Review 2 of Secondary ice production during the break-up of freezing water drops on impact with ice particles – Sylvia Sullivan

RC: I appreciate the authors' efforts to revise the manuscript and find that I understand the proposed mechanism and setup much better now. For example, the paragraph in lines 35-41 is now quite helpful to understand the difference between mode 1 and mode 2 drop freezing and fragmentation, and addition of mechanism 'phase labels' to Figures 3 and 4 is nice. I also appreciate mention of experimental challenges and future work in Section 5. I have a series of minor comments and edits after my second read-through, but otherwise support publication of the manuscript.
AC: We thank Sylvia for her additional comments and appreciate the time she has taken to read our revised manuscript.

Comments

RC: Abstract - The abstract starts brusquely. I would add an initial contextual sentence about the importance of secondary ice processes and the contribution of these experiments to better understanding their mechanisms.
AC: While we agree that the abstract starts brusquely, we feel that adding a contextual sentence about the importance of secondary ice processes reads more like introductory material and is already covered in the introduction. Instead we have rearranged the abstract so that a sentence from lines 6-7 is now at the beginning with a slight rewording, and now informs the reader directly about the purpose of this paper in relation to atmospheric processes.
'We provide the first dedicated laboratory study of collisions of supercooled water drops with ice particles as a secondary ice production mechanism.'

RC: Lines 51-64 – These paragraphs seem to me to fit better after line 23. Then you have discussed the general importance of secondary ice, first to understand discrepancies between INP and ICNC and second to explain persistent generation of ice in thin mixed-phase clouds. After that, you present rime-splintering as the most widely employed and studied mechanism and finish by suggesting that this new mode 2 drop freezing and fragmentation could also be important.
AC: Changed.

RC: Lines 95-96 – Is a more convincing argument here for the relevance of this impact velocity that the mixed-phase region, at least of deep convective clouds where liquid and ice hydrometeors grow to the large sizes here, are highly turbulent? And impact velocities within the turbulent eddies could be quite large?
AC: Thank you for raising this interesting point. We agree that turbulence will have an effect on the impact velocity although and removed 'The differential velocity between the supercooled water drop and ice particle will be less than 9 m s−1 dependent on the nature of the ice particle' and added the following:
'Moreover, turbulence, especially in deep convective clouds, may also affect the impact velocity (Pinsky and Khain, 1998).'

RC: Discussion – I would also add one introductory sentence here to help the reader orient, something like "We discuss some aspects of the experimental setup that may affect the occurrence and rate of secondary drop production and freezing here."
AC: Added

Minor Edits

RC: Line 29 – I would remove "than rime-splintering", as the sentence reads more cleanly then. You could also specific that the variation in "quantification between laboratory studies" is quantification of ice fragment generation rates and temperature dependence in these rates.
AC: Removed rime-splintering and added 'quantification of ice fragment generation rates and temperature dependence in these rates'.

RC: Line 68 – drops that freeze
AC: Changed

RC: Line 98 – (Locatelli and Hobbs 1974) adjust parentheses
AC: Adjusted.

RC: Line 106-107 – You already defined D within We and Re above, but it is perhaps worth reiterating here that you define the length scale in these dimensionless number to be the water drop diameter prior to impact.
AC: Added the following in bold:
'In this case, the fluid is the supercooled water drop, **and the diameter of the supercooled water drop, D, refers to the diameter before impact.**'

RC: Lines 131-133 – I asked why these filaments are only produced at colder temperatures, and I feel it would be worthwhile to mention the point you made about increased viscosity and surface tension of supercooled water explicitly, e.g. "where no ejection of filament-like structures was observed, perhaps due to lower viscosity and surface tension of water at these temperatures"
AC: We have added the following sentence:
'…where no ejection of filament-like structures was observed, perhaps due to higher viscosity and surface tension of water at supercooled temperatures.'

RC: Figure 6 caption – "The error bars represent the standard error in freezing fraction or secondary drop number for the temperature intervals..." Quite minor but just for clarity.
AC: Changed.

RC: Line 167 – "on an elevated ice surface" From this description, it sounds like the setup in Schremb et al. 2018 also used a flat surface for impact (an icy one not glass). But later it is stated that "when a flat surface... is not present, secondary drops are still formed." Could you clarify?
AC: We've rewritten the following sentence to clarify:
'Clearly, secondary drops still form, emitted from the rim of the thin film during impact, when there is no supporting flat surface, such as the glass slide used in this study.'

RC: Line 189 – "we expect the irregular shape of an ice particle to enhance the fragmentation mechanisms" ?
AC: We don't necessarily expect the irregular shape to enhance fragmentation, but we expect it to introduce new or additional fragmentation mechanisms. It could be that these different fragmentation mechanism are not as efficient at breakup, or more efficient, compared to what we have observed when the ice particle is on the glass slide. We have changed the sentence to the following:
'Therefore, we expect the irregular shape of an ice particle to introduce additional fragmentation mechanisms of the supercooled water drop which may enhance secondary drop formation.'

RC: Line 246 – "freezing fraction of the secondary drops" Omit "ice", right?
AC: Yes, thanks – omitted.

RC: Lines 261-262 – suggested rewording to avoid a run-on "We measure about 10 secondary drops per collision. Schremb et al. 2017 observed on the order of tens of drops per collisions for impacts on an elevated ice surface. Finally, Rozhkov et al. 2002 observed hundreds of drops for impacts on steel disks..."
AC: Changed.