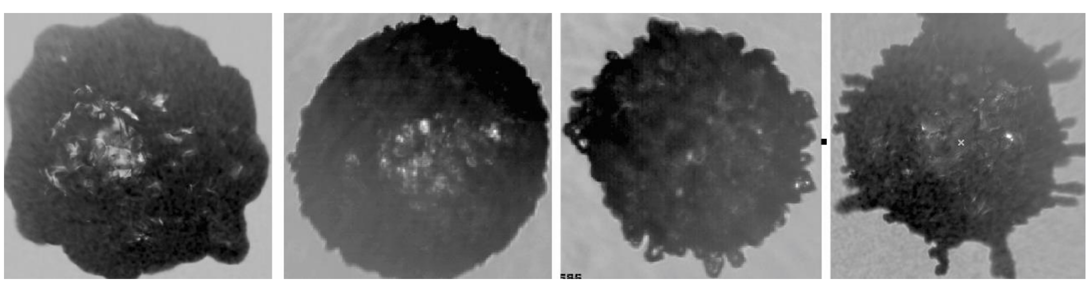
Review of "Fragmentation of ice particles: laboratory experiments on graupel-graupel and graupel-snowflake collisions" by Grzegorczyk,et al.

Comments

Secondary ice production continues to be one of the most controversial cloud microphysical processes generating a wide variety of speculations and dubious explanations. In many ways, this lack of clarity is a function of the significant challenges that exist in obtaining direct in-situ observations and running laboratory studies of secondary ice production processes. The existing laboratory studies of SIP mechanisms are sparse, and many have presented controversial results. Therefore, any attempt made in exploring the efficiency of SIP mechanisms under controlled environmental conditions is greatly appreciated. And this is particularly true for the present work, aimed at the laboratory study of the ice-ice collisional break-up SIP mechanism with a focus on graupel-graupel and graupel-snowflake collision. The laboratory setup sounds reasonable, and it can be used as a basis for subsequent studies of the efficiency of the ice-ice collisional break-up SIP mechanism for different environmental conditions and ice particle shapes. The paper is well-written and should be accepted for publication in ACP. However, I have two comments which should be included in the paper in the form of disclaimers prior to publication.

1. I have a serious concern regarding the parameterization of the ice-ice collisional breakup SIP solely based on CKE. Besides the CKE, the number of fragments generated after collision depends on the mechanical properties of the colliding particles. The mechanical properties of ice particles depend on the history of the environmental condition that this particle experienced in the past. Thus, for the sake of argument, assuming that the mass of the four graupel particles in the picture below is the same, their collision with other graupel will result in a different number of fragments, even though the CKE will be the same.



The morphology and mechanical properties of the graupel surface depend on many parameters such as DSD, LWC, T, P, vertical wind, the graupel's mass, and density. Within the same cloud, graupel may experience a variety of time histories of the above mentioned parameters, which can subsequently generate an infinite number of possible combinations of collisional events between graupel with different mechanical properties of surface ice but having the same CKE.

In the frame of the present study, the fragment size distributions (FSD) and their dependence on CKE (Figs.11-13) were obtained for the graupel formed under approximately the same environmental conditions as described in section 2. Therefore, the obtained parameterization (Eq.3) describes secondary ice production for the specific graupel generated in this lab setup, and it cannot be expanded to the entire variety of possible graupel-graupel collisions. This limitation of the obtained parameterization should be clearly stated in the paper in order to mitigate the use of the obtained SIP parameterization in cloud simulations.

2. The relevance of the environmental conditions employed in the laboratory setup during the depositional growth of ice is another point of concern in this study. As described in section 2.2, that at the location of graupel, the supersaturation over ice and temperature varied in the ranges 20%<Si<27% and -15C<T<-13C, respectively. Such supersaturation over ice corresponds to up to 10% supersaturation of liquid. This is an overly high supersaturation, which normally does not occur in natural clouds, with the exception of short periods of time in vigorous updrafts. The mechanical properties of ice grown at high supersaturation are expected to be different as compared to growth at low supersaturation (e.g., below water saturation) due to an increased number of dislocations (hopper ice growth). The depositional growth of the graupel surface at lower and more realistic supersaturation is slower and may not develop protruding ice shapes (e.g., https://doi.org/10.1175/1520-0450(2004)043%3C0612:LAISOO%3E2.0.CO;2), which is expected to affect the FSD and SIP efficiency. The effect of high supersaturation and relevancy of the environmental condition should be discussed in the paper as well.

Minor comment: Line 102: Rb4 => R4b

Recommendation: I recommend the paper for publication after adding disclaimers as discussed above.

Alexei Korolev