Using Ice Cloud Measurements to Improve Cloud Modeling

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ASR Atmospheric System Research

ARM

DRI Desert Research Institute

Treatment of the Asymmetry Parameter: Conceptual Framework

A number of studies show that asymmetry parameter g is primarily a function of:

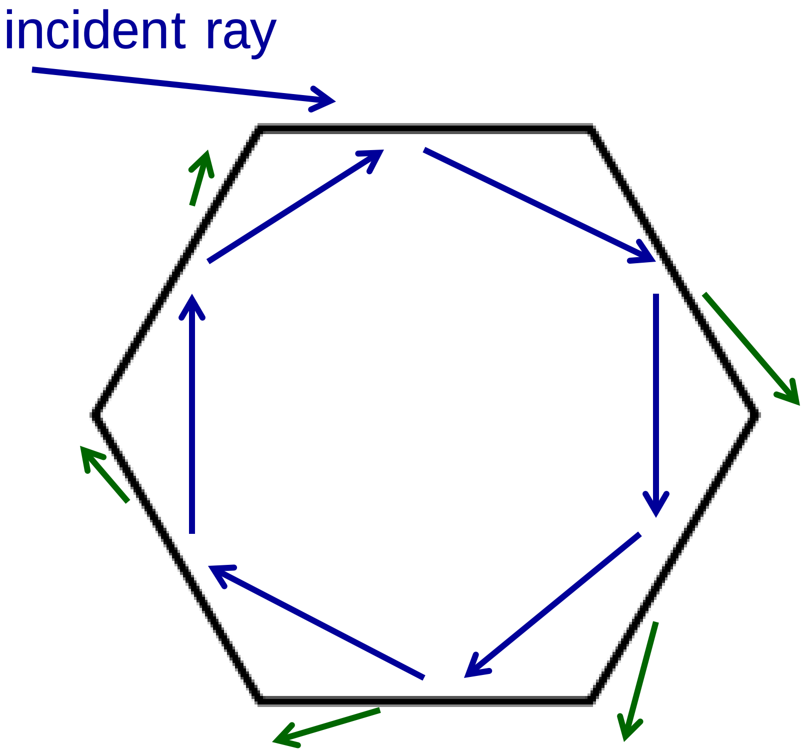
1. Aspect ratio for pristine ice crystals or representative component for complex ice crystals or aggregates

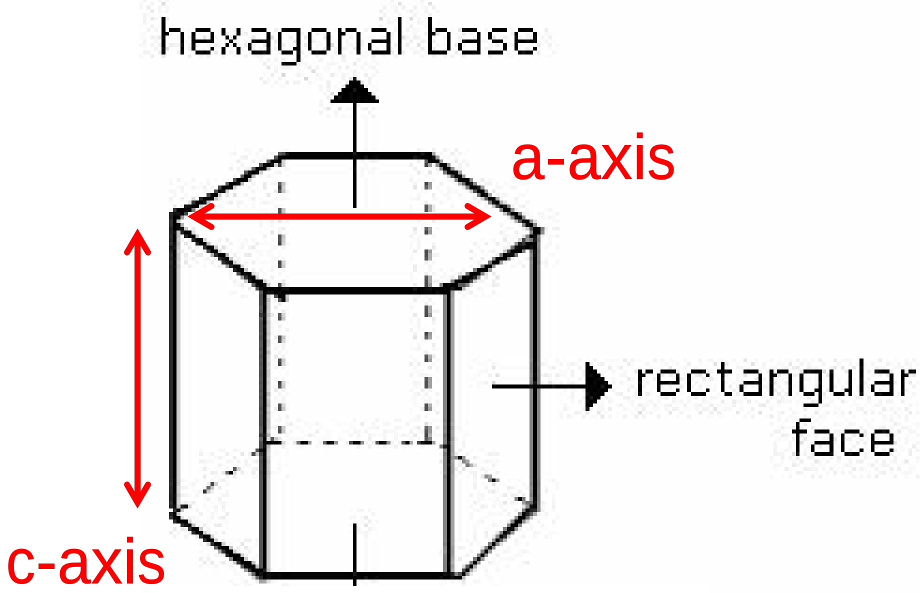
2. Microscale surface roughness

Thus, radiation transfer models need aspect ratio (for a given surface roughness), in addition to effective size and ice water content, to accurately predict ice cloud radiative properties.

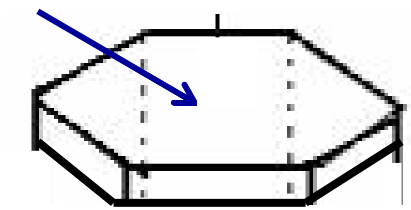
The g-parameterization of Fu (2007, JAS) incorporates this functionality in an elegant and physically realistic manner.

Light can be redirected in more directions when ice crystal aspect ratio is near unity





Aspect ratio = c/a



Light redirected in fewer directions

From van Diedenhoven et al., AMTD, 2012

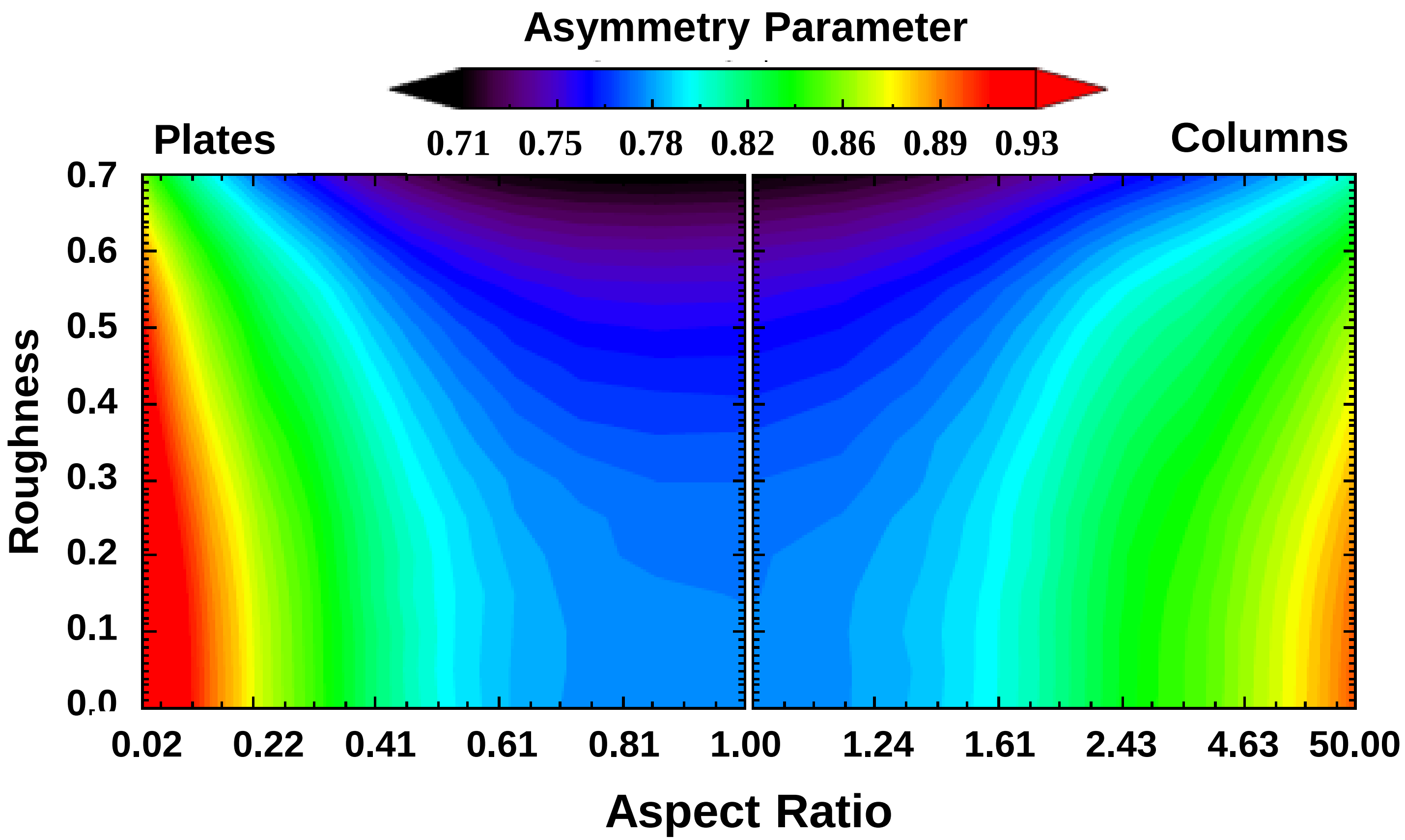
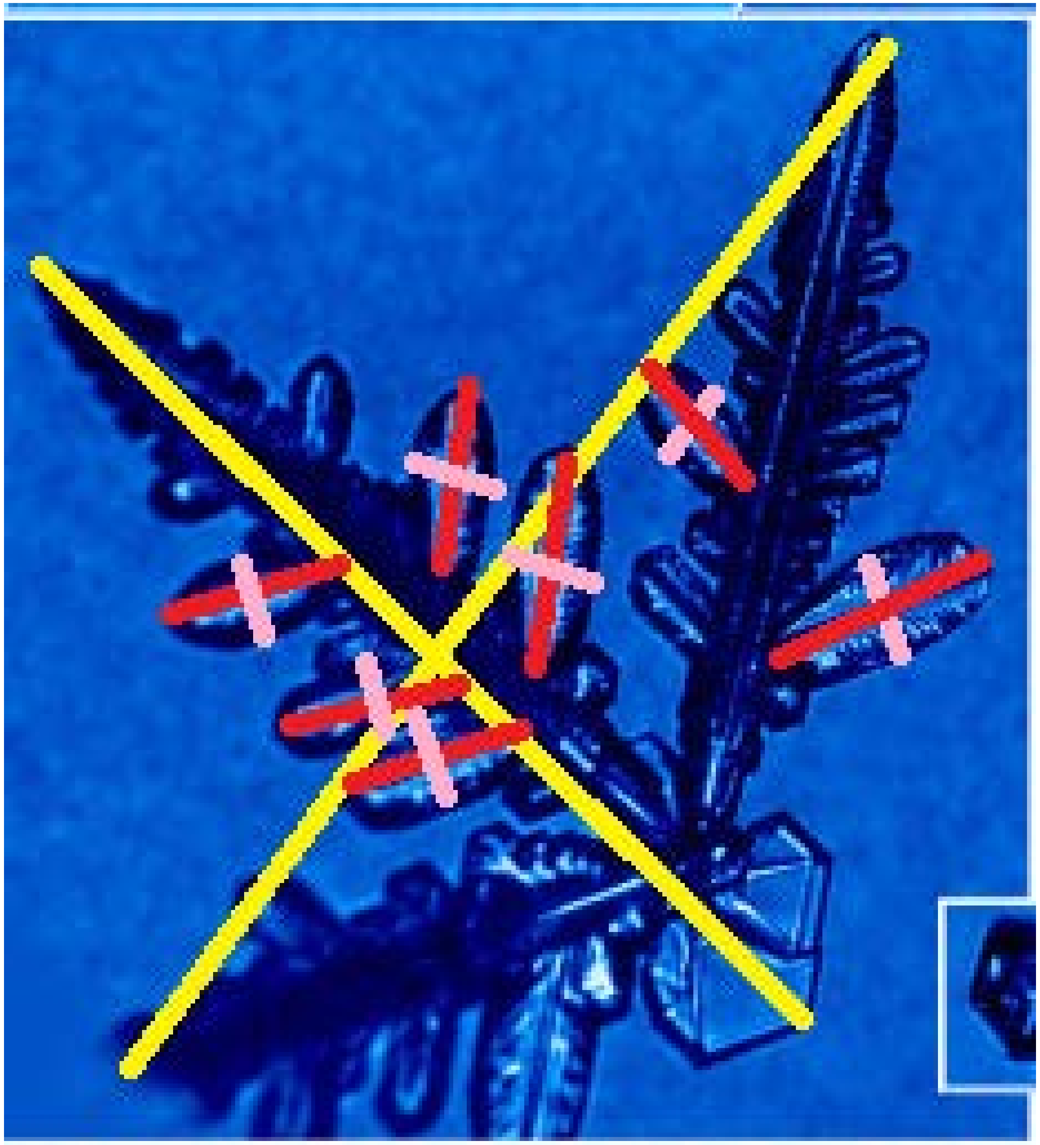


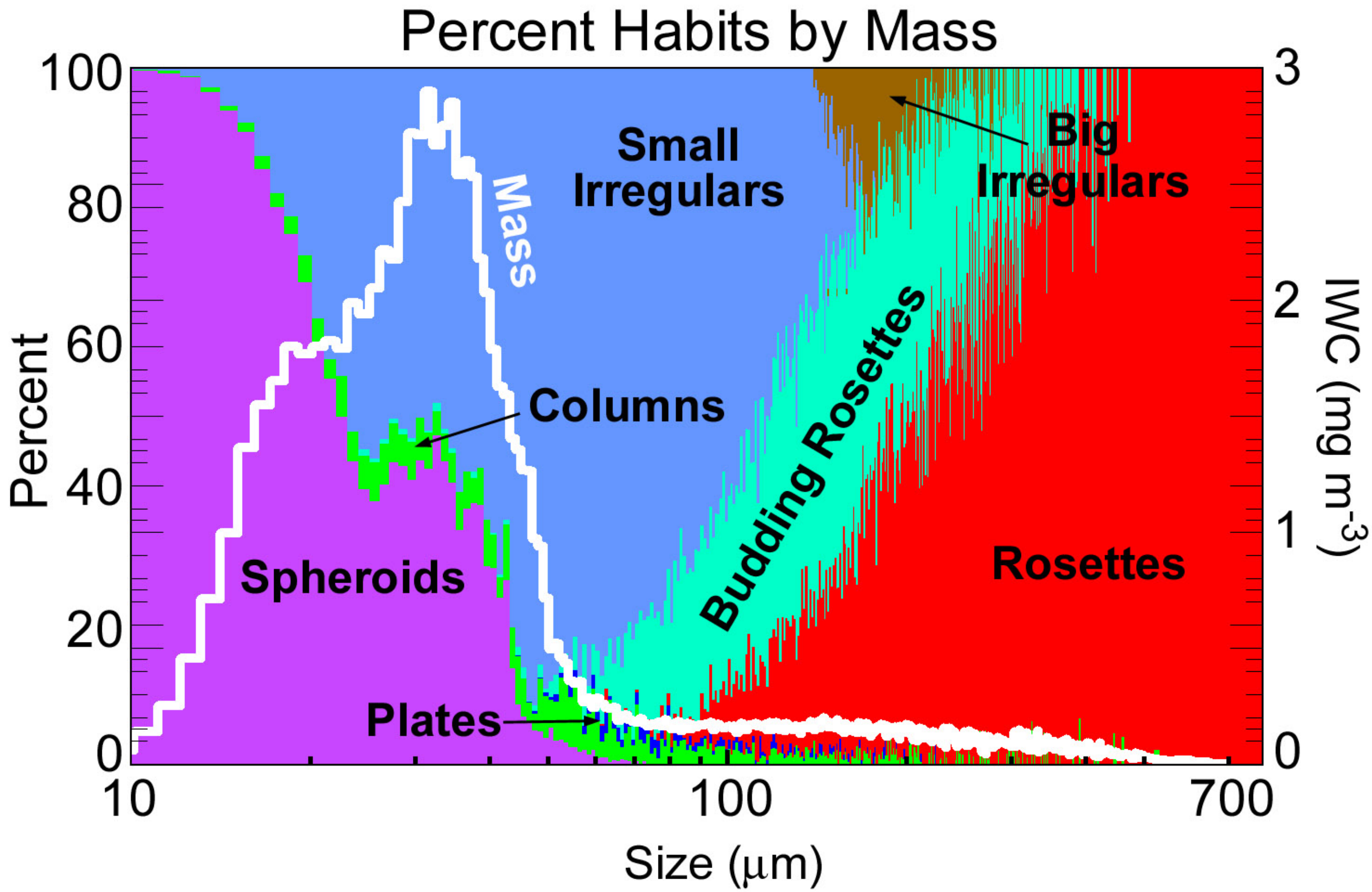
Fig. 1. Asymmetry parameters of plates and columns at 864 nm as a function of their aspect ratio and microscale roughness.

Example: Treatment of Aspect Ratio for Dendrite Components



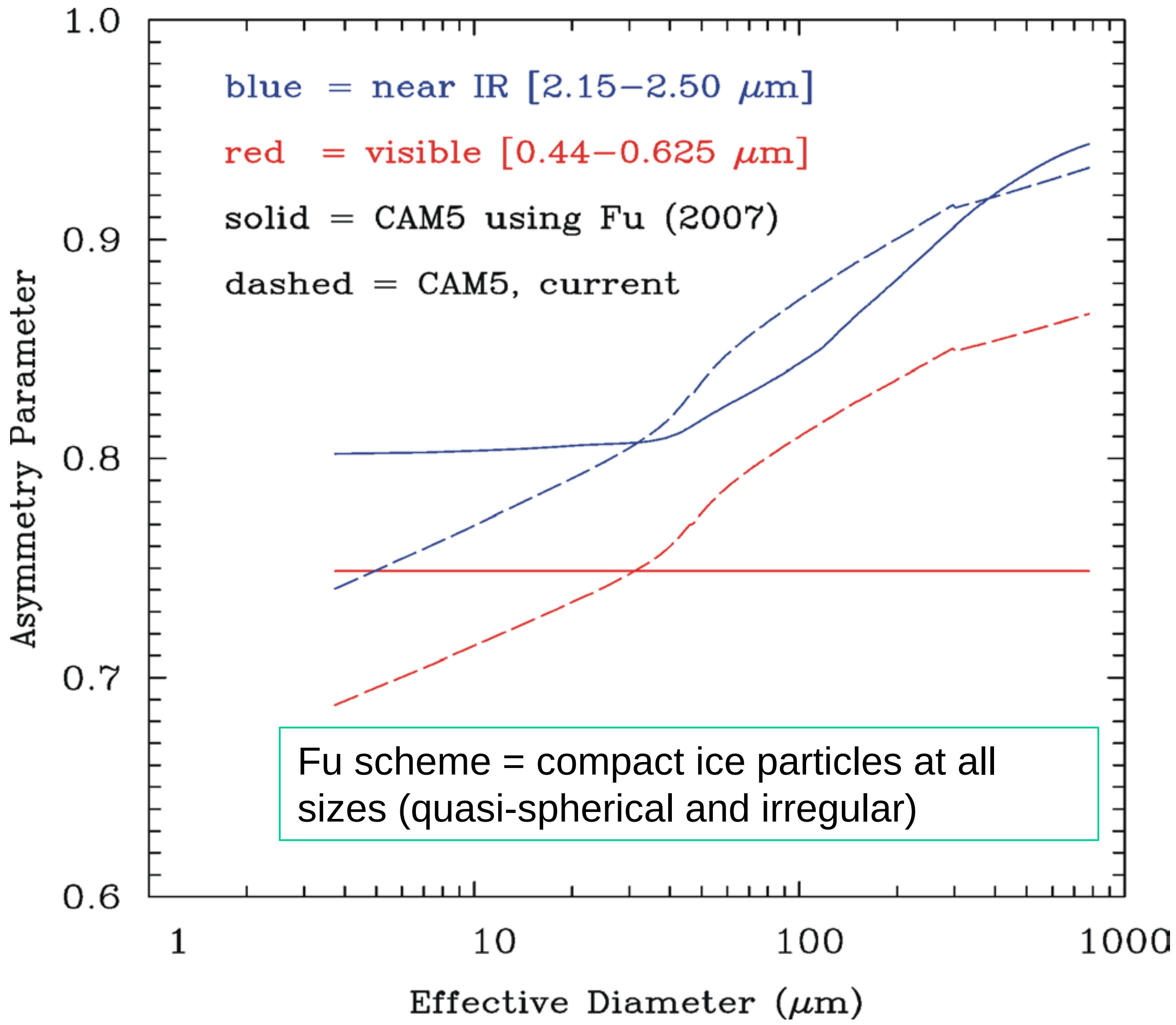
Effective aspect ratio for dendrites can be estimated by taking average of pink and red lines to characterize the planar surface dimension, Dp. From Dp, calculate the component thickness using relationship from Auer & Veal (1970) for dendrites. By ratioing Dp with the dendrite maximum dimension Dmax (yellow lines), Dp can be estimated for any Dmax.

Application of the Fu Scheme to CAM5

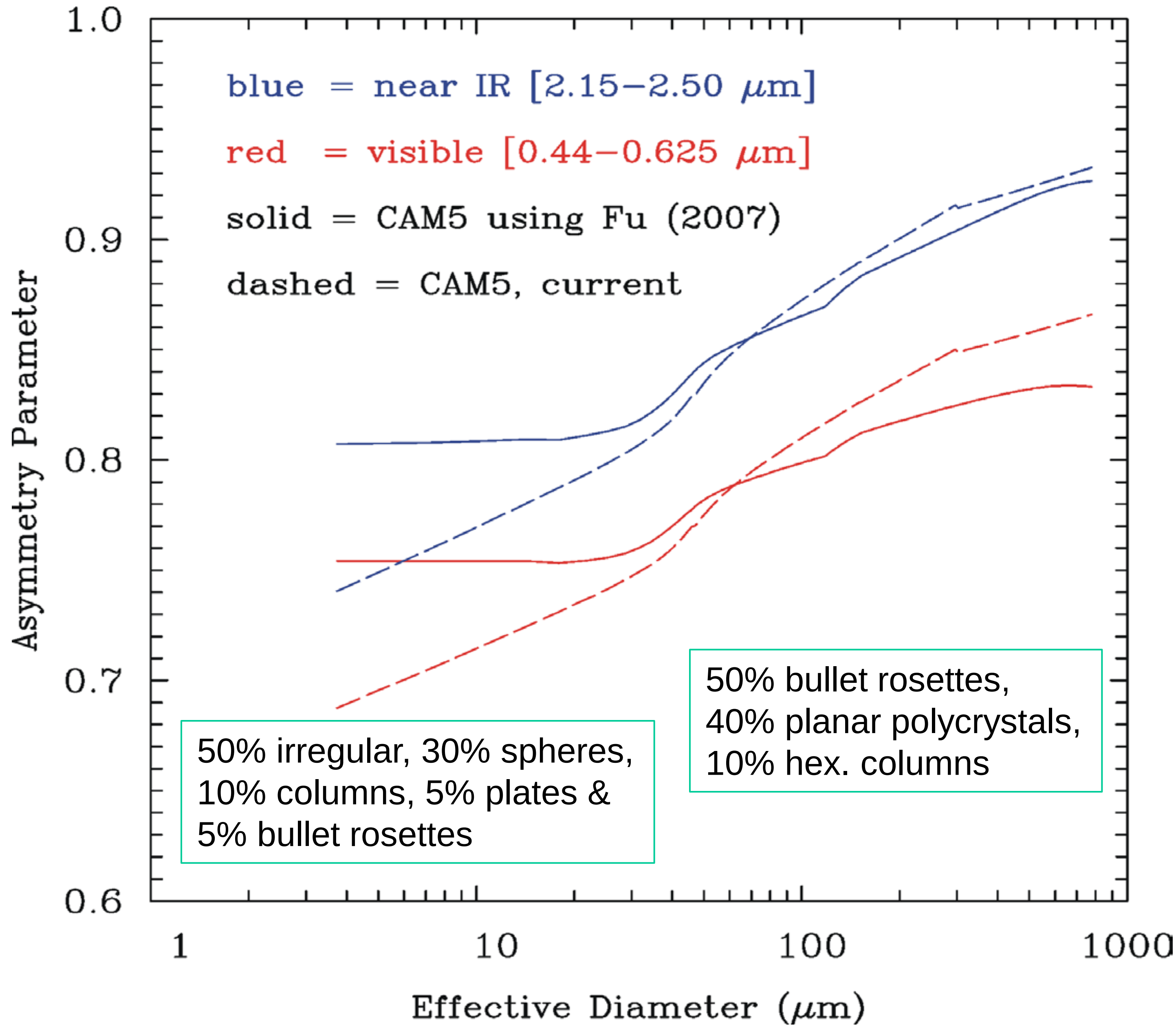


Mass percentage of ice particle habits as a function of particle size. From Lawson et al. 2006, J. Atmos. Sci.

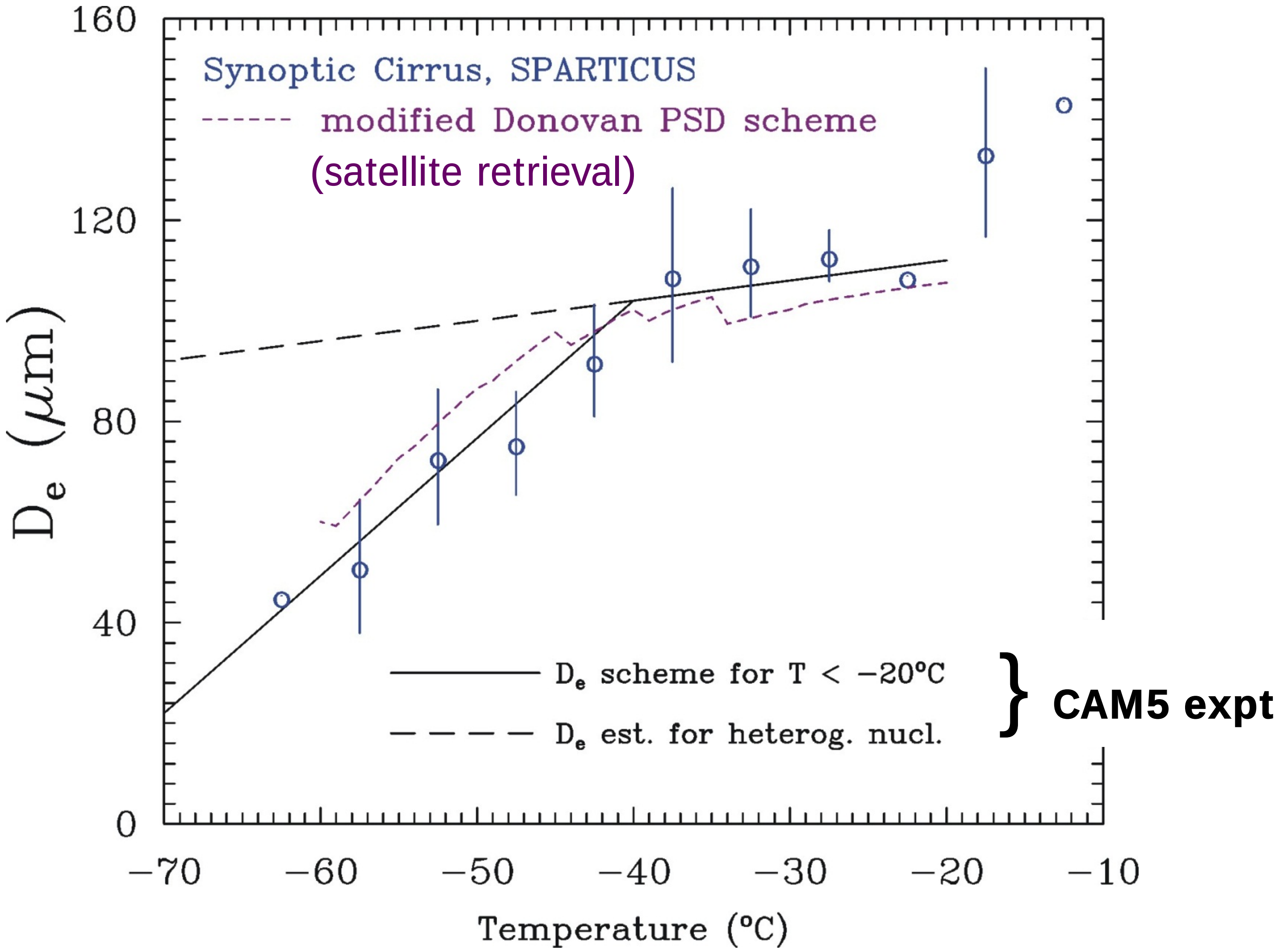
Comparing g from Fu and CAM5 where ice crystal shape is constant across the PSD for the Fu scheme



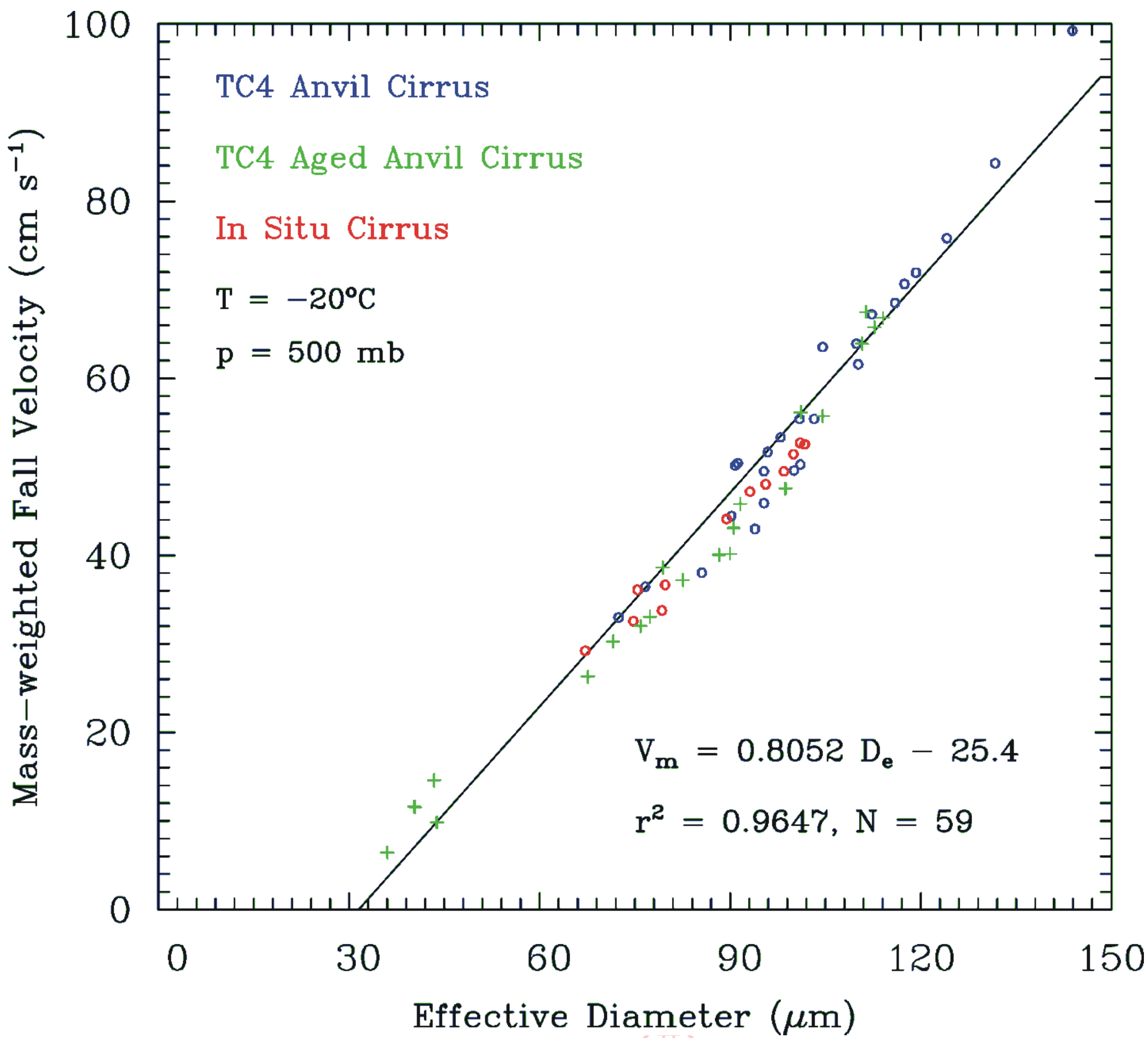
Comparing g from Fu and CAM5 where shape varies across PSD



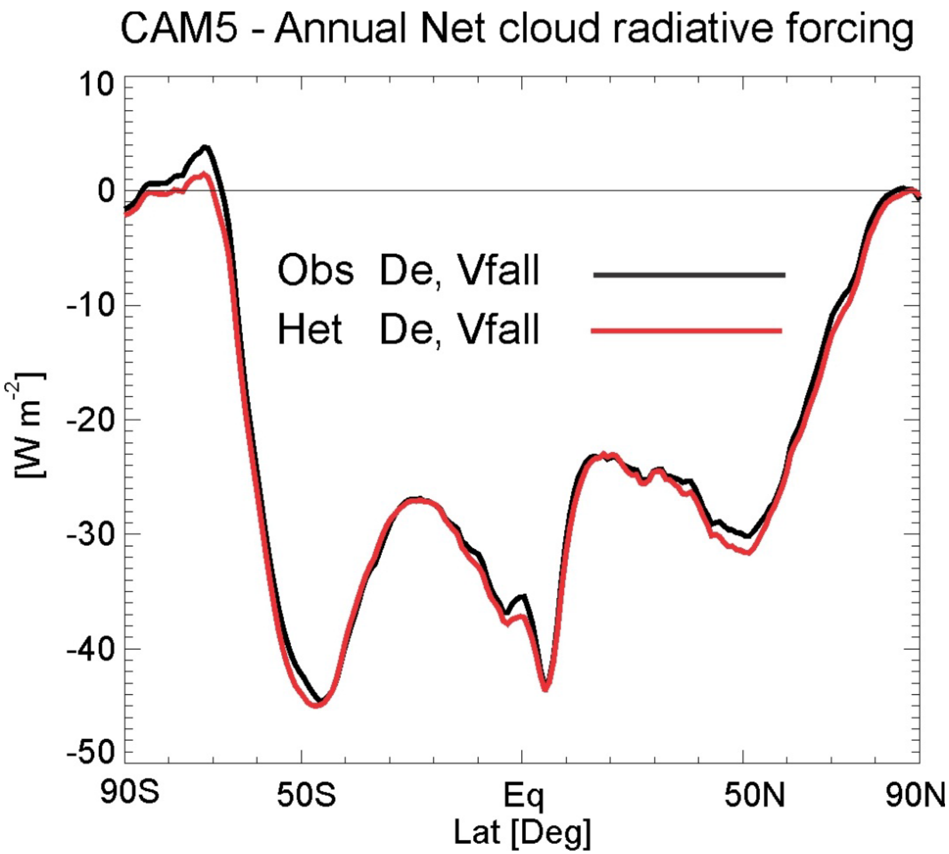
From these in situ and satellite results, a CAM5 experiment was designed to estimate the maximum cooling effect due to efficient heterogeneous nucleation for T < -40°C, based on synoptic cirrus.

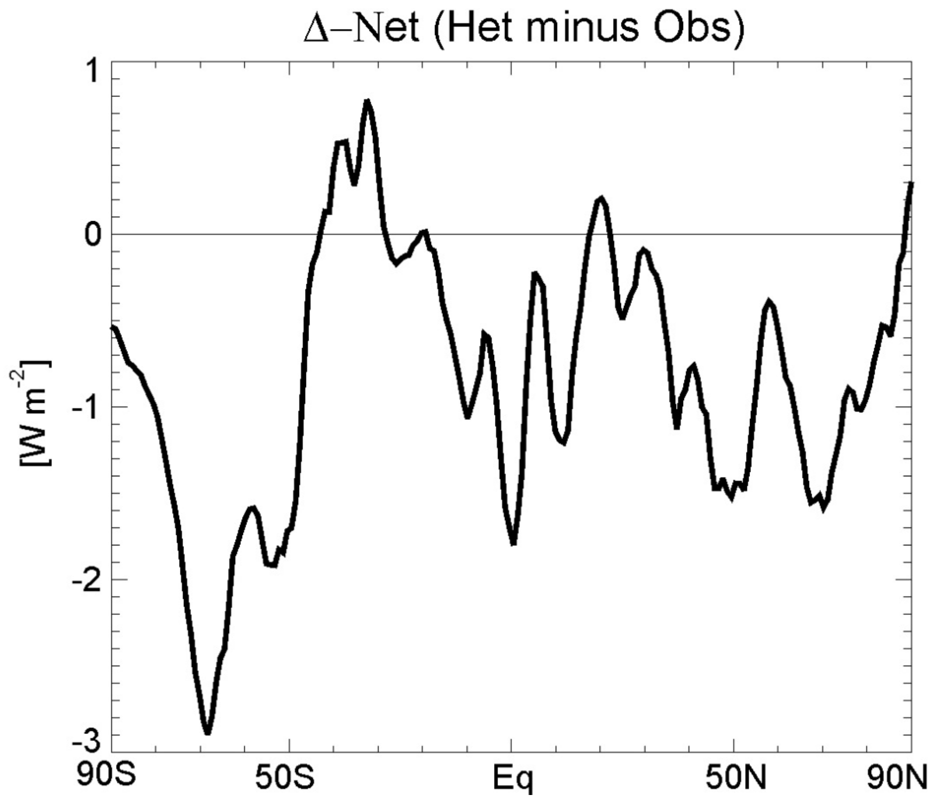


CAM5 experiment relates D_e to T from field measurements and then calculates V_m from D_e (Mitchell et al. 2011, JGR).



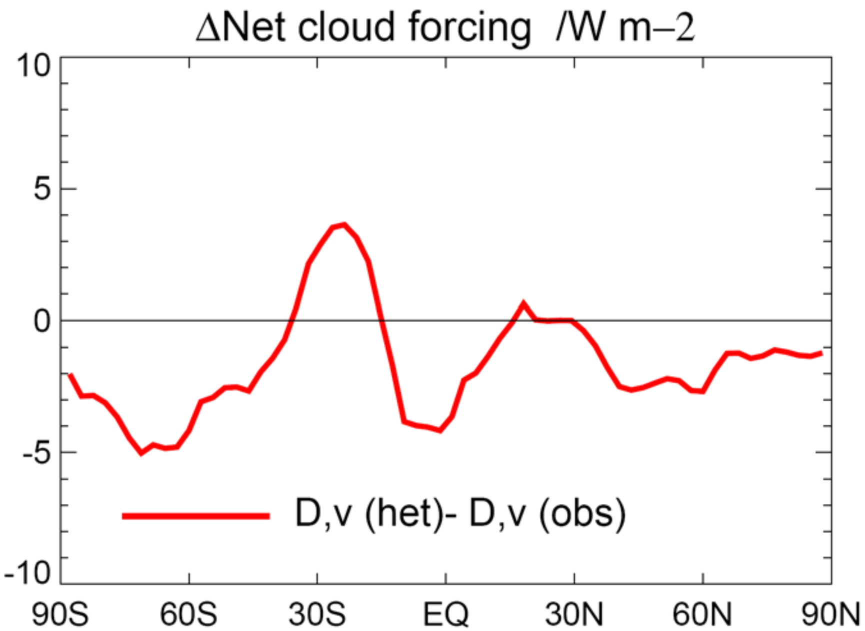
Maximum cooling from heterogeneous nucleation for T < -40°C, based on the 5-year CAM5 simulation with climatological SSTs

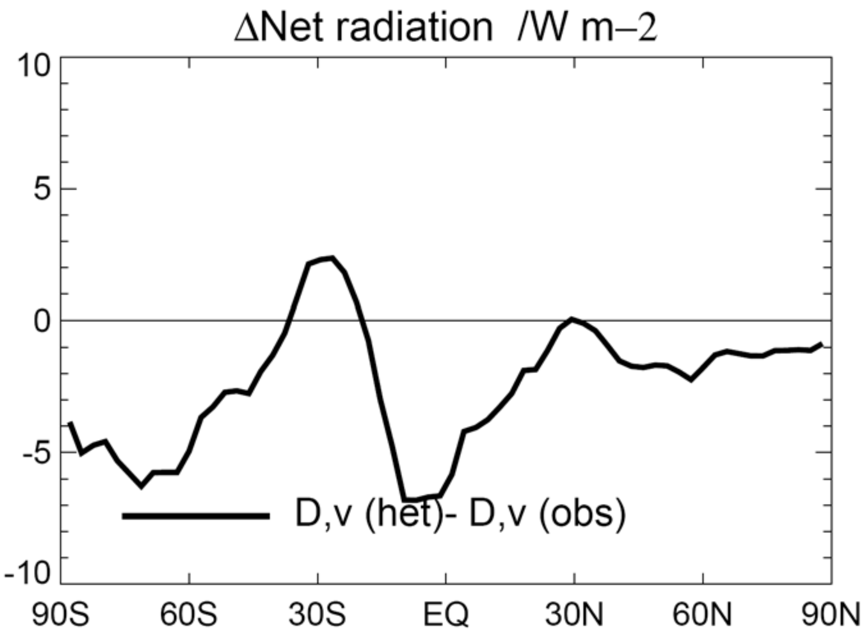




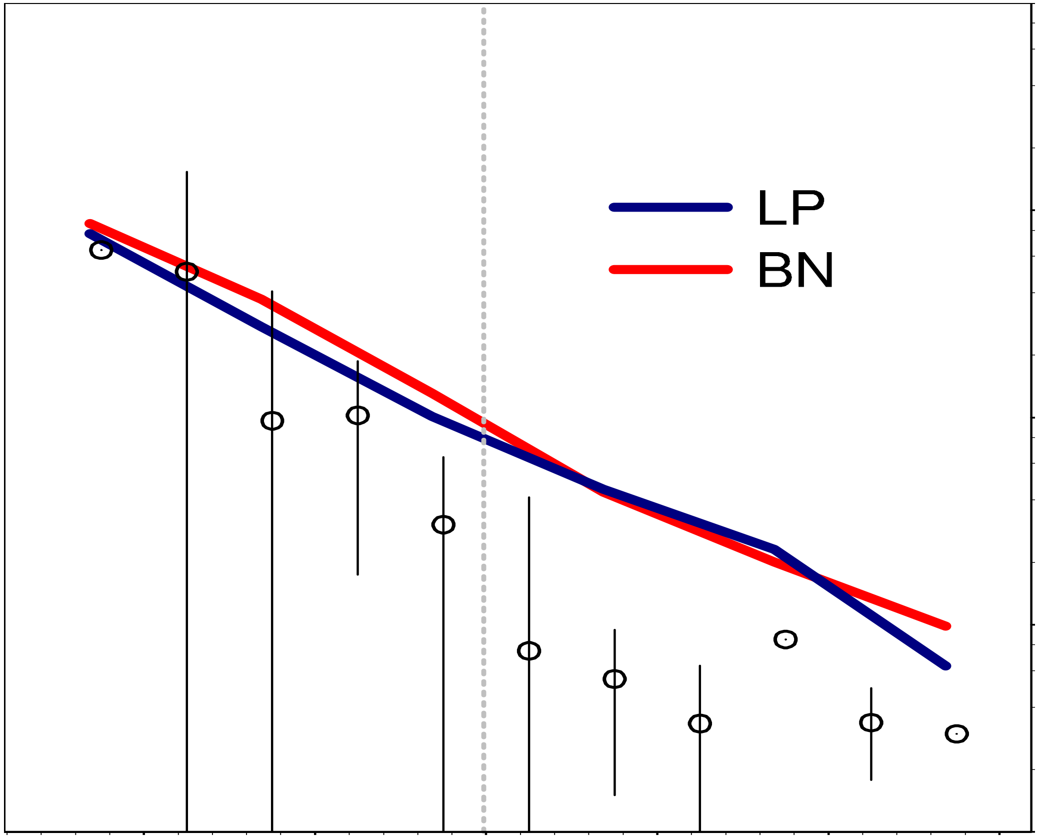
Same as CAM5 expt., but using ECHAM5

- Different GCMs predict different cooling amounts but are similar in N. Hemisphere.
- 5-year simulation from 2000-2004





Evaluating ice nucleation and aggregation in CAM5 with SPARTICUS data



Ice Cloud Discussion Period

Climate Model Deficiencies	Methods for Addressing Deficiency
m-D & A-D power laws	Instrument development, improve existing instruments, laboratory testing of instruments, instrument intercomparison studies, improve data processing methods
Ice nucleation	Analysis of microphys., w & RHi measurements
Quantify aerosol impacts on ice cloud microphysics and radiative properties	In situ measurements combined w satellite &/or ground-based remote sensing → design GCM experiments constrained by measurements
Aggregation efficiency	Combine process modeling with in situ observations to improve Ea(T)
Degree of PSD bimodality (i.e. small ice crystals)	In situ measurements combined with ground-based and satellite remote sensing

ICEPRO: A proposed ASR focus group on ice physical properties and processes that will coordinate individual research activities to address programmatic objectives.

Interested investigators should contact David Mitchell or Greg McFarquhar.