EGUsphere, author comment AC2
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Response to Anonymous Referee #2

Anthony Gruber et al.

Author comment on "Multifidelity Monte Carlo estimation for efficient uncertainty quantification in climate-related modeling" by Anthony Gruber et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-797-AC2, 2022

Dear Anonymous Referee #2,

Thank you for your helpful comments and for your interest in our work. Below are responses to your specific comments, numbered in order of appearance. We are also attaching a color-coded document with the same information in case the mapping between your comments and our responses is not clear.

1) Based on our experience with prior work on MC-based estimation, we do not expect the linearity (or lack thereof) of the model solution to affect the performance of the MFMC estimation procedure.

2) A goal of MFMC estimation is to achieve (using very few samples of the high-fidelity model) the same accuracy as obtained by an MC estimator (that exclusively uses many samples of that model). Certainly, at least one high-fidelity model evaluation is necessary to eliminate bias in the MFMC estimator. Moreover, we find practically that the high-fidelity samples used to "steer" this estimator in an accurate direction, while the low-fidelity samples are used to shrink its variance around the true solution. Note that the dynamics of the example systems are not particularly well resolved by the low-fidelity models relative to the high-fidelity ones; particularly in the case of the barotropic gyre (SOMA) case, there is a noticeable visual difference between the 32km solution and the 8km solution.

3) This has now been corrected. Thank you for your attention.

4) These were the wall-clock times observed when the relevant system was implemented in MATLAB and run on a 2015 MacBook laptop. Therefore, neither the implementation nor the hardware was optimized for computational efficiency.

5) A primary benefit of MFMC over other modern estimation methods such as MCMC is its ability to leverage low-fidelity information to effect cost-savings without sacrificing estimator accuracy. In our experience with MFMC in other settings, this benefit translates to much larger cost savings for a given accuracy tolerance when compared to MCMC as well as other MC-related sampling schemes (e.g., variance reduction MC, importance sampling).

Minor comments:

1) We agree with this reasoning and have changed the name globally throughout the manuscript.

2) This has been fixed, thank you for your attention.

3) It can be shown that the MFMC method presented here is the provably optimal solution (up to rounding) to a particular constrained optimization problem (see Gruber et al 2022, "A multifidelity Monte Carlo method for realistic computational budgets", for a formal statement). Therefore, we do not think it is a stretch to say there is "no guesswork involved" in this context.

4, 5) These have been fixed, thank you for your attention.

6) This is an expression for the fluid thickness. We have clarified this globally throughout the manuscript.

7) This is true. The referenced preprint (to appear in J. Sci. Comput.) establishes the particular MFMC algorithm which has been applied to climate-related examples in this paper. Therefore, we refer interested readers to that manuscript for a more detailed description of the MFMC method. Conversely, we write in that preprint that "Forthcoming work will investigate applications of the present MFMC method to complex systems governed by partial differential equations, particularly in the context of climate modeling.", and provide an empty citation with title and relevant authors. The mentioned work has since become this GMD submission. Since this has caused confusion, we intend to remove the offending citation from the J. Sci. Comput. paper during the proofing stage.

Thanks again, and please let us know if you have other questions.

Best,
Anthony, Max, Lili, Rihui, and Zhu

Please also note the supplement to this comment:
https://egusphere.copernicus.org/preprints/2022/egusphere-2022-797/egusphere-2022-797-AC2-supplement.pdf