Preliminary Results from Charles Darwin Cruise 34A in the Western Equatorial Pacific

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ABSTRACT

In September 1988, the RRS Charles Darwin carried out a survey of the Western Equatorial Pacific between 127°E and 160°E and between 7°N and 3°S. The main instruments used were an undulating SeaSoar, carrying a CTD, which gave temperature and salinity sections down to 250 m, an acoustic doppler current profiler which gave velocities down to 300 m and the IOS MultiMet system measuring surface fluxes.

Data from the cruise is still being worked up. In this paper data from a long section made across the equator at 142°E between 7°N and 7°S is presented. The section is of interest because it shows up the importance of the salinity contrast between the more saline South Equatorial Current and the fresher North Equatorial Counter Current. This contrast shows up in both the almost isothermal near surface waters and in the thermally more complex region of the undercurrent.

1. Introduction.

In September of 1988, the United Kingdom research ship RRS Charles Darwin made a survey of the Western Equatorial Pacific between 127°E and 160°E and between 7°N and 3°S. The main instruments deployed were an undulating SeaSoar carrying a CTD, which gave temperature and salinity sections down to 250 m, an acoustic doppler current profiler (ADCP) which gave water velocities down to 300 m and the IOS MultiMet set of instruments measuring surface meteorological fluxes. Other instruments included a thermosalinograph, Transit and GPS satellite navigation, to give accurate position and absolute velocity of the ship, a precision echo sounder and a gravimeter.

The track of the ship during the survey is shown in Fig.1. The region covered is at the heart of the Western Pacific warm pool where sea surface temperatures can exceed 30°C. As a result atmospheric convection is very important (the region lies under the rising branch of the main Pacific Walker cell) and rainfall is high. Both the average winds in the region and the wave heights are very low, so surface mixing of the ocean by these two processes should be less than normal.

Interest in the region has increased in recent years because it may be responsible for triggering El Nino events. Simmons et al. (1983) also show that the region is involved in determining the position of atmospheric highs and lows in the northern hemisphere. The triggering of El Ninos may occur as a result of westerly wind bursts (Luther et al., 1983) an ocean temperature anomaly coupled to atmospheric convection (Gill, 1980) or the reflection of oceanic Rossby waves.

However because of its remoteness, the amount of good data available from the region has always been sparse and this has hindered the development of theoretical models of the coupling of the ocean and atmosphere in the region. For example one approximation that is often made when modeling the ocean near the equator, is that changes in salinity have only a small effect on ocean density and so can be ignored. In contrast, as we shall see, in the Western Equatorial Pacific the salinity often has an important effect.

Data from the cruise is still being worked up but in this paper we present preliminary

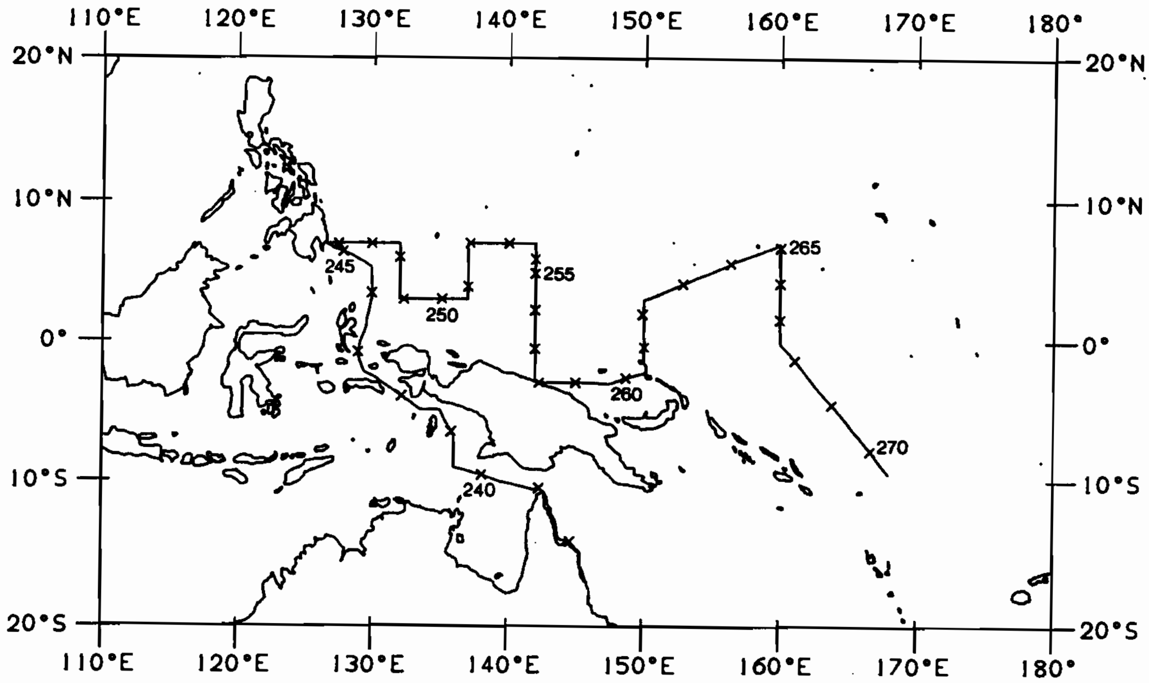


FIG.1. Tack of the RRS Charles Darwin during cruise 34A/1988. The crosses mark the ship's position at 000Z on the days indicated.

results from the long north-south section carried out on 142°E. Results are presented from the ADCP, showing the main current systems, and the SeaSoar, showing the structure of the temperature and salinity fields along the section.

2. The section on 142°E.

a. East-West Velocities

Currents were measured using a hull mounted R D Instruments ADCP. This was calibrated using the procedure described in Pollard and Read (1989). The instrument measures velocities relative to the ship averaged over 180 s intervals. Absolute velocities need the addition of the ship's speed and direction which is obtained from GPS, when available, and from Transit satellites. The latter fixes are carefully screened before use.

The east-west component of velocity obtained with this system is shown in Fig.2. Note that for plotting the data has been averaged into 12 km bins along the ship's track.

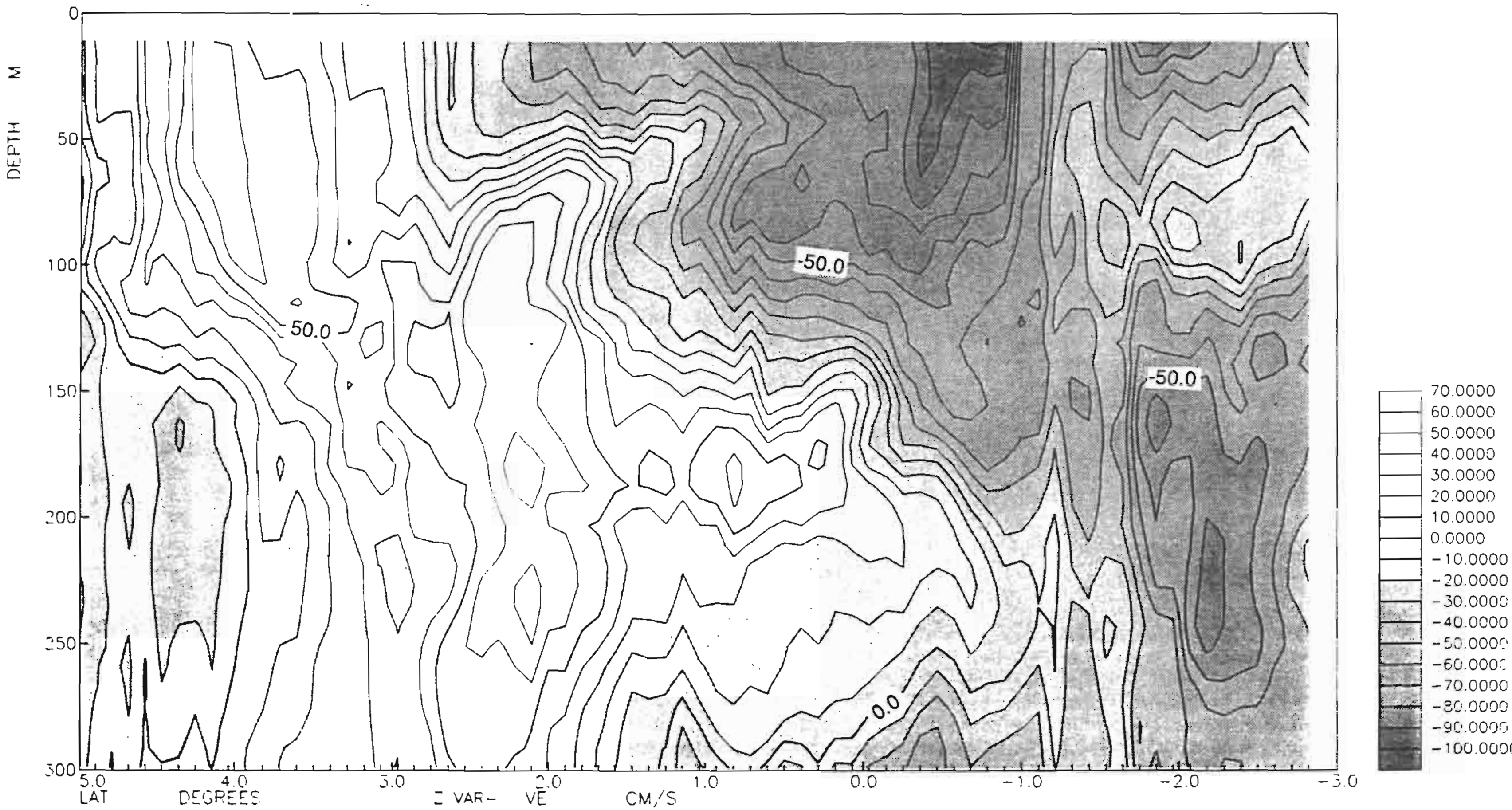
Near the surface the main core of the South Equatorial Current lies between 1°N and 1°S. Westward velocities in excess of 50 cm s^{-1} extend down to 100 m and the maximum velocity of 1 m s^{-1} is found near the southern boundary of the core region.

Further north the core of the North Equatorial Counter Current (NECC) is observed between 3°N and 5°N. The current also extends down to 100 m and has a maximum velocity in excess of 60 cm s^{-1}.

Below these lies the eastward flowing Equatorial Undercurrent. The outer limits extend from 1°S to 4°N, (the latter joining with the NECC), but the main current region lies between the equator and 3°N with a core at 2°N. Most of the current has speeds of over 30 cm s^{-1} and these rise to 70 cm s^{-1} in the core region.

Below the SEC, the undercurrent is limited in depth to a range between 150 m and 250 m but in its core region it has a much larger vertical extent, from 60 m to more than 300 m. Similar complex vertical structures has been observed by Eldin (1989).

Figure 2. East-west velocities on the section at 142E



Near 3°S the New Guinea Coastal Undercurrent is observed between 100 and 300 m. It has a widths of about 100 kms and maximum velocities to the west of over 60 cm s^{-1}. At the surface, the flow is also westward, presumably this is another branch of the South Equatorial Current, but below this and extending from 60 m to 100 m is a region of weak easterly flows. The following section on 3°S shows this flow continuing to the east.

b. The temperature and salinity sections

Figs. 3 and 4 show the temperature and salinity fields measured by the CTD mounted in the SeaSoar. Calibration checks were made before and after the cruise and against water bottles during the cruise. Because of the possibility of fouling of the sensor, the salinity was checked at the top of each cycle against the ship mounted thermosalinograph. T/S profiles were also plotted during each cycle of the SeaSoar to check for jumps due to fouling but in the unproductive waters of the region such events were relatively rare. For plotting figures 3 and 4, data has been averaged into 4 km bins along the ships track.

The primary feature of the temperature record is the high and almost uniform near surface temperatures. The main thermocline lies below 100 m and the water above this appears reasonably well mixed in both the vertical and the horizontal.

The salinity on the section is shown in Fig 4. The main feature is a thick intrusion of high salinity South Pacific water, with salinities of over 34.8, which appears to be pushing northward into the less saline North Pacific waters.

However although the intrusion appears as a coherent feature, there is an important boundary at a depth of approximately 130 m between South Pacific waters advected westwards into the region by the surface South Equatorial current and by the deeper New Guinea Coastal Undercurrent.

In the lower layer, salinities of over 35.3 are found at a depth of 170 m extending from the New Guinea coast to 1°N. Slightly diluted the intrusion extends to 2°N where, with the upper layer, it meets the North Pacific water in a strong front right at the core of the Equatorial Undercurrent. Temperatures in the lower layer are generally less than 24°C.

The source of the upper layer appears to be the South Equatorial Current which brings South Pacific water into the region from the surface to 150 m with temperatures of over 28°C. This results in a sharp thermocline separating water from the two sources. Note also that despite their different origins, the two water masses combine to form a single intrusion into the North Pacific waters.

In the upper layer there is no high salinity core associated with the South Equatorial Current but there is continuity in water type between the water being advected westward by this current and the northward extension of the intrusion. Thus the change of salinity on an isopycnal between 0.5°S and 2°N is only 0.2 parts per thousand whereas the change in salinity across the front near 2.2°N is over 0.5 parts per thousand.

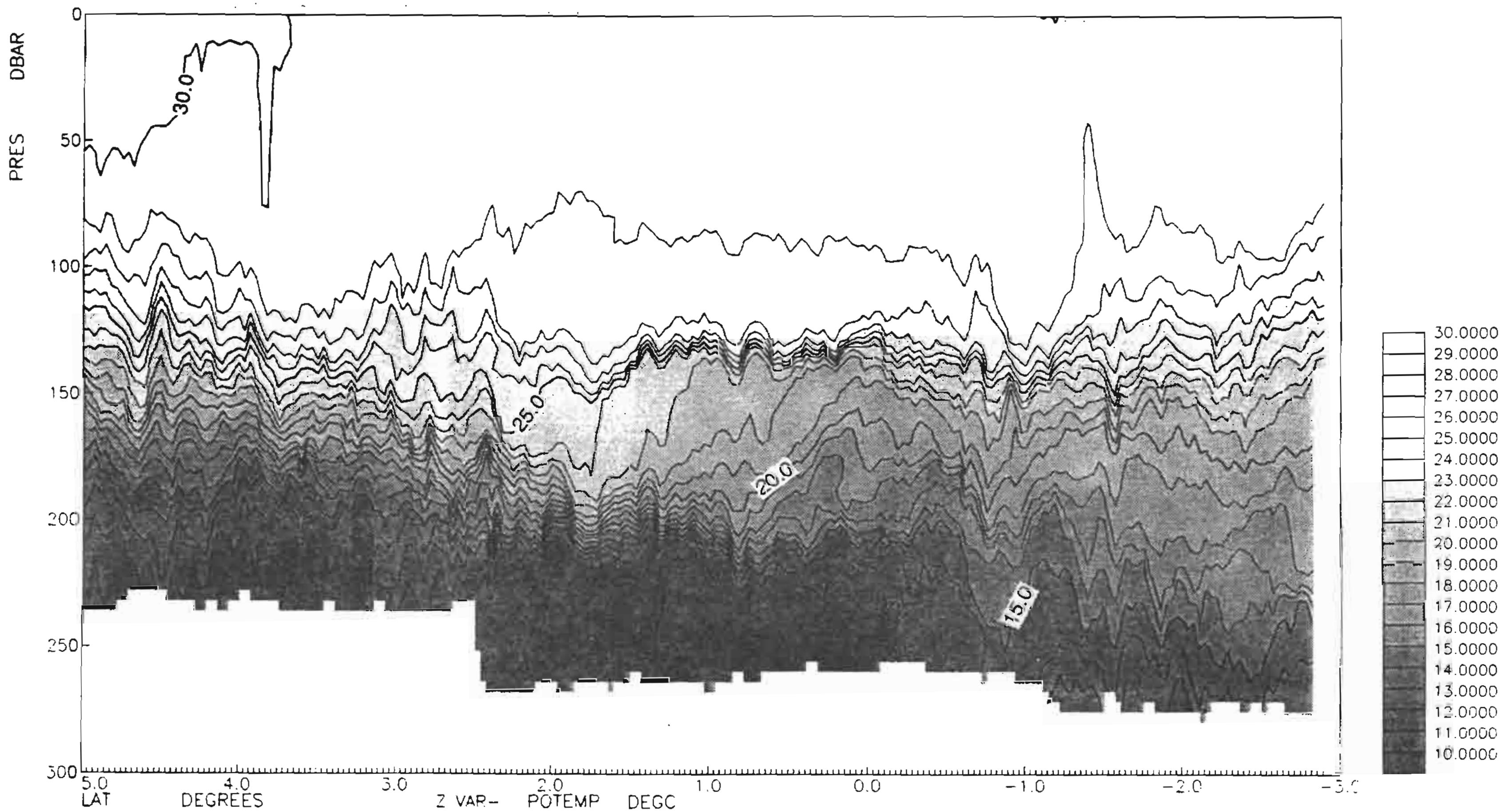
Between 0.5°S and 2°N the upper surface of the intrusion is marked by a strong halocline at a depth of 50 m. This halocline lies in a region of weak vertical temperature gradients. It has similarities to that reported by Lukas and Lindstrom (1987) but has a much larger salinity difference.

Another feature of this halocline is that it also marks the line of the upper extension of the equatorial undercurrent. Unfortunately the vertical resolution of the ADCP is not as good as that of the SeaSoar/CTD but the line of maximum westward flow follows the line of the main halocline in this region with more easterly flows in the North and South Pacific waters above and below.

The near surface halocline also extends, and affects the currents, right into the maximum current core of the South Equatorial Current at 0.5°S.

Between 1°S and 2°S the strong halocline disappears and in places the surface layer is mixed down to depths of 120 m and more. Similar deep mixed layers also show up in the surface North Pacific waters between 3°N to 4°N.

Figure 3. Temperature on the section at 142E



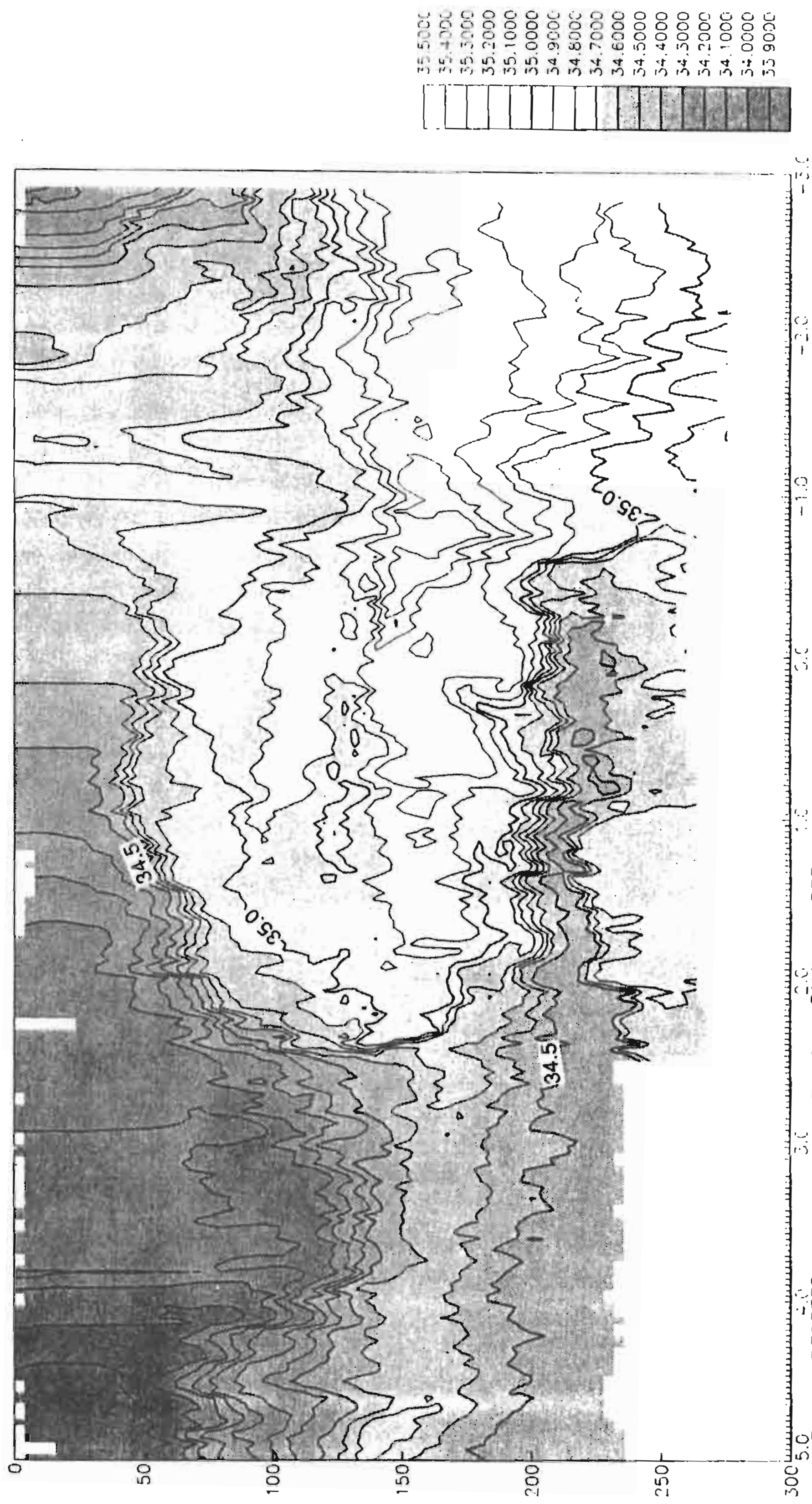


Figure 4. Salinity on the section at 142E

At the northern end of the section the North Pacific has a maximum salinity at a depth of 150 m. Above this salinities of below 34.0 are found in the surface layer. Similar low surface salinities are seen in the south at the New Guinea, probably the effect of river discharges.

At 220 m, below the main intrusion of South Pacific water, there is a further shallow intrusion of North Pacific water extending south to the equator and overlying another layer of South Pacific water at 250 m. The southern end of the intrusion at 220 m also corresponds to the southern edge of the Equatorial Undercurrent. Other small intrusions can be seen within the main South Pacific water mass, for example between the equator and 1°N at depths between 100 and 150 m.

3. Discussion.

The analysis of the data is still at an early stage but already a number of features are apparent. First the salinity contrast between the North and South Pacific water types is important with intrusions and strong fronts developing at the boundary of the two regions.

In the section along 142°E, the core of the Equatorial Undercurrent was found to be displaced north from the equator to 2°N. This may be connected to the observation that the core of the undercurrent coincides with the position of the northern limit of the main intrusion of South Pacific water or it may be coincidental. However at shallow depths the maximum eastward current follows the line of the halocline so the salinity front must be having some effect on the dynamics. Cooper (1988) also emphasizes the importance of salinity in tropical regions.

The strong halocline observed between the equator and 2°N at depths near 50 m between is very similar to that which has been observed using CTD casts in the region. The present results show that it can arise as a result of the saline South Pacific water intruding into the less saline North Pacific water.

The sharpness of the halocline at 50 m (and the one below the intrusion at 200m), is especially noticeable when compared to the more uniform north-south change in salinity in the top 50 m. Within the region surveyed, little turbulence is produced at the surface because of the low average winds and waves, so the observed fronts may be being sharpened up by turbulence caused by the strong vertical current shears present.

It is also noticeable that the strong near surface halocline has little effect on the ocean temperature structure in the top 100 m. The vertical flux of heat into the layers above and below the halocline must be small - at least compared to that due to advection or diffusion in from other areas unaffected by the halocline.

To conclude, data from RRS Charles Darwin cruise 34A is still being worked up by the results so far confirm that salinity is important in the Western Equatorial Pacific and that shear produced turbulence may also be important.

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