Referee Report

This manuscript investigates the sensitivity of convective cloud microphysics and precipitation to varying urban aerosol emissions using the COSMO-DCEP-MUSCAT model. The authors perform a series of emission-scaling experiments for two convective events over Leipzig and analyze the resulting changes in cloud microphysics, dynamics, and precipitation using trajectory analysis and ensemble simulations.

The topic is relevant and interesting. The systematic emission scaling is an interesting idea that has the potential to provide additional insight into aerosol-cloud interactions. However, I have significant concerns regarding the novelty of the study and the interpretation of the results (see the details in the comments below).

Major comments

1. The scientific novelty with respect to the author's previous publication should be more clearly justified.

The manuscript is closely related to the authors' previous paper (Keil et al., 2025), which already used the same model, the same two convective cases, the same trajectory analysis, the same ensemble approach, and reached essentially the same physical conclusions regarding the dependence of aerosol effects on meteorological conditions.

The principal addition of the present study is the systematic scaling of urban emissions and the resulting emission-response curves. While this is a useful sensitivity analysis, it is not clear that it provides fundamentally new scientific insight. The Introduction and Discussion should explicitly explain what scientific questions are addressed here that could not already be answered by the previous publication. At present, the manuscript reads primarily as an extension of the earlier work.

2. The trajectory averaging may obscure important cloud processes.

The moving-box analysis averages cloudy and cloud-free grid cells together, and the authors acknowledge that the resulting cloud droplet concentrations are much lower than the actual in-cloud values. This raises concerns because cloud microphysical responses are fundamentally in-cloud processes.

Including large cloud-free areas dampens the signal, mixes cloudy and environmental air, and complicates the physical interpretation. The authors should discuss why unconditional averaging is preferable and whether cloud-only averages lead to similar conclusions.

3. The proposed mechanism is plausible but not fully demonstrated.

The manuscript attributes enhanced precipitation to increased ice nucleation, enhanced latent heat release, stronger updrafts, and subsequent invigoration of ice-phase processes. However, this mechanism is inferred from simultaneous changes in several variables rather than demonstrated directly. No analysis of latent heating rates or individual microphysical process rates is presented. Consequently, the proposed mechanism remains suggestive rather than fully supported.

4. The interpretation of the threshold behavior deserves more caution.

The manuscript repeatedly argues that responses emerge only above emission scaling factors of roughly 100-500. However, thresholds in cloud models can arise from the parameterizations, activation schemes, saturation adjustment, and other model-specific factors.

The authors do not investigate whether the threshold is robust to alternative microphysics schemes, activation parameterizations, or model resolution. Therefore, the manuscript should avoid presenting this threshold as a physical atmospheric property. Instead, it should be described as a threshold within the current modeling framework.

Minor comments

1. The discussion of previous aerosol invigoration studies should be expanded to include the physical mechanisms proposed in those studies.
2. I would consider moving all or part of the results for the second case to the Supplementary Information to improve the readability of the manuscript.
3. The manuscript frequently uses qualitative expressions such as *remarkable*, *substantial*, and *strong*. Whenever possible, these should be replaced with quantitative statements.
4. Several grammatical issues remain throughout the manuscript and should be corrected during revision.

Recommendation

The manuscript addresses an important problem. However, the scientific advance beyond the authors' previous publication is currently not sufficiently convincing, and the interpretation of the extreme emission experiments requires a more careful discussion.