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Comment on acp-2021-586

Anonymous Referee #2

Referee 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-RC2, 2021

Overview

This study applies cloudy updraft and tracked thermal frameworks to analyze updraft statistics in LES simulations of relatively isolated deep convection near Houston, TX. Sensitivity of updrafts to aerosol concentration between 500 and 4000 cm^{-3} is analyzed. Although cloud droplet and raindrop concentrations change significantly in response to aerosol changes, latent heating and vertical wind speed show little sensitivity. Buoyancy and thermal number sensitivities to aerosol concentration are non-monotonic. Both frameworks show similar sensitivities of updraft properties to aerosols. The primary difference is in the upper troposphere were the tracked thermal framework produces stronger updrafts. Magnitudes of effects also vary, but this is understandable given the two different sampling methods.

Overall, this is an interesting study comparing two different techniques that are commonly used for studying convective updrafts. I'm not aware of other such comparisons, which makes the results publishable. The aerosol sensitivities are also publishable, particularly since they disagree with many papers, some of which are case studies, that claim that increasing aerosol concentration increases convective vigor through the ice phase.

The primary issue with the study is that it stresses how the tracked thermal framework is superior to static cloudy updraft frameworks and that thermals are fundamental building blocks of convection that act as natural cloud chambers, but that is all very subjective without much evidence to support it. There are differences between the two framework results that make sense based on how they are sampling the model output. Despite that, they give results that are more similar than different with respect to aerosol sensitivities. Why one or the other is better connected to convective dynamics and microphysics understanding and parameterization is not clearly presented. Rather, it seems like each could be useful, particularly in providing context to each another and in supporting greater confidence in results when similar microphysical and dynamical sensitivities are similar in each, like seems to mostly be the case in this study. Without further results, it seems that this should instead be the message that is stressed most.

Comments

- The results and conclusions that are stressed most (use thermal framework for analyses; thermal framework yielding an abundance of additional information; thermals are dynamical and microphysical building blocks) are not well supported. If anything, most results are similar between the thermal framework and the cloudy updraft framework. Some are different, notably dynamics at upper levels, which is understandable given the low thresholds in the cloudy updraft framework that will pick up on detrained, buoyant air. How relevant these differences are for understanding or parameterizing convective clouds is not clear. It is simply stated that they are important with the thermal framework being superior, but what analyses support this? However, I don't believe that these are the most important conclusions anyway. I suggest shifting some of the focus to reflect the most important conclusions: (i) for liquid convective clouds, the thermal and cloudy updraft frameworks provide similar results (which is great since we don't have to disregard many past studies), (ii) for mixed phase and ice portions of convective clouds, substantial dynamical differences appear but microphysical sensitivities to aerosols remain similar, (iii) non-monotonic aerosol effects on liquid cloud updraft thermal number and buoyancy are seen, but no clear effects on the mixed phase and ice portions of updrafts are seen despite large sensitivities of cloud droplets to aerosol concentration. This last result is consistent with some recent studies showing warm phase invigoration without cold phase invigoration but goes against much of the aerosol deep convection invigoration studies concluding cold phase invigoration occurs, particularly in warm cloud base, isolated deep convection like this study examines.
- There is a lot of subjective language and confusing terms used.
  - Lines 42-43: "in which the dynamics of convection are resolved" is ambiguous. What dynamics? The primary updraft or downdraft size, average intensity, peak intensity? Many would not consider 250-m grid spacing sufficient to resolve primary updrafts of many types of moist convection. Studies like Bryan et al. (2003) and Lebo and Morrison (2015) show that 250 m is barely enough to resolve the peak in the kinetic energy spectra, but those studies are also for continental squall lines that may have larger, more intense updrafts than in other regimes such as those in oceanic regions.
  - Lines 47-48: Not all moist convection is necessarily constituted of short-lived thermals. Supercells, for example, can have 10-km wide plume updrafts with slab inflow layers. Morrison et al. (2020) and Peters et al. (2020) describe a thermal to plume spectrum dependent on updraft width and environmental conditions such as humidity, instability, and wind shear.
  - Lines 70-72: I don't understand what it means for microphysical processes to be contained within thermals and driven by their internal circulations. This seems obvious that a microphysical process rate will depend on its local environment, whether advection, condensation, phase changes, or hydrometeor interactions.
  - Line 73-74: What does it mean to be the basic dynamical entity of a cumulus cloud?
  - Line 89: Is this implying that the urban region heating is key for the sea breeze forcing initiating convection? A review of NEXRAD from this event shows convective precipitation initiating all along a sea breeze between Galveston, Houston, and Beaumont regardless of land cover with the most intense observed cells over rural locations in between Houston and Beaumont.
  - Line 115: Thermals are possible once resolution is sufficiently high, but that doesn't

    - mean that these have been observed as is stated.
    - Lines 142-143: Clarify what is meant here. Bryan et al. (2003) say that 250 m is sufficient for obtaining an inertial subrange, but this is also for a squall line and all results still do not converge at 125 m.
    - Line 162: I understand the thermal as an entity, but it seems overboard to call it a natural cloud chamber when it clearly has significant exchanges across its boundaries.
    - Line 246: I don't understand why this suggests that thermals act as cloud chambers.
    - Line 318: What are "thermal microphysics quantities"?
    - Second to last sentence of abstract: Cumulus thermals can serve as a stronger foundation for improving sub-grid parameterizations than what? Which parameterizations? Why?
    - Last line of abstract: How do the result suggest that cumulus thermals are more realistic dynamical building blocks of cumulus convection and what are they more realistic than? What suggests that they are natural cloud chambers?
- There are several results left unexplained or with interpretations not well supported by analyses.
    - Line 170: If supersaturation lowers, then condensation (and latent heating) increases, so what is compensating this extra latent heating to produce no net latent heating change? This should be explained.
    - Lines 183-185: How does the vertical wind speed profile highlight the importance of microphysical processes when its impact on microphysical processes aren't quantified?
    - It's not clear how robust (i.e., significant, which is a word that is used in the text) any inter-simulation differences are relative to variability expected from an ensemble with perturbed initial conditions. This is admitted by the authors – that it is difficult to discern a signal from the noise, but then the differences are described anyway as though they are robust.
    - There are different sensitivities to changes in aerosols depending on the magnitude of aerosol concentrations, but it isn't explained why this is and why changes are only visible for low-mid levels where presumably the thermals are dominated by liquid. I suggest reviewing previous studies on these topics.
    - Line 245, 270-276: This also may be a result of larger regions of detrained, rising cloudy air at upper levels than at low levels, which could easily be examined. Since this is the largest difference between the two frameworks, an attempt at explaining it with a bit of investigation is warranted.
    - Lines 281-282: These results show that a thermal framework produces some differences to the cloudy updraft framework, but it isn't clear why this implies their important role in cloud microphysics and dynamics. Clearly the most active portions of updrafts matter, but is the thermal definition needed for analyses of updraft processes? The cloudy updraft definition is admittedly arbitrary and is a low bar for inclusion. If thresholds were increased, would results approach those of the thermal framework? The thermal framework rejects many updrafts. Does that influence interpretation of aerosol sensitivities?
- How are aerosols initialized in the free troposphere? If they are removed through deposition, how are they replenished?

References

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