UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

Convection During AMIE/DYNAMO: CRM Simulations and Radar Observations

Matthew A. Janiga[1] and Chidong Zhang[1]

University of Miami, RSMAS[1]

1) Introduction and Methodology

Introduction

- Cloud permitting models (CPMs)—of which there are several types—hold significant promise for simulating the MJO (e.g., Miura et al. 2007, Benedict and Randall 2009). However, microphysics parameterizations in CPMs still have significant issues in reproducing the properties of convective systems (e.g., Varble et al. 2011).
- An unprecedented amount of information on convective systems associated with the MJO was collected during the AMIE/DYNAMO experiment.
- In this study, observations from the Northern Sounding Array (NSA) were used to force a simulation with the System for Atmospheric Modeling (SAM) CPM. This simulation was then compared to observations from the NCAR dual-polarimetric radar (SPOL) (data provided by Angela Rowe).
- One focus of this study is too examine the ability of the 2-moment Morrison microphysics scheme to reproduce the variability of convection observed by SPOL. Another focus is on the contrasts in the properties of specific cloud types between suppressed, enhanced, and transitional phases of the MJO event observed in late Nov. 2011.

Simulation Setup and Methodology

- Simulations were forced by NSA 3D temperature and moisture advective tendencies with 2 h time-scale nudging for horizontal winds. Nov. 5 – Dec. 15, 2011 is simulated with 48 h allowed for spinup.
- Horizontal grid-spacing of 1 km (256x256 grid points) with a vertical grid-spacing of ~250 m in the free-troposphere (106 levels).
- CAM radiation, Morrison 2-moment microphysics, 1.5 order TKE closure, and gravity wave damping applied between 20-30 km.

Shallow – 5 dBZ echo tops < 4 km.

Congestus – 5 dBZ echo tops 4-7 km and rough 2.5 km reflectivity.

Deep Convection – 5 dBZ echo tops >7 km and rough 2.5 km reflectivity.

Stratiform – 5 dBZ echo tops > 4 km and smooth 2.5 km reflectivity.

2) Overview of Event 2

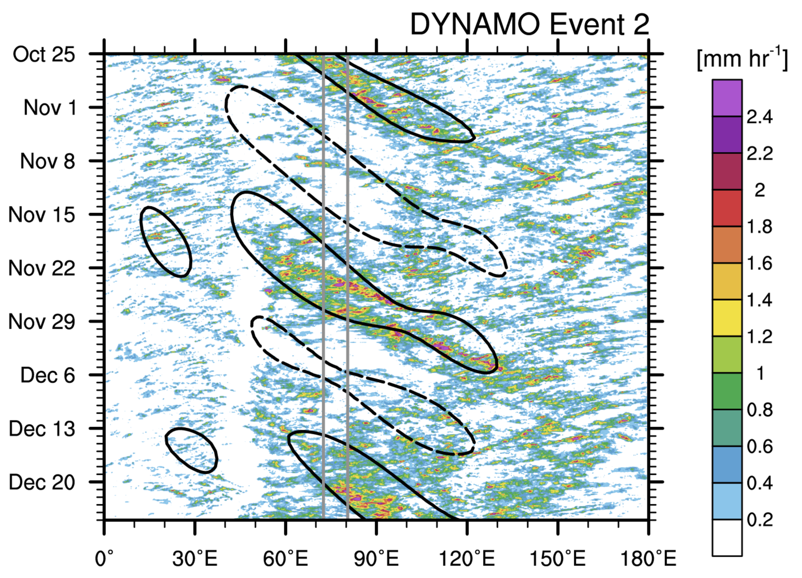

Fig 1. Unfiltered (mm hr^{-1}, shaded) and MJO-filtered (contoured every 1 mm hr^{-1}) TRMM 3B42 rain rate averaged between 10°S-10°N. The DYNAMO NSA is shown with gray lines.

MJO Event Periods

1. Suppressed: 11/05 – 11/14
2. Developing: 11/14 – 11/21
3. Mature: 11/21 – 11/27
4. Dissipating: 11/27 – 12/01

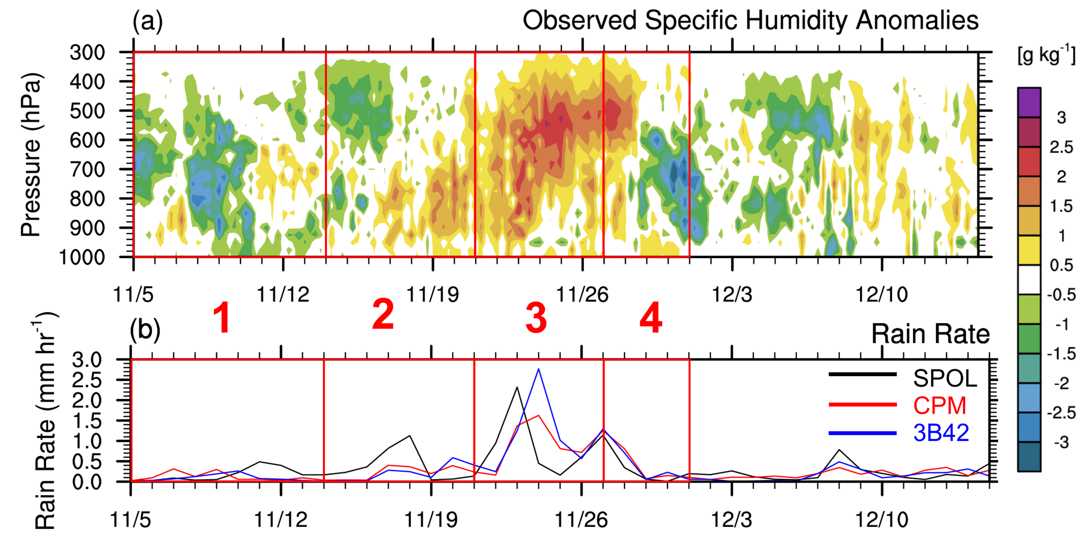

Fig 2. (a) Observed radiosonde specific humidity anomalies (g kg^{-1}, shaded) and (b) **(blue) TRMM 3B42**, **(black) SPOL**, and **(red) CPM** rain rates over the NSA.

3) Precipitation

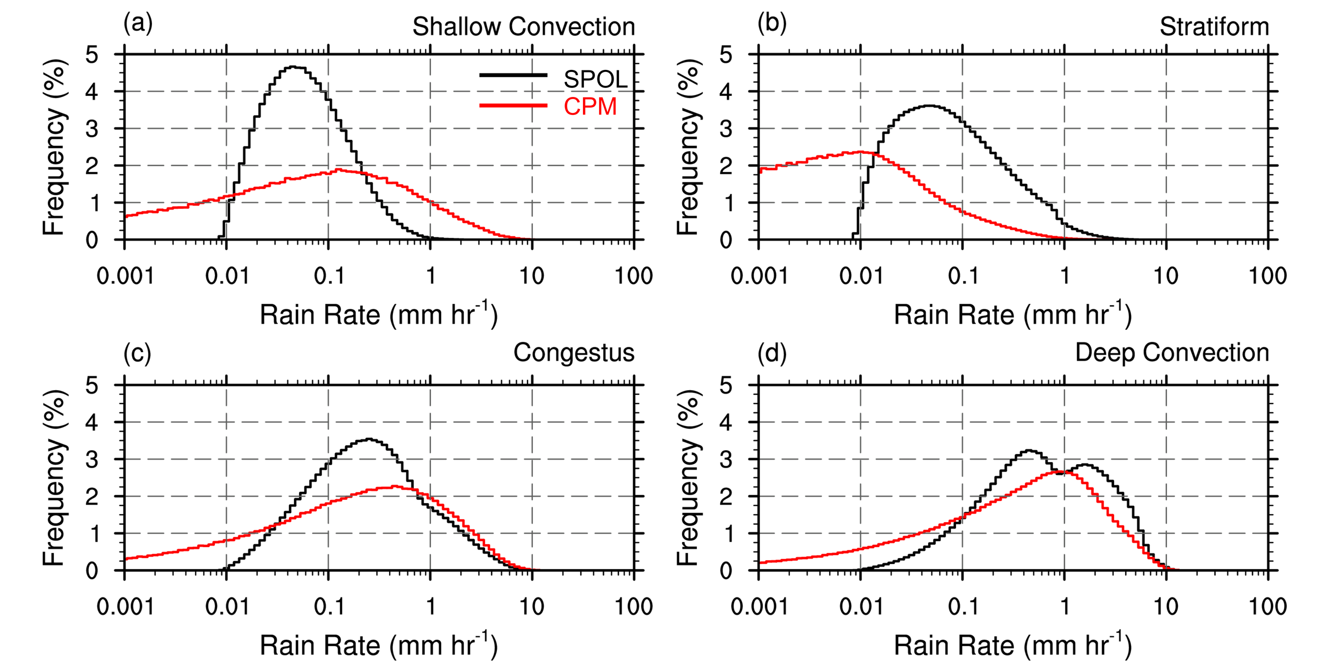

Fig 3. Frequency (%) of different rain rates for (a) shallow convection, (b) stratiform, (c) congestus, and (d) deep convection. Lines indicate **SPOL (black)** and **CPM (red)**.

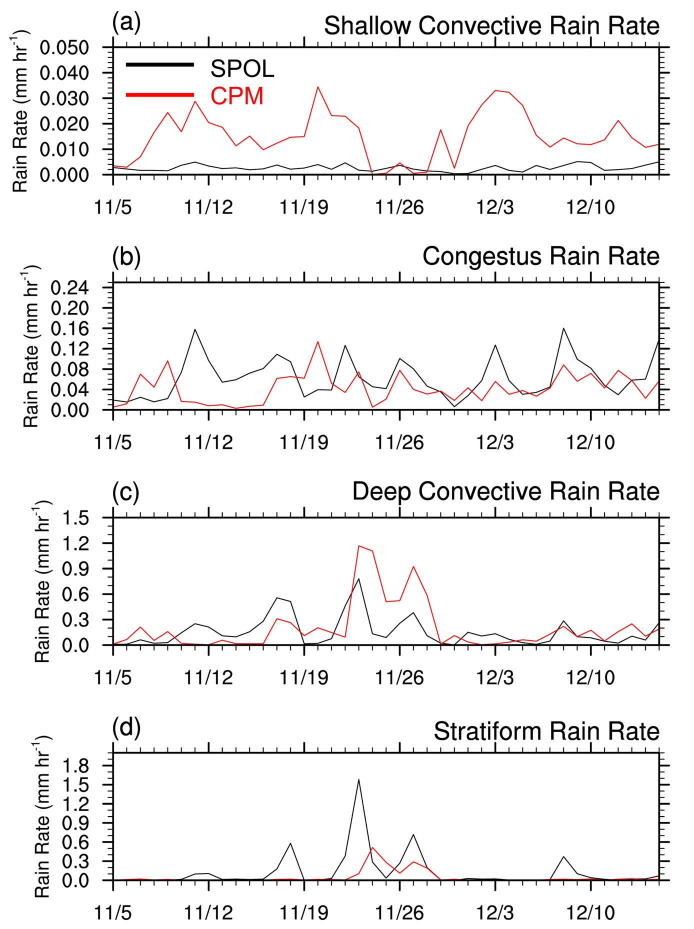

Fig 4. Time series of rain rates (mm hr^{-1}) from **SPOL (black)** and the **CPM (red)** for different cloud types.

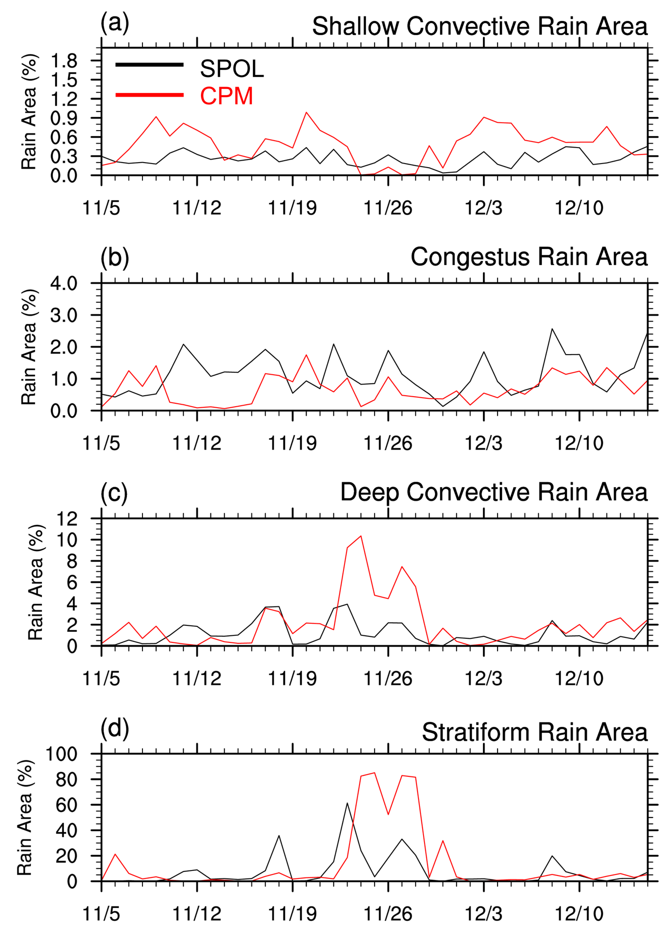

Fig 5. Time series of rain area (%) from **SPOL (black)** and the **CPM (red)** for different cloud types.

4) Reflectivity

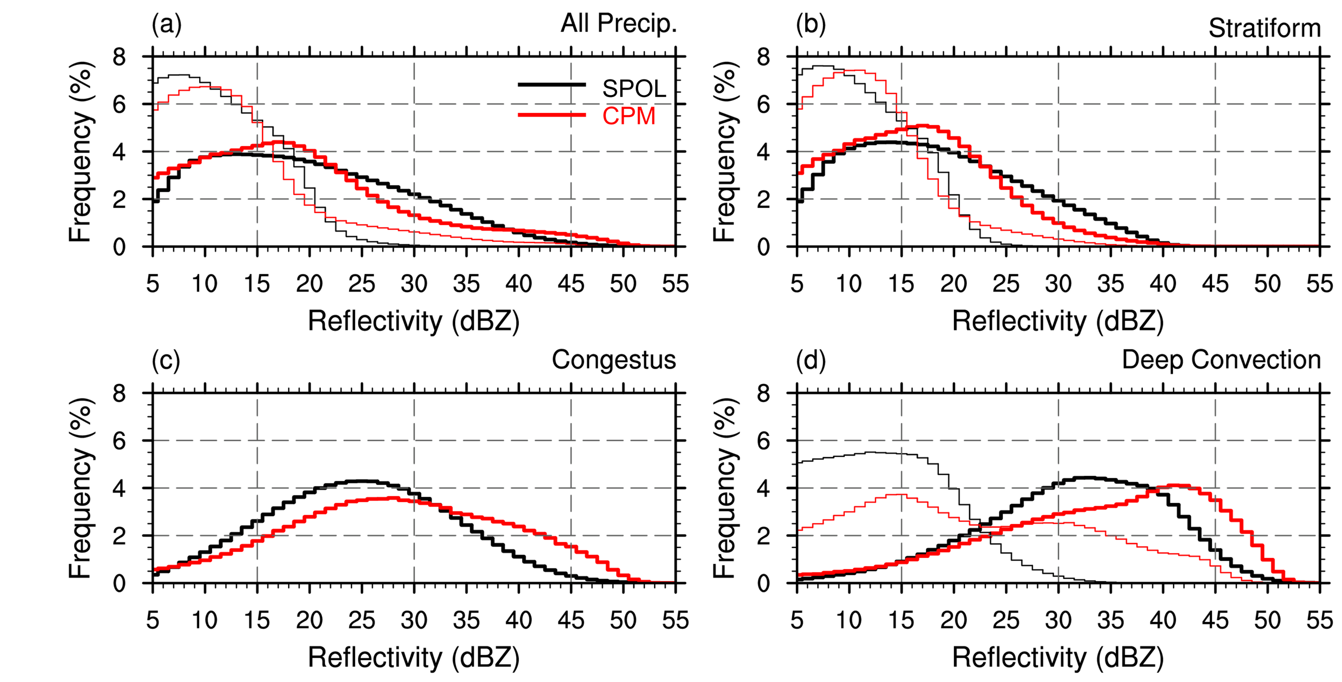

Fig 6. Frequency (%) of reflectivity values at **2.5 (thick)** and 7.5 km (thin) for each cloud type.

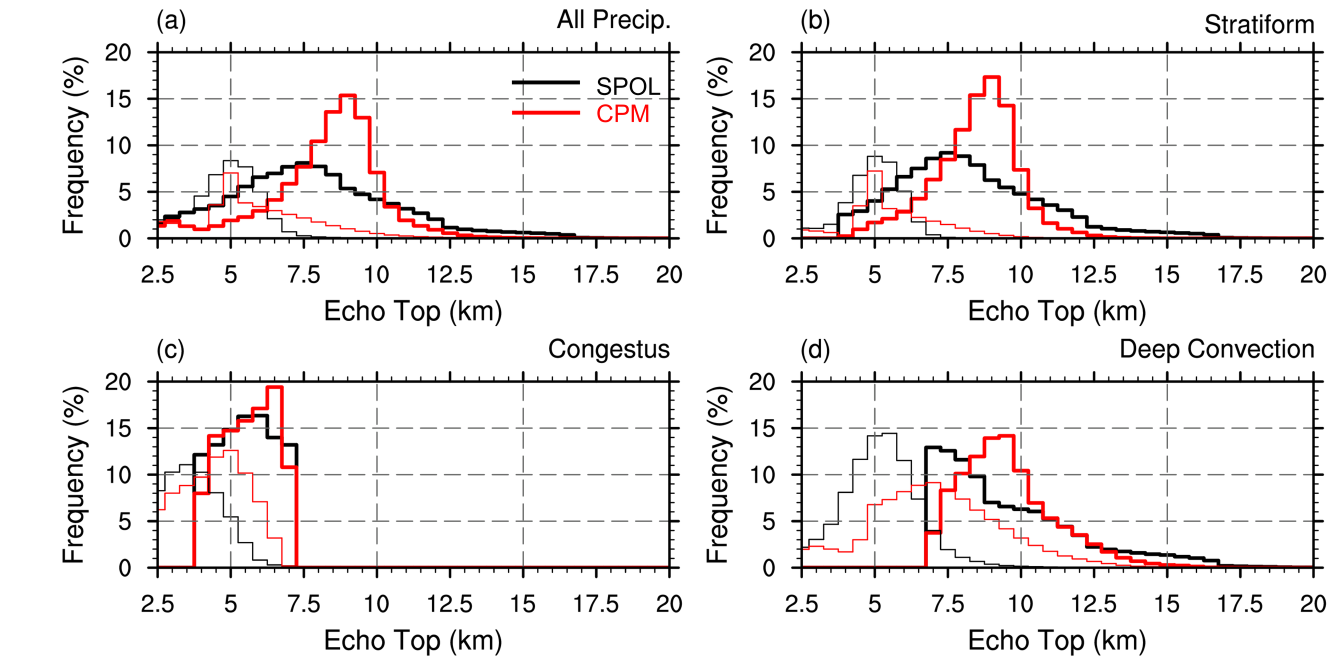

Fig 7. Frequency (%) of **5 dBZ (thick)** and 25 dBZ (thin) echo tops for each cloud type.

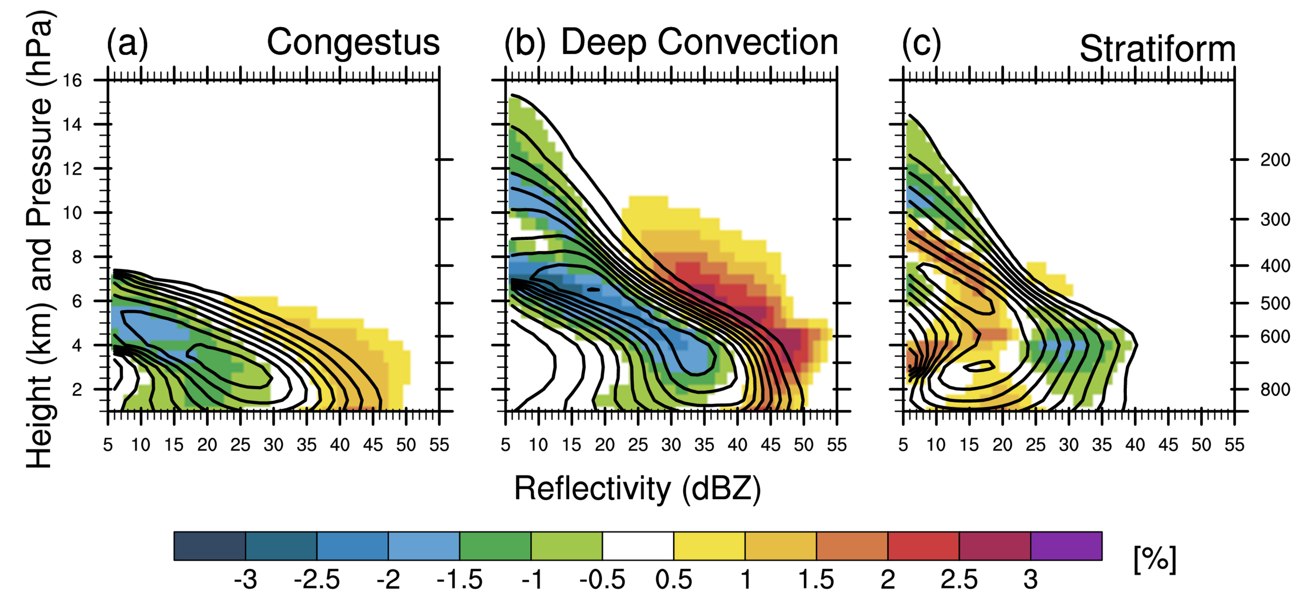

Fig 8. Frequency of SPOL reflectivity occurrence (contoured every 0.5%) and the difference between CPM and SPOL frequency (%, shaded) for (a) congestus, (b) deep convective, and (c) stratiform clouds.

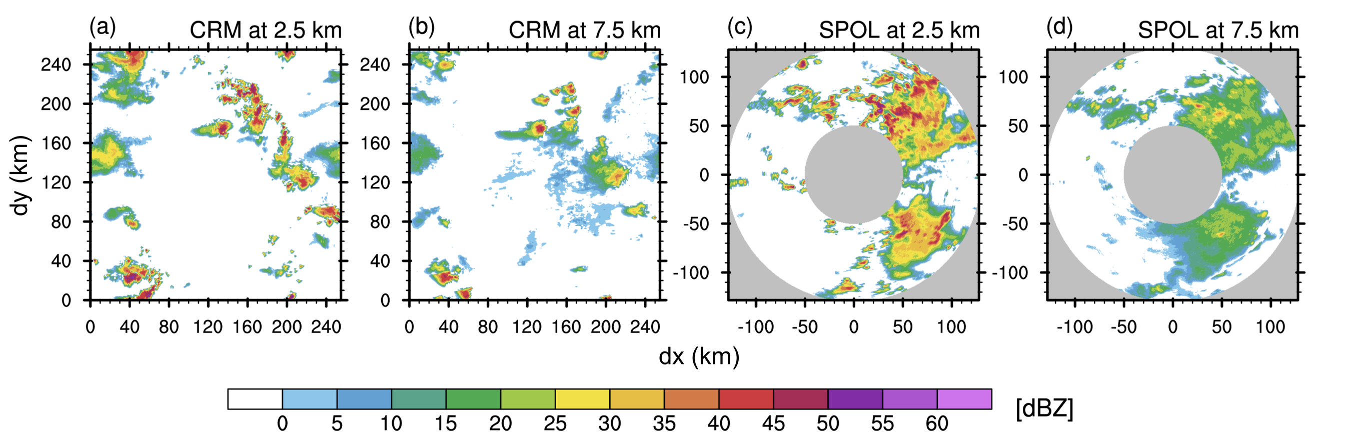

Fig 9. Snapshots of (a, b) CPM and (c, d) SPOL reflectivity (dBZ) at 2.5 and 7.5 km. Regions outside the SPOL 50-130 km range (excluded from computations) are masked.

5) Hydrometeor Species

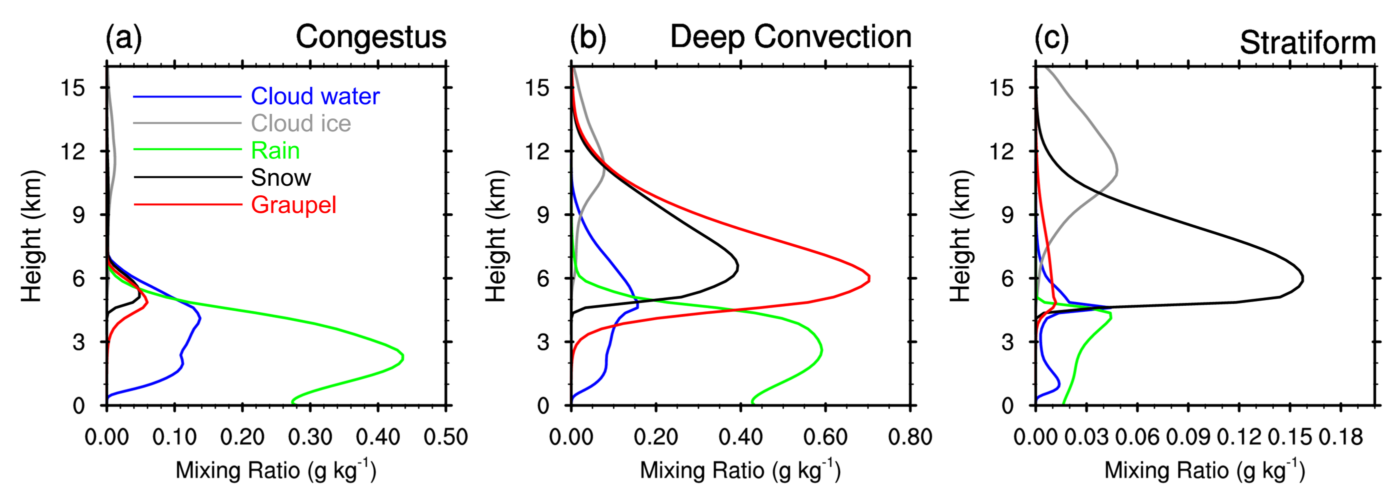

Fig 10. CPM hydrometeor mixing ratios (g kg^{-1}) for (a) congestus, (b) deep convective, and (c) stratiform cloud.

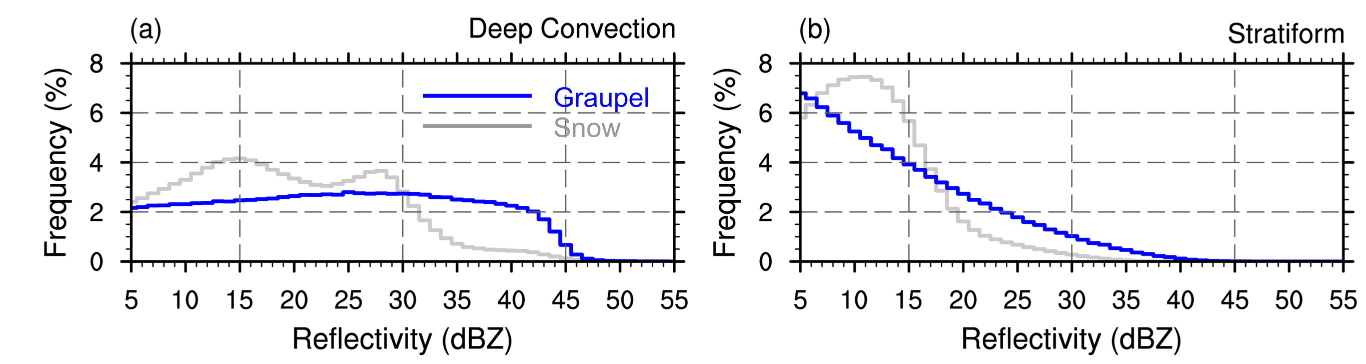

Fig 11. Frequency of reflectivity values (%) for snow (gray) and **graupel (blue)** in (a) deep convective and (b) stratiform cloud in the CPM.

6) Contrasts Between Phases

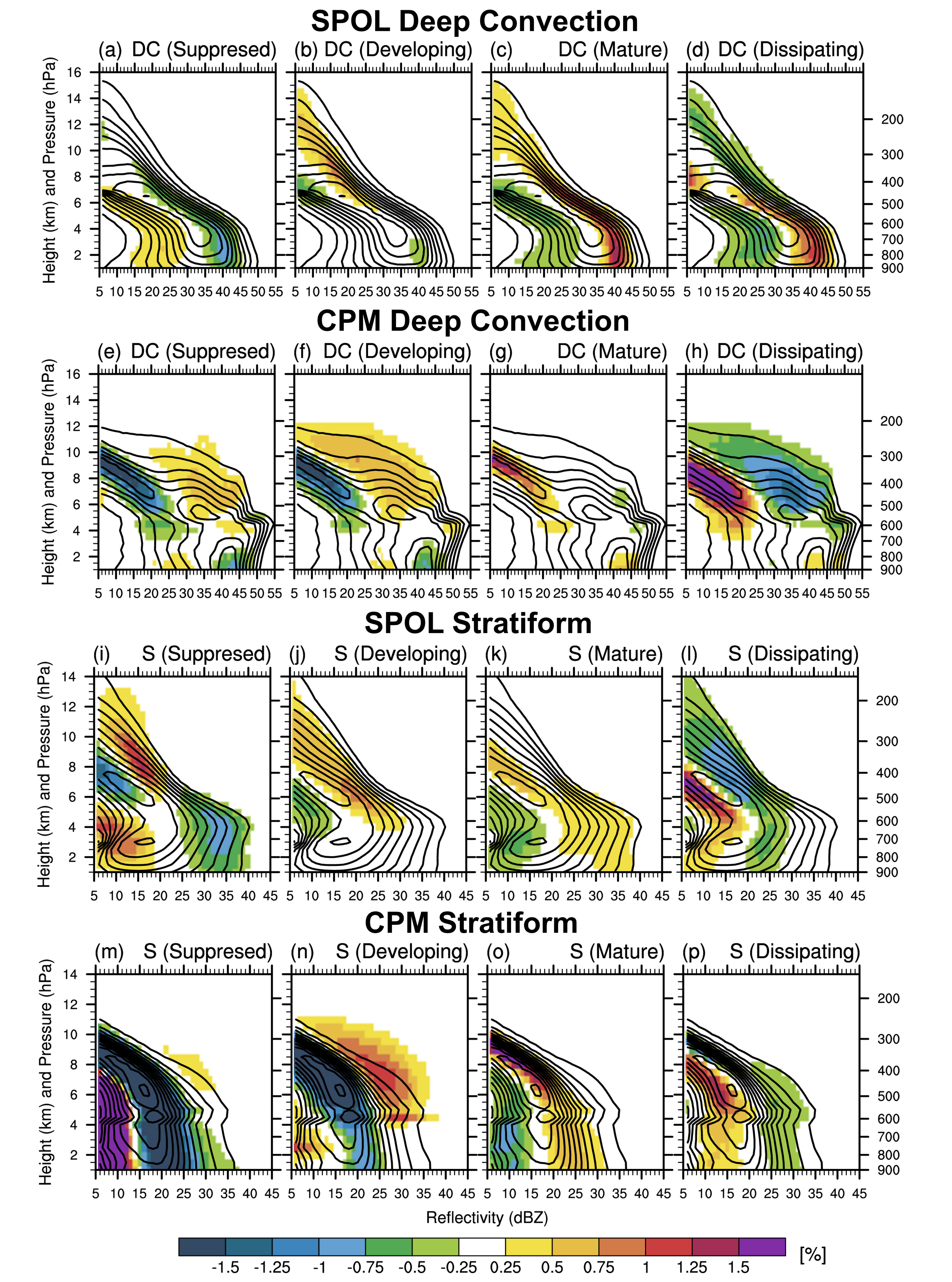

Fig 12. Frequency of reflectivity occurrence for the entire event (contoured every 0.5%) and the anomalous frequency in each period relative to the entire event (%, shaded) for the SPOL radar and CPM in each period: (column 1) suppressed, (column 2) developing, (column 3) mature, (column 4) dissipating (see Panel 2 definitions).

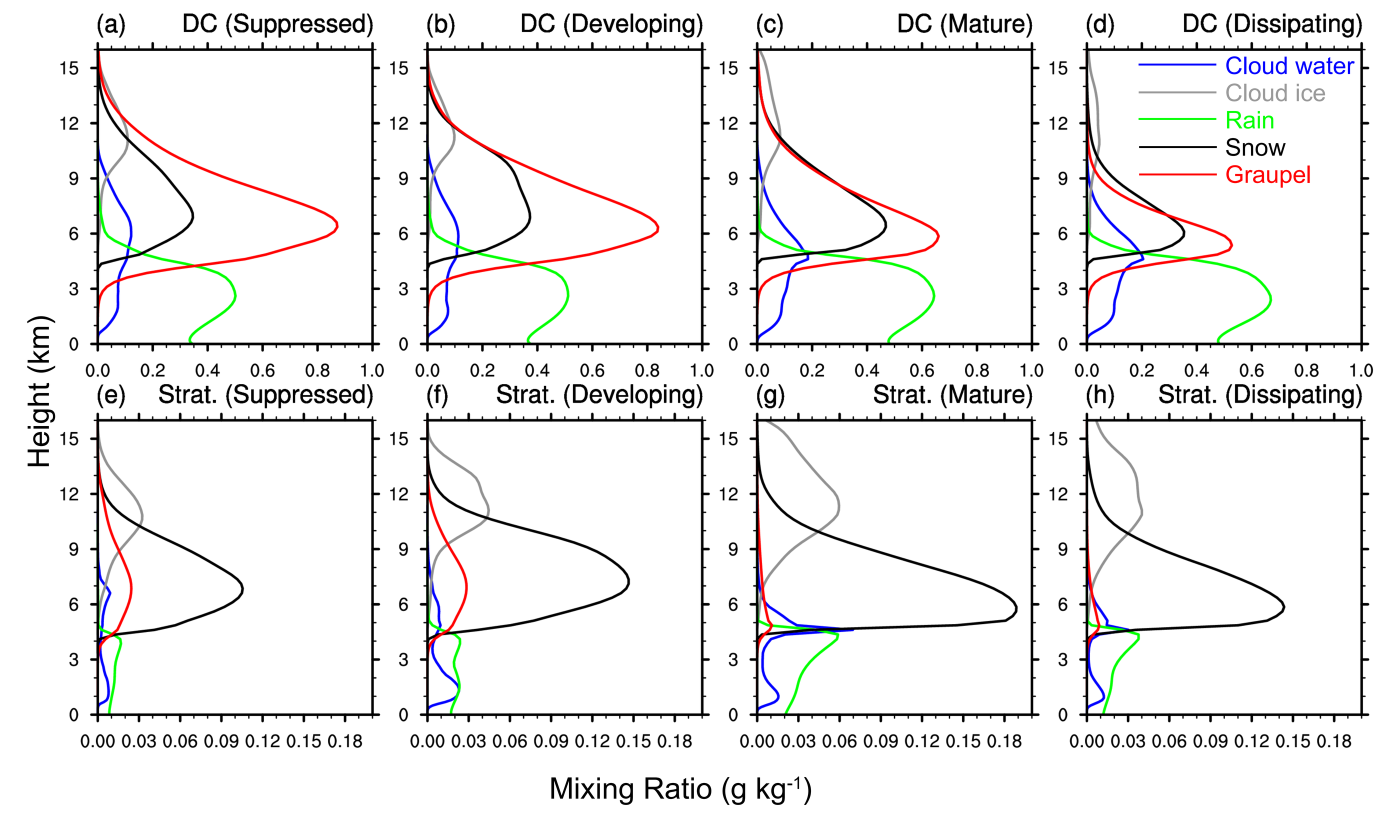

Fig 13. CPM hydrometeor mixing ratios (g kg^{-1}) for (a-d) deep convective and (e-h) stratiform for the (column 1) suppressed, (column 2) developing, (column 3) mature, and (column 4) dissipating phases (see Panel 2 definitions).

7) Discussion and Summary

CRM and SPOL Comparison

- The intensity of shallow convection in the model is significantly overestimated (**3a**) while the area is only sightly overestimated (**5a**). The probability distribution function (PDF) of deep convective rain in the model is similar to SPOL (**3d**) but areal coverage is too high (**5d**). Stratiform rain is biased towards weak rain rates (**3b**) and excessive coverage (**5b**).
- Deep convective reflectivity at 2.5 km is slightly biased towards high values in the model while reflectivity at 7.5 km is dramatically overestimated in the model (**6d**). This is consistent with the overestimation of 25 dBZ echo tops (**7d**) and the CPM-SPOL contoured frequency altitude diagram (CFAD) comparison (**8b**). This tendency is also clearly found in snapshots of reflectivity at 7.5 km (**9bd**). Graupel is primarily responsible for the high reflectivity values at 7.5 km (**11a**). These results suggest that convective updrafts are too strong in the model. Previous studies have found that a 1 km horizontal grid-spacing is too coarse to resolve entrainment in updrafts (e.g Bryan and Morrison 2012).
- The PDFs of 2.5 km stratiform reflectivity from the model and SPOL compare well (**6b**). However, further investigation suggests that the hydrometeor size distribution is biased towards toward large raindrops which compensate for the low rain mixing ratio (**10c**).

Differences between MJO phases

- A clear tilt in specific humidity anomalies was observed over the NSA during the late Nov. MJO event of DYNAMO (**2a**).
- Following Riley et al. (2011), MJO-filtered TRMM 3B42 and its time derivative are used to identify MJO phases (**Panel 2**).
- SPOL and CPM deep convective CFADs suggest that upper and mid-level reflectivity is enhanced the most in the developing phase (**12bf**). This is consistent with the increase in graupel mixing ratios (**13b**). This does not translate to enhanced low-level reflectivity (**12bf**) or rain (**13b**), perhaps due to increased evaporation. In addition, deep convective area is low during this period (**5d**).
- In contrast, the dissipating phase is characterized by reduced upper and mid-level reflectivity with an increase or no change in low-level reflectivity (**12dh**), consistent with changes in mixing ratios (**13d**). Here, reduced evaporation may compensate for the reduced updraft strength when stability increases.
- Similar behavior is observed in the stratiform clouds. The suppressed and developing period have enhanced upper-level reflectivity (**12ijmn**) and graupel (**13ef**) but reduced low-level reflectivity and rain. In contrast the mature period sees enhanced snow production (**13g**), weaker upper-level reflectivity (**12ko**), higher low-level reflectivity, and increased rain mixing ratios.