Review comments on “Introduction of prognostic aerosols in the P3 microphysics scheme: Simulation of layered Arctic mixed-phase clouds” by Cholette et al.

In this manuscript, the authors introduce prognostic water-friendly and ice-friendly aerosol number mixing ratios into the P3 microphysics scheme and evaluate their effects on Arctic mixed-phase clouds using 1-km GEM simulations over the Inuvik region. The study compares simulations with surface observations, ground-based radar measurements, and EarthCARE retrievals, and further examines the sensitivity of cloud phase partitioning to different ice nucleation parameterizations. The results indicate that the aerosol-aware configuration produces fewer but larger ice particles, modifies riming and reflectivity, and tends to maintain more supercooled liquid water than the baseline configuration. The implementation has potential value for improving aerosol-cloud interactions in high-resolution numerical weather prediction models. The manuscript is generally well written and the results are interesting. It could be suitable for publication after major revision and after the following points are adequately addressed.

Major comments:

P5, Lines 133-143: The meanings of the terms in Eqs. (2)-(4) should be described in the order in which they appear.

P7, Lines 208-210: The prescribed Na,i value for the AERO-DM10_Nai3 experiment is stated as 15×105 kg-1, which is inconsistent with Table 2. Please clarify the value actually used in the simulation. In addition, Lines 211-213 do not clearly state that Na,i remains prognostic in this experiment. This should be explicitly indicated in Table 2.

P10, Lines 244-246: The presentation of Eqs. (5a)-(7b) could benefit from clearer definitions of the units of all variables and terms for reproducibility.

P11, Lines 279-281: Figure 4 shows relatively small differences in vertically integrated cloud water content between AERO and BASE east of Inuvik, whereas vertically integrated ice water content is lower in AERO. The physical origin of the associated longwave-radiation differences is therefore not entirely clear. Does the reduced IWP decrease the cloud infrared optical depth, while the presence of lower and warmer cloud layers in AERO increases the effective radiating temperature, thereby contributing to a higher cloud-top brightness temperature and stronger outgoing longwave radiation? In addition, a comparison between BASE-DM10_Nai1 and AERO-DM10_Nai1 would be particularly informative for separating the effect of prognostic aerosol evolution from that of the ice-nucleation parameterization. Please clarify whether these two simulations show appreciable differences in IWP, cloud-top temperature and outgoing longwave radiation.

P14, Lines 295-298: For all sounding times, the 1-km simulation shows better agreement with the observed temperature profiles above 800 hPa than CAPS. The authors attribute this improvement mainly to the larger number of vertical levels used in the 1-km simulation. However, CAPS and AERO differ not only in vertical resolution, but also in horizontal grid

spacing, microphysics, and other model configurations. Therefore, the current comparison does not clearly demonstrate that the improved temperature profiles are primarily attributable to the increased vertical resolution. I suggest adding a sensitivity experiment within the AERO configuration in which only the number of vertical levels is changed while the other model settings are kept unchanged. This would provide a more direct assessment of the effect of vertical resolution.

P17, Figure 6: Please clarify the temporal matching and plotting method used for the relative humidity, temperature, and other variables shown in Figure 6. It is currently unclear whether the model value at a given output time is assumed to represent the conditions within a ±0.5 h window around that time. In addition, the current presentation appears to show multiple temperature or relative-humidity values corresponding to the same time at some points. I suggest clarifying the temporal matching procedure and considering a more intuitive plotting method to avoid this ambiguity.

P37, Lines 611-614: The aerosol fields are relaxed toward the climatological values using a timescale of 1.5 h. Given the relatively short relaxation timescale, such a strong constraint may limit the natural evolution of the prognostic aerosol concentrations associated with transport, sedimentation, aerosol activation, and cloud processing, and may therefore influence the aerosol–cloud interactions and the resulting cloud properties discussed in this study. Please provide the physical justification for choosing a 1.5h relaxation timescale.

P38, Lines 624-641: The implementation of the ARG cloud-droplet activation scheme appears to assume a single effective, internally mixed lognormal CCN mode, with fixed modal radius, geometric standard deviation, and chemical composition, while Na,w and Na,i are treated as prognostic variables. Please state explicitly how the aerosol population is represented in the implementation and clarify whether the summation over aerosol modes in Eq. (B6) is actually evaluated for more than one mode. The I in this equation should also be clearly defined, including whether it represents different aerosol modes or chemical components. In addition, please specify the assumed soluble fraction of the aerosol size distribution in the initial conditions.

Minor comments:

1. P3, Line 94: The citation “Morrison and Pinto, (2005, 2006)” is not formatted correctly. Please revise it according to the journal’s citation style and carefully check the entire manuscript for consistency and accuracy in the formatting of in-text citations and references.

2. P11, Line 273: Please verify whether the reference to “integrated IWC (Fig. 5a-b)” is correct. Based on the context, this appears to refer to Figure 4 rather than Figure 5. Please check and correct the cross-reference accordingly.

3. Figure 4: The panel labels for ice water content in the figure caption appear to be incorrect. They should be (d–f). Please check and correct the caption accordingly.

4.Throughout the manuscript: There are several grammatical and language issues throughout the manuscript, for example, P20, Lines 400-401; P44, Line 740; and Line 744 in the Author Contributions section. The authors are encouraged to carefully proofread the entire manuscript to correct grammatical errors and improve the clarity and readability of the text.

5. Figures 10-13: There are several errors or inconsistencies in the figure captions. For example, the (c), AERO in Figure 10 appears to be incorrect. Please carefully check and revise all captions for Figures 10-13.

6. Figure 8: I suggest using the same x-axis representation in panel (b) as in panel (a) to ensure consistency between the two panels.