

We thank Dr. Joachim Segschneider for his prompt and very thorough review of our manuscript. We have now addressed all of his comments (in **bold**) with point-by-point (i) responses (in *italics*) and/or (ii) description of changes made in the revision (in **blue**) detailed below. Changes in the revision can also be seen in the attached revised manuscript with highlighted changes (**red** and **blue** depicts older and revised version, respectively).

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.

We agree with this assessment and have accordingly revised the 'Results' section, figure captions and supplementary material.

In the revised manuscript, we have made some improvements in the abovementioned components of the manuscript, add more references to the (revised) supplementary materials. Since many of the figures in the previous supplement materials, especially those showing results from NorESM2-LM version, closely resemble those of NorESM2-MM in the main manuscript, we have removed these figures.

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.

We agree and have followed your advice accordingly. We've gone through the revised manuscript and inserted specific figure references where they fit.

Changes are applied throughout the manuscript, especially in the Results section.

Specific comments

p5 ln 19 and 23 better: 'atmosphere-ocean coupling' instead of 'ocean coupling'

Done.

Both changed to 'atmosphere-ocean coupling'.

Section 2.3 p6 ln 6-10: 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

Thank you for noticing these inconsistencies. We have updated and expanded Section 2.3, as follows:

- Changed the reference from Six and Maier-Reimer (2006) to Kloster et al. (2006), which is the updated parameterization currently used in our model.
- Revised equation (1) and provided an improved description for source and sink terms associated with detritus export production, bacterial consumption, and photolysis.
- Revised equation (2), through renaming the different terms.
- Added equations for loss terms due to bacterial consumption and photolysis are now added in the revision.

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?

We follow your suggestion. Some terms initially carry 'DMS' as it is computed as a function of the DMS concentration in the model.

The term 'Phy' has been replaced with simply 'prod' (for production) and 'DMS's are removed in all terms in the revised eq. (1).

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

We agree.

Moved the sentence referencing Fig. 1 to the end of the 3rd paragraph in the same section.

**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 alkalinity to quantify the inorganic () carbon pump ().**

Correct. We have revised the sentence to:

“Following Bernardello et al. (2014), PO_4^{pre} is used to quantify the organic (soft tissue, DIC^{soft}), whereas both PO_4^{pre} and ALK^{pre} are used to quantify the inorganic (carbonate, DIC^{carb}), biologically-mediated carbon pump (Eqs. 12-14)”.

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)

We agree. The sentence has been revised (see previous response).

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

In our updated code, we have assumed that during organic production and remineralization, both changes in nitrate and phosphate alter the proton concentration and therefore change the alkalinity (see also Section 3.1.3 of Paulmier et al., 2009). We have included the following statement in the revision:

Equation 14 is slightly different than that in Bernardello et al. (2014), $r_{N:P} + 1$ instead of $r_{N:P}$, because, in our updated code, we do not neglect the contribution of phosphate to alkalinity changes during biological production and remineralization. For instance, both nitrate and phosphate produced during organic remineralization increase the concentration of proton and therefore reduce the alkalinity (see also Section 3.1.3 of Paulmier et al., 2009).

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'

We have rephrased the sentence as suggested to:

“The end of the model spin-up is used as a starting point for ...”

p15 ln 20 see above

Rephrased to:

“Simulation (3) is furthermore used as a starting point for “

p16 ln24 rephrase 'at subsurface 500 m'

Rephrased to:

“At 500 m depth, ...”

**p16 ln25/26 'improvements ... in deviation' does not sound good.
→ improvements in agreement, better agreement**

Rephrased to:

“... shows better agreement with data throughout ...”

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

It was meant to describe that most of the high CFC-11 values are mostly simulated between the surface and 1 km depth. We have revised the sentence to:

“Similar to the observations, high values of CFC-11 are generally simulated in the upper 1 km in both the Atlantic and Pacific, with the exception of the North Atlantic ... “

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)

Yes, thank you. We have rephrased the sentence to:

“Consistent with the lower surface ocean (than the atmospheric) pCO₂, the ocean carbon uptake continues to increase ...”

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

Done.

Replaced left, right, top, and bottom with 'a,c', 'b,d', 'a,b', and 'c,d'.

Fig. 9 is never discussed in the text

In the revised section 5.6, towards the end, we have added the following (previously missing) discussion on Silicate (Fig. 9):

“The silicate spatial distribution in NorESM2 resembles closely the phosphate distribution (Figs. 9a-c and 7a-c), with similar biases across the vertical sections of Atlantic and Pacific (Figs. 9e-f and 7e-f). At high-latitudes, NorESM2 overestimates the surface silicate concentration (Fig. 9d), which could be attributed to the reduced opal export sinking speed relative to our earlier model version (30 instead of previously 60 m day⁻¹).”

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.

We followed the reviewer's suggestion.

We have revised both figures 14 and 19 and renamed the region to “Mid-latitude southern hemisphere”. The corresponding texts have been revised too.

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

The supplementary material has been revised.

In addition, we have also reduced the number of supplemental figures (from 16 to 7; Figures S6 and S7 are new), since many of the figures (i.e., distributions of biogeochemical tracers, maps of limiting nutrient, surface pCO₂ and CO₂ fluxes, DMS concentration, and mean primary

production and transfer efficiency) from NorESM2-LM are qualitatively and visually very similar to those of NorESM2-MM (shown in the main manuscript).

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

We have checked for and revised the above phrases as suggested.

**in the following 'ct' stands for 'correct to'
p1 ln 5 correct 'allow for'**

Corrected to: "allow for".

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

The sentence has been revised to: "have recently been...".

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

Rephrased to: "ESM simulations can therefore be used to estimate historical carbon budgets and future carbon emission pathways under specified scenarios."

p2 ln 8 remove 'us'

Rephrased to: "... ESMs are state-of-the-art tools used to study ...".

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

Done. "(... new hardware systems, higher resolution, etc.)".

p2 ln 16 complex interplay between what and what?

Replaced "... complex interplay of internal climate variability." with "... complex interactions with the internal climate variability."

p2 ln 21 remove 'through'

Done.

p4 ln 3 check use of 'implications on' (correct: implications of sth. for sth.) should be 'consequences for', 'impact on', or similar

Replaced with 'consequences for'.

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

Done. "... insights into the ocean's ...".

p4 ln 26 ct'in Section 4.'

Corrected.

p4 ln 28 ct'in Section 6.'

Corrected.

p4 ln 32 delete 'for'

Removed 'allows for a'.

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

Revised to 'We also applied ...'.

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

Used 'which is within the range'.

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

Added 'the'.

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

Removed 'assumed to be bio-available and'.

p7 ln 16 ct Particle export (without plural s)

Corrected.

p8 ln 1 ctinterior biogeochemistry 'using' the different (not 'in')

Replaced 'in' with 'using'.

p8 Eq. 4 dot between mu and max misplaced

Corrected.

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

Changed as suggested.

p9 ln 11 ct where the strength 'of' this

Corrected.

p 11 Eq. (12) dot after 0.5 misplaced

Corrected (now Eq. 14).

p11 Eq. (13) remove leading dot

Done (now Eq. 15).

p11 ln24 insight into

Corrected.

p11 ln29 correct 'allow for'

Rephrased to 'The inclusion of natural tracers provides substantial saving ...'.

p12 ln 5 remove 'to' before (ii)

Done.

p12 ln10 correct 'allow for'

Rephrased to 'In order to allow comparison between different ...'

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

Done.

p14 ln 16 ct , as follows (add s)

Done.

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

Done.

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

Done.

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

Done.

p15 ln 3 → atmospheric pCO₂

Done.

p16 ln 8 correct 'the the'

Done.

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

Used 'the majority of the mean ...'.

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

Corrected.

p17 ln 31 ct'a' deep MLD

Done.

p18 ln 5 delete 'depth' after upper 1 km

The sentence has been rephrased: "Similar to the observations, high values of CFC-11 are generally simulated in the upper 1 km in both the Atlantic and the Pacific, ..."

p18 ln 16 ct material being

Corrected.

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

Corrected.

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

Done.

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

Replaced 'in' with 'of'.

p18 ln 27 ctNADW as the main watermass ...

Corrected.

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

Yes, we meant Fig. 8i (not 8e). Thank you.

Corrected.

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

Corrected.

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

Thank you.

Done.

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

Done.

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

Done.

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

Deleted.

p20 ln 9 coastal areas (not grids)

Corrected.

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

Both corrected.

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

Done.

p20 ln 26 correct 'Fig. 2c' to Fig. 2d; ctsimulates a lower ...

Both corrected.

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

Done.

p21 ln 24 ct As at the surface...

Done. Replaced “As in the surface ...” with “As at the surface ...”.

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

Done.

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

Done.

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

Corrected as suggested.

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

Corrected as suggested.

p22 ln 26 ct Nevertheless, the

Done.

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

Replaced “ ... relatively comparable with that from the ...” with “comparable to that from ...”.

p23 ln 26 ct the warming in esm-hist

Done.

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

Done.

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

Done.

p24 ln 9 correct allowing for

Done.

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

Done.

p24 ln 27 correct allow for

Corrected to 'which enable us to'.

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

Corrected.

p25 ln 8 ct the equatorial Pacific OMZ

Corrected.

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

Corrected.

p25 ln 14 replace allowing for by 'resulting in'

Done.

p25 ln 20 ct simulates a considerable bias

Corrected.

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

Corrected.

p25 ln 26 attention to (not of)

Revised "attention of" to "attention to".

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

Corrected.

p25 ln 33 ct penetrating too far north..

Corrected.

p26 ln 1 ct biogeochemical components in ESMs...

Corrected.

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

Checked and corrected.

p26 ln 3 ct a lot of effort

Corrected.

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

Replaced 'allowed for additional constraints' with 'provided additional valuable constraints'

p26 ln 15 correct allow for

Replaced 'allow for efficient optimization of the current ecosystem parameterization' with 'enable us to perform optimization of the current ecosystem parameterization more efficiently'.

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

Corrected.

p26 ln 27 ct to investigate the sensitivity of

Corrected.

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

Corrected.

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

Corrected.

**Table 2: ct ... simulation periods over which their climatological values have been averaged.
ct Average of the three remote sensing products...**

Both phrases have been corrected.

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

Agree, and corrected.

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

Corrected.

**Fig. 3 caption: ct 'Differences between ... are
also Fig. 4, 7, 8, 9, 11, 13, 16, 17, 21, 22, 23**

Corrected for all mentioned Figures.

**Fig. 14 averaged over all months.
also Fig. 19**

Done.

**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)**

Corrected. Thank you.