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Interactive comment on "Ocean biogeochemistry in the Norwegian Earth System Model version 2 (NorESM2)" *by* Jerry F. Tjiputra et al.

Joachim Segschneider (Referee)

joachim.segschneider@ifg.uni-kiel.de

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Review of GMD-2019-347

Ocean biogeochemistry in the Norwegian Earth System Model version 2 (NorESM2)

by Jerry F. Tjiputra, Jörg Schwinger, Mats Bentsen, Anne L. Moree, Shuang Gao, Ingo Bethke, Christoph Heinze, Nadine Goris, Alok Gupta, Yanchun He, Dirk Olivie, Öyvind Seland, and Michael Schulz

In their study, the authors report on the further development of the ocean biogeochemical model iHAMOCC as component of the Norwegian Earth System Model version 2 (NorESM2). In particular, the changes of the model compared to the version used in NorESM1 are first described, and then the performance of iHAMOCC in NorESM2 is

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evaluated in relation to observations and the predecessor model NorESM1 in a subset of CMIP6 experiments (control and historical).

Overall, the authors find that the numerous changes lead to a better match of the climatological mean state of various biogeochemical parameters with observations, and thus reduce the overall model bias.

The changes to the iHAMOCC model code are fairly substantial, ranging from the introduction of a depth-dependent settling velocity for detritus, the simulation of DMS emissions, updated riverine input (including nutrients and DIC/ALK), atmospheric nitrogen deposition, a changed formulation for nitrogen fixation and air-sea gas exchange, adjustments to the iron cycle and various ecosystem parameters, to the simulation of carbon isotopes (intended to be used in paleo studies), and the introduction of new 'preformed' and 'natural' tracers (the latter operating at pre-industrial atmospheric CO2 levels) for additional analyses. In summary this justifies a new documentation/publication in GMD.

The paper is generally quite well written, with some room for improvement mainly in the 'Results' section, the figure captions, and the supplementary material.

The supplementary material could be better justified and introduced, hardly any of the figures are discussed in the main text.

Also, the reader's life could be made easier by a more specific referencing to the figures (like pointing to the specific panel, not only the Fig., and perhaps the particular feature like 'blue curve in Fig X.x').

In summary I recommend publication of the manuscript after a careful revision addressing the below comments. Due to the length of the paper, my comments are quite numerous, but by nature I would consider the requested changes as minor revisions.

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Specific comments

p5 ln 19 and 23

better: 'atmosphere-ocean coupling' instead of 'ocean coupling'

Section 2.3 p6 ln 6-ln10

I was a bit confused by this (DMS production) description, in particular there seems to be an error in the use of degradation/production ?

after reading through several papers, I now assume production should be changed do degradation in line 10 - or it should be 'detritus production' of opal/CaCO3

In Six et al. 2013 the k refers to sulphur to carbon ratios in cells of opal/CaCO3

In Six and Maier-Reimer 2006 the gammas to degradation rates of opal/CaCO3

not clear to me what is meant in Eq. 2

please double-check and revise Section 2.3

p6 Eq (1) capital P in Phy irritating - I suggest to use 'phyto' to avoid mixing up with physics

also, is there a reason why some terms carry the 'DMS', others not?

p9 ln16/18

perhaps the ref. to Fig. 1 could be moved to the end of the para, or even toward the end of the section, otherwise one is trying to connect the following statements to Fig. 1

p10 ln25 I presume what is meant here is that preformed phosphate can be used to estimate the organic carbon pump, and preformed alkalinity to estimate the inorganic carbon pump? As the sentence stands now, either can be used to estimate both pumps.

–> Preformed phosphate can be used to quantify the organic (), and preformed alka-

linity to quantify the inorganic () carbon pump ().

p10 ln26 (Eqs. 10-12; Bernardello et al.) is a bit misleading, perhaps (Eqs. 10-12, based on Bernardello et al.) is better suited (the corresponding eqs. are 1-4 in Bernardello e al. 2014)

p11 eq.12 I do not quite follow how eq. 12 is derived (where does the +1 originate from?) +1 not in Bernardello et al. 2014 Eq. 4

p15 ln 18 'branched off into' is not a valid formulation. rephrase to sth like: the PI, control and historical exps are branched off from the spin-up. or 'the simulation is used as a starting point'....

p15 ln 20 see above

p16 ln24 rephrase 'at subsurface 500 m'

p16 ln25/26 'improvements ... in deviation' does not sound good.

–> improvements in agreement, better agreement

p18 ln 5 what is meant by : the simulated .... concentrations are mostly confined to the upper 1 km?

p23 ln 31 ct Consistent with the lower oceanic (than atmospheric) pCO2 partial pressure

(I guess partial pressure is meant here, since the oceanic growth rates are not shown in Fig. 20)

Fig. 2 since the panels are labelled a-d, better use 'a,c' in the caption instead of 'left', etc

Fig. 9 is never discussed in the text

Fig. 14 I am a bit sceptical about the term 'Southern Ocean' for latitudes between 20 deg S and 40 deg S. Why not just call it southern hemisphere mid latitudes.

The content description of the supplementary material is full of errors.

Technical errors

general:

Check all occurrences of 'to allow for' (which means to consider s.th. when planning for s.th., see e.g. dictionary.cambridge.org) and replace by 'allows' or 'enables us to' or similar

change all occurrences of 'insight to' to 'insight into'

check for sgl/pl and past/present mismatches

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in the following 'ct' stands for 'correct to'

p1 ln 5 correct 'allow for'

p1 ln 7 riverine 'input'

p1 ln 7 'are recently' does not make sense -> have recently been ...

p2 ln 6 remove 'us' (who is 'us' here?) or better reformulate whole sentence

p2 ln 8 remove 'us'

p2 ln 13 ct ...hardware systems, higher resolution

p2 ln 16 complex interplay between what and what?

p2 ln 21 remove 'through'

p4 ln 3 check use of 'implications on' (correct: implications of sth. for sth.)

should be 'consequences for', 'impact on', or similar

p4 ln 11 ct 'insight into the ocean's role' ....

p4 ln 26 ct ....'in Section 4.'

p4 ln 28 ct ....'in Section 6.'

p4 ln 32 delete 'for'

p5 ln 2 ct we also now apply (or we also applied)

p5 ln 29 ct 'closer to' (or better, 'which is within the range'....)

p6 ln 24 ct ... an early version of 'the' Global-NEWS model ...

p7 ln 15 ct .... and 'are' added to the nitrate pool .... (otherwise it is not clear if this is only assumed)

p7 ln 16 ct Particle export (without plural s)

p8 ln 1 ct ....interior biogeochemistry 'using' the different .... (not 'in')

p8 Eq. 4 dot between mu and max misplaced

p8 ln 14/15 change to: 1.25 moles dissolved oxygen and 1 mole of alkalinity...

p9 ln 11 ct where the strength 'of' this ....

p 11 Eq. (12) dot after 0.5 misplaced

p11 Eq. (13) remove leading dot

p11 ln24 insight into

p11 ln29 correct 'allow for'

p12 ln 5 remove 'to' before (ii)

p12 ln10 correct 'allow for'

p13 ln 27 ct ... different parameterizations, (add s)

p14 ln 16 ct , as follows (add s)

p14 ln 25 ct 'a quasi-equilibrium state' (remove pl. s)

p14 ln 30 ct ...carbon counterpart of 'the' respective ...

p15 ln 1 ct ...applied 'to' organic ... (not 'for')

p15 ln 3 –> atmospheric pCO2

p16 ln 8 correct 'the the'

p16 ln11 either 'the majority' or 'the major part' (but not 'majority part')

p17 ln 29 ct 'In the subpolar North Atlantic'....

p17 ln 31 ct ....'a' deep MLD ....

p18 ln 5 delete 'depth' after upper 1 km

p18 ln 16 ct .... material being ....

p18 ln 17 ct ... 'at' intermediate depth

p18 ln 18 ct ... 100 and 1500 m depth).

p18 ln 20 ct ... concentrations of all nutrients ...

p18 ln 27 ct ....NADW as the main watermass ...

p19 ln 3 ct ...(see also Fig 8i). - check if 8i was meant, 8e is Atlantic NorESM2

p19 ln 8/9 ct: ...low levels.... limit the phytoplankton growth.

p19 ln 21 correct 'Fig. 9' to 'Fig. 12'

p19 ln 29 ct ... and at high latitudes during summer months.

p20 ln 3 ct ...the spring blooms....

p20 ln 4 delete 'during the boreal spring months' (redundant in sentence)

p20 ln 9 coastal areas (not grids)

p20 ln 20/21 move ref to Weber after 'biogeochemistry' ct ....still simulates too high transfer efficiencies...

p20 ln 22 ct ...are comparable with observations.

p20 ln 26 correct 'Fig. 2c' to Fig. 2d

ct ....simulates a lower ...

p21 ln 8 ct ...at the lower end...

p21 ln 24 ct As at the surface...

p22 ln 12 ct ...translates into stronger carbon sinks...

p22 ln 20 ct of DIC-rich deep watermasses...

p22 ln 21 ct ...strong bias ... is considerably reduced, ...

p22 ln 22 ct ... is approximately reversed compared to observations:

p22 ln 26 ct Nevertheless, the ....

p23 ln 25 ct 0.7 oC, comparable to that from obs...

p23 ln 26 ct the warming in esm-hist ....

p23 ln 30 ct (i.e., is lower than)...

p24 ln 7 ct For the 1980s and 1990s ...

p24 ln 9 correct allowing for

p24 ln 15 ct ...by the ocean for 1850-1994 and 1994-2011 is ....

p24 ln 27 correct allow for

p24 ln 28 ct , and (iii) carbon isotopes that can be used e.g. ....

p25 ln 8 ct the equatorial Pacific OMZ

p25 ln 9 ct ...Southern Ocean, and the equatorial and North Pacific.

p25 ln 14 replace allowing for by 'resulting in'

p25 ln 20 ct simulates a considerable bias

p25 ln 25 ct the CO2-fluxes' seasonal cycle...

p25 ln 26 attention to (not of)

p25 ln 30 ct ... depth of the equatorial Pacific ....

p25 ln 33 ct penetrating too far north..

p26 ln 1 ct biogeochemical components in ESMs...

p26 ln 2 ct the mean climatological state. However, ... (check if the references have to be moved)

p26 ln 3 ct a lot of effort

p26 ln 5 replace allowed for by e.g., 'provided'

p26 ln 15 correct allow for

p26 ln 19 ct ..currently, we use fixed particulate organic carbon emissions ...

p26 ln 27 ct to investigate the sensitivity of ....

p26 ln 35 ct as the results of more complex model simulations

Table 1: ct ... ecosystem parameterisations that have been changed....

Table 2: ct ... simulation periods over which their climatological values have been averaged.

ct Average of the three remote sensing products...

Table 3: ct Annual mean biology-related metrics... (not only primary production is listed)

Fig. 1 ct Blue depicts components, processes, ... (there is only one blue)

Fig. 3 caption: ct 'Differences between ... are ....

also Fig. 4, 7, 8, 9, 11, 13, 16, 17, 21, 22, 23

Fig. 14 averaged over all months.

also Fig. 19

Fig. 20 ct relative to the 1850-1879 period, (b)...

Green depicts results from the .... simulation with NorESM2. The purple line in panel (c) represents .... (only one green, only one esm-hist with NorESM2-LM)

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