Do We Need Cloud Microphysics Parameterization to Simulate Convection?

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Objectives

- Examine how well WRF microphysics schemes reproduce the observed cloud properties compared to a no-microphysics simulation
- Estimate the large-scale convection from simulation without microphysics

WRF Simulations

- Warm-season heavy precipitation event (27-31 May 2001)

- 8 WRF microphysics scheme simulations compared with a no-microphysics simulation

- Two-way nesting: 9- and 3-km grid spacing with 41 vertical levels

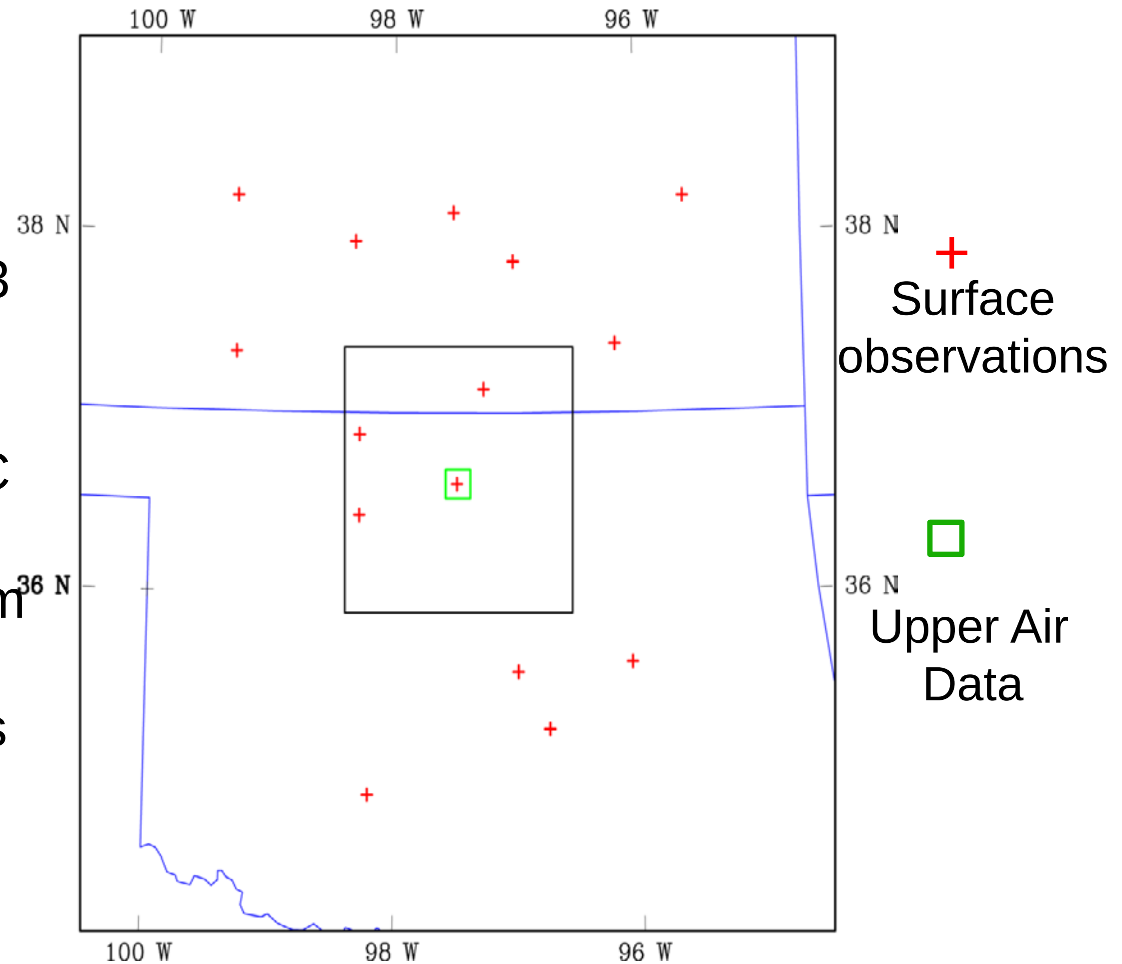
Surface and Upper Air Stations Used for Data Assimilation

- 15 Extended Facility surface observations and 1 Upper air data at SGP Central Facility

- 3DVAR: data assimilated for 3 hrs from 05-07 UTC for 15 Surface stations (hourly) and 1 upper air observation at 06 UTC

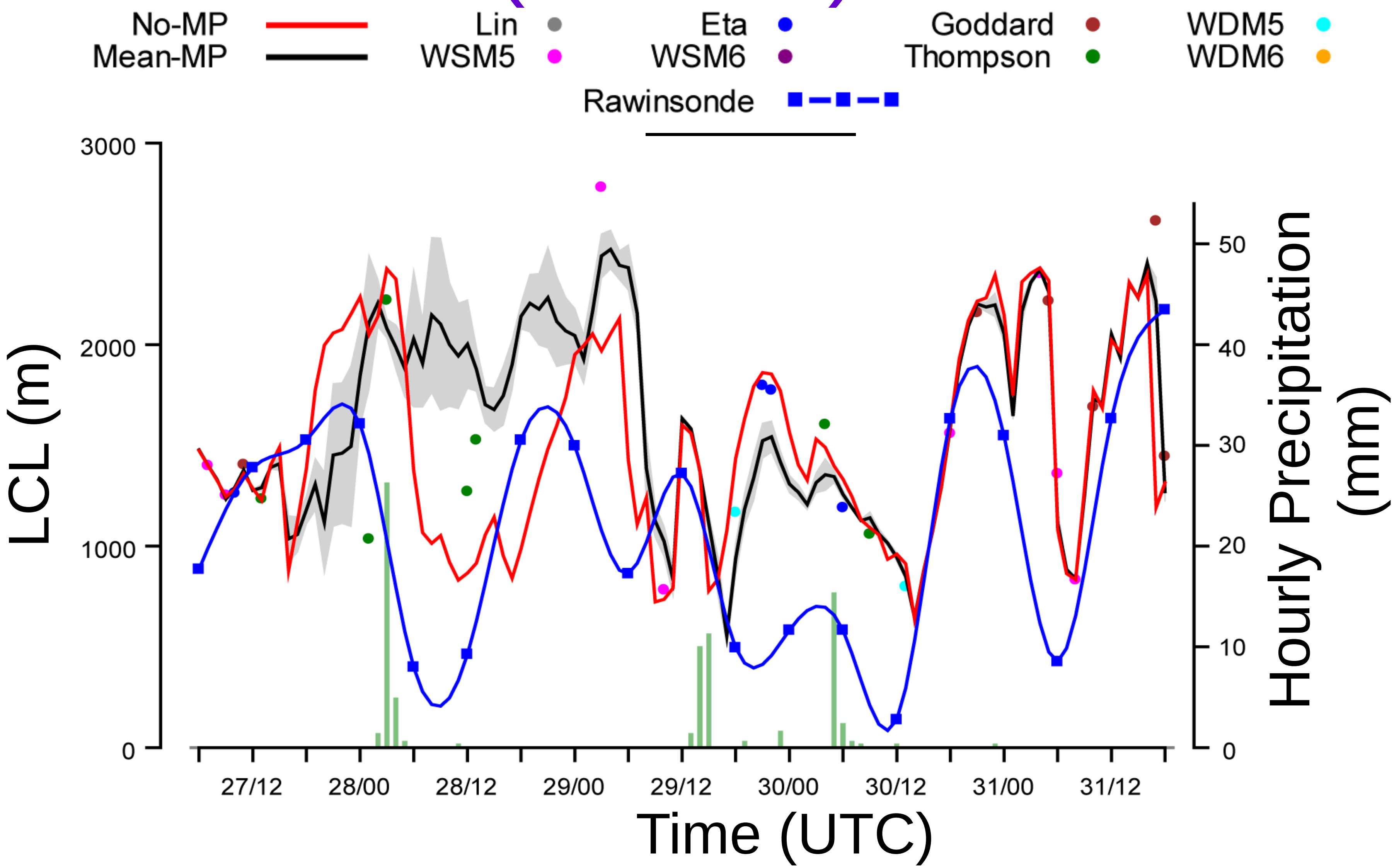
- 4DVAR: data assimilated from 06-12 UTC -- every 1 hr for 15 surface stations and every 6 hrs for 1 upper air station (at 06/12 UTC)

- Control Run (CNTRL): No data assimilation

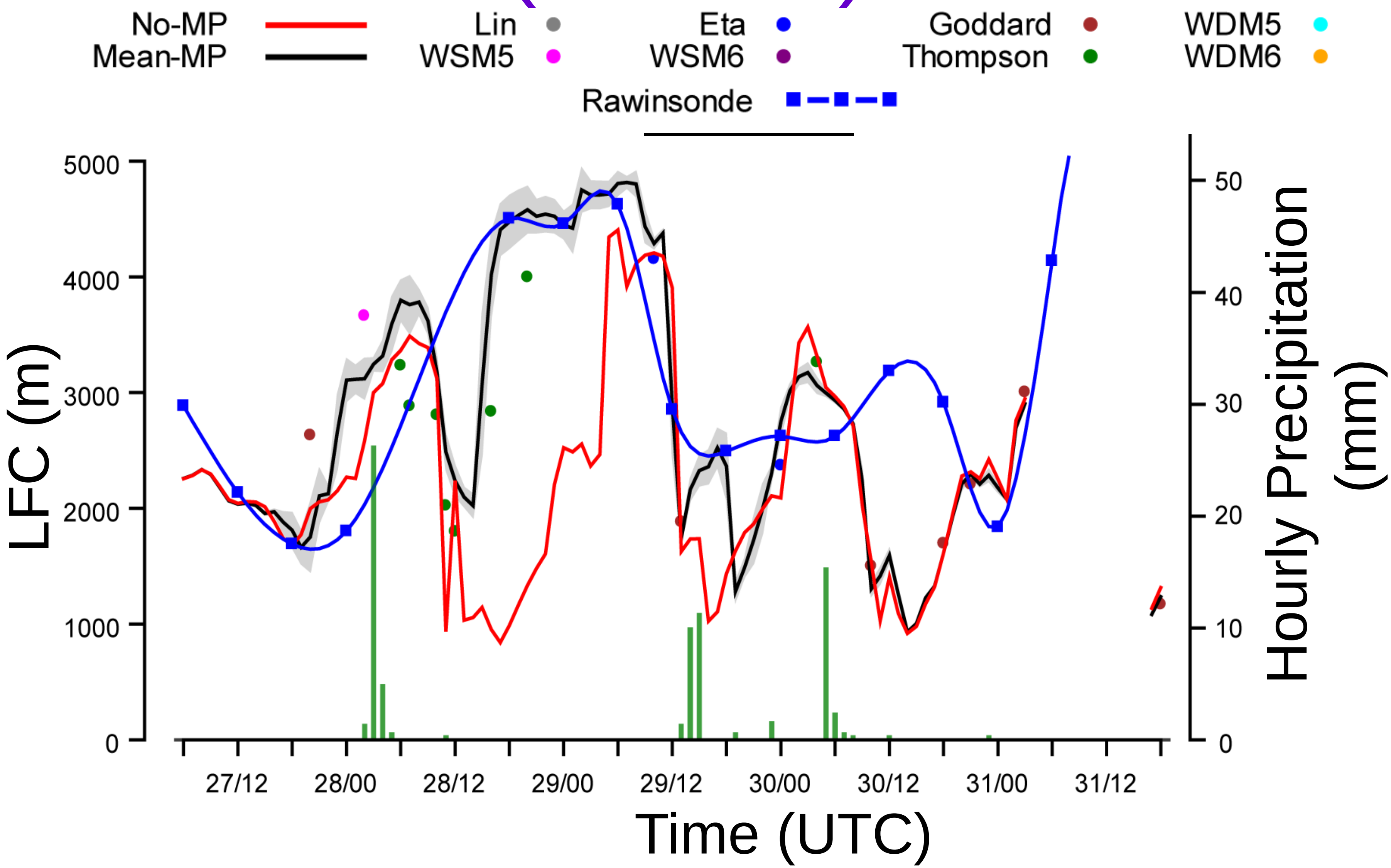


Model Domain

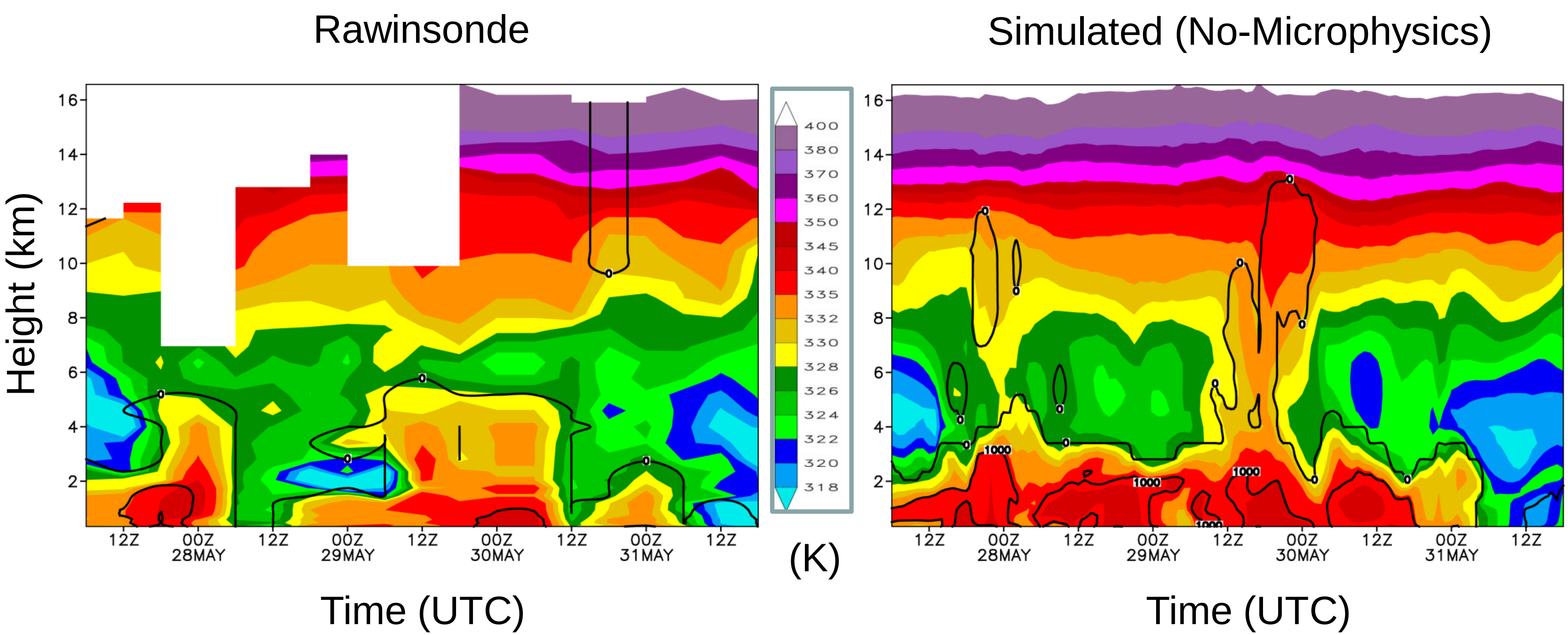
Cloud Stability Parameters -- LCL (CNTRL)



Cloud Stability Parameters -- LFC (CNTRL)

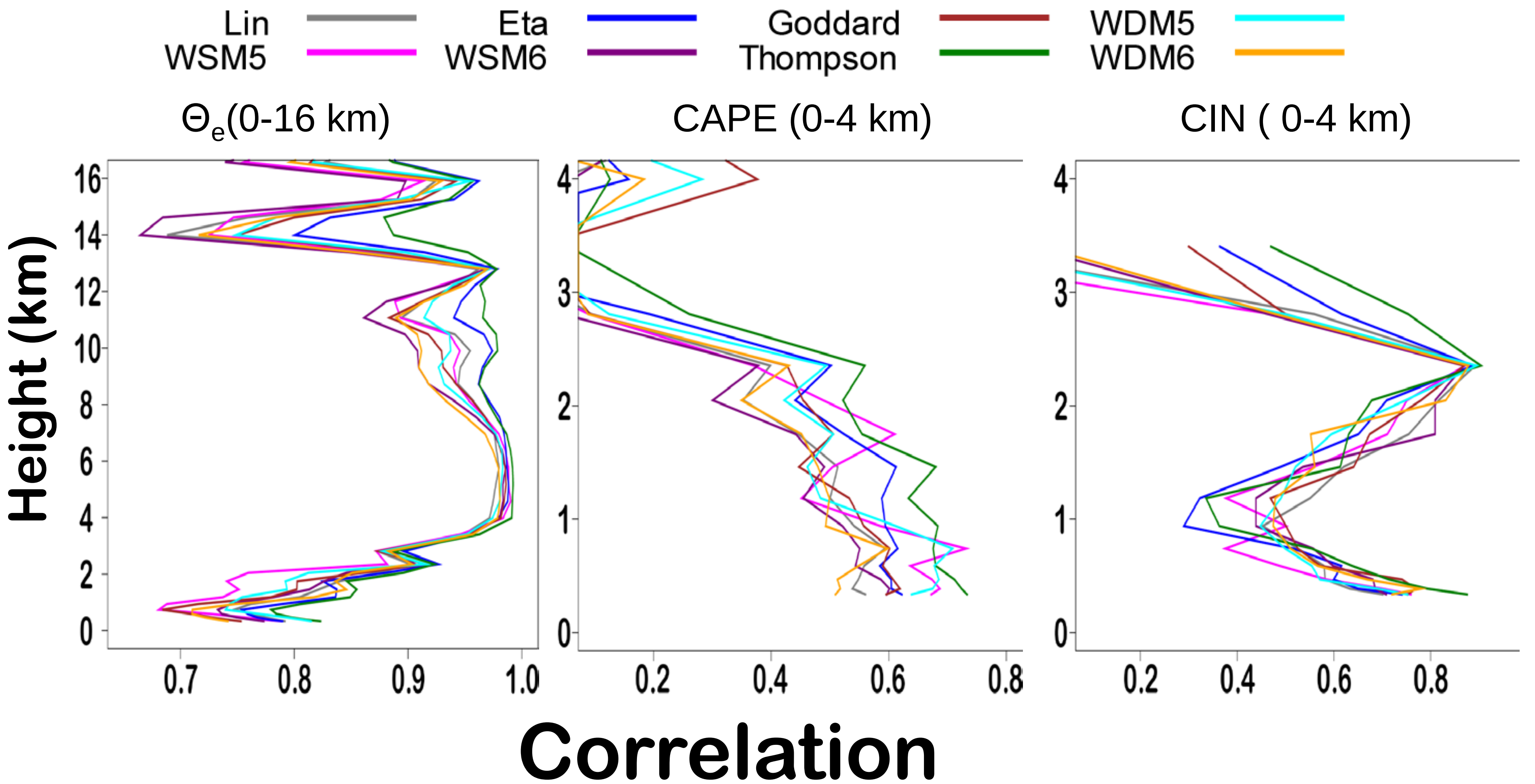


Profiles of Equivalent Potential Temperature and CAPE



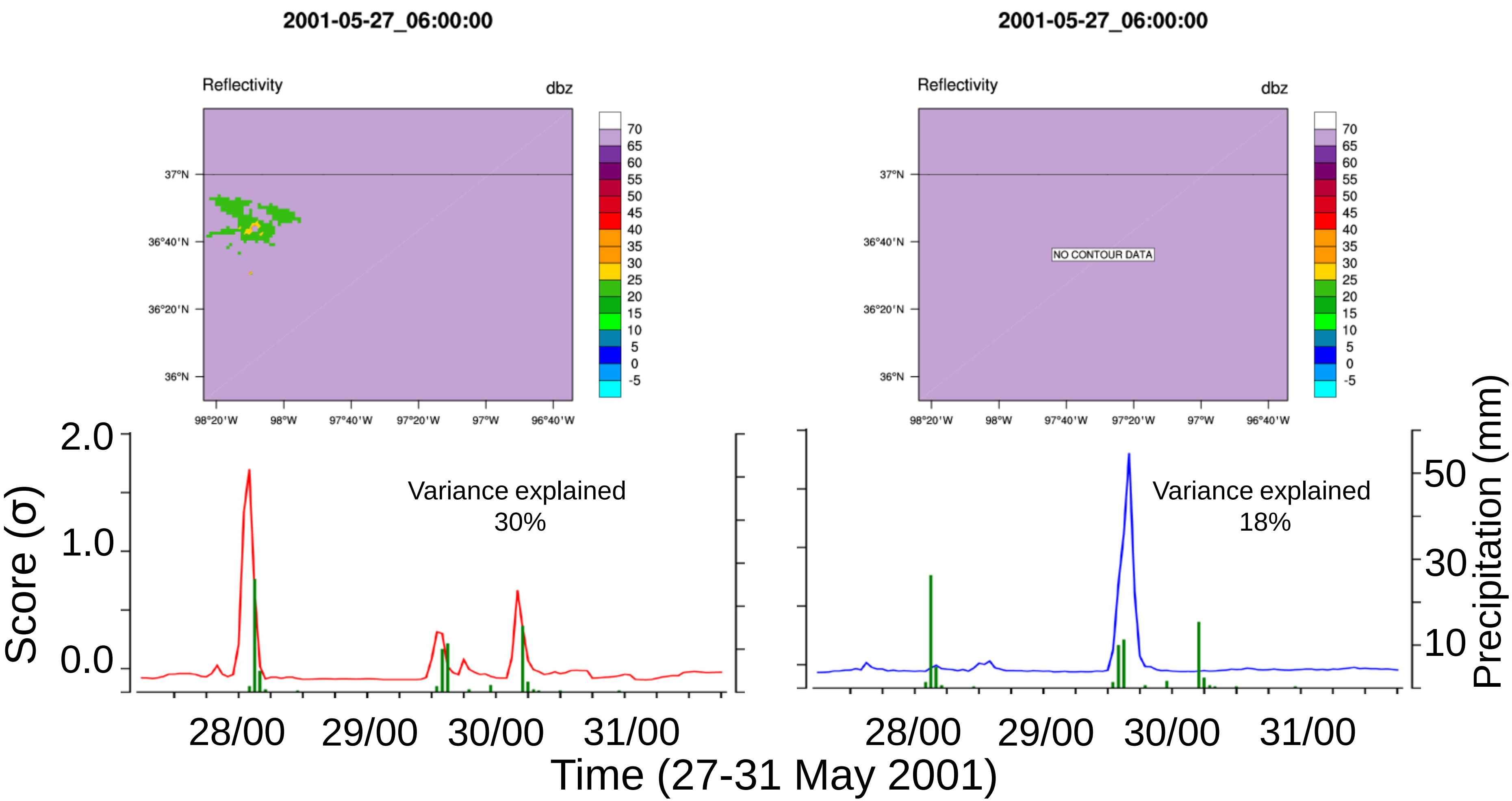
- Temporal θ_e (shading) profile well-captured, but overestimated at low levels
- CAPE (contour) was over estimated

Correlations between No Microphysics and Microphysics Simulations (CNTRL)

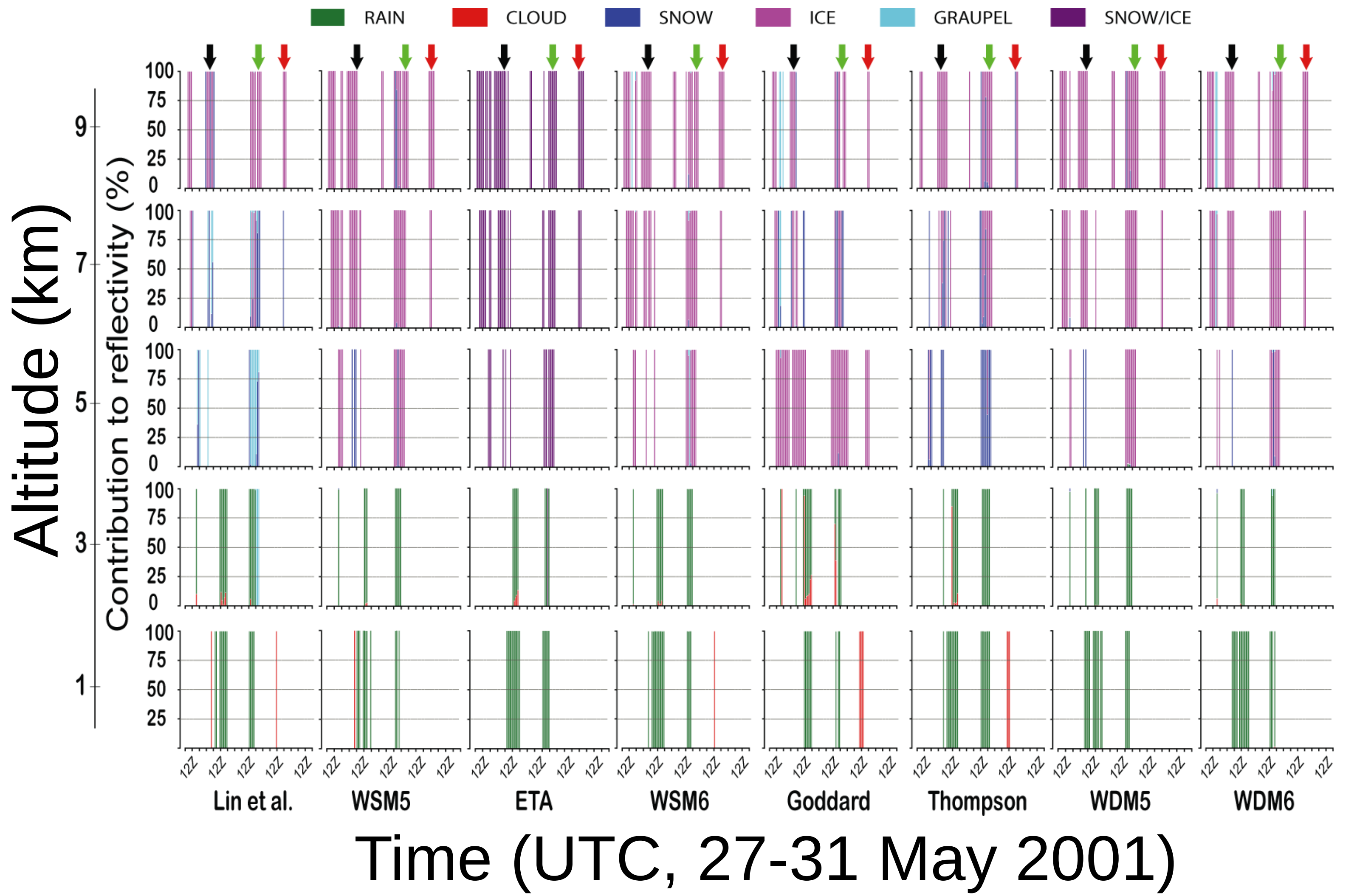


WSR-88D vs. Simulated Weather Radar Reflectivity (for > 20 dBZ)

WSR-88D (Vance AF Base) | SIMULATED (CNTRL)

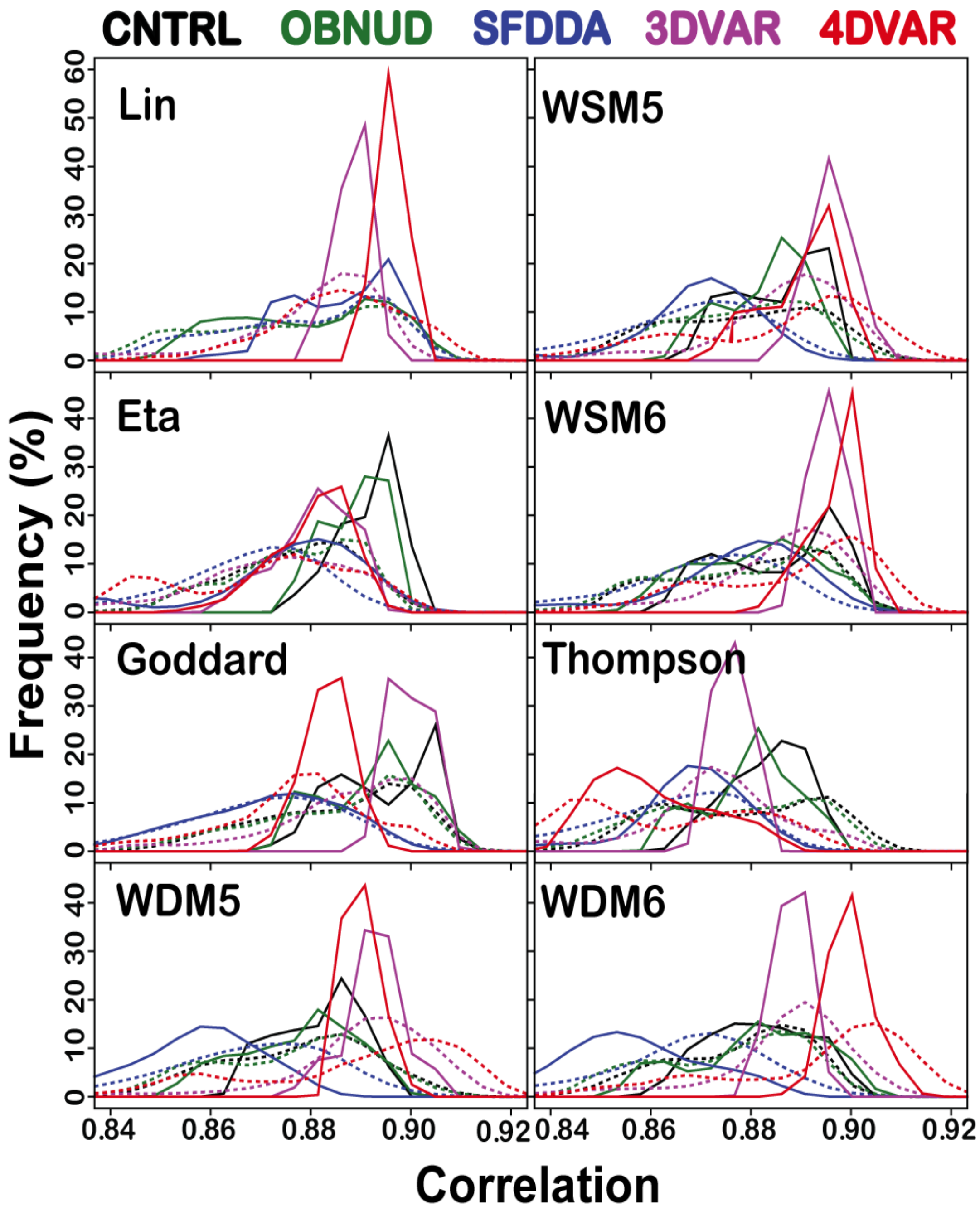


Contribution of Hydrometeors to Cloud Radar Reflectivity (%)



Precipitable Water Vapor (PWV) Correlations

- Correlations between observed and simulated PWV were evaluated for 9 x 9 (solid) and 35 x 35 (dashed) grid points surrounding SGP CF
- Large observed-simulated PWV correlations
- Water vapor very well-simulated in all microphysics scheme simulations
- Modal correlations exceed +0.88 for most microphysics scheme simulations
- Correlations are highest for 3DVAR and 4DVAR data assimilation simulations



Estimation of Large-scale Convection

WRF Microphysics fallout (precipitation) terms are computed as downward flux of hydrometeor mass at each time step →

$$(f_{r,s,i,g})_k = \sum_{k=top}^{bottom} \Delta \left(\rho_a \, q_{r,i,g,s} \, V_{r,i,g,s} \right)_k$$

For No-microphysics simulation "precipitation" is estimated as

$$R \propto \frac{1}{\rho_w} \sum_{p=900\,hPa}^{400\,hPa} \left[(q_v - q_{sw}) \rho_a + (q_v - q_{si}) \rho_a \right] w'$$

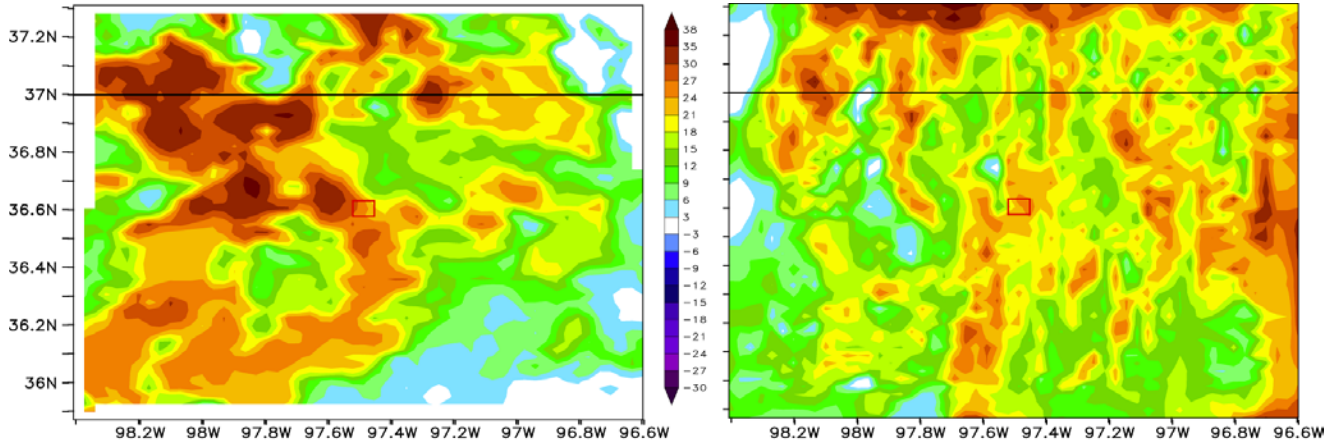
Reflectivity ($mm^6 \, mm^{-3}$) is computed from R($mm \, hr^{-1}$) using the Z-R relationship

$$Z = 300 \, R^{1.4}$$

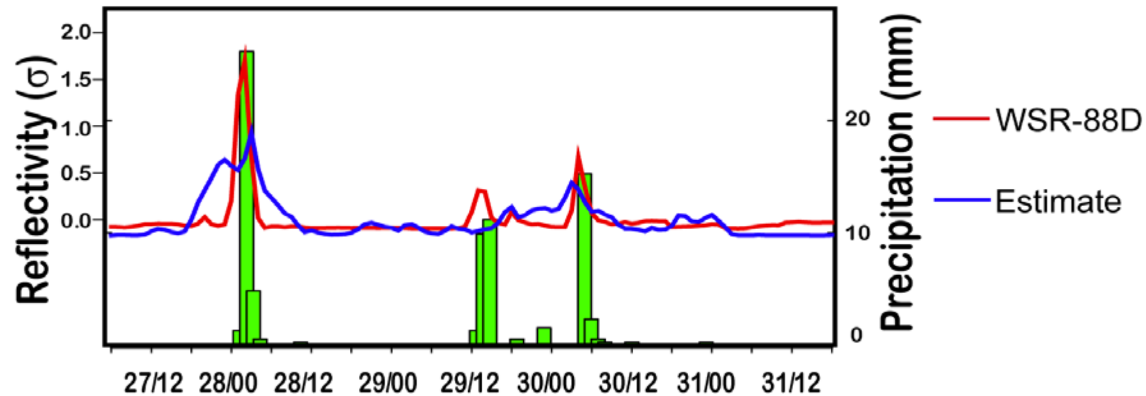
Estimated Large-scale Convection (Contd.)

EOF1

WSR-88D (30%) **ESTIMATED (16%)**



Scores



Key Conclusions

- Thermodynamic structures of 3 consecutive cloud systems over the SGP CF were assessed
- Role of microphysical processes in the life cycles of these organized cloud systems was examined through cloud stability analysis of simulations with and without microphysical schemes
- Equivalent potential temperatures from no-microphysics and microphysics-enabled simulations correlate very strongly
- Misalignment of lower and upper tropospheric convection is one of the reasons for model inability to simulate the first significant convection
- The no-microphysics estimated large-scale convection reproduced more realistically the first significant convection compared to microphysics-enabled simulation results

Thank you

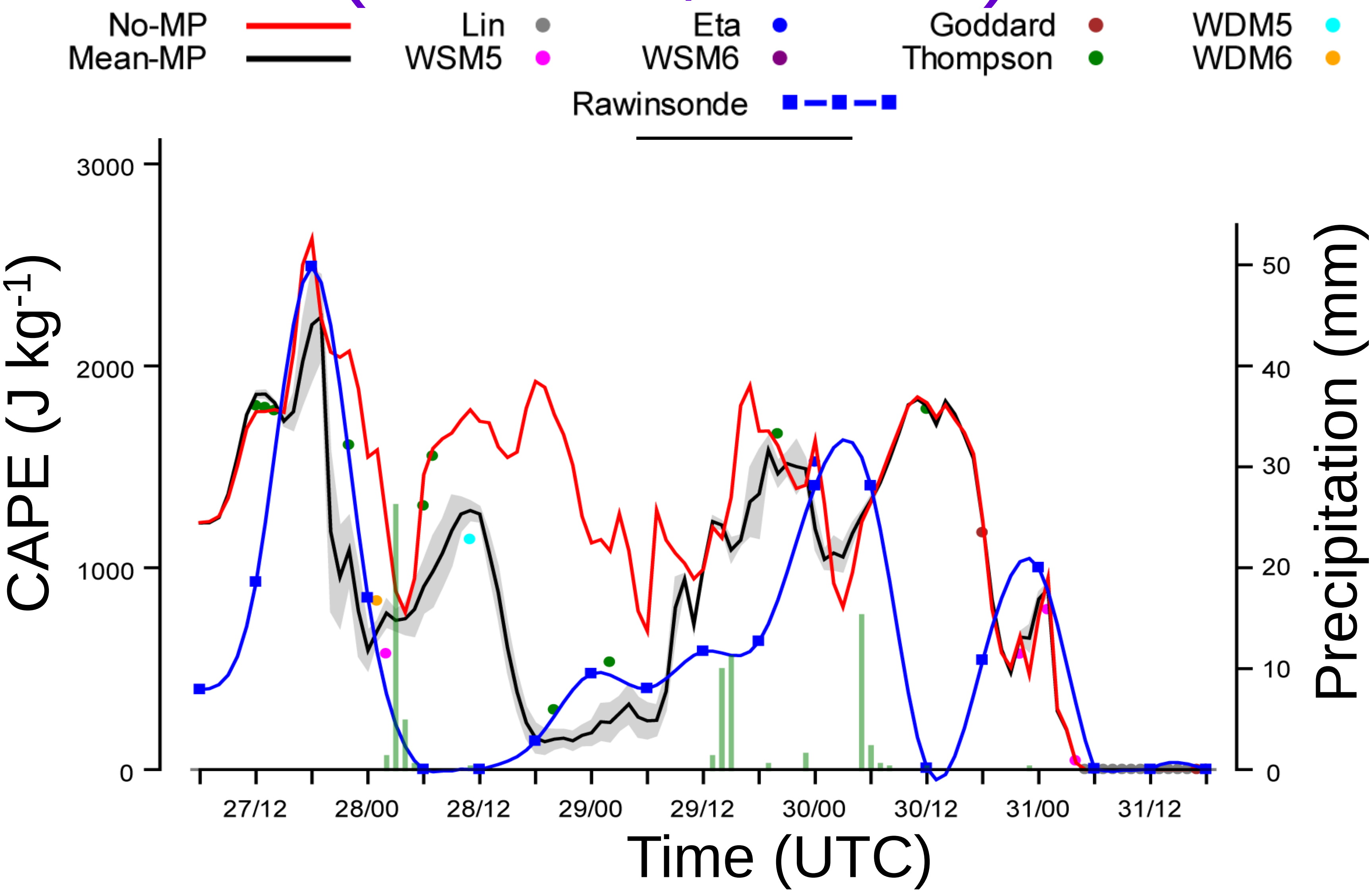
WRF Microphysics Used

- 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 us WSM5, but has double moment rain, cloud and CCN for warm processes
- WRF Double-Moment 6-class scheme (WDM6)
  - Same us WSM6, but has double-moment rain, cloud and CCN for warm processes

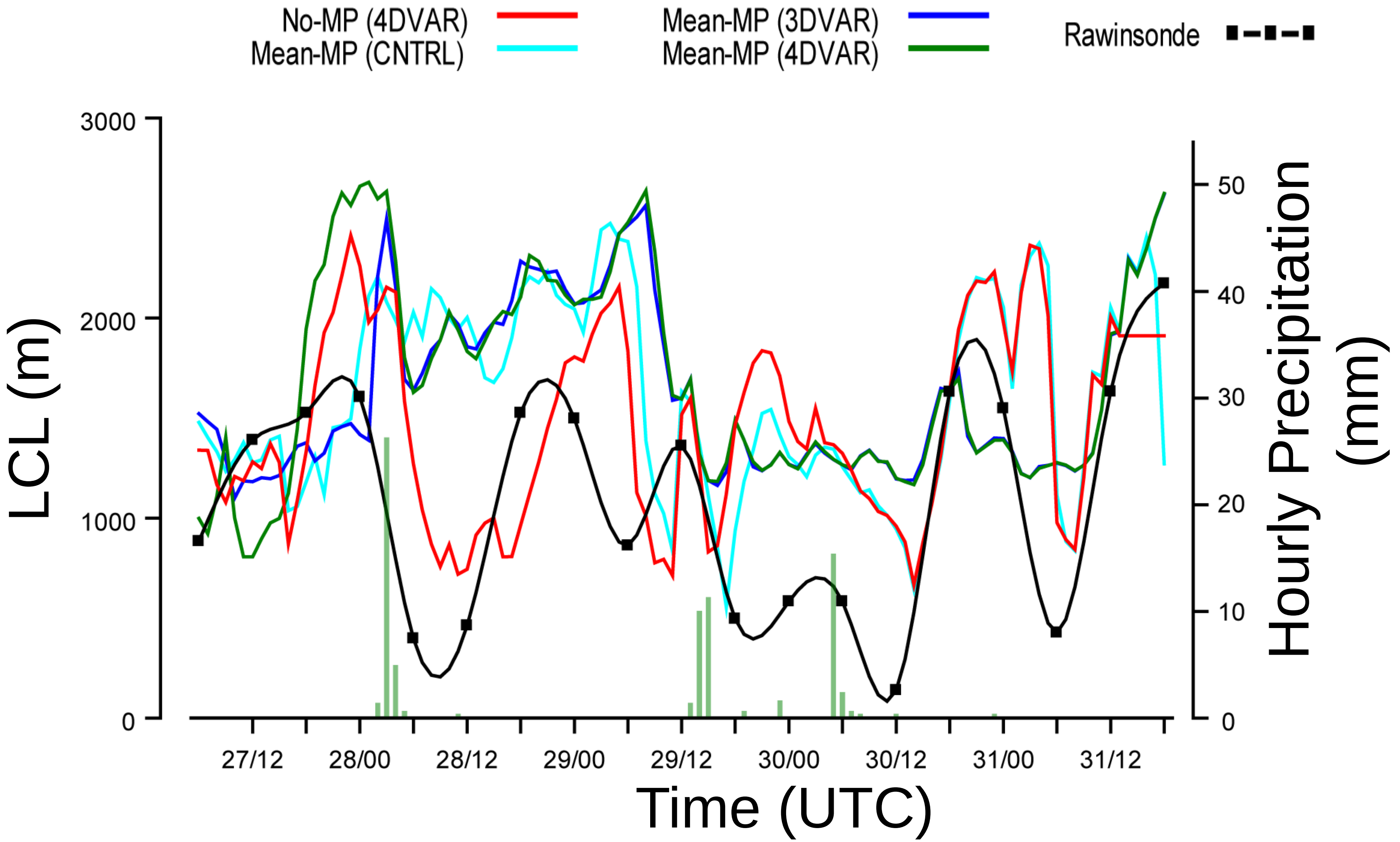
Physics Options

- MM5 5-layer soil temperature Land-Surface Model (LSM)
- The Yonsei University PBL scheme
- Rapid Radiative Transfer Model (RRTM) longwave radiation scheme
- MM5 shortwave radiation scheme
- The Kain–Fritsch cumulus parameterization for the outer 9 km resolution domain
- No convective scheme for the 3-km resolution inner-nested domain
- 6-hrly NCEP’s FNL Reanalysis for initial and lateral boundary conditions

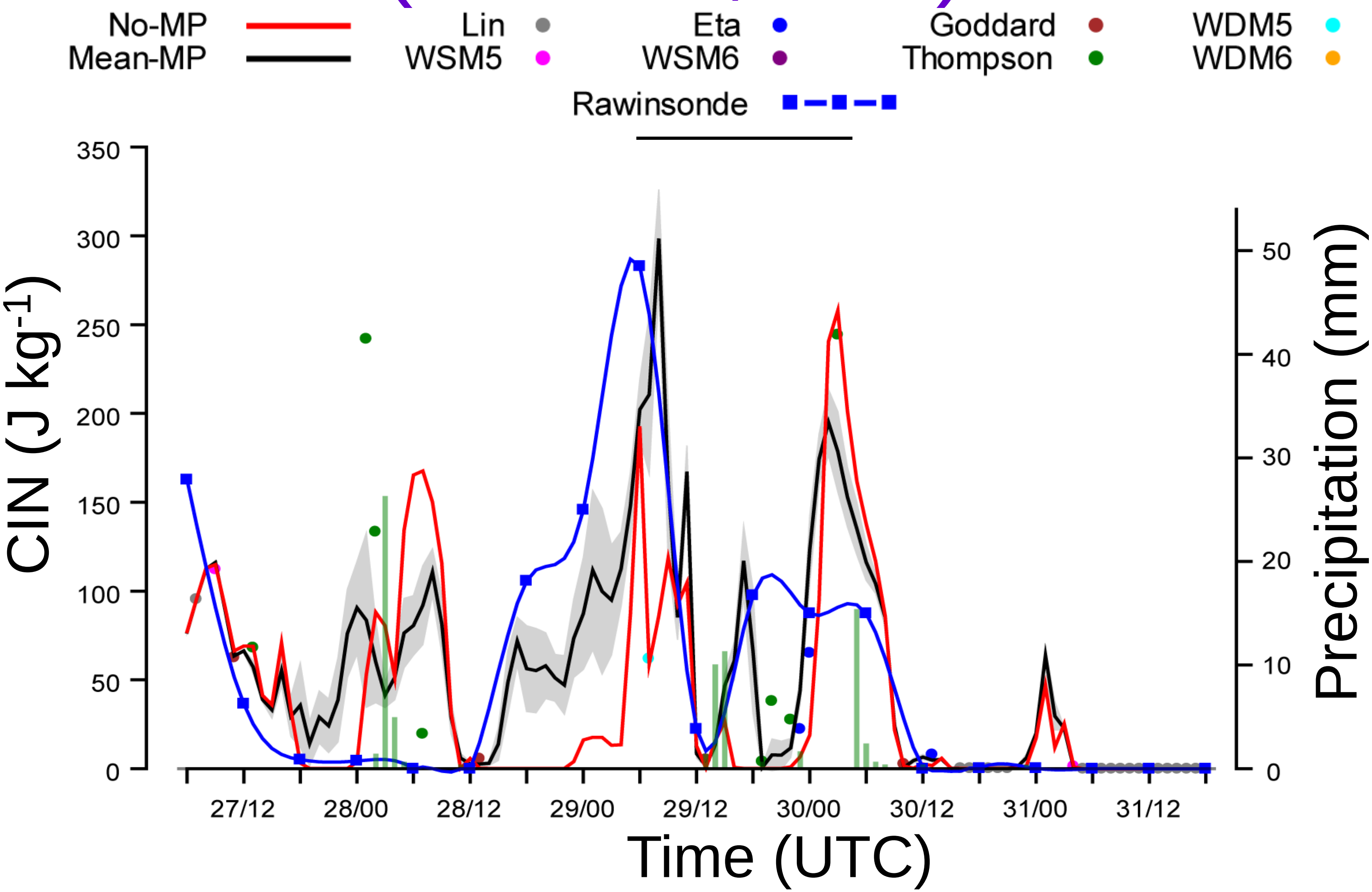
Cloud Stability Parameters (CNTRL, CAPE)



Cloud Stability Parameters -- LCL (Data Assimilation)



Cloud Stability Parameters (CNTRL, CIN)



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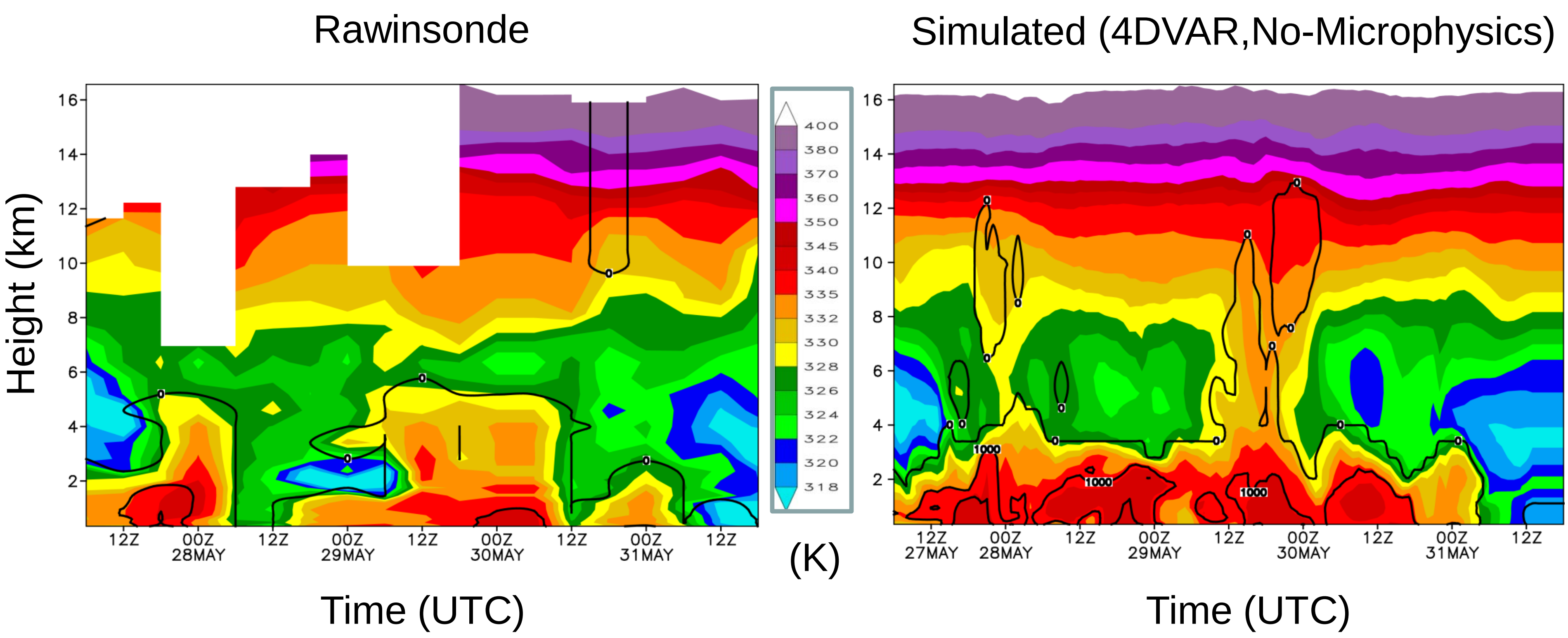

- Temporal θ_e profile well-captured, but overestimated at low levels
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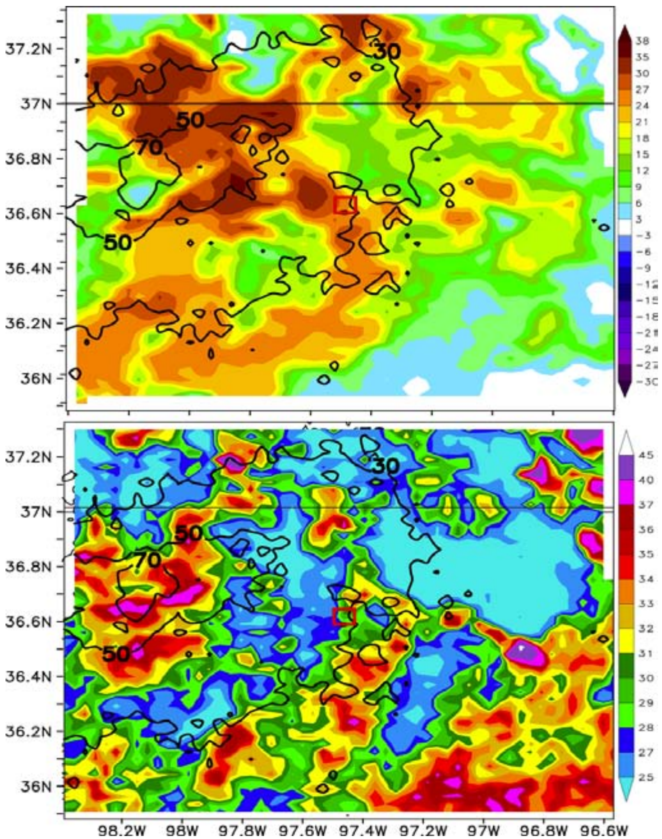
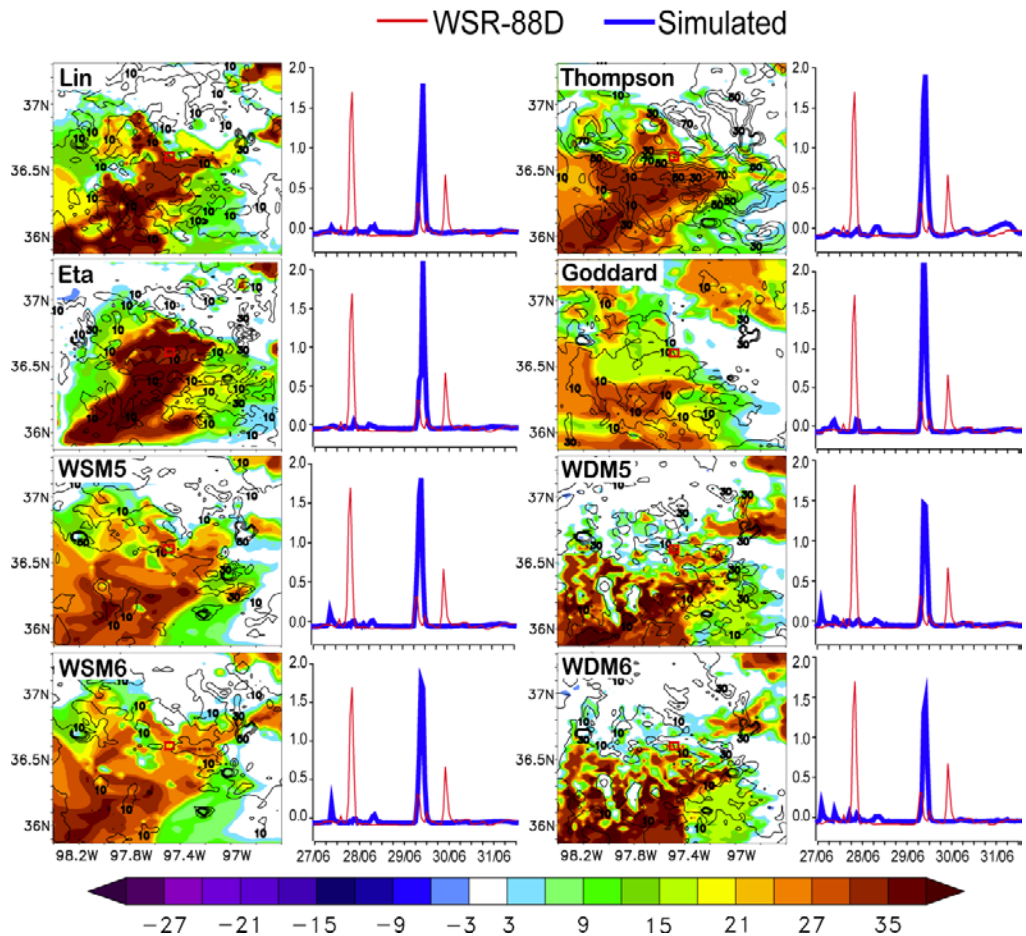
Weather Radar Characteristics

WSR-88D



Simulated



3D-Var -- Three-Dimensional Variational data assimilation
-- Method of obtaining “optimal” estimate of the true atmospheric state at analysis time through iterative solution of a prescribed cost-function (equation attached)
4D-Var -- Four-Dimensional Variational data assimilation
CAM -- NCAR Community Atmosphere Model
CNTRL – Control Run
Data Assimilation -- A method of combining all available information (observations and previous forecasts/background errors) on the atmospheric state in a given time-window to produce an estimate of atmospheric conditions valid at a prescribed analysis time based on laws of physics.
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 – 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

Precip

OMEGA from CMBE