

We are very grateful to the evaluations from the editor, which have allowed us to clarify and improve the manuscript. Below we addressed the editor comments, with the comments in black and our response in **blue**.

### **Reply for Editor**

**Comment#1:** The paper is well-structured; however, it appears that the figures are not presented in order. For example, in line 193 (track change version of the manuscript), Figure 7 is mentioned after Figure 1. There are also other cases. Please ensure that figures are presented in order; you may state that some findings are discussed later, as in the case above, or reorder the figures accordingly. Also, please make sure that all the figures that are presented are addressed in the main text.

**Response:** Thank you for your comment. The issue you mentioned regarding line 193 (in the track-changes version of the manuscript, where Figure 7 is cited after Figure 1) has been resolved. In addition, we paid particular attention to the order of figures and tables in the Supplementary Information. We have reorganized their sequence and removed those that were not referenced in the main text.

Regarding the figures in the main manuscript, we acknowledge that some inconsistencies in order remain. This is mainly because some key figures, such as Figures 2, 6, and 7 (in the track-changes version of the manuscript) are referenced multiple times throughout the manuscript due to their importance. To improve clarity, we have rearranged the positions of Figures 5, 6, and 7, and ensured that all figures are first introduced in the text following their numerical order.

The sentence in Lines 181-183 were modified as (The underlined content is newly added or modified):

“The increase in CCN number due to the addition of organic NPF mechanisms is simulated not only in the locations listed in Table 2 but also on a global scale (see Fig. 7), as further discussed in Section 4.1.”

The sentence in Lines 269-270 were modified as (The underlined content is newly added or modified):

“To analyze the change in ERF<sub>aci</sub>, we also compare the fractional changes of other key variables (nucleation rate, growth rate, aerosol number, CCN number, and CDNC) from PI to PD in Inorg\_Org and Inorg (Fig. 7).

**Comment#2:** Meteorological nudging: Please make sure the nudging is actually every 30 minutes and address the percentage of nudging. A default setting for nudging is usually a nudging of 30 minutes by 10 %, with a 5-hour Newtonian relaxation timescale for nudging (e.g., Tilmes et al, 2015, doi:10.5194/gmd-8-1395-2015)

**Response:** Thank you for your comment. We would like to clarify that in our model (such as the Inorg and Inorg\_Org in Table 1), we actually used 100% nudging (i.e., with a 0.5-hour Newtonian relaxation timescale), which is consistent with the physics timestep of the model. Additionally, for the long-term experiments (lasting over ten years, such as those with the prefixes "PD" and "PI" in the test names in Table 1), we use a free run setup (Tilmes et al., 2015). We have added a detailed explanation of these adjustments in the revised manuscript to avoid any confusion.

The sentence in Lines 131-151 were modified as (The underlined content is newly added or modified):

“Ten-year simulations were performed with  $0.9^\circ \times 1.25^\circ$  spatial resolution and a vertical resolution extending up to approximately 40 km across 32 layers (Emmons et al., 2020) for both present-day (PD) and preindustrial (PI) atmospheres with an additional one-year spin-up period (Table 1). Sea surface temperature and sea-ice extents are prescribed to climatological values for the year 2000 in both PD and PI cases. Anthropogenic and monthly biomass burning emissions are provided by the Community Emission Data System (CEDS v2017-05-18) (Hoesly et al., 2018) and the historical global biomass burning emissions inventory (van Marle et al., 2017) developed for CMIP6. For PD simulation, emissions after 2014 follow the SSP585 scenario, based on the Shared Socioeconomic Pathway 5 (SSP5) (O’Neill et al., 2017). Biogenic emissions are dynamically simulated using the Model of Emissions of Gases and Aerosol from Nature version 2.1 (MEGAN2.1) (Guenther et al., 2012). The Multi-resolution Emission Inventory for China (MEIC) (<http://www.meicmodel.org>) (Li et al., 2017; Yue et al., 2023) was used to replace the CMIP6 emission inventory for China, as CMIP6 underestimates the reduction of SO<sub>2</sub> emissions after 2007. Since meteorological fields are not available for the PI experiment, we use configurations with internally derived free-running (FR) meteorology (Tilmes et al., 2015).

In order to compare simulated CCN with measurements, several short-term simulations were performed, in which meteorological fields (temperature and wind profiles, surface pressure, surface stress, surface heat and moisture fluxes) were nudged toward Modern-Era Retrospective analysis for Research and Applications (MERRA2) reanalysis using a 0.5-hour Newtonian relaxation timescale (i.e., 100% nudging; Tilmes et al., 2015). ~~with a relaxation timescale of 6 hr (Kooperman et al., 2012).~~ The simulation period corresponded to the time of measurements (Table 2), with an additional month for spin-up. ~~Meteorological fields are nudged towards the~~

~~MERRA2 every 0.5 h, which is the same as the physics timestep of the model (Lamarque et al., 2017). The simulated meteorological fields and their deviations from MERRA2 reanalysis are presented in Figure S2.~~

**Comment#3:** It is still not clear to me why CCN have a longer lifetime than aerosol particles. CCN in the model is a diagnostic that includes a specific size (Aitken and accumulation mode). So the lifetime of the burden of Aitken and the accumulation mode should be similar to CCN. However, perhaps the authors mean that the fraction of coarse-mode particles would be removed more quickly than the smaller particles? Please clarify and revise in the text.

**Response:** Thank you for your reminder, and we appreciate your valuable feedback. We would like to emphasize that smaller particles (Aitken mode particles, <50 nm) generally exhibit higher removal efficiencies than CCN. This is because, in addition to wet and dry deposition, ultrafine particles are more likely to be lost through coagulation with larger, pre-existing aerosols, resulting in a shorter atmospheric lifetime (Pierce et al., 2009; Riemer et al., 2009). This is the reasoning behind our original statement that CCN typically have a longer lifetime and broader spatial influence than smaller aerosol particles.

However, as you rightly pointed out, CCN are a diagnostic variable in the model and are influenced by both Aitken mode and accumulation mode particles. Therefore, the original statement may be misleading in the modeling context. To avoid confusion, we have removed the sentence originally located in lines 202-204 of the manuscript, which read as follows:

“Since ultrafine particles (< 50 nm) are quickly lost by coagulation to larger, pre-existing aerosol, CCN typically have a longer atmospheric lifetime and are less efficiently removed than smaller aerosol particles, allowing them to exert influence over wider spatial scales (Pierce et al., 2009; Riemer et al., 2009).

## Reference

Pierce, J. R., & Adams, P. J. (2009). Uncertainty in global CCN concentrations from uncertain aerosol emissions and nucleation rates. *Atmospheric Chemistry and Physics*, 9(4), 1339–1356.

Riemer, N., West, M., Zaveri, R. A., & Easter, R. C. (2009). Estimating black carbon aging time-scales with a particle-resolved aerosol model. *Atmospheric Chemistry and Physics*, 9(4), 1339–1356.  
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Tilmes, S., Lamarque, J.-F., Emmons, L. K., Kinnison, D. E., Ma, P.-L., Liu, X., Ghan, S., Bardeen, C., Arnold, S., Deeter, M., Vitt, F., Ryerson, T., Elkins, J. W., Moore, F., Spackman, J. R., and Val Martin, M.: Description and evaluation of tropospheric chemistry and aerosols in the Community Earth System Model (CESM1.2), *Geosci. Model Dev.*, 8, 1395–1426, <https://doi.org/10.5194/gmd-8-1395-2015>, 2015.