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Water Temperature on the Texas-Louisiana Shelf

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From an analysis of bathythermograph (BT) data collected over approximately twenty years, graphs of the annual variation of temperatures (down to 225 meters or 738 feet) at the outer edge of the shelf, in addition to a series of vertical sections of temperature crossing the shelf off Galveston, have been made. Also, maps of sea-surface temperatures, mixed layer depths (as well as graphs of thermocline strength), and shelf bottom temperatures have been constructed for the Texas-Louisiana shelf. In preparing these various figures, a total of 1428 individual BT traces have been used.

These data suggest that (1) nearshore sea-surface temperatures in the offing of the Sabine River annually range from approximately 14° C to 30° C (57.2° F to 86° F); (2) the depth of the mixed layer displays a seasonal variation, becoming shallower in the spring and summer, and deepening in the fall and winter with a maximum mixed layer depth (MLD) of approximately 75 meters (41 fathoms) over the shelf in the period November through February; (3) shelf bottom isotherms closely parallel depth contours; (4) bottom temperatures shoreward of the stationary 18° C (64.4° F) isotherm (approximately coincident with the 120-meter or 65-fathom depth contour) are seasonally dependent; (5) seaward of the 18° C isotherm, bottom temperatures are subject only to small fluctuations.

Introduction

Temperature, which is basic to any physical description of a body of water, is the easiest and perhaps, therefore, the most common measurement made in such a body. The exchange of heat between the body of water and its surroundings depends strongly on temperature, and the heat storage resulting from exchange appears in the body as change in temperature. The density and consequently the stratification of the body depends largely on temperature. The speed of sound in the body also depends most strongly on temperature except in the deep ocean. The kinds and rates of chemical reactions are influenced by temperature. The conditions of life in such a body are directly related to temperature, and, because the distribution of nutrients and other biologically important substances depend on the temperature, the conditions also are indirectly related to temperature.

In describing the temperature structure over the Texas-Louisiana shelf in the Gulf of Mexico, shelf limits have been fixed geographically to the southwest at 26° N (the Texas-Mexico border) and to the northeast at 89° W (the Mississippi River delta) (Fig. 1). The seaward limit of the shelf is fixed at the conventional 200-meter (or 100-fathom) depth contour. The shelf break (the point on the shelf at which the inclination of the bottom changes markedly) usually occurs somewhere between the 50- and 100-meter (27- and 55-fathom) depth contours. (This is in contrast to the Florida shelf where the shelf break is characteristically deeper.) The shelf extends to a maximum width of approximately 200 kilometers (107 nautical miles) in the vicinity of the Texas-Louisiana border and narrows to about 90 kilometers (49 nautical miles) near the Rio Grande delta. Contiguous bays and estuaries have not been described in this report.

Shepard (1973) gives an excellent geologic description of the Texas-Louisiana shelf. Among the noteworthy features are a number of elongate sand ridges and terraces on the shelf which have been interpreted as drowned barrier islands and beaches. Also, a row of hills located along the outer edge of the shelf has been identified largely as salt domes. The topography of the continental slope off the Texas-Louisiana shelf is denoted by oval hills and depressions suggestive of a seaward continuation of the salt domes of the shelf edge. A unique feature located at the edge of the shelf at approximately 27° 52'N and 93° 49'W is a reef formation called the Flower Gardens. This formation is of great ecological interest, but because of its small size relative to the area of the entire shelf, as represented on a small map, temperature contours cannot be constructed around this and other such small features.

Data used in this report consist entirely of bathythermograph (BT) data, both mechanical (MBT) and expendable (XBT), collected by various Texas A&M University research vessels 1951 to 1973.*

The method used in presenting the data starts offshore with a description of the temperature field in the offshelf region and works shoreward, describing the temperature structure over the shelf. In this context, figures may be grouped into three major categories.

• **Annual variation of temperature for offshore regions.** For this report, the area just seaward of the shelf break has been divided into three regions: western, central and eastern (Fig. 1). Graphs of the annual variation of temperature 225 meters (738 feet) deep have been constructed for each of these three regions (Figs. 2-4). The graphs of annual variation of temperature depict the average temperature at selected depths for each month of the year. These graphs have depth as the ordinate and the months of the year as the abscissa.

• **Vertical sections of temperature crossing the shelf off Galveston.** The series of vertical sections (Figs. 5-15) represent each of the eleven cruise tracks crossing the shelf off Galveston (as depicted in Figure 1), one for each month except December. These vertical sections are intended to show the variation in isotherm depths as one approaches the coast from the offshelf waters of the Gulf of Mexico. While these vertical sections cover only the central portion of the shelf area, it is felt that they are fairly representative of the thermal structure over the entire shelf.

• **Representations of the temperature structure over the shelf.** In order to describe the temperature structure over the shelf, the following aspects of the temperature field have been graphically represented.

Sea-surface temperatures. Maps of surface temperatures have been made for each of six two-month periods (Figs. 16-21).

Depth of the mixed layer (MLD). Maps of mixed layer depths (MLD) have been made for each of six two-month periods (Figs. 22-27); the MLD is defined here to be the maximum depth of the maximum temperature.

Thermocline strength. Graphs of the annual variation of the strength of the thermocline (Figs. 28-30) have been constructed for each of the three offshelf regions previously described; thermocline strength, as used here, is actually a measure of how rapidly the temperature decreases in a layer 30 meters (98 feet) thick situated just below the depth of the mixed layer.

Shelf-bottom temperatures. Maps of bottom temperatures have been made for each of six two-month periods (Figs. 31-36).

Any interpretation of the fields of sea-surface temperatures or mixed layer depths as presented in this report should be restricted to the area immediately over the shelf. Contours extending beyond the shelf limits are intended only to indicate trends and should be used cautiously. It should also be remembered that combining the limited data that range over the large time scales considered in this report necessitates varying degrees of subjectiveness in contouring.

A temperature vs. depth curve characteristic of any region of the shelf can be reconstructed from the various figures presented in this report. For the desired location and time of year, ascertain the surface temperature, mixed-layer depth and bottom temperature (as well as the depth) from the respective maps. Also, determine the value of the thermocline strength from the offshelf region nearest the chosen location. Figure 38 schematically illustrates this procedure. While this procedure will not accurately reproduce every possible configuration of temperature vs. depth found over the shelf, it will, nevertheless, reconstruct a typical curve characteristic of a given location and time.

An unpublished manuscript by Harrington extensively describes the temperature and salinity fields over the Texas-Louisiana shelf 1963 through 1965. Harrington presents chronologically sequenced diagrams of these fields for this period. Harrington's paper differs from the present study in that the latter is more nearly a climatic summary of temperature over the shelf, whereas the former presents greater resolution in comparatively short-term varia-

*The authors wish to acknowledge the assistance of Dr. Thomas J. Bright in assembling a large portion of the data that was used in this report. Dr. Bright's project, "Faunal Survey of West Flower Garden Bank," was funded by the University of Texas Medical Branch at Galveston, Texas.

tions in both temperature and salinity over the Texas-Louisiana shelf.

Seasonal Variation over the Continental Slope

The graphs of annual variation of temperature (Figs. 2-4) show variations in the monthly mean temperatures at selected depths. While all the isotherms exhibit some irregularity (probably related to seasonal changes), the most pronounced effects are confined to roughly the upper 120 meters (394 feet). Depths of the isotherms represented in these graphs demonstrate some variability among the three offshelf regions; however, this variability may be the result of insufficient data. One feature that is consistent throughout all three graphs, however, is that the 18° C (64.4° F) isotherm remains nearly horizontal. Therefore, the depth of this isotherm (approximately 120 meters or 394 feet) may serve as an indication of the depth to which seasonal fluctuations are perceptible.

Monthly Vertical Sections across the Shelf

The series of vertical sections (Figs. 5-15) shows a seasonal change in isotherm slopes over the shelf. In the fall and winter, isotherms shoreward of the 100-meter (328-foot) depth contour are nearly vertical, while in the spring and summer, isotherms shoreward of the same depth contour are nearly horizontal. Since these vertical sections represent individual cruises, they are apt to show more detail than might be inferred from the smoothly contoured maps of surface and bottom temperatures. These sections are useful in illustrating the nature of the temperature-field over the shelf. They couple the graphs of annual variation of temperature with the broad maps of surface temperatures, mixed-layer depths and bottom temperatures. The vertical trend in the isotherms observed near shore in the winter months is the result of thorough mixing caused by wind coupled with cooling. The horizontal trend in the isotherms during the summer is the result of thermal stratification. One peculiarity that is evident only in the vertical sections is the apparent bulging or dipping of the intermediate isotherms near the shelf bottom. This feature is particularly conspicuous midway up the shelf. In attempting to explain the relation between the surface waters of the shelf region and the characteristic subsurface water masses found offshore, Nowlin and Parker (1974) suggested three possible processes: (1) the sinking of dense water which is formed near shore by local processes, (2) the upwelling of deep water onto the shelf caused by offshore winds or (3) the advection into the region of near-surface water with deep water characteristics. It is possible that the observed pattern in the isotherms over the shelf may be related to one or more of these processes.

Thermal Structure over the Shelf

The six two-month maps of surface temperatures (Figs. 16-21) illustrate the seasonal variations in sea-surface temperatures encountered over the shelf. The surface temperatures near shore are greatly influenced by the continental climatology as evidenced by a greater range of surface temperatures near shore than offshore. (Extreme values of surface temperatures may be encountered in bays and estuaries close to shore.) For example, the monthly mean sea surface temperatures in the offing of the Sabine River range from approximately 14° C to 30° C (57.2° F to 86° F) while in offshelf regions, they typically range from 21° C to 29° C (69.8° F to 84.2° F). In general, there is a warming trend toward the south (seaward) in this region. The only exception to this general rule is encountered in July and August when the trend reverses and higher surface temperatures are found near shore.

Maps of mixed-layer depths (Figs. 22-27) demonstrate a seasonal variation in which the MLD becomes shallow in the summer and deepens in the winter, with a maximum mixed-layer depth of approximately 75 meters (41 fathoms) over the shelf between November and February. These maps also show the effects of mixing generated by both wind and solar heating. The wind generates surface waves which in turn mix the surface waters. In general, the stronger the wind, the deeper the mixing induced by the wave action. When the effects of solar heating (or lack of it) are superimposed on the wind-generated mixing, various combinations of surface temperatures and mixed-layer depths will result. As a general rule, however, spring and summer are characterized by light winds and warm temperatures. This combination produces warm sea-surface temperatures and shallow mixed-layer depths. Conversely, fall and winter are characterized by strong winds and cool temperatures. This combination results in cool sea-surface temperatures and deep mixed-layer depths.

Immediately following the MLD maps are graphs depicting the monthly variation of the temperature change over a depth of 30 meters (98 feet) directly below the MLD (Figs. 28-30) for each of the three offshelf regions. The thermocline strength displays a seasonal variation: it is greatest in August, September and October and weakest in February, March and April. While no graphs of the thermocline strength over the shelf have been prepared, it has been observed that the seasonal patterns over the shelf are similar to those in offshelf regions; however, the magnitude of the thermocline strength is generally stronger over the shelf. In addition to giving an indication of the monthly variation in the thermocline strength, these graphs also show the degree to which vertical mixing is inhibited by the thermocline. A well-developed thermocline acts much like a barrier to vertical motion in the upper layers of the ocean. Thus, for example, the distribution of nutrients within the water would be very highly influenced by the presence or absence of a strong thermocline. The seasonal variation in the thermocline strength is related to the same processes that affect the MLD. Basically, the warm surface waters common in summer offer more of a thermal contrast to the deeper and colder waters (and hence a larger thermal gradient) than do the cool surface waters common in winter.

Maps of bottom temperatures (Figs. 31-36) are probably the most interesting of the figures in that the seasonal variations are very intricate. It can readily be seen that the shelf bottom isotherms closely parallel the depth contours, and that much of the seasonal variation occurs on the shoreward half of the shelf bottom. It can also be seen that the bottom temperature pattern near shore closely reflects the corresponding pattern in sea-surface temperatures (for example, bottom temperatures in the offing of the Sabine River range annually from about 13° C to 29° C or 55.4° F to 84.2° F); this is true to the extent that the MLD is sufficiently deep to reach the bottom. However, since the maximum MLD encountered over the shelf is on the order of 75 meters (41 fathoms), any positive correlation between the surface and bottom temperatures should decrease seaward of the 75-meter (41-fathom) depth contour. In this case, the bottom temperature is more nearly determined by the isotherm (from the appropriate graph of offshelf annual variation of temperature) that would intersect the shelf at the depth under consideration. As a broad generalization, it can be stated that in the spring and summer, bottom temperatures are highest near shore and lowest off shore; however, in the fall and winter, bottom temperatures are low both near shore and off shore with relatively higher temperatures somewhere in between. The 18° C (64.4° F) isotherm, whose seasonal variation is depicted in Figure 37, vividly demonstrates this pattern. The spring and summer bottom temperature patterns are characterized by the presence of one 18° C (64.4° F) isotherm, whereas November through February, a second 18° C (64.4° F) isotherm appears shoreward of the more permanent one.

Discussion

Maps of surface temperatures, mixed-layer depths and bottom temperatures are interrelated and should be considered jointly.

In the summer (May-August), the MLD (Figs. 24, 25) is very shallow compared to winter since light surface winds do not mix surface waters to any great depth, and bottom temperatures (Figs. 33, 34) reflect the warm surface temperatures (Figs. 18, 19) only very near the coast where the MLD reaches the bottom. The bottom temperature pattern is governed primarily by the pattern exhibited in the appropriate graph of offshelf annual variation of temperature (Figs. 2-4) wherein the temperature decreases with depth. The horizontal thermal gradient along the shelf bottom is at its maximum strength during July and August.

In the fall (September-October), the MLD (Fig. 26) has deepened noticeably, and the bottom temperatures (Fig. 35) reflect the fall cooling trend in the surface temperatures (Fig. 20) at greater depths (farther seaward) than in the summer since the MLD extends to the bottom farther seaward. However, bottom temperatures continue to decrease with increasing distance from the coast as in summer.

In the winter (November-February), the MLD (Figs. 22, 27) attains its greatest depth as a result of the stronger winds and greater wave action generally experienced in the winter, and bottom temperatures (Figs. 31, 36) reflect cooler winter surface temperatures (Figs. 16, 21) at greater distances from the coast. However, the MLD at its maximum depth, extends to the bottom at approximately the 75-meter (41-fathom) depth contour. Bottom temperatures, like the surface temperatures in winter, increase seaward, but at approximately the 75-meter (41-fathom) depth contour, bottom temperatures again decrease with increasing depth after reaching a relative maximum, while surface temperatures appear to continue warming seaward.

In the spring (March-April), the MLD (Fig. 23) decreases noticeably with the advent of lighter winds and less wave action, and bottom temperatures (Fig. 32) reflect the spring warming trend in surface temperatures (Fig. 17) only near the coast. Once again, bottom temperatures decrease seaward as the annual cycle is completed.

One important feature becomes apparent upon examining the seasonal variation in the 18° C (64.4° F) bottom isotherm (Fig. 37). This isotherm remains very nearly stationary throughout the year, usually between the 109- and 146-meter (60- and 80-fathom) depth contour, except November through February when a second 18° C (64.4° F) isotherm appears shoreward of the more stationary one. The stationary 18° C (64.4° F) isotherm can be interpreted as a demarcation line. Seaward of this contour, bottom temperatures exhibit very little seasonal variation. Here, the bottom temperature pattern apparently depends largely on the various isotherm depths in the appropriate graph of annual variation of temperature. Shoreward of this contour, bottom temperatures are subject to seasonal variations as reflected in variations of the mixed-layer depth.

- Annual ranges of sea-surface temperatures in offshelf regions are smaller than in nearshore regions; that is, in offshelf regions, sea-surface temperatures typically range from 21° C to 29° C (69.8° F to 84.2° F).

- Sea-surface temperatures tend to decrease northward (shoreward) throughout the year except in July and August when higher surface temperatures are found near shore.

- The annual range of monthly mean sea-surface temperatures in the offing of the Sabine River is quite large (temperatures typically range from about 14° C to 30° C or 57.2° F to 86° F) and differs little in the nearshore region from Galveston to Marsh Island, Louisiana.

- The maximum mixed-layer depth encountered over the shelf is roughly 75 meters (41 fathoms) and usually occurs between November and February.

- The thermocline strength is greatest in August-October and weakest in February-April.

- Contours of bottom temperatures closely parallel depth contours.

- Bottom temperatures shoreward of approximately the 120-meter (65-fathom) depth contour vary seasonally while farther seaward, they vary only slightly. This depth contour roughly coincides with the 18° C (64.4° F) bottom isotherm.

- Nearshore ranges of shelf bottom temperatures correspond closely to the ranges of sea-surface temperatures. In the offing of the Sabine River, bottom temperatures annually range from approximately 13° C to 29° C (55.4° F to 84.2° F).

Appendix I — Information Used in Constructing Figures

In constructing graphs of annual variation of temperature for the three offshelf regions (Figs. 2-4), 728 individual BT traces were used. The central region, with 62 percent of the traces, is the best described of the three regions.

Data used in constructing maps of surface temperatures (Figs. 16-21), mixed-layer depths (Figs. 22-27) and bottom temperatures (Figs. 31-36) over the shelf were selected to give a uniform spacing between BT positions and to avoid questionable BT traces. The obvious requirement that the BT trace extend to the bottom (as determined from fathometer records) necessitated a large number of rejections, especially among MBT's in deeper portions of the shelf area. Thus, out of 923 BT traces originally considered for shelf temperature information on the basis of a uniform geographical distribution, only 700 met all the remaining criteria. This number does not include BT data used to construct graphs of seasonal cycles of average temperatures for offshelf areas, as described earlier. It was found that dividing the 700 data points into twelve one-month periods did not give a sufficiently uniform distribution to permit reliable contouring. To ensure an adequate density of data over the entire shelf, it was found necessary to group the data into six two-month periods. In constructing maps of surface temperatures (Figs. 16-21), values of shore temperatures have been considered, especially in contouring nearshore data. The U.S. Dept. of Commerce C. & G. S. Pub. 31-1 and the atlas by Robinson (1973) have been referred to for this information. Robinson's atlas also was considered in constructing mixed-layer depth maps.

Appendix II — Reliability of Results

From a statistical analysis of the data incorporated in this report, it was found that, on an annual basis, there was an average standard deviation of approximately 18 meters (59 feet) in depths of the offshelf isotherms as determined from MBT traces (91 percent of the data was obtained from MBT traces, the remaining 9 percent from XBT traces). A small part of this 18-meter (59-foot) deviation (about 11 percent) can be attributed to instrument error. According to Dinkel and Stawnychy (1973), the depth accuracy of MBT's deteriorates with repeated pressure cyclings, the rate of error change leveling off asymptotically after an initially large error increase. For a test sample size of 12 MBT's with a 0-275 meter (0-900 foot) depth range, they reported a mean depth error of approximately 5 meters (16 feet) after subjecting all 12 MBT's to 300 full-range pressure cyclings in the laboratory to simulate lowering and raising the MBT's from the surface to 275 meters (900 feet) in the ocean. Assuming this error is linear over the 275-meter (900-foot) depth range, this represents an error of approximately 2 meters (6 feet) for a depth of 100 meters (328 feet), the mean depth encountered over the shelf. Assuming that these results are representative of actual field conditions, then it would be reasonable to expect this error to be a valid estimate of instrument error for the purposes of this report. The remaining 89 percent of the original 18-meter (59-foot) deviation is assumed to be due to fluctuations of either an environmental or random nature. Dinkel and Stawnychy (1973) have shown that the average temperature error of MBT's is typically 0.2° C (0.4° F). Thus, variations introduced by temperature errors are negligible compared to variations caused by depth errors.

It is useful to translate this vertical deviation into a horizontal deviation along the shelf bottom. If the average inclination of the Texas-Louisiana shelf is taken to be 5 minutes 30 seconds, and the shelf is assumed to be smooth with an average width of 125 kilometers (67 nautical miles), then Figure 39 is a valid representation of a vertical cross section of the shelf. Let Δy be the average vertical standard deviation (18 meters or 59 feet) about a perfectly horizontal isotherm, then, as can be seen from Figure 39, the horizontal projection of the shelf floor (Δx) can be obtained from the relation $\Delta x = \Delta y \cot(\phi)$, where $\phi = 5'30''$ (the shelf inclination). Thus, the 18-meter (59-foot) vertical deviation becomes approximately a 13-kilometer (seven-nautical-mile) horizontal deviation.

The vertical deviation of 18 meters (59 feet) can also be stated in terms of a deviation of temperature. By examining Figures 2, 3 or 4, it can be seen that a vertical distance of 18 meters (59 feet) is roughly equivalent to a temperature change of 1.5° C (2.7° F) at a depth of approximately 100 meters (328 feet), the mean depth encountered over the shelf.

As a result of the above analysis, it is possible to give an estimate of the deviation to be expected in the bottom isotherm patterns as they are presented here. In terms of horizontal distance along the shelf floor, the isotherms have an average deviation of approximately 13 kilometers; in terms of temperature, the isotherms have a deviation roughly equivalent to 1.5° C (2.7° F). From a statistical interpretation, 68 percent of the analyzed data would fall within 13 kilometers or 1.5° C (2.7° F) of bottom temperature contours depicted in this report.

Appendix III — Figures

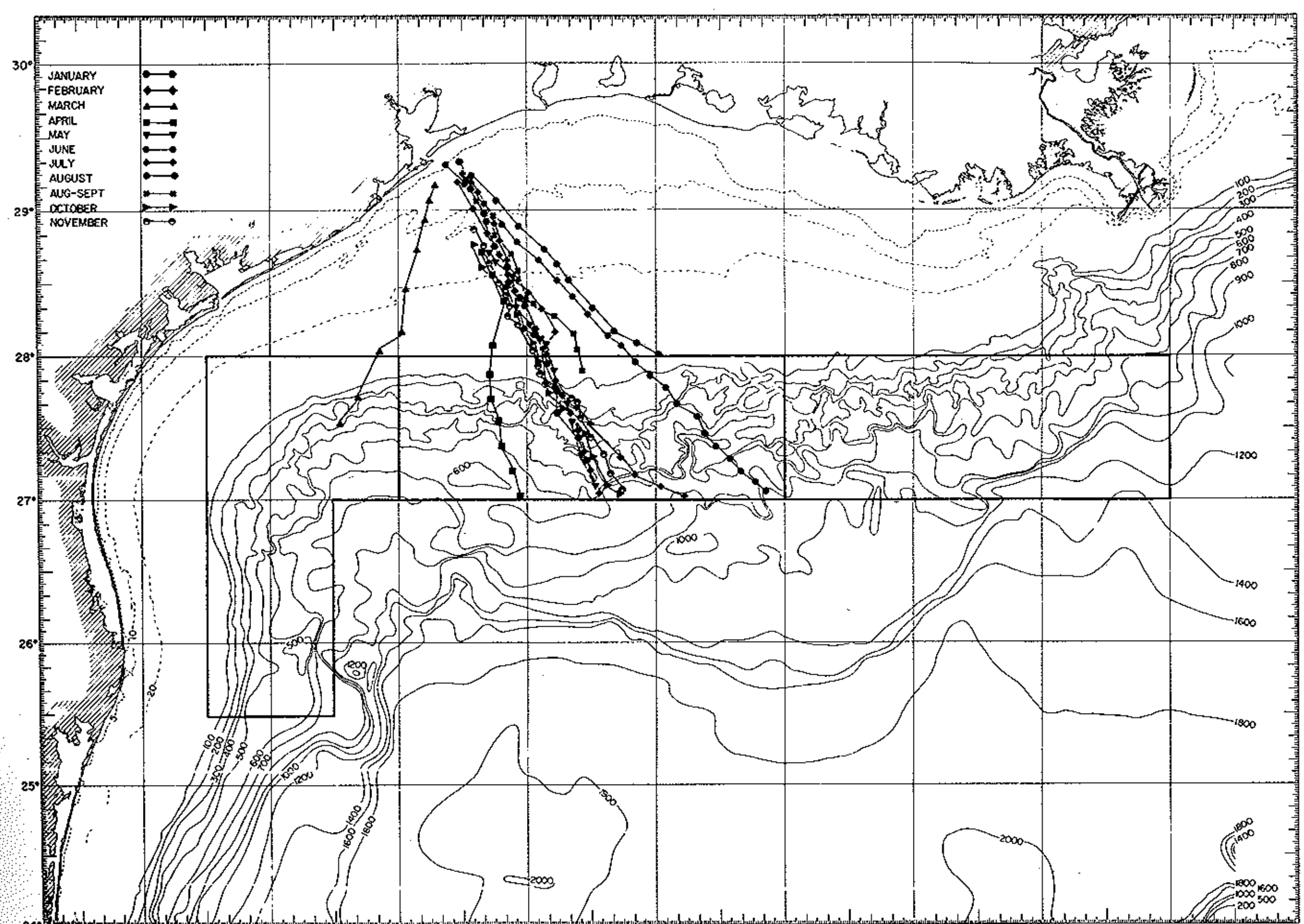

Figure 1. Bathymetry, offshelf regions, and location of vertical sections on the Texas-Louisiana shelf. From left to right, the three offshelf regions are referred to respectively as the Western, Central, and Eastern Regions.

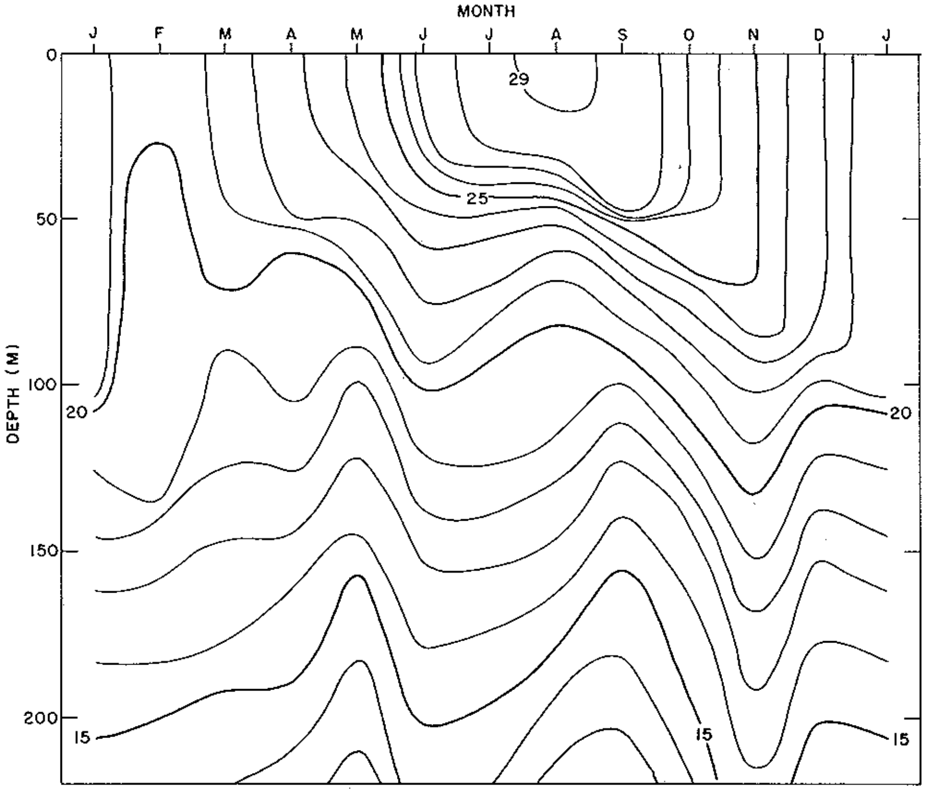

Figure 2. Annual variation of temperature (° C) with depth down to 225 meters for the Western Region.

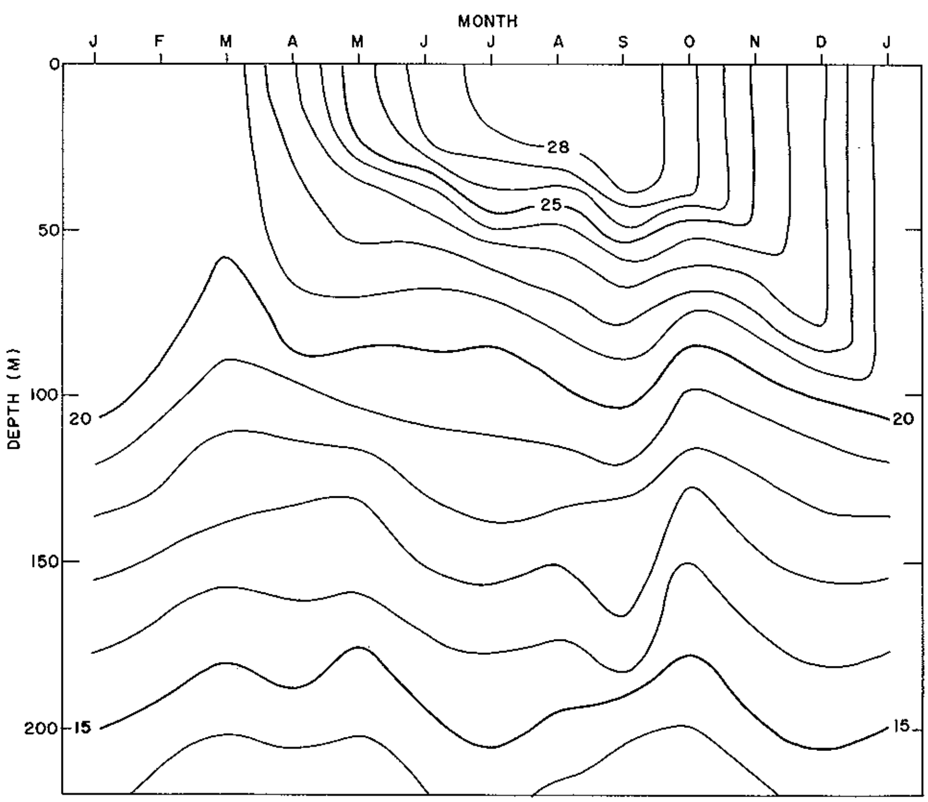

Figure 3. Annual variation of temperature (° C) with depth down to 225 meters for the Central Region.

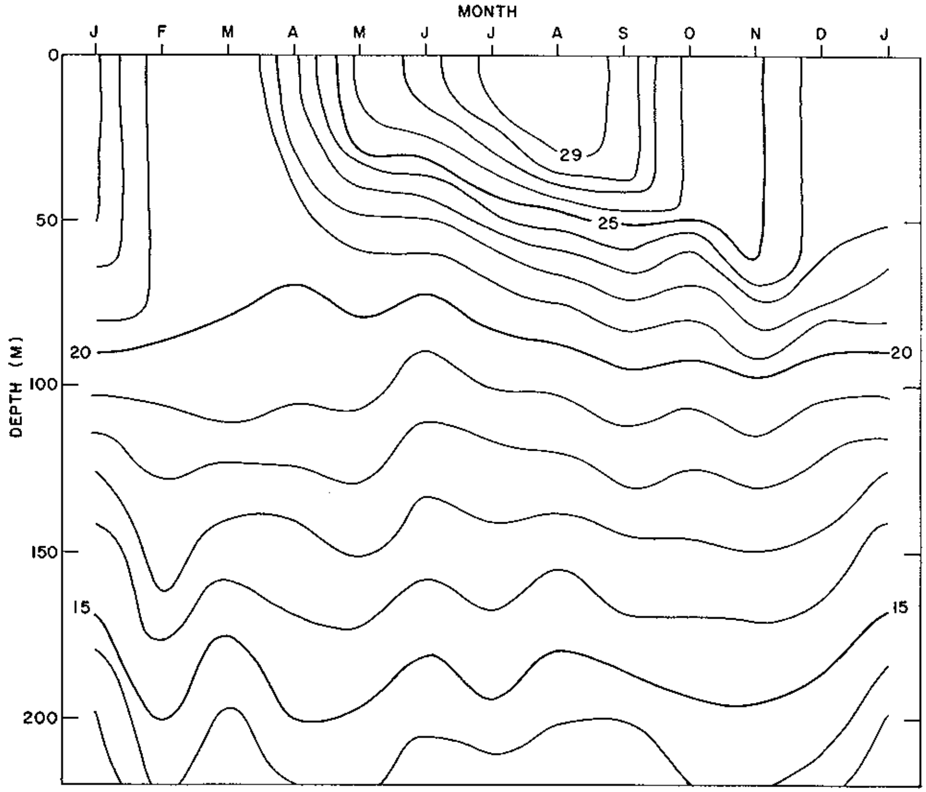

Figure 4. Annual variation of temperature (° C) with depth down to 225 meters for the Eastern Region.

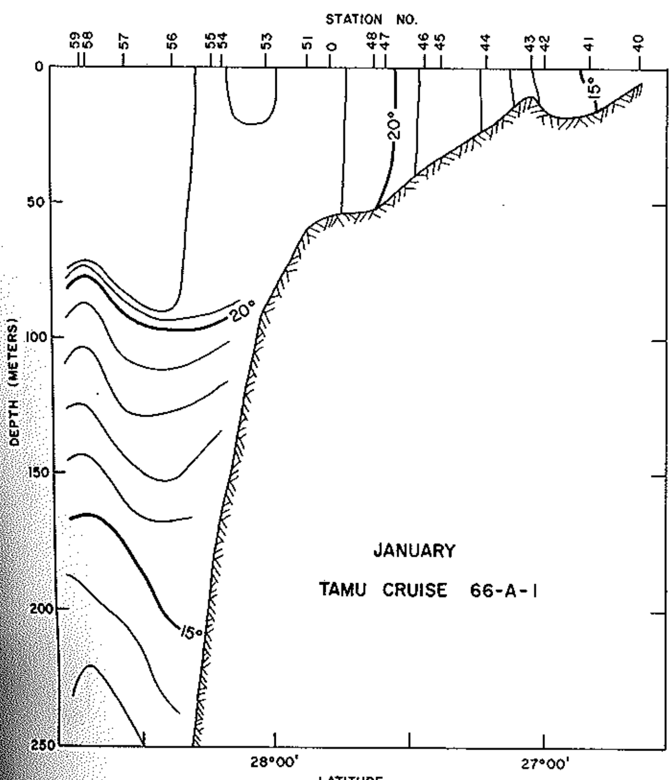

Figure 5. Vertical section of isotherm depths for January. The corresponding cruise track is depicted in Figure 1. All temperatures are in degrees Celsius.

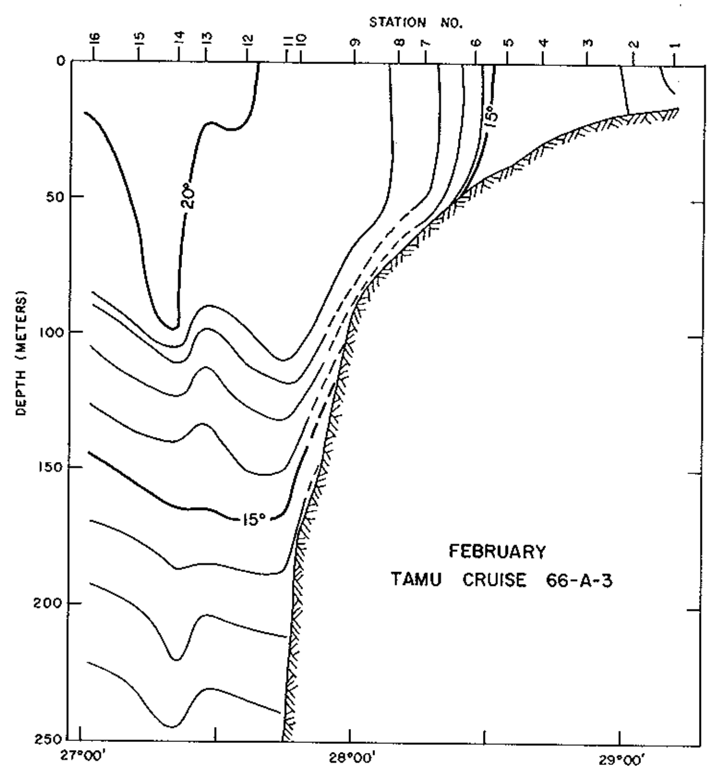

Figure 6. Vertical section of isotherm depths for February. The corresponding cruise track is depicted in Figure 1. All temperatures are in degrees Celsius.

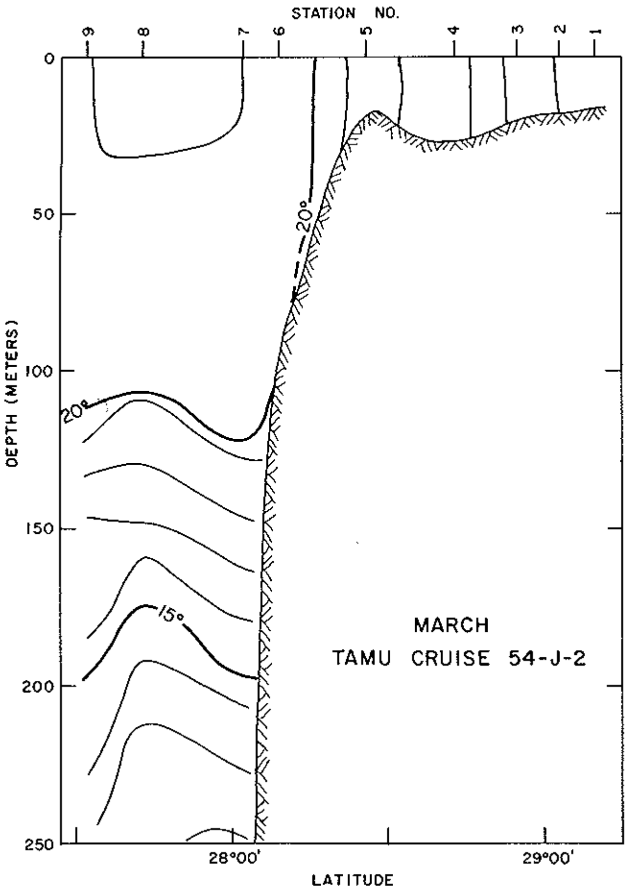

Figure 7. Vertical section of isotherm depths for March. The corresponding cruise track is depicted in Figure 1. All temperatures are in degrees Celsius.

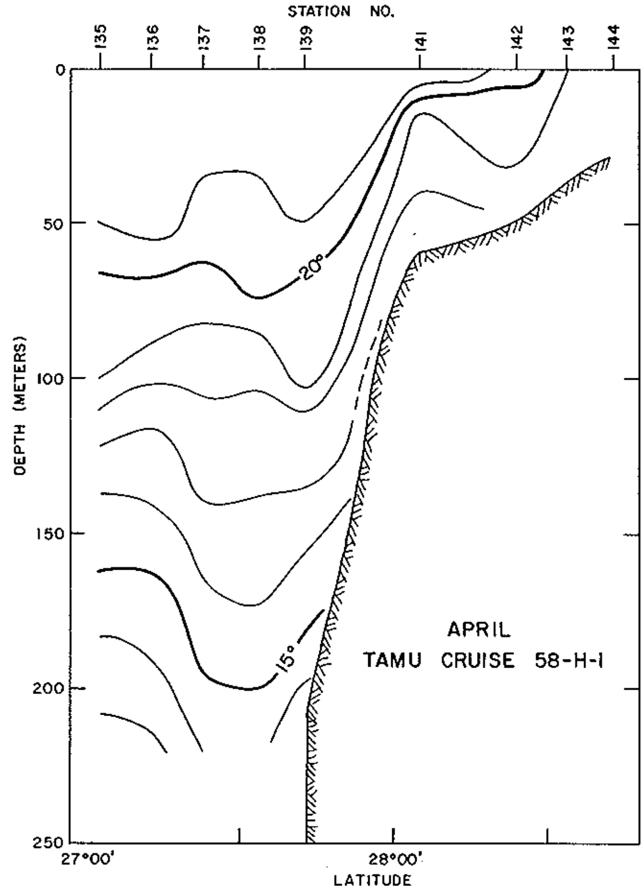

Figure 8. Vertical section of isotherm depths for April. The corresponding cruise track is depicted in Figure 1. All temperatures are in degrees Celsius.

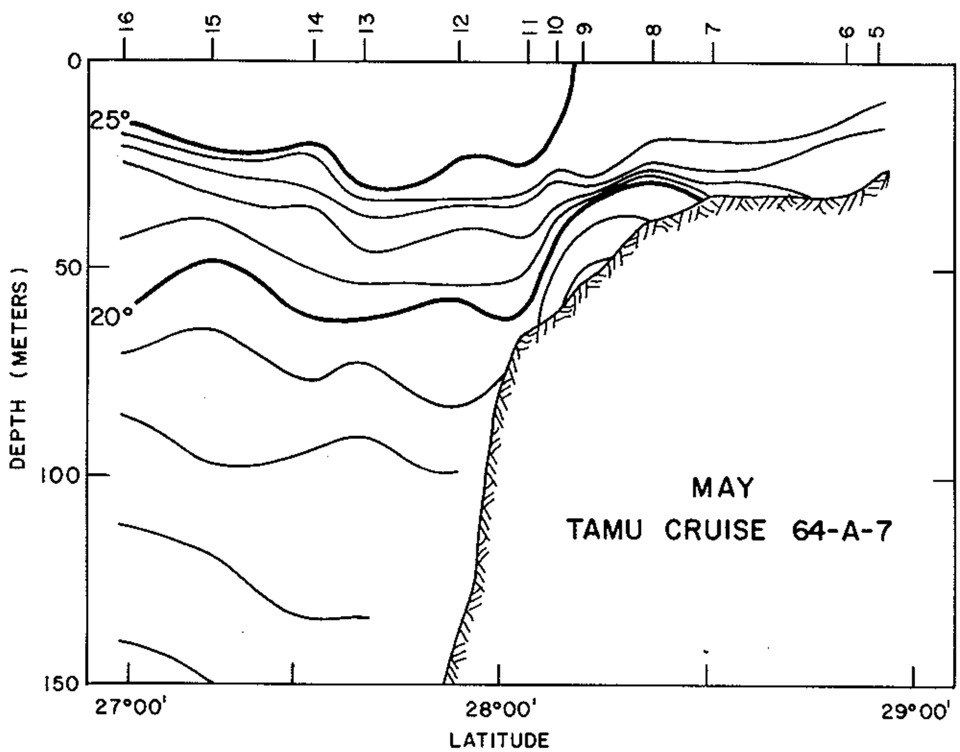

Figure 9. Vertical section of isotherm depths for May. The corresponding cruise track is depicted in Figure 1. All temperatures are in degrees Celsius.

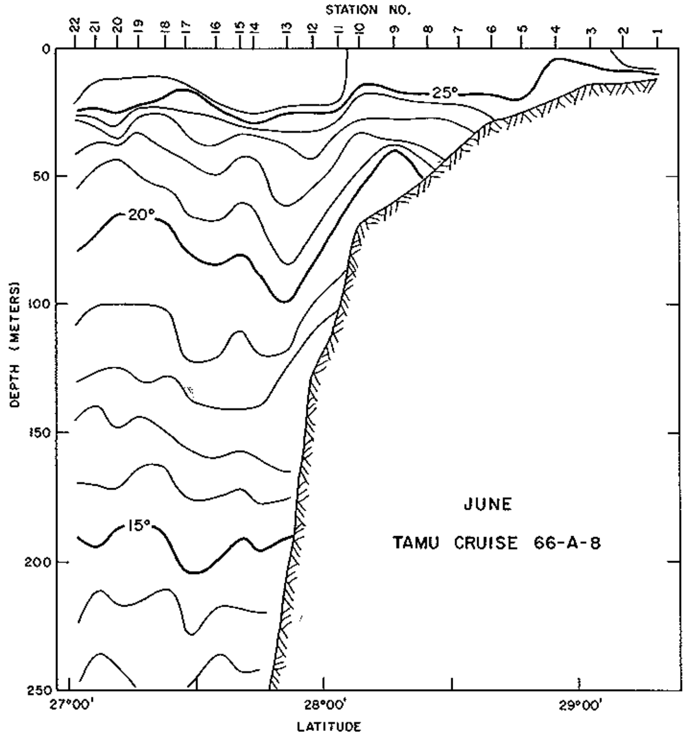

Figure 10. Vertical section of isotherm depths for June. The corresponding cruise track is depicted in Figure 1. All temperatures are in degrees Celsius.

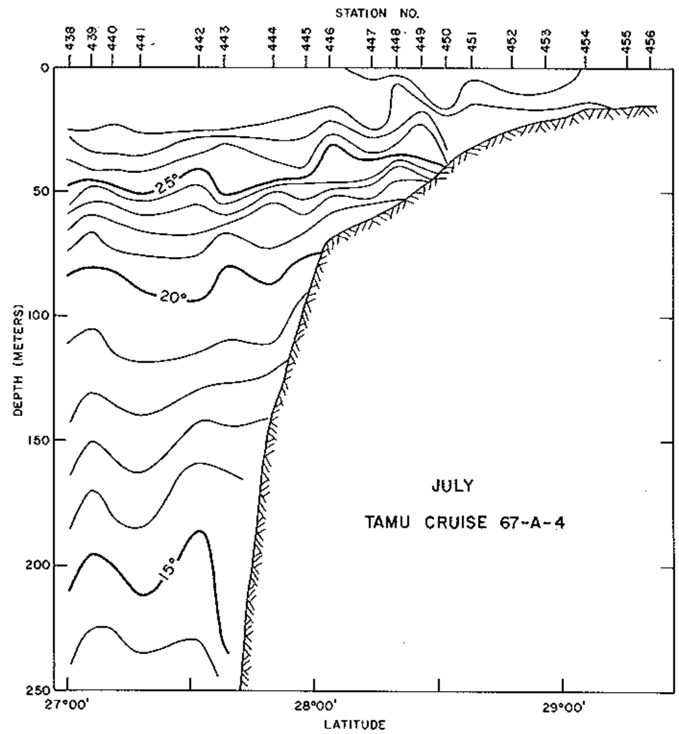

Figure 11. Vertical section of isotherm depths for July. The corresponding cruise track is depicted in Figure 1. All temperatures are in degrees Celsius.

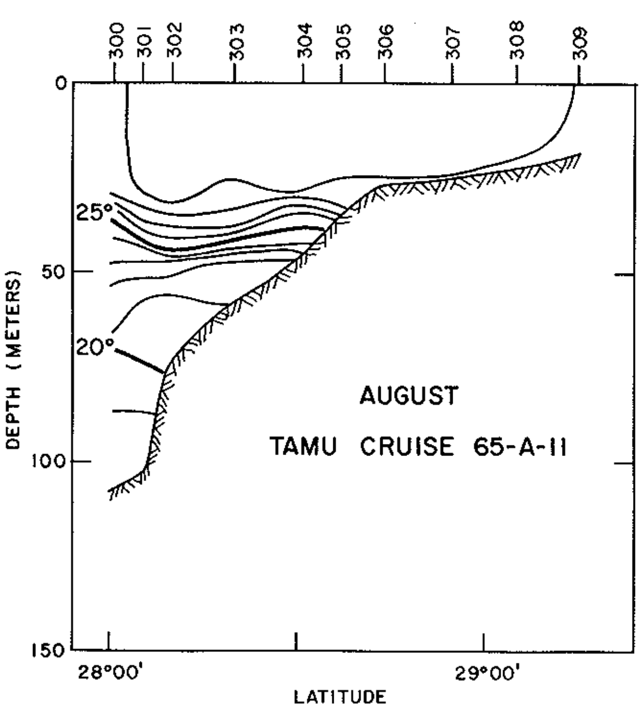

Figure 12. Vertical section of isotherm depths for August. The corresponding cruise track is depicted in Figure 1. All temperatures are in degrees Celsius.

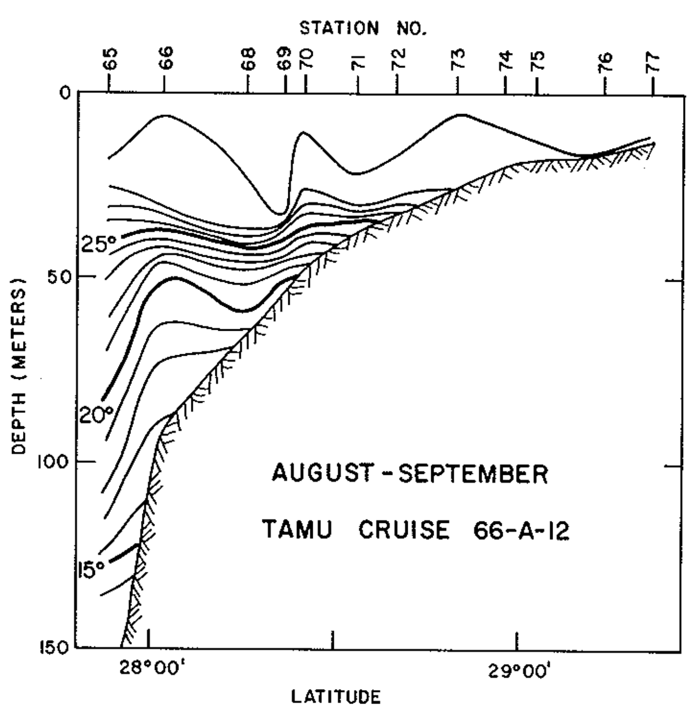

Figure 13. Vertical section of isotherm depths for August-September. The corresponding cruise track is depicted in Figure 1. All temperatures are in degrees Celsius.

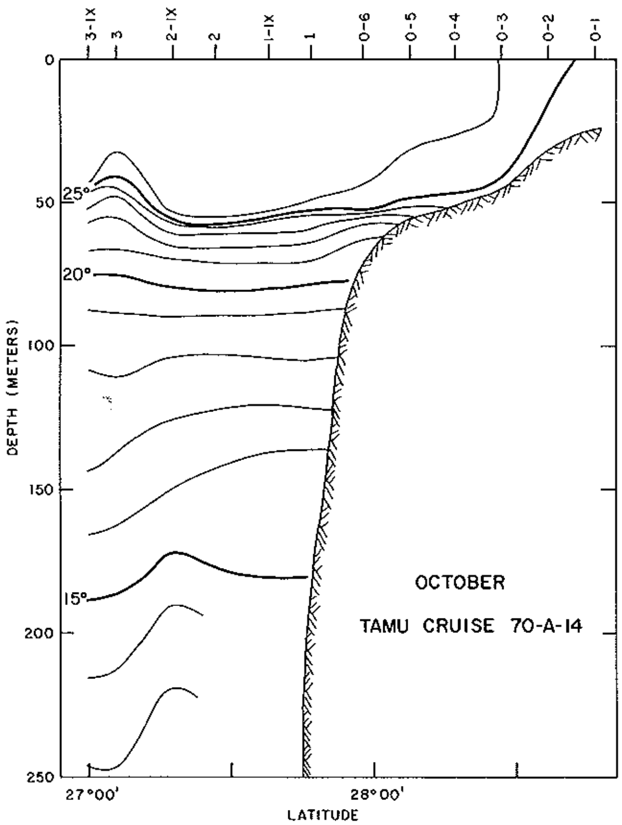

Figure 14. Vertical section of isotherm depths for October. The corresponding cruise track is depicted in Figure 1. All temperatures are in degrees Celsius.

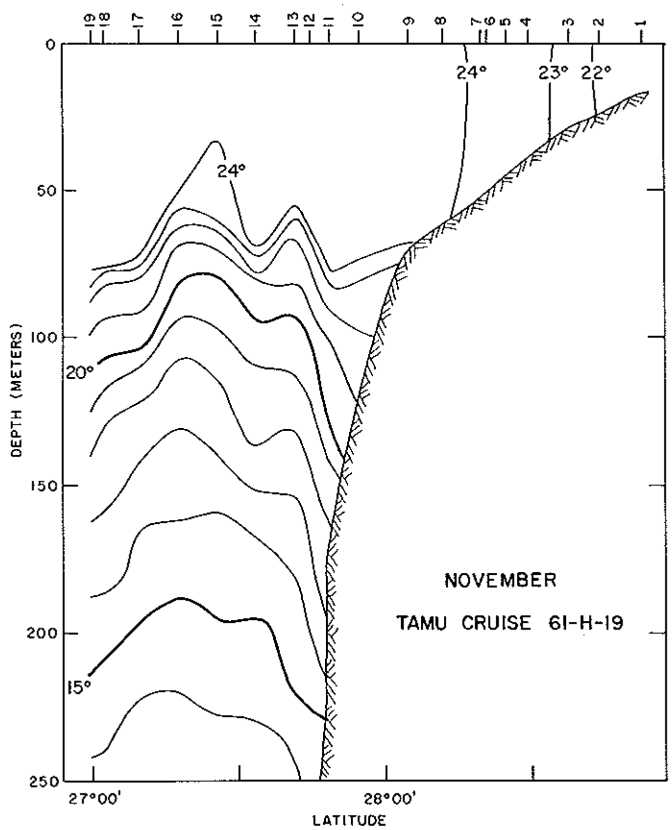

Figure 15. Vertical section of isotherm depths for November. The corresponding cruise track is depicted in Figure 1. All temperatures are in degrees Celsius.

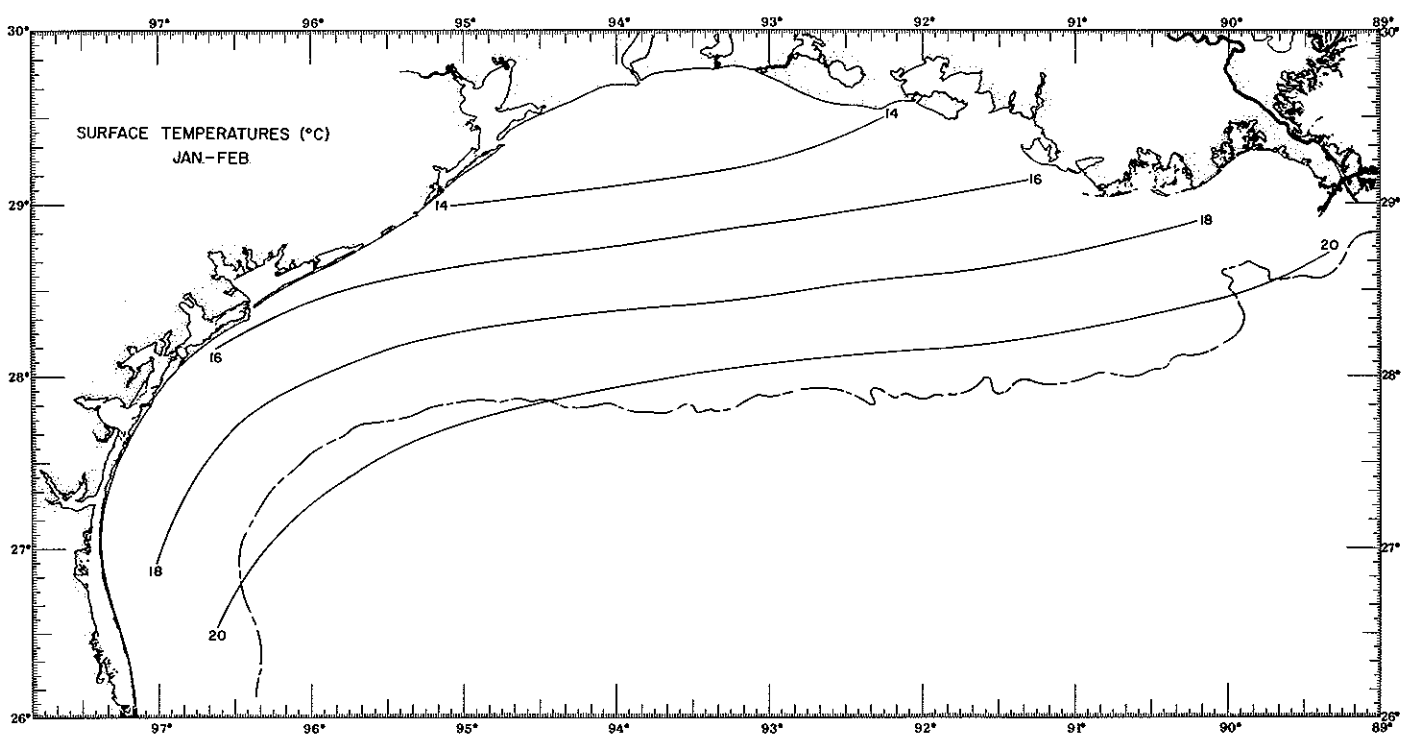

Figure 16. Map of mean surface temperatures (° C) for January-February.

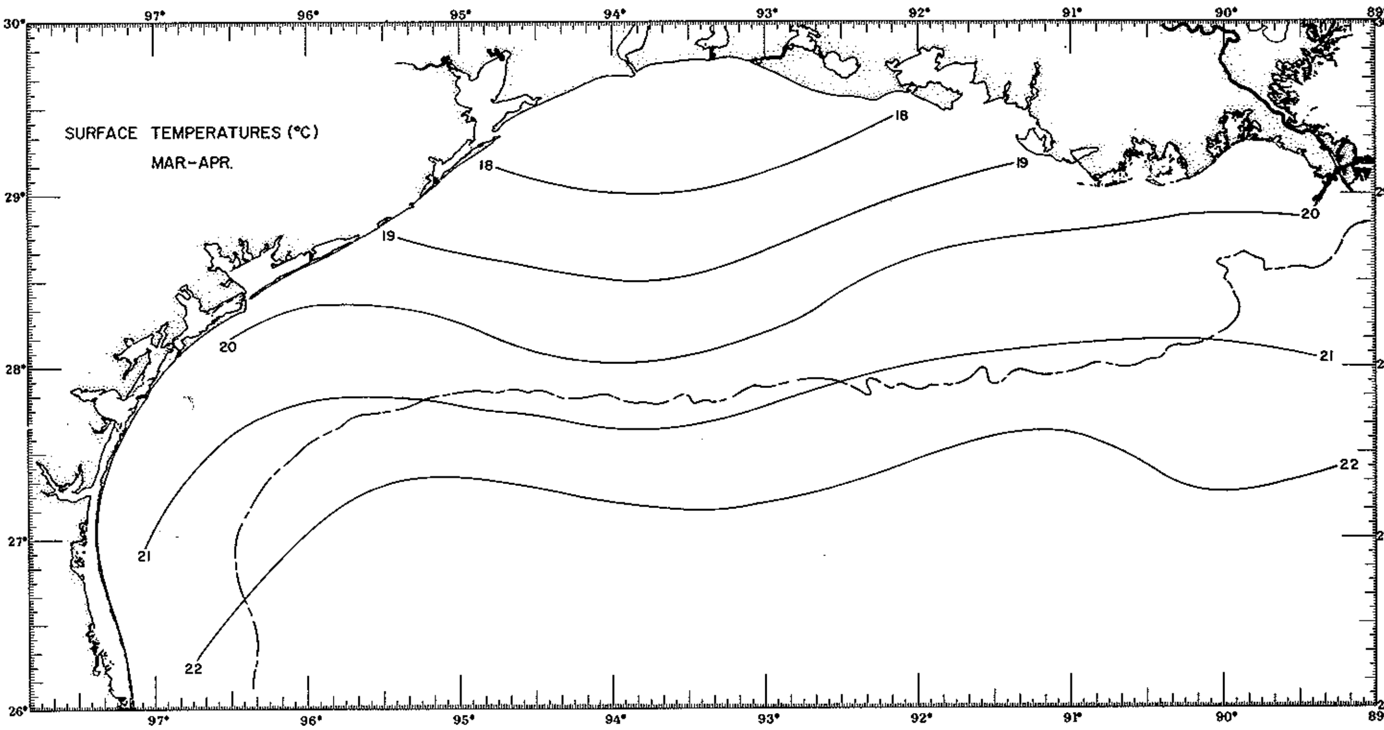

Figure 17. Map of mean surface temperatures (° C) for March-April.

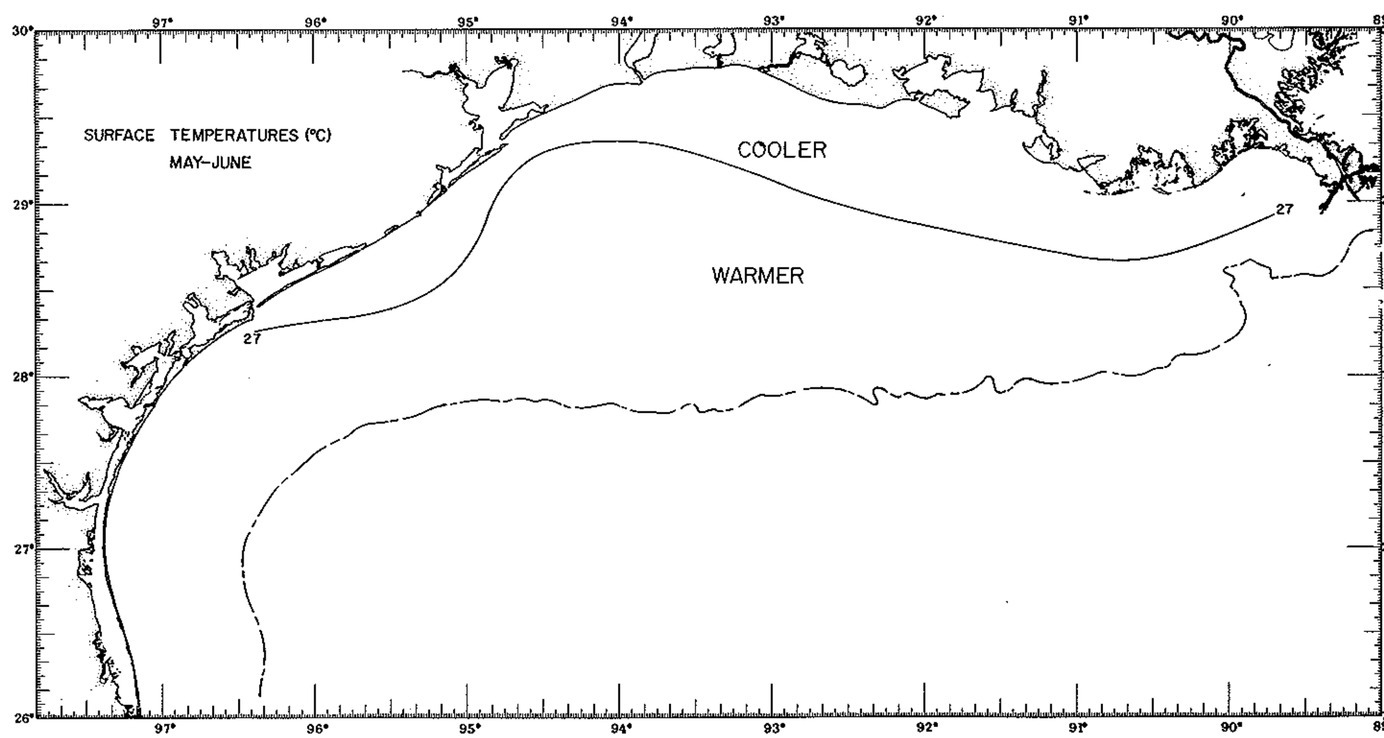

Figure 18. Map of mean surface temperatures (° C) for May-June.

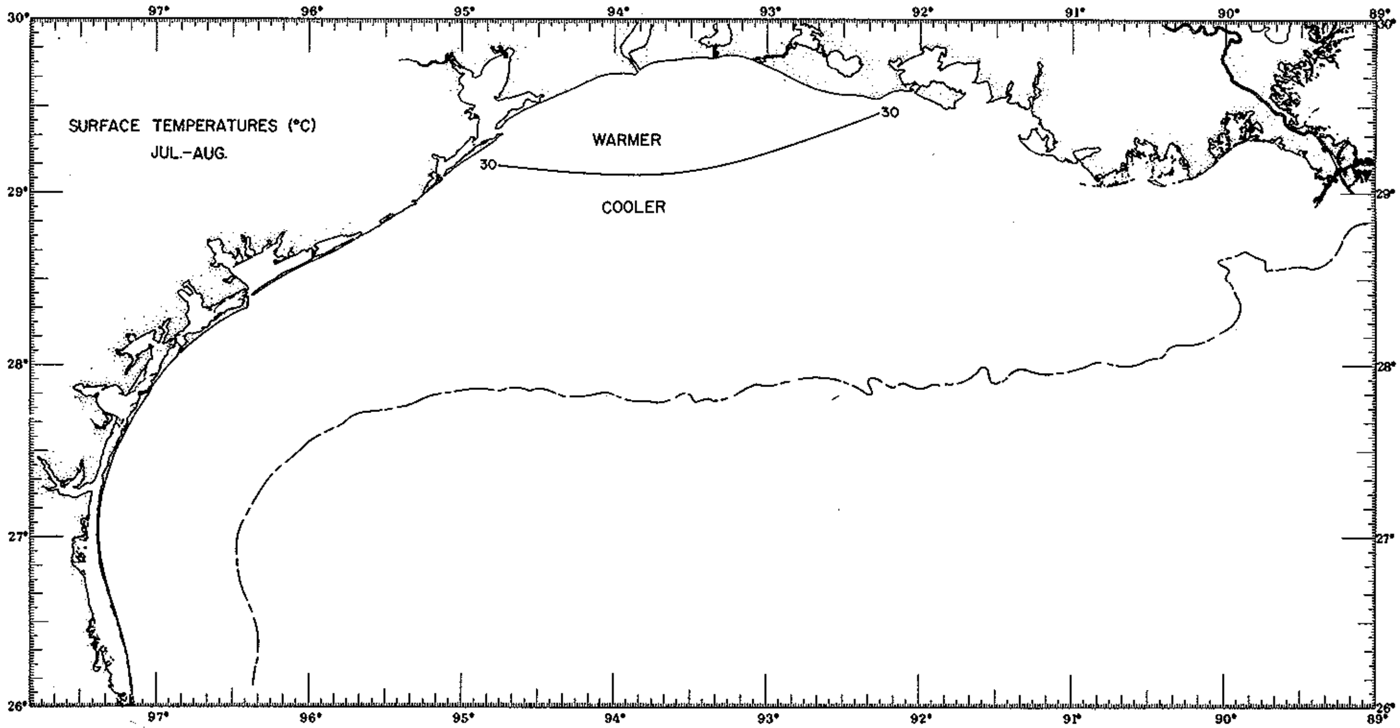

Figure 19. Map of mean surface temperatures (° C) for July-August.

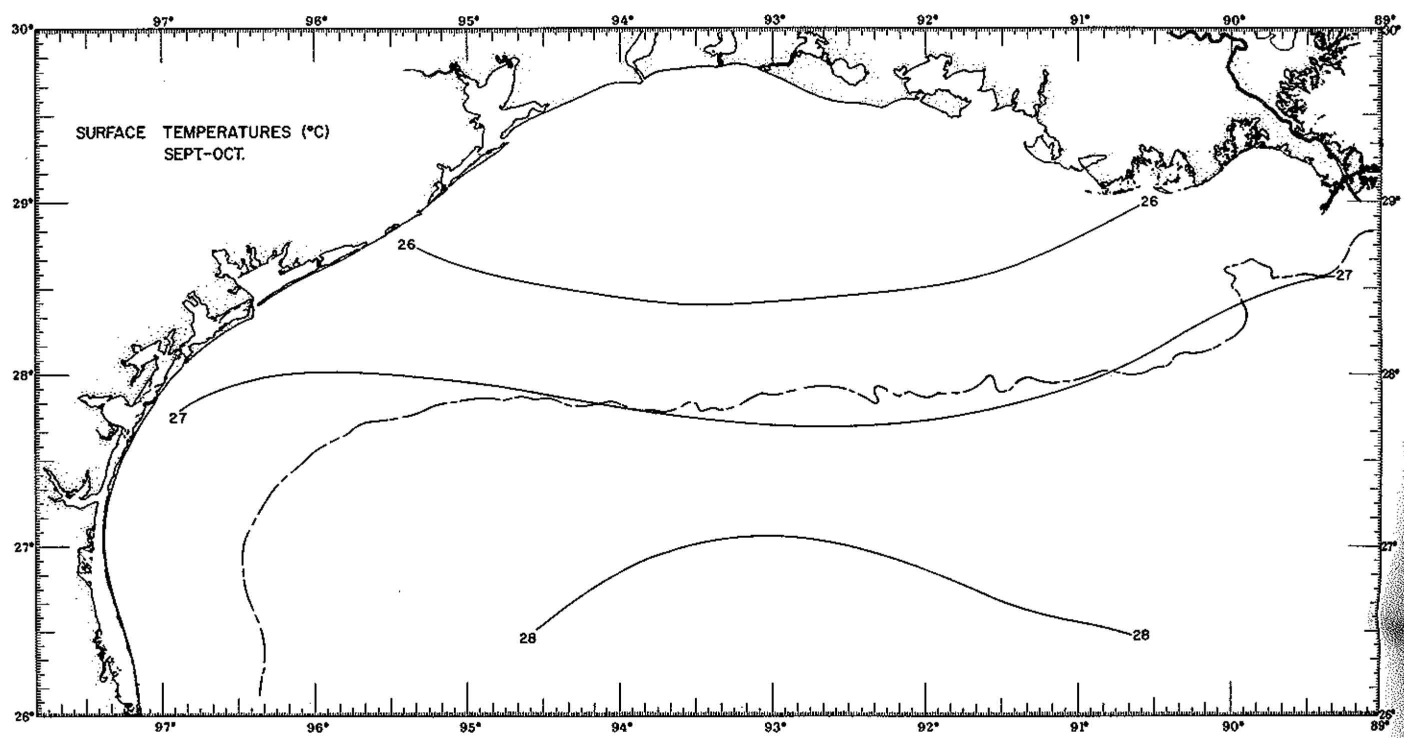

Figure 20. Map of mean surface temperatures (° C) for September-October.

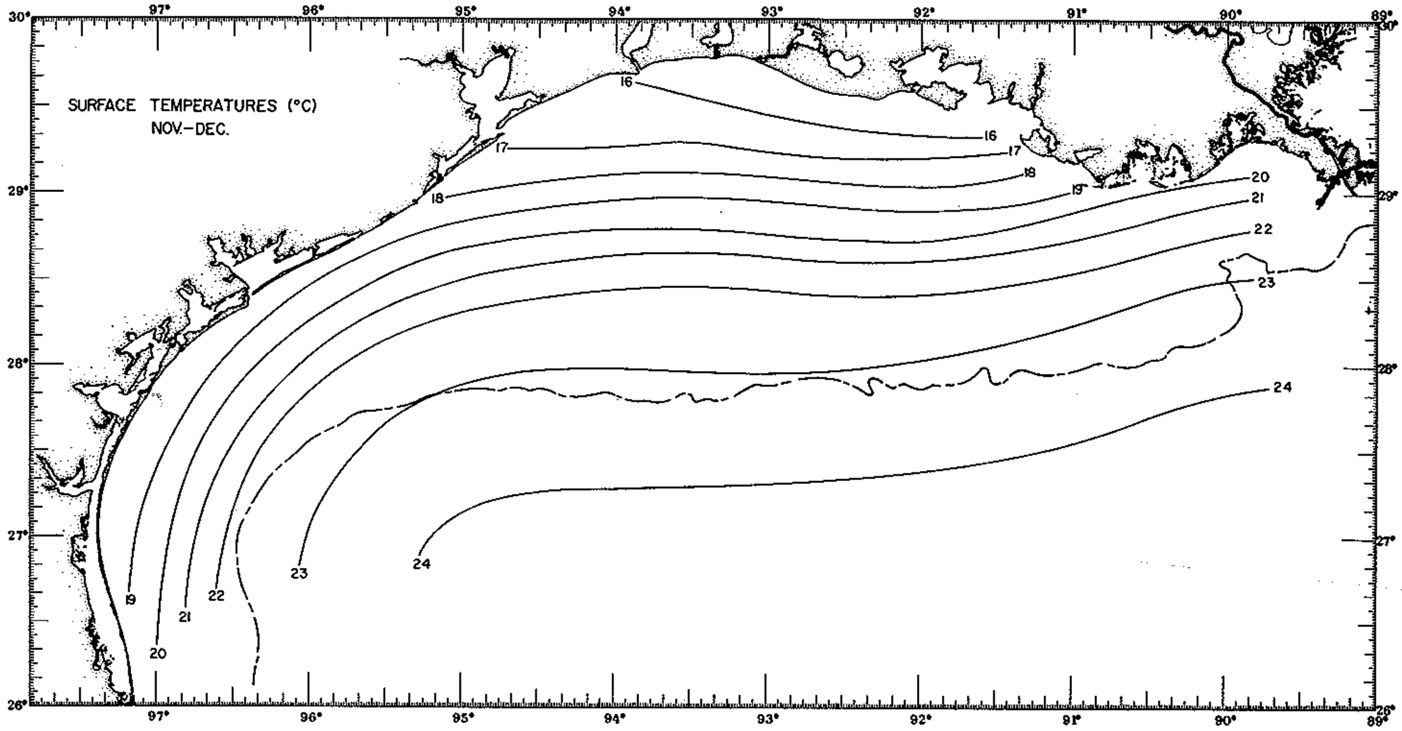

Figure 21. Map of mean surface temperatures (° C) for November-December.

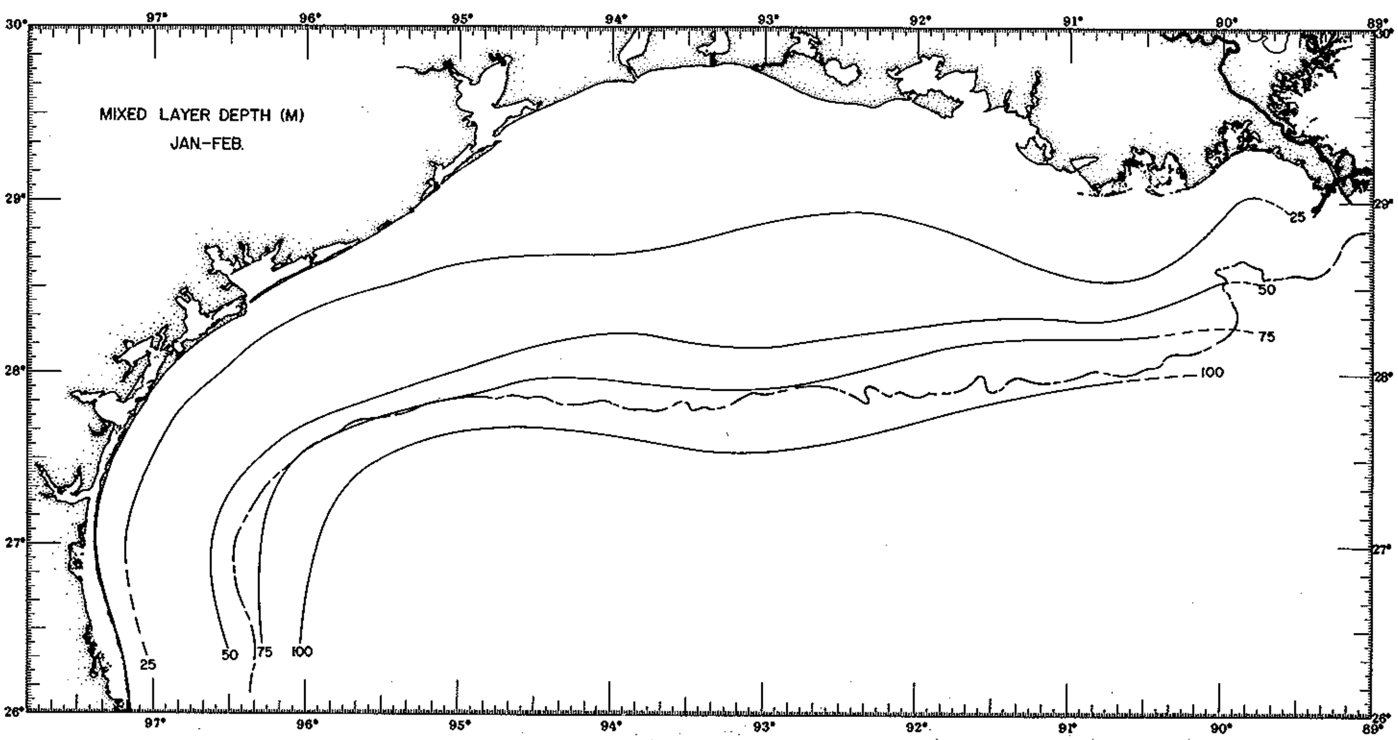

Figure 22. Map of mixed-layer depths (meters) for January-February. Dashed lines indicate lack of data, and curvature of such lines suggest most probable tendency.

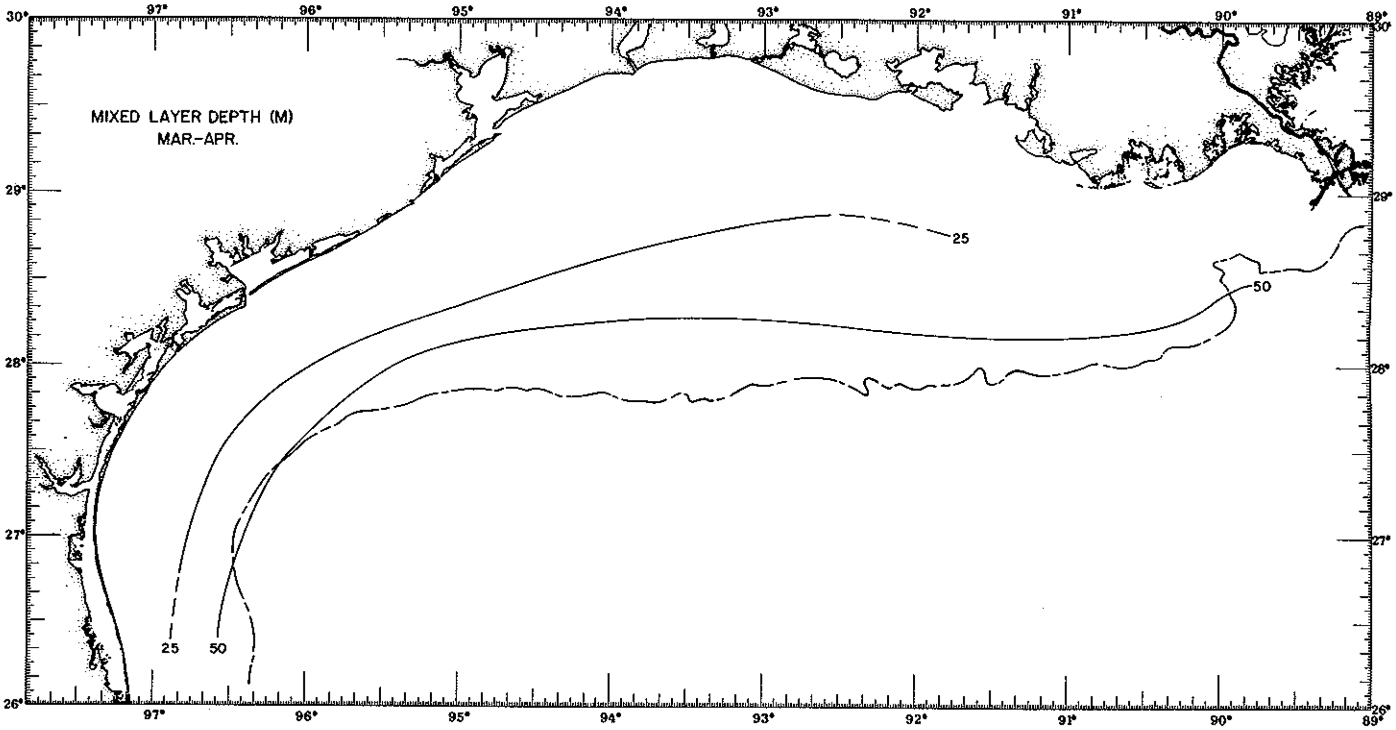

Figure 23. Map of mixed-layer depths (meters) for March-April. Dashed lines indicate lack of data, and curvature of such lines suggest most probable tendency.

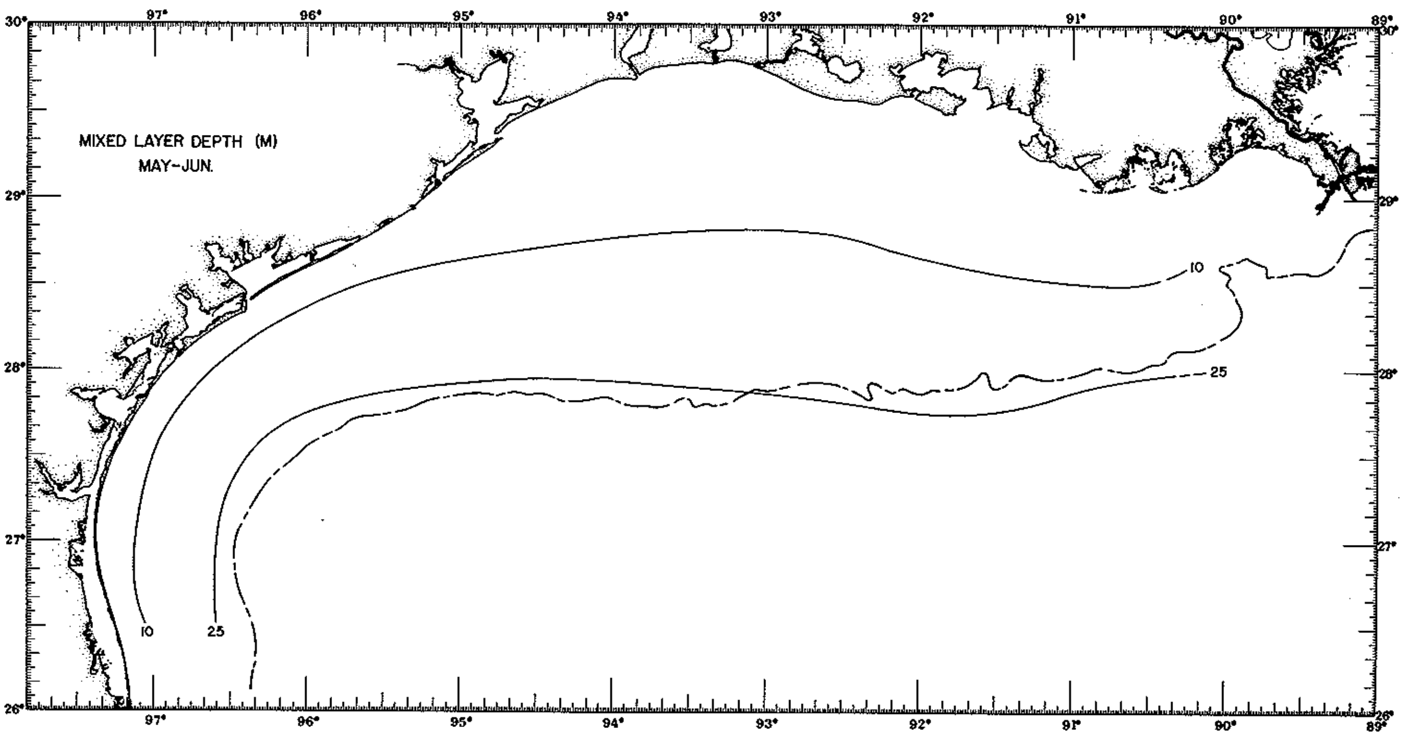

Figure 24. Map of mixed-layer depths (meters) for May-June. Dashed lines indicate lack of data, and curvature of such lines suggest most probable tendency.

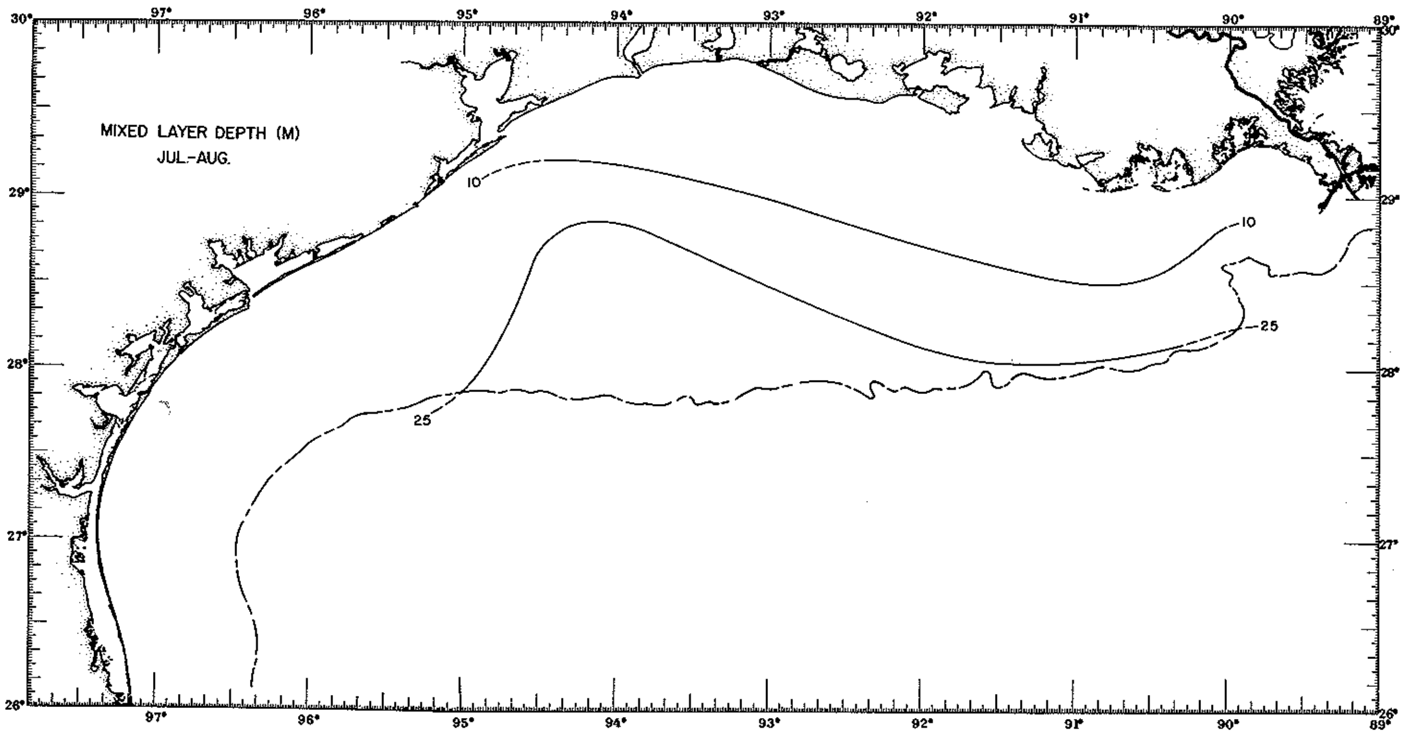

Figure 25. Map of mixed-layer depths (meters) for July-August. Dashed lines indicate lack of data, and curvature of such lines suggest most probable tendency.

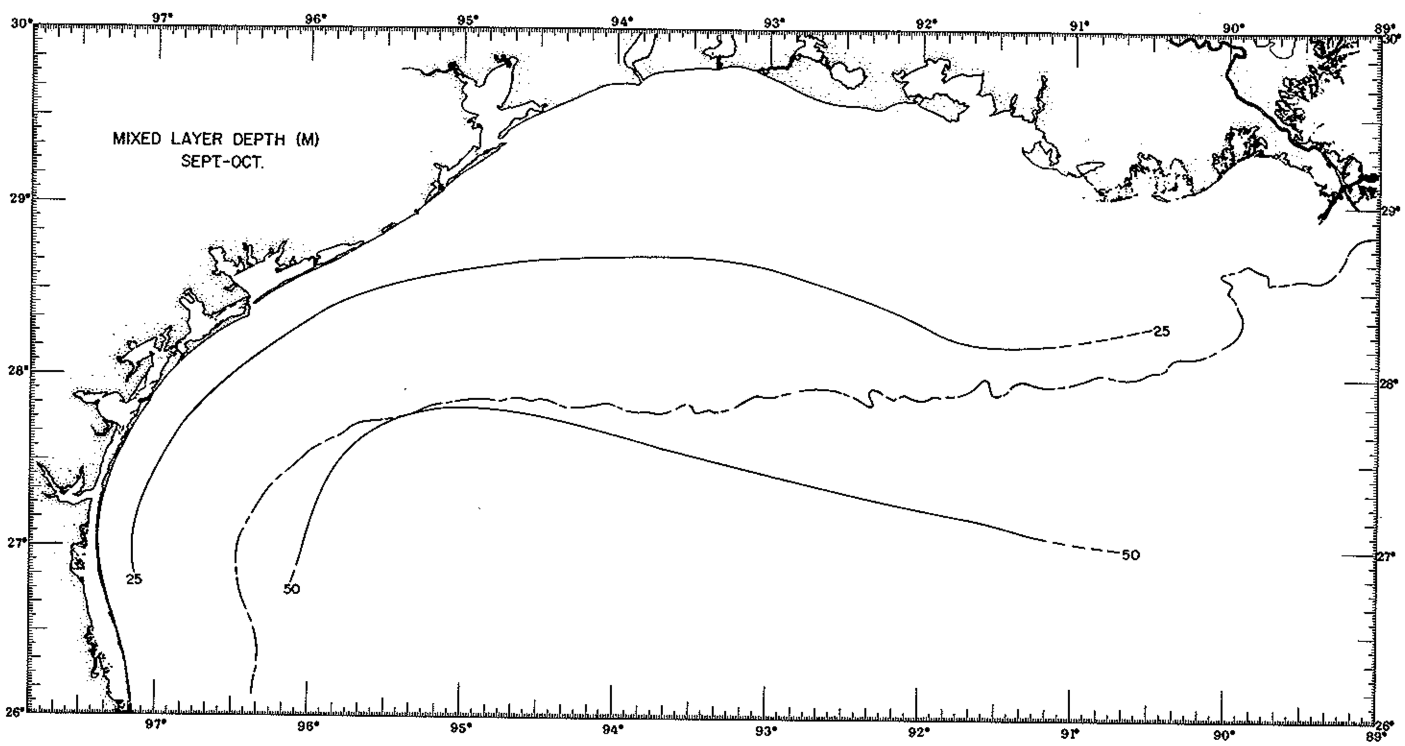

Figure 26. Map of mixed-layer depths (meters) for September-October. Dashed lines indicate lack of data, and curvature of such lines suggest most probable tendency.

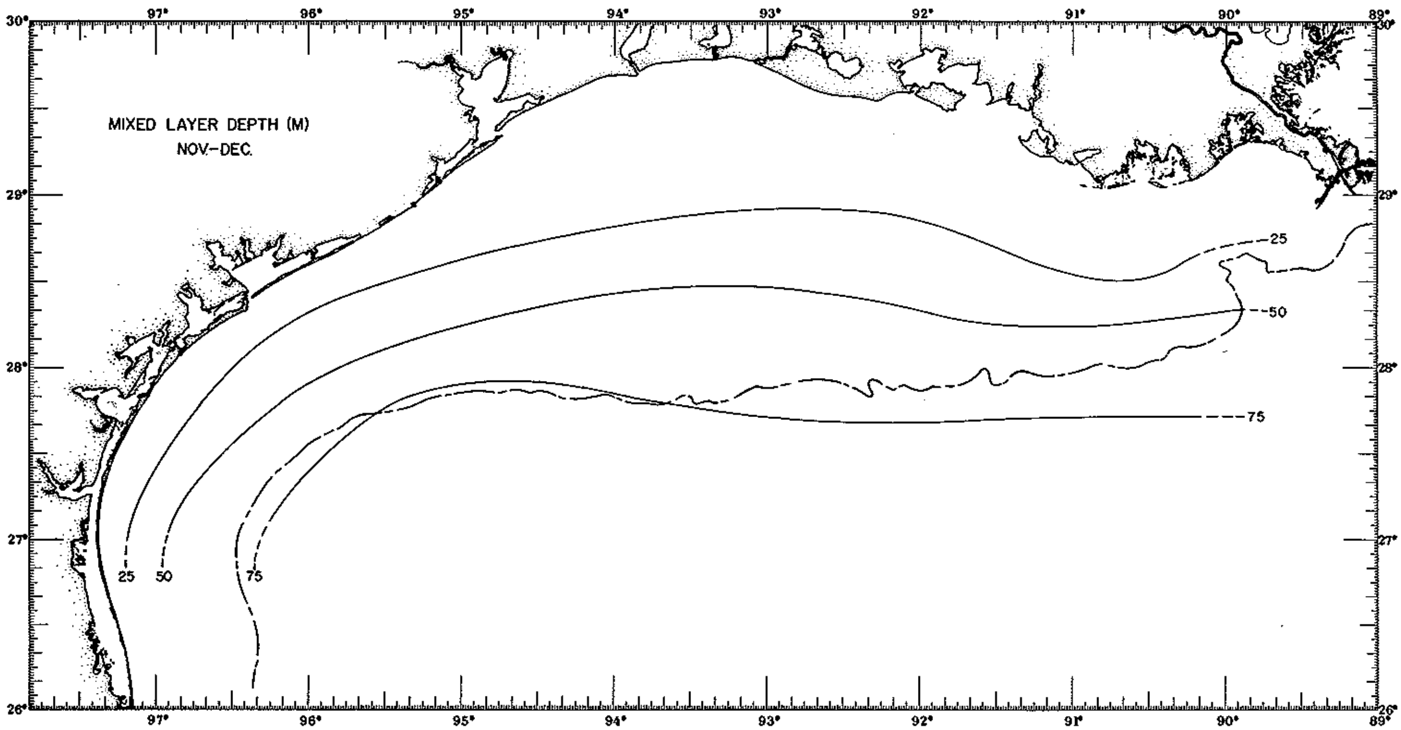

Figure 27. Map of mixed-layer depths (meters) for November-December. Dashed lines indicate lack of data, and curvature of such lines suggest most probable tendency.

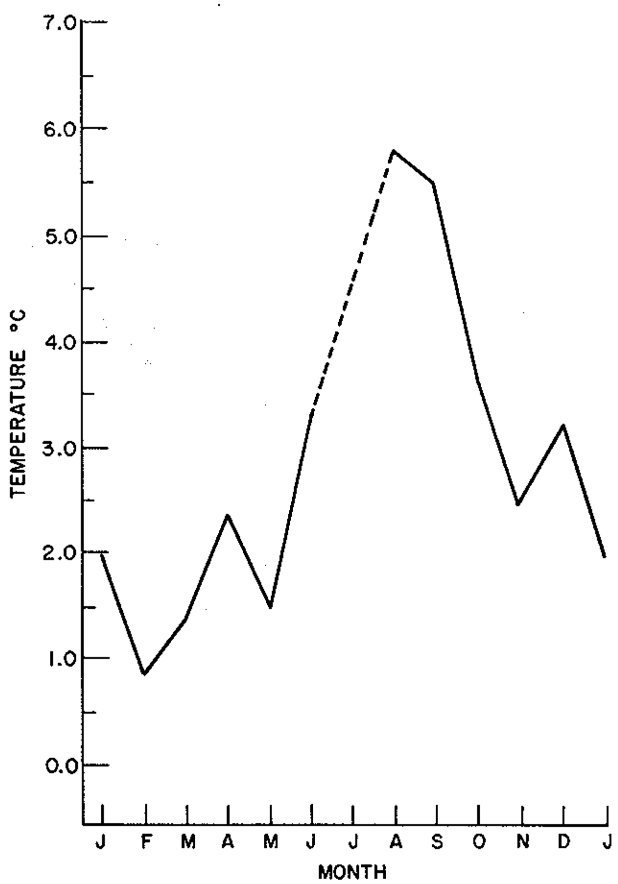

Figure 28. Annual variation of thermocline strength for the Western Region. Thermocline strength is a measure of the decrease in temperature (° C) over 30 meters below depth of mixed layer.

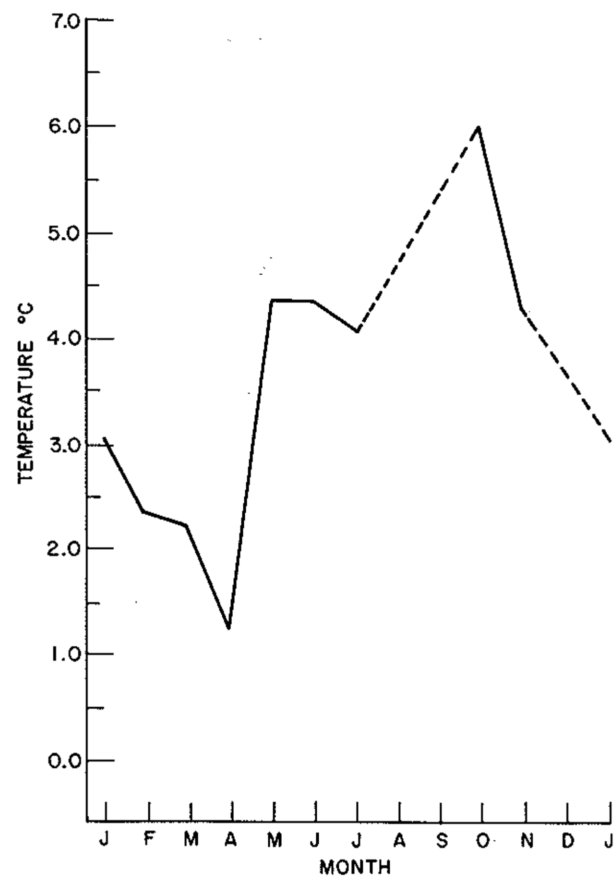

Figure 29. Annual variation of thermocline strength for the Central Region. Thermocline strength is a measure of the decrease in temperature (° C) over 30 meters below depth of mixed layer.

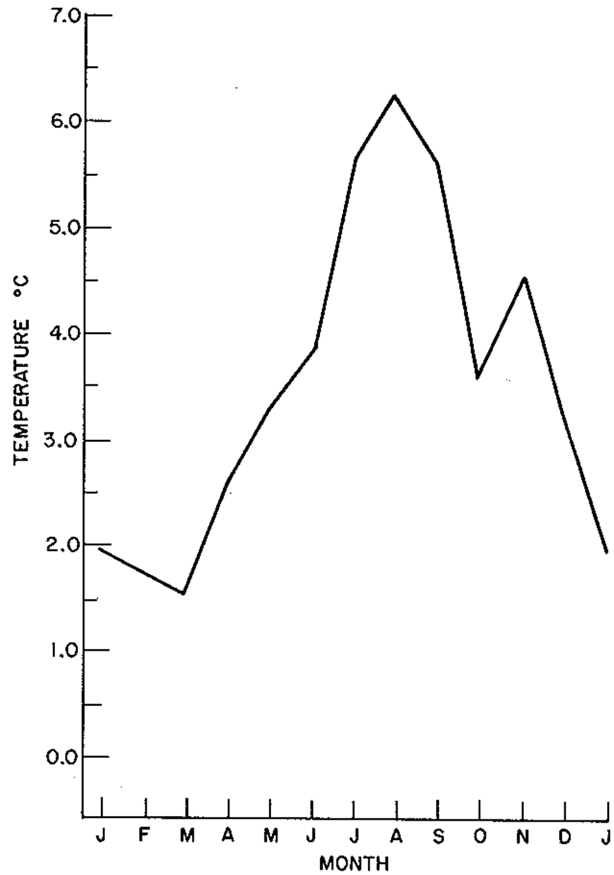

Figure 30. Annual variation of thermocline strength for the Eastern Region. Thermocline strength is a measure of the decrease in temperature (° C) over 30 meters below depth of mixed layer.

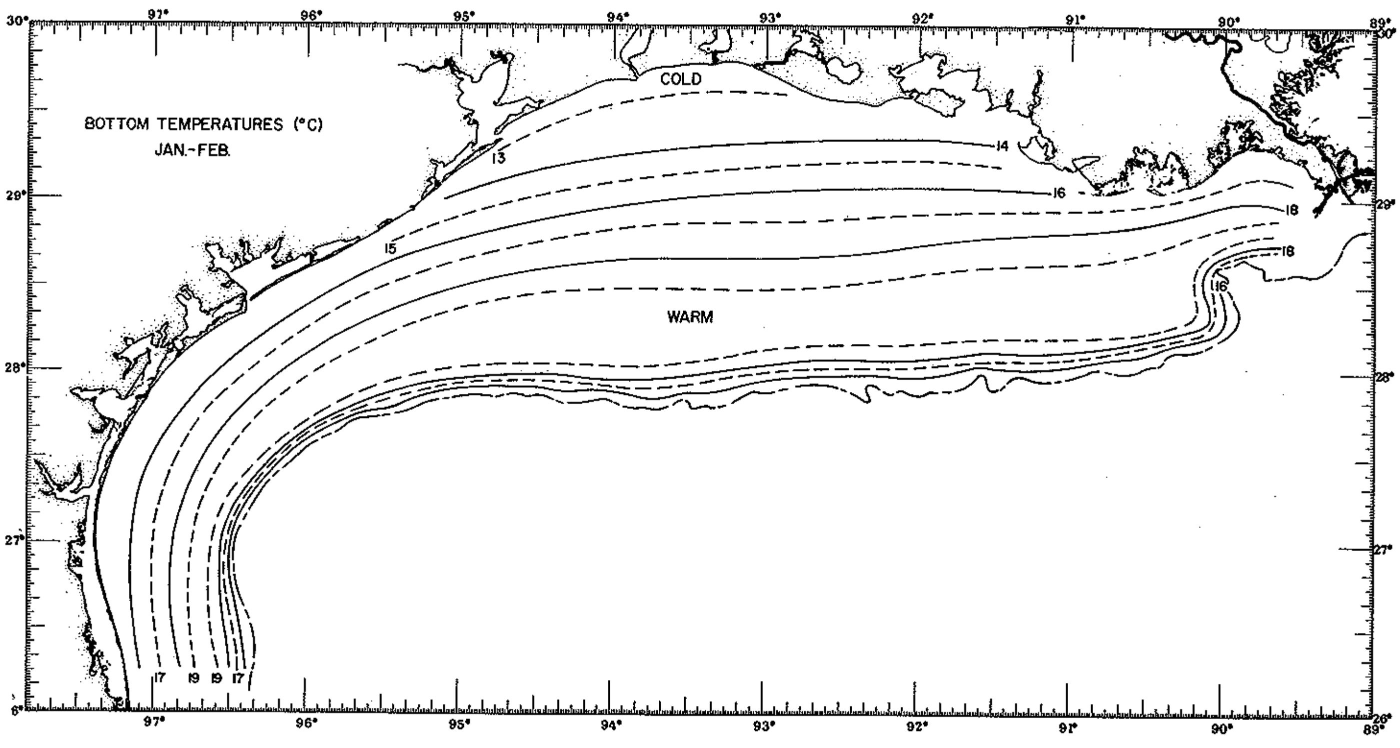

Figure 31. Map of mean bottom temperatures (° C) for January-February. Solid lines represent even values of temperature, dashed lines represent odd values.

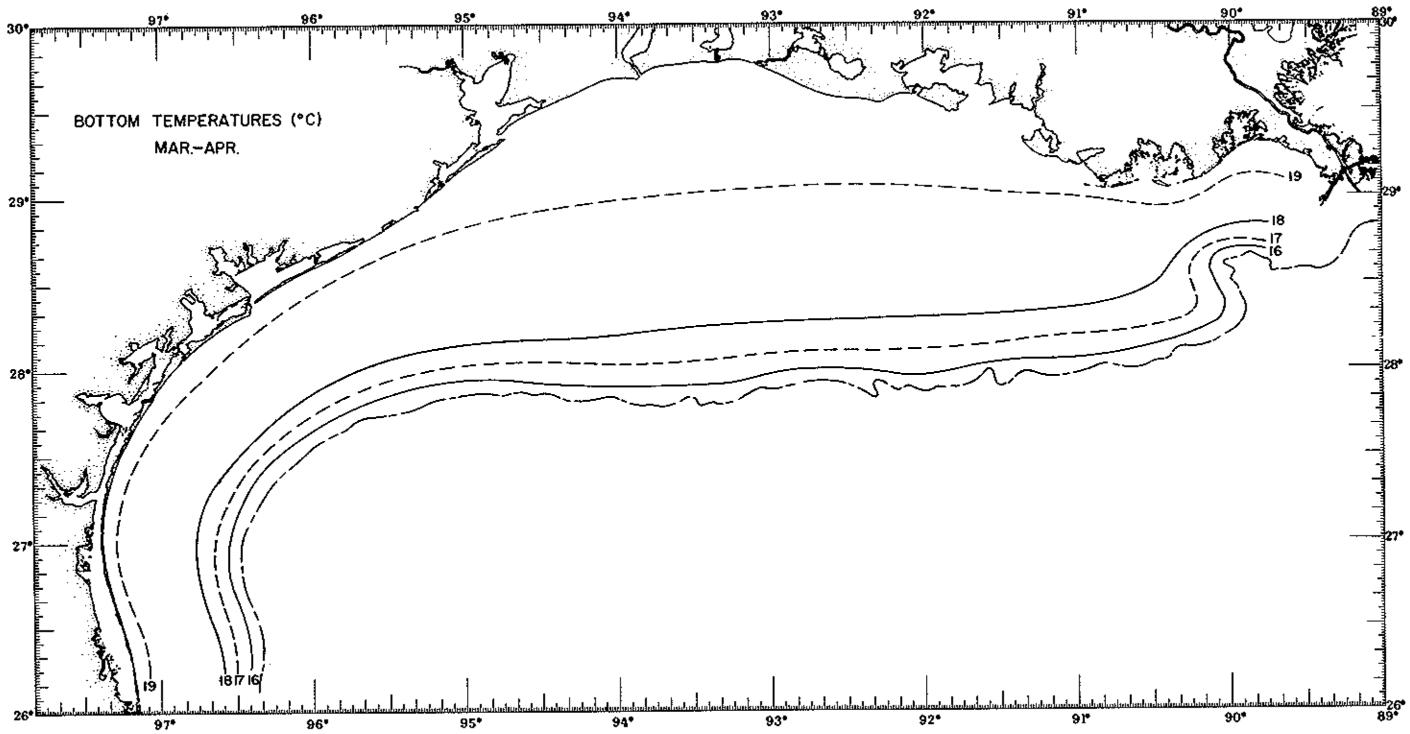

Figure 32. Map of mean bottom temperatures (° C) for March-April. Solid lines represent even values of temperature, dashed lines represent odd values.

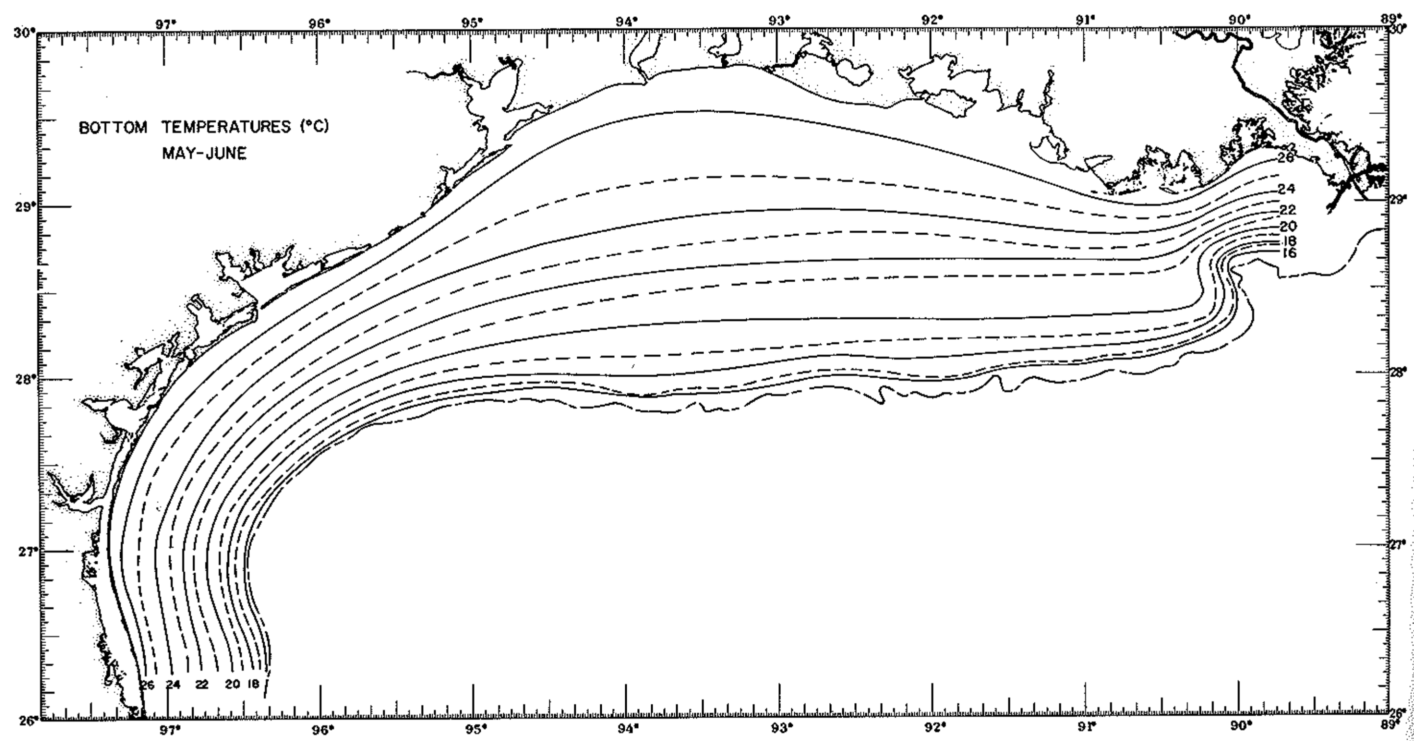

Figure 33. Map of mean bottom temperatures (° C) for May-June. Solid lines represent even values of temperature, dashed lines represent odd values.

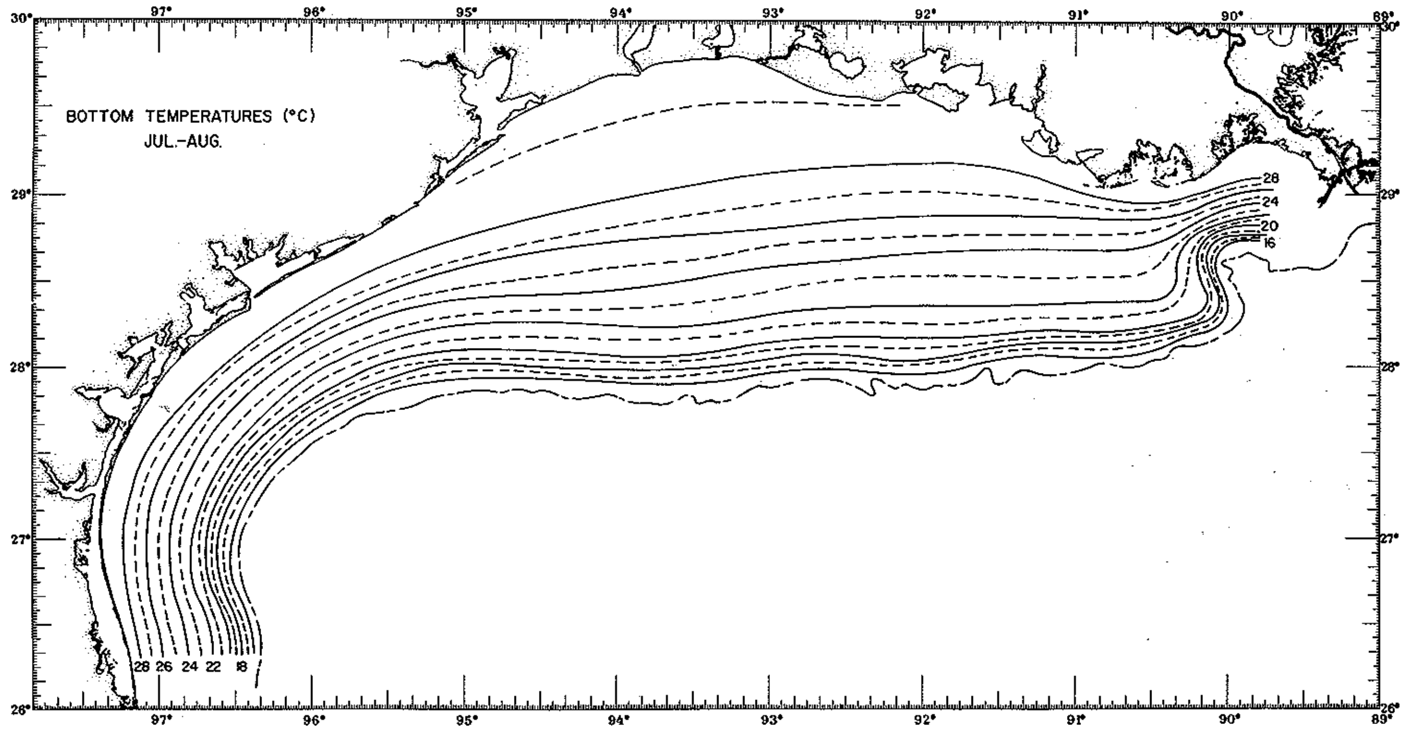

Figure 34. Map of mean bottom temperatures (° C) for July-August. Solid lines represent even values of temperature, dashed lines represent odd values.

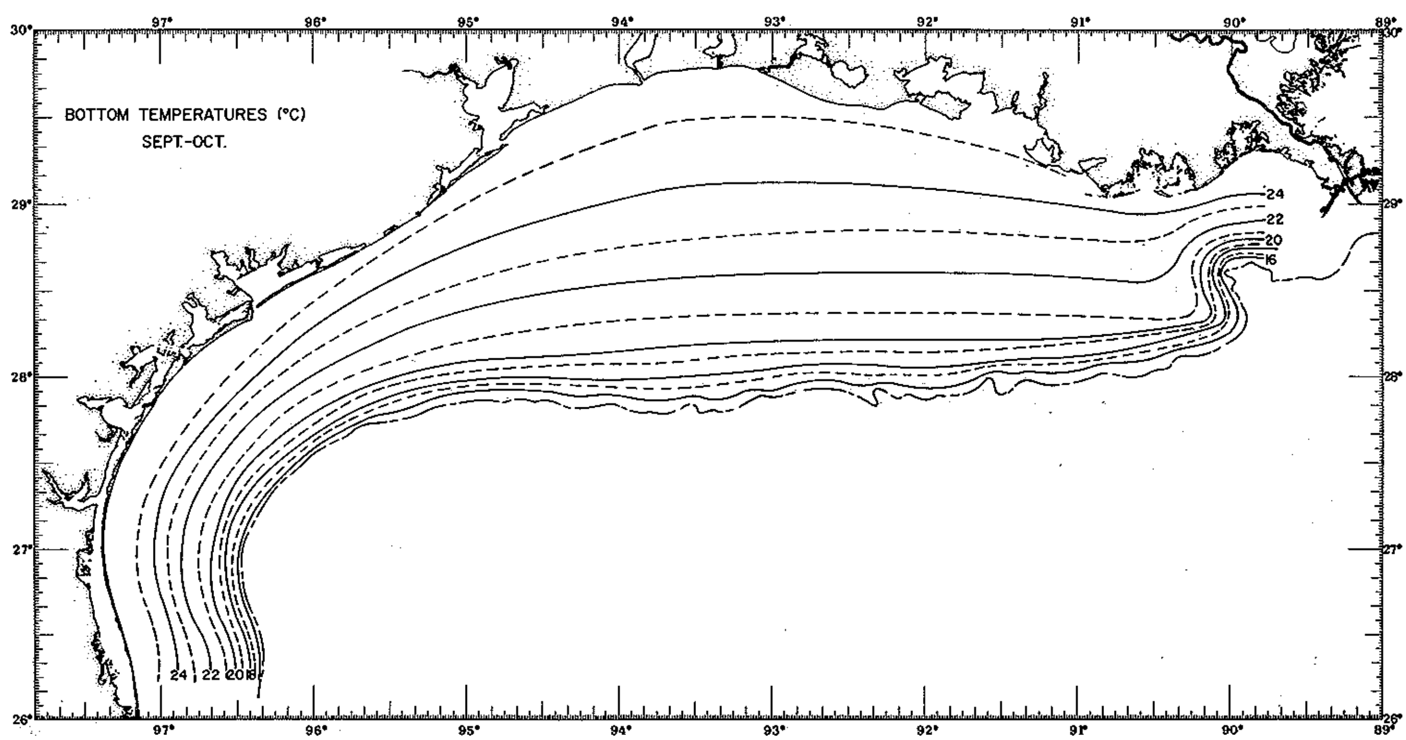

Figure 35. Map of mean bottom temperatures (° C) for September-October. Solid lines represent even values of temperature, dashed lines represent odd values.

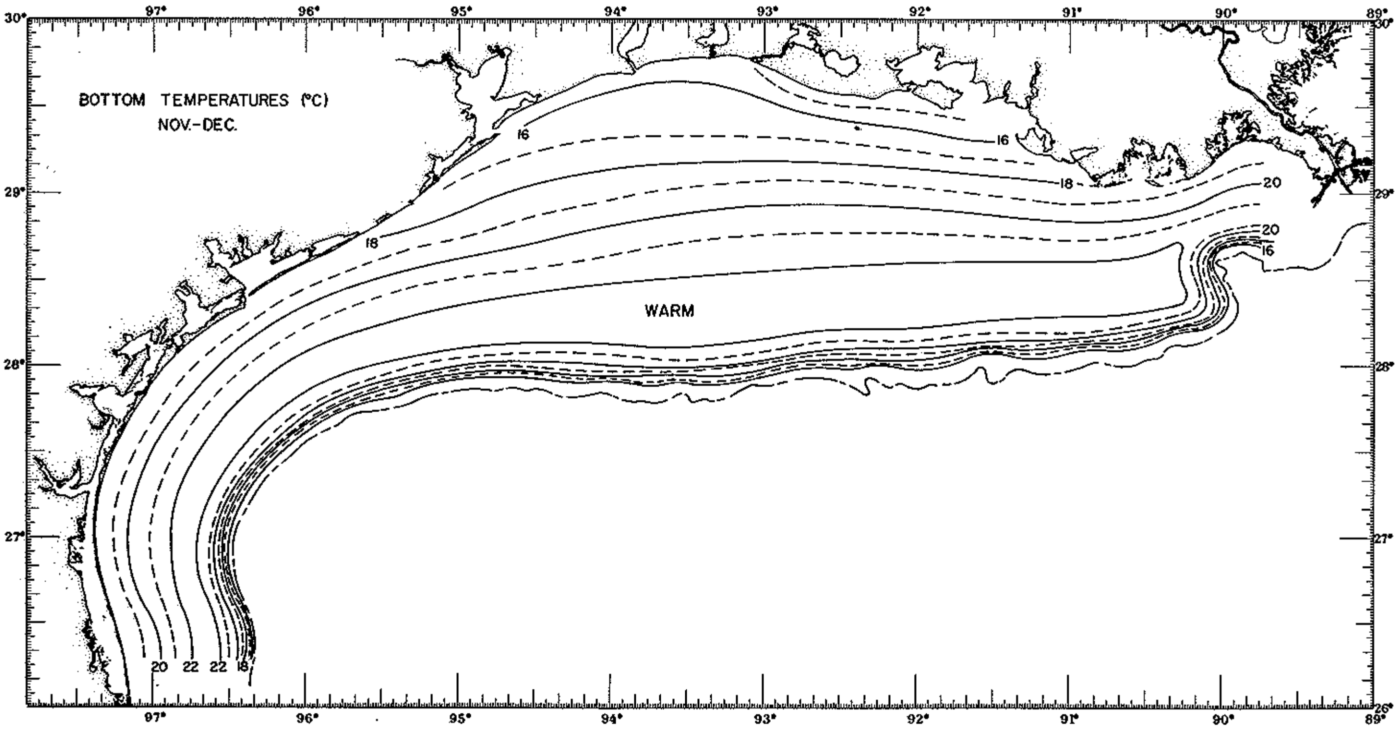

Figure 36. Map of mean bottom temperatures (° C) for November-December. Solid lines represent even values of temperature, dashed lines represent odd values.

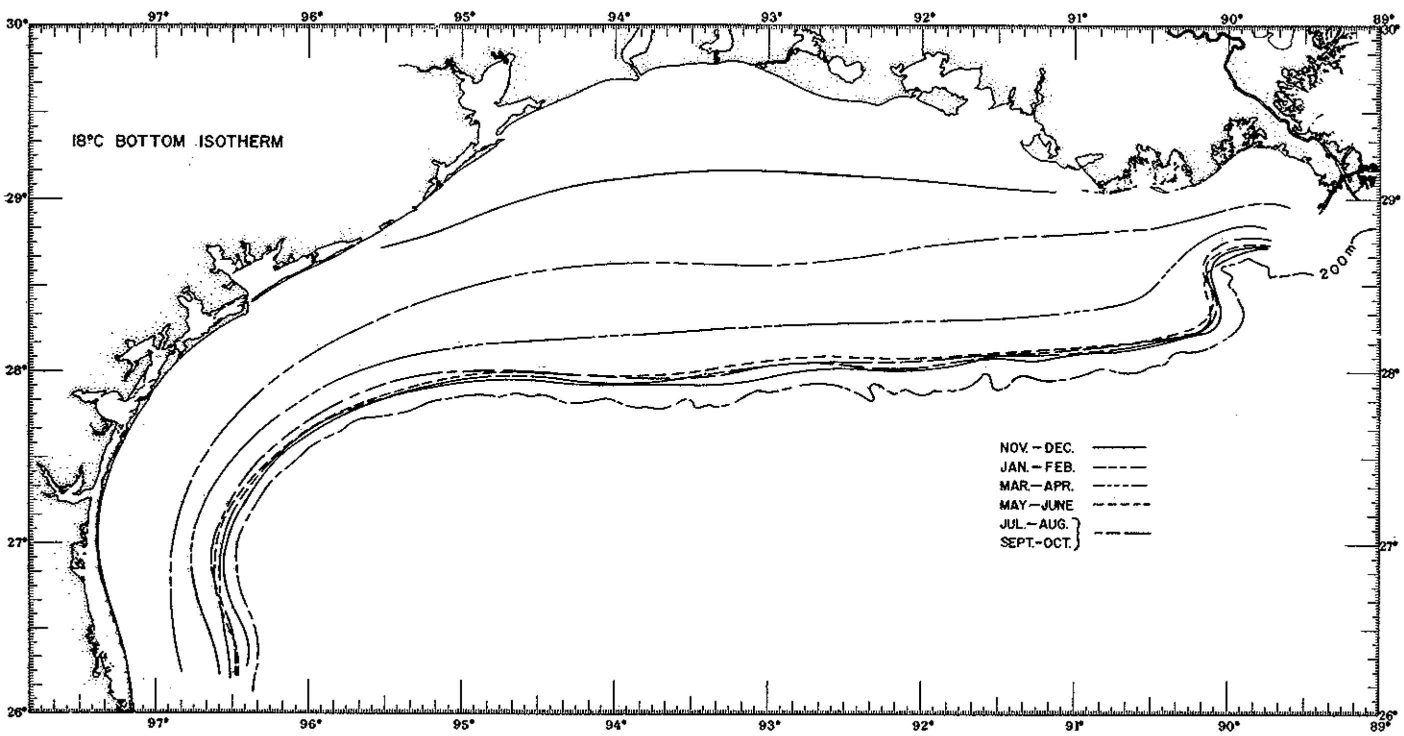

Figure 37. Seasonal variation of the 18° C shelf bottom isotherm. Two isotherms are present for November-December and January-February; only one isotherm is present for all other 2-month periods.

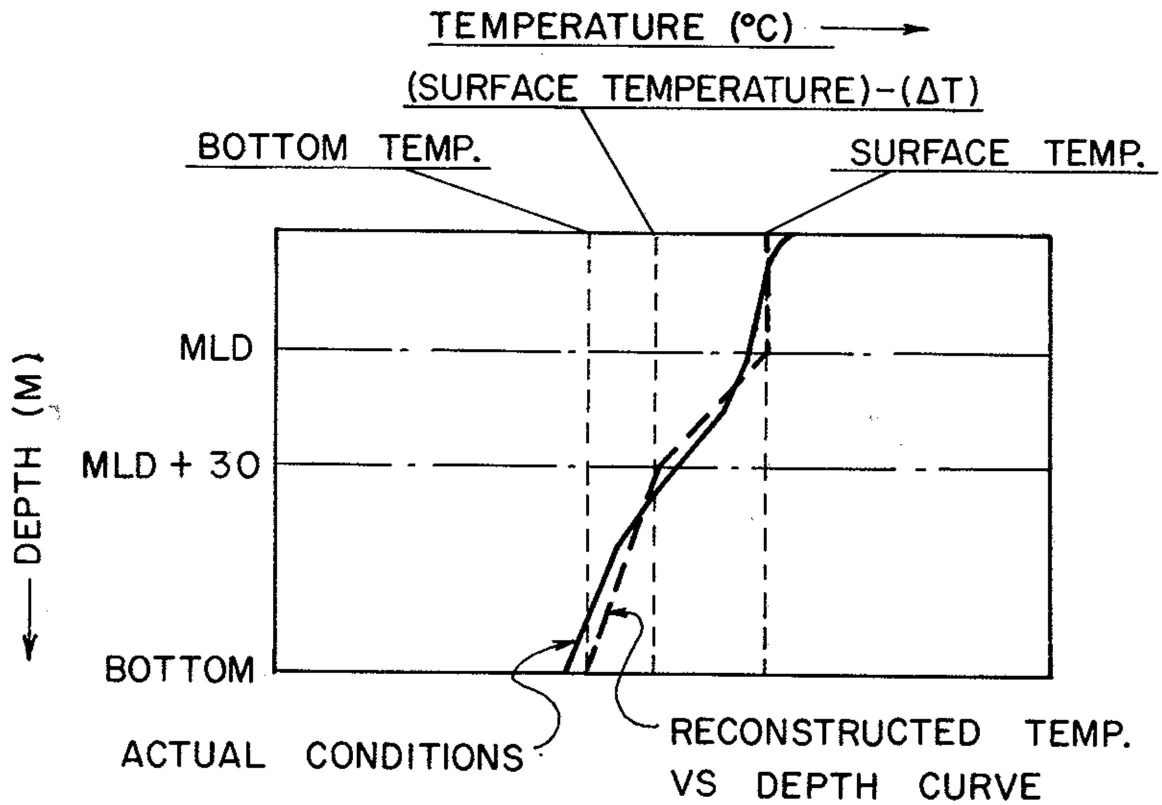

Figure 38. Schematic reconstruction of a temperature vs. depth curve utilizing the results of this report. The hypothetical reconstruction is contrasted with a curve characteristic of actual conditions.

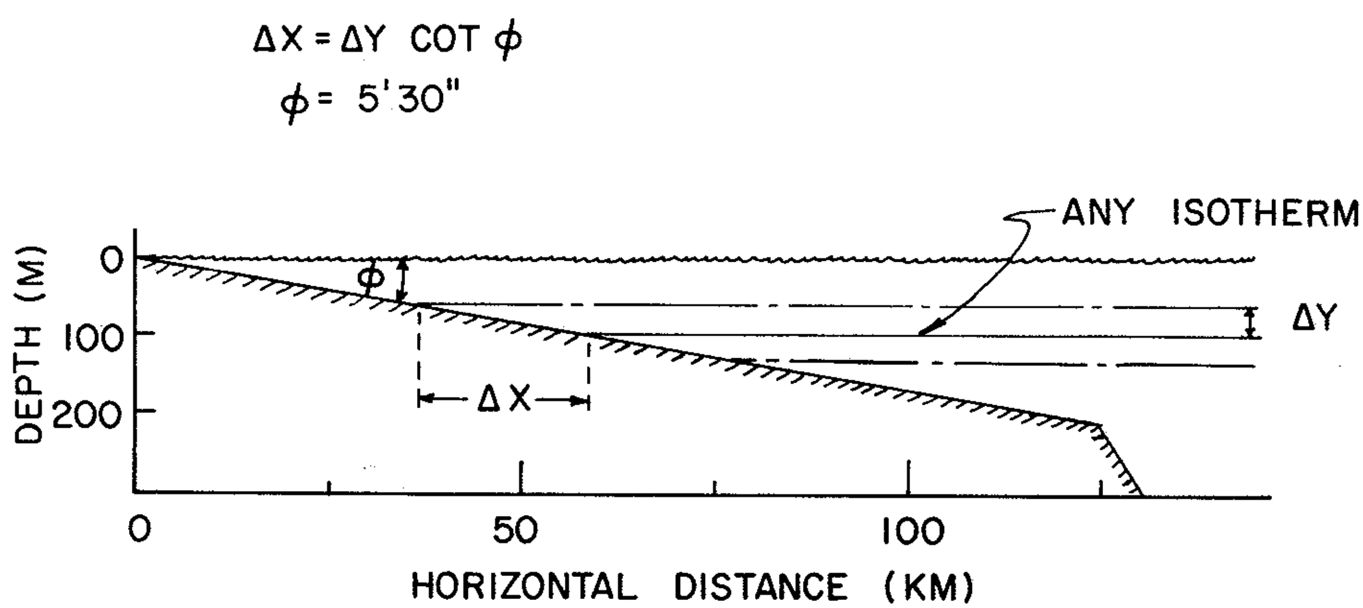

Figure 39. Schematic cross section of the Texas-Louisiana shelf used to illustrate the horizontal displacement resulting from a corresponding vertical displacement.

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