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Surface and Bottom Temperatures, and Surface Salinities: Massachusetts to Cape Sable, N.S., and New York to the Gulf Stream, 1988

by

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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 twelve and thirteen years, respectively. These features during 1988 are compared to the 1978 through 1987 means within a time-space matrix. Although anomalies for the whole of 1988 along the entire transects (or major geographical sections of them) were not significant for any of the features, numerous, highly significant departures occurred over particular time-space areas on both transects. The most dramatic anomalies were seen in surface salinities in the New York Bight where during the late summer low-salinity shelf water was found 200 km seaward of its average location. Also water with salinities in excess of 35 $^0/00$ was brought to the surface in the vicinity of Ambrose Light as coastal water moved offshore during July.

Surface temperatures and salinities, and bottom temperature in the Gulf of Maine were significantly below average at the beginning of the year. This was the remnant of the low salinities which dominated the surface waters of the Gulf of

Maine during 1987. Scattered time-space areas of positive anomaly occurred during the remainder of the year, but these features were of limited extent.

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 (Fig.1). Merchant and other ships of opportunity which regularly pass along these transects make the observations. Annual reports describing the water column and bottom temperature conditions along the New York Bight transect have been prepared (Benway, 1985, 1986, 1987, 1988, 1989; Chamberlin, 1976, 1978; Cook, 1979a, 1979b, 1984, 1885a, 1985b;Cook and Hughes, 1980; Crist and Chamberlin, 1979; Hughes and Cook, 1981a, 1981b, 1982).

The advantages of a time-depth matrix used for the analysis of both the water column and bottom temperature data were recognized and became the basis for an effort to design a standardized time-space matrix into which all transect data (physical and biological) could be incorporated for analyses. Results of surface temperature and salinity monitoring on both the New York Bight and the Gulf of Maine transects were first reported in such form for 1984 (Jossi, 1985). Since then the matrix dimensions and interpolation techniques have been refined, thus allowing map algebra techniques to be used for ecological analyses of not only the different data types taken along these transects, but also any non-transect data to be incorporated into the analyses.

This report presents surface temperature and salinity, and bottom temperature conditions along the Gulf of Maine and the New York Bight transects during 1988 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 the surface, and all of the subsurface and bottom temperatures were obtained from expendable bathythermograph (XBT) deployments along the transects. During the cruise, the XBT data, and synoptic meteorological data were sent by Geostationary Operational Environmental Satellite (GOES) to the National Environmental Satellite, Data, and Information Service (NESDIS), in Washington D.C.

Shelf/slope front positions were determined by using a combination of satellite data, surface and water column temperature distributions, and surface salinity of 35 °/oo. 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 bucket samples, and salinities were determined ashore.

Methods for generating the standardized time-space matrices are described in Jossi and Smith (1989). Briefly, the method included 1) deleting of any samples outside of the transect polygon (Figure 1); 2) calculating the sample's standardized distance along the transect, termed reference distance; 3) using the julian day and reference distance values from a single year of irregularly spaced samples to generate a uniform time-space grid (map) of interpolated values; 4) using the data from 1978 - 1987 to produce a 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 zscores (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. Portrayed are the conditions during 1988, and the departure of these conditions from the 1978 - 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 these results for the New York Bight. Figure 8 illustrates the relationship between bottom depth and reference distance along each transect.

Discussion

Massachusetts to Cape Sable, N.S.

Surface Temperature: Minimum annual temperatures for the entire transect were those less than 2°C occurring near Cape Sable in February and April; and those between 2° and 3°C over a broader portion of the Scotian Shelf from mid-January to the end of April (Figure 2A). The winter minimum dropped below 4°C for all of the transect except the area over Wilkinson Basin. Spring warming began in Massachusetts Bay in early April, and over the eastern end of the transect in mid-May. Maximum values were reached in August, exceeding 22°C just east of Wilkinson Basin, but peaking at just over 10°C over the eastern end of the transect. Temperatures declined rapidly over all the transect except the eastern half of Scotian Shelf during October after which the decline was slower but fairly uniform for the entire transect.

During January and part of February the entire transect showed significantly lower temperatures than average, with anomalies exceeding -3°C over Crowell Basin in January (Figures 2B & 2C). Scattered areas with temperatures one or more degrees below average were found over the central and eastern Gulf during the first half of the year with the exception of small areas of positive departure over the Scotian Shelf in March. This latter departure resulted from the 3 degree isotherm's eastward retreat from its average position during this time of the year. Areas of significantly higher-than-average temperatures occurred over the western half of the Gulf in June, July, and August. In the latter month the anomaly extended eastward to the edge of the Scotian Shelf. The Crowell Basin and outer Scotian Shelf were warmer than average in September and early October. Negative anomalies again began to prevail in the fall and by December significant negative departures existed over much of the length of the transect.

Surface Salinity: The dominant feature of surface salinity is the absence of > 33 $^0/00$ water from the transect west of the Scotian Shelf during the first quarter of the year (Figure 3A). The expected low salinity plume over the western end of the transect in the spring was observed as well as the bulges of low salinity water over the Scotian Shelf throughout the year, and the higher salinities over the ledges and two basins.

Departures from the 1978 - 1987 means occurred at the beginning of the year with the entire transect occupied with water of significantly lower-than-average salinity (Figure 3B & 3C). Over the mid-Gulf the feature persisted to near the end of March, but over the extremities of the transect it had disappeared by mid-February. This was a remnant of a low salinity condition which occupied the entire Gulf of Maine transect during 1987. Scattered departures of relatively small space-time area occurred during the remainder of the year, e.g., over Massachusetts Bay in June a positive departure of > 2 $^0/00$ occurred (not considered significant for this high-variance area); the eastern margin of Crowell Basin was significantly below average in late September; and most of the Scotian Shelf was above average during November.

Bottom Temperature: Coldest temperatures of < 2°C were found south of Cape Sable in February and April, matching the average pattern of surface temperature for this area (Figure 4A). (Please note Figure 8 for the relationship between reference distance and bottom depth.) The western portions of the Scotian Shelf were warmer than 7°C during this time and reached over 9°C during the summer and fall. Crowell Basin bottom temperatures remained generally between 7°C and 9°C all year. An annual minimum of < 5° C was seen during the spring over the central Gulf ledges. Temperatures from 5°C to 7°C prevailed in Wilkinson Basin throughout the year. There was a somewhat unsteady increase in temperature on the bottom of Massachusetts Bay as the year progressed, going from < 4°C in January to < 7°C in September - December.

Much of the transect showed significantly lower than average temperatures at the beginning of the year, with negative anomalies exceeding -2°C over the outer Scotian Shelf and Massachusetts Bay (Figures 4B, 4C & 8). Of equal significance were the departures on the Scotian Shelf throughout the year, with (non-standardized anomaly of -3°C was measured in late December). A March - May negative anomaly occurred in the vicinity of Cashes Ledge recurring again in July. Most of Massachusetts Bay bottom water was colder than average in October and November. By December most of the bottom east of Wilkinson Basin was below average. This pattern was markedly similar to that of surface temperature during 1988. A large area of positive anomaly occurred over outer Massachusetts Bay to beyond Wilkinson Basin during various times in the late winter and spring, and again during August and September. The only other sizable area of positive departure was in Crowell Basin in April.

New York towards Bermuda

Surface Temperature: Annual minimum temperature occurred in mid-February over the inner shelf (< 4°C measured at Ambrose Light Tower), and mid-March farther offshore (Figure 5A). Maximum temperatures occurred in August along the entire transect. However, the August cruise was about two weeks later in 1988 than usual, possibly missing the annual maximum which generally occurs during the first week of that month.

Cooler-than-average temperatures occurred from the outer shelf seaward during most of the first half of the year (Figures 5B &5C). At the shelf slope front (SSF) these were due to a seaward shift of 50 km in the SSF from its average position at approximately 200 km reference distance. The area of negative departures extended shoreward from mid-June to mid-July and was largely confined to the shelf after August. Near shore vernal warming appeared to begin earlier than usual. In the New York Bight the onset of this warming is usually observed later inshore than offshore. During 1988 this onshore-offshore lag was reversed during the period of late March to early June. By late July the time-space pattern of surface temperature had returned to normal. Areas of temperature higher than average were scattered and limited in size. One occupied the outer end of the transect in early January and the other was near shore in February, possibly connecting to a similar feature reaching to mid-shelf in April.

Surface Salinity: Three features dominated the salinity along the New York Bight transect during 1988 (Figures 6A-C). The first was an area of significant negative departure during January and February at the SSF due to the front's 50 km seaward shift from normal, also reflected in the temperature data discussed above.

Second, surface salinities in the New York Bight Apex generally reach annual maxima during December - February. During these months in 1987 and 1988 this cycle was interrupted and water of $33^{0}/00$ occupied the entire shelf area, 100-150 km seaward of its average offshore extent.

Third, in July wind-induced upwelling (Sano and Armstrong, 1989) brought salinities of > 35 $^{0}/00$ to the surface in the nearshore area. This is the highest salinity measured at this location in the 1978 - 1988 record. Also during July warm core ring 88-C was in a position to contribute to high salinity water movement shoreward in Hudson Canyon. During August, as ring 88-C moved farther to the southwest, shelf water was entrained by it and carried offshore to a reference distance of greater than 350 km.

These salinity departures, which dominated the Gulf of Maine transect in 1987, and then were noted in the New York Bight in October 1987, suggest a possible link to the record breaking runoff of the St. Lawrence River system between September 1986 and January 1987.

Bottom Temperature: Descriptions of the cold pool and the shelf-slope front position in the New York Bight during 1988 can be found in Benway (1989). The following is confined to details of the 1988 departures of bottom temperature from the 1978 - 1987 means (Figures 7C and8). Although the year began slightly cooler than normal over most of the transect the main anomaly was the significantly warmer temperatures over most of the shelf during February and March, and over the outer shelf in April. This departure coincides with warmer surface temperatures (Figure 5C), because the time period was prior to the onset of thermal stratification. Another significant departure of bottom temperature was the appearance of negative anomalies in about May, extending to early November, and occupying a good deal of the shelf. This condition most likely was the consequence of onshore movement of bottom water that produced the high salinities near Ambrose Light in July and August.

Acknowledgements

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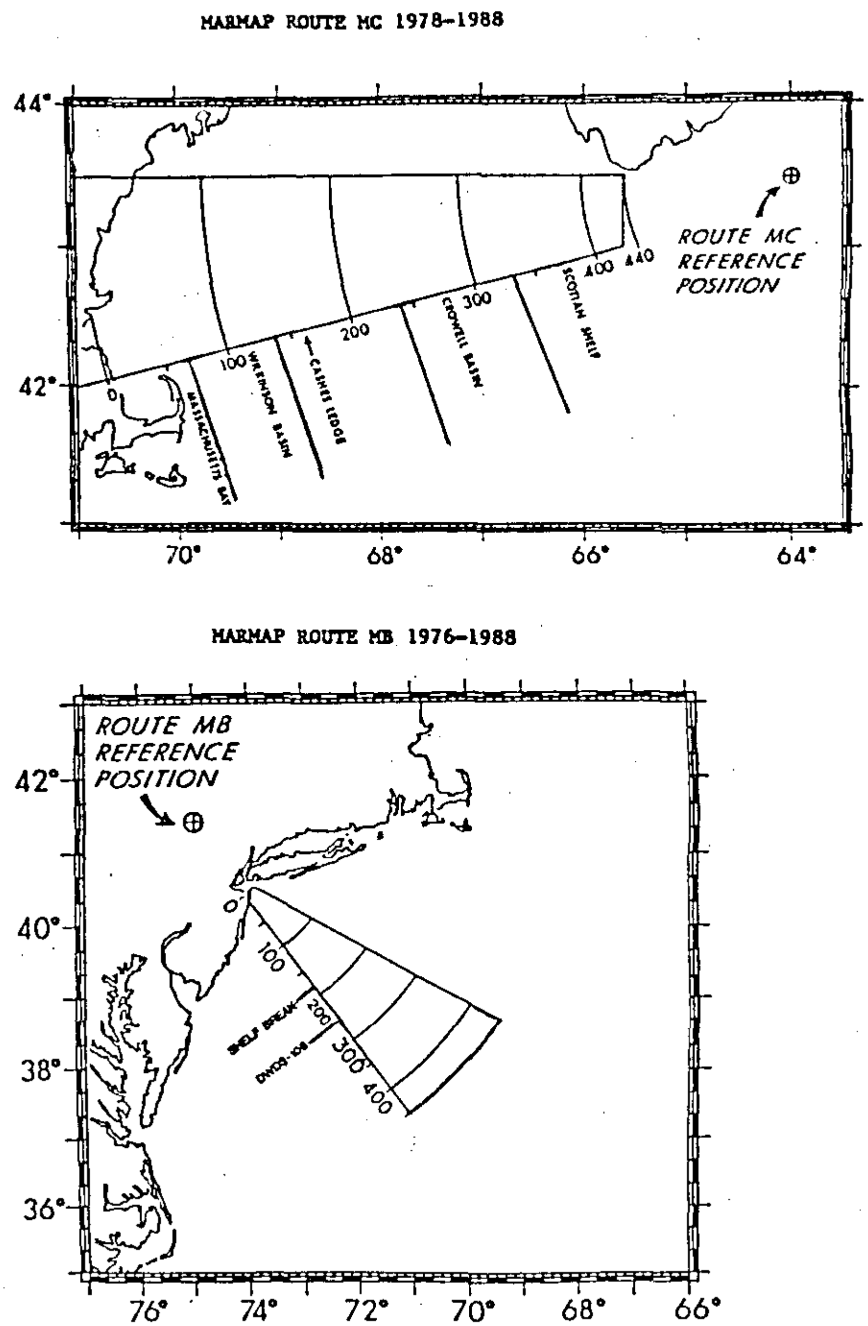

Figure 1. Gulf of Maine (MC) and New York Bight (MB) polygons within which sampling transects are conducted, with standard reference positions and reference distance scales.

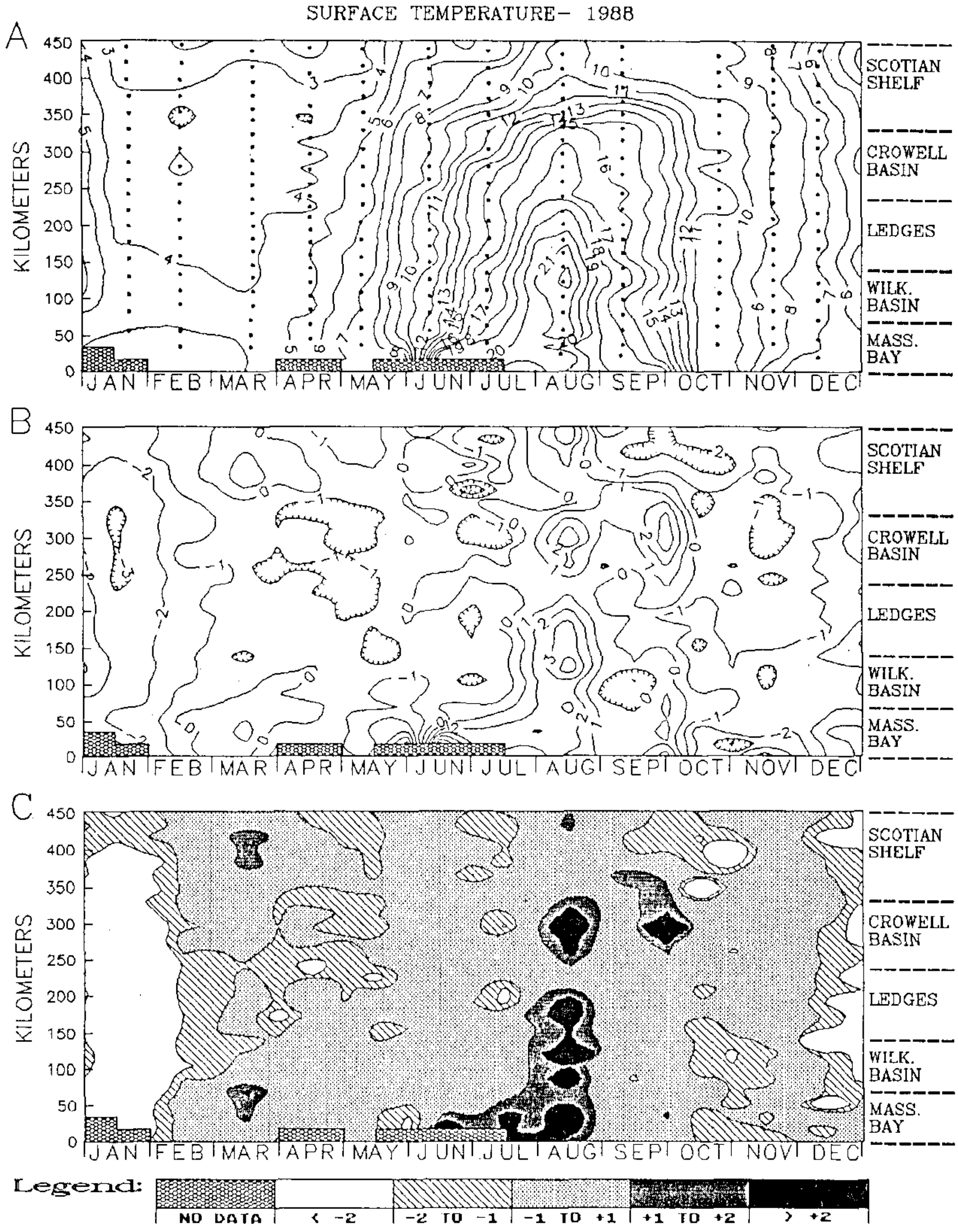

Figure 2. Surface temperature conditions along the Gulf of Maine transect during 1988. A. Measured values (parts per thousand) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. Standardized anomalies (standard deviations) in time 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.

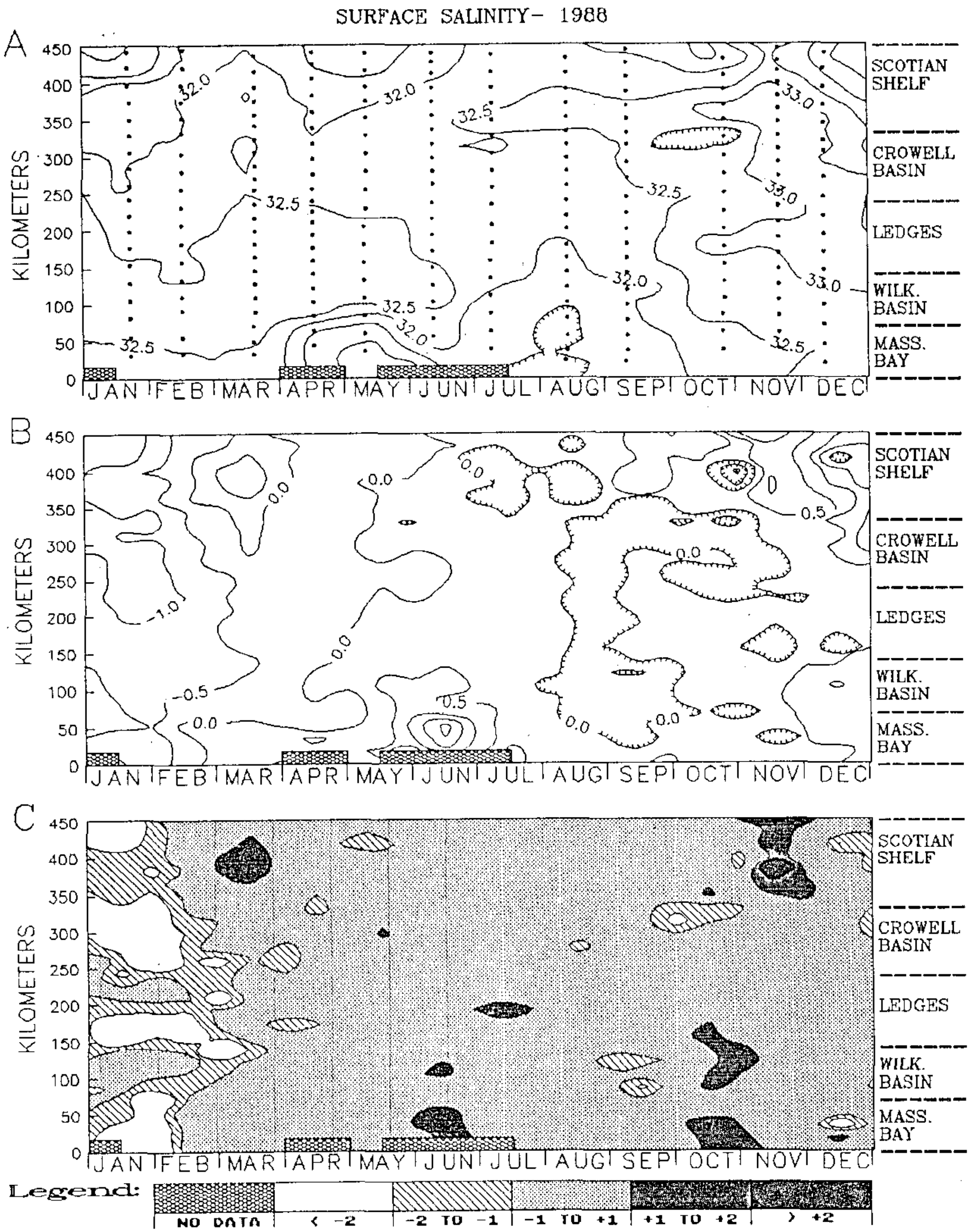

Figure 3. Surface salinity conditions along the Gulf of Maine transect during 1988. A. Measured values (parts per thousand) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1987 means and variances. In panels A and B values decline on those sides of contour lines with hachures.

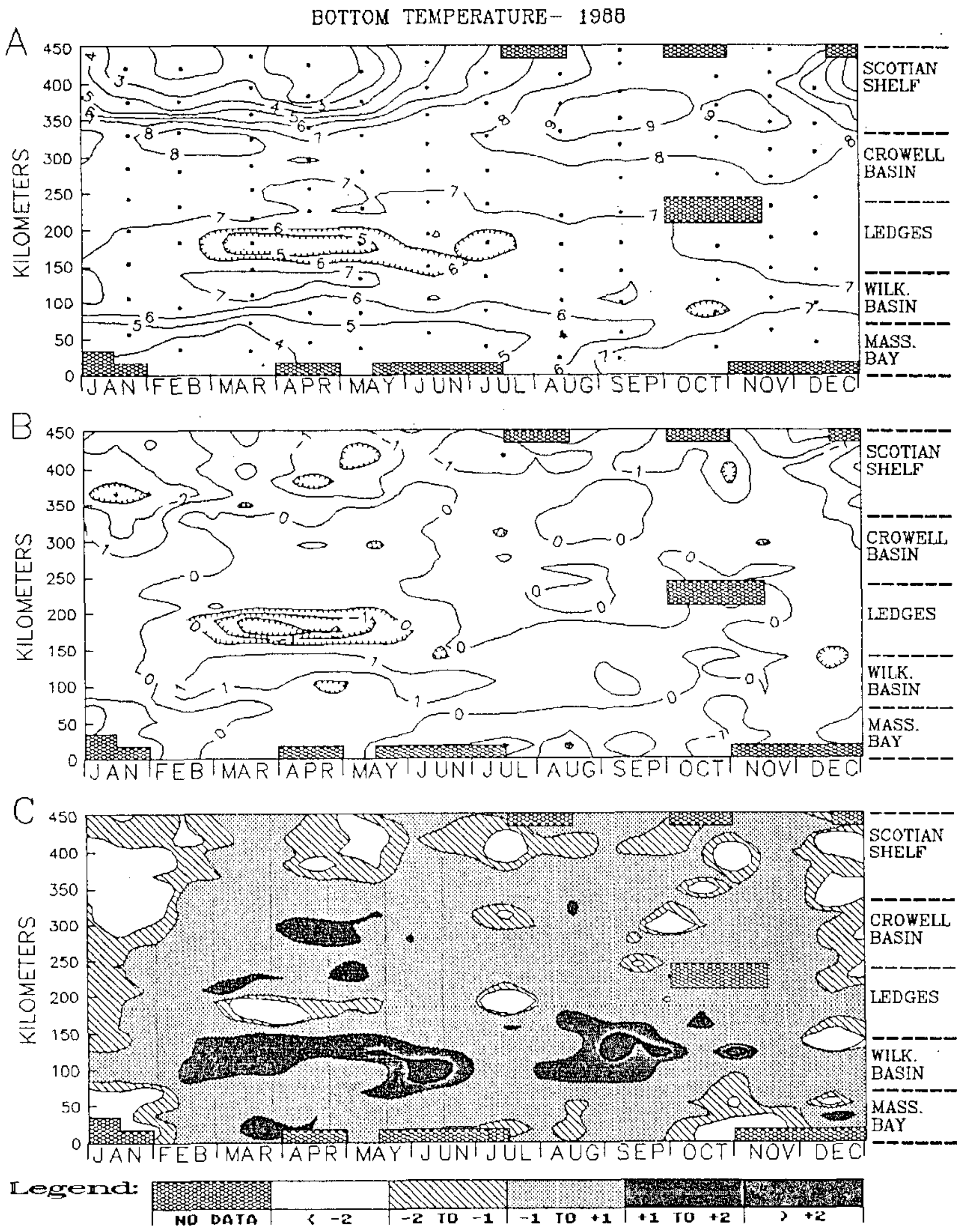

Figure 4. Bottom temperature conditions along the Gulf of Maine transect during 1988. A. Measured values (degrees centigrade) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1987 means and variances. In panels A and B values decline on those sides of contour lines with hachures.

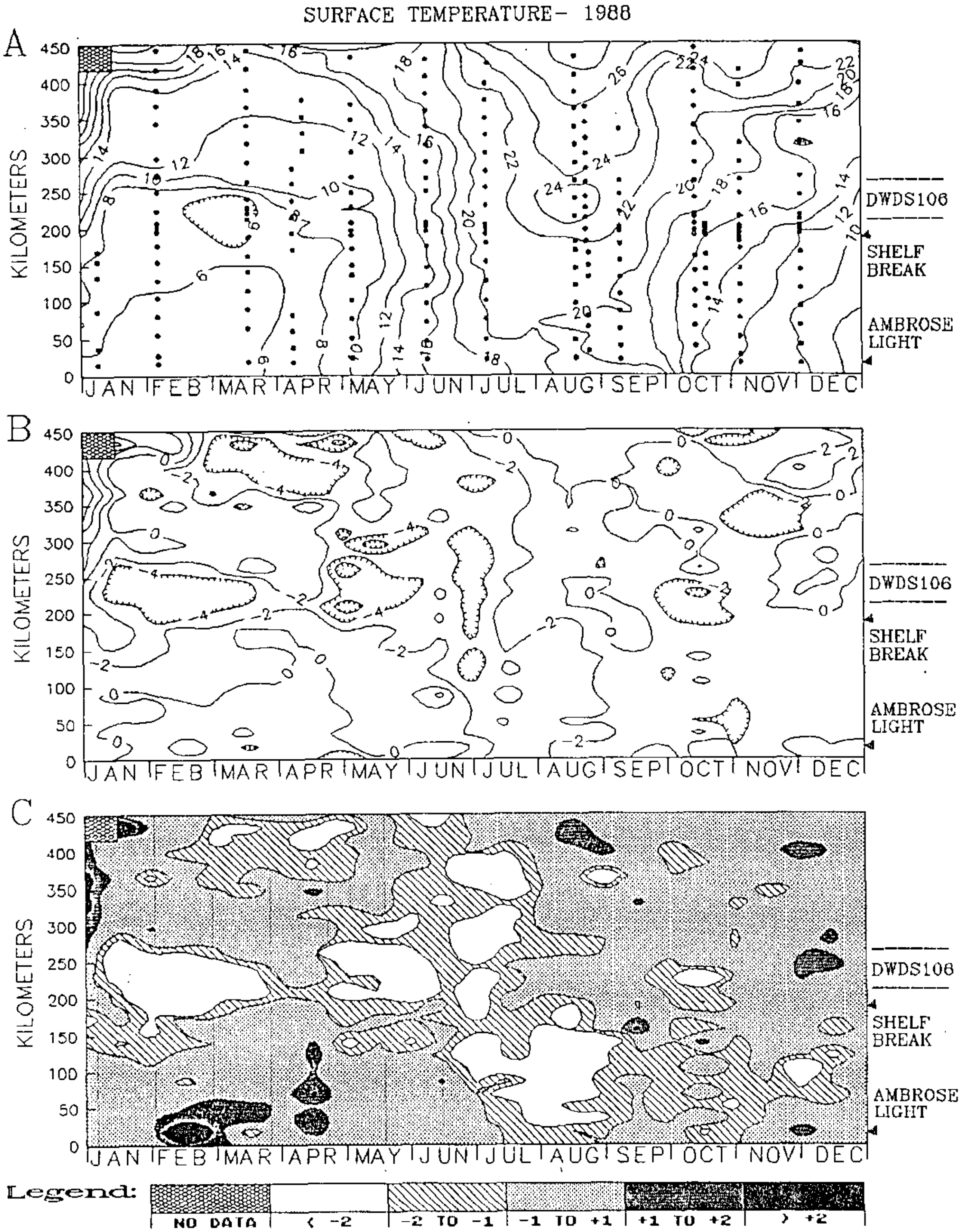

Figure 5. Surface temperature conditions along the New York Bight transect during 1988. A. Measured values (parts per thousand) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. Standardized anomalies (standard deviations) in time 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.

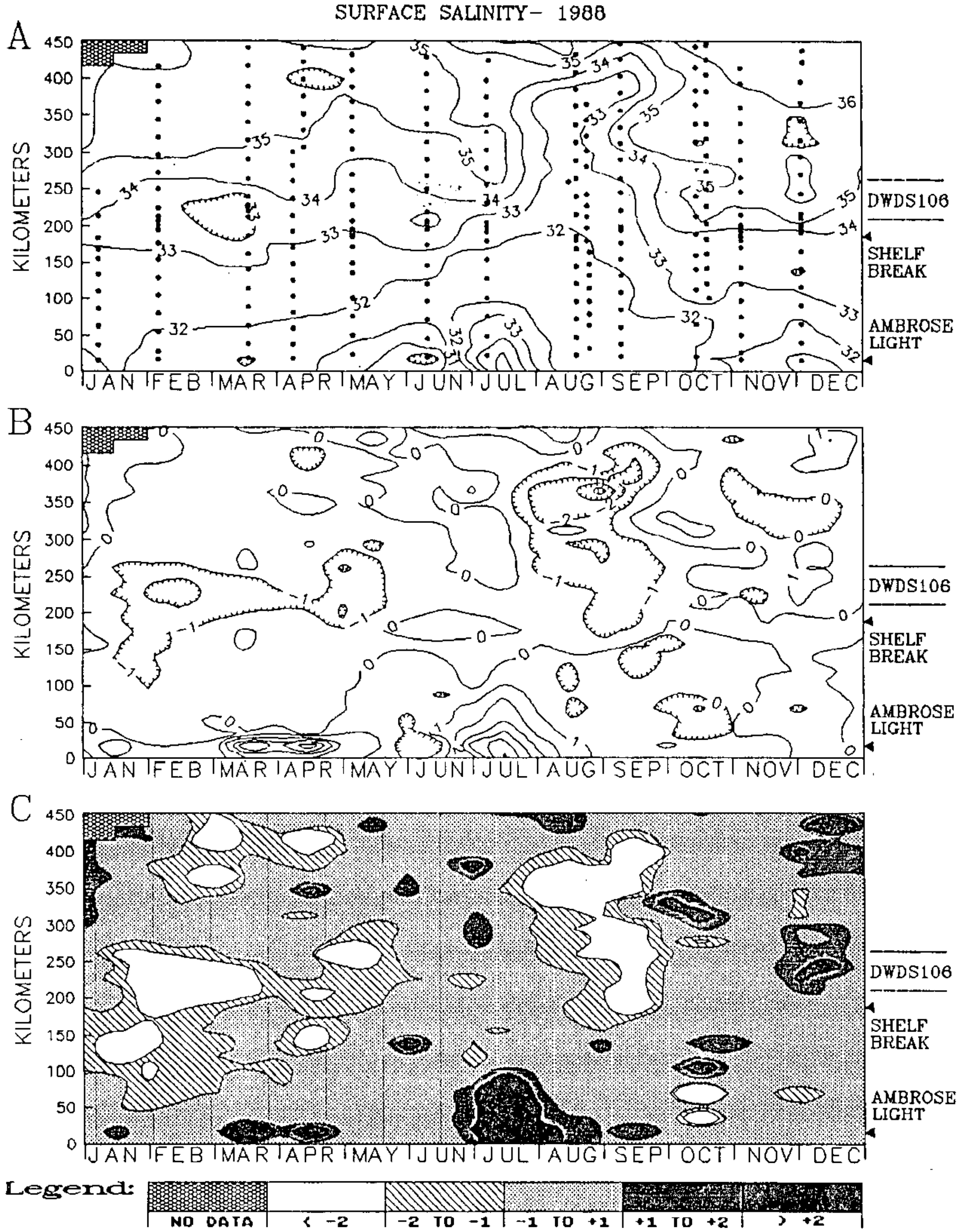

Figure 6. Surface salinity conditions along the New York Bight transect during 1988. A. Measured values (parts per thousand) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1987 means and variances. In panels A and B values decline on those sides of contour lines with hachures.

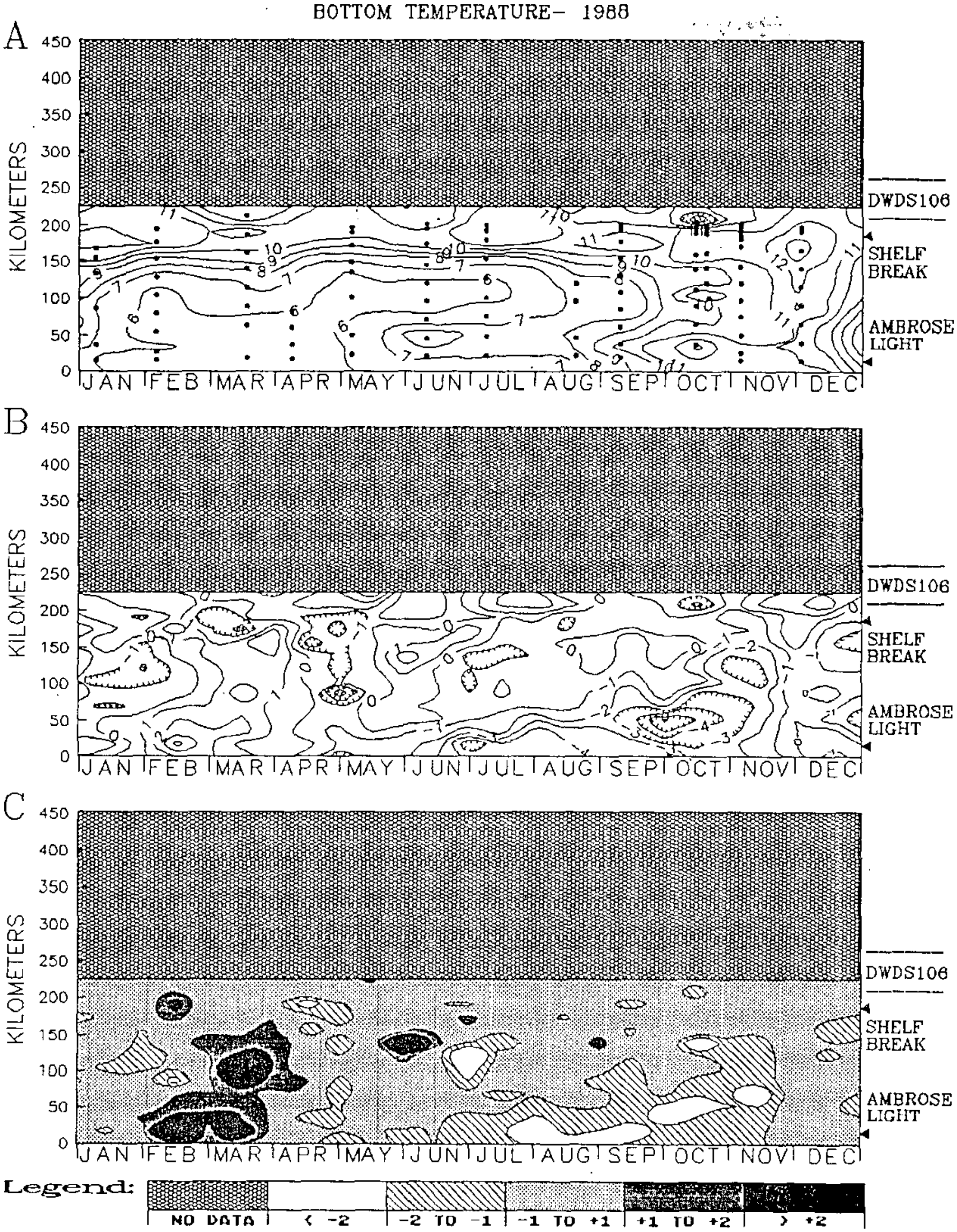

Figure 7. Bottom temperature conditions along the New York Bight transect during 1988. A. Measured values (degrees centigrade) in time and space. Dots indicate sampling locations. B. Anomalies in time and space based on 1978 through 1987 means. C. Standardized anomalies (standard deviations) in time 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.

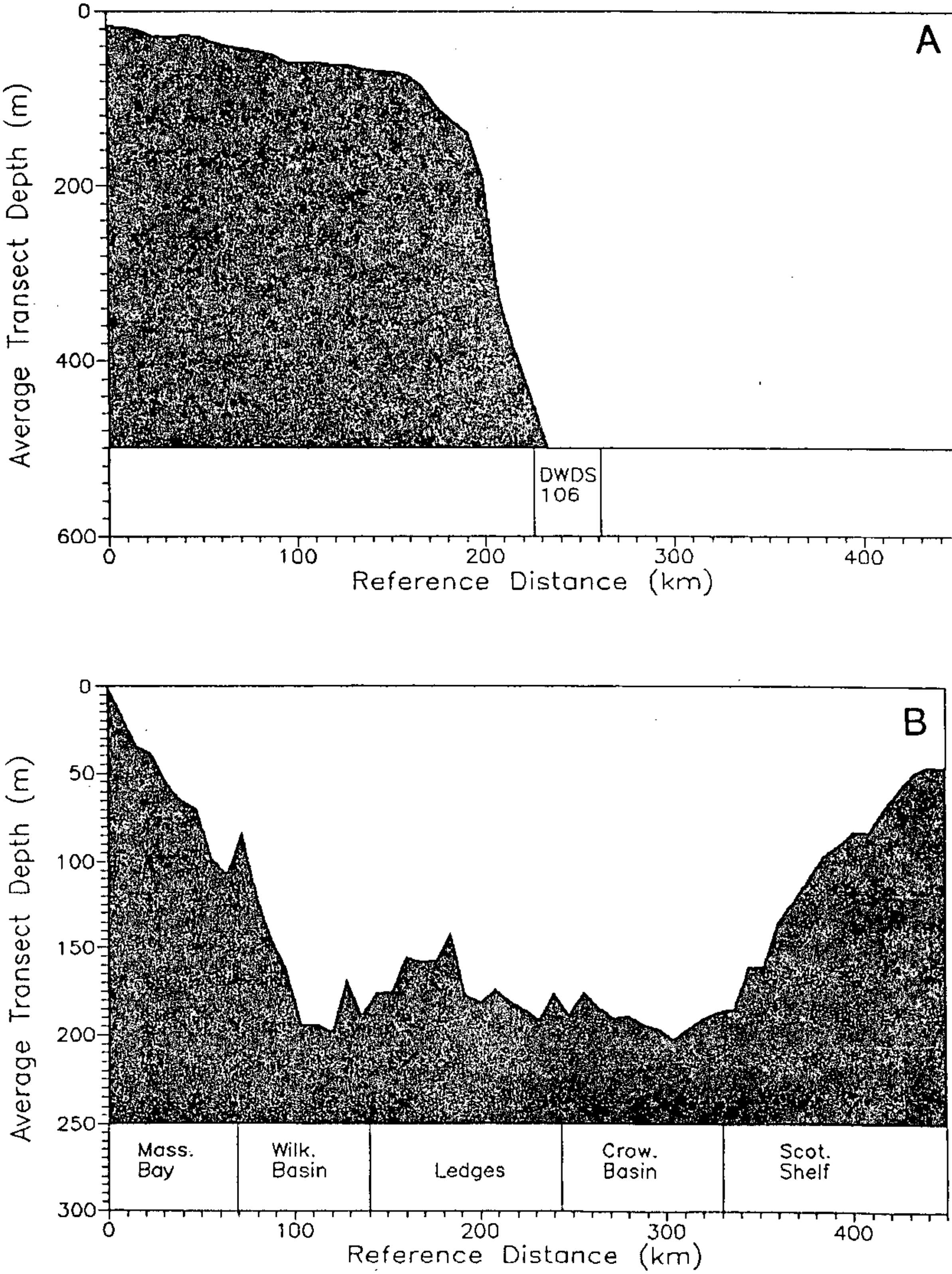

Figure 8. Mean bottom depth along (A) the New York Bight, and (B) the Gulf of Maine transects based on monitoring survey data, 1978 through 1989.