Ice Crystal Population Assumptions and Retrieval Errors: An IcePro-QUICR Collaboration

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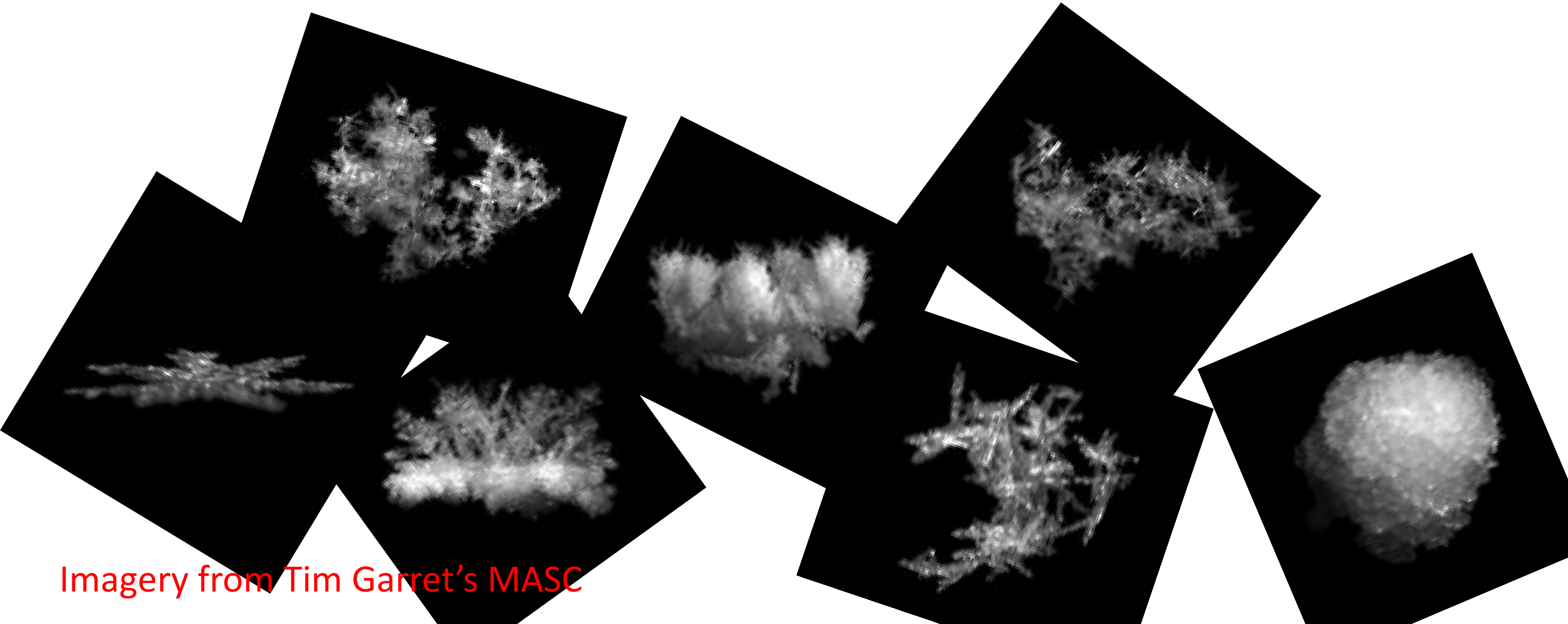
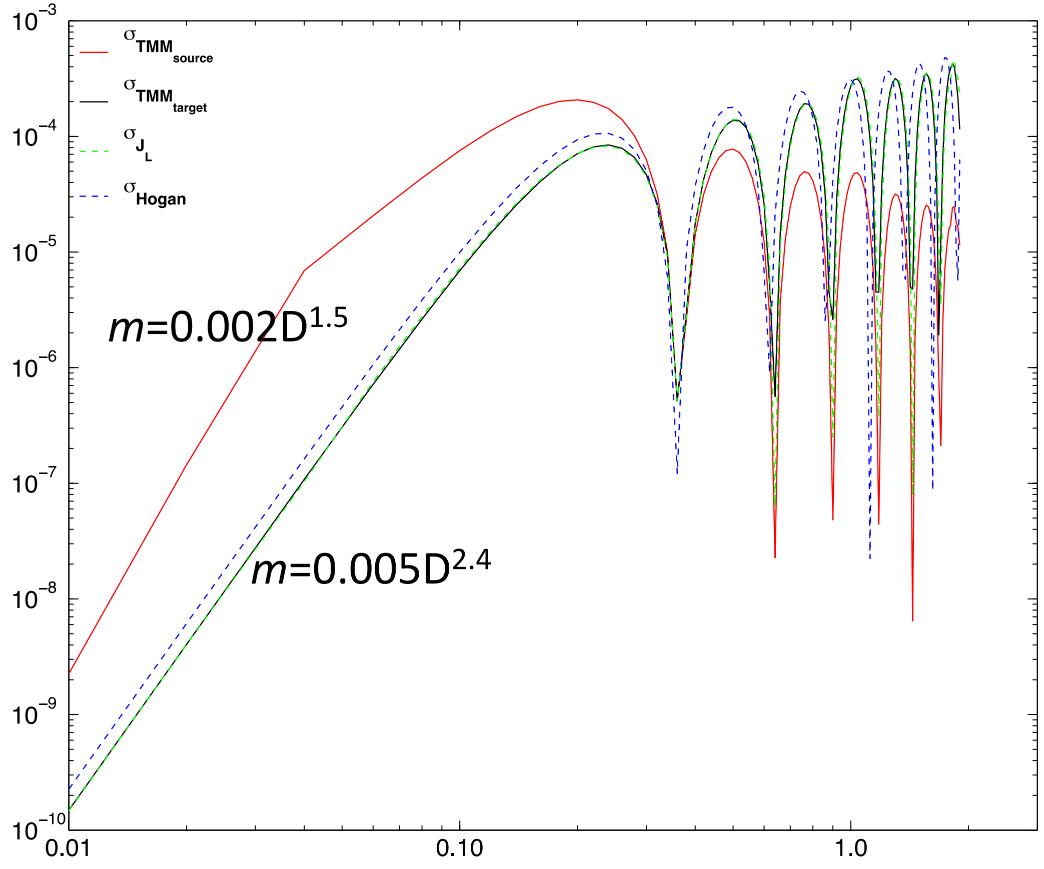
Assumptions regarding ice cloud microphysical properties significantly impact cloud and precipitation property retrievals



Imagery from Tim Garret's MASC

By How Much do Ice Crystal Population Assumptions Influence Retrieval Errors?

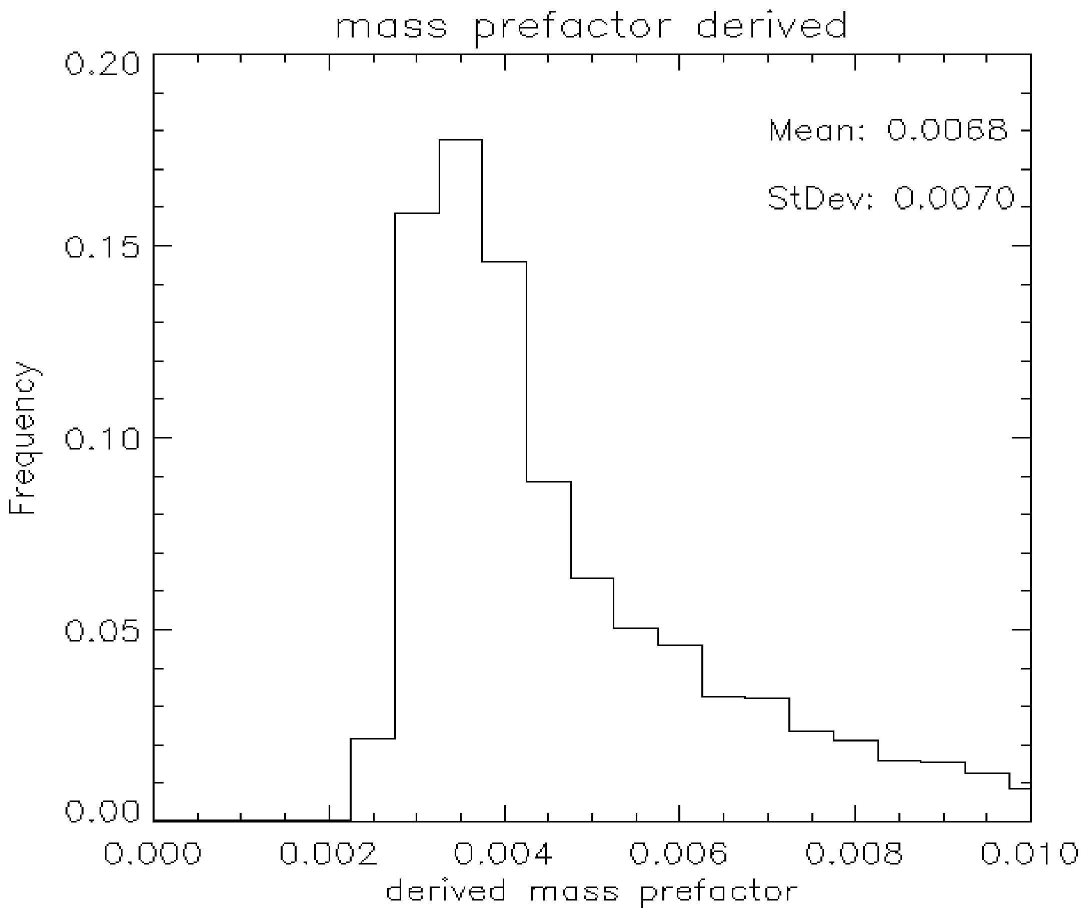
Technique: Scale T-Matrix radar backscatter cross sections for Arbitrary *m*-D power law ($m=a_m D^{bm}$) (Hammonds, et al., 2014)



By How Much do Ice Crystal Population Assumptions Influence Retrieval Errors?

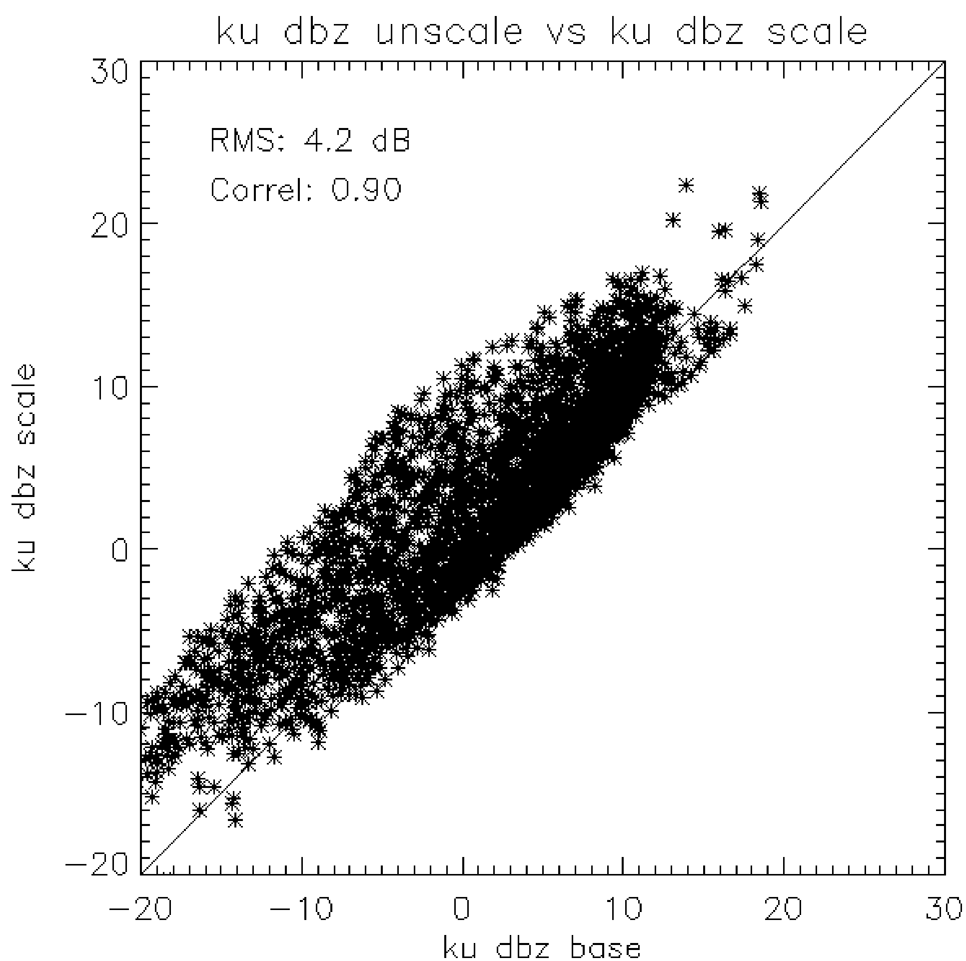
Estimate a realistic distribution of a_m values assuming b_m with aircraft data collected during NSF CAMPS

- Begin with gamma-fitted ice PSDs (~30k PSDs)
- Use measured bulk ice mass from CLH
- Assume b_m=1.9



By How Much do Ice Crystal Population Assumptions Influence Retrieval Errors?

Using a base value of am, and bm (average over CAMPS) and a specific value of am, bm for each PSD, compare forward calculated radar reflectivity



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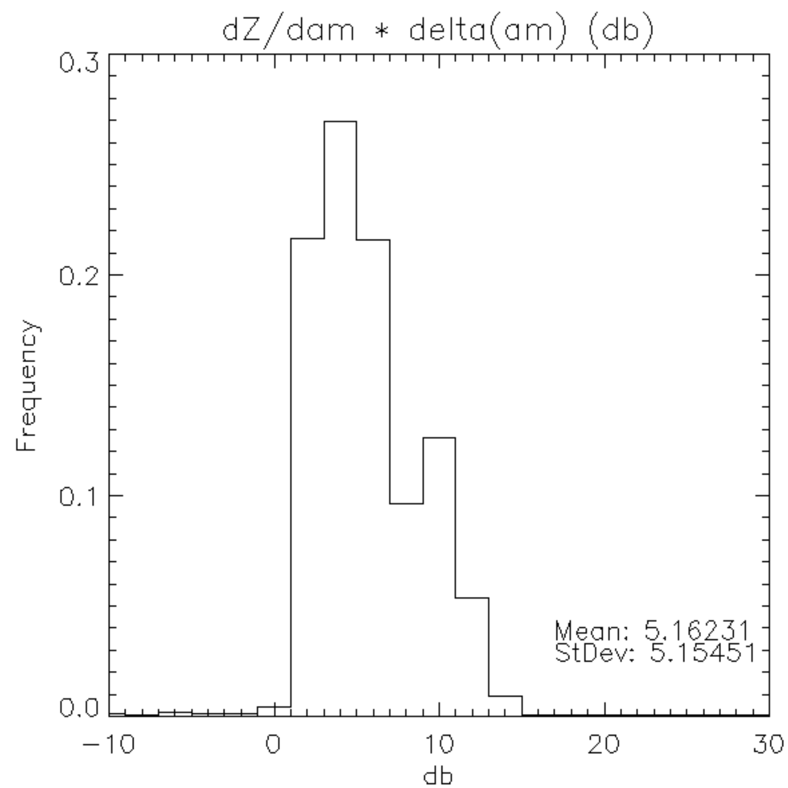
Another approach: Forward model uncertainty in retrievals are calculated like this:

$$\frac{\partial \ln Z}{\partial \ln a_m} \bar{\sigma}_{a_m}$$

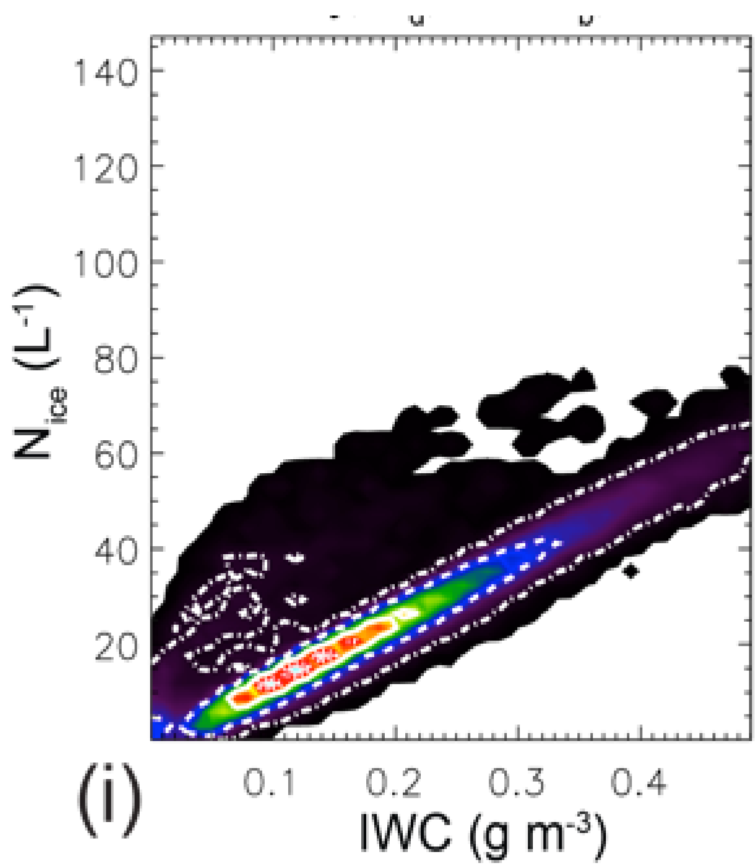
Use finite differences of Z with respect to am and multiply by scaled variance in a_m



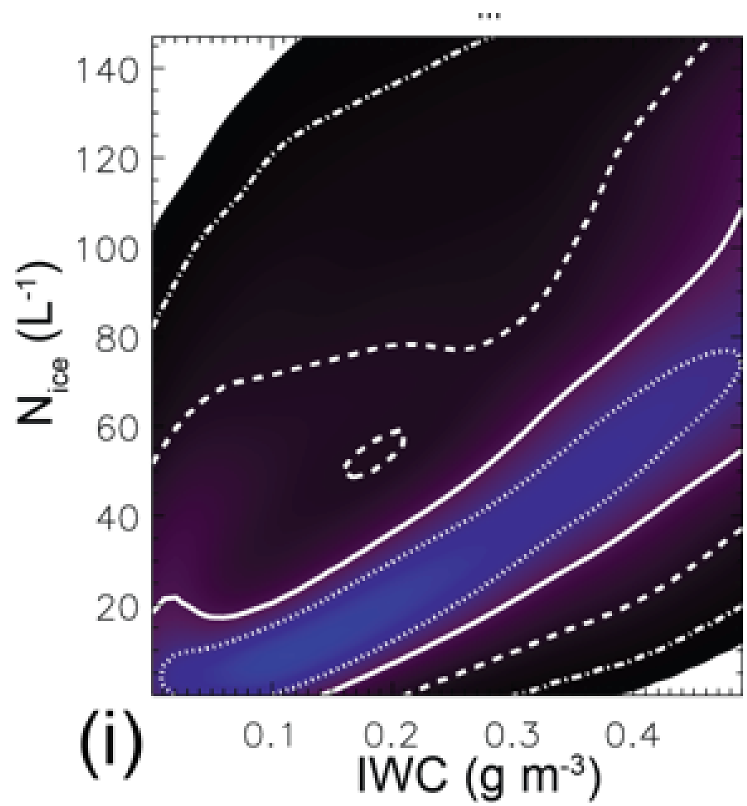
By How Much do Ice Crystal Population Assumptions Influence Retrieval Errors?

Another approach: Use Markov Chain Monte Carlo inversion using Z, Vd, T to map Posterior PDF of retrieved Nd and IWC (Posselt and Mace, 2014)

Assume we know m-D



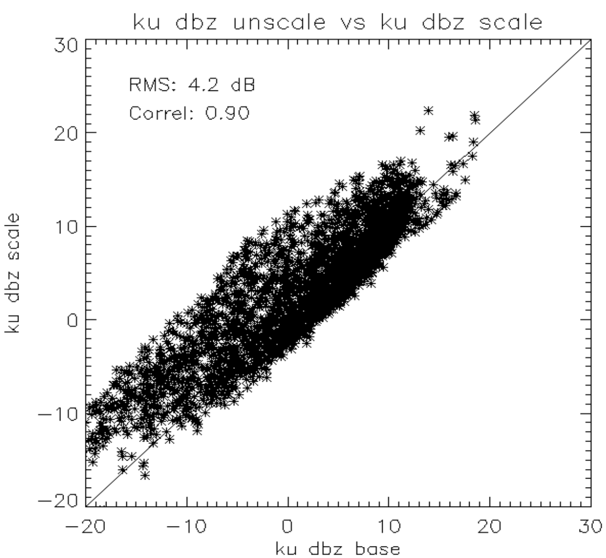
Allow am X 2 and bm 50% uncert.

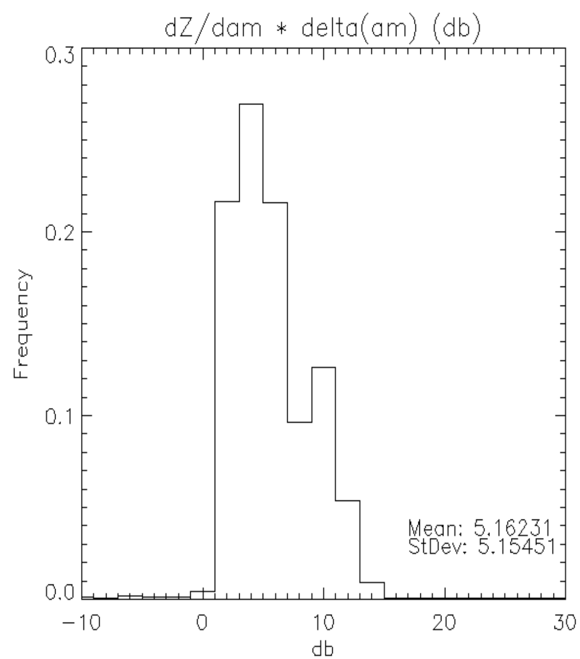


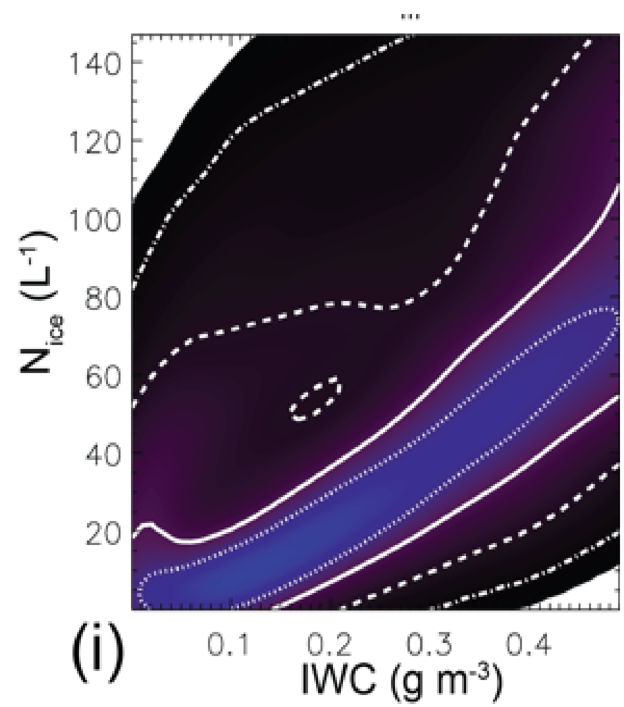
The Results:

So, for a realistic distribution of m-D relationships, we find a 4-5 dB uncertainty in radar reflectivity.

~Equivalent to a factor of 3 uncertainty in retrieved IWC..
Would lead to equivalent errors in other parameters (D, w, lwc, etc…)







Conclusion: Ice Cloud retrievals using **vertically pointing** ARM radar measurements (i.e. MMCR and KAZR) have unquantifiable errors that are factors of many regardless of how "good" the retrieval algorithm is or how much information is thrown at it.

Caveat: Polarimetric techniques can mitigate this uncertainty by narrowing the range of habit.

So what to do?

Forget about doing ice cloud retrievals with vertically pointing radar, ***or***

Propose a series of aircraft campaigns to statistically map (i.e. ***develop covariance matrices***) the microphysical characteristics of as a function of,

- Meteorological State
- Temperature
- Updraft environment
- Radar measureables
- Aerosol background
- Liquid water content
- Etc.

- **Goal would be to develop a library of covariance matrices of critical ice cloud microphysical properties that could be used by modeling and retrieval communities.**

Such an endeavor would require 3-5 years of targeted aircraft measurements (~1000 aircraft hours?) in a broadly diverse set of locations, and environments ranging from cirrus to anvils to mixed phase snow.

Critical Parameters of the covariance Matrices:

- M-D power laws
- A-D power laws
- Aspect ratios
- Autocovariance of mass within the crystals as a function of size

Critical Measurements:

- High quality PSD and particle images (minimize shattering – i.e. 2DS, HVPS)
- Habit (CPI)
- Independent Mass (ice and liqud)
- Independent Area (extinction)
- Radar Reflectivity of the sampled volumes
- Vertical Motion and Turbulence

Members of IcePro should collaborate with member of QUICR to lead this program.