Editor decision: Publish subject to minor revisions (review by editor)

Comments to the author:

Dear Dr. Pasquier,
I would like to thank you for submission of the revised manuscript, and also the two reviewers for their careful read and comments that led to substantial improvements. The use of HOLIMO to relate the freezing of supercooled large droplet to high concentrations of small ice particles is an important contribution to the field. That SLDs and high ice crystal concentrations appear to go hand-in-hand has long been recognized but the explanation has been somewhat mysterious. In my view this paper will help other researchers solidify their understanding of the problem.

To this end, there are two things that I would like to see included in the document, although I leave it up to the authors as to whether either is done. The first is that it appears that INPs are not necessarily a primary mechanism determining ice crystal concentrations in the Arctic. It suggests the focus of future study should perhaps be secondary ice crystal production mechanisms. More emphatic statements to this effect in the abstract and conclusions may be warranted.

Second item that may be desirable is to do some back-of-the-envelope calculations to determine what magnitude and rate of splinter production would be required to account for the HOLIMO observations. For example, line 285 to 289 establish a "likely explanation" that looks like it could be easily tested or constrained with a simple differential equation leading to exponential growth subject to depletion of available SLDs. Supplementing a little mathematics with a cartoon might help readers better understand the jump from correlation to causation, such that parameterizations could eventually be developed.

I look forward to the revision, and also hope acknowledgment can be given in the paper to the reviewers.

Best regards,

Tim Garrett

Answer to the Editor Timothy Garrett

We would like to thank the editor Timothy Garrett for his encouraging remarks and helpful comments, which helped improving the manuscript. We have addressed his two comments below and have included the changes in the text and their line numbers in the revised manuscript. We want to apologize for having forgotten to acknowledge the reviewers, we included them in the acknowledgment section of the revised manuscript.

Regarding the first point, we agree that it is worth mentioning that even if INPs are necessary for the formation of the first primary ice crystals, SIP is controlling the ICNC when it is active. As such it should be prioritized in future studies which aim to quantify the concentration and evolution of ICNC in Arctic MPCs. We have therefore increased the emphasis around this point in the abstract on lines 19-20: "Despite the undeniable necessity of INPs for the formation of the first ice crystals, the extent to which SIP occurs when activated determines the ice crystal number concentration.", as well as in the conclusion on lines 482-485: "Although INPs are necessary for the formation of the first (primary) ice crystals, our results indicate that, when SIP processes are active, they ultimately determine the ICNC. Therefore, the focus of future work investigating the evolution of ice crystal concentrations in Arctic low-level clouds should be placed on SIP."

Regarding the second point, we did some calculations concerning the high SIP case on 11 November 2019 and added this information to strengthen our hypothesis on lines 293-295: "With SLDNC of about 50 L^{-1} and a frozen drop concentration reaching up to 6 L^{-1}, around 10% of the SLDs seem to have frozen, thereby producing on average approximately 15 secondary ice crystals.".
However, it is unfortunately not possible to infer causation with certitude for a specific SIP mechanism occurring in natural clouds, as one does not observe or measure SIP occurring directly, but only its subsequent result: high concentration of small pristine ice crystals. In the cases observed in this study, it is also difficult to exclude the simultaneous occurrence of several SIP processes. Therefore, one would first need to identify the cases where SIP is occurring and then differentiate between the SIP mechanism active in order to come up with a calculation of the number of ice crystals produced from each SIP mechanism. For example, in the above mentioned case where droplet shattering is a 'likely explanation', one can not completely exclude the occurrence of the Hallett-Mossop process. Only taking the SLDNC into account in a parametrization would be inappropriate, as similar SLDNC were measured earlier during this measurement flight with much lower concentration of the small pristine ice crystals (1-3 L^{-1}) and almost no frozen droplets. Moreover, the droplet shattering mechanism is a cascading process (e.g., Lawson et al., 2015), which complicates the derivation of a parametrization.
For these reasons, the calculations are unfortunately not as easily derivable as suggested. We agree that it would be strongly beneficial to use this dataset to develop and/or test SIP parametrizations, but we think that deriving such a parametrization is beyond the scope of this manuscript. Nevertheless, we strongly encourage the scientific community to derive and test SIP parametrizations using this dataset which will be made publicly available.

References

Lawson, R. P., Woods, S., and Morrison, H.: The Microphysics of Ice and Precipitation Development in Tropical Cumulus Clouds, Journal of the Atmospheric Sciences, 72, 2429 – 2445, https://doi.org/10.1175/JAS-D-14-0274.1, 2015.