Improved representations of ice cloud microphysical properties derived from aircraft in-situ observations during ARM field campaigns

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1. Motivation

- Database of ice cloud microphysical properties has been derived from in-situ observations acquired in variety of locations and from clouds formed by different mechanisms
  - Need probability distribution functions of cloud parameters to understand how properties vary in different regimes
- Knowledge of shapes and size distributions (SDs) of ice crystals with dimensions (D_{max}) < 50 μm needed for database
  - Investigate use of forward scattering probes to derive such SDs

2. Data

- **Mid-Latitude Continental Convective Cloud Experiment (MC3E):** Studied convective clouds in vicinity of SGP site in 2011 using UND Citation
- **Storm Peak Laboratory Cloud Property Validation Experiment (STORMVEX) and Colorado Airborne Multi-phase Cloud Study (CAMPS):** Studied winter orographic and frontal clouds near Steamboat Springs at ground (STORMVEX) and with Wyoming King Air (CAMPS)

Probe	2DC	CIP	HVPS
Resolution	30 μm	25 μm	150 μm
Diodes #	32	64	128
Range	30 - 960 μm	25 – 1600 μm	150 - 19200 μm
Photos			

Table 1. MC3E Probe Description

Probe	2DC	Fast 2DC	2DP
Resolution	25 μm	25 μm	200 μm
Diodes #	32	64	32
Range	25 - 800 μm	25 – 1600 μm	200 - 6400 μm
Photos			

Table 2. Probes on King Air; STORMVEX used ground-based CIP and PIP

3. Scattering Library

- Single-scattering properties of hexagonal ice crystals with D < 50 μm and varying aspect ratios (*ARs*, 0.1, 0.25, 0.5, 1.0, 2.0, 4.0) (Fig. 1) calculated using the Amsterdam Discrete Dipole Approximation (ADDA)

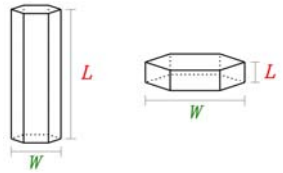

Fig. 1 (top) Length (*L*) & width (*W*) of ice crystals. AR defined as *L*/*W*; long column (left) has higher *AR*, while thin plate (right) has smaller *AR*.

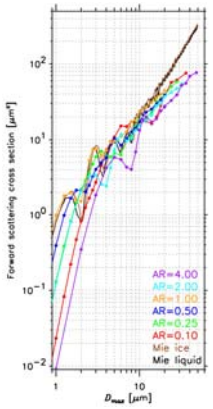

Fig. 2 (right) Calculated forward scattering cross sections of hexagonal ice crystals and spheres that would be detected by FSSP-type probe between 4 and 12°; cross sections very different for liquid/ice spheres and hexagonal crystals with large variety of retrieved sizes possible from cross-section for varying shaped ice crystals

4. Cloud Properties

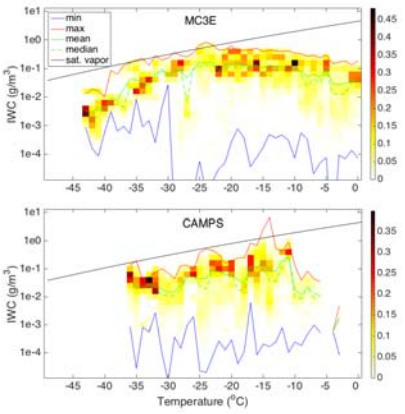

Fig. 3: MC3E and CAMPS PDFs for IWC dependence on temperature; larger IWCs on average in convective clouds

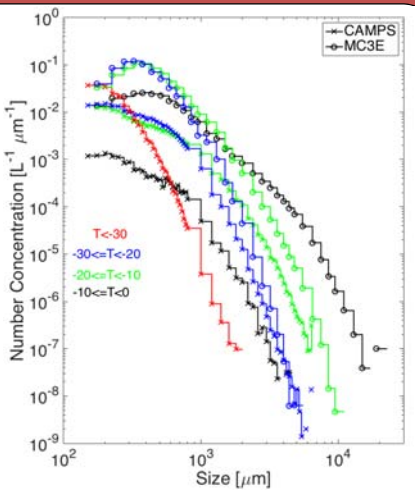

Fig. 4: N(D) from MC3E and CAMPS for varying temperatures; effective radii and median diameter larger for wintertime frontal clouds.

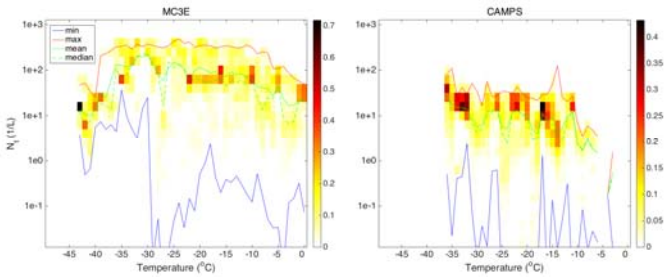

Fig. 5: Total number concentration from MC3E and CAMPS; number concentrations lower for wintertime frontal clouds than for summertime convective clouds. Data in Figs. 3, 4 and 5 currently being used to evaluate model simulations.

5. Particle Sizing by FSSPs

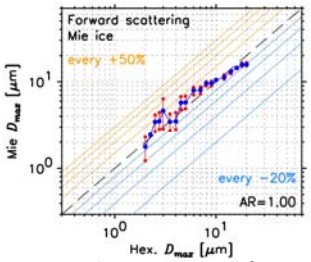

Fig. 6: Crystal size computed from scattering cross section and Mie theory vs actual crystal size. Blue dots represent mean of all possible values, red dots are minimum and maximum values. Every +50% (orange) and -20% (sky blue) from the 1:1 line (black) shown

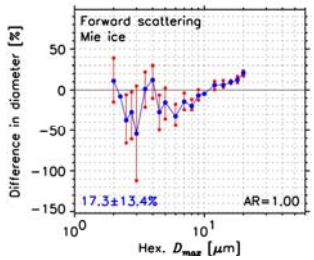

Fig. 7: Difference between actual crystal size and that determined from Mie theory for crystals with AR of 1.0. Mean and standard deviation of absolute values of blue circles are embedded in each panel.

- Differences in particle size smallest for D_{max}~10 μm, larger for D_{max}<10 μm due to interference structures) and for D_{max}>10 μm due to nonsphericity
- Differences are up to 112% non-spherical shapes (*AR*=0.1 and 4.0) have larger differences

6. Summary

1. PDFs of microphysical quantities, complete with uncertainty analysis, now available for several field projects
2. Single-scattering libraries of small crystals being used to study performance of FSSP, and have additional applications as well

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