We thank the reviewer for his careful analysis of our paper and thoughtful comments. Our replies are in red text and new line numbers in the revised manuscript are in red text. We apologize for the clutter in the Track Changes version. Due to new figures and multiple changes in the text it is difficult to follow.

This manuscript presents a highly valuable and comprehensive dataset of in-situ and remote-sensing observations of stratiform boundary-layer clouds collected during the 2024 ARCSIX campaign north of Greenland. Using two research aircraft (NASA P-3 and the SPEC Inc. Learjet) equipped with state-of-the-art microphysical probes—and additionally, aerosol and radar instrumentation—the ARCSIX campaign sampled more than 12,000 km of clouds, including 6,266 km of in-situ measurements. The resulting dataset, covering spring and summer conditions, represents one of the most extensive contemporary observational efforts targeting Arctic mixed-phase clouds.

The study addresses one of the most significant unresolved topics in cloud microphysics: secondary ice production (SIP) in mixed-phase clouds. SIP is known to dominate ice crystal concentrations under certain environmental conditions, yet these conditions—along with the relative contributions of different SIP mechanisms—remain poorly constrained. In this context, the manuscript provides an important observational framework for understanding under which thermodynamic and microphysical conditions SIP may occur in Arctic low-level clouds.

A key strength of the work is the combination of in-situ sampling with remote sensing (Ka-band radar). This approach is especially valuable because in-situ measurements, while precise, offer only localized and momentary snapshots, whereas remote sensing helps place them into a broader spatial and temporal perspective.

The authors document several cases of anomalously high ice concentrations at very warm cloud-top temperatures (≥ −4 °C), far exceeding what can be explained by measured INP concentrations. Importantly, the authors excluded seeding from above and lofting from the surface (including blown snow), strengthening the case that the observed ice is produced internally. While clouds frequently met widely accepted temperature and microphysical conditions for known SIP mechanisms such as Hallett–Mossop (HM), these mechanisms cannot explain all cases—particularly the very warm mixed-phase clouds discussed in the study. Conversely, some clouds that fulfilled HM criteria did not exhibit enhanced ice, emphasizing that the environmental controls on SIP remain elusive.

The manuscript further offers insightful hypotheses regarding additional factors that should be considered in SIP theory—most notably, the size and concentration of graupel, which may play a critical role in the onset or efficiency of HM SIP. The discussion of frozen-drop fragmentation (FFD) is balanced and appropriately cautious given the suboptimal environmental conditions for this mechanism in ARCSIX clouds.

Overall, the manuscript is well written, enjoyable to read, and provides important observations that challenge current understanding of both primary and secondary ice formation in Arctic mixed-phase clouds. The ARCSIX dataset will undoubtedly serve as a cornerstone for future laboratory, modeling, and observational work aimed at disentangling the still-poorly-understood conditions that trigger SIP. Therefore, I recommend the manuscript for publication with some minor suggestions.

Minor suggestions:

1. The ARCSIX campaign sampled a broad range of cloud conditions. While the authors provide a verbal summary of cloud-phase occurrence and include a comprehensive flight table in the supplementary material, an additional overview figure summarizing the campaign-wide findings would help place the selected case studies into a broader observational context. Since the focus of the paper is on ice production, a figure showing, for example, ice crystal number concentration or ice water content as a function of temperature (or a similar integrative metric) would be particularly useful.

We agree. Please see newly-added Figs. 4 and 5 and accompanying text.

2. The manuscript frequently refers to the presence (or absence) of graupel as a key criterion for Hallett–Mossop (HM) rime splintering, and in some cases questions the applicability of HM SIP when insufficient graupel is identified. However, in the classical description of the HM process, the essential requirement is the presence of riming particles, not graupel per se. To my knowledge, any sufficiently large ice particle (typically D ≳ 300 μm) collecting supercooled droplets can act as a rimer and potentially generate splinters (e.g., Hallett & Mossop, 1974; Mossop, 1980). In this context, the observed larger columnar or needle-shaped ice crystals could plausibly serve as rimers. It may therefore be more appropriate to frame the discussion in terms of rimers rather than graupel, which would avoid unnecessarily restrictive assumptions about particle habit and better align with the original HM framework.

We have addressed the reviewer's concern in detail in the third and fourth paragraphs of Section 4.2.1.

Lines 98-101: The authors mention that relatively high ice crystal concentrations in stratiform clouds are not unique to the Arctic. This is true, but it would be advised to add as examples studies from Southern Ocean, as also one of the first reported observations of SIP was done in this region (e.g., Mossop et al., 1968).

The reference has been added – Thank you.

Lines 173-175: Can you give a size range for the ice particle concentrations?

See newly inserted figures 4 and 5.

Lines 226-227: How does the statement that irregular ice crystals are not expected at cloud top temperatures of -7°C fit to the earlier studies that report <1 % pristine fractions in Arctic mixed-phase clouds (Korolev et al., 1999)?

There is no significant relationship to the ARCSIX boundary-layer clouds with $T \geq -7$ °C because data in the Korolev et al., (1999) paper were collected in cirrus and stratus clouds associated with frontal systems, and the large majority of the measurements were in clouds colder than -7 °C

Lines 351-352 and 365-366: The authors talk about primary ice nucleation at -6.1°C but primary ice nucleation alone cannot explain the observed ice crystal concentrations.

Lines 383 – 391: We agree with the reviewer. “Primary” has been deleted.

356-357: Given the large volumes and long residence times of drizzle-sized droplets, to what extent can freezing at relatively warm temperatures be explained by size-dependent freezing probabilities rather than invoking extremely rare ice-nucleating particles?

Lines 392 – 394: This is a good point. We added a sentence noting the increased probability of immersion freezing as a function of drop volume.

Figure 10: Including vertical wind velocity in the time series, if available, could help to assess the potential role of cellular dynamics.

We would like to show meaningful vertical velocity measurements, but unfortunately the variance in vertical velocity is typically very small, about ± 1 m s^{-1}, which is on the order of the precision of the instrument.

References

Hallett, J., & Mossop, S. (1974). Production of secondary ice particles during the riming process. Nature, 249(5452), 26–28. https://doi. org/10.1038/249026a0

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Mossop, S., Ruskin, R., & Heffernan, K. (1968). Glaciation of a cumulus at approximately- 4c. Journal of the Atmospheric Sciences, 25(5), 889–899. https://doi.org/10.1175/1520-0469(1968)025<0889:goacaa>2.0.co;2

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