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# INTERANNUAL VARIABILITY IN THE EASTERN PACIFIC WARM POOL THROUGH HIGH RESOLUTION SATELLITE OBSERVATIONS

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## 1. INTRODUCTION

The eastern Pacific warm pool (EPWP) is a body of water adjacent to the west coast of Mexico and Central America with sea surface temperature (SST) upward of 28.5°C. The spatial variability, seasonal cycle, and interannual variability of the EPWP are only beginning to be defined within the context of a coupled system involving the ocean, atmosphere and land. Numerous prior studies explicitly state that further understanding of the interannual variability of precipitation in the Inter-Americas region depends on an improved understanding of what controls the SST variability in the EPWP. However, the role of the EPWP and its interactions with the atmosphere and land in ocean biology and the hydroclimate of the Inter-Americas is largely excluded from present research programs.

Infrared satellite measurements of SST and precipitation have been made for multiple decades and provide a suitable record for studying the interannual variability of the EPWP. More recently, the advent of high resolution microwave satellite remote sensing, altimetry, and scatterometry provide a means to understand the spatial structure and covariability of SST, sea level, ocean color, surface winds, precipitation, land surface temperature in detail never before possible.

The general theme of interest is understanding what governs the interannual variability of SST in the eastern Pacific warm pool. To understand the interannual variability of the warm pool requires a basic understanding of the mean spatial structure and seasonal cycle of SST, winds, currents, as well as important meteorological and biological aspects of the region such as precipitation and chlorophyll-*a* concentration upon which interannual variability acts.

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## 2. SEASONAL VARIABILITY

In terms of SST, the EPWP has a well-defined seasonality ranging from a broken structure in the winter as a result of strong gap winds flowing through the Cordillera, to a spring and summertime when the EPWP is very large and warm. In the fall, the warmest SSTs are oriented coastwise along Central America and Mexico. During all seasons, the Costa Rica Dome is present near 9°N,90°W as a result of strong wind-curl induced upwelling. In addition to the Costa Rica Dome as a robust feature of the EPWP, the EPWP appears to consist of three subregions: a large, warm portion to the northwest of the Costa Rica Dome (EPWP-NW), the cool Costa Rica Dome itself, and a smaller warm section to the southeast of the Dome (EPWP-SE).

In contrast to SST, the total surface chlorophyll-*a* concentration in the EPWP does not exhibit a strong seasonality. However, it is interesting to note that at different times of the year, different processes are responsible for maintaining the chlorophyll field. During the fall and winter months, the gap winds originating over Tehuantepec and Papagayo mix up the nutrients sufficiently to produce a strong chlorophyll signal, while in the summer the upwelling in the Costa Rica Dome and coastal upwelling are enough to produce strong summertime chlorophyll signals. It should also be noted that around February of nearly every year, a patch of chlorophyll is observed to break off from the EPWP at around 12°N and co-propagate with the westward Rossby waves.

The monsoon system of Central America, Mexico, and the southwest US is related to the seasonality of the regional winds as well as the warm SSTs of the EPWP. This is evident in a strong northward moisture surge that propagates along the coast of Central America into Mexico and beyond, carrying with it moist air from the EPWP and producing abundant precipitation over the land.

## 3. INTERANNUAL VARIABILITY

### 3.1 *Sea Surface Temperature*

Given the strong relationships between SST and regional (and often global) hydrological and biological considerations, an appropriate objective would be to model the tropical Pacific with interannually varying momentum, energy, and freshwater forcing to understand those process, both oceanographic, atmospheric, and interactive, that govern the interannual variability of SST in the EPWP. While preparations for a series of OGCM simulations are being made, a thorough analysis of SST anomalies and modes of variability of SST and many other variables was performed. The standard deviation of interannual anomalies (Fig. 1) shows clearly that there is a great deal of interesting variability in the SSTs of the EPWP.

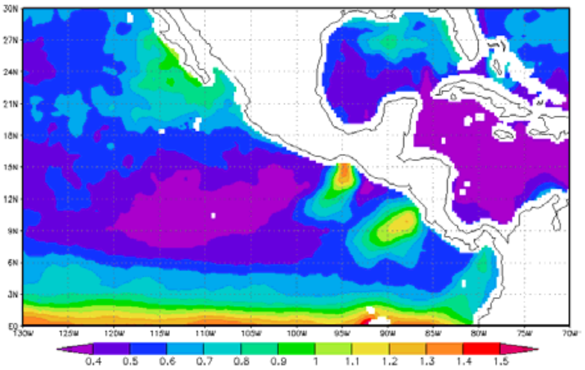

**Figure 1.** Standard deviation of SST in the north eastern tropical Pacific ocean. Based on TMI SST, 1998-2005.

Part of that variability is clearly related to the gap winds and the Costa Rica Dome. Other processes including ENSO are at also at work. All of these processes will also be closely tied to those of interest to surface chlorophyll-*a* concentration.

A series of SSTA indices, targeting the EPWP as a whole and its constituent subregions, were constructed to characterize the scales of the anomalies, the extent to which ENSO dominates the variability, as well as determine how distinct the subregions really are (Fig. 2).

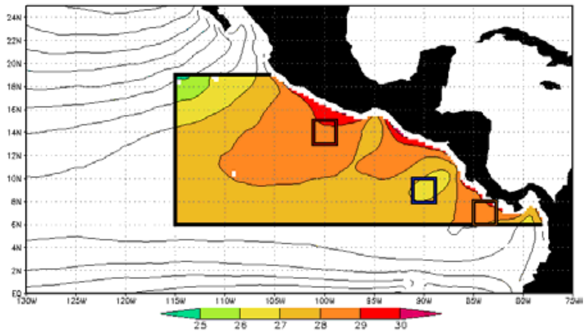

**Figure 2.** Schematic of SST indices used in the present study, overlaid upon the long-term annual mean SST field, based on TMI SST, 1998-2005.

It turns out that all of these indices are quite well behaved (Gaussian), and are useful for making some first guesses as to what processes govern the temporal variability. When compared with NINO3, the EPWP-SE subregion and the Costa Rica Dome track closely, however delayed according to their respective distances from the equator (Fig. 3).

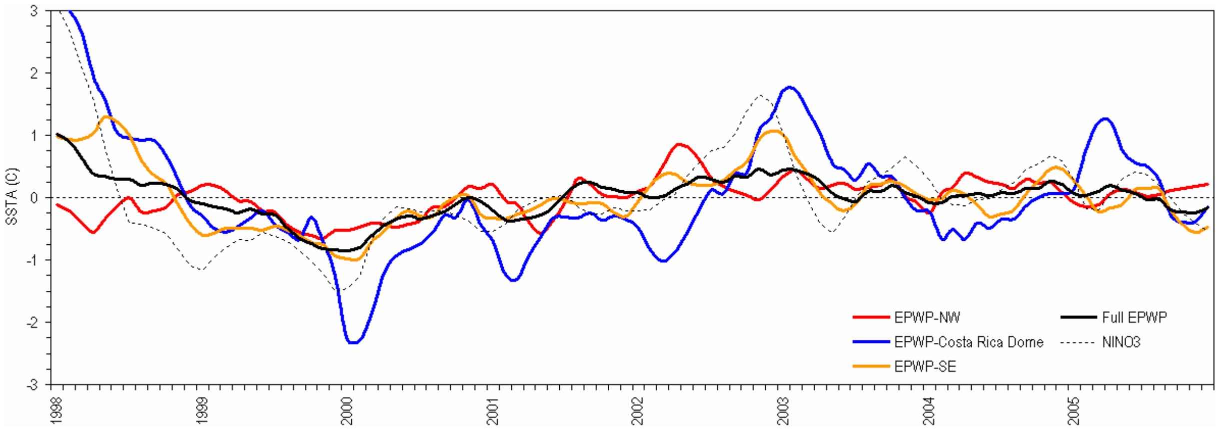


**Figure 3.** Time series of 3-month centered moving average SST anomalies for the EPWP (black) and its subregions (colors), as well as NINO3 (dashed). TMI SST, 1998-2005.

Given the very shallow thermocline of the Costa Rica Dome, that is where anomalies of the greatest magnitude occur. Although by the mean spatial structure and seasonal cycle, the EPWP-NW appears fundamentally similar to- and the largest part of a rather uniform EPWP, it is nearly unaffected by ENSO's direct influences (control over the thermocline and advection via Kelvin/Rossby wave reflection).

Directly relating SST anomalies with precipitation anomalies yields very poor linear correlations. However, SST operating through the land-sea temperature contrast that is thought to be important in this (and any) monsoon circulation is being investigated. During wet anomalies over the moisture-surge region of Central America and Mexico, low-level wind and moisture flux convergence anomalies reveal anomalous westerly flow over the EPWP, with the opposite being the case for dry anomalies (Fig. 4).

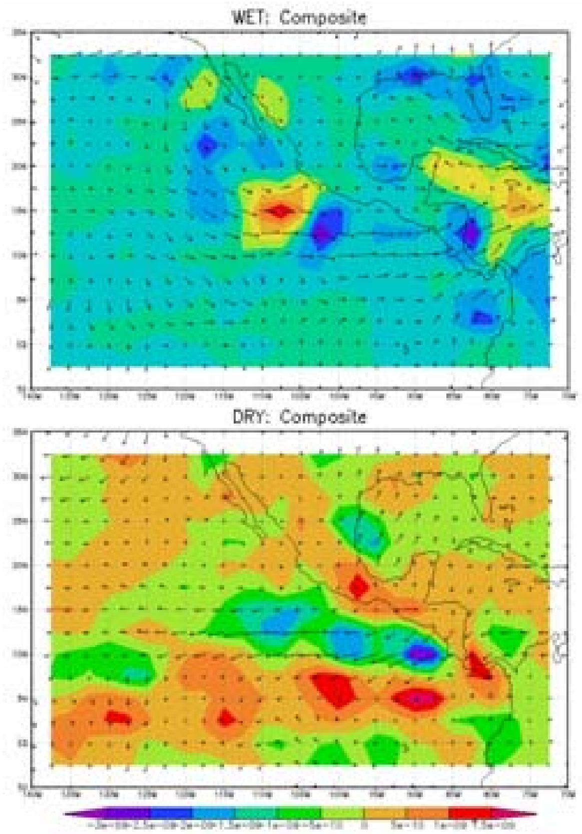


**Figure 4.** Composite 925 hPa wind and moisture flux convergence anomalies for wet and dry events over Central America and southern Mexico. Based on ERA-40 data.

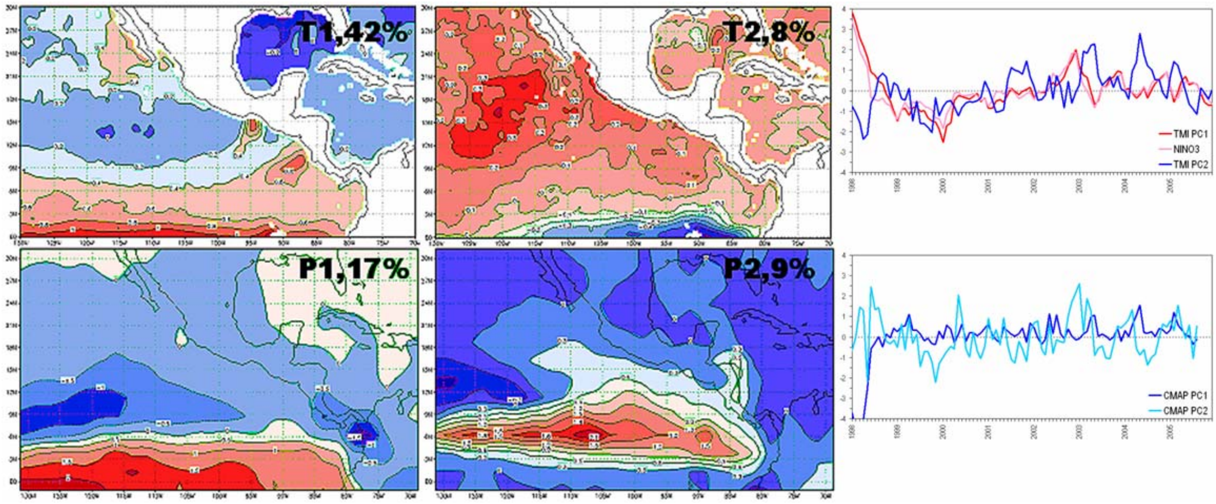


**Figure 5.** First two EOFs and PCs of SST and precipitation in the north eastern tropical Pacific region. Based on TMI SST and CMAP precipitation, 1998-2005.

The first principal component of SST in the north eastern tropical Pacific ocean (NETP) is of course ENSO. This is correlated 0.64 with the first principal component of precipitation and 0.36 with the second principal component of precipitation. The second principal component of SST in the NETP is correlated 0.51 with the first principal component of precipitation, the spatial EOF of which appears to resemble the moisture surge in the spatial pattern of the monsoon circulation (e.g. compare to July precip field). Although the second EOF of SST only accounts for at most a quarter of the variance of SSTA that ENSO does, it is a potentially important piece of what causes interannual variability in the monsoon circulation.

### 3.2 *Surface Chlorophyll-*a *Concentration*

Chlorophyll-*a* concentration as measured from space is related to the amount of phytoplankton present in the surface ocean and, as such, is an indicator of marine bioproductivity. Interannual variability of phytoplankton biomass is of vital importance in the global carbon cycle because such bioproductivity effectively removes $CO_2$ from the atmosphere through photosynthesis. Because of the strong influence that gap winds and Costa Rica Dome upwelling have on chlorophyll, the spatial pattern of high interannual standard deviation of surface chlorophyll-*a* concentration reveals a well-defined region of high variability collocated with the EPWP (Fig. 6).

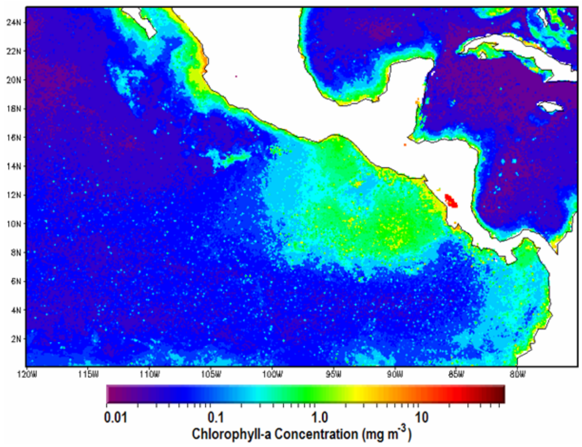


**Figure 6.** Standard deviation of surface chlorophyll-*a* concentration in the north eastern tropical Pacific ocean. Based on SeaWiFS, 1998-2005.

There is a strong negative linear correlation between monthly anomalies SST in the Costa Rica Dome and surface chlorophyll-*a* concentration in the EPWP region (-0.8). What can also be seen in the scatter diagrams (Fig. 7) is the fact that when chlorophyll concentrations become high, the relationship between the two reverses from negative to positive.

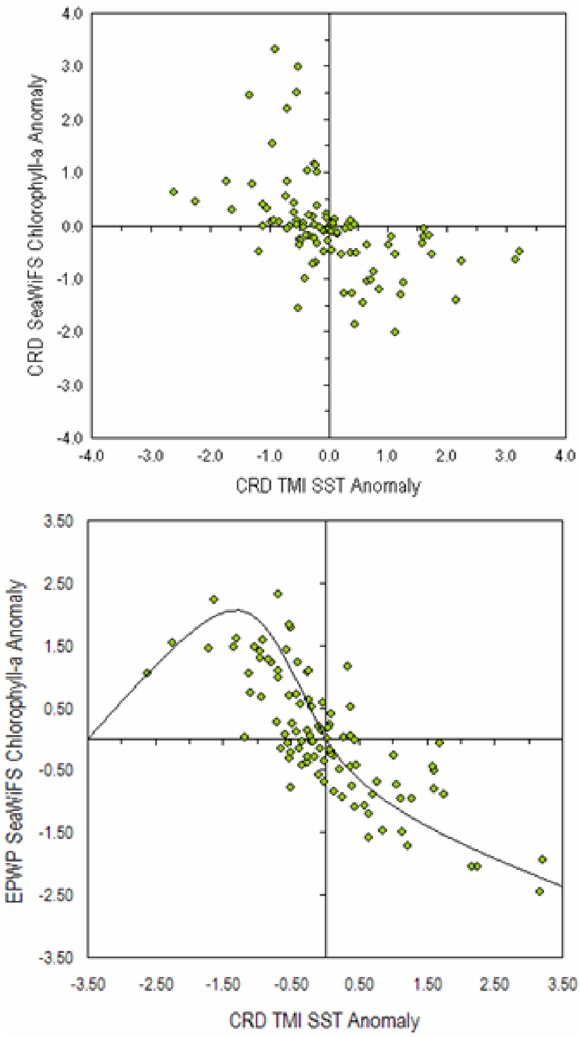


**Figure 7.** Scatter diagrams of standardized Costa Rica Dome surface chlorophyll-*a* anomaly and Costa Rica Dome SST anomaly (top), and EPWP surface chlorophyll-*a* anomaly and Costa Rica Dome SST anomaly (bottom). Based on TMI SST and SeaWiFS, 1998-2005.

This is purely satellite-based evidence of the chlorophyll feedback. Through attenuation, surface chlorophyll affects mixed layer warming by allowing less shortwave radiation to penetrate through the mixed layer. Most OGCMs do not account for this negative feedback of chlorophyll on SSTA. Thus, prior to any modeling attempt, it is important to understand this feedback in a regional and somewhat quantitative sense.

The first two EOFs and principal components of surface chlorophyll are also shown, and both are correlated with SST anomalies in the Costa Rica Dome and EPWP-SE subregion (from 0.42 to 0.69), but not with EPWP-NW SSTA. The spatial EOFs suggest that gap wind variability, upwelling in the Costa Rica Dome, and coastal processes (possibly coastal Kelvin wave propagation) are of first order importance, with the Costa Rica Dome dominating the second leading mode. Some of the chlorophyll interannual variability in the EPWP will ultimately be related to ENSO-driven mixed layer depth variations, but relative contributions of gap winds, wind curl-related upwelling in the Costa Rica Dome, and coastal processes have yet to be determined.

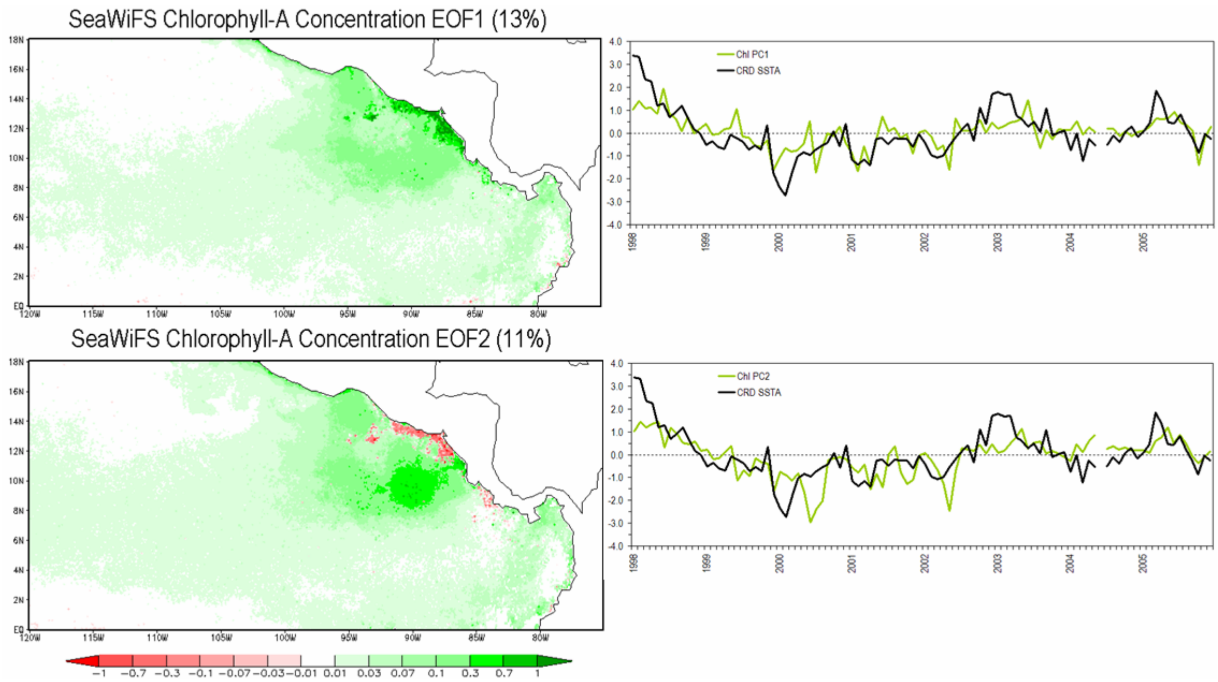


**Figure 8.** First two EOFs and PCs of surface chlorophyll-*a* concentration in the north eastern tropical Pacific Ocean. Based on SeaWiFS, 1998-2005.

## 4. ONGOING WORK

Current and future work is directed at addressing the key issue: explaining the observed interannual variability with a series of OGCM experiments isolating the effects of momentum, energy, and freshwater fluxes. In light of the importance of the regional and gap winds, only high resolution wind products will be used. Finally, the question of how this variability influences the climate of the Inter-Americas region and beyond will be returned to with sensitivity experiments of precipitation in a regional atmospheric model (Eta) and further analyses of the role of the EPWP as a heating center in the global atmospheric circulation.