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Comment on acp-2021-674

Anonymous Referee #2

Referee comment on "Radiative and microphysical responses of clouds to an anomalous increase in fire particles over the Maritime Continent in 2015" by Azusa Takeishi and Chien Wang, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-674-RC2, 2021

Review of “Radiative and microphysical responses of clouds to an anomalous increase in fire particles over the Maritime Continent in 2015” submitted to ACP by Takeishi and Wang

This study uses the Weather Research and Forecasting model coupled with Chemistry (WRF-Chem) to understand the impacts of these fire particles on cloud microphysics and radiation during the peak biomass burning season in September over the Maritime Continent region with 4-km grid spacing. The authors show a clear sign of precipitation and cloud top height enhancement by fire particles. Such a study is certainly of great interest to the community and fits well to the ACP scope. Long-time cloud resolving model simulations covering a large region for aerosol-cloud interaction study is precious. The analysis in the current paper is not that comprehensive and strict yet. I think major changes are needed in terms of determining what mechanisms are responsible for the convective invigoration before the study can be accepted as a publication in ACP. Hope my specific comments below help the authors improve the paper.

Specific comments:

- Method section, the Quick Fire Emissions Dataset (QFED) is a relatively new fire inventory that usually gives much high emission of fore aerosols than FINN. From Figure 6, the model underestimates AOD a lot. I think QFED would help. I understand it is challenging to rerun the model simulations with the new emission. Adding some discussion about this would be fine.
- Section 3.1 and Figure 5, the simulation without fire already substantially overestimated precipitation in Region 2 and 3. Considering fire aerosols makes the simulation further deviate from the observations. The reason for the poor performance of the WRF model simulations might be discussed. Did you evaluate water vapor, T, and SST with observations? For maritime conditions, ECMWF reanalysis data is generally better for initial and boundary conditions than NCEP FNL since it assimilated water vapor data from satellite over the ocean. Also, literature studies with WRF

documented various reasons for overestimating precipitation such as overestimated surface latent heat fluxes, and the problems with the physics scheme used such as MYNN PBL and Morrison 2-moment microphysics in your case. The relevant literature studies should be discussed to provide potential reasons for such a large discrepancy between model and observed precipitation.

- L135-140, the underestimation of AOD can be also because of the largely overestimated precipitation which usually scavenges aerosols efficiently, besides the underestimated fire emissions from FINN. Vice versa, the underestimation of AOD can also be one of the reasons for the largely overestimated precipitation because large AOD can suppress convection and precipitation through aerosol radiative effect as shown in many literature studies. It is a little surprising that you did not find fire aerosol impact through aerosol radiative effect. Did you look at the clear-sky temperature changes? The robust way is to do a sensitivity test by turning off the aerosol radiative effect in the radiation scheme.
- L157-158, incorrect statement. The increase in rainfall and cloud top height are only the indication of invigoration, but this could be achieved through mechanisms other than what was proposed in Rosenfeld et al. 2018 which is through enhanced ice processes. For example, the enhanced latent heat from condensation as suggested in Sheffield et al. 2015 (JGR) and Fan et al. 2018 (Science). Also, the microphysical effect of aerosols can be an important factor contributing to the increased cloud top height as shown in Fan et al. 2013 (PNAS).
- L172-174, The mass for each hydrometeor is increased. Also, precipitation is increased. This means that the conversion of water vapor to condensed phase is enhanced a lot. Both condensation and deposition play a role in this increase. Those two processes generally dominate the latent heat release and need to be explained. The increase of condensation heating can play a much larger role in invigorating convection than the same amount of latent heating from ice-related processes as shown in Fan et al. (2018) and Lebo et al. (2018, JAS). Often the increase in condensation heating is larger than the other processes in magnitude. Therefore, I think more analysis is needed to figure out whether warm-phase invigoration through condensation also contributes to the invigoration or not, besides the cold-phase invigoration as described in Rosenfeld et al. 2018. If you do not have outputs of condensation and deposition rates, you may do restart runs for a selected short time period to output them to look at. Another option is to look at the vertical profile of supersaturation change from the nofire to fire cases for the convective updraft cores only (such as use $W > 5$ m/s) to see where the maximum reduction in supersaturation occurs.
- Also, there is no support to say "surface rainfall seems to largely stem from melted snow and graupel". For the tropic convection, warm rain should have a significant contribution, particularly in the nofire case where background aerosols are low and the formation of warm rain should be quick. You may output warm rain and melted rain separately to verify this by restarting both simulations at a time of interest and running for a short time like 6 hours only (this way you can also address b better). With the addition of a large number of fire aerosols, warm rain may be severely suppressed which can lead to the dominance of melted rain, but this needs to be shown. To clearly show this, either through the comparison of warm rain and melted rain or autoconversion rate.
- L178-182, I think the most important is the number of supercooled droplet is increased a lot, which allows more tomes of snow accretion and riming growth for both snow and graupel.
- L189, as mentioned earlier, this has been documented well in literature studies such as Fan et al. 2013.
- Conclusion, I suggest adding discussion about wildfire heat impacts, which is excluded in this study but can play an important role in changing low-level temperature and impacting convection. Zhang et al. (2019, GRL) presented a revised WRF-Chem with wildfire heat impacts considered.