Direct comparisons of ice microphysical properties simulated by the Community Atmosphere Model CAM5.4 with ARM SPartICus observations

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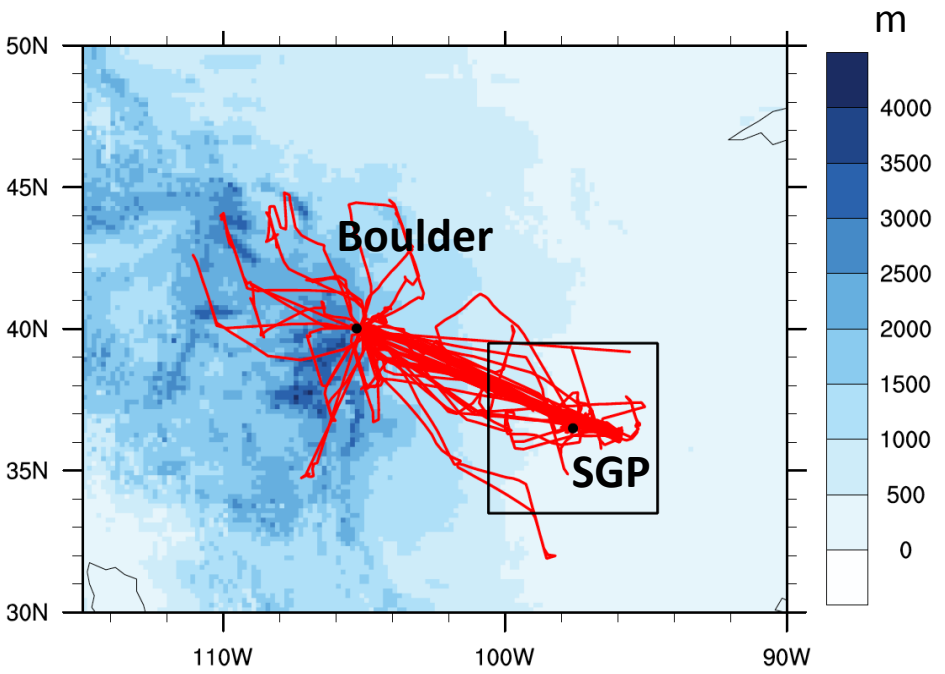
Motivations

- Cirrus clouds are one of the key components in the climate system, and are vital to global energy balance and hydrologic cycles.
- There are large uncertainties in the model representations of clouds and aerosol-cloud interactions, especially for cirrus clouds, e.g., ice crystal properties, ice nucleation, aggregational growth of ice crystals
- Cloud micro-physical properties vary greatly in time and space. In-situ observations are valuable for providing insights into the discrepancies in model simulations of cirrus clouds.

SPartICus: Small Particles In Cirrus
January-June 2010

- **Routine** aircraft in situ measurements in cirrus over ARM SGP
- New generation of probes designed to minimize artifacts due to ice shattering
- **Resolution: ~150 m; Duration: ~155 hr**
- **Cirrus analysis restricted to T≤-40°C;** Ice crystals (10.0 µm - 3000 µm)
- ***in situ* cirrus** observed over SGP (6°×6°).



Aircraft trajectories during the SPartICus field campaign. Color shading shows the surface elevation. The square indicates a 6°×6° (~600 km×600 km) area centered at SGP, within which the measurements are used.

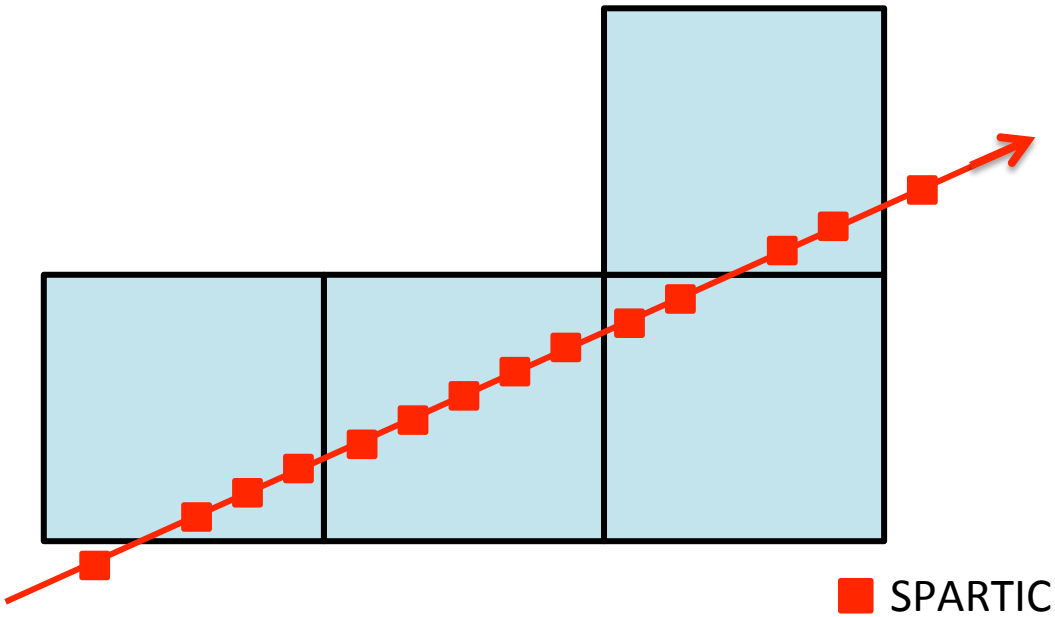
- Evaluate modeled statistics of Ni, IWC, Di, etc.
- Constrain the formation mechanism of ice crystals
- Constrain the aggregational growth of ice crystals

Community Atmospheric Model (CAM5.3+)

- **Model: CAM5.3+** (1.9°×2.5°) with MG2 cloud microphysics (Gettelman and Morrison 2015).
- **Direct comparisons** are made by:

  (1) nudging model meteorology (*U*, *V*, *T*) towards NASA GEOS-5 analysis for SPartICus period (Jan-June 2010);

  (2) collocating model output with aircraft flight tracks.

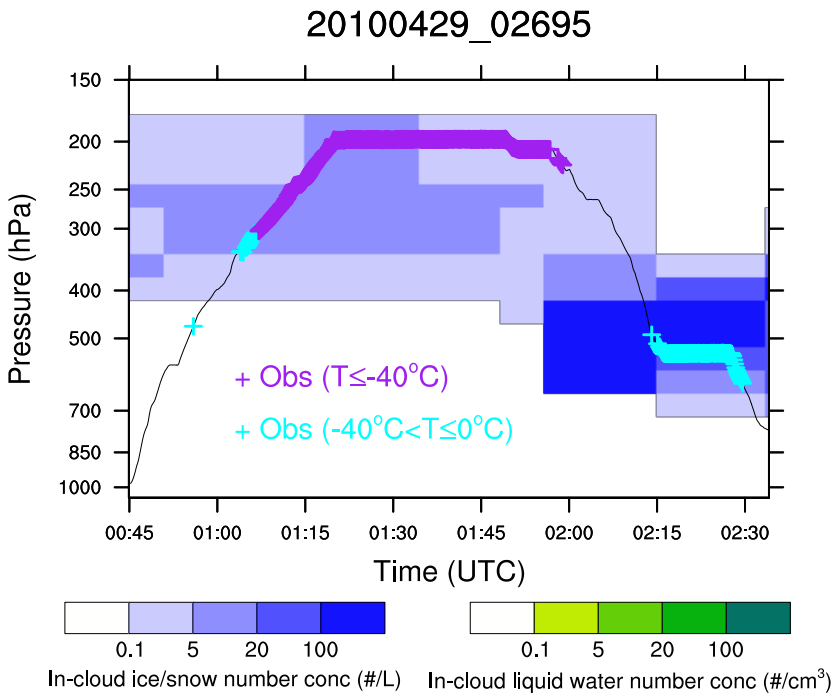


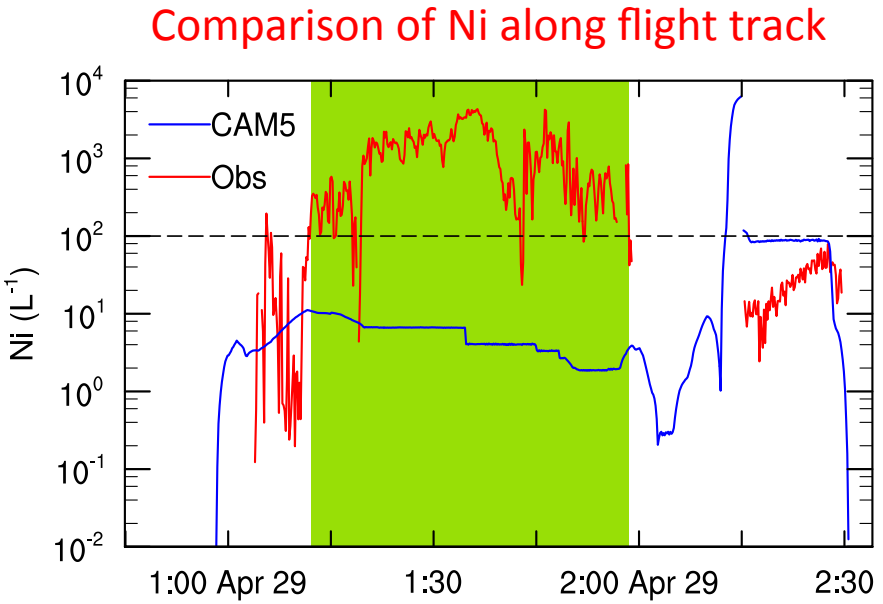
CAM5.3+ simulations

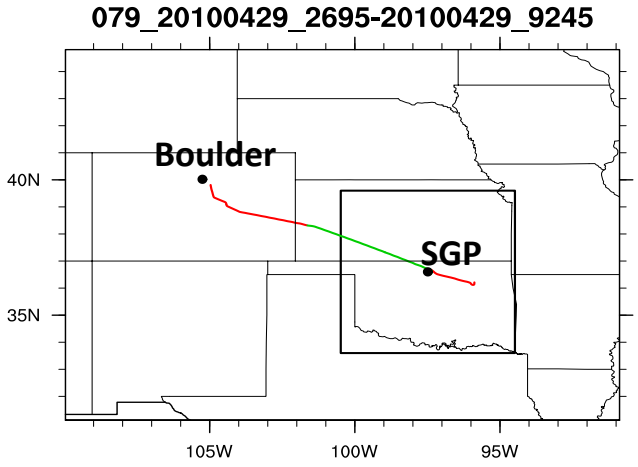
Simulation	Wsubi upper limiter	Preexisting ice	Ice nucleation	Dcs
Control	yes	no	Hom/Het	150 μm
PRE-ICE	**no**	**yes**	Hom/Het	150 μm
HET	yes	no	**Het**	150 μm
DCS	yes	no	Hom/Het	**250 μm**

- Wsubi upper limiter: vertical velocity variance from TKE is limited to **0.2 m/s**
- Pre-existing ice: consider the effects of pre-existing ice on ice nucleation so as to remove artificial Wsubi limiter (Shi et al. 2015)
- Hom/Het: Liu & Penner (2005) ice nucleation parameterization
- Dcs: threshold size for autoconversion of cloud ice to snow

Cloud occurrences during the flight on April 29, 2010 (SPartICus)



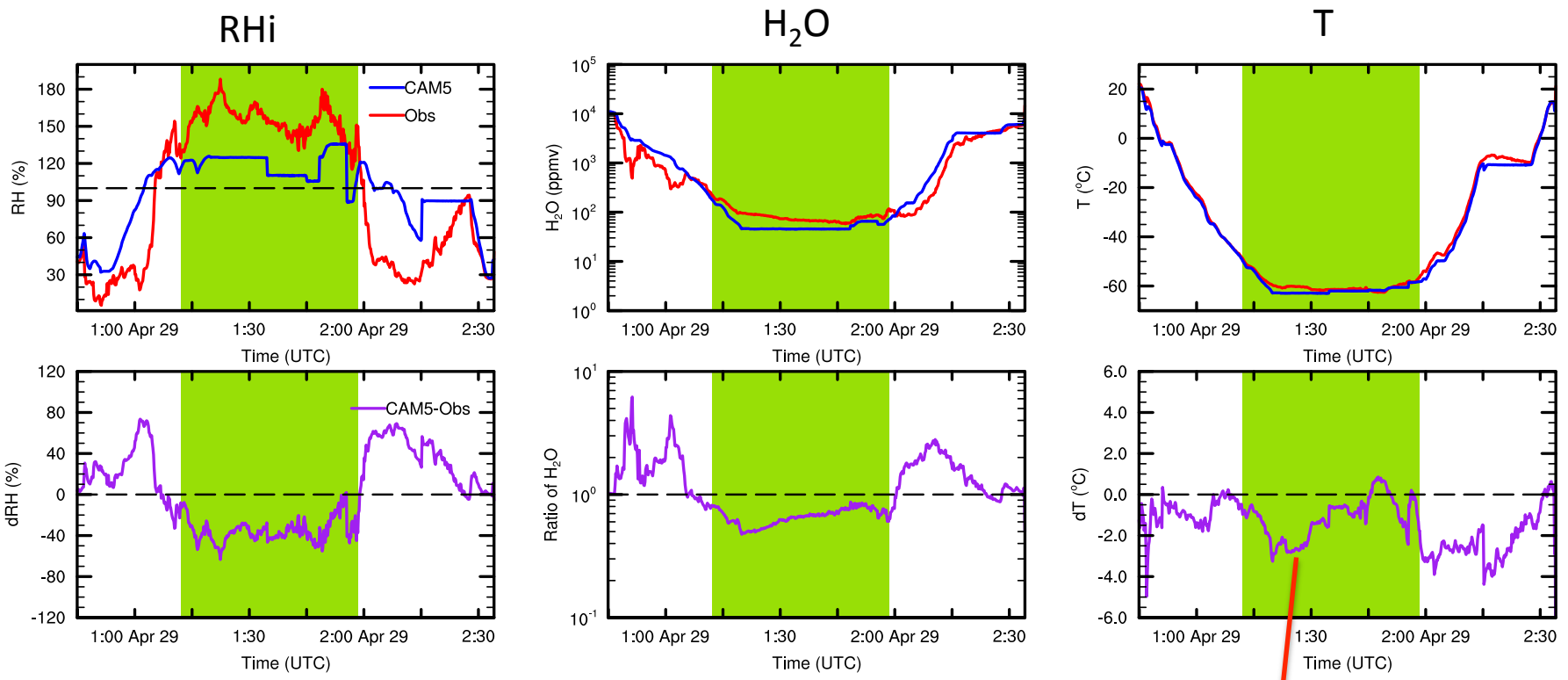




Green shaded (T<=-40°C):
Ni (obs) ~100 -1000 L^{-1}, homogeneous
Ni (mod) ~10 L^{-1}, heterogeneous

Model significantly underestimates Ni.

Comparison of RHi, H_2O and T



RHi (obs): ~140-160%
RHi (mod): ~120%

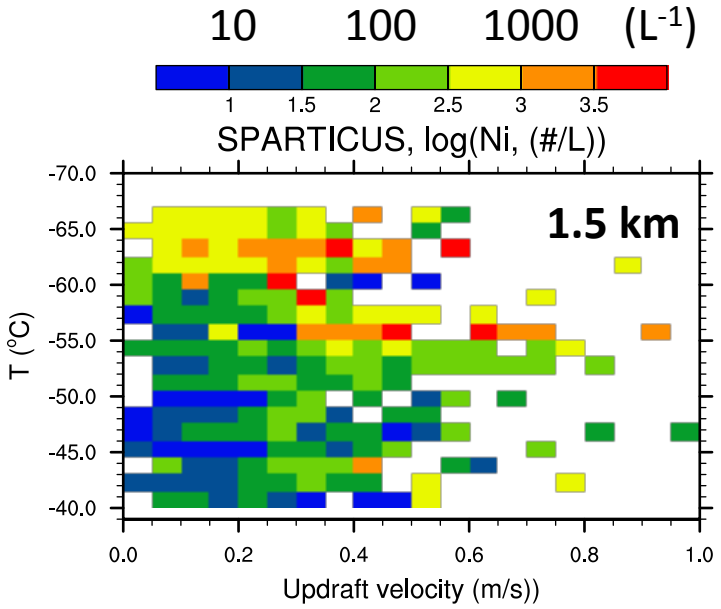
RHi bias mainly from water vapor bias (a factor of 2)

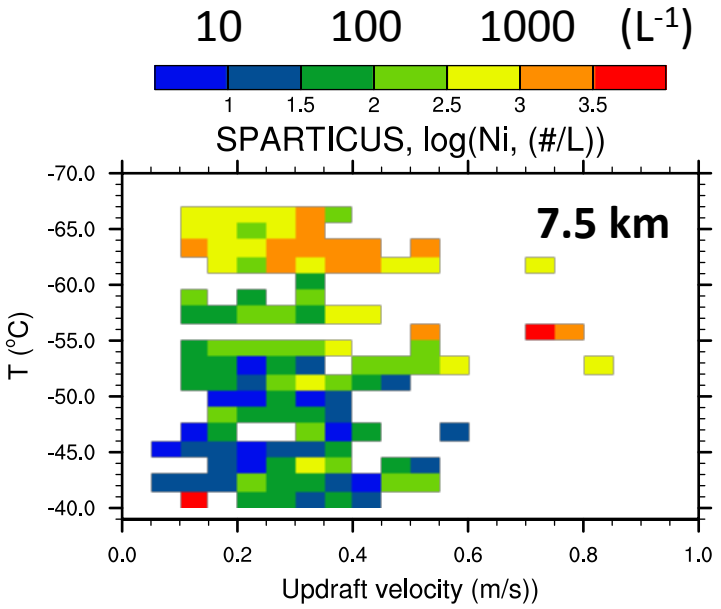
Lower T will lead to higher RHi.

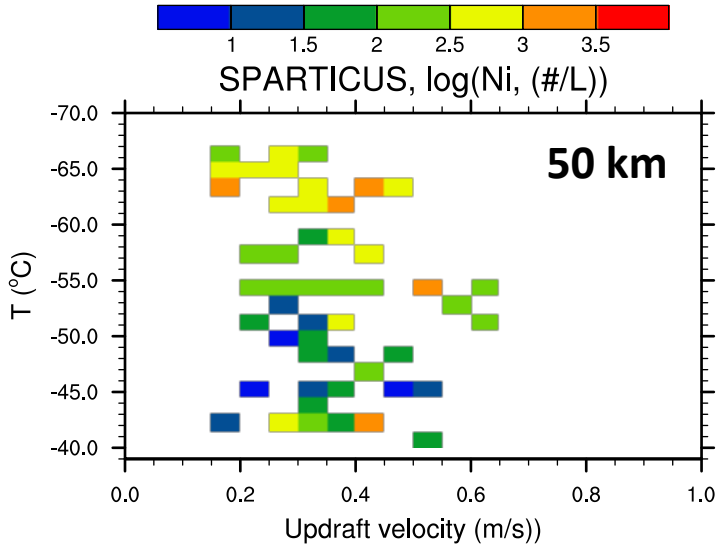
Caveat: Observed water vapor may not be less reliable during the SPartICus and needs to be corrected.

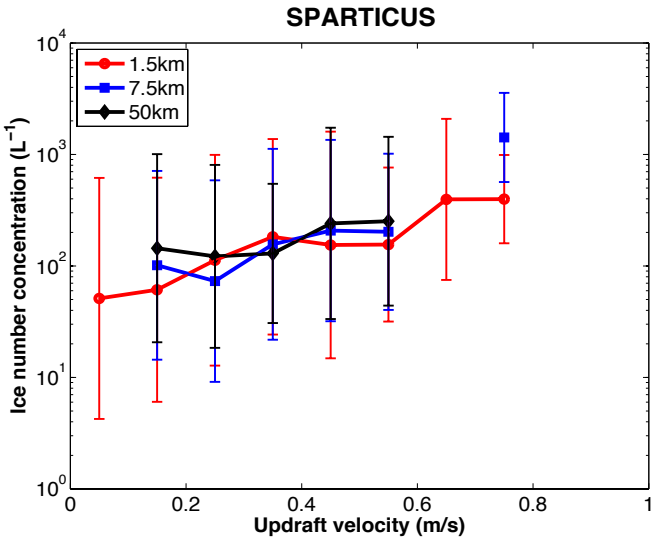
Ice Number vs. Vertical Velocity Variance σ_w, T

Obs.



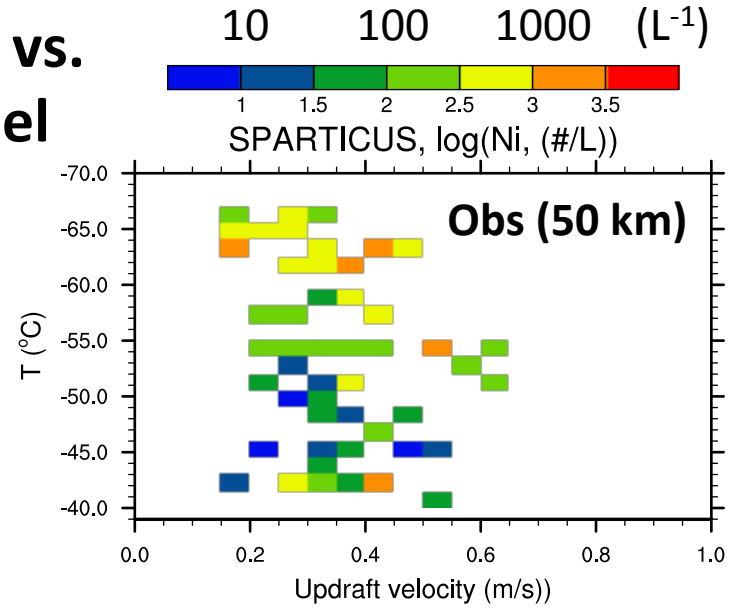


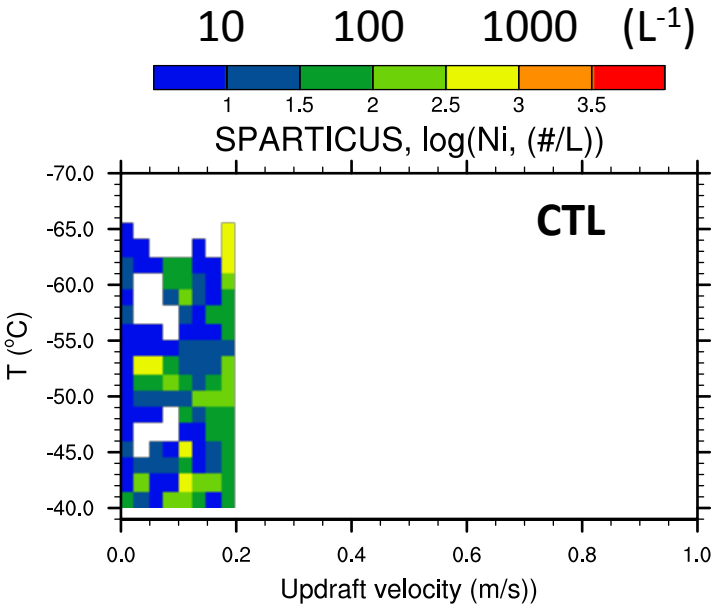


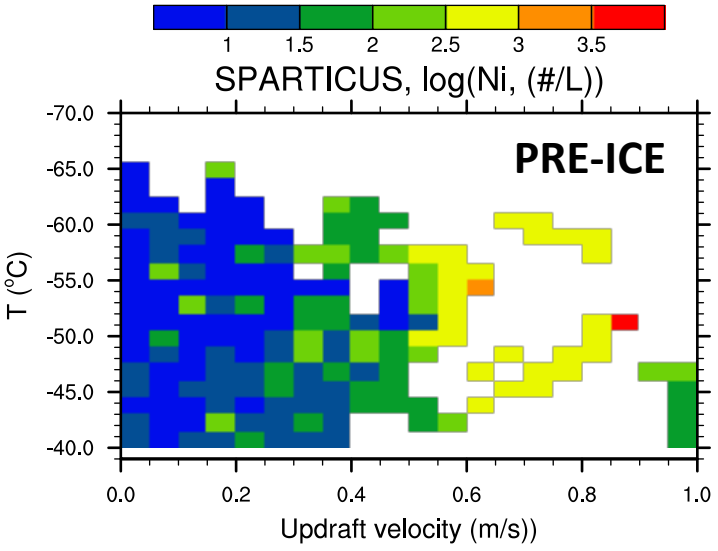


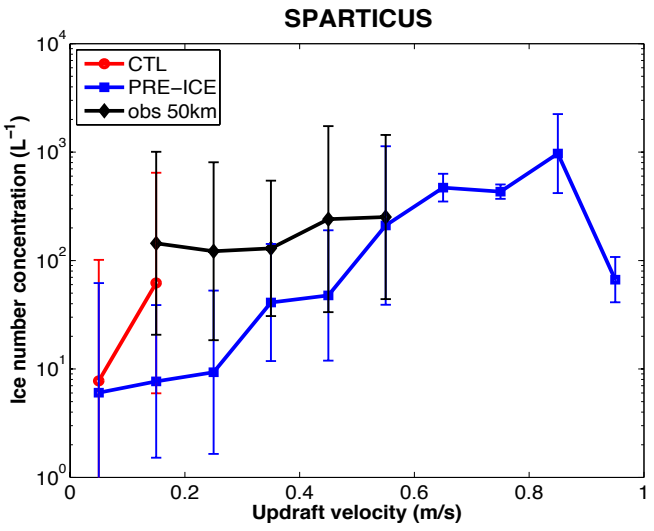
Ice Number vs. Vertical Velocity Variance σ_w, T

Obs. vs. Model

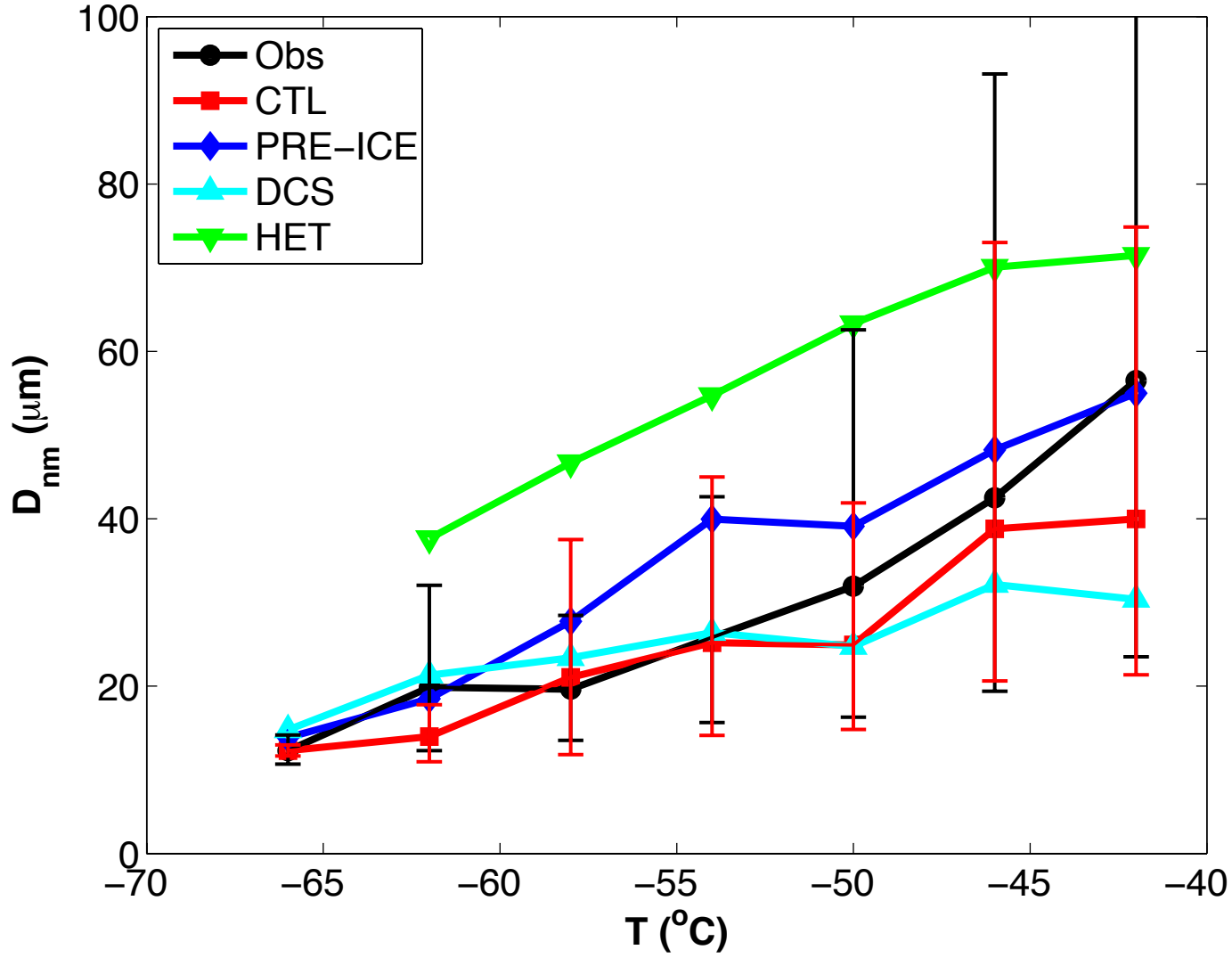




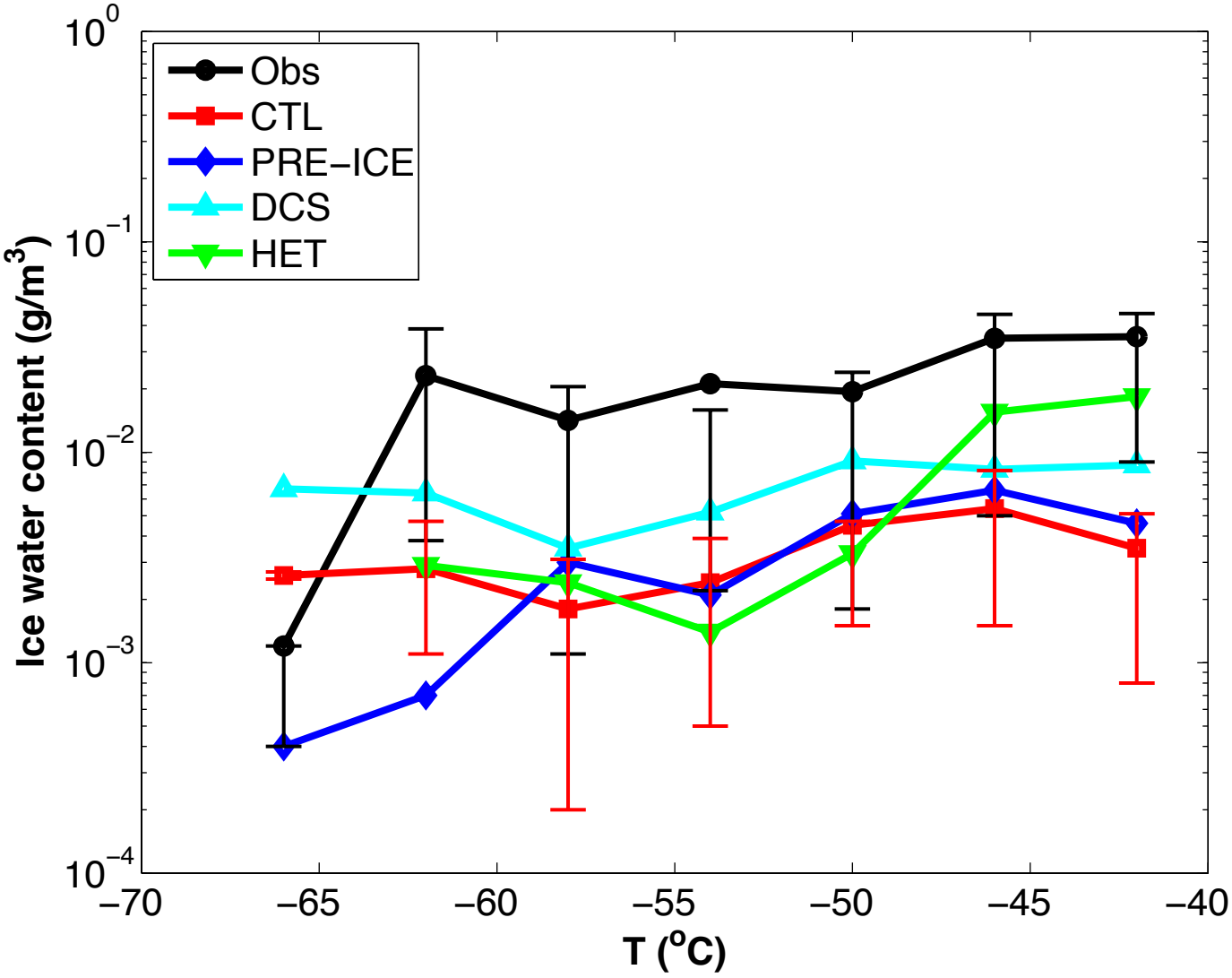




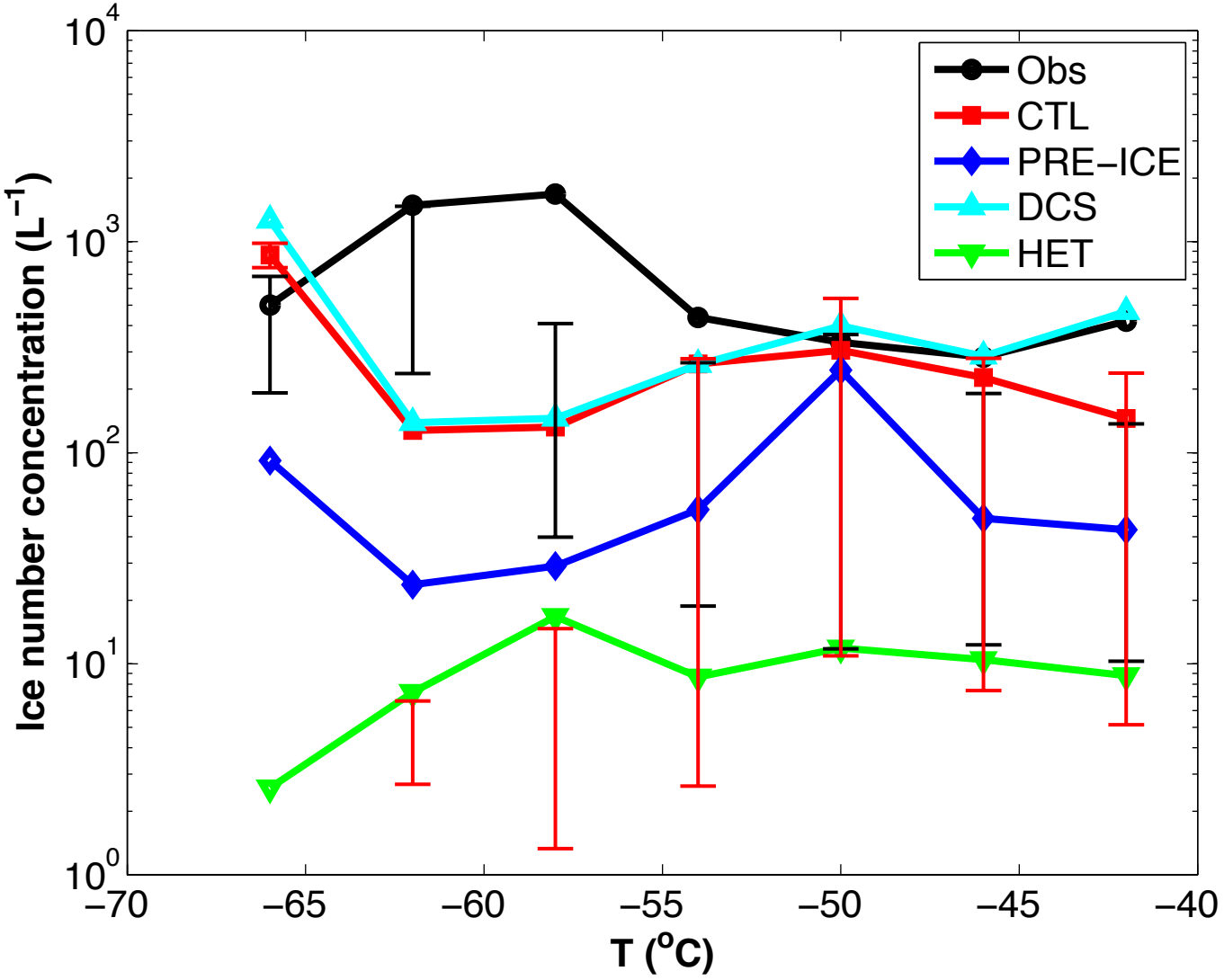
Ice Crystal Size (D_{nm}) vs. T



Ice Water Content vs. T



Ice Number vs. T



Summary

- Direct comparison of CAM5.3+ simulated ice clouds against SPartICus observations is conducted by collocating model output with aircraft flight tracks.
- CAM5.3+ significantly underestimates IWC and N_i, although produces much better ice particle sizes compared to observations.
- Model bias in N_i is often due to the RH bias attributed mostly to the bias of water vapor, not in T.

Caveat: need reliable water vapor measurements.