High-resolution MM5 Simulations of Hurricane Erin 2001: Role of Microphysical Processes

Henian Zhang*, Greg. M. McFarquhar*, Gerald Heymsfield, Robbie Hood, Jimy Dudhia, Jeffrey B. Halverson, and Frank Marks Jr.

***Department of Atmospheric Sciences**
University of Illinois at Urbana-Champaign

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Goal: **Determine if MM5 predictions of rain and graupel are consistent with high resolution observations of Hurricane Erin 2001**

Method: **Compare the observed and simulated radar reflectivity (Z), Doppler winds and microwave brightness temperatures (Tb) obtained during the Fourth Convection and Moisture Experiment (CAMEX-4)**

Outline:

- **Model setup**
- **Sensitivity to microphysics scheme**
- **Sensitivity to graupel fall speeds**
- **Application of a new iterative condensation scheme**

Acknowledgments:

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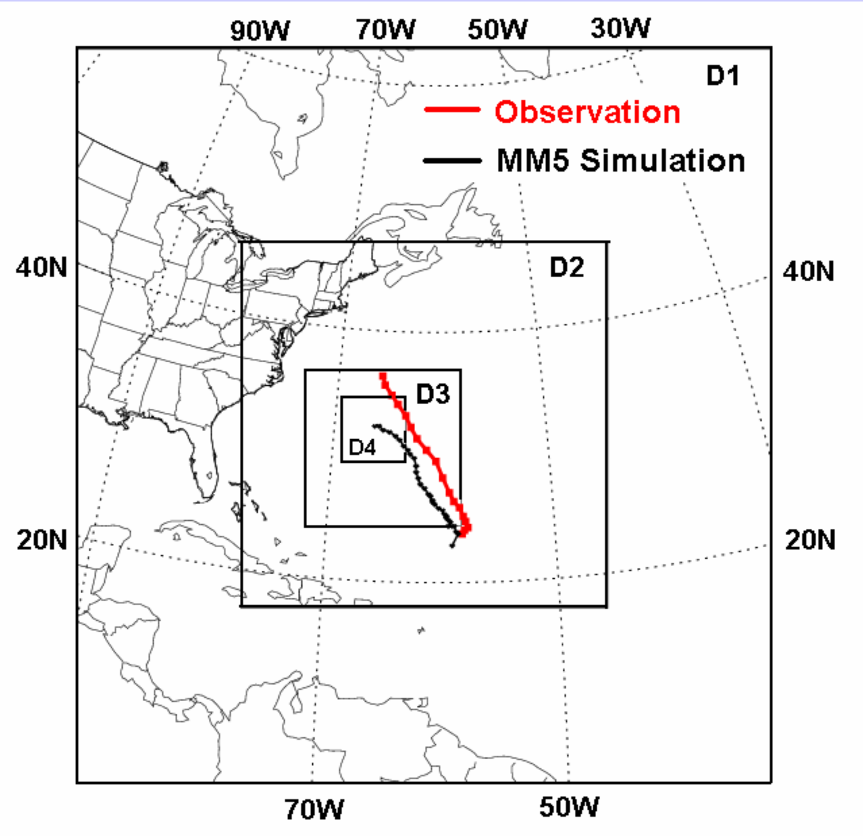
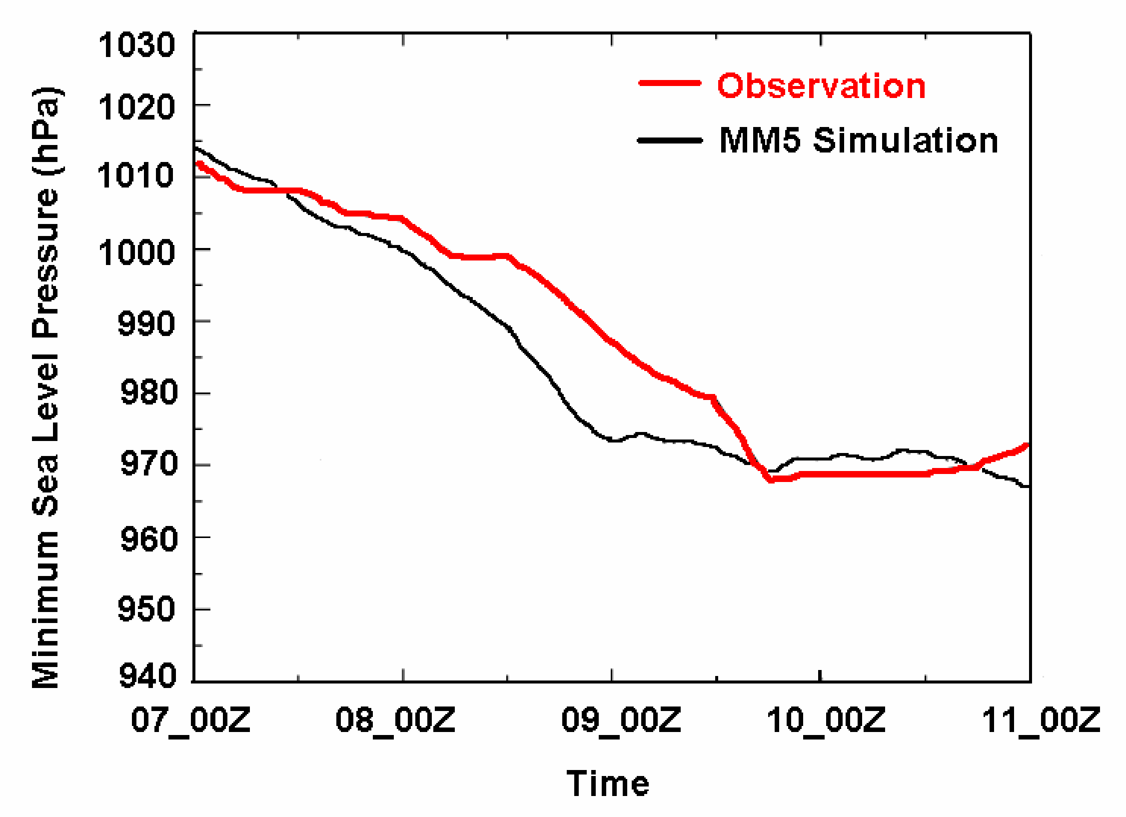
Model Setup

* Time period: 0000 UTC 7 September to 0000 UTC 11 September
* Four domains with horizontal resolutions of 54, 18, 6, 2 km
* 36 sigma levels in the vertical

- Burk Thompson planetary boundary layer scheme
- Betts-Miller cumulus parameterization for Domains 1, 2 and 3
- **Control simulation: Goddard microphysics scheme**





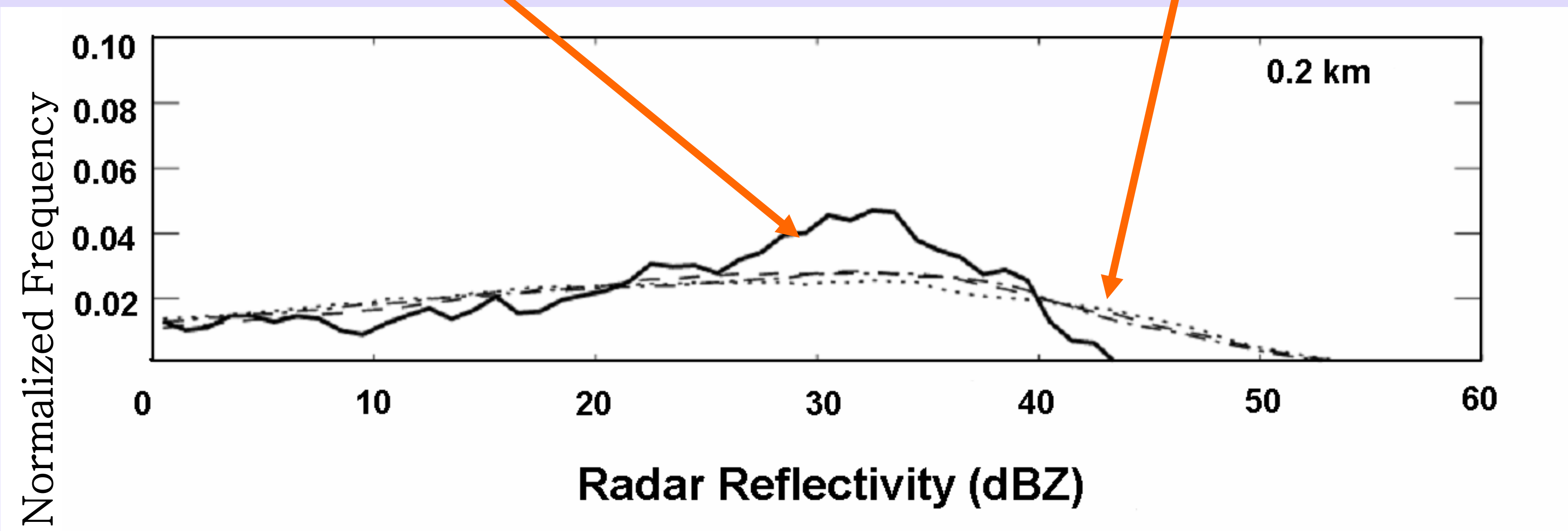
Results

1. Sensitivity to microphysics scheme

- – · – · Simple ice
- – – – Reisner mixed phase
- · · · · · Goddard (control simulation)
- —— Observation: from the ER-2 Doppler Radar

Underestimate Z between 20 and 40 dBZ

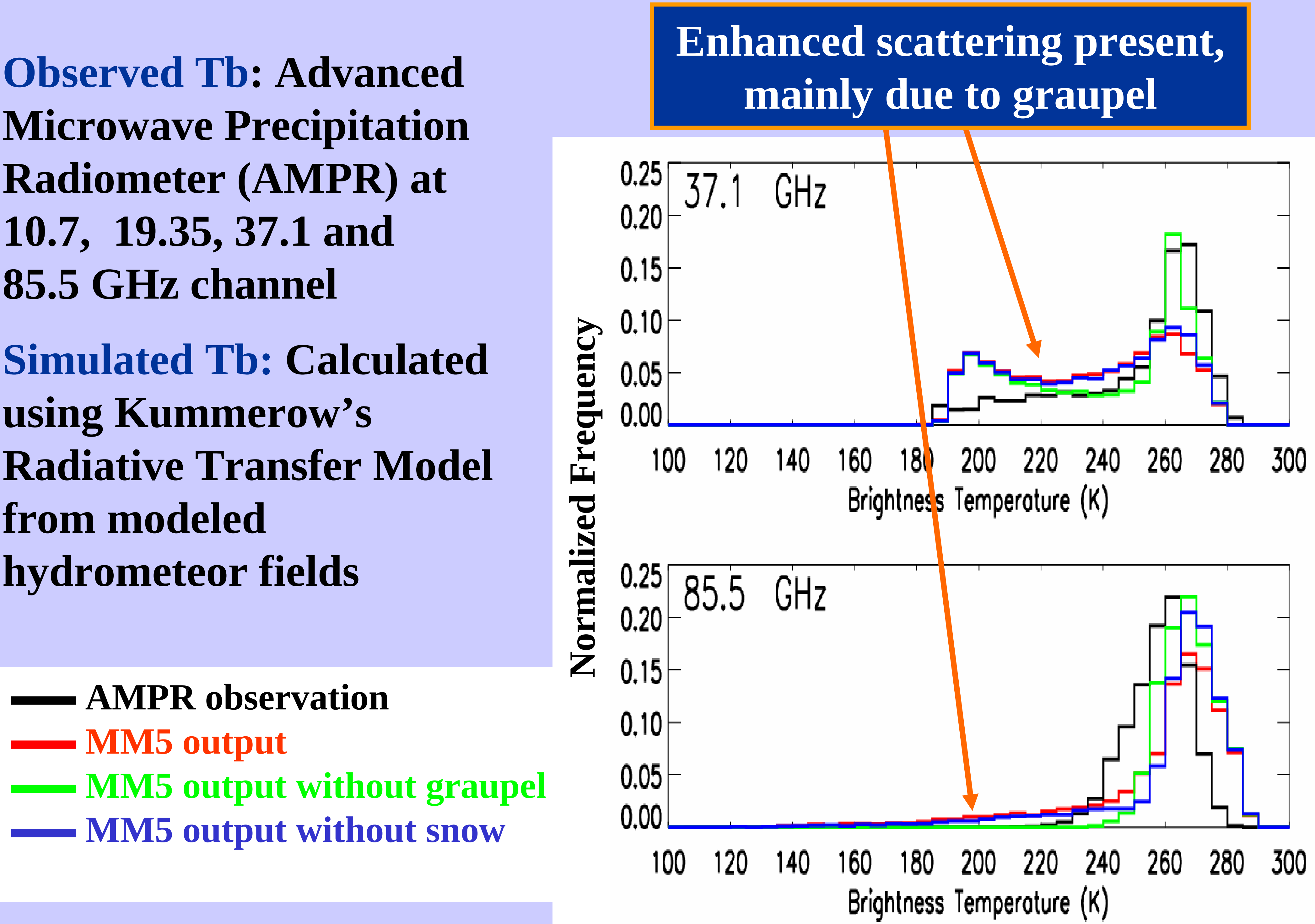
Overestimate Z > 40 dBZ



Comparison of the observed and simulated Tb

Observed Tb: Advanced Microwave Precipitation Radiometer (AMPR) at 10.7, 19.35, 37.1 and 85.5 GHz channel

Simulated Tb: Calculated using Kummerow's Radiative Transfer Model from modeled hydrometeor fields



Are Graupel Mixing Ratios q_g for Erin Too Large?

- **Less than 1% of q_g are > 0.5 g/kg observed in Hurricane Norbert (1984) and Emily (1987) near melting level (McFarquhar and Black 2004).**

- **More than 10% of q_g are > 0.5 g/kg for simulated Erin.**

Are Predicted Updrafts for Erin Too Large?

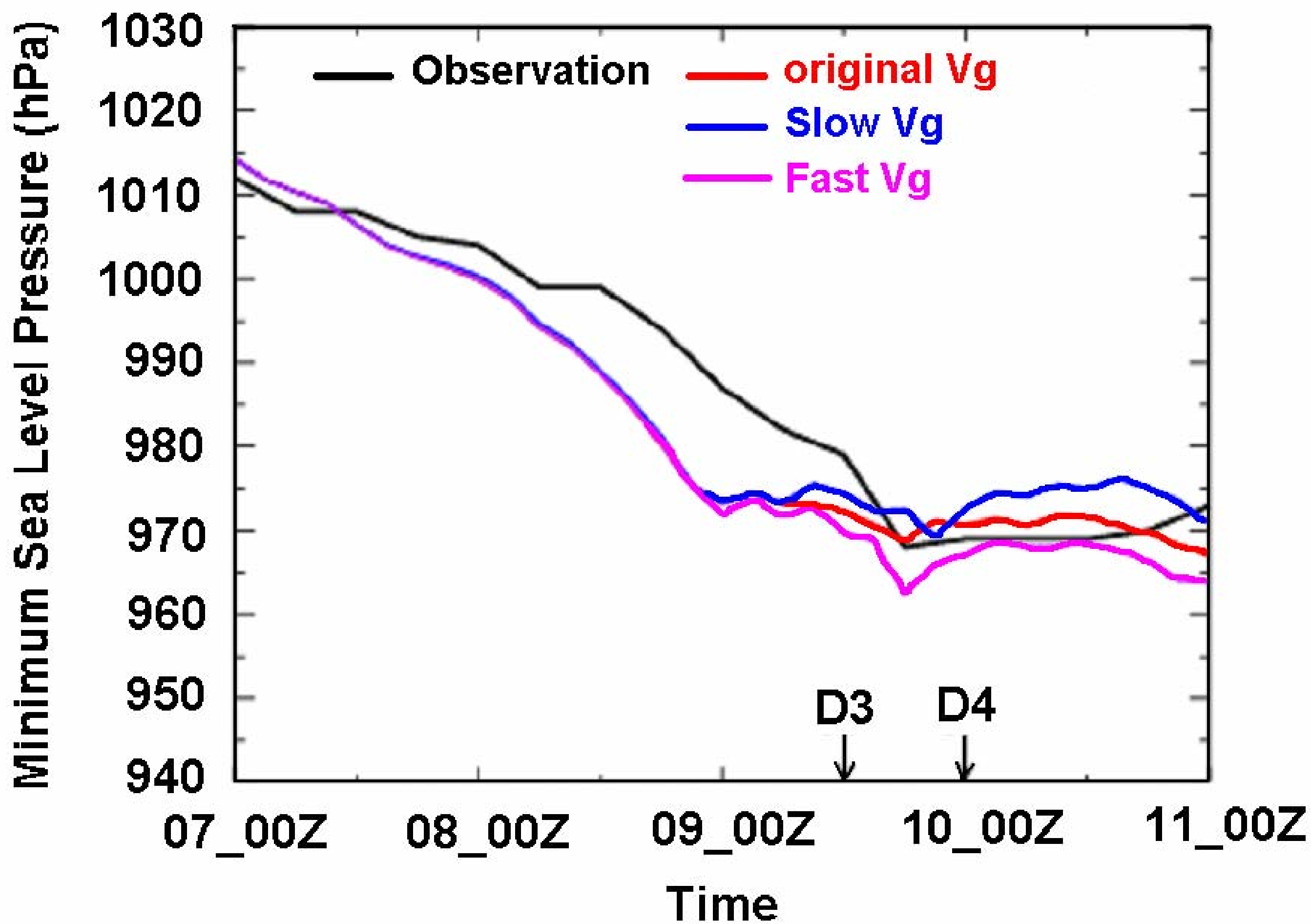
- **Black et al. (1996) showed that only 5% of updrafts in the eyewall at 9 km are stronger than 5 m s^{-1} (averaged over 7 tropical cyclones).**

- **Control simulation produces more than 30% of updrafts stronger than 5 m s^{-1} for Erin.**

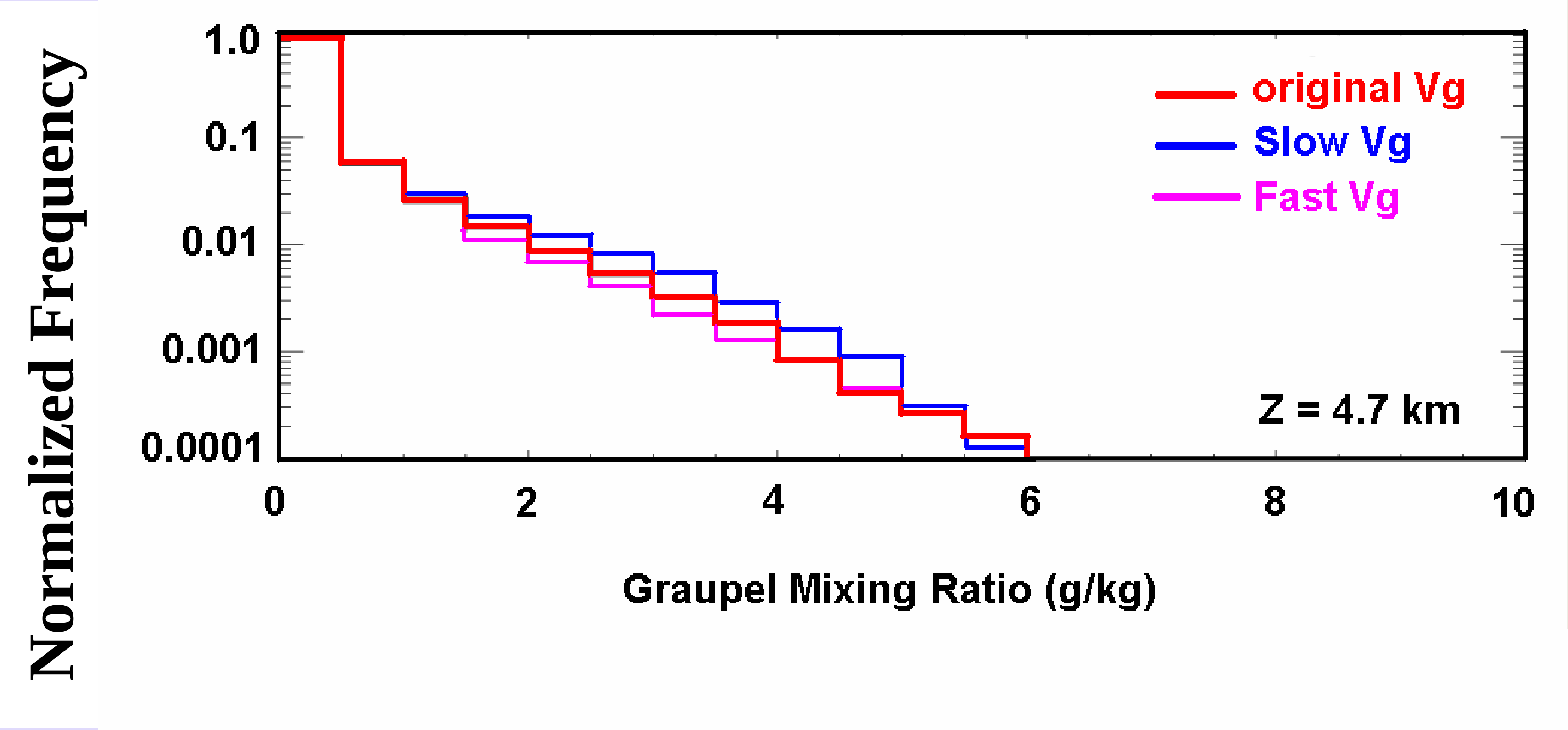
2. Sensitivity to graupel fall speeds V_g ($V_g = aD^b$)

Slow V_g : a=199.9, b=0.25
MM5 Original V_g : a=351.2, b=0.37
Fast V_g : a=700.1, b=0.75

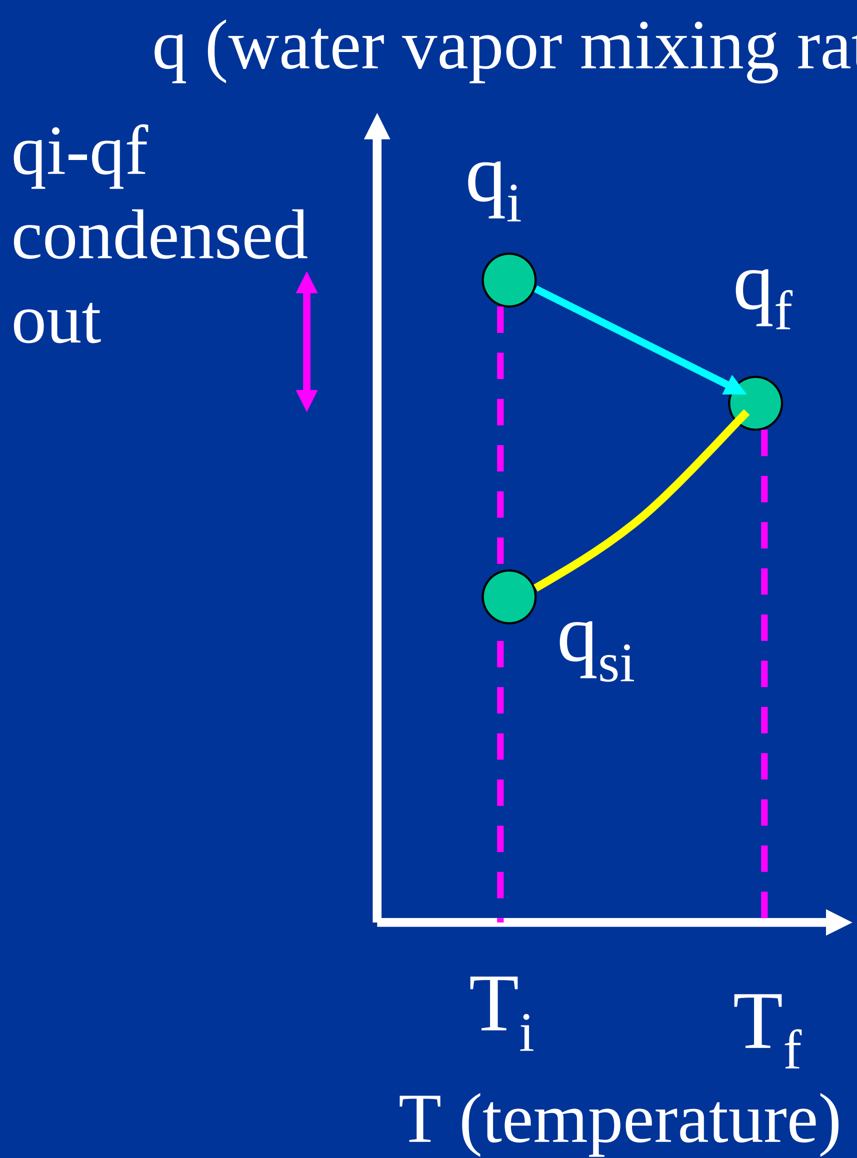
Locatelli and Hobbs (1974)



Simulations with varying (a,b) have no significant impact on frequency distribution of the 18-hour averaged q_g.



3. Application of a new iterative condensation scheme (McFarquhar et al. 2005)



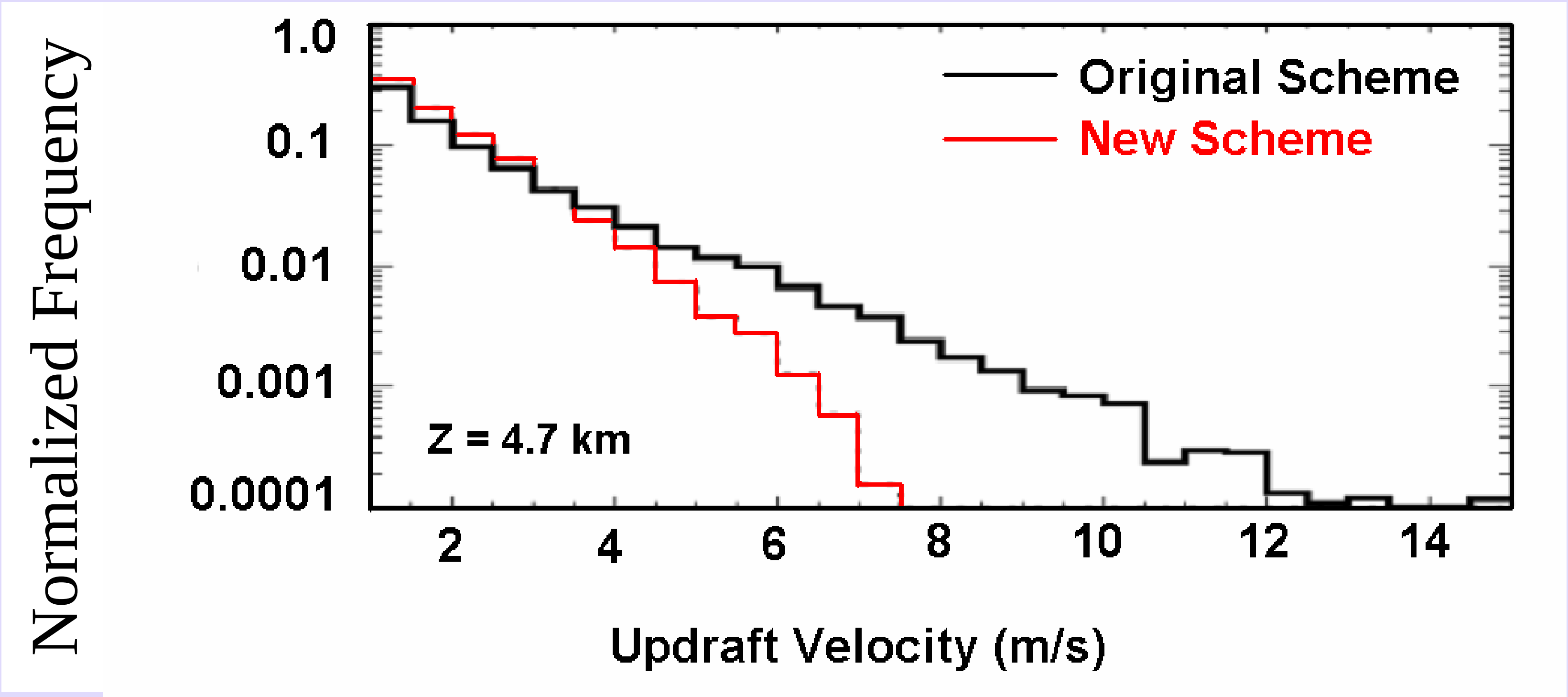
$$q_i - q_f = \frac{q_i - q_{si}}{\left(1 + \frac{\boxed{q_s} L_v^2}{c_p R_v \boxed{T}^2}\right)}$$

MM5: q_{si}, T_i

Over prediction of condensation

New scheme: T_f and q_f are obtained from an iterative approach.

New scheme suppressed the strongest updrafts



The new scheme reduced the frequency of w > 3 m s^{-1} and the maximum Z from 53 dBZ to 47 dBZ near the melting level. But such conditions contribute less than 5 % to Erin's area.

Conclusions

1. **Simulations with various microphysics schemes overestimate the frequency of higher Z and underestimate that of moderate Z.**

2. **Enhanced scattering at 37.1 and 85.5 GHz channels produced by the control simulation is mainly due to over-prediction of graupel.**

3. **Varying representation of graupel fall-out produces a difference up to 7 mb in central pressure, but has no significant impact on the time-averaged graupel mixing ratio frequency distribution.**

4. **An improved condensation scheme that limits artificial increases of Θ_e reduces the areas of highest Z and strongest updrafts. However, such areas represent less than 5% of Erin's area.**