Ice Cloud Particle Ensemble Parameterizations for Temperatures of 0 to -90C

Andrew Heymsfield and Aaron Bansemer
NCAR, Boulder CO

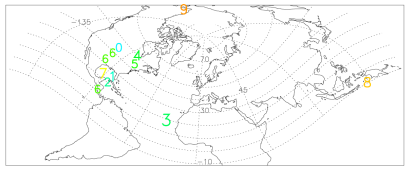
Parameterization Needs

Climate Models [for the ice phase]

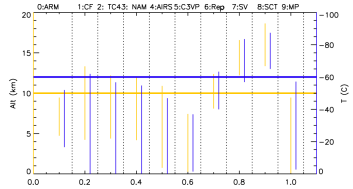
Weather Forecast Models

Remote Sensing

-For GPM/PMM, -developing algorithms that relate ice water content and precipitation rates to radar reflectivity, lidar extinction, IR brightness temperatures



0–ARM: ARM 2000, Atmospheric Radiation Measurement (ARM) Field Campaign, 2000
1: CF: CRYSTAL–FACE, The CirrusRegional Study of Tropical Anvils and Cirrus Layers – Florida Area Cirrus Experiment, 2002
2: TC4: The Tropical Composition, Cloud and Climate Coupling (TC4) Field Campaign, 2007
3: NAM: NAMMA – The NASA African Monsoon Multidisciplinary Analyses Campaign, 2006
4: AIRS: AIRS_2, Alliance Icing Research Study II, 2003–2004
5: C3VP: Canadian CloudSat/CALIPSO Validation Program, 2006–2007
6: Rep: Replicator Observations, First ISCCP Research Experiment (FIRE)–2, 1991
7: SV, Subvisual: Experiments with CF and pre–AURA Validation Experiment, 2002 and 2004
8: SCT, SCOUT: StratosphericDClimate Links w/Emphasis on the Upper Troposphere/Lower Stratosphere, 2003
9: MPACE: Mixed–Phase Arctic Cloud Experiment, 2004



Analysis

For each 5-sec average particle size distribution, we have fit the size distributions with Gamma functions,

$$N = N_0 D^{\beta} e^{-\lambda D}$$

and log normal functions. The fitted PSDs are for particles 100 microns and above for temperatures >-60C, >2 to 10 microns below -60C. Gamma fits produced the best results and are used here.

Ice water contents are directly measured (except for "REP). For algorithm development, also needed are mass-dimensional relationships and area-size relationships, necessary inputs into calculations of terminal velocity-diameter relationships, snowfall rates, radar reflectivity, among others. Mass is derived based on the measured IWCs and PSDs used together. The following fits to 2D particle images were done to develop area size relationships

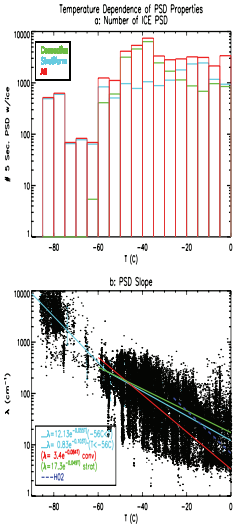
$$Area = \pi/4 \sum N(D) D^2 A_r(D)$$

$$A_r(D) = \alpha D^{\beta}$$

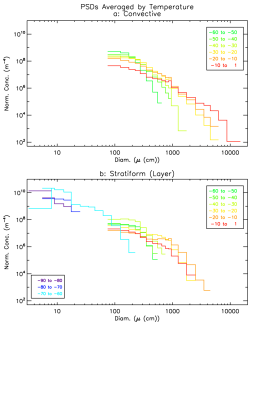
We are in the process of developing fall velocity-diameter relationships.

Results

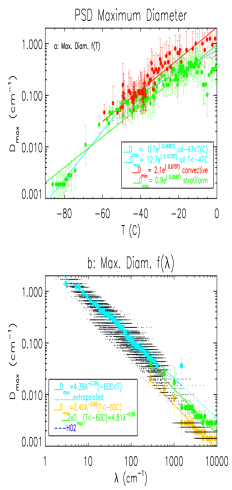
The following summarizes the range of conditions encountered in the various experiments and relationships developed from the data.



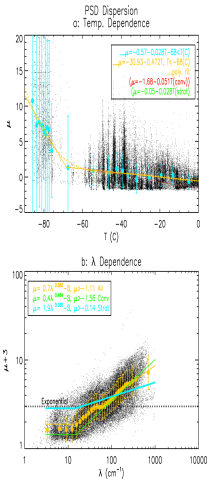
1-The top panel shows the number of 5 sec average PSDs used in the analysis as a function of the air temperature. The lower panel shows the slope of the PSD as a function of temperature, with exponential fits given for all data combined and also subdivided by clouds sampled in the immediate vicinity or within convection and for stratiform (layer) clouds.



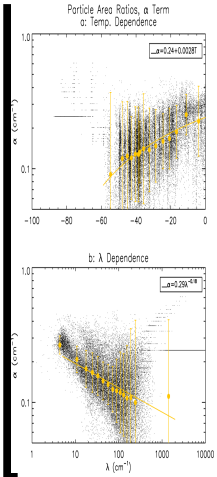
2-Measured size distributions, averaged in 10C temperature intervals, separated by convective (top) and stratiform (layer) clouds (Concentrations in each size bin is the average of concentration recorded when present.



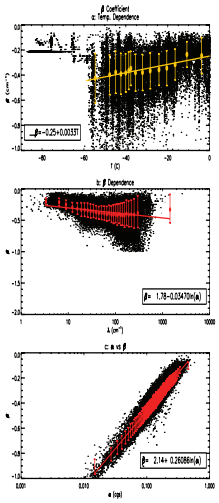
3. The largest diameter of each PSD, shown as a function of (top) Temperature and (bottom) slope of the PSDs. Curve fits are given, with the fits for all data combined and separated according to convective and stratiform clouds.



4. Dispersion of the PSD, shown as a Function of the (top) temperature, and (bottom) slope of the PSD. Curve fits For all data combined and partitioned by convective and stratiform cloud layers are shown.



5. The prefactor in the area ratio versus diameter relationship, shown as a function of the (top) temperature, and (bottom) slope of the PSD. Curve fits representing the observations are shown. [See equation developed for A_r, left panel.]



6. Exponent in the area ratio diameter relationship, shown as a function of the (top) temperature, (middle) slope of the PSD, and (bottom), and as a function of incept parameter. [See equation developed for A_r, left panel.]

Conclusions

We have examined data from ten field programs covering a wide range of sub-freezing temperatures and have represented the measured particle size distributions as a gamma function. Given the wide range of cloud conditions sampled, there is considerable scatter in the parameters of the Gamma distributions. Nonetheless, certain features are prominent. The dependence of the parameters in the gamma fit on temperature and other variables has been examined. Particle cross-sectional areas have also been examined and relationships with temperature and other variables examined. believe that these relationships can be reliably applied to GPM/PMM algorithm development to form a robust set of algorithms to derive cloud properties from single and multi-wavelength radars and radiometers.

Credits

We wish to thank the NASA GPM/PMM Program for supporting this research, as well as a number of investigators who contributed to the results presented in this poster.