

Atmos. Chem. Phys. Discuss., referee comment RC1
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Comment on acp-2021-513

Anonymous Referee #1

Referee comment on "Model emulation to understand the joint effects of ice-nucleating particles and secondary ice production on deep convective anvil cirrus" by Rachel E. Hawker et al., Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2021-513-RC1>, 2021

Review of Hawker et al, 2021: Model emulation to understand the joint effects of ice-nucleating particles and secondary ice production on deep convective anvil cirrus.

In this study an ensemble of LES are used to investigate the influence of INP concentrations, slope of the INP parametrization and Hallett-Mossop rime splinter production rates on deep convective clouds. The authors conduct a very nice statistical method to show that indeed the concentration of INPs and slope of the INP parametrization used have significant impacts on the anvils of deep convective clouds as well as the ice crystals within them. Additionally, they show that the slope of the INP parametrization can play an important role in convective invigoration and this is aided by the HMP. I would like to congratulate the authors on an exceptionally well written and carefully conducted study. I just have a few minor comments and am in full support for publication in ACP after their incorporation/consideration. I thoroughly enjoyed reading this study!

General comments:

What happens to snow particles once they reach a certain size? Are they immediately precipitated to the surface or can they continue to contribute to the rime mass and produce splinters via HMP? This did not seem to be addressed and could have an influence on the NINP-38/INP slope feedback on HMP.

Is it known that if in the extremely active simulations (in terms of INP) if there is actually

enough dust to produce these high numbers of ice crystals predicted? Or how is this linked to the dust. There is quite some discussion on this but it is not immediately clear how it works for in the simulations if INP are actually calculated based on available dust.

How dependent are the observed sensitivities purely related to the fact that NINP-38 has the largest variance (more than 6 orders of magnitudes versus just 3 for HMP)?

How sensitive are these results to the updraft speed within the convective core? Do you expect NINP-38 to still be important when updraft speeds are approaching 50 m/s as quoted in the text? In general, the in-cloud updraft velocities are close to the previously calculated/edge of where heterogeneous nucleation competes with homogeneous freezing (~ 1 m/s e.g. Korolev 2006) and therefore is it possible that the role of INPs and their slope are more important here than in stronger convective clouds?

When discussing the role of INP parametrization slope, how sensitive is this to no scavenging? For example in a real world situation, the slope of the INP parametrization would influence the amount of INP remaining at colder temperatures. However in this case, since no scavenging is occurring, the cumulative concentration in the cloud is significantly higher for a less steep slope than a steep one even though both slopes have the same NINP-38 value. Is this really a fair comparison then? Rather, should the cumulative INP concentration across the slopes for a given NINP-38 be constant, since no scavenging is occurring?

Minor comments:

Line 157-158: If dust is not scavenged, does this mean that the dust concentration always remains the same throughout the simulations? Does this mean that the new ice formed due to primary nucleation in each time step is the cumulative sum of INP up to the temperature of the cloud parcel? What impacts does this have on the importance of INP slope and overall number?

Figure 3: The values of precipitation seem very low. Is this calculated over the entire domain or just underneath the convective cell?

Line 265-266: But the INP profile in Fig. 4b does not show that the concentration of INPs is constant with height, which indicates that the dust is not typically advected to all heights or is this outside of a convective core? Regardless, the NINP-38 is then set to the minimum between 1 cm^{-3} and the ns value, if 1 cm^{-3} is used, it is way above the

available dust.

Line 277: Is it really appropriate to assume that the active site density continues to have the same slope at temperatures warmer than -5 C? Due to such low efficiencies, it probably does not make much difference, but basically dust is completely inactive at such warm temperatures. Why wasn't -5 used as the warmest temperature where n_s was calculated?

Line 285/Equation3: This is a bit confusing. So it is either $NINP-38$ or $n_s(-38)$, whichever is smaller? Perhaps this can be clarified. Also, is the (T) missing after n_s ?

Equation 5: Should -38P be +38P or the -38 in the exponent be +38?

Line 408-414/Figure 6: Why is there such a reduction in homogenous freezing at 11.5 km but then a large increase again above 12 km? I see the two order of magnitude scale difference but I wonder why there is a reduction towards 11.5 km? Is this a time issue?

Figure 6: should it be column integrated (between 5.5 and 7 km) like in Figure 9?

Line 461-462: Again, isn't this threshold for homogeneous freezing rate highly dependent on the simulated updraft?

Line 511-512: Is this result not the opposite of what was found in Hawkler et al, (2021)?

Line 515-519: are a bit repetitive as this had already been discussed above

Line 521-523: Since aerosols are not scavenged, can new CCN be activated if the water saturation is high enough? Again, this process is highly sensitive to updraft velocity

Line 552-560: How is the ice that falls back through the HMP region influencing secondary ice production? Does the ice that forms higher up not offset the influence of the slope of the INP parametrization through this region or is there not enough time for the ice to fall into this altitude in the simulations? With this in mind, there is some precipitation, so if the ice doesn't fall through this layer is it all due to warm rain processes?

Edits:

Line 66: add "the" after "This determines"

Line 272: Should it be "N_{INP}" here?

Line 321: "properties"

Line 361: "that" --> "than"

Line 508: What does this mean: " λ_{INP} of 10 cm⁻³."? Should "of" be "at"

Line 508: "INP" should be "NINP-38" for consistency I think.

Line 569: Should it be "red outline"?

Line 666: add "." After citation

Line 801: "ti" --> "to"