Variations of the tropical Atlantic and Pacific SSS minimum zones and their relations to the ITCZ rain bands (1979-2009)

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Context & Objectives

Sea Surface Salinity (SSS) shows spatial patterns that reflect regional variations in the difference between Evaporation and Precipitation (E-P) and is thus often considered as the oceanic signature of the global water cycle (e.g. Schmitt, 2008). In the tropical Atlantic and Pacific oceans, the lowest SSS values (hereafter SSSmin) roughly match the lowest E-P values (hereafter E-Pmin), found underneath the Atlantic and Pacific Inter-Tropical Convergence Zones (ITCZ) and the South Pacific Convergence Zone (SPCZ), on average. However, when convergence zones migrate meridionally around their mean position, it is not clear whether the relation between SSSmin and E-Pmin stands or not. The aim of this study is to investigate changes in the meridional position of the SSS and E-P minima at different time scales (seasonal, interannual, long-term trends), their connection, and the extent to which migration of the SSS minima can be used as a proxy for the migration of the convergences zones.

1- Data

All data are monthly products commonly available on the 1979-2009 period.

- SSS : in situ 1°x1° gridded products for the Atlantic (Reverdin et al., 2007) and Pacific (Delcroix et al., 2011) oceans. See Fig. 1.
- Precipitation : GPCP, 2.5°x2.5° (Adler et al., 2003)
- Evaporation : OAFLUX, 1°x1° (Yu et al., 2007)
- SST: TropFlux, 1°x1° (Praveen et al., 2012)
- Wind: ERA-interim 2°x2° (Dee et al., 2011)

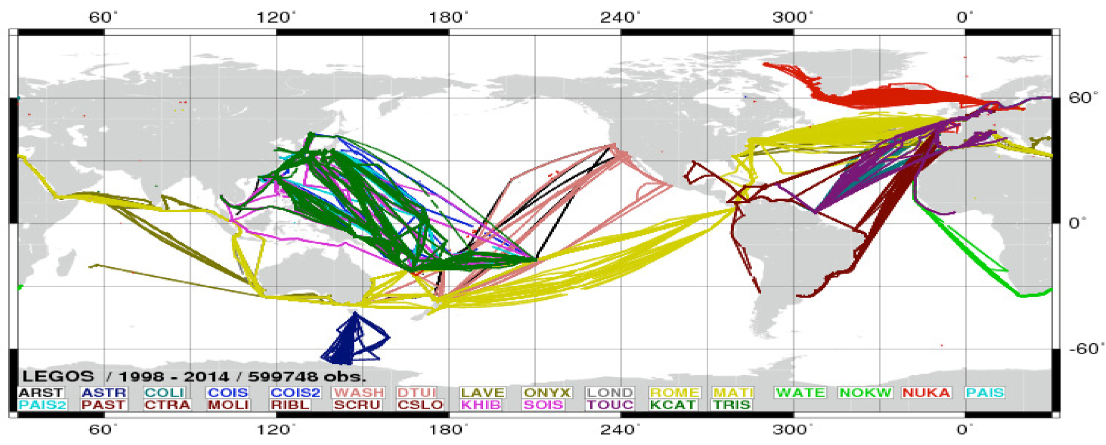

Figure 1 : SSS data collected by the French SSS Observation Service (Alory et al., 2015) with Voluntary Observing Ships (VOS). They have been combined with other available VOS, mooring, Argo and CTD observations to build the gridded SSS products used in this study.

2- Results

2.1- Mean structures

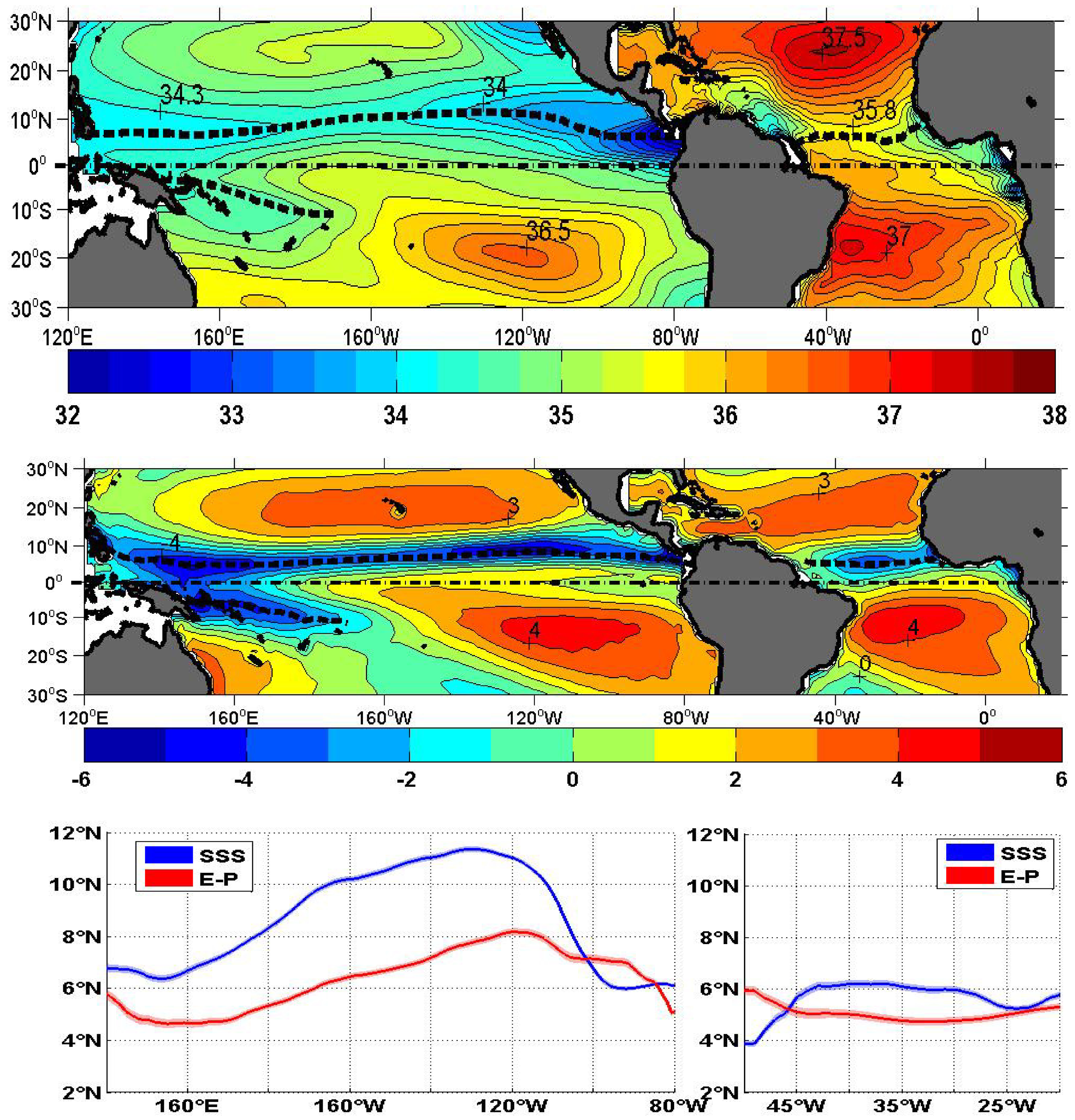

Figure 2: Spatial distribution of the 1979–2009 averaged SSS (top, in pss-1978) and E-P budget (middle, in mm/d). Comparison of the mean positions of SSSmin and E-Pmin (bottom).

The Atlantic and Pacific SSSmin stretches within 4-6°N and 6-12°N respectively. They are both 1-3° poleward of E-Pmin. This shift results mostly from the meridional Ekman salt transport driven by trade winds (Delcroix et al., 1991).

2.2- Atlantic SSS/E-Pmin distribution

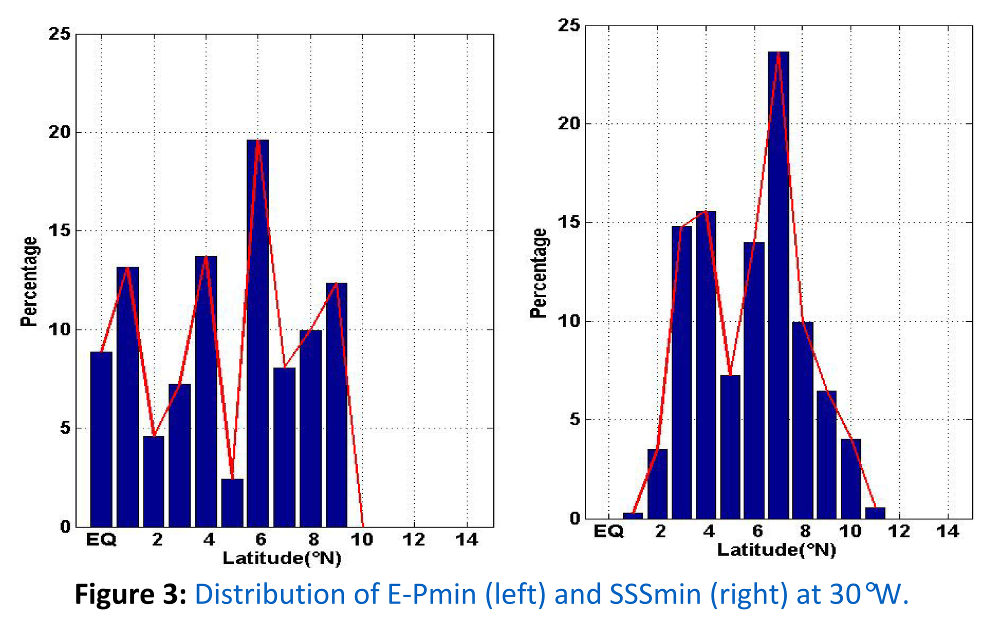

Figure 3: Distribution of E-Pmin (left) and SSSmin (right) at 30°W.

In the Atlantic, the SSS histogram has a somewhat bimodal distribution with one peak at 3°N–4°N and the other at 7°N, which probably reflect (more than E-Pmin) the abrupt ITCZ northward shift in spring called «monsoon jump» (Sultan et Janicot, 2000).

2.3- Seasonal Variability in the ITCZ regions

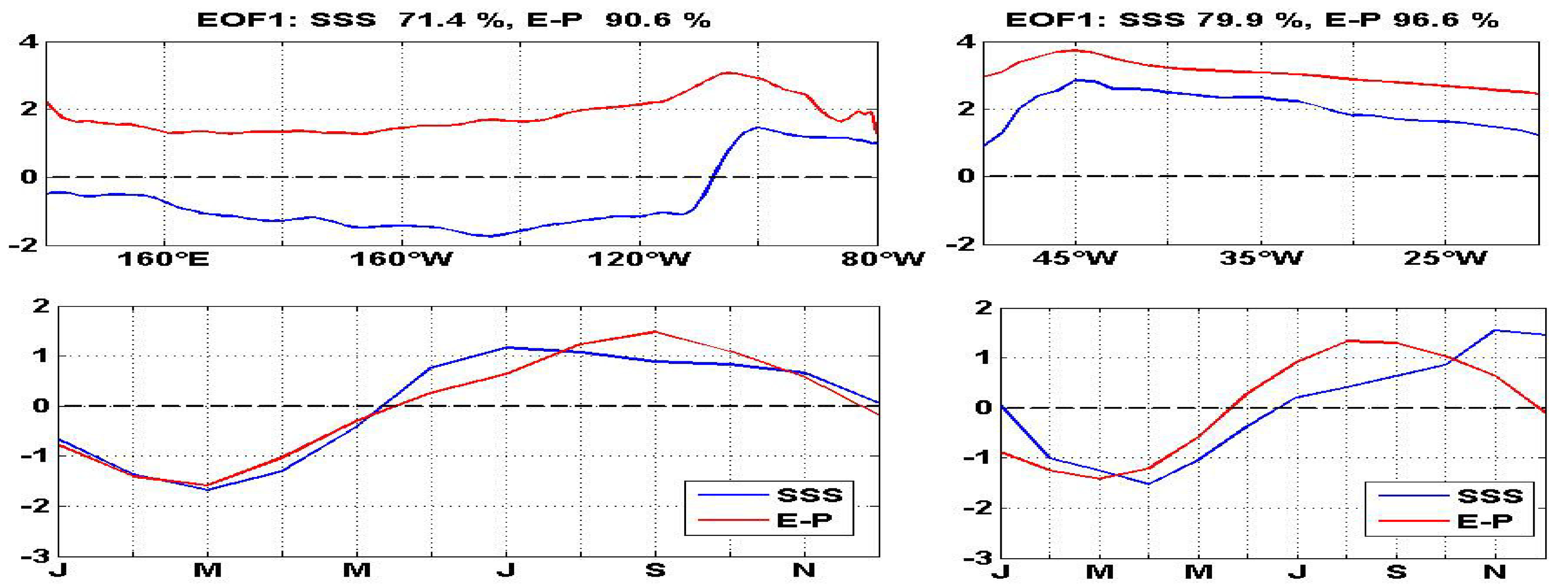

Figure 4: Spatial patterns (top) and time functions (bottom) of the first seasonal EOF mode of the latitudes of SSSmin and E-Pmin.

Seasonal migrations of SSSmin and E-Pmin are in phase in the Atlantic and east Pacific (east of 110°W). The northern-most latitudes are reached by the end of boreal fall, SSSmin lagging behind E-Pmin by 2-3 month. Surprisingly, seasonal migrations of the SSSmin and E-Pmin are in anti-phase in the central and western Pacific (west of 110°W).

2.4- Interannual Variability

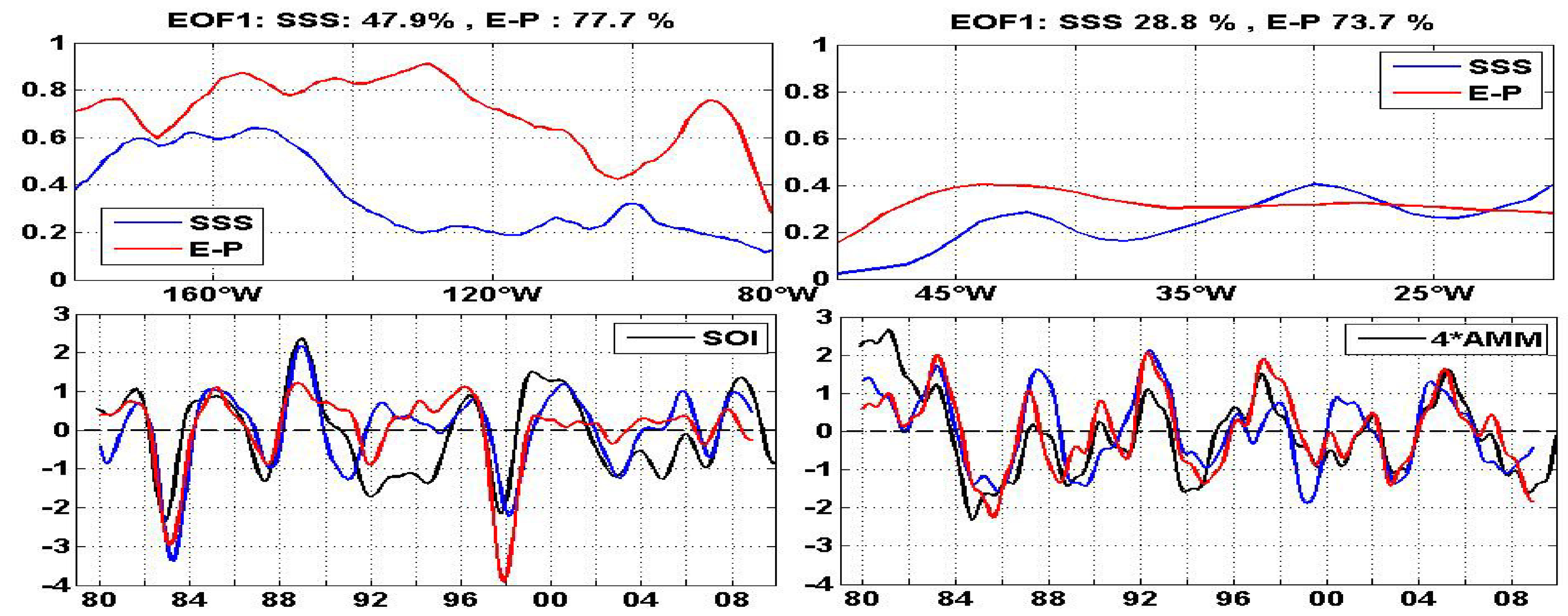

Figure 5: Spatial patterns (top) and time functions (bottom) of the first interannual EOF mode of the latitudes of SSSmin and E-Pmin.

The EOF time series are well correlated with the Atlantic Meridional Mode (AMM) index in the Atlantic and the Southern Oscillation index (SOI) in the Pacific. Both SSSmin and E-Pmin move poleward during a positive phase of AMM or la Niña period, equatoward during a negative AMM phase or El Niño period in the Atlantic and Pacific, respectively.

2.5- Long-term trend

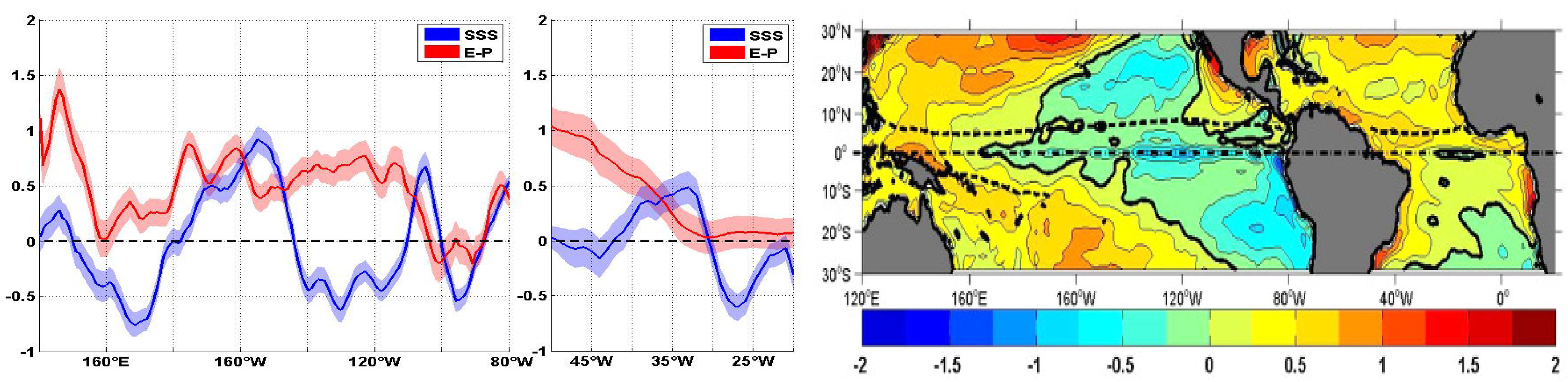

Figure 6: Zonal distribution of 1979-2009 linear trends of SSSmin and E-Pmin for the Pacific (left) and Atlantic (middle). Linear trends of SST (right, in °C) with mean position of E-Pmin (dashed black lines).

There is a zonal alternative north/southward long-term displacement of SSSmin in the two oceans. E-Pmin shows a poleward displacement in most of the Pacific and in the western half of the Atlantic, maximum at the western boundaries. SST trends show meridional gradients that could explain this poleward displacement of E-Pmin.

Summary & Discussion

Results confirm the existence of a 1-3° latitude shift between the mean position of the ITCZ (E-Pmin) and SSS minimum. SSSmin seasonal migration is a good proxy of the ITCZ for the Atlantic and east Pacific regions. It is not the case in the central and western Pacific, which is probably due to the fact that the Ekman salt transport is the dominant term in the mixed-layer salinity budget in this region (Yu et al., 2015). At interannual time scale, both E-P and SSS minima are affected by ENSO in the Pacific and the AMM in the Atlantic, migrating toward the warmer regions. The long term poleward displacement of E-Pmin in the western part of the oceans may be related to the long-term trends in meridonal SST gradients. No clear explanation was found to account for the long-term migration of the SSS minima in other regions. This study is mostly qualitative and a mixed-layer budget would be necessary to quantify the causes for SSSmin displacements. Also, in the Atlantic, the influence of large rivers (Amazon) on SSS should be taken into account for further investigation.

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