Response to Referee #2

We express our gratitude to Referee #2 for his/her useful comments. Our response to the reviewer's comments and the corresponding revision are described in detail and separately below. The numbers of pages, lines, equations, tables and figures are those in the revised manuscript unless otherwise described.

General comment:
"I applaud the authors for providing such a well-revised, organized and thought-out manuscript. My critique is minimal and provided as a suggestion for two general areas of improvement: (1) expansion of explanation of transition matrices, namely automation-based and (2) expansion of the discussion."

Response:
We are grateful to the reviewer for appreciation of our work.

Please see our response to specific comments by the reviewer below regarding suggestions (1) and (2).

Changes in manuscript (Page numbers/Line numbers):
Please see our changes in manuscript in response to specific comments below.

Specific comment 1:
"The manuscript would benefit from an expansion on the LABS simulation approach; automation-based transition matrices described in the methods could be more thorough. As written, the paper requires unfamiliar readers to investigate this approach outside of the paper. This could also be achieved in the introduction."

Response:
Agreed. Except that we prefer to add the details of the LABS approach to Section 2 rather than to the Introduction.

Changes in manuscript (Page numbers/Line numbers):
We added more explanation of the LABS simulations as well as the transition matrices to Section 2.2.2 (P8/L218-P9/L241).

Specific comment 2:

"While this model will be applied to interpreting archives of geologic events and such events are cited as motivation, there is little to no discussion later in the paper of the significance of their experiments with regard to these events. For example, what is the significance of the model result in which coarse fraction species become more dominant, in terms of records of past abrupt events of environmental change? Perhaps the authors decided to stay away from interpreting their model development results in terms of geologic applications, but some model-data comparison may be warranted in the discussion. This may or may not include a more representative simulation of an early Eocene hyperthermal event."

Response:
As a model development paper, we decided to stay away from detailed attempts to use the model for interpreting a specific geologic record. Nonetheless, general implications may be useful for the reader to have ideas about potential use of IMP. As an example, a geological event can be differently recorded by different biological species as recognized by e.g., offsets in the timing of isotopic excursions (e.g., Kirtland Turner et al., 2017). Such offsets between species might be able to be explained by IMP as illustrated in our example simulation where fine and coarse species are explicitly simulated with different dissolution and bio-mixing properties (Section 3.2.3).

Please note that we added Section 3.3 where a model-data comparison was made for 14-C age although we did not intend to fully reproduce the observations with the model (please see our response to specific comment 3 by the reviewer).

Changes in manuscript (Page numbers/Line numbers):
We mentioned the potential application of IMP in the description of the relevant simulation results (P20/L597-600).

Please also see our changes in manuscript in response to specific comment 3 by the reviewer.

Specific comment 3:
"Following this more generally, the discussion section of the manuscript is slightly limited and could be expanded. For example, how does this new model and the results of experiments in this study inform understanding of examples of processes outlined in the introduction? How might the findings here bias proxies in specific geologic archives (e.g., size fraction differences previously unaccounted for in proxy records)? This type of expansion would not necessarily require re-interpretation of records of e.g. the PETM, but rather clearly lay out the implications of their experiments which may be significant to a proxy-based researcher in the field."

Response:
We agree with the reviewer that more implications regarding interpretation of geological records can

be useful. The feature of IMP that species-specific records can be simulated will be useful for interpretation of the geological record where isotopic records are differently recorded by different biological species (e.g., Kirtland Turner et al., 2017). We further added a sensitivity analysis where 14-C age in the mixed layer is calculated as a function of the rain fraction of fine species, total sediment rain and water depth. This experiment was in parts motivated as the 14-C age problem (Broecker et al., 1991) is mentioned in the Introduction. The simulated relationships between the ^{14}C-age and $CaCO_3$ wt% can differ between coarse and fine species and bulk $CaCO_3$ (Fig. 16). Our intention here is not to perfectly reproduce the observations, but the agreement between simulated and observed ^{14}C trends (Fig. 16) illustrates the utility of IMP to explain proxy signals in a way not possible when considering only bulk $CaCO_3$.

Changes in manuscript:
We added a sensitivity analysis for 14-C age as Section 3.3 (P20/L601-P22/L646) and Fig. 16 (P44).