Oceanographic sampling gear

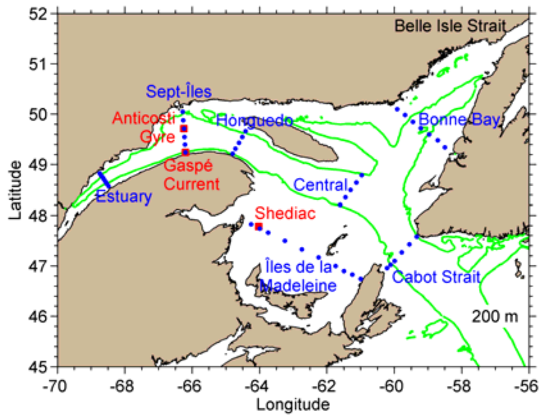

Figure 1. Map showing the positions of standard oceanographic sections (blue dots) and fixed stations (red squares) in the Gulf of St. Lawrence.

State of the Ocean 2003: Physical Oceanographic Conditions in the Gulf of St. Lawrence

Background

The physical oceanographic environment influences the yield (growth, reproduction, survival), and behaviour (distribution, catchability) of marine organisms as well as the operations of the fishing industry. Changes in this environment may contribute directly to variations in food source (plankton), resource yield, reproductive potential, catchability, year-class size (recruitment) and spawning biomass and may also influence the perception of the status of resources 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 Zonal Monitoring Program*** *(****AZMP****). Additional hydrographic, meteorological and sea ice data are obtained from a variety of sources, research studies, ships-of-opportunity, fishing vessels, and remote sensing (satellites).*

All of the 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

- In 2003, colder than normal winter air temperatures led to above normal sea ice cover area and volume in the Gulf of St. Lawrence. The volume of sea ice exported on the Shelf seaward of Cabot Strait reached a 41-year record high.
- Warmer than normal air temperatures and surface water temperatures were observed in the fall. The annual mean air temperature at Îles de la Madeleine was 0.7°C warmer than normal.
- The volume of near-freezing ($T < -1°C$) and salty ($S > 32.35$) waters imported through the Strait of Belle Isle during winter reached a 9-year record high. As a result, the summertime thickness and volume of $T < 0°C$ and $T < 1°C$ waters increased by 300% and 40% respectively from 2002 to 2003.
- In the southern Gulf, there was a spectacular 25-fold increase in the bottom area bathed with $T < 0°C$ waters. In the northern Gulf, the area of the bottom bathed by these cold waters nearly doubled.
- The mid-summer index of the CIL minimum temperature cooled by 0.65°C relative to 2002.

- The annual mean runoff of the St. Lawrence River at Québec City was 13.4% below normal. The very low runoff values of the first months of 2003 probably caused the higher than normal surface salinities and weaker than normal surface stratification observed at the AZMP fixed stations.
- The 100 to 200 m deep layer had colder than normal temperature but close to normal salinity.
- The 200 to 300 m deep layer had close to normal temperature and salinity in 2003.

Introduction

The waters of the Gulf of St. Lawrence are subject to seasonal, interannual and interdecadal variations in physical properties such as temperature, salinity and ice cover. These fluctuations are attributable to two main factors: (1) interactions with the atmosphere (heat exchange between water and air, precipitation, evaporation, ice formation), and (2) water mass exchanges between the Gulf and the Atlantic Ocean through Cabot Strait and the Strait of Belle Isle (Figure 1).

A common feature of the vertical temperature structure in the Gulf of St. Lawrence is the layer of < 1°C water, commonly referred to as the cold intermediate layer or CIL (Figure 2). This winter-cooled water remains trapped during the summer and early fall months between the seasonally heated surface layer and the warmer near-bottom water mass originating from the continental slope region. In general, the CIL is thickest and has the coldest minimum temperatures in the northeast Gulf.

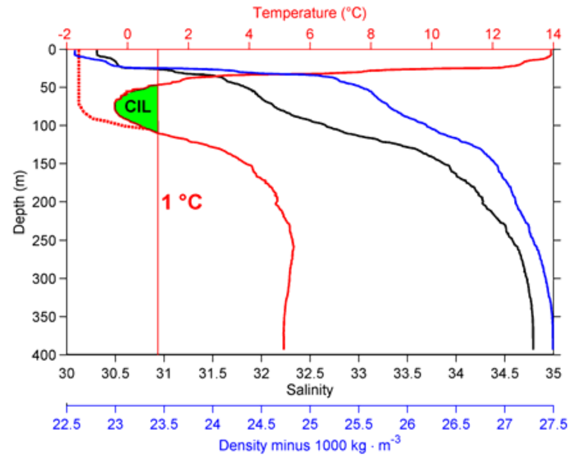

Figure 2. Typical profile of temperature (red), salinity (black) and density (blue) observed during the summer in the Gulf of St. Lawrence. The cold intermediate layer (CIL) is defined as the part of the water column which is colder than 1°C. The dashed red line shows a schematic winter profile with near-freezing temperatures in the top 70 meters.

Throughout this report, whenever the length of the data record allows it, we compared the 2003 meteorological, sea ice and oceanographic observations to a standard 1971-2000 reference period. This is in agreement with internationally adopted standard climatological methods and practices.

Air temperature

There are several weather stations around the Gulf of St. Lawrence, but we only show here the monthly air temperature observations from Îles de la Madeleine, a centrally located site within the Gulf that is sufficiently remote from the continent to give it a ‘marine’ character. In 2003, monthly mean air temperatures at Îles de la Madeleine were about 1°C colder than normal from February to April but became 1°C to 3°C warmer than normal from September to December (Figure 3).

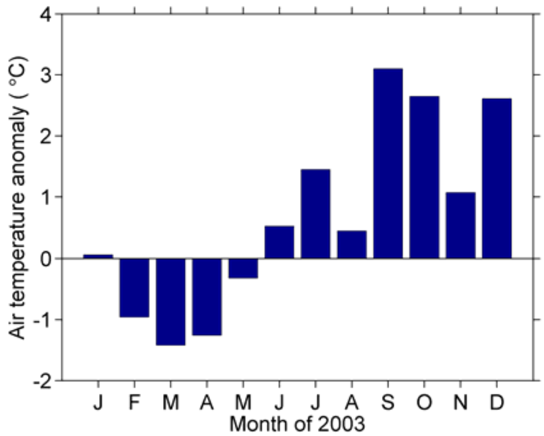

Figure 3. Monthly air temperature anomaly in 2003 at the Îles de la Madeleine.

The long-term trends in air temperature are shown on figure 4, where we also include the time series from the Mont-Joli station due to its very long, high-quality data record. The 2003 air temperature anomaly was +0.7°C at Îles de la Madeleine and +0.3°C at Mont-Joli. At both locations, the change in annual mean air temperature from 2002 to 2003 was less than 0.2°C. The 1999 annual temperature anomaly (2.2°C) represents the highest temperature ever observed in the 128-year long record at Mont-Joli.

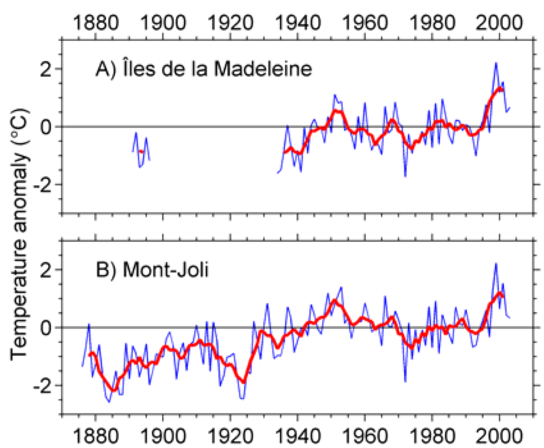

Figure 4. Annual air temperature anomalies (thin blue line) and 5-year running means (thick red line) at the Îles de la Madeleine and Mont-Joli.

Sea ice

Ice cover area was above normal in 2003, due mostly to the very severe March ice conditions (Figure 5). The times of first appearance of ice in the Gulf of St. Lawrence were generally 0-15 days earlier than normal while last presence of ice was generally 0-15 days later than normal. Ice duration was 21 days longer than normal, making the 2003 ice season the fifth longest in 41 years. The ice-area-days index (Figure 6) was very close to the 1971-2000 average. The volume of sea ice exported on the Shelf seaward of Cabot Strait reached a 41-year record high.

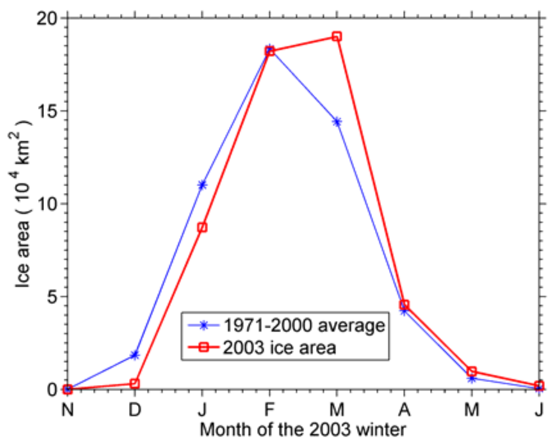

Figure 5. Monthly mean ice area in the Gulf of St. Lawrence in winter 2003 (red) compared with the 1971-2000 average (blue).

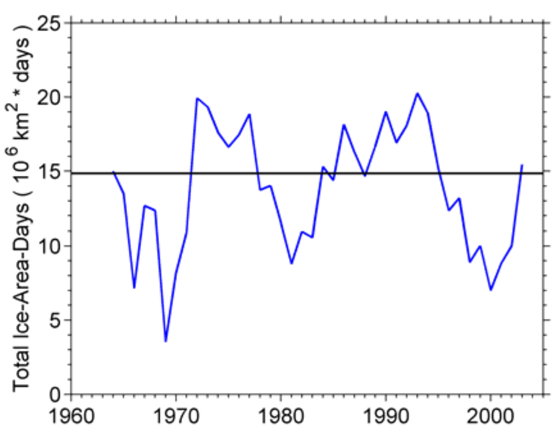

Figure 6. Ice-Area-Days index for the Gulf of St. Lawrence representing the annual sum of ice area times the number of days with ice.

Freshwater discharge

Precipitations were below normal over the drainage basin of the Great-Lakes and St. Lawrence River during the winter of 2003. This was followed by slightly below normal precipitations in the spring and summer of 2003, and above normal precipitation in the fall. This is reflected in the freshwater discharge index at Québec City (Figure 7), which shows that except for August, runoff was below normal in the first ten months of 2003. The largest negative runoff anomalies (25–33% below normal) occurred between March and May.

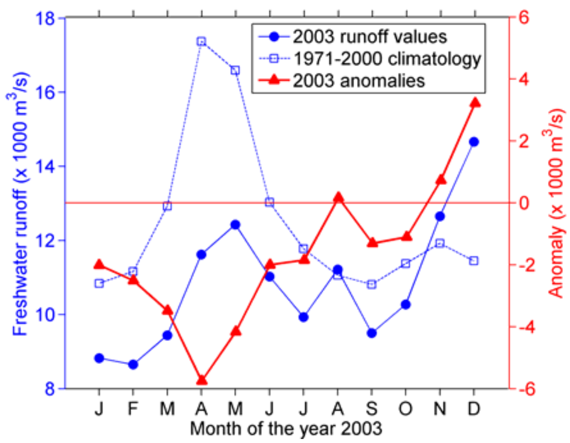

Figure 7. Monthly averaged freshwater discharge of the St. Lawrence River at Quebec City in 2003 (blue line with filled circles) compared with the 1971-2000 climatology (dashed blue line). The red line (right scale) shows the deviations of the 2003 runoff values from climatology.

The 2003 annual mean freshwater discharge at Québec City was 1670 m^3/s (13.4%) below the 1971-2000 normal. This is the 9th lowest runoff in the last 49 years (Figure 8).

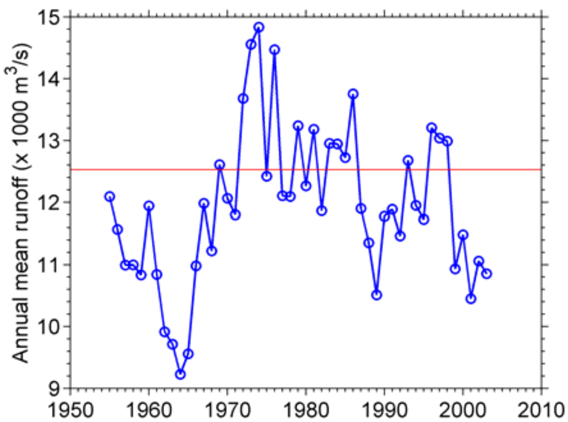

Figure 8. Yearly averaged freshwater discharge of the St. Lawrence River at Quebec City (blue) compared with the 1971-2000 average (red).

AZMP fixed stations

As part of the Atlantic Zone Monitoring Program, oceanographic measurements are collected 10 to 20 times a year at the Anticosti Gyre, Gaspé Current and Shédiac stations (Figure 1). As this monitoring program only began in 1996, we cannot compare the 2003 observations to a 1971-2000 climatology. Temperature and salinity anomalies with respect to the 1996-2003 reference period are presented in figure 9.

At the Anticosti Gyre station, near-surface (5 m) temperatures were slightly below normal in the spring but were above normal from August to October. At 50 m depth, the temperatures were about 1°C warmer than normal in winter but became about 0.5°C colder than normal in spring and summer 2003. At 100 m and 300 m depth, temperatures were generally warmer than normal in 2003. Meanwhile, salinities were higher than normal at all depths except for the months of September and October at 5 m depth. During the spring, surface stratification (0-25 m) was much weaker than normal.

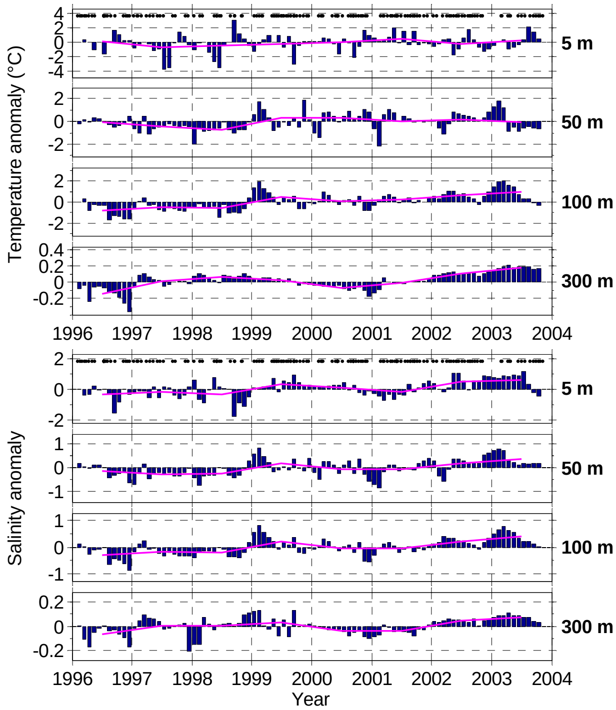

Figure 9. Deviations of temperature and salinity from the 1996-2003 average for various depths at the Anticosti Gyre station. Blue bars represent monthly anomalies while magenta lines show annual anomalies. Black dots at the top indicate the dates of data collection.

Cold intermediate layer

Vertical profiles of temperature and salinity collected from May to September were used to compile information on the CIL, roughly located between 30 and 100 m depth in the Gulf of St. Lawrence. The minimum temperature within this layer is subject to variations of about ± 1°C on decadal time scales (Figure 10).

During winter 2003, colder-than-normal air temperature conditions (Figure 3), a larger-than-normal volume of ice formation (Figure 5) and a major inflow of relatively cold and salty waters from the Strait of Belle Isle all contributed to a thicker, colder and saltier than normal surface mixed layer during the month of March. These temperature and salinity anomalies persisted into the summer and fall after spring heating created the CIL by warming the top 30 m or so of the water column (Figure 2).

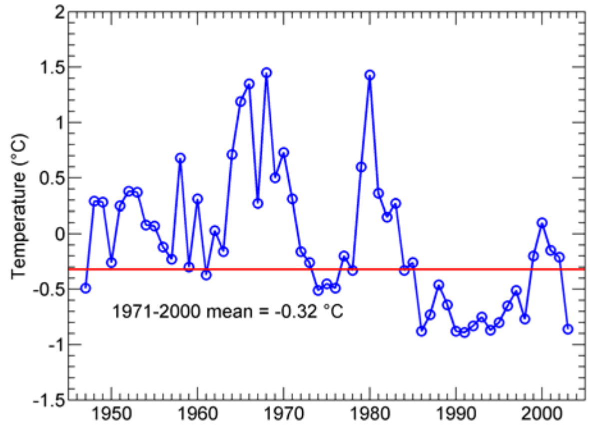

Figure 10. Mid-summer index of CIL minimum temperature in the areas of the Gulf of St. Lawrence deeper than 100 m.

In 2003, the CIL minimum temperature decreased by 0.65°C relative to 2002, and became 0.54°C colder than the 1971-2000 average, the 5th coldest in 57 years. Moreover, the thickness and volume of the CIL measured during the summer groundfish survey greatly increased compared to 2002, especially for T < 0°C and T < 1°C waters (Figure 11).

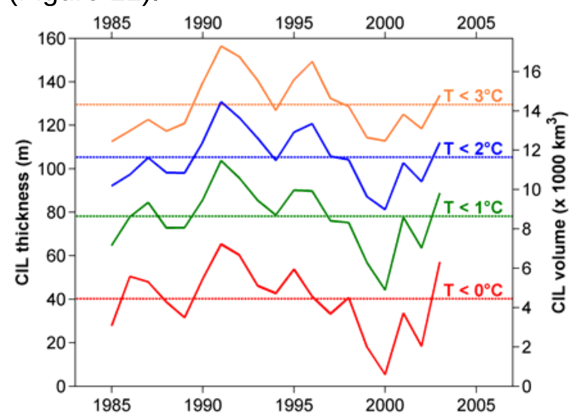

Figure 11. Thickness and volume of waters with temperature less than 0°C, 1°C, 2°C and 3°C during the 1985-2003 August-September shrimp and groundfish surveys in the Gulf of St. Lawrence.

Bottom temperatures

Given the vertical structure of temperature profiles in the Gulf of St. Lawrence during the summer (Figure 2), the near bottom temperature experienced by demersal fish and benthic animals will be a function of local bottom depth. We thus expect to find warm bottom temperatures (up to 20°C) in depths less than 30 m, cold temperatures (< 3°C) between 30 m and 150 m, and warmer temperatures again (3 to 6°C) deeper than 150 m, as shown on figure 12 for the 2003 groundfish survey.

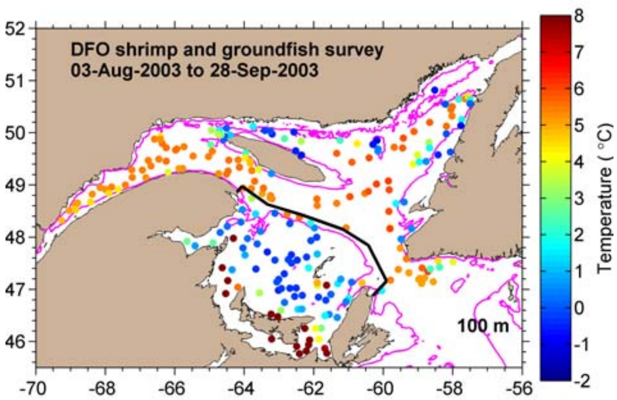

Figure 12. Bottom temperatures observed during the August-September 2003 shrimp and groundfish assessment survey. The black line shows the boundary between the southern and northern Gulf of St. Lawrence that was used to compute time series of bottom area with temperatures < 0°C and < 1°C.

In the southern Gulf, a large expanse of the sea bed lies within the depth range of the cold intermediate layer (Figures 2 and 12). In September 2003, the bottom area with temperatures < 1°C increased by 32% relative to 2002 while waters < 0°C went from being almost completely absent in 2002 (700 km^2) to occupying as much as 18000 km^2 of the seafloor in 2003 (Figure 13). The 2003 bottom area occupied by these cold waters is above the 1971-2000 average.

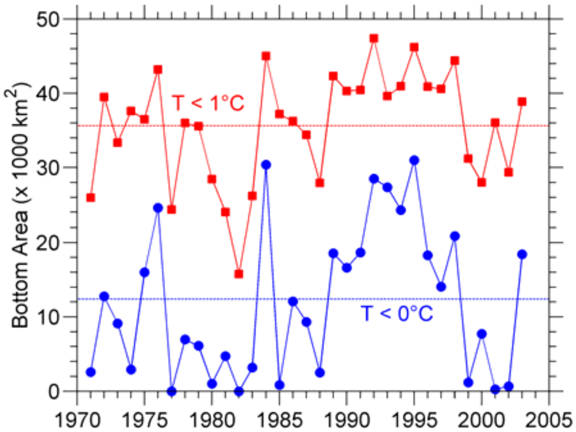

Figure 13. Bottom area with T < 0°C (blue) and T < 1°C (red) in September in the southern Gulf of St. Lawrence. The dashed lines represent the 1971-2000 averages.

In the northern Gulf, the CIL comes in contact with the bottom mainly along the sloping sides of the deep channels. In August 2003, the bottom area with temperatures < 0°C and < 1°C increased by 85% and by 36% respectively compared with August 2002 (Figure 14). The 2003 bottom areas occupied by these cold waters were well above the 1984-2003 average.

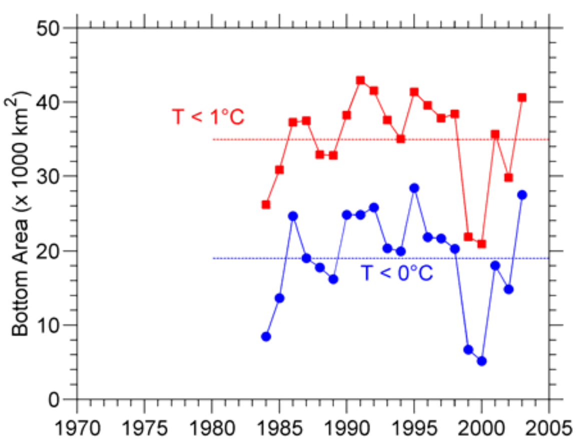

Figure 14. Bottom area with T < 0°C (blue) and T < 1°C (red) in August in the northern Gulf of St. Lawrence. The dashed lines represent the 1984-2003 averages.

Layer-averaged temperatures and salinities

Temperature and salinity measurements were analysed by dividing the water column (Figure 2) into four layers: 1) a warm upper layer (0 to 30 m deep), 2) a cold intermediate layer (30 to 100 m deep), 3) a transition layer (100 to 200 m deep), and 4) a warm and salty deep layer (200 to 300 m deep). Average temperatures within these four layers were calculated for the Gulf as a whole. We do not present results from the 0 to 30 m layer because we have not sufficiently well defined the very strong seasonal cycle for this layer yet.

The mid-July Gulf-wide average temperature of the 30-100 m layer in 2003 was the 4th coldest in 58 years, 0.5°C colder than in 2002 and 0.6°C colder than the 1971-2000 average (Figure 15). In the 100-200 m layer, temperature cooled by 0.9°C relative to 2002 and was the 17th coldest in 58 years, 0.6°C colder than the 1971-2000 average. Finally, the temperature of the 200-300 m layer in 2003 was the 19th warmest of the last 58 years, exactly matching the 1971-2000 average.

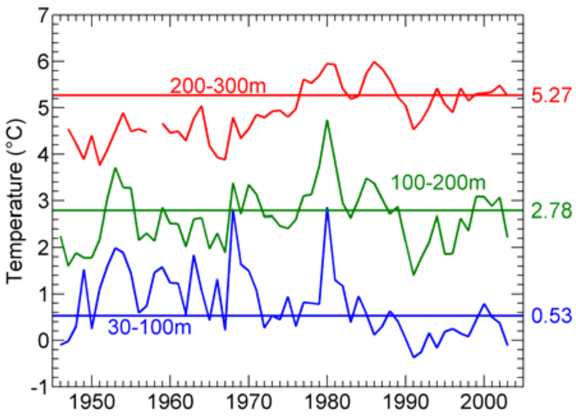

Figure 15. Layer-averaged temperatures in the Gulf of St. Lawrence. For the 30-100 m layer, the data were extrapolated to July 15. The horizontal lines show the 1971-2000 averages.

The Gulf-wide average salinity of the 30-100 m layer in 2003 was the 9th highest in 58 years, 0.05 higher than in 2002 and 0.11 higher than the 1971-2000 average (Figure 16). In the 100-200 m layer, salinity decreased by 0.12 relative to 2002 and was the 27th lowest in 58 years, 0.07 lower than the 1971-2000 average. Finally, the salinity of the 200-300 m layer in 2003 was the 21st highest of the last 58 years, very close to the 1971-2000 average.

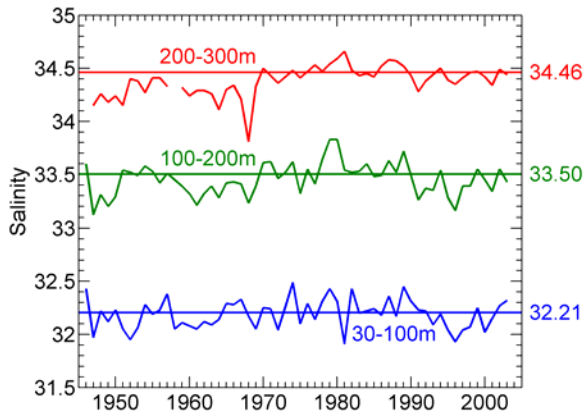

Figure 16. Layer-averaged salinities in the Gulf of St. Lawrence. The horizontal lines show the 1971-2000 averages.

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