P.2.15 TORNADOGENESIS AND TORNADOGENESIS FAILURE IN SIMULATED SUPERCELLS

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1. INTRODUCTION

Recently, Naylor and Gilmore (2014) found several noticeable differences in the evolutions of simulated tornadic and nontornadic supercells. Using backwards-integrated trajectories, they found that descending parcels entering the near-surface circulation in the tornado producing supercells (1) experienced more negative vertical vorticity generation via the tilting of horizontal vorticity, (2) encountered stronger downward velocities, and (3) produced more baroclinically generated horizontal vorticity than descending air parcels in the nontornadic simulations.

One of the more intriguing results of Naylor and Gilmore (2014) was that the cold pools in the tornadic simulations tended to have larger deficits of pseudoequivalent potential temperature (θ_{ep}) at the time of tornadogenesis than did the nontornadic simulations at the time of tornadogenesis failure (Fig. 1). This result is seemingly in contrast with several notable observational (e.g., Markowski et al. 2002) and idealized modeling studies (e.g., Snook and Xue 2008), which have suggested that weaker cold pools should be more favorable for the development of violent tornadoes.

The goal of this current work is to revisit the simulations of Naylor and Gilmore (2014) and determine if modulating the cold pools of the simulated supercells (via changes to the microphysics parameterization) produces a consistent change in the intensity and/or longevity of tornado-like vortices.

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2. METHODOLOGY

All simulations were completed using version 14 of Cloud Model 1 (CM1; Bryan and Fritsch 2002). Isotropic grid spacing of 100 m was used, and the computational domain was 120x120 km in the horizontal and 16 km in the vertical. The lower boundary was free slip. Simulations were initialized with different RUC-2 soundings associated with significantly tornadic supercells (Thompson et al. 2003) Convection was initiated using the updraft nudging technique of Naylor and Gilmore (2012). For a more detailed description of the methodology, refer to Naylor and Gilmore (2014).

Two different microphysics parameterizations were used: the single-moment LFO parameterization and the double-moment Morrison parameterization. Previous studies have shown that double-moment microphysics parameterizations produce weaker cold pools compared to single-moment schemes by reducing the amount of evaporation in downdrafts [e.g., Dawson et al. 2010].

Cold pool strength was quantified via virtual potential temperature perturbation (θ'_v) at the lowest model level. Herein, θ'_v is defined as

$$\theta'_v = \theta_v - \overline{\theta}_v = \theta\left(1+0.608q_v\right) - \overline{\theta}\left(1+0.608\overline{q}_v\right),$$

where θ is potential temperature, q_v is the water vapor mixing ratio, and overbars denote base-state values.

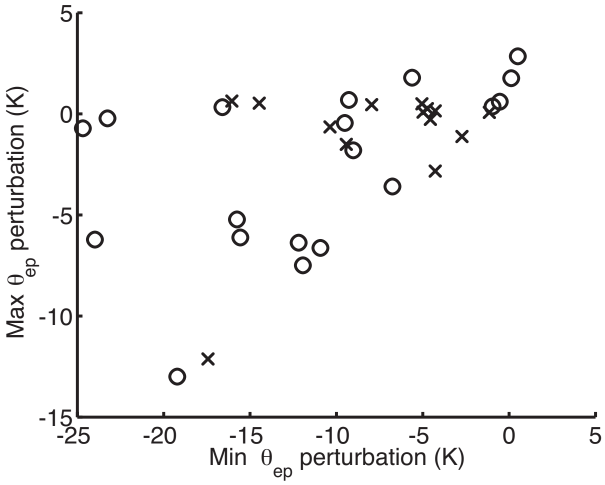

Figure 1. Maximum and minimum perturbations of pseudoequivalent potential temperature (θ_{ep}) within 1 km of the surface circulation from the tornadic (o's) and nontornadic (x's) simulations. Perturbations are relative to the surface value in the base state environment. From Naylor and Gilmore (2014).

Note that θ'_v is being used in place of θ'_{ep} (as in Naylor and Gilmore 2014) because θ'_v is a more direct measure of parcel buoyancy—which is believed to be the most physically relevant quantity. However, qualitatively similar results are achieved regardless of whether cold pool properties are quantified using θ'_{ep} or θ'_v.

3. RESULTS

Table 1 shows a summary of the results from simulations initialized with six different RUC-2 soundings. Each case was simulated twice: once with single-moment LFO microphysics, and once with double-moment Morrison microphysics.

All six simulations using LFO microphysics produced tornado-like vortices. Tornado duration ranged from 2 min to 28 min in these simulations, with maximum pressure drops ranging from ~10 mb to 30 mb in the tornadic vortices.

In contrast, only four of the six simulations using Morrison microphysics produced tornadoes. Two of these simulations produced weaker and shorter-lived tornadoes compared to the analogous LFO simulations (Table 1; Cases B and D), while the other two simulations produced stronger, longer-lived tornadoes (Table 1; Cases C and F). The two Morrison simulations with stronger and longer-lived tornadoes also produced stronger cold pools compared to the analogous LFO simulations. Thus, in all six cases, the simulation that produced the strongest cold pool (as measured via average θ'_v within the immediate vicinity of the near surface circulation) produced the strongest, longest-lived tornado.

4. SUMMARY AND CONCLUSIONS

This work investigated the effect of microphysics parameterization on the intensity and longevity of tornado-like vortices in idealized simulations of supercells. Six of the tornadic cases from Naylor and Gilmore (2014) were chosen for resimulation with Morrison double-moment microphysics. The results from these simulations were then compared to the results of the original simulations of Naylor and Gilmore (2014) which used single-moment LFO microphysics.

Simulations with Morrison microphysics produced supercells with weaker cold pools (compared to simulations using single-moment microphysics) in four of the six cases analyzed. Of these four, two produced weaker and shorter-lived tornadoes compared to the analogous LFO simulations, and two failed to produce tornadoes at all. Two of the cases did in fact produce stronger, longer-lived tornadoes with Morrison microphysics, however these were cases in which the Morrison simulations yielded stronger cold pools.

In summary, for each of the six cases analyzed, tornado duration and intensity decreased when the cold pool was weakened. Clearly, much additional analysis is needed to fully interpret these results. Nevertheless, this current study should serve as an indication that future work is needed to further explore the relationship between tornadogenesis, cold pool properties, and microphysics.

5. ACKNOWLEDGEMENTS

Much of this work was supported by NSF grant ASG-0843269. Computational Resources were provided through XSEDE allocations TG-ATM100048 and TG-ATM130011. Additional support was provided by NorthWest Research Associates.

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Table 1. Overview of simulations initialized with six different significantly tornadic RUC-2 proximity soundings. θ'_v was averaged over a 1 km x 1 km box centered on the low-level circulation at (or near) the time of tornadogenesis or tornadogenesis failure. The pressure drop (p_{drop}) is the minimum surface pressure perturbation associated with the tornado. Missing values for p_{drop} indicates the simulation did not produce a tornado.

	LFO Simulations				*Morrison Simulations*			
	Tor duration	p_{drop} (mb)	avg θ_v' (K)	min θ_v' (K)	Tor duration	p_{drop} (mb)	avg θ_v' (K)	min θ_v' (K)
Case A	2 min	10.61	-9.99	-13.46	0 min	-	-7.12	-7.64
Case B	5 min	21.07	-1.98	-3.71	4.5 min	17.83	-1.56	-4.75
Case C	4.5 min	11.51	-0.59	-1.97	6 min	24.07	-1.9	-3.29
Case D	17 min	25.99	-3.46	-5.75	10 min	13.44	-0.78	-4.61
Case E	10 min	19.23	-5.84	-11.78	0 min	-	-1.05	-4.51
Case F	28 min	30.21	-0.97	-2.03	60 min	47.67	-1.94	-3.15

a.) LFO microphysics **b.) Morrison microphysics**

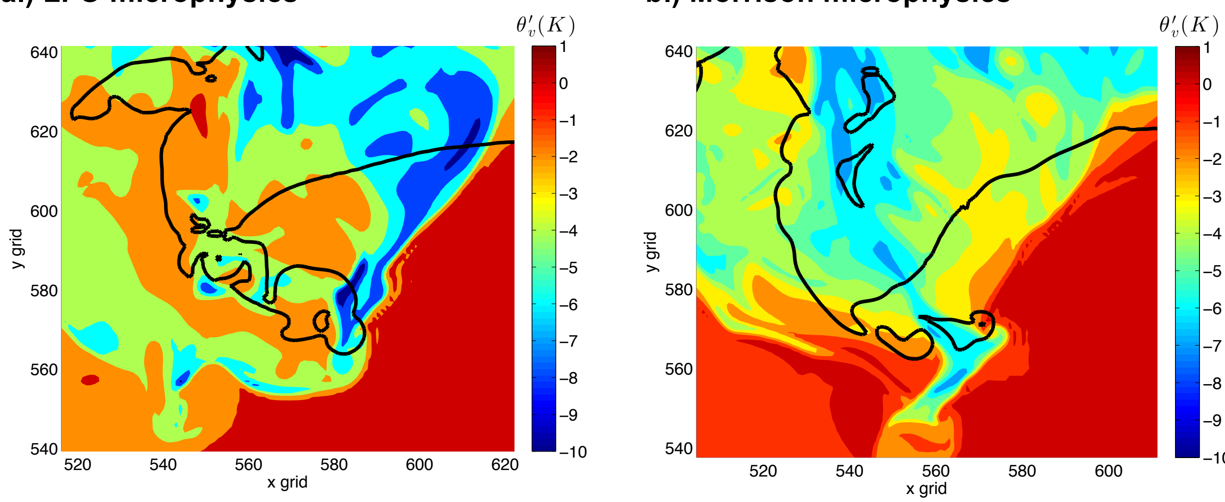

Figure 2. Near-surface virtual potential temperature (θ_v) deficits (relative to the base-state environment) of two simulations using the same initial RUC-2 sounding (Case D in Table 1). The simulation on the left used LFO microphysics, and the simulation on the right used Morrison microphysics. The simulation with LFO microphysics produced a 17 min tornado, with a maximum pressure drop of 25.99 mb, while the simulation with Morrison microphysics produced a 10 min tornado with a maximum pressure drop of 13.44 mb.

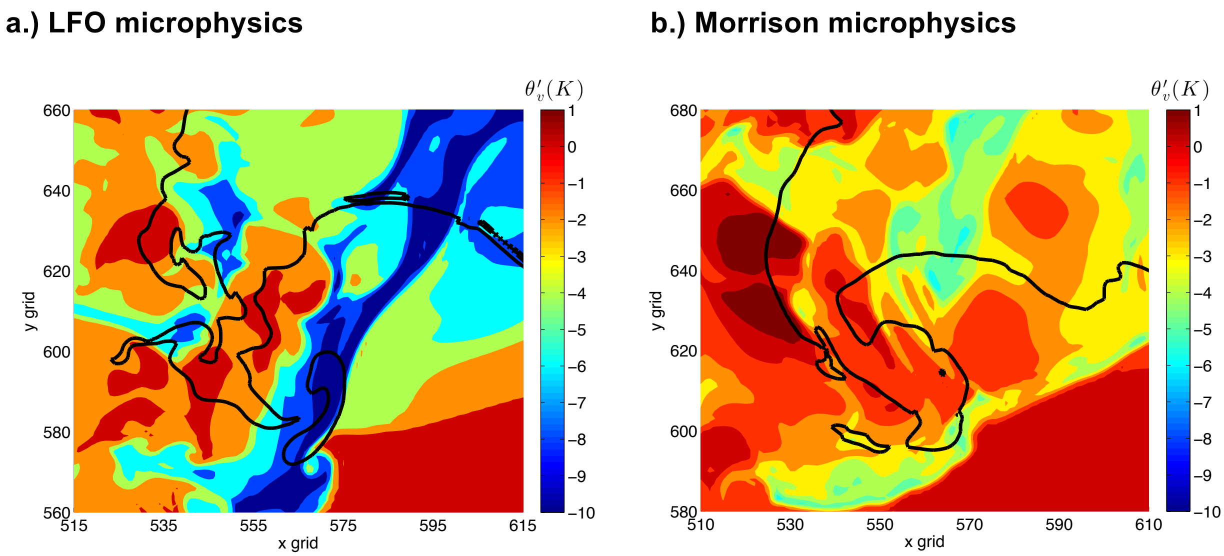

Figure 3. Same as Figure 2, except for Case E.