

Interactive comment on “Long-term trends in ocean plankton production and particle export between 1960–2006” by C. Laufkötter et al.

Anonymous Referee #3

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Interactive comment on "Long-term trends in ocean plankton production and particle export between 1960-2006" by C. Laufkötter, M. Vogt and N. Gruber

This contribution analyzes the mechanisms underlying simulated trends in plankton production, export, and export efficiency in a ~50 year ocean-ecosystem simulation forced with atmospheric reanalysis. Global primary production and export production are found to decline by 6% and 7% between 1960 and 2007, with pronounced spatial heterogeneity in both the magnitude and direction of simulated trends. The analysis suggests that, to first order, the global trends can be understood as the result of enhanced stratification decreasing primary production and export efficiencies in nutrient limited regions. Declining export efficiency is found to amplify declines in export relative to declines in primary production. Surprisingly, the decline in export efficiency

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is predominantly linked to decreases in small phytoplankton (and associated coccolithophores) rather than suppression of diatoms through increased stratification. This is contrasted with past work (e.g., Bopp et al., 2005) where trends in export efficiency were linked to diatom declines.

I found the analysis to be useful and interesting. I suspect, however, that a significant part of the contrast between the Bopp et al. (2005) results and those herein is due to the fact that the 1960-2007 trends in the North Atlantic and Southern Ocean are due to low frequency climate variability and not change. In the North Atlantic, century-scale climate change predictions show robust increases in stratification and declines in primary production as the effects of continued increases in greenhouse gases take hold (e.g., Capotondi et al., 2012; Steinacher et al., 2010). This contrasts sharply with the reduced stratification in these regions over the contemporary period. This doesn't nullify the statement concerning export efficiencies being sensitive to biology (see also, for example, Tauscher and Oschlies, 2011), but the results herein do not imply similar divergence in mechanisms under climate change. This needs to be discussed in the "implications for future change" and "caveats" sections.

More generally, the potential role of climate variability in generating the trends analyzed needs to be discussed more prominently. It seemed implicit that any trend between 1950-2007 was "climate change", yet this is not the case - particularly at regional scales (e.g., see Deser et al., 2012). This should be clearly stated in both the introduction and in the caveats.

There was an extended discussion of the roles of top-down versus bottom-up perturbations in generating trends over the 50 year hindcast, leading to the conclusion that the trends primarily reflect a bottom-up influence. While this discussion was carefully caveated by pointing out that the run only considers only one minor element of the potential top-down forcing, one has to wonder whether the experimental design warrants an extended discussion of this issue. The external forcing in the experiment is essentially bottom-up, assessing the relative roles of top-down versus bottom-up would seem

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to require a more comprehensive treatment of top-down forcing (changes in fishing/fish populations?). I have no issues with including some carefully caveated discussion of this issue, but I'm not sure it should be a central thread of the paper given the experimental design. Of course, as the authors point out, the ultimate response of phytoplankton to a bottom-up perturbations depends dynamics adjustments of all relevant growth and loss processes.

My last substantial comment pertains to the comparison of chlorophyll trends relative to those analyzed in Boyce et al. (2010). I was hoping for a Figure comparing the simulated trends here with those inferred by Boyce et al. (2010). Also, while trends in some areas may be consistent with those of Boyce et al. (2010), the magnitude of the trend here is considerably smaller. Boyce et al.'s 1%/year value translates to an alarming decline in chlorophyll of ~40% over 50 years and >60% over the last century. Through a more substantive comparison with the Boyce data and contrasting these trends, this paper could make an important contribution to the controversy that Boyce's alarming analysis has stirred.

I hope these comments are useful. I've also included a number of minor ones below.

p. 5924, line 3: 1950-2006 or 1960-2006 as the title suggests?

p. 5925, line 3: lead = led.

p. 5925, line 24: suggest citing Bopp here in addition to or rather than Steinacher. To my knowledge, Bopp's 2001 analysis was the first paper to lay out this argument in detail.

p. 5927: is surface salinity relaxed to climatological values in these simulations? My understanding is that this is generally the case for CORE-forced runs. If so, it should be noted.

p. 5929, lines 1-8: Detrital remineralization rates are assumed to be independent of temperature?

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p. 5931, line 5: $4.8 \text{ Pg C yr}^{-1} = 4.8 \text{ Pg C month}^{-1}$? 48 Pg C yr^{-1} ?

p. 5932, line 1: Export efficiency discussed here is just particles?

p. 5932, line 10-12: I don't see an increase in export production in the polar Southern Ocean in Fig. 1 or Fig. 2; please clarify what you mean here.

p. 5933: lines 1-4, Fig. 3 shows only the global case and thus does not effectively support the text here. Suggest modifying the figure to address this.

p. 5936, line 9: weak oh = weak?

p. 5937, line 12-15: I suspect the wind stress changes reflect low-frequency climate variability (e.g., NAO/NAM in the North Atlantic). You should at lead clarify that the origin of these wind stress changes do not necessarily reflect a climate-change driven trend.

p. 5941, line 16: exponentially = quadratically?

p. 5942, line 16: we can = we omit?

p. 5948, line 6-7: I would strongly suggest parsing the difference between supporting some decline in productivity versus supporting Boyce's result (see general comments).

References (other than those already cited)

Capotondi et al., (2012) Enhanced upper ocean stratification with climate change in the CMIP3 models. *JGR-Oceans*, 117.

Deser et al., (2012) Uncertainty in climate change projections: the role of internal variability. *Climate Dynamics*, 38, 527-546.

Tauscher and Oschlies, (2011) Can we predict the direction of marine primary production change under global warming? *Geophysical Research Letters*, 38.

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