

Impact of microphysics on idealized squall line simulations

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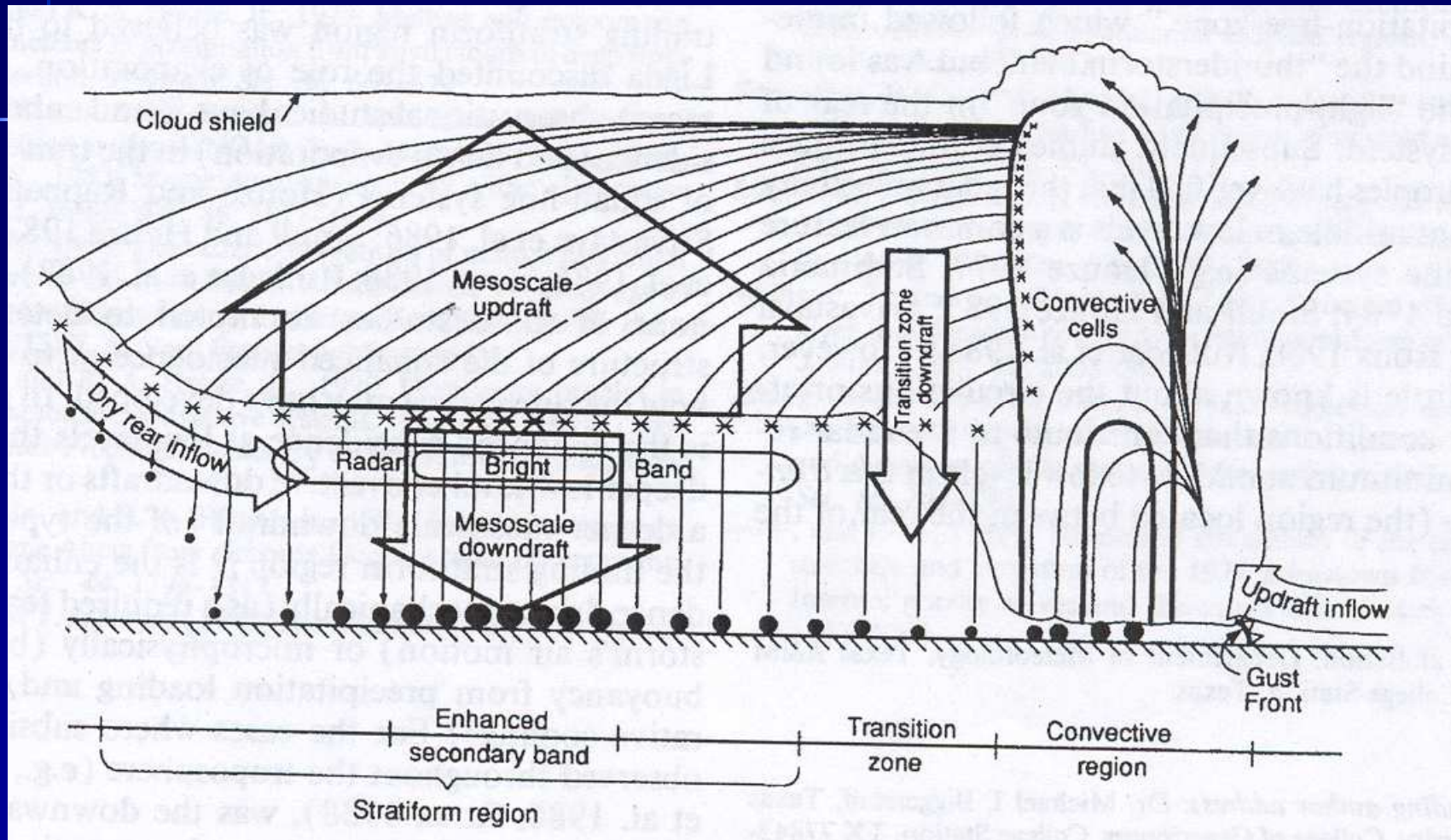


NCAR, Mesoscale and Microscale Meteorology

With greater use of higher resolution convection-permitting simulations in both NWP and climate (e.g., superparameterization) models, microphysics parameterization is a potentially important driver of organized convection since it directly couples with convective dynamics.

Goal here is to better understand how microphysics schemes impact structure of organized deep convection, with a focus on mid-latitude squall lines. Sensitivity to microphysics is also compared with sensitivity to horizontal grid spacing.

Prototypical squall line structure



from Biggerstaff and Houze (1993)

Microphysics scheme is bulk scheme that predicts 5 species: cloud droplets, cloud ice, snow, rain, graupel/hail (Morrison et al. 2005, 2008)

Now available in WRFV3

Focus is on sensitivity to three key areas:

- 1. Two-moment versus one-moment treatment of microphysics**
- 2. Treatment of dense precipitation ice (hail versus graupel)**
- 3. Horizontal grid spacing (1 vs. 4 km)**

1-moment vs. 2-moment schemes

Gamma size distribution for cloud/precipitation species:

$$N(D) = N_0 D^\mu e^{-\lambda D}$$

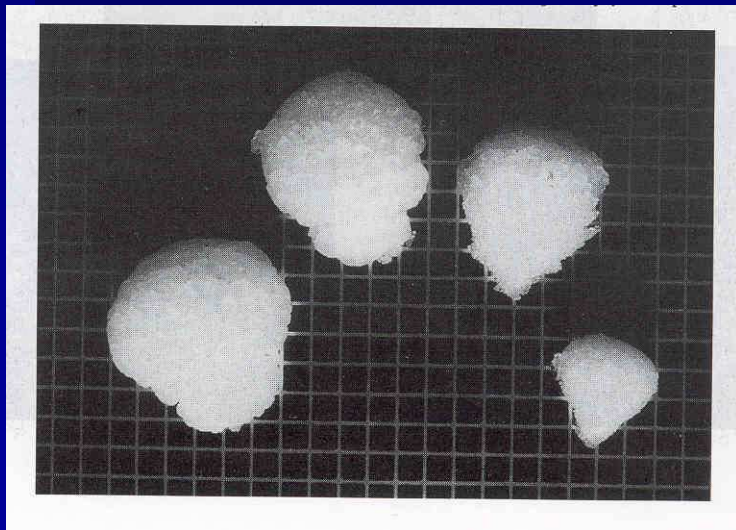
- **In 1-moment scheme, only mixing ratio is predicted, N_0 is specified as constant for each precipitation species (rain, snow, hail/graupel)**
- **In 2-moment scheme, N_0 varies as free parameter from the predicted number concentration and mass mixing ratio**
- **Here we use exponential distributions, i.e., $\mu=0$!**

Treatment of precipitating ice

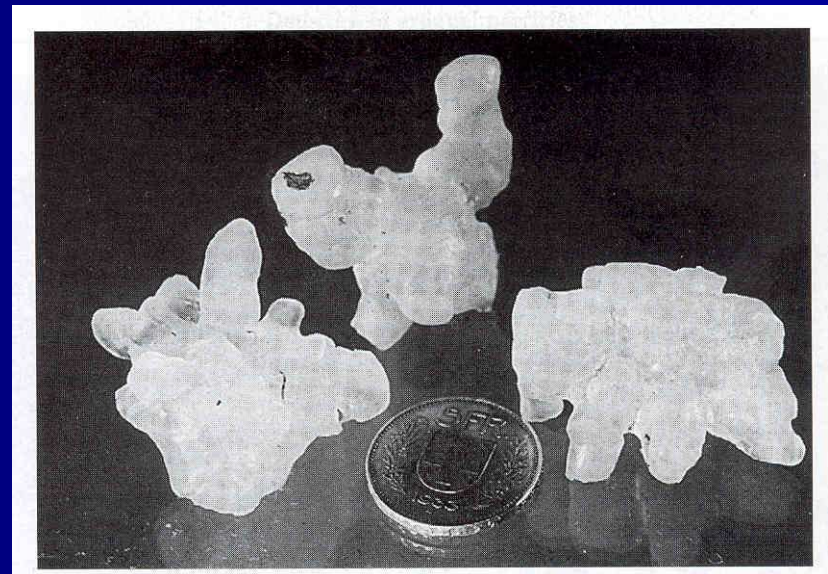
Graupel – lower density (400 kg m^{-3}) and fallspeed ($\sim 3 \text{ m/s}$), higher N_0 (1-moment scheme)

Hail – higher density (900 kg m^{-3}) and fallspeed ($\sim 10 \text{ m/s}$), lower N_0 (1-moment scheme)

Graupel



Hail

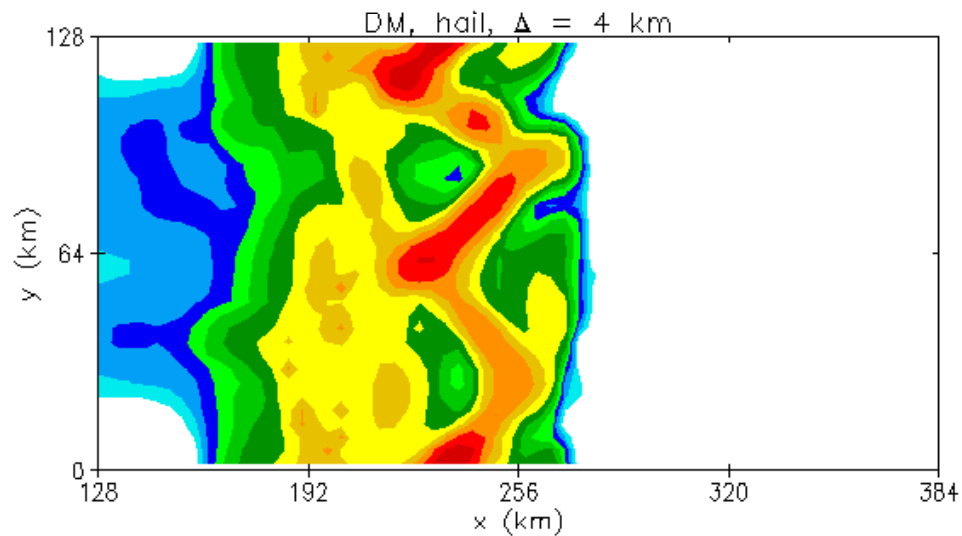
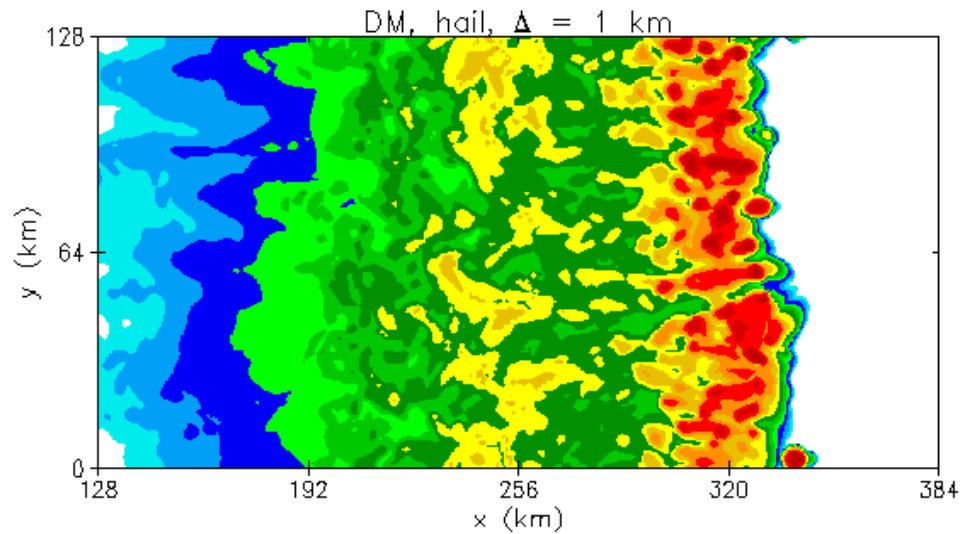


From Pruppacher and Klett 1997

3D Idealized Simulations

- **Numerical model of Bryan and Fritsch (2002)**
- **Weisman-Klemp sounding**
- **Domain size: 512 x 128 x 18 km, periodic Y, open X**
- **Vertical grid spacing: 250 m**
- **Ambient wind profile: Weak low-level shear (10 m/s over 2.5 km)**
- **Initiation method: Warm line thermal (+2 K plus small random perturbations)**
- **No surface friction, radiation, terrain, or Coriolis acceleration**

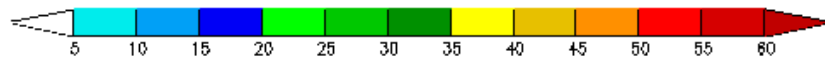
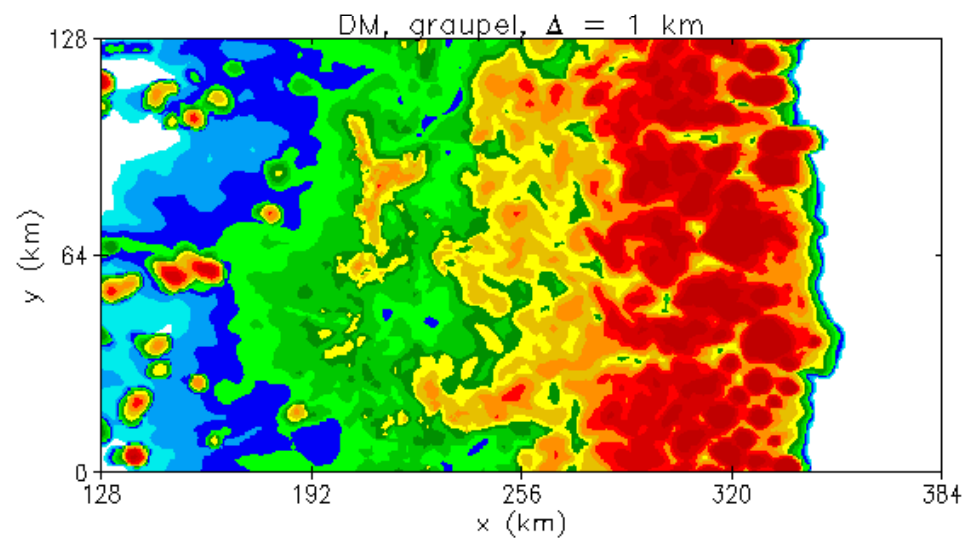
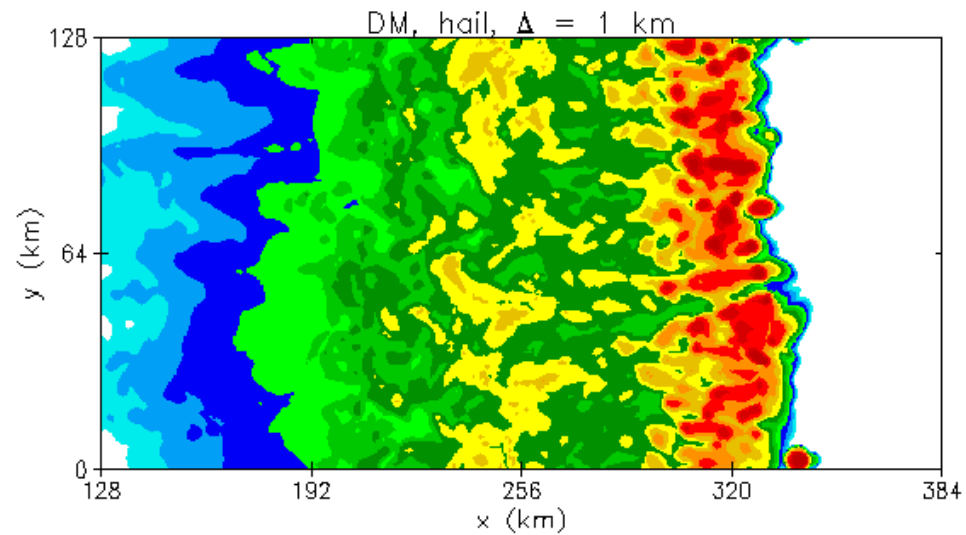
Composite reflectivity (dBZ), t = 6 h



1 km vs. 4 km
horizontal
grid spacing

~ 3 km above surface

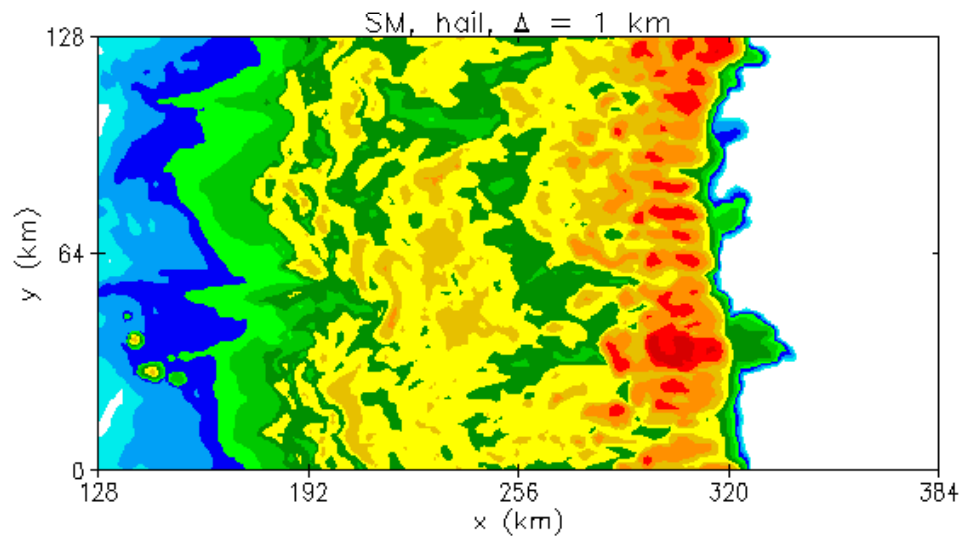
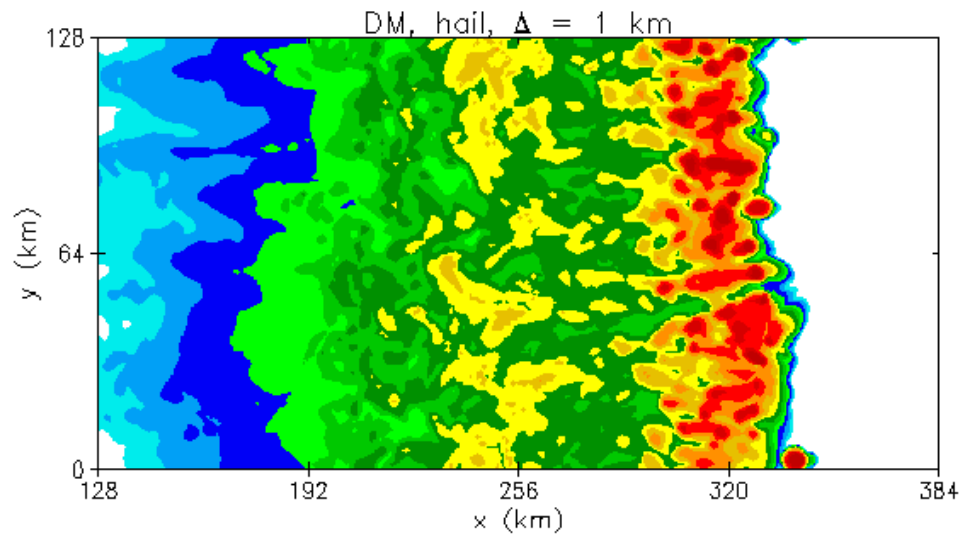
Composite reflectivity (dBZ), t = 6 h



Hail vs. graupel

~ 3 km above surface

Composite reflectivity (dBZ), t = 6 h

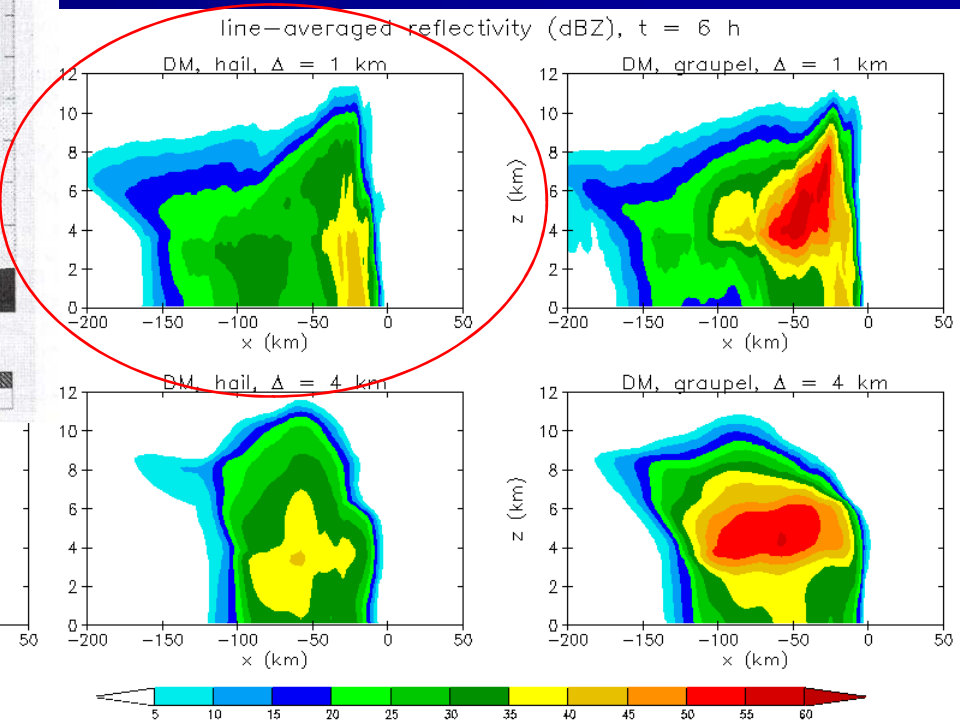
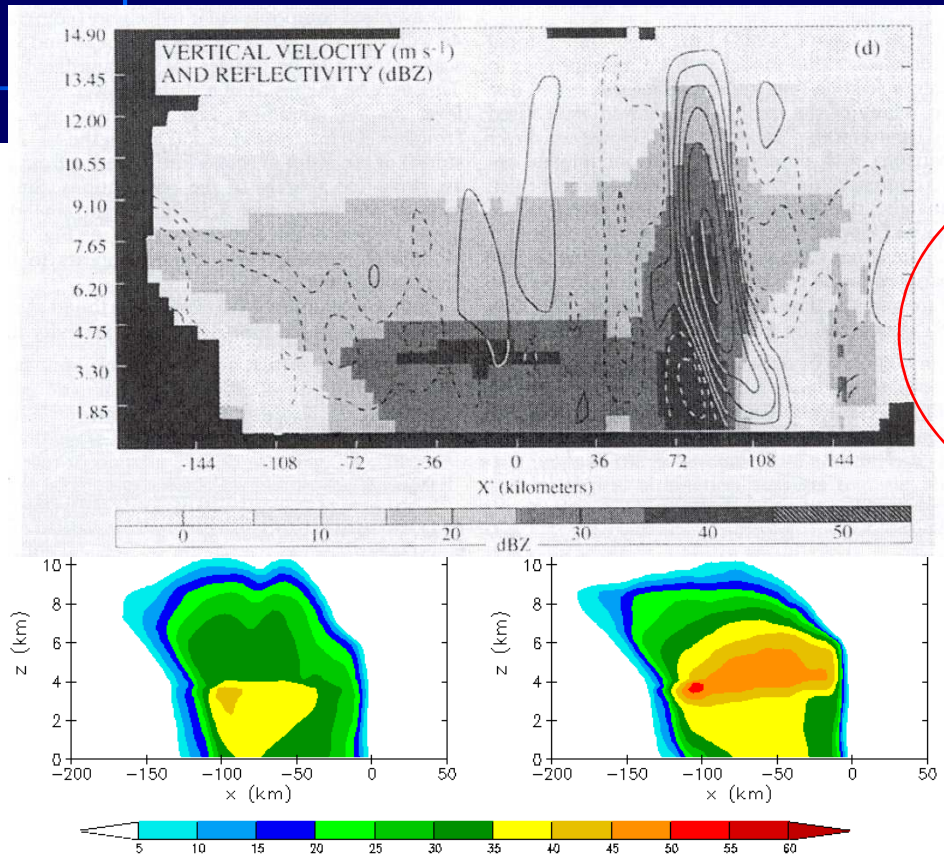


2-moment vs. 1-
moment scheme

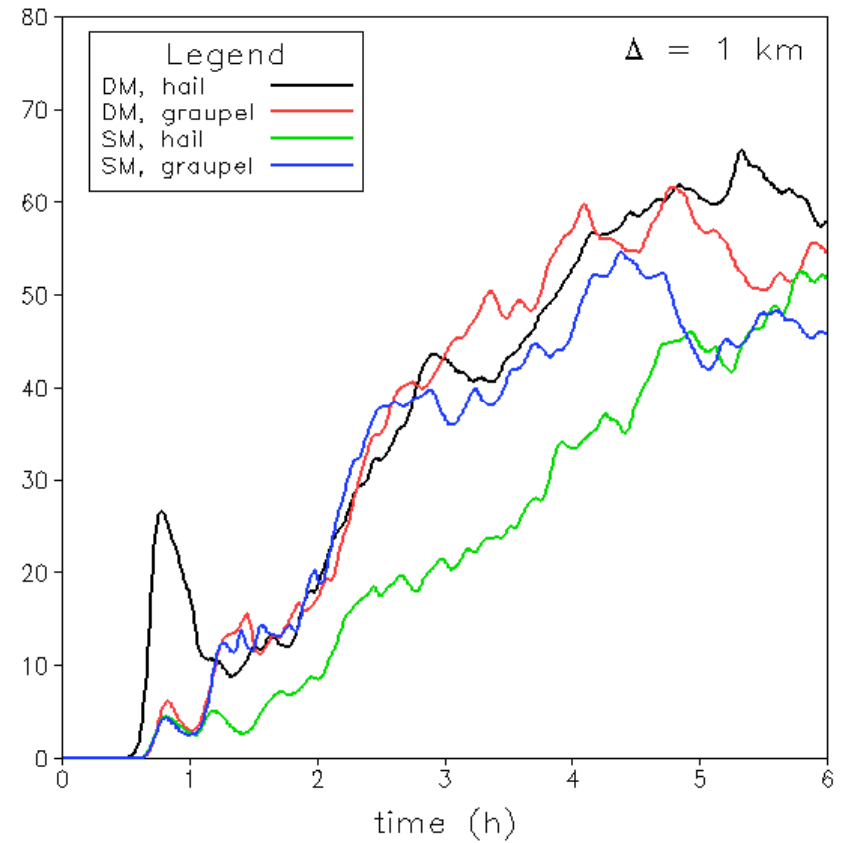
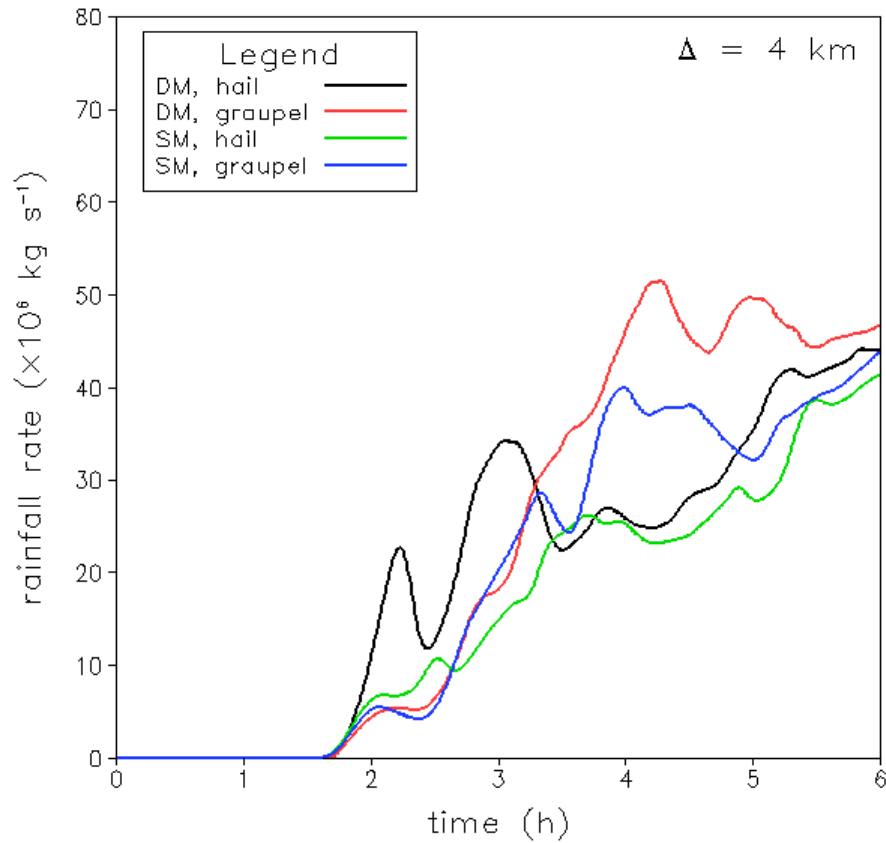
~ 3 km above surface

from Biggerstaff and Houze (1993)

Two-moment

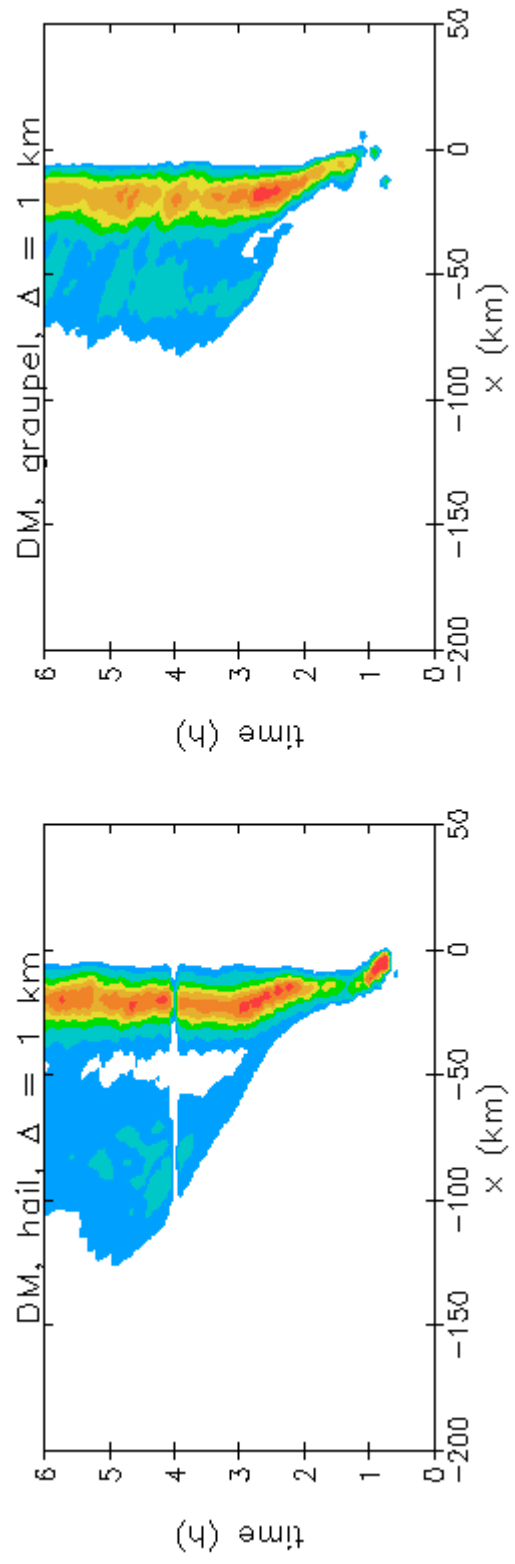


Mean surface rain rate

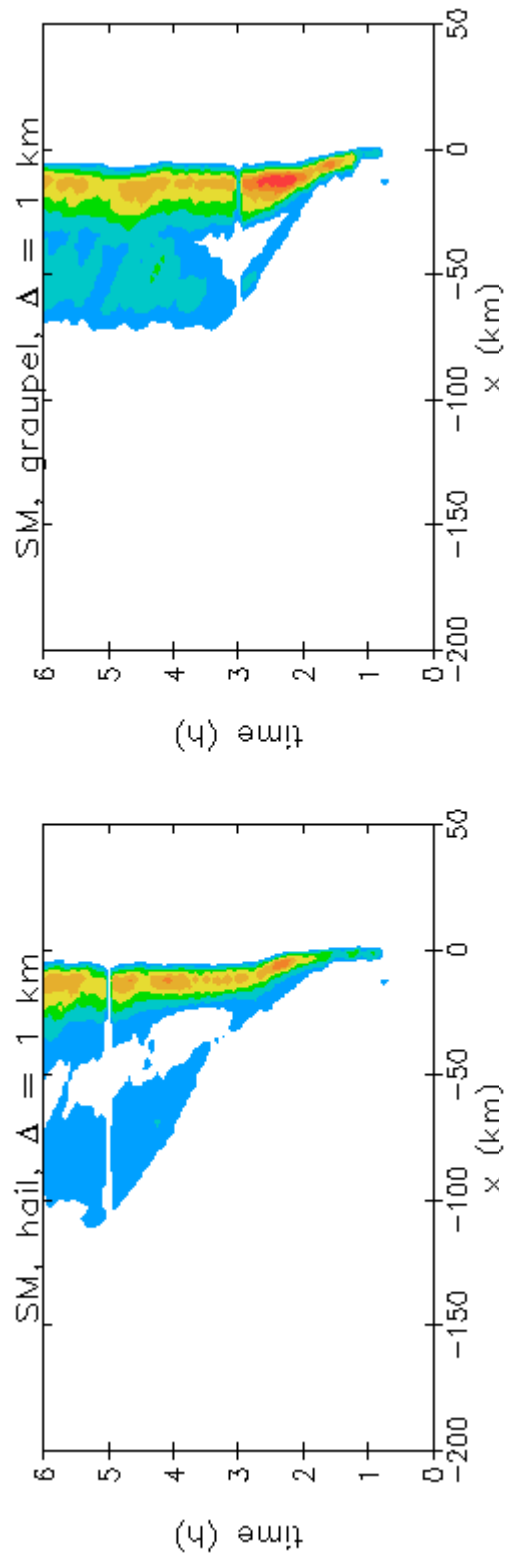


Somewhat greater precipitation in 2-moment scheme than 1-moment.

line-averaged surface precipitation rate (in/hr)

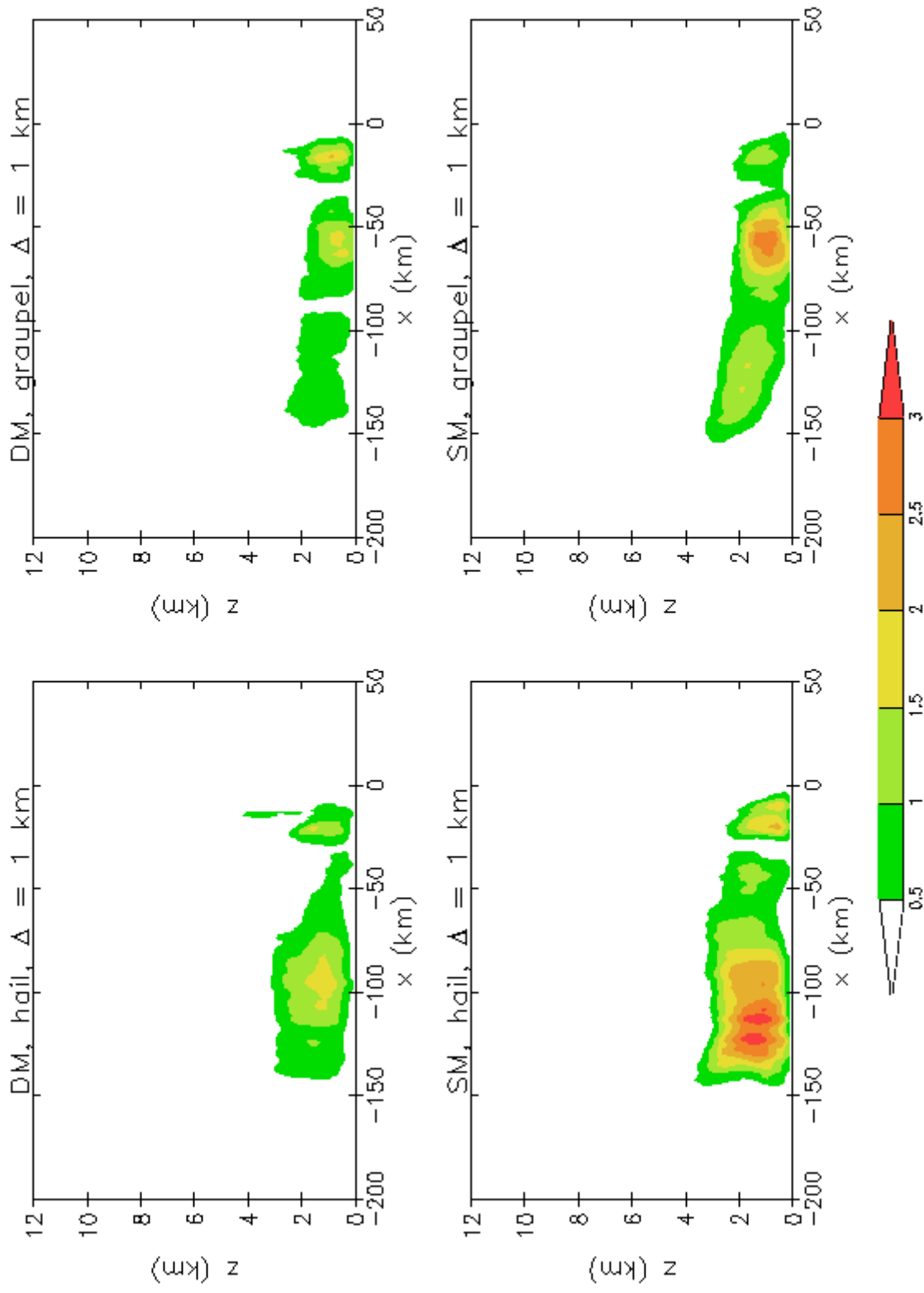


line-averaged surface precipitation rate (in/hr)

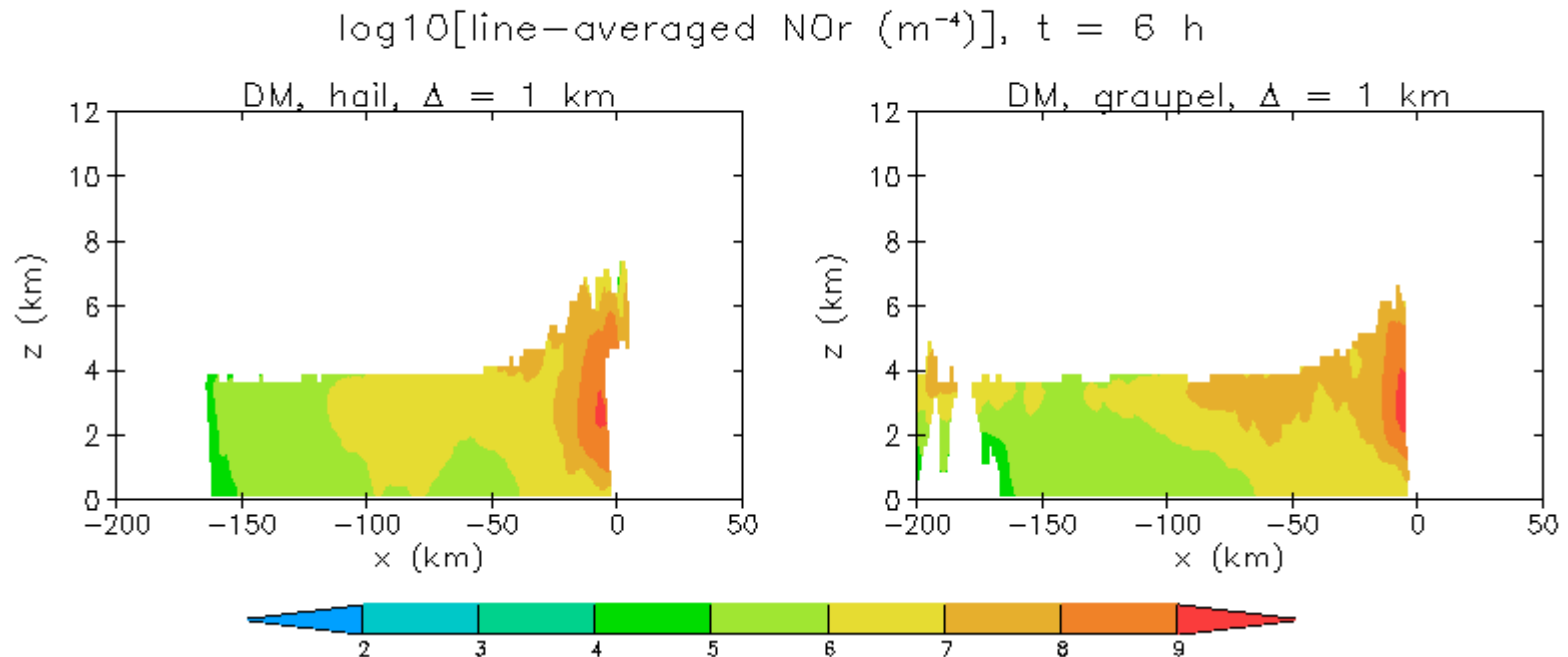


Differences between 1-moment and 2-moment simulations are mostly due to differences in treatment of rain. Differences in treatment of snow/hail/graupel between 1-moment and 2-moment have limited impact.

line-averaged rain evaporation rate ($\text{g kg}^{-1} \text{ hour}^{-1}$), $t = 6 \text{ h}$



Predicted rain N_0 for 2-moment scheme



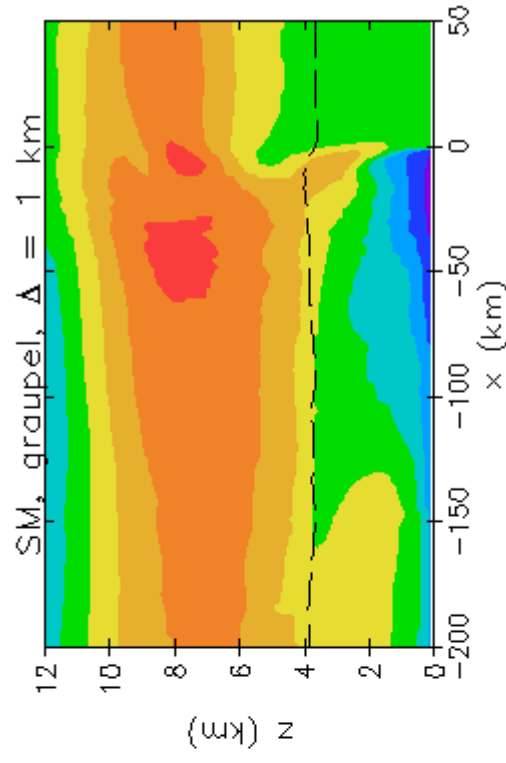
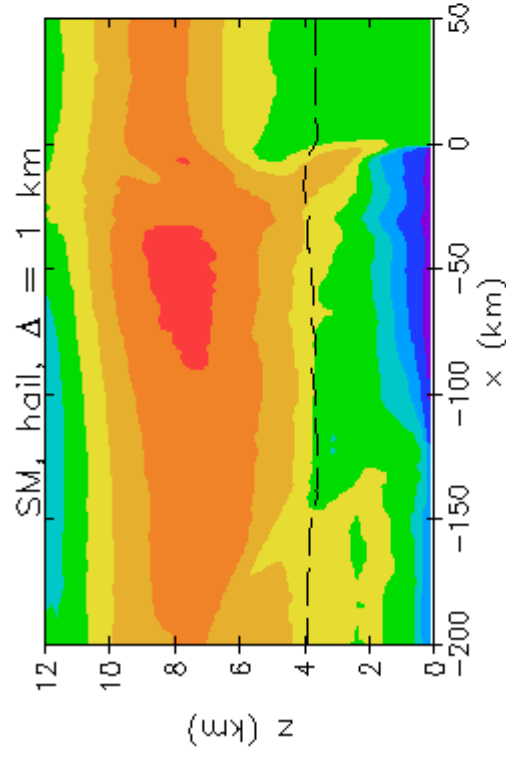
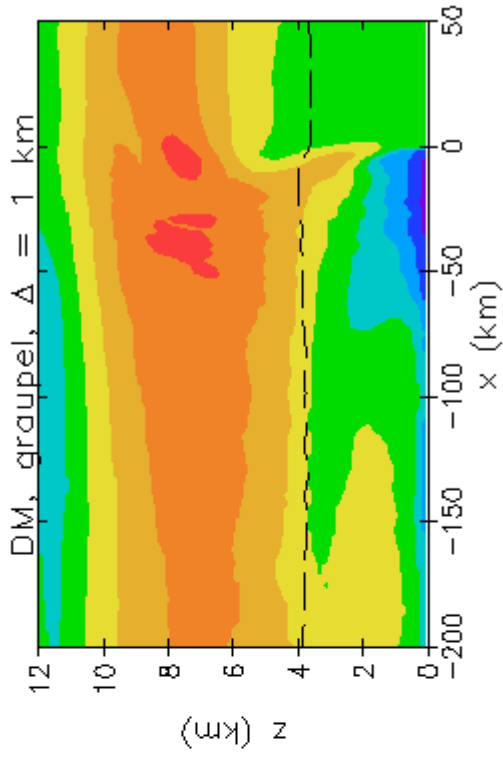
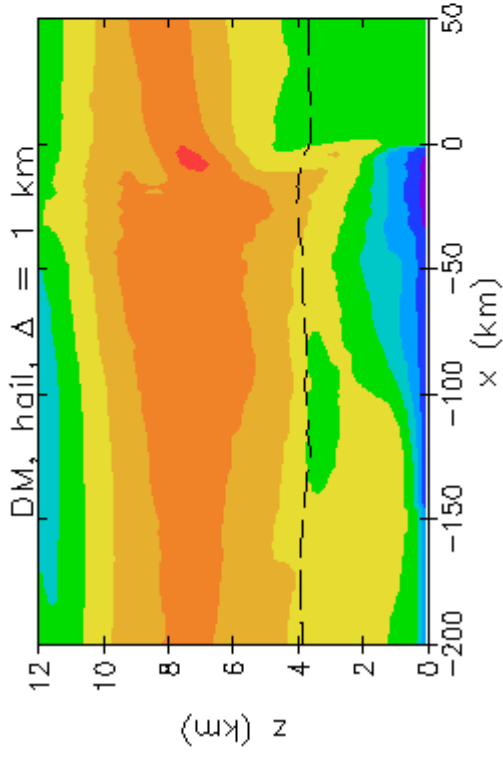
In 1-moment scheme, rain $N_0 = 10^7 m^{-4}$. This leads to greater evaporation in stratiform region, less in convective region near melting level.

n Is this difference in modeled rain N_0 between stratiform and convective regions observed? Yes!

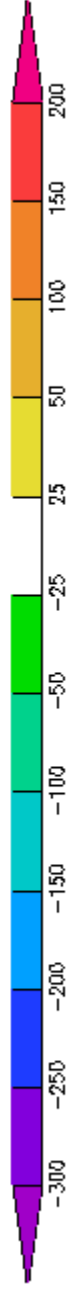
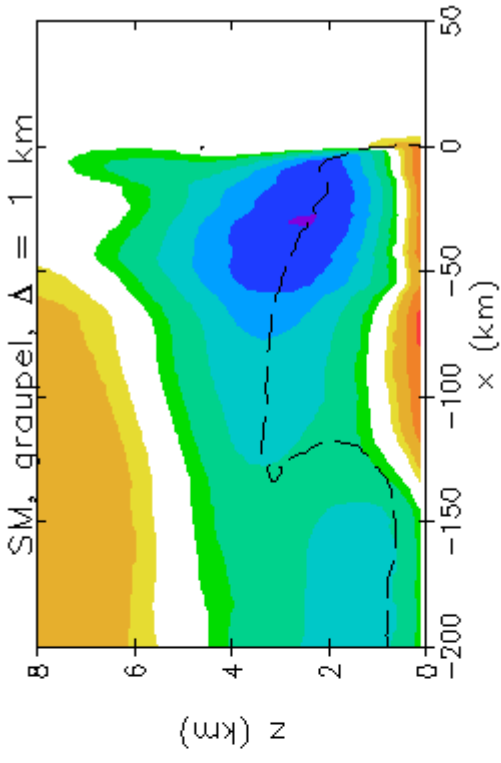
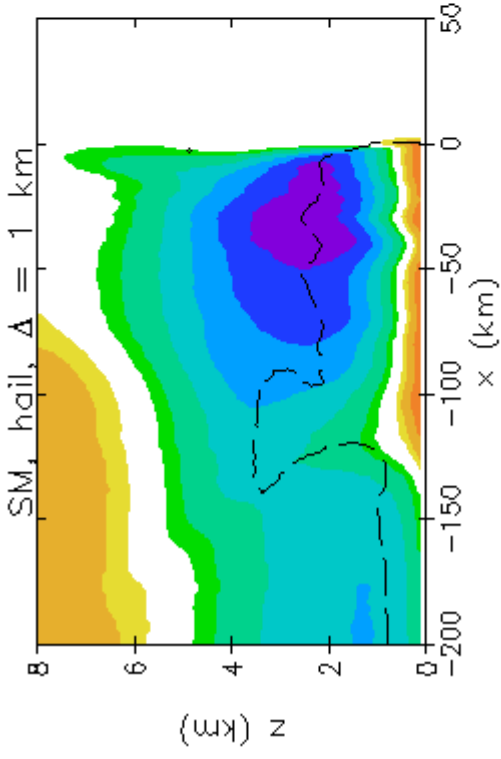
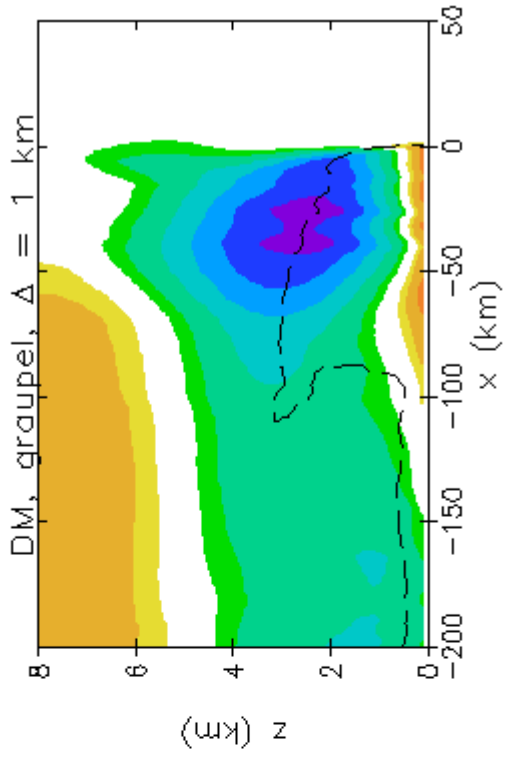
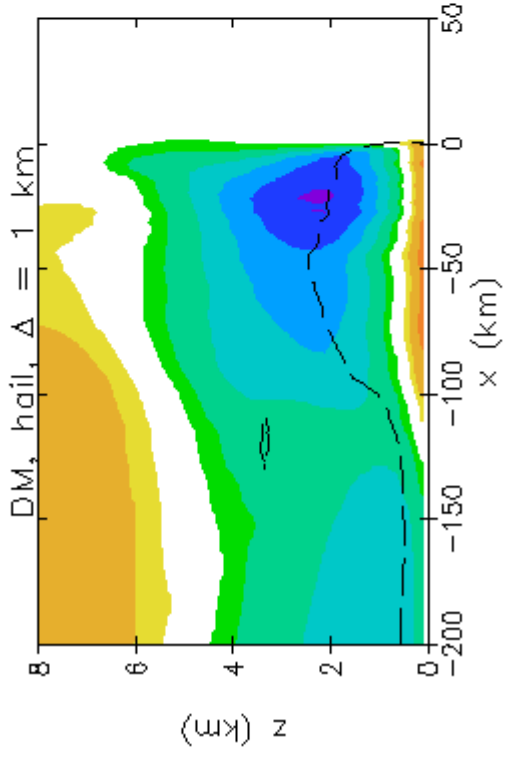
Disdrometer-measured N_0 in a tropical squall line
(Tokay and Short 1996)

" N_0 jump"

line-averaged potential temperature perturbation (K), $t = 6$ h



line-averaged p' (Pa) and cold pool depth (dashed), $t = 6$ h



Summary

- **Broadly, results were most sensitive to 1) horizontal grid spacing, 2) treatment of precipitating ice (graupel vs. hail, 3) 2-moment vs. 1-moment.**
- **Possibility of other important microphysics sensitivities (e.g., shape parameter of rain PSD, evaporation of drop number concentration).**

Future Work

- **Need to validate results with observations. Evaluate for real cases (e.g., case 3 of workshop), including detailed comparison with observed rain size distributions from disdrometer.**
- **Test impact of our new ice microphysics scheme (Morrison and Grabowski 2008) for squall line cases.**