Biogeosciences

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Discussions

Interactive comment on "Drivers and uncertainties of future global marine primary production in marine ecosystem models" *by* C. Laufkötter et al.

C. Laufkötter et al.

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We wish to thank reviewer #2 for the detailed analysis of our paper and his/her thoughtful comments, which have been very helpful and greatly improved the quality of this manuscript. A detailed reply to each point follows below:

Reviewer Comment: This study investigates the effects of climate change on ecosystem dynamics and biogeochemical fluxes in several CMIP5 models. The main focus is to illuminate the between-model-differences and underlying mechanisms. While this is a very important and interesting study, it is difficult for the reader to pull out the key findings from the current manuscript, as well as differences to previous studies. As I see it, major findings of this study are

the role of temperature dependence of the different ecosystem processes, the balance between them (if different temperature curves are applied within the same model), and the particular role of zooplankton grazing in controlling NPP and biogeochemical fluxes. I think the paper could be shortened quite a bit, as (a) a lot of the information is very repetitive, and (b) the highlight should be put on the key findings mentioned above, and not the general findings that have already been discussed in previous studies. Overall, some arguments are very repetitive, and appear 4 or 5 times throughout the text, e.g. regional patterns of the NPP response and associated mechanisms. This could be condensed quite a bit. Maybe it would be worthwhile to restructure the paper. In general, some of the structuring seems rather odd, i.e. some methods are described in the results section or discussion (e.g. calculation of correlations with observations, Taylor decomposition of NPP). The paper has 9 sections and I would prefer a classic separation (intro, methods, results, discussion and conclusion). I think this would also help to avoid being too repetitive, as well as highlighting the key findings of this study. And the key findings are indeed important! It is interesting too show how much influence the choice of temperature sensitivity has, as well as its specific application for zooplankton grazing. In this regard, it would be nice to have a more extended discussion about the scientific basis for this. . . What are the used parameterizations based on? Are they justified? And how much do we know about this topic at all? Will temperature dependence really matter in a physiological way, or will organisms just follow their preferred temperature or evolutionary adapt? I would be happy to read an extended discussion on this, as this seems to be the main finding of the whole study!

Author Response: We have substantially shortened the manuscript to remove the redundancy, and also changed the structure and reduced the number of sections. We have added a discussion of the temperature parameterizations used in the models:

While we emphasize here the role of temperature in the models, our understanding of how temperature controls the most important ecological and biogeochemical processes in real marine ecosystems is not well established. Most models base their parameterizations of temperature effects on laboratory studies that show - within favourable thermal ranges - an exponential increase of growth with increasing temperature (Eppley, 1972; Bissinger et al., 2008). However, there are major uncertainties in quantifying the temperature sensitivities of different physiological processes and of functional types (Ikeda et al., 2001; Lomas et al., 2002; Hirst and Bunker, 2003; Hancke and Glud, 2004; Sand-Jensen et al., 2007). Several authors suggest a stronger temperature response of heterotrophs than autotrophs (Lo Ìapez-Urrutia et al., 2006; Rose and Caron, 2007), which would lead to major consequences for the metabolic balance of the oceans under rising temperatures (Duarte et al., 2013; Williams et al., 2013; Ducklow and Doney, 2013; Garcia-Corral et al., 2014). Furthermore, in current implementations both phyto- and zooplankton grow faster with increasing temperatures without any upper thermal limit beyond which growth rates may come down. The underlying assumption is that if the temperature rises to values outside the optimal range of a certain species, the species will be replaced by another species with a higher temperature tolerance. However, particularly in the tropics, it is unclear if this assumption holds. Thomas et al. (2012) show that warming might lead to a decrease in diversity in the tropics, which could potentially lower NPP due to the loss of highly productive species. Finally, due to the lack of measurements, synergistic effects of multiple stressors are barely considered in current models. Recently, temperature sensitivity has been shown to be reduced under nutrient limitation (Staehr and Sand-Jensen, 2006; Tadonleke, 2010; Maranon et al., 2014) which would result in an overestimation of temperature sensitivity and therefore NPP in the oligotrophic regions of the ocean. Overall, the temperature assumptions on which current model projections are based are afflicted with high uncertainties.

Specific comments Reviewer #2

Reviewer Comment: Table 2: Recom has 3 nutrients, not 4 Also the caption should be extended to explain the stoichiometry. . . probably R means Redfield and V means variable, but this should be mentioned somewhere.

Author Response: Done

Reviewer Comment: Table 3: to what temperature does the Q10 refer? By definition, the Q10 gives the change of a biological rate when temperature increases by 10%. However, all models use exponential functions for temperature dependence, so the Q10 will change depending on the temperature range considered (imagine Q10 between 0 and $10°C$ compared to Q10 between 20 and $30°C$).
Author Response: The Q10 is the rate of change of a biological rate when temperature increases by $10°C$. The functions in the models are designed that the Q10 stays constant over different temperature ranges, with REcoM2 being the only exception. As an example: The temperature function in PISCES and TOPAZ is of the form $e^{0.063 \times T}$. The function that describes the rate of change by a temperature increase of $10°C$ is:

$$\frac{e^{0.063 \times T}}{e^{0.063 \times (T-10)}}$$

which is a constant function with the value 1.87.

Reviewer Comment: Table 5: Usually, the relationship between prey concentration and grazing rate is described by Holling. . .
Author Response: Yes - we have now added a description of the grazing functions using the Holling classification.

Reviewer Comment: Table 6: more detailed caption needed. What does NPP in % stand for? Satellite data?

Author Response: Done. NPP in % refers to the percentage that a certain region contributes to global NPP.

Reviewer Comment: Table 7 and 8: I think the given numbers are unitless (correlation coefficient), so the units in brackets should be deleted

Author Response: Done - the unit is only needed for the bias, we have made this more clear now.

Reviewer Comment: Table A7: zooplankton have no number for growth rate

Author Response: Done

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/12/C4859/2015/bgd-12-C4859-2015-supplement.pdf

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