Biogeosciences Discuss., 10, C528–C532, 2013
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Biogeosciences
Discussions

Interactive comment on "The impact of global warming on seasonality of ocean primary production" *by* S. Henson et al.

Anonymous Referee #1

Received and published: 26 March 2013

The authors use a century-long output of 6 biogeochemical models to investigate the impact of rising temperature, under the AR5 scenario, on the seasonality of Primary Production (PP) in the global oceans. The authors provide an original contribution by analysing changes in PP both in terms of seasonal amplitude, annual mean and timing of peak. They show a decrease in both PP seasonal amplitude and annual mean, and an advance in timing of peak in most ocean biomes from by 2100. The authors further estimate the number of years of continuous data required to distinguish long-term trend from natural variability in the annual mean and seasonal amplitude of rates of PP. The latter results are very interesting and clearly shown in Figure 5.

The study is particularly relevant in context of climate change impact assessment, however the paper needs essential revisions on some of the terminology employed before

it can be published.

In particular, I would like to draw attention to the inaccurate use of the term 'phenology' in several instances in the present manuscript. Phenology relates specifically to the study of timing of events. The term can be used to describe the timing at which changes in the rate of PP occur, but it should not be used to describe changes in amplitude of PP. Phenological changes are expressed in units of time (e.g. days, weeks, month...) with dimension [T], whereas changes in seasonal amplitude of PP can be expressed in terms of mass of carbon converted (fixed) per unit area of water per unit time, with dimensions [M L$-$2 T$-$1]. Phenology and rates of primary production describe two fundamentally different properties of the ecosystem. They may or may not influence each other, however they cannot be directly compared. Furthermore, it is one of the key findings of the paper that the monthly resolution of model output is not sufficient to detect climate-driven trends in the timing of peak PP (i.e. phenology).

Please see specific comments below: Abstract: 1) Page 1422, Line 1: "The seasonal cycle (i.e. phenology) of oceanic primary production", please remove the term "phenology". It is really the seasonality of PP that is analysed and discussed in the present paper, not phenology sensu stricto. 2) Page 1422, Line 6: "PP itself" can be replaced by "PP values" or "PP annual mean". 3) Page 1422, Lines 16-17: "On average, 36 yr of data are needed to detect a climate change-driven trend in the seasonal amplitude of PP, compared to 32 yr for mean annual PP." Given the uncertainty $\pm$3 yr in each of this estimate (provided on Line 21-22, Page 1432), it might be more informative to provide a range in the number of year required to detect a climate-driven trend (e.g. $\sim$30-40 yr). 4) Page 1422, Lines 17-19: "We conclude that analysis of phytoplankton phenology is not necessarily a shortcut to detecting climate change impacts on ocean productivity." This sentence is misleading and needs to be redrafted. As stated in the general comment above, phenology and rate of PP represent two fundamentally different properties of the ecosystem and they have different dimensions. The main conclusion and opening to this paper could be on the implication of the relative rapidity ($\sim$35yrs according

to the study) at which marine ecosystem responds to climate warming.

Introduction: 5) Page 1424, Lines 4-6: "Substantial interannual variability in phytoplankton phenology is also evident (e.g. Henson et al., 2009; Sasaoka et al., 2011; Sapiano et al., 2012)." For completeness, please add references: Platt et al. (2009, http://dx.doi.org/10.1016/j.ecolmodel.2008.11.022) and Zhai et al. (2011, doi:10.1093/icesjms/fsq175) showing interannual variability in the Northeast Atlantic; Thomalla et al. (2011, www.biogeosciences.net/8/2849/2011/doi:10.5194/bg-8-2849-2011) showing interannual variability in the Southern Ocean; Kahru et al. (2011, doi: 10.1111/j.1365-2486.2010.02312.x) showing interannual variability in the Artic; Racault et al. (2012, http://dx.doi.org/10.1016/j.ecolind.2011.07.010) showing interannual variability in the global oceans. 6) Page 1425, Line 1: The expression "phenological markers" needs to be replaced by "markers of phytoplankton seasonality". 7) Page 1425, Lines 4-6: "We also investigate the length of time series needed to distinguish global warming signals in phytoplankton phenology from the natural variability." This sentence needs to be removed. The authors could not investigate trends in phenology and conclude about this in Lines 18-19 (Page 1429) by stating "the monthly resolution (in the PP model output) discretises the time series to the extent that calculating trends (in timing of peak PP) is unreliable"; and furthermore in the second paragraph of the discussion Pages 1435-1436 by stating "Detecting changes in timing of peak PP (or timing of any other seasonally recurring event) is limited by the monthly resolution of the model output, i.e. only changes in peak PP timing of greater than 1 month are resolved. In some regions changes in peak timing far exceed 1 month by 2100, but if shifts in the peak timing are more subtle, higher temporal resolution output will be required to detect them." 8) Page 1425, Lines 8-9: "Here, we investigate whether climate change-driven trends are detectable more rapidly in PP phenology than in PP itself." This sentence needs to be redrafted to "[. . .] more rapidly in the seasonal amplitude of PP than in PP mean".

Methods: 9) Page 1425, Line 25: Please replace "phenological markers" with "markers

of phytoplankton seasonality" or "seasonality metric" (as employed on Page 1428, Line 29).

Results: 10) Pages 1431-1432, First paragraph of section 3.4: The argumentation is not coherent with the rest of the results described in this section. Please consider removing "As phenology has been suggested as a particularly sensitive indicator of climate change (Sparks and Menzel, 2002), here" and start the paragraph by the sentence "We examine the hypothesis that global warming driven trends may be more rapidly detectable in the amplitude of the PP seasonal cycle than mean annual PP by comparing the length of time series required to detect trends in both metrics."

Discussion: 11) Page 1435, Line 14: The term "seasonality" needs to be added to the title, because seasonality and not just phenology is discussed in this section. The title can read as "4.2 Detecting climate change trends in phytoplankton phenology and seasonality". 12) Page 1435, Lines 15-24: The argumentation in this first paragraph needs to be adjusted to match with the rest of the discussion in this section. I suggest removing the first two sentences: "A key aim of this study was to investigate the hypothesis that global warming may be detectable in phenological markers more rapidly than in other metrics (Sparks and Menzel, 2002). Henson et al. (2010) suggested that 30–40 yr of continuous PP data is needed to distinguish a climate change trend from natural variability." Because A) The detection of trends in phenology was shown to be unfeasible given the monthly resolution of the model ouput used in this study (this is clearly stated and further discussed by the authors on Page 1435, Lines 25-28 to Page 1436, Lines 1-13); and B) The second sentence is stated as identical earlier in the manuscript (Page 1425, Lines 6-8). 13) Page 1437, Lines 3-5: "However, as shown here, analysis of phytoplankton phenology is not necessarily an automatic shortcut to detecting climate change impacts on ocean ecosystems." This sentence needs to be removed. As stated in the above comments, phenology and amplitude of rate of PP are two fundamentally different properties of the ecosystem. Furthermore, the authors do not show here trends in phenology, they show trends in the seasonal amplitude of

PP and in the annual mean of PP.

Interactive comment on Biogeosciences Discuss., 10, 1421, 2013.