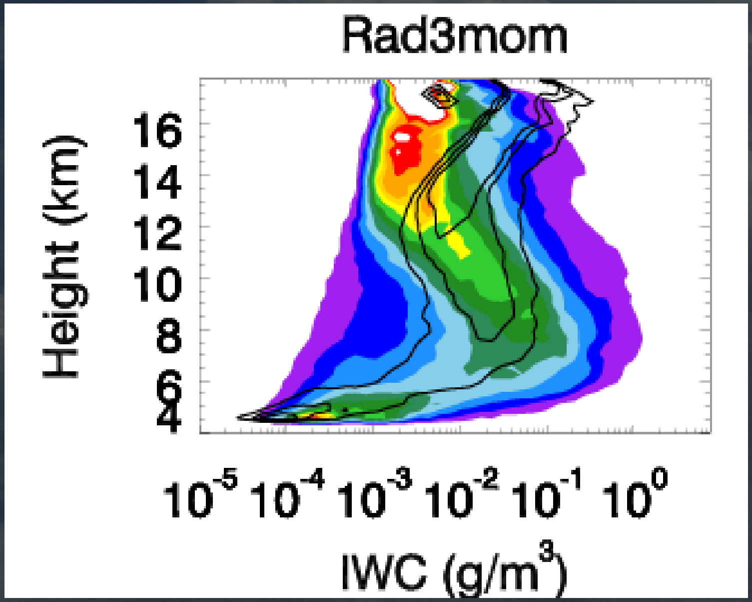
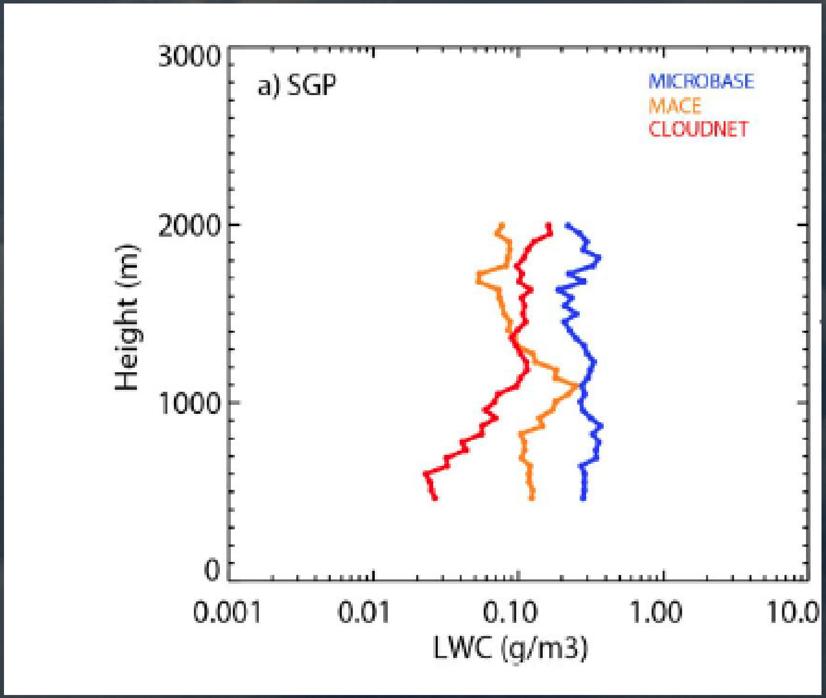
Assessment of Uncertainty in Cloud and Precipitation Property Retrievals: Black Art or Engineering?

Comparison of Radar-only Ice cloud at Darwin, 2005-2009



Comparison of liquid water content at SGP. 6-month average.



Because our forward models are generally very sensitive to our assumptions, the covariance of those assumptions in a given situation must be known to make a reasonable inference of an atmospheric state and to know the information content and know the uncertainty of the inference.

$$\Phi(x,y,a) = \left(y - F(x)\right)^T S_y^{-1}\left(y - F(x)\right) + (x-a)^T S_a^{-1}(x-a)$$

$$S_x = \left(K_x^T S_y^{-1} K_x + S_a^{-1}\right)^{-1}$$

$$H \propto \frac{S_a}{S_x} = S_a\left(K_x^T S_y^{-1} K_x + S_a^{-1}\right)$$

The Achilles heel of cloud retrievals (and model simulations)!

$$S_y = S_\varepsilon + K_b S_b K_b^T$$

Sy is important because it quantifies our effective forward modeling skill – i.e. the sensitivity to calibration uncertainty and forward model assumptions!

This is absolutely key…

$$S_y = S_\varepsilon + K_b S_b K_b^T$$

S_E is measurement error – think calibration uncertainty.

In cloud and precipitation remote sensing (especially in ice) the 2nd term is an order of magnitude larger than S_E!

Kb, like Kx, is the sensitivity of the forward model to the model assumptions. It is reasonably strairghtforward to calculate.

$$\frac{\partial V_d}{\partial a_m}, \frac{\partial Z}{\partial b_m}$$

Sb is how the assumed parameters covary statistically in the atmosphere. In other words, to know Sy (To minimize the cost function, to determine the most likely atmospheric state x given the measurements y), **we must be able to apply a statistically meaningful Sb**.

$$m = a_m D^{b_m} \qquad V = a_v D^{b_v} \qquad \frac{\sigma_b(D)\lambda^4}{D^6 \pi^5 |k_w|^2} = a_Z D^{b_Z}$$

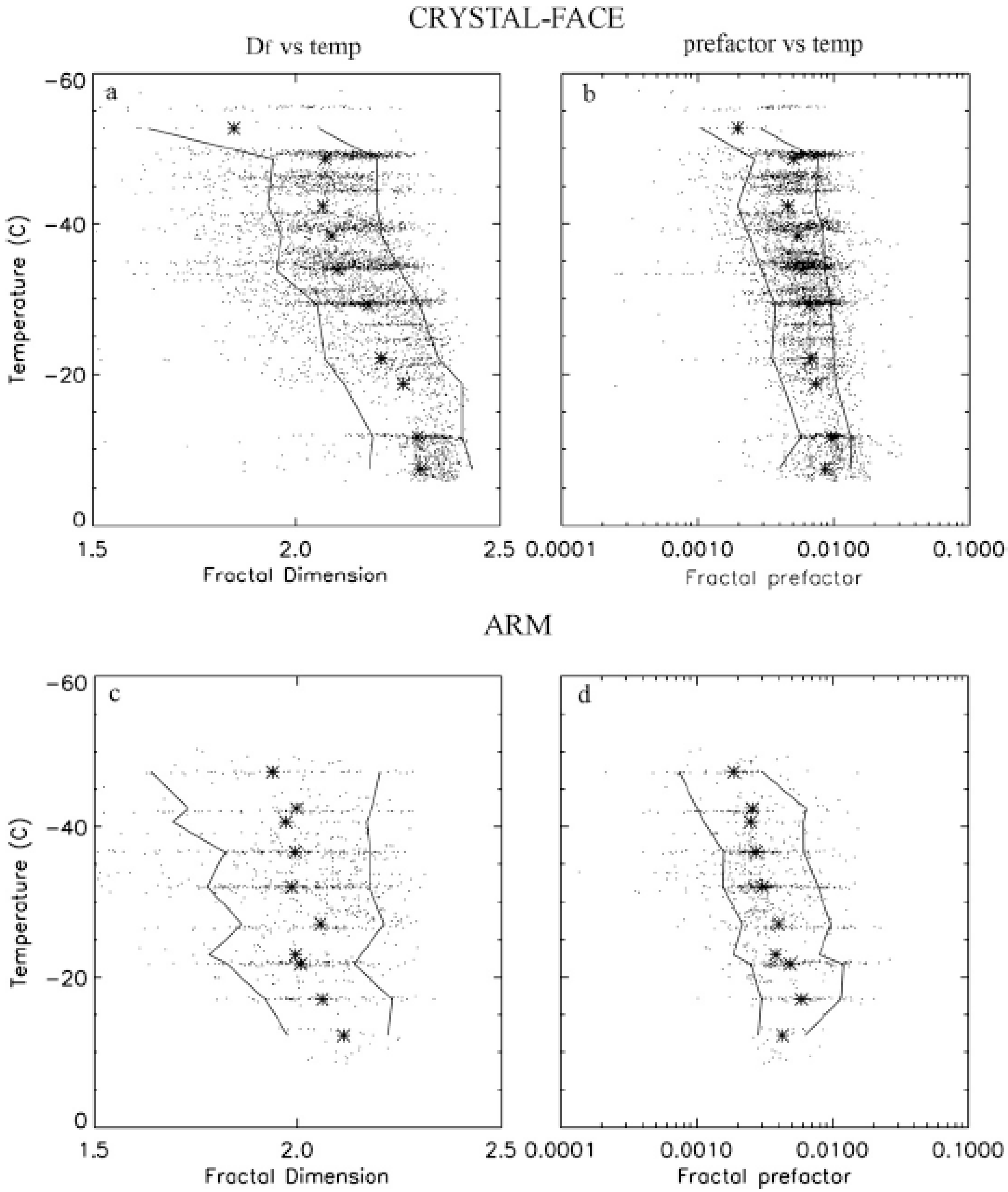


FIG. 7. Trends in fractal dimension and fractal prefactor by temperature. Stars represent the median values and thin lines represent the 10th and 90th percentiles for each temperature range.

Stormvex case study 2/4/2011

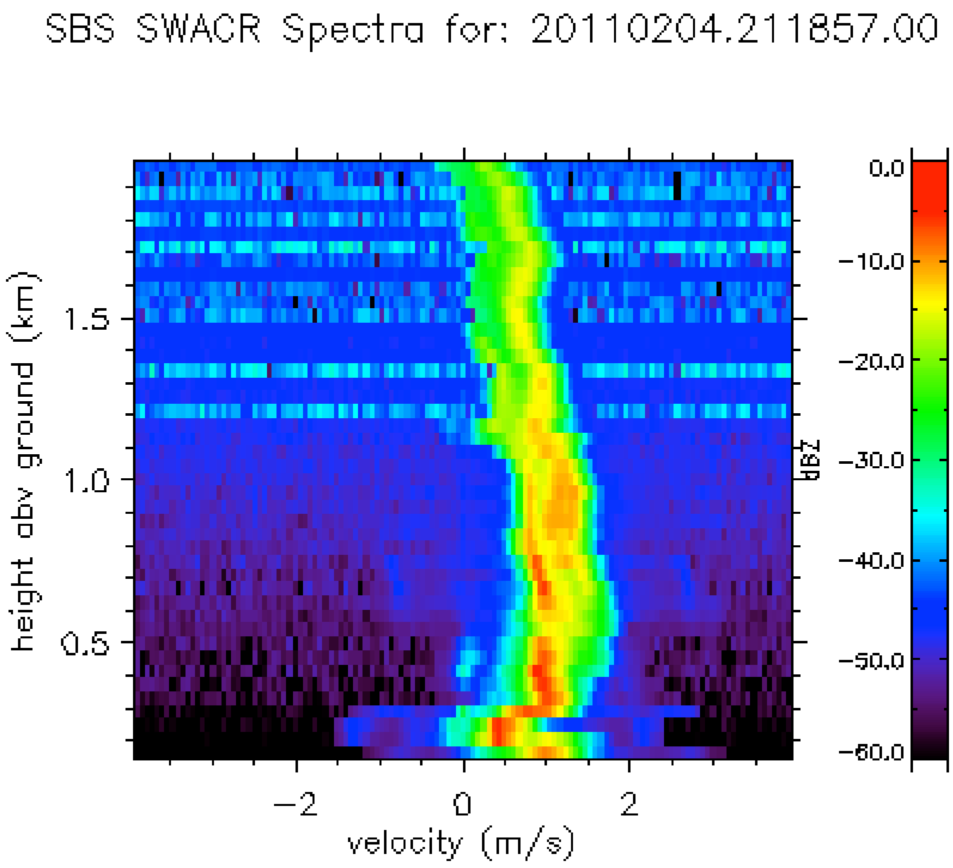
At 21:16 UTC on 2/4:

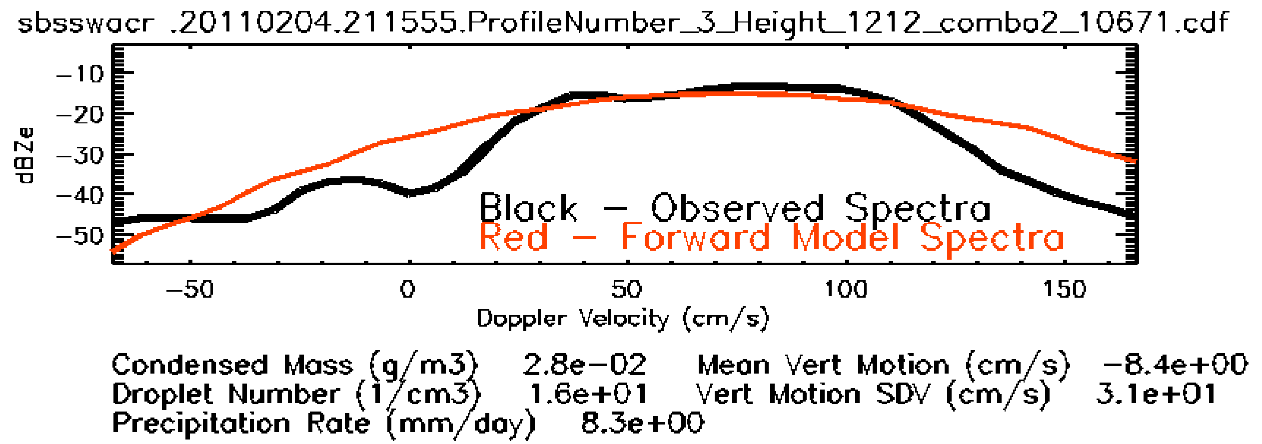
Temperature ~-10C

LWP ~60 g/m^2

Column Visible Tau ~8

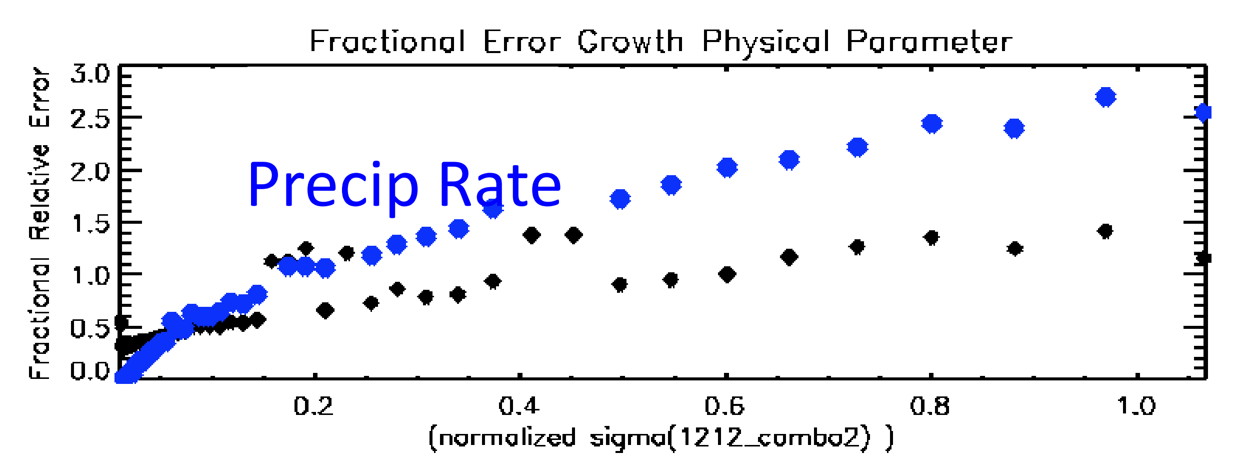
Cloud Base
~ 300m above radar



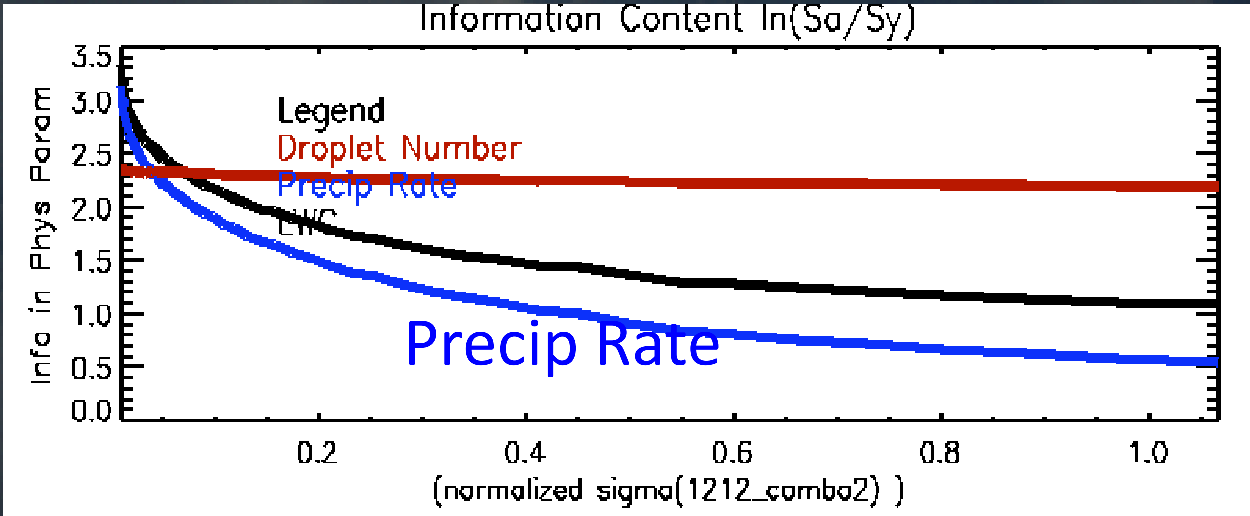


Allow uncertainty in mass prefactor to grow by up to x2 in optimal estimation inversion algorithm…

- Error in Precip Rate grows by a factor of ~3.

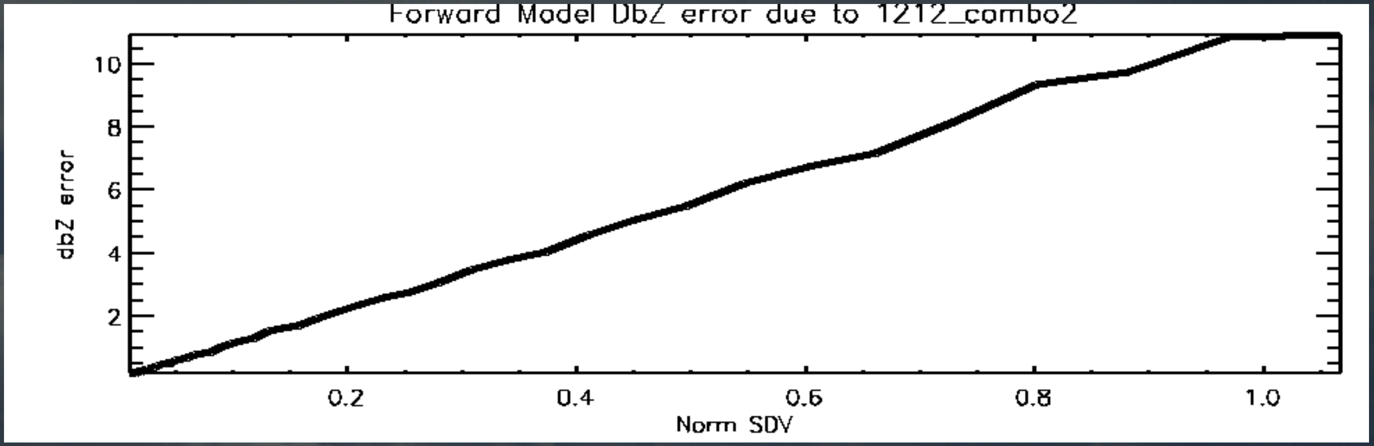


- Information content of measurements decays to near climatology

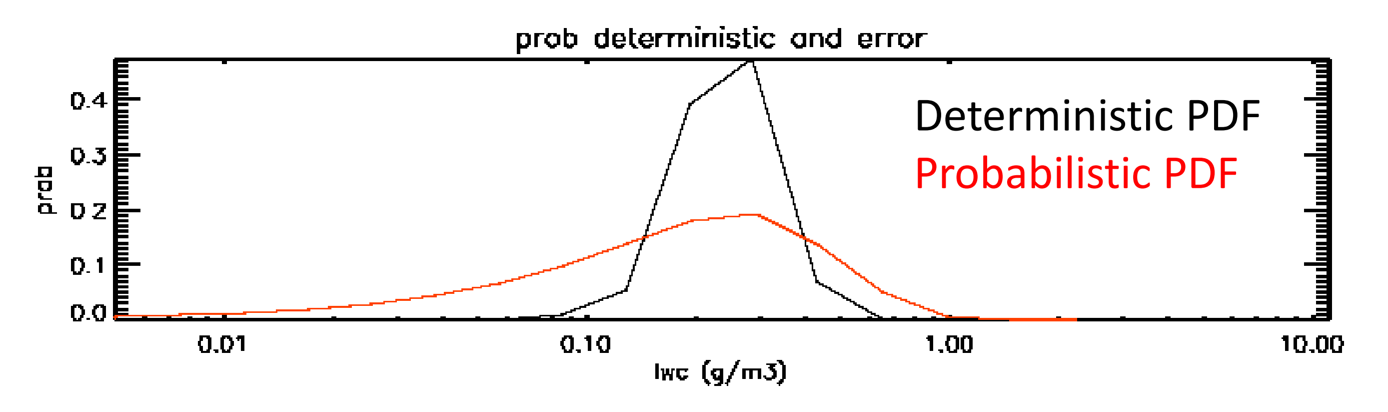


Allow uncertainty in mass prefactor to grow by up to x2 in optimal estimation inversion algorithm…

- Uncertainty in radar forward model increases to near 10 dBZe.



- Case study PDF of IWC broadens substantially



Conclusions:

Knowledge of the statistics of Ice Crystal empirical relationships as a function of observable atmospheric states are absolutely fundamental to

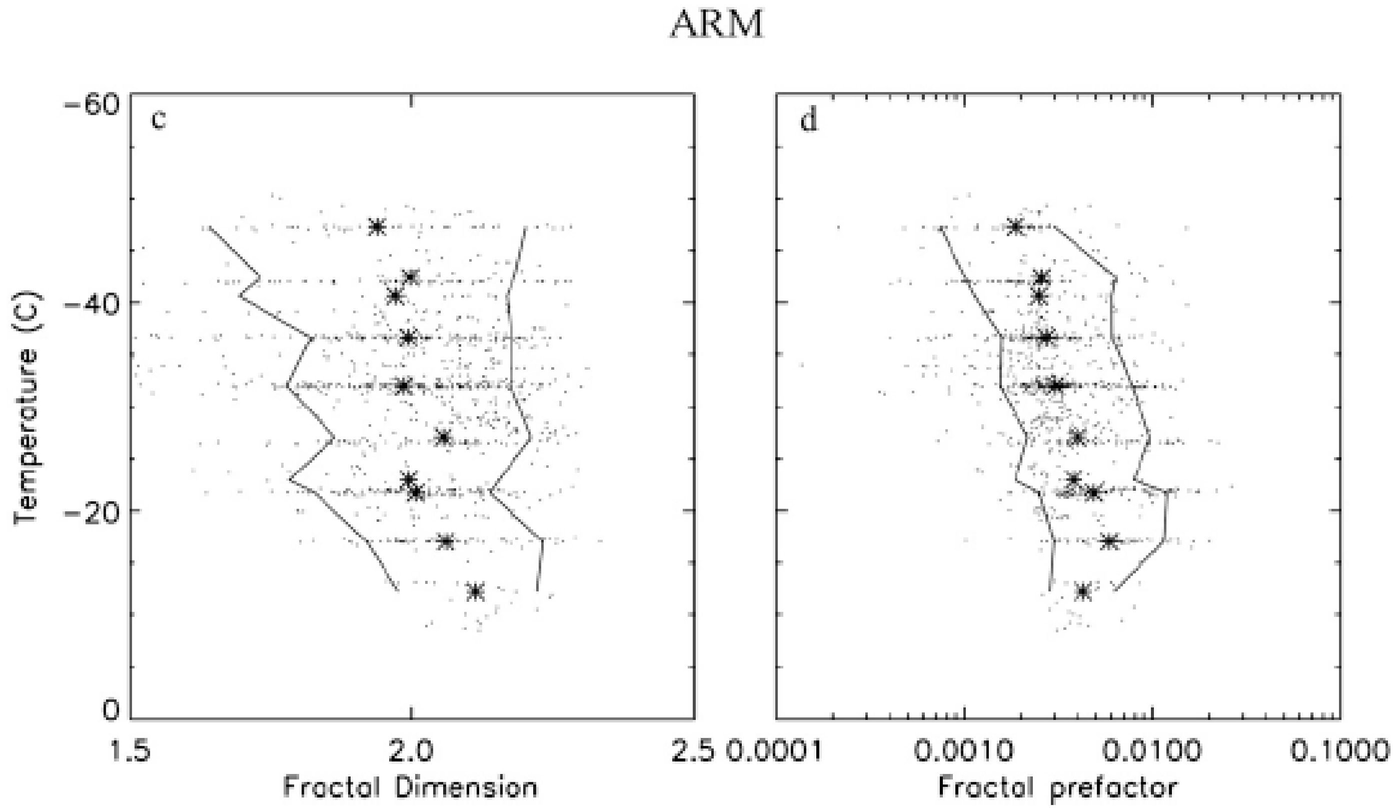
1. Remote sensing objectives
    - Realistic uncertainties
    - Knowing how to combine multiple data streams optimally to answer science questions

2. Modeling ice processes ALWAYS cite fall speed, mass, aspect ratio, area, etc. assumptions as a limiting uncertainty.

Proposal: Multi-year, multi-site aircraft campaign to develop a world class data base of ice crystal empirical relationships (mass, area, habit, aspect ratio, etc).

Such a database will be *invaluable* to ASR modeling and observational communitities

i.e. Fill in the Schmitt and Heymsfield figure as a function of cloud type and meteorological regime.



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