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Discussions

# *Interactive comment on* "Factors challenging our ability to detect long-term trends in ocean chlorophyll" *by* C. Beaulieu et al.

**Anonymous Referee #1**

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General Comments:

Beaulieu et al. present sea surface chlorophyll trends globally and in 14 biomes using 10 years of SeaWiFS data and determine whether these trends are statistically significant (real trends) or an artifact resulting from autocorrelation (red noise). The authors also discuss the effects of interrupting the collection of ocean colour data (discontinuity) on our ability to detect statistically robust long-term trends in phytoplankton biomass with satellite sensors. They conclude that global and regional trends in chlorophyll concentrations based on SeaWiFS data are not discernible from red noise except for 2 of the 14 biomes studied and that a minimum of 27 years of observations are required to detect a 'real' trend in surface chlorophyll globally. The results from this study are novel, interesting, well presented and highlight the value of satellite ocean colour (OC)



observations for understanding the connection between ocean biogeochemistry and climate. The authors were very creative in combining novel statistical methods with coupled climate-ocean biogeochemistry models, an approach that should be considered in future studies analyzing OC time series. Overall this manuscript is well written and deserves to be published after revisions.

Specific Comments:

My only concern is that the authors did not take advantage of the MODIS-Aqua OC record for their analyses. They effectively demonstrate how varying degrees of discontinuity affect the number of years of observations necessary to detect a 'real' trend (n*) from satellite chlorophyll records in the global ocean, and emphasize the importance of ensuring overlap between OC records from different sensors. Overlap among different satellite records would indeed avoid discontinuity effects and thus a statistically robust global trend in surface chlorophyll would be available within the next few years after, for example, validating the quality of VIIRS data. This is a crucial statement as support for OC sensors seems to be deeming over time. In light of this observation, I would have expected the authors to take advantage of the MODIS-Aqua OC record in combination with the 10 years of SeaWiFS data presented in this study for conducting their analyses. As mentioned in the Introduction section, there are several years of overlap between these two sensors and thus a more extensive satellite chlorophyll time series (perhaps until the end of 2010?) would have been available to better determine trends magnitude, their statistical significance and n*. The authors acknowledge the value of the overlap among these datasets and yet they do not explain why they used the SeaWiFS record exclusively, or why MODIS-Aqua OC data was not included in this study. They should either consider conducting these statistical analyses with an extended time series that includes MODIS data or explain why they chose to work with the 10-years SeaWiFS record only. Would have 3 or 4 more years of data made a difference in the trend values and statistical significance? Indeed, combining OC measurement from different sensors can be problematic but the authors should briefly address the

challenges of using a multi-sensor dataset if they chose to use measurements from a single satellite.

Technical Corrections:

Introduction section, page 16421, lines 10-13: Measurements from HOT and BATS time-series sites show that chlorophyll a is increasing in the oligotrophic North Pacific and North Atlantic, respectively. Karl et al. (2001), Corno et al. (2007) and Lomas et al. (2010) should be cited here as well.

Introduction section, page 16422, line 8: A period is missing after 'chlorophyll'.

Introduction section, page 16422, line 19: add a sentence expanding on the definition of red noise.

Introduction section, page 16424, lines 16-24: I would suggest deleting this paragraph.

Data and Methods section, page 16425, line 12: The sentence "Figure 2 presents the global. . ." should be moved to the Results section.

Data and Methods section, page 16425, line 17: Perhaps include the atmospheric CO2 concentration by 2100 in parentheses.

Data and Methods section, page 16425, lines 21-22: This should not be mentioned in the Methods section but in the Results section.

Data and Methods section, page 16425, line 25, page16426, line 7: This paragraph belongs to the Discussion section. The Methods section should only describe how the study was carried out.

Data and Methods section, page 16428, line 22: Consider replacing 'number of years of observation or data collection, or necessary to detect trends, etc' by n* here and thereafter. For example, 'the number of years necessary to detect trends', which is kind of a long term, is mentioned five times on page 16436 (Discussion section). Using n* would make the reading a bit easier.



Data and Methods section, page 16429, line 6: 'T0 represents the number of observations before discontinuity'. According to the list of notations on page 16440 T0 is the timing of the discontinuity. The authors should either change the definition here of in the list of notations for consistency.

Data and Methods section, page 16429, lines 17-19: This should be mentioned earlier in this section, perhaps after line 25 in the previous page.

Results section, page 16431, lines 10-12: Explain here how chlorophyll is standardized as in Figure 2 (the mean is subtracted from the time series and then the time series is divided by its standard deviation).

Results section, page 16432, line 20: include the multi-model mean value in parentheses here, which should be -1.53 x10-4.

Results section, page 16432, lines 25-27: without discontinuity, right?

Results section, page 16432, line 28, page 16433, lines 1-2: I don't see these values (66 to 105 years) in Figure 4. The GFDL-TOPAZ trend value (0.4) is between the 80 and 120-years contours with continuous observations and between the 120 and 160-years contours with a discontinuity halfway through.

Results section, page 16433, lines 4-24: This entire paragraph should be moved to the Discussion section.

Results section, page 16434, lines 1-3: 25 Years of observations to detect a trend with the same magnitude as the multi-model mean trend assuming zero discontinuity, right?

Results section, page 16434, lines 6-8: Perhaps the authors should refer to Fig. A2 here?

Results section, page 16434, lines 13-16: the lower value is more like $\sim$55 yr with no discontinuity. At zero fraction of data before discontinuity the multi-model trend mean is between the 50 and 55-yr contours.

Discussion and conclusion section, page 16435, lines 1-3: Refer to Table 1 too.

Discussion and conclusion section, page 16435, lines 22-26: This was already mentioned in lines 4 to 24 of page 16433.

Discussion and conclusion section, page 16436, line 4: projected.

Discussion and conclusion section, page 16436, line 12: remove 'the' after if.

Appendix A, page 16438, line 20: remove 'the' after present.

Table 1: Highlight the biomes that show statistically significant trends with, for example, bold captions.

Figure 4: The scale in the y-axis in (a) should be x10-3 so that trend values in the figure can be compared to those in Table 2 more easily. Also, the sentence 'the standard deviation and autocorrelation used in the calculations were estimated from global SeaWiFS data from 1998-2007' should be moved to section 'b' in the figure caption. Refer to Table 2 after '. . .as well as the model mean trend'.

Figure 5: The sentence 'the standard deviation and autocorrelation used in the calculations were. . .' should be removed since SD and autocorrelation data from each biome are not shown in this figure. It should also be mentioned that trends are in absolute values and that trend values are available in Table 2.

Figure A3: Biomes showing significant trends should be indicated with a star (*) with the corresponding colour.

Figure B1: The sentence 'the standard deviation and autocorrelation used in the calculations were. . .' should be removed since SD and autocorrelation data from each biome are not shown in this figure.

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