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Modeling the effects of physical and biogeochemical processes on phytoplankton species and carbon production in the equatorial Pacific Ocean

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The primary objective of this research is to investigate phytoplankton community response to variations in physical forcing and biological processes in the Cold Tongue region of the equatorial Pacific Ocean at 0˚N, 140˚W. This research objective was addressed using a one-dimensional multi-component lower trophic level ecosystem model that includes detailed algal physiology, such as spectrally-dependent photosynthetic processes and iron limitation on algal growth. The ecosystem model is forced by a one-year (1992) time series of spectrally-dependent light, temperature, and water column mixing obtained from a Tropical Atmosphere-Ocean (TAO) Array mooring.

Autotrophic growth is represented by five algal groups, which have light and nutrient utilization characteristics of low-light adapted *Prochlorococcus*, high-light adapted *Prochlorococcus*, *Synechococcus*, Autotrophic eukaryotes, and large diatoms. The simulated distributions and rates are validated using observations from the 1992 U.S. Joint Global Ocean Flux Study Equatorial Pacific cruises. The model-data comparisons show that the simulations successfully reproduce the temporal distribution of each algal group and that multiple algal groups are needed to fully resolve the variations observed for phytoplankton communities in the equatorial Pacific.

The 1992 simulations show seasonal variations in algal species composition superimposed on which are shorter time scale variations (e.g., 8-20 days) that arise from the changes in the upwelling/downwelling environmental structure. The simulated time evolution of the algal groups shows that eukaryotes are the most abundant group, being responsible for half of the annual biomass and 69% of the primary production and export. Filtering out low frequency physical forcing results in a 30% increase in primary production and dominance of high-light adapted *Prochlorococcus* and large diatoms. Sensitivity studies show that iron availability is the primary control on carbon export and

production; whereas, algal biomass concentration is largely regulated by zooplankton grazing. Recycled iron is an important component of the ecosystem dynamics because sustained growth of algal groups depends on remineralized iron which accounts for 40% of the annual primary production in the Cold Tongue region.

The effects of El Niño-Southern Oscillation (ENSO) processes

on the lower trophic levels of Cold Tongue region were examined with eight-year simulations for a time, 1991-1999, that included three ENSO cycles. As a comparison, simulations were done for a region in the western Pacific at 165°W at the equator, which is known as the Warm Pool. The simulated response of the lower trophic levels in the two regions of the equatorial Pacific to ENSO cycles differs in community structure and level of production. For the Cold Tongue region, the ENSO warm phase results in a shift to small algal forms (e.g., *Prochlorococcus* spp. and *Synechecoccus*) and low primary productivity (25 mmol C m^{-2} d^{-1} versus an annual average of 75 mmol C m^{-2} d^{-1}). For the Warm Pool region, the phytoplankton community is dominated by larger algal forms (e.g., autotrophic eukaryotes) and primary production increases (150 mmol C m^{-2} d^{-1} versus an annual

average of 59 mmol C m^{-2} d^{-1}). Also, during ENSO events carbon production and export in the Cold Tongue are limited by iron, whereas relative abundance of iron and macro-nutrients (i.e. nitrate, silicate) limits production and export in the Warm Pool.

The results from this modeling study suggest that for conditions of increased stratification and temperature, carbon export in the Cold Tongue region would increase and the phytoplankton community would shift towards smaller algal forms (e.g., *Prochlorococcus* spp. and *Synechecoccus*). Moreover, increased stratification can result in decreased iron concentrations and reduced vertical velocities, both of which would result in decreased carbon export. Also, stratified conditions enhance the remineralization rate of nutrients (e.g., iron) which enhances carbon production and export. Thus, inclusion of iron dynamics in climate models may be needed to fully represent the effect of climate variability on equatorial Pacific ecosystems.