Impact of cloud microphysics on stratiform precipitation associated with squall lines

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Motivation

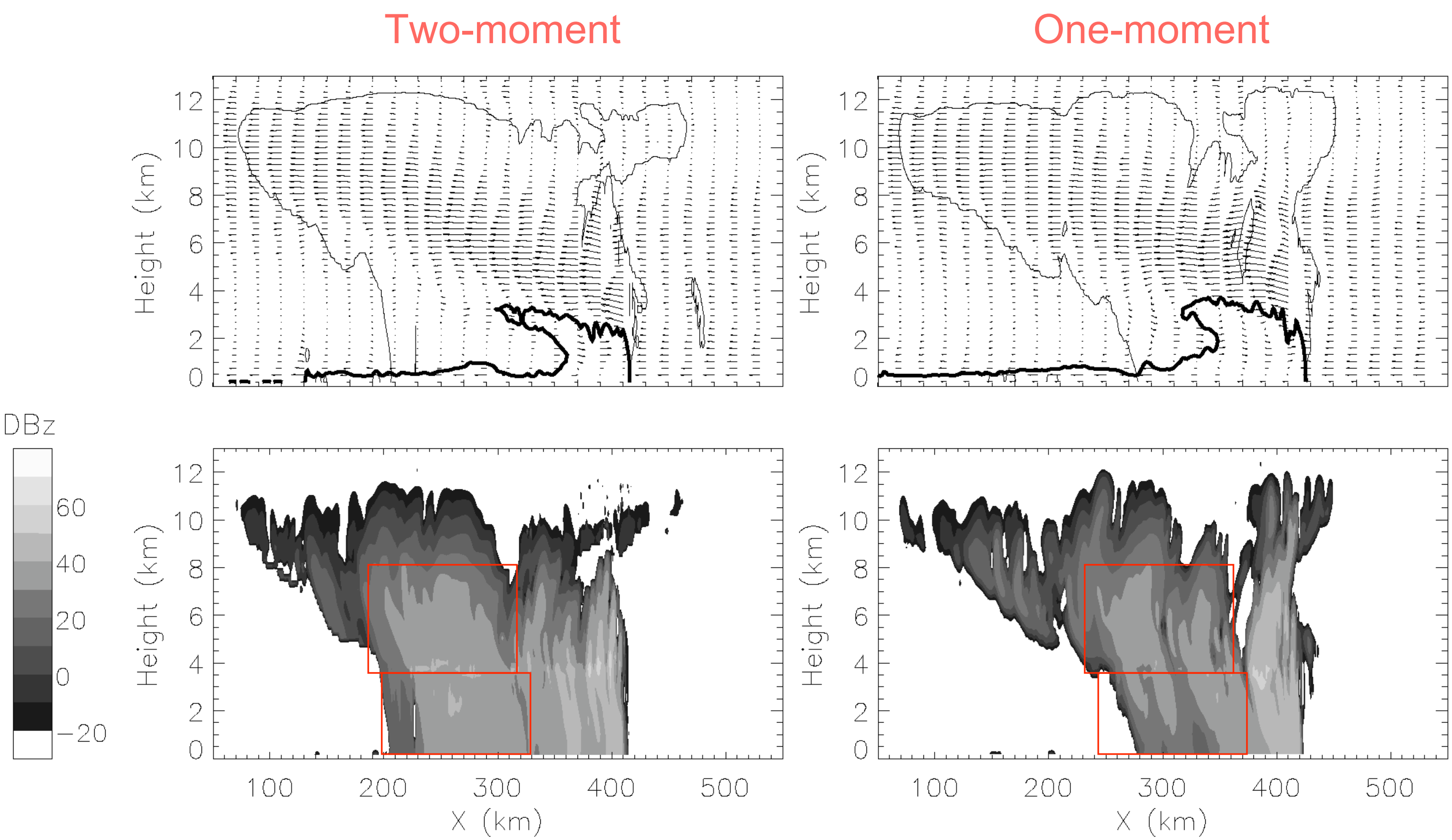
- Poor simulation of general squall line structure, i.e., leading edge convection and trailing stratiform precipitation (e.g., Tao et al. 2007)
- Impact of stratiform precip on latent heating, cold pool formation, propagation speed, convective intensity, etc.

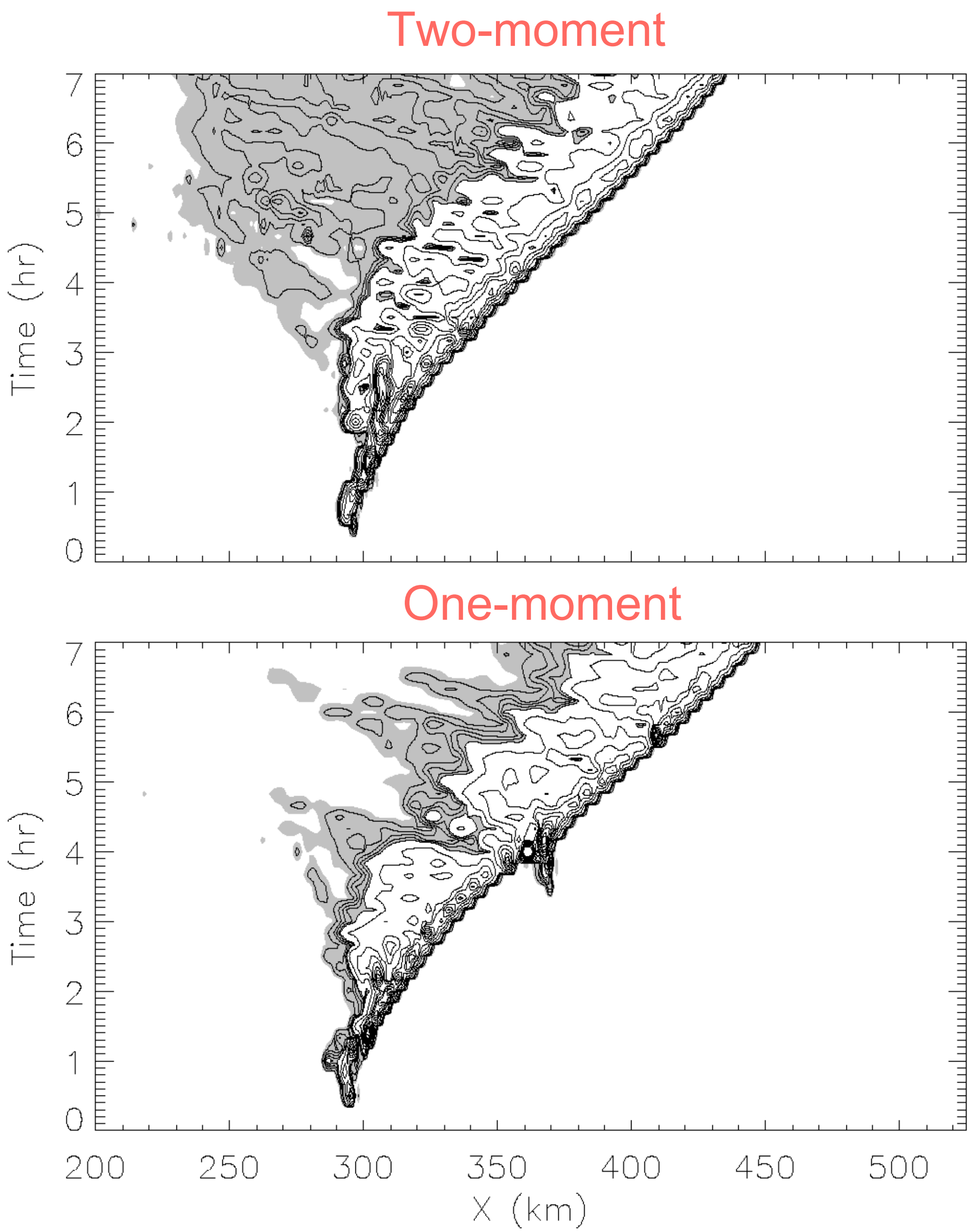
Experimental Design

- Idealized 7 hr 2D squall line simulations using WRF (dx = 1 km), Weisman-Klemp sounding, moderate ambient low-level wind shear

- Focus is impact of 1-moment versus 2-moment microphysics for rain, snow, graupel (i.e., prediction of N and q for rain, snow, graupel, vs. only q)

- Much more widespread trailing stratiform region using two-moment scheme




Two-moment
One-moment
Time (hr)
X (km)
0
1
2
3
4
5
6
7
200
250
300
350
400
450
500

Rain rate

- What is the main cause of this difference?
- Rain microphysics is the key!

- In both schemes, rain size distribution is treated by:

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

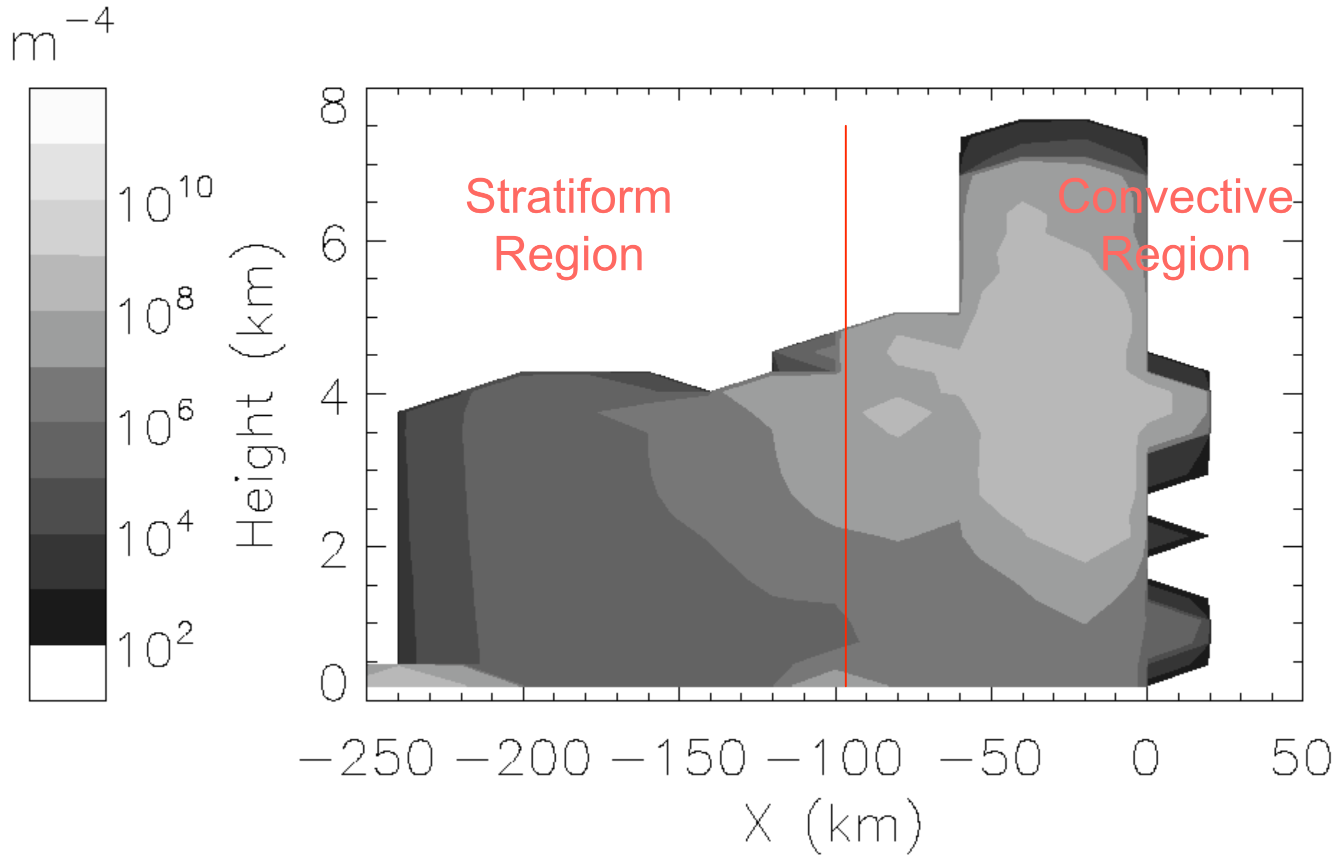
- In one-moment scheme, N_0 rain is fixed at 10^7 m^{-4}.
- In two-moment scheme, N_0 freely evolves with predicted N and q.

- Predicting rain q and N in two-moment scheme has two major impacts relative to the one-moment scheme:

I. Smaller N_0, larger mean drop size in stratiform region → reduced evaporation.

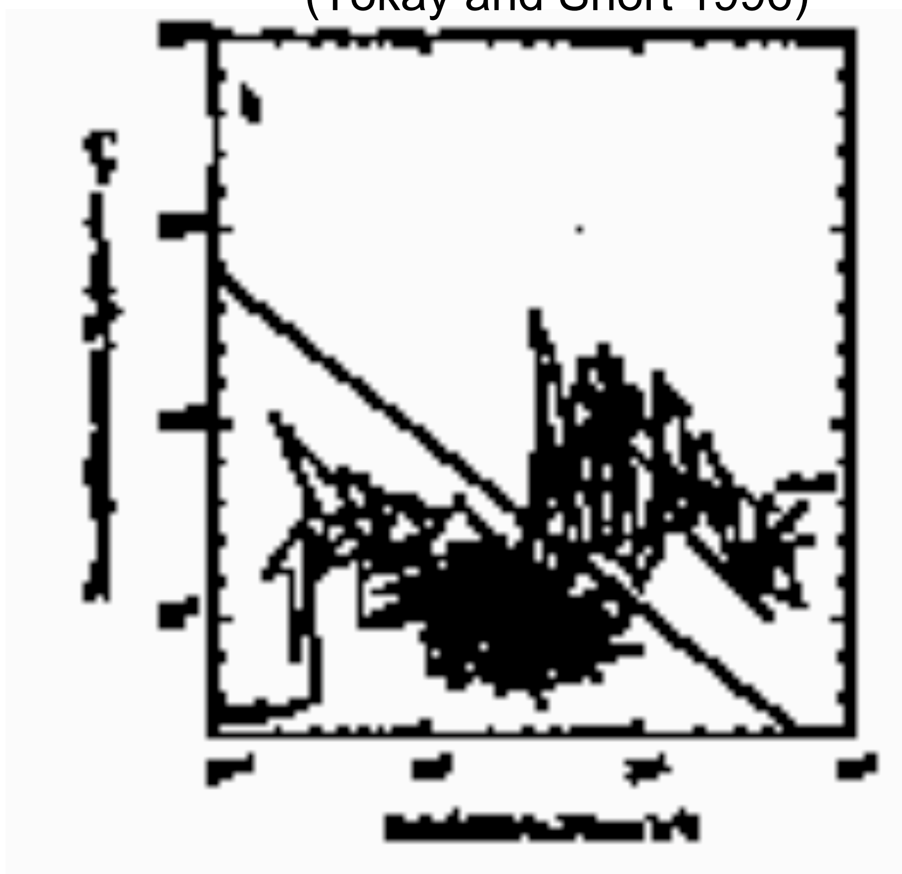
II. Larger N_0, smaller mean drop size in convective region → increased evaporation, reduced updraft intensity, increased detrainment of buoyancy at mid-levels, stronger mesoscale updraft in stratiform region, faster ice growth rates

Modeled N_0 for rain using two-moment scheme

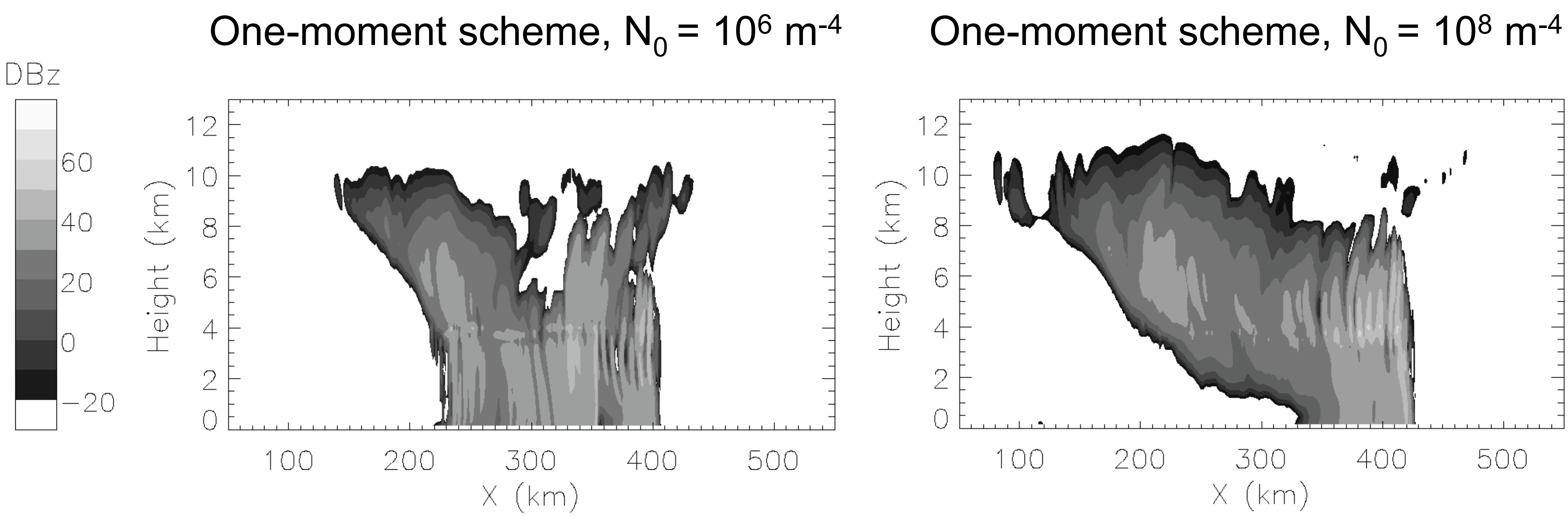


- Is this difference in modeled rain N_0 between stratiform and convective regions observed? Yes!

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



- Key point is that no single value of constant N_0 in the one-moment scheme can reproduce results of two-moment scheme.



Next Steps

- Simulation of real 3D squall line cases, comparison with obs and bin model as part of WMO Cloud Modeling Workshop intercomparison

- Impact of new ice microphysics (implement Morrison and Grabowski, 2008)