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Surface and Bottom Temperatures, and Surface Salinities: New York to the Gulf Stream, Massachusetts to Cape Sable, N.S., 1996

by

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Abstract

Monthly monitoring of surface and water column temperature, and surface salinity across the Middle Atlantic Bight (MAB) and Gulf of Maine (GOM) has been conducted for twenty-one and twenty years, respectively. Water temperature and salinity patterns observed in 1996 are compared to 1978 through 1992 means within a time-space matrix. In 1996 in the MAB surface and bottom temperatures and surface salinities were the lowest since the beginning of the baseline in 1978. Surface temperatures averaged over all of 1996 and over the entire transects averaged 1.9°C lower for the MAB and 1.1°C lower for the GOM than the 1978-1992 means. Similarly averaged bottom temperatures were -0.8°C cooler over the shelf portion of the MAB transect, and 0.2°C warmer along the GOM transect. No surface salinity samples were collected in the GOM for 1996, although thermal-salinograph data were collected but are still undergoing calibration. In the MAB, average 1996 surface salinity was 1.17 psu below the 15-year base period.

In the more detailed time-space sense, MAB surface temperatures were significantly lower than average 1) over the mid- to outer shelf from February through April, 2) over the outer shelf and slope during July and August, 3) over the mid-shelf in October, and 4) well offshore in November. Negative departures of surface salinity occurred over the shelf throughout 1996 and after July over the entire transect reaching the Gulf Stream. MAB bottom temperatures were significantly below average on the mid-shelf during January, expanding to near Ambrose Light by April. An additional departure occurred in the 150- to 200-km reference distance area during the early summer, and continued through most of the remainder of 1996. GOM surface temperatures were significantly below the baseline from January through March in Massachusetts Bay, extending eastward to Crowell Basin in March. At this same time surface temperatures were as much as 4°C above average on the Scotian Shelf. From July through September colder than average temperatures existed across the entire GOM transect. GOM bottom temperatures were cooler than normal during January in Mass Bay and in June through December on the Scotian Shelf. Starting in January in the Central Gulf Ledges warmer than average bottom temperatures were observed. Significant positive anomalies reached the Scotian Shelf in February, Massachusetts Bay by March, and continued in the mid-Gulf until July.

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 (Fig. 1a) and across the Gulf of Maine since 1977 (Fig. 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 1996, 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 transect.

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 affects the definition of the data reported here as "surface" temperature. 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 (Fig. 1a and 1b); 2) calculating each 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 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 surface and bottom temperature data for the Gulf of Maine transects are presented as contoured time-space plots (Fig. 2-6). Portrayed are the conditions during 1996, 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 7 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 the continental shelf to a limit of approximately 200 km reference distance, because bottom depths farther offshore exceed sampling depth of the expendable bathythermographs employed.

Discussion

Middle Atlantic Bight

Surface and bottom temperature, and surface salinity conditions along the Middle Atlantic Bight transect during 1996 were record breaking for the period 1978-1992. This was true for the absolute values measured and/or for the time-space extent over which they occurred.

Surface Temperature: Surface temperatures during 1996 ranged from less than 2°C in the near-shore waters in February to greater than 26°C at the extreme off-shore end of the transect during late-August and into October (Fig. 2). Annual minimum temperatures occurred over the entire transect in February, approximately one month earlier than the 15-year base period. Particularly inshore, 1996 began with 2°C colder than average temperatures, a carry over from 1995s colder than average December. The entire shelf area during the period of January through late April exhibited surface temperatures in excess of 2°C, and isolated cases exceeding 3°C below average. This condition was repeated when cold surface water was observed during late June and continued through the rest of the year in the shelf/slope region. Record breaking snowfall, increased cloud cover and reduced solar radiation (National Climatic Data Center, 1996) all contributed to the anomalous condition observed. Surface temperatures for the year for the

transect as a whole were -1.9°C colder than the 1978-1992 means (Table 1). This represents one of the largest negative departures in the Middle Atlantic Bight transect recorded by this project to date.

Surface Salinity: Surface salinities along the MAB transect during 1996 were by far lower than those of any year since monitoring began in 1978 (Fig. 3). Surface water over the inshore 35 km of the transect was more than 2 psu below the 1978-1992 baseline during January, and during March through early-November. In May salinities off Ambrose Light declined to <17.5 psu, over 12 psu below average. The entire shelf was 0.5 psu below average with the majority of its area more than 1.5 below average. Low salinity water spread to the offshore end of the transect, reaching a minimum of <33 psu in late October. Some comparisons of 1996 to 1984 (the second freshest year in the series) are noteworthy. Lowest salinities in both years occurred in May off Ambrose Light; in 1984 they declined to 22.5 psu--in 1996 to <17.5 psu. In both years low salinity water spread towards the offshore end of the transect in the latter half of the year; in 1984 it declined to just under 34 psu on two brief occasions (generally 35-36 psu)--in 1996 34 psu water was present over the outer end of the transect most of the time after June, and in October declined to <32.5 psu.

Bottom Temperature: The relationship between bathymetry and reference distance is shown in Fig. 7a. Bottom temperatures ranged from less than 4°C from late January to mid-March on the inner shelf to greater than 15°C over the inner shelf during September (Fig. 4). Based on water column data, the annual fall overturn began during mid-September and was nearly completed on the shelf by mid-November. The "Cold Pool," described by Cook (1985) as bottom water less than 10°C, which normally is confined to the inner 160 km of the transect, was present over the entire sampled area between March and September, producing significantly negative anomalies in July. Significantly negative departures occurred over the mid-shelf from February through March and over much of the shelf in April. These coincided with an increase in coastal storms, mixing winds, and colder than normal air temperatures beginning in December 1995 (National Climatic Data Center, 1996). Annual means of bottom temperature on the continental shelf averaged -0.8°C below the 1978-1992 baseline (Table 1).

Gulf of Maine

Surface Temperature: Surface temperatures ranged from less than 2°C in Massachusetts Bay during mid-February to greater than 16°C in the western region of the transect during the July period (Fig. 5). Significant negative anomalies occurred from Massachusetts Bay out to Crowell Basin during January through February, dropping over 2°C below the 1978-1992 means. Highly significant positive anomalies were observed during the same period on the Scotian Shelf end of the transect. These positive anomalies exceeded the baseline by over 3°C. During July and continuing through September significant negative anomalies in the middle and eastern end of the transect were observed. These follow the lower than normal air temperature weather pattern for the New England area mentioned above (National Climatic Data Center 1996). For the transect as a whole, surface temperatures averaged 8.0°C, or -1.9°C colder than 1978-1992 means (Table 2).

Bottom Temperatures: The relationship between bathymetry and reference distance is shown in Fig. 7b. Annual minimum bottom temperatures for the transect of less than 3°C occurred in Massachusetts Bay during the February-March period. Equally low temperatures also were observed in January at the Scotian Shelf or eastern end of the transect (Fig. 6). Maximum bottom temperatures occurred in the Crowell Basin region during January and again for a more extended period in May. Positive anomalies reaching in excess of 3°C occurred over the Scotian Shelf beginning in late April and continued through late May. This warmer than normal condition continued and expanded westward to include the Central Ledges during the June through October period. For the transect as a whole, bottom temperatures in the Gulf of Maine exceeded the base line temperatures of 6.7°C by only .2°C (Table 2).

Acknowledgements

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

	1996 MEAN	1978-1992 MEAN	1996 ANOMALY
Surface temperature	15.2	17.1	-1.9
Bottom temperature[1]	8.5	9.3	-0.8
Surface salinity	32.86	34.03	-1.17

[1] Data only presented for the Continental Shelf, <200 meters.

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

	1996 MEAN	1978-1992 MEAN	1996 ANOMALY
Surface temperature	8.0	9.1	-1.1
Bottom temperature	6.9	6.7	0.2
Surface salinity		No Samples Collected	

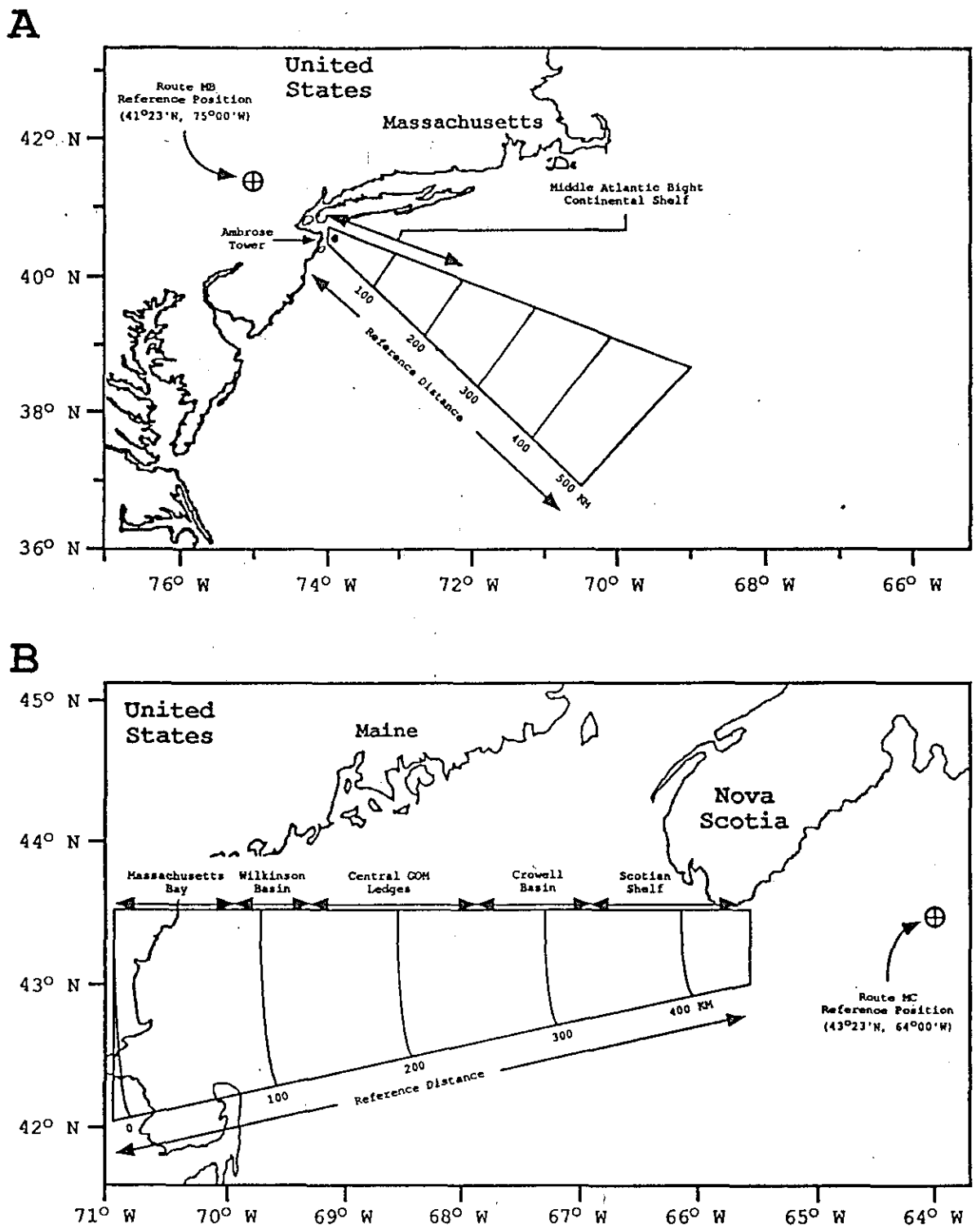

Figure 1. The (A) Middle Atlantic Bight (MAB)-Route MB, and (B) Gulf of Maine (GOM)-route MC polygons, within which monitoring transects occurred, showing reference positions and distances, location of Ambrose Tower, and major geographical features through which all sampling took place.

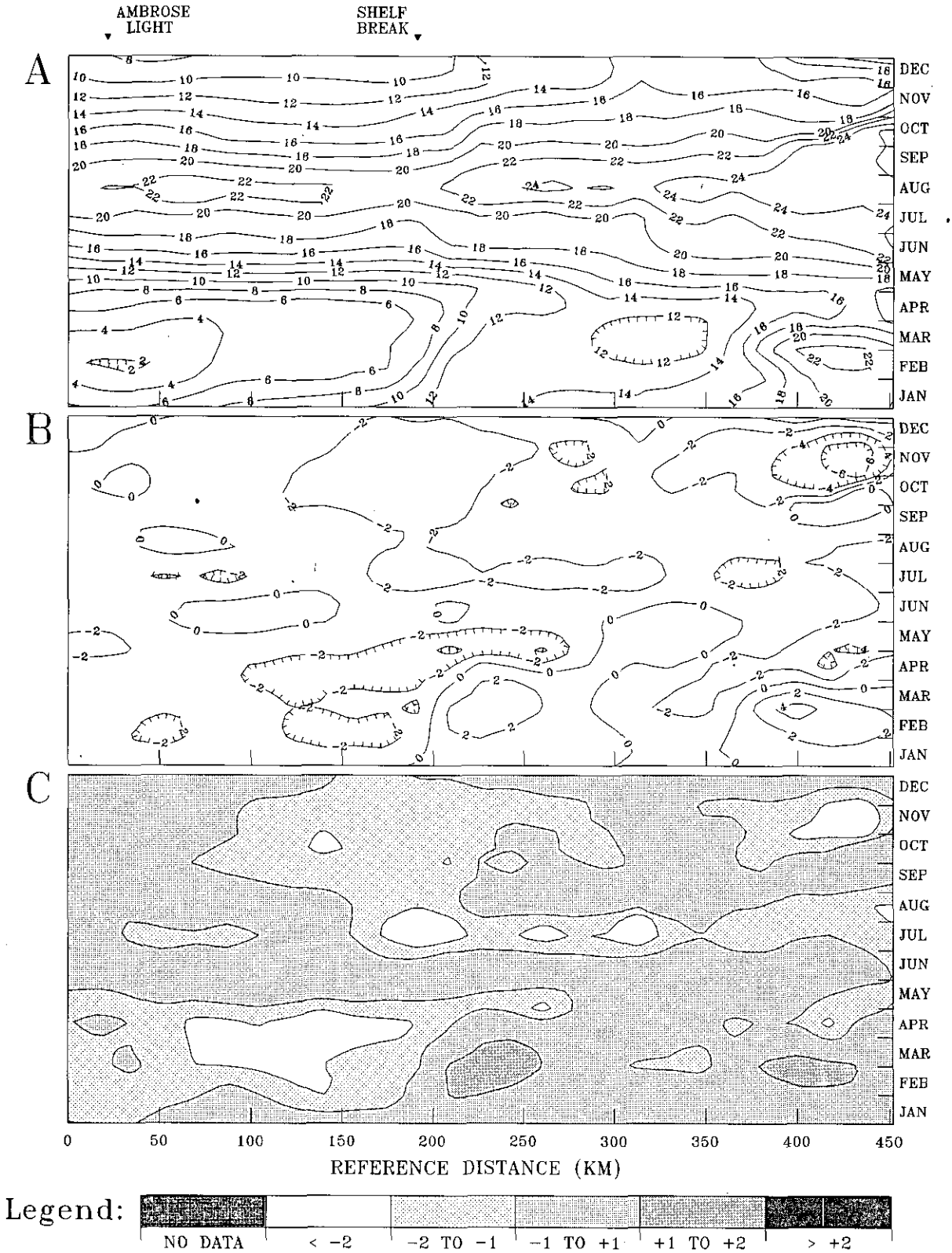

Figure 2. Surface temperature conditions along the Middle Atlantic Bight transect during 1996. A. Measured values (degrees centigrade) in time and space. B. Anomalies in time and space based on 1978 through 1992 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1992 means and variances; scale given in legend. In panels A and B values decline on those sides of contour lines with hachures.

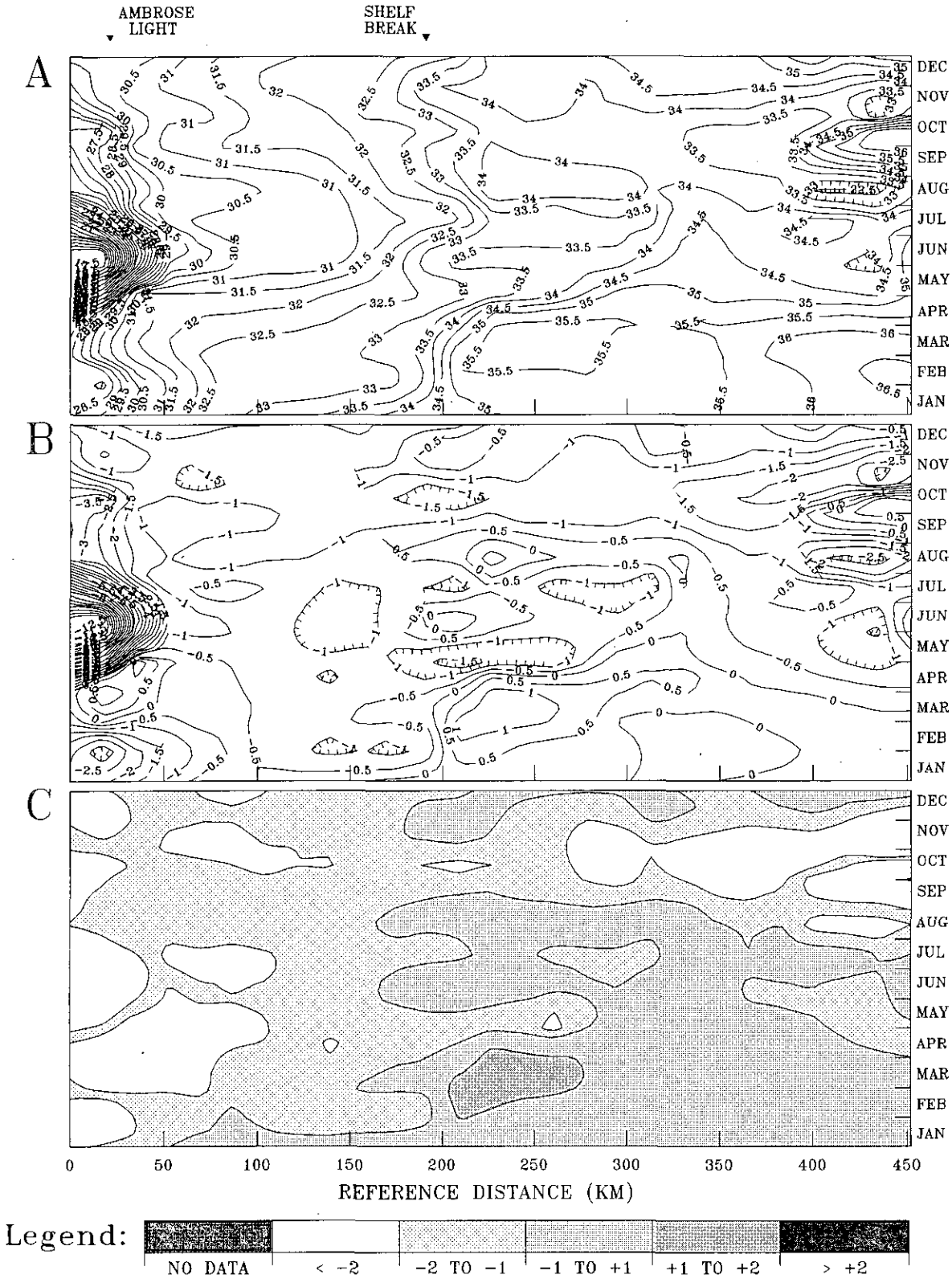

Figure 3. Surface salinity conditions along the Middle Atlantic Bight transect during 1996. A. Measured values (practical salinity units) in time and space. B. Anomalies in time and space based on 1978 through 1992 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1992 means and variances; scale given in legend. In panels A and B values decline on those sides of contour lines with hachures.

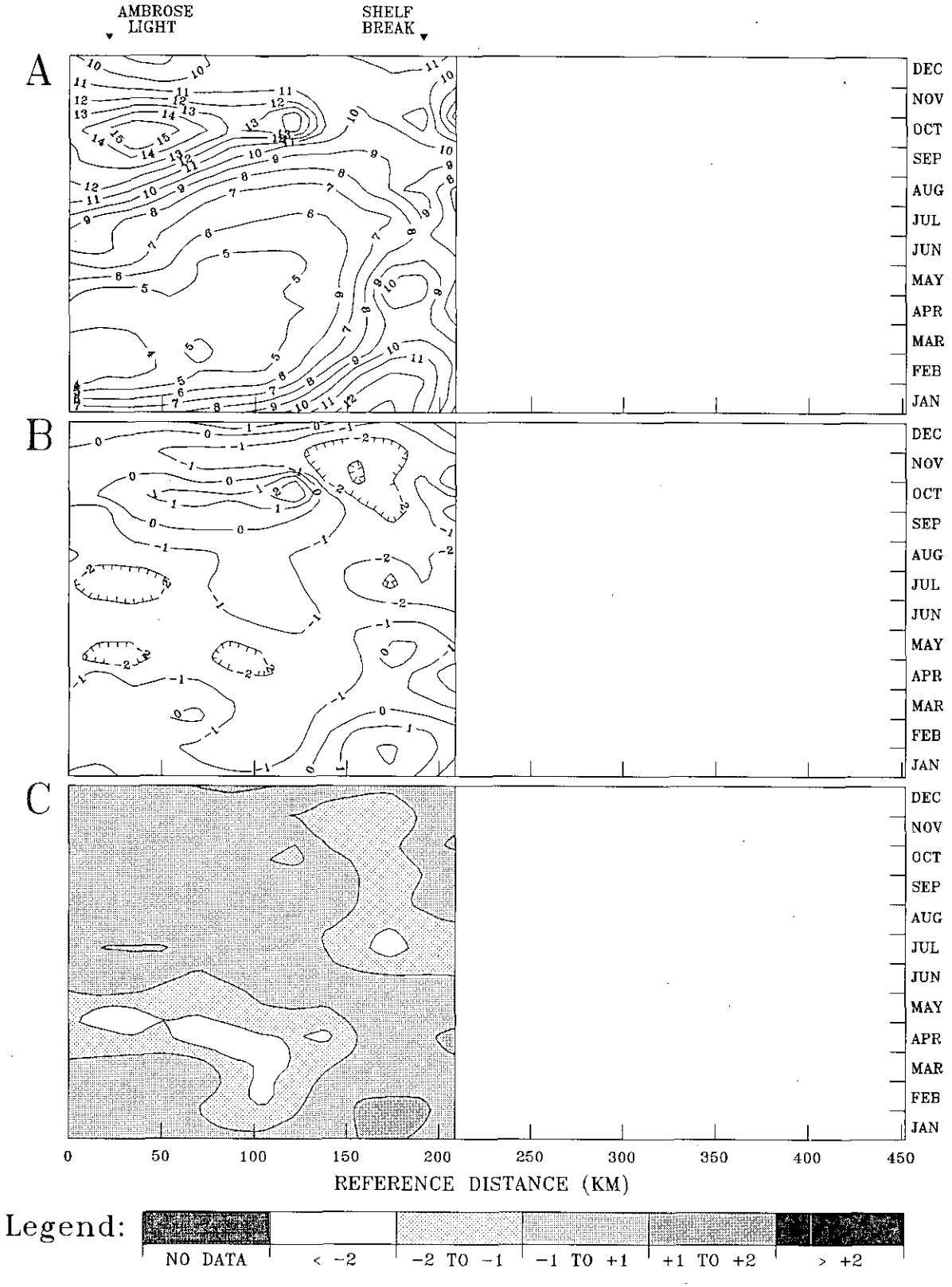

Figure 4. Bottom temperature conditions along the Middle Atlantic Bight transect during 1996. A. Measured values (degrees centigrade) in time and space. B. Anomalies in time and space based on 1978 through 1992 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1992 means and variances; scale given in legend. In panels A and B values decline on those sides of contour lines with hachures.

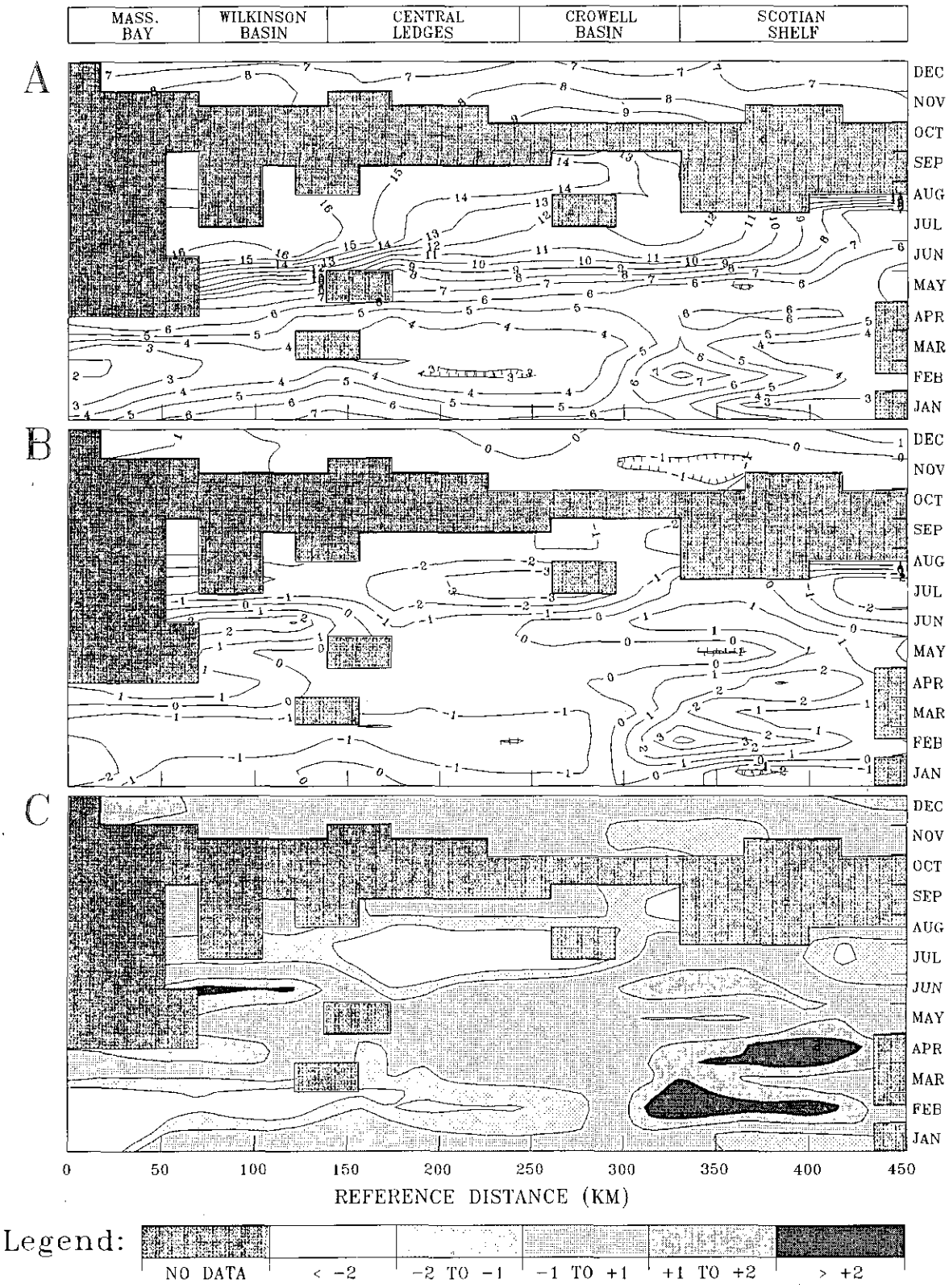

Figure 5. Surface temperature conditions along the Gulf of Maine transect during 1996. A. Measured values (degrees centigrade) in time and space. B. Anomalies in time and space based on 1978 through 1992 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1992 means and variances; scale given in legend. In panels A and B values decline on those sides of contour lines with hachures.

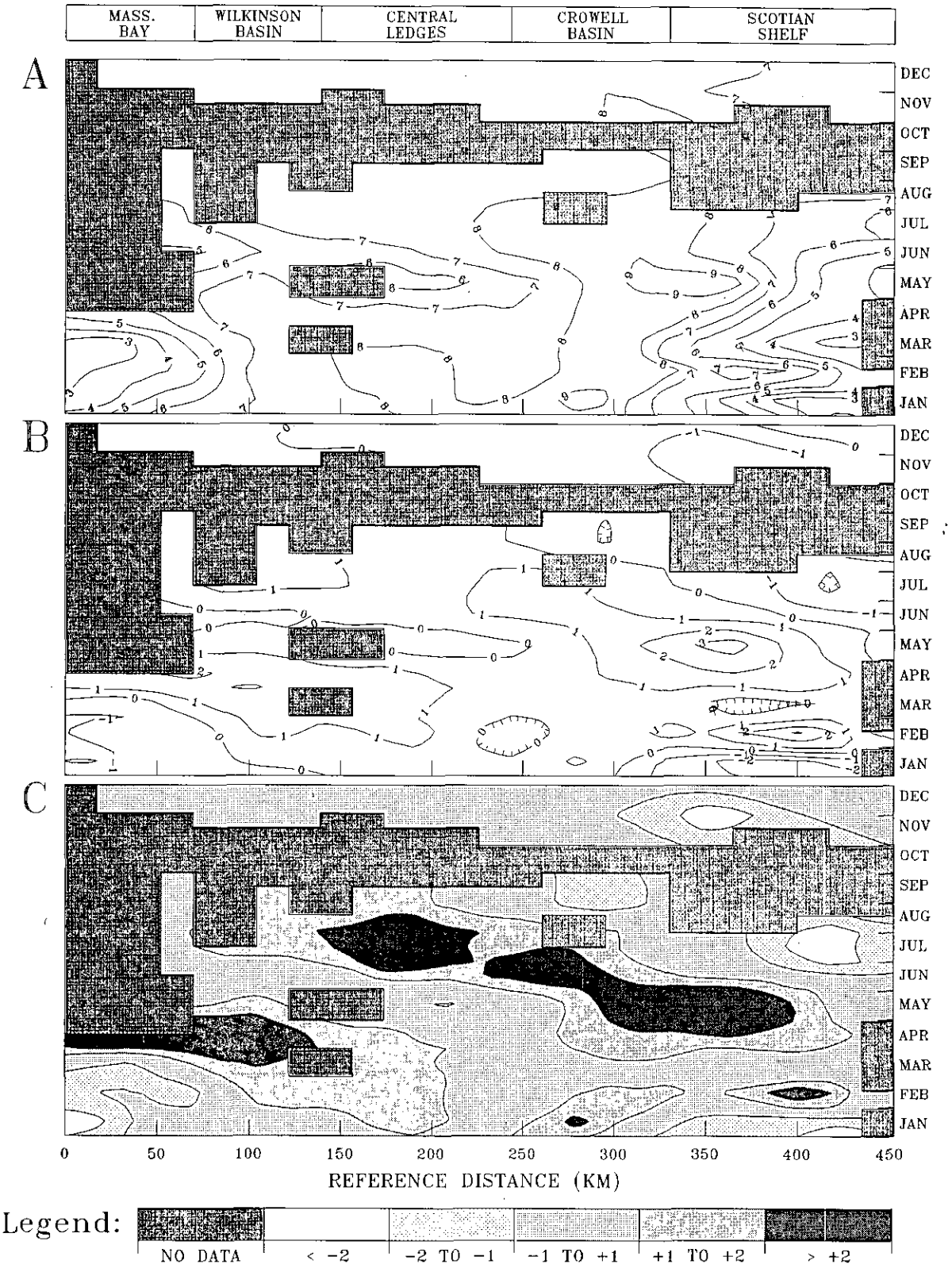

Figure 6. Bottom temperature conditions along the Gulf of Maine transect during 1996. A. Measured values (degrees centigrade) in time and space. B. Anomalies in time and space based on 1978 through 1992 means. C. Standardized anomalies (standard deviations) in time and space based on 1978 through 1992 means and variances; scale given in legend. In panels A and B values decline on those sides of contour lines with hachures.

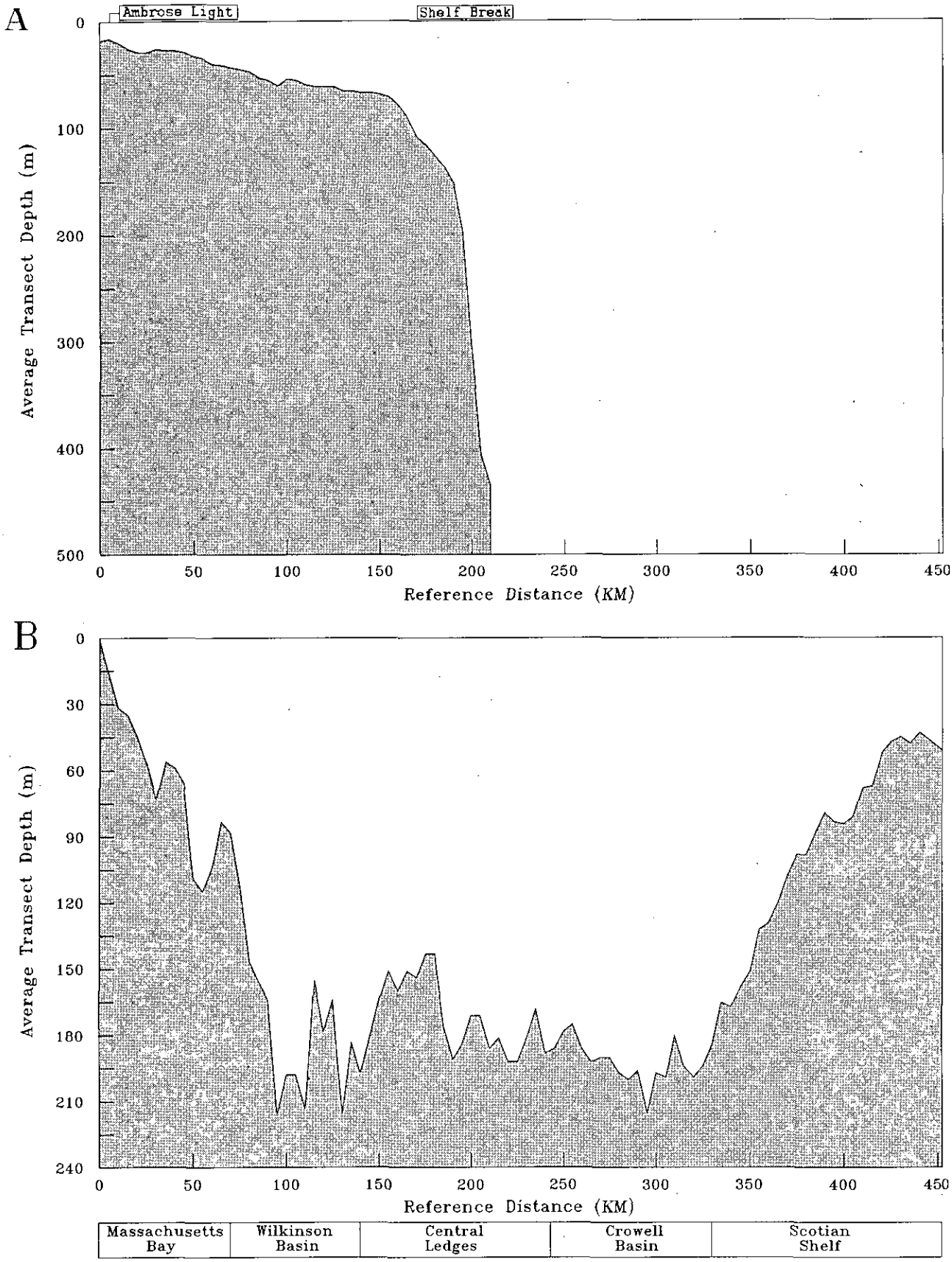

Figure 7. Mean bottom depth along the transects based on monitoring survey data, 1978 through 1992. A. Middle Atlantic Bight. B. Gulf of Maine.