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Canadian Science Advisory Secretariat
Science Advisory Report 2006/017

STATE OF THE OCEAN 2005: PHYSICAL OCEANOGRAPHIC CONDITIONS ON THE SCOTIAN SHELF, BAY OF FUNDY AND GULF OF MAINE

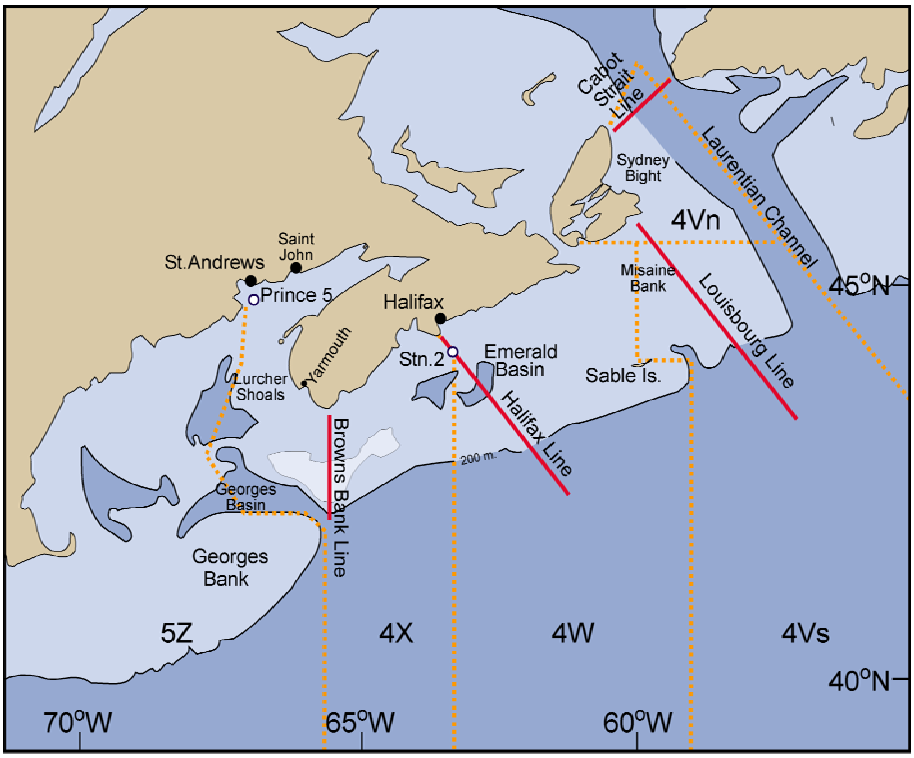

Figure 1. Scotian Shelf-Gulf of Maine region.

Context

The physical oceanographic environment influences the yield (growth, reproduction, survival), and behaviour (distribution, catchability, availability) of marine organisms as well as the operations of the fishing industry. Environmental changes may contribute directly to variations in resource yield, reproductive potential, catchability, year-class size (recruitment) and spawning biomass; they may also influence the perception of the resource status and the efficiency and profitability of the industry.

*Physical oceanographic conditions (mainly water temperature and salinity) are therefore measured during research vessel resource surveys and regularly at fixed sites as part of the **Atlantic Zone Monitoring Program (AZMP)**. Additional hydrographic, meteorological and sea ice data are obtained from a variety of sources, including standard monitoring stations, research studies, ships-of-opportunity, fishing vessels and remote sensing (satellites). A state of the ocean report is completed annually for each region of the Atlantic coast based on this information.*

All hydrographic data are edited and archived in Canada's national Marine Environmental Data Service (MEDS) database. A working copy is maintained in a Northwest Atlantic database at the Bedford Institute of Oceanography.

Canada

SUMMARY

- The North Atlantic Oscillation Winter Index was above normal in 2005 for the first time since 2000, increasing substantially from the 2004 value.

- Annual air temperatures in 2005 over the Scotian Shelf, Bay of Fundy and eastern Gulf of Maine were 0.3°C to 0.7°C above normal, 0.9 to 1.2°C warmer than in 2004.

- Sea ice cover seaward of Cabot Strait was considerably less than normal in 2005 and substantially less than the coverage in 2004.

- Sea-surface temperatures were 0.1-1°C below normal for the Scotian Shelf and eastern Gulf of Maine, slightly warmer than in 2004.

- Slightly warmer to slightly colder than normal conditions prevailed in subsurface waters over the Scotian Shelf and eastern Gulf of Maine, considerably warmer overall in 2005 compared to 2004.

- Bottom temperatures during the July 2005 groundfish survey were about 0.02°C below normal, 1.3°C warmer than in 2004.

- Vertical stratification (0-50m) for the Scotian Shelf was higher than average, spatially variable and stronger than in 2004.

BACKGROUND

Temperature and salinity conditions in the Scotian Shelf, Bay of Fundy and Gulf of Maine regions are determined by heat transfer between the ocean and atmosphere, inflow from the Gulf of St. Lawrence supplemented by flow from the Newfoundland Shelf, exchange with offshore slope waters, freshwater runoff, direct precipitation and melting of sea-ice. Water properties have large seasonal cycles, east-west and inshore-offshore gradients, and vary with depth (Petrie et al. 1996). Temperature and salinity are modified by diffusion, mixing and currents. Shelf topography is a major factor affecting the circulation. In this report, the reference period used for climate normals is 1971-2000.

ASSESSMENT OF CONDITIONS IN 2005

The North Atlantic Oscillation (NAO) is the dominant atmospheric pattern in the North Atlantic Ocean; it affects water properties and circulation through air-sea heat exchange and wind stress. In 2005, the NAO Winter Index was above normal (4.1 mb) for the first time since 2000, a large change from the -9.0 mb anomaly in 2004 (Figure 2). Above normal NAO anomalies are generally accompanied by colder than normal winters and the production of colder than normal waters in the Labrador Sea. These waters can subsequently be transported into the Scotian Shelf-Gulf of Maine, affecting the region's ocean conditions.

Annual air temperatures over the Scotian Shelf and eastern Gulf of Maine were about 0.3°C-0.7°C above normal in 2005, 0.9 to 1.2°C warmer than in 2004. The monthly anomalies were dominated by warmer than normal summer and fall values, when air temperatures were more

than 2°C above normal for Sable Island (Oct-Dec), Yarmouth (Oct) and Saint John (Nov). Sable Island temperatures increased for the first time since the long-term high of 1999 (Figure 3).

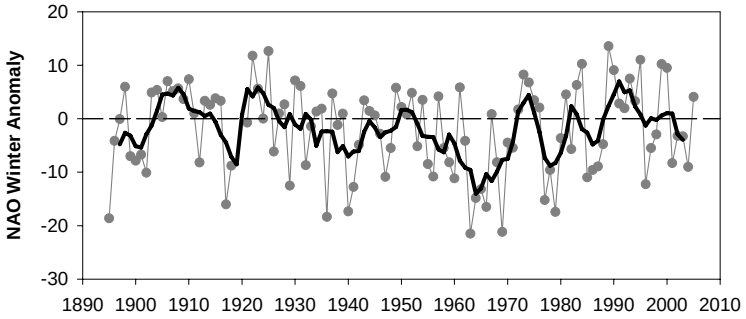

Figure 2. North Atlantic Oscillation winter anomaly relative to the 1971-2000 means. The annual anomaly (grey line, dot) and 5 year running means (black line) are shown.

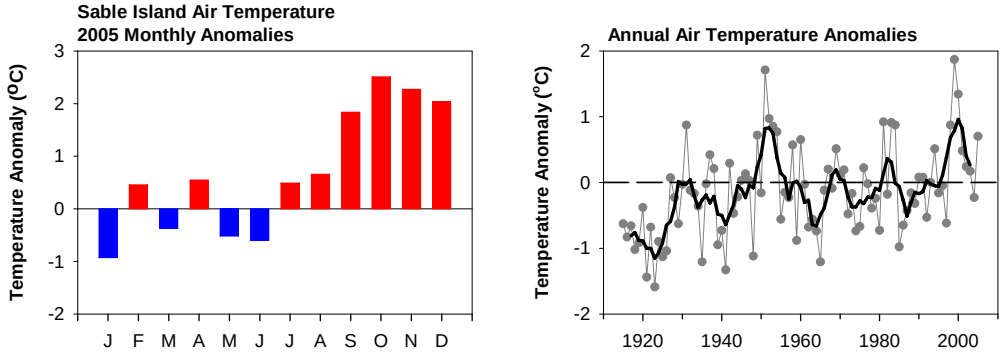

Figure 3. Sable Island monthly air temperature anomalies for 2005 relative to the 1971-2000 long-term means (left panel). Time series of annual air temperature anomalies (grey line and dots) and 5 year running means (heavy, black line; right panel).

The Jan-May 2005 sea ice cover seaward of Cabot Strait was below normal and substantially less than in 2004 (Figure 4). The coverage was 31% of the normal ice cover; 2005 ranked 13th lightest cover in the 44 year record.

The annual average sea-surface temperature in 2005 at St. Andrews, N.B. was 0.07°C below normal, making it the 49th coldest in 85 years. At Halifax, the annual anomaly was 0.98°C below normal, making 2005 the 8th coldest in 80 years. At Prince 5, monthly average temperatures at all depths were dominated by colder than average values leading to annual anomalies of 0.4°C below normal. Temperatures increased by about 0.5°C relative to 2004. The monthly salinities were below normal for most of 2005. Annual values were 0.42 below normal at 0 m and 0.17 below normal at 90 m (Figure 5).

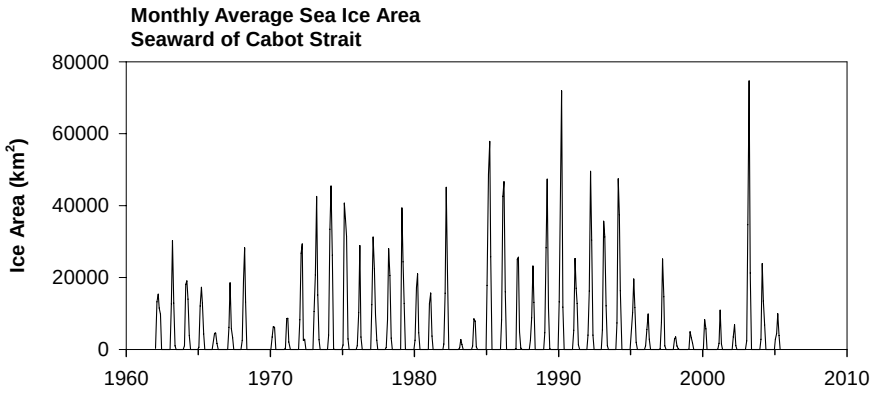

Figure 4. Time series of monthly average sea ice area seaward of Cabot Strait.

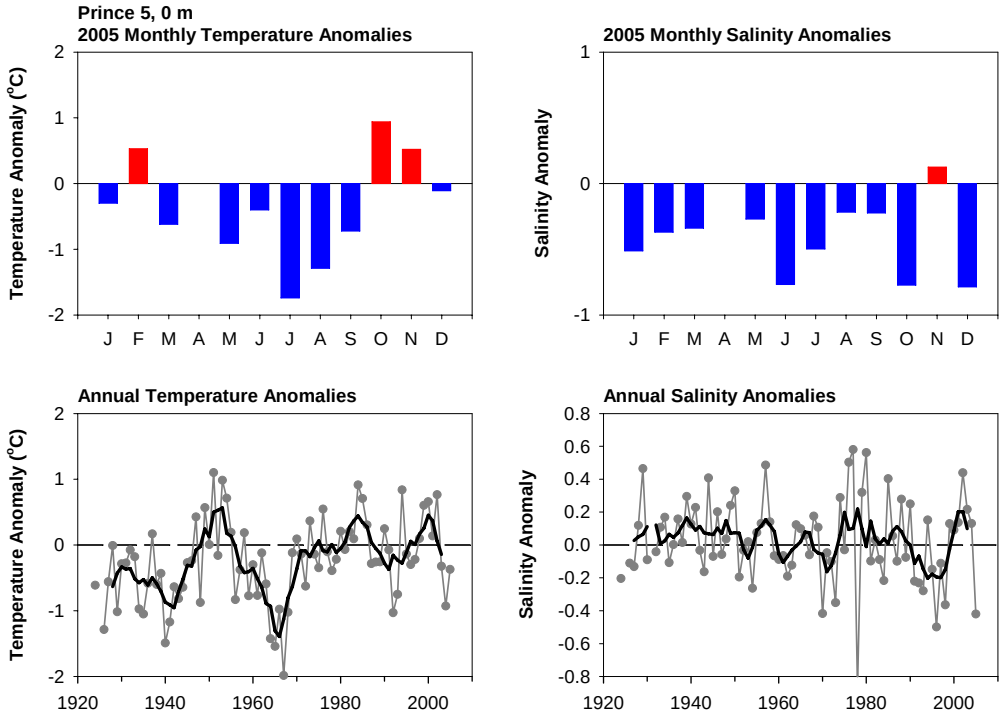

Figure 5. Monthly surface temperature anomalies for 2005 relative to the 1971-2000 long-term means for the Prince 5 station at the mouth of the Bay of Fundy (top left panel). Time series of annual surface temperature anomalies (grey line and dots) and 5 year running means (heavy, black line; lower left panel). Monthly surface salinity anomalies for 2005 (top right panel) and the time series of annual surface salinity anomalies (grey line and dots) and 5 year running means (heavy, black line; lower right panel).

In the Laurentian Channel to the east of the Scotian Shelf, temperatures in the deep (200-300 m) waters at Cabot Strait in 2005 were 0.06°C above the long-term mean, just 0.1°C lower than in 2003 and 2004. In 2005 in Emerald Basin, the temperatures near the surface were above normal (Figure 6). There was a transition to negative anomalies between 20 and 50 m. The largest negative anomaly was at 100 m with an annual value of -1.65°C. Anomalies decreased to near zero at 225 to 250 m.

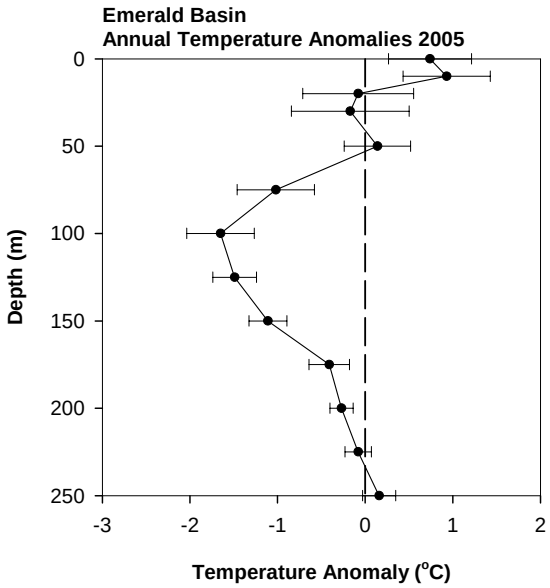

Figure 6. Depth profile of the annual temperature anomalies (dots) based on averages of the monthly anomalies for Emerald Basin, 2005. Horizontal bars are estimates of the standard error.

Temperature anomalies over the Scotian Shelf and eastern Gulf of Maine during the 2005 July groundfish survey varied with depth (Figure 7). At the surface, temperatures were above normal by 0-3^{o}C over the eastern Scotian Shelf and by up to about 1^{o}C near the coast in southwestern Nova Scotia. Negative anomalies prevailed over the rest of the region. At 50 m, most of the Scotian Shelf had above normal temperatures, generally by 0-1^{o}C. The eastern Gulf of Maine and Bay of Fundy had below normal temperatures typically by 1^{o}C. The anomaly patterns at 100 m and at the bottom were similar: the largest positive values on the outer portion of the eastern Scotian Shelf; the largest negative anomalies were found in the Bay of Fundy.

The average bottom temperature for the area covered in the 2005 July groundfish survey was about 5.8^{o}C, about 0.02^{o}C below the 1971-2000 mean temperature, i.e. essentially normal (Figure 8). This contrasts with 2004 which had the coldest bottom temperatures over the entire time series.

The spring oceanographic survey of the Cabot Strait, Louisbourg, Halifax and Browns Bank lines found a mixture of positive and negative temperature anomalies on all lines with a magnitude of 0.5^{o}C. In October, the dominant feature on the lines was the above normal temperatures below 100 m in Cabot Strait and on the inner half of the Halifax and Browns Bank sections. Small scale spatial variations of the temperature anomalies were evident on all lines but particularly the three westernmost ones (Figure 9).

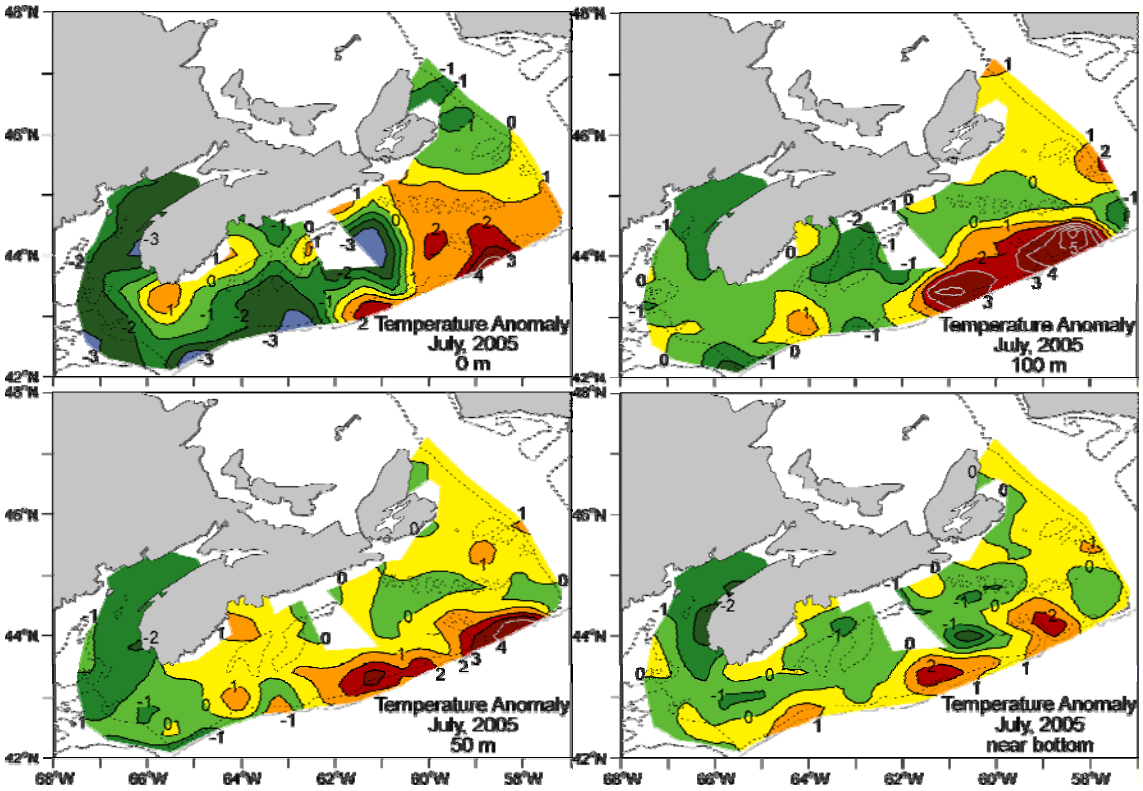

Figure 7. Plan views of the temperature anomalies at 0, 50, 100m and near the bottom for the Scotian Shelf in July 2005. The anomalies are based on observations collected during the annual groundfish survey.

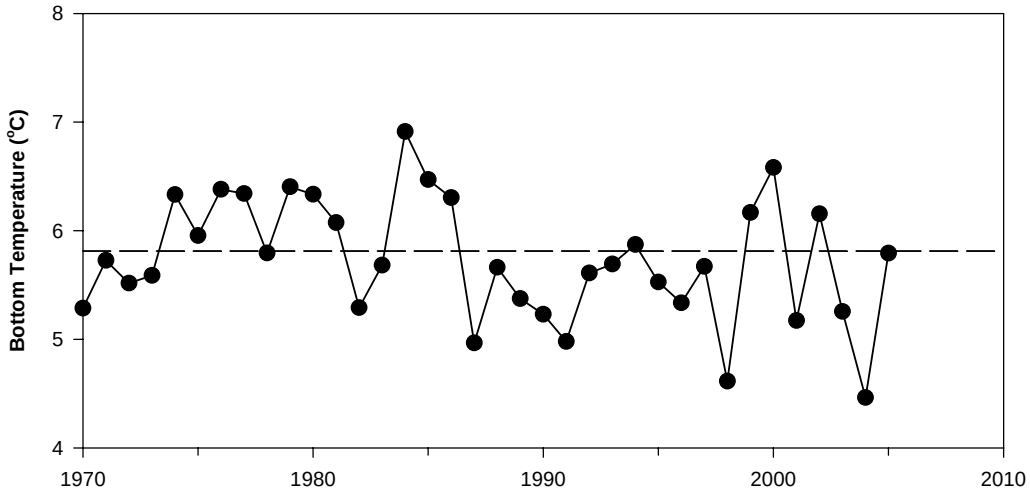

Figure 8. Time series of the average bottom temperature for the Scotian Shelf based on data from the annual July groundfish survey. The broken line is the 1971-2000 mean.

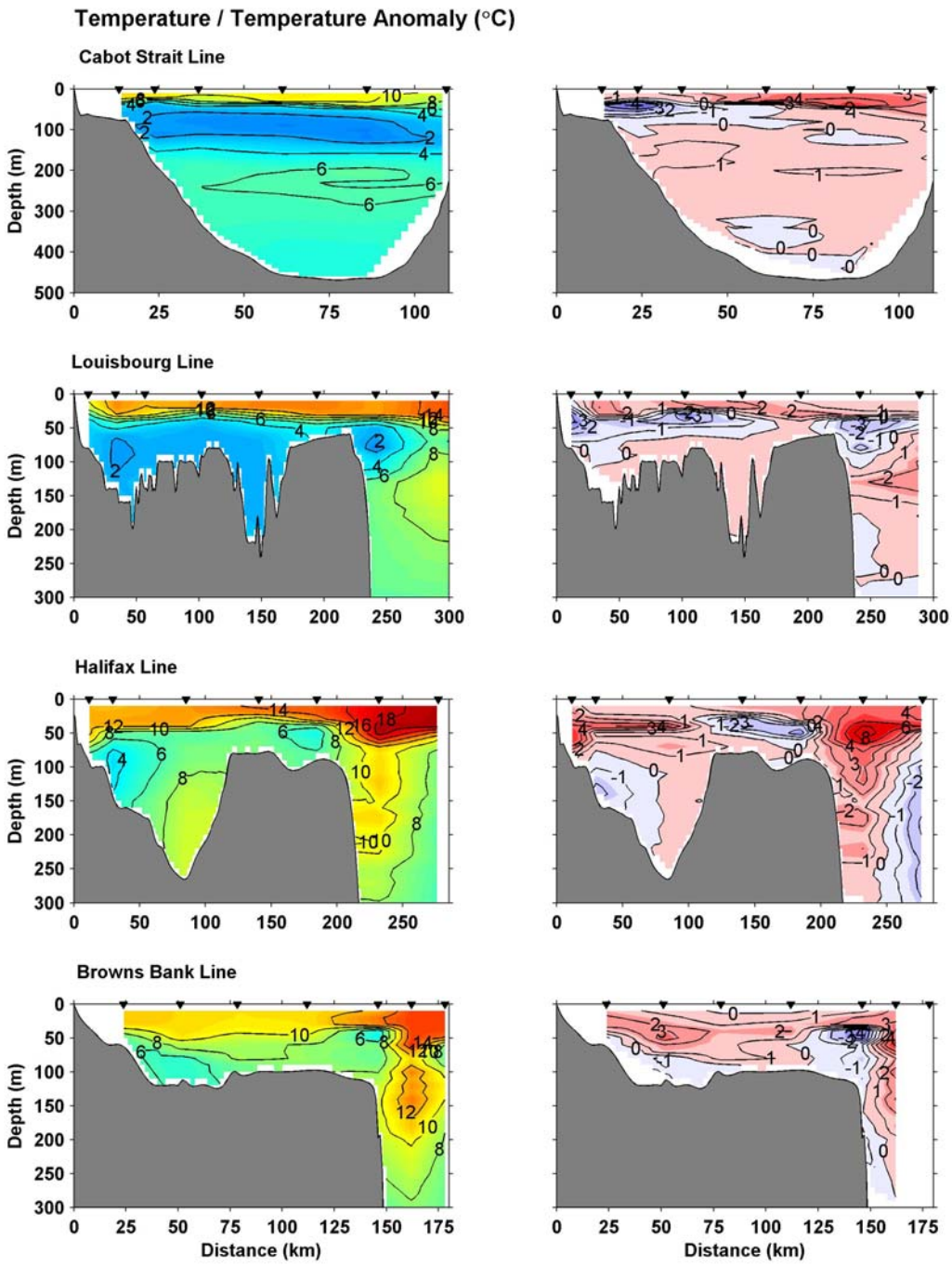

Figure 9. October 2005 temperature and temperature anomaly sections from the Biological Ocean Science's fall survey of the Scotian Shelf. Below (above) normal temperatures are shaded blue (red) in the left hand panel.

In 2005, temperature anomalies in Sydney Bight (100 m), Misaine Bank (100 m), Emerald Basin (250 m), Lurcher Shoals (50 m), Georges Basin (200 m) and eastern Georges Bank (50 m) were 1, 0.1, 0.2, -0.3, -0.22 and -1.1^{o}C respectively (Figure 10). The overall tendency then was for slightly above normal temperatures in the eastern half of the region and slightly below normal values in the western half.

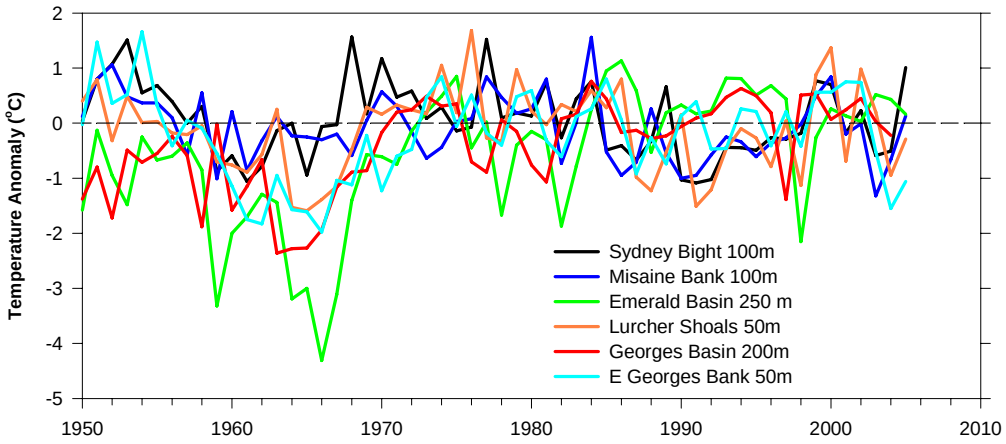

Figure 10. Time series of annual ocean temperature anomalies from various sites on the Scotian Shelf and in the Gulf of Maine.

Seawater density depends on temperature, salinity and pressure and increases with depth in the ocean. The density difference between waters at two depths is referred to as the density stratification. The density stratification divided by the depth difference is called the stratification index. In the 1990s, the average 0 to 50 m index over the Scotian Shelf increased significantly. From the mid to late 1990s, the index was at or near its maximum over the 50-year record (Figure 11). Increased stratification inhibits vertical mixing, can decrease nutrient fluxes to the surface waters and thus affect phytoplankton production. In 2005, stratification was slightly higher than average; however, there was considerable spatial variability over the Scotian Shelf.

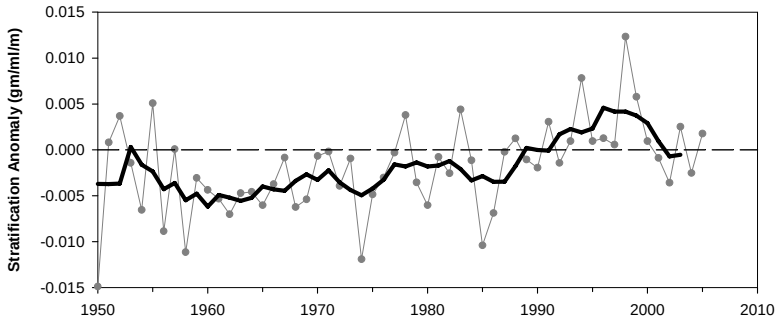

Figure 11. Time series of the density stratification anomaly over the Scotian Shelf. The annual anomaly (grey line, dot) and 5 year running means (black line) are shown.

The average positions of the temperature boundary between shelf and slope waters (Shelf/Slope front) and between slope and Gulf Stream waters in 2005 were seaward of their long-term means by about 6 and 8 km.

CONCLUSIONS

Year to year, water temperatures on the Scotian Shelf and in the Gulf of Maine are among the most variable in the North Atlantic Ocean. Moreover, within the region, some areas may experience above normal, others normal, and still others below normal ocean temperature

anomalies during the same year. A summary of many of the time series already shown indicates the year to year and within year variability (Fig. 12). The results are displayed as the number of standard deviations above (red) and below (blue) normal; the deeper the shade of red (blue) the more the temperatures are above (below) normal. Annual anomalies are calculated using 1971-2000 as the reference period for the mean values and the standard deviations; individual anomalies for each variable have been normalized by dividing by its standard deviation.

Figure 12 illustrates the temporal and spatial variability in the region. For example, the periods 1987-1993 and 2003-2004 were predominantly colder than normal while 1999-2000 was warmer than normal. From 1979 to1986, temperatures tended to be warmer than normal but, except for 1984, not as dominantly so as 1999-2000. In 2004, 17 of the 18 variables had below normal values, indicated by their blue shading. The only exception was the 250 m temperature in Emerald Basin. Conditions changed significantly in 2005, when 10 of the 18 variables had below normal values. Below normal conditions prevailed in the western half of the region, while above normal conditions dominated the eastern half.

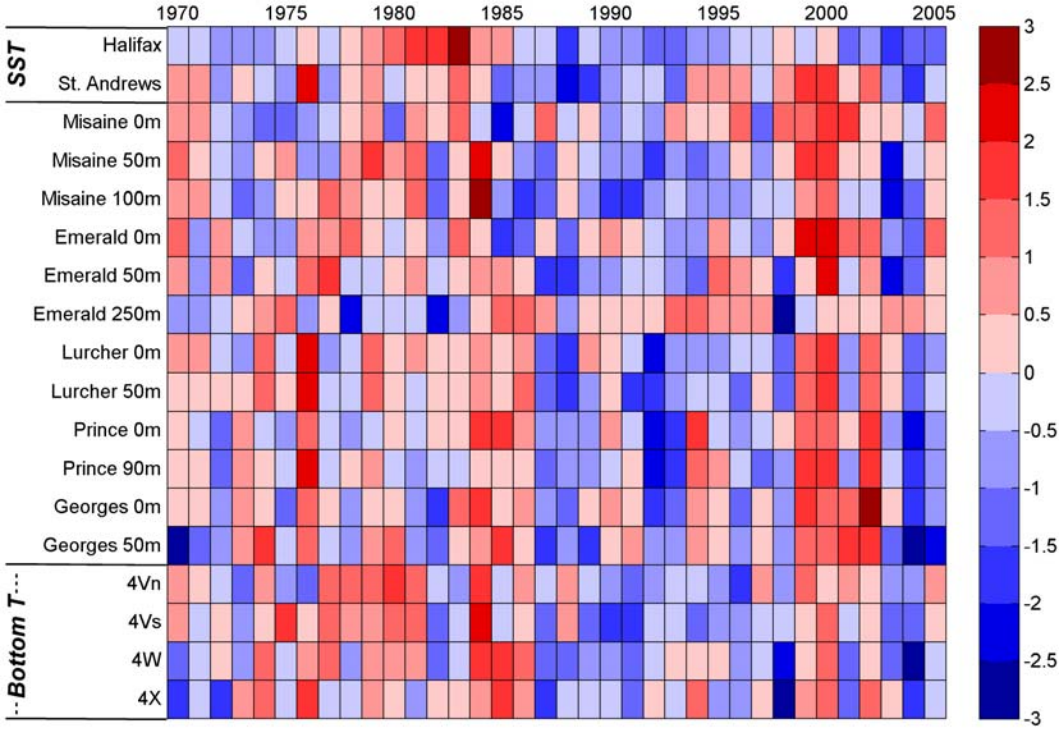

Figure 12. Normalized annual anomalies of bottom temperatures and temperatures at discrete depths for the Scotian Shelf-Gulf of Maine region. The normalized anomalies are the annual anomalies based on the 1971-2000 means, divided by the standard deviation. The scale represents the number of standard deviations an anomaly is from normal; blue indicates below normal, red above normal.

SOURCES OF INFORMATION

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