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Reply on RC3

Daniel Hernandez-Deckers et al.

Author comment on "Updraft dynamics and microphysics: on the added value of the cumulus thermal reference frame in simulations of aerosol–deep convection interactions" by Daniel Hernandez-Deckers et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-586-AC3, 2021

In the following we provide a point by point response to comments by Reviewer #3, where we quote in italics the original comments. We have numbered all comments in boldface, based on the reviewer number and comment number so that the different replies can be easily referred to within the text (e.g., R2C3 refers to comment number 3 from Reviewer #2).

"Review of "Updraft dynamics and microphysics: on the added value of the cumulus thermal reference frame in simulations of aerosol-deep convection interactions"

Model-based analysis of aerosol indirect effects, or other properties of convection in general, typically relies on some definition of an updraft. Often this is done by considering all cloudy points in a model with some threshold vertical velocity value. The authors here use object tracking code to follow individual thermals, offering this as an alternative to the cloudy grid points method. They use this method to investigate some simple aerosol indirect effects in simulations of deep convection. Generally the aerosol effects on the warm part of the storms are as expected, and are fairly consistent between the two methods, but some differences are seen in the upper levels that suggest the thermal tracking method could be a useful way to investigate processes in deep convection.

Overall I think the paper is interesting, novel, and sound, but I offer some comments and suggestions below to help improve and clarify the discussions."

We thank reviewer #3 for these useful comments and suggestions, which we reply to in the following text:

"Comments:

R3C1*: It seems to me that the authors overstate the importance of their method compared to the traditional approach. There is no "correct" answer in how to do the analysis. Both methods may prove useful for examining different characteristics or different types or regions of storms. It's especially concerning to me that the authors concentrate on the differences in the upper levels, yet this study doesn't at all investigate the ice phase. It's difficult to conclude anything about microphysics in the upper levels of a storm if only cloud and rain are included in the analysis. This merits some mention at* *least. What implications might the differences between these two approaches offer when examining the ice phase?"*

We agree that we may have overstated the importance of the thermal framework, and refer to the general comment from reviewer #2 (R2GC), where we deal with this issue. Regarding the differences found in the upper levels, we agree that since we cannot really investigate the ice phase in this study, it is not possible to reach any conclusions regarding the microphysics. In fact, reviewer #2 suggested we investigate this further in comment R2C3.4, but we do not think this is warranted given the lack of robust ice microphysics processes in these simulations. Thus, here we can only describe certain dynamical responses we find at upper levels, but a detailed examination of the ice phase and its implications in terms of the two approaches must be left for a future study.

R3C2: *"Line 170: It doesn't seem consistent that there could be huge increases in nucleation rates, but not in latent heating. Is this being balanced by evaporation?"*

As now noted per response to comment R2C3.1 and in added text in lines 19, one possible explanation is that sustained supersaturation within thermal cores exists within the context of relatively unchanged vapor condensation rates, and confirming that hypothesis would motivate reporting diabatic heating source contributions in future work.

R3C3: *"Line 172: I think it would be better to show at least some of this information. I found myself wondering about the properties of the thermals and the variability of those properties at multiple times while reading, and was frustrated to keep seeing "not shown". "*

Reading again through this part of the text we notice that the way it is written indeed gives the impression that there are many important results that we do not show. However, this concerns 2 types of plots: first, thermal's composite lifetime, vertical distance traveled (DZ), and radius; and second, histograms of these quantities. Except for the thermal's lifetime, notice that Fig. 6 shows vertical profiles of these quantities, which provides even more detailed information than the simple average composites, since the latter would be averaged over vertical levels. So in fact, instead of saying "not shown", we can refer to these plots instead. We have modified this sentence at line 172 to (lines 205-207 in the track changes version): "We do not find any prominent trends in terms of the thermals' composite lifetime, vertical distance traveled (DZ) or radius (R). For R and DZ, this can be inferred from the vertical profiles shown in Figs. 6b,d."

Regarding the histograms, we include them here for the review process (Fig. R12), but we do not think that an additional figure in the manuscript is warranted. As mentioned in the paper, they do not show any important changes when aerosol concentrations are increased.

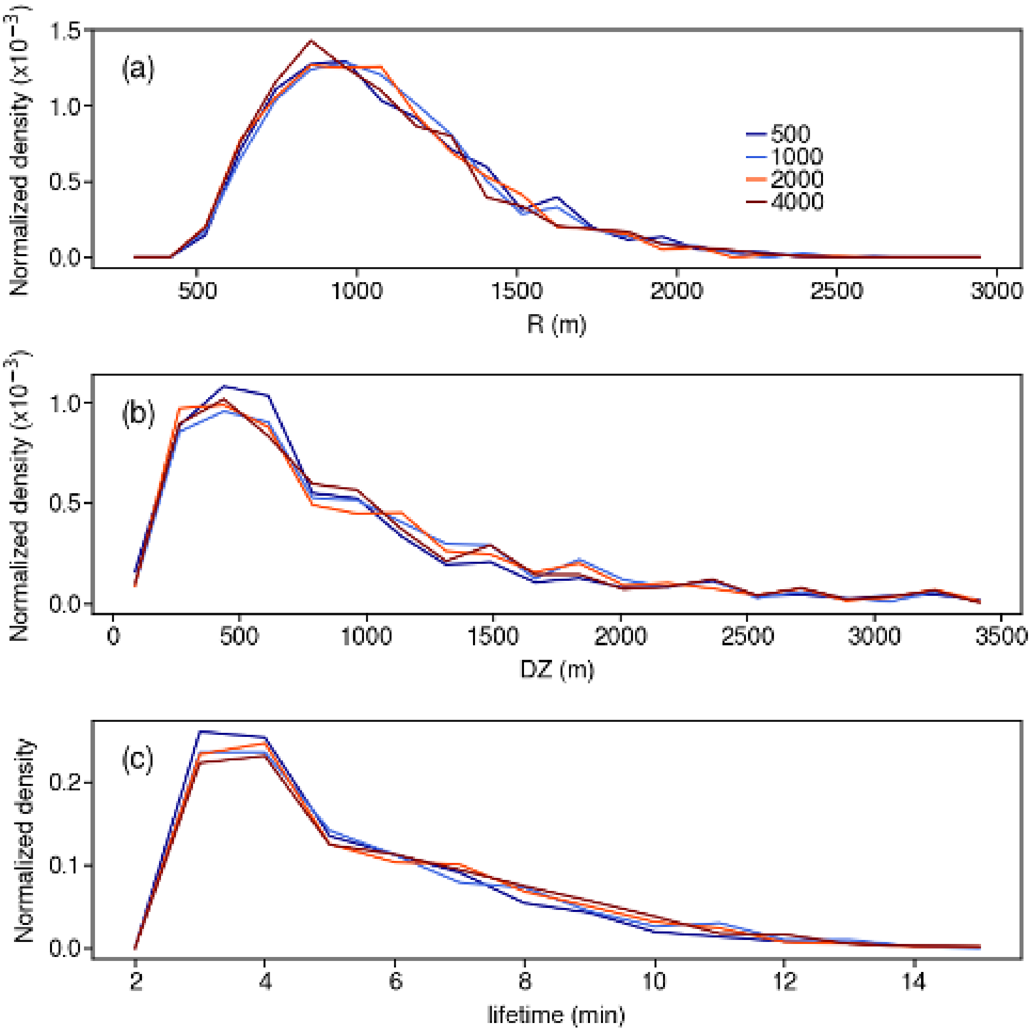

Fig. R12: Normalized distributions (their integrals must equal unity) of a) thermals' radius R, b) vertical distance traveled by thermals DZ, and c) thermals' lifetime in the experiments with successive doubling of aerosol concentrations (see legend in top panel, in cm^{-3}).

R3C4: *"Line 188: While it is likely true that the convective core is more tightly linked at upper levels to fewer, stronger updrafts, the fact remains that the additional updrafts not captured as thermals do exist there, and are certainly quite relevant for microphysics. By only looking at the strongest updrafts in the upper levels, it may better capture that core, but is ignoring stratiform processes. It's not clear that one of these methods would be better than the other in general - it depends on the question being asked. "*

We agree, and this comes back to comment R3C1, and to the general comment R2GC from reviewer #2. Please refer to our replies to those comments, which address this issue.

R3C5: *"Line 210: I'm not sure that I buy that it's representative of the total mass flux. In figure 4 you show that the profiles have different shapes as well as the difference in magnitude. They are not really looking at the same thing, which is your point, so how is one representative of the other?"*

Thank you for pointing this out. The problem here is that the "total mass flux" can be a rather subjective quantity, because it depends on the sampling strategy. We have rephrased this to make it consistent with what Hernandez-Deckers and Sherwood (2016) show, which is that it is representative of the “entire convective activity” (see modified text at lines 250-251 in the track changes version).

R3C6: *"Figure 6: How are there 300 individual thermals in this fairly small domain?"*

We realize now that we had not mentioned explicitly the size of this sampling domain where thermals are tracked (100x100km), but only showed it graphically in Fig. 1. We now do this at line 113 (lines 139-140 of the track changes version). Notice that this is actually a large area compared to the typical size of thermals. Furthermore, these numbers are accumulated over a 3-hour period in each simulation, so it is perfectly possible to have 300 thermals in this volume. Actually, this is most likely only a fraction of the “actual” number of thermals.

R3C7: *"Figure 6: With 250m grid spacing, an average radius of 500m doesn't make a lot of sense. These thermals are barely resolved, and this being the average means you are also tracking thermals that are fewer than 4 points across."*

By construction, the thermal tracking algorithm does not track any thermal with a radius smaller than twice the horizontal grid spacing, so no tracked thermal has a radius under 500m. Notice from Fig. 6b that only at the lowest layer below z=1km (where only a handful of thermals are tracked), does the average radius reach values below 1000m, but never 500m. Above this level, where most thermals are tracked, it is always larger than ~1000m, thus at least 8 or more grid points across a thermal’s diameter. In fact, the medians (which are lower than the means) of the distributions in Fig. R9 are 1020m, 1031m, 1018m and 990m, and more than ~85% of the thermals have radii larger than 750m in all simulations, thus more than 6 grid points across.

In order to make this clear to the reader, we have added the following text to the manuscript after line 125 (lines 154-155 in the track changes version): “The smallest radius permitted for a thermal is twice the model grid spacing, thus 500m in this case. Smaller thermals are discarded.”