Detection of the eastern edge of the western Pacific warm pool

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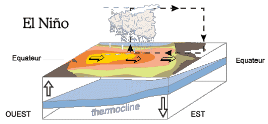
Abstract :The processes controlling the warm sea surface temperatures (SSTs) permanently found in the western equatorial Pacific and known as the warm pool, are central to defining climate and determining the character of large scale and deep atmospheric convection. Detection of very high SST (around 30°C) within the warm pool is associated with the strong intraseasonal variability of hot events. Zonal migrations of the warm pool are also important for the onset of the El Niño Southern Oscillation (ENSO) phenomenon. The separation between the cold tongue in the eastern-central equatorial Pacific and the warm pool relies at the heart of a recent revised delayed oscillator theory of ENSO. The variability of the eastern edge of the warm pool is thus crucial to understand and to monitor within the context of seasonal-to-interannual climate variations. However, the eastern edge of the warm pool along the equator could not be properly defined by a front in SST but have distinct hydrological features and ecosystem dynamics. This feature will be exploited in order to demonstrate how satellite-based ocean color observations are useful to detect the eastern edge of the equatorial Pacific warm pool.

The analysis of satellite-based ocean color data shows that low concentrations of surface chlorophyll-a (chl-a) found in the equatorial region of the Pacific Ocean varies in phase with the eastern edge of the warm pool. As is true for high sea surface temperatures, the existence and maintenance of these low concentrations are linked to the upper ocean stratification due to salinity. The present study also establishes the quasi permanence of a frontal zone in chlorophyll-a separating the regimes of the western region and the eastern-central cold tongue and, through the identification of this front in satellite-based ocean color data, it provides, for the first time, a reliable method for locating the eastern edge of the warm pool from surface observations only. Finally, the recognition of this front offers the opportunity to define a simple and robust index of the horizontal extension of the equatorial Pacific warm pool within the context of the ENSO variability.

Introduction



The processes controlling the warm sea surface temperatures (SSTs) permanently found in the western equatorial Pacific and known as the warm pool (Wyrtki, 1989), are central to defining climate and determining the character of large scale and deep atmospheric convection. Detection of very high SST (around 30°C) within the warm pool is associated with the strong intraseasonal variability of hot events (Qin *et al.,* 2007). Zonal displacement of the warm pool is also important for the onset of the El Niño Southern Oscillation (ENSO) phenomenon (Picaut *et al.,* 1996; Ando and Hasegawa 2009). The separation between the cold tongue in the eastern-central equatorial Pacific and the warm pool relies at the heart of the revised delayed oscillator theory of ENSO proposed by Picaut *et al.* (1997). The variability of the eastern edge of the warm pool is thus crucial to understand and to monitor within the context of seasonal-to-interannual climate variations. However, the eastern edge of the warm pool along the equator is not properly defined by a front in SST but has distinct hydrological features and ecosystem dynamics (Le Borgne *et al.* 2002). In this study, we document the possibility of using satellite-based observations of chlorophyll-a (chl-*a*) to detect the eastern edge of the warm pool in the equatorial Pacific Ocean.

Comparisons between satellite-based ocean color with in situ observations

We begin with a comparison of satellite-based and in situ observations collected during three different oceanographic cruises staged from the IRD center along the equator as a part of the FRONTALIS project. The main objective of this program was to find and to sample the eastern edge of the warm pool in April 2001, April 2004 and April-May 2005 (Figure 1). During the cruises, chlorophyll-a samples were pressure filtered through Whatman GF/F filters and stored in liquid nitrogen and, upon return to Nouméa, analyzed by fluorometry after methanol extraction. The vertical sections of in situ chl-a along the equator are shown on the Figure 2 as well as the surface observations vs. the composites of SeaWiFS and MODIS/Aqua data measured during the same week. The red crosses indicate the position of the main thermocline whereas the white lines delineate the region where the static stratification is dominated by the salinity following the methodology of Maes (2008).

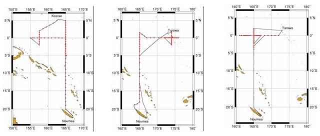
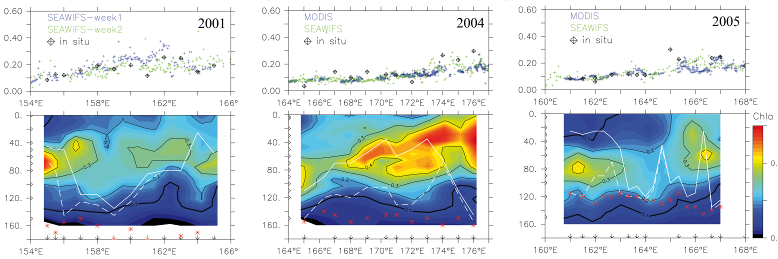


FIGURE 1: Trajectories and stations of the three cruises staged by the FRONTALIS project.

FIGURE 2: Surface distributions and vertical sections of the chl-a observed during the three cruises of FRONTALIS (2001, 2004 and 2005) along the equator. In the top, the weekly composite from satellite-based ocean color are superimposed.



Along the entire equatorial section the agreement is quite good, although the strongest observed values, eastward of the eastward front of the warm pool, are slightly underestimated by the satellite-based products. In agreement with other physical and biogeochemical parameters, the chl-*a* observations reinforce the determination of the position in longitude of the eastward front of the warm pool along the equator.

The consistency between the salinity stratification at depth and chlorophyll values at the surface suggests that a similar process is at work to maintain low values of chl-*a* and high SSTs in the warm pool surface. In the western part of the section, the chl-*a* profiles exhibit a deep maximum between 60 and 100 m depth, a region that is clearly inside the warm pool and dominated by the salinity stratification (similar as the one depicted by the so-called barrier layer). We try to exploit this remarkable feature.

Linking the eastern edge of the Warm Pool with the ocean color variability

Hereafter, we used the computation of the salinity stratification from the temperature and salinity profiles observed by the ARGO floats during the period 2002−2004 (Maes *et al.,* 2006). These values are then associated with the satellite-based chl-*a* concentration values through application of a daily median filter to data within a 30 km radius of each ARGO profile. The scatter diagrams for the different pairs of chl-a and SSS, SST and the salinity stratification, are displayed on Figure 3. As expected, the scatter is large for the warm SSTs, but more surprisingly, the relationship with the SSS is not clear. In contrast, the larger values of chl-*a* are generally associated with low salinity stratification and as stratification increases the chlorophyll concentration decreases. For chl-*a* concentrations below about 0.1 mg m^{-3} the salinity stratification is always non-zero and the scatter is large. This latter point indicates that the salinity stratification is not the only one process acting on the variability of chl-*a*.

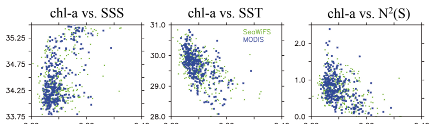
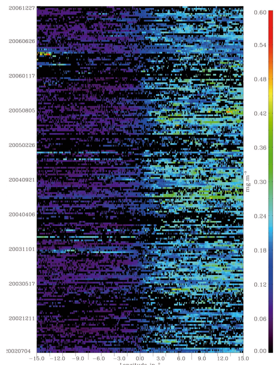


FIGURE 3: Scatter diagrams between chl-a (x-axis) and SSS, SST, and the salinity stratification, respectively.

FIGURE 4 ► Timeseries of the chl-a data as referred from the 0.1 mg m^{-3} value (the missing values are displayed in black)



We were able to locate a significant transition point in the chl-*a* concentration by searching east to west for the longitude where the satellite-derived chl-*a* concentration first falls below 0.1 mg m^{-3}. The timeseries of the SeaWiFS data for longitudes extending from 15° west to 15° east of the transition point is shown on the Figure 4.

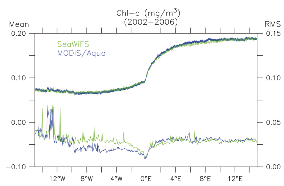
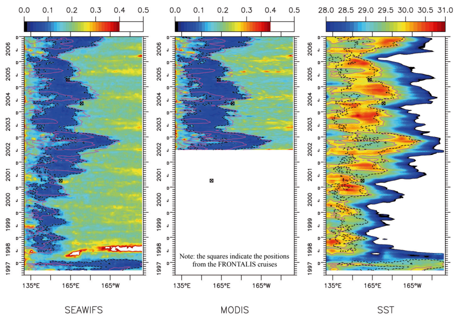


FIGURE 5: Time averages (left axis, upper lines) and standard deviations (right axis, lower lines) of chl-*a* concentrations for locations within 15° east and west of the 0.1 mg m^{-3} value (central line)

Westward of the transition point, the chl-*a* concentration is nearly constant and remains below 0.1 mg m^{-3} (Figure 5). Eastward of the transition point, the concentration increases abruptly over 5−6 degrees to approach a constant value just below 0.2 mg m−3. These characteristics of the SeaWiFS and MODIS/Aqua curves on either sides of the central position suggest that this transition point consistently represents a frontal region that separates the oligotrophic and mesotrophic regimes of the western Pacific warm pool.

Relationships with the warm SSTs and climate variability



The ability to locate accurately the eastern edge of the warm pool provides a tool to monitor the progress of ENSO events. The timeseries of the chl-a products from SeaWiFS and MODIS as well as the SST warmer than 28°C are shown on the Figure 6. Note that the detection of the chl-*a* transition point is always possible and it is always found within waters warmer than 28°C. During the period of time shown, the chl-*a* transition point may be as much as 20° of longitude farther west than the 28°C isotherm.

With respect to temporal variability, Figure 7 and Table 1 show that the position of the chl-*a* transition point varies in phase with the SST anomalies in the NINO3.4 box and with the Southern Oscillation Index (SOI). The correlations using the chl-*a* data are similar to those using the 28°C isotherm, giving us further confidence in our use of the satellite-based chl-*a* data for monitoring the eastern edge of the warm pool.

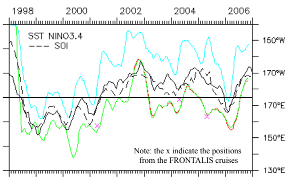
◄ FIGURE 6: Timeseries of the chl-a data from SeaWiFS and MODIS/Aqua as well as SSTs warmer than 28°C. The dash line on the SSTs is the 0.1 mg m^{-3} value from SeaWiFS.

FIGURE 7: Timeseries of the SOI and NINO3.4 ► index (black) superimposed with the time evolution of the eastern edge of the warm pool detected by the chl-a data (in green) and by the 28°C isotherm (in cyan).

Table 1. Correlation coefficients between the monthly position of the eastern edge of the warm pool as detected by the chl-a front or the 28°C isotherm, and the NINO3.4 SST anomalies (upper) and SOI (lower) for the two different satellite periods. Note that, for the same periods, the correlation coefficients between the NINO3.4 SST and SOI are equal to −0.73 and −0.92, respectively. The SOI and NINO3.4 SST data are provided by the NOAA Climate Prediction Center.

	28°C	MODIS/Aqua	SeaWiFS
08/2002−10/2006	0.83 −0.77	0.90 −0.64	0.90 −0.62
10/1997−10/2006	0.90 −0.92	no data available	0.88 −0.85

(from Maes et al., 2010)



Reference relative to this poster : Maes C., Sudre J., Garçon V., 2010: Detection of the eastern edge of the equatorial Pacific warm pool using satellite-based ocean color observations. *SOLA*, 6, 129-132, *doi:10.2151/sola.2010-033*.