Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences
Quebec Region
Canadian Science Advisory Secretariat
Science Advisory Report 2009/019

STATE OF THE OCEAN 2008: PHYSICAL OCEANOGRAPHIC CONDITIONS IN THE GULF OF ST. LAWRENCE

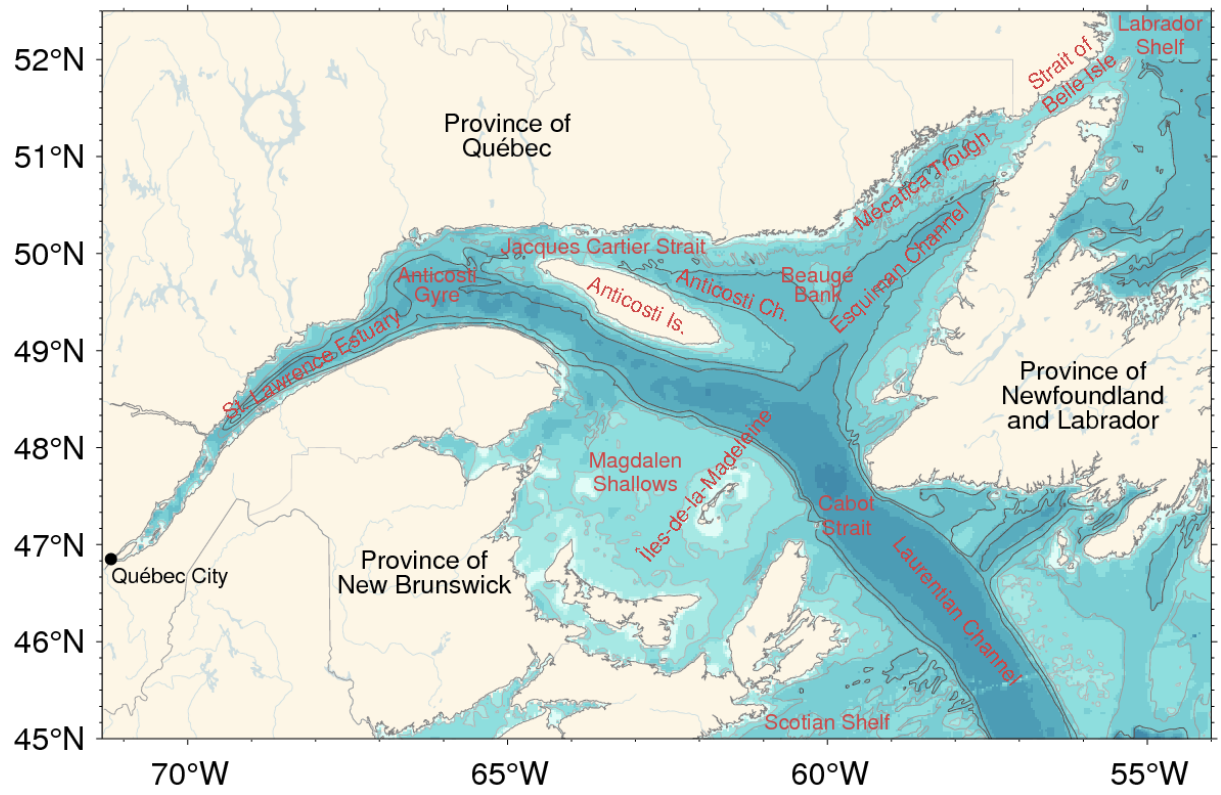


Figure 1: Gulf of St. Lawrence

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.*

Hydrographic data are edited and archived in the Oceanographic Data Management System on the St. Lawrence Observatory (www.osl.gc.ca) and at the Integrated Science Data Management (ISDM) database.

SUMMARY

- Air temperatures were close to normal when averaged from January to March, contributing to an ice cover volume that was also close to the climatological mean. Air temperatures were in general either normal or above normal for the remainder of the year.
- The monthly averaged runoff measured at Québec City was normal overall in 2008 but consisted of above-average runoff in summer compensated later by lower runoff in the fall. The high summer runoff contributed to higher-than-normal stratification
- Near-surface water temperatures were generally above normal throughout the Gulf for the months of May, July and November and were also above-normal on the Magdalen Shallows in June and in the northern Gulf from August to October. In August the northern parts of the Gulf saw positive anomalies while the southern parts experienced negative anomalies. This lead to the unusual occurrence that the waters around Prince Edward Island and in Northumberland Strait had higher temperature in July than in August 2008.
- On the Magdalen Shallows, a large bottom area was covered by water with temperatures < 0°C in 2008, similar to the cold period observed in the 1990s and contrary to conditions present in September 2005, 2006 and 2007 when no such waters were observed.
- Maximum sea-ice volume within the Gulf and on the Scotian Shelf was 81 km³, which is near normal.
- Winter inflow of cold and saline water from the Labrador Shelf occupied the Mécatina Trough from top to bottom in winter 2008 (up to 235 m in depth). Its volume of 1850 km³ was similar to the 2001 and 2006 observations.
- The winter cold mixed layer volume was 13 700 km³, a value higher than the 1996–2008 average by 0.8 SD. This cold-water volume corresponded to 41% of the total water volume of the Gulf.
- The CIL index for summer 2008 was -0.70°C, which is comparable to the very cold conditions observed in 2003. This was a large decrease in the index of 0.47°C since the summer of 2007. This is likely attributable to the very cold air temperatures in March 2008, late ice melt and delayed spring warming. Higher than normal summer stratification may also have played a role.
- Regional patterns of the August and September CIL show that the layers for T < 1°C and < 0°C were much thicker in most parts of the Gulf in 2008 than in 2007 and had a generally lower core temperature everywhere..
- In the northern Gulf, the area covered by low temperature water (bins from < -1°C through 0°C to 1°C) increased in 2008 relative to 2007 conditions.
- Seasonal and regional patterns observed in water column temperatures are summarized as follows: Temperatures in June 2007 were characterized by a very thick and cold CIL in most regions except the Estuary and by warm deep waters in the Estuary and the northwest Gulf. This overall pattern persisted in the August–September mean conditions. By October–November, CIL conditions were still thick and cold, and waters above the CIL were anomalously warm.
- Overall, temperature and salinity were generally normal from 150 m to 300 m, with the exception that temperature was slightly lower (by 0.6 SD) at 150 m due to the thick CIL. Temperature and salinity in this depth range decreased for a second consecutive year, from 2007 to 2008. The near-normal Gulf-wide water temperatures at 300 m were composed of warmer waters in the Estuary, near-normal temperatures in the northwest and centre, and colder waters coming into the Gulf at Cabot Strait.

BACKGROUND

Temperature and salinity conditions in the Gulf of St. Lawrence (Figure 1) are influenced by heat transfer between the ocean and atmosphere, exchanges through Cabot Strait and the Strait of Belle Isle, freshwater runoff, precipitation, production and melting of sea-ice, vertical mixing and advection by currents. The deep layer is a mixture of Labrador and Slope Water that enters the Laurentian Channel from the continental shelf and slope and is advected up the Channel as a consequence of estuarine circulation. The 0-150 m layer undergoes seasonal variations from exchanges with the atmosphere. The winter near-freezing mixed layer reaches an average of 75 m, but can extend to more than 200 m in the less stratified Mécatina Trough. The upper layer is stratified in spring by the melt of sea-ice and freshwater runoff, but a Cold Intermediate Layer (CIL) persists through summer and is gradually eroded until the following winter.

Where possible, observations are expressed as differences or anomalies from their long-term averages. The standardized reference period used for climate normals is 1971-2000. Tables are used to illustrate how far anomalies deviate from climatological normals using colour codes (Figure 2). Anomalies smaller than half the standard deviation are considered to be normal conditions and are displayed in white. Conditions corresponding to warmer than normal (higher temperatures, reduced ice volumes, reduced cold water volumes or areas) by more than 0.5 standard deviation (SD) as red cells, with more intense reds corresponding to increasingly warmer conditions. Similarly, blue represents colder than normal conditions. Higher than normal freshwater inflow and stratification are shown as red, but do not necessarily indicate warmer than normal conditions.

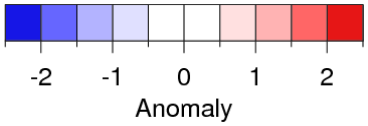


Figure 2. Scorecard anomaly colour palette. Time series are normalized by first subtracting the climatological mean to obtain an anomaly, and then dividing these anomalies by the standard deviation (SD) of the time series. This results in normalized anomalies. Data that fall within ± 0.5 SD are colour-coded in white, and progressively more anomalous data are colour-coded in darker shades of blue (for cold) or red (for warm).

ASSESSMENT OF CONDITIONS IN 2008

The monthly air temperatures and their anomalies for several stations around the Gulf are shown in Figure 3 as well as the average of the nine stations. While air temperatures were generally normal (i.e., within ±0.5 SD) or higher than normal for the greater part of 2008, the southern and eastern parts of the Gulf experienced higher anomalies than the northwest. March was exceptionally cold (by 2.5^{o}C on average) at nearly all stations, however the average air temperature from January to March was normal. If an annual cycle resembles an oscillation, the winter portion appeared broadened (extending both earlier and later in time, with cold months of December 2007 and March 2008) and clipped (the minimum much less pronounced than normal in January and February). Air temperatures were in general either normal or above normal for the remainder of the year except at Blanc-Sablon in December.

The monthly averaged runoff measured at Québec City was close to normal overall in 2008 (see Galbraith et al, 2009), but consisted of above-normal runoff in summer, especially in August,

compensated later by lower-than-normal runoff in the fall. Note that a strong toxic algae bloom occurred in the St. Lawrence Estuary in August, an event associated with low surface salinity and high run-off.

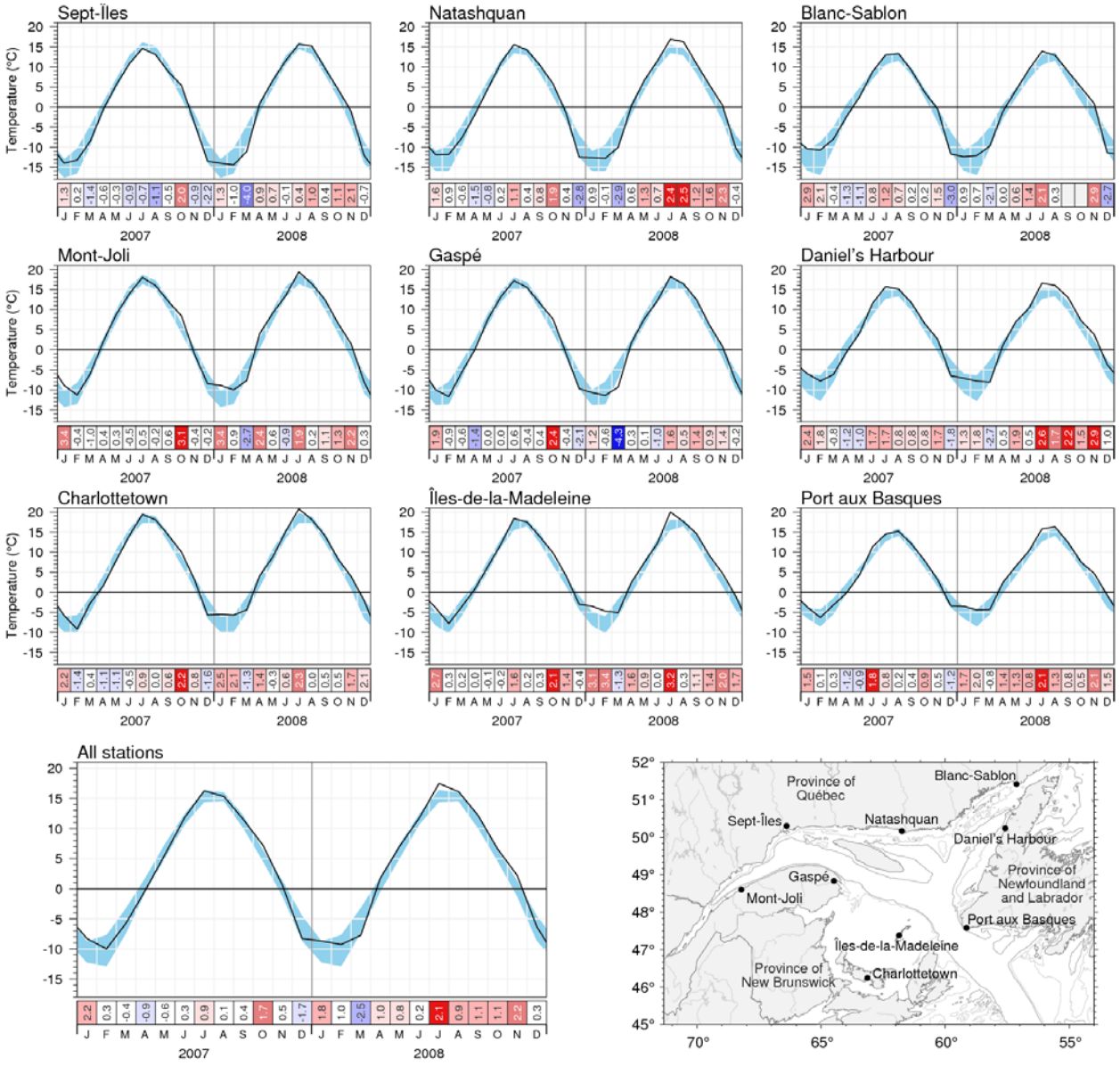


Figure 3. Monthly air temperatures and anomalies for 2007 and 2008 at nine selected stations around the Gulf as well as the average for all nine stations. The blue area represents the 1971–2000 climatological monthly mean plus and minus one standard deviation. The bottom scorecards are colour-coded according to the monthly standardized anomalies based on the 1971-2000 climatologies for each month, but the numbers are the monthly anomalies in ºC.

The surface layer conditions of the Gulf are monitored by various complementary methods: the thermograph network, the shipboard thermosalinographs, research and assessment surveys and NOAA satellite remote sensing. All data from these monitoring programs gave fairly consistent results in terms of anomalies, in spite of using different reference periods. The NOAA satellite remote sensing results are presented here; details from the other data sources can be found in Galbraith et al (2009). The 2008 quasi-monthly mean sea-surface temperatures,

consisting of four 7-day composites per month covering the first 28 days of each month, are shown on Figure 4 as colour-coded maps. The temperature anomaly maps, derived from the 1985-2008 monthly climatologies, are shown in Figure 5 for ice-free months. The NOAA SST information, summarized in Table 1, shows the 2007 and 2008 monthly surface temperature anomalies spatially averaged over the eight regions of the Gulf delimited in Figure 6.

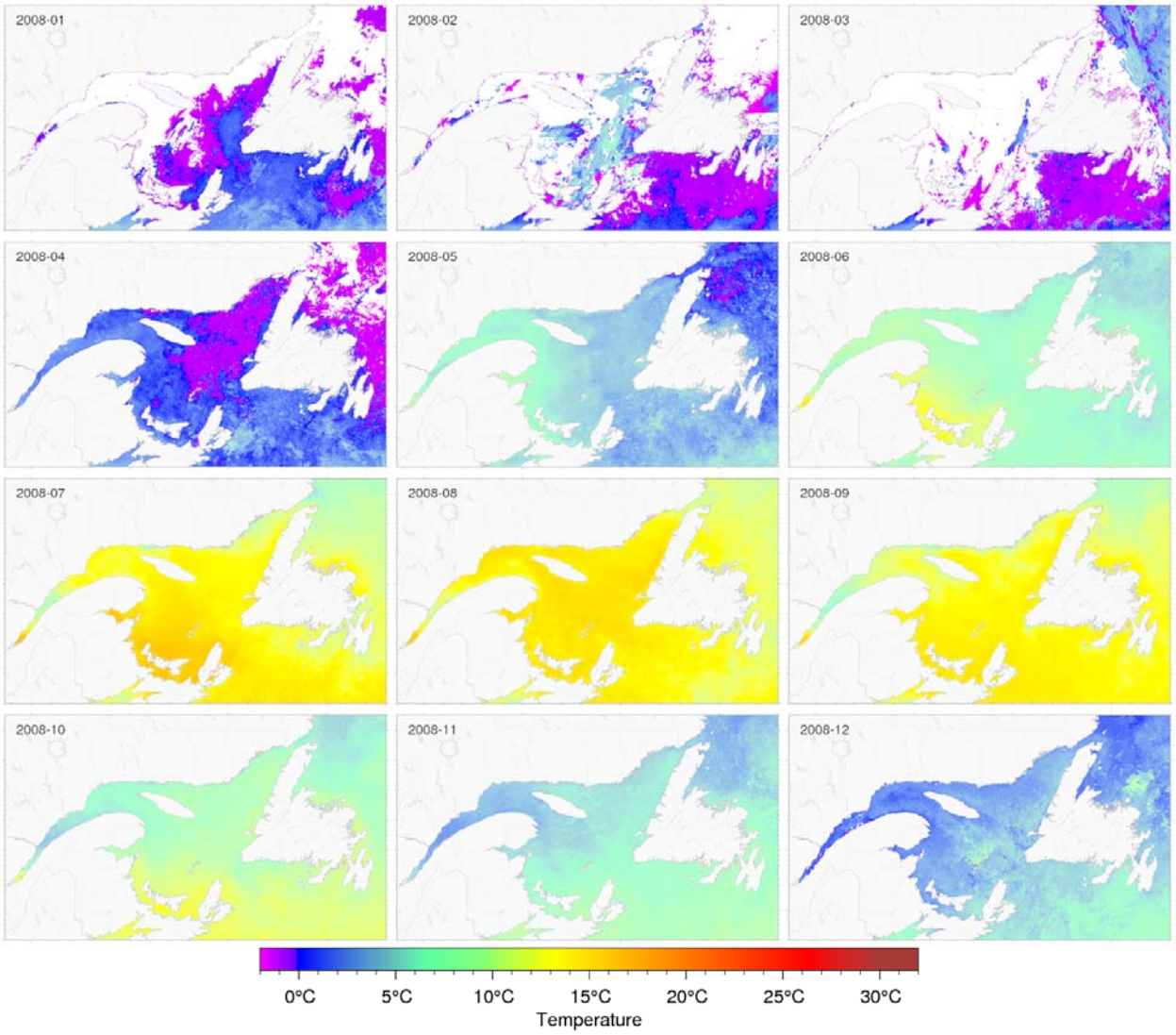


Figure 4. Sea-surface temperature averages for the first 28 days of each month of 2008 as observed with NOAA AVHRR remote sensing. White areas have no data for the period due to ice cover.

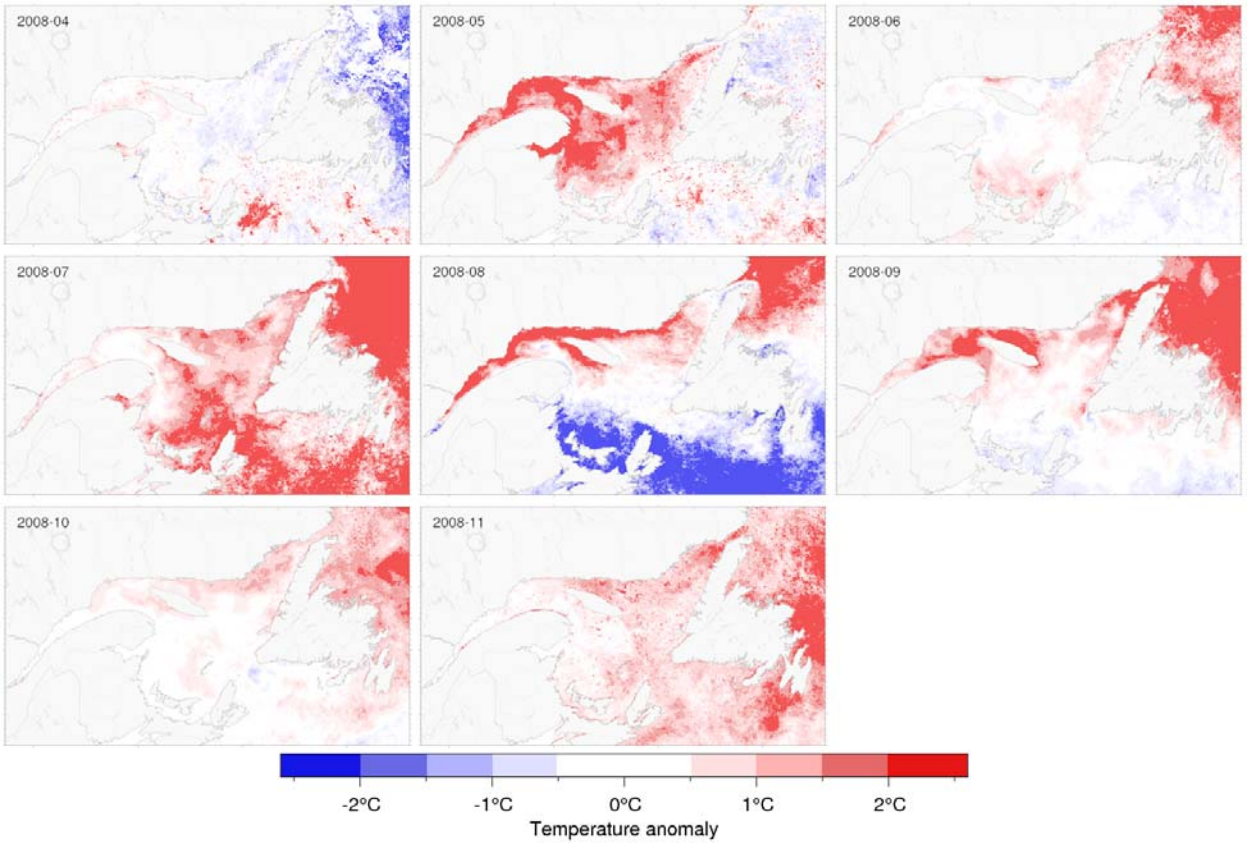


Figure 5. Sea-surface temperature anomalies for the first 28 days of April through November 2008 based on monthly climatologies calculated for the 1985–2008 period observed with NOAA AVHRR remote sensing. Only ice-free months are shown.

Table 1. NOAA SST May to November monthly anomalies averaged over the eight regions of the Gulf for 2007 and 2008 (April also shown for the Estuary and Northwest Gulf). The scorecards are colour-coded according to the monthly standardized anomalies based on the 1985-2008 climatologies for each month, but the numbers are the monthly average temperatures in ºC.

	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
1 - Estuary	1.1	4.8	9.4	10.6	9.7	6.8	5.9	2.1					1.6	6.5	8.9	11.2	12.6	8.7	4.6	2.4
2 - Northwest Gulf	0.6	3.6	9.2	13.3	12.7	8.8	6.5	3.3					0.9	6.1	9.0	13.3	14.9	11.9	6.7	3.7
3 - Anticosti Channel		1.7	6.8	12.8	13.7	10.2	7.4	3.8						4.0	7.2	13.2	15.0	12.5	8.2	5.2
4 - Mécatina Trough		1.1	6.0	10.3	12.1	10.0	5.6	3.2						2.8	6.1	11.0	13.2	11.6	7.9	4.5
5 - Esquiman Channel		2.3	7.9	12.9	14.5	11.8	8.0	4.6						3.4	7.4	13.1	15.2	13.1	8.8	5.4
6 - Central Gulf		2.4	7.8	13.8	15.2	11.7	8.5	4.7						4.2	7.7	14.6	16.0	13.4	8.9	5.2
7 - Cabot Strait		2.7	8.6	13.4	15.4	12.9	9.1	6.0						3.3	8.0	14.7	15.0	13.9	9.8	7.1
8 - Magdalen Shallows		4.3	10.6	16.1	16.8	14.3	10.9	6.3						5.5	10.7	17.2	15.5	14.5	10.5	6.5
						2007										2008				

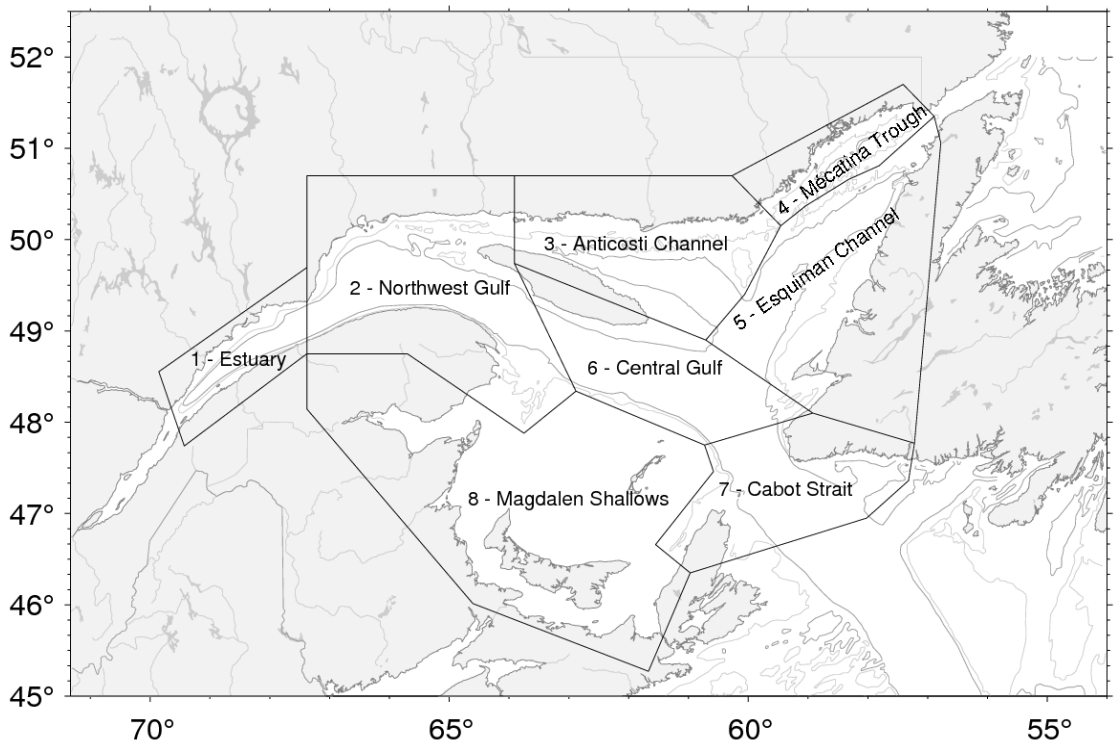


Figure 6. Gulf of St. Lawrence divided into eight oceanographic regions. The intersection of regions 3, 4 and 5 was altered since the previous annual report.

Near-surface water temperatures in the Gulf were above normal everywhere in May, July and November and were also above-normal on the Magdalen Shallows in June and in the northern Gulf from August to October. It is unusual for the waters around PEI and in Northumberland Strait to have higher temperatures in July, as seen in 2008, than in August. However, in August 2008, Southern Gulf near-surface water temperatures were significantly below normal with a strong negative anomaly extending onto the Scotian Shelf.

Sea ice is typically produced in the northern parts of the Gulf and drifts towards the Îles-de-la-Madeleine and Cabot Strait during the ice season. The combined Gulf and Scotian Shelf ice volume shown in the top panel of Figure 7 is indicative of the total volume of ice produced in the Gulf, including the advection out of the Gulf, but it also includes the thicker sea ice that drifts into the Gulf from the Strait of Belle Isle. The volume shown on the bottom panel of Figure 7 corresponds to that found seaward of Cabot Strait and represents the volume of ice exported from the Gulf (although not the total export since it melts on the Shelf before the end of the ice season).

In 2008, the Gulf and Shelf maximum ice volume was 81 km^3, near the 1971-2000 climatological mean, with the years 1993 and 2003 showing the highest ice volumes of the time series. The 2007-08 ice season was anomalously long. The first occurrence of ice was typically 15 to 20 days earlier than normal and the last occurrence of ice was also later than normal in almost every region, e.g. by 8 days on the Magdalen Shallows (Galbraith et al, 2009). More information concerning the sea-ice areal coverage in the Gulf of St. Lawrence can be found in an annually published research document on meteorological and sea-ice conditions (e.g., Petrie et al. 2008).

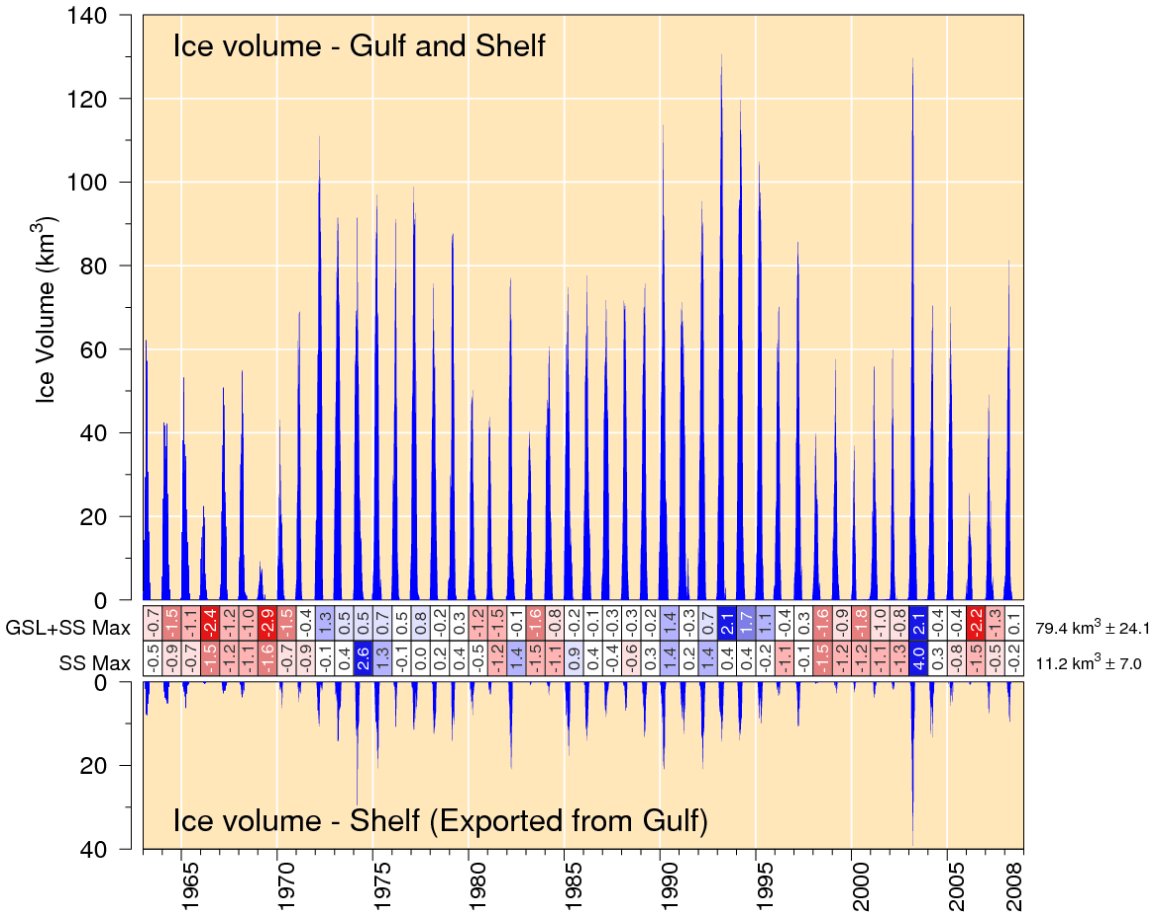


Figure 7. Estimated ice volume in the Gulf of St. Lawrence and on the Scotian Shelf seaward of Cabot Strait (upper panel) and on the Scotian Shelf only (lower panel). Scorecards show numbered standardized anomalies for the combined Gulf and Shelf volume and the Shelf-only volume. The mean and standard deviation are indicated on the right side using the 1971-2000 climatology.

A wintertime survey of the Gulf of St. Lawrence waters (0–200 m) has been undertaken in early March since 1996 using a Canadian Coast Guard helicopter. Figure 8 shows gridded interpolations of near-surface temperature, thickness of Labrador Shelf intrusion and cold layer thickness. The surface mixed layer is usually very close to the freezing point in many regions of the Gulf in March, and this was the case in 2008 except for an area extending from the northeast side of Cabot Strait northward to Esquiman Channel. Indeed, relatively warm water (~ 0°C to -1°C) entered the Gulf on the northeast side of Cabot Strait, similar to previous years, and flowed northward along the west coast of Newfoundland. However, the inflow was warmer than in 2007 and its volume and area were much larger.

Near-freezing waters with salinity >32.35 (colour-coded in violet) are considered to be too saline to have been formed from waters originating within the Gulf and are presumed to have been advected from the Labrador Shelf through the Strait of Belle Isle. These waters occupied the surface over the Mécatina Trough and a large area northeast of Anticosti Island. An estimate of the thickness of this intrusive layer for 2007 and 2008 is shown in the middle panels of Figure 8. It occupied the Mécatina Trough from top to bottom again in winter 2008 (up to 235 m depth); however, its spread was confined slightly closer to the coast compared to 2007, leading to an overall smaller volume of 1850 km³ and representing 13% of all cold waters (< -1 °C) found in the Gulf. The volume of the intrusion was similar to the 2001 and 2006 values.

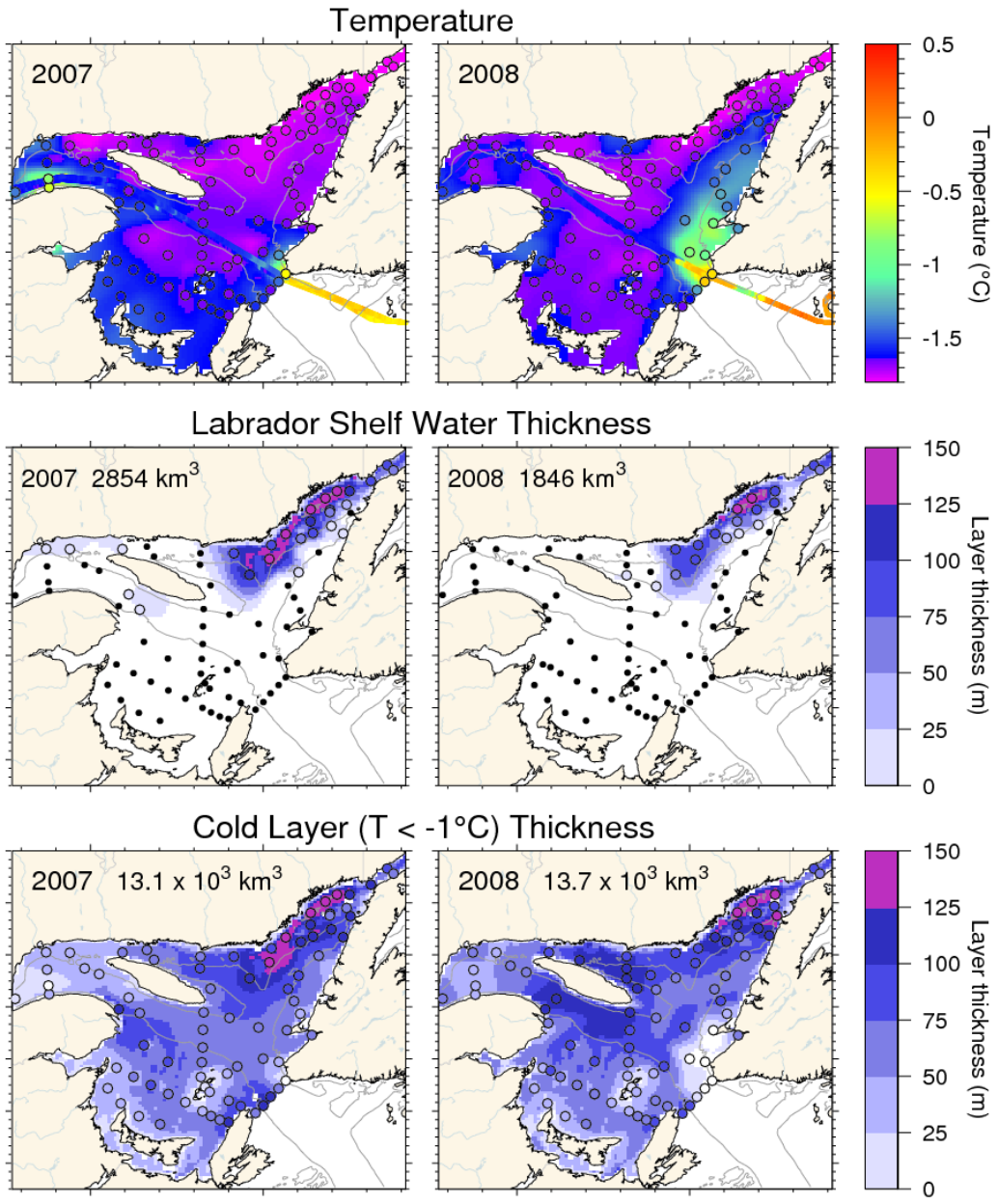


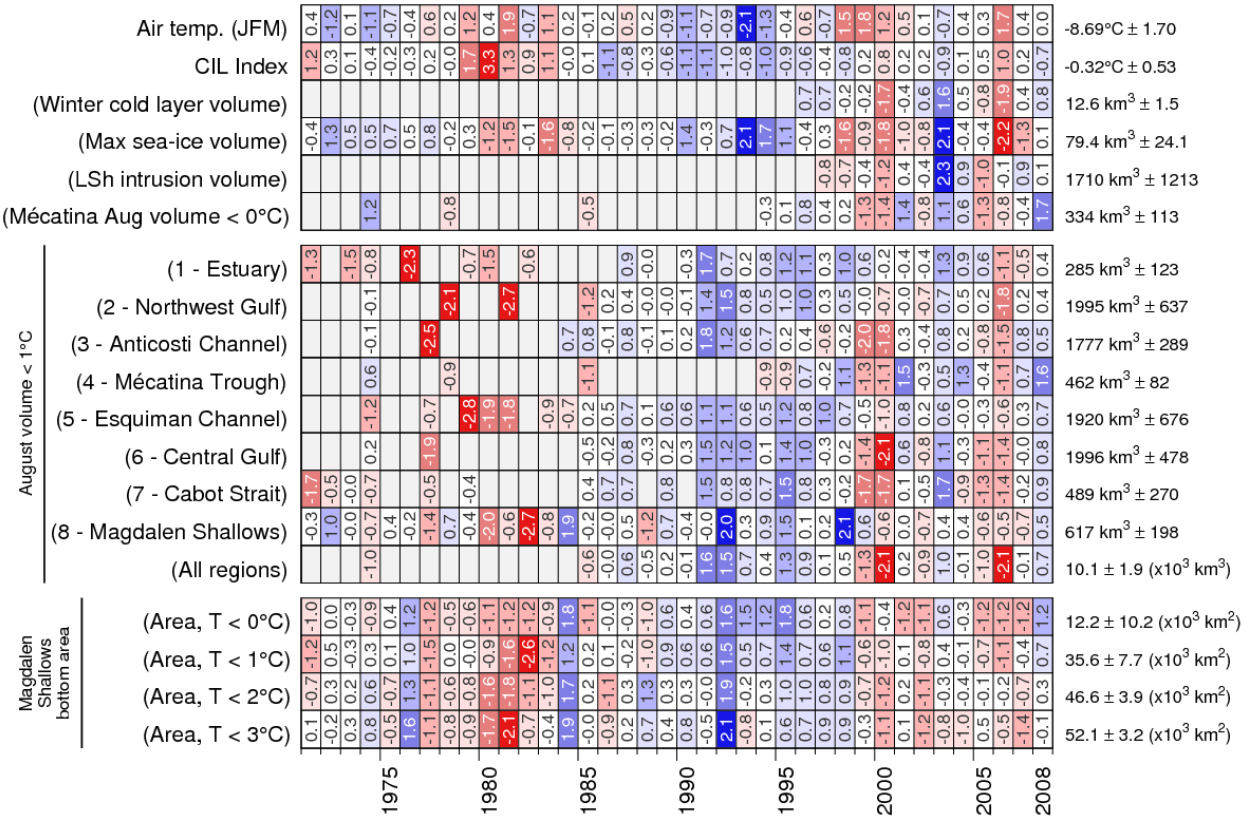
Figure 8. Surface water temperature (top), estimate of the thickness of the Labrador Shelf water intrusion (middle) and cold layer (T < -1°C) thickness (bottom) for the March 2007 and 2008 helicopter surveys. The symbols are coloured according to the value observed at the station, using the same colour palette as the interpolated image. A good match is seen between the interpolation and the station observations where the station colours blend into the background. The temperature measurements from shipboard thermosalinographs taken during the survey are also shown in the top panels.

The cold (< -1°C) mixed layer depth typically reaches an average of about 75 m in the Gulf, but in 2008 this layer was thicker than usual (see bottom right panel of Figure 8). Integrating the mixed layer depth over the area of the Gulf yields a cold-water volume of 13 700 km³, a value higher than the 1996–2008 average by 0.8 SD. This cold-water volume corresponded to 41% of the total water volume of the Gulf (34 000 km³). The time series of winter cold layer volume is shown in Table 2.

The CIL index is defined as the mean of CIL minimum, or core, temperatures observed between May 1 and September 30 of each year, adjusted to July 15. This index is highly correlated with the total volume of cold water (< -1°C) measured the previous March. This is expected because the CIL is the remnant of the winter cold surface layer. A measurement of the volume of cold water present in March is therefore a valuable tool for forecasting the coming summer CIL conditions. The above-normal volume of cold water (13 700 km³) observed in March 2008 led to a CIL minimum temperature index forecast of -0.47°C issued in last year's report (DFO, 2008).

The CIL index was updated using all available temperature profiles measured within the Gulf between the months of May and September inclusively since 1947 (bottom panel of Figure 9). The CIL index for summer 2008 was -0.70°C, a decrease from the 2007 CIL index of -0.23°C and similar to the cold values observed in 2003 and most of the 1990s. The index is colder than the prediction of -0.47°C based on the March 2008 observations. The difference is likely caused by the very cold air temperatures that prevailed in March after the winter survey that delayed ice melt and spring warming in the Gulf, combined with increased summertime stratification that limited the erosion of the CIL by mixing.

Table 2. CIL and related properties. The top block shows the scorecard time series for winter (January to March) air temperature averaged over eight stations, the CIL index, March cold layer (< -1°C) volume, yearly maximum sea-ice volume, volume of Labrador Shelf Water intrusion in the Gulf observed in March, and the August–September volume of cold water (< 0°C) observed in the Mécatina Trough. Titles in parentheses have their colour coding reversed (blue for high values). The middle block shows scorecard time series for August–September CIL volumes (<1°C) for all eight regions and for the entire Gulf when available. The bottom block shows the scorecard time series for the bottom areas of the Magdalen Shallows covered by waters colder than 0, 1, 2 and 3°C.



Maps of the CIL thickness < 1°C and < 0°C and of the CIL minimum temperature were interpolated using temperature profiles from all sources for the months of August and September 2007 and 2008 (Figure 10). The majority of the data come from the multi-species surveys in September for the Magdalen Shallows and August for the rest of the Gulf. Similar maps were produced for all years back to 1971 (although some years have no data in some regions), allowing the calculation of volumes for each year, for each region of the Gulf as delimited in Figure 6. The time series of the regional CIL volumes (< 1°C) are shown in Table 2. These time series were recalculated since last year's report because of a small change in the position of the intersection between regions 3, 4 and 5. All regions except Anticosti Channel show an increased CIL (< 1°C) volume in 2008 compared to 2007, although this increase was very slight in the northwest Gulf. The CIL volumes < 1°C and < 0°C over the entire Gulf are displayed in the top panel of Figure 9. Both show a sharp increase since 2007. The 2008 average temperature minimum over the entire interpolated grid was -0.54°C (Blue line, bottom panel of Figure 9). This is a decrease of 0.4°C since 2007. The overall 2008 CIL water mass properties were similar to those observed in 1998 an 2003.

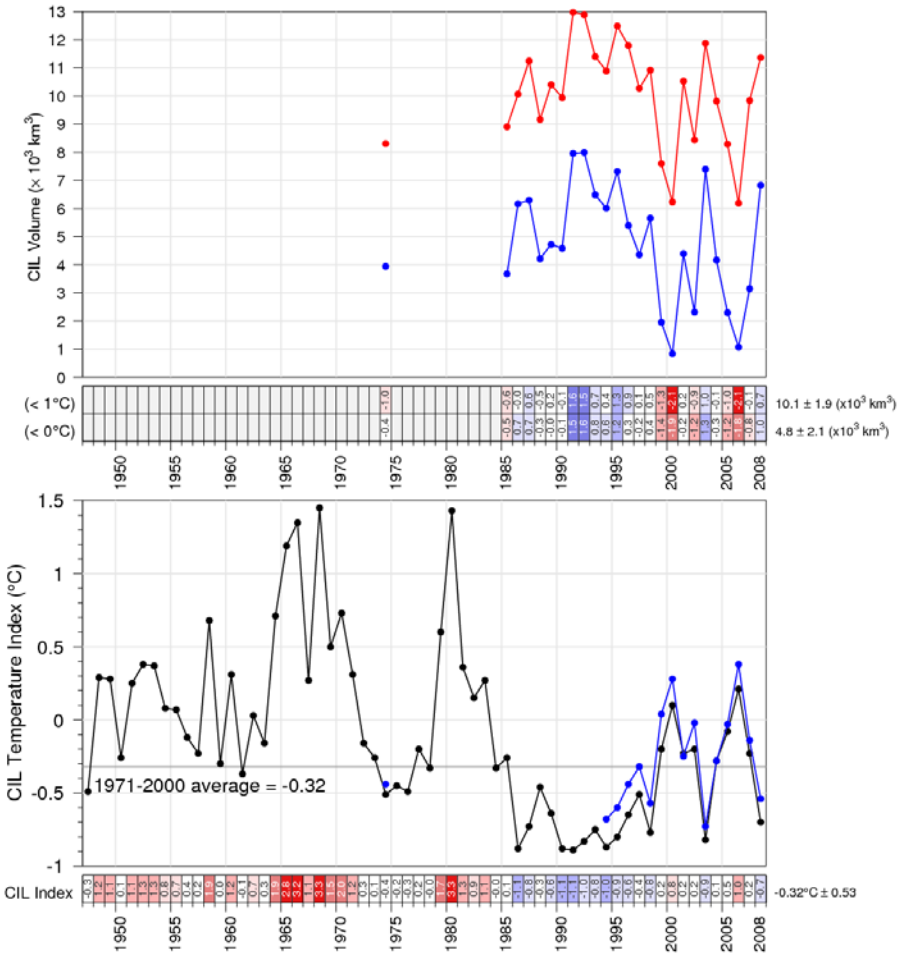


Figure 9. CIL volume (top panel) in August-September, delimited by the over- and underlying 0ºC (in blue) and 1ºC (in red) isotherms, and CIL minimum temperature index (bottom panel) in the Gulf of St. Lawrence. The volumes are integrals of each of the annual interpolated thickness grids such as the top panels of Figure 10. In the lower panel, the black line is the updated Gilbert & Pettigrew (1997) CIL index interpolated to July 15 and the blue line is the spatial average of each of the annual interpolated grid such as the two bottom panels of Figure 10.

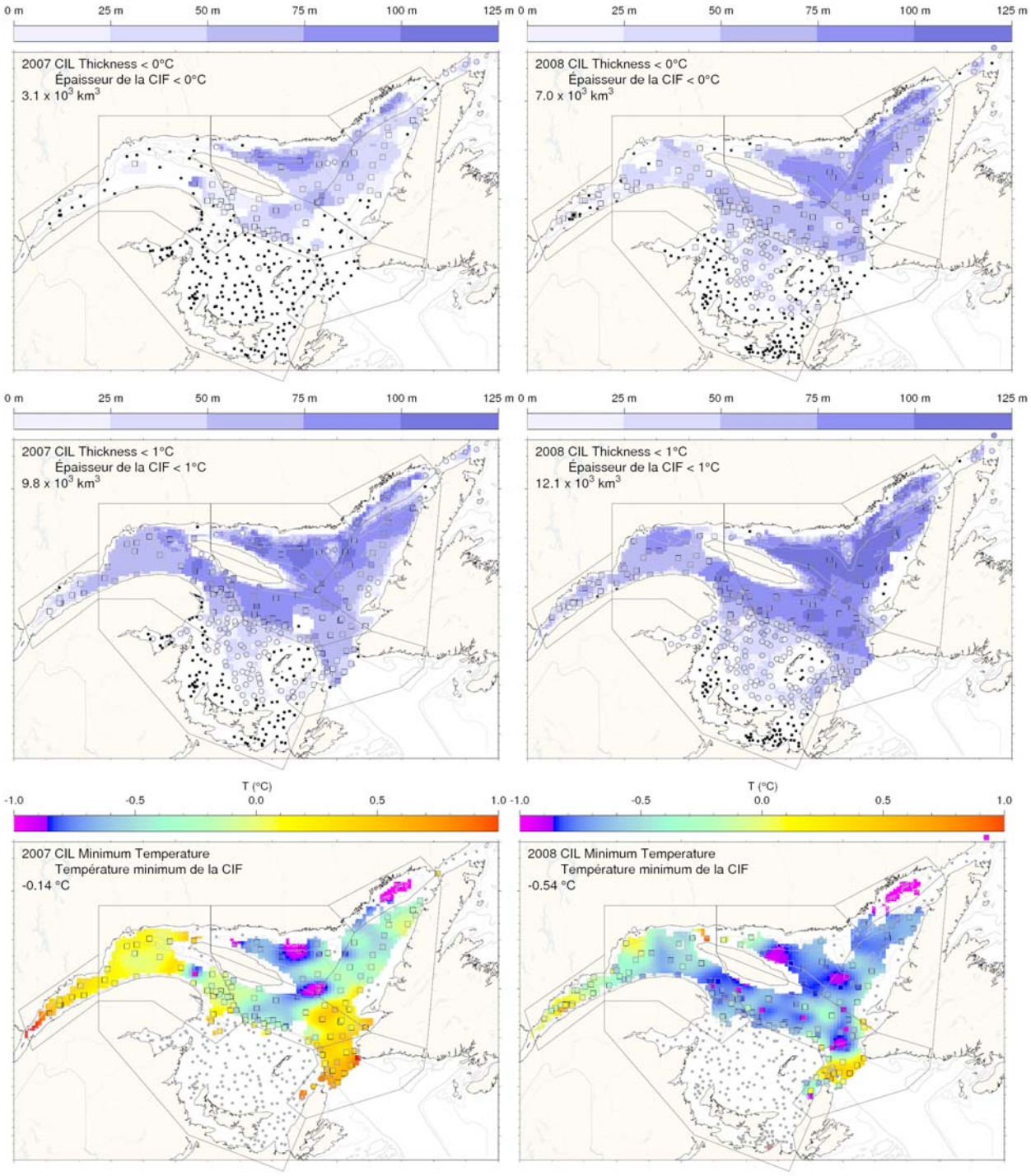


Figure 10. Cold Intermediate Layer thickness (T < 0ºC, top panels; T < 1ºC, middle panels) and minimum temperature (bottom panels) in August and September 2007 (left) and 2008 (right).

Water temperatures on the bottom of the Magdalen Shallows are affected by the extent of the CIL. Bottom temperatures based on data obtained in September of each year from the multi-species survey (1971-present) typically range from <1°C to >18°C and are mostly depth-dependant. The deeper areas (50–80 m) are typically covered by waters with temperatures <1°C, which have slowly warmed since the previous winter.

Bottom temperature anomalies were slightly negative over most of the southern Gulf deeper waters, and positive near the coast of New Brunswick and Prince Edward Island (Figure 11) and also later Figure 14 in a higher resolution scale). Waters significantly cooler than normal were present in the areas surrounding Îles-de-la-Madeleine. Time series of the bottom area covered by various temperature intervals were estimated from the gridded temperature data (Figure 12). Unlike conditions in September 2005, 2006 and 2007, a large bottom area was covered by water with temperatures < 0°C in 2008, similar to the cold period observed in the 1990s. The time series of areas of the Magdalen Shallows covered by water colder than 0, 1, 2 and 3°C are shown in Table 2. While waters colder than 0°C and 1°C covered more of the bottom in 2008 than normal, the coverage of waters colder than 2°C and 3°C was near normal.

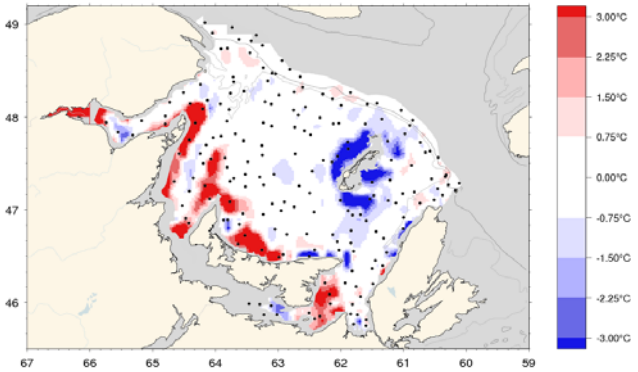


Figure 11. Near-bottom temperatures anomalies from the 1971-2000 climatology in the southern Gulf of St. Lawrence during the 2008 September multi-species survey.

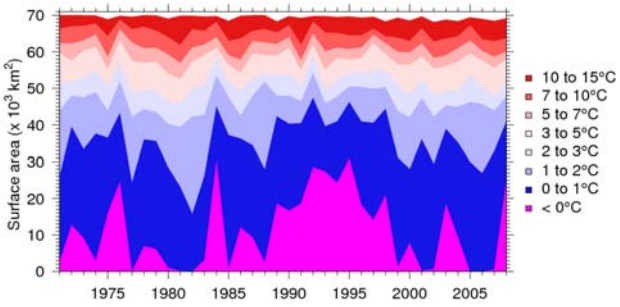


Figure 12. Time series of the areas of the Magdalen Shallows covered by water in different temperature bins in September.

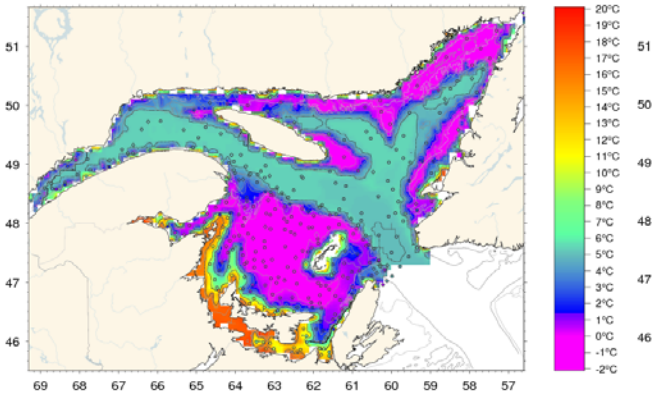


Figure 13. Near-bottom temperatures during the 2008 August and September multi-species surveys in the northern and southern Gulf respectively.

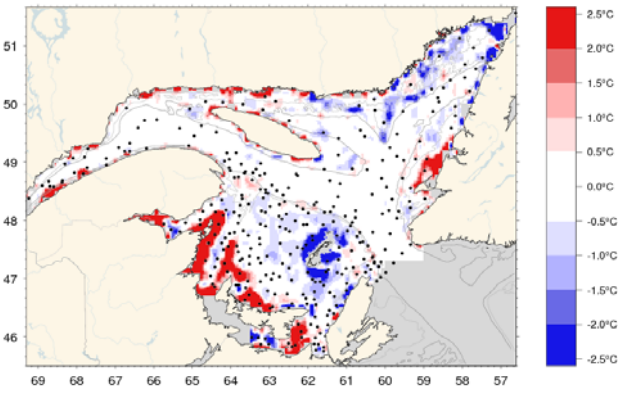


Figure 14. Near-bottom temperature anomalies based on the 1971–2000 climatology in the Gulf of St. Lawrence during the 2008 August and September multi-species surveys.

Bottom temperatures are obtained for all regions of the Gulf by combining the CTD surveys for the northern Gulf in August and for the Magdalen Shallows in September (Figure 13). While the bottom temperature contours are very much dependent on bathymetry, the Mécatina Trough nevertheless stands out with very cold bottom waters in a wider range of water depths due to the intrusion of cold Labrador Shelf waters.

Figure 14 shows the bottom water temperature anomaly referenced to the 1971–2000 climatology. Because the temperature variability differs greatly with depth, it is difficult to produce such a map that illustrates the variability everywhere using a single scale. Figure 14 shows Mécatina Trough, Beaugé Bank and the bank east of Anticosti Island to have very cold bottom water. The cold anomaly was also observed throughout the summer months at the Beaugé Bank station of the thermograph network (Galbraith et al, 2009).

In order to show the seasonal progression of temperature profiles, regional averages at discrete layers and their anomalies were computed for periods corresponding to the main annual surveys of the Gulf: the March helicopter survey, the June AZMP survey, the August multi-species survey (September survey for the Magdalen Shallows) as well as the November AZMP survey. These are illustrated in Galbraith et al. (2009) and are summarized here in Table 3. The March 2008 water temperature conditions were discussed at length earlier. Temperatures in June 2008 were characterized by a very thick and cold CIL in most regions except the Estuary, and by warm deep waters in the Estuary and the northwest Gulf, although the CIL was thinner than in 2007 in Anticosti Channel. This overall pattern persisted in the August–September mean conditions. By October–November, CIL conditions were still thick and cold while waters above the CIL were anomalously warm.

Regional yearly averages of temperature are presented in Table 4 for 200 and 300 m (For salinity see Galbraith et al, 2009). Temperature anomalies at these depths typically travel up-channel from Cabot Strait to the northwestern Gulf in about two to three years. The regional averages are weighted into a Gulf-wide average in accordance to the surface area of each region at the specified depth. These Gulf-wide average are shown for 200, 250 and 300 m in Table 4.

In 2008, the temperature and salinity were generally normal from 150 m to 300 m, with the exception that temperature was slightly low (by 0.6 SD) at 150 m, associated with the thicker than normal CIL. Temperature and salinity in this depth range decreased for a second consecutive year, from 2007 to 2008. The near-normal Gulf-wide water temperatures at 300 m were composed of warmer waters in the Estuary (region 1), near-normal temperatures in the northwest and centre (regions 2 and 6), and colder waters coming into the Gulf at Cabot Strait (region 7). This cold anomaly is expected to propagate inward during the next few years, as it appears to be from the decrease in average temperature from 150 m to 300 m between 2007 and 2008.

The deeper waters of the Laurentian Channel are not ventilated during winter like surface waters, and are slowly advected toward the head of the Laurentian, Esquiman and Anticosti Channels. Therefore the dissolved oxygen concentrations and saturation percentages are lowest at the channel heads, and in particular at the head of the longer Laurentian Channel. Dissolved oxygen decreased very slightly in 2008 compared with 2007 observations but have remained relatively stable since 2001. In the 1930s and early 1970s, oxygen levels were above the hypoxic threshold of 30% saturation. The deep waters of the Estuary were briefly hypoxic in the early 1960s and have consistently been hypoxic at about 19-21% saturation since 1984.

Table 3 Depth-layer monthly average temperature summary for months corresponding to the eight Gulf-wide oceanographic surveys in 2007 and 2008. The colour-coding is according to the temperature anomaly relative to the monthly 1971-2000 climatology of each region, except for March for which the climatology extends to 2008.

1 - Estuary / Estuaire

	2007				2008			
	Mar	June	Aug	Nov	Mar	June	Aug	Oct
0 m	-0.41	8.6	9.4	4.0	-1.39	7.9	11.7	4.1
10 m	-0.19	6.0	7.0	4.0	-1.35	6.0	10.8	4.1
20 m	0.1	3.1	4.4	3.7	-0.92	3.8	8.7	3.9
30 m	0.9	2.0	3.0	3.5	-0.54	2.3	6.3	3.4
50 m	0.4	1.0	1.1	2.5	0.1	0.7	1.7	2.4
75 m	1.2	-0.0	0.8	1.1	0.8	-0.2	0.2	1.1
100 m	1.7	0.6	1.6	0.8	2.0	0.3	0.9	0.8
150 m	3.9	2.6	3.2	3.0	3.4	2.6	2.9	2.0
200 m	4.8	4.0	4.2	4.3	4.1	3.8	4.1	3.7
250 m		4.7	4.8	4.9		4.6	4.8	4.6
300 m		5.1	5.2	5.2		5.1	5.1	5.0
350 m		5.2	5.2			5.1	5.2	5.1

2 - Northwest Gulf / Nord-ouest du Golfe

	2007				2008			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.46	10.8	10.8	4.8	-1.62	10.1	15.6	4.0
10 m	-1.45	8.2	9.2	4.7	-1.64	6.8	12.8	4.0
20 m	-1.38	3.9	4.5	4.7	-1.63	2.5	7.8	3.9
30 m	-1.27	2.2	2.5	4.3	-1.61	0.9	5.2	3.2
50 m	-0.47	0.4	0.7	2.4	-1.04	-0.1	1.2	1.2
75 m	0.9	0.3	0.3	1.1	-0.20	-0.1	0.0	0.7
100 m	2.0	1.0	0.8	1.1	1.0	0.8	0.6	1.1
150 m	4.4	3.3	3.0	3.2	3.4	3.0	2.7	2.8
200 m	4.9	4.6	4.5	4.5	4.4	4.4	4.2	4.4
250 m		5.3	5.2	5.2		5.2	5.1	5.1
300 m		5.4	5.4	5.4		5.4	5.4	5.4
350 m		5.4	5.4	5.4		5.4	5.4	5.4
400 m		5.5	5.4				5.4	5.4

3 - Anticosti Channel / Chenal Anticosti

	2007				2008			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.73	7.1	13.4	4.3	-1.70	7.3	16.8	6.1
10 m	-1.72	6.0	12.8	4.3	-1.71	6.2	15.8	6.1
20 m	-1.72	2.7	6.0	4.3	-1.71	3.5	8.1	6.0
30 m	-1.72	1.2	2.2	4.2	-1.70	1.7	4.2	6.0
50 m	-1.70	-0.7	0.2	3.2	-1.68	0.4	0.5	2.0
75 m	-1.07	-1.0	-0.3	1.3	-1.43	-0.6	-0.4	0.7
100 m	0.2	-1.0	-0.4	0.5	-0.98	-0.8	-0.3	0.5
150 m	2.2	-0.3	1.5	2.4	1.5	0.9	1.6	1.3
200 m	4.7	3.2	4.8	4.7	3.9	3.4	4.4	3.9
250 m			5.8	5.7			5.4	5.4

4 - Mécatina Trough / Cuvette de Mécatina

	2007				2008			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.77	5.9	12.1	3.5	-1.74		15.0	4.7
10 m	-1.77	4.5	11.4	3.5	-1.75		14.8	4.7
20 m	-1.77	0.8	8.2	3.5	-1.75		9.0	4.7
30 m	-1.77	0.4	4.4	3.3	-1.75		4.7	4.7
50 m	-1.77	-0.7	1.7	2.9	-1.75		1.0	3.7
75 m	-1.77	-1.1	0.3	2.4	-1.74		-0.5	3.5
100 m	-1.77	-1.3	-0.5	1.8	-1.75		-0.9	3.2
150 m	-1.78	-0.9	-0.4	0.7	-1.77		-0.6	-0.3
200 m	-1.77	-0.1	0.9	1.3	-1.78		-0.5	-0.2

5 - Esquiman Channel / Chenal Esquiman

	2007				2008			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.71	8.1	15.0	5.1	-1.43	8.1	16.7	6.4
10 m	-1.71	8.0	14.1	5.1	-1.45	7.2	13.8	6.4
20 m	-1.71	4.1	8.4	5.0	-1.46	4.2	6.0	6.2
30 m	-1.70	1.4	2.6	4.6	-1.45	1.4	2.0	5.6
50 m	-1.62	0.0	0.4	2.6	-1.41	-0.5	-0.3	1.1
75 m	-1.07	-0.0	-0.0	0.6	-1.09	-0.5	-0.5	-0.1
100 m	-0.10	0.1	0.3	0.5	-0.32	-0.5	-0.2	0.1
150 m	2.3	2.5	2.7	2.2	1.9	1.0	2.2	2.0
200 m	3.9	4.9	4.9	4.7	3.9	3.6	4.4	4.3
250 m		5.6	5.7	5.6		5.4	5.3	5.3
300 m			5.7	5.7			5.4	5.4

6 - Central Gulf / Centre du Golfe

	2007				2008			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.66	9.6	15.4	5.1	-1.49	8.2	17.8	6.6
10 m	-1.66	8.4	13.5	5.0	-1.48	7.9	16.5	6.5
20 m	-1.66	6.0	6.0	5.0	-1.46	5.0	7.8	6.4
30 m	-1.66	3.4	2.7	5.0	-1.44	1.7	2.5	6.1
50 m	-1.57	0.4	0.7	2.3	-1.43	-0.3	0.1	1.0
75 m	-0.26	0.2	0.2	0.4	-1.19	-0.7	-0.6	0.1
100 m	1.3	1.1	0.3	0.6	0.2	-0.1	-0.2	0.4
150 m	3.2	3.4	2.5	3.0	2.7	2.1	1.7	2.3
200 m	5.0	5.1	4.7	4.8	4.6	4.3	4.1	4.4
250 m		5.6	5.6	5.5		5.2	5.3	5.4
300 m		5.6	5.6	5.5		5.4	5.5	5.5
350 m		5.4	5.4	5.4		5.4	5.3	5.3
400 m		5.3	5.2	5.3		5.2	5.2	5.2
450 m		5.1	5.1	5.1				5.1

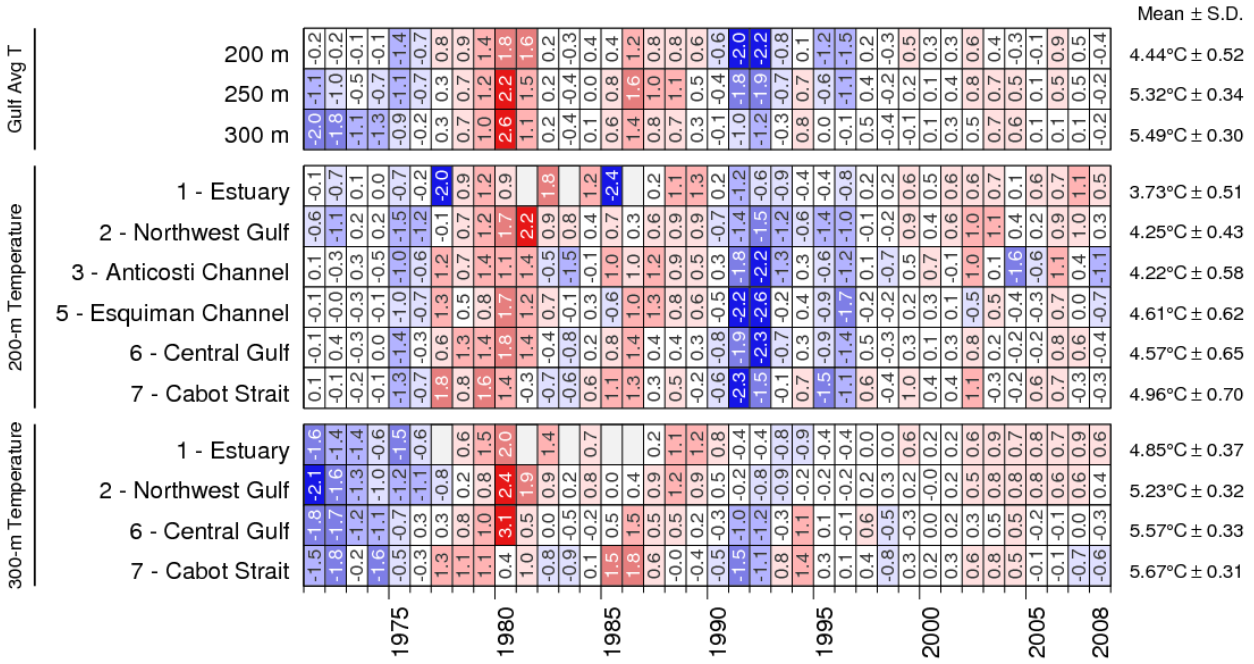
7 - Cabot Strait / Détroit de Cabot

	2007				2008			
	Mar	June	Aug	Nov	Mar	June	Jul	Nov
0 m	-1.39	10.2	17.0	7.4	-1.22	10.1	17.6	8.7
10 m	-1.43	9.1	13.1	7.3	-1.18	8.3	15.0	8.6
20 m	-1.40	4.2	6.1	7.0	-1.16	5.3	7.9	8.3
30 m	-1.38	2.2	3.2	6.6	-1.13	1.8	3.4	7.7
50 m	-1.33	0.9	1.3	4.5	-1.12	-0.1	0.6	2.5
75 m	-0.95	0.7	0.9	2.3	-0.50	0.5	0.5	1.4
100 m	-0.44	1.1	0.9	1.3	1.0	0.9	0.7	1.1
150 m	2.8	2.7	3.2	3.0	3.8	2.8	2.9	2.1
200 m	4.8	4.5	4.9	4.8	5.4	4.7	4.8	4.4
250 m		5.4	5.5	5.4		5.5	5.5	5.6
300 m		5.5	5.4	5.5		5.5	5.5	5.6
350 m		5.3	5.2	5.3		5.3	5.3	5.4
400 m		5.1	5.1	5.2		5.0	5.1	5.1
450 m		4.9	4.9	5.0		5.0	5.0	5.0
500 m			4.8	4.9			5.0	5.0

8 - Magdalen Shallows / Plateau madelinien

	2007				2008			
	Mar	June	Sep	Nov	Mar	June	Sep	Nov
0 m	-1.60	11.8	14.3	7.1	-1.60	12.9	15.9	7.6
10 m	-1.62	9.9	14.1	7.0	-1.67	9.3	15.8	7.5
20 m	-1.63	5.7	12.8	7.0	-1.68	4.7	12.0	7.1
30 m	-1.65	2.3	8.0	6.7	-1.68	1.1	6.2	5.8
50 m	-1.59	0.3	1.3	4.1	-1.63	-0.6	0.6	2.3
75 m	-1.56	-0.0	0.6	1.1	-1.34	-0.7	-0.2	0.2
100 m							0.4	

Table 4. Deep layer yearly-average temperatures. Gulf averages are shown for 200, 250 and 300 m and regional averages are shown for 200 and 300 m.



CONCLUSION AND OUTLOOK

Post-winter water temperatures in the Gulf of St. Lawrence during 2008 were generally warm from the surface down to the base of the CIL, but not as anomalously as in 2006. The near-normal winter air temperature contributed to a normal maximum ice volume, but the delayed melt and cold March contributed to a cold summertime CIL reminiscent of 2003 and the 1990s. Cold water <0°C occupied the bottom of the Magdalen Shallows in September after three years of absence at that time of year. The temperature and salinity were generally normal at 150 m to 300 m when considering the Gulf as a whole, but warm in the Estuary and cold in Cabot Strait.

The March 2009 winter survey provides an outlook for CIL conditions expected for the remainder of 2009. Figures are shown in Galbraith et al. (2009) and only descriptions are given here. The intrusion of cold and saline water from the Labrador Shelf through the Strait of Belle Isle occupied a slightly smaller area closer the coast in March 2009 compared to 2008 but extended to the surface again. Its volume of 1460 km³ was down from 1850 km³ in March 2008 and closer to the 1620 km³ recorded in March 2006. The winter surface cold layer (< -1°C) was thicker than usual and its overall volume increased slightly from March 2008 conditions to reach 14 600 km³ in March 2009, making it the second largest volume recorded in 14 years after the March 2003 maximum of 14 900 km³. The relation between the March cold water volume and the following summer CIL index forecasts cool summertime CIL conditions in 2009 with an index of -0.58ºC. However, this would be a temperature increase from the -0.70ºC index of 2008 despite a larger winter cold water volume than in 2008. The CIL was colder than expected in 2008 likely because of the late spring warming and high summertime stratification. The high ice cover observed in March 2009 may lead to similar late warming and to a CIL index below -0.58ºC for the summer of 2009.

SOURCES OF INFORMATION

DFO, 2008. State of the Ocean 2007: Physical Oceanographic Conditions in the Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/016.

Galbraith, P.S., R.G. Pettipas, J. Chassé, D. Gilbert, P. Larouche, B. Pettigrew, A. Gosselin, L. Devine, C. Lafleur. Physical Oceanographic Conditions in the Gulf of St. Lawrence in 2008. DFO Can. Sci. Advisory Sec. Res. Doc. 2009/014: 69 p.

B. Petrie, R.G. Pettipas, W.M. Petrie. An Overview of Meteorological, Sea Ice and Sea-Surface Temperature Conditions off Eastern Canada during 2007. DFO Can. Sci. Advisory Sec. Res. Doc. 2008/016: 42 p.

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