ATMOSPHERIC AND OCEANIC SCIENCES

DEPARTMENT OF GEOSCIENCES

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Dec 7th, 2025

Dear ACP Editor,

Thank you for your feedback and careful reading of our manuscript. We are happy to submit a revised manuscript, "*Resolving the roles of soot and dust in cirrus cloud ice formation at regional and global scales: insights from parcel and climate models*". We highly appreciate your time and valuable suggestions. Below, we provide detailed responses to all reviewer comments. For clarity, the reviewer comments are presented in **gray**, our responses in **black**, and revised text in **blue**. We hope that our revisions address all concerns.

Best wishes,
Xiaohan Li, Songmiao Fan, Huan Guo, Paul Ginoux

Reply to the Editor

Thank you for submitting a revision of the manuscript entitled "Resolving the roles of soot and dust in cirrus cloud ice formation at regional and global scales: insights from parcel and climate models" to Atmospheric Chemistry and Physics. I have two received two reviews of your revised manuscript. Both reviewers recommend publication of the manuscript in the present form. Based on the recommendation of the reviewers and my own review of the manuscript, I recommend acceptance of your article in Atmospheric Chemistry and Physics pending the following few minor revisions:

1. Please revise the title and line 82 of the manuscript to "a climate model" (singular, not plural) as GFDL AM4-MG2 is the only climate model used in the study.

3. Lines 121-123: please reference the heterogeneous nucleation schemes for dust and soot used in the parcel model.

Reply to Q1&Q3: Thanks for raising these points. We have revised the manuscript accordingly as suggested.

2. Please include a description of the results pertaining to the role of dust in cirrus cloud formation in the Abstract. The Abstract currently focuses on soot.

Reply to Q2: We thank the Editor for this helpful suggestion. We have we have revised the abstract to incorporate a description of the dust-related results, ensuring that the roles of both dust and soot in cirrus formation are represented. The current abstract reads:

"Atmospheric aerosols can serve as ice-nucleating particles (INPs), influencing cirrus cloud formation and properties. While mineral dust is recognized as an effective INP, the role of soot remains less explored, limiting climate impact assessments. Here we use cloud parcel model simulations to examine the competitive ice nucleation behavior of soot and dust, alongside homogeneous nucleation. **These process-level simulations reveal that dust dominates heterogeneous ice nucleation at colder temperatures (T < 210 K),** whereas soot becomes effective at warmer temperatures (T > 215 K), particularly when dust concentrations are low or under strong updrafts. To evaluate their global-scale implications, we integrate these results into the GFDL AM4-MG2 climate model. We find that **dust shapes the baseline spatial and seasonal ice crystal number concentration (ICNC) patterns,** while soot (represented in the model as black carbon, BC) enhances global-mean ICNC by ~5%. However, BC-driven increases in ICNC can be much larger in the upper troposphere (500–250 hPa), reaching up to 90%. The strongest enhancements are found during boreal spring across Eurasia and the Maritime Continent, and during austral spring over South America and the South Atlantic. Radiatively, BC INPs can enhance the annual global longwave cloud radiative effect by approximately 0.24 W m^{-2} and cause statistically significant net warming in both polar regions during their respective winters. These results highlight the coupled roles of dust and soot in cloud ice formation, underscoring the need to assess the impacts of rising wildfire emissions on atmospheric ice processes and associated climate effects.**"**