Ice-Phase Particle Size Distributions in May 20 MC3E Convective System

Sensitivity to Ice Collection Kernel

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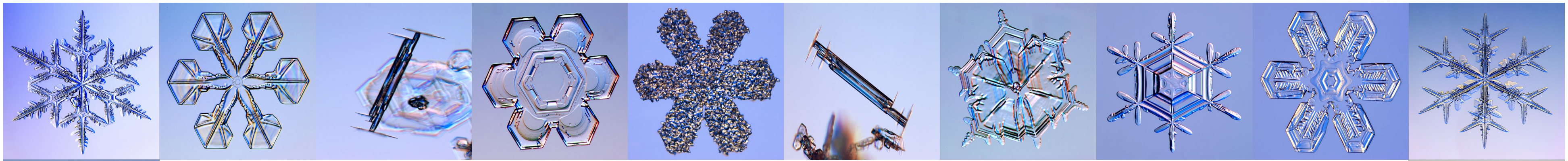
Motivation

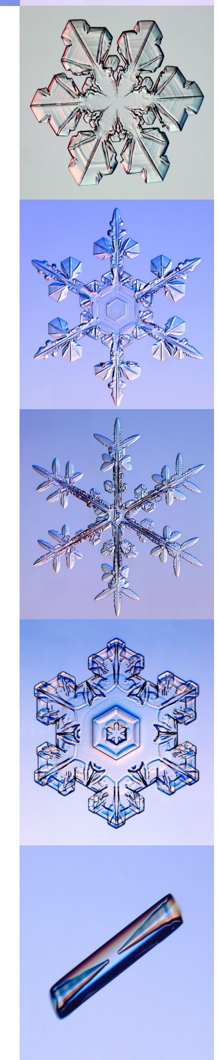
- Ice-phase particles are crucial to surface rainfall formation and atmosphere radiation budget;
- They significantly affect GPM rainfall retrievals;
- Physical processes associated with ice-phase particle formation and growth are poorly understood, and therefore poorly represented in weather prediction models.

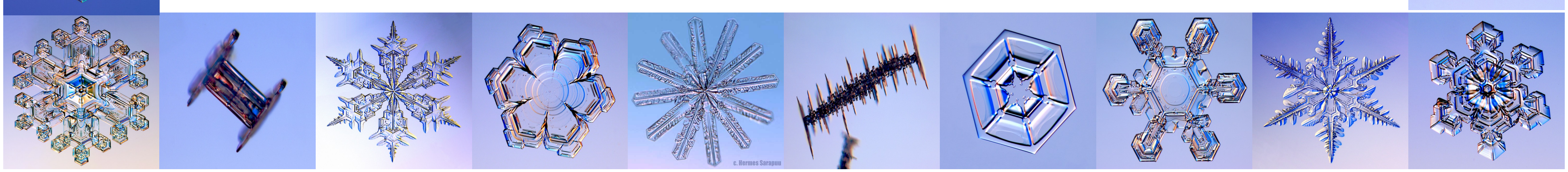


Factors affecting the evolution of ice-phase particle size spectra

large uncertainties in:

- density
- shape
- terminal fall velocity
- collision /coalescence
- ice nucleation
- cloud dynamics…





Collision/Coalescence process is governed by:

$$\frac{dn_k}{dt} = \frac{1}{2}\int_0^{m_k=m_i+m_j} K_{k-j,j}\, n_{k-j}\, n_j\, dm_j - n_k \int_0^{\infty} K_{kj}\, n_j\, dm_j$$

The collection kernel between two particles:

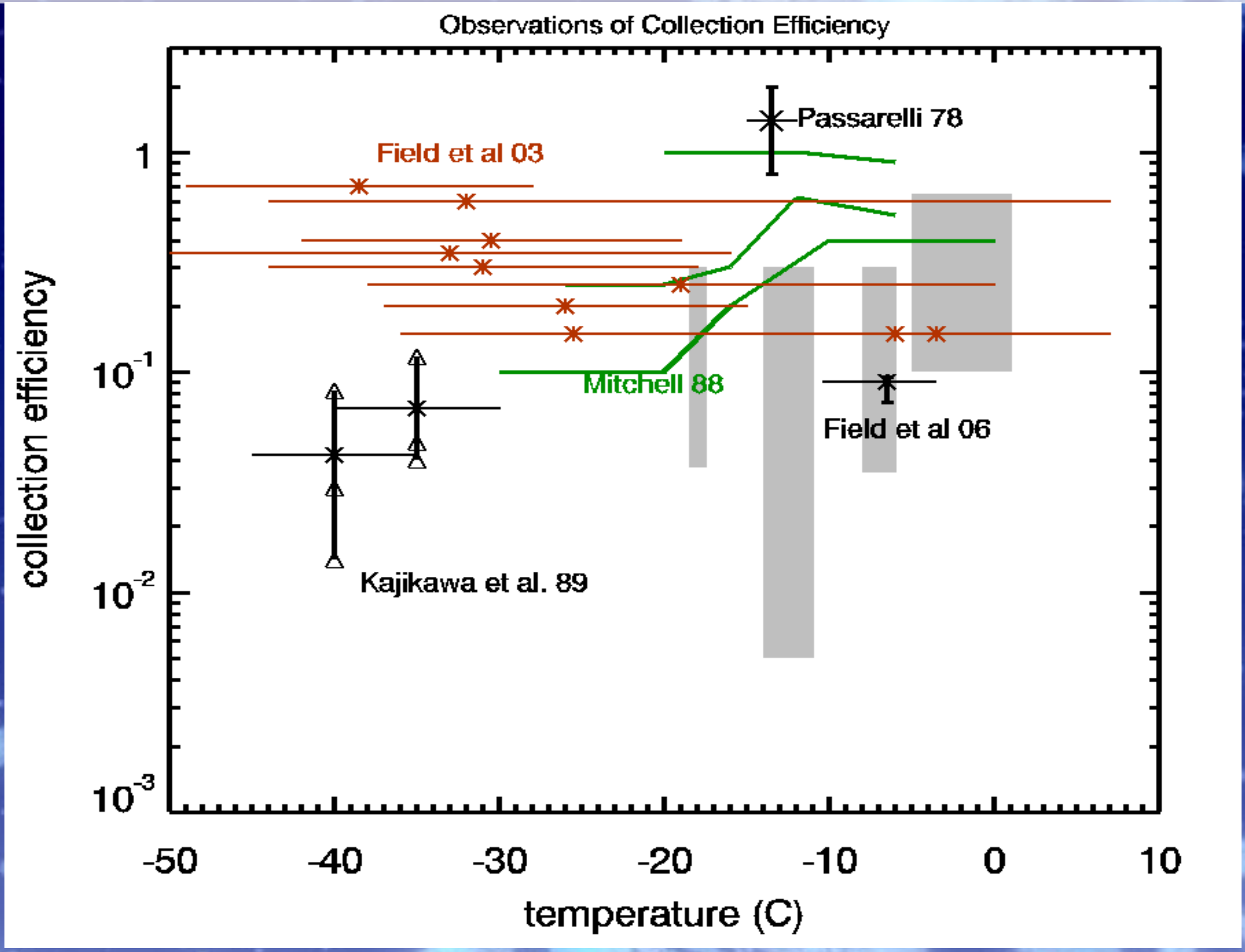
$$K_{ij} = \frac{\pi}{4}\left(D_i + D_j\right)^2 \left|v_i - v_j\right| E_c$$

size

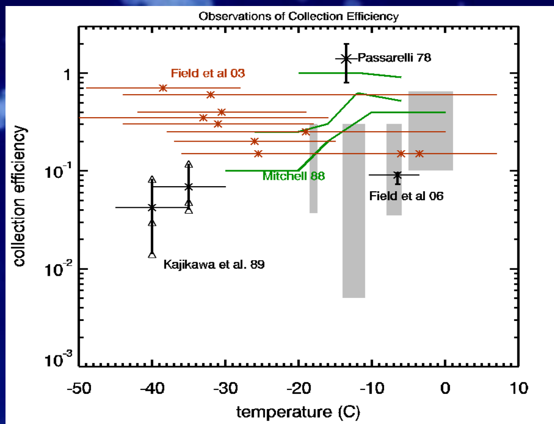
Fall velocity

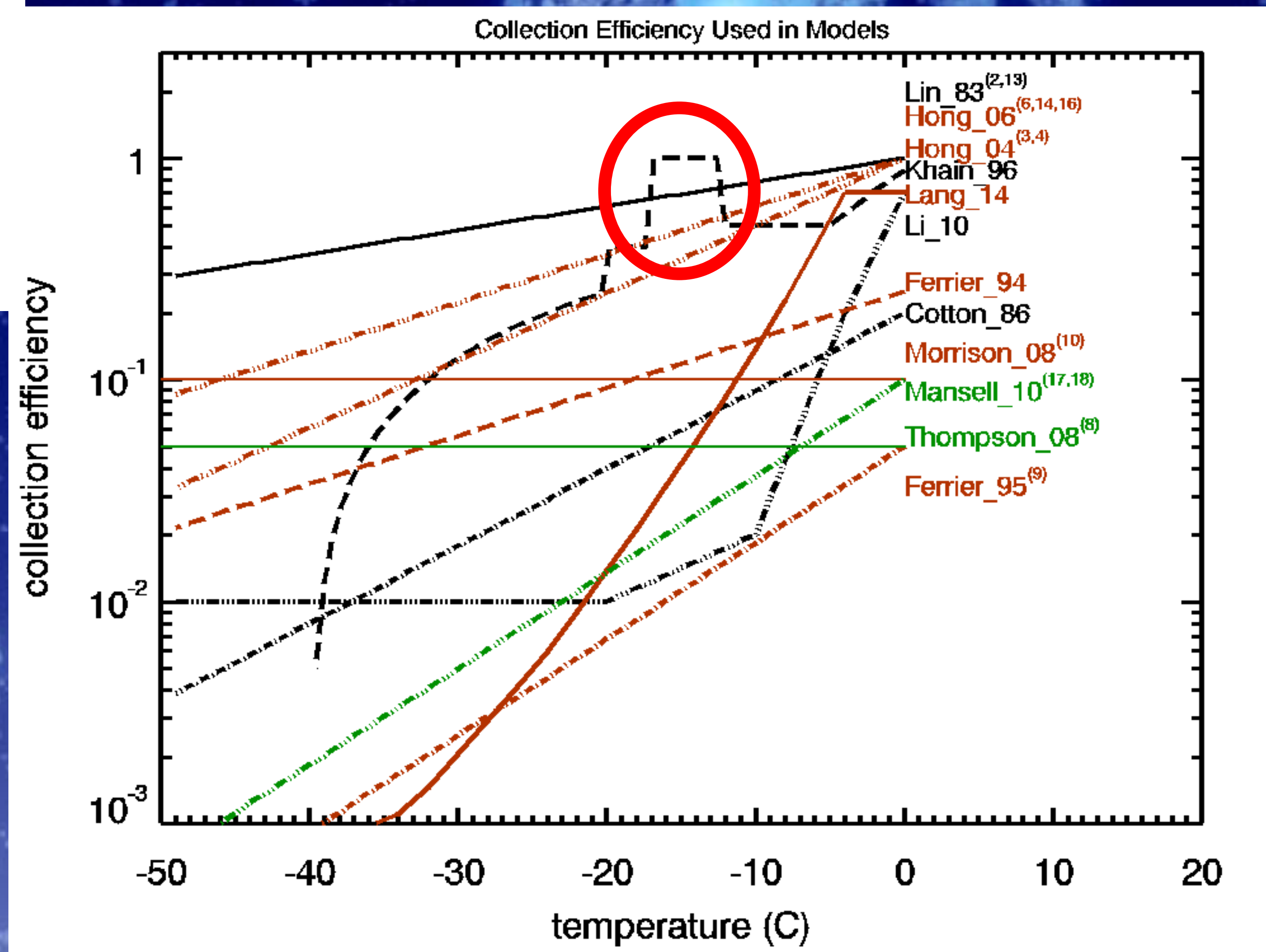
Collection Efficiency (T, RH)

Collection Efficiencies Ec(T) in Observations



Collection Efficiency in Models





Study Goal

To Reduce Uncertainties in Ec(T)

Using case studies with:

- **In-situ PSD observations;**
- **Radar and GPM profiles;**
- **Cloud-resolving model with a detailed spectral bin microphysics scheme.**

Steady precipitation systems:

- Trailing stratiform region of Mesoscale Convective Systems **(MC3E)**;
- Orographic precipitation **(IPHEx, OLYMPEx)**.

Presentation Outline

Conclusion:

Models we tested overestimate Ec (T).

- We will show three pieces of supporting evidence through MC3E case study:
  1. Comparison with in-situ ice-phase particle size distributions.
  2. Sensitivity test by reducing the Ec improved results.
  3. A previous study using surface radar and TRMM PR comparison with an earlier version of SBM scheme reached similar conclusion.

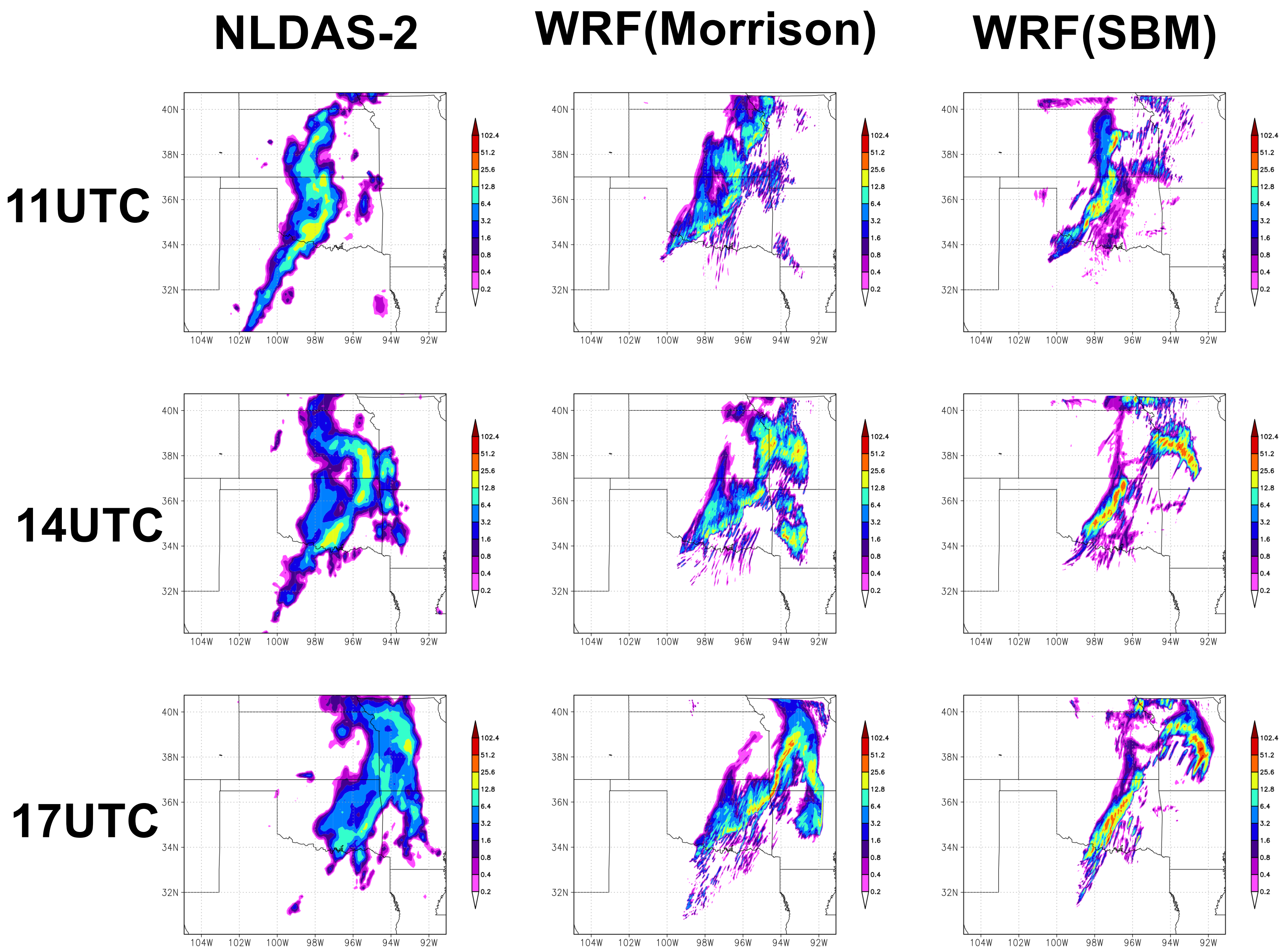
Model Description

- WRF v3.6.1, single domain, 24-hour simulation;
- 2-km horizontal resolution, 44 vertical levels;
- Initiated with NCEP FNL Operational Global Analysis staring at 00 UTC, May 20, 2011;
- Hebrew U Spectral Bin Microphysical Scheme (SBM):

43 mass-doubling size bins representing particle size distributions for 3 shapes of ice crystals (column, plate, dendrite), snow aggregate, graupel, hail and cloud/rain.

- Morrison 2-Moment Microphysical Scheme:

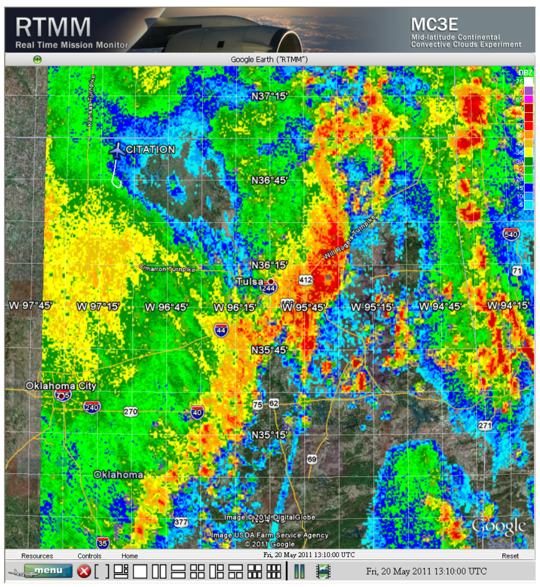
Ice, snow graupel and rain use inverse exponential distributions; cloud droplet uses gamma distribution.



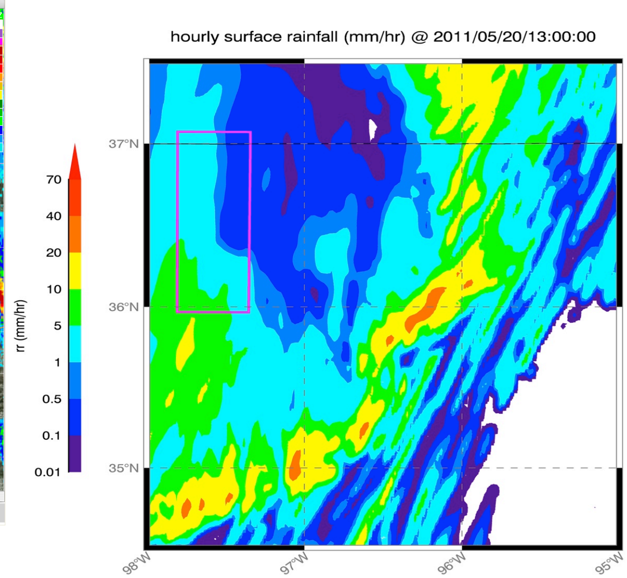
Surface Rainfall Comparisons

Comparison with In-situ PSD data

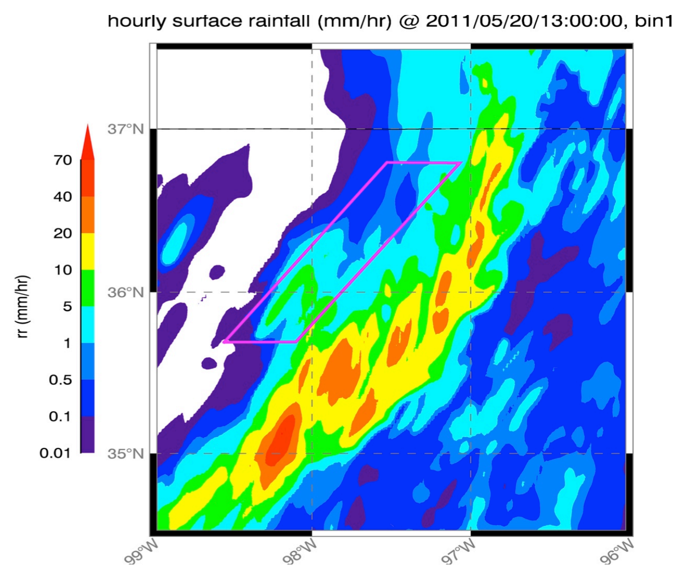
Citation flight track



Morrison scheme sample



SBM scheme sample

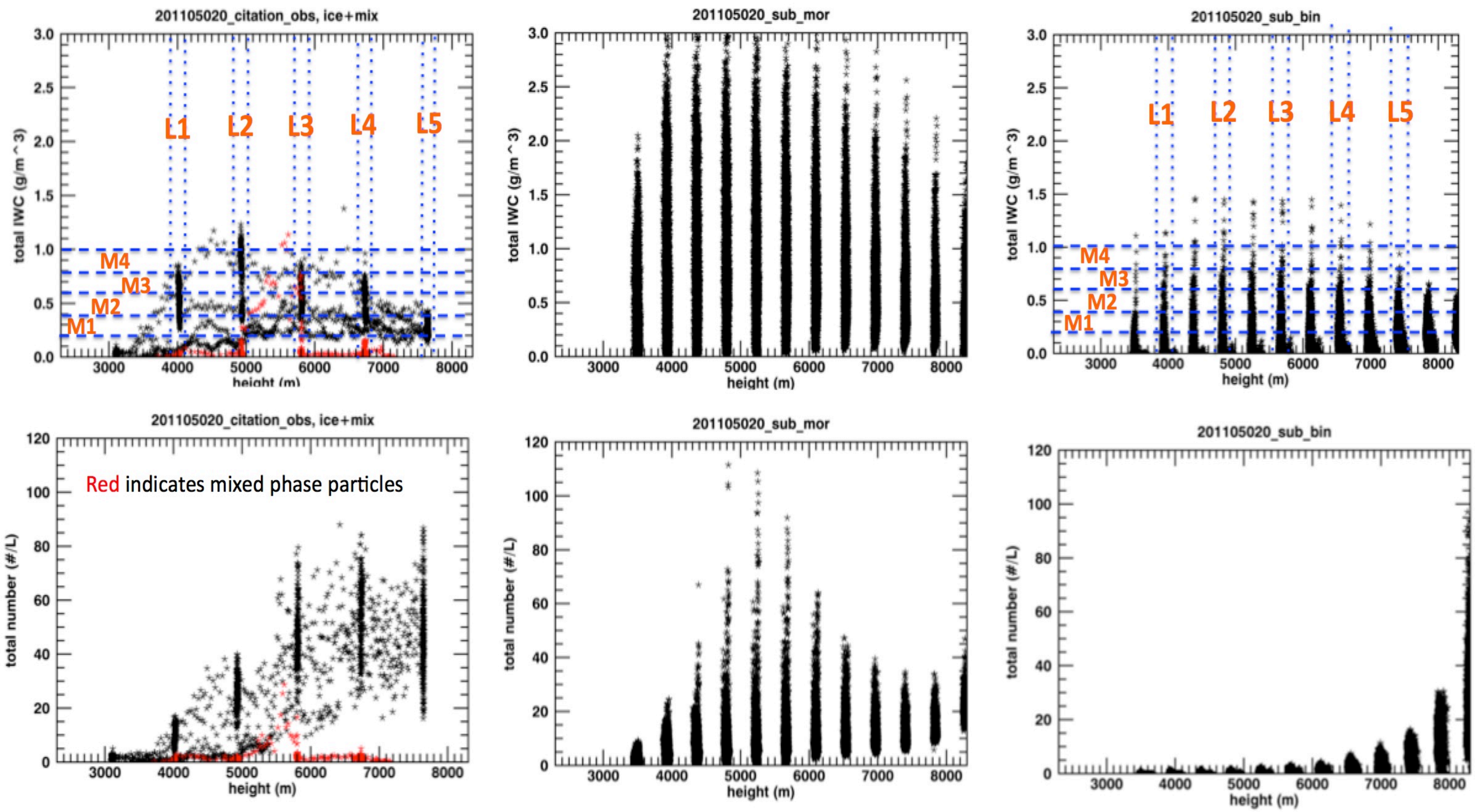


Comparison with In-situ PSD data

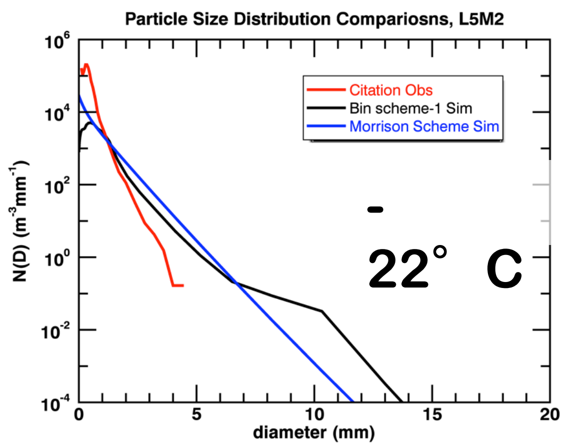
Citation Obs | **WRF Morrison Sim** | **WRF SBM Sim**

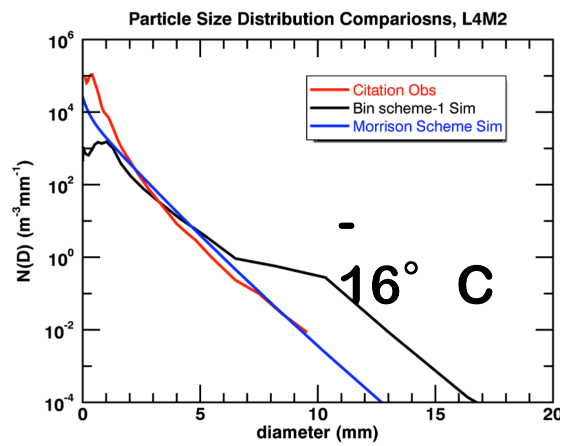
IWC

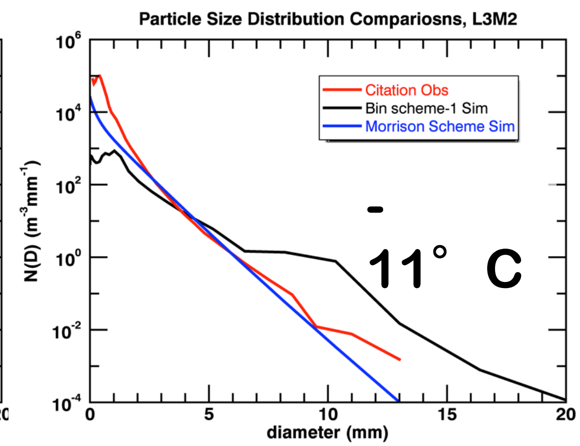
Total Num

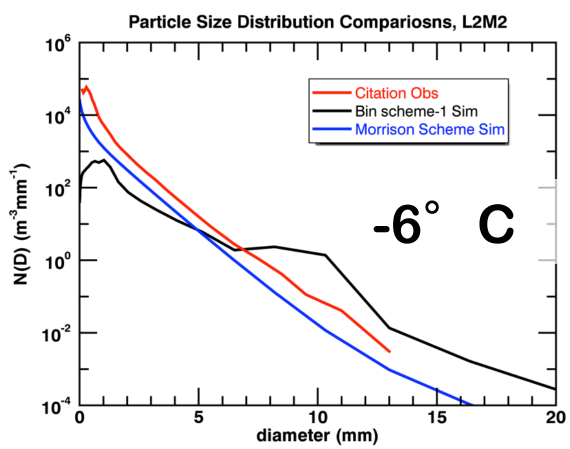


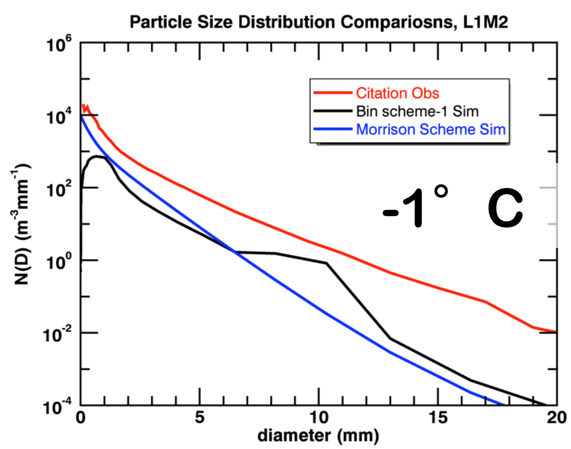
Comparison with In-situ PSD data







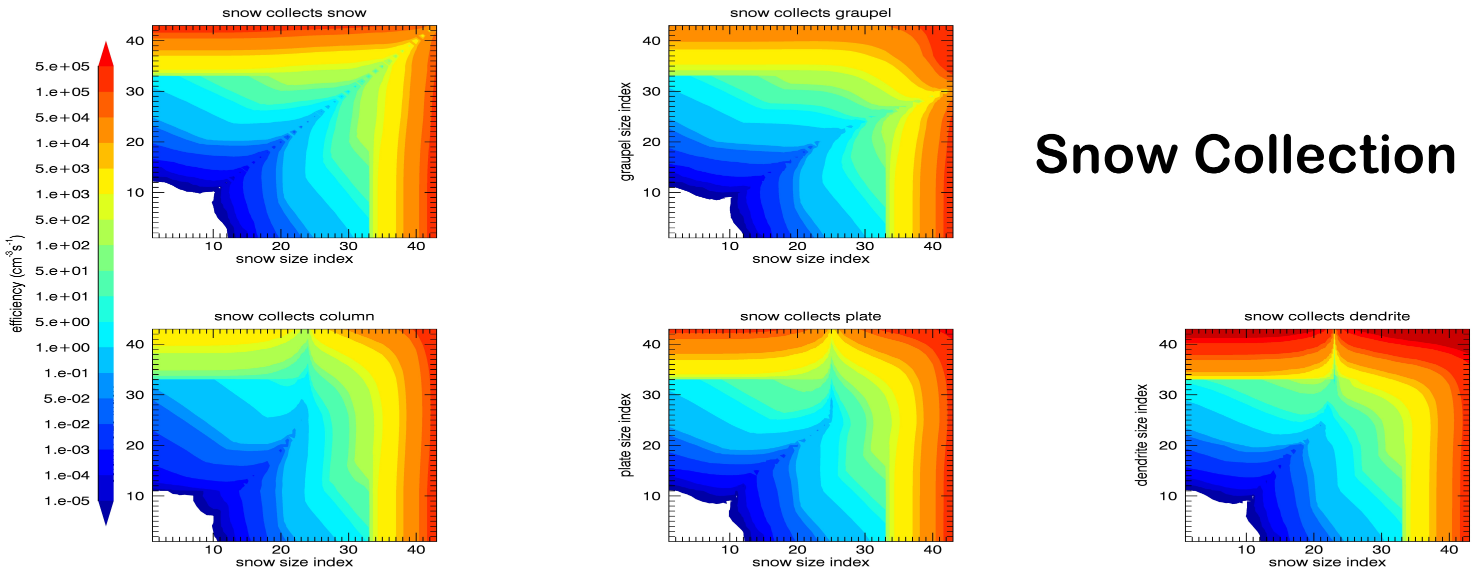




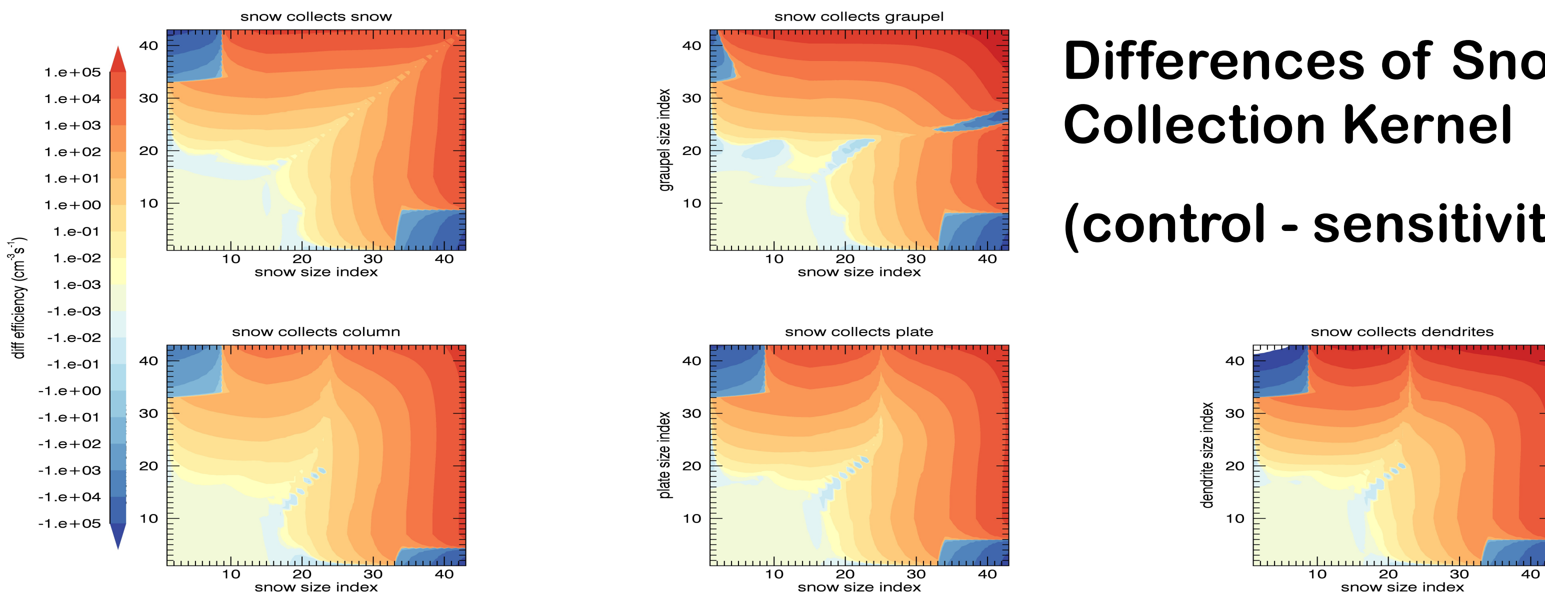
Comparisons indicate that both microphysical schemes have too strong collection.

For IWC between 0.4 ~ 0.6 g/m^3

Sensitivity Test with Reduced Ec



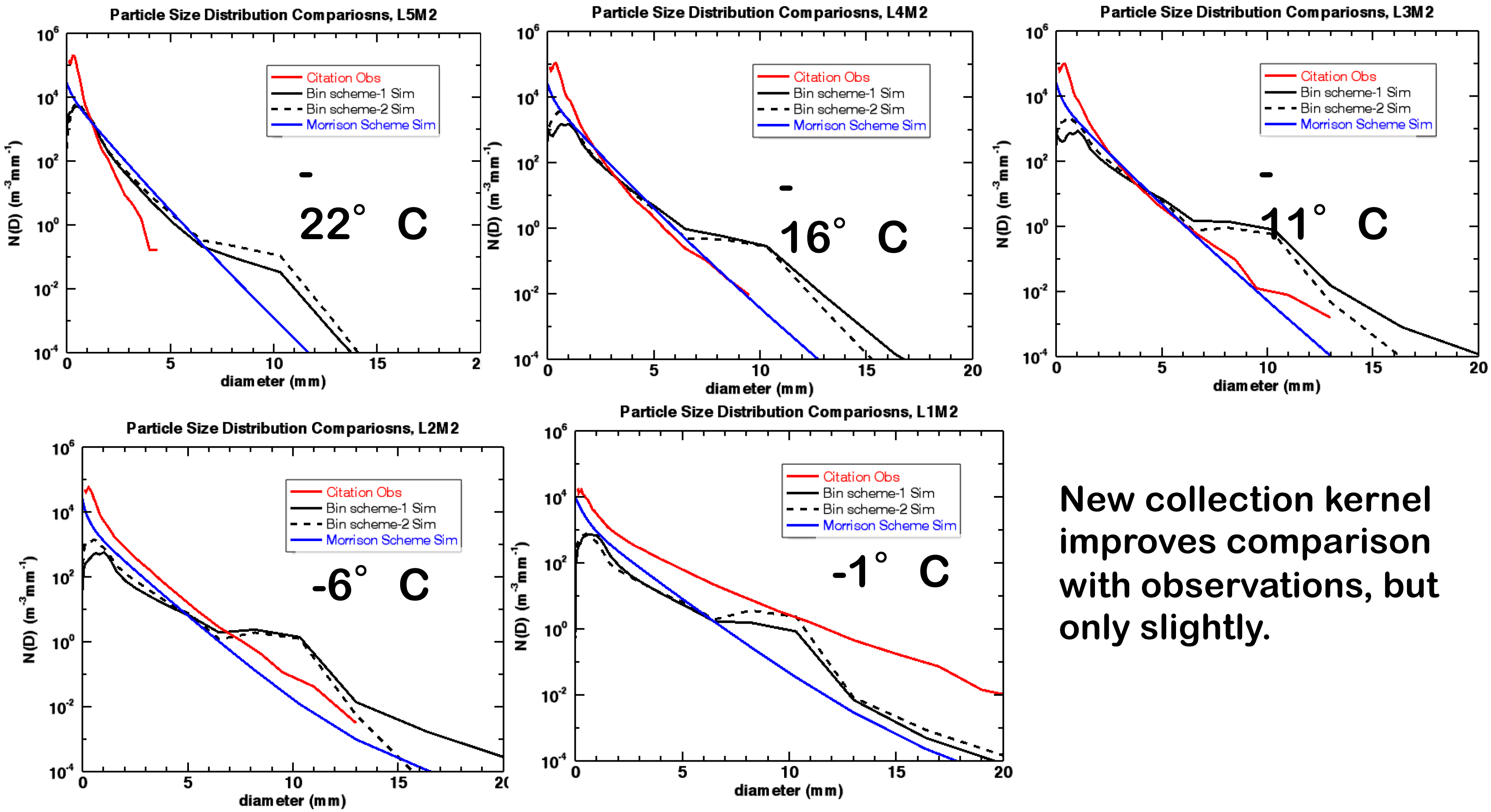
Snow Collection Kernel



Differences of Snow Collection Kernel

(control - sensitivity)

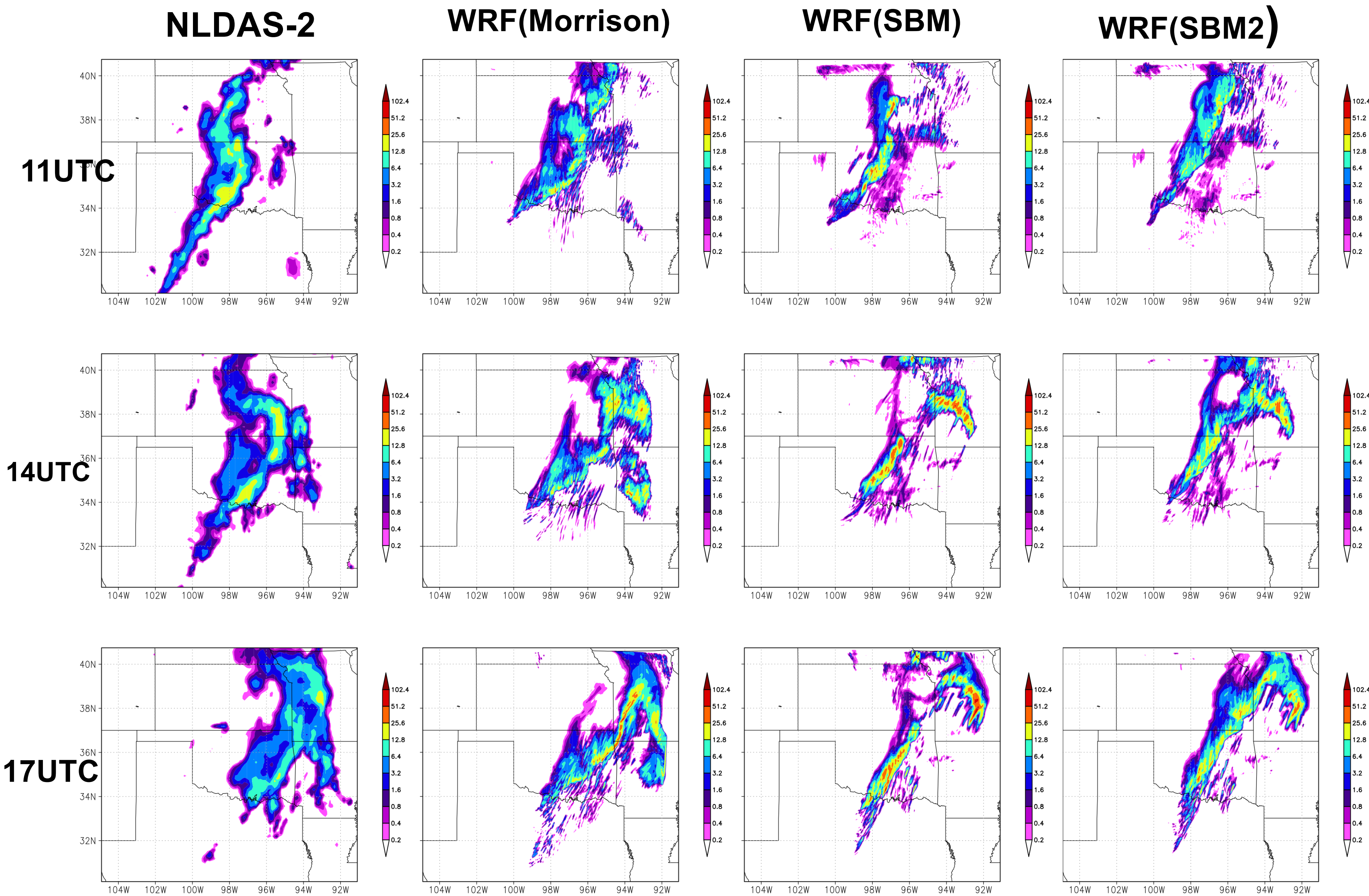
Sensitivity Test with Reduced Ec



New collection kernel improves comparison with observations, but only slightly.

For IWC between 0.4 ~ 0.6 g/m^3

Sensitivity Test with Reduced Ec

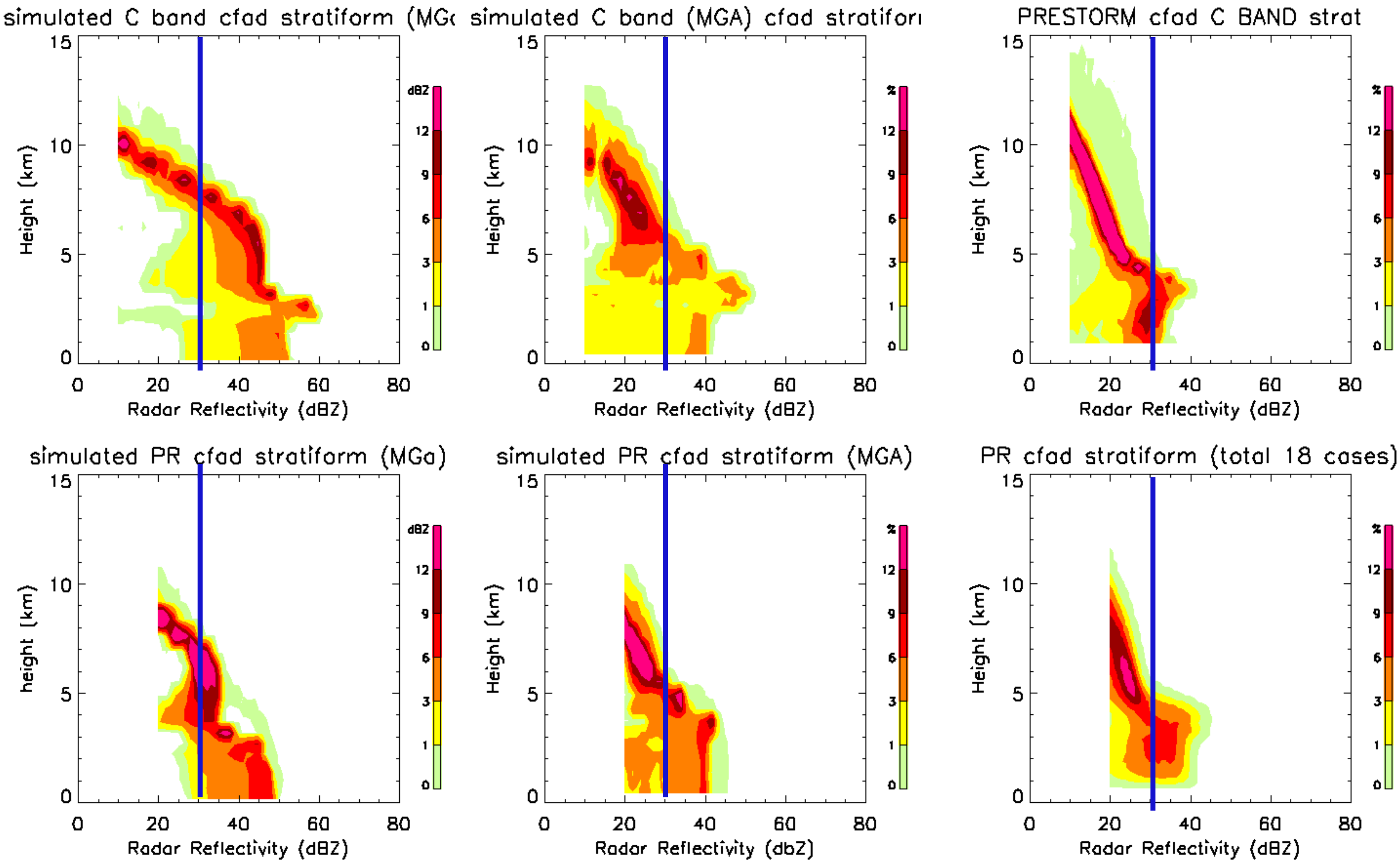


Reducing Ec (T) produces better Radar CFADs Comparisons

Original | **Reduce Ec** | **Observed**

C-Band

TRMM PR



Conclusion:

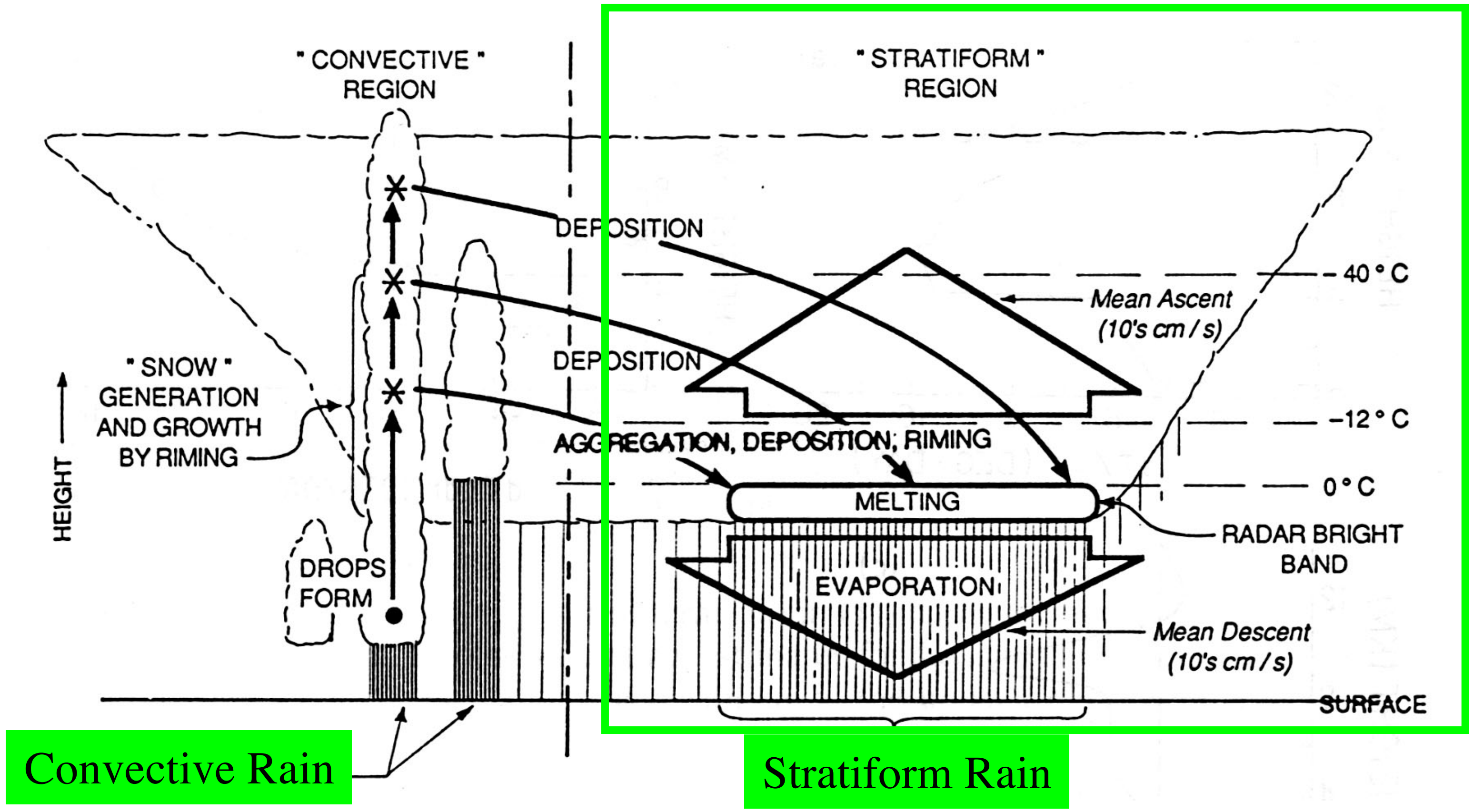
Models we tested overestimate Ec.

1. Comparisons with in-situ ice-phase particle size distributions and their vertical variations indicated Ec overestimation.
2. Sensitivity test by reducing the Ec improved PSD comparison and stratiform structure.
3. A previous study using surface radar and TRMM PR drew a similar conclusion.

Future Plans:

1. Check rain DSD and see if the signals of large particles show.
2. Sensitivity tests by varying Ec(T) in the model.
3. Compare radar reflectivity profiles with airborne and GPM DPR.
4. Extend case studies to IPHEx and OLYMPEx.

MCSs have extensive, homogeneous stratiform region



Houze, 1989: Observed structure of mesoscale convective systems and implications for large-scale heating. *Quart. J. Roy. Meteor. Soc.*, **115**, 425-461.