Response to Reviewer Comments on "Impacts of Environmental Conditions and Ice Nuclei Recycling on Arctic Mixed-Phase Cloud Properties"

Response to Reviewer 1:

We would first like to thank the reviewer for taking the time to read through our updated manuscript and for offering their feedback.

I would like to thank the authors for their meticulous and thorough revision work. I am satisfied with their responses to each of my comments. Nonetheless, I find it unfortunate that some results of the additional tests conducted during the revision were not included in the main manuscript (even if only briefly mentioned).
In particular, I am referring to:
• the additional simulation on a larger domain and the convergence of the results with those obtained using the smaller (default) domain;
• the clarification regarding the explanation of the re-emission process (in response to comments on lines 124–135);
• the discussion of a possible enhancement of surface INP emissions when the mixed layer reaches the surface.
Once these very minor points are addressed, I fully recommend the publication of the article in ACP.

We apologize for not including some of our tests and responses to the previous round of revisions in the updated manuscript. We have now done so with the following changes:

Regarding the large-domain simulation, we have included two new supplemental figures, A1 and A2, which are nearly identical to Figures R3 and R4 in the last R2R, but are included here as well.

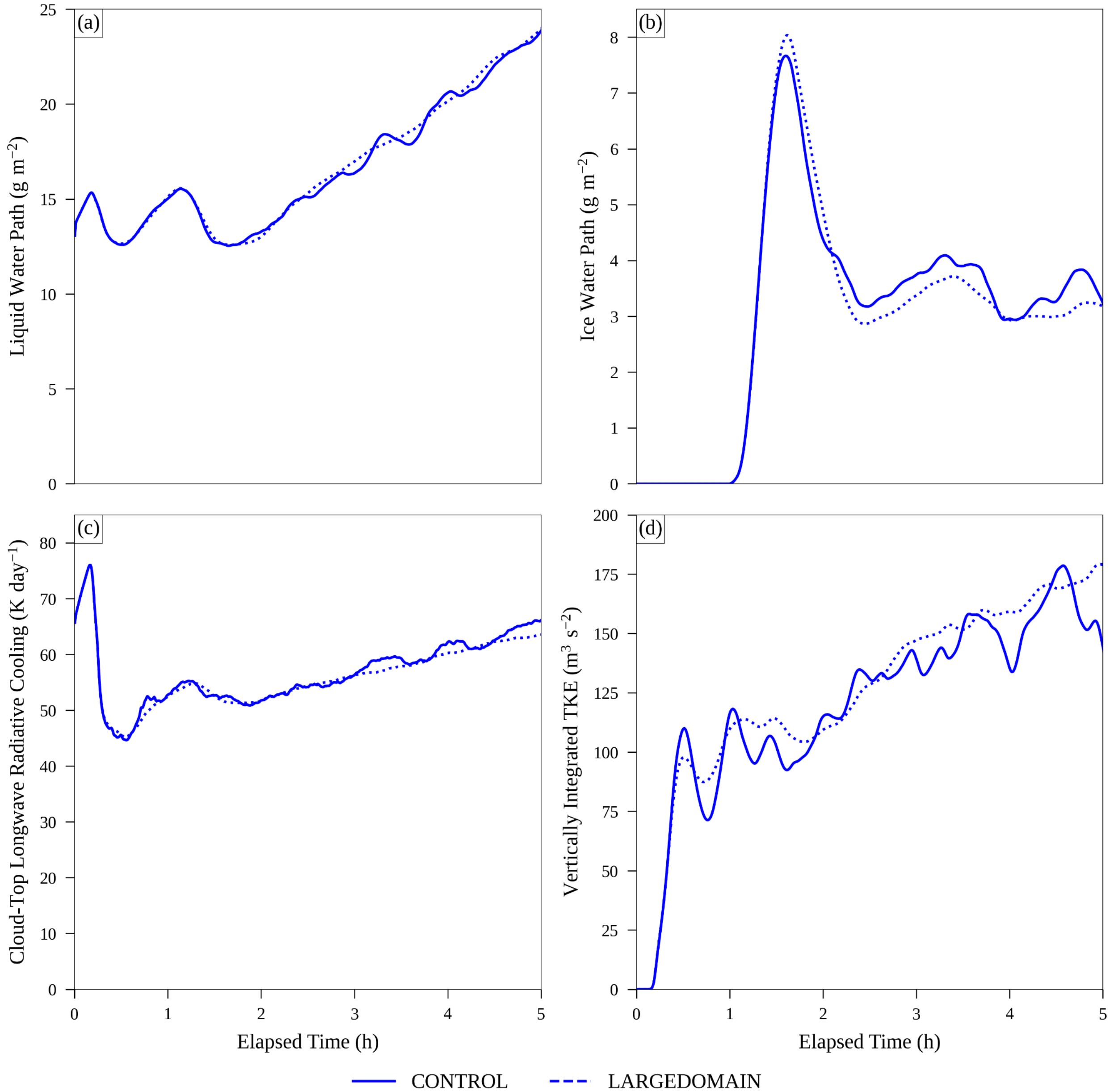

Figure A1: Time series of LWP (a), IWP (b), cloud-top longwave radiative cooling rate (c), and vertically-integrated TKE (d) in the CONTROL (solid blue) and LARGEDOMAIN (dotted blue) simulations.

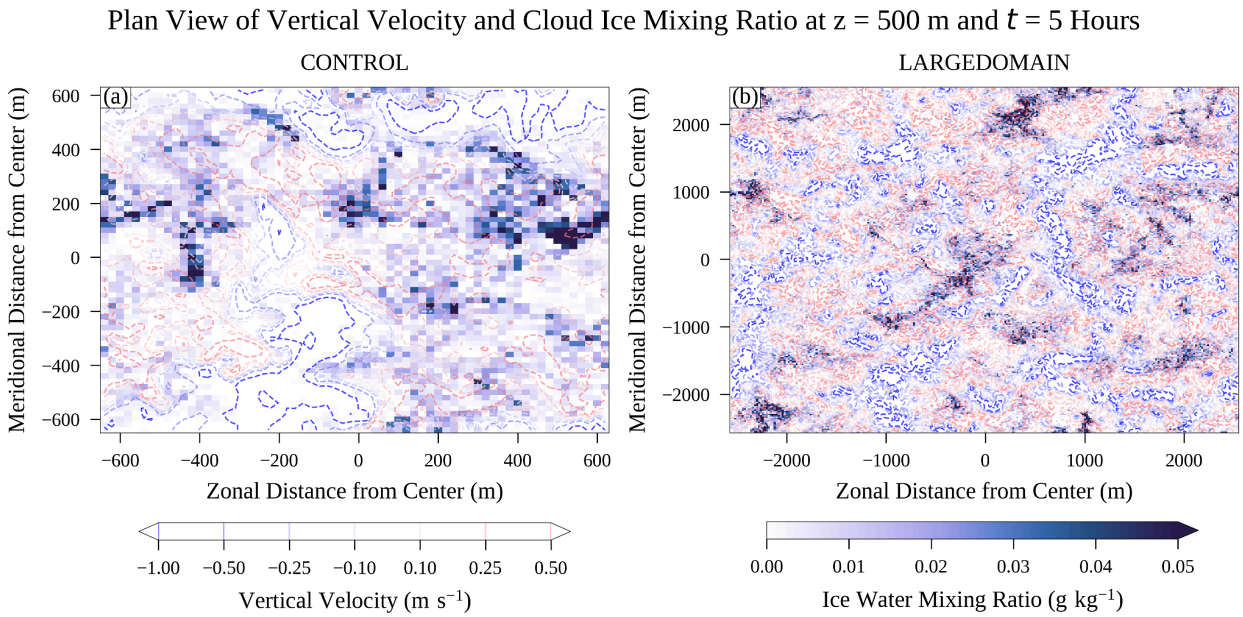

Figure A2: Plan view comparison of the CONTROL (a) and LARGEDOMAIN (b) simulations at z = 500 m and \emph{t} = 5 hours. Vertical velocity is shown in the red and blue dashed lines, while ice water mixing ratio is indicated with blue shading.

We have also added the following paragraph on <u>Lines 156-164:</u> (note that here and elsewhere, green indicates added text, red deleted text, and blue is unchanged)

We also ran one simulation to assess the sensitivity of our results to the model horizontal domain extent, though we do not discuss it in detail below. This simulation, denoted as LARGEDOMAIN, was run with 256 grid points in each horizontal dimension and 144 vertical levels. Vertical and horizontal grid spacing were the same as in CONTROL, meaning that the domain in LARGEDOMAIN was 4 times as wide as CONTROL along each horizontal dimension. Due to computational restraints, we were only able to conduct this simulation for 5 hours. During this time, LWP, IWP, cloud-top radiative cooling, and TKE were of similar magnitude in both CONTROL and LARGEDOMAIN (Fig. \ref{fig:s1}). Likewise, the horizontal extent of updrafts, downdrafts, and regions of ice water were also broadly consistent between CONTROL and LARGEDOMAIN (Fig. \ref{fig:s2}). This indicates that our use of a smaller domain for the other six simulations is unlikely to have significantly influenced our results.

To justify our INFLUX and DRY_INFLUX simulations, the following text was added on Lines 148-151:

~~Finally, to~~ We should emphasize that the INFLUX and DRY_INFLUX simulations are not meant to represent a specific process such as surface emission of INP. Rather, they serve as a counterfactual to the CONTROL and DRY simulations, allowing us to disentangle the effects of free-tropospheric thermodynamics from INP recycling on the cloud microphysical properties.

We have also added a short discussion on the possible enhancement of ice nucleation from surface-based IN, as accumulated IN within a near-surface stable layer are advected into the cloud once the below-cloud mixing layer reaches the surface. This is on Lines 551-558:

Interestingly, our findings also indicate that recycled IN from desiccating ice crystals can be trapped in a "band" of stably stratified air below the sub-cloud mixed layer and just above the surface. Once the sub-cloud mixed layer reaches the surface, these IN are mixed throughout the boundary layer and back into the cloud. A similar phenomenon could occur with surface IN emissions under conditions of low surface wind speeds and surface sensible heat fluxes. In such an environment, the well-mixed layer stretching down from the cloud might not initially extend all the way to the surface, allowing IN to build up near the surface. Once the sub-cloud mixed layer reaches the surface, this elevated concentration of marine IN could be advected into the cloud and increase the rate of ice nucleation, potentially increasing IWP within the cloud.

In addition to these changes, the following very minor additions were made to increase consistency in our use of the term “water vapor mixing ratio”.

Line 135-139: Initially, these were a CONTROL case using the same initial atmospheric profile as that used in Ovchinnikov et al. (2014), a DRY case in which the water vapor mixing ratio above 825 m was reduced from 1.2 to 0.8 g kg^{-1}, a WEAKINV case in which the inversion strength was reduced from 3.5 K to 1.5 K, and a DRY_WEAKINV case combining the weaker inversion strength of WEAKINV and the reduced above-cloud water vapor mixing ratio of DRY.

Table 1 Caption: "Above-Cloud Water Vapor Mixing Ratio" refers to the above-cloud water vapor mixing ratio at initialization.

Lines 324-327: The relative lack of drying in WEAKINV, despite the greater entrainment rate, is due to the fact that the above-cloud air in WEAKINV is at a higher relative humidity than that in CONTROL, as a consequence of reducing the inversion strength while leaving the above-cloud water vapor mixing ratio unchanged.

Lines 448-450: This suggests that, under the environmental conditions of the ISDAC simulation, the effects of perfectly efficient IN recycling and the magnitude of the water vapor mixing ratio decrease in DRY cause a similar magnitude of supersaturation depletion within the cloud.

Lines 509-510: In WEAKINV, the inversion strength above the cloud top is reduced while the water vapor mixing ratio is unchanged.

We would also like to thank Reviewer 2 for taking the time to review the second draft of our paper.