4420

(50)

TEMPERATURE VARIABILITY OF THE OCEANIC UPPER LAYER IN THE WESTERN PACIFIC DURING THE COARE INTENSIVE OBSERVING PERIOD

Gérard ELDIN and Yves du PENHOAT,
Groupe SURTROPAC, ORSTOM, Nouméa, New Caledonia

THE DATA

Data for this study originate mainly from the COARE-POI cruise, carried out on board R/V Le Noroit from December 1992 to February 1993 along 156°E, from 5°S to 5°N. Altogether 18 meridional sections were recorded, of currents, using an ADCP, and of temperature and salinity fields using a SeaSoar and closely spaced CTD casts. In addition, 51 surface drifters were deployed. Additional data from the TOGA-TAO moorings array and model results from ECMWF are also used. More details on data acquisition and processing can be found in the cruise report (Delcroix et al., 1993).

NEAR SURFACE TEMPERATURE VARIABILITY

Along 156°E:

A time-latitude plot of temperature at 5m along 156°E, obtained from merged and gridded CTD and SeaSoar data at the first common depth level gives a general picture of large-scale near-surface temperature (NST) variability in the COARE domain (Figure 1). In December and until January 5, NST decreases continuously, from more than 30°C to 28.5-29.3°C. The amplitude of variability is maximum around 4°S, with a decrease of more than 1.5°C in one month. In the 2°S-2°N band the cooling is quasi symmetrical, with the NST maximum continuously centered close to the equator. After January 5, NST increases almost everywhere, but the symmetry is broken by a stronger warming south of the Equator. Temperatures do not return to their previous values of early December, and exceed 29.5°C only locally. North of 3°N temperatures stay generally cooler than elsewhere by about 0.3°C. In February, moderate cooling and warming alternate (about ± 0.5°C), with a larger amplitude south of 3°S. Daily averaged wind measurements from the TOGA-TAO mooring array are objectively analyzed in space (M. Cronin, pers. comm.), and provide time-series of wind vectors along

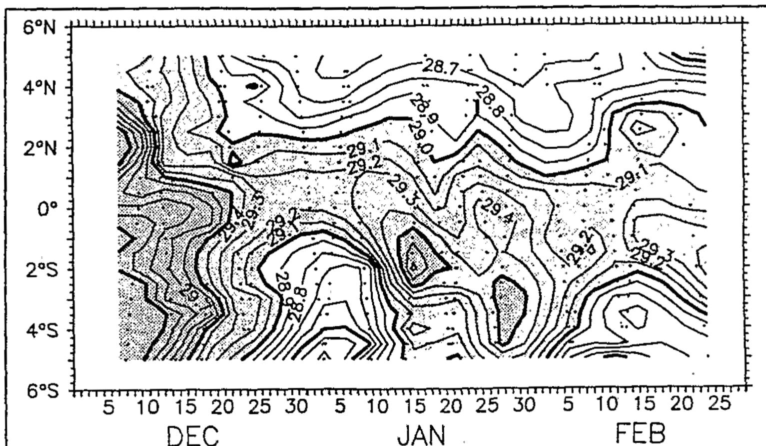

Figure 1 - Near-surface temperature (NST) from CTD and SeaSoar data along 156°E, December 1992 - February 1993. Dots show cruise track.

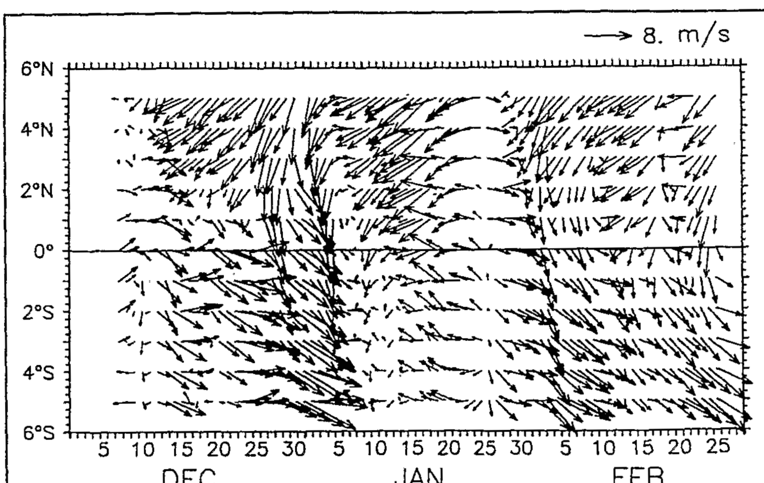

Figure 2 - Objectively analysed winds from the TOGA-TAO array along 156°E.

156°E (Figure 2). During the first half of December weak winds of less than 5 m/s predominate, then north-easterlies develop north of 3°N. South of that latitude, westerlies increase in two phases and reach their maximum (more than 10 m/s) between Christmas and January 5, forming a "westerly wind burst" (WWB). Its appearance is linked to the formation of tropical cyclone Kina in the Southern Hemisphere. After the end of the WWB and a return to calm winds south of the equator northeasterlies extend southward and cross the equator. On January 15-25 the wind field is easterly from at least 5°S to 5°N. In February, a few calm days are followed by two episodes of northwesterlies south of the equator, again caused by cyclogenesis to the south of the Solomon Islands. North of 3°N northeasterlies are persistent, but weaker than in January. In between, weak northwest- or northeasterlies prevail.

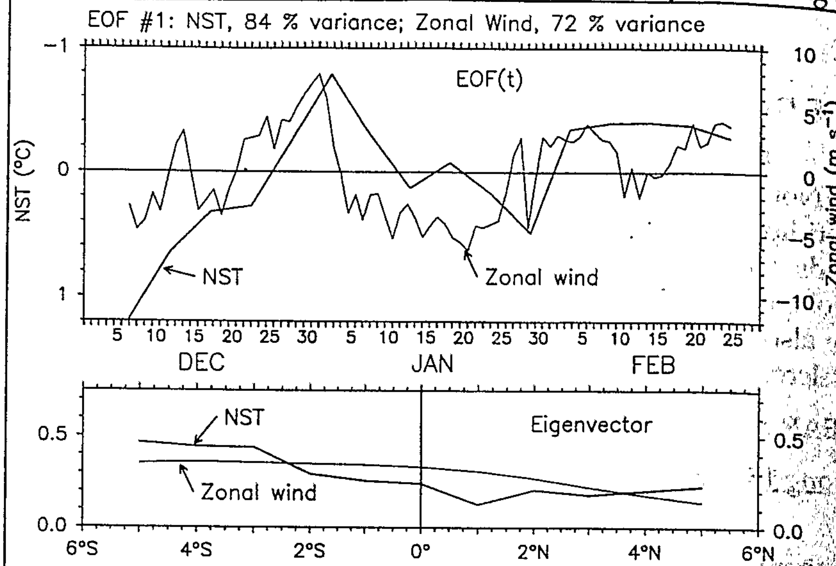

Figure 3 - First EOF's of POI cruise near-surface temperatures and TAO zonal winds along the 156°E meridian.

To point out the main patterns of variability, an EOF analysis is performed on near-surface temperatures from the POI cruise and wind field from the TOGA-TAO mooring array (Figure 3). The first EOFs show in-phase response along 5°S-5°N for temperature and zonal wind, but opposite time variations (note the inverted temperature scale): westerlies are associated with cooling, while easterlies are linked to warming. This result confirms that vertical advection from wind forcing (equatorial upwelling) is not a dominant mechanism in NST changes in the Warm Pool, as already noted at 165°E (McPhaden and Hayes, 1991).

<u>In the COARE domain:</u>

Figure 4 presents the wind field in and around the COARE domain for two significant

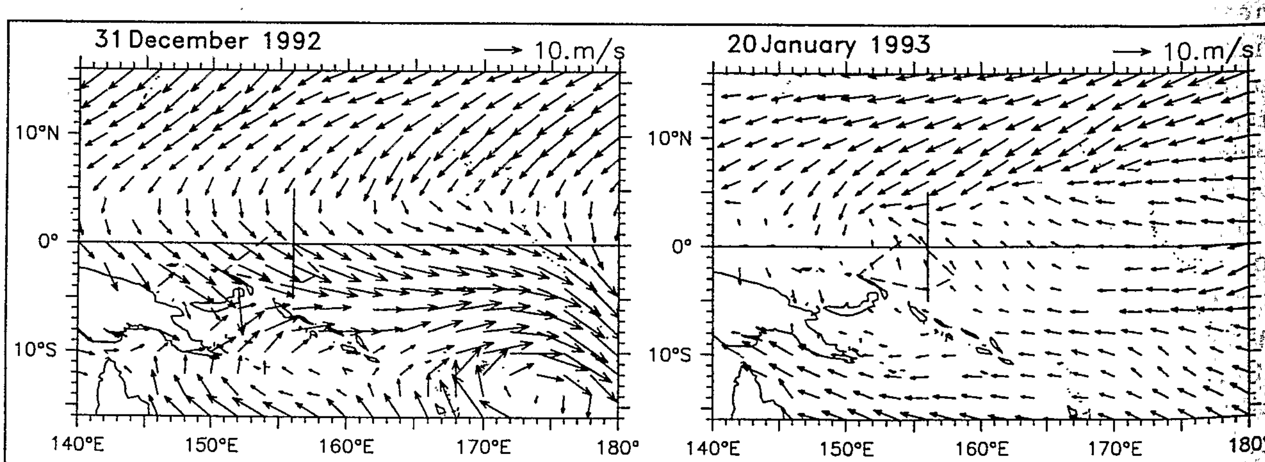

Figure 4 - ECMWF winds around the COARE domain at the peak of the December 92 WWB (31 December 92), and at the end of the easterly episode (20 January 1993)

situations: the westerly wind burst at the end of December 1992, which mostly affects the Southern Hemisphere, in relation to cyclogenesis in the south-east part of the region; the moderate easterly episode of mid-January 1993, more intense in the Northern Hemisphere, associated to a strengthening of the north-east trade winds.

Surface drifters released during the COARE IOP and cruise data are merged and objectively analysed to provide maps of the circulation and near-surface temperature fields in the COARE domain away from the 156°E meridian. To obtain an estimation of the spatial scales of NST variability, differences are computed for two significant periods of the IOP: 1) during the December WWB (10 to 30 December 92) and 2) during the recovery from the WWB (30 December 92 to 20 January 93). Figure 5 shows that evaporative cooling associated with the WWB is found everywhere, but is strongest west of 156°E, and in the Southern Hemisphere. Drifters trajectories suggest that some zonal advection of that cooler water from the west also takes place in the surface eastward current associated with the WWB. After the WWB, the Southern Hemisphere warms, but evaporative cooling persists north of the equator, where easterlies are more intense.

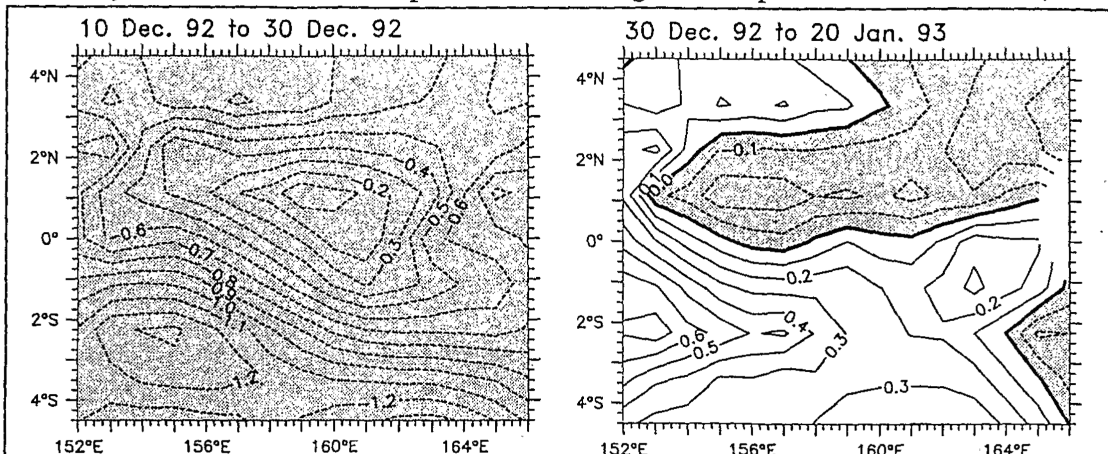

Figure 5 - Variation of NST (°C) for two opposite episodes of wind forcing: during the moderate WWB (10 to 30 December 92); during easterlies (30 Dec. 92 to 20 Jan. 93). Cooling is shown by shading.

SUB-SURFACE VARIABILITY

The "sub-surface" is defined here as the first 60-70m, roughly the average depth of the 28°C isotherm. In this layer flow reacts immediately to the varying wind forcing (Eldin et al, 1994).

A 2°S-2°N average of NST and the underlying thermal structure and a plot of temperature at 60-70m present sub-surface temperature variability of the Warm Pool (Figure 6): In December, the steadily increasing wind speed does not only cool the surface, but also enhances vertical mixing, which results in a 0.4°C cooling of the whole layer at the end of the westerly wind burst. From 15 to 25 January, during easterlies, the base of the layer cools by about 2°C, while NST stays almost constant. The horizontal and vertical sections of zonal current (Figure 7 and 8) show that this cooling is closely related to the westward flow at that depth in early January, which was already present in deeper layers during the WWB, as observed in previous occasions (McPhaden et al., 1988; Delcroix et al., 1993). Easterly wind stress in surface and increased

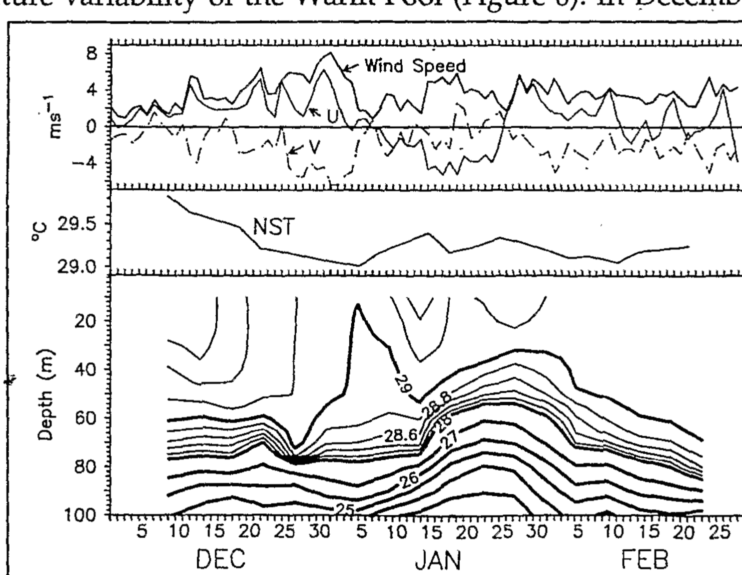

Figure 6 - Time-series of wind , NST, and sub-surface temperature, averaged over 2°S-2°N, at 156°E. Isolines every 0.2°C above 28°C.

westward flow induce divergence and upwelling at the base of the surface layer, contributing to its strong cooling. However, the meridional flow (not shown) is not clearly divergent at that time. In February, the westward flow weakens, isotherms deepen, and NST cools slightly, so that the surface layer is again well mixed. The vertical section (2°S-2°N average, figure 8) shows that the underlying circulation is linked to the variability of the surface layer, and that remote processes may also play a role: during the westerly burst at the end of December the South Equatorial Current is accelerated in the upper thermocline, below the surface eastward jet. The increased vertical shear may cause entrainment cooling at the base of the surface layer at the end of the burst. The Equatorial Undercurrent has also been subjected to a low frequency upward displacement since December, possibly of remote origin, which is reinforced at the end of January at the time of wind-forced upwelling. The variability of meridional circulation (not shown) is mostly confined above the thermocline, where 10-15-day current oscillations predominate. These oscillations also contribute to temperature variability at the equator by meridional advection.

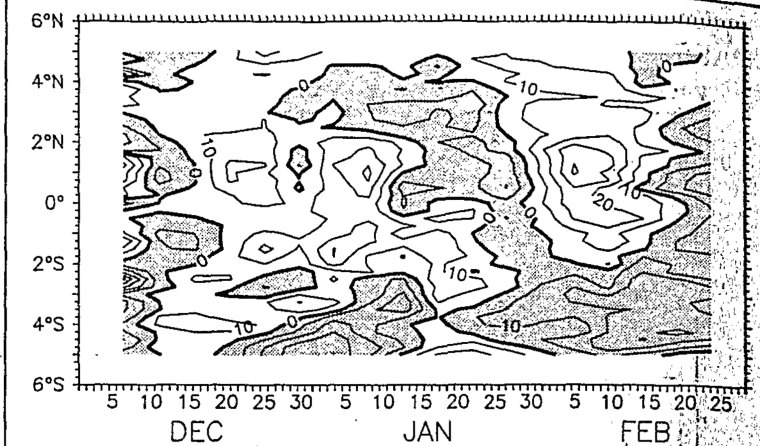

Figure 7 - Variability of zonal circulation at the base of the temperature mixed layer (60-70 m) at 156°E. Westward flows are shaded.

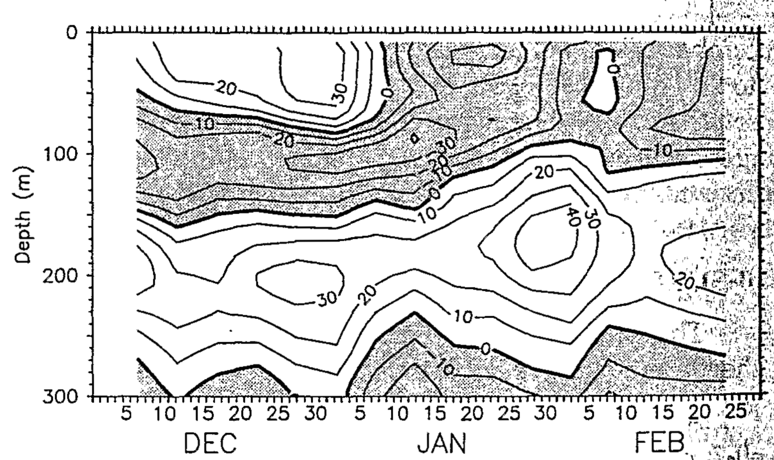

Figure 8 - Variability of zonal circulation, averaged over 2°S-2°N, at 156°E. Westward flows are shaded.

CONCLUSION

During the COARE IOP, in and around the 156°E meridian, NST variability is for a large part governed by changes in local wind forcing, which induce variations of air-sea latent heat fluxes, with some contribution of horizontal advection at times of strong surface circulation. At the base of the surface layer, temperature variations are out of phase with NST: strong westerlies cause a deepening of the surface layer but cool NST; moderate easterlies associated to low frequency displacements of the thermocline cool the deeper levels, while NST warms slightly.

REFERENCES

Delcroix, T., G. Eldin and C. Hénin, 1993: Campagne COARE-POI à bord du N.O. Le Noroit, 1er décembre 1992 - 2 mars 1993, Rap. Miss. Sci. Mer, 10, ORSTOM Nouméa, 338 pp.

Delcroix, T., G. Eldin, M. McPhaden, A. Morlière, 1993: Effects of westerly wind bursts upon the western equatorial Pacific Ocean, February-April 1991, J. Geophys. Res., 98, 16,379-16385.

Eldin, G., T. Delcroix, C. Hénin, K. Richards, Y. du Penhoat, J. Picaut and P. Rual, 1994: Large-scale current and thermohaline structures along 156°E during the COARE Intensive Observation Period, Geophys. Res. Lett.,21, 2681-2684.

McPhaden, M., P. Freitag, S. Hayes, B. Taft, Z. Chen, and K. Wyrtki, 1998: The response of the equatorial Pacific ocean to a westerly wind burst in May 1986, J. Geophys. Res., 93, 10,589-10,603.

McPhaden, M., and S. P. Hayes, 1991: On the variability of winds, sea surface temperature, and surface layer heat content in the western equatorial Pacific, J. Geophys Res., 96 suppl., 3331-3342.

PROCEEDINGS OF THE

International Scientific Conference on

TROPICAL OCEAN GLOBAL ATMOSPHERE (TOGA) Programme

(2-7 April 1995, Melbourne, Australia)

WCRP-91 - WMO/TD No. 717

VOLUME I

December 1995