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 migration of the warm pool is 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 relaxes 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 face distinct hydrological features and ecosystem dynamics. This feature will be exploited in order to demonstrate how satellite-based ocean color observations can be used 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 such for high sea surface temperatures, the existence and maintenance of these low concentrations are linked to the upper ocean stratification due to salinity variability. The present study also establishes the quasi-permanent of a frontal zone in chlorophyll-a separating the regimes of the western region and the eastern-controlled 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.

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 by 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. The analysis of in situ data was performed in April 2001, April 2004 and April-May 2005 (figure 1). During the cruises, chlorophyll-a samples were preserved filtered through Whatman GF/F filters and stored in liquid nitrogen and, upon return to Nouméa, analyzed fluorometrically 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 composite of SeaWiFS and MODIS/Aqua data measured during the same week. The red crosses indicate the position of the main thermocline whereas the white line delimitates the region where the strong stratification is dominated by the salinity following the methodology of Maes (2000).

Along the entire equatorial section the agreement is quite good, although the strongest observed values, eastward of the eastern 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 eastern edge of the warm pool along the equator.

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

Figure 3 presents scatter diagrams between chlorophyll-a and sea surface salinity (SSS) at the three locations of the eastern edge of the warm pool (129°W, 131°W, 150°E) as well as the satellite-derived chl-a concentration values. The scatter diagrams for the different pairs of chl-a and SSS, SST and the salinity stratification are illustrated on Figure 3, with the sea surface salinity values. The scatter diagrams indicate that the scale is larger for the SSS, but more surprisingly, the relationship with the SST 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 process acting on the variability of chl-a.

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 timings 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 temperature 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 NINONG 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.