The conclusions in ACP articles are required to include all of the following aspects:

Summary: Summarize the main results and relate them to the objectives, questions, or hypotheses of the study. The summary should include the main quantitative results.

Synthesis/interpretation: Explain and interpret the results concisely to enable readers to make sense of them as a whole.

Comparison and context: Compare the results with previous studies to put them in context. Explain consistencies, inconsistencies, and advances in knowledge.

Caveats and limitations: State how these affect confidence in the overall results, and where future work is needed.

Implications: Discuss what the results mean for our understanding of the state and/or behaviour of the atmosphere and climate, which is the main requirement for publication in ACP

Please refine Sec. 4 Summary and conclusions of your manuscript according to these requirements. At least, in my opinion, some important quantitative results might be added to support your conclusions.

Response: We sincerely thank the Editor for the constructive and insightful comments. We have re-written the Section 4 following the requirements.

"*4. Summary and conclusions*

Using a cloud-resolving fully coupled WRF-Chem model, this study investigates a heavy snowfall event occurred in GZB+GZBs from 26 to 28 January 2022, with a focus on disentangling the roles of ACIs and ARIs under different aerosol loadings. The model reasonably reproduces the observed evolution of air pollutants and snowfall, with IOAs exceeding 0.60 for $PM_{2.5}$, O_3, and NO_2, and 0.85 for accumulated precipitation. A series of sensitivity simulations covering aerosol loadings from relatively clean to heavily polluted conditions are conducted to quantify the nonlinear responses of cloud microphysics and snowfall to anthropogenic aerosols.

Sensitivity results reveal that ARIs substantially modify the thermodynamic *structure of the lower troposphere. Increasing aerosol loading reduces the mean PBLH by approximately 34%, while producing cooling below 1.8 km and weak warming aloft, thereby enhancing lower-tropospheric stability and inducing secondary downward motion within the PBL and upward motion aloft. These dynamical adjustments redistribute atmospheric moisture, decreasing RHW below 3 km while enhancing RHI in the mixed-phase cloud layer under polluted conditions. Consequently, CND of cloud droplets exhibits a nonlinear response to aerosol loading, with a threshold occurring at an AESF of approximately 2.5 when ARIs are included. Meanwhile, the increase in IWP under polluted conditions is primarily associated with enhanced collection of cloud water by ice crystals.*

The response of precipitation to ARIs and ACIs is different in GZB and GZBs. In the GZB, excluding ARIs leads to a weak increase in three-day accumulated precipitation with increasing emissions. Although increasing aerosols considerably decrease the liquid-phase precipitation, the ACI-induced increase in ice-phase precipitation outweighs the decrease in liquid-phase precipitation. ARIs increase the precipitation in the GZB when the AESF exceeds 0.6, due to ARI-induced increase in RHI which increase IWP and facilitate survival ice-phase particles in the atmosphere. In contrast, precipitation in the GZBs decreases with increasing aerosols, reflecting the dominance of liquid-phase precipitation that is strongly suppressed by ACIs and further reinforced by ARI-induced reductions in RHI. Increasing anthropogenic emissions do not substantially alter the precipitation pattern in GZB+GZBs, but can modify the frequency distribution of precipitation intensity.

Compared with previous studies over the GZB, which have primarily reported aerosol-induced suppression of precipitation through cloud microphysical effects (e.g., Yang et al., 2013a, b; Bei et al., 2025), the present study demonstrates that the response of winter snowfall cannot be explained solely by warm-cloud microphysics. Instead, the competition between liquid-phase suppression and ice-phase enhancement, together with ARI-induced thermodynamic adjustments, determines the net snowfall response. These results highlight that aerosol impacts on winter mixed-phase precipitation depend strongly on cloud phase partitioning and ambient thermodynamic conditions, providing new understanding of aerosol–cloud–radiation coupling under polluted winter environments. The identified regional contrast also suggests that aerosol effects on snowfall may vary considerably within the same synoptic system owing to differences in cloud microphysical characteristics and background humidity, emphasizing the *importance of representing coupled aerosol–radiation–cloud processes in numerical weather prediction and regional climate models.*

The sensitivity experiment design used to separate ARIs and ACIs is subject to uncertainties arising from the nonlinear coupling between radiation, thermodynamics, and cloud microphysics. The differencing approach does not fully isolate pure ARIs but rather includes contributions from nonlinear interactions between ARIs and ACIs. While this approach is widely used in the previous studies (Bei et al., 2025; Ding et al., 2019; Wu et al., 2018), the quantitative ARIs effects reported here may contain some uncertainty, particularly in regions with strong aerosol-cloud-radiation feedbacks. Nevertheless, the robust regional contrast in precipitation responses that enhancement in the GZB versus suppression in the GZBs is substantially larger than the estimated uncertainty due to nonlinearities, and the qualitative conclusions of this study remain robust. In addition, the present conclusions are based on a single snowfall event, and their broader applicability should be evaluated using additional winter precipitation cases. Future studies combining long-term observations, multi-case simulations, and more advanced radiative perturbation approaches will further improve the quantitative attribution of ARIs and ACIs and help assess the generality of the threshold behaviors identified in this study."