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# Surface and Bottom Temperatures, and Surface Salinities: New York to the Gulf Stream, Massachusetts to Cape Sable N.S. 1994

by

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**Abstract**

Monthly monitoring of surface and water column temperature, and surface salinity across the Middle Atlantic Bight and Gulf of Maine has been conducted for nineteen and eighteen years, respectively. Water temperature and salinity patterns observed in 1994 are compared to 1978 through 1992 means within a time-space matrix. Surface temperatures and salinities along both transects and averaged over all of 1994 were slightly above the 1978-1992 means. Annual mean bottom temperatures were cooler over the shelf portion of the Middle Atlantic Bight transect and warmer in the Gulf of Maine. No surface salinity samples were collected in the Gulf for 1994. In the Middle Atlantic Bight, average 1994 surface salinity was above the base period.

In the more detailed time-space sense below average conditions for all 3 data types prevailed over most shelf sections of the transects during the first half of the year. Bottom temperatures in the Middle Atlantic Bight were cooler than average over much of the inner-shelf in 1994, and generally warmer than long-term mean conditions in June offshore. Over the Scotian Shelf in the Gulf of Maine, bottom temperatures were colder than normal from February through April, and generally colder than average in the area of Massachusetts Bay during January through August. Warmer than average bottom temperature developed in Crowell Basin during April to June.

## Introduction

Monitoring of water column and bottom temperatures, and surface salinities has been conducted by the Northeast Fisheries Science Center along monthly transects from New York towards Bermuda since 1976 (Figure 1a) and across the Gulf of Maine since 1977 (Figure 1b). Measurements are made from merchant and other ships of opportunity which regularly pass along these transects. The objective is to monitor changes in the U.S. Northeast Shelf Ecosystem in relation to possible effects on the long-term sustainability of fishery yields of the system (Sherman *et al.*, 1988). Reports describing the water column and bottom temperature conditions along these two routes are prepared annually, and were summarized through 1990 in Benway *et al.* (1993). This report presents surface temperature and salinity, and bottom temperature conditions along the Middle Atlantic Bight transect and surface and bottom temperature conditions along the Gulf of Maine transect, during 1994 and describes their departures from average conditions for the fifteen-year period, 1978 through 1992.

## Methods

In the Middle Atlantic Bight, sampling intervals averaged 22 km over the shelf, 11 km near the shelf break, and 22 km offshore of the shelf break. In the Gulf of Maine, sampling intervals averaged 44 km along the entire route.

All of the surface temperatures for the Gulf of Maine, and over 90% for the Middle Atlantic Bight resulted from expendable bathythermograph (XBT) deployments. Bucket temperatures were taken for calibration purposes, and for cases of XBT failure. This combination of sources effects the definition of the data reported here as "surface" temperature. What is actually represented are temperatures in approximately the upper 2 meters of the water column. Samples of surface water were taken from bucket samples for salinity determinations. 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 navigational charts at sea, and from bottom impact marks on analog traces.

During the cruises, XBT and synoptic meteorological data were transmitted via Geostationary Operational Environmental Satellite (GOES) to the National Environmental Satellite, Data, and Information Service (NESDIS)/NOAA in Washington D.C.

Methods for generating standardized time-space matrices are described in Benway *et al.* (1993). Briefly, the method involved (1) deleting any samples outside of the transect polygon (Figure 1a and 1b); 2) calculating the sample's standardized distance along the transect, termed reference distance; 3) calculating a uniform time-space grid using julian day and reference distance from all data in a single-year to make a single year map; 4) generating a uniform time-space grid using all data over the base period to make a mean annual map; 5) producing an estimated standard deviation map for the transect's base period; 6) calculating residuals of raw data for a single year from the mean map and griding these residuals to make an anomaly map; and 7) dividing the anomaly map by the standard deviation map to obtain a standardized anomaly map. Annual means and departures for the transects (Tables 1- 2) were obtained by 1) averaging values from the single-year map, the anomaly map, and the mean map.

## Results

Surface temperature and salinity, and bottom temperature data for the Middle Atlantic Bight and the Gulf of Maine transects are presented as contoured time-space plots (Figures 2-7). Portrayed are the conditions during 1994, and departure of these conditions from the 1978 through 1992 means, in terms of algebraic anomalies (data units) and standardized anomalies (standard deviation units). Figure 8 illustrates the mean bottom depth at 5 km intervals of reference distance along each transect.

Annual means and departures of these variables along the transects are presented in Tables 1 and 2. Bottom temperatures in the Middle Atlantic Bight (Table 1) are averaged over only the continental shelf (to approximately 200 km reference distance), because more offshore bottom depths exceed sampling depth of the expendable bathythermographs employed.

## Discussion

### Middle Atlantic Bight

**Surface Temperature**: Surface temperatures during the year ranged from less than 2°C in the nearshore waters in February and March to greater than 28°C at the extreme offshore end of the transect during July and August (Figure 2). In 1994 annual minimum temperatures occurred over the entire transect in February, approximately a month earlier than the 15-year base period. During February through April, surface temperatures in general across the shelf waters were much colder than average. This below average condition persisted in the nearshore from late January to early May and then again in late July through early September but to a lesser degree. Much warmer than usual surface temperatures developed in waters beyond the shelf break, with the passage of a warm core ring. Surface temperatures for the year for the transect as a whole were 0.5°C higher than the 1978-1992 means (Table 1).

**Surface Salinity**: Salinities in the Middle Atlantic Bight for 1994 ranged from a low of less than 28.0 psu nearshore in March to greater than 36.5 psu at the offshore end of the transect from late March through mid-May , and again through the month of September (Figure 3). Below average salinities were detected starting in May and continuing into August in the waters shoreward of the shelf break due to the persistence of a warm core ring. Much below average salinities occurred during July and August in the offshore waters as a result of offshore transport of low salinity shelf water due to the semi-stationary warm core ring in the Bight from late May to mid-September. Lower than average conditions were noted again near the shelf break during late September through October. Surface salinity in 1994 for the transect as a whole was 0.03 psu higher than average (Table 1).

**Bottom Temperature**: The relationship between bathymetry and reference distance is shown in Figure 8a. Bottom temperatures on the shelf and upper slope for 1994 are presented in Figure 4. The relationship between bottom relief and reference distance is portrayed in Figure 8a, showing that bottom depth was beyond sampling depth (500 m) seaward of about 210 km reference distance. Bottom temperatures ranged from less than 2°C from mid-February to mid-March in the nearshore to greater than 15°C also in the nearshore during October. Below average bottom temperatures occurred during the first two thirds of 1994. In 1994 fall overturn began in the nearshore in mid-September while bottom water temperatures were near normal. Warmer than normal conditions were observed during late November through December over most of the shelf. Annual means of bottom temperature on the continental shelf averaged 0.7°C below the 1978-1992 baseline (Table 1).

**Gulf of Maine**

**Surface Temperature**: Surface temperatures ranged from less than 1.0°C on the Scotian Shelf end of the transect in late February into early March to higher than 21°C over Wilkinson Basin and the Central Ledges in July (Figure 5). Negative anomalies occurred over Massachusetts Bay from January into March and again during July and on the Scotian Shelf during February through about April. The lack of coverage makes it uncertain of the time span for this negative anomaly in the early part of 1994. These exceeded 2 standard deviations below the 1978-1992 means. Positive anomalies occurred over Massachusetts Bay in December. Over much of the Gulf in June and July, surface temperatures were in excess of 1°C above average. Positive anomalies amounting to more than 1°C occurred over the central Gulf ledges, Crowell Basin and the Scotian Shelf from June into September. For the transect as a whole, surface temperatures averaged 9.1°C, or 0.2°C warmer than 1978-1992 means (Table 2).

**Surface Salinity**: No salinity samples were collected along the Gulf of Maine Transect in 1994 (Figure 6).

**Bottom Temperatures**: Annual minimum temperatures for the transect of less than 2°C occurred over the Scotian Shelf during March, and of less than 3°C over parts of Massachusetts Bay during the same time (Figure 7). The relationship between bathymetry and reference distance is shown in Figure 8b. Maximum bottom temperatures occurred over the outer Scotian Shelf in October. Negative anomalies in excess of 1°C occurred from January into March in Massachusetts Bay and western Wilkinson Basin. Negative departures exceeding 2°C and 2 standard deviations occurred over the Scotian Shelf in March. Warm water in Crowell Basin persisted from January through June with significant anomalies during that period. Annual mean bottom temperatures exceeded the baseline temperature of 6.7°C for 1994 by 0.5°C (Table 2).

## Acknowledgements

Appreciation is extended to the officers and crews of the C/V Oleander, Bermuda Container Lines, and the C/V Skogafoss, Skogaline Ltd, St. John, Antigua for their generous cooperation in the continued success of this program. Appreciation also is proffered to all the volunteers who have collected data aboard the Oleander. Special thanks are extended to the members of the National Ocean Service, Office of Ocean Observations, for their continued support.

## References

Benway, R. L., J. W. Jossi, and K. P. Thomas. 1993. Variability of temperature and salinity in the Middle Atlantic Bight and Gulf of Maine 1978-1990. NOAA Tech. Rep NMFS 112, 108 p.

Sherman, K., M. Grosslein, D. Mountain, D. Busch, J. O'Reilly, and R. Theroux. 1988. The continental shelf ecosystem off the northeast coast of the United States. Chapter 9., pp. 279-337. In H. Postma and J.J. Zijlstra (Eds.) Ecosystems of the World 27--Continental Shelves. Elsevier, Amsterdam.

Table 1. Water temperature (°C) and surface salinity (psu) for the Middle Atlantic Bight transect.

| | 1994 MEAN | 1978-1992 MEAN | 1994 ANOMALY |
|---|---|---|---|
| Surface temperature | 17.6 | 17.1 | 0.5 |
| Bottom temperature | 7.4 | 8.3 | -0.7 |
| Surface salinity | 34.06 | 34.03 | 0.03 |

Table 2. Water temperature (°C) and surface salinity (psu) for the Gulf of Maine transect.

| | 1994 MEAN | 1978-1992 MEAN | 1994 ANOMALY |
|---|---|---|---|
| Surface temperature | 9.1 | 8.9 | 0.2 |
| Bottom temperature | 7.2 | 6.7 | 0.5 |
| Surface salinity | No Samples Collected | | |

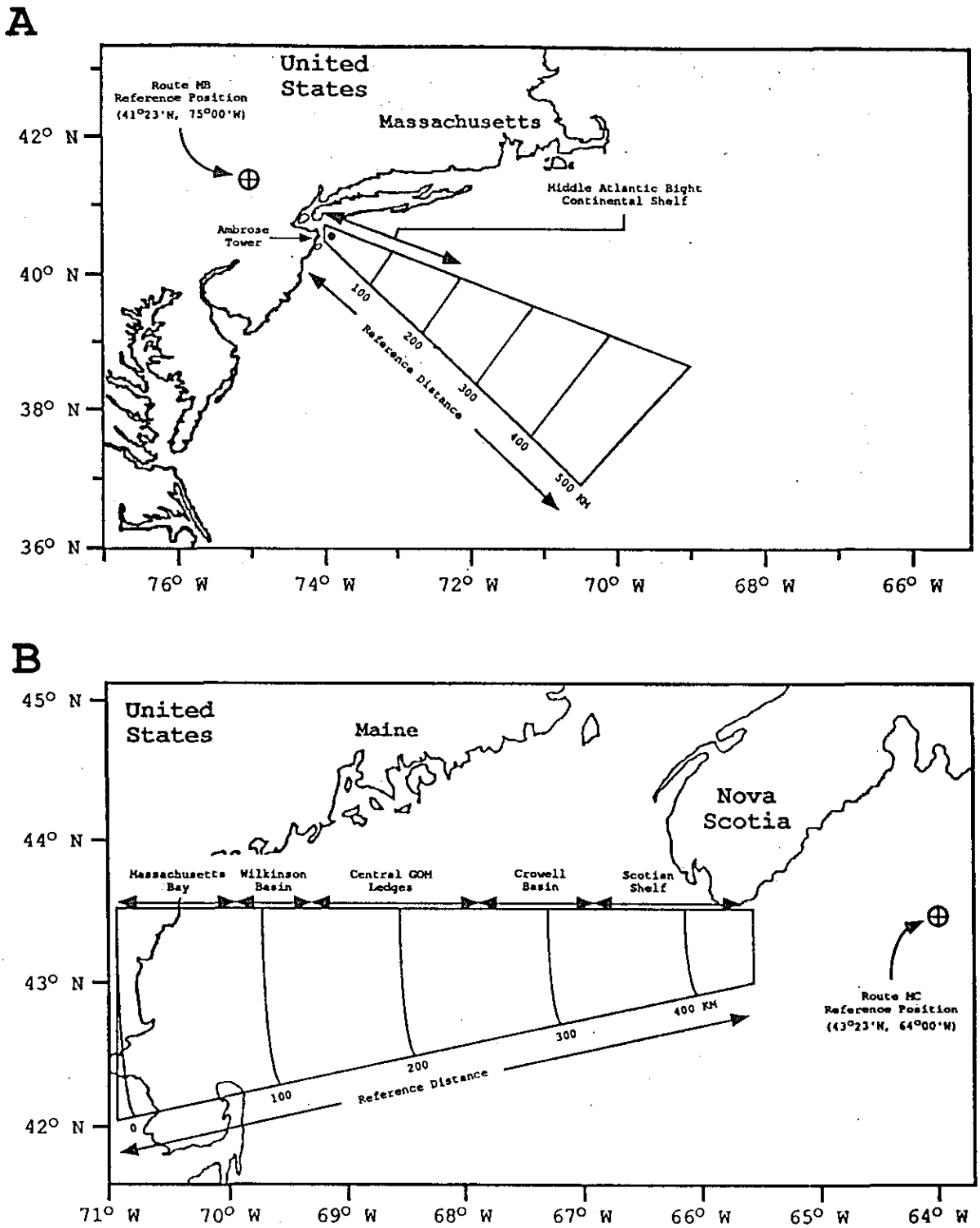



Figure 1. The (A) Middle Atlantic Bight (MAB)-Route MB, and (B) Gulf of Maine (GOM)-route MC polygons, within which monitoring transects occurred, showing reference positions and distances, location of Ambrose Tower, and major geographical features through which all sampling took place.

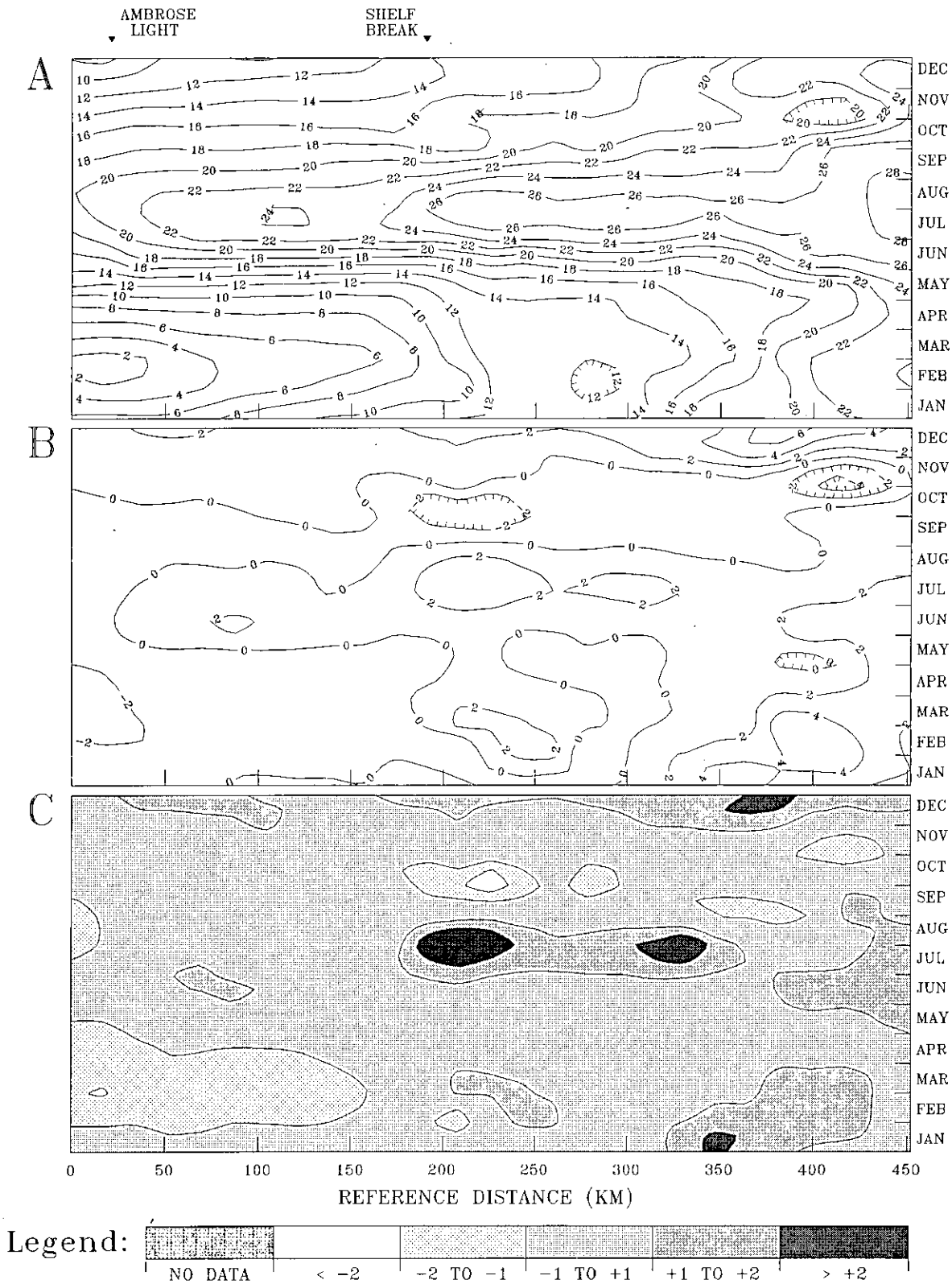



Figure 2. Surface temperature conditions along the Middle Atlantic Bight transect during 1994. A. Measured values (degrees centigrade) in time and space. B. Anomalies in time and space based on 1978 through 1992 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1992 means and variances; scale given in legend. In panels A and B values decline on those sides of contour lines with hachures.

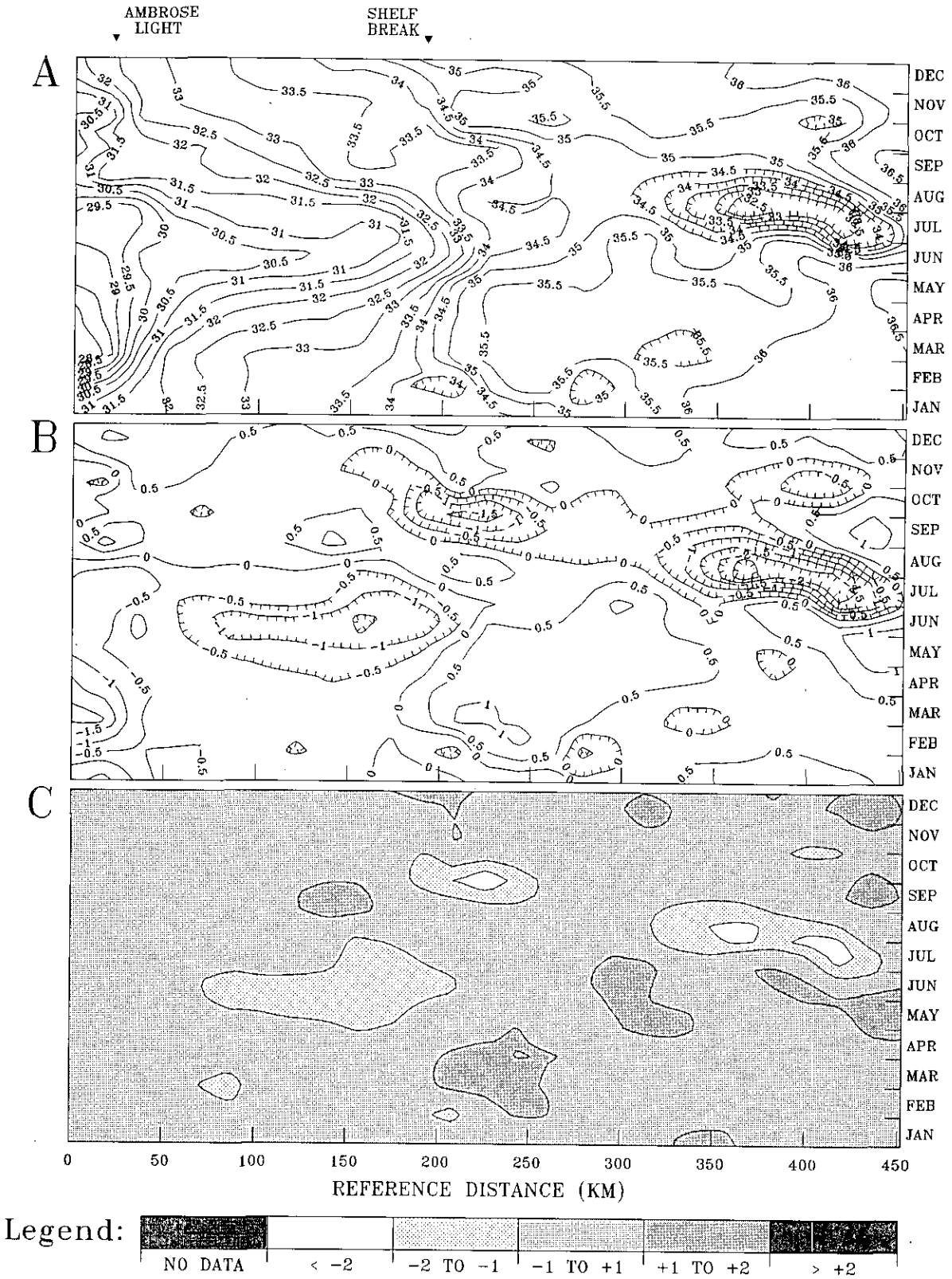



Figure 3. Surface salinity conditions along the Middle Atlantic Bight transect during 1994. A. Measured values (practical salinity units) in time and space. B. Anomalies in time and space based on 1978 through 1992 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1992 means and variances; scale given in legend. In panels A and B values decline on those sides of contour lines with hachures.

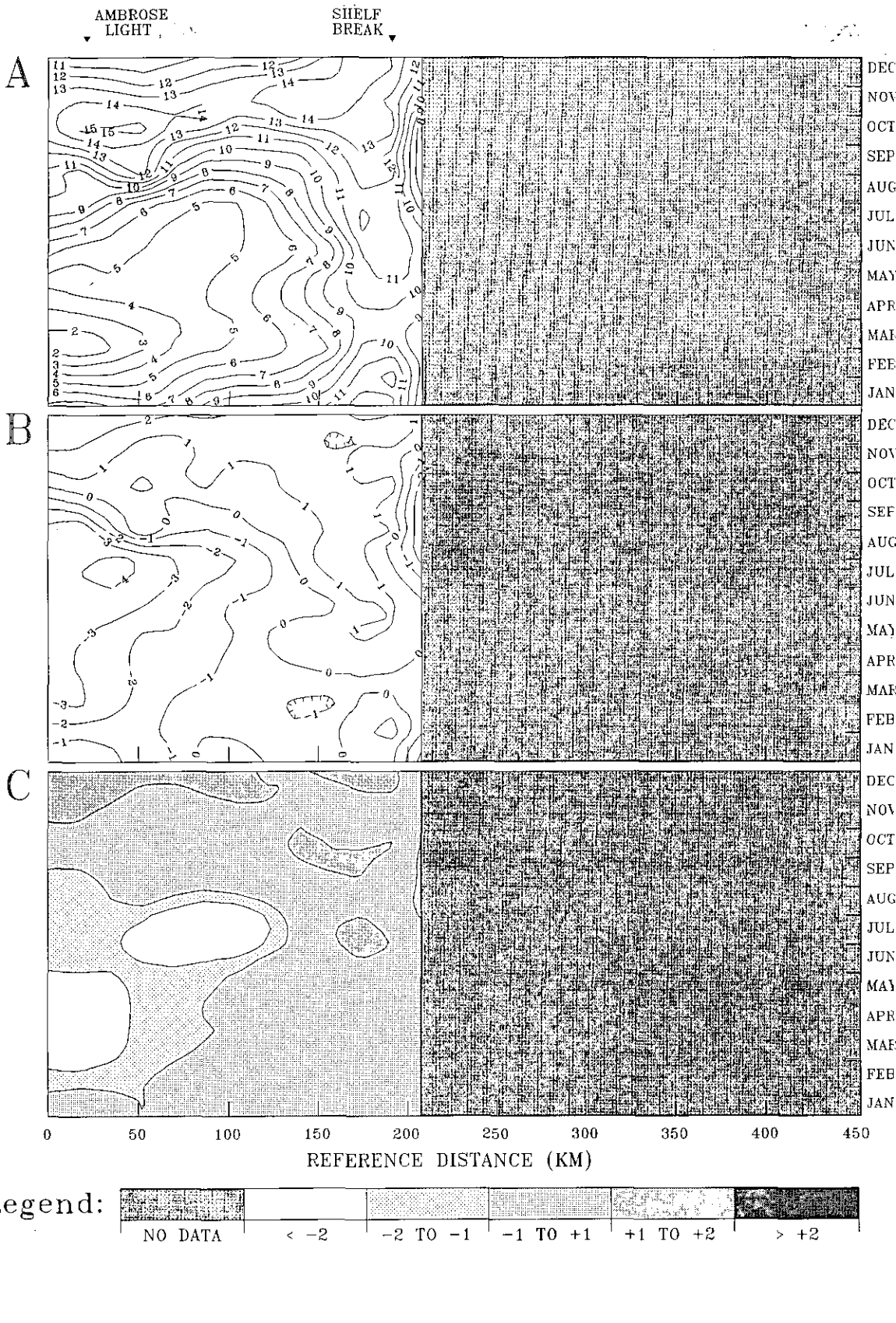



Figure 4. Bottom temperature conditions along the Middle Atlantic Bight transect during 1994. A. Measured values (degrees centigrade) in time and space. B. Anomalies in time and space based on 1978 through 1992 m C. Standardized anomalies (standard deviations) in time and space based on through 1992 means and variances; scale given in legend. In panels A values decline on those sides of contour lines with hachures.

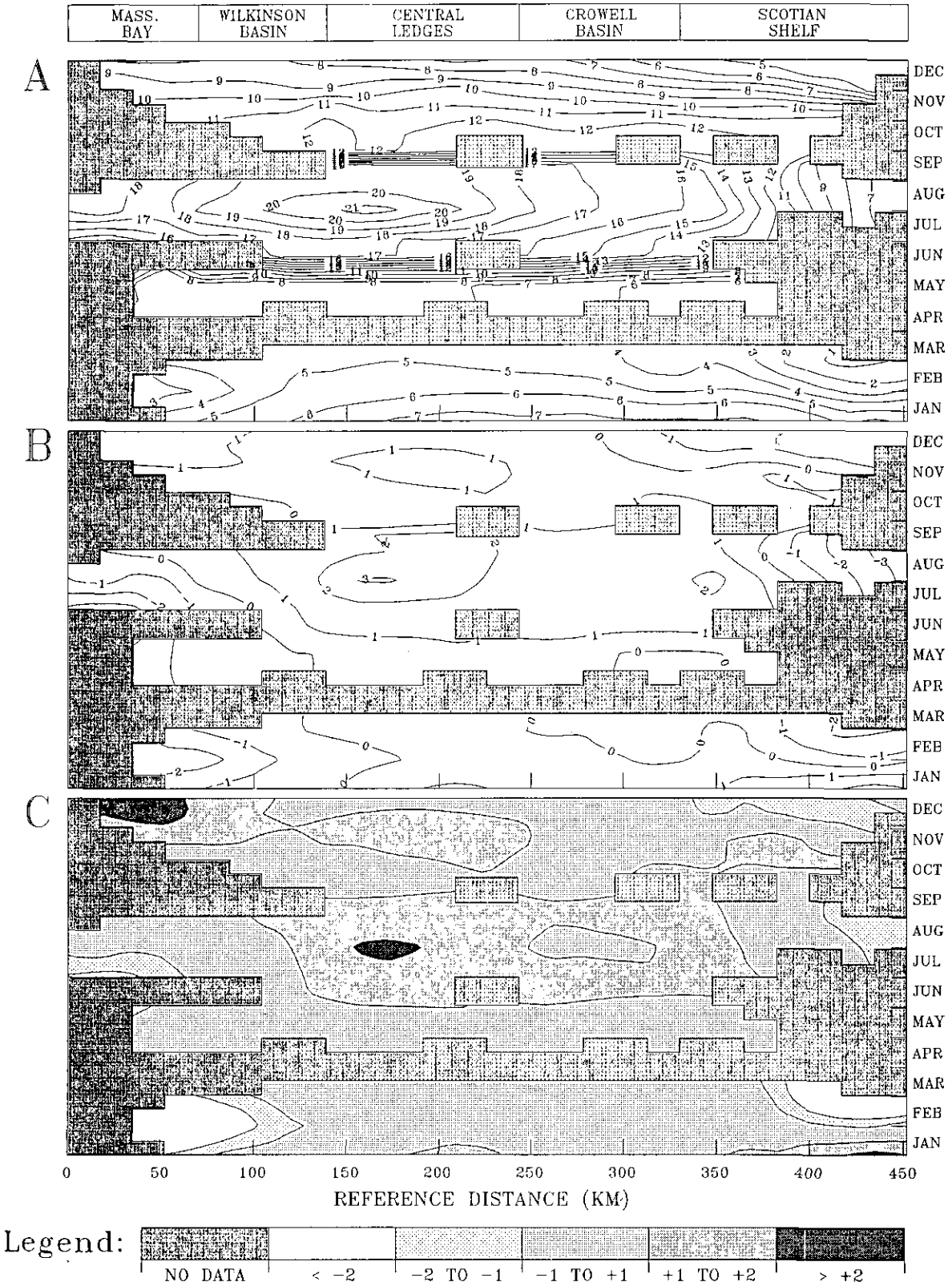
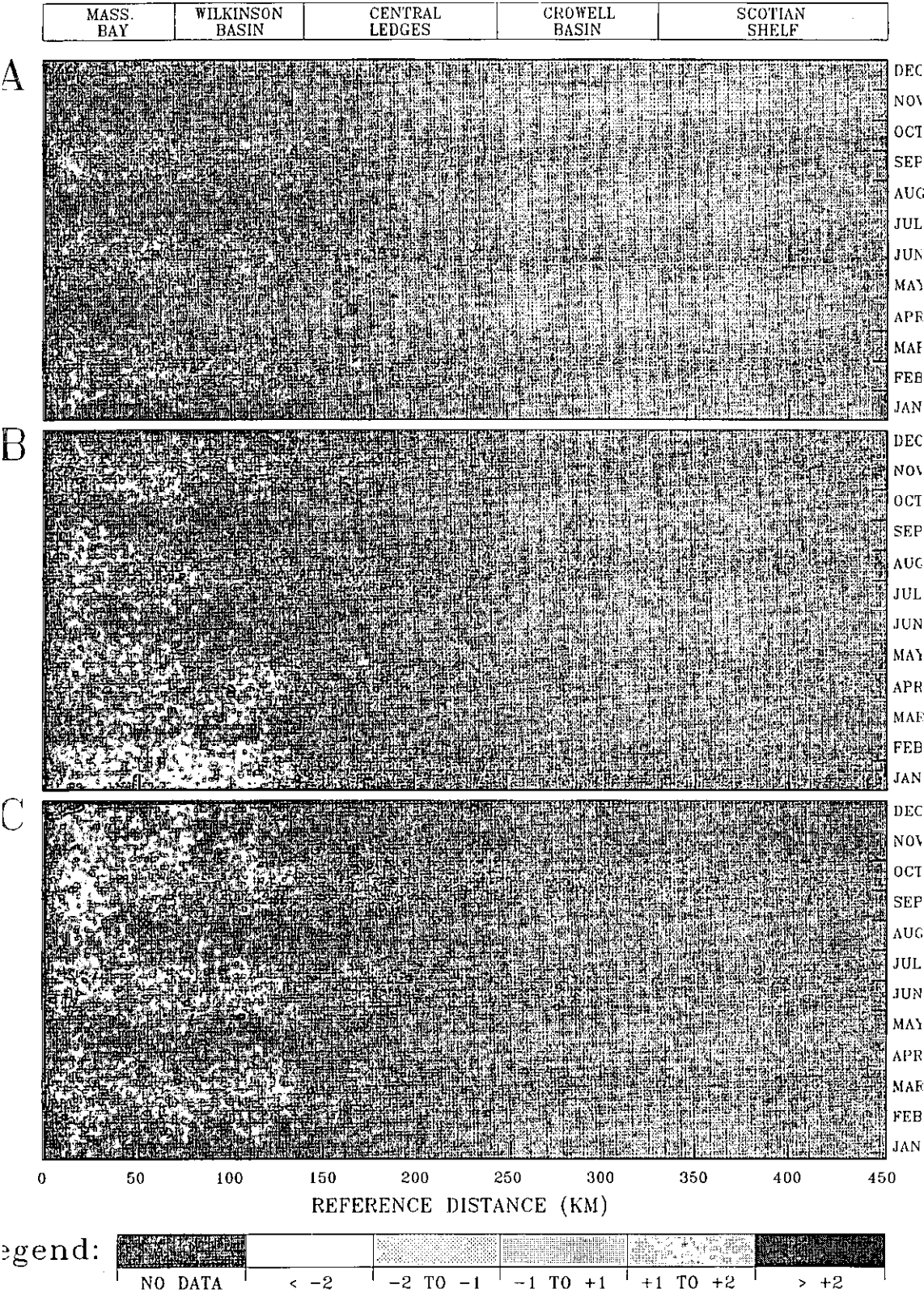



Figure 5. Surface temperature conditions along the Gulf of Maine transect during 1994. A. Measured values (degrees centigrade) in time and space. B. Anomalies in time and space based on 1978 through 1992 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1992 means and variances; scale given in legend. In panels A and B values decline on those sides of contour lines with hachures.




igure 6. Surface salinity conditions not measured along the Gulf of Mai
ransect during 1994.

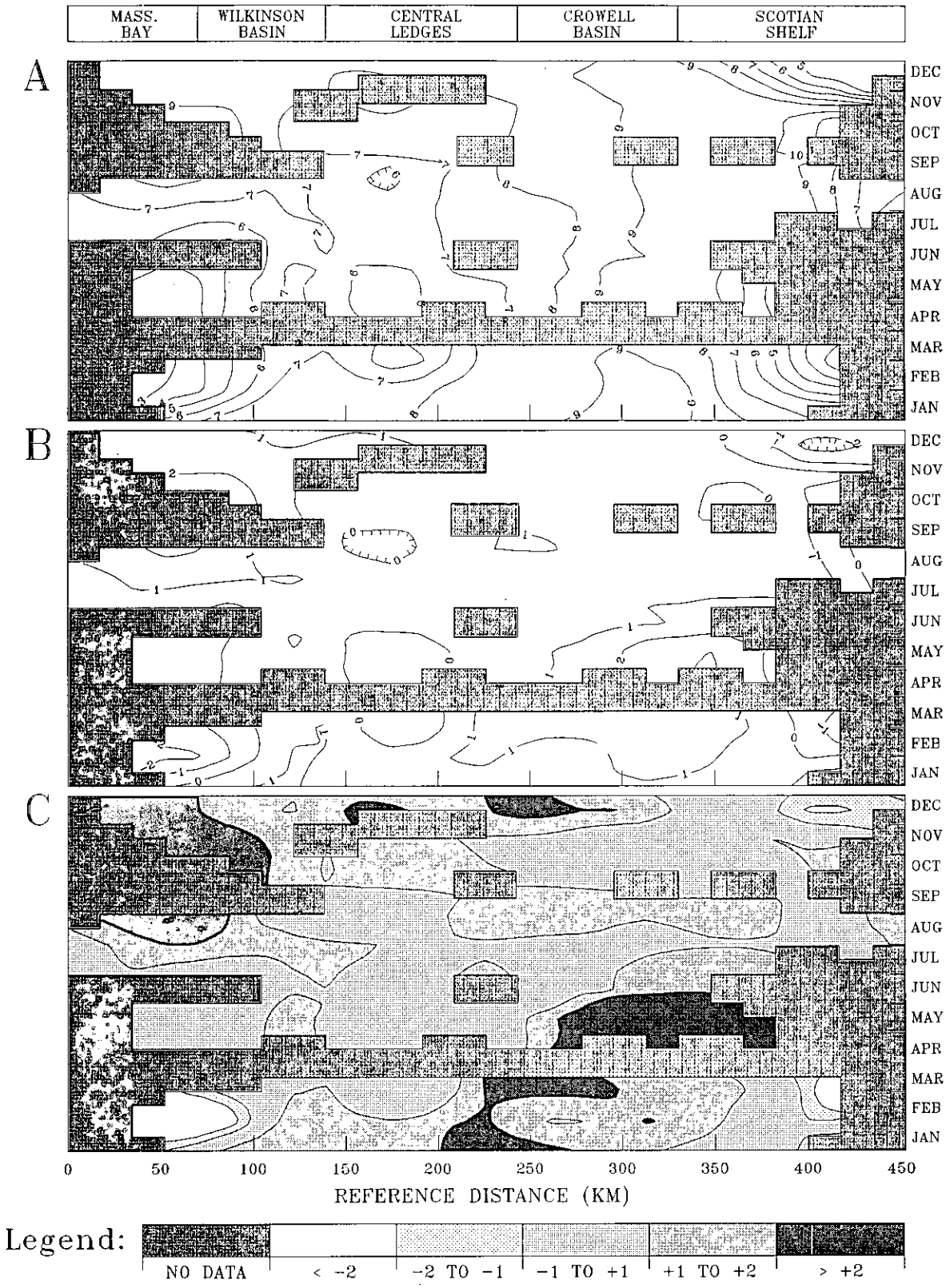



Figure 7. Bottom temperature conditions along the Gulf of Maine transect during 1994. A. Measured values (degrees centigrade) in time and space. B. Anomalies in time and space based on 1978 through 1992 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1992 means and variances; scale given in legend. In panels A and B values decline on those sides of contour lines with hachures.

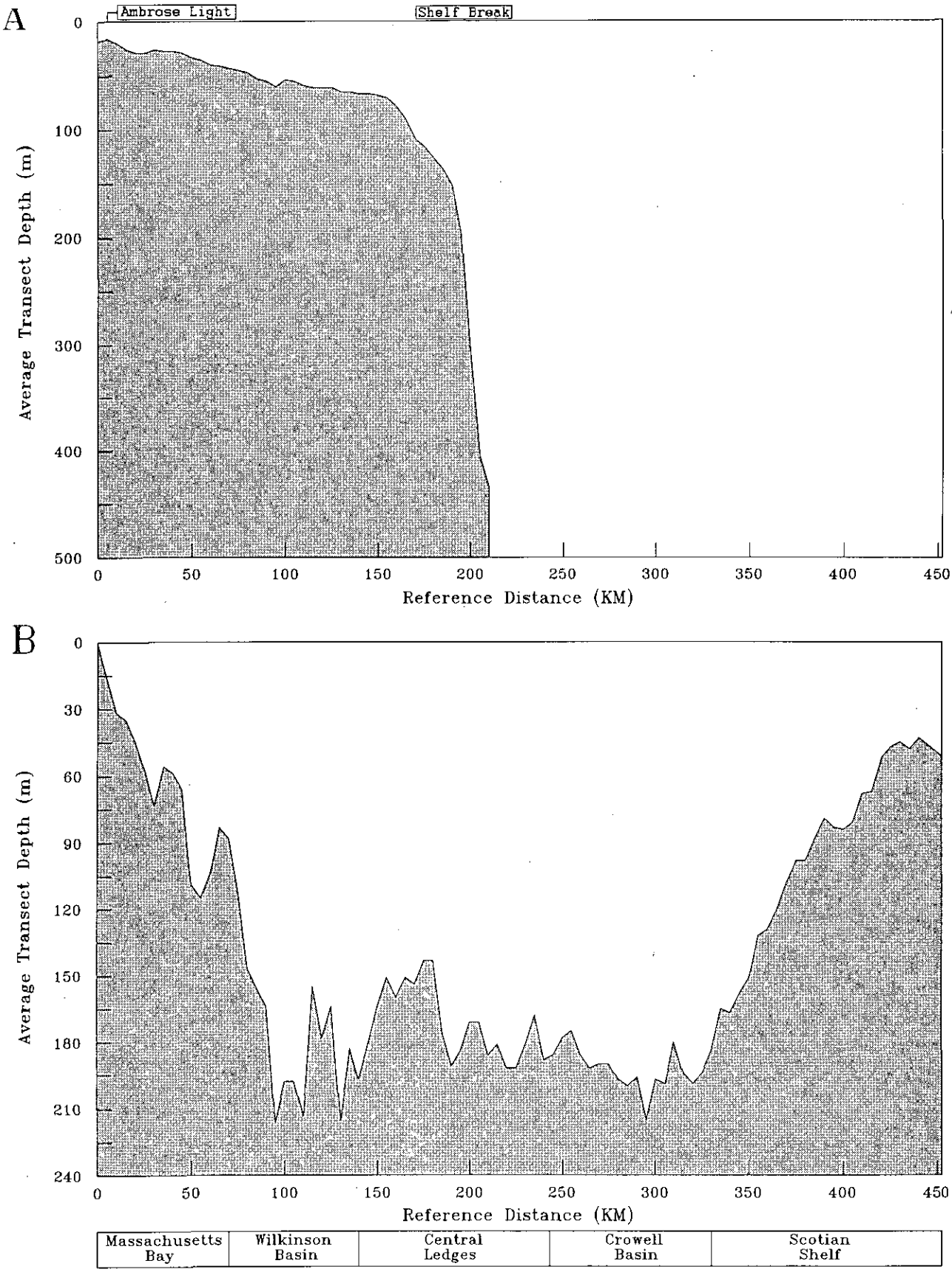



Figure 8. Mean bottom depth along the transects based on monitoring survey data, 1978 through 1992. A. Middle Atlantic Bight. B. Gulf of Maine.