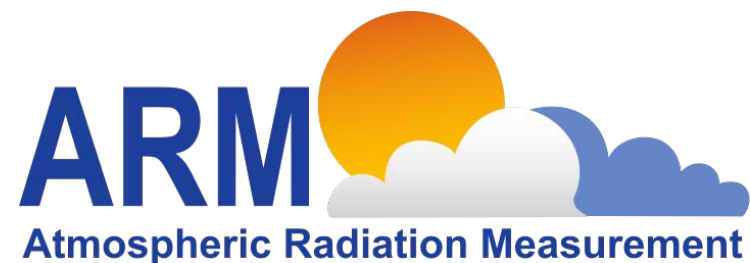# Application of a Cirrus Statistical Model To Recent Cirrus Particle Size Distribution Data

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# Purpose and Method

- Compare historical cirrus PSD datasets with more modern datasets collected using 2D-S (SPartICus, MACPEx, TC[4])

- Do so by applying a cirrus PSD statistical model developed using older 2DC/2DP data to 2D-S data
    - "Statistical Properties of the Normalized Ice Particle Size Distribution"  [Delanoe et al., 2005]
    - Not a commentary on the parameterization technique—rather, a comparison with older cirrus datasets

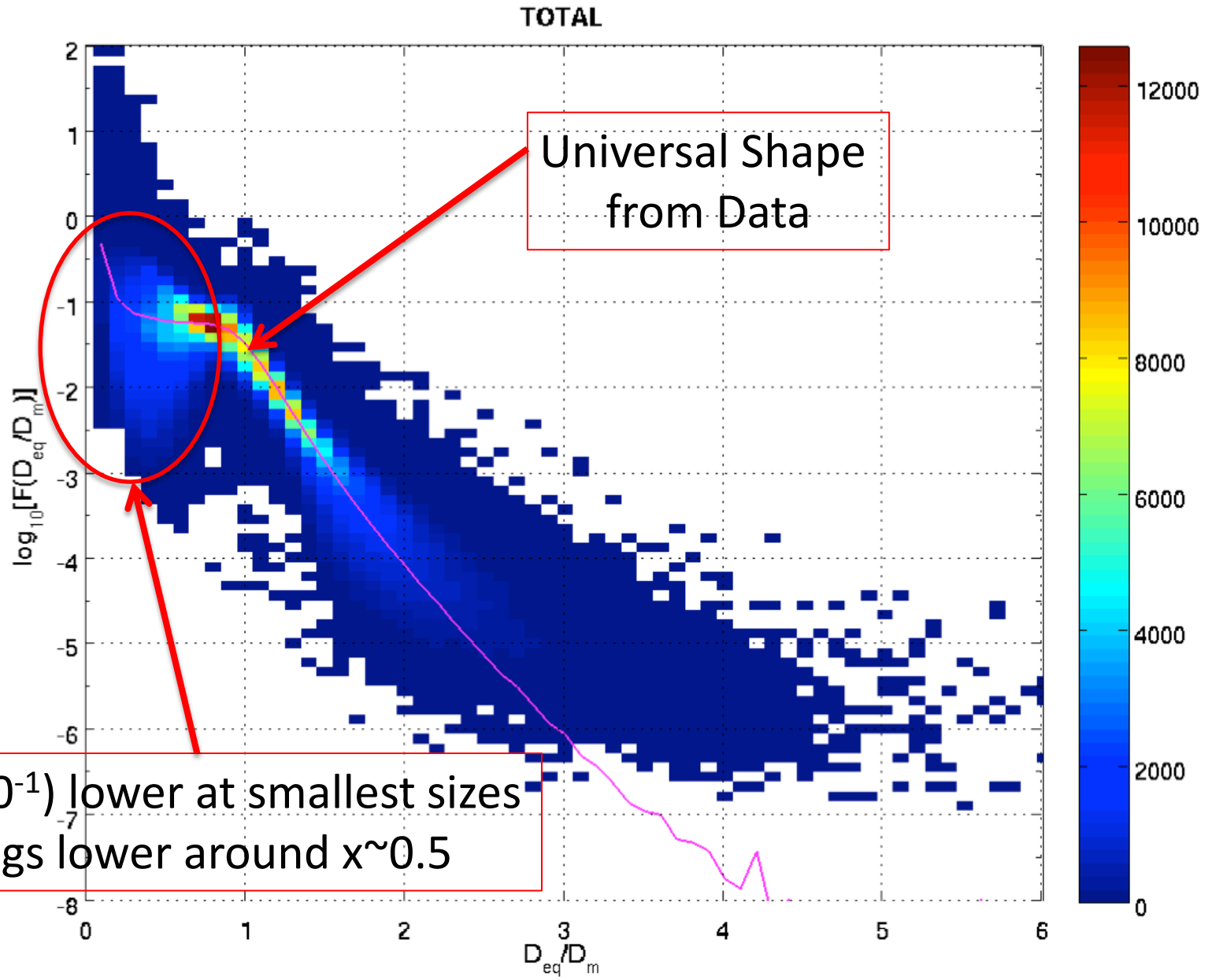- Compare results of "2DC" with variables computed directly from 2D-S data

# Normalization of PSD's

- Ice PSD's transformed to spherical liquid-equivalent using density/dimensional relationship
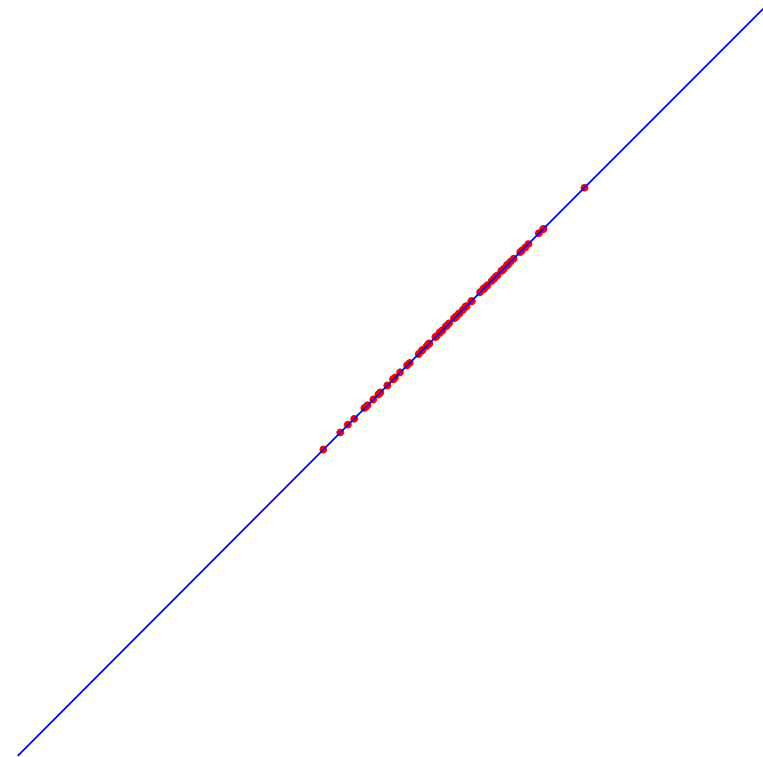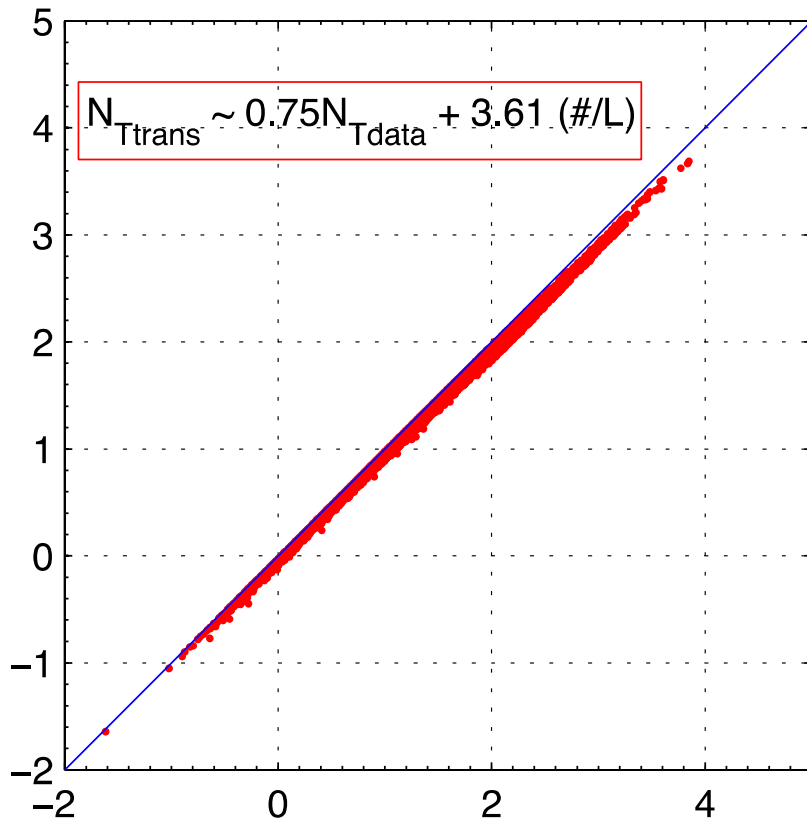
$$n_{D_e}(D_e) = N_0^* F(D_e/D_m) \qquad N_0^* = \frac{4^4}{\pi \rho_w} \frac{IWC}{D_m^4}$$

- True values of *N\** and $D_m$ computed from 2D-S data, also parameterized by T and Z

- Transform 2D-S data and normalize by true values of *N\** and $D_m$ to get "universal normalized PSD"
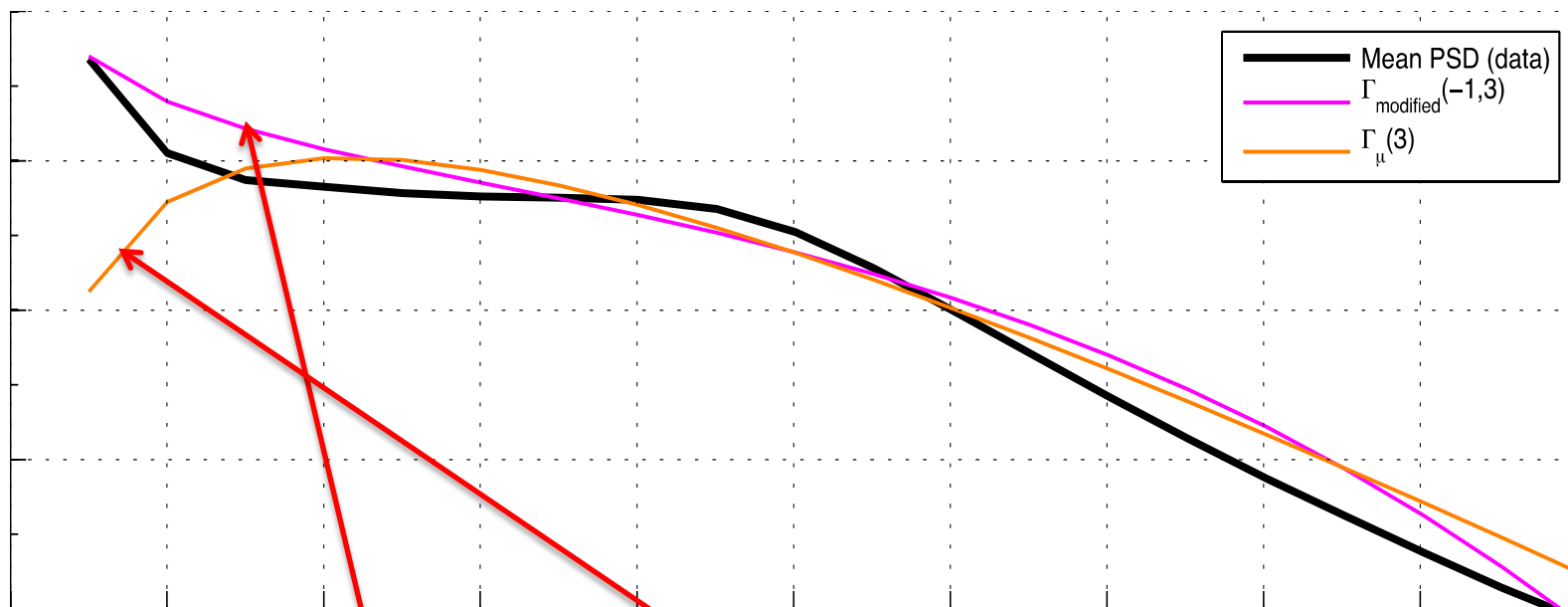
# Transformed Sparticus, TC4, Macpex:



TOTAL

Universal Shape from Data

~O($10^{-1}$) lower at smallest sizes
Digs lower around x~0.5

# Universal Shape and True N* and $D_m$ Reproduce Total Number and Mass as Designed



$N_{Ttrans} \sim 0.75 N_{Tdata} + 3.61$ (#/L)

Statistical model using N* and $D_m$ from 2D-S data correctly describes 2D-S data
Confirmation of Delanoe et al. normalization scheme

# Universal Shape From 2D-S Compared with Universal Shape from 2DC Data (parametric fits)



Legend:
- Mean PSD (data)
- $\Gamma_{modified}(-1,3)$
- $\Gamma_{\mu}(3)$

$$F_{\alpha,\beta}(x) = \beta \frac{\Gamma(4)}{4^4} \frac{\Gamma\left(\frac{\alpha+5}{\beta}\right)^{4+\alpha}}{\Gamma\left(\frac{\alpha+4}{\beta}\right)^{5+\alpha}} x^\alpha exp\left[-\left(x\frac{\Gamma\left(\frac{\alpha+5}{\beta}\right)}{\Gamma\left(\frac{\alpha+4}{\beta}\right)}\right)^\beta\right]$$
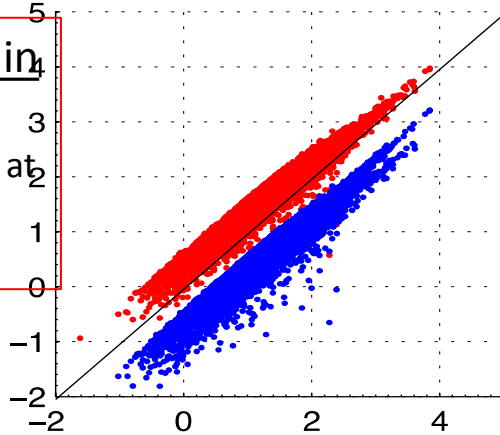
$$F_{\mu}(x) = \frac{\Gamma(4)}{4^4} \frac{(4+\mu)^{4+\mu}}{\Gamma(4+\mu)} x^\mu exp[-(4+\mu)x]$$

# Using True Values of $N*$ and $D_m$: Gamma-mu (BLUE) fails to capture concentration in new dataset— exclude it
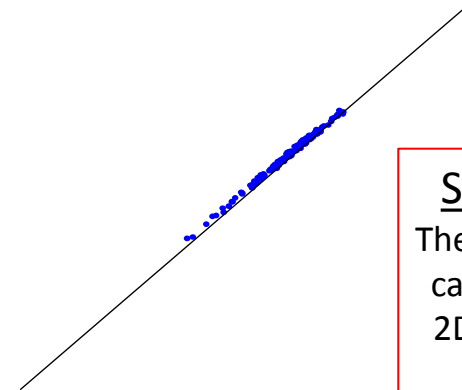


### Most Uncertain Moment
Modified gamma at least in neighborhood

### Riding the Coat-tails of Mass
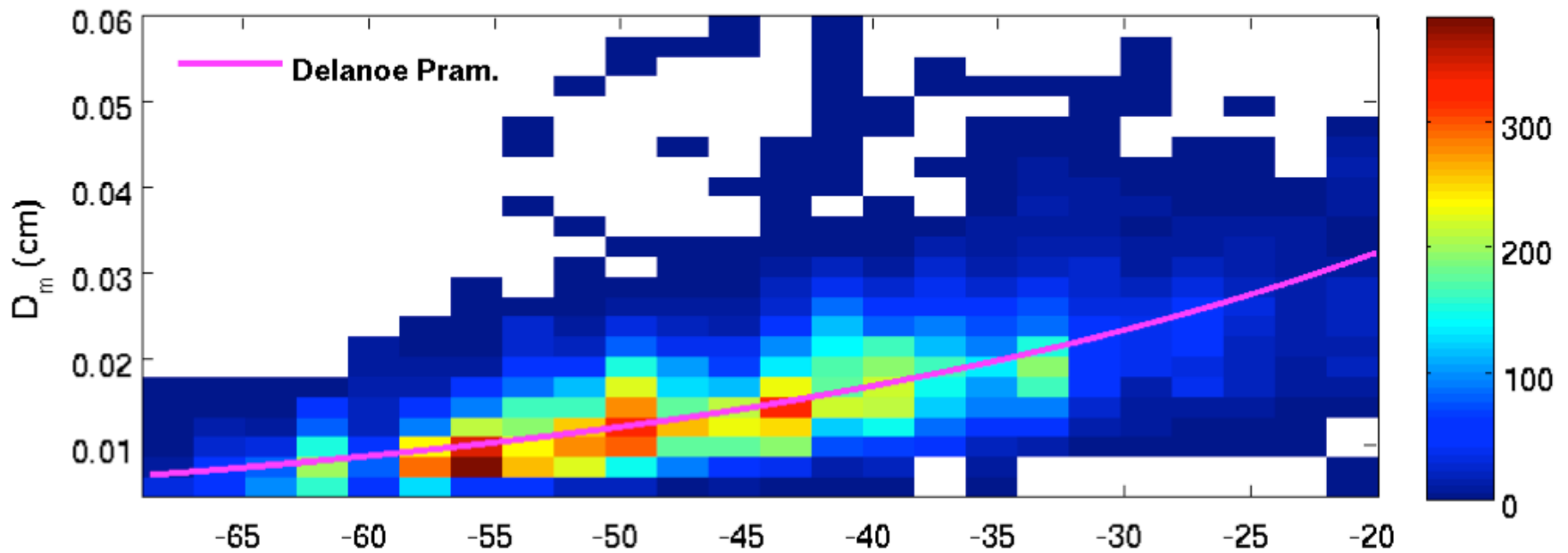
### Fit by design
Independent of PSD shape

### Smoking Gun
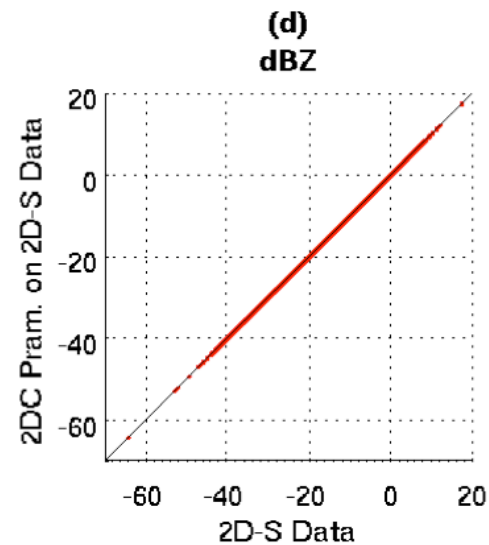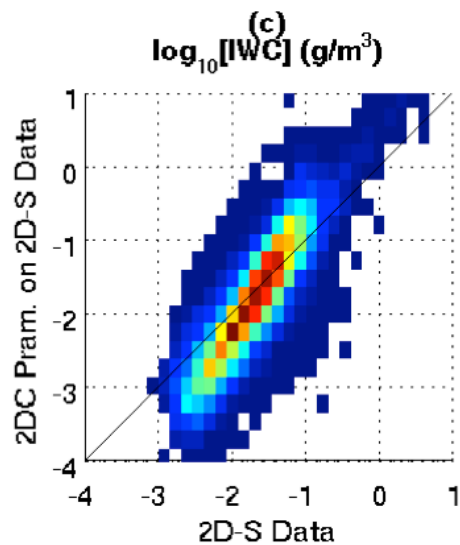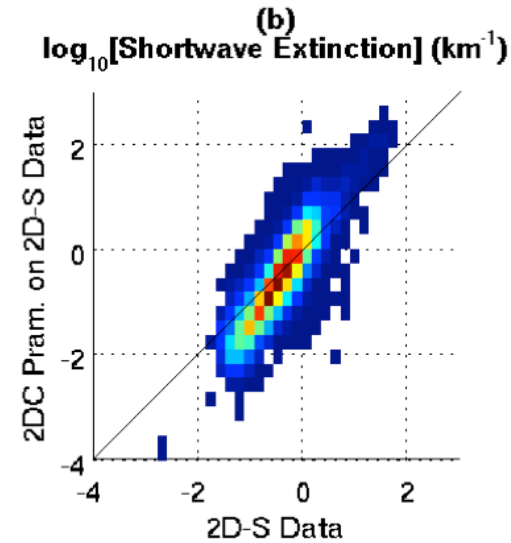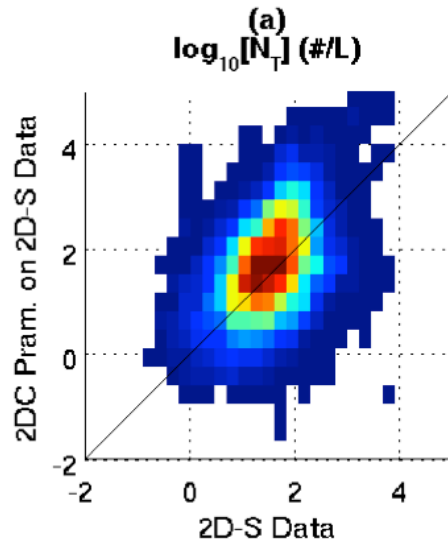The 2DC data shape cannot reproduce 2D-S Z—skewness will propagate

# Use True $D_m$, Parameterize N* by Z
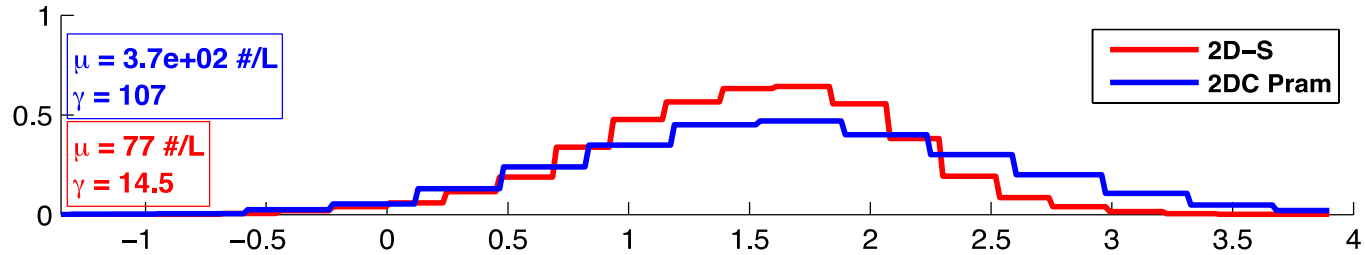## "2DC" skewed in mass and extinction compared to 2D-S

# Add in Parameterization of $D_m$ by temperature

# Relationships "2DC" and 2D-S Spread Out: Offset seen Clearly

# Statistically Significant Bias in Quantities Computed Using 2DC-based Model vs. Computations directly from 2D-S

# Summary

- Number concentrations of particles at smallest scaled diameters is lower in 2D-S than older 2DC datasets

- Ratio of parameterized means to data

| $N_T$ | 4.7 | 6.8 dB |
|-------|-----|--------|
| Ext | 2.2 | 3.4 dB |
| IWC | 2.2 | 3.4 dB |

- Does parameterization based on older 2DC data sufficiently represent data collected by newer 2D-S?  It depends on how accurate you need to be.

- More flight campaigns, w/newer instrumentation and processing techniques, needed to more accurately quantify global cirrus microphysics