# OBSERVED FRESHENING AND WARMING OF THE WESTERN PACIFIC WARM POOL

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## 1. INTRODUCTION

The Warm Pool of the Western Pacific Ocean is characterized by some of the warmest Sea Surface Temperature (SST) of the global ocean, and by Sea Surface Salinity (SSS) lower than 35 pss. Its importance for earth's climate and its relation to El Nino events make it a key region. From the perspective of decadal variability and global warming, this study explores whether the Warm/Fresh Pool size, eastern extend and properties changed in recent decades, during the 1955-2003 period. It also attempts to give explanations for the observed freshening.

## 2. DATA

We used SST data from HadiSST product [1] and compared it to other products to check the robustness of our results. SSS data originate from surface samples, thermosalinographs, TAO/TRITON moorings and research cruises. Data processing are described in [2]. An optimal interpolation gridding method is applied to produce a 1° per 1° monthly product SSS field with associated errors.

## 3. WARMING AND FRESHENING

Firstly, an important and well-known warming is observed in the tropical Pacific Ocean (Fig. 1a). It is worth noting that the warming is robust in the Warm Pool region, whatever the SST product and the time-period is. The mean SST of waters warmer than 28.5°C increased by 0.29°C per 50 years. An important freshening also took place, more striking in the low-salinity regions (Fig. 1b). Warmer waters undergo stronger freshening. Interestingly, increasing SSS trends are observed in high salinity regions, reinforcing the regional SSS contrasts. Superimposed on these linear trends, decadal variations of similar amplitude also occur, with clear different spatial patterns.

As a consequence of these warming and freshening, the Warm/Fresh Pool extended. At the equator, the position of the eastern edge of the Warm Pool, associated to an oceanic convergence zone and a salinity front, is a key parameter for ENSO dynamics. We show that in 50 years, a clear eastward shift of this edge of 17°+-3° is visible (Fig. 1c,d). This shift is however strongly modulated by decadal variability. Under the SPCZ, a SSS front also exists [3]. We show that a clear eastward and southward displacement of this front, also modulated by decadal variability of similar amplitude, is visible.

We also show that the Warm and Fresh Pools size significantly increased during the last decades, more rapidly after the 1976-77 climate shift (Fig. 2). For example, the surface covered by waters warmer than 29.5°C increased by a factor of 4 to 6. The Warm Pool also expended vertically by around 10m in 50 years, leading to a 60-65% warm water volume increase (for waters warmer than 28.5°C).

## 4. IS THE WATERS FRESHENING A CONSEQUENCE OF THE WARMING?

What causes the warm waters to freshen? To answer properly this question, we need long salt budget time series. Long-term trends in available products of precipitation, evaporation, winds and oceanic horizontal and vertical advection since the 1950s cannot be used to infer with confidence the causes of Warm Pool freshening trends. As an alternative, we attempt to quantify if the theoretical expected increase in evaporation (E) and precipitation (P) over warming waters may explain a significant part of these observed changes in salinity.

According to the Clausius-Clapeyron (CC) relationship, and following [4] assumptions, we computed the change in SSS resulting from changes in freshwater fluxes only (E-P), all the other terms being unaffected. We show that qualitatively and quantitatively, the theoretical increase in hydrological cycle is largely able to explain observed SSS changes. Some geographical discrepancies may possibly be explained by SSS redistribution by oceanic advection and mixing.

## 5. CONCLUSIONS AND IMPLICATIONS

As a conclusion, a significant freshening (up to 0.75 pss per 50 years) concurrent with an important warming (up to 1.2°C per 50 years) was detected in the western tropical Pacific since 1955. An increase in SSS is, in contrast, observed in high SSS regions. Both geographical and seasonal SSS patterns are enhanced. Our results suggest that an increase of the hydrological cycle, predicted by a simple CC scaling, is consistent with these observed SSS changes. The implication of surface density changes for upper stratification is complex, and we did not observe a systematic shallowing of the mixed layer.

The Warm/Fresh Pool and associated ocean heat content expanded and SSS fronts located at the equator and under the SPCZ migrated eastward and southward, with strong decadal variations of the same magnitude. This may be important for ENSO dynamics, when considering the advective-reflective oscillator theory [5] and the role of intraseasonal wind forcing whose fetch depend on the Warm pool extend. This may also alter climatic conditions of Pacific Islands countries.

As many others, this study suggests that salinity is an important indicator of climate change. The existence of sustained observational systems providing long time series is vital to infer the impacts of climate change and distinguish it from decadal variability.

## 6. FIGURES

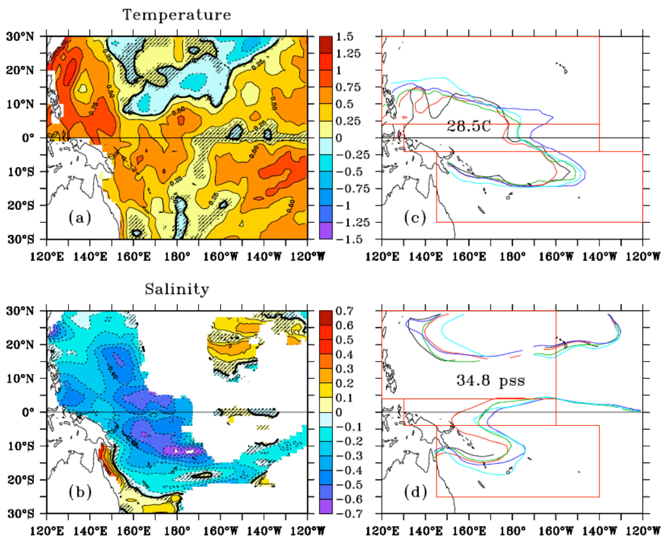


*Figure 1: Linear trends in SST (a) and SSS (b) from 1955 to 2003. Units are °C and pss per 50 years. The regions not significant at the 90% confidence level are hatched in black. Positions of the 28.5°C isotherms (c) and of the 34.8 isohalines (d), averaged during 1956-1965 (black), 1966-1975 (red), 1976-1985 (green), 1986-1995 (blue) and 1996-2003 (light blue).*

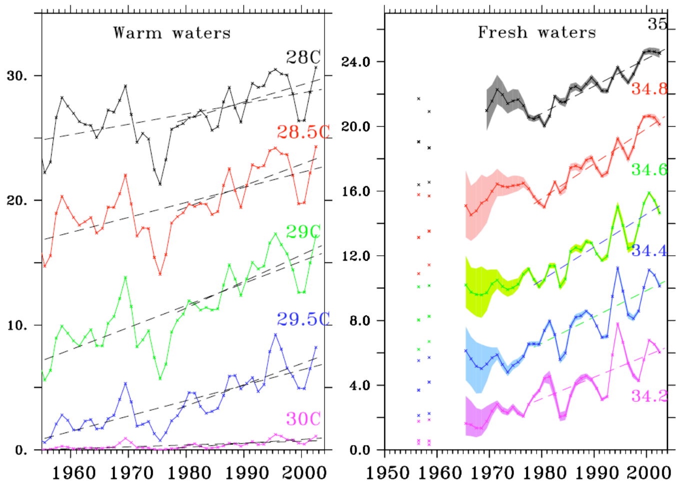


*Figure 2: Surface area (in 106km2) covered by warm (left) and fresh (right) waters computed inside the red boxes plotted in Fig1. Data are yearly means. Calculations are made if more than 70% of the max. surface area is well sampled. Error bars are given*

## 7. REFERENCES


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