Review of "Continuous secondary ice production initiated by updrafts through the melting layer in mountainous regions" by Lauber et al.

Overview

The paper consists of two parts. The first part presents the results of in-situ observations of cloud particles from a HoloGondel platform, which allowed vertical travel (490m) along the mountain slope. The paper is based on the measurements of cloud particles shapes and their concentrations collected by HOLIMO 3G during the case study - when the melting layer was located between the highest and lowest points of the platform travel. The results from the measurements showed a significant number of pristine (monocrystalline) ice particles, predominantly plates, at subfreezing temperatures T>-3C. Based on the comparisons with the concentration of INPs it was concluded that the pristine ice crystals originate from secondary ice production (SIP). The main mechanism of SIP was assigned to the fragmentation of freezing large drops. The formation of large drops above the melting layer was explained by recirculation of melted ice through the freezing level.

In the second part, the authors explore the parameterizations of SIP based on the results of present observations and past lab studies.

I found the results of the first part undoubtedly interesting. If these results are to be confirmed by other research groups, then the role of the melting layer as a source of SIP should be reconsidered in cloud and NWPs simulations. However, the second part raised concerns, which are discussed in comments 8 and 9.

The paper deserves publication in ACP after addressing the comments listed below.

Recommendation: Accept after major revisions.

Comments:

1. Visual assessment of the images in Fig.1 suggests that many pristine ice crystals (plates, thick plates, short columns, columns) were not identified as such and fall into a different category. This could occur due to their orientation (as mentioned in the text), which could hinder their classification. The eyeball recognition used in this study has a subjective component and it depends on the experience of the expert performing the recognition. A more objective way would be to use a neural network recognition trained on ice analogue crystals (e.g. Ulanowski et al. JQSRT, 2006) or synthetic images of pristine ice particles with different orientations. Developing this technique is obviously time consuming, and this is rather a suggestion for future research. Regarding this work, I am concerned that the number of pristine ice crystals were underestimated. Consequently, this may affect the parameterization, which you attempted in the second part of your paper. I would strongly suggest reassessing the number of pristine ice particles. For training purposes, you may consider a ray tracing software (e.g. Zemax or equivalent) to generate the appearance of facetted hexagonal ice crystals with different orientations.

2. In addition to the previous comment, could you classify each particle in Fig.1. This will be useful for the assessment of the quality of image recognition and help understand the results of the particle classification.

3. Could you include your definition of an ice plate? What is the separation between thick plates and short columns in terms of their aspect ratios (h/L)?

4. Page 11: "*However, the fall velocity of irregular particles is hard to assess and it remains unclear if they have fallen from above or formed at the measurement site by SIP*." You could use for the fall velocity assessment min-max range of the fall velocity based on the aspect ratio of ice particles and their sizes?

5. It would be useful to show the statistical significance of the amount of sampled cloud particles in a separate table, e.g. total number of sampled droplets, droplets >40um, total number of crystals, number of columns, plates, irregulars, aged ice, etc. The histogram in Fig.1 shows concentrations of ice particles with different habits. However, it is not clear what the statistical significance of these measurements.

6. It would be extremely beneficial and informative for this study to show the profiles of the air temperature, relative humidity, droplet concentration for each platform ascent, and show types of hydrometeors observed on different levels.

7. Page 13, line 16: "*The estimated updraft in this case study is about 0.6 m s^{-1}, which is equal to the fall speed of a 150 μm droplet*". 0.6m/s is a terminal fall velocity of 150μm diameter droplet. At the updraft velocity 0.6m/s this droplet will be suspended at the same altitude. In order to bring this droplet above the melting layer the updraft velocity should be u_z>0.6m/s.

8. Check Eq.2: E is a function of d and d_i. Summing should be performed over E as well. Not sure where 2 is coming from. Should it be 4?

9. The rate of splinter production is expected to depend on droplet concentration (CDNC). For example, if CDNC=0, then G_{sp}=0. However, none of the equations Eq.5 and Eq.6 includes CDCN. Please, check Eq.5 and Eq.6.

10. Page 8, line 19: "of of"

11. Page 13, line 28: "*Korolev et al. (2020) argued that INP activation in transient supersaturation around freezing drops could not be shown to be active in the atmosphere*." This is an overstatement. The mentioned work suggested that this mechanism is unlikely to be active in a relatively warm environment (e.g. T>-4C). However, this mechanism may be active in convective clouds with strong updrafts at temperatures T<-20C.

12. Tale 1: remove duplicated line 3.

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