Response letter

February 15, 2026

Dear Prof. Andreas Petzold，

We would like to thank you for the careful handling and valuable guidance throughout the review process, which have played a crucial role in polishing the paper and ensuring its academic rigor. We have added a paragraph which put our findings into context and discuss the implications of the findings for better understanding atmospheric physical processes. The corresponding revisions have been made accordingly in the manuscript, and listed. They are listed in this letter marked with blue text.

Our findings on the distinct flux regimes of dust and anthropogenic aerosols during a winter haze event in Beijing provide new process-level insights that extend previous research. While earlier studies have established the importance of northwesterly transport for dust episodes and the role of the boundary layer in pollutant accumulation (e.g., Huang et al., 2020; Zhang et al., 2020), this study quantifies the type-resolved vertical and horizontal flux structures and their emission rates. The high correlation in horizontal fluxes but weaker correlation in vertical fluxes between dust and non-dust aerosols advances the understanding that while synoptic-scale advection controls the co-transport of different aerosol types, their surface-atmosphere exchange processes (e.g., emission vs. sedimentation) are governed by fundamentally different mechanisms. This result is consistent with the conceptual model of external versus local source dominance and provides lidar-based vertical flux evidence for such a decoupling in the NCP.

From the perspective of atmospheric physical processes, our results clarify the coupling relationship between synoptic-scale meteorological processes (westerly jet, cold air advection) and boundary-layer-scale dynamics (PBL height, turbulence) in regulating aerosol flux structure over the NCP: the upper-level westerly jet controls the vertical transport range of aerosols, while the boundary layer dynamics dominate the near-surface aerosol accumulation and diffusion, and their joint action determines the temporal and spatial distribution of air pollution in Beijing. This coupling mechanism is a key part of the atmospheric circulation-pollution interaction in the East Asian winter monsoon region, and the quantitative flux data obtained in this study can provide a reliable observational constraint for improving the parameterization of aerosol transport in atmospheric numerical models. For the understanding of atmospheric composition and climate effects, the decoupling of dust and non-dust aerosol fluxes helps to accurately assess their different radiative forcing effects: dust aerosols (mainly in the elevated layer) have a direct radiative effect on the upper boundary layer, while non-dust aerosols (accumulated in the near-surface layer) mainly affect the surface radiation balance and boundary layer development. The quantitative results of their transport fluxes provide a basis for further studying the contribution of different aerosol types to the regional climate of the NCP.

Best regards,

Longlong Wang on behalf of all the authors