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Comment on acp-2021-323

Anonymous Referee #3

Referee comment on "Multi-thermals and high concentrations of secondary ice: a modelling study of convective clouds during the Ice in Clouds Experiment – Dust (ICE-D) campaign" by Zhiqiang Cui et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-323-RC3, 2021

The authors discussed observations of ice crystal concentrations measured in-situ during the ICE-D field campaign in Cape Verde during August 2015. It was suggested that, based on INP measurements, primary nucleation alone could not explain the high ice crystal concentrations and so secondary ice processes, e.g. rime splintering, occurred in the convective cloud.

Simulations with one or multiple thermals were performed with several configurations of the heterogeneous ice nucleation scheme. The maximum ice crystal concentrations were than compared with the ones measured during aircraft passes through the cloud.

Major Comments

The vertical and horizontal extent as well as the lifetime of the modeled cloud are not compared to the observed cloud, for example by utilizing weather radar data. The microphysics of the model are also very sensitive to the initial conditions, especially the vertical profile of water vapor. The authors used initial profiles combined from dropsonde measurements and NCEP/NCAR reanalysis data, but did not show these profile or discuss which parts of the simulated clouds are located in the region approximated with reanalysis data. The authors should put more emphasis on linking observations with model results and discussing uncertainties of initial conditions.

A major part of the work focuses on evaluating the contribution of secondary ice from rime splintering. The authors identified secondary ice by observing the temperature zone where the Hallett-Mossop (HM) processes is active, e.g. between -3 and -8 °C., and attributed ice crystals in that temperature range to rime splintering. However, transport processes, e.g. advection and sedimentation of ice crystals from the colder part of the cloud into the HM zone, are not discussed.

Furthermore a majority of the sensitivity experiments increased the onset freezing temperature from -8 °C to – 3 °C or higher, hence heterogeneous nucleation is now possible inside the HM zone. This makes it very difficult to distinguish between ice from rime splintering and primary nucleation in that temperature range. The authors should build a stronger argument that increased ice crystal concentrations in the HM zone did indeed originate from enhanced rime splintering. For example sensitivity simulations without rime splintering could be performed and included in the comparisons.

Minor & technical comments

Line 63: clarify that homogeneous formation refers to homogeneous freezing of cloud/rain or solution droplets. Whereby the latter is often just referred to as homogeneous nucleation.

Line 64: with temperature

Line 76: there are also newer review papers relevant for secondary ice processes e.g. Korolvel et al. (2020)

Line 93: missing full stop after Field et Al

Line 119: missing full stop after aerosol

Line 134-143: there are a few mismatches in the figure references

Line 151-153: Fig. 3 does not provide information about temperature. The statement that ice appeared only at T < -10 °C is supported with Fig. 2.

Line 153-154: this section has to be expanded to support the statement that measured ice concentrations were lower than what primary nucleation would suggest since Fig. 2 and 3 do not show INP concentrations

Line 164: other relevant microphysical processes, which do not require interaction of cloud particles, like sedimentation and particle growth by deposition of water vapor should be mentioned. Also the Hallett-Mossop temperature zone is mentioned multiple times in this work and the temperature range should be explicitly stated in this section

Line 191-193: include information about model time steps and intervals of writing output. The latter is important for how clearly you can identify nucleation events in your data.

Line 209: -14 °C instead of -14C

Line 213: misspelled graupel

Line 216: check grammar of last sentence in this line

Line 221: parenthesis without content

Line 266: this statement should be better connected to the figure, that actually shows the increase in ice crystal concentrations

Line 288: misspelled increase

Line 332: remove ‘also’ before ‘approximately’

Line 334: remove space between m and s^{-1}

Line 340: check grammar in second part of the sentence

Line 367: panel d in Fig. 12 does not exist

Line 367-377: there are no ice particles shown in Fig. 13

Fig 4.: labels of isotherms are barely visible, but important for interpreting the plot. Purple is misspelled in the plot label.

Fig. 5: color bar should be changed so that the colors below the dark blue are more continuous. Also a logarithmic plot would be good since ice crystal concentrations below 1 /L are hidden, but important in how ice in the top of the cloud and the HM zone connect.

Fig. 7: RLX10 is called RLXTEN in the text

Fig. 8: the color bar is very hard to read. A continuous color bar should be used instead. Also the plot label misses the information that maximum ice crystals concentrations are shown. RLX10 is called RLXTEN in the text

Fig. 9: color bar should be changed so that the colors below the dark blue are more continuous.

References

Korolev, A. and Leisner, T.: Review of experimental studies of secondary ice production, Atmos. Chem. Phys., 20, 11767–11797, https://doi.org/10.5194/acp-20-11767-2020, 2020.