**Biogeosciences
Discussions**

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Interactive comment on "Large-scale shifts in phytoplankton groups in the Equatorial Pacific during ENSO cycles" *by* I. Masotti et al.

I. Masotti et al.

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Dear Referee 2

Thank you very much for your valuable comments and suggestions. Please find our responses below (referee (R), author (A)).

(R) However, because the manuscript is not very well written and the results are not well discussed within the context of previous research done, the main results remain unclear and thus unconvincing.

(A) In the revised MS version, an exhaustive review has been included in the methods, results and discussions sections to improve and clarify the main results of our work.

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(R) Paper focuses on NO3 control of phytoplankton groups but neglects iron, while there is consensus that iron is the main limiting nutrient in the Cold Tongue region. Why iron results of PISCES are not shown, is it simply because they are correlated with NO3 (or are they decoupled)?

(A) In the NEMO-PISCES model iron is clearly the simulated dominant limiting factor in the east part of the Equatorial Pacific (EQPAC) region, but it is not the case of the west part where fluxes of iron input from the shallow New Guinea-Indonesia/region continental shelves are simulated using NEMO-PISCES model. We focused on the simulated NO3 because we may better understand the forcing environmental conditions that produce PFT shifting during ENSO cycles. Our eventual focus on NO3 is supported by the fact that i) regional-mean PO4 concentrations show almost similar inter-annual variations than NO3 in the 180°W-80°W, 10°N-10°S region, but with a much smaller relative amplitude (+- 20% for PO4 concentrations vs +- 100% for NO3 concentrations) ii) mean Fe concentrations during early state of the El Niño condition show a decrease simultaneous to NO3 and PO4 in the 180°W-80°W, 10°N-10°S region, and iii) although regional NO3/Fe present decoupling episodes at inter-annual scales in the 180°W-80°W, 10°N-10°S region, NO3/Fe show almost similar inter-annual variations in the core of the PFT variability region (140°W-100°W, 10°N-10°S, see results presented in section 3, Fig. 6 in the MS). Moreover, figure R1 shows the NO3, PO4 and Fe anomaly in the 140°W-100°W, 10°N-10°S region. As can be seen, NO3, PO4 and Fe show almost similar inter-annual variation, except during mature El Niño conditions (September 1997 to March 1998) when a decoupling between Fe and NO3 seems to appear. This agrees with the NO3/Fe decoupling shown to occur at the decadal time-scale and in the eastern part of the EQPAC region (150°W-90°W, 2°N-2°S) (Rodgers et al., 2008). In the 180°W-80°W, 10°N-10°S region it is clearly NO3 that controls/limits productivity in NEMO-PISCES model and we therefore focus on the 180°W-80°W, 10°N-10°S region where NO3 appears to be a more representative nutrient to explain any PFT variability. We introduce these new comments to clarify the choices of nutrients control/limitation in the methods section of the MS revised version

and figure R1 will be included as supplemental material.

(R) There is an extensive list of publications that focus on Equatorial Pacific under different states of ENSO (Murray et al., 1995; Radenac and Rodier, 1996; Ishizaka et al., 1997; Mackey et al., 1997; Dunne et al., 2000; Aufdenkampe et al., 2001; Aufdenkampe and Murray, 2002; Le Borgne et al., 2002, Salihoglu, 2009) and on EqPac phytoplankton composition (Chavez, 1989; Iriarte and Fryxell, 1995; Lindley et al., 1995; Bidigare and Ondrusek, 1996; Chavez et al., 1996; Coale et al., 1996b; Landry et al., 1996, 2000; Latasa et al., 1997; Higgins and Mackey, 2000) that the authors seem to be unaware of.

(A) In the revised manuscript we cite many of these relevant papers, especially in the discussion section (please see the specific particular comments concerning Landry et al., 1996 study at the end of this response).

Specific comments:

(R) *I am not sure I follow what is suggested in the last sentence of the abstract. If the authors are suggesting that functional group modelling is important, this has been discussed extensively in various publications and this sentence is superficial as is.

(A) Sentence removed in the revised version of MS.

(R) *Introduction needs to better give the justification of using the model.

(A) Acknowledged and addressed. The introduction has been rewritten. The new introduction is reproduced hereafter.

Productivity in the global ocean is important in governing the oceanic carbon cycle and thus exerts a significant control on the climate of the Earth. Any climate change over coming decades could affect primary productivity (PP) through modifications to the environmental conditions of the surface ocean, such as nutrient supply, stratification and acidification. Recent models that aim to forecast future climate include a representation of the ocean carbon cycle and hence also marine productivity. They all predict a global

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decrease in PP towards the end of the 21st century (Bopp et al., 2001; Steinacher et al., 2009). Monitoring ocean productivity at the global scale is essential to evaluate such predictions and is only possible at basin scales and greater using ocean color satellite data, which have been routinely available since the end of the 90's, in particular from the OCTS (1996-1997), SeaWiFS (1997-) and MODIS (2002-) sensors. Such data allow for the quantification of chlorophyll a concentrations (Chla) in ocean surface waters, which is necessary to estimate PP (Behrenfeld and Falkowski, 1997). In the Equatorial Pacific (EQPAC) region, observed changes in productivity have been associated with regional climatic events, such as the El Niño Southern Oscillation (ENSO) (e.g., Chavez et al., 1999; Gregg and Conkright, 2002), one of the major natural climatic events that occurs regularly but with a variable intensity. Behrenfeld et al., (2006) estimated that the major El Niño and La Niña (ENLN) transitions between 1997 and 1999 resulted in a 262 Tg increase in global PP. Changes in PP during ENLN are essentially associated with the changes in the supply of the nutrients necessary for phytoplankton photosynthesis (e.g., nitrogen, phosphorous, iron). Photosynthetic performances and nutrient demands differ between different phytoplankton groups. For example, diatoms are twice as efficient as typical equatorial picoplankton (e.g., Prochlorococcus and Synechococcus) in carbon fixation, despite having a higher nutrient demand (e.g., Veldhuis et al., 2005; Sarthou et al., 2005). In this context, it is unsurprising that the composition of the phytoplankton community also changes during ENLN transitions (Chavez et al., 1999). Consequently it can be anticipated that observed changes in PP during ENLN depend on the specific phytoplankton group composition. The characterization of the specific phytoplankton group composition is possible from space using the PHYSAT algorithm (Alvain et al., 2005). The PHYSAT algorithm detects the Phytoplankton Functional Type (PFT) when they are dominant and has already been used to show a major diatom bloom during La Niña 1998 in the eastern EQPAC region using SeaWiFS data (Alvain et al., 2008). Our goal here is to use satellite archives to study the variability in the distribution of PFTs during the ENSO cycle in the EQPAC over the last decade. In order to cover the totality of the 1997 El Niño event that started prior to

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the SeaWiFS era, we have used OCTS data. We have adapted the PHYSAT algorithm to also process OCTS data in order to be able to analyze phytoplankton changes during the particularly strong 1997-1998 ENLN events. The PHYSAT algorithm is used here to detect the distribution of four PFTs (i.e., Prochloroccocus, Synechococcus, nanoeucaryotes and diatoms) in the EQPAC region between November 1996 and December 2007. In addition, we use simulated nutrients fields from the NEMO-PISCES model to better understand the link between the phytoplankton changes detected by PHYSAT and variability in environmental conditions.

(R) *Sections 3.1 and 3.2: To my knowledge La Nina was strongest during 1998 (McPhaden, 1999). Highest SeaWiFS chl concentrations are also observed during June-August 1998 (Murtugudde, 1999) , and towards the end of 1998 chl concentrations went down to pre ENSO conditions, it would be really interesting if the authors present results from 1998 La Nina and not only 1999.

(A) In the section 3.1 we did not include global distribution of the dominant PFTs for La Niña 1998 because in this section we essentially aimed to examine whether OCTS PFT detections were comparable at the global scale with SeaWiFS. To support this, we needed to compare monthly global PFT distribution from OCTS with one typical SeaWiFs year. We did not use the climatology, as we needed to compare monthly products from the equivalent PHYSAT composition procedure. The choice of 1999 was because this year seems representative of the SeaWiFS PFT climatology as shown in figure R2. In the figure R2 we show a comparison between the monthly areal coverage (in percentage) by each PFT obtained from SeaWiFs in 1999 and SeaWiFS climatology (between 1997-2007). In the section 3.2, we show time series of the PFT dominance for equatorial and tropical region of Pacific and Atlantic Oceans to obtain a comparable overview of PFT variability and finally we focus our attention on EQPAC region where an increase of diatom dominance is observed during the La Nina of 1998. The relationships between diatom dominance and chlorophyll are further discussed in the section 3.3. We agree with the reviewer that the June-August 1998 La Niña was strongest,

as we also show in section 3.3 the maximum SeaWiFs Chl levels associated with high diatoms dominance across the EQPAC region (140°W-100°W, 10N-10S, cf. Figure 6c and d in the MS). Therefore we do not think it appropriate to reproduce the results from the La Niña of 1998 in Section 3.1 (as they essentially appear in other sections that do not focus on evaluating OCTS and SeaWiFS captors).

(R) *page 2532 line 5: references should be given

(A) Acknowledged and addressed. Veldhuis and Kraay (2004) cited in the revised version of MS.

(R) *Section 3.3: poorly written, it is not possible to follow the last sentence of page 2533 and the following part.

(A) Acknowledged and addressed. The new section 3.3 is reproduced hereafter.

3.3 PFT dominance shifts in the Equatorial Pacific and Chlorophyll a concentrations To more precisely analyze the PFT dominance shifts during ENLN events, we compared the anomalies of the three most dominant and variable PFTs, i.e., Synechococcus, nanoeucaryotes and diatoms with the Chla concentration estimated with OCTS and SeaWiFS (Fig. 6). The decrease in Synechococcus and the increase in nanoeucary-otes dominance is observed over the entire EQPAC region (180°W-80°W, Figs. 6a and 6b) during both strong (May-June 1997) and the moderate (May-July 2006) El Niño events. A coincident decrease in Chla concentrations is also observed during these two El Niño events (Fig. 6d), with mean values of 0.13 mg m-3 in May-June 1997 and 0.17 mg m-3 in May-July 2006 (the mean Chla value in May-July for the whole 12-year period is 0.19 mg m-3, not including strong ENLN events). The decrease in phyto-plankton biomass in this region during El Niño has already been noted (e.g., Strutton et al., 2008). However we show here that this decrease in biomass is associated with a decrease in the Synechococcus PFT and an increase in nanoeucaryote dominance. Furthermore, analyzing PFTs from PHYSAT in parallel to Chla suggests that this na-noeucaryotic dominance during the early stages of El Niño is not due to increases in

this PFT's abundance, but rather because Synechoccoccus almost disappears from surface waters due to unfavorable environmental conditions.

The increased dominance of diatoms observed during the La Niña event of 1998 covered almost the entire EQPAC region (Fig. 6c) and coincided with the highest mean Chla value over 1996-2007 period (an average of 0.25 mg m-3 for the month of August 1998, Fig. 6d). On the contrary, we observe a disappearance of diatoms dominance in the eastern EQPAC region associated with the lower chlorophyll values typical of El Niño events (e.g. during 1997 and 2006 El Niño events). Similar to the PFT changes observed during El Niño events, it is likely that the increase in both the dominance of diatoms and Chla are connected with changes in the environmental conditions during La Niña, such as changes to nutrient availability and sea-surface temperature that are directly controlled by ENLN events (Ryan et al., 2002; Pennington et al., 2006). Alternatively, diatoms are relatively dominant (even if 4-5 fold lower than the other groups) during strong to moderate la Niña events (1996, 1998, 2000 and 2005-2006, cf. Fig. 5g) when nutrients are more abundant. A detailed analysis of these increases in diatom dominance show that this PFT exhibits a variable geographic distribution in the EQPAC region during La Niña events, including the recent 2007 event. For example, in our longitude-time plots of diatom dominance distributions (Fig. 6c), we find that diatoms merely dominated as small patches that did not extend westward of 140°W during the La Niña years, with no widespread dominance of the entire EQPAC region. The 'patchy' nature of diatom dominance during La Niña events probably explains the lower integrated diatom dominance anomaly values over the entire EQPAC observed during these years (cf. Fig. 5g). On the other hand, widespread regional diatom blooms are observed in the early and strong La Niña of 1998 (August, Fig 6c), whereas they are more scattered in the later and more moderate la Niña of 1996 (November).

(R) *pg 2535: authors should check the paper by Landry et al 1996 and the JGOFS data, there are some picoplankton data from 140W during the 1992 ENSO

(A) We thank referee 2 for suggesting a review of paper by Landry et al 1996 and the

JGOFS data. Clearly these sources present relevant information regarding changes of relative Synechococcus dominance during El Niño conditions. Our PHYSAT analysis show that even if Synechococcus decreases during the early stages of the 1997 El Niño (May-Jun, SOI = -2.0, cf. Fig. 2 in the MS), there is a subsequent increase in Synechococcus dominance during mature phase of the 1997 El Niño (Sep-Nov, SOI =-3.0). This agrees with Landry et al. (1996) , who showed that Synechococcus was more numerous during the mature conditions of the 1992 El Niño (Feb-March, SOI= -3.5) along the 140°W transect (at 12°S and 12°N), than during the weak conditions of the 1992 El Niño (August-September, SOI= -0.4).These results are also consistent with the purported 'resilience' of Synechococcus dominance as El Niño conditions mature, as we suggest in this work. This new interpretation has been included in the discussion section of the MS revised version.

(R) *It is not possible to read the legends of Figs 3 and 6.

(A) Acknowledged and addressed.

Reference cited in this answer to comments from referee 2:

Landry, M.R., Kirshtein, J., and Constantinou, J.: Abundances and distributions of picoplankton populations in the central equatorial Pacific from 12°N to 12°S, 140°W. Deep-Sea Res. II 43: 871-890, 1996.

Rodgers, K. B., Aumont, O., Menkes, C., and Gorgues, T.: Decadal variations in equatorial Pacific ecosystems and ferrocline/pycnocline decoupling, Global Biogeochem. Cycles, 22, GB2019, doi:10.1029/2006GB002919, 2008.

Veldhuis, M.J.W., and Kraay, G.W.: Phytoplankton in the subtropical Atlantic Ocean: towards a better assessment of biomass and composition, Deep Sea Research Part I, 51,4,507–530, 2004.

Interactive comment on Biogeosciences Discuss., 7, 2523, 2010.
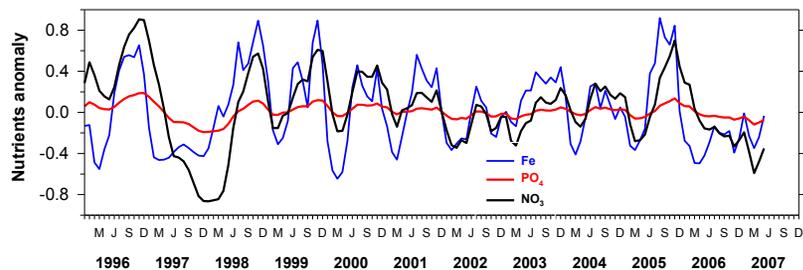
Fig. R1. Anomaly of nutrients in the core of the PFT shift region (140°W-100°W, 10°N-10S) during ENSO cycles.

Fig. 1.
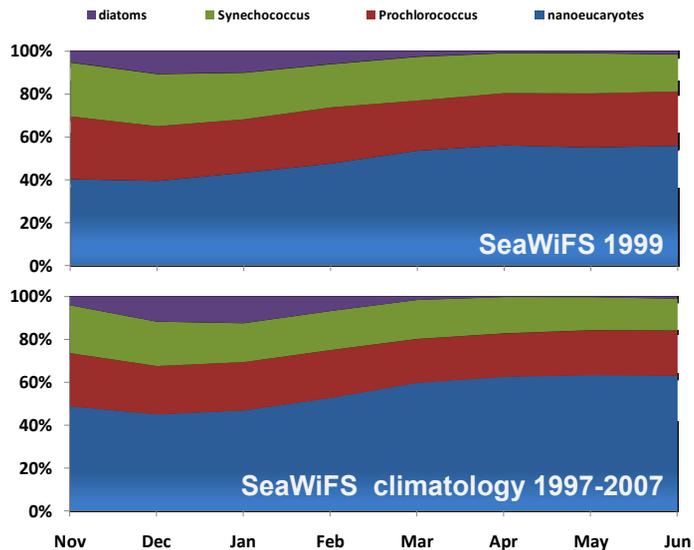
Fig. R2. A comparison of the monthly areal coverage (in percentage) by each PFT obtained from SeaWiFS 1999 year (upper panel) and SeaWiFS climatology between 1997-2007 (bottom panel).

Fig. 2.

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