Authors’ response to comments made by anonymous reviewer #2:

Summary

The present study introduces the reduced organic aerosol module ORACLE-lite, which utilizes a simplified volatility basis set to provide a computationally less expensive solution for global chemistry-climate models. The authors demonstrate that the new module yields reasonable results and address its limitations. Publication is recommended, subject to the following minor remarks

We thank the reviewer for the positive assessment of our work and for the constructive comments. Below is a point-by-point response (in black) to the reviewer’s comments and suggestions (in blue).

Comments

1. *p.4 l.144: The relationship among the ORACLE family models is unclear. Is ORACLE-IVOC derived from ORACLE-2d or ORACLE-base?*

We thank the reviewer for pointing out this ambiguity. ORACLE-IVOC is derived directly from ORACLE-base and is not an extension of ORACLE-2D. We have revised the corresponding text to clarify the relationship among the different ORACLE configurations.

2. *Figure 1: ‘Short Term’ should replace ‘Sort Term’. In the ORACLE-lite box, the term ‘Identify’ implies an analysis of trade-offs between computational cost and accuracy. If sensitivity studies were not conducted to determine the current setup, consider revising the wording.*

We thank the reviewer for these comments. The typo has been corrected, and the term “Identify” has been removed.

3. *Figure 2: A more detailed figure description would be beneficial. The SOA classes remain unclear.*

We thank the reviewer for this suggestion. We have revised Figure 2 to explicitly define SOA-sv, SOA-iv, and SOA-v as secondary organic aerosol formed from SVOC, IVOC, and VOC oxidation, respectively.

4. *p.6 ll.188 ff.: Please specify the underlying emission inventories. Is there a risk of double counting IVOC emissions?*

We thank the reviewer for this comment. We have added the underlying emission inventories to the model description. Anthropogenic emissions are based on the CAMS v4.2 global inventory, while open biomass-burning emissions are calculated online based on observed dry matter burned. In principle, there is no double counting of IVOC emissions. The additional IVOC emissions are introduced to account for the fraction of organic compounds that is not represented in traditional emission inventories. We have revised Section 2.3.1 to clarify this treatment.

5. *Table 1: Does each VOC group include two associated product classes? Consider adding the product classes to the table. Additionally, is 'SOA yield' the most accurate term, or would 'stoichiometric yield' be more appropriate, given that it does not describe the gas-to-particle partitioning?*

We thank the reviewer for these helpful suggestions. Each VOC group produces two SOG product classes corresponding to the two volatility bins used in ORACLE-lite. We have added these product classes to Table 1. We also agree that "stoichiometric yield" more accurately describes the coefficients used to distribute the VOC oxidation products between the two volatility bins, since gas–particle partitioning is calculated separately. We have therefore replaced "SOA yield" with "stoichiometric yield" in Table 1 and the corresponding text.

6. *Reaction R5 and R6: Do these reactions apply exclusively to anthropogenic species, or are biogenic species also included? Additionally, the meaning of 'a' is not defined.*

We thank the reviewer for pointing out this. Reactions R5 and R6 apply to anthropogenic VOC-derived species, while the aging of biogenic SOA is assumed not to produce a net increase in SOA mass. We have revised the text to clarify this and to define aSOG/aSOA as anthropogenic VOC-derived species.

7. *Figure 3: The figure references SOAlv, which is not addressed elsewhere in the manuscript.*

We thank the reviewer for pointing this out. "SOA-lv" was included in Figure 3 by mistake and has been removed. LVOCs are already represented in the lowest-volatility bin and are therefore not further oxidized in ORACLE-lite. We have also revised Section 2.3.1 to clarify that SOA-sv and SOA-iv denote SOA formed from the oxidation of SVOCs and IVOCs, respectively, and that no separate LVOC-derived SOA class is represented.

8. *Figure 4: The color scheme in panel (a) is relatively dark. Consider selecting a color scheme that assigns zero to white or a brighter color.*

We thank the reviewer for this suggestion. We have revised the color scheme in Figure 4a to use a brighter color for values close to zero, improving the visibility of the spatial patterns.

9. *p.12 l.379. How does the figure in the supplement support this statement?*

We thank the reviewer for pointing this out. The reference to Figure S1 was included erroneously and does not support this statement. We have therefore removed the reference to Figure S1.

10. *Figure 7: Instead of plotting seasonal averages, consider including regression lines.*

We thank the reviewer for this suggestion. We would like to clarify that the points in the scatter plots do not represent seasonal averages. Each point represents the mean concentration of an individual observational dataset, while the colors indicate the season during which the measurements were conducted. This representation allows the seasonal dependence of model performance to be visualized while preserving the individual model–observation comparisons. The 1:1 and factor-of-two lines directly illustrate model agreement with the observations. We have revised the figure caption to make this clearer.

11. *A general suggestion for your discussion is to include a direct comparison of ORACLE-lite and ORACLE-base with the observational data to highlight performance differences, potentially across different regions.*

We thank the reviewer for this valuable suggestion. ORACLE-base retains a higher volatility resolution and therefore provides, in principle, a more detailed representation of the volatility distribution and atmospheric evolution of primary organic compounds and their oxidation products, as well as of the products formed from VOC oxidation. The purpose of the observational evaluation in the present study is to assess whether the reduced-complexity representation introduced in ORACLE-lite retains sufficient accuracy for the long-term global applications targeted here. The consequences of the reduced volatility resolution relative to ORACLE-base are examined directly in Section 3.1, while Section 3.2 evaluates ORACLE-lite against AMS/ACSM observations across different regions and environments. We have clarified this rationale at the end of Section 3.1.