Northwest Atlantic Fisheries Organization

Serial No. N2126 NAFO SCR Doc. 92/72

SCIENTIFIC COUNCIL MEETING - JUNE 1992

AFAP Climate Studies in the Scotia-Fundy Region

by

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ABSTRACT

This paper describes ocean climate studies on the Scotian Shelf and in the Gulf of Maine undertaken as part of the Atlantic Fisheries Program (AFAP). The focus of these studies are to determine the dominant spatial and temporal scales of variability in temperature and salinity and to establish a long-term monitoring program. A climate indices database has been established including various oceanographic, meteorological, and hydrological datasets. In addition, a temperature and salinity database has been assembled that includes all available T,S data for the Gulf of Maine and the Scotian Shelf. Initial research has identified high vertical coherence in temperature at low-frequencies (periods of 10 yr) in Emerald Basin. Similar trends have been identified in the waters from the Gulf of Maine to the Laurentian Channel. It is suggested that these trends are forced through oceanic advection and mixing of slope waters onto the Shelf. A monitoring strategy for the deep water basins in the Scotia-Fundy region is described.

INTRODUCTION

This paper provides a brief summary of the background, objectives, activities, and research initiatives of the Scotia-Fundy Shelf Climate Working Group which is funded under the Atlantic Fisheries Adjustment Program (AFAP). Members of the interdisciplinary working group include physical oceanographers (B. Petrie, J. Loder, P. Smith, D. Lawrence, C. Mason, and K. Drinkwater, PCS, BIO) and fisheries scientists (S. Smith, BSB, BIO; F. Page, BSB, St. Andrews Biological Station).

Background and Objectives

In December of 1989 the Report of the Scotia-Fundy Groundfish Task Force (Haché 1989), made a number of recommendations in an attempt to help conserve and rebuild the groundfish stocks in the region. These included recommendations relating to science and the adequacy of existing scientific information. For example, they noted that quota projections did not exceed 2 yr due to an inability to predict long-term trends in growth and reproduction of fish. Such trends are thought to be linked to large-scale environmental factors, however, studies to investigate such relationships have been hampered by an absence of a long-term environmental monitoring program in the Scotia-Fundy region. To address this issue, a Shelf Climate Working Group was established at BIO. The group has initially focused on temperature and salinity variability because of the large existing database and because temperature, in particularly, is often considered one of the most important factors influencing the distribution and abundance of many groundfish species. The working group also felt it was most prudent to undertake an analysis of the historical temperature and salinity database before establishing any monitoring program. The following main objectives of the project were established:

(1) to identify the dominant temporal and spatial scales of variability in temperature and salinity in the Scotia-Fundy region;

(2) to establish time series of climatic indices;

(3) to compare these indices with those from other regions in order to place Scotia-Fundy in the broader context of climate change in the Northwest Atlantic;

(4) to identify the primary forcing functions controlling climate in the region;

(5) to initiate a monitoring program for climatic variability in temperature and salinity at some key locations in the Scotia-Fundy region; and

(6) to help fisheries managers incorporate information on ocean climate variability into the estimates of fish abundance through the CAFSAC.

The remainder of this paper provides information on some of the activities and results of the working group.

CLIMATE INDICES DATABASE

As a first step in investigating the temporal and spatial scales of variability, the working group began to assemble a database of climate indices, primarily monthly or annual means or values. These included oceanographic, meteorological and hydrological datasets that were readily available or that scientists have traditionally used in climate or fisheries related studies. It was felt that these indices should be maintained in a central repository and updated on at least an annual basis and also that they be quickly accessible to any scientist or manager upon request. The indices include coastal SST data such as those collected at St. Andrews or Boothbay Harbor; offshore SSTs determined from ships-of-opportunity and averaged over topographic or oceanographic regimes; subsurface hydrographic data from stations such as Prince 5, Station 27 off St. John's, and the lightship data; river discharge data; air temperature and air pressure information; large scale atmospheric indices such as the North Atlantic Oscillation (NAO) index; sea ice indices; the position of boundaries between water masses such as the Shelf/Slope front and the north wall of the Gulf Stream; etc. Existing indices are being updated, where necessary, and additional indices are being sought.

This work is being coordinated with similar activities at the Northwest Atlantic Fisheries Center in St. John's, Newfoundland, under R. Myers. Use of a common format for computer files has resulted in ease of file transfers between regions. A technical report describing and graphically displaying, many of the indices together with some standard statistical quantities is presently being prepared. It is hoped to complete these reports within the present year.

HISTORICAL T,S DATABASE

Concurrently, the working group has been assembling an historical temperature and salinity (T,S) database for the Gulf of Maine and Scotian Shelf, the geographical boundaries of which are shown in Fig. 1. This database will be used to further assess the scales of variability of temperature and salinity. It will also be used to determine the representativeness of the climate indices and to develop new indices, if necessary. Temperature and salinity data were obtained from the Marine Environmental Data Service (MEDS) in Ottawa and from the the National Oceanographic Data Center (NODC) in the United States. We have also obtained additional datasets that were not in either of the national archives. Data types include or will include those collected with bottles and reversing thermometers, bucket thermometers, various kinds of BTs, CTDs, BATFISHes, and moored instruments. They also include TESAC messages. Data in the AFAP database have been through a rigorous quality control procedure, initially at MEDS and then further editing at BIO. The present database contains a total of 82,566 stations and 1,970,500 records in the Scotian Shelf and 88,988 stations and 1,650,776 records in the Gulf of Maine. An annual update from MEDS and NODC is planned. Also during the coming year we will be attempting to obtain more datasets that have been identified within our area of interest but are not yet in our database.

Because of the size of the database it was recognized that a special database management system was needed to provide efficient and quick storage, retrieval, analysis and display of the data. Initial examination showed that commercial database systems, e.g. ORACLE, were very slow and inefficient, hence we developed our own system. A contract was recently completed that has provided us with a management and analysis software package which runs on a STARDENT computer. It allows us to extract data from our database for any prescribed volume in space and time, determine simple statistics such as means and standard deviations, analysis routines to determine correlations, regressions, and EOF (Empirical Orthogonal Function) modes, will interpolate the data onto any size grid in time or space using optimal estimation techniques, and will display the data graphically. The system has been developed independent of proprietary (i.e. commercial) software packages in order to be more transportable. We are presently evaluating the system and hope to add additional features during the coming year.

In cooperation with the Maurice Lamontagne Institute in Mont Joli, Quebec, and given sufficient funding, we are planning this year to extent our T,S database to include the Gulf of St. Lawrence. A T,S database has recently been assembled for the Newfoundland region by Brad DeYoung (Memorial University). We hope to be able to combine his and our data in order to have a single database that will cover most of the continental shelf off eastern Canada.

SCIENTIFIC STUDIES

Investigations of the low-frequency variability in temperature in the Scotia-Fundy region within the AFAP program has already begun with an initial examination of data from Emerald Basin in the central Scotian Shelf (Petrie et al. 1991). Monthly averaged temperatures at standard depths from Emerald Basin for the period 1945-88 were obtained. Annual cycles were determined by calculating monthly mean temperatures over the entire period which were then subtracted from the raw data to obtain temperature anomalies. These anomalies show several interesting features. First, the low-frequency (periods of order 10 yr) variations were discernible and showed strong similarity at all depths (Fig. 2). They included a peak warm period in the 1950s, a cooling trend to a minimum in the mid-1960s, followed by a rise into the 1970s. Secondly, these trends showed strong coherence with both surface and deep temperature time series from the Mid-Atlantic Bight to the Laurentian Channel (Fig.3) but does not extend to the Grand Banks and the waters off northern and eastern Newfoundland. Thirdly, the maximum variance at low-frequencies occurred at depth (near 100 m) which suggests an oceanic source for the observed temperature variability. Work is continuing within AFAP to quantify the atmospheric and offshore ocean affects on the shelf climate in our region.

As part of that research, we have contracted J. Umoh from Dalhousie University to use a model he developed of atmospheric heating and ocean mixing to determine what role the net surface heat flux might play in the temperature variability on the Shelf. His results have shown that the heat fluxes can not account for the observed interannual variations in temperature, thereby adding further support that advection and mixing of offshore waters onto the Shelf plays a large role in the low-frequency temperature variability.

Other research activities within AFAP include investigations of the local atmospheric climatology using air temperature records from eastern North America. We wish to determine the spatial and temporal scales of the variability and what is the connection with the ocean variability. We have also obtained monthly air pressure records for the entire North Atlantic in order to update the work begun by Thompson and Hazen (1983). These data will be used to explore the relationship between our local regional climate and the large-scale atmospheric circulation. Finally, together with R. Myers from Newfoundland, we are digitizing the positions of the shelf/slope and Gulf Stream fronts.

MONITORING

Extensive monitoring of sea surface temperature (SST) within the region is operational through other existing programs. Coastal sea surface temperatures are monitored on a regular basis at Halifax (since 1926), St. Andrews (since 1921) and Boothbay Harbor (since 1905). Within the last decade near surface temperatures have been recorded at a large number of coastal sites as part of the long-term temperature monitoring program (R.H. Loucks Oceanology Limited et al., 1991). SST data for the offshore regions is available from research vessels and ships-of-opportunity. These data (back to 1971) have been presented annually to NAFO as monthly means for 24 areas covering much of the Northwest Atlantic shelf region (see e.g. Drinkwater and Trites 1991).

Monitoring of subsurface temperature and salinity data have generally been less systematic. The only long-term stations presently being monitored on a monthly or seasonal basis within Canadian waters are Prince 5 and 6, at the mouth of the Bay of Fundy, which were begun in the 1920s. The Emerald Basin study has suggested that opportunistic sampling should prove useful in documenting long-term climate changes (Petrie et al. 1991). Of particular note was that the low-frequency changes (decadal time scales) were larger than within year variance in the deep waters (> 75 m) so that the aliasing of the low-frequency signal due to irregular sampling is not as important as previously thought (Mann and Needler 1967). The working group has thus initiated an opportunistic monitoring strategy for the deep water basins in the Gulf of Maine and on the Scotian Shelf. We identified 10 sites where we are asking chief scientists on cruises to these areas to collect hydrographic data (Fig. 4). An evaluation of the program will be carried out at the end of this year. Although the low-frequency temperature variability observed in the deep waters extends to the surface, increasing high-frequency energy and smaller vertical scales towards the surface means will require a different strategy to adequately monitor near-surface variability.

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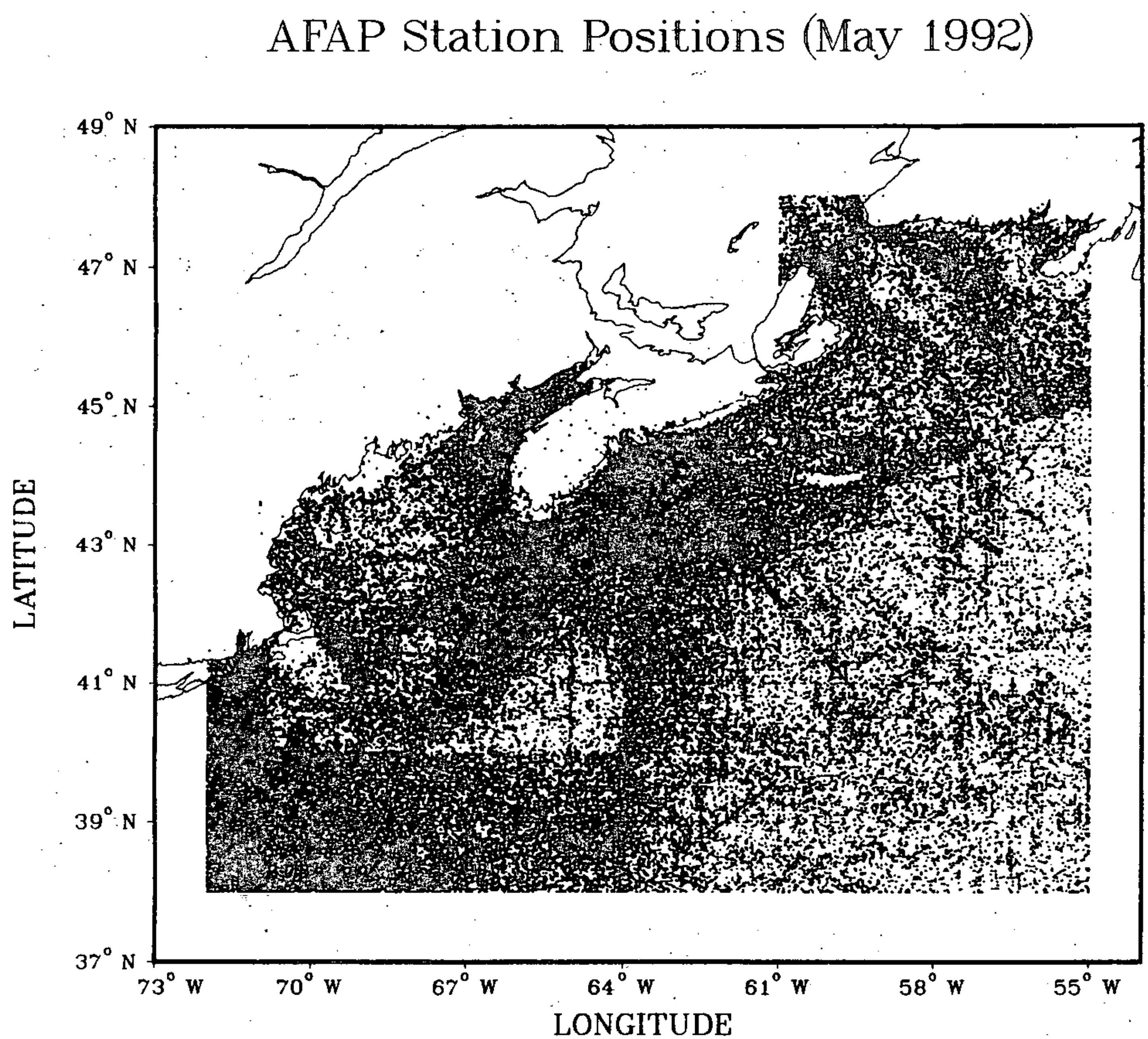

Fig. 1. Map showing the station locations and geographical boundaries for the Scotia- Fundy T,S database.

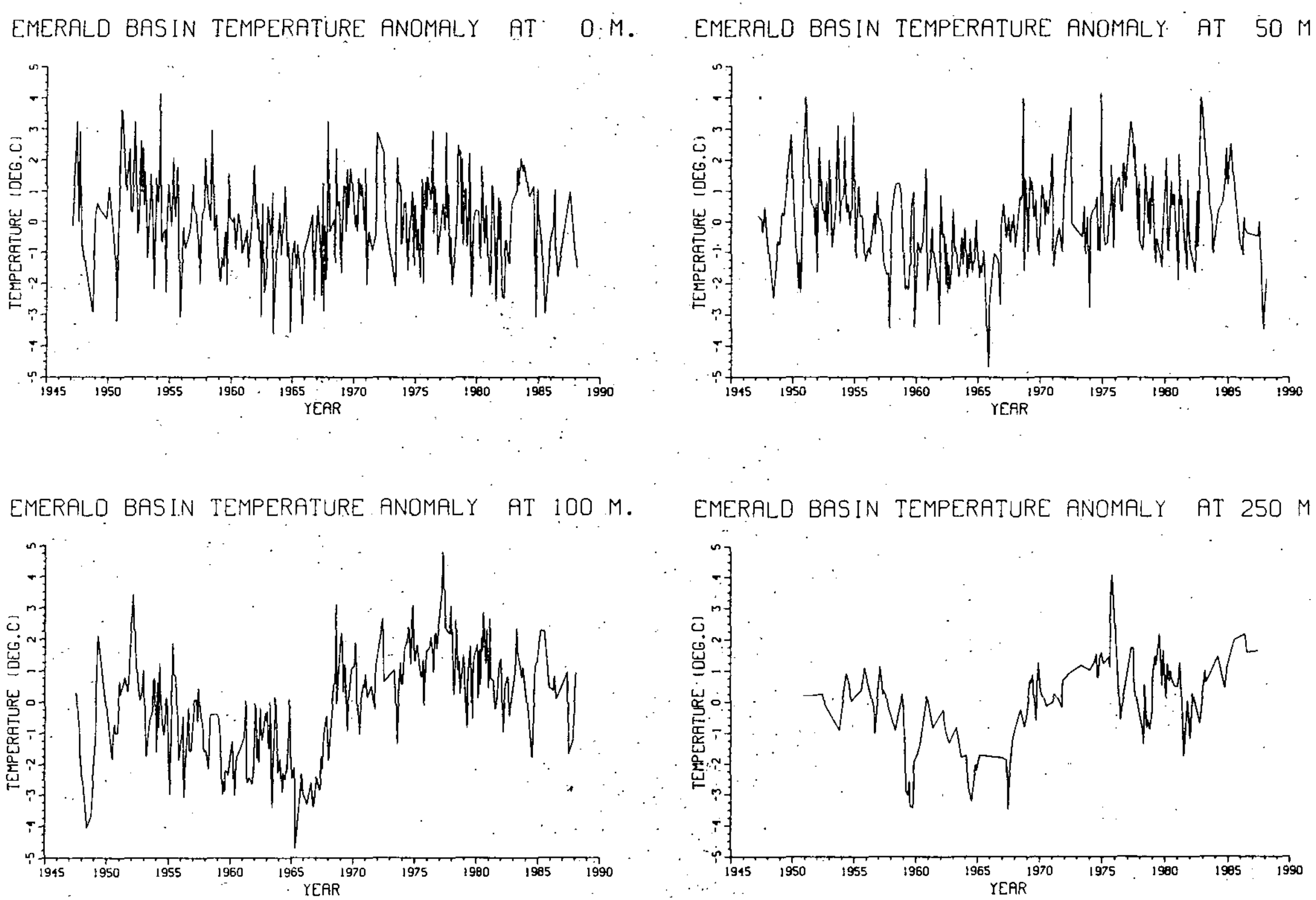

Fig. 2. Temperature anomalies in Emerald Basin at 0, 50, 100 and 250 m.

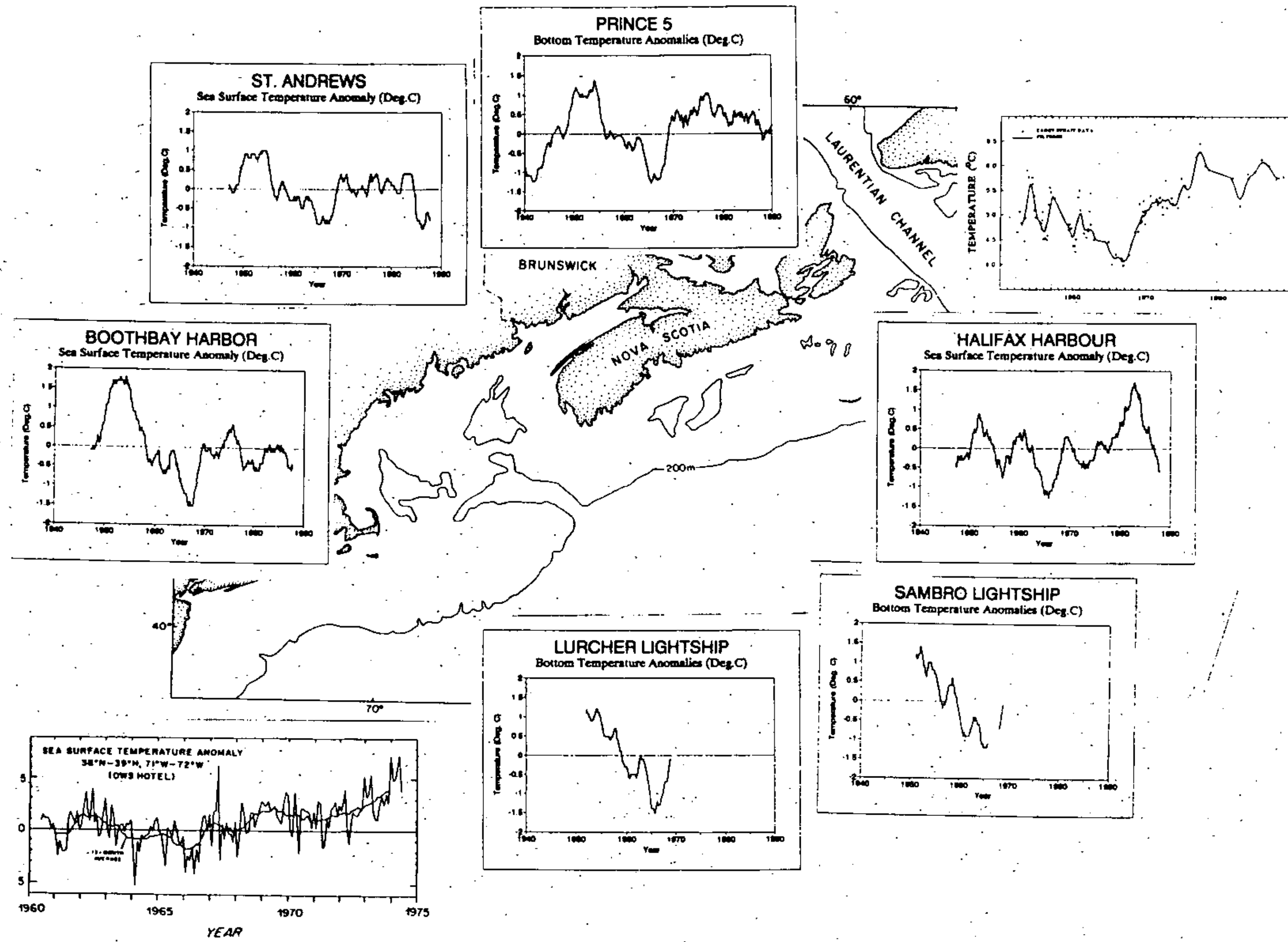

Fig. 3. Temperatures or temperature anomalies at several locations between the Gulf of Maine and the Laurentian Channel.

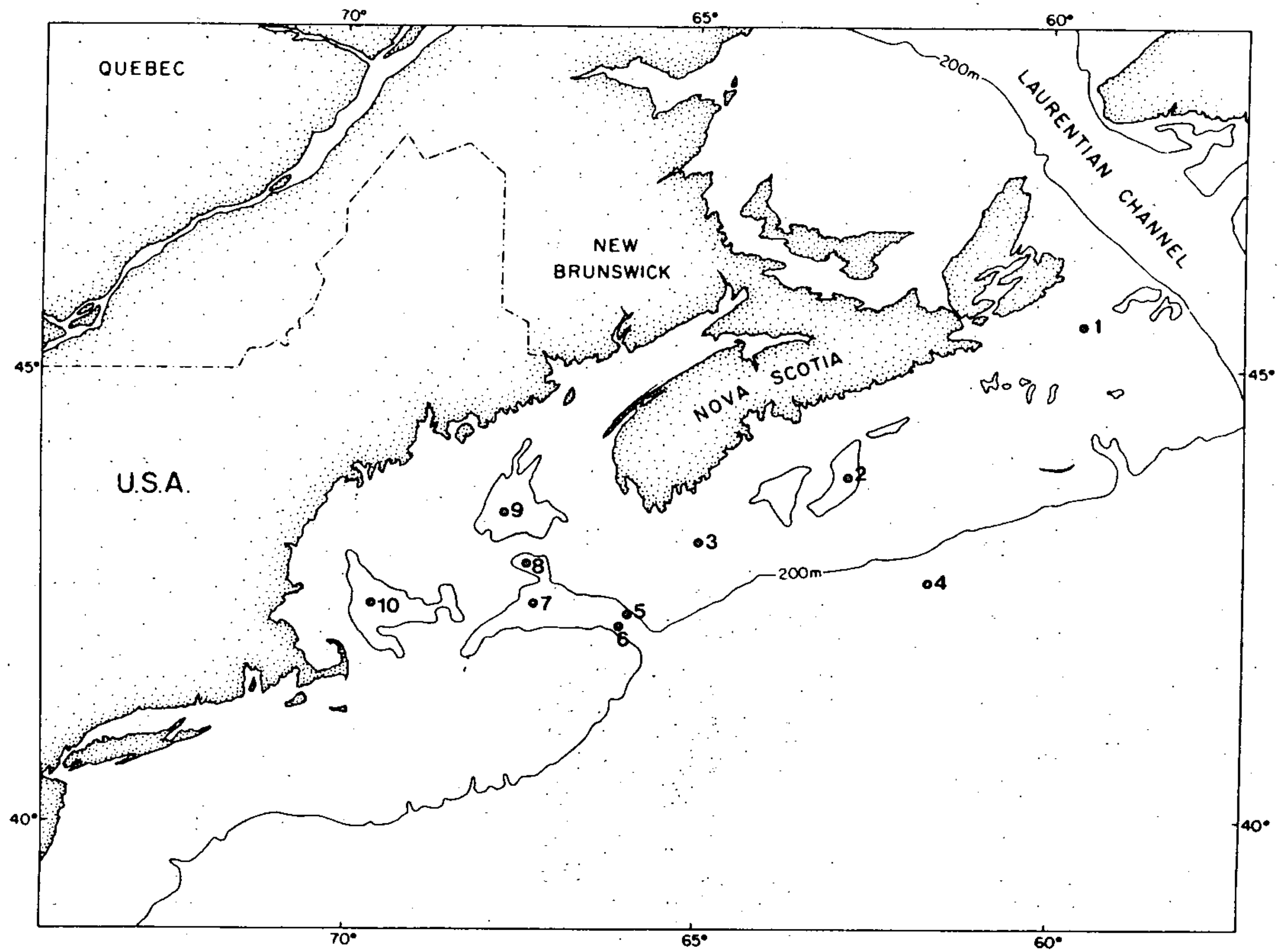

Fig. 4. Monitoring sites on the Scotian Shelf and in the Gulf of Maine.