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Interactive comment on "Development of BFMCOUPLER (v1.0), the coupling scheme that links the MITgcm and BFM models for ocean biogeochemistry simulations" *by* Gianpiero Cossarini et al.

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In their manuscript, the authors present a new modular coupling scheme between the MIT hydrodynamic and the BFM biogeochemical model. They explore the numerical efficiency of this new coupled model and assess the trade-off between coupling time steps and simulation speed. The coupled model is successfully tested in an idealised and a realistic setup.

General comments

The manuscript's scientific significance is good. One could state that this is only yet

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Discussion paper

another example of a coupled system borne out of existing submodels. More than just combining the two existing submodels, however, the authors create an added value with their detailed description of the coupling process and with their conceptually modular approach to model coupling that can be (and should be) reused in the wider community for subsequent coupling attempts.

The scientific quality of the manuscript is very good. Methods are explained in detail, and conclusions are based solely on the material presented. I should be fairly straightforward to reproduce the work independently; some information on upgrading the GCHEM is missing.

The language used is clear and concise; the manuscript is well structured, all tables and figures are helpful. Unfortunately, the technical quality of the figures is not reaching the standard of the written material. All figures should improved or redesigned. At the current state, they are not acceptable for publication. Neither is the mathematical typesetting which also needs major improvements.

Specific comments

Abstract Within the abstract, the main properties of the BFM should be added (e.g, that it is a NPZD type model). The sentence "efficient scheme that manages communication and memory sharing" needs clarification, as it is not clear what "efficient" refers to (memory, time, ...). Also, tell the reader what the "expected theoretical" and the "observed" behaviour is.

p1 l33f There is much information on the feedback of BGC on hydrodynamics, but this feedback is not realized in the model presented. It is, however used to motivate the coupling of hydrodynamic and BGC models. Please disentangle.

p2 l4 I don't agree with your wording "because of". The improvements are not causally

related to better computer resources; rather these increased resources have enabled the inclusion of more processes.

p2 l6 Please provide a reference for increased “flexibility and modularity” of applications. This is neither (again) caused by increased resources, nor do I see much evidence for increased flexibility and modularity yet. What is your exact definition of modularity (and flexibility?)

p2 l15f I disagree with the statement “hydrodynamic codes are far more complex than BGC codes”, and I disagree with the word “because”. I think the reason is historic, because we started numerical simulations with hydrodynamic models and added more processes (among them BGC) onto the hydrodynamic model. Once physical oceanographers claimed their stakes in handling these hydrodynamic models with BGC “appendices” it became difficult for other disciplines to establish an alternate working mode, like building a BGC model where the hydrodynamics is the “simpler” appendix.

Moreover, the seemingly complicated (not complex!) mathematical description and notation used by physical oceanographers (see Eqs. 1–9 in this manuscript) might have excluded researchers from other fields to drive development of coupled hydrodynamic models. And while the maths involved in solving Eqs. 1–9 is certainly complicated, the many more interactions in biological systems make the ecology and biogeochemistry the more complex part of a coupled model system.

Talking about code complexity, much of the code base of physical ocean models is concerned with input and output, with infrastructure to define the model domain and its boundaries, and not the hydrodynamic core. BGC can be slimmer when they are coupled to such ocean models that provide all the infrastructure. And, of course, a major process (tracer advection diffusion) is shared by both BGC quantities and physical quantities and contributes to code complexity of either one (or both) the BGC and the physical model.

p2 l16f "is preferable" is a valuing statement that should be avoided. Also, the reason given "it facilitates upgrades" is not substantiated. In contrast, some might argue that a centralized/monolithic system is better to handle w.r.t. upgrading. Please elaborate (here or at a different suitable place)

p2 l25ff Name those existing couplings with MITgcm specifically, name the "specific high-complexity model". Why are those coupled models not "state-of-the-art"; if it is the lack of multi-nutrient/multi-species support, then make a causal statement.

p2 l30 You give no motivation why us do not use one of the existing couplings of BFM with another hydrodynamic model. Please elaborate on your motivation to do yet another coupling to another ocean model. Also, I would like to see a discussion why you did not consider to include BFM in the FABM framework, as this would give you instant modular coupling to a multitude of ocean models that already implement FABM.

p2 l33 "coupling tools were not used because ... want to preserve performance". Now that is exactly the raison d'etre for a coupling tool like ESMF, which has been proven to preserve performance and have a very low overhead. A more in-depth discussion for not choosing ESMF (or similar) is required at this point. And, of course, a better substantiation for your conclusion to disregard existing coupling tools.

p2 l38 How do numerical accuracy and good performance lead to flexibility? I dont' understand your "Therefore". Throughout the manuscript, please make sure you argue both your points "performance" (which is well substantiated) and "flexiblity" (less so) consistently, or drop flexibility as a goal of your coupling if not substantiated better.

p3 l6 sometimes, BGC models do *not* solve equations but provide tendencies only that are solved by the hydrodynamic model, as well.

p3 l10 I would agree to ignore effects of BGC on hydrodynamics, but you use exactly this argument to motivate coupling in your introduction. Please resolve this conflict within your manuscript.

p3 l15ff The typesetting of the equations is poor and hinders understanding. It is unacceptable for publication, please use professional math typesetting. Major issues are font sizes and spacing within the equations, it is hard to see subscripts, implied multiplications appear in subscript, bold face is not clearly distinguishable ...

p3 l27 Subscripts h and v (horizontal, vertical) not explained

p3 l28 Acronym RHS = right hand side not explained

p3 l29 There is not plain F, but subscripted F

p4 l1 see above for typesetting Eqs. Here, especially, the problem with subscripts is apparent. I suggest they should be upright roman if words (like bio, BFM) and space to exclude misunderstanding as B * F * M implicitly.

p4 l8 "can be handled". Who decides to handle Eq. 8? This is a serious modular coupling issue that deserves more discussion. What is your solution, specifically and why?

p4 l22 All code and filenames should be in a typewriter font. (i.e starting from "use") and also "data.pkg"

p4 l23 Check exact versioning and typesetting for model version of MITgcm

p4 l24 Unclear typesetting, why all caps TRACERS? please set PTRACERS in typewriter font.

p5 l1ff Typesetting. You may consider to introduce a specific typesetting scheme for your code parts, but you need to explain it beforehand. This applies to the entire manuscript.

p5 l1ff Consider to put this information in a table.

p6 l4 Where are these alterations "upgrades" to GCHEM documented? Where are they available (as a patch?, in the MITgcm distro?)

p6 l36 The star "*" is not a mathematical symbol

p6 l18 Do not extend the "≈" sign over the subscript

p8 l11,19 inconsistent subscript "s" to PAR and many more equation typesetting problems

p9 l35 Under what license is BFMcoupler distributed (MIT)? Also name the license for BFM (GPL) at the appropriate place earlier in the text. How do these licenses play together. Did you include any code parts from BFM into the coupler and how did you deal with changing the license?

p9 l35 Who ensures long-term availability of the code if hosted on github? Could the currently used version (which git sha?) be archived and provided as SOM?

p11 l40 Dt_trc is not explained, please check all your acronyms and subscripts for existing explanations. Consider a table of symbols.

p12 l6f Please motivate your choice of the 0–200 m depth range for integration of Chl. Maybe provide some infomation on the typical depth distribution of Chl in this region. Also, use correct typography (en-dash and not hyphen between number and unit).

p12 l22 Provide evidence that the floating point rounding led to this error. How is the mass budget affected by different choices of the LS option?

p13 l38 pCO2 not explained, also bad typography.

p14 l5 for how many cores did you come up with a simulation time of 65 hrs per year?

p15 l29 I don't agree with the term "framework". You describe a coupling and a coupling strategy, but certainly not a framework.

p16 l3ff This paragraph is entirely unclear to me. Both FABM and MESSy are capable of domain decomposition and have been shown to scale very well. Please better substantiate or argue your reasons not to use these somehow established coupling frameworks.

p17 l10 I would recommend to add a section and paragraph "Code availability" here with the web resources, git/archive information, version numbers, and licenses. Move the content from appendix A4 here to this main section.

Figure 1 Spelling of Omnivorous, Oxidation. From the figure, it is unclear what the superscript numbers (1) etc. denote, please explain. If (as I believe) this is a mere index, then the notation is rather unusual and confusing. Could you find a better notation or make transparent why you use this one? Why do you not use the subscript i for your inorganic nutrients but spell them out, this is inconsistent.

Figure 2 There is a need to synchronize all symbols with those used in the main text, also refer to the (suggested) table of symbols, if available. Some simplifications in terminology could help, why E-P-R, if EPR is sufficient—or call it moisture balance; why the sum of Q_x where Q_θ is sufficient. Help the reader distinguish between C for carbon and C for concentration, especially as subscript; make sure the notation aligns with figure 1.

Figure 3 Align typesetting with (revised) typesetting in-text. Clean up, e.g., why pTracer and PTRACER in the same figure? Please explain, how you numerically handle the equation pTracer=pTraders + dt*gchemTendency with regard to CFL and possible under/overflows.

Figure 4 Thanks for choosing an accessible colormap! Avoid redundancy in graph (of geographic location), do not let axis labels overlap. Provide more context in the caption to which experiment (i.e. idealized closed basin) this graph belongs. Move unit from caption to colorbar; clarify whether this is magnitude of 3D speed or magnitude of speed projected on z-plane.

Figure 5 Remove negative signs wherever possible. Depth is usually a positive number increasing from the surface do the bottom, adhere to this more common convention. Do not denote the contour with a minus sign: concentrations and NPP cannot be negative (that's the first impression I get...). Give color-coded and contoured quantity at the same place in the figure, like "color: T, contour: MLD". Make sure you explain all acronyms, sometimes a word might work instead of the symbol, e.g. "Temperature" instead of T. Be consistent with units and exponents. Move unit of color-coded quantity to colorbar. rotate the "m" unit on y-axis as it falsely gives the impression of an "E" at first glance; add "Depth" to y-axis to help the reader. Avoid overlap of numbers between graphs. Spell Hovmöller with a "v". Give context on experiment as in figure 4. Make sure font sizes are similar to Figure 4, 6 (and all other figures).

Figure 6 Again, use consistent exponents, explain all acronyms. Add more meaning to the very technical caption. Pay attention to detail like the mismatch between the statement "root mean square error" and RMSD (unexplained, but I suppose "deviation"); add your choice of acceptable RMSD threshold to graph. Consider using stacked bars instead of area plot for left axis. Improve looks of figure.

Figure 7 Explain "Eta" (or use greek symbol as suggested for text, and add seman-

tics for sea surface height), tautology “alkalinity concentration”, use consistent name “alkalinity” or “total alkalinity”. Align style of figure to other figures in your manuscript. Replace “1 layer” with “surface layer”. Improve overall look of figure (ticks, legend, line width/styles, labels, title ,....).

Figure 8 Improve overall figure quality. Choose more contrast for depth colormap (consider established terrain/ocean floor colormaps); larger font sizes throughout. Unit of geographic coordinates is degree N or E. Add padding between text and figure margins. Make all named features (river entry points, site location, Otranto strait) more visible. Possibly combine with figure 9 showing 3 panels alongside? The line showing Otranto strait is not identical to the extent shown in figure 11.

Figure 9 Avoid redundancy in y-axis (Latitude); be consistent with unit (see figure 8), it is not helpful to show 10 times “N” along the axis. S not explained, again different notation for chlorophyll (CHLa, in other places Chl). Add information on countrou quantity in the plot (near the colorbar). Panel a) surface current magnitude needs a scale bar. Panel b) I prefer Chl to be shown on a log scale. Blue contour unfortunately collides with blue color in Ionian Basin, try different color for this contour.

Figure 10 Negative depth axes, log scale, colliding lines and text, font sizes, misleading y-axis label... please pay attention to these details. Suggestion: add “Adriatic Pit” and “Ionian deep” to a) and b) to improve intuitive access to figure. Visually separate years and spell out the full year 2008 etc. under the x-axis. Add “contour” in caption,

Figure 11 Negative depth axes, colliding lines and text and colliding texts, missing axis labels, undefined acronyms ... Avoid redundant x-axis (longitude) information, add units to colorbar, add contour info within figure. Consider different scaling of colored quantities, e.g. log or square root (with workaround for negative values)

to show more detail in the small numbers. Added semantics like “Vertical section” to caption.

Technical corrections

p2 l7 “is” should be “has become”

p2 l40 “following” should be “subsequent”

p3 l8 delete “very”

p4 l22 composed of

p4 l31f use a proper em-dash and not a hyphen

p5 l11 “custom” instead of “customary”

p11 l25 well-lit, not “well-lighted”

p12 l17 “eta” should η?

p13 l35ff use consistent exponent, e.g, either m^{-1} or $\frac{1}{m}$ or $1/m$, but only use one of those styles in the text. I prefer the first with negative exponent. Check entire manuscript.

p15 l1 “consistent” not “consistently”

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