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

Anonymous Referee #2

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This manuscript investigates the impacts of cloud condensation nuclei (CCN) and dynamic condition on pyro-clouds using a 2-D Active Tracer High Resolution Atmospheric Model (ATHAM) with a double-moment cloud microphysical scheme. Wide ranges of CCN concentration and convection strength were used to configure the sensitivity simulations with totally over 1000 runs. By carefully assessing the budget and evolution of hydrometeors as well as microphysical processes rates, the paper sorted out the different sensitivity regimes for aerosol and updraft velocity individually, and potentially shed some light on physical mechanism involved in the aerosol-cloud interaction. However, there are several problems that need to be adequately addressed before the paper can be accepted for publication.

1) In the abstract, authors emphasized that aerosols suppress the surface precipitation

when aerosol concentration is between 1000 to 3000 cm-3. However, Li et al. (2008, JGR) showed the opposite aerosol effect during the same aerosol range for the cumulus cloud. It indicates that CCN values here are not representative as thresholds to distinguish the aerosol effect.

2) Fig. 1 doesn't deliver many messages, especially in the introduction part. I would suggest move it to the conclusion part and replace the question mark by the major findings in this study.

3) Each simulation was conducted for only three hours. Is three-hour long enough to capture the lifetime of a typical pyro-cloud? From Fig. 12, it is clear that the precipitation was still going on after three hours.

4) The prescribed aerosol budget used in this study could bias aerosol effects. Wang et al. (2013, JGR) has pointed out that prescribed aerosol scheme overestimates the magnitude of aerosol effects, and even changes the sign of aerosol effects with bulk microphysics. Similar discussion is necessary here and an implementation of a prognostic aerosol approach would be more valuable.

5) Page 7787 line 20, the statement "As NCN or FF increases, their impact becomes weaker" is not accurate. Clearly from Fig. 3b, sensitivities of cloud droplets to FF become larger after 4*104 W m-2.

6) Page 7788 line 4, the statement "when we evaluate the cloud responses to the changes in the ambient aerosol particles for global models or satellite data, we should focus more on the aerosol effect on cloud droplet number concentration, rather than on the liquid water path" is problematic. From Fig. 3c, it is clear that the sensitivities of cloud mass to CCN is quite pronounced under low updraft condition with CCN concentration less than 2000 cm-3. Meanwhile, this is the typical maritime condition for stratocumulus clouds, which are prevalent over the most ocean region. Therefore, the aerosol effect on cloud liquid contend is very important.

7) Section 3.2.2, there is no physical explanation of the complicated response of the raindrop concentration to aerosols and updrafts.

8) Page 7789 line 19-22, it is reported that "greater concentrations of aerosol result in more snow and less graupel", but actually some other studies suggested that elevated aerosols could increase the graupel/hail in the convective system (Khain et al., 2009, JGR; Wang et al., 2011, ACP). This is attributed to the competing effects of aerosols on the graupel formation. Since graupel is mainly formed by the accretion of supercooled drops by ice or snow, the smaller but more abundant supercooled cloud droplets in the polluted condition could be either favorable or not for graupel formation.

9) It is nice to see that authors stress the importance of a longer period simulation. Actually, Fan et al. (2013, PNAS) and Wang et al. (2014, Nature Communication) have done some long-term (more than one month) cloud-resolving modeling studies over certain cloud regions. Please discuss accordingly.

10) I'm concerned about the way authors calculate the microphysical process rates. Since the rates are averaged over the whole domain, I would expect that the cloud occurrence/fraction over the domain might significantly affect the microphysical rates there. It will be important to report the rates from cloud-only-points as well.

11) In Fig. 13 and 15, g/h/s/imer should be melting to form raindrops, rather than "multiplication to form ice crystals".

12) In Fig. 11 and 13, it shows that autoconvertion rate from cloud droplets to raindrops is higher in the high aerosol scenario (HA) than that in the clean case (LA). Why?

13) Page 7795 line 7, what is the reason behind the phenomena "although snow is the dominant constituent of frozen particle mass (Fig. S4), the deposition of vapor on ice (vdi) rather than on snow is the major pathway for frozen particles"?

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