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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Air pockets and secondary habits in ice from lateral-type growth" *by* Jon Nelson and Brian Swanson

Anonymous Referee #1

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The authors studied the formation mechanisms of air pockets and other secondary habits in snow crystals. The topics coincide with the scope of Atmos. Chem. Phys. Discuss., and the secondary habits of snow crystals are interesting from the fundamental viewpoint. However, first of all, this manuscript is too lengthy (26 figures are shown in the manuscript of 51 pages in total), and too many subjects are included in a mixed-up way. Therefore, I need to say the presentation quality is poor. Second, the authors insist that the formation of corner air pockets (the main subject in this manuscript) cannot be explained by the traditional growth mechanisms based on lateral step motion, and by the morphological instability based on the inhomogeneous distribution of vapor density. Then the authors conclude that the lateral-type (protruding) growth, which is the key mechanism in this study, is a novel concept. However, I cannot agree with such

authors' claims (for details, see the comment 2). Hence, I believe that the scientific significance of the present manuscript is also poor. Since the amount of revisions is significantly large and the conceptual revisions are necessary, I do not recommend the publication of this manuscript.

Following 1-3 are major comments. 1. Too lengthy: one paper should have one main claim. Then, I believe that the following topics should be presented in separated papers: # the formation mechanism of the corner air pockets, # quantitative discussion about the kinetics of the lateral-type (protruding) growth, and # secondary habits other than the corner air pockets (these topics can be also moved into supplementary information)

2. The formation mechanism of the corner air pockets: the authors mentioned that the normal growth via step motion and the standard hollowing theory based on the morphological instability caused by the inhomogeneous vapor density cannot explain the formation of the corner air pockets. Then, I shall explain the formation of the corner air pockets by the traditional concepts. The key is the morphology of a snow crystal at the beginning of the growth. 1) When a starting crystal is fully faceted, the local vapor density becomes maximum at the corner of the crystal, providing a hollow not at the corner but at the center of the crystal face, as the authors explained. 2) In contrast, when a starting crystal is partly rounded, the layer-by-layer growth of the faceted face (located at the center of the crystal) proceeds. Then a spreading edge appears as shown in Fig. 1b (marked by e) and Fig. 8c. Since the spreading edge shows an angular shape and the corner of the crystal is still rounded, the local vapor density at the tip of the spreading edge becomes higher than that at the rounded corner, providing the overhang as shown in Fig. 1d and Fig. 8d. After once the overhang was produced, the overhang is developed spontaneously (the authors call this process the protruding growth), and the corner air pocket is formed. These processes never violate the traditional concepts of the layer-by-layer growth and the morphological instability. In addition, the authors emphasize the importance of the diffusion of admolecules on

the crystal surface (the surface diffusion of admolecules). Then the authors named this process “adjoining surface transport (AST)”. I fully agree with the importance of the surface diffusion for the formation of the overhang and the subsequent protruding growth. However, the concept of the surface diffusion of admolecules is very traditional (firstly proposed by Frank and coworkers in the 1960s, and then experimentally proved by the growth of various crystals). Therefore, the authors should clearly show what is the authors' novel concept and what is not.

3. Throughout the manuscript, the authors should clearly explain what is the authors' new finding and what is not, with respect to phenomena and formulas as well.

Followings are minor comments. 4. The term “droxtal”: since many readers (including me) are not familiar with this term, the authors need to explain it properly at the beginning.

5. The section 1.2 gives the impression that the authors do not fully understand the fundamental growth mechanism of crystal growth. The concept of the surface diffusion of admolecules (AST) is widely accepted in the crystal growth of wide variety of materials: not only for the metal whiskers, but also for semiconductor crystals, molecular crystals and ice crystals as well (as studied by Hallett, Mason et al, Kobayashi, and Asakawa et al.) Hence, for me, the application of the surface diffusion to the lateral and protruding growth by Yamashita (2015) does not look a significant revision, since the lateral and protruding growth can be explained easily, as shown in my above-mentioned comment 2. By the way, it is impossible to obtain the reference Yamashita 2015. The page numbers of the references Yamashita 2013 and 2016 should be 165-176 and 393-400, respectively: the page numbers of 23-33 and 15-22 are those in the issues 60 (3) and 63 (5).

6. The authors should show the schematic illustration of the new crystal-growth apparatus (CC2) in this study, since the reference Swanson and Nelson 2019 is still in preparation.

7. In the section 3.4, from Fig. 4, I cannot understand the difference between the expanding boundary of the basal face and growing macro-steps. The authors also should clearly explain the kinetic models I, II and III in the main text (of a separated paper), since the quantitative discussion has no meaning without obtaining the complete understanding of the models. By changing the value of h/xs arbitrarily, one can easily fit the experimental data. Hence, here the authors need to explain the causes of the change in the value of h/xs (I believe that the cause of the change is the evolution of macro-steps) and also whether the change is appropriate or not. The authors also need to discuss the values of h and xs.

8. In the section 3.9, the authors should explain the impossibility and instability much more in detail.

9. The sections 3.10-3.22: If these sections have scientific significance, the authors should explain them in separated papers. If their scientific significance is not so large, the authors should move them into the supporting information.

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