

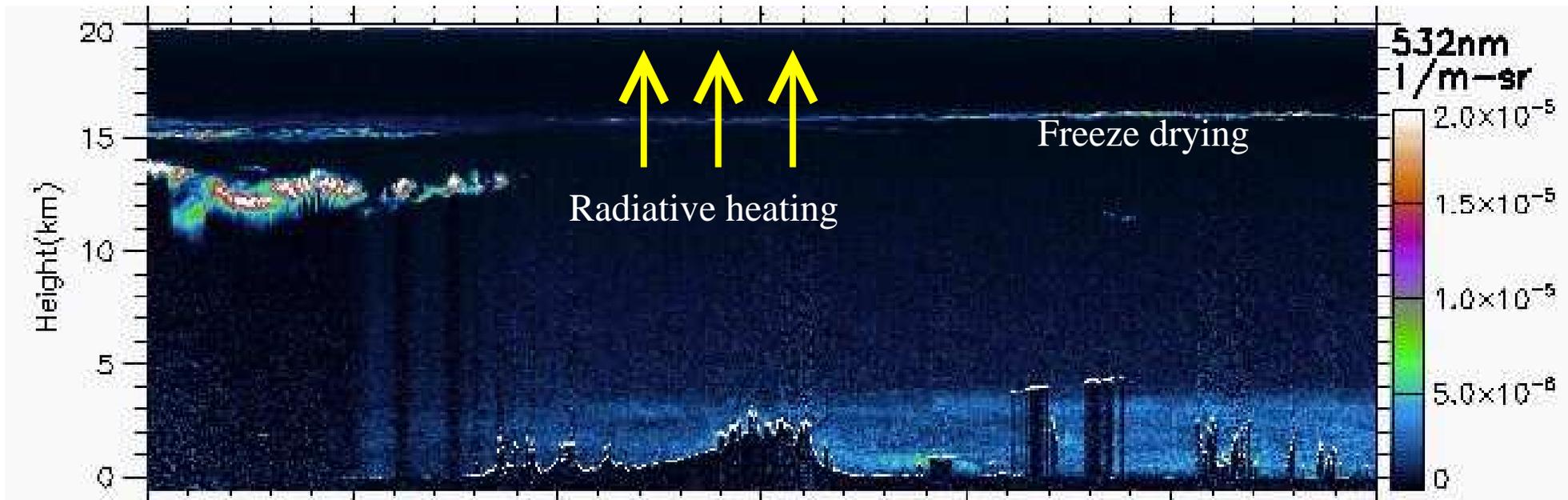
# Ice Concentrations and Extinctions in Tropical Tropopause Layer Thin Cirrus

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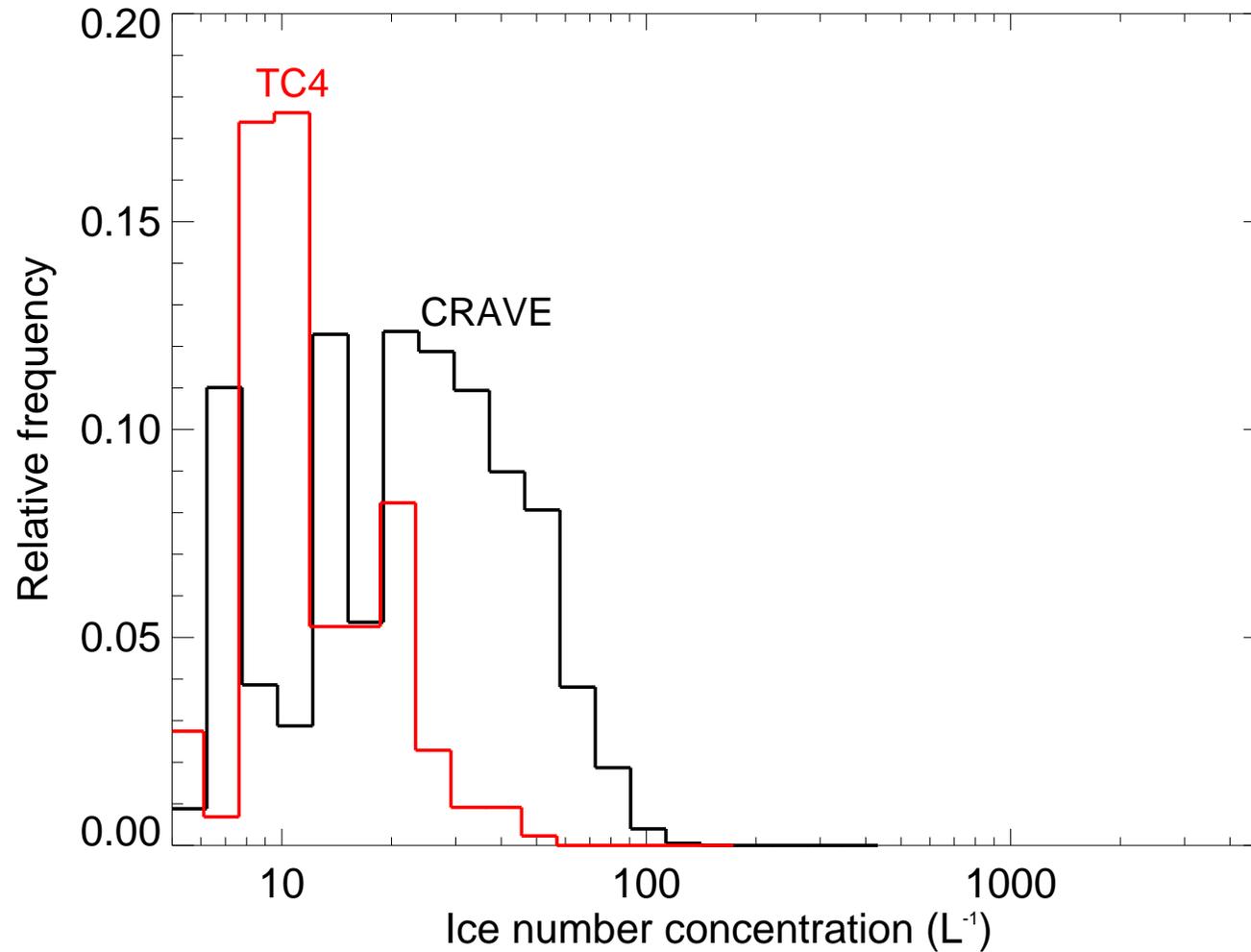
Daniel Murphy

NOAA Earth System Research Laboratory  
Chemical Sciences Division

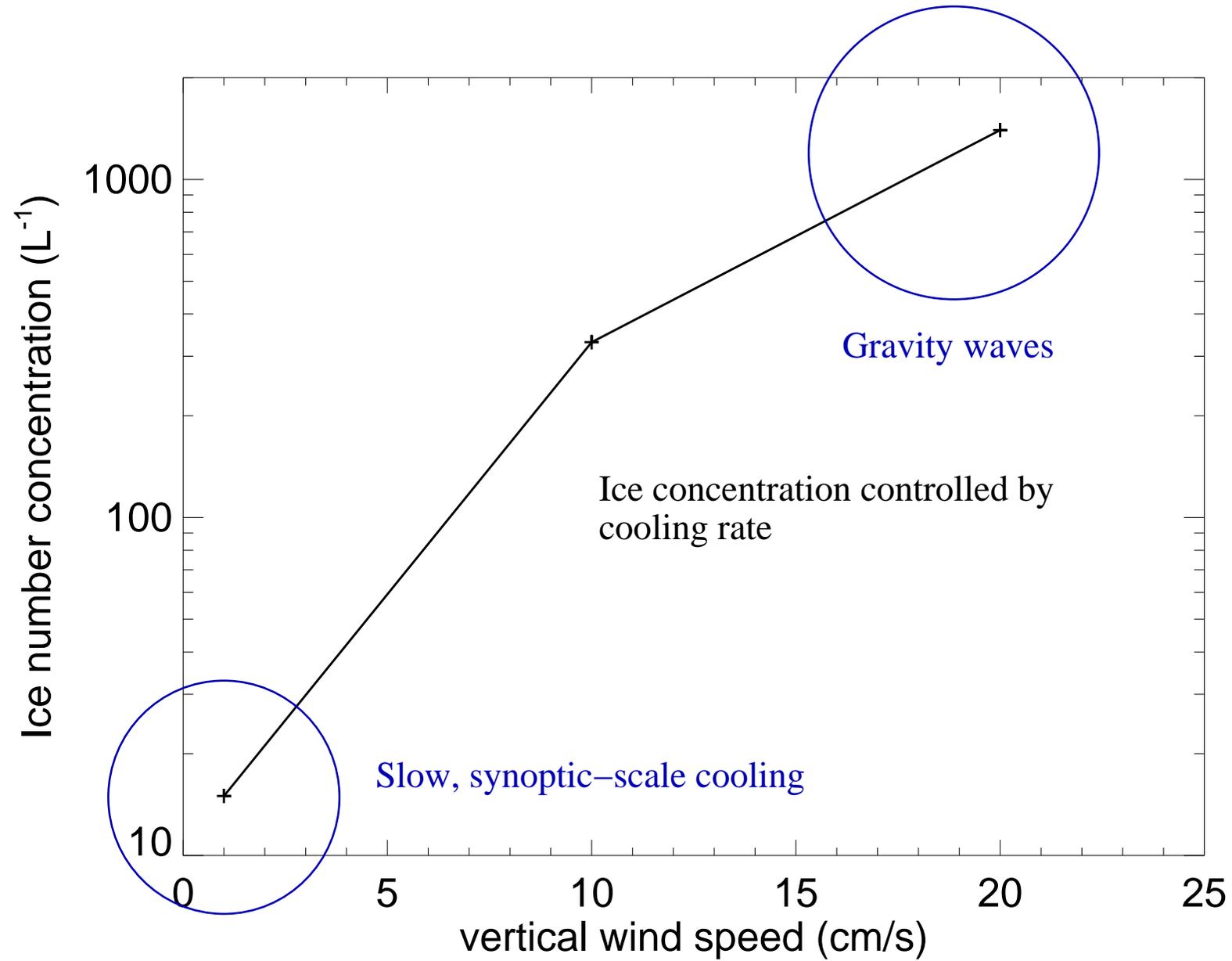


- Measured low ice concentrations, broad size distributions, and low extinctions

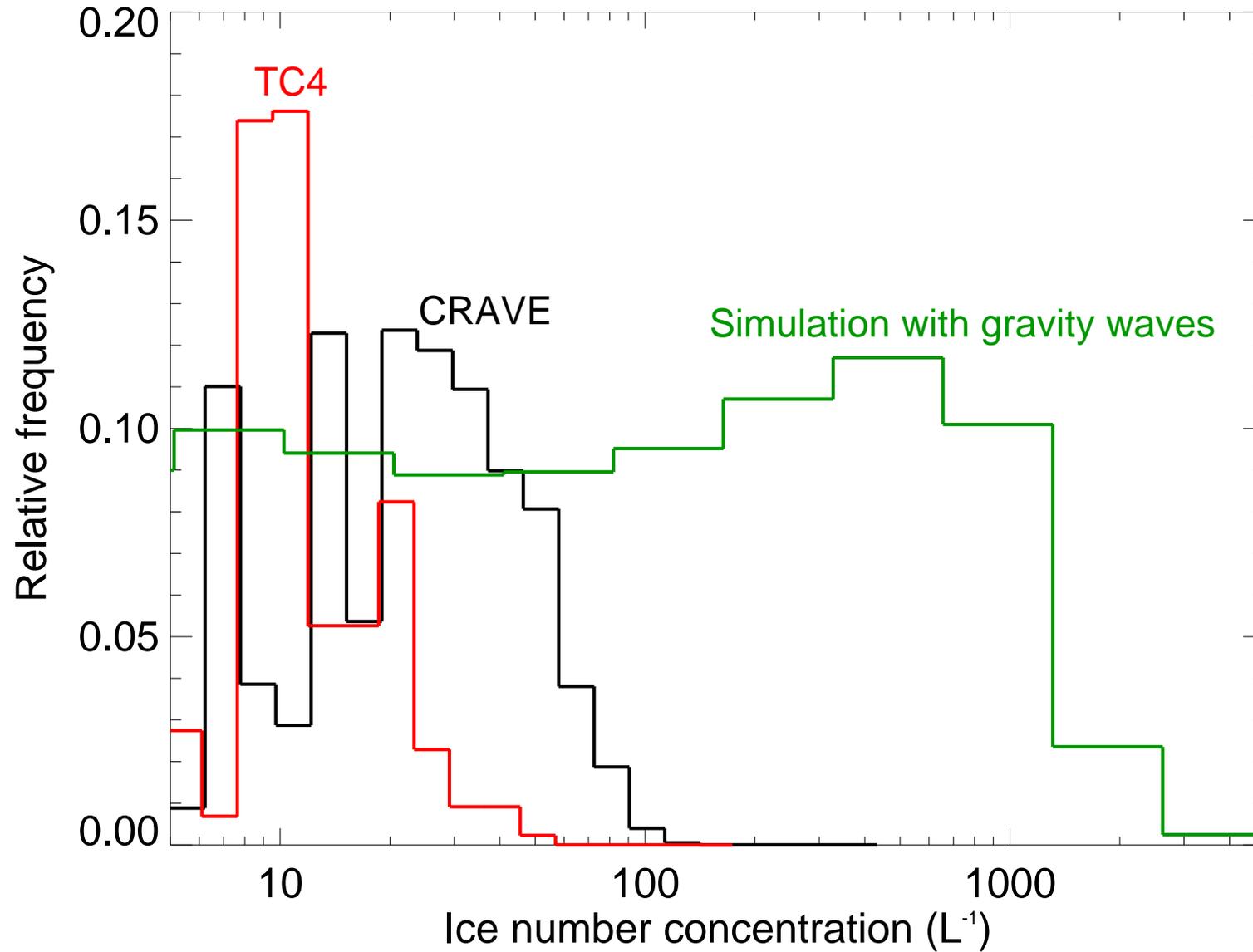
## Subvisible cirrus ice number concentrations



# Homogeneous freezing



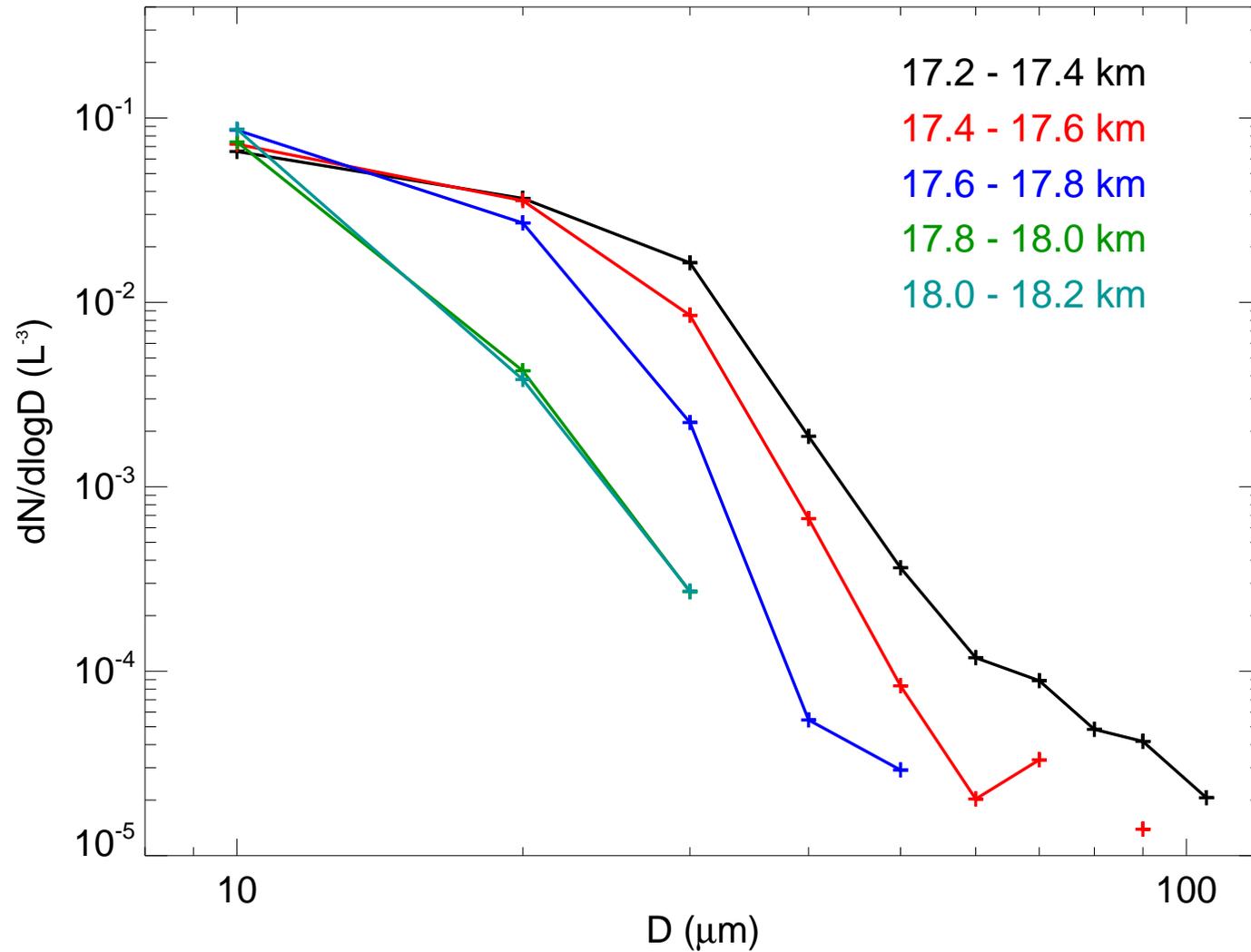
## Subvisible cirrus ice number concentrations



- Measured ice concentrations are far lower than theory predicts.

# TTL cirrus ice crystal size distributions

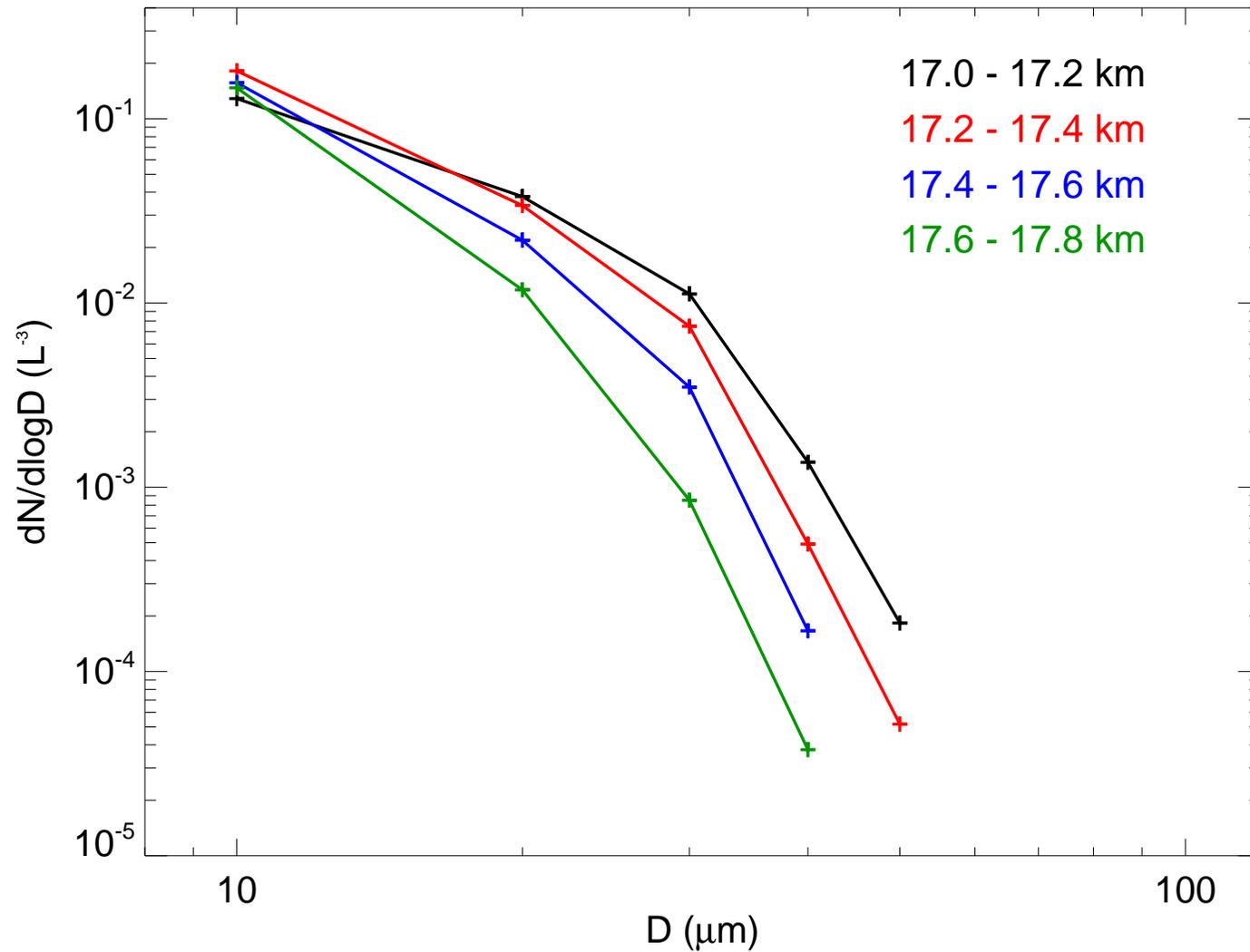
01 Feb SVC 2D-S



- Measured ice crystal size distributions are broad.

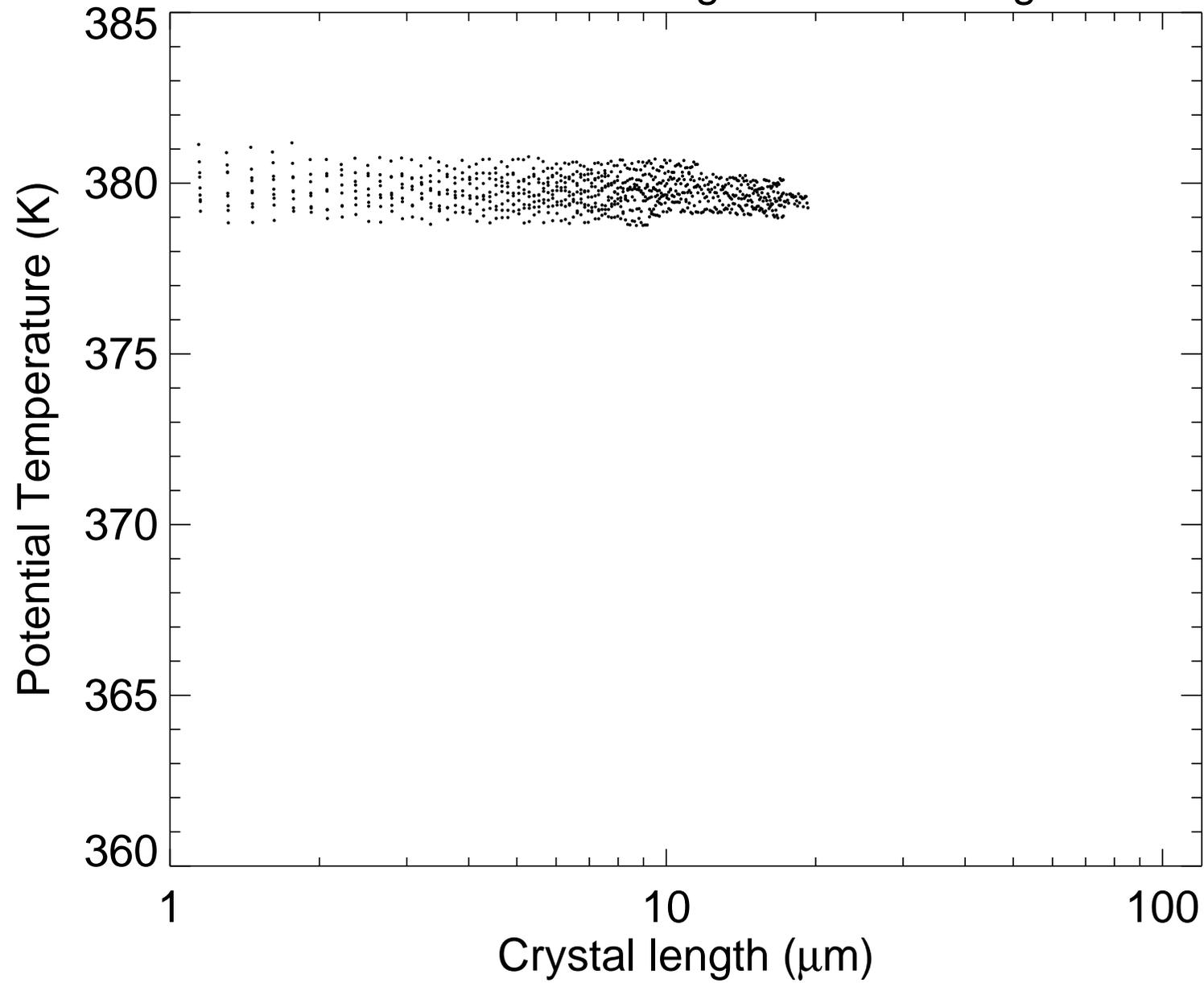
# TTL cirrus ice crystal size distributions

02 Feb SVC 2D-S

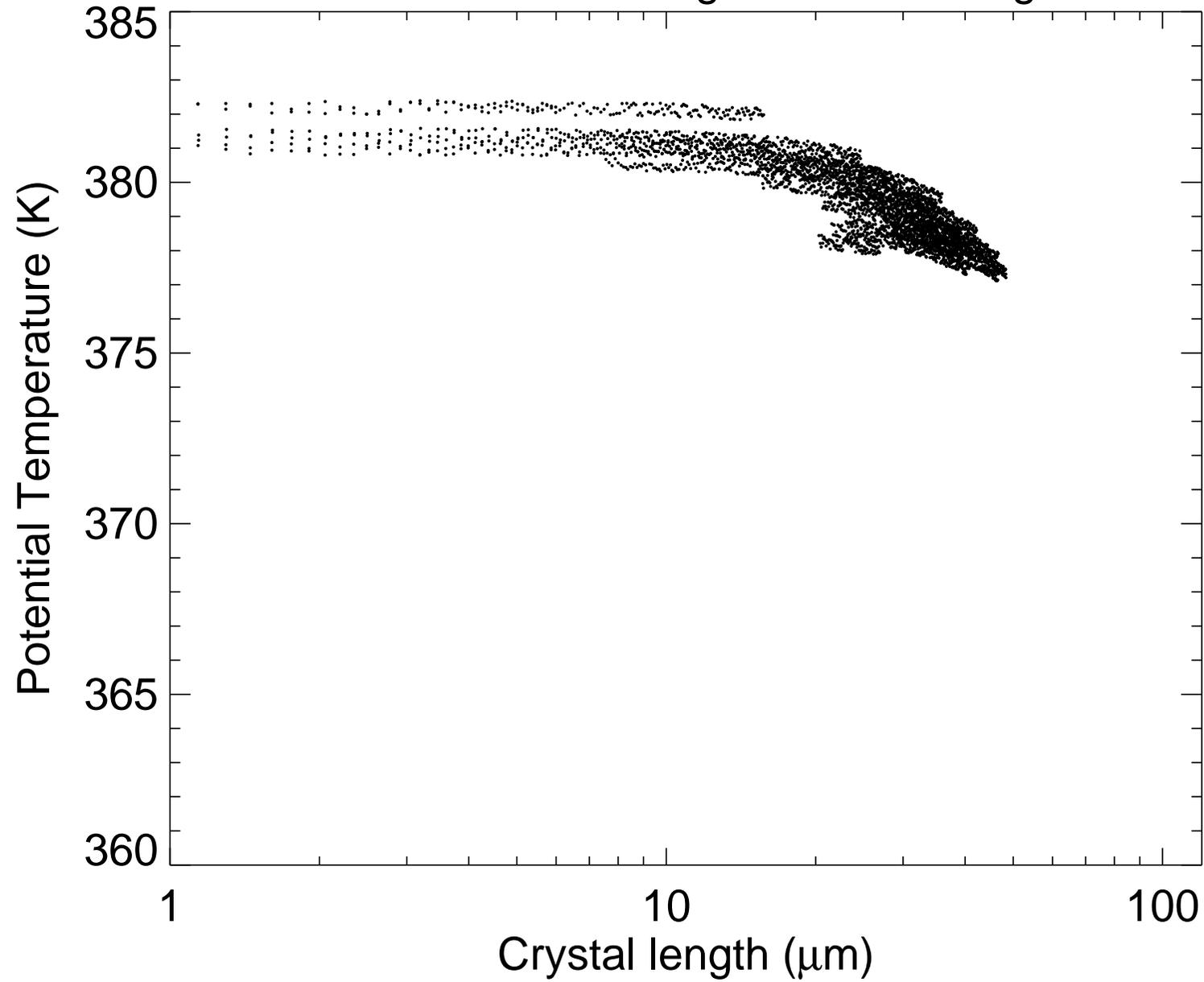


- Measured ice crystal size distributions are broad.

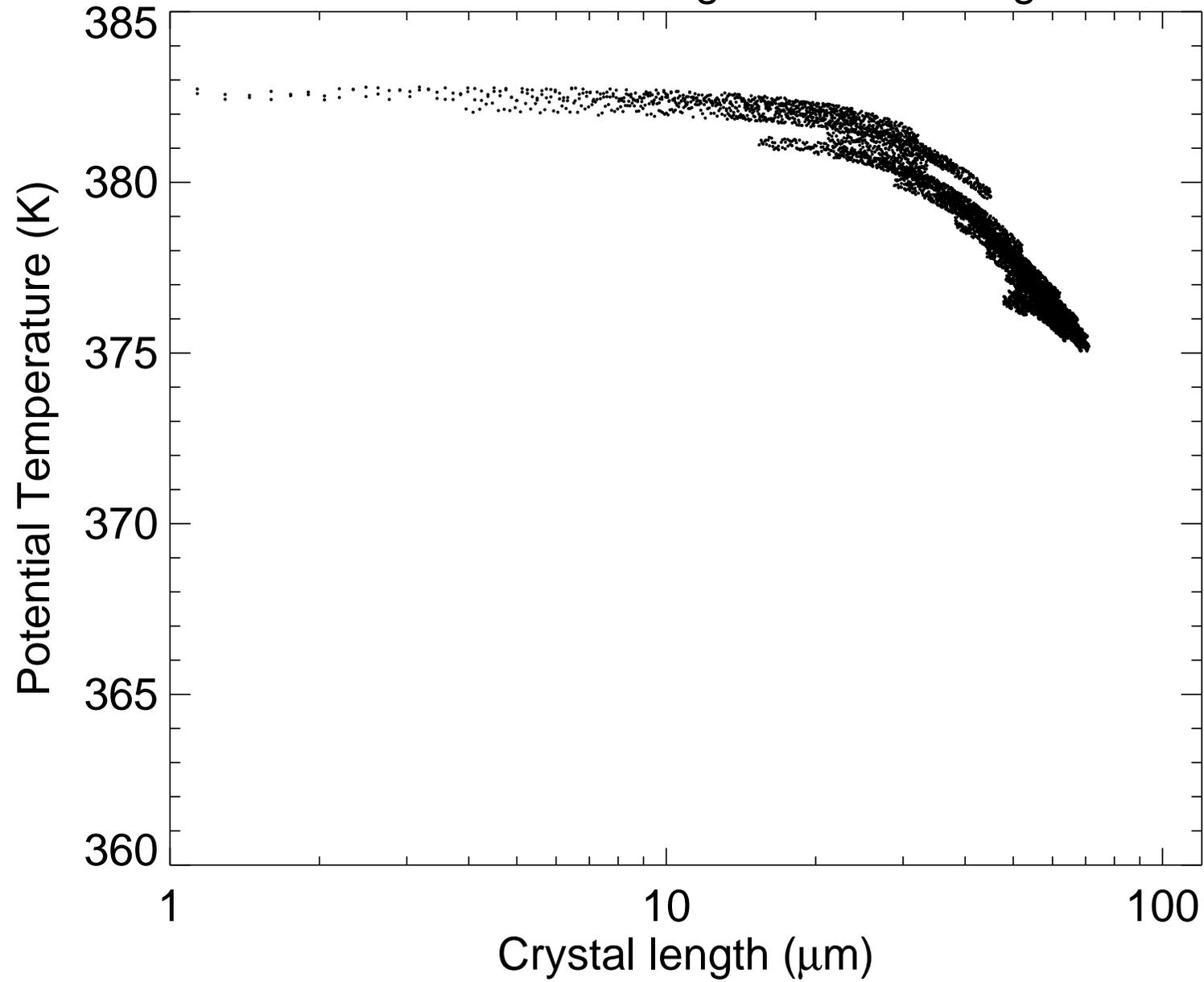
Simulated PSD: homogeneous freezing event



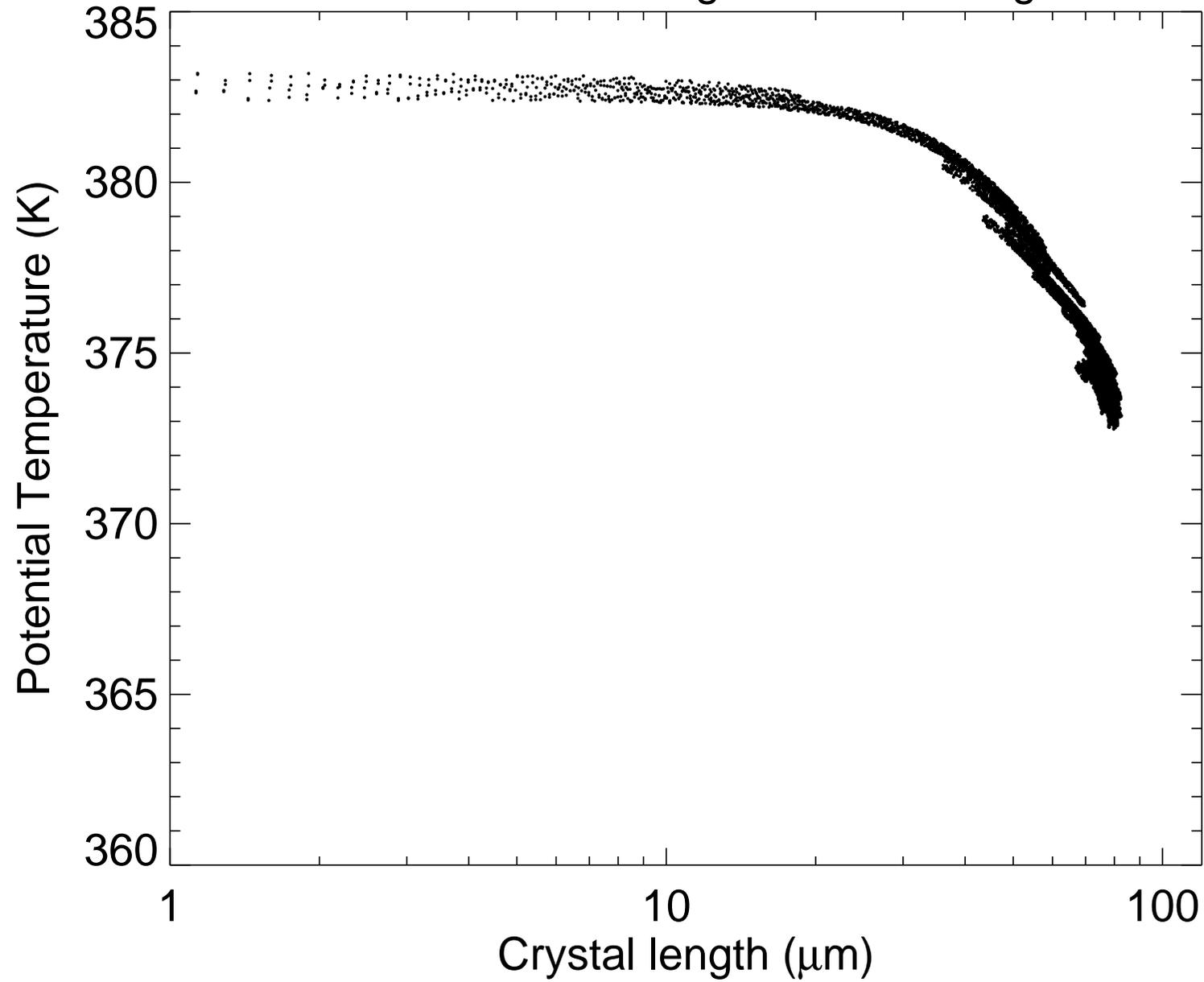
Simulated PSD: homogeneous freezing event



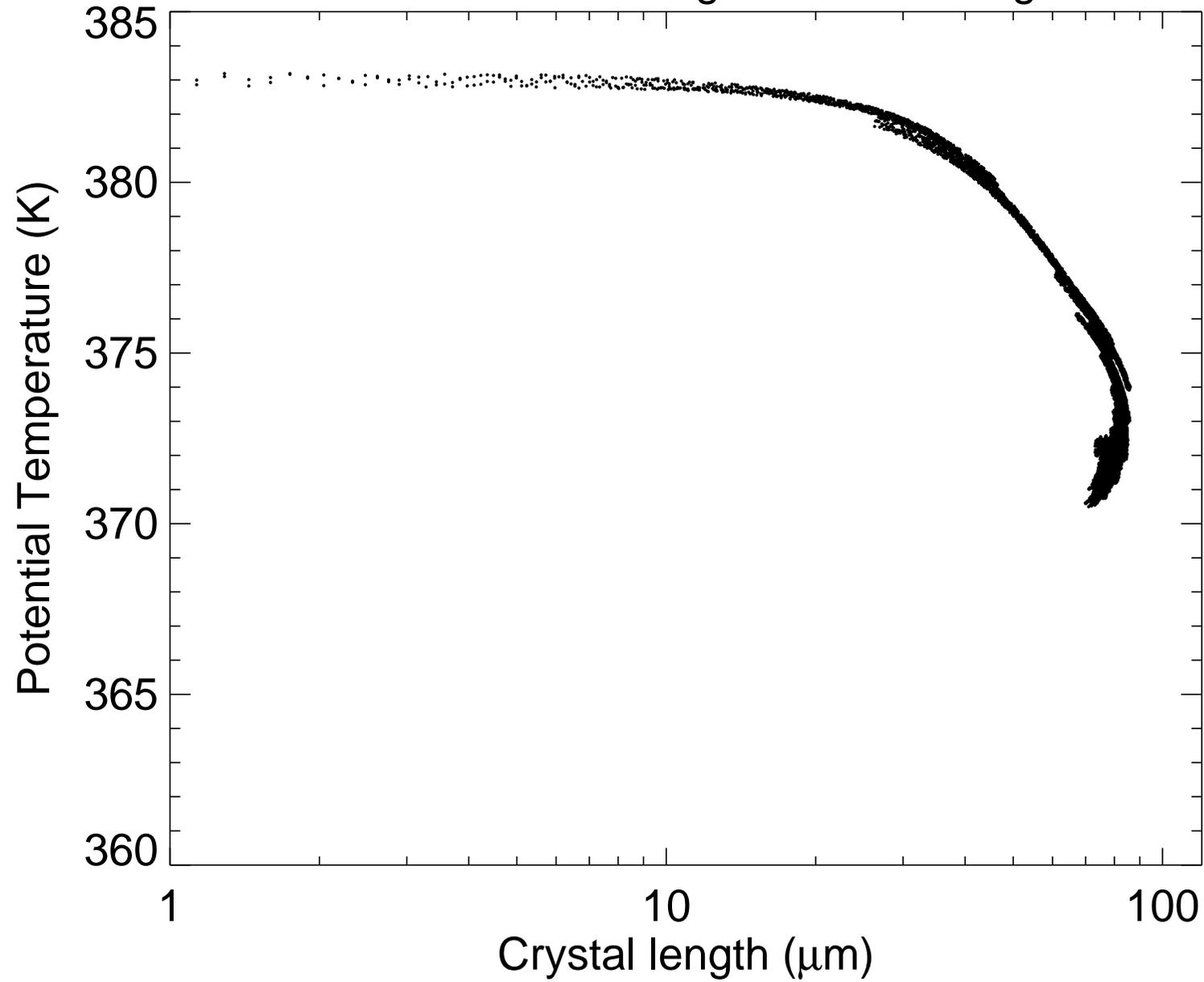
Simulated PSD: homogeneous freezing event



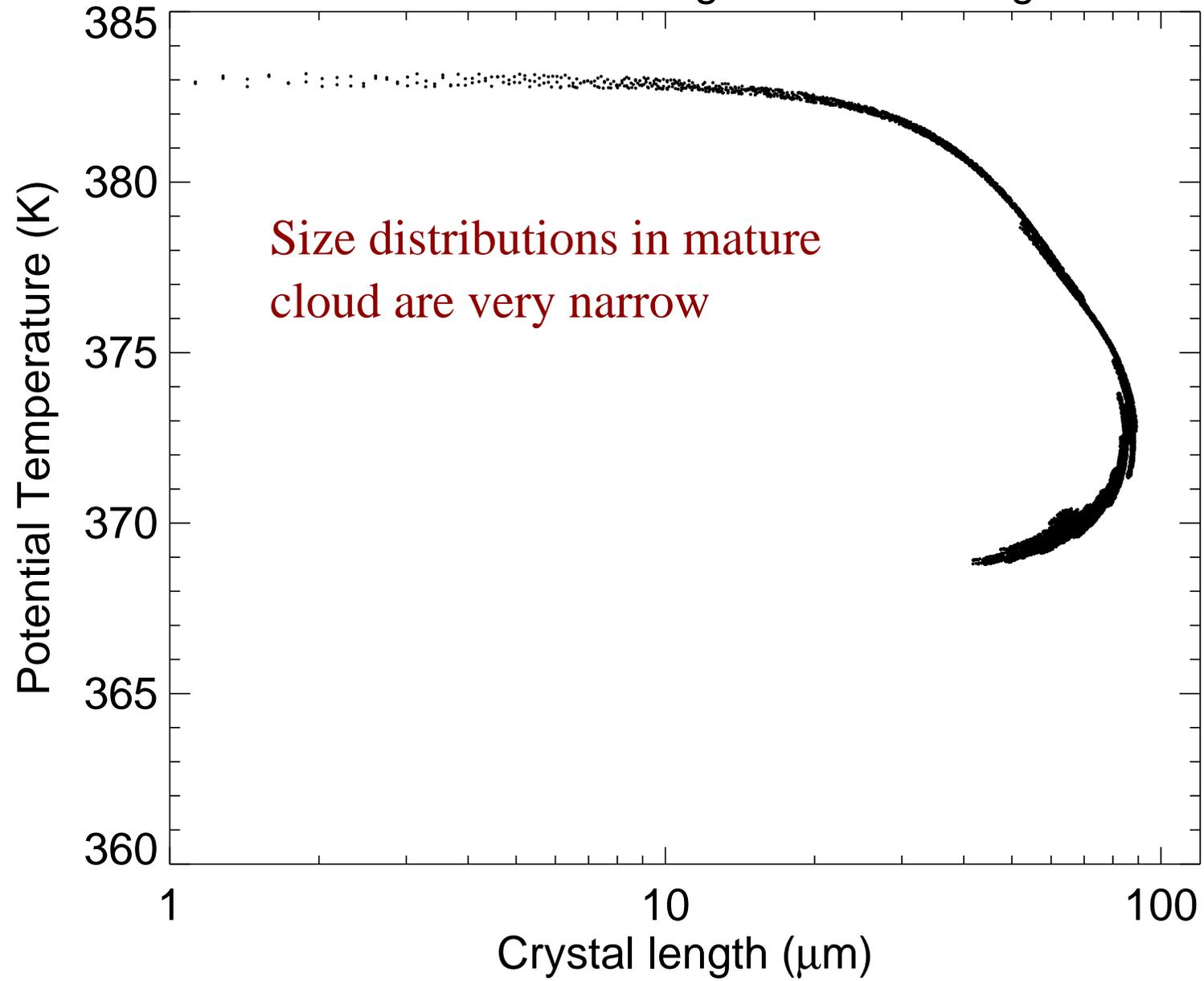
Simulated PSD: homogeneous freezing event



Simulated PSD: homogeneous freezing event



Simulated PSD: homogeneous freezing event



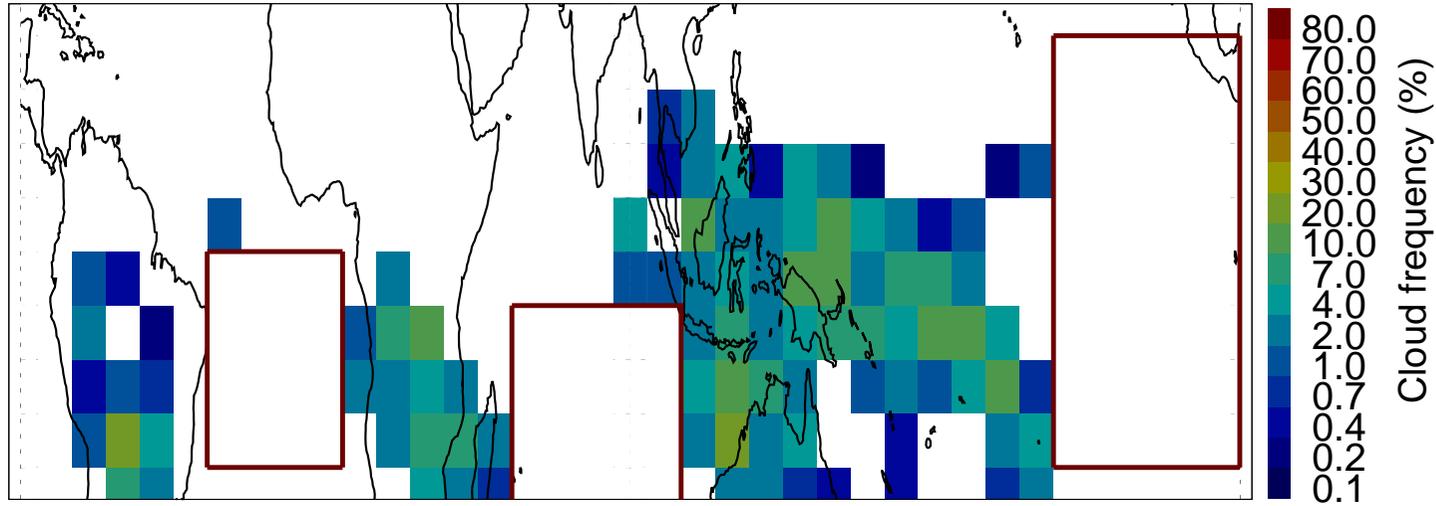
Hypothesis: Numerical models overestimate TTL  
cirrus ice concentrations, and they should correspond-  
ingly overestimate cloud extinction.... Compare with  
CALIPSO

## Modeling approach

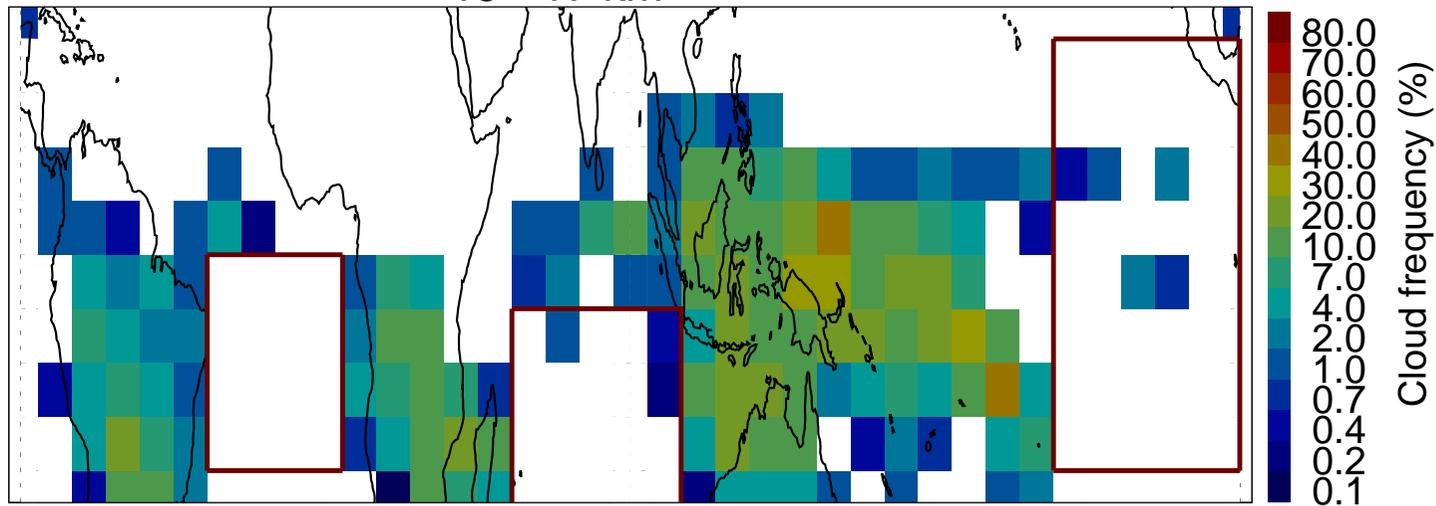
- 40-day diabatic back trajectories from a 5 by 5 grid of points using GEOS-4 analyses and GSFC trajectory model.
- Time-height curtains of T along trajectories. Temperatures adjusted for agreement with radiosondes.
- Include a synthetic spectrum of gravity, Rossby-Gravity, and Kelvin waves.
- Use 1-D (height) full microphysical model with vertical ascent derived from Fu and Yang radiative heating calculations including CALIPSO clouds.
- Convective injection of water included using geostationary satellite imagery.
- see L. Pfister poster for details

# Convective cloud frequency

17 - 19 km



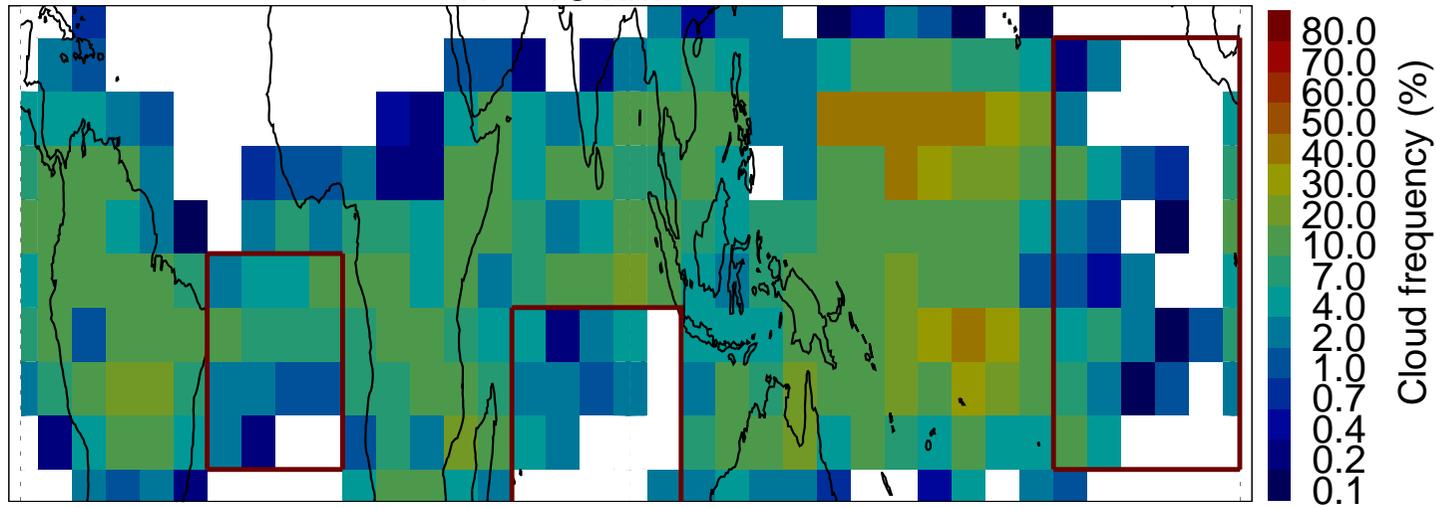
15 - 17 km



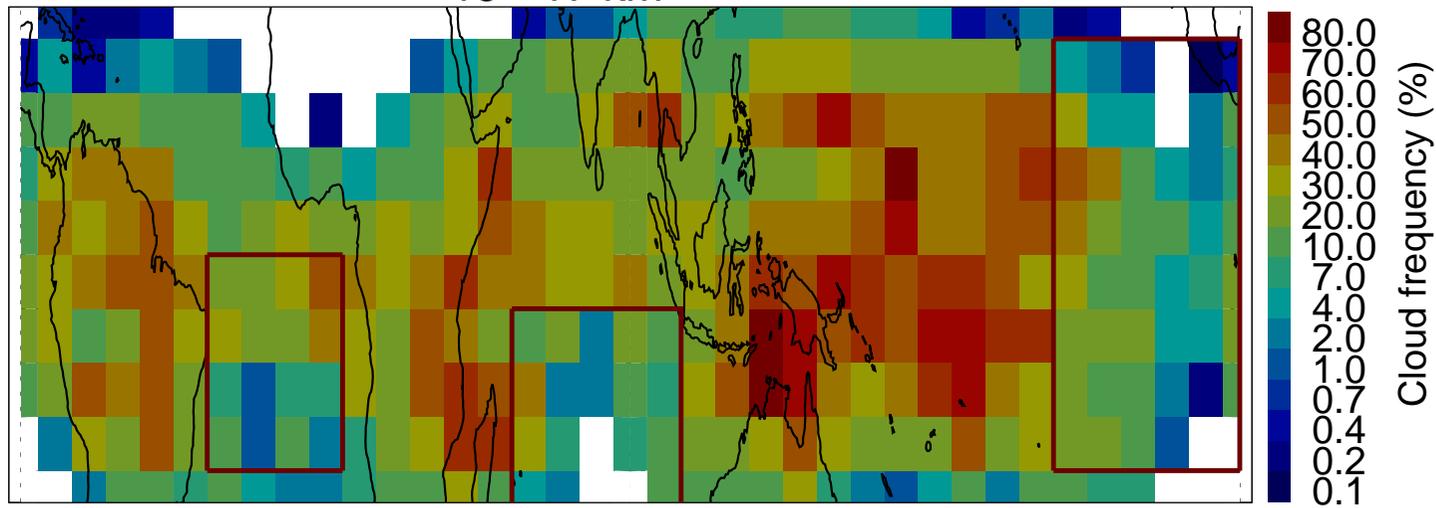
- Focus on regions with only in situ clouds

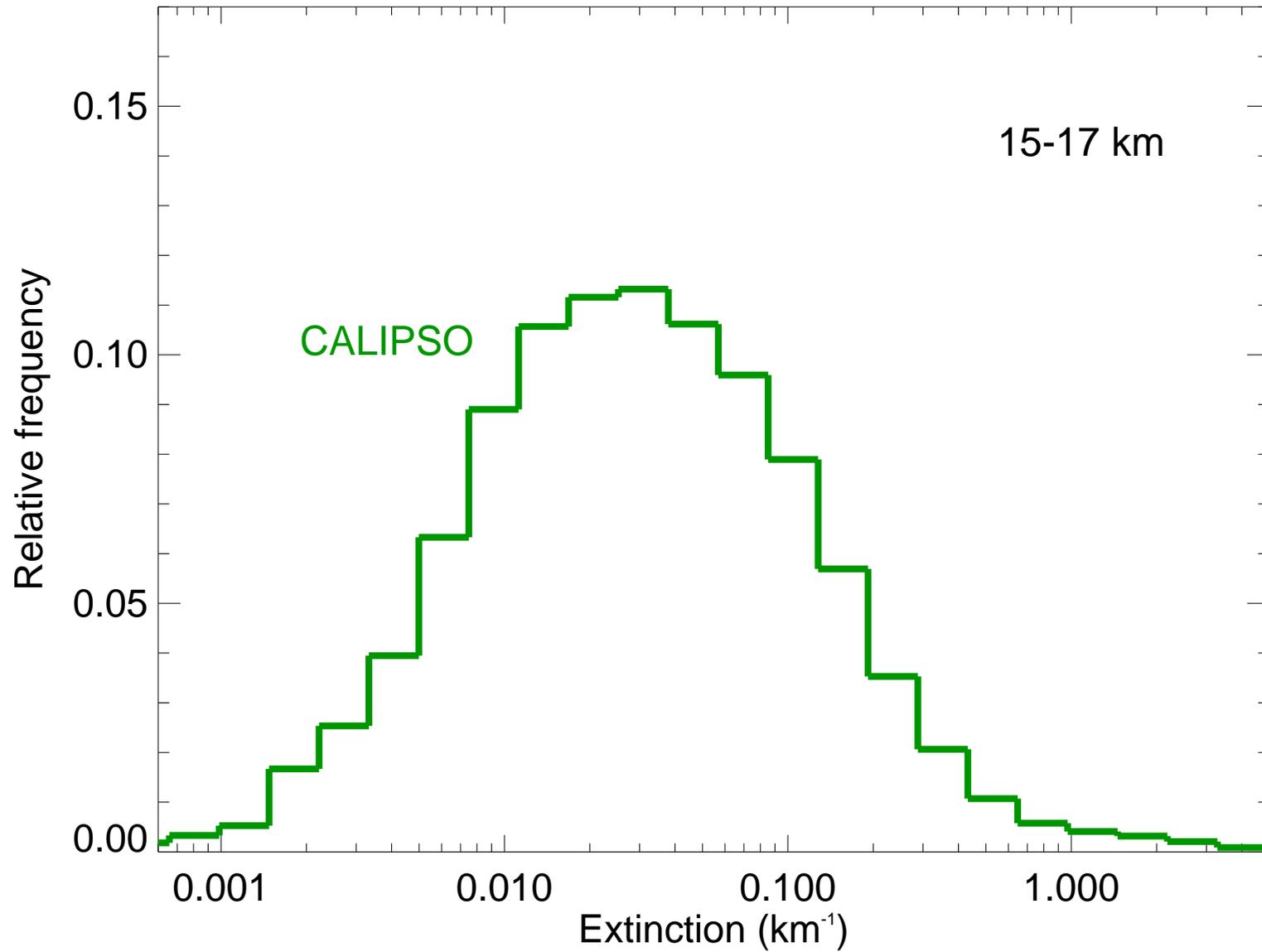
# Simulated in situ cloud frequency

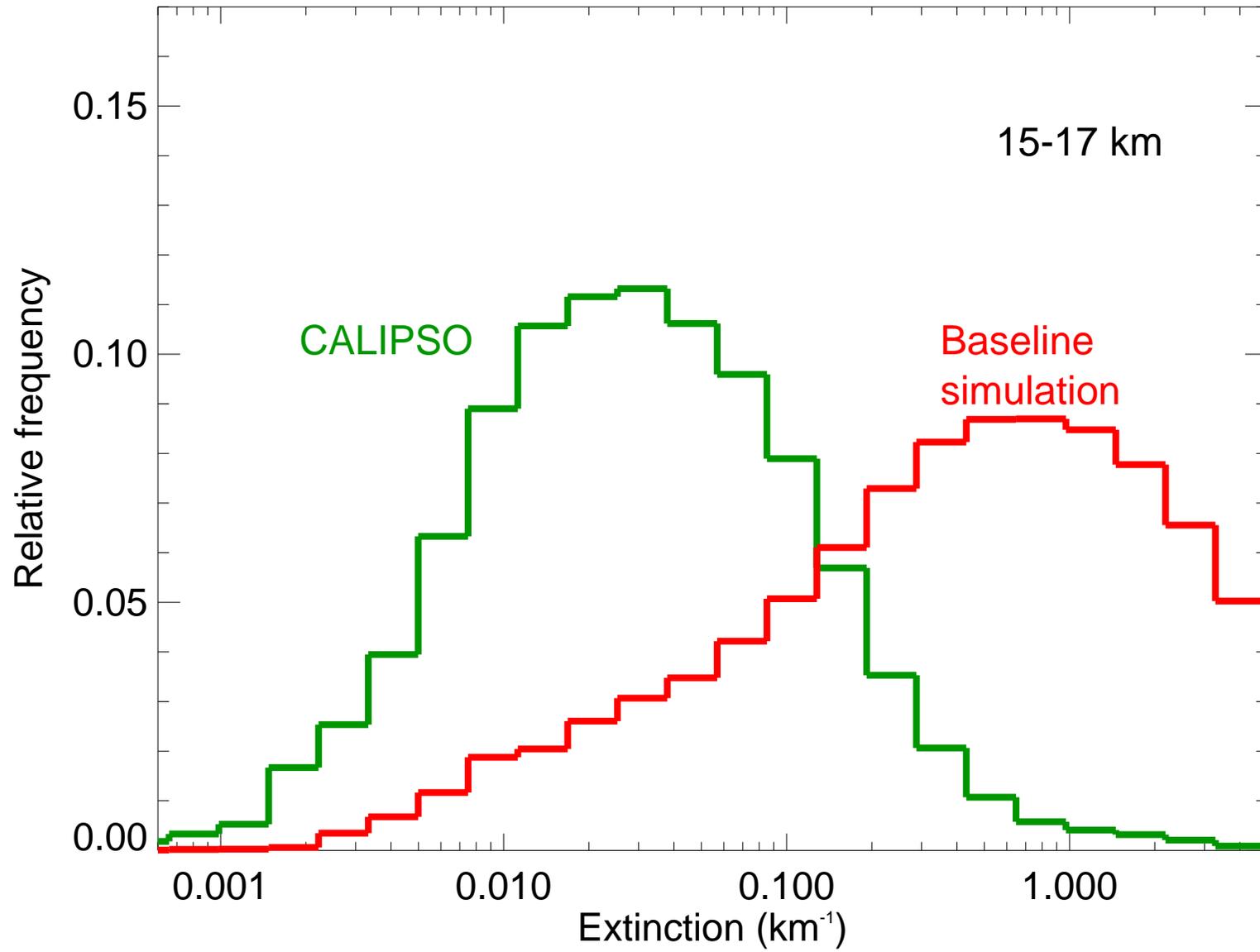
17 - 19 km

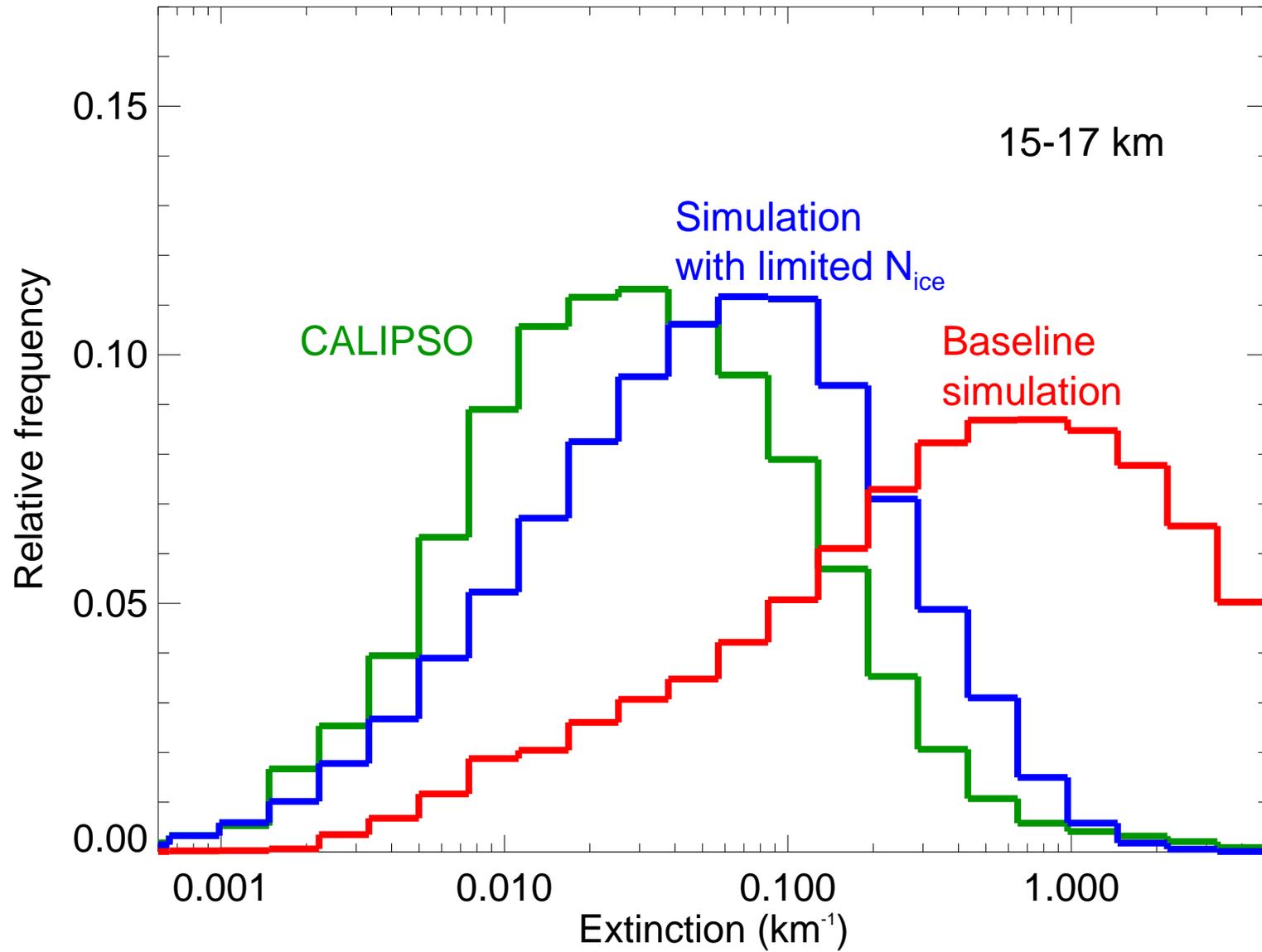


15 - 17 km









## To get lower ice concentrations and broader distributions...

- Generate  $\simeq 50 \text{ L}^{-1}$  ice crystals first
  - Moderate ice nuclei (**ammonium sulfate**, oxalic acid, ...)
  - However, IN should be scavenged
  - Variable organic content spreads out nucleation over a range of supersaturations
- Differential ice growth
  - Cubic ice
  - Favorable defects/habits
- Only a small fraction of aerosols can freeze
  - Organic-containing aerosols transition to glassy state at low T, preventing nucleation [*Zobrist et al.*, 2008; *Murray*, 2008]

## Summary

- Measured ice concentrations are far lower than nucleation theory predicts.
- Measured ice size distributions are much broader than theory predicts.
- CALIPSO cloud extinctions are much lower than theory predicts.
- Limiting ice nucleation in model improves agreement with CALIPSO extinctions.
- Potential implications for TTL cirrus frequency, radiative properties, and dehydration.