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Interactive comment on "Aerosol and dynamic effects on the formation and evolution of pyro-clouds" *by* D. Chang et al.

Anonymous Referee #3

Received and published: 5 May 2014

This paper reports on results of 1000s of 2D aerosol-cloud model simulations to study the impact of aerosols on a pyro-convective cloud under various aerosol and dynamical conditions. The quality of the work is very good because it provides a parameter space explaining where to expect clouds to be sensitive to aerosol effects and what conditions are not conducive to aerosol effects. The first half of the paper is well written. It was a pleasure to read. However, the discussion of the results became quite confusing. There were not good interpretations of the results. The study is limited to the 2D framework, and may be even more limited to certain environmental conditions (T, RH, and wind profiles). The limitations of the present study and the interpretation of results must be discussed more fully before publishing the paper.

Major comments:

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While it makes sense to do 2D simulations in order to conduct 1000s of simulations, the ability of the 2D simulations should be evaluated with a comparison of results to a 3D simulation. This has been common practice in many past cloud modeling studies.

I recommend including all the supplementary material in the main manuscript. I found the supplementary figures relevant to the discussion and quite interesting. I also recommend removing the normalized number and mass concentrations (Fig 2c-f, Fig 4c-f, Fig 6c-f, and Fig 8b-c) and replacing them with the relative sensitivity plots in Figures 3, 5, 7, and 9. Better yet, would be to just remove the former and keep the relative sensitivity plots in separate figures.

I believe the intended audience is the aerosol-cloud community, and not necessarily the pyro-cumulus community. The cloud community is much more concerned about updraft speeds than the forcing of the convective updrafts. Thus, I strongly recommend that the approximate updraft strength (maximum vertical velocity is a good measure) be given along with the fire forcing values as another axis in the plots. The readers would then be able to put this paper's results in context of their knowledge of convective storms.

The results presented in sections 3.2 and 3.3 are quite complicated. I would recommend introducing the results in a simpler manner before Figure 2 is discussed. My suggestion would be to show an instantaneous cross-section of the cloud for the LULA, LUHA, HULA, and HUHA cases. The cloud could be color coded by droplet number concentration or cloud mass concentration (or cloud and rain mass concentration). This type of figure would allow the reader to see a figure of something they are familiar with, and allow the authors to introduce the more complicated subsequent figures (Figures 2-9).

The main reason the results become difficult to understand is because a lot of jargon is used, and the authors mostly describe what is shown in the figure, but don't do a very good job of interpreting what the figure says. For example, instead of saying "FF exhibits positive effects on raindrop formation", it could be written like, "as the fire

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forcing (or updrafts) increases in magnitude, the amount of rain increases (Figure 4b), but the size of rain drops vary because of the complex behavior of the response of the rain drop number with fire forcing (Figure 4a)". The other reason the results are difficult to comprehend is that the text jumps from one figure to another in a single sentence. Some of this jumping would be reduced by putting the relative sensitivity plots in the same figure as the contour plots (as a function of aerosol number concentration and fire forcing).

Specific comments:

1. p. 7784, line12. Are the aerosols distributed uniformly in the vertical direction too? What are the initial horizontal winds? Do initial horizontal winds vary with height? That is, is there any vertical wind shear? (Fan et al., 2009 show how aerosol-cloud-precipitation results vary with vertical wind shear)

2. p. 7785, line 20. As it is spring convection season here in the United States, it is important to note that severe convection has updrafts much greater than 20 m/s. Severe convection also transports much more mass to the upper troposphere and delivers more precipitation to the surface than the smaller storms found over the U.S. Thus, I recommend saying that the updrafts simulated represent those found in air mass thunderstorms or trade wind cumulus.

3. p. 7787, lines 3-24. I was confused as to why Figure 2 was introduced here, but not explicitly discussed before Figure 3 was discussed on line 20. Here is an example of why I think Figure 3 should replace Figure 2c-f.

4. p. 7787, lines 21-24. Can you show how the cloud system buffering effect is affecting the droplet number concentration? I thought this study was modeling a single convective storm (p. 7782, line 4) and therefore do not see a cloud system effect for this study. A better explanation is needed.

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5. p. 7789. Perhaps it is because I am used to U.S. convective storms where hail is common, but why is there no hail in 3 of the 4 cases shown in Figure S4? Hail is only in the LULA case, which does not make sense since hail is associated with high updrafts. I am concerned about the worthiness of these results.

6. p. 7789. I am also surprised that the primary loss of cloud water to any of the ice hydrometeors is through cloud drop freezing. Does this mean that cloud drops do not transfer to the ice hydrometeors until they are at temperatures < -40°C? In my past work (albeit, with microphysics not quite as sophisticated as that presented here), the most common way for cloud drops to freeze was through the riming process, especially snow accreting cloud drops, or graupel accreting cloud drops.

7. p. 7790, lines 8-14. Why does the rain rate (Figure 8a) behave so differently from rain mass concentration (Figure 4b)?

8. p. 7790, lines 19-20, Could the authors please clarify where these precipitation-enhanced and suppressed regimes are on the figure?

9. p. 7792, lines 4-8. At what updraft speeds does the change in updraft speed not significantly influence the N_{CD} to N_{CN} ratio?

10. Section 3.3, While these results are interesting and useful, I was wondering if there is anything interesting in the time evolution of these microphysics processes. Are the relative contributions of the different processes shown in the figures hold true at different times in the simulation?

11. Section 4, Conclusions. I recommend removing the jargon for those people who just read the conclusions. Explaining the meaning of the results to our understanding of the aerosol-cloud science would be a bonus.

12. p. 7796, lines 5-12. Isn't conclusion 1 a conclusion of Reutter et al. (2009)? I'm

not sure it needs to be repeated here.

13. p. 7796, lines 26-27. Conclusion 4 reports a result, but does not explain why it happens. An explanation should be included.

Technical comments:

p. 7782, line 25. Do the authors mean "soil processes"?

p. 7785, line 12-13. It may be better to say, "summarizes all the microphysical processes and their acronyms"

p. 7787-7790, please state what aerosol and FF (updraft speeds) values constitute the low and high aerosol cases and the low and high updraft cases.

Figures 2-15, please label individual panels. This can easily be done as part of the panel title.

p. 7789, line 25. It seems like Rosenfeld's Science paper should be cited here.

p. 7790, line 10. The Tao et al. Geophys. Res. (2012) review would be very good to cite here. Tao, W.-K., J.-P. Chen, Z. Li, C. Wang, and C. Zhang (2012), Impact of aerosols on convective clouds and precipitation, Rev. Geophys., 50, RG2001, doi:10.1029/2011RG000369.

p. 7793, line 21. To be consistent, write "rain drops" instead of droplets

p. 7793, line 22. Should be melted snow (singular)

p. 7798, line 14. It may be good to cite Van den Heever and Cotton's work here. I think they were the first to show the aerosol-cloud-precipitation effects at longer time scales (> 12 hours).

Figure S2. Could this figure be shown on a skew-T plot and have the horizontal winds included? It may also be useful to show how big of a temperature increase occurs as the fire forcing increases.

Interactive comment on Atmos. Chem. Phys. Discuss., 14, 7777, 2014.