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Canadian Science Advisory Secretariat
Science Advisory Report 2007/028

STATE OF THE OCEAN 2006: PHYSICAL OCEANOGRAPHIC CONDITIONS ON THE SCOTIAN SHELF, BAY OF FUNDY AND GULF OF MAINE

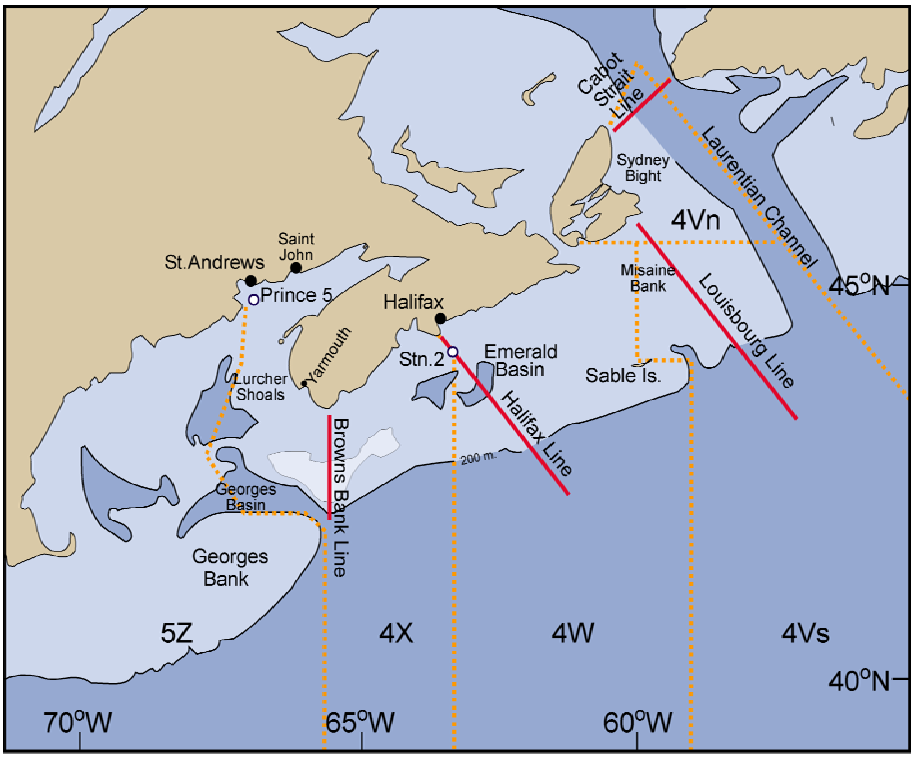

Figure 1. Scotian Shelf-Gulf of Maine region showing the main topographical features and the locations of AZMP monitoring sites and sections.

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.

SUMMARY

- The North Atlantic Oscillation Winter Index was below normal in 2006 after a weak above normal value in 2005.

- Annual air temperatures in 2006 over the Scotian Shelf, Bay of Fundy and eastern Gulf of Maine were 1.3°C to 1.4°C above normal, nearly 1°C warmer than in 2005.

- Sea ice cover seaward of Cabot Strait was considerably less than normal in 2006, a further reduction from the below normal coverage in 2005.

- Sea-surface temperatures were 1°C above normal for the Scotian Shelf and eastern Gulf of Maine, and normal over eastern Georges Bank, warmer conditions than in 2005.

- Generally warmer (~1°C) than normal conditions prevailed in subsurface waters over the Scotian Shelf and eastern Gulf of Maine in 2006, considerably warmer than in 2005.

- Bottom temperatures during the July 2006 groundfish survey were about 0.7°C above normal, 0.8°C warmer than in 2005.

- Vertical stratification (0-50 m) for the Scotian Shelf was higher than average, spatially variable and stronger than in 2005.

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, local mixing, 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). 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 2006

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 2006, the NAO Winter Index was below normal (-3.3 mb), a decrease from the 4.1 mb anomaly in 2005 (Figure 2). Below normal NAO anomalies are generally accompanied by warmer than normal winters leading to warmer 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 1.3°C-1.4°C above normal in 2006, ~1.0°C warmer than in 2005. The monthly anomalies were dominated by warmer than normal values throughout the year but particularly in January, when air temperatures were ~4°C above normal at Sable Island, Yarmouth and Saint John. Sable Island temperatures continued their upward trend (Figure 3).

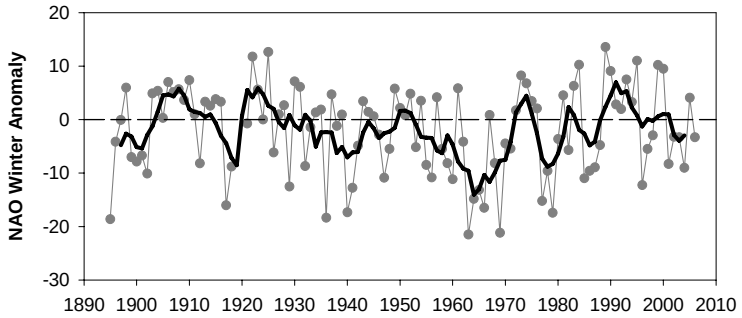

Figure 2. North Atlantic Oscillation winter anomaly relative to the 1971-2000 means. The annual anomaly (grey line with dots) and 5 year running means (black line) are shown.

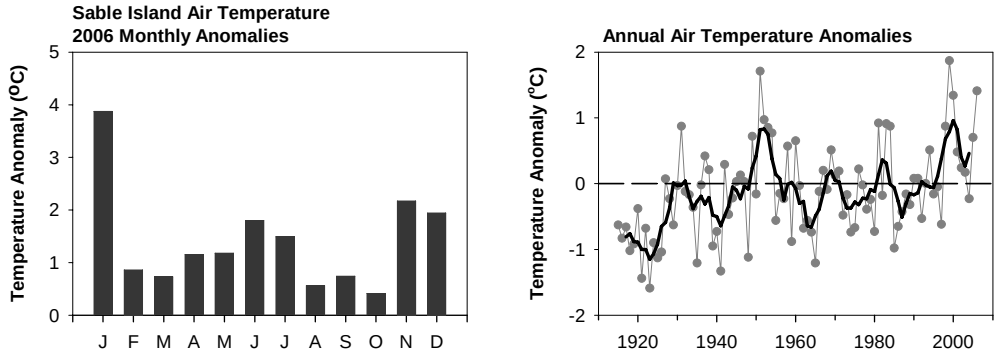

Figure 3. Sable Island monthly air temperature anomalies for 2006 relative to the 1971-2000 long-term means (left panel). Time series of annual air temperature anomalies (grey line and dots) and 5 year running means (heavy, black line; right panel).

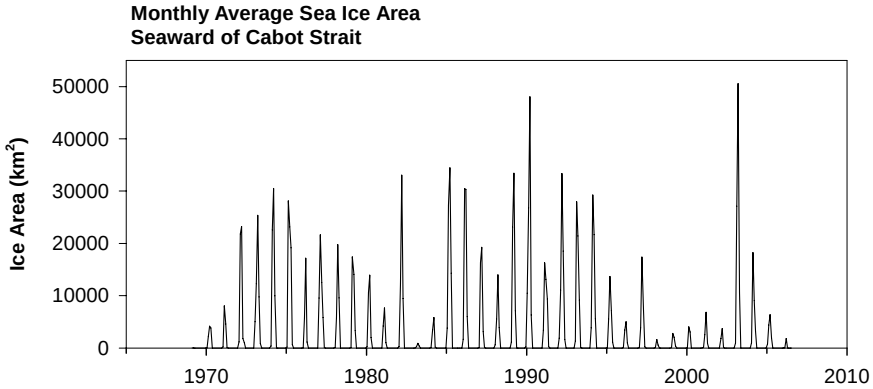

Figure 4. Time series of monthly average sea ice area seaward of Cabot Strait.

The January-May 2006 sea ice cover seaward of Cabot Strait was below normal and substantially less than in 2005 (Figure 4). The coverage was 5% of the normal ice cover; 2006 ranked 3rd lightest cover in the 38 year record.

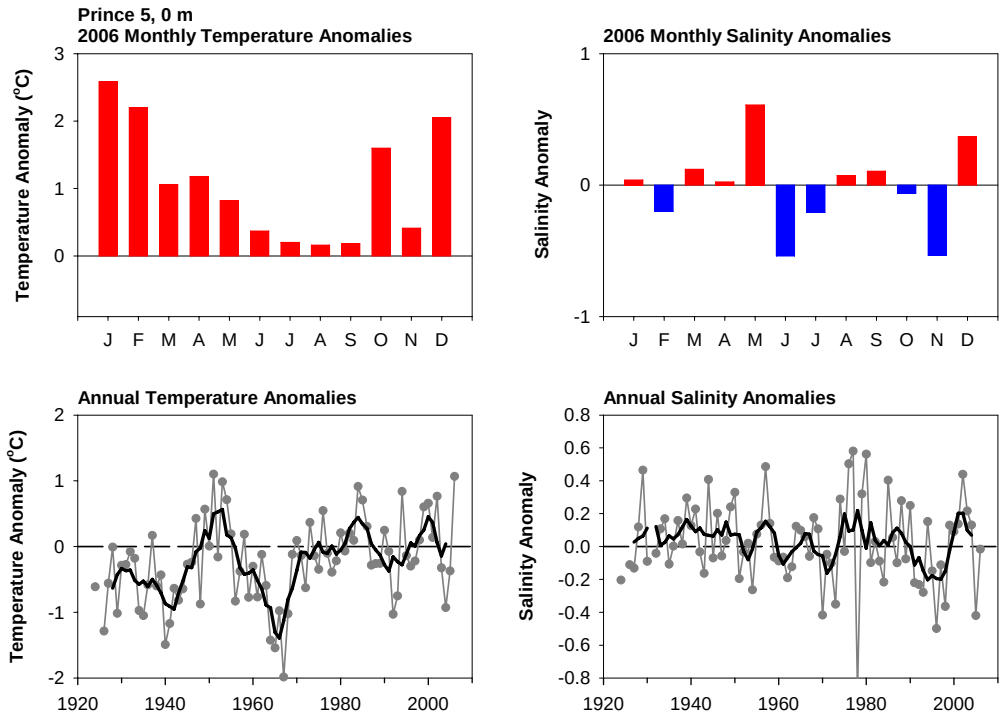

Figure 5. Monthly surface temperature anomalies for 2006 relative to the 1971-2000 long-term means for the Prince 5 station at the mouth of the Bay of Fundy (top left panel). Time series of annual surface temperature anomalies (grey line and dots, lower left panel) and 5 year running means (heavy, black line; lower left panel). Monthly surface salinity anomalies for 2006 (top right panel) and the time series of annual surface salinity anomalies (grey line and dots, lower left panel) and 5 year running means (heavy, black line; lower right panel).

The annual average sea-surface temperature in 2006 at St. Andrews, N.B. was 1.3°C above normal, making it the warmest in 86 years. Whereas at Halifax, the annual surface temperature anomaly was only 0.3°C above normal, making 2006 the 17th warmest in 81 years. At Prince 5, monthly average temperatures at all depths were dominated by warmer than normal values leading to annual anomalies of 1°C above normal. Temperatures increased by about 1.4°C relative to 2005. The monthly salinities were slightly below normal for most of 2006. Annual values were ~0.05 below normal from 0 to 70 m and ~0.2 above normal at 90 m (Figure 5).

In the Laurentian Channel to the east of the Scotian Shelf, temperatures in the deep (200-300 m) waters at Cabot Strait in 2006 were 0.1°C above the long-term mean, about the same as in 2005. In 2006 in Emerald Basin, the temperatures near the surface were about 1.5°C above normal (Figure 6). The anomalies decreased with depth to about 0.4°C above normal at 250 m.

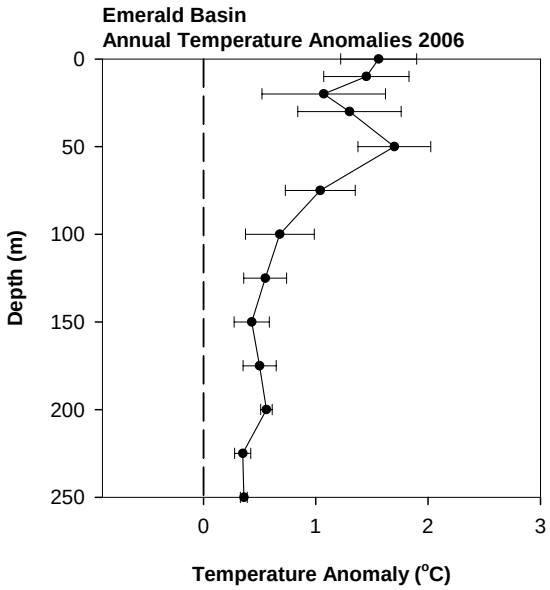

Figure 6. Depth profile of the annual temperature anomalies (dots) based on averages of the monthly anomalies for Emerald Basin in 2006. Horizontal bars are estimates of the standard error.

Temperature anomalies over the Scotian Shelf and eastern Gulf of Maine during the 2006 July groundfish survey varied with depth but the overall pattern was dominated by positive anomalies (Figure 7). At the surface, temperatures were above normal by 1-3°C. At 50 m, most of the Scotian Shelf had above normal temperatures, generally by 0-2°C. The eastern Gulf of Maine had slightly below normal temperatures typically by <1°C. The anomaly patterns at 100 m and at the bottom were similar: the largest positive values on the central Scotian Shelf; weak negative anomalies in the eastern Gulf of Maine.

The average bottom temperature for the area covered in the 2006 July groundfish survey was about 6.6°C, about 0.7°C above the 1971-2000 mean temperature and the third highest in 37 years (Figure 8). This is a substantial increase from 2005, and an even greater increase from 2004, the year with the coldest bottom temperatures over the entire time series.

The spring oceanographic survey of the Cabot Strait, Louisbourg, Halifax and Browns Bank lines found that positive temperature anomalies dominated with magnitudes of ~1°C. In October, the main feature was the above normal temperatures on the inner half of the Halifax and outer Browns Bank line. Small scale spatial variations of the temperature anomalies were evident on all lines (Figure 9).

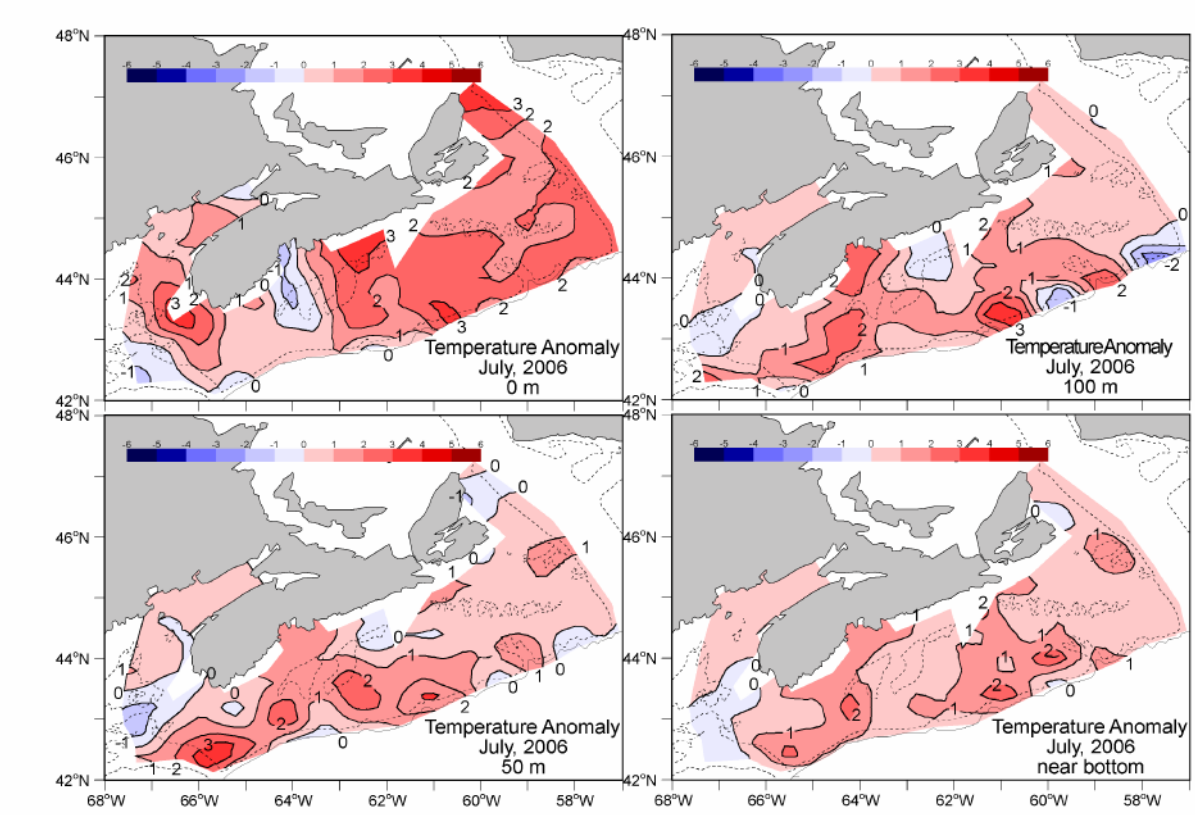

Figure 7. Plan views of the temperature anomalies at 0, 50, 100m and near the bottom for the Scotian Shelf in July 2006. The anomalies are based on observations collected during the annual groundfish survey.

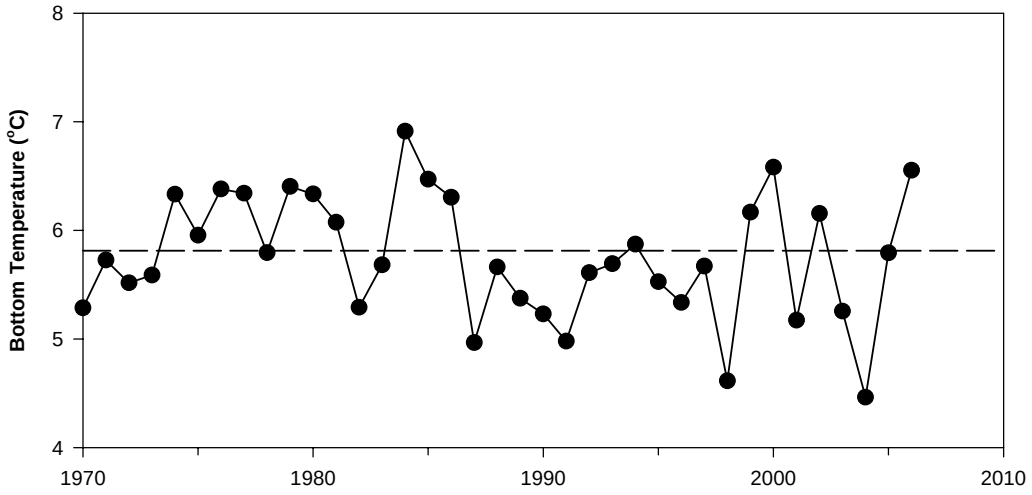

Figure 8. Time series of the average bottom temperature for the Scotian Shelf based on data from the annual July groundfish survey. The broken line is the 1971-2000 mean.

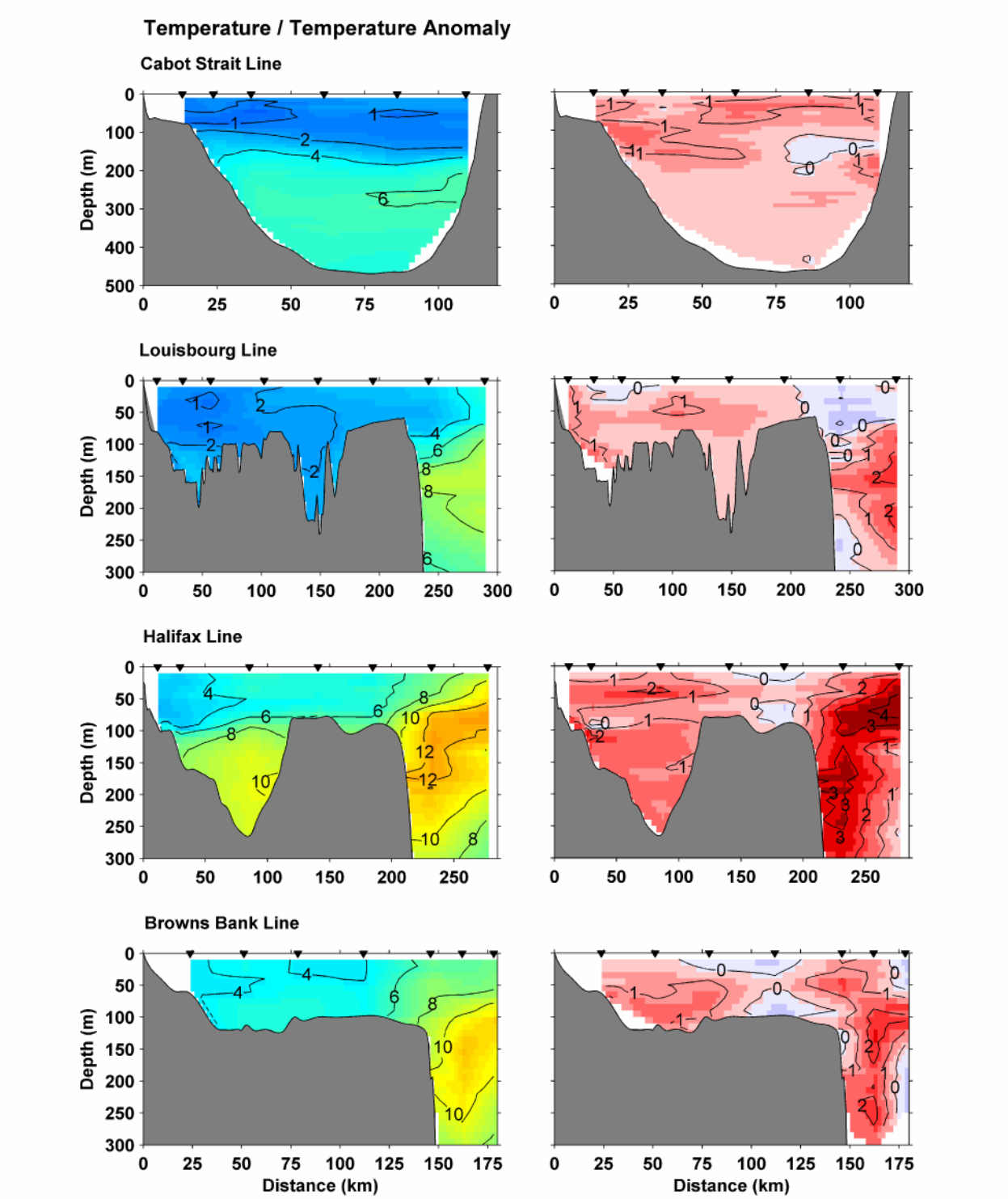

Figure 9. October 2006 temperature and temperature anomaly sections from Biological Ocean Science's fall survey of the Scotian Shelf. Below (above) normal temperatures are shaded blue (red) in the left hand panel.

In 2006, 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 0.7, 0.6, 0.4, 1.2, 0.4 and -0.1^{o}C respectively (Figure 10). The overall tendency then was

for above normal temperatures over the Scotian Shelf and in Georges Basin, and slightly lower than normal values on Georges Bank.

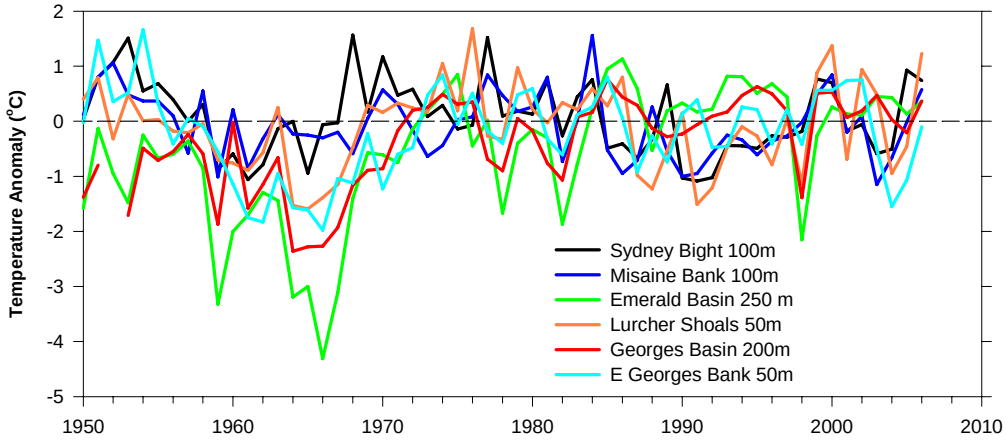

Figure 10. Time series of annual ocean temperature anomalies from various sites (Fig. 1) on the Scotian Shelf and in the Gulf of Maine.

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 2006, stratification increased and was higher than average; however, there was considerable spatial variability over the Scotian Shelf.

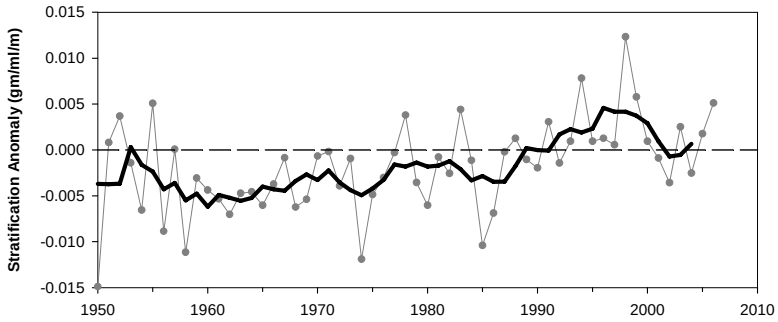

Figure 11. Time series of the density stratification anomaly over the Scotian Shelf. The annual anomaly (grey line, dot) and 5 year running means (black line) are shown.

The average position of the temperature boundary between shelf and slope waters (Shelf/Slope front) was south of its long-term mean position by about 8 km in 2006; the boundary between slope and Gulf Stream waters was north of its long-term mean by about 6 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 in 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 to 1986, 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 2006, when 17 of the 18 variables had above normal values, many substantially above normal. The only variable with a below normal value was the 50 m temperature on eastern Georges Bank.

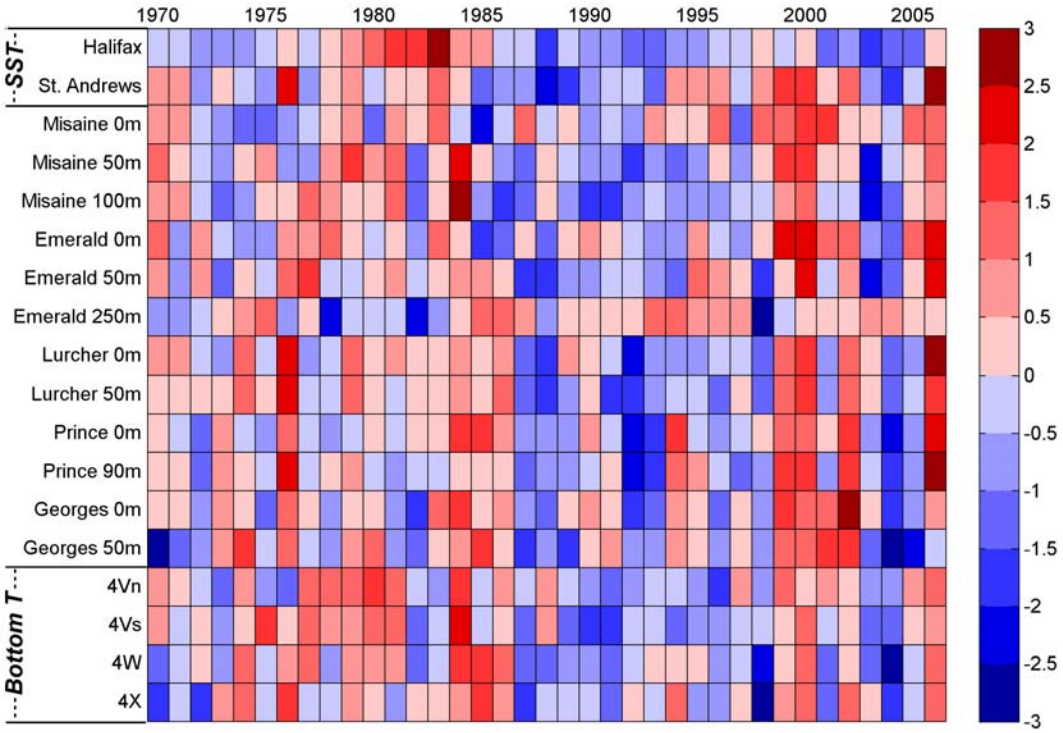

Figure 12. Normalized annual anomalies of bottom temperatures and temperatures at discrete depths for the Scotian Shelf-Gulf of Maine region. The normalized anomalies are the annual anomalies based on the 1971-2000 means, divided by the standard deviation. The scale represents the number of standard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

SOURCES OF INFORMATION

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ISSN 1480-4913 (Printed)

La version française est disponible à l'adresse ci-dessus.

CORRECT CITATION FOR THIS PUBLICATION

DFO, 2007. State of the Ocean 2006: Physical Oceanographic Conditions on the Scotian Shelf, Bay of Fundy and Gulf of Maine. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/028.