Large-Scale Dynamic and Thermodynamic Responses to Cloud Microphysics Parameterization

Zewdu T. Segele[1], Lance M. Leslie[2], and Peter J. Lamb[1, 2]

[1]Cooperative Institute for Mesoscale Meteorological Studies/[2]School of Meteorology

The University of Oklahoma, Norman, OK

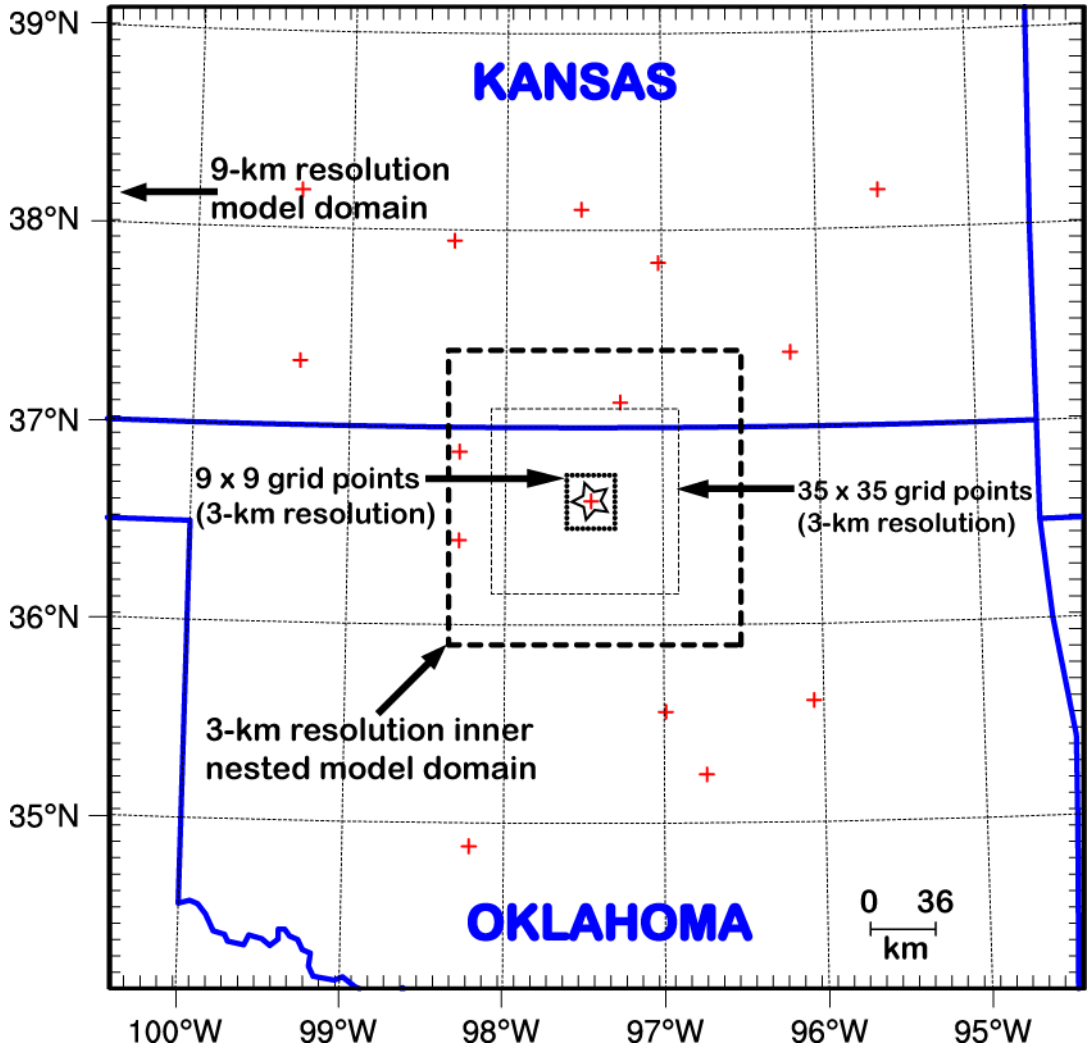
(zewdu@ou.edu)

Objectives

- Examine thermodynamic and dynamic characteristics of WRF microphysics scheme simulations (θ_e, CAPE, temperature, vertical velocity, water condensate amounts)
- Examine cloud structure of simulated deep convection (water condensates, vertical velocity, saturated moist static energy)
- Examine model responses to microphysics parameterization schemes relative to a no-microphysics simulation (vertical velocity, saturated moist static energy)

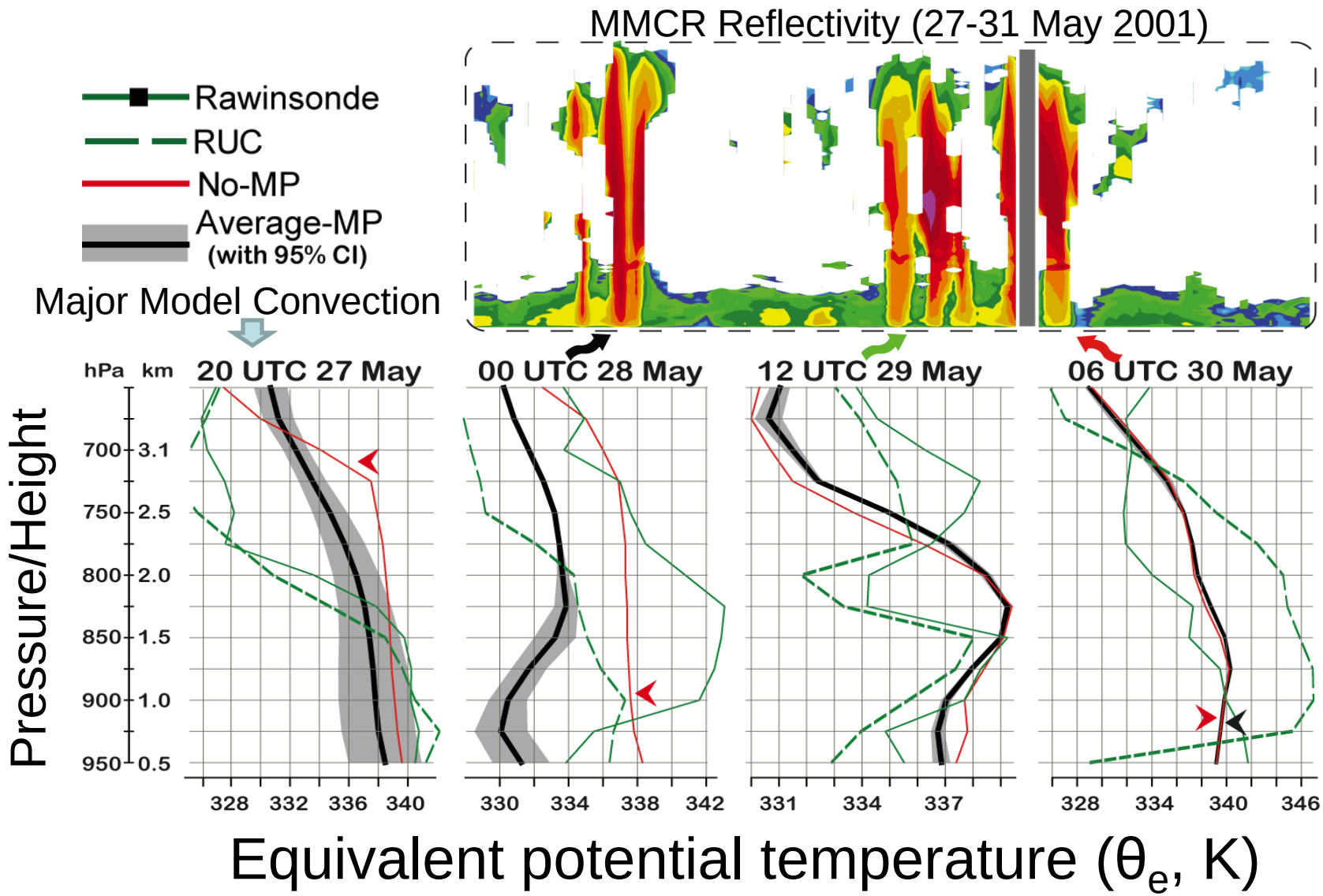
WRF Simulations

- Warm-season heavy precipitation event (27-31 May 2001)
- 8 WRF microphysics schemes with YSU PBL scheme simulations
- No-microphysics simulation
- Two-way nesting: 9- and 3-km grid spacing with 41 vertical levels



Model Domain

PBL and Stability Structure

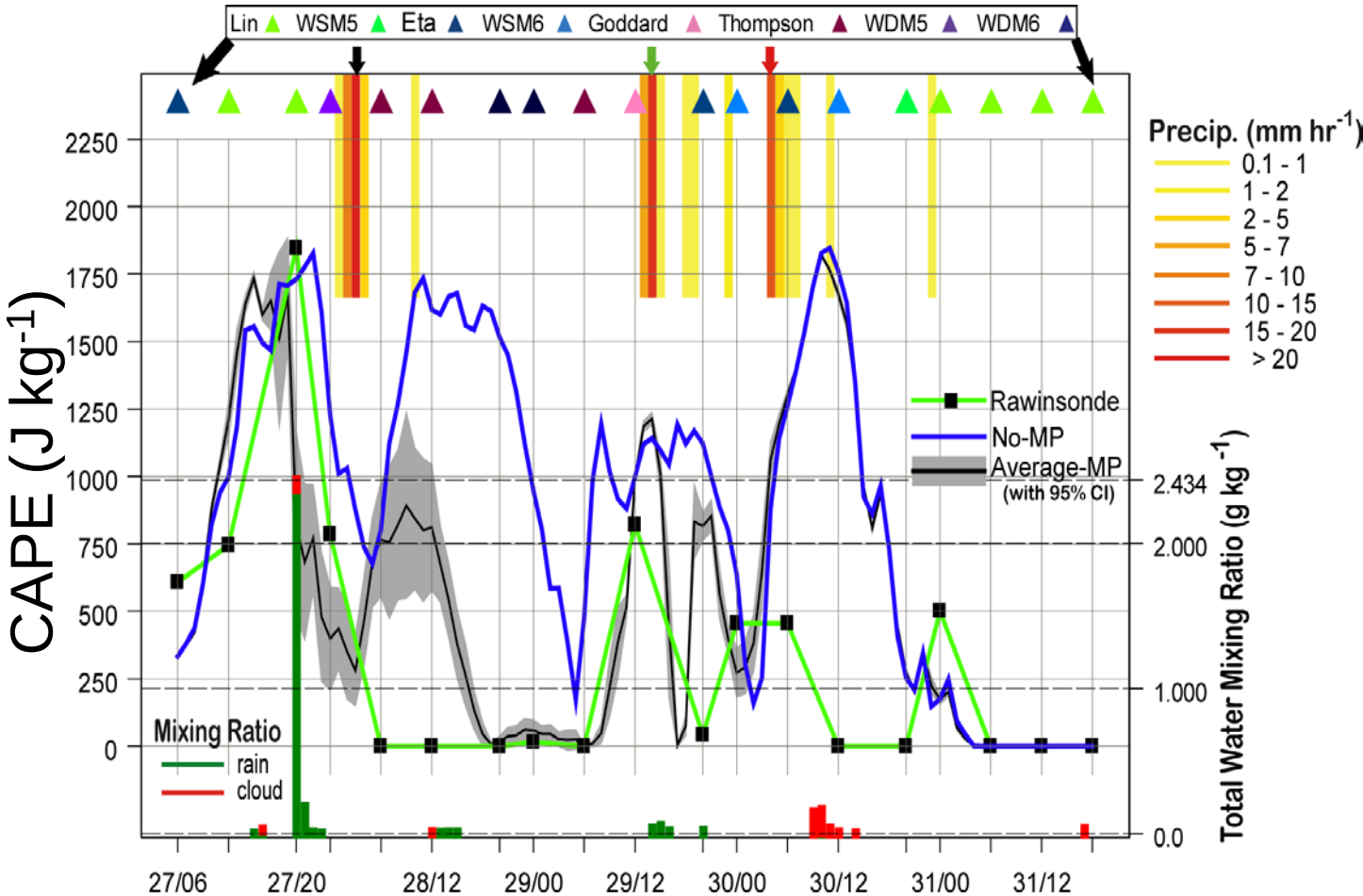


CAPE & Cloud Condensates (850 hPa)

-Average CAPE for 8 microphysics schemes (black line) and their 95% confidence interval (shading)

-Microphysics scheme with the largest total condensate (color coded at top)

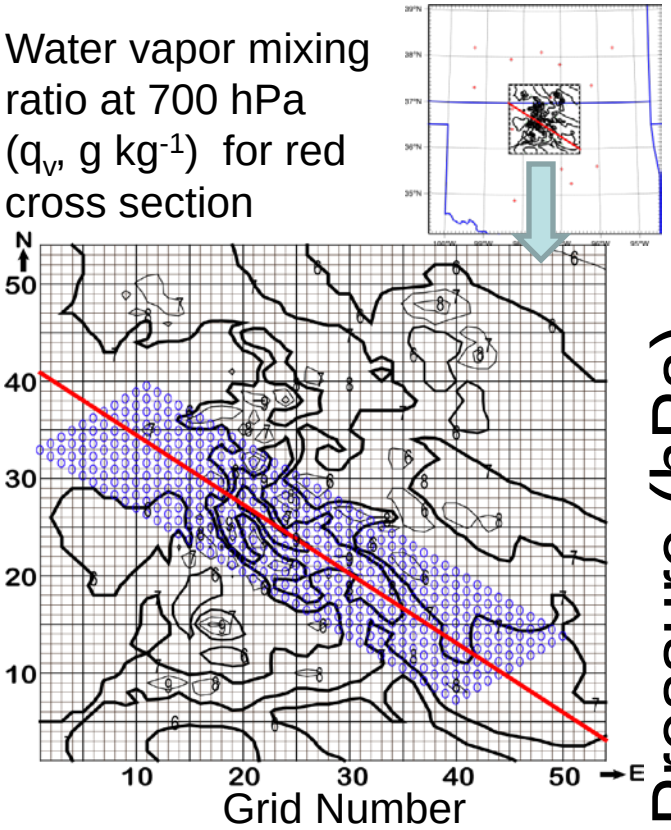
- Observed convection events from SGP CF precipitation rates (bars from top axis)



Day/UTC (27-31 May 2001)

Cloud Structure (Lin Microphysics)

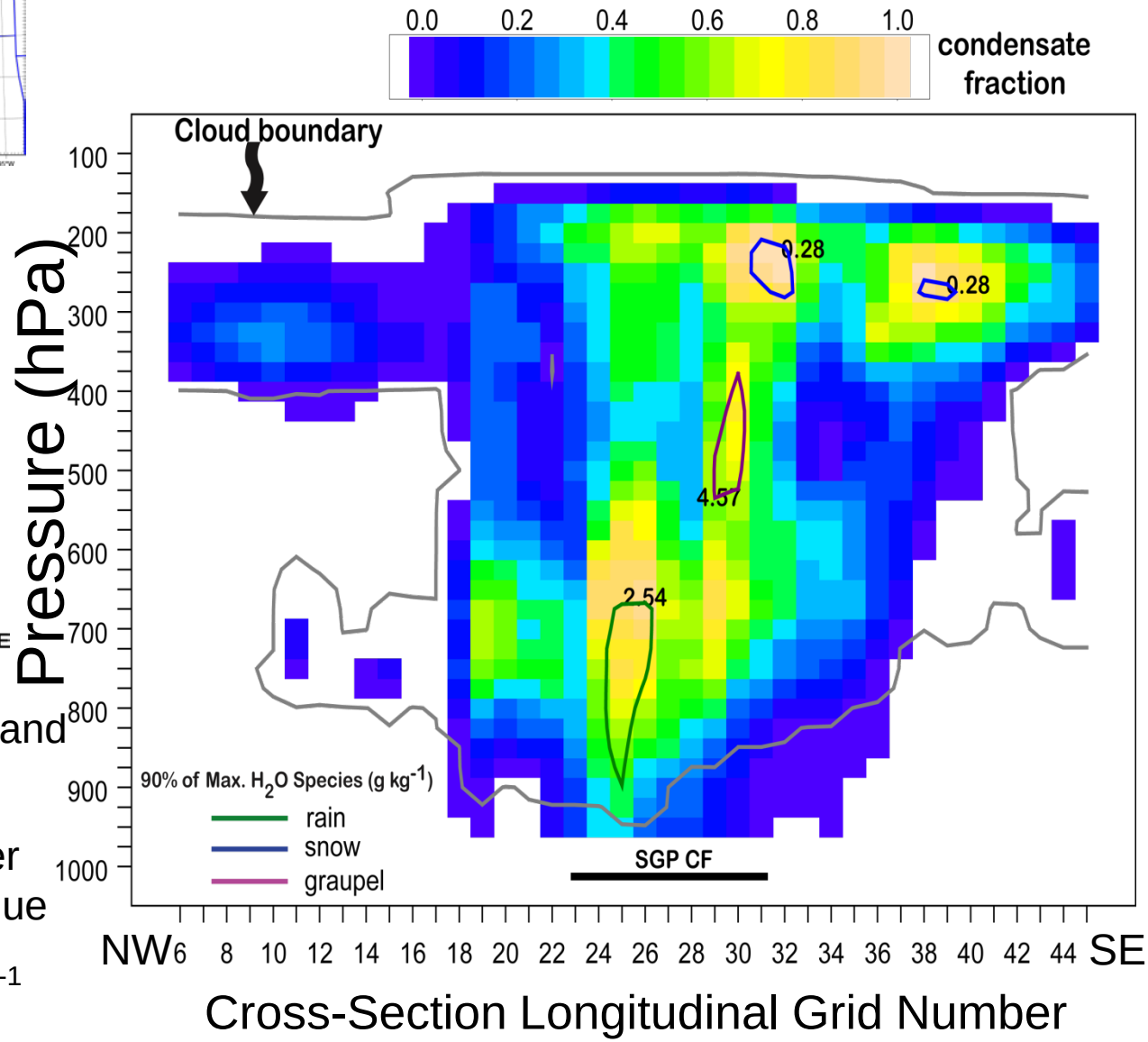
Water vapor mixing ratio at 700 hPa (q_v, g kg^{-1}) for red cross section



- Identify maximum 700 hPa q_v and fit a regression line (x, y)

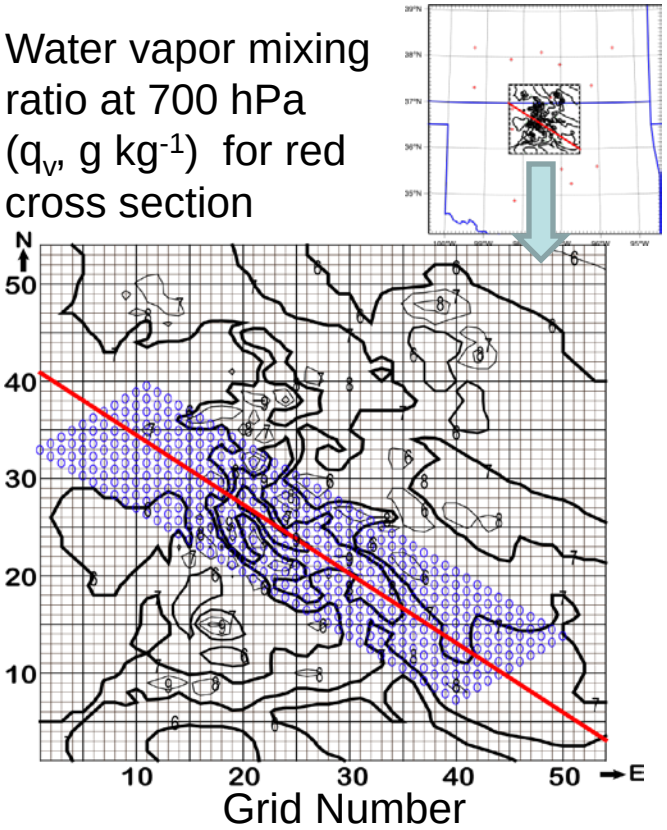
- Normalize pressure level water species (q_x) by maximum q_x value

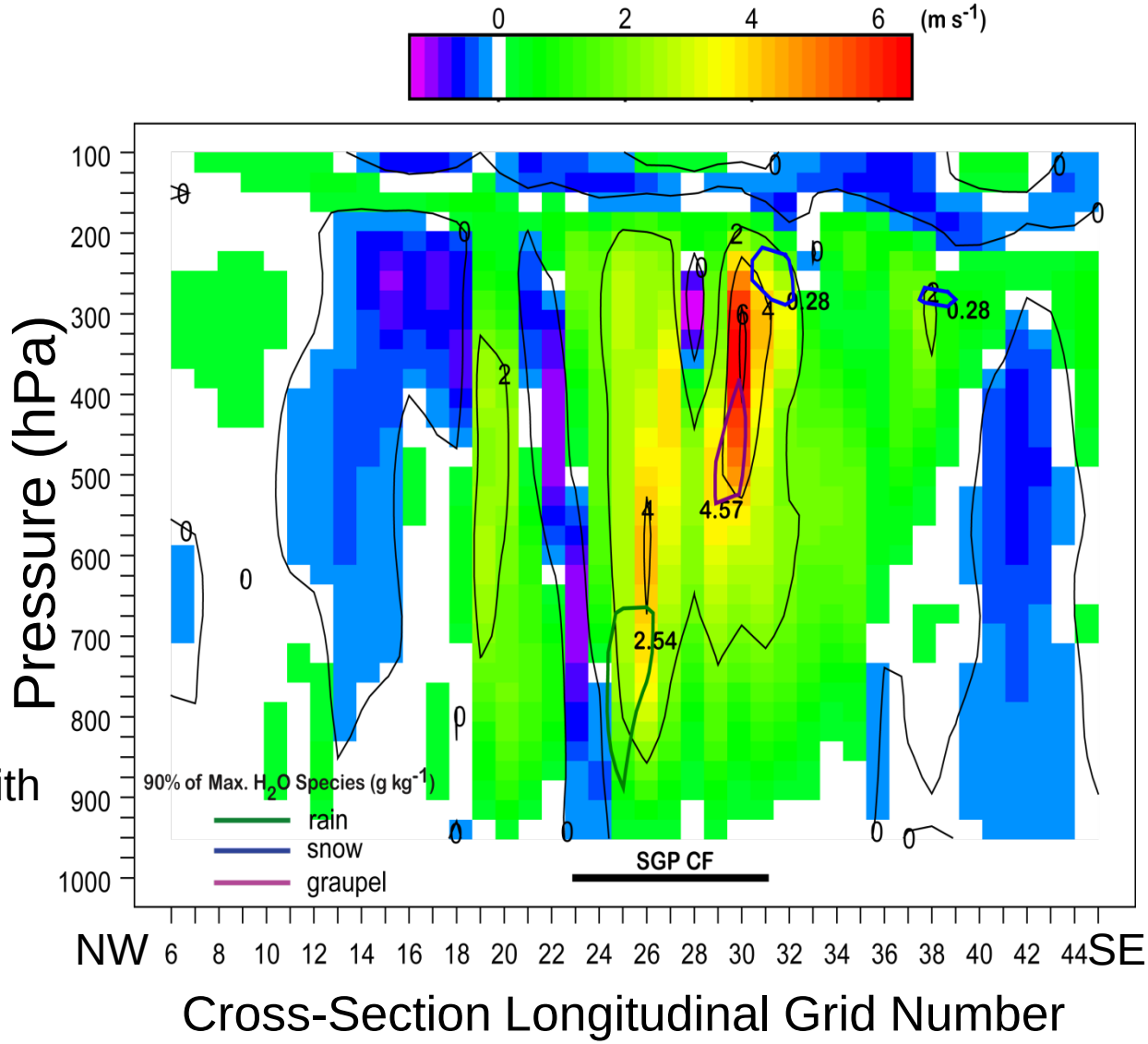
- Cloud boundary from 1 mg kg^{-1} non-precipitating hydrometeors



Vertical Velocity (Lin Microphysics)

Water vapor mixing ratio at 700 hPa (q_v, g kg^{-1}) for red cross section



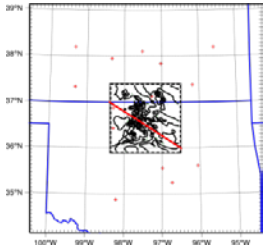


- Graupel dominates the storm; highest production coincides with the strongest updraft core

- Small amount of snow in the upper troposphere

Saturated Moist Static Energy (Lin)

Same water vapor mixing ratio at 700 hPa (q_v, g kg^{-1}) for red cross section



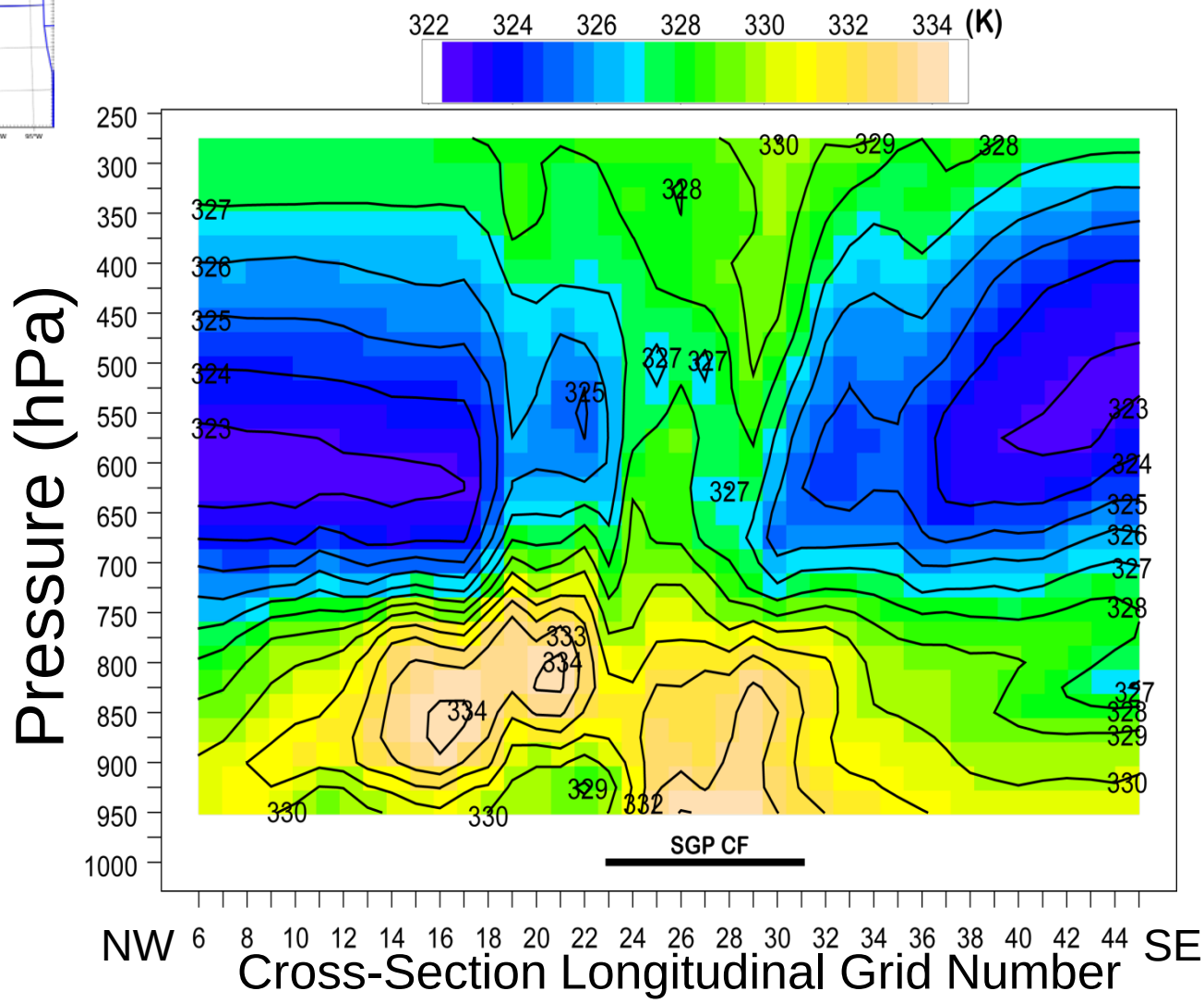
$$h_s = c_pT+gz+L_cq_s$$

h_s/c_p in temperature unit

- Conserved for both dry and moist adiabatic processes

- Deep convection coincides with high h_s

- Air near top of PBL has high saturated moist static energy



Saturated Moist Static Energy

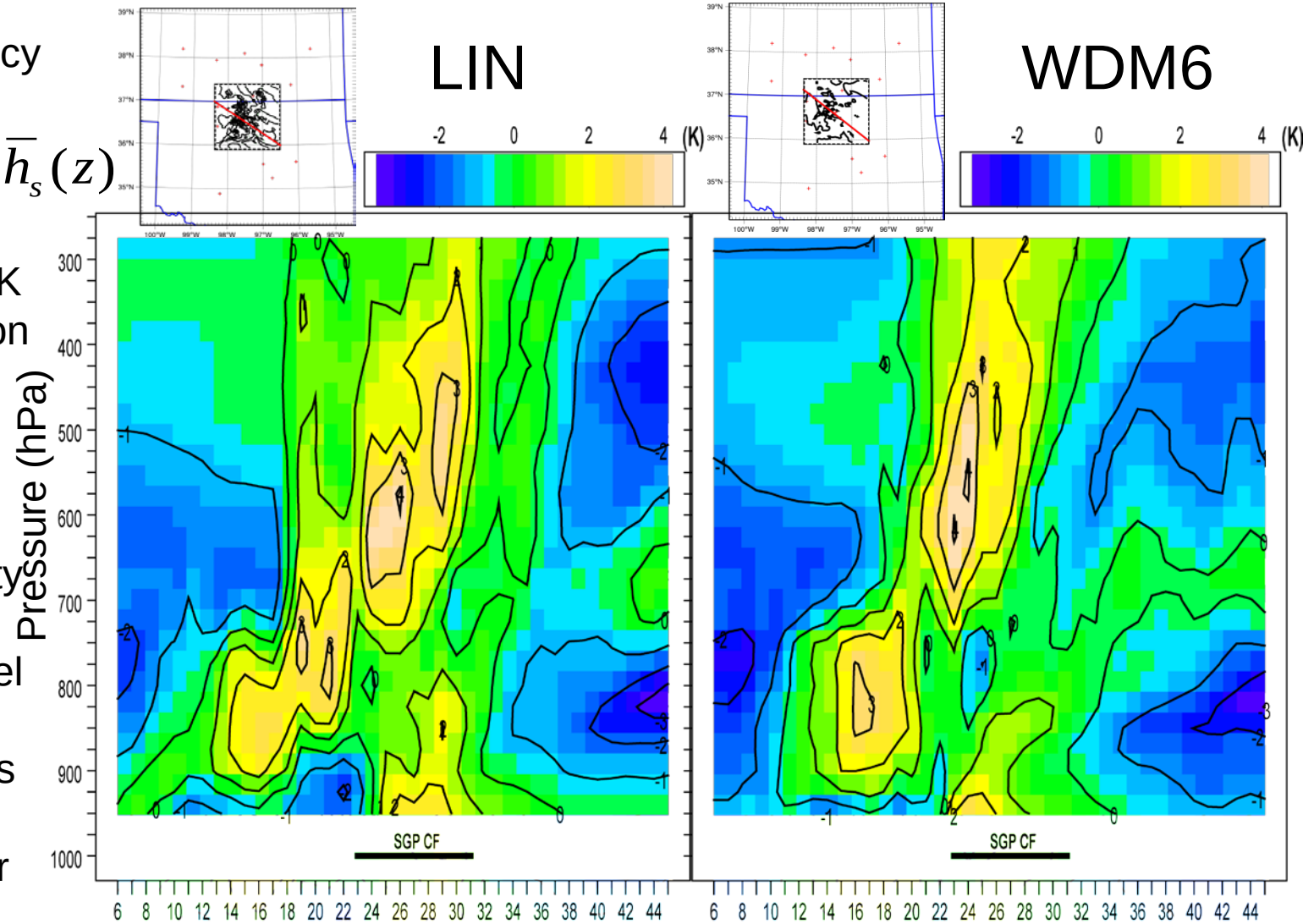
Thermal buoyancy proportional to

$$h_s^{'} = h_s(x,z) - \overline{h}_s(z)$$

- Maximum $h_s^{'}$ ~ 4K in deep convection core near maximum precipitation

Cold pool intensity ~ 1-2 K near lowest model level

- Lin microphysics strong cold pool below its stronger descending motion



Cross-Section Longitudinal Grid Number

Correlations between Saturated Moist Static Energy Differences (Microphysics minus No-Microphysics) and Total Condensate Mixing Ratios

Correlations

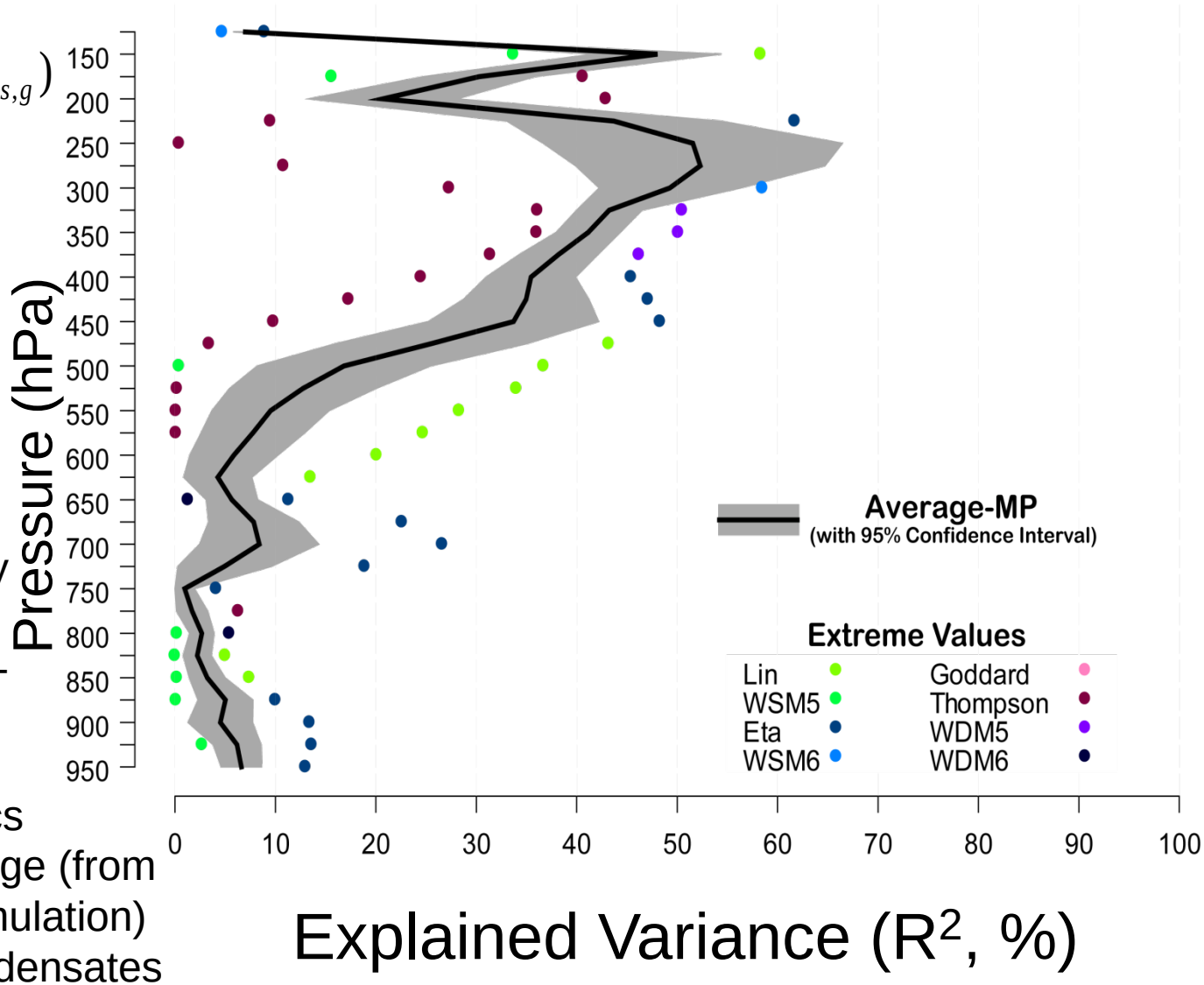
$(h_{mp} - h_{no-mp})$ *and* $(\sum q_{c,r,i,s,g})$

- Mean R^2 (black) and 95% confidence interval for 8 microphysics schemes (shading)

- extreme values shown with filled circles

- Largest vertical velocity and total condensate correlation between 300-250 hPa

- Thompson microphysics moist static energy change (from the no- microphysics simulation) least related to total condensates



Correlations between Vertical Velocity Differences (Microphysics minus No-Microphysics) and Total Condensate Mixing Ratios

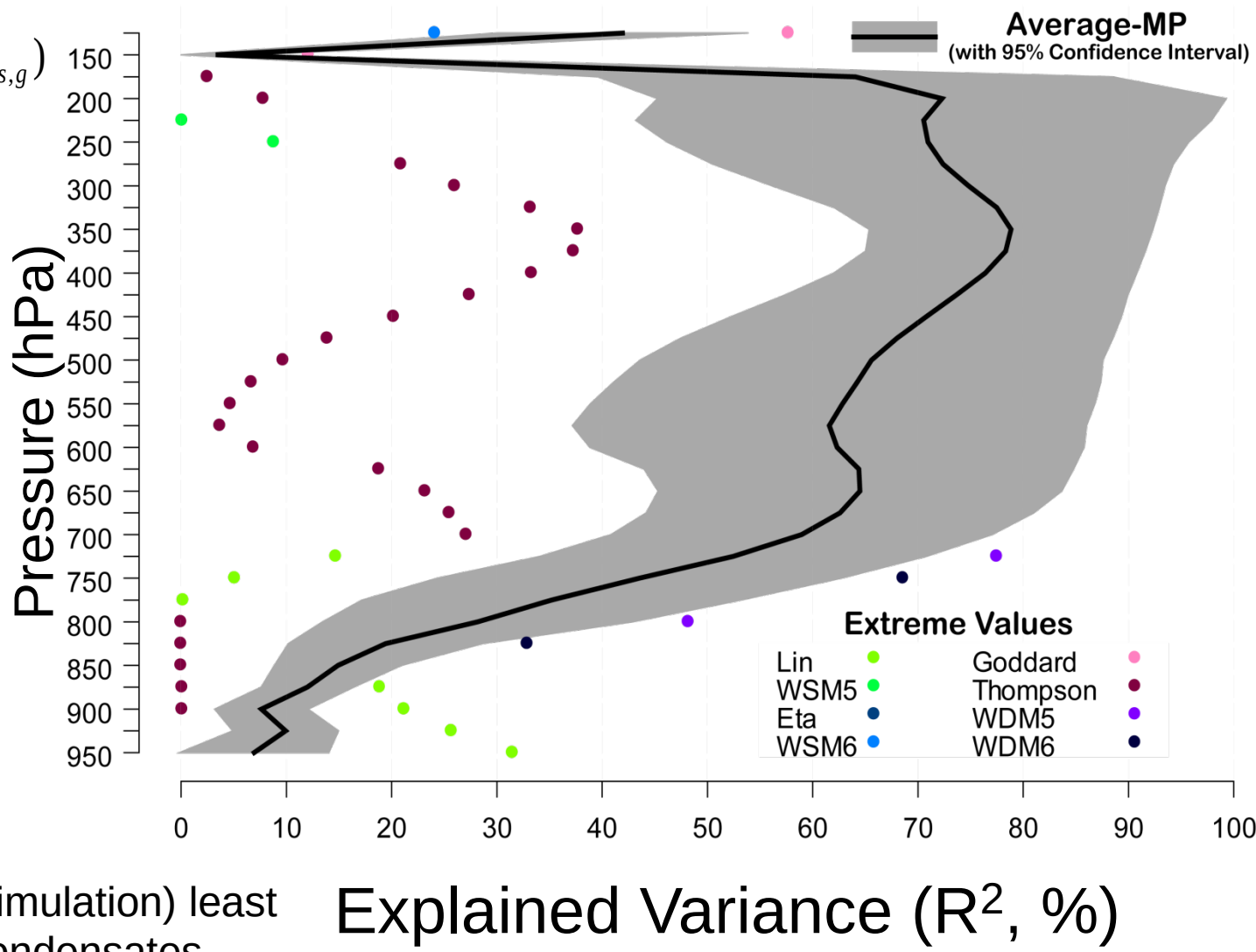
Correlations

$(w_{mp} - w_{no-mp})$ *and* $(\sum q_{c,r,i,s,g})$

- Large explained variance for vertical velocity compared to that for saturated moist static energy

-Largest vertical velocity and total condensate correlation above 350 hPa

-Thompson microphysics vertical velocity change (from the no-microphysics simulation) least correlated with total condensates



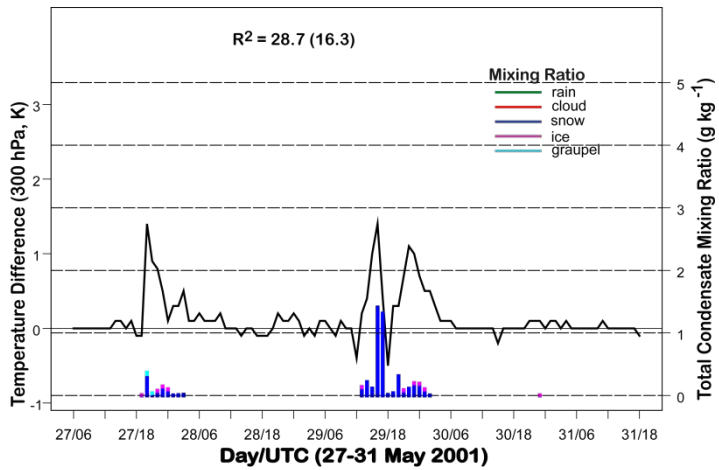
Co-variability of Total Condensate Mixing Ratios and Atmospheric Variables (vs. No-Microphysics, 300 hPa)

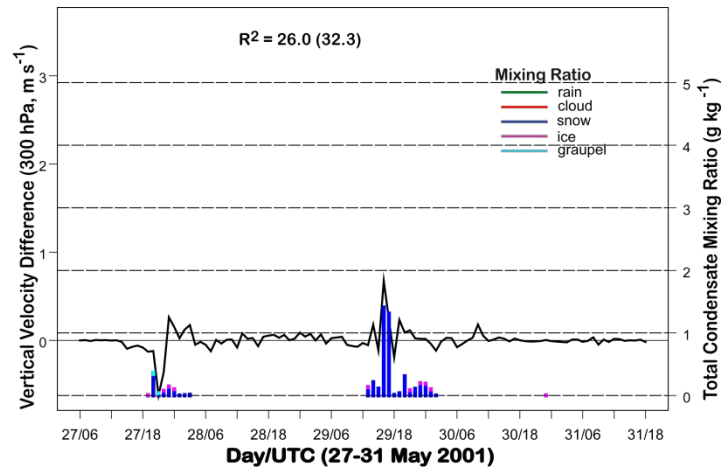
Temperature $(T_{mp} - T_{np-mp}); (\sum q_{c,r,i,s,g})$

Vertical Velocity $(w_{mp} - w_{np-mp}); (\sum q_{c,r,i,s,g})$

Thompson

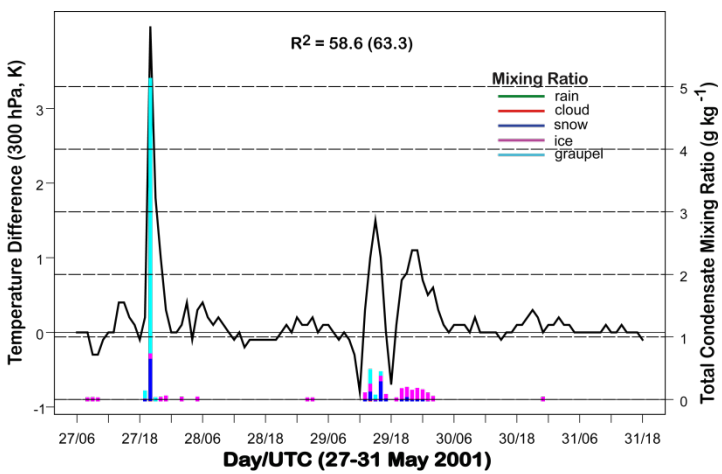
@27/20 UTC
6.7% graupel
93.0% snow
0.3% ice
0.0% cloud

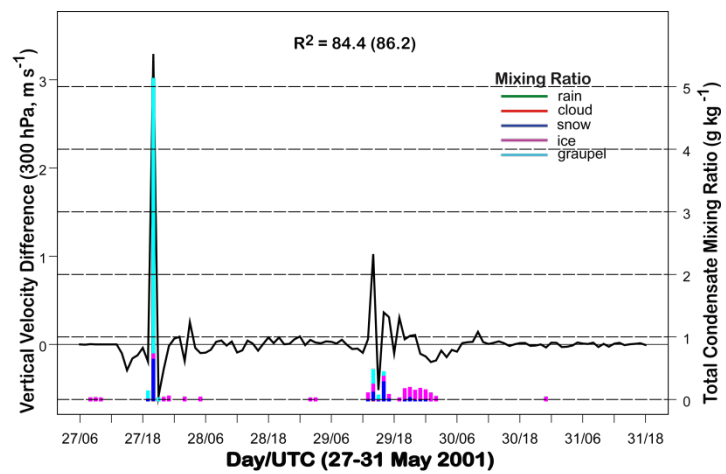




WDM6

@27/20 UTC
85.0% graupel
13.2% snow
1.7% ice
0.1% cloud





Vertical Velocities for RUC (CMBE) and WRF Simulations and their Correlations

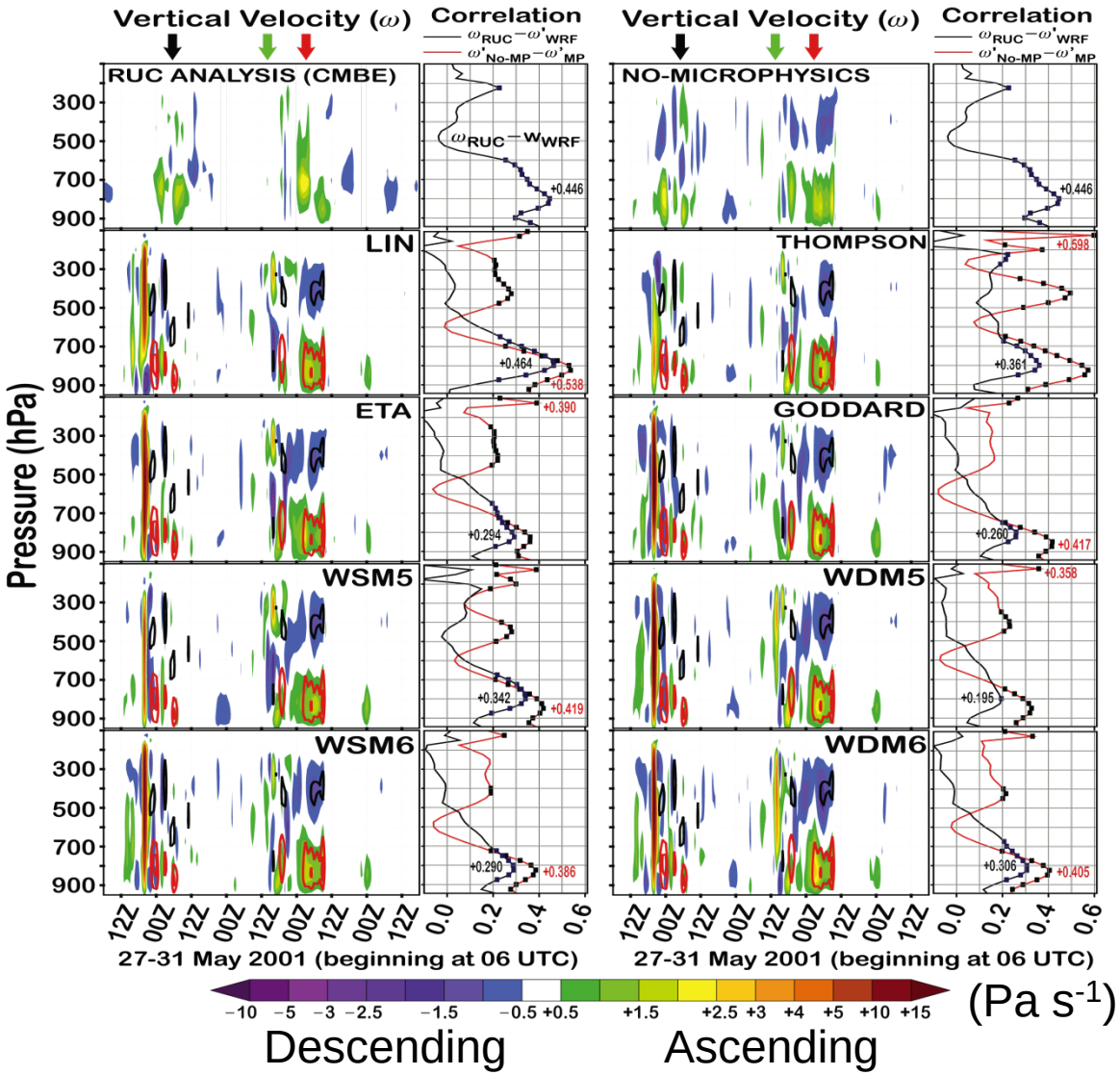
Vertical Velocity Conversion

$$\omega'(p) = -\rho g w(z)$$

Correlation between WRF ω'(p) and w(z) is +0.99

-Vertical velocities for the 8 microphysics schemes are much stronger than those for RUC Reanalysis

- Correlations are higher between RUC and No-microphysics vertical velocities



Key Conclusions

- The vertical structure of the strongest model convective cloud structure was examined
- The deepest convective cloud has the largest in-core saturated moist static energy (h_s) and is more buoyant than the surrounding. The largest ascending motion also coincides with this high h_s.
- Vertical velocity for no-microphysics simulation correlates more strongly with the Thompson microphysics counterpart, which has a substantially different treatment for snow (a combination of exponential and gamma PSD and a bulk density with an inverse diameter dependence) compared to other microphysics schemes.

Thank you