Sensitivity of a simulated mid-latitude squall line to parameterization of raindrop breakup

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Background

• Several decades of research has indicated the sensitivity of moist deep convection to representation of microphysics (e.g., Lord et al. 1984, Fovell and Ogura 1989, Liu et al. 1997, Dudhia 1989, McCumber et al. 1991, Ferrier et al. 1995, Gilmore et al. 2004, Morrison et al. 2009).

• Recent work has shown large differences in simulations of deep convection using different two-moment schemes of similar complexity (Morrison and Milbrandt 2011; van Weverberg et al. 2011).

• Different treatments of raindrop breakup (a process not treated in 1-moment schemes) were found to be important in explaining many of these differences.

Methodology

• Extend previous work to systematically investigate sensitivity of a squall line to treatment of raindrop breakup.

• Goals

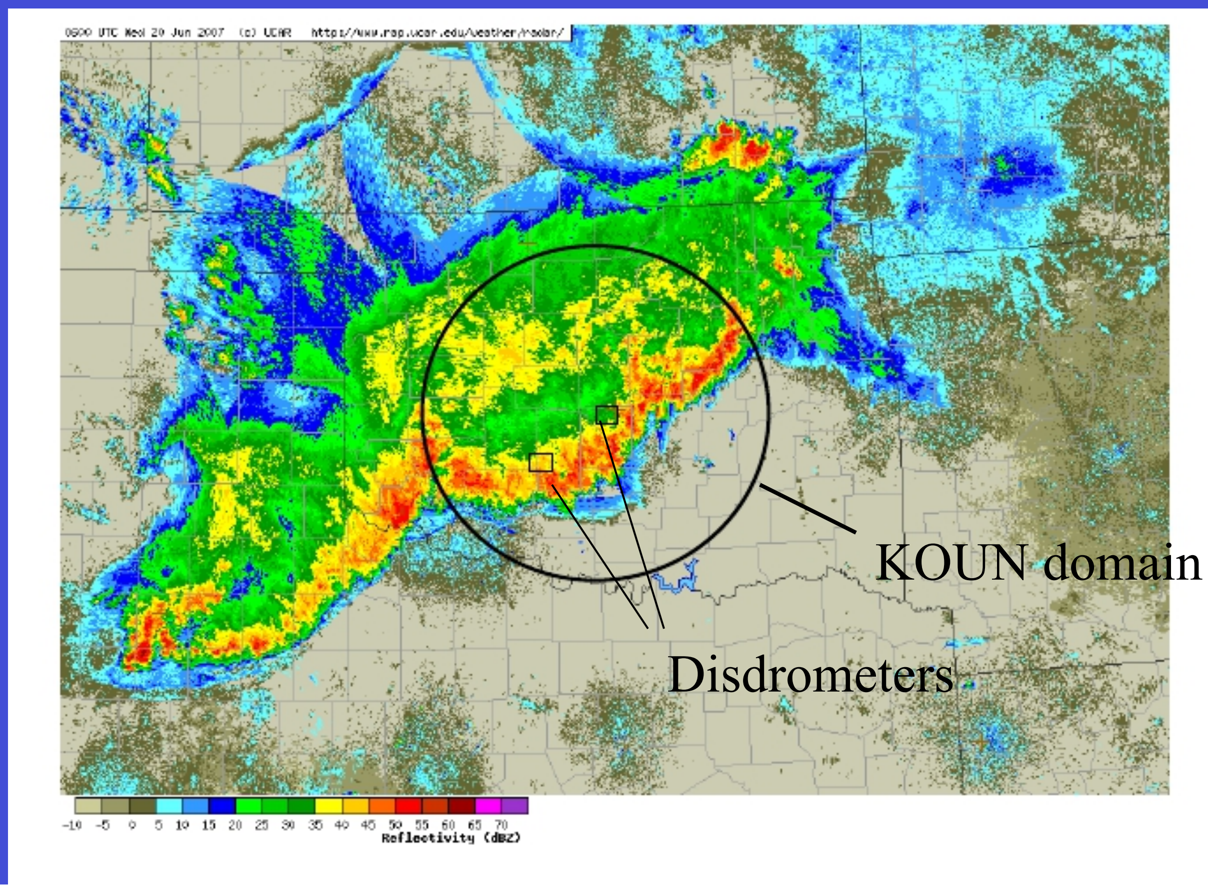
- develop a well-characterized mid-latitude squall line by synthesizing a suite of observations
- assess model performance against these observations
- quantify sensitivity of the model to raindrop breakup

The case study

- 20 June 2007 squall line in central Oklahoma

- Observed by a combination of dual-polarization radar, mesonet, and two video disdrometers

Mosaic reflectivity ~0600 UTC



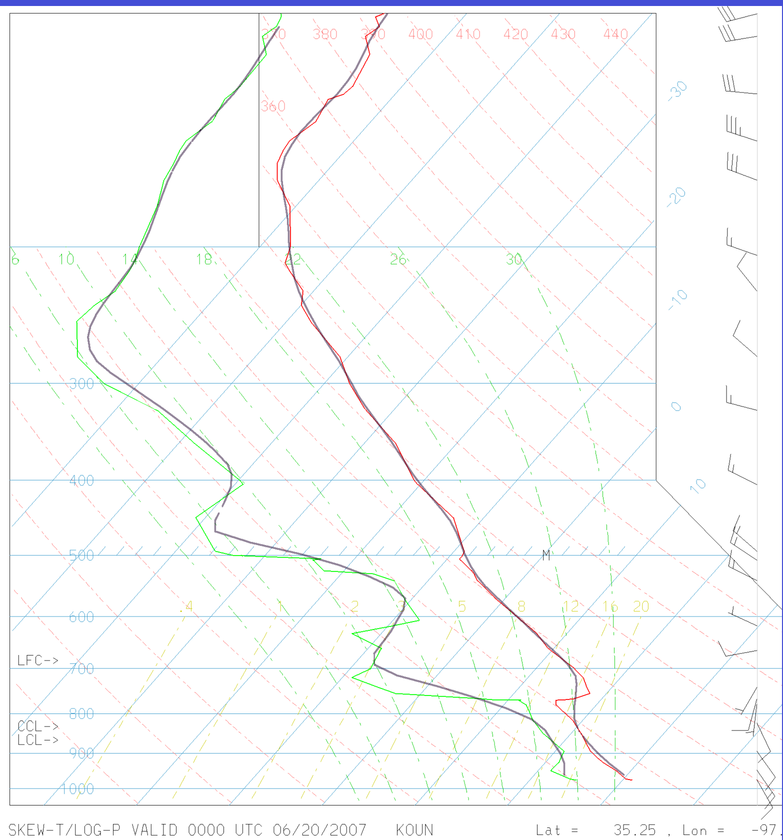
Model setup

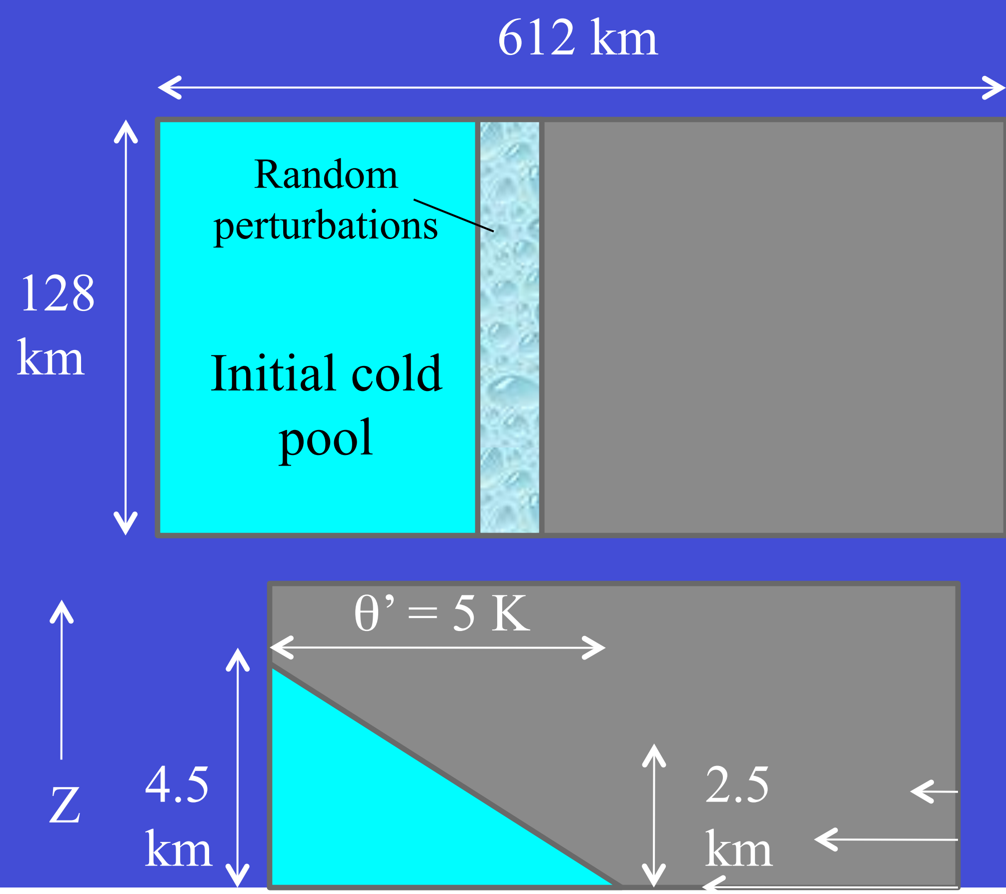
- 3D simulations using WRFV3.1
- Quasi-idealized domain w/ periodic lateral bc's perpendicular to line and open lateral bc's parallel to the line
- Domain size: 612 x 128 x 20 km
- Grid spacing: Δx = 1 km, Δz ~ 250 m
- No radiation, no surface fluxes, free slip lower bc's
- 2-moment microphysics (Morrison et al. 2009)

- Initial conditions from observed KOUN sounding at 000 UTC

- Idealized linear vertical wind shear profile

- Convection initiated by inserting a cold pool (Weisman et al. 1997; Bryan and Morrison 2011)

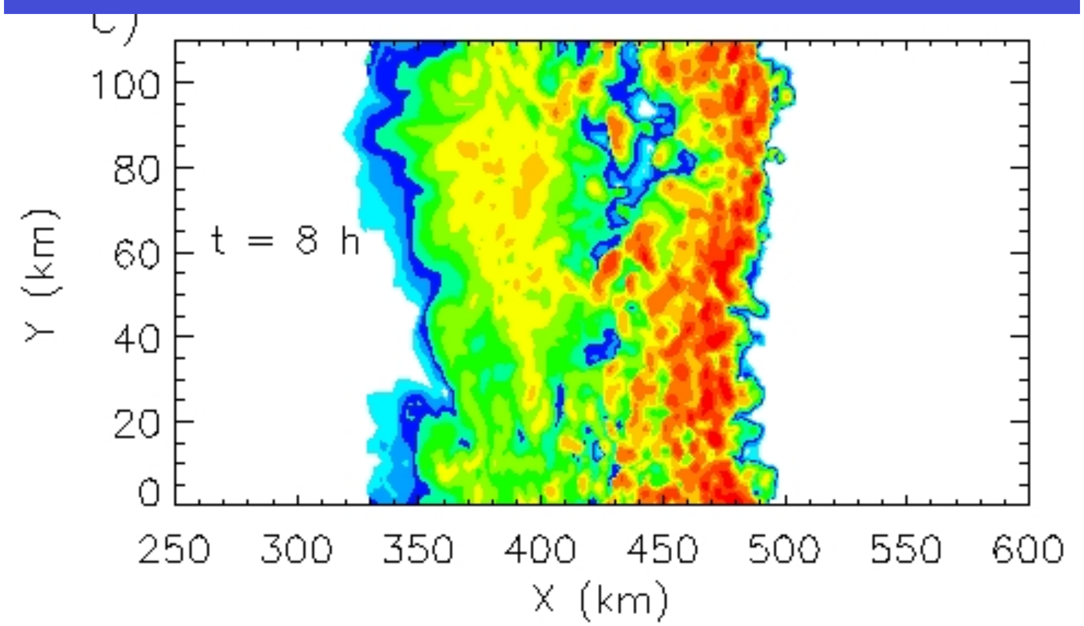


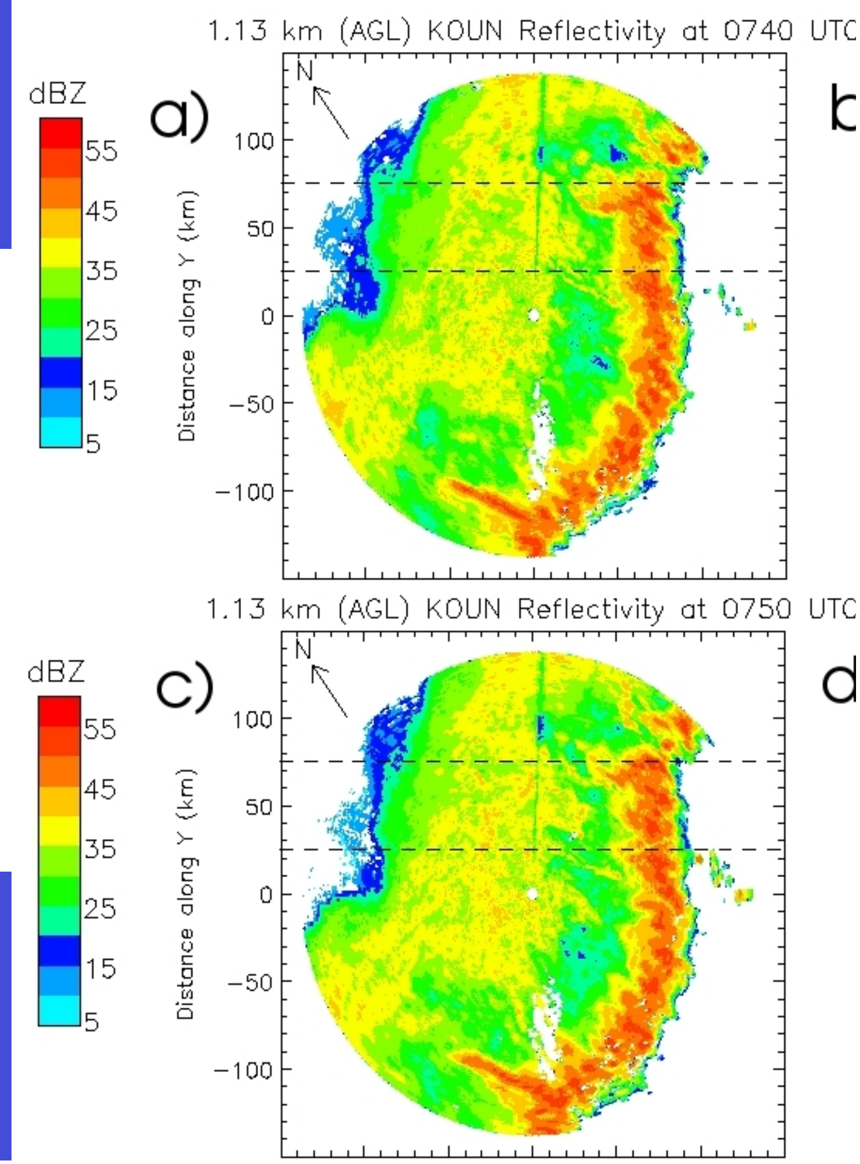


Results

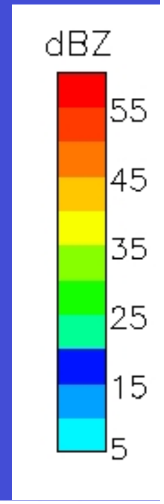
- **Baseline simulations w/ modified Verlinde and Cotton (1993) breakup**

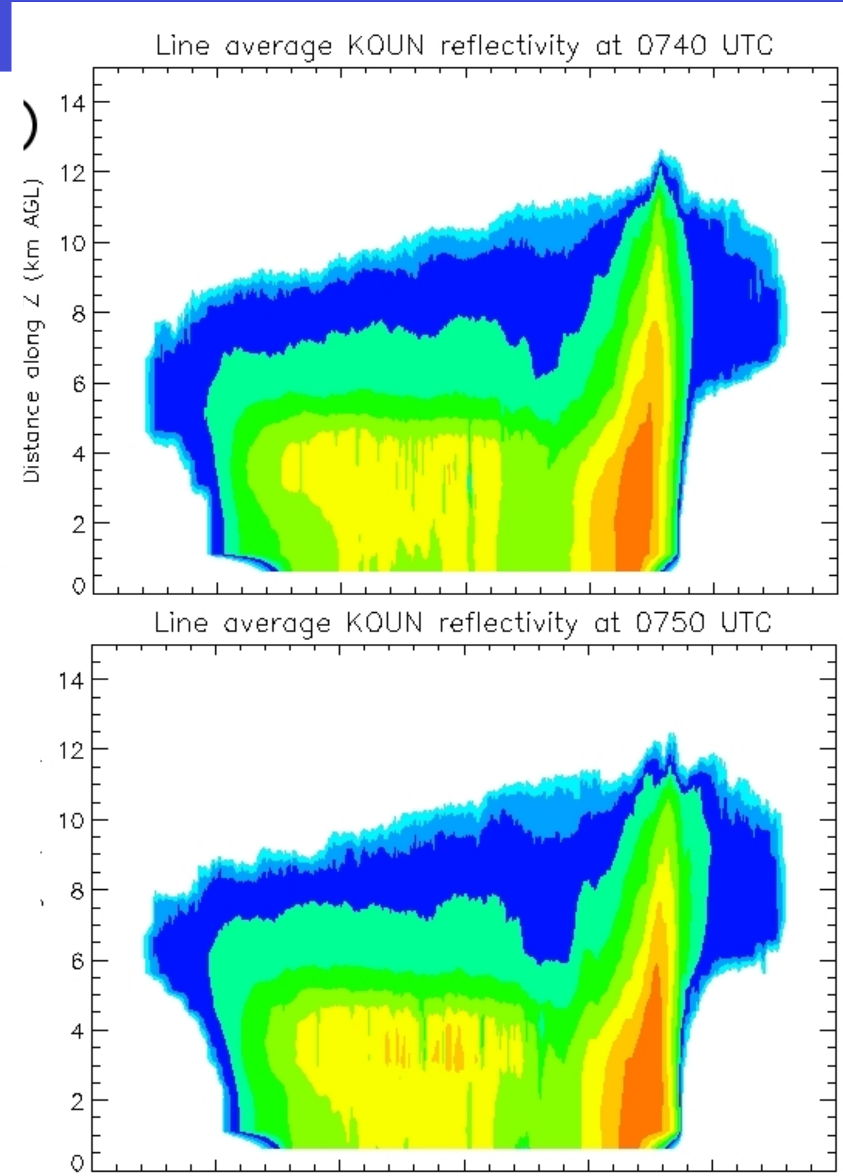
Model reflectivity at t = 8 h, z = 1.13 km



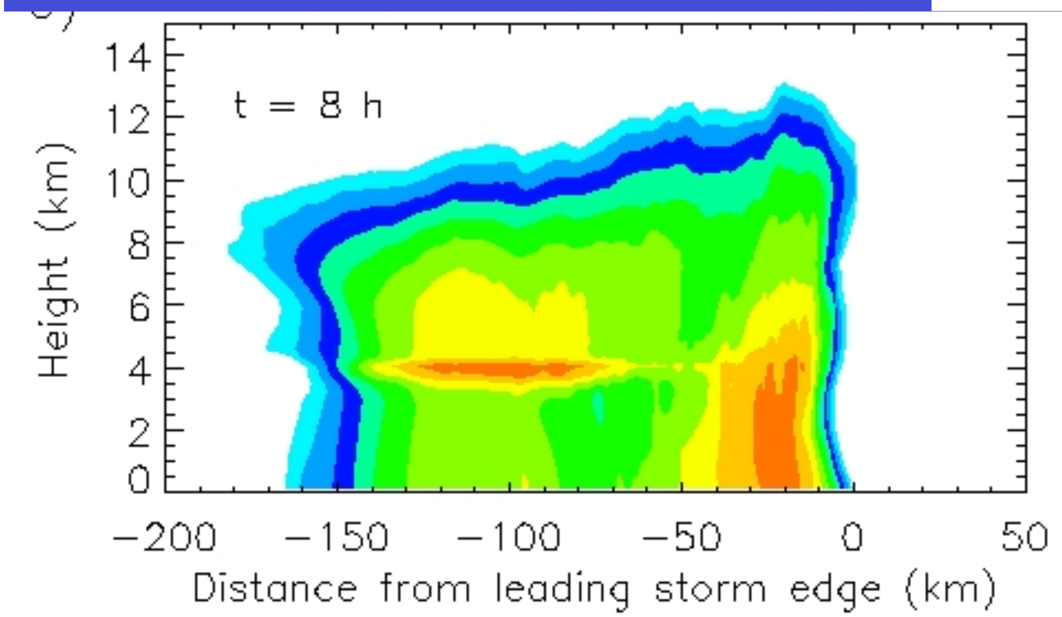


• **Comparison of vertical cross sections of line-averaged reflectivity**





Model reflectivity at t = 8 h

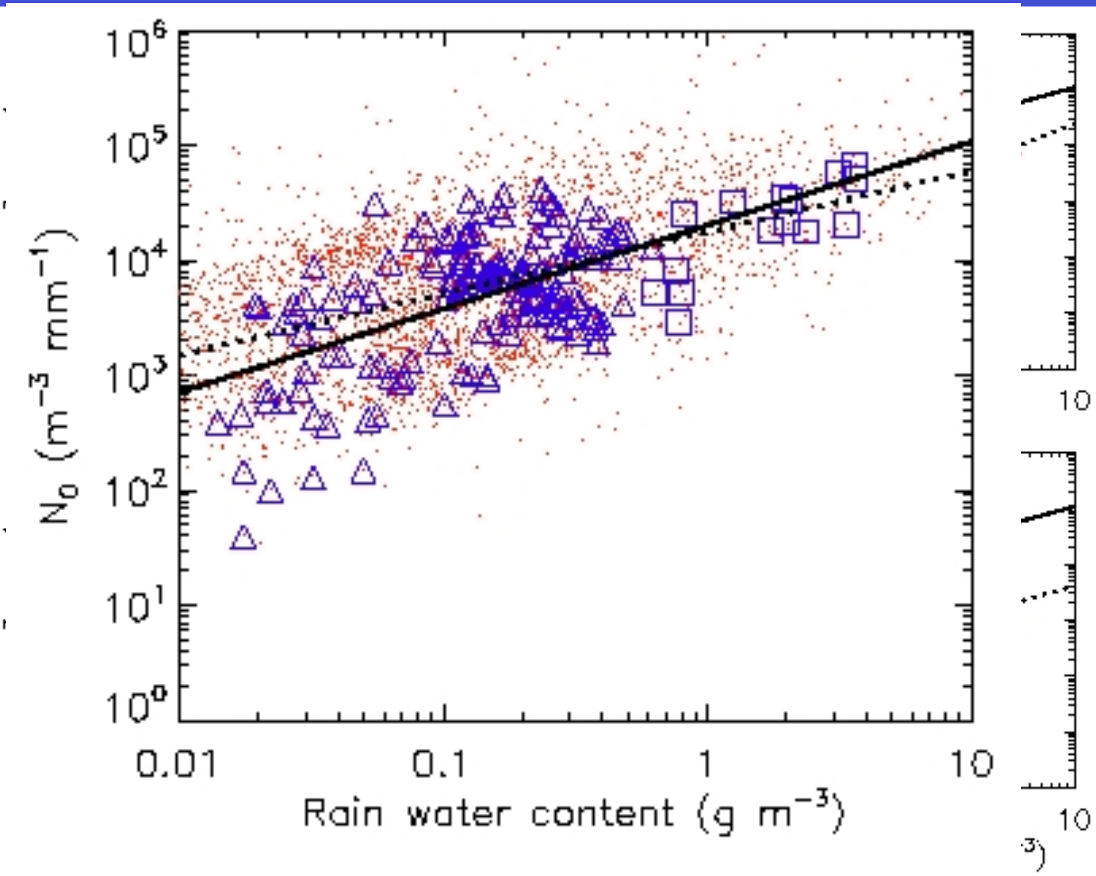


• **Sensitivity to raindrop breakup**

$$E_c = 1, D_r < D_{th}$$

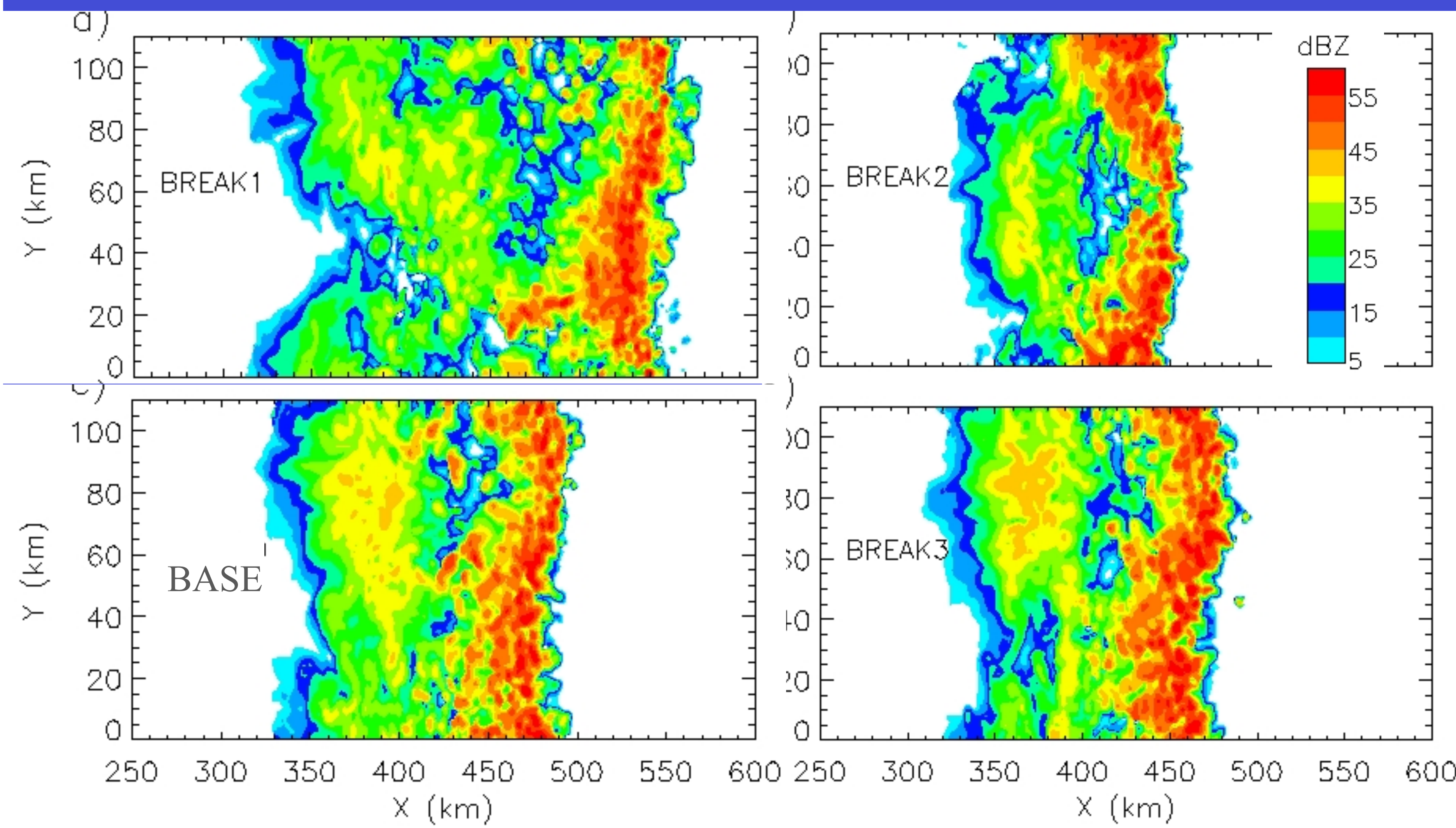
$$E_c = 2 - \exp[2300(D_r - D_{th})], D_r > D_{th}$$

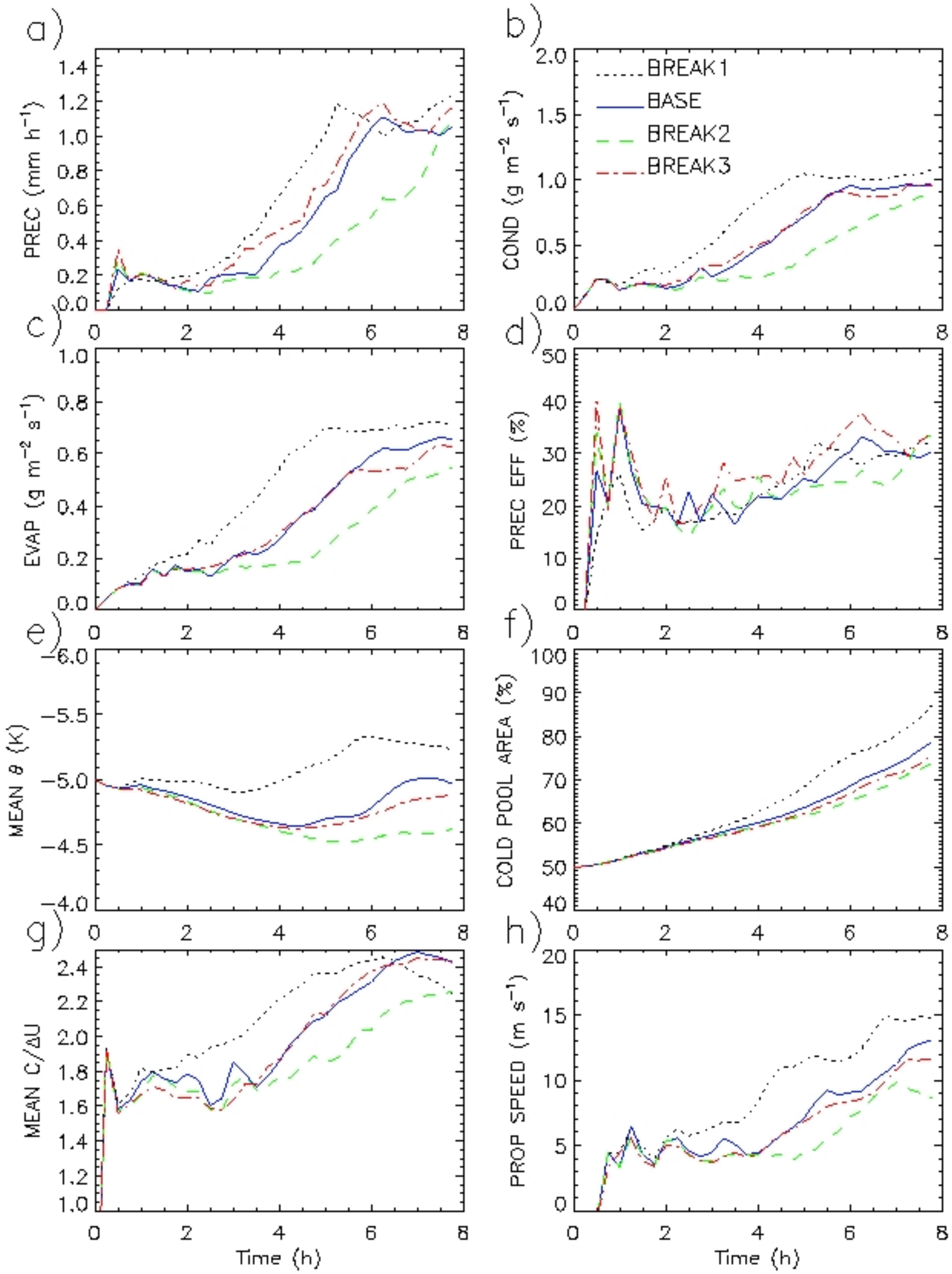
• **D_{th} is systematically modified to alter breakup efficiency: larger D_{th} → larger E_c and less efficient breakup**



RUN	D_{th} (mm)
BREAK1	0.095
BASE	0.300
BREAK2	0.405
BREAK3	0.510

• **Large sensitivity of storm structure to breakup**




a)
PREC (mm h^{-1})
b)
COND (g m^{-2} s^{-1})
BREAK1
BASE
BREAK2
BREAK3
c)
EVAP (g m^{-2} s^{-1})
d)
PREC EFF (%)
e)
MEAN θ (K)
f)
COLD POOL AREA (%)
g)
MEAN C/ΔU
h)
PROP SPEED (m s^{-1})
Time (h)
Time (h)

• Surface precipitation is higher w/ more efficient breakup, due to interactions between microphysics, cold pool evolution, and dynamics:

more efficient breakup → smaller drops → more evaporation → stronger cold pools → faster propagation → larger storm size → greater total condensation → more precipitation

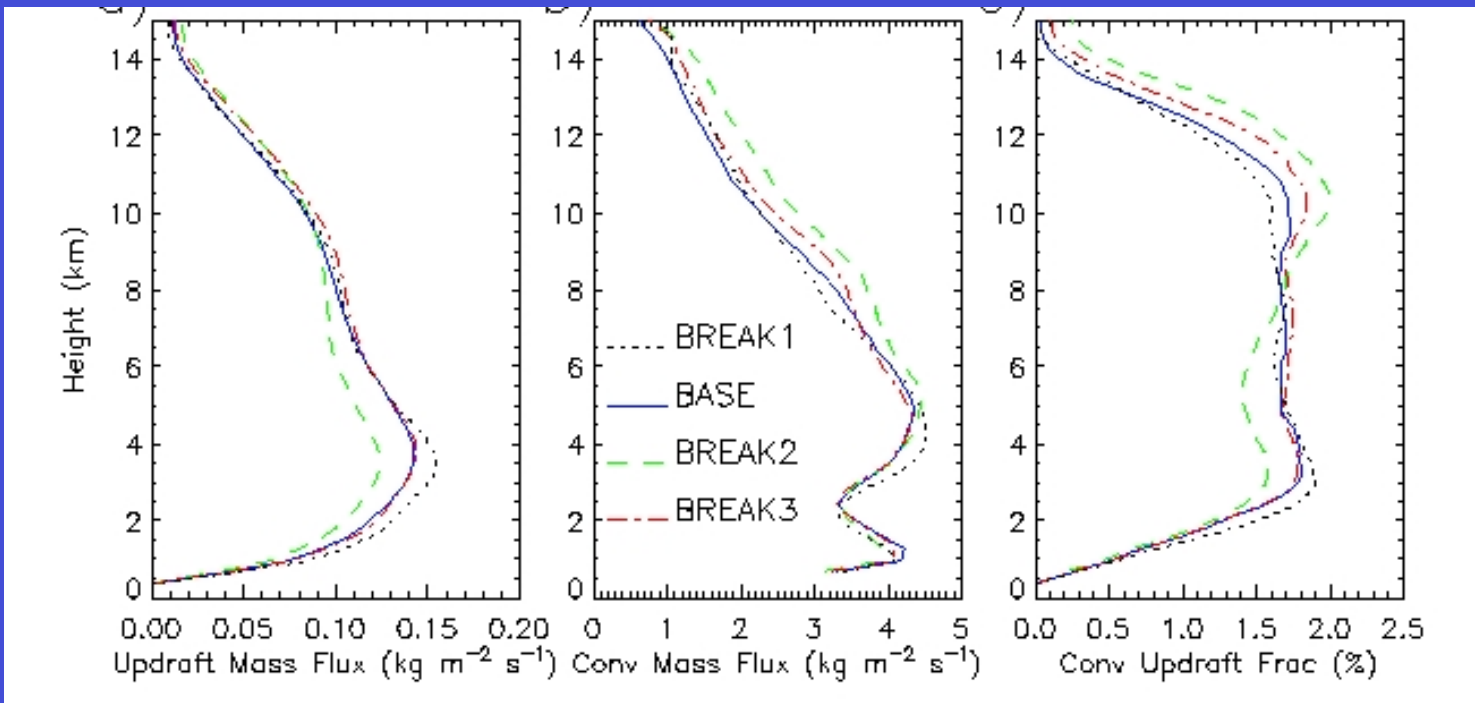
• The non-monotonic response is due to complications arising from the impact of breakup and drop size on mass-weighted fallspeed (shown by addiitonal sensitivity tests).

• Similar results for different environmental wind shears, except that response is monotonic for higher wind shears.

• **How do these results fit with RKW theory?**

RKW theory: maximum storm intensity occurs when C/ΔU ~ 1 (Rotunno et al. 1988)

General support for RKW theory, but some measures of storm strength are greatest with largest C/ΔU (i.e., in BREAK1): surface precipitation, total condensation, total updraft mass flux



Future work

- This framework can be readily applied to other case studies (from ASR/ARM, etc.)

- More systematic testing of microphysics, including longer-term (multi-day) simulations

- Intercomparison case for the 8th WMO Cloud Modeling Workshop

 - July 23-27, 2012, the week *before* ICCP, in Warsaw, Poland

 - co-chairs Wojciech Grabowski and Andreas Muhlbauer

 - for details see: http://www.atmos.washington.edu/~andreasm/workshop2012/index.html