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Discussions

Interactive comment on "GENIE-M: a new and improved GENIE-1 developed in Minnesota" *by* K. Matsumoto et al.

Anonymous Referee #3

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Review of: "GENIE-M: a new and improved GENIE-1 developed in Minnesota" by **K. Matsumoto**, **K. S. Tokos**, **A. Price**, and **S. Cox**

Description

This paper describes an exercise to improve the GENIE-1 model, and make it more suitable for biogeochemical (BGC) simulations. The protocol followed by the authors involves three stages: 1. a process in which the base model resolution is changed, and of order 10 parameters are objectively tuned; 2. a series of 6 generally process-based changes are applied to the tuned model, with 3 successful improvements retained in the model; 3. the model's performance over the domain of 2 biogeochemical parameters is explored, with the best values for these parameters chosen. The authors present

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the performance of the model at each of these stages and conclude with a discussion of future improvements, with particular focus on biogeochemistry.

Summary

The manuscript is well-written and describes a generally valuable exercise in model development and tuning. However, I have significant concerns about some of the decisions made during the three phases of the model development.

Specifically, while objective tuning is used at the first stage, it is only applied to an early version of the final model. Later stages of the model development are somewhat less objective, and introduce significant structural changes to the model that may have been compromised by the earlier tuning (e.g. the adoption of the Gasex improvement is clearly suggested by the literature, but discarded by the authors). Furthermore, the authors introduce (and discard) one structural change (seasonal winds) before NSGA-II tuning, but curiously do not do this for the others. Also, the authors (rightly) place emphasis on particular biogeochemical fields during model validation (e.g. radiocarbon for deep ocean ventilation), but these are ignored during the objective tuning phase. Given that the tuned model performs significantly differently (worse) compared to the final GENIE-M model on these criteria, one is left questioning the validity of this original tuning phase. Overall, these deficiencies are suggestive of a development protocol that had higher aims (use of BGC fields for tuning) but which was steered on practical grounds by existing procedures (use of physical climatology fields).

While I appreciate the time- and resource-consuming nature of the kind of objective tuning employed by the authors, I believe that this study requires a more serious attempt to combine tuning with both the structural changes to the model and the BGC fields that form the key backdrop to model performance. While the authors' aims are entirely laudable, I would recommend publication only after major changes to address these deficiencies.

Specific comments

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Title

I don't often comment on the titles chosen by authors, but in this case the title is rather vague on the manuscript's content (something about BGC might be useful). Also, given that the GENIE-M model is in large part related to the GENIE-1 model, it might be more helpful if its name were to denote this. Perhaps something like GENIE-1M might convey this. Otherwise, when GENIE-2, etc., are released, it may be difficult for readers to place this particular version in context. More generally on this point, is there an established naming scheme for GENIE-derived models? Given that variants of the model are appearing, it would seem important that the GENIE community agrees some standard nomenclature.

Abstract

The balance between cited development goals and the protocol followed to achieve them seems slightly wrong, with insufficient emphasis on the latter. The former is both discussed as specific goals, and then also as specific results. Also, while the protocol followed is described transparently in the manuscript, a reader browsing the abstract has little idea of the combination of objective physical tuning and separate BGC calibration used by the authors. More generally, the improvements listed by the authors (vertical resolution, mixed layer, vertical diffusion) appear somewhat haphazardly in the abstract, when it might make more structural sense to describe them once, and in order.

Introduction

* Pg. 3, line 10: put Plattner reference in list into correct chronological order; actually I now see that where multiple papers are cited, they are done so in alphabetical order.

* Pg. 3, line 11: "EMICs played" to "EMICs play" or "EMICs have played"

* Pg. 3, line 16: the authors mention the "post-industrial" timeframe but don't specify what they mean by this. It could mean "post-fossil fuel" or it could refer to some future

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return to agrarian lifestyles - the authors should be clear which. And the time-scale itself is probably worth mentioning - reading between the lines, GENIE-M should allow its users to simulate order 10-100Ky periods, but is this what the authors have in mind?

* Pg. 3, line 24: add commas: "... so that, in theory, one can ..."

* Pg. 4, line 19: probably just my ignorance, but doesn't the GENIE-1 model include short-wave seasonality (which may, of course, be ignored by GENIE-1 biology)?

* Pg. 5, line 6: regarding the OCMIP mention, while in broad outline GENIE-1 is similar to the BGC model in OCMIP-2, there appear to be differences. Can the authors spell out the connections/differences more clearly? I'm thinking of things like: does the model include DOP? Alternatively, when GENIE-M is described later, it might be worth getting into this. On that note, a couple of quick questions: is ^{14}C coupled to the biological pump at all? And if not, does that then require the use of a parallel abiotic DIC tracer? From the cited papers, that appears to be how OCMIP handled ^{14}C.

Rationale for improving GENIE-1

* Pg. 5, line 23: delete "more"

* Pg. 6, line 1: change "... really means" to "... is really a representation of"

* Pg. 6, line 12: since it's quite important later on, it might be worth explaining a bit about what ^{14}C tells us, e.g. ventilation age. Perhaps some numbers from important ocean regions (NADW, CDW, PDW) would help here

Description of GENIE-M

* Pg. 7, line 27: spelling of "Ridgwell"

* Pg. 8, line 12: by "user-supplied" do you mean "free"?

* Pg. 9, line 8: I don't think that the abbreviation NSGA has been spelt out by this point

* Pg. 9, line 23: a more common approach to include temperature dependence is the

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so-called Eppley curve of phytoplankton growth against temperature. This has a very different shape from that the authors use, so it would be helpful if the authors explained why they favoured this form. Particularly since later temperature relationships in the model appear to use something more akin to the Eppley curve (Q_{10})

* Pg. 10, line 6: in passing, I'd be interested to know how the various limitation terms regulate growth in the final GENIE-M simulation. A figure (probably later in the manuscript rather than here) showing the spatial distribution of the values of the different terms would be nice; especially given that the carbon term is not one commonly used in such models

* Pg. 11, line 26: can the authors explain what the limitation on air-sea gas exchange alluded to is, and why it is artificial

* Pg. 12, line 5: why not show the results for all of the failed "improvements" in table 2?

* Pg. 12, line 7: in describing why the seasonal wind stresses were not used two interesting points occur: 1. unlike other potential improvements, this change to the model appears to have been made prior to the NSGA; 2. since the other improvements were made post-NSGA, it's unclear how fair this omission of seasonal winds is. While the authors have described what they did in a fairly transparent manner, the rationale for handling different improvements in different ways is not.

* Pg. 12, line 25: here the authors suggest that just because one improvement (Gasex) wasn't as big as that of another (K_v) it wasn't retained. But the authors point out that the Gasex improvement is strongly encouraged by the recent literature. Again, its omission is not clearly justified.

Calibration and control run of GENIE-M

* Pg. 13, lines 8-12: this statement simply doesn't make sense. If, as the authors themselves suggest, BGC properties are better for constraining ocean physics than physical properties such as T S (and ^{14}C age is likely to be good for this), the approach

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the authors have taken doesn't make much sense. It would presumably be better if the NSGA-II stage incorporated an objective evaluation of the resulting ^{14}C field.

* Pg. 13: figure 1 gives a good overview of the NSGA-II procedure, but I think it would be very helpful to have a figure that similarly clearly illustrated the three stages of the calibration procedure used in this work. This would allow readers to understand exactly which model was being used at each stage (e.g. GENIE-1?), what had been done to it from a structural perspective (e.g. winds, Gasex, K_v), what was being optimised (e.g. parameters) and what was it being optimised against (e.g. tracer fields). While the description in the current manuscript does cover this, for such a complicated calibration process it'd be very helpful for readers to see, simply and quickly, what was going on.

* Pg. 14, line 17: what does "elitist" mean in this context?

* Pg. 15: this consists of one giant paragraph describing the kriging process. It is very difficult to read and follow. I would suggest breaking it up in to more discernable and concise sections, or simplifying it - figure 1 should cover it.

* Pg. 16, lines 18-22: this isn't very clear, how about: "Since the model atmosphere is 2D and unchanged, an increase in the 3D resolution of the ocean biases the proportion of model/observation comparisons towards ocean observations. As a result, the optimal point selected achieves a better representation of the ocean interior with a less optimal representation of atmospheric humidity."

* Pg. 17, line 12: the abbreviations for the various ocean water masses (CDW, PDW) are not explained in the caption for table 2. This could be addressed by explaining them here instead.

* Pg. 18, line 18: why a 25

* Pg. 19, lines 21-23: it's unclear to me why linking K_N and K_P in this way makes N more important than P. The authors need to explain this point.

* Pg. 21, line 3: "by all accounts" sounds a bit informal, or like gossip; try "... as

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evidenced by several metrics ..." instead

* Pg. 21, line 27: spelling "Lenton"

* Pg. 22, line 2: seem to have a surplus "GENIE-1" here

Tables

* Table 1: The separation of NSGA-II and "target-tuned" values here might be a little confusing. Since they're described in the text, perhaps the "target-tuned" values don't need to appear in this table at all?

* Table 2: a number of suggestions here. Firstly, it might be worth organising the metrics into the order in which they were used - physics first, then BGC. Secondly, since the numbers appear in the text, might it be an idea to include sea-ice (and atmospheric T, Q) in this table? Finally, I wonder if it might be an idea to convey the idea that as one moves from left to right, different tuning methods have been brought into play? The "control" here could have a super-caption for NSGA-II; the "Season" to "Drake" sims could have a "Target-tuned" super-caption; the "GENIE-M" sim could be labelled with a "Calibration" super-caption?

Figures

* Figure 1: OK

* Figure 2: OK

* Figure 3: OK

* Figure 4: panels 'e' to 'j' have bad colour scales that render the plotted data indistinct. While it might be boring to use the same colour scale all the time, that used on panels 'a' to 'd' would allow a clearer comparison. Alternatively, perhaps use more extreme colours at either end of the scale to allow a broader and more discernable colour palette.

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* Figure 5: x and y axes need units

* Figure 6: as Figure 5

* Figure 7: panel 'a' needs a better colour scale (as per Figure 4). Might it be possible to include an observational comparison for these figures? It seems odd to do this earlier but not here

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