Using PROVOR floats to assess the link between ENSO and the salinity variability in the Western Pacific warm pool

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Introduction

The distribution of salt in the global ocean and its variability on different time scales are of great importance in understanding the ocean's role in the Earth's climate. Notable in this regard are salinity changes in the western tropical Pacific, which influence air-sea interactions involved in the El Niño Southern Oscillation (ENSO) phenomenon. This region, usually referred to as the warm pool, is characterized in permanence by the warmest water in the World Ocean, with sea surface temperature (SST) warmer than 28°-29°C over an area larger than the western Europe, and with relatively low sea surface salinity (SSS) fresher than 35 (Figure 1). Because of the high mean SSTs in this region, model results indicate that small SST anomalies, O(0.5 to 1°C), result in significant changes in the ocean-atmosphere coupling of relevance to ENSO and extra-tropical weather anomalies (Palmer and Mansfield, 1984; Hoerling and Kumar, 2003).

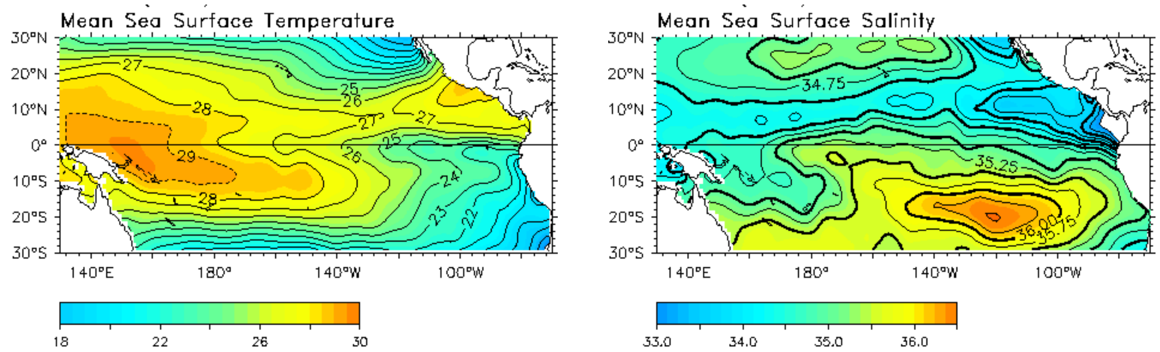

Figure 1

Mean sea surface (left) temperature and (right) salinity in the tropical Pacific

The eastern edge of the warm pool is most often characterized by a zonal sea SSS front which results from the convergence of low- and high-salinity water masses advected from the western and central Pacific, respectively (Picaut et al., 1996). The position of this front is subject to large eastward and westward displacements of as much as 8000 km in synchrony with El Niño and La Niña event (Delcroix and Picaut, 1998). Aside from the existence of a well-marked SSS front in longitude, the warm pool is also characterized by a peculiar thermohaline structure in the vertical. There, the temperature mixed layer (typically extending to about 80 m depth) is not mixed in salinity most of the time, so that the density mixed layer (typically extending to about 50 m depth) is controlled by the salt stratification. The difference between the bottom of the density mixed layer and the bottom of the temperature mixed layer has been called the barrier layer (Lukas and Lindstrom, 1991) and its formation results from different mechanisms that implied surface forcing and complex dynamical responses of the oceanic upper layers (Figure 2).

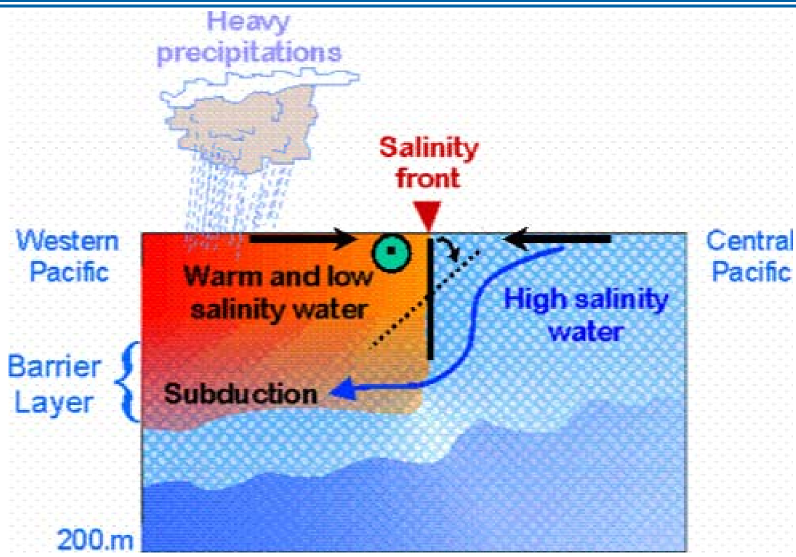

Figure 2

Schematic of the longitude-depth thermohaline structure along the equator and at the eastern edge of the western Pacific warm pool.

In the presence of a relatively thin salinity-controlled mixed layer and barrier layer, the ocean can develop a very energetic response to wind and heat flux forcing (Vialard and Delecluse, 1998). Sensitivity experiments with coupled models indicate that the existence of a barrier layer is crucial for the El Niño development (Maes et al., 2002). Moreover, regional comparisons between dynamic height anomalies computed from temperature and salinity profiles (or altimeter-derived SLA) versus dynamic height anomalies computed from temperature profiles and mean TS curves highlighted differences of the order of 5-10 cm (Delcroix et al., 1987). These differences reflect the contribution of the salinity variability in sea level (Maes et al., 2000). Models assimilating altimeter data and correcting only the temperature field do not account for this contribution. Such an approach may yield to inaccurate initial conditions resulting from the assimilation process (Ji et al., 2000) and potentially affects ENSO prediction (Ballabrera et al., 2002). It is thus crucial to improve our understanding of the actual role of salinity changes in the western Pacific warm pool and to ensure that vertical projections of the sea surface height variability are correctly ensured in terms of both salinity and temperature anomalies.

First results

Due to the relative lack of in situ measurements in the western Pacific warm pool, ten PROVOR floats were deployed along the equator in April 2005 during the FRONTALIS 3 cruise onboard the R/V Alis (Figure 3). For the first time, these drifters provide almost-continuous time series of the thermohaline changes on each side of the zonal salinity front located at the eastern edge of the warm pool. (Note that 10 PROVOR floats were also deployed between 10°S and 20°S along 165°E during the cruise, for scientific objectives which are not discussed here).

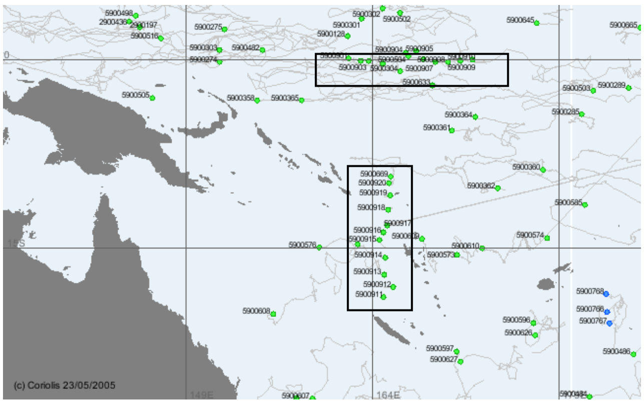

Figure 3

(left) Location on May, 23, 2005, of the 20 PROVOR floats deployed during the FRONTALIS 3 cruise on board the R/V l'Alis. (right) Deployment of one float in the western Pacific warm pool with calm sea conditions (credits IRD).

The returned measurements are presently being analyzed, as one year of data is at least required to derive robust conclusions. Early results were however obtained regarding, at least: a) the quality of the PROVOR sensors and, b) the analysis of temperature and salinity profiles collected prior to the FRONTALIS 3 cruise.

Figure 4 shows the excellent agreement between the temperature and salinity measurements derived from the descent profile of the PROVOR (WMO-ID 5900904) and nearby CTD profile, obtained at 0°-166°E on May, 5, 2005. Similar encouraging results were obtained from the other descent profiles of the floats, as well as when comparing the deepest PROVOR measurements with the 165°E climatology established by Gouriou and Toole (1993). Moreover, Time series of 10-day apart temperature and salinity data on the 27.4 kg.m^{-3} isopycne (located within 950 and 1100 m depth) show a remarkable stability of the sensors for most floats, at least for the first year of data. This is illustrated in Figure 5 for a given PROVOR float (WMO-ID 5900911), with a salinity increase of about 0.05 during the May 2005 – April 2006 period. Such an increase likely reflects a real physical feature which is presently being analyzed.

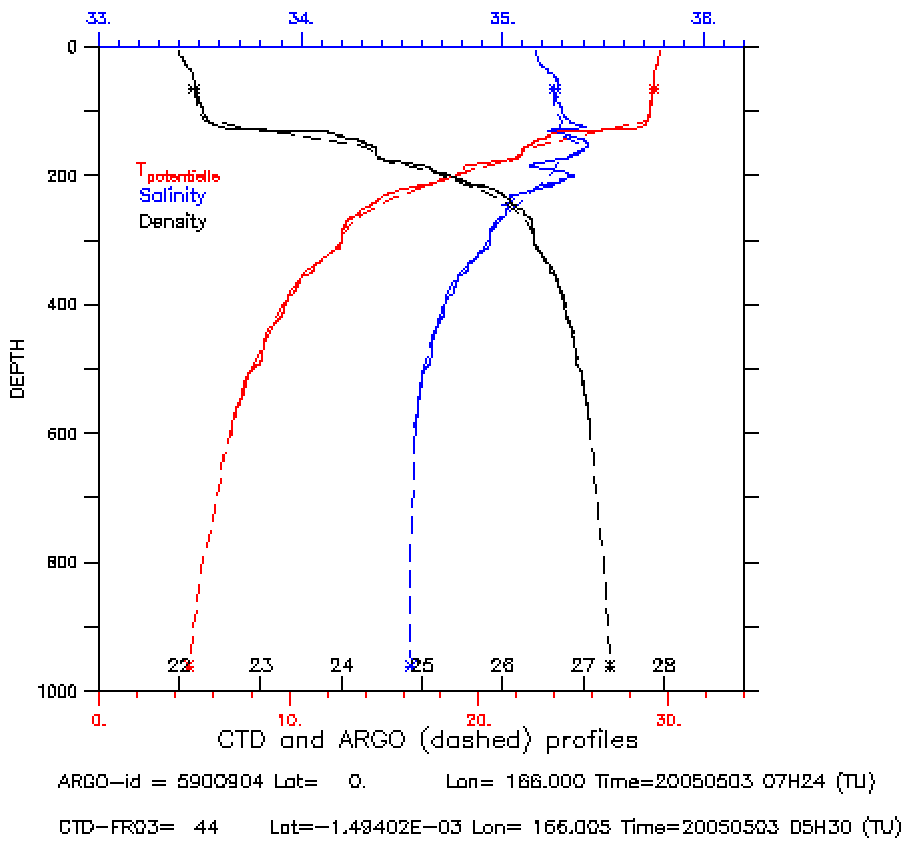

Figure 4

Vertical profiles of (red) potential temperature, (blue) salinity, and (black) potential density derived from the descent profile of the WMO-ID 5900904 PROVOR (full lines) and almost concomitant CTD profile (dashed lines) collected at 0°-166°E on May, 5, 2005.

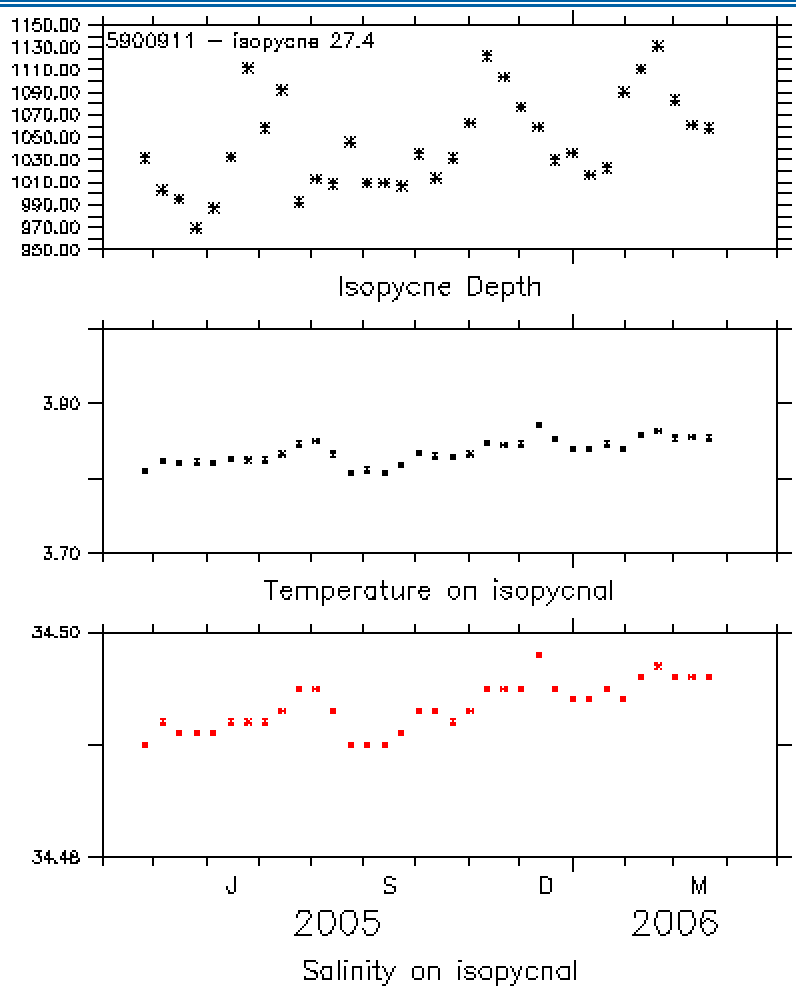

Figure 5

Times series of (top) the depth of 27.4 kg.m^{-3} isopycne, (middle) the temperature and (bottom) the salinity on this isopycne for a PROVOR float (WMO-ID 5900911) deployed by the end of May 2005 along the equator in the western Pacific warm pool.

Figure 6 shows the longitude-time section of SSS and SST changes averaged within 3°N-3°S for the 3-year period preceding the deployment of the PROVOR floats. It reveals that the warmest SST are mainly found near and just west of the SSS salinity front, with values higher than 29.75°C well above the 28°-29°C threshold required for organized atmospheric convection featuring the ENSO ocean-atmosphere coupling. The ongoing analysis of the ten PROVOR-derived measurements, now deployed for one year in the western Pacific warm pool, will provide us the unique opportunity to assess the key role of salinity in this coupling.

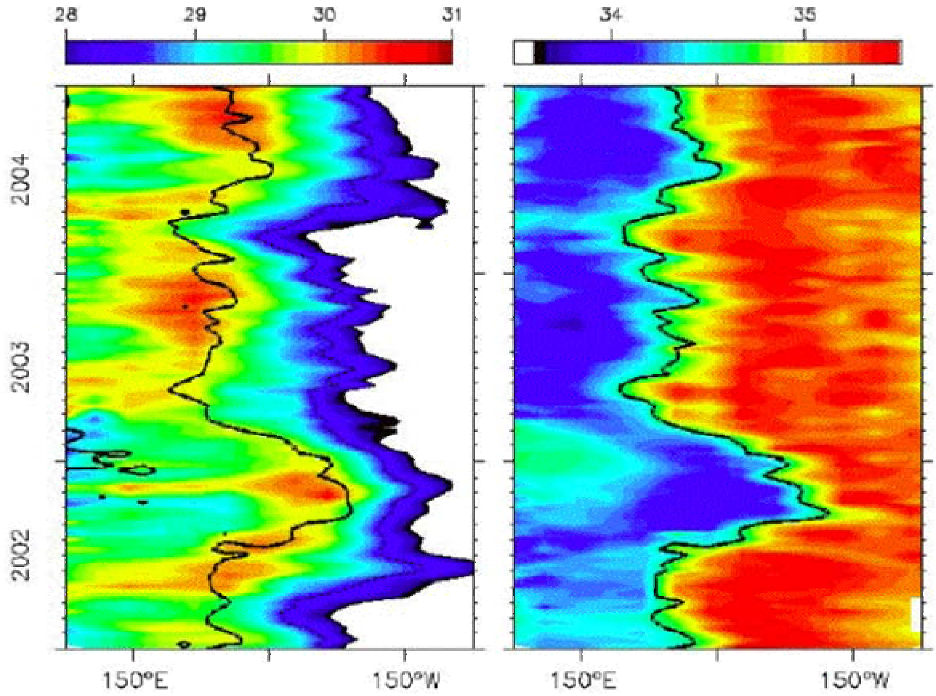

Figure 6

<3°N-3°S> averaged SST (left) and SSS (right) variability in the western Pacific, as obtained from the combined use of TAO/TRITON, TSG and ARGO data (Adapted from Maes et al., 2006).

Acknowledgements

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