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Surface and Bottom Temperatures, and Surface Salinities: Massachusetts to Cape Sable, N.S., and New York to the Gulf Stream, 1989

by

Jack W. Jossi
Ecosystems Dynamics Branch, Northeast Fisheries Center, NMFS/NOAA
28 Tarzwell Drive, Narragansett, RI 02882, USA

and

Robert L. Benway
Physical Oceanography Branch, Northeast Fisheries Center, NMFS/NOAA
28 Tarzwell Drive, Narragansett, RI 02882, USA

Abstract

Monthly monitoring of surface and water column temperature, and surface salinity across the Gulf of Maine, and from New York toward Bermuda has been conducted for thirteen and fourteen years, respectively. Water temperature and salinity patterns observed in 1989 are compared to the 1978 through 1987 means within a time-space matrix.

In the Gulf of Maine, surface temperatures were as much as 2° C below normal in January, and 2°-3° C below normal in December over the entire transect. Spring warming began nearly 30 days early over the Scotian Shelf. Surface salinities were more than 1‰ below normal over Crowell Basin during January and February, and much of the transect after May had scattered positive anomalies, which, at the Scotian Shelf/Crowell Basin boundary, exceeded 0.5‰ in November and December. A below-average bottom temperature condition for most of the transect, which started in November 1988, continued through January, and for the eastern portion of the transect until March, where anomalies in excess of +2° C developed. During the latter half of the year bottom water were generally cooler than average, by as much as 3° C near both ends of the transect in December.

For the New York Bight, surface temperatures and salinities during the first half of 1989 over the inner- and mid-shelf were generally above average. Positive anomalies also occurred offshore due to the passage of warm core rings. During this same period at the shelf break, surface temperatures and salinities were below average due to the offshore migration of the shelf/slope front. Temperature anomalies in excess of $-2°$ C occurred in offshore surface waters from October through December, and in excess of $-2°$ C on the shelf at the surface and bottom in December. In June and July, just seaward of DWDS-106, salinities dipped more than $1°/_{oo}$ below average. The low- salinity plume associated with Hudson-Raritan River runoff appeared more than 30 days earlier than average in 1989. Bottom temperatures on the inner shelf in February and March exceeded the long-term averages by as much as $+4°$ C, and during July-October they were as much as $+9°$ C warmer than average. This latter event appears to have resulted a nearshore downwelling centered in August.

Introduction

Monitoring of water column and bottom temperatures, and surface salinities has been conducted by the Northeast Fisheries Center along monthly transects across the Gulf of Maine since 1977, and from New York toward Bermuda since 1976 (Figure 1). Merchant and other ships of opportunity which regularly pass along these transects make the observations. Reports describing the water column and bottom temperature conditions along these two routes are prepared annually, and are summarized in Jossi and Benway, (MS,1990). This report presents surface temperature and salinity, and bottom temperature conditions along the Gulf of Maine and the New York Bight transects during 1989 and describes their departures from average conditions for the ten year-period, 1978 through 1987.

Methods

For the New York Bight, sampling intervals averaged 22 km over the shelf, 11 km near the shelf break, and 22 km offshore of the shelf break. For the Gulf of Maine, sampling intervals averaged 44 km for the entire transect. Approximately 50% of the surface temperatures for the Gulf of Maine, and over 90% for the New York Bight came from expendable bathythermograph (XBT) deployments. Bucket temperatures were taken for calibration purposes, for cases of XBT failure, and, in the Gulf of Maine, at locations between the XBT stations. This combination of sources resulted in the data reported here as "surface" temperature, actually representing temperature in the upper 2 m of the water column. All of the subsurface and bottom temperatures were obtained from (XBT) deployments along the transects. During the cruise, XBT and synoptic meteorological data were transmitted via Geostationary Operational Environmental Sattellite (GOES) to the National Environmental Satellite, Data, and Information Service (NESDIS) in Washington, D.C.

Along the New York Bight transect, shelf/slope front positions were determined by using a combination of satellite data, surface and water column temperature distributions, and a surface salinity indicator of $34.5^{\circ}/_{\circ\circ}$.

Bottom temperatures all came from those XBT casts which obtained valid data until reaching the ocean bottom. Depths for bottom temperatures were checked against the ship's fathometer records and navigational charts.

Samples of surface water were taken from the bucket samples for salinity determinations.

Methods for generating standardized time-space matrices are described in Jossi and Smith (1989). Briefly, the method included 1) deleting any samples outside of the transect polygon (Figure 1); 2) calculating the sample's standardized distance along the transect-termed reference distance; 3) generating a uniform time-space grid (map) of interpolated values using the julian day and reference distance values from a single year of irregularly spaced samples; 4) using the data from 1978 through 1987 to produce a ten year, long-term mean map; 5) calculating the yearly anomaly (single year map minus long-term map); and 6) using the long-term standard deviation to calculate Z-scores (yearly anomaly map divided by long-term standard deviation map).

Results

Surface and bottom temperature, and surface salinity data for the Gulf of Maine and the New York Bight transects are presented as contoured time-space plots (Figures 2-7). Portrayed are the conditions during 1989, and the departure of these conditions from the 1978 through 1987 means, in terms of algebraic anomalies (data units) and standardized anomalies (standard deviation units). Figures 2-4 show the Gulf of Maine results for surface temperature, surface salinity, and bottom temperature, respectively. Figures 5-7 show the same results for the New York Bight. Figure 8 illustrates the mean bottom depth at 5 km intervals of reference distance along each transect.

Discussion

Massachusetts to Cape Sable, N.S.

Surface Temperature: Minimum annual temperatures in 1989 for the entire transect were those less than 2° C, occurring near Cape Sable at the end of February (Figure 2A). Winter minimum temperatures were less than 5°C for all of the transect in March. The spring appearance of 6°C water along the transect is usually 60 days earlier over Massachusetts Bay than over the eastern end of the transect. In 1989 this difference was shortened to only 30 days. Maximum values were reached in August over the entire transect. Significant departures from the 1978 through 1987 means occurred in three areas of the transect during 1989 (Figures 2B & 2C). During January over the whole transect, and February and March over the central Gulf surface temperatures were significantly lower than average, with departures exceeding -2°C in early January. Scattered areas with departures of -2°C or more were found over Crowell Basin in July and the eastern and western portions of the transect in October. A second large area of negative anomalies occurred over most of the transect during December, with temperatures in the western Gulf as much as 3°C below normal. This event coincided with the record-breaking cold air temperatures experienced over much of New England in December 1989. A major area of above-average temperatures were seen on the Scotian Shelf from late March through June. This was a result of the spring warming beginning approximately 30 days earlier than usual on the Scotian Shelf in 1989.

Surface Salinity: Salinities of $>33°/_{oo}$, absent from the transect during early 1988 were found in 1989 over Wilkinson Basin and the central Gulf ledges from January through March (Figures 3 A, 3B, and 3C). Conditions over Crowell Basin were significantly below the 1978 through 1987 average, reaching $-1°/_{oo}$ in February. Scattered positive anomalies were found along the transect for the rest of the year. The largest of these were over the Scotian Shelf and eastern Crowell Basin during late April through early June; over the eastern end of the transect during September through December; and over the Scotian Shelf/Crowell Basin boundary during November and December; where salinities were $>0.5°/_{oo}$ above average.

Bottom Temperature: Annual minimum temperatures for the transect of <2°C occurred over the Scotian Shelf during February and March (Figure 4A). (Please note Figure 8 for the relationship between reference distance and bottom depth.) Lowest temperatures on the Massachusetts Bay end of the transect were below 3°C in March and April. Maximum bottom temperatures of >10°C occurred on the Scotian Shelf during September and early October. Departures from the 1978 through 1987 means are shown in Figures 4B and 4C. Temperatures were below average over most of the transect in January, and significantly below average for the portion east of the central Gulf ledges. Below average temperatues persisted into February in the Crowell Basin and to the end of March on the Scotian Shelf. These cold temperatures were a continuation of those for this area beginning in November, 1988. During March and April positive departures occurred on the eastern end of the transect, in Crowell Basin and in Wilkinson Basin. In the latter area above-average temperatures persisted into June. Most of the rest of the year was characterized by below-average bottom temperatures, the extremes of which were -3°C on the Scotian Shelf and in Massachusetts Bay in December.

<u>New York towards Bermuda</u>

Surface Temperature: In 1989 annual minimum temperatures occurred over the entire transect at the end of February, and offshore toward the end of March (Figure 5A). Maximum temperatures occurred across the entire transect in August. Two warm core rings (88K and 88L) were observed at the outer end of the transect during the first half of the year (Sano and Wood, MS 1990). Departures of surface temperature from the 1978 - 1987 means are shown in Figures 5B and 5C. During the first half of the year temperatures over much of the shelf were above average, as were those at the seaward end of the transect. The latter departures, with anomalies in excess of +4°C, were associated with the warm core rings present during this period (88K in January-February and 88L in April-May). Over the outer shelf a somewhat discontinuous band of lower-than-average temperature existed during the first six months of 1989. This condition resulted from the offshore shift of the shelf-slope front from its average position during these months. The latter half of the year showed a string of positive anomalies along much of the transect in October due either to a shift in the timing of the fall overturn and/or the timing of the October sampling. Negative departures of greater than 2°C began offshore in October, and on the shelf in December. Otherwise the last half of the year was near normal.

Surface Salinity: Salinity patterns during the first half of 1989 (Figures 6 A-C) showed some marked similarities to those for surface temperature. Significantly high values offshore during January to mid-February, and April to mid-May were associated with the presence of the two warm core rings. A band of low salinity water along the shelf break from late January through June resulted from the shelf-slope front being further offshore than usual. There also was a sizeable area of significantly lower-than-average salinities offshore during June and July when surface waters of less than 34°/₀₀ extended to as much as 400 km offshore. Other notable departures during the first half of the year were the higher-than-average salinities over the mid- and outer shelf in late February, and especially those nearshore during March through May. Typically, annual minimum salinities (<29°/₀₀) in nearshore waters are associated with high, spring river runoff, and usually occur in the New York Bight Apex from March through mid-May. In 1989 the minimum occurred during February and March. This four to six week difference in timing produced significant positive departures during March through May, even though the salinities in the plume were not greatly different from those for an average runoff period. The difference in timing also produced a negative anomaly in late February, but this departure was not significant for this high variance area. The significant negative anomalies over the inner half of the shelf in October-November were probably related to later than average fall overturn of the water column.

Bottom Temperature: Time-space distribution of bottom temperature during 1989 is shown in Figure 7A. (Please note Figure 8 for the relationship between reference distance and bottom depth.). The time-space extent of water cooler than 5°C on the bottom has been used as a subjective way of estimating winter intensity. During 1989 such water occupied the inner 30 km of the transect during March as compared to the 1978 - 1987 average which shows water of this temperature extending from the coast to 100 kilometers reference distance offshore and lasting from late January until early April. Hence, in 1989 there were apparently milder conditions, and significantly higher-than-average bottom temperatures nearshore during February and March (Figure 7C). Another major area of positive anomalies developed nearshore during July through September when bottom temperatures were as much as 9° C warmer than average. Examination of vertical thermal structure from the XBT data (Figure 9) indicated possible downwelling of surface waters along the coast during this period, which would explain the positive anomalies. In October, bottom waters were as much as 4°C cooler than average at mid-shelf. XBT data indicated that fall overturn of the water column was completed at the end of November in 1989, about two weeks later than average, indicating that this persistence of cool water on the bottom may have resulted from the late fall overturn. In December, bottom waters were cooler than average, paralleling surface temperature patterns.

Acknowledgements

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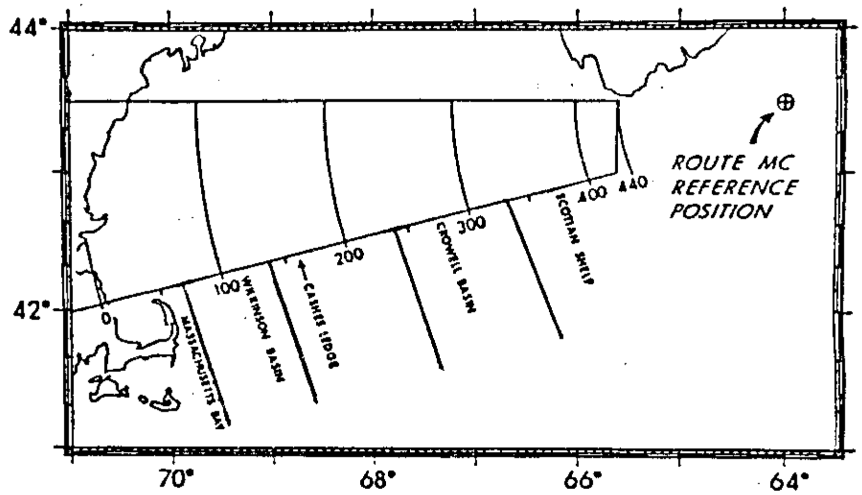
References

Jossi, J. W., and D. E. Smith. 1989. Continuous plankton records: Massachusetts to Cape Sable, Nova Scotia, and New York to the Gulf Stream, 1988. NAFO SCR Doc. 89/59, Serial No. N1639, 19 p.

Jossi, J. W., and Robert L. Benway. MS 1990. Surface and bottom temperatures, and surface salinities: Massachusetts to Cape Sable, N.S., and New York to the Gulf Stream, 1988. NAFO SCR Doc.

Sano, M., and G. B. Wood. MS 1990. Anticyclonic warm core Gulf Stream rings off the northeastern United States during 1989. NAFO SCR Doc.

MARMAP ROUTE MC 1978-1988



MARMAP ROUTE MB 1976-1988

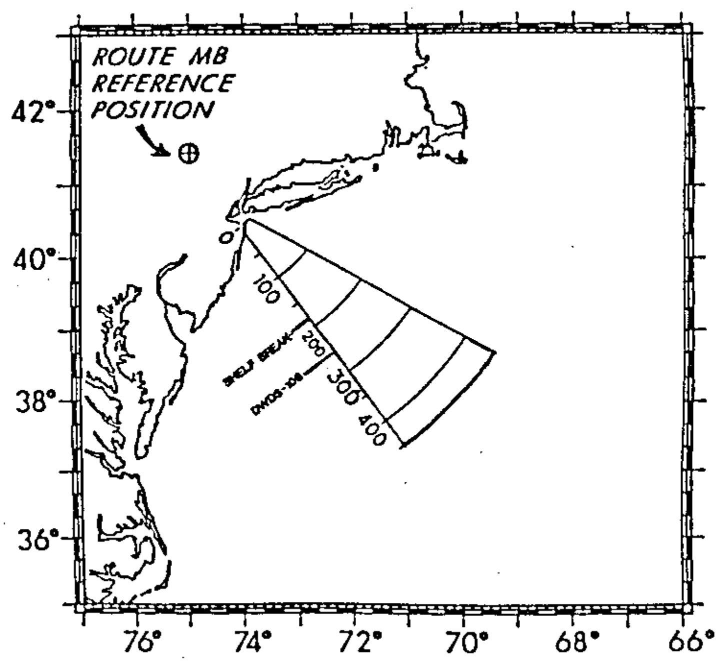


Figure 1. Gulf of Maine (MC) and New York Bight (MB) polygons within which sampling transects are conducted, with standard reference positions and reference distance scales.

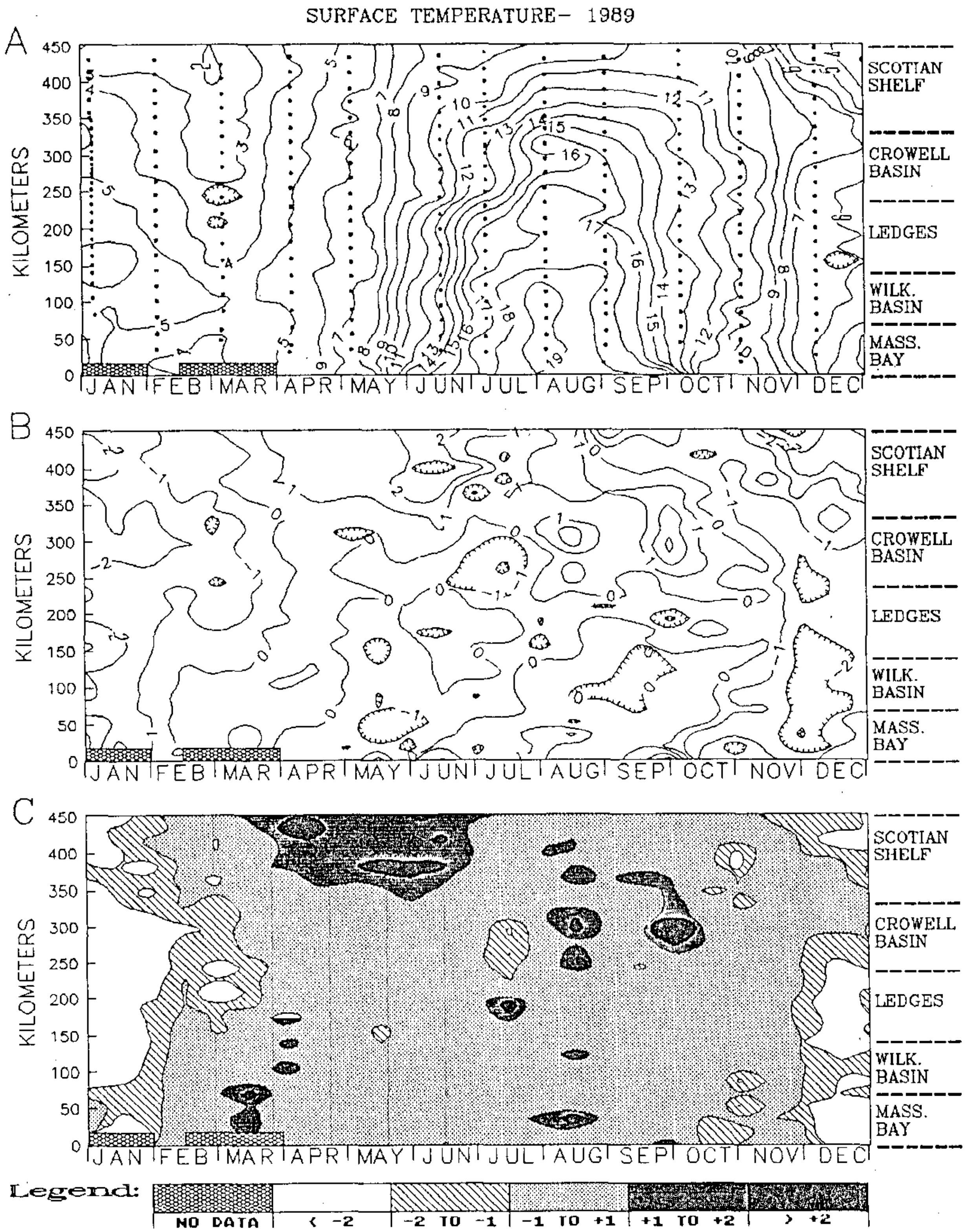


Figure 2. Surface temperature conditions along the Gulf of Maine transect during 1989. A. Measured values (parts per thousand) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. *Standardized anomalies (standard deviations) in time and space based on 1978 through* 1987 means and variances. In panels A and B values decline on those sides of contour lines with hachures.

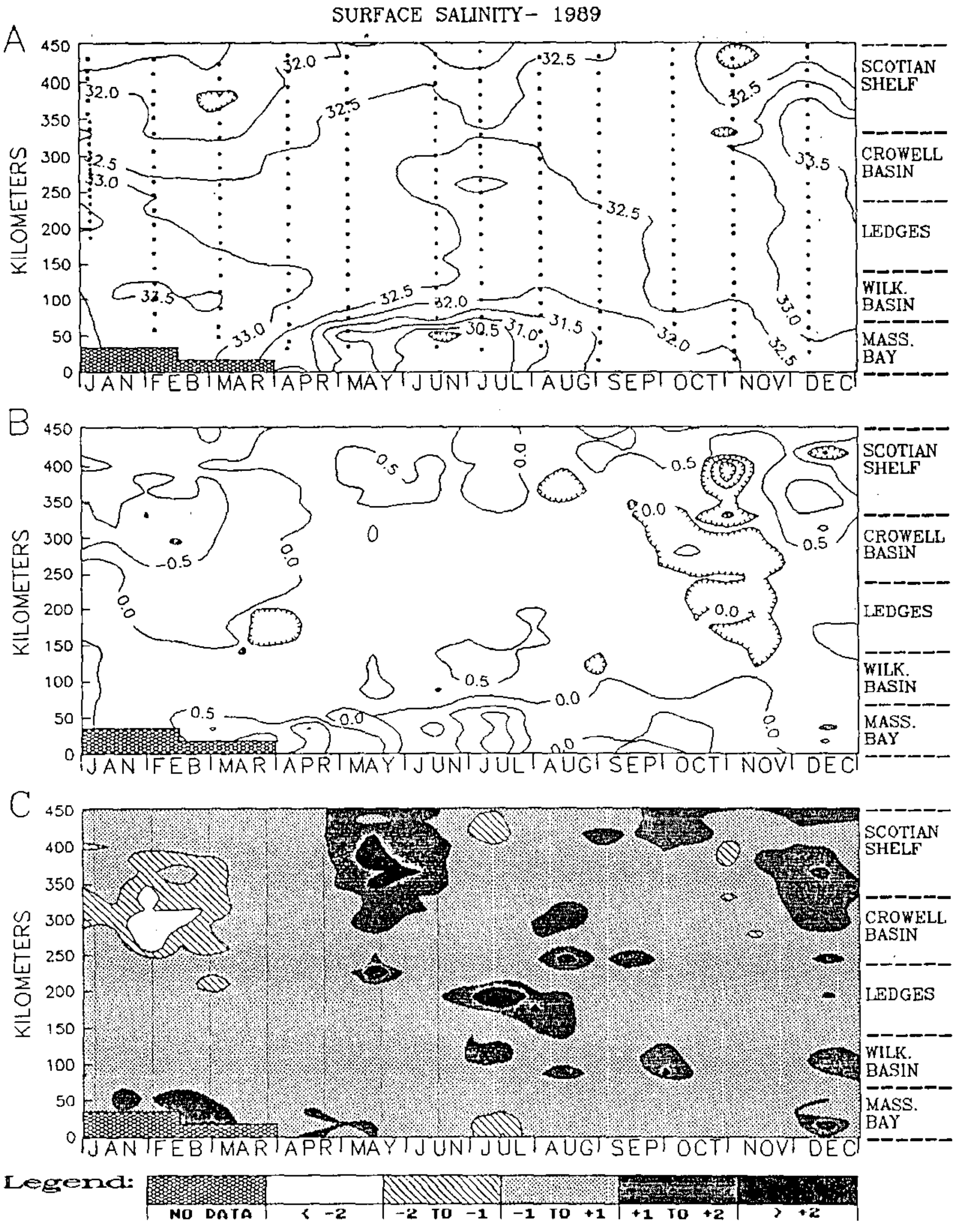


Figure 3. Surface salinity conditions along the Gulf of Maine transect during 1989. A. Measured values (parts per thousand) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1987 means and variances. In panels A and B values decline on those sides of contour lines with hachures.

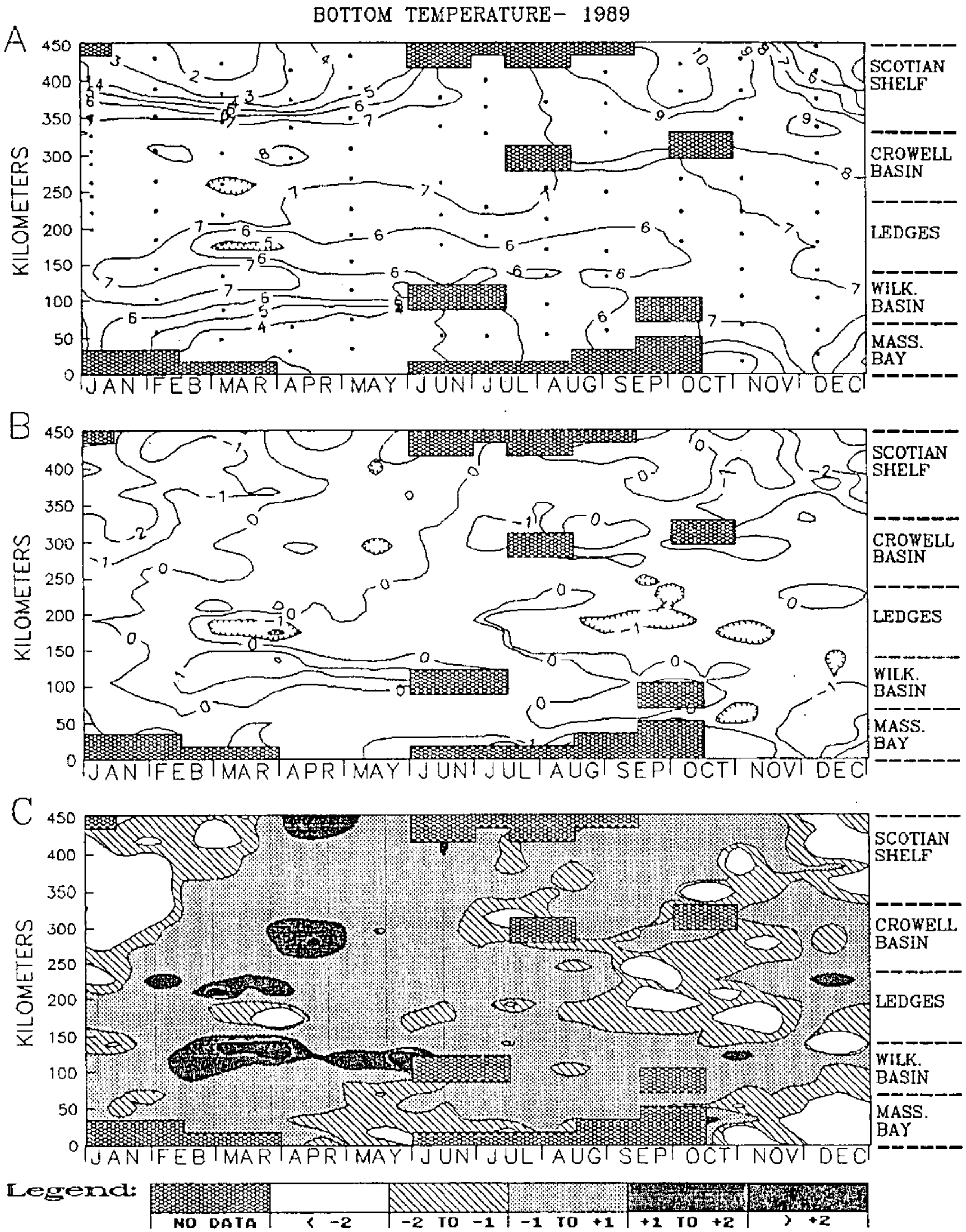


Figure 4. Bottom temperatures along the Gulf of Maine transect during 1989. A. Measured values (degrees centigrade) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1987 means and variances. In panels A and B values decline on those sides of contour lines with hachures.

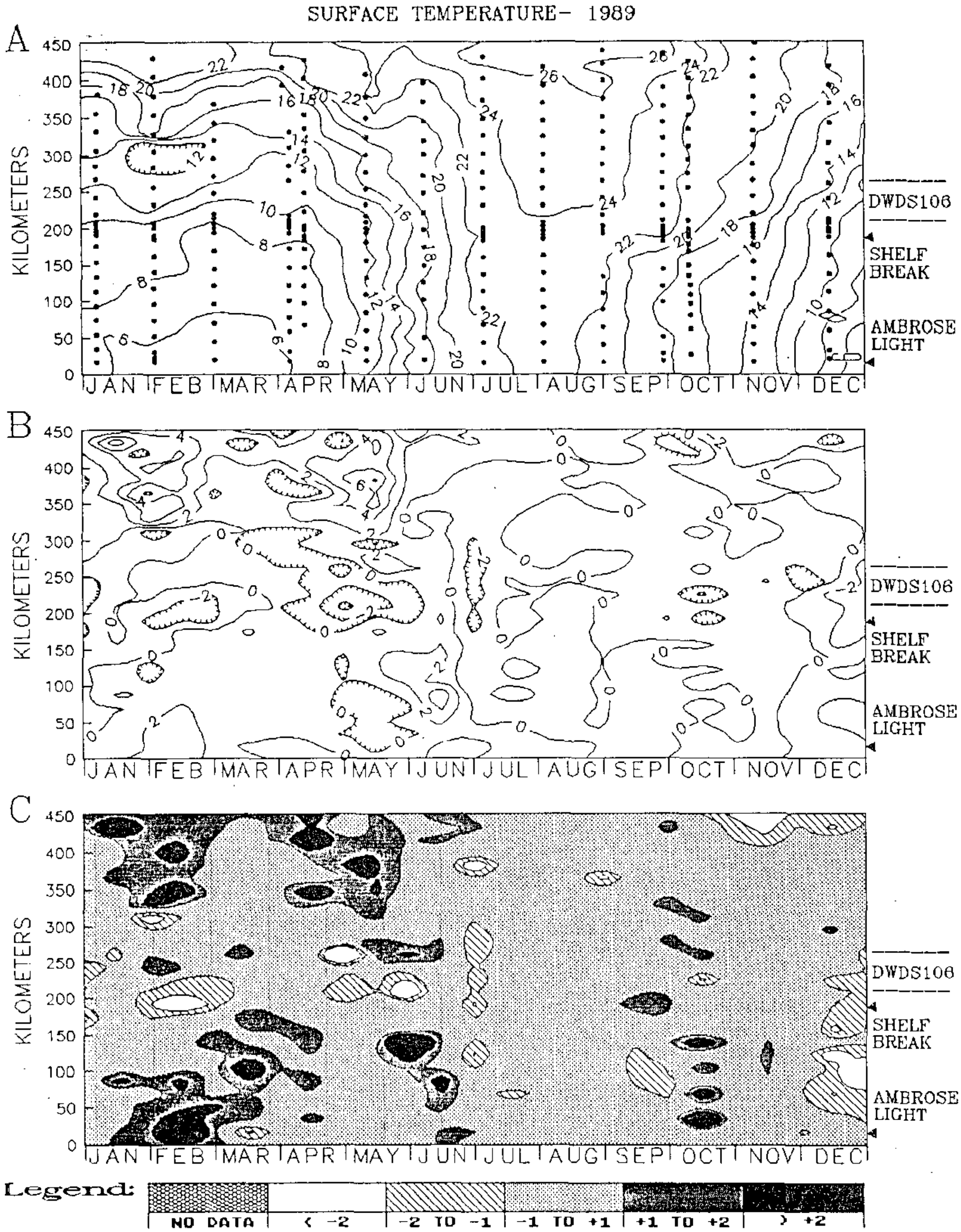


Figure 5. Surface temperature conditions along the New York Bight transect during 1989. A. Measured values (parts per thousand) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1987 means and variances. In panels A and B values decline on those sides of contour lines with hachures.

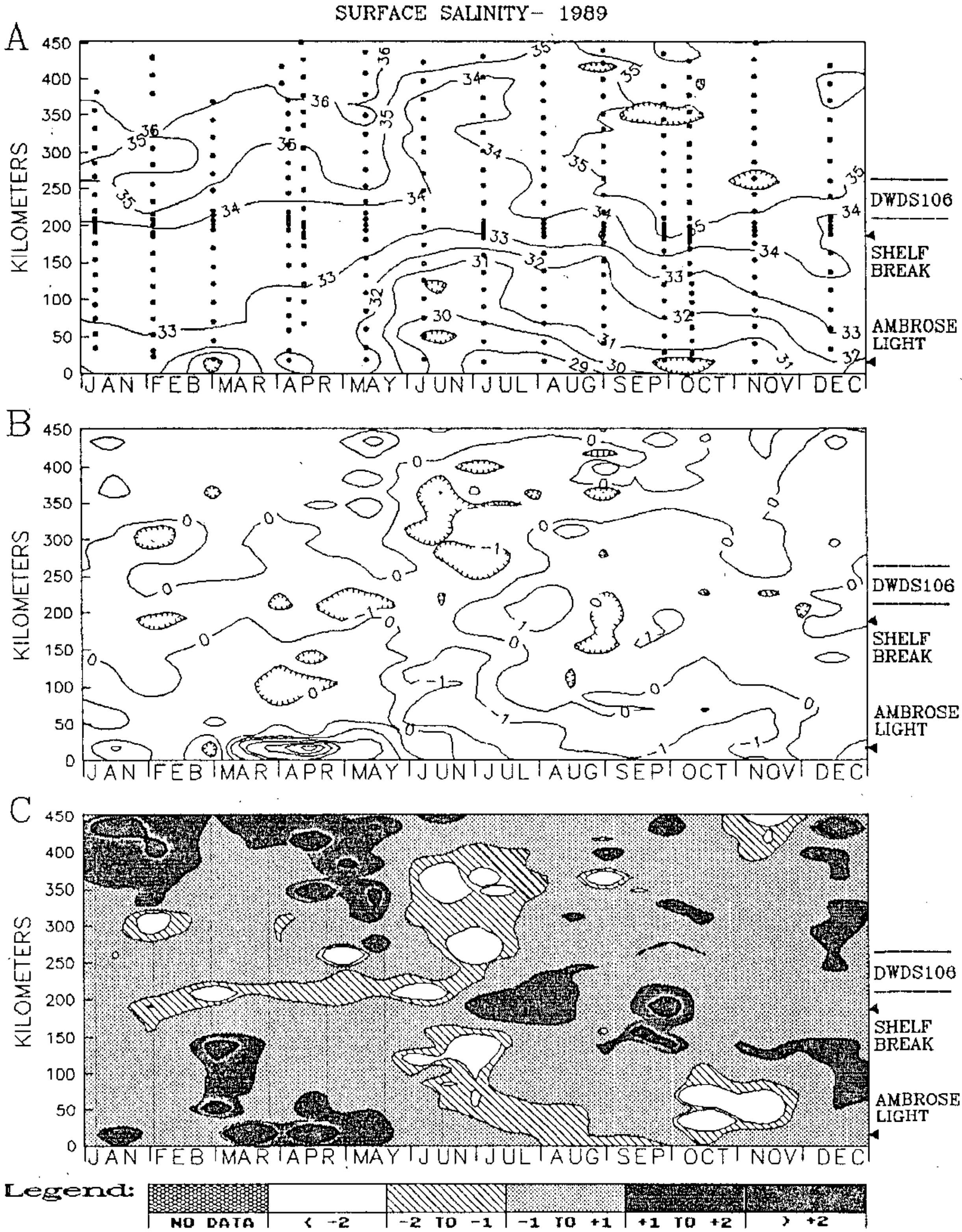


Figure 6. Surface salinity conditions along the New York Bight transect during 1989. A. Measured values (parts per thousand) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1987 means and variances. In panels A and B values decline on those sides of contour lines with hachures.

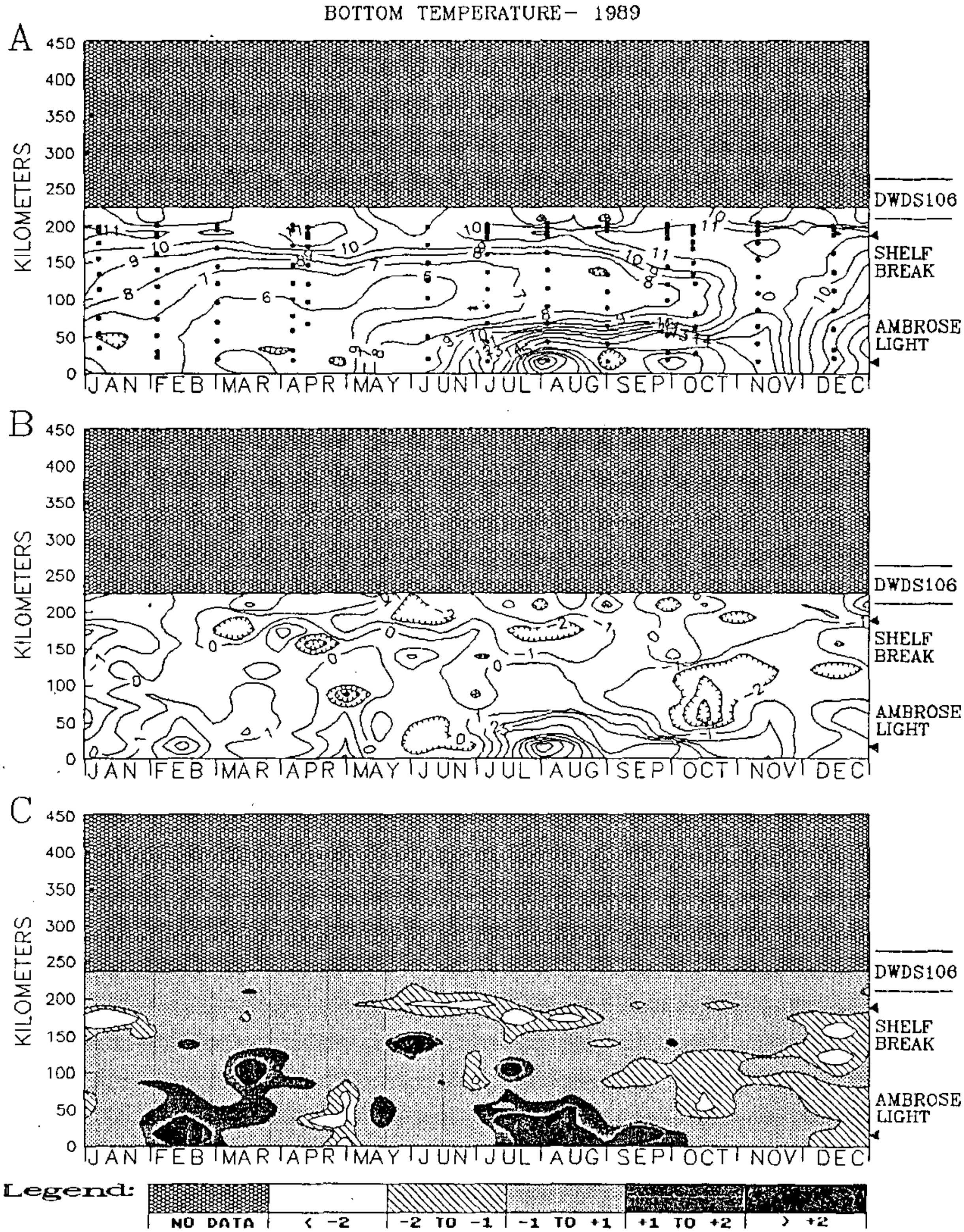


Figure 7. Bottom temperature conditions along the New York Bight transect during 1989. A. Measured values (degrees centigrade) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1987 means and variances. In panels A and B values decline on those sides of contour lines with hachures.

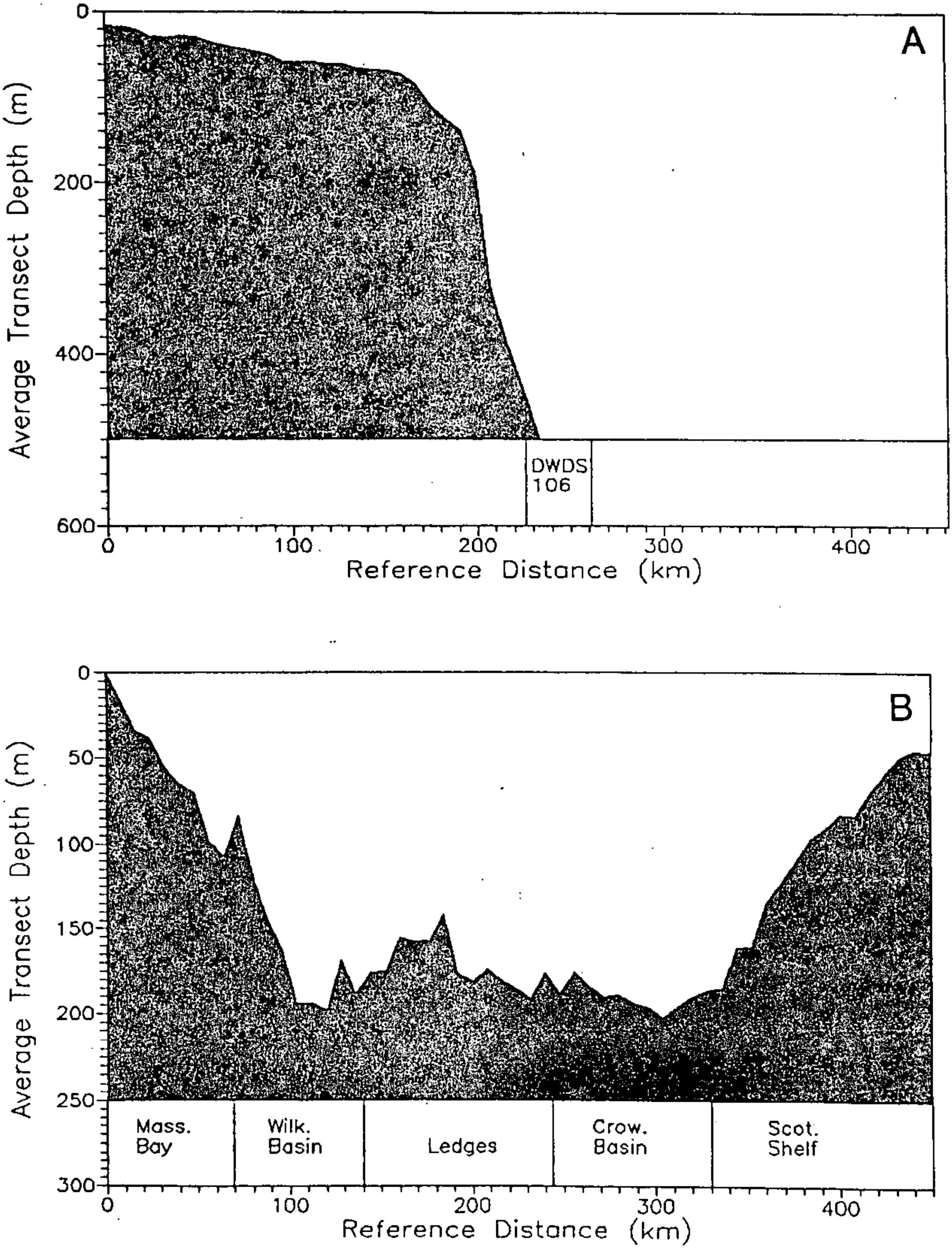


Figure 8. Mean bottom depth along (A) the New York Bight, and (B) the Gulf of Maine transects based on monitoring survey data, 1978 through 1989.

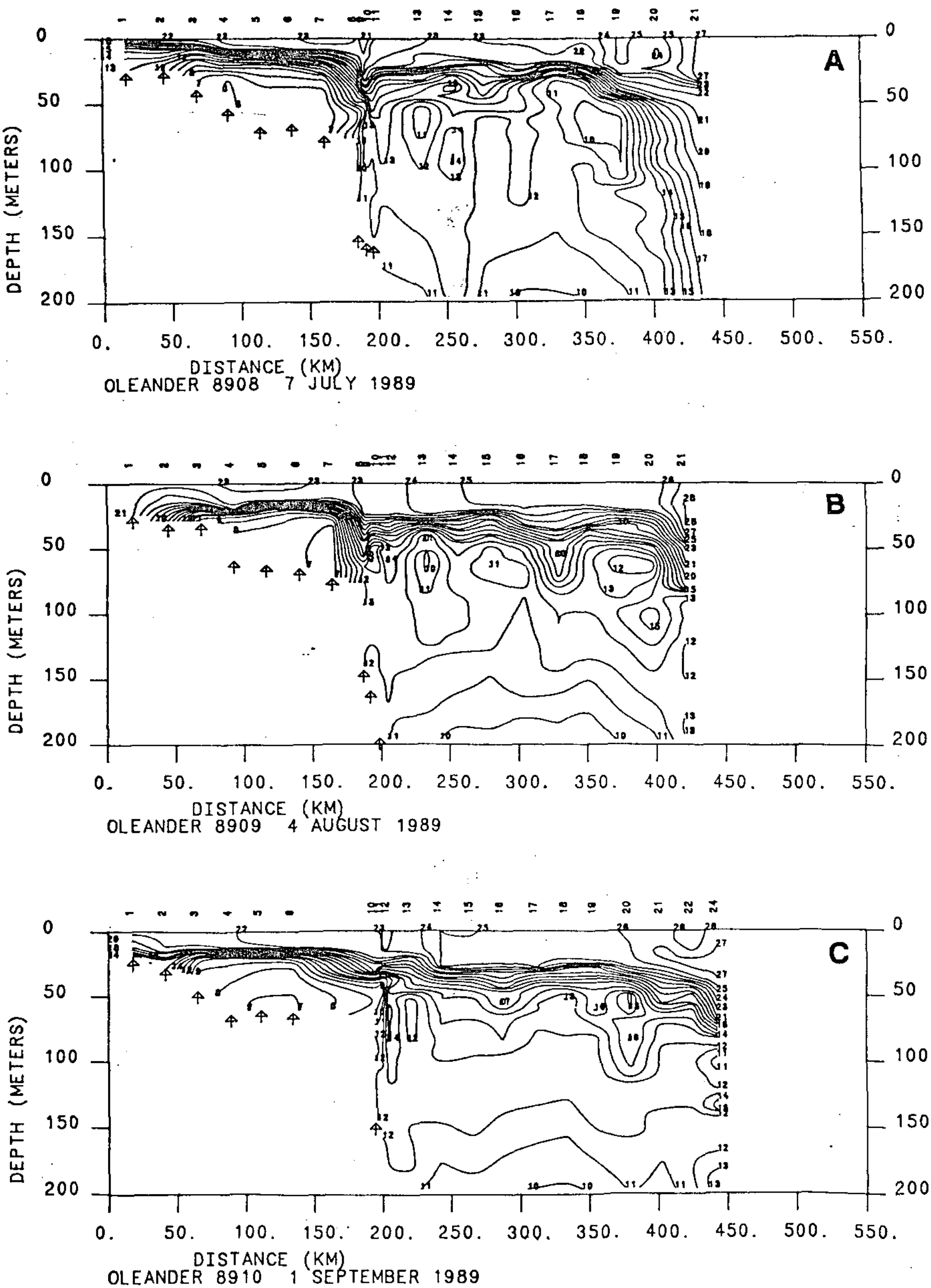


Figure 9. Water column thermal structure in the New York Bight during July through September 1989.