**Biogeosciences
Discussions**

Interactive
Comment

Interactive comment on "Is global warming already changing ocean productivity?" *by* S. A. Henson et al.

S. A. Henson et al.

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1. In response to both reviewer's comments, we have changed the title to, "Detection of anthropogenic climate change in satellite records of ocean chlorophyll and productivity". We have also replaced the majority of instances of 'global warming' with 'global climate change'.

2. Absolutely right - We have added a couple of sentences here to make this clear. "In addition, the chl product represents surface concentrations, whereas PP is an estimate of the depth-integrated productivity. Algorithms to derive PP from satellite data are still subject to fairly large uncertainties (e.g. Joint and Groom, 2000), partly because satellite ocean colour instruments only measure surface conditions and extrapolating to a depth-integrated quantity poses additional difficulties. Uncertainties also arise from

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errors in the input parameters to PP algorithms (i.e. chl, SST and photosynthetically available radiation; Friedrichs et al., 2009). Indeed, in some instances, satellite PP algorithms are no more skilful at reproducing in situ PP measurements than biogeochemical models (Friedrichs et al., 2009)."

3. The manuscript has been altered throughout to reflect Friedrich's findings (more details in response to specific comments below).

Abstract: We've made the changes suggested by the reviewer.

p. 10313, 2nd paragraph: We've added a note here on the long time series available from BATS and HOT. "Long (∼ 20 years) time series of chl and PP have been measured at the BATS and HOT stations. These time series stations have the advantage of measuring sub-surface and biogeochemical properties that cannot be estimated using satellite data."

p. 10314, line 15: We've removed the mention of the A2 scenario here, as it's not necessary. The definition of the A2 scenario remains on page10317.

p. 10314, line 27: A sentence has been added here (see response to comment 2 above).

p. 10315, line 8: We've added a couple of sentences here to reflect the reviewer's comments (see response to comment 2 above).

p.10315, line 23: We've changed this to "Satellite-derived chl, SST and photosynthetically available radiation were used to estimate PP using three different algorithms."

p. 10316, lines 3-15: The CbPM algorithm is an important contribution to the suite of satellite-derived PP estimates, and so we would have liked to include it in our analysis. However, because of its sensitivity to the choice of MLD product used, we excluded it from the analysis.

p. 10316, line 17: Changed.

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p. 10321, line 13: Changed.

p. 10322, line 17: Quite right – we've changed this to 'n** is a factor of 1.59 larger than n*'.

p. 10323, line 24: We've added here, "The spatial distribution of statistically significant trends are similar to the regions of large PP change between 1999 and 2004 shown in Behrenfeld et al. (2006; their Figure 3b)."

p. 10324, line 22: We've changed this to 'The final datapoints of the modelled results in Figures 2 and 3 represent the trend in the 10-year period that overlaps with the SeaWiFS records.'

p. 10324, lines 23, 25: Changed.

p. 10326, line 16: On the recommendation of the other reviewer we have removed this part of the manuscript.

p. 10329, line 19: We've added to the abstract, "In some regions, notably equatorial regions, detection times are predicted to be shorter ($\sim$ 20-30 years)." Parts of the North Pacific have short detection times ($\sim$ 20-30 years), but because of the spatial variability in this region the biome mean is longer ($\sim$ 40 years). We've removed the reference to the North Pacific here to avoid confusion.

p. 10329, line 23: We've removed the reference to the North Pacific here – see above response.

Fig 6: The global maps are presented to demonstrate the degree of spatial variability in detection times, as the biome means in Table 1 do not always reflect the range of values within each biome (see also above comment re the North Pacific). As a measure of the variability, the standard deviation of detection time within each biome has been added to Table 1.

Sections 3.4 and 3.5 and Tables 1 and 2: The methodologies here are different, and

the questions we pose are also subtly different. The detection time (in section 3.4 and Table 1) doesn't specify a date for when we should start observing, i.e. you should be able to look at any 40 year piece of the time series and distinguish a climate change-driven trend from the background variability. Calculations of the year when the climate change trend exceeds natural variability (in section 3.5 and Table 2) were prompted by the question, 'Has global warming-driven change already occurred during the satellite era?' Here we are looking for a specific period during which trend exceeds variability. The conclusion is that, in general, global warming trend has not exceeded the natural variability during the current period of observations. We've altered section 3.4 to hopefully make this point clearer, adding "Note that the methodology used here does not specify a start date for the period of observations. In Section 3.5 the time period during which the climate change-driven signal exceeds natural variability is estimated, specifically to address whether a global warming signal might already be detectable in the satellite ocean colour record."

p. 10334, line 5: Added a couple of sentences here, "These regime shifts may pose difficulties for accurately estimating satellite PP derived from empirical algorithms, as used here. In the tropical Pacific for example, Friedrichs et al. (2009) demonstrated that satellite PP models successfully reproduced in situ PP in the 1990s, but were much less successful in the 1980s."

p. 10335, line 1: We agree that time series sites are absolutely necessary, as we point out in the final 2 sentences of the manuscript. Our intended message here was that monitoring must be continued via a variety of methods (including time series stations), and that satellite data is a crucial component of a monitoring system as it provides the large-scale picture. We have reworded this sentence so hopefully it is more positive, "The substantial spatial variability revealed by this analysis suggests however that time series stations alone are unlikely to be an optimal strategy and instead a global observing system is necessary to detect the PP or chl response to global climate change. Current ocean colour satellites are limited to measuring surface properties, but changes

will occur throughout the water column, altering plankton community composition and trophic dynamics. Therefore, an integrated observing strategy consisting of satellites, time series stations, gliders, floats and moorings will be necessary to detect the full suite of biological responses to global warming."

Interactive comment on Biogeosciences Discuss., 6, 10311, 2009.