Authors' comments to Anonymous Referee #1

We would like to thank the reviewer for the thorough review of our manuscript and insightful feedback. These comments have significantly improved the quality of our work. In the following sections, we present the reviewer's comments (in black), our responses (in red), and the changes made in the revised manuscript (in blue). Please note that all line numbers in our responses correspond to those in the revised manuscript.

Overall comments:

The manuscript proposes a novel ice crystal classification method that employs a two-step process. Initially, a rotated object detection algorithm (IceDetectNet) is applied to categorize the individual component of aggregated ice crystals. Secondly, a multi-label classification scheme is applied, whereby the ice crystals are categorized according to their basic habits, as well as the physical processes that modified them. The IceDetectNet algorithm was trained and tested on data sets obtained from a holographic imager. The proposed classification method represents a step forward and an improvement compared to traditional machine learning approaches. However, in its current form it is subject to a number of limitations.

1. A further critical aspect are the chosen shape categories. Although the selection of ice crystal shapes and physical processes was justified based on the training data set, the selection is however unconventional. For example the distinction between "small" vs "irregular", as small refers to size and irregular refers to shape. Strictly speaking, it is a comparison of size and shape.

   We agree that the distinction between "small" and "irregular" ice crystals is based on a combination of size and shape information rather than a strict size versus shape comparison. "Small" refers to crystals that are often too limited in pixel number to accurately determine their shape. In contrast, "irregular" refers to larger crystals with indistinguishable shapes due to more complex structural features. As stated in the first round of responses (see the response to comment #2 Reviewer #1"), setting a rigid threshold for the 'small' category would result in a loss of valuable shape information for crystals below this size (Fig. 1). Certain shapes, such as 'column', require fewer pixels for accurate recognition, while more complex structures may require additional pixel detail. Thus, keeping these two categories distinct allows greater flexibility in recognizing and classifying ice crystals of varying structural complexity, ensuring that the model captures both size and shape variation without being

forced into rigid thresholds. Also, these categories are based on the ice classification in Pasquier et al. (2022a, 2022b, 2023).

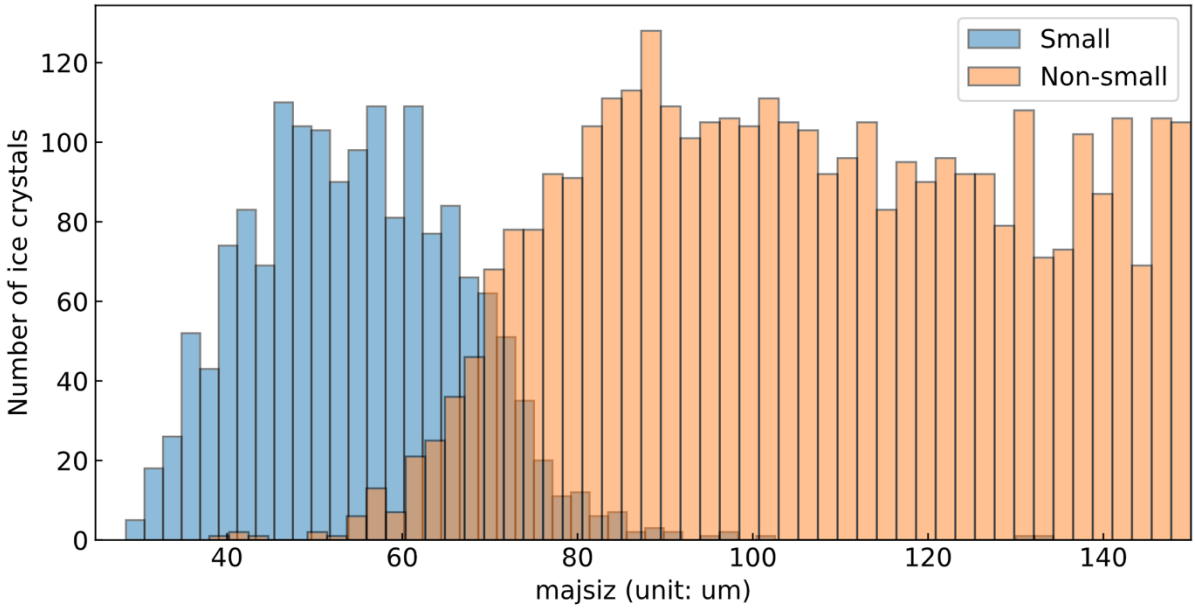

Figure 1: Histogram comparing major axis sizes of 'small' ice crystals and other categories (non-small).

2. Also the choice to differentiate between “pristine” and “aged” is an unlucky selection, in my opinion. Here, pristine refers to shape, while aged refers to a temporal development. While this distinction and the categorization of ice crystals in the manuscript may be applicable to this specific data-set from Ny-Ålesund, it limits the applicability to other data sets and makes it challenging to compare results obtained from IceDetectNet with those from the existing literature.

   Thanks for your insightful comment. Both the terms "pristine" and "aged" as we use them refer to differences in shape, with "pristine" indicating that the ice crystal has just formed and maintained a regular and easily identifiable shape. For example, a pristine column might appear as a well-defined rectangular shape. On the other hand, 'aged' includes crystals that have undergone various microphysical processes, such as riming or sublimation, resulting in more irregular or complex shape features.

   In response to your comment, we have revised the definition of ‘Pristine’ in Table 1 in the manuscript:

   Pristine: Ice crystals with an easily identifiable shape that have not undergone any microphysical processes.

3. In this regard, I acknowledge the discussion of the limitations of the current version of IceDetectNet in Section 5. However, it would be fair to the reader of the manuscript / paper to explicitly mention these limitations in the Introduction and the Conclusion. By "limitations" I refer to the restricted shapes in the training data set as well as the unconventional selection of ice crystal shapes and microphysical classes. The manuscript can be considered for publication, when the limitations from above are explicitly mentioned in the introduction and the conclusion part.

   Thank you for pointing out that the limitations of the IceDetectNet should also be included in the introduction and conclusion. We have added them as follows:

   L73-75:
   However, like all supervised learning methods, our approach is limited to the ice categories present in the training dataset, limiting its applicability until the model is fine-tuned on a new dataset.
   L494-498:
   However, the ice categories used in this study are specific to environmental and microphysical conditions present during the collection of the training data. In addition, the distinction between 'small' and 'irregular' ice categories combines both size and shape information, making it difficult to be classified. While these categories are appropriate for the current dataset, they may pose challenges when applying IceDetectNet to other datasets or comparing results with existing studies. However, adding or refining categories can be easily achieved through model fine-tuning.

   Minor comments: Line 505 / 507: FigB2 is called before FigB1, so I suggested to change the labeling to keep the order.

   Fixed, thanks!

References

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