Oceanographic sampling gear


*Fig. 1. Map showing the positions of standard oceanographic sections (black lines) and fixed stations (red squares) in the Gulf of St. Lawrence.*

# 2002 State of the Ocean: 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 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 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*


- Air temperatures from January to May 2002 were 0.5°C to 2°C warmer than normal at the Magdalen Islands. The 2002 annual mean air temperature was 0.5°C warmer than normal.
- The area of sea-ice was generally below normal during the 2002 winter. Total ice duration was the 2nd shortest and the ice-area-days index was the 9th lowest in the 39-year record.
- The freshwater runoff index from the St. Lawrence River at Québec City was below normal for all months but June during 2002. The largest negative runoff anomalies (15–20% below normal) occurred between March and May.
- The 2002 minimum temperature within the cold intermediate layer (CIL) was slightly cooler (by 0.1°C) than in 2001. However, the thickness of the CIL with T < 1°C and T < 0°C has decreased by 5 m and 10 m compared with 2001, respectively. This led to a reduction

of the bottom area bathed by CIL waters.

- In waters deeper than 100 m, the 2002 temperatures rose slightly relative to 2001, and are among the 11 warmest years of the 56-year record.

## 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 (Fig. 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 (Fig. 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.

Throughout this report, whenever the length of the data record allows, we compared the 2002 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. As this is the first report in which we have shifted our 30-year reference period from 1961-

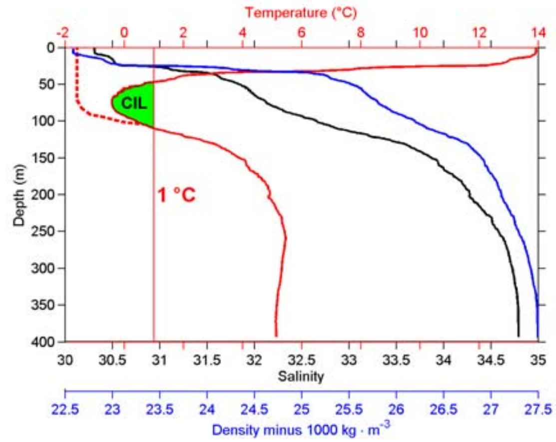


*Fig. 2. Typical profile of temperature (red), salinity (black) and density (blue) observed during the summer in the Gulf of St. Lawrence. The cold intermediate layer (CIL) is defined as the part of the water column which is colder than 1°C. The dashed red line shows a schematic winter profile with near-freezing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

1990 to 1971-2000, this report sometimes includes both reference periods. Future reports will only use the 1971-2000 reference period.

## Air temperature

There are several weather stations around the Gulf of St. Lawrence, but we only show here the monthly air temperature observations from the Magdalen Islands, a centrally located site within the Gulf that is sufficiently remote from the continent to give it a 'marine' character. In 2002, monthly mean air temperatures at the Magdalen Islands were 0.5°C to 2°C warmer than normal from January to May (Fig. 3). Air temperatures then dropped to 1°C below normal in June and returned to normal in July. In August and September, the temperature was about 1°C warmer than normal whereas

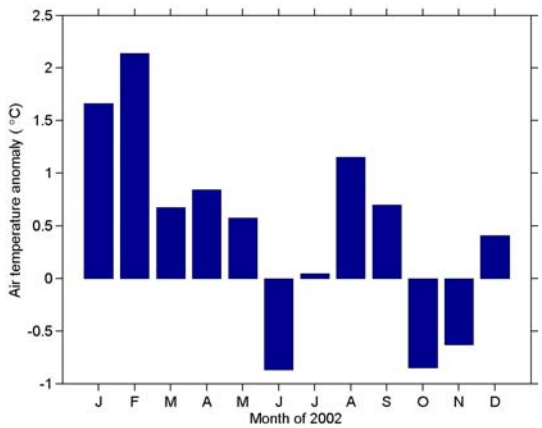


*Fig. 3. Monthly air temperature anomaly in 2002 at the Magdalen Islands.*

October and November were about 1°C colder than normal. December 2002 was 0.4°C warmer than normal.

The long-term trends in air temperature are shown on Fig. 4, where we also include the time series from the Mont-Joli station due to its very long, high-quality data record. The 2002 annual air temperature anomaly was 0.5°C at the Magdalen Islands and 0.4°C at Mont-Joli. This is 1.1°C colder than in 2001 at both locations. The 1999 annual temperature anomaly (2.2°C) represents the highest temperature ever observed in the 127-year long record at Mont-Joli.

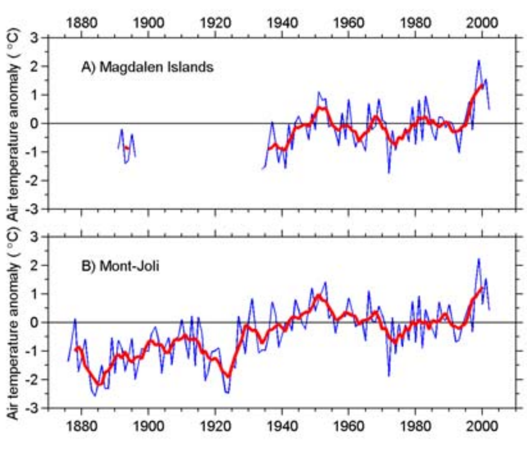


*Fig. 4. Annual air temperature anomalies (thin blue line) and 5-year running means (thick red line) at the Magdalen Islands and Mont-Joli.*

## *Sea ice*

During the 2002 winter, the first presence of ice in the Gulf of St. Lawrence occurred one to two weeks later than normal. The ice edge was generally behind its 1971-2000 median position throughout the ice season. As a result, the monthly mean ice area was much below normal in all months but February, when ice was barely 2% below normal (Fig. 5). The total duration of ice cover was about 35 days shorter than normal and was the 2nd shortest in the 39-year record. The ice-area-days index (Fig. 6) was the 9th lowest in the 39-year record, again indicating that 2002 was a light ice year in the Gulf of St. Lawrence.

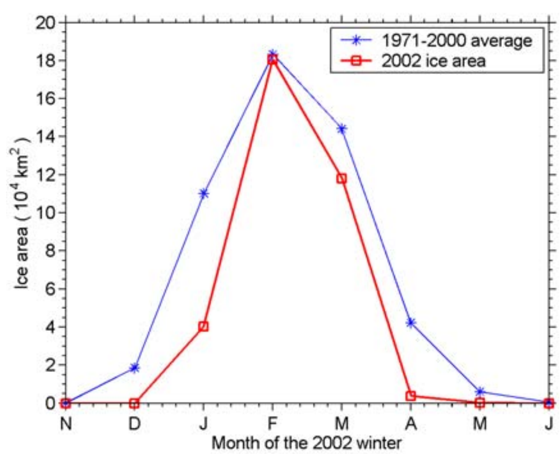


*Fig. 5. Monthly mean ice area in the Gulf of St. Lawrence in the winter of 2002 (red line with open squares) compared with the 1971-2000 average (blue line with asterisks).*

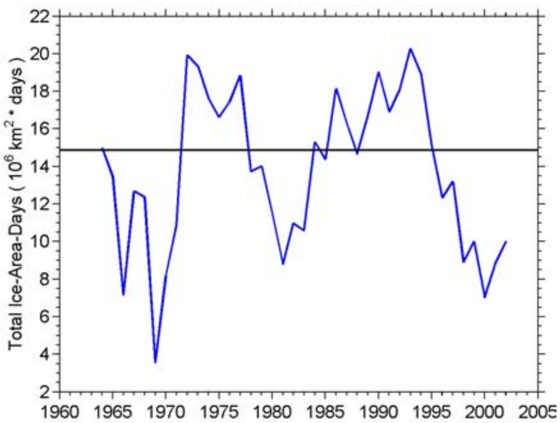


*Fig. 6. Ice-Area-Days index for the Gulf of St. Lawrence representing the annual sum of the ice area times the number of days with ice.*

## *Freshwater discharge*

Precipitation over most of the drainage basin of the St. Lawrence River and Gulf was below normal in 2002. This is reflected in the freshwater discharge index at Québec City (Fig. 7), which shows that freshwater runoff was below

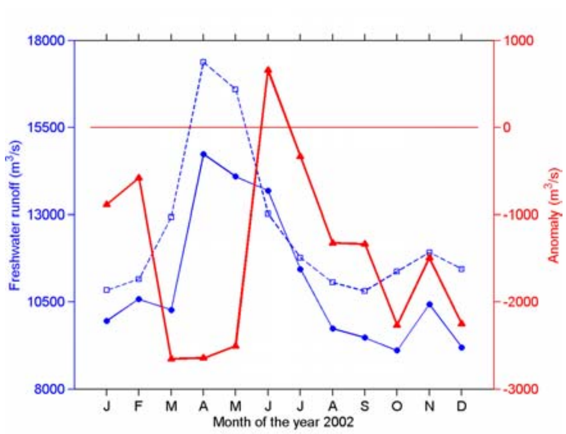


*Fig. 7. Monthly averaged freshwater discharge of the St. Lawrence River at Quebec City in 2002 (blue line with filled circles) compared with the 1971-2000 climatology (dashed blue line). The red line (right scale) shows the deviations of the 2002 runoff values from climatology.*

normal for all months but June. The largest negative runoff anomalies of about -2500 $m^3$ $s^{-1}$ (15–20% below normal) occurred between March and May.

Relative to the 1971-2000 reference period, the 2002 annual mean freshwater discharge at Québec City was about 1500 $m^3$/s (12 %) below normal (Fig. 8), the 13th lowest in the last 48 years.

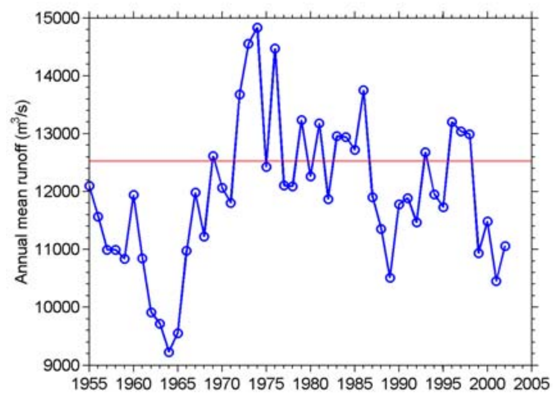


*Fig. 8. Yearly averaged freshwater discharge of the St. Lawrence River at Quebec City (blue) compared with the 1971-2000 climatological value (red).*

## *Gaspé Current fixed station*

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 (Fig. 1). As this monitoring program only began in 1996, we do not yet have sufficiently long time series to compare the 2002 observations with a 1971-2000 climatology and so cannot present anomalies.

In 2002, 18 vertical profiles collected at various times of the year give us information about the annual cycle of temperature and salinity at the Gaspé Current station (Fig. 9). At the surface, we see that temperatures were close to freezing from January to early April, and then warmed to a maximum of a little over 12°C in August before cooling again in the fall. Sea ice and snow melt in April resulted in a salinity minimum in May. Surface salinities remained low until the end of August and then steadily increased in the fall due to wind-induced vertical mixing.

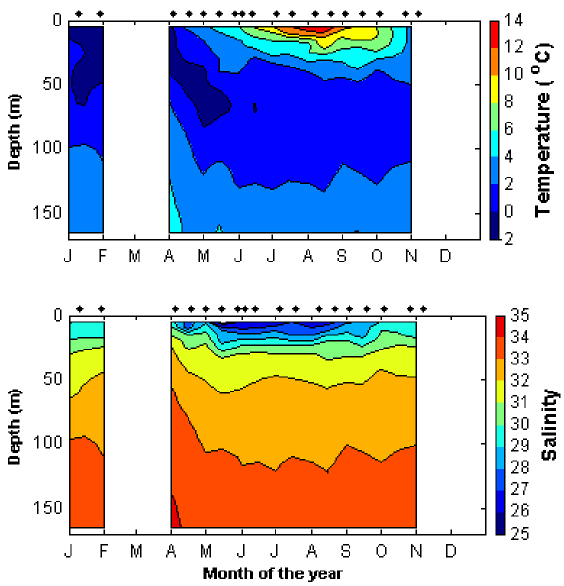


*Fig. 9. Temperature and salinity as a function of depth and time during 2002 at the Gaspé Current station.*

In the 30 to 100 m depth range, we see that the CIL was coldest at the end of winter and that it underwent a slight seasonal warming through the summer and fall. At depths greater than 100 m, temperature and salinity conditions remained fairly constant throughout the year.

## *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 plus or minus 1°C on decadal time scales (Fig. 10).

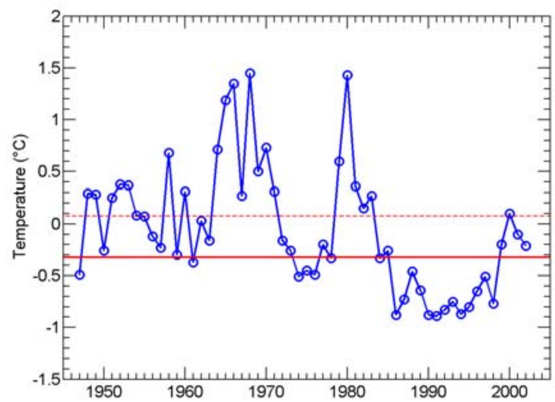


*Fig. 10. Index of CIL minimum temperature in the areas of the Gulf of St. Lawrence deeper than 100m. The thick red line shows the 1971-2000 average ( -0.32°C) whereas the dashed red line shows the 1961-1990 average (0.07°C).*

Relative to 2001, the CIL minimum temperature declined in 2002, but only by 0.1°C in areas of the Gulf deeper than 100 m (Fig. 10) as well as on the Magdalen Shallows (Fig. 11). However, the thickness of CIL waters with temperature below 0°C and 1°C decreased by approximately 10 m and 5 m, respectively, compared with 2001. This is somewhat unusual because a drop in CIL minimum temperature is normally accompanied by an increase in CIL thickness. Over the 56 years (1947-2002) for which the CIL minimum temperature index was calculated, 25 years were colder than 2002 whereas

30 years were warmer, so that the 2002 CIL minimum temperature was close to the long-term 1947-2002 median (Fig. 10). Over the Magdalen Shallows (Fig. 11), 33 years were colder than the 2002 CIL minimum temperature whereas 22 years were warmer.

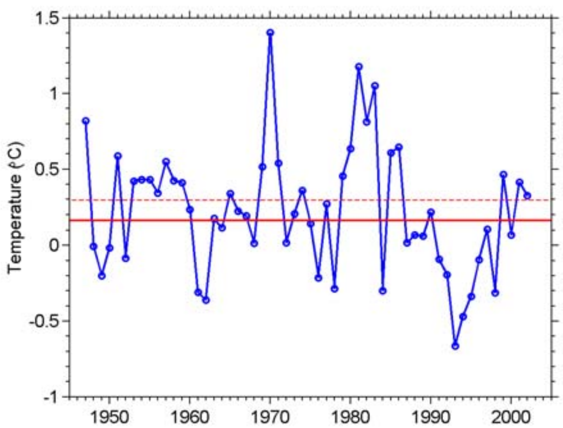


*Fig. 11. CIL minimum temperature index in the southern Gulf of St. Lawrence. The thick red line shows the 1971-2000 average (0.17°C) whereas the dashed red line represents the 1961-1990 average (0.29°C).*

## Bottom temperatures

Given the vertical structure of temperature profiles in the Gulf of St. Lawrence during the summer (Fig. 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 warm temperatures again (3 to 6°C) at depths greater than 150 m (Fig. 12).

In the southern Gulf, a large expanse of the sea bed lies within the depth range of the cold intermediate layer (Fig. 12). In September 2002, the bottom area

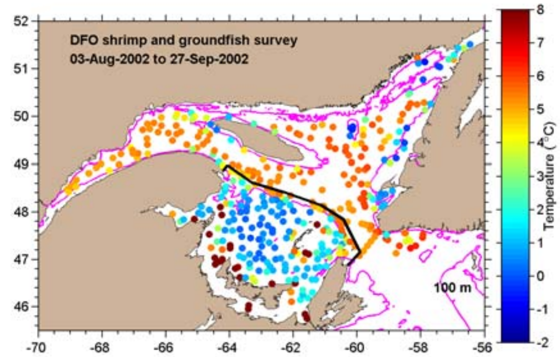


*Fig. 12. Bottom temperatures observed during the August-September 2002 shrimp and groundfish assessment survey. The black line shows the boundary between the southern and northern Gulf of St. Lawrence that was used to compute time series of bottom area with temperatures < 0°C and < 1°C.*

with temperatures < 1°C decreased by 18% relative to 2001 while waters < 0°C remained nearly completely absent from the Magdalen Shallows for the second year in a row (Fig. 13). The 2002 bottom areas occupied by these cold waters are below the 1971-2000 average.

In the northern Gulf, the CIL comes in contact with the bottom mainly along the sloping sides of the deep channels. In August 2002, the bottom area with temperatures < 1°C and < 0°C decreased by 16% and 18% respectively compared with 2001. The 2002 bottom areas occupied by these cold waters are now below the 1984-2002 average (Fig. 14).

## Layer-averaged temperatures

The temperature and salinity measurements from May to September were analysed by dividing the water column (Fig. 2) into four layers: 1) a warm upper layer (0 to 30 m deep), 2) a

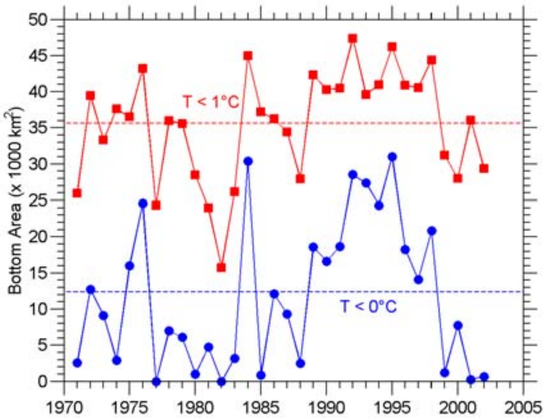


*Fig. 13. Bottom area with T < 0°C (blue) and T < 1°C (red) in September in the southern Gulf of St. Lawrence. The dashed lines represent the 1971-2000 averages.*

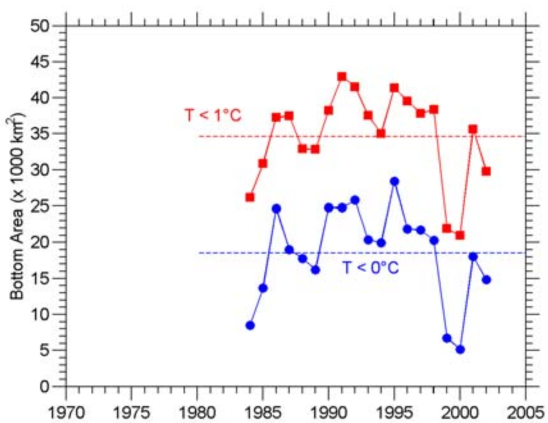


*Fig.14. Bottom area with T < 0°C (blue) and T < 1°C (red) in August in the northern Gulf of St. Lawrence. The dashed lines represent the 1984-2002 averages.*

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 here because we have not sufficiently well defined the very strong seasonal cycle for this layer yet.

As the seasonal cycle also affects the 30-100 m layer but not the two deeper layers, we need to adjust our measured temperatures in the 30-100 m layer to a common date which we take as July 15 of each year. The mid-July Gulf-wide average temperature of the 30-100 m layer in 2002 was 0.3°C warmer than in 2001 and 0.1°C warmer than the 1971-2000 average (Fig. 15). In the 100-200 m layer, temperature warmed by 0.4°C relative to 2001 and became 0.4°C warmer than the 1971-2000 average. Over the 56 years for which we have data, 2002 was the 11$^{th}$ warmest for the 100-200 m layer. Finally, the 2002 temperature in the 200-300 m layer is the 9$^{th}$ warmest of the last 56 years, 0.3°C above the 1971-2000 average.

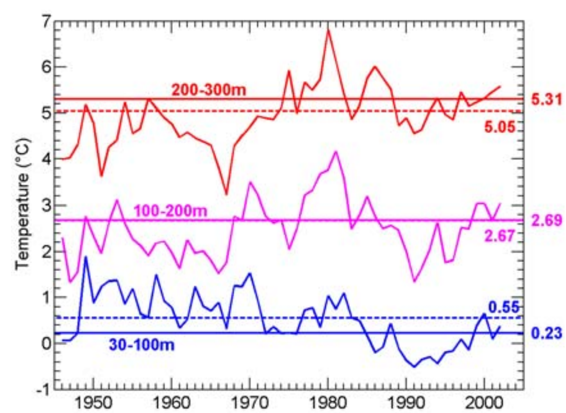


*Fig.15. Layer-averaged temperatures in the Gulf of St. Lawrence. For the 30-100 m layer, the data were extrapolated to July 15. The dashed horizontal lines show the 1961-1990 averages whereas the continuous horizontal lines show the 1971-2000 averages.*

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