JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 88, NO. C10, PAGES 5987–5996, JULY 20, 1983

Surface Mixed Layer Temperature and Layer Depth in Water Off the Argentinian Coast

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Analysis of 26 years of bathythermographic data is used to describe the connection between the sea surface temperature and the layer depth in the western South Atlantic, off the Argentinian coast. The area is influenced by the presence of two water masses, subtropical waters and subantarctic waters. A seasonal analysis was carried out for 5° squares. The plotting of mixed layer depth versus surface temperature provides two types of patterns. Evidence suggests that they might be related to the presence of each of the above-mentioned water masses. A clear relationship was found for data distribution in each subarea. The exponential function $L = a \exp(-bT_s)$ was found to fit best the dependence of the mixed layer depth (L) on the surface temperature (T_s). Very defferent ranges were empirically found for the real constants a and b depending on the predominant water mass in each subarea.

INTRODUCTION

The sea surface temperature and its relationship with the thermocline depth have been the subject of a large number of studies in the last 30 years [*Munk and Anderson*, 1948; *Mazeika*, 1960; *Tully*, 1964; *Kenyon*, 1978]. Many theoretical models [*Kitaigorodsky*, 1960; *Kraus and Turner*, 1967; *Tuner and Kraus*, 1967] were developed to explain the thermal structure of the oceans and its temporal and spatial variations. The problem is quite complex because it involves several physical processes. Accordingly, such models hold only for local geographical regions.

Despite the large amount of data existing for the northern hemisphere, there is little information available in the South Atlantic Ocean and especially near the Argentinian coast. In the present work, about 9100 bathythermograms (BT) from the western South Atlantic Ocean off the Argentinian coast, collected over the period 1954-1980, were analyzed. The aim of this paper is to explore the relationship between the sea surface temperature and the mixed layer depth. Seasonal as well as geographical variations have been studied. Two distinctive relationships were observed that seem to be correlated with the presence of different water masses.

AREA CHARACTERISTICS

The shaded area shown in Figure 1 represents the geographical region for which the BT's were analyzed.

According to the traditional classification [*Deacon*, 1933] in the above-mentioned area, there are two water masses (see Figure 1), namely, subtropical waters (transported by the Brazil current) characterized by its high salinity and temperature values and subantarctic waters (in which Malvinas current [*Gordon*, 1981] becomes predominant) characterized by lower values of salinity and temperature.

Figure 2 shows a current pattern [*Sverdrup et al.*, 1946] for the studied area, where the predominant effects of the two above-mentioned currents can be visualized. As it is well known, the confluence of both currents gives rise to the so-called Convergence Zone , where both northern and southern boundaries are not well defined. This has been pointed out by *Sverdrup et al.* [1946], who mentioned that the location of the Subtropical Convergence is less well defined than the Antarctic Convergence, and, consequently, he considered it more correct to refer to a region instead of referring to a line of convergence[*Defant*, 1938].

Figure 1 schematically shows the distribution of the water masses in the studied area according to *Boltovskoy* [1970]. It should be emphazised that this configuration is only a gross approximation to the actual distribution since the location of the Convergence Zone is highly dependent on seasonal variations.

MIXED LAYER DEPTH VERSUS SURFACE TEMPERATURE

The area was divided in 12 5° square for data anlysis. Mixed layer depth is established as the top of the seasonal thermocline, that is the level where the temperature gradient is more than 0.2° C per 20 m. Mixed layer depth versus surface layer temperature was plotted for every season of the year in each of the above-mentioned subareas.

Figures 3 and 4 show the results for two adjacent subareas (35° S to 40°S, 50°W to 55°W and 35°S to 40°S, 55° W to 60° W). It was found that those subareas mainly influenced by the Subtropical Water Mass exhibit a pattern as that shown in Figure 3. Subareas influenced by the Subantarctic Water Mass exhibit a pattern as shown in Figure 4 which seems to be the mirror image of that shown in Figure 3. For the Convergence Zone, the relationship is not well defined, and both types of patterns occur simultaneously.

The two above-mentioned distinctive patterns are schematically represented in Figure 5. In Figure 6, each subarea is labeled with letters A or B, according to which of the two types of patterns, shown in Figure 5, it exhibits.

Althouh all data turned out to be distributed according to one of the two patterns mentioned above, it must be pointed out that data density was found to be nonuni-

Paper number 2C1935.
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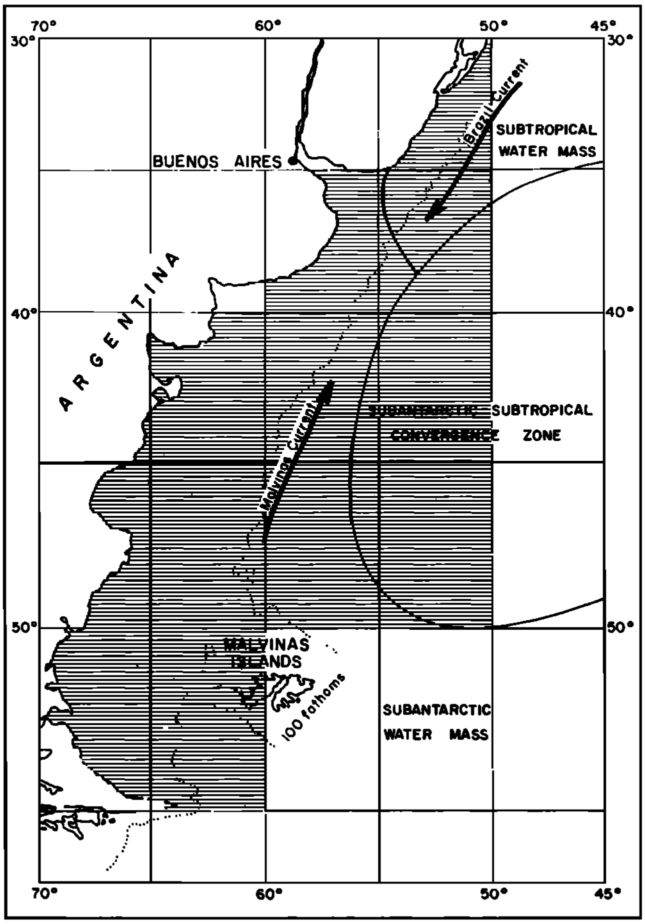

Fig. 1. Map of the area in which BT traces were analyzed, with a schematic distribution of water masses and currents.

form for all the subareas. The number of observations is indicated on each of the scatter plots. The corresponding histograms presented in Figures 7 and 8 show the observed distribution fuctions of mixed layer depth and surface temperature.

Mean values of surface temperature and mixed layer depth were computed monthly for each subarea. The two distinctive relationships appear again as it is shown in Figures 9 and 10 for the subareas lying in the Subtropical Water Mass and Subantarctic Water Mass, respectively. It should be noticed that these figures show the same qualitative behavior obtained by the one-dimensional theorical model of the seasonal thermocline [*Kraus and Turner*, 1967].

Concerning the relationship between the mixed layer depth and the sea surface temperature, it was observed a clear tendency of the plotted points to follow an approximate distribution of the type

$$L = a \cdot \exp\left[-bT_s\right] \qquad (1)$$

where L is the mixed layer depth, T_s is surface temperature and the parameters a and b are real constants. The regressions methods that were applied to the existing data provided the exponential function (equation (1)) as the best fit.

Figure 11 shown the regression lines through the data plots, corresponding to spring, for six different subareas out of the entire area under study. The calculated correlation coefficients are included in each plot as well as the predominant water mass in each of these subareas.

It can be observed that the plots shown in Figure 11 are good examples of the two types of patterns (see Figure 5) and their apparent correlation with the presence of a particular water mass.

Following the two distinct relationships mentioned above, two very different ranges of values were empirically found for the constants a and b. For all the subareas influenced by the Subtropical Water Mass, $0.45\ \text{m} \le a \le 2.00\ \text{m}$ and $b \cong -0.2°\,\text{C}^{-1}$ while for the subareas influenced by the Subantarctic Water Mass, $160\ \text{m} \le a \le 1870\ \text{m}$ and $b \cong 0.3°\,\text{C}^{-1}$.

It is noteworthy that a similar correlation between water masses and the dependence of mixed layer depth on sea surface temperature has been previously observed by *Thompson and Anderson* [1965] in the northwestern Atlantic. They found a clear correlation between the water masses transported by the Gulf and Labrador currents and the behavior of the two parameters under study for an area influenced by both currents.

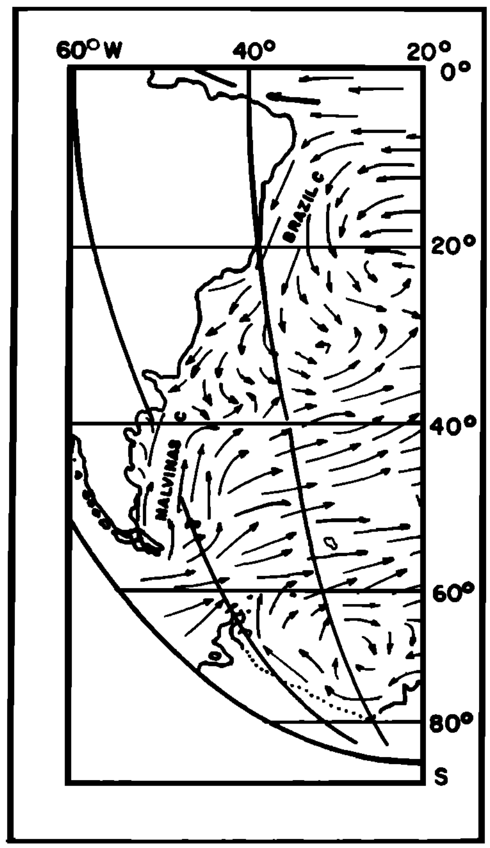

Fig. 2. Chart of ocean surface currents for western South Atlantic [after *Sverdrup et al.*, 1946].

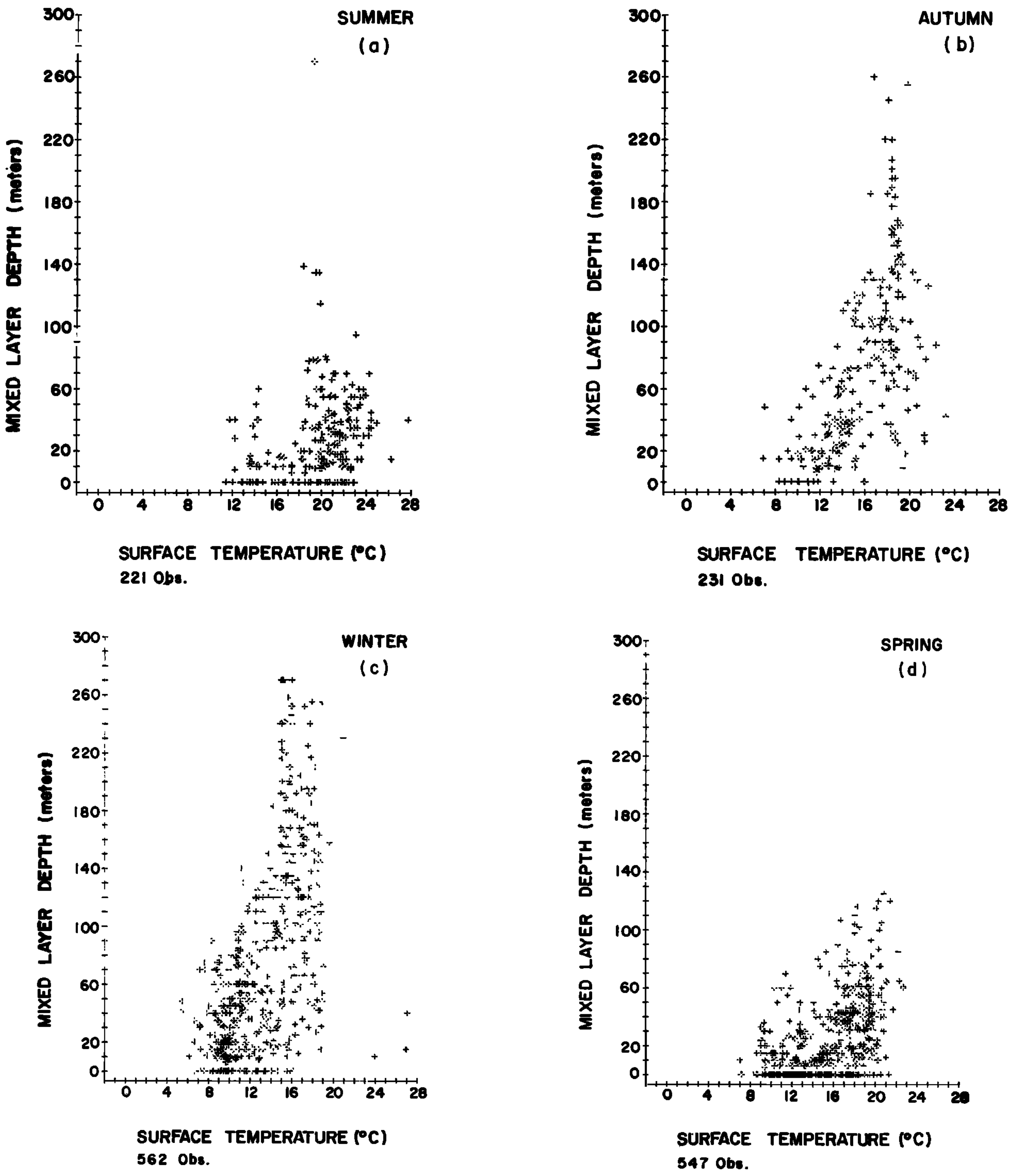

Fig. 3. Mixed layer depth versus sea surface temperature for the western South Atlantic Ocean area (35° S to 40° S, 50°W to 55°W). (*a*) Summer, (*b*) autumn, (*c*) winter, (*d*) spring.

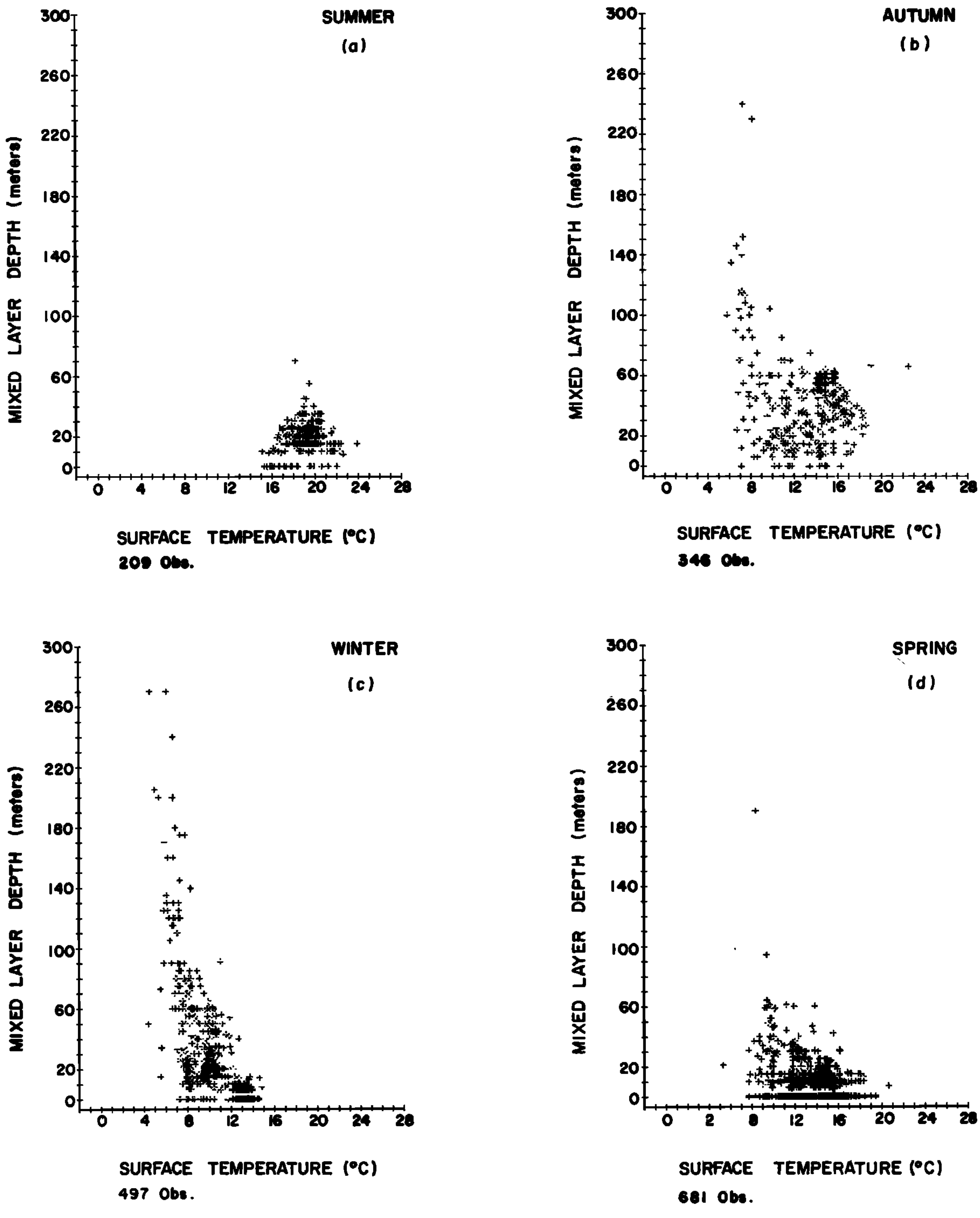

Fig. 4. Mixed layer depth versus sea surface temperature for the western South Atlantic Ocean area (35°S to 40°S, 55°W to 60°W). (*a*) Summer, (*b*) autumn, (*c*) winter, (*d*) spring.

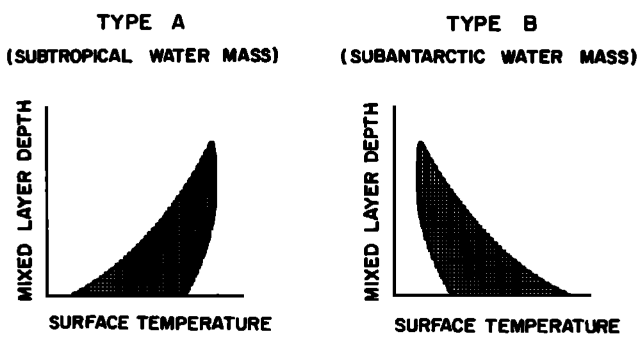

Fig. 5. Qualitative patterns showing the two distinct relationships for mixed layer depth versus sea surface temperature plots, depending on water masses influence.

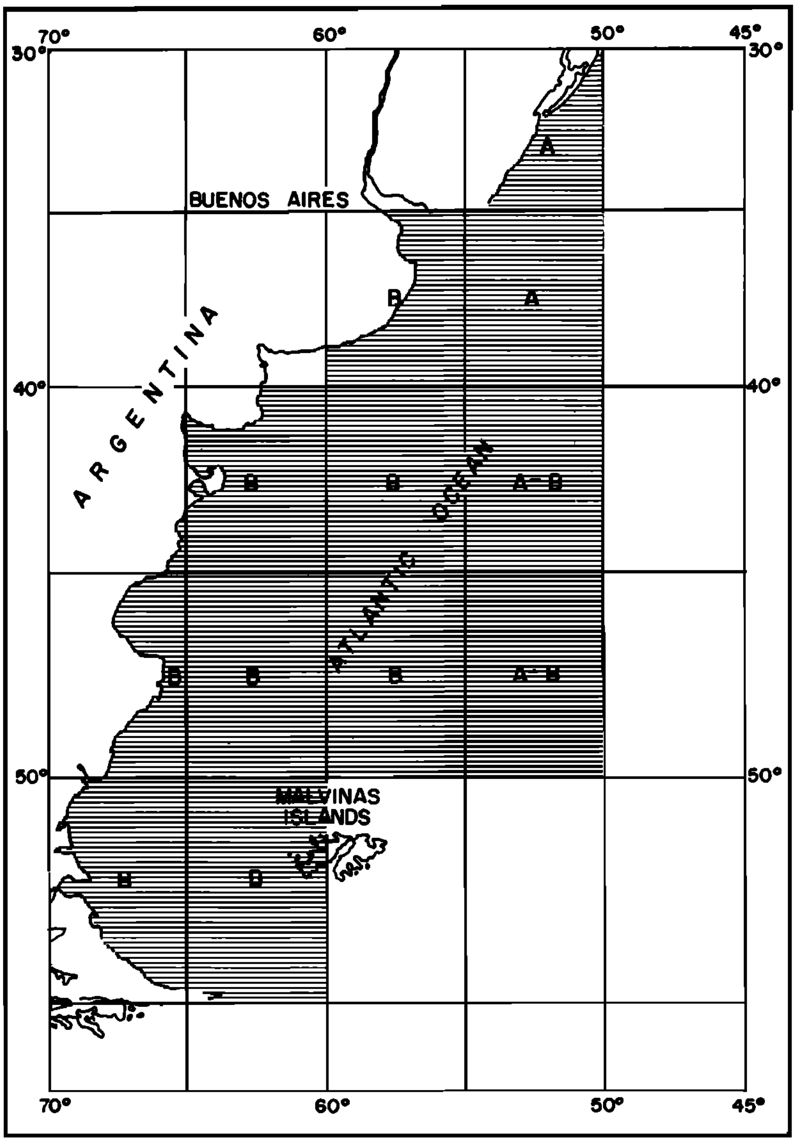

Fig. 6. Distribution of the characteristic patterns, types A or B, in the studied area.

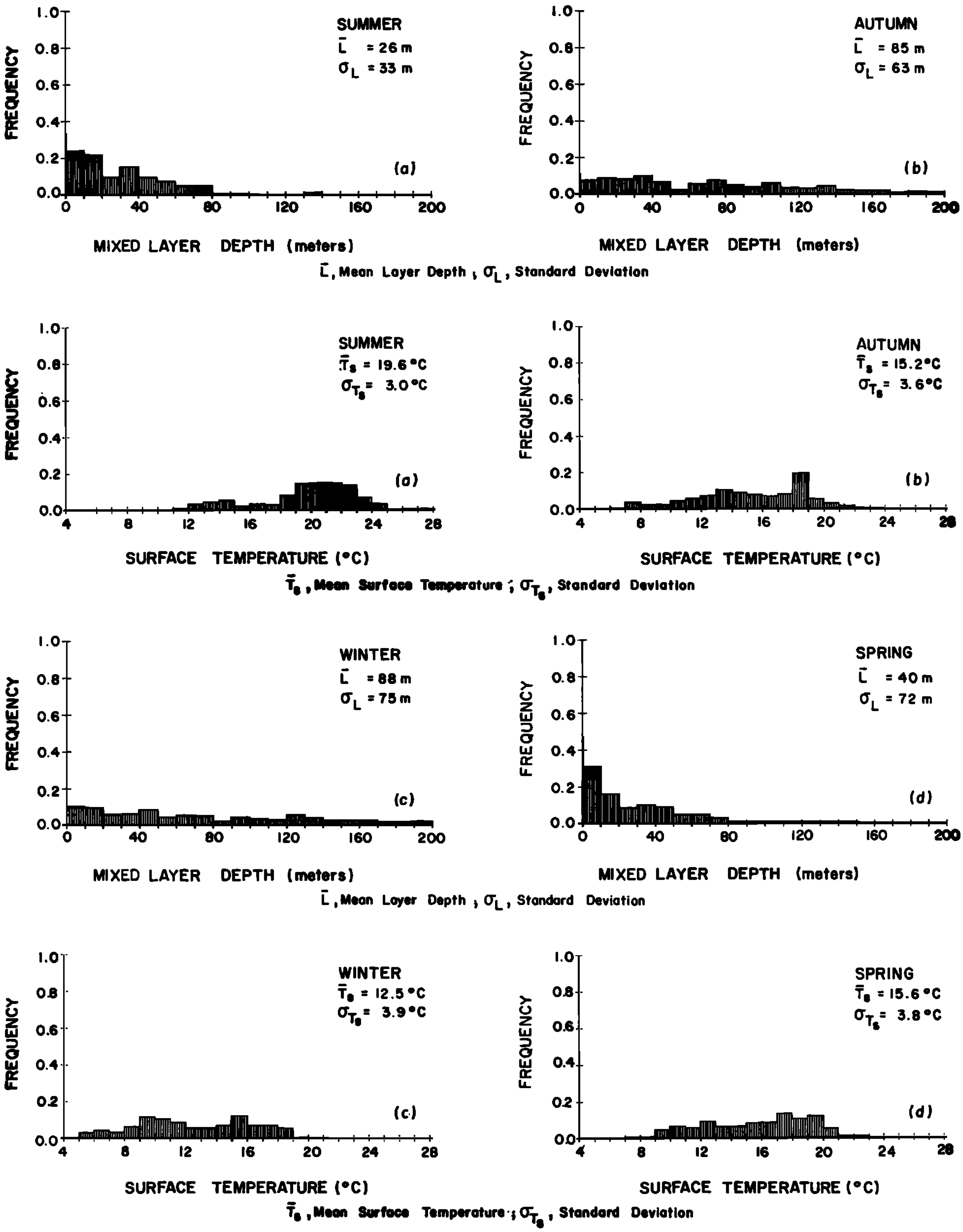

Fig. 7. Histograms relating the frequency of observations with the mixed layer depth and the sea surface temperature, respectively, for the western South Atlantic Ocean area (35°S to 40°S, 50°W to 55°W). (*a*) Summer, (*b*) autumn, (*c*) winter, (*d*) spring.

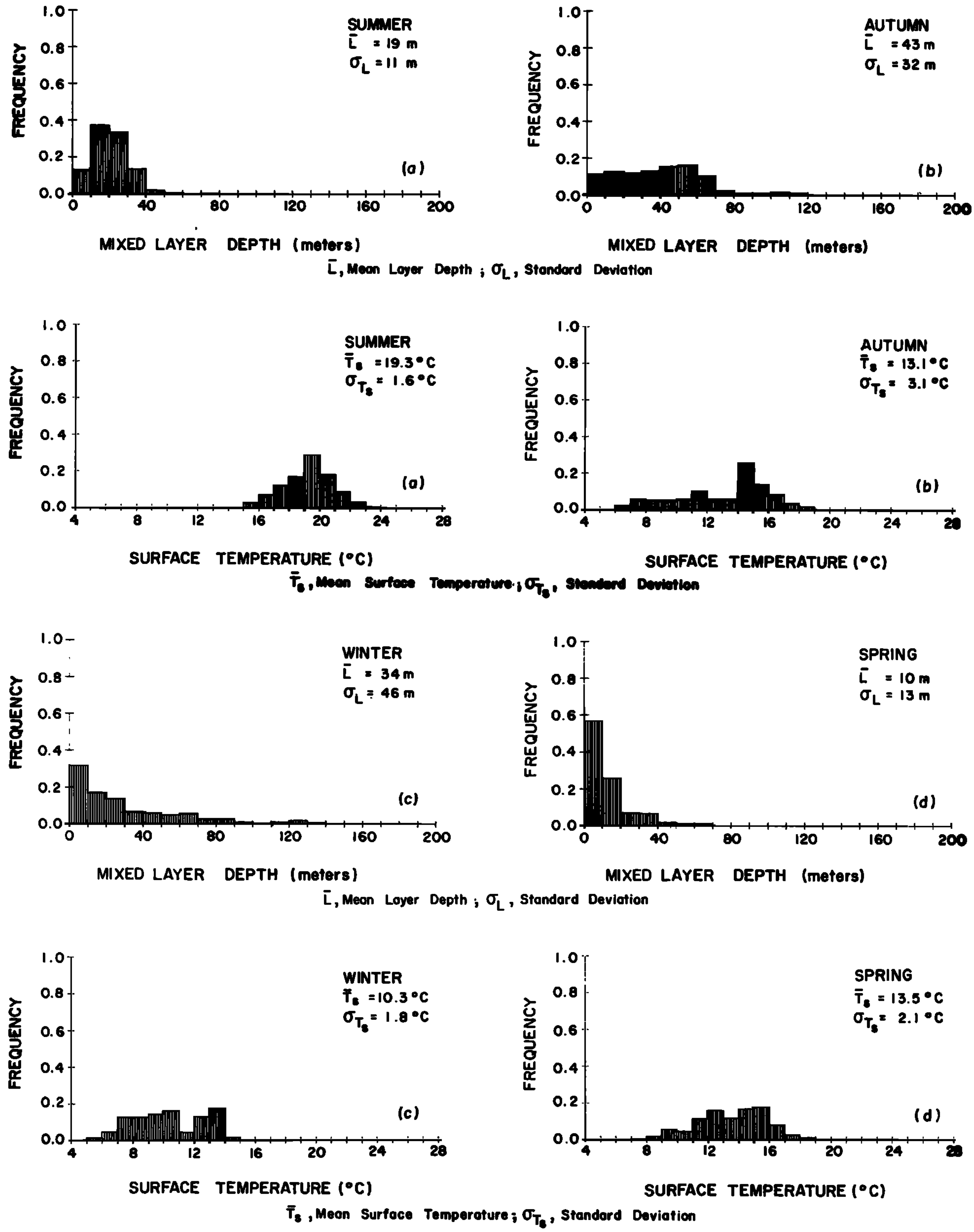

Fig. 8. Histograms relating the frequency of observations with the mixed layer depth and the sea surface temperature, respectively, for the western South Atlantic Ocean area (35° S to 40° S, 55° W to 60° W). (*a*) Summer, (*b*) autumn, (*c*) winter, (*d*) spring.

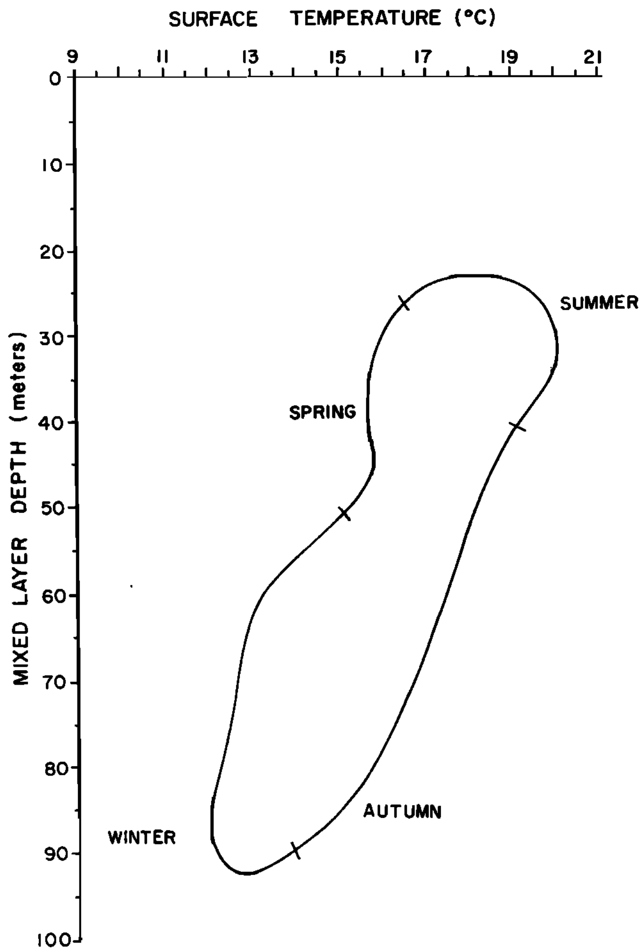

Fig. 9. Mean values of mixed layer depth, averaged over each season of the year, plotted against their corresponding sea surface temperature for the western South Atlantic Ocean area (35°S to 40°S, 50°W to 55°W).

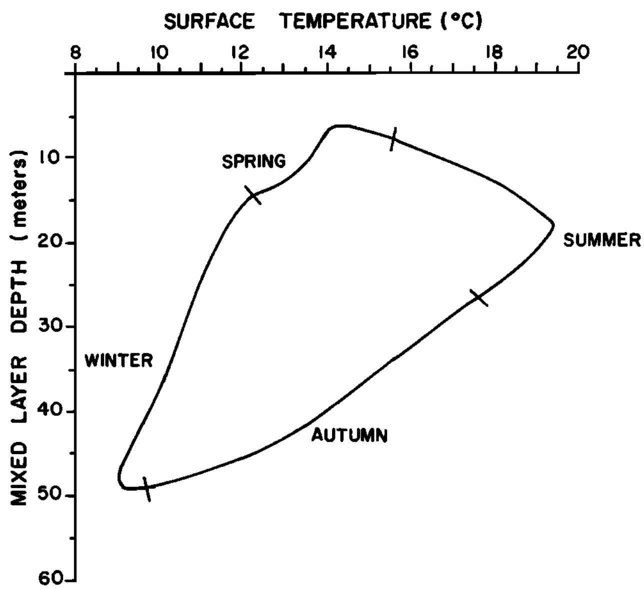

Fig. 10. Mean values of mixed layer depth, averaged over each season of the year, plotted against their corresponding sea surface temperature for the western South Atlantic Ocean area (35°S to 40°S, 55°W to 60°W).

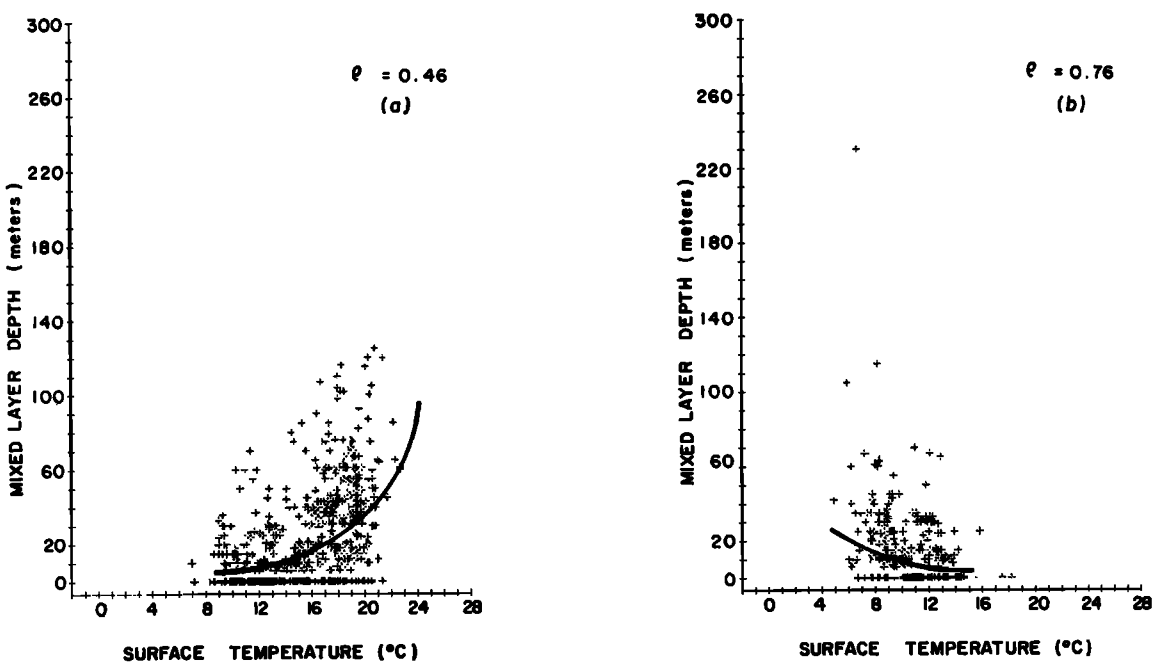

Fig. 11. Regression lines through data plots for six subareas mainly influenced by (*a*) Subtropical Water Mass; (*b*), (*c*), (*d*), (*e*), (*f*) Subantarctic Water Mass. (ρ , correlation coefficient).

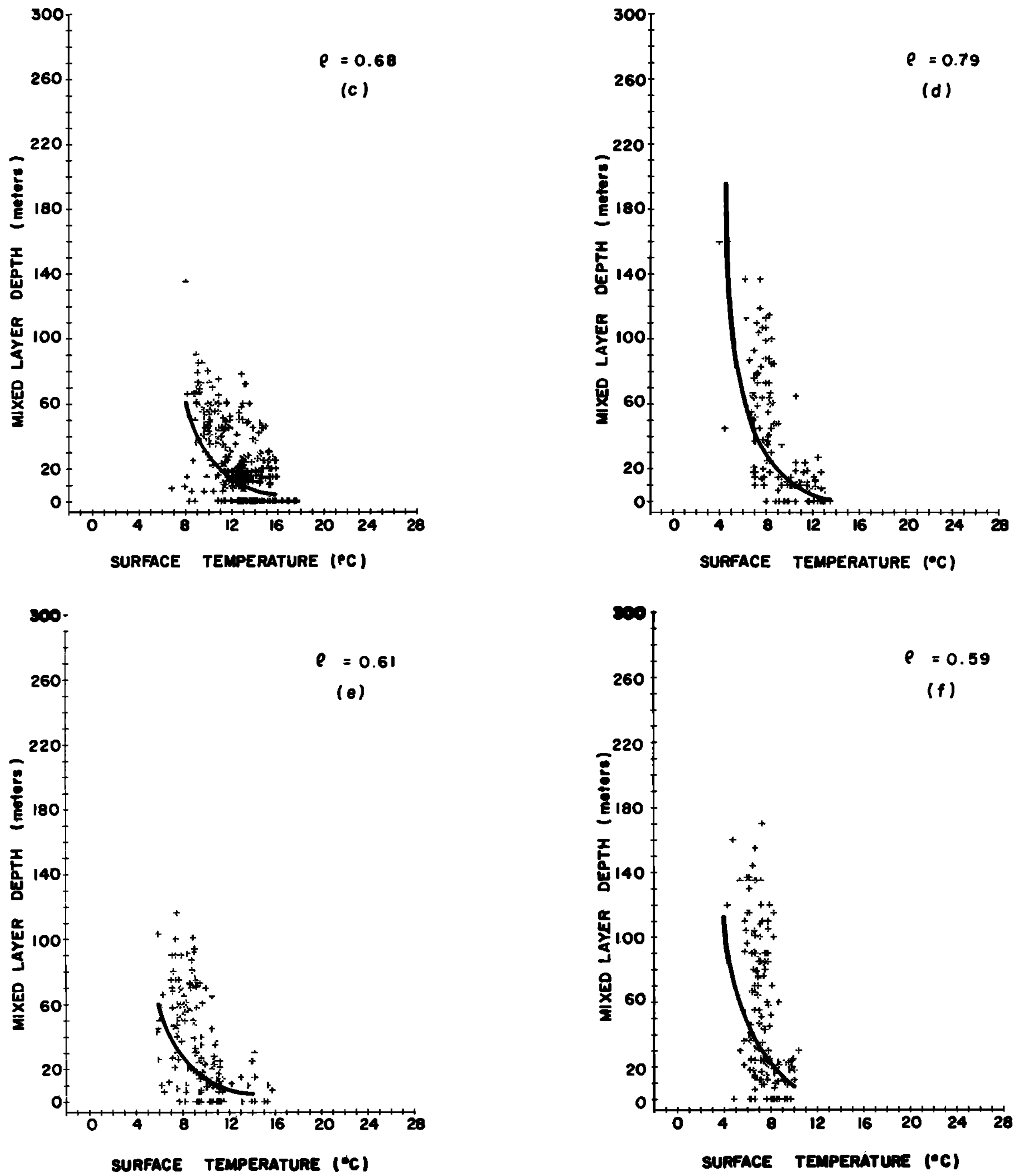

Fig. 11. (continued)

Concluding Remarks

From the available data in the studied area, an exact functional relationship between the mixed layer depth and the surface mixed layer temperature could not be found as it would have been desirable in orden to allow future prediction work on the subject. However, it is unlikely that an exact relationship exists. Some features of an approximate relationship have been visualized. It seems to be governed by the dominant water mass in the area.

Acknowledgments. The authors wish to acknowledge Ana María Coronado who played the major role in the data collection and its analysis, Clementina Pamies, Norberto Gabriel Sabbatella, and Marta Varela de Arufe for their assistance in carrying out this program.

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(Received January 22, 1982;
reviced September 29, 1982;
accepted October 5, 1982.)