# Assimilating surface & rawinsonde data in WRF microphysics simulations of warm-season convection for SGP Central Facility

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# Objectives

- Examine impacts of data assimilation
- Examine how well WRF microphysics schemes reproduce observed cloud properties
- Compare effects of radiation schemes (RRTM vs. CAM)

# WRF Simulations/Data

> 50 sensitivity experiments for warm-season heavy precip case (May 27-31, 2001)

- 3D-Var, 4D-Var, observational nudging, surface analysis nudging
- 15 Extended Facility surface observations
- 1 Upper air data at SGP Central Facility (rawinsonde data not available)

- 8 WRF microphysics schemes
- Control simulation (no data assimilation, CNTRL)
- 2 long-wave and short-wave radiation schemes:
    - Rapid Radiation Transfer Model (RRTM) spectral-band scheme
    - NCAR Community Atmosphere Model (CAM) spectral-band scheme

# Surface and Upper Air Stations Used for Data Assimilation

**3D-Var: Data assimilated for 3 hrs from 05-07 UTC for 15 Surface stations (hourly) and 1 upper air observation at 06 UTC**

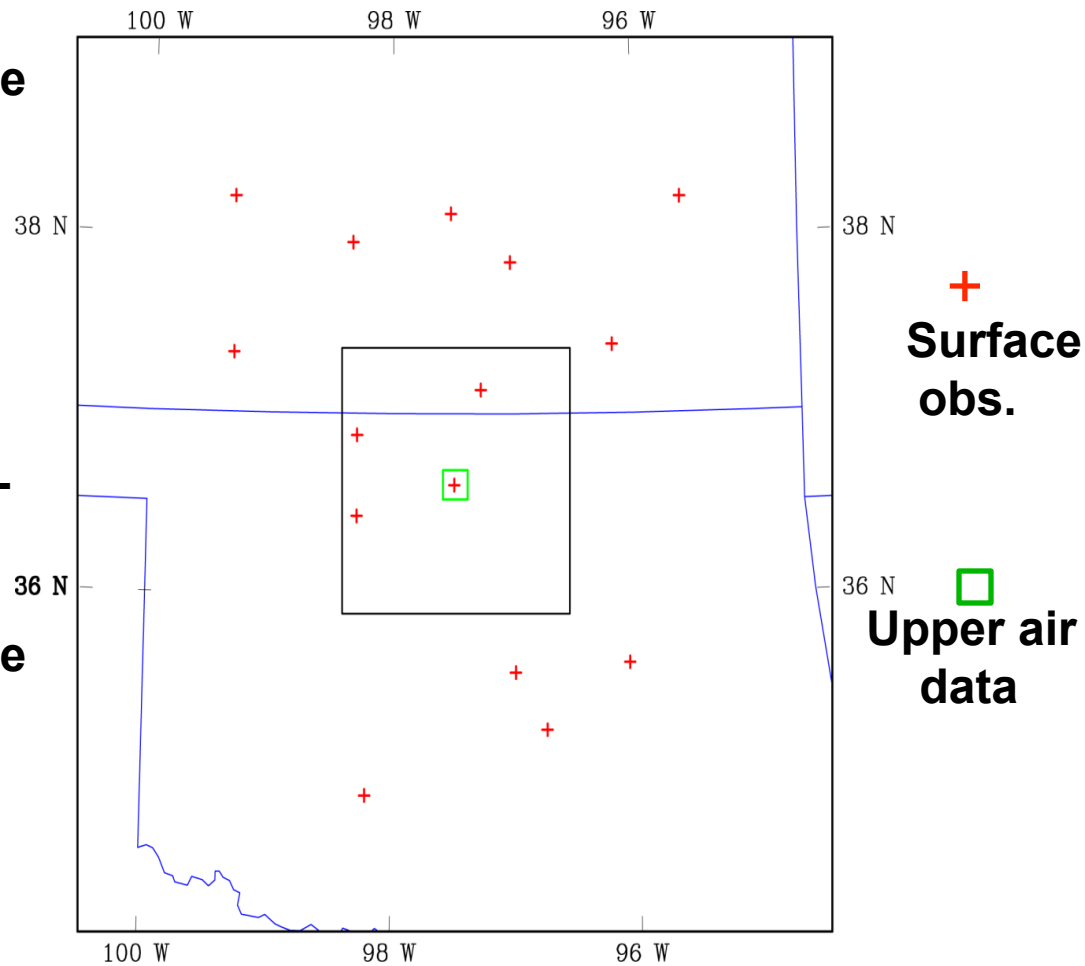
**4D-Var: data assimilated from 06-12 UTC -- 1 hr for 15 surface stations and 6 hrs for 1 upper air station (06/12 UTC)**

**-Global background error for 3D-Var/4D-Var**

**Observational Nudging: Model solutions relaxed towards surface (upper air) observations every 1 (6) hour**

**Surface Analysis Nudging: Same as above but without upper air. Model solutions relaxed towards 6 hr Analyses (grid analysis)**

**Control Run: No data assimilation**

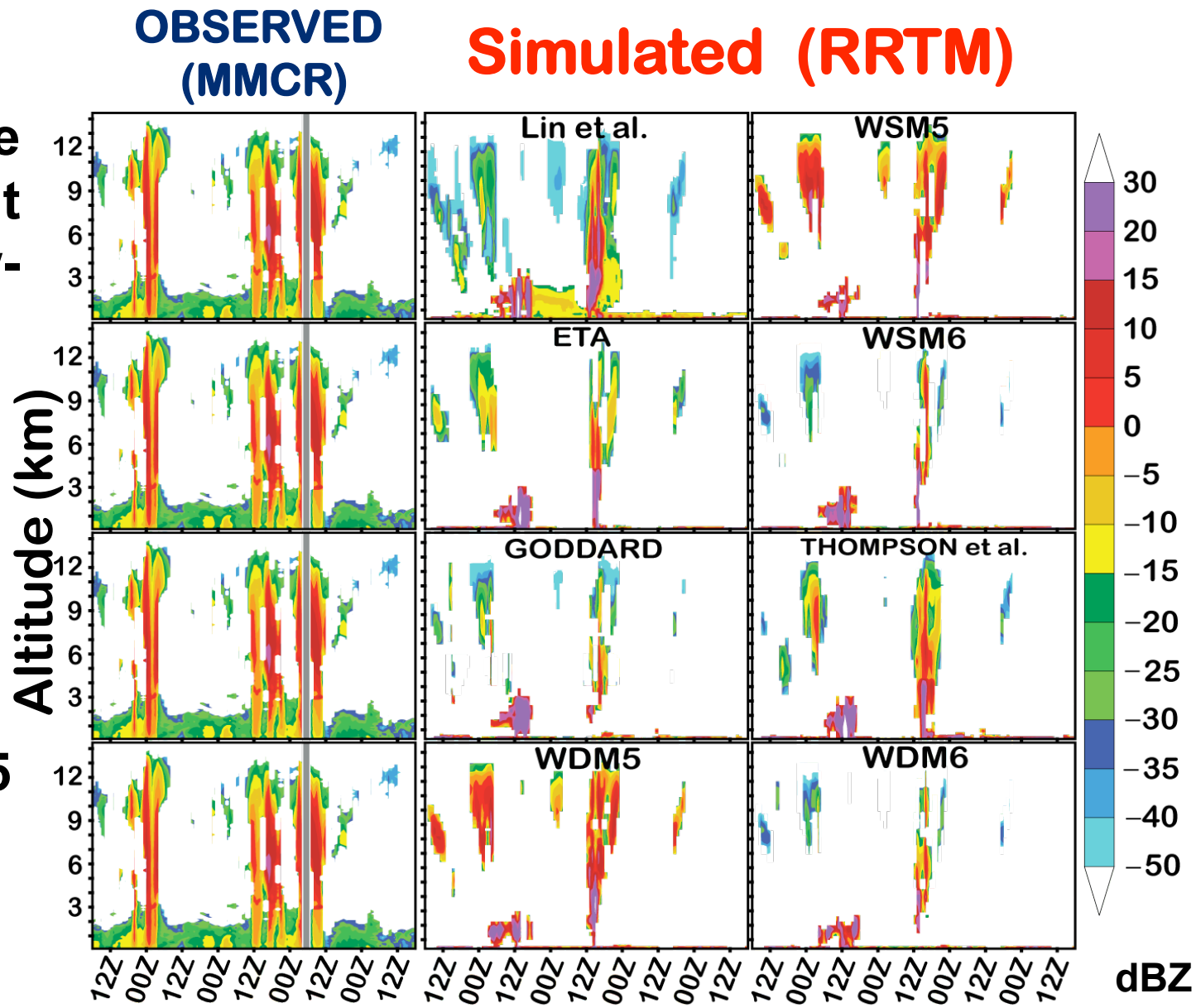



Model Domain

# CLOUD RADAR REFLECTIVITY (CNTRL)

-Lin et al. underestimate reflectivity but produced low-level reflectivity agreeing well with the observations

-WSM5/WDM5 overestimate reflectivity

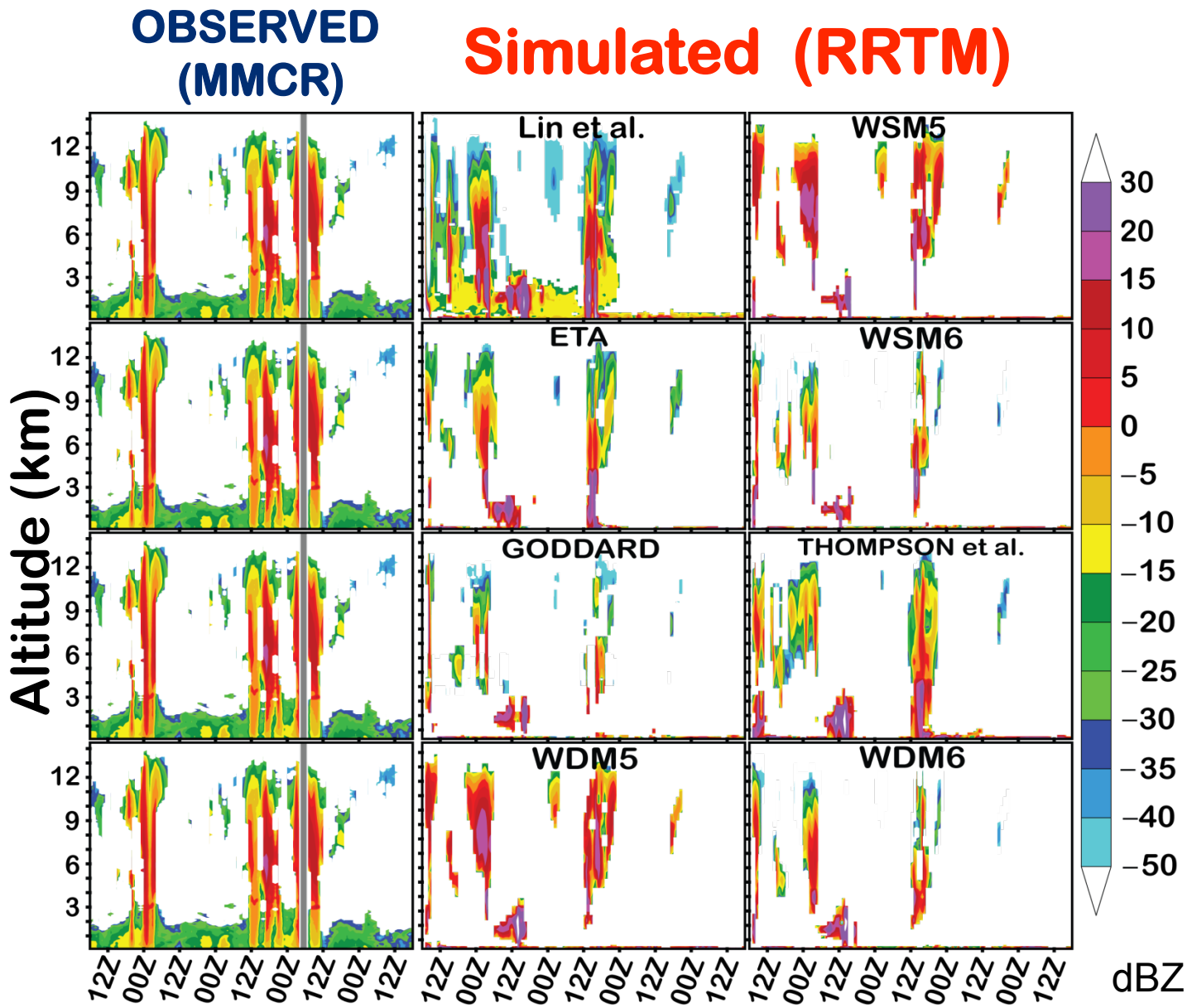



27-31 May 2001

# CLOUD RADAR REFLECTIVITY (4D-Var)

**4D-Var/SFDDA/ Grid Analysis:** Enhanced convection during the assimilation period. Improved reflectivity 50 hr into the simulations

**OBS-NUD/3D-Var:** Little convection during the assimilation period. Improvements minimal for 3D-VAR




**27-31 May 2001**

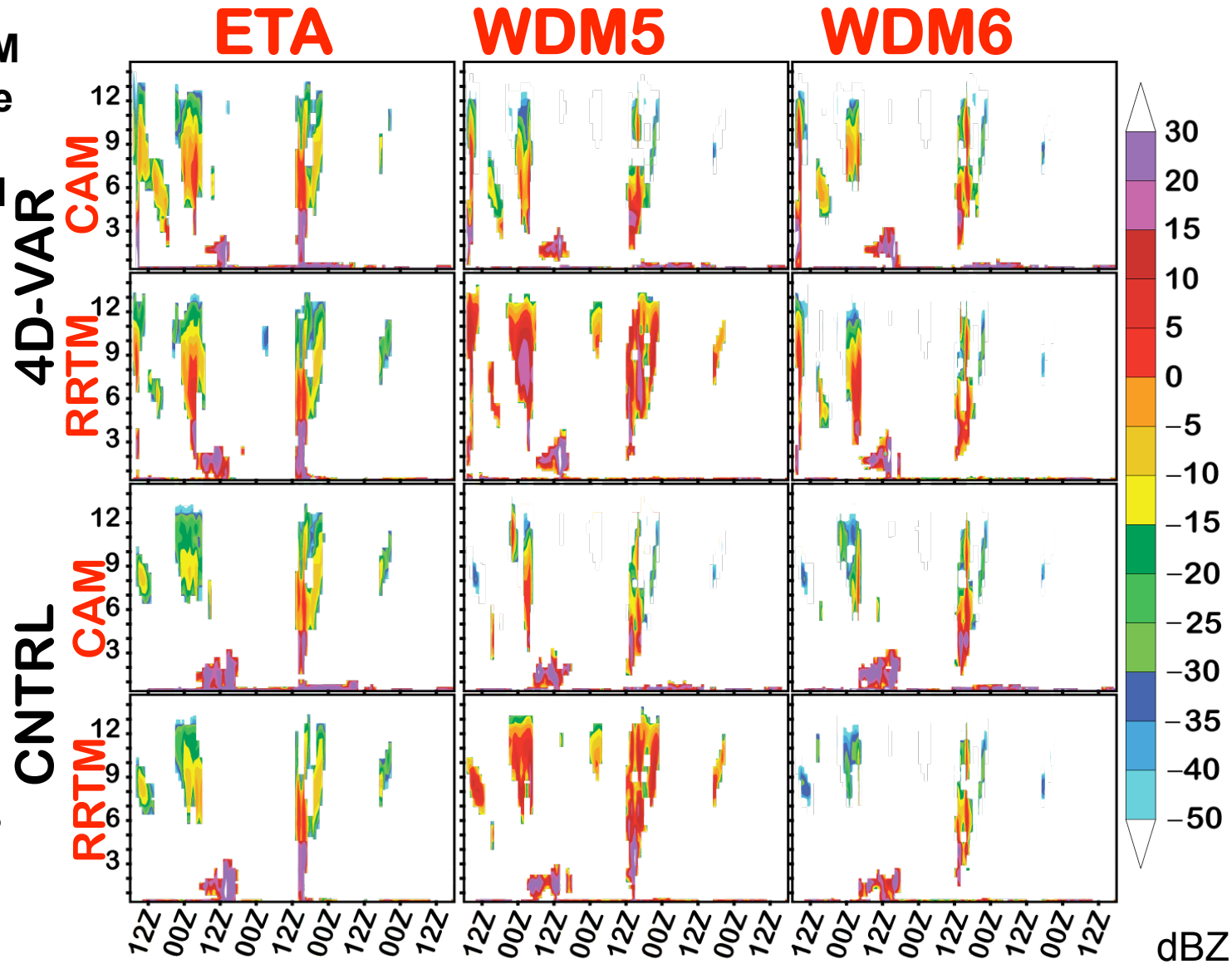
# SIMULATED CLOUD RADAR REFLECTIVITY

-RRTM and CAM short/long-wave radiation schemes tested for 4D-Var

-Lin et al. and Thompson microphysics unstable for CAM

-More early convection in CAM than in RRTM for 4D-Var simulations

-WDM5 better for RRTM than CAM

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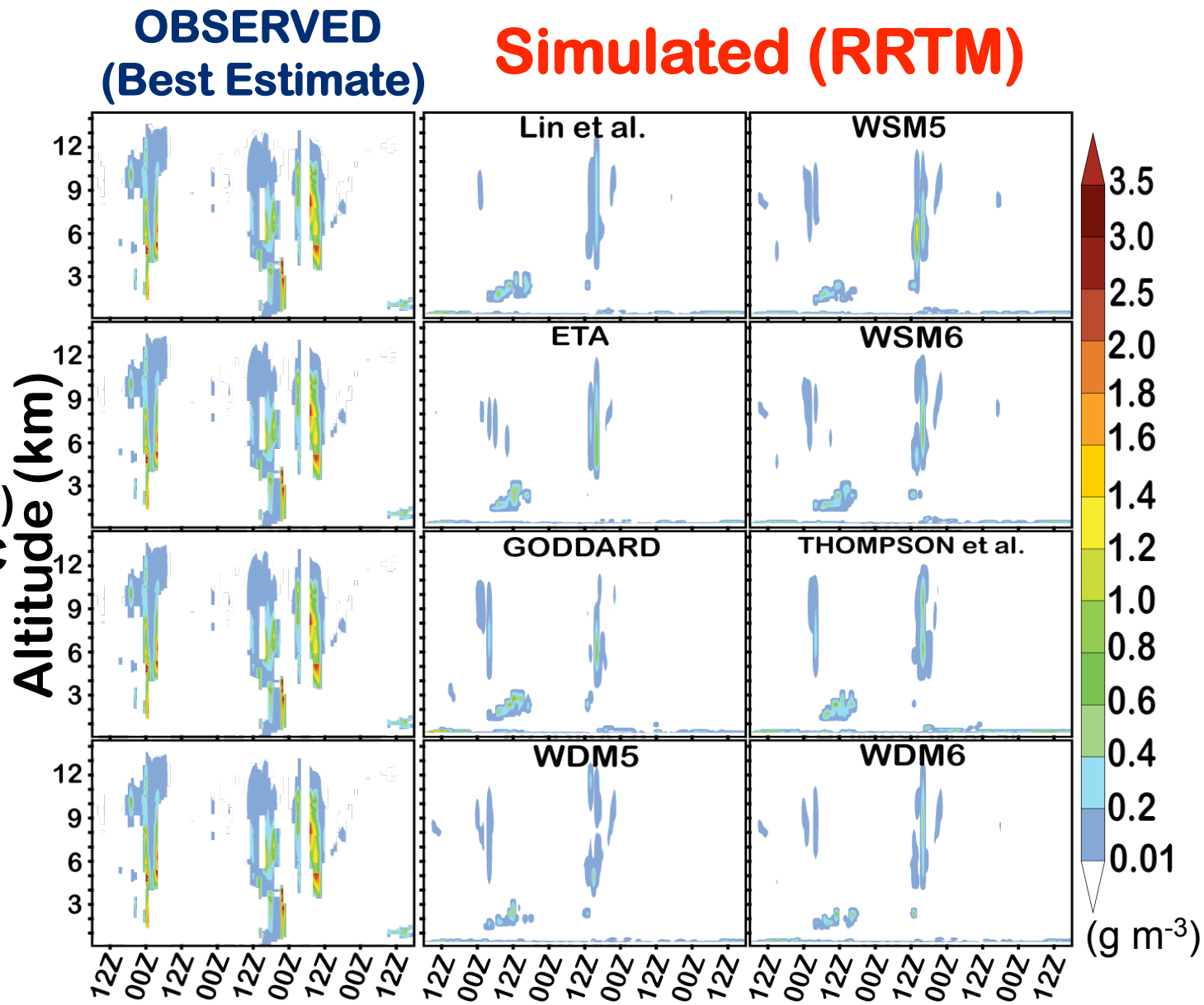
# LIQUID/ICE WATER CONCENTRATION (CNTRL)

-LWC/IWC underestimated for all microphysics;

-Compared to other schemes WSM5 (also Eta) produced > IWC at mid-levels;

-All schemes produced shallow LWC

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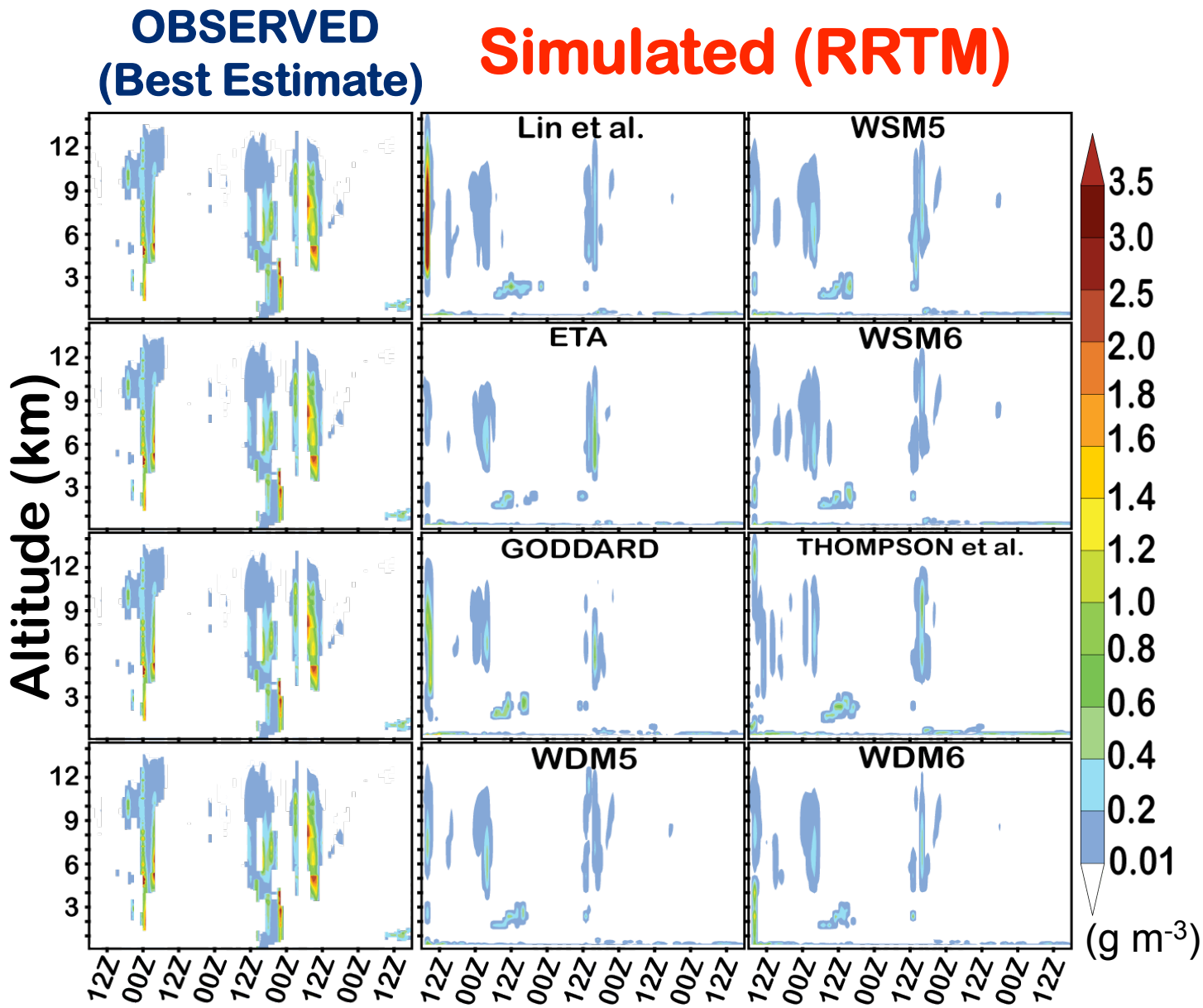
# LIQUID/ICE WATER CONCENTRATION (4D-Var)

-Enhanced convection during assimilation period;

-All schemes produced IWC profiles that compared well with observed initial (00Z) convection;

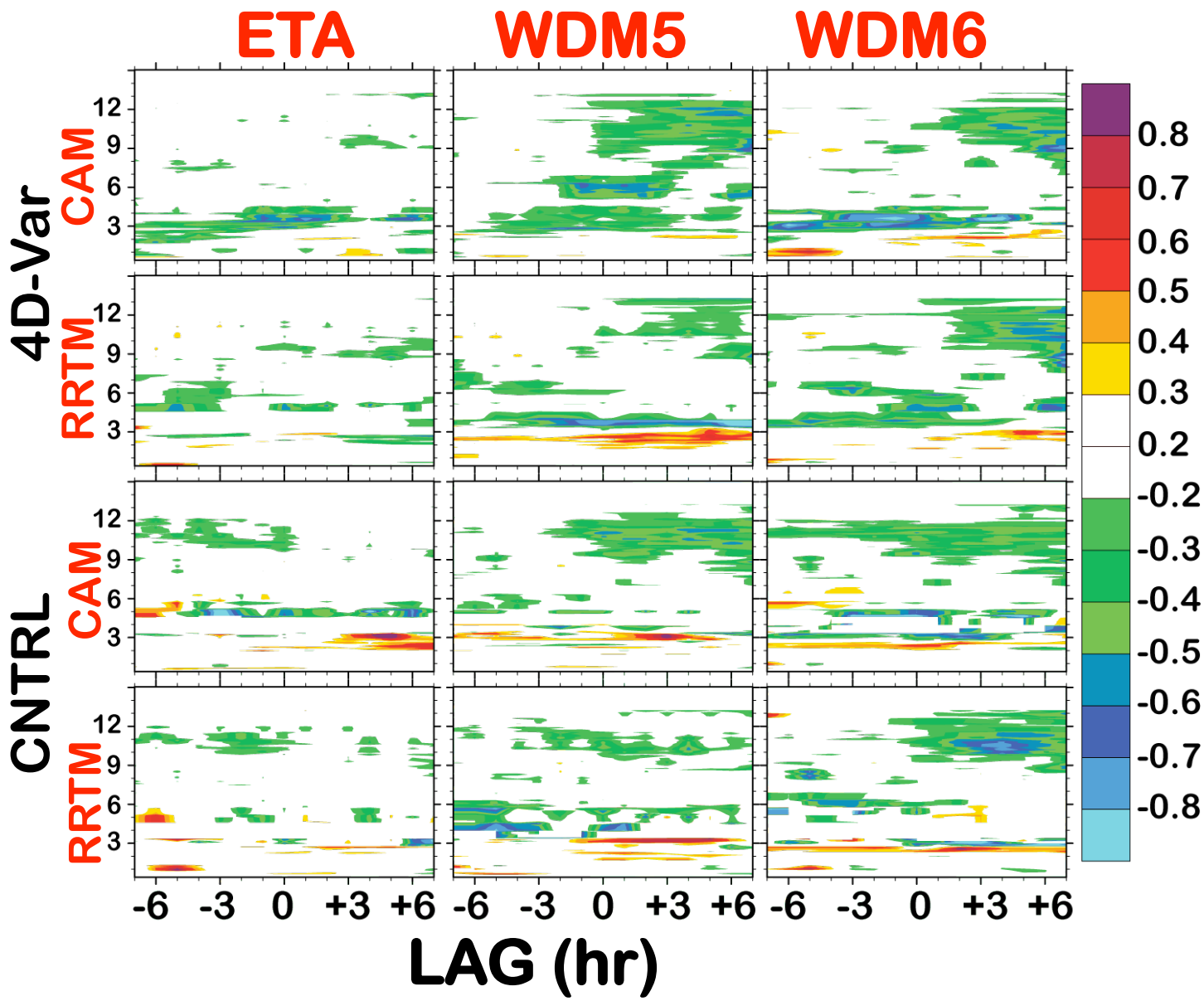
-Eta and Goddard simulated excessive IWC during data assimilation period.




27-31 May 2001

# CLOUD RADAR REFLECTIVITY CORRELATION (MMCR vs. Simulated)

-Number of valid data points vary
-Minimum time series length not specified;
-CAM produced high -ve LWC correlations near zero LAG, signifying early convection;
-Improved performance of WDM5 RRTM With large +ve LWC correlations, especially for 4D-Var.



# Key Conclusions

- All microphysics schemes underestimate LWC/IWC in WRF simulations;
- Only Lin et al. microphysics scheme produced low-level cloud radar reflectivity that compared well with observations; but unstable for 4D-Var CAM and RRTM SFDDA simulations;
- Significant temporal discrepancies from observations, suggesting grid-scale processes exert primary control on timing of convection;
- Improved LWC/IWC for 4D-Var and for grid-analysis with surface analysis nudging.

Questions?

# Summary of acronyms used

- **3D-Var-- Three-Dimensional Variational data assimilation**
- **4D-Var-- Four-Dimensional Variational data assimilation**
- **CAM -- NCAR Community Atmosphere Model**
- **CNTRL=96 Control Run**
- **FDDA/Grid Analysis -- Newtonian nudging in which model solutions are relaxed towards gridded-reanalysis**
- **FNL-- NCEP Final Analysis System**
- **IWC-- Ice Water Concentration**
- **LWC-- Liquid Water Concentration**
- **MMCR=96 Millimeter Cloud Radar**
- **OBS-NUD -- Observational Nudging**

**PBL-- Planetary Boundary Layer**
**RRTM-- Rapid Radiation Transfer Model**
**SFDDA-- Surface Analysis Nudging**
**WDM5-- WRF Double-Moment 5-class scheme**
**WDM6-- WRF Double-Moment 6-class scheme**
**WSM5-- WRF Single-Moment 5-class scheme**
**WSM6-- WRF Single-Moment 6-class scheme**
**WRF-- Weather Research and Forecasting Regional Model**

# WRF Microphysics Used

- Lin et al. scheme (Lin et al.)
  - 6 classes:-- rain, WV, CW, cloud ice (CI), snow, graupel
- WRF Single-Moment 5-class scheme (WSM5)
  - Predicts WV, rain, snow, CI, and CW allows mixed-phase processes
- Eta Microphysics (Eta)
  - Predicts changes in WV, CW, CI, rain, and precipitation ice (snow/graupel/sleet)
- WRF Single-Moment 6-class scheme (WSM6)
  - Extends WSM5 by including graupel and associated processes

- **Goddard Microphysics scheme (Goddard)**
  **-Allows ice, snow, graupel processes**

- **Thompson et al. scheme (Thompson)**
  **-Ice, snow, graupel processes. Predicts rain number concentration**

- **WRF Double-Moment 5-class scheme (WDM5)**
  **-Same as WSM5, but has double moment rain, cloud and CCN for warm processes**

- **WRF Double-Moment 6-class scheme (WDM6)**
  **-Same as WSM6, but has double-moment rain, cloud and CCN for warm processes**

# WRF Simulations/Data (contd.)

- One-way nesting: 9- and 3-km; and 41 vertical levels
- Operational Eta convective scheme for the coarse domain runs, but no cumulus parameterization for the 3-km nested simulations. WRF's default land surface & PBL physics schemes, and default diffusion/damping options
- Mace et al.'s Liquid Water Concentration (LWC), Ice Water Concventration (IWC), and MMCR reflectivity VAPs
- QuickBeam radar simulation package (Haynes et al. 2007) for MMCR equivalent radar reflectivity conversion
- 6-hrly NCEP's FNL Reanalysis for initial and lateral boundary conditions