Using Observations to Constrain Bulk Particle Property Models

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Particle Property Methods of Microphysics

How can laboratory data be used to develop, test, and improve methods of ice growth used in numerical models?

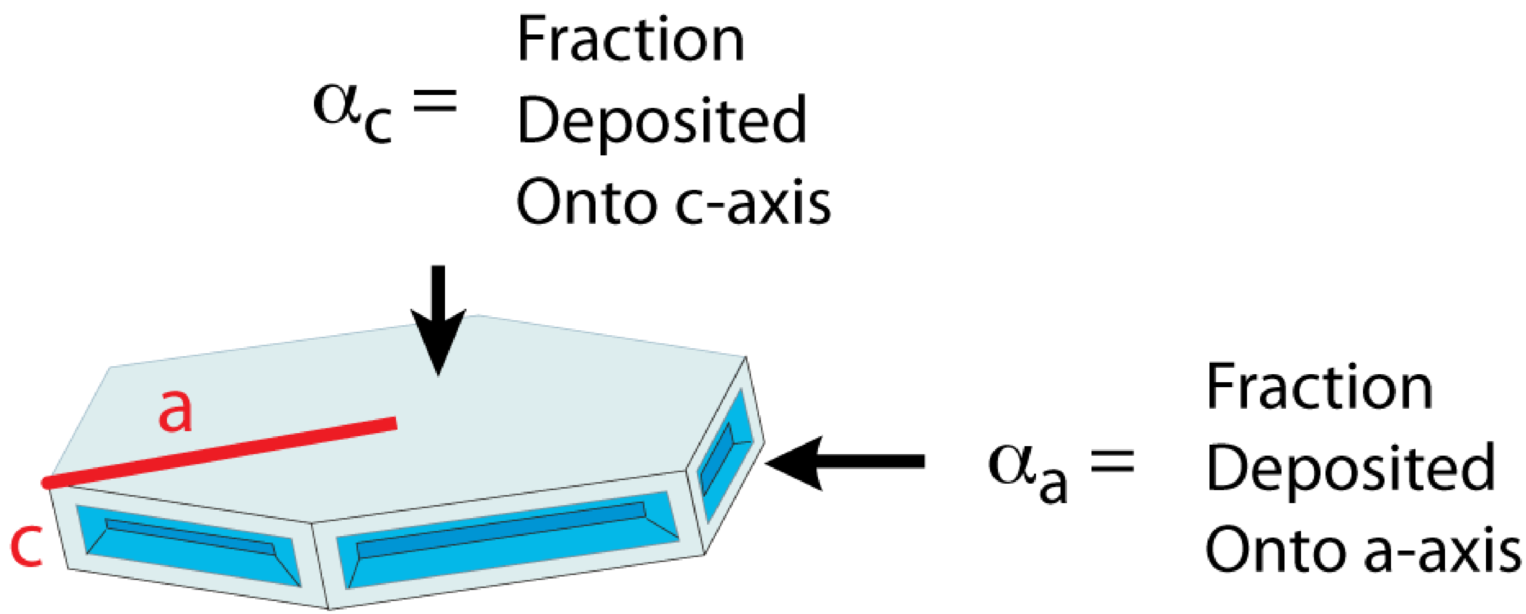
Can we use radar observations to critique, constrain, and improve habit evolving microphysics schemes?

Our scheme: Predicts a major and minor dimension, so radar observations may be useful for constraining the parameterization.

- Example: Vapor Growth -

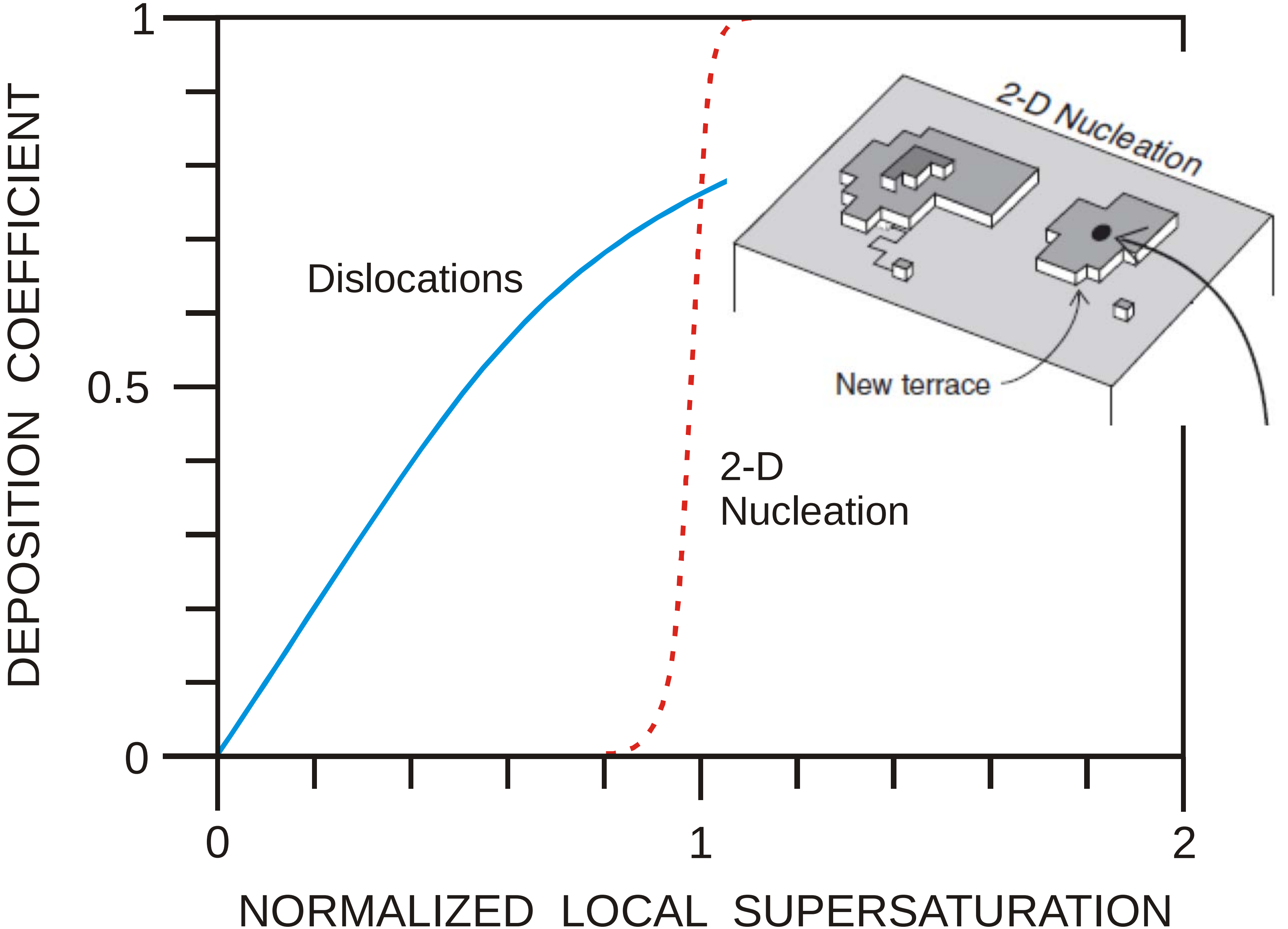
(1) Compute vapor flux onto each crystal face.

(2) Depends on deposition coefficients (α), vary between 0 and 1.



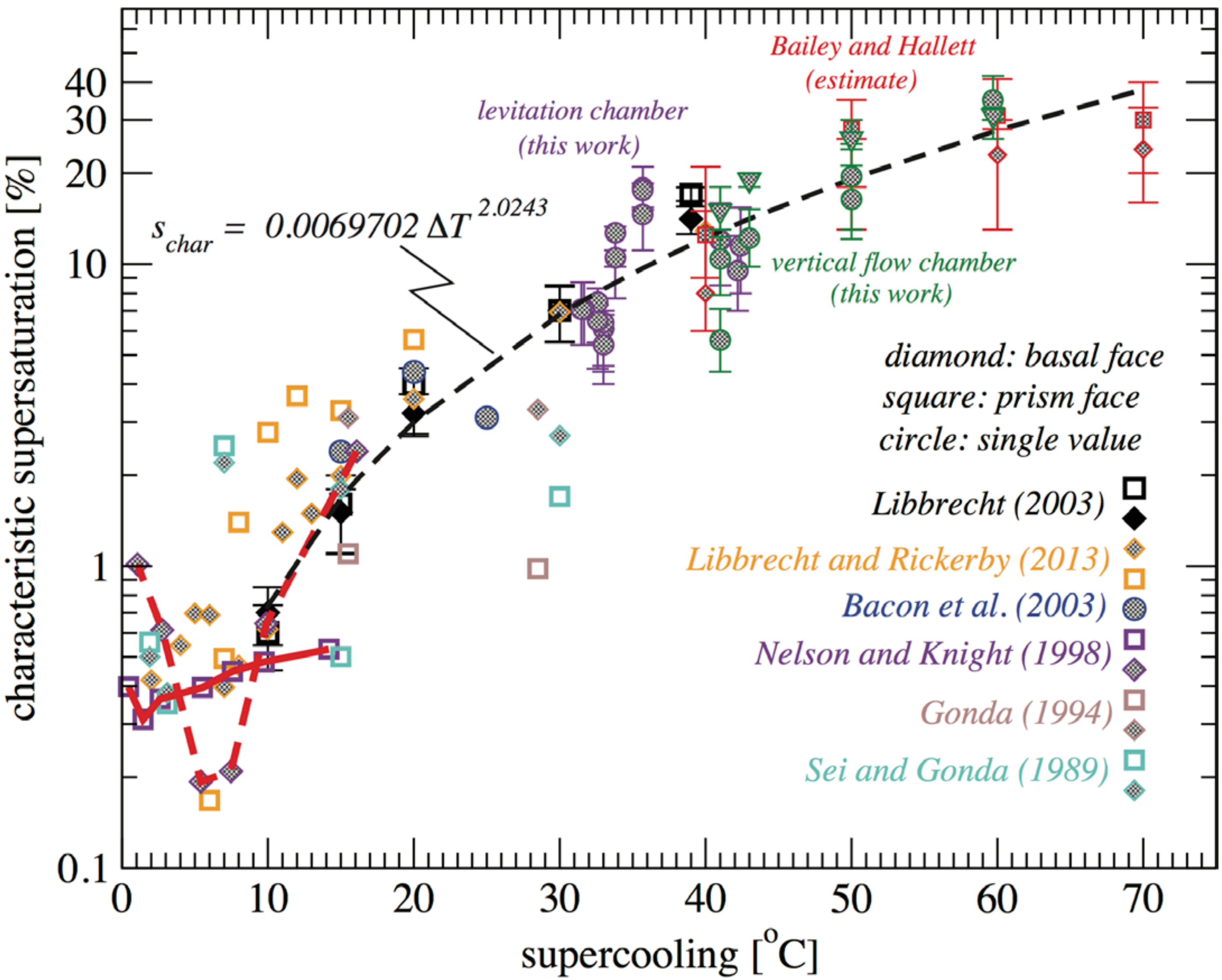
Zhang and Harrington (2015)

Predicting the Deposition Coefficient



- Lab Constraint –

Characteristic (Critical) Supersaturations



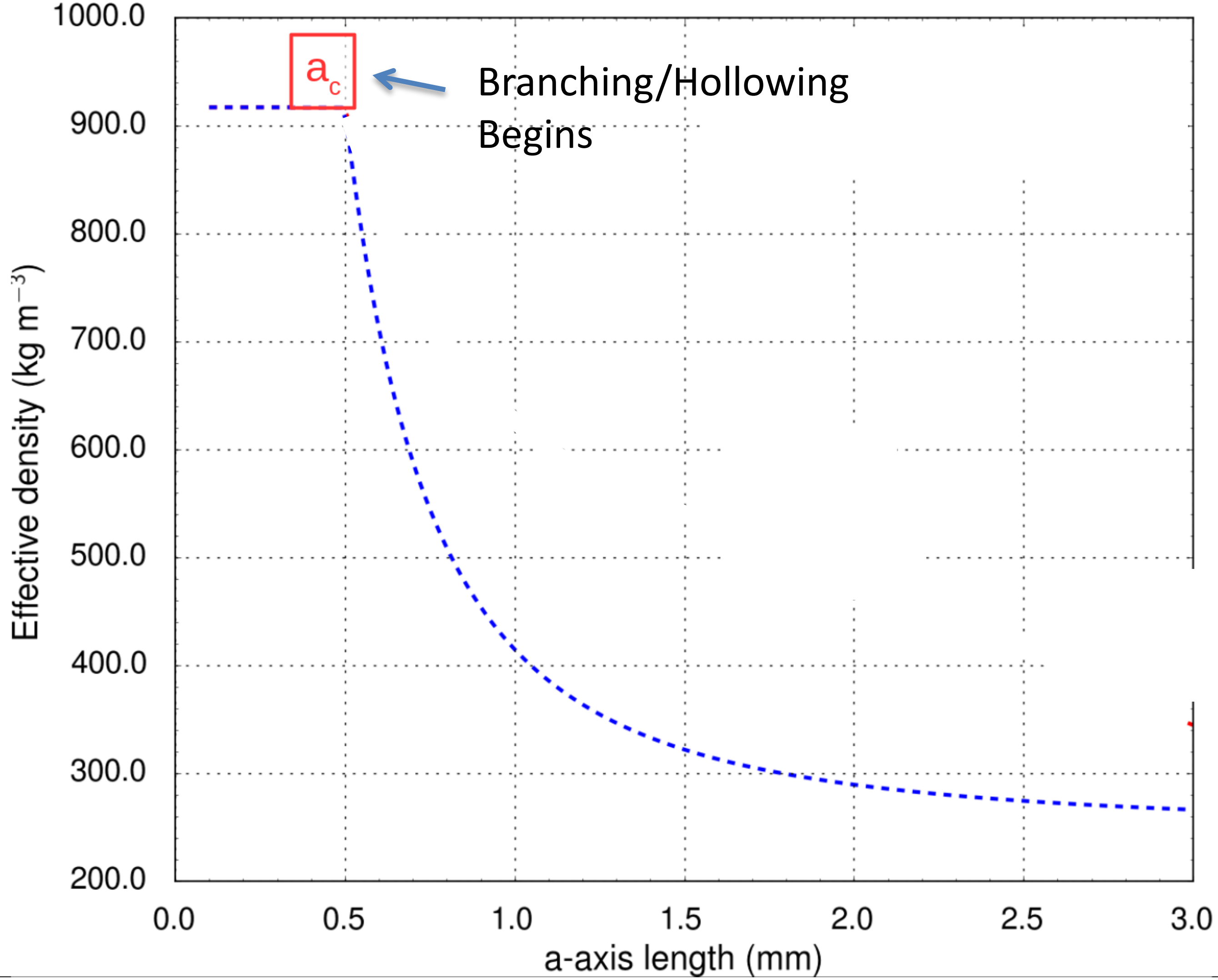
Measured in the laboratory

Predict the axis-dependent deposition coefficients

Controls the evolution of particle shape in time (maximum and minimum dimension)

- Lab Constraint –

Effective Density

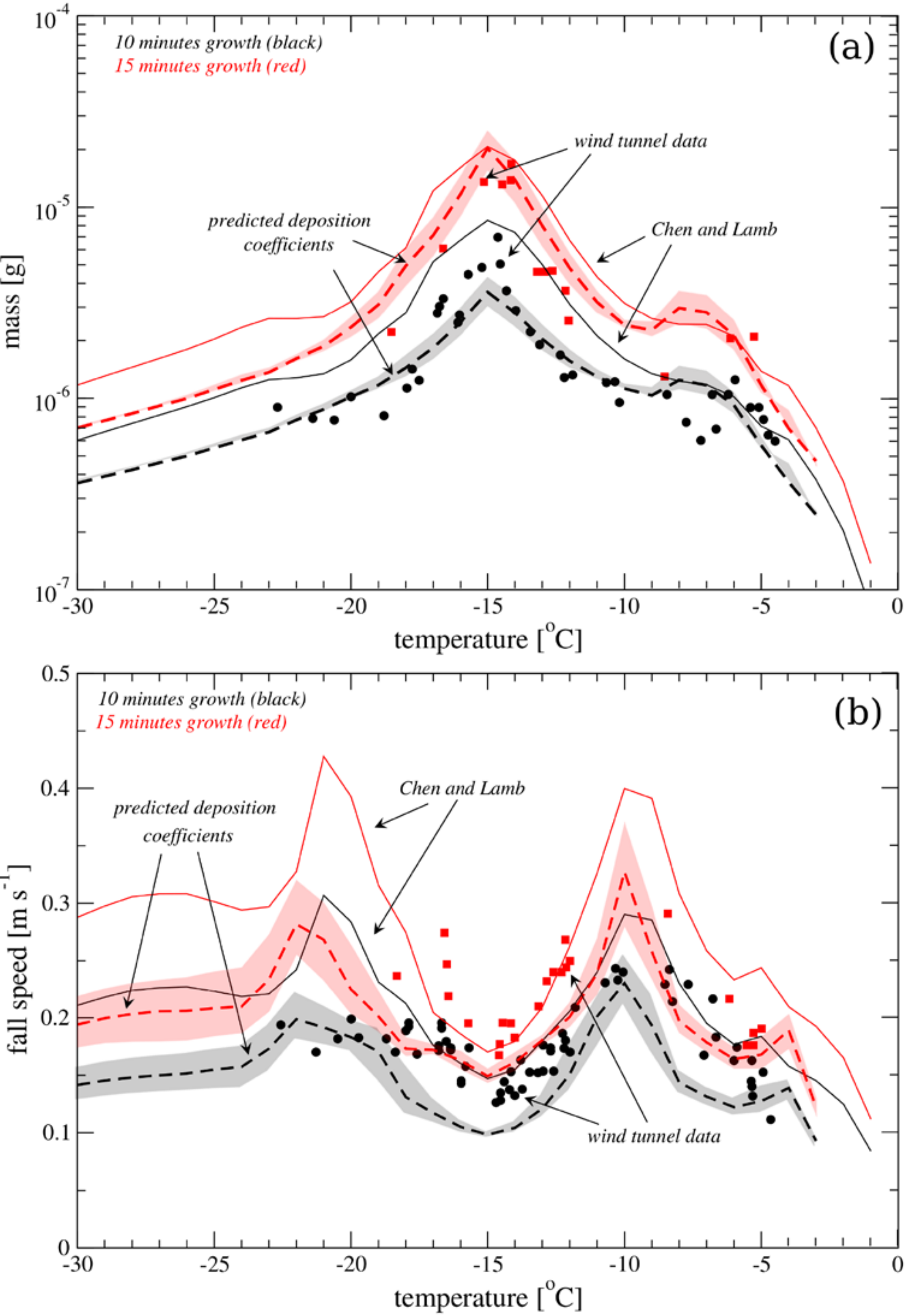


At liquid saturation, crystals branch and hollow.

An "effective" density is usually used to account for the regions that lack mass

Simple functions are often used (Chen and Lamb,1994; Takahashi et al., 1991, etc.)

Schrom et al. (2018)



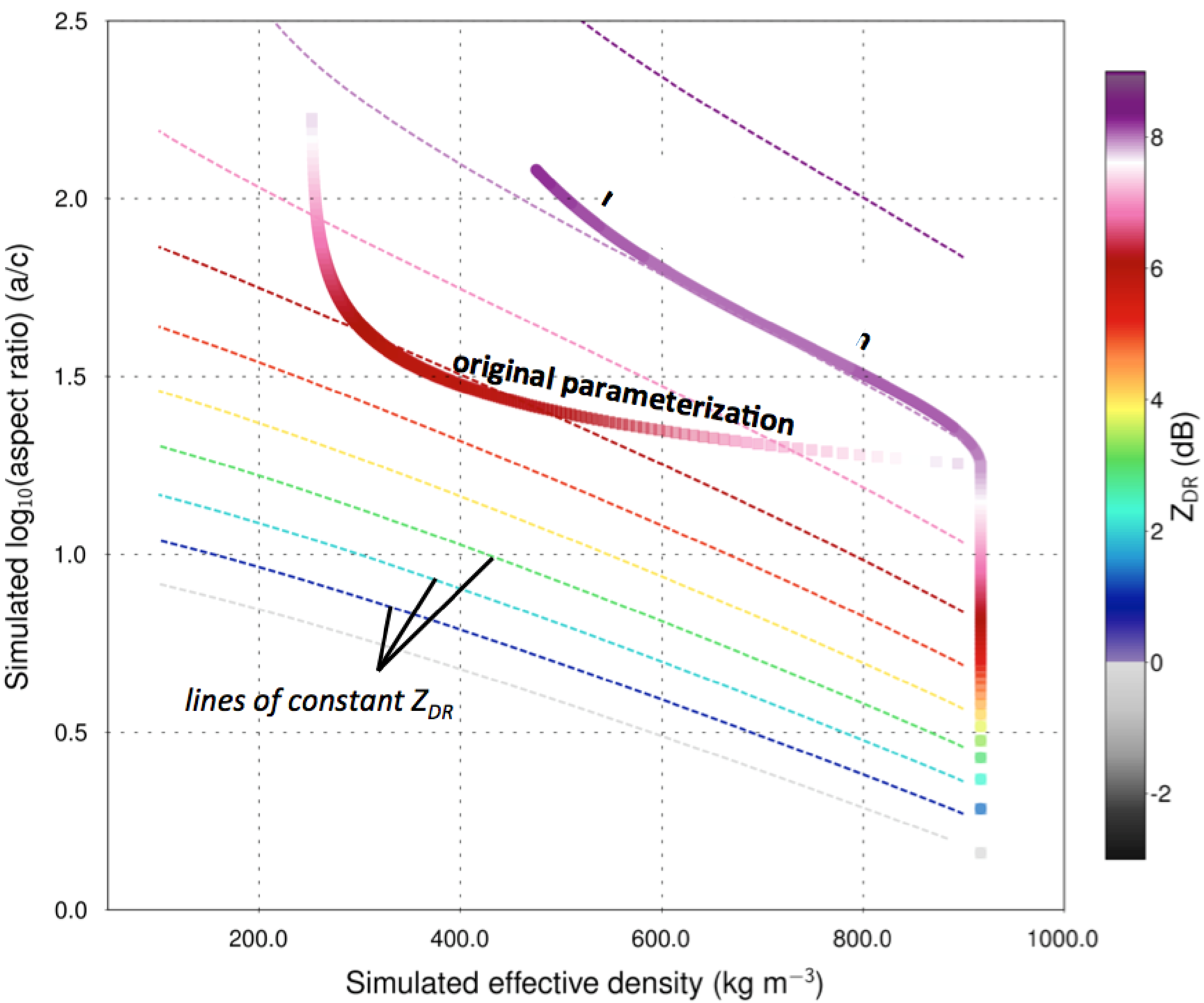
- Lab Constraint -

Vapor growth transition model tested against wind tunnel measurements of ice growth (liquid saturation)

Axis lengths (major, minor), mass, fall speed predicted

All match wind tunnel measurements of ice crystal growth using deposition coefficients to predict axis lengths and effective density to parameterize branching/hollowing.

- Radar Constraint -



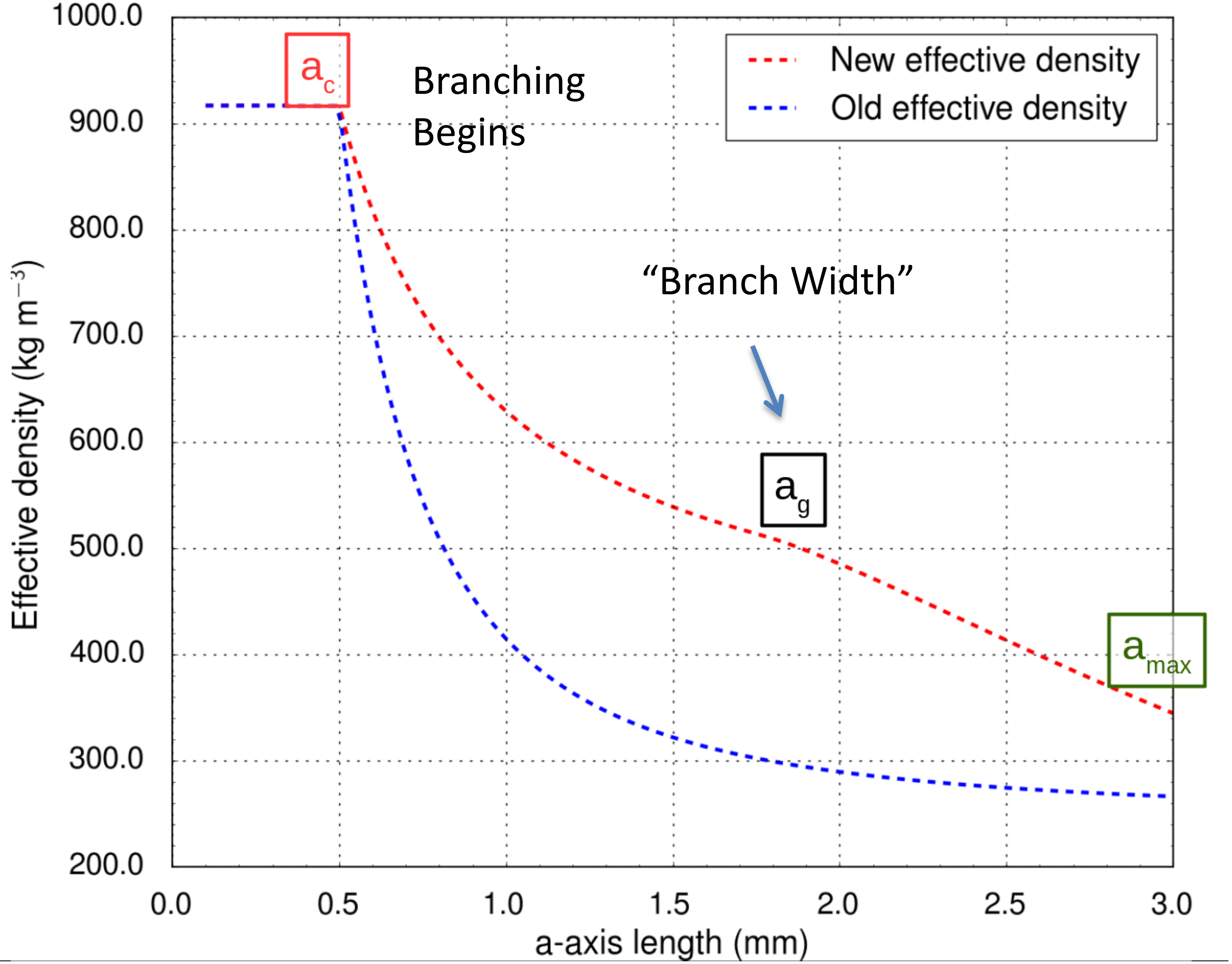
Z_{DR} calculated from modeled crystals indicate that the density falls too quickly:

Z_{DR} actually decreases once branching starts, which should not occur.

Schrom et al. (2018)

- Lab Constraint –

Effective Density



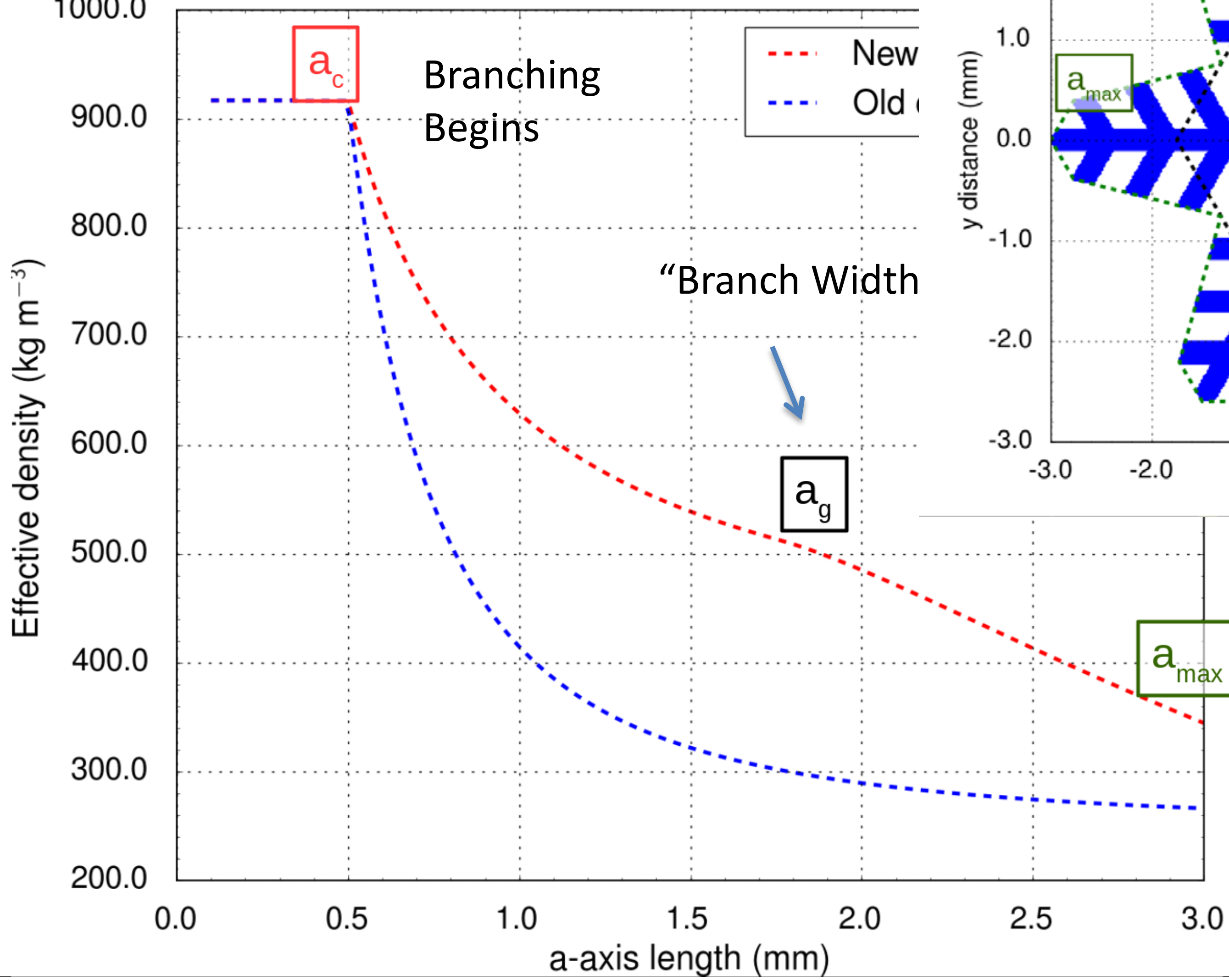
Size-dependent effective density:

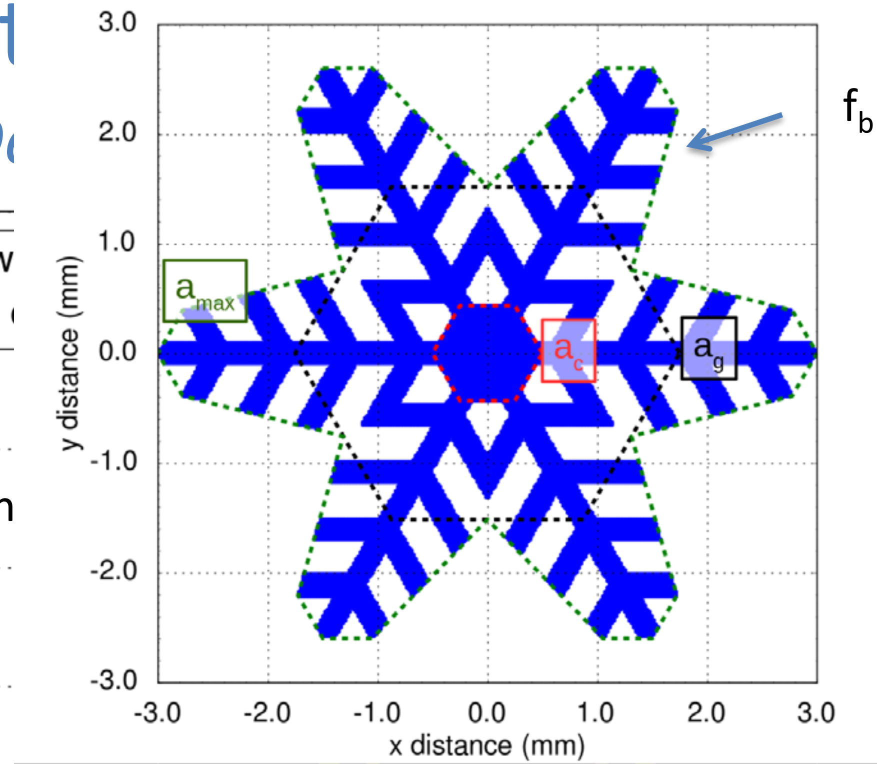
Introduce a parameter, a_g that separates intermediate density from the growth of thin branches.

Schrom et al. (2018)

- Lab Const

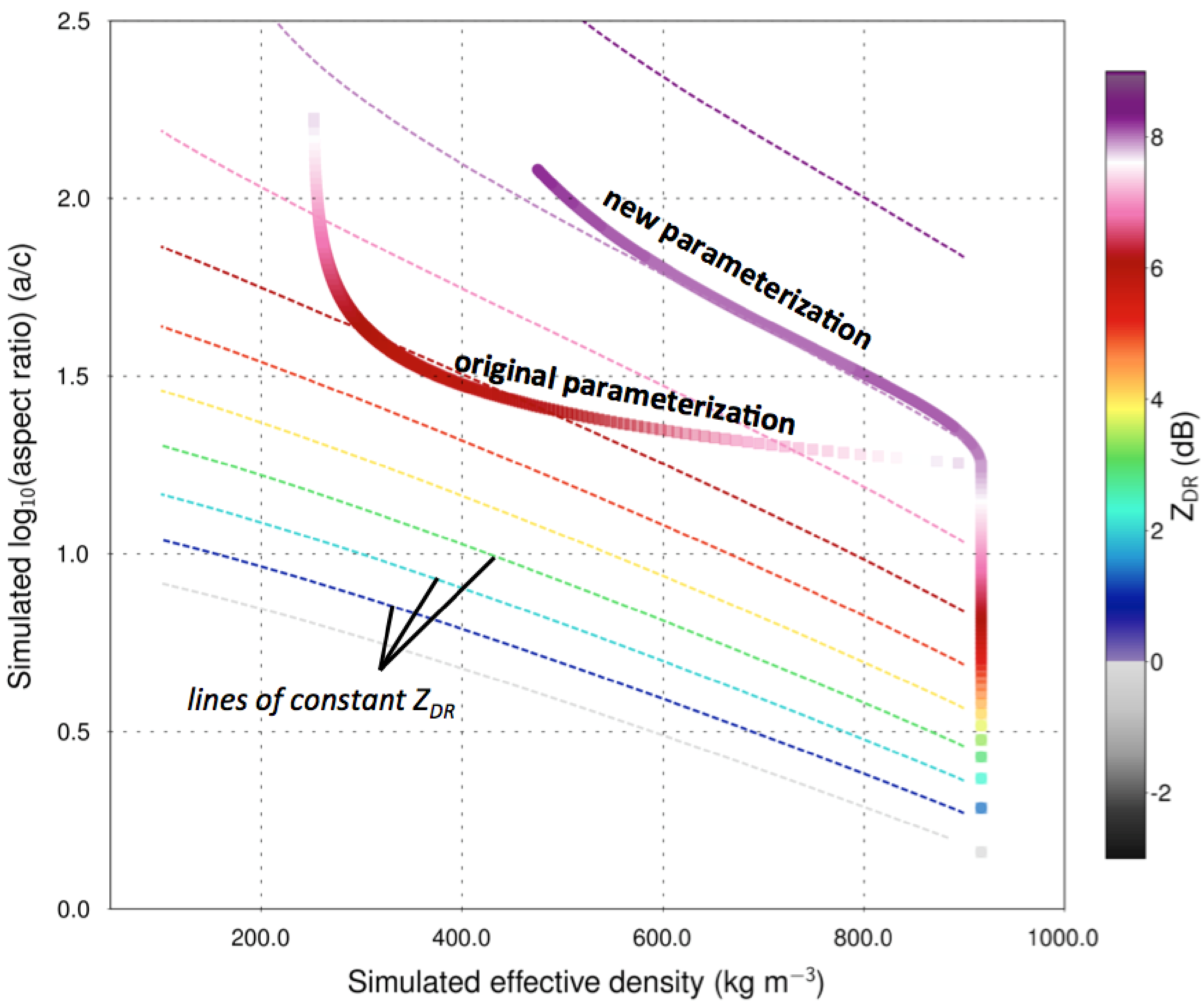
Effective De





Schrom et al. (2018)

- Radar Constraint -



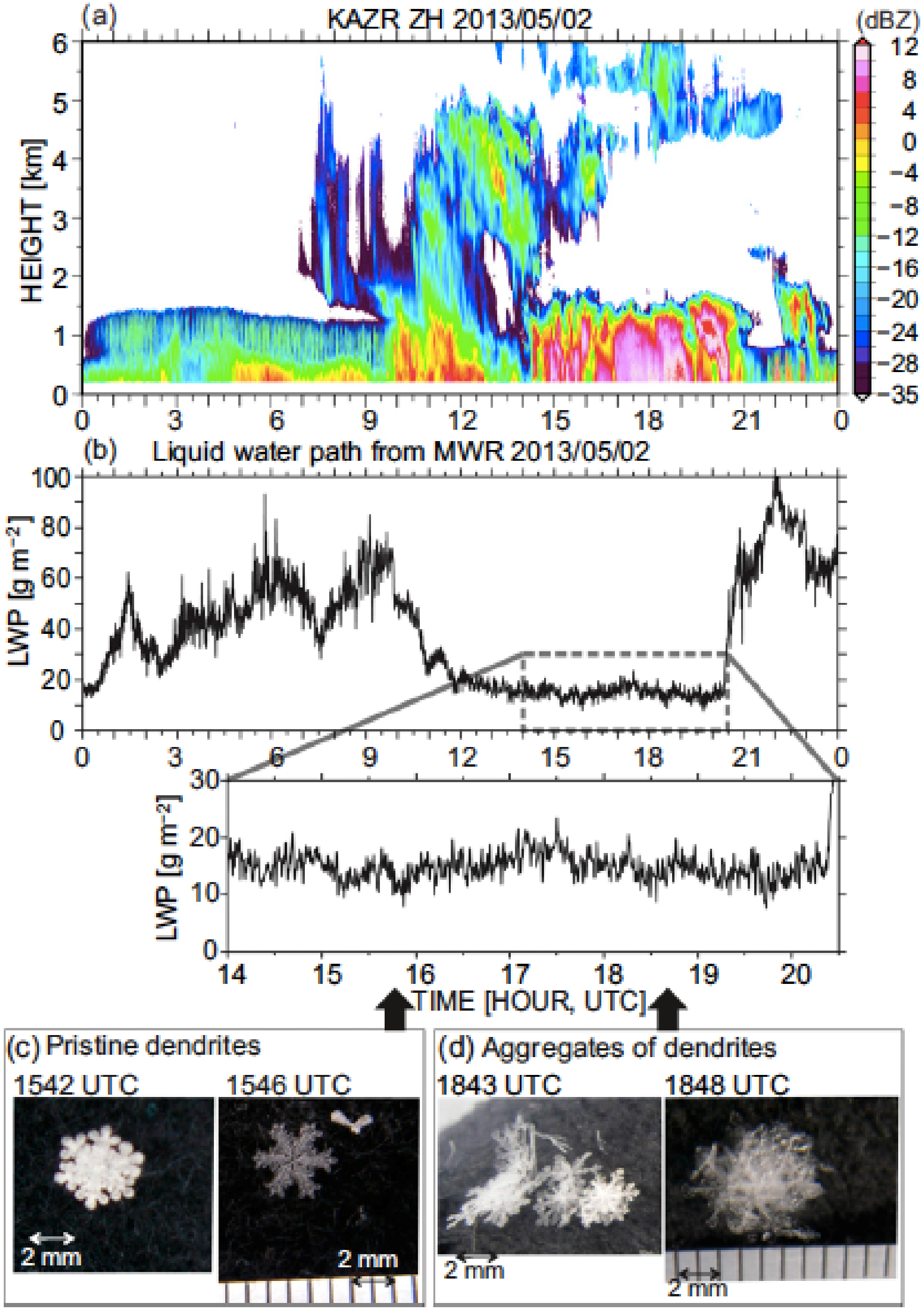
With size-dependent effective density, Z_{DR} behaves physically

Growth is now constrained by lab measurements and scattering information.

Now possible to use actual case studies to extract information about crystal growth

Schrom et al. (2018)

- Observed Cases -



What does this have to do with North Slope research?

We do observe cases with crystals of a single type. Useful for testing and constraint of models.

Simulated May 2, 2013 case for period of primarily dendritic growth

Key Objective: Can we use the KAZR and X-SAPR to estimate the effective density parameters?

Parameter Estimation Approach

Simulate observed case with 1-D TKE model and 2-D kinematic model using habit evolving bulk microphysics.

Use radar forward simulator coupled to the microphysics code, and using new effective densities ("corrected" Z_{DR})

Use Markov Chain Monte Carlo technique to estimate parameters through minimization of errors in model predicted radar reflectivity and Z_{DR}.

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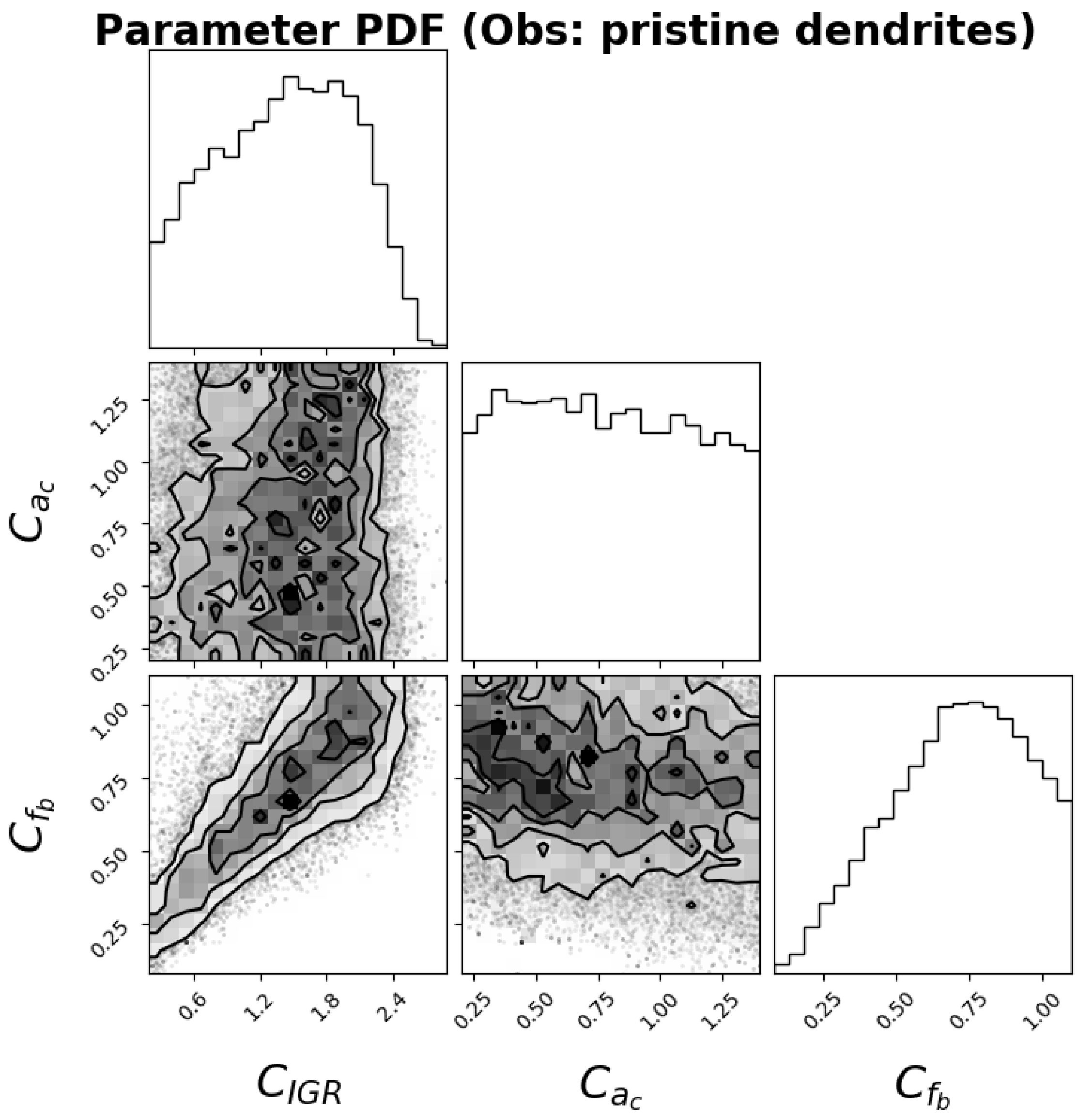
Equations that control density and shape written in terms of multiplicative parameters:

$$dc/da = \alpha_c/\alpha_a * C_{IGR} \quad \text{(controls shape)}$$

$$a_c = a_c(\text{initial})*C_{ac} \quad \text{and} \quad f_b = f_b(\text{initial})*C_{fb} \quad \text{(effective density)}$$

- Estimated Parameters -

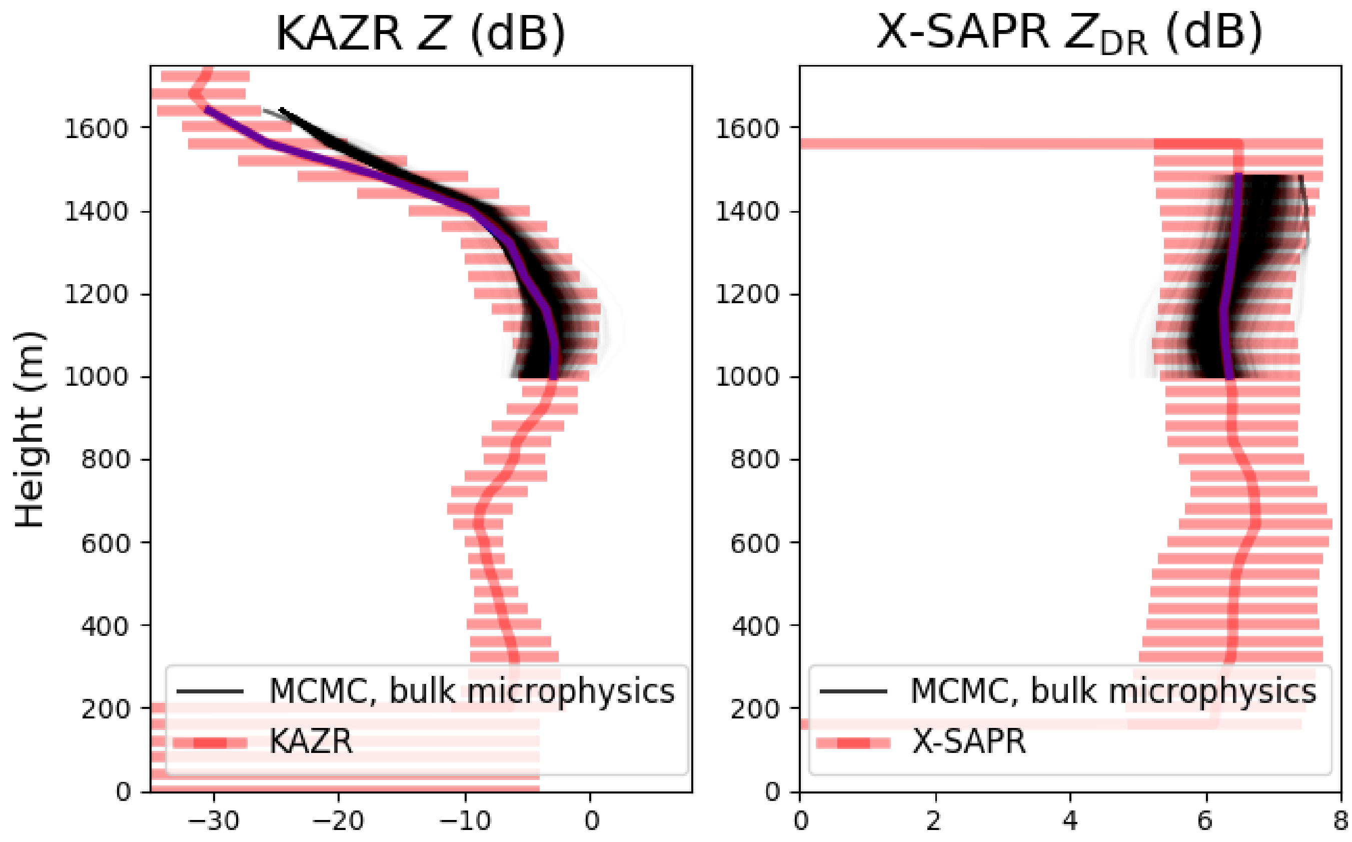


MCMC approach provides estimates of parameters and their respective errors

CIGR and Cfb are well correlated which is physical:

A larger dc/da means THICKER dendrites, and a larger f_b means THICKER branches.

- Simulated Radar Z and ZDR -



Model simulations were able to match the vertical profiles within range of model parameter uncertainties.

- Final Remarks -

Laboratory data is useful for providing mechanistic information on the growth of individual particles, but is of course limited.

Radar scattering information can be used as an extra constraint, and to extract information on parameters that are difficult to measure in the laboratory (such as parameters for the control of effective density).