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Variability of Temperature and Salinity in the Middle Atlantic Bight and Gulf of Maine

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U.S. Department of Commerce

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U.S. DEPARTMENT OF COMMERCE
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John A. Knauss, Under Secretary for Oceans and Atmosphere
National Marine Fisheries Service
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Variability of Temperature and Salinity in the Middle Atlantic Bight and Gulf of Maine†

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ABSTRACT

Monitoring of the waters of the Middle Atlantic Bight and Gulf of Maine has been conducted by the MARMAP Ships of Opportunity Program since the early 1970's. Presented in this atlas are portrayals of the temporal and spatial patterns of surface and bottom temperature and surface salinity for these areas during the period 1978–1990. These patterns are shown in the form of time-space diagrams for single-year and multi-year (base period) time frames. Each base period figure shows thirteen-year (1978–1990) mean conditions, sample variance in the form of standard deviations of the measured values, and data locations. Each single-year figure displays annual conditions, sampling locations, and departures of annual conditions from the thirteen-year means, expressed as algebraic anomalies and standardized anomalies.

Introduction

There has been a growing scientific concern about the influence of climatic change on marine ecosystems. Oceanic factors, such as water temperature and salinity, have been shown to be of prime importance to resident and transient biota, because of direct and indirect environmental influences upon physiological processes such as metabolic rates and reproductive cycles (Colton and Stoddard 1973). Furthermore, it has been suggested that a doubling of atmospheric CO_2 (Bolin et al. 1986) will occur sometime in the next century, possibly resulting in an equilibrium global surface air temperature rise of 3° C. Such a rise is expected to be non-uniform, with the greatest effects in higher latitudes, and with considerable regional differences. Such change will have important effects on the marine biota at scales ranging from individual organisms to whole ecosystems (Frank et al. 1988). The Northwest Atlantic has been suggested as an area where the effects of major climatological change may become significant owing to its proximity to the boundary of the subpolar and subtropical gyres, the fluctuations in major ocean currents, and high fish productivity. The need for time-series of fishery-relevant environmental data are critical to the retrospective analyses that are being applied to these problems (GLOBEC 1989, 1991a, 1991b; Meise-Munns et al. 1990).

The hydrographic properties of the Middle Atlantic Bight and Gulf of Maine are a complex array of important transient phenomena (Bowman and Wunderlich 1977). Seasonal cycles of water temperature and salinity in these two geographic regions are

†MARMAP Atlas Monograph No.4

strongly affected by patterns of insolation, river discharge, evaporation, winds, and currents. Seasonal cycles of temperature and salinity are modified further by intrusions of slope water and Gulf Stream rings. Because of seasonal and interannual environmental variability, it is clear that long-term, systematic measurements of oceanographic conditions are essential to the detection and prediction of climatic changes and their influence on living marine resources.

The British have been conducting, since 1961, monthly monitoring of 10-m depth plankton by 1) using merchant ships along the Scotian Shelf and across the Gulf of Maine, and 2) using U.S. Coast Guard cutters traveling to and from the North Atlantic Ocean Stations *Bravo* and *Delta* (Glover 1967). The National Marine Fisheries Service (NMFS), beginning in the late 1960's, established several interagency and international agreements that either started such monitoring, or supported the continuation of already existing ocean monitoring programs. Fostered by the global expedition of the United States Coastal and Geodetic Survey ship *Oceanographer* in 1967, a meeting was held in Plymouth, England that led to a NMFS/United Kingdom cooperative agreement for extension of the Continuous Plankton Recorder (CPR) survey into additional areas of the western North Atlantic. In mid-1970, another cooperative agreement was developed between the NMFS and the U.S. Maritime Administration to collect surface water samples and deploy expendable bathythermographs (XBT's) from merchant ships operating along the East and Gulf coasts of the United States. In 1972 a NMFS/U.S. Coast Guard agreement was established to add neuston sampling and new CPR routes to their operations on standard Coast Guard cruises, and to bring all the ships of opportunity activities under the direction of the NMFS Marine Resources Monitoring, Assessment, and Prediction (MARMAP) Program (Sherman 1980). As the program developed, routes were chosen across areas of interest to fisheries research, where regular water column and plankton sampling could be expected. The goal was to obtain no less than one transect per month in the transect area (Fig. 1). The program has been known by several names over the years, but now is called the MARMAP Ships of Opportunity Program (SOOP). Reports on the collections from this program have been prepared by Cook (1979a, 1979b, 1984, and 1985); Cook and Hughes (1980); Hughes and Cook (1981a, 1981b, and 1982); Benway (1985, 1986, 1987, 1988, 1989, and 1992); and Jossi and Benway (1985, 1988, 1990, and 1991). MARMAP atlas series 1,2, and 3 were published between 1984 and 1989 by Sibunka 1984, Morse et al. 1987, and Sibunka 1989.

Surface temperature and salinity, and bottom temperature conditions along two routes are presented here for the years 1978 through 1990. The two routes are (1) New York towards Bermuda and (2) Massachusetts to Cape Sable, Nova Scotia. Portrayals in time and space are presented of 1) long-term sampling coverage, 2) long-term means and variances, 3) single-year conditions, 4) single-year anomalies, and 5) single-year standardized anomalies.

Methods

The track lines of the ships of opportunity varied by monthly excursions. For consistency between sampling efforts, route polygons were developed for analysis and portrayal of the data collected. These polygons (Fig. 1, A and B) were established based on composites of all sampling locations, such that oceanographic features were assumed to vary along the long axes of the polygons, but to vary insignificantly normal to the long axes. Only data collected within the polygons were included in analyses. Standard reference positions were chosen for each route from which the radial distance to each sample location was calculated. These positions were located at such distances beyond the narrow ends of the polygons so that arcs passing through the sample location had little curvature (see Figure 1). The calculation also produced a reference distance which was positive from North America seaward.

The Middle Atlantic Bight sampling (Fig. 1A) originated at Ambrose Tower (40° 27.5'N, 73° 49.6'W) and extended offshore approximately 500 kilometers towards Bermuda. This was termed MARMAP Route MB, and the corners of this polygon were defined by the following geographic positions: 40°34'N, 74°00'W; 40°20'N, 74°00'W; 38°30'N, 69°00'W; and 36°44'N, 70°30'W. Sampling generally concluded within the Gulf Stream. Because of the Gulf Stream's varying position, not all sampling transects traversed the entire polygon length. A transect along this route typically passed through shelf, slope, and Gulf Stream water masses, and often crossed a portion of Deep Water Dumpsite 106. The major hydrographic features of this region were summarized by Ingham (1982).

The Gulf of Maine sampling extended from Boston, Massachusetts, to Cape Sable, Nova Scotia (Fig. 1B), for a distance of approximately 452 km. This is termed MARMAP Route MC, and the corners of this polygon were defined by these geographic positions: 43°30'N, 71°00'W; 43°30'N, 65°37'W; 43°00'N, 65°37'W; 42°00'N, 71°00'W. This polygon included the following geographic regions of the Gulf of

Maine: Massachusetts Bay, Wilkinson Basin, the Central Gulf Ledges, southern Jordan Basin, Crowell Basin, and the western Scotian Shelf.

Data Collection

The regimen at every station included the following: deployment of an XBT probe, and concurrent collection of a sea surface bucket sample for temperature calibration and salinity determination. In both polygons, XBT's were used to measure water column temperatures down to a maximum depth of 500 m (Table 1). Stations were positioned on the basis of time intervals rather than actual geographical locations. Sampling was taken hourly in the Middle Atlantic Bight and every two hours in the Gulf of Maine on average. Prior to 1981, all data were collected utilizing Sippican analog recorders, and traces were digitized. Thereafter, data were recorded digitally on magnetic tape or disk.

Ship position, time of XBT deployment, and water column depth (taken from a depth chart or fathometer) also were recorded in the computer and on a MARMAP log sheet. Full details on the MARMAP Ships of Opportunity Program (SOOP) operational procedures and theory are in preparation and are available from the authors.

Temporal Scales of the Survey

Monitoring of water temperature and salinity in the Middle Atlantic Bight and Gulf of Maine began in mid-year 1970. However, data collected before 1978 were too incomplete for portrayal in this atlas. In the Middle Atlantic Bight (see Table 2), one or two sampling cruises were conducted per month, generally during the first or second week of each month. Beginning in April 1990, approximately four sampling cruises were performed per month, generally one cruise per week (Figs. 2–4). By comparison, one sampling cruise per month was carried out across the Gulf of Maine (see Table 3), typically during the first week of each month (Figs. 5–7). During 1986, no XBT's were deployed in the Gulf of Maine, so no bottom temperature data were collected. Surface temperature and salinity were measured in 1986.

Table 1

Equations for calculating depth during an expendable bathythermograph deployment (Sippican Corporation 1970).

Probe type	Depth range (m)	Equation[a]
T-4	0–460	$D = [(6.472) * (T - 0.00216) * (T^2)]$
T-6	0–460	$D = [(6.472) * (T - 0.00216) * (T^2)]$
T-7	0–760	$D = [(6.472) * (T - 0.00216) * (T^2)]$
T-10	0–200	$D = [(6.301) * (T - 0.00216) * (T^2)]$

[a] D is the depth of the voltage reading and T is the time of descent.

Spatial Scales of the Survey

In the Middle Atlantic Bight, a typical transect began with the first station at Ambrose Tower (40° 27.5'N, 73° 49.6'W; distance from reference point = 17 km), (Fig. 1A). Generally, additional stations occurred about every hour (every 25–35 km, depending on vessel speed) until the North Wall of the Gulf Stream was reached. Stations were spaced at fifteen minute intervals (7 km) near the continental shelf break. The first station, from Bermuda to New Jersey, was at the Gulf Stream North Wall and sampling proceeded at the same time intervals until Ambrose Tower (Figs. 2–4). Surface water samples and water column temperature profiles were collected at each station (every 7–35 km, or 15–60 minutes depending on vessel speed).

In the Gulf of Maine, sampling was initiated from either end of the Route MC polygon (Fig. 1B). Surface water samples were collected every hour (every 20–30 km depending on vessel speed), and water column temperature profiles were obtained no less than every other hour (Figs. 5–7).

Data Processing

The depth of each XBT voltage reading was derived as a function of time alone, using XBT descent equations shown in Table 1.

XBT voltage readings were converted to temperatures in several steps. First, a SA-810 XBT Controller transmitted hexadecimal voltage values (representing XBT thermistor measurements) to a shipboard HP-85 or IBM personal computer. The voltage measurements, which ranged from 0 to 10 volts, were digitized with 12-bit (4096) resolution, resulting in a range of hexadecimal values from 000 to FFF. Secondly, the XBT program in the HP-85 or IBM PC converted those hexadecimal voltage equivalents to resistance, and then into temperature (degrees Celsius) in the following manner:

Table 2
List of all MARMAP Ships of Opportunity Program (SOOP) cruises through the Route MB polygon during the period 1978–1990. An "X" indicates collection of a particular data type (XBT = expendable bathythermograph drop; SST = sea surface temperature (bucket) sample; SSS = sea surface salinity (bucket) sample.

Cruise	Date	XBT	SST	SSS
1978				
TA7801	1 Jan 1978	X	X	X
AS7801	12 Jan 1978	X	X	X
MR7802	12 Feb 1978	X	X	X
TA7802	16 Feb 1978	X	X	—
MR7803	22 Mar 1978	—	X	X
TA7803	23 Mar 1978	X	X	X
PJ7803	28 Mar 1978	X	X	X
TA7805	10 May 1978	X	X	X
MR7805	1 Jun 1978	X	X	X
TA7806	8 Jun 1978	X	X	X
MR7807	15 Jul 1978	X	X	X
GL7807	27 Jul 1978	X	X	—
MA7807	29 Jul 1978	X	X	X
MA7808	31 Aug 1978	—	X	X
MR7809	23 Sep 1978	X	X	X
TA7811	7 Nov 1978	X	X	X
GL7812	17 Dec 1978	X	X	—
1979				
TA7901	30 Jan 1979	X	X	—
MA7901	25 Feb 1979	X	X	X
MA7902	23 Mar 1979	X	X	X
MR7902	5 May 1979	X	X	X
WH7901	8 May 1979	X	X	X
MA7904	28 May 1979	X	X	X
MR7903	7 Jun 1979	X	X	X
MR7904	16 Jun 1979	X	X	X
TA7904	18 Jul 1979	X	X	X
MR7905	22 Jul 1979	X	X	X
TA7905	23 Aug 1979	X	X	X
MR7906	23 Sep 1979	X	X	X
MR7907	4 Oct 1979	X	X	X
VG7901	5 Oct 1979	X	X	X
MA7908	3 Nov 1979	X	X	X
MR7909	1 Dec 1979	X	X	—
MA7910	14 Dec 1979	X	X	X
1980				
MA8001	22 Jan 1980	X	X	—
MR8001	3 Feb 1980	X	X	X
GL8003	9 Mar 1980	X	X	X
MR8003	6 Apr 1980	X	X	X
GL8004	7 Apr 1980	X	X	X
MA8005	2 May 1980	X	X	—
KE8002	16 May 1980	X	X	X
MR8004	17 May 1980	X	X	X
MA8006	2 Jun 1980	X	X	X
1980				
MA8007	12 Jun 1980	X	X	X
MA8008	1 Jul 1980	X	X	X
KE8028	9 Aug 1980	—	X	X
1980				
MR8005	16 Aug 1980	X	X	—
2TA8002	16 Sep 1980	X	X	X
MR8006	11 Oct 1980	X	X	X
TA8003	11 Oct 1980	X	X	X
TA8004	2 Dec 1980	X	X	X
1981				
OL8101	27 Mar 1981	—	X	X
OL8102	10 Apr 1981	X	X	X
OL8103	15 Apr 1981	X	X	X
OL8104	9 May 1981	X	X	X
OL8105	5 Jun 1981	X	X	X
OL8106	10 Jun 1981	X	X	X
OL8107	10 Jul 1981	X	X	X
OL8108	15 Jul 1981	X	X	X
OL8109	14 Aug 1981	X	X	X
OL8110	19 Aug 1981	X	X	X
OL8111	18 Sep 1981	X	X	X
OL8112	23 Sep 1981	X	X	X
OL8113	16 Oct 1981	X	X	X
OL8114	21 Oct 1981	—	X	X
OL8116	13 Nov 1981	X	X	X
OL8117	19 Nov 1981	X	X	X
OL8118	12 Dec 1981	X	X	X
OL8119	17 Dec 1981	X	X	X
1982				
OL8201	15 Jan 1982	X	X	X
OL8202	20 Jan 1982	X	X	X
OL8203	19 Feb 1982	X	X	X
OL8204	24 Feb 1982	X	X	X
OL8205	12 Mar 1982	X	X	X
OL8206	17 Mar 1982	X	X	X
OL8207	17 Apr 1982	X	X	X
OL8208	21 Apr 1982	X	X	X
OL8209	14 May 1982	X	X	X
OL8210	19 May 1982	X	X	X
OL8211	11 Jun 1982	X	X	X
OL8212	16 Jun 1982	X	X	X
OL8213	16 Jul 1982	X	X	X
OL8214	21 Jul 1982	X	X	X
OL8216	13 Aug 1982	X	X	X
OL8217	18 Aug 1982	X	X	X
OL8218	11 Sep 1982	X	X	X
OL8219	16 Sep 1982	X	X	X
OL8220	15 Oct 1982	X	X	X
OL8221	20 Oct 1982	X	X	X
OL8222	12 Nov 1982	X	X	X
OL8223	17 Nov 1982	X	X	X
OL8224	10 Dec 1982	X	X	X
OL8225	16 Dec 1982	X	X	X
1983				
OL8301	15 Jan 1983	X	X	X
OL8302	28 Jan 1983	X	X	X
OL8303	2 Feb 1983	X	X	X
OL8304	18 Feb 1983	X	X	—
OL8305	11 Mar 1983	X	X	X
OL8306	16 Mar 1983	X	X	X

Table 2 (continued)

Cruise	Date	XBT	SST	SSS
OL8307	16 Apr 1983	X	X	X
OL8308	14 May 1983	X	X	X
OL8309	20 May 1983	X	X	X
OL8310	10 Jun 1983	X	X	X
OL8311	15 Jun 1983	X	X	X
OL8312	29 Jun 1983	—	X	X
OL8313	8 Jul 1983	X	X	X
OL8314	5 Aug 1983	X	X	X
OL8315	10 Aug 1983	X	X	X
OL8316	23 Sep 1983	X	X	X
OL8317	14 Oct 1983	X	X	X
OL8318	19 Oct 1983	X	X	X
OL8319	18 Nov 1983	X	X	X
OL8320	22 Nov 1983	X	X	X
OL8321	2 Dec 1983	X	X	X
OL8322	7 Dec 1983	X	X	X
1984				
OL8401	6 Jan 1984	X	X	X
OL8402	12 Jan 1984	X	X	X
OL8403	3 Feb 1984	X	X	X
OL8404	8 Feb 1984	X	X	X
OL8405	2 Mar 1984	X	X	X
OL8406	7 Mar 1984	X	X	X
OL8407	6 Apr 1984	X	X	X
OL8408	11 Apr 1984	X	X	X
OL8409	11 May 1984	X	X	X
OL8410	17 May 1984	X	X	X
OL8411	8 Jun 1984	X	X	X
OL8412	13 Jun 1984	X	X	X
OL8413	7 Jul 1984	X	X	X
OL8414	11 Jul 1984	X	X	X
OL8415	10 Aug 1984	X	X	X
OL8416	15 Aug 1984	X	X	X
OL8417	7 Sep 1984	X	X	X
OL8418	12 Sep 1984	X	X	X
OL8419	21 Oct 1984	X	X	X
OL8420	25 Oct 1984	X	X	X
OL8421	2 Nov 1984	X	X	X
OL8422	9 Nov 1984	X	X	X
OL8423	7 Dec 1984	X	X	X
OL8424	11 Dec 1984	X	X	X
1985				
OL8501	26 Jan 1985	X	X	X
OL8502	30 Jan 1985	X	X	X
OL8503	15 Feb 1985	X	X	X
OL8504	20 Feb 1985	X	X	X
OL8505	23 Mar 1985	X	X	X
OL8506	26 Apr 1985	X	X	X
OL8507	1 May 1985	X	X	X
OL8508	17 May 1985	X	X	X
OL8509	7 Jun 1985	X	X	X
OL8510	21 Jun 1985	X	X	X
OL8511	12 Jul 1985	X	X	X
OL8512	9 Aug 1985	X	X	X
OL8513	14 Aug 1985	X	X	X
OL8514	6 Sep 1985	X	X	X
OL8515	11 Sep 1985	X	X	X
OL8516	20 Sep 1985	X	X	X
OL8518	16 Oct 1985	X	X	X
OL8519	8 Nov 1985	X	X	X
OL8520	14 Nov 1985	X	X	X
OL8521	7 Dec 1985	—	X	X
1986				
OL8601	10 Jan 1986	X	X	X
OL8602	7 Feb 1986	X	X	X
OL8603	7 Mar 1986	X	X	X
OL8604	21 Mar 1986	—	X	X
OL8605	4 Apr 1986	X	X	X
OL8606	2 May 1986	X	X	X
OL8607	6 Jun 1986	X	X	X
OL8608	4 Jul 1986	X	X	X
OL8609	8 Aug 1986	X	X	X
OL8610	19 Sep 1986	X	X	X
OL8611	10 Oct 1986	X	X	X
OL8612	15 Oct 1986	X	X	X
OL8613	7 Nov 1986	X	X	X
OL8614	12 Nov 1986	X	X	X
OL8615	5 Dec 1986	—	X	X
OL8616	10 Dec 1986	X	X	X
1987				
OL8701	9 Jan 1987	X	X	X
OL8702	6 Feb 1987	X	X	X
OL8703	6 Mar 1987	X	X	X
OL8704	10 Apr 1987	X	X	X
OL8705	8 May 1987	X	X	X
OL8706	13 May 1987	X	X	X
OL8707	5 Jun 1987	X	X	X
OL8708	9 Jul 1987	X	X	X
OL8709	15 Jul 1987	X	X	X
OL8710	25 Jul 1987	—	X	X
OL8711	19 Aug 1987	X	X	X
1987				
OL8712	4 Sep 1987	X	X	X
OL8713	2 Oct 1987	X	X	X
OL8714	23 Oct 1987	X	X	X
OL8715	28 Oct 1987	X	X	X
OL8716	13 Nov 1987	X	X	X
OL8717	5 Dec 1987	X	X	X
OL8718	9 Dec 1987	X	X	X
1988				
OL8801	8 Jan 1988	X	X	X
OL8802	5 Feb 1988	X	X	X
OL8803	18 Mar 1988	X	X	X
OL8804	8 Apr 1988	X	X	X
OL8805	13 Apr 1988	X	X	X
OL8806	6 May 1988	X	X	X
OL8807	10 Jun 1988	X	X	X
OL8809	8 Jul 1988	X	X	X
OL8810	19 Aug 1988	X	X	X
OL8811	24 Aug 1988	—	X	X
OL8812	9 Sep 1988	X	X	X
OL8813	14 Oct 1988	X	X	X
OL8814	19 Oct 1988	X	X	X

Table 2 (continued)

Cruise	Date	XBT	SST	SSS
OL8815	4 Nov 1988	X	X	X
OL8816	2 Dec 1988	X	X	X
1989				
OL8901	7 Jan 1989	X	X	X
OL8902	3 Feb 1989	X	X	X
OL8903	3 Mar 1989	X	X	X
OL8904	7 Apr 1989	X	X	X
OL8905	13 Apr 1989	X	X	X
OL8906	13 May 1989	X	X	X
OL8907	9 Jun 1989	X	X	X
OL8908	7 Jul 1989	X	X	X
OL8909	4 Aug 1989	X	X	X
OL8910	1 Sep 1989	X	X	X
OL8911	29 Sep 1989	X	X	X
OL8912	11 Oct 1989	X	X	X
OL8913	10 Nov 1989	X	X	X
OL8914	15 Dec 1989	X	X	X
1990				
OL9001	5 Jan 1990	X	X	X
OL9002	2 Feb 1990	X	X	X
OL9003	2 Mar 1990	X	X	X
OL9004	6 Apr 1990	X	X	X
OL9005	20 Apr 1990	X	X	X
OL9006	25 Apr 1990	X	X	X
OL9007	4 May 1990	X	X	X
OL9008	9 May 1990	X	X	X
OL9009	30 May 1990	X	X	X
OL9010	8 Jun 1990	X	X	X
1990				
OL9011	13 Jun 1990	X	X	X
OL9012	22 Jun 1990	X	X	X
OL9013	27 Jun 1990	X	X	X
OL9014	6 Jul 1990	X	X	X
OL9015	11 Jul 1990	X	X	X
OL9016	20 Jul 1990	X	X	X
OL9017	25 Jul 1990	X	X	X
OL9018	3 Aug 1990	—	X	X
OL9019	8 Aug 1990	X	X	X
OL9020	17 Aug 1990	X	X	X
OL9021	22 Aug 1990	X	X	X
OL9022	14 Sep 1990	X	X	X
OL9023	19 Sep 1990	X	X	X
OL9024	5 Oct 1990	X	X	X
OL9025	10 Oct 1990	X	X	X
OL9026	26 Oct 1990	X	X	X
OL9027	31 Oct 1990	X	X	X
OL9028	9 Nov 1990	X	X	X
OL9029	15 Nov 1990	X	X	X
OL9030	23 Nov 1990	X	X	X
OL9031	28 Nov 1990	X	X	X
OL9032	7 Dec 1990	—	X	X
OL9033	13 Dec 1990	X	X	X

Table 3

List of all MARMAP SOOP cruises through the Route MC polygon during the period 1978–1990. An "X" indicates collection of a particular data type (XBT = expendable bathythermograph drop; SST = sea surface temperature (bucket) sample; SSS = sea surface salinity (bucket) sample.

Cruise	Date	XBT	SST	SSS
1978				
CU7803	12 Mar 1978	X	X	X
CU7804	13 Apr 1978	X	X	X
CU7805	7 May 1978	X	X	X
CU7855	22 May 1978	X	X	X
CU7806	2 Jun 1978	X	X	X
CU7807	23 Jul 1978	X	X	X
CU7808	16 Aug 1978	—	X	X
CU7888	18 Aug 1978	X	X	—
CU7809	30 Sep 1978	X	X	X
CU7810	11 Oct 1978	X	X	X
CU7811	10 Nov 1978	X	X	X
1979				
DE7901	23 Jan 1979	X	X	X
AC7901	1 Mar 1979	X	X	X
AC7902	1 Apr 1979	X	X	X
CU7901	3 May 1979	—	X	—
CU7902	3 Jun 1979	X	X	—
CU7903	2 Jul 1979	—	X	X
CU7904	3 Aug 1979	X	X	X
CU7905	17 Aug 1979	X	X	X
CU7906	16 Sep 1979	X	X	X
CU7907	31 Oct 1979	X	X	X
CU7908	21 Nov 1979	X	X	X
CU7909	23 Dec 1979	—	X	X
1980				
CU8001	1 Jan 1980	X	X	X
DE8001	9 Feb 1980	X	X	X
CU8002	20 Mar 1980	X	X	X
CU8004	4 Apr 1980	X	X	X
CU8005	5 May 1980	X	X	X
CU8006	4 Jun 1980	—	X	X
CU8008	21 Jul 1980	X	X	X
CU8009	20 Aug 1980	X	X	X
CU8010	2 Sep 1980	X	X	X
CU8011	20 Oct 1980	X	X	X

Table 3 (continued)

Cruise	Date	XBT	SST	SSS
CU8013	11 Nov 1980	X	X	—
CU8014	13 Nov 1980	X	X	X
CU8015	14 Dec 1980	X	X	X
1981				
CU8103	24 Feb 1981	X	X	X
CU8104	9 Mar 1981	X	X	X
CU8105	22 Mar 1981	X	X	X
CU8106	8 Apr 1981	X	X	X
CU8107	30 May 1981	X	X	X
CU8108	10 Jun 1981	X	X	X
1981				
CU8109	22 Jul 1981	X	X	X
CU8110	5 Aug 1981	X	X	X
CU8111	22 Aug 1981	X	X	X
CU8112	6 Sep 1981	X	X	X
AC8103	11 Nov 1981	—	X	X
1982				
DW8201	26 Mar 1982	X	X	X
DE8201	25 Apr 1982	X	X	X
YC8202	21 May 1982	X	X	X
YC8203	11 Jun 1982	X	X	X
YC8206	16 Jul 1982	X	X	X
YC8207	13 Aug 1982	X	X	X
YC8209	10 Sep 1982	X	X	X
YC8210	19 Oct 1982	X	X	X
YC8211	13 Nov 1982	X	X	—
YC8212	20 Nov 1982	X	X	X
YC8213	11 Dec 1982	X	X	X
1983				
YC8301	7 Jan 1983	—	X	X
YC8302	15 Jan 1983	—	X	—
YC8303	29 Jan 1983	X	X	X
YC8304	19 Feb 1983	X	X	X
YC8305	4 Mar 1983	X	X	X
YC8306	15 Mar 1983	X	X	X
YC8307	5 Apr 1983	X	X	X
YC8308	12 Apr 1983	X	X	X
YC8309	6 May 1983	—	X	X
YC8310	9 May 1983	X	X	X
YC8311	13 May 1983	—	—	X
YC8312	25 May 1983	X	X	X
YC8313	11 Jun 1983	X	X	X
YC8314	20 Jun 1983	X	X	X
YC8315	8 Jul 1983	X	X	X
YC8316	23 Jul 1983	X	X	X
YC8317	3 Aug 1983	X	X	X
YC8318	20 Aug 1983	X	X	X
YC8319	9 Sep 1983	X	X	X
YC8320	8 Oct 1983	X	X	X
YC8321	15 Oct 1983	X	X	X
YC8322	26 Oct 1983	X	X	X
YC8323	7 Nov 1983	—	—	X
YC8324	24 Nov 1983	X	X	X
YC8325	9 Dec 1983	X	X	X
YC8326	17 Dec 1983	X	X	X

Cruise	Date	XBT	SST	SSS
1984				
YC8401	7 Jan 1984	X	X	X
YC8402	12 Feb 1984	X	X	X
YC8403	26 Feb 1984	X	X	X
YC8404	10 Mar 1984	X	X	X
1984				
YC8406	21 Mar 1984	X	X	X
YC8407	7 Apr 1984	X	X	X
YC8408	21 Apr 1984	X	X	X
YC8409	16 May 1984	X	X	X
YC8410	19 May 1984	X	X	X
YC8411	9 Jun 1984	X	X	X
YC8412	14 Jul 1984	X	X	X
YC8413	3 Aug 1984	X	X	X
YC8417	21 Sep 1984	X	X	X
YC8418	12 Oct 1984	X	X	X
YC8419	3 Nov 1984	X	X	X
YC8420	8 Dec 1984	—	X	X
YC8421	15 Dec 1984	X	X	X
1985				
YC8501	5 Jan 1985	—	X	—
YC8502	19 Jan 1985	X	X	X
YC8503	2 Feb 1985	X	X	X
YC8505	12 Mar 1985	X	X	X
YC8506	16 Mar 1985	X	X	X
YC8507	9 Apr 1985	X	X	X
YC8508	11 May 1985	X	X	X
YC8510	7 Jun 1985	X	X	X
YC8512	19 Jul 1985	X	X	X
YC8513	13 Aug 1985	X	X	X
YC8514	7 Sep 1985	X	X	X
YC8515	5 Oct 1985	X	X	X
YC8516	2 Nov 1985	X	X	—
YC8518	17 Dec 1985	X	X	X
1986				
YC8601	11 Jan 1986	—	X	X
YC8602	15 Feb 1986	—	X	X
YC8603	25 Feb 1986	—	X	X
YC8604	11 Mar 1986	—	X	X
YC8605	4 Apr 1986	—	X	X
YC8606	6 May 1986	—	X	X
YC8607	6 Jun 1986	—	X	X
YC8608	9 Jul 1986	—	X	X
YC8609	8 Aug 1986	—	X	X
YC8610	12 Sep 1986	—	X	X
YC8620	13 Sep 1986	—	X	X
YC8611	18 Oct 1986	—	X	X
YC8612	8 Nov 1986	—	X	X
YC8613	13 Dec 1986	—	X	X
1987				
YC8701	10 Jan 1987	—	X	X
YC8702	21 Feb 1987	—	X	X
1987				
YC8703	14 Mar 1987	X	X	X
YC8704	11 Apr 1987	X	X	X

Table 3 (continued)

Cruise	Date	XBT	SST	SSS
YC8705	9 May 1987	X	X	X
YC8706	6 Jun 1987	X	X	X
YC8707	11 Jul 1987	X	X	X
YC8708	8 Aug 1987	X	X	X
YC8709	12 Sep 1987	X	X	X
YC8710	3 Oct 1987	X	X	X
YC8711	14 Nov 1987	X	X	X
YC8712	12 Dec 1987	X	X	X
1988				
YC8801	21 Jan 1988	X	X	X
YC8802	15 Feb 1988	X	X	X
YC8803	19 Mar 1988	X	X	X
YC8804	16 Apr 1988	X	X	X
YC8805	10 May 1988	X	X	X
YC8806	11 Jun 1988	X	X	X
YC8807	8 Jul 1988	X	X	X
YC8808	12 Aug 1988	X	X	X
YC8809	9 Sep 1988	X	X	X
YC8810	24 Oct 1988	X	X	X
YC8811	19 Nov 1988	X	X	X
YC8812	10 Dec 1988	X	X	X
1989				
YC8901	4 Jan 1989	X	X	X
YC8902	4 Feb 1989	X	X	X
YC8903	6 Mar 1989	X	X	X
YC8904	7 Apr 1989	X	X	X
YC8905	6 May 1989	X	X	X
YC8906	17 Jun 1989	X	X	X
YC8907	8 Jul 1989	X	X	X
YC8908	5 Aug 1989	X	X	X
YC8909	1 Sep 1989	X	X	X
YC8910	7 Oct 1989	X	X	X
YC8911	4 Nov 1989	X	X	X
YC8912	9 Dec 1989	X	X	X
1990				
YC9001	1 Jan 1990	X	X	X
YC9002	12 Feb 1990	X	X	X
YC9003	5 Mar 1990	X	X	X
YC9004	20 Apr 1990	X	X	X
YC9005	11 May 1990	X	X	X
YC9006	19 May 1990	—	X	X
YC9007	8 Jun 1990	X	X	X
YC9008	6 Jul 1990	X	X	X
YC9009	4 Aug 1990	X	X	X
YC9010	8 Sep 1990	X	X	X
YC9011	5 Oct 1990	X	X	X
YC9012	9 Nov 1990	X	X	X
YC9013	8 Dec 1990	X	X	X

1) Convert hexadecimal value to decimal value.
2) Convert decimal value to (V) voltage:
   $V = 10.0 * \text{Decimal value} / 4096$
3) Convert (V) voltage to (R) resistance (ohms):
   $R = (18094-1490.1) * V$
4) Convert (R) resistance to (T) temperature (°C):
   $T = -273.15 + \{1 / [A+(B*\ln R)+(C*(\ln R)^3)]\}$
   Where: $A = 1.29502 * 10^{-3}$
   $B = 2.34546 * 10^{-4}$
   $C = 9.9434 * 10^{-8}$

This logarithmic equation was first presented by Steinhart and Hart (1968). The constants for this temperature equation were determined empirically from laboratory tests of XBT thermistors (Georgi et al. 1980).

Quality control (QC) software was designed specifically for the digital data format established in 1981. For each sampling station of a given cruise, QC plots of temperature versus depth were produced, and all depth-temperature pairs were listed.

QC plots were used to determine water column depth, surface temperature, and bottom temperature, as well as to delete inaccurate XBT drops. Water column depth was determined by comparing the log sheet depth with any bottom impact marks on the QC plot. Surface bucket temperatures were used to calibrate probe values. Bottom temperatures were chosen from corresponding probe bottom impact marks located on the analog graph output.

Conductivity measurements of sea surface samples were generated by use of a Guildline Model 8400 Autosal. Conductivities were converted to salinity values using the UNESCO standard equations of state (UNESCO 1981).

Time-distance checks were performed on all recorded time and position data to eliminate erroneous log entries of a ship's position.

Analyses of the data revealed considerable temporal and spatial variability for surface temperature, surface salinity, and bottom temperature along most of the routes. As a result, a time-space mapping technique was developed to portray the data in a form that retained most of the original detail, to show long-term means and variances, and to determine departures in individual years from the means. Further, the technique permits extraction of a spatially coherent time series and analysis of relationships among measured values.

Gridding

Grid dimensions and techniques were chosen by considering (after several trial runs utilizing different parameters) the following: (1) the average data coverage in time and space; (2) the closeness of fit between the actual data values and the interpolated grid values; (3) the grid size; (4) the portrayed rates of change of the scalar values; and (5) the desire to ease interpretation and presentation of the final products. The limits in precision and accuracy are reported in Table 4. Distribution of the residuals from the base period grids and of a composite of the residuals from the single-year grids, showing near normal distributions, are presented in Figure 8A and 8B. An inherent bias in this gridding technique is the de-emphasis of extreme amplitudes in the raw data values. However, the tails of the residual distributions (Fig. 8A) do not show that this is a severe problem. The standard deviations of the base period residuals are 2 to 3 times the corresponding standard deviations of the single year residuals. The small size of these last residuals (0.29–0.79° C, 0.17–0.38 PSU) indicate that, taken together, the base period grids and single year grids are a valid portrayal of the data.

To overcome problems associated with irregular sampling in both space and time, the data were subjected to a gridding procedure. The design of the gridding method was developed in part with other research at the NOAA Narragansett Laboratory (Goulet 1990; Jossi et al. 1991; and Thomas 1992,). For each irregular raw data matrix, the gridding technique was used to calculate a curved planar surface from interpolated data values at regular, spatial-temporal grid points. Those gridded data values were contoured, producing three-dimensional representations of space by time by scalar (Figs. 9–91). Furthermore, gridding was used to calculate mean values, standard deviations over the thirteen year base period (1978–1990) (Figs. 9–14); and to compare individual-year data to base period mean values, via algebraic anomalies and standardized anomalies (Figs. 15–91).

Each grid was defined by polygon reference distance (range: 0 to 452 kilometers) along the x-axis, time (range: 0 to 365.25 days) along the y-axis, and sample scalar values along the z-axis. All grids were dimensioned such that grid points occurred at intervals of 17.38 kilometers and 15.22 days, i.e., there were 27 grid columns (26 divisions in x) along each polygon, and 25 grid rows (24 divisions in y) for every year or base period. At every grid point, a Z value was calculated by performing an elliptical search in time and space, weighting all observed values within the ellipse, and by calculating a weighted mean. In the event of fewer than four observations within the search ellipse at a given grid point, that grid point was assigned a missing value, resulting in a blank region within the grid surface (Figs. 15–91). Search radii and gridding techniques were dependent upon data spacing and the type of grid matrix created (Table 5).

The remainder of this section will detail the gridding methodology applied to all data types.

The first step was to generate a (base period) mean grid from all data collected during the thirteen-year base period (Figs. 9–14, panel A). The mean grid for each base period was then used to generate a corresponding grid of standard deviations.

The base period mean grid surface was subtracted from observed values to produce a data set of base period residuals (Fig. 8A), thereby removing the two-

Table 4

Accuracy and precision of the gridding technique expressed as means and standard deviation of the residuals.

Timespan and route	Data type	Mean of residuals	Standard deviation of residuals
Single Year			
MB	Surface Temp.	-0.00017	0.751
	Bottom Temp.	0.025	0.785
	Surface Sal.	0.0079	0.377
Base Period			
MB	Surface Temp.	-0.023	1.865
	Bottom Temp.	-0.035	1.624
	Surface Sal.	0.027	0.902
Single Year			
MC	Surface Temp.	-0.0057	0.424
	Bottom Temp.	-0.0027	0.290
	Surface Sal.	-0.00041	0.165
Base Period			
MC	Surface Temp.	-0.0031	1.129
	Bottom Temp.	-0.0387	0.8032
	Surface Sal.	-0.0209	0.4663

Table 5

Gridding methods and elliptical search radii for each sampling route and grid type.

Route	Grid type	Gridding method	Search radius
MB	Single year	Kriging	60 km x 70 days
MB	Base period (1978–1990)	Inverse distance squared weighting	30 km x 35 days
MC	Single year	Kriging	50 km x 35 days
MC	Base period (1978–1990)	Inverse distance squared weighting	50 km x 35 days

dimensional annual signal. The residual technique subtracted an interpolated grid surface value at the actual spatial-temporal location of each observation. A weighted variance was found by squaring all residual values, and then gridding these squared residuals. Finally, a standard deviation grid (Figs. 9–14, panel B) was created by taking the square root of the variance grid (the calculation did not include the number of observations, which exceeded 70 at all grid points).

Two characteristics of the gridding technique are worth noting. First, all grid matrices associated with the base period mean were interpolated with the base period parameters listed in Table 5. Second, all base period mean and standard deviation grid values were localized in time and space, because each grid value was the weighted mean of all observations within the search ellipse surrounding that grid value.

Single year grid maps of observed, anomaly, and standardized anomaly values were generated for each route and data type. See Table 5 for single year grid methodology. Each annual raw data map was created by gridding all observed data from that year (Figs. 15–91, panel A). For every observation in a given year, algebraic anomalies (residuals) were calculated by subtracting the base period mean gridded value at that point. Each annual anomaly map was created by gridding these anomalies (Figs. 15–91, panel B). By dividing the anomaly at each observation point by the corresponding interpolated standard deviation (taken from the base period standard deviation grid surface), standardized anomalies were calculated for every observation in a given year. Each annual standardized anomaly map was generated by gridding these standardized anomaly values (Figs. 15–91, panel C). For portrayal of statistically significant events, standardized anomaly map contour intervals were chosen by picking the 15.2% and 84.8% percentile levels, as an approximation of one standard deviation, and the 2.3% and 97.7% percentile levels, as an approximation of two standard deviations, from the thirteen-year data set of standardized anomalies.

Results

The initial thirteen years of data collection (1978-1990) were chosen to serve as a base period for computing long-term mean conditions, and for determining departures from mean conditions. Over the thirteen years, a total of 294 cruises were conducted in the Middle Atlantic Bight, and 209 cruises in the Gulf of Maine. Contoured, thirteen-year mean portrayals of surface temperature, bottom temperature, and surface salinity values are shown for the Middle Atlantic Bight (Figs. 9–11) and the Gulf of Maine (Figs. 12–14). Figure 8 displays the average relation between bottom depth and reference distance along the two transects.

Each figure of thirteen-year mean conditions contains three panels: (A) weighted means of the observations for that thirteen-year time frame; (B) estimated standard deviations of the weighted mean observed values; and (C) data location within the thirteen-year base period.

Also presented are annual surface temperature, bottom temperature, and surface salinity variations in time and space for each year, 1978–1990, for the Middle Atlantic Bight (Figs. 15–53) and the Gulf of Maine (Figs. 54–91). Each annual figure contains three panels: (A) observed conditions with the sampling locations; (B) departures of the observed conditions from the thirteen-year mean values expressed as algebraic anomalies; and (C) departures of the observed conditions from the thirteen-year mean values expressed as standardized anomalies. Note that the Gulf of Maine 1986 surface temperature figure was generated solely from bucket temperatures, and that there are no Gulf of Maine 1986 bottom temperature measurements or figures.

In the Middle Atlantic Bight (Fig. 92), the maximum XBT sampling depth (500 m) occurred at a reference distance of less than 225 km. This 500-m depth maximum is 40 meters beyond the working limit of the T-6 XBT probe. Because of slower cruising speed, less than 15 kts, we were able to glean an extra 40 meters of data. Hence, the bottom temperature diagrams for that transect (Figs. 41–53) extend only from the coast to that 225-km reference distance.

Discussion

Baseline Conditions

Baseline conditions of surface temperature across the Middle Atlantic Bight (Fig. 9A) show minimum annual values of less than 4° C in late February very near shore, of 4–8° C during mid-March on the shelf, and of 8–20° during mid-March southeastward through the slope and Gulf Stream water masses. The highest rate of vernal warming takes place along the entire transect during late June, with peak annual temperatures of greater than 22° C over the shelf and greater than 26° C offshore achieved by late August. From August to the end of the year temperatures decline fairly uniformly over the entire transect. The periods of highest variability in these baseline conditions (Fig. 9B) occur on the shelf in early June when standard deviations about the 1978–1990 means are in excess of 2° C. These variations are largely due to interannual differences in the timing of the vernal warming of the surface waters of the Middle Atlantic Bight. Variations in excess of 1° C occur over the inner shelf during the November and December period. The November variations can be partly attributed to the interannual differences of timing of the fall overturn. The December variations include record-breaking, cold winter temperature values in 1978. Offshore, the standard deviations about the baseline values generally range from 2° C to greater than 3° C, with the highest values along the boundary between the slope and Gulf Stream water masses. The baseline values for this region are the most variable along the transect due to the extensive migrations of both the shelf/slope front and the Gulf Stream North Wall.

The dominant features of the time-space surface salinity field across the shelf portion of the Middle Atlantic Bight transect (Fig. 10A) are the meltwater runoff from mid-March to late April, and the shorter duration river discharge in mid-August, both concentrated within 30 km of Ambrose Tower. The shelf-slope front, defined by 34.5 Practical Salinity Units (PSU), shows considerable spatial variation through the year, being just seaward of the shelf break from January through April, then migrating over 100 km further offshore by mid-June, and returning to the area seaward of the shelf break by October. Beyond the 300-km reference distance, salinities exceed 36 PSU in association with meanders of the Gulf Stream. Variations about these baseline conditions (Fig. 10B) are highest nearshore where standard deviations from February through mid-June exceed 3 PSU, and values in excess of 1 PSU occur throughout the year. Variations in excess of 1 PSU occur across the shelf in June and offshore in August and September. The influence of upstream conditions on these values (particularly outflow from the Gulf of Maine) is not easily determined from this one transect but is expected to be a contributing factor.

Baseline conditions of bottom temperatures across the Middle Atlantic Bight shelf (Fig. 11A) show minimum annual values of less than 2° C nearshore in mid-February to less than 7° C at the shelf break in mid-March. The cold pool is a major feature of the bottom temperature regime along this transect. It occurs during the period between the onset of stratification (approximately late March inshore to late April offshore) and fall overturn (early September nearshore to early December offshore) (Cook 1985; Benway et al.; In Press). Fall overturn produces maximum bottom temperatures across the shelf reaching in excess of 16° C nearshore and 13° C offshore to the shelf/slope frontal boundary. Variations about baseline values (Fig. 11B) show standard deviations in excess of 3° C near shore in August, associated with wind mixing of these shallow waters, and upwelling and downwelling events common to that area. A large portion of the inner shelf during September and October, and the outer shelf during October and November have standard deviations of greater than 2° C coinciding with the fall overturn. Beyond the 200-km reference distance, the standard deviations exceed 2° C during most of the year reflecting the influence of the migrating shelf/slope front on the bottom. Midshelf deviations of greater than 1° C occur during all but the winter months and can be largely attributed to interannual variability in cold pool temperature and boundaries.

Baseline conditions of surface temperature across the Gulf of Maine transect (Fig. 12A) range from a minimum of less than 3° C over the Scotian Shelf in mid-March, and less than 4° C over Massachusetts Bay in mid-February, to a maximum of 19° C for Massachusetts Bay and Wilkinson Basin, and near 14° C over the eastern Gulf in August. The highest rate of change due to vernal warming occurs during late May through early July across the entire transect. After August, surface temperatures, with the exception of the mixed portions of the Scotian Shelf, decline rapidly. Periods of highest variability occur during June to late September over much of the transect (Fig. 12B). Fall overturn generally occurs during late October through early December leading to further variability. The high variations over the eastern end of the transect can be attributed to variation in the Scotian Shelf Current.

Gulf of Maine surface salinity conditions vary less than those in the Middle Atlantic Bight but still show a wide range of values over the region (Fig. 13A). Salinities range from a minimum 30 PSU during the peak runoff into Massachusetts Bay in May, to a maximum of 33.5 PSU over the Scotian Shelf in early November. Unlike the nearshore waters of the New York Bight during late summer and early fall, there is no secondary pulse of river runoff. The standard deviation about the baseline conditions is less than 0.5 PSU for much of the time-space area (Fig. 13B). However, deviations reaching 1 PSU occur from April to June over Massachusetts Bay; between 0.5 and 0.7 PSU occur over Crowell Basin and extend to the eastern end of the transect during January to April. In addition, standard deviations from 0.5 to 0.7 PSU occur from August through December beginning over the Scotian Shelf and progressing westward to include Crowell Basin.

Bottom temperature conditions within the Gulf of Maine range from a minimum of less than 3° C over the Scotian Shelf from February through late April, and less than 4° C over Massachusetts Bay during the same time period (Figure 14A). Mid-Gulf bottom temperatures have average minima of between 6 and 7° C. Maximum temperatures of greater than 10° C occurred over the eastern end of the transect from late September through early November. Maximum temperatures on the western end of the transect occurred during the same time period but reached only slightly over 8° C. These times of maximum bottom temperature coincide with fall overturn for these shelf areas. These maxima are absent for the basin areas which are commonly isolated from the overturn event by the Maine Intermediate water. The largest time-space standard deviations about the baseline conditions appear to be associated with the shallower portions of the transect, i.e., Massachusetts Bay, the central Gulf ledges, and the Scotian Shelf (Fig. 14B), amounting to greater than 1° C. These deviations are most evident over the Scotian Shelf during late fall and winter.

Time Series Approach

The transects along which these data were collected initially were designed to provide information about the cross shelf gradients through time. Although the portrayals in this atlas illustrate such gradients, they do not show the information in a convenient time-series format. What is clear in the portrayals is that in the development of any time series, spatial non-homogeneity must be considered. Analyses of the time-space results of this atlas have led to a technique that is believed appropriate for extracting spatially coherent sections of the transects. The data from each section form the ingredients for reliable time-series analyses. The method was first discussed by Jossi et al. (1991), and more completely by Thomas (1992). It involves examining the time-space changes in a departure of variables from a baseline condition, and, through cluster analysis, determining sections of the transect that depart from baseline conditions in a spatially coherent manner. The raw data within these clusters would then be used in time-series analyses. Although such time-series were too voluminous to be included in this atlas, an example from their ongoing development are offered in Figure 93.

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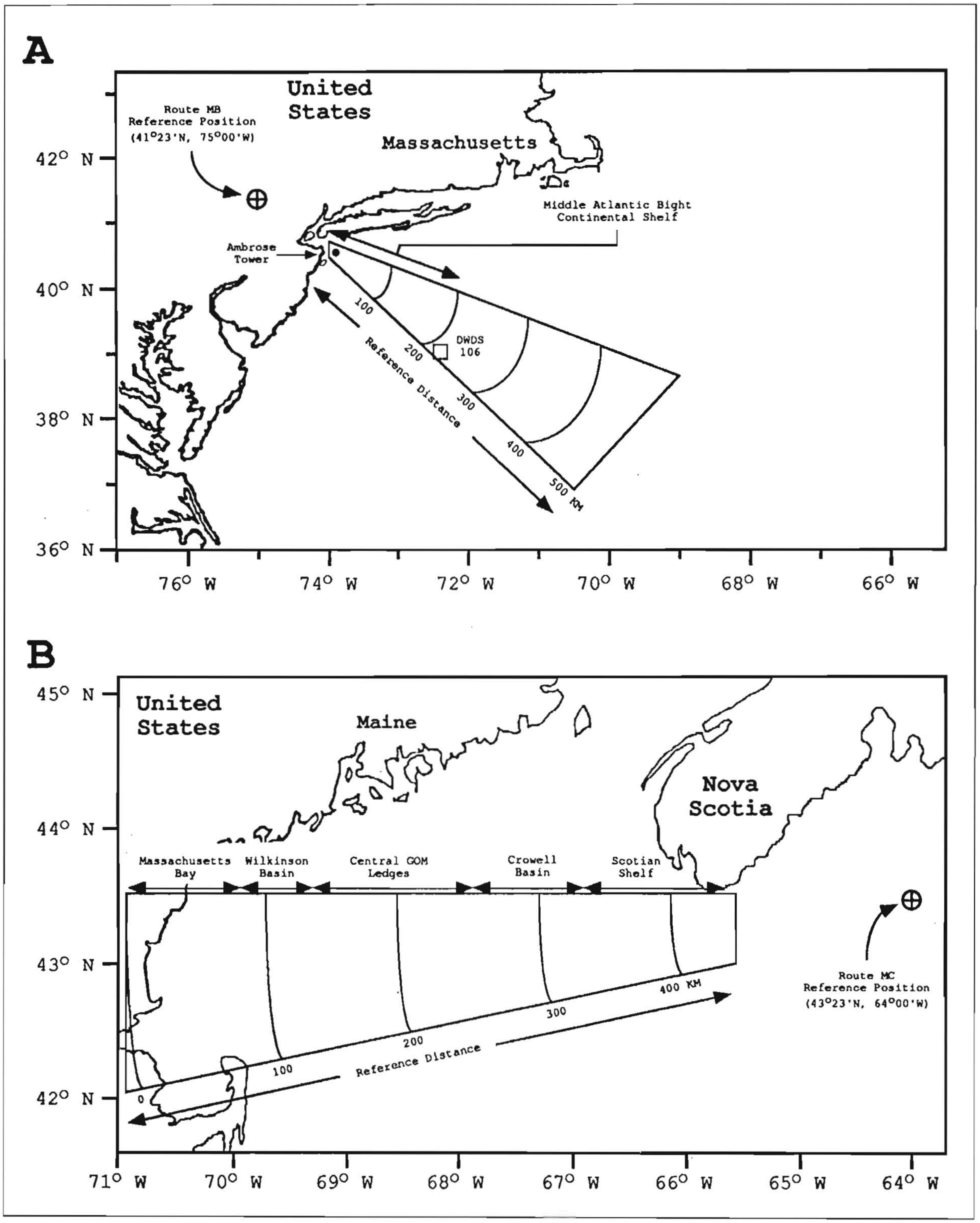

Figure 1

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 the Deep Water Dumpsite 106 (DWDS 106), location of Ambrose Tower, and major geographical features through which all sampling took place.

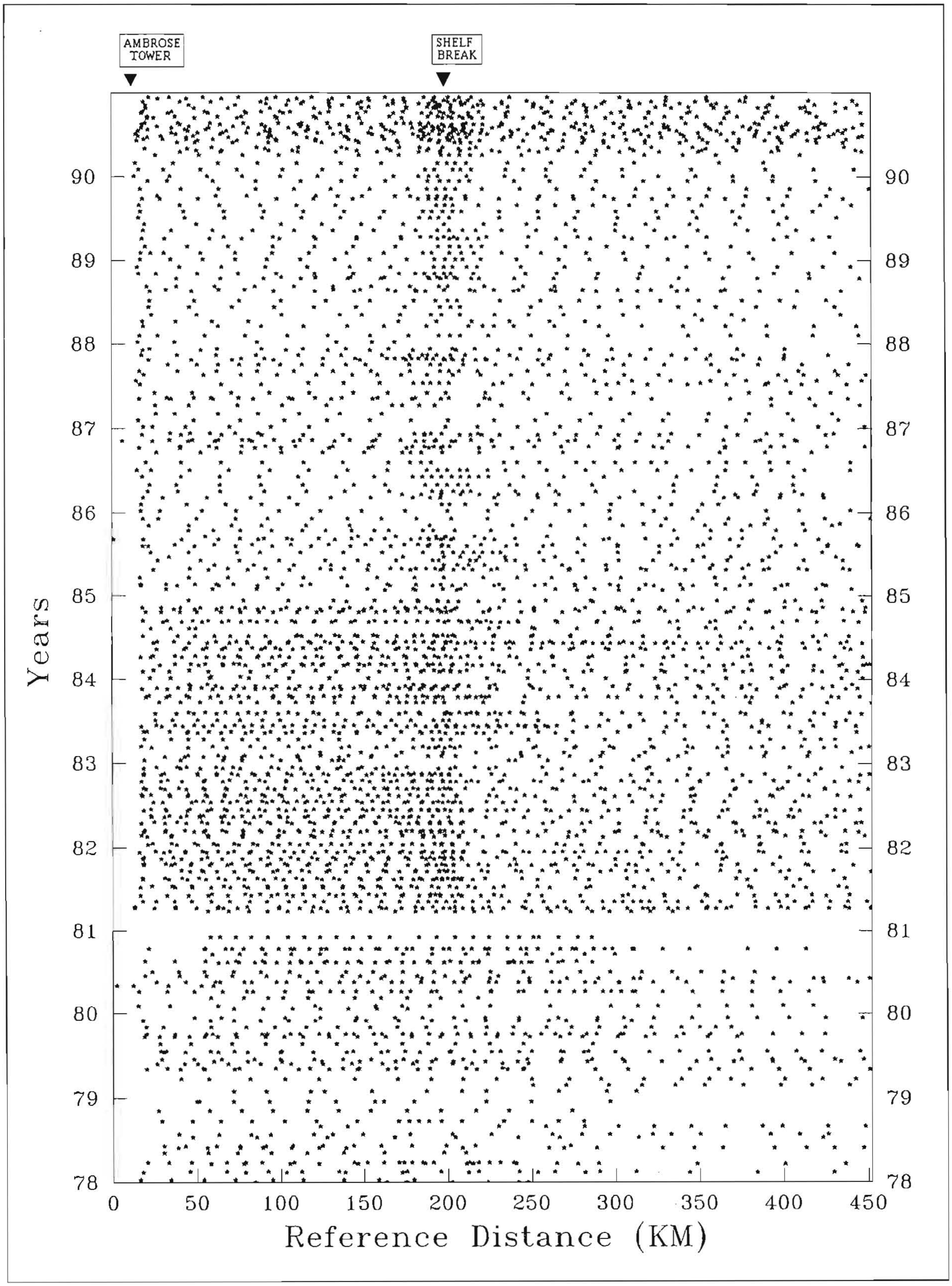

Figure 2
Spatial distribution of surface temperature measurements along the Middle Atlantic Bight (Route MB), 1978 through 1990.

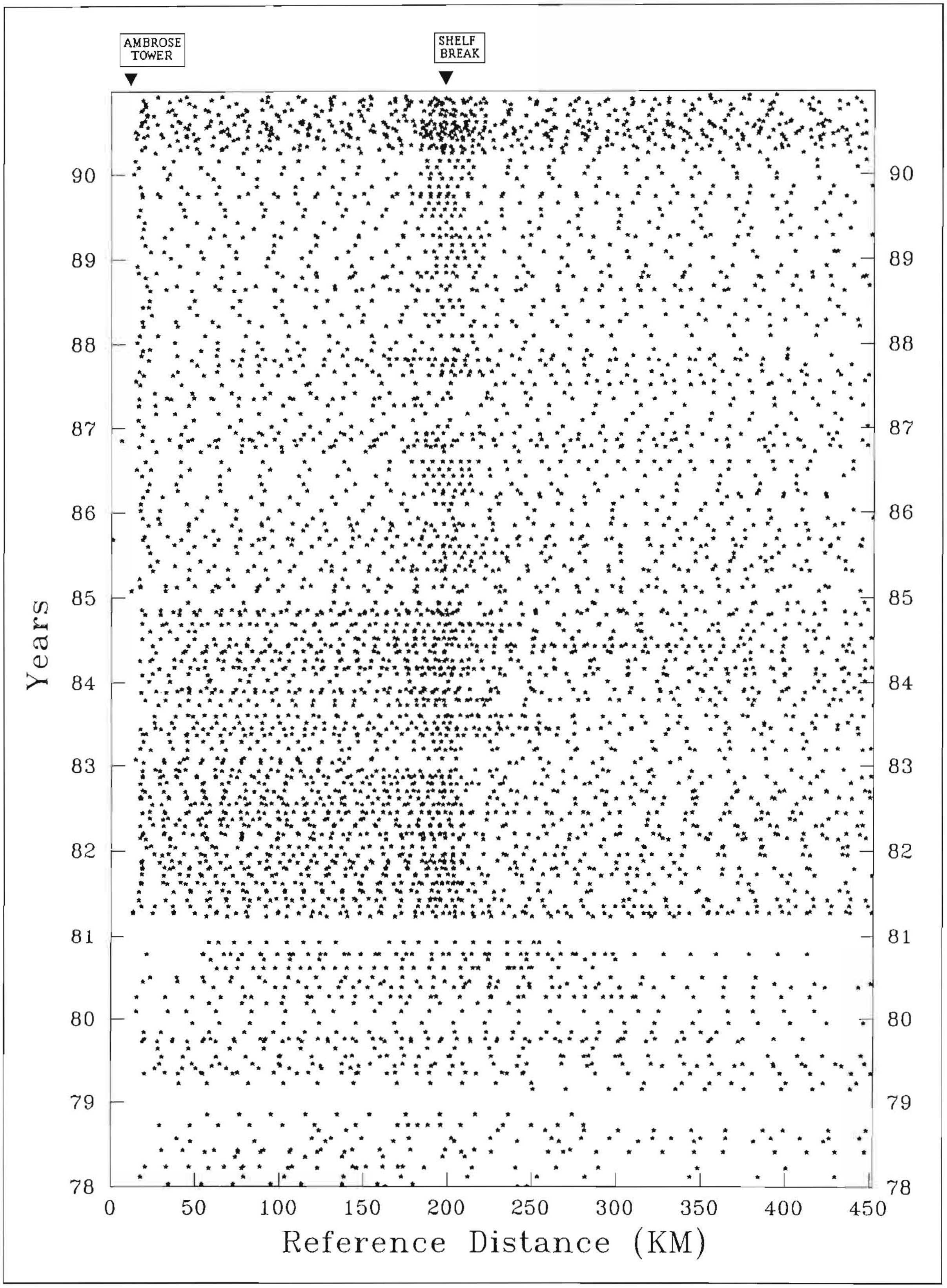

Figure 3

Spatial distribution of surface salinity measurements along the Middle Atlantic Bight (Route MB), 1978 through 1990.

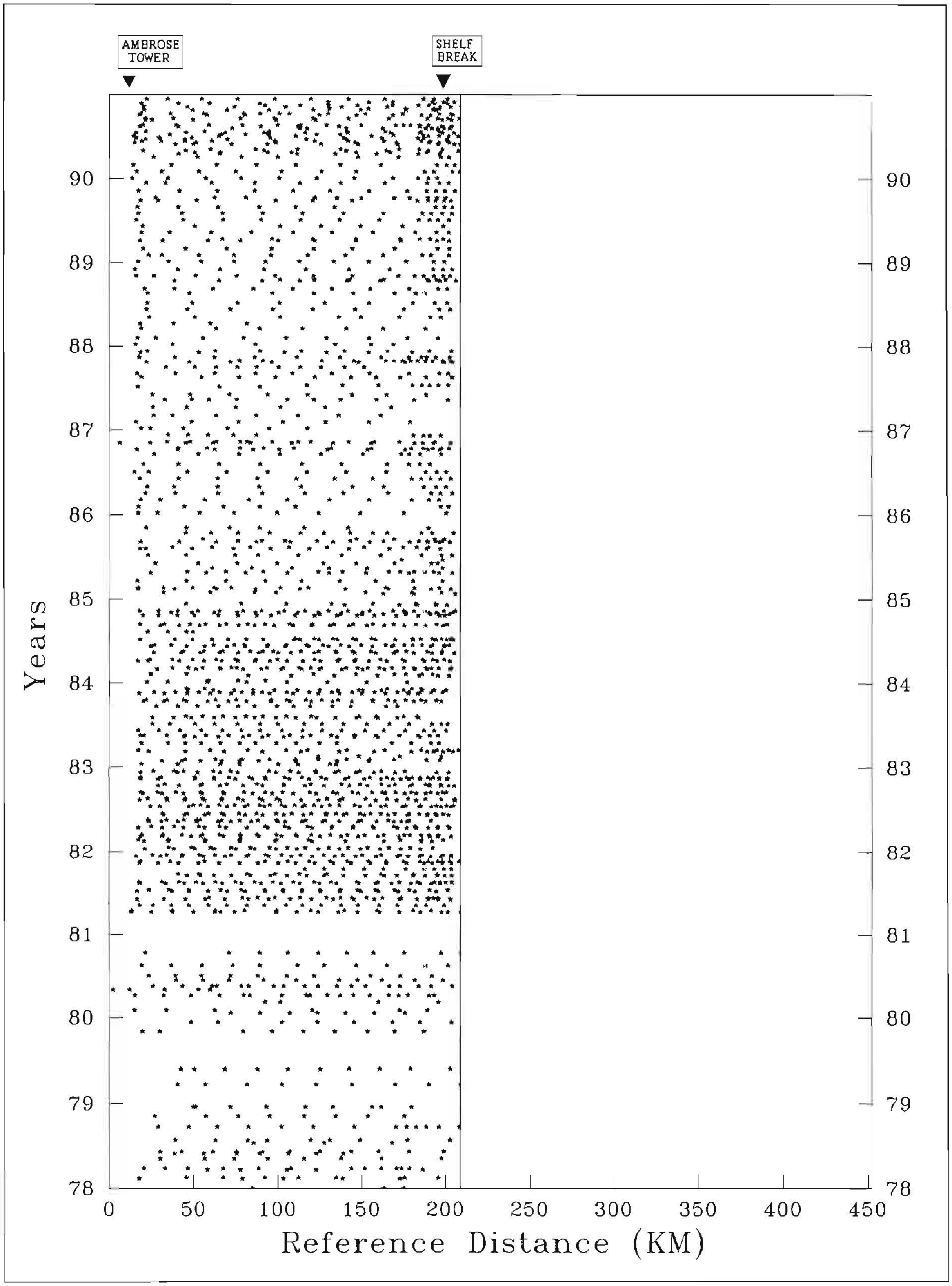

Figure 4
Spatial distribution of bottom temperature measurements along the Middle Atlantic Bight (Route MB), 1978 through 1990.

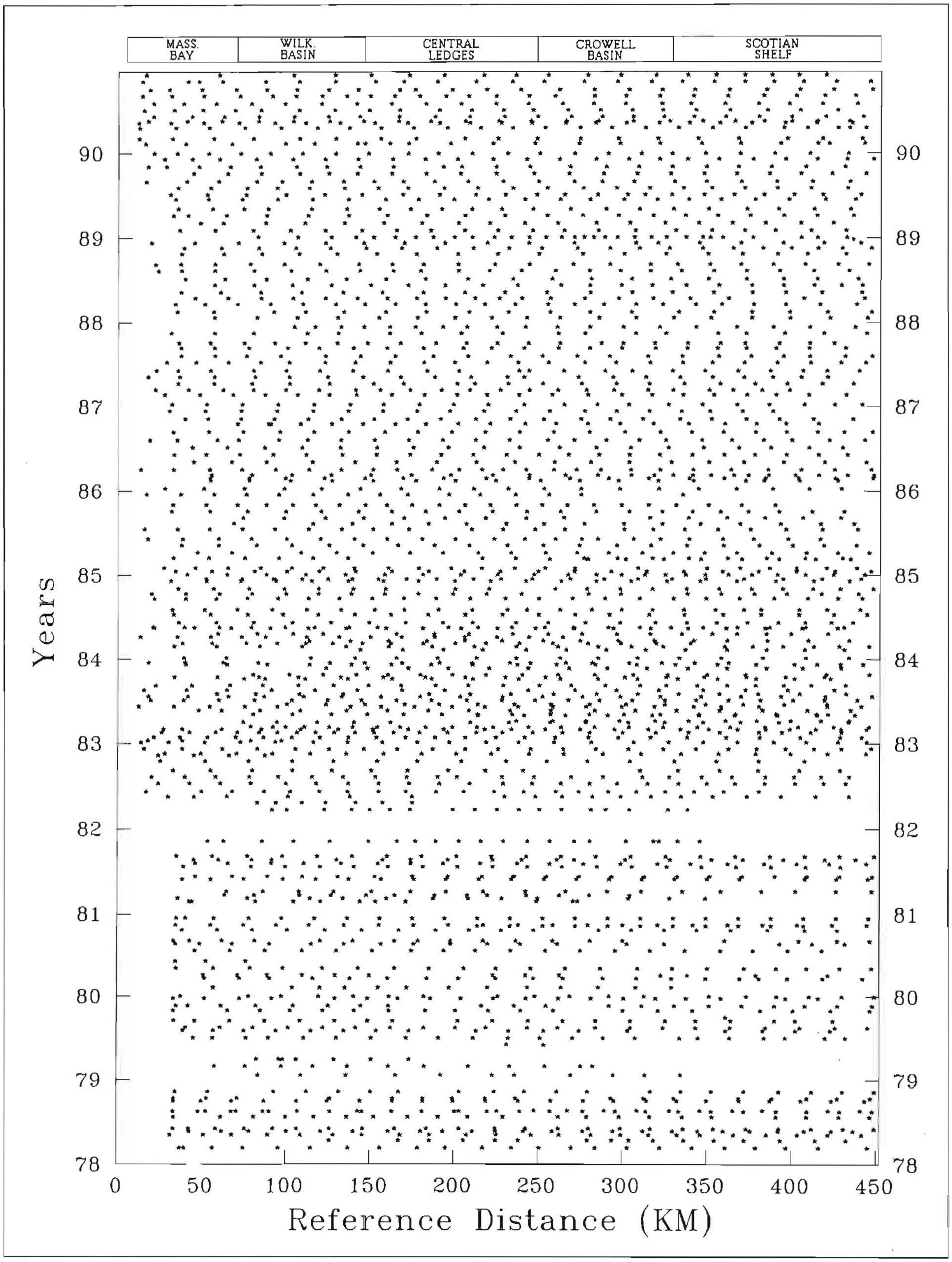

Figure 5
Spatial distribution of surface temperature measurements along the Gulf of Maine (Route MC), 1978 through 1990.

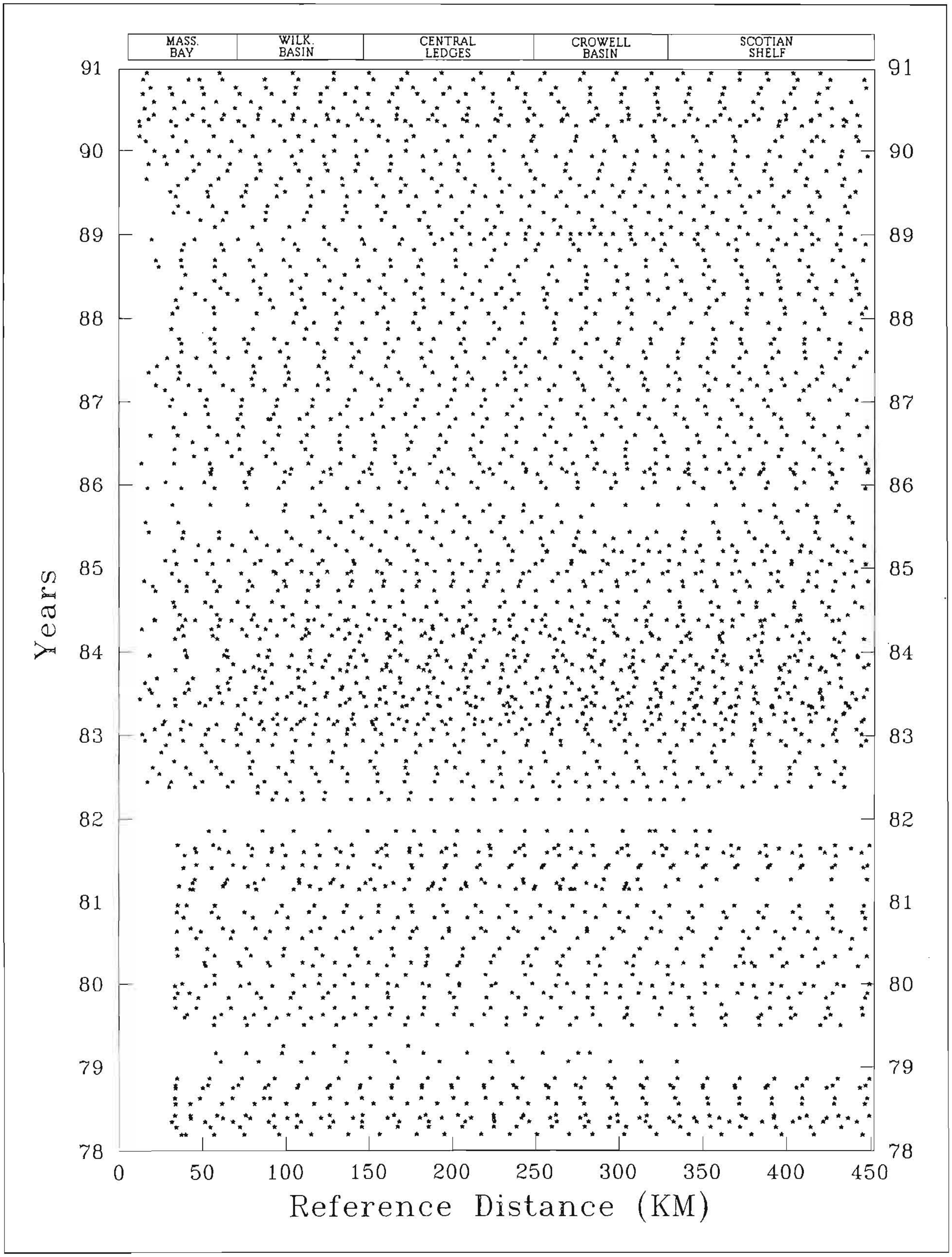

Figure 6
Spatial distribution of surface salinity measurements along the Gulf of Maine (Route MC), 1978 through 1990.

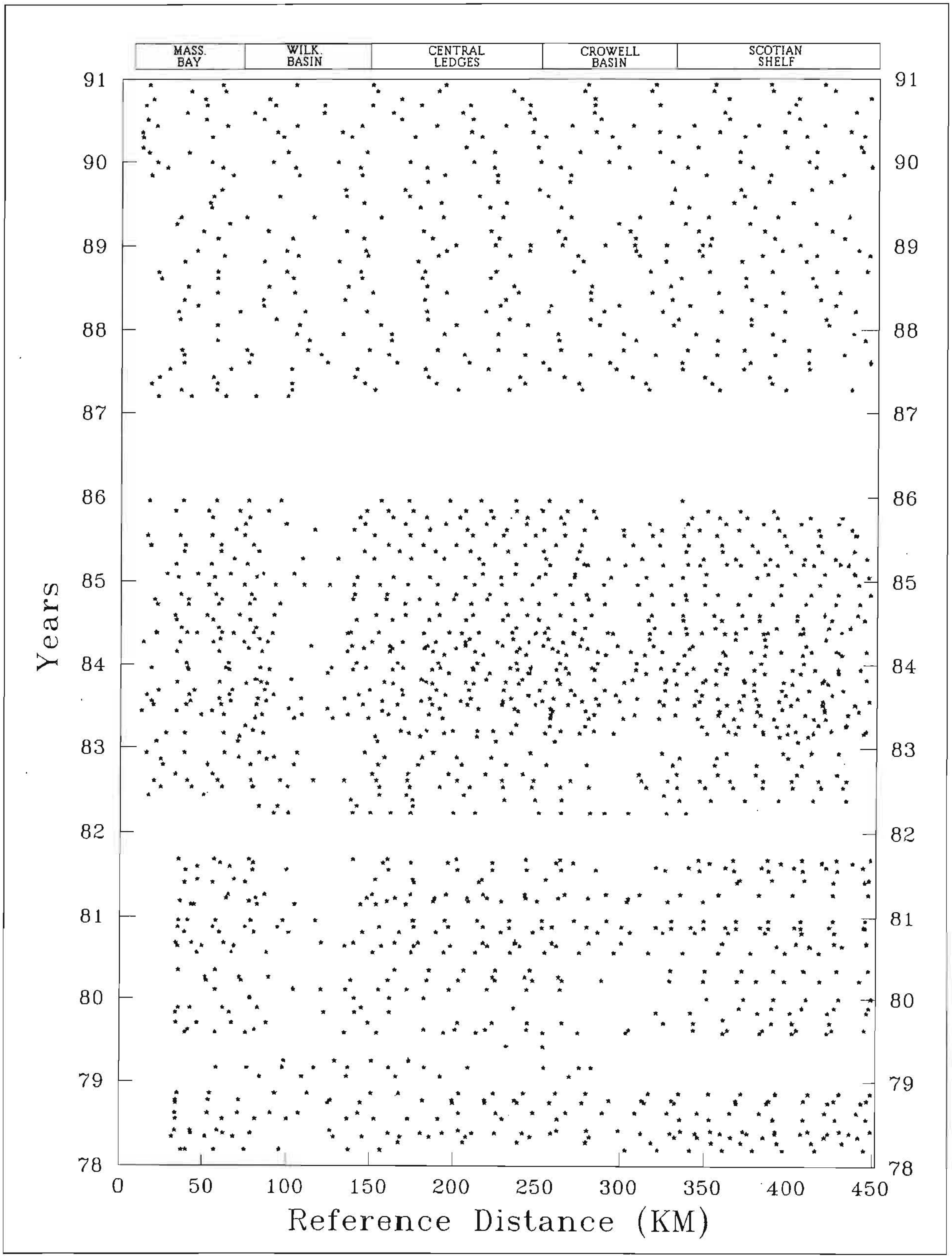

Figure 7
Spatial distribution of bottom temperature measurements along the Gulf of Maine (Route MC), 1978 through 1990.

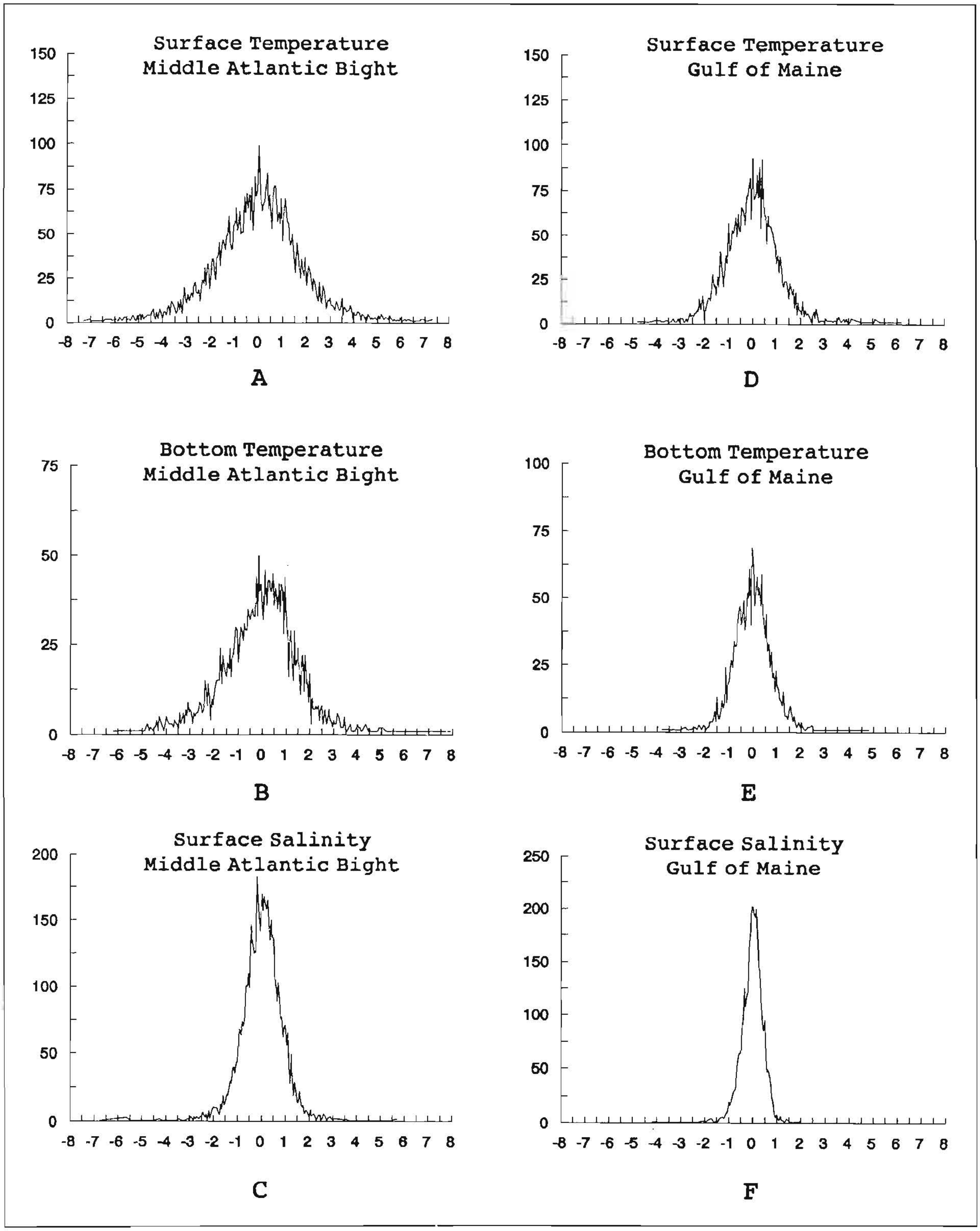

Figure 8A

Distribution of residuals from the base period grids. Panels **A**, **B**, and **C** refer to surface temperature, bottom temperature, and surface salinity within the Middle Atlantic Bight respectively. Panels **D**, **E**, and **F** refer to surface temperature, bottom temperature, and surface salinity within the Gulf of Maine respectively.

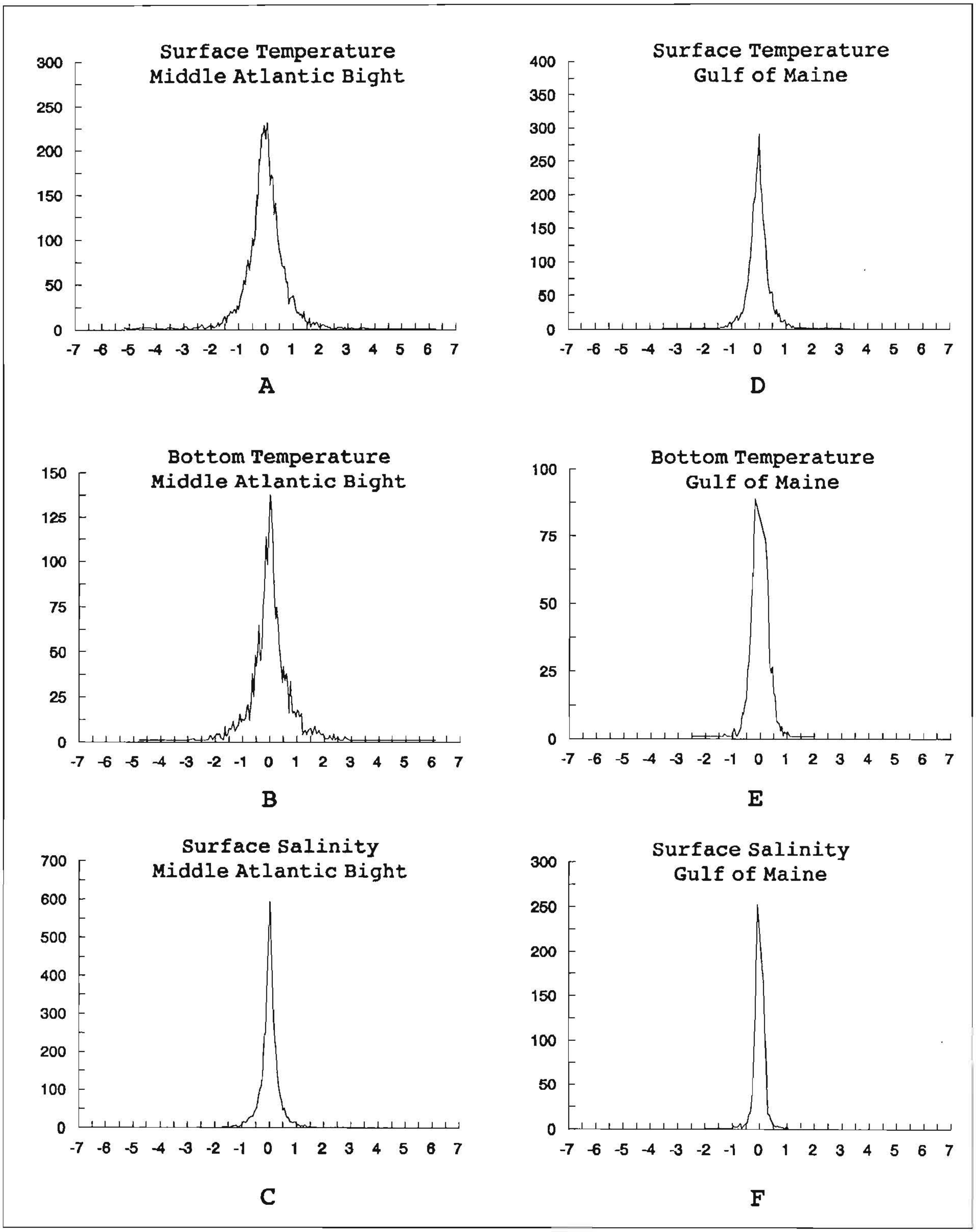

Figure 8B

Distribution of residuals from single year grids composited over all years, 1978 through 1990. Panels **A**, **B**, and **C** refer to surface temperature, bottom temperature, and surface salinity within the Middle Atlantic Bight respectively. Panels **D**, **E**, and **F** refer to surface temperature, bottom temperature, and surface salinity within the Gulf of Maine respectively.

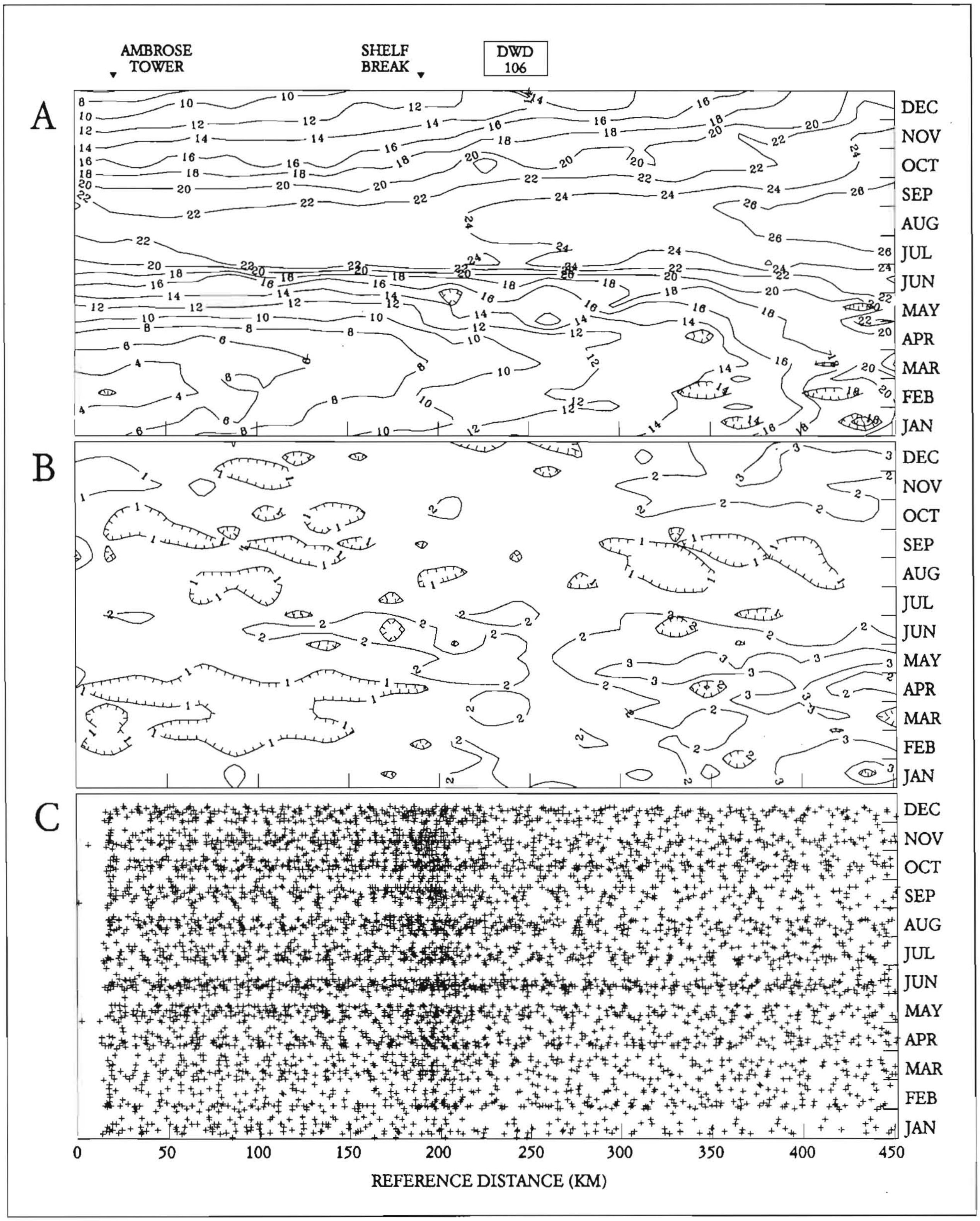

Figure 9
Mean surface temperature conditions along the Middle Atlantic Bight route during 1978 through 1990. (**A**) Means of measured values (degrees Celsius). (**B**) Standard deviations of measured values (degrees Celsius). (**C**) Station locations in time and space. In panels A and B, values decline on those sides of contour lines with hachures.

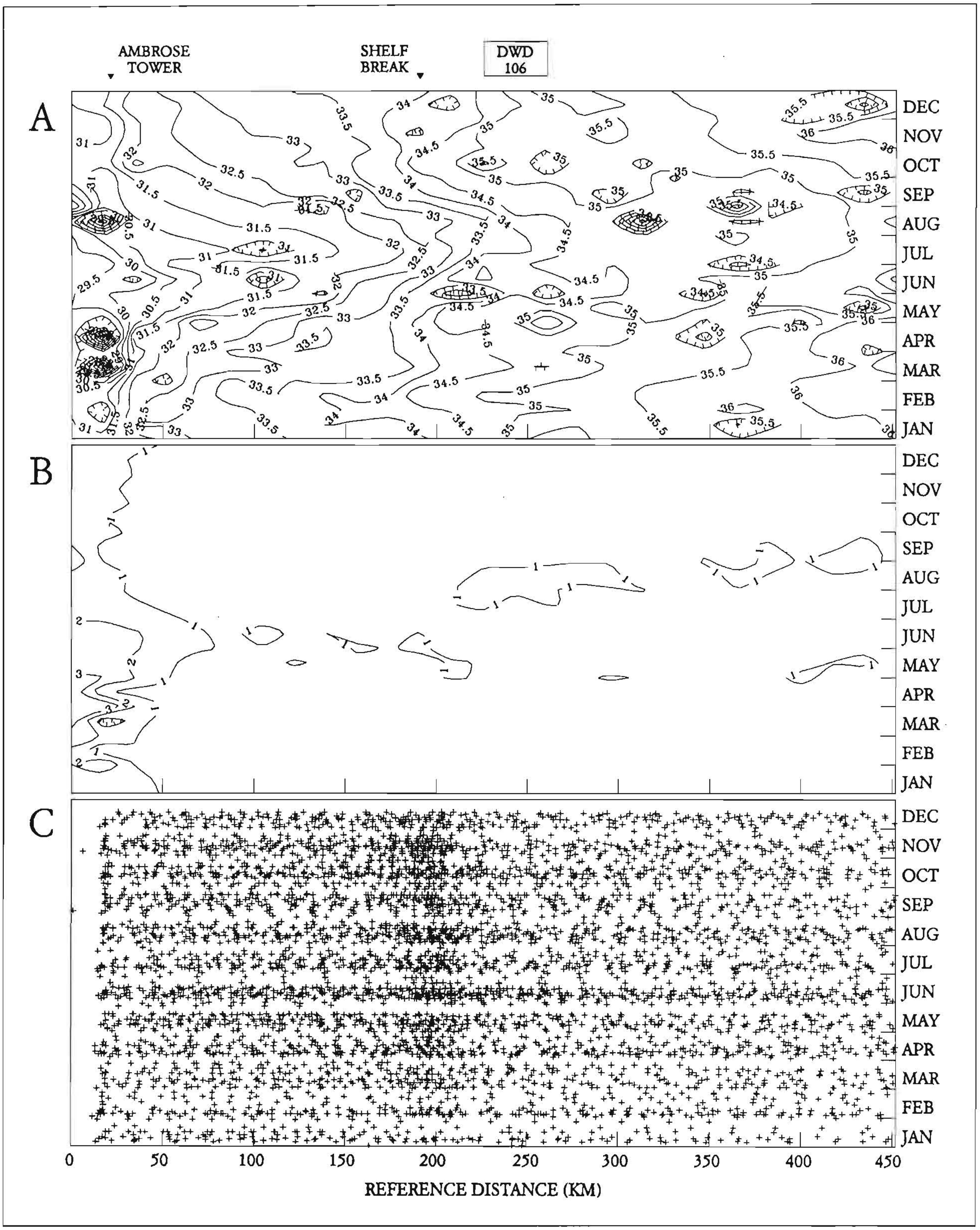

Figure 10

Mean surface salinity conditions along the Middle Atlantic Bight route during 1978 through 1990. (**A**) Means of measured values (practical salinity units). (**B**) Standard deviations of measured values (practical salinity units). (**C**) Station locations in time and space. In panels A and B, values decline on those sides of contour lines with hachures.

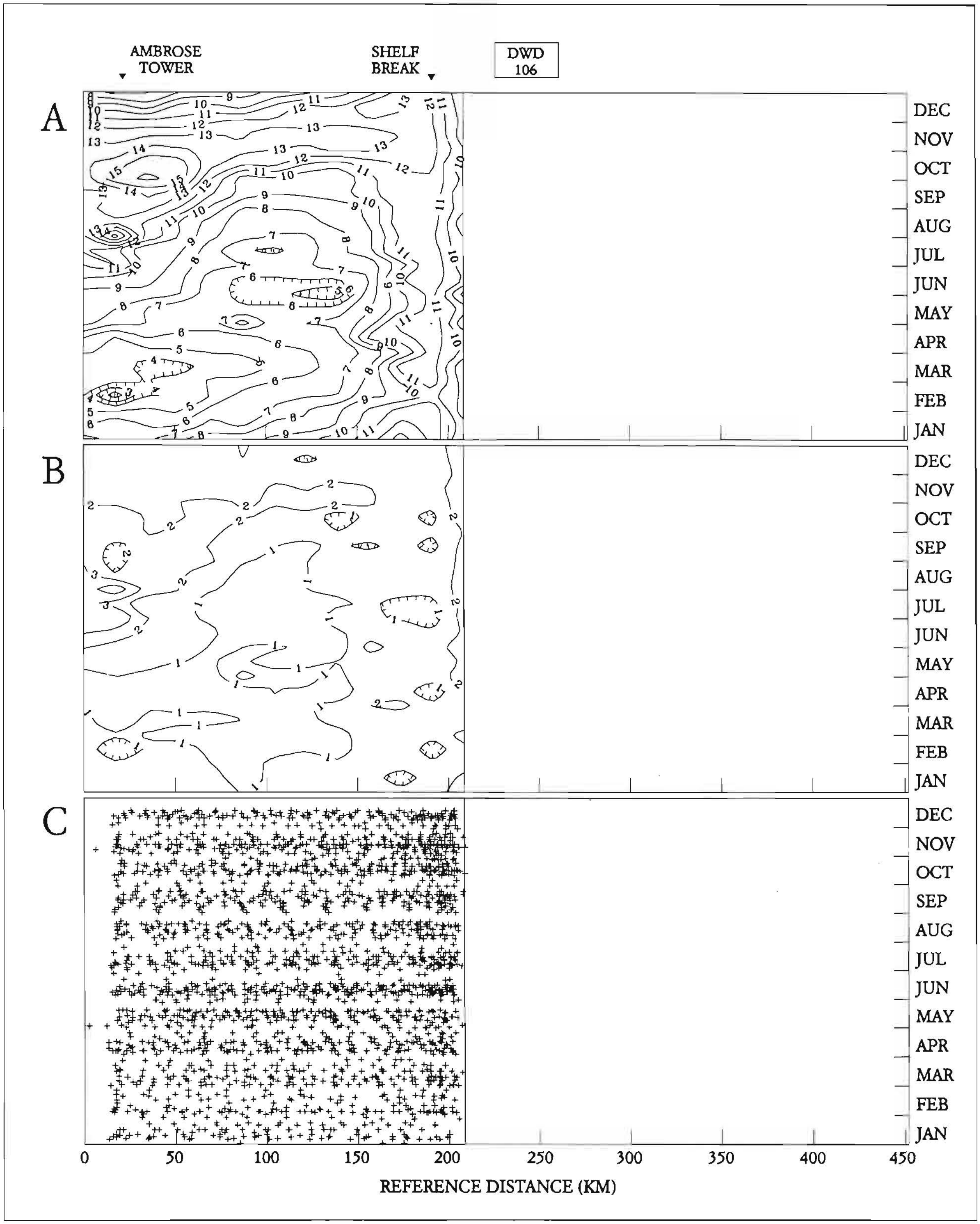

Figure 11

Mean bottom temperature conditions along the Middle Atlantic Bight route during 1978 through 1990. (**A**) Means of measured values (degrees Celsius). (**B**) Standard deviations of measured values (degrees Celsius). (**C**) Station locations in time and space. In panels A and B, values decline on those sides of contour lines with hachures.

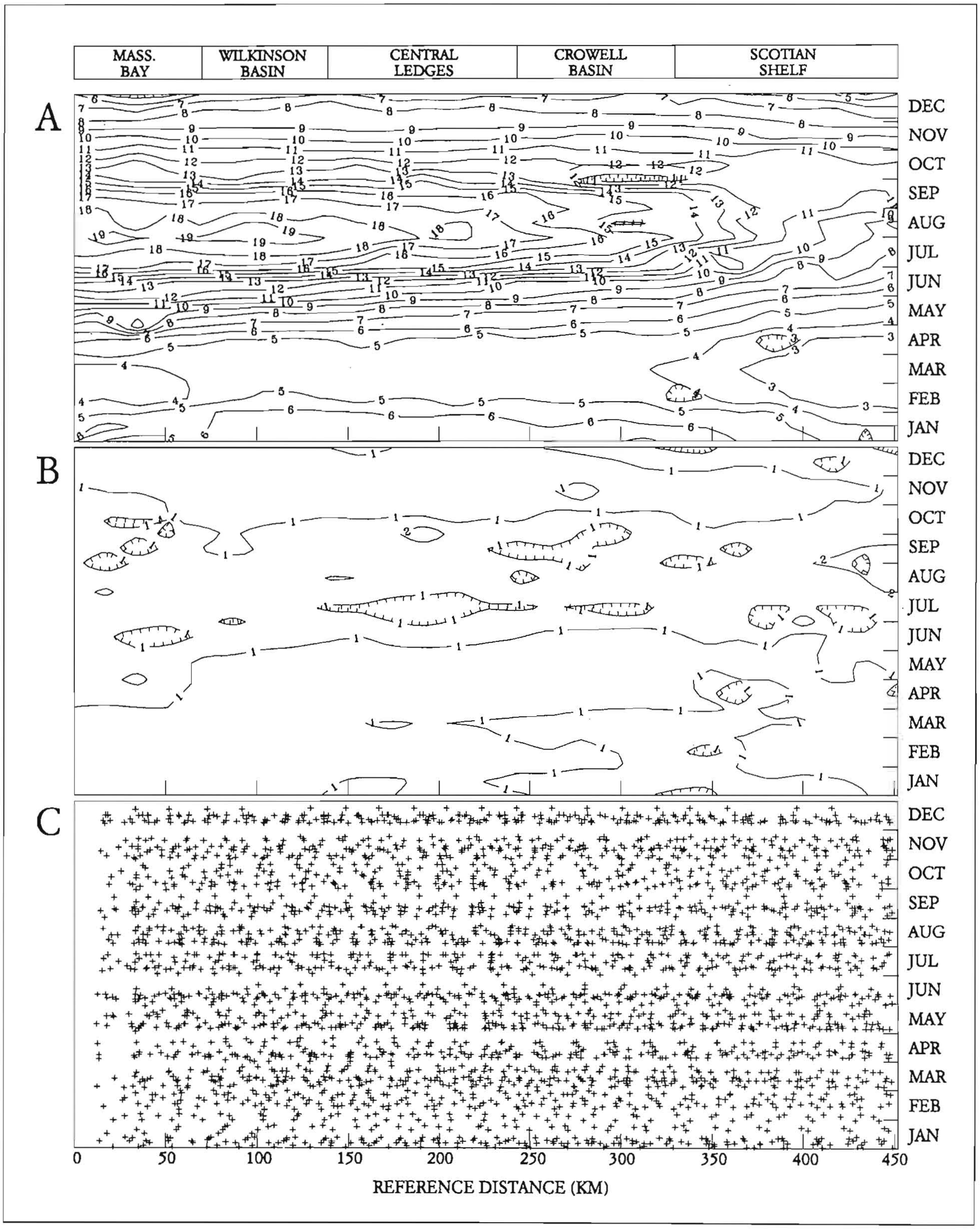

Figure 12

Mean surface temperature conditions along the Gulf of Maine route during 1978 through 1990. (**A**) Means of measured values (degrees Celsius). (**B**) Standard deviations of measured values (degrees Celsius). (**C**) Station locations in time and space. In panels A and B, values decline on those sides of contour lines with hachures.

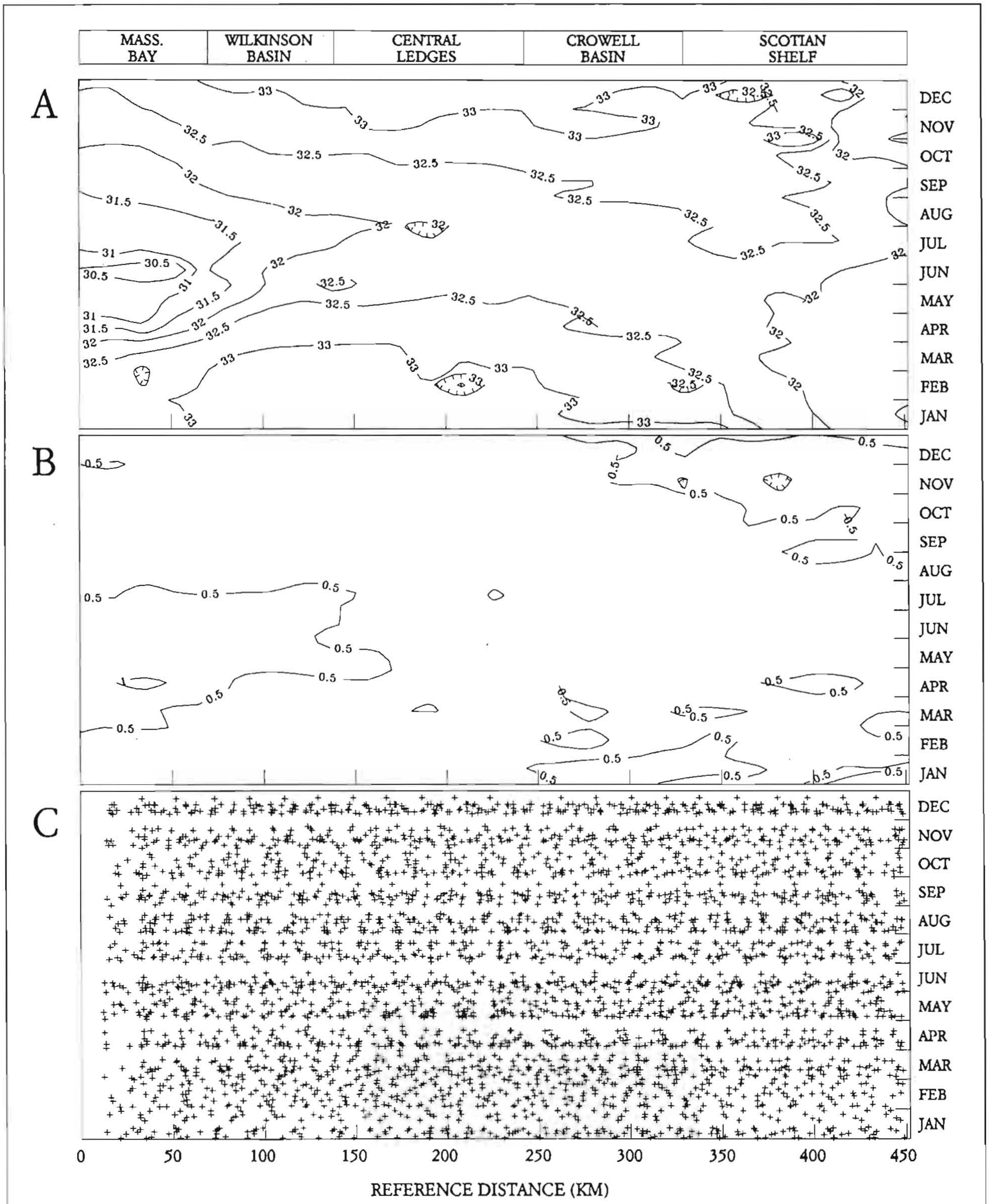

Figure 13
Mean surface salinity conditions along the Gulf of Maine route during 1978 through 1990. (**A**) Means of measured values (practical salinity units). (**B**) Standard deviations of measured values (practical salinity units). (**C**) Station locations in time and space. In panels A and B, values decline on those sides of contour lines with hachures.

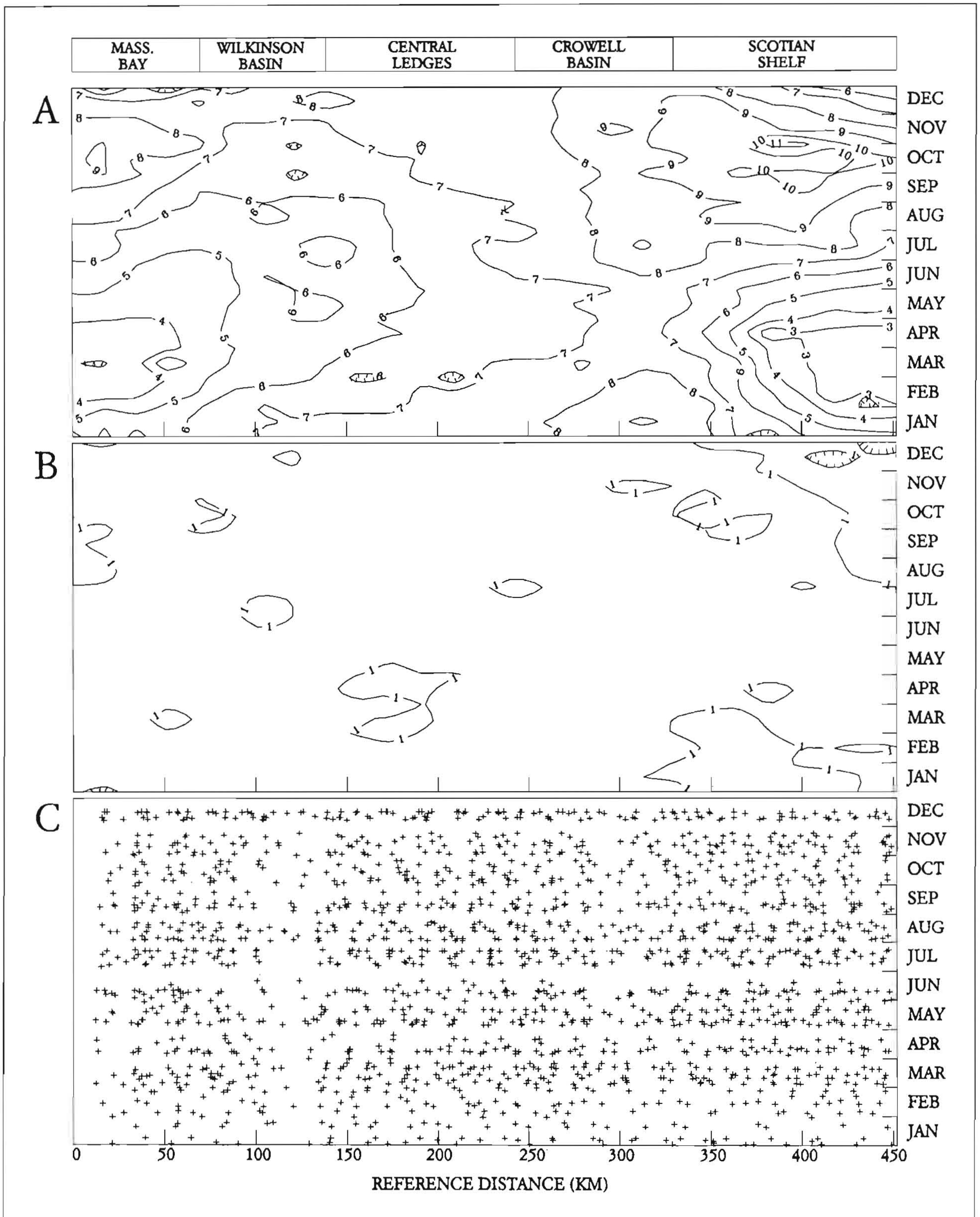

Figure 14

Mean bottom temperature conditions along the Gulf of Maine route during 1978 through 1990, excluding 1986 (see text for explanation). (**A**) Means of measured values (degrees Celsius). (**B**) Standard deviations of measured values (degrees Celsius). (**C**) Station locations in time and space. In panels A and B, values decline on those sides of contour lines with hachures.

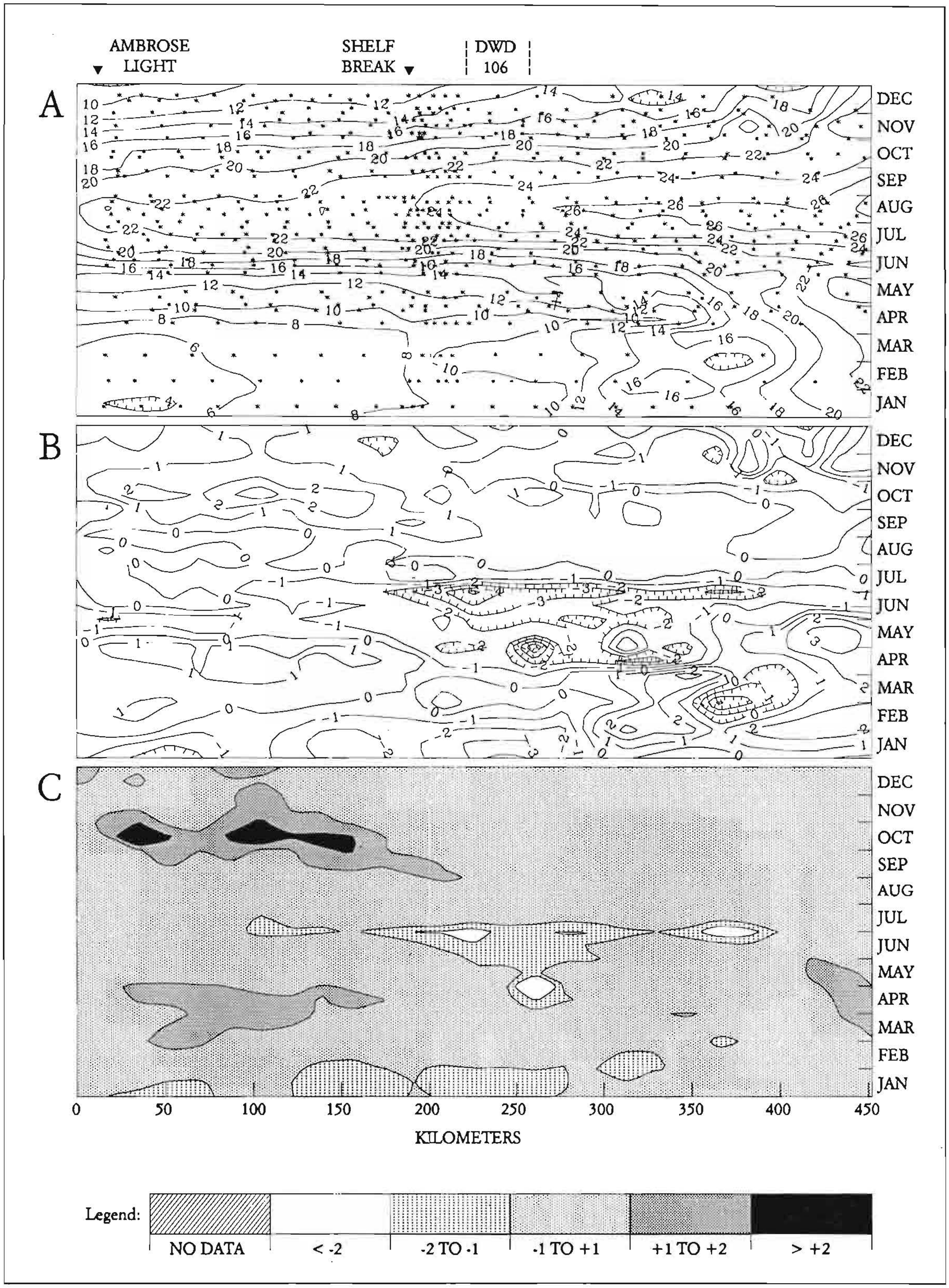

Figure 15

Surface temperature conditions along the Middle Atlantic Bight route during 1990. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

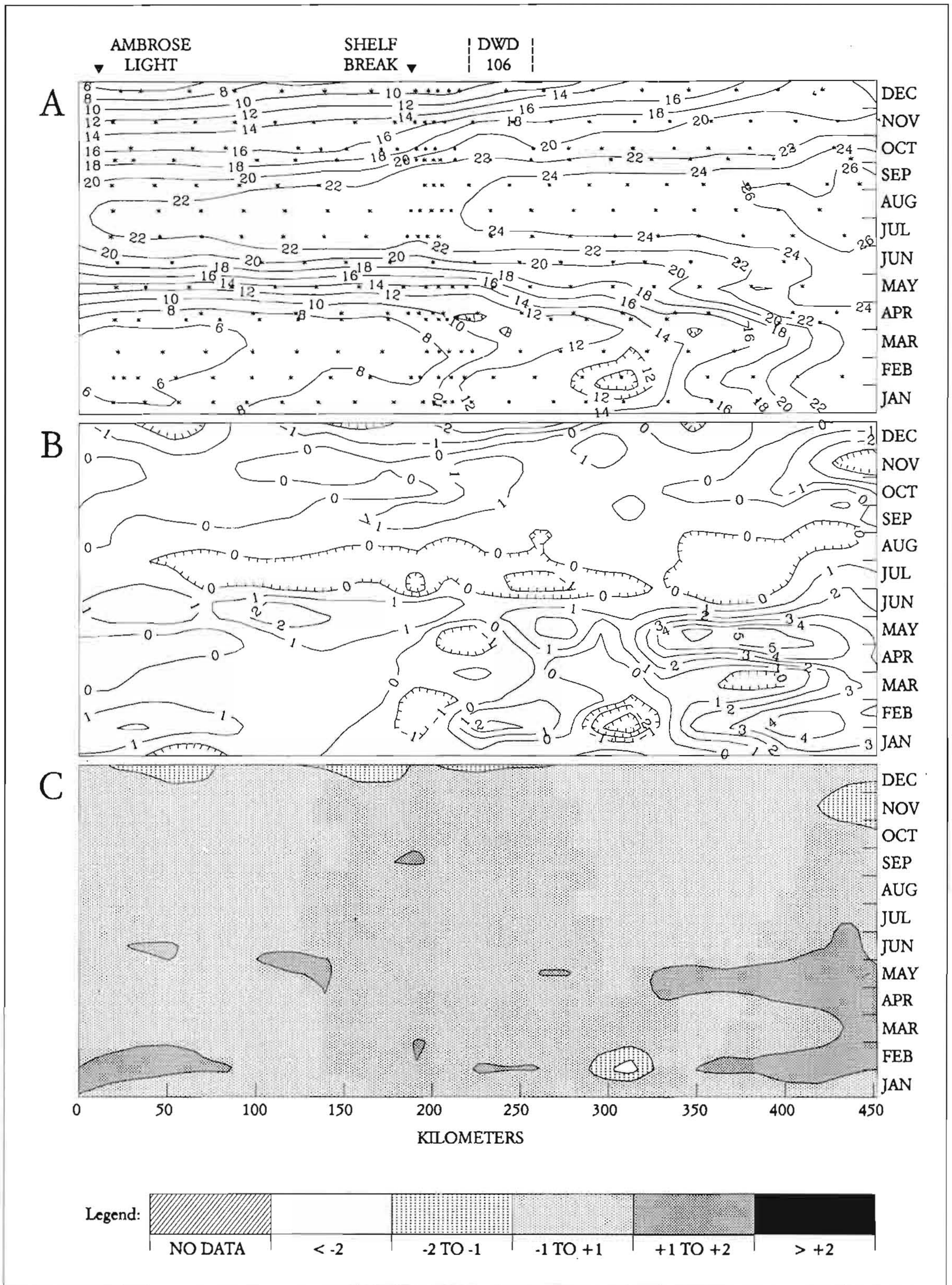

Figure 16

Surface temperature conditions along the Middle Atlantic Bight route during 1989. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

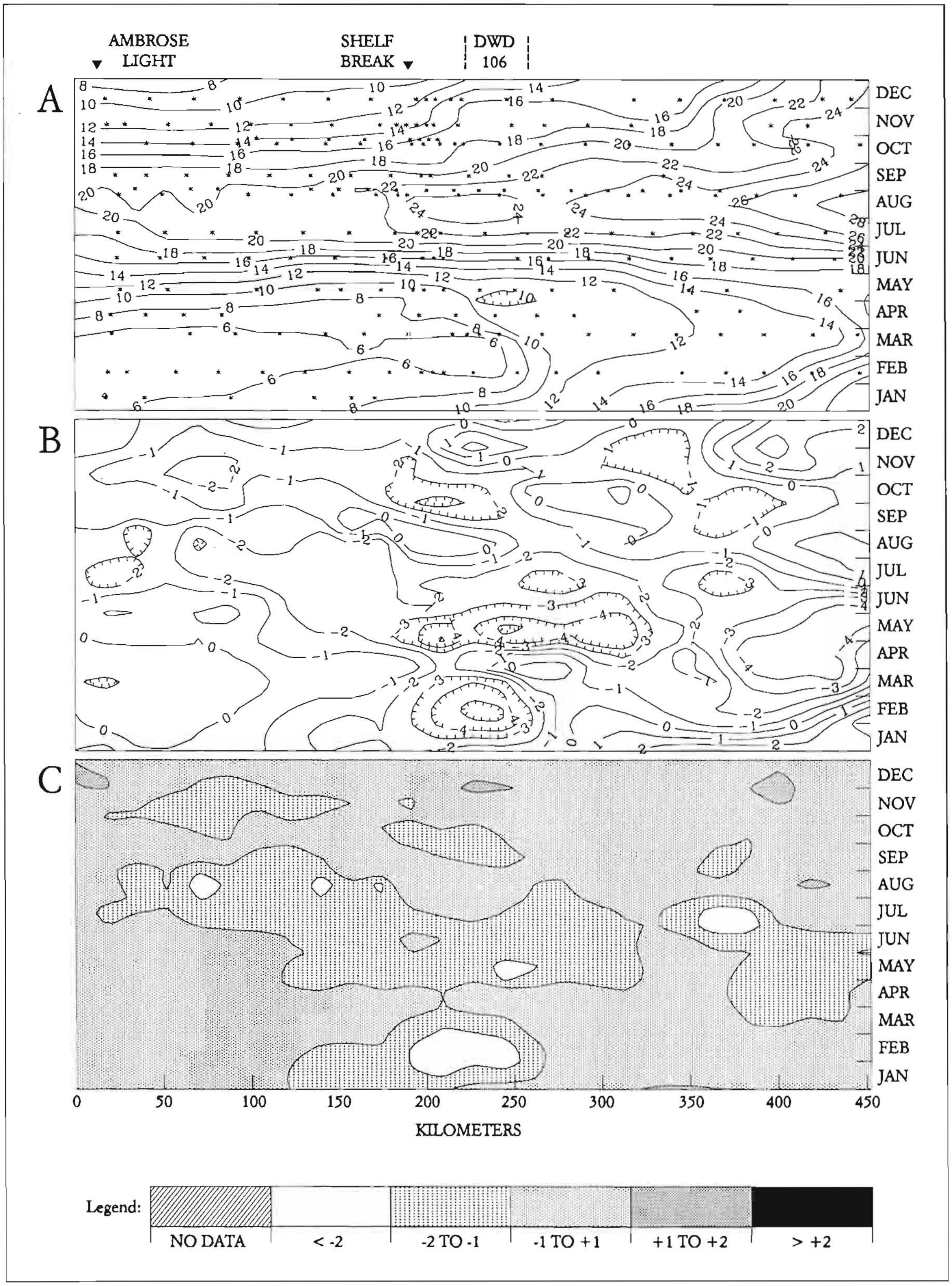

Figure 17

Surface temperature conditions along the Middle Atlantic Bight route during 1988. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

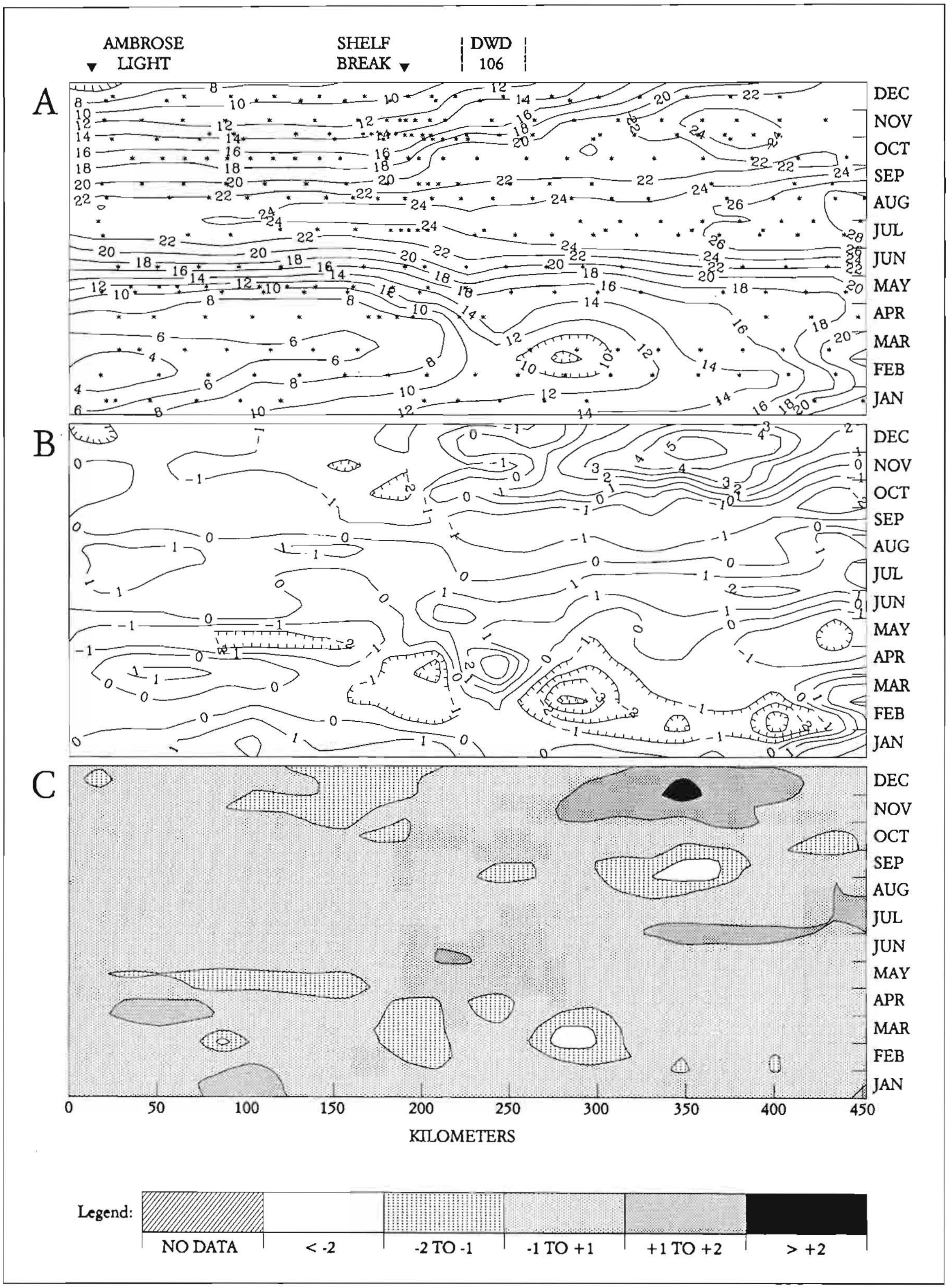

Figure 18

Surface temperature conditions along the Middle Atlantic Bight route during 1987. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

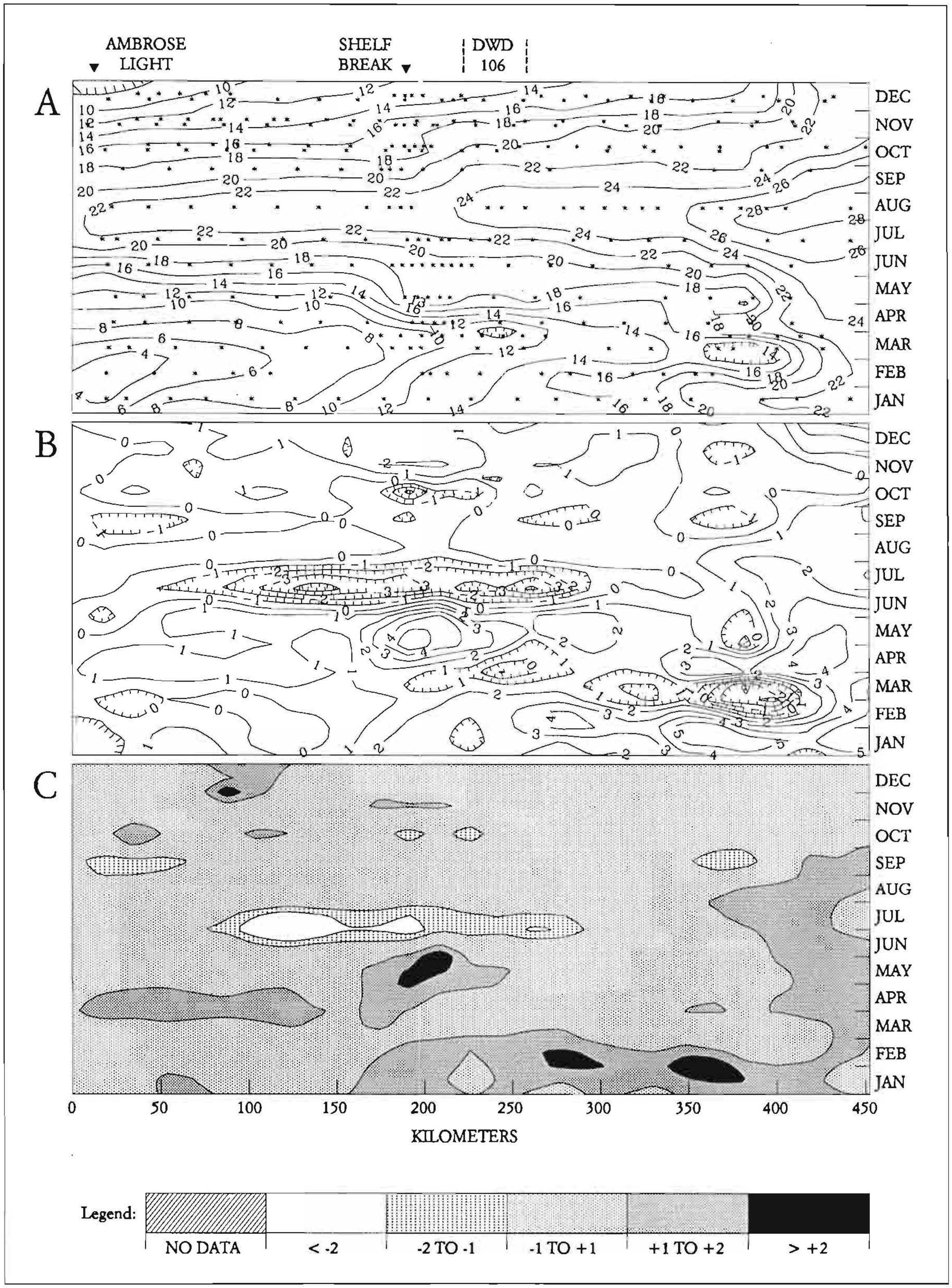

Figure 19

Surface temperature conditions along the Middle Atlantic Bight route during 1986. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

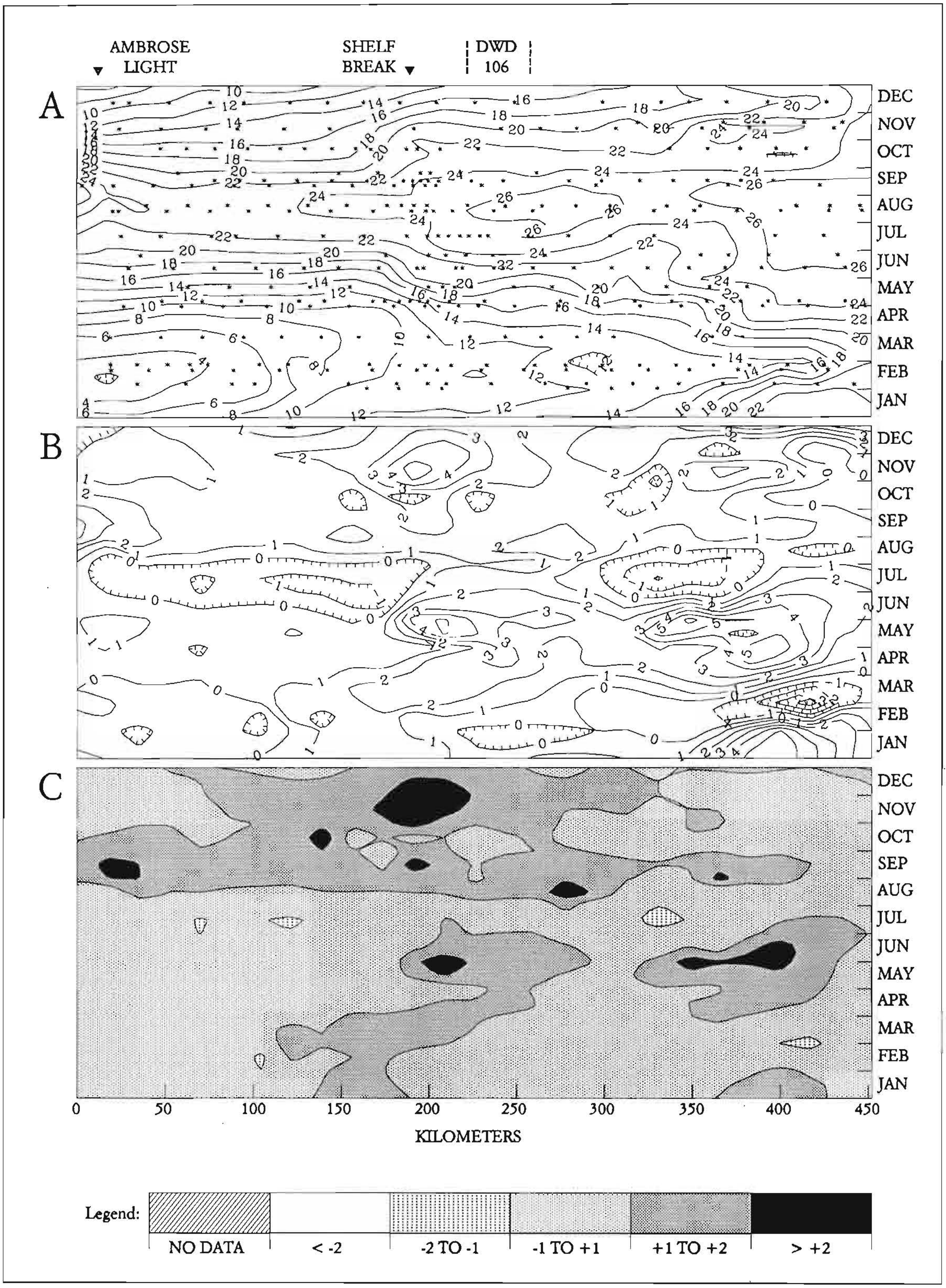

Figure 20

Surface temperature conditions along the Middle Atlantic Bight route during 1985. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

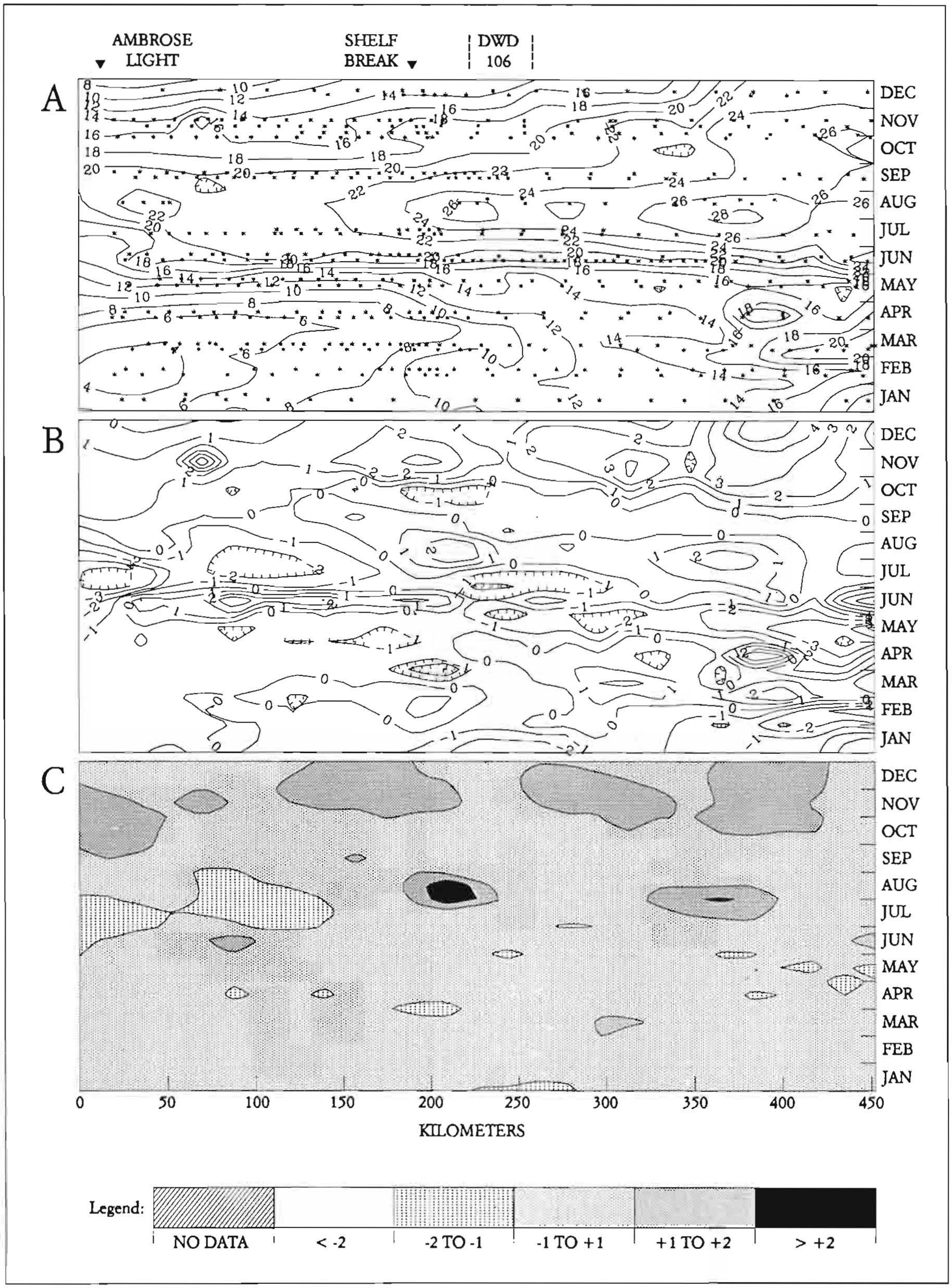

Figure 21

Surface temperature conditions along the Middle Atlantic Bight route during 1984. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

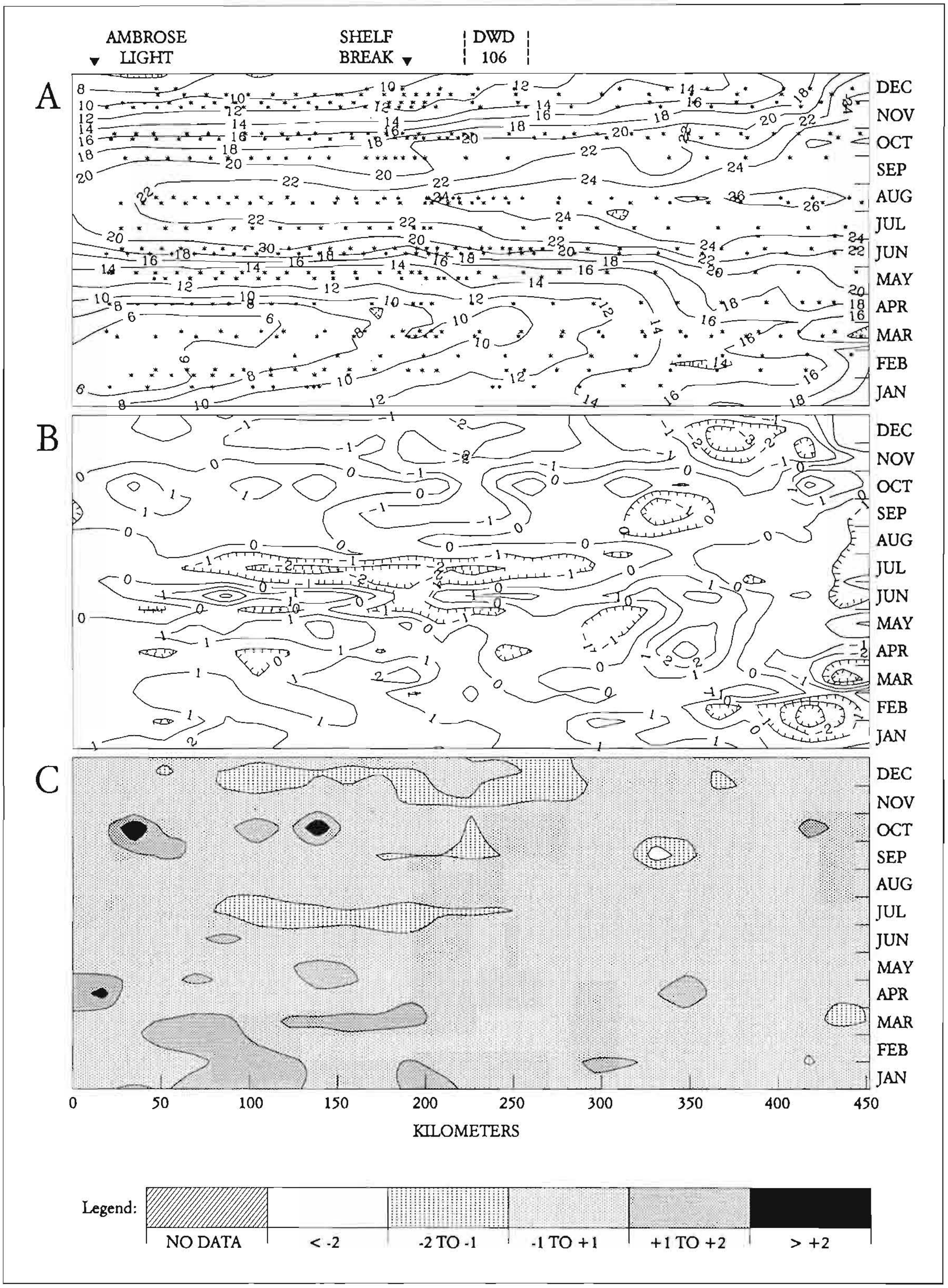

Figure 22

Surface temperature conditions along the Middle Atlantic Bight route during 1983. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

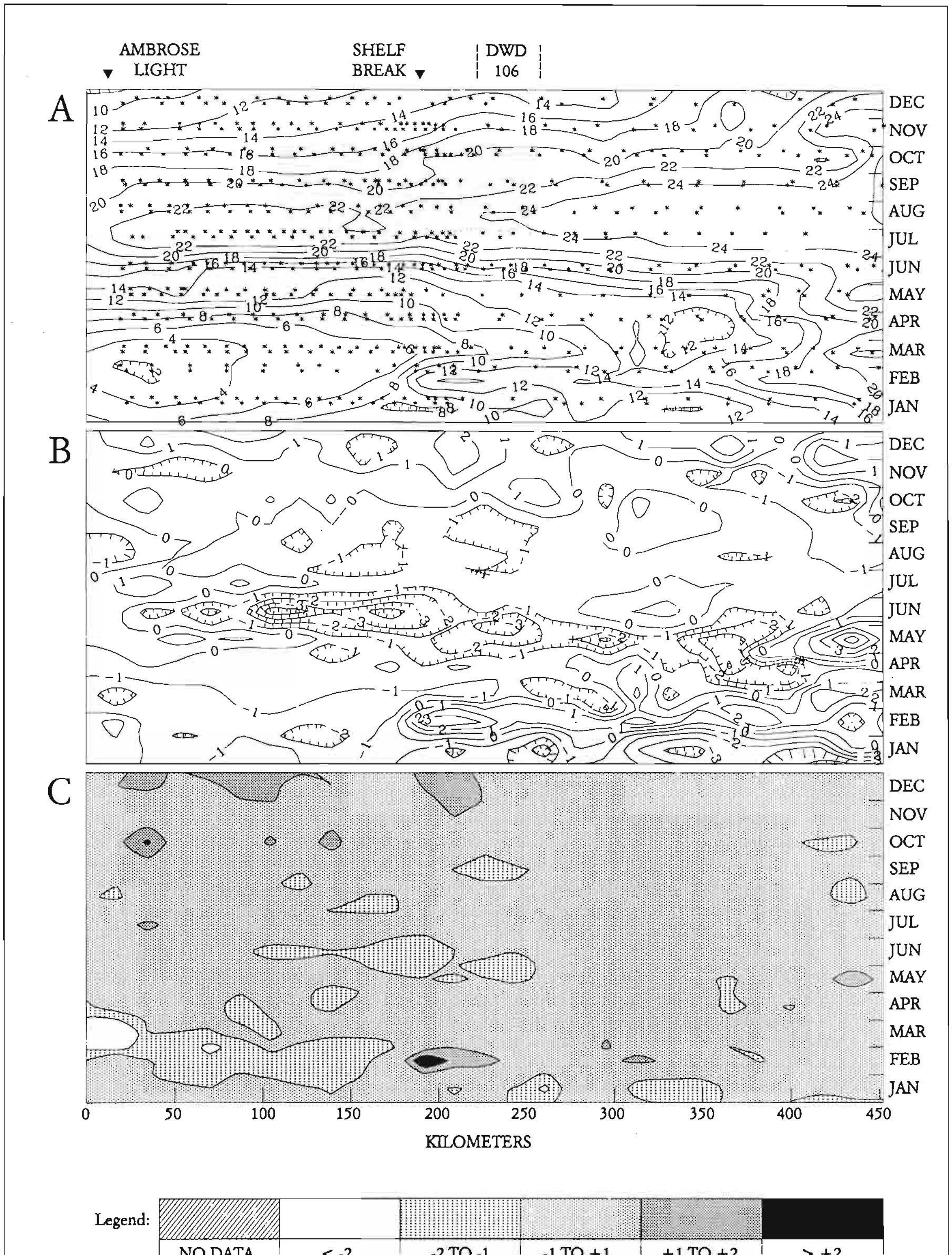

Figure 23

Surface temperature conditions along the Middle Atlantic Bight route during 1982. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

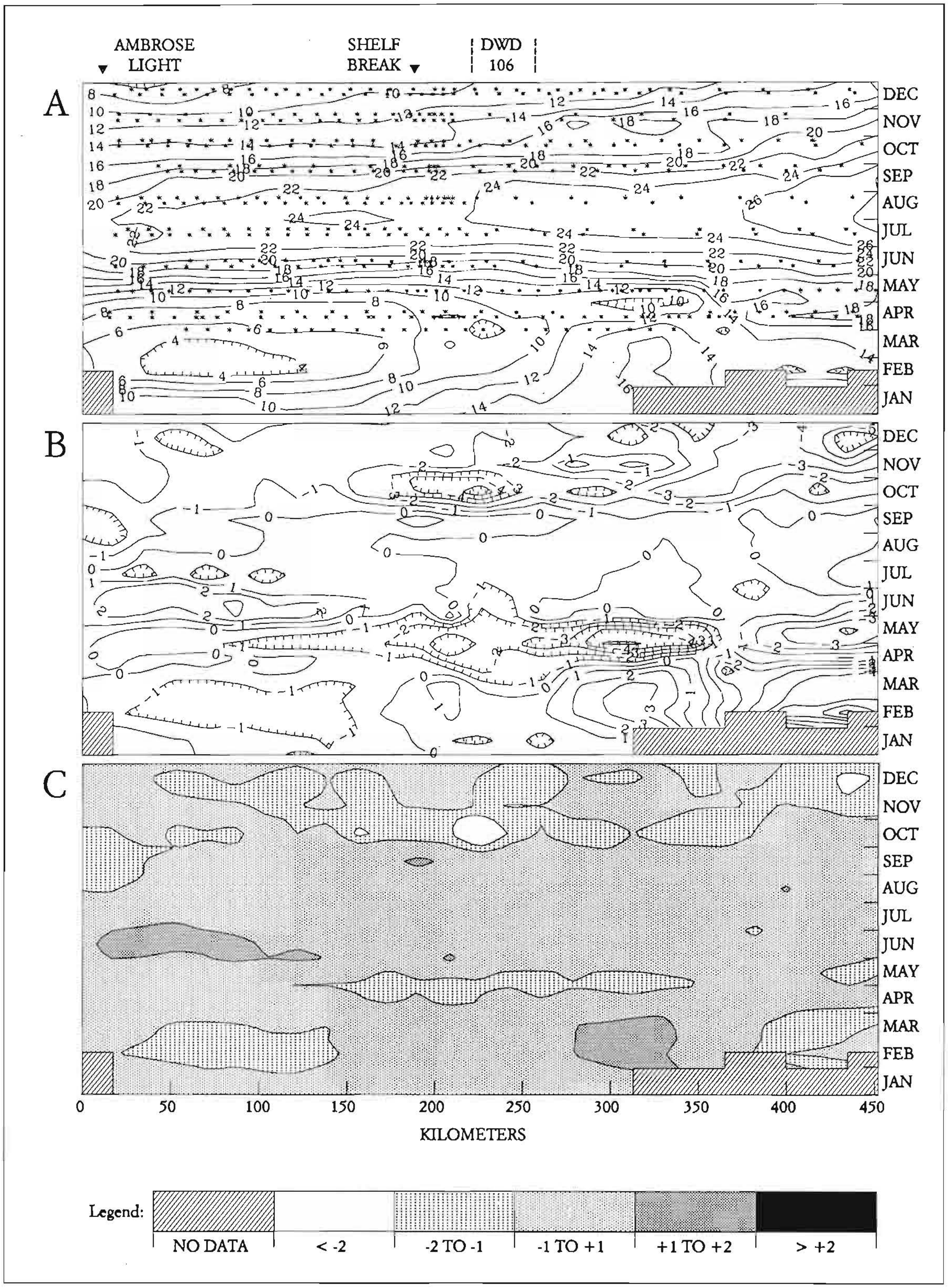

Figure 24

Surface temperature conditions along the Middle Atlantic Bight route during 1981. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

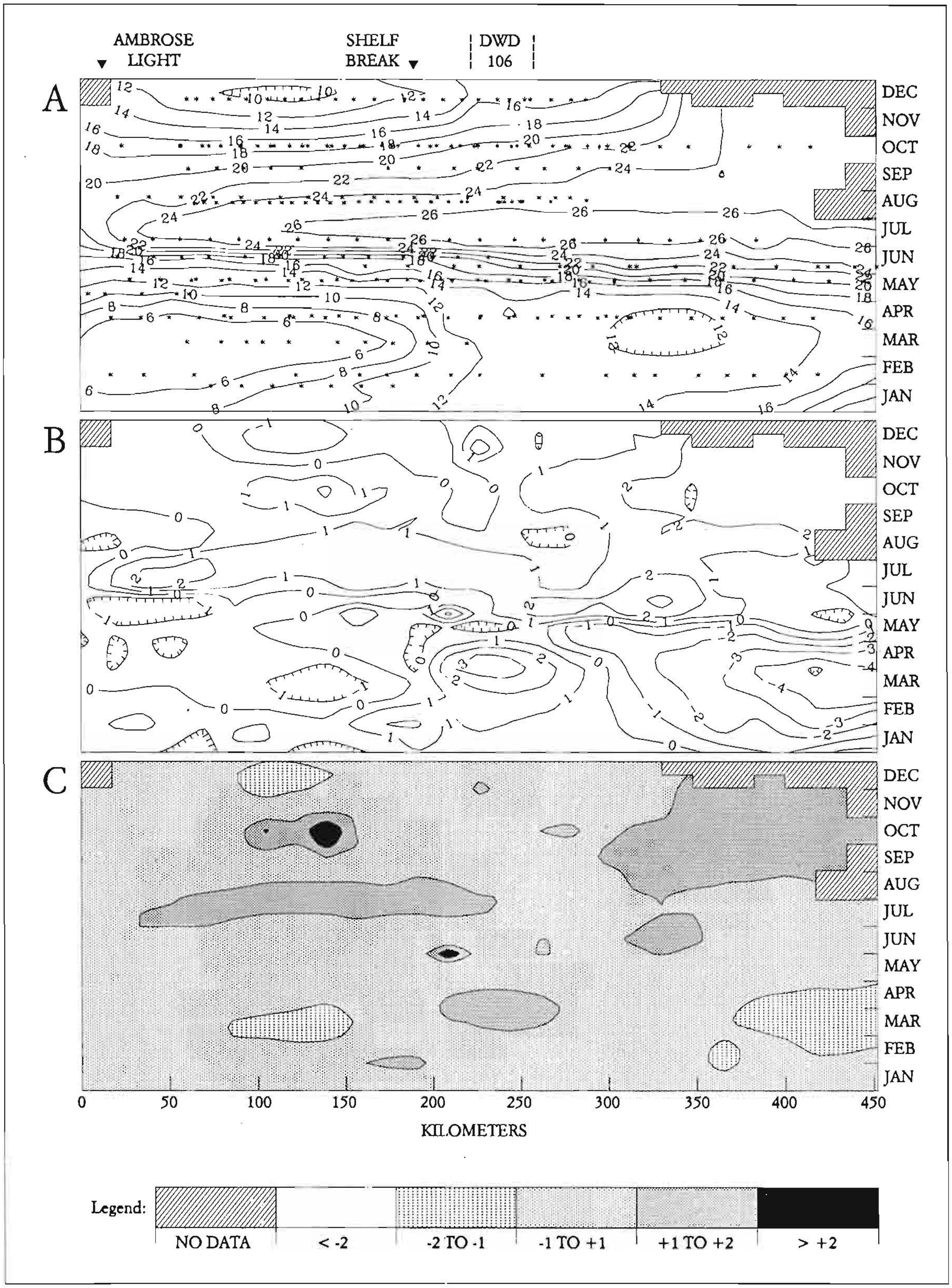

Figure 25

Surface temperature conditions along the Middle Atlantic Bight route during 1980. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

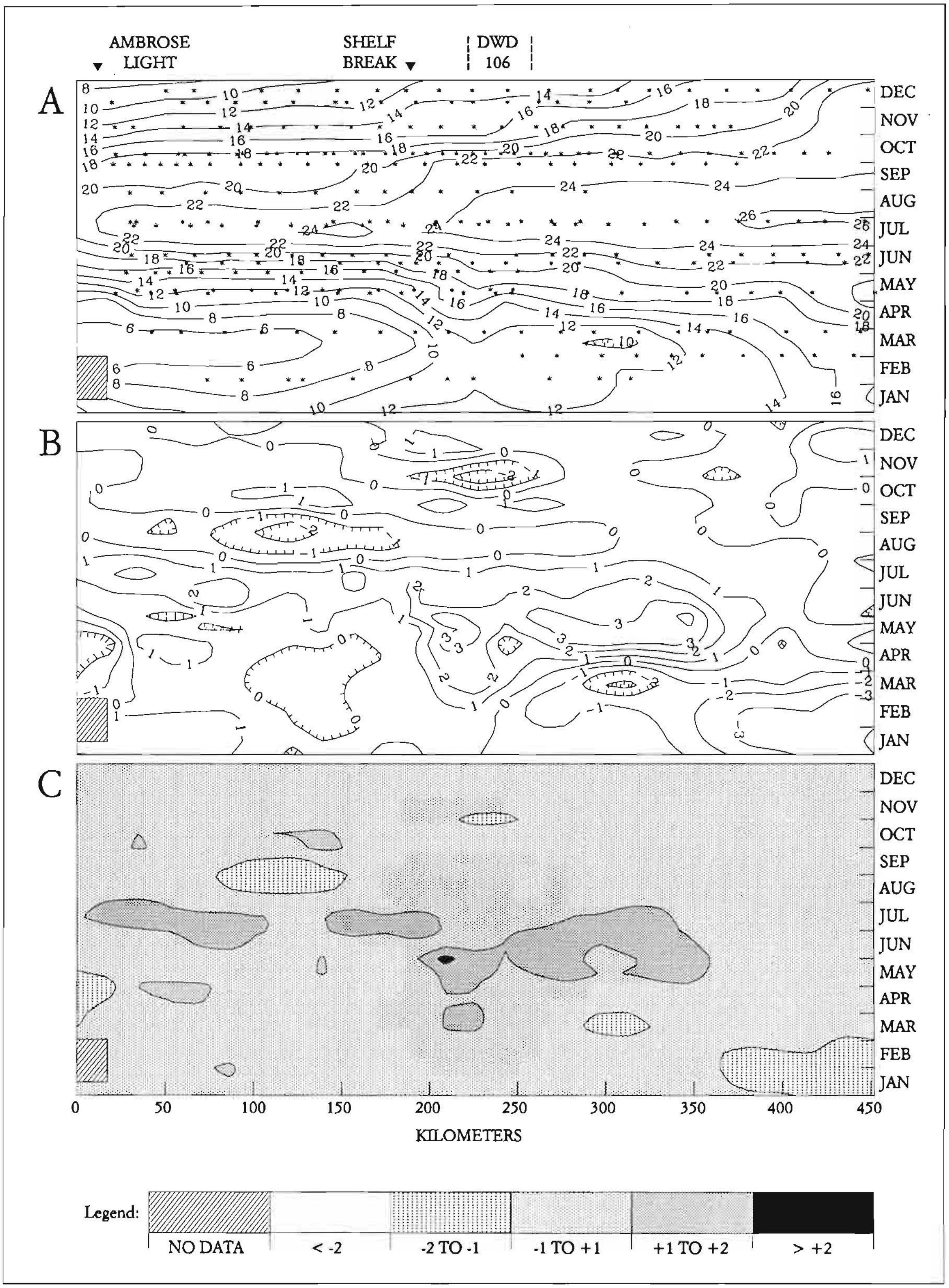

Figure 26

Surface temperature conditions along the Middle Atlantic Bight route during 1979. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

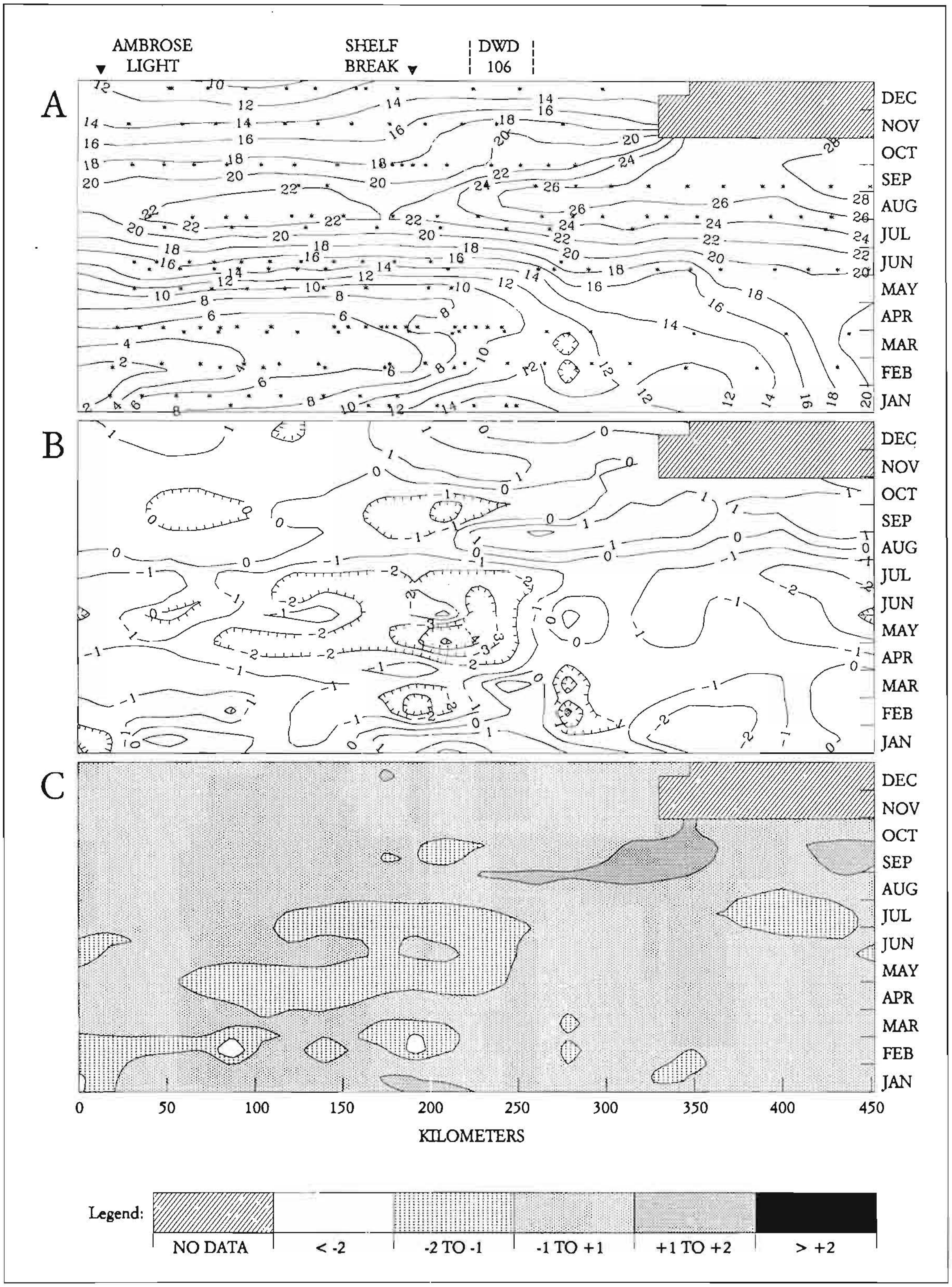

Figure 27

Surface temperature conditions along the Middle Atlantic Bight route during 1978. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

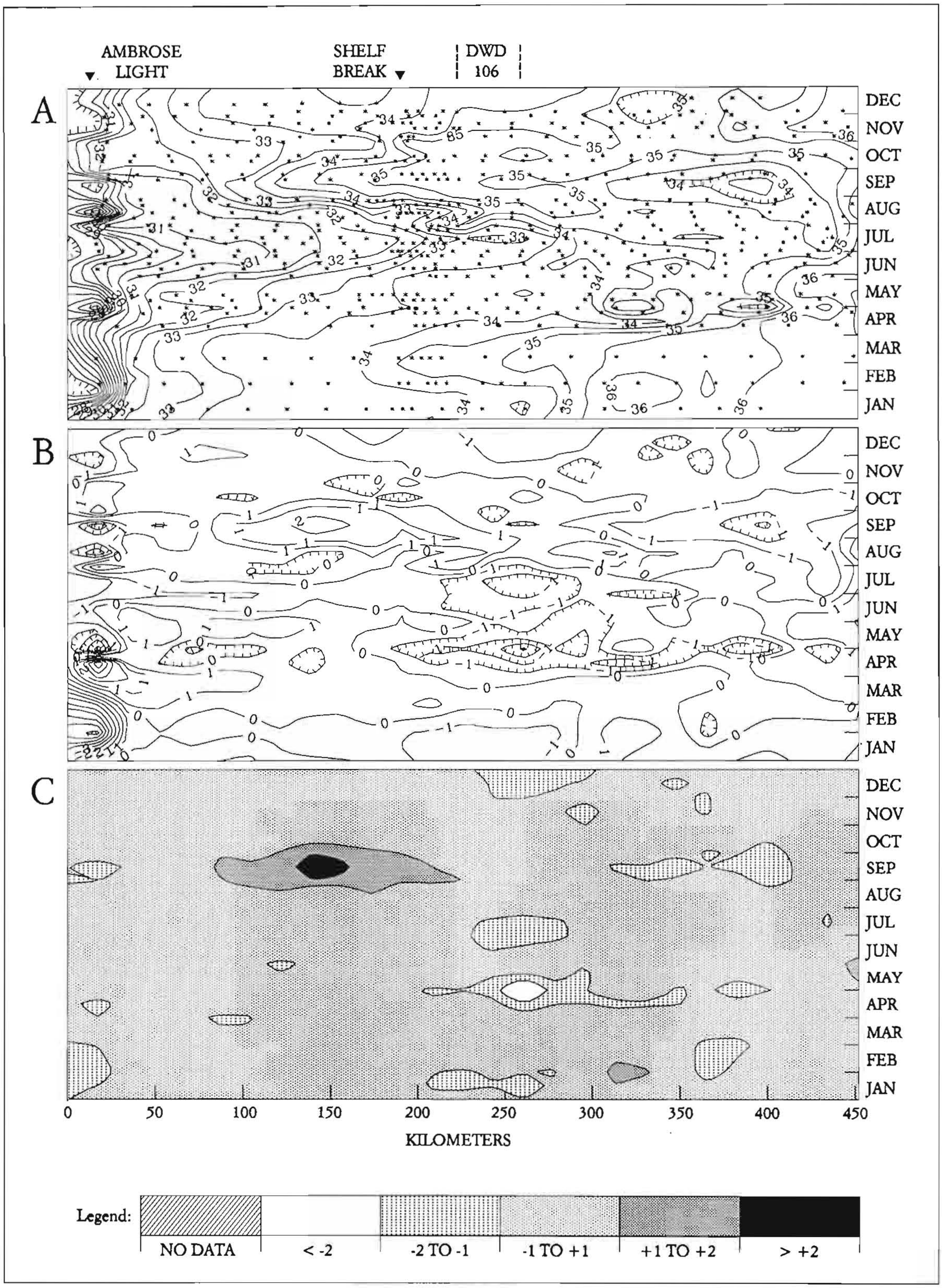

Figure 28

Surface salinity conditions along the Middle Atlantic Bight route during 1990. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

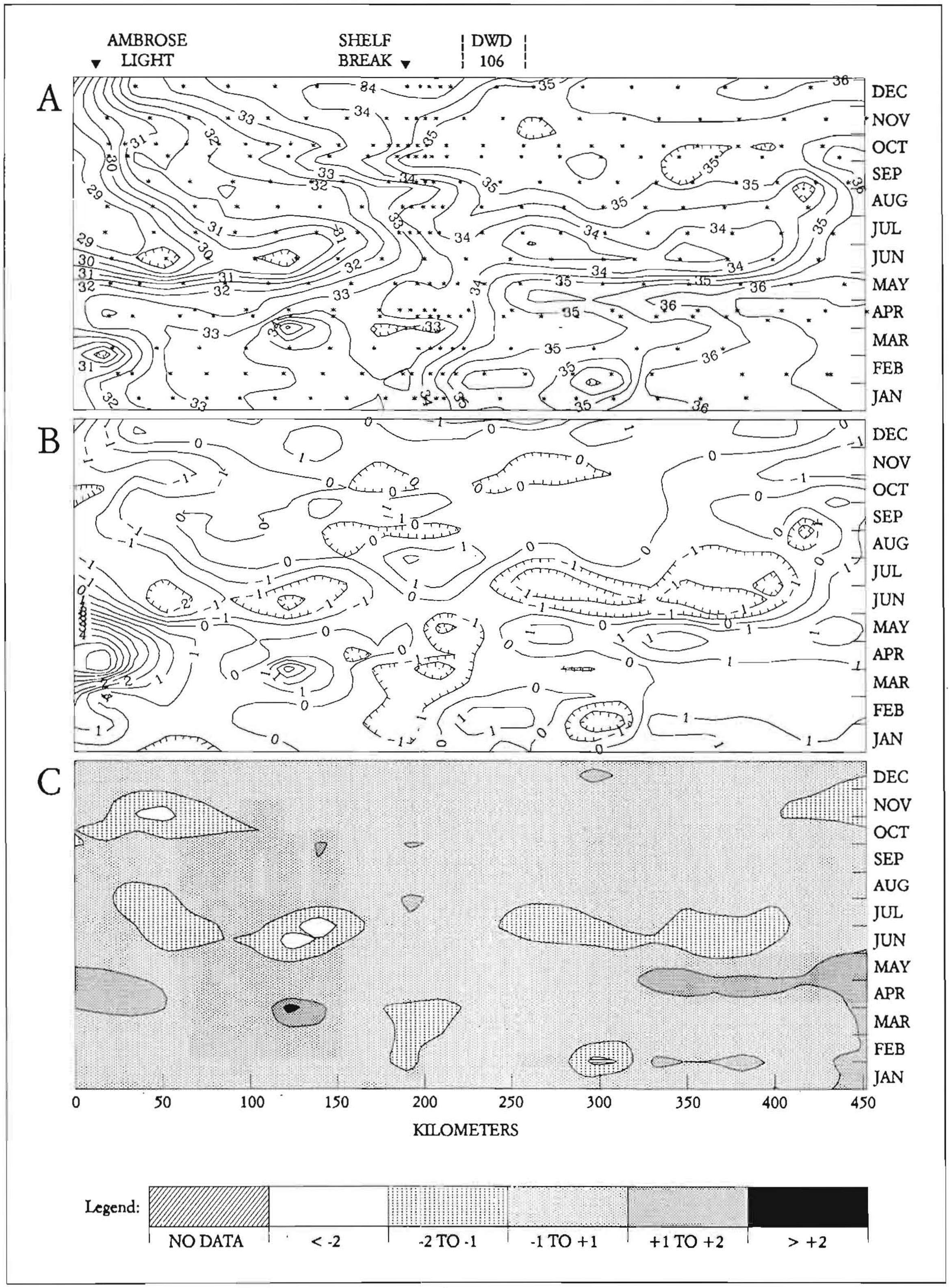

Figure 29

Surface salinity conditions along the Middle Atlantic Bight route during 1989. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

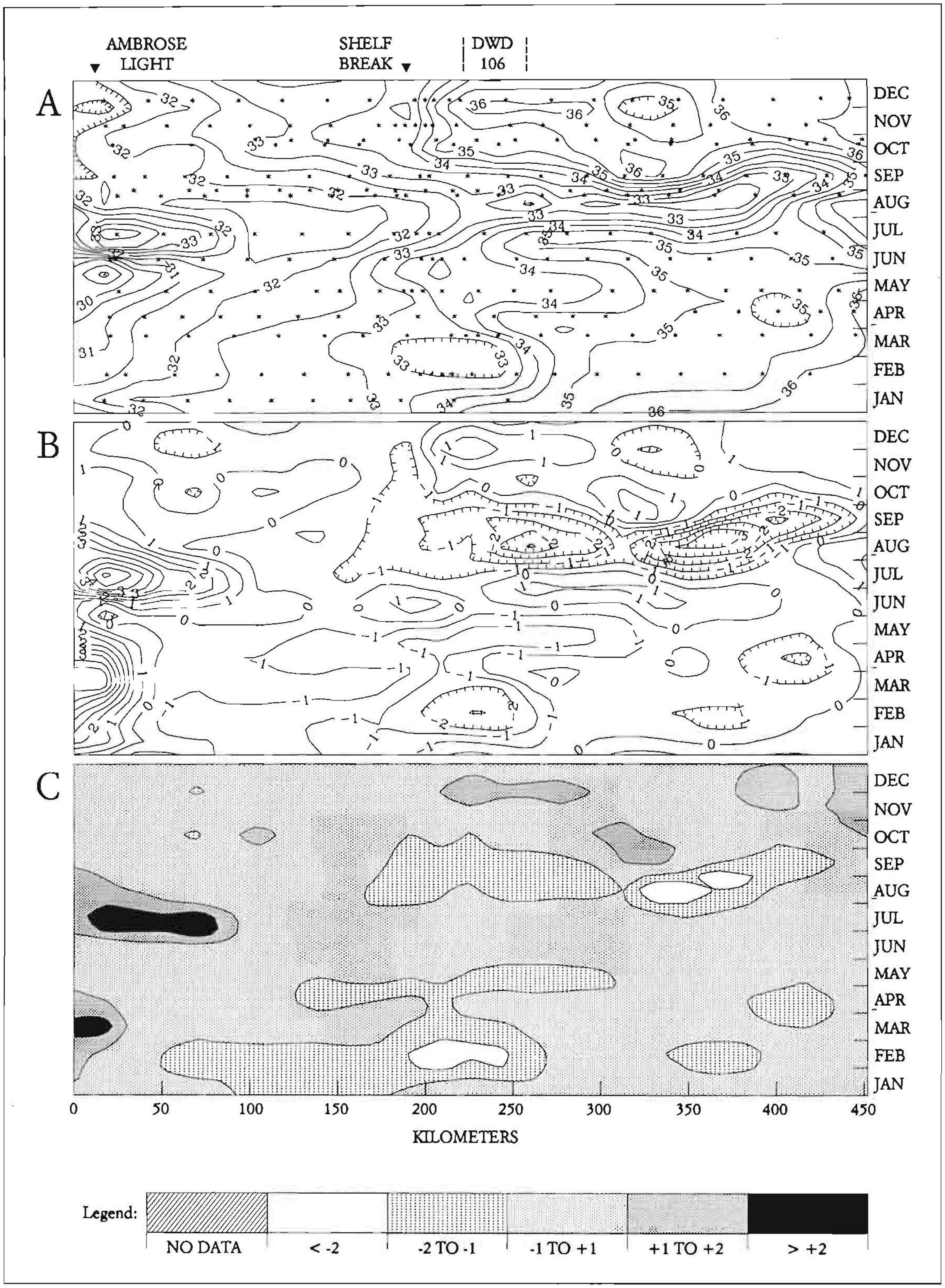

Figure 30

Surface salinity conditions along the Middle Atlantic Bight route during 1988. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

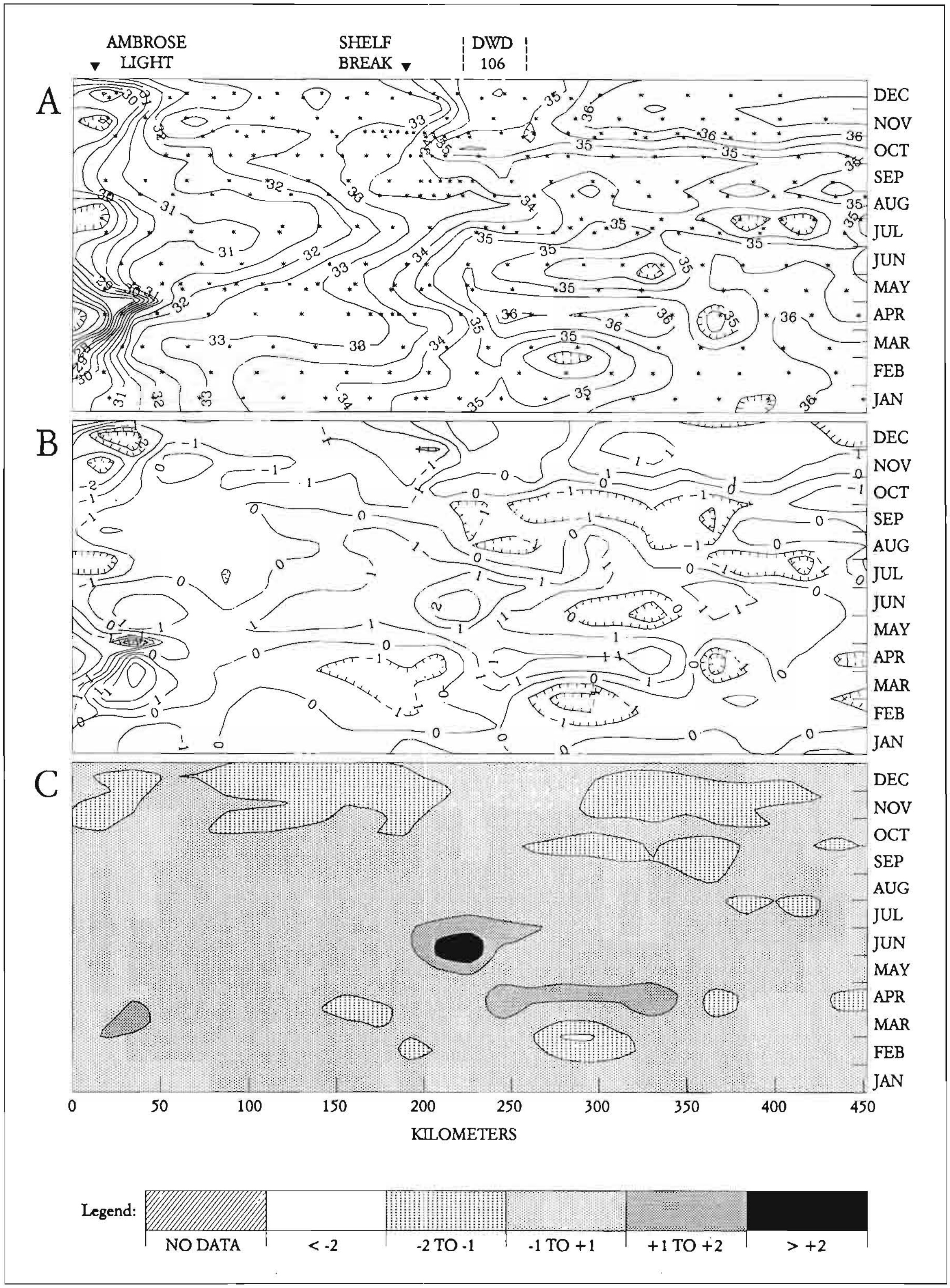

Figure 31

Surface salinity conditions along the Middle Atlantic Bight route during 1987. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

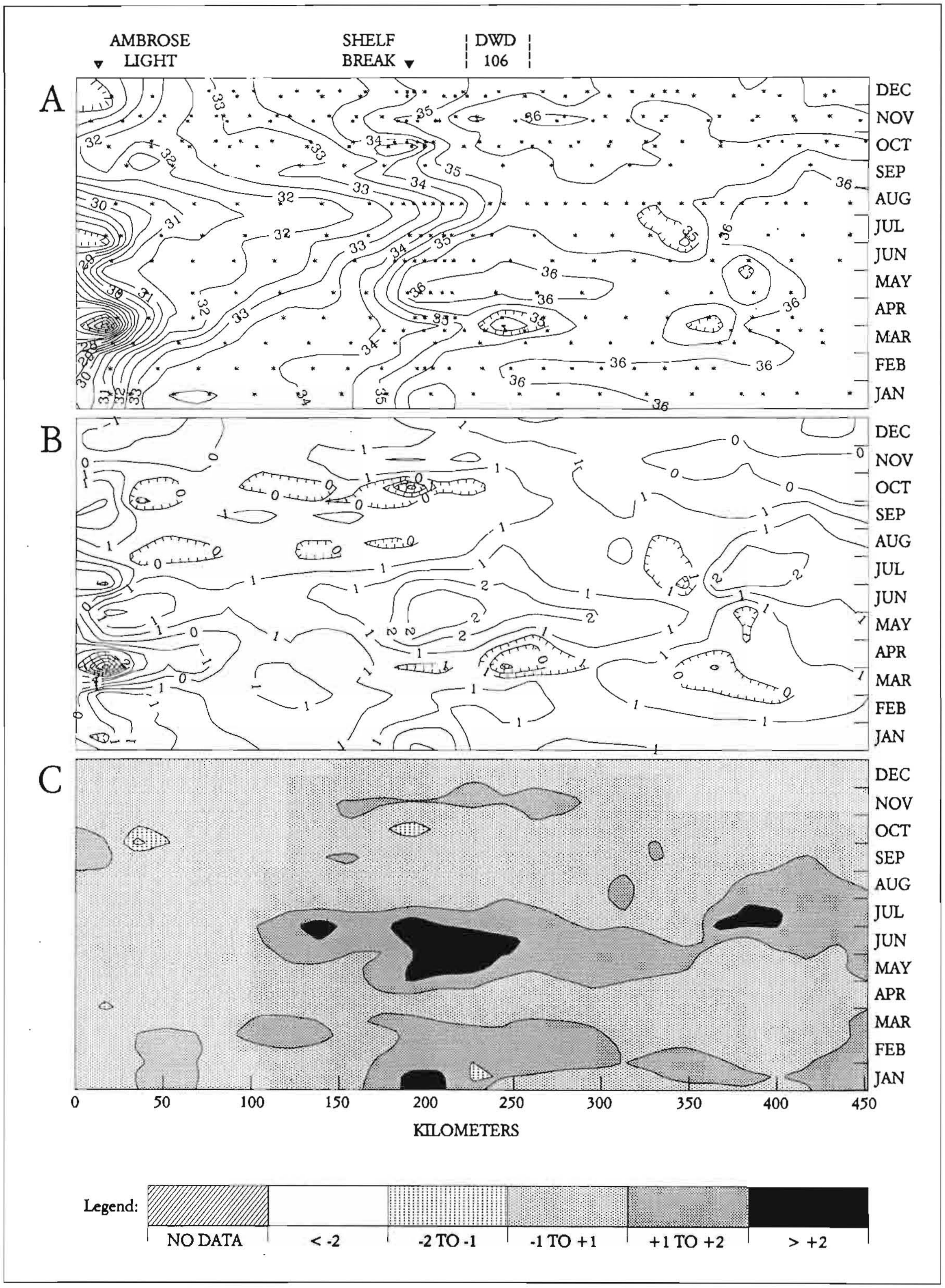

Figure 32

Surface salinity conditions along the Middle Atlantic Bight route during 1986. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

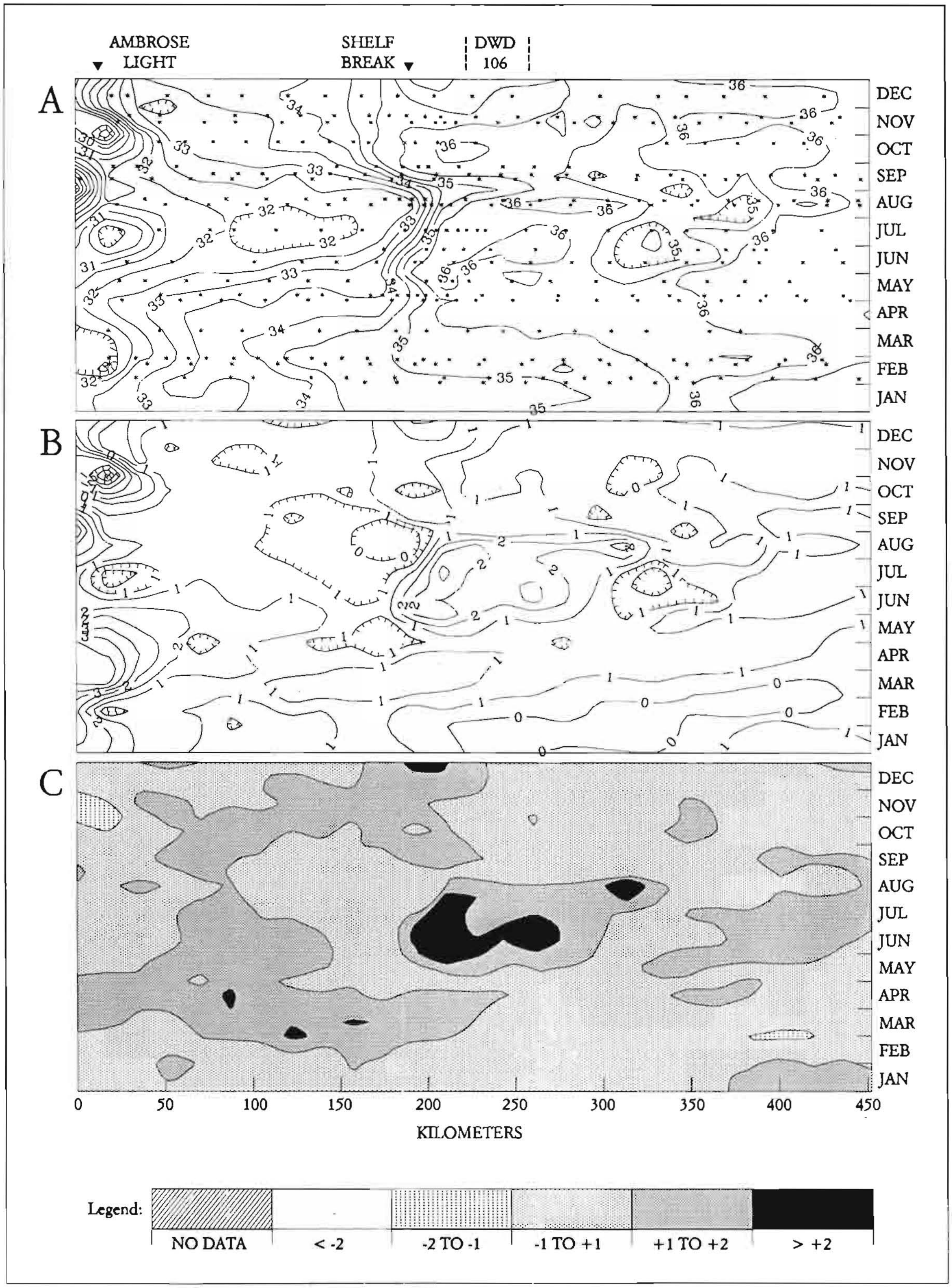

Figure 33

Surface salinity conditions along the Middle Atlantic Bight route during 1985. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

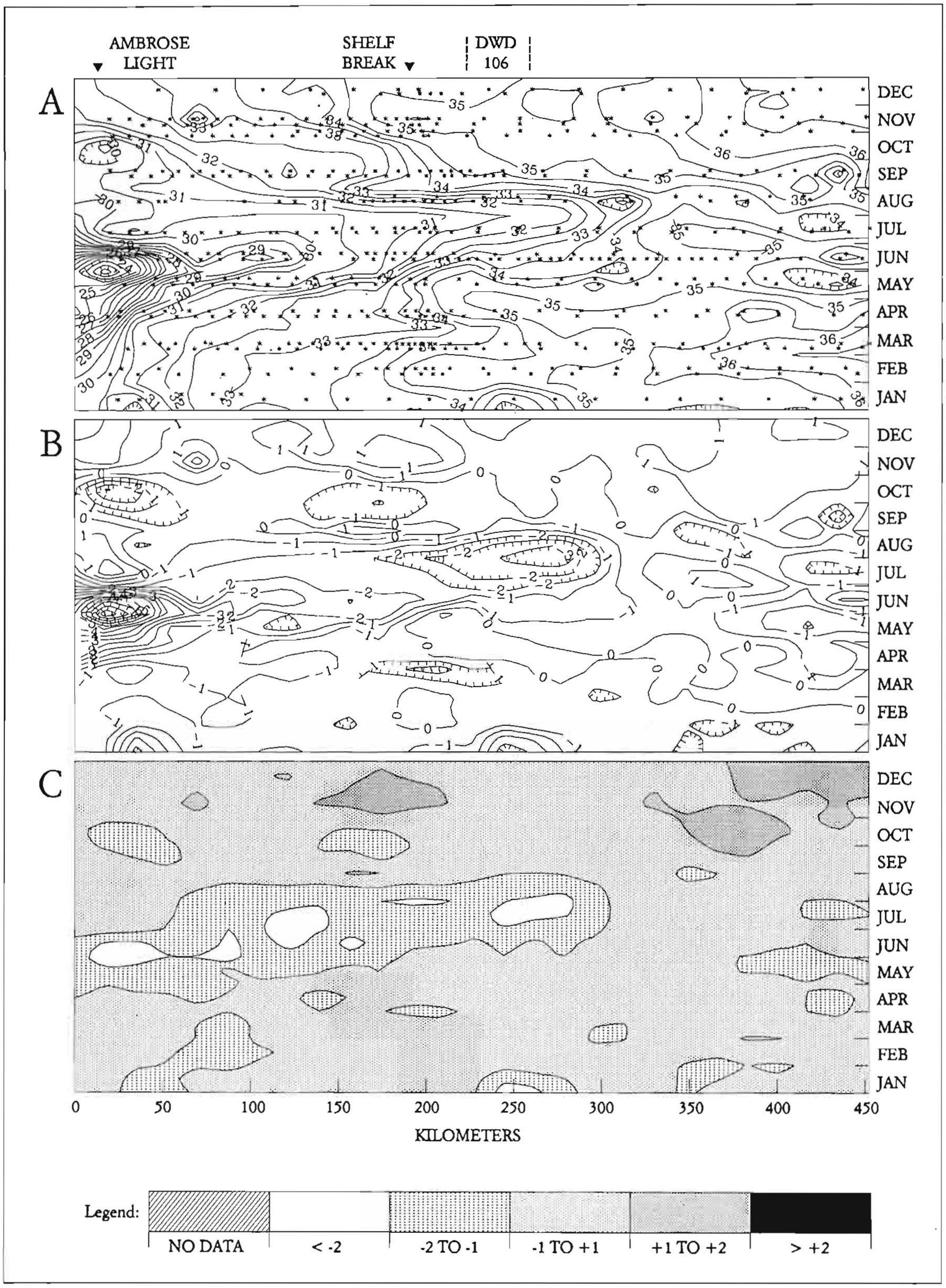

Figure 34

Surface salinity conditions along the Middle Atlantic Bight route during 1984. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

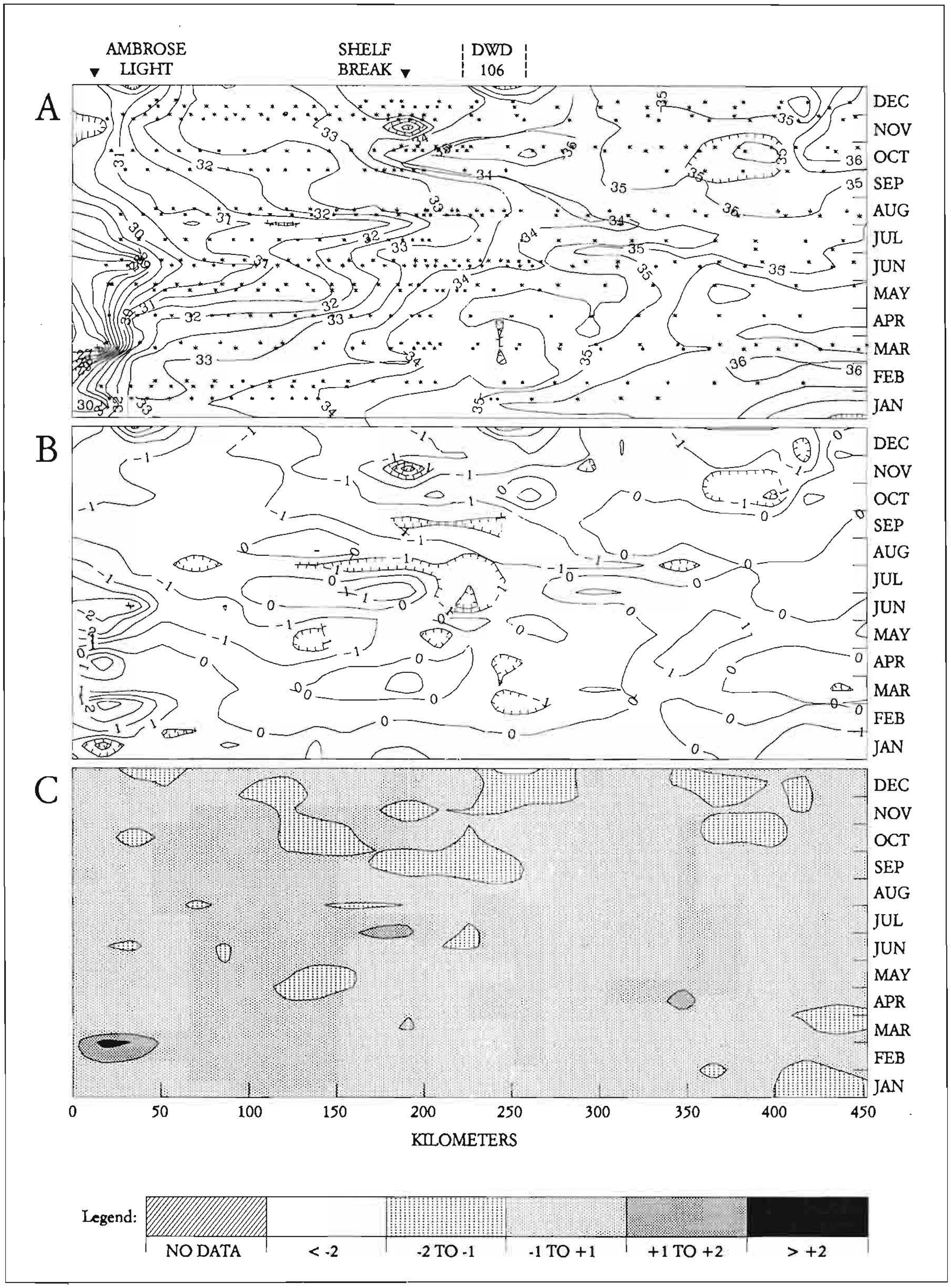

Figure 35
Surface salinity conditions along the Middle Atlantic Bight route during 1983. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

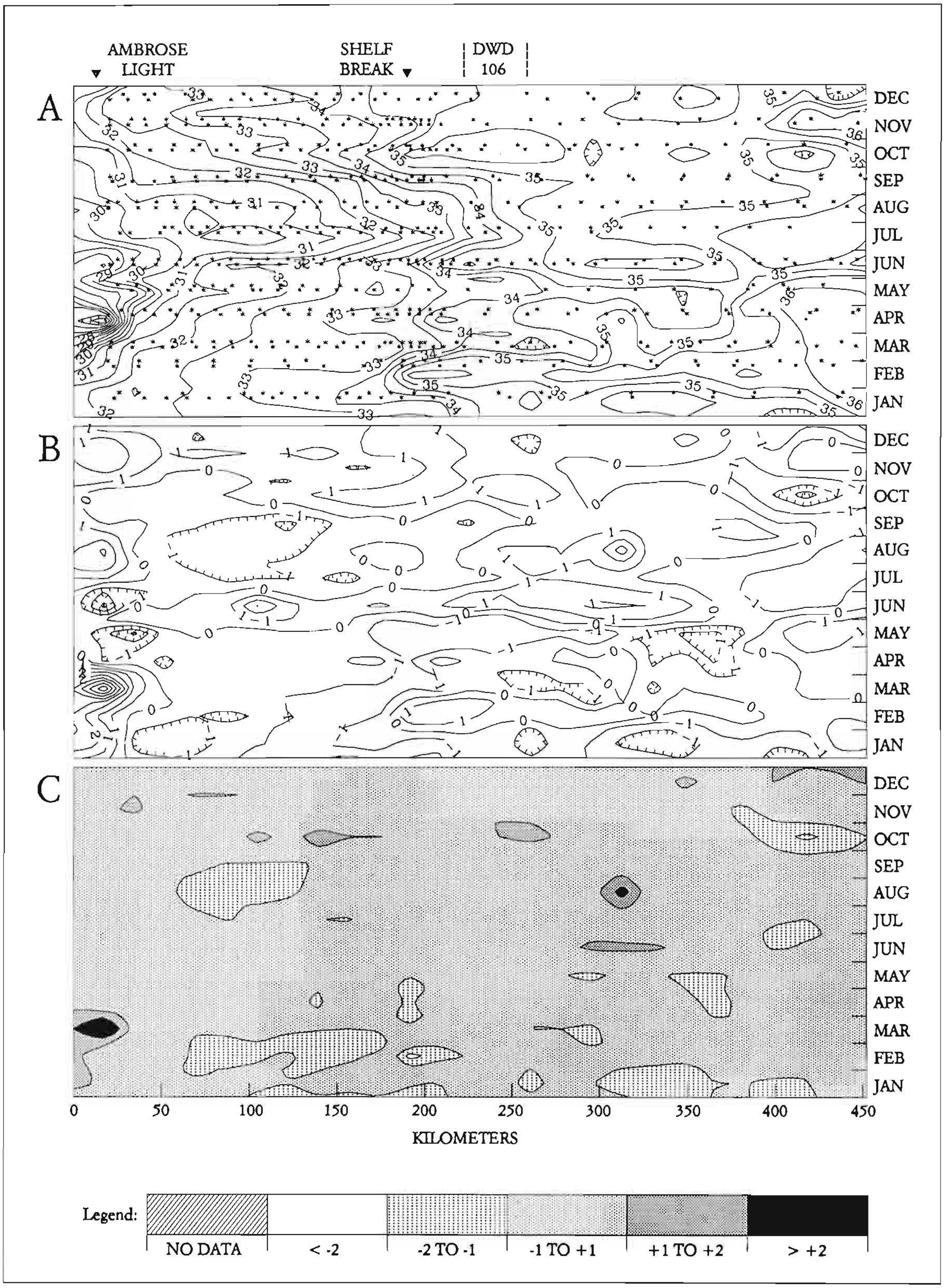

Figure 36

Surface salinity conditions along the Middle Atlantic Bight route during 1982. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

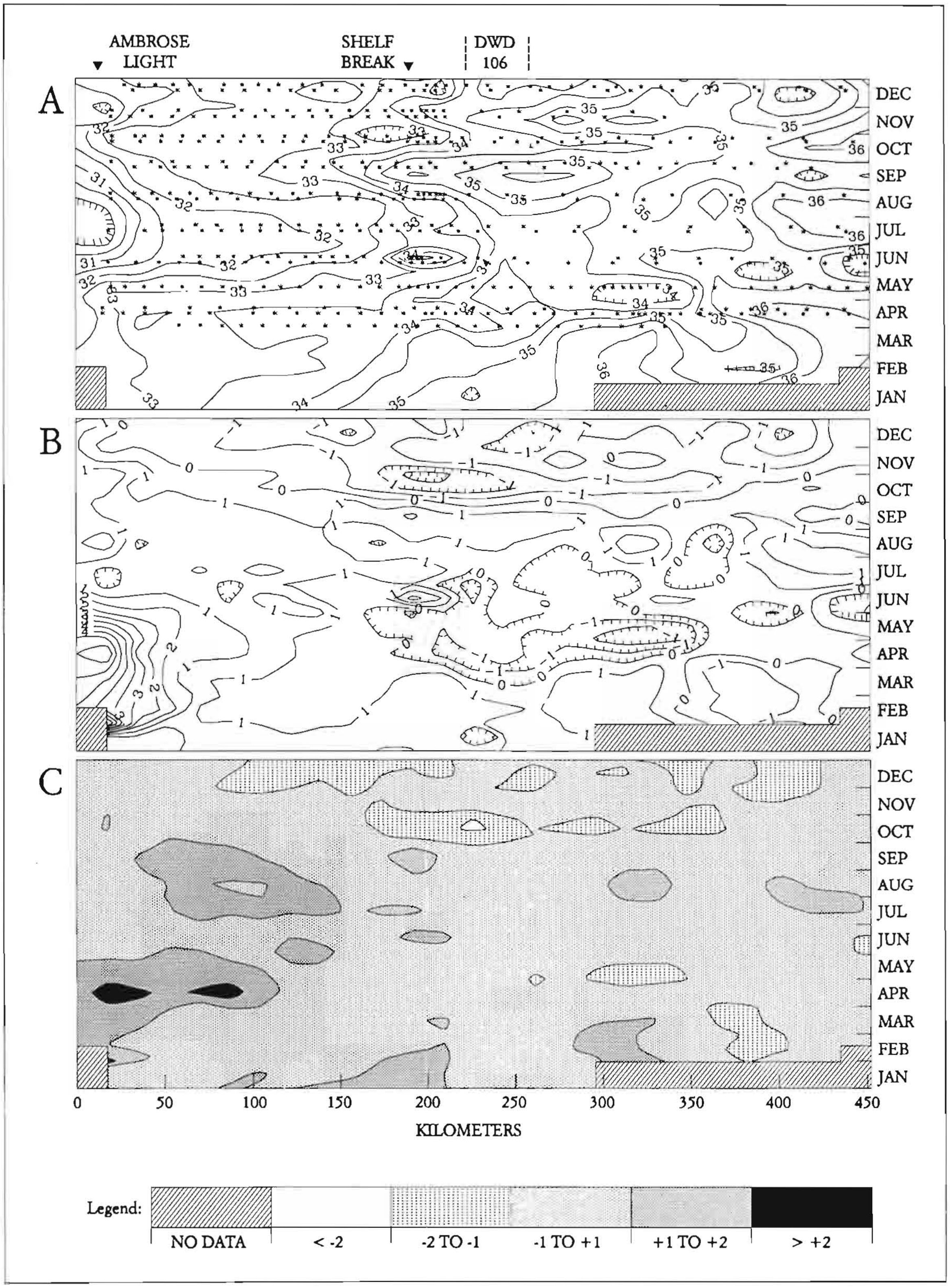

Figure 37
Surface salinity conditions along the Middle Atlantic Bight route during 1981. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

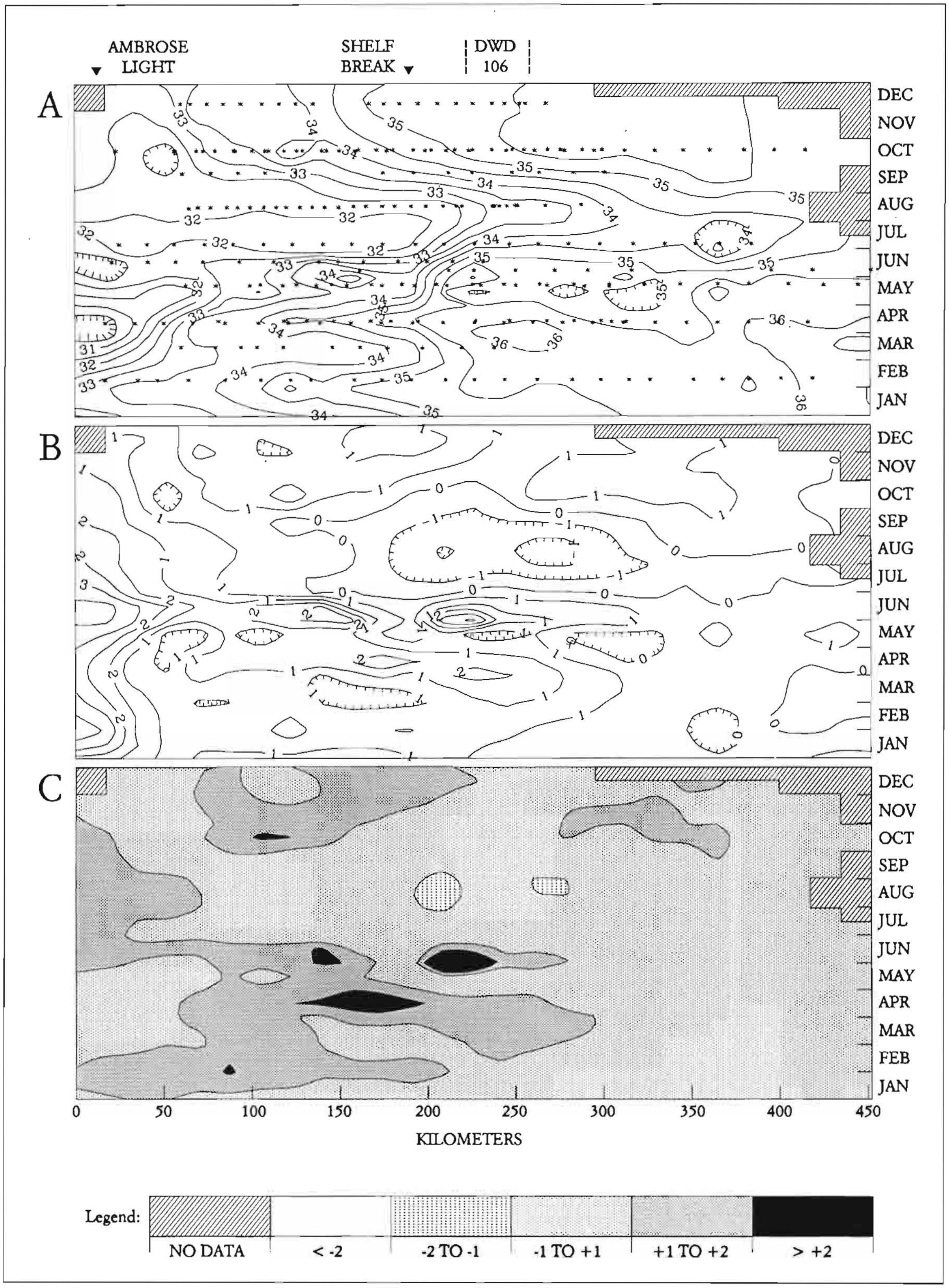

Figure 38

Surface salinity conditions along the Middle Atlantic Bight route during 1980. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

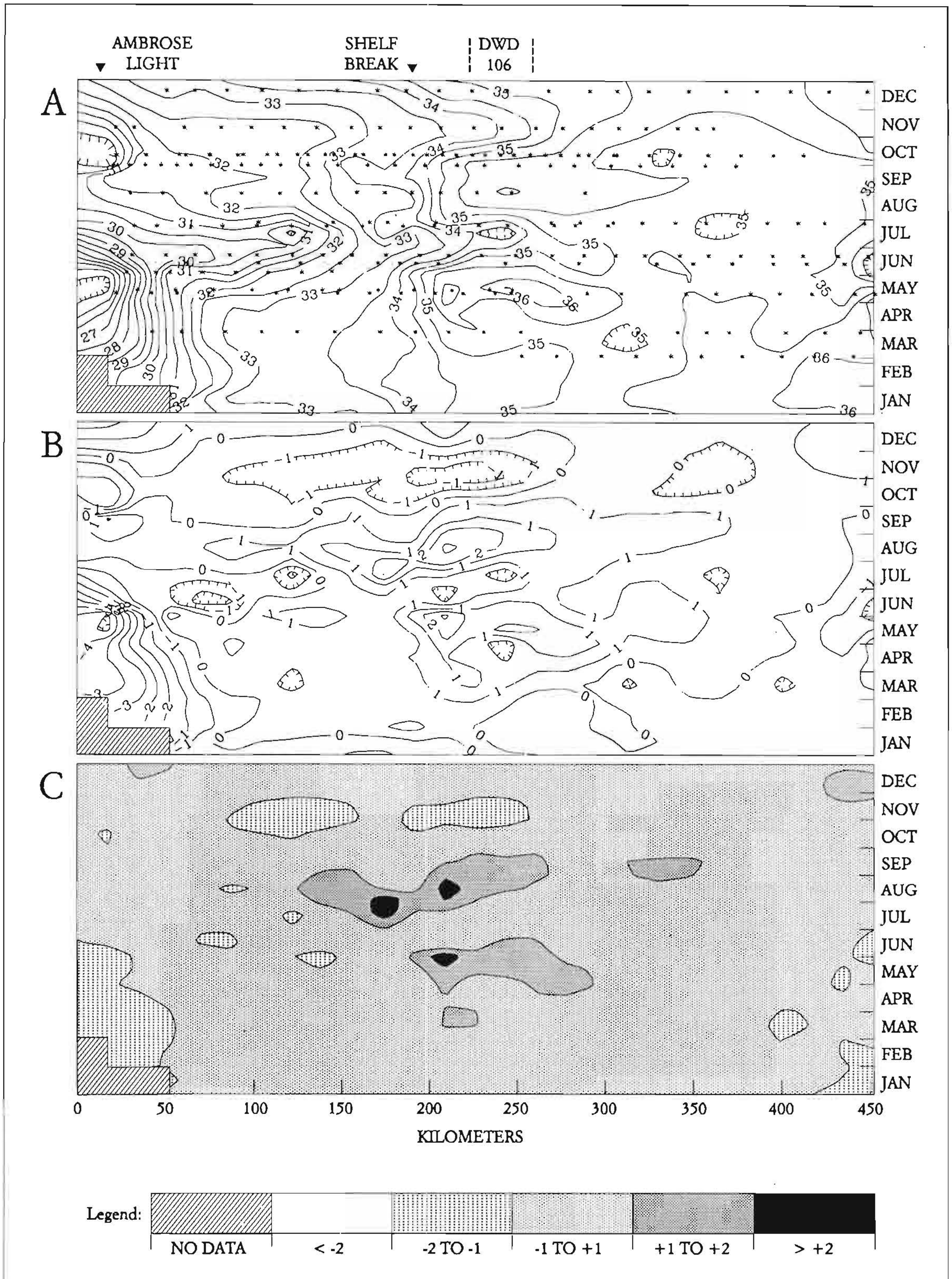

Figure 39
Surface salinity conditions along the Middle Atlantic Bight route during 1979. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

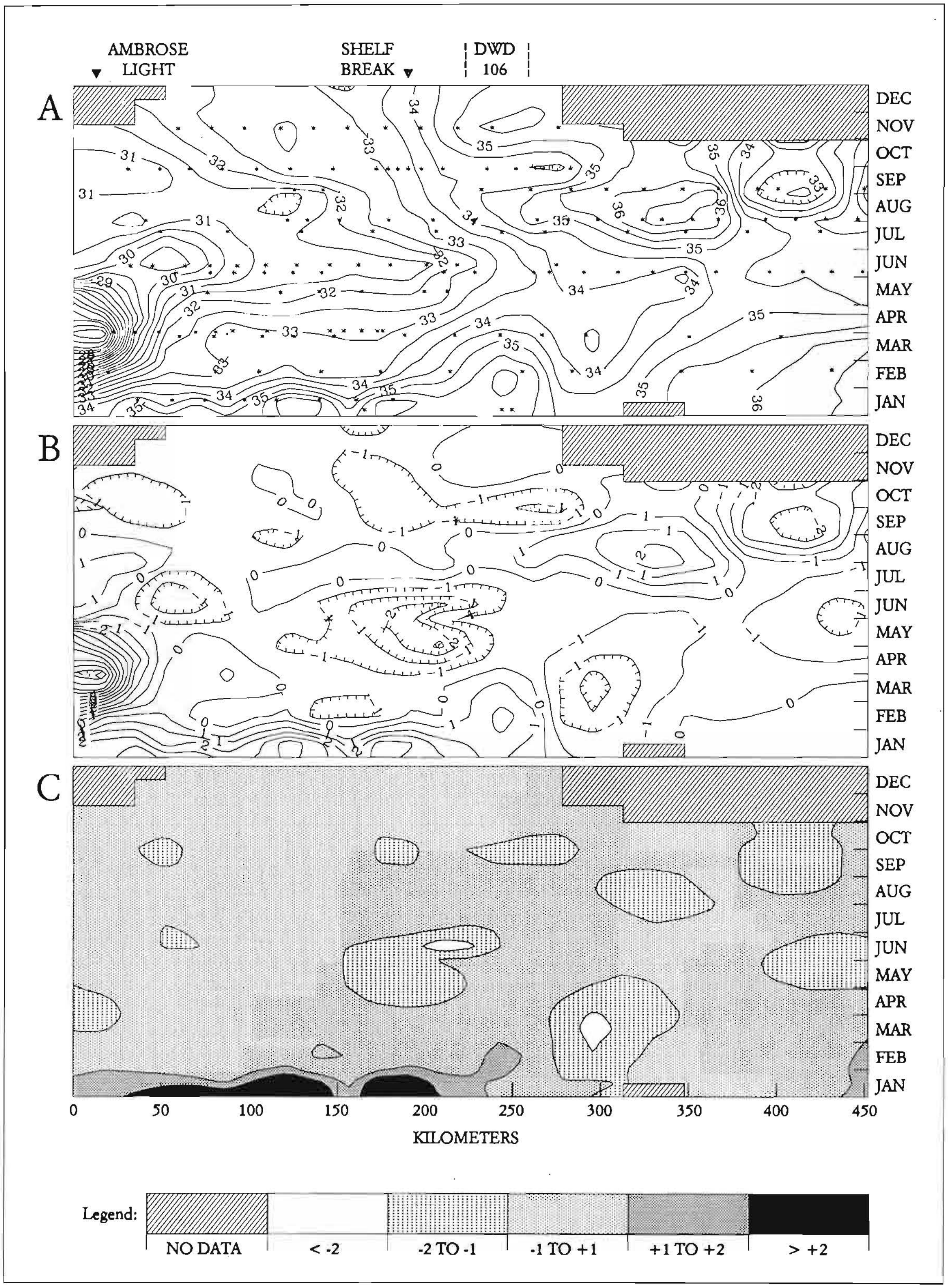

Figure 40

Surface salinity conditions along the Middle Atlantic Bight route during 1978. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

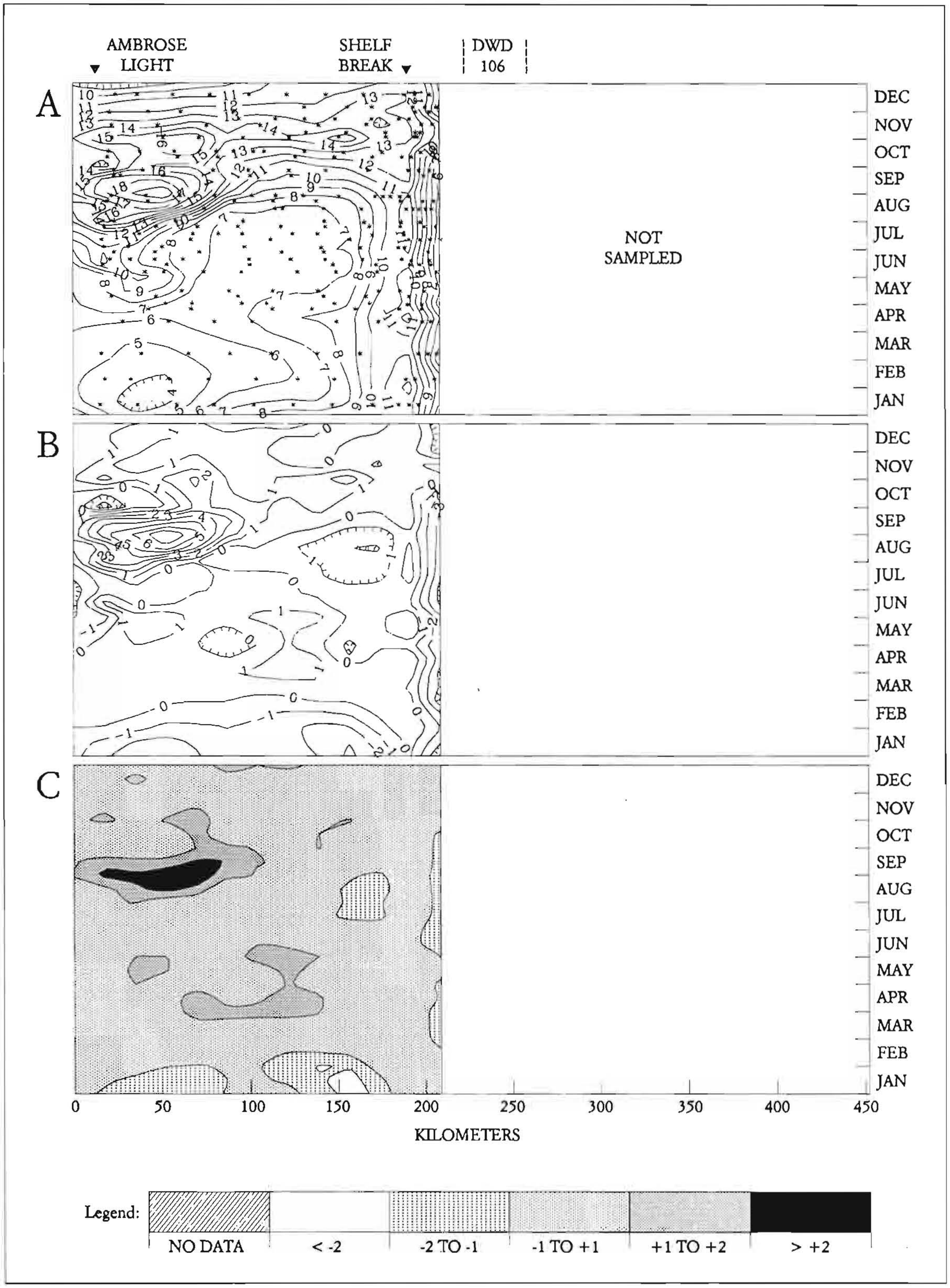

Figure 41

Bottom temperature conditions along the Middle Atlantic Bight route during 1990. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

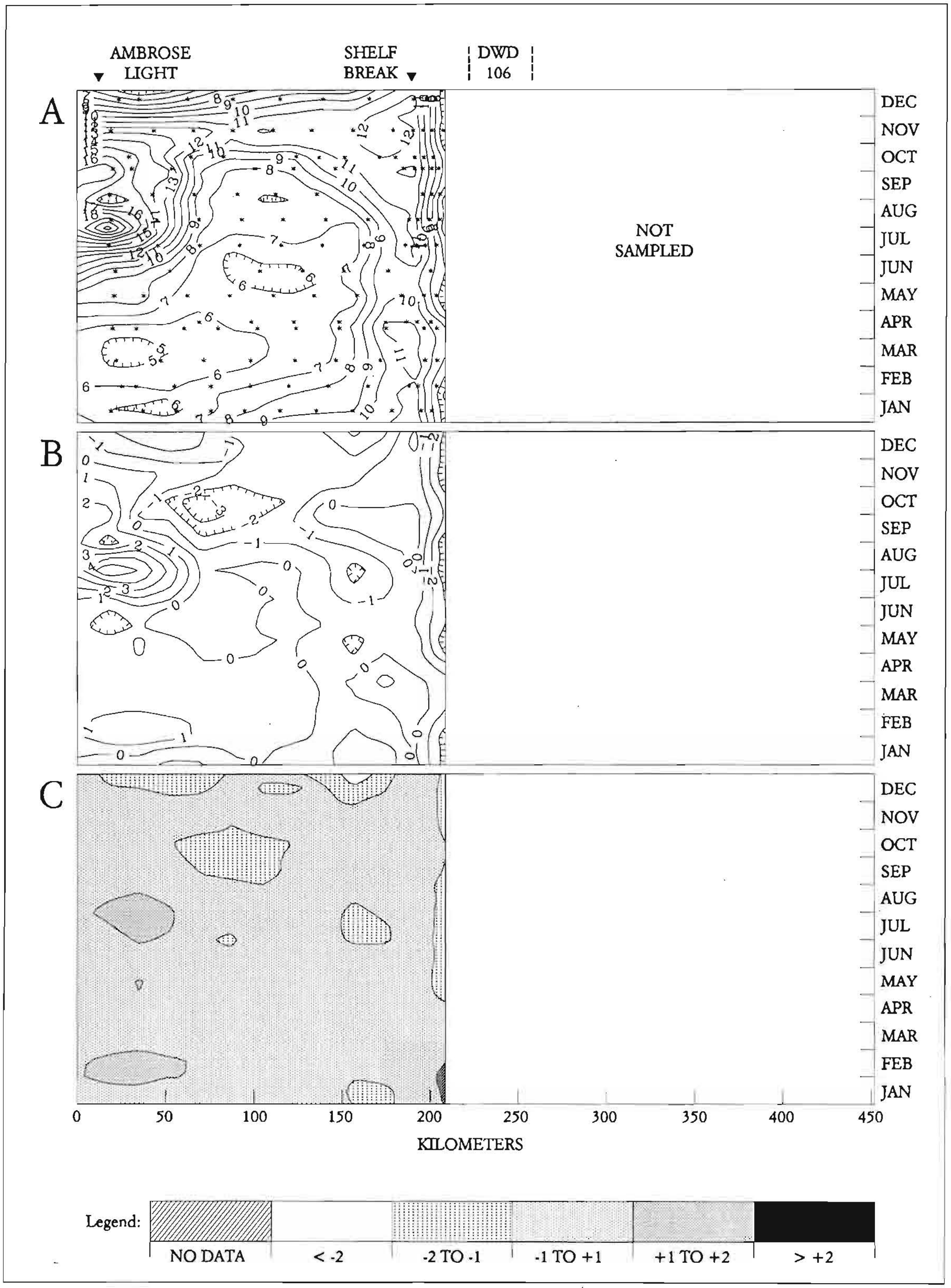

Figure 42

Bottom temperature conditions along the Middle Atlantic Bight route during 1989. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

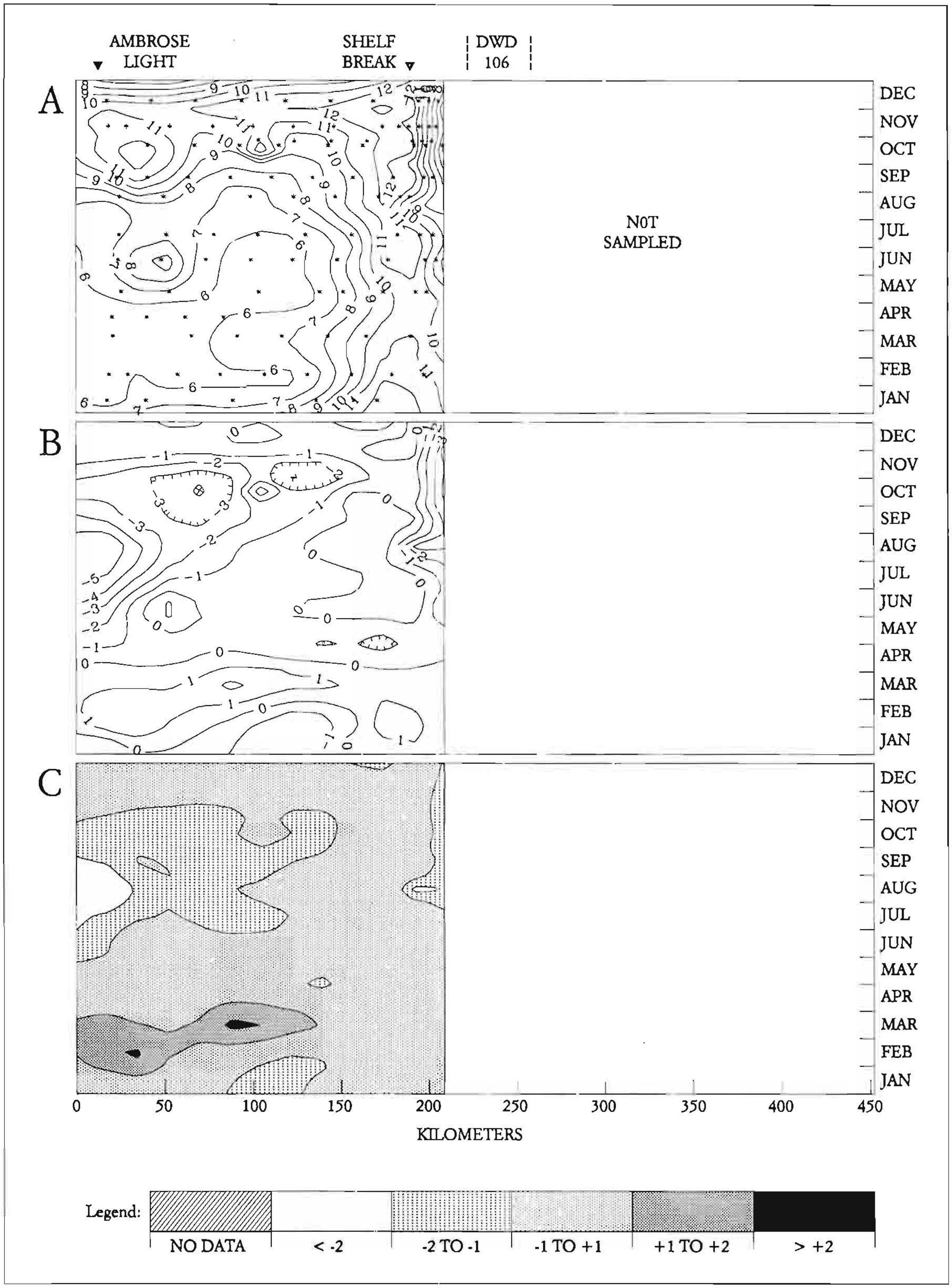

Figure 43

Bottom temperature conditions along the Middle Atlantic Bight route during 1988. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

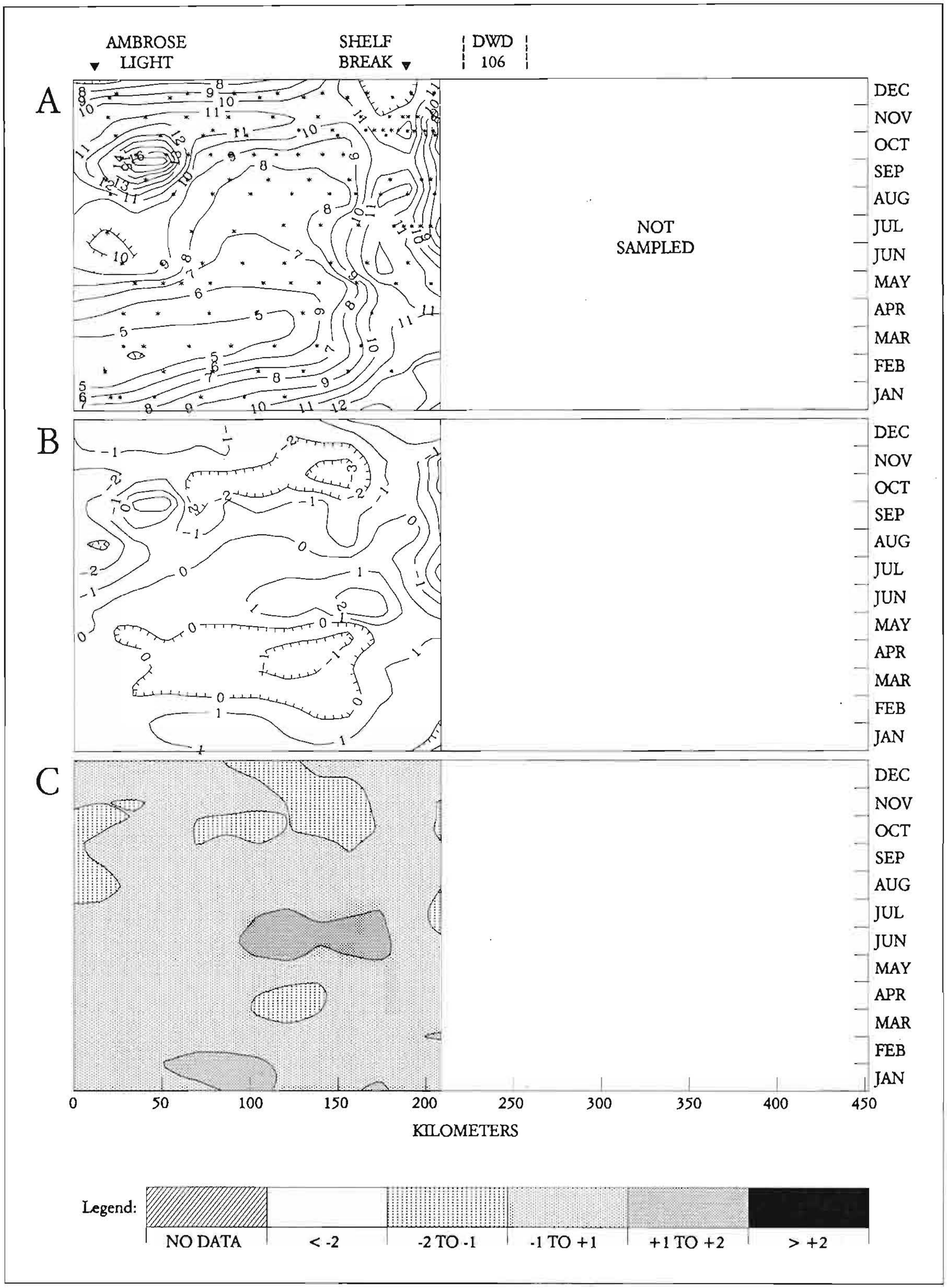

Figure 44

Bottom temperature conditions along the Middle Atlantic Bight route during 1987. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

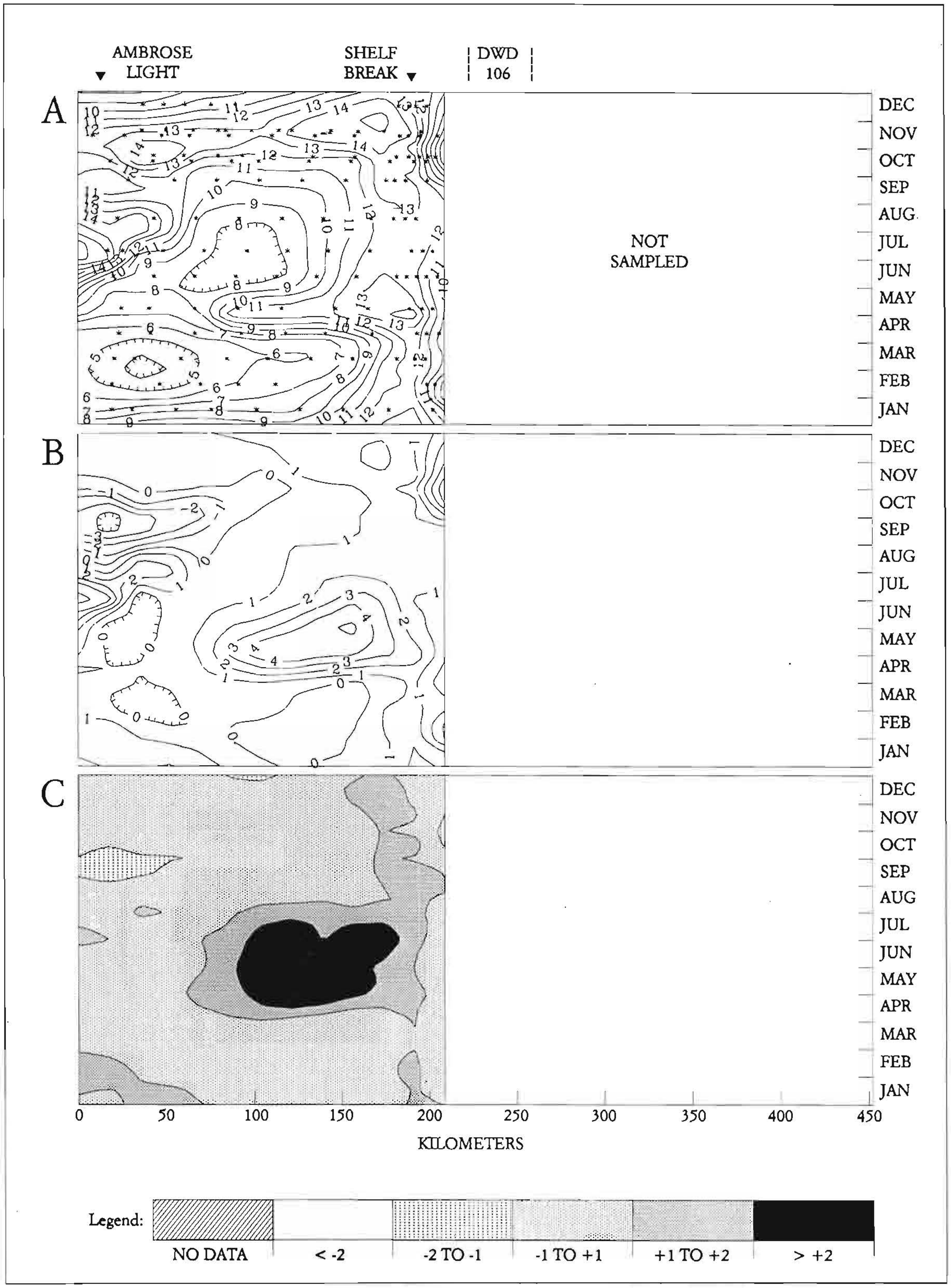

Figure 45

Bottom temperature conditions along the Middle Atlantic Bight route during 1986. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

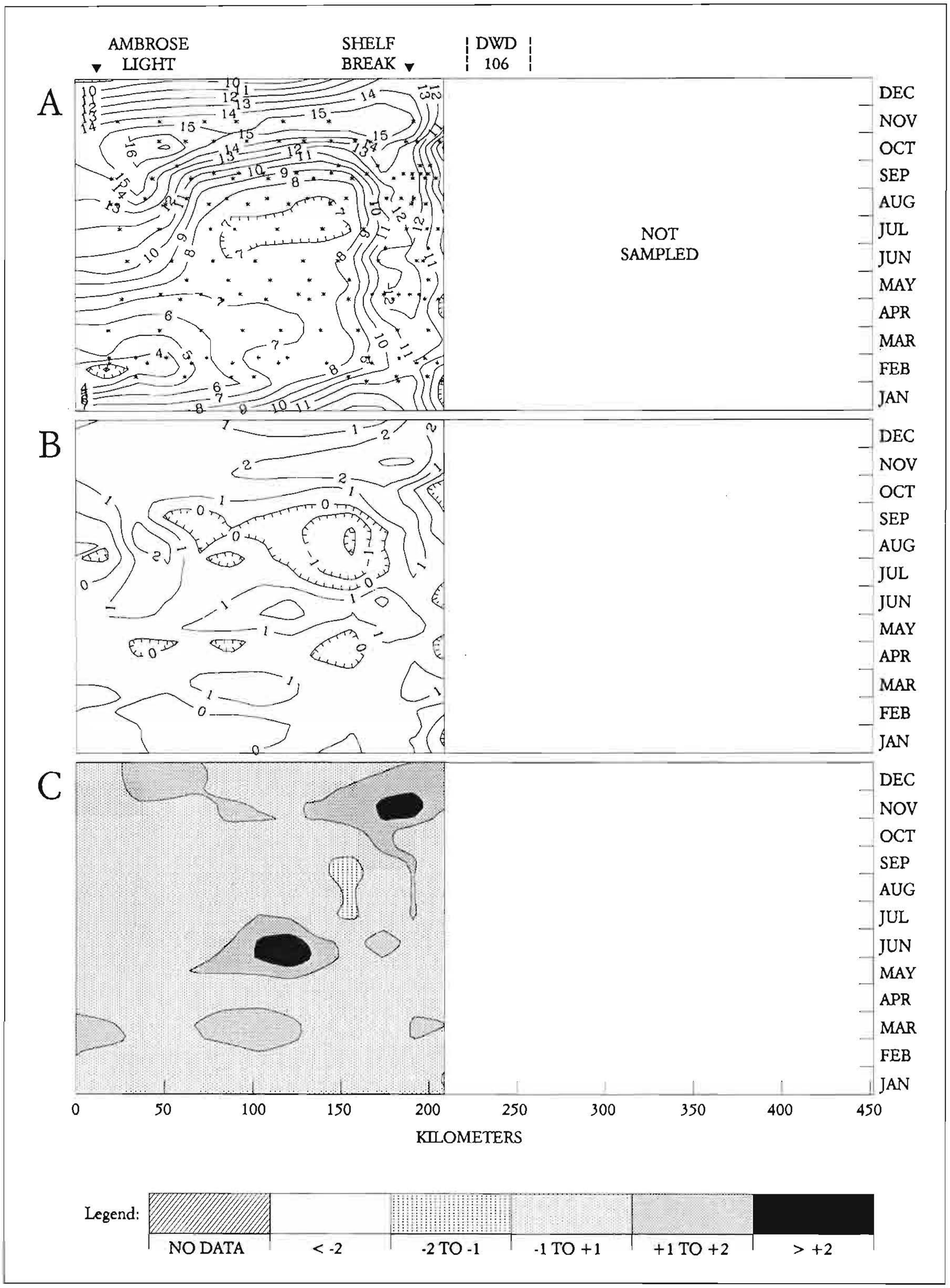

Figure 46

Bottom temperature conditions along the Middle Atlantic Bight route during 1985. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

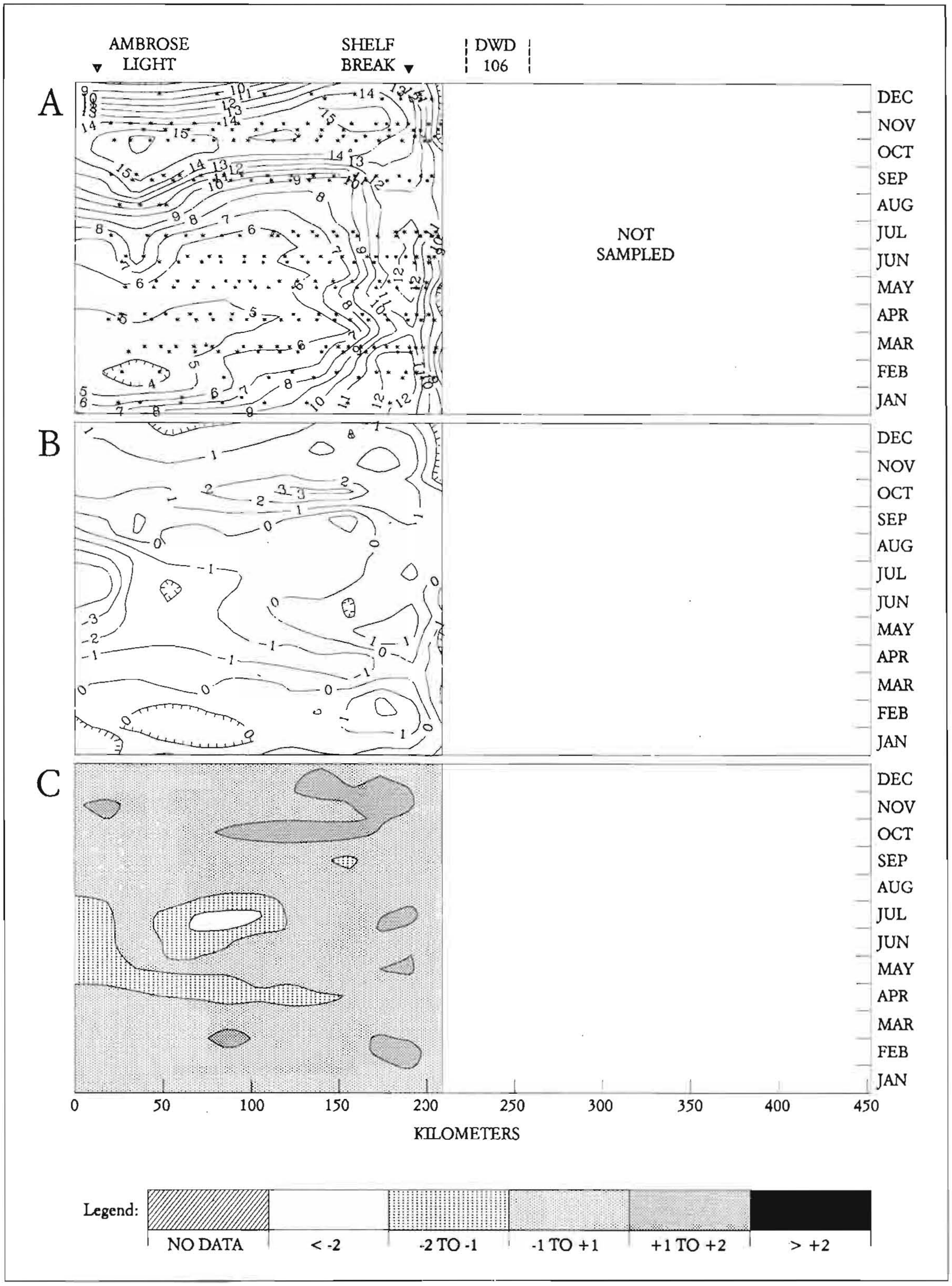

Figure 47

Bottom temperature conditions along the Middle Atlantic Bight route during 1984. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

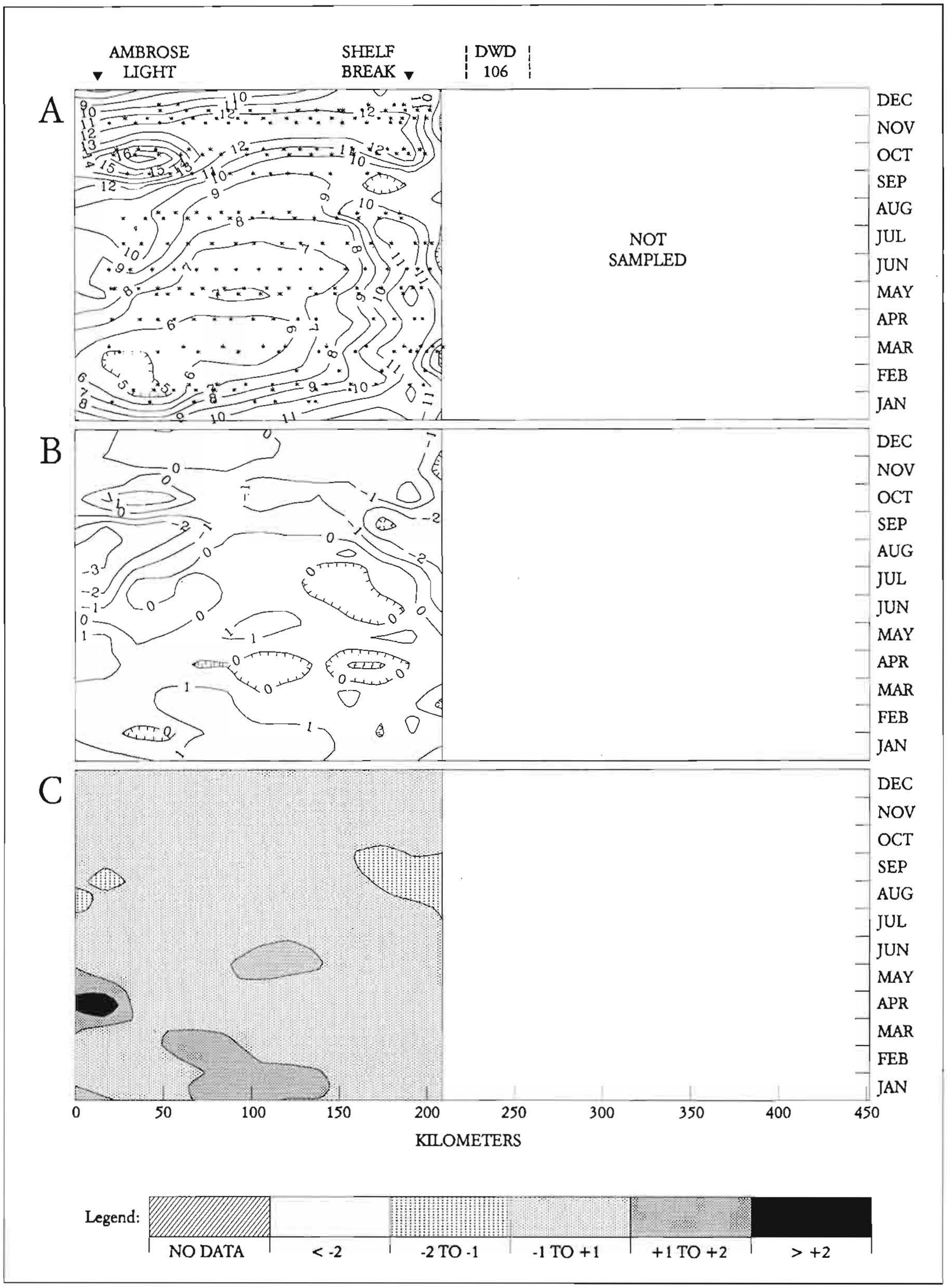

Figure 48

Bottom temperature conditions along the Middle Atlantic Bight route during 1983. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

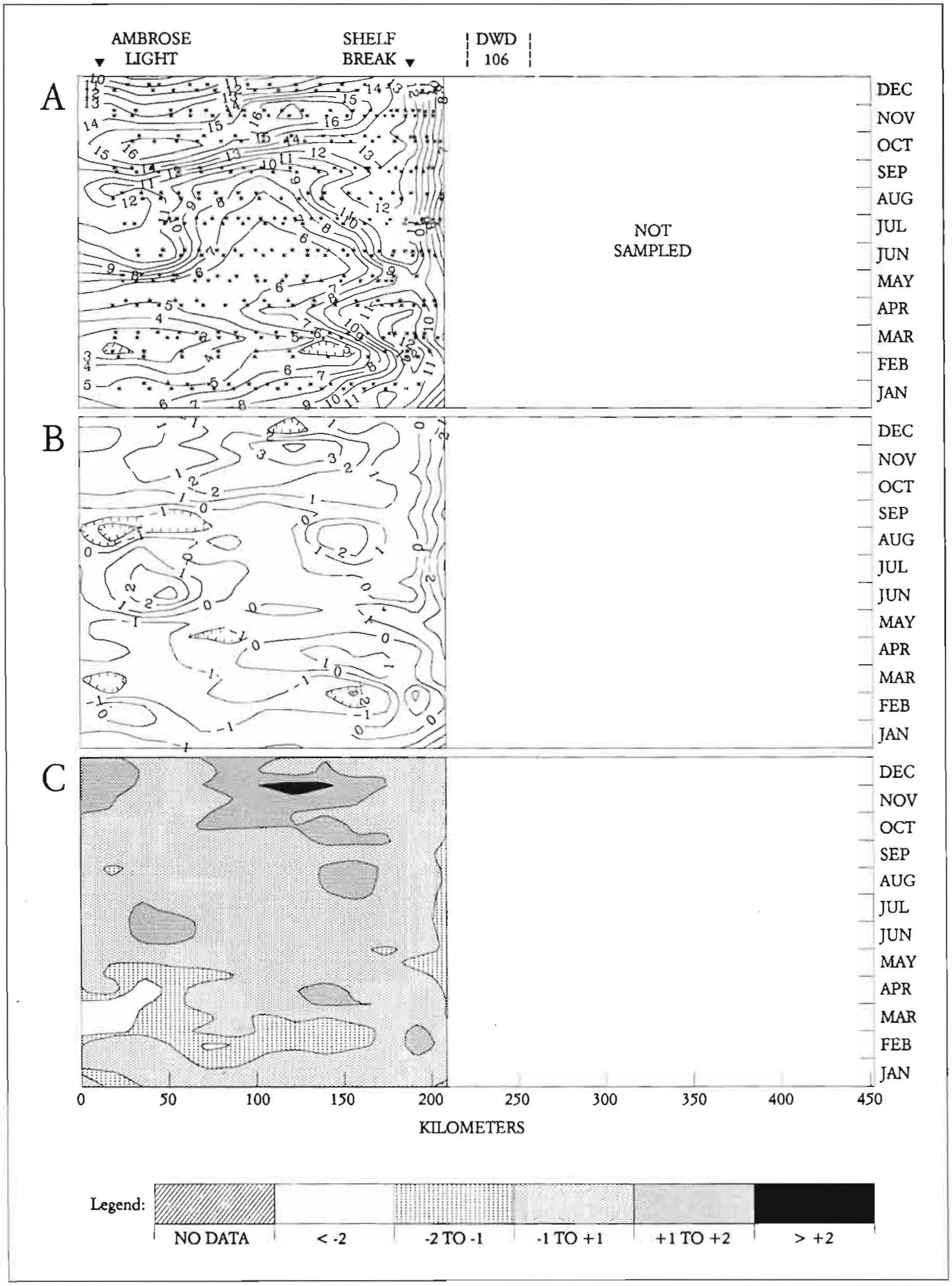

Figure 49

Bottom temperature conditions along the Middle Atlantic Bight route during 1982. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

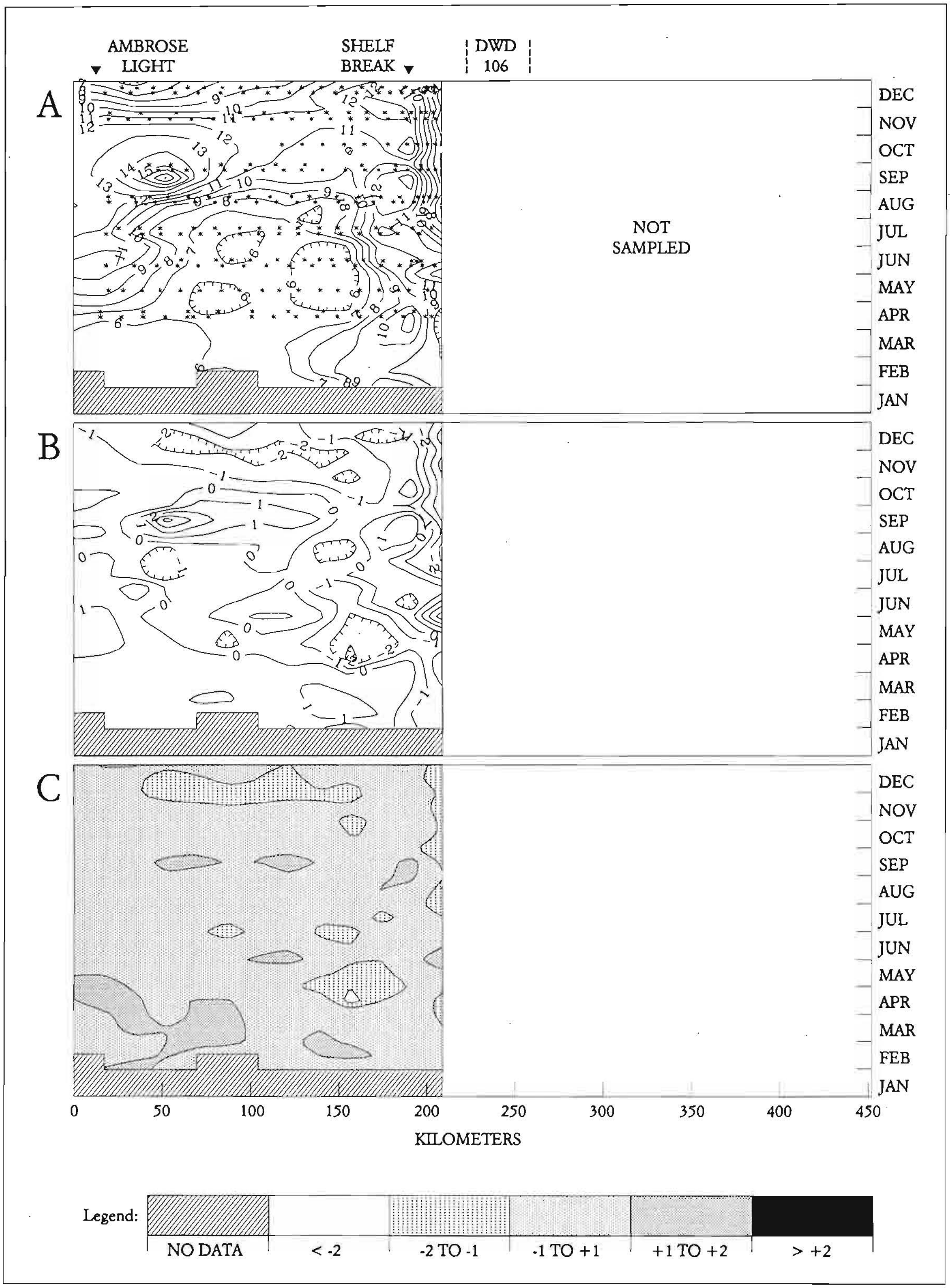

Figure 50

Bottom temperature conditions along the Middle Atlantic Bight route during 1981. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

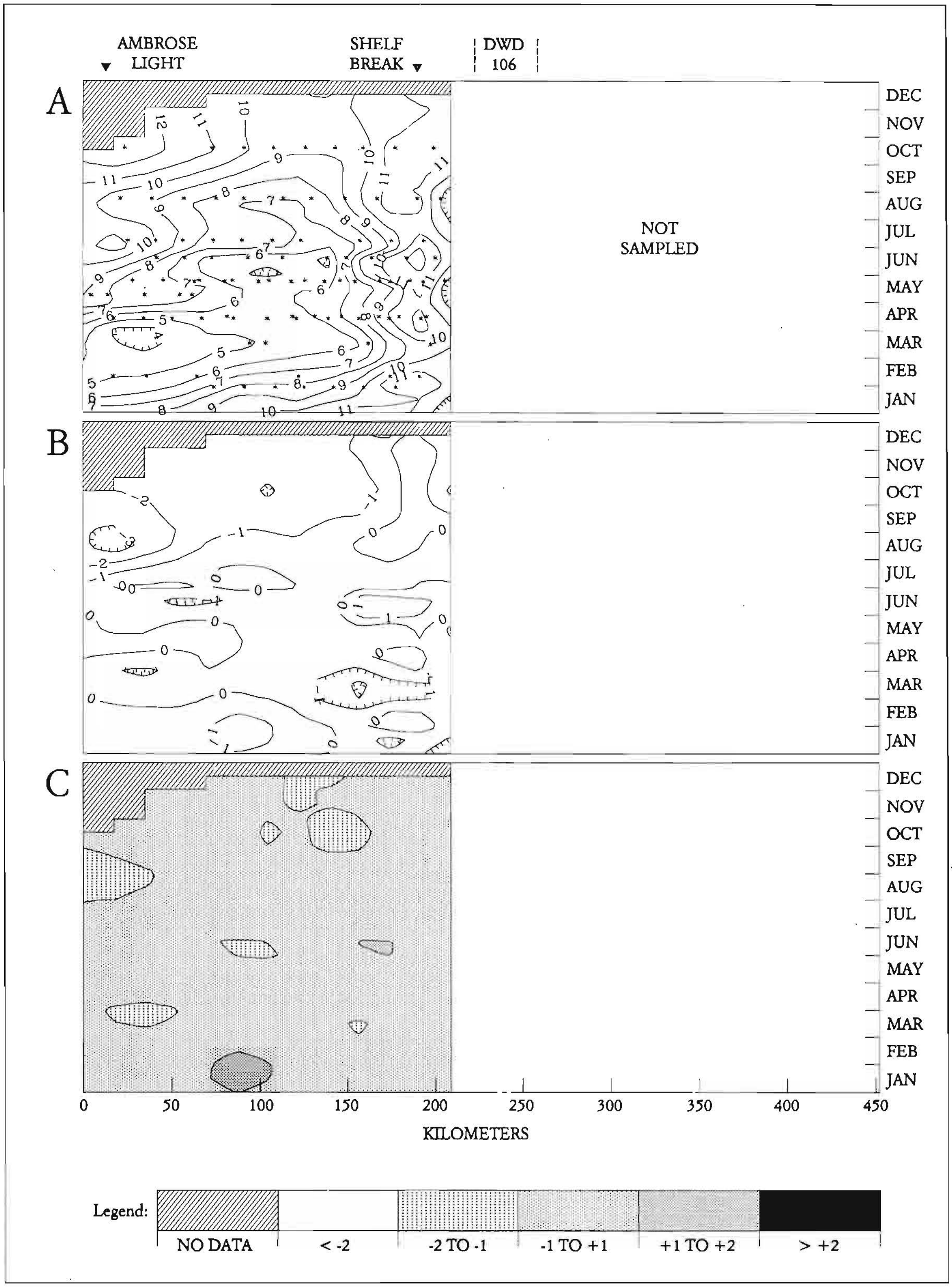

Figure 51

Bottom temperature conditions along the Middle Atlantic Bight route during 1980. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

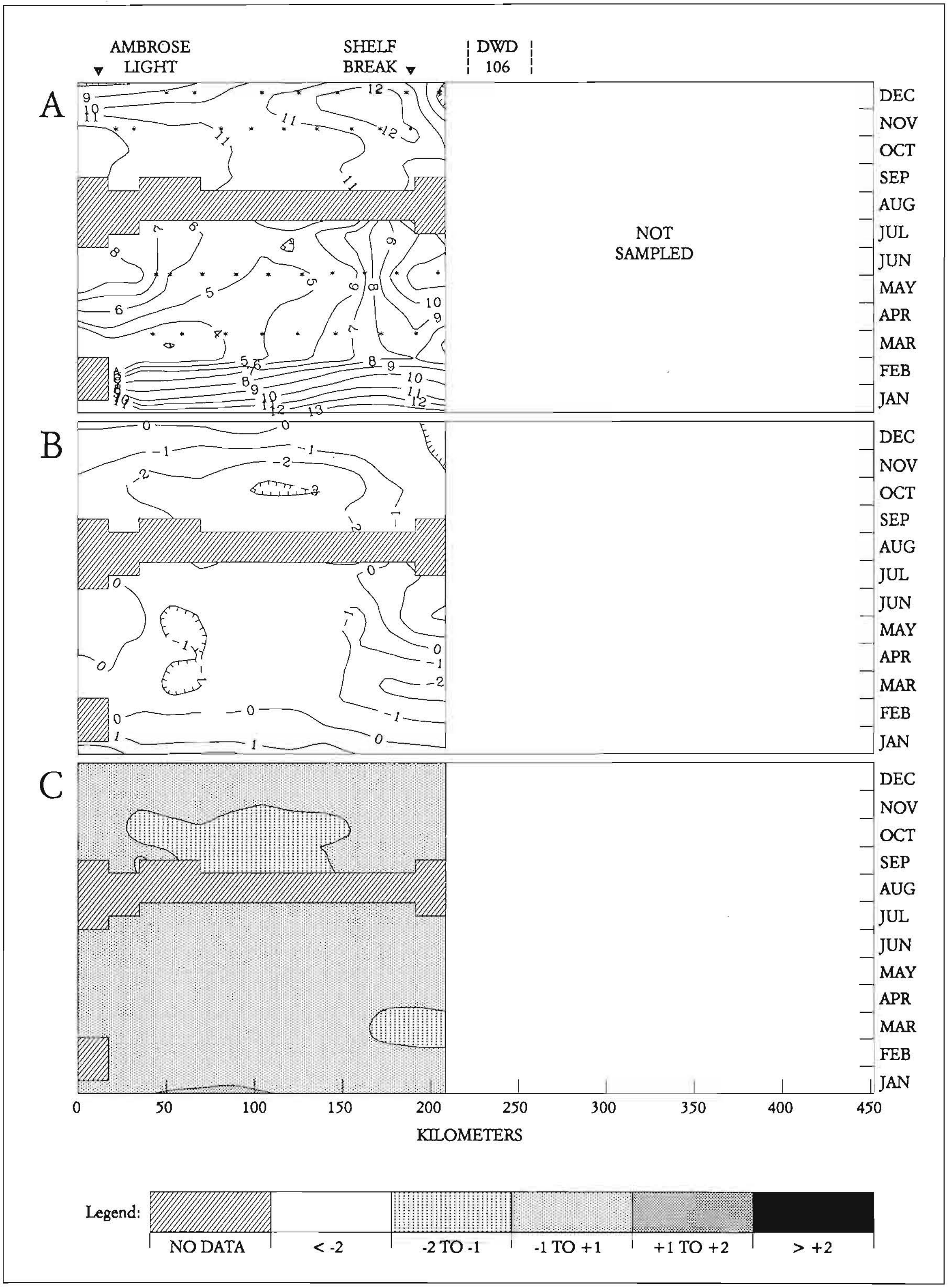

Figure 52

Bottom temperature conditions along the Middle Atlantic Bight route during 1979. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

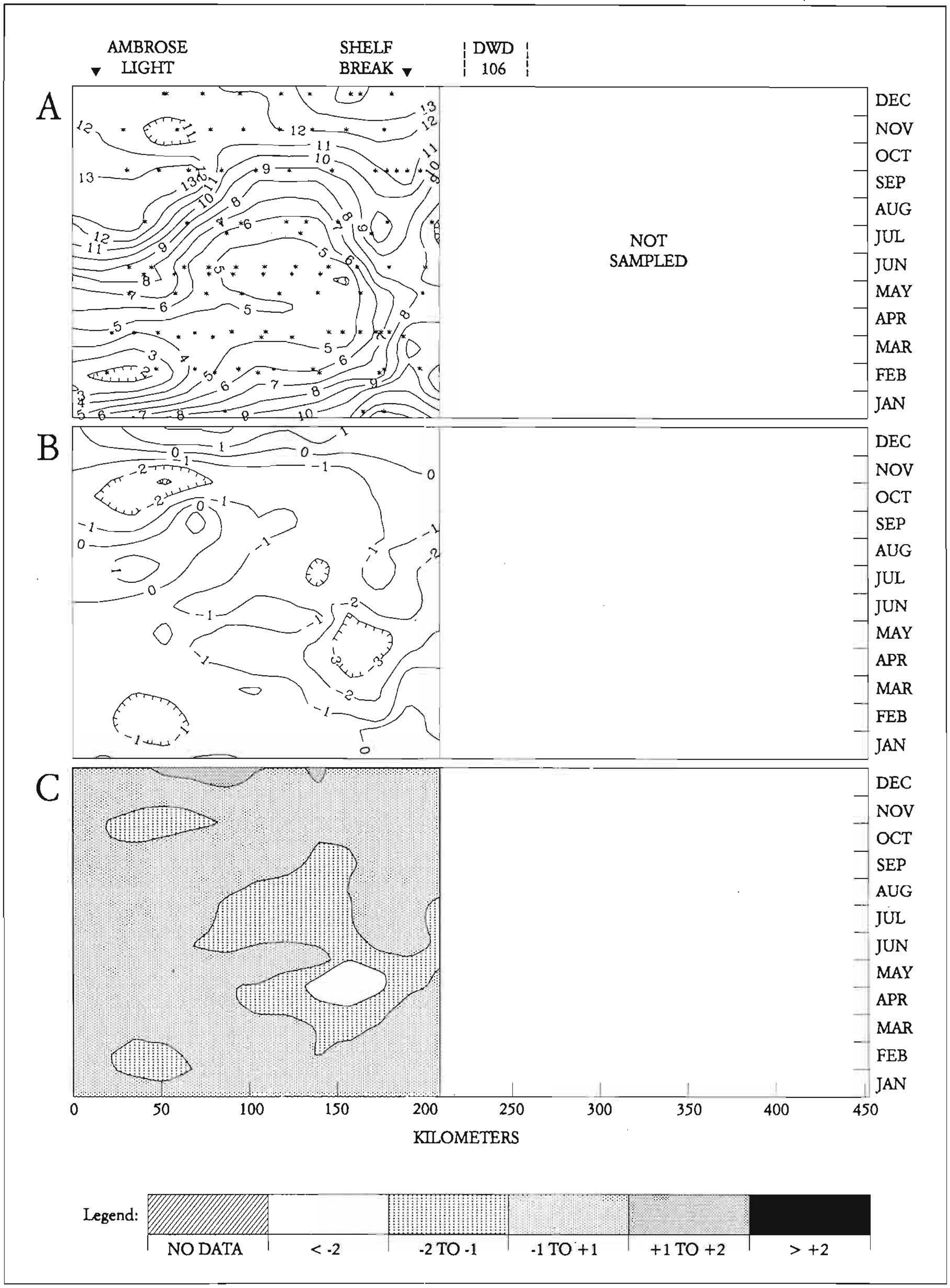

Figure 53

Bottom temperature conditions along the Middle Atlantic Bight route during 1978. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

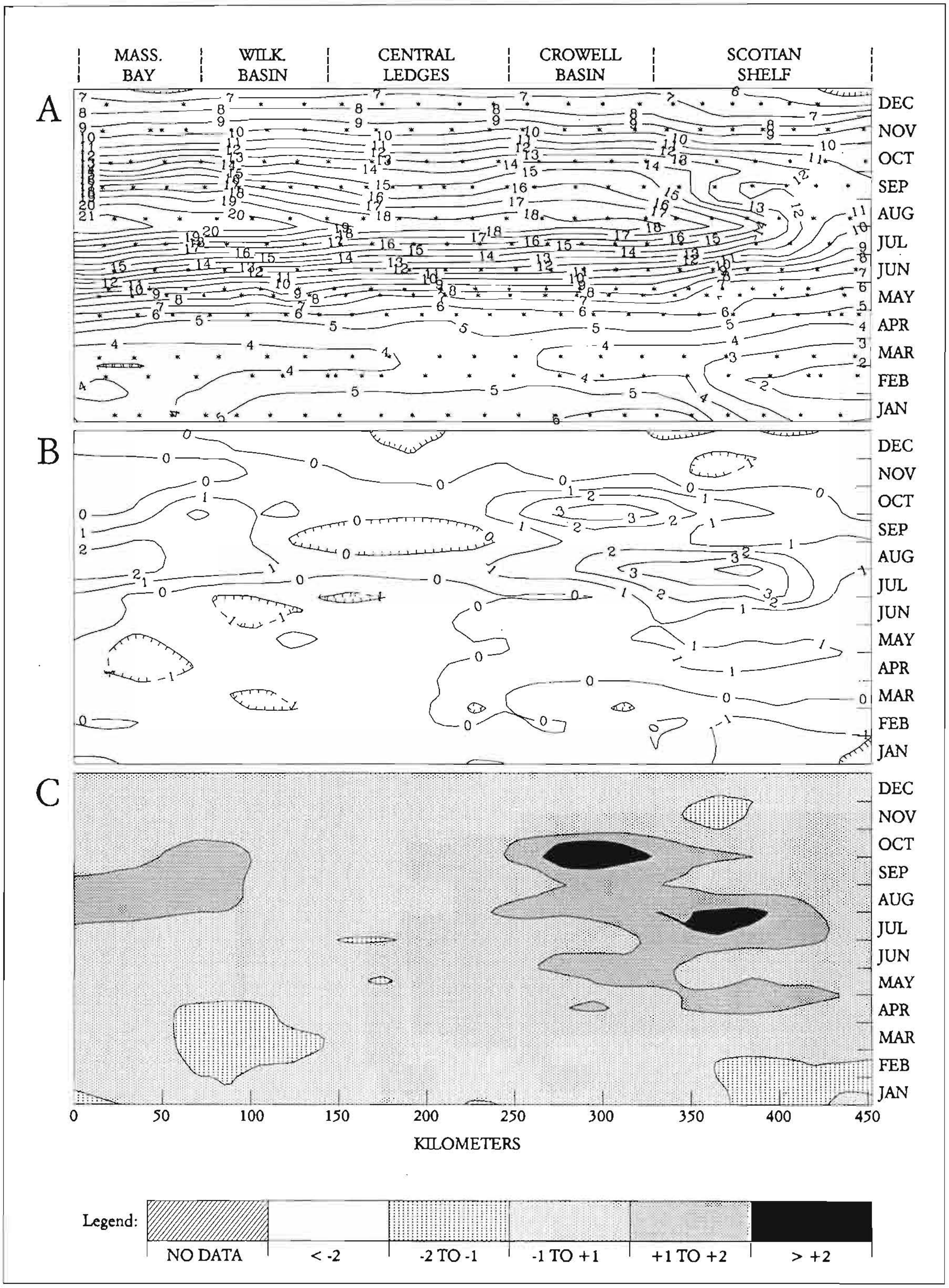

Figure 54

Surface temperature conditions along the Gulf of Maine route during 1990. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

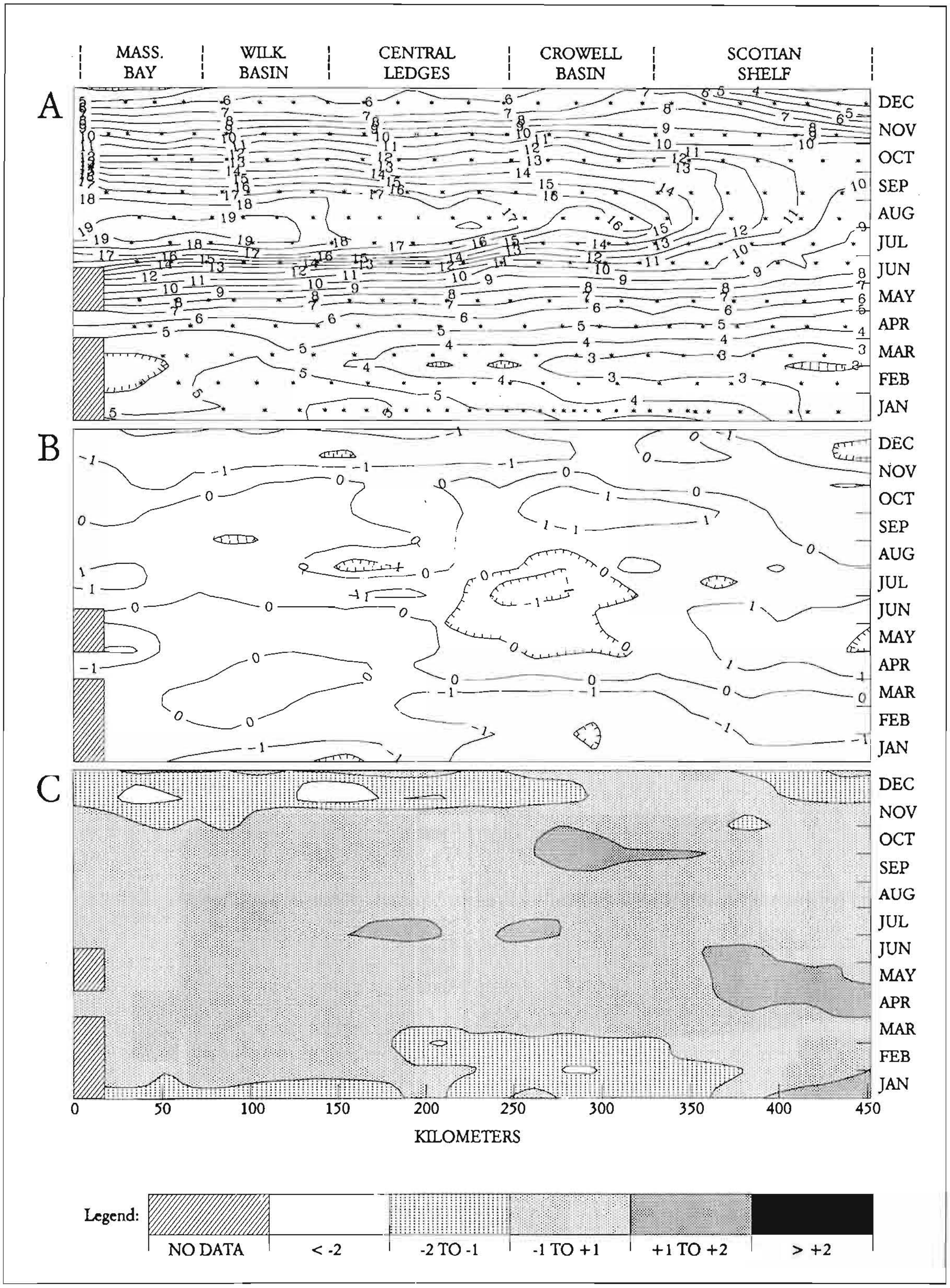

Figure 55

Surface temperature conditions along the Gulf of Maine route during 1989. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

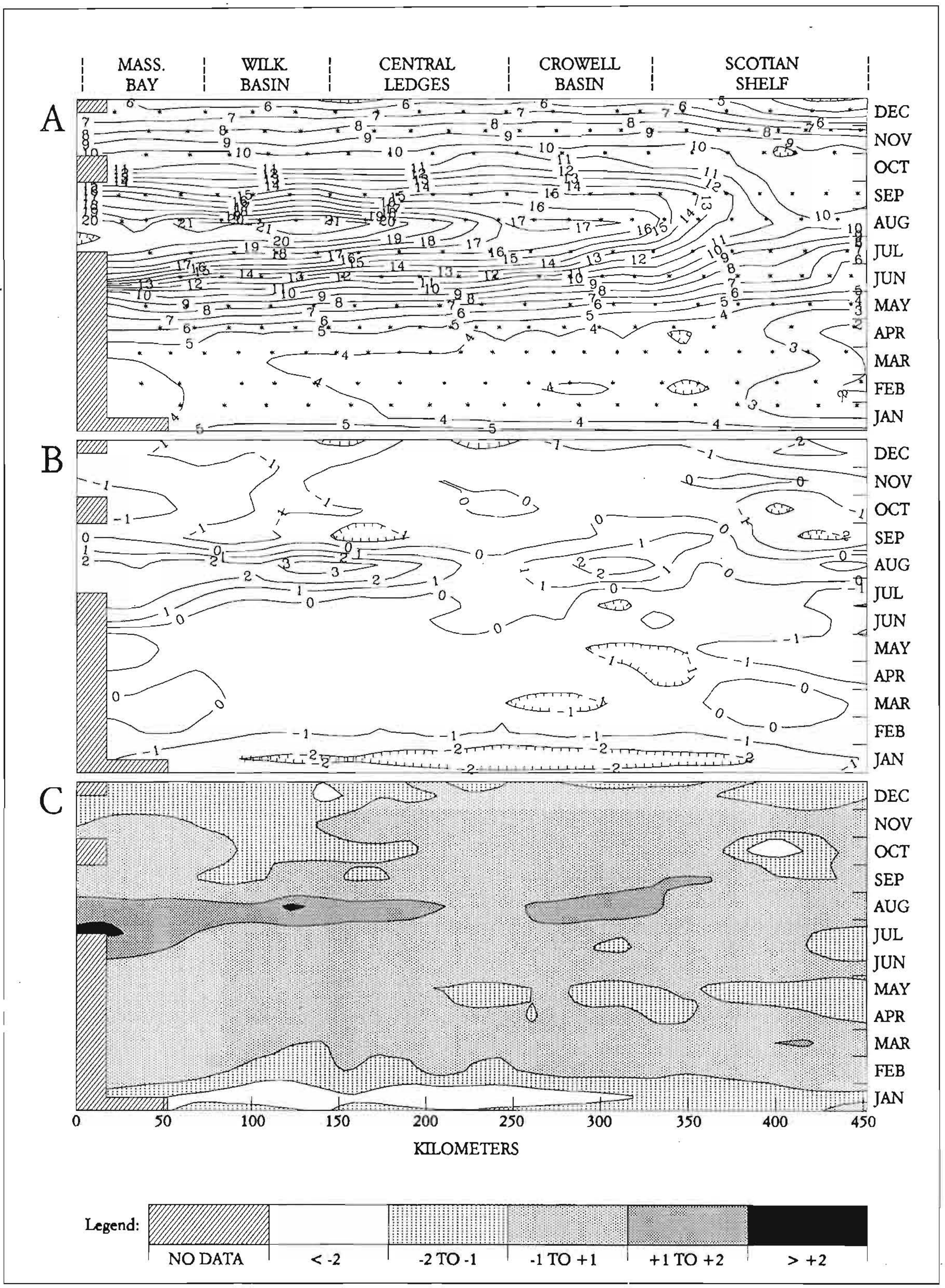

Figure 56

Surface temperature conditions along the Gulf of Maine route during 1988. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

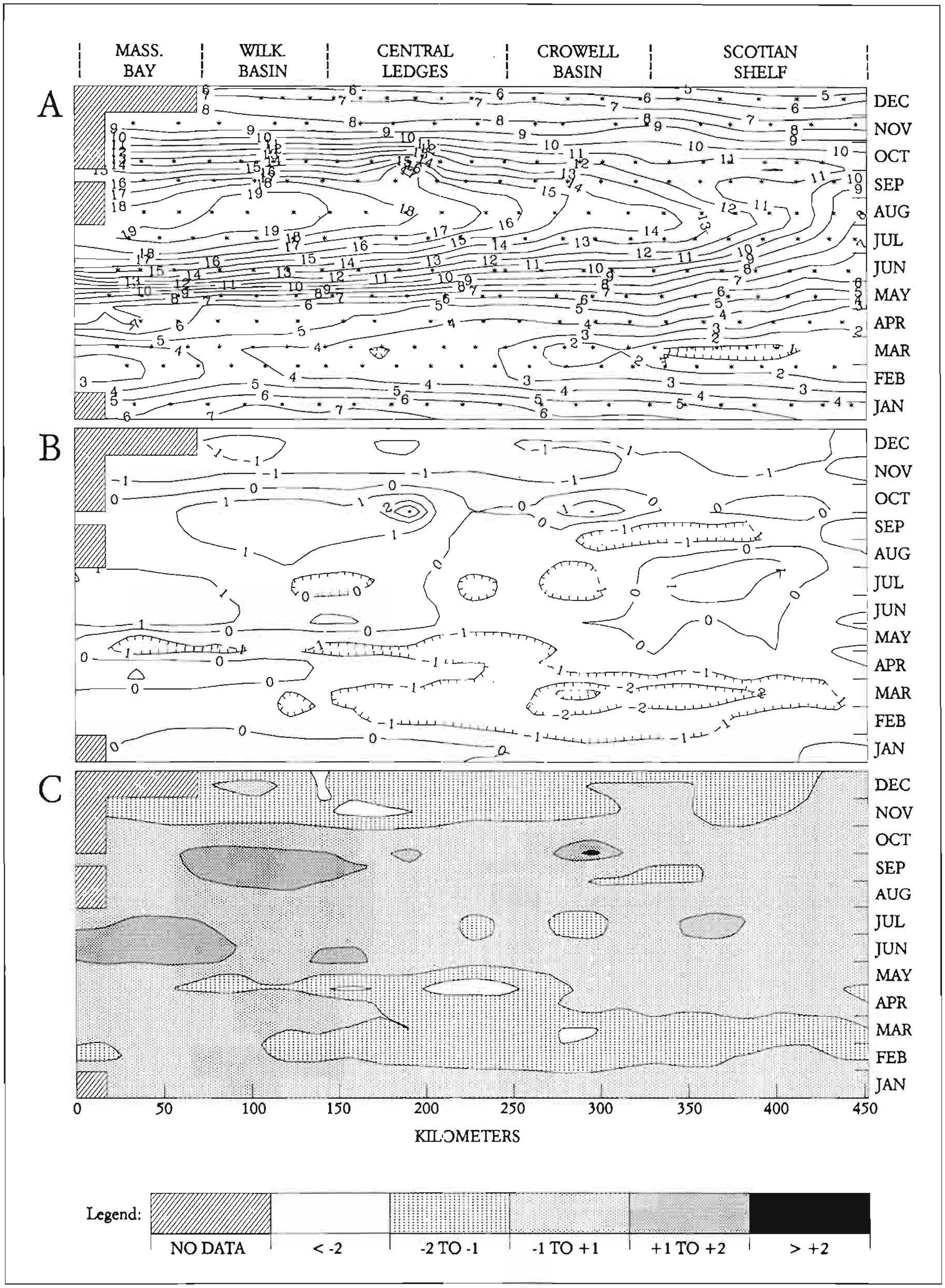

Figure 57

Surface temperature conditions along the Gulf of Maine route during 1987. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

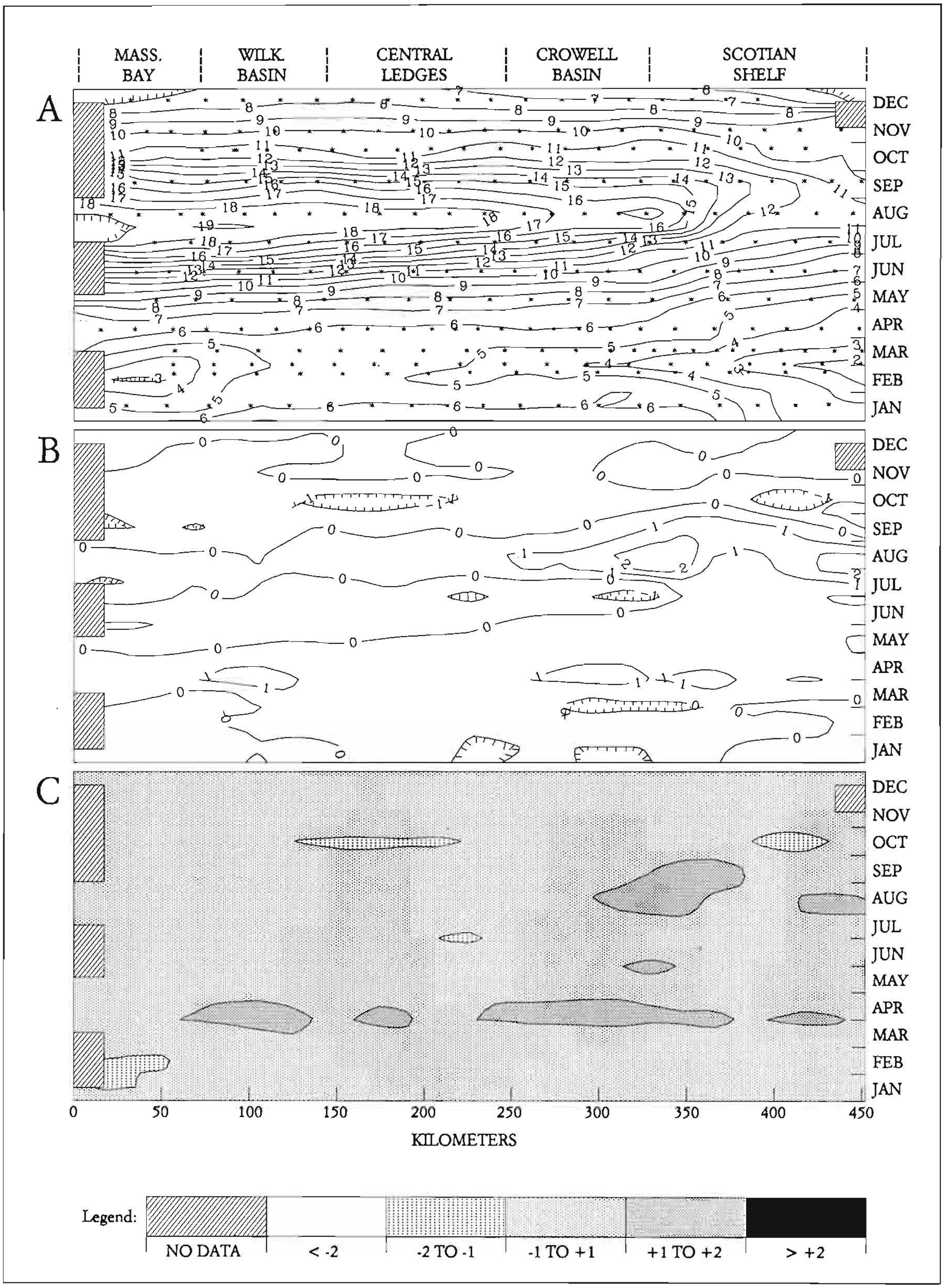

Figure 58

Surface temperature conditions along the Gulf of Maine route during 1986. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

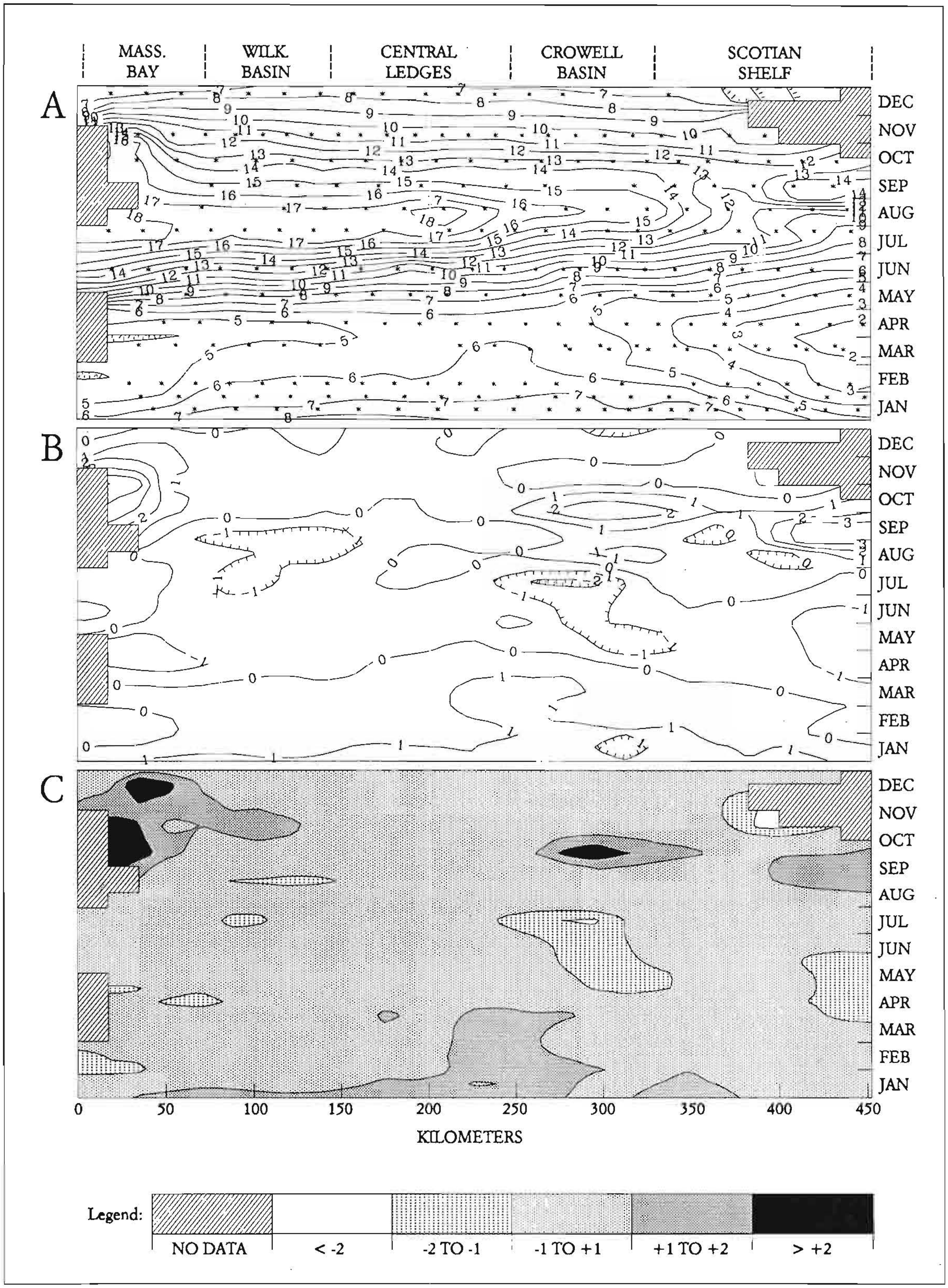

Figure 59

Surface temperature conditions along the Gulf of Maine route during 1985. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

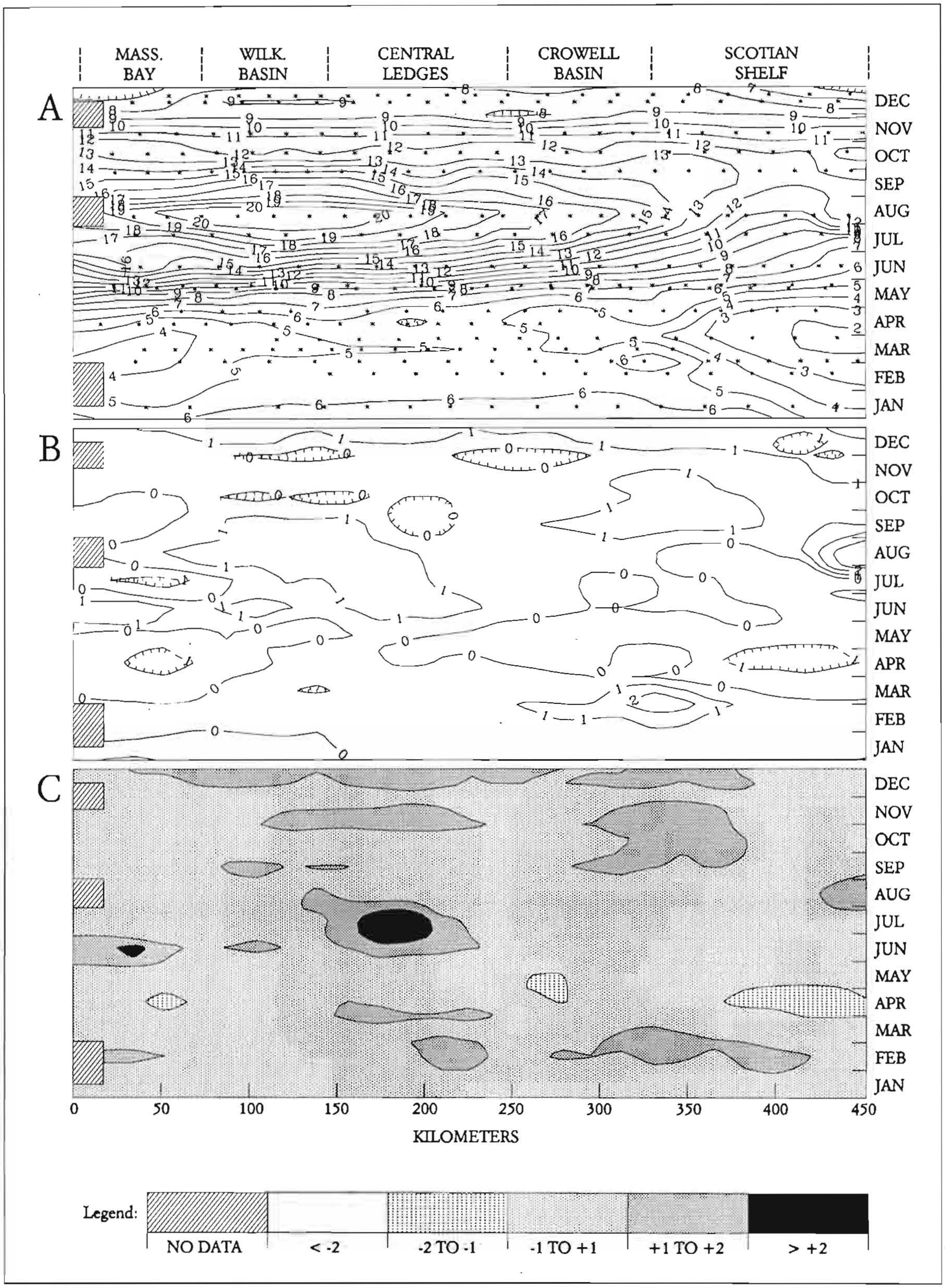

Figure 60

Surface temperature conditions along the Gulf of Maine route during 1984. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

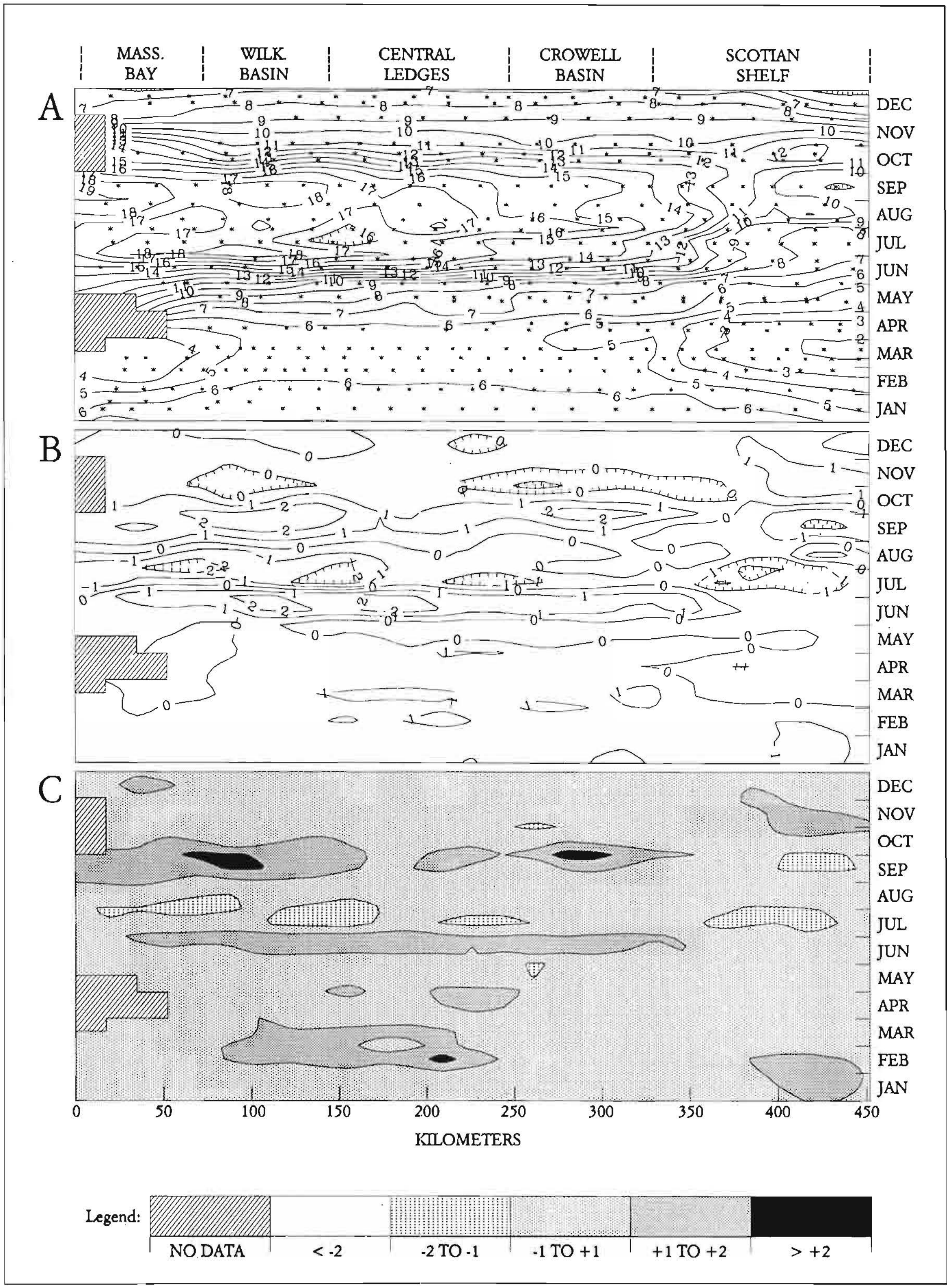

Figure 61

Surface temperature conditions along the Gulf of Maine route during 1983. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

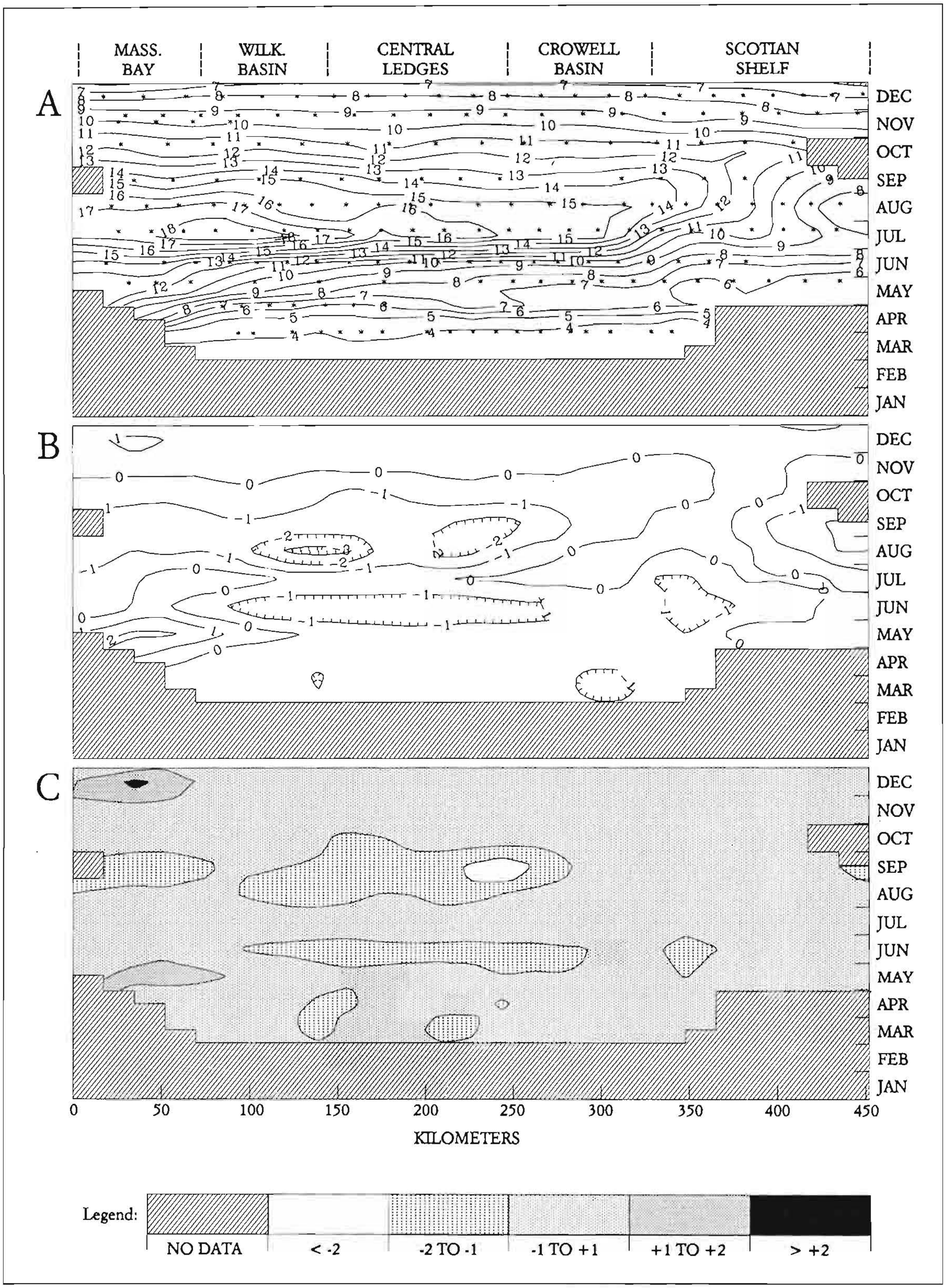

Figure 62

Surface temperature conditions along the Gulf of Maine route during 1982. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

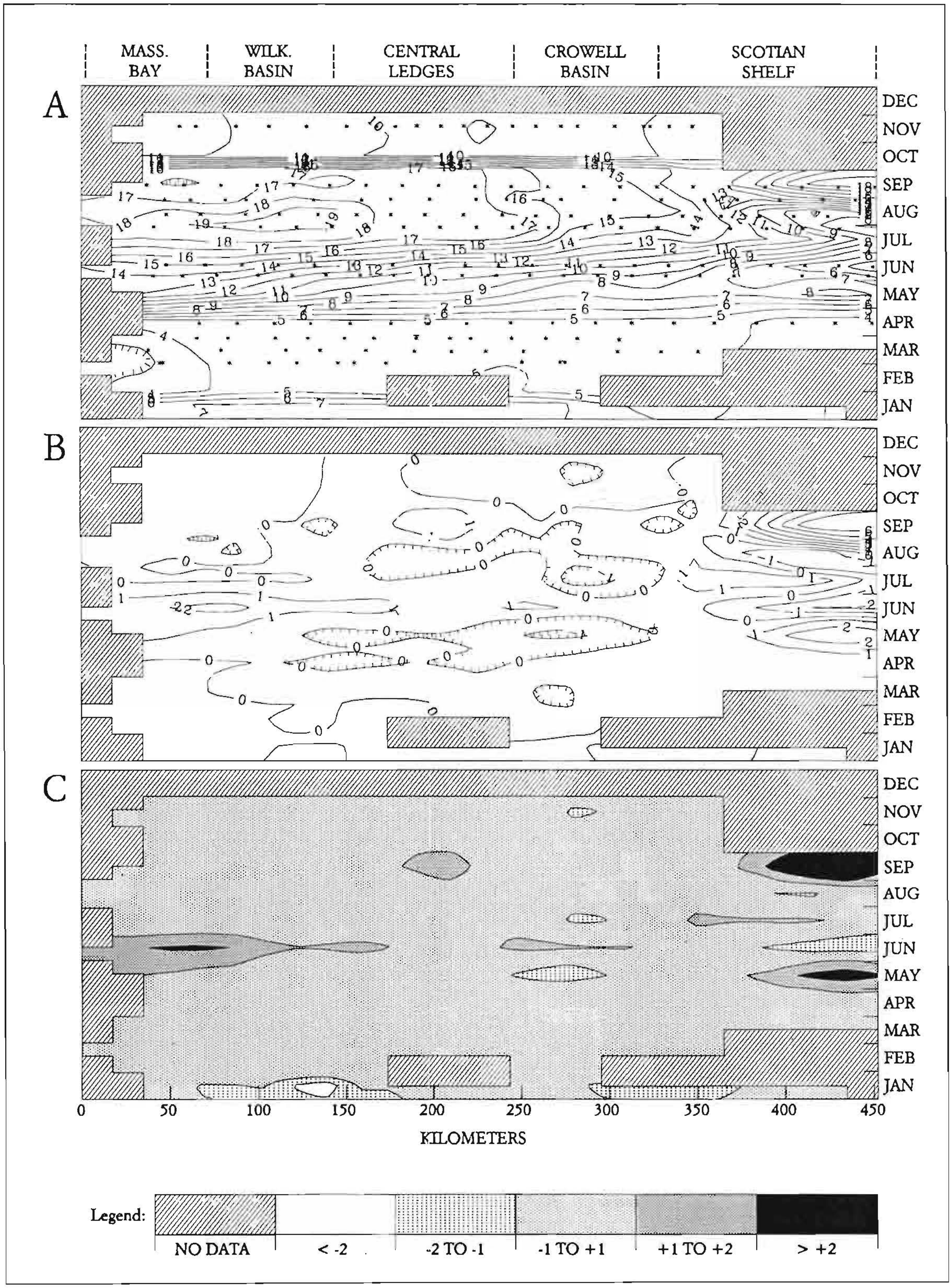

Figure 63

Surface temperature conditions along the Gulf of Maine route during 1981. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

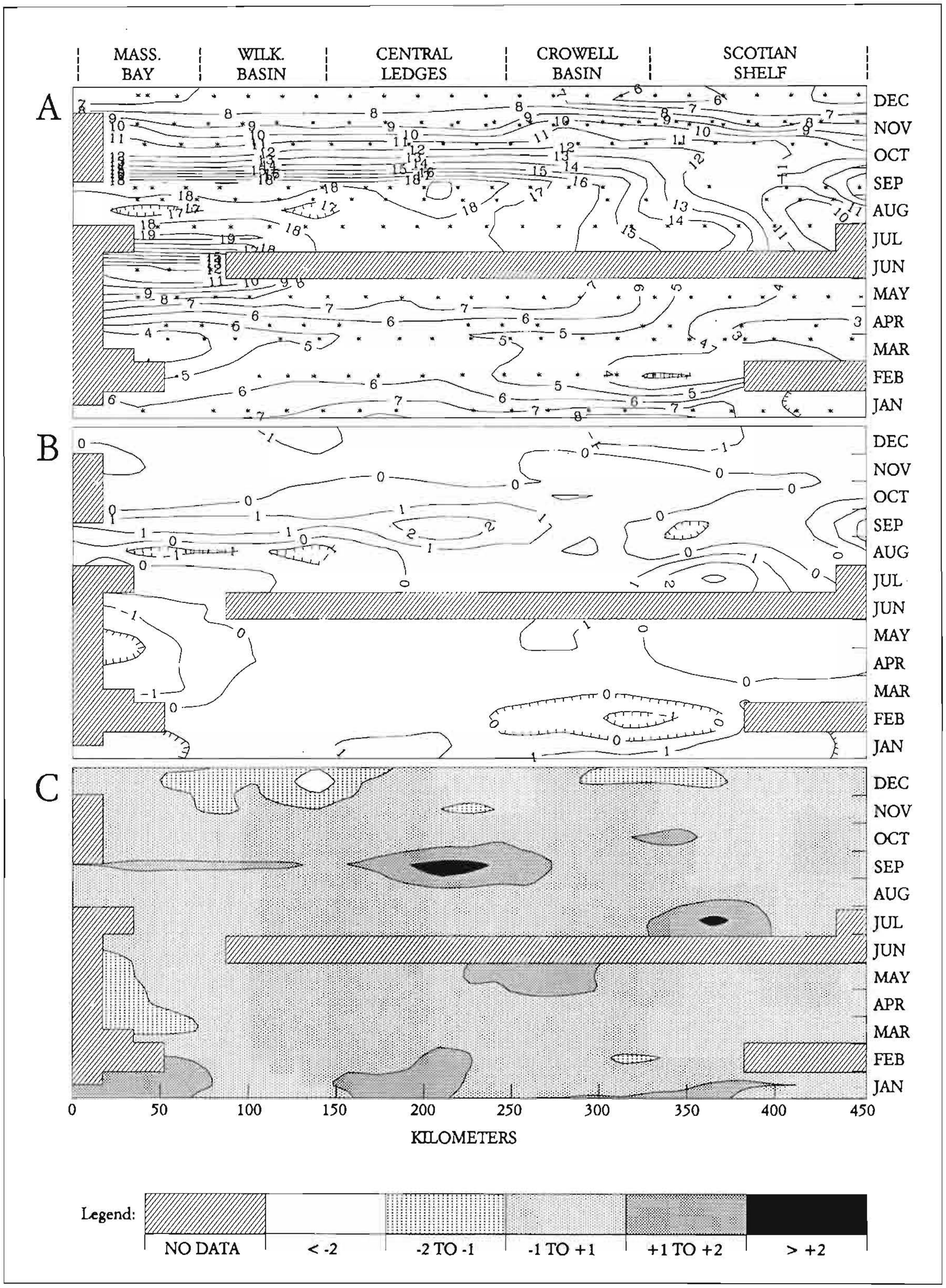

Figure 64

Surface temperature conditions along the Gulf of Maine route during 1980. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

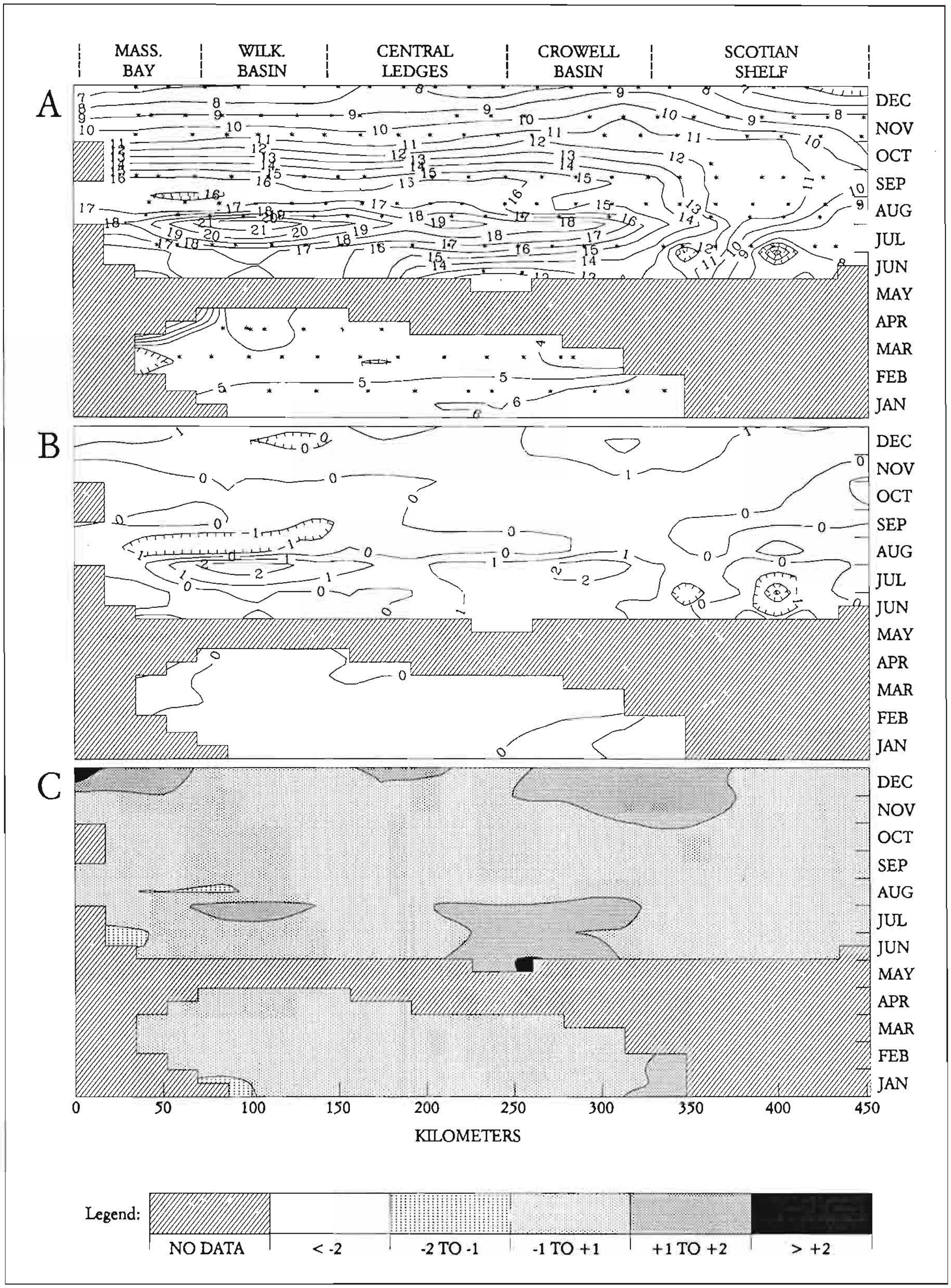

Figure 65

Surface temperature conditions along the Gulf of Maine route during 1979. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

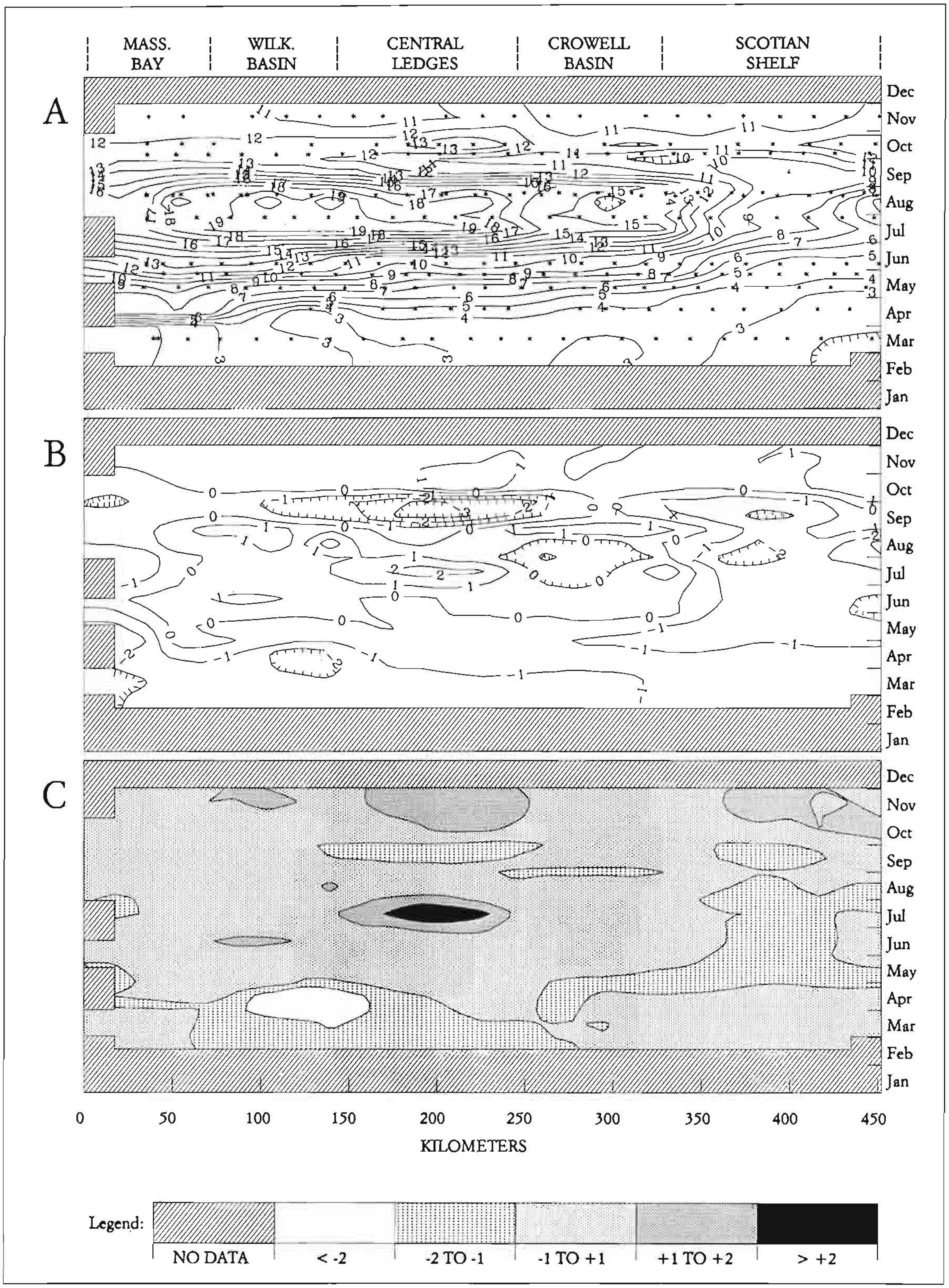

Figure 66

Surface temperature conditions along the Gulf of Maine route during 1978. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

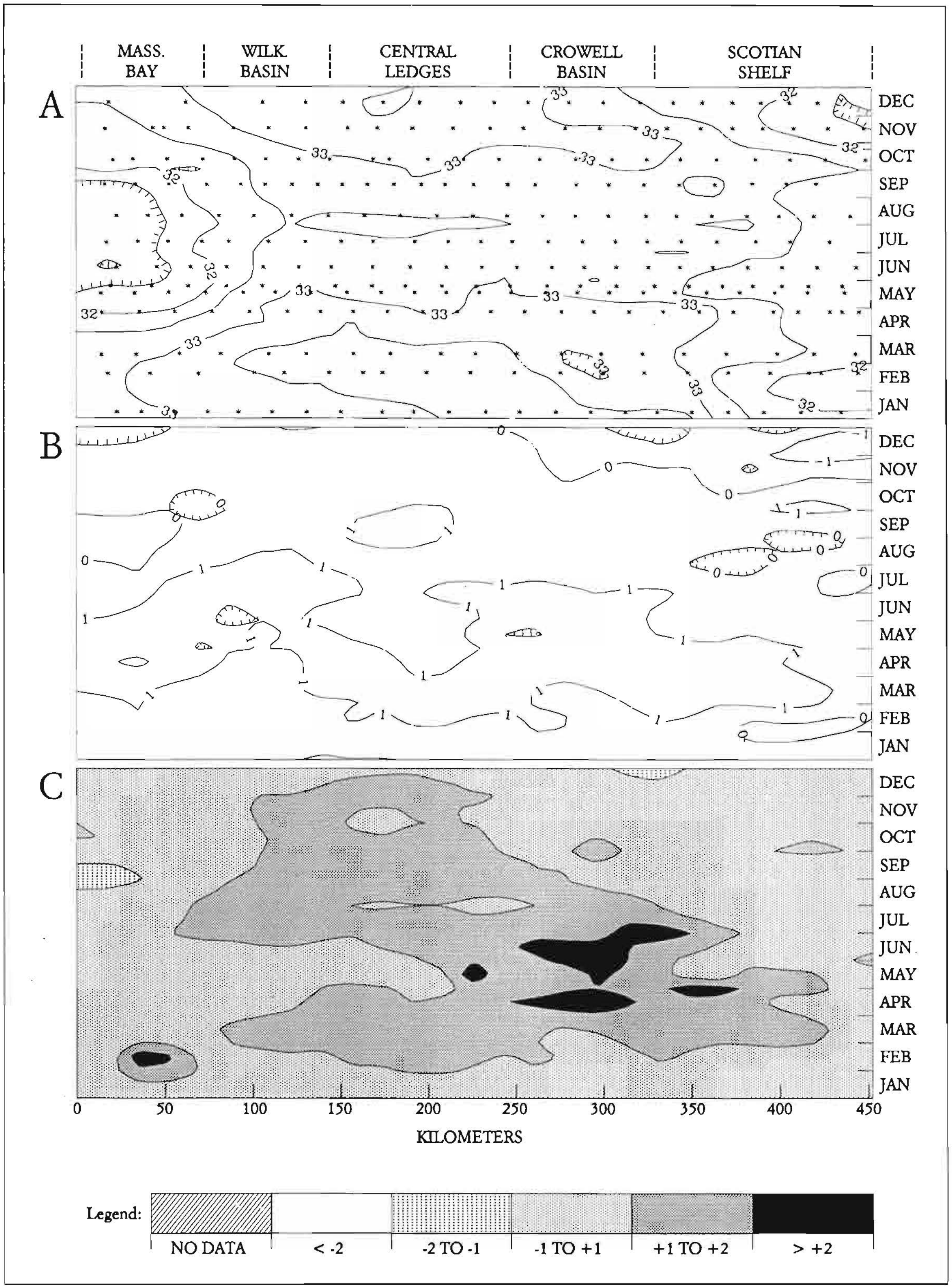

Figure 67

Surface salinity conditions along the Gulf of Maine route during 1990. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

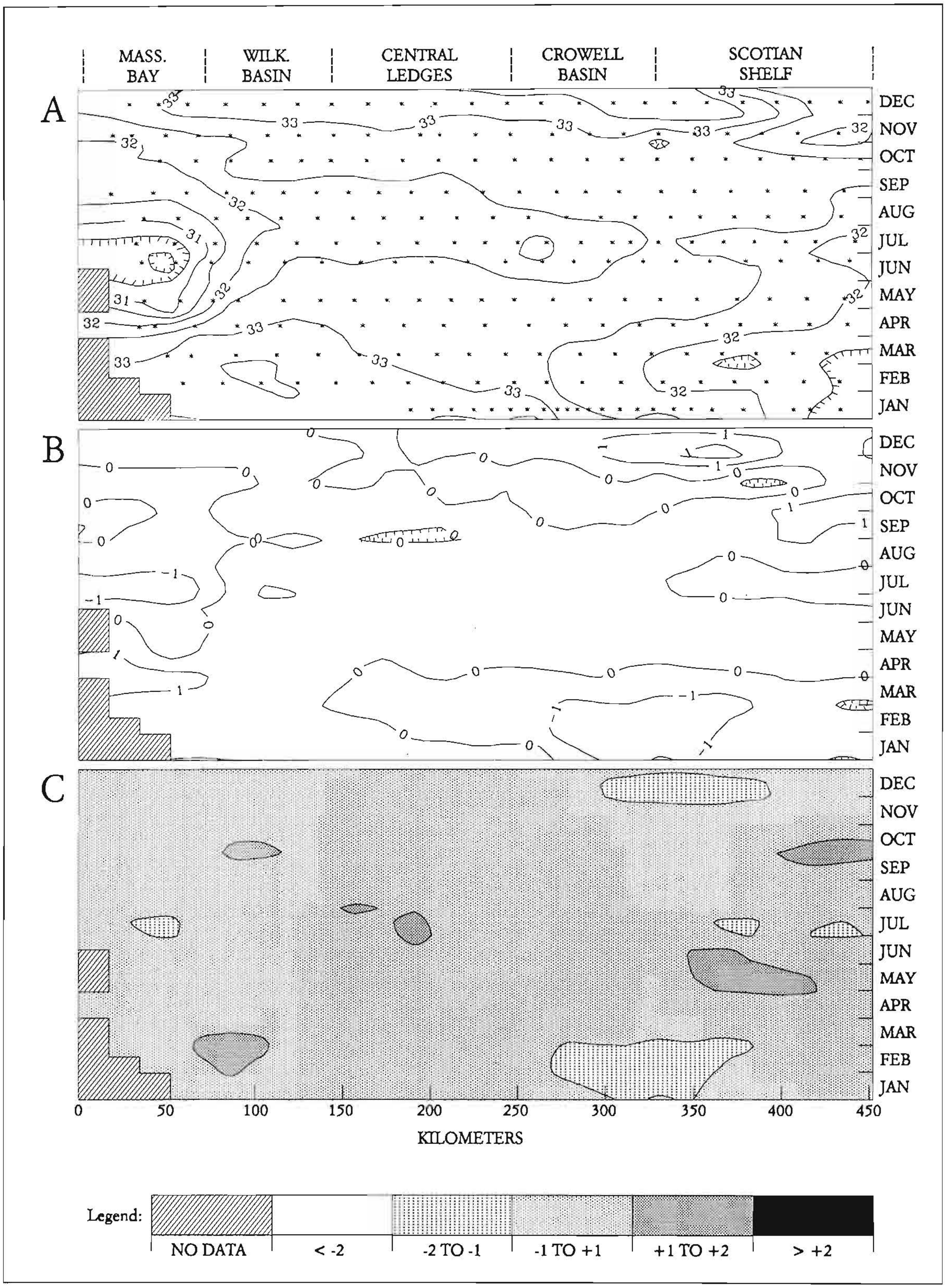

Figure 68

Surface salinity conditions along the Gulf of Maine route during 1989. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

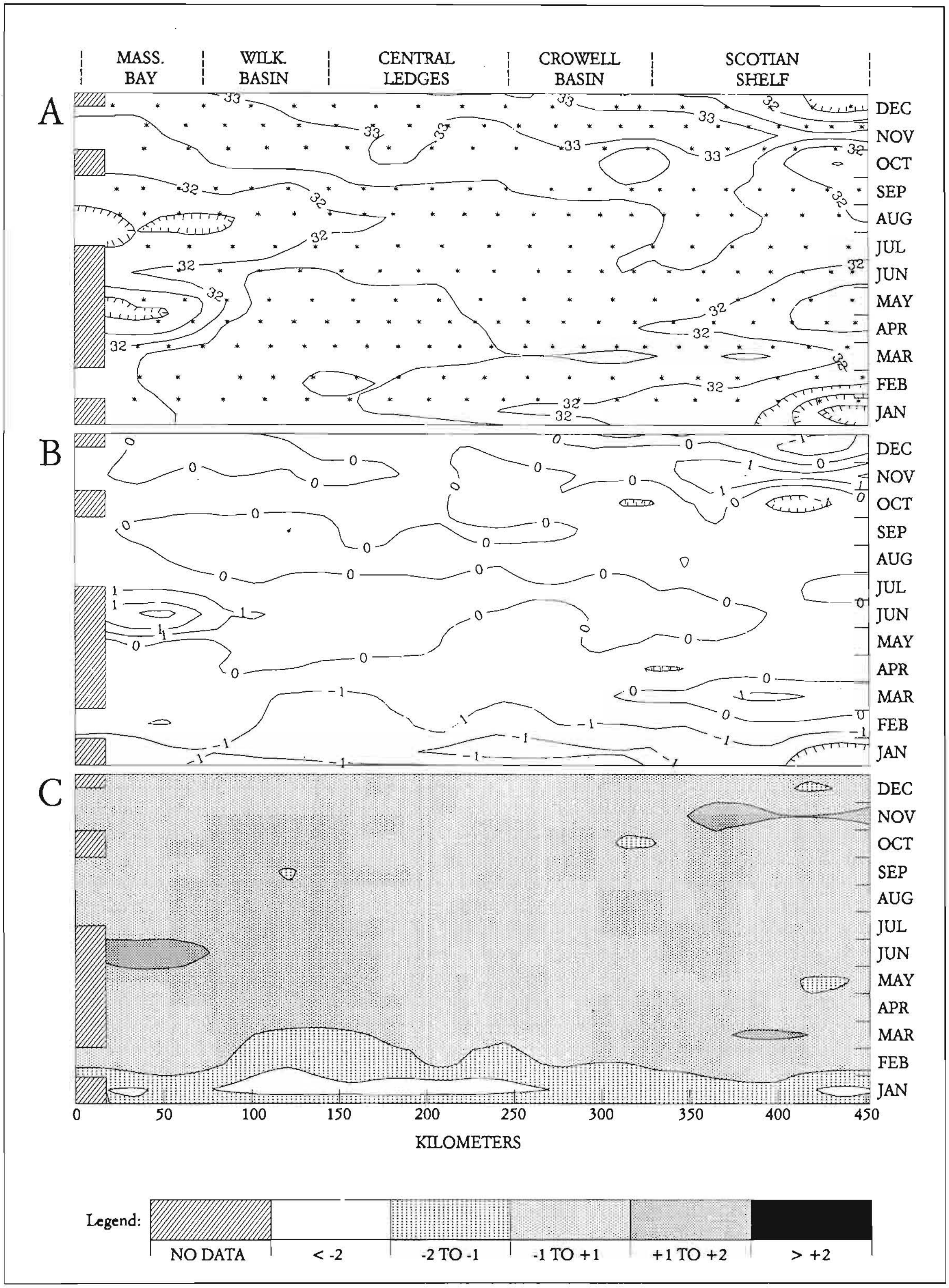

Figure 69

Surface salinity conditions along the Gulf of Maine route during 1988. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

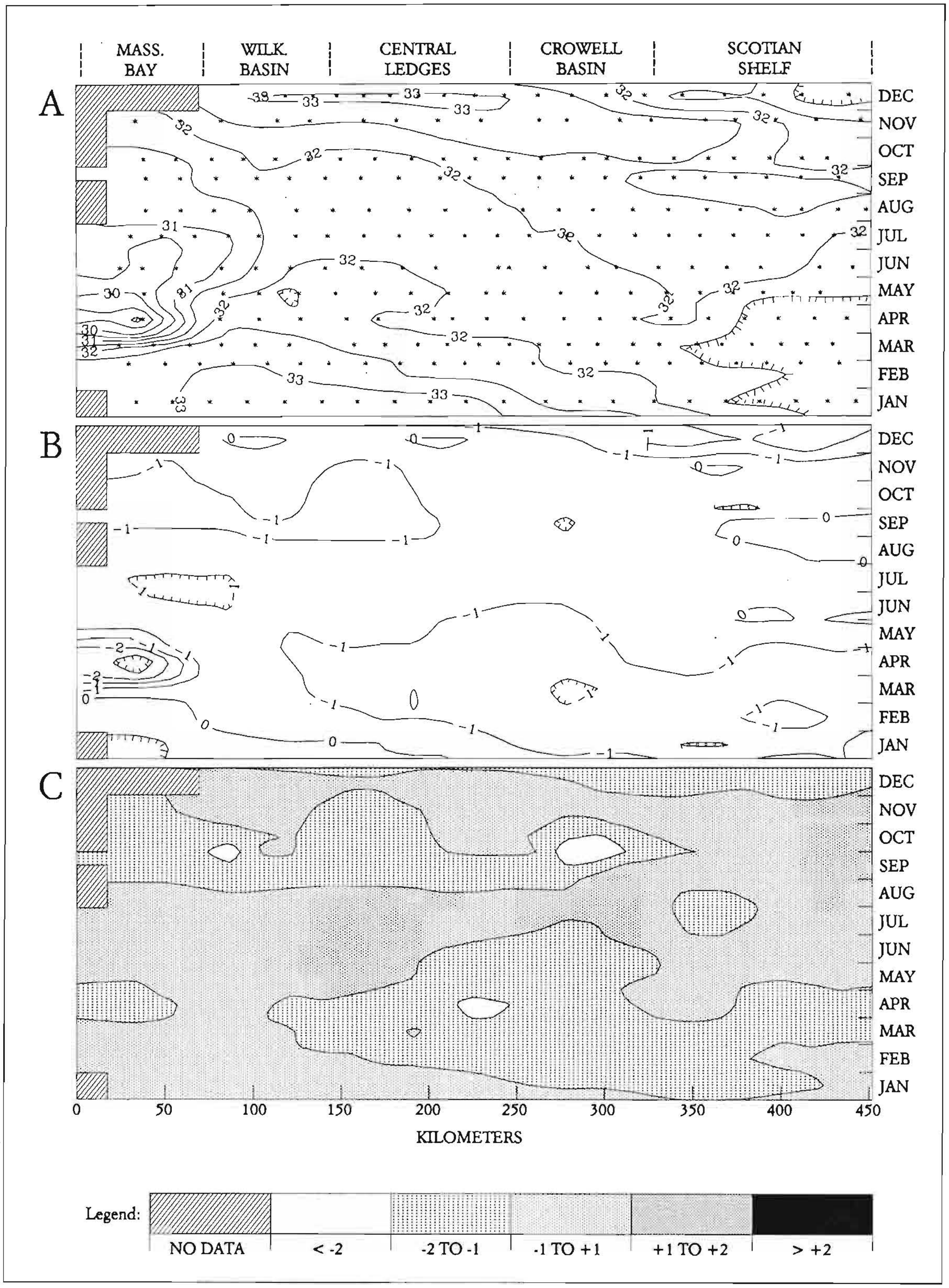

Figure 70

Surface salinity conditions along the Gulf of Maine route during 1987. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

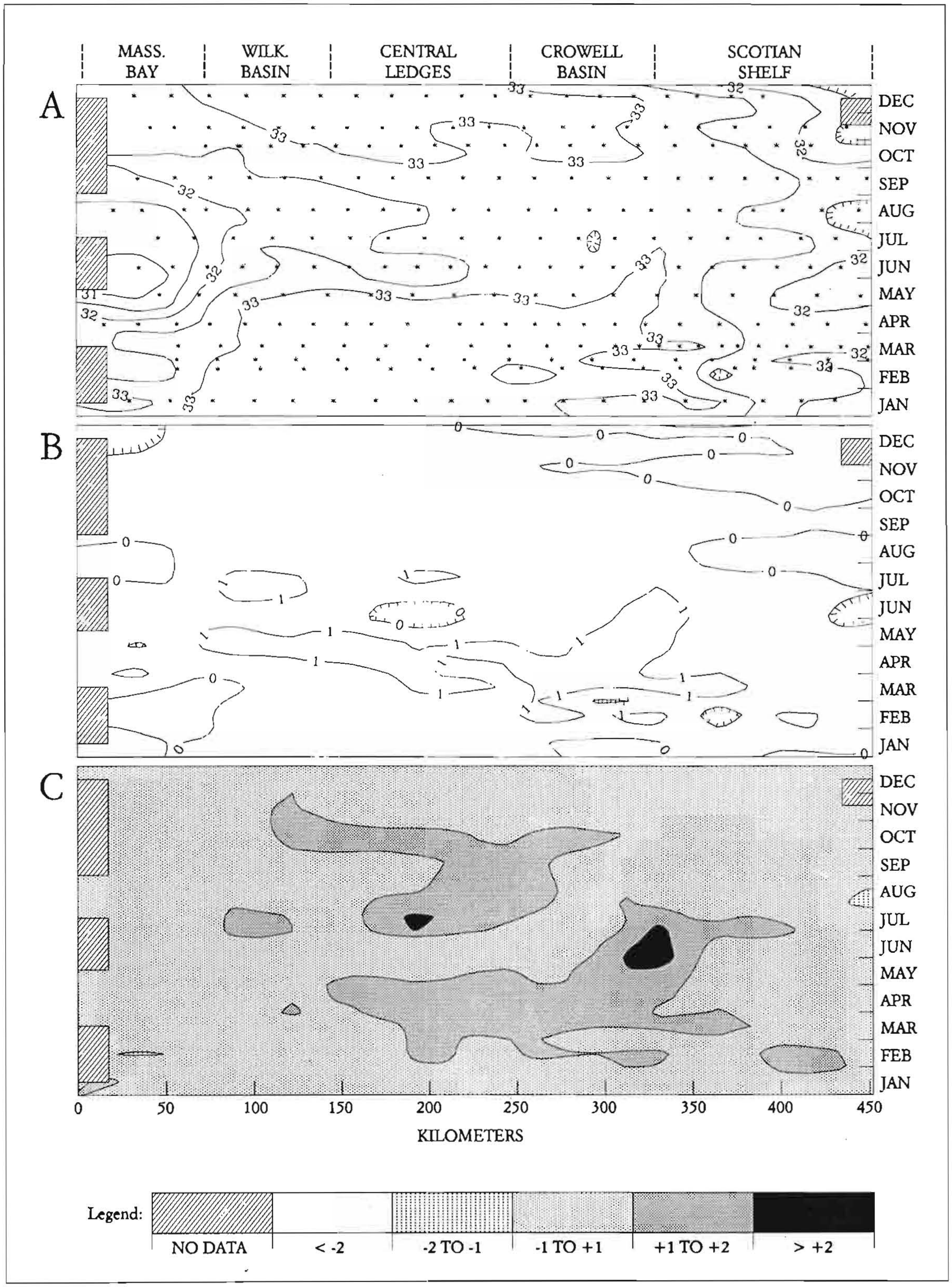

Figure 71

Surface salinity conditions along the Gulf of Maine route during 1986. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

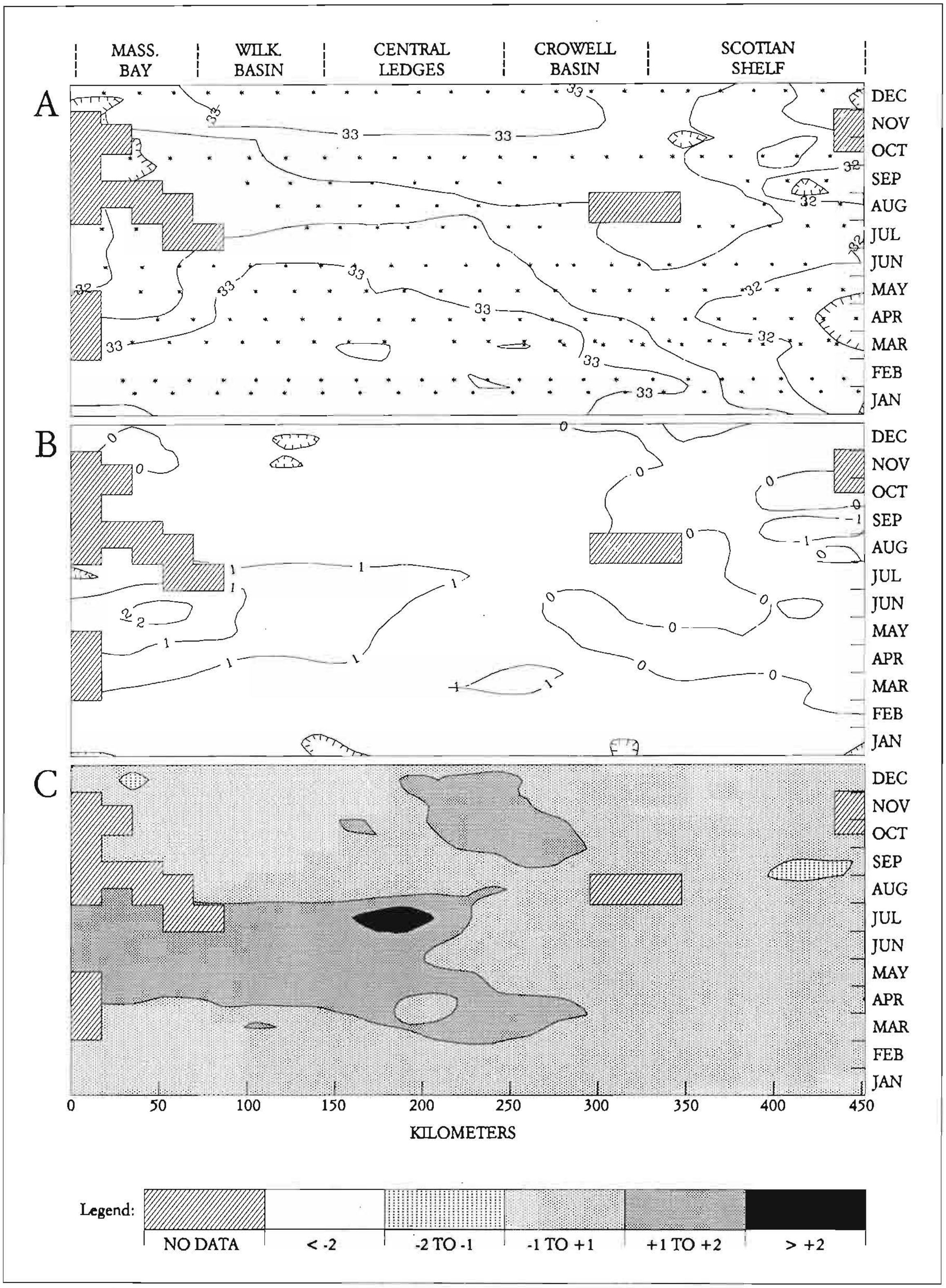

Figure 72

Surface salinity conditions along the Gulf of Maine route during 1985. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

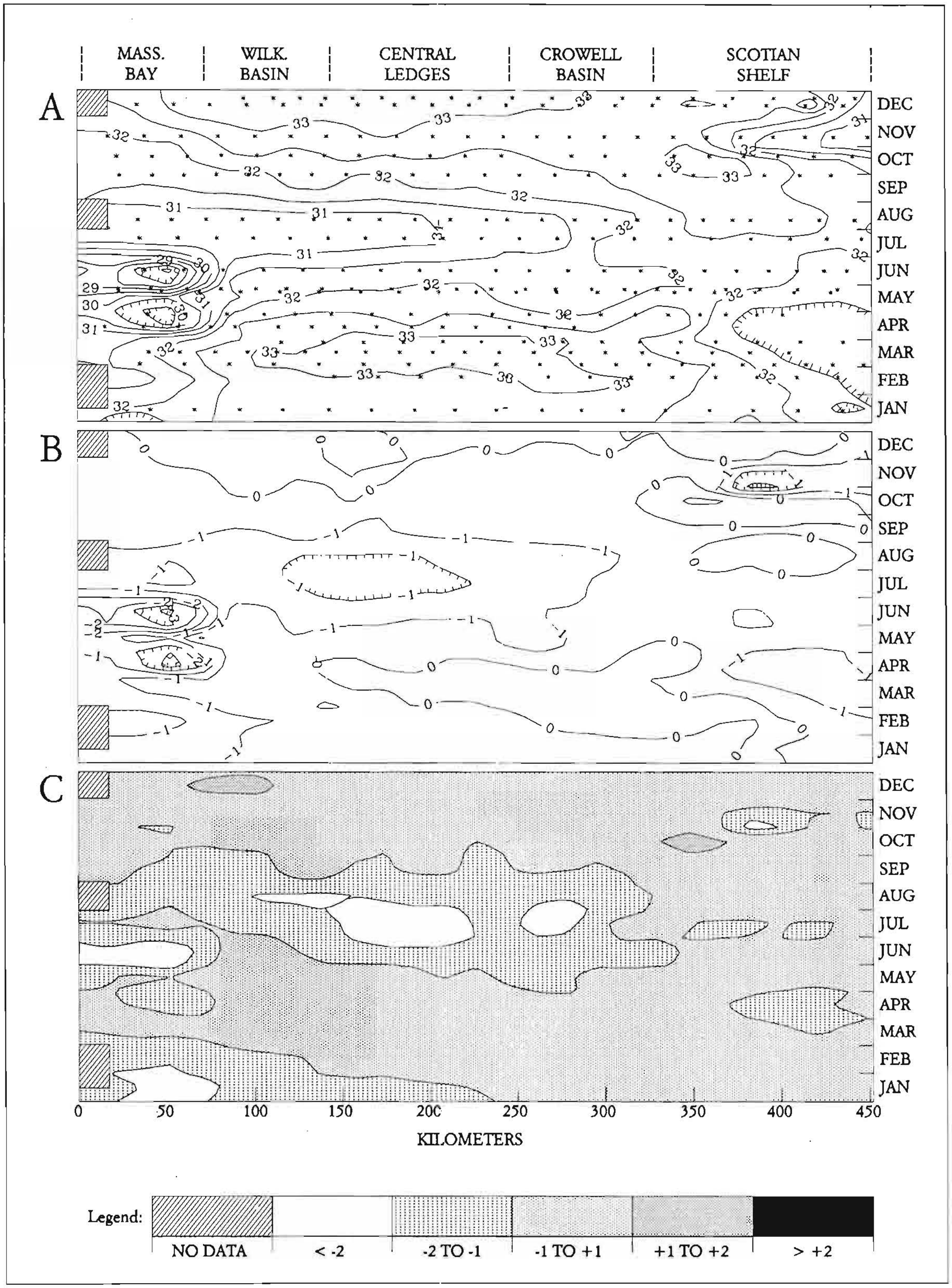

Figure 73

Surface salinity conditions along the Gulf of Maine route during 1984. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

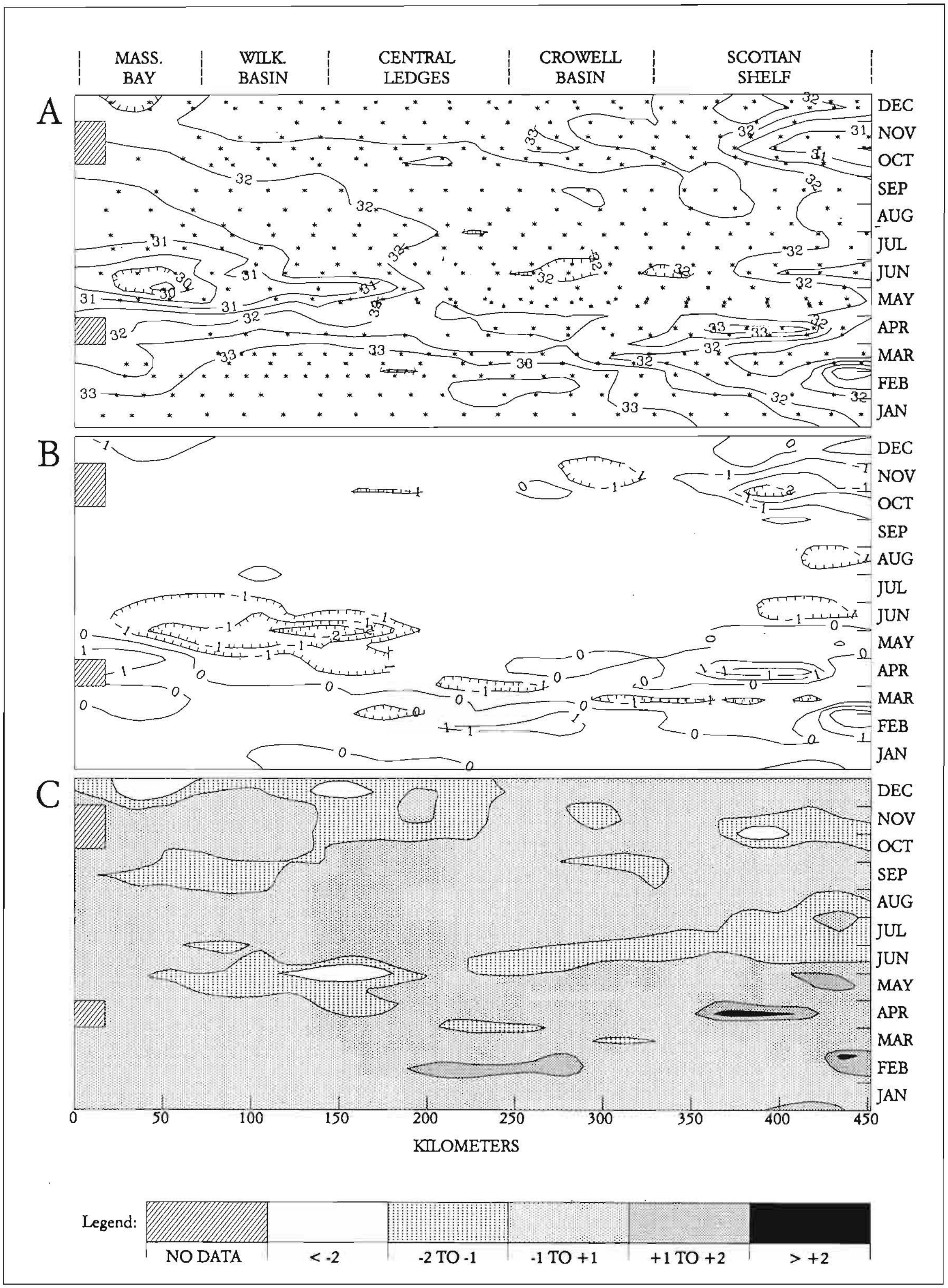

Figure 74

Surface salinity conditions along the Gulf of Maine route during 1983. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

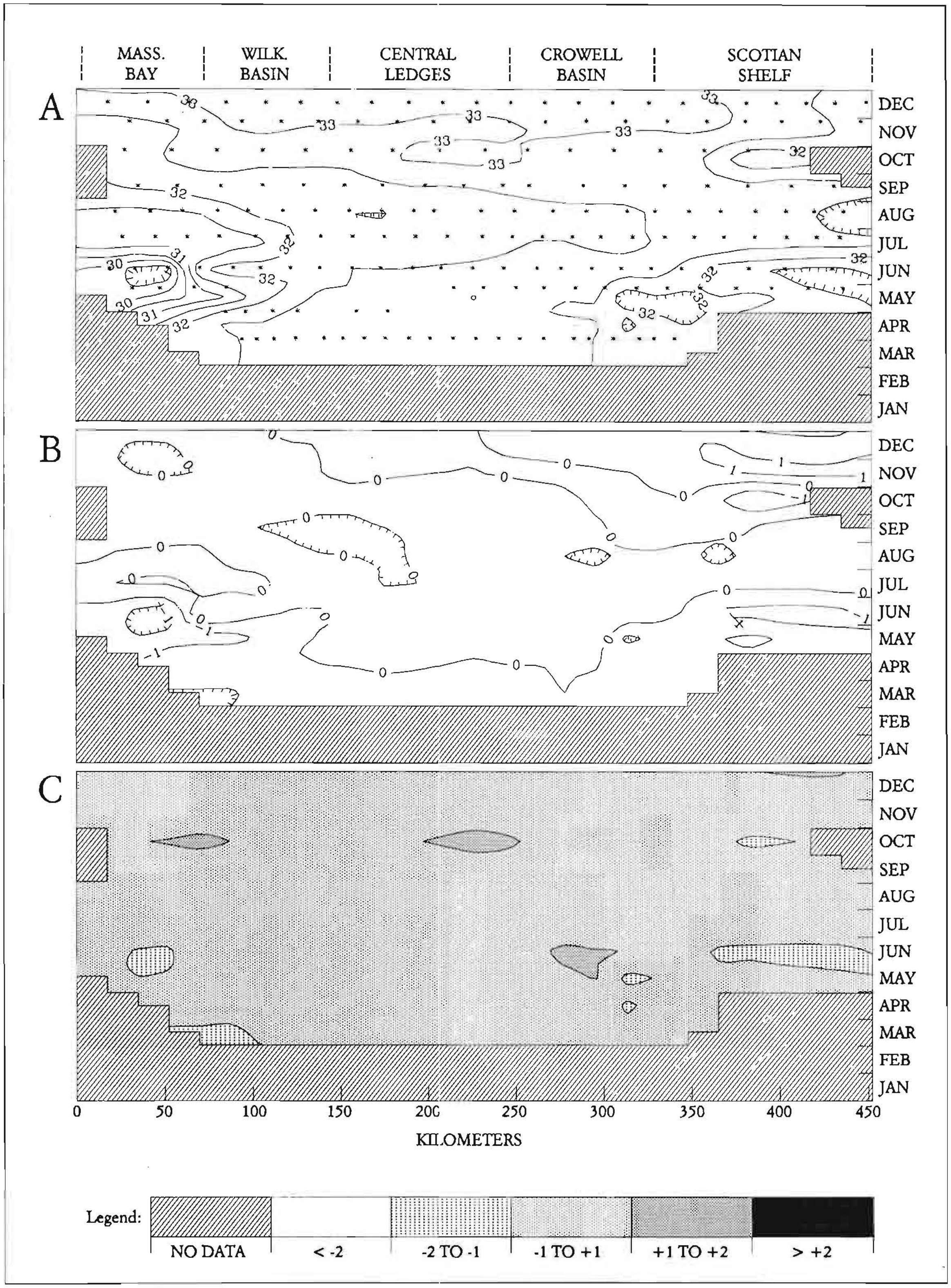

Figure 75

Surface salinity conditions along the Gulf of Maine route during 1982. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

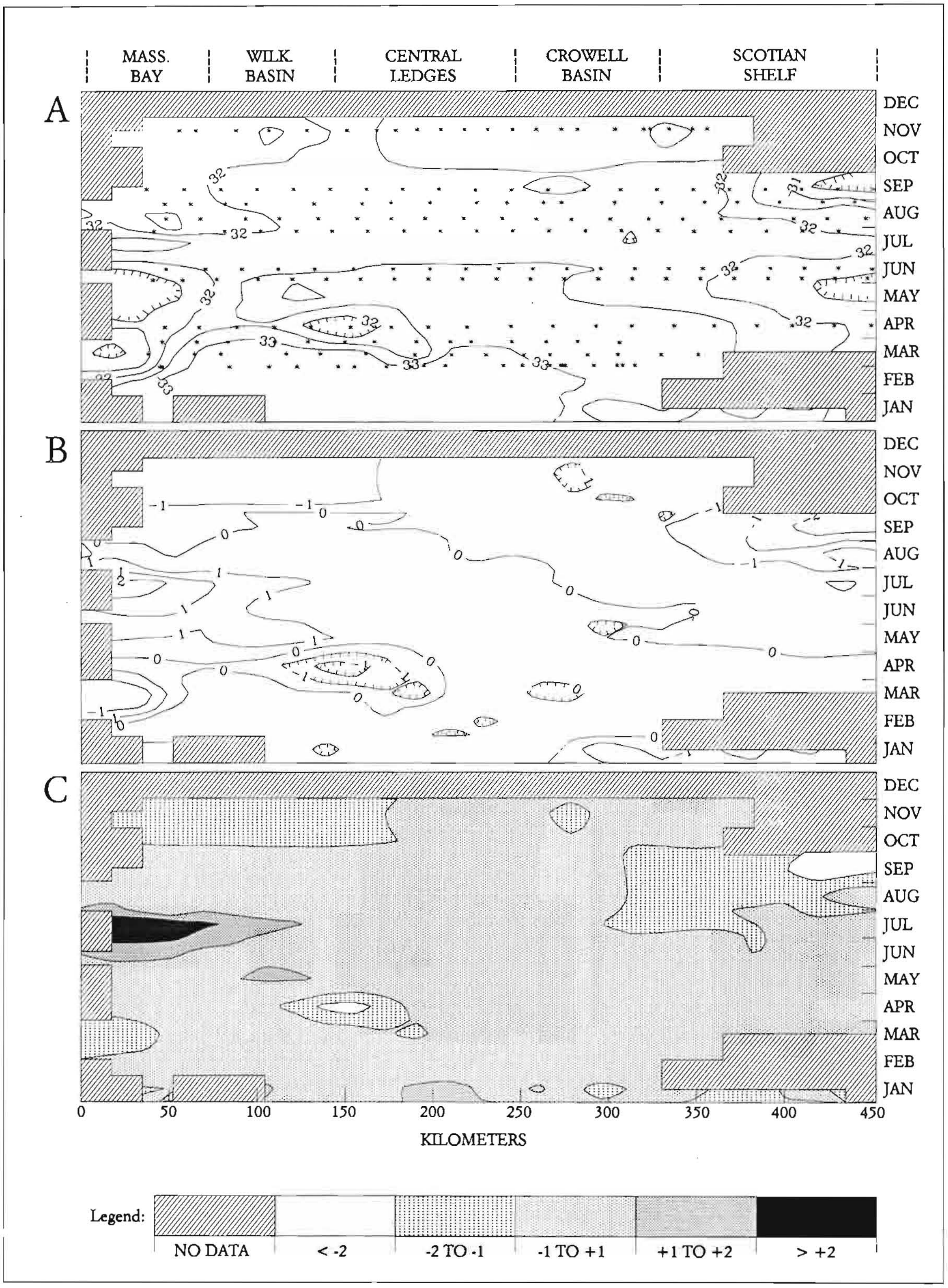

Figure 76

Surface salinity conditions along the Gulf of Maine route during 1981. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

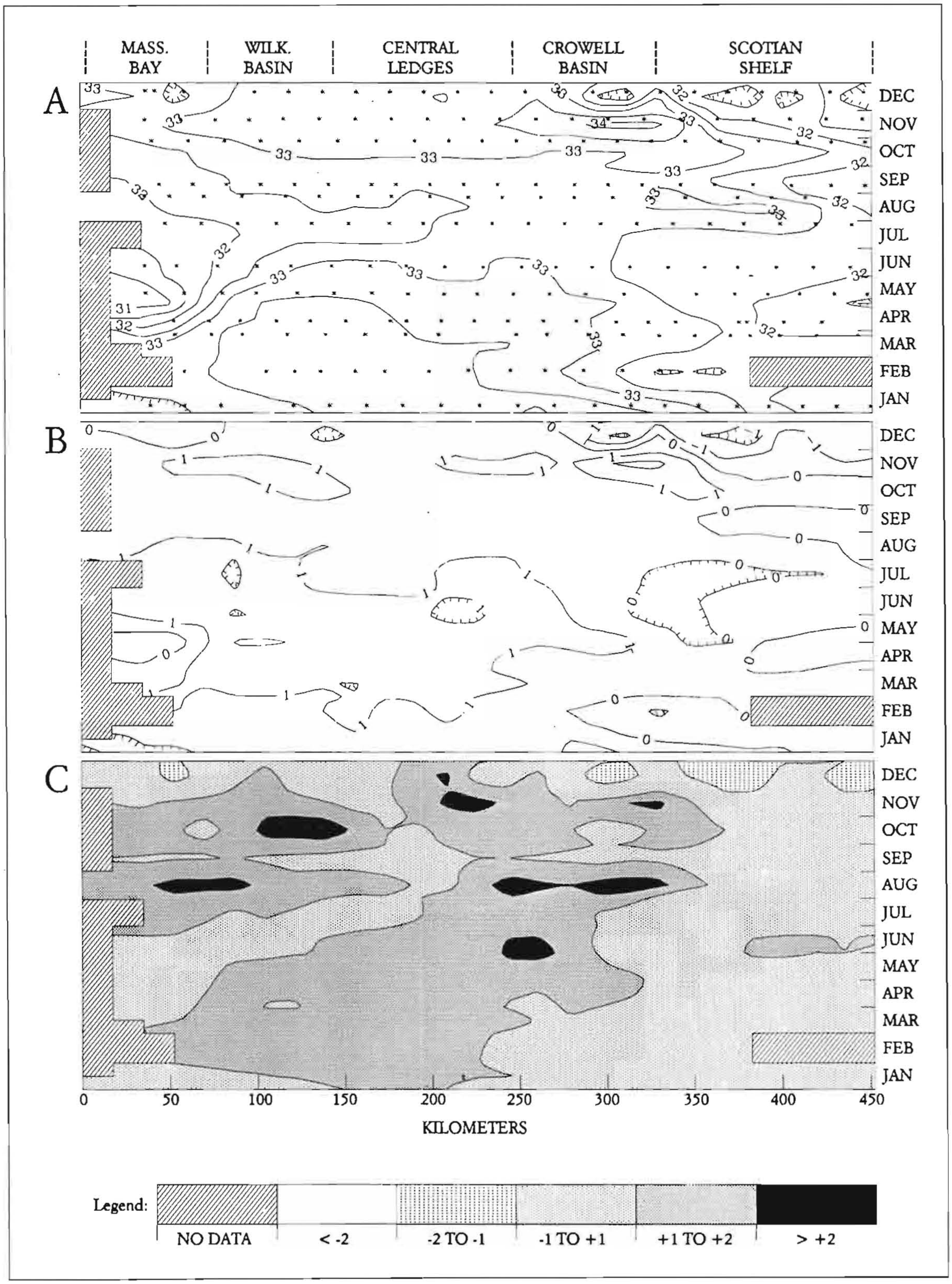

Figure 77

Surface salinity conditions along the Gulf of Maine route during 1980. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

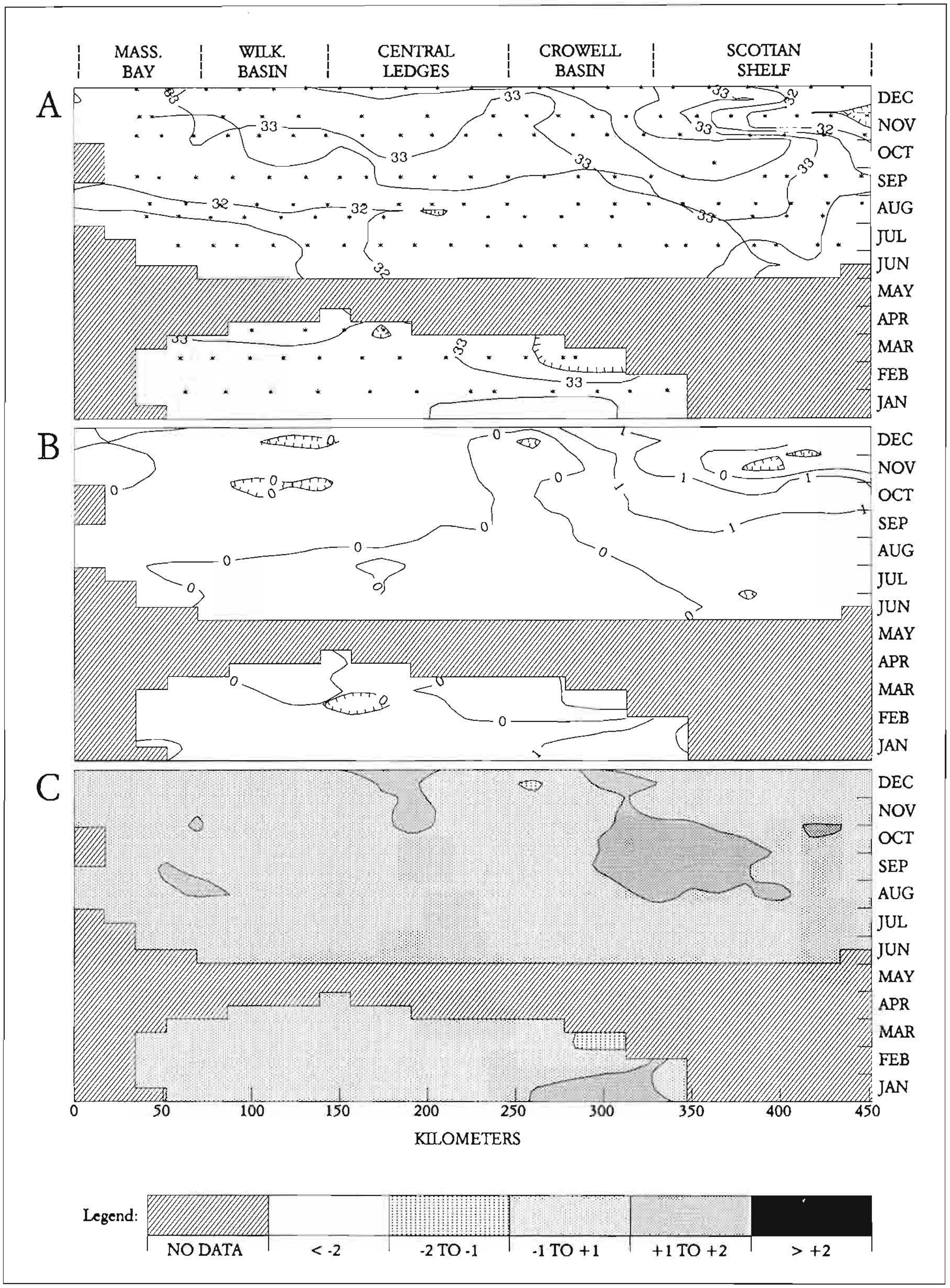

Figure 78

Surface salinity conditions along the Gulf of Maine route during 1979. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

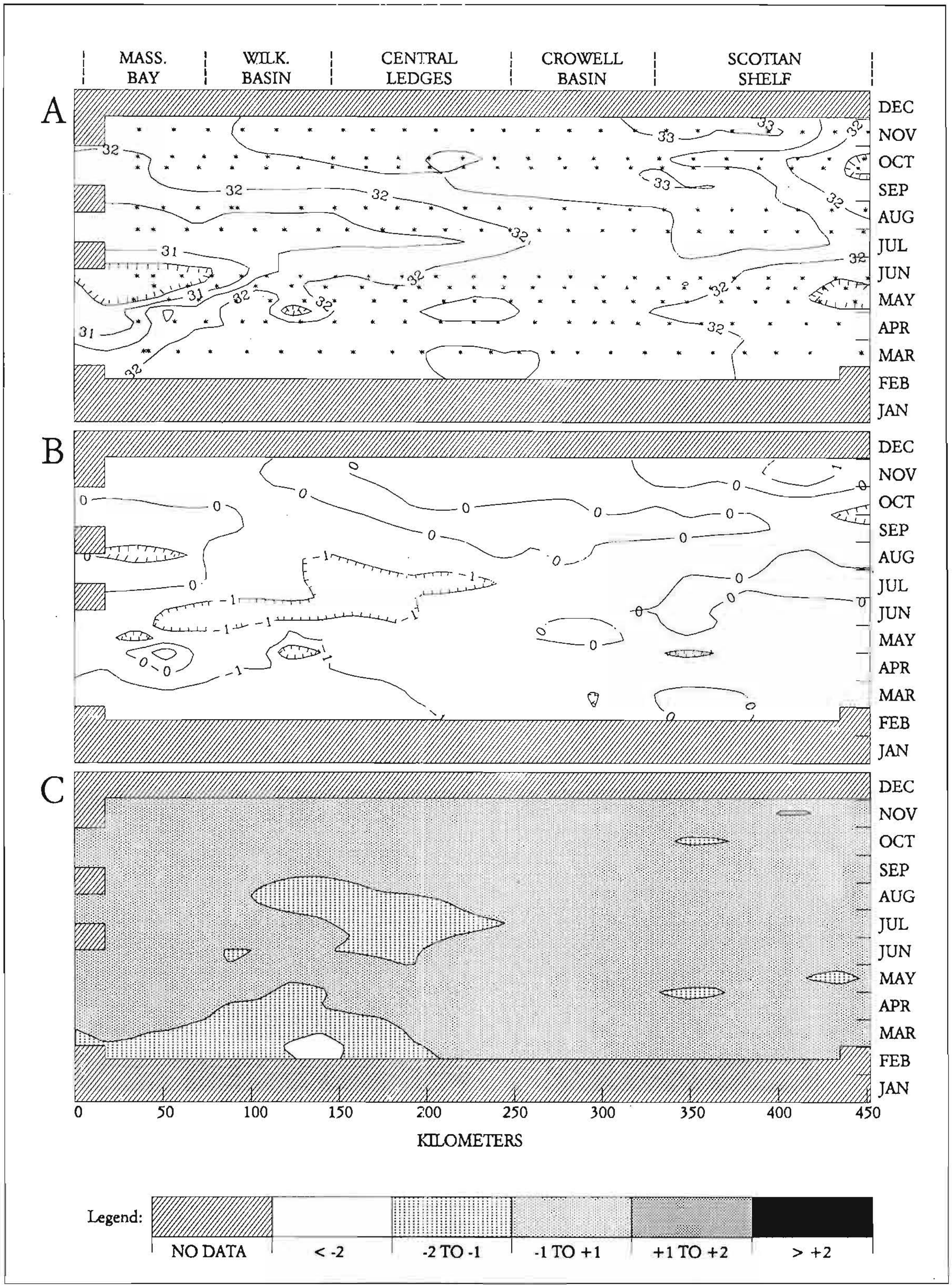

Figure 79

Surface salinity conditions along the Gulf of Maine route during 1978. (**A**) Measured values (practical salinity units). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

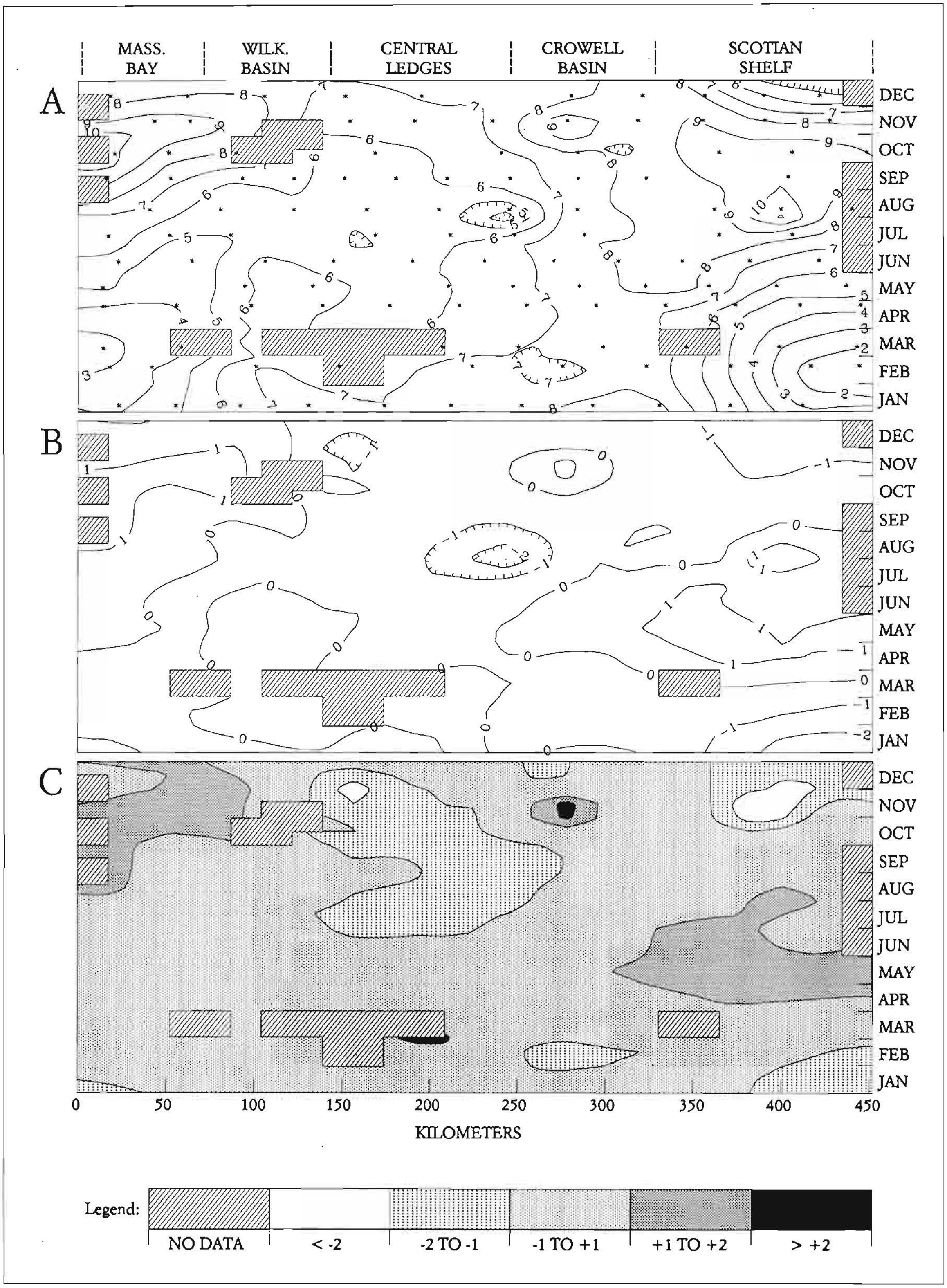

Figure 80

Bottom temperature conditions along the Gulf of Maine route during 1990. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

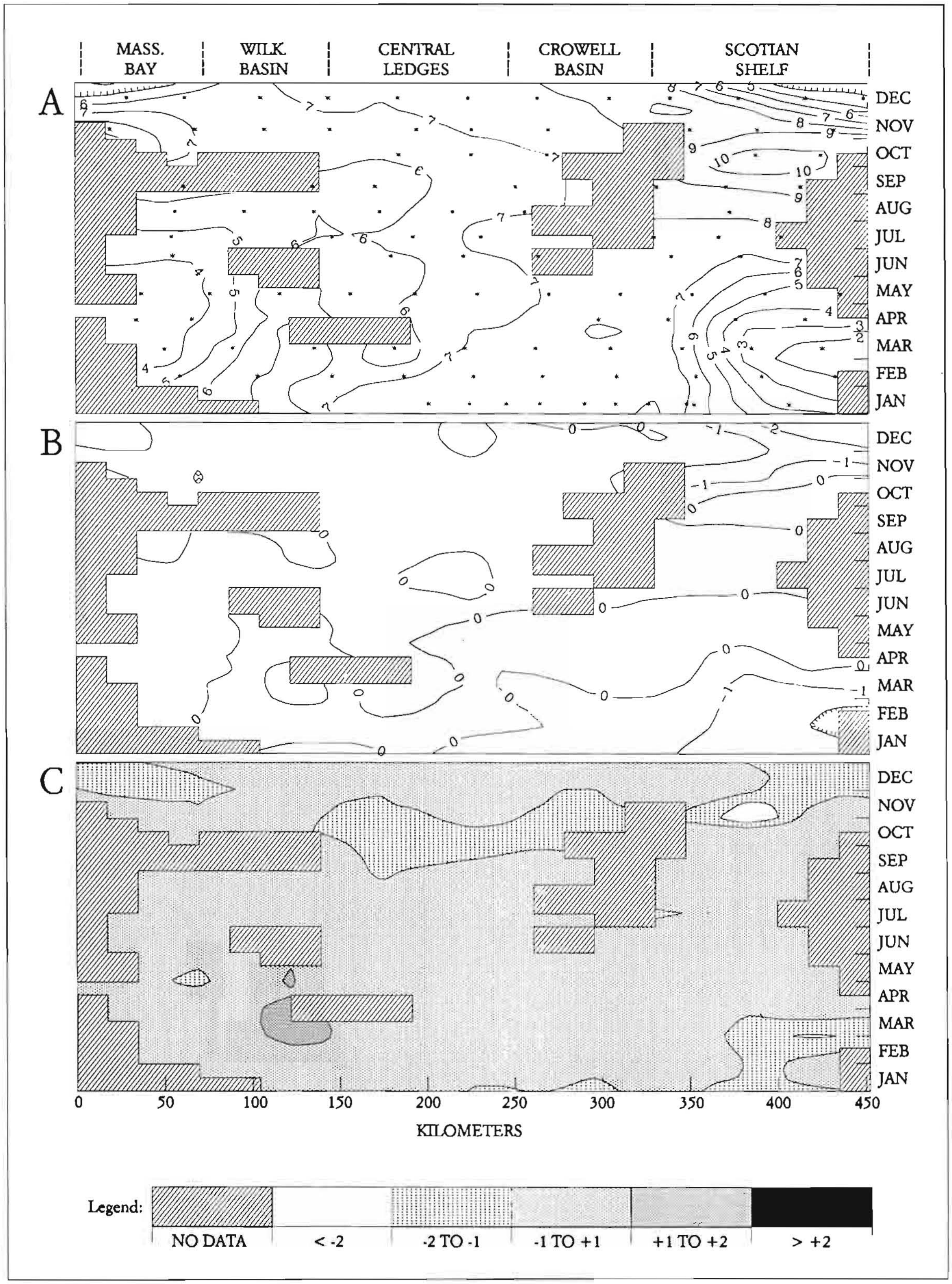

Figure 81

Bottom temperature conditions along the Gulf of Maine route during 1989. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

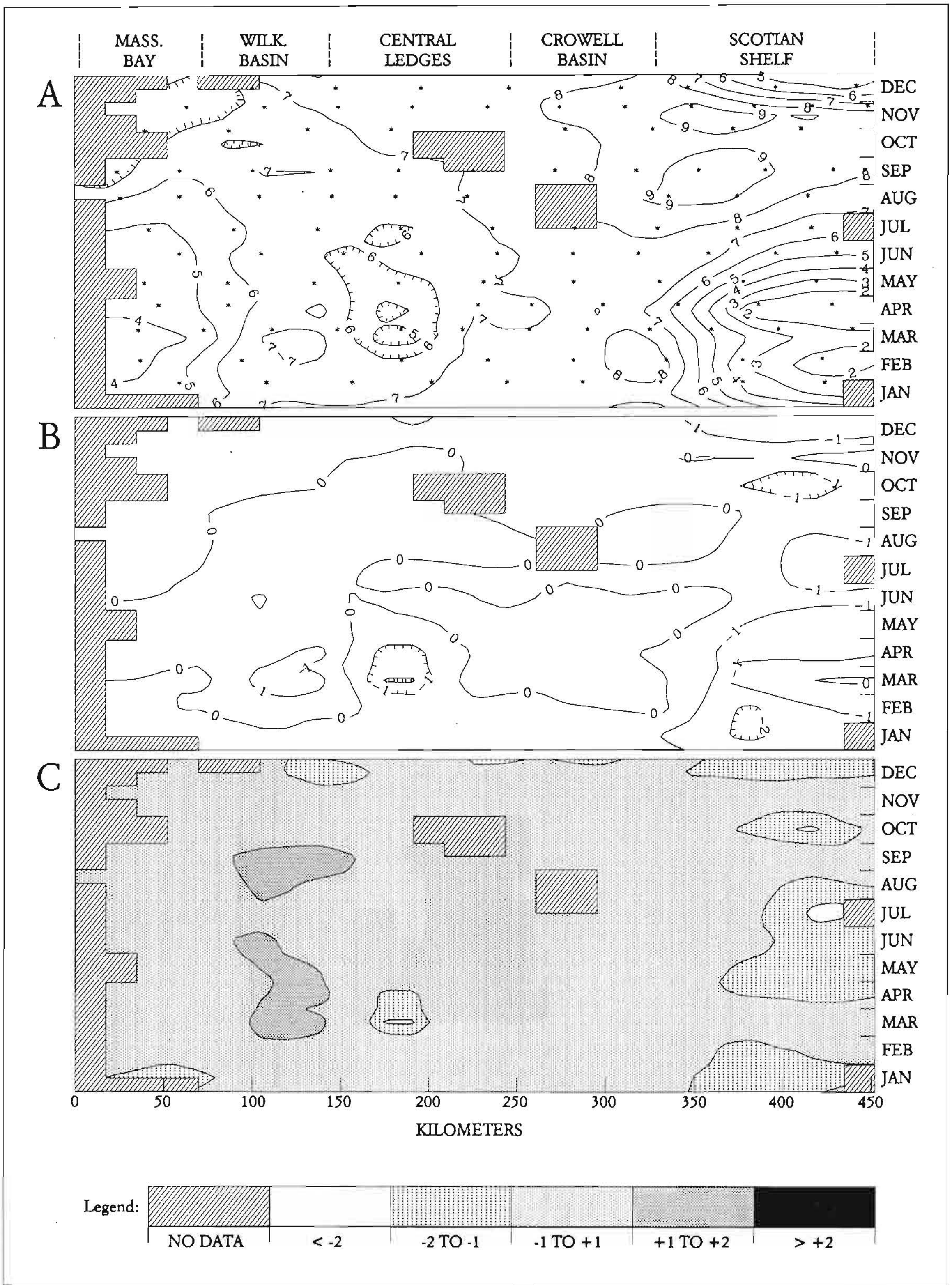

Figure 82

Bottom temperature conditions along the Gulf of Maine route during 1988. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

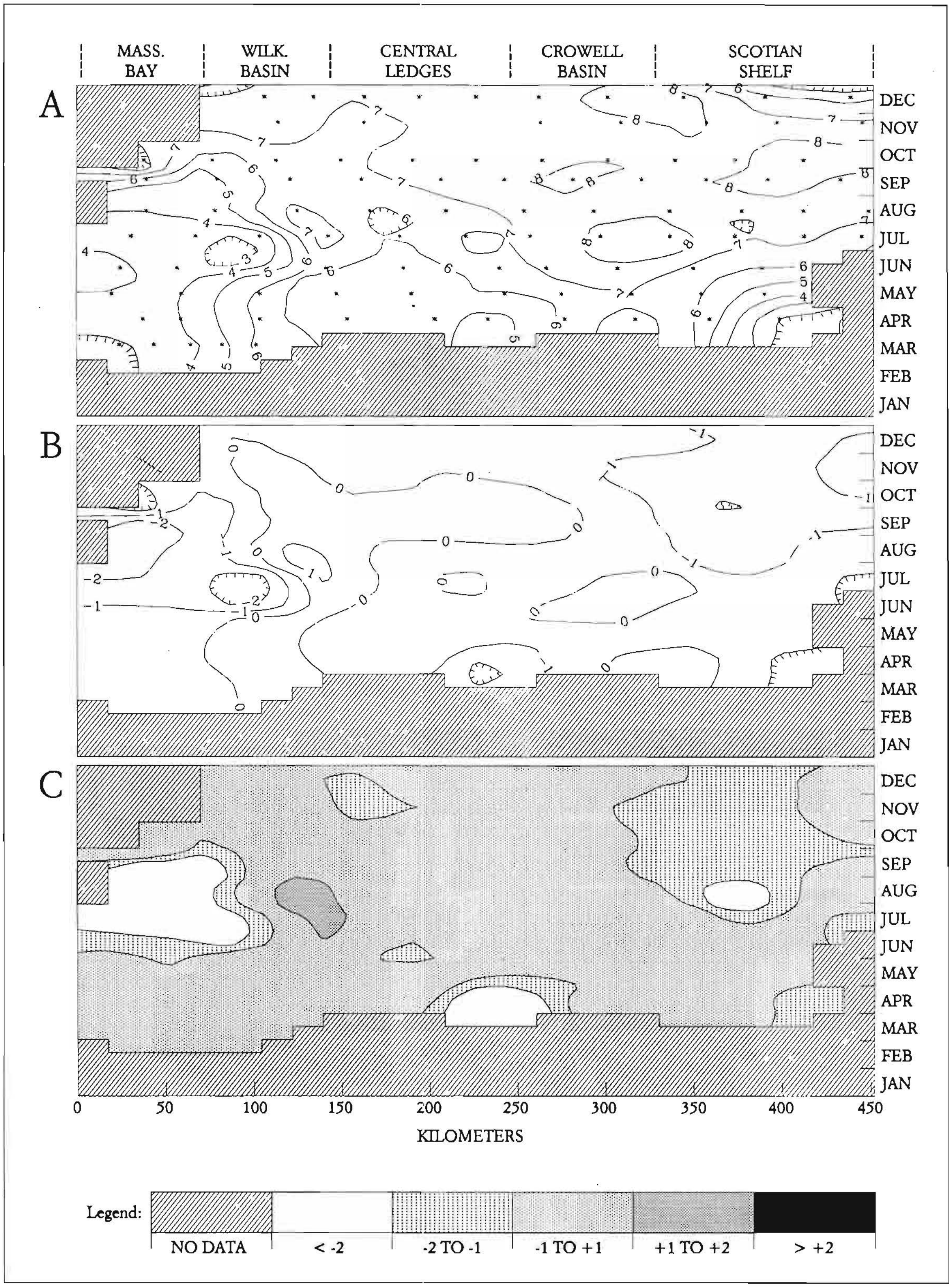

Figure 83

Bottom temperature conditions along the Gulf of Maine route during 1987. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

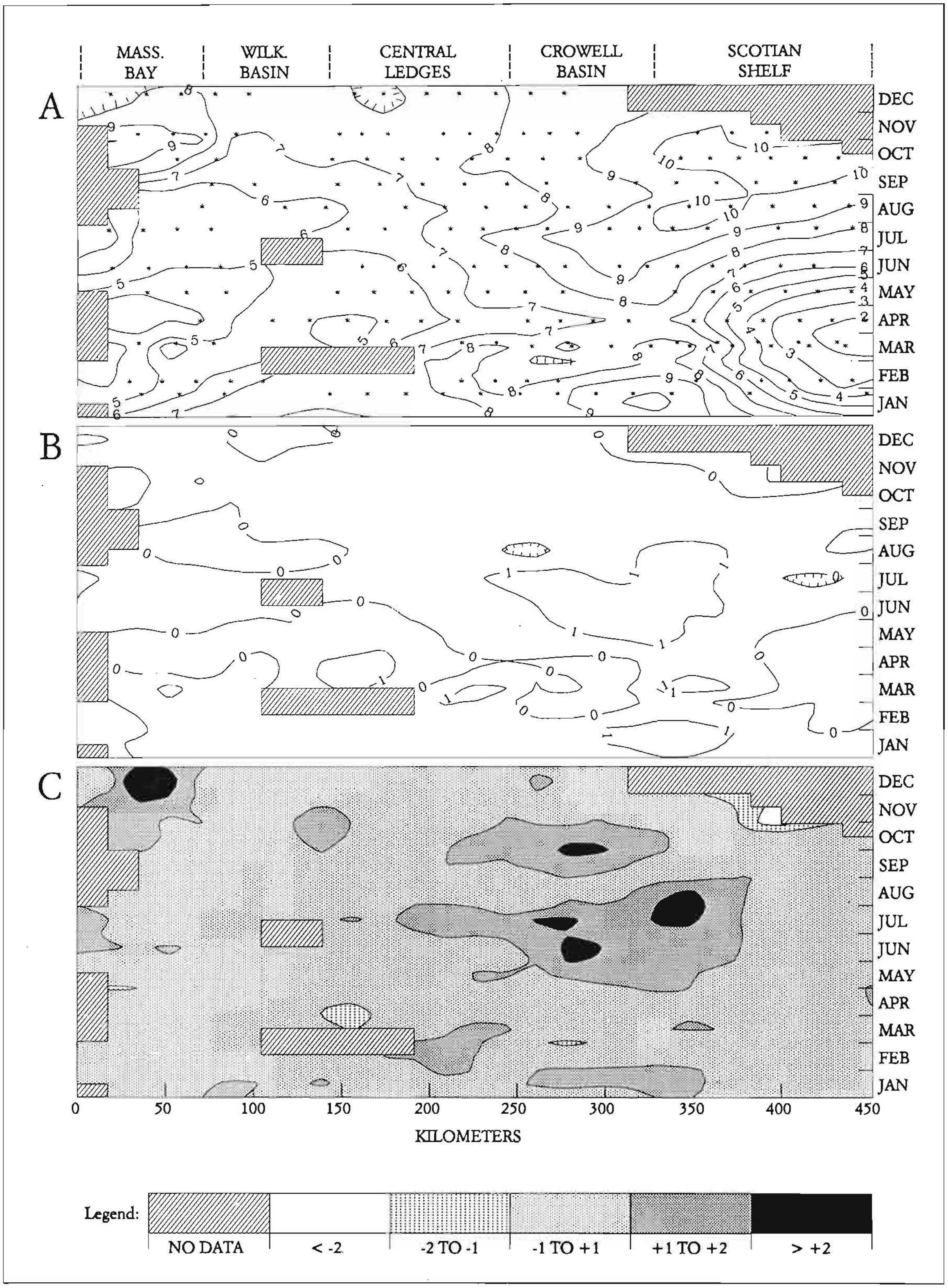

Figure 84

Bottom temperature conditions along the Gulf of Maine route during 1985. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

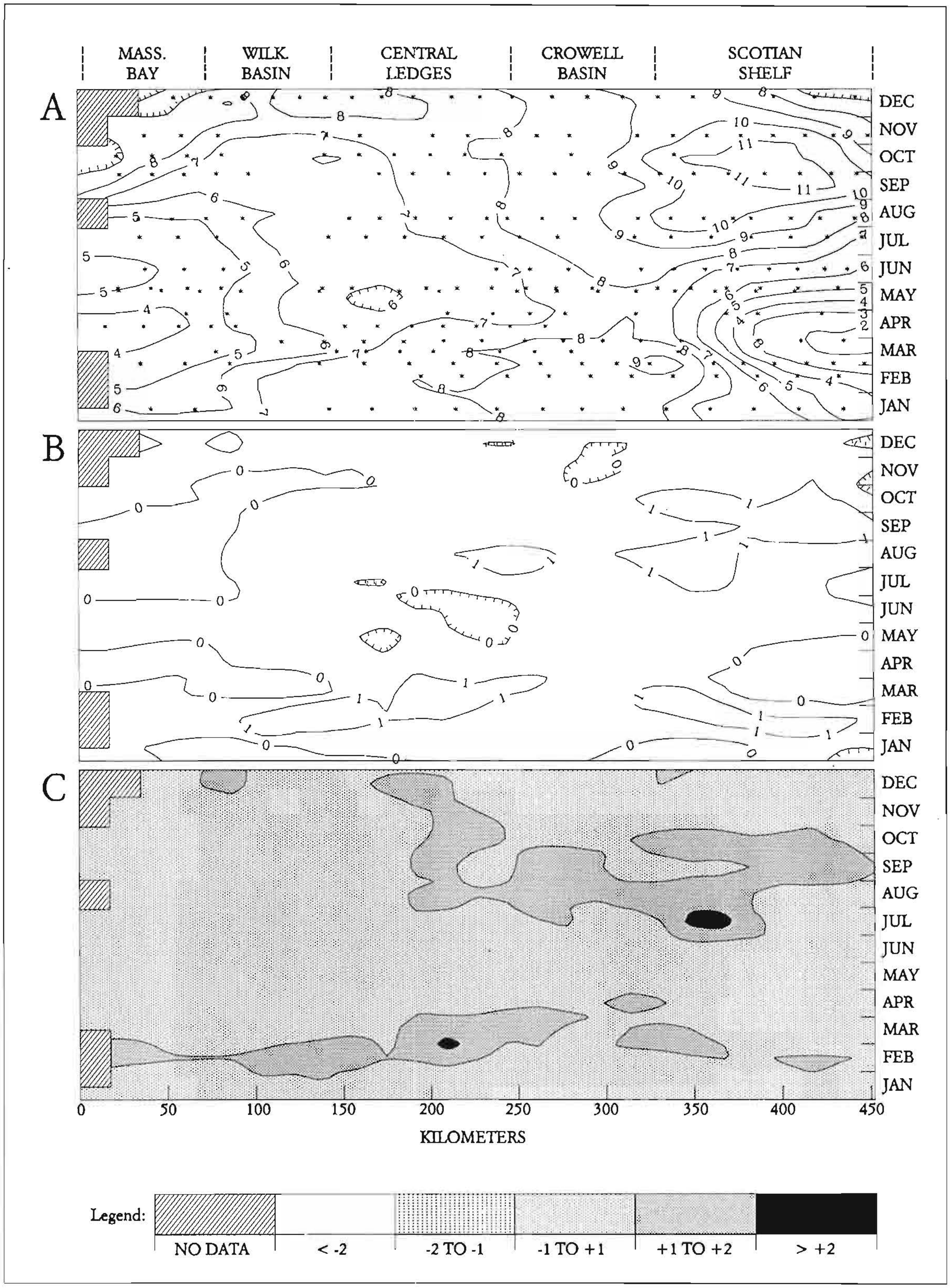

Figure 85

Bottom temperature conditions along the Gulf of Maine route during 1984. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

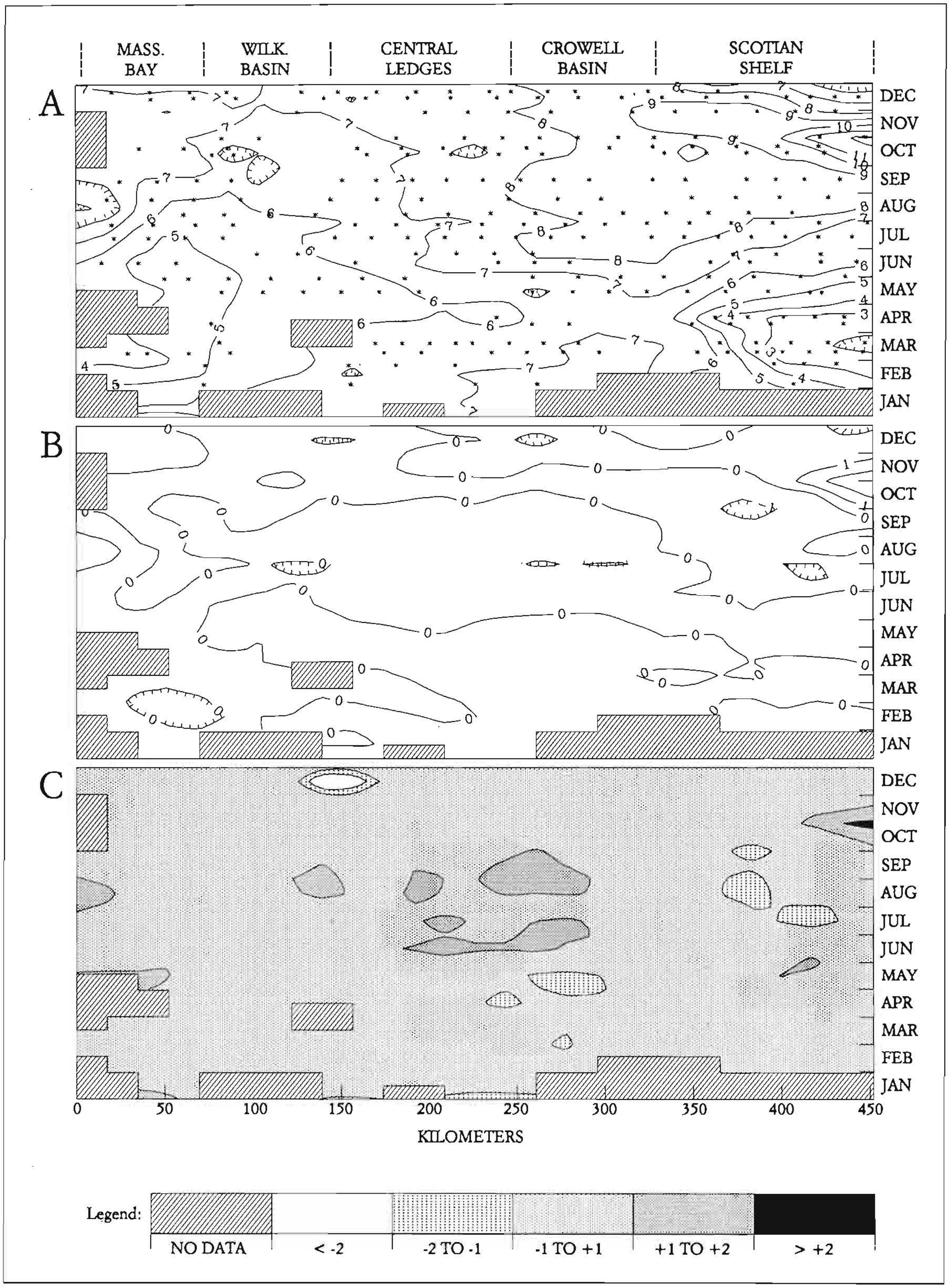

Figure 86

Bottom temperature conditions along the Gulf of Maine route during 1983. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

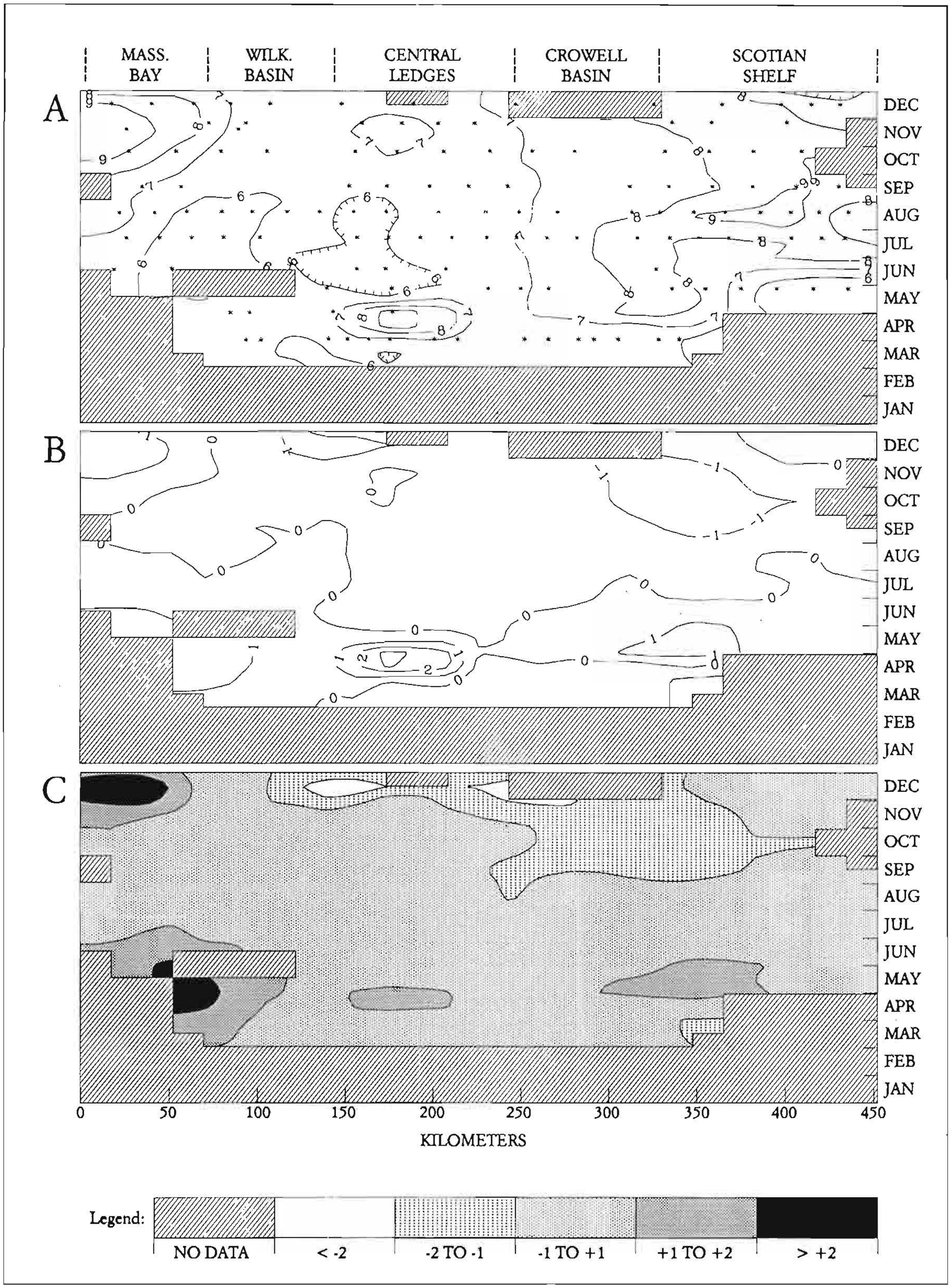

Figure 87

Bottom temperature conditions along the Gulf of Maine route during 1982. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

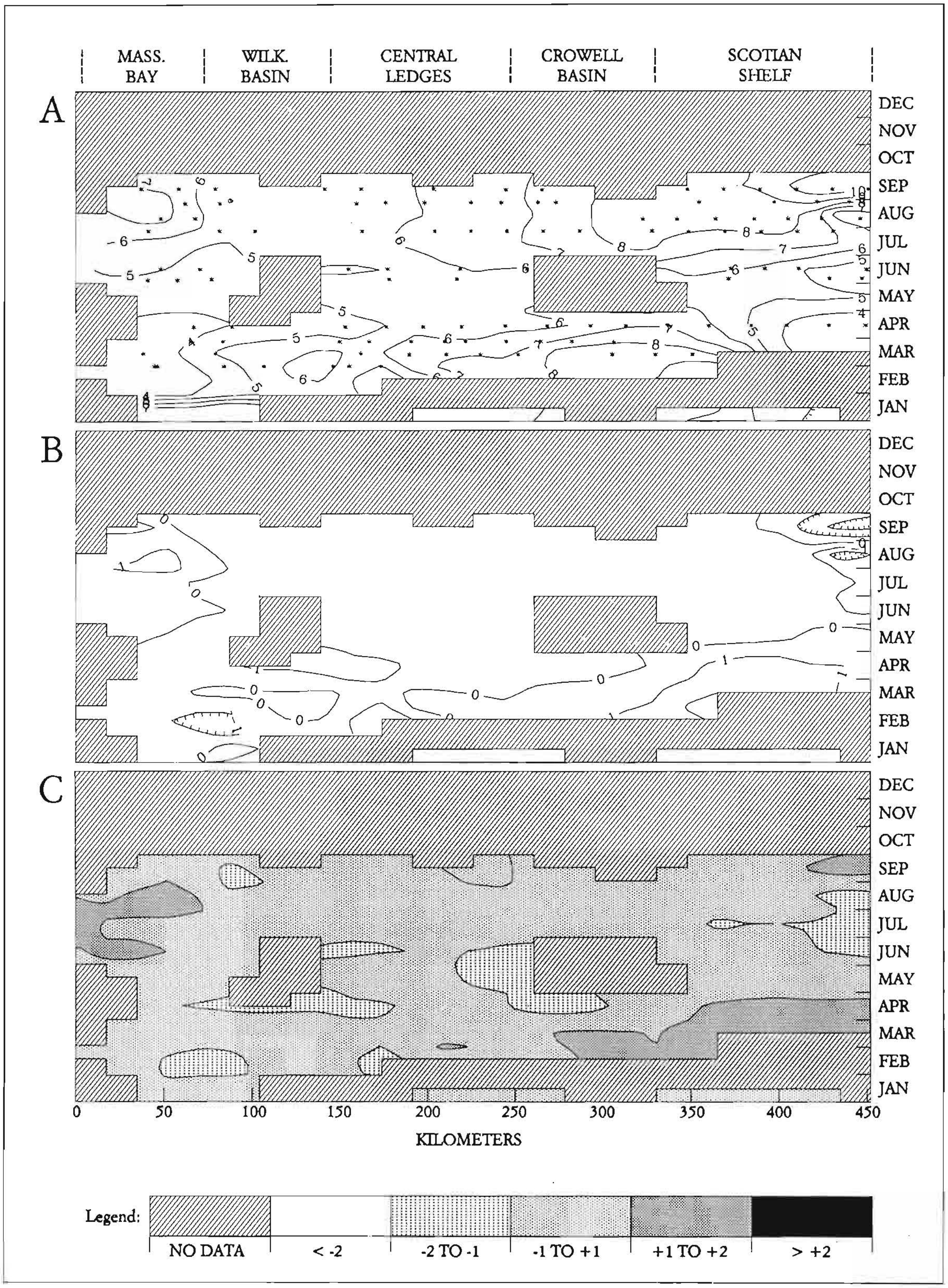

Figure 88

Bottom temperature conditions along the Gulf of Maine route during 1981. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

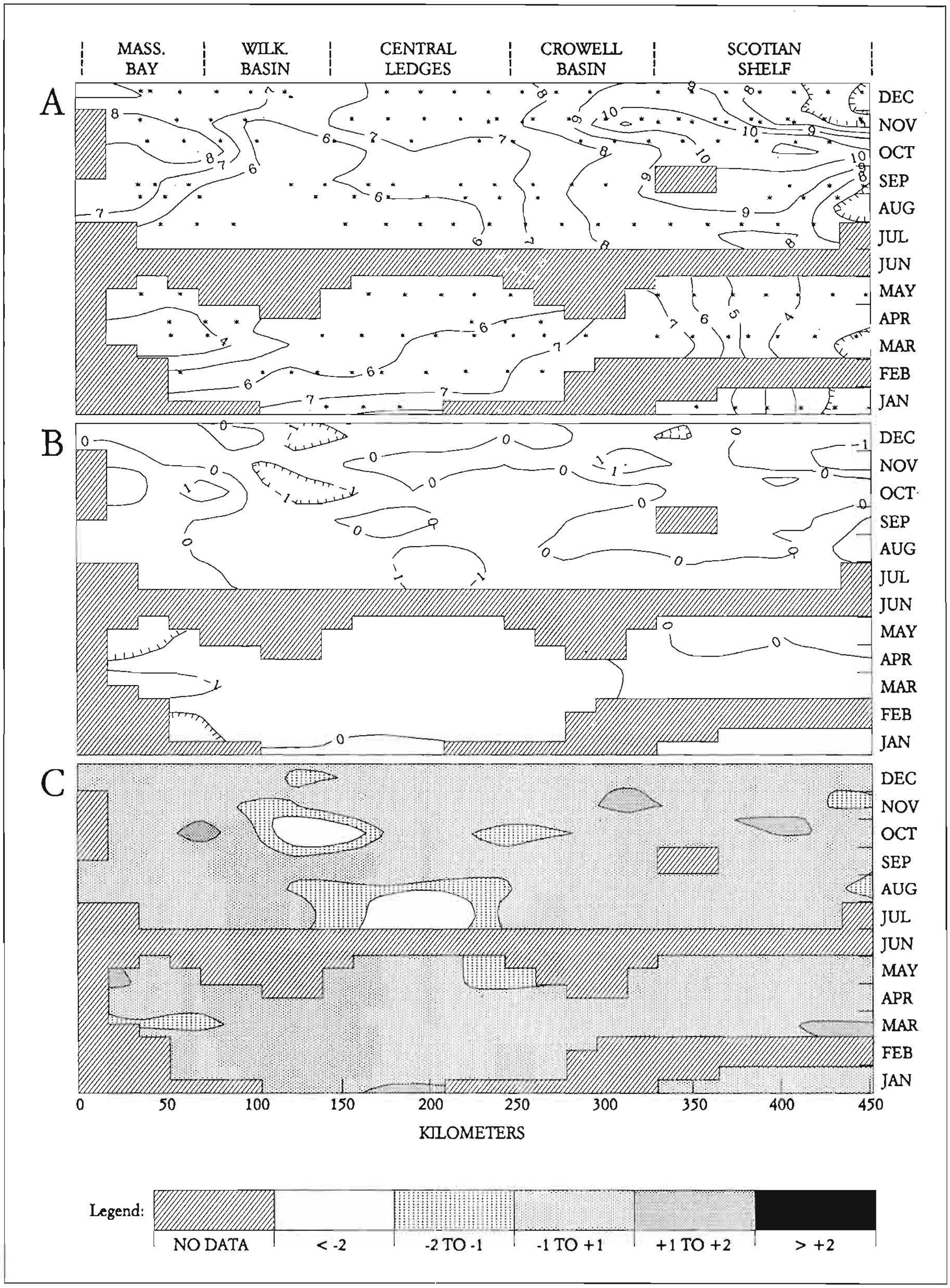

Figure 89

Bottom temperature conditions along the Gulf of Maine route during 1980. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

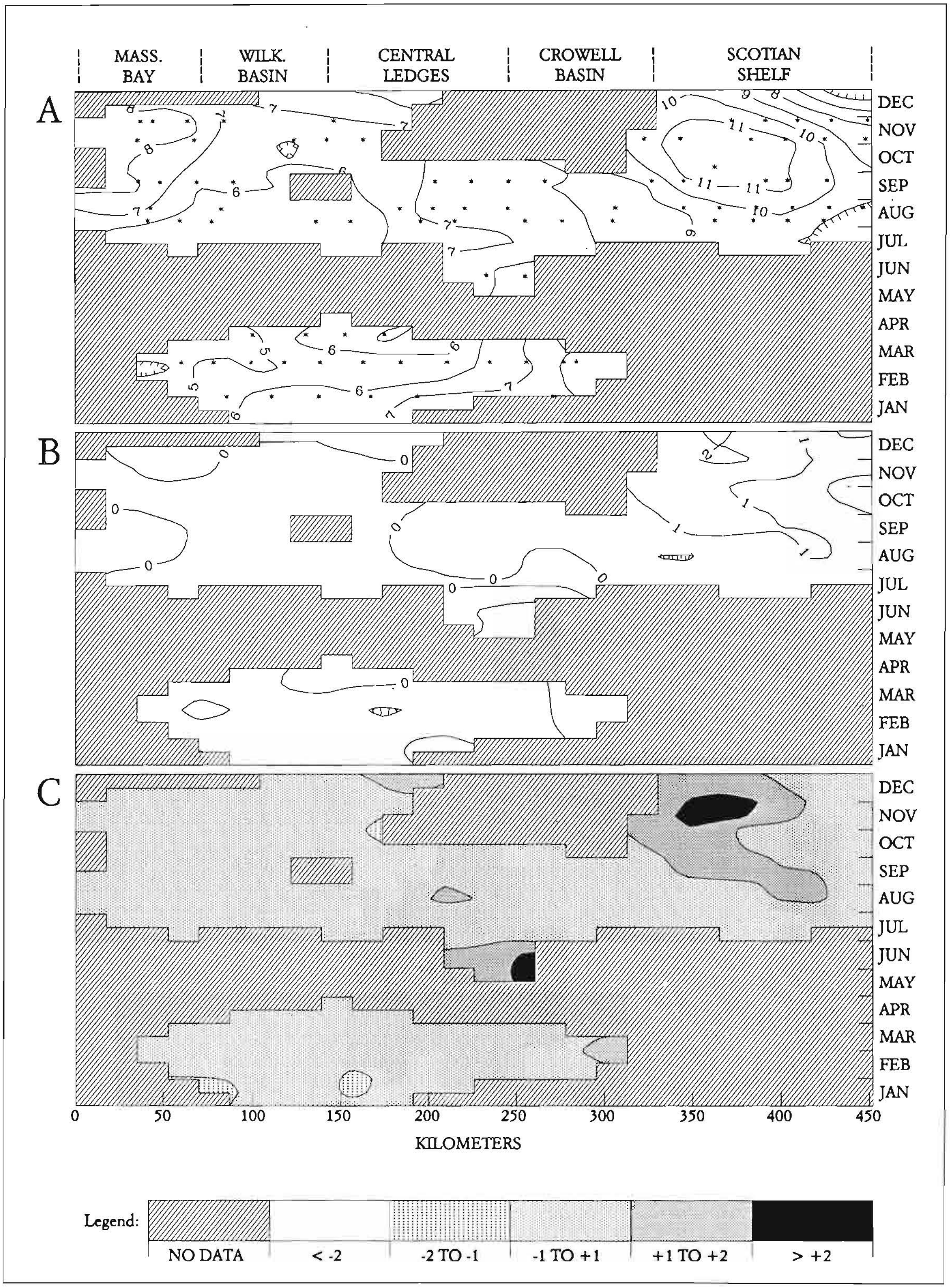

Figure 90

Bottom temperature conditions along the Gulf of Maine route during 1979. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

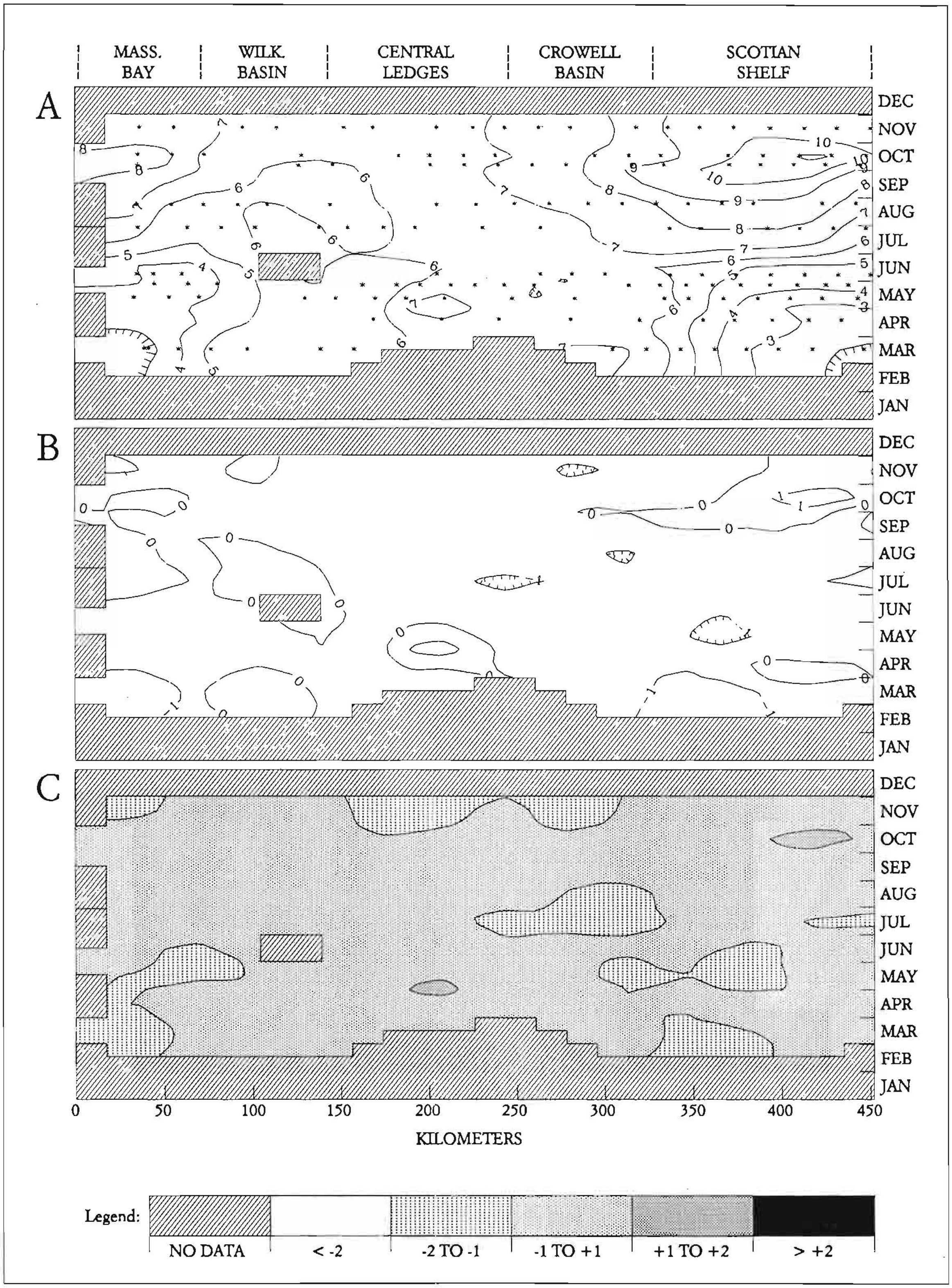

Figure 91

Bottom temperature conditions along the Gulf of Maine route during 1978. (**A**) Measured values (degrees Celsius). Dots indicate sampling locations. (**B**) Anomalies based on 1978 through 1990 means. (**C**) Standardized anomalies (standard deviations) based on 1978 through 1990 means and variances. In panels A and B, values decline on those sides of contour lines with hachures.

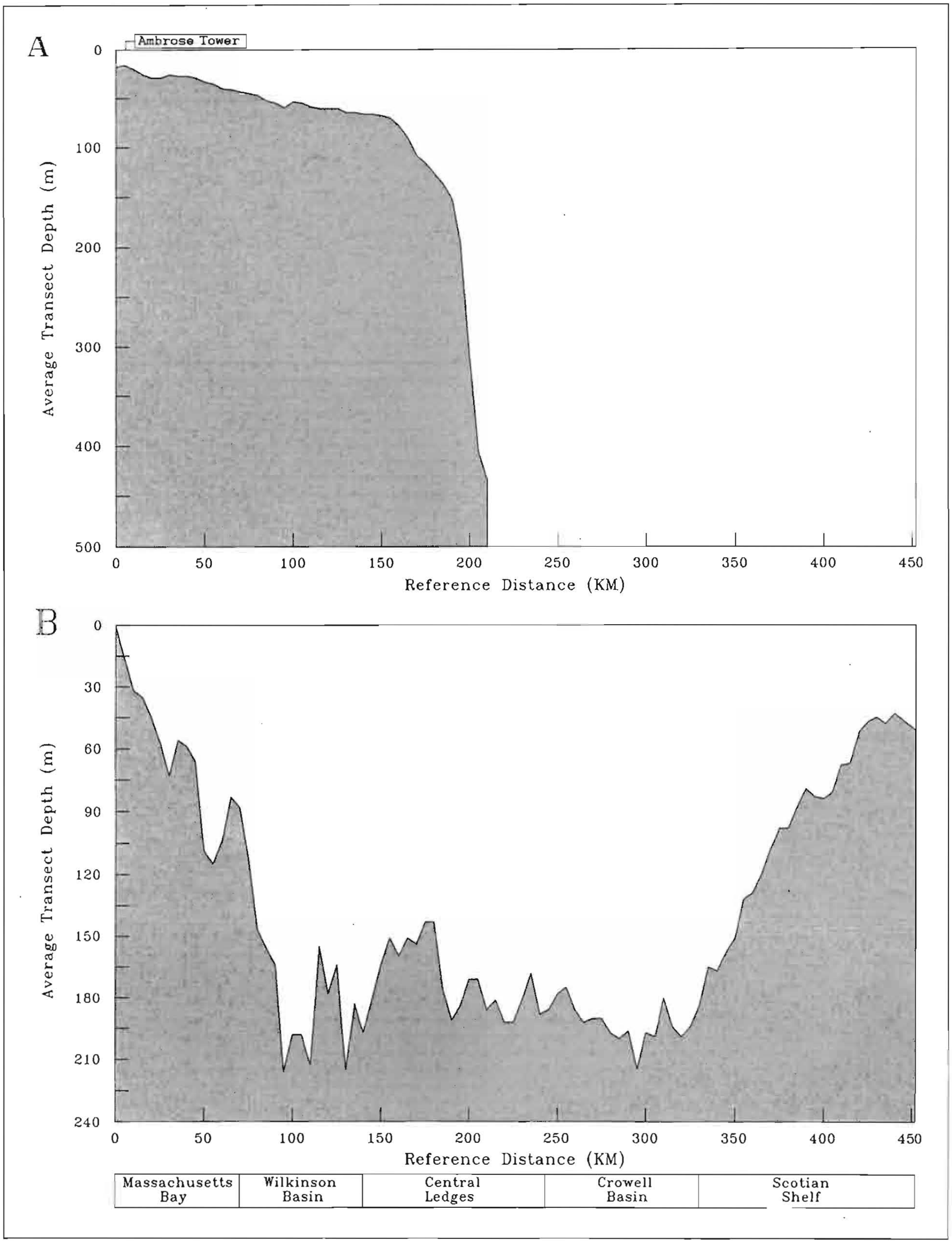

Figure 92

Mean bottom depth along the transects based on monitoring survey data, 1978 through 1990. (**A**) Middle Atlantic Bight. (**B**) Gulf of Maine.

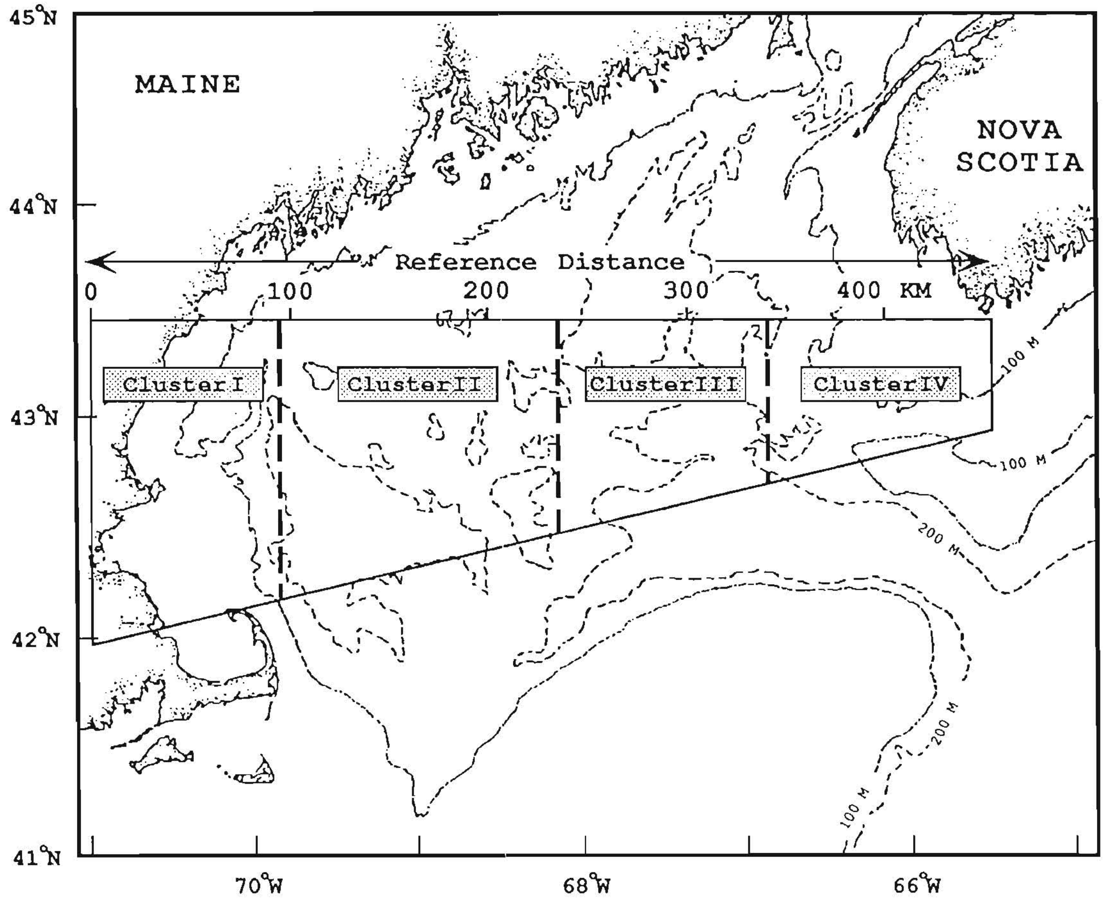

Figure 93

Results of variable cluster analysis of standardized anomalies of sea surface temperatures and salinities along the Gulf of Maine transect 1978 through 1990 base period. Cluster region boundaries were as follows: cluster I, 0–96 km; cluster II, 96–235 km; cluster III, 235–339 km; and cluster IV, 339–452 km. (From Thomas 1992.)

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