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Distribution and Variation of Physical Properties Along the SEAMAP Standard Section

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NOTICE

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DISTRIBUTION AND VARIATION OF PHYSICAL PROPERTIES ALONG THE SEAMAP STANDARD SECTION

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This report presents results from data obtained during late summer of four years along the SEAMAP standard section, a quasi-meridional line (near 160°W) between the Aleutian and Hawaiian islands. The distribution of both temperature and density at 500 m is indicative of currents in the upper and intermediate layers. South of 35°N at 1000 and 1500 m, temperature slopes are not indicative of the weak density slopes. The density field at 2000 m is almost flat and reflects conditions in the deepest water; at 2500 m the temperature distribution is similar to that near the bottom. Variations from mean conditions were greatest at the upper levels south of 30°N and in a region near 40°N. Below 1000 m, however, they were quite small.

1. INTRODUCTION

In 1961 the Coast and Geodetic Survey (now National Ocean Survey) initiated the SEAMAP project, a geophysical mapping program in the area bounded by the Aleutian and Hawaiian islands and 155°W and 180°. In conjunction with this project, various oceanographic measurements were obtained. Many of the oceanographic casts were taken along the SEAMAP standard section, a quasi-meridional line where stations were reoccupied during the period 1961-1966 (see figure 1).

The standard section is in an area characterized by widely-differing current systems, which will be described briefly here. The northern boundary of the counterclockwise gyre of the subarctic Pacific is the narrow, intense Alaskan Stream. Speeds in excess of 75 cm/sec have been

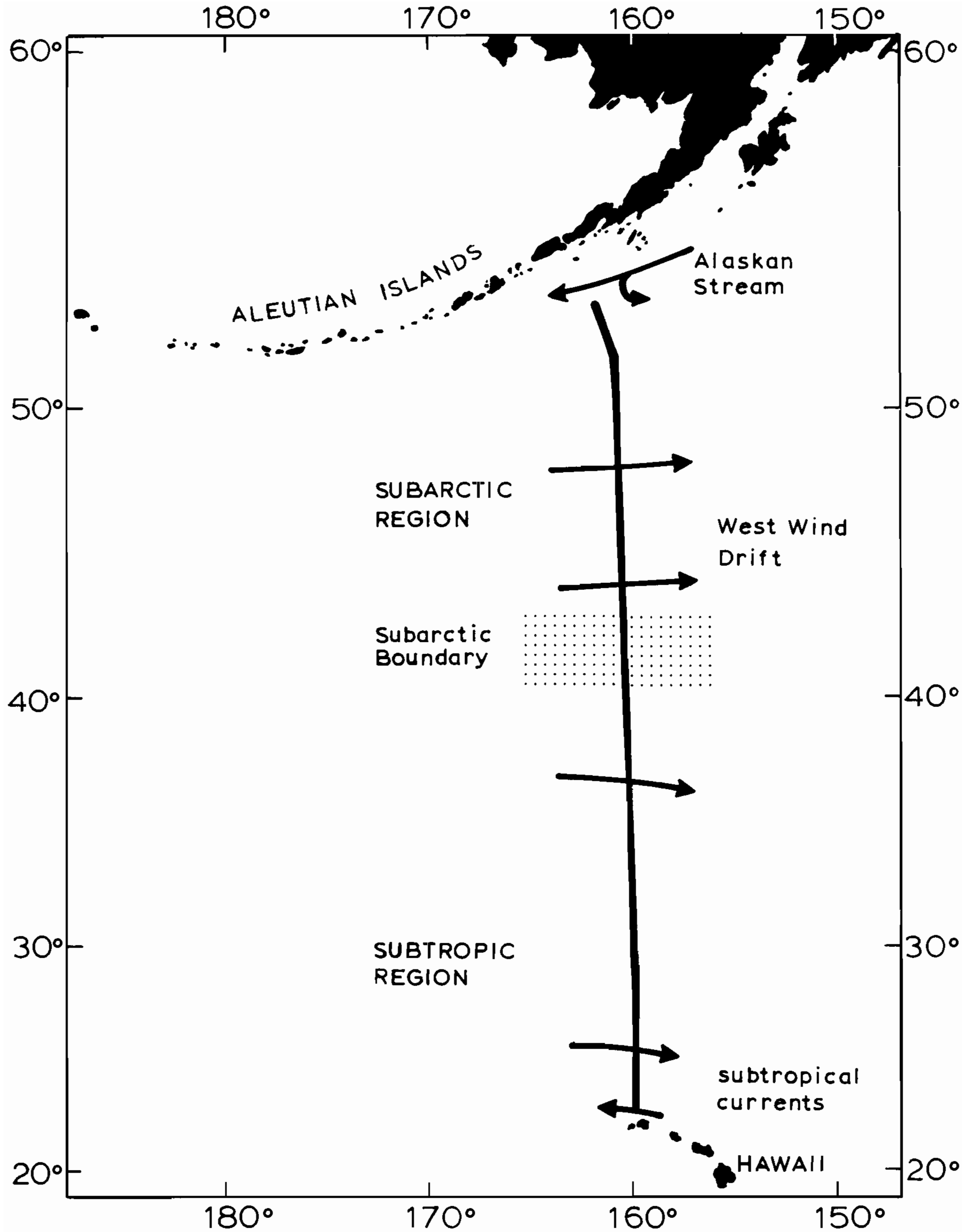

Figure 1. Location of the SEAMAP standard section. The currents and oceanographic regions near the section are also shown.

reported in this flow (Reed and Taylor, 1965). To the south, a broad, easterly flow is present to about 35°N with typical speeds of 5 cm/sec (see e.g., Dodimead et al., 1963). Farther south, the central gyre has long been considered an area of weak or nonexistent currents; Reed (1968), however, showed that relatively intense (20 cm/sec) flows were frequently present north of Hawaii. It seems possible that they may be related to the subtropical countercurrents predicted by Yoshida and Kidokoro (1967). North of about 40°N, circulation patterns similar to those at the surface (but with reduced speeds) are present throughout the water column to depths of about 1500 m; to the south, however, geopotential gradients at 1000 m and below are very weak and ill-defined (Reed, 1970).

This paper reports the distribution and variation of physical properties in the upper 2500 m along the standard section during the period 1961-1966. The deeper data obtained in this area have previously been discussed by Barbee (1965) and Reed (1969).

2. DATA AND METHODS USED

Observations on the SEAMAP standard section were made during the following periods: 30 September-12 October 1961; 23 August-25 September 1962; 7-20 September 1964; and 21 September-2 October 1966. The first two cruises were conducted from the USC&GS Ship PIONEER, and the others were made aboard the USC&GS Ship SURVEYOR. During the first three cruises casts were made with Nansen bottles and reversing thermometers, normally placed at oceanographic standard depths, and salinity was determined by salinometer. In 1966 the upper 1500 m was sampled with an in-situ sensing system (STD), and Nansen bottles were used in the deeper water.

A few observations along this line were made at times other than those listed, but the data density was deemed insufficient for the present study. Although some observations were made in the Alaskan Stream, they were not adequate to properly define it (except west of the line in 1966 and 1967); consequently, these data have not been used here. Data from the cruises listed were used to prepare plots of the distribution of temperature and sigma-t at 500-m intervals from 500 m to 2500 m, and some results are presented below. Salinity values are not shown since they are defined by the temperature-density relationship. Data above 500 m are not presented because it was felt that the frequency and number of observations were inadequate to draw firm conclusions about the events in this upper layer.

3. DISTRIBUTION AT 500 M

The distribution of temperature at 500 m along the SEAMAP standard section is shown in figure 2. The dominant feature is a temperature increase from 50°N to about 30°N. South of 30°N, strong and variable slopes are apparent over a few degrees of latitude. The temperature range is about 4.5°C, increasing from about 3.5°C to approximately 8°C. The most rapid increase occurs in the vicinity of the Subarctic Boundary near 40°N.

The corresponding sigma-t distribution is shown in figure 3. Sigma-t decreases from a high north of 50°N to a low near 30°N. As in the temperature distribution, there are strong and variable slopes south of 30°N.

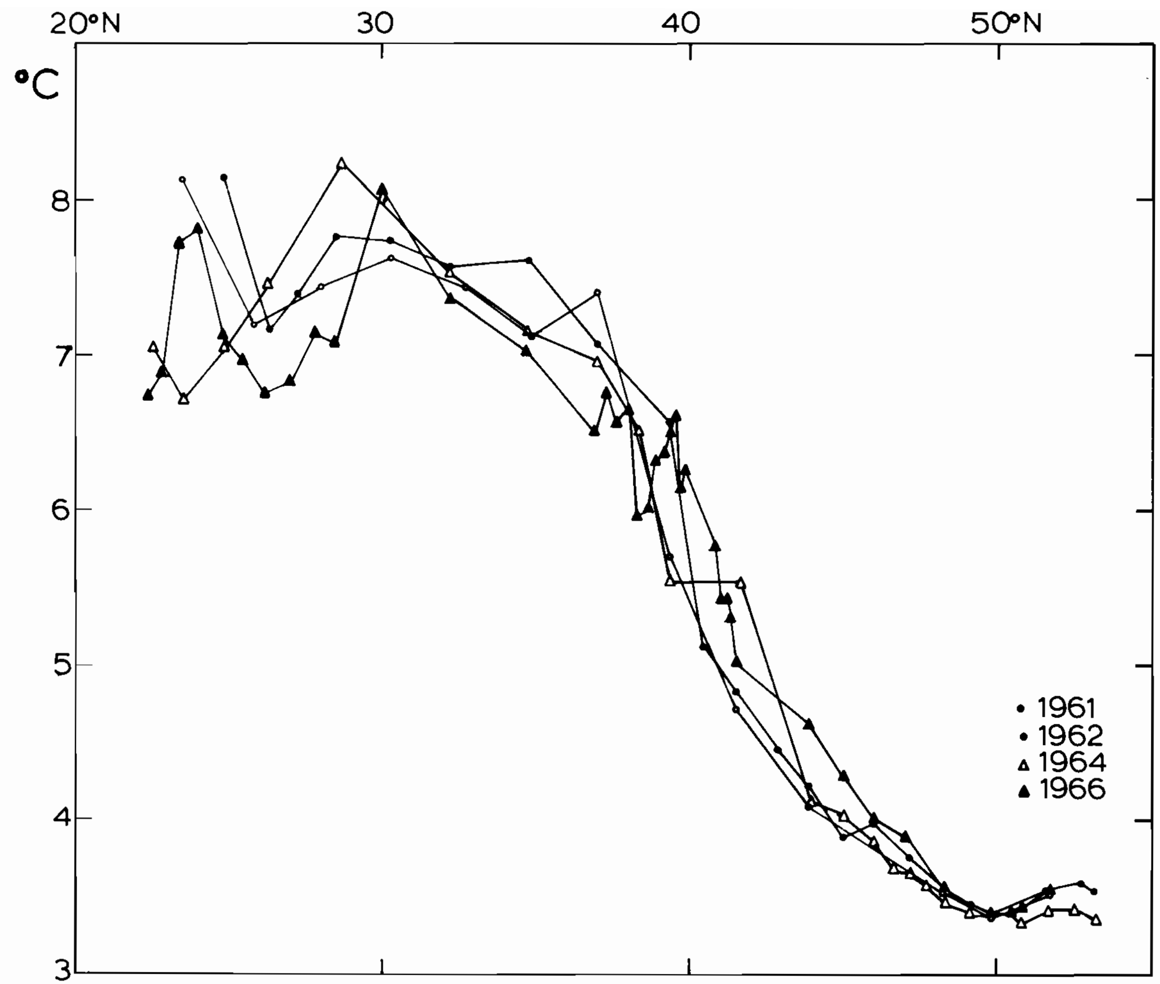

Figure 2. Temperature distribution (°C) at 500 m along the standard section during 1961, 1962, 1964, and 1966.

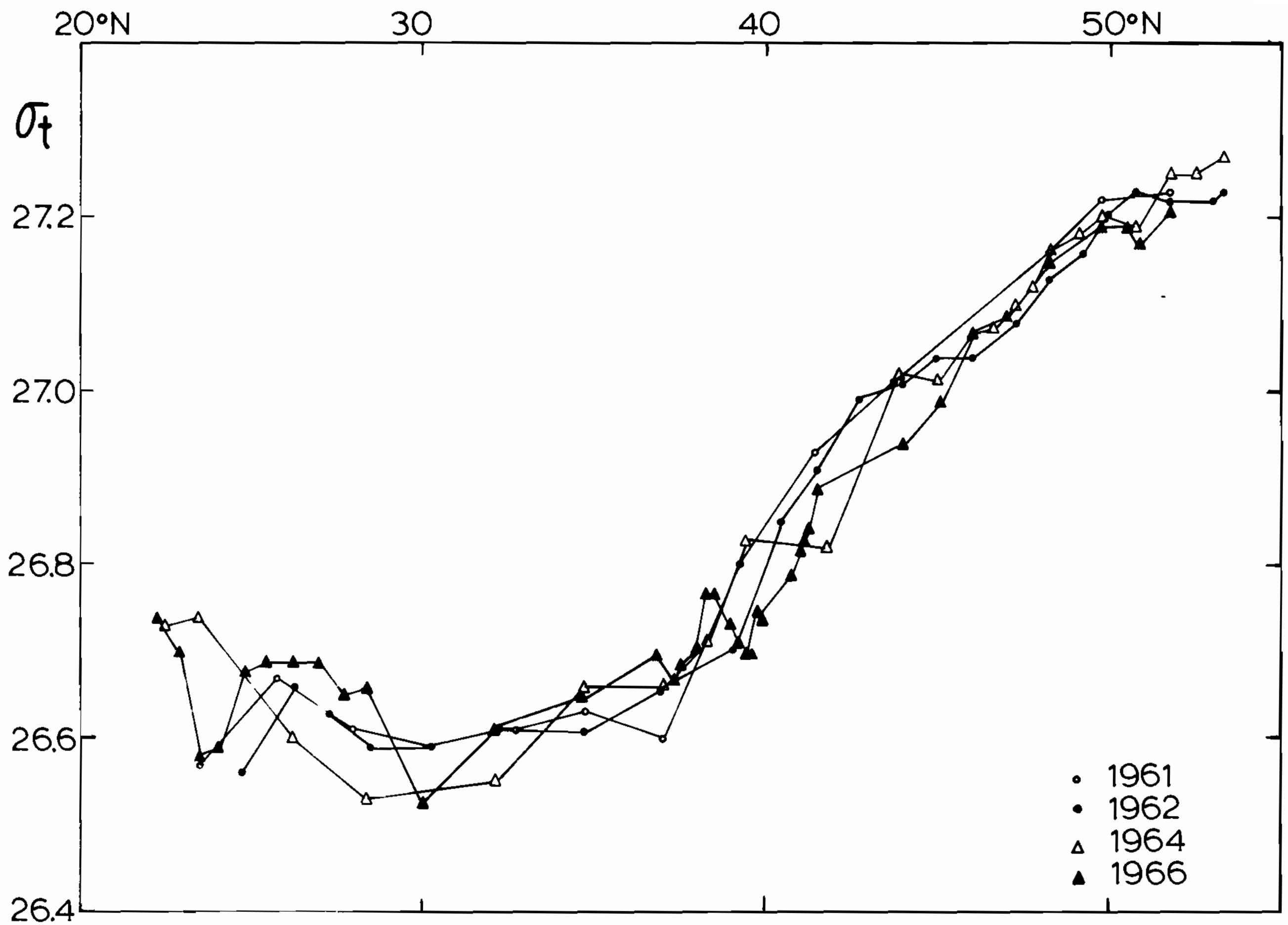

Figure 3. Sigma-t distribution at a depth of 500 m along the standard section during 1961, 1962, 1964, and 1966.

The range of sigma-t is about 0.7 mg/cm^3. A comparison of the temperature and sigma-t distributions indicates that the warmest water is also the lightest water and vice versa. This fact is especially notable in the strong slopes south of 30°N.

Although currents throughout the upper 500 m are similar in direction (especially in the Subarctic Region), the close relationship between the density slopes at 500 m and geostrophic flow in the upper 500 m (as computed from a level of 1000 db) is somewhat surprising because the comparison is between conditions at a single level and pressure gradients integrated over the water column. The easterly drift north of about 35°N is indicated by sigma-t values decreasing to the south. Just south of 40°N, the closely-spaced 1966 data indicate a westward flow imbedded in the general eastward drift. Dodimead (1968) has also reported westward flows in the southern portion of the West Wind Drift elsewhere in the central North Pacific. South of 30°N, the steeper slopes in the density field appear to be associated with subtropical currents of about 20 cm/sec near the surface (see Reed, 1968).

4. DISTRIBUTION AT 1000 and 1500 M

The 1000-m temperature distribution is shown in figure 4. The temperature increases by about 1.3°C from north to south. The most notable differences between the distribution here and at 500 m are the greatly reduced range, the absence of strong slopes near the Subarctic Boundary, and the lack of intense gradients south of 30°N.

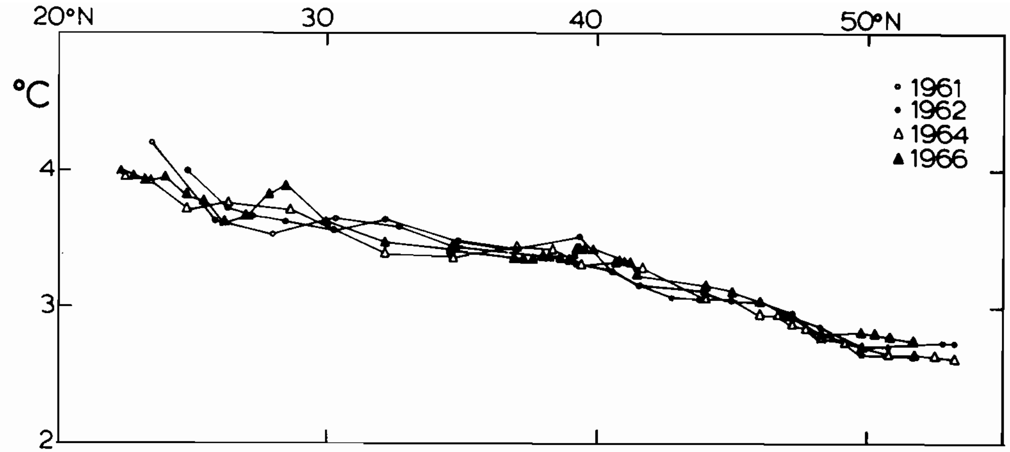

Figure 4. Temperature distribution (°C) at 1000 m along the standard section during 1961, 1962, 1964, and 1966.

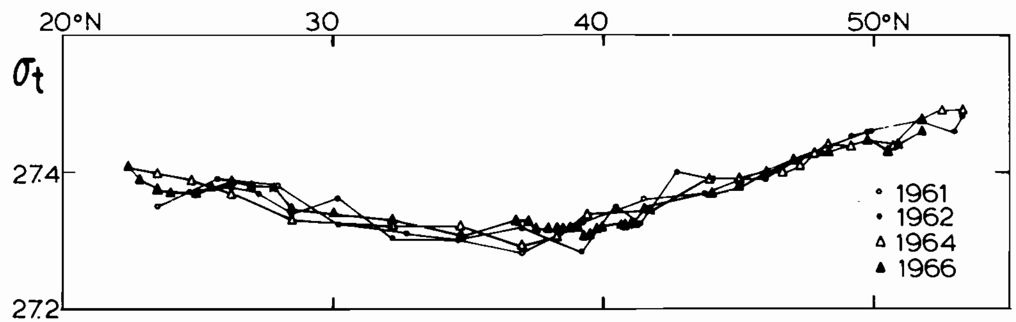

Figure 5. Sigma-t distribution at 1000 m along the standard section during 1961, 1962, 1964, and 1966.

The distribution of sigma-t at 1000 m is presented in figure 5. In general, density decreases from the north to a low near 35°N and then increases slightly to the south. The range along the standard section is about 0.2 mg/cm^3. In contrast to the conditions at 500 m south of 35°N, the general increase of density is associated with a temperature increase rather than decrease. (A few of the trends over short distances, however, do correlate as at 500 m.) The observed density distribution results from a general increase of salinity toward the south at 1000 m (see NORPAC Committee, 1960), which counteracts the temperature increase at this level. Although the sigma-t distribution at 1000 m indicates an eastward flow north of 40°N, south of that latitude the slopes are not generally indicative of the near-surface flows.

The temperature and sigma-t distribution at 1500 m (not shown) is generally like that at 1000 m. Ranges of temperature and sigma-t are about 0.7°C and 0.1 mg/cm^3 respectively. The temperature slope is almost completely linear along the section, and the sigma-t distribution shows almost no slope south of 35°N.

5. DISTRIBUTION AT 2000 AND 2500 M

At 2000 m temperature increases about 0.2°C from north to south (figure 6). Sigma-t decreases from the north to a low near 45°N, increases very slightly, and remains essentially constant south of 35°N (figure 7). Its range is about 0.05 mg/cm^3. At 2500 m the properties are similar to those at 2000 m, except that the warmest temperatures are found near 45°N as in the deepest water (Reed, 1969). The ranges are further reduced and are only slightly greater than those found near the bottom.

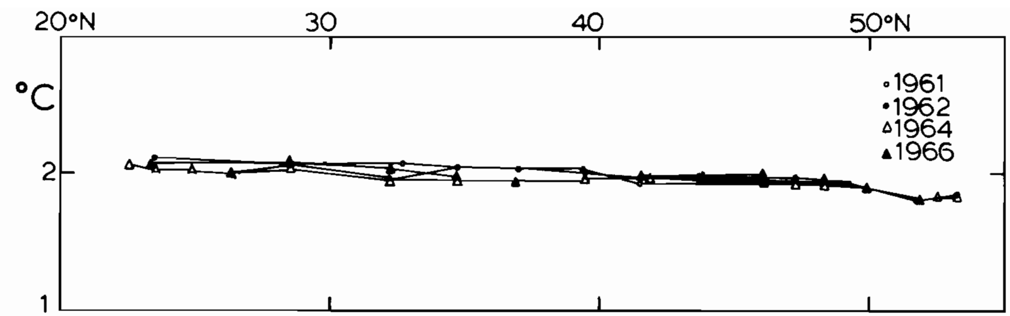

Figure 6. Temperature distribution (°C) at 2000 m along the standard section during 1961, 1962, 1964, and 1966.

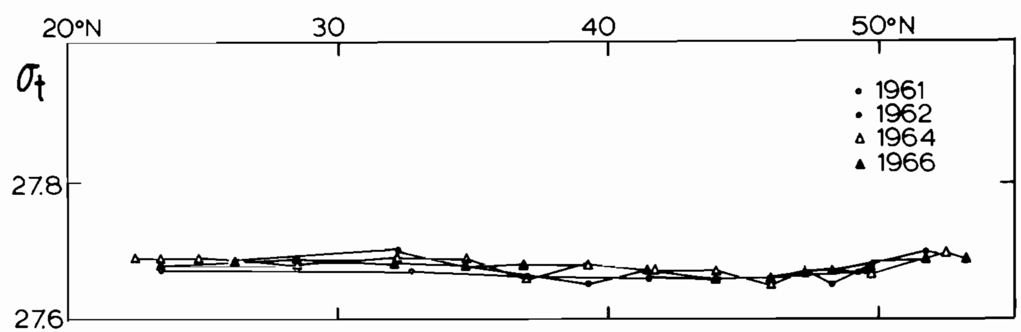

Figure 7. Sigma-t distribution at 2000 m along the standard section during 1961, 1962, 1964, and 1966.

6. VARIATION

Differences in property values measured at the same site and depth at different times may result from a number of causes, some of which are temporary or cyclic (such as internal waves) and others of which may be more permanent in nature (advection, for instance). Other processes (surface heat exchange, evaporation-precipitation, etc.) may be significant in approximately the upper two hundred meters in this region, but they are probably not important below.

The data used here are not suitable for analysis by the usual statistical procedures. Because of obvious differences in variation at different latitudes, it is difficult to establish a meaningful grouping with a sufficient number of values from which to determine means and deviations. In order to provide some measure of the observed variation along the section, however, the range of temperature and sigma-t at 500, 1000, and 2000 m was determined at each degree of latitude from figures 2-7, and the results are presented in figure 8.

At 500 m the range of temperature and sigma-t is considerably greater than at the two deeper levels. In both parameters there are prominent peaks (1) between approximately 35 and 45°N and (2) south of 30°N. At 1000 m the range of density shows little trend with latitude, but the temperature fluctuations are slightly greater south of 30°N than to the north. The range of density and temperature at 2000 m is very small, and the variation is only about the magnitude of the measurement and interpolation errors.

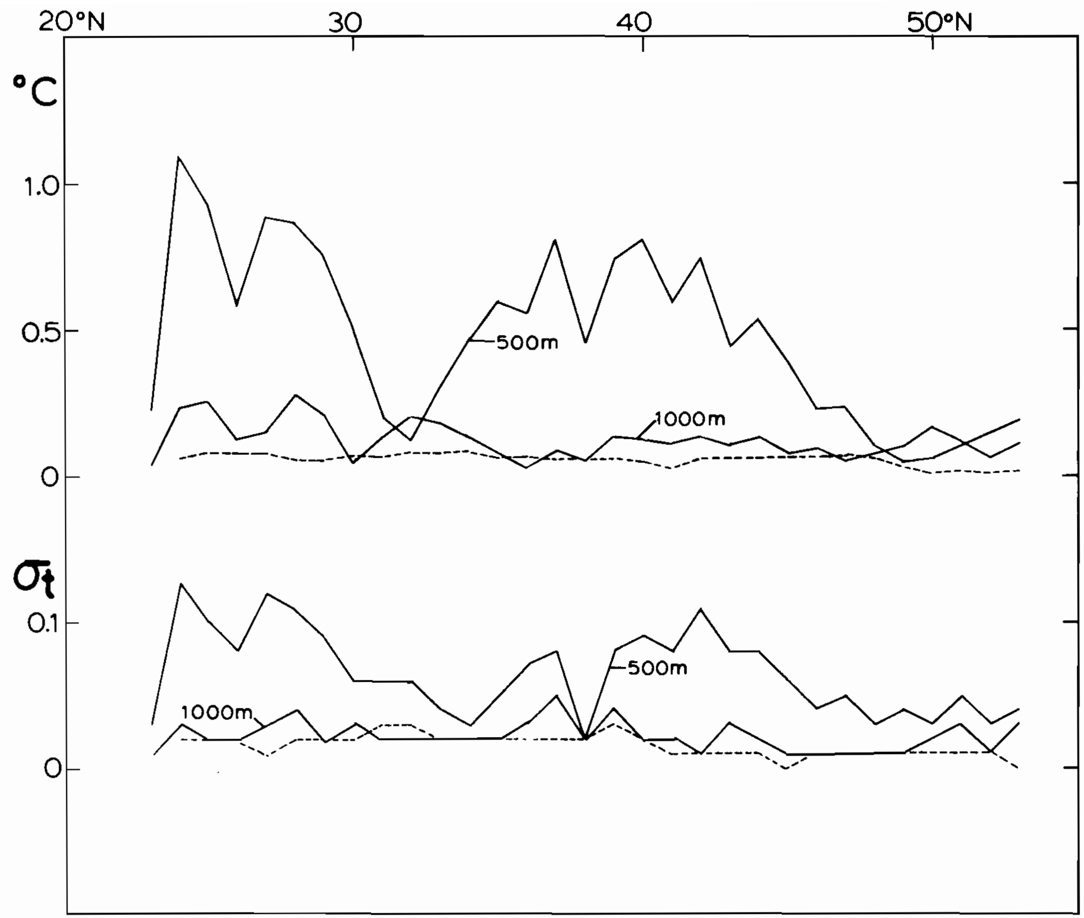

Figure 8. Range of temperature (°C) and sigma-t at 500, 1000, and 2000 m (shown by dashed lines) along the standard section, 1961-1966. (Determined at 1° - intervals from the dsitributions in figs 2-7.)

On the basis of figure 8, one might assume that the zones of large variation (south of 30°N; 35-45°N) result from shifts in currents or in the Subarctic Boundary. On the other hand, they may result mainly from vertical displacements by internal waves. The effects of vertical displacements can be minimized by examining temperature as a function of density, whose surfaces rise and fall with the waves, rather than depth. The sigma-t surface of 26.8 mg/cm^3 was chosen to approximate the 500 m surface; this surface is from 500 to 600 m south of 40°, rises to 300 m near 47°N, and shoals to about 150 m at the northern end of the line. The 27.4 mg/cm^3 surface is typically between 1000 and 1100 m south of 45°N and rises to about 800 m north of 50°N. Temperature at these density surfaces was determined, and the values were plotted as in figures 2-7. The range of values at each degree of latitude are presented in figure 9.

Comparison of figures 8 and 9 indicate that the variation on the 500 m surface is generally at least twice as great as that on the 26.8 mg/cm^3 surface, except north of about 47°N. Thus the large variations at 500 m appear to result mainly from internal waves rather than from property changes caused by advection or mixing. North of 47°N, however, the variations on the upper density surface are greater than those at 500 m. This is probably caused, however, by the fact that the 26.8 mg/cm^3 surface is at depths between 150 and 300 m where lateral gradients are much larger than at 500 m. Thus advection and mixing can alter the water properties more easily in these upper levels. The variations at 1000 m are in general comparable to those on the deeper sigma-t surface, except south of 35°N where they are somewhat greater on the depth surface.

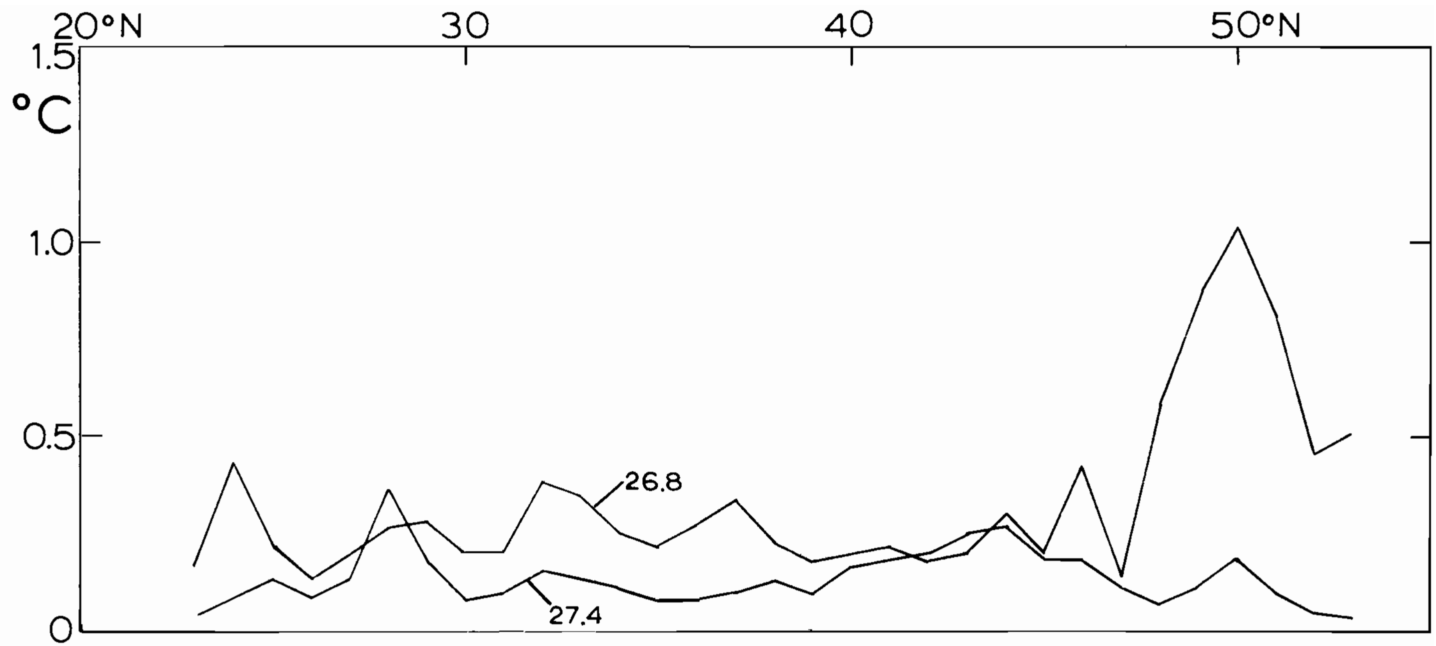

Figure 9. Range of temperature (°C) on the 26.8 and 27.4 mg/cm^3 sigma-t surfaces along the standard section, 1961-1966.

These results imply that internal waves north of 35°N do not seriously affect the property distributions at 1000 m. At 500 m (and most likely above) though they contribute greatly to the observed variation in properties over most of the area considered here.

7. ACKNOWLEDGMENTS

I thank N.P. Laird and J.L. Stephens for suggestions and assistance. T.V. Ryan was an early advocate of the SEAMAP project and the standard section, and he made numerous helpful suggestions during preparation of this report.

8. REFERENCES

Barbee, W.D., 1965, Deep circulation, Central North Pacific: 1961, 1962, 1963, Coast and Geodetic Survey Research Paper, Washington, D.C.

Dodimead, A.J., F. Favorite, and T. Hirano, 1963, Review of oceanography of the Subarctic Pacific region, Int. North Pac. Fish. Comm. Bulletin, 13, 195 p.

Dodimead, A.J., 1968, Oceanographic conditions in the central Subarctic Pacific region, Winter 1966, Fish. Res. Bd. Canada Tech. Report, 75, 10 p., 11 figs.

NORPAC Committee, 1960, Oceanic observations of the Pacific 1955: The NORPAC Atlas, University of California Press and University of Tokyo Press, Berkeley and Tokyo.

Reed, R.K., and N.E. Taylor, 1965, Some measurements of the Alaska Stream with parachute drogues, Deep-Sea Res., 12, 777-784.

Reed, R.K., 1968, Indications of subtropical countercurrents near Hawaii, (Abstract), Trans. Am. Geophys. Un., 49, 702.

Reed, R.K., 1969, Deep-water properties and flow in the central North Pacific, Jour. Mar. Res., 27, 24-31.

Reed, R.K., 1970, Geopotential topography of deep levels in the Pacific Ocean, Jour. Oceanogr. Soc. Japan, 26, 331-339.

Yoshida, K., and T. Kidokoro, 1967, A subtropical countercurrent (II) - A prediction of eastward flows at lower subtropical latitudes, Jour. Oceanogr. Soc. Japan, 23, 231-246.

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