

The Oceanographical Research in the Southern Region of the Hawaiian Islands—IV

Mixing Stages of Water Masses

Yasutaka YUWAKI* and Tomio HENMI*

Abstract

The values of the water temperature and the salinity are determined by drawing the mean T-S curve for several stations obtained in oceanographic surveys from 1977 to 1980 in the southern region of the Hawaiian Islands. The mixing stages of water masses are examined by the T-S curves. The T-S curves can be classified into five groups in the area between 06°N–19° N latitude. At 19° N latitude the T-S curve indicates the eastern North Pacific Central Water. The boundary zone between the water masses from the north and the south is found near 07°N latitude, where the subsurface salinity maximum and minimum are not recognized. The transitional stages with latitudinal change between the Pacific Equatorial Water and the eastern North Pacific Central Water are shown.

1. Introduction

Since 1977, the Keiten Maru (G.T. 860 ton) of Kagoshima University occupied the tuna-fishing operation and oceanographic survey in every May and June in the southern region of the Hawaiian Islands, as shown in Fig. 1.

The results of the oceanographical condition and the distribution of zooplankton are reported in the previous papers (Yuwaki and Henmi, 1978, 1979 and 1980). In the present paper, the mixing stages of water masses in this area are examined using data obtained by the Keiten Maru from 1977 to 1978 in oceanographic surveys. The transitional stages with latitudinal change from the deeper Pacific Equatorial Water to the shallower eastern North Pacific Central Water are discussed.

2. Determination of Water Types

In the southern region of the Hawaiian Islands, a temperature and salinity curve has an inverted form of the letter 'S' characterized by a salinity maximum at a depth of about 100 m–150 m and a salinity minimum at a depth of about 400 m–500 m; the former corresponds to the subsurface saline water and the latter to the subarctic intermediate water.

In order to discuss the mixing stages of water masses in the southern region of the Hawaiian Islands, it is necessary to determine the original values of the water types related to the region under consideration, because a water mass is formed from the

* Training ship Keiten Maru, Faculty of Fisheries, Kagoshima University.

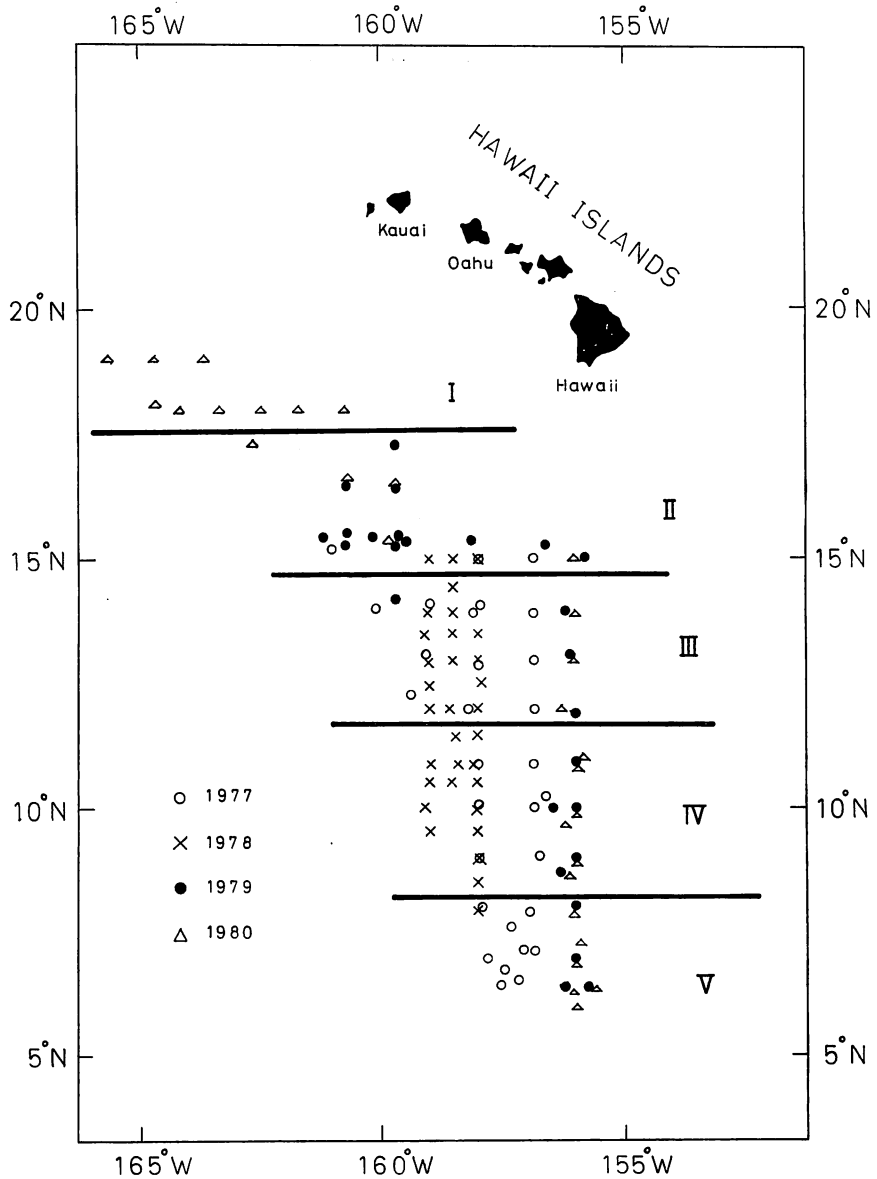


Fig. 1. Map showing the oceanographic stations and the boundaries between five geographical divisions. Symbols: circles, 1977; crosses, 1978; dots, 1979; triangles, 1980.

mixture of certain water types.

In the present paper, the original values of the water types are determined by drawing the mean T-S curve using several data obtained in this region at 18°N–19°N latitude and 164°W–166°W longitude. The mean T-S curve consists of three straight segments. Two intersections which show the respective original water types are obtained by drawing tangents to these straight segments. As shown in Fig. 2, the approximate origin values of the temperature and the salinity are 22.0°C and 35.25‰ in the subsurface saline water, and 9.0°C and 34.05‰ in the subarctic intermediate water. The subsurface saline water and the subarctic intermediate water in the eastern North Pacific Ocean are abbreviated as the EC-water and the EI-water hereafter.

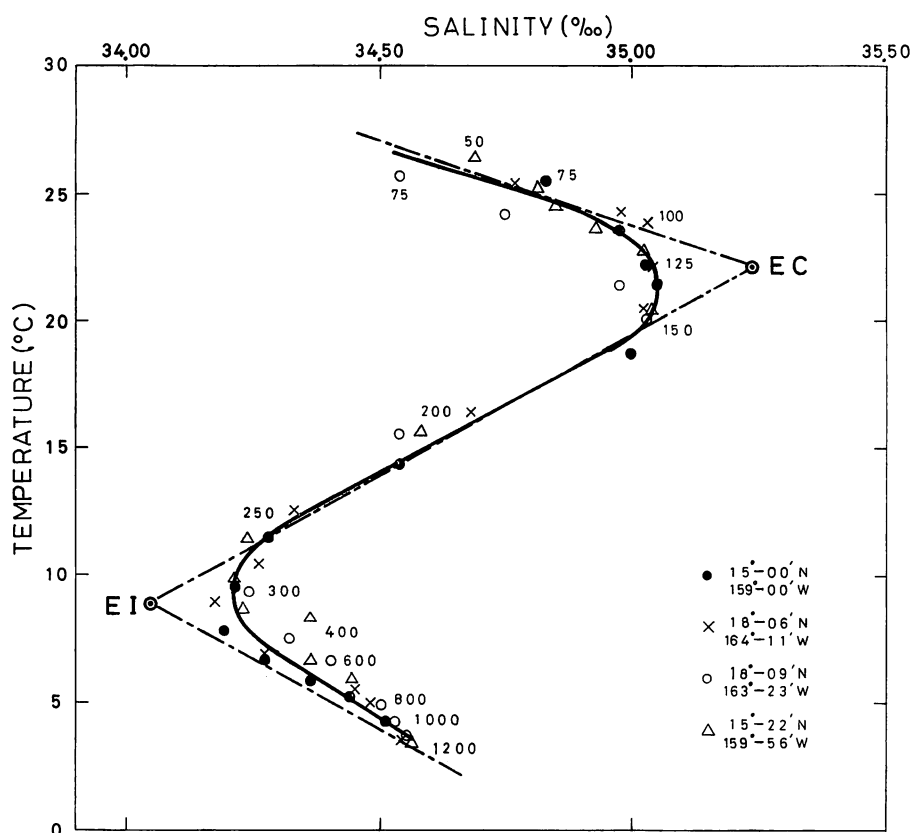


Fig. 2. Example of the mean T-S curve in the southern region of the Hawaiian Islands. Observing depths are entered. (m)

3. Division of the water mass by T-S curves

The T-S curve for each station has various forms according to rate of the mixture

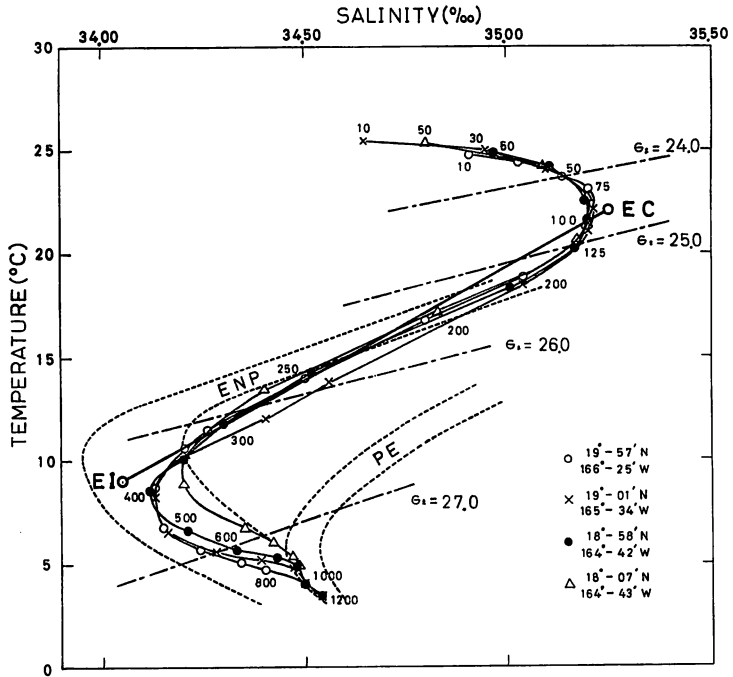


Fig. 3, a. Examples of T-S curves in the first area. Observing depths are entered. (m)
 E. N. P., eastern North Pacific Central Water. P. E., Pacific Equatorial Water.

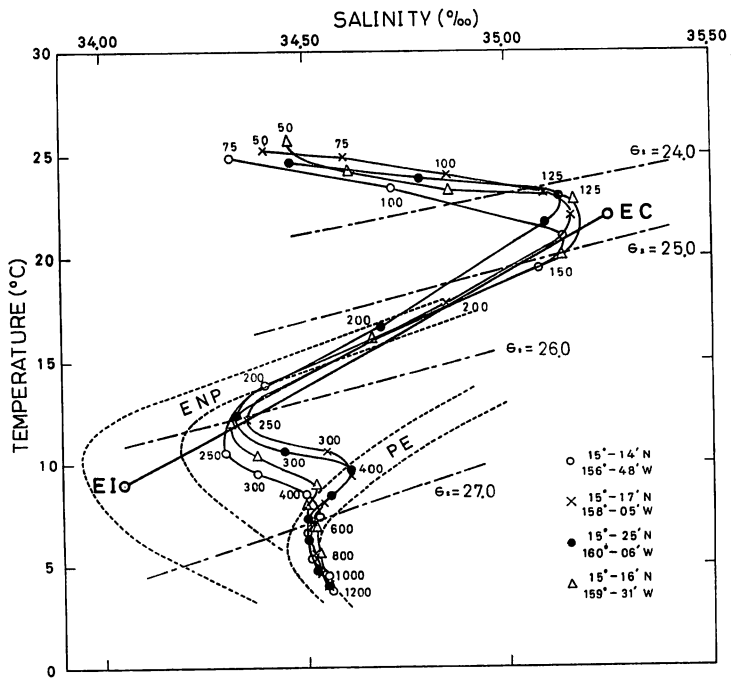


Fig. 3, b. Examples of T-S curves in the second area. Observing depths are entered. (m)
 E. N. P., eastern North Pacific Central Water. P. E., Pacific Equatorial Water.

of the origin water types, and has a quite similar form for the station located within a certain area.

It is convenient, therefore, to divide the region under consideration into several subregions according to the types of T-S curves in order to study the mixing stages of water masses in this area. The T-S curves are shown in Fig. 3 for five subregions (in Fig. 1) in the southern region of the Hawaiian Islands. The eastern North Pacific Central Water and the Pacific Equatorial Water defined by Sverdrup et al (1942) are indicated by dotted bands.

(1) The First Group (Fig. 3, a)

This group is found in the area between 18°N and 19°N latitude, where the North Equatorial Current flows. The EC-water of the salinity maximum is clearly found at a depth of about 100 m–150 m. Below this layer the salinity decreases linearly to the intermediate water. The T-S curves between 200 m–300 m coincide with a straight line passing through the EC-water and the EI-water, showing that the water in the layer is a mixture of these two water masses. The EI-water of the salinity minimum

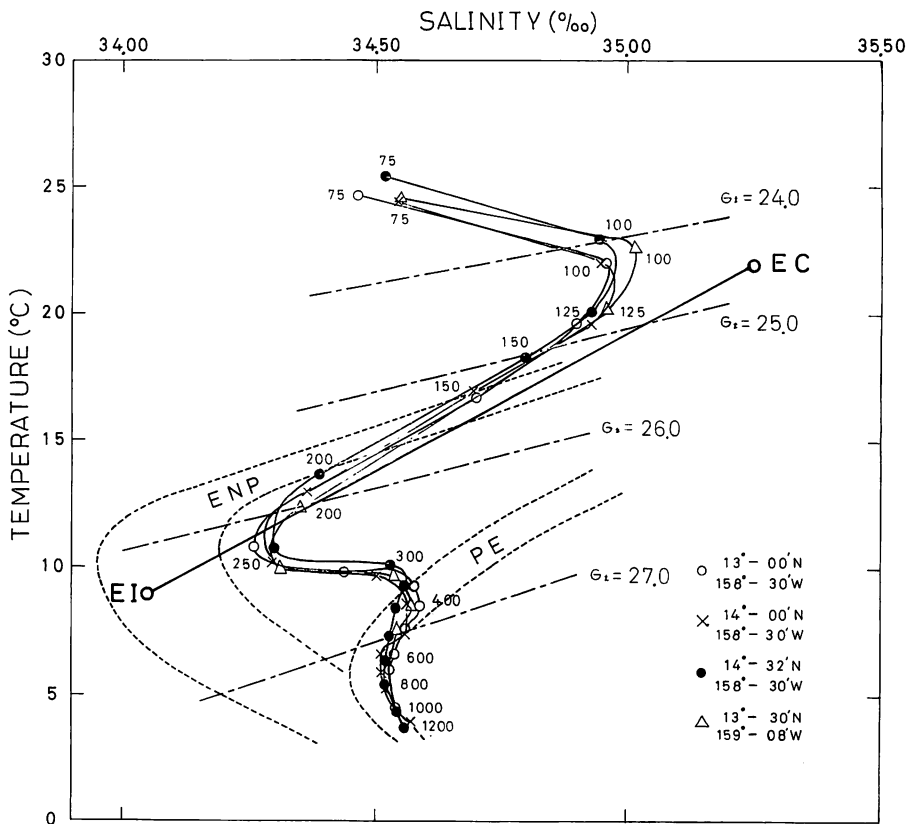


Fig. 3, c. Examples of T-S curves in the third area. Observing depths are entered. (m)
E. N. P., eastern North Pacific Central Water. P. E., Pacific Equatorial Water.

is found at a depth of about 400 m. The T-S curves below at a depth of about 200 m coincide with that of the eastern North Pacific Central Water.

(2) The Second Group (Fig. 3, b)

This group is found in the area between 15°N and 17°N latitude. The low salinity water is found at the surface and the value of the surface salinity is about 34.50‰. The T-S curves between 125 m–200 m is quite similar to that of area 1. The salinity minimum of about 34.30‰ is found at a depth of about 250 m. The salinity minimum is a mixture of the EC-water and the EI-water at a rate of 1:4. The second minimum of salinity is found at a depth of about 800 m and the values of the temperature and the salinity are about 6.0°C and about 34.50‰. The T-S curves below about 400 m in this area coincide with that of the so-called Pacific Equatorial Water mass. (Sverdrup et al. 1942)

(3) The Third Group (Fig. 3, c)

This group is found in the area between 12°N and 15°N latitude, where is the center of the North Equatorial Current. The T-S curves of this area is quite similar to

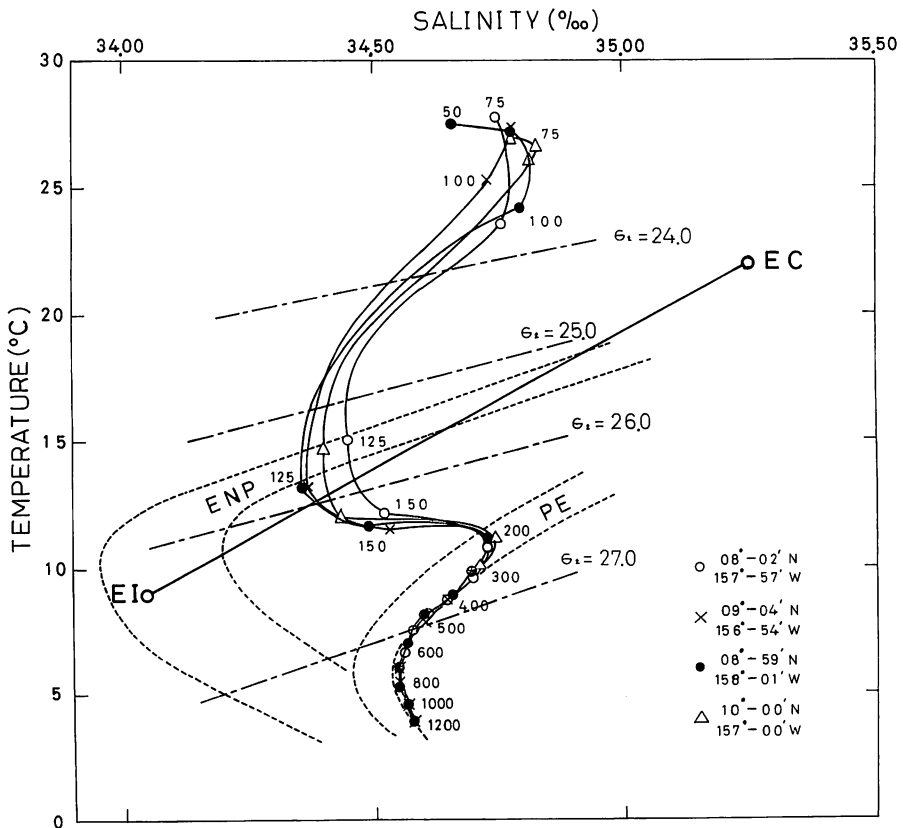


Fig. 3, d. Examples of T-S curves in the fourth area. Observing depths are entered. (m)
E. N. P., eastern North Pacific Central Water. P. E., Pacific Equatorial Water.

that of area II, though the value of the salinity maximum at a depth of about 100 m is somewhat low compared with that of area II. The water of the salinity maximum found at a depth of about 100 m has T =about 22.0°C , S =about 35.00‰ , which consists of the EC-water, mixed with some of the surface water and the EI-water.

(4) The Fourth Group (Fig. 3, d)

This group is found in the area of the southern part of the North Equatorial Current, situated between 08°N and 12°N latitude. The water at a depth of about 100 m has the same value of salinity of the surface water. The effect of the EC-water to the surface water is less than that of area III. The salinity minimum at a depth of about 125 m, showing T =about 14.0°C , S =about 34.40‰ , is a mixture of the EC-water and the EI-water at a rate of 1:3. The T-S curves below at depth of about 200 m coincide with that of the so-called the Pacific Equatorial Water and its depth is shallower compared with those of area II and III.

(5) The Fifth Group (Fig. 3, e)

This group is found in the area between 06°N and 08°N latitude, where the North

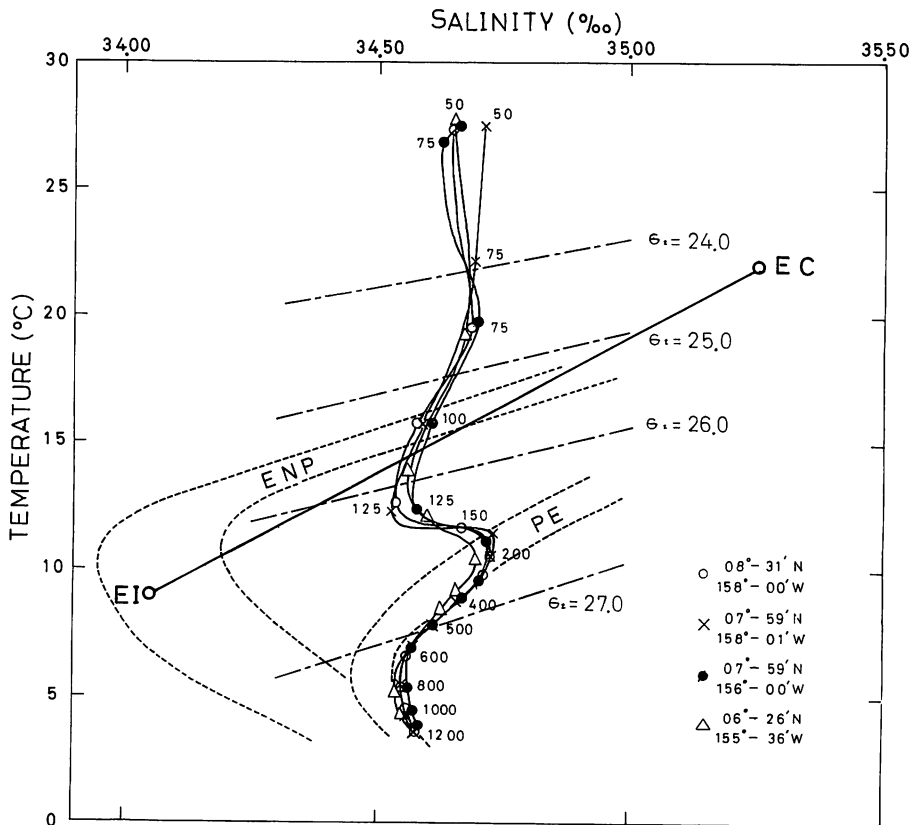


Fig. 3, e. Examples of T-S curves in the fifth area. Observing depths are entered. (m)
E. N. P., eastern North Pacific Central Water. P. E., Pacific Equatorial Water.

Equatorial Countercurrent flows. The salinity maximum already disappears in the area III and the salinity minimum also vanishes in the area IV. The value of the salinity from the surface to a depth about 150 m is almost the same one. The water at a depth of about 125 m is a mixture of the EC-water and the EI-water at a rate of 4: 5. This area may be the boundary zone between the water mass from the north and the south. It seems that there is a vertical motion in the Counter Equatorial region as has been described by Sverdrup et al. (1942).

4. Transition Stage in the area between 07°N and 15°N

To investigate the transition stage between the eastern North Pacific Central Water and the Pacific Equatorial Water, the average T-S curves with latitudinal change are drawn in Fig. 4 and the transition zone, the layer between the eastern North Pacific Central Water and the Pacific Equatorial Water are shown in Fig. 5, respectively.

The transitional stages with latitudinal change from deeper Pacific Equatorial Water to the shallower eastern North Pacific Central Water are clearly seen in Fig. 5. The water is the eastern North Pacific Central Water at 19°N latitude; The water above a depth of about 200 m is the eastern North Pacific Central Water and below

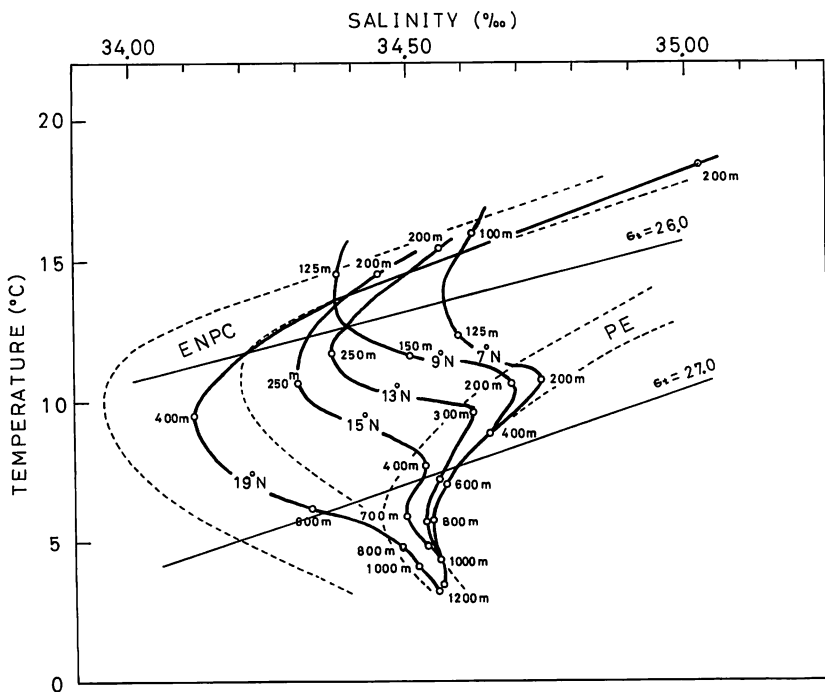


Fig. 4. Average T-S curves with latitudinal change in the area between 07°N and 19°N lat. Observing depths are entered. (m) E. N. P., eastern North Pacific Central Water. P. E., Pacific Equatorial Water.

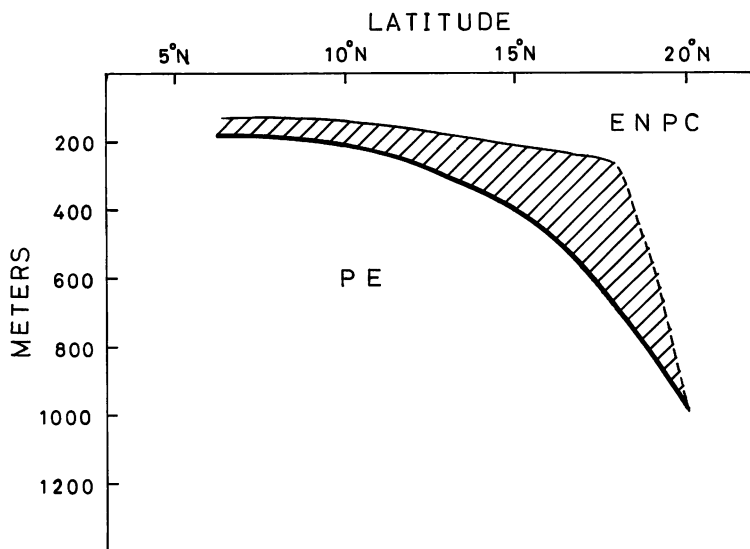


Fig. 5. The transition zone in the southern region of the Hawaiian Islands is indicated by shaded portion.

a depth of about 400 m is the Pacific Equatorial Water at 15°N latitude. The transition zone commences at 400 m and ends at 200 m; while the transition zone lies above 200 m and is less than 100 m thick at 09°N latitude.

Barnes et al (1948) showed the transitional stages between the western North Pacific Central Water and the Pacific Equatorial Water in the Marshall Islands area at 03°S–20°N latitude and 162°E–172°E longitude. The transition zone is found in a layer at a depth of about 1,100 m at 18°N latitude; it commences at 700 m and ends at 400 m at 15°N latitude; it lies above 200 m at 10°N latitude. Though it may be assumed that the depth and the thick of the transition zone were variable according to the vicissitude of the subarctic intermediate water, or due to some other factor, the detail about these factor could not be investigate for lack of the oceanographical data in our research.

5. Summary

The oceanographical observations in the southern region of the Hawaiian Islands were performed yearly from 1977 to 1980. The mixing stages of water masses are examined by the aid of T–S curves using data obtained in oceanographic surveys. The approximate origin values of the water temperature and the salinity are determined by drawing the mean T–S curve for several stations, they have T=about 22.0°C and S=about 35.25‰ in the subsurface saline water, and T=about 9.0°C and S=about 34.05‰ in the subarctic intermediate water.

The types of T–S curves in the region under consideration can be classified into

five groups. In the first group, the salinity maximum of the EC-water at about 100 m–150 m and the salinity minimum of the EI-water at about 400 m are found. The T–S curves below at a depth about 200 m coincide with that of the eastern North Pacific Central Water. In the second group, the salinity maximum of the EC-water is found at a depth of about 125 m–150 m. The water between 150 m–200 m is a mixture of the EC-water and the EI-water. The salinity minimum at a depth of about 250 m is a mixture the EC-water and the EI-water at a rate of 1 : 4. The second minimum which is found at a depth about 800 m, coincide with that of the Pacific Equatorial Water. In the third group, the water of salinity maximum which is found at a depth of about 100 m, consists of the EC-water, mixed with some of the surface water and the EI-water. In the fourth group, the water at a depth of about 100 m is clearly due to the effect of the surface water, but the effect of the EC-water is less than in the area III. The salinity minimum at a depth of about 125 m is a mixture of the EC-water and the EI-water at a rate of 1 : 3. In the fifth group, this is the area of the North Equatorial Countercurrent. The vertical variation of salinity with depth is barely found, where may be considered as the boundary zone between the water masses from the north and the south. The water at a depth of about 125 m is a mixture of the EC-water and the EI-water at a rate of 4 : 5.

The transitional stages with latitudinal change between the Pacific Equatorial Water and the eastern North Pacific Central Water are seen in T–S curves. The transition zone commences at 400 m and ends at 200 m at 15°N latitude. The transition zone becomes shallower toward the south and it lies above a depth of about 200 m at 07°N latitude.

Acknowledgment

The authors wished to express his hearty thanks to Dr. M. Chaen of Kagoshima University for his kind guidance and encouragement.

Reference

- BARNES, C. A., D. F. BUMPUS and J. LYMAN, 1948: Ocean circulation in Marshall Islands area, *Trans. Amer. Geophys. Union*, Vol. **29**, 871–876.
- SVERDRUP, H. U., M. W. JOHNSON and R. H. FLEMING, 1942: *The ocean*, Prentice-Hall, New York, 706–745.
- YUWAKI, Y. and T. HENMI, 1978: The oceanographical research in the southern region of the Hawaiian Islands-I. *Mem. Fac. Fish., Kagoshima Univ.*, **27** (1), 259–272.
- YUWAKI, Y. and T. HENMI, 1979: The oceanographical research in the southern region of the Hawaiian Islands-II. *Mem. Fac. Fish., Kagoshima Univ.* **28**, 217–233.
- YUWAKI, Y. and T. HENMI, 1980: The oceanographical research in the southern region of the Hawaiian Islands-III. *Mem. Fac. Fish., Kagoshima Univ.*, **29**, 179–192.