Evaluating Microphysics in Cloud-Resolving Models using TRMM and Ground-based Precipitation Radar Observations

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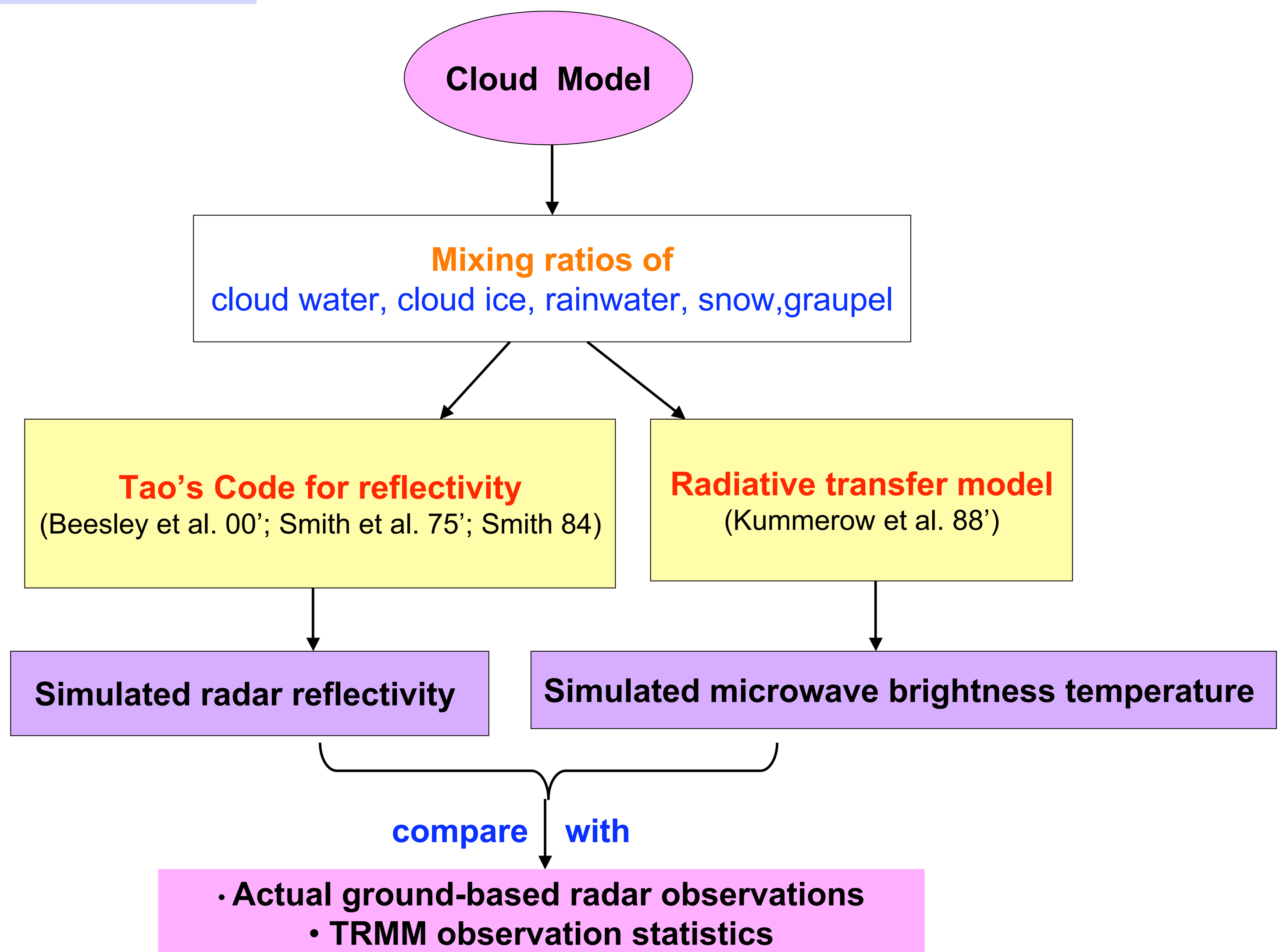
Abstract: A global dataset of tropical cloud system precipitation feature (PF) properties, collected by TRMM (Nesbitt et al. 2000), provides useful observational constraints on cloud system properties. The TRMM PF dataset is used to evaluate the precipitation microphysics of two simulations of deep, precipitating, convective cloud systems. The comparison of the simulated and observed convective microphysical properties indicates that the simulated convection is more extreme than that of all observed MCSs in the region over a 5 year period. The overestimation of graupel content may be responsible for the discrepancy between simulations and observations in the upper troposphere.

Analysis methods:



Model simulations:

• Analyzing two simulations: a 29-day summertime, continental case (ARM Summer 1997 SCM IOP, at the Southern Great Plains site); a tropical maritime case (the Kwajalein MCS of 11-12 August 1999, part of a 52-day simulation).

• The ARM simulation was executed using the UCLA/Utah 2D CRM (domain: 512 km × 18 km, horizontal resolution: 2 km); while the KWAJEX simulation was produced using the 3D CSU CRM (SAM) (domain: 64 km × 64 km ×26 km, horizontal resolution: 1 km).

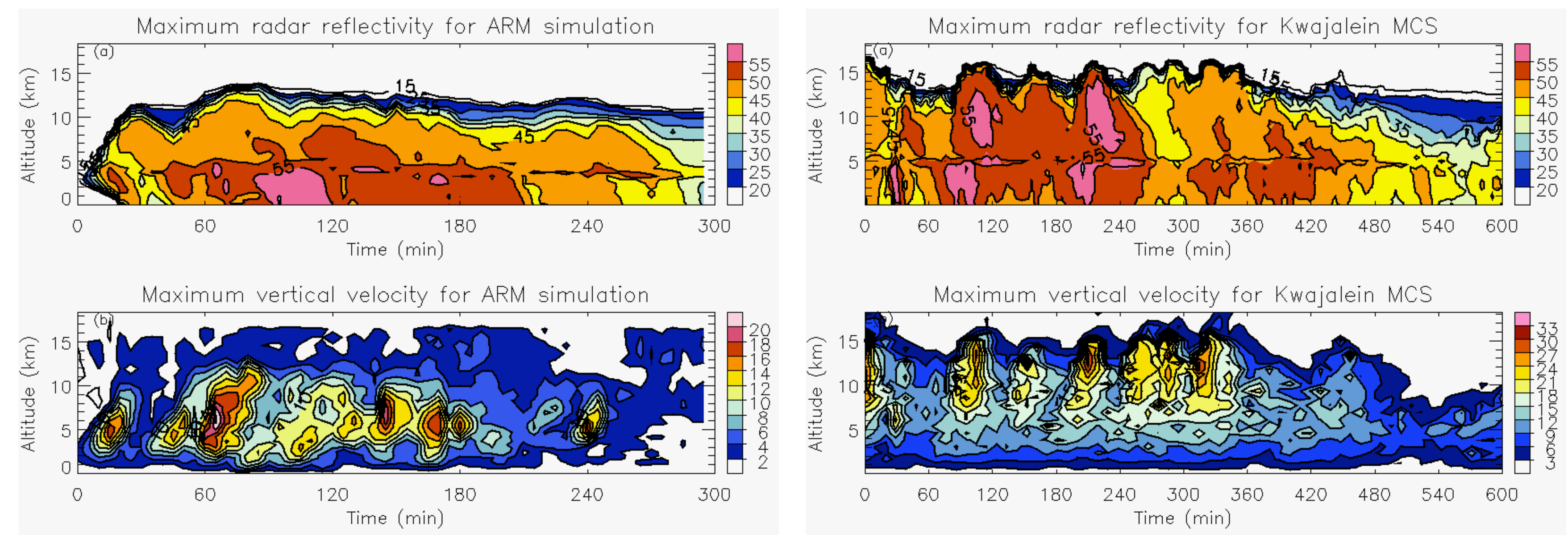
• Two simulations employed the same bulk, three-ice category microphysical parameterization [largely follows Lin et al. (1983) and Lord et al. (1984), improved by Krueger et al. (1995)]

Include five species: *cloud water* (CW), *cloud ice* (CI), *snow* (S), *graupel* (G) *and rain* (R)

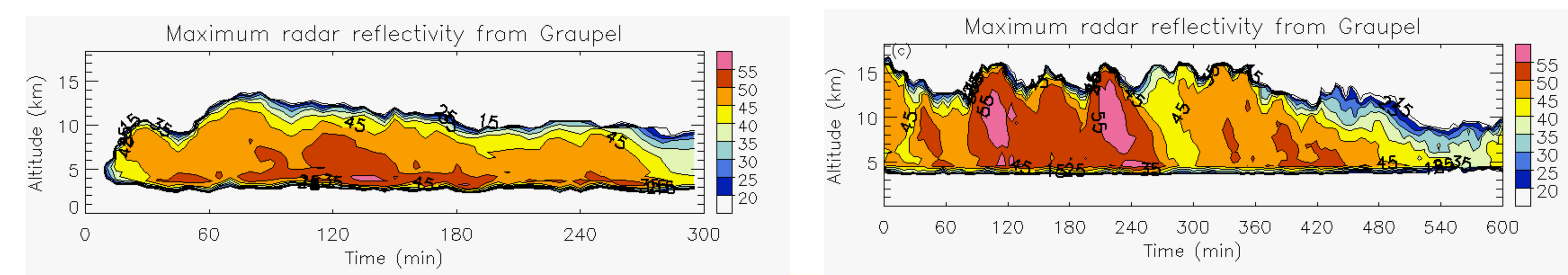
Assume exponential size distributions for each precipitation type

Density (kg m^{-3}): $\rho_R = 1.0 \times 10^3$, $\rho_S = 0.1 \times 10^3$, $\rho_G = 0.4 \times 10^3$

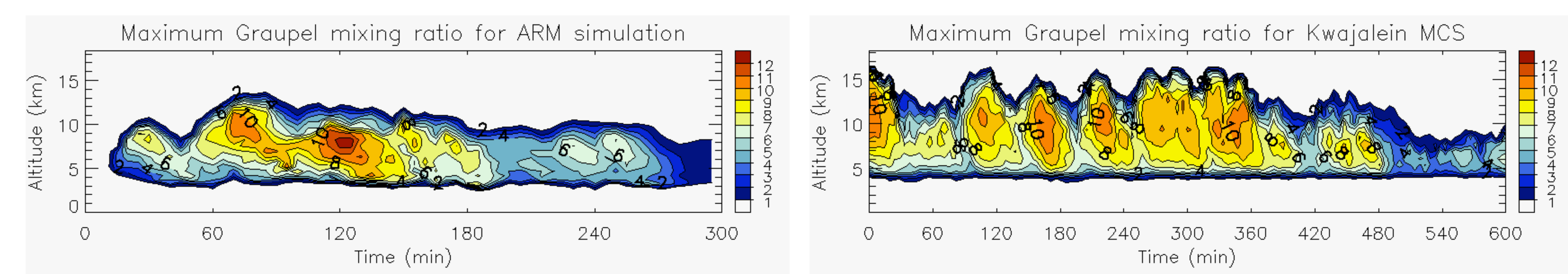
Intercept parameter (m^{-4}): $n_{0R} = 8 \times 10^6$, $n_{0S} = 3 \times 10^6$, $n_{0G} = 4 \times 10^6$



Uniformly high reflectivity at the levels between 5-10 km (ARM case), 5-15 km (Kwajalein MCS)

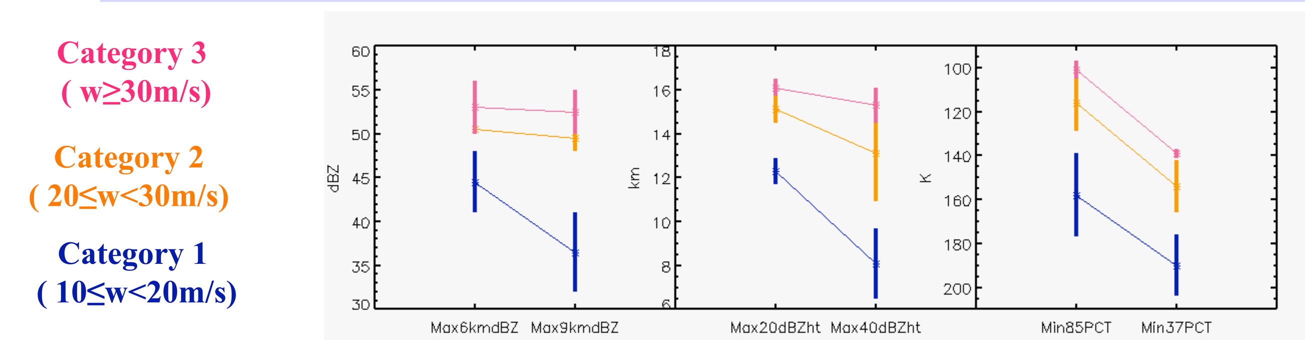


Graupel is major contributor of reflectivity in the ice region



Very large graupel concentrations between about 5-10 km (ARM case), 5-15 km (Kwajalein MCS)
As high as 10 g/kg graupel mixing ratios

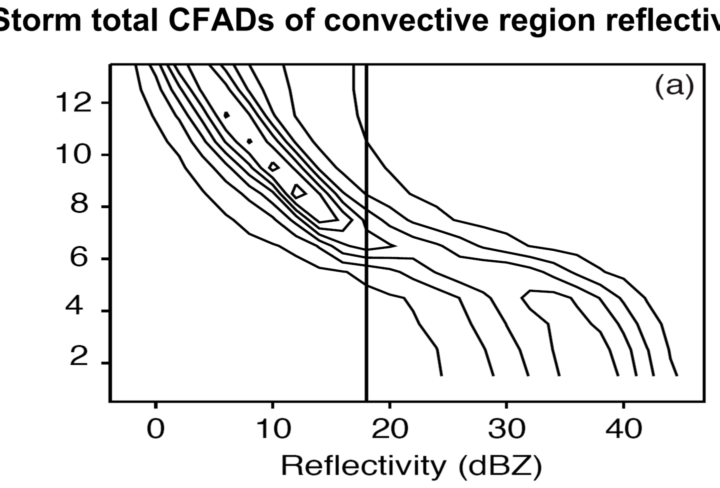
Summary of simulated vertical velocity and TRMM variables for Kwajalein MCS



stronger vertical velocity: larger max reflectivity at 6, 9 km; higher max 20, 40 dBZ height; lower min 85, 37 GHz PCT

Research radar observations

Storm total CFADs of convective region reflectivity



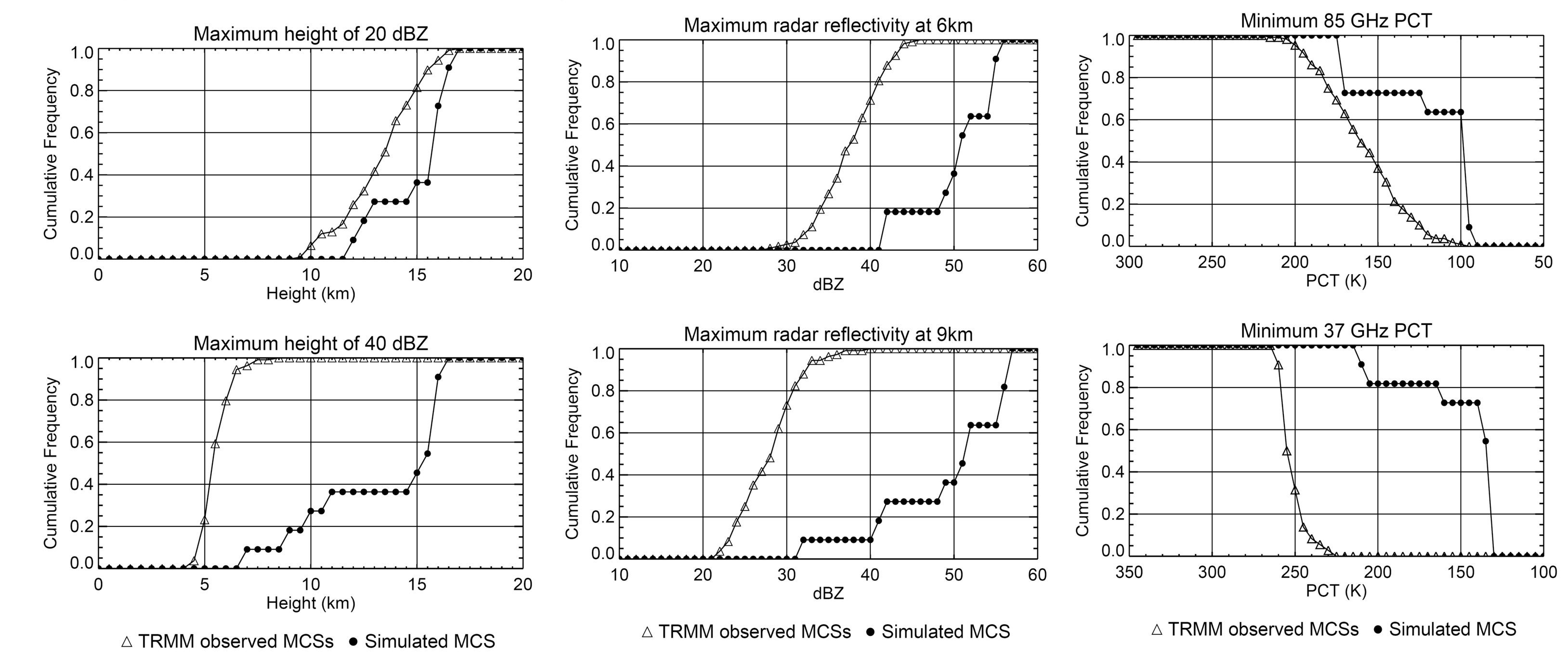
(From Yuter et al. 2005)

There were 38 volume scans taken with the research radars during a 7.6 hour period, and at no time did the 20 (40) dBZ contour exceed a height of 9 (5.3) km
Based on the TRMM statistics, the median height for MCSs in this region is 13.5 (5.5) km.

This MCS is weak-to-average in measures of convective intensity

TRMM variable statistics

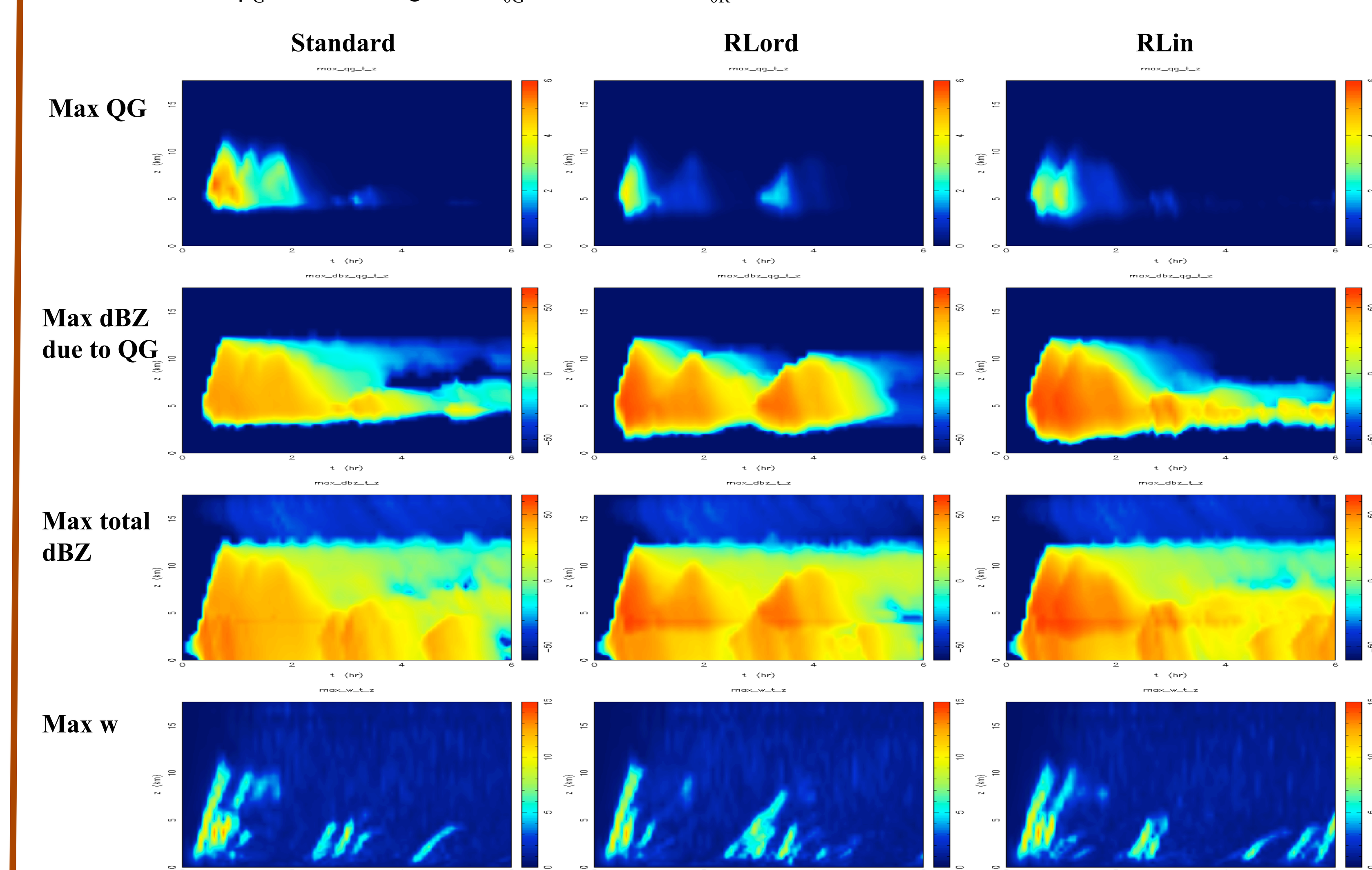
Database of TRMM observations of precipitation features :
5.5 - 12 N and 164 - 172 E (the central tropical Pacific near Kwajalein) for July-Sept. of five years (98, 99, 00,02 and 03). The sample size includes108 MCSs



The simulations are more extreme than all observed MCSs in the region over the 5 year period

Sensitivity of the simulated fields to the intercept parameter and the density of graupel

Standard IMICRO: $\rho_G = 0.4 \times 10^3$ kg m^{-3} $n_{0G} = 4 \times 10^6$ m^{-4} **RLin:** $\rho_G = 0.917 \times 10^3$ kg m^{-3} $n_{0G} = 4 \times 10^4$ m^{-4}
RLord: $\rho_G = 0.3 \times 10^3$ kg m^{-3} $n_{0G} = 4 \times 10^4$ m^{-4} $n_{0R} = 22\times 10^6$ m^{-4}



Reducing the intercept parameter by a factor 100 reduced the maximum graupel mixing ratios but increased the maximum dBZ values. This suggests that the discrepencies between the simulations and the observations must involve the graupel growth rates.

Conclusion:

• The cloud model simulation results are more extreme than all observed MCSs in the region over the 5 year period. The overestimation of graupel content may be responsible for the discrepancy between simulations and observations in the upper troposphere.

• TRMM precipitation feature database provides additional observational constraints on cloud system properties, and can be used as a complementary evaluation of the precipitation microphysics in cloud-resolving models