

Figure 1. While changes occurring in the permanently stratified oceans are responsible for the interannual trends discussed in the manuscript, this does not mean that the cooler seasonal seas have not experienced notable changes at the local scale. Indeed, significant changes are clearly shown in the manuscript in figure 3b for waters with annual average temperatures <15°C. However, when all these cold-water areas are integrated together, they yield no net overall temporal trend ($p > 0.5$), as illustrated here by chlorophyll anomalies for <15°C waters.

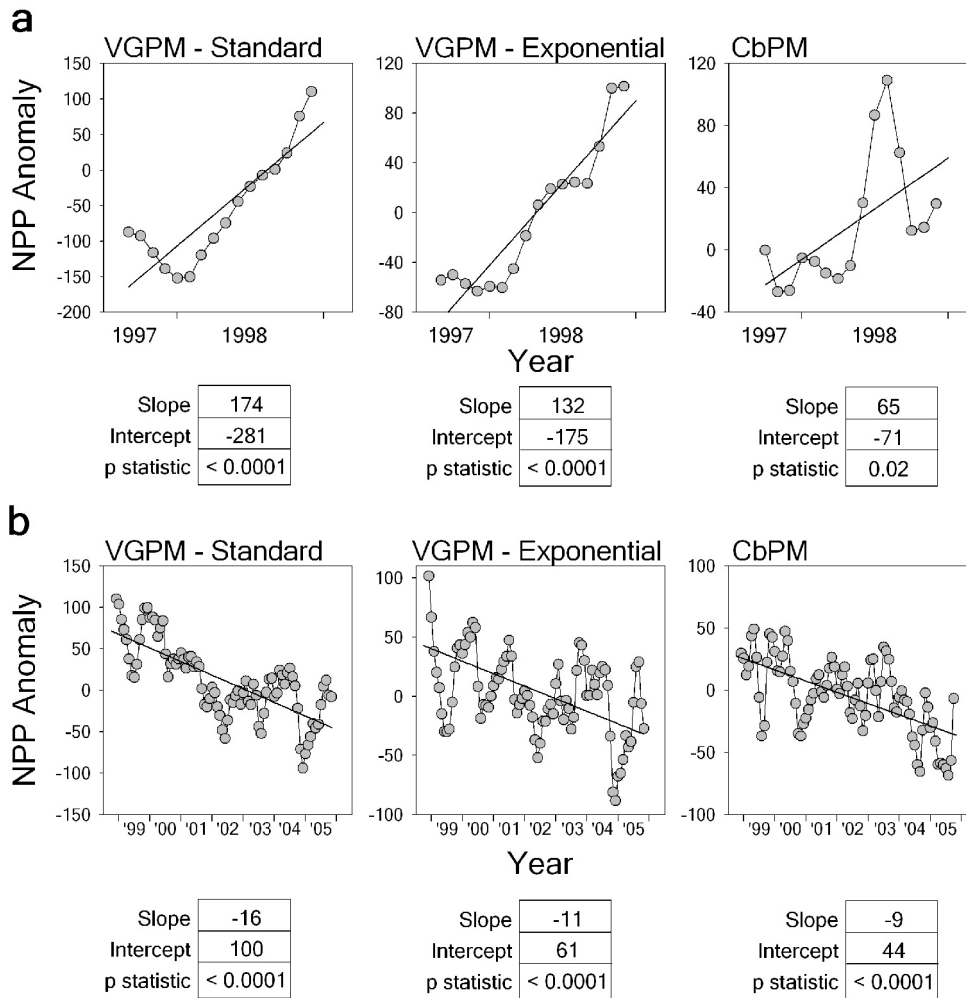


Figure 2. NPP trends for the SeaWiFS record based on three alternative NPP models. (a) NPP anomalies for the 1997-1999 El Niño to La Niña transition period. (b) NPP anomalies for the post-1999 warming period. Model designations are indicated at the top of each panel. The slope and intercept for the least-squares regression results (black lines) are provided below each panel, along with the p statistic for the regression slope.

SeaWiFS Trends for Different Models: Net primary production (NPP) is not a property of marine ecosystems that can be directly measured from space. Instead, it is calculated from information on phytoplankton standing stocks (e.g., chlorophyll), incident light, water column attenuation properties, and descriptions of physiological variability. A variety of NPP models have been developed and intercompared (Campbell et al. 2002, Carr et al. 2006). The primary factor responsible for differences in NPP estimates from these models is the chosen description of algal physiology. For chlorophyll-based models, the required physiological term is the chlorophyll-specific carbon fixation efficiency (P_{opt}^b), and it is most often described as a function

of sea surface temperature (SST). The two most commonly employed temperature-dependent descriptions of P_{opt}^b are the polynomial function originally described for the standard Vertically Generalized Production Model (VGPM) (Behrenfeld & Falkowski 1997) and the exponential function described by Morel (1991) and derived from the temperature-growth relationship of Eppley (1972).

Over most of the open ocean (areas with SST >5°C) (Behrenfeld et al. 2002), relationships between SST and P_{opt}^b do not reflect a direct physiological influence of temperature on photosynthetic efficiencies, but rather a correlation between temperature and physiologically important growth constraints. The two primary environmental drivers for P_{opt}^b variability are light and nutrients. An increase in light decreases the intracellular chlorophyll concentration required to sustain a given level of carbon fixation. This response is referred to as 'photoacclimation' and it causes P_{opt}^b to increase as light increases (Behrenfeld et al. 2002). Nutrient stress, on the other hand, causes a decrease in P_{opt}^b because a greater fraction of photosynthetically generated reductants are used for alternative (i.e., non-growth related) metabolic pathways (Behrenfeld et al. 2004). Nutrient stress and increases in growth irradiance thus have opposing influences on P_{opt}^b . Importantly, both nutrients and mixed layer light levels can covary with SST.

In cooler ocean regions, surface nutrients are generally elevated (Zentara & Kamykowski 1977, Kamykowski & Zentara 1986) so the primary factor driving P_{opt}^b variability is mixed layer light levels (which increase on average with increasing SST). Accordingly, both the polynomial and exponential functions for P_{opt}^b increase with increasing SST to 20°C. In warmer areas, an increase in SST can correspond to increased nutrient stress (thus a decrease in P_{opt}^b as prescribed in the VGPM polynomial) or increased mixed layer light level (which increase P_{opt}^b as in the exponential function). In the field, both responses are observed (Behrenfeld & Falkowski 1997, Muller-Karger et al. 2004).

For our SeaWiFS record, ΣChl varied inversely with SST for the permanently stratified oceans. These waters had an average SST of 24.6°C. Thus, employing the polynomial P_{opt}^b function augments derived temporal trends in NPP. In contrast, employing the exponential function yields P_{opt}^b changes that on average counter the effects of ΣChl changes, thus dampening NPP trends. These effects are illustrated in the left and middle panels of Supplemental Figure 2a,b above. The two left-hand panels show NPP trends based on the polynomial P_{opt}^b function, while the two middle panels show the same trends for NPP calculated using the exponential P_{opt}^b function. As anticipated, trend slopes for the exponential model are slightly less than the polynomial model, but the same overall pattern is observed and all trends are highly significant ($p < 0.0001$).

To further test the sensitivity of our results to choice of NPP model, we reanalyzed the SeaWiFS data set using the Carbon-based Production Model (CbPM) (Behrenfeld et al. 2005). Unlike the chlorophyll-based models described above, the CbPM does not use SST to characterize physiological variability. Instead, this model derives phytoplankton growth rates directly from satellite-based carbon-to-chlorophyll ratios. The CbPM requires information on both particulate light scattering properties and chlorophyll concentrations. These products are provided by the Garver-Siegel-Maritorena (GSM) semi-analytical algorithm (Garver & Siegel 1997, Maritorena et al. 2002). Despite being based on a different remote sensing algorithm than the VGPM variants described above, the CbPM still yields the same two overall temporal NPP trends (right panels in Fig. 2a,b above).

Comparison with Previous Studies: Earlier analyses of temporal trends in sea surface chlorophyll concentrations have been made for shorter periods of the SeaWiFS record. McClain et al. (2004) investigated changes in sea surface chlorophyll in the subtropical gyres of the Atlantic, Pacific, and Indian oceans and reported a general increase in the areal extent of oligotrophic waters with chlorophyll concentrations $\leq 0.07 \text{ mg m}^{-3}$, with the greatest expansions in the North Pacific and North Atlantic gyres. Similarly, Gregg et al. (2005) reported decreasing trends in surface chlorophyll for the 5 central ocean gyres between 1998 and 2003, but an overall 4.1% global increase in chlorophyll for the period. This discrepancy with our results is due to Gregg et al. (2005) executing a single regression analysis on all data (i.e., combining 1997-98 El Niño data with later observations), rather than separating the El Niño to La Niña increase in chlorophyll from the post-1999 decrease. In agreement with our results, Gregg et al. (2005) also reported an increase in average central gyre temperature between 1998 and 2003.

Two additional analyses have attempted to extend the ocean color record by comparing CZCS and SeaWiFS data. Gregg and Conkright (2002) blended satellite and *in situ* chlorophyll data to overcome shortcomings of CZCS data and reported a global decrease in Chl_{sat} of 6% between CZCS and SeaWiFS. In contrast, Antoine et al. (2005) recreated a 'CZCS-like' data set from SeaWiFS (shortcomings and all) and reported a 22% increase in global surface chlorophyll for the same period. Despite tremendous efforts by both groups, it is unlikely that uncertainties in the CZCS record will ever be sufficiently overcome to allow its inclusion as a climate-quality data set.

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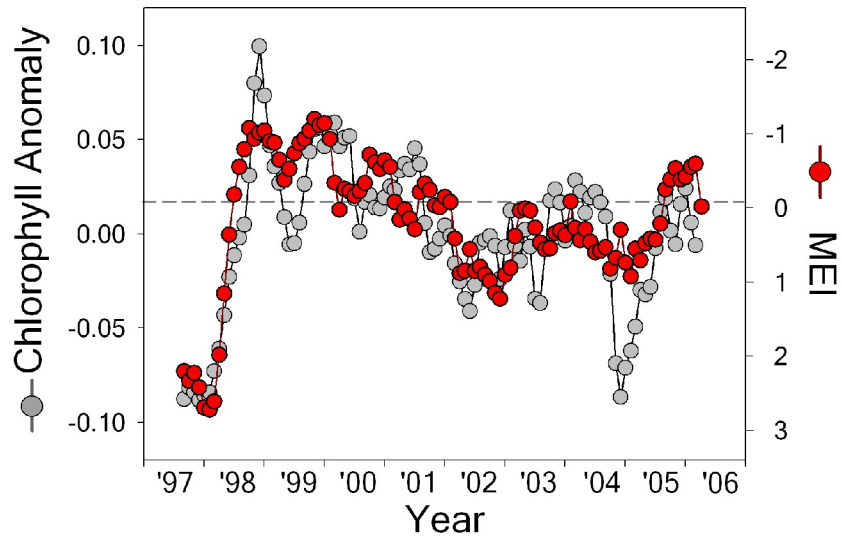


Figure 3. Comparison of the Multivariate ENSO Index (MEI) (red symbols, right axis) (Note negative values at top and positive at bottom) and SeaWiFS monthly anomalies (Tg) in water-column integrated chlorophyll concentrations (gray symbols, left axis) for ocean areas with annual average SST > 15°C. Chlorophyll data are from figure 1b in the manuscript. MEI data are from figure 2a in the manuscript.

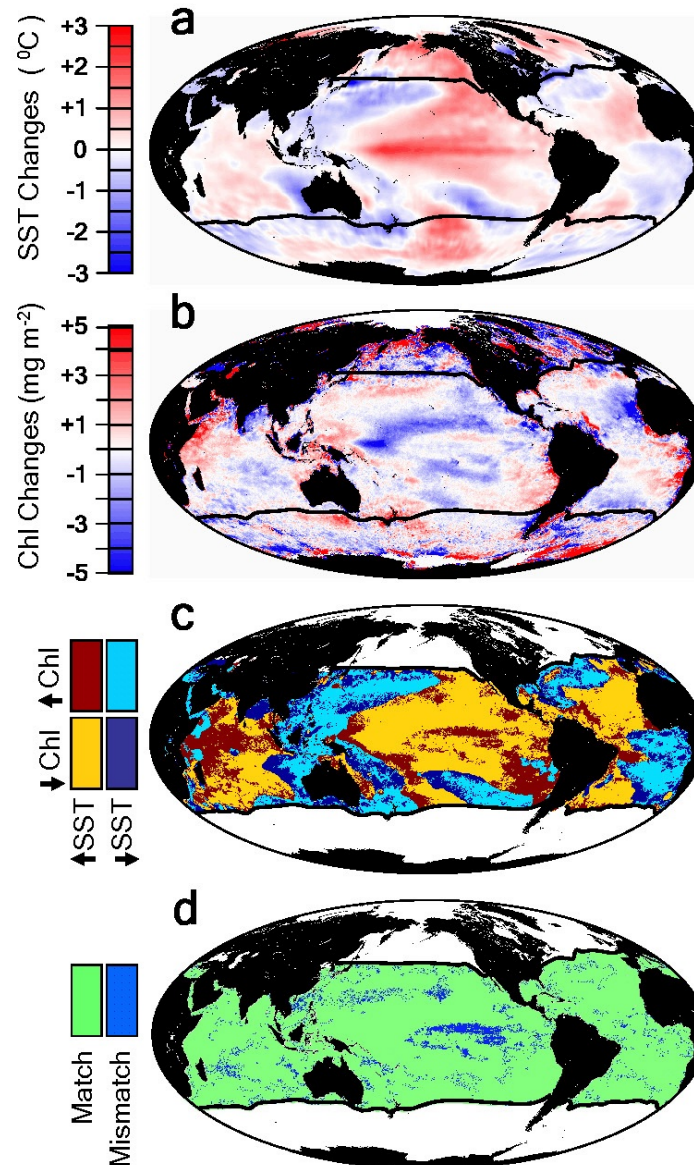


Figure 4. Relationships between 1999 to 2004 changes in (a) SST and (b) water-column integrated chlorophyll concentration (ΣChl). SST anomalies are from figure 3A in the manuscript. (c) As in figure 3c of the manuscript, changes in ΣChl are inversely related to SST changes in ocean areas with annual SST $> 15^\circ\text{C}$. Gold and light blue areas indicate an inverse relationship between ΣChl and SST changes, while dark blue and dark red areas indicate a positive correlation between ΣChl and SST changes. Warm and cool colored regions correspond to areas with increased and decreased SST, respectively. This color scheme gives sharp transition lines because SST changes for the 1999 to 2004 period (panel a) exhibited distinct boundaries. (d) Comparison of figure 3c of the manuscript with panel c above. Green areas (92% of the pixels) indicate where NPP and chlorophyll changes are in the same direction. Blue areas (8% of pixels) are where NPP

and chlorophyll changes differ. One interesting feature in (d) is the cluster of blue pixels in the equatorial Pacific ocean. In this area, ΣChl increased between 1999 and 2004 despite an increase in SST. The reason for this counterintuitive feature is not fully understood, but may reflect responses in species composition and/or grazing pressure.