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

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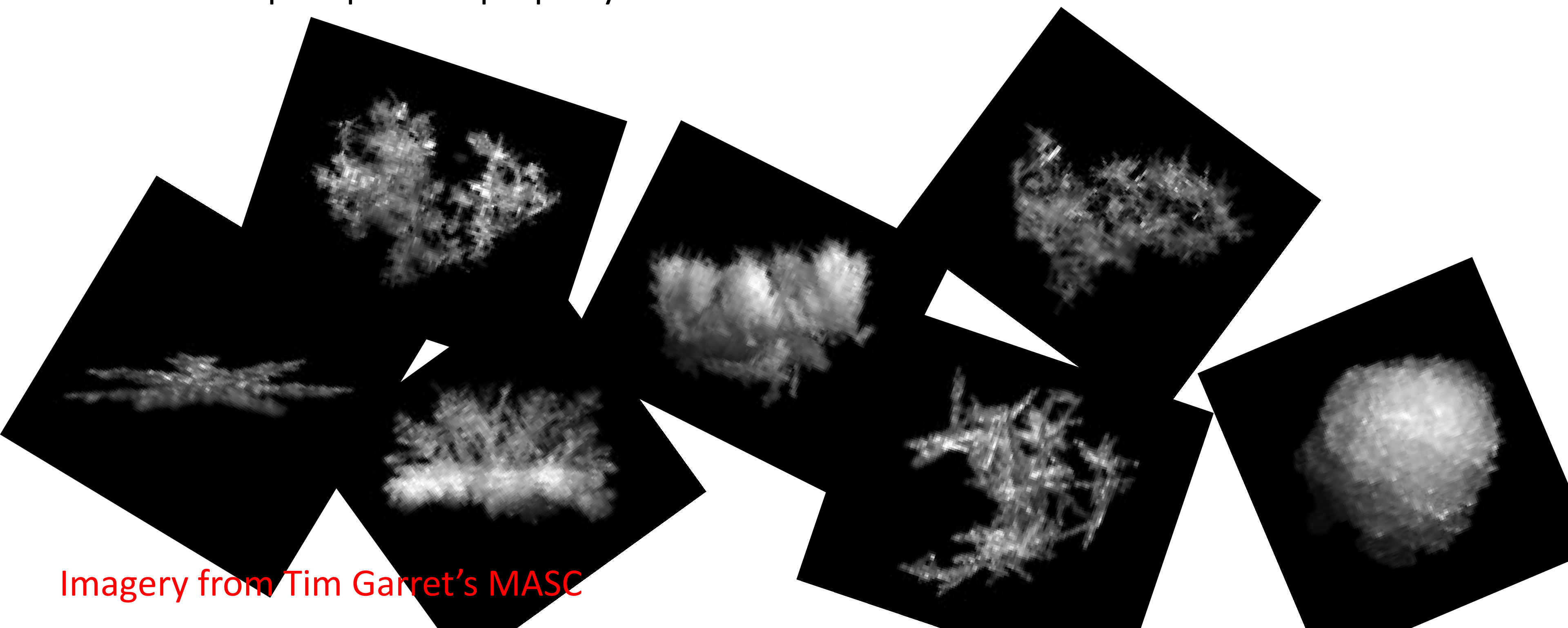
Assumptions regarding ice cloud microphysical properties significantly impact cloud and precipitation property retrievals

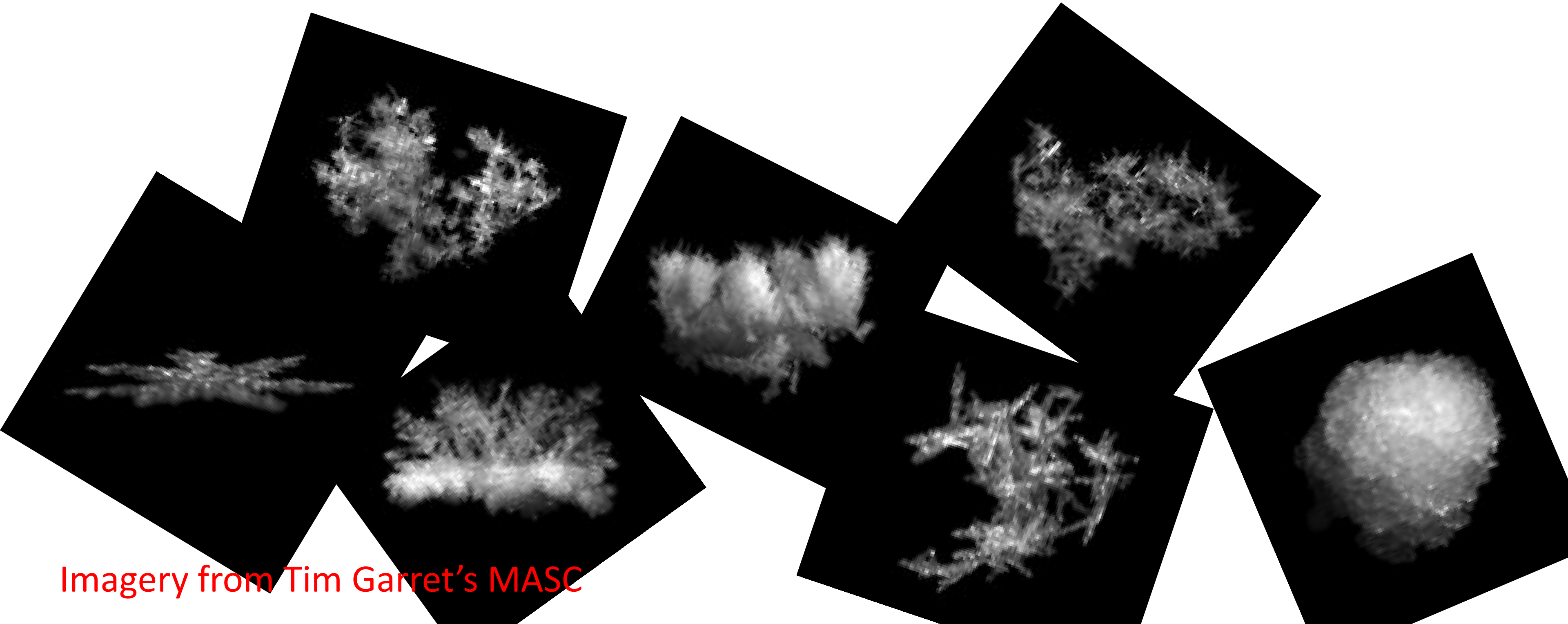


Imagery from Tim Garret's MASC

What do we need to know to quantify errors in ice/snow retrievals?

The microwave single scattering properties depend critically on certain physical properties that define habit. Within the R-G Approximation:

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



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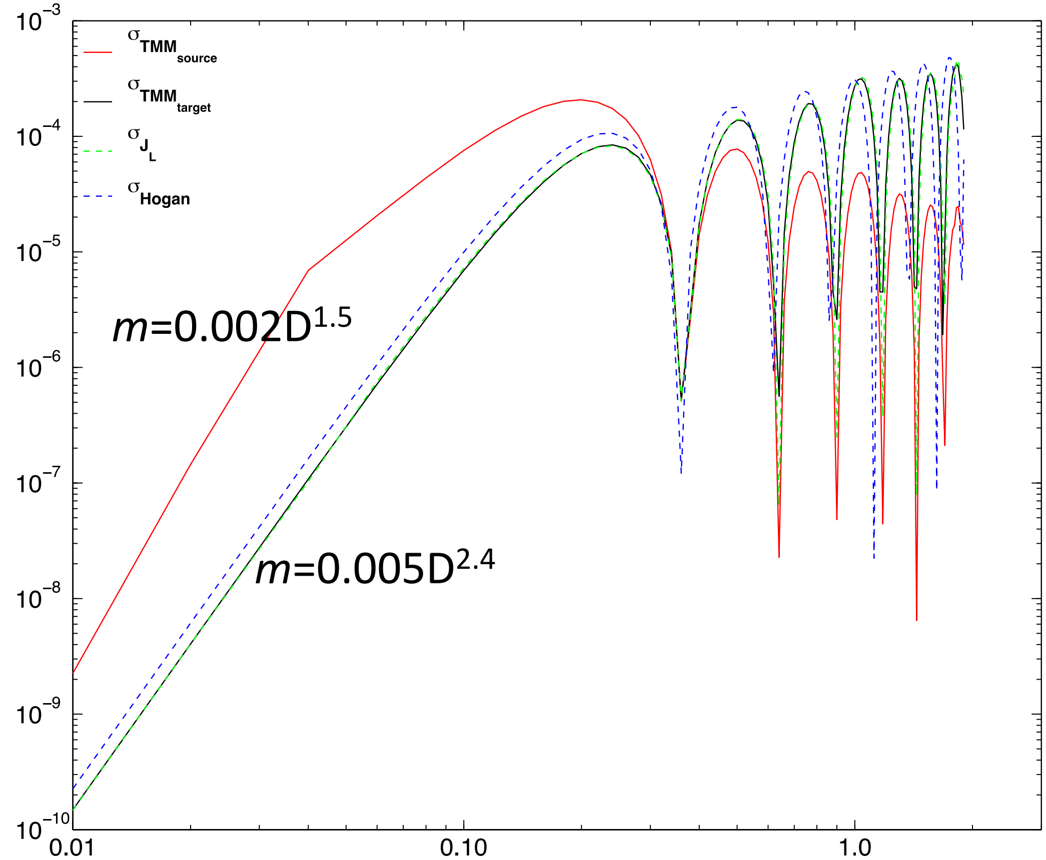
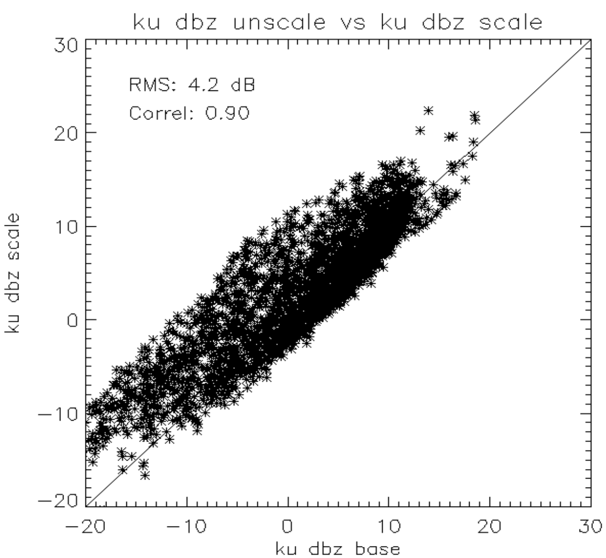
By How Much do Ice Crystal Population Assumptions Influence Retrieval Errors?

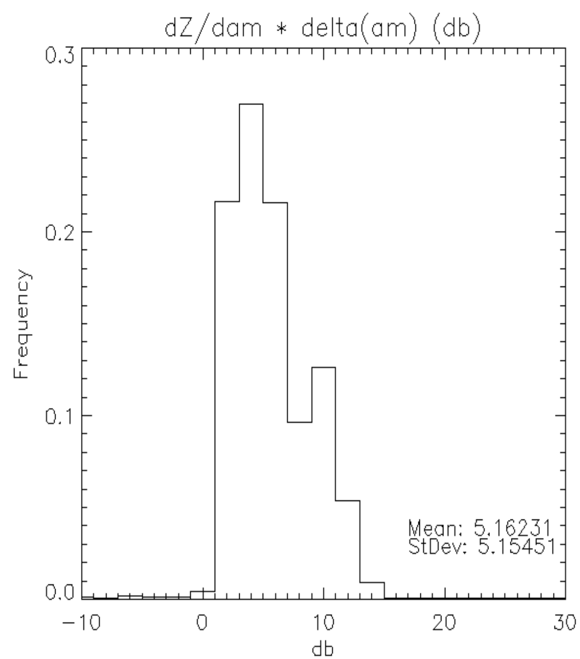
Technique: Scale T-Matrix radar backscatter cross sections for Arbitrary *m*-D power law ($m=a_m D^{bm}$) (Hammonds, et al., 2014)

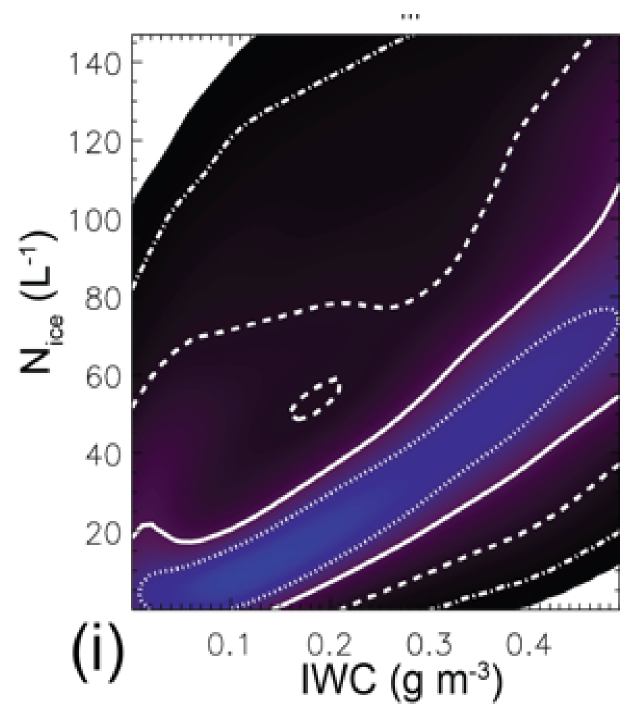


For a realistic distribution of m-D relationships, we find a 4-5 dB uncertainty in radar reflectivity.

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

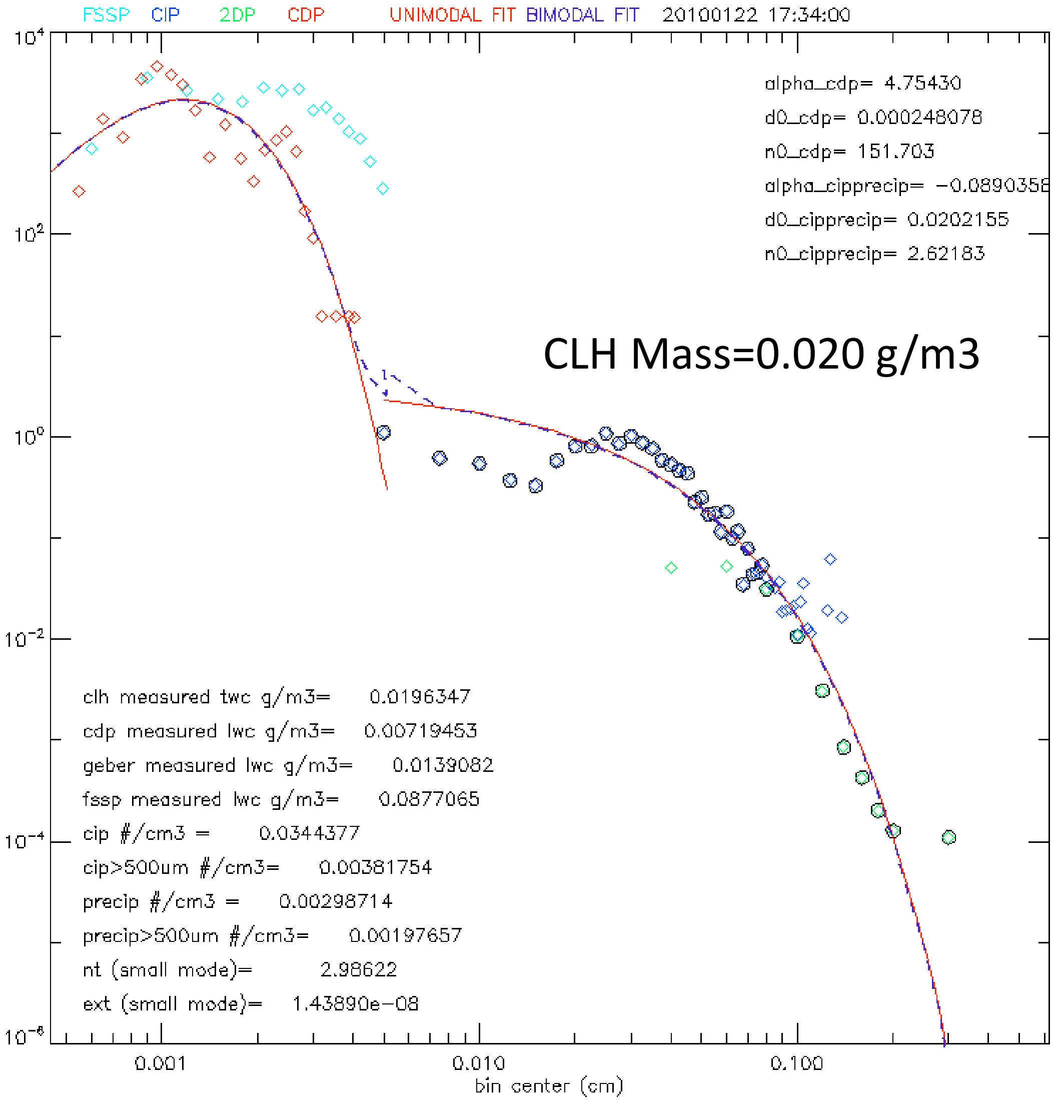




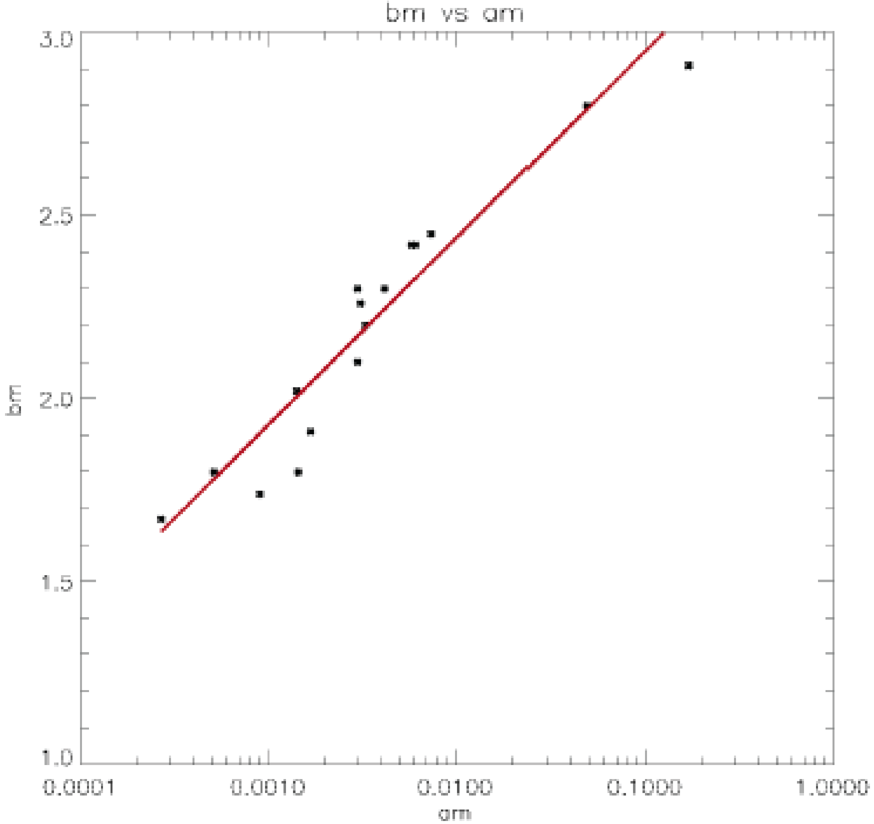


How might we estimate m-D?

Minimally require a psd and an independently measured mass…



Even though am and bm strongly covary, the dependence of total mass on bm does not constrain the problem – i.e. pick any am and I'll give you a bm that is close to the regression line.



am	bm
0.049	2.8
0.0074	2.45
0.003	2.1
0.0033	2.2
0.0031	2.26
0.0042	2.3
0.003	2.3
0.00027	1.67
0.00583	2.42
0.000516	1.8
0.00583	2.42
0.00142	2.02
0.00614	2.42
0.00145	1.8
0.00091	1.74
0.0017	1.91
0.33	2.107

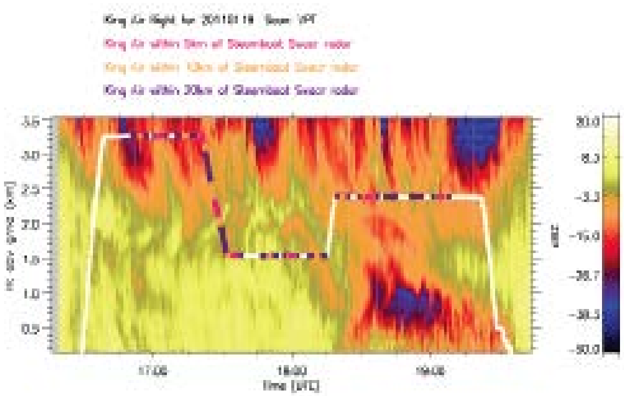
$$b_m = 3.457 + 0.51 \bullet \log_{10}^{a_m}$$

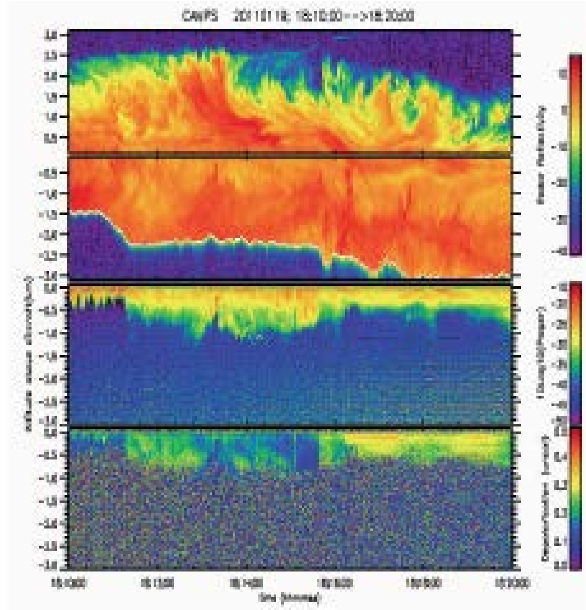
Major references: Mitchell et al. (1996), Pruppacher and Klett (1978), Locatelli and Hobbs (1974)

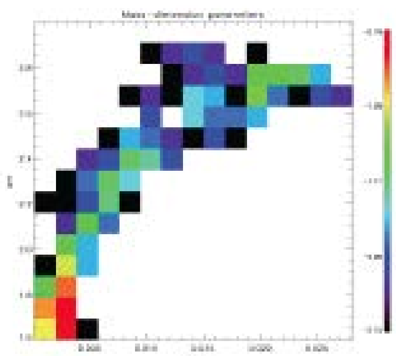
We need another bulk constraint – Radar Reflectivity

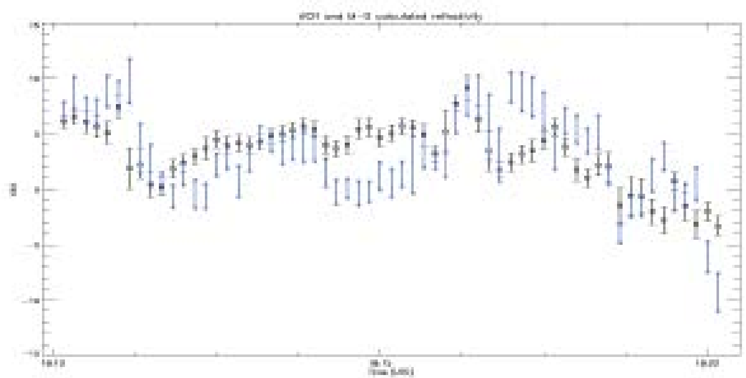
Come up with a range of am/bm that give the mass observed for a PSD.
Find which radar reflectivity from the am/bm combinations agree closest to observed:

Case study: January 19, 2011









Use this as a first guess to an optimal estimation inversion for am/bm….

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.