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ASR CRM Intercomparison Study on Deep Convective Clouds and Aerosol Impacts

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Introduction

- The large spread in CRM model simulations of deep convection and aerosol effects on DCCs makes it difficult to define "benchmarks" and limits their use in modeling simulations and parameterization developments.
- Past model intercomparisons used different models with different complexities of dynamic-microphysics interactions, making it hard to isolate the causes of differences between simulations.

> **A much more constrained intercomparison by using the same model (WRF3.4.1) with the same model setup including aerosols/droplets**

Objectives

Overarching Goals:

- To identify major processes/factors leading to the large spread of CRM deep convection simulations and simulated aerosol impacts
- To identify important processes and feedbacks in deep convection and aerosol-deep convective cloud interactions which need to be improved or represented in GCM parameterizations

Science questions:

- What are the major microphysical processes controlling model differences for warm rain, mixed-phase, and ice phase conditions?
- How do the conversions of droplets (ice) to rain (snow) as well as formation of graupel and hail contribute to the model differences, especially for aerosol impacts?
- What is the relative importance of latent heating versus hydrometeor loading in terms of the feedback to dynamics? How do the microphysical schemes differ?

- **We will have at least two steps of investigation**

Step 1

Identify major contributors from microphysical processes that contribute to model differences using the "piggyback" approach.

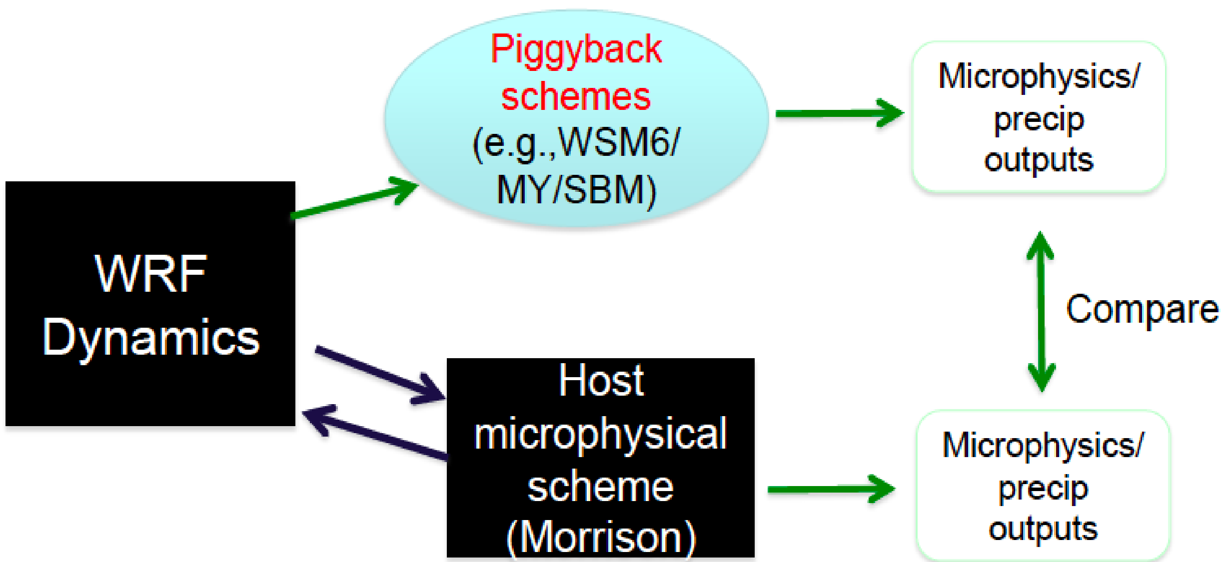
1. Warm-rain processes
2. Ice microphysical processes

Step 2

Identify major feedback processes between microphysics and dynamics that contributing to model differences (by turning on the feedback of microphysical processes one by one).

1. Feedback of latent heat to convection
2. Feedback of hydrometeor loading to updraft/downdraft
3. Cold pool feedback

The piggyback approach (Grabowski, 2014)



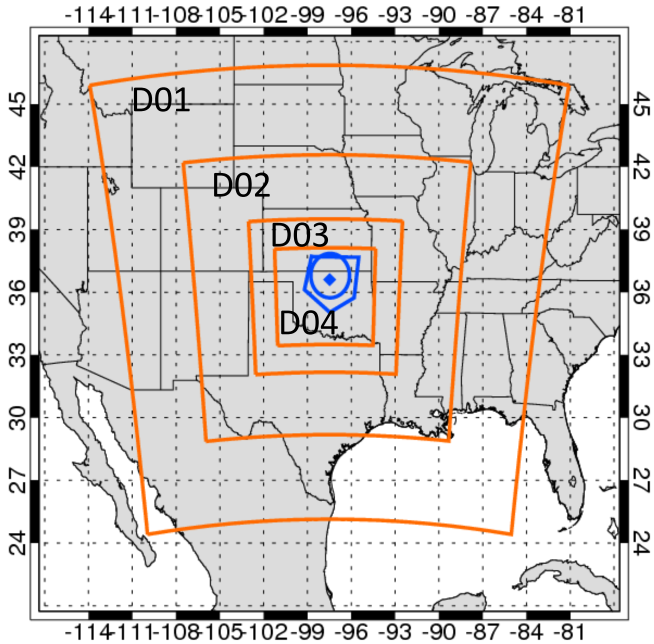
In module_mp_physics_ driver.F (**th and qv are the prognostic variables**):

Tdum = th
Qvdum = qv

Piggyback scheme → **Call SBM** (Tdum, Qvdum, Qcdum,…, Ncdum…, RAINNCD)

Host scheme → **Call Morrison** (th, qv, Qc,…, Nc…, RAINNC)

Model Setup



- MC3E May 20 squall line case; NCEP GFS data for initial and boundary conditions
- 4 Domains (27,9,3,1 km); Domain 4 is of 600x510 km^2.
- Use **the ndown approach** to run D04 separately with various scheme (i.e., initial and 3-hourly boundary data are produced from the Domain 3 simulation)
- Microphysical schemes
  - **Spectral-bin microphysical scheme (FSBM)**
  - **Morrison double-moment scheme (MORR)**
  - **Thompson double –moment scheme (THOM)**
  - **NSSL double –moment scheme (NSSL)**
  - **WSM6 single-moment scheme (WSM6)**

  - P3 scheme
  - TAMU double –moment scheme (TAMU)
  - Milbrandt and Yau scheme (MY2N)

Simulations we are performing

(1) Interactive runs with various schemes

Start at 0000 UTC and end at 2000UTC .

(2) Piggybacking runs:

- Use Morrison scheme as the host scheme
- Cold start at 0800 UTC with the initial conditions produced by the interactive simulations of the Morrison scheme.

a) Runs with the full package of schemes

b) Warm-rain simulations:

c) Polluted simulations:

- Run with CCN or droplet number concentration of 5 times higher.

(3) Interactive runs with all of the schemes starting at 0800 with the same initial and boundary data as the piggybacking runs to compare

MC3E May 20

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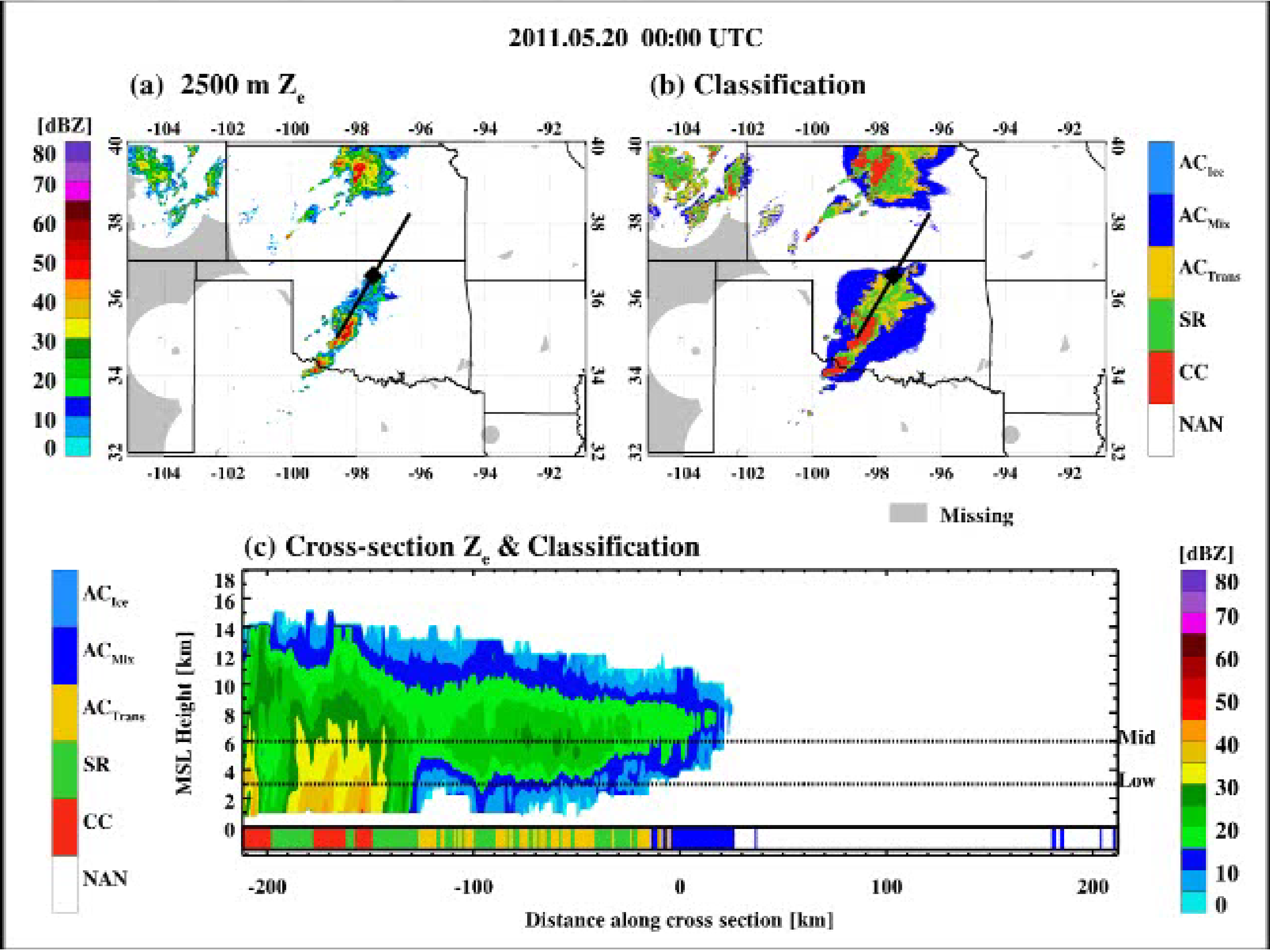
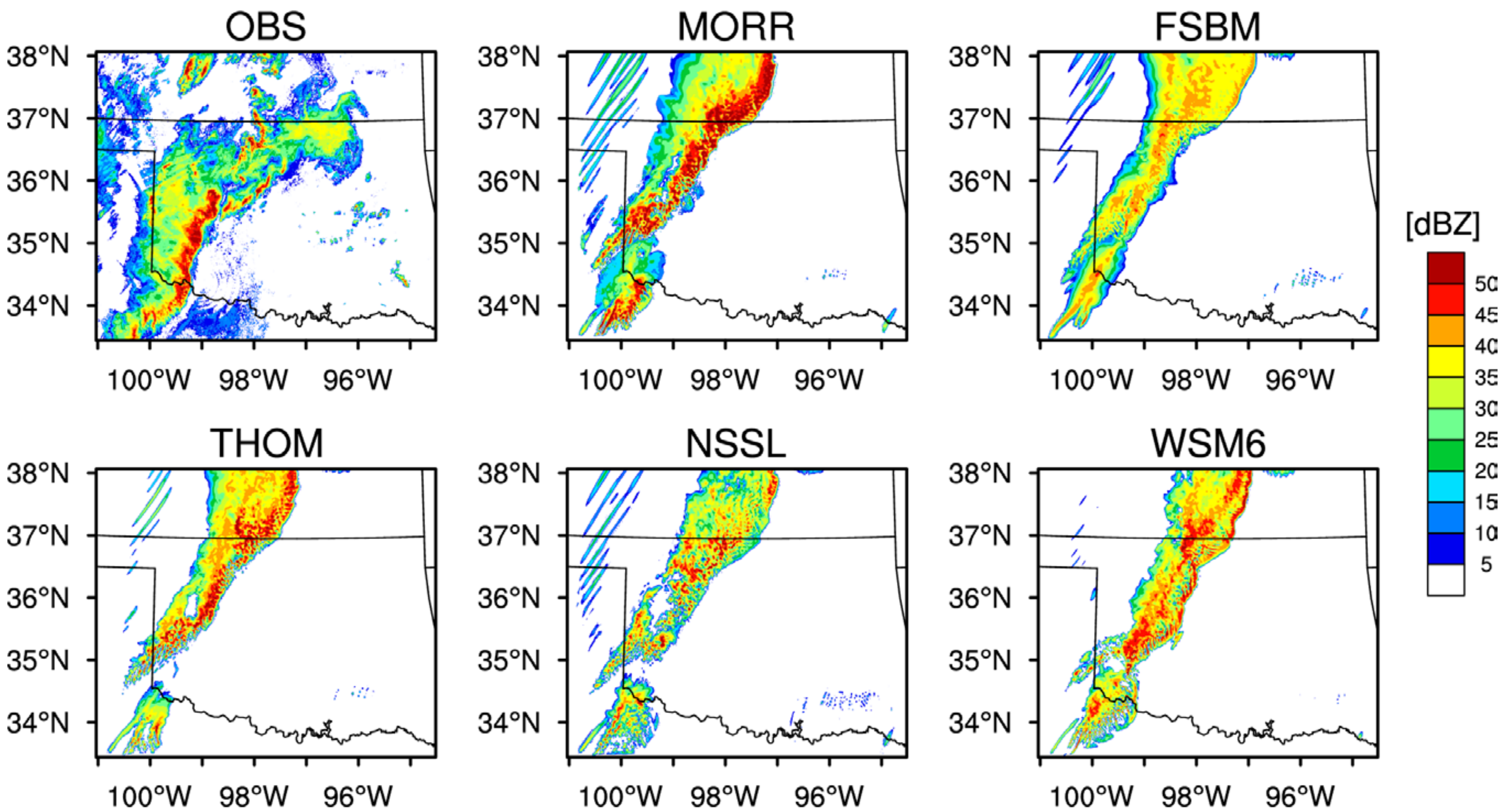


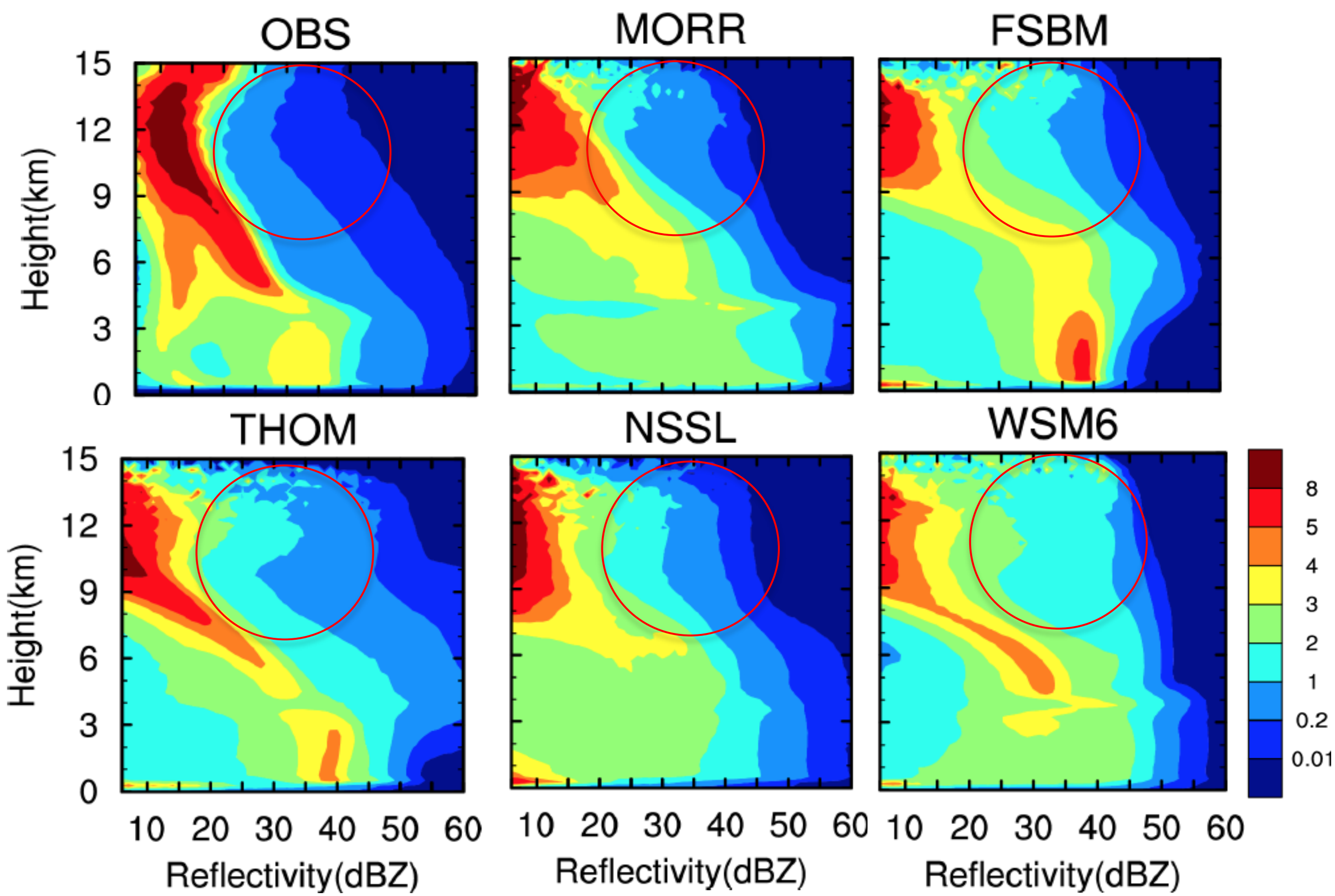
Results of interactive simulations

0800 UTC 2.5 km



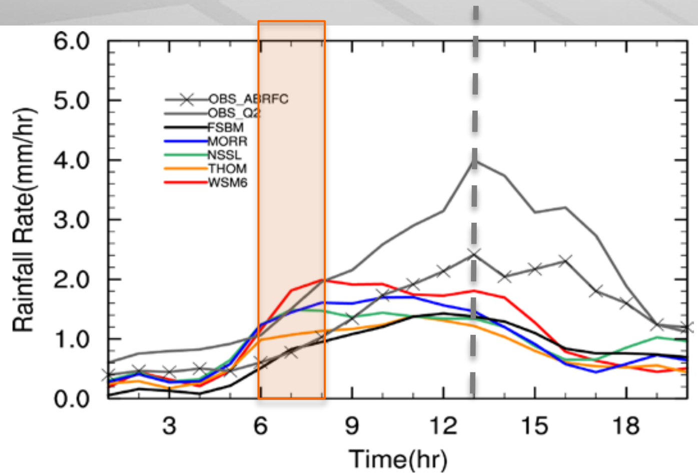
- Models have a stronger north line and much weaker south line
- Lower Ze in FSBM at the leading edge is related to smaller heavy rain rates.

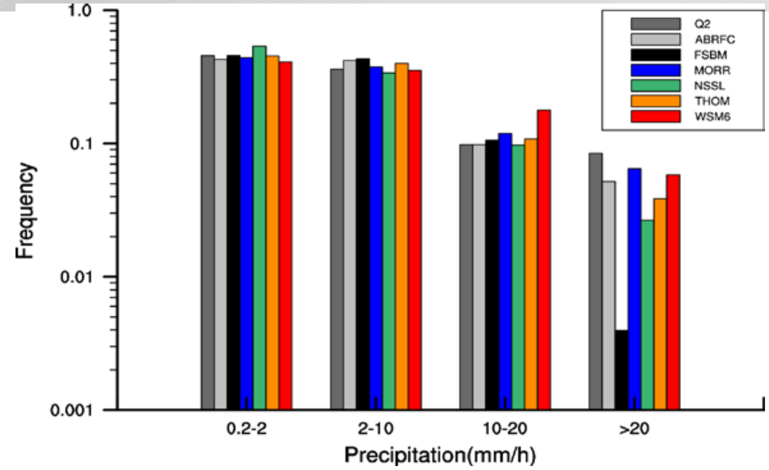
CFAD

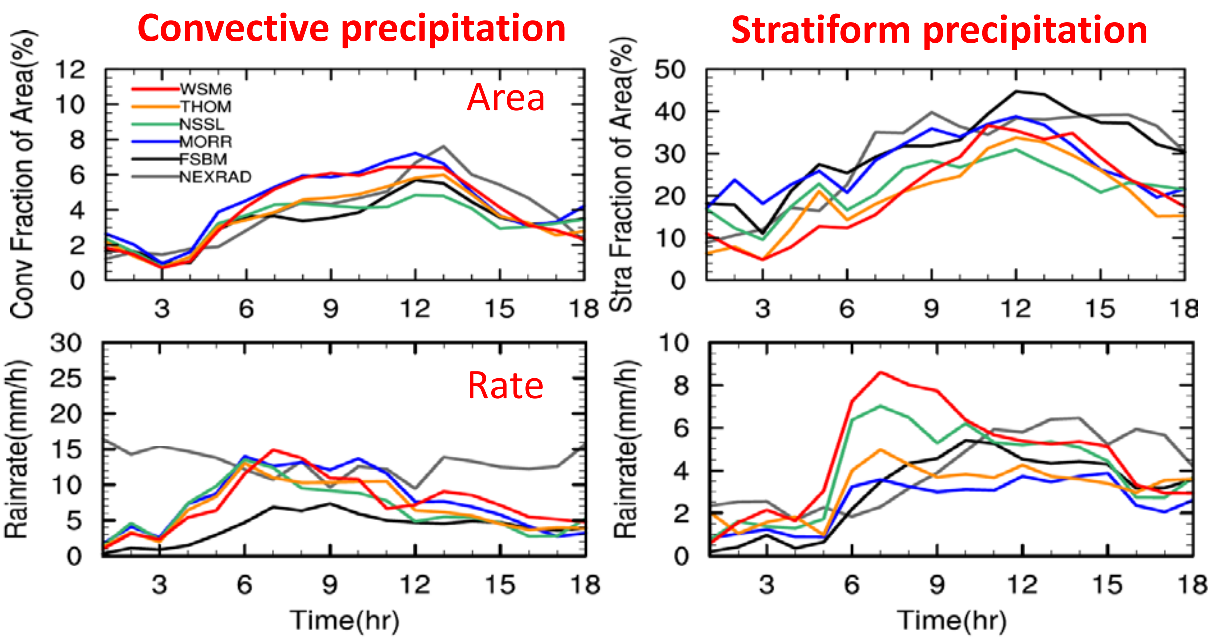


- All schemes consistently overestimate Ze above 6 km (red circle), especially FSBM and WSM6.
- FSBM overestimates the peak of 30-40 dBZ at low-levels while others miss the peak except THOM.

Precipitation







- All schemes underestimate precip because did not get the south line well.
- FSBM and THOM predict the smallest precipitation.
- FSBM predicts stratiform precip area well, while others underestimate stratiform precip area.

Separation is based on Feng et al., 2011 (adopted Steiner et al., 1995)

Compared with sounding data

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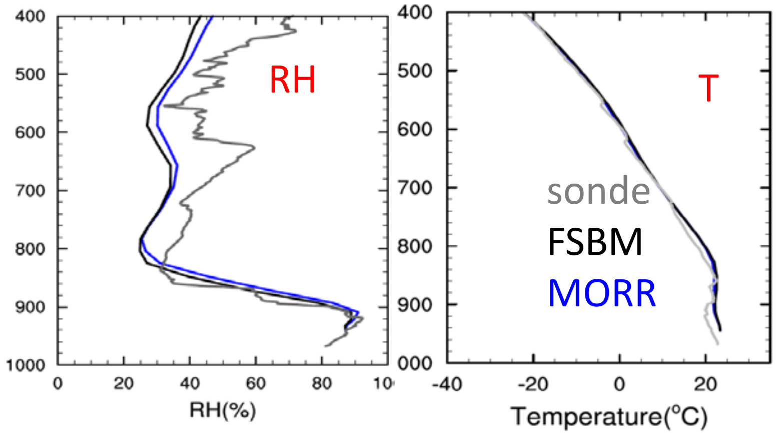
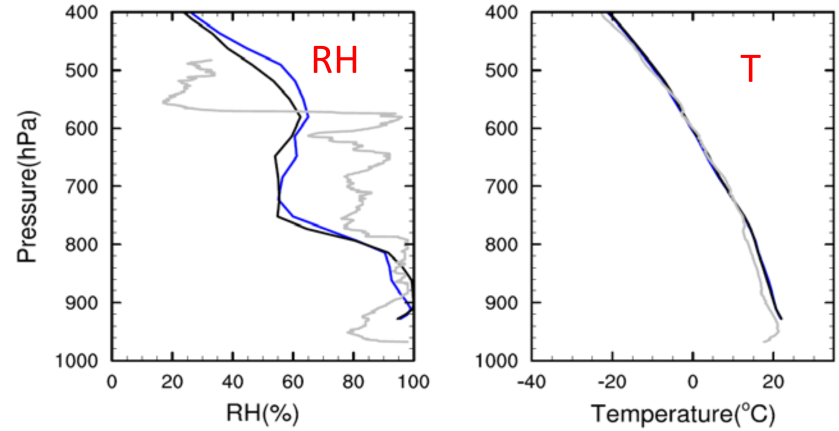
C1_0230



S5_0543



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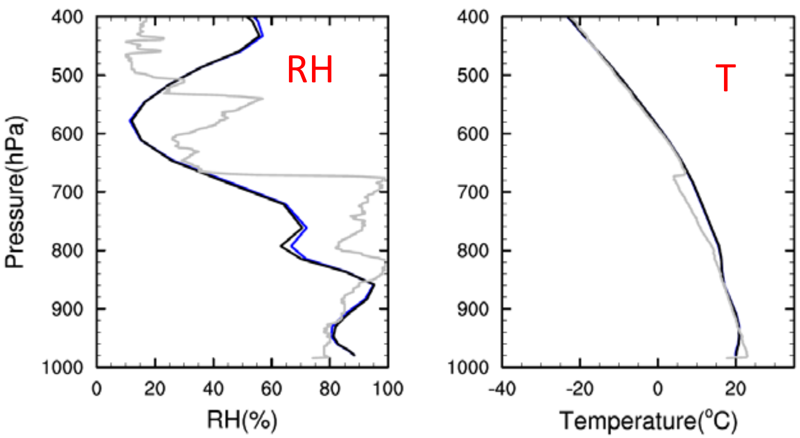
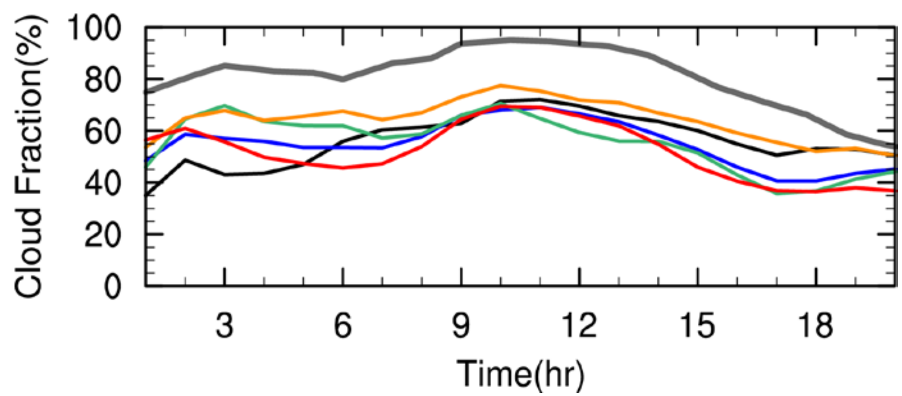
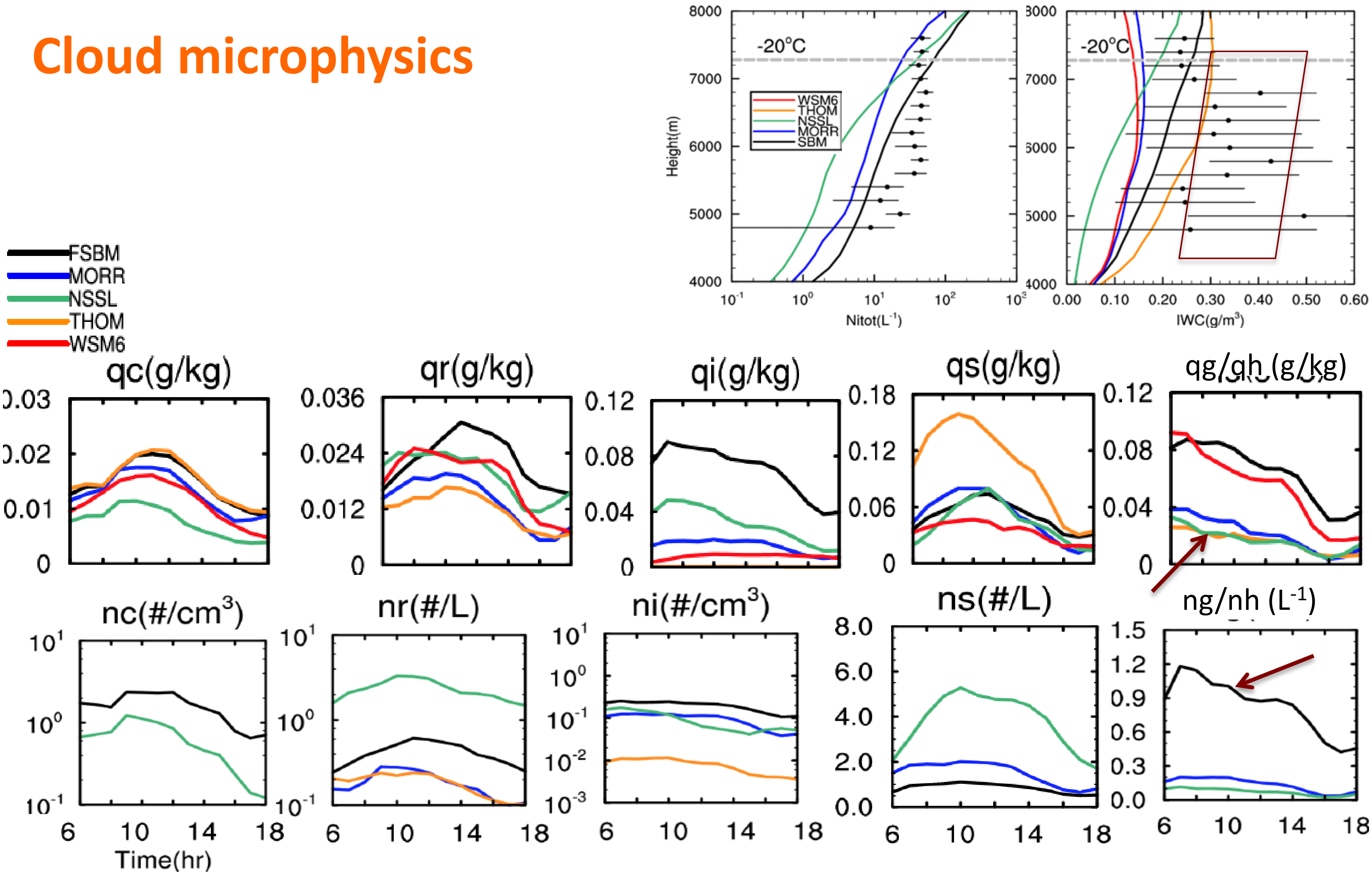


Compared with GOES (> 6 km height)



Cloud microphysics



- Large variations of every hydrometeor number and mass among the schemes.
- Underestimation of heavy rain rates by SBM is likely related to small graupel size; for THOM and NSSL, graupe mass is too low.

Piggybacking simulations

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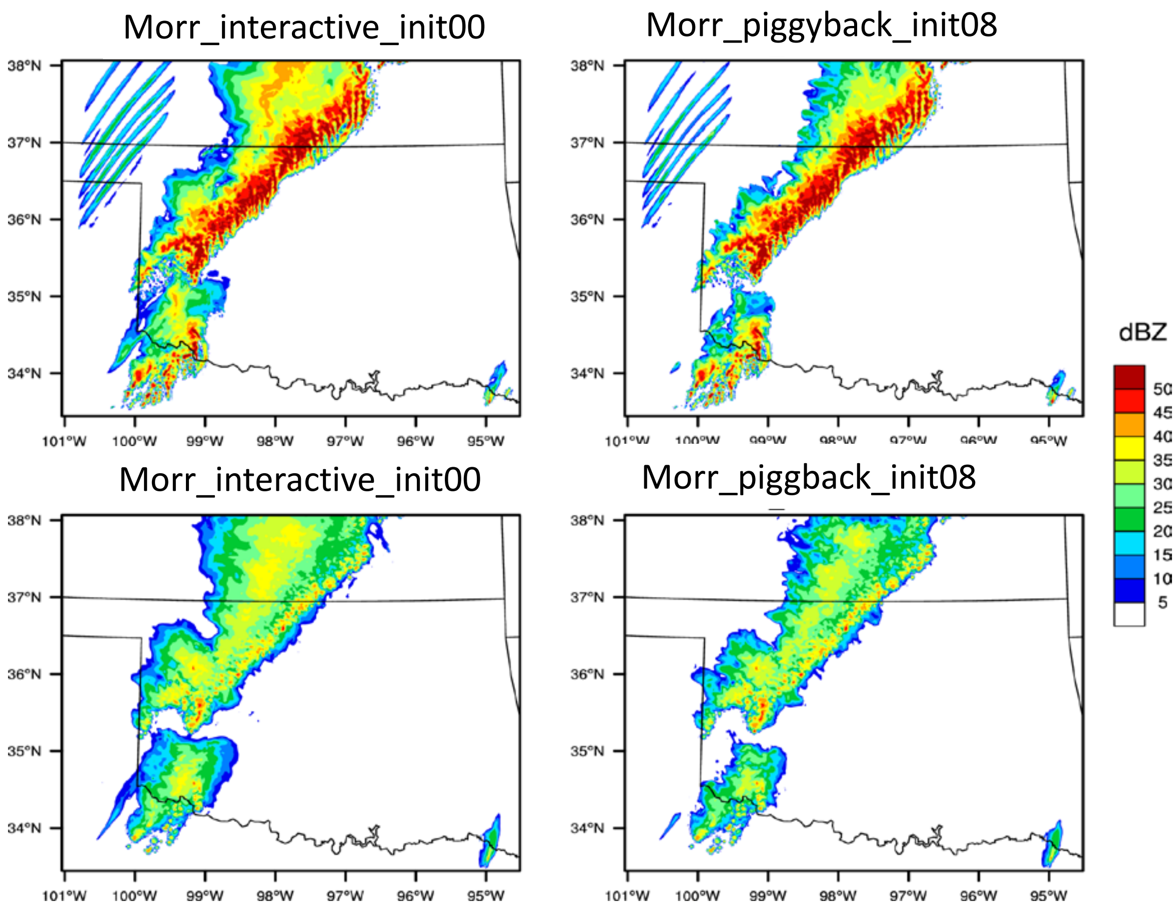
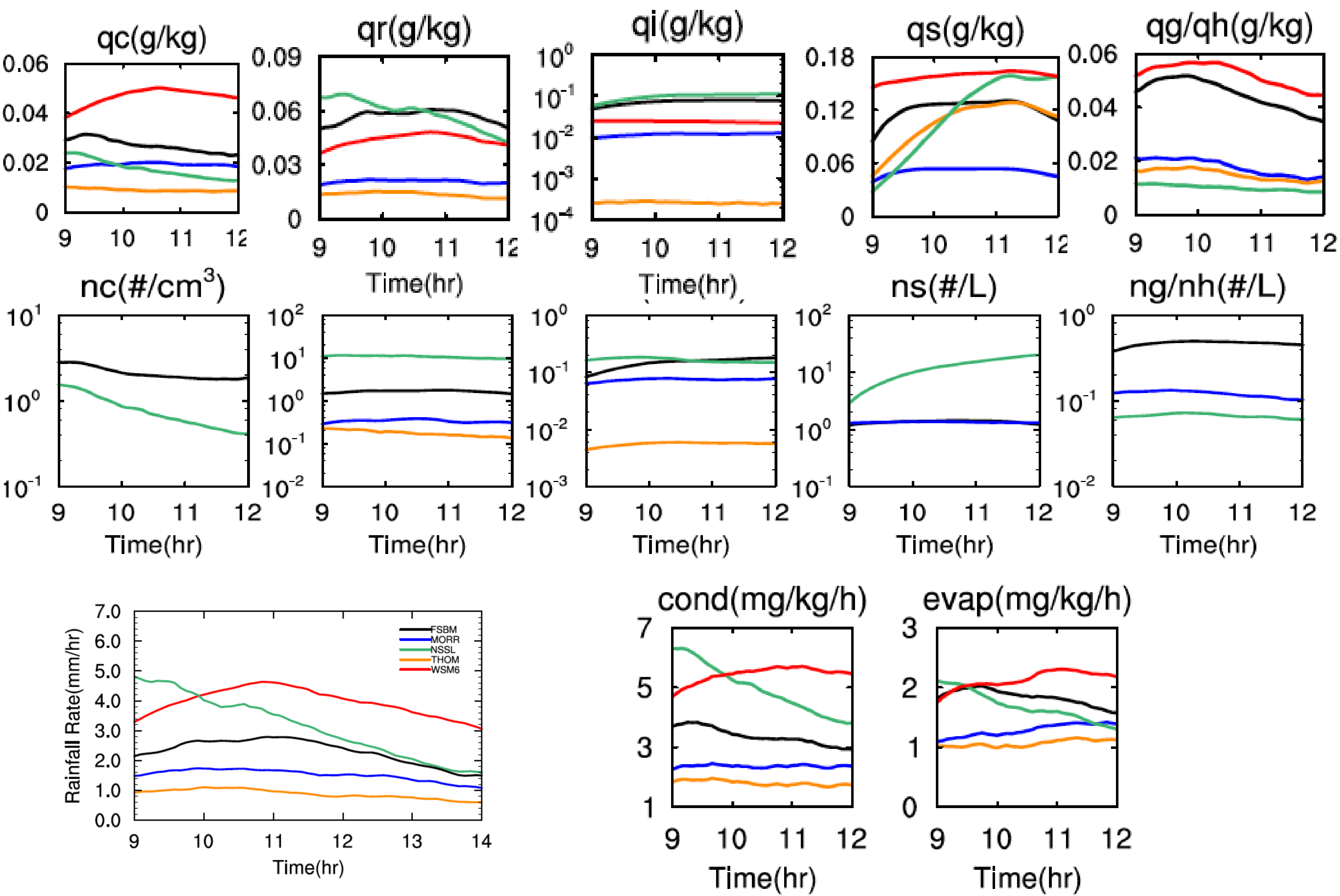
Ze at 0900 UTC between Morr interactive run initiated at 0000 UTC and Morr piggback run initiated at 0800 UTC



Cloud microphysical properties



Work ahead

- **Identify model differences produced by microphysics only through the piggyback simulations.**
- **Identify significant microphysical processes contributing to the model differences by analyzing process rates from the piggyback simulations.**
- **Examine if results of different microphysical schemes are more converged for warm-rain simulations by turning off ice microphysics.**
- **Examine differences of microphysics-dynamics feedback among different schemes (latent heat and cold pool) by intercomparing piggyback with interactive runs, and identify the most important microphysics-dynamics feedback by conducting sensitivity runs.**