Response to Reviewer 1

Thank you for your careful and thorough reading of the manuscript and thoughtful comments and suggestions. Our responses follow your comments (in *Italics*).

General comments:

In this article the authors investigates the impact of horizontal grid spacing on aerosol mass budget, aerosol-cloud interactions, and effective radiative forcing of anthropogenic aerosols by comparing the nudged simulation results for 2016 from the low-resolution model (LR) and the regional refinement model (RRM).They show that a remarkable difference in simulated emissions of natural dust, sea salt, and marine organic matter between in the RRM than in the LR due to larger surface wind speeds, more frequent strong surface winds, or drier soil in the RRM than in the LR. Increasing model horizontal resolution affects the partitioning between large-scale and convective precipitation, and then leads to increased (decreased) aerosol wet scavenging by large-scale (convective) precipitation in the RRM.

As the authors apply nudging globally in the LR and RRM simulations, which used nudging only on the low-resolution meshes but not the high-resolution grids in CONUS, it is better to compare the simulated surface winds and precipitation in the RRM and the LR to the observations in 2016. That is helpful to understand the differences for aerosols simulations are directly caused by circulation and precipitation variation from the LR to the RRM.

Reply:

Thank you for your comments and suggestions. We clarify that nudging is applied to both the low-resolution and high-resolution grids in this study (Line 163 in the revised main manuscript). Unlike Tang et al. (2019) who nudged winds outside the regional-refined domain, we nudge large-scale winds everywhere in both LR and RRM towards the ERA5 reanalysis. This allows us to identify the aerosol forcing signals without lengthy simulations (Kooperman et al., 2012). Previous studies demonstrate that the calculated forcing closely resembles that from free-running simulations (e.g., Zhang et al. (2014)).

In the original manuscript (Lines 265-288 in the revised main manuscript), we evaluated the LR and RRM simulated precipitation against the observational Stage IV dataset. Here we further evaluate the wind fields at different pressure levels against the ERA5 reanalysis (Figures R1-R4). Since wind fields in both simulations are constrained by nudging towards ERA5, their differences are small, except in regions near the Rocky Mountains. While the differences are still minimal at high levels, they become observable at low levels. There are two possible reasons for this. 1) Wind fields are nudged only between 950 and 10 hPa, and the surface drag effect may perturb the low-level wind fields. 2) Topography is better resolved in RRM than in LR, and the topography used in the ERA5 reanalysis model also differs from our simulations.

In short, the large-scale circulations in RRM and LR are very close to ERA5 because of nudging.

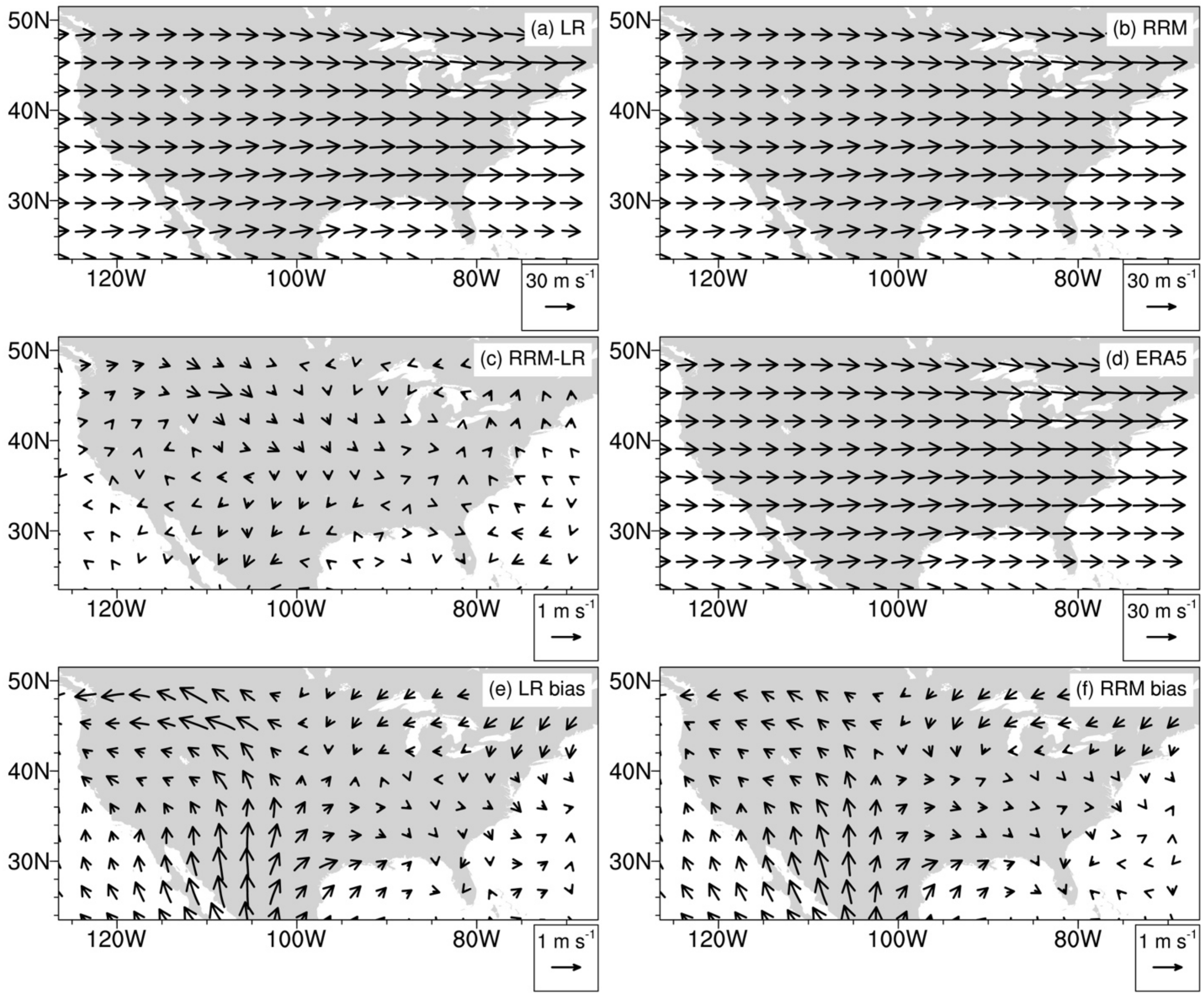

Figure R1. (a-c) Annual mean wind fields at 200 hPa for the (a) LR and (b) RRM simulations and (c) their differences (RRM-LR). (d-f) Annual mean wind fields at 200 hPa from ERA5 and the wind biases of the LR and RRM simulations against ERA5.

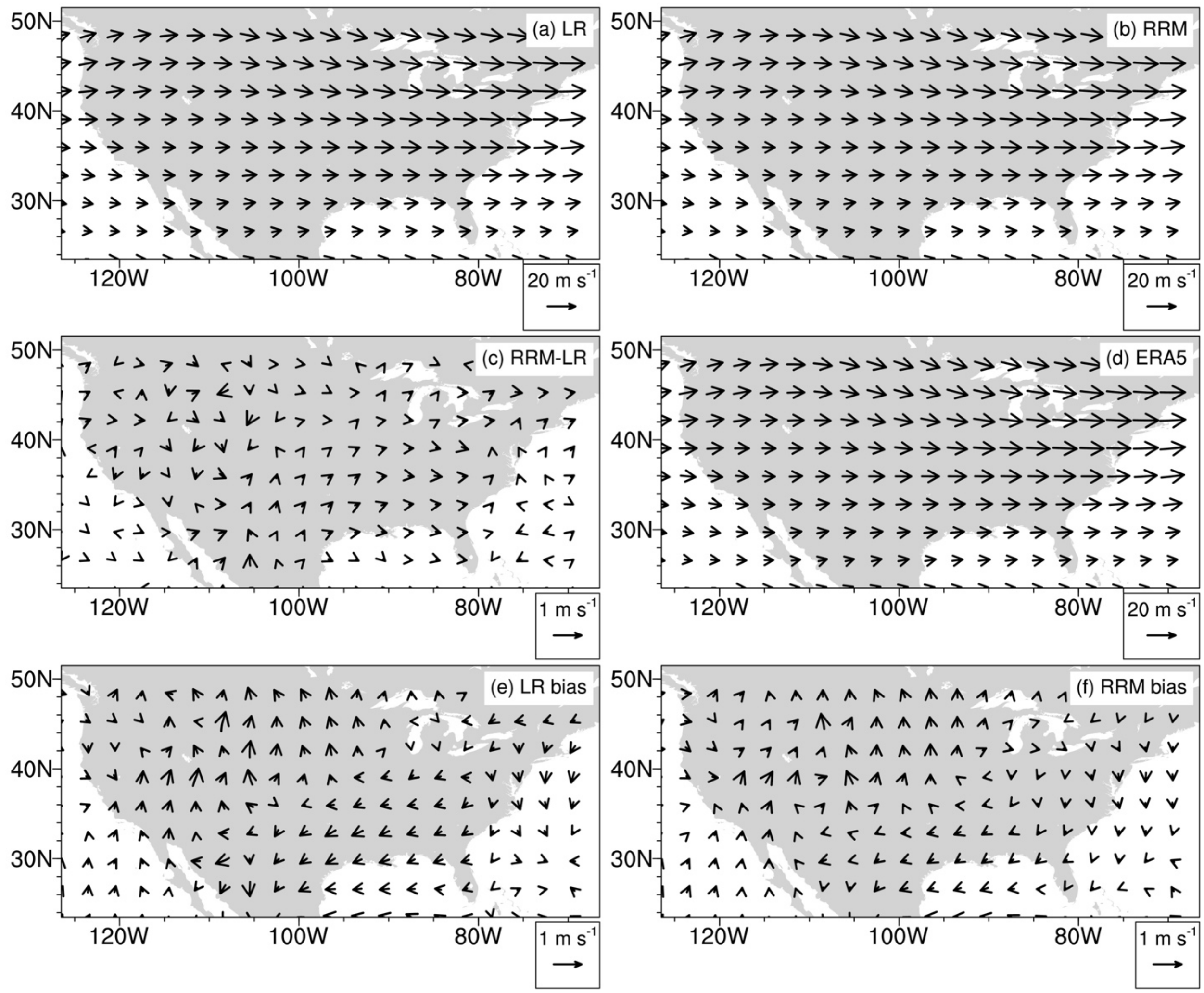

Figure R2. Similar to Figure R1 but for wind fields at 500 hPa.

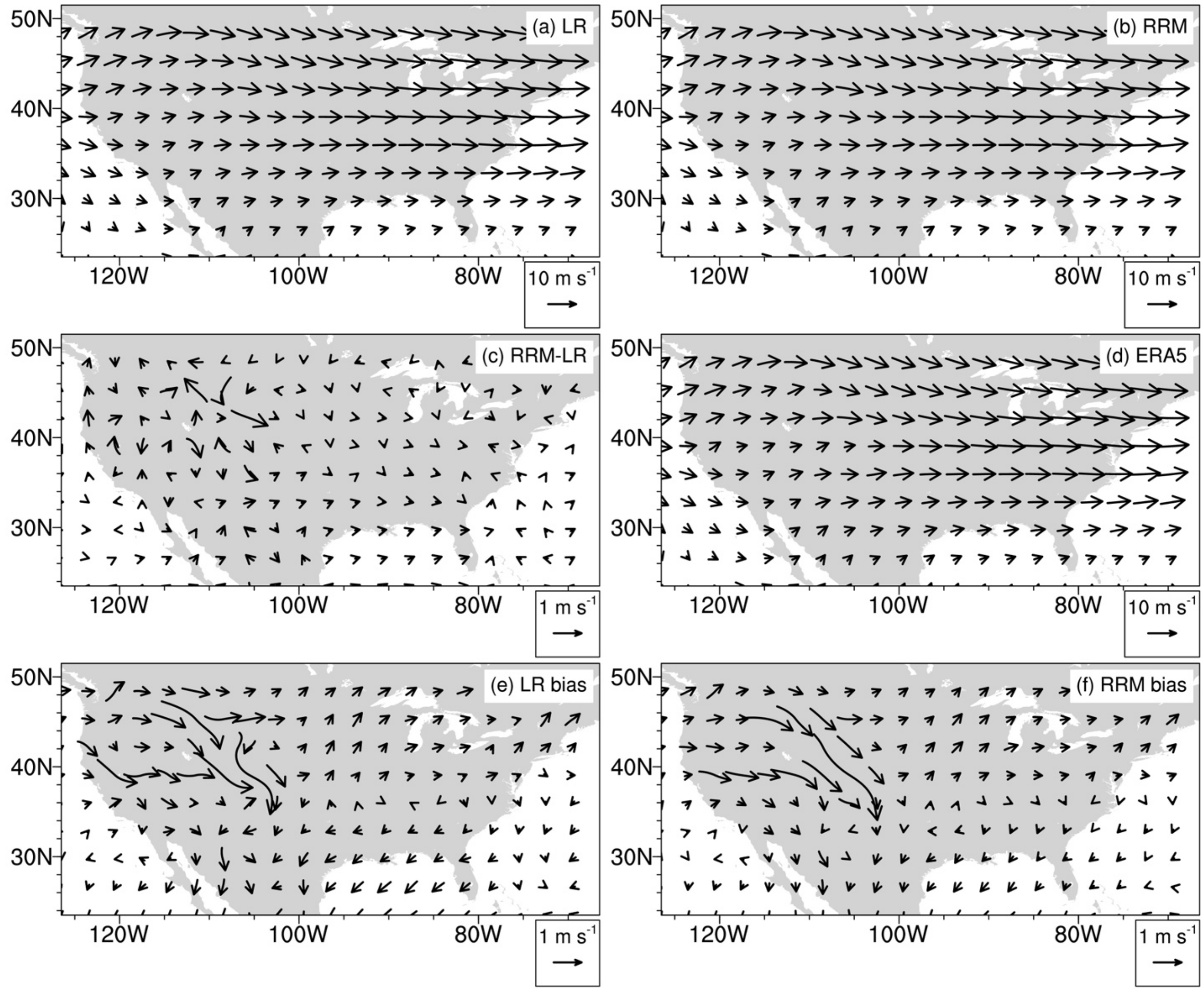

Figure R3. Similar to Figure R1 but for wind fields at 700 hPa.

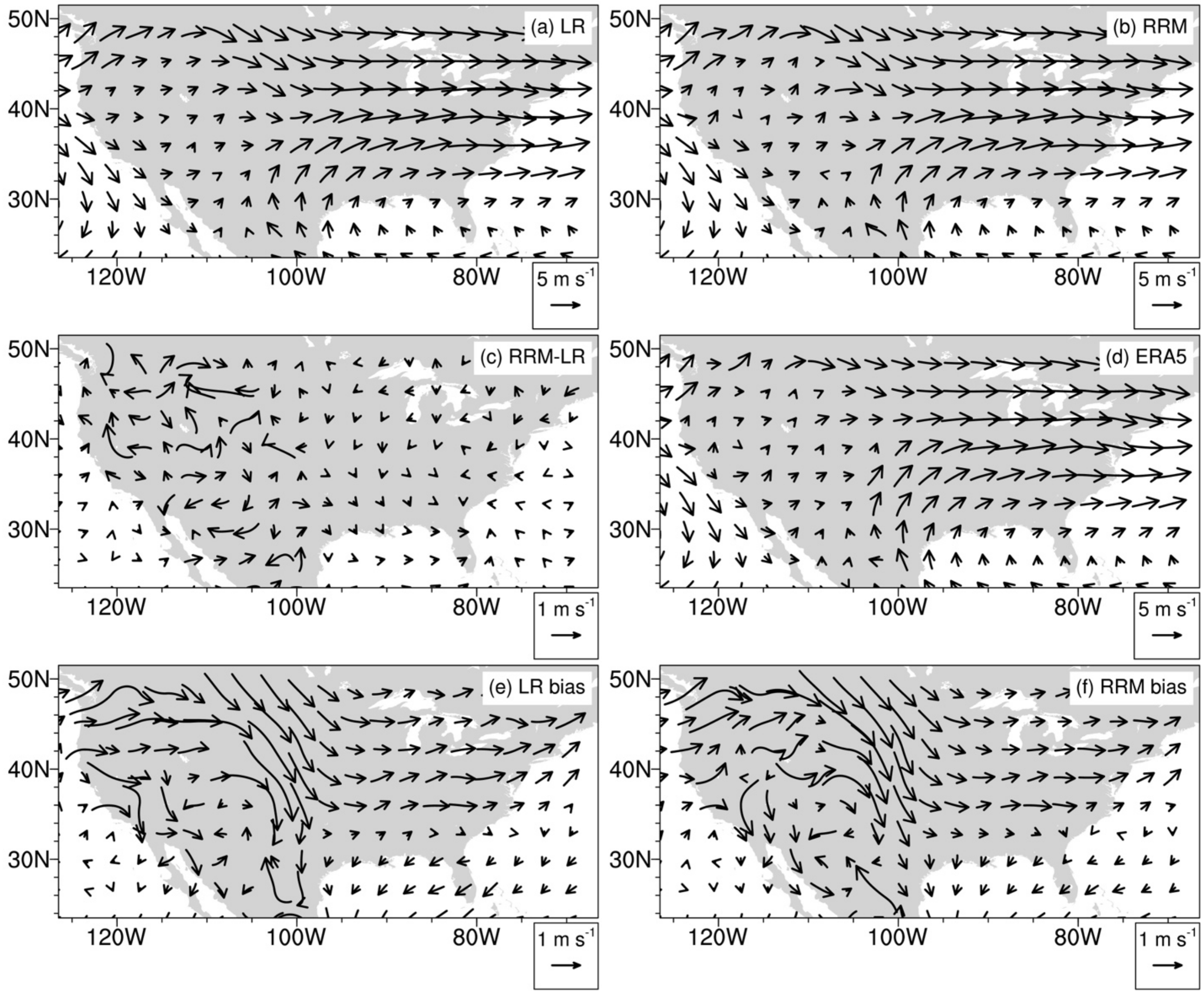

Figure R4. Similar to Figure R1 but for wind fields at 850 hPa.

We employed the same configuration and tuning parameters for both the LR and RRM simulations, based on the default RRM settings. The only exceptions were horizontal resolution and resolution-specific input files, such as topography and wind fields for nudging. Source files for these are interpolated onto different model grids (LR and RRM) to be used in the corresponding simulations.

The default LR configuration, which is used to achieve good model performance for LR against observations, differs from that used in RRM. Using the default RRM configuration in the LR simulation may degrade its performance. Therefore, a direct comparison of LR and RRM performances against observations is not meaningful. Instead, this study focuses on comparing LR and RRM to understand which aspects of aerosols are mainly affected by horizontal resolution. This constructs a useful methodology for future studies aiming to evaluate the fidelity of current aerosol parameterizations at higher resolutions, especially at convection-permitting resolutions (as highlighted in Lines 544-551). Our findings also offer useful insights for the development of aerosol parameterizations at high resolutions.

Minor comments:

In the section "E3SMv1 model description", whether the vertical transport processes of aerosols by deep convection have been included needs to be mentioned.

Reply:

Thank you for your suggestion. E3SMv1 considers the convective transport of aerosols (Wang et al., 2013; Wang et al., 2020). We have added the information in Line 128 in the revised main manuscript.

'The evolution of aerosol particles involves many physical and chemical processes, such as emissions, nucleation, coagulation, condensation, convective transport, activation, dry deposition, wet scavenging, resuspension, and gas-phase and aqueous chemistry.'

References

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Wang, H., Easter, R. C., Rasch, P. J., Wang, M., Liu, X., Ghan, S. J., Qian, Y., Yoon, J.-H., Ma, P.-L., and Vinoj, V.: Sensitivity of remote aerosol distributions to representation of cloud–aerosol interactions in a global climate model, Geoscientific Model Development, 6, 765-782, https://doi.org/10.5194/gmd-6-765-2013, 2013.

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Zhang, K., Wan, H., Liu, X., Ghan, S. J., Kooperman, G. J., Ma, P.-L., Rasch, P. J., Neubauer, D., and Lohmann, U.: On the use of nudging for aerosol–climate model intercomparison studies, Atmospheric Chemistry and Physics, 14, 8631-8645, https://doi.org/10.5194/acp-14-8631-2014, 2014.