Relationships between Raindrop Size Distributions Parameters: Framework to Investigate Assumptions in Model Parameterizations

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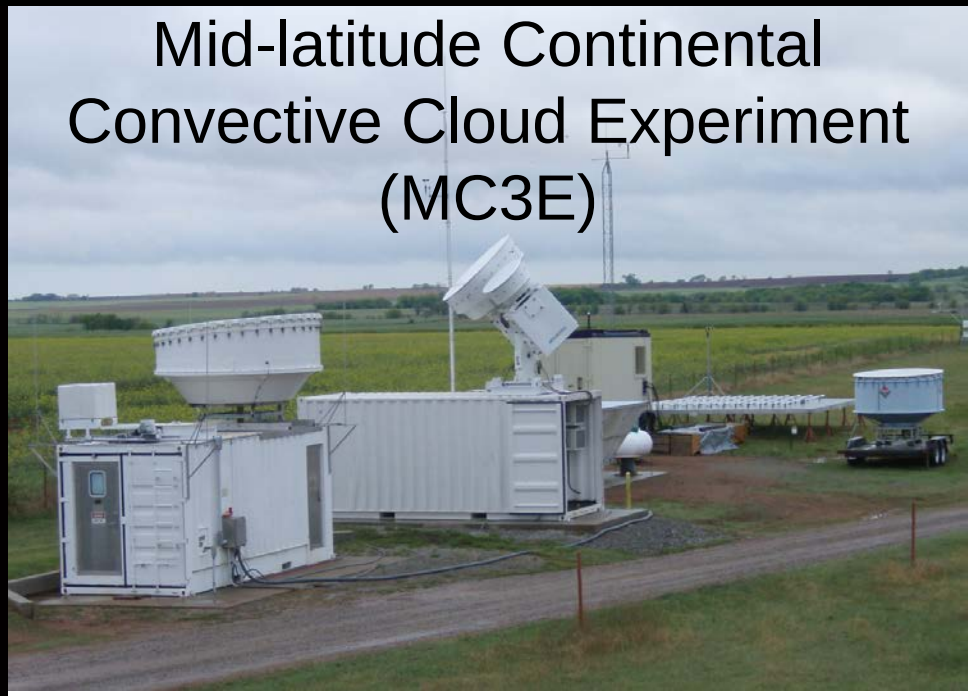
Mid-latitude Continental Convective Cloud Experiment (MC3E)



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NASA PMM Grant: NNX13AF89G

CIRES

Bridging Observations & Algorithms

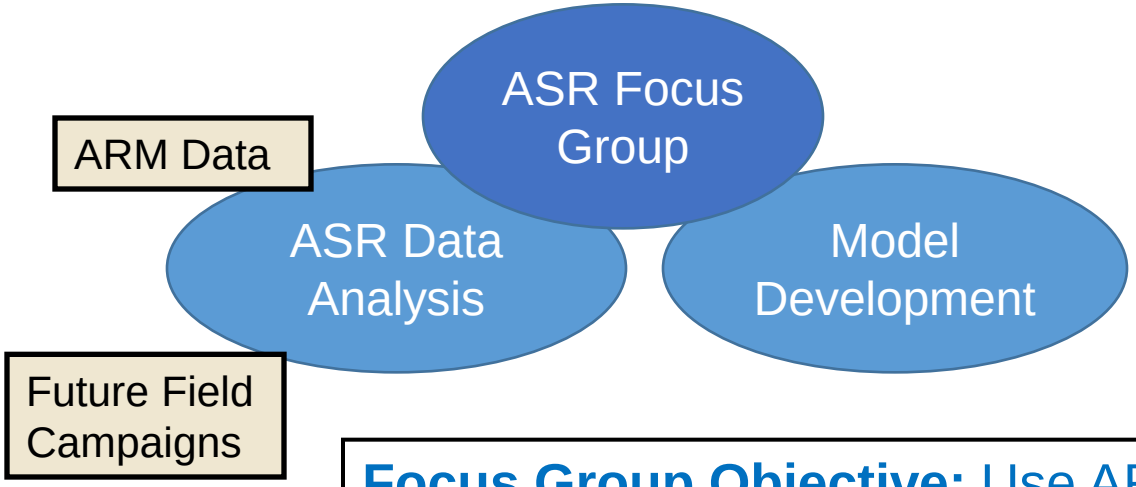
NASA Global Precipitation Mission (GPM) DSD Working Group: Bridging Ground Validation (GV) and Algorithms

DSD WG General Objective: Use Ground Validation (GV) data to support, or justify, assumptions used in satellite retrieval algorithms.

Bridging Observations & Models

NASA Global Precipitation Mission (GPM) DSD Working Group:

Bridging ARM Data and Models



Focus Group Objective: Use ARM Data to support, or justify, assumptions (aka parameterizations) used in models.

Bridging Observations & Models

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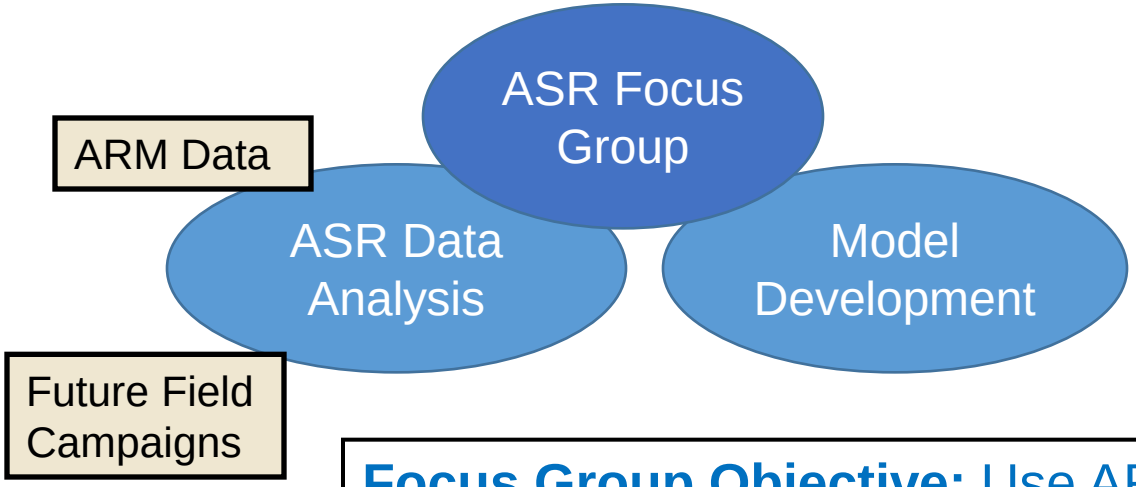


Focus Group Objective: Use ARM Data to support, or justify, assumptions (aka parameterizations) used in models.

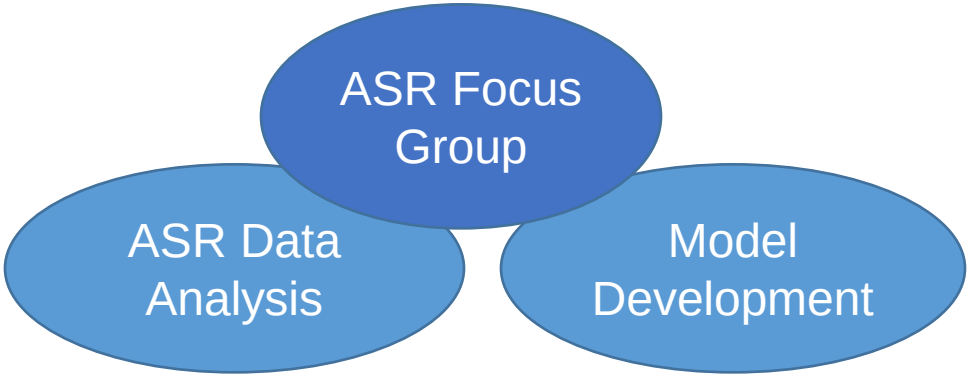
Example of using Data to investigate assumptions:

1. Monday (MC3E/Meso) - Relationships between DSD attributes.
2. Tuesday (ICEPROP) - Framework incorporating findings into Algorithms.

Bridging Observations & Models

NASA Global Precipitation Mission (GPM) DSD Working Group:

Bridging ARM Data and Models



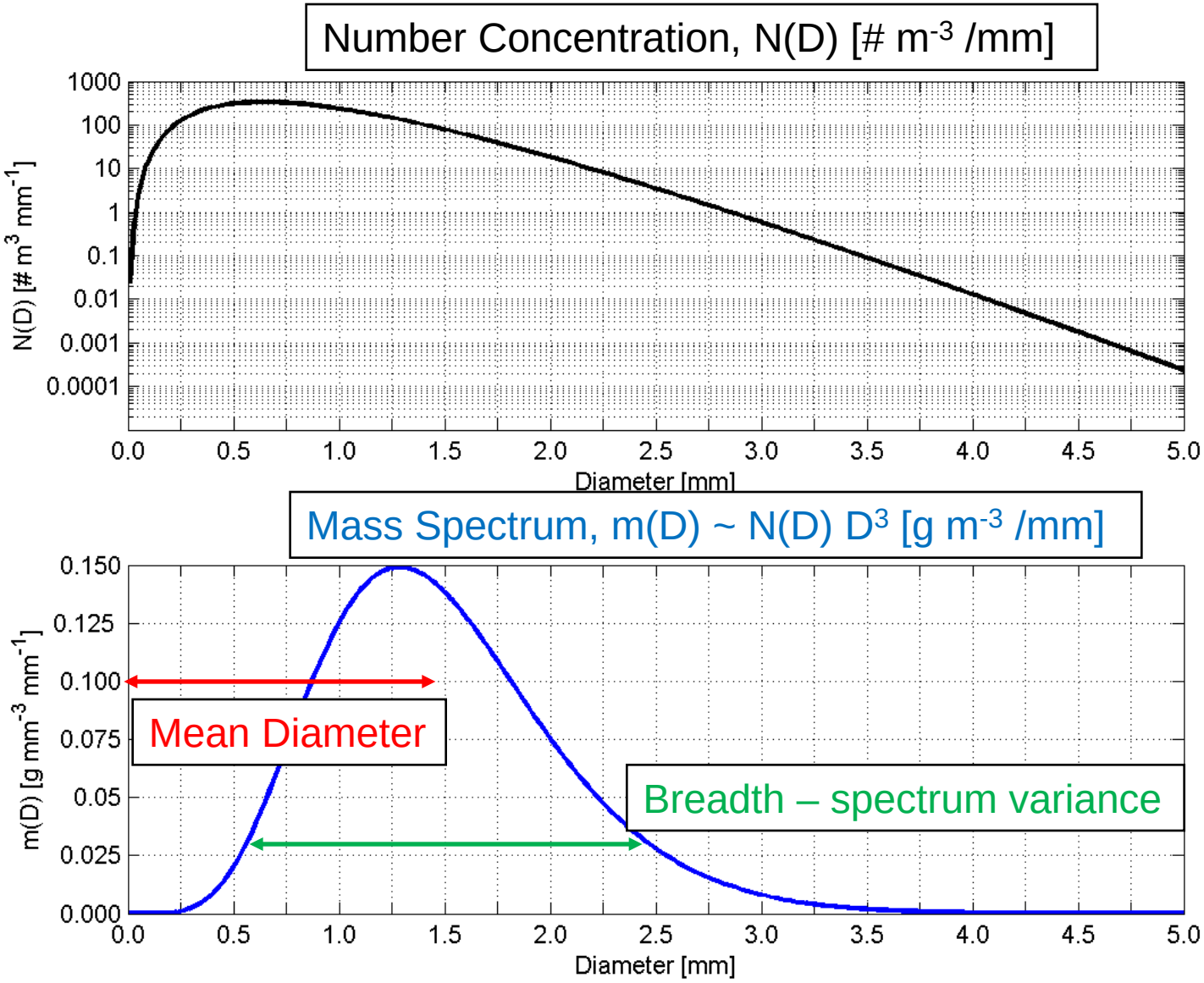
How are Raindrop Size Distributions (DSDs) described?:

Radar & Observations
- 3 parameter gamma function (Nw, Dm, μ)

Cloud Models
- single moment
- double moment
- bin microphysics

Difficult to compare results because of different descriptions.

DSD Mass Spectrum



DSD Mass Spectrum

Mass Spectrum

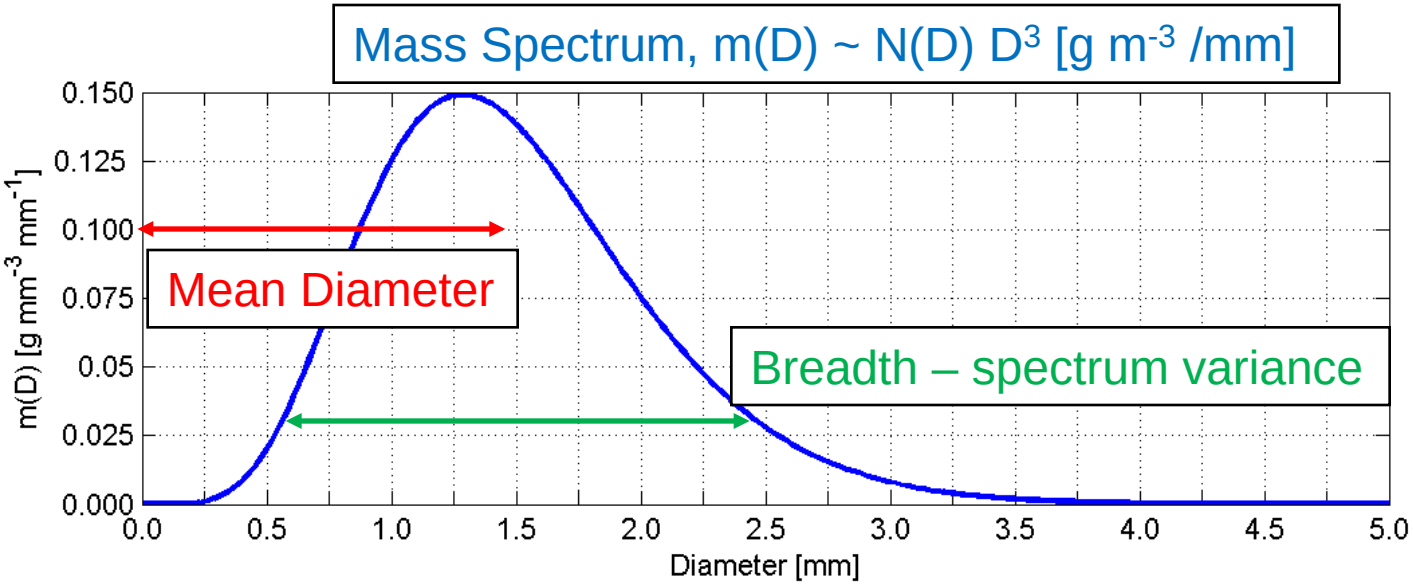
$$w(D) = \frac{\pi}{6 \cdot 10^3} \rho_w N(D) D^3$$

Mean Diameter

$$D_m = \frac{\sum_{D_{\min}}^{D_{\max}} w(D) D dD}{\sum_{D_{\min}}^{D_{\max}} w(D) dD}$$

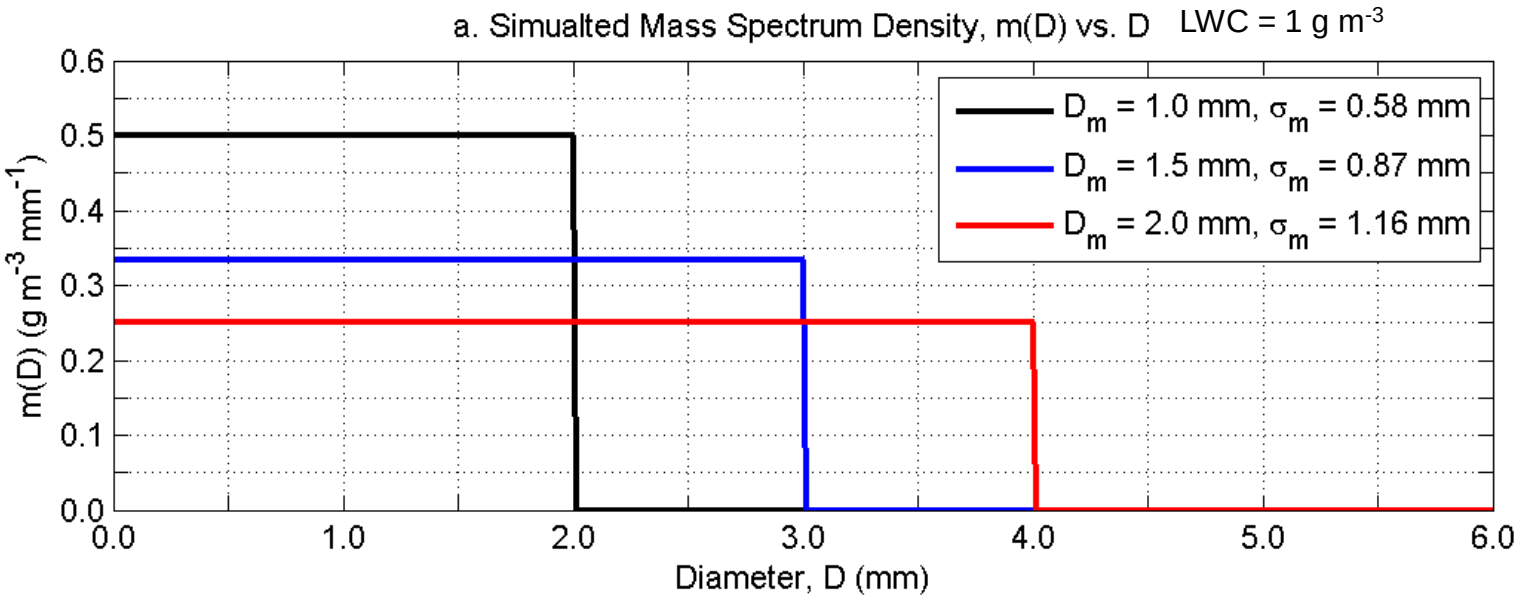
Mass Spectrum Variance

$$\sigma_m^2 = \frac{\sum_{D_{\min}}^{D_{\max}} (D - D_m)^2 w(D) dD}{\sum_{D_{\min}}^{D_{\max}} w(D) dD}$$



Top-Hat Mass Spectra

Raindrop spectra are ‘single sided’
(Can’t have negative raindrop diameters)



Spectrum breadth increases as mean Diameter increases

Simulated Gamma DSD

Raindrop spectra are ‘single sided’
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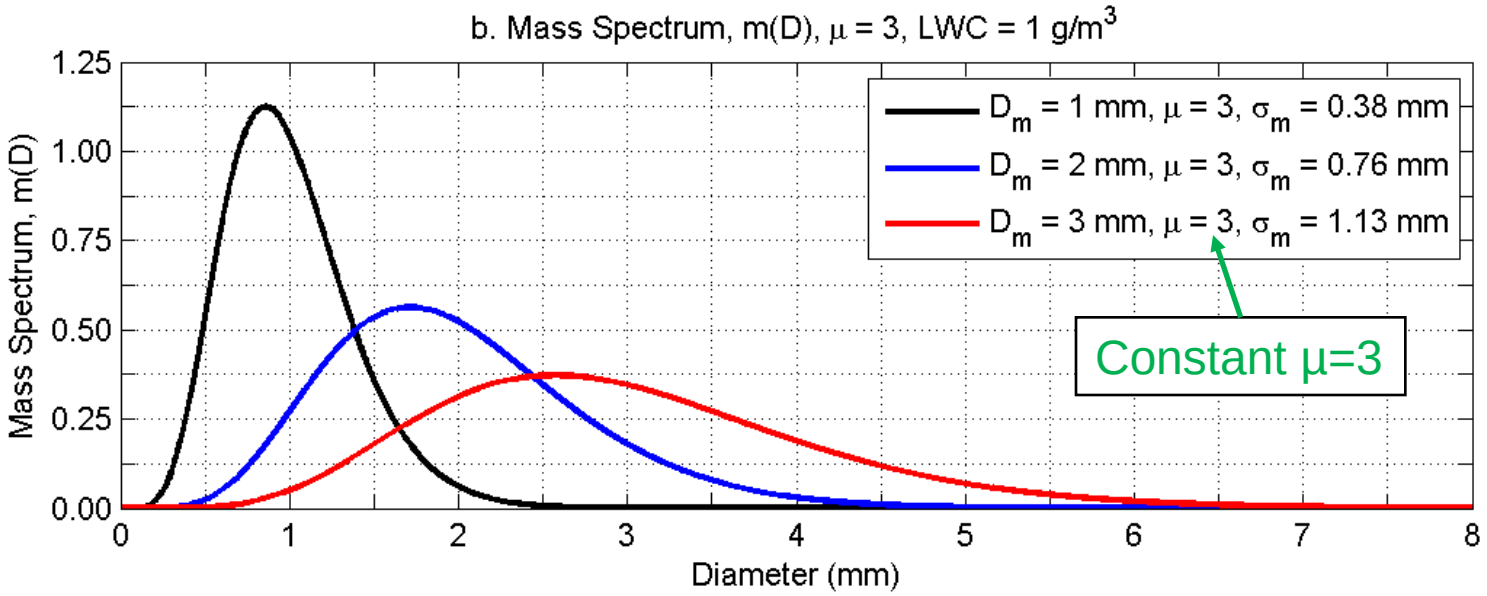


Spectrum breadth increases as mean Diameter increases

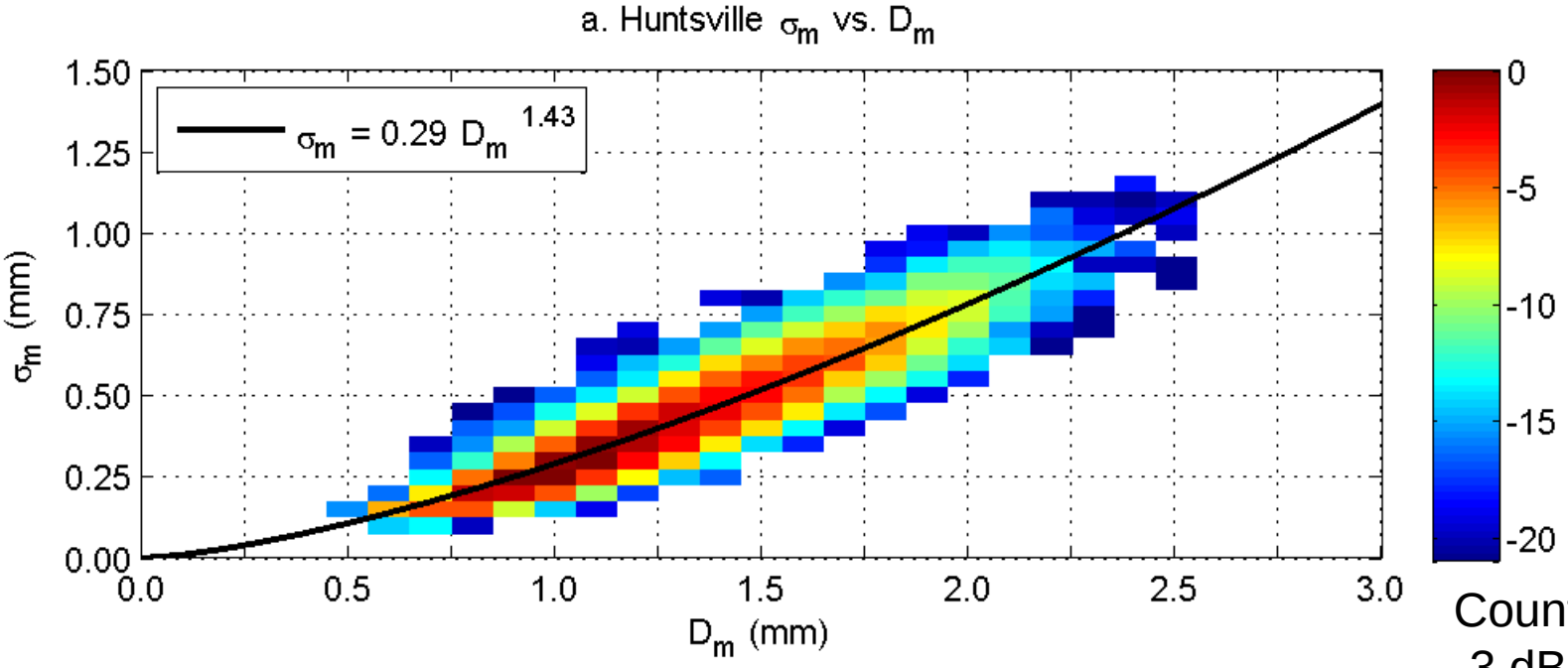
Disdrometer Observations (2DVD)

Frequency of Occurrence

- Observed σ_m & D_m
- No assumed DSD Shape
- Count is in dB
  - pixel with most counts = 0 dB
  - each -3 dB is half as many counts

Huntsville:, 20,954 samples

$\sigma_m = 0.29 D_m^{1.43}$



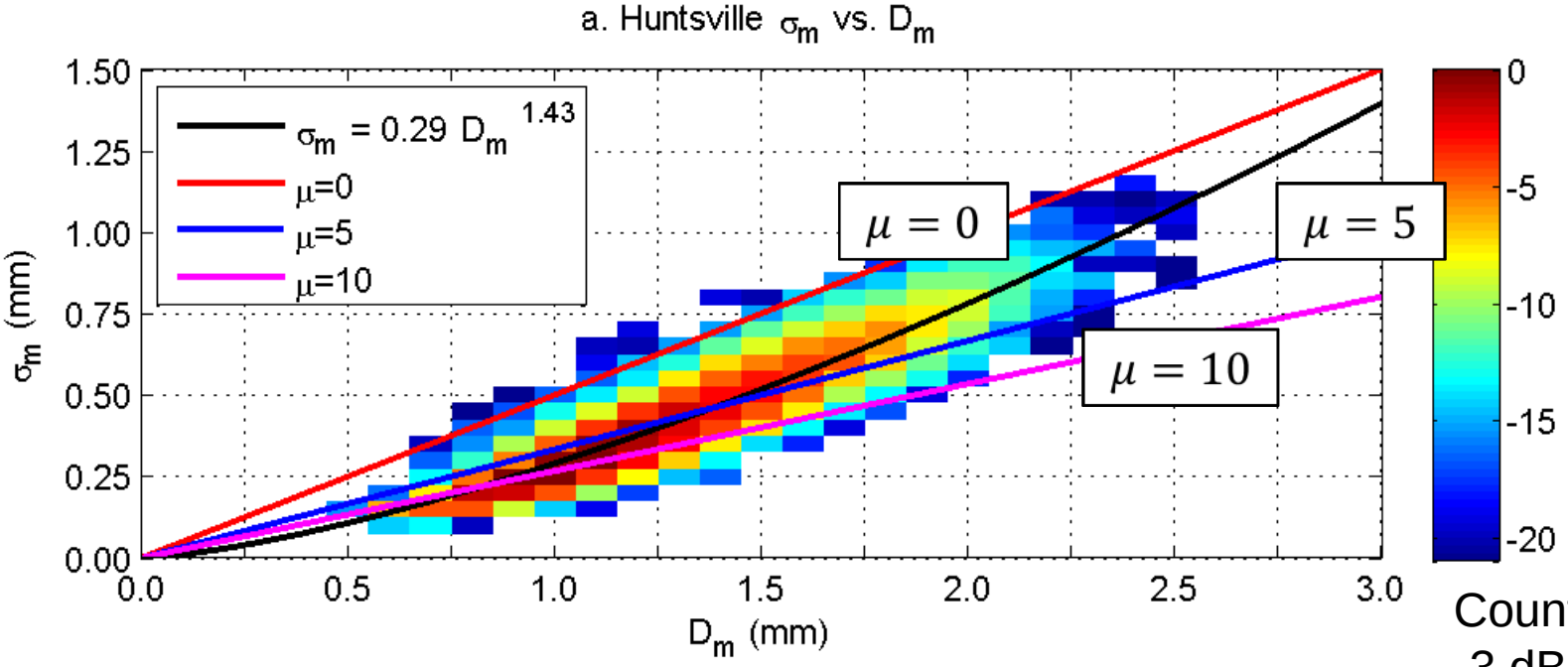
Count in dB
-3 dB = ½ cnt

Disdrometer Observations (2DVD)

If we assume a gamma shape DSD, there is a relationship between $\sigma_m - D_m - \mu$ (Assume the $D_{max} = \infty$) (Ulbrich 1983)

1. Can estimate σ_m from D_m and μ $\quad \sigma_m^2 = \frac{D_m^2}{\mu + 4}$

2. Can estimate μ from D_m and σ_m $\quad \mu = \frac{D_m^2}{\sigma_m^2} - 4$



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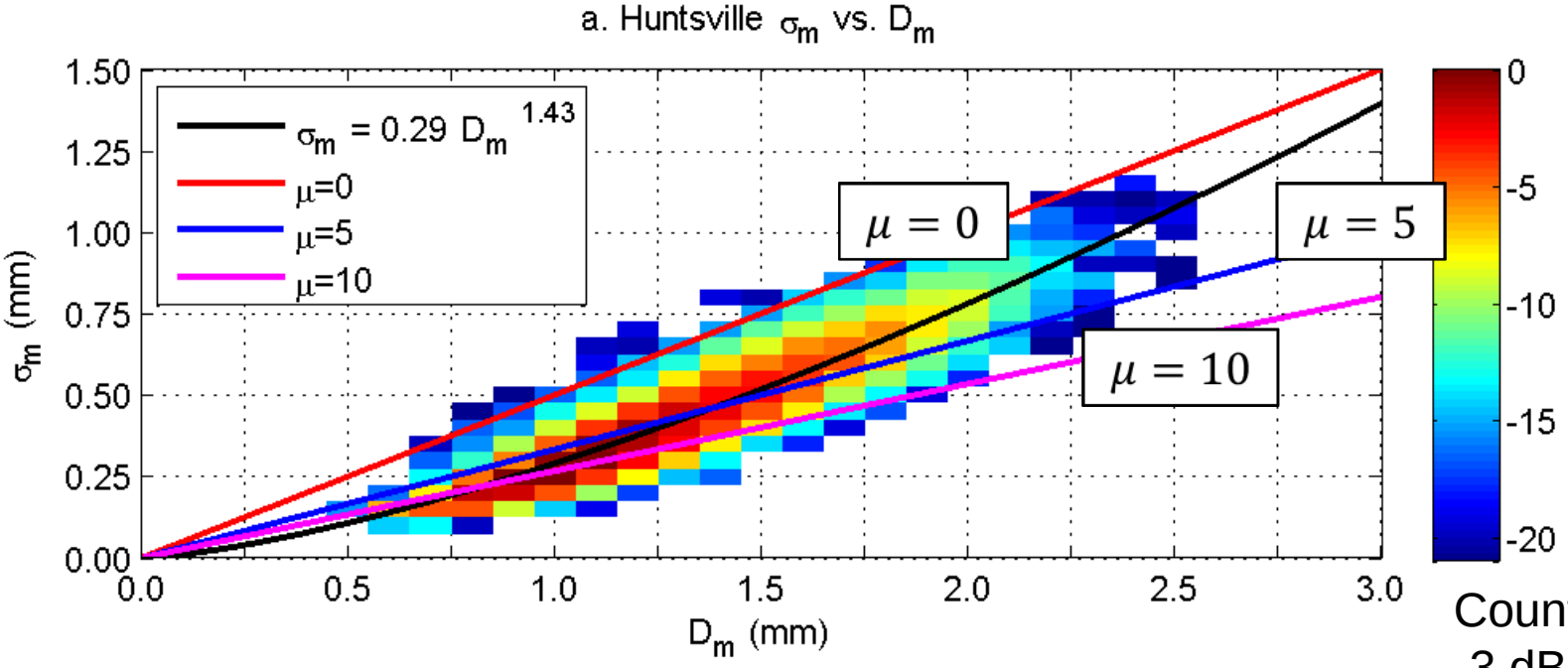
Take-away message: Family of gamma functions can describe the range of shapes that are observed in disdrometer mass spectra



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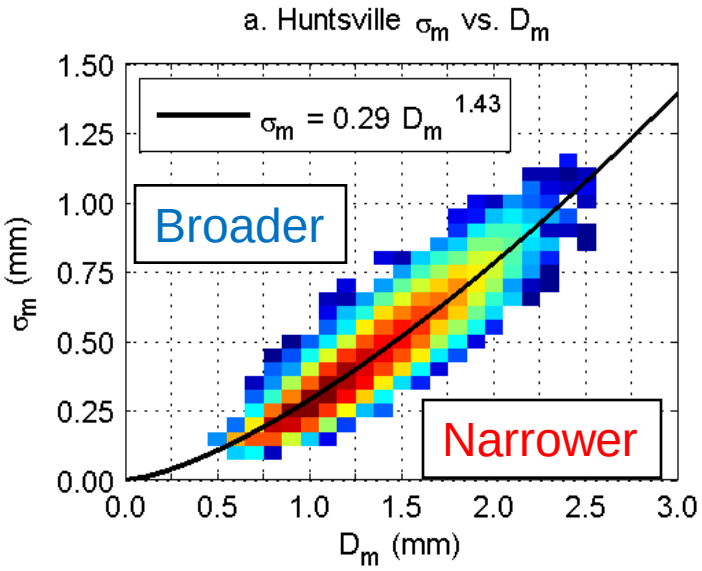
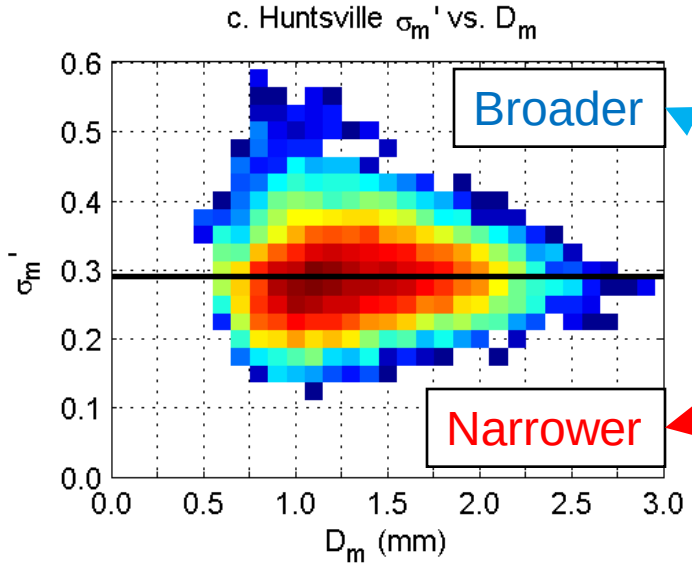
Normalized Mass Spectrum STD





Power-law Relationships:

$$\sigma'_m = \frac{\sigma_m}{D_m^b}$$

$$\sigma_m = \sigma'_m D_m^b = \sigma'_m D_m^{1.43}$$

Uncorrelated: $r^2(\sigma'_m, D_m) = 0$

Haddad et al. (1996)

Power-law represents expected value.

$$\sigma_m = \overline{\sigma_m'} D_m^b = 0.29 D_m^{1.43}$$

Broader Spectra:

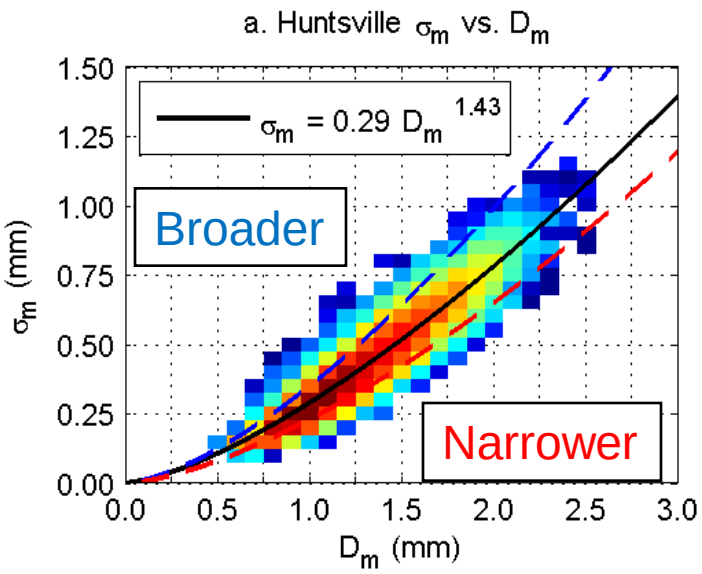
$$\sigma'_m > \overline{\sigma_m'}$$

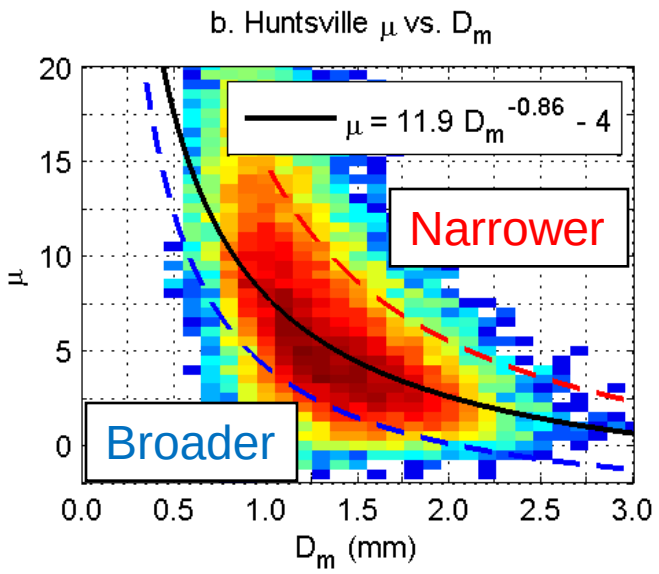
Narrower Spectra:

$$\sigma'_m < \overline{\sigma_m'}$$

Deviations have physical meaning

Mapping into Gamma DSD Space

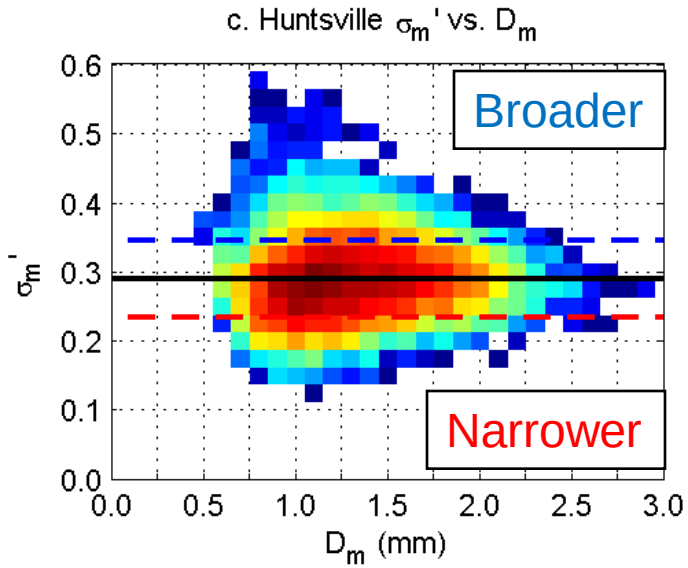


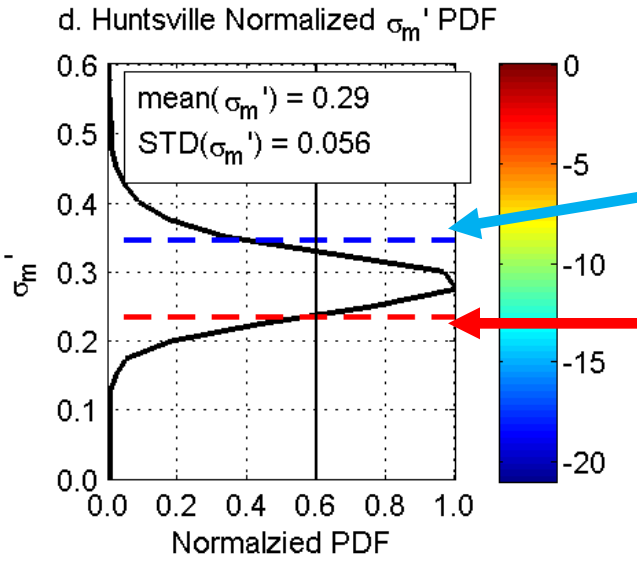


Assume:
gamma DSD

$$\mu = \frac{D_m^2}{\sigma_m^2} - 4$$

$$\sigma_m = \sigma'_m D_m^{1.43}$$





Mean + STD

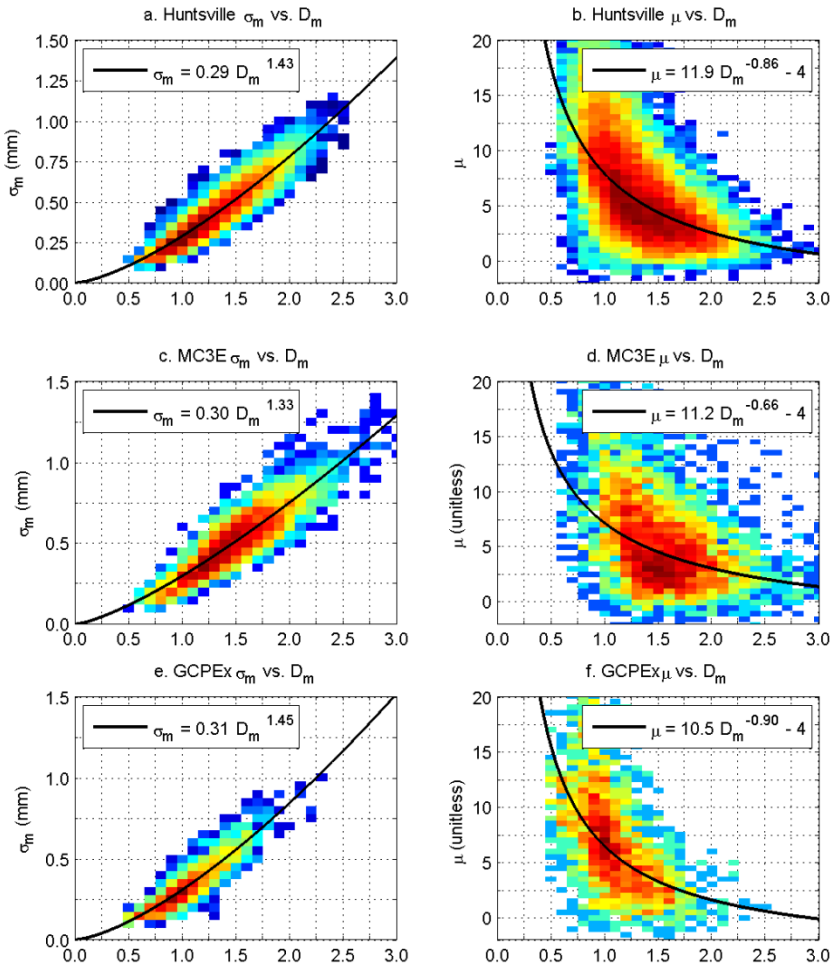
Mean - STD

74% of obs. are within +/- 1 STD

Multiple Sites: Similar Power-laws

Observed σ_m vs. D_m

Calculated μ vs. D_m



Huntsville:, 20,954 samples

$\sigma_m = 0.29 D_m^{1.43}$

MC3E: 5,175 samples

$\sigma_m = 0.30 D_m^{1.33}$

GCPEx: 2,218 samples (Finland)

$\sigma_m = 0.31 D_m^{1.45}$

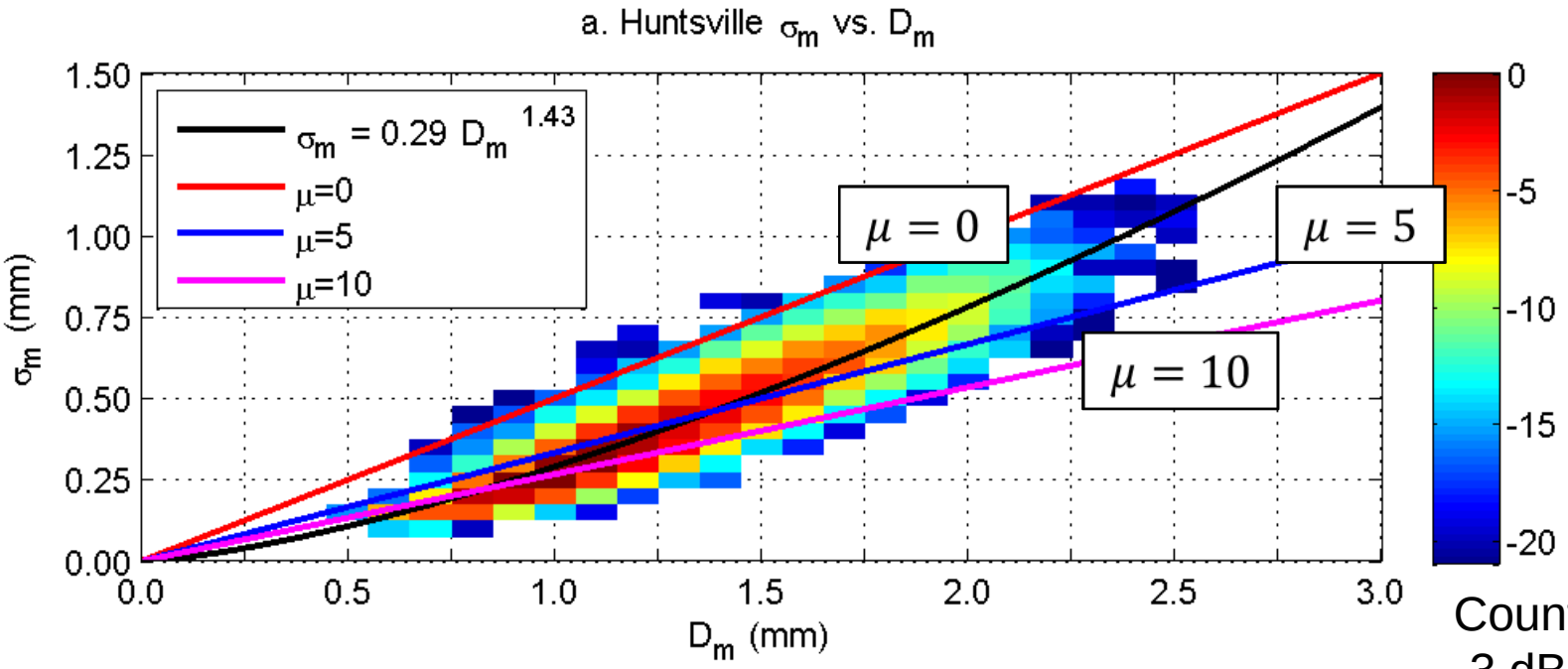
Ensemble: 27,347 samples

$\sigma_m = 0.29 D_m^{1.42}$

Concluding Remarks

Analyze ARM Data to evaluate model parameterizations

- What $\sigma_m - D_m$ distributions are in cloud models?
- Can $\sigma_m - D_m$ power-law be a model parameterization?



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