LARGE-SCALE SEA-SURFACE SALINITY CHANGES IN THE WESTERN EQUATORIAL PACIFIC OCEAN DURING 1992-1994

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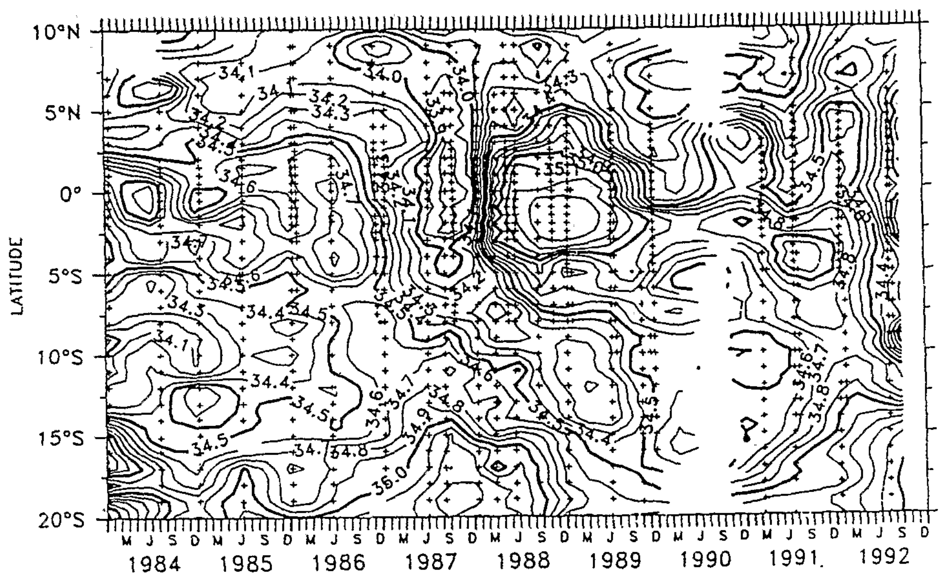
INTRODUCTION

In the western Pacific region, several studies have emphasized the importance of sea surface salinity (SSS) upon the dynamics of the ocean upper layer in relation with the Precipitation/Evaporation net budget. For example « barrier layers » reduce vertical mixing (Lukas, 1990), and horizontal SSS gradients generate « fresh equatorial jets » that have been already observed in the western Pacific (Roemmich *et al.*, 1994).

During the 1984-1992 period, oceanographic cruises along 165°E have shown low frequency changes in SSS in the western Pacific ocean, although the cruises were irregularly time spaced. In particular during the 1987 El Niño and 1988 La Niña events, large changes of SSS (1.5 psu) were observed on the equator.



Surtropac cruises along 165°E : salinity at 10 meters

Among the main variations we note:
- the presence of low salinity waters (<34.0 psu) during the 1987-early 1992 El Niño event. At the same time, unusual northward displacement of southern high salinity waters was observed (waters with SSS>35.0 psu have reached and even crossed the 15°S latitude)
- the spreading of high salinity waters (>35.2 psu) over the equatorial band during the 1988-89 La Niña event
- the presence of low salinity waters in the SPCZ area (5-15°S) in 1984-85 and 1988-89 following respectively the 1982-83 and 1987 El Niño events.

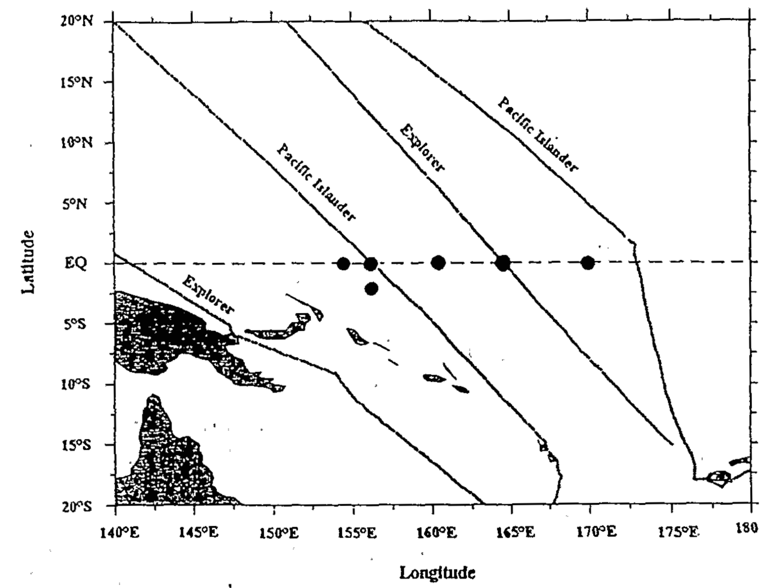
Previous studies (Porte (1992); Delcroix *et al.* (1995)) have shown a large correlation with a time lag of 2 to 4 months between the maximum rainfall and the minimum surface salinity at the location of the wind convergence zones (ITCZ and SPCZ). However in the western equatorial Pacific such correlation does not exist and they suggested that oceanic advection may explain the SSS variability.

This work presents new systematic observations of SSS made during the 1992-94 period in the TOGA-COARE region. (Note that during this period the Southern Oscillation Index presented negative values which correspond to an El Niño like state).

An attempt is made to estimate if zonal equatorial currents might explain the distribution of SSS and its time variability

DATA

In 1992, a bimonthly monitoring of SSS and sea surface temperature (SST) with merchant ships equipped with high-density sampling thermo-salinographs SBE-21 (TSG) has been initiated by ORSTOM Laboratory in Nouméa. SSS and SST were recorded every 5 minutes (approximately every 1 to 2 nautical mile) along four shipping lines. Precise comparisons with CTD data during oceanic cruises showed good stability of TSG with small variance, greatly improving previous systematic SSS measurements (precision of 0.02 psu for TSG instead of 0.2 psu for meteorological bucket technique). The different commercial lines cross the COARE domain in four main longitudes, at a 2 month interval, linking Phillipines and Japan to New-Caledonia and Fiji islands.

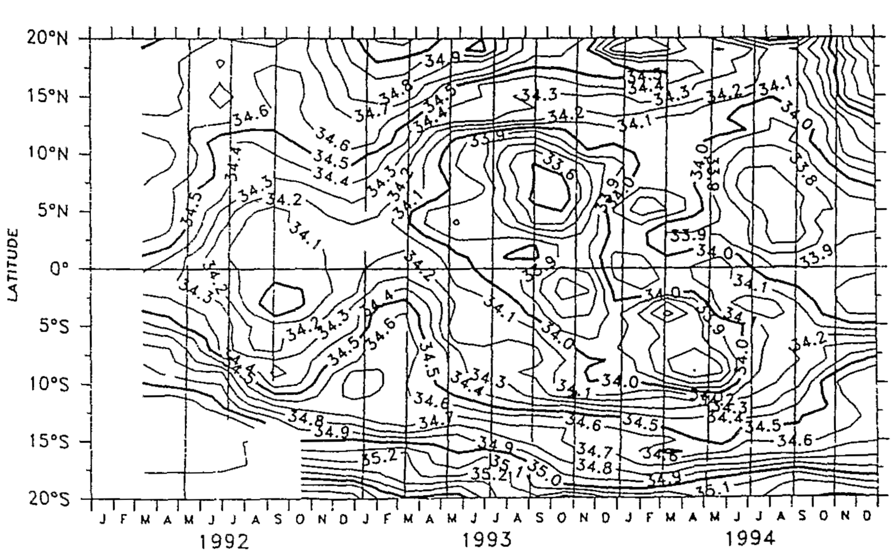


Some continuous records of salinity were also provided by Seacats systems (SBE-16) installed on TAO moorings in the upper layer of the ocean with high frequency sampling (every 5, 10 or 30 minutes). Data from surface drifters of the TOGA-WOCE Surface Velocity Programme (SVP) are presented here providing spatio-temporal current fields in the western Pacific.

TIME VARIABILITY

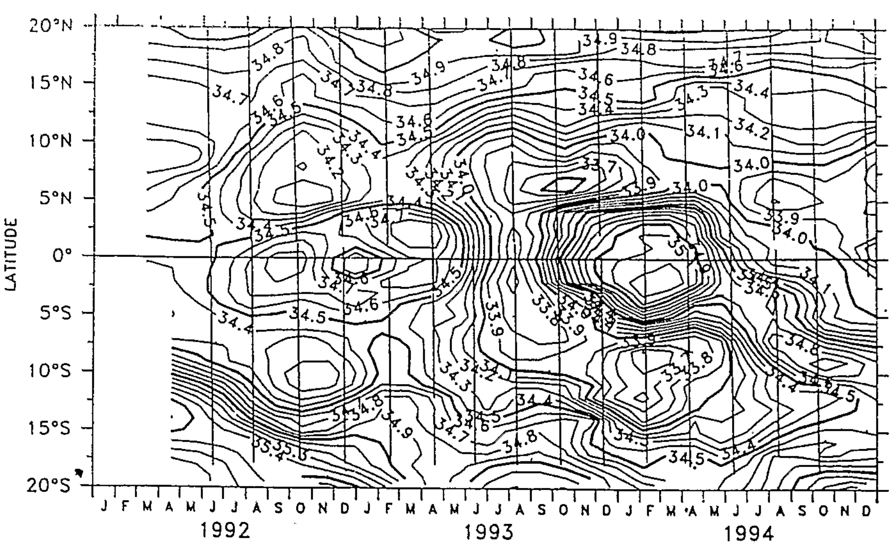
Cross-equatorial transects The MV Pacific Islander provided very regular observations along two cross-equatorial shipping lines crossing the equator near 157°E and 173°E respectively every 2 months.

Time-latitude distribution of sea surface salinity for both routes are presented with data filtered and smoothed along the route and sampled at one hour interval.



Sea-surface salinity : Pacific Islander (Western route)

The temporal evolution exhibits periods of strong SSS variations which can reach nearly 1 psu at the equator in two months. The time variations are different along the two routes located in the western and the eastern part of the COARE domain respectively. They reveal also that similar large temporal and spatial changes occur on both routes in particular through a reinforcement and a poleward spreading of low salinity waters within the convergence zones from early 1993.



Sea-surface salinity : Pacific Islander (Eastern route)

Very strong SSS variations (more than 1 psu) occur abruptly near the equator (4°S-4°N) in the eastern side of the COARE domain in several occasions, *e.g.* April-July 1993, August-December 1993 and April-June 1994. In contrast, SSS variability is weak along the western line.

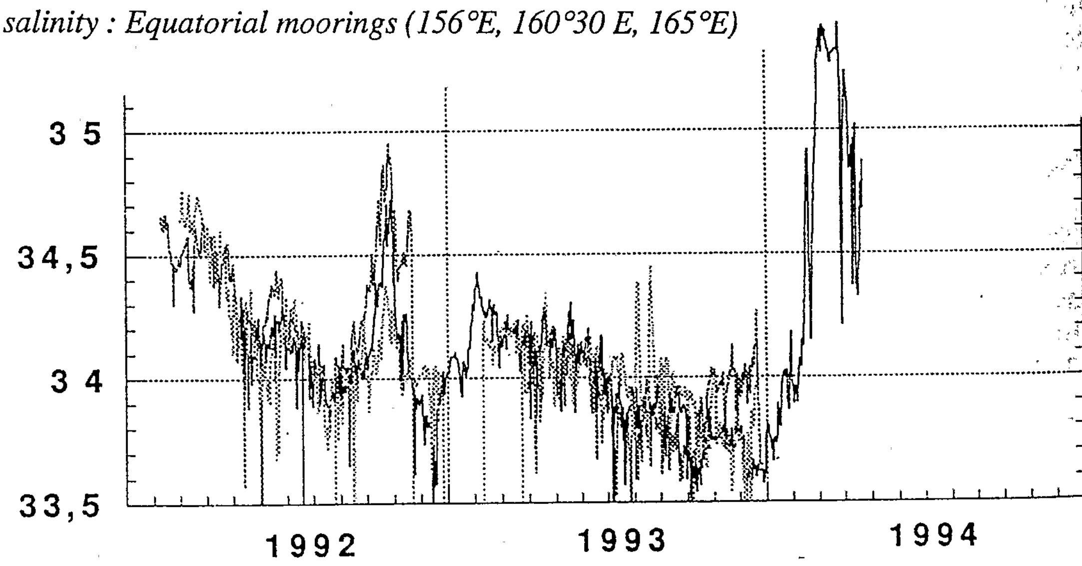
It is important to note that such kind of systematic and regular data collecting appears to be very useful since we have access to SSS meridional gradients. These gradients are strong in the eastern part of the COARE domain whereas in the western part the SSS distribution is more homogeneous.

Moorings

Daily averaged time series of surface salinity at three equatorial moorings are presented, situated in the central part of COARE domain (156°E, 160°30 E, 165°E). Continuous SSS records confirm such very sudden large changes as well as smaller occasional changes.

The salinity decreases continuously during 1993 observed on TSG records on commercial lines

Sea surface salinity : Equatorial moorings (156°E, 160°30 E, 165°E)



crossing the equator, is also well evidenced. The lowest salinity waters in the central part of COARE domain appear in late 1993. Similar changes appear on the three equatorial moorings, in particular the SSS positive anomaly decreasing westward in October 1992, which may be due to a westward advection of salty waters from central equatorial Pacific.

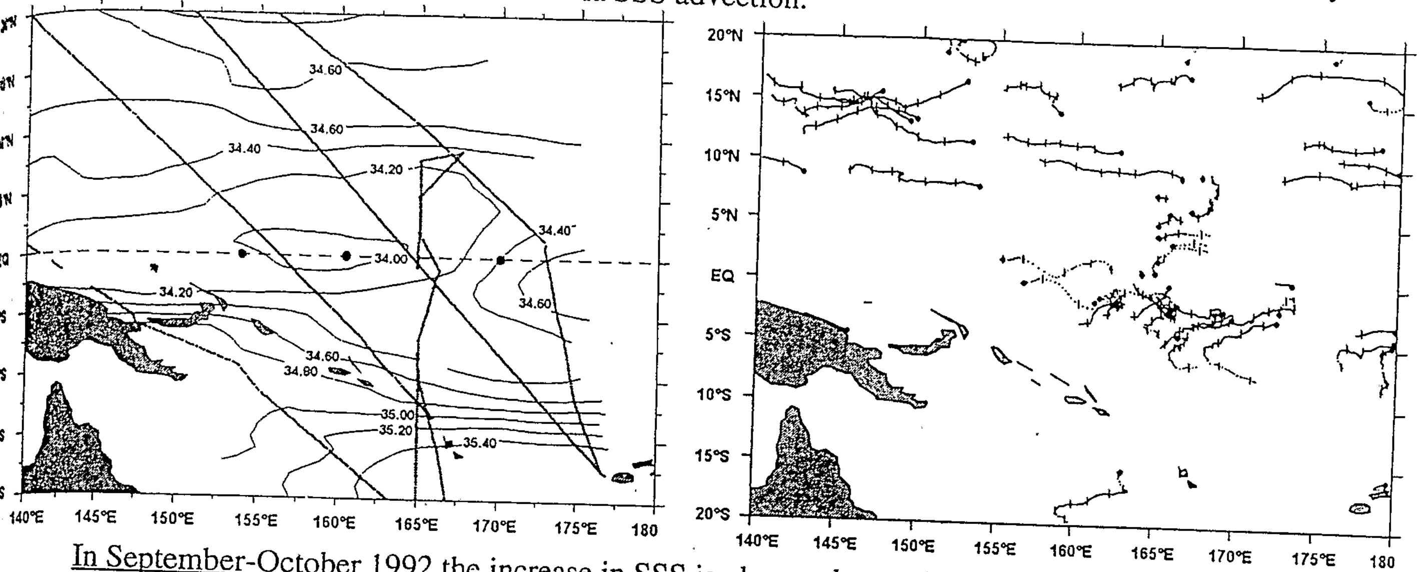
The February abrupt rise of more than 1.5 psu in SSS occurs within a few weeks at 0°-160°E. It appears also at 2°S-156°E although less marked.

SPATIAL DISTRIBUTION

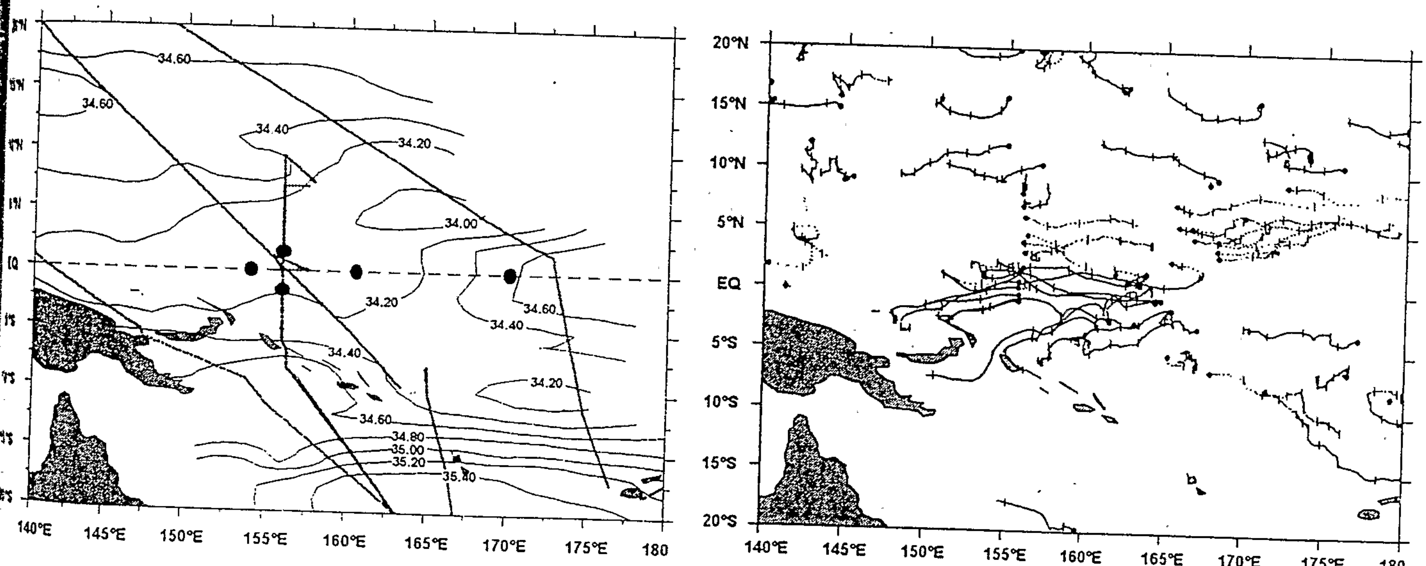
The mean spatial distribution of SSS during this period is constructed by optimal interpolation using all available observations (commercial lines, moorings & oceanographic cruises). By using data from the moorings, (i) a 70 days temporal decorrelation was found and (ii) spectral analysis of two-years daily records presents peaks at 10 days only [within the 0-2 months period window] but of relatively weak amplitude. Points (i) & (ii) allow us to present with confidence bi-monthly spatial SSS maps. These maps reveal highly variable zonal and meridional salinity gradients.

Surface drifters trajectories are also presented at the same periods (westward and eastward displacements are plotted in full and dotted line respectively)

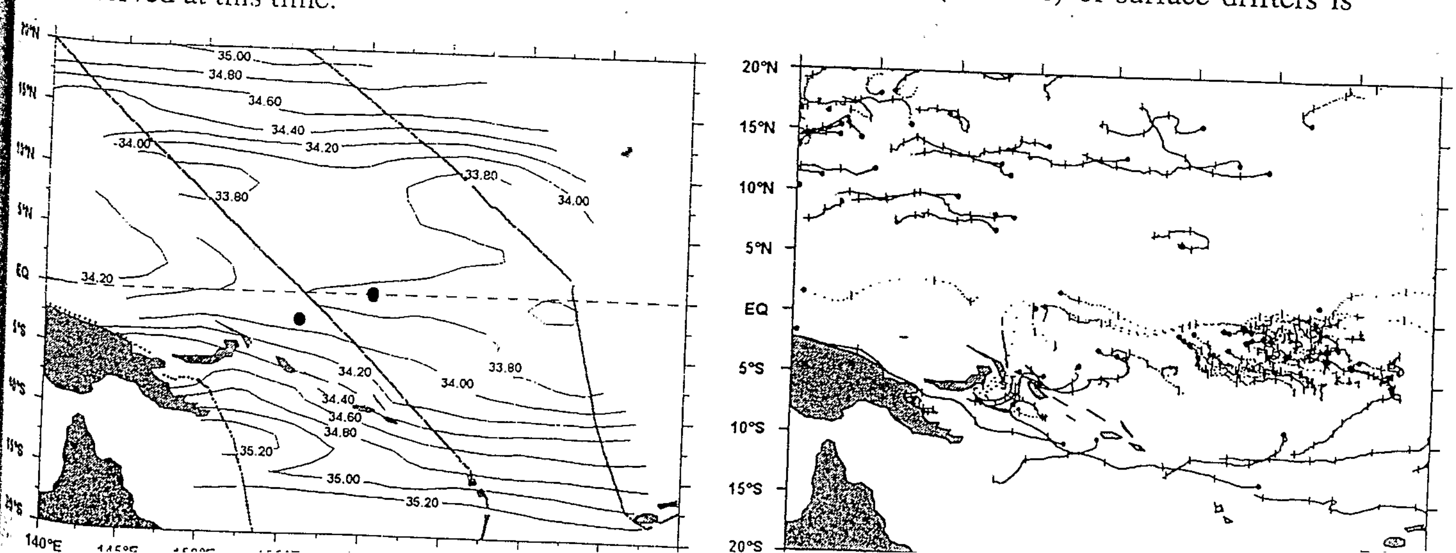
In July-August 1992, low salinity waters (<34.0) are observed on the equator in the central part of the zone while salty waters (>34,6) appear in the east. Available surface drifters exhibit a westward flow in the eastern part and a very weak eastward flow in the western part. This may explain this SSS equatorial distribution via SSS advection.



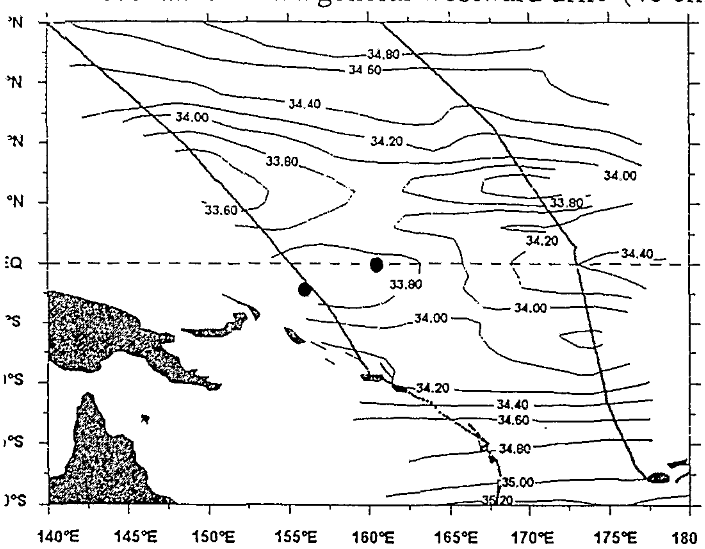
In September-October 1992, the increase in SSS is observed over the whole equatorial band (well evidenced also on moorings). In the meantime, general westward currents are present on the equator.

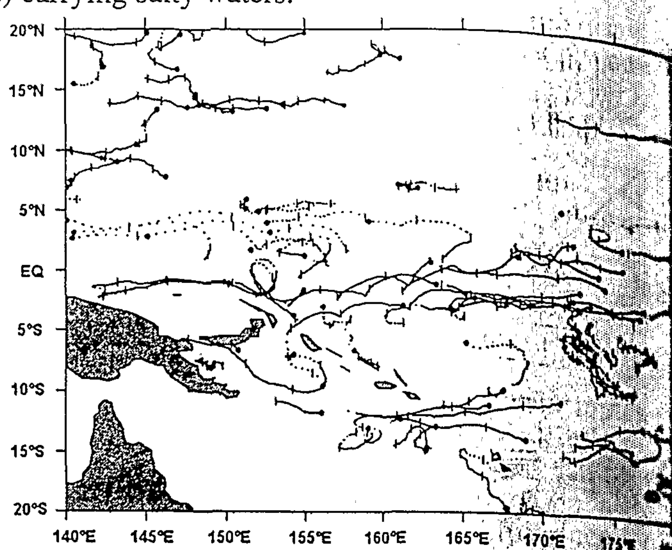


In July-August 1993, low salinity waters invaded the equatorial band (<33.8) and the zonal gradient even reversed along the equator. Large eastward drift (40 cm/s) of surface drifters is observed at this time.



In September-October 1993, in contrast a large zonal salinity gradient (33.6 to 34.4) appears associated with a general westward drift (40 cm/s) carrying salty waters.





WIND FIELD The winds observed on TAO moorings in the COARE area provide a useful data set for the western equatorial Pacific. It shows the seasonal balance of N-E trade winds north of the equator in austral summer winter and the S-E trade winds south of the equator during austral winter. Westerly winds associated with the australasian moonson occur generally during the December-March period from equator to 10°S. Some particular features are observed in the equatorial band. For instance eastward wind stress in July-August 1993 and westward stress during the September 1993 to May 1994 period.

SALT ADVECTION As Delcroix et al (1995) showed that in the COARE region, during 1979-84, rainfall and SSS variations were not correlated, we checked if salt advection is a mechanism explaining observed spatial and temporal variation of SSS near the equator during 1992-94 period.

Eastward (July-August 1993) and westward (September 1993-May 1994) wind stress fields are associated respectively with decrease and increase in SSS. Surface currents react very rapidly to winds and therefore we may suppose that such changes in SSS distribution are due to currents driven by the winds. Direct observations of currents provided by drifters have been used for our purpose: they are certainly the best data set due to a special effort during the COARE period.

Through a crude calculation, if one consider a salt budget with zero Evaporation-Precipitation net flux, and ignore vertical and meridian advection, we obtain:

$u = -(\partial S / \partial t) / (\partial S / \partial x)$ (1)

In the central part of COARE domain, on the Equator and from (1):

(i) between May-June and July-August 1993 periods the mean time and space SSS variations lead to a zonal current of +50 cm/s (eastward);

(ii) and between September-October and November-December 1993 periods we obtain a zonal current of -15 cm/s (westward).

One can note that drifters (see above) give the same magnitude of observed currents.

During Westerly West Burts, the onset of eastward jets near the equator make this mechanism dominant in the decrease of SSS. During easterly winds, in addition to zonal advection, vertical advection due to divergence of surface layer has also to be considered to explain increase of SSS.

CONCLUSION In the COARE area, SSS is shown to have a variable distribution with strong meridional and zonal gradients. This is related to the surface circulation which also presents very strong variations (Reverdin *et al*, 1994). From sea surface salinity observations by ships of opportunity TSG on a two month frequency and circulation observations from drifting buoys, we may anticipate that zonal advection may explain a large part of equatorial SSS changes.

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