Using Dual-Doppler Retrievals to Expose Deep Convective Vertical Velocity Biases in High-Resolution Simulations of a Tropical MCS

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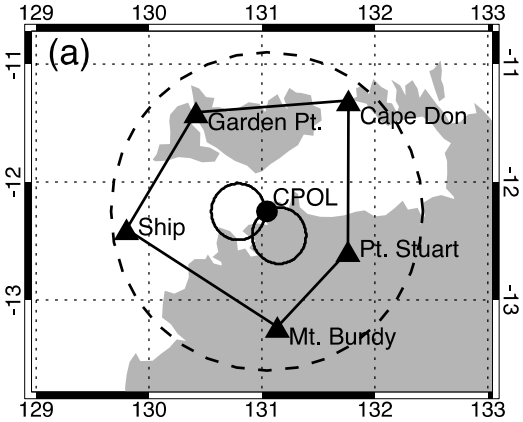
ASR Fall Meeting, 11/5/13

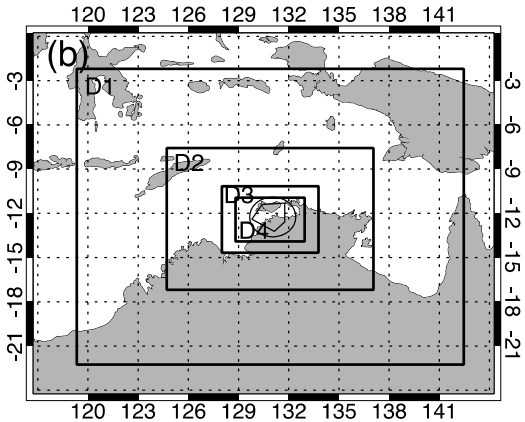
Background

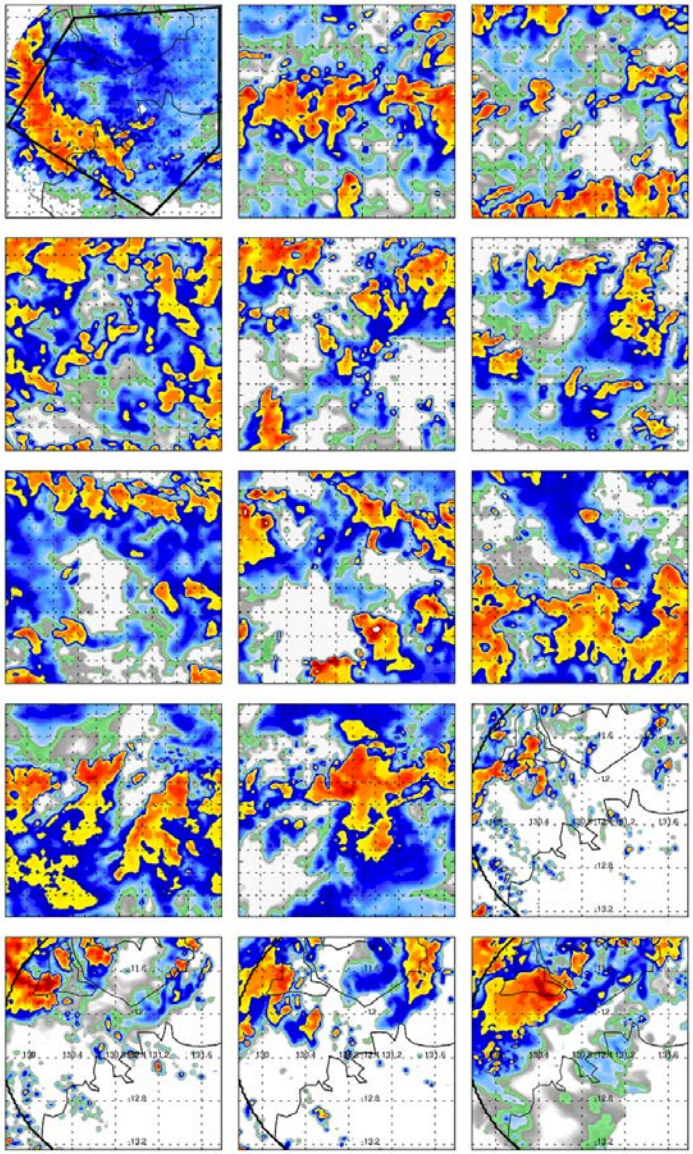
- 1/23/06 TWP-ICE
- 10 CRM and 4 LAM simulations
  - ~1-km horizontal grid spacing with 76-102 vertical levels
  - Various bulk microphysics schemes

CRMs



LAMs





Simulated Convective Radar Reflectivity Bias

High bias in convective radar reflectivity aloft

Commonly attributed to graupel, but can be due to snow in 2-moment, constant density, spherical setups

Is this an ice microphysics problem as is commonly stated in the literature?

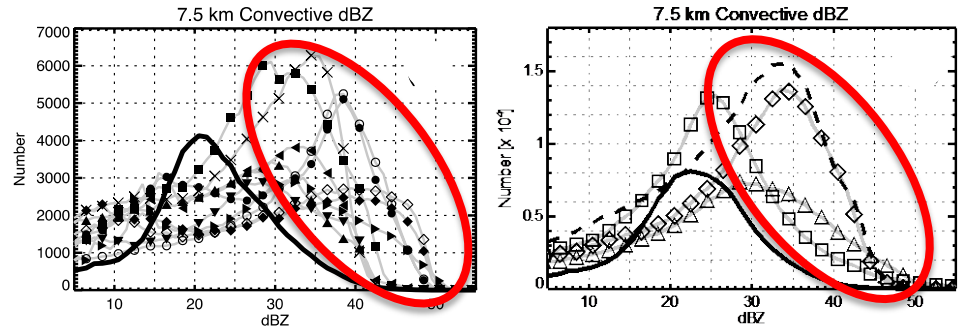
High bias in identified convective area

Some due to periodic boundaries, but LAMs are even more biased

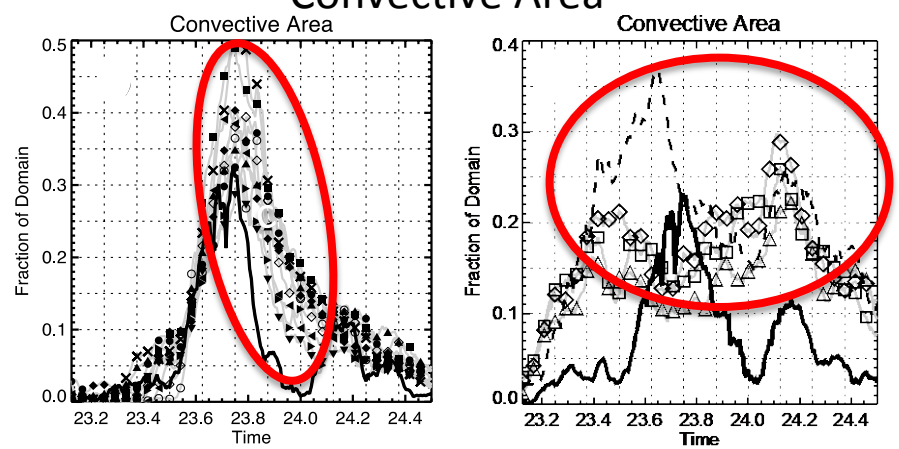
Why is this?

CRMs LAMs

7.5 km Convective dBZ



Convective Area



Bulk microphysics assumptions a cause?

Differences in simulated radar reflectivity are modulated by different assumptions in hydrometeor properties

Hail lowers reflectivity aloft (falls out faster)

Non-spherical m-D lowers reflectivity by putting more mass in smaller particles

μ > 0 can lower reflectivity by narrowing the size distribution if N is predicted

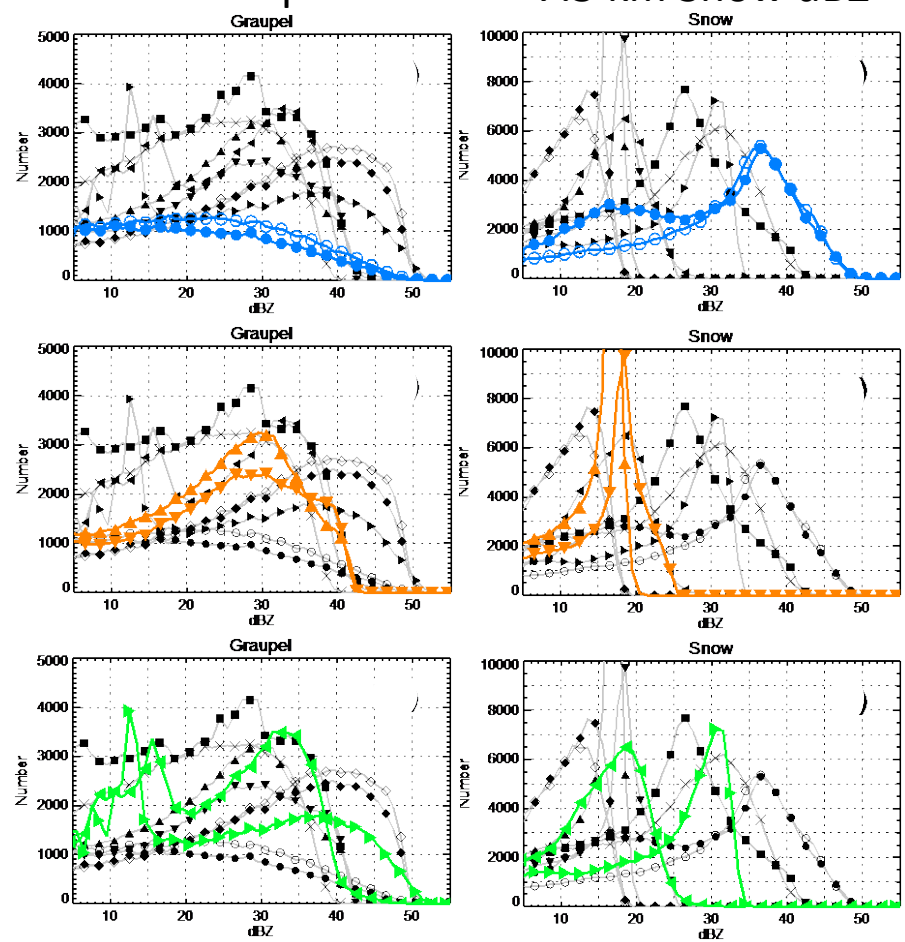
Easy to blame the ice MP parameterization,

BUT all simulations over-predict reflectivity!

$$n(D) = N_0 D^{\mu} e^{-\lambda D}$$

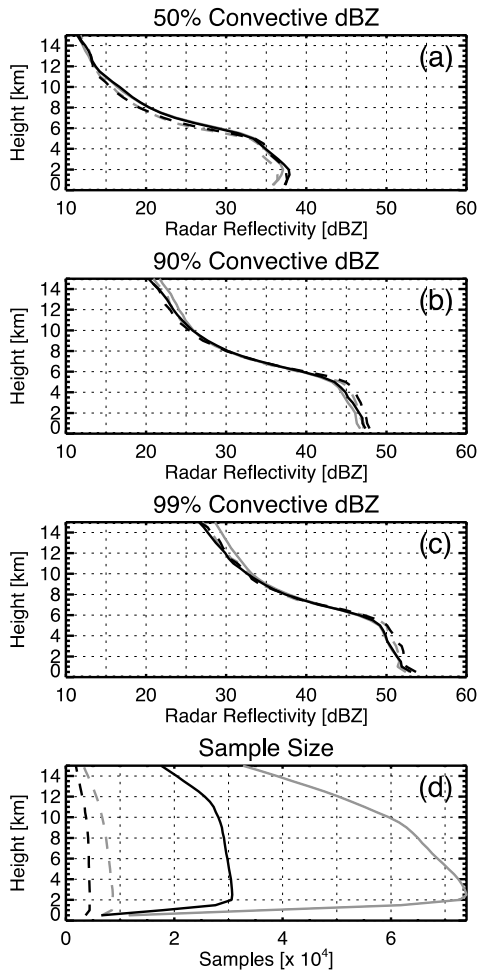
7.5 km Graupel dBZ

7.5 km Snow dBZ



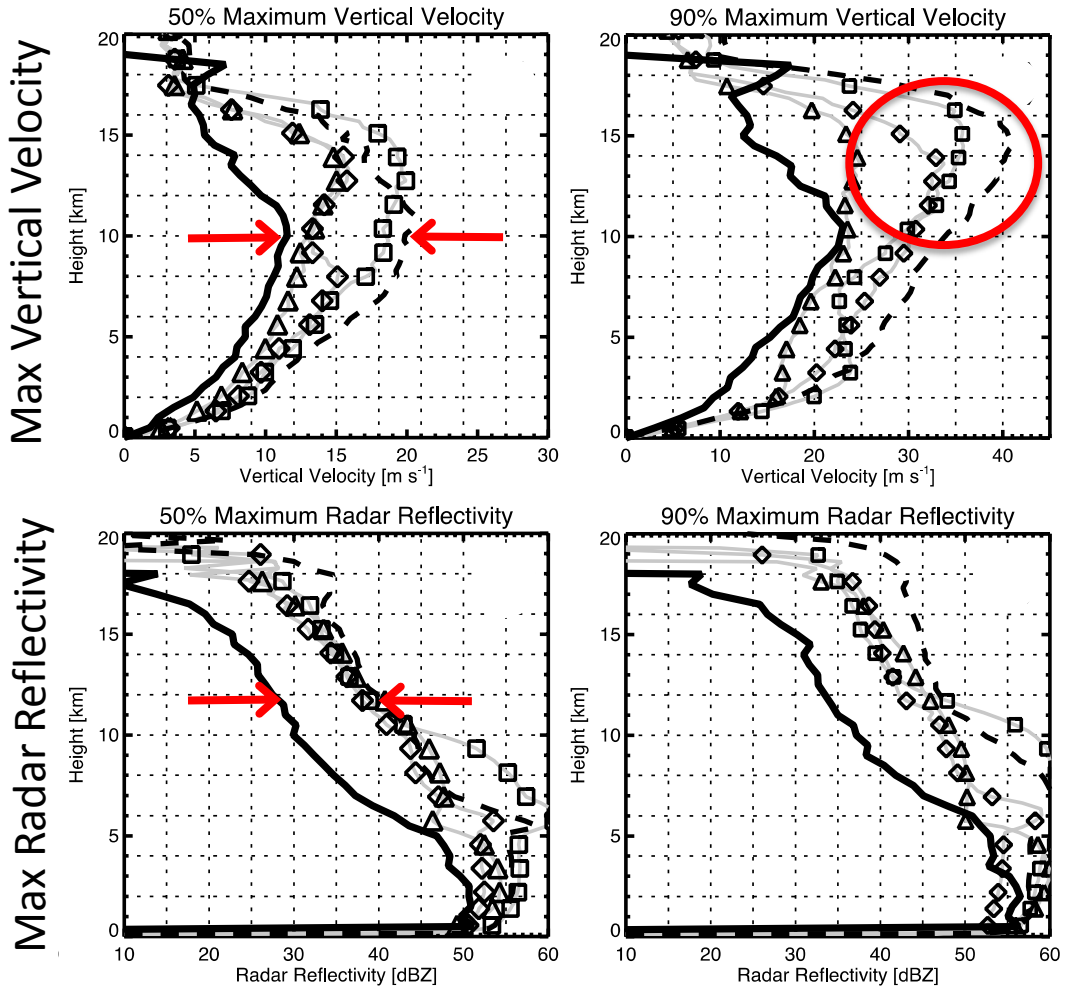
3D Deep Updraft Statistics

Dual-Doppler Representativeness

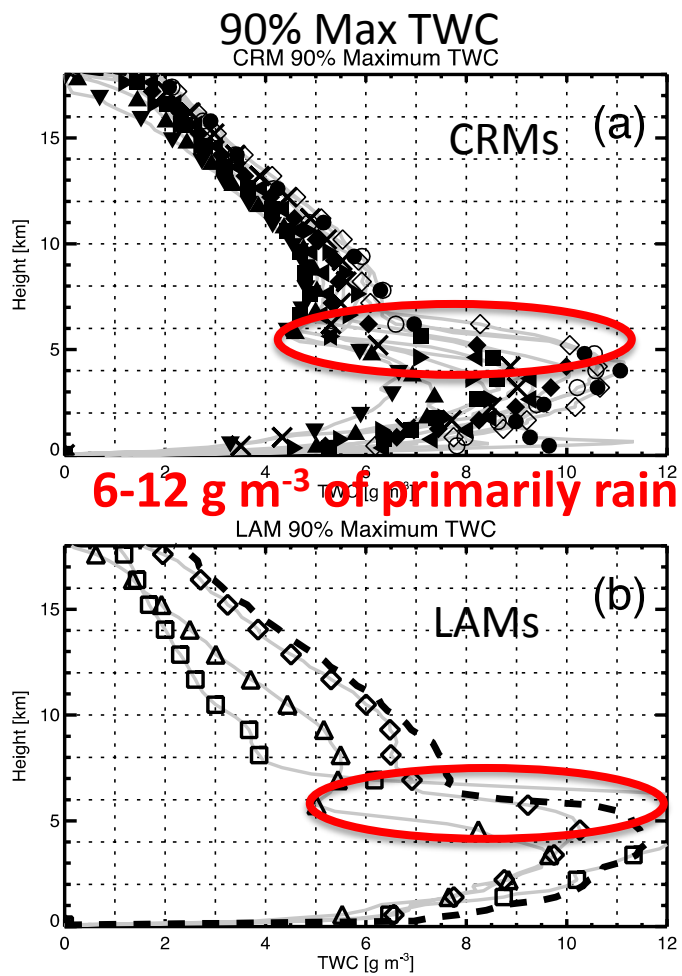


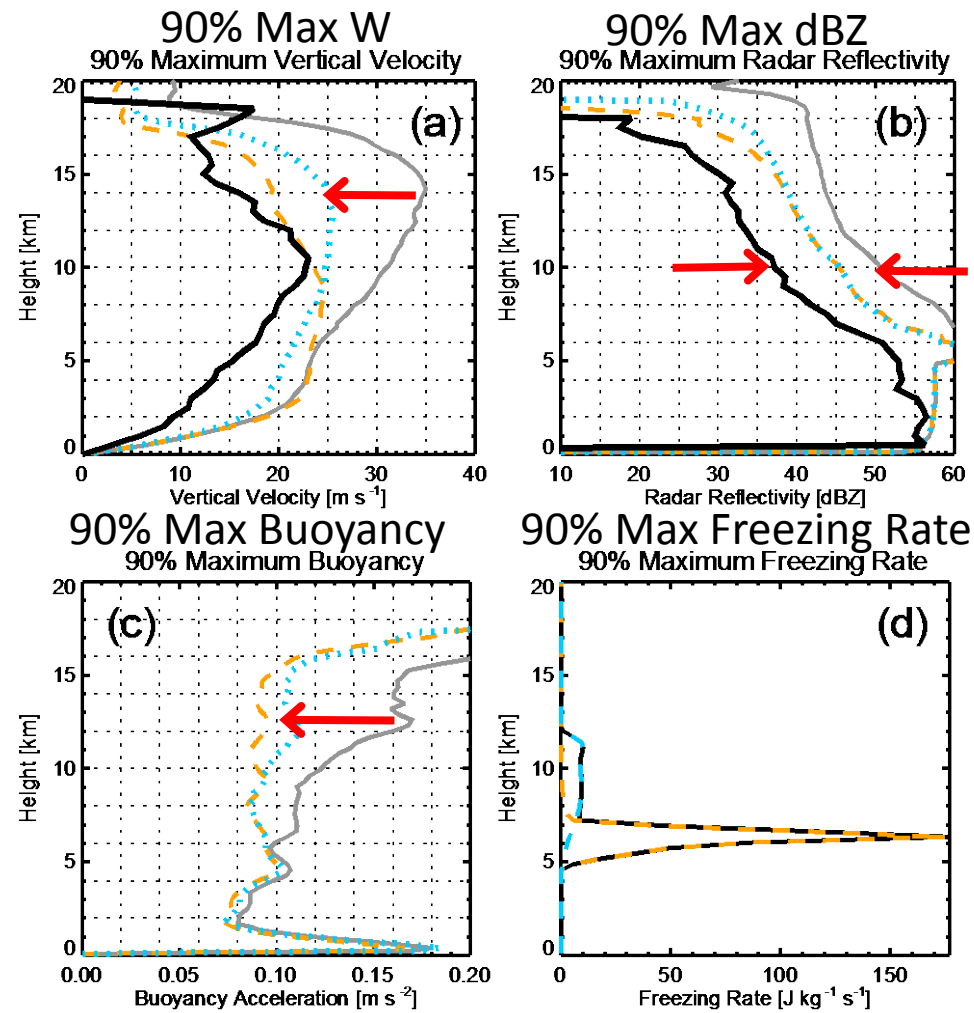
50th percentile

90th percentile



Extreme upper level peak is caused by excessive freezing of lofted rain in large updrafts with nearly undilute cores





Effects on Latent Heating

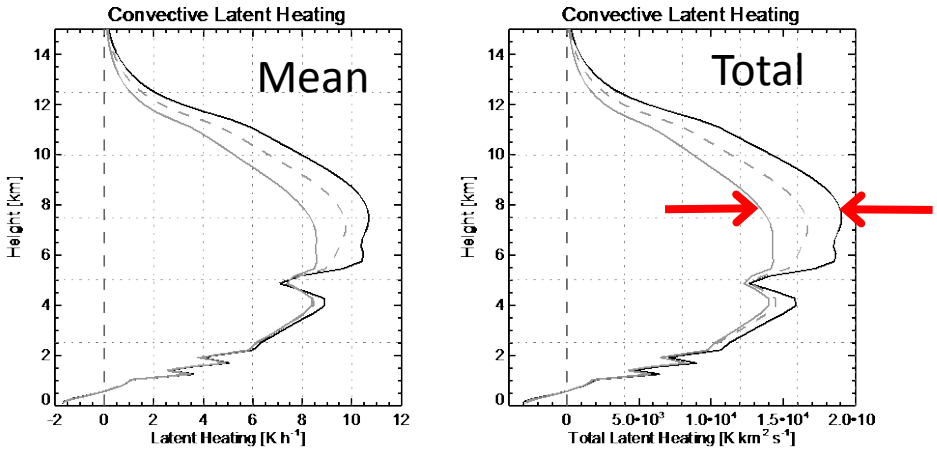
Reducing upper level convective strength by removing the latent heat of fusion for freezing liquid increases detrainment at lower levels

Increases stratiform precipitation by 18%, primarily through rain rate rather than area

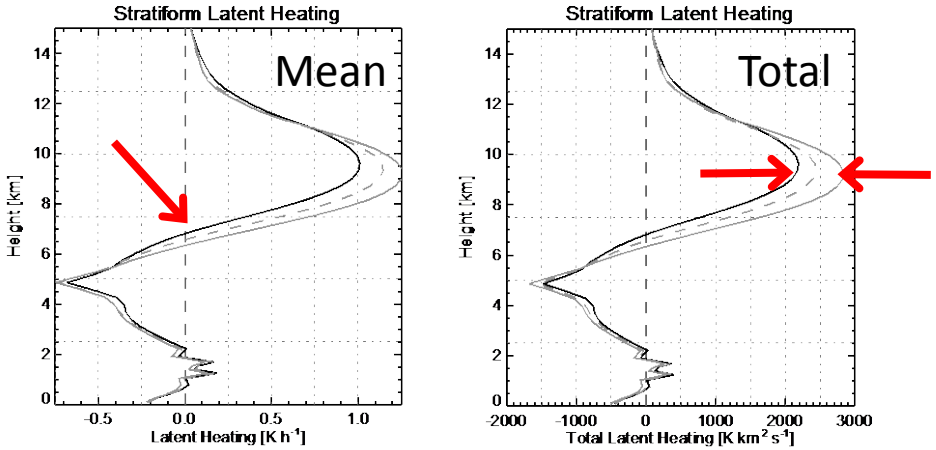
Reduces convective latent heating and lowers the altitude at which it peaks

Increases stratiform latent heating and lowers the altitude at which it peaks

Convective LH Profiles



Stratiform LH Profiles



Properly comparing simulations and retrievals

- Before making comparisons, the limitations of the retrieval need to be taken into account
  - This requires manipulating the dataset to remove untrustworthy data, accounting for uncertainty if possible, and accounting for differences in resolution and sampling
    - Best done with collaborating modelers and retrieval experts
- When properly done, simulation biases can be exposed and models improved
- When not properly done, simulation biases can be covered up and models worsened

What is needed for future progress in understanding deep convection?

1. Uncertainty estimates

2. Validation of LES results against observations

3. To get precipitation and cloud properties correct, you need buoyancy and condensate loading in convective drafts to be correct

   – How do we accurately retrieve the distribution of condensate mass in association with vertical wind speeds?

   – Environmental winds and thermodynamics with scanning radar coverage provide important context

4. Simulations are likely most biased for typical tropical deep convection than stronger land convection