

Referee 2

This manuscript presents results from 1 km WRF model simulations of supercell storms moving across an urban area. Various experiments are conducted for different urban sizes and characteristics. Eleven member ensembles are used for each experiment and results compared with an ensemble that has no urban area. Convection initiation is produced using a warm bubble in each ensemble member. Results indicate that the urban area leads to a mean weakening the supercell, with larger urban areas producing more weakening for most variables. The results are interesting, but I have a number of significant concerns that merit attention and should be answered.

We thank the referee for the careful review of our manuscript. A response to all the concerns is provided hereafter.

1) The plot of normalized mean UH (Figure 5) shows that the number of ensemble members changes across the different urban sizes. For Figure 5a there are 8 members for an urban diameter of 15 km and 7 members for an urban diameter of 60 km. Some urban diameters have as few as 5 members displayed on the plot.

It is earlier stated that every experiment has eleven ensemble members, indicating that only some of the simulated supercells are actually reaching the urban area before they dissipate. This large variability in the number of the members that are used in the analysis is a significant concern. This variability influences the calculations of ensemble mean UH from the urban runs (Figures 6b-f) which show large fluctuations from the beginning of the storm track and could be due in part to having fewer members. It also will influence the calculations of mean slope shown in Table 9. The no_urban ensemble has the most consistent mean UH track of the ensembles; other tracks show greater variation in mean UH along the track. If roughly half the supercells are dissipating before reaching the city within such a favorable environment, then this behavior raises questions about the experimental design. For example, Figure 7 shows that the developing supercell dissipates entirely before reaching the city (and doesn't appear to produce a left-moving storm) while Figure 10 shows only small differences in environmental conditions in this area of storm demise that is well outside the zone of perturbations associated with the urban areas shown in Figures 12-15. It is important to understand what is causing so many storms to dissipate within such a favorable environment prior to reaching the city, as this behavior clearly influences (and indeed may dominate) your results.

The number of ensemble members decreases because the storm dissipates. In fact, the experiment with the smallest number of ensemble members corresponds to the largest city, where urban-induced environmental perturbations are more pronounced. However, we agree with the referee that it is an important point to observe that, in some ensemble

members, dissipation occurs well before the storm reaches the urban plume. Following the reviewer's comment, we investigated this aspect in more detail.

First, we noted that in the control run, the storm does not dissipate, even in experiments with a 30 km city. Examining the difference in MU CAPE between ensemble member 3, where the storm also does not dissipate, and the control runs at 4 pm (the same time step as in Fig. 14) for the no-urban experiment, an increase in CAPE of up to 80 J/kg is observed (Fig. R4). In contrast, the same comparison between the control run and ensemble member 0, where the storm dissipates immediately after the bubble is released, shows lower MU CAPE values, reaching up to -150 J/kg (Fig. R5).

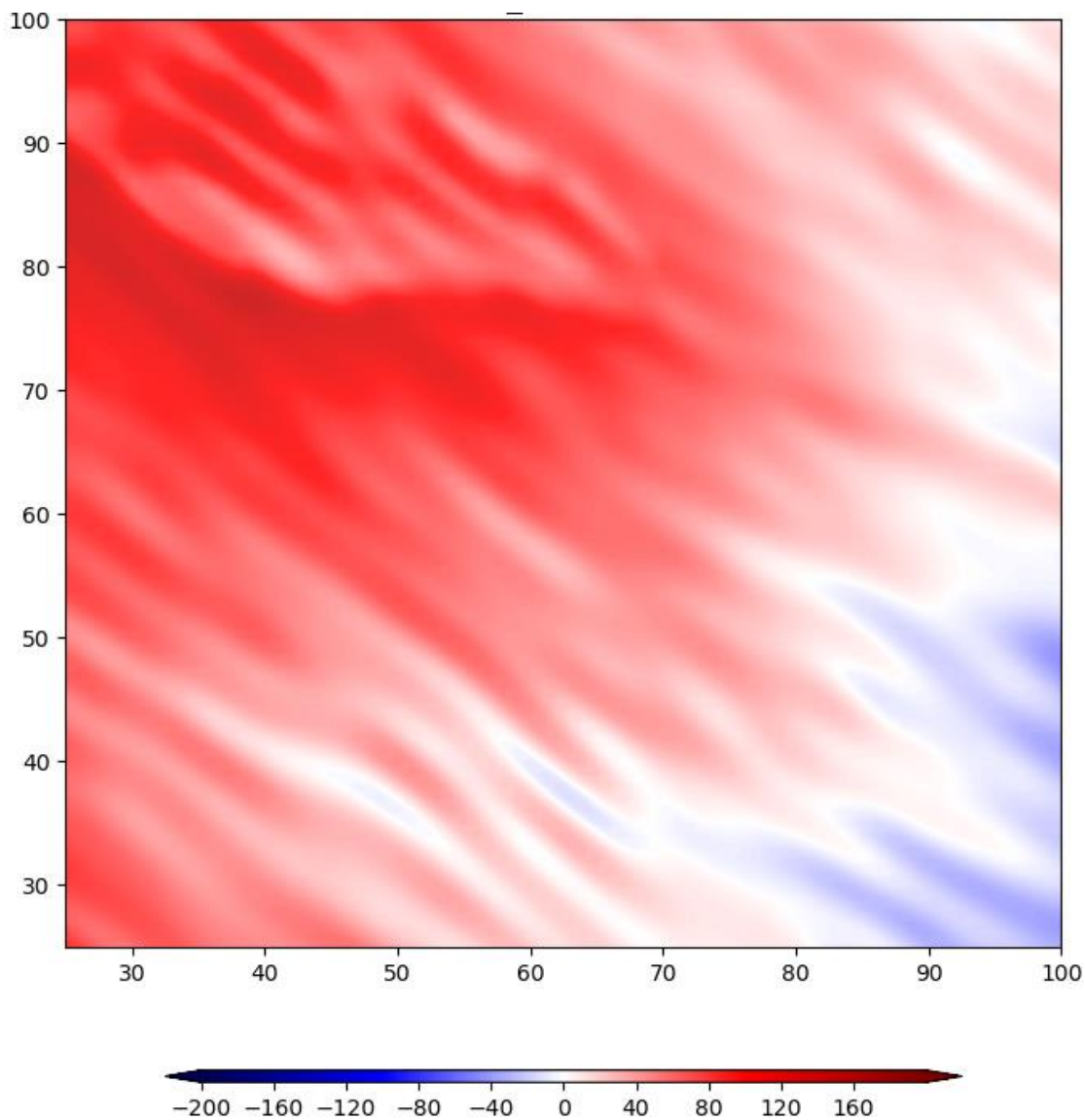


Fig R4: MU CAPE difference between ensemble member 3 and the control run in the no urban experiment at 4 pm.

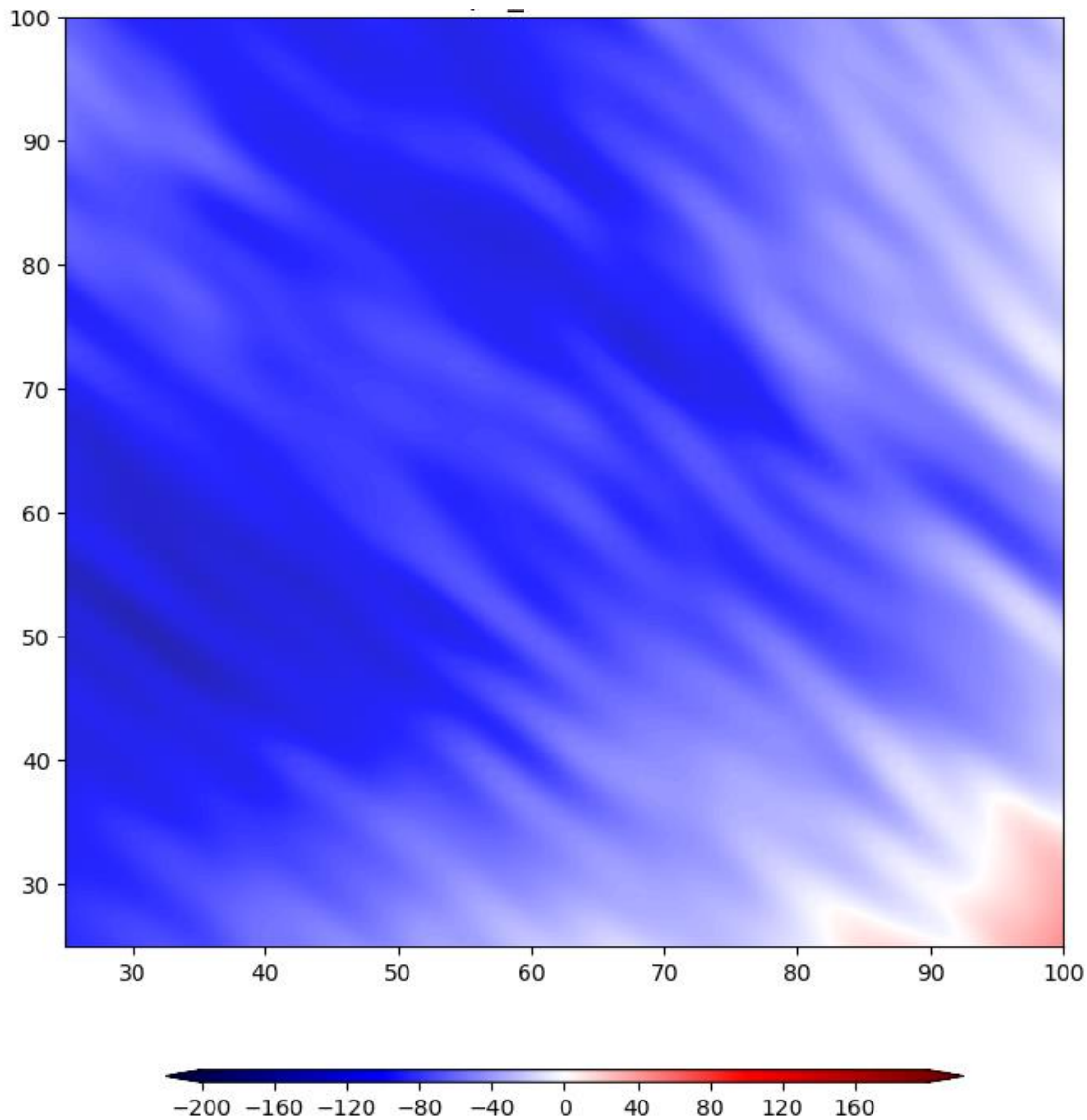


Fig R5: As in Fig. 3, but the difference between ensemble member 0 and the control run is shown.

Thus, in ensemble member 0 (and similarly in other ensemble members exhibiting early dissipation), the environment is less supportive of storm maintenance. Nevertheless, a storm is simulated in the no-urban experiment, as well as in many other experiments with a relatively small city. Therefore, the storm dissipation is still driven by the presence of the city, even though the initially less favorable environment in some ensemble members facilitates it. This is the key point: what is being observed is ultimately an effect of the city.

Looking back at the initial design of our study, we would likely have selected a slightly different thermodynamic profile, with less dry air above the planetary boundary layer (PBL). We found it challenging to reproduce an idealized storm with the radiation scheme activated without triggering spurious convection across the domain. The chosen initial profile represents a compromise that allows us to achieve the desired control simulation in the no-urban case. We believe it remains representative of a typical severe-weather environment.

A natural follow-up question is why early dissipation occurs upstream of the city. A detailed comparison between the 30 km urban experiment and the no-urban case for ensemble member 0 (in which the storm dissipates) reveals some differences at model level 25, corresponding to the top of the PBL (approximately 1.8 km AGL). Around the storm initiation point (grid point 40,40), the potential temperature is slightly higher (+0.2 K, Fig. R6), the equivalent potential temperature is slightly lower (−0.5 K, Fig. R7), and a weak downward motion (−0.2 m s^{−1}, Fig. 8) is present. The latter appears to be associated with a gravity-wave pattern generated by the city.

These urban-induced gravity waves are qualitatively similar to those reported by Baik et al. (2008) in their idealized simulations of urban dry convection. The waves seem to amplify perturbations that are generally present across the region west of the city at this level. The decrease in moisture (reflected in the reduction of θ_e) and the increase in temperature are consistent with the 850 hPa fields shown in the supplemental material (Fig. S8). Notably, this pattern is observed across all ensemble members, regardless of whether the storm dissipates.

Overall, conditions west of the city near the top of the PBL appear to exhibit slightly stronger inhibition (higher temperature) and enhanced entrainment (lower moisture and θ_e). These factors may explain the observed storm dissipation. Although these environmental modifications are relatively weak, they appear sufficient to cause early storm decay. Importantly, we do not identify any anomalous behavior in the simulations that would suggest fundamental numerical issues.

We plan to mention this additional analysis in the manuscript because it might be a concern also for other readers.

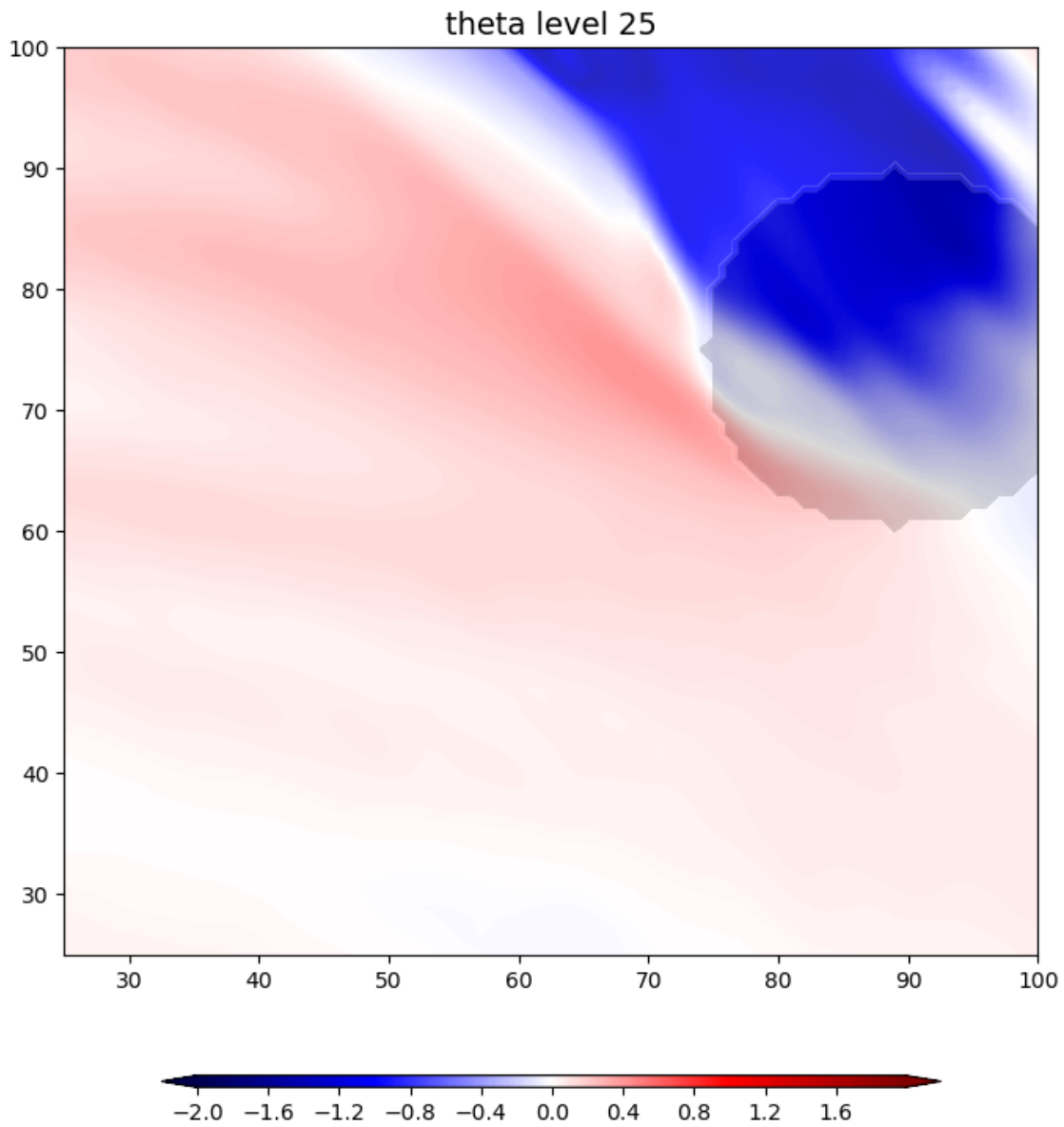


Fig R6: differences of potential temperature between the 30 km experiment and the no urban case for ensemble member 0 at model level 25.

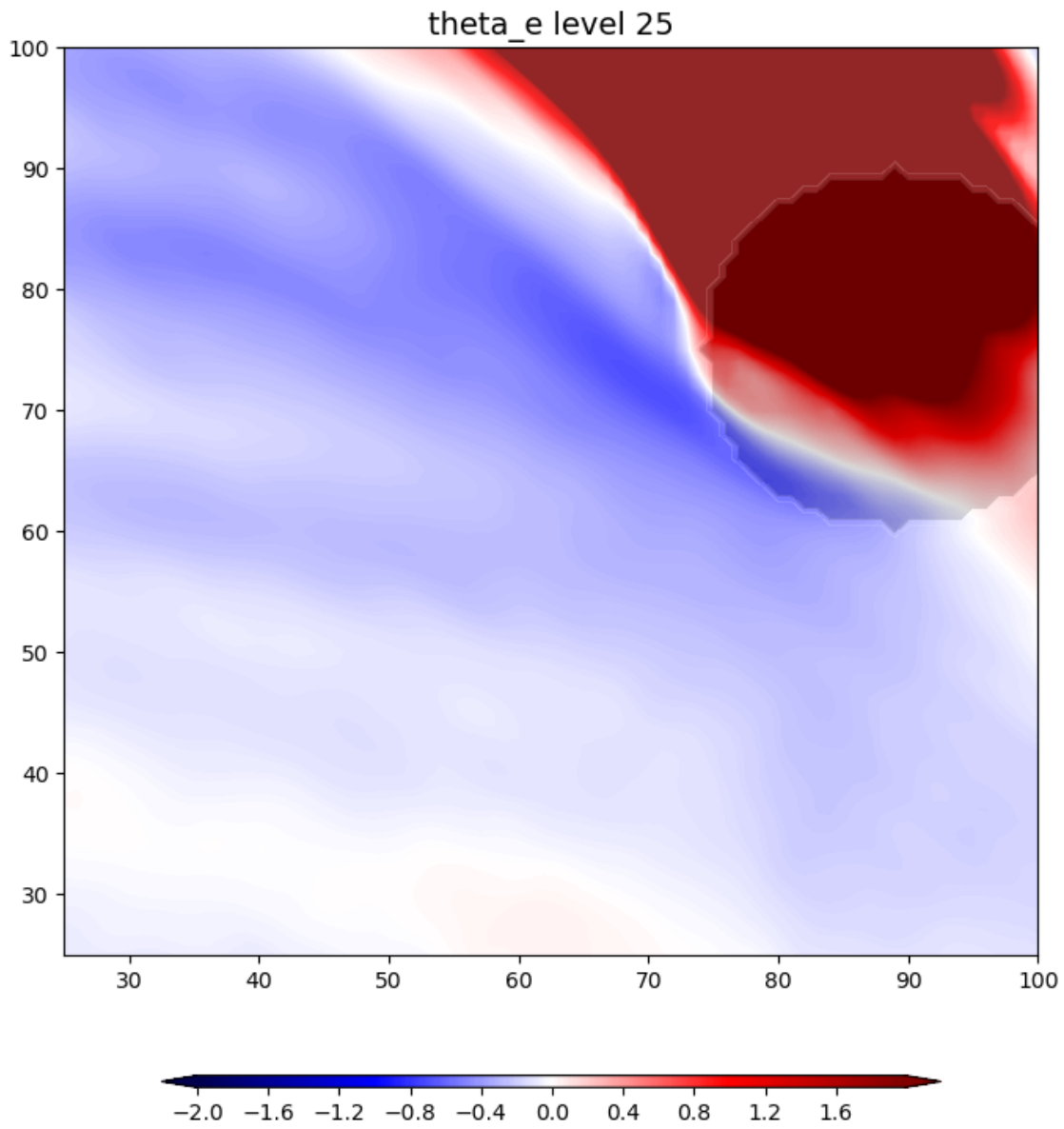


Fig. R7: as in Fig. R5 but differences in equivalent potential temperature are shown.

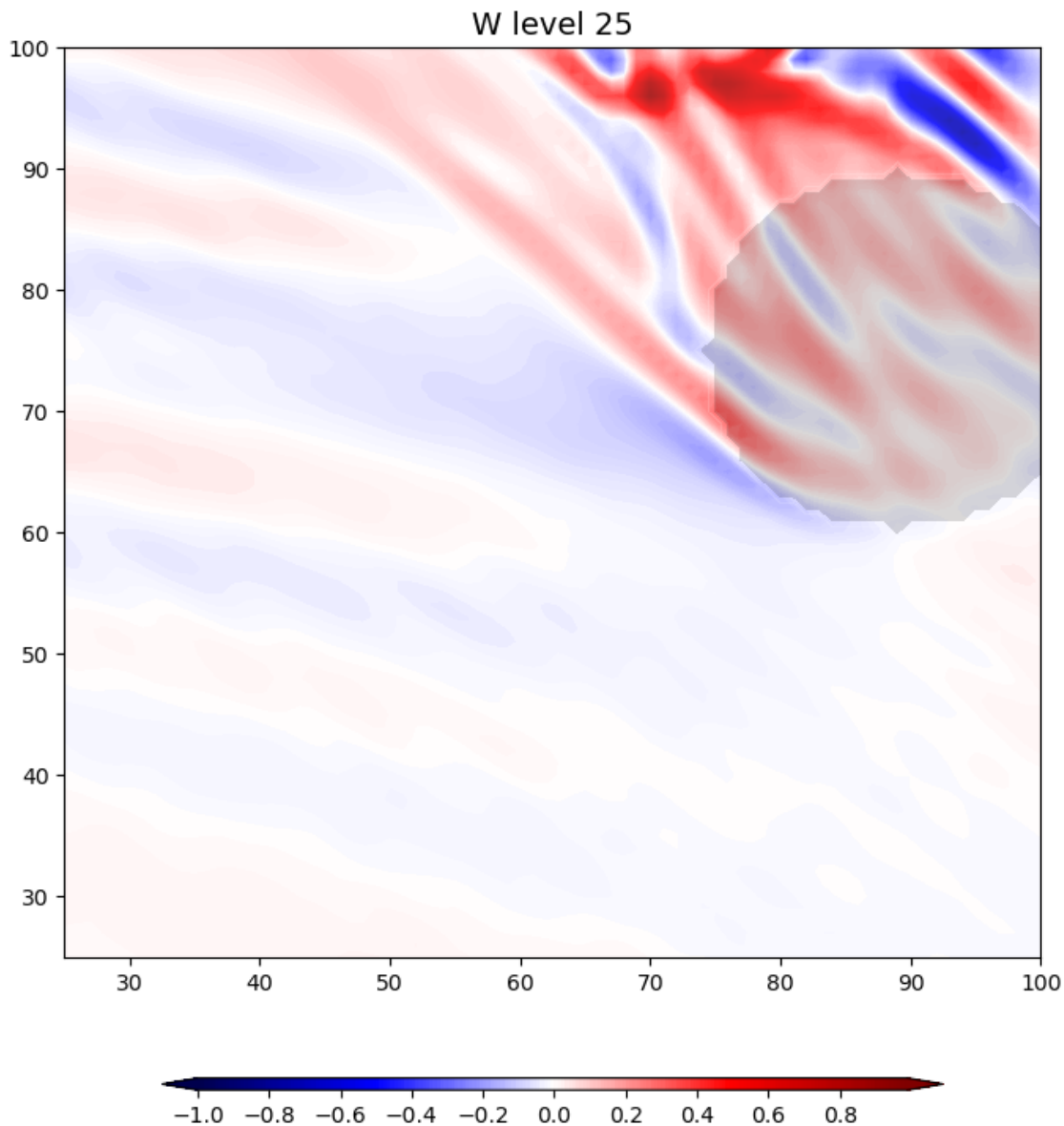


Fig: R8: as in Fig. R6 but differences in vertical velocity are shown.

Baik, J. J., Kim, Y. H., & Chun, H. Y. (2001). Dry and moist convection forced by an urban heat island. *Journal of applied meteorology*, 40(8), 1462-1475.

2) Your results show that many supercell characteristics decrease as city size increases, but the results also have large spread and some members intensify as city size increases. A deeper dive is needed to understand this behavior.

Results shown in the supplemental materials indicate that the supercell tracks from the ensemble members deviate from each other sufficiently to pass over different parts of the urban area in the no_urban run. Similar tracks are expected for the urban runs, such that some storms may pass along the southern urban edge, while others may pass along the northern urban edge. Results from Reeves and Stensrud (2018) indicate that the impact of

the urban area on the supercell is influenced by the location of the urban area relative to the storm.

Since the figures of normalized UH as a function of urban area size show both enhanced UH and reduced UH, the question of where the urban area is located relative to the storms for these simulations is important to address. One way to explore this question is to look at a few of the members with the largest normalized UH and compare with the same number of members with the lowest normalized UH for a fixed urban size. Plot the tracks, explore the supercell characteristics, and determine if these storms are passing consistently across different parts of the urban area.

Supercells do not deviate sufficiently to traverse portions of the urban area characterized by substantial environmental differences. This can be clearly seen in Fig. R9, where supercell tracks from numerical experiments with a 30 km radius are overlaid on the CAPE differences (the same plot of Fig. 13a). In Reames and Stensrud (2018), the authors noted a strong sensitivity of supercell dynamics to urban area location when the storm is displaced by 50–100 km from its initial position. In our case, however, the tracks differ by only about 5 km over the urban area. Therefore, we do not expect this to significantly affect supercell evolution. It may introduce some noise, but this is inherent to the ensemble approach and is, in fact, intentional to strengthen the robustness of the final outcome. Despite the slightly different supercell tracks, the storm consistently exhibits overall weakening.

The increase in normalized mean UH noted in Fig. 5 is an effect of the stochastic variability introduced by the ensemble. In Fig. R10, the same plot as Fig. 5a is shown without normalization relative to the no_urban case. The overall weakening of the storm becomes even more evident in this representation. As can be seen, ensemble members that show an increase in mean UH are associated with anomalously low UH values in the no_urban case. This point was previously mentioned in footnote 3 on page 15. We prefer to use normalized variables because they facilitate comparison across different variables. Additionally, this approach allows us to focus on the slope of the linear fit while neglecting the intercept, which varies considerably among ensemble members due to differences in mean UH values.

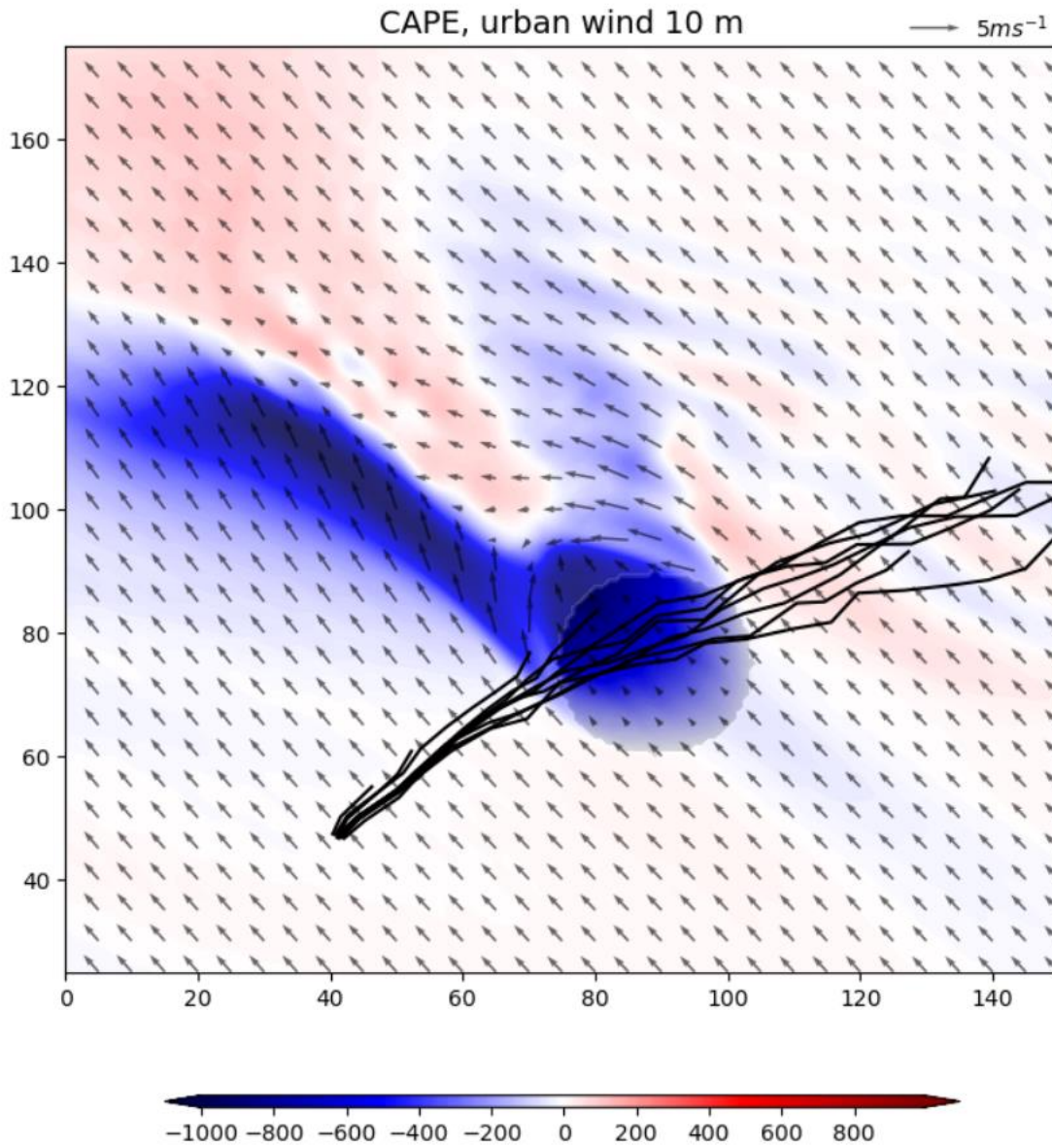
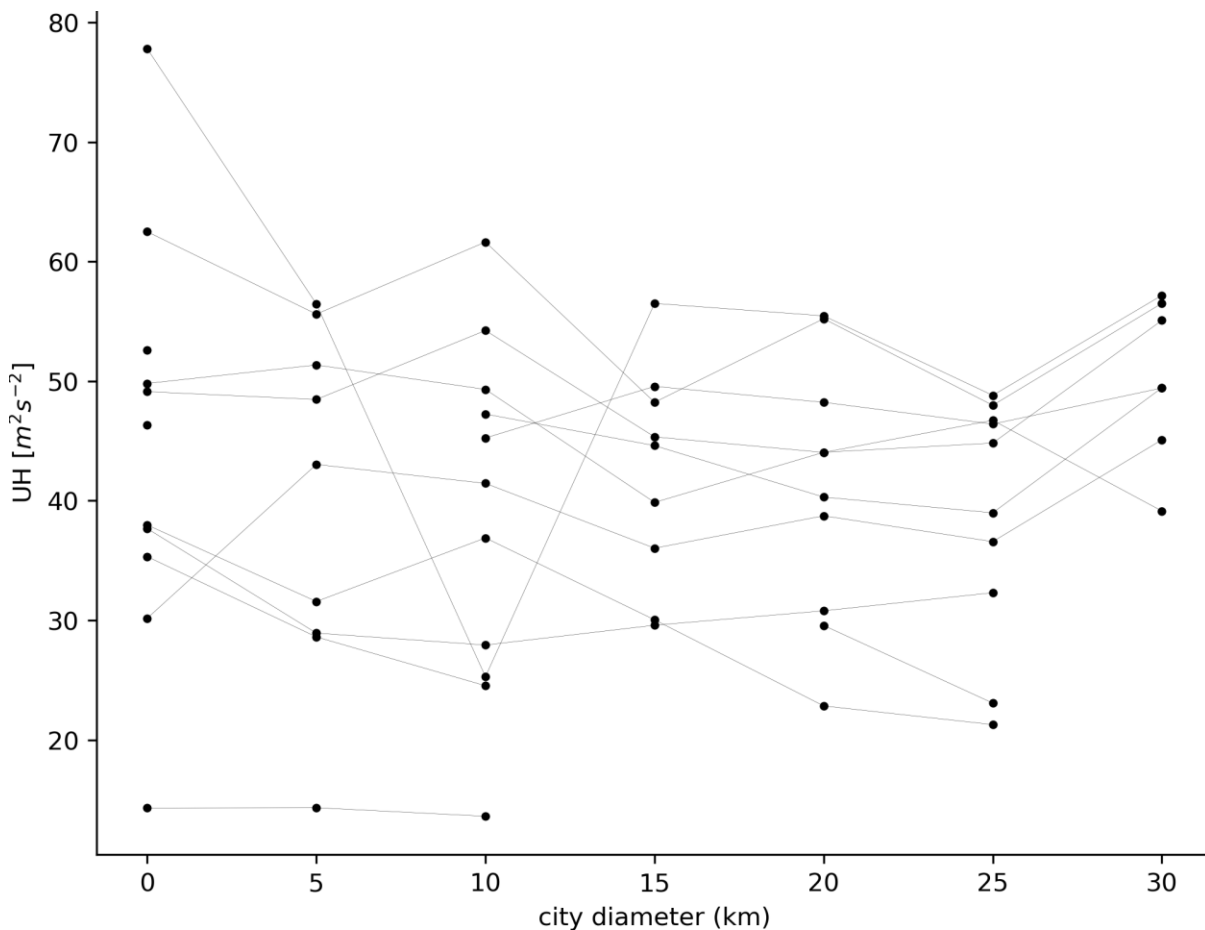


Fig. R9: mean ensemble difference between the 30 km simulations and the no_urban case. Wind at 10 m AGL in the urban case is plotted. The black lines are the tracked storms in the 30km run.



R10: As Fig. 5a, but UH is not normalized.

3) The control no_urban ensemble plot of cumulative ensemble mean UH (Figure 6a) shows a lowering/break of mean UH over the city location that is specified. This suggests that the simulated supercells are undergoing some transition at this point. Thus, all the supercell storms likely all pass over the urban area at a time when the storm behavior in the control ensemble is arguably most sensitive to the environment, as the storm is in transition. This needs to be mentioned and discussed, as it could influence the results.

We plan to highlight this in the discussion. However, we do not expect it to significantly affect our results. The only environmental differences among the sensitivity experiments are those induced by urban effects.

4) The simulated sounding at storm initiation (4 pm LST) shows that the surface winds are quite weak at this time (Figure 1b). This will greatly reduce the impact of friction owing to buildings on the flow. This deserves greater attention in the discussion.

Agreed, this will be emphasized in the revised manuscript.

5) It is also important to mention that the no_urban run shows SBCAPE, 0-3 SRH, and 0-1 SRH all decreasing by storm initiation time. Thus, the supercells are moving into a less favorable environment as they approach the city, which could influence your results.

Agreed, this point will be discussed in more detail in a revised manuscript. However, the environment is kept constant across the sensitivity experiments; therefore, it should not significantly affect comparisons among them.

6) Details are missing and need to be added for completeness and reproducibility.

We agree, we plan to add these details in the updated version of the manuscript.

These include:

Soil moisture in urban and cropland regions. It's 0.34 in both regions. The urban soil moisture is then modified by BEP-BEM.

Depth used in UH calculation (2-5 km AGL?) Yes, it's the 2-5 km layer.

How mean UH is calculated (over what area? How determined?) It's the mean within the 8 km radius around the storm center.

Multiple figures show comparisons without a time stamp (Figures 11-14). You're right! Time step is 4 pm for all Figs. 11-14.

7) You state on lines 100-101 "the most accurate parameterization of urban processes in mesoscale modeling." This is an opinion, unless you have a reference to a study that clearly shows this. Please delete.

It's a widely recognized opinion, but we plan to remove it.