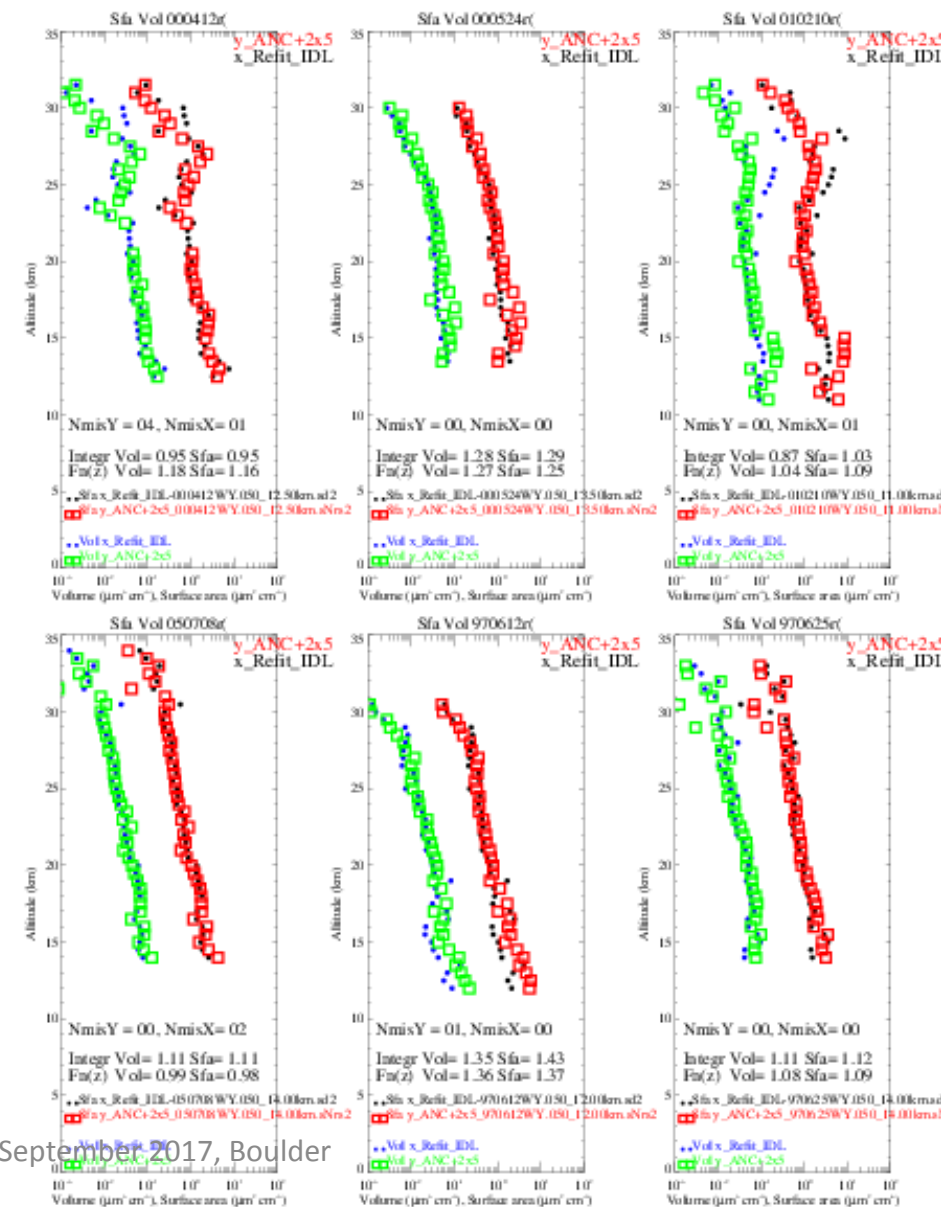
- This required revising the algorithm to determine aerosol size distributions
 - From straight forward routines easily tied to the data
 - To searches of the lognormal parameter space to identify the coefficients which minimize the fitting error.
 - Then checks that the result from the straight forward routines and parameter space search provided similar results if the CDF was not included.

Comparison with previous fitting routine

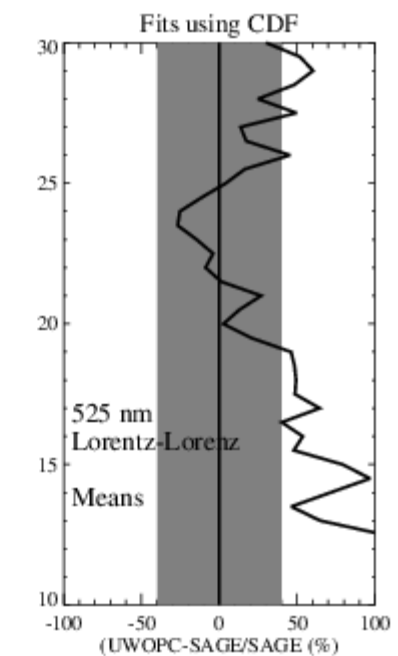
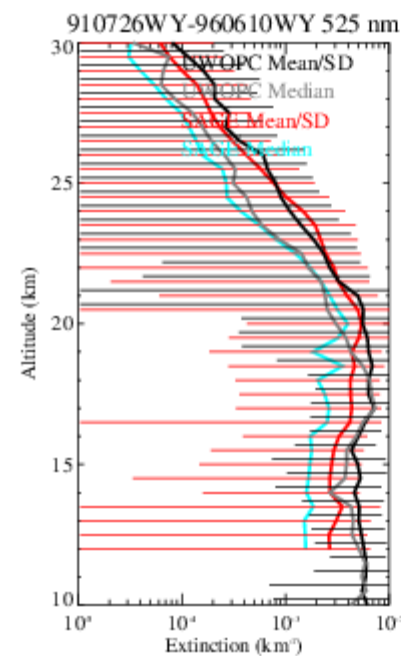
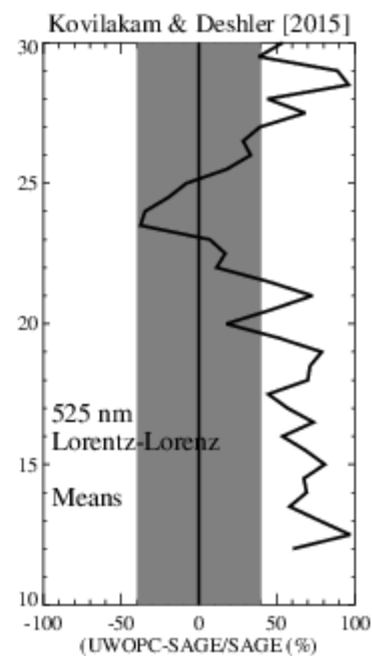
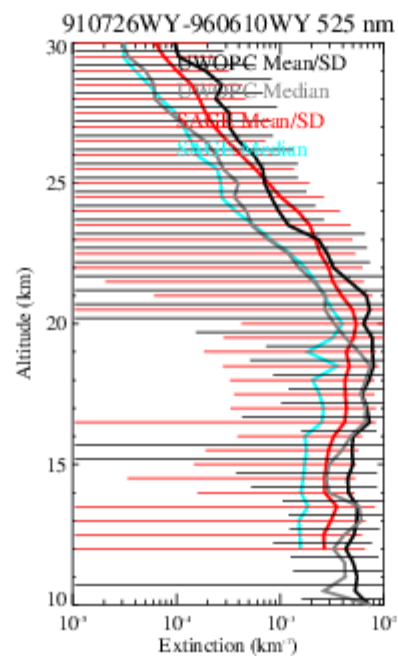
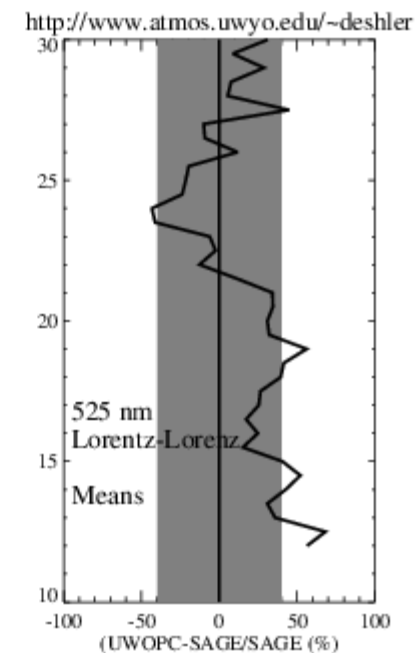
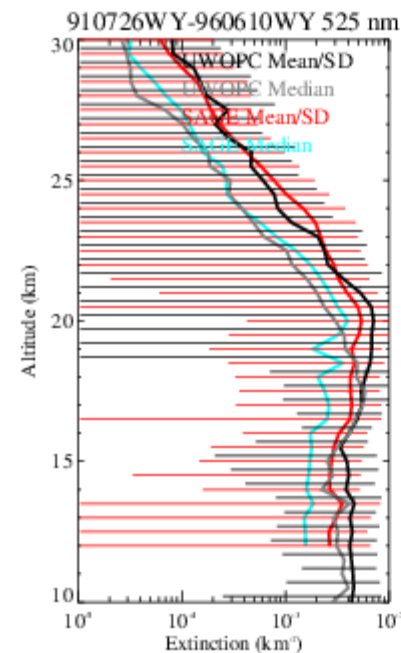
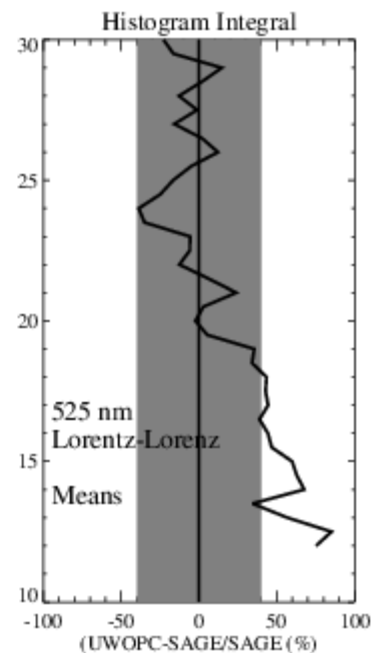
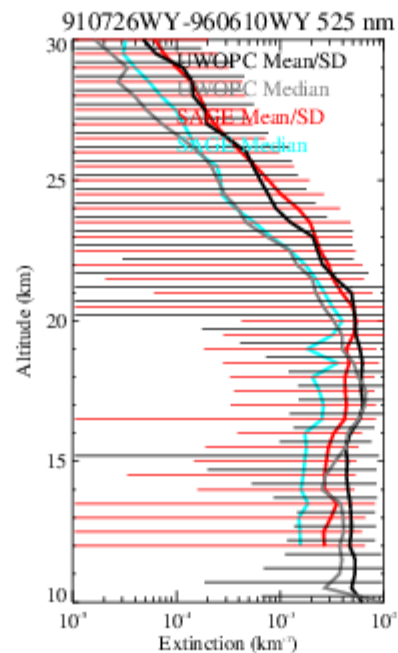
Pinatubo period



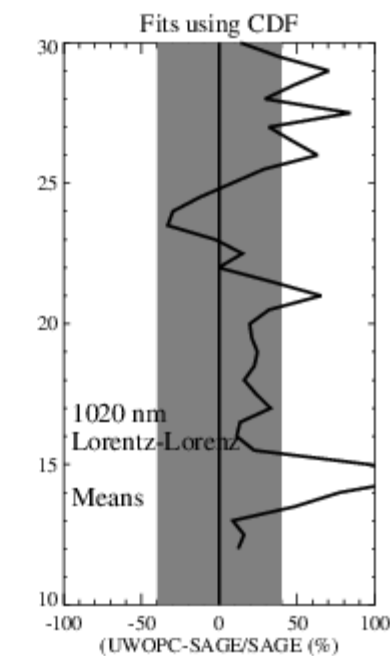
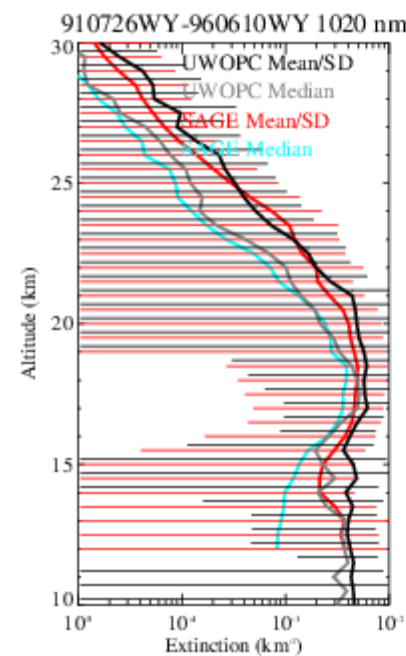
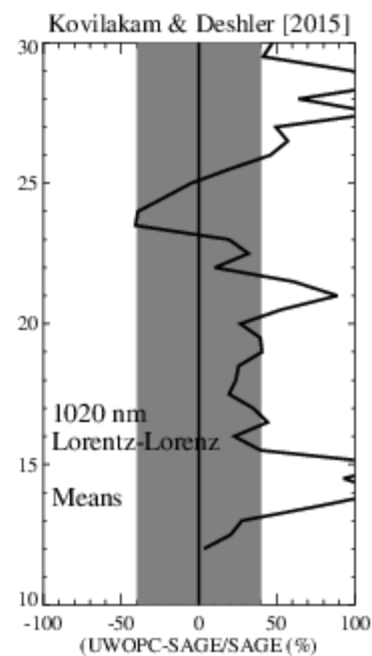
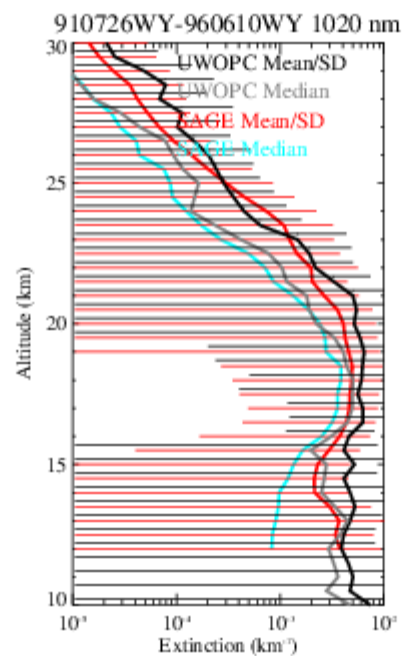
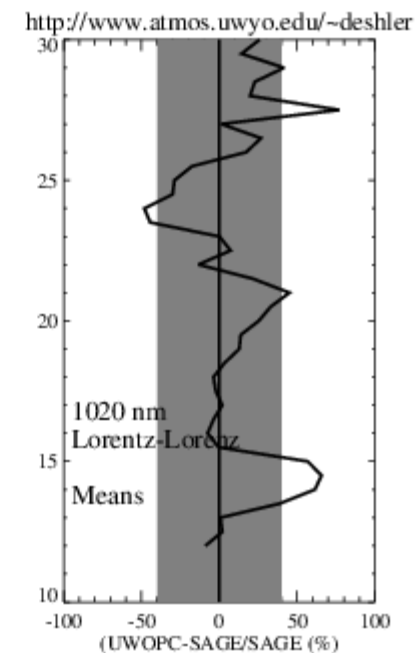
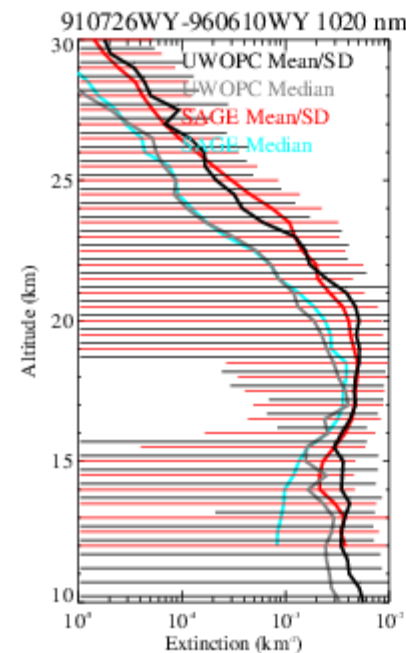
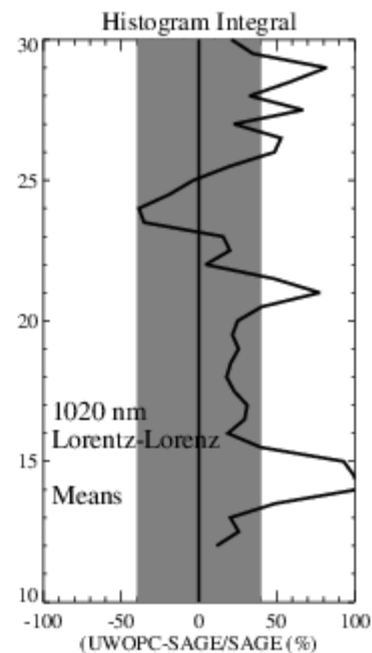
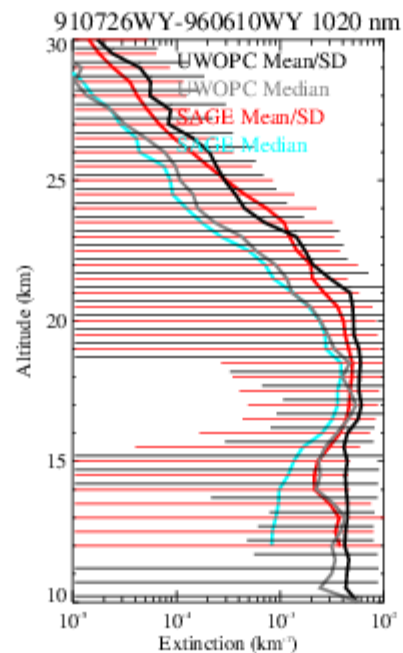
Non-Volcanic period



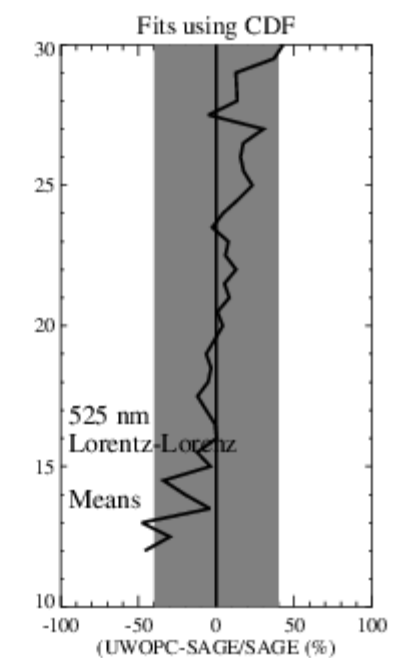
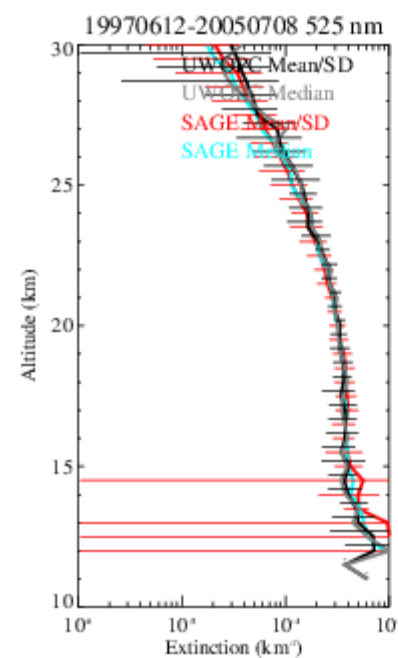
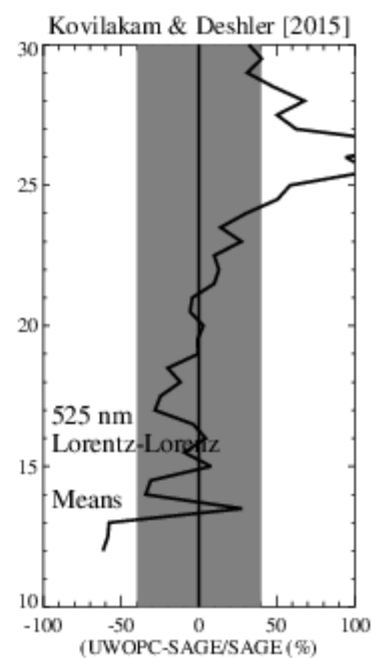
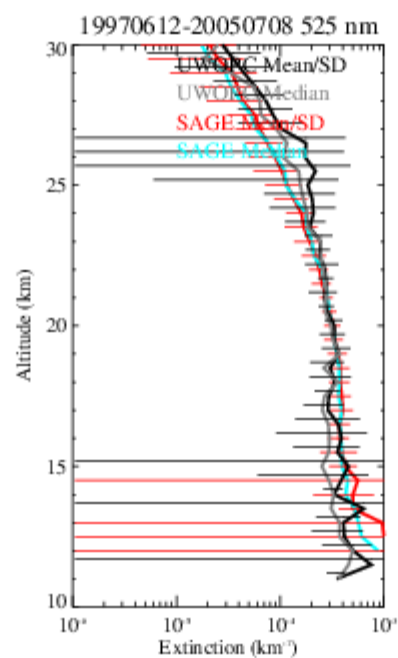
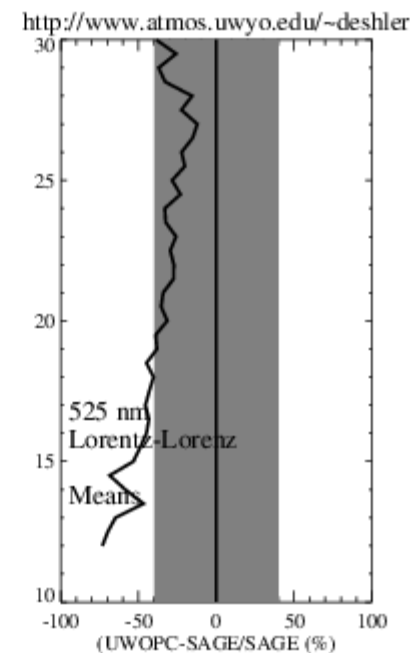
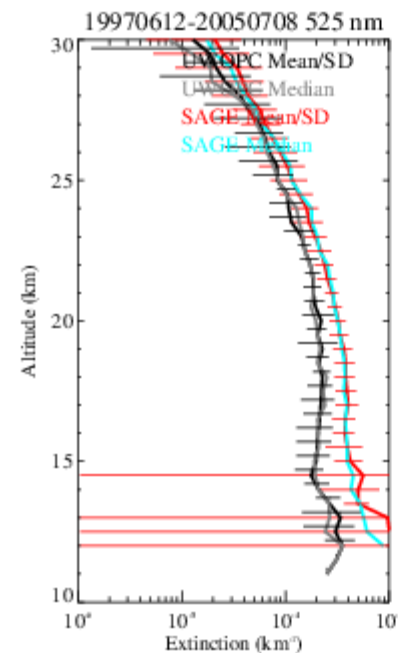
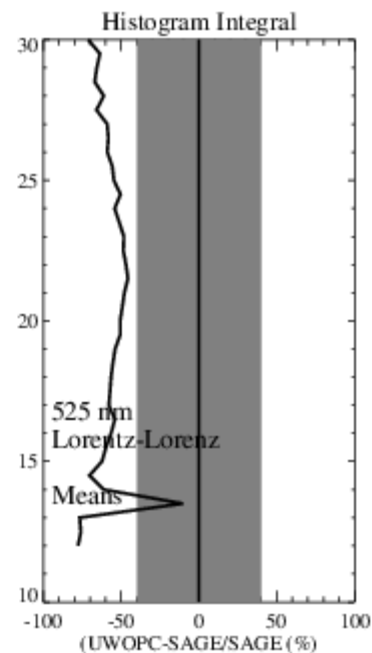
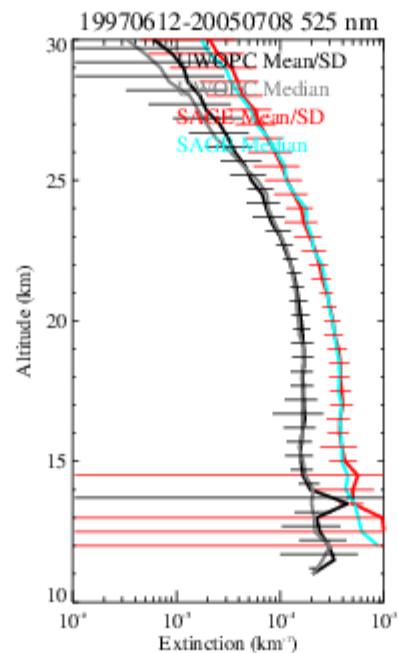
1991-1996
525 nm



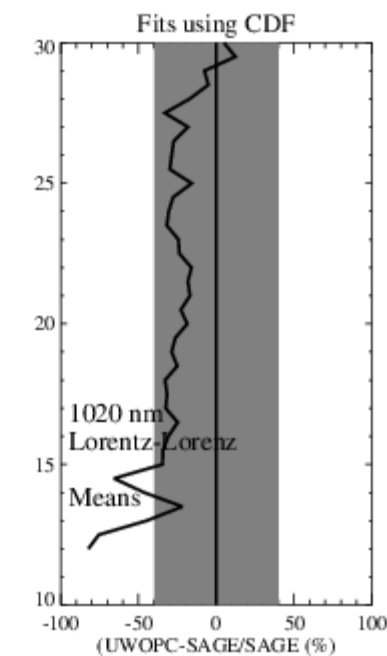
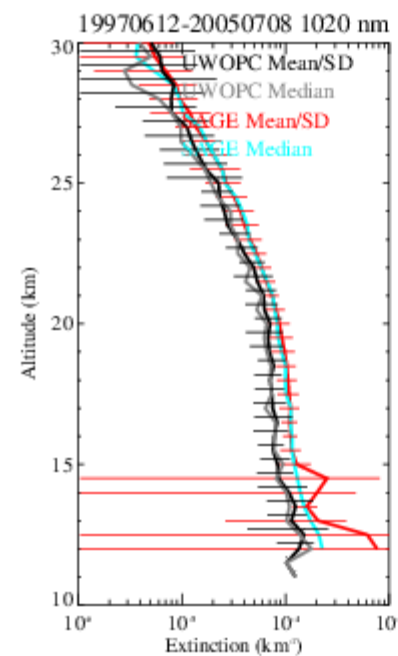
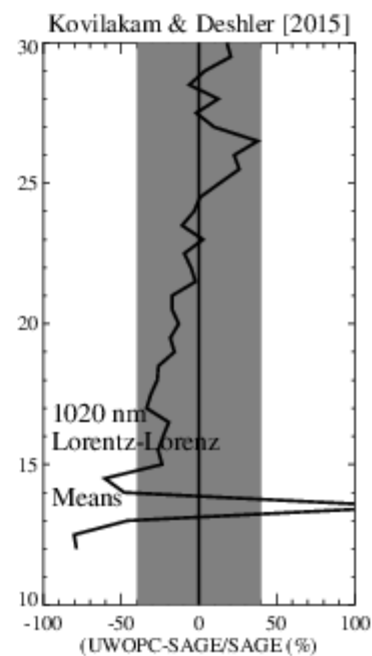
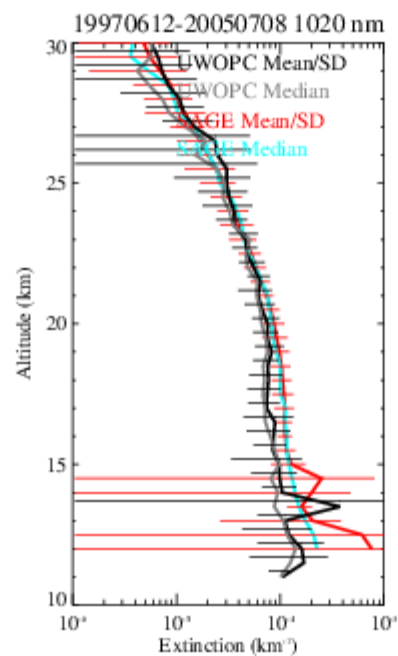
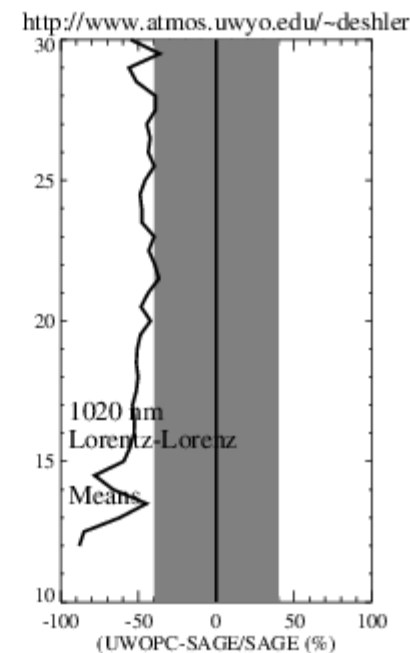
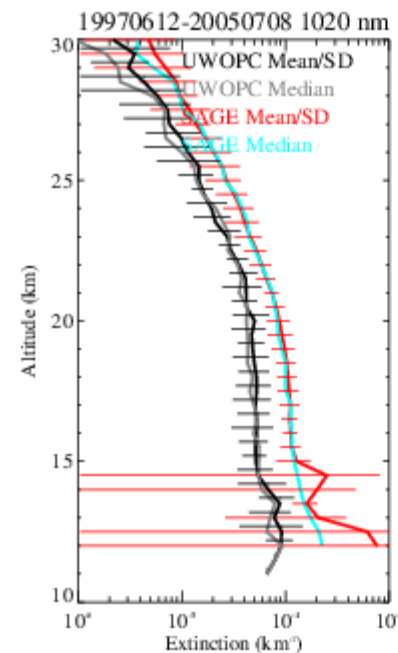
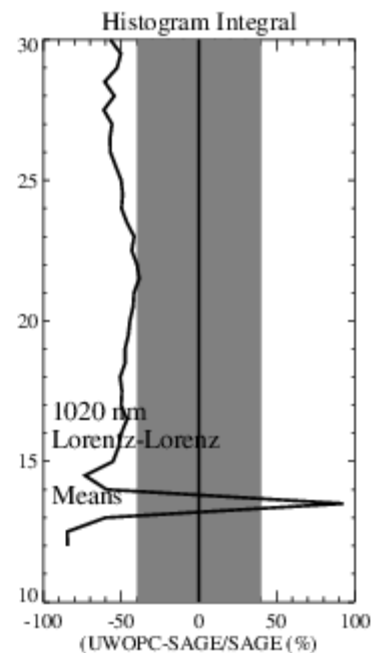
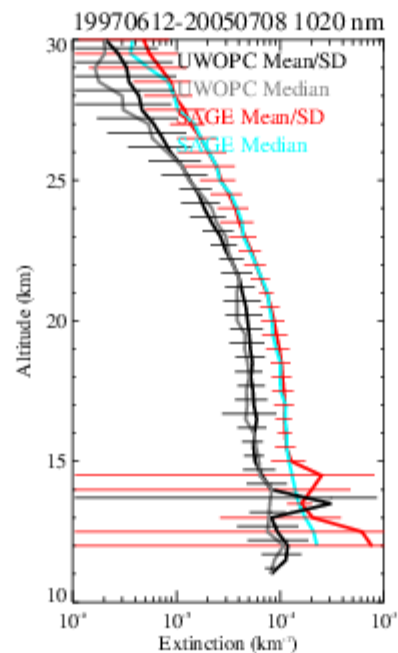
1991-1996
1020 nm



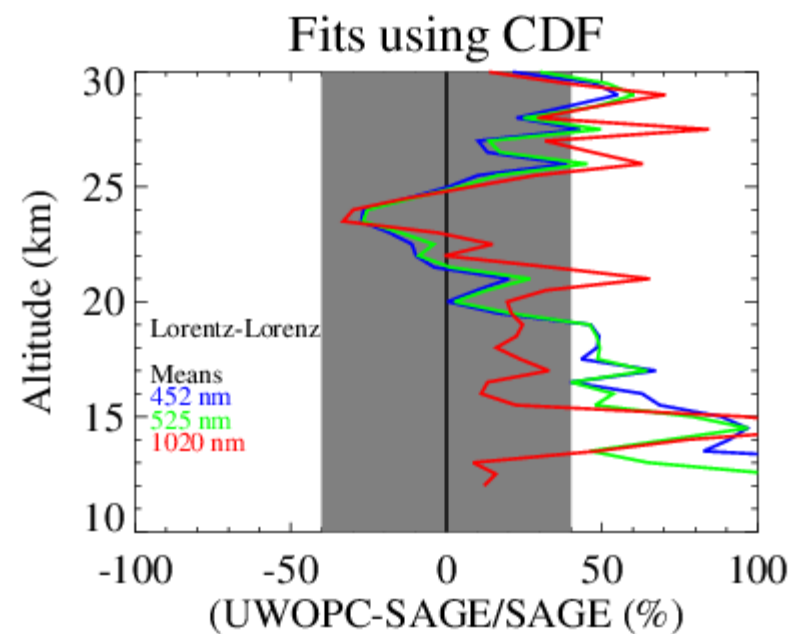
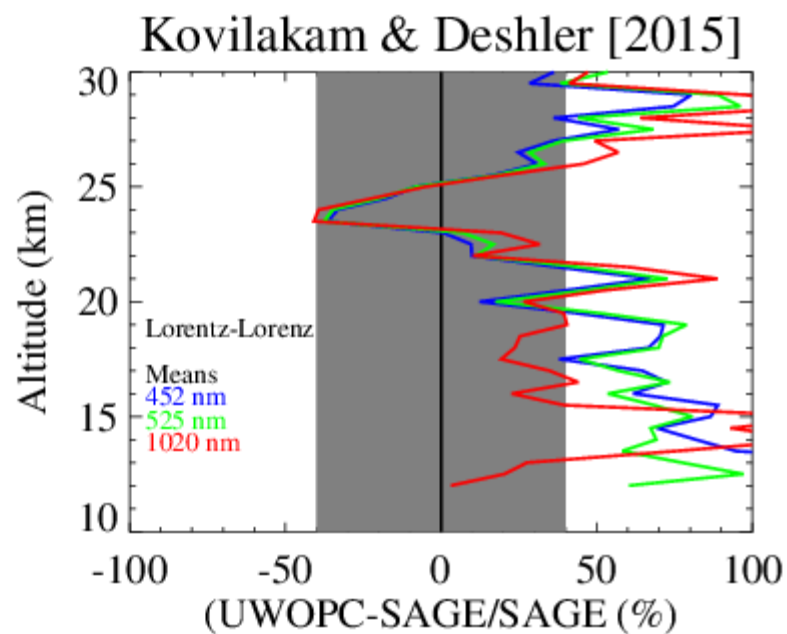
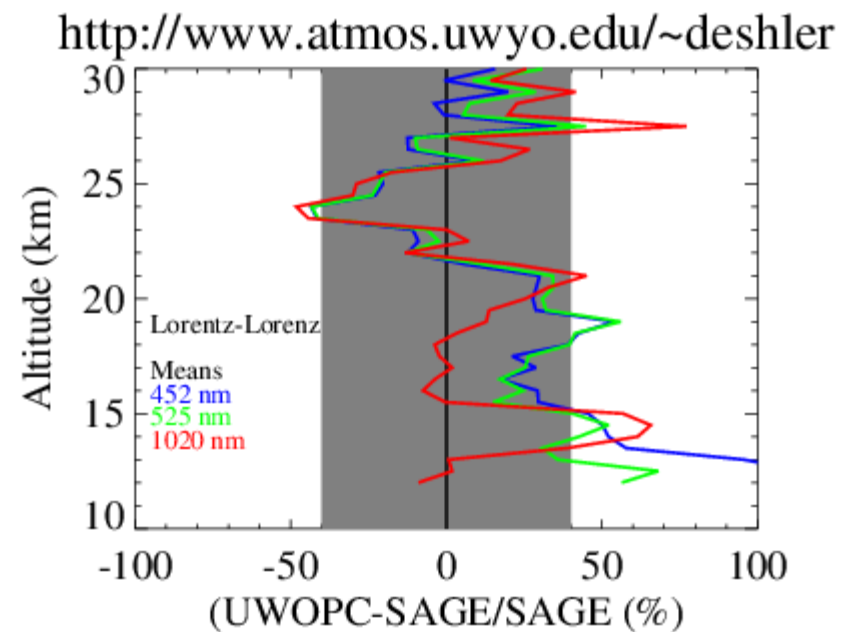
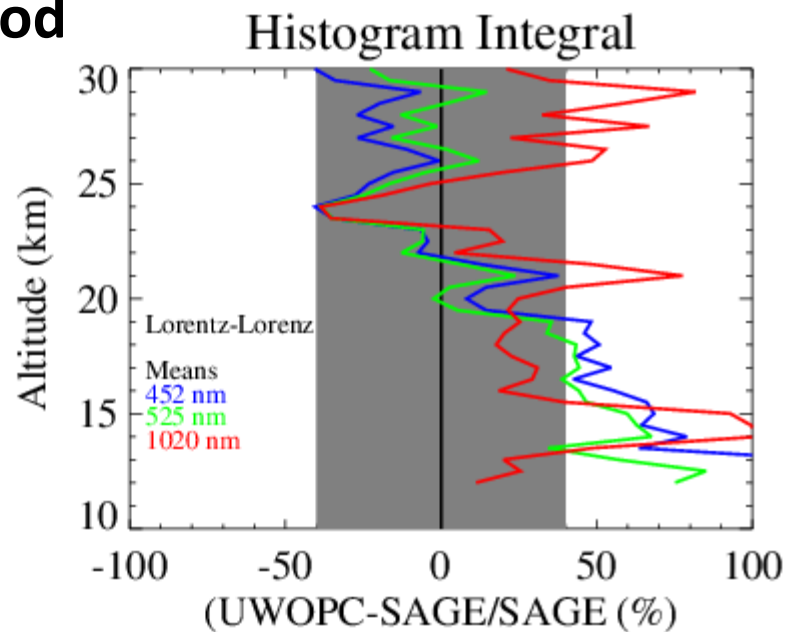
1997-2005
525 nm



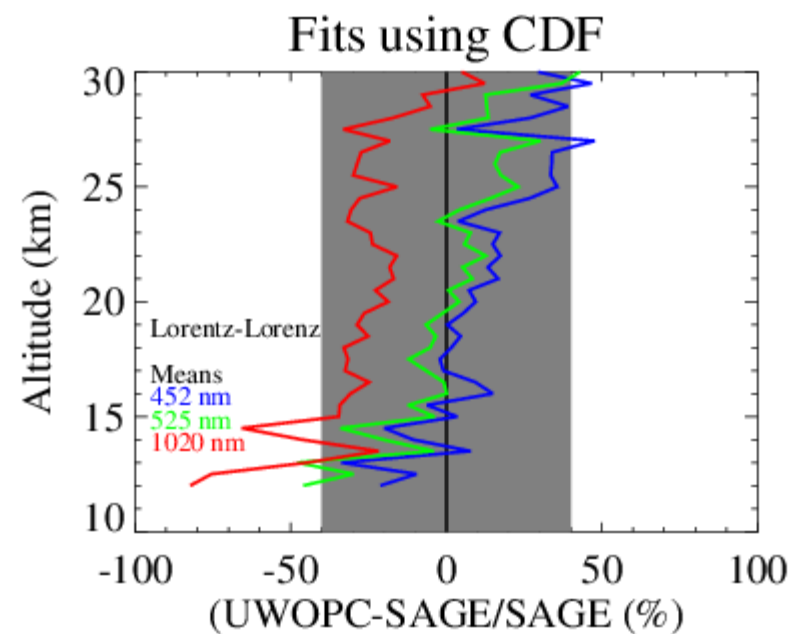
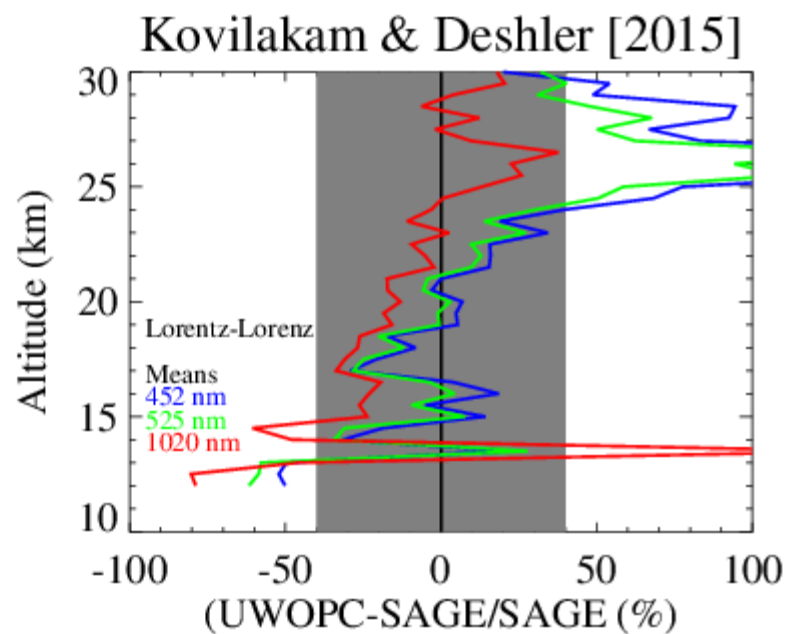
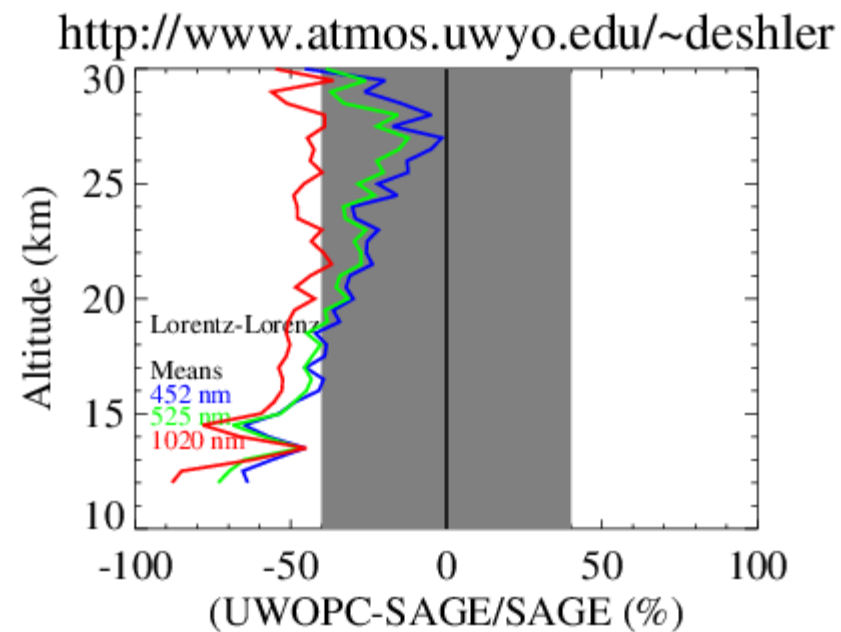
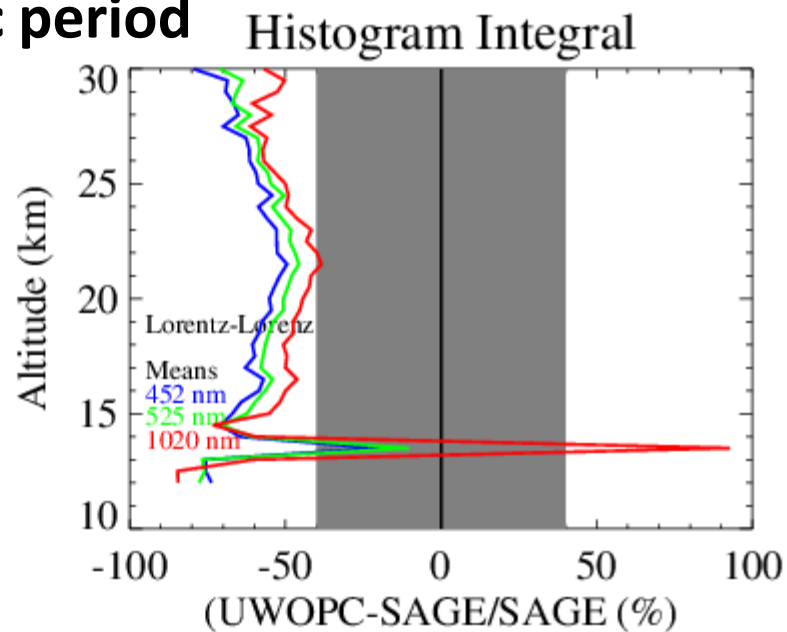
1997-2005
1020 nm



Volcanic period

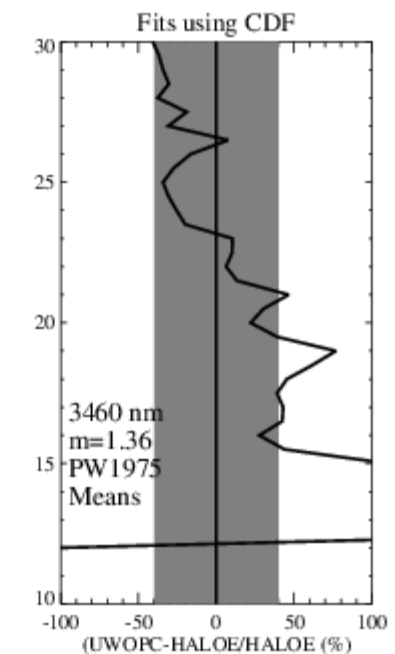
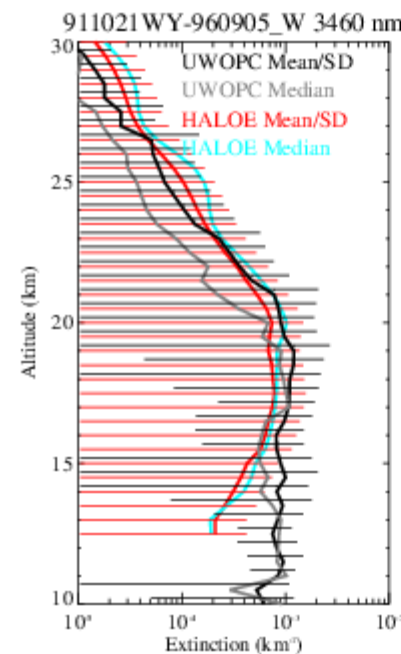
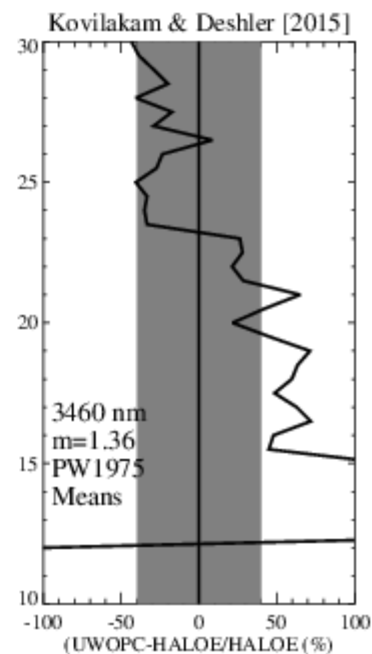
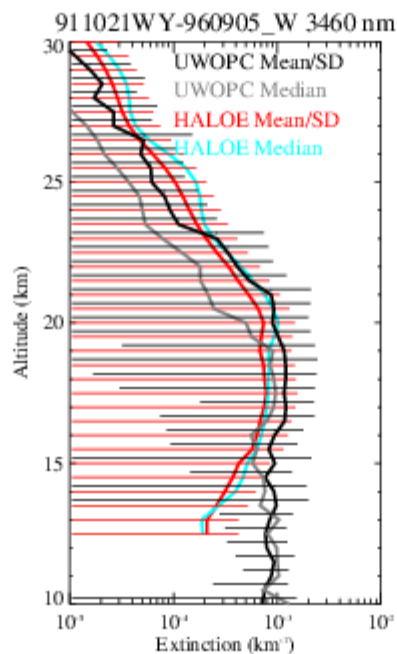
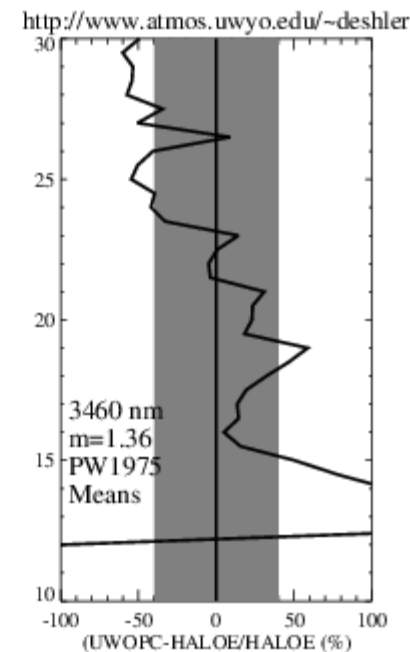
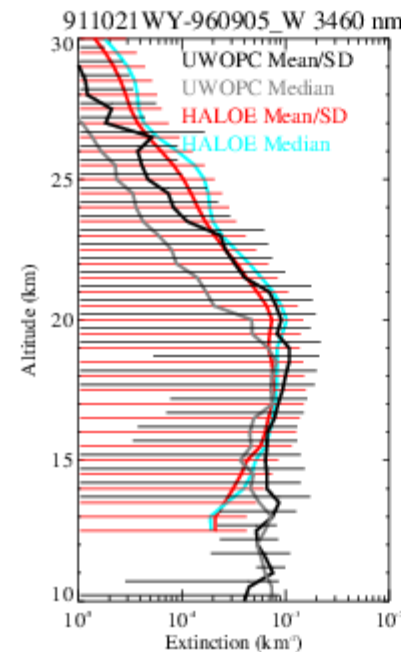
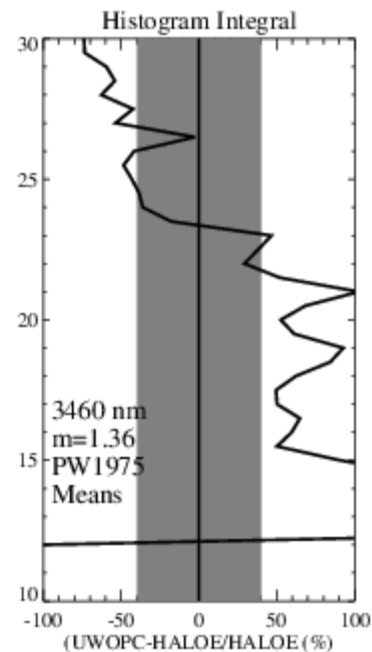
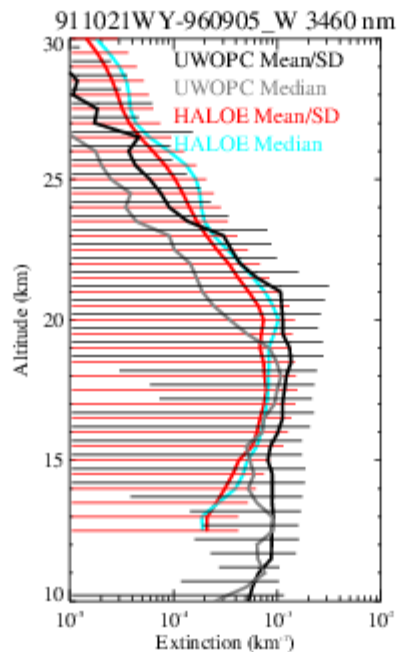


Non Volcanic period



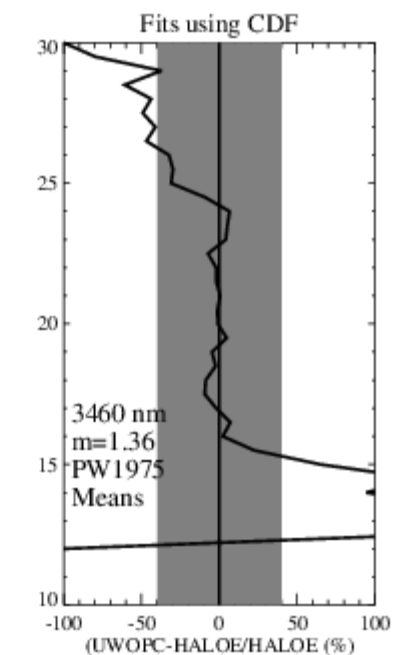
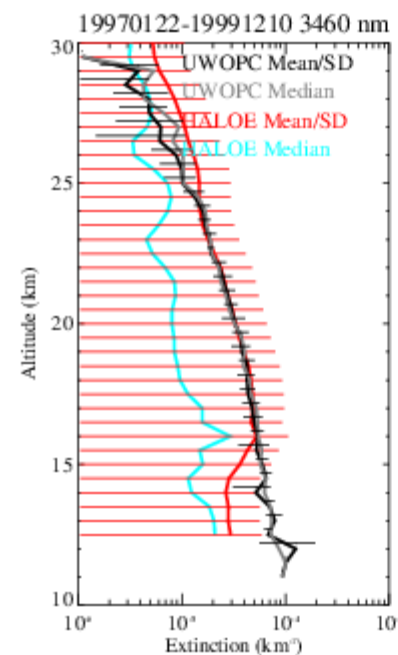
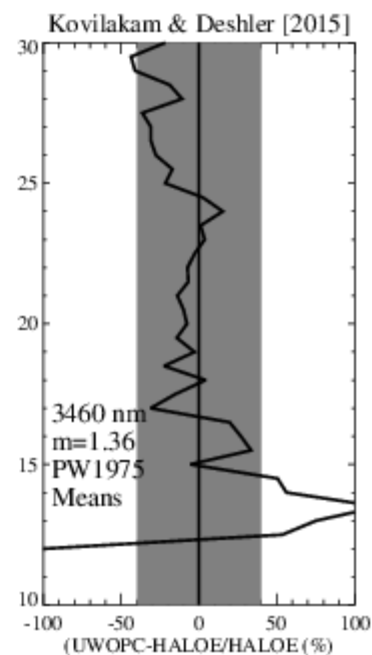
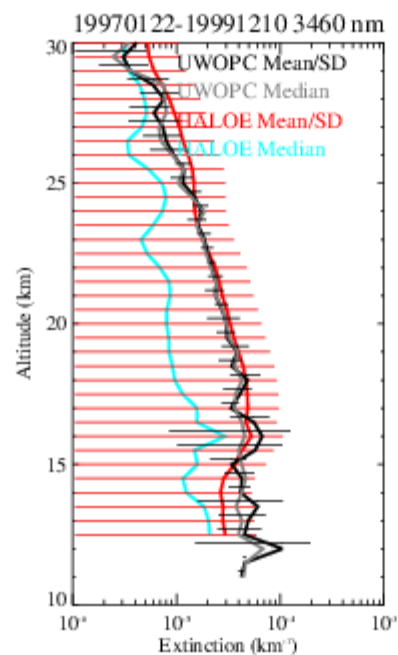
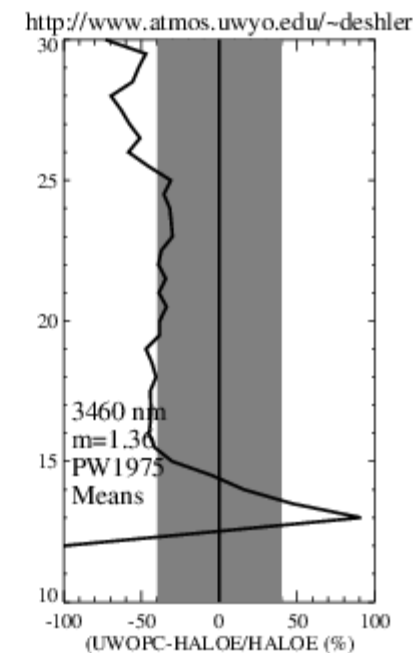
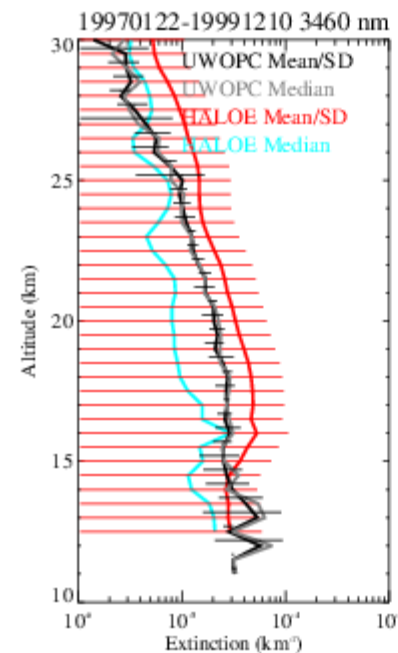
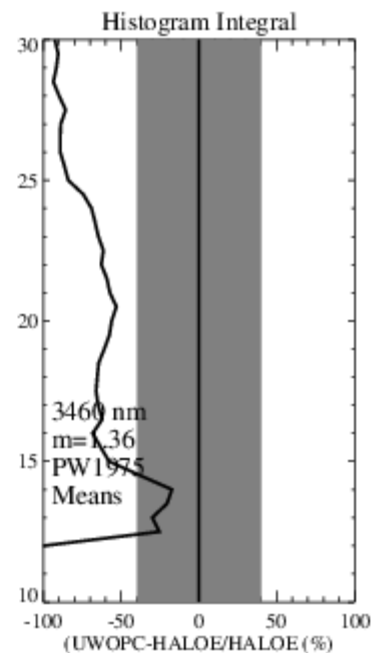
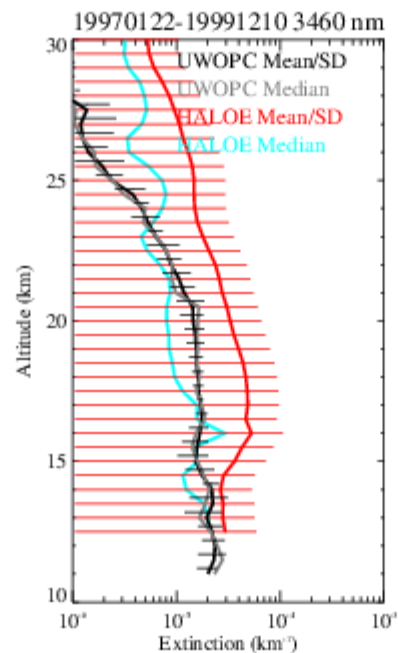
1991-1996
3460 nm

No Profiles
HALOE 75
OPC 31

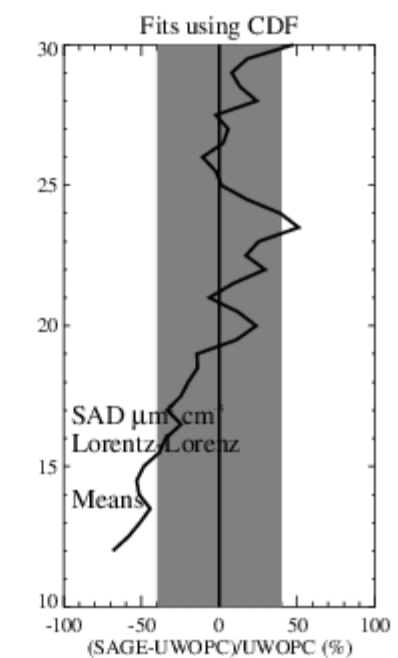
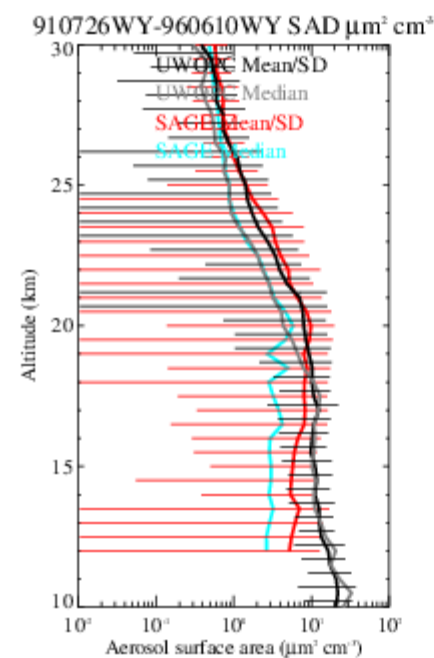
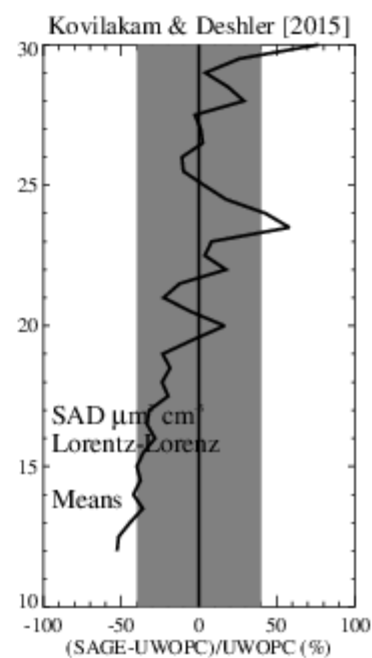
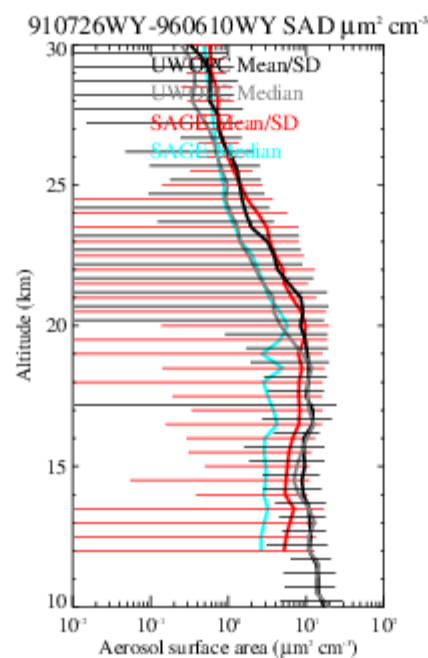
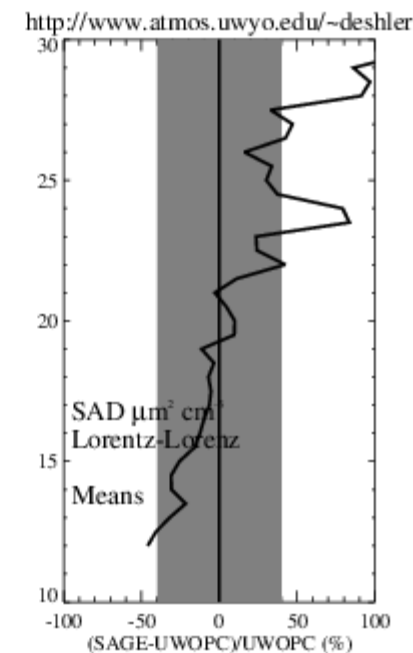
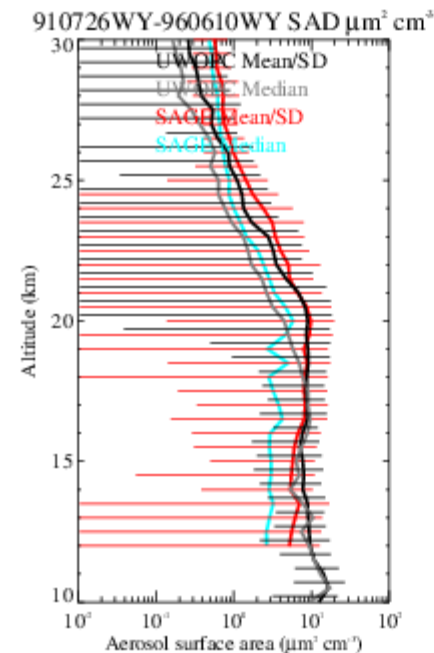
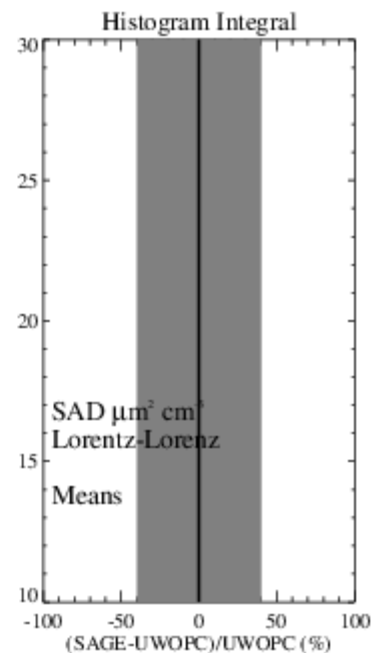
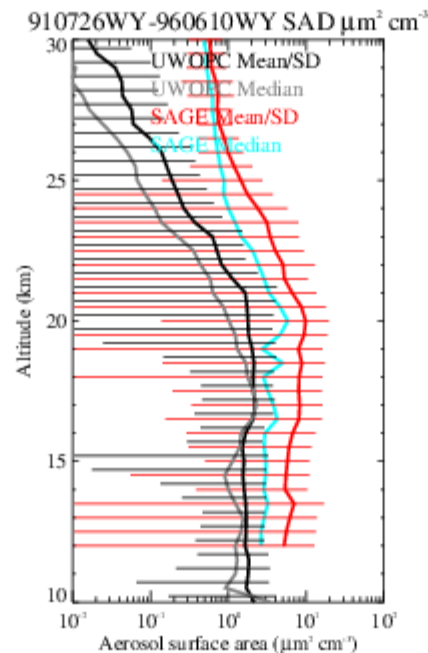


1997-2005
3460 nm

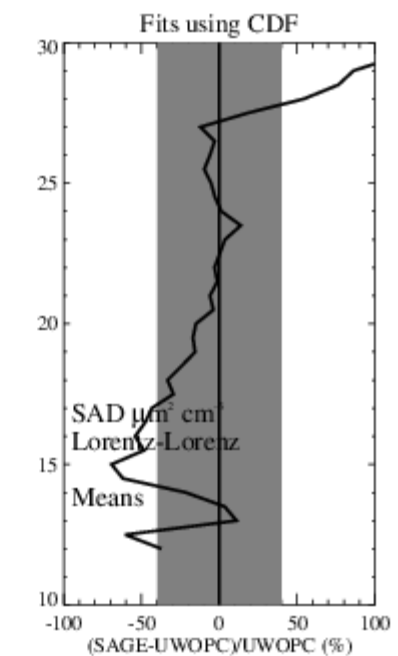
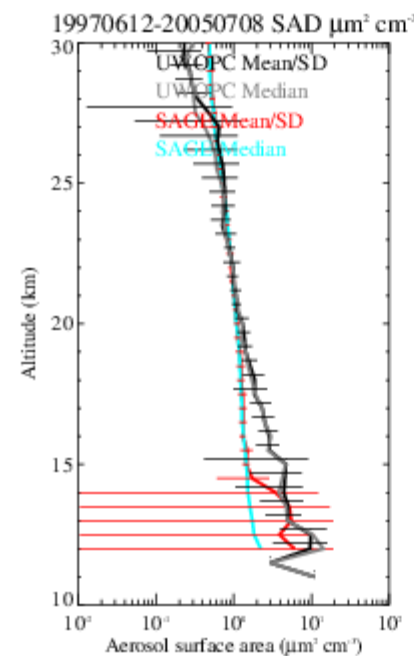
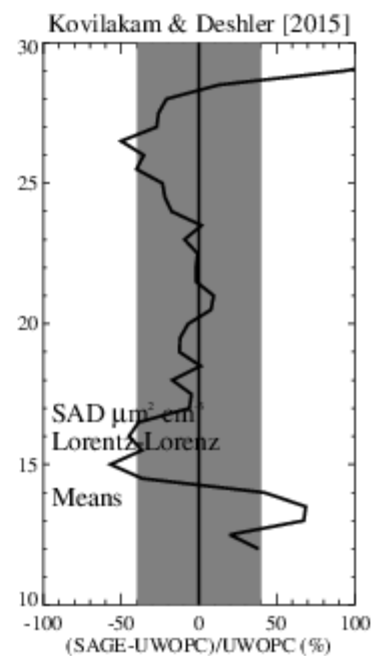
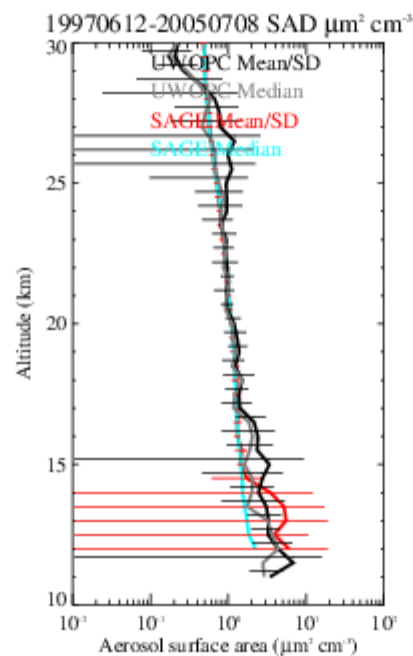
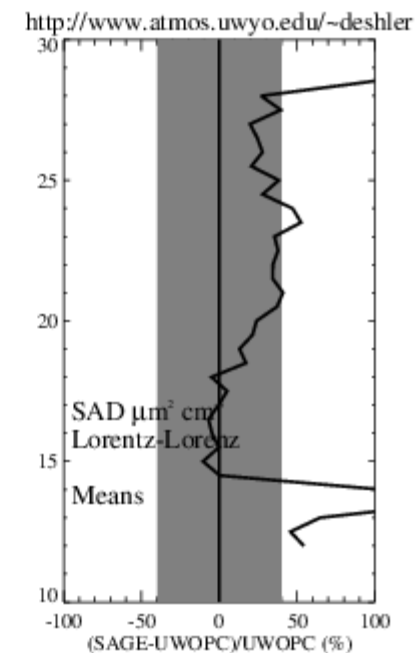
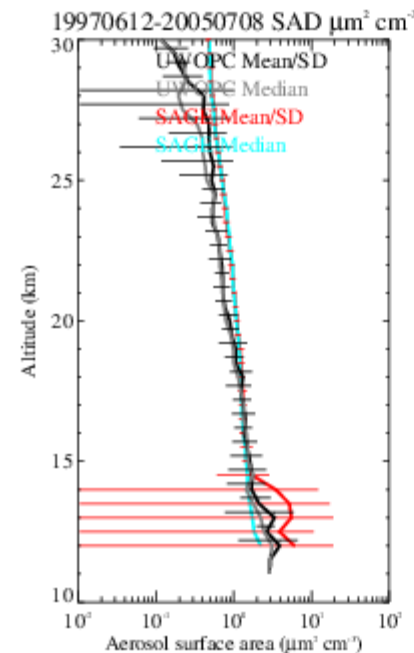
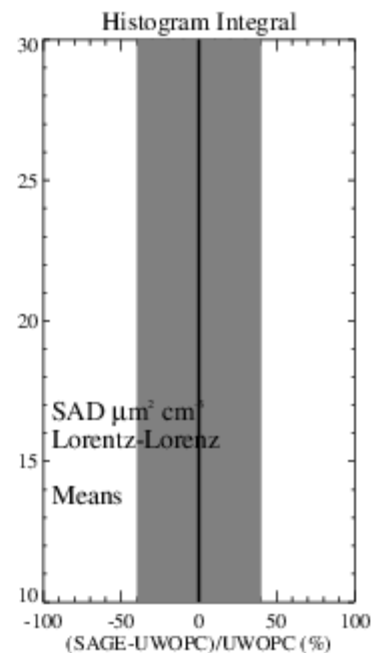
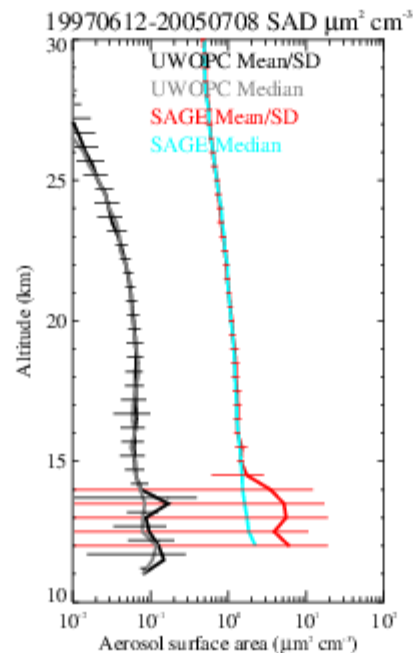
No Profiles
HALOE 14
OPC 5



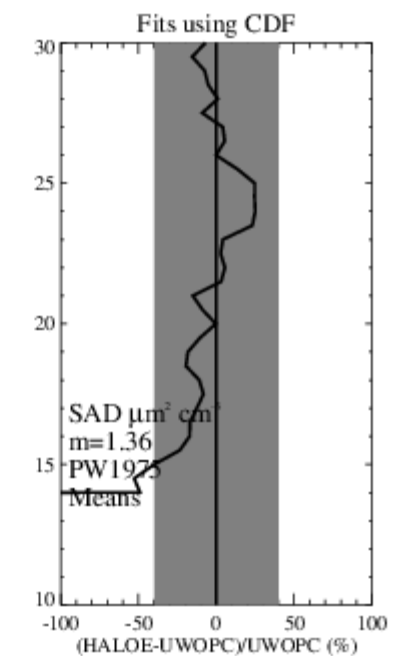
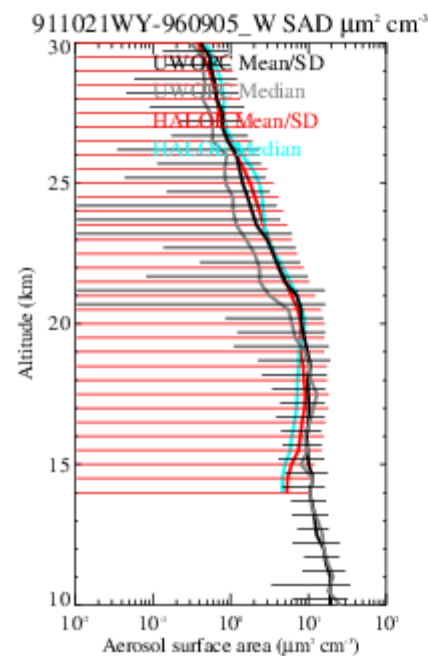
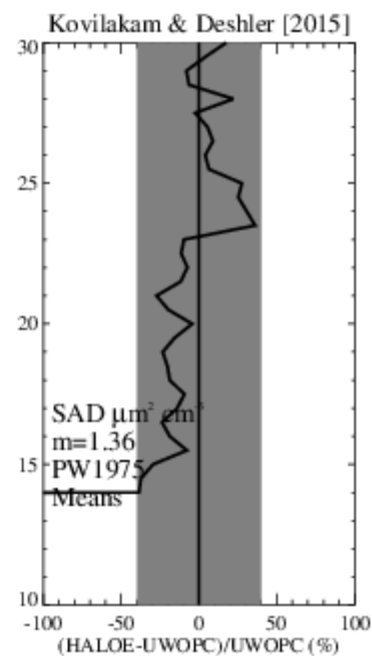
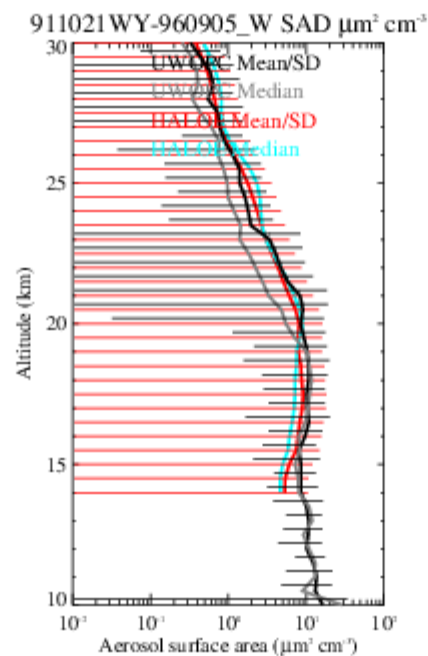
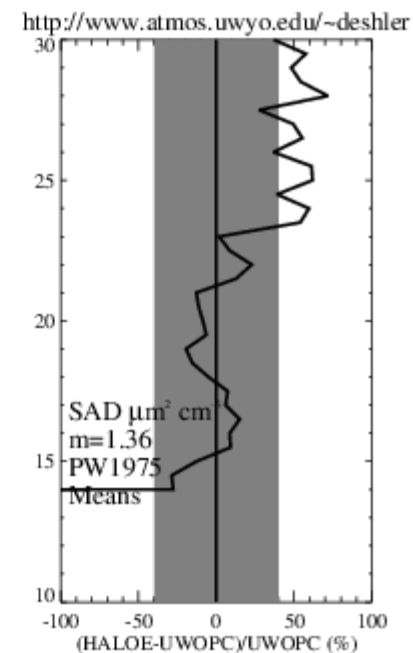
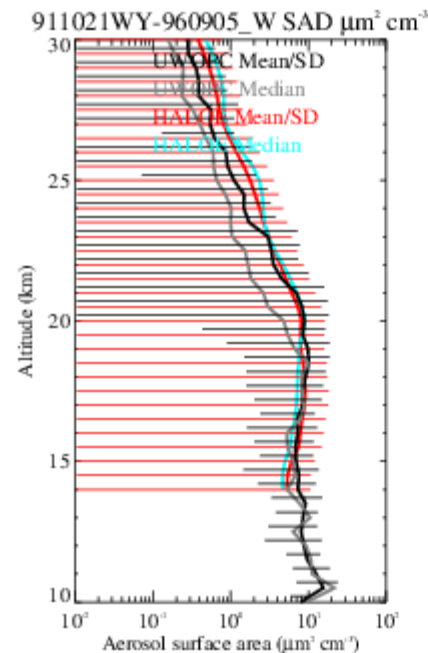
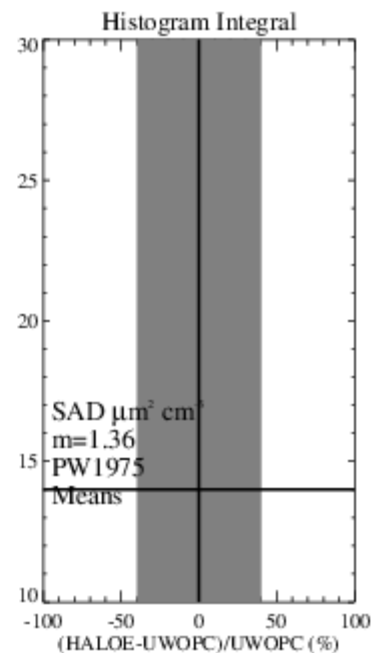
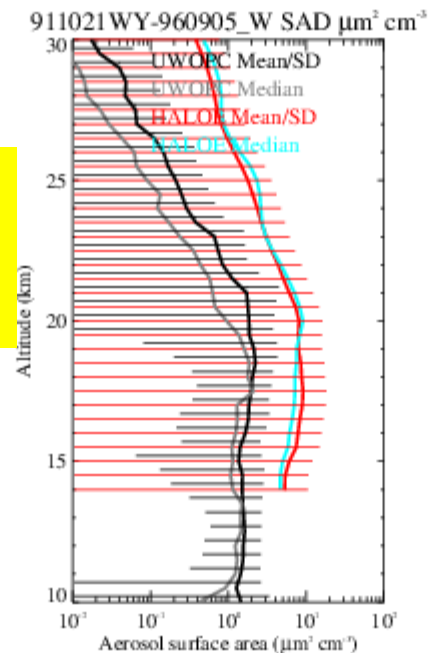
1991-1996 SAD - SAGE



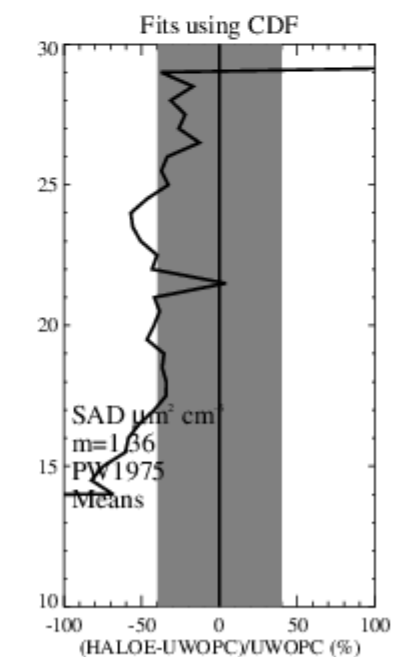
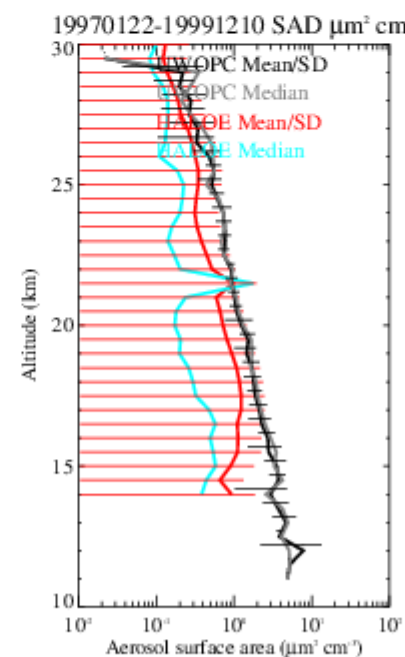
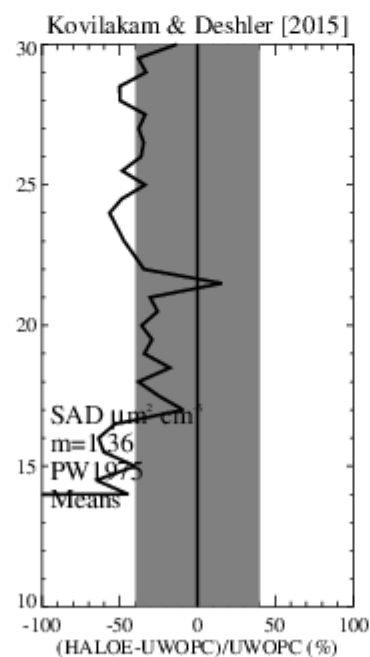
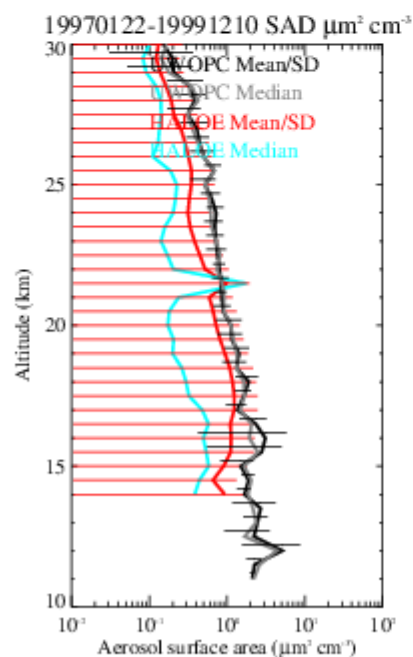
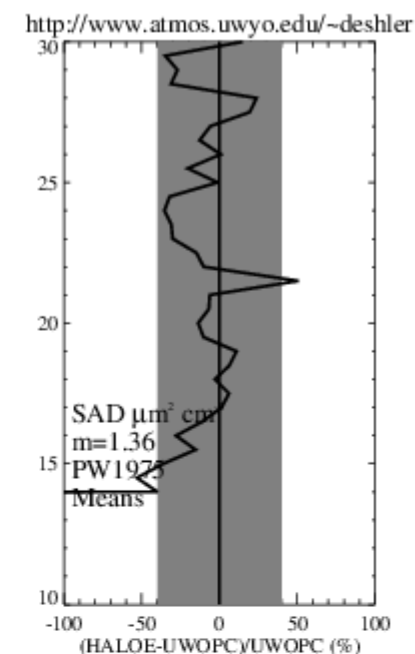
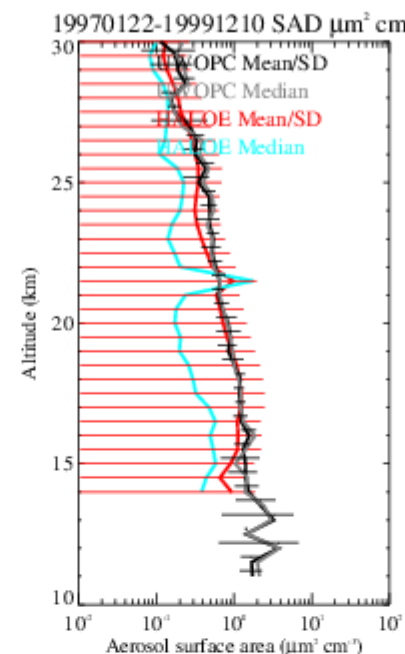
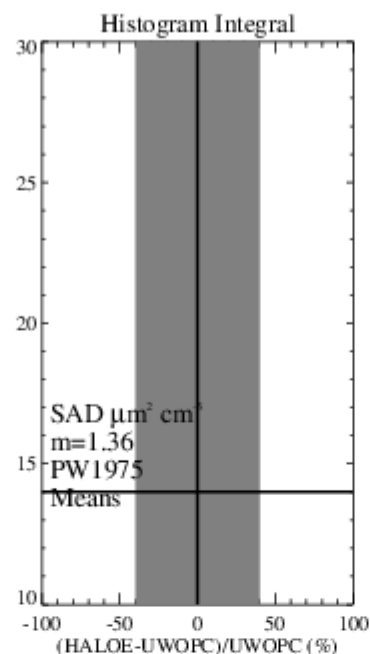
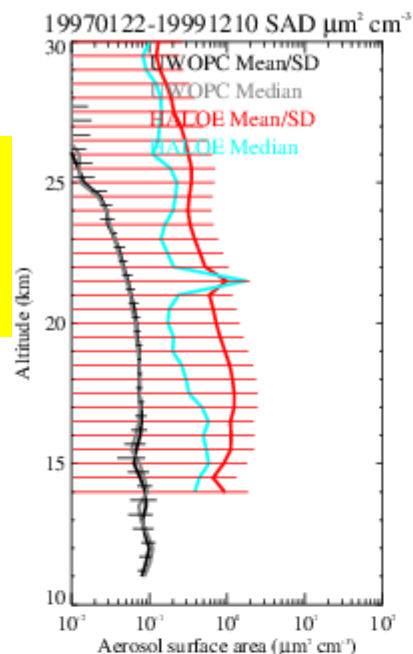
1997-2005 SAD - SAGE



1991-1996 SAD - HALOE



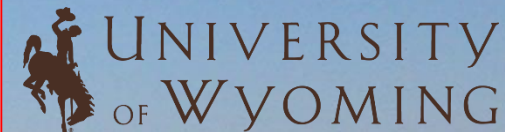
1997-2005 SAD - HALOE



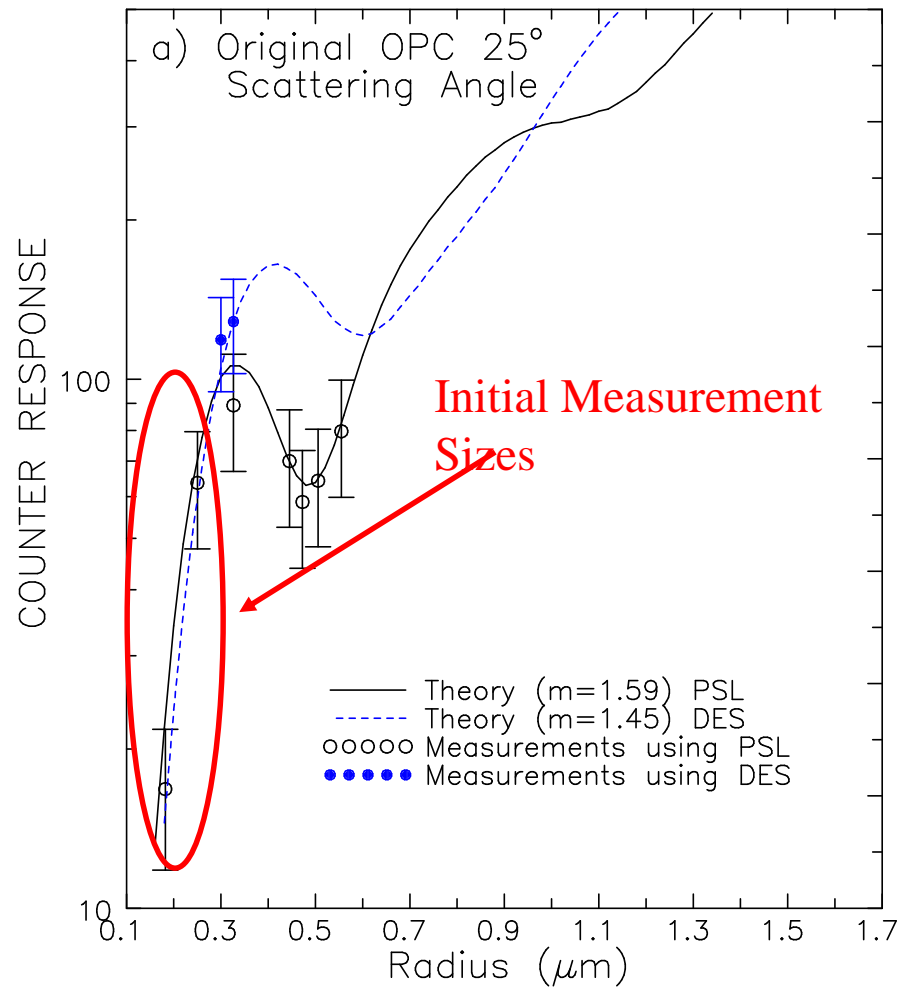
Conclusions



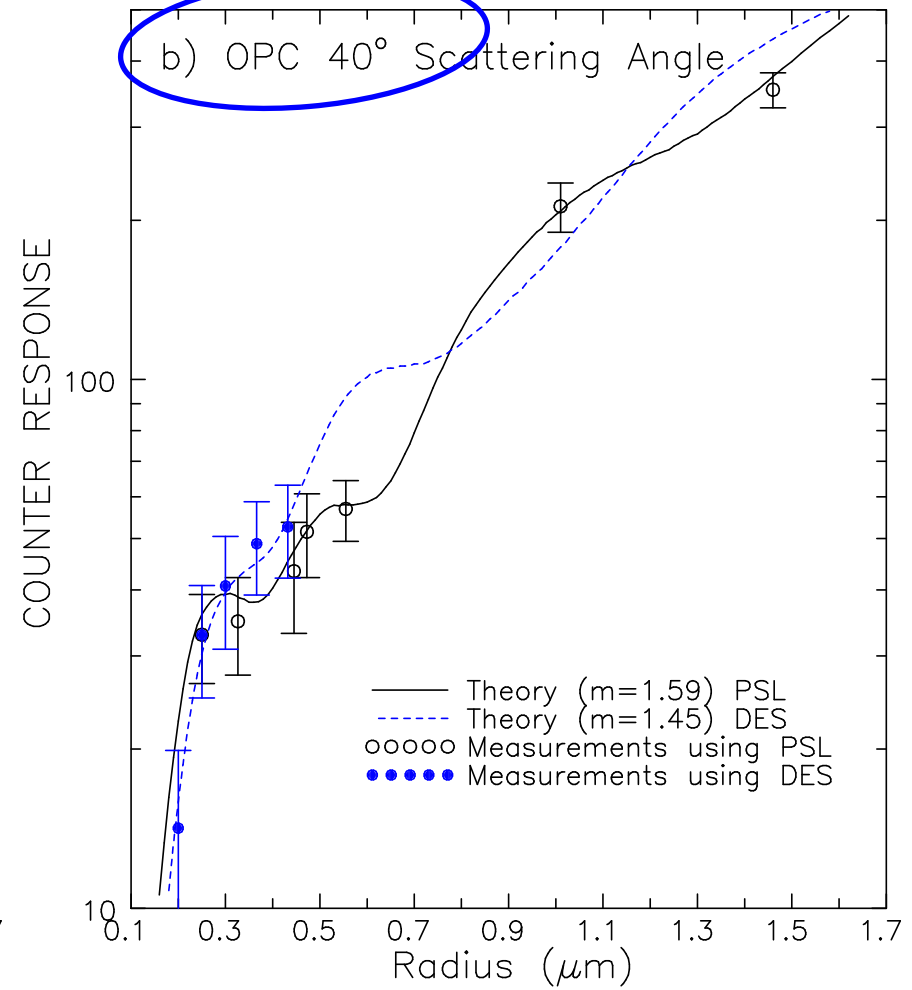
- The laboratory data generated in support of the work by Kovilakam and Deshler [2015] has been used to fit counting efficiency curves, CDFs, to the first three channels of the Wyoming OPC. These data are used to extrapolate CDFs to larger sizes.
- The CDFs are folded into the retrieval of aerosol size distribution.
- Aerosol extinctions derived from the revised aerosol size distribution retrievals are in good agreement with both SAGE and HALOE during both volcanic and non-volcanic periods.
- This is similar to the results of Kovilakam and Deshler improving the agreement with satellite measured extinctions during the non-volcanic period where there had been disagreement with the current in situ size distributions from the Wyoming OPC.
- The advantage, over Kovilakam and Deshler, of the new retrieval involving CDFs is that the primary measurement of the OPC, the aerosol number concentration, is not modified.



1971 - 1990



1990 - present



High Gain

