Response to Reviewer 2

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

Review on the "Assessing the Sensitivity of Aerosol Mass Budget and Effective Radiative Forcing to Horizontal Grid Spacing in E3SMv1 Using A Regional Refinement Approach" by Li et al.

Atmospheric aerosols are important implications for the Earth's climate system. The present study explores the impact of horizontal resolution of aerosols of the E3SMv1 model in the climate system. The impact of the resolution of the regional refinement model (RRM) in 0.25 degree is estimated by comparing with the traditional and coarser low-resolution model (LR) in 1 degree. The analysis has been comprehensively conducted by comparing aerosol emission, horizontal and vertical distributions of aerosols and precursors, meteorological conditions, and direct radiative effect for the preindustrial and present-day period, between two simulations. The method is scientifically sounding, and the manuscript is overall well organized and written.

However, I have two major issues. First, there is no evaluation of the simulated aerosols throughout the paper. I see quite significant differences between the two simulations as shown in dust and seasalt emissions. It is extremely difficult to judge if RRM is better than LR or the other way. I would strongly encourage to add evaluations with available observation data such as remote sensing AOD, IMPROVE, or field experiment. Secondly, there is a major issue in experiment design, since there are more factors involved between two models other than horizontal grid spacing as indicated in the title. This is also written in the method section of the manuscript. Considering a hierarchical nature of numeral models, it is extremely difficult to separate the impact of the horizontal gridding, from the other. I think this issue should be solved in the revision. For those reasons I would recommend "accept with major revision".

Reply:

Thank you for your comments and suggestions. For convenience, we address the second issue first.

We want to emphasize that both the LR and RRM simulations utilize the same configuration and tuning parameters, based on the default RRM settings. The only exceptions are horizontal resolution and resolution-relevant input files (e.g., nudging-prescribed wind fields and topography), as explained in Lines 150-151 and 192-194 in the revised main manuscript. Source files for these input files are interpolated onto their respective LR and RRM model grids (LR and RRM).

Horizontal resolution may affect large-scale circulations and in turn, affect aerosols. Therefore, we applied the same nudging strategy to both simulations to mitigate this effect (Line 163). This ensures that the differences between the LR and RRM results are primarily attributable to horizontal resolution, minimizing the influence of other factors. While we acknowledge that interactions and feedback among various physical and chemical processes can introduce some residual influence from factors beyond horizontal resolution, we find that the LR and RRM simulations produce similar results in low-resolution areas (Lines 194-196), and the apparent discrepancies between LR and RRM are only identified in the RRM region. This indicates that the differences in the RRM region are primarily due to horizontal resolutions, although not entirely.

Theoretically, we could further reduce the minor impact of large-scale circulations or meteorology by specifying the same meteorology (such as precipitation, wind, pressure, etc.) in the LR and RRM simulations. This can be easily done in chemical and transport models (CTMs) (e.g., GEOS-Chem) due to their offline meteorology, allowing the use of identical meteorology (except for regridding) regardless of horizontal resolution. However, it is impractical to implement this approach in E3SM. Deactivating the dynamical core, while technically possible, would require extensive modifications and the resulting model would not represent the original E3SM anymore. This is also inconsistent with the methodology used in other E3SM studies.

We, therefore, opted to utilize the same model configuration as employed in the current RRM. We have also made every effort to minimize the influence of other factors (e.g., model time steps, initial conditions) on the comparison between LR and RRM simulations.

Now we return to the first issue.

Since tuning is widely used in Earth System Models (ESMs) and we used the same configuration and tuning parameters (based on the default RRM configuration) for the LR and RRM simulations, the LR simulation may not achieve its best model performance. Therefore, it is unfair to conclude whether LR or RRM is better than the other based on evaluations of the current simulations against observations. This was not our intention in the first place. Instead, by comparing LR and RRM, we aim to understand which aspects of aerosols can be exclusively affected by horizontal resolutions. This approach helps to evaluate the sensitivity of current aerosol parameterizations to model resolution and provides insights on how to refine them in high-resolution E3SM simulations, particularly at convection-permitting scales (Lines 544-551).

Although assessing the model results is not the focus of the study, following the suggestion, we have evaluated the LR and RRM simulated aerosol optical depth (AOD) at 550 nm and aerosol concentrations against observations from MODIS (Moderate Resolution Imaging Spectroradiometer), AERONET (AErosol RObotic NETwork), and IMPROVE (Interagency Monitoring of Protected Visual Environments) below. Figure R5 and Table R1 provide the global evaluations of annual, JJA, and DJF mean AOD against MODIS in 2016, while Figure R6 and Table R2 focus on the RRM region. Overall, both simulations can generally capture the global spatial distribution patterns of AOD at 550 nm, but they significantly underestimate AOD over the contiguous United States (CONUS). Slight improvements are found in the CONUS when horizontal resolution becomes finer (Table R2) based on our current configuration. Figure R7 evaluates the LR and RRM simulated annual mean AOD at 550 nm and aerosol mass concentrations against AERONET (AOD) and IMPROVE (BC, organic carbon (OC), and SO_4) data. The model results are comparable to observations within a factor of two except for SO_4 with significant overestimations. Figure R8 displays the seasonal cycles of AOD, BC, OC, and SO_4 from observations and model results. The LR and RRM simulations roughly capture the observed seasonal cycle patterns. Again, SO_4 is significantly overestimated in E3SM compared to the IMPROVE observations.

Minor differences are found between the LR and RRM simulations in the figures and tables below (Figures R5-R8 and Tables R1-R2). It is hard to determine which one is better, which is not the purpose of the study either. Nevertheless, we have added Figures R5 and R7 and Table R1 to the revised supplement (Lines 13-51) for reference and cited them in Line 134 in the revised main manuscript. All figure numberings have been updated as well.

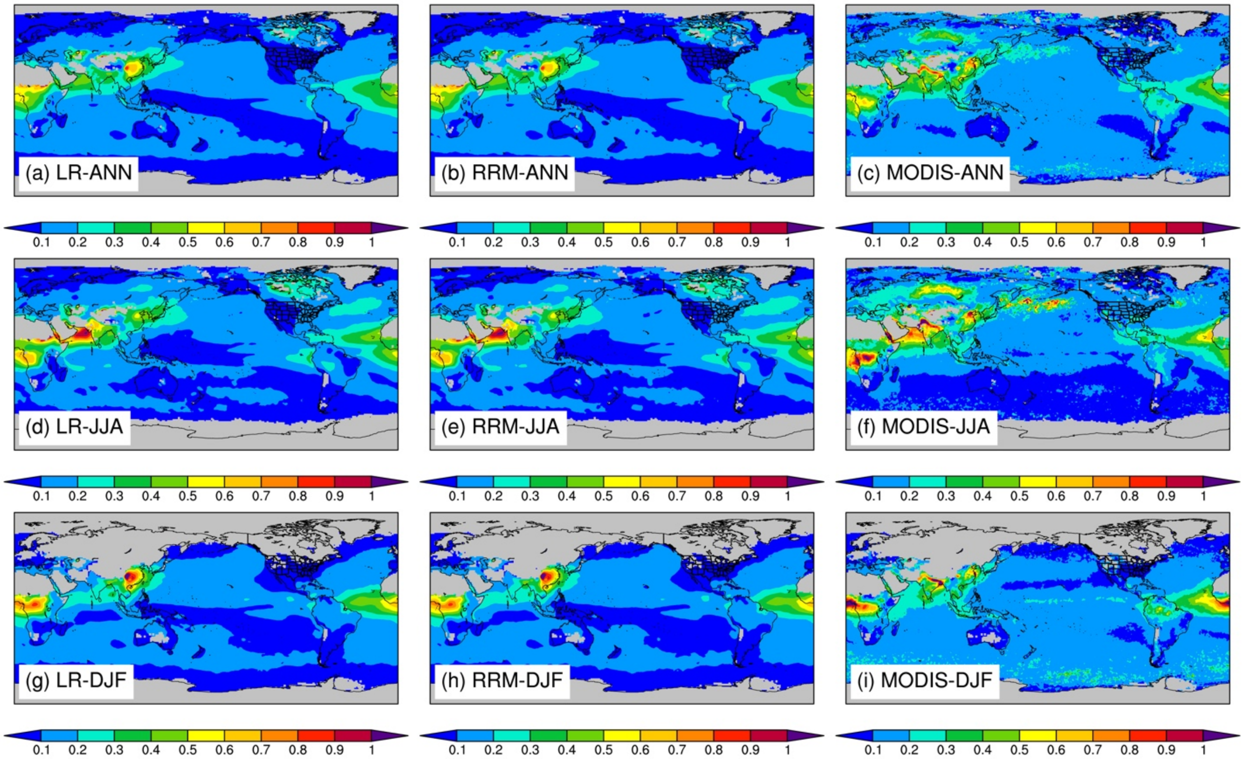

Figure R5. Spatial distributions of AOD at 550 nm from the (a, d, g) LR and (b, e, h) RRM simulations and (c, f, i) MODIS datasets in 2016. (a, b, c) ANN refers to the annual mean, (d, e, f) JJA indicates June, July, and August, and (g, h, i) represents December, January, and February. Here, we use the level-3 MODIS gridded monthly Dark Target AOD products (MOD08_M3 and MYD08_M3). The averages of monthly MOD08_M3 and MYD08_M3 AOD are used to calculate the MODIS annual, JJA, and DJF mean AOD in the figure. For the LR and RRM simulations, we output averaged AOD during 10:00-11:00 Local Solar Time (LST) and 13:00-14:00 LST each day to match MOD and MYD observations, respectively. Monthly AOD from the LR and RRM simulations are then filtered using the corresponding data availability of MOD08_M3 and MYD08_M3 AOD. Finally, we calculate the annual, JJA, and DJF mean AOD for the LR and RRM simulations and the MODIS datasets.

Table R1. AOD evaluation statistics based on Figure R5

	MODIS	LR	RRM

	Mean[1]	Mean	RMSE	r	Mean	RMSE	r
ANN	0.159	0.130	0.084	0.66	0.130	0.084	0.66
JJA	0.164	0.149	0.098	0.72	0.149	0.099	0.72
DJF	0.162	0.130	0.092	0.68	0.129	0.093	0.68

[1] "Mean" refers to the global mean; RMSE (root-mean-square-error) and r (Pearson correlation coefficient) are against MODIS observations.

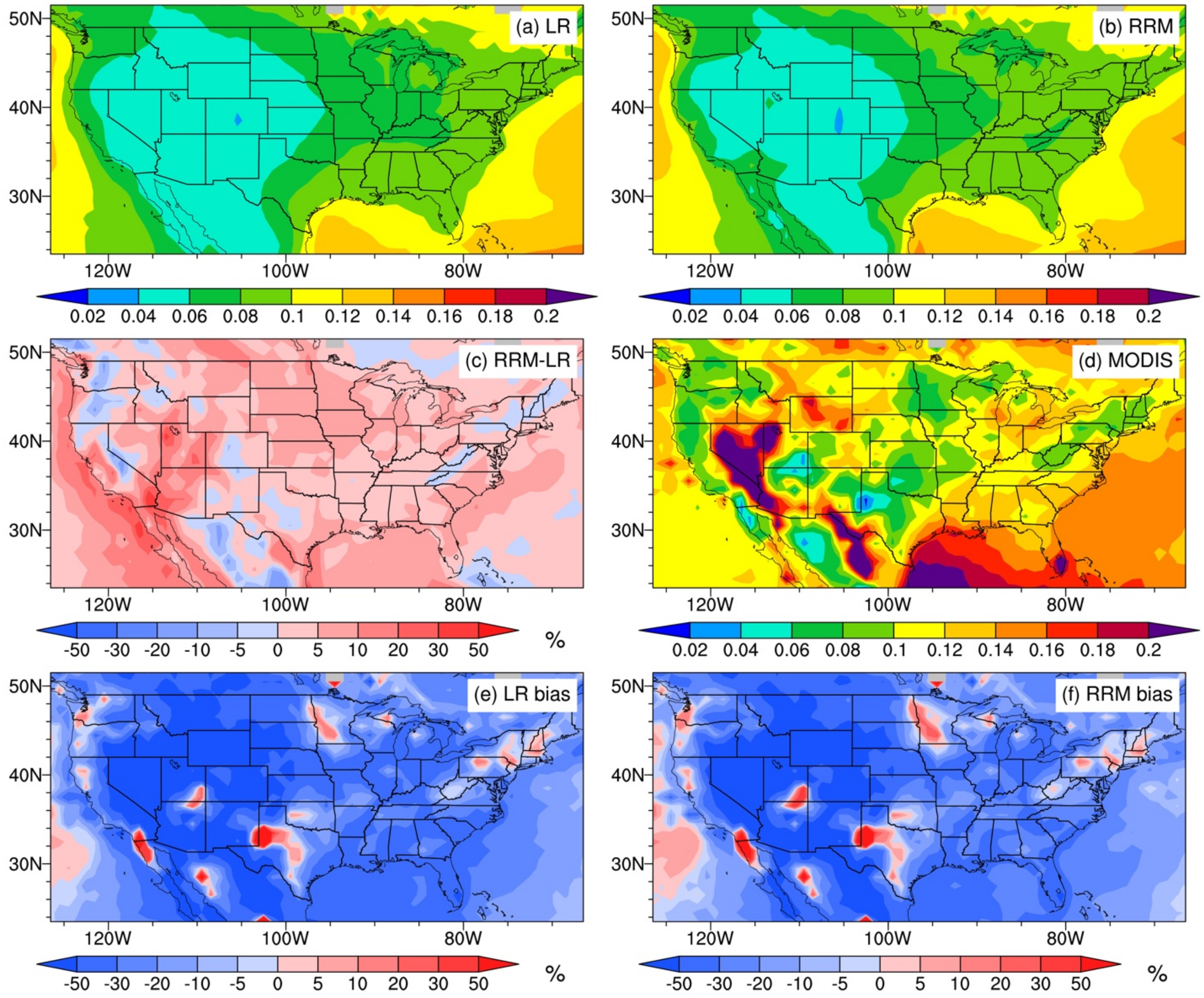

Figure R6. (a, b, d) the same as Figures R5a-c but for the RRM region. (c) The relative differences in annual mean AOD at 550 nm between the RRM and LR simulations ((RRM/LR-1)×100%). (e, f) are similar to (c) but for the relative differences between (e) LR or (f) RRM and MODIS.

Table R2. AOD evaluation statistics based on Figure R6

	MODIS	LR			RRM		
	mean	mean	RMSE	r	mean	RMSE	r
ANN	0.125	0.083	0.057	0.32	0.086	0.054	0.34
JJA	0.158	0.115	0.071	0.07	0.119	0.068	0.09
DJF	0.095	0.059	0.058	0.26	0.062	0.056	0.26

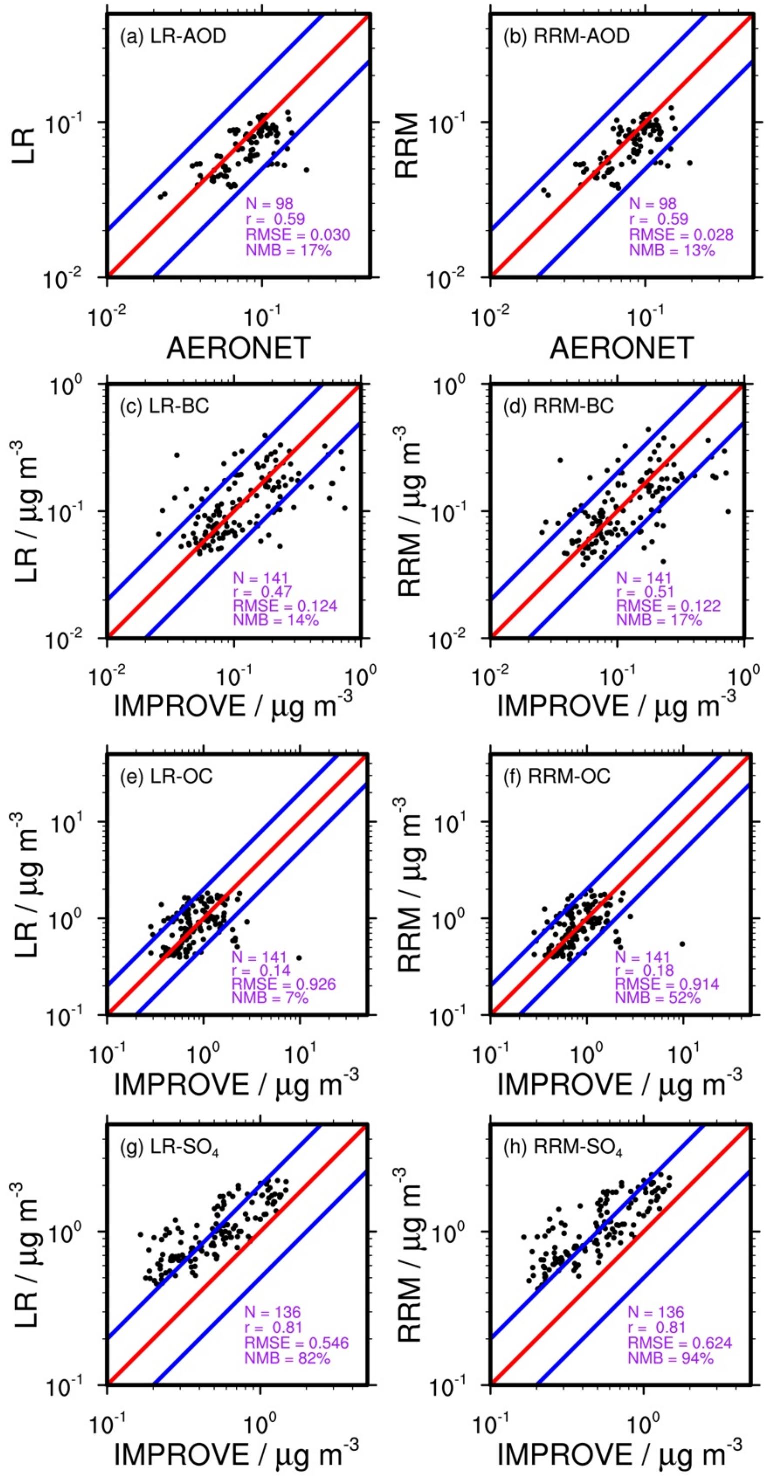

Figure R7. Evaluations of the (left column) LR and (right column) RRM simulated annual mean (a, b) AOD at 550 nm and fine (c, d) BC, (e, f) OC, and (g, h) SO_4 mass concentrations against ground-based observations from AERONET and IMPROVE in the RRM region in 2016. AERONET level 2.0 provides daily mean AOD at 500 nm and daily mean Angstrom exponent for 440-870 nm, which are used to derive daily mean AOD at 550 nm. IMPROVE provides daily mean mass concentrations of fine BC, OC, and SO_4. The daily mean observations are used to calculate monthly means, which are then used to select coincident model monthly results. Notably, we use the regridded (1°× 1°) LR and RRM simulation results to match observational sites to make the comparisons fair to both simulations. Each dot in the figure denotes one observational site. “N” refers to the number of observational sites; “r” is the Pearson correlation coefficient; “RMSE” is the root mean square error; and “NMB” indicates the normalized mean bias.

We apply the following equations to calculate the model fine BC, OC, and SO_4 to be compared with observations.

SO_4(fine) = SO_4(accumulation mode) + SO_4(Aitken mode) + Sea salt(accumulation) + Sea salt(Aitken)

OC(fine) = (POM(primary carbon) + POM(accumulation) + SOA(accumulation) + SOA(Aitken))/1.4

BC(fine) = BC(accumulation) + BC(primary carbon)

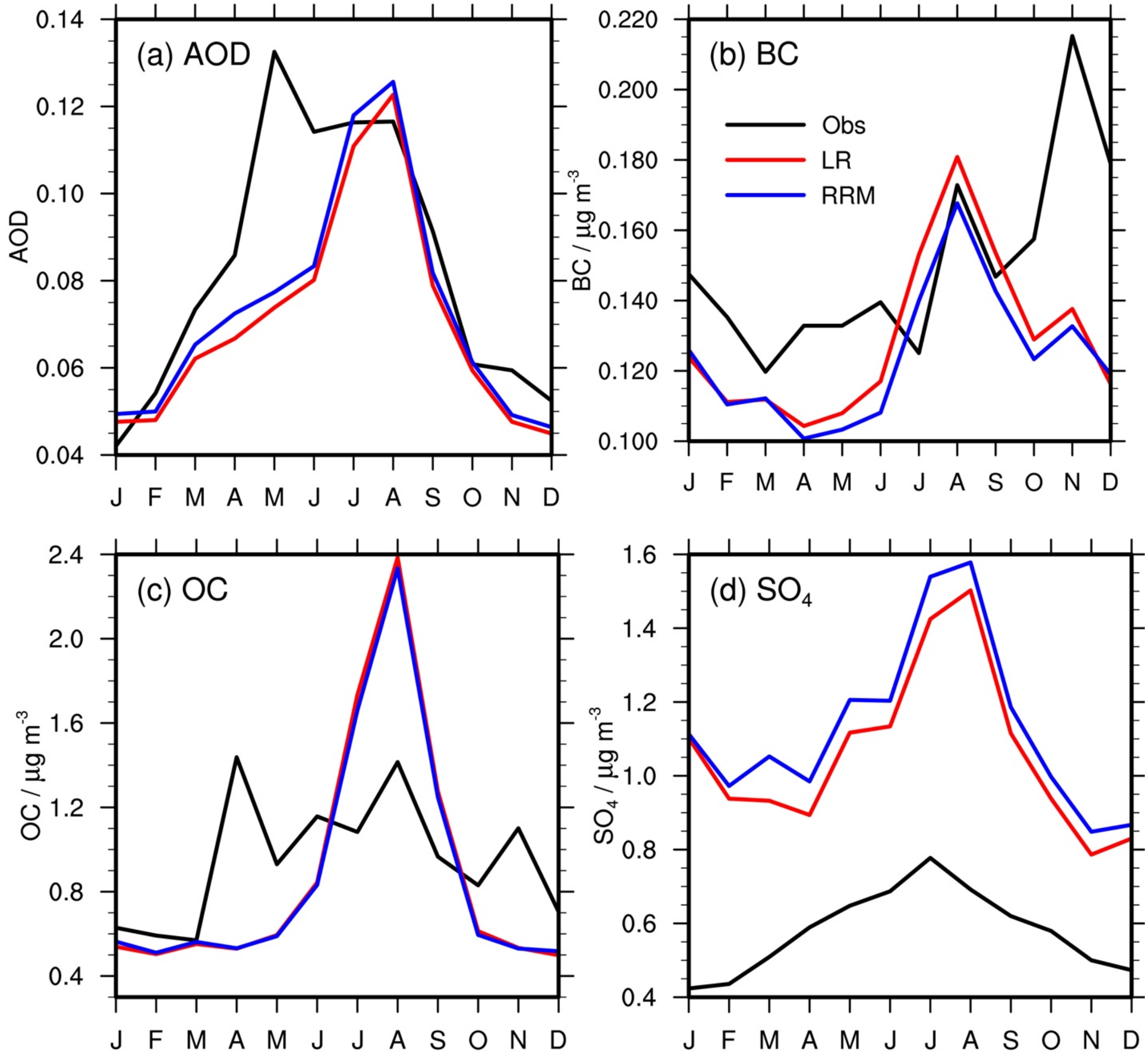

Figure R8. The seasonal cycles of (a) AOD at 550 nm and fine (b) BC, (c) OC, and (d) SO_4 mass concentrations from (black lines) observations (AERONET for AOD and IMPROVE for fine BC, OC, and SO_4) and the (red lines) LR and (blue lines) RRM simulations. Here, we use the averages of all observational sites (or coincident 1°× 1° grids for the LR and RRM simulations). BC, OC, and SO_4 from the model simulations are calculated using the equations in Figure R7.

Comments

L46: Please state how is ERF_aer is defined.

Reply:

Effective radiative forcing (ERF) is the change in net top-of-atmosphere downward radiative flux due to some imposed perturbation (Myhre et al., 2013). It allows atmospheric temperatures, water vapor, and clouds to adjust to the imposed perturbation but fixes sea surface temperatures and sea ice cover at climatological values. For ERF_aer, the addition of anthropogenic aerosols relative to the preindustrial period is the imposed perturbation. ERF is a concept adopted by the Intergovernmental Panel on Climate Change (IPCC) and widely used in climate change studies; therefore, we would like to avoid repeating the definition in the manuscript.

L134-135: Please be more specific what are the known model biases. Also please be specific if the two simulations are identical other than gridding related configurations. If not, please clarify them.

L178 and the paragraph: It shows now there are more differences between LR and RRL than resolution. How can authors resolve the difference between two simulations is due to resolution or differences are from other than resolution? It sounds me that the experiment is not precisely designed. I suggest elaborating the common and differences between LR and RRM. I think a table would be an efficient way.

L505: Again, it seems that LR and RRM are different in gridding schemes and associated other various factors.

Reply:

Thank you for your comments. Since the above three questions are about the same issue, we answer them together.

We have added two examples of the E3SMv1 model biases in Lines 136-137. Some other model biases in precipitation, temperature, clouds, aerosols, and so on can be found in Golaz et al. (2019), Xie et al. (2018), Zhang et al. (2019), and Wang et al. (2020).

‘Our investigation focuses on comparing LR and RRM simulations, and the known model biases, such as the dry biases over the Great Plains of the US, the Amazon region, and Southeast Asia (Xie et al., 2018) and the cold bias between the 1950s and the 2000s (Golaz et al., 2019), are not expected to affect the overall model sensitivity to the resolution change.’

As we explained above, the LR and RRM simulations have the same configuration except for horizontal resolutions and resolution-relevant input files, which we have highlighted in Lines 192-194 in the revised main manuscript.

‘With such changes, LR shares the same configuration as RRM, except for regional refinement around CONUS (Figure 1) and resolution-relevant input files (e.g., topography and nudging-prescribed wind fields).’

L138: Please be specific about the land component. Does it mean land model option?

Reply:

Yes, it does. We generally use “component” to indicate different model parts in E3SM and CESM (Community Earth System Model). In Lines 146-147 in the revised main manuscript, we explained the land component (or model) used in our simulations.

L141: I think 3 month spin-up is too short for the aerosol-climate interaction in the upper atmosphere. Please state more justifying the short spin-up. At least cite previous studies. "FC5AV1C-04P2" looks too model specific. Please clarify the name.

Reply:

We agree that a 3-month spin-up is too short for global model simulations starting from scratch since it takes years to exchange air between the troposphere and stratosphere. However, as mentioned in Lines 149-150, the initial conditions of our LR and RRM simulations are from an earlier E3SMv1 simulation which has reached equilibrium, which can significantly reduce the spin-up time. In Lines 167-172 in the revised main manuscript, we highlighted that, with nudging, the simulation approach could reproduce global and regional mean aerosol mass and energy flux perturbations from the E3SM AMIP-type simulations, as shown in Zhang et al. (2022). Following your suggestion, we have cited the paper in Line 144 and rewritten the sentences related to “FC5AV1C-04P2” in Lines 144-148.

‘The component set used in the simulations comprises the coupling of an active atmospheric component — EAMv1, an active land component (version 4.5 of the Community Land Model — CLM4.5) (Oleson et al., 2013), a simplified active sea ice component, and a data ocean model with prescribed historical sea surface temperature and sea ice fractions (Hurrell et al., 2008).’

L160: Please describe more about "nudging" such as which fields and how. It states that the model includes meteorological fields for nudging in below sentences. How about aerosols?

Reply:

In E3SM, nudging is achieved by adding a tendency term to the prognostic equation of variable X (U or V in our simulations). The tendency term has a form of $-\frac{X_M - X_P}{\tau_X}$. Here, X_M is the model predicted value, X_p is the nudging-prescribed value (from ERA5 in our study), and τ_X is the relaxation time. Further details can be found in Zhang et al. (2014) and Sun et al. (2019).

We only nudged horizontal wind fields (U and V) between 950 and 10 hPa with a relaxation time of 6 hours, as explained in Lines 176-178 in the revised main manuscript.

Since we aimed to investigate the impact of horizontal grid spacing on aerosols, aerosol fields are not nudged.

L210-213: It states that stronger wind is found in higher resolution. How about the changes of the area of strong wind? Please specify the difference of the area of strong wind in LR and RRM. Why does it happen? Is due to resolution, gridding, physical parameterization, or aerosol-radiation-cloud interaction?

Reply:

Thank you for your suggestions, but the area of strong wind cannot be used directly in our analysis. The area of strong wind only considers the spatial dimension but neglects the temporal dimension. A more robust way is to compare the PDFs of wind speeds between LR and RRM, as we showed in Figures 3d-3e. PDFs provide the occurrence frequency of strong winds, reflecting both spatial and temporal information.

The differences in strong winds between LR and RRM can only be attributed to horizontal resolution or resolution-relevant input files — the only discrepancies between the LR and RRM simulation configurations.

L223: The differences in soil water content of -7.1% is quite large, since the two models trying to run same atmospheric conditions such as nudging technique. Please more elaborate the differences in the soil moisture and also wind.

Reply:

Thank you so much for your comment. Ideally, we hope to use the same meteorology in the LR and RRM simulations. However, as demonstrated above, it is not doable in E3SM with a dynamic core. Nudging can help constrain large-scale circulations, but we should not expect to obtain the same meteorology between the LR and RRM simulations. Therefore, in this study, the differences in aerosol properties between LR and RRM somewhat contain the meteorological effect (e.g., surface wind speed and soil water content), which, however, is also caused by horizontal resolution. We have added two sentences to highlight this point in Lines 555-559 in the revised main manuscript.

‘Moreover, although nudging is applied in the study to minimize the impacts of large-scale circulations on aerosol properties as horizontal resolution changes, differences in meteorology still exist between the RRM and LR simulations (e.g., surface wind speed and precipitation). Therefore, the results above contain the meteorological effect, although the meteorological differences are also caused by the change in horizontal grid spacing.’

Table 1 and Figure 1: The factor of 2-3 difference in dust emission between RRM and LR is concerning, since it implies very large differences in wind fields which may not be enough with the resolution effect. It needs more thorough investigation on this other than the wind strength. Please discuss friction wind and soil moisture, and the percent difference between the two *simulations. How about other meteorological fields such as wind at 500 mb and PBL height? Are they also very sensitive to resolution e.g., compared to 0.25 degree linear-grid?*

Reply:

Thank you for your comment. We displayed the changes in volumetric soil water content in Figure 3b, which may explain the increases in dust emissions in Region 2 in the RRM simulation compared to the LR simulation, as mentioned in Lines 225-232. The PDFs of friction velocity (*FV*) are similar between the RRM and LR simulations in both Region 1 and Region 2 (Figure R9), which cannot explain the increase in dust emissions in the RRM simulation.

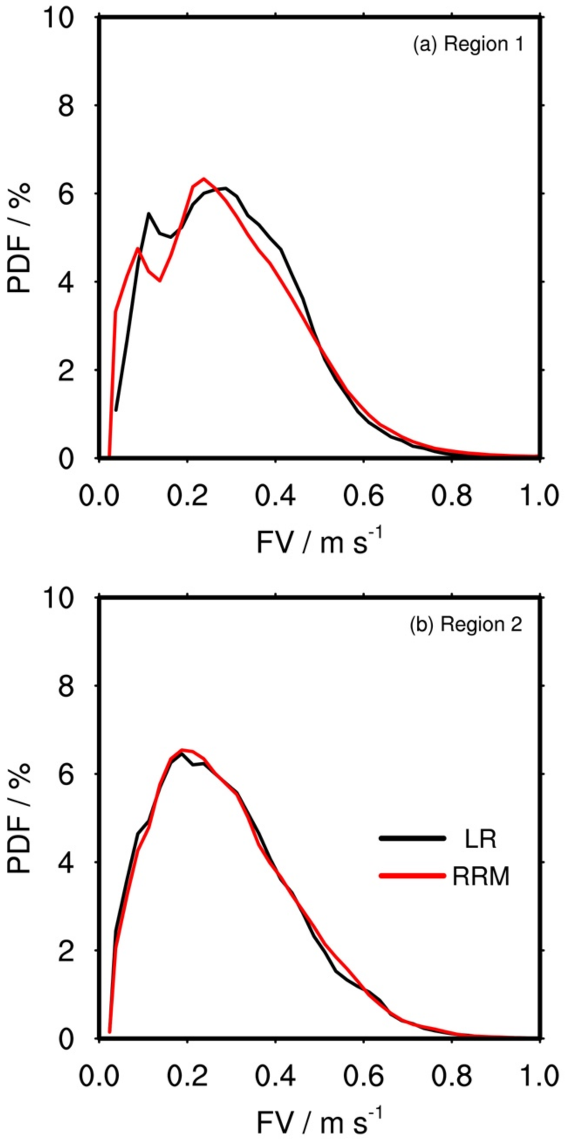

Figure R9. PDFs of *FV* in (a) Region 1 and (b) Region 2. The black lines are for the LR simulation, while the red lines are for the RRM simulation. *FV* on native model grids with an output frequency of 15 minutes is used to derive the corresponding PDF.

The difference by a factor of two to three in dust emission is due to the nonlinear relationships between surface wind speed and soil water content and dust emission.

In the E3SMv1 dust emission parameterization, horizontal dust emission flux is calculated as follows.

$$Q_s = \frac{c_s \rho u_*^3}{g}\left(1 - \frac{u_{*t}}{u_*}\right)\left(1 + \frac{u_{*t}}{u_*}\right)^2 \text{ for } u_* > u_{*t}\text{; otherwise, } Q_s = 0 \qquad (1)$$

where $c_s = 2.61$, ρ is the atmospheric density, u_* is the wind friction speed, g is the acceleration of gravity, and u_{*t} is the threshold wind friction speed, which considers the nonlinear impact of soil water content.

$$u_* = FV + 0.003 \times \left(U_{10} - \frac{U_{10} \times u_{*t}}{FV}\right)^2 \text{ for } U_{10} \geq \frac{U_{10} \times u_{*t}}{FV}\text{; otherwise, } u_* = FV \qquad (2)$$

where U_{10} is the 10-m wind speed, and FV is friction velocity. U_{10} is a function of FV, wind speed at reference height, and Monin-Obukhov length. Equation (2) considers the Owen effect — the positive feedback of saltation upon surface roughness length and friction speeds (Zender et al., 2003).

Equations (1) and (2) indicate complex and nonlinear relationships between U_{10}, FV, and soil water content and Q_s. However, Namikas and Sherman (1997) found that Q_s was almost exponentially related to u_*.

Since Figure R9 shows similar PDFs of FV between the RRM and LR simulations, the second term of the right-hand side of Equation (2) dominates the u_* change as model resolution increases.

If we ignore the change in u_{*t}, we can make a few reasonable assumptions to estimate the change in Q_s with the U_{10}_*Dust* PDFs from Figure 3d in the revised main manuscript.

$$u_* = \alpha U_{10}^2 + \beta \qquad (3)$$

where α and β are constants.

After ignoring the low-order terms, we have

$$Q_s \propto U_{10}^6 \qquad (4)$$

According to Figure 3d, which is based on U_{10}_*Dust* on native model grids with an output frequency of 15 minutes,

$$\overline{U_{10-RRM}} = 1.11 \times \overline{U_{10-LR}} \qquad (5)$$

where $\overline{U_{10-RRM}}$ is the average of *U10* with a PDF as that for RRM in Figure 3d, similar to $\overline{U_{10-LR}}$.

However,

$$\overline{Q_{s-RRM}} \propto \overline{U_{10-RRM}^{6}} = 3.57 \times \overline{Q_{s-LR}} \propto \overline{U_{10-LR}^{3}} \qquad (6)$$

In other words, with an increase of 11% in mean surface wind speed, dust emission can increase by 257%. Remind that Q_s is zero when $u_* \leq u_{*t}$. To mimic this function, we further assume

$$Q_s = 0 \text{ for } U_{10} \leq 5 \qquad (7)$$

Then,

$$\overline{Q_{s-RRM}} = 3.73 \times \overline{Q_{s-LR}} \qquad (8)$$

The dust emission increases by 273% with the RRM U_{10}*_Dust* PDF compared to the LR U_{10}*_Dust* PDF!

Our simplified derivation indicates that the exponential-like relationships between dust emissions and surface wind speed can lead to a much larger change in dust emissions with a minor change in surface mean wind speed. Moreover, dust emissions are more sensitive to strong winds due to the exponential-like relationships, as we highlighted in Lines 217-218.

Wind fields at 500 hPa and planetary boundary layer heights (PBLH) are not used directly in the E3SMv1 dust emission parameterization. Following your suggestion, we compare wind fields at 500 hPa and PBLHs from the LR simulation with those from the RRM simulation below. Minor differences are found in wind fields at 500 hPa between the two simulations. PBLHs are generally somewhat lower in the RRM simulation compared to the LR simulation. However, as we applied nudging to constrain large-scale circulations in both simulations, we can't make an accurate conclusion on how horizontal resolution would affect wind fields at 500 hPa and PBLHs.

To summarize, we have emphasized the relationship between dust emissions and friction velocity and the similar PDFs of friction velocity between the LR and RRM simulations in Lines 112-113 and 222-227 to make the descriptions more accurate and clearer. Besides, Figure 3 is updated to also show the *U10* used in the dust emission parameterization, which is different from the *U10* outputted in the atmospheric component. The PDFs of *U10_Dust* are displayed in Figure 3 instead of the PDFs of *U10*. Relevant numbers are also updated in Lines 218 and 222, as well as figure numbering.

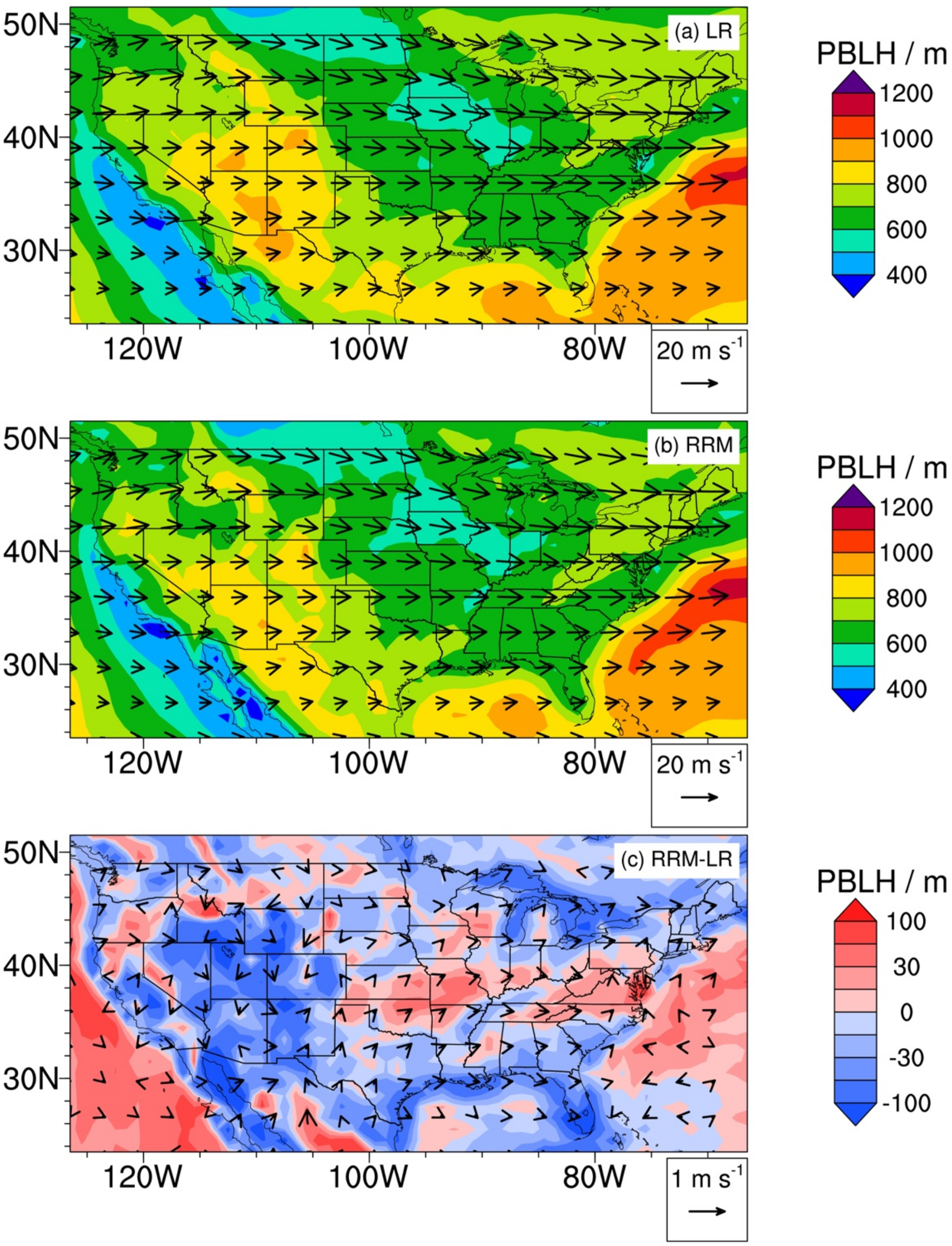

Figure R10: Spatial distributions of annual mean planetary boundary layer height (PBLH, colored contours) and wind fields (vectors) at 500 hPa for the (a) LR and (b) RRM simulations and (c) their differences (RRM-LR).

Figure 2 right column is the difference between LR and RRM. Dust, Seasalt, MOM are highly variable. Since these aerosols are from natural sources, the differences are the result of the change of meteorology especially surface wind both over land and ocean. It needs further analysis to explain them.

Reply:

Thank you for your suggestion. In Lines 112-114, we mentioned that dust emission is a function of surface wind speed, soil erodibility (read from offline files), friction velocity, and a friction velocity threshold, which is related to soil moisture. In Lines 114-115 and 238-239, we highlighted that sea salt and MOM emissions are functions of surface wind speed and sea surface temperature (prescribed in our simulation). We discussed the differences in surface wind speed, friction velocity, and soil water content in the surface layer between the RRM and LR simulations in Figure 3 and Lines 214-241, which contained the key factors affecting these natural aerosol emissions. Again, although we applied nudging to constrain large-scale circulations in both simulations, minor differences in meteorology still exist between the two simulations, which partially contribute to our discussed impacts of horizontal grid spacing on aerosol properties in this study, as emphasized in Lines 555-559 in the revised main manuscript.

Figure 2b: Why dust emission in Region 2 is so storing? Is it supported by observations? If true, please show here.

Reply:

The strong dust emission in Region 2 is consistent with the high dust AOD (DAOD) in the region and downwind areas based on the MODIS DAOD data, which is from https://acros.umbc.edu/data-and-models/decadal-global-dust-aod-database/ (last access: Dec 1, 2023). Notably, the DAOD data contains the transport effect. Considering the DAOD spatial distribution and mid-latitude prevailing westerlies, we conclude that there are strong dust emissions in Region 2.

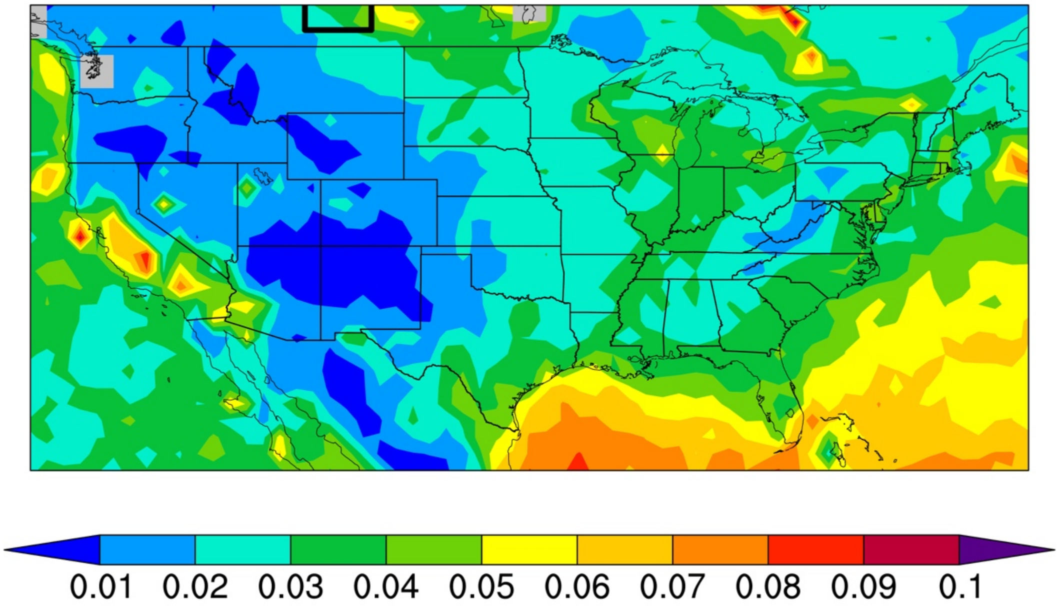

Figure R11. Spatial distribution of the annual mean MODIS DAOD in the RRM region in 2016. The black box labels Region 2, the same as Figure 2b.

Figure 2c-d: Why sea-salt emitted over land?

Reply:

There are two reasons for that. 1) We regrid the unstructured LR and RRM simulation results to 1°×1°, which may induce minor errors with sea salt and MOM emissions over land grids. 2) The land-ocean boundary used in the plot has a much higher resolution than 1°×1°. Grids crossing the land-ocean boundary may show sea salt emissions over the land in the plot. These minor issues do not affect our analyses and results.

Figure 3a and 2b: Please be specific if the difference if RRL - LR or LR - RRM. Also please check the difference in wind field is consistent with the difference in emission over Utah. It seems me that the pattern is opposite between the two.

Reply:

Thank you for your comments.

The differences refer to RRM – LR. We have clarified them in the figure captions in Lines 247 and 254 in the revised main manuscript.

The mean wind speed differences do not have to be consistent with the dust emission differences. As mentioned above and in Lines 112-114 and 217-218, dust emission is a nonlinear function of surface wind speed, friction velocity, and friction velocity threshold (which is related to soil moisture).

L251-254: Please be specific it is same for LR too.

Reply:

We have rewritten the sentences in Lines 261-264 to make them clearer.

‘In the RRM region, wet scavenging is the primary sink for most aerosol species in both simulations except for dust and sea salt, the sinks of which are dominated by dry deposition. To understand the impact of horizontal grid spacing on aerosol wet scavenging, it is necessary first to investigate how precipitation differs between the LR and RRM simulations.’

L304-305: Please add numbers for cloud scavenging and below cloud scavenging.

Reply:

Added in Lines 315-316. Thanks.

‘In-cloud scavenging is the dominant process for all aerosol species in the RRM region, accounting for ~80% of the wet removal of sea salt and dust and more than 98% of the other aerosol species.’

References:

Golaz, J. C., Caldwell, P. M., Van Roekel, L. P., Petersen, M. R., Tang, Q., Wolfe, J. D., Abeshu, G., Anantharaj, V., Asay-Davis, X. S., and Bader, D. C.: The DOE E3SM coupled model version 1: Overview and evaluation at standard resolution, Journal of Advances in Modeling Earth Systems, 11, 2089-2129, https://doi.org/10.1029/2018MS001603, 2019.

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