Small cloud particle shapes in mixed-phase clouds

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1. Motivation

- **Mixed-phase clouds ubiquitous in many locations, including Arctic**
- **Partitioning of mass into liquid and ice poorly understood, yet affects radiative properties, sedimentation and microphysical process rates**
- **In-situ observations permit investigation of small-scale variation in cloud particle characteristics in mixed-phase clouds**
- **Can high-resolution (2.3 μm) images from a Cloud Particle Imager (CPI) differentiate if small (< 60 μm) cloud particles composed of water or ice?**
- **To what extent are these CPI images contaminated by large crystal shattering?**

2. Are CPI Images Real or Shattered Particles?

- **Use data from mixed-phase arctic clouds recorded by CPI Version 1.0 during M-PACE and Version 2.0 during ISDAC**
- **CPI records 2.3 μm resolution images of cloud particles, but particles might shatter on surfaces (Figure 1)**
- **Poisson statistics give probability that multiple particles will occur in same image frame which can be compared against observed distribution of multi-particle frames (Figure 2)**

Figure 1: Photo of CPI installed on Convair-580 during ISDAC

- **Shattering a problem for ice-clouds, not for liquid and perhaps for mixed-clouds**
- **Restrict analysis to single particle images to avoid shattered artifacts**

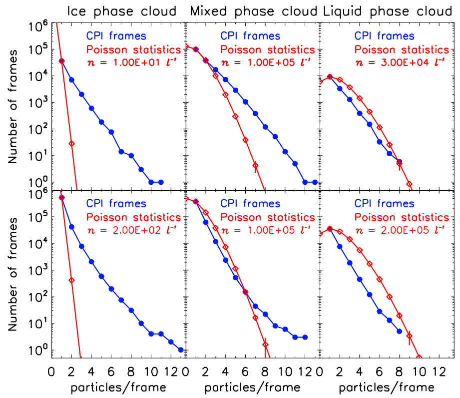

Figure 2: Frequency of occurrence of frames with indicated # of particles during ISDAC (top) and M-PACE (bottom) compared to expected distribution from Poisson statistics

3. CPI Image Analysis

Differences in area ratio (α) of liquid particles observed during M-PACE/ISDAC established that particles with D_{max} > 35 μm and focus > 45 appropriate for image analysis (Figure 3)

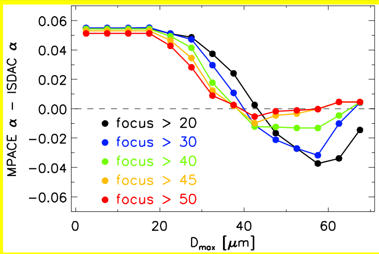

Figure 3: α from M-PACE - α from ISDAC in liquid clouds as function of D_{max} & focus

4. Mixed-Phase Cloud Hydrometeor Images

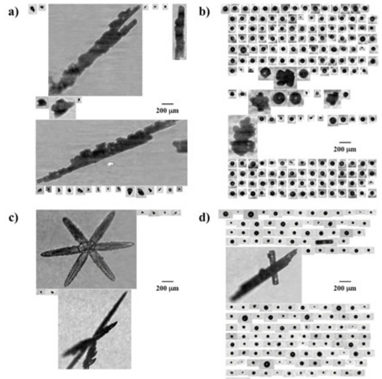

Fig. 4: Examples of particles imaged in mixed-phase clouds for liquid fraction f a) 0.18 (MPACE), b) 0.80 (MPACE), c) 0.12 (ISDAC), and d) 0.86 (ISDAC), where f=LWC/TWC (LWC, liquid water content; TWC total water content). In addition to more ice for low f, shapes of small particles also different (Fig. 5)

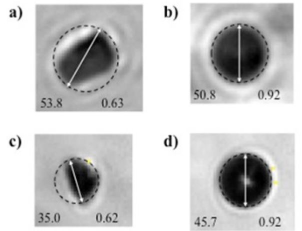

Fig. 5: Magnified image of small particles with D_{max} in μm (left) and α (right) embedded. Fig. 5a is particle from Fig. 4a, 5b from 4b, etc. Difference in small particle shape between water- and ice-dominated clouds noted.

5. Dependence of Particle Shape on LWC/TWC

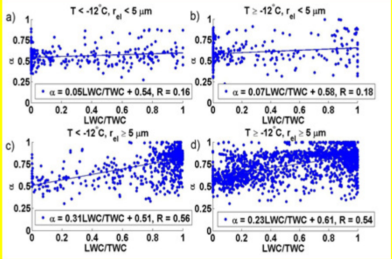

Fig. 6: Mean α as function of LWC/TWC for ISDAC and M-PACE mixed-phase clouds for different temperature (T) & liquid effective radii (r_{el}). Mean α correlated with LWC/TWC only for r_{el} > 5 μm.

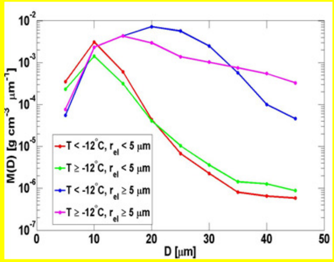

Fig. 7: Average mass distribution function m(D) measured by forward scattering probes for different T and r_{el} ranges during ISDAC/M-PACE.

- **Small particles have different shapes when LWC/TWC > 0.5 than when LWC/TWC < 0.5, but mean α not always correlated with LWC/TWC**
- **This depends on r_{el} of liquid drops because CPI threshold of 35 μm permits imaging of liquid particles only for larger r_{el}**

6. Conclusions

- **CPI can consistently obtain shape information for particles with D_{max} > 35 μm and focus > 45**
- **Not all small particles in mixed-phase clouds are supercooled water: some are ice with fraction depending on total LWC/TWC**

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