Atmospheric Chemistry and Physics Discussions

Atmos. Chem. Phys. Discuss., referee comment RC2
https://doi.org/10.5194/acp-2021-781-RC2, 2021

Comment on acp-2021-781

Emma Järvinen (Referee)

Referee comment on "Microphysical processes producing high ice water contents (HIWCs) in tropical convective clouds during the HAIC-HIWC field campaign: dominant role of secondary ice production" by Yongjie Huang et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-781-RC2, 2021

Review of "Microphysical processes producing high ice water contents (HIWCs) in tropical convective clouds during the HAIC-HIWC field campaign: dominant role of secondary ice production" by Huang et al.

Overview

In this study, simulations of tropical deep convective clouds performed with the Weather Research and Forecasting (WRF) model are evaluated against observations from the High Altitude Ice Crystals (HAIC)-HIWC experiment. As a companion paper to Huang et al., 2021, a closer look on the role of secondary ice production (SIP) to generate observed HIWC regions is taken. Three SIP mechanisms are investigated: the Hallett–Mossop (H-M) process, ice–ice collision fragmentation (IICB) and raindrop freezing breakup (RFZB). It is found that simulations including all three SIP processes successfully produces HIWC regions in all three temperature levels that were investigated. The results highlight the importance of SIP processes in controlling the ice water content in the studied tropical convective clouds. The paper is well written and the model experiments are easy to follow. There are only minor shortcomings that should be addressed before publication. First, the ice crystal observations would have deserved more discussion and ideally, the authors could have included their best estimation of the magnitude of the uncertainties related to these observations. Furthermore, the uncertainties related to the existing SIP parameterisations should be highlighted more. After these minor revisions the manuscript is recommended for publication.

Recommendation: It is recommended that this manuscript is accepted after minor revisions.

General comments

- For evaluation of the role of SIP it is crucial to have reliable observations of ice crystal number concentrations (Ni). However, the authors do not discuss the Ni observations during the HAIC-HIWC field campaign or, more importantly, their uncertainties. Although Huang et al., 2021 contains information of cloud microphysical observations, the relevant measurement methods should be summarised also in this manuscript. For example, Huang et al. (2021) states that the Ni measurements were derived from the Two Dimensional Stereo Imaging Probe (2D-S) and the Precipitation Imaging Probe (PIP) fro the size range for Dmax>50 µm but in this manuscript use a higher lower size limit of 100 µm. This choice should be discussed.
- How is the model sampled in order to get Ni and IWC values in the size range of 0.1-12.845 mm? How is the ice particle size defined in the model? What is the possible error in Ni if the model and observations have a different definition for size?
- The sensitivity of the model to horizontal resolution and aerosol profile is discussed in Sec. 3.2. The results are discussed in terms of Ni/IWC values but it is not well justified why the 250m-resolution model was chosen for the sensitivity studies including SIP processes.
- Fragmentation of ice in ice-ice collisions is shown to dominate the ice particle production rates outside the updraft core region even at temperatures warmer than -15°C. Do the authors consider this as a realistic outcome or a result of the way ice-ice collisions were implemented in the model?
  Laboratory studies suggest that the number of ice ejected in collisions has a strong dependence of temperature with a maximum around -18°C (Takahashi, Nagao & Kushiyama, 1995). The break-up of ice crystals in ice-ice collisions is explained by the different ice crystal surface properties (brittle surface with plate-like growth or dendrites colliding with compact graupel). Plate-like and dendritic growth contributing to fragmentation is taking place in the temperature region between -15°C and -20°C, which explains the observed maximum in ice production rate in the laboratory studies. Ice crystals around -5 and -10°C have more compact columnar shapes. Is this difference in shapes taken into account in the parameterisation?
- It is important to state that there are severe uncertainties in the parameterisations of SIP mechanisms. Although there is a statement about this in Summary and Conclusions, this could be also stated earlier in the manuscript (e.g. in Sec. 2.1). Ideally, some additional sensitivity tests by tuning the different SIP parameterisations could have been performed.

Minor comments

Line 203: Can the authors explain the choice to discuss the results in the form of Ni/IWC? What is the additional value in this representation?

Figure 4: Can the observations be added to the corresponding subplots or even combine Figures 3 and 4?

Figure 5: Same as for Fig. 4. It would be helpful to have the observations included. In addition, please explain the acronyms HM, RFZB, IICB and SIPs in the figure caption to improve readability.

Line 256: What kind of significance test was performed? Please add this information.

Line 345: Some discussion of how generating more ice in the early or lower parts of the cloud though SIP will lead to HIWC regions with more small ice crystal at colder and higher part of the cloud would be helpful to visualise the dynamics of these systems.

References

Takahashi, T., Nagao, Y., & Kushiyama, Y. (1995). Possible high ice particle production during graupel-graupel collisions. Journal of the Atmospheric Sciences. https://doi.org/10.1175/1520-0469(1995)052<4523:PHIPPD>2.0.CO;2