Small cloud particle shapes in mixed-phase clouds during ISDAC and M-PACE

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Cloud phase breakout, 5 November 2013

Key Questions about Mixed-Phase Clouds

- *From Baumgardner et al. (2012)*

1. **What is the definition of a mixed-phase cloud?**
   - **What is minimum ratio of LWC/IWC required to identify cloud as mixed-phase**

2. **What are spatial scales of mixing between liquid & ice and how do they vary with height & meteorological conditions?**

3. **How are liquid & ice partitioned with respect to particle sizes (e.g., are all small particles liquid & all large particles ice)**

4. **How can small particles be distinguished from supercooled droplets & do frozen drops evolve in shape according to condition?**

Phase Partitioning: In-Situ Observations

- Partitioning of mass into liquid & ice poorly understood, yet affects radiative properties, sedimentation and microphysical process rates

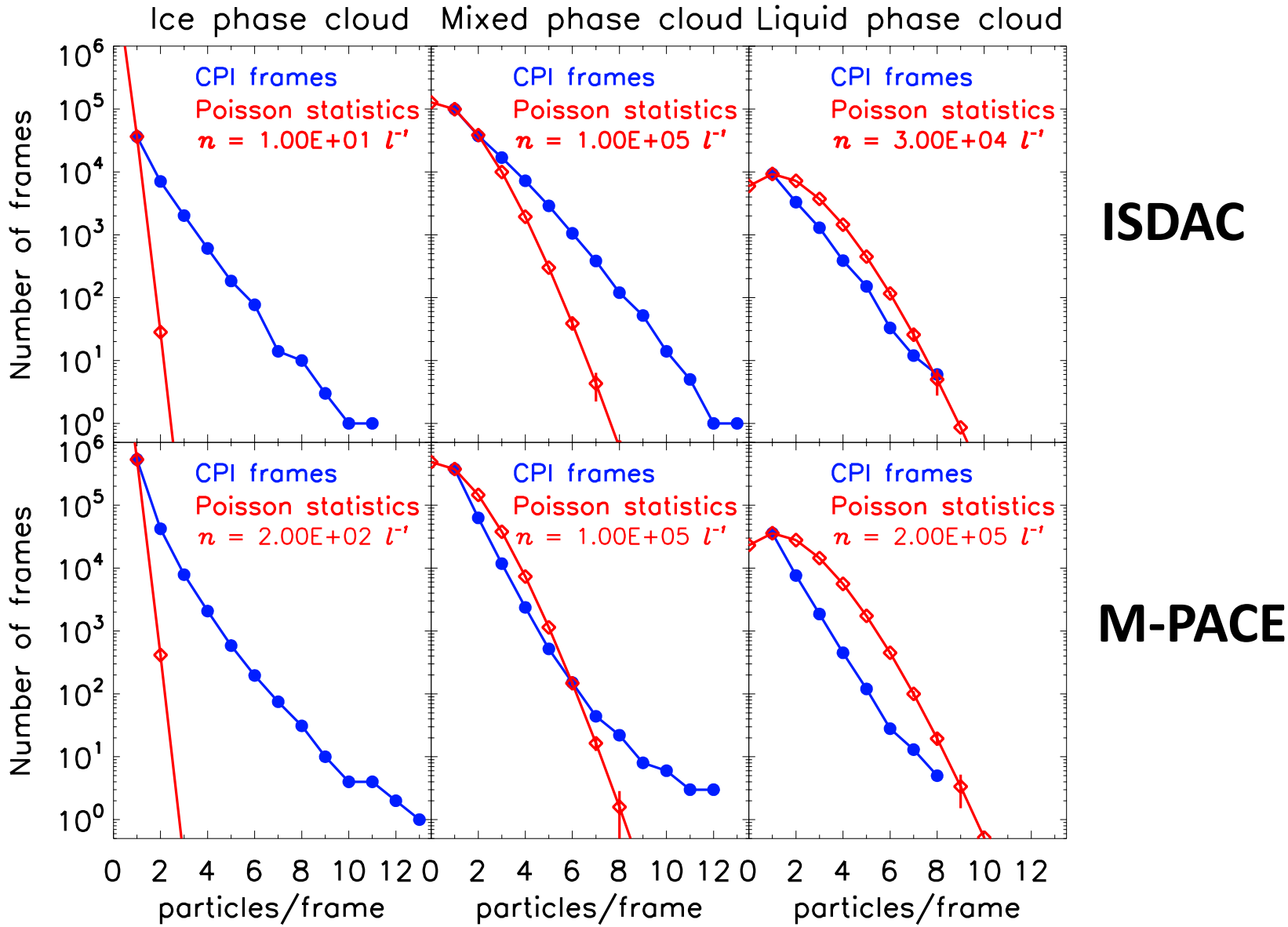
- In-situ observations permit investigation of small-scale variation in cloud particle characteristics in mixed-phase clouds

- Can high-resolution CPI (2.3 μm) observations differentiate whether small cloud particles are composed of water or ice?

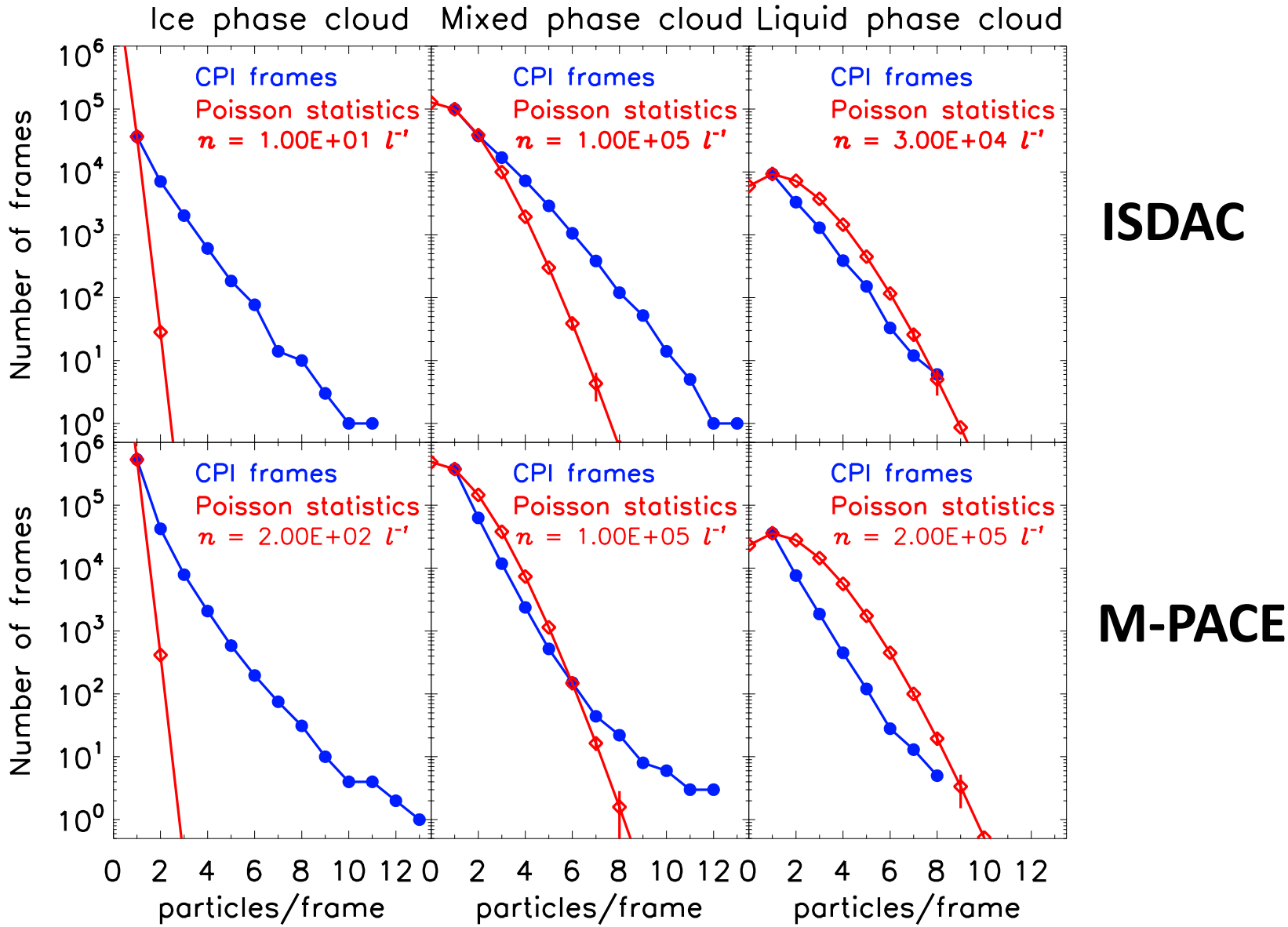
- To what extent are CPI images contaminated by large crystal shattering?

Are CPI Images Real or Shattered Particles?

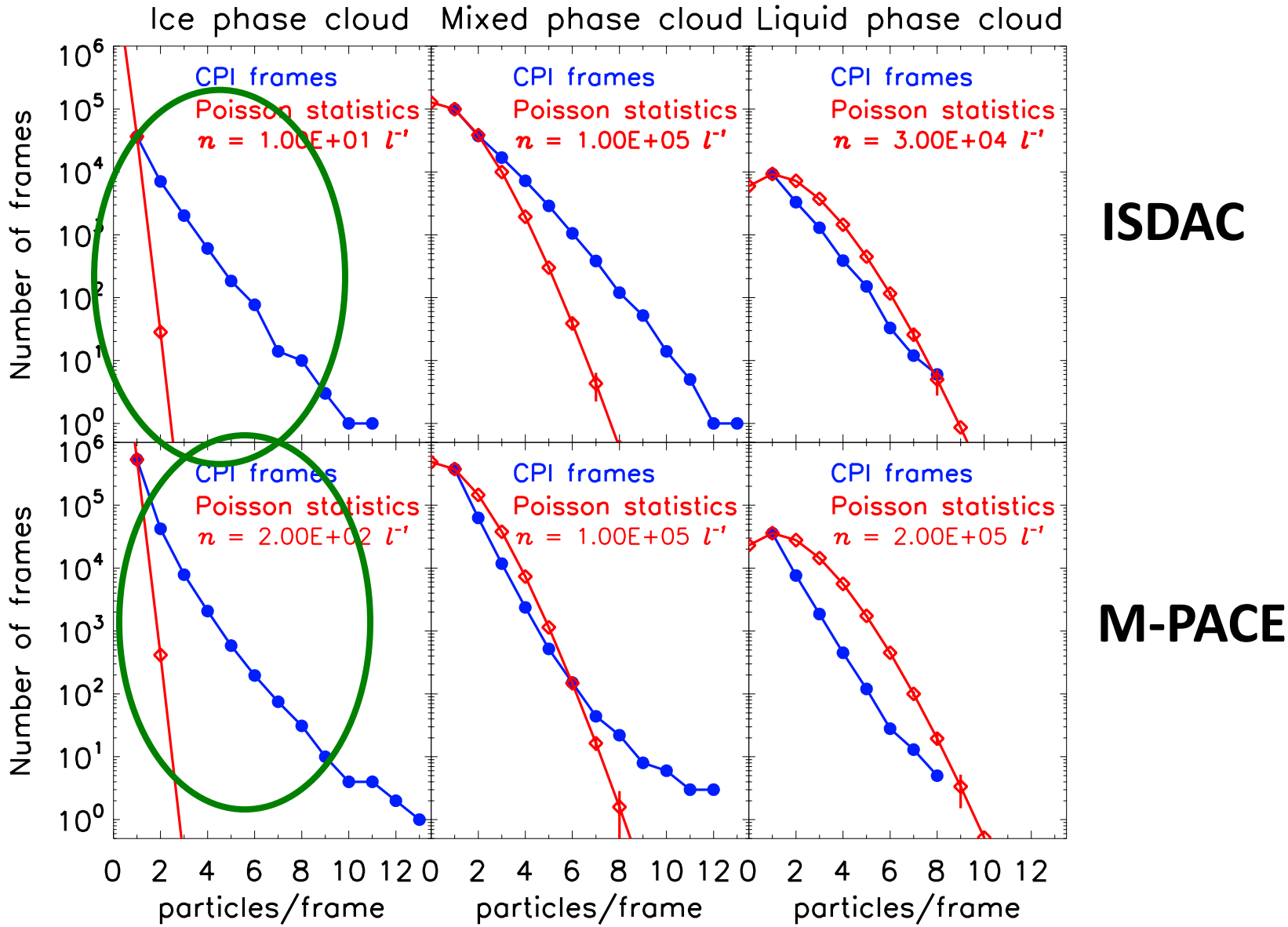
- Use data from mixed-phase arctic clouds recorded by CPI Version 1.0 during M-PACE and Version 2.0 during ISDAC
- CPI is triggered when at least 1 particle in sample volume
- Poisson statistics give probability that multiple particles will occur in same image frame which can be compared against observed distribution of multi-particle frames



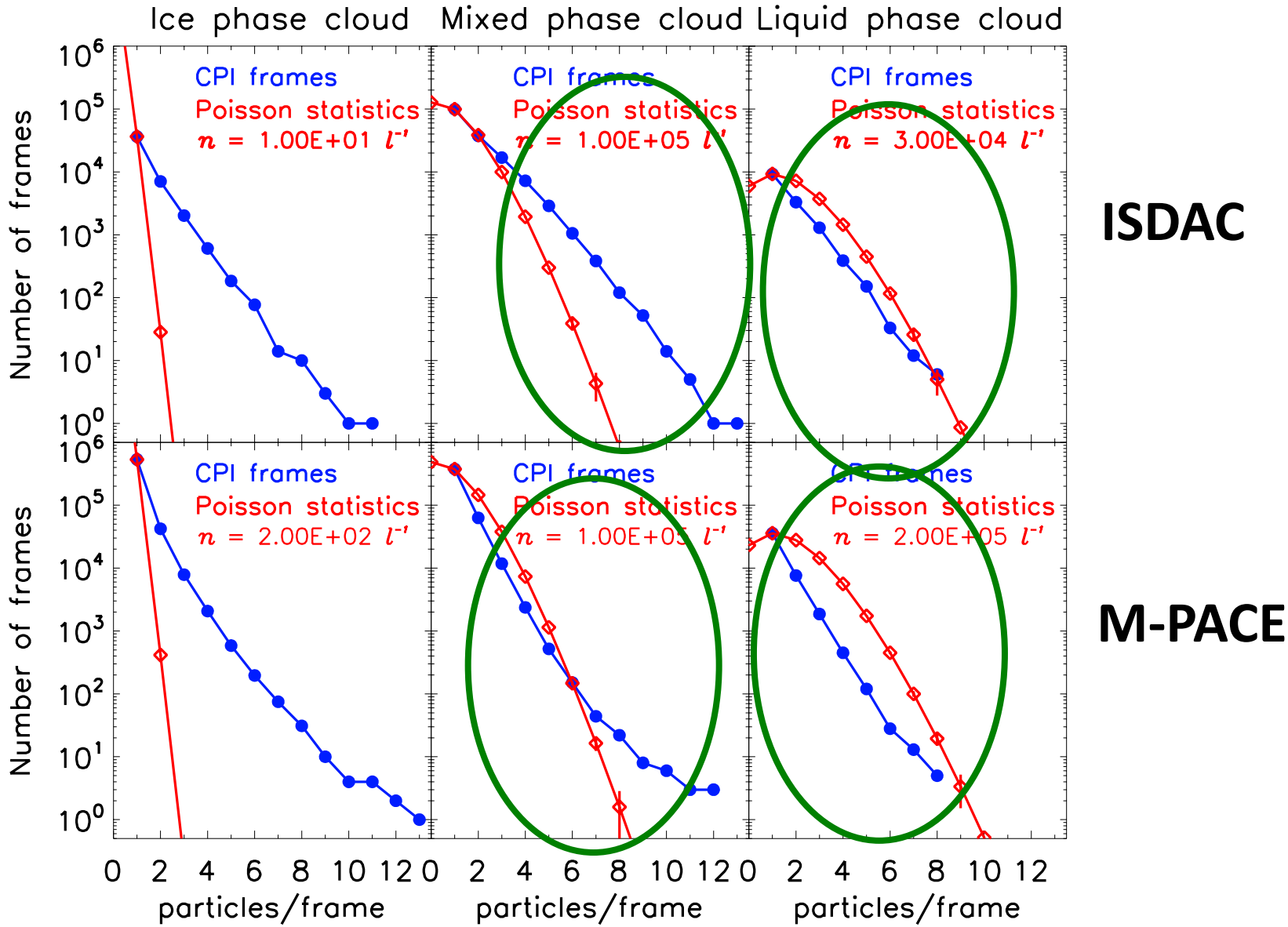
Blue curve shows frequency of occurrence of frames with indicated # of particles per frame;



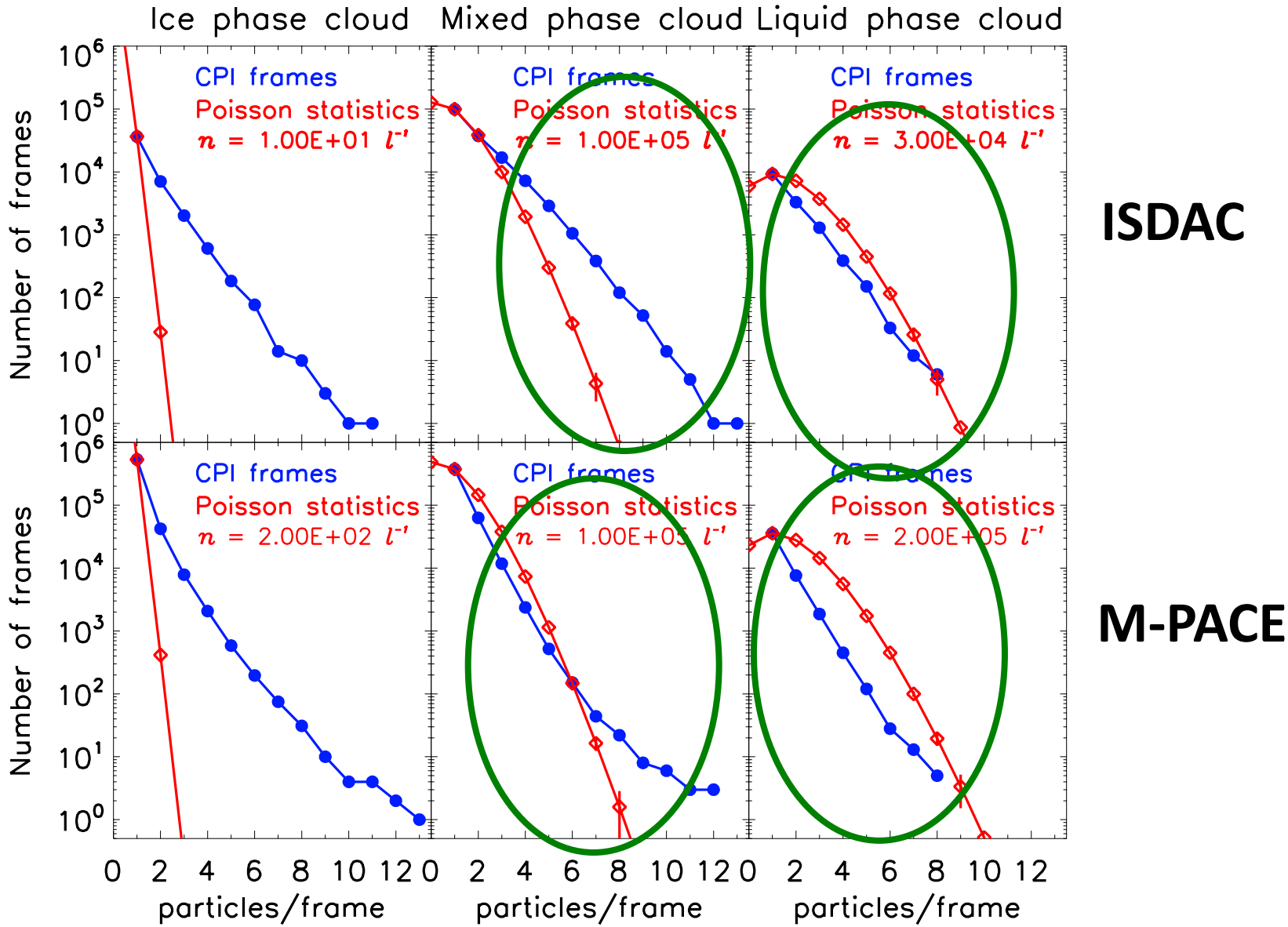
Blue curve shows frequency of occurrence of frames with indicated # of particles per frame; red curve shows expected distribution from Poisson statistics



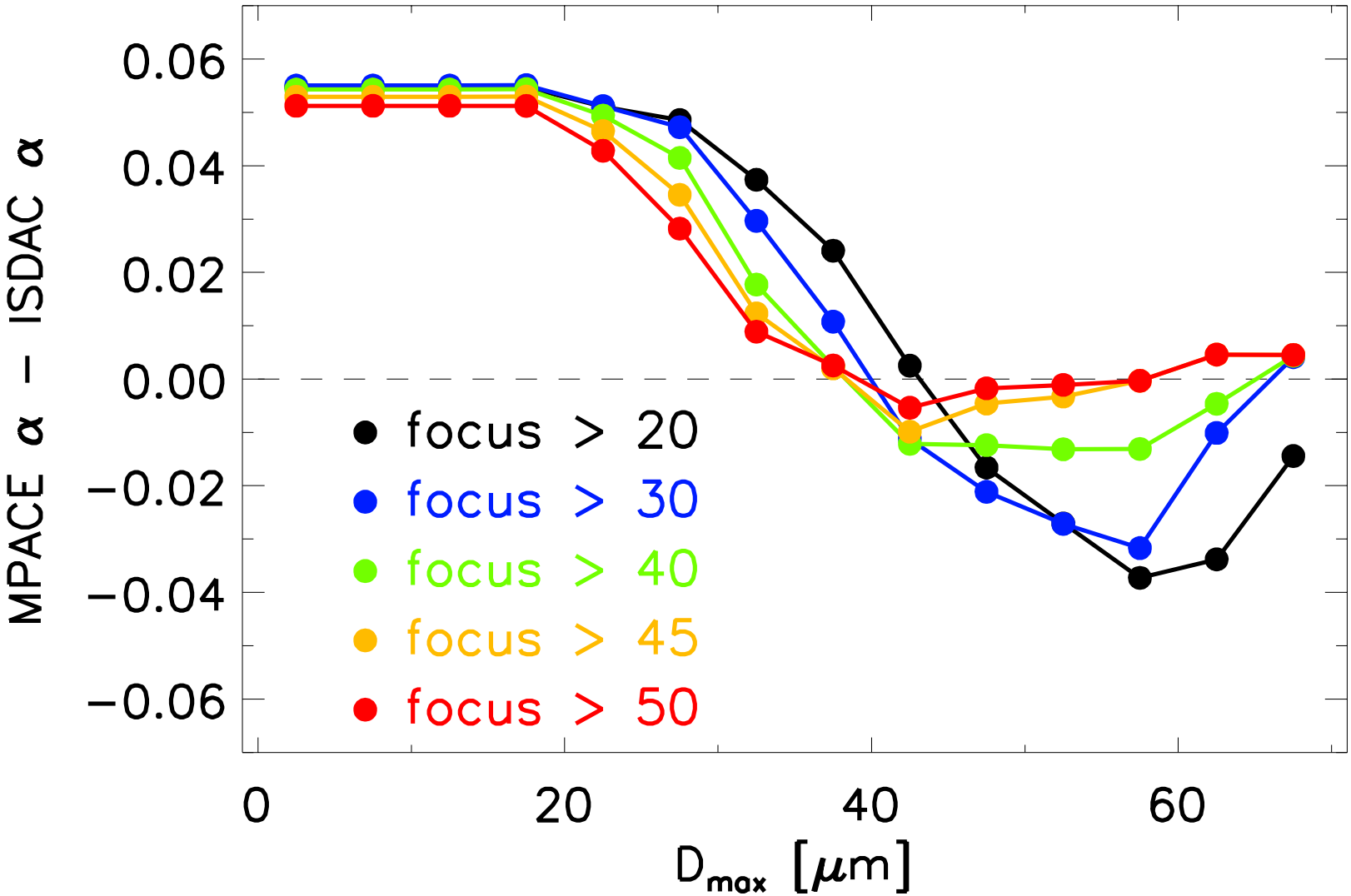
For ice clouds, more particles occurring than expected for both ISDAC & M-PACE



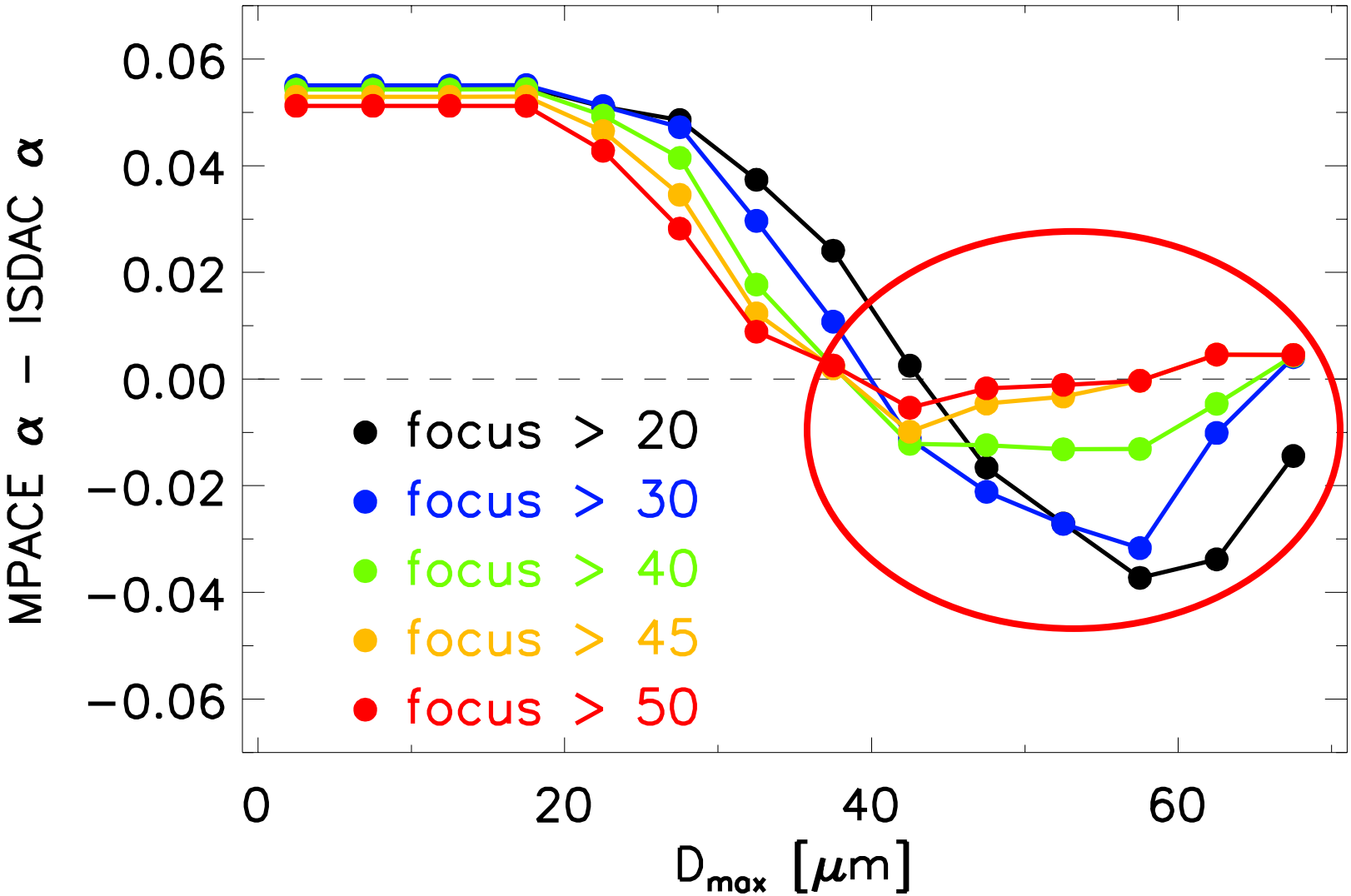
For liquid and mixed-phase clouds, observed & expected distributions similar



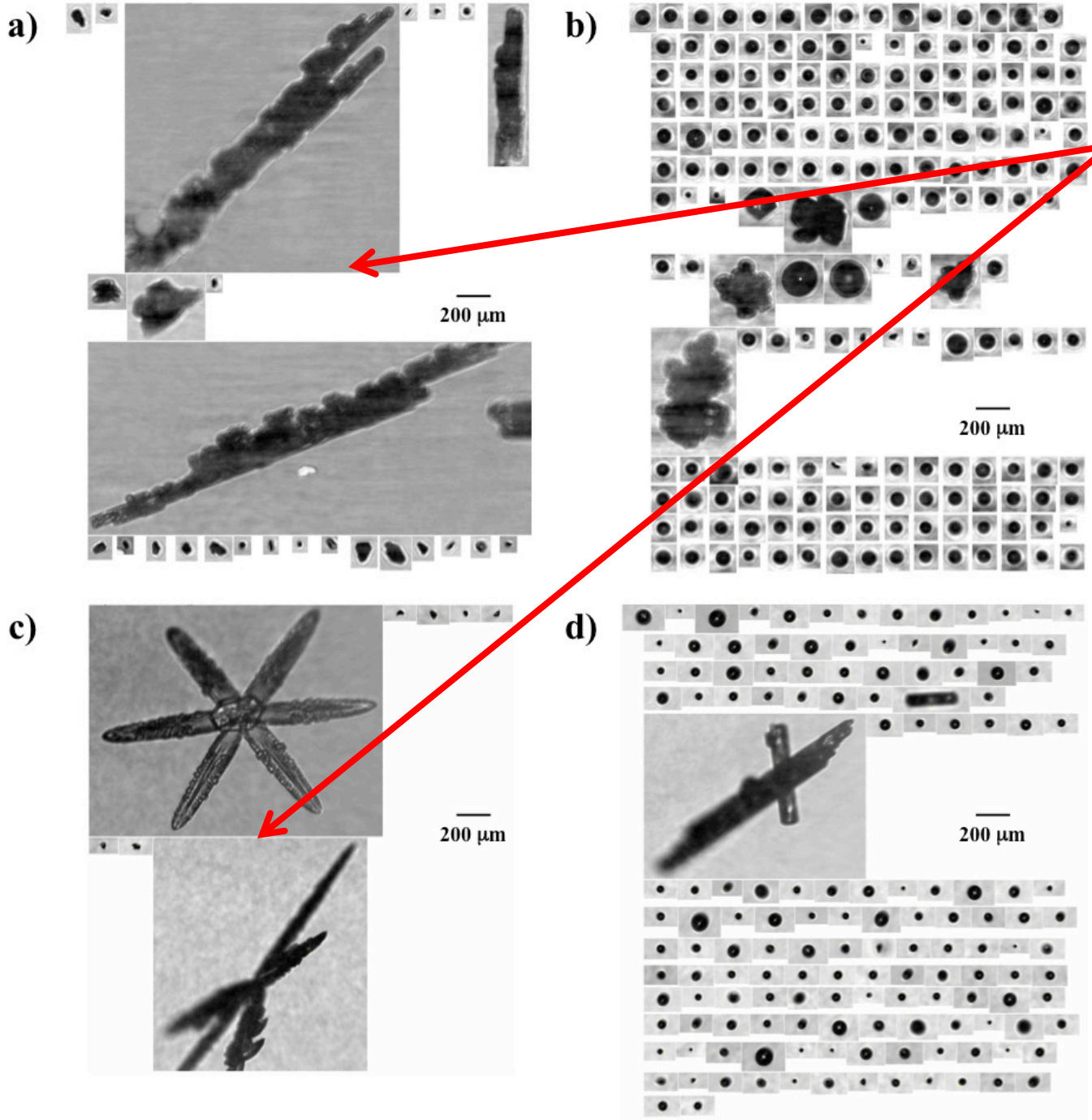
For liquid and mixed-phase clouds, observed & expected distributions similar → Shattering not problem for mixed- & ice-phase clouds, but in any event, we restrict analysis to images with single-frame



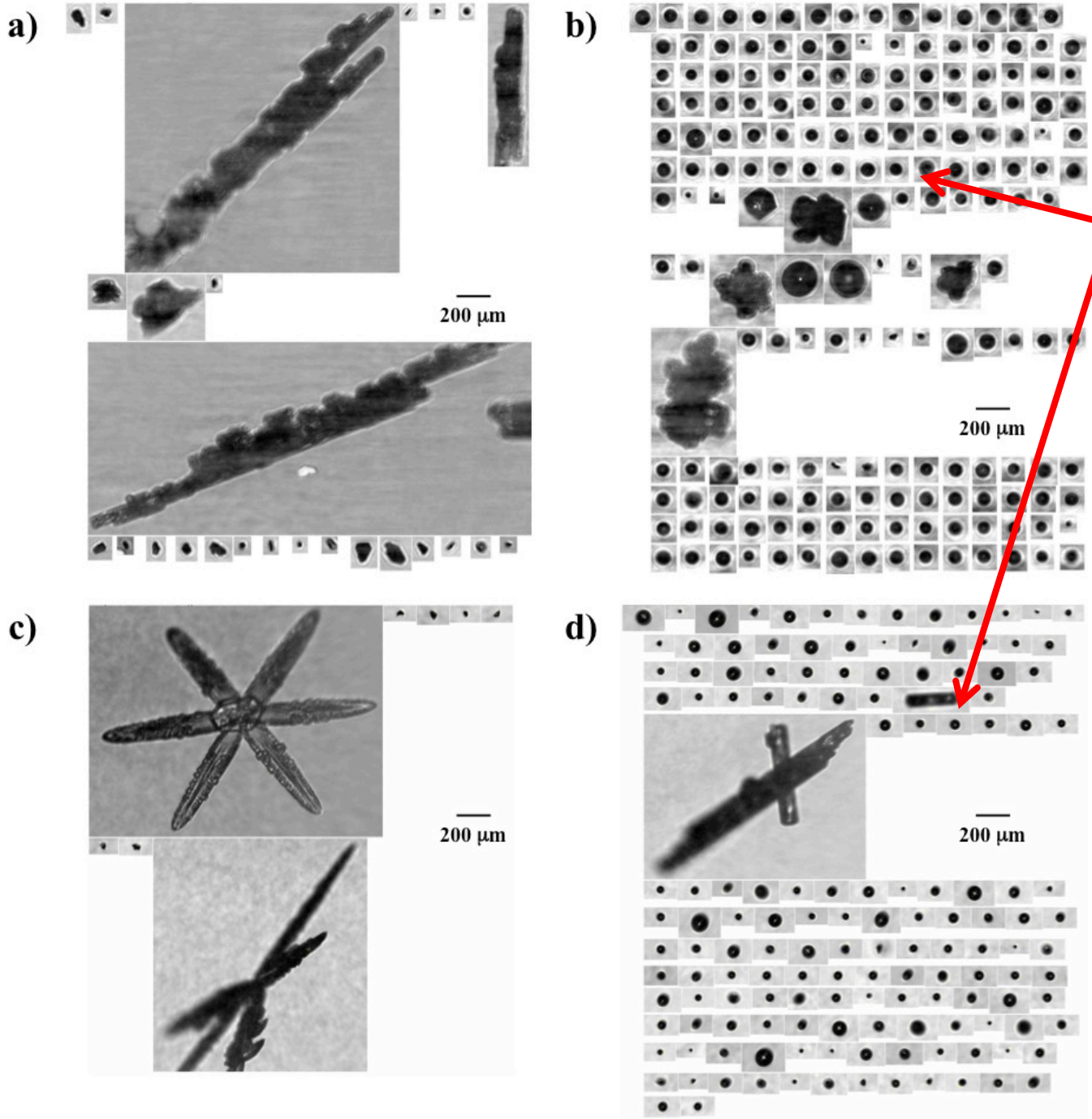
Differences in area ratio (α) of liquid particles observed during M-PACE/ISDAC



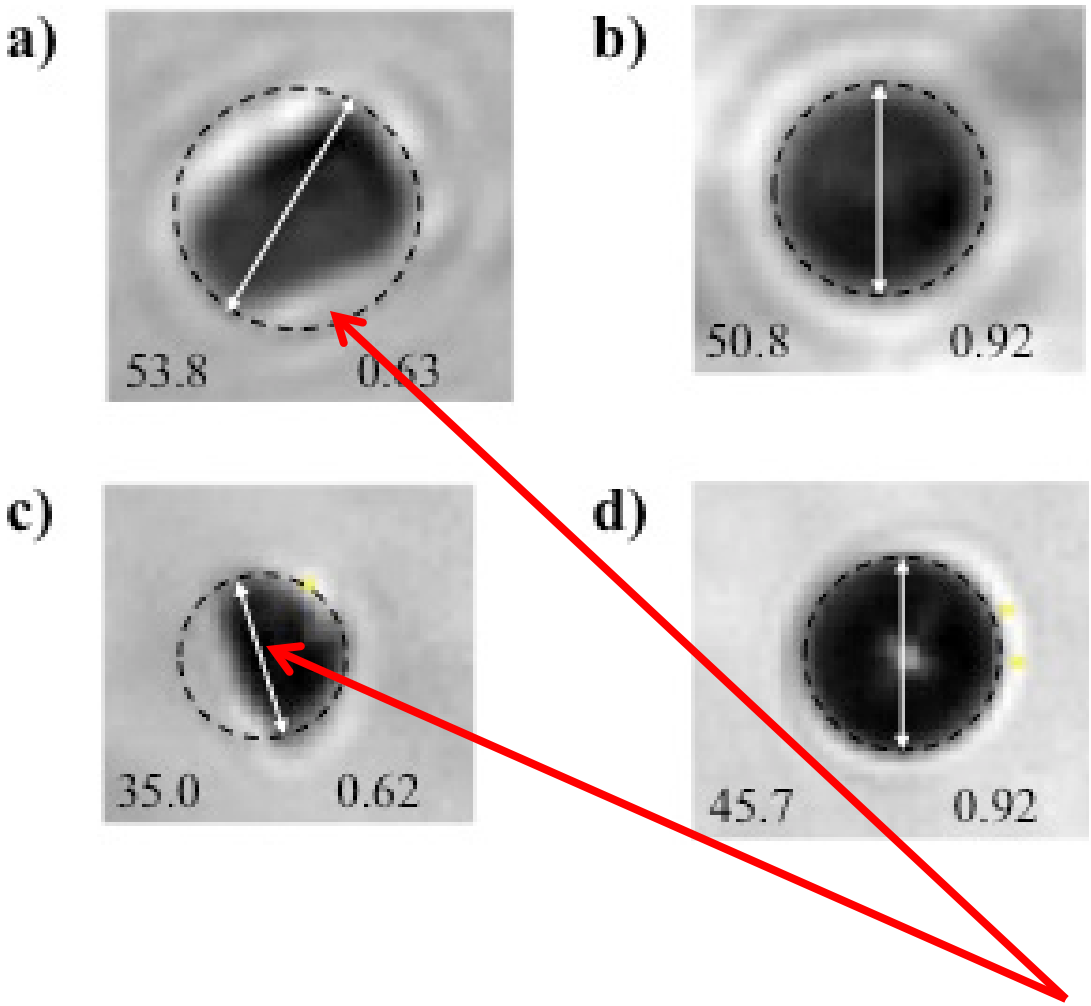
Differences in area ratio (α) of liquid particles observed during M-PACE/ISDAC establishes that particles with D_{max} > 35 μm and focus > 45 appropriate for image analysis



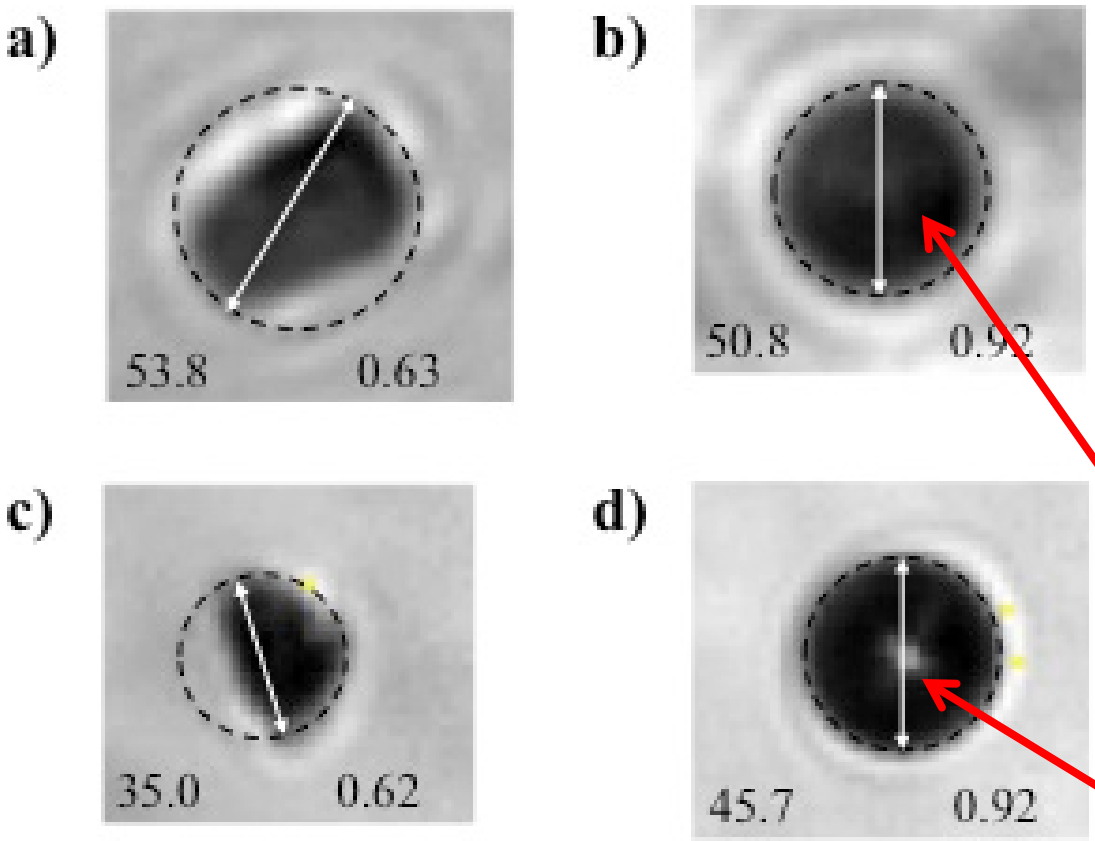
Images from ice-dominated



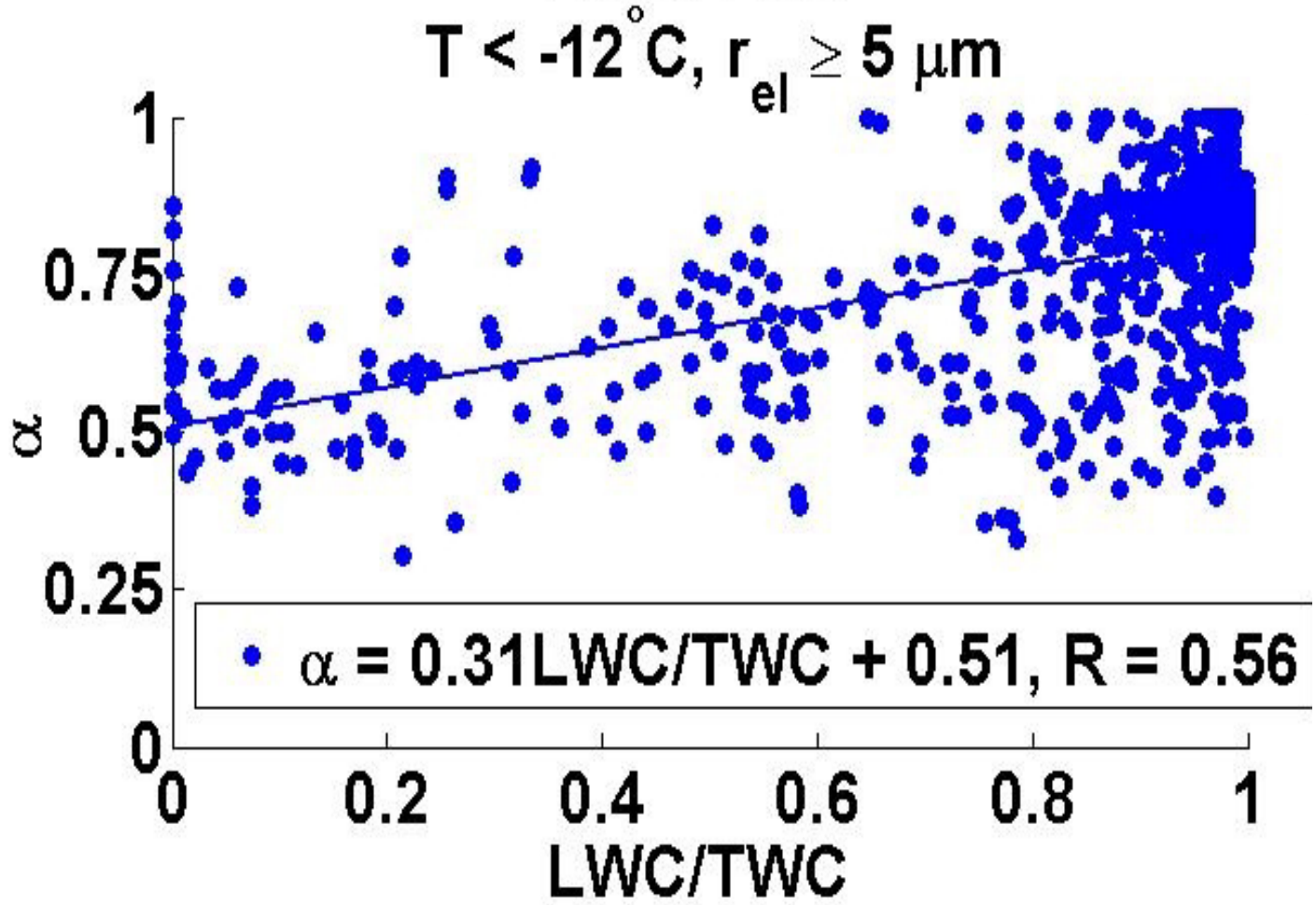
Images from ice-dominated and liquid-dominated mixed-phase clouds



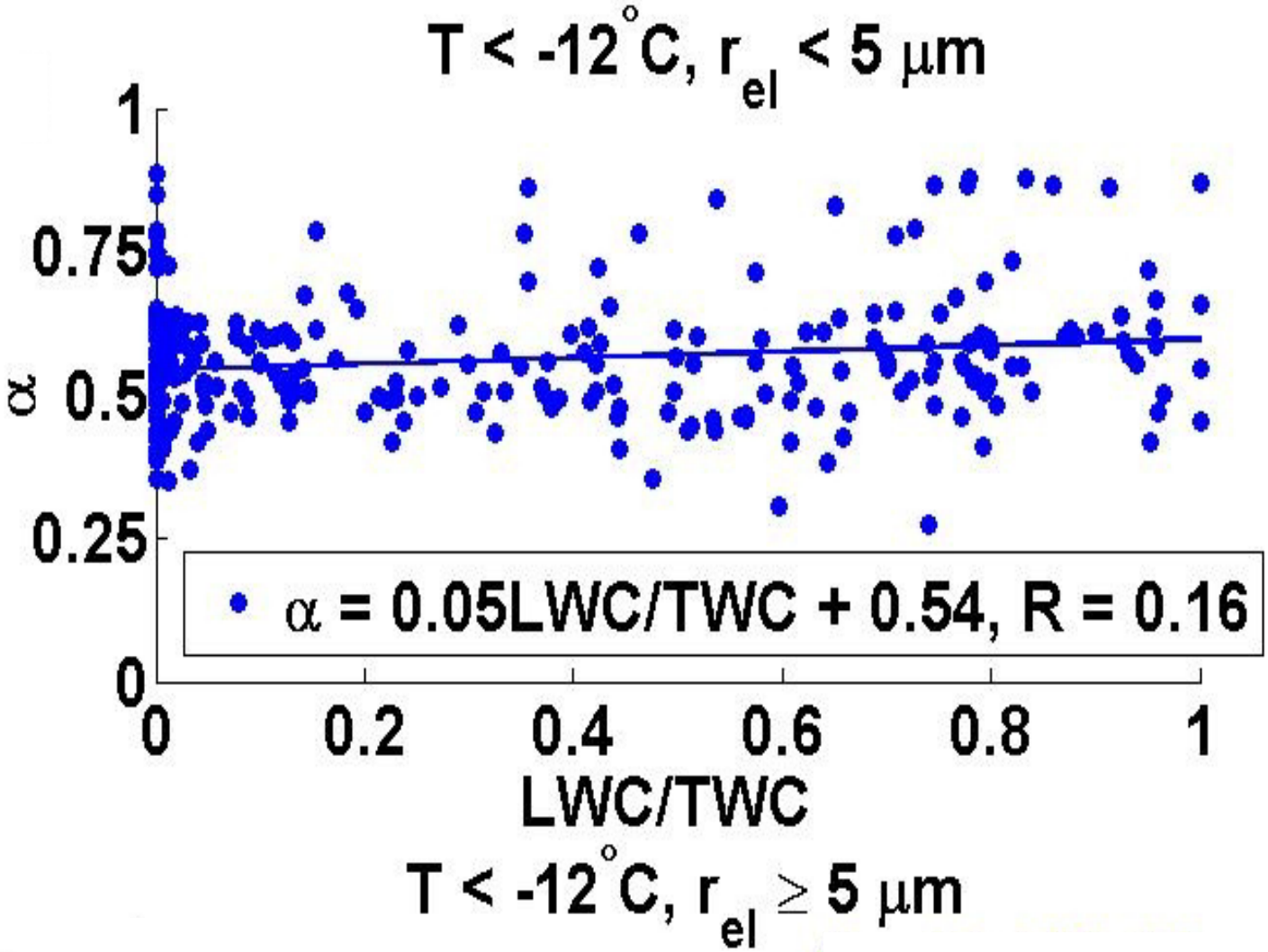
Magnified image of small particles in ice-dominated



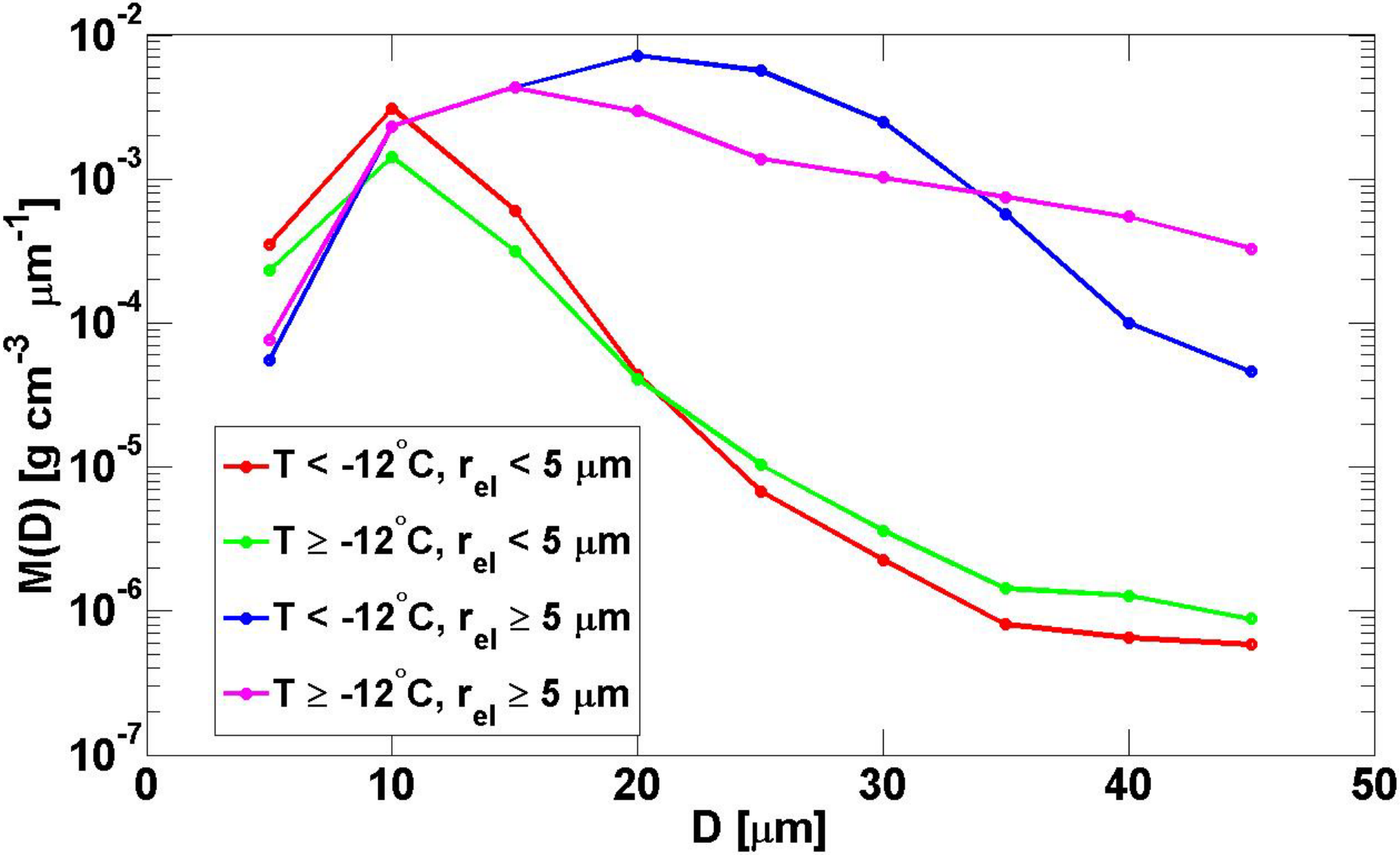
Magnified image of small particles in ice-dominated and water-dominated mixed-phase clouds noted.



Characterizing mean area ratio α, derived from 10-sec averages of all CPI images, as function of LWC/TWC show strong correlation in some conditions



Characterizing mean area ratio α, derived from 10-sec averages of all CPI images, as function of LWC/TWC show strong correlation in some conditions, but not in others



Difference related to effective radius: CPI able to detect liquid drops only when effective radii is large

Conclusions & Future Steps

- CPI provides reliable shapes for D_{max} > 35 μm and focus > 45
- Not all small particles in mixed-phase are supecooled water: some are ice and fraction varies with LWC/TWC
- CPI can somewhat distinguish between water/ice hydrometeors but
  - Discrimination between water/ice for smallest hydrometeors still difficult
- Elimination of shattered artifacts from probes still requires care and caution
- Fine spatial resolution observations required to determine spatial scale of mixing
- Observations in greater range of aerosol concentrations/compositions & meteorology

THE FUTURE

- **Workshop on Data Analysis and Presentation of Cloud Microphysical Measurements**
  - **Boston, MA, July 5-6 2014**
  - **Purpose to test & compare as many processing and analysis methodologies and algorithms as possible**
  - **Test data sets and synthetic data sets will be used in comparisons**
  - **Document processing & analysis methodologies, their similarities & differences, and if possible recommend optimum procedures and their uncertainties**