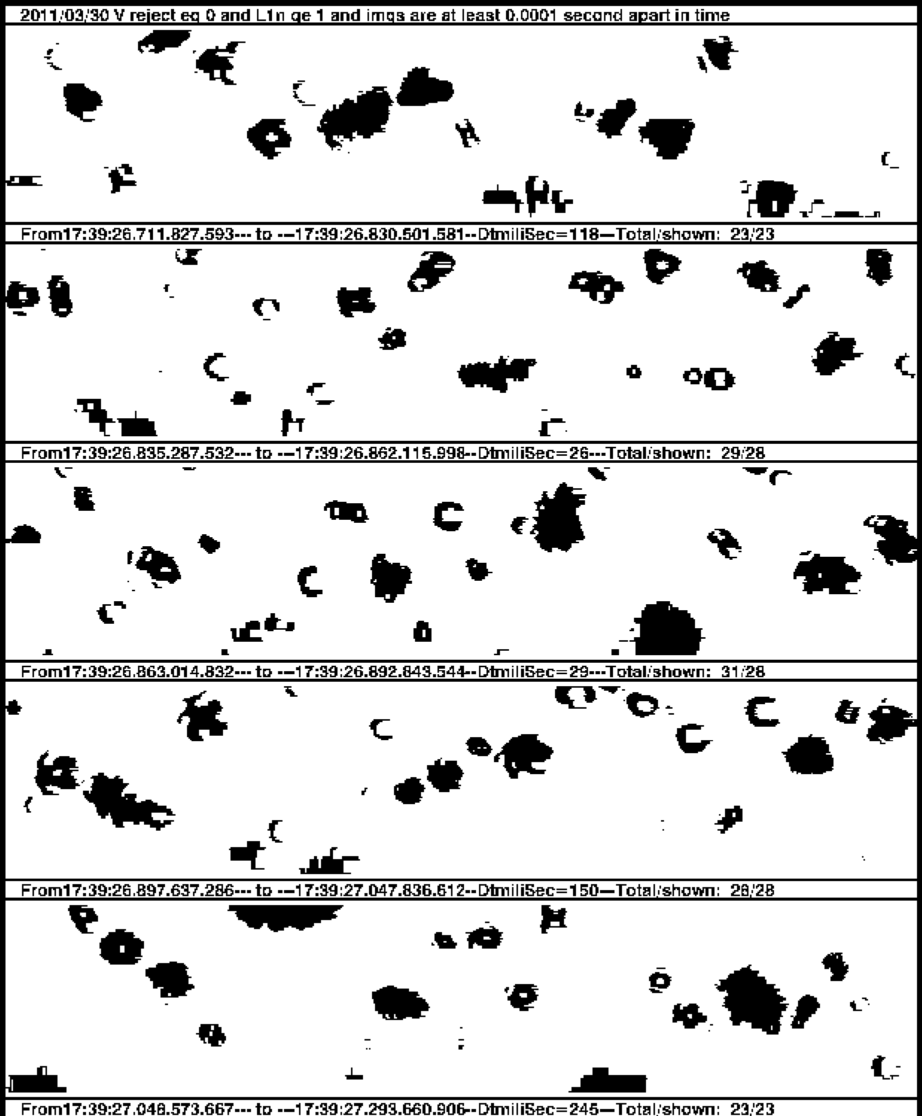
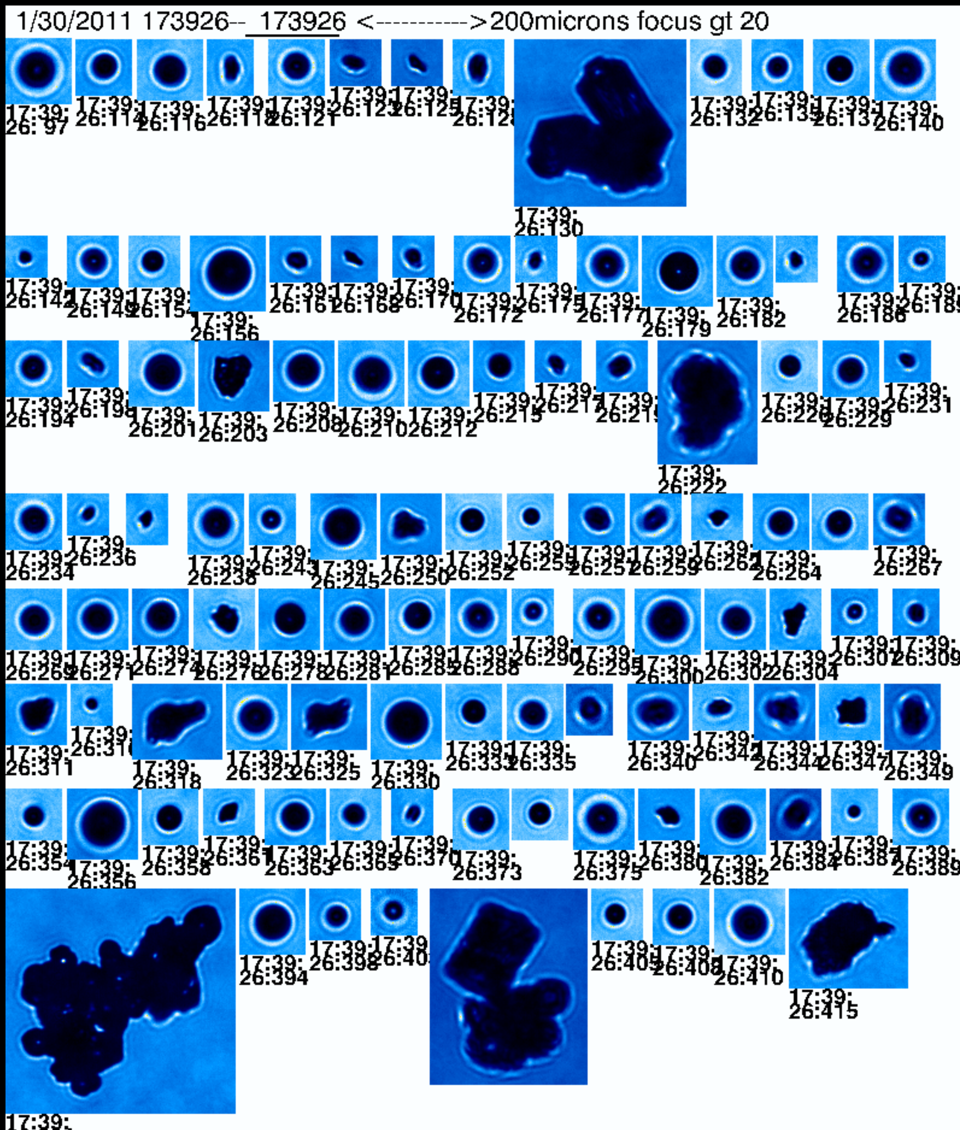
Learjet Operational Summary

- The Learjet flew a total of 12 ICE-T Missions.
- Learjet Penetrated 137 Cumulus Cloud Turrets with Temperatures between +22 C and -24 C.
- The Principal Role of the Learjet was to Penetrate New, Growing Turrets in the Region of -5 to -10°C to Search for Ice Initiation and then Climb with the Developing Turret.

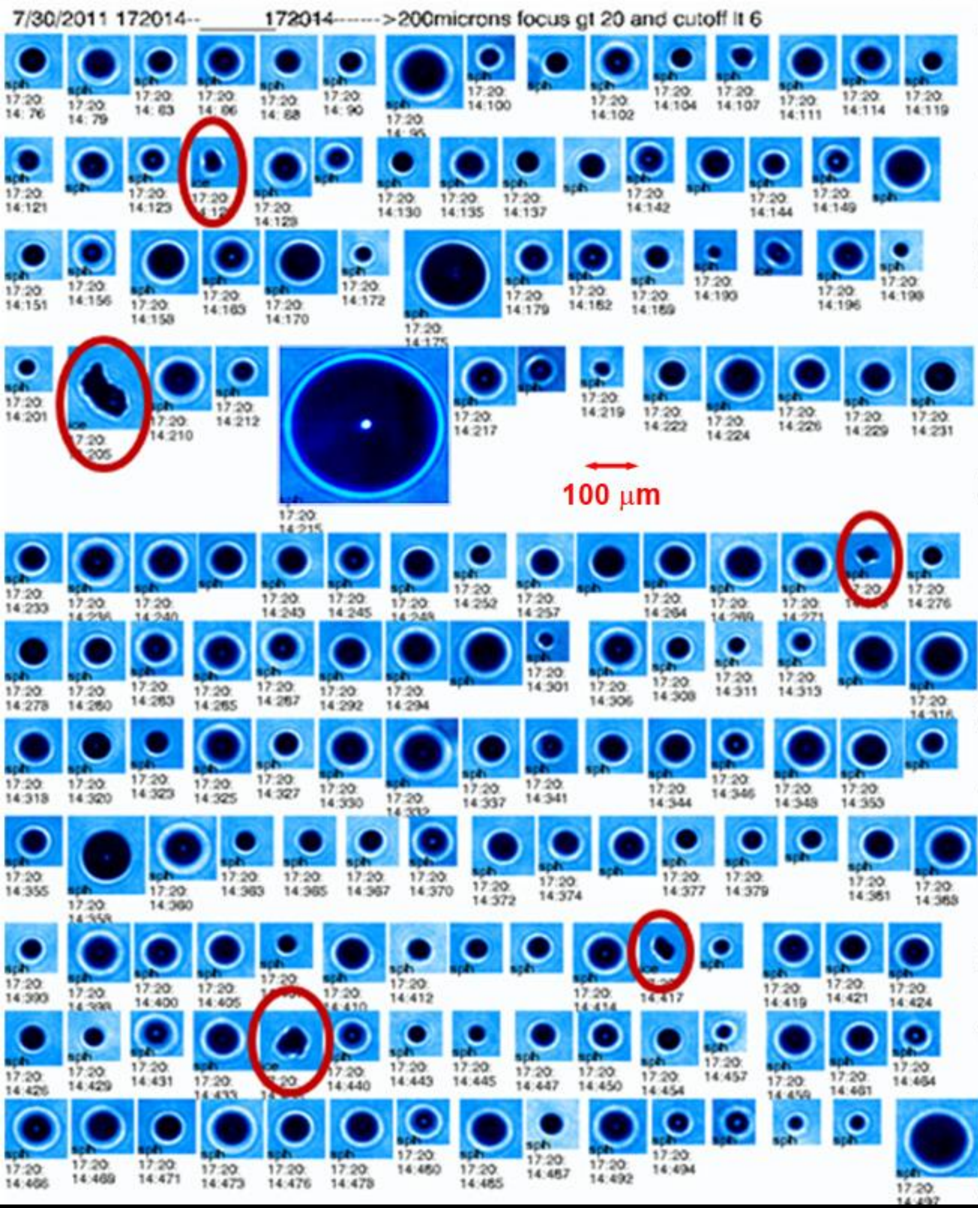
An Example of 2D-S Images in (Mixed-phase?) Cloud

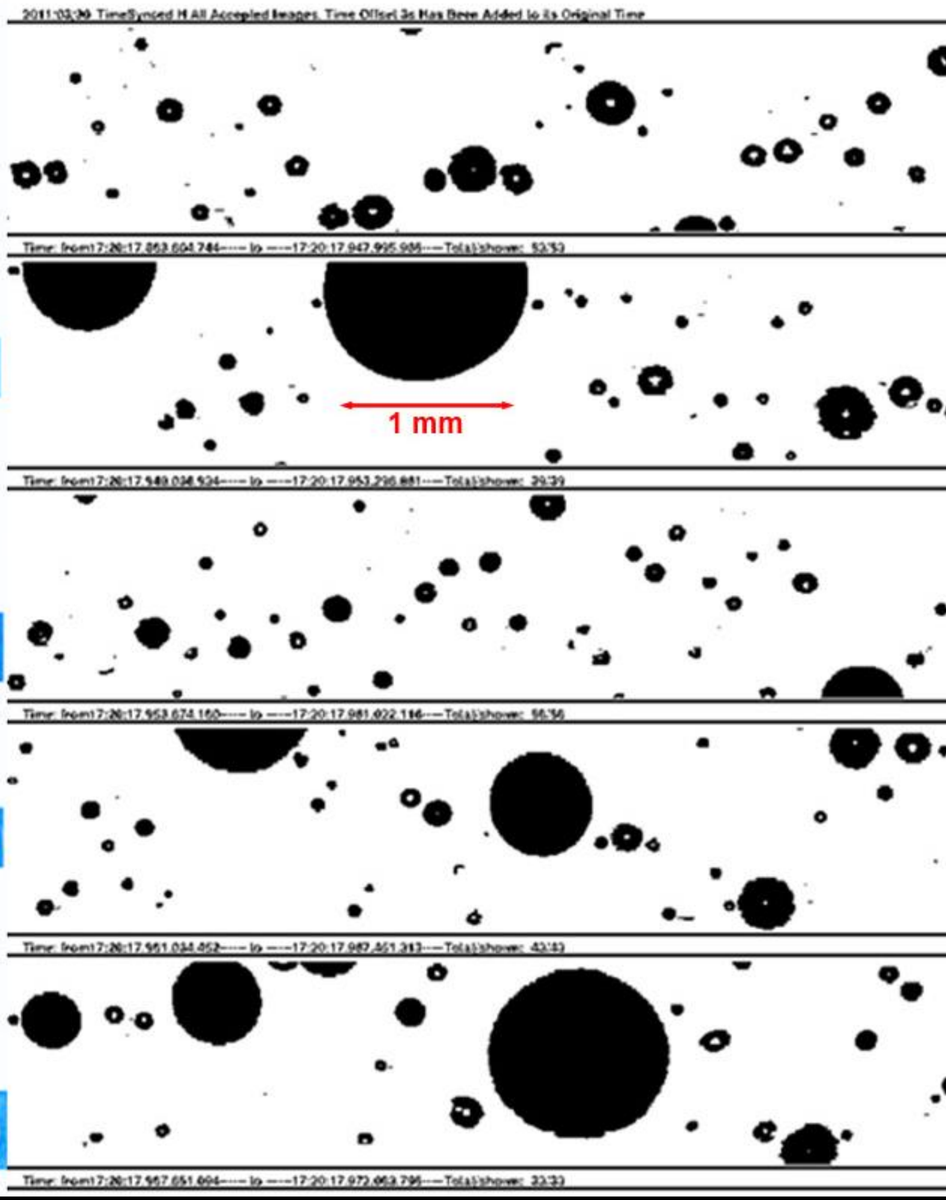


CPI Images Show Several Supercooled Drops (No Activity on Icing Probe)



Example of First Ice Observed at -8 °C in the Middle of an Updraft with Supercooled Millimeter Drops

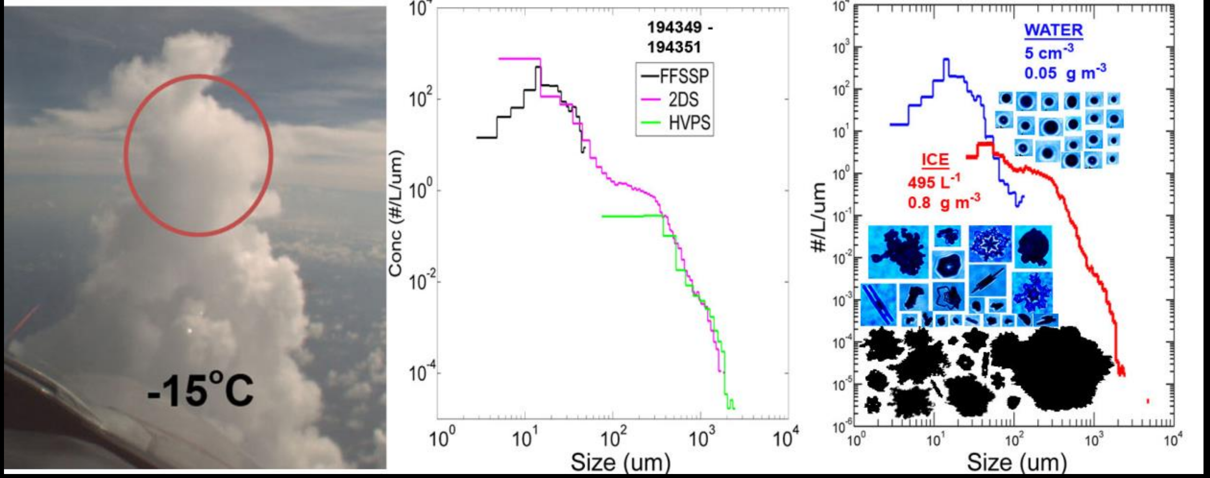




3V-CPI (CPI Portion) Images are used in Conjunction with 2D-S Image Data to Provide Quantitative Water Drop and Ice Particle Size Distributions

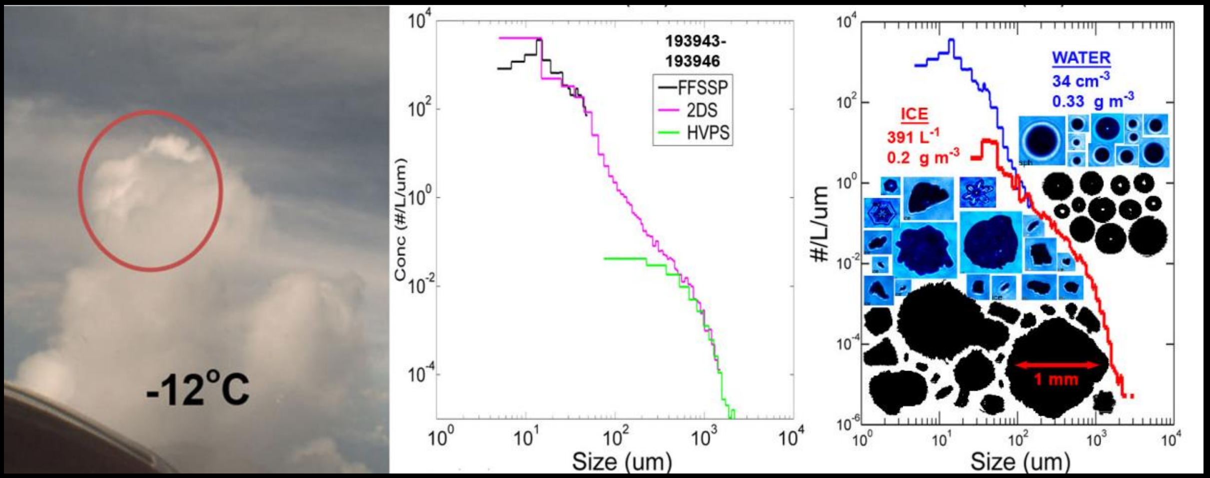
and Derived Quantities

4 min Later: Cloud Nearly Glaciated - Only Small Supercooled Drops Remain.

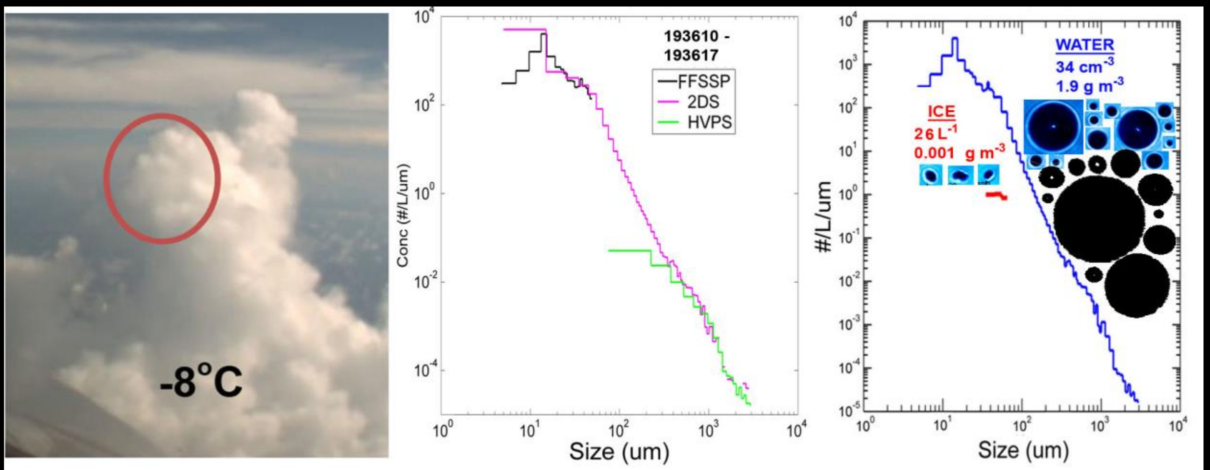


3 min Later: Rapid Glaciation,

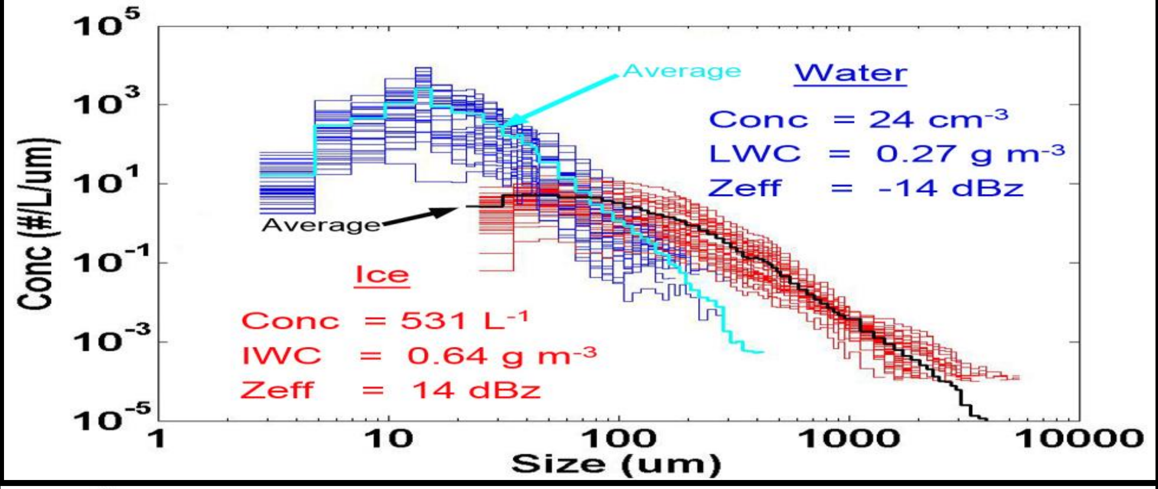
Millimeter Drops Frozen.



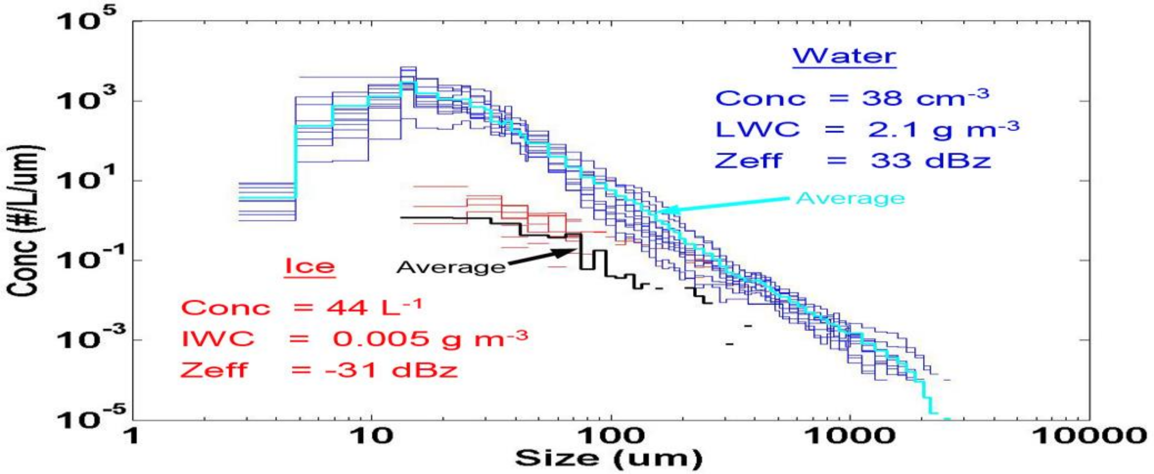
First Ice Penetration: 2 g m^{-3} LWC, Millimeter Drops, Very Low Concentration of Small Ice



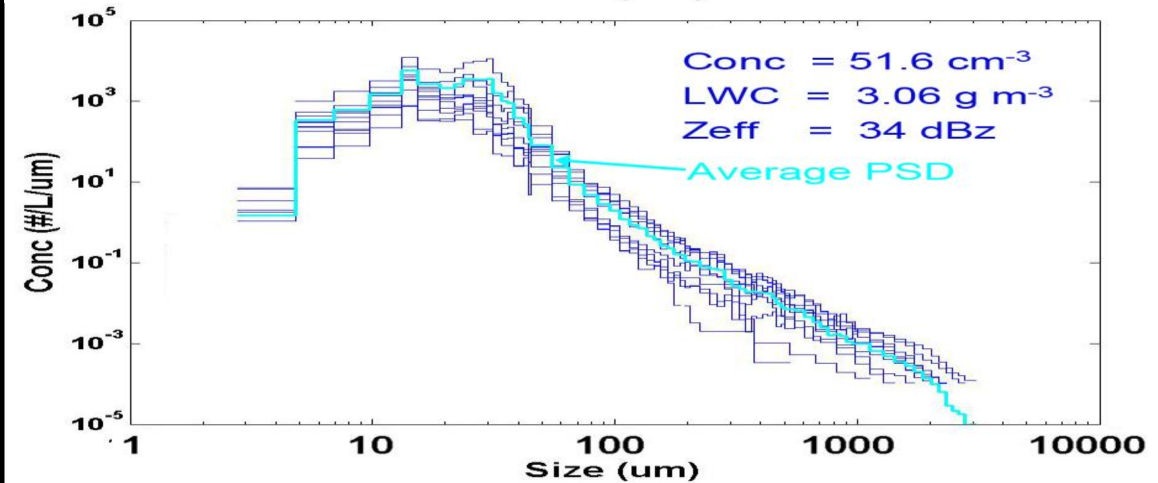
-12 to -15 °C Size Distributions Separated into Water And Ice in Rapid Glaciation Region



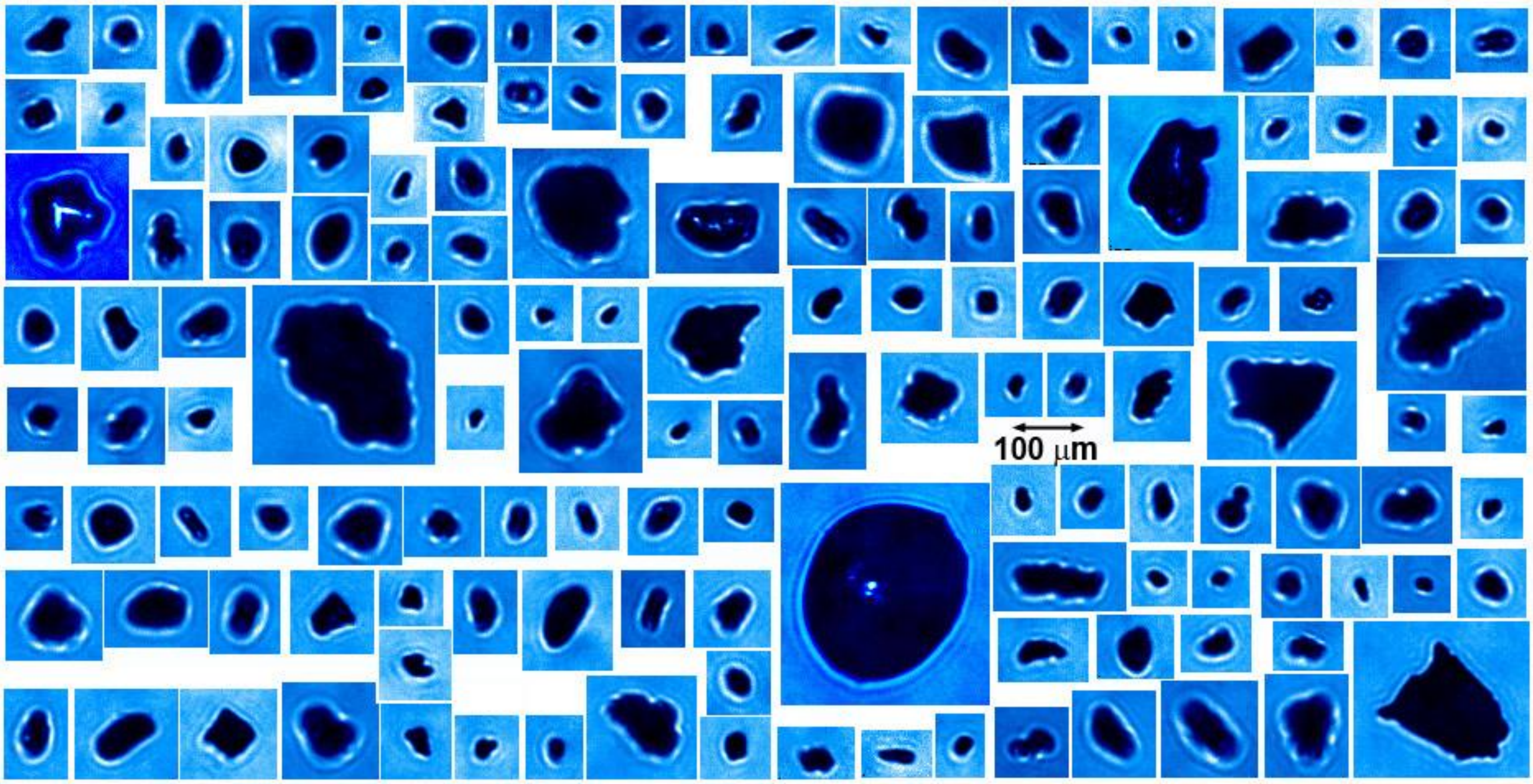
-8 to -12 °C Size Distributions Separated into Water And Ice Using CPI Images in First Ice Region



Cloud Base to -5 °C Drop Size Distributions From Penetrations In All-Liquid Clouds



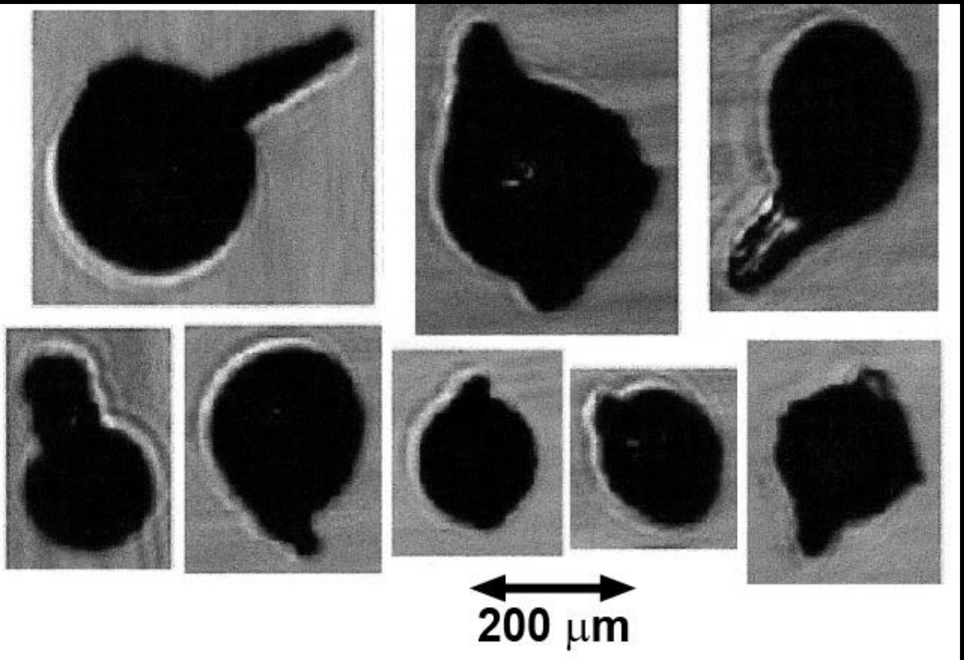
CPI Images of "First Ice" from 12 Penetrations of Strong Updrafts in New ICE-T Turrets.



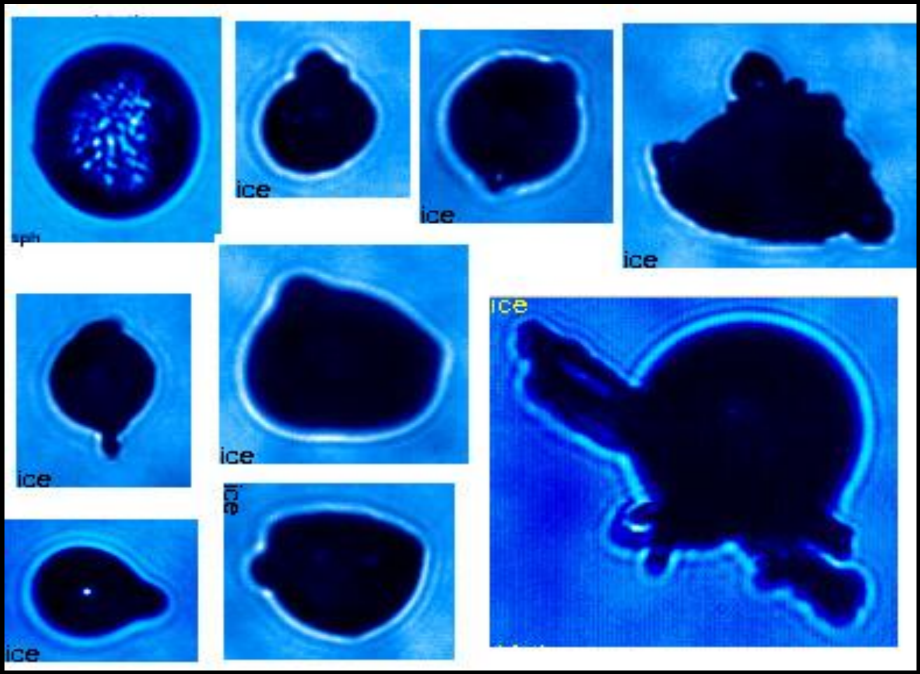
Where does the "First Ice" come from in the strong new updrafts?

- Ice Nuclei estimates in ICE-T at T > -12 ° C are Poorly Characterized
- If small ice crystals from outside the updrafts were entrained they would grow to larger sizes than observed
- Biological aerosols are active at T< -5 °C but were not measured in ICE-T
- Artifacts?

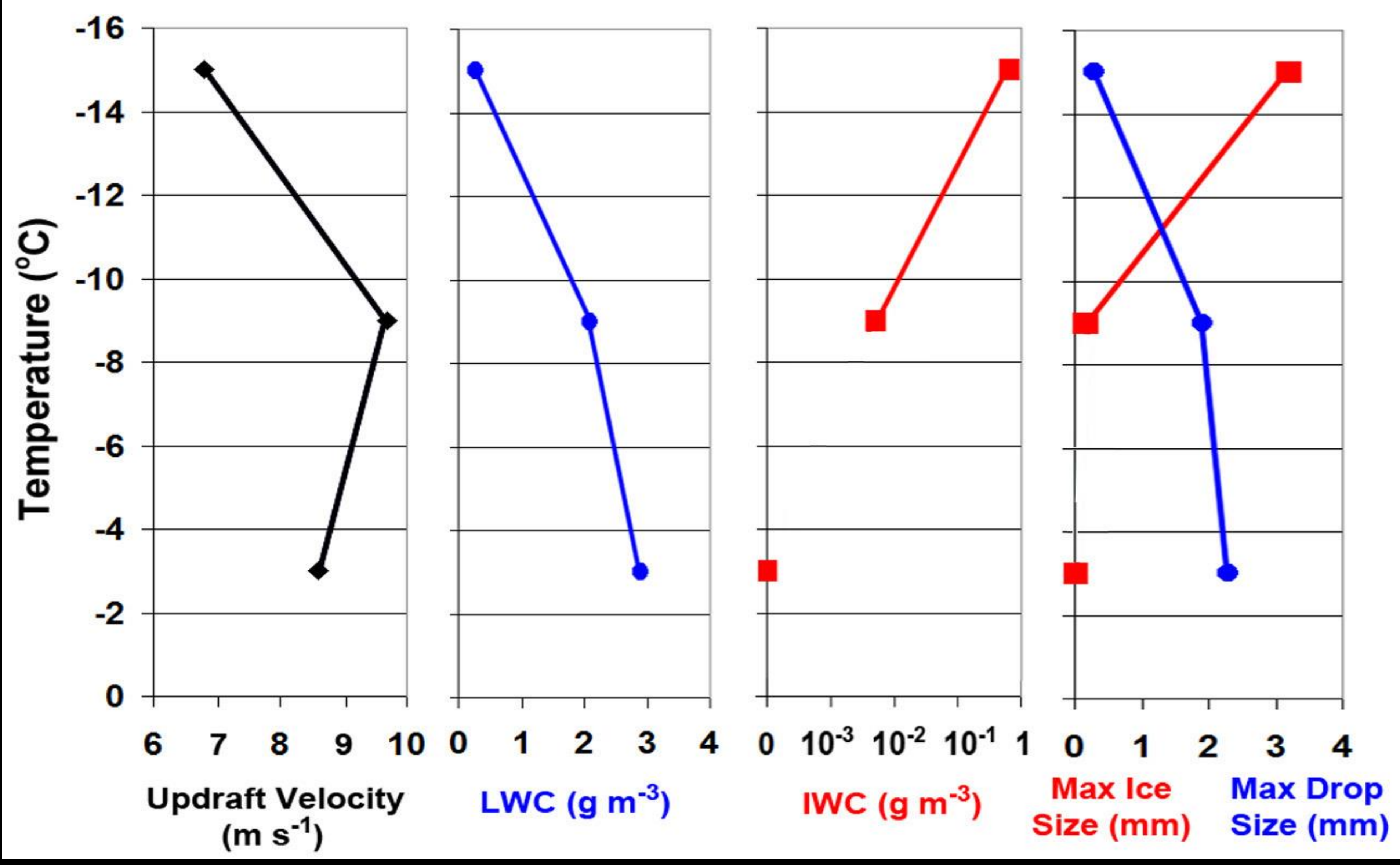
Korolev et al. (2004) Observed from Laboratory Experiments that Freezing Drops >100 μm Produced Spikes, Protrusions and Spicules



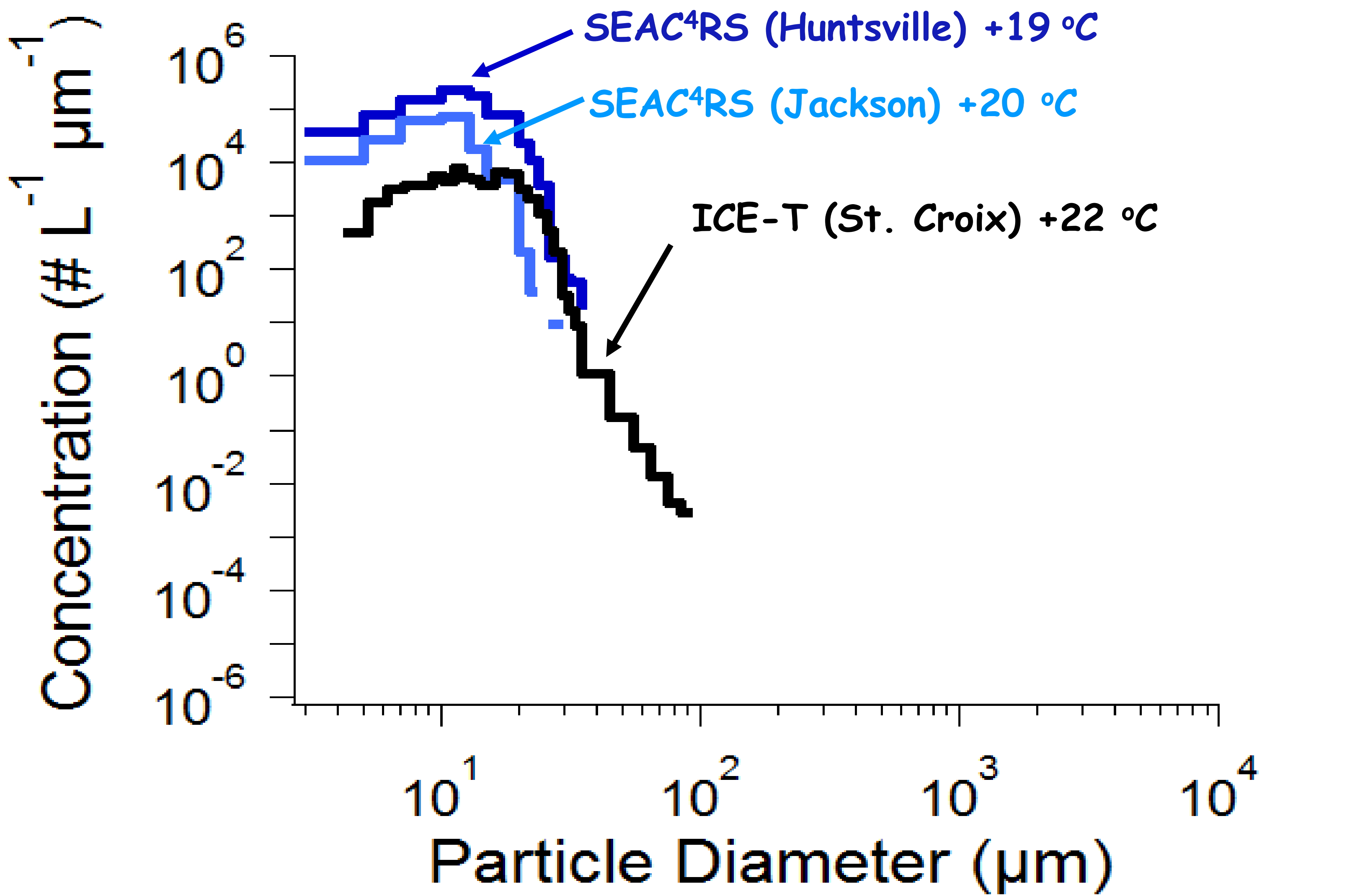
Examples of Frozen (and possibly freezing) Drops in the Rapid Transition Region of ICE-T Clouds



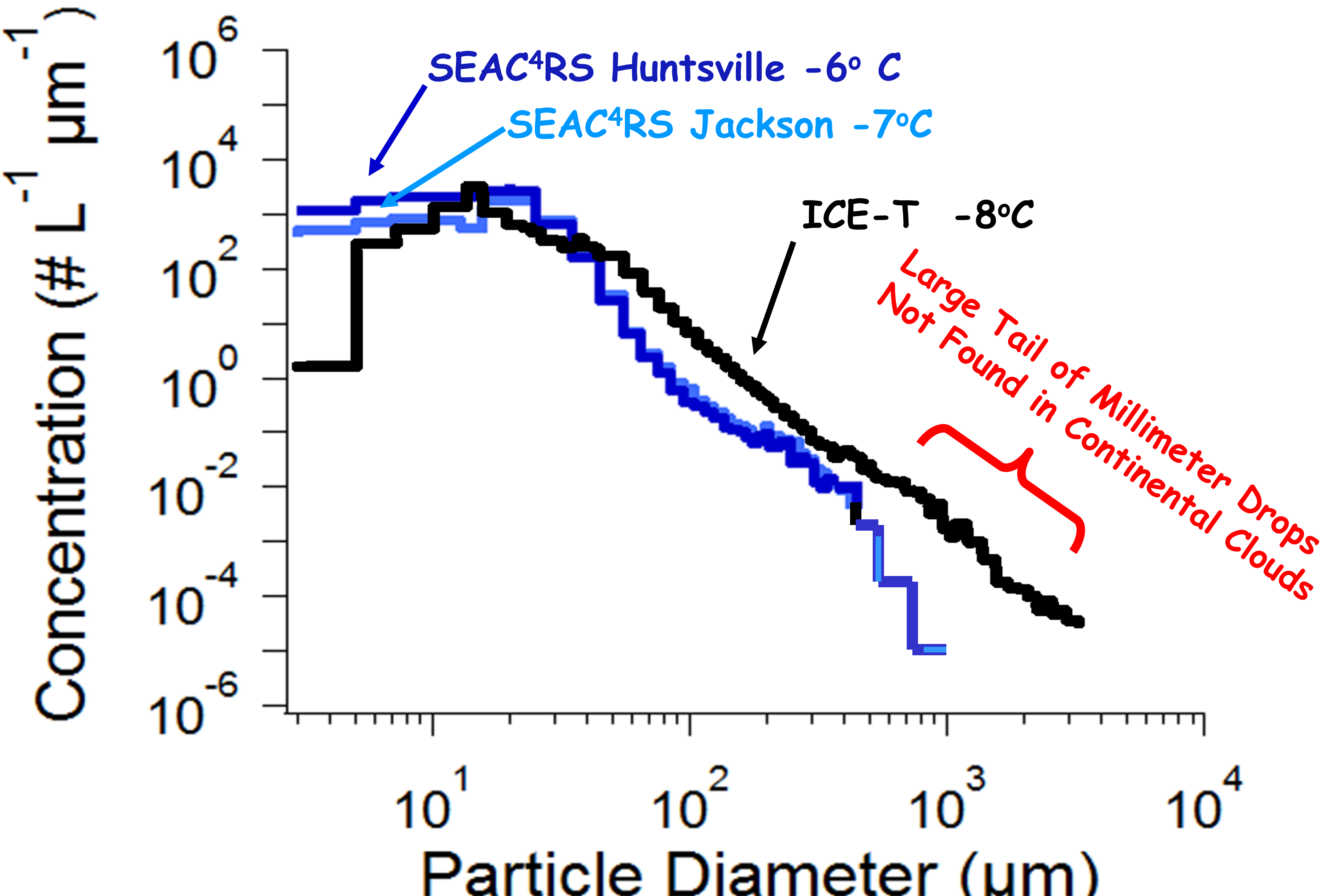
Vertical Profile of Average Bulk Properties Derived from 69 Learjet Penetrations During ICE-T



St. Croix/Gulf Coast Comparison of Cloud Base DSD

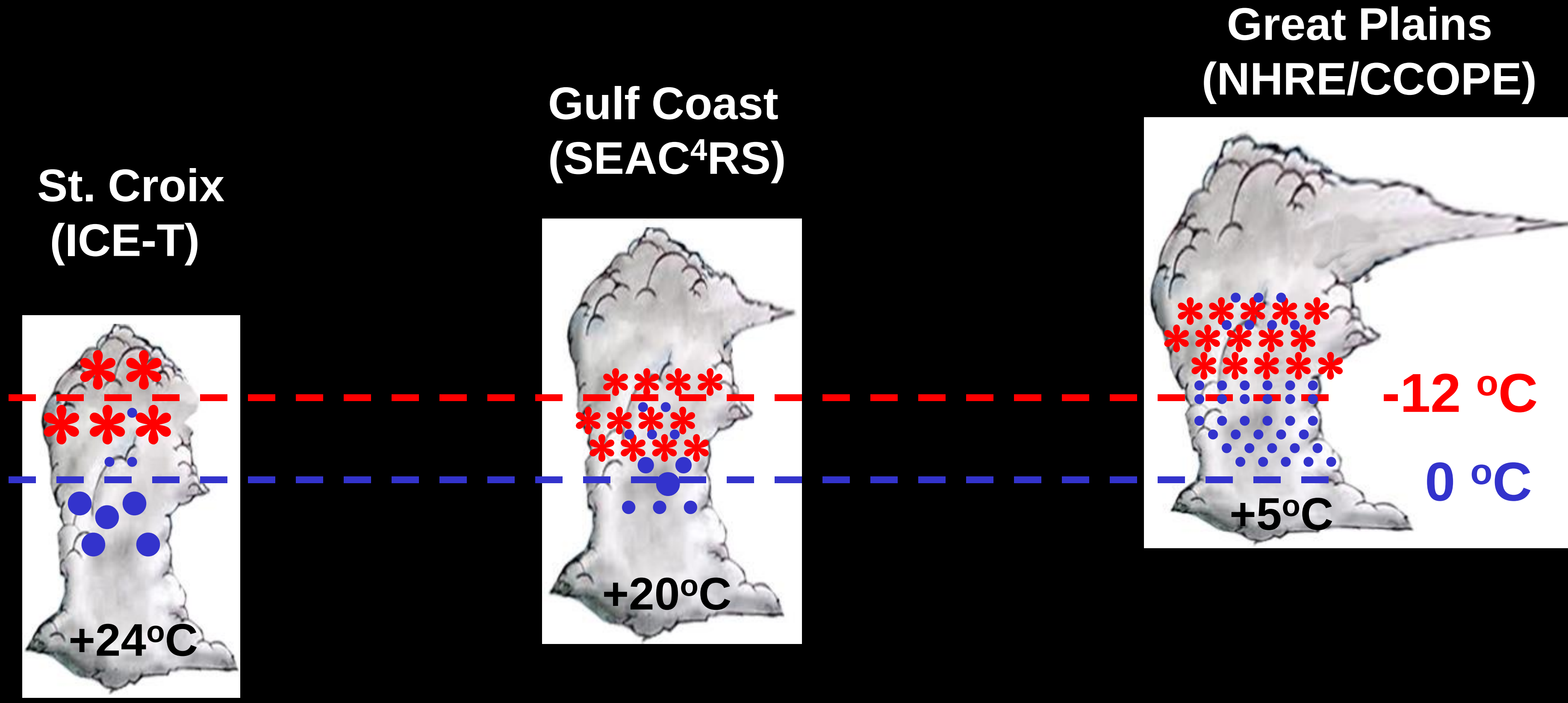


Continental/Maritime Comparison of Drop Size Distribution



Variation in Cloud Microphysics with Latitude:

Cloud Base Temperature and Drop Spectra have a Significant Impact on the Development of Drop Size Distribution and Ice Formation



Simplified Morrison-Grabowski CRM

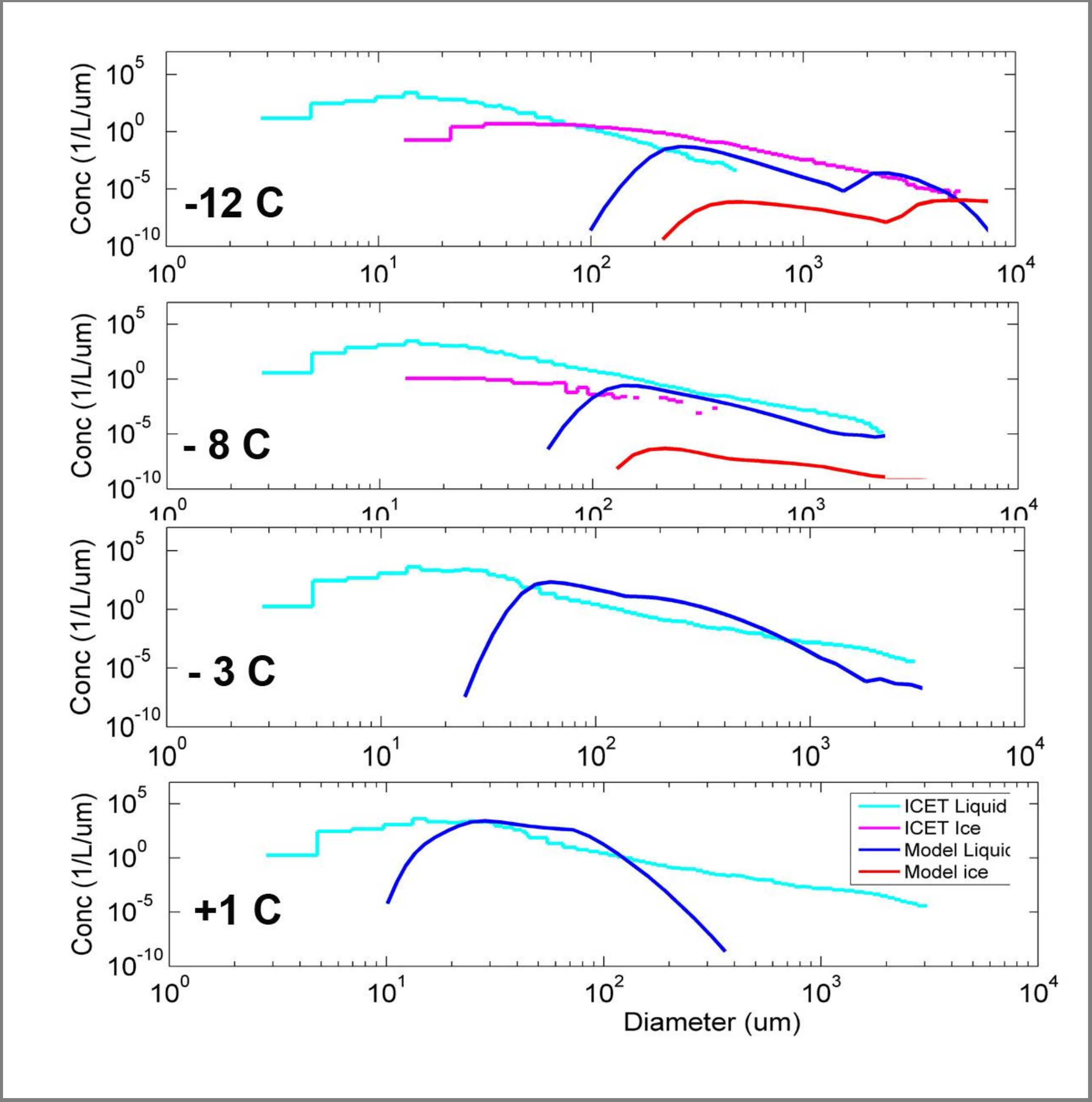
Currently:

- 1-D model with constant updraft
- Bigg ice parameterization.
- No entrainment, Breakup, Secondary Drop Activation

Eventually:

- Input ice and drop size distributions from obs.
- Add entrainment and secondary drop activation
- Tune model to agree with obs.
- Determine if Coalescence/Sedimentation explains rapid glaciation between -8 °C and -12 °C

Preliminary Model-Observations Comparison



Summary

- Millimeter drops form in strong (~10 m s^{-1}) updrafts by the +5 °C level.
- Virtually no ice observed in fresh turrets with strong updrafts at T > -8°C.
- Low concentrations of small ice particles observed at -8 to -12 °C in strong updrafts in conjunction with millimeter drops. Biologic Nuclei?
- Rapid glaciation of cloud in the -12 to -15 °C region.
- Morrison-Grabowski cloud resolving model is being used to determine if differential fall velocities between small ice and large drops can account for rapid glaciation, or if some secondary ice production process (e.g. splintering) is needed.