Intensive Measurements of Sea Surface Temperature and Salinity in the Western Pacific

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Temperature and salinity play a critical role in oceanic circulation, and therefore in the distribution of water masses. For this reason, the description and analysis of sea surface salinity (SSS), sea surface temperature (SST) distributions and of their seasonal and inter-annual variations are essential for understanding the influence of oceans on global climate. The inter-tropical western Pacific happens to be the oceanic area of the planet where rainfall is most abundant, which results in a marked lowering of surface salinity (Lukas and Lindstrom, 1991), and it is also the place where the warmest waters in the upper layers are found, acting as the planet's heat reserve, and usually referred to as the 'Warm Pool'.

While global surface ocean temperatures have been fairly well documented through satellite remote measurements, available data of salinity are scarce.

In 1969 ORSTOM Centre in Noumea developed a network of commercial vessels operating between New Caledonia and Japan. By regrouping surface temperature and salinity measurements from meteorological buckets, taken along the shipping routes, Donguy and Hénin (1978) and Delcroix and Hénin (1989) were able to correlate salinity distribution, rainfall and the movements of the Convergence Zones of the Wind. The bucket technique by volunteer crews allows only 4–6 measurements per day. Furthermore the accuracy is estimated to be only 0.2 to 0.3°C in temperature and 0.2 in salinity respectively.

The annual number of measurements taken by the vessels within the ORSTOM Pacific network has varied, reaching as much as 10,000 observations/year between 1977–83. Unfortunately, this figure is gradually decreasing, due to difficulties encountered. During 1994 less than 2,000 observations were made.

Development of the automated TSG network

We have just pointed out the need to introduce automation in the measurement of surface temperature and salinity, *i.e.* the need for better accuracy, for simplicity of method and for a much greater number of observations. We selected the SBE21 thermosalinograph (TSG) manufactured by SeaBird Electronics Inc. The conductivity cell incorporate tributyl tin coatings to reduce biological fouling. TSGs installed on commercial ships in tropical regions .the biological fouling process may be crucial. It has to be set as close as possible to the engine water intake mainly to reduce increase of temperature. Depending on the ship this was generally possible.

Median values of temperature and salinity over 20 measurements are recorded every 5 minutes. For the geographical positioning we were able to interface our equipment with an inexpensive separate satellite positioning system. A complete description of the system can be found in Grelet *et al.* (1992). The new automated technique constitutes a notable improvement in the accuracy of both surface temperature and salinity over the old bucket sampling technique. From comparisons with CTD surface observations during four oceanographic cruises in the western equatorial Pacific differences of 0.00 to 0.03 in salinity were observed while the temperature measured by TSG was 0.1 to 0.3°C greater than CTD surface temperature. In order to improve sea surface temperature measurements we actually compare temperature from separate sensors at the entrance of water intake and fixed to the hull to *in situ* observations. Tests are in progress at ORSTOM Centre.

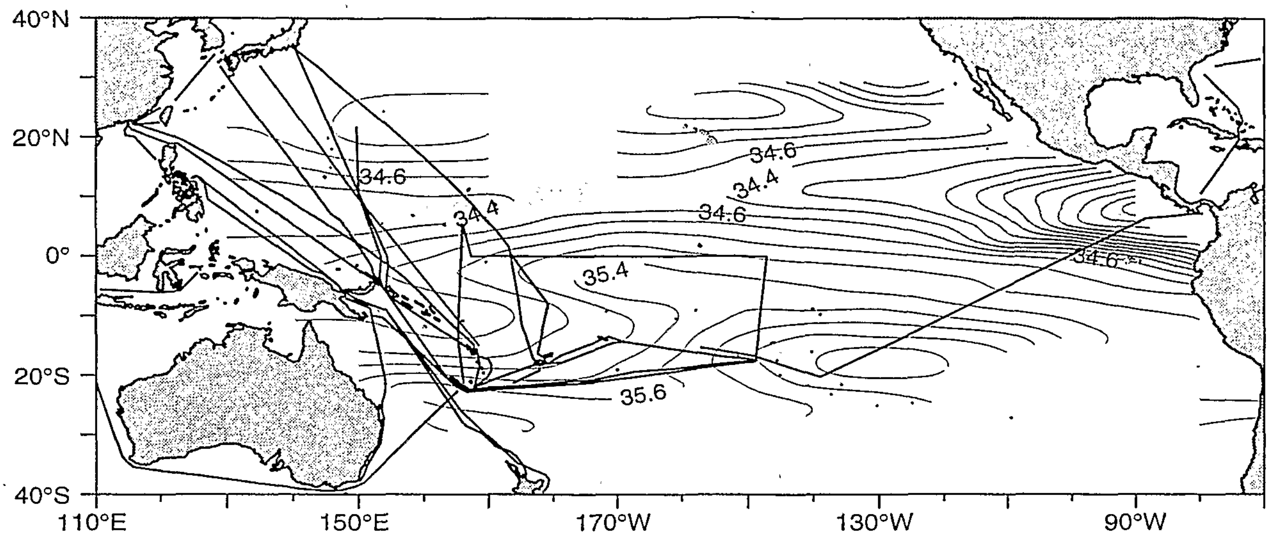

Figure 1. TSG network in the Pacific Ocean during 1994 and mean sea surface salinity for the 1974–1989 period.

The TSGs were regularly calibrated at the SeaBird factory. From basic data (frequencies) and pre- and post-calibration coefficients for 4 different SBE21 systems during the 1993–95 period operating on commercial vessels we observed that salinity drift was never more than 0.001 per month which is comparatively very small (Bitterman and Millard, 1994). A calibration every year or every two years may give the guarantee that the change in salinity is of the order of 0.01–0.02. The associated change in temperature is less than 0.005°C.

Since late 1990, six commercial vessels and three Research Vessels were selected to refine and perfect the automated surface water measurement system. The monitoring effort was focused on the western and central Pacific where the salinity distribution is well contrasted with high salinity waters of more than 36.2 near French Polynesia and low salinity waters (less than 34.8) under the convergence zones (Intertropical Convergence Zone [ITCZ] and South Pacific Convergence Zone [SPCZ]). The area of observation extends from Japan to New Zealand, and from Southeast-Asia and Australia to French Polynesia (Fig. 1).

Variability of SSS and SST observed with TSG network

From the recent intensive automated observations of SSS and SST by TSG we may present some results:

The temperature diurnal cycle

In the western equatorial Pacific during the intensive observation period (IOP) of the COARE programme (Coupled Ocean Atmosphere Response Experiment) we had the opportunity to observe the diurnal cycle with our TSG system. During a three month period (December 1992 to February 1993), RV Le Noroit cruised along 18 cross-equatorial tracks, experiencing varying cloud cover and wind strength. These affected the amplitude of the diurnal temperature cycle, and disturbed the description of temperature distribution along the 5°S–5°N runs (each one lasting approximately three days). During the 20–23 January 1993 section (Fig. 2) while the wind was very weak during three days the diurnal heating is well observed on the SST records with an amplitude of about 0.7°C and a maximum occurring at approximately 1400 to 1500 local time.

Effect of rainfall

Local rainfall affects both temperature and salinity. The effect on temperature is small (a 0.1–0.3°C temperature drop has been frequently observed during a rain squall), but much greater on surface salinity. Depending on the intensity and duration of rainfall, this latter may vary by as much 1.0 (observed from RV Le Noroit between 3°N and 4°N in January 1993). The rainfall lowers the sea surface salinity and the sea surface temperature. This effect and the diurnal heating are seen in T-S diagram on Fig. 3.

This temperature diurnal variability, coupled with the effect of localized rainfall in tropical areas, could lead one to question the validity of surface temperature and salinity measurements taken by the traditional network of

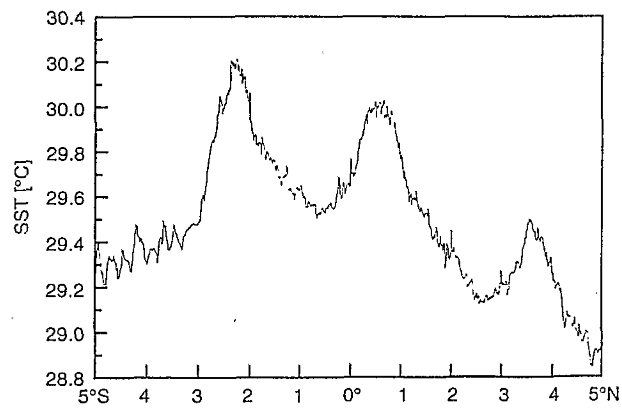

Figure 2. Sea surface temperature (°C) along 156°E between 5°N–5°S during a light wind period (20–23.1. 1993)

commercial vessels, and even those gathered by research vessels. Studies are being carried out on the diurnal temperature cycle and on the effect of freshwater impact on the surface layer of oceans. The automated TSG bring new observations for these studies.

Surface Salinity fronts

Along the Equator, a very large zonal surface salinity front was observed in October 1994 during the Flupac cruise with a sharp gradient near 172°W (33.8–34.5 west of 175°W and 35.2–35.3 east of 170°W). These observations reflect the El Niño event with the eastward extension of low salinity waters of the Warm Pool and the strong zonal salinity gradient on its eastern edge.

SSS structures along the quasi meridional merchant ship routes were already described by Delcroix and Hénin (1991). From traditional bucket observations they described the seasonal and the interannual variations. The new thermosalinographs records now allow to observe fine sea surface structures along the shipping lines. Fig. 4 presents the SSS distribution during the 1992–1995 period along the Japan–Tarawa–Fiji line crossing the equator near 174°E (every two months since June 1992 and every month since August 1995). Low salinity waters are observed under the ITCZ near 7°N and SPCZ near 9°S. During this El Niño period very large SSS variability is detected on the equator (from less than 33.6 in August 1993, more than 35.2 in March 1994 and since April 1995). This induces very pronounced meridional salinity fronts (more than 1.0 over a few miles respectively near 4°N and 4–8°S) between high salinity equatorial surface waters and low salinity waters associated with ITCZ and SPCZ. These fronts would not be so well described with bucket sampling. Recent work using drifters and SSS TSG data suggests that in addition to evaporation and rainfall zonal currents and equatorial upwelling may explain such equatorial SSS distribution (Hénin *et al*, 1995).

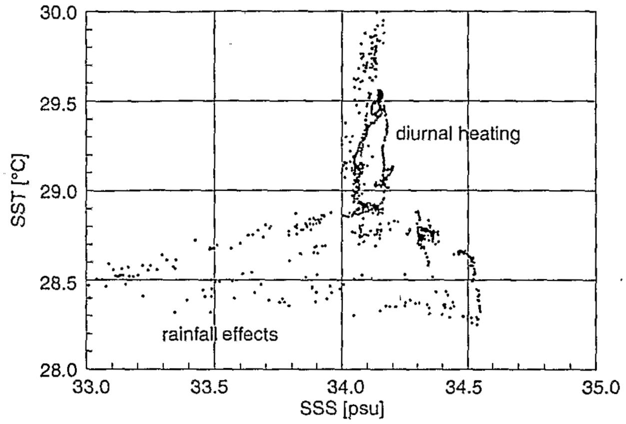

Figure 3. Temperature/Salinity diagram observed along 156°E on the 5°S–5°N section showing rainfall and diurnal heating effects (3–6 January 1993).

Conclusion

The study of the variability of tropical SST and SSS distribution using first three years of intensive observations by TSG on commercial vessels has proved to be somewhat difficult to carry out due to the high frequency variations introduced by the diurnal cycle (in the case of temperature) and by rainfall (in the case of salinity). By developing intensive automatic observation systems and using smoothing and filtering techniques we may eliminate these local effects.

During the experimental period, and using a limited number of ships, we were thus able to demonstrate that intensive automated surface water monitoring was indeed possible, and that it improved the accuracy of the data and the density of coverage along the tracks followed.

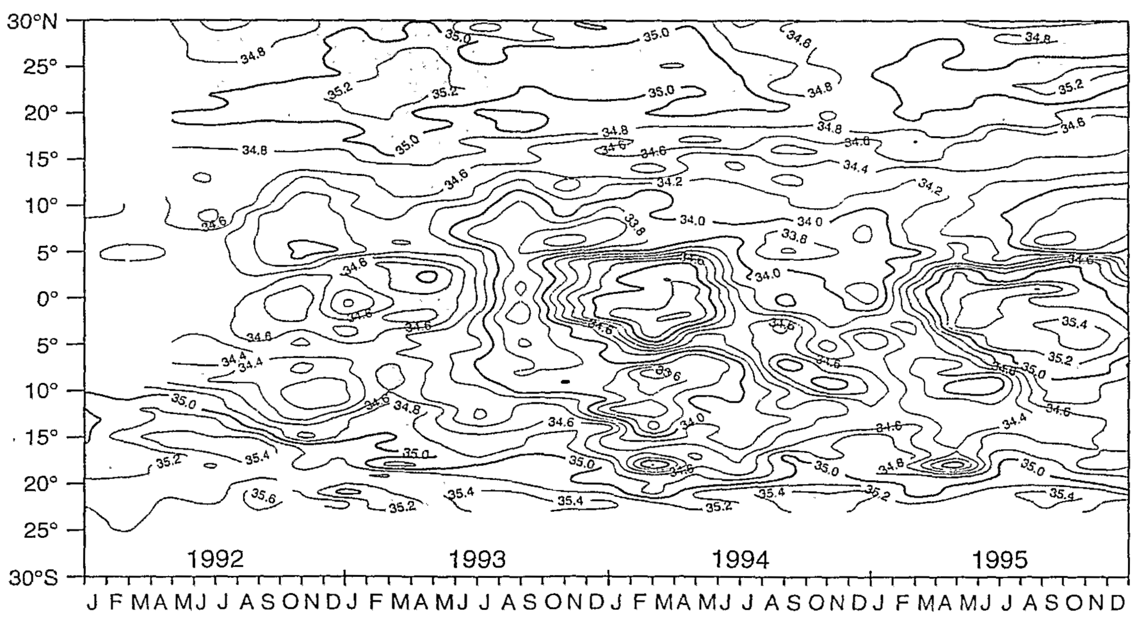

Figure 4. Sea Surface Salinity distribution along the Japan–Tarawa–Fiji line for the 1992–95 period.

References

Bitterman, D.S., and R.C. Millard, 1994: Shipboard thermosalinograph intercomparison test results from the NOAA RV Malcolm Baldrige. NOAA Technical Memorandum ERL AOML-82.

Delcroix, T, and C. Hénin, 1989: Mechanisms of subsurface thermal structure and sea surface thermohaline variabilities in the southwestern tropical Pacific during 1979-85. J. Mar. Res., 47, 777–812.

Delcroix, T., and C. Hénin, 1991: Seasonal and interannual variations of sea-surface salinity in the tropical Pacific Ocean. J. Geophys. Res., 96, 22135-22150.

Donguy et Hénin, 1978: Hydroclimatic anomalies in the South Pacific. Oceanologica Acta Vol. 1, 1, 25–30.

Grelet, J., B. Buisson et C. Hénin, 1992: Installation et utilisation d'un thermosalinographe à bord d'un navire marchand. Notes Techniques, Sciences de la mer, Oceanographie physique, 7, Centre ORSTOM de Noumea, Nouvelle Caledonie, 99pp.

Lukas, R., and E. Lindstrom, 1991: The mixed layer of the western equatorial Pacific Ocean. J. Geophys. Res., 96, Suppl., 3343–3357.

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