Response to Reviewer 2:

We would like to express our gratitude to Reviewer 2 for their thorough review of our manuscript and their attention to detail in the language used, particularly considering the manuscript's length. We carefully went through the whole manuscript again and to our best knowledge have identified and corrected all typos and mistakes therein. Below, we outline in detail how we have addressed the comments provided (text in black denotes the comments provided, while text in blue denotes our response):

Comments (in black): This manuscript addresses the improvement of aerosol simulations in the CESM model by revising emission schemes for dust and marine aerosols and incorporating aqueous chemistry for SOA formation. The authors present a clear and systematic approach, starting with the implementation of revised aerosol schemes, followed by the comparison of their updated simulation results with various aerosol observational measurements to evaluate their proposed simulations. In particular, the authors design sensitivity experiments in a further discussion to capture the uncertainties in the simulations of these several aerosol species. Given the focus of the study, the methodologies used, and the conclusions presented, this manuscript meets the criteria for publication in Geoscientific Model Development.

However, the manuscript in its current form requires better organization and clarity. I recommend publication after the following revisions are made:

Response (in blue): We appreciate Reviewer 2 for the useful suggestions that have helped us to improve our paper. As indicated in the responses that follow, we have taken all these comments and suggestions into account in the process of revision.

Page 2 Line 33: change “indicate” to “indicates”.

Corrected.

Page 2 Line 43: change “is” to “are”.

Corrected.

Page 2 Line 52: add comma before “and even…”.

Corrected.

Page 3 Line 87: change “comprising of” to “comprising”.

Corrected.

Page 3 Line 90: add “the” before “Earth system”. Change “is” to “are”.

Corrected.

Page 4 Line 114: remove “the” before “Owen’s effect”.

Corrected.

Page 6 Line 143: remove “By” before “corresponding to”.

Corrected.

Page 6 Line 154: change “shows” to “show”.

Corrected.

Page 7 Line 173: change “region” to “regions”.

Corrected.

Page 8 Line 197: change “varies” to “vary”.

Corrected.

Page 9 Line 226: add “the” before “majority”.

Corrected.

Page 10 Line 249: change “dicarbonyls” to “dicarbonyl”.

Corrected.

Page 10-11 Section 2.2: The authors mentioned that a "CYCLE" experiment, along with a case study and several other sensitivity experiments, was conducted. To enhance readability, a table-like presentation should be included.

Thank you for your constructive suggestion. We agree that to present the "CYCLE" experiment, along with the case study and other sensitivity experiments, in a table format would improve the readability and clarity of this section. We included a Table around L283, summarizing the key details of these experiments, as follows.

Table 1: List of all simulation experiments in this study.

Experiment set	Annotation/Name	Horizontal resolution	Brief descriptions
CYCLE	CYCLE-original	1.9˚ × 2.5˚	2009-2012, CAM6-chem default scheme
	CYCLE-updated	1.9˚ × 2.5˚	2009-2012, updated scheme in this study
Case study of dust events	Case-original	0.9˚ × 1.25˚	1 January 2021 to 1 April 2021, CAM6-chem default dust emission scheme

	Case-updated	0.9° × 1.25°	1 January 2021 to 1 April 2021, updated dust emission scheme
Sensitivity experiments on sea-salt aerosol scheme	SS-Gong	1.9° × 2.5°	2009-2012, *Gong* source function
	SS-Gong+SST	1.9° × 2.5°	2009-2012, *Gong* function together with SST-dependent correction factor
	SS-Gong+RH	1.9° × 2.5°	2009-2012, *Gong* function together with RH-dependent correction factor
Sensitivity experiments on MPOA scheme	MPOA-diatom	1.9° × 2.5°	2009-2012, [Chl *a*] input only from diatom
	MPOA-diazotroph	1.9° × 2.5°	2009-2012, [Chl *a*] input only from diazotroph
	MPOA-small phyto.	1.9° × 2.5°	2009-2012, [Chl *a*] input only from small phytoplankton

Page 11 Line 271: remove the article "a" before "dust events".

Corrected.

Page 11 Line 278: change "a" to "an".

Corrected.

Page 11 Line 280: change "involves" to "involve".

Corrected.

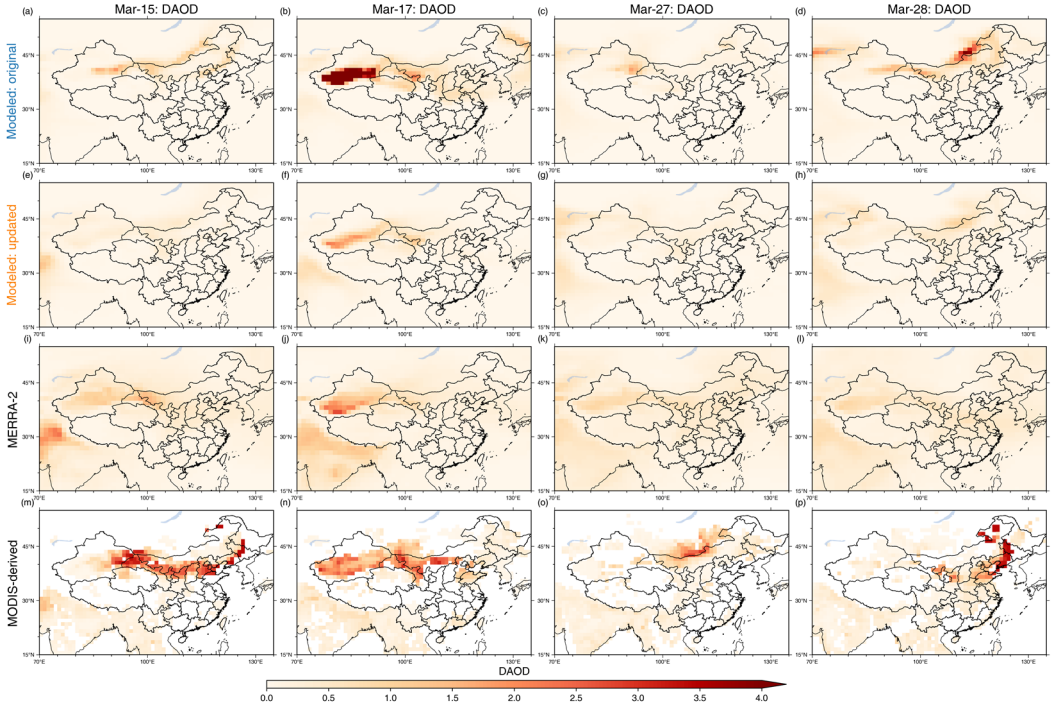
Page 12 Line 302: Two statistical metrics are mentioned here for model evaluation. A description of these two metrics should be added, and their use should be consistent in other similar time series comparisons throughout the manuscript.

Thank you for your suggestion. We added a description of the two statistical metrics mentioned to clarify their definitions and significance in the context of our model evaluation:
L327-329 "*In the following discussion, the evaluation metrics used are the Kendall's correlation coefficient (R) and root mean square error (RMSE). Kendall's correlation, which does not assume a specific data distribution, is used to assess the statistical dependence between observed and simulated values. RMSE measures the average error between observation and simulated results.*"

We also revised Figure 13 to make sure these metrics are consistently applied in all similar time series comparisons.

Page 17 Figure 7: The color bar needs adjustment. The current maximum value doesn't adequately represent the information in certain areas.

Thank you for pointing out the issue with the color bar in Figure 7. We adjusted the maximum value to ensure that the range of color bar more accurately represents the information in the relevant areas.



Page 22 Line 524: add “a” before “comparison”.

Corrected.

Page 24 Line 558: change “corresponds” to “correspond”.

Corrected.

Additional changes:

- Minor wording adjustments and corrections throughout the manuscript.
- Added annotation to the right side of each panel in Figure 4, 9, and 15 to provide clearer context.
- Standardized the formatting of PM2.5 in the text to display as $PM_{2.5}$ in subscript.

We hope that we have adequately addressed all the suggestions raised by Reviewer 2, and appreciate their constructive feedback