Use of radar observations to improve microphysical parameterization

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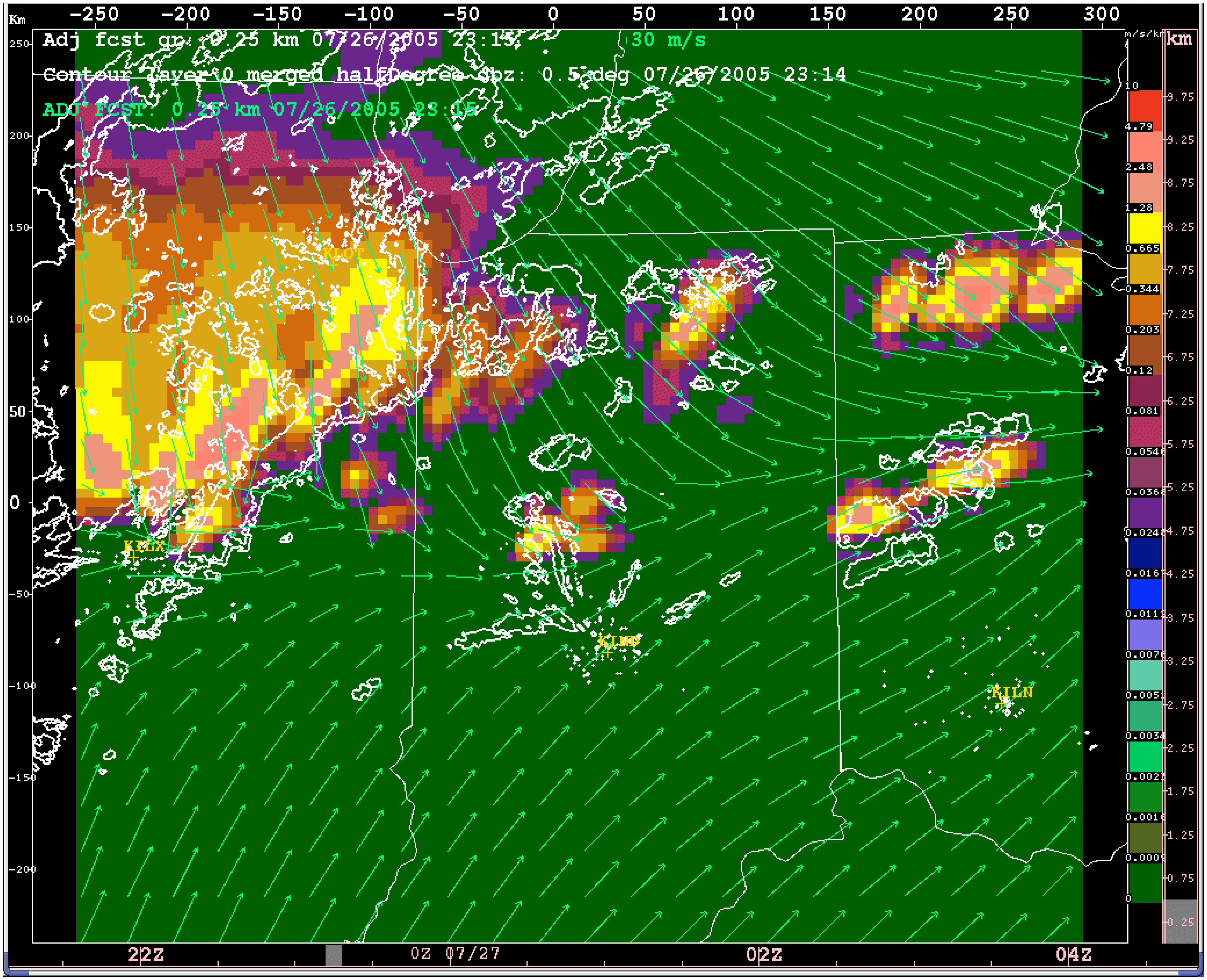
Outline

- Overview of the 4DVar radar data assimilation system -- VDRAS
- Microphysical parameter estimation
- Improvement of DSD using radar and disdrometer observations

Overview of VDRAS

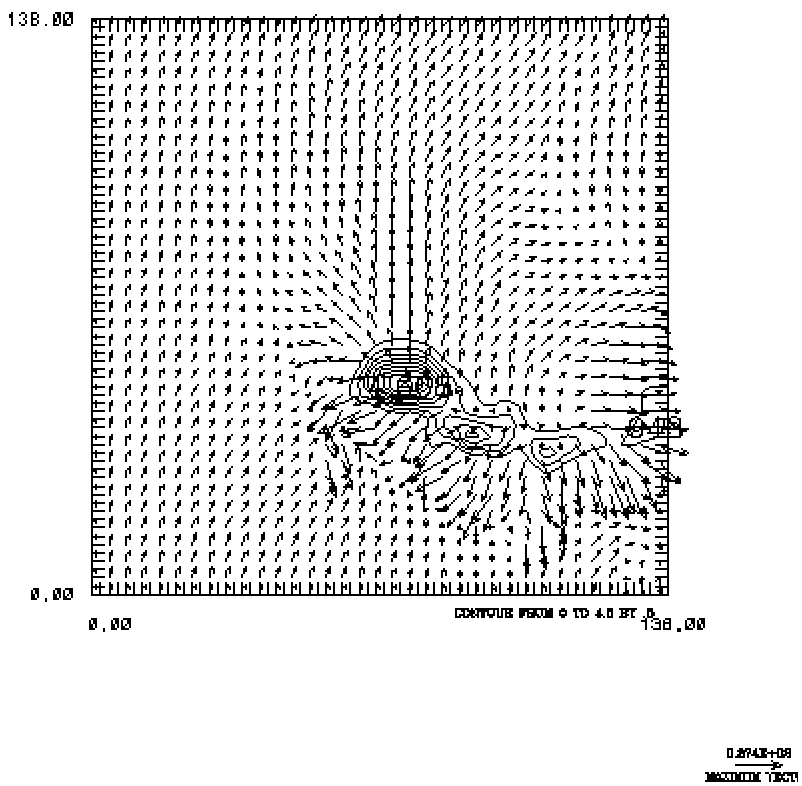
- **A 4D-Var system with the full adjoint of an anelastic cloud-scale model with Kessler-type warm rain parameterization.**
- **Radar data are assimilated with a 4D-Var cycling procedure.**
- **Large-scale observations are analyzed before the 4D-Var radar DA.**
- **A recursive filter is used for preconditioning and background error correlation.**
- **Implemented in a domain (5 WSR-88Ds) near Chicago for real-time analysis and 1-hour forecast.**

Loop of a series of 1-hour model forecast verified by radar observations (white contours)

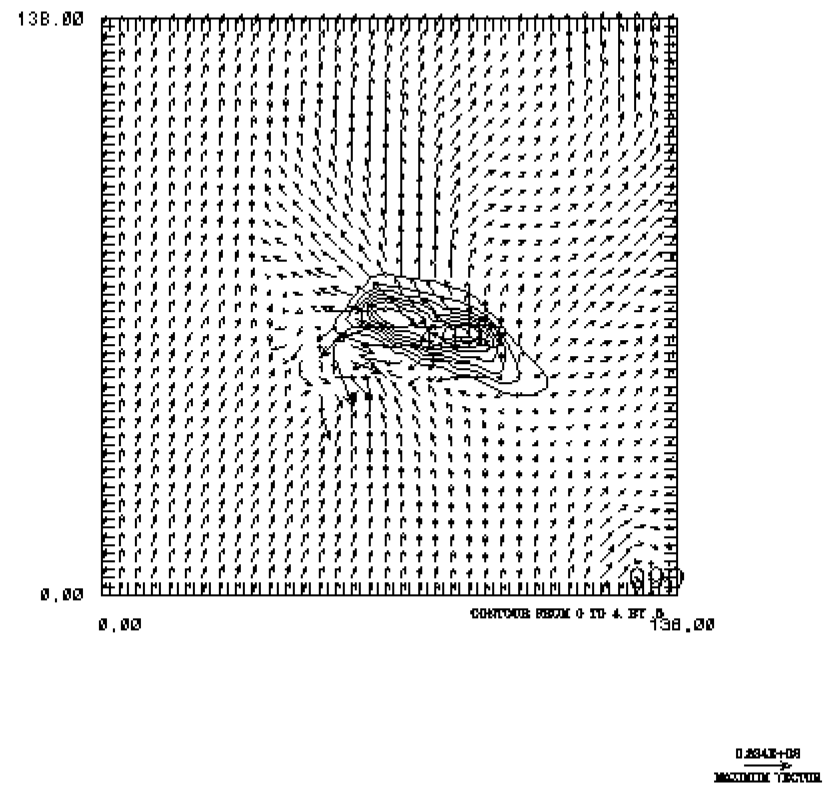


3-hour forecast of an observed supercell storm

Evaporation rate = 0.06



Evaporation rate = 0.02



Problems in microphysical parameterization

Raindrop terminal velocity: $V_{Tm} = V_0 a(\rho q_r)^{0.125}$

Evaporation rate of rain: $R_e = \beta_e (q_v - q_{vs})(\rho q_r)^{0.65}$

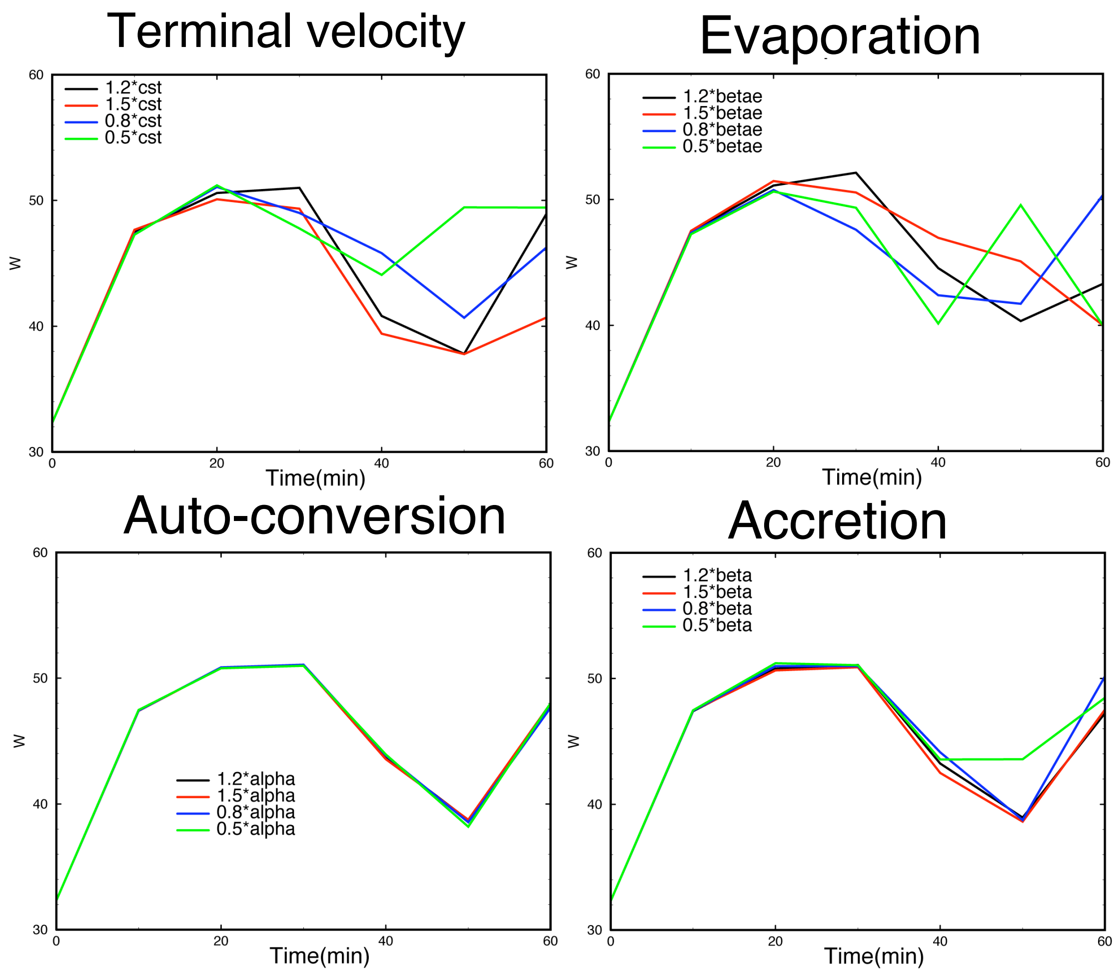
Accretion and **Auto-convertion**

- Parameters are theoretically or empirically determined
  Problem: not optimal in terms of producing the best forecast
  Solution: optimal estimation through data assimilation, along with the initial conditions

- Based on the Marshall-Palmer (M-P) raindrop size distribution (DSD)
  Problem: over-predict convective rain and under-predict stratiform rain
  Solution: Constrained-Gamma (C-G) DSD retrieved from distrometer and polarimetric observations

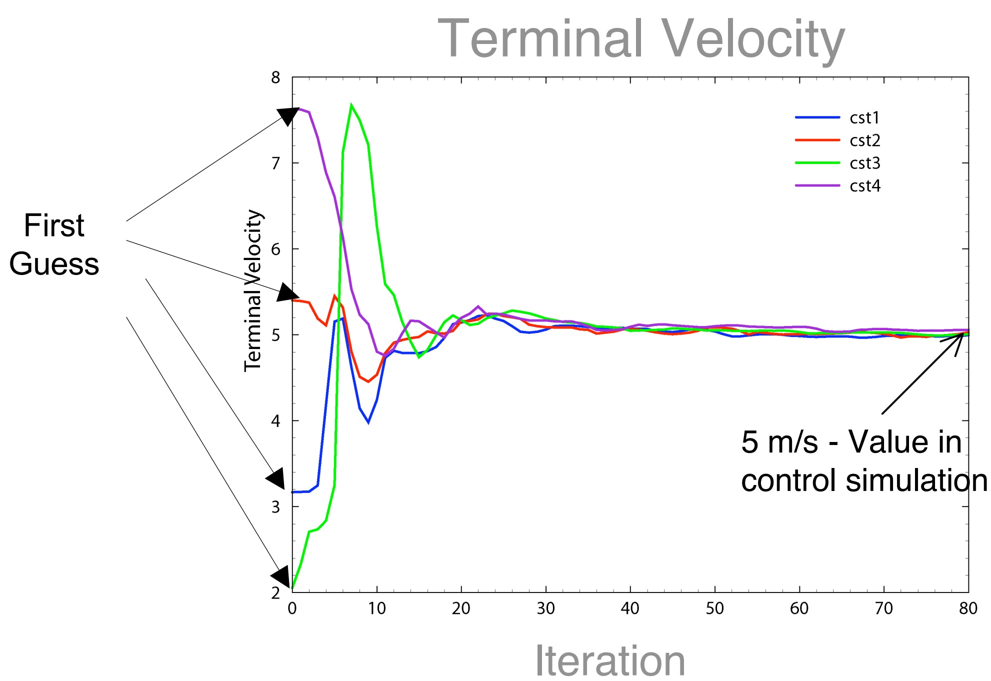
Sensitivity of the simulation with respect to the microphysical coefficients

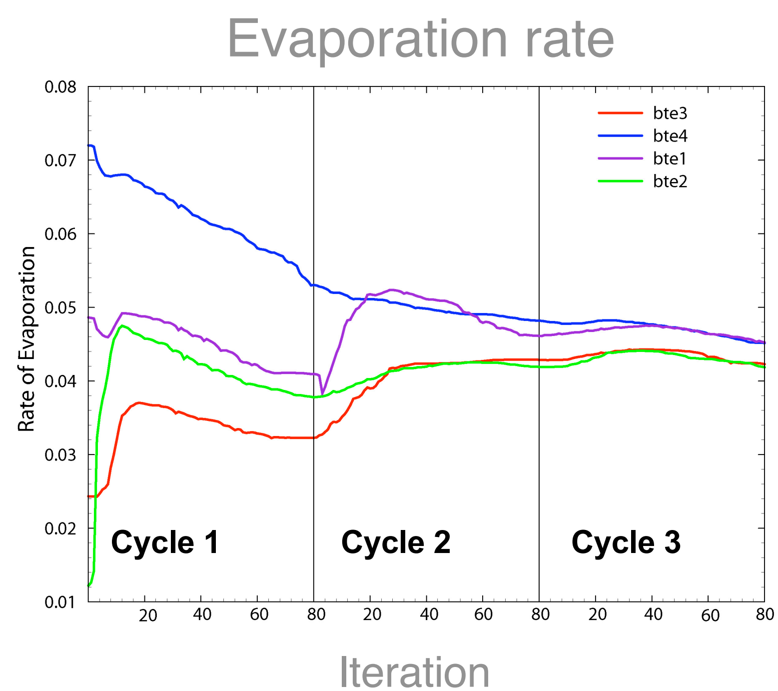
Maximum vertical velocity vs. time



Experiments with a simulated supercell storm

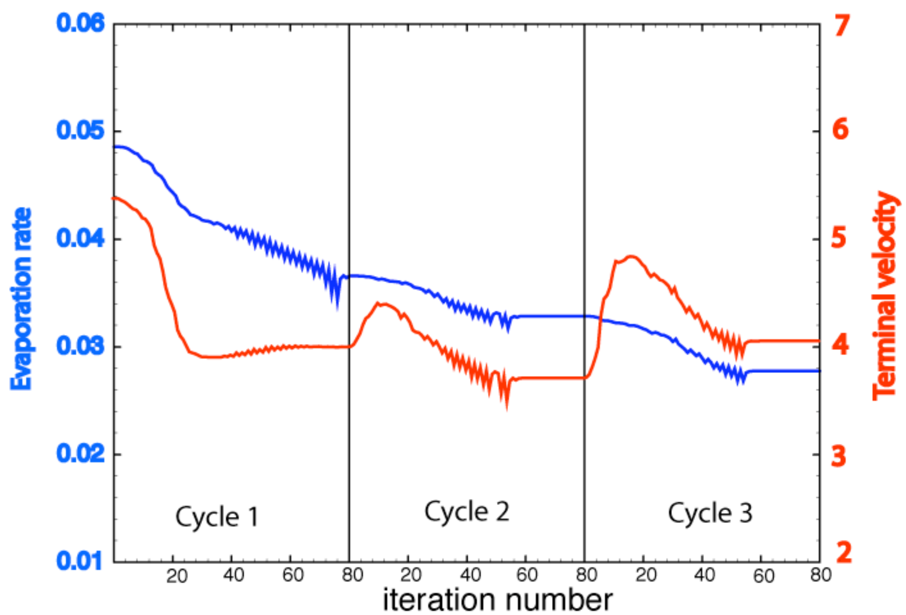
Change of the parameter with respect to iteration number



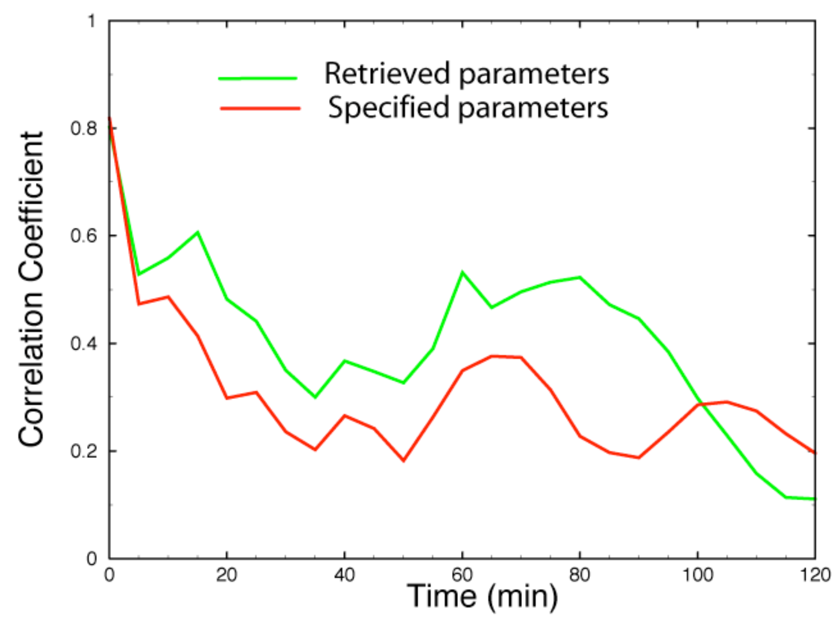


Real data experiments
(two parameters; three cycles)

Change of parameters w.r.t. iteration number



Rainwater correlation coefficient vs. forecast time



Optimal estimation of the terminal velocity resulted in the improvement of the forecast

M-P and C-G DSD model

Marshal-Palmer rain DSD model: $N(D)=N_0\exp(-\Lambda D)$, $N_0=8X10^6\ m^{-4}$

$Z_H \longrightarrow q_r$

Gamma rain DSD model: $N(D)=N_0 D^{\mu}\exp(-\Lambda D)$

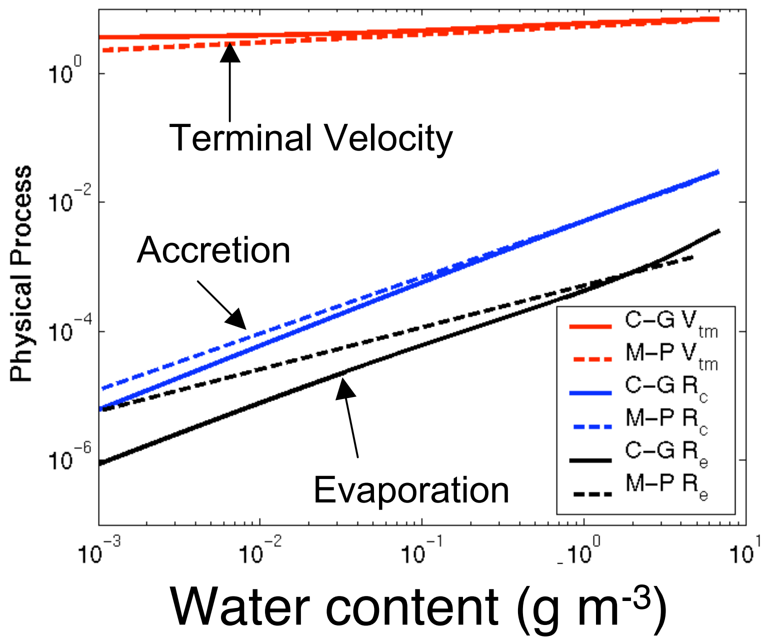
Constraint:

$(Z_H, Z_{DR}) \longrightarrow (q_r, D_0)$

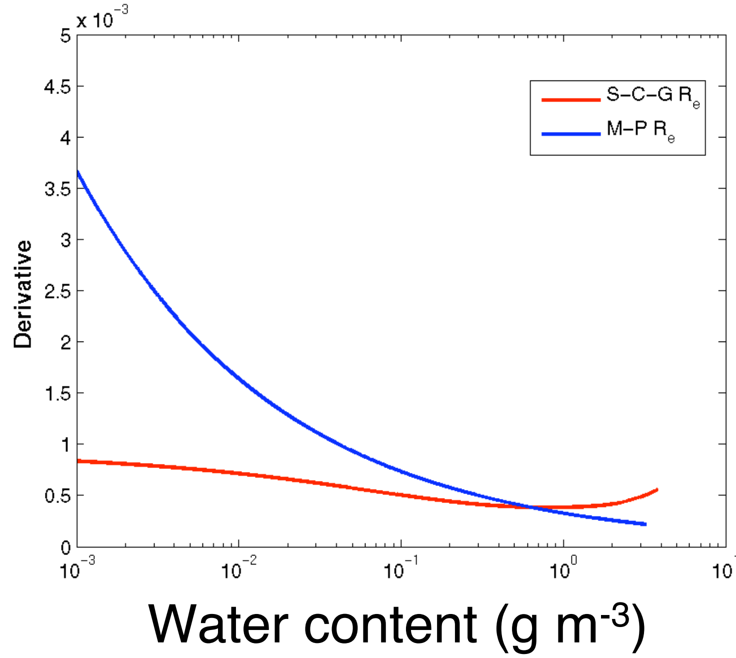
Verification by disdrometer observations indicated that the parameterization scheme based the C-G model agreed better with observations (Zhang et al. 2005, Brandes 2005).

Comparison of the M-P and C-G schemes

Parameterized Process

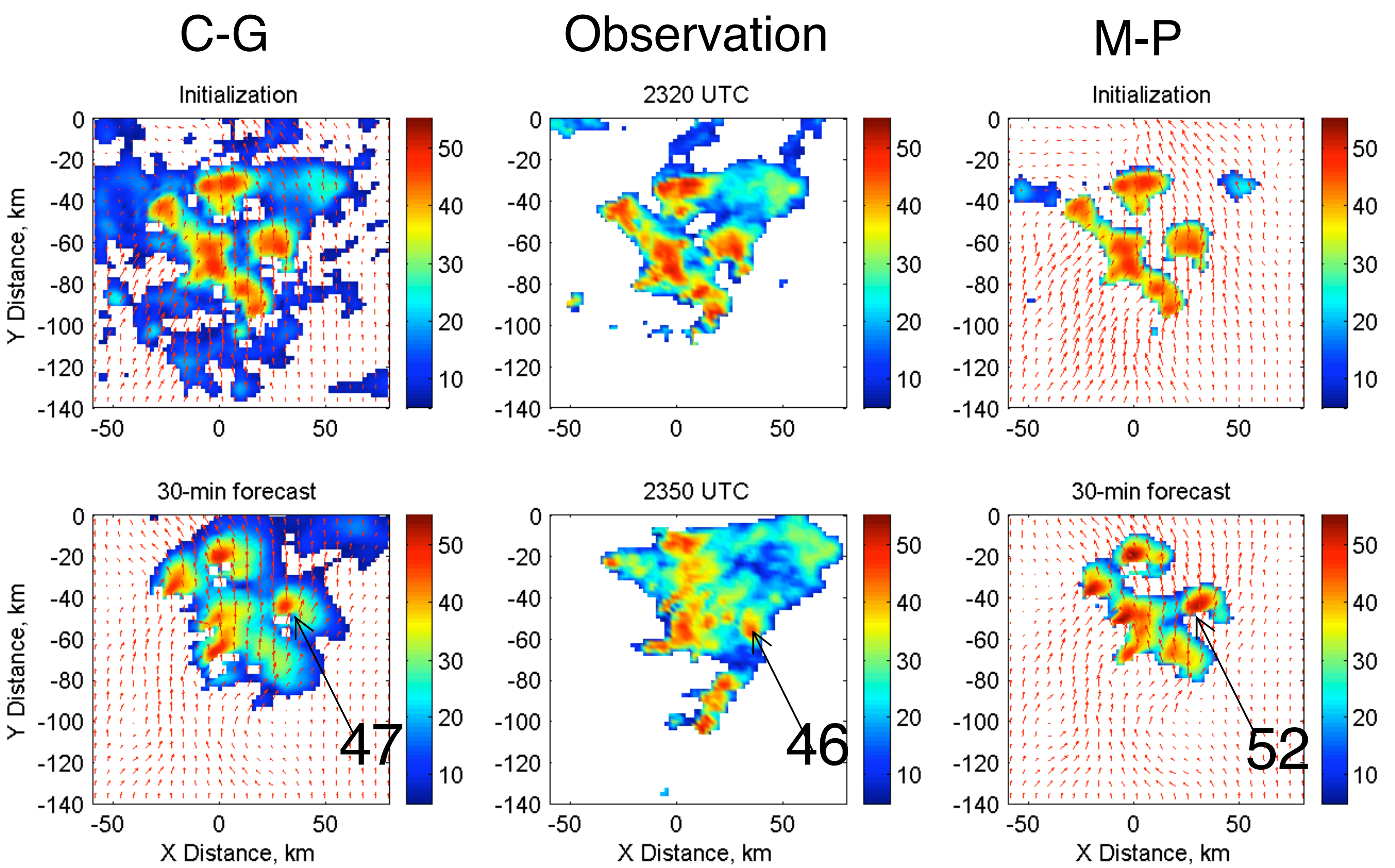


Derivative of evaporation rate



C-G DSD reduces the nonlinearity of the parameterized microphysical processes, which is an advantage for 4D-Var data assimilation

Comparison of model simulations (reflectivity) using C-G scheme with M-P scheme



C-G model can better assimilate and forecast the light precipitation and the intensity of the convective cells.

Concluding remarks

Microphysical parameterization is one of the major source of errors for NWP of precipitation.

Two methods to improve model bulk microphysics parameterization are being investigated.

Both are promising, but many questions remain that require further study.