STATE OF THE OCEAN 2007: PHYSICAL OCEANOGRAPHIC CONDITIONS IN THE GULF OF ST. LAWRENCE

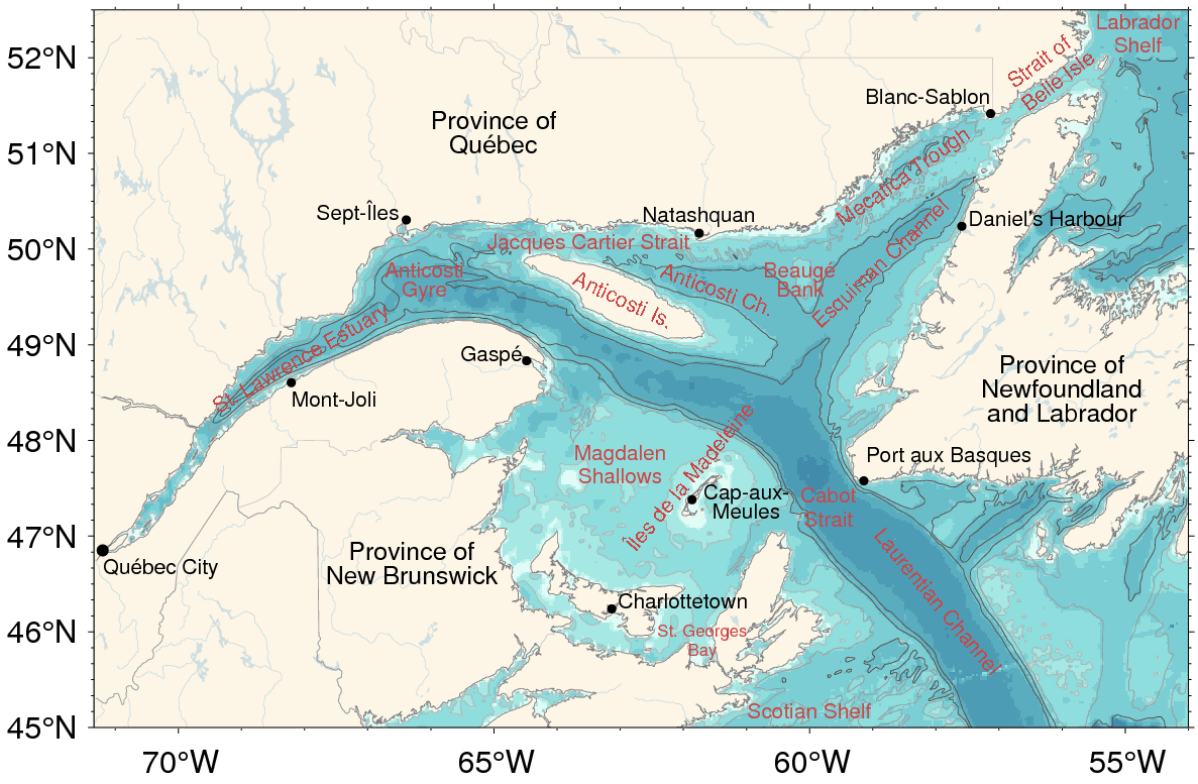


Figure 1: Gulf of St. Lawrence

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 ranged from normal to cooler than normal for most of the year in the western parts of the Gulf, contrasting with the very warm conditions in 2006. However, the eastern regions were only significantly cooler than normal in April and May. October was very warm almost everywhere, and December was cool. Averaged over the whole Gulf for the entire year, air temperature was normal in 2007 and only slightly above normal (by 0.3 × standard deviation) when considering only the January to March period.

- The monthly averaged runoff measured at Québec City was consistently below normal in 2007. The annual mean was 1.5 standard deviations below normal, which is comparable to values observed from 2001 to 2003 but higher than the record low conditions observed from 1962 to 1965.

- Near-surface waters were anomalously warm in the St. Lawrence Estuary in January and February. After a rather uneventful spring, the summer maximum temperatures occurred earlier than usual everywhere in the Gulf (early August instead of mid-August). Earlier-than-usual cooling followed the maximum, and temperatures were below normal for the rest of the year except for October in the Estuary. Near-surface water temperatures were much cooler in 2007 than in 2006 in all regions of the Gulf.

- Near-surface waters in the northeast were consistently lower than normal in May and September and variable to below-normal during other months. Near-surface waters in the southern Gulf were either normal or warmer than normal from May to July and generally lower than normal from August to the end of records in October.

- On the Magdalen Shallows, there was (almost) no bottom area covered by water with temperatures < 0°C in September 2007 (as for 2005 and 2006), which contrasts with the cold period observed in the 1990s. Waters colder than 1°C covered slightly more of the bottom in 2007 than in 2006, but the opposite can be said for waters colder than 3°C.

- Maximum sea-ice volume within the Gulf and on the Scotian Shelf was below normal by 1.5 times the standard deviation but still much higher than recorded in 2006 (the lowest recorded value since 1969).

- Winter inflow of cold and saline water from the Labrador Shelf occupied the Mécatina Trough from top to bottom in winter 2007 (up to 235 m in depth). The spread of the intrusion had an area similar to that of 2006, but its volume was much larger (2850 km^3), similar to that observed in 2004.

- The winter cold mixed layer volume was nearly normal at 13100 km^3, higher than the 1996–2007 average but only by 0.4 × the standard deviation. This cold-water volume corresponded to 39% of the total water volume of the Gulf.

- The CIL minimum temperature index for summer 2007 was -0.23°C, comparable to conditions observed in 2004. This was a large decrease in the index of 0.44°C after three consecutive years of warming and brought it close to the 1971–2000 time series average of –0.32°C. This was fairly well predicted following the March 2007 survey of the cold mixed layer water volume in the Gulf. Part of the decrease of the CIL index was due to the larger-than-normal winter intrusion of Labrador Shelf water from the Strait of Belle Isle.

- Regional patterns of the CIL show that the layers for T < 1°C and < 0°C were much thicker everywhere except the Magdalen Shallows in 2007 than in 2006, and that the CIL had a generally lower core temperature as well. The exception was the Mécatina Trough, where core temperatures were similar to 2006 conditions, presumably due to the similar area extent of the cold Labrador Shelf water intrusion during both winters.

- Seasonal and regional patterns of water temperatures: Temperatures in June were generally close to the 1971–2000 climatology at all depths, except for the very thick and cold CIL in the Anticosti Channel and Mécatina Trough, and warm deep waters in the Estuary and the northwest Gulf. This overall pattern persisted in the August–September mean conditions, except for the then-normal CIL in Mécatina Trough and warm deep waters also found in Anticosti Channel. However, by October–November, conditions were about normal everywhere except for anomalously warm near-surface mixed layers in the northwest Gulf and warm near-surface waters on the Magdalen Shallows and in Cabot Strait.

- Temperature and salinity were generally normal at 150 m to 300 m after a decrease at most depths from 2006 to 2007. At 300 m, the near-normal temperatures were composed of warmer waters near the Estuary (regions 1 and 2), near-normal temperatures in the centre (region 6) and colder waters coming into the Gulf at Cabot Strait (region 7).

- Dissolved oxygen in the deep waters of the St. Lawrence Estuary remained hypoxic at 20%, having decreased very slightly in 2007 compared with 2006 observations.

- The outlook for 2008 from the March 2008 survey is for a slight cooling of the CIL index to -0.47°C resulting from a thicker winter cold surface layer.

BACKGROUND

Temperature and salinity conditions in the Gulf of St. Lawrence 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 is advected up the Channel by estuarine circulation. The 0-150 m layer undergoes seasonal variations from exchanges with the surface. The winter near-freezing mixed layer reaches an average of 75 m, but can reach over 200 m in the less stratified Mécatina Trough. The surface is stratified in spring by the melt of sea-ice and freshwater runoff, but a Cold Intermediate Layer persists through summer which 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. Scorecards 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 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.

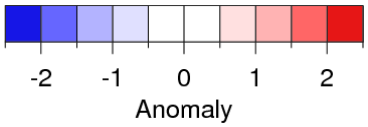


Figure 2. Scorecard anomaly colour palette. Time series are normalized by first subtracting the climatological mean to obtain an anomaly, and then dividing these anomalies by the standard deviation (SD) of the time series. This results in normalized anomalies. Data that fall within ± 0.5 SD are colour-coded 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 2007

The monthly air temperature anomalies for several stations around the Gulf are shown in Figure 3. The 1971–2000 monthly climatologies expressed as the mean plus and minus one standard deviation are also shown for each station as well as an anomaly scorecard showing the average temperature anomaly for each month. The western parts of the Gulf experienced mostly normal or cooler-than-normal temperatures for the greater part of the year, contrasting with the very warm conditions in 2006. However, the three easternmost stations were only cooler than normal (by more than half of the standard deviation) in April, May and December. October was very warm almost everywhere, and December was cool.

Annual mean air temperatures were either normal or slightly above normal at all stations, contrasting with the much above normal temperatures in 2006 (2.3 × standard deviation above normal; see Galbraith et al, 2008). The average of the nine stations provides an overall temperature index for the entire Gulf. It was normal in 2007 (only 0.1 × standard deviation above normal). A bulk air-temperature winter-severity index was also constructed by averaging the air temperature of all stations except Cap-aux-Meules (time series too short) from January to March of each year. It also was only slightly above normal in 2007 (by 0.3 × standard deviation).

The monthly averaged runoff measured at Québec City was consistently below normal in 2007 (see Galbraith et al, 2008), and only the runoffs for January and March were within 0.5 × standard deviation of the mean. The annual mean was 1.5 standard deviations below normal, comparable to values observed from 2001 to 2003 but higher than the record low conditions observed from 1962 to 1965.

The surface layer conditions of the Gulf are monitored by various methods that complement each other: the thermograph network, the shipboard thermosalinographs, research surveys and NOAA satellite remote sensing. Thermosalinographs have been installed on commercial ships Cicero (now retired) in 1999 and Cabot in 2006, both of Oceanex Inc. The ships sail year-round between Montréal and St. John's, making a return trip once per week. Near-surface (3 m) water temperature and salinity are sampled using the shipboard thermosalinographs. Figure 4 (left panel) shows the mean annual cycle of water temperature at a depth of 3 m along the Montréal to St. John's shipping route from 2000 to 2007. The data were averaged for each day of the year at intervals of 0.1 degree of longitude to create a composite along the ship track. Perhaps the most striking feature is the area at the head of the Laurentian Trough (69.5°W), where strong vertical mixing leads to cold summer water temperatures (around 5 to 6°C and sometimes lower) and winter temperatures that are always above freezing. The progression to winter conditions is shown to first reach near-freezing temperatures in the Estuary. Freezing conditions then progress eastward with time, usually just reaching Cabot Strait by the end of the winter. Figure 4 also shows the water temperature composite for 2007 and its anomaly relative to the average. Sporadic winter thaws occurred in the St. Lawrence Estuary in early January

and again in February that explain the above-freezing surface waters. After a rather uneventful spring, the summer maximum temperatures occurred earlier than usual everywhere in the Gulf (early August instead of mid-August). Earlier-than-usual cooling followed the maximum, and temperatures were below normal for the remainder of the year, especially in September, except for warm conditions in the Estuary in October.

The thermograph network consists of 23 stations with moored instruments measuring and logging water temperature every 30 minutes. Most instruments are installed on Coast Guard buoys that are deployed in the ice-free season, but a few stations are occupied year-round. The 22 stations that have sufficiently long time series to permit the calculation of climatologies with standard deviations are shown in Figure 5, and the average monthly temperatures for each station and depth are listed in Table 1.

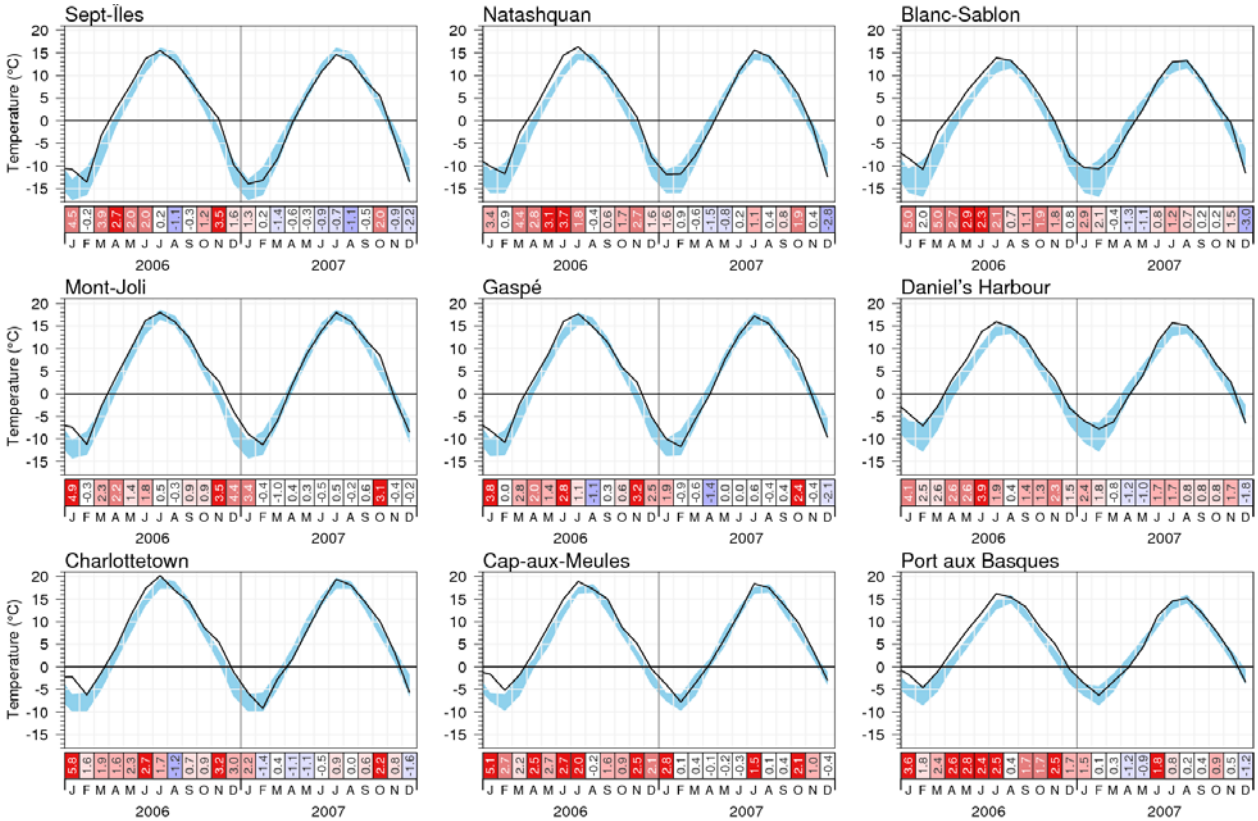


Figure 3. Monthly air temperature anomalies for 2006 and 2007 at 9 selected stations around the Gulf (shown in Figure 1). The blue area represents the 1971–2000 climatological monthly mean plus or minus one standard deviation. The bottom scorecards are colour-coded according to the monthly standardized anomalies for each month, but the numbers are the monthly anomalies in ºC.

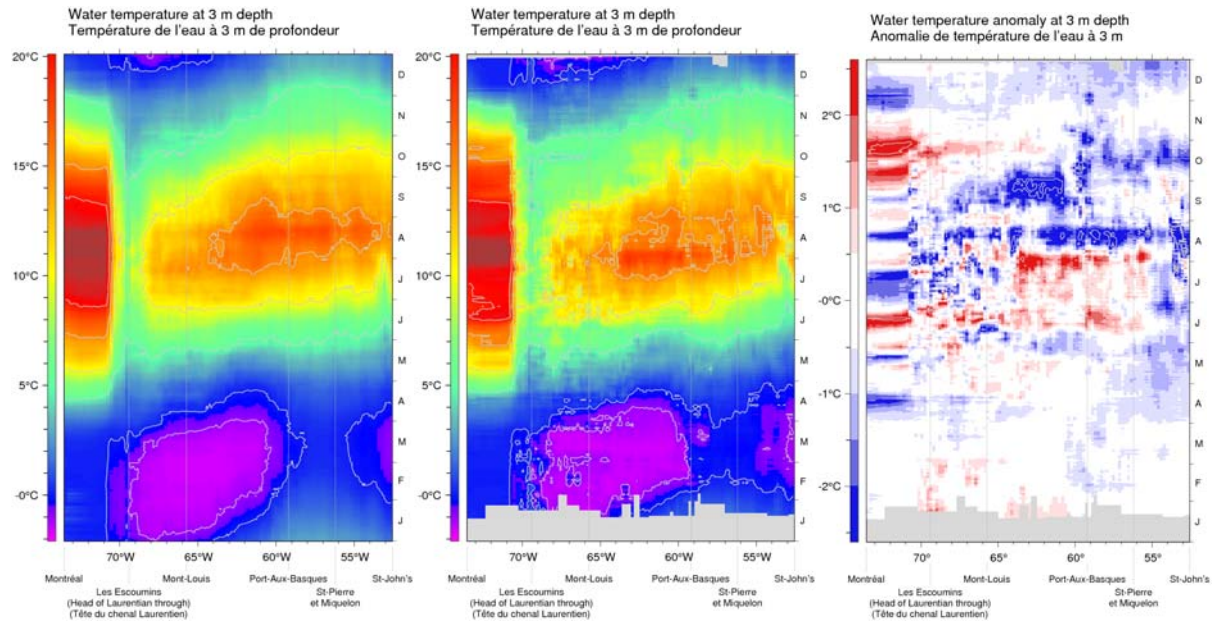


Figure 4. Thermosalinograph data at 3-m depth along the Montréal to St. John's shipping route: composite mean annual cycle of the water temperature for the 2000–2007 period (left panel), composite annual cycle of the water temperature for 2007 (middle panel) and water temperature anomaly for 2007 relative to 2000–2007 mean (right panel).

The Estuary near-surface water temperatures were above normal in October and below normal in September, as previously noted with the thermosalinograph network. However, while near-surface waters in July and August were generally cool, the pattern is more variable than suggested from the thermosalinograph network (which is based on a shorter climatology and a longer sampling interval of twice-a-week). The thermograph network provides information in the northeast and southern Gulf, where there are almost no shipboard thermosalinograph measurements. The pattern that emerges in the northeast from Table 1 is of consistently lower-than-normal near-surface temperatures in May and September. Water temperatures in May were consistent with air temperature anomalies, but those in September and October were less so. Water temperatures in other months were variable but tended to be below normal. Near-surface waters at southern Gulf stations were either normal or warmer than normal from May to July and lower than normal from August to the end of records in October, except for above-normal conditions in October and November at the Irving Whale station. While 2006 was truly an exceptionally warm year, the warm conditions did not continue into 2007.

The NOAA satellite remote sensing observations show similar conditions as the thermograph and thermosalinograph data (not shown; see Galbraith et al. 2008). They confirm that near-surface water temperatures were much cooler in 2007 than in 2006 not only along the main shipping route, but in other parts of the Gulf as well.

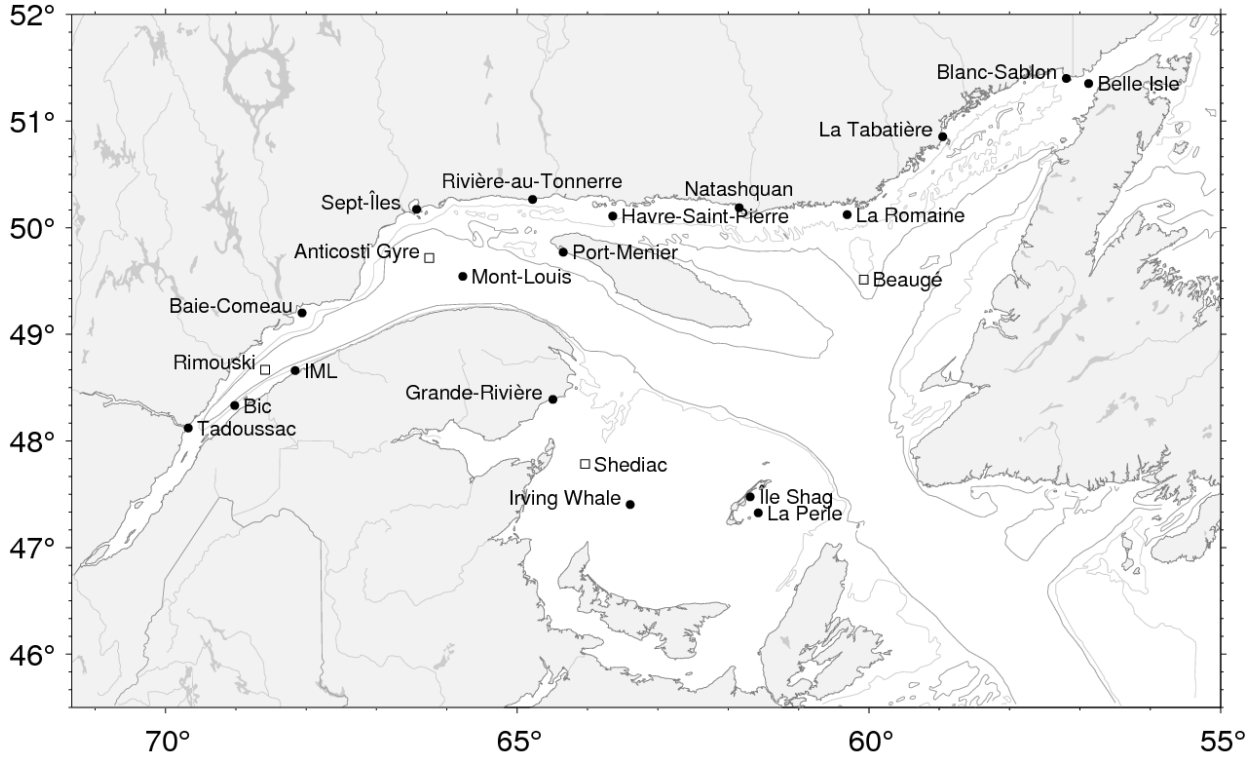


Figure 5. Locations of the Maurice Lamontagne Institute thermograph network stations in 2007, including regular stations where data are logged internally and recovered at the end of the season (filled circles) and oceanographic buoys that transmit data in real time (open squares).

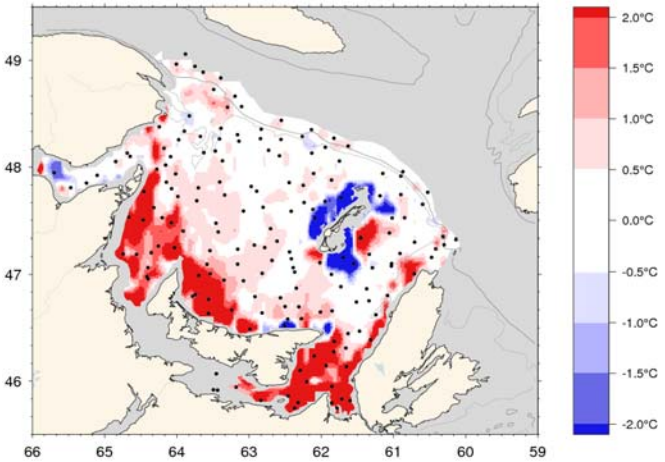


Figure 6. Near-bottom temperatures anomalies from the 1971-2000 climatology in the southern Gulf of St. Lawrence during the 2007 September multi-species survey.

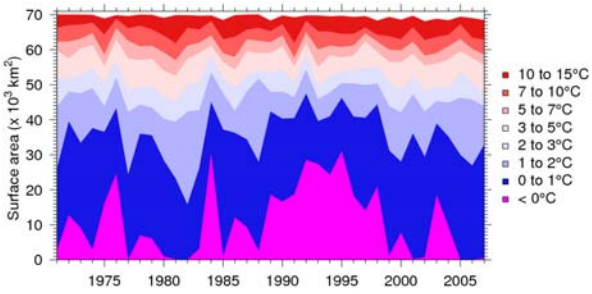
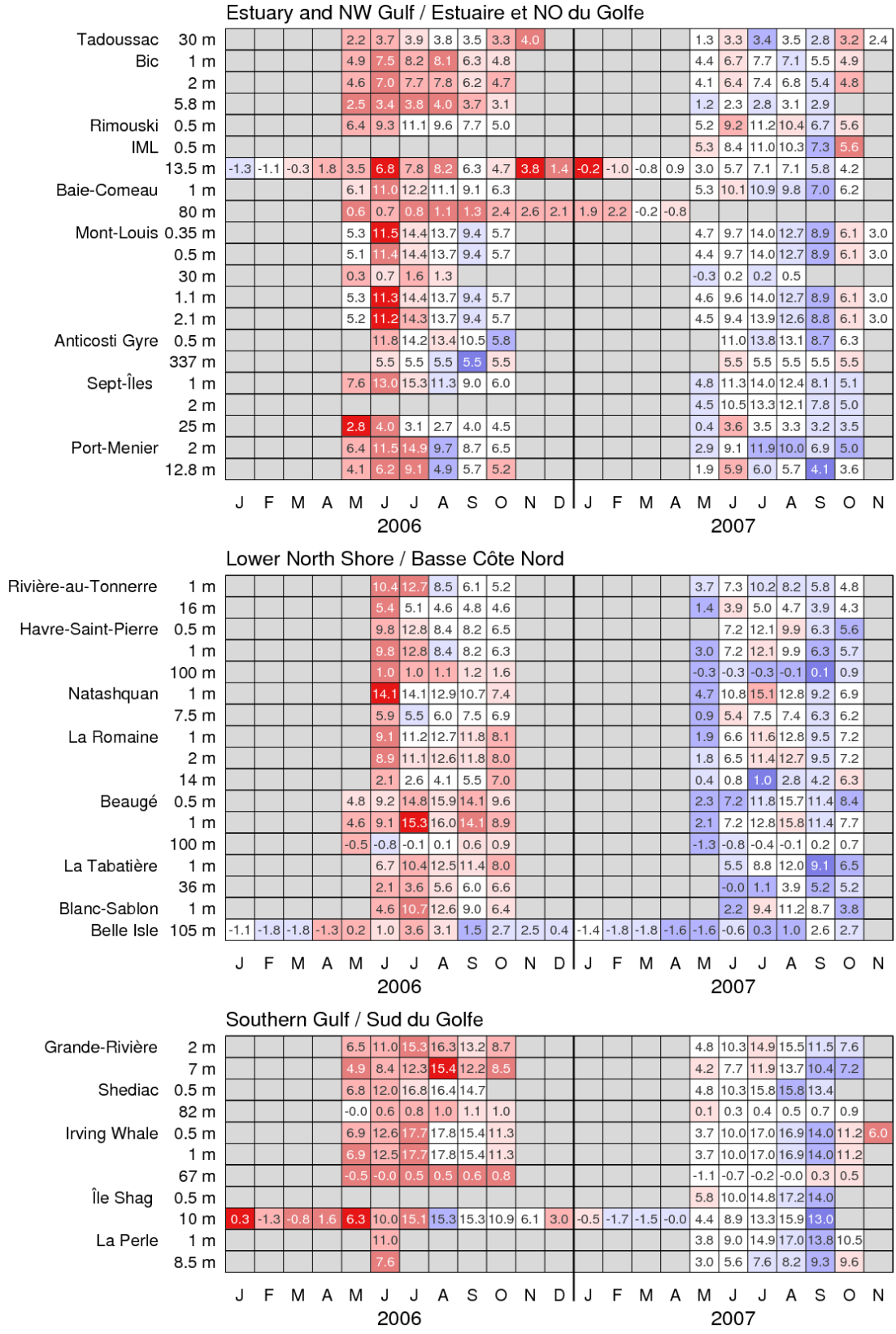


Figure 7. Time series of the areas of the Magdalen Shallows covered by water in different temperature bins in September.

Table 1. Monthly mean temperatures (values shown) at all stations of the thermograph network in 2006 and 2007. The colour-coding is according to the temperature anomaly relative to the climatology of each station for each month.



Water temperatures on the bottom of the Magdalen Shallows are obtained in September of each year from the multi-species survey (1971-present). Bottom temperatures 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 over most of the southern Gulf were slightly warmer than normal in September 2007 (Figure 6). The highest positive anomalies (> +3°C) appeared in shallow water along the coast of New Brunswick and in St. Georges Bay, as in 2006. From the gridded temperature data, time series of the bottom area covered by various temperature intervals were estimated (Figure 7). As in September 2005 and 2006, there was (almost) no bottom area covered by water with temperatures < 0°C in 2007, which contrasts with the cold period observed in the 1990s. However, the area covered with water with temperatures from 0 to 1°C was slightly larger in September 2007 than in 2006. The time series of areas of the Magdalen Shallows covered by water colder than 0, 1, 2 and 3°C are also shown at the bottom of Table 2. While waters colder than 1°C covered slightly more of the bottom in 2007 than in 2006, the opposite can be said for waters colder than 3°C.

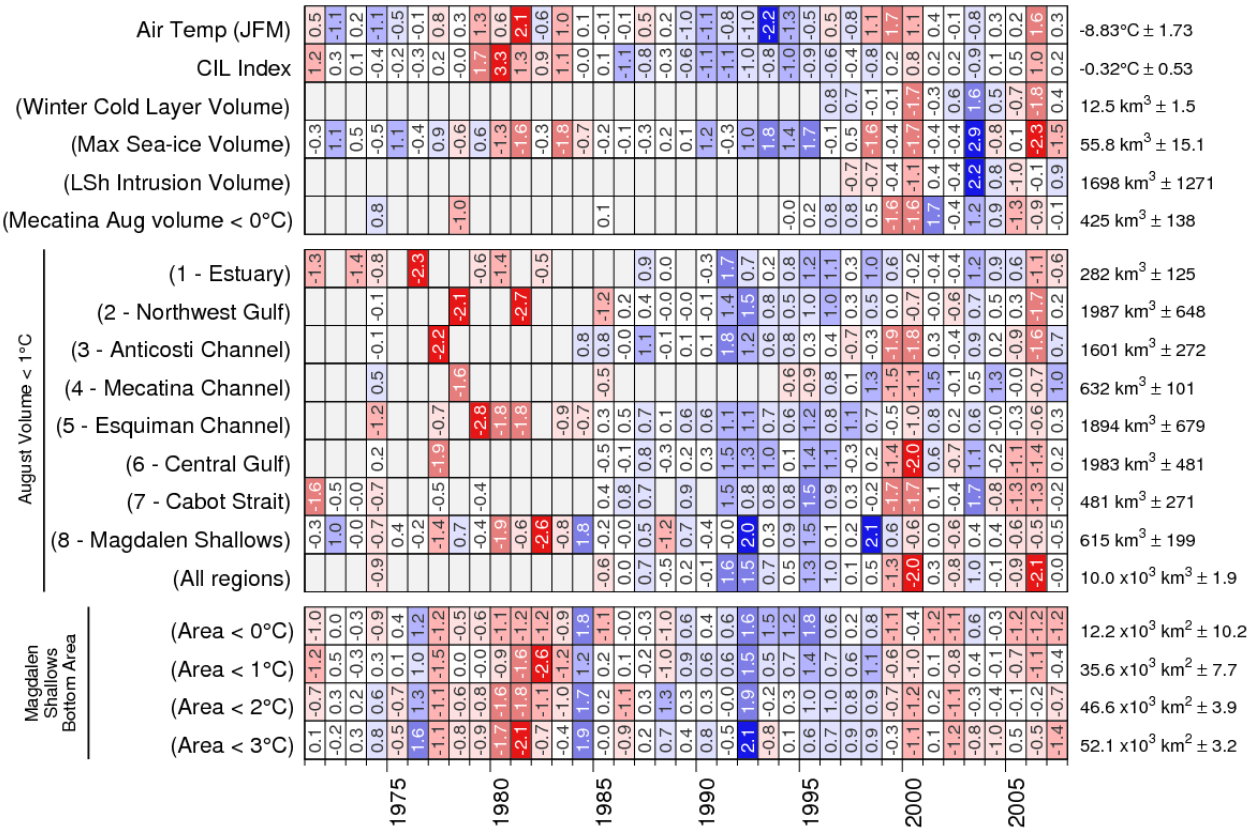
Sea ice is typically produced in the northern parts of the Gulf and drifts towards the Îles-de-la-Madeleine and Cabot Strait. The combined Gulf and Scotian Shelf ice volume shown in the top panel of Figure 8 is indicative of the total volume of ice produced in the Gulf, including the advection out of the Gulf, but 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 8 corresponds to that found seaward of Cabot Strait and represents the volume of ice exported from the Gulf.

In 2007, the maximum Gulf and Shelf ice volume was 34 km^3, which was below normal by 1.5 times the standard deviation but still much higher than the 20 km^3 recorded in 2006 (at -2.3 times the standard deviation, the lowest recorded value since 1969). The maximum ice volume reached during each winter is shown as a time series scorecard in Table 2.

A helicopter-based survey has been monitoring wintertime conditions in the Gulf of St. Lawrence since 1996. The 2007 survey of 85 stations took place from March 5 to 16. Figure 9 shows gridded interpolations of near-surface characteristics (temperature, cold layer thickness and thickness of Labrador Shelf intrusion). 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 2007 in contrast to warm conditions in 2006. Relatively warm water (~ -0.5°C) entered the Gulf on the northeast side of Cabot Strait, similar to 2004, 2005 and 2006, and flowed northward along the western coast of Newfoundland. However, the patch was cooler than in previous years and its volume and area were smaller.

Near-freezing waters with salinity > 32.35 are considered to be too saline to be formed from waters originating within the Gulf and are presumed to have been advected from the Labrador Shelf through the Strait of Belle Isle. The thickness of this intrusive layer is estimated in the middle panel of Figure 9. It occupied the Mécatina Trough from top to bottom in winter 2007 (up to 235 m depth) as well as a large area northeast of Anticosti Island. The spread of the intrusion had an area similar to that of 2006 but its volume of 2850 km^3 was much larger, similar to the 2004 volume. The recent history of the Labrador Shelf water intrusion volume is shown in Table 2.

Table 2: CIL and related properties. The top block shows the scorecard time series for winter air temperature averaged over 8 stations, the Gilbert & Pettigrew (1997) 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. Numbers in the right side of each scorecard line are its mean ± standard deviation. Numbers within the boxes are normalized anomalies.



The winter cold (< -1°C) mixed layer depth usually reaches an average of 75 m in the Gulf, and conditions in 2007 were only slightly thicker than usual (see bottom panel of Figure 9). Integrating the mixed layer depth over the area of the Gulf yields a cold-water volume of 13100 km³, a value higher than the 1996–2007 average by 0.4 × the standard deviation. This cold-water volume corresponded to 39% of the total water volume of the Gulf (34000 km³). The time series scorecard is included in Table 2.

The total volume of cold water (< -1ºC) in winter is related to the following summer's CIL index since the CIL is the remnant of the winter cold surface layer. The near-normal volume of cold water of 13100 km³ observed in March 2007 was used to issue a 2007 CIL index forecast of -0.38°C based on the correlation between the winter cold-water volume and the summertime CIL index for 1996–2006 (DFO, 2007). This was a predicted decrease of nearly 0.6°C from the previous year. A large part of that decrease can be associated with the large increase in the volume of the Labrador Shelf water intrusion. Indeed, the linear relation between winter cold-water volume and summer CIL index implies that the 2850-km³ intrusion accounts for a 0.5°C cooling of the CIL index.

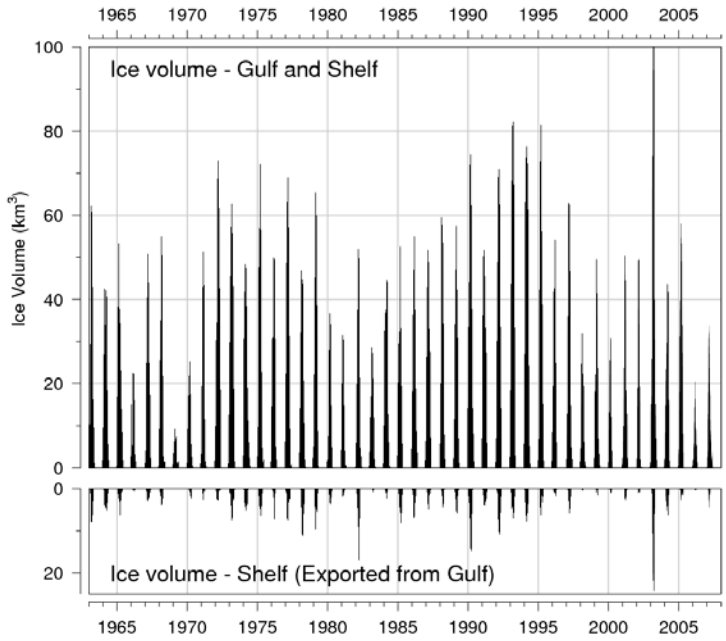


Figure 8. Estimated ice volume in the Gulf of St. Lawrence and on the Scotian Shelf seaward of Cabot Strait (upper panel) and on the Shelf only (lower panel).

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. It was updated using all available temperature and salinity profiles measured within the Gulf between the months of May and September inclusively since 1947 (Figure 10). The CIL index for summer 2007 was -0.23°C. This was somewhat warmer than the prediction of -0.38°C based on the March survey; it was comparable to conditions observed in 2004, as was the case for the winter cold-water volume. This was a large decrease of the index of 0.44°C after three consecutive years of warming and brought it close to the 1971–2000 time series average of –0.32°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 (Figure 12). The majority of the data come from the September groundfish survey for the Magdalen Shallows and the Maurice Lamontagne Institute groundfish survey in August for the rest of the Gulf. It is apparent that the CIL < 1°C and < 0°C was much thicker everywhere except the Magdalen Shallows in 2007 than in 2006 and had a generally lower core temperature everywhere except the Mécatina Trough. Similar maps were produced for all years back to 1971 allowing the calculation of volumes for each region for each year (although some years have no data in some regions). The time series of the regional CIL volumes < 1°C are shown in Table 2 and the regions are shown in Figure 11. All regions show an increased CIL (< 1°C) volume in 2007 compared to 2006, although this increase was very slight on the Magdalen Shallows. The 2007 average temperature minimum over the entire standard grid was -0.14°C. This is a decrease of 0.62°C since 2006. The overall 2007 CIL water mass properties were similar to those observed in 2004.

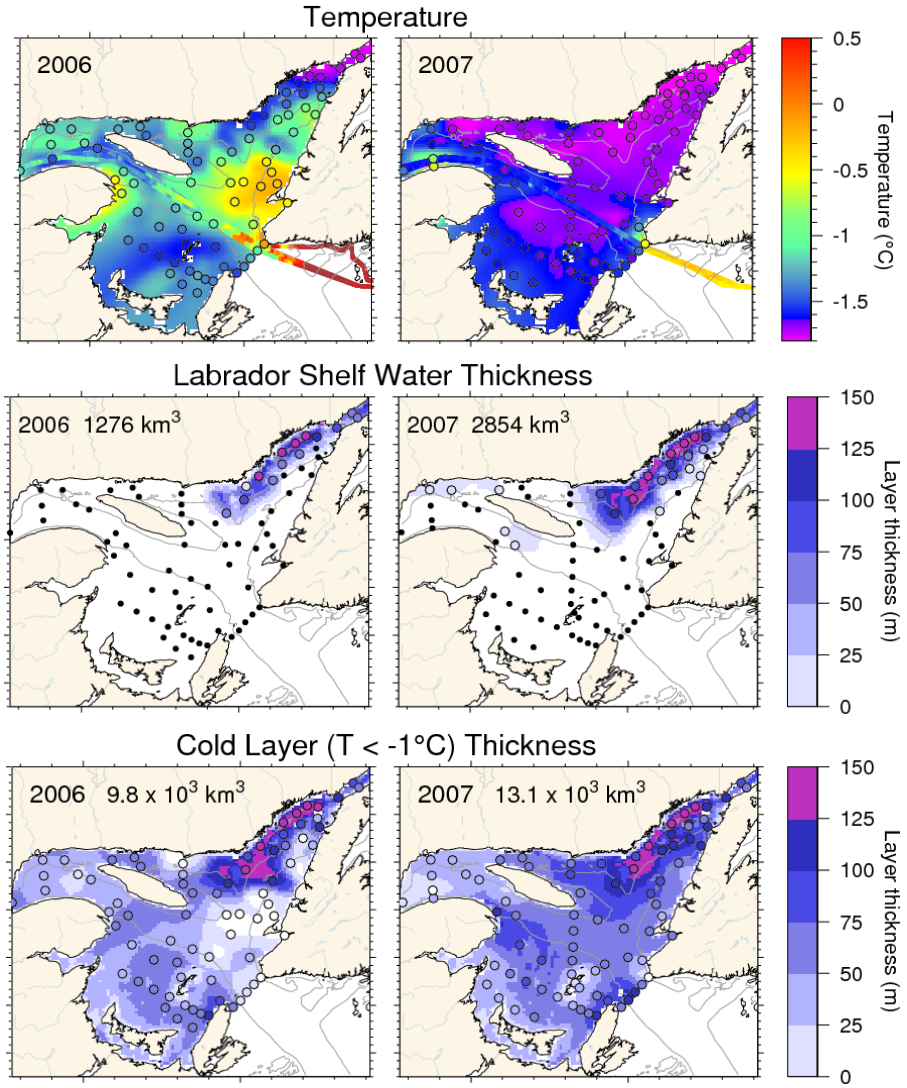


Figure 9. Surface water temperature (top), estimate of the thickness of the Labrador Shelf water intrusion (middle) and cold layer (T < -1°C) thickness (bottom) for the March 2006 and 2007 helicopter surveys. The symbols are coloured according to the value observed at the station, using the same colour 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.

In order to follow the seasonal progression of water temperatures, regional average profiles were computed for the 8 main geographical regions of the Gulf for the March helicopter survey, the June AZMP survey, the August multidisciplinary survey (September survey for the Magdalen Shallows) as well as the November AZMP survey, and this for 2006 and 2007. These average profiles were compared to 1971-2000 monthly climatologies within each region. These are illustrated in Galbraith et al. (2008) and are summarized here as discrete-depth layer averages in Table 3. The March 2007 water temperature conditions were discussed at length in earlier sections. Temperatures in June 2007 were generally close to the 1971–2000 climatology at all depths, except for the very thick and cold CIL in Anticosti Channel (region 3) and Mécatina Trough (region 4), and warm deep waters in the Estuary (region 1) and the northwest Gulf (region 2). This overall pattern persisted in the August–September mean conditions, except for the then-normal CIL in Mécatina Channel and warm deep waters also found in Anticosti Channel. However, by October–November, conditions were about normal everywhere except

for anomalously warm near-surface mixed layers in the northwest Gulf and warm near-surface waters on the Magdalen Shallows (region 8) and in Cabot Strait (region 7).

Regional yearly averages of temperature are presented in Table 4 for 200 and 300 m (For salinity see Galbraith et al, 2008). Temperature anomalies at these depths typically travel up-channel from Cabot Strait to the northwest Gulf in 2 to 3 years. The regional averages are weighted into a Gulf-wide average in accordance to the surface area of each region at the specified depth. Gulf-wide yearly averages are shown for 200, 250 and 300 m in Table 4.

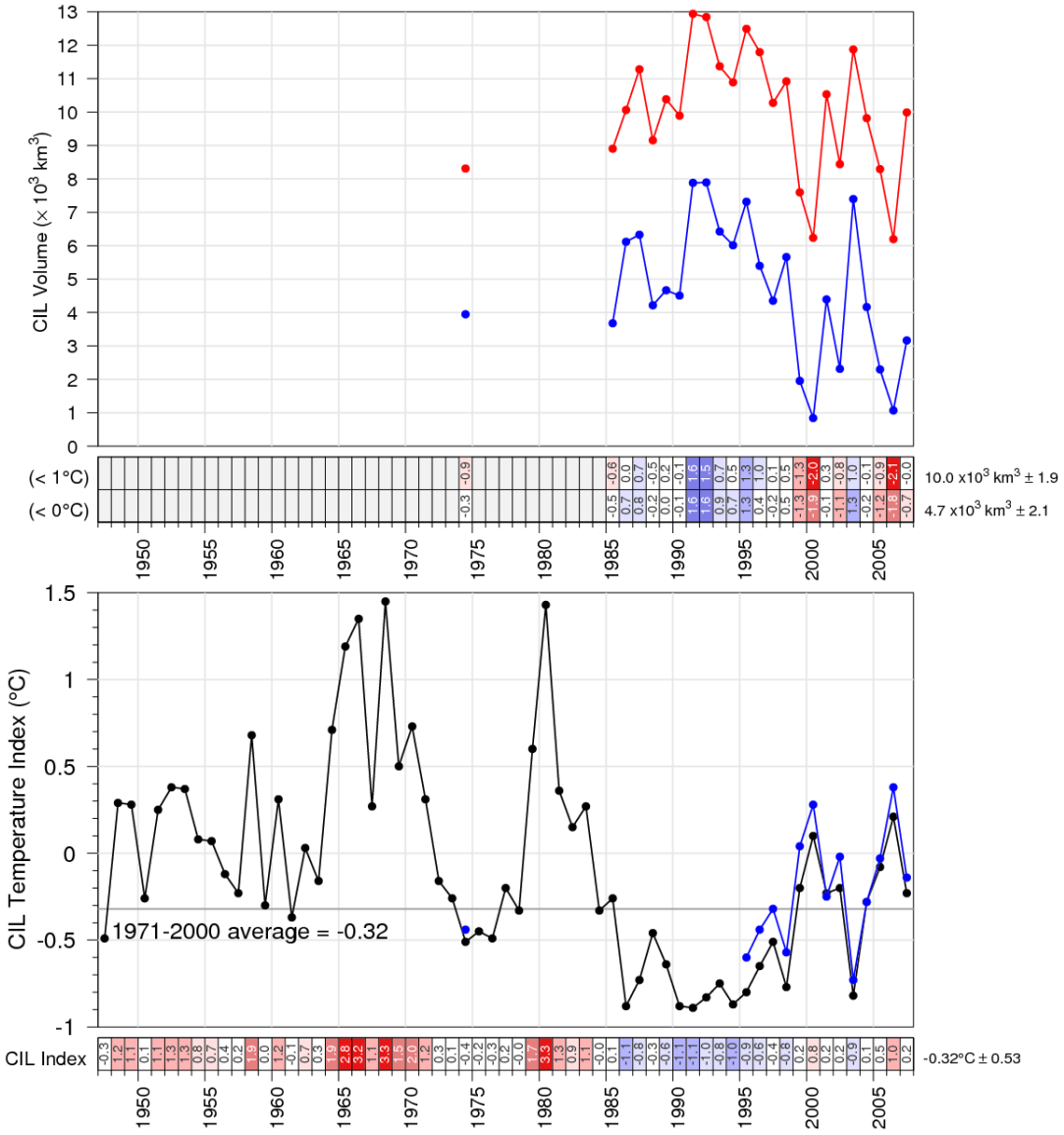


Figure 10. CIL volume (top panel) in August-September, delimited by the top and bottom 0ºC (in blue) and 1ºC (in red) isotherms, and CIL minimum temperature index (bottom panel) in the Gulf of St. Lawrence. The volumes are integrals of each of the annual interpolated thickness grids such as the top panels of Figure 12. 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 12.

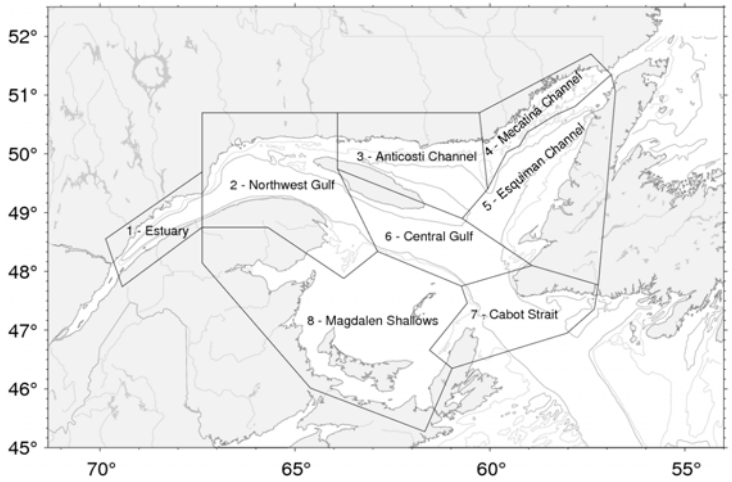


Figure 11. The eight regions of the Gulf of St. Lawrence.

In 2007, the temperature and salinity were generally normal at 150 m to 300 m (salinity was only above normal at +0.5 × the standard deviation at 200 m). Temperature and salinity in this depth range decreased from 2006 to 2007, except for temperature at 300 m which remained constant. The near-normal Gulf-wide water temperatures at 300 m were composed of warmer waters near the Estuary (regions 1 and 2), near-normal temperatures in the centre (region 6) and colder waters coming into the Gulf at Cabot Strait (region 7). This cold anomaly would be expected to propagate inward during the next few years. However, the cold anomaly at Cabot Strait may have been a short-lived event since it was not observed in November (Table 3) and therefore may not be not indicative of a longer-term trend. However, a cold anomaly was also present in the deepest waters of Cabot Strait throughout the year.

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. 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 since 1984. The mean dissolved oxygen value at depths greater or equal to 295 m in the St. Lawrence Estuary decreased very slightly in 2007 compared with 2006 observations, and was at 20% saturation.

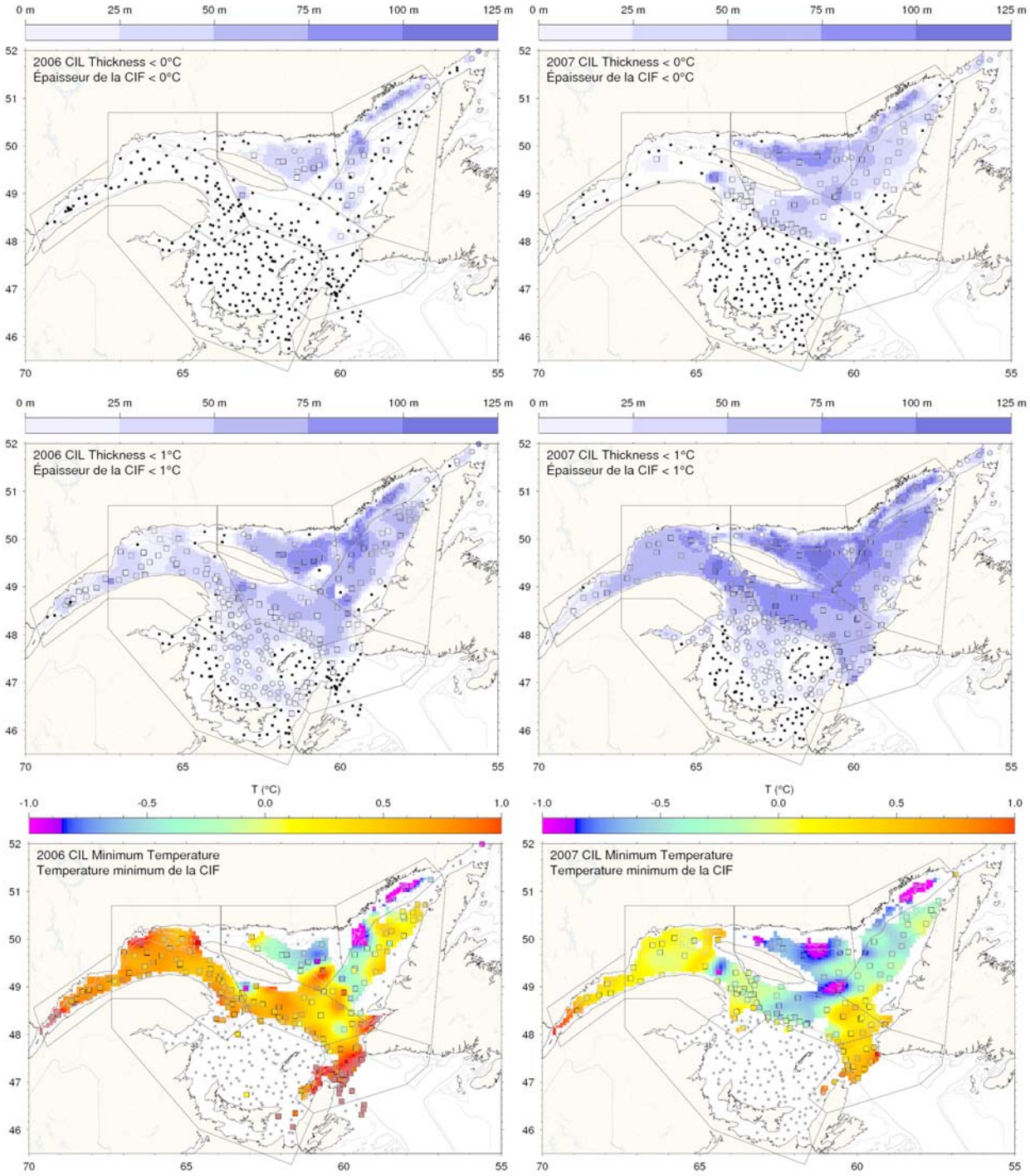


Figure 12. Cold Intermediate Layer thickness (T < 0ºC, top panels; T < 1ºC, middle panels) and minimum temperature (bottom panels) in August and September 2006 (left) and 2007 (right).

Table 3. Scorecard depth-layer average temperature summary of the eight Gulf-wide oceanographic surveys in 2006 and 2007. The colour-coding is according to the temperature anomaly relative to the monthly climatology of each region.

1 - Estuary / Estuaire

	2006				2007			
	Mar	June	Aug	Nov	Mar	June	Aug	Oct
0 m	-0.25	8.6	8.7	4.9	-0.41	8.2	8.8	3.7
10 m	-0.19	7.0	7.3	4.9	-0.19	5.8	6.6	3.6
20 m	0.0	5.4	4.8	5.1	0.1	2.8	3.9	3.4
30 m	0.2	4.0	3.1	5.2	0.9	1.9	2.8	3.2
50 m	-0.06	1.7	1.3	4.7	0.4	1.0	1.1	2.2
75 m	0.7	0.6	1.1	3.8	1.2	-0.0	0.7	1.2
100 m	1.6	1.4	1.6	2.5	1.7	0.4	1.3	1.3
150 m	3.2	3.3	3.5	1.9	3.9	2.5	3.0	2.9
200 m	4.3	4.3	4.5	3.3	4.8	4.0	4.2	4.1
250 m		4.9	5.0	4.5		4.6	4.8	4.8
300 m		5.2	5.3	5.1		5.0	5.2	5.1
350 m		5.2	5.3	5.2		5.2	5.2	5.2

2 - Northwest Gulf / Nord-ouest du Golfe

	2006				2007			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.02	11.9	12.3	5.3	-1.46	10.8	10.8	4.7
10 m	-1.09	10.3	10.6	5.3	-1.45	8.2	9.2	4.7
20 m	-1.16	6.1	4.4	5.3	-1.38	3.9	4.5	4.7
30 m	-1.06	3.9	2.4	4.9	-1.27	2.2	2.5	4.3
50 m	-0.20	1.3	1.1	3.4	-0.47	0.4	0.7	2.4
75 m	0.9	0.6	1.1	2.4	0.9	0.3	0.3	1.1
100 m	1.9	1.4	1.8	1.9	2.0	1.0	0.8	1.1
150 m	3.7	3.3	3.6	2.6	4.4	3.3	3.0	3.2
200 m	4.9	4.5	4.7	4.2	4.9	4.6	4.5	4.5
250 m	5.4	5.1	5.3	5.0		5.3	5.2	5.2
300 m	5.5	5.4	5.4	5.3		5.4	5.4	5.4
350 m	5.5	5.4	5.4	5.4		5.4	5.4	5.4
400 m			5.3	5.4		5.5	5.4	

3 - Anticosti Channel / Chenal Anticosti

	2006				2007			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.19		14.4	6.4	-1.72	7.6	13.3	4.5
10 m	-1.20		13.1	6.4	-1.71	6.4	12.9	4.5
20 m	-1.20		4.1	6.4	-1.71	4.2	6.2	4.5
30 m	-1.16		1.9	6.4	-1.70	1.9	2.4	4.5
50 m	-1.03		0.6	5.5	-1.68	-0.3	0.2	3.1
75 m	-0.04		0.1	2.8	-0.88	-1.0	-0.3	0.4
100 m	1.1		0.3	1.1	0.5	-1.0	-0.4	0.2
150 m	3.3		3.1	1.9	3.3	-0.3	1.5	2.4
200 m	4.6		5.1	4.9	4.7	3.2	4.8	4.7
250 m			5.6	5.6			5.8	5.7

4 - Mecatina Channel / Chenal Mécatina

	2006				2007			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.50	9.9	14.9	5.1	-1.77	6.1	12.6	3.8
10 m	-1.55	7.2	14.6	5.1	-1.77	4.8	11.5	3.8
20 m	-1.62	3.0	12.3	5.1	-1.77	0.6	7.3	3.8
30 m	-1.66	1.5	7.0	5.0	-1.77	0.3	3.7	3.5
50 m	-1.71	0.2	3.5	3.9	-1.77	-0.9	1.3	3.1
75 m	-1.75	-0.5	1.3	3.0	-1.75	-1.1	0.2	2.5
100 m	-1.76	-0.6	-0.2	2.1	-1.70	-1.2	-0.5	1.6
150 m	-1.52		-0.9	0.9	-1.65	-0.9	-0.4	0.7
200 m	-1.75		0.1	0.2	-1.77	-0.1	0.9	1.3

5 - Esquiman Channel / Chenal Esquiman

	2006				2007			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-0.75	10.6	16.0	6.4	-1.71	8.1	15.0	5.1
10 m	-0.81	10.1	15.9	6.4	-1.71	8.0	14.1	5.1
20 m	-0.86	7.1	12.5	6.1	-1.71	4.1	8.4	5.0
30 m	-0.81	4.5	5.2	5.7	-1.70	1.4	2.6	4.6
50 m	-0.74	1.0	1.3	2.0	-1.62	0.0	0.4	2.6
75 m	-0.32	0.1	0.6	0.8	-1.07	-0.0	-0.0	0.6
100 m	0.8	0.5	0.7	0.9	-0.10	0.1	0.3	0.5
150 m	3.3	3.5	3.1	3.3	2.3	2.5	2.7	2.2
200 m	4.8	5.3	4.9	5.1	3.9	4.9	4.9	4.7
250 m		5.7	5.6	5.7		5.6	5.7	5.6
300 m			5.7	5.6			5.7	5.7

6 - Central Gulf / Centre du Golfe

	2006				2007			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-0.91	13.4	16.4	7.3	-1.66	9.6	15.4	5.1
10 m	-0.88	11.8	16.0	7.3	-1.66	8.4	13.5	5.0
20 m	-0.93	9.2	10.2	7.3	-1.66	6.0	6.0	5.0
30 m	-0.93	4.0	3.6	7.1	-1.66	3.4	2.7	5.0
50 m	-0.72	0.8	1.1	2.8	-1.57	0.4	0.7	2.3
75 m	0.2	0.8	0.8	1.6	-0.26	0.2	0.2	0.4
100 m	1.5	1.1	0.9	1.4	1.3	1.1	0.3	0.6
150 m	3.7	3.5	3.1	3.0	3.2	3.4	2.5	3.0
200 m	5.1	5.2	5.0	5.0	5.0	5.1	4.7	4.8
250 m		5.6	5.6	5.6		5.6	5.6	5.5
300 m		5.5	5.6	5.6		5.6	5.6	5.5
350 m		5.2	5.3	5.4		5.4	5.4	5.4
400 m		5.1	5.1	5.2		5.3	5.2	5.3
450 m			5.1	5.1		5.1	5.1	5.1

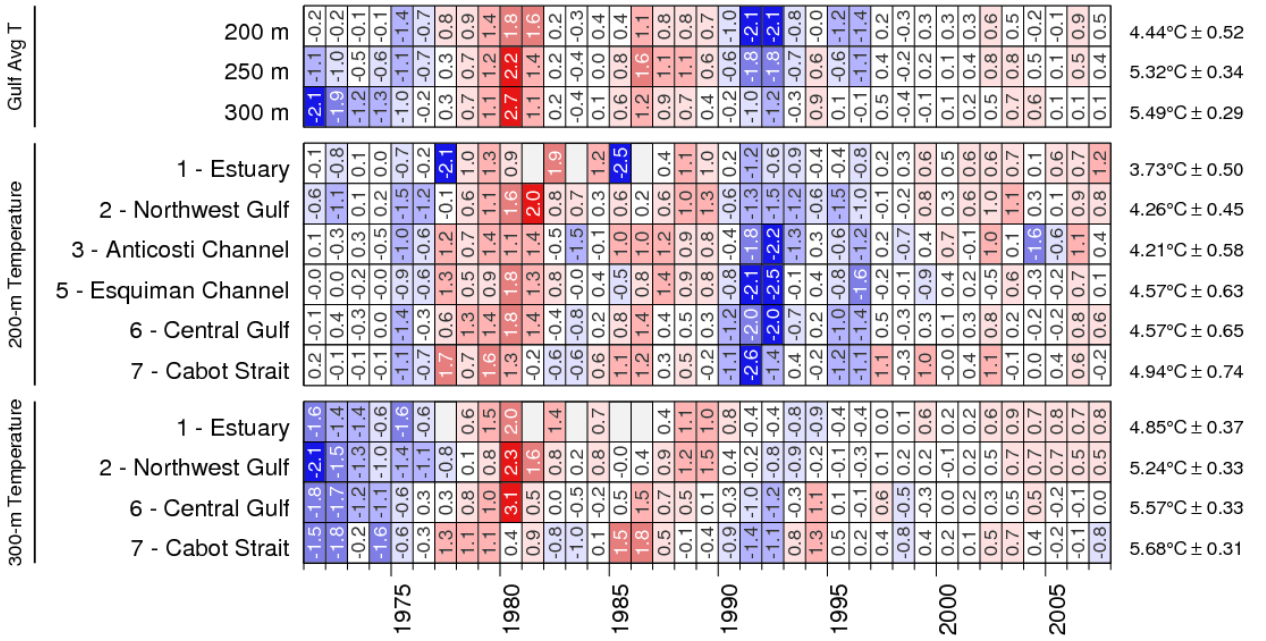
7 - Cabot Strait / Détroit de Cabot

	2006				2007			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.13	13.4	15.5	7.8	-1.39	10.2	17.0	7.4
10 m	-1.15	12.3	13.9	7.8	-1.43	9.1	13.1	7.3
20 m	-0.98	7.7	6.8	7.6	-1.40	4.2	6.1	7.0
30 m	-0.82	3.7	3.2	7.5	-1.38	2.2	3.2	6.6
50 m	-0.68	1.6	1.7	5.0	-1.33	0.9	1.3	4.5
75 m	-0.13	1.3	1.4	2.4	-0.95	0.7	0.9	2.3
100 m	0.8	1.6	1.8	1.8	-0.44	1.1	0.9	1.3
150 m	3.4	4.1	4.3	2.9	2.8	2.7	3.2	3.0
200 m	5.6	5.8	5.5	5.0	4.8	4.5	4.9	4.8
250 m		5.9	5.8	5.9		5.4	5.5	5.4
300 m		5.6	5.6	5.8		5.5	5.4	5.5
350 m		5.3	5.3	5.4		5.3	5.2	5.3
400 m		5.0	5.1	5.2		5.1	5.1	5.2
450 m		5.0	5.0	5.1		4.9	4.9	5.0
500 m			5.0	5.0			4.8	4.9

8 - Magdalen Shallows / Plateau Madelinien

	2006				2007			
	Mar	June	Sep	Nov	Mar	June	Sep	Nov
0 m	-1.34	14.8	15.9	6.2	-1.60	11.7	14.3	7.1
10 m	-1.45	12.0	15.8	6.2	-1.62	9.8	14.1	7.0
20 m	-1.46	4.4	12.3	5.9	-1.63	5.7	12.8	7.0
30 m	-1.46	2.1	6.6	5.2	-1.65	2.3	8.0	6.7
50 m	-1.37	0.8	1.0	2.2	-1.59	0.3	1.3	4.1
75 m	-0.50	0.6	0.9	1.6	-1.55	-0.0	0.6	1.1
100 m		0.8	1.2					

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

Water temperatures in the Gulf of St. Lawrence during 2006 were generally very warm from the surface down to the base of the CIL, but this did not continue into 2007. Near-surface conditions were typically near-normal or cooler than normal in 2007, and the CIL returned to a normal core temperature and normal overall volume <1°C after 3 years of warming. 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 2008 winter survey provides an outlook for CIL conditions expected for the remainder of 2008. Figures are shown in Galbraith et al. (2008) and only descriptions are given here. The waters were near-freezing almost everywhere, the main exception being the warm water entering the Gulf on the eastern side of Cabot Strait as was also observed in many recent years. This warm layer extended to cover Esquiman Channel almost entirety. The intrusion of cold and saline water from the Labrador Shelf through the Strait of Belle Isle occupied a slightly larger area in March 2008 compared to 2007, and it extended to the surface. But since it was a thinner layer than in 2007, that translated to a lower volume of 1850 km³ (down from 2850 km³ in March 2007, but still up from 1620 km³ in March 2006). The cold layer (< -1°C) is thicker than usual south of Anticosti Island and its overall volume increased slightly from March 2007 conditions to 13.7 x 10³ km³, similar to conditions in 1996 and 1997. The relation between the cold water volume and the CIL index forecasts cooler summertime CIL conditions in 2008 with an index of -0.47°C.

SOURCES OF INFORMATION

DFO, 2007. State of the Ocean 2006: Physical Oceanographic Conditions in the Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/036.

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