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Physical Oceanographic Conditions in the Gulf of St. Lawrence in 2010

Conditions océanographiques physique dans le golfe du Saint-Laurent en 2010

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ABSTRACT

An overview of physical oceanographic conditions in the Gulf of St. Lawrence in 2010 is presented. Air temperatures reached record highs when averaged from January to March and from October through December as well as annually. The monthly averaged freshwater runoff measured at Québec City was normal overall in 2010 but was unusually high during winter and fall, and the spring freshet was almost absent. Near-surface water temperatures in the Gulf were normal or above normal all year and in all regions except for the Mécatina Trough and Esquiman Channel in June. Maximum sea-ice volume within the Gulf and on the Scotian Shelf was 11 km³, a record low since 1969. The duration of the 2009–2010 ice season was shorter than normal and associated with the early ice melt. Winter inflow of cold and saline water from the Labrador Shelf occupied the Mécatina Trough over the entire column in winter 2010. The spread of the intrusion was confined close to the Strait of Belle Isle, leading to an overall small volume of 809 km³. However, this intrusion volume represented 29% of the unusually small volume of mixed layer waters that were colder than -1°C. The winter cold mixed layer volume in the Gulf, excluding the Estuary, was 13 900 km³, a value higher than the 1996–2009 average by 0.7 SD. This cold-water volume corresponded to 42% of the total water volume of the Gulf. However, it was very warm, on average about 1°C above the freezing point. This is the first time in 15 years of winter surveys that such high temperatures were recorded. The cold intermediate layer (CIL) index for summer 2010 was -0.04°C, which is similar to observations in 2000. This is an increase of 0.38°C since 2009. On the Magdalen Shallows, none of the bottom area was covered by water with temperatures < 0°C in September 2010, similar to conditions in 2005, 2006, 2007, and 2009. In other regions of the Gulf, very few areas had bottom temperatures below 0°C. Regional patterns of the August and September CIL show that the layers for T < 1°C and < 0°C were much thinner in most parts of the Gulf in 2010 than in 2009 and had a generally higher core temperature everywhere. Conditions in March 2010 were characterized by a very thick winter mixed layer, although very warm, including a thick intrusion of Gulf waters into the Estuary. By June 2010, the CIL thickness returned to near-normal but still had above-normal minimum temperatures. The CIL warming rate appeared to be slower than usual because core temperatures were closer to normal in certain regions by August and more so by November. The warm deep waters in the Estuary in 2009 were replaced by colder-than-normal waters by June 2010. Colder-than-normal deep waters also occupied the northwest Gulf at that time. Very warm waters occupied Cabot Strait in June at 250 m—the depth of the temperature maximum—and there is a hint that the top portion of this water mass was sampled during the March survey. The warm deep waters were still present in Cabot Strait in August as well as in November. Gulf-wide average temperatures were below normal at 200 to 300 m and salinities were below normal from 150 to 300 m. Temperatures at 300 m increased marginally overall but significantly (by 1 SD) at Cabot Strait, where the anomaly is now +1 SD. Salinity at 200 m and 300 m decreased overall by 0.6 SD but increased at Cabot Strait to reach +0.6 SD at 200 m. The 300 m waters of the Estuary are expected to cool further during the next two years, but it will be interesting to follow the warm anomaly present in 2010 at Cabot Strait as it progresses up the channel toward the Estuary. The surface mixed layer in November was anomalously thick but more importantly very warm, warmer in fact than in November 2009 which were the preconditions for the record conditions of March 2010.

RÉSUMÉ

Le présent document donne un aperçu des conditions d'océanographie physique qui ont prévalu dans le golfe du Saint-Laurent en 2010. Les températures de l'air moyennées de janvier à mars, d'octobre à décembre, ainsi qu'annuellement ont atteint des niveaux records. L'apport d'eau douce mensuel moyen mesuré à Québec a été normal pour l'ensemble de l'année 2010, mais a été supérieur à la moyenne au cours de l'hiver et l'automne, ce qui fut compensé par une crue printanière presque absente. Les températures de l'eau près de la surface ont été normales ou supérieures à la normale dans l'ensemble du golfe pendant tous les mois de l'année, à l'exception de la région de la cuvette de Mécatina et du chenal Esquiman au cours du mois de juin. Le volume maximal des glaces dans le Golfe s'est établi à 11 km³, une valeur minimum depuis 1969. La durée de la saison de glace 2009-2010 a été plus courte que la normale et était associée à une fonte précoce. Les entrées hivernales d'eaux froides et salées du plateau du Labrador ont rempli entièrement la cuvette de Mécatina au cours de l'hiver 2010. La propagation de cette intrusion s'est davantage limitée près du détroit de Belle Isle et de la côte nord comparativement aux conditions observées en 2009, se traduisant par un volume global plus faible (809 km³). Ce faible volume a néanmoins représenté 29% de la couche hivernale de surface plus froide que -1 °C. Le volume de cette couche hivernale, sélectionnée avec un critère moins strict de la température, sous 0 °C au lieu de – 1 °C, était de 13 900 km³ (excluant l'estuaire). C'est une valeur supérieure de 0,7 fois l'écart type à la moyenne de la période 1996-2009, et correspondait à 42 % du volume d'eau total présent dans le Golfe. Cependant, la couche de surface hivernale était chaude, autour de 1 °C au dessus du point de congélation. Ce fut la première fois en 15 ans de monitorage hivernal que de telles conditions ont été observées. L'indice de la CIF (couche intermédiaire froide) d'été pour 2010 s'est établi à – 0,04 °C, ce qui est comparable aux conditions observées en 2000 et représente une forte augmentation (de 0,38 °C) par rapport à l'été 2009. Sur le Plateau madelinien, aucune partie du fond n'était couverte par des eaux de température < 0 °C en septembre 2010, tel qu'observé aussi en 2005, 2006, 2007 et 2009. Les profils régionaux de la CIF d'août et de septembre indiquent que les couches où T < 1 °C et < 0 °C ont été beaucoup plus minces dans la plupart du Golfe en 2010 comparativement à 2009 et que la température minimale était en général supérieure dans l'ensemble du Golfe. Les températures dans la colonne d'eau observées en mars 2010 ont été caractérisées par une couche de surface très épaisse dans la plupart des régions, mais particulièrement chaude, et caractérisée par une épaisse intrusion d'eaux du Golfe dans l'Estuaire. Dès le mois de juin, la CIF s'était amincie vers des épaisseurs normales mais avait encore des températures minimales au dessus de la normale. Le taux de réchauffement de la CIF a semblé plus faible qu'habituellement car les températures minimales de la CIF étaient près de la normale dès le mois d'août dans certaines régions, et davantage en novembre. Les eaux profondes de l'estuaire qui étaient chaudes en 2009 ont été remplacées par des eaux plus froides que la normale dès juin 2010. Des eaux très chaudes occupaient le détroit de Cabot en juin à 250 m, la profondeur du maximum de température, et il y a des signes que la partie supérieure de ces eaux a été échantillonnée en mars. Ces eaux chaudes étaient encore présentes dans le détroit de Cabot durant les relevés d'août et de novembre. Dans l'ensemble, la température a été généralement sous la normale à une profondeur allant de 200 à 300 m, tandis que la salinité était sous la normale de 150 à 300 m. Les températures à 300 m ont globalement augmenté légèrement, mais de façon significative au détroit de Cabot (par 1 écart-type) où l'anomalie atteignait +1 écart-type. La salinité à 200 m et 300 m a diminué globalemnt de 0,6 écart-type mais a augmenté au détroit de Cabot pour atteindre +0,6 écart-type à 200 m. Les eaux profondes de l'estuaire devraient se refroidir durant les deux prochaines années, l'anomalie chaude présente en 2010 dans le détroit de Cabot qui devrait remonter le chenal Laurentien vers l'estuaire par la suite. La couche de surface était épaisse et très chaude en novembre 2010, plus chaude même que les conditions de novembre 2009 qui étaient précurseurs de l'hiver record de 2010.

INTRODUCTION

This paper examines the physical oceanographic conditions and related atmospheric forcing in the Gulf of St. Lawrence in 2010 (Fig. 1). Specifically, it discusses air temperature, freshwater runoff, sea-ice volume, surface water temperature and salinity, winter water mass conditions (e.g., the near-freezing mixed layer volume, the volume of dense water that entered through the Strait of Belle Isle), the summertime cold intermediate layer (CIL), and the temperature, salinity, and dissolved oxygen of the deeper layers. Some of the variables are spatially averaged over distinct regions of the Gulf (Fig. 2). The report uses data obtained from the Department of Fisheries and Oceans' (DFO) Atlantic Zone Monitoring Program (AZMP), other DFO surveys, and other sources. Environmental conditions are usually expressed as anomalies, i.e., deviations from their long-term mean or normal conditions calculated for the 1981–2010 reference period when possible. Furthermore, because these series have different units (^{o}C, m^3, m^2, etc.), each anomaly time series is normalized by dividing by its standard deviation (SD), which is also calculated using data from 1981–2010 when possible. This allows a more direct comparison of the various series. Missing data are represented by grey cells, values within 0.5 SD of the average as white cells, and 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, but do not necessarily correspond to warmer-than-normal conditions. The last detailed report of physical oceanographic conditions in the Gulf of St. Lawrence was produced for the year 2009 (Galbraith et al. 2010). In that report, the 30-year climatology was based on 1971–2000. Since the 2001–2010 decade is now completed, the climatology is shifted by a decade and the reference period 1981–2010 is used in this report. This has the caveat that as long-term trends are incorporated into the climatology, some events that were previously considered anomalous become near normal. While this issue must be kept in mind, the advantage of the decadal shift is the increased number of data sets that will have climatologies that are based on the same period, with more recent time series that were initiated after 1971.

The summertime water column in the Gulf of St. Lawrence consists of three distinct layers: the surface layer, the cold intermediate layer (CIL), and the deeper water layer (Fig. 3). Surface temperatures typically reach maximum values in mid-July to mid-August. Gradual cooling occurs thereafter, and wind mixing during the fall leads to a progressively deeper and cooler mixed layer, eventually encompassing the CIL. During winter, the surface layer thickens partly because of buoyancy loss (cooling and reduced runoff) and brine rejection associated with sea-ice formation, but mostly from wind-driven mixing prior to ice formation (Galbraith 2006). The surface winter layer extends to an average depth of 75 m and up to 150 m in places (and even more in the northeast, where intruding waters from the Labrador Shelf at the Strait of Belle Isle may extend from the surface to the bottom [>200 m] in Mécatina Trough) by the end of March and exhibits temperatures near freezing (-1.8 to 0ºC) (Galbraith 2006). During spring, surface warming, sea-ice melt waters, and continental runoff produce a lower-salinity and higher-temperature surface layer, below which cold winter waters are partly isolated from the atmosphere and become known as the summer CIL. This layer will persist until the next winter, gradually warming up and deepening during summer (Gilbert and Pettigrew 1997) and more rapidly during the fall as vertical mixing intensifies.

This report considers these three layers in turn. First, a significant driver of the surface layer—the air temperature—is examined, followed by the freshwater runoff. The winter sea ice and winter oceanographic conditions are described; these force the summer CIL, which is presented next. The deeper waters, mostly isolated from exchanges with the surface, are presented last along with a summary of major oceanographic surveys. Quantities are often averaged over regions of the Gulf depicted in Fig. 2.

AIR TEMPERATURE

The monthly air temperature anomalies for several stations around the Gulf are shown in Fig. 4 for 2009 and 2010. Only Daniel's Harbour experienced negative anomalies in 2010, for two months during summer. Averaged over the Gulf, air temperature has been above the 1971–2000 normal between November 2009 and December 2010 except for the near-normal month of June. Shifting to the 1981–2010 climatology changes the September anomaly to near normal (+0.5 SD). This is a remarkably sustained run of positive anomalies that began with an exceptionally warm winter and that was also spatially consistent throughout the Gulf. Gulf-wide monthly average air temperatures were record highs (since 1945) in February, April, and December 2010.

The annual mean temperature time series are shown in Table 1 for the nine stations along with their 1981–2010 average. Annual mean air temperatures in 2010 were record highs at all stations (since 1945 at Sept-Îles, 1915 at Natasquan, 1983 at Blanc-Sablon, 1943 at Mont-Joli, 1969 at Gaspé, 1947 at Daniel's Harbour, 1943 at Charlottetown, 1934 at Îles-de-la-Madeleine, and 1904 at Port aux Basques). The average of the nine stations provides an overall temperature index for the entire Gulf, which was above normal in 2010 by 2.4°C (+2.5 SD)—a record-high since 1945—breaking the previous 2006 record of 1.6°C (+1.6 SD). The last negative annual anomaly occurred in 2002.

A bulk winter severity air temperature index is also shown in Table 1. This index, which was constructed by averaging the air temperatures of all stations sampled from January to March of each year, was above normal in 2010 by 4.70°C (+2.5 SD), a record high since 1945, breaking the previous 1958 record of 4.55°C (+2.4 SD). Temporally, it was composed of the third-warmest anomaly since 1945 for the month of January (4.6°C, 2.3 SD), the record-high anomaly for February (6.4°C, 2.2 SD), and the fifth-highest anomaly for March (3.2°C, 1.6 SD). Air temperatures were almost as warm in February (-3.3°C) as they were in March (-2.0°C) in absolute terms and were not much below the freezing temperature of sea water (around -1.7°C). Spatially, the winter-severity index was a record high at six stations (since 1945 at Sept-Îles, 1983 at Blanc-Sablon, 1943 at Mont-Joli, 1969 at Gaspé, 1944 at Charlottetown, 1934 at Îles-de-la-Madeleine), second highest at Natasquan (after 1958), and third highest at Port aux Basques (after 1958 and 1969).

Fig. 5 shows the annual and seasonal mean air temperature anomalies averaged over the nine stations since 1945. Again, this shows the record-high 2010 annual and winter conditions, third-warmest spring conditions, and above-normal summer conditions. The fall conditions were also a record high since 1945, characterized by very warm air temperatures in December 2010 that did not even fall below 0°C averaged over the nine stations. This is very warm pre-conditioning of the 2011 winter mixed layer.

A warming trend in the annual air temperature since 1971 does not persist when the time series is considered back to 1945; however, a warming trend of 0.8 to 2°C per 100 years is found for Pointe-au-Père and Charlottetown between the 1880s and the early 1950s (not shown).

PRECIPITATION AND FRESHWATER RUNOFF

Runoff data for the St. Lawrence River were obtained from the St. Lawrence Global Observatory (http://ogsl.ca/en/runoffs/data/tables.html), where they are updated monthly (Modelling and Operational Oceanography Division, Canadian Hydrographic Service, Maurice Lamontagne Institute, Fisheries and Oceans Canada) using the water level method from Bourgault and Koutitonsky (1999). The annual average runoff measured at Québec City was close to normal overall in 2010 (Fig. 6), but consisted of above-normal runoff in February and March during the mild winter and exceptionally high runoff in October and December. These high runoffs were compensated by the absence of the usual April–May spring runoff peak followed by very low runoff throughout the summer. In absolute terms, the December runoff was surprisingly higher than the spring freshet in 2010 and even surpassed the March runoff.

The shift in the climatology reference period from 1971–2000 to 1981–2010 resulted in substantial changes because the runoff has been decreasing since the early 1970s. The decade with the highest runoff (1971–1980) was removed and replaced by one with below-average values (2001–2010). The annual climatological mean decreased from 12 500 to 12 000 m^3s^{-1}, and the spring freshet decreased from 17 400 m^3s^{-1} (SD 2 700 m^3s^{-1}) to 16 400 m^3s^{-1} (SD 2 600 m^3s^{-1}).

A hydrological watershed model was used to estimate the monthly runoff since 1948 for all major rivers flowing into the Gulf of St. Lawrence, with discharge locations as shown in Fig. 7. The precipitation data (NCEP reanalysis, six hourly intervals) used as input in the model were obtained from the NOAA-CIRES Climate Diagnostics Center (Boulder, Colorado, USA; Kalnay et al. 1996). The data were interpolated to a ¼° resolution grid and the water routed to river mouths using a simple algorithm. When air temperatures were below freezing, the water was accumulated as snow in the watershed and later melted as a function of warming temperatures. Runoffs were summed for each region shown and the climatology established for the 1981–2010 period. Monthly anomalies of the summed runoffs for 2009 and 2010 are shown in *Table 2*. Rivers other than the St. Lawrence contribute another 5 000 m^3s^{-1} runoff to the Estuary, the equivalent of 40% of the St. Lawrence River, while the other tributaries distributed along the border of the GSL provide an extra 3 500 m^3s^{-1} in freshwater runoff to the system. The 2010 data show that other rivers behaved similarly to the St. Lawrence River, with lower-than-normal runoff in summer and much higher than normal in the fall, although summer runoffs were high for rivers flowing into Mécatina Trough.

SURFACE LAYER

The surface layer conditions of the Gulf are monitored by various complementary methods. The shipboard thermosalinograph network typically provides year-round, near real-time coverage and is especially useful for monitoring the winter freeze-up and the evolution of the spring thaw. Its drawbacks are that it provides data only along the main shipping route and that semi-weekly ship tracks are irregular both in time and in the position where each longitude is crossed. The second data source is the thermograph network. It provides an inexpensive, growing record of near-surface temperatures at fixed stations and at short sampling intervals, but not (for the most part) in real-time nor during winter months. However, its coverage of the southern and northeastern Gulf, areas not sampled by the thermosalinograph network, is very informative. It also provides station climatologies based on more years of data than the thermosalinograph network. NOAA satellite remote sensing, the third tool, provides 1 km spatial resolution of ice-free waters with data back to 1985.

Before showing results specific to 2010, let us examine the climatology expected for the region. The expected May to November cycle of weekly averaged surface temperature is illustrated in Fig. 8 using a 1985–2010 climatology based on AVHRR remote sensing data for ice-free months complemented by 2001–2010 thermosalinograph data for the winter months. Maximum temperatures are reached on average during the second week of August but can vary by up to several weeks from year to year. The maximum surface temperature averages 15.6ºC over the Gulf during the second week of August (1985–2010 average), but there are spatial differences: temperatures on the Magdalen Shallows are the warmest of the Gulf, averaging 18.1ºC over the area, and the coolest are at the head of the St. Lawrence Estuary and upwelling areas along the lower North Shore. Thermosalinograph data (not shown) have demonstrated that the cooling of offshore surface waters of the Gulf during fall and winter first reaches near-freezing temperatures in the Estuary, then progresses eastward with time, usually just reaching Cabot Strait by the end of the winter. The exception is the head of the St. Lawrence Estuary (Fig. 8), where the upwelling and mixing of the CIL to the surface layer keep the waters cool in summer and well above freezing in winter.

SHIPBOARD THERMOSALINOGRAGHS

The shipboard thermosalinographs were described by Galbraith et al. (2002) and by Gilbert et al. (2004). To summarize, thermosalinographs (SBE-21; Sea-Bird Electronics Inc., Bellevue, WA) have been installed on various ships starting with the commercial ship *Cicero* of Oceanex Inc. in 1999 (retired in 2006) and now on the *Cabot* since 2006. Oceanex ships sail year-round between Montréal, QC, and St. John's, NL, making a return trip once per week. Near-surface (3 m) water temperature and salinity are sampled using the shipboard thermosalinographs.

Fig. 9 shows a mean annual cycle of water temperature at a depth of 3 m along the Montréal to St. John’s shipping route based on data collected from 2000 to 2010. Data were used from any instrumented ship within the main shipping route area to fill data gaps. 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. 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 (Galbraith et al. 2002). The progression to winter conditions is shown to first reach near-freezing temperatures in the Estuary and then progress eastward with time, usually just reaching Cabot Strait by the end of the winter.

Fig. 9 also shows the water temperature composite for 2010 and its anomaly. Unfortunately, the *Cabot* was in dry-dock during the early winter, so winter coverage begins only in mid-February. Nevertheless, the data show that near-surface water temperatures were above normal in late winter until mid-June. The Gulf near-surface waters in March were generally between 0.5°C and 1°C above normal, where normal is usually near freezing at this time of year. Such a temperature difference is very signficant at this time of year. This was followed by a brief colder-than-normal period until early August except for warmer conditions in the Estuary in July. Next, except for cold conditions in the Estuary in August, most of the of the ship track in the Estuary and Gulf experienced warmer-than-normal conditions until the end of 2010, notwithstanding missing data between mid-October and mid-December. The summer maximum temperatures were much higher than usual. The existence of warm anomalies of over 1.5°C at the beginning of winter is a substantial preconditioning of the winter mixed layer if the fall mixed layer is thick.

Temperature anomaly time series and 2000–2010 climatologies were constructed for selected sections that are crossed by the ship. Although the anomalies are quite similar between the two sections, Table 3 shows how different the near-surface temperature climatologies are at Tadoussac (head of the Laurentian Trough) compared with those nearby in the Estuary, as noted above. Winter temperatures are on average 0.7°C warmer at the Tadoussac section; the maximum monthly mean temperature in summer is only 6.5°C compared with 8.4°C at the nearby Estuary section and up to 13.2°C at the Mont-Louis section. The table provides a quick look at the interannual near-surface temperature variations at the selected sections as well as monthly averages for the year in review. The table highlights the same patterns described from Fig. 9.

THERMOGRAPH NETWORK

The thermograph network, described in detail in previous reports (Gilbert et al. 2004, Galbraith et al. 2008), consists of a number of stations with moored instruments recording water temperature every 30 minutes (Fig. 10). 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 data are typically only available after the instruments are recovered except for the five oceanographic buoys that transmit data in real-time. Data from Shediac station acquired by the DFO Gulf Region are also shown.

In order to compare the 2010 observations to temperature measurements from previous years, climatological daily average temperatures were calculated using all available data for each day of the year at each station and depth. Daily averages for all stations are shown in Fig 11, 12, and 13 along with daily climatologies (± 1 SD; shown in blue). Monthly average temperatures are also shown, with the magnitude of their anomaly colour-coded. Table 4 repeats these average monthly temperatures for each station at shallow sampling depths (< 20 m) for 2009 and 2010.

Monthly anomalies were fairly consistent across all stations of each of the three regions listed in Table 4, although there is a northeast gradient toward cooler anomalies along the lower north shore. May to October near-surface water temperatures were generally normal to above normal in the Estuary and northwest Gulf (top panel) as well as in the Southern Gulf (bottom panel), where summer temperatures were overall much warmer than during the summer of 2009. The three stations recording winter temperatures showed above-normal temperatures from January to May, consistent with the record-high winter air temperatures.

Table 5 shows information similar to Table 4, but for thermograph sensors moored deeper than 20 m. The deep (> 300 m) waters of the Estuary and northwest Gulf show below-average temperatures in 2010.

Table 6 shows the history of monthly averaged temperature anomalies for selected stations both in the northeastern and southern Gulf. The cold period from 1993 to 1998 (except 1996) is evident at Île Shag (as it was for air temperature in Table 1), and this long record helps to put the current year into perspective. In the summer of 2010, near-surface temperatures were generally normal to above normal except for below-normal temperatures recorded at Blanc-Sablon.

NOAA SATELLITE SST

The 2010 quasi-monthly mean sea-surface temperatures are shown in Fig. 14 as colour-coded maps, and temperature anomalies with respect to the 1985–2010 monthly climatology are shown in Fig. 15. These maps are generated using National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) satellite images available from the Maurice Lamontagne Institute sea-surface temperature processing facility. The raw data acquired by the three DFO and four NOAA satellite receiving stations are processed using the Terascan software to detect clouds, correct navigation errors, and project the results onto a national geo-referenced grid of 1 km resolution covering all Canadian waters. The processing also includes a temporal consistency check using sequences of individual images. Mean sea-surface temperatures at each grid node are then calculated for every averaging period of 1, 3, 5, and 7 days. Here, the area covering the Gulf is extracted from four successive 7-day-mean images for each month and are averaged together to produce a mean for the first 28 days of each month, hence the quasi-monthly mean. The anomalies are shown only for the months of May to November when coverage is complete, because ice cover biases the results for the other months (even though December has been ice-free in recent years, it would be difficult to construct a valid climatology). April is included only for the usually ice-free Estuary and Northwest Gulf.

Fig. 15 is in relative agreement with the thermograph measurements that have climatologies spanning fewer years. The Gulf had its coolest anomalies in June while the Estuary was still above normal. The thermosalinograph cool anomalies in the Estuary in August were from ship tracks that did not pass through the warmer coastal areas seen on the SST images.

The NOAA SST information is summarized on Table 7, showing the 2009 and 2010 monthly surface temperature anomalies spatially averaged over the Gulf and over each of the eight regions delimited by the areas shown in Fig. 2, and further into sub-regions of the Estuary as shown in Fig. 16. Near-surface water temperatures in the Gulf were normal or above normal all year and in all regions except for the Mécatina Trough and Esquiman Channel in June, in partial agreement with near-normal air temperatures at Blanc Sablon and Daniel’s Harbour. Gulf and surface water temperatures were above normal everywhere in August, consistent with the warm air temperatures.

Table 8 and Table 9 show the full 1985–2010 time series of monthly surface temperature anomalies spatially averaged over the Gulf of St. Lawrence and over the eight regions of the Gulf. These results show that, over the spatial scale of the Gulf, the warm anomalies observed in 1999 and 2006 are still exceptional. While none of the regions exhibited outstanding conditions in 2010, most regions did not experience a single month with below-normal surface temperatures and only two experienced one month with below normal conditions, both in June.

Sea-surface temperature monthly climatologies and time series were also extracted for more specific regions of the Gulf. The monthly average SST for the St. Lawrence Estuary as a whole (region 1) is repeated in Table 10 along with averages for the Manicouagan Marine Protected Area (MPA), the St. Lawrence Estuary MPA, and the Saguenay – St. Lawrence Marine Park (Fig. 16). The overall pattern is similar across regions, but there are differences associated with episodic local events such as eddies and upwellings. The climatology averages also differ. For example, the Manicouagan maximum monthly average temperature is 0.8°C warmer than for the Estuary as a whole. The common feature among most regions for 2009 is the positive anomaly in August.

The Magdalen Shallows, excluding Northumberland Strait, is divided into western and eastern areas as mapped on Fig. 17. The monthly average SST for the Magdalen Shallows as a whole (region 8) is repeated in Table 11 along with averages for the western and eastern areas. Climatologies differ by roughly 0.5°C to 1°C between the western and eastern regions. The common features among regions are the positive anomalies in May and June, negative anomaly in July, followed by a positive anomaly in August, normal conditions for September and October, and positive anomalies in November.

An interesting new product this year is the number of weeks in the year that the mean weekly temperature is above 10°C for each pixel (Fig. 18, Table 12). This integrates summer surface temperature conditions into a single map displaying the length of the warm season. The anomalies of the number of weeks for 2010 are shown in Fig. 19. The Estuary had near-normal to below-normal summer surface temperature conditions while the rest of the Gulf experienced a near-normal to above-normal number of weeks with mean surface temperatures above 10°C.

SEA ICE

Ice volume is estimated from a gridded database of ice cover and ice categories obtained from the Canadian Ice Service, consisting of weekly files for 1969–1997 and daily files thereafter. Standard average thicknesses are attributed to each ice category to estimate the volume. Sea ice is typically produced in the northern parts of the Gulf and drifts towards Îles-de-la-Madeleine and Cabot Strait during the ice season. The maximum ice thickness that occurred in 2010 is shown in Fig. 20 and compared with previous minimum and maximum conditions observed in 1969 and 2003 (2010 will set a new minmum record). The combined Gulf and Scotian Shelf ice volume shown in the top panel of Fig. 21 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 highest ice volumes of the time series occurred in 2003 followed closely by 1993. The volume shown on the bottom panel of Fig. 21 corresponds to that found seaward of Cabot Strait. It would represent the volume of ice exported from the Gulf provided that no melt had already occurred. Table 13 shows the day of first and last occurrence of ice in each of the regions of the Gulf of St. Lawrence, extracted from the same database, as well as duration of the ice season and maximum observed volume during each season. Caution should be used in over interpreting the table since the database from which it is produced is coarse in time resolution (weekly) up to 1997.

The correlation between annual maximum ice volume and the winter severity air temperature index (i.e. January-March average), both repeated in Table 14, accounts for 68% of the variance using the 1969–2010 time series.

In 2010, the Gulf and Shelf maximum ice volume was 11 km³, the record low of the 1969–2010 time series. No ice was exported from the Gulf of St. Lawrence onto the Scotian Shelf. This record is consistent with the record-high winter severity air temperature index (the January to March air temperature average). The duration of the 2009–10 ice season was shorter than usual in all regions, mostly associated with the early retreat of ice (Table 13). The duration was not defined for the Central Gulf and Cabot Strait regions because ice never exceeded 5% of the largest volume recorded in these regions.

The 1981–2010 climatological mean maximum ice volume of 70.8 km³ indicates a decrease from the 76.6 km³ mean for 1971–2000, but the variability has increased with an SD of 30.2 versus 23.7 km³.

WINTER WATER MASSES

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. This has added a considerable amount of data to the previously very sparse winter data for the region. The survey, sampling methods, and results concerning the cold-water volume formed in the Gulf and the estimate of the water volume advected into the Gulf via the Strait of Belle Isle over the winter are described in Galbraith (2006) and in Galbraith et al. (2006). Eighty-nine stations were sampled during the 8–16 March 2010 survey using 41.6 flight hours. Fig. 22 and Fig. 23 show gridded interpolations of near-surface temperature, temperature above freezing, salinity, cold layer thickness and where it contacts the bottom, and thickness of the Labrador Shelf water intrusion for 2009 and 2010. Interpolations for all years were reanalyzed for this report using the new 500 m resolution bathymetry grid and now include the Estuary.

The surface mixed layer is usually very close (within 0.1°C) to the freezing point in many regions of the Gulf in March, but for the first time in the 15 years since the inception of this winter survey this was not the case in 2010, when the mixed layer was on average 1°C above freezing. During typical winters, surface waters in the temperature range of ~ 0°C to -1°C are only found on the northeast side of Cabot Strait, entering the Gulf and flowing northward along the west coast of Newfoundland. This inflow was also much warmer than usual in 2010 and affected a very large area, reaching Anticosti Island. During previous mild winters, near-surface waters still reached near-freezing temperatures and it was the layer thickness that varied, leading to variability in the cold-water volume between mild and severe winters. The mixed layer during March 2010 was thicker than normal in spite of mild conditions, an unusual combination possibly caused by stronger winds over the Gulf. This remains to be fully investigated.

Near-freezing waters with salinities of around 32 are responsible for the (local) formation of the CIL since that is roughly the salinity at the temperature minimum during summer. These are coded in blue in the salinity panel of Fig. 22 and are typically found to the north and east of Anticosti Island but occupied less area in 2010 because surface salinities were generally lower than usual in the Gulf.

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 (Galbraith 2006) and are presumed to have been advected from the Labrador Shelf through the Strait of Belle Isle. These waters occupied the surface only near the Strait of Belle Isle and occupied a thin submerged layer in the southwestern Mécatina Trough (top panels of Fig. 23). The recent history of Labrador Shelf water intrusions is shown in Fig. 24, where its volume is shown as well as the fraction it represents of all the cold-water volume in the Gulf. The volume was below normal in March 2010, at 809 km³ (-0.7 SD), but the percentage of cold water it represents was high, at 29% (+1.7 SD), owing to the low overall cold-water (< -1°C) volume.

The cold mixed layer depth typically reaches about 75 m in the Gulf and is usually delimited by the -1°C isotherm because the mixed layer is typically near-freezing and deeper waters are much warmer, such that little water has temperatures in the vicinity of -1°C. But in 2010 much of this layer was warmer than -1°C such that the criterion of T < 0°C was also used (see middle panels of Fig. 23). The cold surface layer is the product of local convection as well as cold waters advected from the Labrador Shelf, and can consist either of a single water mass or of layers of increasing salinity with depth. Integrating the cold layer depth over the area of the Gulf (excluding the Estuary) yields a < -1°C record low cold-water volume of 2 800 km³, mostly adjacent to the Labrador Shelf intrusion. The mixed layer volume jumps to 14 600 km³ when water temperatures < 0°C are considered, 13 900 km³ when the waters present in the Estuary are excluded. This is somewhat surprising, considering the near-normal winter air temperatures, and is about the same as the winter 2009 volume of water < -1°C. This volume of cold water corresponds to 42% of the total water volume of the Gulf (33 300 km³, excluding the Estuary). The time series of winter cold-water (< -1°C) volume observed in the Gulf (excluding the estuary) is shown in Table 14.

Of particular note again for 2010 is the very thick cold layer observed in the Estuary. Winter surface waters formed within the Estuary have lower salinity than those formed in the Gulf (Galbraith 2006). Below this surface layer, and separated by a thin warm layer, a thick cold layer was observed. It had salinities associated with the winter cold surface layer of the Gulf and was presumably being advected upstream by estuarine circulation. This type of intrusion towards the head of the Channel normally occurs later in the spring but was also observed in March 2009.

COLD INTERMEDIATE LAYER

PREDICTION FROM THE MARCH SURVEY

The summer CIL minimum temperature index (Gilbert and Pettigrew 1997) has been found to be highly correlated with the total volume of cold water (< -1°C) measured the previous March (Galbraith 2006). 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 relation is shown in Fig. 25 but cannot be applied directly to the anomalously warm conditions recorded in March 2010 because the layer was not near freezing; it had a head-start in warming toward summer conditions. The volume of water with T < 0°C, also shown in Fig. 25, was considered to represent the mixed layer volume for March 2010. The corresponding CIL index prediction was then offset by the estimated average difference in temperature of the mixed layer between the anomalously warm 2010 conditions and that of more typical winters. Simply using the mixed layer temperature of all CTD casts yields a temperature difference of 0.75°C, but there is a sampling bias toward the cold conditions of Mécatina Trough. Although a thorough estimation over all the volume has not yet been computed, a more typical temperature difference is likely closer to 1°C. Thus the mixed layer volume (13 900 km³, excluding the Estuary) observed in March 2010 gives a CIL minimum temperature index forecast of between +0.25°C and +0.5°C based on the correlation between the winter cold-water volume and the summertime CIL index for 1996–2009 (excluding 1998) and a temperature offset. However, the correlation used for the prediction assumes that the CIL core temperature is related to the volume of the layer, the mecanism being that a thicker layer protects its core temperature from erosion. Usually, warm CIL layers have been produced from thin winter layers, but the winter mixed layer in 2010 was very thick. It is therefore possible the warming rate may have been reduced in 2010.

Part of the CIL index variability is associated with the volume of the Labrador Shelf water intrusion. Indeed, although the linear relation between winter cold-water volume and the summer CIL index implies that the 809 km³ intrusion accounts for a 0.1°C cooling of the CIL index, the 2 800 km³ of water with T < -1°C are likely a product of mixing with Labrador Shelf water and that volume accounts for a 0.5°C cooling of the CIL index.

UPDATE OF THE AUGUST CIL TIME SERIES BASED ON THE MULTI-SPECIES SURVEY

The CIL minimum temperature and the CIL thickness and volume for T < 0°C and <1°C were estimated using temperature profiles from all sources for August and September. Most data come from the multi-species surveys in September for the Magdalen Shallows and August for the rest of the Gulf. The CIL minimum temperature grid was calculated by first finding the minimum temperature and its depth for each profile. Each cast must have at least some data between 30 and 120 m to be considered. The temperature minimum is defined as simply the lowest recorded temperature for casts with data >100 m. For shallower casts, a temperature minimum is considered only if the temperature rises by at least 0.5°C below the minimum. The CIL minimum temperatures and core depths are then interpolated to a regular grid; a mask of where a CIL core was found is also interpolated. This interpolated minimum temperature grid is then checked at every grid point. Interpolated minimum temperatures are removed (and blanked) from the grid if the interpolated core depth is deeper than local bathymetry or if the interpolated core-presence mask implies that there should be no CIL core at the location.

CIL thickness was calculated by interpolating both the over- and underlying CIL isotherms on a regular grid and then checking the bathymetry at every grid point to see if the interpolated isotherms reached the bottom. If so, the thickness at the grid point was reduced appropriately.

Fig. 26 shows the gridded interpolation of the CIL thickness < 1°C and < 0°C and the CIL minimum temperature for August–September 2009 and 2010. The CIL thickness < 1°C and < 0°C was generally less in 2010 than in 2009 and had a generally warmer core temperature. 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 region for each year. The time series of the regional CIL volumes are shown in Fig. 27 (for < 0°C and < 1°C) and in Table 14 (for < 1°C). All regions show a decreased CIL (<1°C) volume in 2010 compared to 2009, except for very slight increases in the Northwest. Fig. 28 shows the average CIL core temperature and the total volume of CIL water (< 0°C and < 1°C) of the August–September interpolated grids (e.g., Fig. 26). The CIL volume as defined by either temperature decreased significantly compared to 2009 conditions and reached a near record-low value in the case of the volume delimited by 0°C.

The time series of the CIL regional average minimum core temperatures are shown in Fig. 29. All regions show an increase in core temperature for the second consecutive year. The 2010 average temperature minimum over the entire interpolated grid was +0.12°C and is shown in Fig. 28 (bottom panel, blue line). This is an increase of 0.32°C since 2009 and of 0.67°C since 2008. The overall 2010 CIL water mass properties were similar to those observed in the record years of 2000 and 2006.

UPDATE OF THE GILBERT AND PETTIGREW (1997) CIL INDEX BASED ON ALL AVAILABLE DATA

The Gilbert and Pettigrew (1997) CIL index is defined as the mean of the CIL minimum core temperatures observed between 1 May and 30 September of each year, adjusted to 15 July. It was updated using all available temperature profiles measured within the Gulf between May and September inclusively since 1947 (black line of the bottom panel of Fig. 28, and Table 14). As expected, the CIL core temperature interpolated to 15 July is almost always colder than the estimate based on August and September data for which no temporal corrections were made. This is because the CIL is eroded over the summer and therefore its core warms over time.

This CIL index for summer 2010 was -0.04°C. The 0.38°C increase from the summer 2009 CIL index of -0.42°C is consistent with the sharp decrease in CIL volume between August 2008 and 2009 discussed above and with the increase of 0.32°C in the areal average of the minimum temperature in August. This large increase of the index makes it above normal by 0.9 SD.

The CIL index forecasted from the March survey did not materialize in spite of a large increase in the index. As suggested above, the dynamics of the evolution of the winter mixed layer and CIL appear to have been different from previous years due to the very thick yet warm nature of the layer, presumably reducing the temperature gradients and the associated heat fluxes and mixing rates.

BOTTOM WATER TEMPERATURES

Bottom temperatures are obtained for all regions of the Gulf by combining all available CTD data from August and September, thus including the multispecies surveys for the northern Gulf in August and for the Magdalen Shallows in September. An interpolation scheme is used to estimate temperature at each 1 m interval on a 2 km resolution grid; bottom temperature is then estimated at each point by looking up the interpolated temperature at the depth level corresponding to a bathymetry grid provided by the Canadian Hydrographic Service. The method is fully described in Tamdrari et al. (ISMER, unpublished manuscript). A climatology was obtained by averaging all maps since 1985, when coverage of the entire Gulf became regularly adequate for such a calculation; suitable data are available since 1971 for the Magdalen Shallows.

Bottom temperatures typically range from <0°C to >18°C and are mostly depth dependent. The Mécatina Trough nevertheless stands out, with very cold bottom waters in a wider range of water depth due to the intrusion of cold Labrador Shelf waters (*Fig. 30*). The coldest areas are those covered by the CIL and temperatures <1°C, which have slowly warmed since the previous winter. These typically occur in the 50–120 m range. This includes the Magdalen

Shallows, where bottom temperature anomalies were generally positive (*Fig. 31*). The coastal anomalies must be viewed with caution because of high temporal variability of bottom temperatures at depths close to the thermocline. At these depths, the mixed layer may extend to the bottom one day and not on the next, perhaps in response to wind forcing.

Time series of the bottom area covered by various temperature intervals were estimated from the gridded temperature data (Fig. 32 and Fig. 33). Unlike the very cold conditions observed on the bottom in 2008, almost none of the bottom of the Magdalen Shallows was covered by water with temperatures < 0°C in 2010; this condition is similar to those in 2005, 2006, 2007, and 2009. The time series of areas of the Magdalen Shallows covered by water colder than 0, 1, 2, and 3°C are also shown in Table 14. Waters colder than 0, 1, and 2°C covered less of the bottom than normal in 2010.

In many other regions of the Gulf, no bottom area was covered by waters colder than 0°C in 2010 (Fig. 32 and Fig. 33). Even in the Anticosti Channel and Mécatina Trough—areas affected by the winter intrusion of cold Labrador Shelf water—bottom areas with this temperature range were considerably reduced compared to previous years. The reader is cautioned that temperature variability is much lower in the deeper waters, meaning that the white areas in the Laurentian Channel may not all represent normal temperatures even though they are within 0.5°C of the mean climatology. In spite of this, the deep bottom waters were warmer than normal in Cabot Strait and colder than normal in Esquiman and Anticosti channels as well as in the Laurentian Channel beginning north of the tip of Gaspé Peninsula. The figures also show compression of the bottom habitat area in the temperature range of 5–6°C in 1992, but there was no similar remarkable event in 2010. Because deep water temperature variability is much lower than nearer to the surface, the bottom water temperature map from Fig. 30 was redone in Fig. 34 using the deep water temperature scale used for Fig. 32. This highlights deep variability, for example in Esquiman Channel.

Another long-standing assessment survey covering the Magdalen Shallows takes place in June for mackerel. Temperature profiles from these surveys have been objectively interpolated on a regular grid. Table 15 shows the time series of depth-layer temperature averages over the interpolation grids at 0, 10, 20, 30, 50 and 75 m for all years when interpolation was possible, as well as SST June averages since 1985, for both western and eastern regions of the Magdalen Shallows as shown in Fig. 17. This analysis again shows that near-bottom waters were warmer in 2010 than in 2009, reaching above-normal values in June. Anomalies were warmer on the eastern shelf than on the western shelf.

SEASONAL AND REGIONAL AVERAGES OF TEMPERATURE PROFILES

In order to show the seasonal progression of temperature profiles, regional averages are shown in Fig. 35 through Fig. 38 based on the data collected during the March helicopter survey, the June AZMP and mackerel surveys, the August multi-species survey (September survey for region 8), and the November AZMP survey, but including all archived CTD data for those months. The temperature scale was adjusted to highlight the CIL and deep-water features; the display of surface temperature variability is best suited to other tools such as remote sensing and thermographs. During the surveys, a total of 89 CTD casts in March, 205 casts in June, 140 casts in August, 177 in September, and 67 in November were obtained. The discontinuities near 175 m in the 2009 average temperature profile for Mécatina Trough are caused by the large horizontal gradient in deep water properties there, sampled by only three deep casts that end at different depths.

Monthly temperature and salinity climatologies for 1981–2010 were constructed for various depths using a method similar to that used by Petrie et al. (1996) but using the geographical regions shown in Fig. 2. All available data obtained during the same month within a region and close to each depth bin are first averaged together for each year. Monthly averages from all available years and their standard deviations are then computed. This two-fold averaging avoids the bias that occurs when the numbers of profiles in any given year are different. The temperature climatologies are shown in grey as the mean value ± 1 SD (Fig. 35–38).

The March water temperature conditions were discussed at length in earlier sections and are included here for completeness (Fig. 35), but caution is needed in interpreting the mean profiles. Indeed, regional averaging of winter profiles does not work very well in the northeast Gulf (regions 4 and 5) because very different water masses can be averaged together: the cold Labrador Shelf intrusion with saltier and warmer deeper waters of Esquiman Channel. For example, the sudden temperature decrease near the bottom of Mécatina Trough for the 2010 regional average resulted from the deepest cast used in the average, which contained colder Labrador Shelf intrusion water. Large changes near 200 m are due to our usual sampling cutoff near 200 m for the March airborne survey, with some casts being slightly deeper than others. In particular, the unusual shift in temperature below 200 m in the mean profiles for the Estuary (region 1) and Northwest Gulf (region 2) appears because only one station in each region, the Rimouski and Anticosti Gyre AZMP stations, respectively, is sampled beyond 200 m. The highlights of March water temperatures shown in Fig. 35 are the previously discussed winter mixed layer, with temperatures atypically well above freezing and thickness also above normal, as well as a thick cold layer intrusion from the Gulf in the Estuary.

Temperatures in June 2010 (Fig. 36) were characterized by CIL conditions that were normal in thickness but still had above-normal minimum temperatures. The warm deep waters that still persisted in the Estuary a year earlier were replaced by colder-than-normal waters. These were also observed by the deep (> 300 m) stations of the thermograph network, at the Rimouski and Anticosti Gyre stations (Table 5). Colder-than-normal deep waters also occupied the northwest Gulf. Very warm waters occupied Cabot Strait in June at 250 m, the depth of the temperature maximum. There is a hint that the top portion of this water mass was sampled during the March survey, but cast depths are limited to 200 m in this area because of helicopter refueling constraints. The warm deep waters were still present in Cabot Strait in August and November. The CIL warming rate appeared to be slower than usual because its core temperature was closer to normal in certain regions by August (Fig. 37) and more so by November (Fig. 38), perhaps explaining why the CIL prediction from the March survey never materialized. By November the surface mixed layer was anomalously thick but, more importantly, very warm. This winter mixed layer is even milder than that observed during fall 2009. Average discrete-depth layer conditions are summarized for the months of the 2009 and 2010 AZMP surveys in Table 16.

The changeover from the 1971–2000 to 1981–2010 climatologies has amplified the normalized anomalies because the standard deviations have mostly decreased in the new climatologies. Climatological mean salinities have remained mostly unchanged, but mean temperatures have increased in the surface mixed layer in most areas as well as below 200 m in the estuary and northwest Gulf. The normal conditions and cold anomalies found in the near-surface and deep waters of the Estuary and northwest Gulf would have been respectively above-normal and normal according to the 1971–2000 climatology.

DEEP WATERS (> 150 m)

The deeper water layer (>150 m) below the CIL originates at the entrance of the Laurentian Channel at the continental shelf and circulates towards the heads of the Laurentian, Anticosti, and Esquiman channels without much exchange with the upper layers. The layer from 150 to 540 m is characterized by temperatures between 1 and 6.5°C and salinities between 32.5 and 35 (e.g. Fig. 39). Interdecadal changes in temperature, salinity, and dissolved oxygen of the deep waters entering the Gulf at the continental shelf are related to the varying proportion of the source cold–fresh / high dissolved oxygen Labrador Current water and warm–salty / low dissolved oxygen slope water (McLellan 1957, Lauzier and Trites 1958, Gilbert et al. 2005). These waters travel from Cabot Strait to the Estuary in roughly three to four years (Gilbert 2004), decreasing in dissolved oxygen from in situ respiration and oxidation of organic material as they progress to the channel heads. The lowest levels of dissolved oxygen are therefore found in the deep waters at the head of the Laurentian Channel in the Estuary.

TEMPERATURE AND SALINITY

The calculation of monthly temperature and salinity climatologies mentioned earlier using a method similar to that of Petrie et al. (1996) also provides time series of monthly averaged values. These monthly averages were further averaged into regional yearly time series that are presented in *Table 17* for 200 and 300 m. The 300 m observations in particular suggest that temperature anomalies are advected up-channel from Cabot Strait to the northwestern Gulf in two to three years, consistent with the findings of Gilbert (2004). 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 averages are shown for 200, 250, and 300 m in *Table 17* as well as for 150, 200, and 300 m in Fig. 39.

In 2010, the gulf-wide average temperatures were below normal at 200 to 300 m and salinity averages were below normal from 150 to 300 m. Temperature at 300 m increased marginally overall but significantly (by 2 SD) at Cabot Strait, where the 2010 anomaly is positive by 0.6 SD. Salinity at 200 m and 300 m decreased overall by 0.6 SD but increased at Cabot Strait to reach +0.6 SD at 200 m and 0 SD at 300 m. The 300 m waters of the Estuary are expected to cool further during the next two years, but it will be interesting to follow the warm anomaly present in 2010 at Cabot Strait progress up the channel.

DISSOLVED OXYGEN AND HYPOXIA IN THE ST. LAWRENCE ESTUARY

Fig. 39 shows an update of the Gilbert et al. (2005) oxygen time series, providing the mean dissolved oxygen value at depths ≥295 m in the St. Lawrence Estuary expressed as a percentage of saturation at surface pressure. Since some of the variability is associated with changing water masses, the temperature at 300 m in the Estuary is also shown. *Table 17* shows regional averages at 300 m since 2000 based on fall CTD data; the dissolved oxygen sensor was calibrated with Winkler titrations.

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 (Fig. 39). Dissolved oxygen increased very slightly in 2009 compared with 2008 observations but has remained relatively stable since 2001. The inflow of colder waters to the Estuary ameliorates the hypoxic conditions since these colder waters are typically richer in dissolved oxygen. This is seen in the regional time series shown in *Table 17*, where an overall tendency towards increasing dissolved oxygen during the last decade is observed broadly throughout the Gulf, associated with the change in temperature from the water mixture richer in Labrador Water. However, it is surprising that the strong cooling observed in 2010 in the deep waters of the Estuary did not coincide with an increase in dissolved oxygen, but rather a decrease (Table 17 and Fig. 39).

CURRENTS AND TRANSPORTS

Currents and transports are derived from a numerical model of the Gulf of St. Lawrence, Scotian Shelf, and Gulf of Maine. The model is prognostic, i.e., allows for evolving temperature and salinity fields. It has a spatial resolution of 1/12° with 46 z-levels in the vertical. The atmospheric forcing is taken from the GEM model run at the Canadian Meteorological Center (CMC). Freshwater runoff is taken from observed data and the hydrological model, as discussed in the freshwater runoff section. A simulation was run for 2006–2010 from which transports were calculated. The reader is cautioned that the results outlined below are not measurements but simulations and that improvements in the model may lead to changes in them.

Fig. 40–42 show seasonal depth-averaged currents for 0–20 m, 20–100 m, and 100 m to the bottom for 2010. Currents are strongest in the surface mixed layer, generally 0–20 m, except in winter months when the 20–100 m averages are almost as strong and when even the deep (100 m to the bottom) averages are very high (note the different scale for this depth). Currents are strongest along the slopes of the deep channels. The Anticosti Gyre is always evident but strongest during winter months, when it even extends strongly into the bottom-average currents.

Monthly averaged transports across seven sections of the Gulf of St. Lawrence are shown in Table 18 and Table 19. The first table shows transports related to estuarine circulation. The net transport integrates both up and downstream circulation and corresponds to freshwater runoff at the Pointe-des-Monts section. The outflow transport integrates all currents heading toward the ocean, while the estuarine ratio corresponds to the outflow divided by the net transports. *Table 19* shows only net transports for sections within the Gulf. Transports were typically normal or higher than normal in 2010 across the Honguedo (outflow transport) and Jacques Cartier (net transport) sections. Transport on sections under the direct estuarian influence of the St. Lawrence River (e.g., Pointe-des-Monts) have a more direct response to change in freshwater runoff while others (e.g., Cabot Strait, Bradelle Bank) have a different response, presumably due to redistribution of circulation in the GSL under varying runoff. The estuarine circulation ratio is determined by the mixing intensities within the estuary and is greatly influenced by stratification. It is greatest during winter months and weakest during the spring freshet. In fact, it is sufficiently reduced in spring that the overall outward transport at Pointe-des-Monts reaches its minimum value in June even though this month corresponds to its highest net transport of the year.

TIME SERIES OF TEMPERATURE AND SALINITY PROFILES AT FIXED AZMP STATIONS

Sampling by the Maurice Lamontagne Institute began in 1996 at two stations (Fig. 43) that were to become part of the AZMP (Therriault et al. 1998) in the northwest Gulf of St. Lawrence: the Anticosti Gyre (49° 43.0' N, 66°15.0' W) and the Gaspé Current (49° 14.5' N, 66° 12.0' W). Both stations were to be sampled at 15-day intervals, but logistical problems have often led to less frequent sampling (Fig. 43). The AZMP station in the Shediac Valley (47° 46.8' N, 64° 01.8' W) is sampled on a regular basis by the Bedford Institute of Oceanography as well as occasionally by the Maurice Lamontagne Institute during their Gulf-wide surveys. This station has been sampled since 1947, nearly every year since 1957, and more regularly during the summer months since 1999, when the AZMP program began. However, observations were mostly of temperature and salinity prior to 1999. A station offshore of Rimouski (48° 40' N 68° 35' W) has also been sampled since 1991, typically once a week during summer and less often during spring and fall, but almost never in winter. Of the four stations, the Rimouski station has been sampled with regularity in summertime for the longest period, since 1993. The sampling activities at the Rimouski station are described in Plourde et al. (2009)

Isotherms and isohalines as well as monthly averages of layer temperature and salinity, stratification, and CIL core temperature and thickness at <1°C are shown for the Rimouski station in Fig. 44. Similar figures are provided for the Gaspé Current station (Fig. 45), the Anticosti Gyre station (Fig. 46), and the Shediac Valley station (Fig. 47). The scorecard climatologies are calculated from all available data at all stations except for Shediac, where the time series since 1981 is considered (1981–2010).

At the Rimouski station (Fig. 44), the CIL was thin and warm in March 2010, reaching 100 m in thickness. Its thickness was normal from April to July and then thinner than normal until November, when it became normal again. However, it was warmer than normal for almost all months. Salinity in the top 75 m was below normal in March and April, higher than normal at 10 m depth from May through August, and below normal in October and November, coincident with periods of low and high freshwater runoff, respectively. The limited number of sorties to the Gaspé Current and Anticosti Gyre stations limit our interpretation of these data, but the CIL was thick and warm throughout the year at the Gaspé Current station (Fig. 45), and salinity was typically below normal at all depths during winter. At the Anticosti Gyre station (Fig. 46), the CIL was warm at nearly all times, and waters 100 m and deeper had temperatures and salinities below normal until at least June. At the Shediac Valley station (Fig. 47), water temperatures were generally above normal except close to the surface in May and June despite above-normal recorded SST in May.

Table 20 shows the interannual variability of some bulk layer averages from May to October for the four stations. The data were not sufficient to calculate indices for the Gaspé Current and Anticosti Gyre stations in 2010. The CIL was thinner and warmer than normal at the Rimouski station. Bulk surface layer temperature, salinity, and stratification were normal at Rimouski station, while surface layer temperature and salinity were above normal at Shediac Valley station, leading to below-normal stratification there.

OUTLOOK FOR 2011

Air temperatures in December 2010 were at record highs since 1945 over the Gulf of St. Lawrence, averaging 6.1°C above normal over the nine weather stations. This was followed by air temperatures 4.1°C above normal in January 2011 but near-normal conditions in February and March (not shown). This led to a very small sea-ice cover and an anomalously warm winter surface layer, the latter measured during the March 2011 survey (Fig. 48). While not as ice-free and warm as during the record-breaking winter of 2010, these conditions are still very unusual, having occurred only twice in the last 16 years of recorded observations. The surface mixed layer is usually close to freezing almost everywhere in the Gulf during winter.

The volume of near-freezing water is generally a good predictor for the following summer's CIL minimum temperature index (i.e., Fig. 25). During most winters, the bulk of these cold waters have temperatures fairly close to the freezing point, and a threshold of -1°C works well to calculate the cold-layer volume. This is because waters with temperatures in the vicinity of -1°C are rare; the mixed layer is typically much colder and the waters underneath much warmer. But as in March 2010, the mixed layer in March 2011 was generally warmer than this threshold. Only 7 600 km³ of water had temperatures lower than -1°C (Fig. 48, lower left). The thickest portions of the layer corresponded to waters of the Labrador Shelf intrusion into the Gulf that typically occupies Mécatina Trough (Fig. 48, middle right).

In previous mild winters such as 2006, the winter mixed layer was still near-freezing but its thickness was smaller than normal. In 2011, the winter mixed layer was warmer than normal but extended over a large thickness. In fact, if waters colder than 0°C are considered, the volume of 13 400 km³ observed in 2011 (excluding the volume found within the Estuary) compares well with the mixed layer volume observed during many recent winters (Fig. 25). One hypothesis raised in last year's report is that the mixed layer deepened normally in late-fall and early-winter, but heat was not removed sufficiently fast for the layer to reach near-freezing temperatures before the end of the winter. In March 2010, there was evidence that the stratification was also weaker than normal down to 200 m in the northwest Gulf and in Anticosti Channel, possibly caused by stronger wind mixing during winter. This was not the case in March 2011, and deeper waters were warmer than in 2010.

The unusual conditions observed in March 2011 make it difficult to predict what the CIL will look like during summer 2011. The volume of winter mixed layer colder than -1°C is much higher than in 2010 but still lower than the previous record of 2006. The volume colder than 0°C is lower than in 2010 but compares well with those of 2000 and 2006. The surface water temperatures are mostly above normal, but not so much as in 2010, while the deeper waters are warmer than in 2010. Therefore, the CIL conditions in summer 2011 will likely fall within the range of conditions observed in 2000, 2006, and 2010, that is, with a Gilbert and Pettigrew (1997) index between +0.2 and 0°C.

SUMMARY

- Winter air temperatures (January–March) reached record-high values (since 1945) with an average anomaly of +4.70°C (+2.5 SD), consistent with the record-low (since 1969) maximum ice volume in the Gulf of 11 km³. Air temperatures were above normal for the remainder of the year except for two months at Daniel's Harbour, and the fall average for October through December was a record high (+2.8°C), leading to a record-high annual average air temperature over the Gulf (+2.4°C, +2.5 SD).

- The annual average runoff measured at Québec City was normal overall in 2010 but had a very unusual temporal pattern. It was above average during the mild winter and the usual spring freshet was absent, leading to higher values in March than in April or May. Runoff remained very low through August and was compensated by extremely high values in October and December such that the highest monthly value occurred in December rather than in springtime.

- Near-surface water temperatures in the Gulf were normal or above normal all year and in all regions except for the Mécatina Trough and Esquiman Channel in June. They were very high in August, reaching an average of 16.3°C over the Gulf, consistent with high air temperatures. The winter mixed layer reached record-high (since 1996) temperatures, on average around 1°C above the freezing point.

- Maximum sea-ice volume within the Gulf and on the Scotian Shelf was 11 km³, a record low since 1969, consistent with the above-normal mixed layer temperatures. The duration of the 2009–10 ice season was much shorter, ending earlier than normal. No ice was exported onto the Scotian Shelf.

- Winter inflow of cold and saline water from the Labrador Shelf occupied the Mécatina Trough over the entire water column in winter 2010 (up to 235 m in depth). The spread of the intrusion was confined slightly closer to the Strait of Belle Isle compared to 2009 conditions, leading to an overall smaller volume of 809 km³. However, the intrusion volume represented 30% of the unusually small volume of mixed layer waters that were colder than -1°C.

- The winter cold mixed layer volume in the Gulf, excluding the Estuary, was 13 900 km³. This layer accounted for 42% of the total water volume of the Gulf. However, it was very warm, on average about 1°C above the freezing point. Usually, the criterion used to calculate the winter mixed layer volume is temperature lower than -1°C, but in 2010 only 2 800 km³ of water met this criterion, found mostly in areas surrounding the Labrador Shelf intrusion.

- The CIL index for summer 2010 was -0.04°C, which is similar to observations in 2000. This increase of 0.38°C since 2009 makes it above normal by 0.9 SD.

- Regional patterns of the August and September CIL (T < 1°C and < 0°C) were much thinner in most parts of the Gulf in 2010 than in 2009 and had a generally higher core temperature throughout.

- On the Magdalen Shallows, none of the bottom area was covered by water with temperatures < 0°C in September 2010, similar to conditions in 2005, 2006, 2007, and 2009. In many other regions of the Gulf, no bottom area was covered by waters colder

than 0°C in 2010. Even in the Anticosti Channel and Mécatina Trough, which are regions affected by the Labrador Shelf cold water winter intrusion, these areas were considerably reduced compared with previous years.

- March temperatures were characterized by a very thick yet warm surface mixed layer, including a thick intrusion of Gulf waters into the Estuary. CIL conditions were normal in thickness by June but still had above-normal minimum temperatures. The CIL warming rate appeared to be slower than usual because core temperatures were closer to normal in certain regions by August and more so by November.

- The warm deep waters in the Estuary in 2009 were replaced by colder-than-normal waters by June 2010, when colder-than-normal deep waters also occupied the northwest Gulf. Very warm waters occupied Cabot Strait in June at 250 m, the depth of the temperature maximum, and there is a hint that the top portion of this water mass was sampled during the March survey. The warm deep waters were still present in Cabot Strait in August as well as in November. By November the surface mixed layer was anomalously thick but more importantly very warm, warmer in fact than that observed during fall 2009 which were preconditions of the record winter mixed layer conditions observed in march 2010.

- Gulf-wide average temperatures were below normal at 200 to 300 m, and salinities were below normal from 150 to 300 m. Temperature at 300 m increased marginally overall, but significantly (by 2 SD) at Cabot Strait, where the anomaly is now positive by 0.6 SD. Salinity at 200 m and 300 m decreased overall by 0.6 SD but increased at Cabot Strait to reach +0.6 SD at 200 m and 0 SD at 300 m. The 300 m waters of the Estuary are expected to cool further during the next two years, but it will be interesting to follow the warm anomaly present in 2010 at Cabot Strait as it progresses up the channel.

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REFERENCES

Bourgault, D. and V.G. Koutitonsky. 1999. Real-time monitoring of the freshwater discharge at the head of the St. Lawrence Estuary. *Atmos. Ocean*, 37 (2): 203–220.

Galbraith, P.S. 2006. Winter water masses in the Gulf of St. Lawrence. *J. Geophys. Res*., 111, C06022, doi:10.1029/2005JC003159.

Galbraith, P.S., F.J. Saucier, N. Michaud, D. Lefaivre, R. Corriveau, F. Roy, R. Pigeon and S. Cantin. 2002. Shipborne monitoring of near-surface temperature and salinity in the Estuary and Gulf of St. Lawrence. *Atlantic Zone Monitoring Program Bulletin*, Dept. of Fisheries and Oceans Canada. No. 2: 26–30.

Galbraith, P.S., R. Desmarais, R. Pigeon and S. Cantin. 2006. Ten years of monitoring winter water masses in the Gulf of St . Lawrence by helicopter. *Atlantic Zone Monitoring Program Bulletin*, Dept. of Fisheries and Oceans Canada. No. 5: 32–35.

Galbraith, P.S., D. Gilbert, C. Lafleur, P. Larouche, B. Pettigrew, J. Chassé, R.G. Pettipas and W.M. Petrie. 2008. Physical oceanographic conditions in the Gulf of St. Lawrence in 2006. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2008/028, 56 pp.

Galbraith, P.S., R.G. Pettipas, J. Chassé, D. Gilbert, P. Larouche, B. Pettigrew, A. Gosselin, L. Devine and C. Lafleur. 2010. Physical oceanographic conditions in the Gulf of St. Lawrence in 2009. *DFO Can. Sci. Advis. Sec. Res. Doc.* 2010/035. iv + 73 pp.

Gilbert, D. 2004. Propagation of temperature signals from the northwest Atlantic continental shelf edge into the Laurentian Channel. ICES CM, 2004/N:7, 12 pp.

Gilbert, D. and B. Pettigrew. 1997. Interannual variability (1948-1994) of the CIL core temperature in the Gulf of St. Lawrence. *Can. J. Fish. Aquat. Sci.,* 54 (Suppl. 1): 57–67.

Gilbert, D., P.S. Galbraith, C. Lafleur and B. Pettigrew. 2004. Physical oceanographic conditions in the Gulf of St. Lawrence in 2003. *DFO Can. Sci. Advis. Sec. Res. Doc*. 2004/061, 63 pp.

Gilbert, D., B. Sundby, C. Gobeil, A. Mucci and G.-H. Tremblay. 2005. A seventy-two-year record of diminishing deep-water oxygen in the St. Lawrence estuary: The northwest Atlantic connection. *Limnol. Oceanogr.*, 50(5): 1654–1666.

Kalnay, E., M. Kanamitsu, R. Kistler, W. Collins, D. Deaven, L. Gandin, M. Iredell, S. Saha, G. White, J. Woollen, Y. Zhu, M. Chelliah, W. Ebisuzaki, W. Higgins, J. Janowiak, K. Mo, C. Ropelewski, J. Wang, A. Leetmaa, R. Reynolds, R. Jenne and D. Josephé. 1996. The NCEP/NCAR 40-year reanalysis project. *Bull. Am. Meteorol. Soc.* 77, 437–470.

Kelley, D.E. and P.S. Galbraith. 2000. Gri: A language for scientific illustration, *Linux J*., 75, 92–101.

Lauzier, L.M. and R.W. Trites. 1958. The deep waters of the Laurentian Channel. *J. Fish. Res. Board Can.* 15: 1247–1257.

McLellan, H.J. 1957. On the distinctness and origin of the slope water off the Scotian Shelf and its easterly flow south of the Grand Banks. *J. Fish. Res. Board. Can.* 14: 213–239.

Petrie, B., K. Drinkwater, A. Sandström, R. Pettipas, D. Gregory, D. Gilbert and P. Sekhon. 1996. Temperature, salinity and sigma-t atlas for the Gulf of St. Lawrence. *Can. Tech. Rep. Hydrogr. Ocean Sci.,* 178: v + 256 pp.

Plourde, S., P. Joly, L. St-Amand and M. Starr. 2009. La station de monitorage de Rimouski : plus de 400 visites et 18 ans de monitorage et de recherche. *Atlantic Zone Monitoring Program Bulletin*, Dept. of Fisheries and Oceans Canada. No. 8: 51-55.

Therriault, J.-C., B. Petrie, P. Pépin, J. Gagnon, D. Gregory, J. Helbig, A. Herman, D. Lefaivre, M. Mitchell, B. Pelchat, J. Runge and D. Sameoto. 1998. Proposal for a Northwest Atlantic zonal monitoring program. Can. Tech. Rep. Hydrogr. Ocean Sci., 194: vii + 57 pp.

Table 1. Normalized mean air temperature anomalies: annual (top) and January–February–March (bottom) averages. The numbers on the right are the 1981–2010 climatological means and standard deviations. The numbers in the boxes are normalized anomalies. The colour palette used for this and subsequent tables is shown at the bottom. Numbers within 1.5 SD of normal are in black font and stronger anomalies are typeset in white.

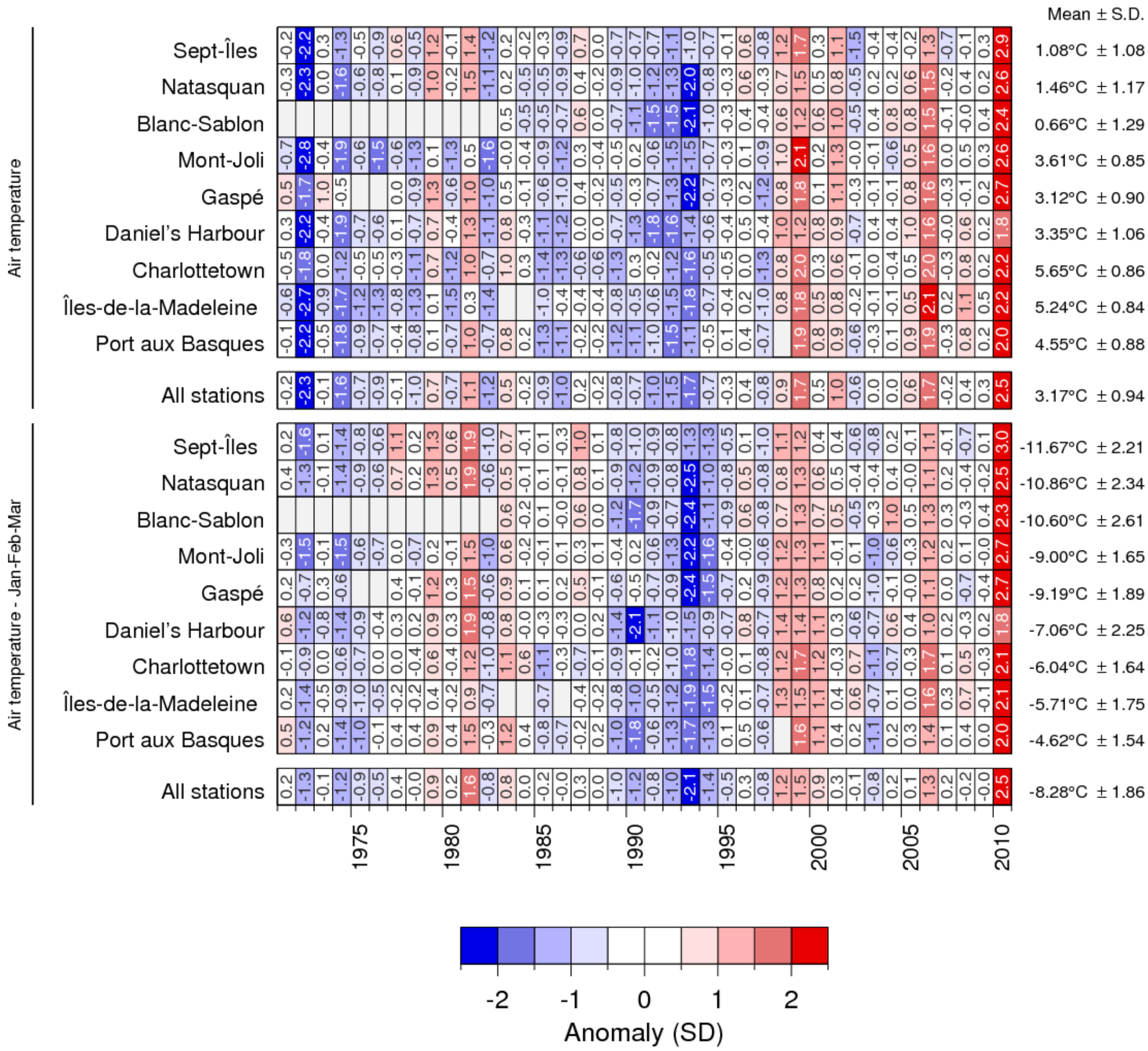

Table 2. Monthly anomalies of the St. Lawrence River runoff and sums of all other major rivers draining into separate Gulf regions for 2009 and 2010. The scorecards are colour-coded according to the monthly normalized anomalies based on the 1981–2010 climatologies for each month, but the numbers are the monthly average runoffs in m^3 s^{-1}. Numbers on the right side are annual climatological means.

	2009 J	F	M	A	M	J	J	A	S	O	N	D	2010 J	F	M	A	M	J	J	A	S	O	N	D	
St. Lawrence	9855	11210	12157	17928	13831	13577	13836	11133	9828	11107	10542	10989	11001	11957	13894	13612	10635	10083	9933	9680	10629	12766	11864	14244	11994 m^3 s^{-1}
1 - Estuary	623	282	601	3115	9263	16706	12641	5744	2936	3754	3739	1324	768	473	405	3132	8241	7930	6541	4952	6004	5353	3729	3860	4980 m^3 s^{-1}
2 - Northwest Gulf	24	15	117	628	2129	4680	3212	1283	793	1154	861	284	131	110	119	753	2050	2779	2063	1090	1166	1438	1284	1503	1129 m^3 s^{-1}
3 - Anticosti Channel	101	12	169	723	2022	4881	4189	1703	892	1202	1012	455	214	159	207	1001	2398	3319	2226	960	830	1550	1429	1231	1235 m^3 s^{-1}
4 - Mécatina Trough	48	2	50	219	772	2086	1787	788	603	605	461	260	112	86	81	423	1199	2054	1768	588	346	870	752	581	597 m^3 s^{-1}
5 - Esquiman Channel	133	42	93	249	356	326	91	32	95	172	251	193	90	35	47	203	309	159	47	43	99	115	120	228	162 m^3 s^{-1}
8 - Magdalen Shallows	229	106	372	1338	2025	1605	670	69	193	732	642	463	319	189	446	1192	1325	427	133	217	683	732	1048	1632	615 m^3 s^{-1}

Table 3. Thermosaligraph near-surface temperature monthly anomalies for various sections along the main shipping lane. The numbers on the right are the 2000–2010 climatological means and standard deviations. The numbers in the boxes are normalized anomalies. The map shows all TSG data sampled in 2010. Those drawn in colour are within the main shipping corridor and are used in this report. Monthly average anomalies of temperatures measured close to the indicated blue section lines are shown in the other scorecard panels.

Tadoussac

Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± SD
J	-0.6	-0.4	0.5	0.8	-1.4	0.0	-0.7	1.8				-0.09°C ± 0.57
F	-0.8	-0.1	-1.3	1.6	0.0	-1.0	-0.7	1.4	-0.1		0.9	-0.19°C ± 0.50
M	0.5	0.1	0.2	1.8	-1.2	-1.3	0.3	0.2	-1.3		0.8	0.13°C ± 0.50
A	-0.5	0.1	1.7	-0.3	-1.7	-0.7	0.7	-0.7	0.4		1.0	1.34°C ± 0.42
M	-0.3	1.9	0.1	-0.8	-1.7	-0.3	0.8	-0.6	0.9		0.0	3.57°C ± 0.87
J	-1.9	1.2	0.0	-1.1	-0.0	-0.4	0.9	0.9	1.1		-0.6	5.51°C ± 1.05
J	-0.6		1.0	-1.1	0.6	-1.5	0.3	-0.7	1.3		0.6	6.51°C ± 0.46
A		0.3	0.0	-0.4	-1.5	0.0	0.3	-0.4	2.2		-0.7	6.41°C ± 1.24
S	-0.2	-0.5		-1.4	0.0	2.2	0.5	-0.7	-0.2		0.4	5.46°C ± 0.89
O	-0.9	-0.1	-0.6	-1.2	0.1		2.1	0.8	-0.6		0.3	4.17°C ± 0.80
N	0.4	-0.5	-1.1	-1.2	0.8	-0.0	2.0	-0.1	-0.3			2.71°C ± 0.66
D	0.4	0.5	-0.5	-1.8	-0.6	-0.1	1.8	-0.2	-0.7		1.1	0.95°C ± 0.69

Mont-Louis

Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± SD
J	1.0	0.7	-0.2	0.4	-0.8	-2.0	0.9	0.1				-1.17°C ± 0.14
F	-0.5	-0.4	-0.6	-0.5	0.1	-0.6	0.0	0.6	-0.5		2.6	-1.45°C ± 0.25
M	0.7	0.5	-0.8	-0.6	-0.8	-0.8	0.8	0.0	-1.1		2.0	-1.08°C ± 0.35
A	-0.8	0.4	0.8	-1.4	-0.7	-0.8	0.9	-0.3	0.1		1.9	0.80°C ± 0.58
M	-0.6	1.5	-1.1	-0.2	-1.2	-0.9	0.2	-0.2	1.1		1.4	4.43°C ± 1.11
J	-0.2	1.3	-0.8	-0.1	-1.3	-0.4	0.8	-0.9	-0.3		1.8	9.11°C ± 0.91
J	-0.5	-1.4	-0.3	-0.6	0.4	2.0	0.7	0.1	-1.1		0.8	13.20°C ± 0.98
A		0.5	1.2	-0.1	-1.0	-1.9	0.3	-0.7	0.7		0.9	12.84°C ± 0.80
S	-0.9	0.8	0.3	-0.7	-0.9	-0.2	-0.2	-1.0	2.0		1.0	10.07°C ± 1.09
O	-0.9	0.2	-1.1	0.0	0.7		-1.3	-0.0	0.5		1.9	6.09°C ± 0.99
N	-0.1	-0.5	-1.3	-1.3	0.9	1.4	1.2	-0.3	-0.1			3.62°C ± 1.14
D	0.8	-0.2	-0.8	-1.4	-0.1	-0.2	1.2	-0.8	-0.4		1.9	0.92°C ± 0.59

Cabot Strait / Détroit de Cabot

Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± SD
J	0.4	-0.4	0.1	-1.8	-0.0	0.1	1.8	-0.3				1.43°C ± 0.61
F	-0.8	0.4	0.4	-1.9	-0.1	1.1	1.5	-0.7	-0.2		0.5	-0.08°C ± 0.77
M	0.2	0.2	-0.4	-2.2	0.4	1.1	0.1	-0.7	-0.0		1.4	-0.32°C ± 0.56
A	0.2	0.2	-0.9	-2.2	-0.1	0.6	0.8	-0.1	-0.1		1.5	0.56°C ± 0.72
M	-0.6	0.7	-1.2	-0.9	-0.7	-0.2	2.1	-0.3	0.6		0.5	3.18°C ± 0.80
J	0.1	1.0	-0.7	-0.6	-1.5		1.9	0.2	0.0		-0.6	7.19°C ± 1.08
J			-1.4	-0.5	-0.5		1.5	0.2	1.1		-0.5	12.82°C ± 1.20
A		1.5	-0.2	-1.4	0.1		0.1	-1.3	0.6		0.7	16.60°C ± 0.94
S	-0.5	0.8		-1.3	-0.8		0.7	-0.9	1.3		0.8	13.43°C ± 1.15
O	-0.6	1.2	-1.8	1.0	0.1	0.6	0.5	-1.4	-0.2		0.6	9.45°C ± 1.49
N	0.3	0.1	-2.1	-0.6	0.6	0.8	1.0	-0.8	0.7			6.36°C ± 1.43
D	0.2	-0.1	-1.9	-0.7	-0.3	0.6	0.8	-1.0	0.7		1.6	3.94°C ± 0.98

Estuary / Estuaire

Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± SD
J	-0.6	-0.1	1.3	-0.5	-1.5	-0.1	-0.0	1.6				-0.81°C ± 0.27
F	-0.5	0.0	-0.6	0.4	-0.9	-0.8	-0.7	0.4	0.2		2.5	-0.83°C ± 0.37
M	1.3	-0.1	0.2	0.6	-1.0	-1.2	0.3	-0.2	-1.4		1.6	-0.10°C ± 0.46
A	-0.8	0.2	1.5	-0.2	-1.6	-0.7	0.9	-0.9	0.5		1.1	1.63°C ± 0.44
M	0.0	1.1	-0.4	-0.8	-1.5	-0.8	0.6	-0.8	1.6		0.9	4.26°C ± 0.69
J	-1.0	1.4	-0.5	-1.3	-1.0	-0.4	0.9	0.1	1.4		0.6	6.86°C ± 0.99
J	-0.3		1.7	-0.8	0.4	1.2	-0.5	-1.3	-0.8		0.3	8.37°C ± 0.80
A		-0.3	0.9	-0.3	-0.6	0.0	-0.3	-1.0	2.2		-0.7	8.20°C ± 1.04
S	-0.9	-0.3	0.7	-0.6	-1.1	2.0	-0.3	-1.0	0.5		1.0	6.20°C ± 0.56
O	-1.0	-0.1	-0.2	-1.5	0.0		0.7	1.2	-0.7		1.6	4.44°C ± 0.57
N	0.5	-0.3	-1.2	-1.4	0.7	0.0	1.9	-0.2	-0.0			2.54°C ± 0.70
D	-0.2	0.7	-0.3	-1.4	-0.5	0.1	1.8	-0.8	-0.7		1.4	0.57°C ± 0.66

Centre

Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± SD
J	-0.2	0.4	-0.5	-1.2	0.2	-1.2	1.3	1.3				-0.39°C ± 0.44
F	-0.6	-0.1	-0.7	-1.0	-0.1	-0.9	1.4	-0.0			1.9	-1.35°C ± 0.29
M	0.1	-0.2	-0.6	-0.9	-0.5	-0.5	0.8	0.1	-0.8		2.5	-1.22°C ± 0.33
A	0.1	-0.1	-0.6	-1.3	-0.2	-0.5	1.4	-0.4	-0.5		2.1	0.08°C ± 0.69
M	-0.6	1.5	-0.8	-1.2	-0.8	-0.8	1.4	-0.1	1.0		0.3	3.30°C ± 1.27
J	-0.8	1.5	-0.6	-0.4	-1.4		1.6	0.2	-0.1		0.0	8.10°C ± 1.48
J	-0.1		-1.1	-1.2	-0.7		1.8	0.3	0.7		0.1	14.18°C ± 1.33
A		-1.1	-1.2	-0.3	0.4		-0.4	0.0	1.9		0.7	15.71°C ± 0.98
S	0.6	-0.7		0.5	-0.6		0.4	-2.0	1.0		0.8	12.67°C ± 1.09
O	-1.1	1.2	-1.2	1.6	0.6		0.3	-0.8	-0.3		-0.5	8.03°C ± 0.68
N	0.6	-0.8	-1.7	-1.0	0.2	0.8	1.4	-0.1	0.6			4.58°C ± 0.77
D	0.4	-0.2	-1.2	-1.0	-0.0	0.3	1.5	-1.1	-0.4		1.6	2.00°C ± 0.68

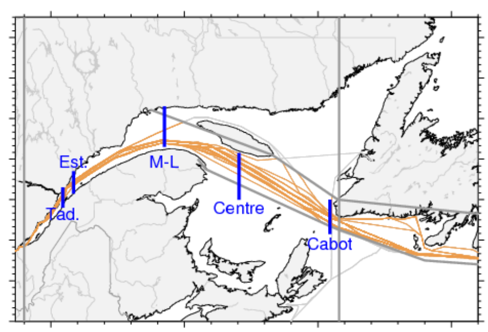

Table 4. Monthly mean temperatures at all shallow sensors of the Maurice Lamontagne Institute thermograph network in 2009 and 2010 as well as at Shediac station from DFO Gulf Region. The number of years that each station and depth has been monitored is indicated on the far right. The colour-coding is according to the temperature anomaly relative to the climatology of each station for each month. Numbers are monthly average temperatures.

Estuary and NW Gulf / Estuaire et NO du Golfe

		J 2009	F 2009	M 2009	A 2009	M 2009	J 2009	J 2009	A 2009	S 2009	O 2009	N 2009	D 2009	J 2010	F 2010	M 2010	A 2010	M 2010	J 2010	J 2010	A 2010	S 2010	O 2010	N 2010	D 2010	
Tadoussac	1 m																	4.7	6.6	8.1	7.6	8.0	5.6	3.1		5 y
Bic	1 m					3.8	5.7	8.6	8.6	5.9	4.4							4.7	5.9	7.8	7.5	6.6	4.7			14 y
	2 m					3.5	5.4	8.3	8.3	5.7	4.4							4.3	5.5	7.3	7.0	6.4	4.7			17 y
Rimouski	0.5 m					5.0	7.8	10.0	10.8	7.1	5.2							6.6	9.1	9.8	10.8	7.9	5.1	3.2		9 y
IML	0.5 m					5.0	7.1	9.4	12.6	8.2	4.6							6.9	9.5	11.0	10.8	8.2	5.2			17 y
	10.8 m	-1.3	-1.0	-1.0	1.2	3.2	4.8	7.4	8.4	6.2	4.3	3.0	0.2	-0.7	-0.8	0.3	1.8	3.9	5.6	7.5	7.3	6.9	4.8			17 y
Baie-Comeau	1 m					4.5	9.2	12.8	12.1	7.5	6.8							6.4	9.8	12.3	11.9	10.3	6.2			12 y
Gaspé Current	0.5 m					5.9	9.4	12.1	14.1	8.9	5.9							9.2	10.6	13.8	13.2	9.9				6 y
Mont-Louis	0.5 m					3.7	9.1	12.3	14.8	10.2	6.6							6.0	11.3	14.9	14.8	11.1	6.8	2.9		17 y
	1.1 m					3.9	9.0	12.2	14.8	10.2	6.6							6.2	11.3	14.8	14.8	11.1	6.8	2.9		12 y
	2.1 m					3.8	8.9	12.1	14.6	10.2	6.6							6.1	11.2	14.7	14.6	11.0	6.8	2.9		12 y
Anticosti Gyre	0.5 m					3.5	8.5	12.8										5.9	11.0	14.7	14.8	11.1	6.7			6 y
Sept-Îles	1 m																	5.8	10.0	15.2	13.5	11.5	5.7			9 y
	2 m					3.8	10.1	15.0	14.5	8.2	7.2							5.6	9.8	14.4	13.1	11.3	5.7			15 y
Port-Menier	2 m					3.0	9.9	14.3	12.0	7.6	6.6							2.1	8.2	13.3	12.7	9.7	5.7			16 y
	12.8 m					1.8	6.7	10.2	6.3	5.3	6.3							1.1	4.8	6.3	8.6	7.2	4.4			12 y

Lower North Shore / Basse Côte Nord

		J 2009	F 2009	M 2009	A 2009	M 2009	J 2009	J 2009	A 2009	S 2009	O 2009	N 2009	D 2009	J 2010	F 2010	M 2010	A 2010	M 2010	J 2010	J 2010	A 2010	S 2010	O 2010	N 2010	D 2010	
Rivière-au-Tonnerre	1 m					2.9	6.9	13.2	10.9	6.4								3.6	7.3	10.6	9.9	10.2	5.7			12 y
	16 m					0.7	3.5	11.1	7.7	5.1								1.6	3.9	6.6	5.9	7.9	5.0			15 y
Havre-Saint-Pierre	0.5 m					2.5	7.5	13.4	12.7	8.8								3.8	7.4	10.7	11.8	11.8	7.6			7 y
	1 m					2.3	7.3	13.4	12.7	8.7								3.6	7.4	10.6	11.6	11.7	7.6			14 y
Natashquan	1 m					5.5	12.0	15.8	14.1	8.9								5.9	9.7	14.2	15.0	12.0	7.3			16 y
	5.4 m					0.0	4.6	11.4	7.5	6.2								2.8	4.6	7.3	7.8	9.8	6.7			15 y
La Romaine	1 m					1.6	7.9	12.5	13.1	9.7								3.4	5.4	9.9	14.8	12.1	7.7			13 y
	2 m					1.4	7.7	12.5	13.1	9.7								3.5	5.4	9.8	14.7	12.1	7.7			17 y
Beaugé	0.5 m					1.9	8.2	13.3	16.0	11.9								3.6	6.1	11.7	16.4	12.7	8.0			6 y
	1 m																	3.7	6.1	11.7	16.4	12.7	7.9			12 y
La Tabatière	1 m					2.3	7.3	11.8	11.4	9.7								3.1	4.6	9.2	12.3	11.1	7.2			9 y
Blanc-Sablon	1 m						4.6	7.0	11.1	7.7									2.2	6.4	10.3	7.9	5.9			12 y

Southern Gulf / Sud du Golfe

		J 2009	F 2009	M 2009	A 2009	M 2009	J 2009	J 2009	A 2009	S 2009	O 2009	N 2009	D 2009	J 2010	F 2010	M 2010	A 2010	M 2010	J 2010	J 2010	A 2010	S 2010	O 2010	N 2010	D 2010	
Grande-Rivière	2 m					5.1	9.5	13.3	16.2	13.0								5.9	10.8	14.8	16.2	13.1	9.2			17 y
	10 m					4.2	7.2	10.4	14.8	12.1								5.1	9.1	12.2	14.0	11.8	9.1			15 y
Borden	1 m	-1.5	-1.6	-1.5	1.8	9.8	14.9	19.0	19.7	16.8	10.9	7.1	1.3	-0.7	-0.8	1.0	5.5	11.1	15.4	19.1	19.6	17.8	11.7	6.6		13 y
Shediac Valley	0.5 m					5.7	11.3	15.7										5.9	10.8	16.4	17.7	14.1	9.5			7 y
Irving Whale	0.5 m																	5.5	10.0	17.2	18.9	15.0	9.5	5.7		11 y
Île Shag	1 m					5.2	10.2	14.3	18.3	14.7								6.4	10.2	15.9	19.0	16.5				13 y
	10 m						9.2	12.8	15.9	14.6	10.4	5.9	2.8	-0.1	-1.2		2.8	6.0	9.6	14.6	17.6	15.0				18 y
La Perle	1 m					3.9	9.9	14.3	18.4	14.9	10.2	5.8						5.1	9.0	15.5	18.9	15.2	10.7	7.0		15 y
Shediac	5 m					9.1	13.9	18.0	17.9	16.2	10.7	6.0						9.4	13.9	19.0	19.8	17.5	12.3	7.5		10 y

Table 5. Monthly mean temperatures at all sensors deeper than 20 m of the Maurice Lamontagne Institute thermograph network in 2009 and 2010 as well as at Shediac station from DFO Gulf Region. The number of years that each station and depth has been monitored is indicated on the far right. The colour-coding is according to the temperature anomaly relative to the climatology of each station for each month. Numbers are monthly average temperatures, with greater number of significant digits included when variance is lower.

Estuary and NW Gulf / Estuaire et NO du Golfe

		2009												2010												
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
Tadoussac	36.6 m					0.7	2.5	5.3	3.9	2.4	4.0							1.8	2.9	3.8	3.9	4.4	3.1	2.4		11 y
Bic	30.5 m					1.2	2.2	4.4	3.6	2.9	3.3							1.8	2.5	3.6	3.8	4.0	3.2			15 y
Rimouski	330 m					5.192	5.144	5.115	5.087	5.083	5.019							4.789	4.749	4.739	4.829	4.836	4.833	4.836		6 y
Baie-Comeau	82.3 m	1.1	0.5	-0.1	-0.6	-0.3	-0.3	0.2	0.4	0.7	2.8	1.1	1.3	0.8	0.4	-0.2	-0.3									10 y
Gaspé Current	165 m					3.9	3.8	3.5	3.7	3.8	2.6							3.1	3.0	3.2	3.4	3.3	3.5			6 y
Mont-Louis	30 m					-0.8	-0.6	-0.4	2.5	1.3	0.7							-0.1	0.0	0.2	0.3	1.6	2.4	1.3		15 y
Anticosti Gyre	337 m					5.381	5.353	5.336	5.316	5.314	5.313							5.202	5.167	5.168	5.178	5.181	5.181			6 y
Sept-Îles	21.9 m					-0.3	2.4	9.2	4.8	3.8	7.3							0.8	2.6	4.6	4.0	5.8	3.7			14 y

Lower North Shore / Basse Côte Nord

		2009												2010												
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
Havre-Saint-Pierre	120 m					0.0	0.1	0.2	0.6	0.6								0.0	0.4	0.8	0.9	1.4	1.6			13 y
La Romaine	21.9 m					-0.9	0.7	6.1	3.3	6.1								1.2	1.9	2.8	3.9	7.4	5.7			14 y
Beaugé	97 m					-0.1	-0.4	0.0	0.4	0.5								-0.4	0.2	0.4	0.3	0.6	0.9			12 y
La Tabatière	39 m					-0.5	1.0	4.4	3.5	6.6								-0.1	1.1	3.1	4.1	7.1	5.8			9 y
Blanc-Sablon	22 m						3.5	5.5	7.3	6.7								0.6	1.7	5.4	6.1	6.9	5.5			11 y

Southern Gulf / Sud du Golfe

		2009												2010												
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
Shediac Valley	82 m					0.0	0.2	0.4	0.5	0.7								-0.1	0.2	0.4	0.6	0.6	1.6			6 y
Irving Whale	67 m																	-0.5	-0.0	0.3	0.4	0.6	1.2	1.3		9 y
La Perle	26 m					1.8	6.3	7.1	10.1	12.2	9.5	5.9						4.3	6.9	9.6	9.2	9.1	8.9	6.9		12 y

Table 6. Time series of the monthly averaged temperature anomalies for selected stations of the thermograph network. The colour-coding is according to the temperature anomaly relative to the climatology of each station for each month. Numbers are monthly average temperatures. The mean and standard deviation are indicated for each month on the right side of the table.

Station	Month	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± SD
Natashquan - 1 m	M								4.9	7.5	6.1			7.2		4.6	6.7	5.5	5.9	6.04°C ± 1.05
	J		9.6	9.7	10.8		10.6	11.7	10.3	10.1	8.5	10.6	9.4	11.4	14.1	10.8	9.5	12.0	9.7	10.56°C ± 1.31
	J		13.9	14.8	14.1		14.1	12.7	14.8	13.3	14.4	13.6	15.5	13.4	14.1	15.1	16.4	15.8	14.2	14.39°C ± 0.99
	A		13.0	12.3	15.5		11.6	14.9	16.1	13.5	14.4	15.0	12.3	11.2	12.9	12.8	16.7	14.1	15.0	13.83°C ± 1.64
	S		9.7	10.3	11.0		12.3	13.1	8.0	10.3	10.1	9.2	7.8	12.7	10.7	9.2	12.0	8.9	12.0	10.46°C ± 1.63
	O		7.8	6.9	6.2		4.9	7.0	4.6	7.1	4.4	8.2	7.9	8.6	7.5	6.9	7.3		7.3	6.84°C ± 1.27
La Tabatière - 1 m	M										0.6					1.4		2.3	3.1	1.84°C ± 1.11
	J										5.4	5.5	5.4	7.3	6.7	5.5	7.0	7.3	4.6	6.07°C ± 1.00
	J										7.9	10.2	8.3	9.1	10.4	8.8	9.1	11.8	9.2	9.43°C ± 1.18
	A										11.7	12.8	10.9	11.0	12.5	12.0	13.8	11.4	12.3	12.07°C ± 0.91
	S										10.0	10.9	11.0	12.1	11.4	9.1	11.0	9.7	11.1	10.71°C ± 0.93
	O											7.4	7.1	7.7	8.0	6.4	8.3		7.2	7.43°C ± 0.60
Blanc-Sablon - 1m	J							4.7	4.2	2.8	3.2	2.5	1.8	3.9	4.6	2.2	3.2	4.6	2.2	3.33°C ± 1.06
	J							9.0	8.4	7.8	8.4	8.8	6.2	8.1	10.7	9.4	9.4	7.0	6.4	8.28°C ± 1.31
	A							12.1	12.9	11.3	10.8	10.4	13.1	10.7	12.6	11.2	12.0	11.1	10.3	11.56°C ± 0.98
	S							9.2	9.9	8.3	7.3	8.9	8.1	9.9	9.0	8.7	10.1	7.7	7.9	8.75°C ± 0.93
	O							5.0	5.0	6.8	3.1	7.5	4.5	6.0	6.4	3.8	6.3		5.9	5.49°C ± 1.33
Irving Whale - 0.5 m	M						6.0			3.8	4.0		3.4	1.9	6.9	3.7			5.5	4.40°C ± 1.61
	J						11.4	12.8	10.5	12.2	10.1	9.3	9.1	9.1	12.6	10.0			10.0	10.64°C ± 1.37
	J						16.9	17.5	16.5	16.9	15.9	16.8	16.0	16.7	17.7	17.0			17.2	16.84°C ± 0.58
	A						16.3	16.7	19.2	18.6	17.7	17.3	18.3	18.3	17.8	16.9			18.9	17.82°C ± 0.94
	S						15.1	15.3	14.7	15.9	13.6	14.8	14.1	16.6	15.4	14.0			15.0	14.96°C ± 0.85
	O						9.0	8.7	9.8	11.7	10.6	11.2	11.3	11.2	11.3	11.2			9.5	10.50°C ± 1.05
	N						4.5	5.1		5.4	5.1	4.8				6.0			5.7	5.25°C ± 0.53
Île Shag - 10 m	J		-1.7	-1.3	-1.6	-0.8	-1.5	-1.7	-0.6	-0.8	-0.6	-0.9	-0.8	-1.4	0.3	-0.5	-1.4		-0.1	-0.96°C ± 0.59
	F		-1.8	-1.7	-1.7	-1.7	-1.7	-1.7	-1.4	-1.3	-1.4	-1.3	-1.6	-1.7	-1.3	-1.7	-1.7		-1.2	-1.55°C ± 0.21
	M		-1.7	-1.5	-1.5	-1.5	-1.1	-1.4	-0.8	-0.8	-1.3	-1.2	-1.5	-1.4	-0.8	-1.5	-1.6			-1.31°C ± 0.30
	A		-0.4	-0.7	0.1	-0.5	0.8	0.8	1.7	0.6	0.7	0.1	0.2	0.1	1.6	0.0	0.2		2.8	0.50°C ± 0.92
	M		3.2	2.9	4.3	3.5	5.8	4.5	4.8	4.9	3.7	3.7	4.5	4.3	6.3	4.4	4.4		6.0	4.45°C ± 0.97
	J		7.0	8.2	8.4	7.6	9.9	10.2	8.5	9.9	8.1	7.6	7.9	8.6	10.0	8.9	9.1	9.2	9.6	8.76°C ± 0.97
	J		13.3	13.6	13.4	12.9	13.4	15.2	14.3	14.4	12.7	11.9	12.7	13.4	15.1	13.3	14.6	12.8	14.6	13.62°C ± 0.93
	A		16.0	16.6	16.6	15.9	15.3	16.3	17.1	17.5	15.5	14.8	16.7	17.1	15.3	15.9	16.9	15.9	17.6	16.28°C ± 0.81
	S		14.5	13.1	15.6	14.8	13.2	16.0	15.2	16.1	14.9	14.9	13.7	15.9	15.3	13.1	14.3	14.6	15.0	14.71°C ± 0.96
	O	10.1	9.0	10.5	10.8	10.7	9.1	10.0	10.9	11.9	10.2	12.2	11.1	11.5	10.9	10.6		10.4		10.62°C ± 0.87
	N	5.4	5.7	6.5	6.6	5.9	5.4	5.2	6.9	6.6	5.3	6.3	5.6	6.5	6.1	6.6		5.9		6.03°C ± 0.55
	D	1.6	1.1	1.2	2.8	1.2	1.2	3.2	2.3	2.5	1.8	2.4	1.5	2.5	2.9	1.0		2.8		2.01°C ± 0.75
Shediac - 5 m	M									7.1	7.6	5.9	8.2	6.0	9.5	7.4	6.3	9.1	9.4	7.65°C ± 1.35
	J									11.0	13.2	11.1	12.9	9.6	14.8	14.2	11.9	13.9	13.9	12.64°C ± 1.67
	J									12.9	17.5	15.4	18.1	15.1	17.2	17.9	15.1	18.0	19.0	16.62°C ± 1.90
	A									14.3	19.7	17.0	20.4	18.2	18.6	19.1	17.1	17.9	19.8	18.21°C ± 1.77
	S									13.2	17.3	17.0	16.6	17.7	17.4	17.2	16.3	16.2	17.5	16.65°C ± 1.31
	O									10.1	11.9	13.5	12.5	13.1	12.4	13.1	12.2	10.7	12.3	12.17°C ± 1.06
	N										4.2	6.9	4.9	8.0	7.3	6.4	7.4	6.0	7.5	6.50°C ± 1.26
	D											1.4	0.0	2.6	1.9	-0.7	2.1			1.23°C ± 1.29

Table 7. NOAA SST May to November monthly anomalies averaged over the Gulf, the eight regions of the Gulf, and management regions of the St. Lawrence Estuary for 2009 and 2010 (April results are also shown for the Northwest Gulf, the Estuary, and its regions). The scorecards are colour-coded according to the monthly normalized anomalies based on the 1985–2010 climatologies for each month, but the numbers are the monthly average temperatures in ºC.

	2009									2010										
	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N
GSL		2.9	8.9	13.2	16.4	12.0	8.3	4.6						3.9	7.9	13.8	16.3	13.1	8.9	5.2
1 - Estuary	1.3	4.0	7.9	10.0	11.1	7.0	4.9	2.9					1.9	5.7	8.9	11.2	10.6	8.4	5.1	2.3
2 - Northwest Gulf	0.5	3.2	8.8	12.8	14.7	9.6	7.2	3.9					1.0	4.6	9.5	14.2	14.2	11.5	7.0	3.8
3 - Anticosti Channel		1.6	8.1	12.1	14.9	10.3	7.4	3.3						3.0	6.5	11.9	14.9	12.3	8.0	5.0
4 - Mécatina Trough		0.9	6.9	10.3	13.5	9.9	4.9	2.0						1.2	4.0	9.6	13.7	10.7	7.5	4.2
5 - Esquiman Channel		1.6	7.5	12.3	16.3	11.8	7.0	3.8						2.8	6.1	11.5	16.1	12.6	8.6	5.5
6 - Central Gulf		2.1	8.1	13.5	17.2	12.9	8.7	4.8						3.0	7.0	13.5	17.2	13.7	9.3	5.4
7 - Cabot Strait		2.9	8.7	13.6	17.5	13.3	9.9	6.0						3.3	7.0	13.6	17.4	14.3	10.4	6.7
8 - Magdalen Shallows		4.6	11.1	15.1	18.6	14.6	10.4	6.2						5.2	10.0	17.0	18.7	15.1	10.5	6.1
PMSSL (Saguenay)	0.1	3.0	10.3	11.7	13.9	9.6	1.9	1.3					0.5	6.0	10.3	13.7	12.5	7.9	3.4	0.5
PMSSL (Estuary)	1.3	3.7	6.8	8.8	9.5	6.4	4.2	2.7					1.7	4.6	7.1	9.3	8.8	7.5	5.1	2.3
St. Lawrence Estuary MPA	1.6	4.5	7.8	9.7	10.9	7.3	4.7	2.8					2.0	5.5	8.5	10.6	10.1	8.2	5.2	2.3
Manicouagan MPA	1.2	4.1	8.4	11.1	11.7	7.5	5.8	2.9					1.9	6.0	9.6	12.1	11.8	9.1	5.2	2.5

Table 8. NOAA SST May to November monthly anomalies averaged over the Gulf of St. Lawrence and over the first four regions of the Gulf. The scorecards are colour-coded according to the monthly normalized anomalies based on the 1985–2010 climatologies for each month, but the numbers are the monthly average temperatures in ºC. The mean and standard deviation are indicated for each month on the right side of the table. April anomalies are included for the Estuary and the Northeast Gulf because those regions are typically ice-free by then. The May to November average is included for the Gulf of St. Lawrence (top panel).

Region	Month	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± SD
GSL SST Anomaly	M	2.0	3.4	2.9	3.1	2.0	1.7	1.8	2.0	2.3	3.0	3.4	2.8	2.0	4.2	4.1	3.0	3.9	2.3	2.6	2.5	2.9	5.0	2.8	4.1	2.9	3.9	2.94°C ± 0.86
	J	6.6	6.8	8.5	7.1	8.1	6.8	7.5	7.4	7.6	8.1	8.9	9.0	7.5	9.1	9.8	8.3	9.4	7.7	7.9	7.2	8.7	10.0	8.5	8.5	8.9	7.9	8.15°C ± 0.92
	J	12.3	11.8	13.6	12.7	13.4	11.9	11.7	11.1	12.1	14.4	14.3	13.0	13.1	13.9	14.6	13.7	13.5	12.9	13.7	13.6	13.7	15.0	13.9	14.6	13.2	13.8	13.29°C ± 0.99
	A	15.0	14.4	15.1	15.5	14.5	14.8	14.5	13.6	15.8	15.7	15.9	16.4	15.1	15.2	15.8	16.6	16.0	15.8	15.7	16.0	15.0	15.7	14.9	16.0	16.4	16.3	15.46°C ± 0.73
	S	12.6	11.3	12.2	11.7	11.2	12.3	11.7	12.7	12.7	12.8	12.2	13.6	13.1	13.1	14.4	13.2	13.3	12.2	12.8	12.1	13.7	13.4	11.8	13.3	12.0	13.1	12.63°C ± 0.77
	O	8.4	7.6	8.4	7.6	6.4	8.7	8.7	7.7	8.1	9.2	9.3	8.5	8.8	7.9	9.0	8.5	9.5	7.8	9.5	8.9	9.1	9.4	8.5	8.8	8.3	8.9	8.51°C ± 0.72
	N	4.0	3.5	3.6	4.0	3.7	3.1	4.9	3.5	4.0	5.3	5.4	4.9	4.7	4.4	4.2	4.6	4.7	3.6	4.2	4.8	5.3	5.6	4.7	5.2	4.6	5.2	4.45°C ± 0.68
	M-N	8.7	8.4	9.2	8.8	8.5	8.5	8.7	8.3	9.0	9.8	9.9	9.7	9.2	9.7	10.3	9.7	10.0	8.9	9.5	9.3	9.8	10.6	9.3	10.1	9.5	9.9	9.35°C ± 0.63
1 - Estuary	A								1.6	1.7		1.8	1.4				1.6		2.4	0.8	0.8	1.2	1.7	0.9	1.1	1.3	1.9	1.44°C ± 0.46
	M		5.1	5.0	5.0	3.3	4.2		3.6	4.2	6.5	4.9	4.2	4.4	5.2	5.9	4.8	6.1	4.2	4.0	3.6	3.3	5.3	4.3	5.6	4.0	5.7	4.69°C ± 0.89
	J	7.3	6.3	7.5	8.1	7.4	7.3	8.0	7.8	9.0	8.7	8.4	8.7	8.2	9.3	8.6	7.9	9.4	8.2	8.0	7.8	7.9	9.5	9.2	8.7	7.9	8.9	8.22°C ± 0.75
	J	9.4	9.3	10.5	10.9	10.4	8.8	8.9	9.4	12.3	11.4	11.4	10.3	10.3	10.5	9.8	11.7	9.9	11.3	11.3	11.4	11.3	11.4	10.6	11.1	10.0	11.2	10.58°C ± 0.92
	A	9.8	9.4	10.2	10.8	8.3	10.2	10.2	8.5	12.0	10.4	10.9	10.8	9.6	8.9	10.6	11.7	10.4	11.4	11.6	9.7	9.5	10.7	9.8	12.3	11.1	10.6	10.37°C ± 1.02
	S	8.0	6.5	6.5	6.3	6.6	7.0	6.5	7.4	8.0	7.5	7.2	8.9	8.5	9.1	9.0	7.3	7.5	8.3	7.2	7.2	8.2	7.9	6.6	8.3	7.0	8.4	7.57°C ± 0.85
	O	5.0	4.2	4.1	3.6	2.7	4.0	4.0	3.6	3.6	5.9	5.1	4.5	5.0	4.3	5.2	4.2	4.9	4.9	4.6	4.8	5.4	5.0	5.6	4.5	4.9	5.1	4.57°C ± 0.72
	N	1.6	1.3	1.2	1.6	1.0	0.9	2.0	1.1	1.1	3.7	1.8	1.9	2.1	2.0	2.0	2.3	2.2	1.5	1.3	2.7	2.8	3.4	2.1	2.2	2.9	2.3	1.97°C ± 0.72
2 - Northwest Gulf	A	0.1	0.6	1.1	0.1	0.0	0.3	0.4	0.7	0.5	-0.1	0.6	0.6	0.5	0.8	1.4	0.3	0.1	0.3	-0.2	0.1	-0.3	0.9	0.5	0.5	0.5	1.0	0.43°C ± 0.41
	M	2.6	4.9	3.5	4.1	2.5	2.5	2.2	2.9	3.5	4.2	4.5	3.1	2.9	5.3	4.9	3.5	5.2	2.9	3.8	2.6	3.0	5.3	3.3	5.6	3.2	4.6	3.71°C ± 1.03
	J	7.9	7.0	8.7	7.9	9.2	7.7	8.1	8.1	9.2	9.6	10.1	10.2	8.7	9.9	9.9	8.7	9.7	8.1	8.9	7.9	9.3	10.5	9.1	9.0	8.8	9.5	8.91°C ± 0.89
	J	12.1	11.2	12.8	13.3	13.3	11.3	11.1	11.1	13.3	14.0	14.4	12.9	12.8	13.3	13.3	13.7	12.6	12.8	13.2	13.2	14.3	14.3	13.4	13.5	12.8	14.2	13.00°C ± 0.98
	A	13.5	13.0	12.7	14.5	12.2	13.7	13.1	11.7	15.7	13.2	14.4	14.3	13.2	13.5	14.1	15.2	13.5	14.3	14.4	13.6	12.8	13.6	12.9	15.2	14.7	14.2	13.74°C ± 0.95
	S	11.2	9.1	9.3	9.0	9.3	9.9	10.1	10.6	10.7	10.0	10.4	11.7	11.7	12.1	12.1	10.3	10.6	10.0	10.2	9.5	11.3	10.4	8.9	11.7	9.6	11.5	10.42°C ± 0.99
	O	6.5	5.8	5.9	5.3	4.2	5.9	6.2	5.3	5.3	8.2	6.8	6.8	7.4	6.3	7.4	6.0	6.7	5.8	7.1	7.0	7.3	6.8	6.5	6.6	7.2	7.0	6.43°C ± 0.84
	N	2.7	2.0	1.9	2.5	2.0	1.9	3.7	2.0	2.0	4.7	3.1	3.2	3.3	3.4	3.0	3.2	3.0	2.5	2.4	4.2	4.3	4.7	3.4	3.5	3.9	3.8	3.09°C ± 0.86
3 - Anticosti Channel	M	1.3	2.0	1.8	1.9	1.1	0.4	0.8	1.1	1.6	1.8	2.5	2.0	1.0	3.2	3.2	1.8	2.8	1.5	1.1	1.4	2.2	4.1	1.6	3.5	1.6	3.0	1.93°C ± 0.91
	J	5.0	5.2	7.6	6.1	7.3	4.5	6.1	5.8	6.7	6.4	7.6	8.4	6.3	7.9	8.3	6.5	7.9	6.5	6.5	6.0	8.4	9.5	6.6	7.0	8.1	6.5	6.88°C ± 1.17
	J	11.0	10.6	12.4	11.3	12.6	10.2	9.9	10.1	10.7	12.2	12.7	11.8	11.9	12.6	12.6	12.1	11.7	11.7	12.0	12.5	12.8	13.8	12.9	13.2	12.1	11.9	11.89°C ± 0.98
	A	13.1	13.3	13.6	13.7	12.5	12.8	12.9	12.1	14.6	13.3	13.8	14.8	13.5	13.2	14.2	15.2	13.7	14.3	14.9	13.9	12.4	14.2	13.8	15.5	14.9	14.9	13.81°C ± 0.90
	S	11.3	10.2	10.9	9.6	10.2	9.8	10.0	10.6	10.1	11.3	11.4	12.6	12.1	12.0	13.4	11.1	11.7	10.8	10.7	10.5	12.3	12.3	10.3	12.3	10.3	12.3	11.16°C ± 1.02
	O	6.8	6.9	7.7	6.6	5.2	7.2	7.2	6.8	5.9	8.5	8.6	7.3	8.1	6.9	8.3	6.8	8.4	6.7	7.7	8.5	8.6	8.5	7.4	8.1	7.4	8.0	7.47°C ± 0.89
	N	2.6	2.4	3.0	3.6	2.9	2.6	4.3	2.6	2.8	4.4	4.9	4.0	3.8	3.1	3.4	3.8	4.3	3.1	3.4	4.5	4.9	5.5	3.7	4.8	3.3	5.0	3.72°C ± 0.88
4 - Mécatina Trough	M		1.1	1.3	1.8	-0.0		1.0	1.3	0.8		1.0	1.6	0.6	1.4	2.1	1.3	1.7	1.0	1.5	1.0	2.2	3.5	0.9	1.7	0.9	1.2	1.34°C ± 0.68
	J	4.7	3.9	6.7	4.7	4.9	3.8	4.6	4.2	4.8	5.5	5.8	5.8	5.0	6.1	6.6	6.1	5.8	5.6	5.1	4.7	7.2	7.3	5.6	5.8	6.9	4.0	5.43°C ± 0.99
	J	8.3	9.3	10.4	8.7	9.7	9.5	7.9	6.9	7.9	10.5	10.1	9.2	10.4	10.7	11.2	10.9	9.8	9.5	10.4	10.0	9.6	11.8	10.3	11.0	10.3	9.6	9.76°C ± 1.12
	A	11.5	12.1	13.2	12.1	12.2	11.5	10.8	10.1	11.0	12.1	13.6	13.9	12.5	12.1	14.4	14.1	13.7	12.7	13.4	13.1	12.3	14.1	12.6	13.8	13.5	13.7	12.70°C ± 1.13
	S	9.5	9.1	10.5	9.7	8.4	10.5	8.0	9.6	9.3	10.4	9.5	10.3	9.5	9.5	12.9	11.8	11.7	10.3	11.5	10.9	11.9	11.9	10.0	11.6	9.9	10.7	10.34°C ± 1.18
	O	5.7	4.8	7.0	5.9	5.3	7.8	6.5	6.2	6.5	6.3	7.7	5.2	6.5	5.3	6.7	7.2	7.7	4.9	8.5	6.6	7.2	7.7	5.4	7.7	4.9	7.5	6.49°C ± 1.07
	N	1.3	1.7	2.7	3.6	2.0	1.6	2.9	2.1	3.0	3.7	4.5	2.5	2.2	2.2	2.8	2.5	3.5	1.5	3.6	3.1	2.9	3.4	3.0	4.0	2.0	4.2	2.80°C ± 0.86

Table 9. NOAA SST May to November monthly anomalies averaged over the remaining four regions of the Gulf. The scorecards are colour-coded according to the monthly normalized anomalies based on the 1985–2010 climatologies for each month, but the numbers are the monthly average temperatures in ºC. The mean and standard deviation are indicated for each month on the right side of the table.

Region	Month	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± SD
5 - Esquiman Channel	M	1.7	2.1	2.1	2.2	0.7	1.1	1.2	1.0	1.1	1.8	2.2	1.8	0.9	2.7	3.1	2.1	2.8	1.4	1.4	1.8	2.5	4.1	2.0	3.0	1.6	2.8	1.98°C ± 0.80
	J	5.0	5.6	7.6	6.0	6.2	4.9	5.6	5.5	6.1	6.1	7.6	7.0	6.0	8.0	8.3	6.8	8.5	6.2	6.5	5.4	8.0	8.8	7.6	7.4	7.5	6.1	6.70°C ± 1.13
	J	11.1	11.3	12.9	10.8	12.5	10.9	10.3	9.7	9.7	12.1	12.6	11.4	11.8	12.9	14.1	11.9	12.3	11.5	12.3	12.6	11.9	14.1	12.9	13.2	12.3	11.5	11.95°C ± 1.13
	A	14.6	14.3	15.2	15.1	14.3	14.0	13.8	13.1	14.0	15.4	15.3	16.1	14.7	14.7	15.4	16.7	15.7	15.3	15.4	16.2	14.7	15.9	14.9	16.0	16.3	16.1	15.12°C ± 0.89
	S	12.1	11.2	12.6	12.3	10.7	12.5	11.0	12.1	11.9	12.8	11.5	13.2	12.2	11.7	14.4	14.0	13.1	11.5	13.4	12.3	13.3	13.8	12.0	13.3	11.8	12.6	12.44°C ± 0.94
	O	8.2	7.0	8.4	7.5	6.2	8.6	7.7	7.5	8.0	8.9	9.1	7.7	8.1	7.2	9.2	8.6	9.1	6.7	10.1	8.2	8.1	9.5	8.0	8.8	7.0	8.6	8.16°C ± 0.91
	N	3.3	3.6	3.9	4.3	3.5	2.9	5.0	3.0	4.1	4.9	5.9	4.6	3.9	4.3	4.2	4.2	4.3	2.7	4.5	4.5	4.8	5.3	4.3	5.2	3.8	5.5	4.25°C ± 0.80
6 - Central Gulf	M	1.0	2.7	2.5	2.2	1.2	0.8	1.2	1.2	1.8	1.7	3.2	1.8	1.3	3.5	3.0	2.4	3.0	1.2	1.6	1.7	2.5	4.5	2.3	3.7	2.1	3.0	2.20°C ± 0.93
	J	5.8	6.4	8.5	6.3	7.7	5.9	6.7	6.7	6.8	6.7	8.6	8.1	6.8	8.3	9.1	7.2	8.8	6.6	6.9	6.2	8.1	9.4	7.6	7.5	8.1	7.0	7.38°C ± 1.00
	J	12.6	11.5	13.8	12.3	13.6	11.5	11.5	11.2	11.6	14.1	14.5	13.1	13.0	14.0	14.9	13.3	13.8	12.5	12.7	13.5	13.7	15.3	13.8	14.6	13.5	13.5	13.21°C ± 1.12
	A	16.0	15.2	15.4	16.4	15.3	14.8	14.7	14.3	16.4	16.4	16.6	17.2	15.9	16.0	16.0	17.6	16.8	16.3	16.1	17.1	15.8	16.6	15.5	17.0	17.2	17.2	16.14°C ± 0.85
	S	13.3	12.2	13.0	12.6	11.2	12.7	12.4	13.2	13.2	13.6	12.7	14.4	13.9	13.6	15.0	14.2	13.7	12.4	13.7	12.5	13.7	14.5	12.1	13.7	12.9	13.7	13.24°C ± 0.85
	O	8.3	8.2	8.8	8.1	6.4	8.8	9.0	8.0	8.5	9.5	9.5	9.0	9.3	8.0	9.2	8.9	9.5	8.1	9.6	9.3	9.0	10.0	8.6	9.0	8.7	9.3	8.79°C ± 0.73
	N	4.1	3.5	3.7	3.9	3.6	3.1	5.0	3.8	4.2	4.6	5.6	4.9	4.7	4.3	4.2	4.7	4.4	3.9	4.0	4.9	5.2	5.9	4.6	5.0	4.8	5.4	4.46°C ± 0.69
7 - Cabot Strait	M	1.2	3.0	2.6	2.9	1.8	1.1	1.4	1.6	2.0	2.3	3.1	2.5	1.6	3.9	3.8	3.1	3.3	1.9	2.3	2.4	3.2	4.5	2.4	2.9	2.9	3.3	2.57°C ± 0.86
	J	5.8	6.6	7.5	6.4	7.2	6.4	6.2	6.8	6.8	7.7	7.8	7.9	6.7	8.3	9.9	8.1	8.7	7.2	7.2	6.5	8.1	9.1	8.2	7.8	8.7	7.0	7.48°C ± 0.98
	J	11.9	11.4	13.7	12.2	13.1	12.0	11.8	10.6	11.6	15.0	13.5	13.2	12.8	14.0	15.5	13.9	14.0	12.3	13.7	13.8	13.2	14.9	13.6	15.0	13.6	13.6	13.22°C ± 1.22
	A	16.0	15.3	16.6	15.9	16.1	15.6	15.1	14.7	16.5	17.8	16.9	17.6	16.0	17.1	17.6	18.0	17.4	17.1	16.5	17.6	16.1	16.5	15.7	16.4	17.5	17.4	16.57°C ± 0.89
	S	13.7	12.9	14.5	13.2	12.2	14.1	12.5	14.8	14.4	14.8	13.2	14.6	14.1	14.5	16.1	14.4	14.9	13.2	13.5	13.2	15.5	14.7	13.2	14.4	13.3	14.3	14.01°C ± 0.93
	O	9.6	8.9	10.2	9.4	7.6	10.5	10.6	8.9	10.9	10.9	11.1	10.5	10.3	9.8	10.2	10.0	11.9	8.6	11.7	10.0	10.5	11.2	9.3	10.1	9.9	10.4	10.11°C ± 0.96
	N	5.7	5.4	4.6	5.5	5.1	4.4	5.8	5.2	5.9	6.3	7.2	6.6	6.7	6.7	5.7	6.6	6.4	4.3	5.6	6.5	6.8	6.9	5.8	6.8	6.0	6.7	5.97°C ± 0.80
8 - Magdalen Shallows	M	2.8	4.2	3.7	3.9	3.4	2.5	2.8	2.7	3.0	3.9	4.1	4.1	2.9	5.8	5.1	4.0	4.7	3.5	3.6	3.7	3.5	6.3	4.0	5.0	4.6	5.2	3.96°C ± 0.97
	J	8.2	8.9	10.3	8.7	10.1	9.2	10.3	9.6	9.0	10.2	10.6	11.1	9.2	10.9	12.1	10.5	11.5	9.7	9.9	9.2	9.7	11.8	10.5	10.8	11.1	10.0	10.12°C ± 0.97
	J	14.6	13.9	15.9	15.4	15.5	14.8	14.8	13.4	14.5	18.1	17.2	15.5	15.7	16.4	17.5	16.4	16.5	15.5	16.8	15.9	16.2	17.4	16.4	17.5	15.1	17.0	15.92°C ± 1.17
	A	17.6	16.3	17.5	18.0	17.2	17.9	17.3	16.4	18.4	18.7	18.6	18.9	17.8	17.7	18.0	18.3	19.1	18.2	17.6	18.6	18.2	18.0	17.2	17.1	18.6	18.7	17.92°C ± 0.72
	S	14.7	13.3	14.3	14.2	13.9	15.0	14.5	15.3	15.7	15.2	14.7	15.8	15.4	15.2	16.4	15.5	16.1	15.0	15.2	14.7	16.3	15.5	14.5	15.1	14.6	15.1	15.05°C ± 0.71
	O	10.8	9.4	10.3	9.3	8.6	11.2	11.4	9.7	10.5	10.3	11.4	10.7	10.7	9.9	10.6	10.7	12.0	10.8	11.3	11.1	11.3	11.2	11.1	10.7	10.4	10.5	10.62°C ± 0.76
	N	5.7	4.7	4.6	4.9	5.3	4.5	6.3	5.0	5.4	6.7	6.5	6.7	6.2	5.5	5.5	5.9	6.0	5.3	5.6	5.4	6.5	6.5	6.3	6.3	6.2	6.1	5.74°C ± 0.67

Table 10. NOAA SST April to November monthly anomalies averaged over the Estuary (region 1 of the Gulf) and subregions for the Saguenay – St. Lawrence Marine Park (PMSSL), the proposed St. Lawrence Estuary Marine Protected Area (MPA), and Manicouagan MPA. The monthly numbers are the normalized anomalies (monthly mean minus climatological mean, divided by the standard deviation of the climatology). The mean and standard deviation are indicated for each month on the right side of the table.

		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± S.D.
Estuary	A								0.3	0.6		0.7	0.0				0.4		2.1	-1.5	-1.4	-0.5	0.6	-1.2	-0.7	-0.4	1.0	1.44°C ± 0.46
	M		0.5	0.3	0.3	-1.6	-0.5		-1.2	-0.6	2.1	0.3	-0.5	-0.3	0.6	1.3	0.1	1.6	-0.6	-0.8	-1.2	-1.5	0.7	-0.4	1.1	-0.7	1.1	4.69°C ± 0.89
	J	-1.3	-2.5	-1.0	-0.2	-1.1	-1.2	-0.3	-0.5	1.0	0.6	0.3	0.6	-0.0	1.5	0.5	-0.4	1.6	0.0	-0.3	-0.5	-0.5	1.7	1.3	0.6	-0.5	0.9	8.22°C ± 0.75
	J	-1.3	-1.3	-0.0	0.4	-0.2	-2.0	-1.8	-1.2	1.9	0.9	0.9	-0.3	-0.3	-0.1	-0.8	1.2	-0.7	0.8	0.8	0.9	0.8	0.9	-0.0	0.6	-0.7	0.6	10.58°C ± 0.92
	A	-0.5	-1.0	-0.2	0.4	-2.0	-0.1	-0.2	-1.8	1.6	0.1	0.6	0.4	-0.7	-1.5	0.2	1.3	0.0	1.0	1.2	-0.7	-0.9	0.3	-0.6	1.9	0.8	0.3	10.37°C ± 1.02
	S	0.5	-1.3	-1.3	-1.5	-1.2	-0.7	-1.2	-0.2	0.5	-0.1	-0.4	1.6	1.0	1.8	1.7	-0.3	-0.1	0.8	-0.5	-0.5	0.7	0.4	-1.2	0.9	-0.6	1.0	7.57°C ± 0.85
	O	0.5	-0.5	-0.6	-1.3	-2.7	-0.8	-0.8	-1.3	-1.3	1.8	0.7	-0.1	0.6	-0.3	0.9	-0.4	0.5	0.4	0.0	0.4	1.2	0.7	1.4	-0.1	0.5	0.7	4.57°C ± 0.72
	N	-0.5	-0.9	-1.1	-0.5	-1.4	-1.5	0.1	-1.2	-1.3	2.4	-0.2	-0.1	0.2	0.1	0.1	0.4	0.4	-0.7	-0.9	1.0	1.1	2.0	0.2	0.3	1.2	0.4	1.97°C ± 0.72
PMSSL (Saguenay)	A	-1.4	0.4	1.6	-0.6	-3.2	-0.5	-1.3	0.1	0.5	0.8	0.8	0.2	1.1	-0.3	-0.5	1.1	0.4	-0.2	-0.3	-1.3	0.3	-0.1	0.2	1.0	0.2	1.1	0.07°C ± 0.36
	M	-2.1	0.9	0.7	-0.1	-0.5	-0.8	-1.0	-0.1	0.5	0.8	0.5	-0.1	-1.7	0.4	0.9	-0.1	1.9	-0.7	-0.1	-1.1	-0.9	1.3	-0.0	-0.3	-0.4	2.0	3.50°C ± 1.23
	J	-1.1	-2.0	-0.4	-1.1	-0.8	-0.3	0.6	-1.0	0.5	1.4	0.8	0.5	-1.4	0.0	2.1	0.8	0.6	-1.1	0.1	-1.3	0.7	1.3	0.5	0.1	0.3	0.4	9.82°C ± 1.41
	J	0.9	-1.7	-0.0	0.3	-0.9	-0.6	-0.6	-1.5	1.2	2.0	1.8	-0.6	-1.0	-0.6	0.4	-0.4	-0.6	-1.1	-0.4	0.5	0.8	1.1	-0.1	1.2	-0.9	0.6	12.85°C ± 1.29
	A	-0.8	-1.8	-1.6	-0.6	-1.3	0.7	-0.2	-0.1	1.3	0.5	1.3	1.1	-0.9	-1.2	-0.4	0.4	1.3	1.0	1.5	-0.4	-0.2	-0.2	-1.2	0.7	1.2	-0.3	12.75°C ± 0.96
	S	-1.2	-2.1	-1.9	-0.3	-0.5	-0.6	-1.4	-0.1	-0.0	0.6	-1.3	1.4	1.2	-0.3	1.6	-0.0	0.6	0.5	1.3	0.9	0.7	0.4	0.0	0.3	0.9	-0.7	8.62°C ± 1.03
	O	-0.1	-0.9	-0.1	-1.7	-1.5	-0.8	-0.0	-0.7	-0.3	1.7	1.9	-0.5	0.9	-0.7	-0.7	0.7	1.6	-0.5	0.6	0.5	1.1	-0.2	1.3	0.1	-1.5	-0.2	3.71°C ± 1.25
	N	-0.3	-1.7	-1.2	1.5	-0.2	1.4	-0.4	-1.2	-0.8	0.4	-0.1	-1.0	1.4	-0.6	0.8	0.0	1.2	-0.7	-0.6	-1.0	0.2	0.0	-0.4	2.4	0.8	-0.1	0.64°C ± 0.80
PMSSL (Estuary)	A								0.1	-0.3		0.7	0.4				0.9		2.4	-1.5	-1.0	-0.2	0.3	-1.0	-0.9	-0.4	0.3	1.51°C ± 0.55
	M		0.3	0.3	0.6	-0.9	0.3		-1.6	-0.7	1.5	-0.1	-0.5	-1.4	1.4	1.2	0.2	2.1	-0.7	-0.9	-1.2	-0.9	0.6	-0.5	1.0	-0.7	0.5	4.24°C ± 0.73
	J	-0.9	-1.8	-0.3	-0.5	-1.3	-1.4	-0.6	-1.7	-0.1	0.7	0.3	0.1	-0.4	1.5	0.8	-0.4	1.4	0.5	-0.2	-0.1	0.0	2.1	1.2	1.3	-0.2	0.2	6.96°C ± 0.73
	J	0.0	-1.3	-0.1	-0.6	-1.1	-2.1	-2.2	-1.3	1.4	1.2	0.1	0.3	-0.5	1.0	-0.3	0.9	0.1	0.7	-0.3	1.2	0.0	0.9	-0.0	1.2	0.0	0.6	8.83°C ± 0.78
	A	-0.4	-0.2	-0.2	-0.2	-2.2	-0.6	-0.3	-2.0	0.5	0.0	0.3	0.5	-0.2	-1.2	-0.3	1.5	0.2	1.4	0.9	-0.5	-0.8	0.8	-0.5	2.3	0.9	-0.1	8.83°C ± 0.74
	S	-0.0	-1.6	-1.2	-1.6	-1.2	-1.3	-0.9	-0.1	1.0	0.3	-0.8	1.6	1.5	1.5	1.4	-0.2	-0.1	1.2	-0.6	0.1	0.5	0.1	-0.5	0.6	-0.5	1.1	6.76°C ± 0.65
	O	1.3	-0.4	-0.6	-1.2	-2.7	-0.7	-1.1	-1.0	-1.2	1.7	0.5	-0.2	0.8	-0.3	0.7	0.0	0.5	0.3	-0.2	-0.1	1.4	0.7	1.4	-0.1	-0.3	0.9	4.46°C ± 0.70
	N	-0.4	-1.4	-0.7	-1.0	-1.6	-1.2	-0.0	-1.3	-1.0	2.4	0.1	-0.4	0.4	-0.2	0.1	0.3	0.6	-0.7	-0.5	1.1	0.8	2.1	0.6	0.4	1.1	0.4	1.97°C ± 0.66
St. Lawrence Estuary MPA	A			1.5					0.1	-0.2		0.0	-0.3				0.4		2.2	-1.5	-1.1	-0.1	0.4	-1.3	-0.9	-0.1	0.8	1.62°C ± 0.50
	M		0.1	-0.2	0.6	-1.7	-0.1		-1.2	-0.6	1.8	0.3	-0.4	-0.7	0.9	1.3	0.3	1.7	-0.5	-1.0	-1.1	-1.5	0.8	-0.6	1.2	-0.4	0.9	4.82°C ± 0.75
	J	-1.1	-2.2	-1.0	-0.5	-1.2	-1.1	-0.4	-1.0	0.8	1.0	0.4	0.3	-0.5	1.6	0.5	-0.3	1.6	0.0	-0.2	-0.5	-0.2	1.9	1.2	0.8	-0.4	0.6	8.09°C ± 0.73
	J	-0.9	-1.5	0.1	0.1	-0.5	-1.8	-1.8	-1.4	1.9	1.2	0.5	-0.1	-0.4	0.3	-0.7	1.2	-0.5	1.1	0.1	1.1	0.5	1.1	-0.0	0.8	-0.7	0.4	10.21°C ± 0.79
	A	-0.6	-1.1	-0.4	0.2	-2.1	-0.3	-0.3	-1.7	1.4	0.4	0.5	0.7	-0.4	-1.6	-0.0	1.4	-0.1	1.1	0.9	-0.8	-0.3	0.5	-0.4	2.1	1.0	0.1	10.08°C ± 0.87
	S	0.2	-1.4	-1.4	-1.6	-1.2	-1.2	-1.1	-0.4	0.7	0.0	-0.3	1.8	1.1	1.5	1.7	-0.3	0.0	1.1	-0.2	-0.1	0.7	0.1	-0.8	0.8	-0.5	0.9	7.61°C ± 0.68
	O	0.7	-0.3	-0.7	-1.3	-2.7	-1.0	-0.8	-1.0	-1.3	1.6	0.7	-0.2	0.6	-0.1	0.5	-0.2	0.5	0.5	-0.3	0.5	1.3	0.6	1.9	-0.0	-0.1	0.7	4.70°C ± 0.69
	N	-0.4	-1.0	-1.0	-0.7	-1.4	-1.5	-0.3	-1.2	-1.1	2.4	0.0	-0.0	0.6	-0.2	0.2	0.5	0.6	-0.8	-0.8	1.0	0.7	2.0	0.2	0.3	1.2	0.5	1.99°C ± 0.67
Manicouagan MPA	A								0.2	1.0		0.3	0.7				1.2		1.2	-1.4	-1.7	-0.7	0.7	-1.2	-0.4	-0.7	0.9	1.53°C ± 0.45
	M		0.7	-0.1	0.1	-1.6	-0.7		-0.7	-0.1	2.2	0.6	-0.4	0.1	0.6	1.1	-0.2	1.5	-0.9	-1.0	-1.4	-1.6	0.8	-0.2	0.9	-0.9	1.1	4.95°C ± 0.98
	J	-0.8	-2.7	-0.8	-0.5	-0.9	-1.1	-0.1	-0.1	1.6	0.3	-0.0	0.6	0.2	1.3	0.1	-0.5	1.0	-0.5	-0.2	-0.5	-0.2	1.6	1.7	0.8	-0.7	0.7	8.96°C ± 0.87
	J	-1.5	-1.3	-0.1	0.7	-0.4	-1.7	-1.6	-1.1	2.2	1.2	0.9	-0.4	-0.6	-0.2	-0.9	1.3	-0.7	0.4	1.0	0.7	0.7	1.0	0.2	0.3	-0.5	0.5	11.58°C ± 1.12
	A	-0.6	-0.8	0.1	0.0	-2.0	0.4	0.6	-1.8	1.7	-0.2	0.3	0.3	-0.7	-1.3	0.1	1.5	0.0	0.8	1.3	-1.0	-0.8	-0.1	-0.6	2.0	0.4	0.5	11.30°C ± 1.07
	S	0.3	-1.5	-1.2	-1.6	-1.4	-0.6	-1.3	-0.2	0.3	0.4	-0.3	1.7	1.0	1.9	1.6	-0.4	-0.4	0.8	-0.3	-0.1	0.8	0.3	-1.1	0.6	-0.7	0.9	8.15°C ± 0.99
	O	0.0	-1.0	-0.8	-1.3	-2.4	-0.8	-0.3	-1.3	-1.3	1.7	1.1	-0.1	0.7	-0.7	1.0	-0.5	0.5	0.2	0.3	0.6	1.3	0.7	1.2	-0.1	1.0	0.2	4.95°C ± 0.81
	N	-0.4	-0.8	-1.1	-0.4	-1.1	-1.6	0.0	-1.2	-1.3	2.3	-0.3	-0.1	0.6	0.4	0.1	0.8	0.3	-0.9	-0.8	0.8	1.1	1.9	-0.0	0.2	1.2	0.6	2.03°C ± 0.72

Table 11. NOAA SST May to November monthly anomalies averaged over the Magdalen Shallows (region 8 of the Gulf) and the eastern and western subregions of the Magdalen Shallows. The monthly numbers are the normalized anomalies (monthly mean minus climatological mean, divided by the standard deviation of the climatology). The mean and standard deviation are indicated for each month on the right side of the table.

		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± S.D.
Magdalen Shallows	M	-1.2	0.3	-0.2	-0.1	-0.6	-1.5	-1.2	-1.3	-1.0	-0.1	0.2	0.1	-1.1	1.9	1.2	0.1	0.8	-0.5	-0.3	-0.3	-0.5	2.5	0.0	1.1	0.7	1.2	3.96°C ± 0.97
	J	-2.0	-1.2	0.2	-1.5	-0.1	-0.9	0.1	-0.5	-1.2	0.0	0.5	1.0	-0.9	0.8	2.1	0.4	1.4	-0.4	-0.2	-0.9	-0.4	1.7	0.4	0.7	1.0	-0.2	10.12°C ± 0.97
	J	-1.1	-1.7	0.0	-0.4	-0.4	-0.9	-0.9	-2.1	-1.2	1.9	1.1	-0.4	-0.2	0.4	1.3	0.4	0.5	-0.4	0.7	-0.0	0.2	1.2	0.4	1.3	-0.7	0.9	15.92°C ± 1.17
	A	-0.5	-2.3	-0.6	0.1	-0.9	-0.1	-0.9	-2.0	0.7	1.1	0.9	1.3	-0.2	-0.3	0.1	0.6	1.6	0.4	-0.4	1.0	0.4	0.1	-1.0	-1.1	1.0	1.0	17.92°C ± 0.72
	S	-0.5	-2.4	-1.1	-1.2	-1.6	-0.1	-0.8	0.3	0.9	0.2	-0.5	1.0	0.6	0.3	1.9	0.7	1.5	-0.1	0.2	-0.5	1.8	0.7	-0.8	0.1	-0.6	0.1	15.05°C ± 0.71
	O	0.3	-1.6	-0.4	-1.8	-2.6	0.8	1.1	-1.2	-0.2	-0.4	1.0	0.1	0.0	-0.9	-0.1	0.1	1.9	0.2	1.0	0.6	0.8	0.7	0.7	0.1	-0.3	-0.1	10.62°C ± 0.76
	N	-0.1	-1.5	-1.6	-1.3	-0.7	-1.9	0.8	-1.1	-0.5	1.4	1.2	1.4	0.7	-0.4	-0.4	0.2	0.4	-0.7	-0.2	-0.4	1.2	1.1	0.8	0.8	0.7	0.5	5.74°C ± 0.67
Eastern Magdalen Shelf	M	-1.3	0.5	-0.5	0.1	-0.5	-1.5	-1.1	-1.5	-0.9	0.2	0.1	0.0	-1.3	1.8	1.1	0.2	0.7	-0.5	-0.1	-0.3	-0.0	2.6	-0.1	0.8	0.6	1.1	2.95°C ± 1.01
	J	-1.9	-0.9	0.4	-1.6	-0.2	-1.2	-0.4	-0.5	-1.2	-0.0	0.2	0.9	-0.8	1.0	2.2	0.4	1.5	-0.2	-0.4	-0.7	-0.1	1.6	0.6	0.7	1.1	-0.3	8.92°C ± 1.05
	J	-1.3	-1.5	0.1	-0.6	-0.3	-0.8	-0.8	-2.0	-1.5	1.8	0.7	-0.4	-0.2	0.4	1.6	0.5	0.7	-0.3	0.5	0.2	-0.0	1.5	0.2	1.4	-0.5	0.8	15.30°C ± 1.36
	A	-0.2	-1.9	-0.2	-0.6	-0.9	-0.9	-1.1	-1.9	-0.3	1.5	0.7	1.4	-0.4	0.1	0.5	0.6	1.5	0.4	-0.3	1.2	0.2	0.0	-1.0	-1.0	1.0	1.3	18.04°C ± 0.87
	S	-0.6	-2.0	-0.2	-1.1	-1.4	-0.3	-1.2	0.6	0.9	0.8	-1.0	0.6	0.5	-0.1	2.0	1.0	1.5	-0.1	0.2	-0.6	1.7	0.6	-1.1	0.0	-0.5	-0.4	15.26°C ± 0.79
	O	-0.6	-1.5	-0.1	-1.2	-2.5	0.1	1.5	-1.1	0.5	-0.2	0.9	0.5	0.3	-1.2	-0.5	0.2	2.1	-0.5	1.2	0.7	0.8	0.6	0.4	0.5	-0.4	-0.1	10.95°C ± 0.73
	N	0.1	-1.4	-2.0	-0.9	-0.4	-2.2	0.4	-1.1	-0.1	0.6	1.0	1.9	0.8	-0.3	-0.6	1.0	0.4	-0.9	-0.1	-0.7	0.9	0.5	1.0	1.1	0.5	0.7	6.07°C ± 0.67
Western Magdalen Shelf	M	-1.0	0.4	0.2	-0.3	-0.8	-1.3	-1.3	-1.4	-0.8	-0.5	0.3	-0.2	-1.0	2.0	1.1	0.1	0.6	-0.5	-0.4	-0.2	-0.6	2.4	0.1	1.5	0.6	1.0	3.45°C ± 0.97
	J	-1.8	-1.2	0.8	-1.6	0.2	-1.0	0.2	-0.3	-1.3	-0.3	0.7	1.1	-0.8	0.9	1.9	0.1	1.4	-0.4	-0.3	-1.0	-0.4	1.6	0.2	0.5	0.9	-0.4	9.65°C ± 1.00
	J	-0.9	-1.6	0.2	-0.3	-0.1	-1.2	-1.3	-2.0	-1.3	1.7	1.4	-0.4	-0.2	0.5	1.3	0.4	0.4	-0.4	0.6	-0.1	0.4	1.3	0.5	1.2	-0.6	0.7	15.48°C ± 1.17
	A	-0.3	-2.1	-0.7	0.6	-1.0	-0.4	-1.2	-2.3	1.1	0.6	1.0	1.2	-0.2	-0.3	-0.3	0.9	1.3	0.2	-0.5	0.7	0.6	0.4	-1.1	-0.6	0.9	1.1	17.43°C ± 0.78
	S	-0.3	-2.0	-1.0	-0.8	-2.0	-0.0	-0.8	-0.0	0.8	0.1	-0.4	1.4	0.9	0.5	1.5	0.6	1.1	-0.5	0.1	-0.8	1.8	0.8	-1.2	0.5	-0.6	0.4	14.32°C ± 0.79
	O	0.5	-1.7	-0.4	-1.9	-2.8	0.9	0.8	-1.3	-0.3	-0.4	0.9	0.5	0.3	-0.6	-0.1	0.2	1.6	0.4	1.0	0.6	0.9	0.7	0.2	0.2	0.1	-0.1	9.78°C ± 0.79
	N	0.1	-1.5	-1.7	-1.6	-1.0	-1.6	0.9	-0.9	-0.7	1.4	1.2	1.6	0.6	-0.5	-0.4	0.2	-0.1	-0.3	-0.4	-0.1	1.3	1.2	0.5	0.6	1.0	0.4	5.12°C ± 0.72

Table 12. Yearly number of weeks with mean weekly surface temperature > 10°C, averaged for the entire Gulf and each region of the Gulf. The scorecards are colour-coded according to the normalized anomalies based on the 1985–2010 time series, but the numbers are the average number of weeks above 10°C for each year.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± S.D.
Gulf of St. Lawrence	11.4	10.4	13.0	11.0	12.1	12.0	11.8	10.8	12.4	14.0	14.9	14.8	13.7	14.4	16.2	14.1	15.6	12.7	14.8	13.1	14.2	16.3	13.8	14.4	14.2	14.2	13.5 w ± 1.6
1 - Estuary	4.9	3.5	5.1	6.6	5.4	5.5	5.0	5.2	10.1	6.9	7.4	8.1	7.6	7.9	8.2	8.0	7.8	8.1	6.9	5.8	6.7	9.1	6.6	8.7	6.3	8.8	6.9 w ± 1.6
2 - Northwest Gulf	11.0	8.0	9.0	9.2	10.7	10.0	9.6	9.4	13.0	12.6	13.6	15.0	12.6	14.6	15.1	12.3	13.1	11.1	12.6	10.5	12.7	13.8	11.6	13.0	11.9	13.9	11.9 w ± 1.9
3 - Anticosti Channel	9.5	8.8	11.5	8.9	11.4	7.3	7.7	8.9	9.4	11.4	12.6	13.4	12.0	13.0	15.2	11.3	12.9	11.3	11.9	10.8	13.0	14.6	10.7	11.9	12.7	12.5	11.3 w ± 2.0
4 - Mécatina Trough	4.6	5.4	9.0	6.7	5.9	7.7	2.9	2.8	4.2	8.3	7.8	7.8	8.8	8.4	12.5	11.6	10.7	8.0	11.8	9.5	9.7	11.7	8.6	10.2	9.9	9.1	8.2 w ± 2.7
5 - Esquiman Channel	9.9	9.4	13.0	10.8	10.9	10.9	8.9	8.2	9.2	12.9	13.1	11.9	12.4	12.6	15.6	13.6	14.5	10.1	15.3	11.8	12.6	16.8	13.1	13.3	13.3	12.6	12.2 w ± 2.1
6 - Central Gulf	12.3	10.9	14.2	11.3	12.4	12.2	12.6	11.8	12.8	14.6	15.5	15.4	13.9	14.2	16.7	14.2	16.1	12.4	15.3	13.3	13.8	17.2	13.1	13.9	14.9	13.9	13.8 w ± 1.6
7 - Cabot Strait	11.6	11.1	15.0	11.8	12.6	14.4	13.6	11.3	14.1	16.1	16.9	16.1	14.6	15.6	17.3	15.4	18.1	12.5	16.2	14.0	15.6	17.4	15.4	15.4	15.8	15.0	14.7 w ± 1.9
8 - Magdalen Shallows	14.8	14.5	16.6	14.1	15.5	16.3	17.6	15.1	16.1	17.5	18.8	18.2	16.8	17.4	18.6	17.6	19.8	17.4	18.1	17.8	17.9	19.5	18.7	18.2	17.7	17.6	17.2 w ± 1.5

Table 13. First and last day of ice occurrence, ice duration, and maximum seasonal ice volume by region. The time when ice was first and last seen in days from the beginning of each year is indicated for each region, and the colour code expresses the anomaly based on the 1981–2010 climatology, with blue representing earlier first occurrence and later last occurrence. The threshold is 5% of the largest ice volume ever recorded in the region. Numbers in the table are the actual day of the year rather than the anomaly, but the colour coding is according to normalized anomalies based on the climatology of each region.

First occurrence of ice

Year	1 - Estuary	2 - Northwest Gulf	3 - Anticosti Channel	4 - Mécatina Trough	5 - Esquiman Channel	6 - Central Gulf	7 - Cabot Strait	8 - Magdalen Shallows
1969	17	17	57	80	80			17
1970	12	12	12	12	58	37	30	12
1971	-10	15	15	15	15	15	29	-1
1972	0	0	0	0	14	21	28	0
1973	-12	-12	-2	-12	-2	3	15	-12
1974	-3	-3	9	9	16	23	23	9
1975	-8	8	15	8	29	29	29	8
1976	-5	-5	9	-5	37	16	37	9
1977	-14	-14	7	-7	16	16	16	-14
1978			8	8	36	22	29	8
1979	-21	-21	14	-28	14	14	42	-21
1980	-6	8	-6	1	29	36	36	8
1981	-24	-1	22	-1	36	15	15	-1
1982	-9	14	14	21	28	42	35	14
1983	-5	9	-5	-12	44	23	51	9
1984	3	3	15	3	15	15	43	3
1985	2	2	2	2	2	23	23	2
1986	-13	-6	8	-13	8	15	22	-6
1987	-14	-7	-14	-14	7	21	35	-14
1988	-8	-1	24	3	17	24	31	-1
1989	-5	-5	2	-5	9	16	30	-5
1990	-21	-21	-21	-21	8	8	8	-21
1991	0	7	7	-11	7	14	21	-7
1992	-12	-5	2	-5	23	23	23	-5
1993	-17	-3	4	-3	4	11	25	-3
1994	-4	3	-4	3	24	10	17	3
1995	2	16	9	2	16	30	44	2
1996	-20	8	29	-20	15	22	36	-13
1997	6	6	34	20	41	34	41	6
1998	-9	3	9	6	17	29	40	-2
1999	0	3	9	2	14	13	35	2
2000	2	16	16	15	41	29	39	15
2001	-5	12	26	5	23	36	50	4
2002	5	19	18	17	25	35	41	17
2003	-21	8	5	-2	15	19	25	7
2004	-21	3	28	25	43	15	25	10
2005	-8	3	17	10	23	26	31	5
2006	-12	2	31	-3	31	52	60	33
2007	14	24	29	14	29	37	37	18
2008	-15	6	7	0	21	26	46	1
2009	-19	7	19	18	27	18	25	5
2010	-2	19	32	24	36			24
Mean ± S.D.	-8 ± 10	5 ± 9	12 ± 14	3 ± 13	22 ± 12	23 ± 10	33 ± 12	3 ± 11

Last occurrence of ice

Year	1 - Estuary	2 - Northwest Gulf	3 - Anticosti Channel	4 - Mécatina Trough	5 - Esquiman Channel	6 - Central Gulf	7 - Cabot Strait	8 - Magdalen Shallows
1969	80	80	57	132	80			94
1970	84	77	98	119	119	70	98	105
1971	64	78	71	92	85	85	92	106
1972	101	108	136	122	129	136	136	136
1973	71	85	99	134	120	99	127	127
1974	72	93	149	177	163	107	107	107
1975	71	85	127	162	141	113	127	127
1976	93	100	121	142	121	100	100	100
1977	86	86	100	121	128	93	114	114
1978	99	99	127	134	134	106	106	113
1979	84	91	105	133	77	98	98	112
1980	80	80	92	120	99	80	106	106
1981	55	62	83	90	62	69	62	83
1982	77	77	140	140	119	99	105	105
1983	100	100	93	114	86	79	100	114
1984	99	99	129	143	129	99	87	136
1985	79	79	128	156	149	93	107	107
1986	78	85	134	141	127	106	106	113
1987	84	112	119	119	119	91	126	126
1988	87	80	129	136	108	94	101	108
1989	79	86	86	128	121	107	114	107
1990	57	92	148	155	155	120	113	106
1991	98	91	168	182	119	119	119	119
1992	79	100	128	149	135	121	135	135
1993	81	109	116	158	133	116	116	123
1994	87	101	157	157	143	115	108	115
1995	100	121	142	149	142	107	121	121
1996	71	92	106	120	100	92	100	113
1997	83	97	153	146	125	118	132	125
1998	85	91	105	126	120	106	91	108
1999	86	90	115	137	123	94	114	109
2000	80	84	84	114	80	82	79	90
2001	82	79	118	135	132	85	114	114
2002	85	85	91	109	96	95	91	92
2003	82	93	157	152	149	114	115	107
2004	88	93	101	128	118	101	111	116
2005	86	98	98	111	106	89	115	113
2006	76	78	115	118	107	64	85	87
2007	85	84	113	154	127	84	88	89
2008	93	101	105	147	116	103	114	109
2009	86	83	113	129	115	98	104	106
2010	53	55	63	124	48			83
Mean ± S.D.	82 ± 12	90 ± 14	118 ± 25	136 ± 19	117 ± 24	99 ± 15	106 ± 16	109 ± 14

Duration of ice season

Year	1 - Estuary	2 - Northwest Gulf	3 - Anticosti Channel	4 - Mécatina Trough	5 - Esquiman Channel	6 - Central Gulf	7 - Cabot Strait	8 - Magdalen Shallows
1969	64	64	1	53	1			78
1970	73	66	87	108	62	34	69	94
1971	75	64	57	78	71	71	64	108
1972	102	109	137	123	116	116	109	137
1973	84	98	102	147	123	97	113	140
1974	76	97	141	169	148	85	85	99
1975	80	78	113	155	113	85	99	120
1976	99	106	113	148	85	85	64	92
1977	101	101	94	129	113	78	99	129
1978	110	105	120	127	99	85	78	106
1979	106	113	92	162	64	85	57	134
1980	87	73	99	120	71	45	71	99
1981	80	64	62	92	27	55	48	85
1982	87	64	127	120	92	58	71	92
1983	106	92	99	127	43	57	50	106
1984	97	97	115	141	115	85	45	134
1985	78	78	127	155	148	71	85	106
1986	92	92	127	155	120	92	85	120
1987	99	120	134	134	113	71	92	141
1988	96	82	106	134	92	71	71	110
1989	85	92	85	134	113	92	85	113
1990	79	114	170	177	148	113	106	128
1991	99	85	162	194	113	106	99	127
1992	92	106	127	155	113	99	113	141
1993	99	113	113	162	130	106	92	127
1994	92	99	162	155	120	106	92	113
1995	99	106	134	148	127	78	78	120
1996	92	85	78	141	86	71	65	127
1997	78	92	120	127	85	85	92	120
1998	95	89	97	121	104	78	52	111
1999	87	88	107	136	110	82	80	108
2000	79	69	69	100	40	54	41	76
2001	88	68	93	131	110	50	65	111
2002	81	67	74	93	72	61	51	76
2003	104	86	153	155	135	96	91	101
2004	110	91	74	104	76	87	87	107
2005	95	96	82	102	84	64	85	109
2006	89	77	85	122	77	13	26	55
2007	72	61	85	141	99	48	52	72
2008	109	96	99	148	96	78	69	109
2009	106	77	95	112	89	81	80	102
2010	56	37	32	101	13			60
Mean ± S.D.	91 ± 12	86 ± 18	106 ± 32	134 ± 25	96 ± 33	76 ± 22	74 ± 21	107 ± 22

Maximum ice volume (km^3)

Year	1 - Estuary	2 - Northwest Gulf	3 - Anticosti Channel	4 - Mécatina Trough	5 - Esquiman Channel	6 - Central Gulf	7 - Cabot Strait	8 - Magdalen Shallows	Scotian Shelf	GSL + Scotian Shelf
1969	1.6	4	1	1	1	0	0	10	0	17
1970	1.6	7	4	3	4	4	3	18	6	42
1971	1.9	13	7	3	7	9	5	23	4	65
1972	2.2	13	13	6	17	13	10	35	10	99
1973	2.3	9	8	6	13	8	7	31	13	83
1974	2.0	9	8	6	18	6	11	19	25	84
1975	2.5	9	6	5	19	10	11	28	18	85
1976	1.7	9	7	5	20	10	9	23	9	82
1977	2.1	11	8	6	18	11	8	30	10	88
1978	2.1	12	5	6	8	7	8	27	10	66
1979	5.3	12	8	5	12	9	10	31	12	82
1980	1.2	5	4	5	6	5	6	19	7	46
1981	2.6	9	3	2	4	8	5	18	3	42
1982	2.6	6	4	6	13	6	9	22	19	69
1983	2.4	9	3	4	4	1	1	18	1	40
1984	2.0	11	7	6	9	7	3	24	3	61
1985	2.1	7	5	8	15	6	7	25	19	75
1986	1.6	7	6	8	15	7	8	24	14	78
1987	2.4	10	7	6	14	5	5	33	9	70
1988	2.2	13	5	5	16	7	7	25	7	72
1989	1.9	8	6	7	18	7	7	20	14	74
1990	1.4	11	10	11	36	10	12	25	21	117
1991	1.6	9	9	6	16	8	7	22	14	71
1992	2.6	14	8	6	18	11	10	30	20	96
1993	2.5	18	12	5	21	17	14	61	14	134
1994	2.5	12	14	10	25	18	11	48	14	120
1995	3.4	16	17	8	15	14	11	43	10	106
1996	2.0	13	6	4	10	11	5	29	3	72
1997	1.4	12	7	7	17	10	11	30	11	86
1998	1.4	6	4	4	5	3	2	17	1	41
1999	1.1	8	9	6	9	5	5	26	3	57
2000	1.6	6	3	2	2	6	5	18	2	37
2001	1.2	7	4	9	8	3	5	34	5	59
2002	2.9	10	6	5	8	6	3	20	2	60
2003	1.3	7	6	10	30	17	22	41	42	139
2004	2.0	4	4	5	10	2	9	33	9	63
2005	2.1	11	6	4	4	10	5	33	4	68
2006	1.1	5	2	6	4	2	2	11	1	25
2007	0.9	4	4	6	9	4	4	16	6	38
2008	1.4	17	7	4	13	8	7	32	7	76
2009	1.7	8	5	4	8	7	8	33	14	65
2010	1.0	2	2	3	2	0	0	5	0	11
Mean ± S.D.	1.9 km^3 ± 0.6	9.3 km^3 ± 3.8	6.4 km^3 ± 3.4	5.9 km^3 ± 2.2	12.6 km^3 ± 8.2	7.5 km^3 ± 4.7	7.0 km^3 ± 4.3	27.2 km^3 ± 11.2	9.7 km^3 ± 8.8	70.8 km^3 ± 30.2

Table 14. CIL and related properties. The top block shows the scorecard time series for winter air temperature averaged over eight stations, the Gilbert and Pettigrew (1997) CIL index, yearly maximum sea-ice volume, winter (March) cold-layer (< -1°C) volume, volume of Labrador Shelf Water intrusion into the Gulf observed in March, and the August–September volume of cold water (< 0°C) observed in the Mécatina Trough. Labels in parentheses have their colour coding reversed (blue for high values). The second block shows scorecard time series for August–September CIL volumes (<1°C) for all eight regions and for the entire Gulf when available. The third 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 during the September survey. The last block shows the November survey CIL volume (<1°C) and average CIL minimum temperature in the Estuary (no update available in 2010).

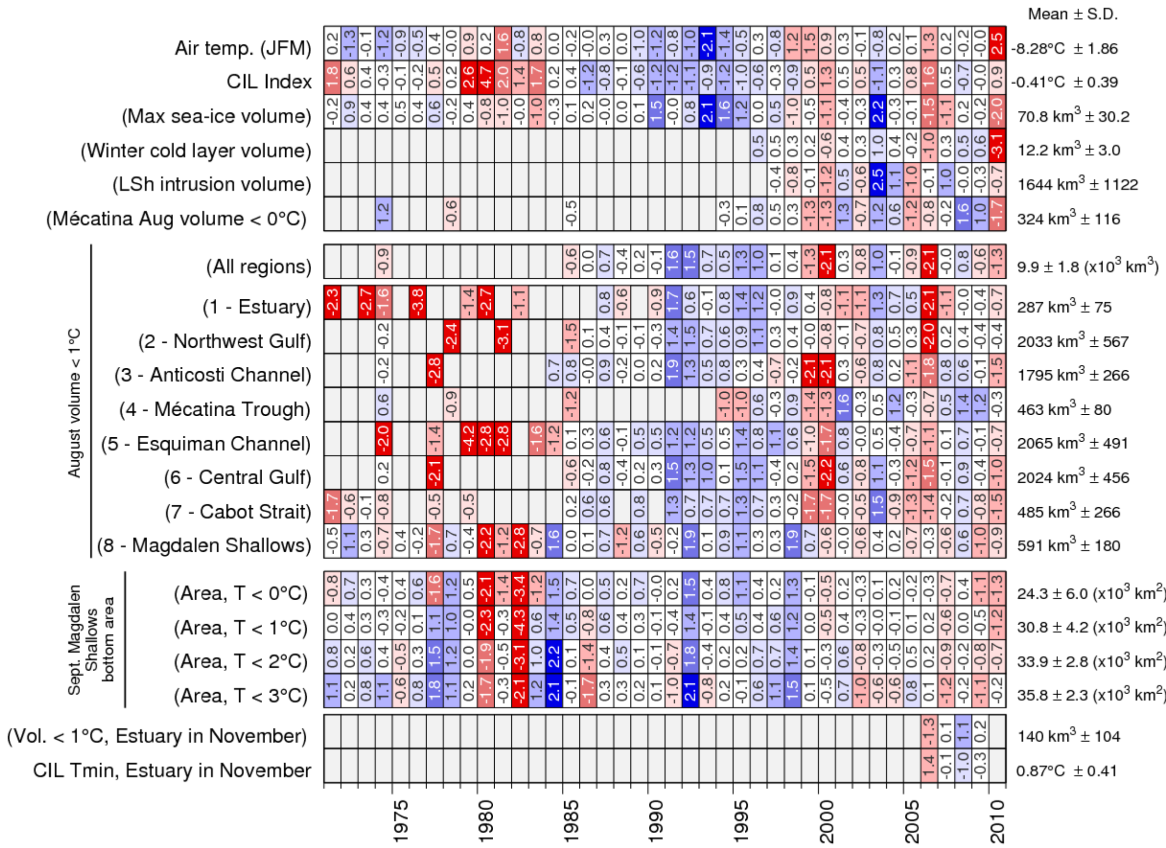

Table 15. Depth-layer average temperature anomalies for western and eastern Magdalen Shallows for the June mackerel survey. The SST data are June averages from NOAA remote sensing repeated from Table 11. The colour-coding of the 0 to 75 m lines are according to normalized anomalies based on the 1971–2000 climatologies, but the numbers are mean temperatures in ºC. The SST colour-coding is based on the climatology of the entire time series and the numbers are mean temperatures in ºC.

Year	Eastern Shelf SST June	Eastern Shelf 0 m temp.	Eastern Shelf 10 m temp.	Eastern Shelf 20 m temp.	Eastern Shelf 30 m temp.	Eastern Shelf 50 m temp.	Eastern Shelf 75 m temp.	Western Shelf SST June	Western Shelf 0 m temp.	Western Shelf 10 m temp.	Western Shelf 20 m temp.	Western Shelf 30 m temp.	Western Shelf 50 m temp.	Western Shelf 75 m temp.
1965		5.8	5.6	4.5	1.6	0.1	-0.9		5.9	5.5	4.0	2.2	0.3	-0.2
1966		9.2	7.8	4.9	2.1	0.8	0.6		8.8	6.8	3.3	1.6	0.3	0.0
1967		10.1	6.5	2.4	0.8	0.3			7.6	5.8	3.4	2.0	0.5	0.2
1968		10.0	9.5	5.7	2.2	0.1	1.1		10.2	9.5	6.2	2.4	-0.2	-0.1
1969		10.5	8.8	5.9	4.1	1.6	1.7		9.5	7.4	4.6	2.6	0.8	0.8
1970		8.6	8.1	6.8	5.0	1.9	2.1		8.0	6.9	4.6	2.9	1.3	1.7
1971		7.8	6.9	3.6	1.9	-0.4	0.0		8.2	7.0	4.5	3.2	0.2	0.5
1972		11.3	8.3	3.2	0.8	-0.2	1.5		11.6	8.3	2.6	0.3	-0.3	
1973		6.8	5.7	4.1	1.9	0.3	1.3							
1974														
1975		6.5	5.5	3.6	1.4	0.1	0.2		9.1	7.5	4.9	2.2	0.0	-0.3
1976		11.1	9.5	6.0	2.1	-0.7	-0.5		11.8	10.0	6.2	2.5	-0.4	-0.3
1977		9.8	7.9	4.3	2.0	0.9	2.1		9.2	7.1	4.0	2.5	0.7	0.3
1978		11.5							11.2	9.6	6.7	4.1	0.7	0.2
1979														
1980		11.4	10.0	7.7	4.6	1.1	0.7		11.7	10.4	7.6	4.6	1.5	0.4
1981														
1982		9.7	8.6	5.3	2.2	0.7	0.9		10.8	9.8	5.5	2.4	0.8	0.2
1983														
1984														
1985	6.9							7.8						
1986	8.0							8.5						
1987	9.4	10.9	9.2	4.6	1.6	-0.1	0.1	10.4	11.7	10.9	5.7	1.8	-0.5	-0.1
1988	7.3	10.2	9.7	6.4	2.9	0.2	1.2	8.1	10.1	8.8	5.1	2.5	-0.2	-0.3
1989	8.7	12.1	9.7	4.0	0.7	-0.2		9.8	13.4	10.2	5.4	2.0	-0.0	
1990	7.7	10.4	9.1	5.3	3.0	-0.1		8.6	10.0	8.6	5.3	3.3	0.3	
1991	8.5	8.7	7.6	5.8	2.8	-0.3		9.8	11.3	8.5	6.1	3.6	-0.2	-0.4
1992	8.4	11.0	8.6	4.2	1.1	-0.7	0.3	9.4	12.2	9.5	5.4	2.3	-0.3	-0.3
1993	7.7	9.6	7.9	5.3	0.8	-1.4		8.4	9.2	7.5	5.5	2.1	-1.3	
1994	8.9	11.1	9.6	6.0	2.0	-0.6		9.3	9.8	7.9	4.4	2.0	-0.5	-0.5
1995	9.1							10.3						
1996	9.9	11.9	10.7	6.1	2.2	0.2	0.3	10.7	11.8	10.4	5.0	2.2	-0.2	-0.7
1997	8.1	6.9	6.0	3.8	2.0	0.6	0.2	8.8	9.2	7.8	4.6	3.1	0.1	-0.7
1998	10.0	11.1	9.2	4.8	1.5	-0.4	-0.4	10.6	11.6	9.8	4.0	0.5	-0.5	
1999	11.2	12.2	10.9	7.4	4.2	1.4	0.9	11.6	13.5	10.4	5.6	2.6	0.3	-0.2
2000	9.3	11.7	10.2	7.2	4.6	1.0	1.0	9.8	11.8	10.1	6.6	3.7	0.3	-0.1
2001	10.4	10.3	8.4	4.5	1.5	0.1	0.4	11.1	11.4	8.3	3.6	1.6	0.1	-0.4
2002	8.7	8.7	7.9	5.3	2.6	0.7	0.9	9.2	9.2	8.2	5.2	2.1	0.2	-0.0
2003	8.5	8.2	7.5	4.5	1.8	-0.4	-0.4	9.3	9.9	8.3	4.6	2.3	-0.3	-0.6
2004	8.2	8.6	8.0	6.1	4.2	0.8	0.3	8.7	9.1	8.4	5.9	3.5	0.3	-0.7
2005	8.8	9.0	7.8	4.7	2.6	0.8	1.0	9.3	9.3	8.2	3.8	2.1	0.3	-0.1
2006	10.6	15.9	11.4	4.5	1.6	0.7		11.3	14.2	10.6	4.7	2.5	0.7	0.6
2007	9.5	11.1	9.1	4.6	2.0	0.4	0.8	9.8	11.2	10.0	6.6	2.9	0.4	0.1
2008	9.7	12.3	10.2	6.2	2.1	-0.4	0.3	10.2	12.0	9.3	5.0	1.8	-0.3	-0.5
2009	10.0	10.1	9.6	6.8	3.7	0.2	0.9	10.6	10.9	9.1	5.1	2.3	0.0	-0.1
2010	8.6	9.0	8.7	7.1	5.5	2.9	1.2	9.3	9.5	8.4	6.2	3.8	0.9	0.4
Mean ± SD	8.92°C ± 1.05	10.44°C ± 1.83	8.98°C ± 1.25	5.43°C ± 1.06	2.46°C ± 1.21	0.26°C ± 0.85	0.55°C ± 0.49	9.65°C ± 1.00	10.98°C ± 1.47	9.13°C ± 1.00	5.21°C ± 0.79	2.46°C ± 0.76	0.01°C ± 0.49	-0.22°C ± 0.36

Table 16. Depth-layer monthly average temperature summary for months during which the eight Gulf-wide oceanographic surveys took place in 2009 and 2010. The colour-coding is according to the temperature anomaly relative to the monthly 1981–2010 climatology of each region.

1 - Estuary / Estuaire

	2009				2010			
	Mar	June	Aug	Oct	Mar	June	Aug	Nov
0 m	-1.07	7.4	8.5	4.3	0.4	7.2	9.8	2.8
10 m	-1.25	5.0	6.8	4.3	0.3	4.8	7.2	2.8
20 m	-1.07	2.8	4.6	4.5	0.2	2.9	5.0	2.8
30 m	-0.76	1.7	3.3	4.5	0.2	2.2	3.4	3.1
50 m	-0.98	0.2	1.0	4.2	-0.15	0.7	1.4	3.4
75 m	-0.68	0.2	0.4	2.1	-0.39	0.2	0.8	1.9
100 m	0.4	1.2	1.3	1.1	0.3	0.9	1.4	1.1
150 m	2.2	2.9	3.0	2.0	1.7	2.5	2.9	2.1
200 m	3.6	3.9	4.1	3.5	3.1	3.5	3.9	3.8
250 m	4.7	4.7	4.8	4.4	4.1	4.3	4.5	4.4
300 m	5.1	5.0	5.0	4.9	4.6	4.7	4.8	4.8
350 m		5.1	5.1	5.0		4.8	4.9	4.8

2 - Northwest Gulf / Nord-ouest du Golfe

	2009				2010			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.56	9.5	13.4	4.4	-0.58	9.0	15.7	4.2
10 m	-1.62	7.5	11.1	4.4	-0.60	7.0	12.9	4.3
20 m	-1.65	4.1	5.2	4.4	-0.66	4.1	6.1	4.0
30 m	-1.65	1.6	3.0	3.8	-0.73	2.4	3.1	3.2
50 m	-1.20	-0.0	0.7	2.1	-0.50	0.6	1.0	1.7
75 m	-0.43	0.2	0.4	1.0	-0.10	0.3	0.4	1.3
100 m	0.3	1.2	1.1	0.7	0.5	0.6	0.8	1.6
150 m	3.1	3.1	3.0	2.3	2.2	2.1	2.6	2.8
200 m	4.4	4.5	4.3	3.9	3.6	3.6	4.1	4.2
250 m	5.3	5.1	5.0	4.8	4.7	4.7	4.9	4.9
300 m	5.4	5.3	5.3	5.2	5.1	5.1	5.2	5.2
350 m		5.3	5.3	5.3	5.2	5.2	5.2	5.2
400 m			5.3	5.3				

3 - Anticosti Channel / Chenal Anticosti

	2009				2010			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.66	6.2	15.7	3.4	-0.90	6.5	15.2	5.7
10 m	-1.69	5.5	13.3	3.5	-0.91	5.2	13.7	5.8
20 m	-1.70	3.3	5.5	3.4	-0.90	3.0	5.6	5.7
30 m	-1.70	1.7	2.3	3.4	-0.88	1.4	2.7	5.5
50 m	-1.65	-0.5	0.3	3.0	-0.88	0.5	1.0	3.0
75 m	-1.12	-0.7	-0.2	1.4	-0.81	-0.0	0.2	1.5
100 m	-0.00	-0.5	-0.1	0.8	-0.40	0.1	0.0	0.9
150 m	2.3	1.6	1.8	1.1	1.9	1.5	2.7	2.0
200 m	4.4	3.4	3.6	3.1	3.4	3.8	4.3	4.2
250 m			5.1	4.9			5.2	5.1

4 - Mécatina Trough / Cuvette de Mécatina

	2009				2010			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.68	6.1	13.3	2.0	-1.47	2.5	12.5	
10 m	-1.69	5.9	12.0	2.0	-1.50	2.4	12.1	
20 m	-1.70	3.7	3.9	2.1	-1.50	2.1	7.0	
30 m	-1.71	1.1	2.3	2.1	-1.50	2.0	4.1	
50 m	-1.61	0.0	0.5	2.1	-1.53	0.1	2.1	
75 m	-1.53	-0.9	-0.6	2.0	-1.56	-0.3	0.2	
100 m	-1.56	-1.2	-0.6	1.9	-1.56	-0.4	-0.3	
150 m	-1.77	-1.2	-0.1	0.7	-1.52	0.2	0.8	
200 m	-1.77	-1.0	-0.1	-0.1	-1.18	0.3	1.2	

5 - Esquiman Channel / Chenal Esquiman

	2009				2010			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.68	5.7	17.1	3.8	-0.10	5.4	15.5	6.1
10 m	-1.69	5.5	16.0	3.8	-0.15	5.1	15.0	6.0
20 m	-1.69	4.8	9.1	3.7	-0.21	4.3	9.0	6.0
30 m	-1.68	2.0	4.3	3.6	-0.24	3.2	4.5	5.8
50 m	-1.52	0.6	0.7	1.9	-0.22	0.4	0.9	1.5
75 m	-0.44	-0.2	-0.0	0.5	-0.32	-0.2	0.0	0.7
100 m	0.6	0.3	0.4	0.7	0.7	0.5	0.5	1.1
150 m	2.2	2.6	2.1	2.1	2.6	2.6	2.7	2.8
200 m	3.9	4.5	4.0	4.0	4.4	4.4	4.5	4.4
250 m		5.2	5.0	4.9		5.1	5.1	5.2
300 m			5.2	5.1			5.2	5.2

6 - Central Gulf / Centre du Golfe

	2009				2010			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.67	8.7	17.1	5.4	-0.31	6.9	17.9	6.3
10 m	-1.68	8.0	15.3	5.4	-0.36	6.6	16.3	6.3
20 m	-1.68	5.6	9.0	5.4	-0.35	5.1	6.9	6.2
30 m	-1.67	2.6	4.9	5.4	-0.33	2.4	3.1	6.1
50 m	-1.45	-0.2	1.2	2.8	-0.35	0.3	1.0	2.6
75 m	-0.66	0.0	0.1	1.1	-0.18	0.3	0.5	1.1
100 m	0.3	0.8	0.4	0.7	0.2	0.8	0.7	1.1
150 m	2.3	3.3	2.3	2.5	1.8	2.4	2.5	2.7
200 m	4.1	4.8	4.2	4.3	3.6	4.0	4.4	4.5
250 m		5.3	5.1	5.1		4.9	5.3	5.4
300 m		5.4	5.3	5.3		5.2	5.5	5.5
350 m		5.3	5.3	5.3		5.3	5.4	5.5
400 m		5.2	5.2	5.2		5.2	5.3	5.3
450 m		5.1	5.1	5.1			5.2	5.4

7 - Cabot Strait / Détroit de Cabot

	2009				2010			
	Mar	June	Aug	Nov	Mar	June	Aug	Nov
0 m	-1.52	9.4	17.2	6.8	0.1	8.0	17.5	8.4
10 m	-1.52	8.3	14.9	6.8	-0.06	7.9	15.6	8.4
20 m	-1.52	4.9	7.9	6.8	-0.10	6.6	8.1	8.3
30 m	-1.48	2.9	4.0	6.5	-0.06	5.1	4.6	7.8
50 m	-1.01	0.5	1.0	5.4	0.0	2.9	2.5	5.5
75 m	-0.17	0.5	0.7	2.3	0.3	1.1	1.4	3.1
100 m	0.5	1.2	1.1	1.6	0.9	1.4	1.3	1.7
150 m	3.0	3.7	3.4	2.8	2.5	3.7	3.1	3.1
200 m	4.9	5.0	4.9	5.0	4.8	5.8	5.9	5.7
250 m		5.3	5.3	5.6		6.2	6.2	6.2
300 m		5.3	5.3	5.4		5.8	6.0	6.0
350 m		5.3	5.3	5.3		5.2	5.6	5.7
400 m		5.1	5.2	5.2		5.2	5.4	5.4
450 m		5.0	5.1	5.1		5.3	5.4	5.3
500 m			5.0	5.0			5.4	5.4

8 - Magdalen Shallows / Plateau madelinien

	2009				2010			
	Mar	June	Sep	Nov	Mar	June	Sep	Nov
0 m	-1.66	10.5	14.7	6.1	-0.43	9.8	15.8	6.8
10 m	-1.67	9.3	14.7	6.1	-0.56	8.9	15.6	6.7
20 m	-1.68	5.0	13.4	6.1	-0.67	6.9	12.0	6.6
30 m	-1.69	1.9	8.5	6.2	-0.75	4.7	6.5	6.3
50 m	-1.68	-0.1	1.5	4.4	-0.80	1.1	1.7	4.1
75 m	-1.59	-0.2	0.5	2.2	-0.92	0.3	0.8	2.2
100 m			1.2					

Table 17. Deep layer temperature, salinity, and dissolved oxygen. Gulf averages for temperature and salinity are shown for 150, 200, 250, and 300 m, and regional averages are shown for 200 and 300 m. Only recent regional averages at 300 m are shown for dissolved oxygen, with an inverted colour scheme. The numbers on the right are the 1981–2010 climatological means and standard deviations. The numbers in the boxes are normalized anomalies.

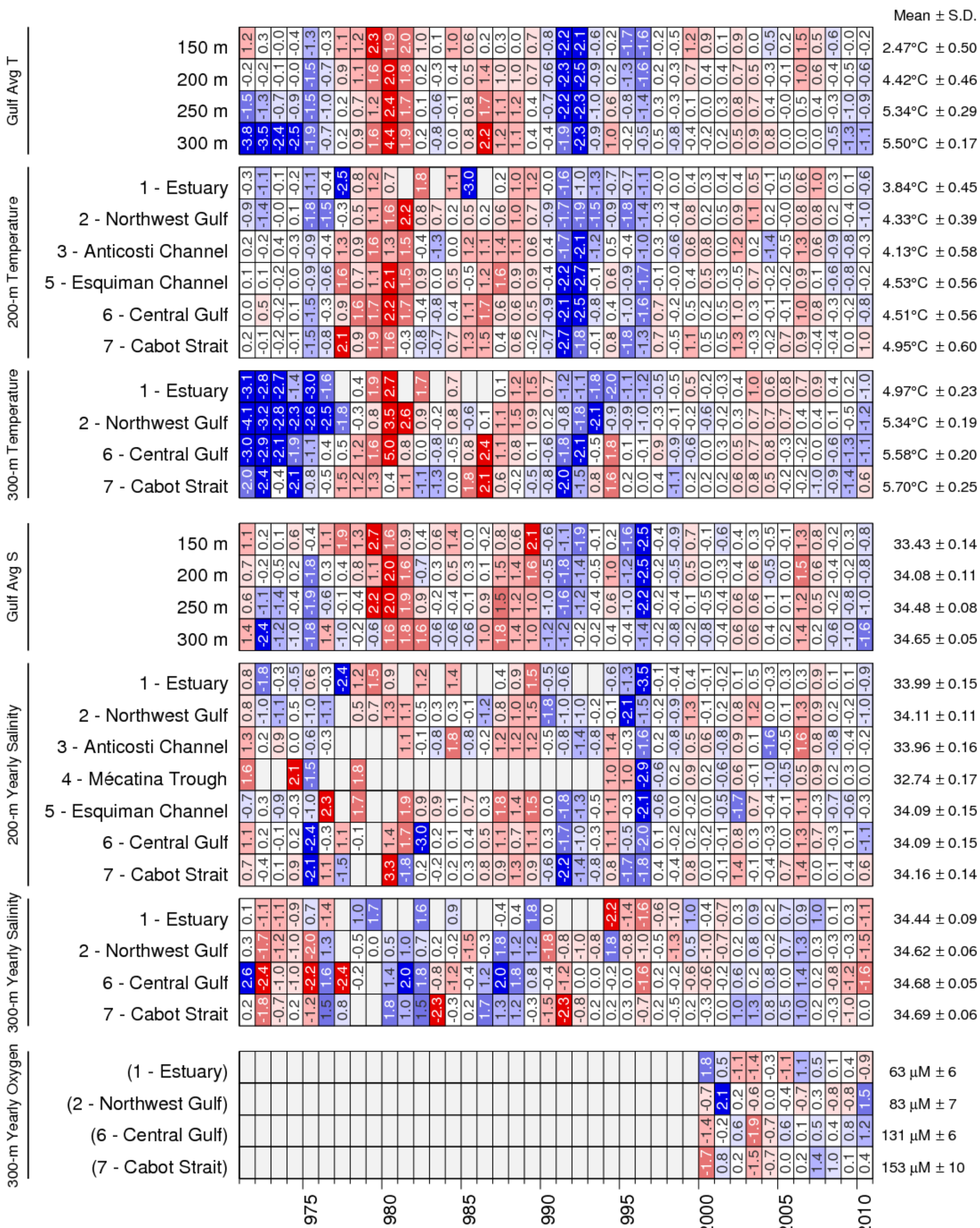

Table 18. Monthly averaged modelled transports and estuarine ratio across sections of the Gulf of St. Lawrence since 2006. The numbers on the right are the 2006–2010 means and standard deviations. The numbers in the boxes are normalized anomalies. Colours indicate the magnitude of the anomaly. Sv (Sverdrup) are units of transport equal to 10^6 m^3s^{-1}.

Net Transport

Section	Month	2006	2007	2008	2009	2010	Mean ± SD
Pointe-des-Monts	J	-0.0	0.5	1.0	-1.6	0.2	13.08 $\times10^3$ m^3 s^{-1} ± 1.2
	F	1.0	-1.4	-0.6	0.4	0.6	12.72 $\times10^3$ m^3 s^{-1} ± 1.9
	M	-1.4	1.2	0.7	-0.5	-0.1	14.81 $\times10^3$ m^3 s^{-1} ± 0.7
	A	0.5	-0.6	0.9	0.7	-1.5	20.60 $\times10^3$ m^3 s^{-1} ± 2.5
	M	0.3	-0.9	1.6	-0.2	-0.8	24.92 $\times10^3$ m^3 s^{-1} ± 3.3
	J	-0.2	-0.8	1.7	0.1	-0.8	28.06 $\times10^3$ m^3 s^{-1} ± 4.2
	J	-0.7	-1.2	1.0	1.0	-0.1	24.77 $\times10^3$ m^3 s^{-1} ± 5.0
	A	-0.4	-1.3	1.3	0.6	-0.2	18.36 $\times10^3$ m^3 s^{-1} ± 3.3
	S	1.5	-1.3	-0.2	-0.3	0.3	16.25 $\times10^3$ m^3 s^{-1} ± 1.1
	O	1.5	-1.0	-0.7	-0.0	0.3	17.03 $\times10^3$ m^3 s^{-1} ± 3.2
	N	1.5	-1.0	-0.6	-0.4	0.5	17.33 $\times10^3$ m^3 s^{-1} ± 2.9
	D	0.8	-1.2	-0.8	-0.1	1.2	14.43 $\times10^3$ m^3 s^{-1} ± 3.3
Honguedo	J	0.2	-1.5	0.1	-0.1	1.3	0.164 Sv ± 0.028
	F	0.1	-1.6	-0.2	0.9	0.7	0.114 Sv ± 0.064
	M	1.1	0.1	-1.6	-0.2	0.6	0.122 Sv ± 0.030
	A	-0.4	-0.0	-1.4	1.3	0.5	0.157 Sv ± 0.059
	M	-0.6	-0.9	0.9	-0.6	1.3	0.130 Sv ± 0.038
	J	-0.9	-0.7	1.5	0.6	-0.6	0.287 Sv ± 0.040
	J	-0.2	-1.3	-0.5	1.0	1.0	0.464 Sv ± 0.049
	A	0.3	-0.6	1.4	-1.2	0.2	0.487 Sv ± 0.055
	S	-0.2	-0.4	0.7	-1.3	1.2	0.471 Sv ± 0.025
	O	0.0	-1.3	-0.3	0.1	1.5	0.484 Sv ± 0.058
	N	-0.9	1.0	1.1	-0.9	-0.2	0.455 Sv ± 0.079
	D	-1.6	-0.2	0.1	1.0	0.7	0.322 Sv ± 0.084
Cabot	J	-1.1	-1.1	0.6	0.7	0.9	0.469 Sv ± 0.095
	F	0.1	-1.6	0.2	1.2	0.0	0.410 Sv ± 0.031
	M	-0.8	-1.1	0.5	1.3	0.1	0.360 Sv ± 0.026
	A	0.9	-0.1	1.1	-1.3	-0.6	0.249 Sv ± 0.037
	M	1.4	0.3	0.2	-0.8	-1.1	0.152 Sv ± 0.057
	J	-1.0	1.1	-0.4	1.0	-0.8	90.86 $\times10^3$ m^3 s^{-1} ± 41.5
	J	-1.1	0.2	-1.0	0.9	1.0	72.83 $\times10^3$ m^3 s^{-1} ± 21.9
	A	0.5	-0.6	0.9	-1.4	0.7	0.243 Sv ± 0.034
	S	0.8	-1.5	-0.1	-0.2	1.0	0.378 Sv ± 0.046
	O	0.4	-0.7	0.6	1.0	-1.4	0.530 Sv ± 0.052
	N	-0.9	0.4	-0.8	-0.3	1.5	0.550 Sv ± 0.021
	D	-0.8	-0.6	-0.1	-0.1	1.7	0.534 Sv ± 0.029

Outward Transport

Section	Month	2006	2007	2008	2009	2010	Mean ± SD
Pointe-des-Monts	J	-0.1	-0.5	0.2	-1.1	1.6	0.271 Sv ± 0.040
	F	-1.2	1.0	0.7	0.4	-0.9	0.260 Sv ± 0.057
	M	-0.7	0.7	-1.4	0.9	0.6	0.230 Sv ± 0.029
	A	-0.3	0.6	0.2	1.1	-1.5	0.235 Sv ± 0.040
	M	-0.7	0.7	-0.9	1.4	-0.6	0.211 Sv ± 0.035
	J	-0.5	-1.1	-0.1	1.6	0.0	0.162 Sv ± 0.028
	J	-0.4	-1.0	-0.5	1.6	0.3	0.218 Sv ± 0.052
	A	-0.2	-0.1	1.6	-1.2	-0.1	0.231 Sv ± 0.041
	S	-0.6	-0.4	0.1	-0.8	1.7	0.222 Sv ± 0.031
	O	1.7	-0.2	-0.9	-0.1	-0.6	0.260 Sv ± 0.024
	N	-0.6	1.0	1.2	-1.1	-0.5	0.261 Sv ± 0.035
	D	-0.9	-0.6	-0.4	0.3	1.6	0.328 Sv ± 0.095
Honguedo	J	-0.3	-1.2	-0.6	0.9	1.2	0.808 Sv ± 0.162
	F	-0.9	-0.3	-1.0	1.1	1.0	0.606 Sv ± 0.093
	M	-0.7	0.4	-1.3	0.5	1.1	0.574 Sv ± 0.059
	A	0.8	-0.5	-1.4	1.1	-0.0	0.623 Sv ± 0.080
	M	-1.0	1.4	-0.9	-0.1	0.6	0.509 Sv ± 0.092
	J	0.8	-0.2	-0.7	-1.2	1.2	0.537 Sv ± 0.081
	J	-0.4	-1.1	-0.6	1.3	0.8	0.570 Sv ± 0.059
	A	-0.3	-0.9	1.7	-0.1	-0.4	0.658 Sv ± 0.080
	S	-0.0	-0.2	0.4	-1.5	1.3	0.720 Sv ± 0.064
	O	0.5	-1.5	-0.5	1.1	0.5	0.789 Sv ± 0.051
	N	-1.2	0.2	0.7	-0.8	1.1	0.923 Sv ± 0.104
	D	-0.9	-0.6	0.4	-0.5	1.5	1.109 Sv ± 0.270
Cabot	J	-0.5	0.1	0.7	1.1	-1.4	2.051 Sv ± 0.204
	F	-1.6	0.9	0.8	0.1	-0.2	2.102 Sv ± 0.122
	M	-0.6	1.8	-0.4	-0.3	-0.5	2.180 Sv ± 0.275
	A	0.8	1.2	-1.3	-0.1	-0.6	2.112 Sv ± 0.229
	M	0.8	0.4	-1.3	-0.8	1.0	1.656 Sv ± 0.136
	J	-1.0	-0.2	0.7	-0.9	1.3	1.452 Sv ± 0.130
	J	-0.2	-0.5	0.6	-1.2	1.3	1.506 Sv ± 0.181
	A	0.3	1.4	0.0	-1.4	-0.3	1.541 Sv ± 0.172
	S	0.1	1.4	0.3	-0.6	-1.2	1.194 Sv ± 0.175
	O	-1.0	1.6	-0.6	-0.1	0.1	1.156 Sv ± 0.138
	N	0.1	1.2	0.0	-1.6	0.2	1.507 Sv ± 0.241
	D	-0.4	1.7	-0.9	0.1	-0.6	2.288 Sv ± 0.123

Estuarine ratio

Section	Month	2006	2007	2008	2009	2010	Mean ± SD
Pointe-des-Monts	J	-0.1	-0.9	-0.5	-0.2	1.7	20.72 ± 2.60
	F	-1.1	1.4	0.6	-0.0	-0.8	21.35 ± 7.73
	M	-0.2	0.2	-1.6	1.0	0.6	15.53 ± 2.01
	A	-0.9	1.4	-0.5	0.7	-0.8	11.40 ± 1.51
	M	-0.7	1.0	-1.3	1.0	-0.1	8.64 ± 2.12
	J	-0.3	-0.5	-1.2	1.3	0.7	5.82 ± 1.04
	J	0.3	-0.0	-1.7	0.8	0.6	8.88 ± 1.46
	A	0.1	1.3	0.1	-1.5	0.0	12.82 ± 2.55
	S	-1.2	0.3	0.2	-0.7	1.4	13.68 ± 2.01
	O	-0.8	1.5	0.4	-0.1	-0.9	15.56 ± 2.09
	N	-1.1	1.2	0.9	-0.4	-0.6	15.54 ± 4.11
	D	-1.8	0.5	0.2	0.4	0.6	23.04 ± 5.03
Honguedo	J	-0.7	0.2	-1.1	1.5	0.1	4.93 ± 0.62
	F	-0.5	1.8	-0.4	-0.5	-0.5	12.89 ± 18.88
	M	-1.3	-0.1	1.5	0.2	-0.3	4.94 ± 1.15
	A	0.4	-0.4	1.5	-0.9	-0.7	4.41 ± 1.56
	M	-0.2	1.6	-1.0	0.3	-0.7	4.22 ± 1.62
	J	0.9	0.2	-1.1	-1.0	1.0	1.92 ± 0.50
	J	-0.5	0.9	-0.7	0.9	-0.9	1.23 ± 0.04
	A	-0.7	-0.4	0.4	1.6	-0.8	1.35 ± 0.13
	S	0.2	0.1	-0.0	-1.7	1.2	1.53 ± 0.06
	O	0.2	0.8	0.0	0.6	-1.7	1.64 ± 0.13
	N	0.1	-1.1	-0.8	0.6	1.3	2.05 ± 0.26
	D	1.2	-0.5	0.2	-1.4	0.6	3.56 ± 0.82
Cabot	J	0.8	1.2	-0.4	-0.3	-1.3	4.52 ± 1.00
	F	-0.9	1.6	0.2	-0.7	-0.2	5.15 ± 0.59
	M	-0.2	1.8	-0.5	-0.7	-0.4	6.10 ± 1.11
	A	-0.3	0.7	-1.5	1.1	0.1	8.66 ± 1.58
	M	-1.0	-0.4	-0.6	0.5	1.5	12.22 ± 4.90
	J	0.9	-1.0	0.2	-1.1	1.0	19.01 ± 8.41
	J	0.9	-0.5	1.2	-1.1	-0.5	22.46 ± 7.87
	A	-0.3	1.6	-0.7	0.3	-0.8	6.41 ± 0.99
	S	-0.4	1.6	0.1	-0.3	-1.1	3.24 ± 0.88
	O	-0.8	1.4	-0.7	-0.6	0.8	2.21 ± 0.43
	N	0.3	1.2	0.2	-1.6	-0.2	2.74 ± 0.42
	D	0.3	1.4	-0.5	0.1	-1.3	4.30 ± 0.38

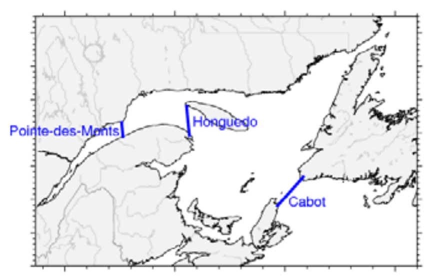

Table 19. Monthly averaged modelled transports across sections of the Gulf of St. Lawrence since 2006. The numbers on the right are the 2006–2010 means and standard deviations, with positive values toward east and north. The numbers in the boxes are normalized anomalies. Colours indicate the magnitude of the anomaly (e.g., negative anomalies are still shown in red when the mean transport is negative across the section).

Jacques-Cartier

Month	2006	2007	2008	2009	2010	Mean ± SD
J	-0.2	1.6	-0.1	-0.1	-1.2	-0.149 Sv ± 0.028
F	-0.1	1.6	0.2	-0.9	-0.8	-0.100 Sv ± 0.061
M	-1.1	0.0	1.5	0.1	-0.6	-0.103 Sv ± 0.030
A	0.4	0.0	1.4	-1.3	-0.5	-0.132 Sv ± 0.060
M	0.6	0.9	-0.7	0.6	-1.4	-0.101 Sv ± 0.037
J	0.9	0.7	-1.4	-0.7	0.5	-0.253 Sv ± 0.036
J	0.1	1.3	0.6	-0.9	-1.1	-0.434 Sv ± 0.047
A	-0.3	0.5	-1.3	1.4	-0.3	-0.466 Sv ± 0.053
S	0.3	0.3	-0.7	1.3	-1.2	-0.452 Sv ± 0.025
O	0.0	1.2	0.4	-0.1	-1.5	-0.466 Sv ± 0.056
N	0.9	-1.0	-1.1	0.9	0.3	-0.435 Sv ± 0.081
D	1.6	0.1	-0.1	-1.0	-0.6	-0.306 Sv ± 0.083

Bradelle

Month	2006	2007	2008	2009	2010	Mean ± SD
J	0.3	-0.7	0.9	-1.4	0.8	-0.325 Sv ± 0.087
F	1.6	-0.9	0.0	-0.8	0.1	-0.231 Sv ± 0.049
M	0.2	-1.7	0.6	0.2	0.7	-0.165 Sv ± 0.083
A	-0.6	-1.1	1.1	-0.5	1.0	-0.141 Sv ± 0.066
M	1.3	-1.1	-0.2	0.7	-0.7	-0.138 Sv ± 0.050
J	0.4	-0.8	-1.0	1.5	-0.2	-85.71 x10^3 m^3 s^{-1} ± 71.9
J	1.1	-1.6	-0.1	0.5	0.2	-0.124 Sv ± 0.038
A	0.4	-1.7	-0.1	0.5	0.9	-0.124 Sv ± 0.028
S	0.1	-0.1	0.8	0.8	-1.6	-0.152 Sv ± 0.036
O	-0.2	0.8	0.2	0.8	-1.6	-0.188 Sv ± 0.096
N	0.1	0.4	-1.6	1.1	-0.0	-0.255 Sv ± 0.071
D	-0.5	0.3	-0.9	-0.5	1.6	-0.374 Sv ± 0.105

Northumberland

Month	2006	2007	2008	2009	2010	Mean ± SD
J	0.5	0.4	-0.3	-1.6	0.9	2.92 x10^3 m^3 s^{-1} ± 2.3
F	0.1	-1.5	0.8	1.0	-0.4	-1.38 x10^3 m^3 s^{-1} ± 0.8
M	0.3	0.1	-1.2	-0.7	1.4	0.11 x10^3 m^3 s^{-1} ± 2.2
A	0.6	-0.3	-1.6	0.6	0.8	2.04 x10^3 m^3 s^{-1} ± 4.0
M	-1.7	0.0	0.2	0.5	0.9	3.26 x10^3 m^3 s^{-1} ± 4.3
J	-0.7	-0.5	1.6	-0.8	0.4	3.90 x10^3 m^3 s^{-1} ± 3.7
J	-0.6	0.1	0.1	1.5	-1.1	8.15 x10^3 m^3 s^{-1} ± 1.9
A	-0.6	-0.1	1.6	0.2	-1.1	5.26 x10^3 m^3 s^{-1} ± 5.7
S	-0.8	-0.2	1.0	-1.1	1.1	-1.19 x10^3 m^3 s^{-1} ± 3.6
O	1.2	-0.8	-0.9	-0.5	0.9	-2.62 x10^3 m^3 s^{-1} ± 4.0
N	-0.0	-0.7	0.3	-1.1	1.5	-0.31 x10^3 m^3 s^{-1} ± 4.3
D	0.3	-0.9	-0.8	-0.2	1.6	8.79 x10^3 m^3 s^{-1} ± 4.2

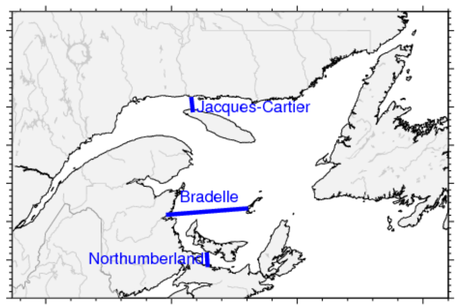

Table 20. May to October temperature and salinity layer averages for the fixed monitoring stations as well as stratification expressed as the density difference between 0 and 50 m. Numbers in the temperature and stratification panels are monthly average values and numbers in the salinity panel are normalized anomalies. Three months of anomaly data, between May and October, are required to show an average anomaly for any given year.

Variable	Station	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Mean ± SD
T [0-100 m]	Rimouski	2.2	1.7	2.2	1.2	2.2	2.4	1.3	2.4	3.1	2.8	3.2	3.0	2.3	1.4	2.4	2.7	2.3	2.3	2.8	2.5	2.33°C ± 0.57
	Gaspé Current						2.7	2.0	2.8	2.4	2.3	2.6	3.1	2.3		2.6	3.2		2.5	2.9		2.62°C ± 0.35
	Anticosti Gyre						1.8	1.9	1.2	1.4	2.0	2.2	2.4	1.8		1.6	1.8		1.9	1.9		1.82°C ± 0.32
	Shediac Valley		7.6					5.5		7.9	7.9	7.9	6.9	6.4	5.7	5.6	6.5	8.5	8.8	6.7	7.9	7.27°C ± 1.17
S [0-50 m]	Rimouski	0.8	-0.7	-1.3	-0.1	0.6	-1.7	-1.0	-0.6	1.0	0.7	0.8	1.5	1.6	-0.2	-0.6	0.2	1.2	-1.0	-1.5	0.1	29.21 ± 0.43
	Gaspé Current						0.4	-1.5	-1.9	1.3	0.0	0.3	0.3	1.6		-0.3	-0.4		-0.5	0.7		29.79 ± 0.30
	Anticosti Gyre						-1.5	-0.8	-1.2	0.9	0.3	0.3	1.4	1.4		-1.1	-0.1		-0.4	0.8		31.46 ± 0.19
	Shediac Valley		-0.0							-0.1	0.0	0.2	1.0	2.1	-0.9	-0.7	-0.2	1.0	-1.8	-0.2	0.6	29.97 ± 0.29
$\Delta\sigma_t$ [0,50 m]	Rimouski	3.7	4.7	5.0	4.8	4.0	5.5	5.5	4.0	3.3	4.5	3.7	4.1	3.9	4.7	4.4	4.6	4.5	5.6	4.7	4.3	4.48 kg m^{-3} ± 0.62
	Gaspé Current						3.7	4.8	4.1	3.9	4.5	4.1	5.0	4.5			3.8		5.3	3.8		4.31 kg m^{-3} ± 0.55
	Anticosti Gyre						3.3	3.0	2.9	2.8	2.9	3.4	2.8	2.9		2.8	2.9		3.7	2.7		3.00 kg m^{-3} ± 0.29
	Shediac Valley		3.6							3.5	3.8	3.3	3.5	3.6	3.7	3.9	3.9	3.3	5.0	3.8	3.3	3.68 kg m^{-3} ± 0.45
T [CIL min]	Rimouski	-0.71	-0.56	-0.59	-0.29	-0.66	-0.21	-0.19	-0.63	-0.21	0.08	0.27	0.35	-0.27	-0.29	-0.22	0.53	0.10	-0.05	-0.05	0.25	-0.17°C ± 0.36
	Gaspé Current						-0.38	-0.27	-0.69	-0.34	0.03	-0.20	0.13	-0.45		-0.29	0.54		-0.44	-0.25		-0.22°C ± 0.32
	Anticosti Gyre						-0.32	-0.48	-0.67	-0.46	0.07	-0.10	0.03	-0.61		-0.41	0.48		-0.38	-0.45		-0.28°C ± 0.33
CIL thick. < 1°C	Rimouski	91		83	59	73	60	50	60	49	50	31	36	69	59	53	31	43	54	47	39	55 m ± 16
	Gaspé Current						73	62	64	65	52	57	48	75		67	29		58	58		59 m ± 12
	Anticosti Gyre						60	69	70	54	40	42	36	53		71	34		61	56		54 m ± 13

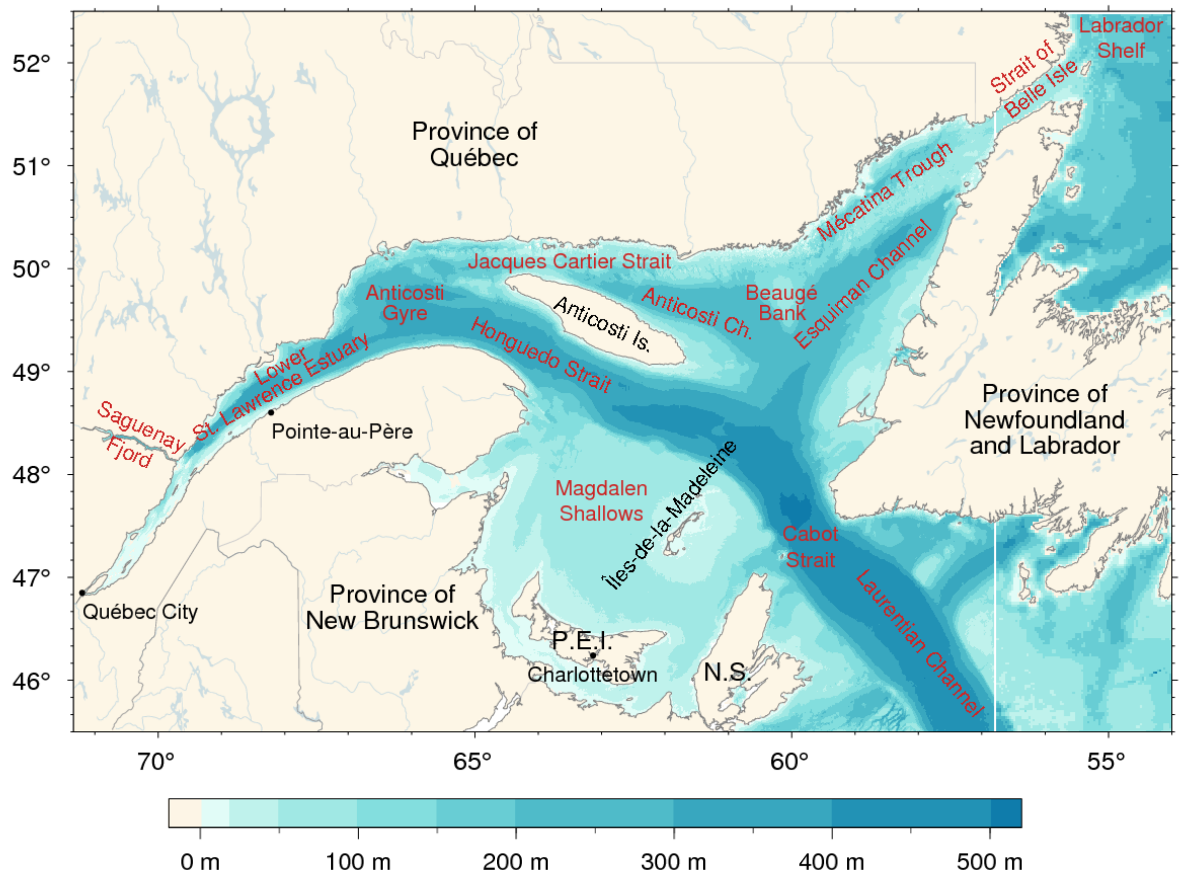

Fig. 1. The Gulf of St. Lawrence, with 500 m horizontal resolution bathymetry provided by the Canadian Hydrographic Service. Locations discussed in the text are indicated. The vertical white line marks the separation between bathymetry datasets used, with data from the Canadian Hydrographic Service to the left and TOPEX data to the right.

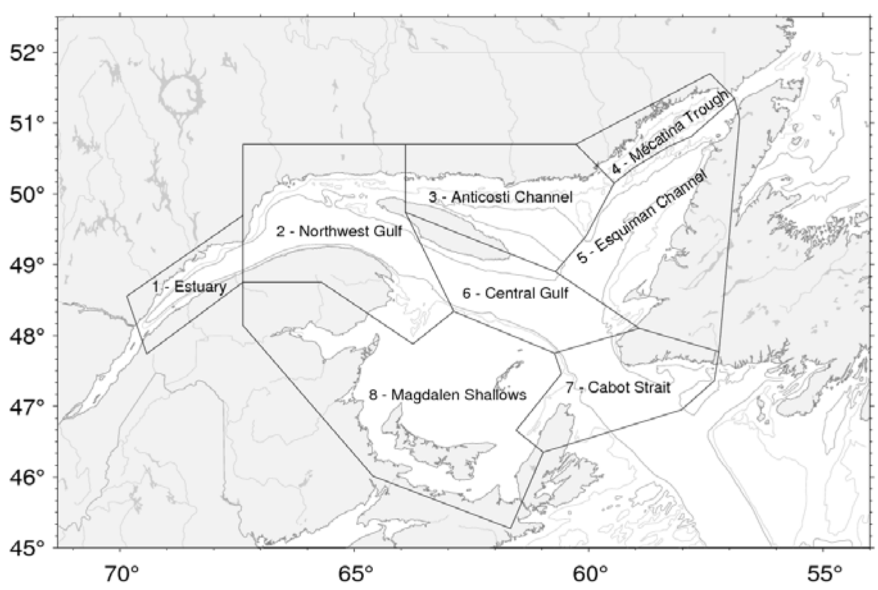

Fig. 2. Gulf of St. Lawrence divided into eight oceanographic regions.

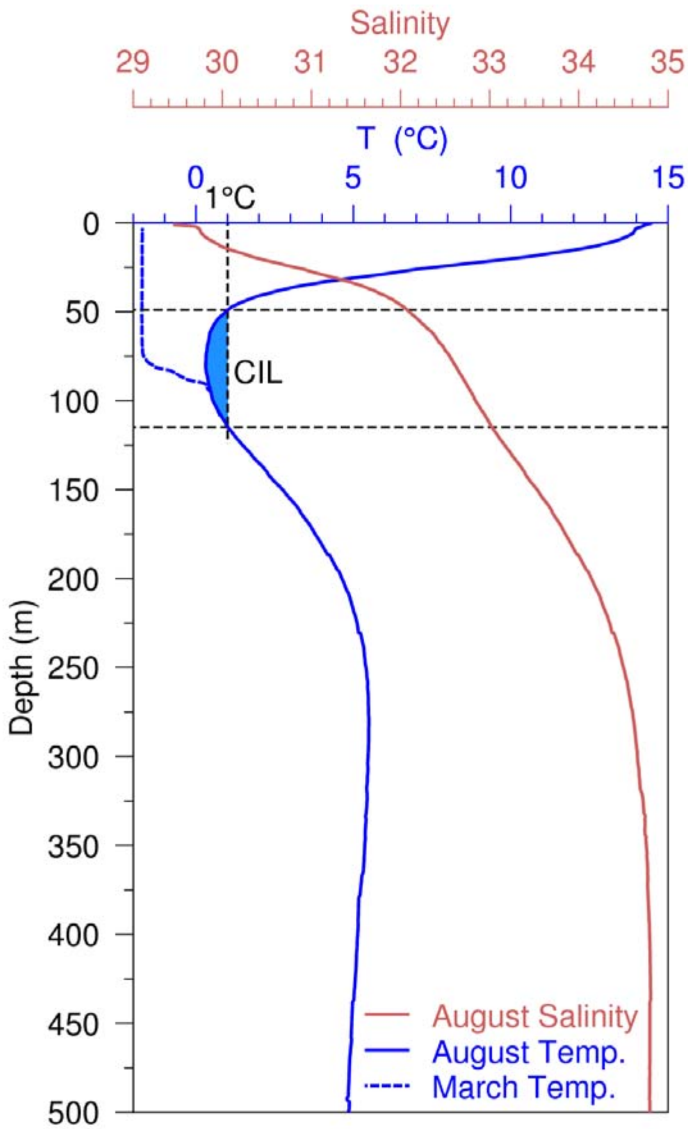

Fig. 3. Typical depth profile of temperature and salinity observed during the summer in the Gulf of St. Lawrence. Profiles are averages observed in August 2007 in the northern Gulf. The cold intermediate layer (CIL) is defined as the part of the water column that is colder than 1°C, although some authors use a different temperature threshold. The dashed line at left shows a winter temperature profile measured in March 2008, with near-freezing temperatures in the top 75 m.

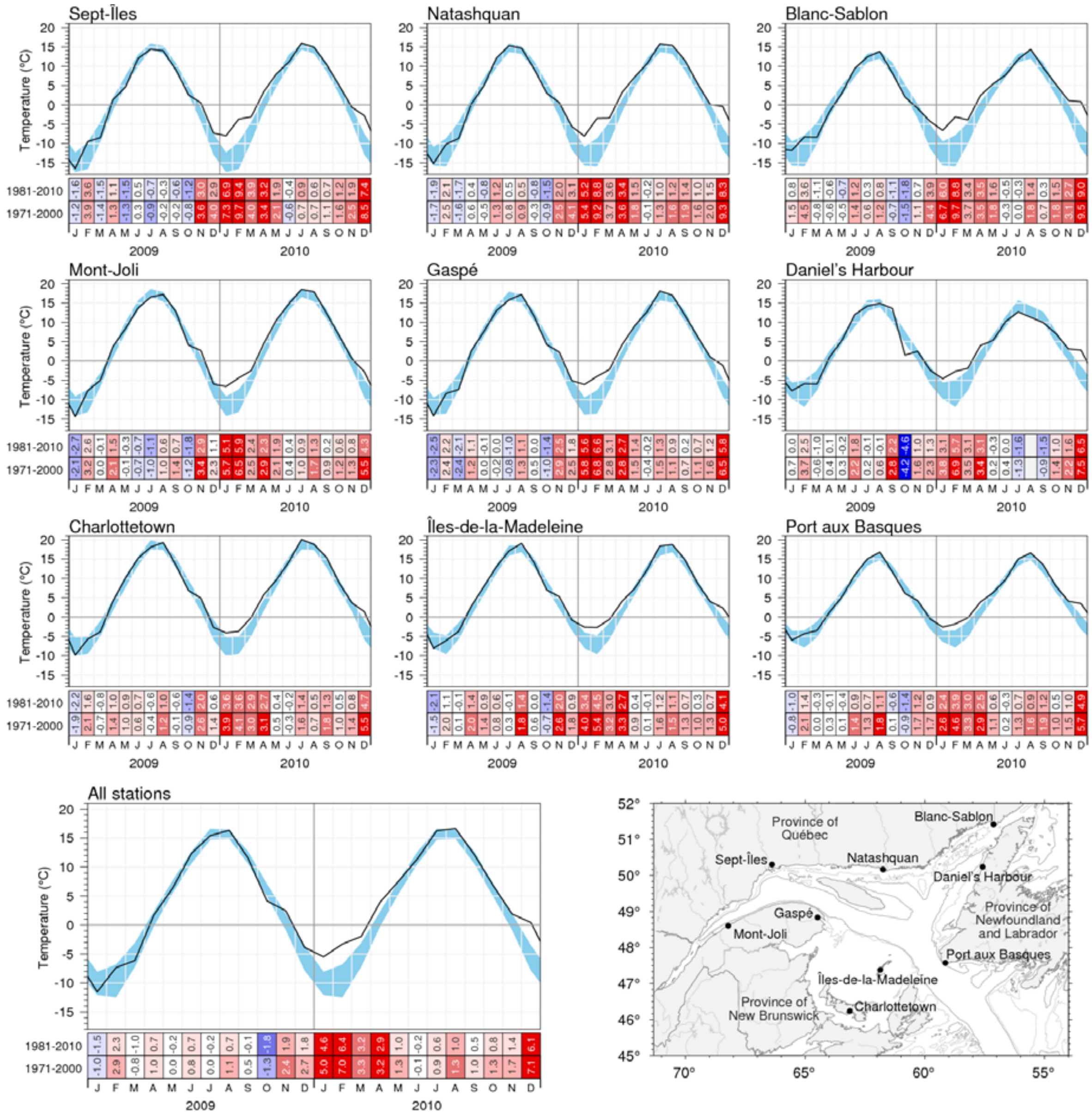

Fig. 4. Monthly air temperatures and anomalies for 2009 and 2010 at nine selected stations around the Gulf as well as the average for all nine stations. The blue area represents the 1981–2010 climatological monthly mean ± 1 SD. The bottom scorecards are colour-coded (see Table 1) according to the monthly normalized anomalies based on the 1971–2000 and 1981–2010 climatologies for each month, but the numbers are the monthly anomalies in ºC.

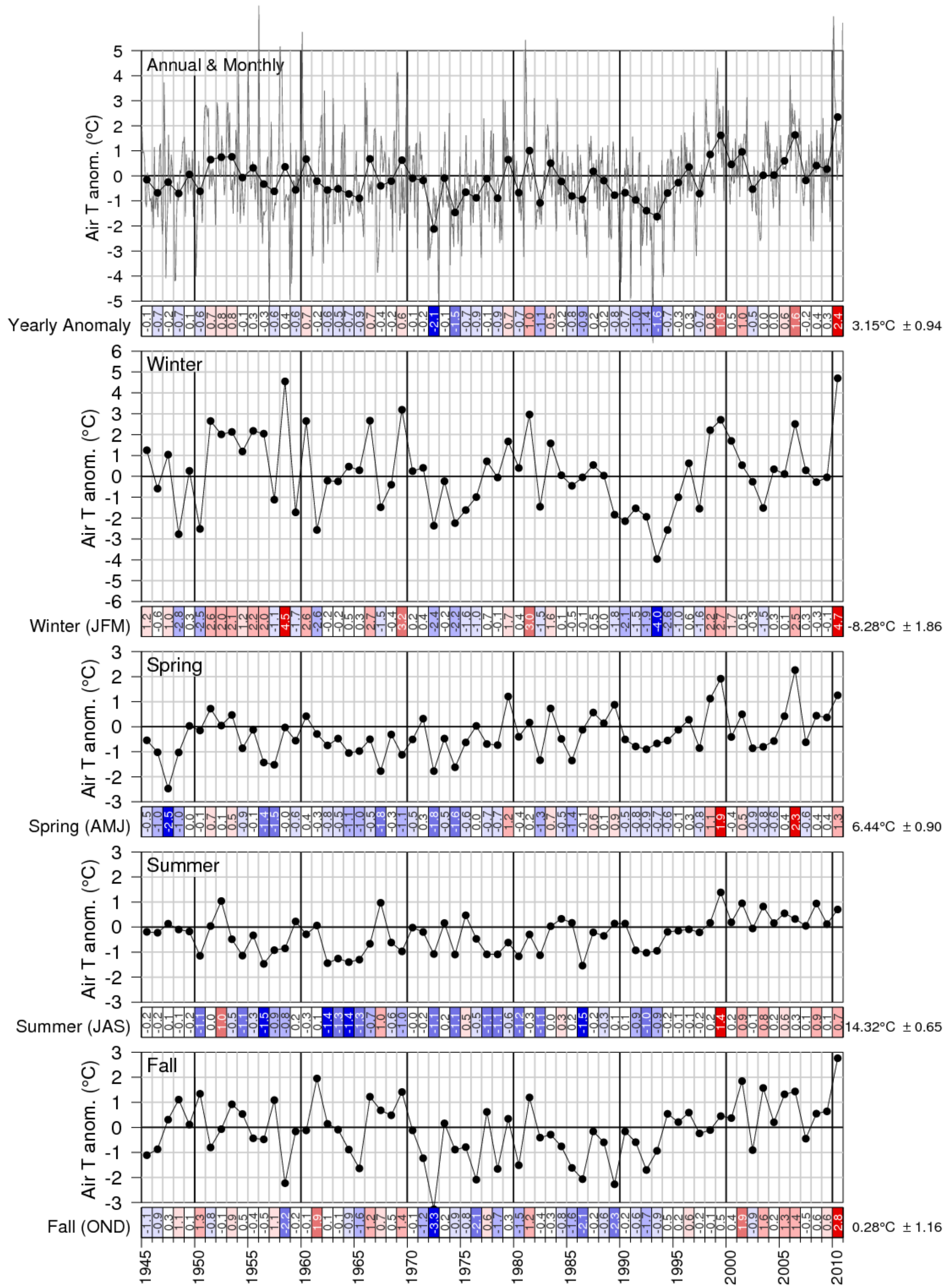

Fig. 5. Annual and seasonal mean air temperature anomalies averaged for the nine selected stations around the Gulf. The bottom scorecards are colour-coded according to the normalized anomalies based on the 1981–2010 climatology, but the numbers are the anomalies in ºC.

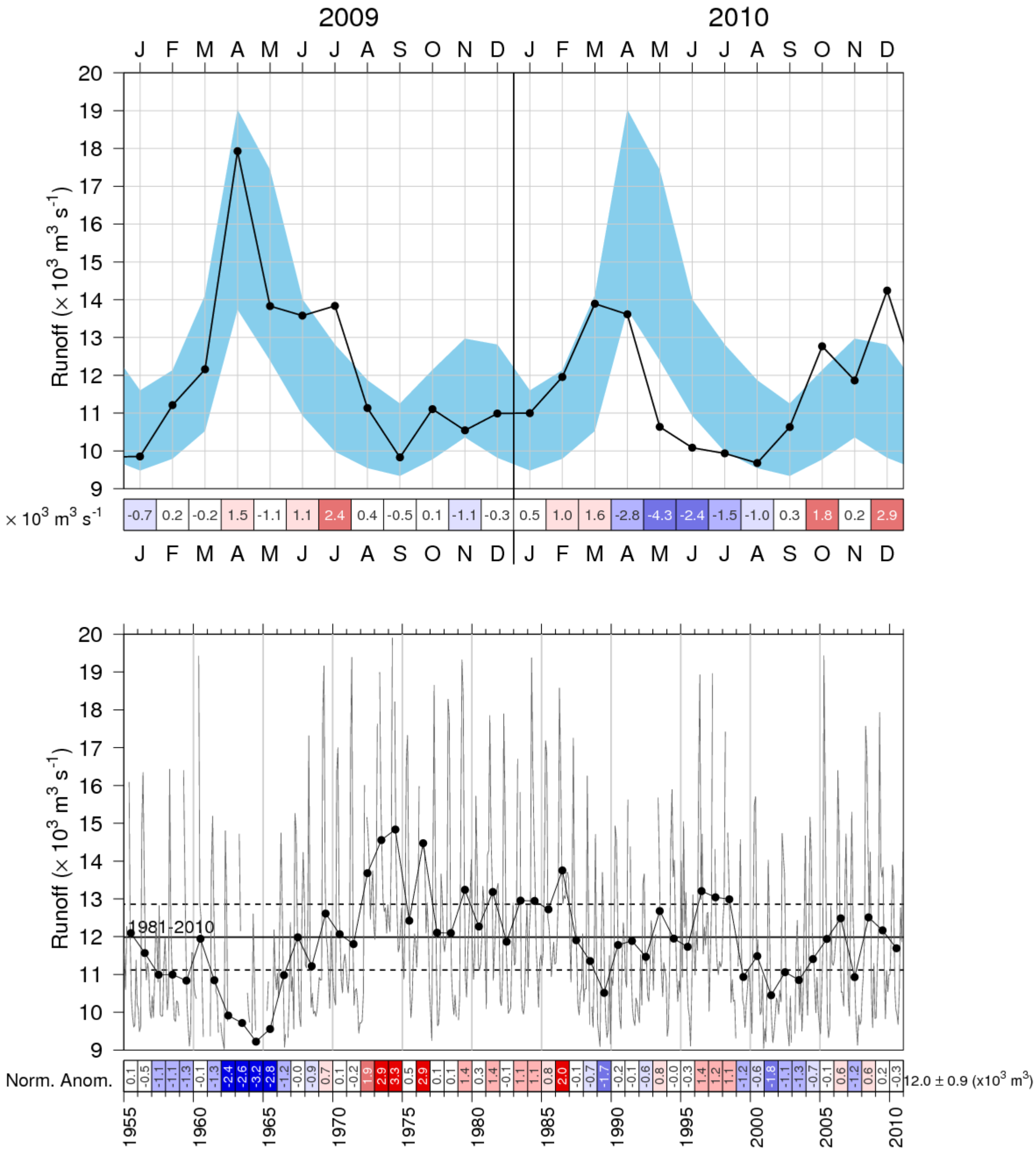

Fig. 6. Monthly (top panel) and annual (bottom panel) mean freshwater flow of the St. Lawrence River at Québec City. The 1981–2010 climatological mean (± 1 SD) is shown for each month in the top panel (blue shading) and as horizontal lines for the annual time series in the bottom panel. The top-panel scorecard is colour-coded according to the monthly anomalies normalized for each month of the year, but the numbers are the actual monthly anomalies in 10^3 m^3 s^{-1}. The bottom-panel scorecard shows numbered and colour-coded normalized anomalies for which the mean and standard deviation are indicated on the right side.

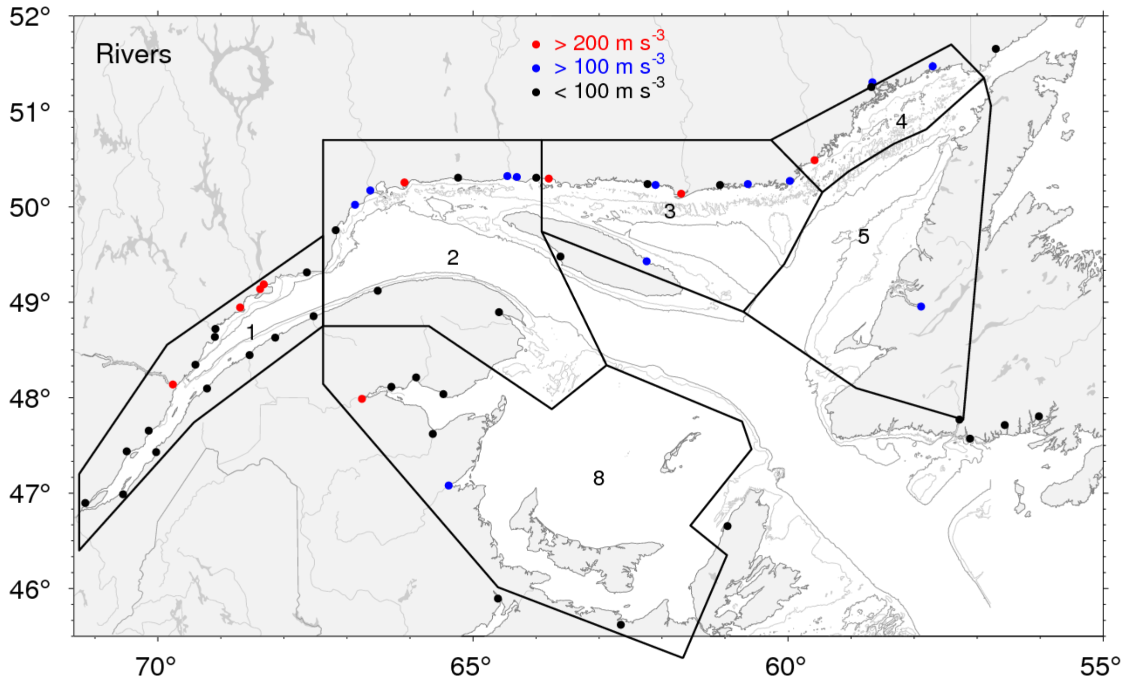

Fig. 7. River discharge locations for the regional sums of runoffs listed in Table 2. Red and blue dots indicate rivers that have climatological mean runoff greater than 200 m s^{-1} and between 100 and 200 m^3 s^{-1}, respectively.

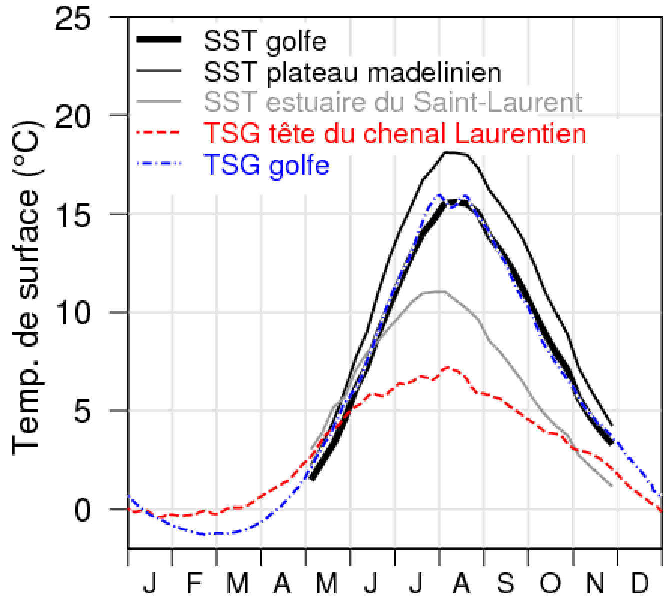

Fig. 8. Sea-surface temperature climatological seasonal cycle in the Gulf of St. Lawrence. NOAA AVHRR temperature weekly averages for 1985 to 2010 are shown from May to November (ice-free months) for the entire Gulf (thick black line), the warmer Magdalen Shallows (black line), and the cooler St. Lawrence Estuary (grey line). Thermosalinograph (TSG) data averages for 2000 to 2010 are shown for the head of the Laurentian Channel (69.5°W, red line) and for the average over the Gulf waters along the main shipping route between 66°W and 59°W (blue line).

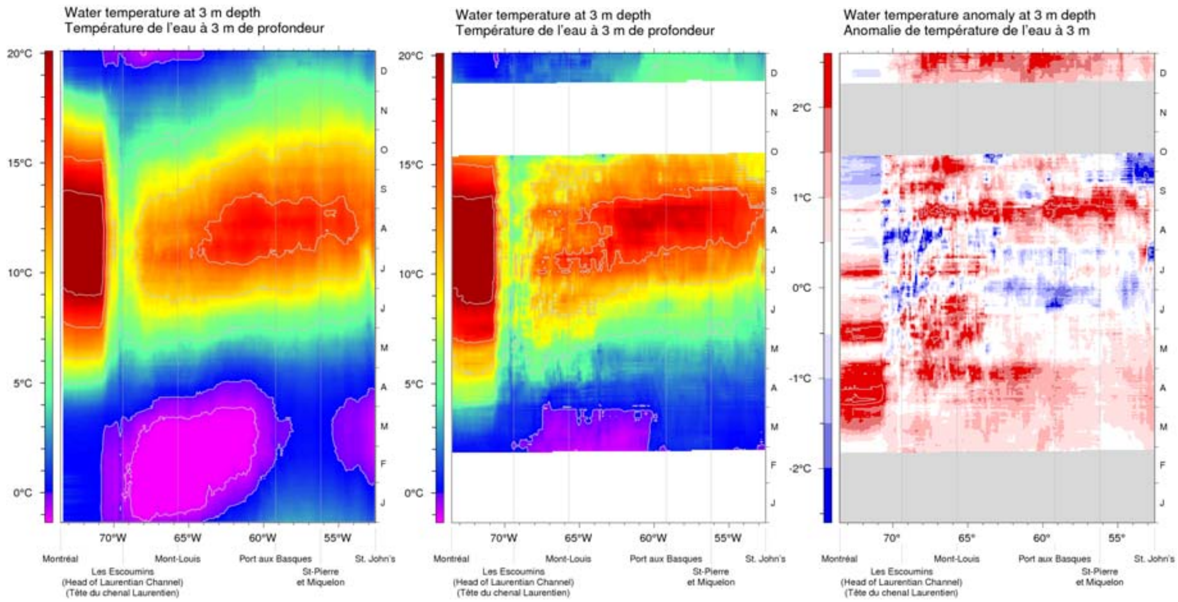

Fig. 9. Thermosalinograph data at 3 m depth along the Montréal to St. John's shipping route: composite mean annual cycle of the water temperature for the 2000–2010 period (left panel), composite annual cycle of the water temperature for 2010 (middle panel), and water temperature anomaly for 2010 relative to the 2000–2010 composite (right panel).

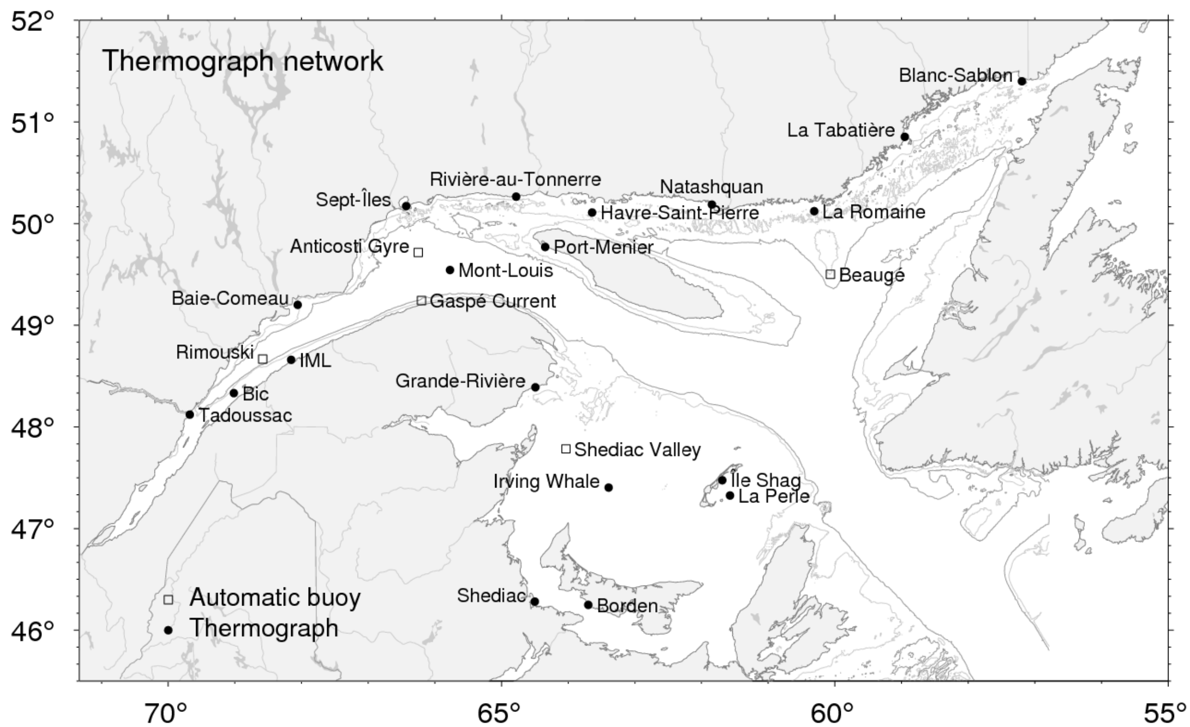

Fig. 10. Locations of the Maurice Lamontagne Institute thermograph network stations in 2010, including regular stations where data are logged internally and recovered at the end of the season (filled circles) and oceanographic buoys that transmit data in real time (open squares). Shediac station from DFO Gulf Region is also shown.

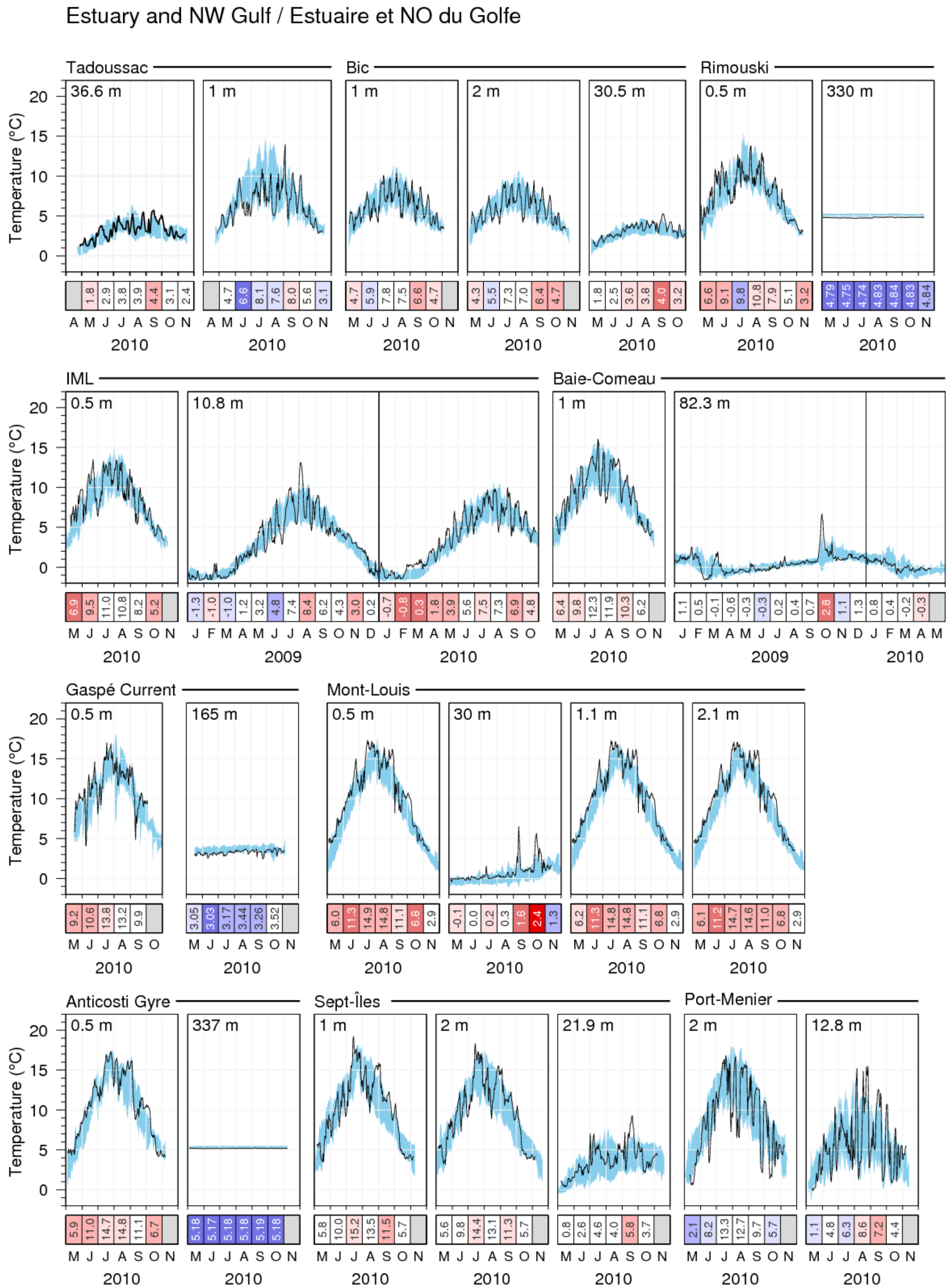

Fig. 11. Thermograph network data. Daily mean 2010 temperatures compared with the daily climatology (daily averages ± 1 SD; blue areas) computed from all available stations in the Estuary and northwestern Gulf. Scorecards show monthly average temperature. Data from 2009 are included if they were not all shown in the previous report (Galbraith et al. 2010).

Lower North Shore / Basse Côte Nord

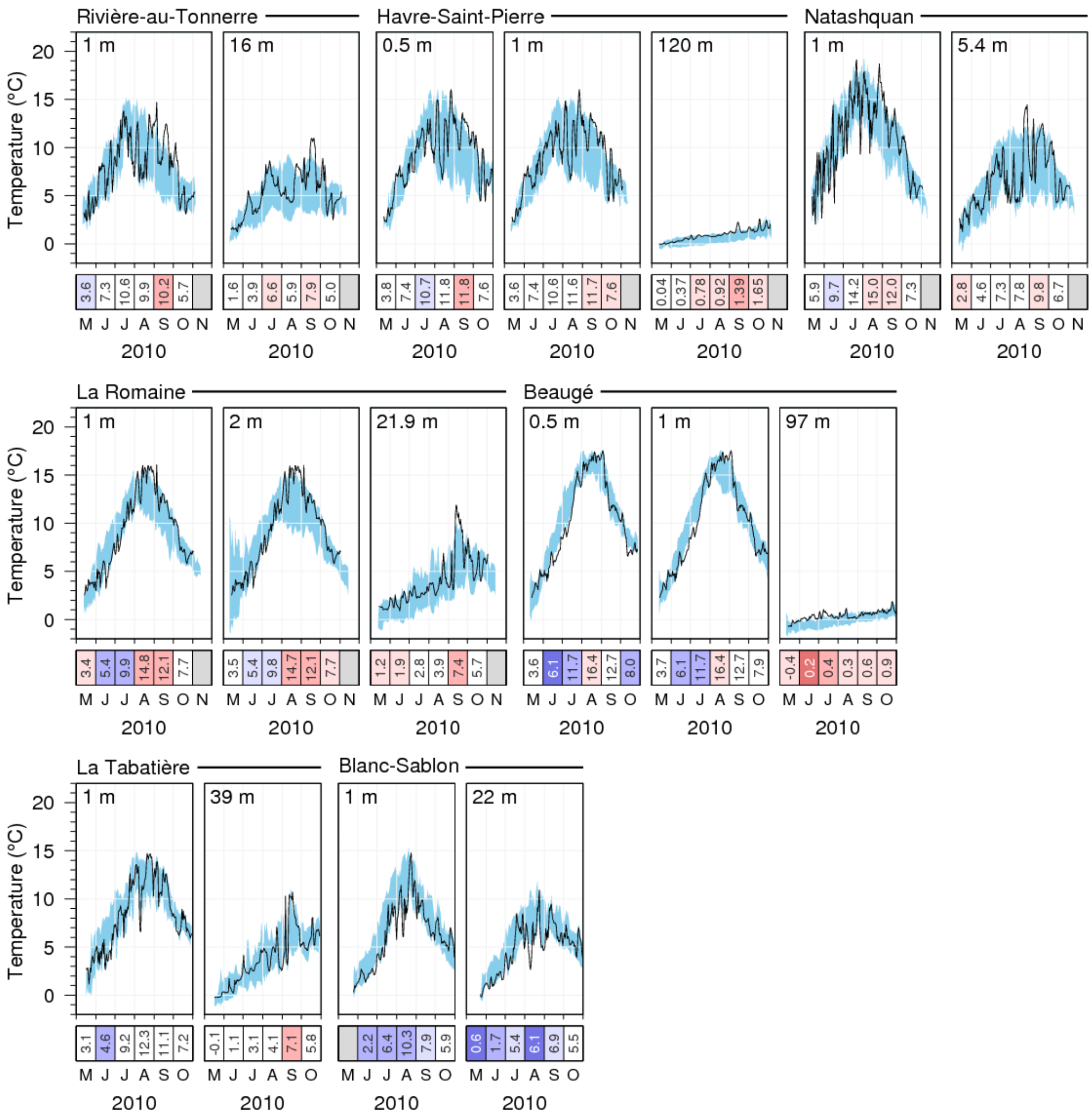

Fig. 12. Thermograph network data. Daily mean 2010 temperatures compared with the daily climatology (daily averages ± 1 SD; blue areas) computed from all available stations of the lower north shore.

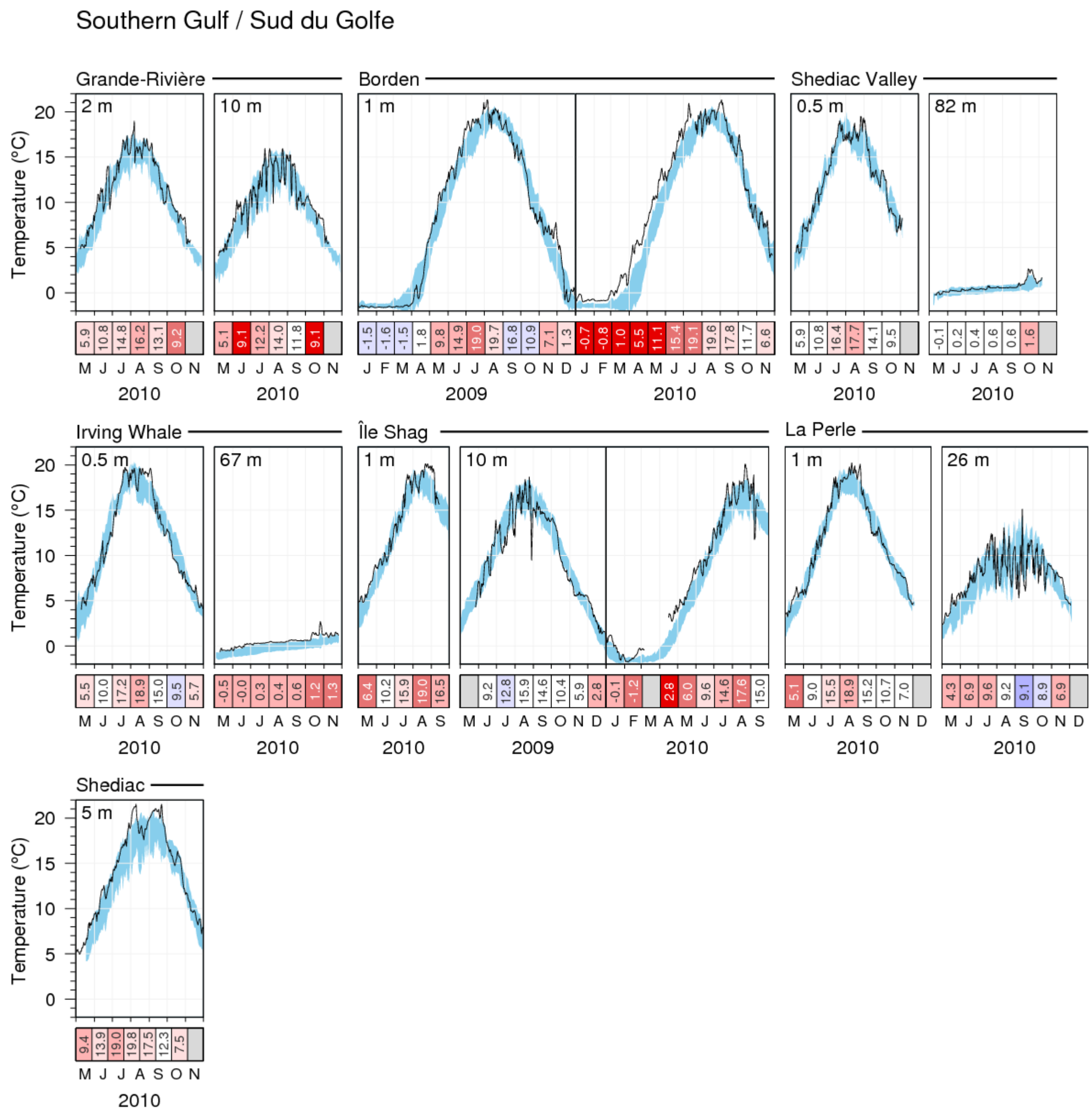

Fig. 13. Thermograph network data. Daily mean 2009 temperatures compared with the daily climatology (daily averages ± 1 SD; blue area) computed from all available stations of the southern Gulf. Shediac station from DFO Gulf Region is also shown.

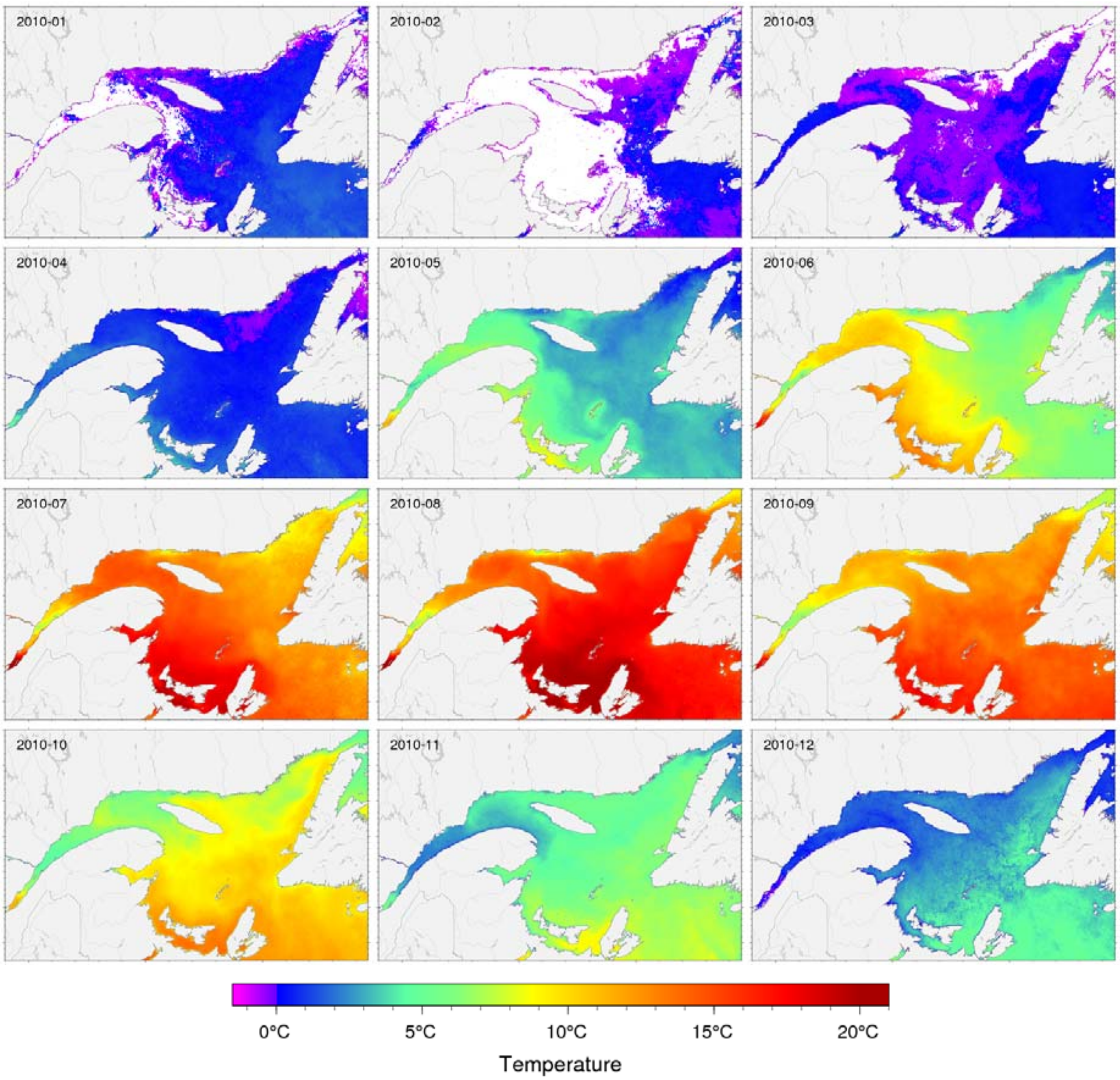

Fig. 14. Sea-surface temperature averages for the first 28 days of each month of 2009 as observed with NOAA AVHRR remote sensing. White areas have no data for the period due to ice cover.

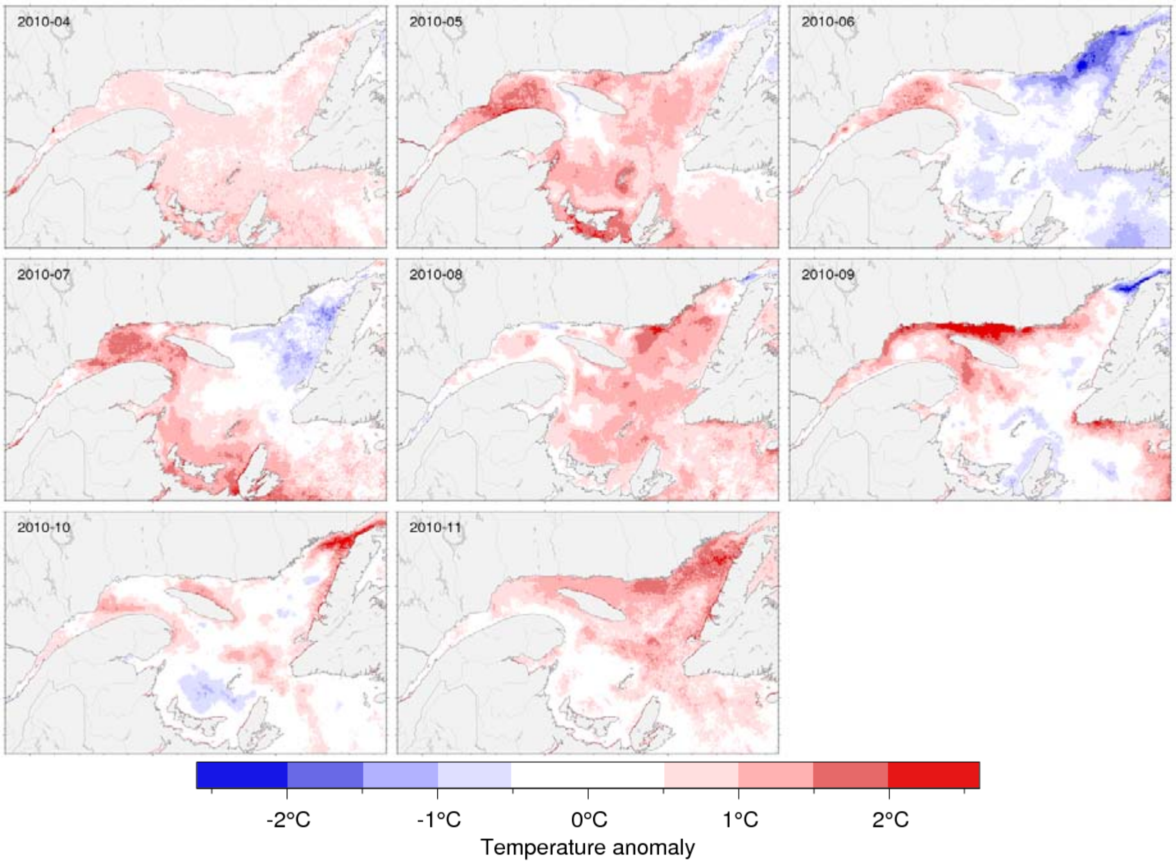

Fig. 15. Sea-surface temperature anomalies for the first 28 days of April through November 2009 based on monthly climatologies calculated for the 1985–2009 period observed with NOAA AVHRR remote sensing. Only ice-free months are shown.

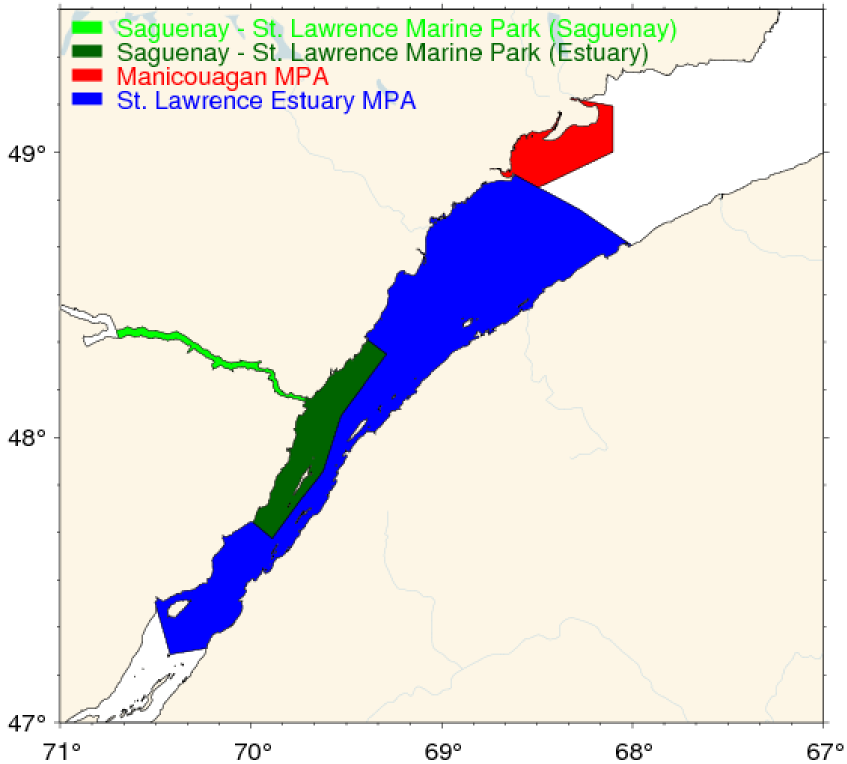

Fig. 16. Map showing the Manicouagan MPA, the St. Lawrence Estuary MPA, and the Saguenay – St. Lawrence Marine Park for the purpose of SST extraction from NOAA imagery.

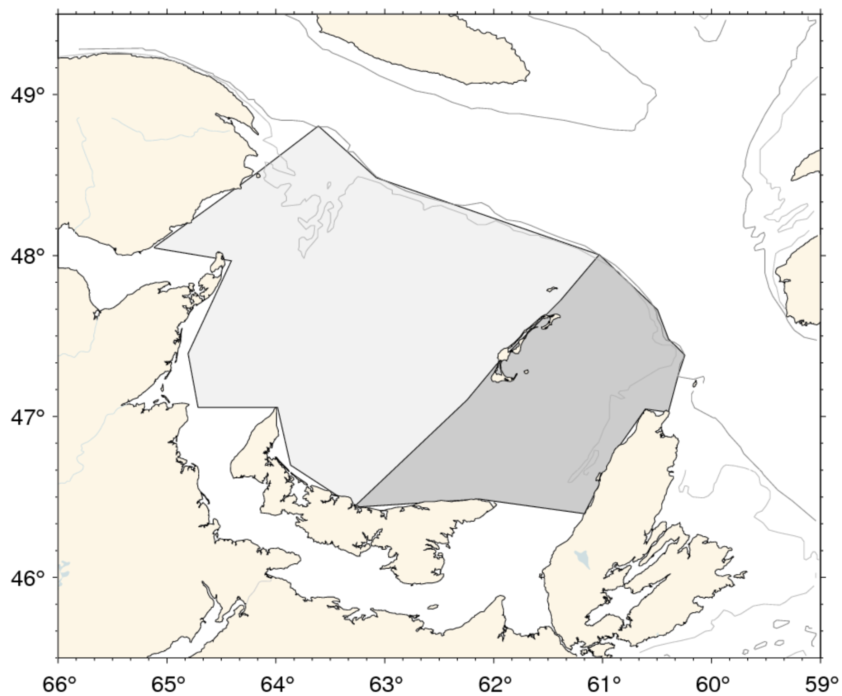

Fig. 17. Areas defined as the western and eastern Magdalen Shallows.

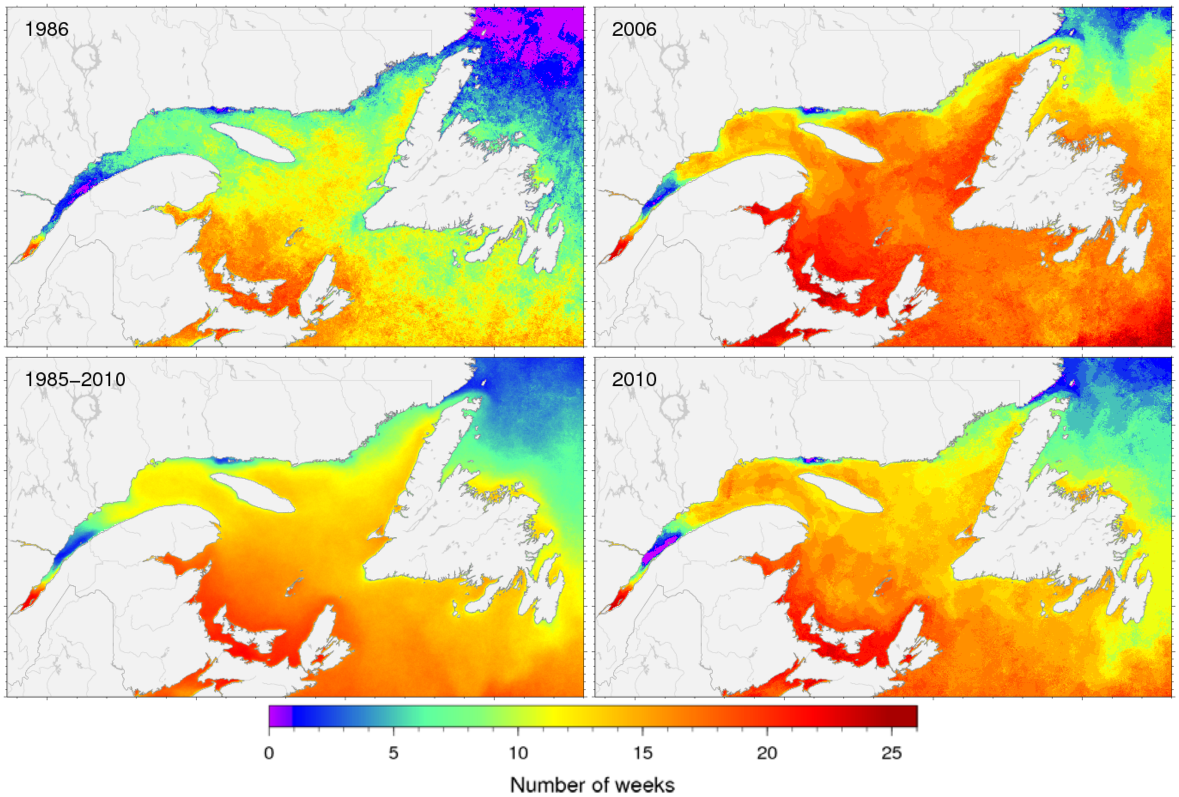

Fig. 18. Yearly number of weeks with mean weekly surface temperature > 10°C. Years with the minimum (1986, top left) and maximum (2006, top right) number of weeks are shown along with the 1985–2010 climatological average (lower left) and the chart for 2010.

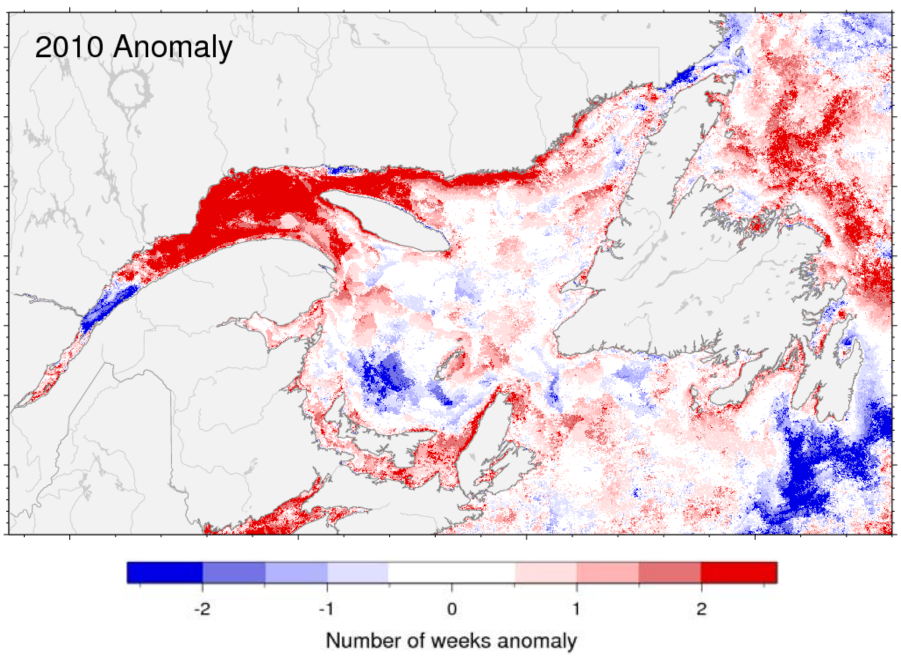

Fig. 19. Anomaly of the number of weeks in 2010 with mean weekly surface temperature > 10°C using the 1985–2010 climatological average from Fig. 18.

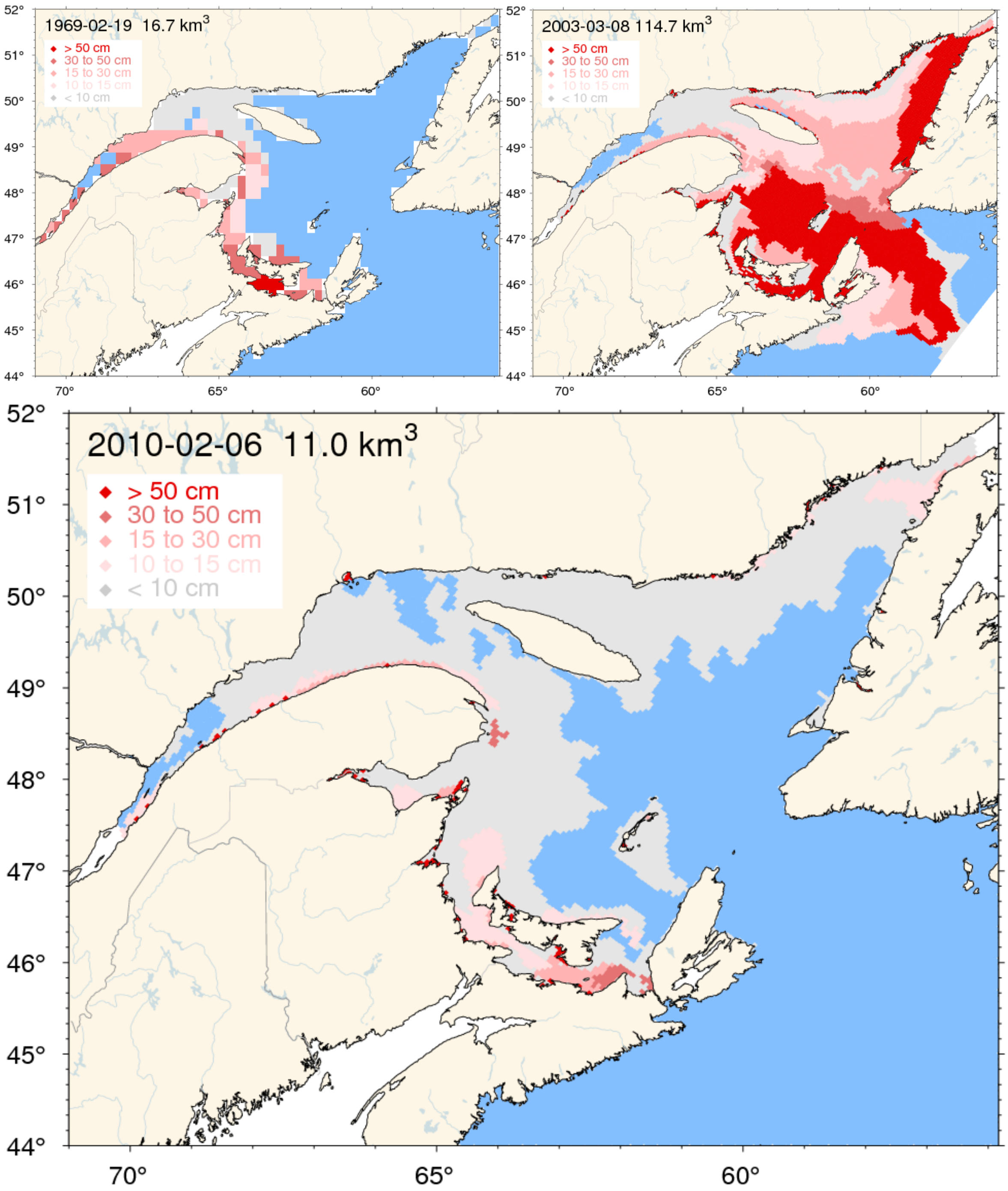

Fig. 20. Ice thickness map for 2010 for the day of the year with the maximum annual volume (lower panel) and similarly for 1969 and 2003, the years with the (previously) smallest and largest annual ice volumes, respectively.

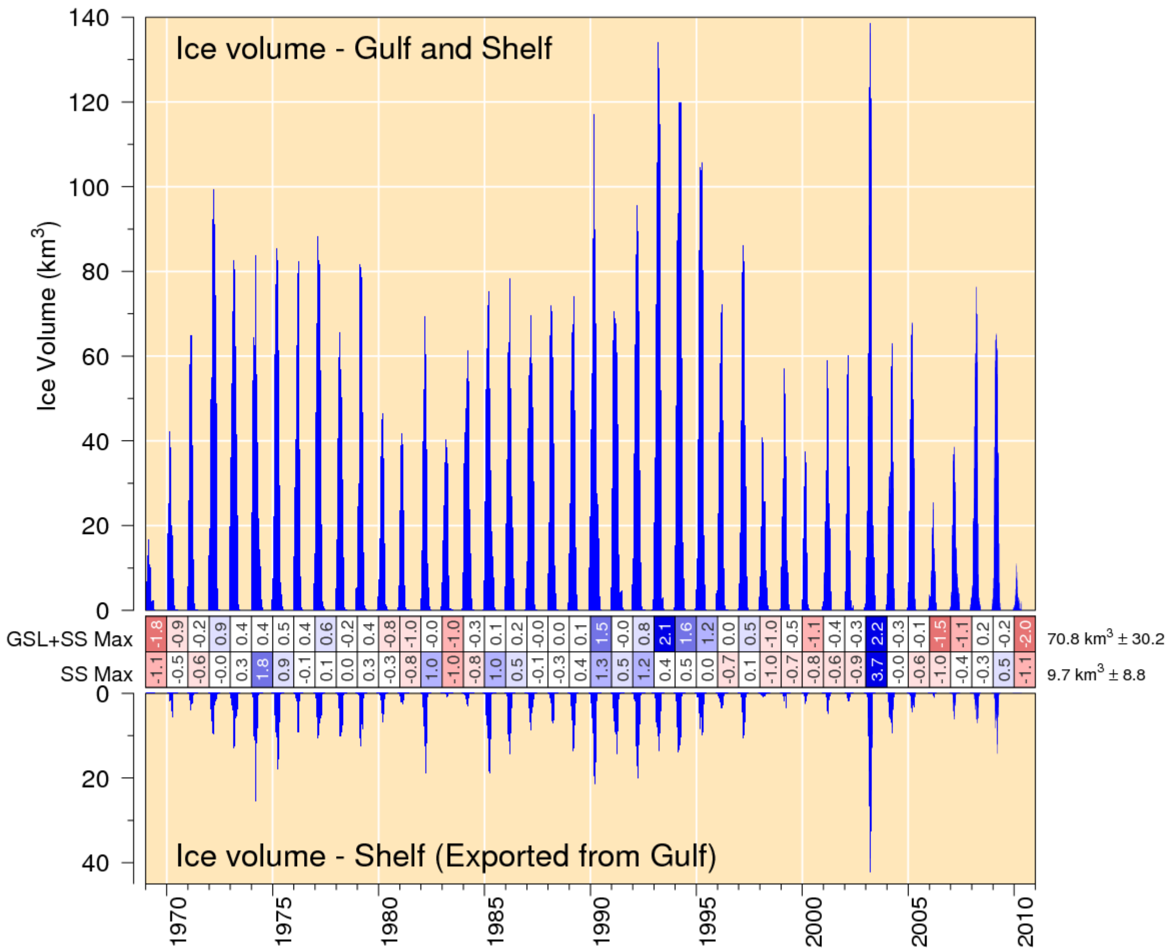

Fig. 21. Estimated ice volume in the Gulf of St. Lawrence and on the Scotian Shelf seaward of Cabot Strait (upper panel) and on the Scotian Shelf only (lower panel). Scorecards show numbered normalized anomalies for the combined Gulf and Shelf and Shelf-only annual maximum volumes. The mean and standard deviation are indicated on the right side using the 1981–2010 climatology.

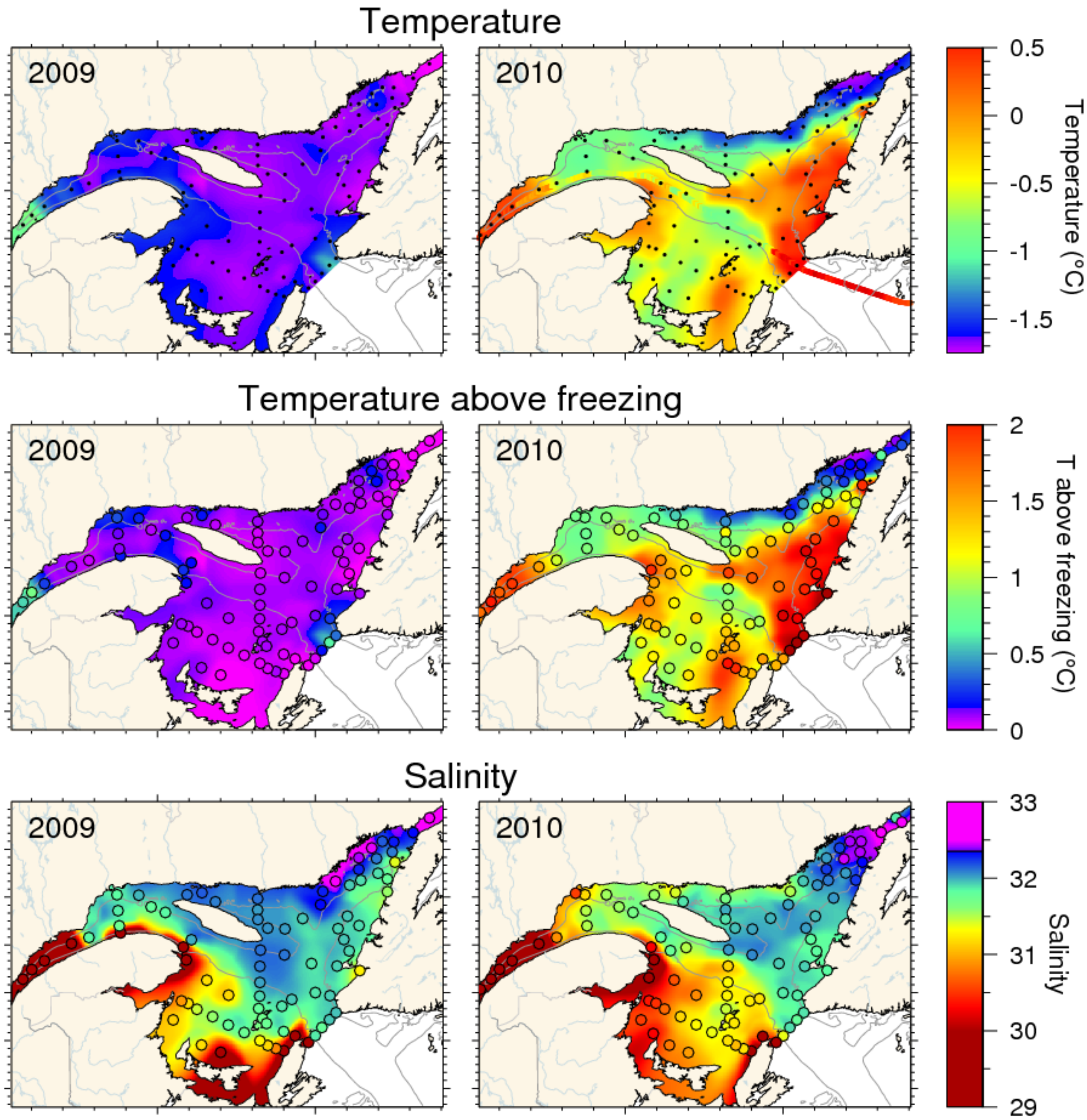

Fig. 22. Winter surface layer characteristics from the March 2009 and 2010 helicopter surveys: surface water temperature (upper panel), temperature difference between surface water temperature and the freezing point (middle panel), and salinity (lower panel). The temperature measurements from shipboard thermosalinographs taken during the 2010 survey are also shown in the upper panel. 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.

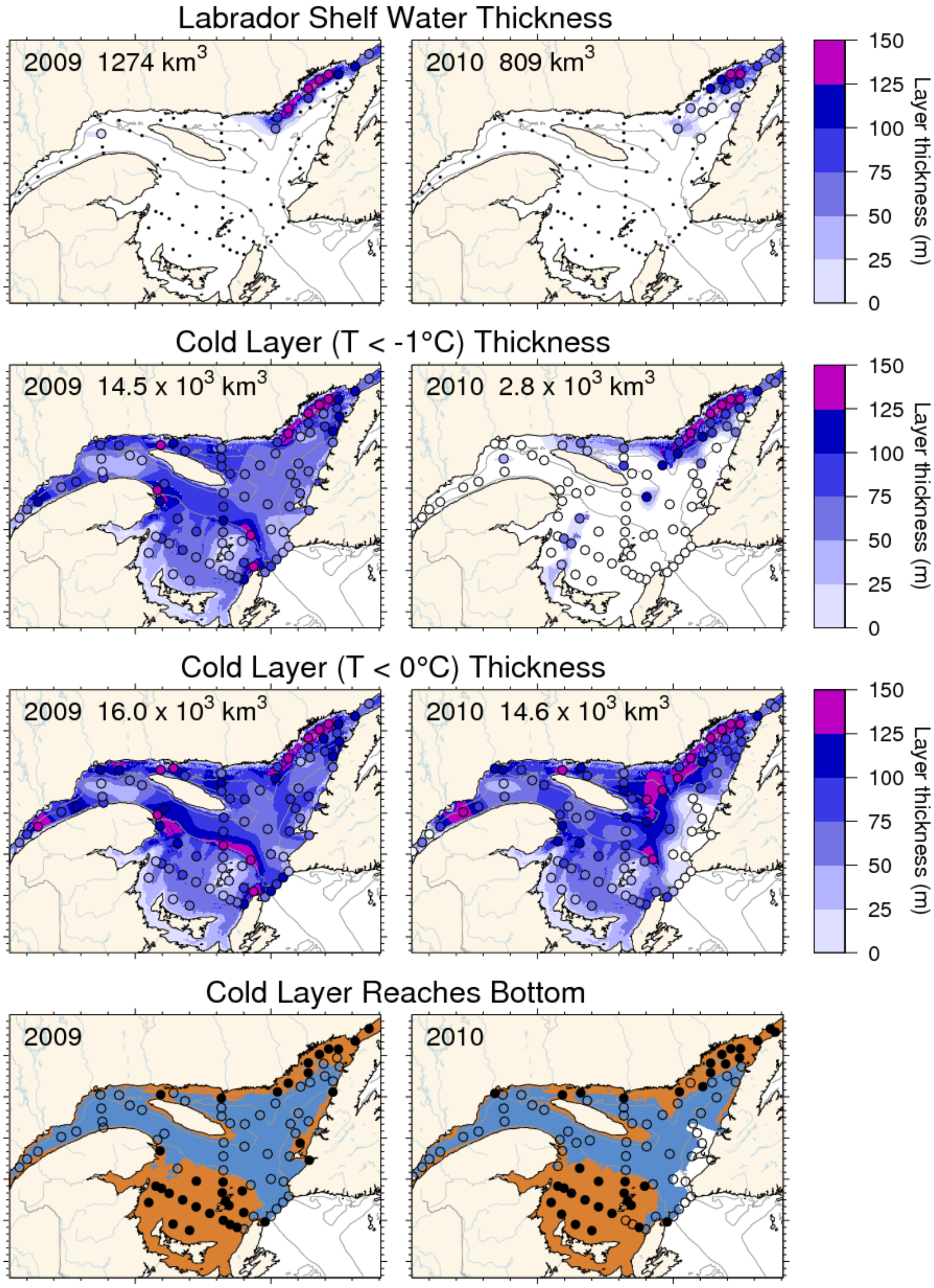

Fig. 23. Winter surface layer characteristics from the March 2009 and 2010 helicopter surveys. Estimates of the thickness of the Labrador Shelf water intrusion (upper panels), cold layer (T < -1°C, T < 0°C) thickness (middle panels), and maps indicating where the cold layer (T < -1°C for 2009 and T < 0°C for 2010) reaches the bottom (in brown; lower panels). Station symbols are coloured according to the observed values as in Fig. 22. For the lower panels, the stations where the cold layer reached the bottom are indicated with filled circles while open circles represent stations where the layer did not reach the bottom. Integrated volumes are indicated for the first six panels.

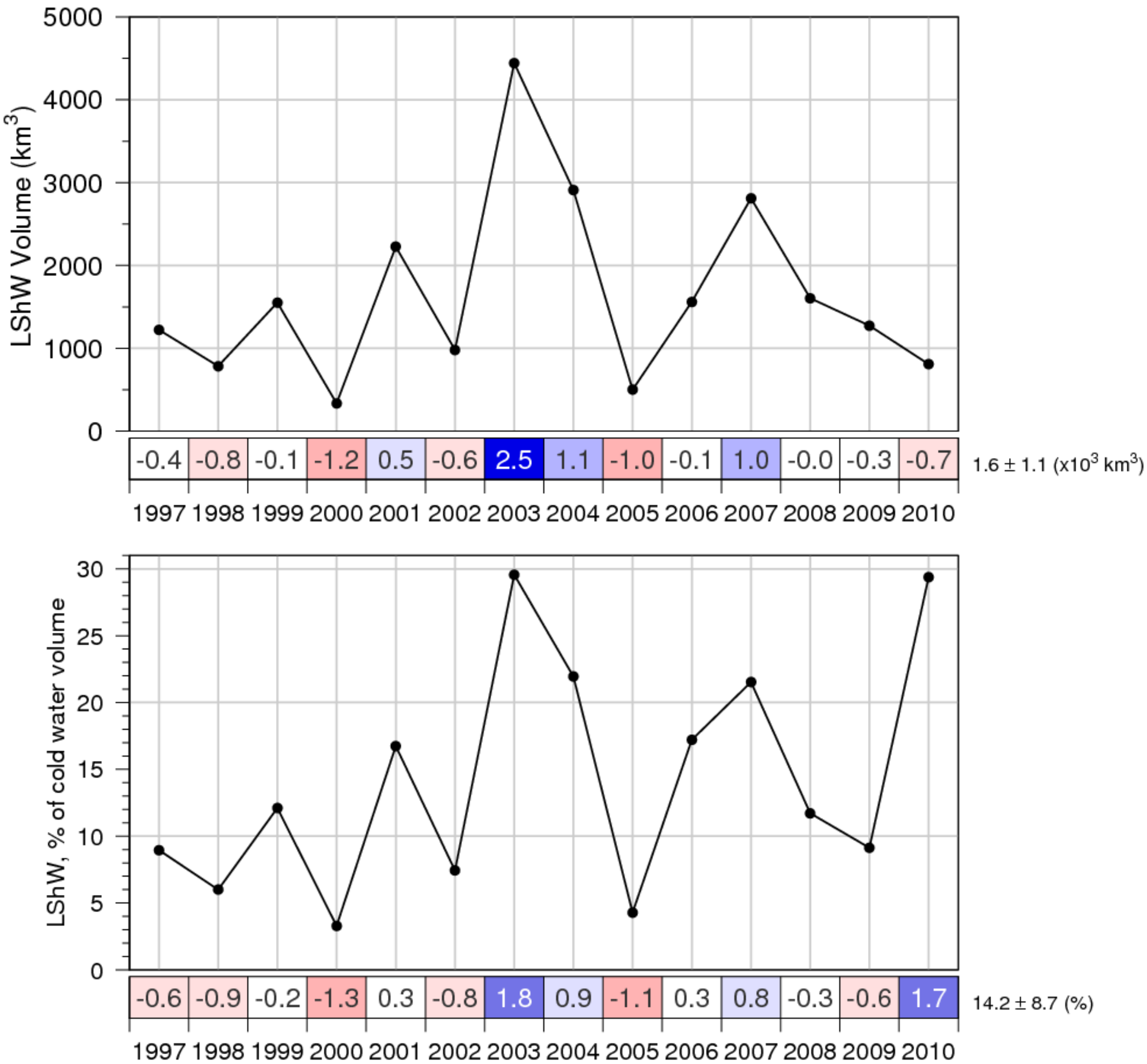

Fig. 24. Estimated volume of cold and saline Labrador Shelf water that flowed into the Gulf over the winter through the Strait of Belle Isle. The bottom panel shows the volume as a percentage of total cold-water volume (< -1ºC). The numbers in the boxes are normalized anomalies.

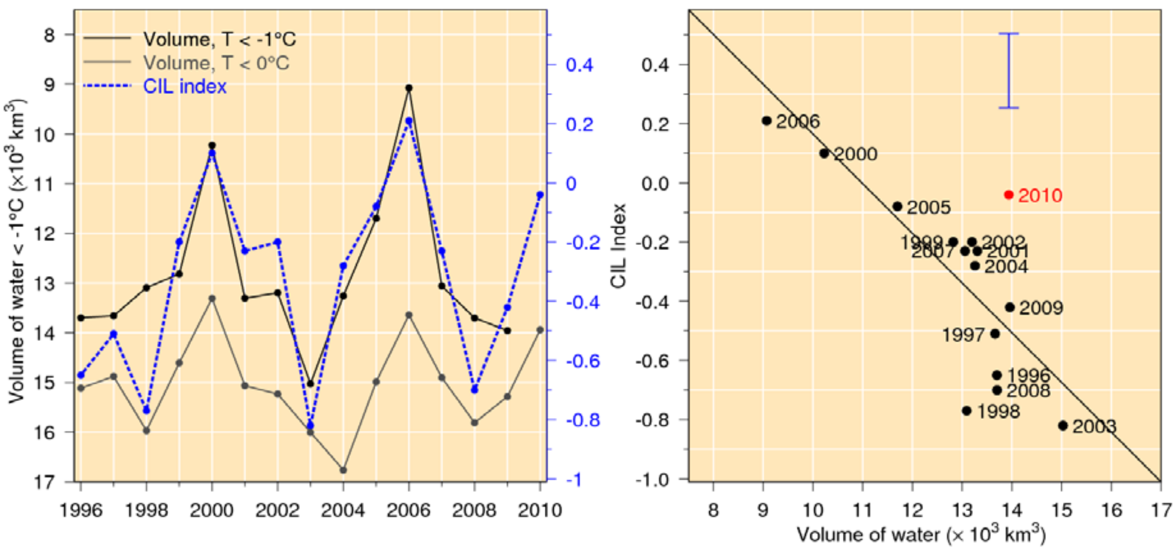

Fig. 25. Left panel: winter surface cold (T < -1°C and T < 0°C) layer volume time series (black and grey lines) and summer CIL index (blue dashed line). Right panel: relation between summer CIL index and winter cold-water volume with T < -1°C excluding the Estuary (regression excludes the 1998 data pair; see Galbraith 2006). Note that the volume scale in the left panel is reversed. The volume with T < 0°C observed in March 2010 was used to forecast a CIL index within the range of 0.25ºC and 0.50ºC (range indicated in blue) for summer 2010, based on the CIL index expected for such a volume of winter mixed water and the average temperature difference between the 2010 mixed layer and more typical winter conditions. The actual 2010 CIL index observed later in the year is also indicated (in red).

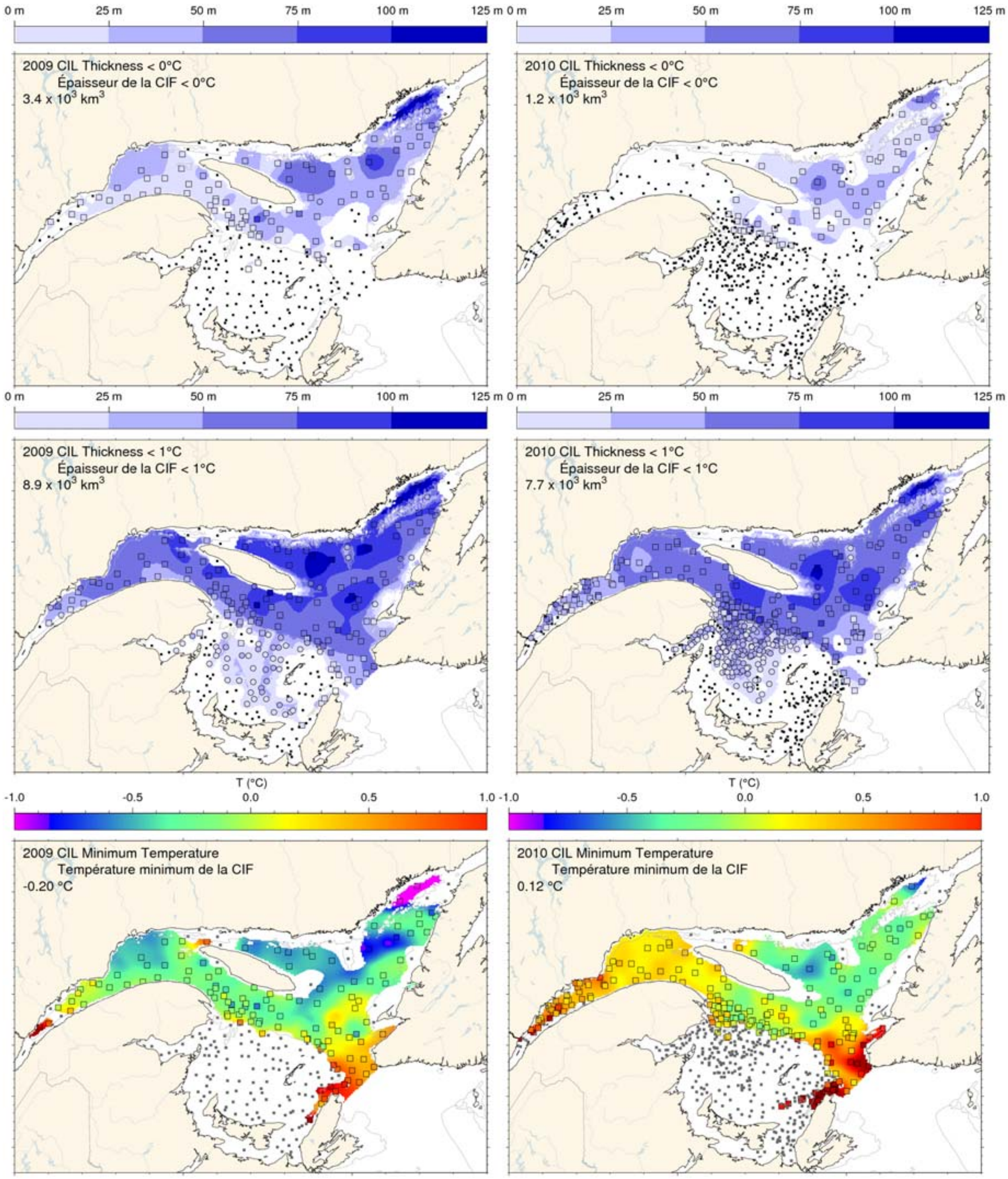

Fig. 26. Cold intermediate layer thickness (T < 0ºC, top panels; T < 1ºC, middle panels) and minimum temperature (bottom panels) in August and September 2009 (left) and 2010 (right). The colour-coding is according to the temperature anomaly relative to the climatology of each station for each month. Numbers in the upper and middle panels are integrated CIL volumes and in the lower panels are monthly average temperatures.

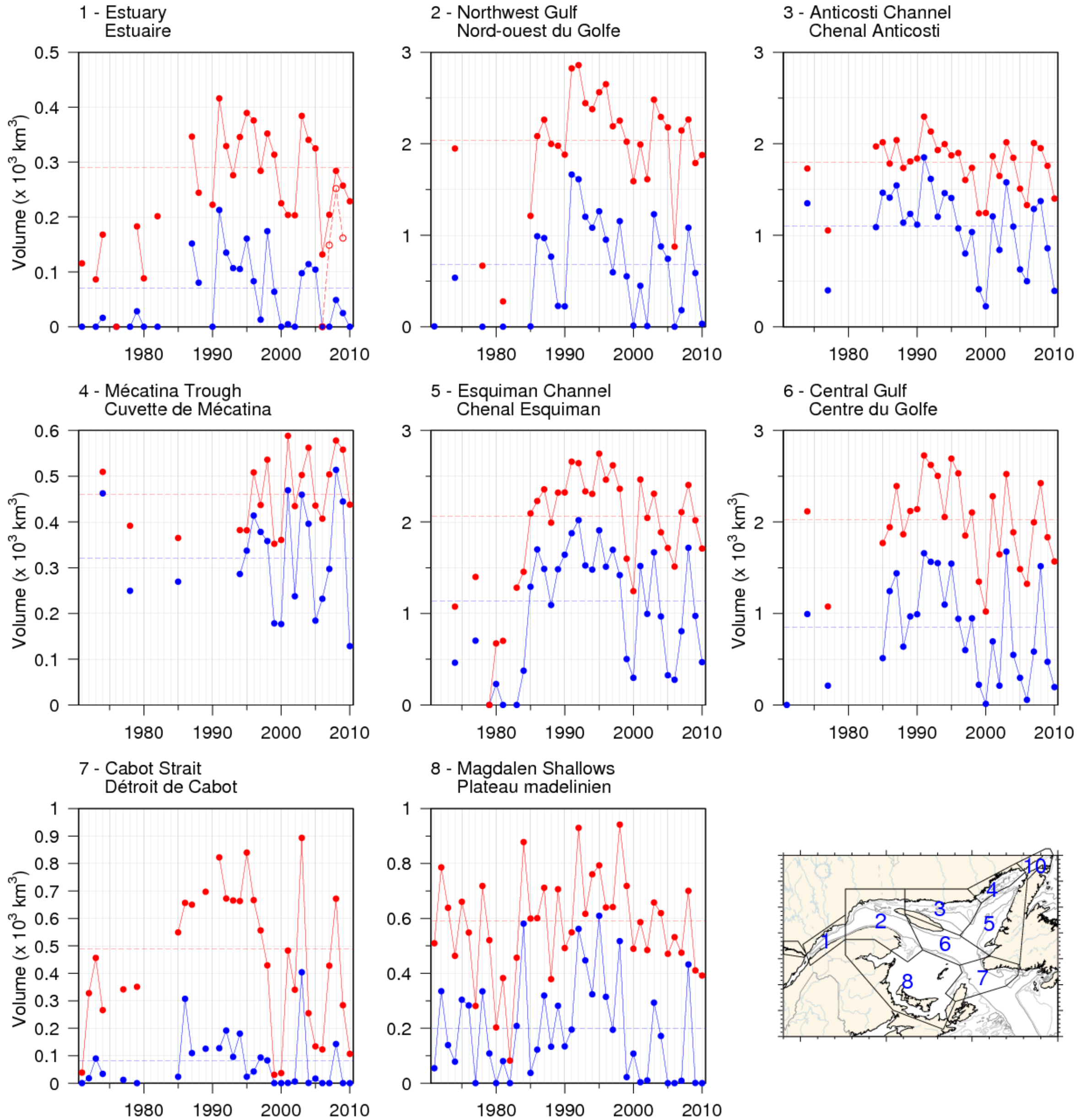

Fig. 27. Volume of the CIL colder than 0ºC (blue) and colder than 1ºC (red) in August and September (primarily region 8 in September). The volume of the CIL colder than 1ºC in November 2006 to 2009 is also shown for the St. Lawrence Estuary (dashed line).

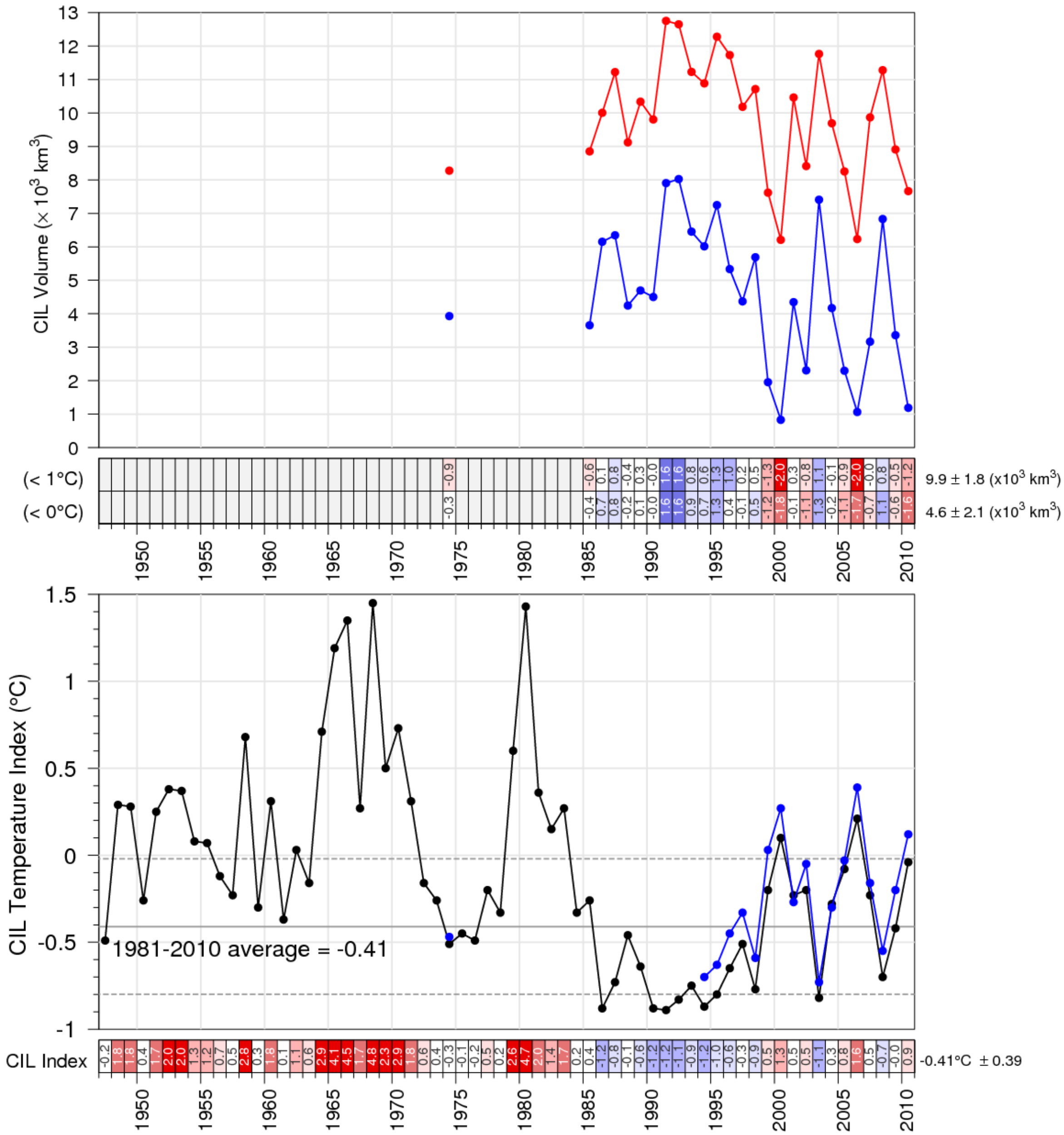

Fig. 28. CIL volume (top panel) delimited by the over- and underlying 0ºC (in blue) and 1ºC (in red) isotherms, and minimum temperature index (bottom panel) in the Gulf of St. Lawrence. The volumes are integrals of each of the annual interpolated thickness grids such as those shown in the top panels of Fig. 26. In the lower panel, the black line is the updated Gilbert and Pettigrew (1997) index interpolated to 15 July and the blue line is the spatial average of each of the annual interpolated grid such as those shown in the two bottom panels of Fig. 26. The numbers in the boxes are normalized anomalies.

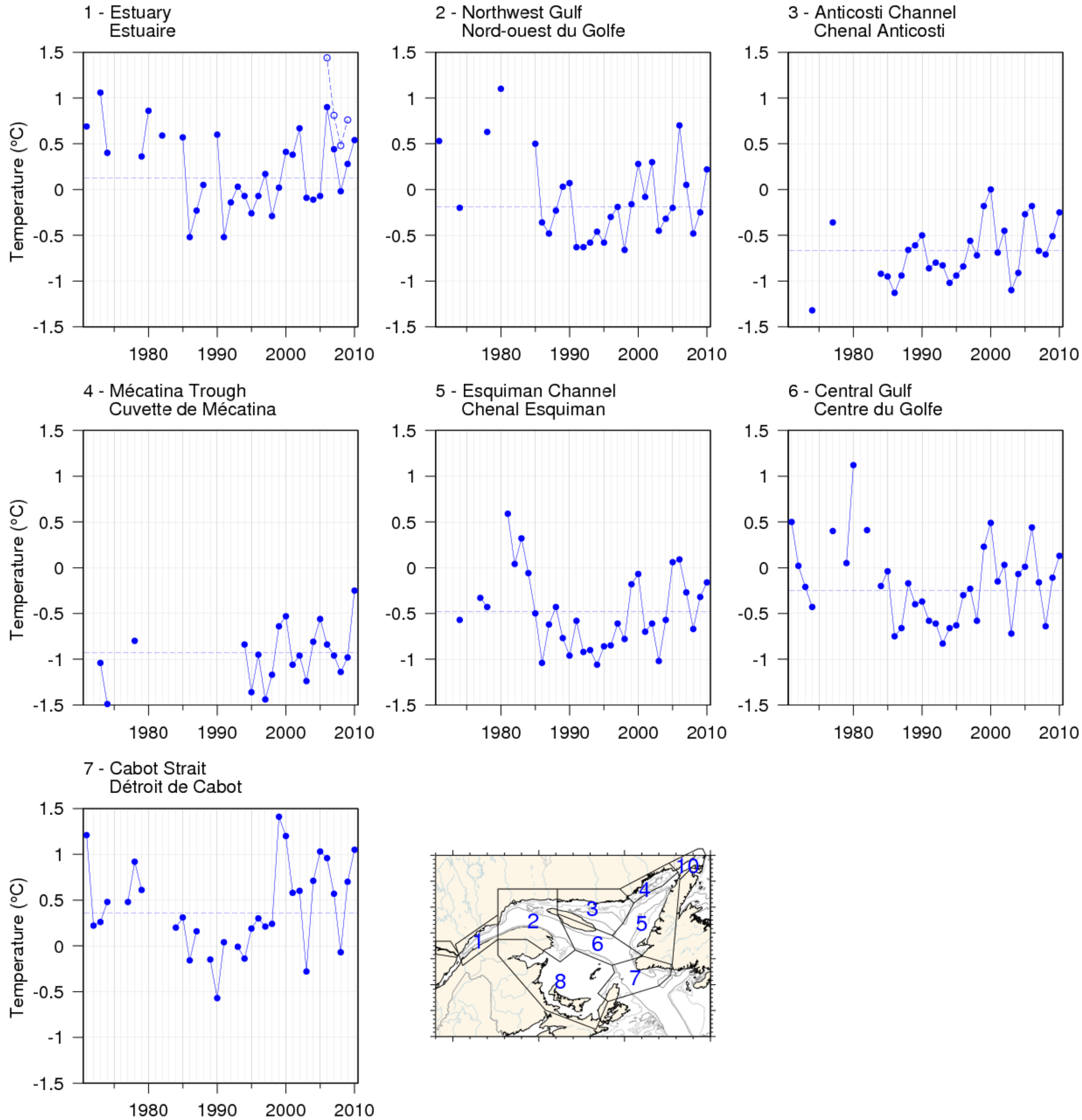

Fig. 29. Temperature minimum of the CIL spatially averaged for the seven areas where the CIL minimum temperature can be clearly identified (i.e., deeper than 100 m). The volume of the CIL colder than 1ºC in November 2006 to 2009 is also shown for the St. Lawrence estuary (dashed line).

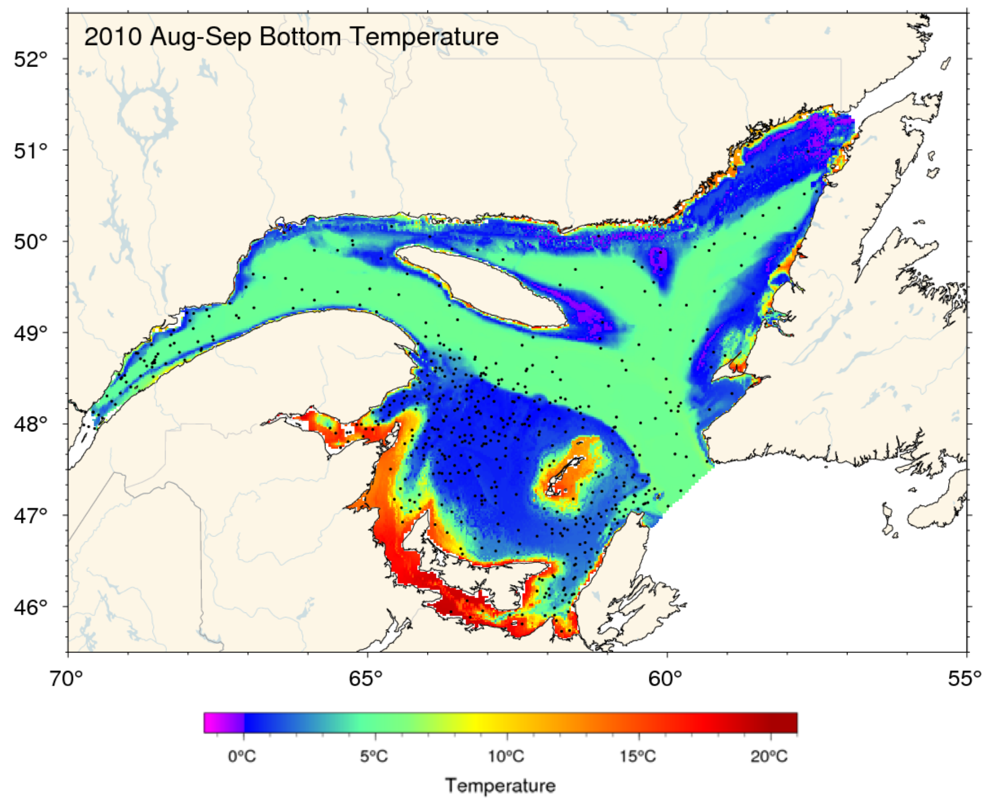

Fig. 30. Near-bottom temperatures during August and September 2010.

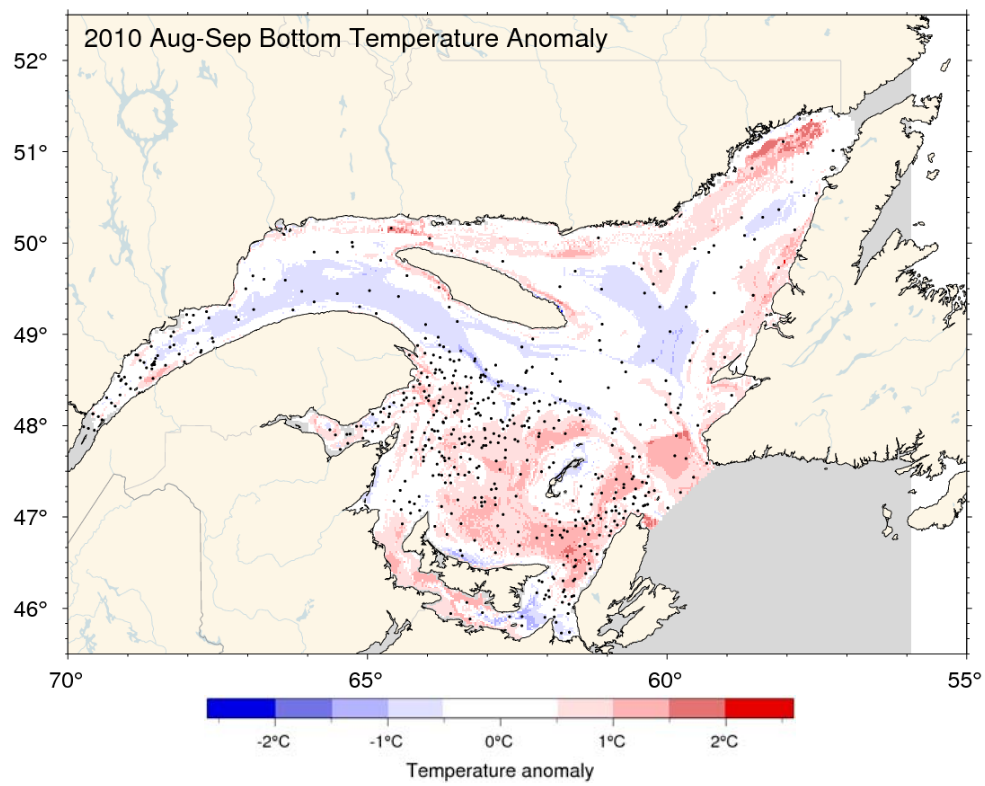

Fig. 31. Near-bottom temperature anomalies based on the 1985–2000 climatology.

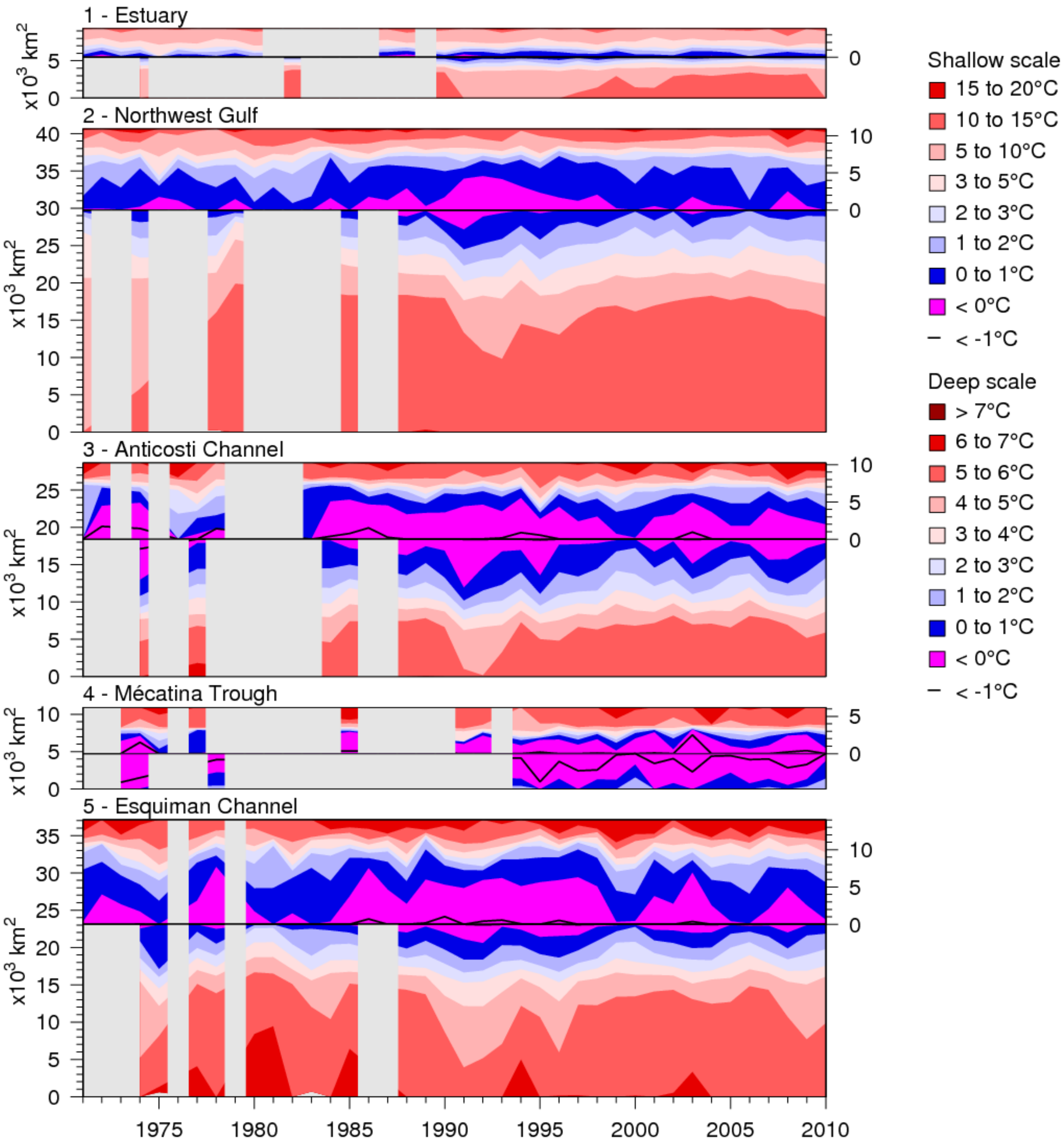

Fig. 32. Time series of the bottom areas covered by different temperature bins in August and September for regions 1 to 5. The panels are separated by the black horizontal line into shallow (< 100 m) and deep (> 100 m) areas to distinguish between warmer waters above and below the CIL. The shallow areas are shown on top using the area scale on the right-hand side and have wamer waters shown starting from the top end. The deep areas are shown below the horizontal line and have warmer waters starting at the bottom end. The CIL areas above and below 100 m meet near the horizontal line.

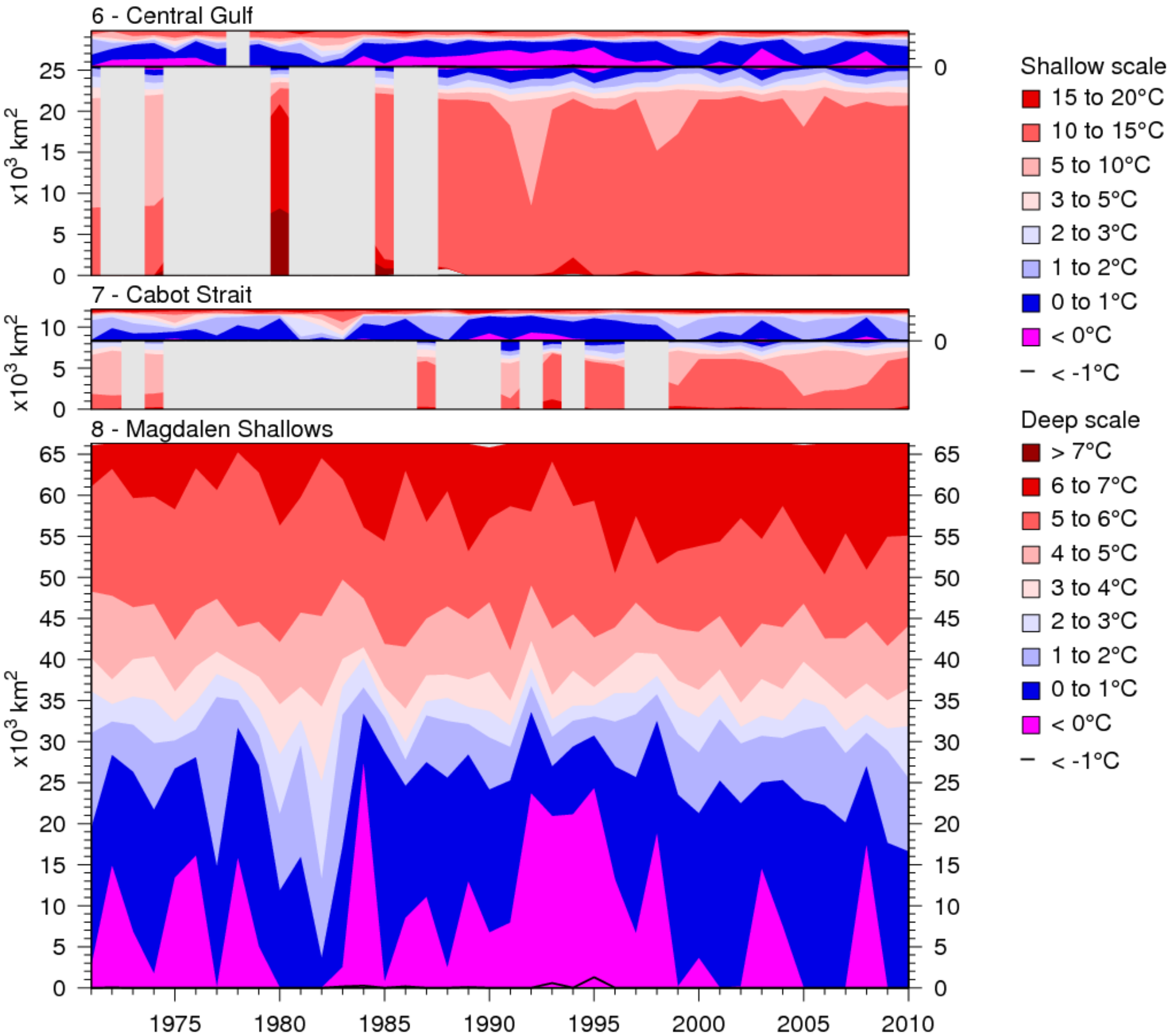

Fig. 33. Time series of the bottom areas covered by different temperature bins in August and September for regions 6 to 8. The panels are separated into shallow (< 100 m) and deep (> 100 m) areas to distinguish between warmer waters above and below the CIL, except for region 8, which does not have deep waters. See Fig. 32 caption.

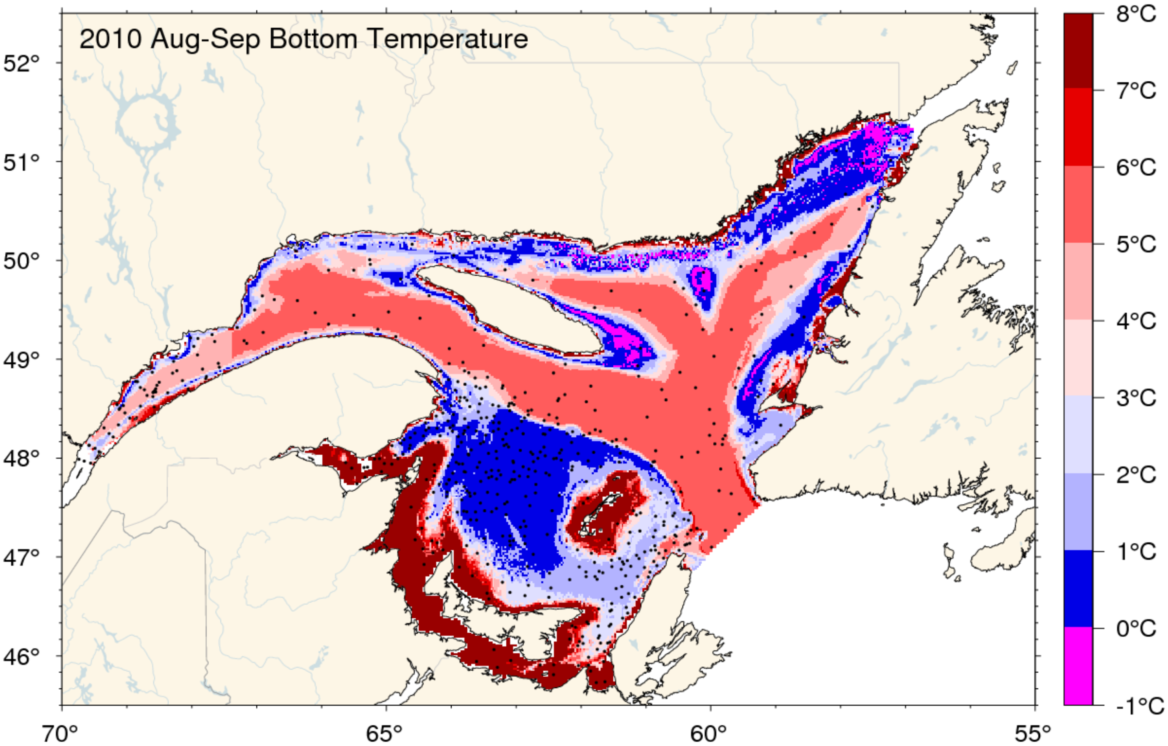

Fig. 34 Near-bottom temperatures during August and September 2010. This figure is the same as Fig. 30 but uses the deepwater scale of Fig. 32 and Fig. 33.

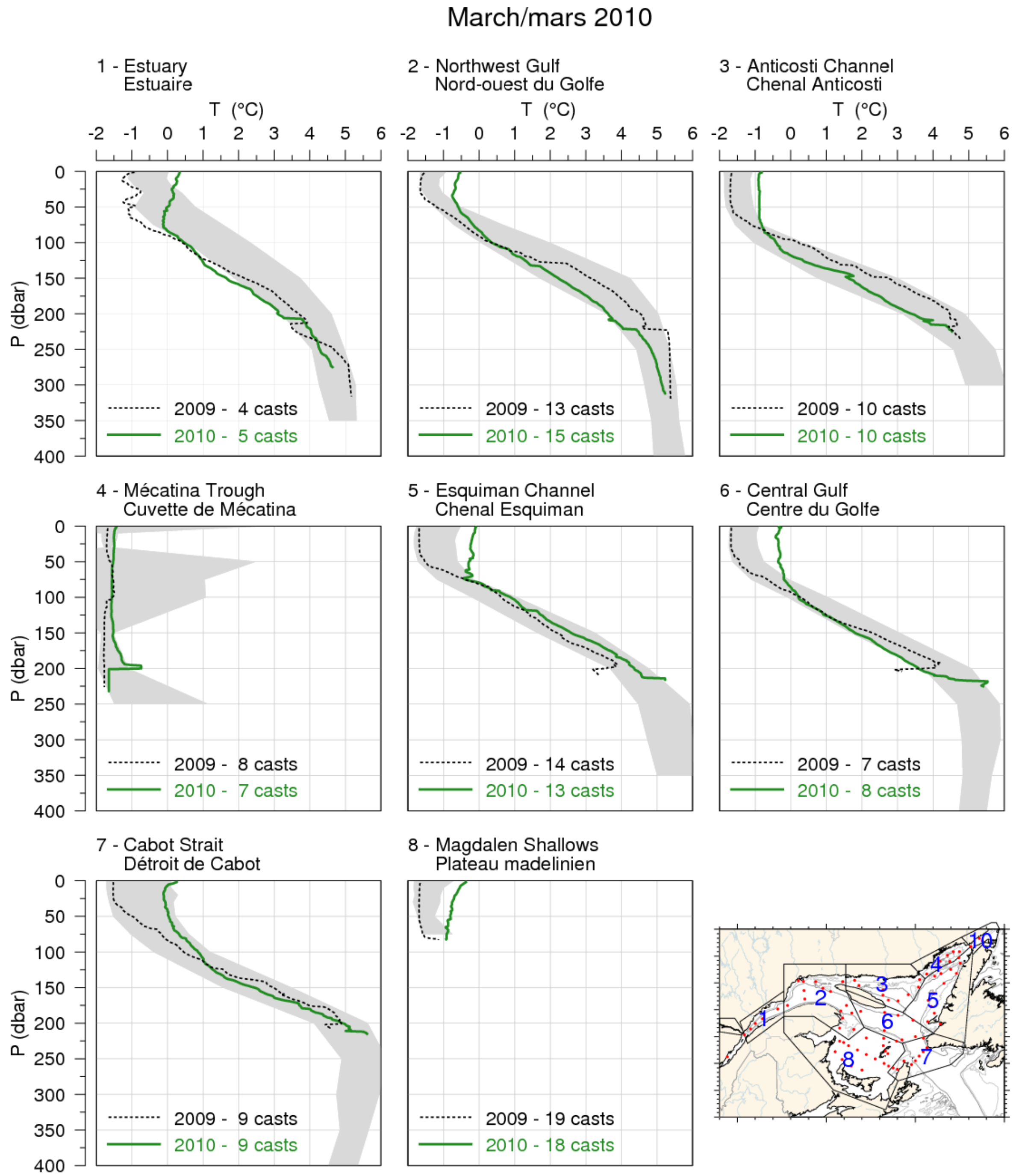

Fig. 35. Mean temperature profiles observed in each region of the Gulf during the March helicopter survey. The shaded area represents the 1981–2010 (but mostly 1996–2010) climatological monthly mean ± 1 SD. Mean profiles for the 2009 survey are also shown for comparison.

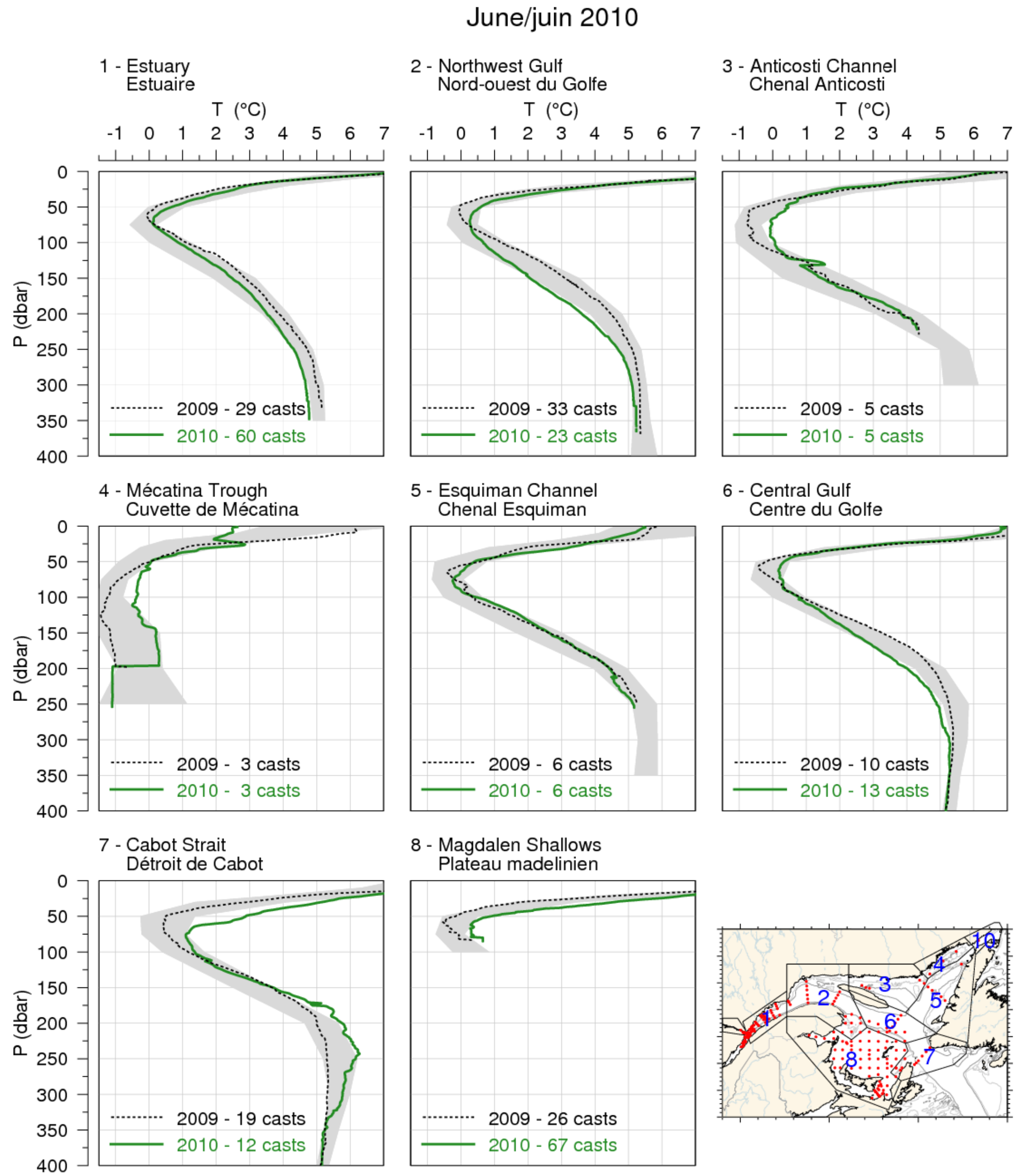

Fig. 36. Mean temperature profiles observed in each region of the Gulf during June. The shaded area represents the 1981–2010 climatological monthly mean ± 1 SD. Mean profiles for the 2009 survey are also shown for comparison.

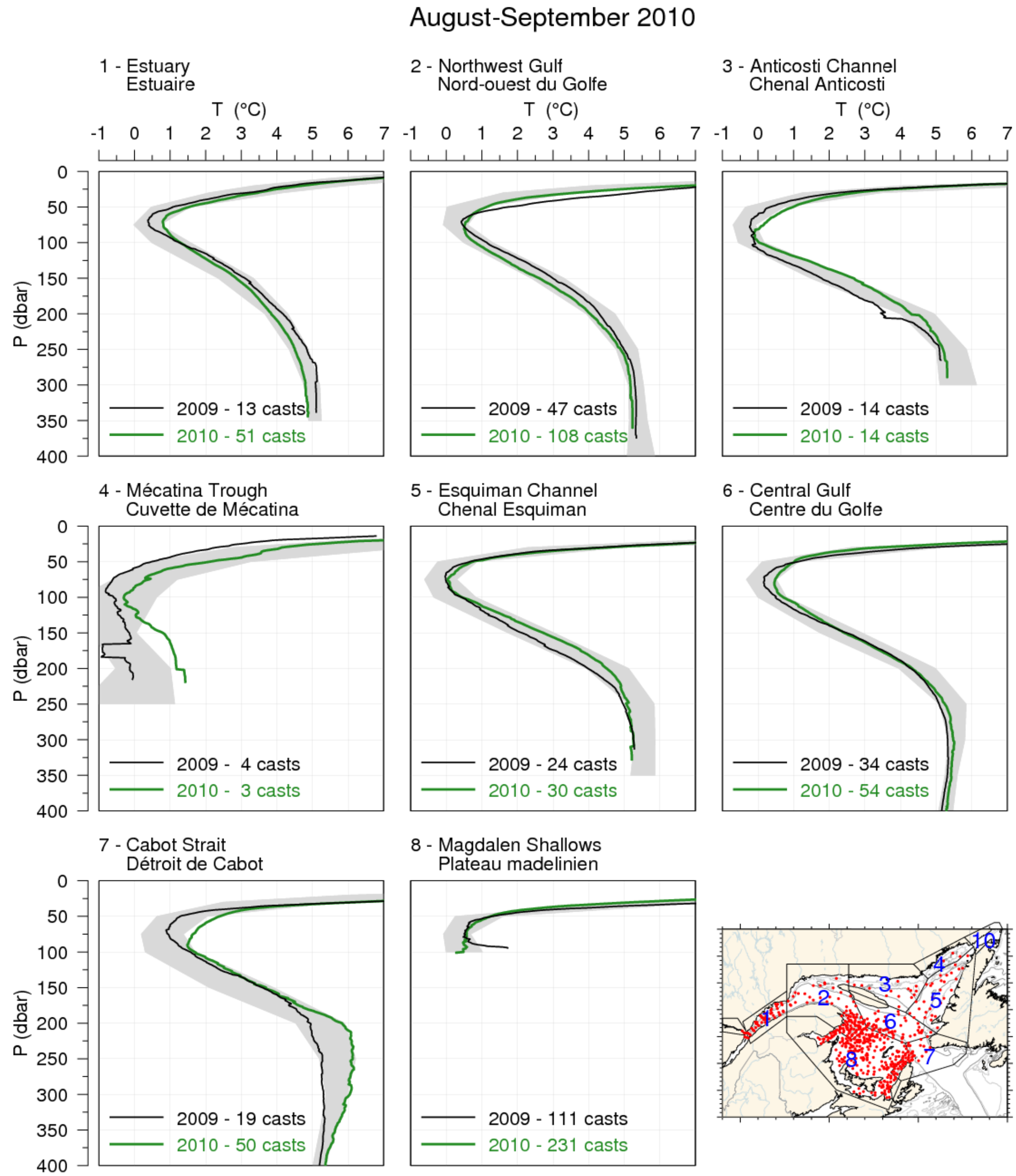

Fig. 37. Mean temperature profiles observed in each region of the Gulf during August and September. The shaded area represents the 1981–2010 climatological monthly mean ± 1 SD for August for regions 1 through 7 and for September for region 8. Mean profiles for the 2009 survey are also shown for comparison.

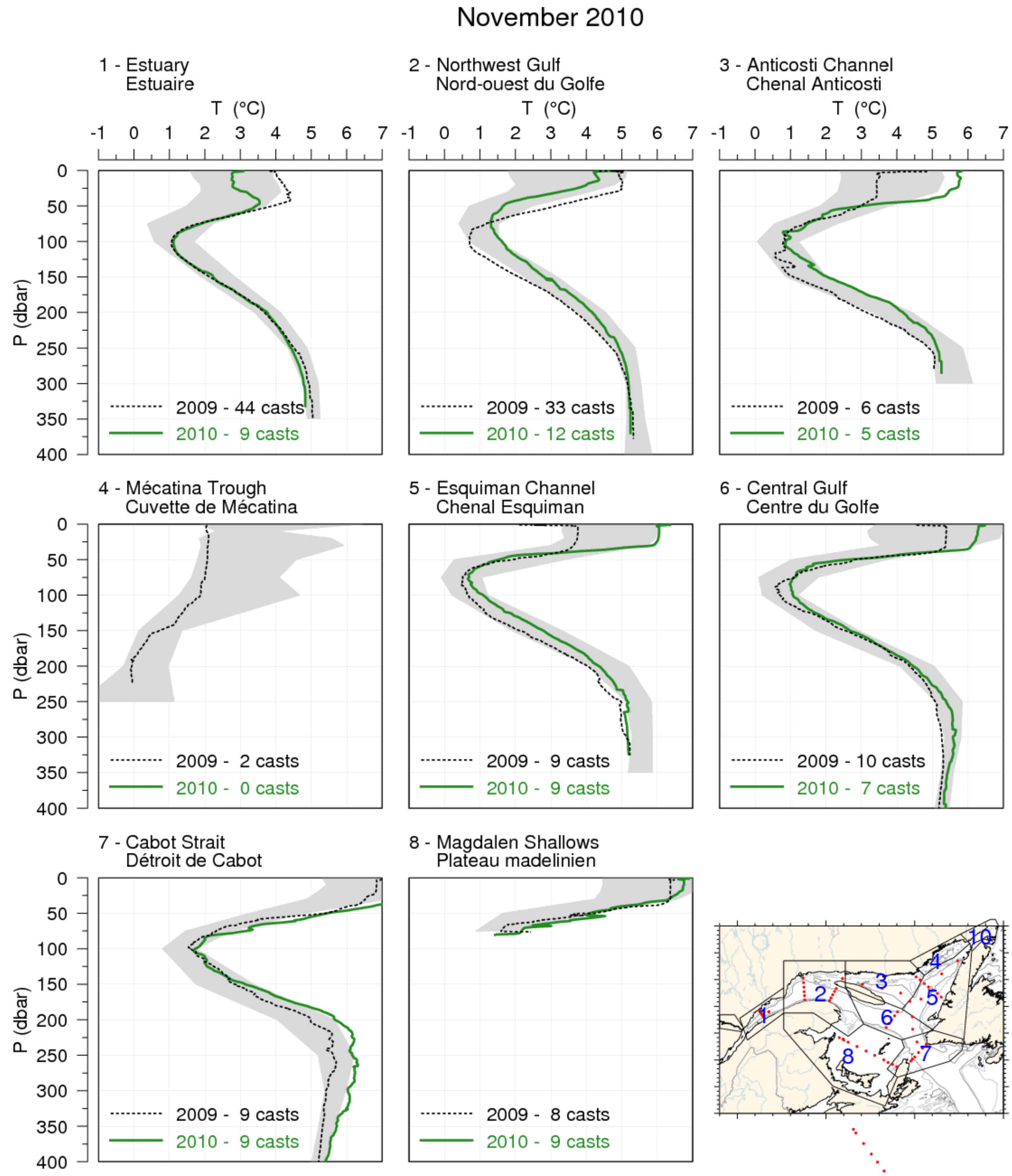

Fig. 38. Mean temperature profiles observed in each region of the Gulf during the November AZMP survey. The shaded area represents the 1981–2010 climatological monthly mean ± 1 SD. Mean profiles for the 2009 survey are also shown for comparison.

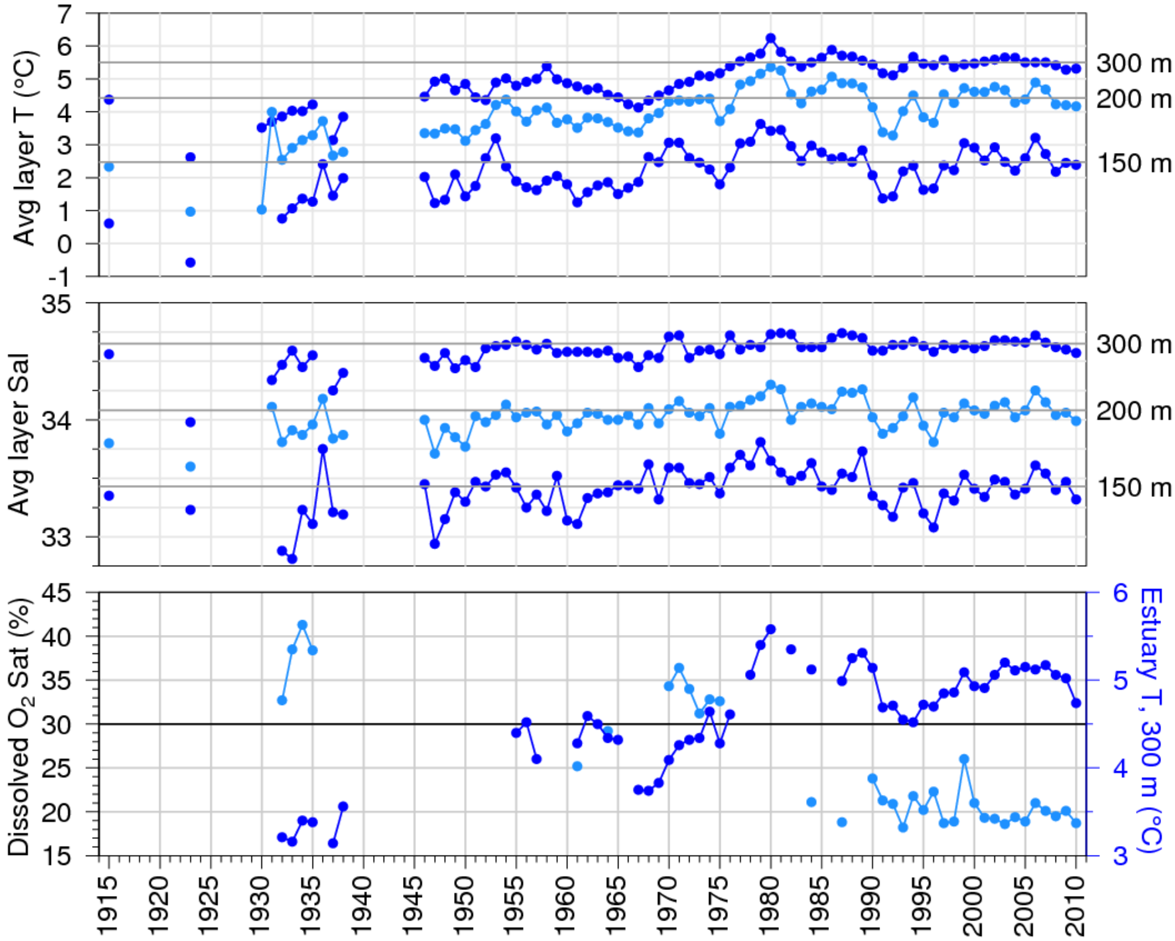

Fig. 39. Layer-averaged temperature and salinity time series for the Gulf of St. Lawrence and dissolved oxygen saturation between 295 m and the bottom in the deep central basin of the St. Lawrence Estuary. The temperature and salinity panels show the 150 m, 200 m, and 300 m annual averages and the horizontal lines are 1981–2010 means. The horizontal line in the oxygen panel at 30% saturation marks the threshold of hypoxic conditions. In addition to the oxygen percent saturation time series (light blue), the lower panel also shows temperature (dark blue) at 300 m in the Estuary.

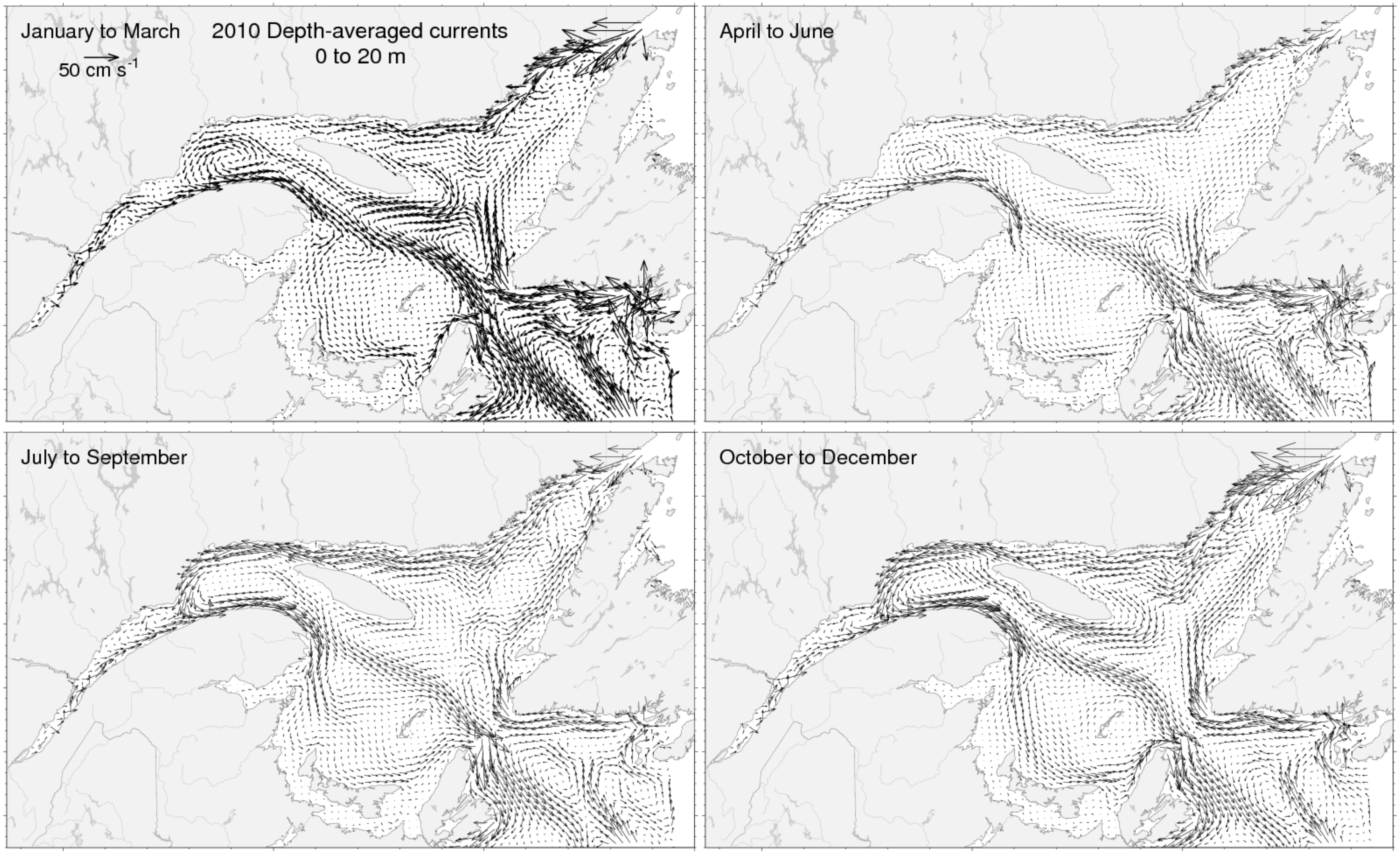

Fig. 40. Depth-averaged currents from 0 to 20 m for each three-month period of 2010.

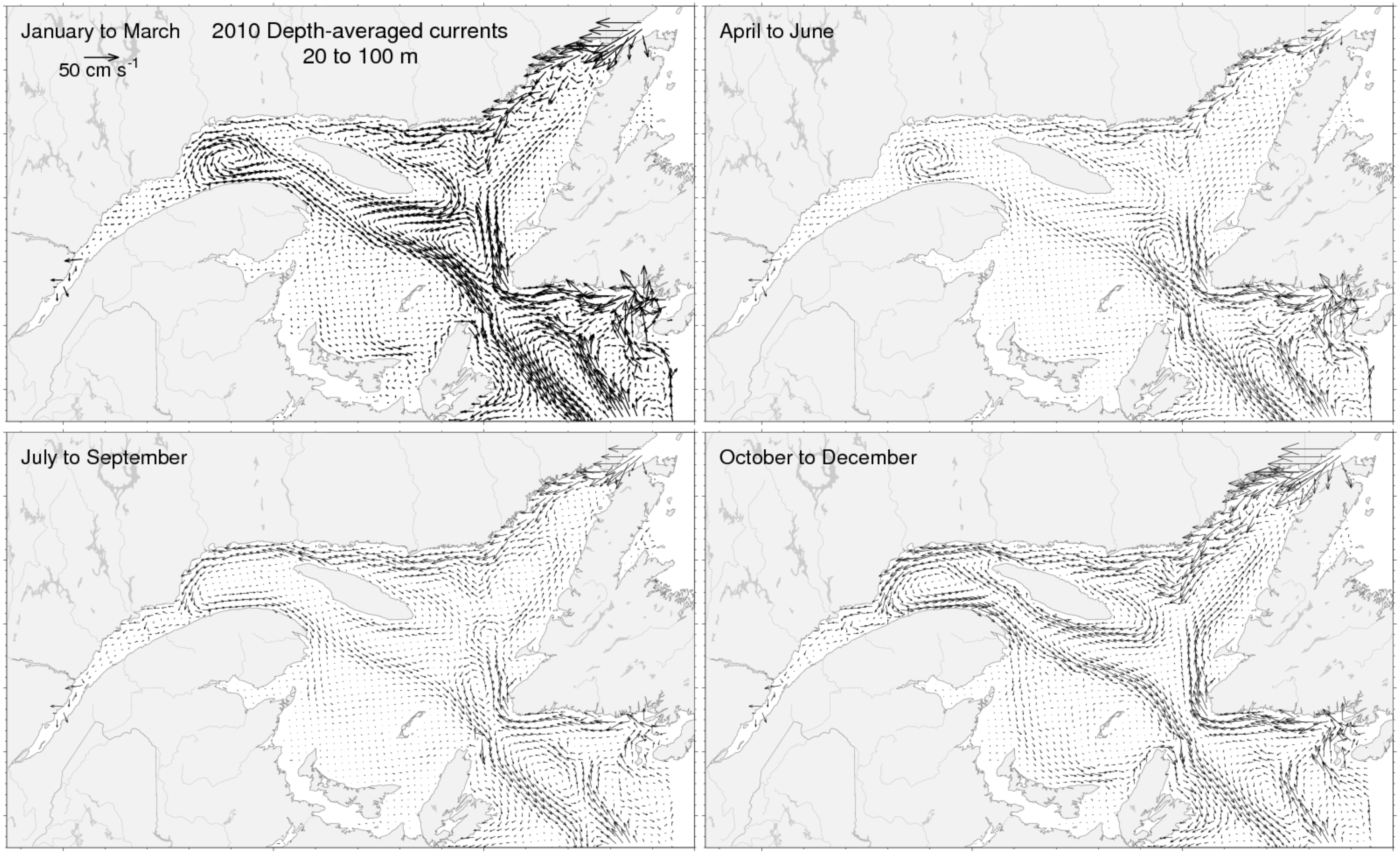

Fig. 41. Depth-averaged currents from 20 to 100 m for each three-month period of 2010.

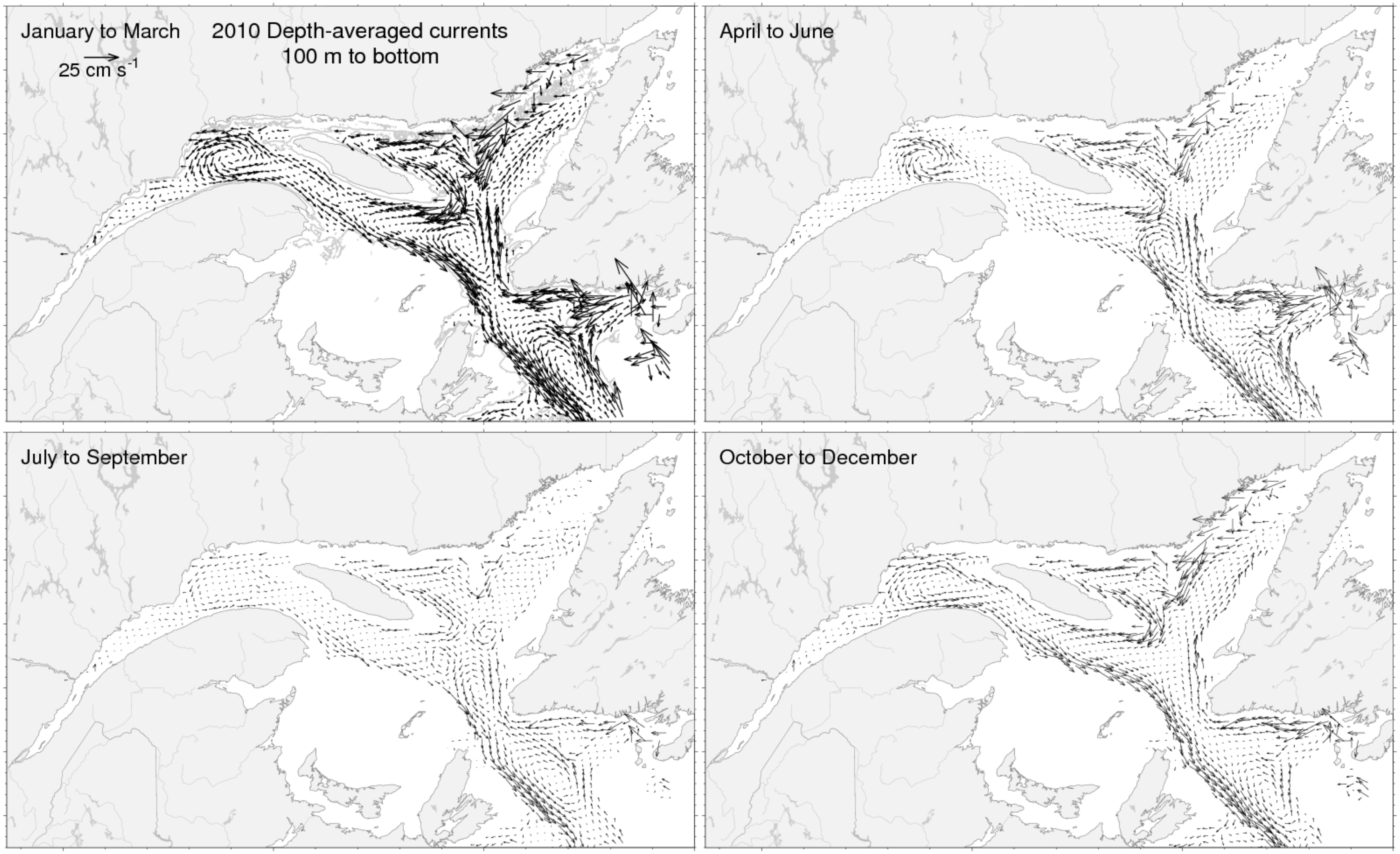

Fig. 42. Depth-averaged currents from 100 m to the bottom for each three-month period of 2010.

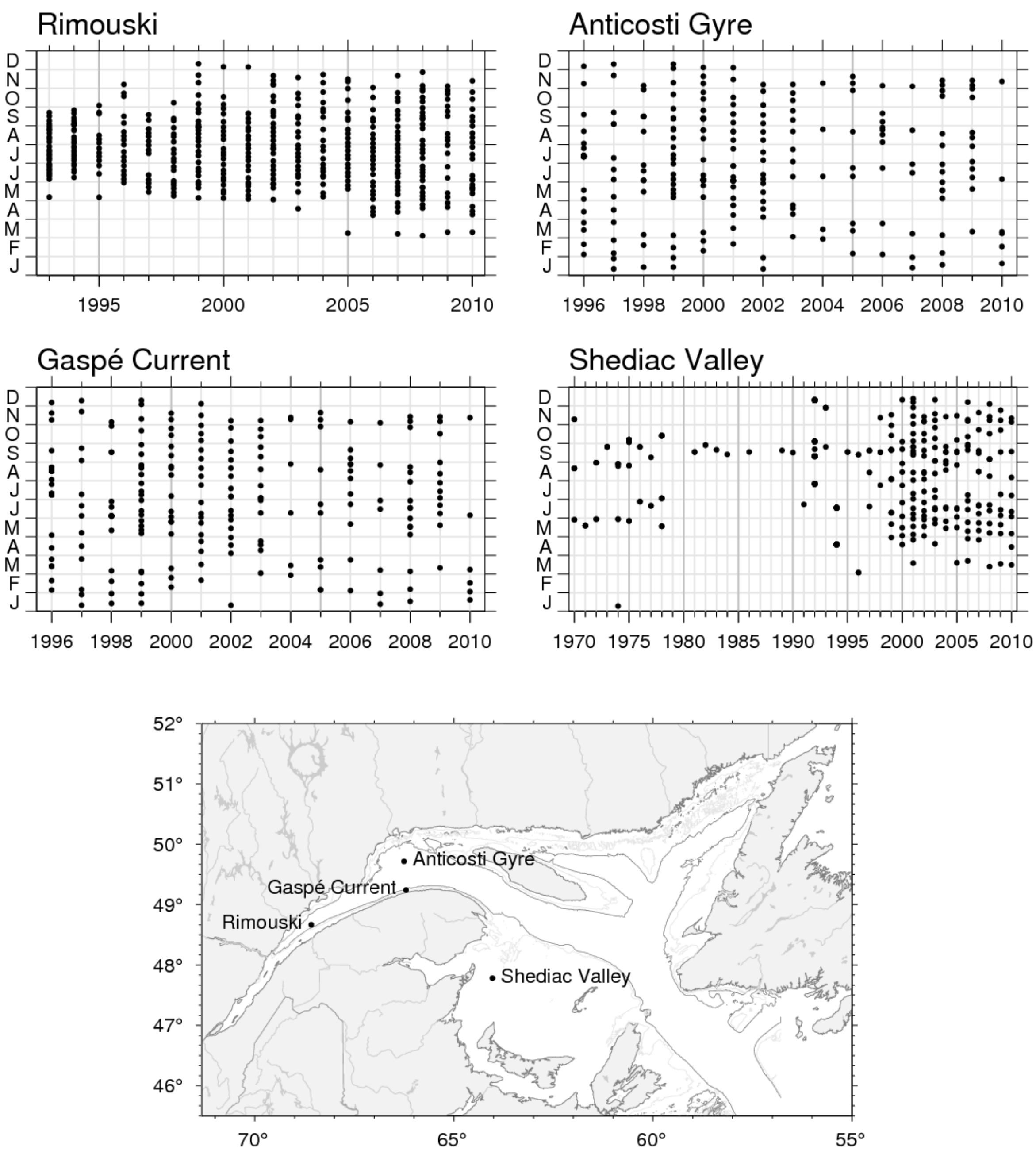

Fig. 43. Sampling frequency and positions of the AZMP stations (Rimouski, Anticosti Gyre, Gaspé Current, and Shediac Valley).

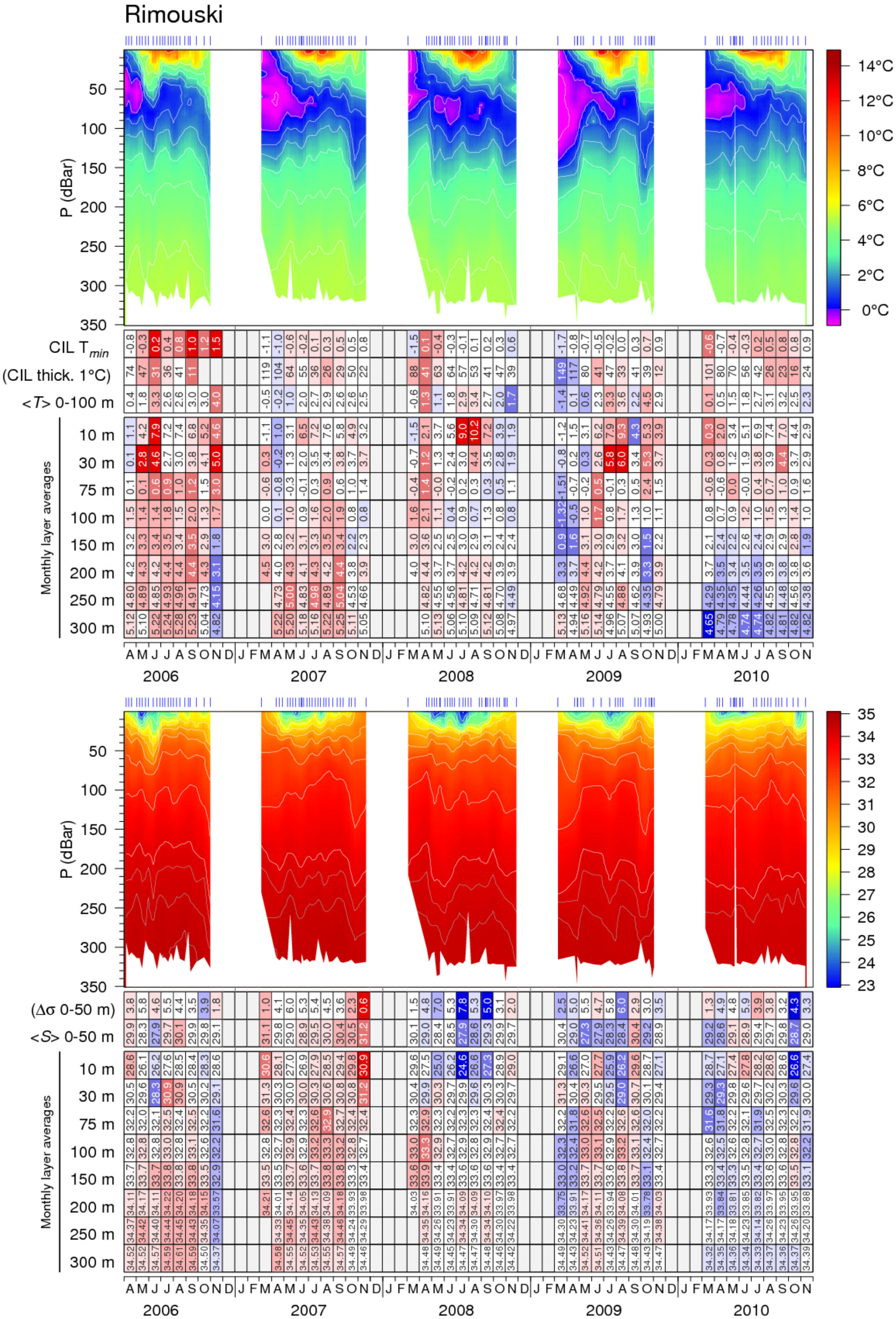

Fig. 44. Isotherm (top) and isohaline (bottom) time series at the Rimouski station; tick marks above indicate sample dates. The scorecard tables are monthly layer averages colour-coded according to the anomaly relative to the 1993–2010 monthly climatology for the station (yearly climatology for 250 m and deeper).

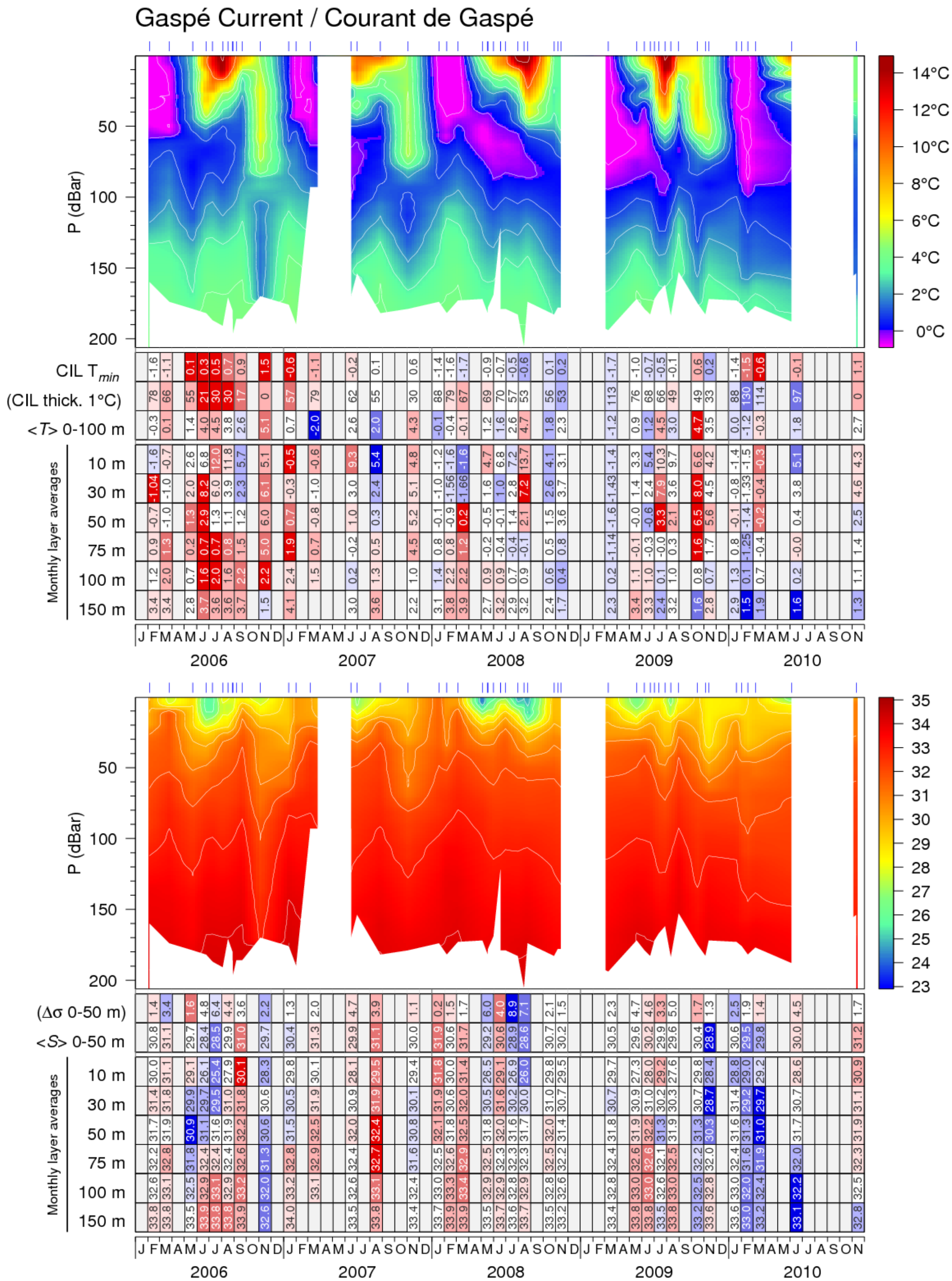

Fig. 45. Isotherm (top) and isohaline (bottom) time series at the Gaspé Current station; tick marks above indicate sample dates. Scorecard tables are monthly layer averages colour-coded according to the anomaly relative to the 1996–2010 monthly climatology for the station.

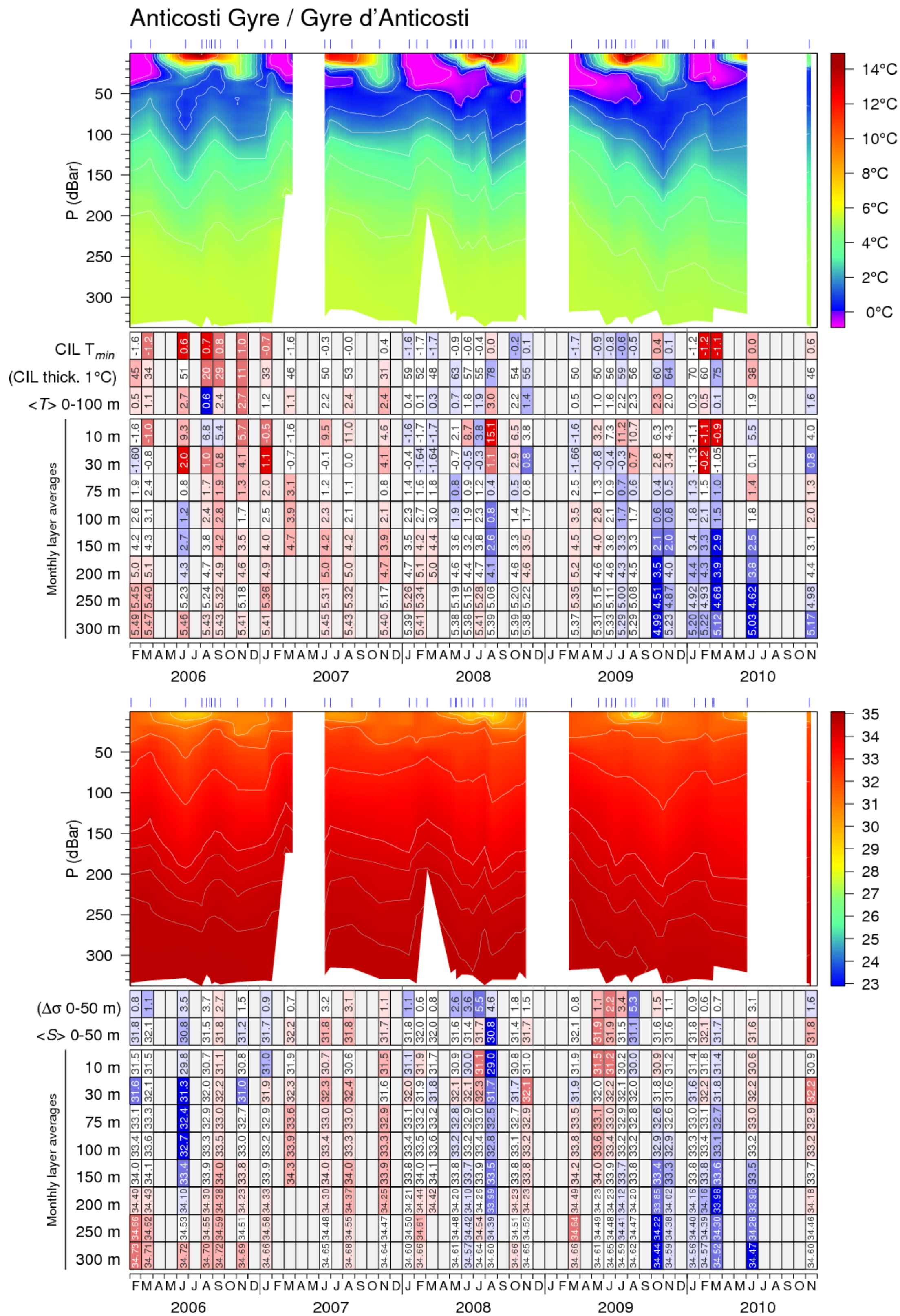

Fig. 46. Isotherm (top) and isohaline (bottom) time series at the Anticosti Gyre station; tick marks above indicate sample dates. Scorecard tables are monthly layer averages colour-coded according to the anomaly relative to the 1996–2010 monthly climatology for the station (yearly climatology for 250 m and deeper).

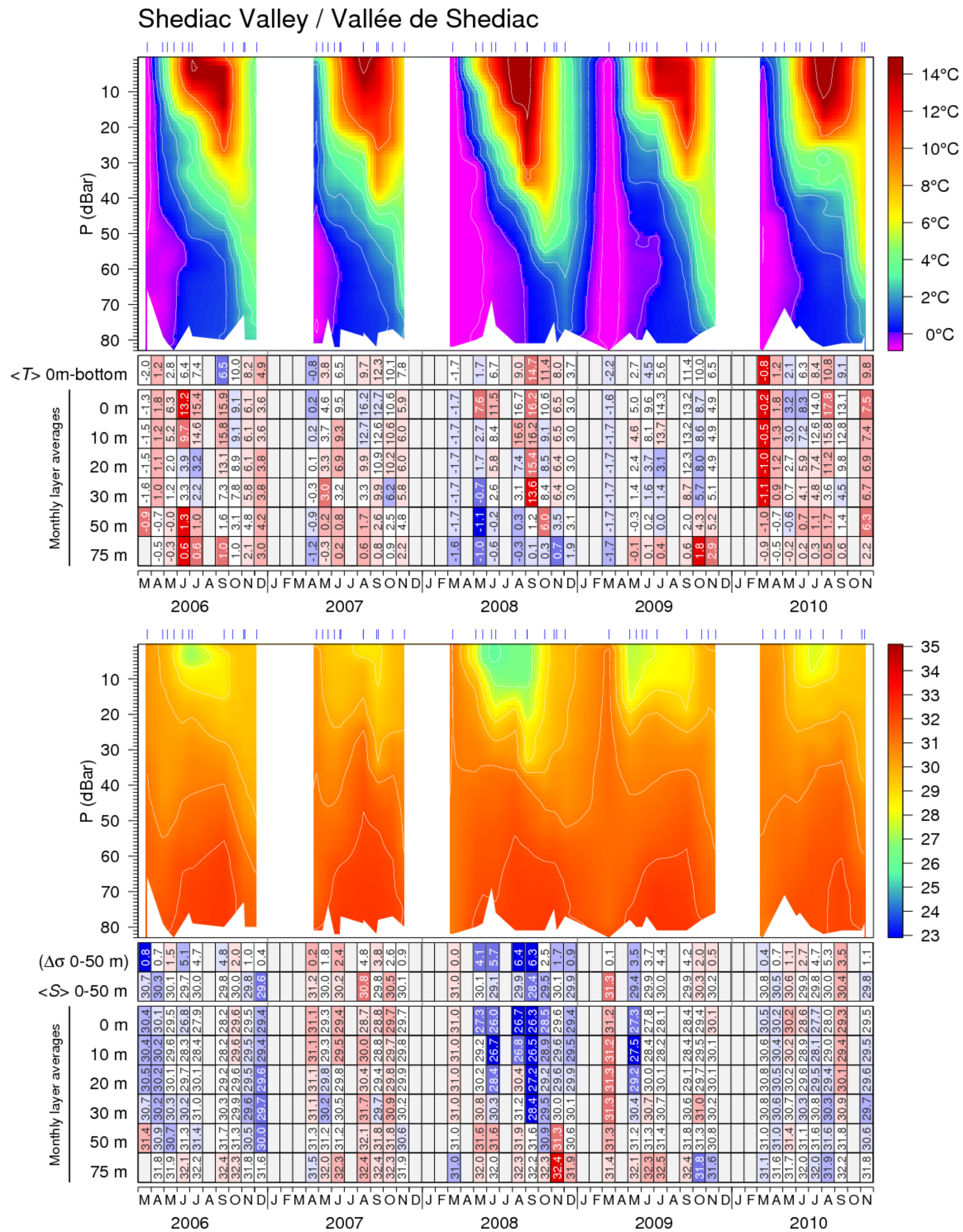

Fig. 47. Isotherm (top) and isohaline (bottom) time series at the Shediac Valley station; tick marks above indicate sample dates. Scorecard tables are monthly layer averages colour-coded according to the anomaly relative to the 1971–2010 monthly climatology for the station.

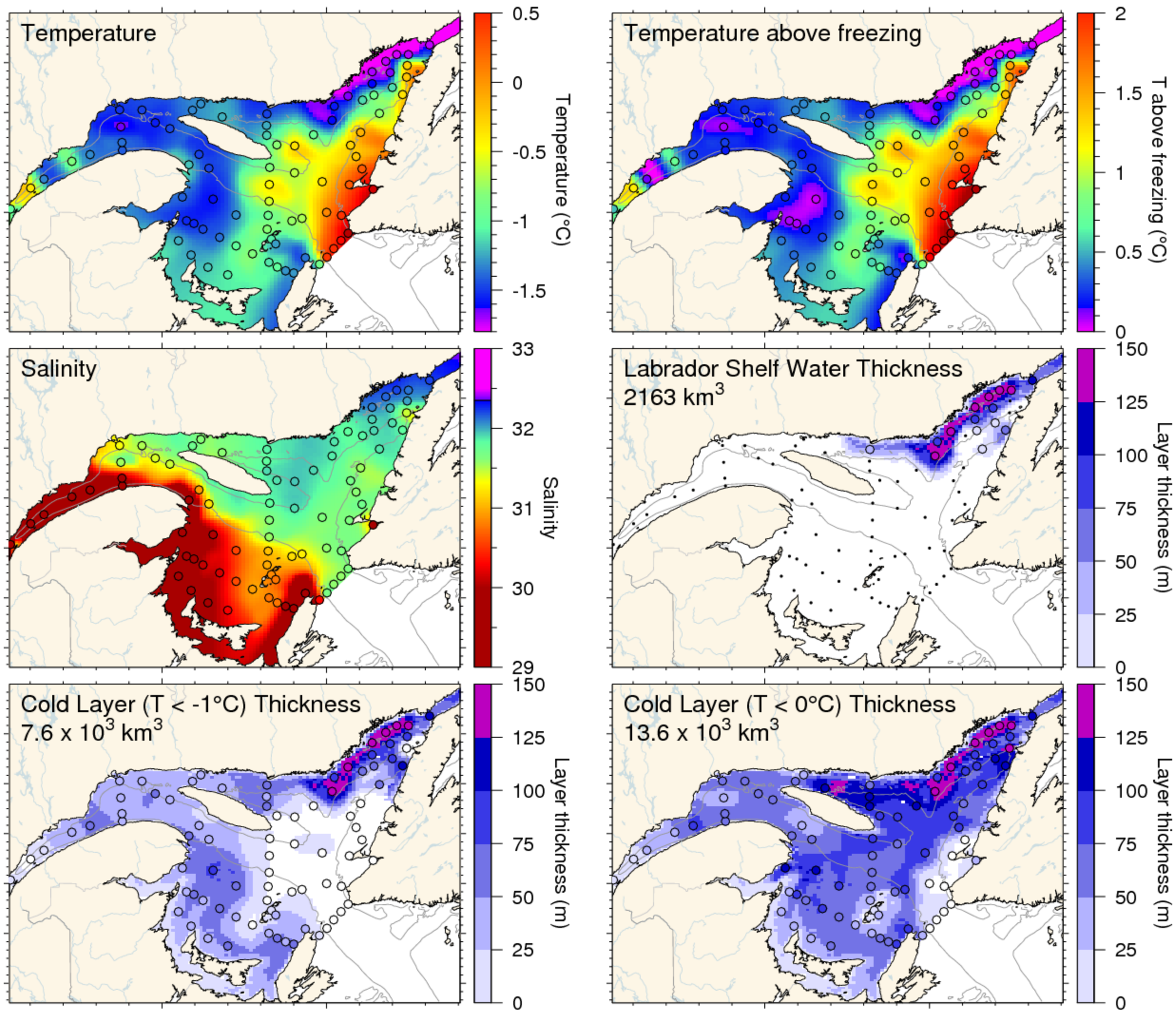

Fig. 48. March 2011 surface cold layer characteristics: surface water temperature (upper left), temperature difference with the freezing point (upper right), salinity (middle left), estimate of the thickness of the Labrador Shelf water intrusion (middle right), and cold layer (T < -1°C and < 0°C) thicknesses (lower left and right). 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.