III. ABIOTIC METRICS

A. Geology, Chemistry

Geologic and chemical features significantly influence the physical and biological components of this ecosystem. Although data on these factors exists, few time series are available.

We do not include geological metrics in this report because the extant data and expertise in this area reside with the United States Geological Survey. From an ecosystem perspective, we need definitions of major geologic regions, including the distributions of major sediment/bottom types, and delineations of high/low energy areas in the ecosystem. Some information on the marine geology of the region is summarized in Backus (1987). Time series of geological characteristics may not be essential for understanding ecosystem dynamics, particularly in the context of living resources. Because these issues are beyond our expertise, they should be considered (and currently are) in collaboration with the USGS.

In the case of chemical metrics, we need to identify key chemical indicators from an array of important nutrients, metals, and toxins. We also need to be able to track their concentrations through time and space. Few time series data exist for these chemicals. Some chemicals have been sampled by our Highlands, NJ Lab over time at particular locations. However, we do not know the spatial extent and resolution of sampling needed to synoptically understand how these chemicals influence ecosystem dynamics. Important questions to address include:

how often do we need to sample, what selection of representative chemicals should we monitor, and what are the major gaps of information? These questions need to be addressed before we can develop chemical metrics for this ecosystem.

B. Physics

1. NAO Index

Time: 1823-2000

Spatial: North Atlantic Ocean

Contributed by: Brodziak

Figures A.1 and A.2

Methodology and Data Source

The NAO index is calculated as the air pressure difference between sites in Iceland and southern locations at the Azores or Gibralter (Jones et al. 1997). The NAO index time series was computed using data available from the Climate Research Unit at the University of East Anglia. This data may be accessed at http://www.cru.uea.ac.uk/. The NAO winter index is reported here. In year y, the NAO winter index is the arithmetic average of monthly NAO values for December in year y and January-March in year y+1. The winter index is available for 1823-2000. The five-year moving average of the NAO index in year y is computed as the arithmetic average of NAO values in years y-2, y-1, y, y+1, and y+2; the five-year average is available for 1825-1998.

Key Points and Major Observations

The North Atlantic Oscillation (NAO) is one of the major features of the global climate system. There is an upward trend in the NAO from the 1960s to the early 1990s. The NAO index is highly variable and the largest recorded interannual change in the NAO index occurred from 1994 to 1995. The latitude of the Gulf Stream has been correlated with the NAO over the last 30 years (Taylor et al. 1998). Large positive NAO values are associated with colder air and stronger winds over the North Atlantic and a larger cold intermediate water layer on the Labrador Shelf. Large negative NAO values are associated with warmer air and weaker winds over the North Atlantic and a smaller cold intermediate water layer on the Labrador Shelf.

2. Shelf wide Temperature anomaly

Time: 1963-2000

Spatial: Shelf wide

Contributed by: Mountain

Figure A.3

Methodology and Data Source

These are the surface and bottom temperature anomalies for NMFS fall bottom trawl survey, averaged over the whole shelf region from Cape Hatteras through the Gulf of Maine (Holzwarth and Mountain 1992; Taylor and Bascunan 2001). For each temperature observation made on a survey, its anomaly was determined by comparison with annual cycles of temperature derived from the MARMAP program (1978-1987). This procedure takes into account the day of the year on which the observation was made and its specific location. All of the anomaly values for a survey were averaged on an area weighted basis to determine the values plotted.

Key Points and Major Observations

The variability of 2-4 degrees C has been consistently observed over the past four decades. The late 1960s were a particularly cold period. The 1990s appear to be slightly warmer than preceding decades.

3. MAB Volume, Salinity & Temperature anomaly

Time: 1977-2000

Spatial: Mid-Atlantic Bight

Contributed by: Mountain

Figure A.4 (a-c)

Methodology and Data Source

The volume and average temperature and salinity of Shelf Water in the MAB have been determined for each NEFSC cruise that made temperature and salinity observations through the MAB area (Mountain 1991). Shelf Water is defined as water with salinity < 34 PSU, and is in contrast to the oceanic Slope Water that is found seaward of the shelf/slope front. From the surveys averaged values for the volume, temperature and salinity of Shelf Water in the MAB, annual cycles were derived for each variable. Anomalies for each variable were determined relative to these characteristic annual cycles

Key Points and Major Observations

There is very large variability in the amount of Shelf Water in the MAB. Additionally, there is large variability in the salinity of the Shelf Water in the MAB. The Shelf Water volume in the 1990s was substantially higher than in the 1980s and the salinity in the 1990s was lower than in the 1980s. The source of the volume and salinity variations is largely advective from the Gulf of Maine – and from variation in the inflows to the Gulf.

4. Surface and Bottom Temperature anomalies

Time: 1963-2000

Spatial: All the major subregions

Contributed by: Mountain, Brodziak

Figure A.5 (a-h)

Methodology and Data Source

These are the surface and bottom temperature anomalies for NMFS bottom trawl survey, averaged for each of the major subregions (Holzwarth and Mountain 1992; Taylor and Bascunan 2001). For each temperature observation made on a survey, its anomaly was determined by comparison with annual cycles of temperature derived from the MARMAP program (1978-1987). This procedure takes into account the day of the year on which the observation was made and its specific location. All of the anomaly values for a survey were averaged on an area weighted basis to determine the values plotted.

Key Points and Major Observations

There is large variability in the surface and bottom temperatures in each region. The late 1960s were a particularly cold period. Little trends are observed in any region through the 1970s and 1980s, although there may be slightly warmer waters in the 1990s for a few regions. The differences between the regions show no consistent pattern.

5. MAB Temperature anomalies, by 5 provinces

Time: 1990s, Annual, composite average

Spatial: Mid-Atlantic Bight

Contributed by: Mountain

Figure A.6

Methodology and Data Source

The shelf water temperature anomalies during the 1990s for five regions of the MAB (from north to south) have been averaged for three periods of the year (in essence, for thirds of the year) (Mountain 2001). The anomalies are relative to the MARMAP period (1978-1987). The methods for determining the shelf water anomalies were describe earlier.

Key Points and Major Observations

During the winters of the 1990s the MAB became progressively warmer from north to south as compared to the MARMAP period. The summer period exhibited some cooling in the central MAB. The fall period was generally a bit warmer than the MARMAP period. Overall, the MAB was about 1 C warmer in the 1990s than during the MARMAP period.

6. Massachusetts Bay Surface Temperature, Surface Salinity, Bottom Temperature Anomalies

Time: 1978-2000

Spatial: Massachusetts Bay

Contributed by: J. Jossi

Figure A.7

Methodology and Data Source

These data were collected as part of the MARMAP Ships of Opportunity Program (Benway et al. In Review; Jossi et al. In Review). Expendable bathythermograph and surface salinity measurements were taken monthly by merchant vessels between Boston, MA and Cape

Sable, NS. Values were gridded in time and space (distance along transect). Grids of long term means and standard deviations; and single year conditions, anomalies, and standardized anomalies are produced. Grids were sliced through time at a distance representing Massachusetts Bay for this portrayal, which also shows a smooth curve based on a 15 month running average (Benway et al 1993). The location chosen to represent Massachusetts Bay was at 48 km reference distance, or approximately 70º 20'W, along the transect.

Key Points and Major Observations

Surface Temperature- With the exception of isolated monthly departures near, or in excess of two standard deviations, the period 1978 through 1988 exhibited no enduring anomalous surface temperatures. From 1992 to mid-1994 mostly colder than average conditions prevailed. No trend during the time period was apparent.

Surface Salinity- Salinities generally increased from 1978 through 1980, declined through 1984 to a period minimum, rose sharply in 1985, were below average in 1987, and after 1990 they again declined to the end of the sampling period in 1993. The longest sustained anomalous period was that of low salinities in 1983 and 1984.

Bottom Temperature- From 1978 to 1981 values were near normal. Higher temperatures occurred during 1982 and 1983 followed by near average values in the mid-1980s. From 1987 through 1990, and 1992 to 1994 values were generally negative, after which departures became inconsistent, with several significantly warm months. Departures in the late 1990s were more excessive than in the earlier period, and might result in a warming trend for these data.

7. Mid-Atlantic Bight Surface Temperature, Surface Salinity, Bottom Temperature Anomalies

Time: 1978-2000

Spatial: Mid-Atlantic Bight and mid-Continental Shelf

Contributed by: J. Jossi

Figure A.8

Methodology and Data Source

These data were collected as part of the MARMAP Ships of Opportunity Program (Benway et al. In Review; Jossi et al. In Review). Expendable bathythermograph and surface salinity measurements taken monthly by merchant vessels along a transect from New York City towards Bermuda to the Gulf Stream. Values were gridded in time and space (distance along transect). Grids of long term means and standard deviations; and single year conditions, anomalies, and standardized anomalies are produced. Grids were sliced through time at a distance representing the continental shelf, generally unaffected by river runoff and/or slope water, for this portrayal. The portrayal also shows a smooth curve based on a 15 month running average (Benway et al. 1993). The location chosen to represent the Middle Atlantic Bight was at 101 km reference distance, or approximately 40º N; 73º W, along the transect.

Key Points and Major Observations

Surface Temperature- Isolated months through the 1978-2000 time period exhibit significant departures from the 1978-1990 means. Departures in excess of 2 standard deviation were more numerous in the 1990s than in the previous years, even after adjustments to account for the 1990s not being included in the base period. Sequential, monthly positive or negative departures were more consistent in the 1990s than in previous years. Finally, the surface temperatures appear to be trending upwards between 1978 and 2000.

Surface Salinity- Isolated months exhibit significant departures during the time period, and are more prevalent in especially the late 1990s than earlier periods. There is more month-to-month consistency of the surface salinity departures than of the surface temperatures. Uninterrupted positive departures of two years (1980-1981; 1985-1986; 1994-1995), and negative departures of two to three years (1996-1998; 1998-1999) occurred. No trend during the time period was apparent.

Bottom Temperature- Greater departures in the 1990s also occurred in the bottom temperature data. Aside from beginning the time period in a negative phase and ending in a positive phase, a possible trend is not as clear as with surface temperature. However, the phase changes of the smoothed values are quite similar through the time period for these two features.

8. W. Gulf of Maine Surface Temperature, Surface Salinity, Bottom Temperature Anomalies

Time: 1978-2000

Spatial: Gulf of Maine

Contributed by: J. Jossi

Figure A.9

Methodology and Data Source

These data were collected as part of the MARMAP Ships of Opportunity Program (Benway et al. In Review; Jossi et al. In Review). Expendable bathythermograph and surface salinity measurements taken monthly by merchant vessels along a transect from Boston, MA to Cape Sable, NS.. Values were gridded in time and space (distance along transect). Grids of long term means and standard deviations; and single year conditions, anomalies, and standardized anomalies are produced. Grids were sliced through time at a distance representing approximately Wilkinson Basin for this portrayal. The portrayal also shows a smooth curve based on a 15 month running average (Benway et al. 1993). The location chosen to represent the western Gulf of Maine was at 165 km reference distance, or approximately 68° 55' W along the transect.

Key Points and Major Observations

Surface Temperature- Variations from 1978 through 1990 followed a similar pattern to those for surface temperature in Massachusetts Bay, except that they were of slightly larger magnitude. High values occurred from 1983 to 1985, and low values occurred in 1982, for a fairly prolonged period from 1986 to 1991, and again from mid-1991 to 1994. This was followed in 1996 and 1997 by the lowest temperatures of the period, from which point temperatures began increasing to reach the highest values of the period by 2000. Neither of these last two conditions were seen to any extent in Massachusetts Bay. No trend was apparent, although the last four years of the period exhibited a dramatic increase.

Surface Salinity- The western Gulf of Maine surface salinity pattern follows that of Massachusetts Bay very closely. The only major exception was that in the western Gulf of Maine the 1985 high persisted to the beginning of 1987. No trend was apparent during the time period.

Bottom Temperature- Patterns here were also very similar to those for bottom temperature in Massachusetts Bay, although the departures were of less magnitude. Time period low occurred in late-1994 followed by the series high in 1995. Similarly, variations were larger in the late-1990s than earlier in the period. No trend was apparent.

9. Relationships Among NAO, Salinity, Plankton, and Cod on Georges Bank

Time: 1970-1996

Spatial: Georges Bank

Contributed by: Mountain

Figure A.10

Methodology and Data Source

The early spring plankton displacement volume on Georges Bank is compared with a detrended, inverted NAO series and with salinity variability on the bank (Mountain et al. 2000). A cod survival index (ratio of the number of recruits to the spawning stock biomass, with both series hanned before the ratio was taken) is also compared with the detrended NAO series. The plankton displacement volume series was determined by J. Kane from the Center's plankton survey data. The salinity anomalies were derived from the Center temperature and salinity data, relative to annual cycles of salinity derived from the MARMAP data set. The cod series were from stock assessment documents. The NAO was from a NAO website. The method was straight forward of plotting the predetermined series.

Key Points and Major Observations

The displacement volume appears to follow the detrended NAO and the salinity variability quite well. There are large interannual differences in the displacement volume. The cod survivorship series also seems to follow the NAO quite well. There are no obvious processes that connect these series.

C. Summary of Abiotic Metrics

Various graphics of temperature and salinity data from Ship-of-Opportunity (SOOP) data and shelfwide research cruise data were examined. Preliminary examination of the average of surface and bottom temperatures from the Autumn Bottom Trawl data, shelf-wide for all regions from Cape Hatteras to Nova Scotia, showed the 1960s were cold and the remaining years were variable without any apparent trend. It is questionable if the 1990s were slightly warmer than preceding decades. When these data are sorted out spatially into subregions, they exhibit a similar pattern.

Data on the volume of water, salinity and temperature were examined for the Mid-Atlantic Bight (MAB) shelf water inside the shelf/slope boundary. In the 1990s, the following were observed: 1) a 25-30% increase in the amount of shelf water volume in the Bight was apparent over that of the long term mean; 2) salinity was lower in the 90s; similar to observations made for northwestern Georges Bank; and 3) temperature was about 1 degree warmer in the 90s.

The MAB data were broken out into shelf sectors (SNE, NYB1, NYB2, SS1, SS2, north to south orientation). It was noted that the apparent warming in the MAB in the 1990s concentrated in the southern regions (SS1, SS2) during the winter. Atmospheric heat flux seems the likely source and needs to be investigated. Further, there is some indication that advective events present in the Gulf of Maine (GOM) have affected SNE and NYB temperature and salinity. For example, GLOBEC data indicates a shift in the basic circulation into GOM from 1 part Scotian Shelf water and 2 parts Oceanic current, to 2 parts Scotian Shelf and 1 part Oceanic water. Documentation of changes in the major inflows into the GOM is needed.

Given the extent of the variability in the data, what metrics are useful to see system-wide changes? Several data sets were examined relative to the detrended North Atlantic Oscillation (NAO) which shows significant 3-5 year variability over a strong 30 year trend. Large changes in zooplankton volume occurred over the 1970-1995 period. Volumes decreased in the early 1980s, followed by a large increase in 1985-1990 period. Plankton volume fluxes correlated with the detrended, inverse of the NAO (see chapter 4 for further details). Plankton volume and salinity anomalies may have a relationship and other covarying parameters may exist. These relationships merit further examination. Additionally, an index of cod recruitment and standing stock biomass (SSB) data correlate with the detrended, inverted NAO data. Possible relationships between the cod survival anomaly, the SSB and detrended NAO data also merit examination. Chlorophyll data is also needed to help corroborate production, particulary of the plankton (i.e., volume) and the NAO trends.

No linkage is apparent between offshore waters and the NAO events of the 1960s through the 1990s, however, the linkage between coastal water temperatures and NAO needs to be examined.

D. References

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Taylor, M.H. and Bascunan, C. 2001. Description of the 2000 oceanographic conditions on the northeast continental shelf. National Marine Fisheries Service, Northeast Fisheries Science Center, Center Reference Document 01-01.

Figure A.1. ***NAO Index***

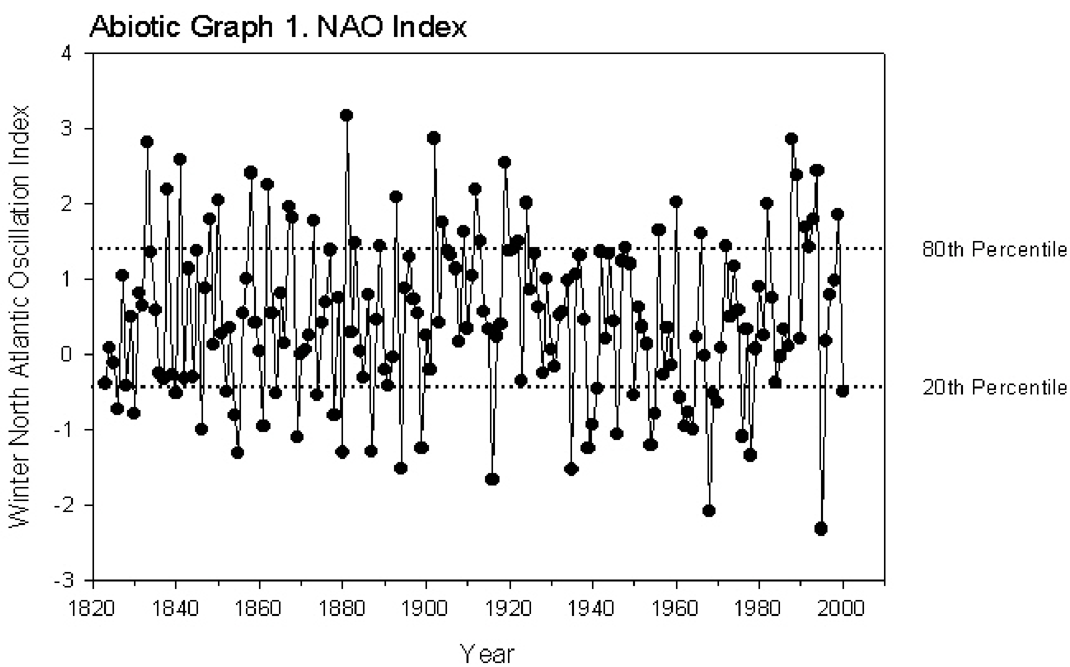


Figure A.2. ***NAO Index***

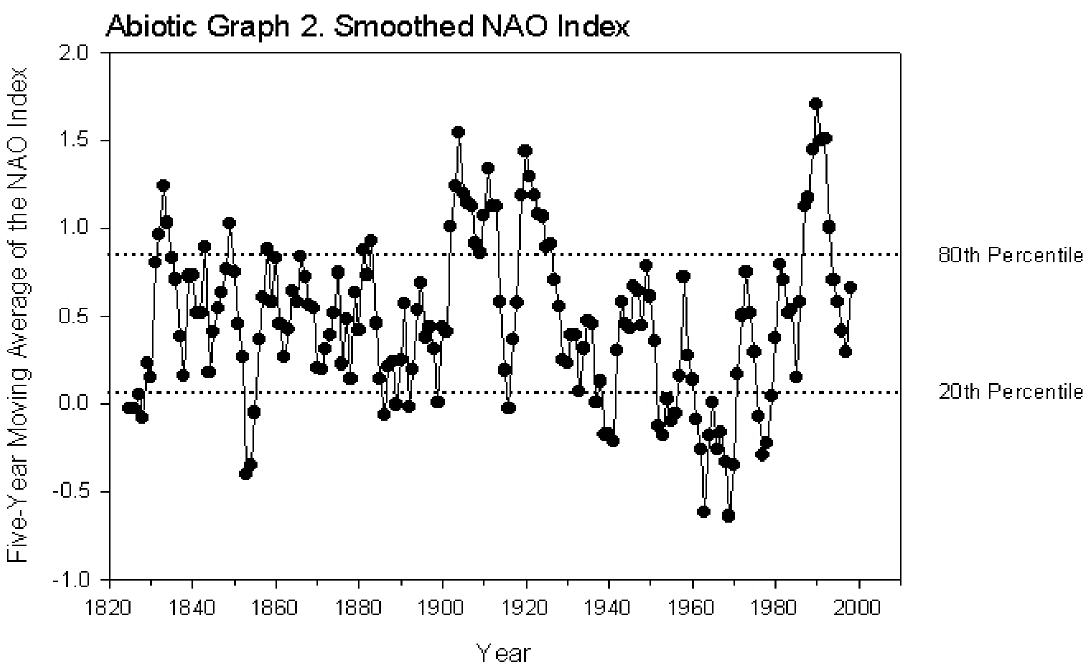
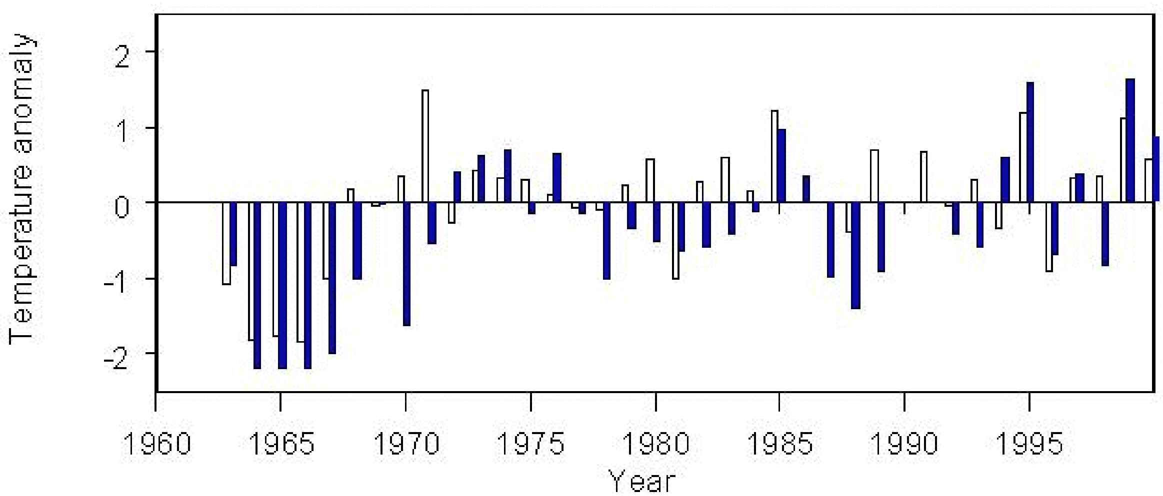


Figure A.3. ***Shelf wide Temperature anomaly***



Shelf-wide, fall surface (open bars) and bottom (filled bars) temperature anomalies:

Figure A.4a. ***MAB Volume, Salinity & Temperature anomaly***

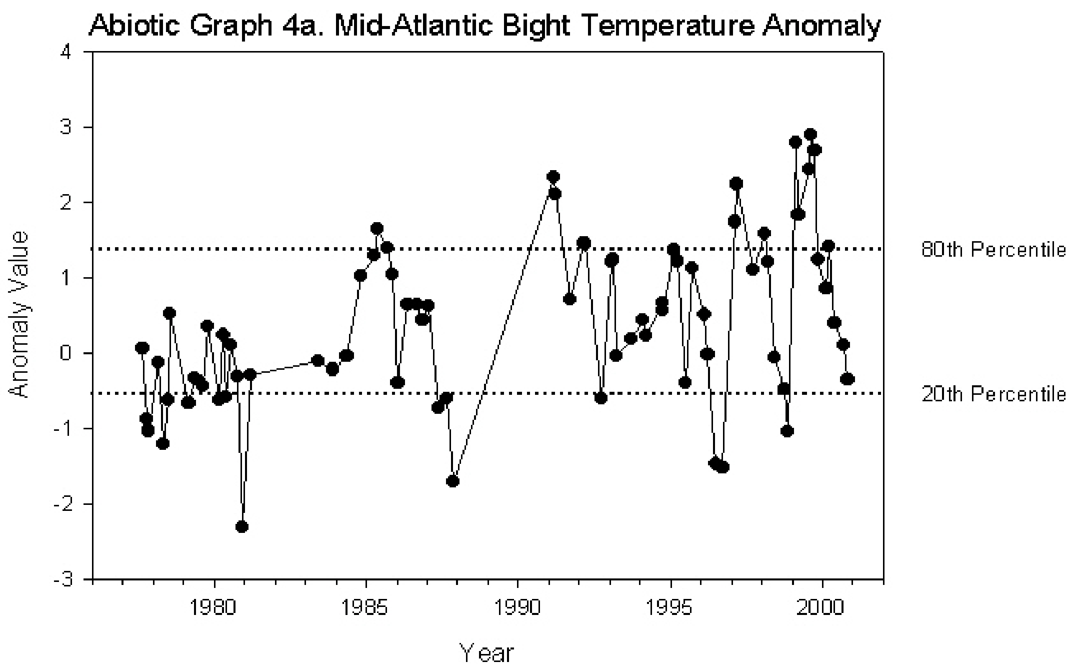


Figure A.4b. ***MAB Volume, Salinity & Temperature anomaly***

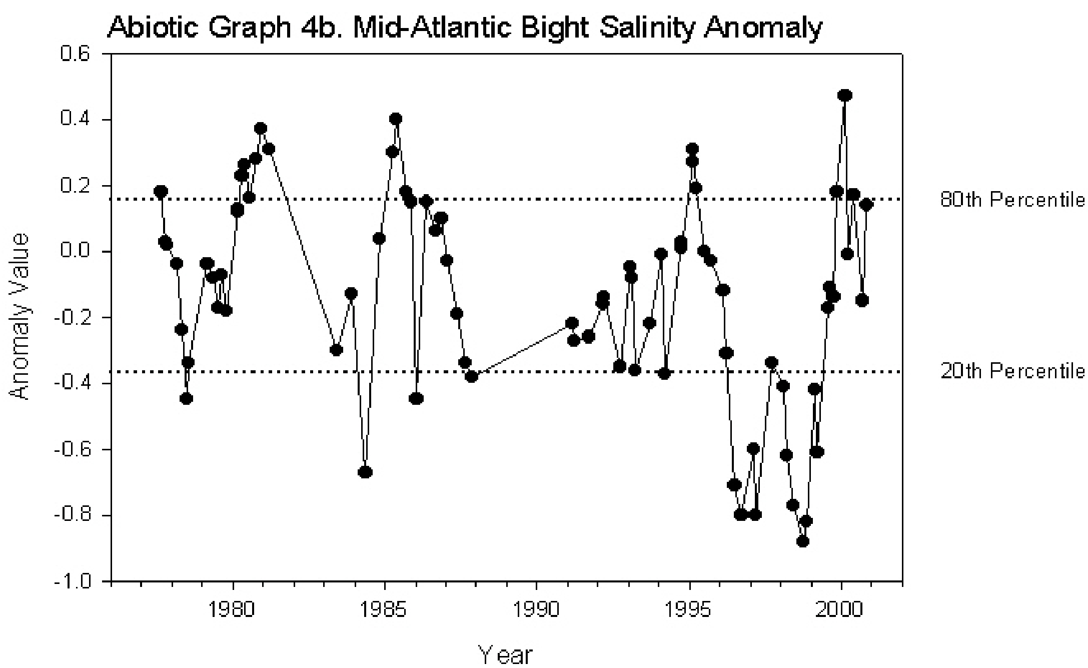


Figure A.4c. ***MAB Volume, Salinity & Temperature anomaly***

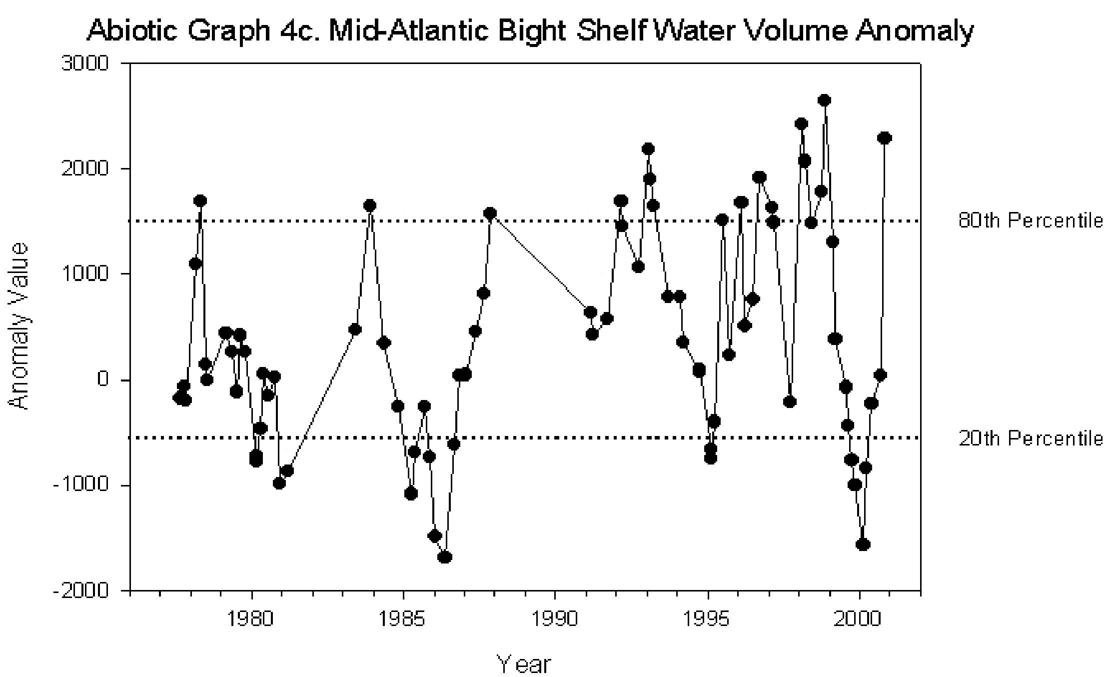


Figure A.5a. ***Surface and Bottom Temperature anomalies***

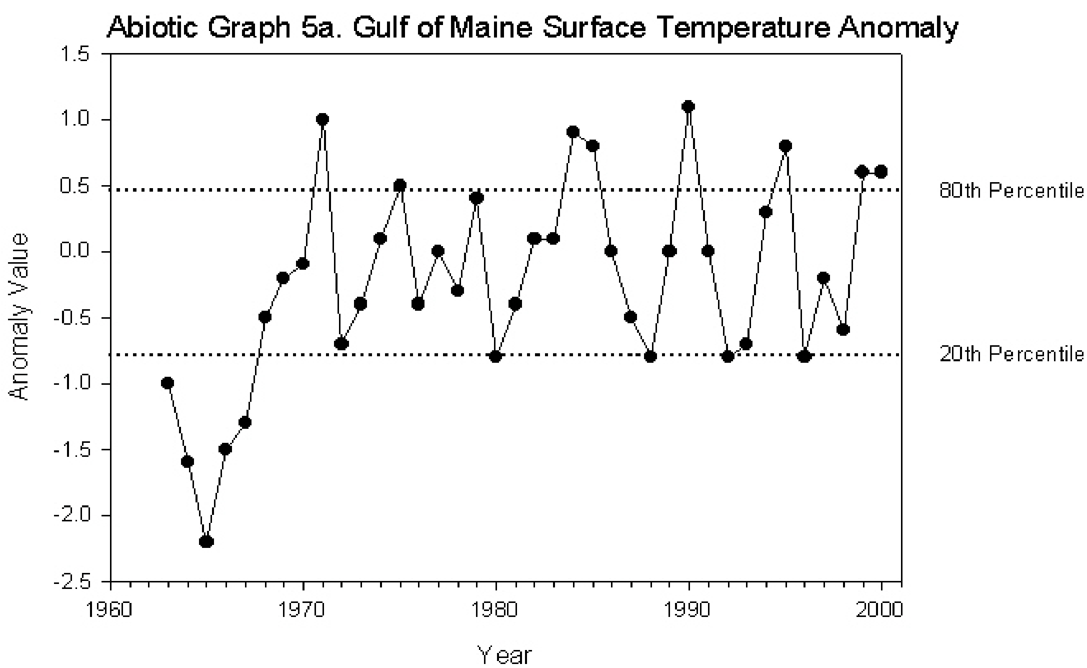


Figure A.5b. ***Surface and Bottom Temperature anomalies***

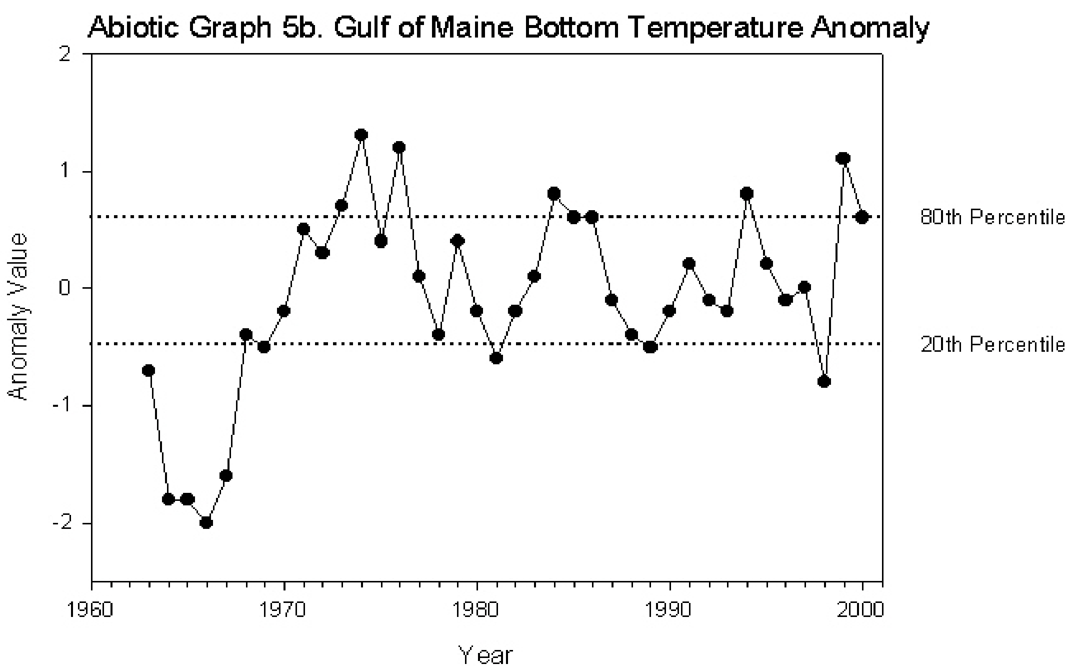


Figure A.5c. ***Surface and Bottom Temperature anomalies***

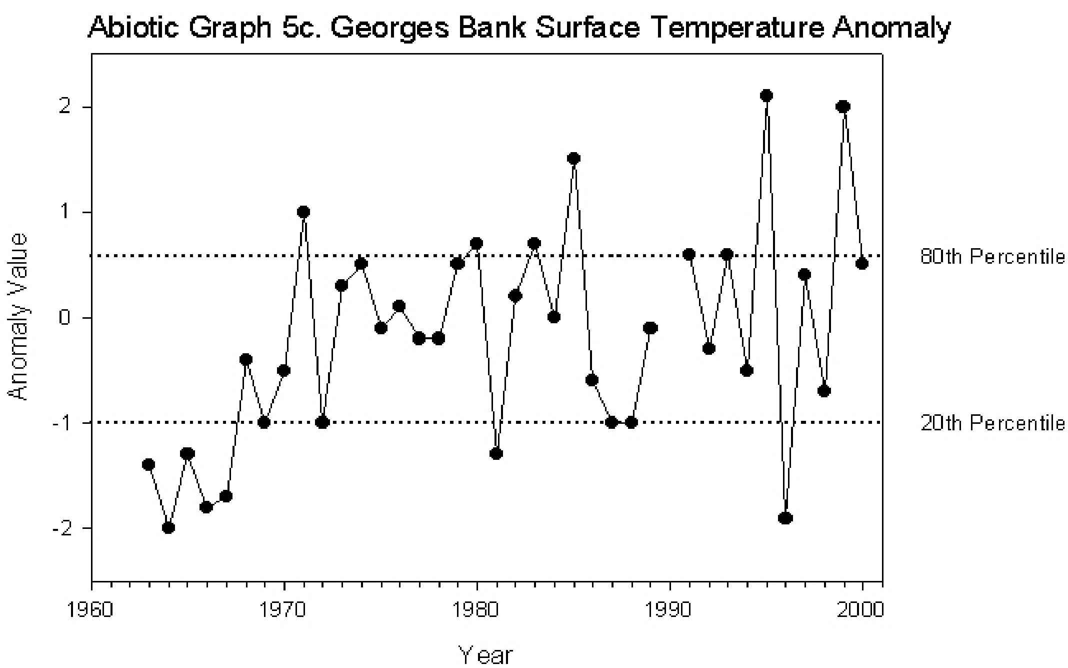


Figure A.5d. ***Surface and Bottom Temperature anomalies***

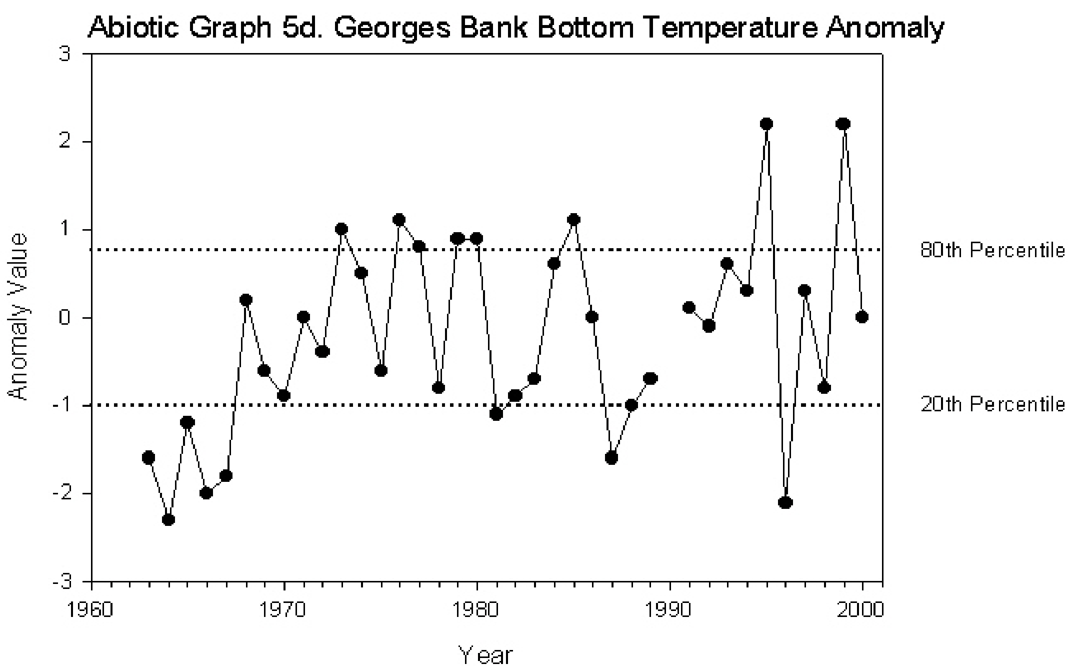


Figure A.5e. ***Surface and Bottom Temperature anomalies***

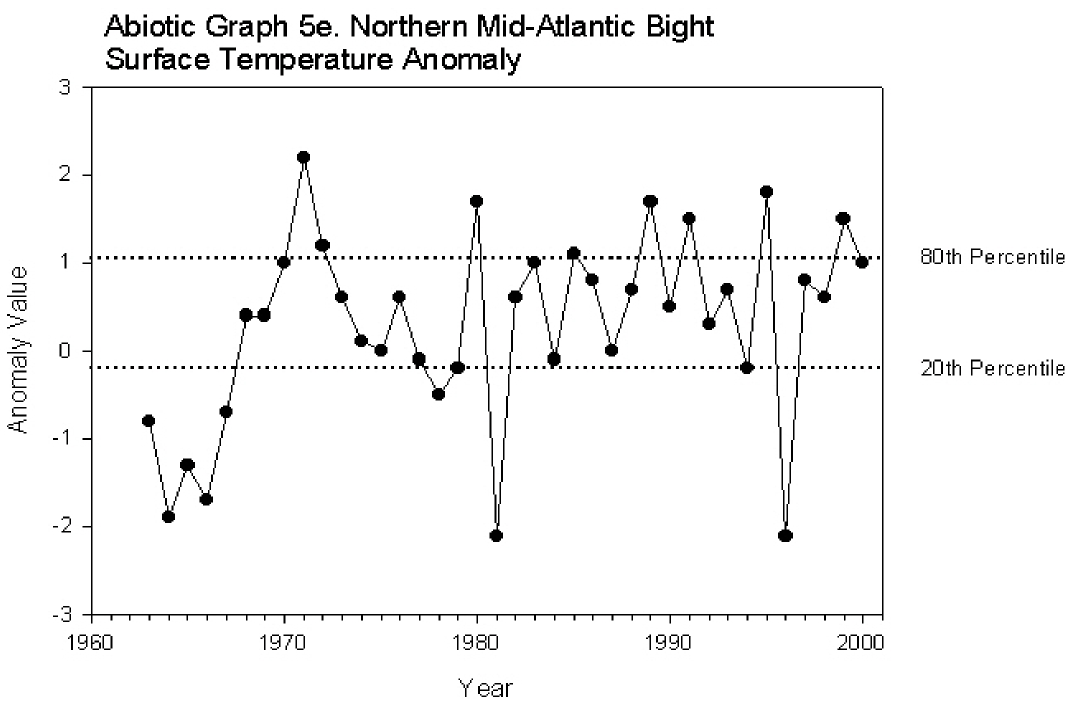


Figure A.5f. ***Surface and Bottom Temperature anomalies***

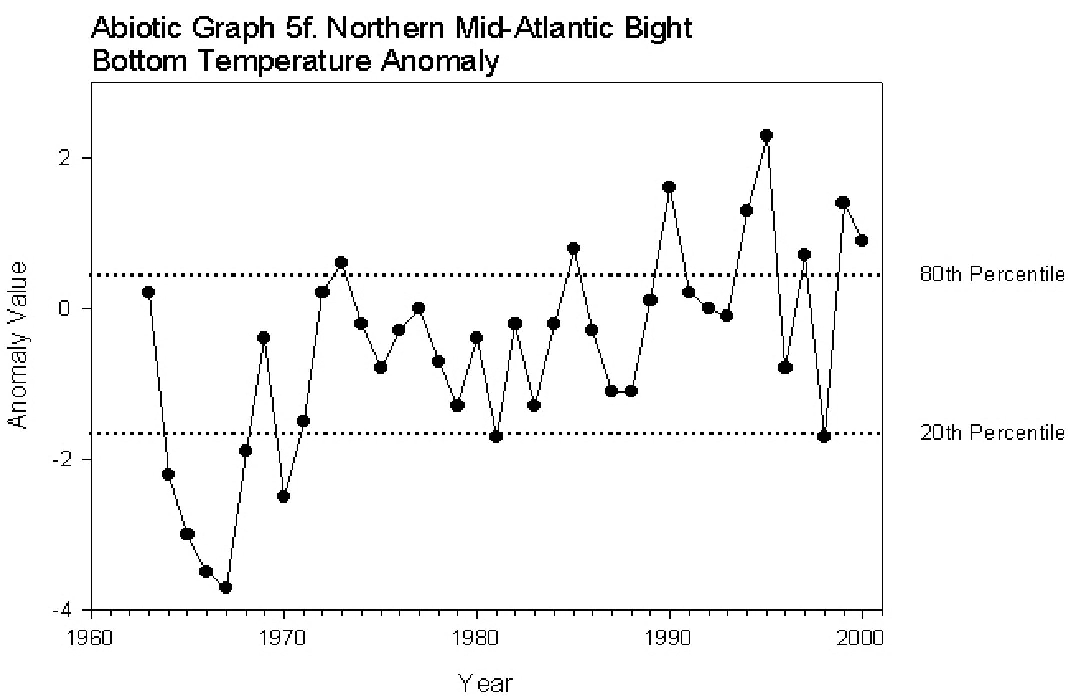


Figure A.5g. ***Surface and Bottom Temperature anomalies***

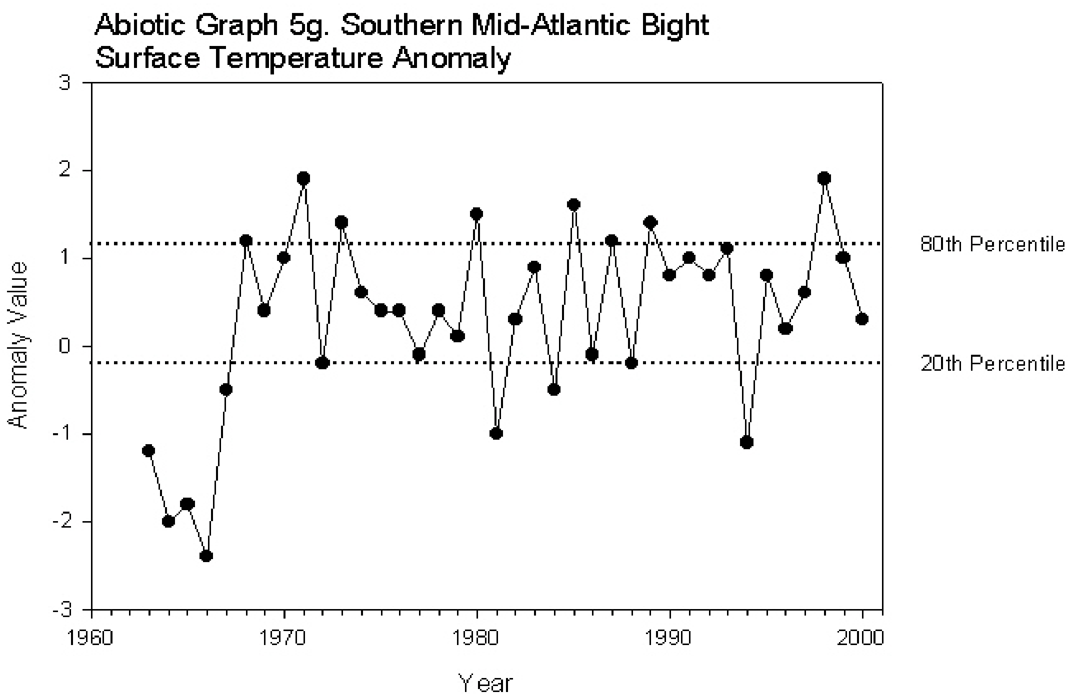


Figure A.5h. ***Surface and Bottom Temperature anomalies***

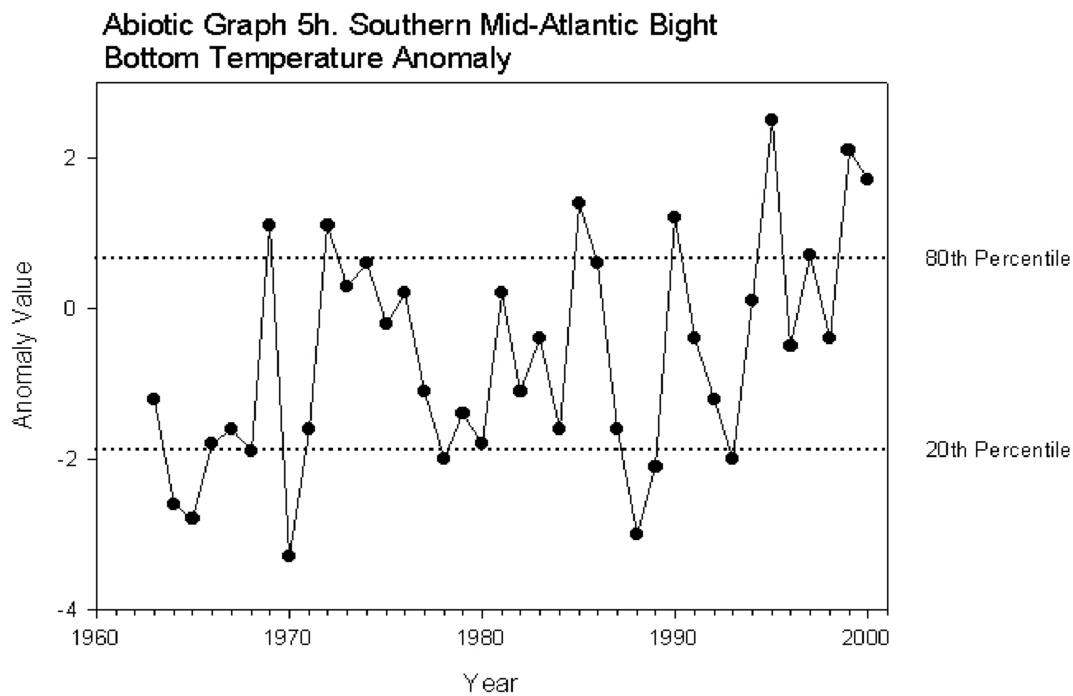
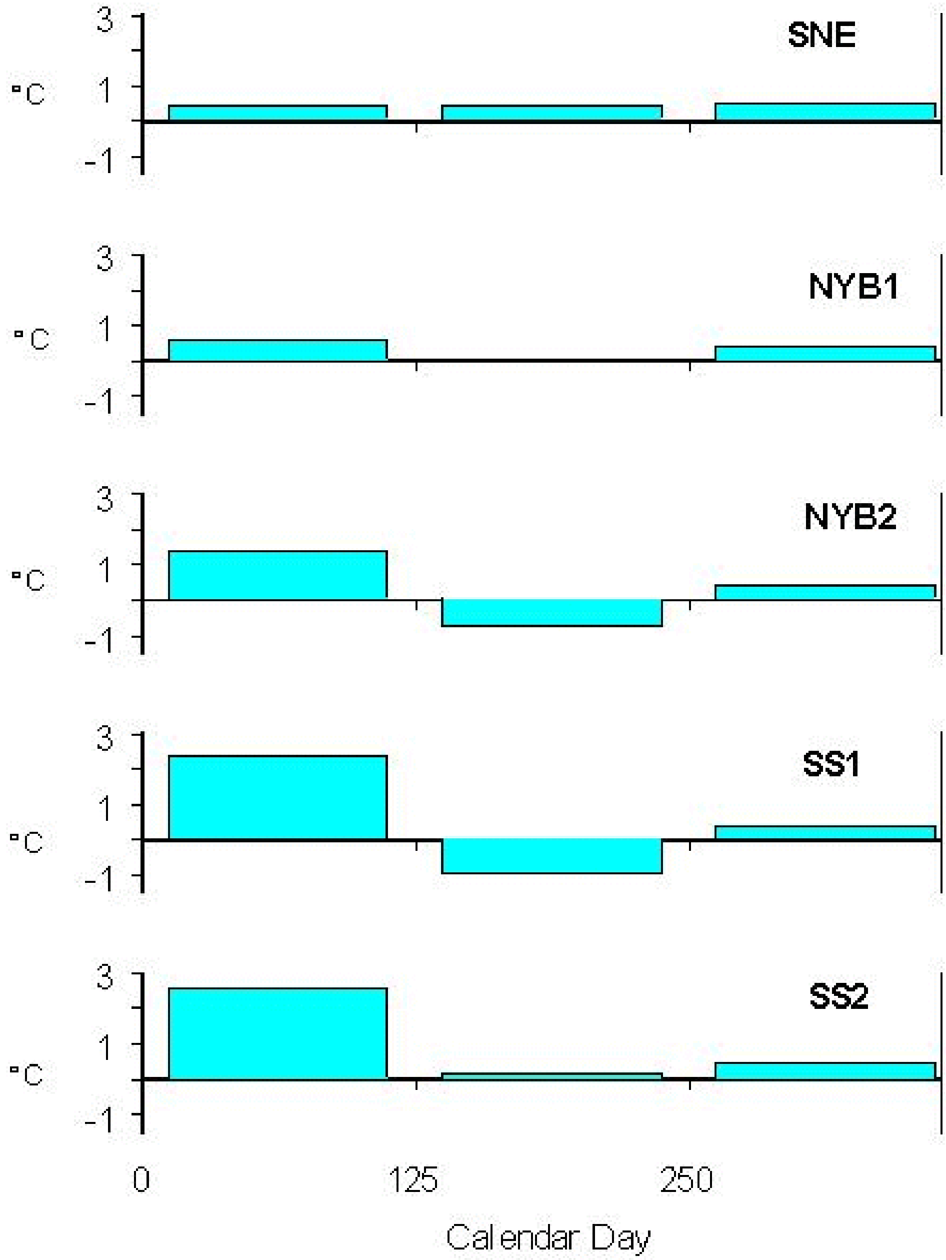
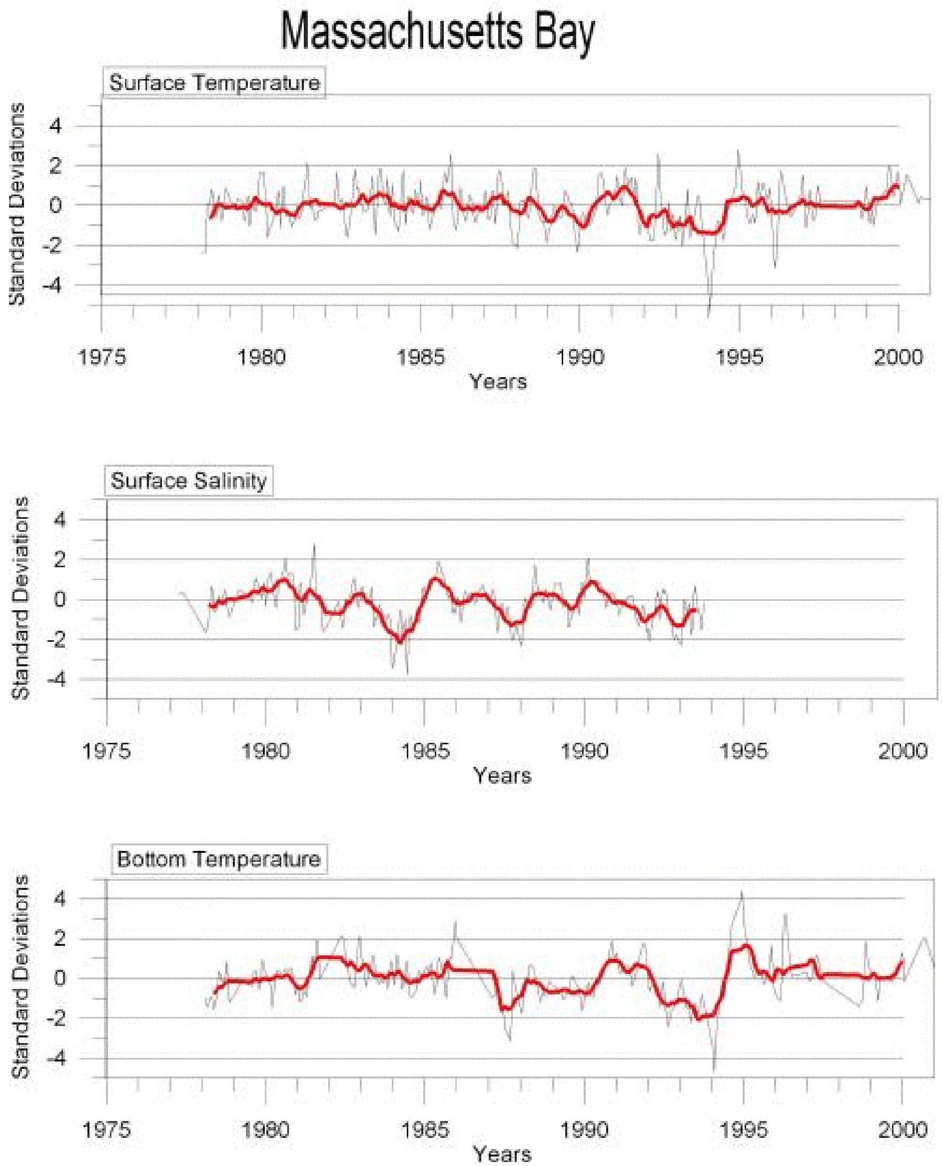


Figure A.6. ***MAB Temperature anomalies, by 5 provinces***



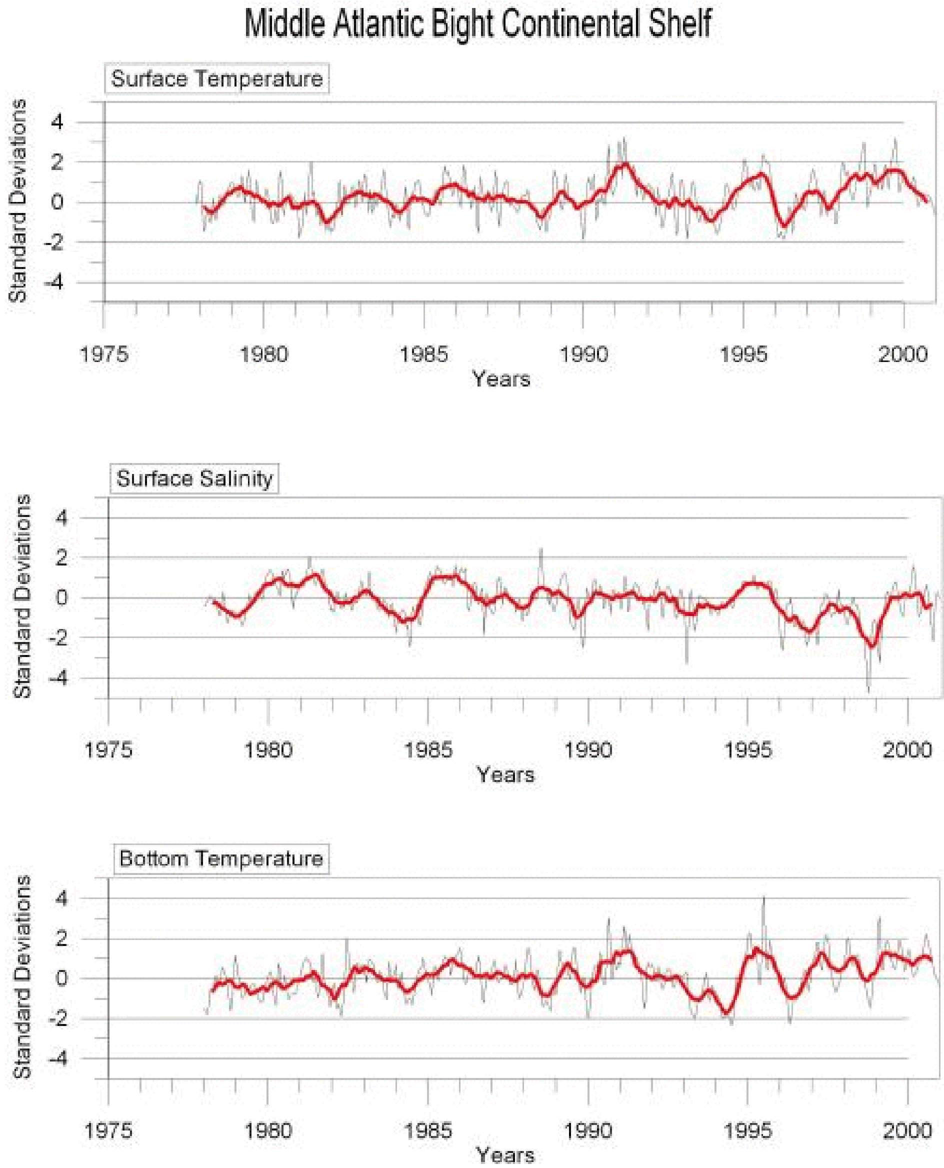
Average shelf water temperature anomaly in the 1990's relative to MARMAP (1977-1987) for five regions in the Middle Altantic Bight (from north to south), for thirds of the year.

Figure A.7. ***Massachusetts Bay Surface Temp, Surf. Salinity, Bottom Temp. Anomalies***



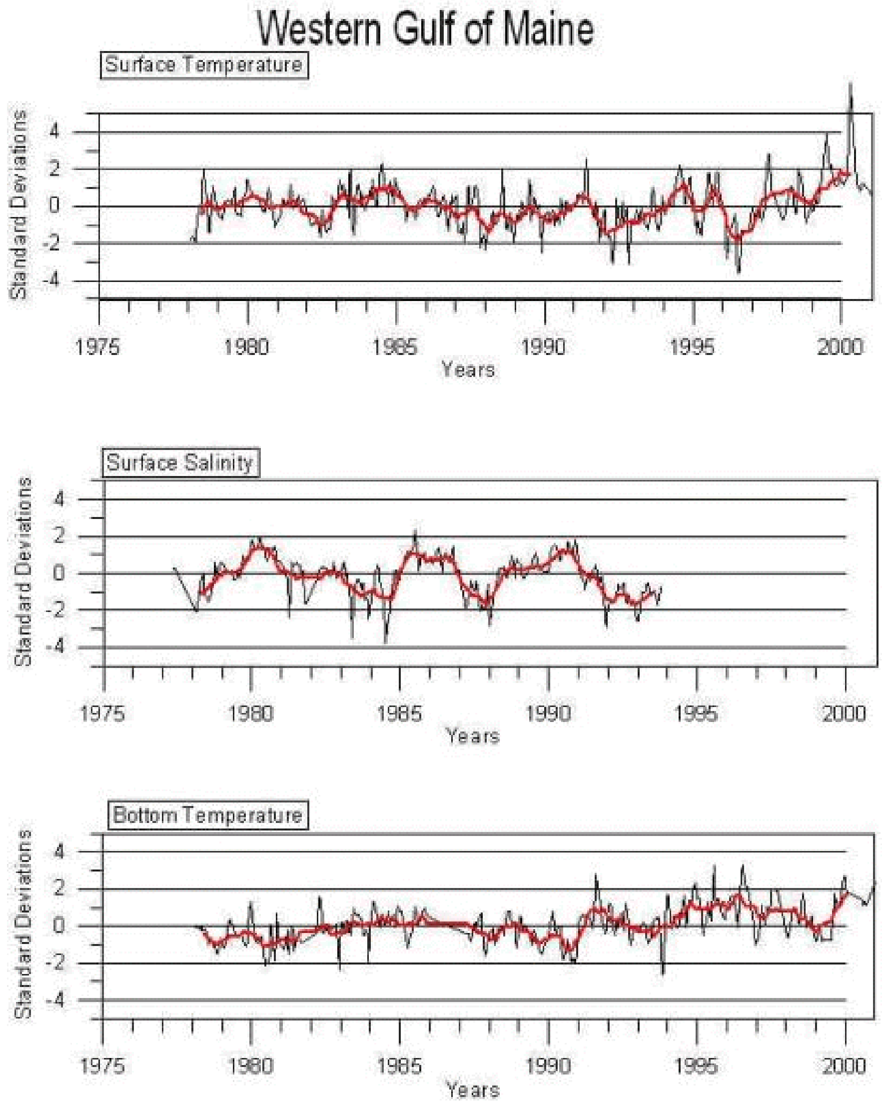
Time plots of standardized departures of surface temperature, surface salinity, and bottom temperature from 1978-1990 means, at a transect location representing Massachusetts Bay. From: MARMAP Ships of Opportunity Program

Figure A.8. ***Mid-Atlantic Bight Surface Temp, Surf. Salinity, Bottom Temp. Anomalies***



Time plots of standardized departures of surface temperature, surface salinity, and bottom temperature from 1978-1990 means, at a transect location representing the Middle Atlantic Bight continental shelf. From: MARMAP Ships of Opportunity Program.

Figure A.9. ***W. Gulf of Maine Surface Temp, Surf. Salinity, Bottom Temp. Anomalies***



Time plots of standardized departures of surface temperature, surface salinity, and bottom temperature from 1978-1990 means, at a transect location representing the western Gulf of Maine. **Fifteen month running average line fitted.**

Figure A.10. ***Relationships Among NAO, Salinity, Plankton, and Cod on Georges Bank***