

Physical Oceanographic Conditions in the Gulf of St. Lawrence during 2025

Peter S. Galbraith, Joël Chassé, Jean-Luc Shaw, Denis Lefaivre,
Marie-Noëlle Bourassa

Fisheries and Oceans Canada
Québec Region
Maurice Lamontagne Institute
P.O. Box 1000
Mont-Joli, QC
G5H 3Z4

2026

**Canadian Technical Report of
Hydrography and Ocean Sciences 418**

Canadian Technical Report of Hydrography and Ocean Sciences

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By

Peter S. Galbraith¹, Joël Chassé², Jean-Luc Shaw¹, Denis Lefaivre¹, Marie-Noëlle
Bourassa¹

¹Fisheries and Oceans Canada
Québec Region
Maurice Lamontagne Institute
P.O. Box 1000
Mont-Joli, QC
G5H 3Z4

²Fisheries and Oceans Canada
Gulf Fisheries Centre
P.O. Box 5030
Moncton, NB
E1C 9B6

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Cat. No. Fs 97-18/418E-PDF ISBN 978-0-660-99618-9 ISSN 1488-5417

<https://doi.org/10.60825/a1qy-zx55>

Correct citation for this publication:

Galbraith, P.S., Chassé, J., Shaw, J.-L., Lefaivre, D., and Bourassa, M.-N. 2026. Physical Oceanographic Conditions in the Gulf of St. Lawrence during 2025. Can. Tech. Rep. Hydrogr. Ocean Sci. 418: v + 94 p. <https://doi.org/10.60825/a1qy-zx55>

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ABSTRACT

Galbraith, P.S., Chassé, J., Shaw, J.-L., Lefaivre, D., and Bourassa, M.-N. 2026. Physical Oceanographic Conditions in the Gulf of St. Lawrence during 2025. Can. Tech. Rep. Hydrogr. Ocean Sci. 418: v + 94 p. <https://doi.org/10.60825/a1qy-zx55>

This overview of physical oceanographic conditions in the Gulf of St. Lawrence in 2025 is an outcome of the Atlantic Zone Monitoring Program. The seasonal maximum ice volume and area both ranked 6th lowest of records that begin in 1969. The August cold intermediate layer average minimum temperature was the sixth highest since 1985. The seasonal average May-November SST for the whole of the Gulf was above normal for the fifth consecutive year, albeit not as high of an anomaly as the four previous years. The average water temperature at 300 m increased overall in the Gulf from 2009 to a record-high in 2022, with inward advection from Cabot Strait, but has decreased every year since. This cooling has not yet reached the Estuary where temperature reached another record high. Temperatures at 300 m have increased since 2024 in Cabot Strait, Laurentian Hermitage and Mouth, indicating a possible stop to the cooling trend at that depth.

RÉSUMÉ

Galbraith, P.S., Chassé, J., Shaw, J.-L., Lefaivre, D., and Bourassa, M.-N. 2026. Physical Oceanographic Conditions in the Gulf of St. Lawrence during 2025. Can. Tech. Rep. Hydrogr. Ocean Sci. 418: v + 94 p. <https://doi.org/10.60825/a1qy-zx55>

Cet aperçu des conditions océanographiques physiques présentes dans le golfe du Saint-Laurent en 2025 est issu du Programme de monitoring de la zone atlantique. La superficie et le volume maximal saisonnier de glace de mer se sont tous deux classés au 6^e rang des valeurs les plus faibles enregistrées depuis 1969. La température minimale moyenne de la couche intermédiaire froide en août était la 6^e plus élevée depuis 1985. La température de surface moyenne de mai à novembre du golfe était supérieure à la normale pour la cinquième année consécutive, bien que l'anomalie soit moins marquée que lors des quatre années précédentes. La température moyenne des eaux à 300 m a globalement augmenté dans le golfe de 2009 jusqu'à un niveau record en 2022, sous l'effet de l'advection provenant du détroit de Cabot, mais a diminué chaque année depuis. Ce refroidissement n'a pas encore atteint l'estuaire, où la température a de nouveau atteint un niveau record. Les températures à 300 m ont augmenté depuis 2024 dans le détroit de Cabot, Hermitage et l'embouchure du chenal Laurentien, ce qui indique un possible arrêt du refroidissement à cette profondeur.

1. INTRODUCTION

This document presents the physical oceanographic conditions and related atmospheric forcing in the Gulf of St. Lawrence in 2025 (Fig. 1). It complements similar reviews of the environmental conditions on the Newfoundland and Labrador Shelf and the Scotian Shelf and Gulf of Maine as part of the Department of Fisheries and Oceans' (DFO) Atlantic Zone Monitoring Program (AZMP; see Therriault et al. 1998 for background information on the program, as well as Coyne et al. 2025 and Layton et al. 2025 for examples of past reviews of physical conditions in other AZMP regions, and Blais et al. 2025 for chemical and biological oceanographic conditions in the Estuary and Gulf of St. Lawrence) in support of the zonal state of the ocean report (e.g. Galbraith et al. 2025a). The last detailed report of physical oceanographic conditions in the Gulf of St. Lawrence was produced for the year 2024 (Galbraith et al. 2025b). These AZMP reports serve as an important source of information for the State of Canada's Oceans reports.

Some of the variables presented are spatially averaged over distinct regions of the Gulf (Fig. 2) into what will be termed "regional averages", developed for the ecosystem approach to fisheries management (EAFM). This report uses data obtained from the AZMP, other DFO surveys, and from Environment and Climate Change Canada (ECCC) for sea ice and air temperature data. Environmental variables are usually expressed as anomalies, i.e., deviations from their long-term mean. The long-term mean (or normal conditions) is calculated for the World Meteorological Organization (WMO) standard 1991–2020 reference period when possible. Furthermore, because these series have different units ($^{\circ}\text{C}$, m^3 , m^2 , etc.), each anomaly time series is normalized by dividing by its standard deviation (SD), also calculated for the same reference period. This allows a more direct comparison of the various series. Missing data are represented by grey cells in the tables, values within ± 0.5 SD of the average are considered to be near normal and are shown 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 is shown as red, but does not necessarily correspond to warmer-than-normal conditions. Salinity values are shown as practical salinity (PSU) but written without units throughout the text and figures.

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 early to mid-August (Galbraith et al. 2012). Gradual cooling occurs thereafter, and wind forced mixing during the fall leads to a progressively deeper and cooler mixed layer, eventually encompassing the CIL. During fall and winter, the surface layer thickens partly because of buoyancy losses (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, but may reach > 150 m in places such as the Mécatina Trough where near freezing waters (-1.8 to 0°C) from the Labrador shelf entering through the Strait of Belle Isle may extend from the surface to the bottom in depths > 200 m (Galbraith 2006). During spring, surface warming, sea-ice melt waters, and continental runoff produce a lower-salinity and higher-temperature surface layer. Underneath this surface layer, cold waters from the previous winter are partly isolated from the atmosphere and form the summer CIL. This layer will persist until

the next winter, gradually warming up and deepening during summer (Gilbert and Pettigrew 1997; Cyr et al. 2011).

This report considers air temperature and freshwater runoff, both significant drivers of the sea surface temperature and salinity, which are discussed next. Winter sea ice conditions and the winter mixed layer are then presented. The latter is the precursor to the summer CIL, which affects bottom temperatures on the Magdalen Shallows. The deeper waters, mostly isolated from exchanges with the surface, are then presented along with a summary of major oceanographic surveys, modelling results on currents and transports, and details of observations at high frequency sampling stations.

2. AIR TEMPERATURE

Air temperatures up to and including 2024 come from the fourth generation of homogenized surface air temperature data set, which is part of the Adjusted and Homogenized Canadian Climate Data (AHCCD), and accounts for shifts due to the relocation of stations, changes in observing practices, and automation (Wan et al. 2025). In last year's report, the third generation product was used (Vincent et al., 2020) and long term trends have changed due to different choices made to join multiple stations at long term locations such as Charlottetown and Mont-Joli/Pointe aux Pères. Because the AHCCD extends to the end of 2024, air temperature data for 2025 were extracted from Environment Canada's National Climate Data and Information Archive (NCDIA). Differences between the two data sets for the last year are typically found to be minor when AHCCD is updated.

The monthly air temperature and anomalies for several stations around the Gulf are shown in Fig. 4 for 2024 and 2025, as well as the average of anomalies at all stations. There were no monthly records set at any stations around the Gulf in 2025, however Natashquan saw its warmest January since 1958. Fig. 5 shows the annual, winter (December-March), and April-November mean air temperature anomalies averaged over all available stations shown in Fig. 4 since 1873. Record-high annual and winter temperatures occurred in 2010 and 2024 holds the record-high April-November average temperature. Using the third generation of the AHCCD, we previously reported an annual warming trend of 1.6 °C per century that was uneven through seasons, with winters warming almost twice as quickly as the rest of the year (2.3 °C per century versus 1.3 °C per century). New results show a slightly more rapid annual warming rate of 1.9 °C per century, with April-November and winter rates closer together at respectively 1.8 and 2.1 °C per century. These new trends were calculated over a period that starts in 1893 when coverage of reporting stations reached one third.

The average April-November air temperature at weather stations surrounding the Gulf but excluding the estuary has been identified to be a good proxy for May-November sea-surface temperature over the Gulf (Galbraith et al. 2012, 2021; see also Fig. 27 below). An updated comparison using data shown in this report finds high correlation ($R^2 = 0.81$, 1982-2025; see below) and a warming trend of the sea-surface temperature proxy of 1.5 °C per century between 1893 and 2025. December-February and December-March air temperatures in the Gulf were found to be highly correlated with sea-ice properties ($R^2 = 0.72$, 1969-2012, Galbraith et al. 2013; $R^2 = 0.75$ to 0.86; 1969-2024, Galbraith et al. 2024). Correlations using time series used here are equally high ($R^2 = 0.77$ to 0.83; 1969-2025).

The December-March air temperature average was above normal (+1.6 °C, +1.1 SD; Fig. 4, All stations panel). The 2025 April-November and annual averages were slightly above normal (+0.5 °C, +0.5 SD and 0.7 °C, +0.8 SD).

3. PRECIPITATION AND FRESHWATER RUNOFF

A freshwater runoff hindcast for the St. Lawrence River is updated using the model and methods described in Lefaiivre et al. (2016). Observations of water levels at the Saint-Joseph-de-la-Rive station were used at the downstream boundary of the model. The runoff at the upstream boundary of the model was calculated using the stage-discharge relationships at the outlets of Lake Deux-Montagnes and Lake Saint-Louis. In addition, a correction was made to minimize the difference between modeled and observed water levels at the Varennes station; this station is directly influenced by the outflow from both lakes and allows the validation of the upstream flow of the St. Lawrence River. The runoff at Québec City is extracted from the model at 3-minute intervals, filtered to remove the tidal signal and sub-sampled at noon local time (EST) every day (Fig. 6). The dataset is available [online](#) (Fisheries and Oceans Canada, 2023). To combine it with runoffs downstream and recreate the runoff that feeds the Estuary, the time series is then lagged by 21 days to approximate the time taken to reach the Estuary at the height of the Saguenay mouth¹, and new monthly means are computed (Fig. 7, middle curve).

A hydrological watershed model was used to estimate the monthly runoff since 1948 for all other major rivers flowing into the Gulf of St. Lawrence, with discharge locations as shown in Fig. 8.; see Lambert et al. 2013 and Lavoie et al 2017 for details. The waters that flow into the Estuary (Fig. 8) were added to the lagged St. Lawrence River runoff (above) to produce the RIVSUM II index (Fig. 7, upper curve).

Monthly anomalies of the summed runoffs for 2024 and 2025 are shown in Fig. 9. Rivers other than the St. Lawrence contribute about $5\,000\text{ m}^3\text{ s}^{-1}$ runoff to the Estuary, the equivalent of 40% of the St. Lawrence River, while the other tributaries distributed along the border of the Gulf provide an additional $4\,000\text{ m}^3\text{ s}^{-1}$ in freshwater runoff to the system. River regulation has a strong impact on the relative contributions of sources. For example, in May 2024 the higher-than-average river runoff into the Estuary (an effect of the previous high precipitation and river regulation) compensated low runoff of the St. Lawrence River to yield a near normal RIVSUM II. The long-term time series are shown, summed by large basins, in Fig. 10. The annual average runoff of the St. Lawrence River at Québec City and RIVSUM II both show a general downward trend from the mid-1970s until 2001, an upwards trend between 2001 and 2009 followed by a decrease then another stronger upwards trend between 2012 and 2019 (Fig. 10). Years since have been variable. In 2025, the annual runoff was near normal at $11\,900\text{ m}^3\text{ s}^{-1}$ (-0.4 SD) for the St. Lawrence River and below normal at $16\,700\text{ m}^3\text{ s}^{-1}$ (-0.7 SD) for the RIVSUM II index.

4. SEA SURFACE TEMPERATURE AND SALINITY

The seasonal cycle of weekly averaged sea surface temperature (SST) over the Gulf of St. Lawrence is illustrated in Fig. 11 using data streams that are described below. Galbraith et al. (2012) have shown that Gulf-averaged monthly air temperature and SST climatologies match up

¹ Senneville and Lefaiivre 2010, unpublished manuscript

quite well with SST lagging air temperature by half a month, and this is shown to remain true with climatologies updated to 1991–2020 and using a different SST dataset in Fig. 11. The climatological maximum sea-surface temperatures are reached during the first and second week of August but that can vary by a few weeks from year to year. The maximum surface temperature averages to 16.5°C over the Gulf from the fourth week of July to the third week of August (1991–2020), but there are spatial differences: temperatures in the Northumberland Strait region are the warmest in the Gulf, averaging 19.5 °C over that area for the first week of August, and the coolest are at the head of the Laurentian Channel in the St. Lawrence Estuary (7.0 °C) and in upwelling areas along the north shore. The annual observations will be explored below. This section will first present data from three data sources for sea surface temperature and salinity and will then present an integrated assessment of SST in 2025 along with a marine heatwave analysis.

4.1 SHIPBOARD THERMOSALINOGRAPH

The surface layer temperature and salinity conditions of the Gulf are monitored by various complementary methods. The first is the shipboard thermosalinograph network (Galbraith et al. 2002), which consists of temperature-salinity sensors (SBE-21; Sea-Bird Electronics Inc., Bellevue, WA) that have been installed on various ships starting with the commercial ship Cicero of Oceanex Inc. in 1999 (retired in 2006) and on the (Oceanex) Cabot from 2006 to fall 2013. The (Oceanex) Connaigra, was outfitted with a thermosalinograph in early 2015. Fig. 12 shows a mean annual cycle of water temperature at a depth of 8 m along the Montréal to St. John's shipping route based on thermosalinograph data collected from 2000 to 2020. The data were averaged for each day of the year at intervals of 0.1 degrees of longitude to create a climatological composite along the ship track. The most striking climatological feature is the area at the head of the Laurentian Channel (69.5°W), where strong vertical mixing leads to cold summer water temperatures (around 5 °C to 6 °C and sometimes lower) and winter temperatures that are always above freezing (see also Fig. 11). The climatological cycle shows the progression to winter conditions, first reaching near-freezing temperatures in the Estuary and then progressing eastward with time, usually reaching Cabot Strait by the end of the winter (but no further). Data acquisition for 2025 was briefly interrupted in April and stopped in early November when the ship went into refit.

4.2 THERMOGRAPH NETWORK

The second data source is the Maurice Lamontagne Institute thermograph network (Pettigrew et al. 2016, 2017), which consists of a number of stations with moored instruments recording water temperature every 5 to 30 minutes (Fig. 13). Most instruments are installed on Coast Guard buoys that are deployed in the ice-free season, but a few stations are monitored year-round. The data are typically only available after the instruments are recovered except for oceanographic buoys that transmit data in real-time.

Thermograph network observations are examined as anomalies relative to daily average temperatures (or salinities) calculated using all available years of data for each day of the year at each station and depth (Fig. 14 to Fig. 17). The seasonal cycle of near-surface temperature is measured by shallow instruments, while the cold intermediate layer warming from spring to fall is captured by instruments moored between 30 m and 120 m depth. Monthly averages are also shown, with the magnitude of their anomaly colour-coded.

The Saguenay Sill 1 station is located just inside the first sill connecting the Saguenay Fjord to the St. Lawrence Estuary. The salinity of the water (hence its density) determines the type of circulation that renews basin waters. These time series extend those first presented in Belzile et al. (2016) and Galbraith et al. (2018). A second mooring was deployed just inside the inner and deepest basin of the Fjord (Saguenay Sill 3). The sharp changes in temperature (Fig. 14) as well as the increases in salinity in late January 2025 (Fig. 17) correspond to deep renewal events. The slow decrease of salinity after sudden increases is indicative of vertical mixing occurring in the deep basin, which reduces water density and preconditions the fjord to subsequent deep renewal events.

The Île Shag (10 m) station shows bottom temperatures close to Îles-de-la-Madeleine that are important to the lobster fishery. Temperatures were normal to above normal at this station in 2025, including a strong marine heatwave in March (Fig. 16). The Île Shag panel shows with a red line spanning historical dates when spring temperature last increased over 1.5 °C at 10 m, a temperature associated with increased lobster mobility, as well as the mean date (April 25th) plus and minus 0.5 SD (5 days). In 2025, this crossing occurred early, on April 17th. After the 1.5 °C threshold is reached at 10m, it can take up to two additional weeks for warming to extend to 30 m, the depth at which lobsters are typically found at the start of the fishing season in this area.

4.3 SST FROM SATELLITE REMOTE SENSING BLEND

The satellite-based sea surface temperature product blends data from Pathfinder version 5.3 (4 km resolution for 1982–2020; Casey et al. 2010), Maurice Lamontagne Institute (MLI; 1.1 km resolution for 1985–2013; Larouche & Galbraith 2016) with the NOAA STAR CoastWatch Advanced Clear-Sky Processor for Ocean (ACSPO) L3S-LEO-Daily “super-collated” v2.81 product (0.02 degree resolution for 2000 to current; Jonasson et al 2022). See Galbraith et al. (2024) for a full description of the processing and calibration against our thermograph network. Calibration cools the NOAA/LEO daily composite values by 0.24 °C at 0 °C and by 0.02 °C at 20 °C.

We also examined trends on calibration coefficients, comparing calibrated satellite data to thermograph data for each year (Fig. 18). We unfortunately found a bug in the code that generated this figure in last year’s report that mostly changed the sign of the differences (regressions were reversed). We had reported a trend in the MLI data where it reads too warm from 1994 to 2002, and too cool from 2008 to 2013. In actuality, readings at 0 °C tend to always be too warm with a slight trend, readings at 10 °C were too cold between 1994 and 2000 and too warm starting in 2003, and readings at 20 °C are too cold until 2002 and variable afterwards. L3S-LEO-Daily SST remote sensing data for 2025 were very close to thermograph observations, ranging from 0.11 °C too cool at 5 °C to no difference at 20 °C. Comparisons to offshore thermograph and buoy surface temperatures indicates that satellite data were, on average, colder than observations by 0.09 °C at 0 °C and warmer by 0.03 °C at 20 °C (Fig. 18). 73% of satellite observations were within the daily diurnal range of thermograph station observations.

Monthly mean sea-surface temperatures from satellite imagery are presented as maps (Fig. 19), temperature anomaly maps against the 1991–2020 climatology (Fig. 20), and spatial averages and anomalies (Fig. 21 and Fig. 22). Sea-surface temperature and anomaly time series were also computed for more specific regions of the Gulf. The region of the Magdalen Shallows,

excluding Northumberland Strait, is divided into western and eastern areas as shown in Fig. 23. We also include the monthly time series since 1982 for Gulf regions (Fig. 24 and Fig. 25).

Seasonal trends in relation to air temperature are examined by first displaying weekly averaged satellite SST in the Gulf for all years between 1982 and 2025 (Fig. 26) with years on the x-axis and weeks of the year on the y-axis (See Galbraith and Larouche 2013 for a full description). Isotherms show the first and last occurrences of temperature averages of 12 °C over the years, chosen to be representative of spring (and fall) transitions to (and from) typical summer temperatures. Although the selected temperature is arbitrary, the results that follow are not particularly sensitive to the exact temperature chosen because the surface mixed layer tends to warm and cool linearly in spring and fall (e.g., Fig. 11) and a 10 °C threshold is also used to demonstrate this. However, in some recent years sudden surface fall cooling has occurred from post-tropical storms mixing the water column, introducing more variability. The interannual variability in the time of year when the 12 °C threshold is cross-correlated with June-July average air temperature for the summer onset (0.8 weeks sooner per 1 °C increase; $R^2 = 0.61$) and with September average air temperature for the fall (0.8 weeks later per 1 °C increase; $R^2 = 0.60$). These air temperature averages, shown in Fig. 26, can be used as proxies prior to 1982 and for climate change predictions. The implication is that the duration of the Gulf of St. Lawrence warm season has increased and will increase by about 1.6 weeks for each 1 °C of seasonal warming (e.g., associated with anthropogenic climate change).

As noted above in the air temperature section, average April-November air temperature at weather stations surrounding the Gulf but excluding the estuary has been identified to be a good proxy for May-November sea-surface temperature over the Gulf (Galbraith et al. 2012, 2021). Fig. 27 shows an updated comparison using air temperature anomalies from the 10 meteorological stations located in the Gulf (map of Fig. 4). The SST and air temperature proxy are highly correlated ($R^2 = 0.81$, 1982-2025). The warming trend of the combined proxy and SST time series for the period of 1893-2025 (when meteorological station coverage begins to exceed $\frac{1}{3}$) is 1.5 °C per 100 years. The proxy is still shown prior to 1893 but is not considered to be as reliable.

4.4 SEA SURFACE TEMPERATURE IN 2025

Thermosalinograph data show well above average temperatures in the latter half of November 2024, remaining generally above normal into winter 2025, with near-freezing surface layer conditions first appearing later than normal, driving late onset of sea ice, and of its last occurrence earlier than normal in the spring (Fig. 12). Temperature anomalies within the Gulf varied between below normal to normal in May as well as in mid-July to mid-August, and normal to above normal at other times, reaching values of +4.5 °C in September and +3.8 °C in late October.

The summer pattern of sea surface temperature observed by remote sensing data (Fig. 20 and Fig. 21) shows most regions experiencing normal to above normal temperatures except for persistent coastal cold anomalies along the north shore of the Gulf in August, presumably caused by wind-driven upwelling. Warming to summer temperatures (Fig. 21 and Fig. 26) occurred slightly earlier than normal to 10 °C but at a near normal date to 12 °C. The Gulf slightly above-normal weekly maximum was reached in mid-August (Fig. 21) but that month's average was normal (16.3 °C, Fig. 22) because of a negative anomalies at the beginning of the month (Fig. 21). Fall cooling below 12 °C occurred later than normal by 1.1 week and was 2.5

weeks late to 10 °C, second latest of the time series (Fig. 26). Fall cooling to to 10 °C has been very late for the last 5 years (Fig. 26).

The seasonal May-November average was above normal in all regions, but no records were set (Fig. 21). For the Gulf, the May-November average was also above normal (10.9 °C, +0.8 °C, +1.5 SD). It is the fifth consecutive above-normal year, albeit not as high of an anomaly as the four previous years (Fig. 25 and Fig. 27).

4.5 MARINE HEATWAVES

Marine heatwaves (MHWs) are defined as prolonged discrete anomalously warm water events or, quantitatively, by temperatures exceeding the 90th percentile of temperatures for that day of year during at least 5 consecutive days (Hobday et al., 2016; Oliver et al., 2021). Because of the existence of the widespread thermograph network in the Estuary and Gulf and the fact that the data are gap-free, marine heatwaves are analyzed here using these data rather than satellite based SST. However, similar analyses are also done based on regionally averaged satellite SST, with results used to complement discussion of events outside the temporal coverage of thermograph network data. It is recommended that the 90th percentile thresholds be calculated over a full 30 year climatology, but similar results can be obtained using as few as 10 years (Schlegel et al., 2019). Here, the standard 30 year reference period of 1991-2020 is applied on all thermograph time series of 15 years or longer with some time series starting as late as 2005 (without data during the first half of the climatological period). MHW metrics obtained for time series using the 1991-2020 and 2005-2020 reference periods are similar (not shown), which suggests that having temporal coverage of differing lengths during the reference period does not introduce a bias between metrics calculated for different stations.

MHWs are commonly discussed in terms of intensity (I), i.e., the difference between temperature and the daily climatology. Single events are then summarized using four standard metrics: duration (D), average intensity (I_{mean}), maximum intensity (I_{max}), and integrated intensity (I_{cum}). These metrics were calculated for thermograph time series using the implementation of Hobday et al. (2016) written by Eric Oliver. Following Hobday et al. (2018), MHWs with I_{max} values greater than 1, 2, 3, and 4 times the difference between the 90th percentile and the climatology are respectively referred to as moderate, strong, severe and extreme events. Strong, severe and extreme MHWs occurred in respectively 0.8%, 0.2% and 0.05% of our data. Most of the thermograph data have higher variability in summer and lower variability in winter, which results in a seasonal bias: summer and winter moderate thresholds correspond to different intensity values. To facilitate comparison of events during different seasons, we therefore calculate c , the intensity normalized by the difference between the 90th percentile and the climatology, and the corresponding standard event metrics. This normalized intensity is a continuous equivalent to the Hobday et al. (2018) category system. Event metrics for individual years are then further aggregated into the annual metrics shown in Fig. 28 (sum of durations, ΣD ; annual maximum intensity, $\hat{c}_{\text{max}}$; annually integrated intensity, Σc_{cum} ; and the MHW event count) where temperature anomalies from all thermograph stations within each region of the Gulf are averaged.

Strong MHW events were detected in four regions of the Gulf during 2025, i.e., the Estuary, Northeast Gulf, Magdalen Shallows, and Mécatina and Belle Isle (Fig. 28). The Σc_{cum} metric

emphasizes, however, that more intensity was cumulated in the Magdalen Shallows than elsewhere.

In the Estuary, two short events (6 and 8 days) briefly peaked at strong intensity values in June and September. The strong event in the Northeast Gulf was observed in October, and occurred at strong intensity when the moorings were recovered. Analysis of the Satellite SST time series shows that this MHW continued to grow in intensity for six days after the recovery of the moored instruments, returning to temperatures just above the moderate threshold by mid-November, and ended on December 1st. Similarly, the strong event in the Mécatina and Belle Isle region started in October and instruments were recovered during its occurrence. This event was detected as moderate and peaked two days after the end of moored data collection, as seen using satellite SST data. The duration and cumulative intensity are underestimated by the thermograph network data for this region, but the peak values should be well represented.

The most intense MHW activity of 2025 was observed in the Magdalen Shallows region, where five strong events were detected. The most notable are the winter event which peaked in March, the end of summer events (spanning together from August 11 to September 20 with a 4-day interruption in between), and the Fall event which was the most intense in the Gulf during 2025 ($C_{\max} = 2.8$).

In summary, 2025 was characterized by the absence of severe and extreme events having regions with no MHW detections. The many metrics near or below their long-term average stand in contrast with the 2020 to 2024 period (Fig. 28), describing a year of comparatively weak MHW activity.

5. SEA ICE

Ice cover area, duration and volume are estimated from ice cover products obtained from the Canadian Ice Service (CIS), then converted into regular grids that are used in analyses as detailed in Galbraith et al. (2024). These are weekly Geographic Information System (GIS) charts covering the period 1969–2025 and daily charts covering the period 2009–2025. All charts were gridded on a 0.01° latitude by 0.015° longitude grid (approximately 1 km resolution). Thickness (and therefore volume) are estimated from stages of ice growth from new ice (stage 1, <10 cm: 5 cm), nilas (stage 2, <10 cm): 5 cm), gray ice (stage 4, 10–15 cm: 12.5 cm), gray-white ice (stage 5, 15–30 cm: 22.5 cm), thin first-year ice (stage 7, 30–70 cm: 50 cm), medium first-year ice (stage 1·, 70–120 cm: 95 cm) and thick first-year ice (stage 4·, >120 cm: 160 cm). Prior to 1983, the CIS reported ice categories into fewer classifications using a single category of first year ice (≥ 30 cm) with a suggested average thickness of 65 cm. We have found this value to lead to underestimates of the seasonal maximum thickness and volume based on high interannual correlations obtained between the estimated volume and area of the weekly seasonal maximums. The comparison pre- and post-1983 provided an estimate of 85 cm in the Gulf of St. Lawrence and of 95 cm on the Newfoundland and Labrador Shelf. To avoid a spatial discontinuity and preferring slightly underestimating ice volume in the northeast Gulf rather than over-estimating it everywhere else, we choose to set it at 85 cm.

Several products were computed to describe the sea-ice cover interannual variability: day of first and last occurrence and duration maps (Fig. 29) and regional extreme values (Fig. 30); distribution of ice thickness during the week of maximum estimated volume (Fig. 31, four upper

panels) and maximum thickness reached at any week during the season (Fig. 31, lower panels); daily evolution of the estimated sea-ice volume and area in relation to the climatology and historical extremes (Fig. 32); estimated seasonal maximum ice volumes within the Gulf as well as on the Scotian Shelf (Fig. 33); time series of seasonal maximum ice volume, area (excluding thin new ice) and ice season duration in relation with December-to-March air temperature anomaly (Fig. 34). The durations shown in Fig. 30 and Fig. 34 are different products. The first corresponds to the number of weeks where the volume of ice anywhere within the region exceeded 5% of the climatological maximum, while the second is the average duration at every pixel of Fig. 29, which is much shorter than the first.

Ice typically forms first in December on the coast of the St. Lawrence Estuary (in the recent 1991–2020 climatology versus the entire estuary in the previous 1981–2010 climatology) and in shallow waters along New Brunswick, Prince Edward Island and the north shore of the Gulf, and melts last in the northeast Gulf where the ice season duration tends to be longest apart from shallow bays elsewhere (Fig. 29). Offshore 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. Sea ice found past Cabot Strait generally formed in Gulf and has drifted there.

In 2025, the sea-ice cover formed several weeks later than usual in most areas, and did not form at all in a large area from the southern half of the west coast of Newfoundland out to Anticosti Island and Jacques Cartier Strait, and near Îles-de-la-Madeleine (Fig. 29). Last occurrence was earlier than normal (Fig. 29). Ice volume progressed well below normal, as did the area (Fig. 32) which peaked close to the arbitrary threshold for an “nearly ice-free winter” of one quarter of the Gulf area (see below).

There has been a declining trend in ice cover metrics since 1990 with rebounds in 2003 and 2014 (Fig. 34). The interannual variability includes years with complete ice cover and years with almost no ice, with high correlation between annual maximum ice volume (including the cover present on the Scotian Shelf) and the December-March air temperature anomaly from Fig. 5 ($R^2 = 0.77$, Fig. 34; See also Galbraith et al. 2024). The correlations between air temperature and ice season duration and maximum area are also very high ($R^2 = 0.82$ – 0.83). Sensitivity of the ice cover to air temperature increase (e.g., resulting from anthropogenic climate change) can be estimated using 1969–2025 co-variations between winter air temperature and sea-ice parameters, which indicate losses of 19 km³, 34 000 km² and 14 days of sea-ice season for each 1 °C increase in winter air temperature.

Prior to 2025, only six winters since 1873 had December-to-February (DJF) temperature anomalies of +2.8°C or more (the next was of +2.1°C), and December-to-March (DJFM) temperature anomalies greater than +2.3°C (the next was of +1.8°C), and they all coincide with the only winters that were nearly ice-free in the Gulf of St. Lawrence, defined as a maximum cover not exceeding the threshold of a quarter of the area covered by ice of stage 4 (gray ice of 10–15 cm in thickness) or greater (see Galbraith et al. 2024, but numbers updated here to the fourth generation of the homogenized surface air temperature data set). These winters are 1958, 1969, 2010, 2011, 2021 and 2024. The 2025 winter breaks this clear separation, whereby the DJF and DJFM temperature anomalies were of +1.7 and +1.6°C (Fig. 4), while the ice area remained just below the threshold. The 2025 maximum area (59 000 km²) and volume (15.7 km³) both rank 6th lowest since 1969, immediately following the winters listed above. Moving the “near ice-free” threshold from 25% to 21% coverage restores the separation of all warmest/lowest ice cover winters from the others.

Other sea ice metrics for 2025 were also below normal: the area-weighted ice season duration of 24 days (-1.5 SD; Fig. 34) ranked 6th lowest and the January-April average volume (reported in the AZMP zonal report) of 4.9 km³ (-1.3 SD; Fig. 33) ranked 4th lowest. In the 16-year span since 2010, 11 of the 16 lowest seasonal maximum ice volumes of the time series have occurred (Fig. 34). In 2025, 2.2 km³ (-0.6 SD) ice made it past Cabot Strait onto the Scotian Shelf (Fig. 31 to Fig. 33). The maximum area of ice past Cabot Strait was 10 000 km², the first near-normal value (-0.4 SD) since 2018 (not shown).

6. WINTER WATER MASSES

A wintertime survey of the Gulf of St. Lawrence waters (typically 0–200 m) has been undertaken in early March since 1996, typically using a Canadian Coast Guard helicopter but using Canadian Coast Guard ships in 2016 and 2017. The survey, sampling methods, and results of the cold-water volume analysis 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). Fig. 35 and Fig. 36 show gridded interpolations of near-surface temperature, temperature difference above freezing, salinity, cold layer thickness and bottom contacts, and thickness of the Labrador Shelf water intrusion (detailed below) for 2025 as well as climatological means.

The March surface mixed layer is usually very close (within 0.1 °C) to the freezing point in most regions of the Gulf but thickness of the surface layer varies, resulting in variability in the cold-water volume between mild and severe winters rather than in temperature. One exception was 2010 when, for the first time since the inception of the winter survey, 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 from the northeast side of Cabot Strait spreading into the Gulf. Some of these warm waters presumably enter the Gulf during winter and flow northward along the west coast of Newfoundland. However it is also possible that local waters could have simply not cooled close to freezing; this is likely to have been the case again in 2025. The mixed layer in March 2025 was near-freezing only in Baie des Chaleurs, around Prince Edward Island and south of Îles-de-la-Madeleine, parts of the northeast Gulf and Mécatina Trough (Fig. 35). These areas corresponded to those where sea ice was found at the peak cover a week earlier (Fig. 31). Elsewhere, most of the Gulf mixed layer was >0.7-0.9 °C above freezing with some areas up to >2 °C above freezing. Contrary to March 2024, the cold layer (T < 0 °C) did reach the sea floor at most stations on the Magdalen Shallows (Fig. 36).

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 green-blue in the salinity panel of Fig. 35 and are typically found to the north and east of Anticosti Island. Surface salinities were higher than the climatology in the northeast Gulf during the winter of 2025.

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 as an intrusion from the Labrador Shelf through the Strait of Belle Isle. These cold high-salinity waters were not present at the surface in March 2025 in Mécatina Trough (Fig. 35). However, Labrador Shelf waters can have lower salinity than this threshold. A second criterion based on temperature-salinity (T-S) signatures of water

(Galbraith 2006, revisited in Shaw & Galbraith 2023) is used to identify intruding Labrador Shelf waters that have exhibited no evidence of mixing with warm and saline deep Gulf water. For March 2025, the T-S criteria selects cold waters with salinity greater than approximately 32.1–32.2 as Labrador Shelf Waters.

This layer was partly subsurface and partly from the surface depending on location and reached the bottom at >200 m in Mécatina Trough (top-right panel of Fig. 36). The recent history of Labrador Shelf water intrusions is shown in Fig. 37, where its volume is shown as well as the fraction it represents of all the cold-water volume in the Gulf. See Shaw and Galbraith (2023) for a comparison to measured transports in the Strait of Belle Isle, updated in Fig. 37 (blue and red lines). This volume was near normal in March 2025 at 1340 km³, but represented an above normal 18% (+0.7 SD) of the cold water ($T < -1$ °C) in the Gulf. The volume lines up quite well with the integrated current observed at the mooring in the Strait of Belle Isle (blue line in Fig. 37). The near-bottom thermograph in the Strait of Belle Isle (Fig. 15) showed that water temperature increased above -1 °C slightly earlier than normal (-0.6 SD) on May 14th 2025, indicating the end of the inflow of cold Labrador Shelf Water. This is also shown by the sudden decrease in salinity at the same time (Fig. 17).

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 (Galbraith 2006). In March 2010 and 2011, much of the mixed layer was warmer than -1 °C such that the criterion of $T < 0$ °C was also introduced (see middle panels of Fig. 36). The cold surface layer is the product of local formation 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. This layer reaches the bottom in many regions of the Gulf, with interannual variability of the deepest parts of the Magdalen Shallows or of Mécatina Trough being reached (see bottom panels of Fig. 36). The thickness of the winter layer is usually greatest north and northeast of Anticosti Island, and the doming of the Anticosti Gyre isopycnals appears in the climatology as a thinner centre part. There is some interannual variability in the extent of the warm area centered on Port Aux Basques, expressed as thinning in the climatology. Again in 2025, the area that never reached near-freezing temperatures by the end of winter was very large in the southeast portion of the Gulf, with no waters of $T < -1$ °C even as far into the Gulf as Îles-de-la-Madeleine and Anticosti Island.

Integrating the cold layer (< -1 °C) depth over the area of the Gulf (excluding the Estuary and the Strait of Belle Isle) yields a below normal (-1.5 SD) volume of 7 600 km³ in 2025, about the same as in 2023. The interannual variability of winter volumes of water colder than 0 °C and 1 °C are shown in Fig. 38. The mixed layer volume increases to 13 800 km³ (-1.1 SD) when water temperatures < 0 °C are considered, similar to 2024 and about 400 km³ more than in 2023. This volume of cold water corresponds to 41% of the total water volume of the Gulf (33 500 km³, excluding the Estuary), compared to the 1996–2020 average of 44%.

7. COLD INTERMEDIATE LAYER

The summer cold intermediate layer (CIL) is a subsurface cold layer either formed locally or advected into the Gulf through the Strait of Belle Isle during the previous winter, and is typically defined by threshold temperatures that are sufficiently cold to make sure of that none of the water was locally formed more than one winter prior (e.g. 1 °C). The minimum temperature, also

called core temperature, varies spatially. The CIL tends to be thickest and coldest in the Northeast Gulf, as shown by 1991-2020 climatological maps in Fig. 39. Metrics of volume and average minimum temperature are calculated by snapshot surveys such as the northern Gulf August (Chamberland et al. 2025) and Southern Gulf September (Savoie et al. 2014) ecosystemic surveys. The Gilbert and Pettigrew (1997) CIL index is a seasonal average, defined as the mean of the CIL core temperatures observed between 1 May and 30 September of each year, adjusted to 15 July with a region-dependent warming rate.

7.1 FORECAST FROM THE MARCH 2025 SURVEY

The summer CIL minimum temperature index (Gilbert and Pettigrew 1997) has been found to be highly correlated with the Gulf (excluding the estuary) volume of cold water ($< -1^{\circ}\text{C}$) measured the previous March when much of the mixed layer is near-freezing (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 (Fig. 38, right panel). In the outlook for 2025 section of Galbraith et al. (2025b), we forecasted a seasonal CIL index between 0.12°C and 0.28°C similar to those of summer 2023 (0.24°C), based on volumes of water colder than -1 and 0°C measured in March 2025. The actual outcome is described next.

7.2 AUGUST–SEPTEMBER CIL

The CIL minimum temperature, thickness and volume for $T < 0^{\circ}\text{C}$ and $< 1^{\circ}\text{C}$ were estimated using temperature profiles from all sources for August and September. Most data are from the ecosystemic surveys in September for the Magdalen Shallows and August for the rest of the Gulf. Using all available temperature profiles, spatial temperature interpolations of the Gulf were done for each 1 m depth increment, with the interpolated field bound between the minimum and maximum values observed within each of the different regions of the Gulf (Fig. 2) to avoid spurious extrapolations. The CIL thickness at each grid point is simply the sum of depth bins below the threshold temperature, and the CIL minimum temperature is only defined at grid points where temperature rises by at least 0.5°C at depths greater than that of the minimum, or if the grid point minimum temperature is below the CIL spatial average of the Gulf.

Fig. 39 shows the gridded interpolation of the CIL thickness $< 1^{\circ}\text{C}$ and $< 0^{\circ}\text{C}$ and the CIL minimum temperature for August–September 2025 as well their 1991–2020 climatology (1994–2020 for Mécatina Trough). 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 as well as the climatologies shown on the left side of Fig. 39. Fig. 40 shows the volume of CIL water ($< 0^{\circ}\text{C}$ and $< 1^{\circ}\text{C}$) and the areal averaged CIL minimum core temperature from the yearly August–September interpolated grids (e.g., Fig. 39). The CIL areal minimum temperature average and volume shown in Fig. 40 exclude data from Mécatina Trough which has very different water masses from the rest of the Gulf; it is influenced by inflow through the Strait of Belle Isle and is therefore not indicative of the climate in the rest of the Gulf. The time series of the regional August–September CIL volumes are shown in Fig. 41 (for $< 0^{\circ}\text{C}$ and $< 1^{\circ}\text{C}$) and CIL regional average minimum core temperatures in Fig. 42.

Most regions showed only small changes in August CIL volumes in 2025 relative to 2024 (Fig. 41) and similar core temperatures since 2023 (Fig. 42). Overall, volumes defined by $T < 0^{\circ}\text{C}$ and $< 1^{\circ}\text{C}$ were similar to 2024, with still barely any recorded volume of CIL colder than 0°C and still fifth lowest volume colder than 1°C of the time series (Fig. 40). The 2025 average

temperature minimum (excluding Mécatina Trough, the Strait of Belle Isle and the Magdalen Shallows) decreased slightly from 0.58 to 0.48 °C (Fig. 40 bottom panel, green line and right-hand axis), sixth highest of the time series (+1.4 SD). The climatological difference between this CIL index and the Gilbert and Pettigrew (1997) index (described below) is 0.26 °C because of the warming between mid-June and the August survey. After adjusting for timing, this 2025 index would correspond to a Gilbert and Pettigrew (1997) seasonal index of 0.22 °C.

7.3 NOVEMBER CIL CONDITIONS IN THE ST. LAWRENCE ESTUARY

Since 2006, the AZMP November survey usually provides a good number of conductivity-temperature-depth (CTD) casts in the St. Lawrence, allowing a good estimation of CIL properties in the Estuary. The data show the temporal warming (Fig. 42) and thinning (Fig. 41) of the CIL since the August survey. Fig. 42 also shows that the fairly rapid increase of the CIL minimum temperature occurring between August and November is fairly constant interannually in spite of the differences in August temperature. Results indicate no CIL colder than 1 °C in the fall of 2025 in the Estuary.

7.4 SEASONAL MEAN CIL INDEX

The Gilbert and Pettigrew (1997) CIL seasonal index 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. 40). As noted above, the CIL minimum 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 (green line and axis on right-hand side) because the CIL is eroded over the summer and therefore its minimum core warms over time.

This CIL index for summer 2025 was +0.09 °C. Thus the seasonal CIL index for 2025 was slightly colder than predicted from the March cold layer volumes and than expected from the August CIL conditions.

The highest CIL index in recent years of 2021 is still far below the record highs observed in the 1960s and in 1980 (Fig. 40). A new CIL index (Galbraith, in prep.) does not have these high values.

7.5 SUMMARY OF CIL CONDITIONS

As a summary, Fig. 43 shows selected time series of winter and summertime CIL conditions (June and September bottom temperatures also related to the CIL are outlined below) and highlights the strong correlations between these various time series. Conditions related to the 2025 CIL were generally warmer than normal for the fifth consecutive year, and CIL volume has been fairly constant for the last three.

8. BOTTOM WATER TEMPERATURES ON THE MAGDALEN SHALLOWS

A long-standing assessment survey covering the Magdalen Shallows has taken place in June for mackerel assessments and was since merged with the June AZMP survey. This survey provides good coverage of the temperature conditions that are greatly influenced by the cold intermediate layer that reaches the bottom at roughly half of the surface area at this time of the year.

Near-surface waters warm quickly in June, midway between the winter minimum and the annual maximum in early August. This can introduce a bias if the survey dates are not the same each year. To account for this, the seasonal warming observed at the Shediac Valley AZMP monitoring station was evaluated by Galbraith and Grégoire (2015). A linear regression was performed of temperature versus time for each metre of the water column for each year with monitoring data at Shediac Valley between May and July. Visual inspection showed that the depth-dependent warming rate was fairly constant for all years and an average was computed for every depth. Warming is maximal at the surface at 18 °C per 100 days and, in spite of some uncertainties between 30 m and 55 m, decreases almost proportionally with depth to reach 2 °C per 100 days at 40 m, followed by a further linear decrease with depth to reach a warming of 1 °C per 100 days at 82 m.

All available temperature profiles taken in June from a given year are binned at 1 m depth intervals (or interpolated if the resolution is too coarse) and then adjusted according to the sampling date to offset them to June 15th according to the depth-dependent warming rate extracted from Shediac Valley monitoring data. An interpolation scheme is used to estimate temperature at each 1 m depth layer on a 2 km resolution grid. Fig. 44 shows temperatures and anomaly maps at depths of 20 m, 30 m, 40 m and 50 m; see Fig. 19 and Fig. 20 for surface values. Fig. 45 shows averages over the grids at 10 m, 20 m, 30 m, 50 m and 75 m for all years when interpolation was possible, as well as SST June averages since 1982, for both western and eastern regions of the Magdalen Shallows (Fig. 23). In 2025, temperatures were on average above normal in both regions at all depth, except at 20 m on the western Shelf (Fig. 44 and Fig. 45).

Bottom temperature is then estimated at each point of the grids constructed from the June survey by looking up the interpolated temperature at the depth level corresponding to a bathymetry grid provided by the Canadian Hydrographic Service with some corrections applied (Dutil et al. 2012). The method is fully described in Tamdrari et al. (2012). A climatology was constructed by averaging all available temperature grids between 1991 and 2020, and anomaly grids were then computed for each year based on that climatology. The June bottom temperature climatology as well as the 2025 reconstructed temperature and anomaly fields are shown in Fig. 46. The same method just described was applied using the available CTD data from August and September, mostly from the ecosystemic surveys for the northern Gulf in August and for the Magdalen Shallows in September. Bottom temperatures were from near normal to above normal on the Magdalen Shallows in June and August/September 2025, except in shallow coastal waters in August (Fig. 46).

Time series of the bottom area covered by water in various temperature intervals were estimated from the gridded data for the June surveys as well as for the September ecosystemic survey on the Magdalen Shallows (Fig. 47). Areas below and above 70 m depth (typical of the CIL minimum temperature) are shown separately. The time series of areas of the Magdalen Shallows covered by water colder than 0, 1, 2, and 3 °C in June and September are also shown in Fig. 43 as part of the CIL summary. In 2025, areas were smaller than normal at threshold temperatures from < -1 °C to < 3°C in June. Areas were smaller than normal at threshold temperatures from < -1 °C to < 2°C in September, and near normal for areas < 3°C.

9. 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 break and circulates towards the heads of the Laurentian, Anticosti, and Esquiman channels without much exchange with the upper layers. The layer from 150 m to 540 m is characterized by temperatures between 1 and > 7 °C and salinities between 32.5 and 35 (except for Mécatina Trough where near-freezing waters may fill the basin to 235 m in winter and usually persist throughout the summer). Decadal 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 and oxygen-rich Labrador Current water and warm—salty and oxygen-poor slope water also known as North Atlantic Central Waters (McLellan 1957, Lauzier and Trites 1958, Gilbert et al. 2005, Jutras et al. 2020). The mixing ratio may be controlled by the retroreflection of the Labrador Current at the tip of the Grand Banks (Jutras et al. 2023a) and was reported to have reached 100% warm North Atlantic Central Waters for waters entering the Gulf in 2021 (Jutras et al. 2023b). The deeper waters travel from the mouth of the Laurentian Channel to the Estuary in roughly three to four years (Gilbert 2004, Rousseau et al. 2025), 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 (10.9% saturation at Rimouski station in 2024; Blais et al 2025) are therefore found in the deep waters at the head of the Laurentian Channel in the Estuary.

9.1 BOTTOM WATER TEMPERATURES IN DEEP WATERS

As described above, bottom water temperature was computed for the entire Gulf using all available CTD data from August and September, mostly from the ecosystemic surveys for the northern Gulf in August and for the Magdalen Shallows in September (Fig. 48). We also included selected temperature casts from a trawl mounted SBE19plus that yields data at a vertical resolution of 5 m for 2019 to 2025. Areal averages for the sea floor deeper than 200 m are shown at the bottom of Fig. 49. While almost all of the Gulf deep bottom water temperatures were well above normal in 2023, in 2024 this excluded Cabot Strait where they were within 0.5 °C of the climatological mean. In 2025, the near-normal area spread north into Centre Gulf (white-colored anomalies on Fig. 48). Bottom temperatures decreased from 2024 values, except in the Estuary where they increased to tie the record high of 2022 (Fig. 49).

As done for the Magdalen Shallows (Fig. 47), time series of the bottom area covered by water in various temperature intervals were also estimated for the other regions of the Gulf based on August-September temperature profile data (Fig. 50). The figures show compression of the bottom habitat area in the temperature range of 5–6 °C in 1992, offset by the larger colder 4–5 °C habitat. In 2012, a return of > 6 °C temperatures to the sea floor began. By 2015, there was a large decrease of the 5–6 °C habitat in the northeast Gulf, this time replaced by a warmer 6–7 °C habitat. The 6–7 °C area then increased sharply in Central and northwest Gulf in 2017, and increased sharply again in northwest Gulf in 2018 and again in 2019. Some 7–8 °C habitat appeared for the first time in the northeast Gulf in 2020 and increased in 2021. In 2021, the 6–7 °C area increased dramatically in the Estuary. In 2022, the 6–7 °C area increased slightly in the combined Estuary and northwest Gulf area, but the 7–8 °C area decreased slightly in the northeast Gulf in favour of increased 6–7 °C area. In 2023, the 6–7 °C and 7–8 °C areas reverted to conditions very similar to those of 2021; the first indication of deep water temperatures stabilizing in the Gulf. In 2024 and again in 2025, no bottom waters warmer than

7 °C were observed in the Gulf and the 6–7 °C area retracted in Centre and Cabot Strait, indicating further cooling.

9.2 DEEP TEMPERATURE MAXIMUM

The warm waters found at the bottom of the Laurentian Channel and elsewhere are associated with the deep temperature maximum evident in the temperature profiles in these areas (e.g., the temperature maximum observed at spatially and interannually variable depth between 200 and 300 m on Fig. 3). The recent interannual progression to current conditions of the deep temperature maximum is shown on Fig. 51. Temperatures above 7 °C had been recorded since 2012 in the Gulf near Cabot Strait and occupied a large area in the northeast Gulf for the first time in 2020, extending further towards the heads of Esquiman and Anticosti channels; none were found in 2024 or 2025. The Gulf-wide average and regional areal averages of the deep temperature maximum are shown in Fig. 49. The Gulf-wide average of the deep temperature maximum increased from 5.2 °C in 2009 to a record high of 7.0 °C in 2022, dropping slightly back down to 6.9 °C in 2023 which is the same value as in 2021, then to 6.7 °C in 2024 and further to 6.4 °C in 2025. In Cabot Strait, the 2025 temperature maximum averaged 6.6 °C, below 7°C for the second consecutive year. This cooler (but still above normal) anomaly is propagating into the Gulf; the average deep temperature maximum has cooled since 2024 in all regions except the Estuary where the average is nearly as high as the 2022 record high (Fig. 49).

9.3 TEMPERATURE AND SALINITY ANNUAL MEANS

Monthly temperature and salinity averages were constructed for various depths using a method used by Petrie et al. (1996) but for the geographical regions shown in Fig. 2. In this method, 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 from 1991 to 2020 and their standard deviations are then computed for climatologies. This two-fold averaging process reduces the bias that occurs when the numbers of profiles in any given year are different. These monthly averages were further averaged into regional yearly time series that are presented in Fig. 49 (temperature) and Fig. 52 (salinity) for 200 m and 300 m. The 300 m observations suggest that temperature anomalies are advected up-channel from Cabot Strait to the Estuary in three to four years, consistent with the findings of Gilbert (2004) and Rousseau et al. (2025), while variability at 200 m often appears or disappears in all regions at the same time, suggesting vertical changes. 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 150 m, 200 m and 300 m in Fig. 49, Fig. 52 and Fig. 53. Linear trends calculated in temperature and salinity at 300 m over 1915–2025 are of 2.5 °C and 0.3 per century, respectively, although the temperature increase was 1.3 °C per decade during the rapid warming period of 2009–2022 (5.2 times the long-term rate of change).

In 2025, Gulf-wide average temperatures at 300 m continued to decrease from 2022 series record highs to 6.5 °C (+1.7 SD). The 200 m average temperature is similar to that of 2024 at 5.7 °C (+1.8 SD) whereas the 150 m average temperature increased a bit to 3.8 °C (+1.7 SD) (Fig. 49 and Fig. 53). Gulf-wide average salinities decreased to 34.73 at 300 m (a value similar to that of 2017), but remained stable at 200 m (34.17) and increased at 150 m to 33.46 (Fig. 52 and Fig. 53).

The high 2022 temperatures at 150 and 200 m are likely attributed to halocline vertical upward motion rather than by a change in water mass properties. Looking at August surveys, the mean temperature of waters at a salinity of 34 (generally found close to 200 m depth) decreased slightly in 2023 to 5.4 °C from the 2022 peak of 5.5 °C (Fig. 53), the 0.1 °C difference in water mass characteristics is much less than the decrease of 0.5 °C observed at 200 m. The mean depth of waters at the salinity of 34 was shallowest since 1985 in 2022 (167 m) and increased by 16 m in 2023 (to 183 m, green line in Fig. 53); thus most of the 0.5 °C decrease is associated with a deepening of the thermocline/halocline. This implies a change in estuarine circulation or perhaps the inflow of thicker mid-depth intrusions that must be compensated for by either outflow or reduced inflow at greater depths.

On the other hand, the decrease of the mean temperature at 300 m from the 2022 maximum does appear to be associated with water mass changes. The average temperature of salinity 34.7 waters tracks the average temperature at 300 m well (black line overlying temperature at 300 m in Fig. 53). In recent years the salinity at 300 m has increased to 34.8 and the average Gulf temperature at that salinity has decreased from a maximum value of 7.2 °C in 2022 to 6.5 °C in 2025 (red line in Fig. 53).

In 2025, temperatures at 200 m were variable depending on location, with an increase to a record high in the Estuary, and a decrease to the first below normal value since 2013 in Laurentian Hermitage. Gulf temperatures at 300 m generally decreased throughout the Gulf from 2024 values, except in the Estuary where they increased to a record high and Cabot Strait where they increased slightly (Fig. 49). The latter was surprising considering the near normal temperature of 6.2 °C observed in 2024 in Laurentian Hermitage, upstream of Cabot Strait. The values at 300 m were: Estuary (6.4 °C, +3.6 SD), northwest Gulf (6.5 °C, +3.0 SD), Centre Gulf (6.4 °C, +1.7 SD), Cabot Strait (6.5 °C, +1.1 SD). We also note the deep thermograph at 445 m at station Old Harry where the colder than normal temperatures between 5.8 and 5.9 °C recorded in 2024 decreased further to 5.5 °C (Fig. 16). Temperatures at 300 m in Laurentian Hermitage and Mouth increased in 2025 from 2024 values, indicating a possible stop to the cooling trend in the Gulf deep waters.

10. SEASONAL AND REGIONAL AVERAGE TEMPERATURE STRUCTURE

In order to show the seasonal progression of the vertical temperature structure, regional averages are shown in Fig. 54 to Fig. 57 based on the profiles collected during the March helicopter survey, the June AZMP and mackerel survey, the August ecosystemic survey (September ecosystemic survey for the Magdalen Shallows), and the October AZMP survey. All additional archived CTD data for those months were also used. 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. Average discrete depth layer conditions are summarized for the surveyed months of 2024 and 2025 in Fig. 58 for temperature and in Fig. 59 for salinity and 0–50 m stratification. The anomalies were computed relative to monthly temperature and salinity 1991–2020 climatologies calculated for each region, shown in grey as the mean value $\pm$ 0.5 SD in Fig. 54 to Fig. 57.

Caution is needed in interpreting mean profiles. Indeed, regional averaging of winter profiles does not work very well in the northeast Gulf because very different water masses are present

in the area such as the cold Labrador Shelf intrusion with saltier and warmer deeper waters of Anticosti Channel or Esquiman Channel. Similarly, the deeper portions of the Magdalen Shallows averaging region consists of two widely separated zones to the north and southeast.

The highlights of March 2025 water temperatures shown in Fig. 54 include the previously discussed cold layer volumes which were well below normal, as evidenced here by mixed layers warmer than the -1°C or 0°C thresholds in many regions as well as shallower mixed layers and thermoclines. The mixed layer was again shown to end abruptly at 50 m depth over the Magdalen Shallows and portions of the Shallows sea floor between 50 and 100 m depth were atypically bathed in temperatures above -1°C but mostly colder than 0°C (Fig. 36). Mécatina Trough was filled to the bottom with cold water that inflowed from the Labrador Shelf in winter (Fig. 36), but by August the temperature at 200 m had increased to between 1 and 2°C . Other months show general cooling at depths greater than 250 m since 2024 except in the Estuary (Fig. 55 to Fig. 57).

11. CURRENTS AND TRANSPORTS

Currents and transports are derived from a NEMO (Nucleus for European Modelling of the Ocean) numerical model of the Gulf of St. Lawrence, Scotian Shelf, and Gulf of Maine. The model is prognostic, i.e., it allows for evolving temperature and salinity fields. It has a spatial resolution of $1/12^{\circ}$ with 46 depth-levels in the vertical axis. The atmospheric forcing is taken from the Global Environmental Multiscale (GEM) model running at the Canadian Meteorological Center (CMC). Freshwater runoff is obtained from observed data and the hydrological model discussed in the freshwater runoff section. The spring freshet may therefore differ from what was described in an earlier section of this document. A simulation was run for 2006–2025 from which transports were calculated. The reader is reminded that the results outlined below are not measurements but simulations and improvements in the model may lead to changes in the transport values.

Fig. 60 to Fig. 62 show seasonal depth-averaged currents for 0–20 m, 20–100 m, and 100 m to the bottom for 2025. 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 high, and the 100 m to bottom averages are still much higher than during other seasons (note the different scale for this depth). Currents are also strongest along the slopes of the deep channels. The Anticosti Gyre (Fig. 1) is usually visible throughout the whole year, but strongest during winter months when it also extends more strongly into the bottom-average currents (Fig. 62). The Gaspé Current usually flows along the Gaspé Peninsula but may meander in the Estuary, sometimes hugging the north shore and forming gyres. In 2025, the Gaspé Current was strongest along the south shore of the Estuary in winter, with strongest upstream flow along the north shore in summer (Fig. 60).

Monthly averaged transports across sections of the Gulf of St. Lawrence are shown in Fig. 63 for three sections with estuarine circulation, and in Fig. 64 for three sections where only net transports are relevant. In Fig. 63, the net transport integrates both up and downstream circulation and, for example, corresponds to freshwater runoff at the Pointe-des-Monts section. The outflow transport integrates all (eastward) currents heading towards the ocean, while the estuarine ratio corresponds to the outflow divided by the net transports. Note that the only section where estuarine circulation is dominant is at Pointe-des-Monts. The net transport at

Honguedo is on average 15 times higher than at Pointe-des-Monts, consisting mostly of circulation around Anticosti Island first observed at the Jacques-Cartier section. Similarly, the net transport at Cabot Strait is outflow that is mostly balanced by inflow from the Strait of Belle Isle, such that an estuarine ratio is perhaps a misleading description. Transports through sections under the direct estuarine 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 Gulf under varying runoff. The estuarine circulation ratio is determined by the mixing intensities within the estuary and is greatly influenced by stratification, but also includes horizontal estuarine-like circulation that occurs when waters flow from the Anticosti Gyre and into the Estuary at Pointe-des-Monts. It is on average greatest during winter months and weakest during the spring freshet. In fact, it is sufficiently reduced in spring that the climatological outflow transport at Pointe-des-Monts reaches its minimum value in June even though this month corresponds to the third highest net transport of the year, i.e., the estuary becomes sufficiently stratified that freshwater runoff tends to slip on top of the denser salty waters underneath. This occurred in 2019 when the exceptionally high May-June freshet led to decreased modelled estuarine circulation and decreased outflow transport by entrainment at the Pointe-des-Monts section. In contrast, the weak freshet of 2021 coincided not only with increased estuarine circulation but also with increased outflow transport. The estuarine circulation ratio at the Pointe-des-Monts section was generally above normal in 2025, reaching monthly record highs in January and October; this continues a pattern of above normal conditions since 2020 (Fig. 63). Thus the normal to well below normal net transports at Pointe-des-Monts in 2025 produced generally normal to above normal outward transport from enhanced estuarine circulation.

11.1 TRANSPORT THROUGH THE STRAIT OF BELLE ISLE

Transport through the Strait of Belle Isle is estimated using data from an acoustic Doppler current profiler (ADCP) moored off of the northern coast in the Strait (Fig. 13). Studies have shown that although low-frequency currents through the strait are sheared, they are towards the Gulf over most of the cross section and coherent across the strait (Garrett and Petrie 1981; Petrie et al 1988); they are driven by large-scale meteorological forcing. Transports are therefore computed here by assuming velocity at the mooring to be representative of the whole cross-section, although it may underestimate transport towards the Labrador Shelf. The methodological details can be found in Shaw and Galbraith (2023).

Transport through the Strait is largely towards the Gulf, with monthly values ranging up to 8.1 (deci-Sverdrups, dSv; Fig. 65). On average, transport switches between low values (0.5-1 dSv) from April to July and stronger values (3-5 dSv) from September to February. Monthly-averaged transport is occasionally towards the Labrador Shelf during the spring and early summer and has been measured up to 1.1 dSv (May 2011). Strong transport towards the Gulf was measured during November 2024 and February 2025 (-7.4 dSv in both cases). Transport anomalies were high in February, April and May, then below normal in June, ending the winter inflow of cold Labrador Shelf Water early in 2025.

12. HIGH FREQUENCY SAMPLING AZMP STATIONS

Sampling by the Maurice Lamontagne Institute began in 1991 at a station offshore of Rimouski (48° 40' N 68° 35' W, 320 m depth; Plourde et al. 2009), typically once a week during summer and less often during spring and fall and almost never in winter (Fig. 66). In 2013, following

several analyses that identified good correlations and correspondences between the prior AZMP Anticosti Gyre and Gaspé Current stations with the Rimouski station, it was decided to drop sampling efforts at these logistically difficult stations and officially integrate the Rimouski station into the AZMP program, and begin winter sampling there when opportunities arose. The AZMP station in the Shediac Valley (47° 46.8' N, 64° 01.8' W, 84 m depth) is usually sampled by the Bedford Institute of Oceanography, by DFO Gulf Region and by the Maurice Lamontagne Institute (Fig. 66). This station has been sampled irregularly since 1947, nearly every year since 1957, and more regularly during the summer months since 1999 when the AZMP program began.

Oceanographic moorings have been deployed on rotation since the summer of 2015 at these two AZMP stations, providing data to fill sampling gaps in winter or during other times of the year. In 2025, oceanographic buoys equipped with an automatic temperature and salinity profiler suffered technical issues and carried out only 28 partial-depth casts at Shediac Valley station and 120 casts to 300 m at Rimouski station.

Isotherms and isohalines as well as monthly averages of layer temperature and salinity, stratification, and CIL minimum core temperature and thickness at < 1 °C are shown for 2023–2025 for the Rimouski station in Fig. 67 and for the Shediac Valley station in Fig. 68. Climatologies are calculated from 1991 to 2020 data, but there are few data prior to 1999 for Shediac Valley. Mooring data are also used to fill winter gaps in the isotherms and isohalines, and are used throughout the tables of monthly averages when available at the corresponding depths. Fig. 69 shows the interannual variability of some seasonal layer averages from May to October for the two stations.

At the Rimouski station, the gradual shift of cold-fresh deep anomalies at 200–300 m present in 2010 to warmer-saltier waters advected from Cabot Strait led to a shift to warm anomalies by summer 2014 (not shown). A slow but persistent warming has been observed at 320 m at the station. A monthly average record high of 6.55 °C was recorded in April 2025 (Fig. 67) and the May–November average near bottom temperature (290 m) was at a record high in 2025. Thus the deep cooling that has begun to occur in the Gulf has still not yet reached the Estuary. The CIL was warmer and thinner than normal for all recorded months, leading to above normal May to October average CIL minimum temperature (Fig. 69). However the May–October 0–50 m and 0–100 m average temperatures were near-normal for the first time since 2020.

Conditions at the Shediac Valley station in 2025 show generally normal to above-normal temperatures (Fig. 68). The winter mixed layer did not quite reach the bottom, a repeat of 2024. However temperature still averaged below 0 °C at -0.7 °C in March at 75 m, contrary to March 2024 when they averaged 0.3 °C. Temperatures averaged from May to October 2025 from 0 to 50, from 0 to the bottom (0–84 m) and near the bottom (75 m) were all above normal.

13. SUMMARY

Fig. 70 summarizes SST, summertime CIL and deep-water average temperatures. The August SST was normal and the May–November average was above normal (+1.5 SD). The average temperature at 300 m continued to decrease from the 100+ year series record highs of 2022 but remained higher at 6.46 °C than when the 100 year record was broken in 2016, at 6.30 °C. Average temperature at 150 m increased slightly since 2024 and temperature at 200 m was

stable; both are above normal at +1.7 and +1.8 SD respectively. The seasonal CIL core temperature was above normal (+1.2 SD).

Another summary of the temperature state of the Gulf of St. Lawrence over a shorter time span (since 1971) allows the inclusion of more datasets, and three sets of four time series are chosen to represent surface, intermediate and deep conditions (Fig. 71). The SST summer and fall timing are from Fig. 26 (12 °C threshold) with air temperature proxies used prior to 1982. Sea-ice is grouped as an intermediate feature since all are associated with winter formation. Fig. 71 shows the sums of these three sets of anomalies representing the state of different parts of the system and is reproduced on Fig. 72 with each time series contribution shown as stacked bars (Petrie et al. 2007). These composite indices measure the overall state of the climate system with positive values representing warm conditions and negative representing cold conditions. The plot also indicates the degree of co-variability between the various measures of the environment across the zone, as anomalies are often of the same sign.

While the index of surface anomalies was above normal (+0.9 SD) in 2025, it ended a 4-year sequence of very high values. The index of intermediate layer anomalies was above normal (+1.5 SD) for the 6th consecutive year. The index of deep temperature anomalies decreased again slightly from the 2022 series record high to the 6th highest value (+1.9 SD).

14. KEY FINDINGS

- The annual runoff was near normal at 11 900 m³s⁻¹ (-0.4 SD) for the St. Lawrence River and below normal at 16 700 m³s⁻¹ (-0.7 SD) for the RIVSUM II index
- The timing of summer onset of the surface layer warming to 10 °C and 12 °C was respectively slightly earlier than normal (-0.5 week, -0.8 SD) and near normal. Post-season cooling was later than normal by 1.1 weeks (+1.2 SD) to 12 °C and by 2.5 weeks (+4.2 SD) to 10°C. The last five years have experienced very late cooling to 10°C.
- Marine heatwaves were comparatively weak.
- The seasonal maximum ice volume of 15.7 km³ (-1.3 SD) and area of 58 600 km² (-1.7 SD) both ranked 6th lowest of records that begin in 1969. In the 16-year span since 2010, 11 of the 16 lowest seasonal maximum ice volumes of the time series have occurred.
- The winter surface mixed cold layer (< -1 °C) volume of 7 600 km³ was below normal (-1.5 SD). The mixed layer volume increases to 13 800 km³ (-1.1 SD) when water temperatures < 0 °C are considered. The Labrador Shelf water intrusion volume into Mécatina Trough of 1340 km³ was near normal and transport measured at the Strait of Belle Isle mooring indicates that inflow after the March survey stopped slightly early in mid-May.
- The August cold intermediate layer (CIL) average minimum temperature was above normal at 0.48 °C (+1.4 SD), 6th highest since 1985. The Gilbert & Pettigrew (1997) minimum temperature index, which includes data over a longer season and adjusted to mid-July, was above normal at 0.09 °C (+1.2 SD).
- On the Magdalen Shallows, the areas covered by water with low temperatures were smaller than normal at threshold temperatures from < -1 °C to < 3 °C in June, and from < -1 °C to < 2 °C in August/September.

- The overall seasonal average May-November SST for the Gulf was above normal (10.9 °C, +0.8 °C, +1.5 SD) for the fifth consecutive year, albeit not as high of an anomaly as the four previous years. The seasonal August maximum was normal at 16.3 °C.
- Gulf-wide average temperatures at 300 m continued to decrease from 2022 series record highs to 6.5 °C (+1.7 SD). The 200 m average temperature is similar to that of 2024 at 5.7 °C (+1.8 SD) whereas the 150 m average temperature increased slightly to 3.8 °C (+1.7 SD). Gulf temperatures at 300 m generally decreased throughout the Gulf from 2024 values, except in the Estuary where they increased to a record high and Cabot Strait where they increased slightly.
- Temperatures of the deep maximum decreased slightly in Cabot Strait from 2024 values, indicating continued cooling in upcoming years to make its way into the Gulf. However temperatures at 300 m in Cabot Strait, Laurentian Hermitage and Mouth increased, indicating a possible stop to the cooling trend at that depth.

15. OUTLOOK FOR 2026

Air temperatures were 1.6 °C below normal over the Gulf in December 2025, leading to near normal timing of first occurrence of sea ice in the Estuary and Western Gulf for the first time since 2020. However air temperatures were near normal in January 2026 and above normal in February, especially in the Eastern Gulf, limiting sea ice cover to below normal seasonal maximum area and volume. This was the setting for the March 2026 survey, which provides an outlook for CIL conditions expected for the remainder of 2026. Fig. 73 shows the March 2026 surface mixed layer temperature, salinity, and thickness (at $T < -1$ °C and $T < 0$ °C), as well as the thickness and extent of the cold and saline layer that has intruded into the Gulf from the Labrador shelf.

The often-observed pattern of slightly warmer waters off the southern part of Newfoundland's west coast was present in March 2026, with temperatures even above 0 °C in Cabot Strait offshore of Port aux Basques and towards Anticosti Island. Temperatures 1 °C above freezing extended to Anticosti Island and halfway up the coast of Newfoundland.

The predictive relations between the winter volume of water colder than -1 °C and the following summer CIL minimum temperature index (Fig. 38) forecasts a CIL index of +0.03 °C. Another relation between the winter volume of water colder than 0 °C and the following summer CIL temperature minimum would predict a similar index of +0.01 °C. A continuation of warm CIL conditions is therefore the forecast for summer 2026, albeit slightly cooler than in 2025.

Also noted was the absence of very warm waters at 200 m depth, where temperature exceeded 6 °C at only 3 stations out of 24 that recorded past that depth, the highest of them at 6.2 °C. By comparison, during the record warm year of 2022 temperature exceeded 6 °C at half the stations and reached 8.45 °C in Cabot Strait.

16. ACKNOWLEDGEMENTS

We are grateful to the people responsible for CTD data acquisition during the surveys used in this report:

- Rimouski station monitoring : Félix St-Pierre, Michel Rousseau, Anthony Ouellet, Nicolas Coulombe, Guillaume Mercier, Myranda Blouin, Sylvain Dubé, Bruno St-Denis, Geneviève Perrin and the Canadian Coast Guard ship workshop crew.
- Shediac Valley monitoring station: Quebec Region AZMP surveys, Renée Allain, François Turcotte, François-Etienne Sylvain, Stéphanie Ratelle, Félix St-Pierre, Sylvain Dubé.
- 2025 March survey: Peter Galbraith, Michel Rousseau, Michel Dubé, Tommy Lévesque.
- 2026 March survey: Peter Galbraith, Jean-Luc Shaw, Olivier Talbot, Jonathan Fontaine.
- June AZMP survey: Marjolaine Blais, Véronique Desborbes, Guillaume Mercier, Myranda Blouin, Marie-Noëlle Bourassa, Hélène Talbot, Talia Koll-Egyed, Jean-Luc Shaw; the officers and crew of the CGCS Capt. Jacques Cartier.
- June mackerel egg survey: Caroline Lehoux, Guillaume Mercier, Laurence Lévesque, Geneviève Perrin, Mélanie Boudreau, Anthony Ouellet; the officers and crew of the CGCS Capt. Jacques Cartier.
- August ecosystemic survey: Guillaume Mercier, Myranda Blouin, Bruno St-Denis; the officers and crew of the CCGS Cabot
- September ecosystemic survey: Nicolas Rolland and David Fishman (Gulf Region) for providing the CTD data.
- October-November AZMP survey: David Leblanc, Marie-Noëlle Bourassa, Caroline Lafleur, Mélanie Boudreau, Marie-Pier Boulanger, Hélène Talbot, Anthony Ouellet, Sylvain Dubé; the officers and crew of the Coriolis II.
- Northumberland Strait survey: Renée Allain, Natalie Asselin, Patricia Henley and the officers and crew of the CCGS M. Perley.
- Southern Gulf snow crab survey: Renée Allain, Jean-François Landry, Tobie Surette.
- Southern Gulf herring survey: François Turcotte, Jacob Burbank.
- Southern Gulf scallop survey: Monique Niles.
- Data management: Caroline Lafleur, Marie-Noëlle Bourassa and David Fishman.

CTD maintenance: Myranda Blouin.

Mooring conception: Nicolas Coulombe

Data from the following sources are also gratefully acknowledged:

- Air temperature: Environment and Climate Change Canada.
- Sea-ice: Canadian Ice Service, Environment and Climate Change Canada. Processing of GIS files by Jean-Luc Shaw.
- Runoff at Québec City: Denis Lefavre (emeritus) and Hatem Yazidi.
- Runoff from hydrological modelling: Joël Chassé and Diane Lavoie.

- Historical SST remote sensing (IML): Pierre Larouche (retired), Bernard Pettigrew (retired).
- Thermograph network: Guillaume Mercier and Jean-Luc Shaw.
- Thermosalinograph: Anthony Ouellet, Nicolas Coulombe, Myranda Blouin, Félix St-Pierre Guillaume Mercier, Peter Galbraith. From Oceanex: Capt. Richard Belley and Yves Morissette, Engineers Steeve Cotton and Patrice Racine.
- Update of the Gilbert & Pettigrew (1997) seasonal CIL index: Jacqueline Dumas.

All figures were made using the free software Gri (Kelley and Galbraith 2000).

We are grateful to Jared Penney and Blair Greenan for reviewing the manuscript and providing insightful comments, and Jean-Martin Chamberland as the technical report editor.

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18. FIGURES

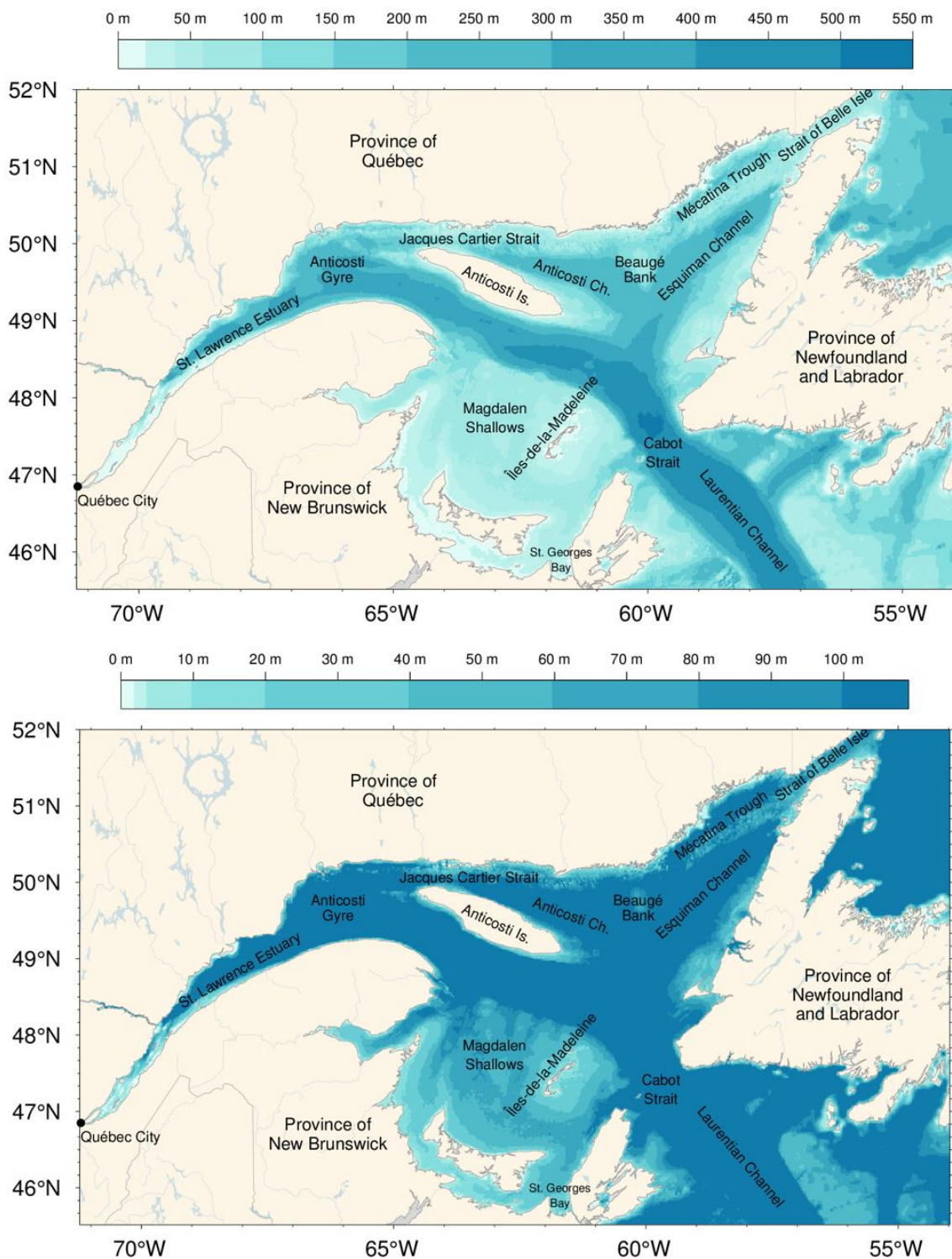


Fig. 1. The Gulf of St. Lawrence. Locations discussed in the text are indicated. Bathymetry datasets used are from the Canadian Hydrographic Service to the west of 56°47' W (with some corrections applied to the Baie des Chaleurs and Magdalen Shallows) and TOPEX data to the east. Bottom panel shows detail for 0–100 m bathymetry.

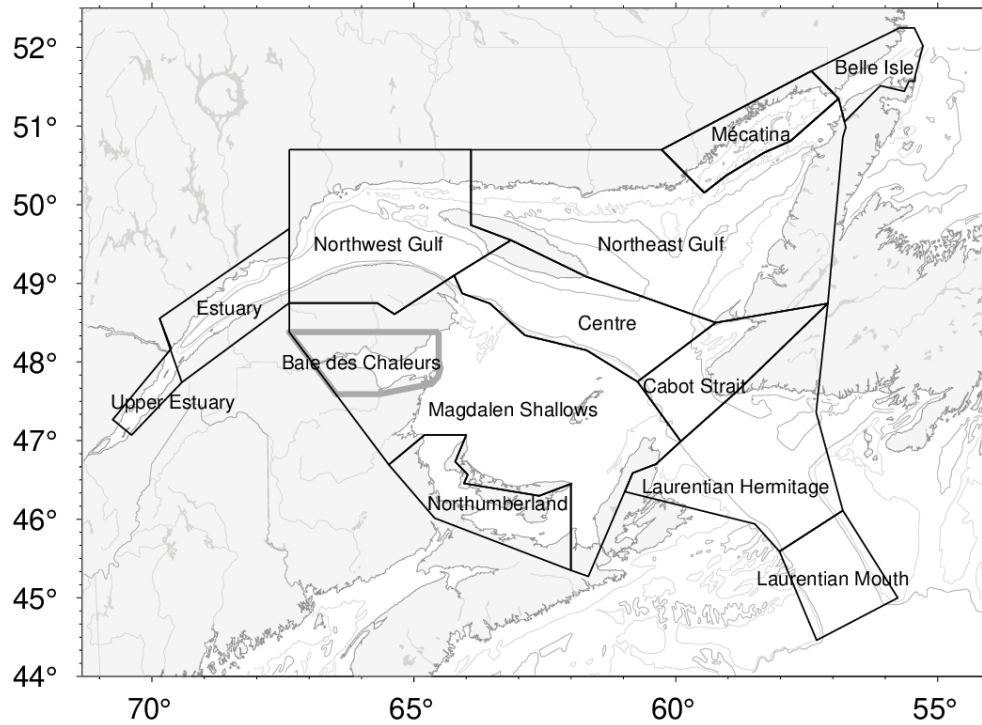


Fig. 2. Gulf of St. Lawrence divided into oceanographic regions used in spatial averaging. Baie des Chaleurs is sometimes reported separately but is always included in the Magdalen Shallows.

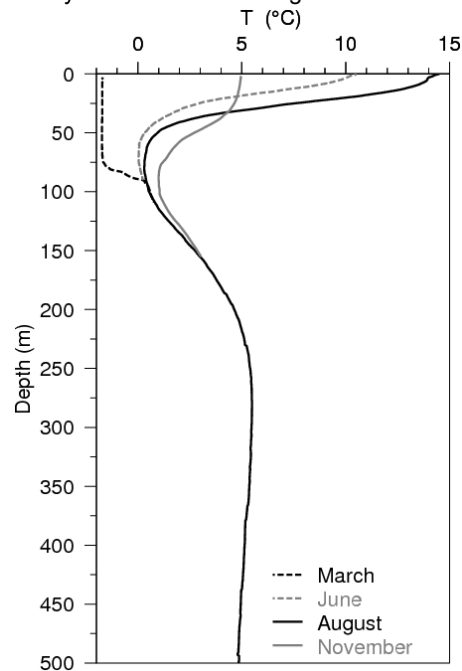


Fig. 3. Typical seasonal progression of the depth profile of temperature observed in the Gulf of St. Lawrence. Profiles are averages of observations in August, June and November 2007 in the northern Gulf. The dashed line at left shows a single winter temperature profile (March 2008), with near freezing temperatures in the top 75 m. 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. Figure from Galbraith et al. (2012).

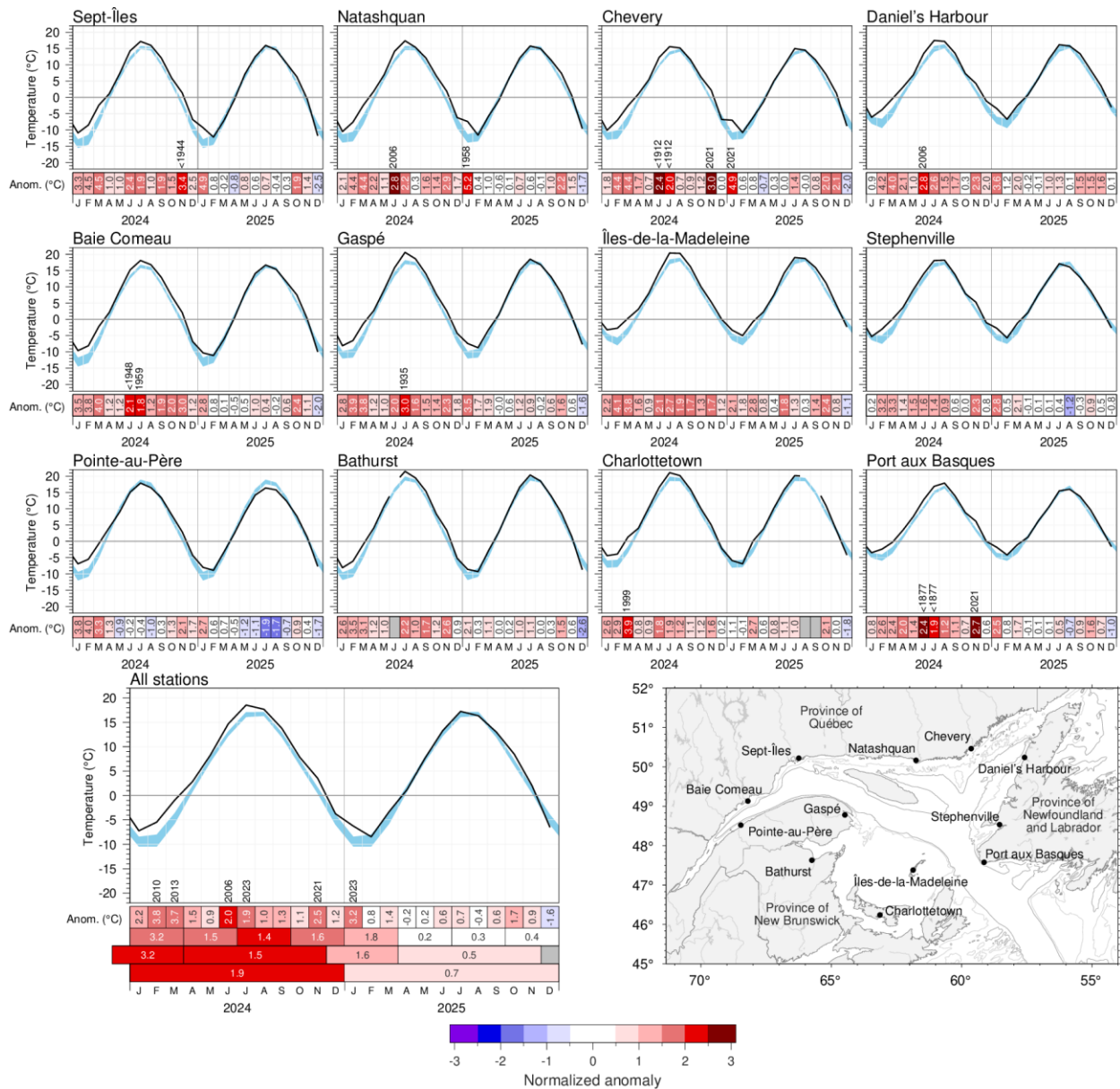


Fig. 4. Monthly air temperatures and anomalies for 2024 and 2025 at selected meteorological stations around the Gulf as well as the average for all stations. The blue area represents the 1991–2020 climatological monthly mean $\pm$ 0.5 SD. Months with 4 or more days of missing data are omitted. The bottom scorecards are colour-coded according to the monthly normalized anomalies based on the 1991–2020 climatologies for each month (colour palette at bottom), but the numbers are the monthly anomalies in °C. For anomalies greater than 2 SD from normal, the prior year with a greater anomaly is indicated, with < used to indicate a series record. Seasonal, December–March, April–November and annual anomalies are included for the all-station average.

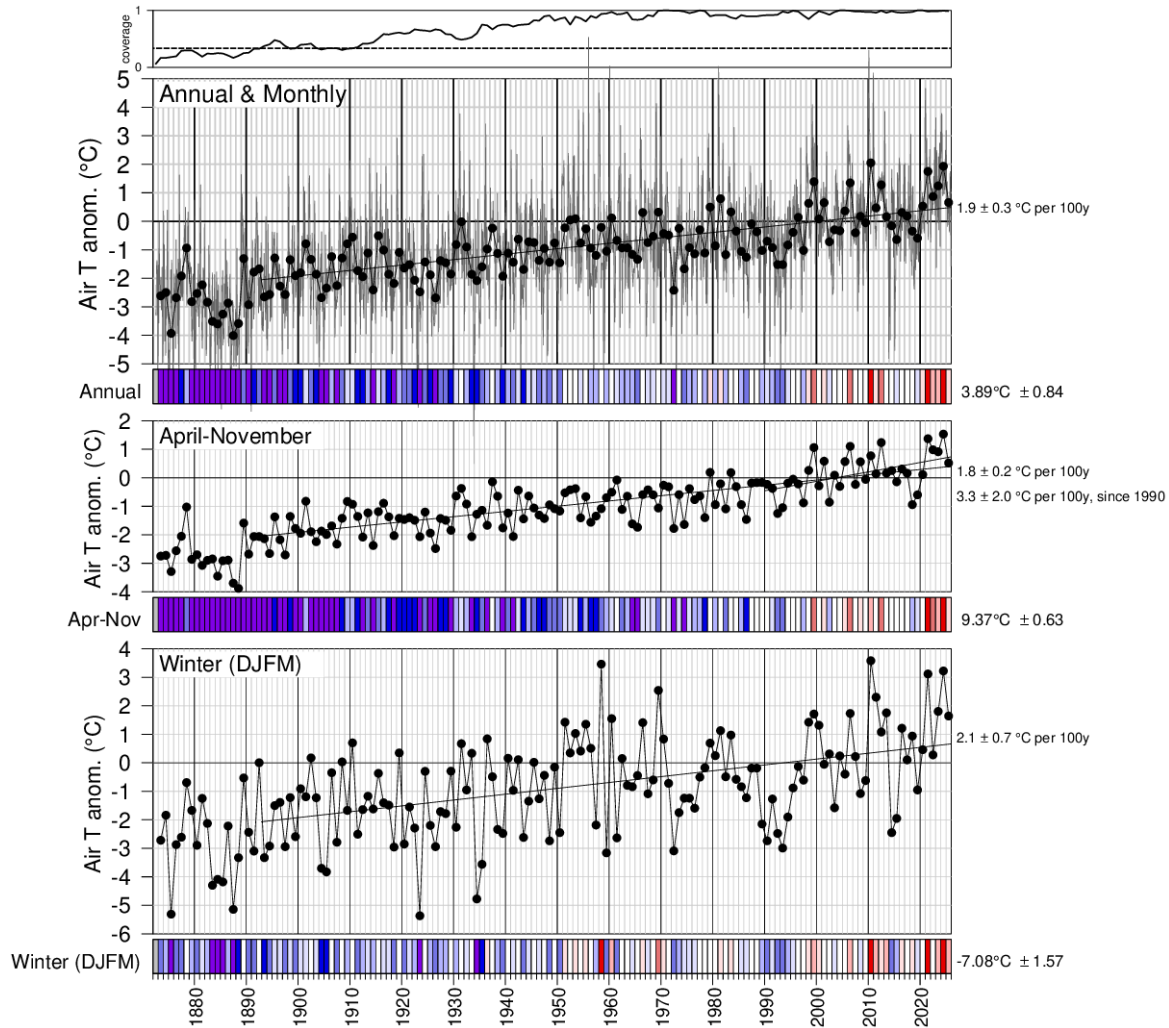


Fig. 5. Annual, April–November, and December–March mean air temperature anomalies averaged for the selected stations around the Gulf from Fig. 4. The top panel shows the annual coverage of meteorological stations and the dash line indicates 1/3 coverage. The grey line in the annual/monthly panel shows monthly values and the thicker black line and dots show annual averages. The bottom scorecards are colour-coded according to the normalized anomalies based on the 1991–2020 climatology and numbers to the right are means and standard deviations. Trends plus and minus their 95% confidence intervals are shown. Regressions are shown for the period of 1893–2025, when coverage begins to exceed 1/3.

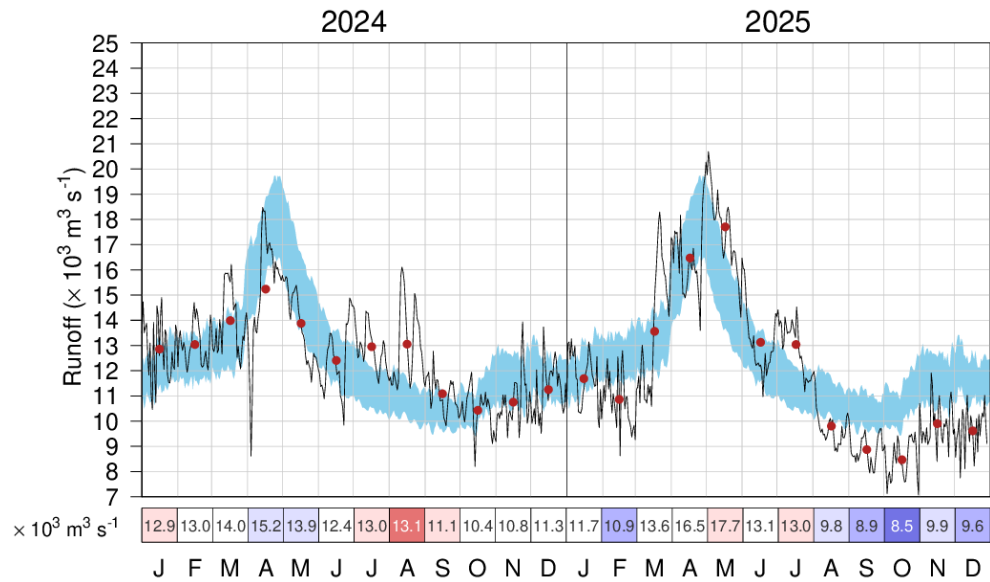


Fig. 6. Daily mean freshwater flow of the St. Lawrence River at Québec City. The 1991–2020 climatological mean (± 0.5 SD) is shown (blue shading). Monthly means are shown by red dots and displayed in the scorecard. It is colour-coded according to the monthly anomalies normalized for each month of the year, but the numbers are the actual monthly anomalies in $10^3 \text{ m}^3 \text{ s}^{-1}$.

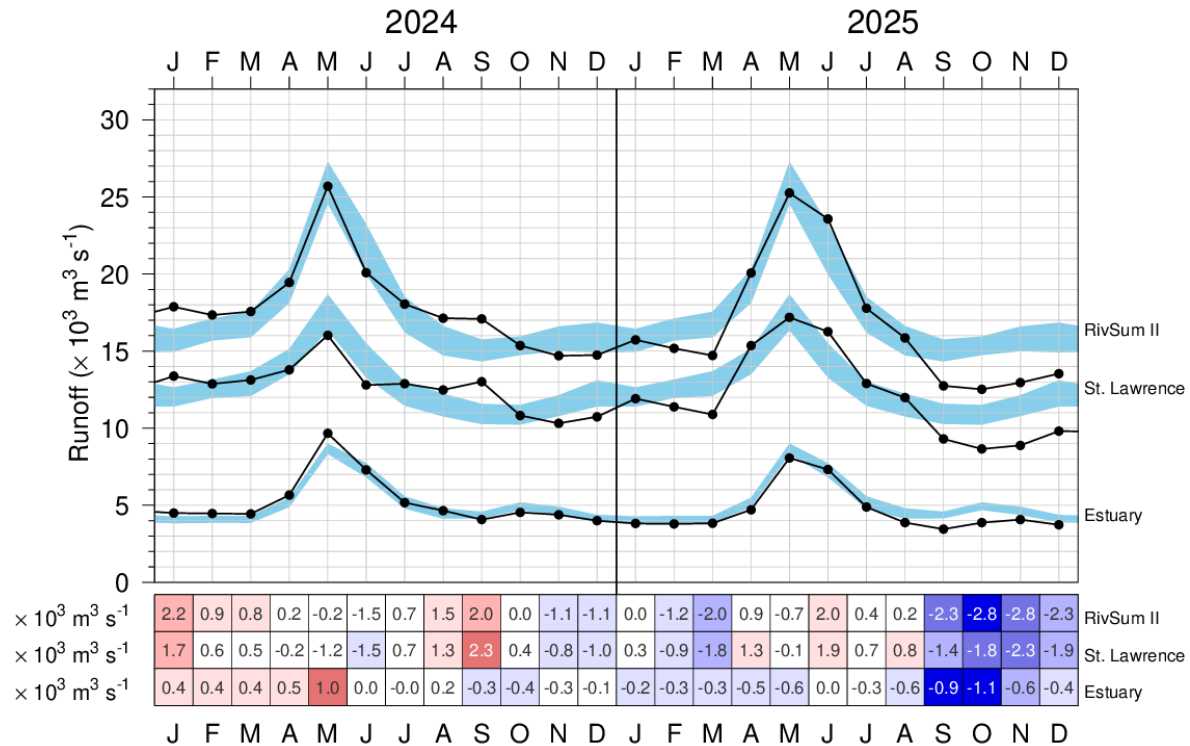


Fig. 7. Monthly mean freshwater flow of RIVSUM II (upper curve), which is the sum of the St. Lawrence River at Québec City lagged by 21 days (middle curve) and rivers flowing into the St. Lawrence Estuary (lower curve). The 1991–2020 climatological means (± 0.5 SD) are shown (blue shading). The scorecards are colour-coded according to the monthly anomalies normalized for each month of the year, but the numbers are the actual monthly anomalies in $10^3 \text{ m}^3 \text{ s}^{-1}$.

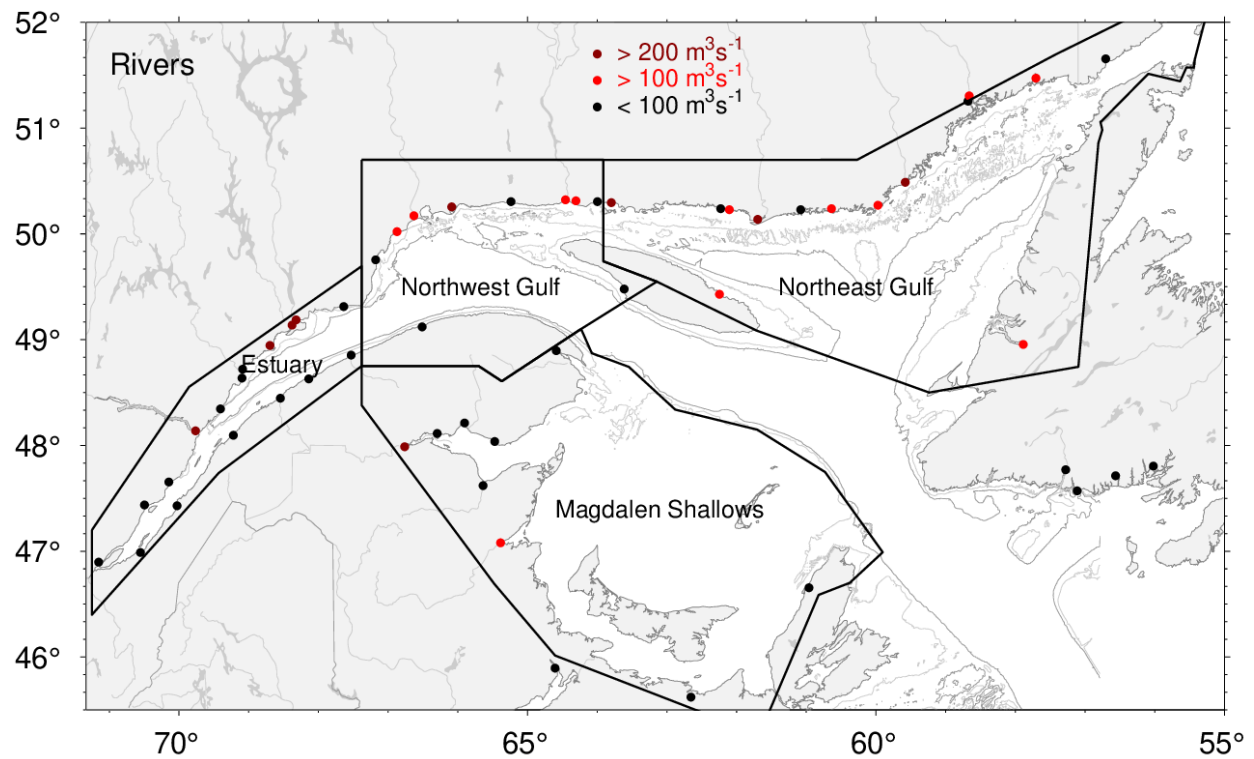


Fig. 8. River discharge locations for the regional sums of runoffs listed in Fig. 9 and Fig. 10. Black, red and dark red dots indicate rivers that have climatological mean runoff less than $100 \text{ m}^3 \text{ s}^{-1}$, between 100 and $200 \text{ m}^3 \text{ s}^{-1}$, and greater than $200 \text{ m}^3 \text{ s}^{-1}$, respectively.

RIVSUM II	17871	17336	17563	19447	25689	20090	18051	17136	17084	15361	14697	14740	15730	15175	14714	20064	25253	23577	17772	15856	12749	12518	12955	13538	17555 $\text{m}^3 \text{ s}^{-1}$
St. Lawrence River	13378	12872	13125	13791	16026	12795	12883	12483	13018	10826	10313	10740	11915	11384	10885	15354	17185	16262	12893	11982	9300	8649	8884	9807	12746 $\text{m}^3 \text{ s}^{-1}$
Estuary	4493	4464	4438	5656	9663	7295	5168	4653	4066	4535	4384	4000	3815	3791	3829	4710	8068	7315	4879	3874	3449	3869	4071	3731	5090 $\text{m}^3 \text{ s}^{-1}$
Northwest Gulf	219	119	319	955	2819	4114	2010	533	279	848	721	493	233	110	214	535	2591	5090	1881	432	446	566	796	469	1177 $\text{m}^3 \text{ s}^{-1}$
Northeast Gulf	561	433	1054	1991	5068	7839	3438	838	114	1307	2441	1611	777	410	657	1003	4599	9947	4541	925	1056	1487	2785	1435	2228 $\text{m}^3 \text{ s}^{-1}$
Magdalen Shallows	439	484	965	1249	1407	452	143	225	232	591	1198	843	358	273	752	1681	1924	437	44	0	0	206	793	528	735 $\text{m}^3 \text{ s}^{-1}$
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	
	2024												2025												

Fig. 9. Monthly anomalies of the RIVSUM II, the 21-day lagged St. Lawrence River runoff and sums of all other major rivers draining into separate Gulf regions for 2024 and 2025 as delimited in Fig. 8. The scorecards are colour-coded according to the monthly normalized anomalies based on the 1991–2020 climatologies for each month, but the numbers are the monthly average runoffs in $\text{m}^3 \text{ s}^{-1}$. Numbers on the right side are annual climatological means. Runoff regulation is simulated for three rivers that flow into the Estuary (Saguenay, Manicouagan, Outardes). This figure in last year's report incorrectly repeated data for 2022–2023.

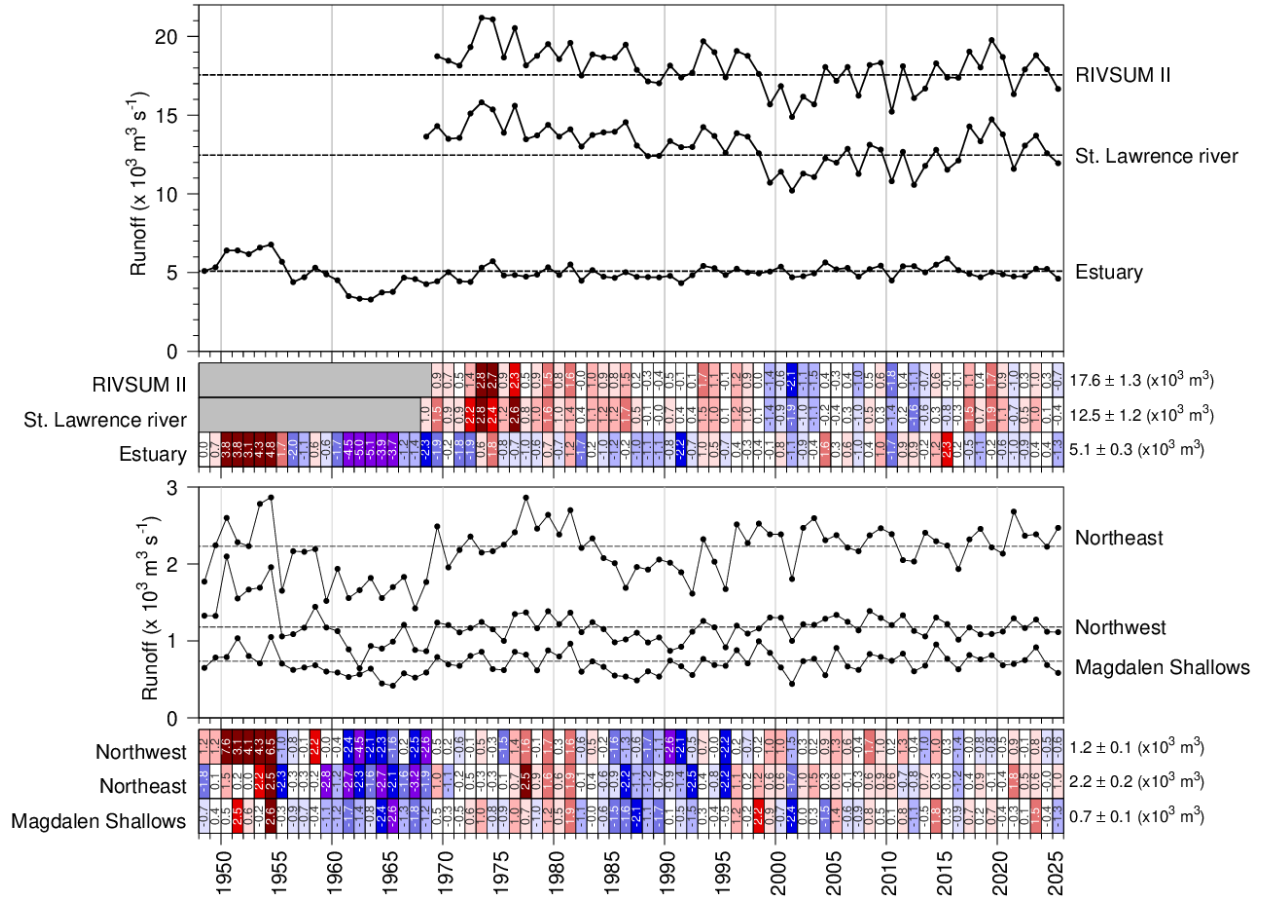


Fig. 10. Annual mean freshwater runoff. (Top panel) Sum of all rivers flowing into the Estuary, the St. Lawrence River at Québec City and their sum, the RIVSUM II. (Bottom panel) Sums of all rivers flowing into three regions of the Gulf. The 1991–2020 climatological means are shown as horizontal lines and indicated on the right side of the scorecards. Numbers in scorecards are normalized anomalies.

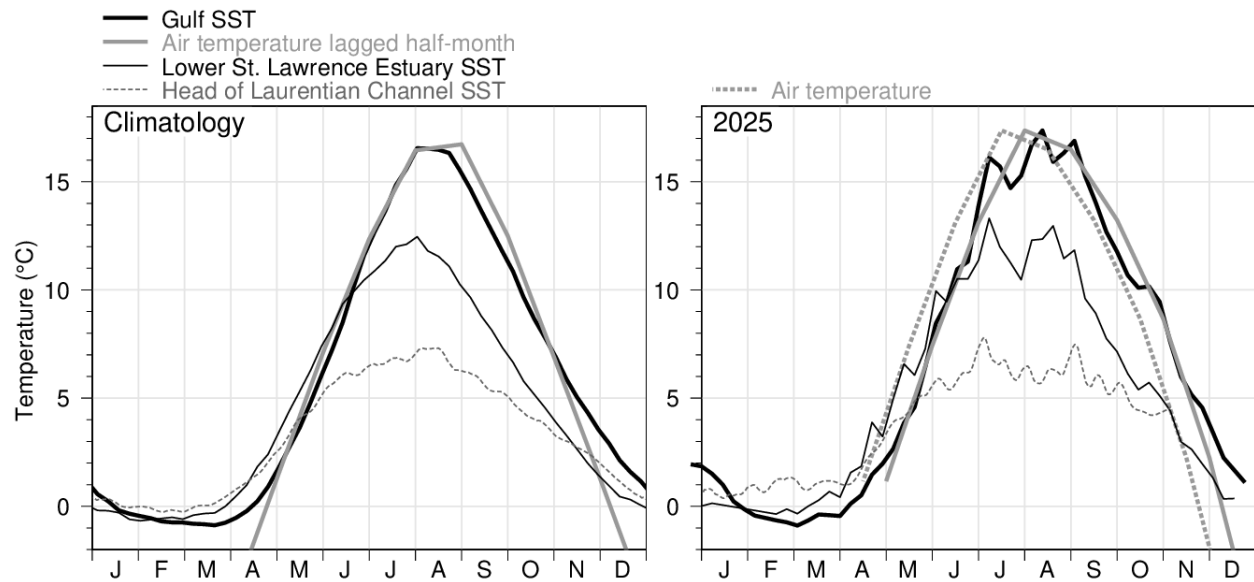


Fig. 11. Sea-surface temperature climatological (1991-2020) and 2025 seasonal cycle in the Gulf of St. Lawrence. Satellite temperature weekly averages are shown for the Gulf (thick black line) and the cooler Lower St. Lawrence Estuary (thin black line). Thermosalinograph data averages are shown for the head of the Laurentian Channel (at 69°30'W, thin grey dashed line). Monthly air temperature averaged over stations in the Gulf of St. Lawrence (excluding the Estuary) are shown offset by 2 weeks into the future (thick grey line; winter months not shown) and also not offset in the annual panel (thick grey dashed line). Figure adapted from Galbraith et al. (2012) using new datasets.

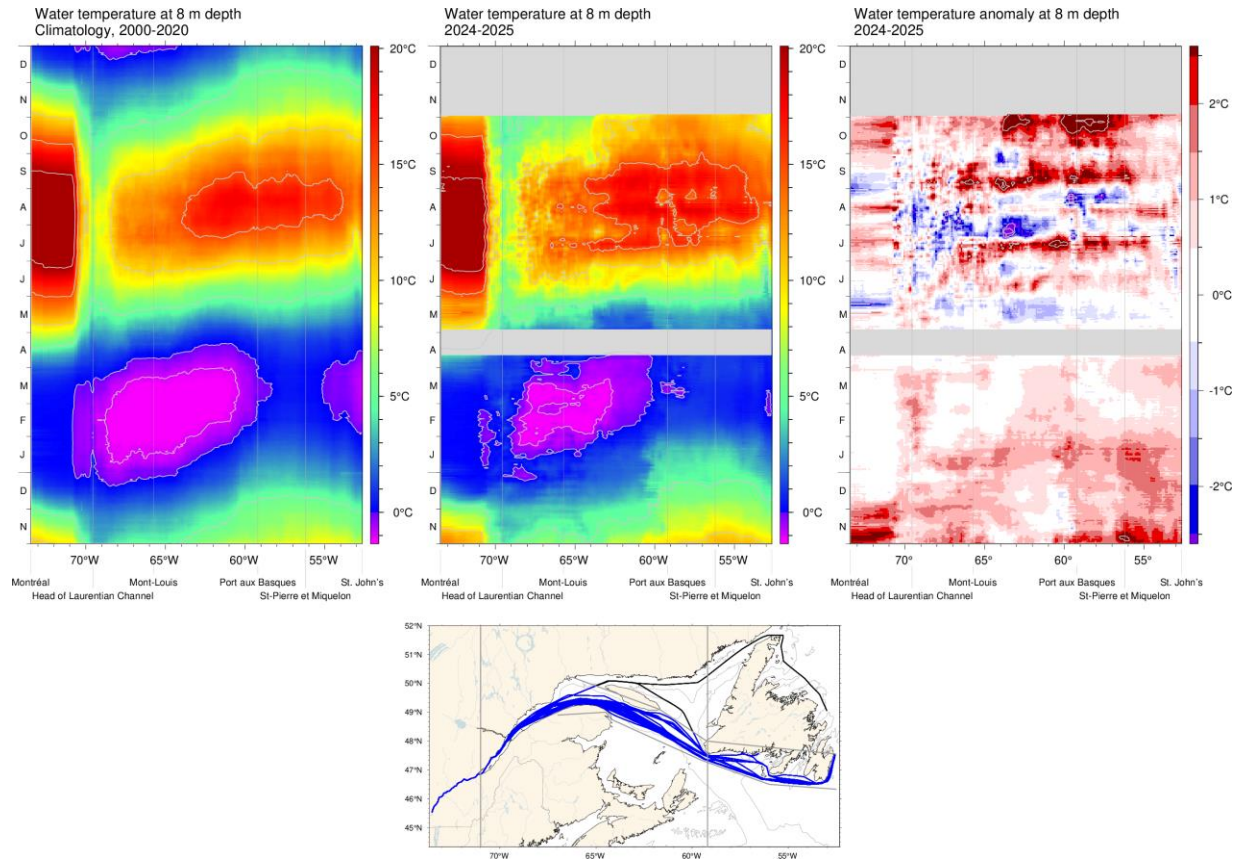


Fig. 12. Hovmöller diagram of thermosalinograph data at 8 m depth along the Montréal to St. John's shipping route: composite mean annual cycle of the water temperature for the 2000–2020 period (top left panel), composite annual cycle of the water temperature for the end of 2024 and 2025 (top middle panel with time increasing along the y-axis), and water temperature anomaly relative to the 2000–2020 composite (top right panel). The map indicates all 89 ship tracks in 2025, with those in blue used in the analysis.

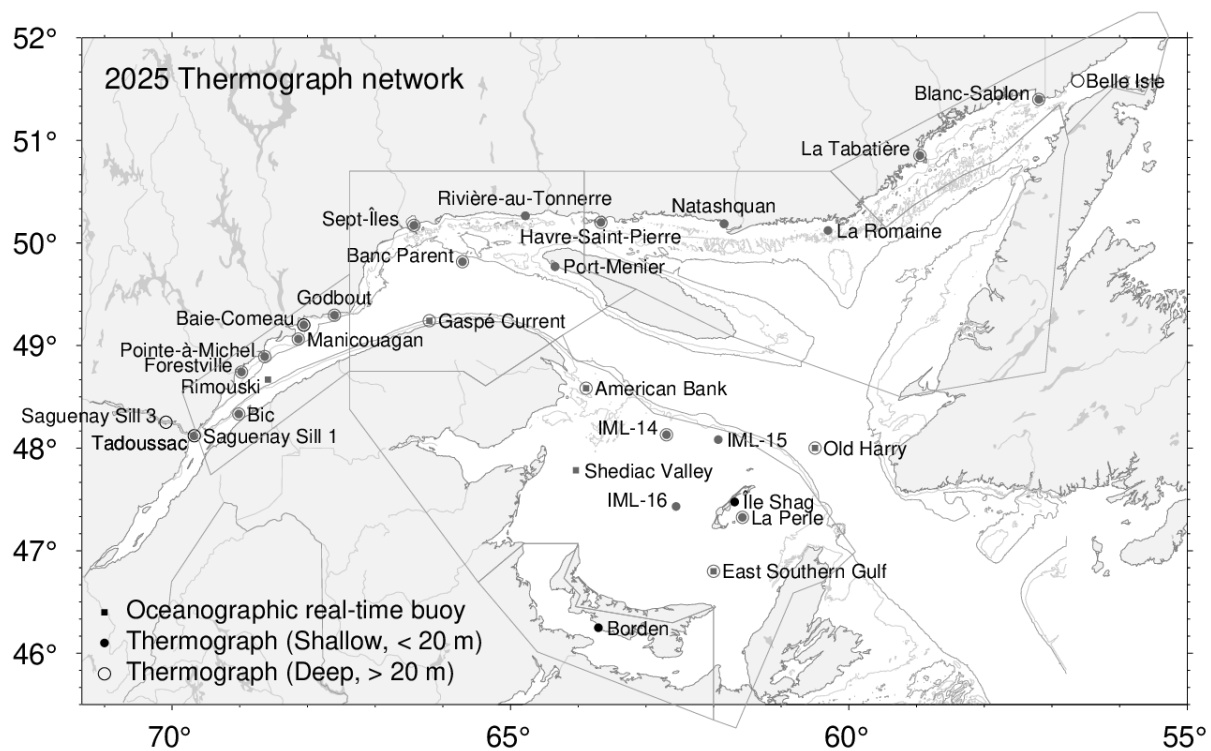


Fig. 13. Maurice Lamontagne Institute thermograph network stations in 2025, including oceanographic buoys that transmit data in real time (squares). Deep and shallow instruments are denoted by open circles and dots, while seasonal and year-round deployments are denoted by grey and black symbols. Belle Isle station includes an upward-looking current profiler (ADCP) to estimate transports through the Strait.

Estuary and NW Gulf / Estuaire et NO du Golfe

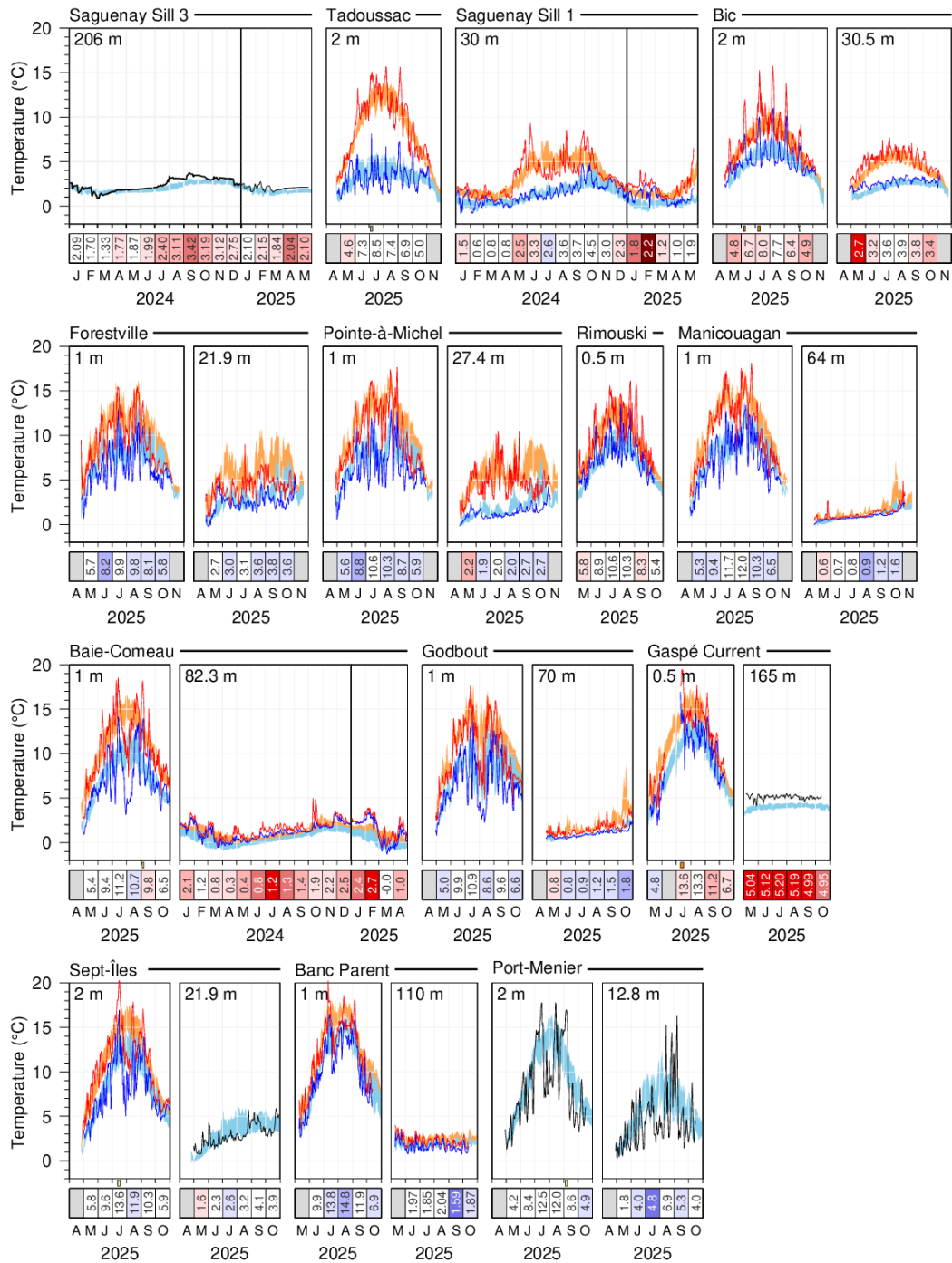


Fig. 14. Thermograph network daily mean temperatures (black line) compared with the daily climatology (blue areas are daily climatological averages ± 0.5 SD) for stations in the Estuary and northwestern Gulf. Stations that exhibit large tidal variations are displayed showing daily minimum (blue) and maximum (red) values, overlying daily climatological averages ± 0.5 SD of the minimum (blue shaded area) and maximum (orange shaded areas) values. Data from 2024 are included for stations collecting data year-round. The scorecards show monthly average temperatures in °C colour-coded according to the monthly normalized anomalies based on the climatologies for each month. Periods of marine heatwave conditions are shown by yellow (moderate), orange (strong), burgundy (severe) or purple (extreme) rectangular patches.

Lower North Shore / Basse Côte Nord

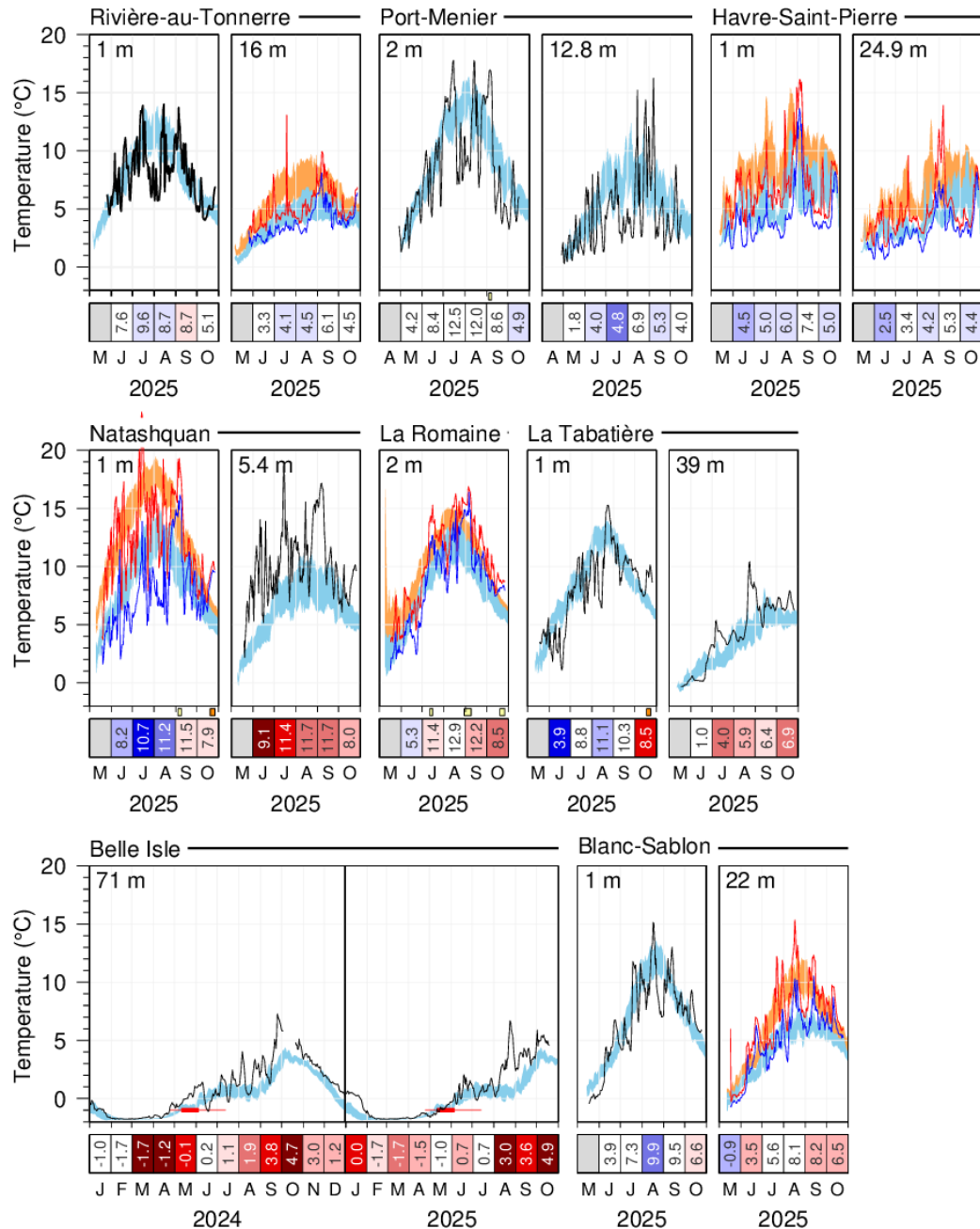


Fig. 15. Thermograph network data. Daily mean temperatures in 2025 (black line) compared with the daily climatology (blue areas are daily climatological averages ± 0.5 SD) for stations of the north shore. Stations that exhibit large tidal variations are displayed showing daily minimum (blue) and maximum (red) values, overlying daily climatological averages ± 0.5 SD of the minimum (blue shaded area) and maximum (orange shaded areas) values. Data from 2024 are included for stations collecting data year-round. Thin red lines in the Belle Isle panel span the historical dates when spring temperature increased over -1 °C, a temperature associated with inflow of winter Labrador Shelf Water into the Gulf. Thick red line indicates mean date plus and minus 0.5 SD. The scorecards show monthly average temperatures in °C colour-coded according to the normalized anomalies based on the climatologies for each month. Periods of marine heatwave conditions are shown by yellow (moderate), orange (strong), burgundy (severe) or purple (extreme) rectangular patches.

Southern Gulf / Sud du Golfe

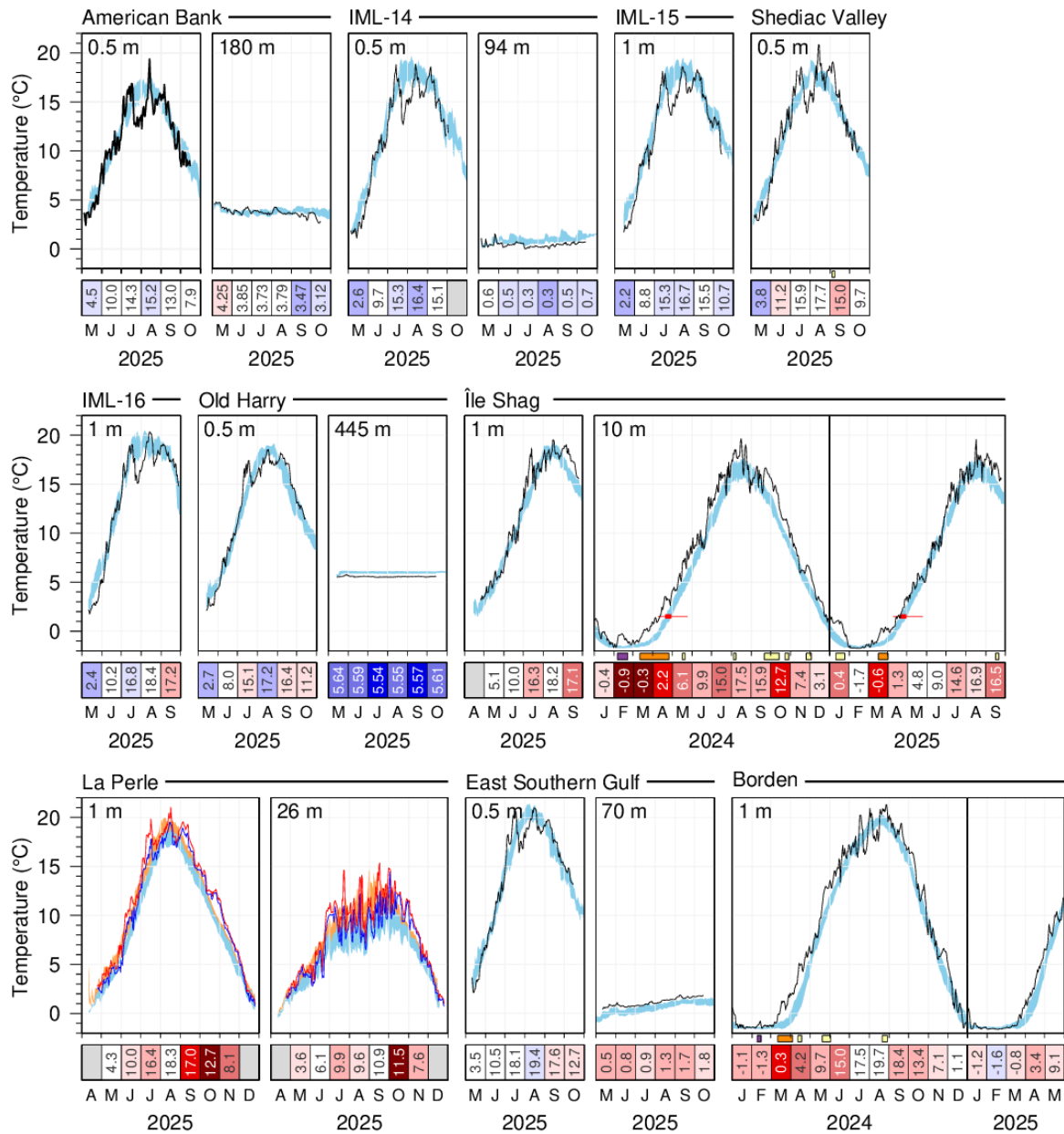


Fig. 16. Thermograph network data. Daily mean 2025 temperatures compared with the daily climatology (daily averages ± 0.5 SD; blue area) for stations of the southern Gulf. Data from 2024 are included for stations collecting data year-round. Thin red lines in the Île Shag panel span the historical dates when spring temperature increased over 1.5°C , a temperature associated with increased lobster mobility. Thick red line indicates mean date plus and minus 0.5 SD. Periods of marine heatwave conditions are shown by yellow (moderate), orange (strong), burgundy (severe) or purple (extreme) rectangular patches.

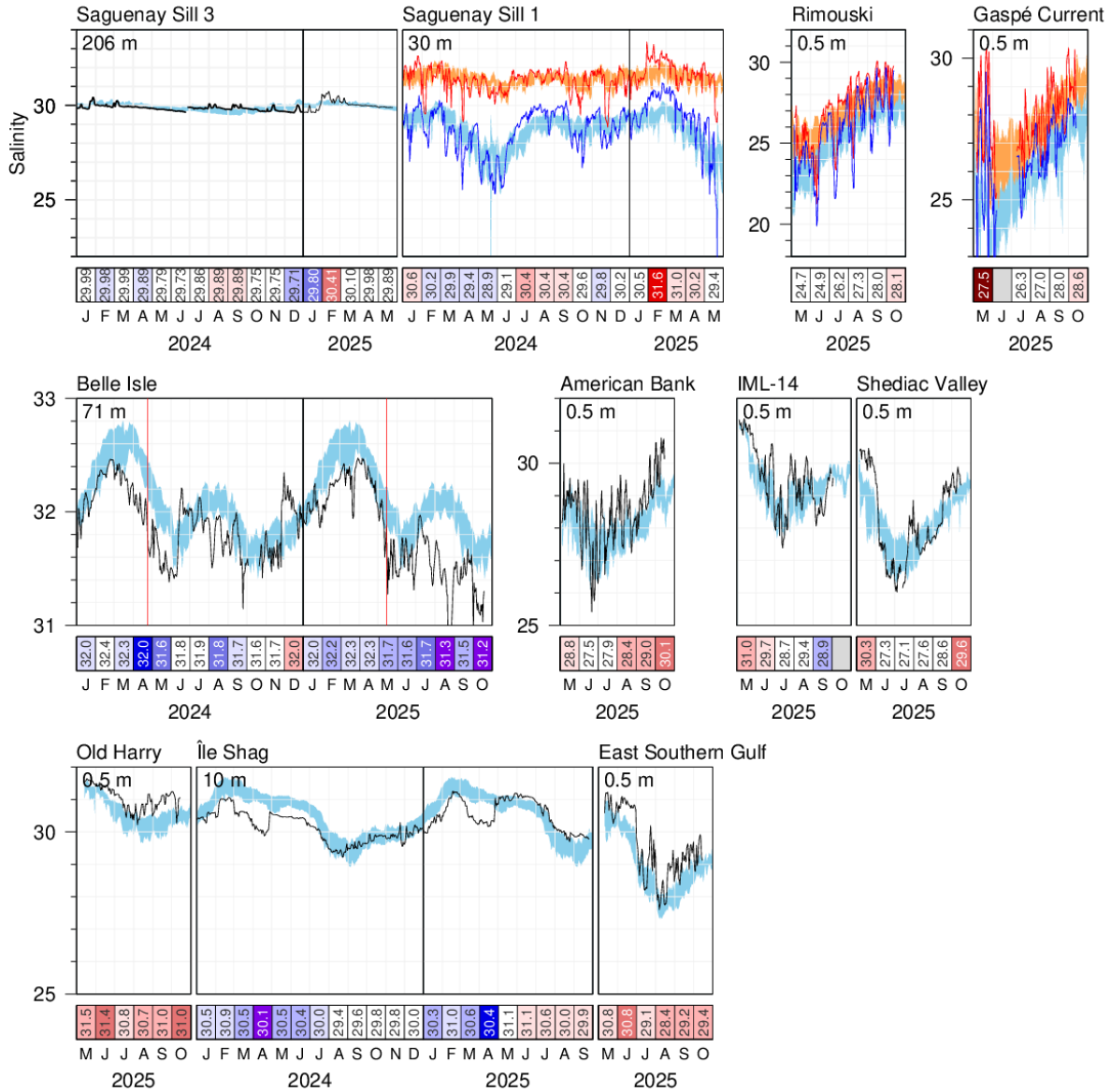


Fig. 17. Thermograph network data. Daily mean 2025 salinities (black lines) compared with the daily climatology (daily averages ± 0.5 SD; blue area) computed from all available stations. Stations that exhibit large tidal variations are displayed showing daily minimum (blue) and maximum (red) values, overlying daily climatological averages ± 0.5 SD of the minimum (blue shaded area) and maximum (orange shaded areas) values. Data from 2024 are included for stations collecting data year-round. The scorecards show monthly average salinities colour-coded according to the normalized anomalies based on the climatologies for each month. Thin red lines in the Belle Isle panel show the date when spring temperature increased over -1 °C (Fig. 15), a temperature associated with inflow of winter Labrador Shelf Water into the Gulf.

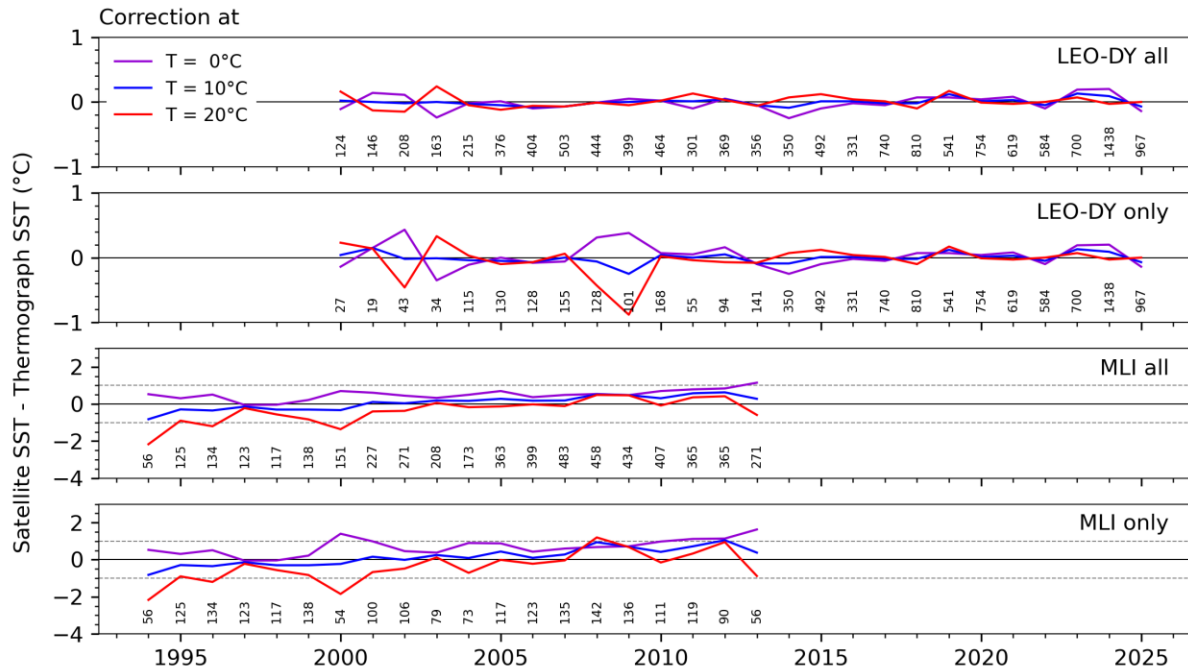


Fig. 18. SST calibration drift, showing the correction that would need to be applied to calibrated SST pixels to best match available daily thermograph/buoy data for each year. Data pairs of offshore thermographs and satellite SST at the corresponding pixels are used when the daily diurnal range at the thermograph is less than the mean value of 1.68°C (i.e. the mean diurnal range of thermograph data up to 2024). Note the different scales for LEO and MLI. Numbers over the abscissa indicate numbers of pairs of pixels.

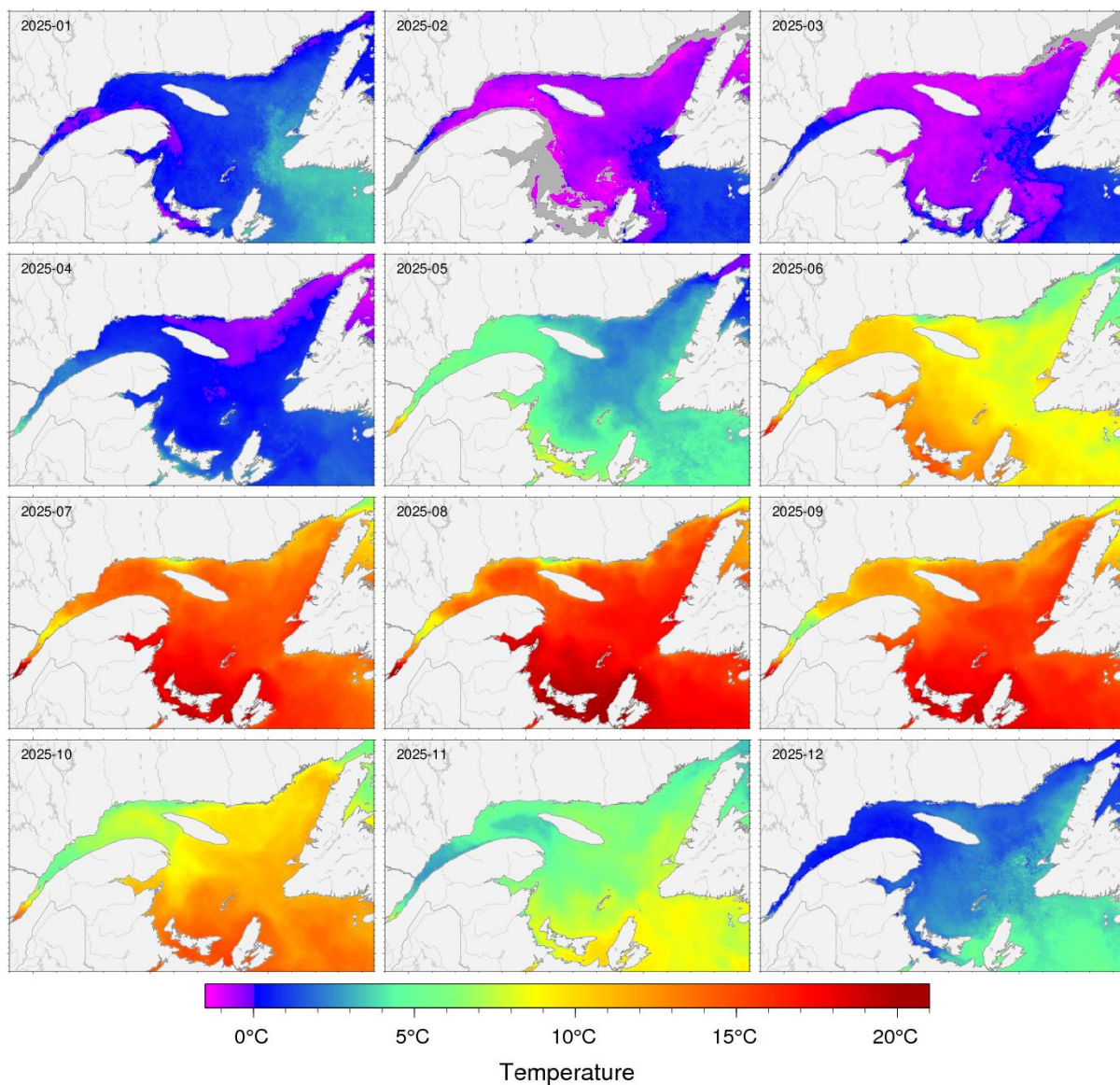


Fig. 19. Sea-surface temperature monthly averages for 2025 as observed with satellite remote sensing. Grey areas have no data for the period due to ice cover or clouds. Temperatures are biased towards warmer ice-free conditions for all months affected by sea ice cover, as the freezing conditions of the ice-covered areas are not captured by satellite.

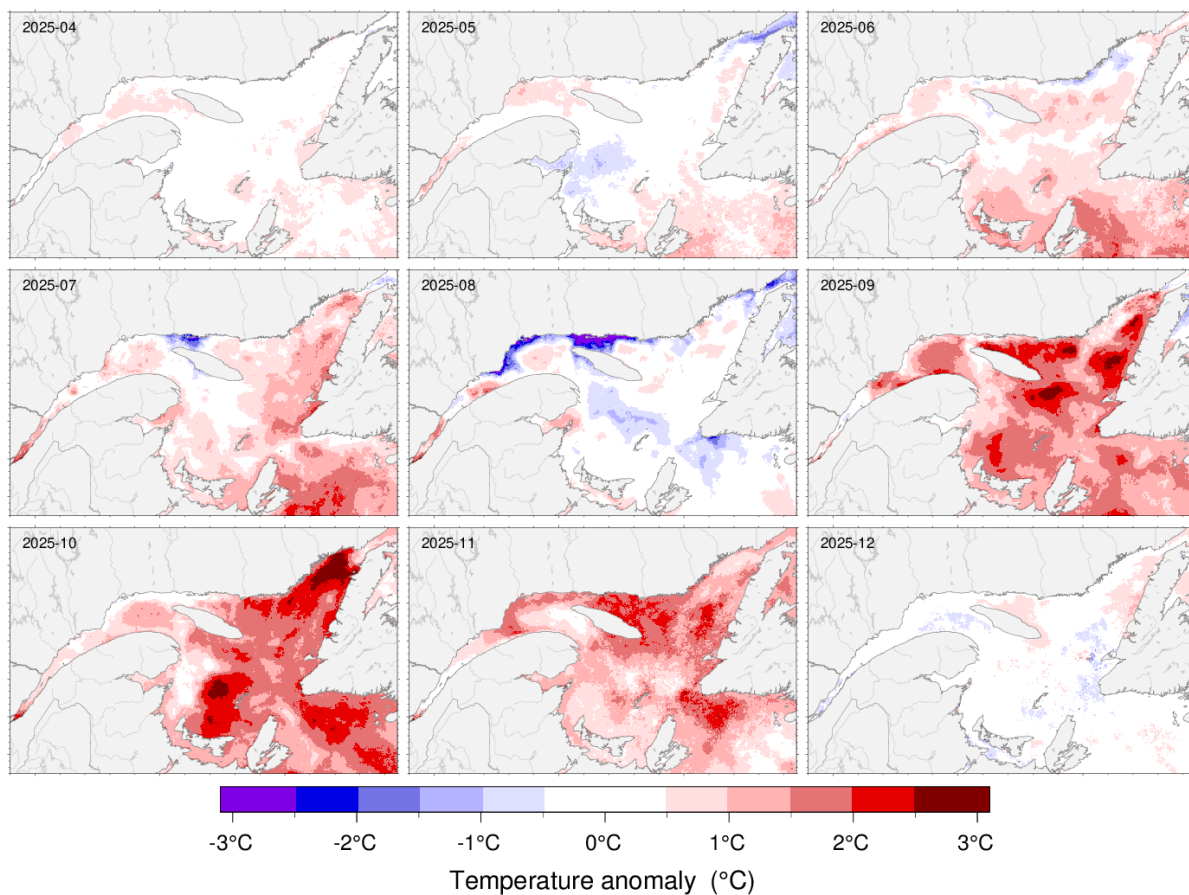


Fig. 20. Sea-surface temperature monthly anomalies for April–December 2025 based on monthly climatologies calculated for the 1991–2020 period observed with satellite remote sensing. Anomalies for January through March are not shown because the climatology maps for those months are heavily biased to warm ice-free conditions in the typical presence of sea ice. The month of April is shown here although there is often sea ice remaining in the Northeast.

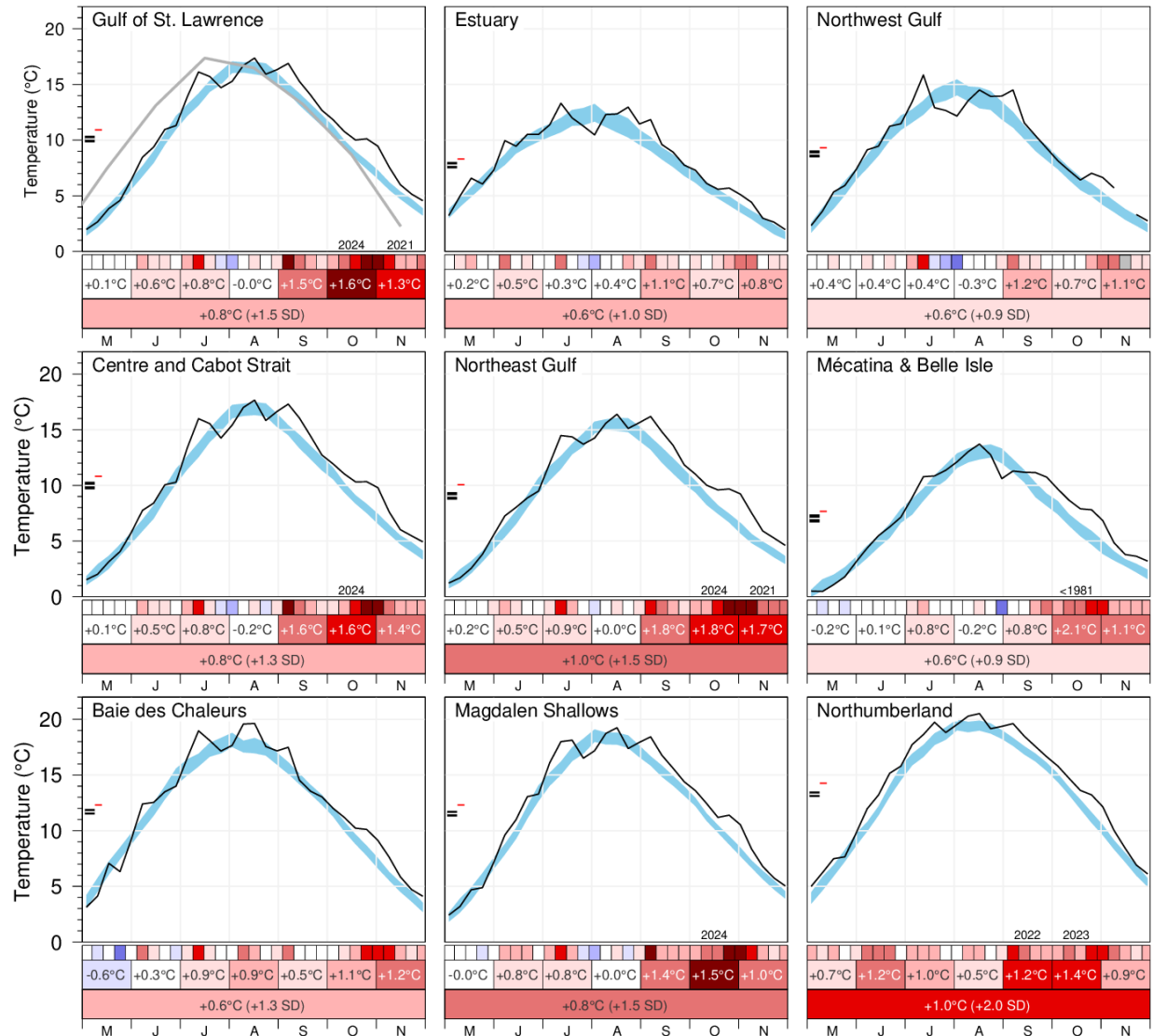


Fig. 21. Satellite SST May to November 2025 weekly, monthly and seasonal averages over the Gulf and over eight regions of the Gulf (December to April are not included as they are not affected by the presence of sea ice in either this year or in the climatology). The blue area represents the 1991–2020 climatological weekly mean ± 0.5 SD. The climatological average plus and minus half the standard deviation of the seasonal mean temperature are indicated by the black double bars on the left side of panels, while the year's seasonal mean is indicated by the red line. For anomalies greater than 2 SD from normal, the prior year with a greater anomaly is indicated, with the less-than symbol (<) indicating a series record since that first year of observations. The thick grey line in the Gulf panel is the monthly average air temperature (Fig. 4). The scorecards are colour-coded according to the normalized anomalies based on the 1991–2020 climatologies for each week (top row), month (middle row) or for the May–November period (bottom row), but the monthly numbers are average temperature anomalies.

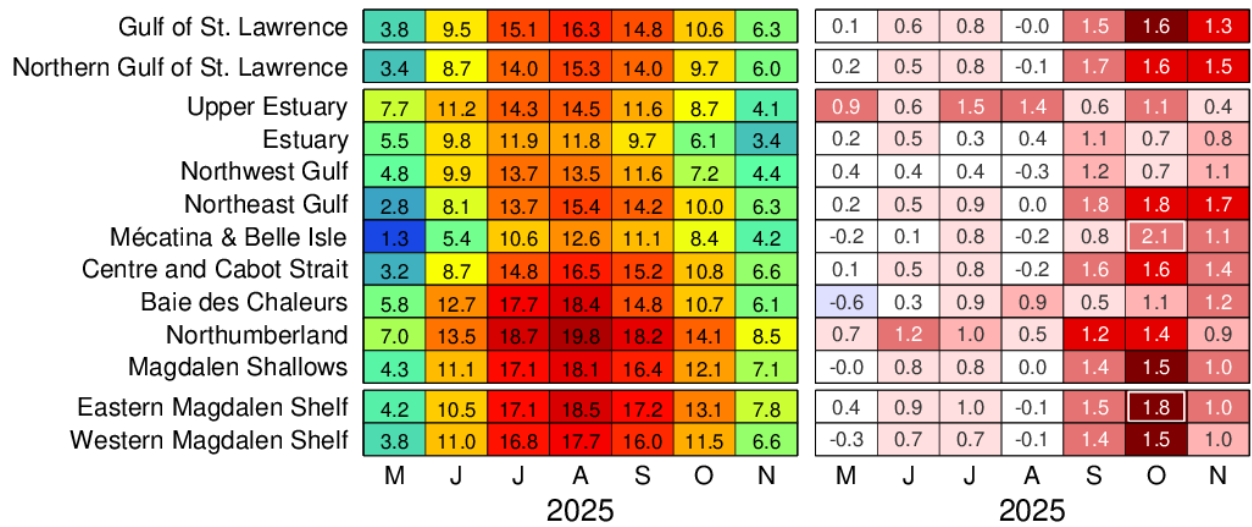


Fig. 22. Satellite SST May to November monthly temperatures and anomalies, averaged over the Gulf and over regions of the Gulf for 2025. The numbers on the left-hand panel are area average temperatures and are colour-coded accordingly. The right-hand scorecards are colour-coded according to the monthly normalized anomalies based on the 1991–2020 climatologies for each month, but the numbers are the monthly average temperature anomalies expressed in °C; series records are indicated by a white outline. The northern Gulf of St. Lawrence region corresponds to northwest Gulf, northeast Gulf, Centre and Cabot Strait and is reported in the AZMP zonal report.

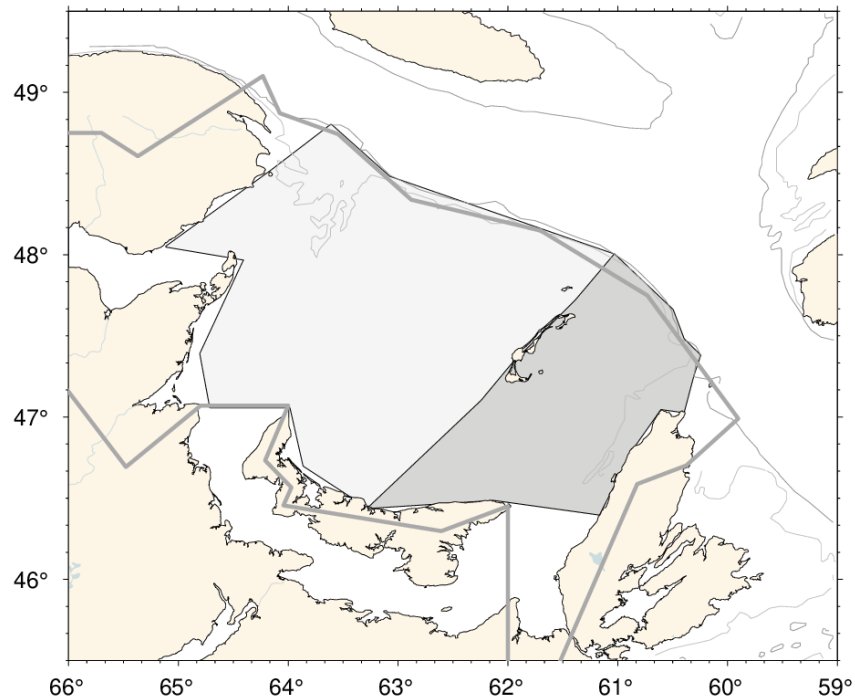


Fig. 23. Areas defined as the western and eastern Magdalen Shelf. The thick grey line shows the outline of the Ecosystem Approach region for the Magdalen Shallows (Fig. 2).

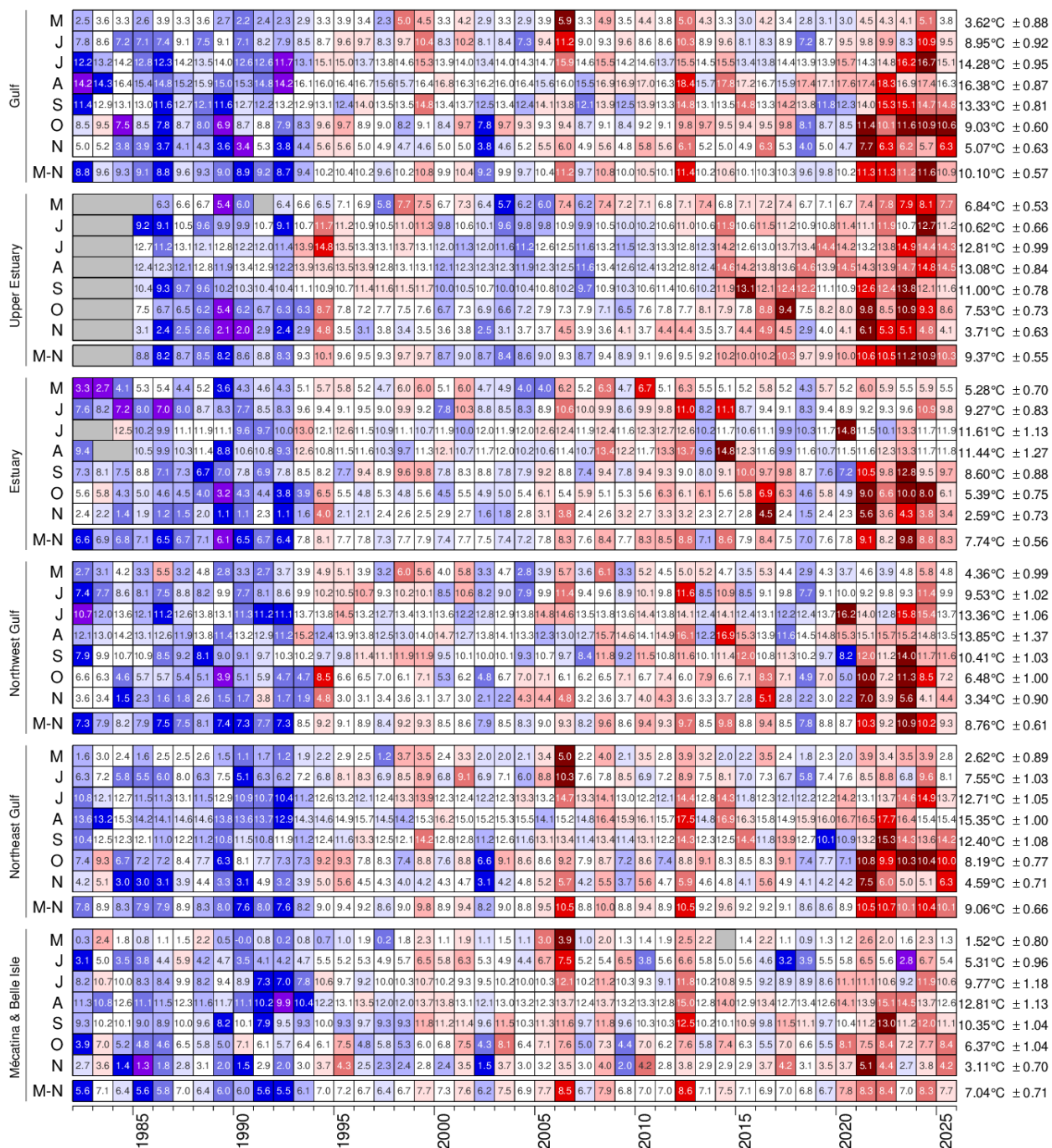
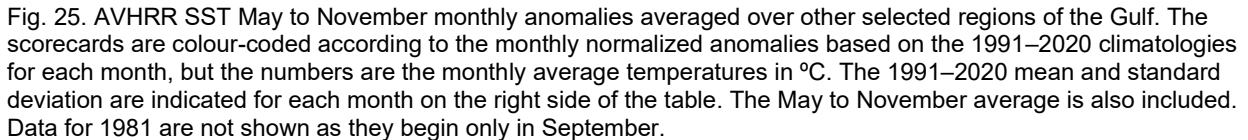


Fig. 24. AVHRR SST May to November monthly anomalies averaged over the Gulf of St. Lawrence and over selected regions of the Gulf. The scorecards are colour-coded according to the monthly normalized anomalies based on the 1991–2020 climatologies for each month, but the numbers are the monthly average temperatures in °C. The 1991–2020 mean and standard deviation are indicated for each month on the right side of the table. The May to November average is also included. Data for 1981 are not shown as they begin only in September.



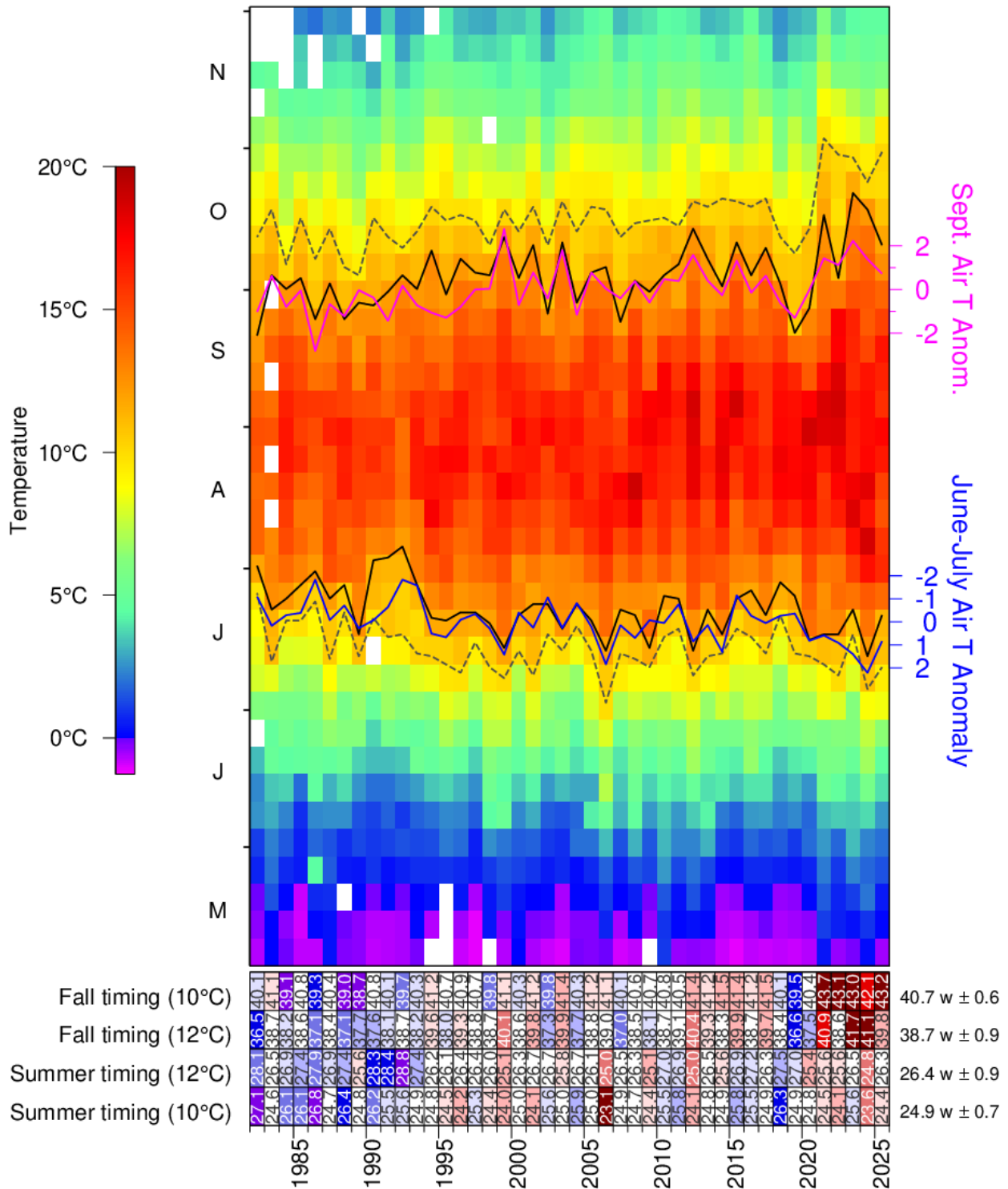


Fig. 26. Weekly average SST (1982–2025) matrix for the Gulf of St. Lawrence. Black lines show the first and last occurrence of the 12 °C isotherm and proxies based on June-July (blue line) and September (magenta) average air temperature anomalies are also shown (axes on right). Dashed gray lines show the first and last occurrence of the 10 °C isotherm. The scorecards are colour-coded according to the normalized anomalies based on the 1991–2020 time series, but the numbers are week numbers when the threshold was crossed. Updated from Galbraith and Larouche (2013).

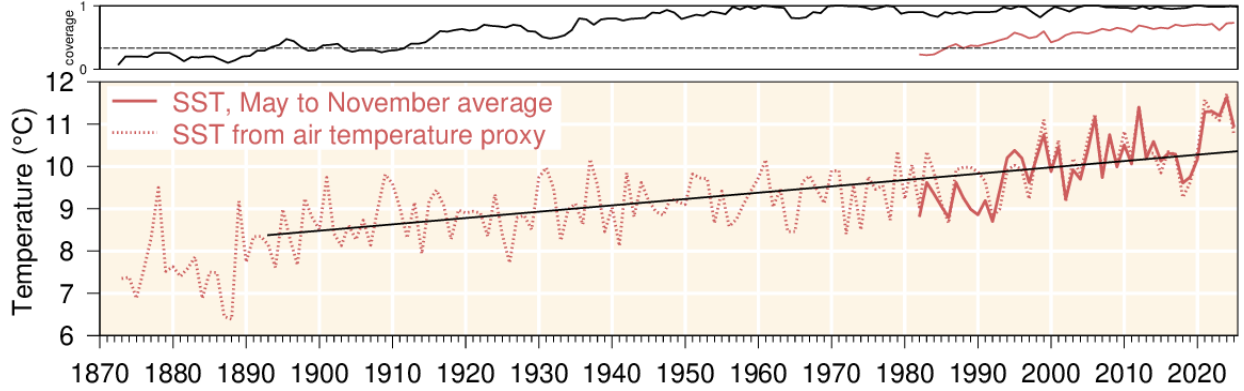


Fig. 27. May-November averaged SST (1982-2025, red solid line) over the Gulf of St. Lawrence, excluding the Estuary, and proxy (dashed line) from averaged April-April-November air temperature from 10 stations located around the Gulf (Fig. 4). The coefficient of determination between the SST and air temperature proxy is $R^2 = 0.81$ over the period 1982-2025. The top panel shows the annual coverage of SST pixels (red) and of meteorological station data (black) and the dash line indicates $\frac{1}{3}$ coverage used as a threshold for meteorological data. The linear regression of the combined proxy and SST time series is shown for the period of 1893-2025, when meteorological station coverage begins to exceed $\frac{1}{3}$. The trend is 1.5°C per 100 years.

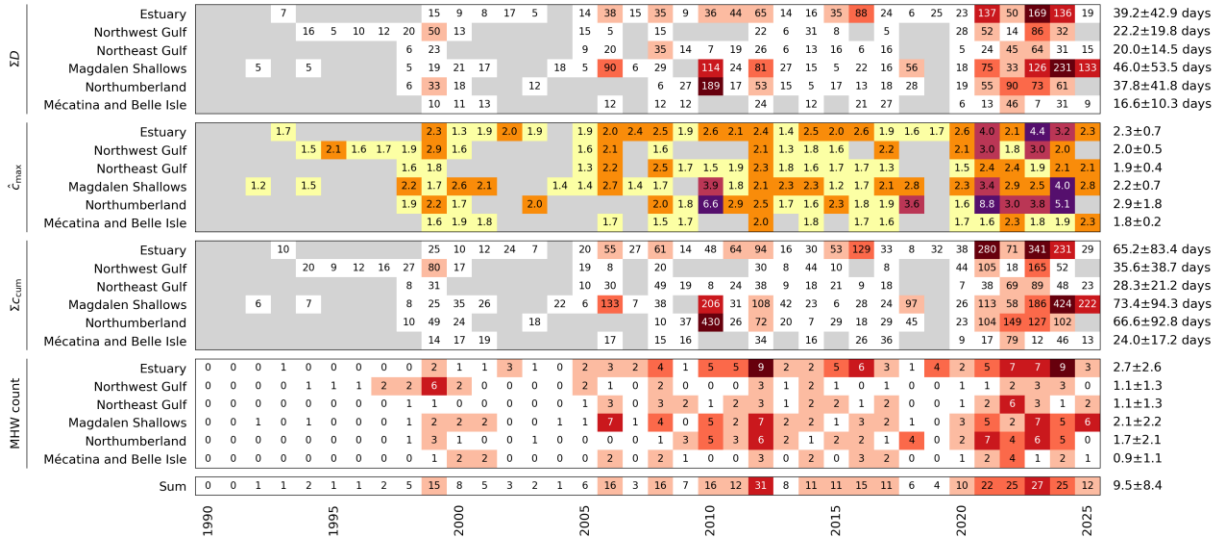


Fig. 28. Aggregated MHW metrics by region. From top to bottom are shown ΣD , $c_{\max}$, ΣC_{cum} , and the number of MHW events. Boxes are colour-coded according to their values. To emphasize larger events, values up to the mean of each panel are coloured white and shades of red darken with increasing values by one standard deviation for each shade. The $c_{\max}$ panel is colour-coded to the corresponding MHW category: yellow (moderate), orange (strong), burgundy (severe) or purple (extreme). The mean and standard deviation are shown to the right for each station. All results are based on daily data from thermograph network stations within each region.

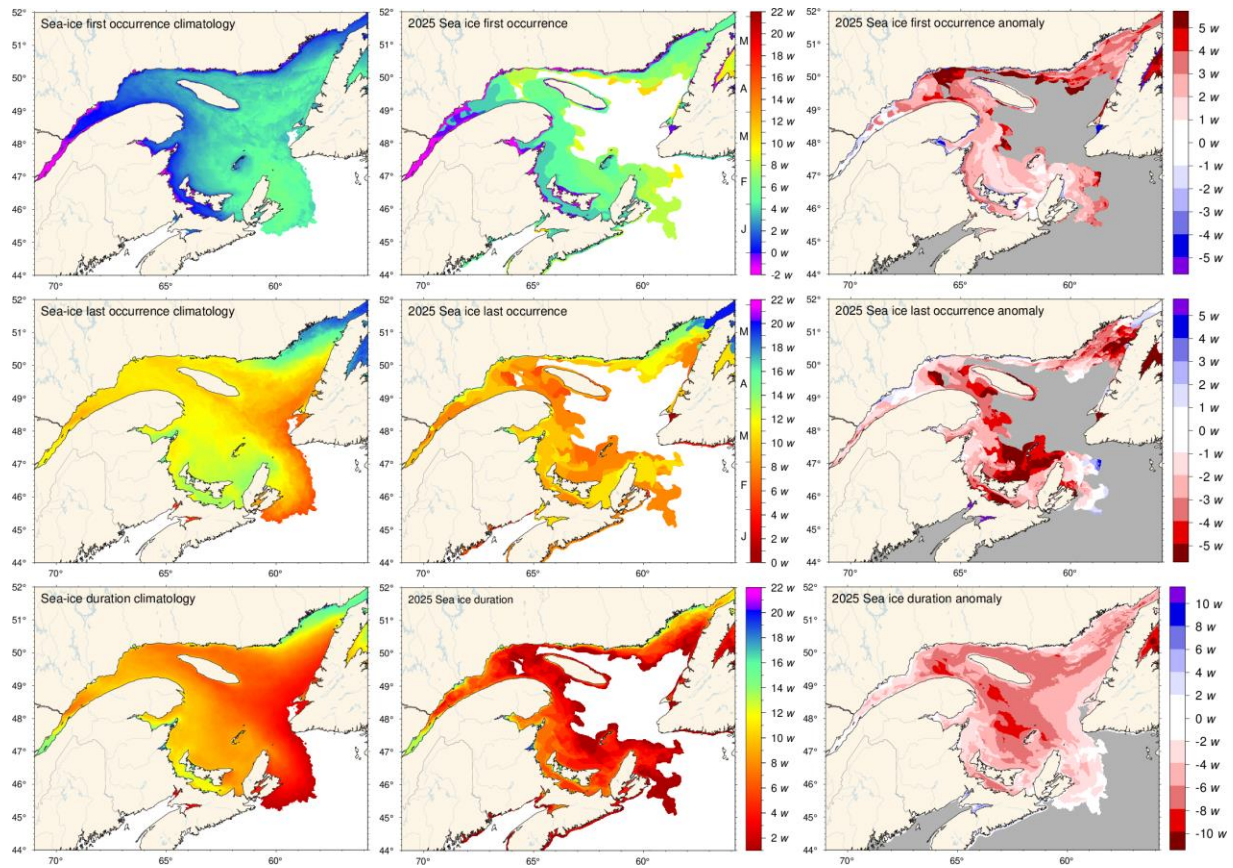


Fig. 29. First and last occurrence of ice and ice season duration based on weekly data. The 1991–2020 climatologies are shown (left) as well as the 2025 values (middle) and anomalies (right). First and last occurrence is defined here as the first and last weekly chart in which any amount of ice is recorded for each pixel and are illustrated as week-of-year. Negative numbers for first occurrence are in December of previous year. Ice duration sums the number of weeks with ice cover for each pixel. Climatologies are shown for pixels that had at least 15 years out of the 30 with occurrence of sea-ice, and therefore also show the area with 50% likelihood of having some sea-ice at any time during any given year.

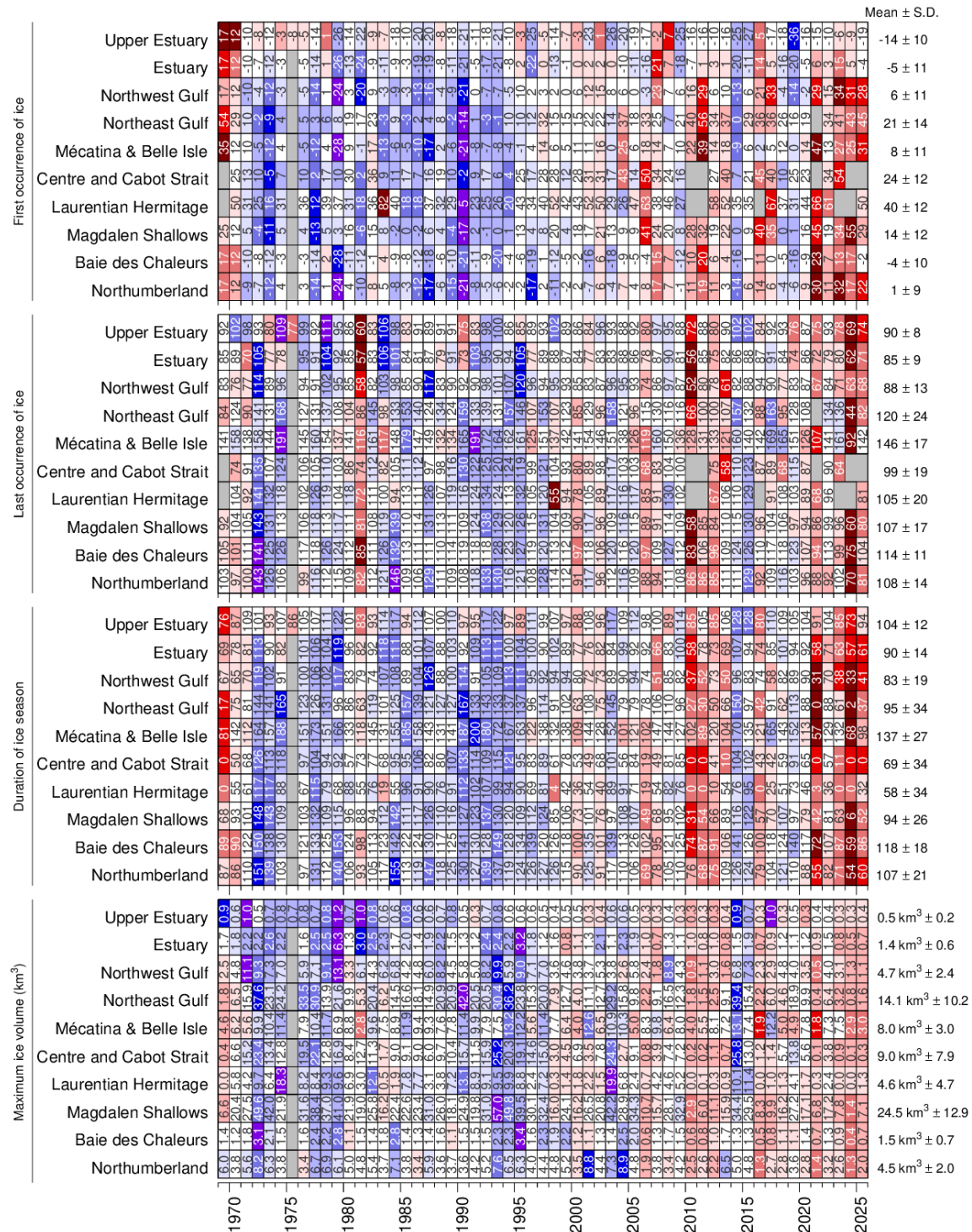


Fig. 30. First and last day of ice occurrence, ice duration and maximum seasonal ice volume by region. The time when ice was first and last seen in days from the beginning of each year is indicated for each region, and the colour code expresses the anomaly based on the 1991–2020 climatology, with blue (cold) representing earlier first occurrence and later last occurrence. Negative numbers are in the previous year. The threshold to determine dates of first and last occurrence is 5% of the largest ice volume ever recorded in the region. Numbers in the table are the actual day of the year or volume, but the colour coding is according to normalized anomalies based on the climatology of each region. Duration is the number of days that the threshold was exceeded. All results based on weekly data.

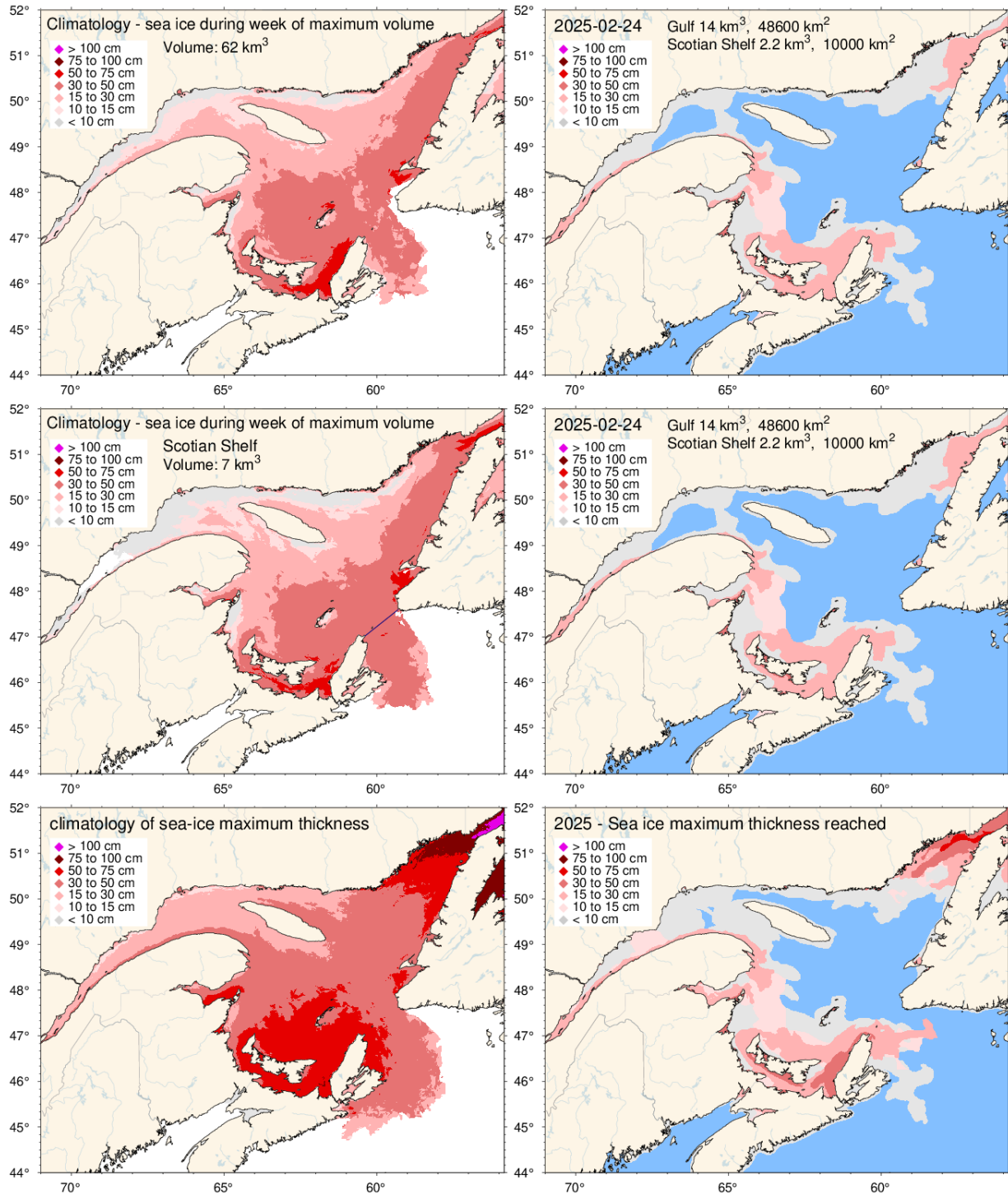


Fig. 31. Ice thickness maps for 2025 for the week of the year with the maximum volume of the Gulf including the portion covering the Scotian Shelf (upper right panel), with the maximum volume on the Scotian Shelf (middle right panel) and similarly for the 1991–2020 climatology of the weekly maximum (upper and middle left panels). The Scotian Shelf is delimited at the blue line in Cabot Strait in the middle left panel. Note that these maps reflect the ice thickness distribution on that week, and not the maximum observed at any given location during the year. That information is shown by the lower panels, showing the 1991–2020 climatology and 2025 distribution of the thickest ice recorded during the season at any location.

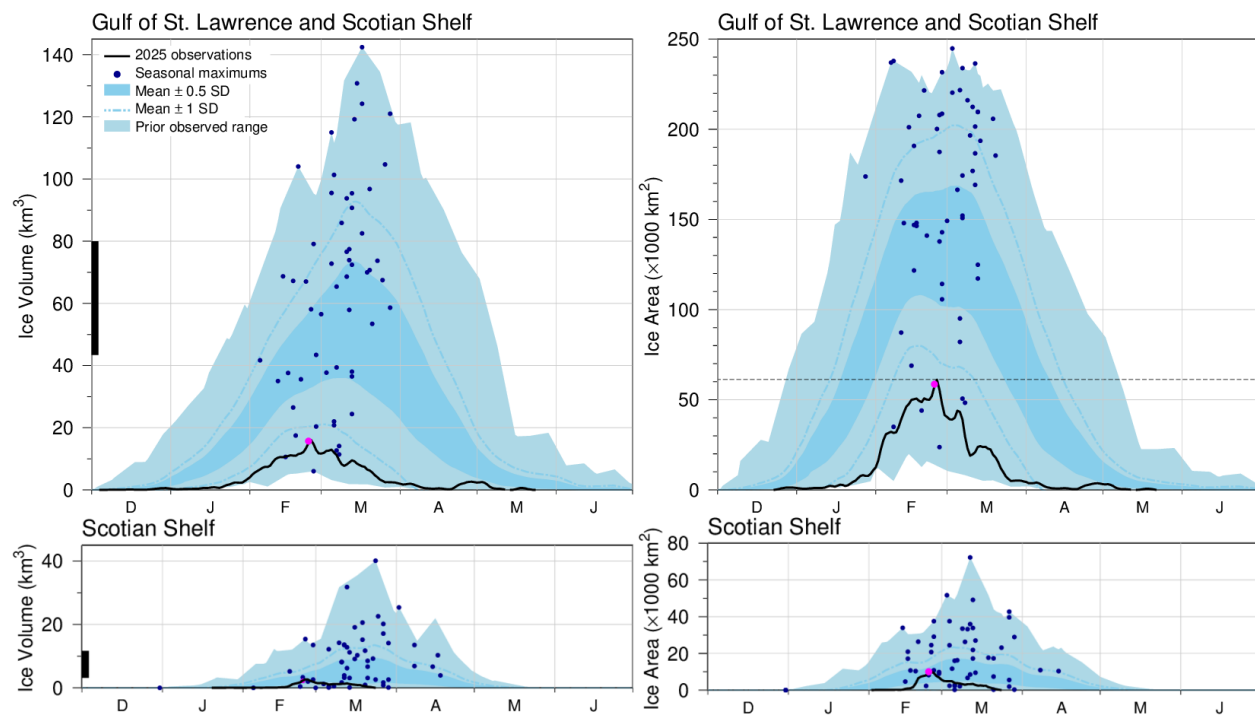


Fig. 32. Time series of the 2024–2025 daily mean ice volume (left) and area (right) for the Gulf of St. Lawrence and Scotian Shelf (top panels, black line) and for the Scotian Shelf (bottom panels, black line). Also shown are the 1991–2020 climatological mean volume plus and minus 0.5 and 1 SD (dark blue area and dashed line), the minimum and maximum span of 1969–2024 observations (light blue) and the date and volumes of 1969–2024 seasonal weekly maxima (blue dots; 2025 weekly chart maximum shown in magenta). The black thick lines on the left indicates the mean volume plus and minus 0.5 SD of the annual maximum ice volume, which is higher than the peak of the mean daily ice volume distribution. The dashed line at 61 200 km² on the area panel indicates the threshold for nearly ice free ice seasons as in Galbraith et al 2024 (one quarter of the 245 000 km² area of the Gulf).

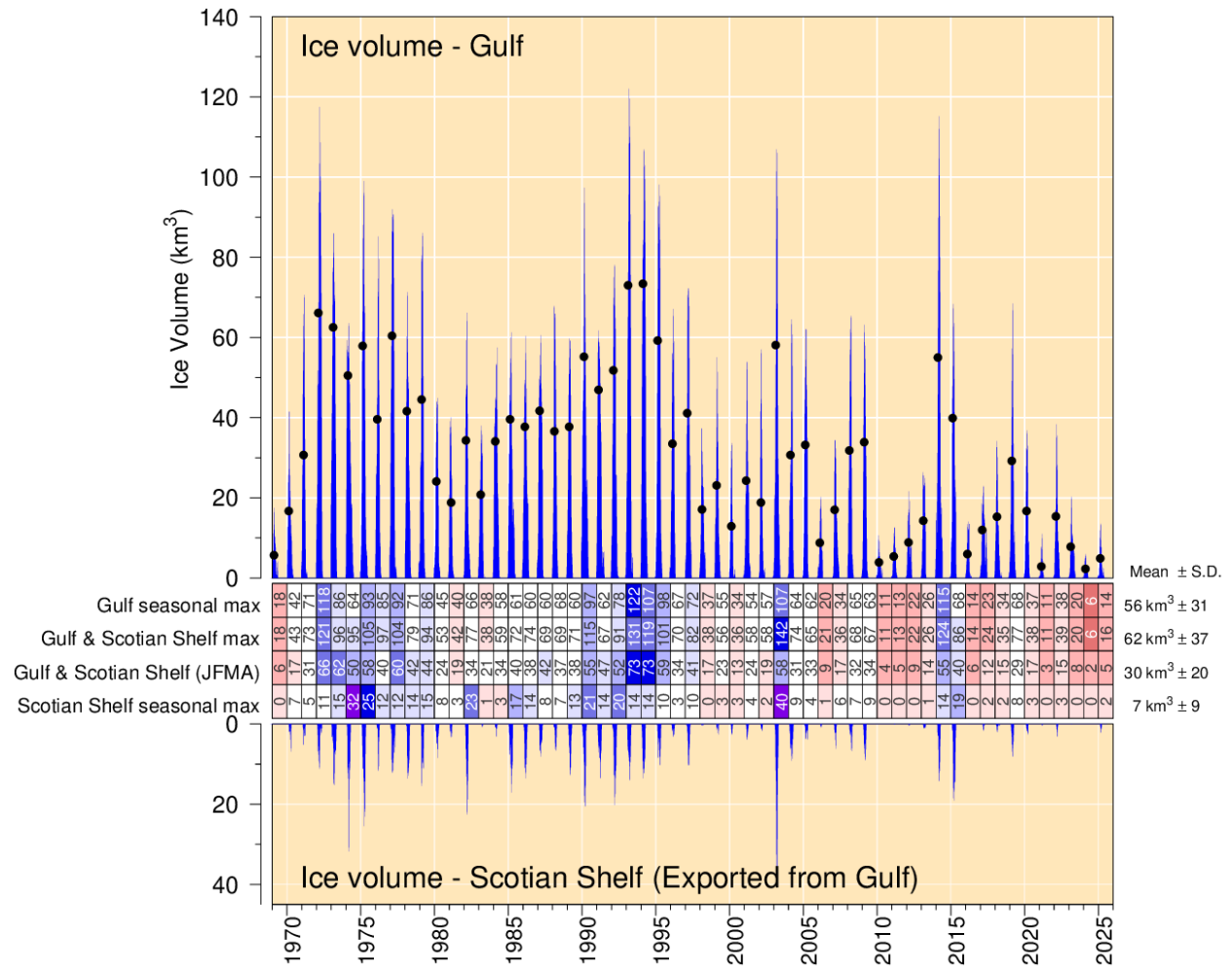


Fig. 33. Estimated weekly maximum ice volume in the Gulf of St. Lawrence (upper panel) and on the Scotian Shelf seaward of Cabot Strait defined by its narrowest crossing (lower panel). Dots show January-April averages of combined Gulf and Scotian Shelf volumes. Scorecards show Gulf seasonal maximums, combined Gulf and Shelf seasonal maximums, combined Gulf and Shelf January to April average, and Shelf-only annual maximum volumes, all from weekly ice data. The mean and standard deviation are indicated on the right side using the 1991–2020 climatology. The colour-coding are according to normalized anomalies based on the 1991–2020 climatologies, but the numbers are volumes in km^3 .

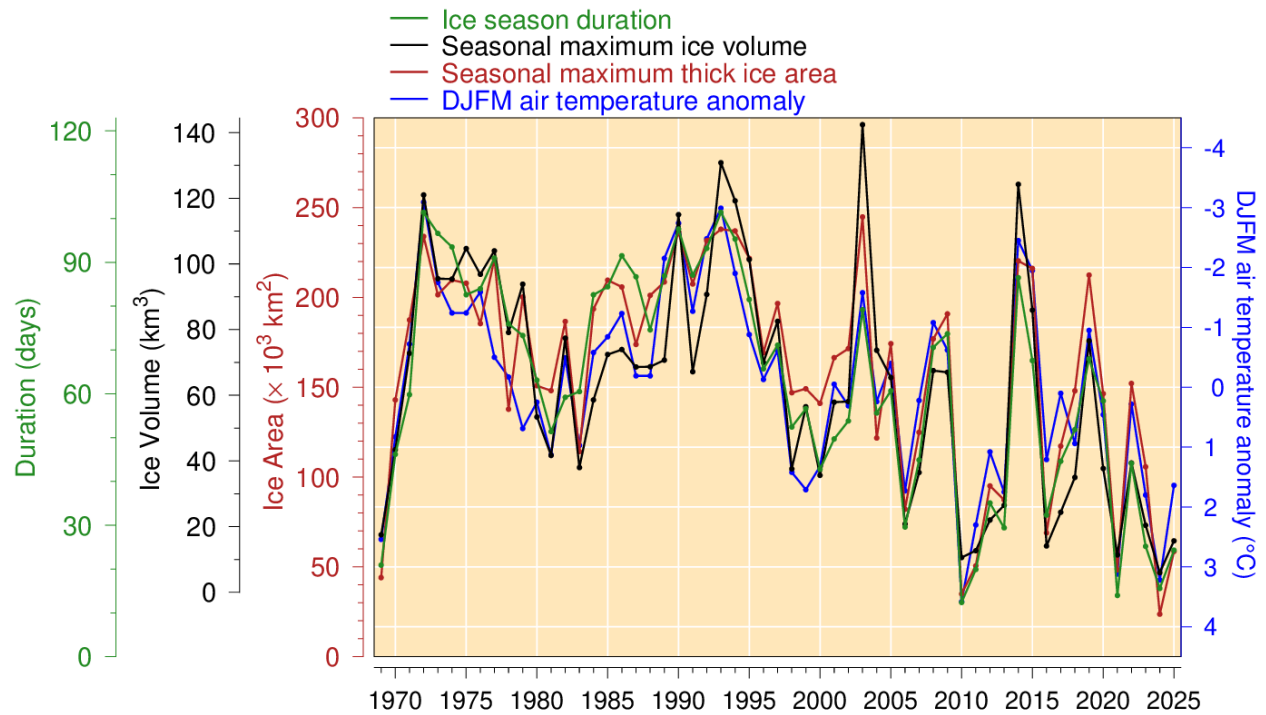


Fig. 34. Seasonal maximum ice volume (black line) and area (red) including the portion on the Scotian Shelf (excluding ice less than 15 cm thick), ice season duration (green) and December-to-March (DJFM) air temperature anomaly (blue). All sea-ice products are based on weekly data. Mean duration obtained as spatial average of Fig. 29, excluding the Scotian Shelf, with zeros counted if no ice is present but the climatology has some. Linear relations indicate losses of 19 km^3 , $34\,000 \text{ km}^2$ and 14 days of sea-ice season for each 1°C increase in winter air temperature (R^2 of 0.77, 0.82 and 0.83 respectively). Figure adapted from Galbraith et al. 2024.

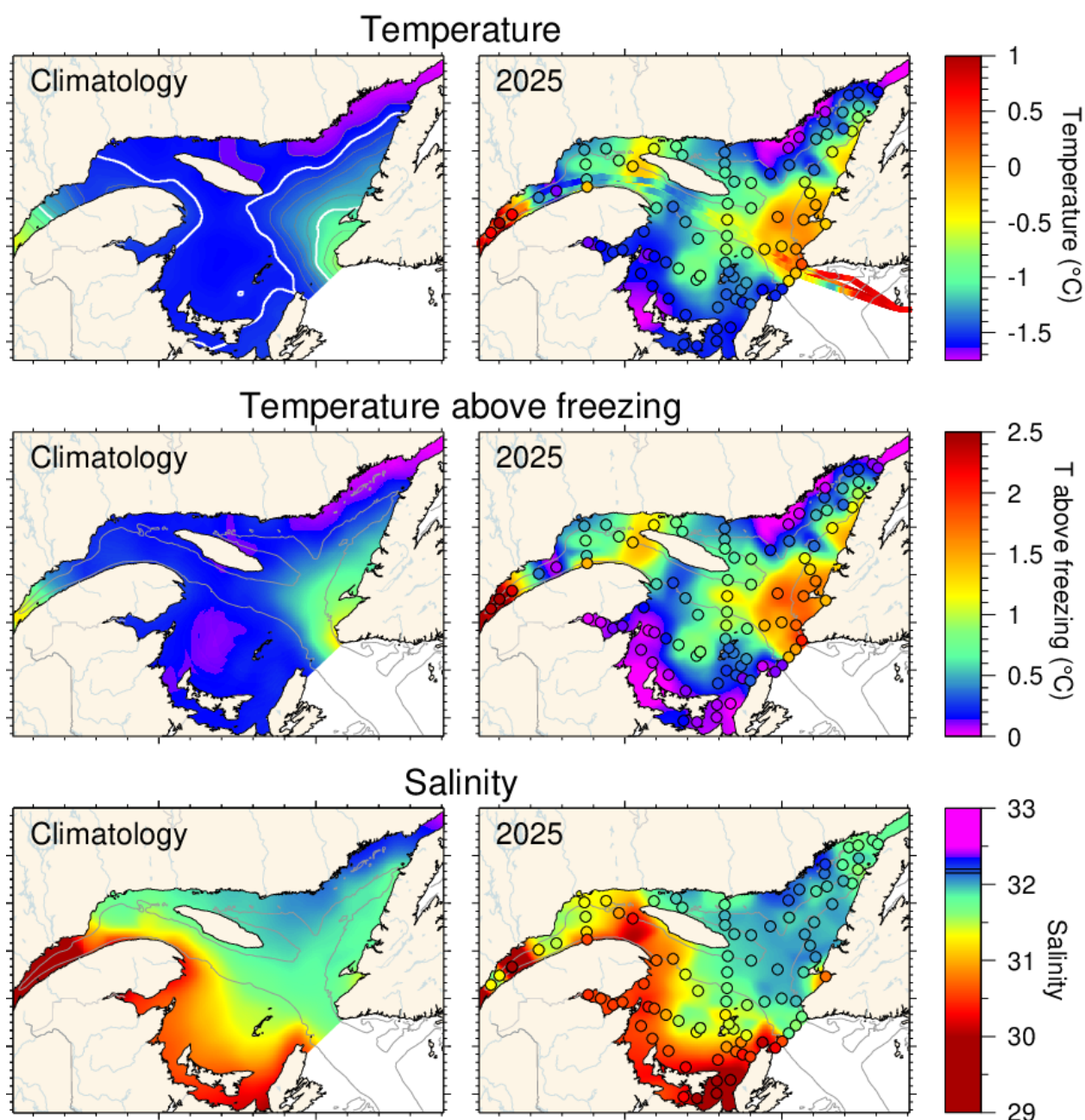


Fig. 35. Winter surface layer characteristics from the March 2025 survey compared with climatological means: surface water temperature (upper panel), temperature difference between surface water temperature and the freezing point (middle panel), and salinity (lower panel). Symbols are coloured according to the value observed at the station, using the same colour palette as the interpolated image. Three crossings of the Oceanex Connaigra thermosalinograph between March 5-14 are also shown. A good match is seen between the interpolation and the station and thermosalinograph observations where the station colours blend into the background. The climatologies are based on 1996–2020 for salinity but exclude 2010 as an outlier for temperature and temperature above freezing (the only unusually warm winter of the 1991-2020 climatology). Near-freezing waters with salinity > 32.35 (indicated in magenta) are generally considered to be too saline to have been formed from waters originating within the Gulf and are presumed to have been advected as an intrusion from the Labrador Shelf through the Strait of Belle Isle. In 2025 specifically, visual analysis of temperature-salinity diagrams suggests that salinities higher than 32.15 to 32.20 (indicated by the black lines in the salinity colour palette) are Labrador Shelf waters.

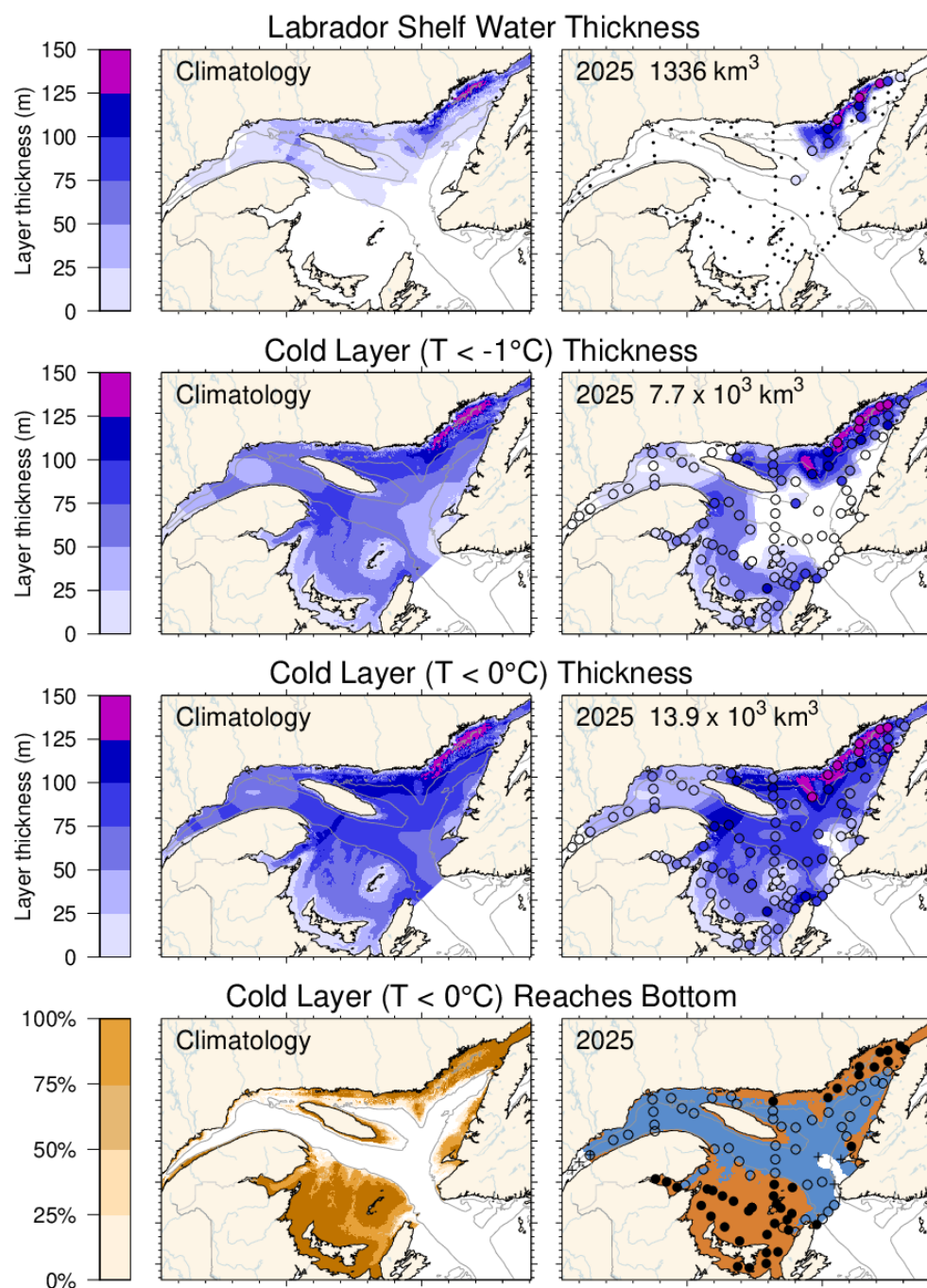


Fig. 36. Winter surface layer characteristics from the March 2025 survey compared with climatological means: estimates of the thickness of the Labrador Shelf water intrusion (upper panels), cold layer ($T < -1^{\circ}\text{C}$, $T < 0^{\circ}\text{C}$) thickness (middle panels), and maps indicating where the cold layer ($T < 0^{\circ}\text{C}$) reaches the bottom (in brown; lower panels; blue indicates the $< 0^{\circ}\text{C}$ layer was present but did not reach the bottom). Station symbols are coloured according to the observed values as in Fig. 35. 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. Crosses indicate no water present colder than the threshold of 0°C . Integrated volumes are indicated for the first six panels (including an approximation for the Estuary but excluding the Strait of Belle Isle). The climatologies are based on 1997–2020 for the Labrador Shelf water intrusion, 1996–2020 for the cold layer ($T < 0^{\circ}\text{C}$) but excludes 2010 for $T < -1^{\circ}\text{C}$. The climatology of the cold layer reaching the bottom is expressed in classes of percentages.

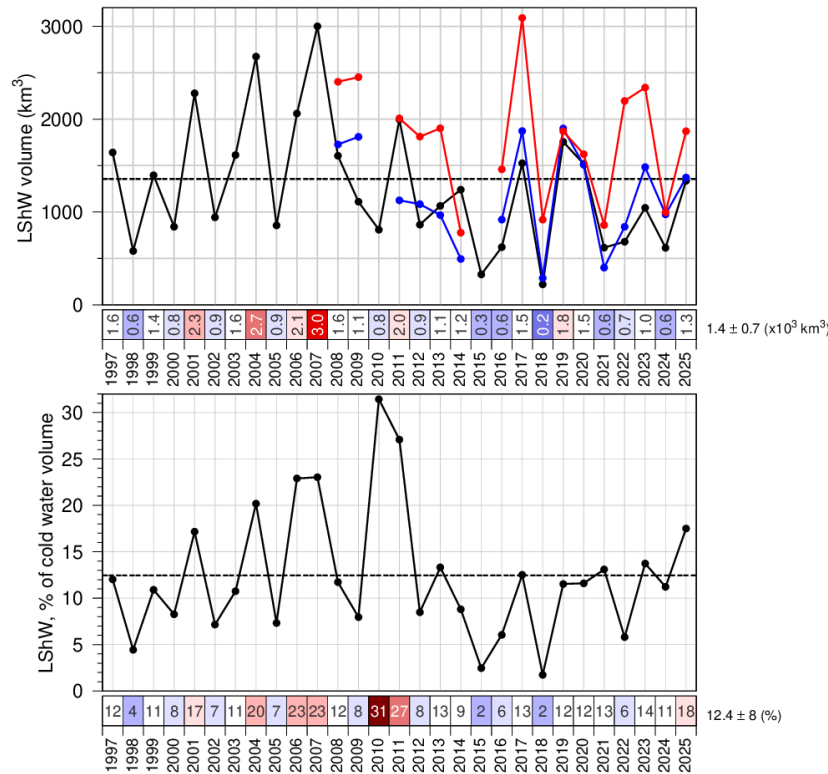


Fig. 37. Estimated volume of cold and saline Labrador Shelf water that flowed into the Gulf over the winter through the Strait of Belle Isle, as measured by temperature-salinity properties observed during March surveys (black). The bottom panel shows the volume as a percentage of total cold-water volume ($< -1^\circ\text{C}$) of the entire Gulf. The numbers in the boxes are actual values colour-coded according to their 1997–2020 climatology anomaly. Coverage of Mécatina Trough was insufficient in 1996 to provide an estimated volume. The top panel also includes the volume integrated from estimated transport in the Strait of Belle Isle up to March 15th (blue) and up to the end of the inflow in late spring (red), an update to Shaw & Galbraith 2023.

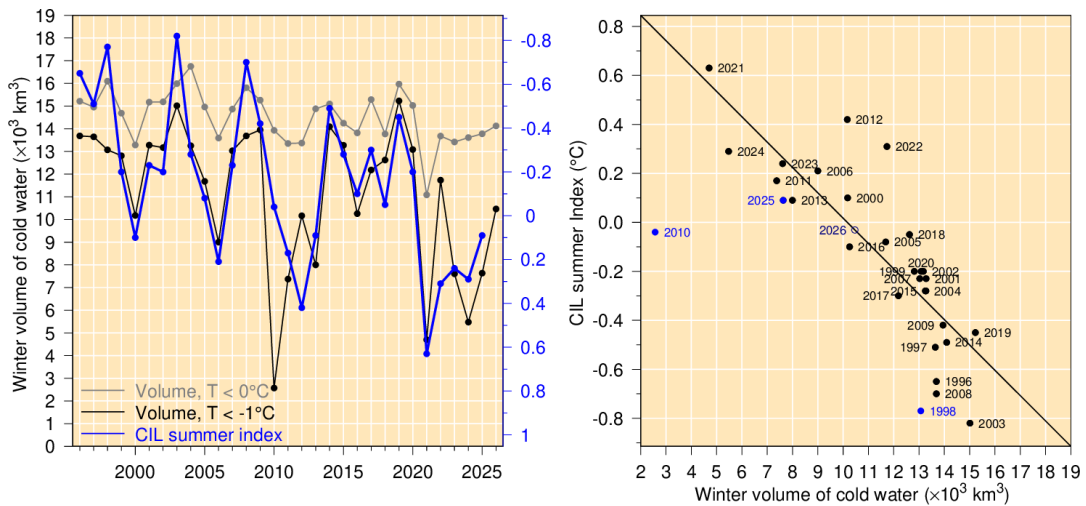


Fig. 38. Left panel: winter surface cold ($T < -1^\circ\text{C}$ and $T < 0^\circ\text{C}$) layer volume (excluding the Estuary and the Strait of Belle Isle) time series (black and grey lines) and summer CIL index (blue line). Volumes include results from March 2026 survey. Right panel: Relation between summer CIL index (Gilbert & Pettigrew 1997) and winter cold-water volume with $T < -1^\circ\text{C}$ (regression for 1996–2025 data pairs, excluding 1998 [see Galbraith 2006] and the 2010 mild winter). Note that the CIL scale in the left panel is reversed. Value for 2025 is also highlighted in blue, and the 2026 CIL summer index prediction from the March 2026 winter cold-water volume ($T < -1^\circ\text{C}$) is shown as a navy blue open circle.

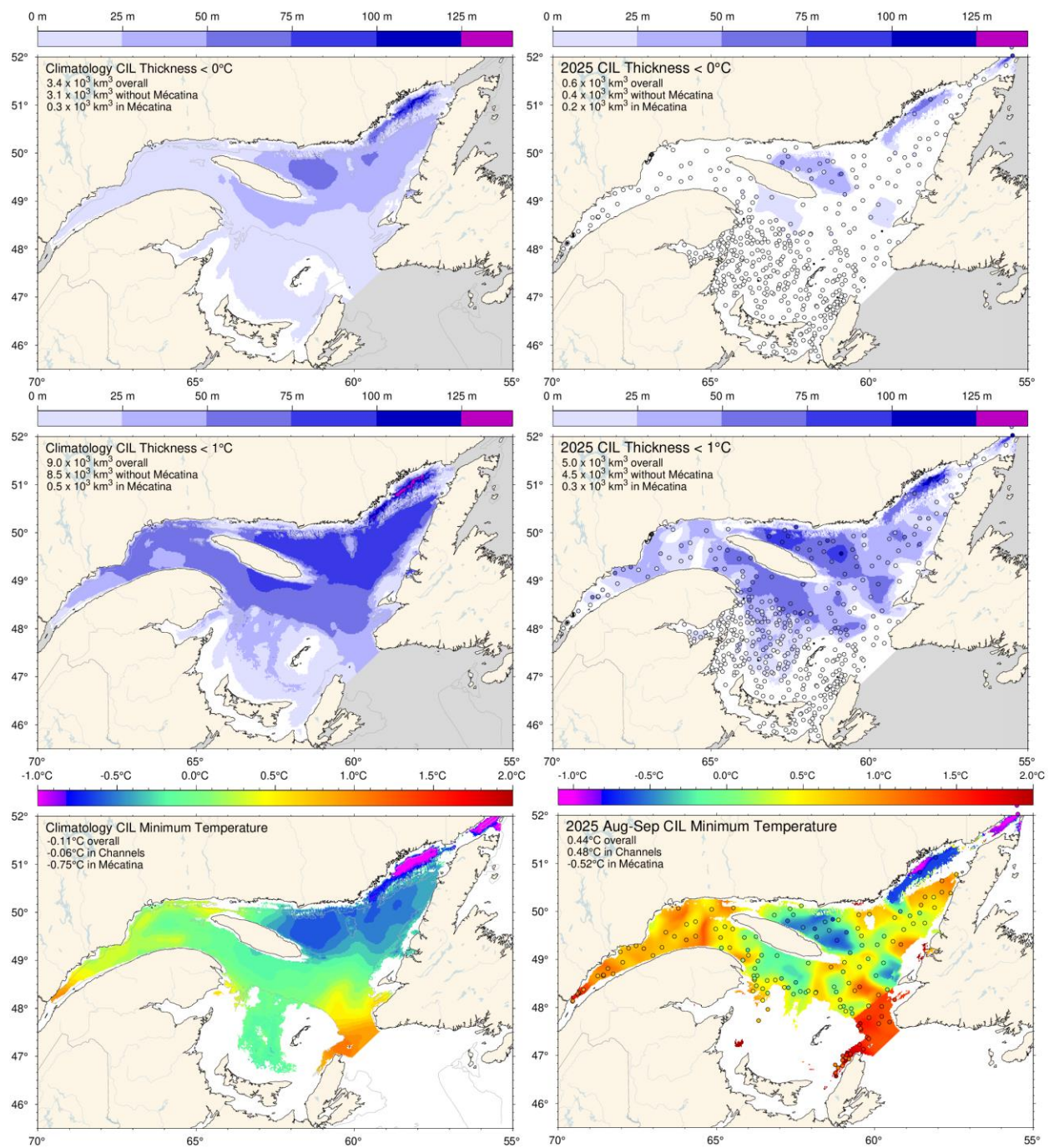


Fig. 39. Cold intermediate layer thickness ($T < 0^{\circ}\text{C}$, top panels; $T < 1^{\circ}\text{C}$, middle panels) and minimum temperature (bottom panels) in August and September 2025 (right) and 1991–2020 climatology (left). Station symbols are colour-coded according to their CIL thickness and minimum temperature. Integrated CIL volumes are indicated in the four top panels and area-averaged temperatures are indicated in the bottom two panels.

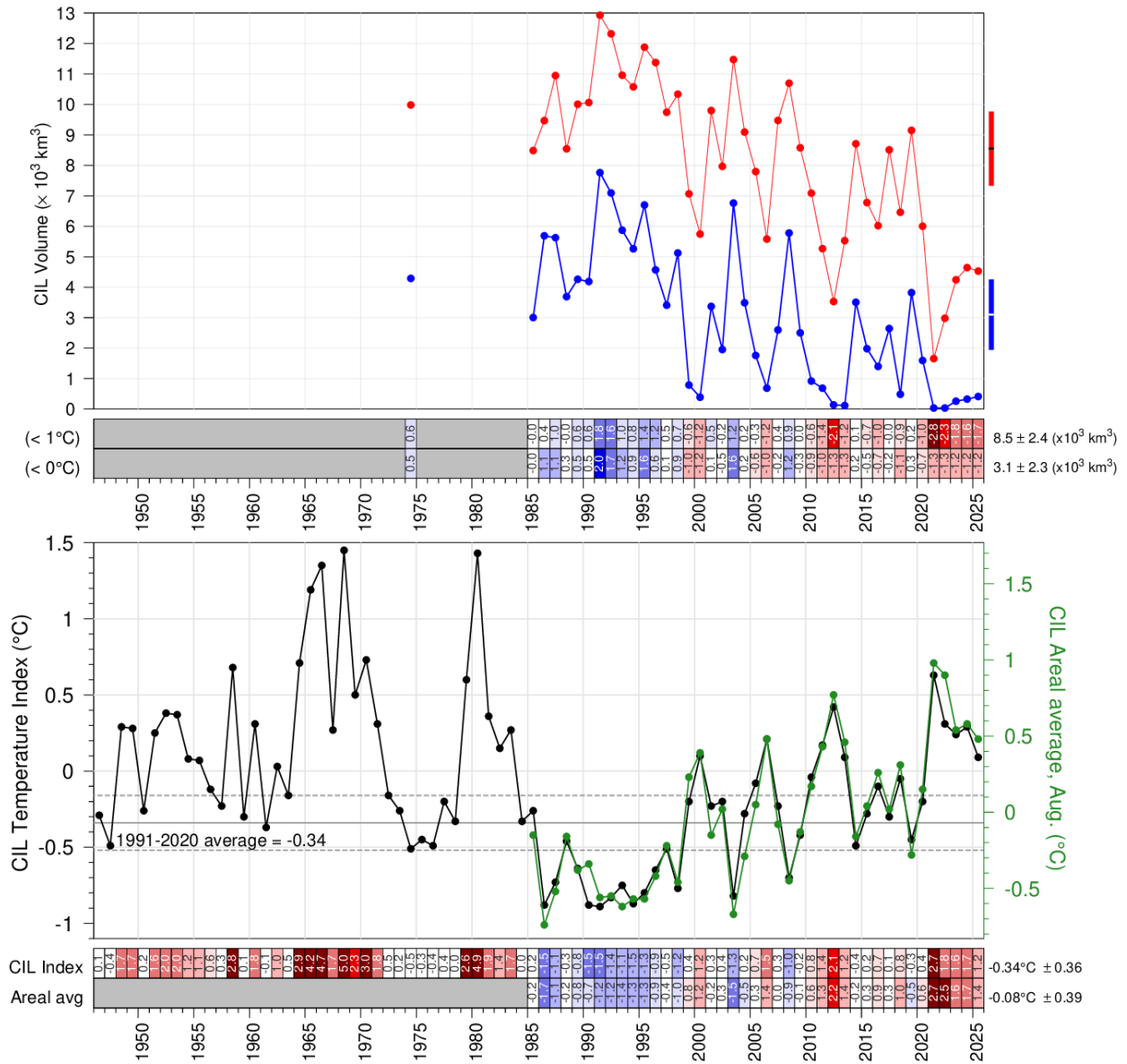


Fig. 40. CIL volume (top panel) delimited by 0°C (in blue) and 1°C (in red), and minimum temperature index (bottom panel) in the Gulf of St. Lawrence. The volumes are integrals of each of the annual interpolated thickness grids such as those shown in the top panels of Fig. 39 excluding Mécatina Trough and the Strait of Belle Isle. Rectangles on the right side show 1991–2020 mean ± 0.5 SD. In the lower panel, the black line is the updated Gilbert and Pettigrew (1997) index interpolated to 15 July (with dashed lines showing mean ± 0.5 SD) and the green line is the spatial average of each of the annual interpolated grids such as those shown in the two bottom panels of Fig. 39, excluding Mécatina Trough, the Strait of Belle Isle and the Magdalen Shallows. The numbers in the boxes are normalized anomalies relative to 1991–2020 climatologies.

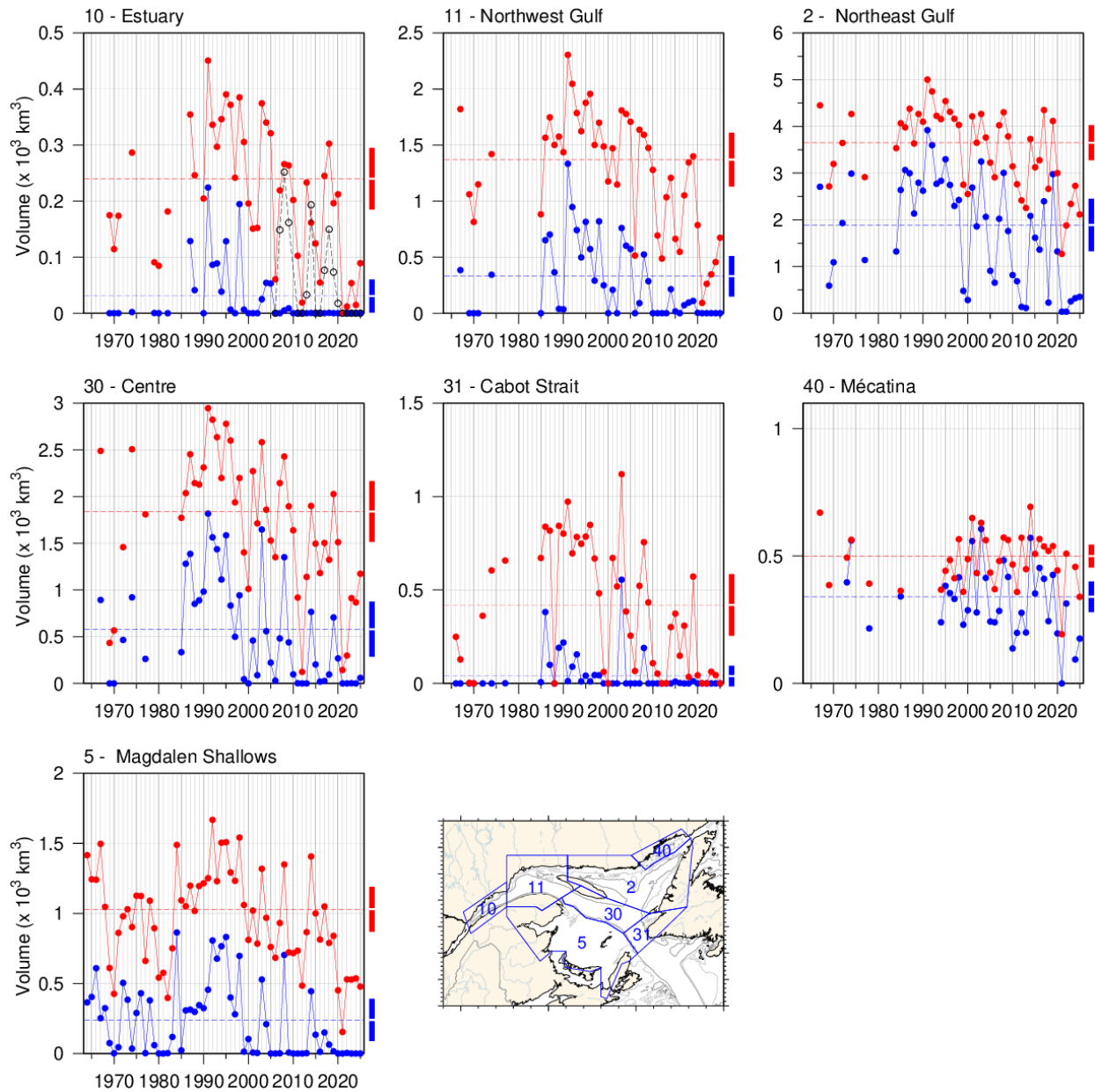


Fig. 41. Volume of the CIL colder than 0 °C (blue) and colder than 1 °C (red) in August and September (data mostly in September on Magdalen Shallows and August elsewhere). The volume of the CIL colder than 1 °C in November for available years since 2006 is also shown for the St. Lawrence Estuary (black dashed line). Red and blue dashed lines are 1991–2020 averages and rectangles on the right side show the 1991–2020 mean $\pm$ 0.5 SD. Map shows outlines of the regions used in other panels.

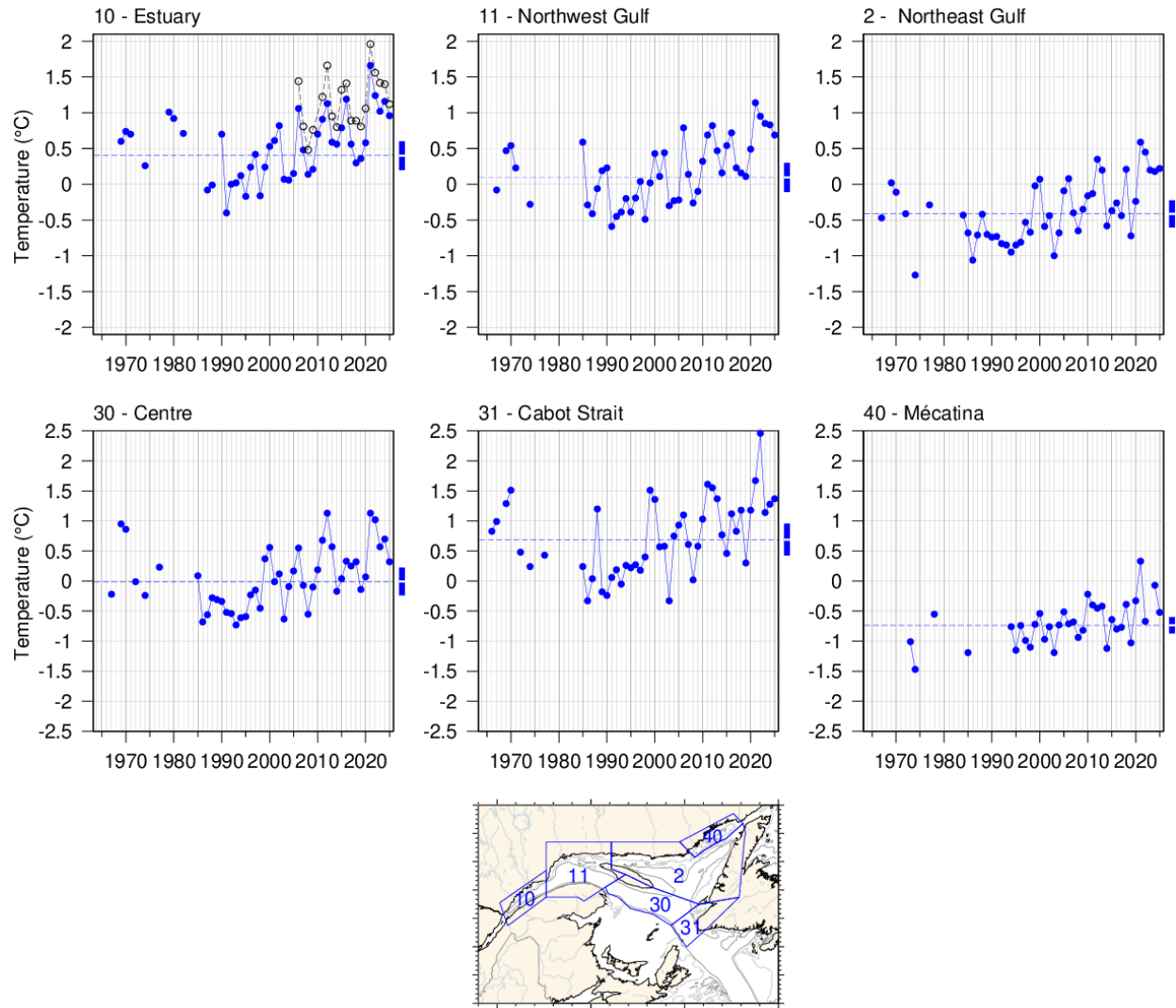


Fig. 42. Temperature minimum of the August and September CIL spatially averaged for selected areas where the CIL minimum temperature can be clearly identified. The Estuary panel also shows the spatial average of the November CIL temperature since 2006 (black dashed line). Blue dashed lines are 1991–2020 averages and rectangles on the right side of panels show the 1991–2020 mean $\pm$ 0.5 SD. Map shows outlines of the regions used in other panels.

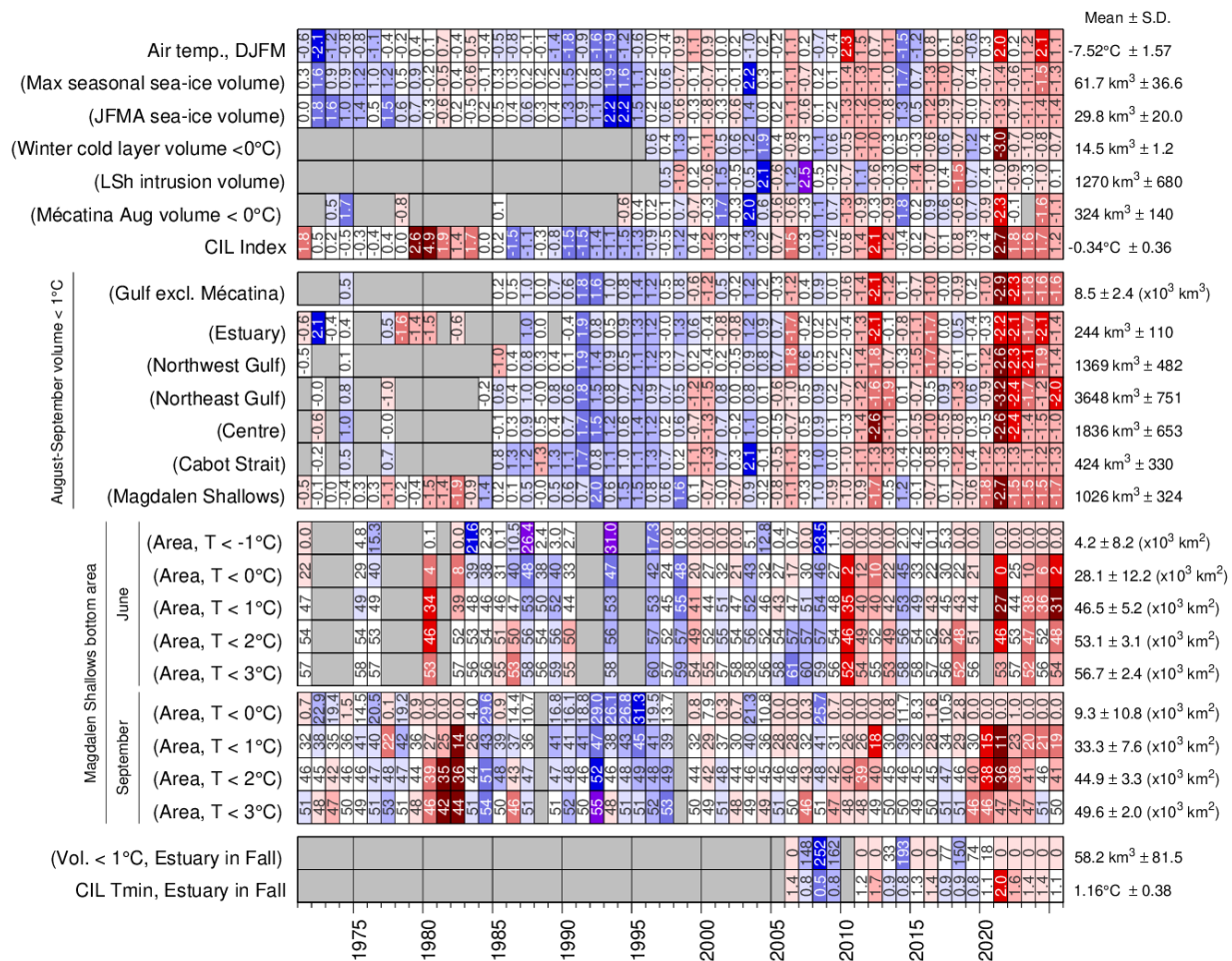


Fig. 43. Winter and summertime CIL related properties. The top block shows the scorecard time series for Dec-Jan-Feb-March air temperature (Fig. 5), yearly maximum sea-ice volume (Gulf + Scotian Shelf), January-April average sea-ice volume, winter (March) cold-layer (< 0 °C) volume, volume of Labrador Shelf Water intrusion into the Gulf observed in March, the August volume of cold water (< 0 °C) observed in the Mécatina Trough and the Gilbert and Pettigrew (1997) CIL index. Labels in parentheses have their colour coding reversed (blue for high values, representing cold conditions). The second block shows scorecard time series for August–September CIL volumes (< 1 °C) for regions of the Gulf. 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 June and September survey. The last block shows the November survey CIL volume (< 1 °C) and average CIL minimum temperature in the Estuary. Numbers in cells express anomalies in units of standard deviation, except for bottom areas and Estuary metrics which are expressed in physical units (because of the occurrence of zeros in areas and volumes).

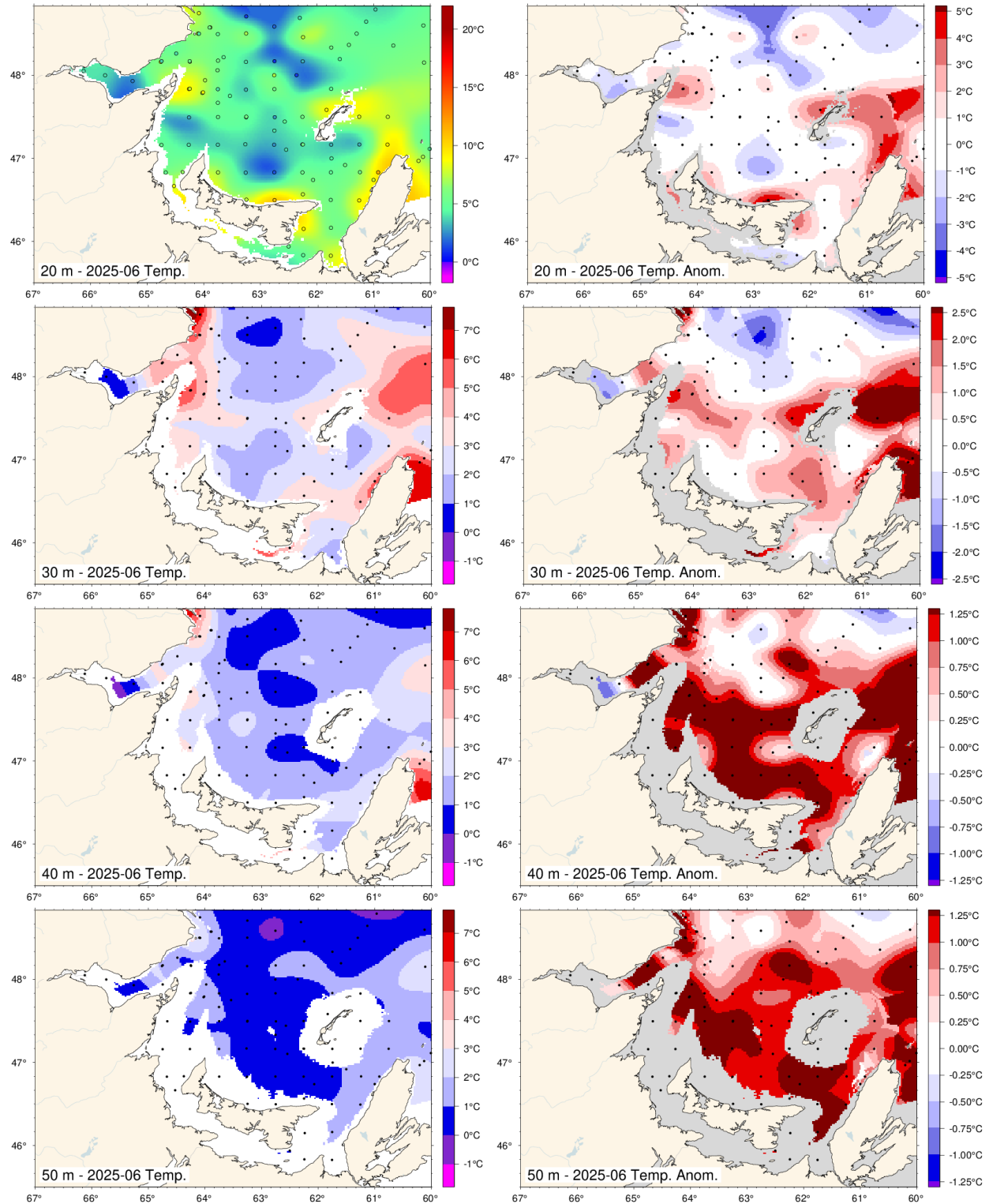


Fig. 44. June depth-layer temperature and anomaly fields on the Magdalen Shallows at 20 m, 30 m, 40 m and 50 m. Anomalies are based on 1991–2020 climatologies for all available years (appearing on Fig. 45). Dots are station occupations.

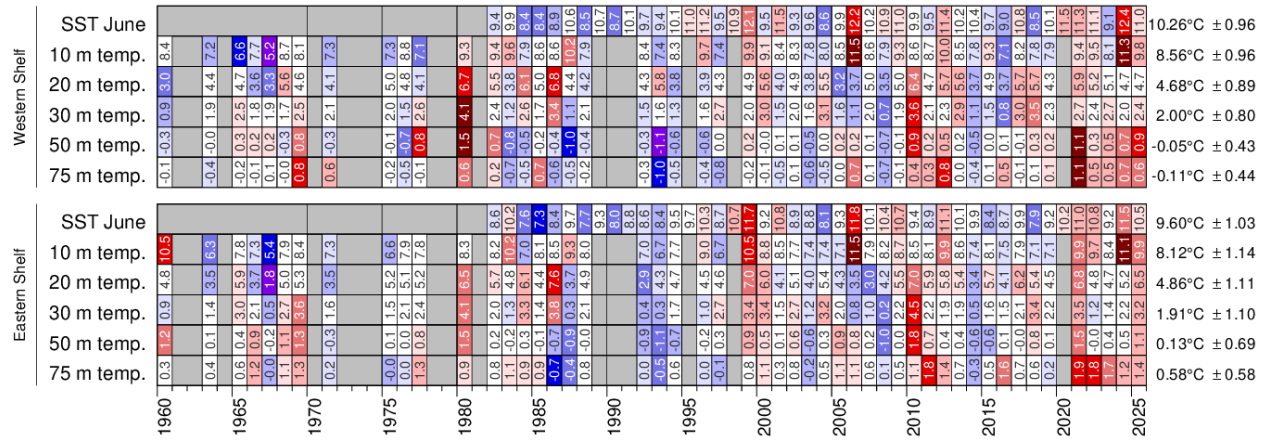


Fig. 45. Depth-layer average temperature anomalies for western and eastern Magdalen Shallows for the June mackerel survey. The SST data are June averages from satellite remote sensing. The colour-coding are according to normalized anomalies based on the 1991–2020 climatologies, but the numbers are mean temperatures in °C.

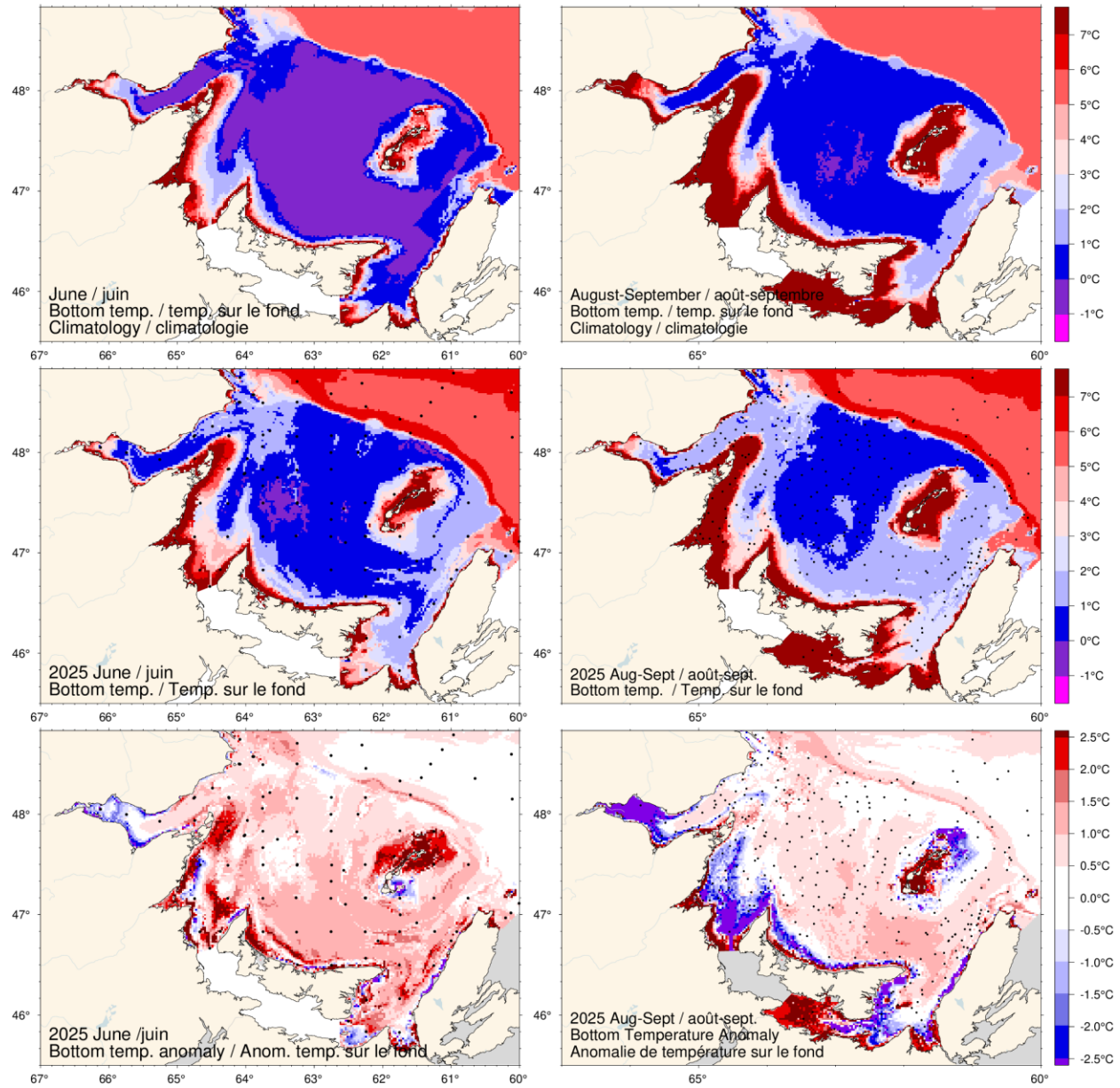


Fig. 46. June (left) and August-September (right) bottom temperature 1991–2020 climatology (top), 2025 observations (middle) and anomaly (bottom) for the Magdalen Shallows.

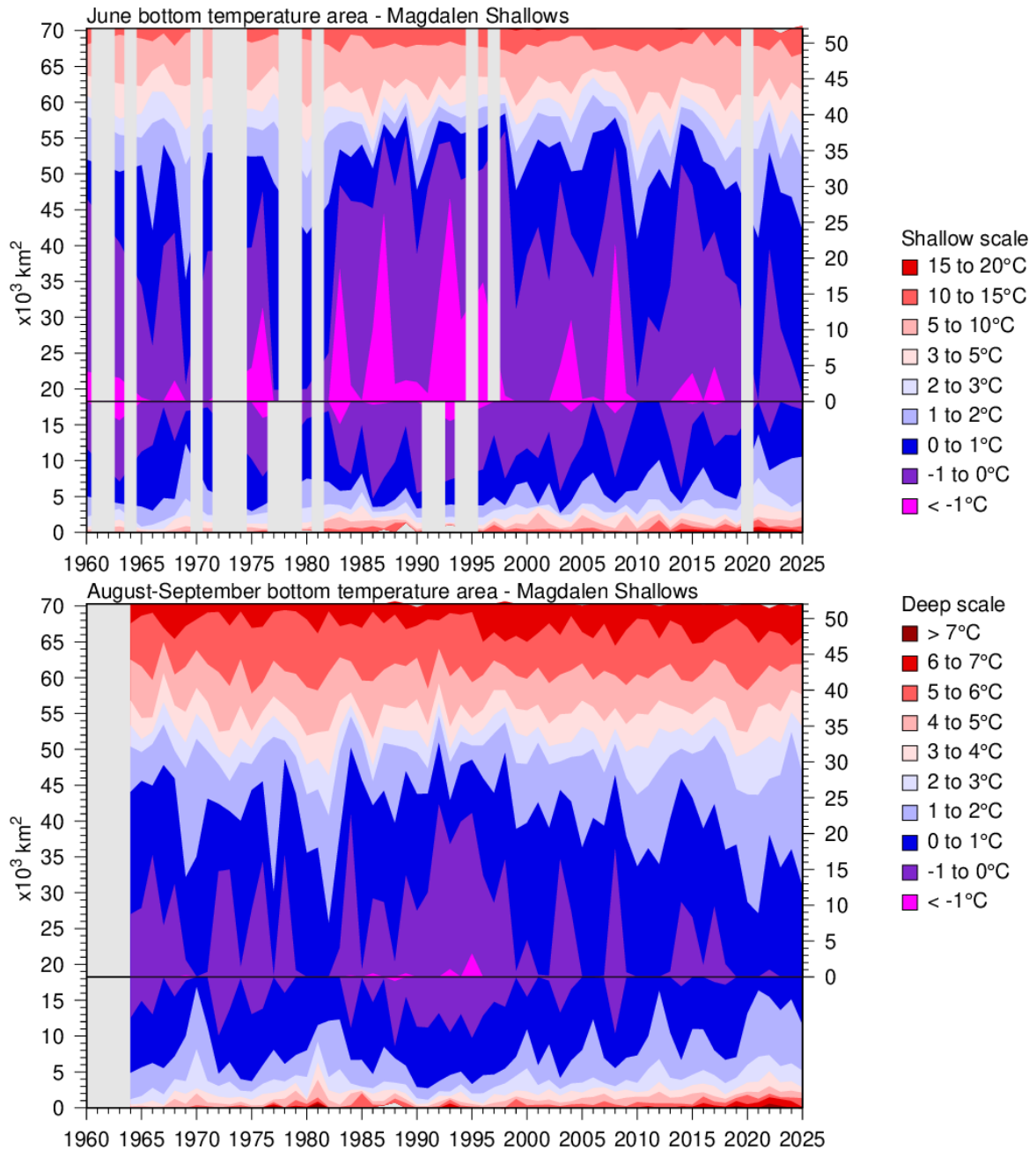


Fig. 47. Time series of the bottom areas covered by different temperature bins in June (top) and August-September (bottom) for the Magdalen Shallows (including Baie des Chaleurs). The panels are separated by a black horizontal line into shallow (< 70 m) and deep (> 70 m) areas to distinguish between 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 warmer 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 70 m meet near the horizontal line.

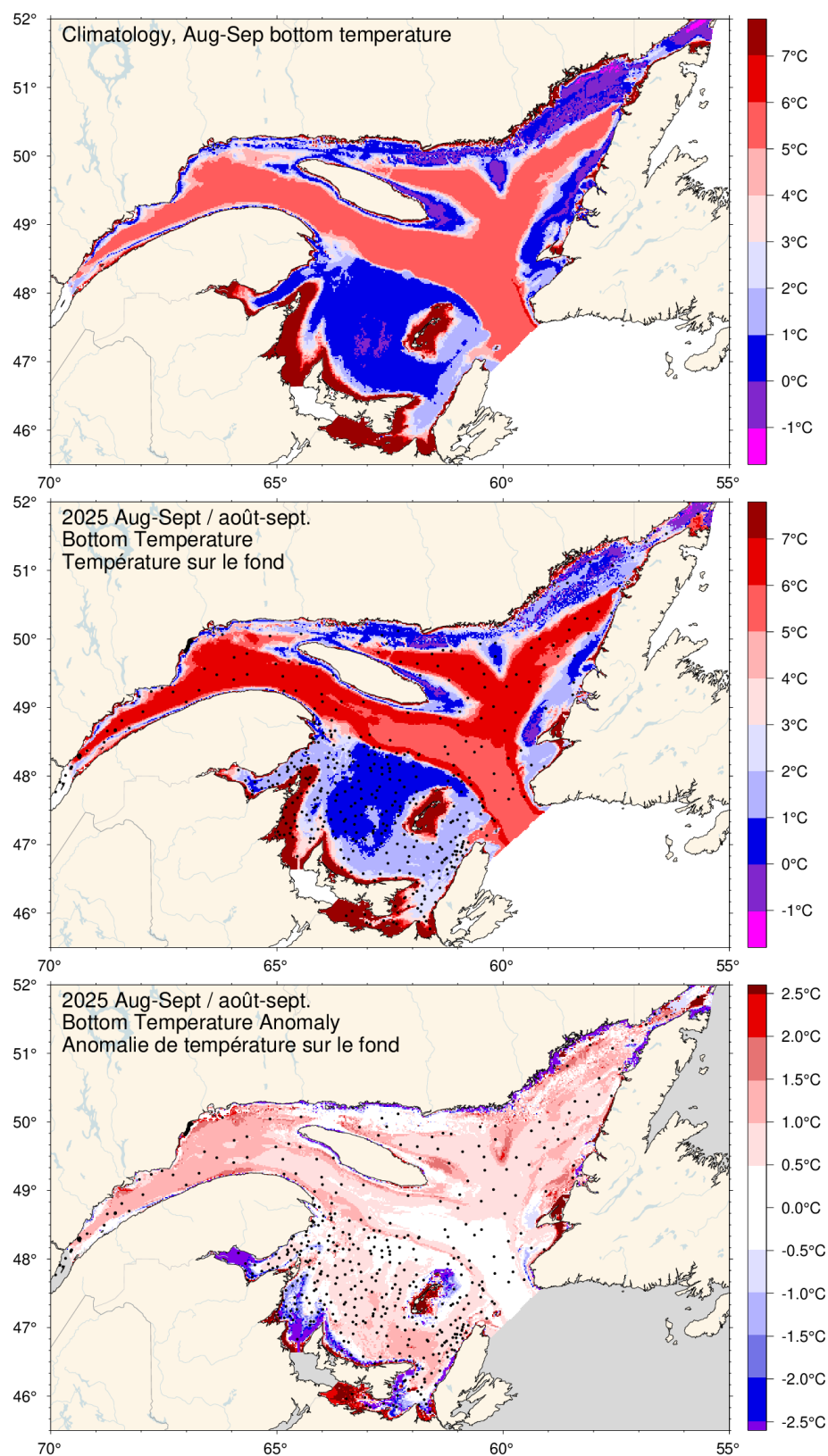


Fig. 48. August-September bottom temperature climatology (top), 2025 observations (middle) and anomaly (bottom). Dots are temperature casts used in the interpolation.

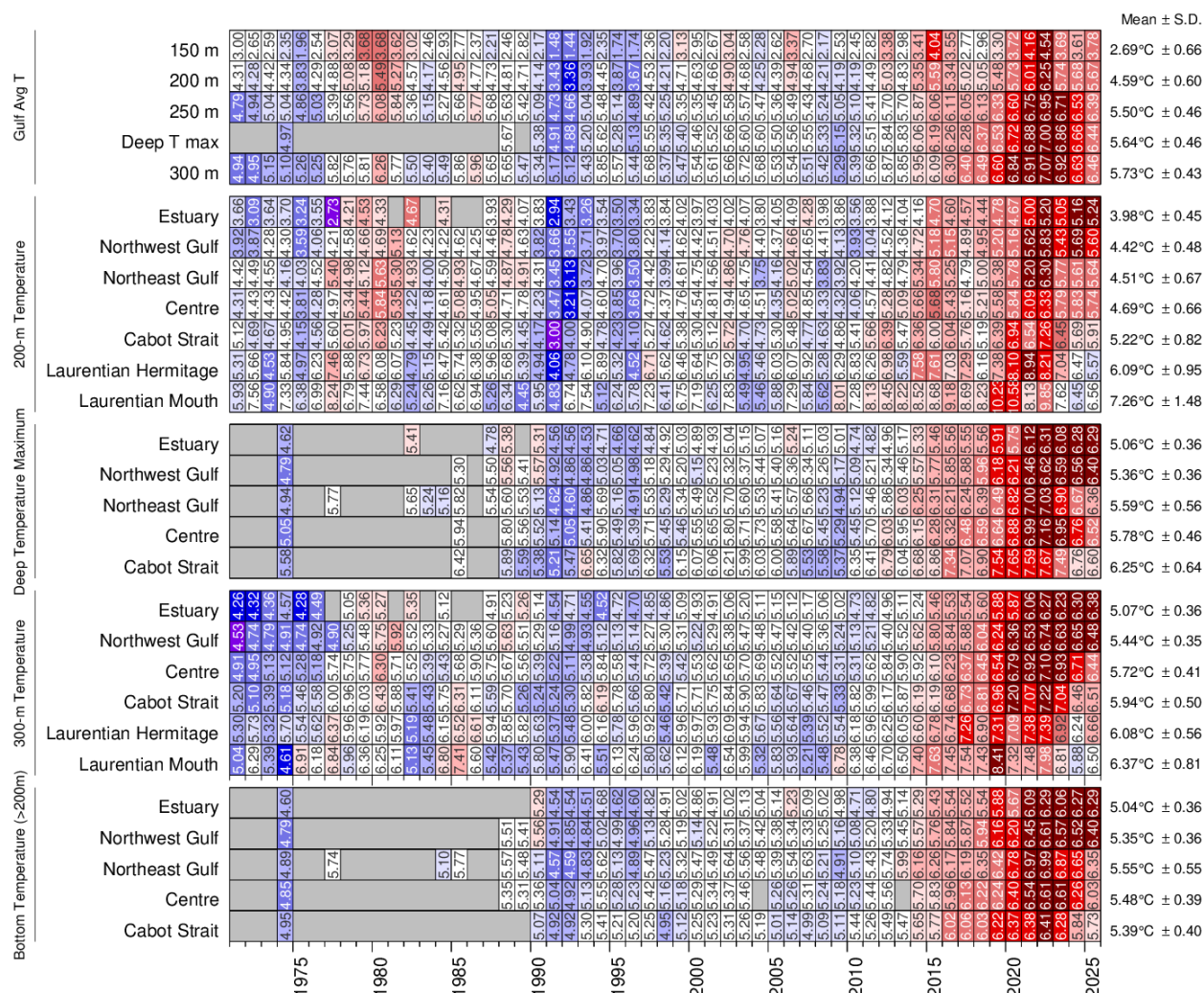


Fig. 49. Areal average temperatures. Gulf averages for temperature are shown for 150, 200, 250, 300 m, as well as for the deep temperature maximum usually found between 200 m and 300 m. Regional averages are shown for 200 m and 300 m, deep temperature maximum and average bottom temperature in waters deeper than 200 m. The numbers on the right are the 1991–2020 climatological means and standard deviations. The numbers in the boxes are average temperatures. The colour-coding is according to the temperature anomaly relative to the 1991–2020 climatology of each region and depth.

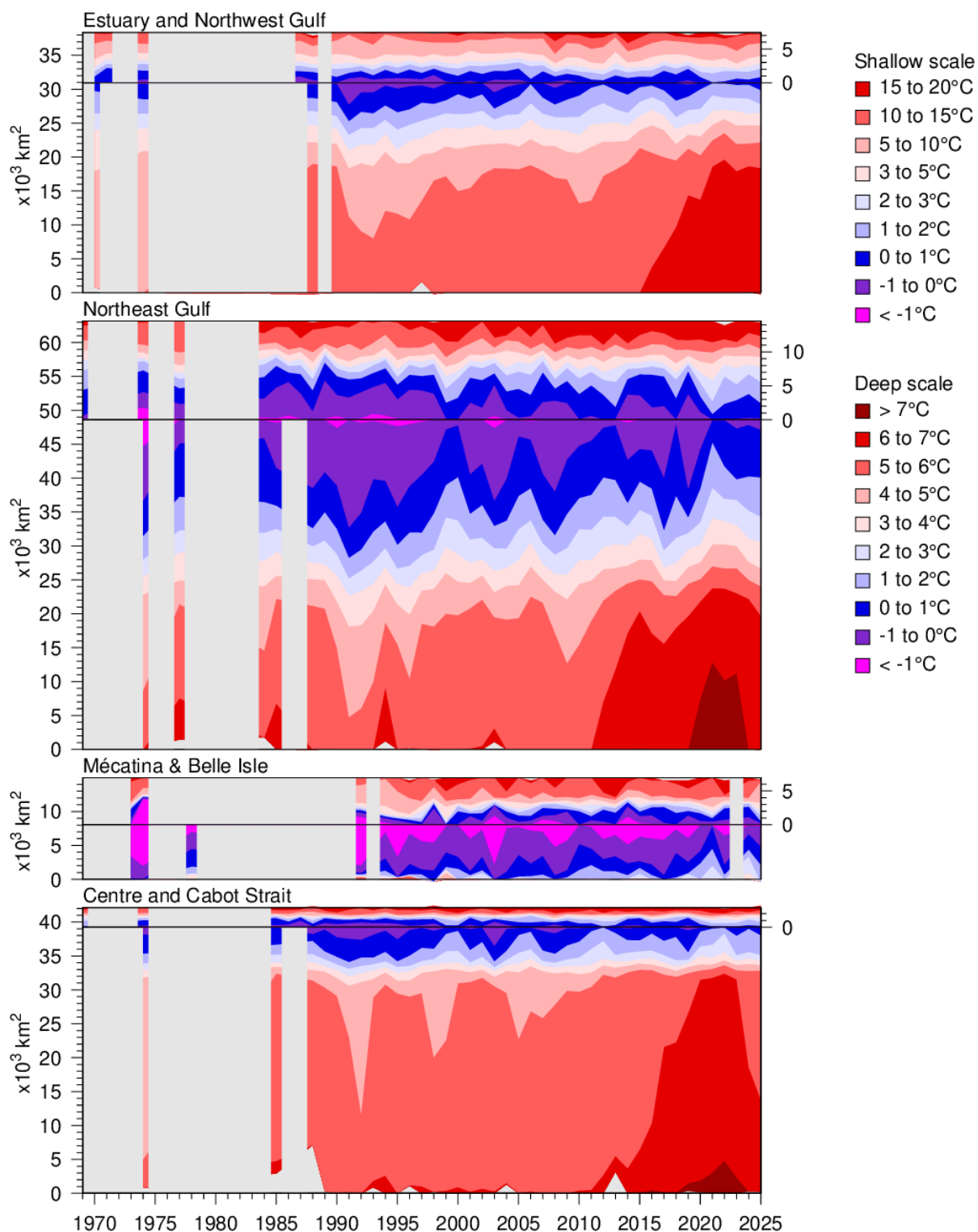


Fig. 50. Time series of the bottom areas covered by different temperature bins in August and September for regions of the northern Gulf. The panels are separated by a black horizontal line into shallow (< 70 m) and deep (> 70 m) areas to distinguish between warmer waters above and below the CIL. The shallow areas are shown on top using the area scale on the right-hand side and have warmer waters shown starting from the top end. The deep areas are shown below the horizontal line and have warmer waters starting at the bottom. The CIL areas above and below 70 m meet near the horizontal line.

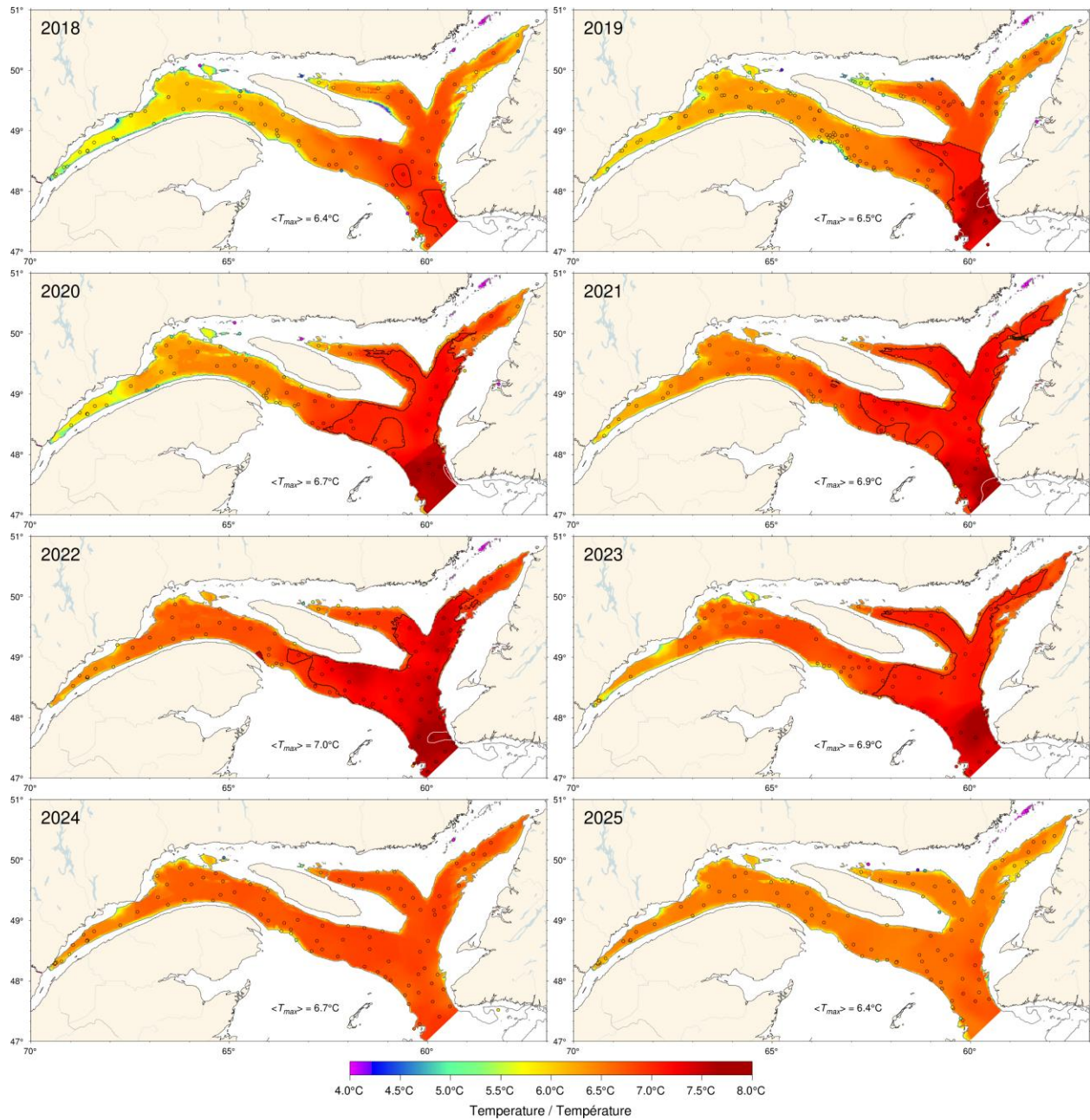


Fig. 51. Map of the deep temperature maximum found typically between 200 m and 300 m, 2018–2025. Maps are interpolated from August–September data available for each year. For 2020, 2021 and 2022, casts made in Cabot Strait during the fall survey were used to fill August sampling gaps (from the earlier BIO survey in October for 2022). The black and white contours are for 7 and 8 °C, respectively.

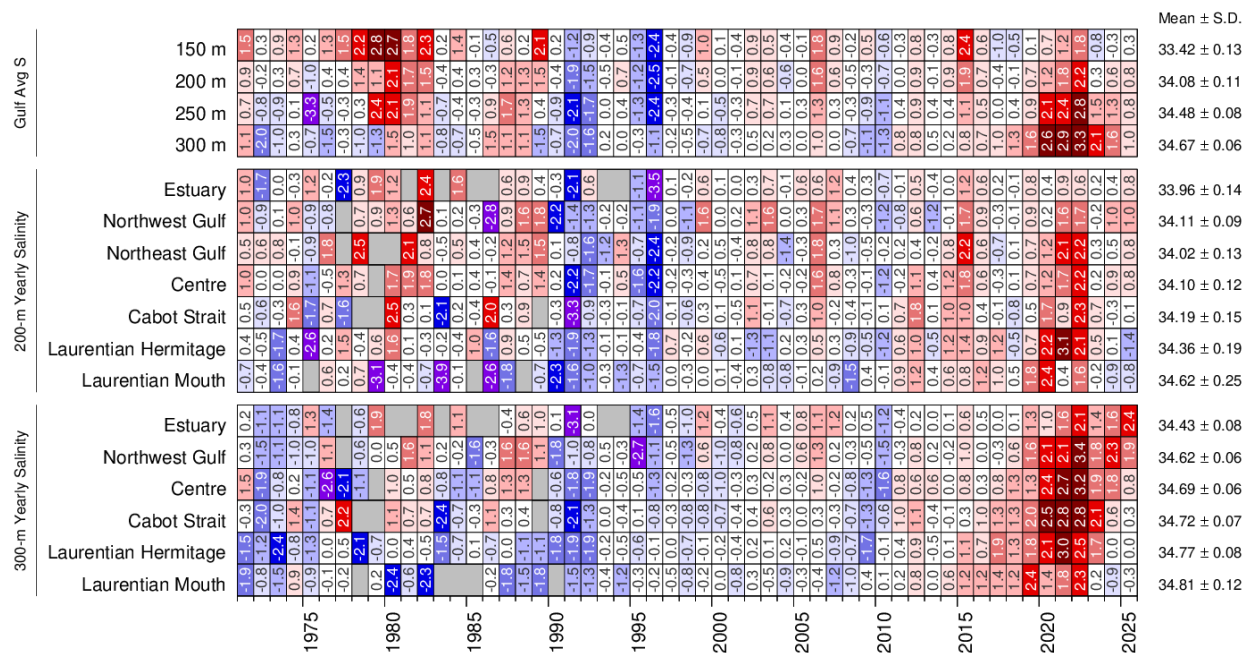


Fig. 52. Deep layer salinity. Gulf averages for salinity are shown for 150, 200, 250, and 300 m. Regional averages are shown for 200 m and 300 m. The numbers on the right are the 1991–2020 climatological means and standard deviations. The numbers in the boxes are normalized anomalies.

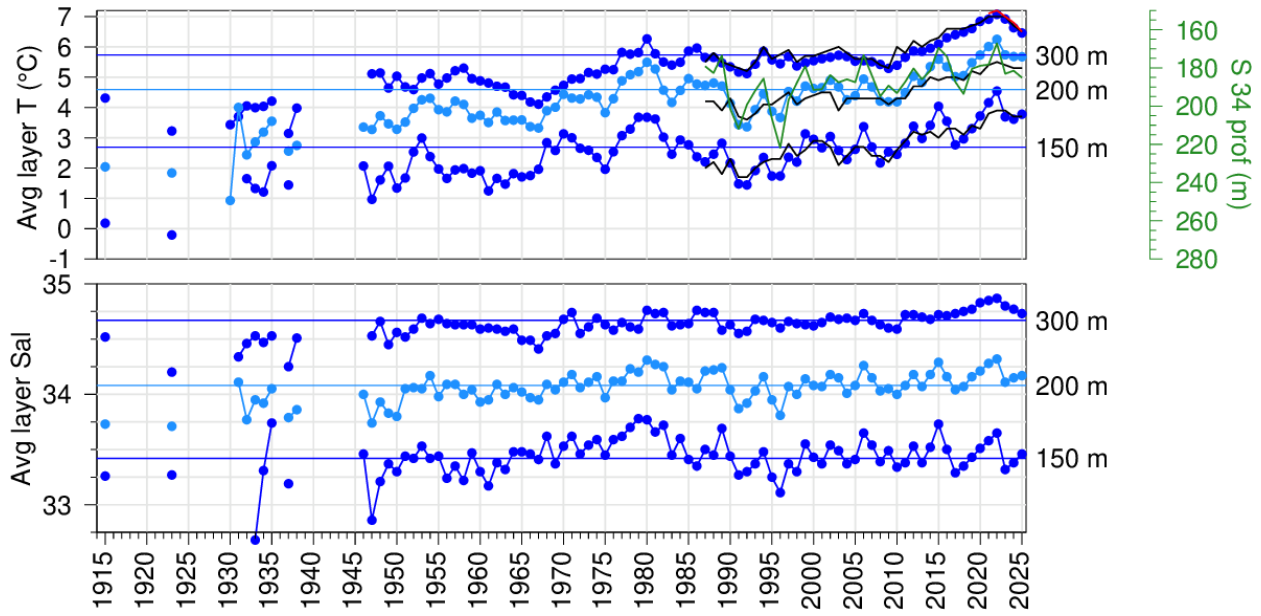


Fig. 53. Layer-averaged temperature and salinity time series for the Gulf of St. Lawrence. The temperature and salinity panels show the 150 m, 200 m, and 300 m annual averages and the horizontal lines are 1991–2020 means. The black line overlying temperature at 300 m is the average temperature of waters of salinity 34.7 in August (1987–2024) while the red line is for salinity 34.8 (2021–2024) more typical of the salinity found at 300 m in recent years. The black line overlying temperature at 200 m is the average temperature of waters of salinity 34 in August, while the green line is its averaged depth (scale shown on right). The black line overlying temperature at 150 m is the average temperature of waters of salinity 33.4 in August.

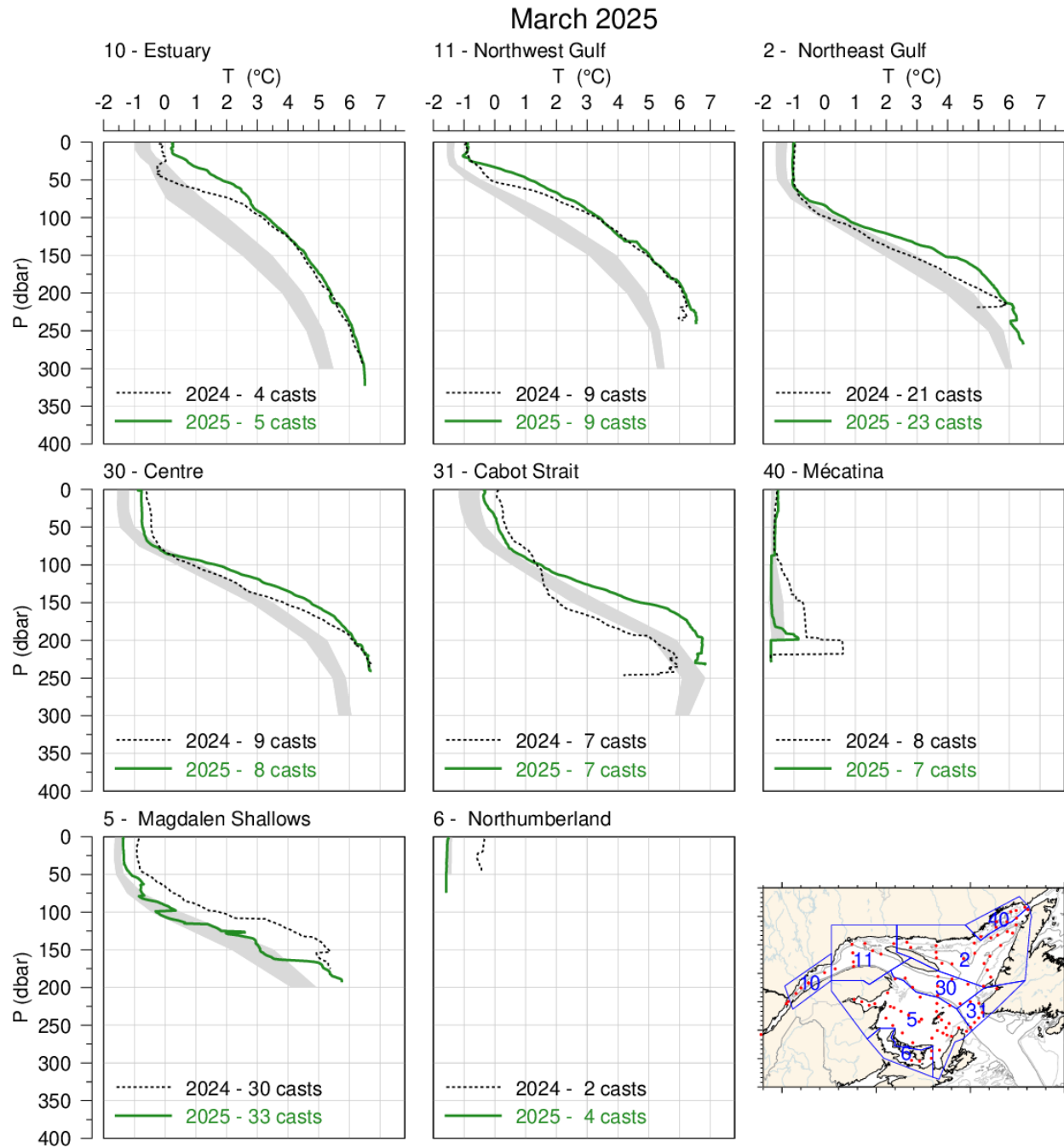


Fig. 54. Mean temperature profiles observed in each region of the Gulf during the March 2025 survey. The shaded area represents the 1991–2020 (but mostly 1996–2020) climatological monthly mean ± 0.5 SD. Mean profiles for 2024 are also shown for comparison.

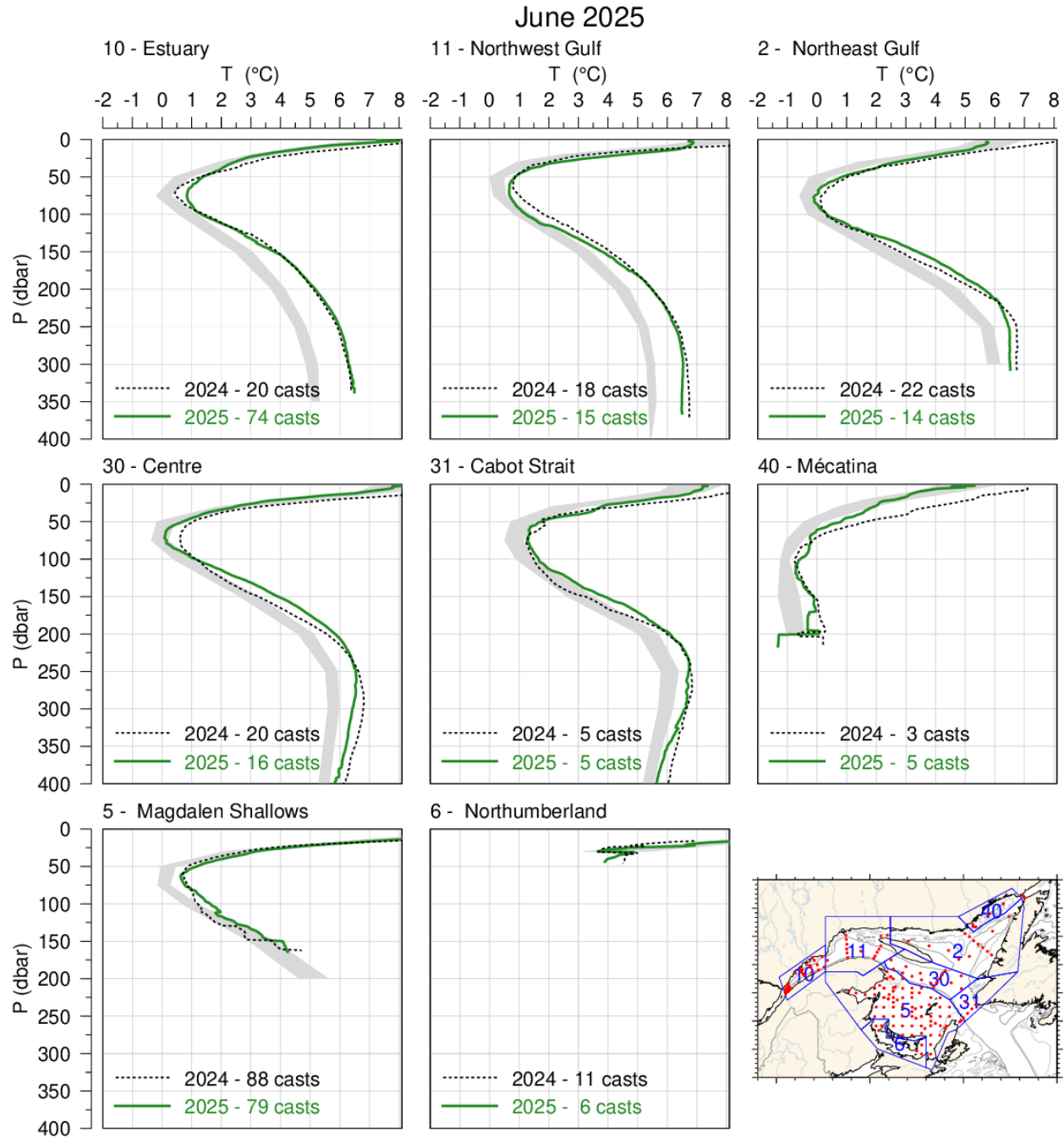


Fig. 55. Mean temperature profiles observed in each region of the Gulf during June 2025. The shaded area represents the 1991–2020 climatological monthly mean ± 0.5 SD. Mean profiles for 2024 are also shown for comparison. Station locations indicated as red dots on map.

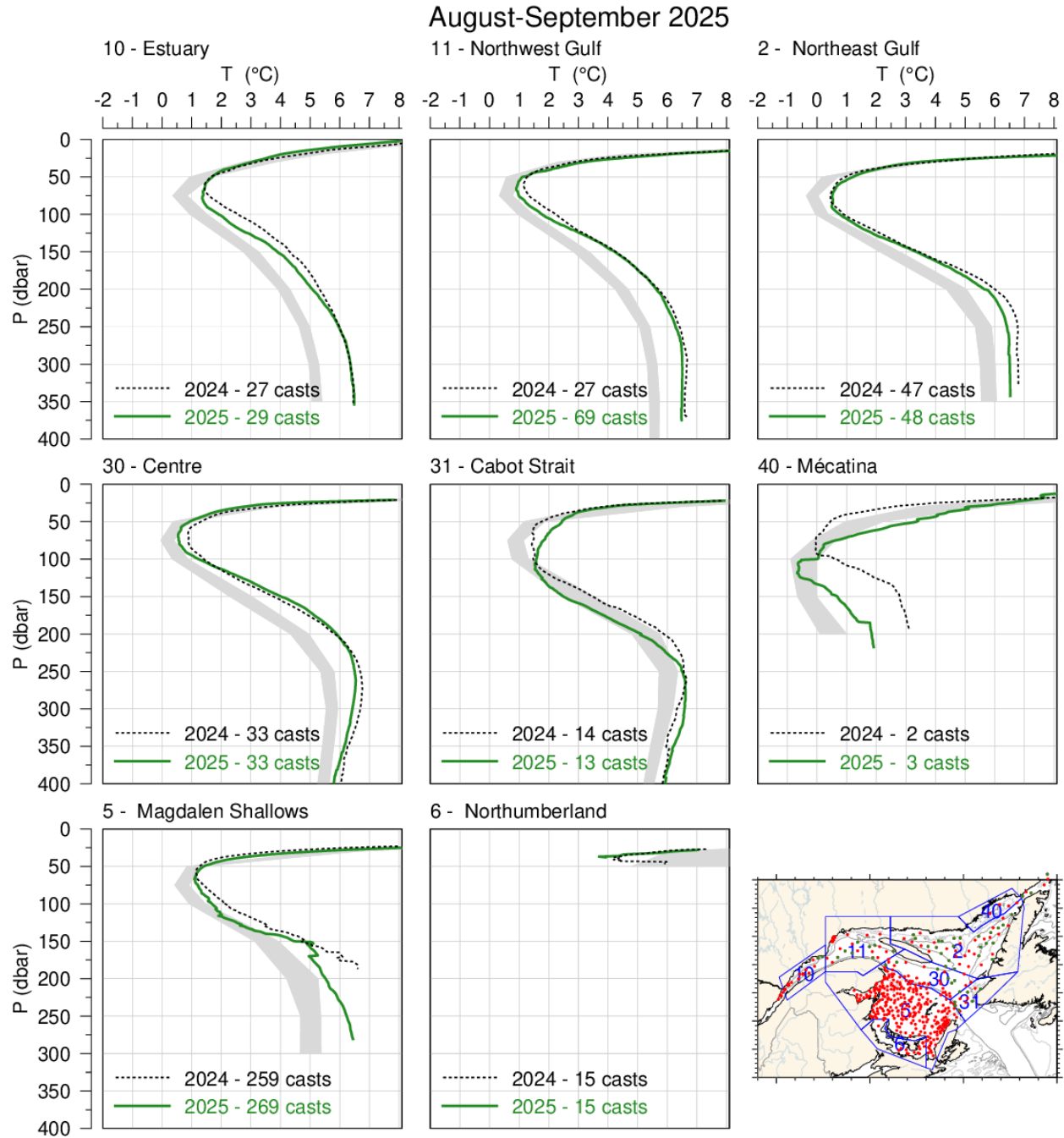


Fig. 56. Mean temperature profiles observed in each region of the Gulf during August and September 2025. The shaded area represents the 1991–2020 climatological monthly mean ± 0.5 SD for August for all regions except the Magdalen Shallows for which September is shown. Mean profiles for 2024 are also shown for comparison. Station locations indicated as red dots on map.

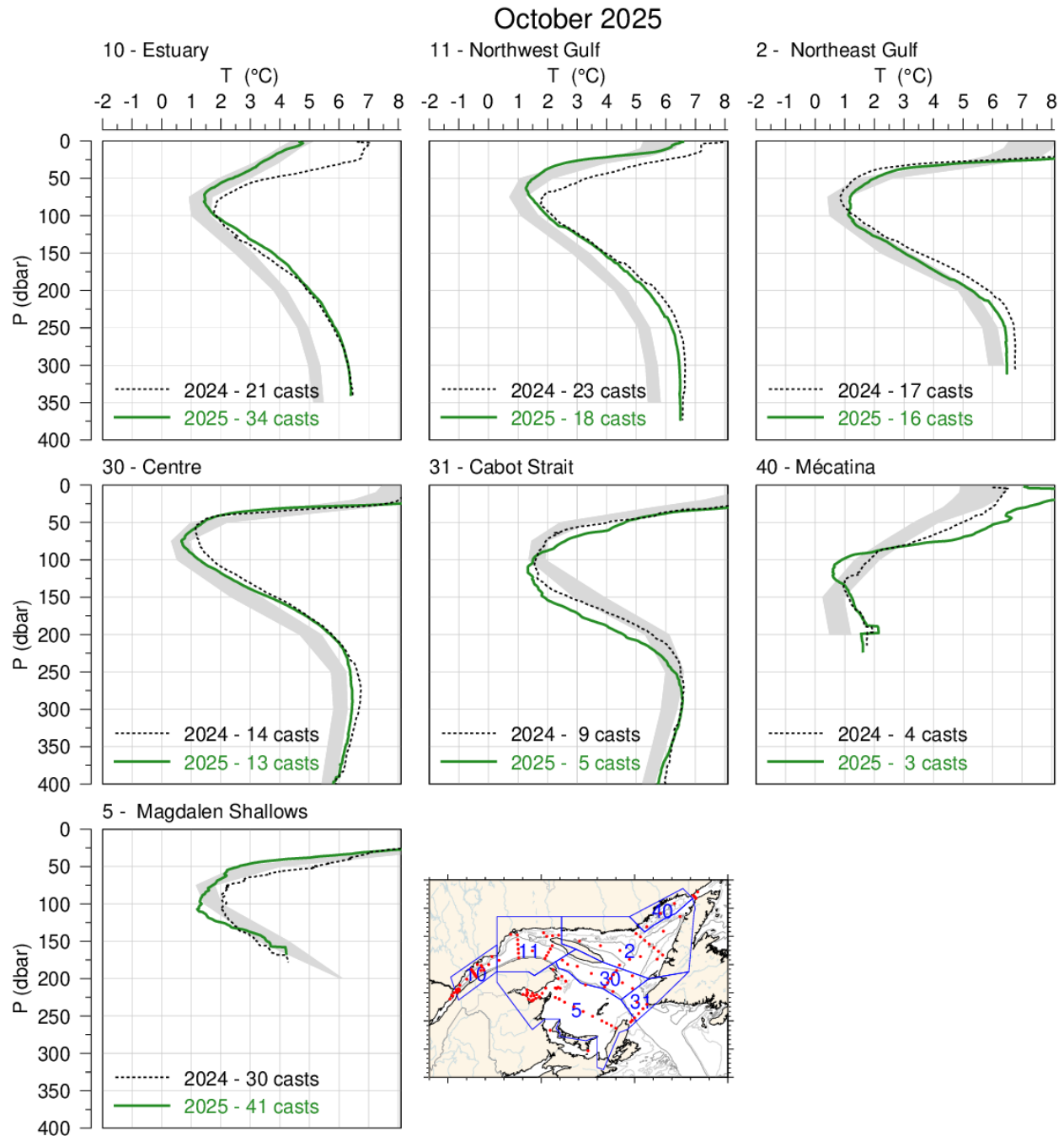


Fig. 57. Mean temperature profiles observed in each region of the Gulf during the October 2025 AZMP survey. The shaded area represents the 1991–2020 climatological monthly mean ± 0.5 SD. Mean profiles for 2024 are also shown for comparison. Station locations indicated as red dots on map.

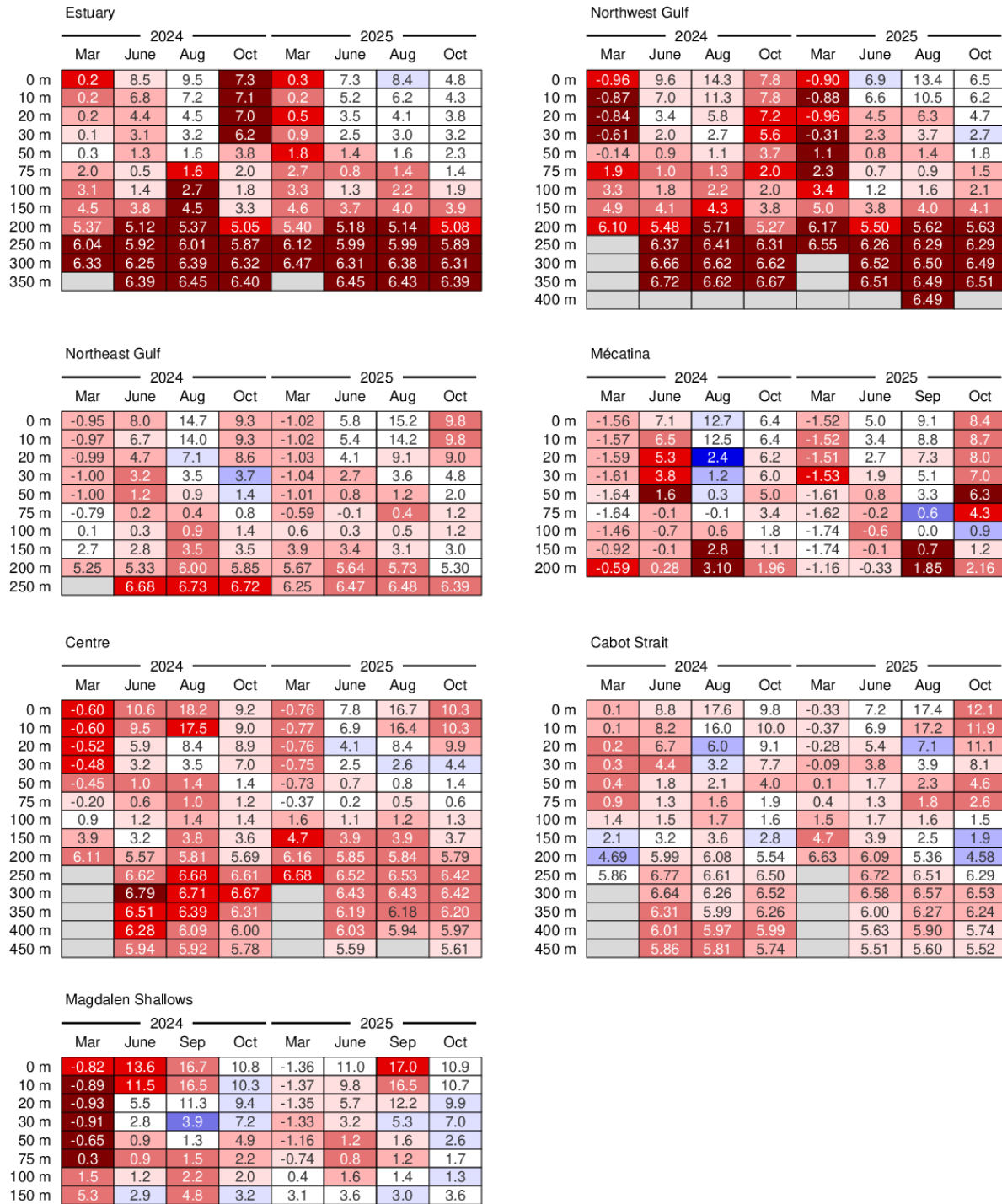


Fig. 58. Depth-layer monthly average temperature summary for months during which the Gulf-wide oceanographic surveys took place in 2024 and 2025. The colour-coding is according to the temperature anomaly relative to the monthly 1991–2020 climatology of each region.

Estuary								
Strat.	2024				2025			
	Mar	June	Aug	Oct	Mar	June	Aug	Oct
Strat.	2.43	5.1	3.8	3.4	1.26	7.0	3.4	2.0
0 m	28.1	25.2	27.8	27.1	30.5	23.0	28.3	29.1
10 m	28.4	26.1	28.8	27.7	30.7	25.8	29.4	29.6
20 m	29.3	27.7	30.0	28.7	31.1	28.3	30.2	30.1
30 m	29.9	29.1	30.7	29.6	31.4	29.9	30.8	30.6
50 m	31.2	30.7	31.6	30.9	32.1	31.3	31.7	31.4
75 m	32.2	31.7	32.3	31.7	32.7	32.0	32.2	32.2
100 m	33.1	32.4	32.9	32.2	33.2	32.4	32.7	32.7
150 m	33.7	33.4	33.7	33.2	33.8	33.4	33.5	33.5
200 m	34.13	34.00	34.11	33.97	34.13	34.04	34.03	34.01
250 m	34.45	34.38	34.41	34.35	34.48	34.42	34.43	34.38
300 m	34.59	34.53	34.60	34.56	34.68	34.59	34.63	34.60
350 m		34.60	34.63	34.60		34.66	34.65	34.64

Northwest Gulf								
Strat.	2024				2025			
	Mar	June	Aug	Oct	Mar	June	Aug	Oct
Strat.	0.98	3.3	4.2	2.0	0.97	3.0	3.8	1.6
0 m	30.6	28.6	28.7	29.4	31.1	28.7	29.0	30.6
10 m	31.0	29.5	29.4	29.4	31.2	28.9	29.7	30.7
20 m	31.4	30.5	30.4	29.8	31.4	29.9	30.7	31.1
30 m	31.5	31.0	31.1	30.1	31.8	30.8	31.3	31.6
50 m	31.8	31.6	31.8	31.3	32.4	31.7	31.8	32.1
75 m	32.6	32.1	32.3	32.0	32.9	32.2	32.3	32.4
100 m	33.2	32.5	32.7	32.5	33.3	32.5	32.6	32.7
150 m	33.9	33.5	33.6	33.4	33.9	33.5	33.5	33.6
200 m	34.37	34.10	34.24	34.02	34.47	34.14	34.19	34.21
250 m		34.53	34.58	34.53	34.70	34.52	34.54	34.56
300 m		34.74	34.76	34.73		34.75	34.76	34.76
350 m		34.81	34.88	34.81		34.83	34.81	34.78
400 m							34.81	

Northeast Gulf								
Strat.	2024				2025			
	Mar	June	Aug	Oct	Mar	June	Aug	Oct
Strat.	0.04	1.6	2.9	1.5	0.07	1.0	2.8	1.5
0 m	31.7	30.4	30.4	30.9	31.9	31.2	30.9	31.2
10 m	31.7	30.7	30.5	30.9	31.9	31.3	31.0	31.2
20 m	31.7	31.1	31.1	31.0	32.0	31.6	31.4	31.2
30 m	31.8	31.2	31.4	31.5	32.0	31.7	31.7	31.6
50 m	31.8	31.6	31.7	31.8	32.0	31.9	31.9	31.9
75 m	31.9	31.9	32.0	32.1	32.2	32.1	32.1	32.2
100 m	32.2	32.3	32.4	32.5	32.6	32.4	32.4	32.5
150 m	33.1	33.1	33.3	33.3	33.5	33.3	33.2	33.2
200 m	33.95	33.97	34.23	34.18	34.16	34.13	34.17	33.99
250 m		34.58	34.63	34.67	34.42	34.55	34.56	34.52

Mécatina								
Strat.	2024				2025			
	Mar	June	Aug	Oct	Mar	June	Sep	Oct
Strat.	0.14	1.0	2.3	0.4	0.19	1.7	1.5	0.4
0 m	32.0	30.9	30.8	31.3	31.9	30.0	30.6	31.1
10 m	32.1	31.0	30.8	31.3	31.9	31.1	30.7	31.1
20 m	32.1	31.2	31.5	31.3	31.9	31.3	31.0	31.2
30 m	32.1	31.3	31.6	31.4	32.0	31.6	31.2	31.1
50 m	32.2	31.5	31.8	31.6	32.2	31.7	31.7	31.3
75 m	32.2	31.8	32.0	31.8	32.2	31.9	32.0	31.6
100 m	32.4	32.0	32.4	32.0	32.3	32.0	32.2	32.1
150 m	32.5	32.4	33.1	32.6	32.4	32.4	32.5	32.5
200 m	32.63	32.52	33.23	32.84	32.50	32.46	32.76	32.85

Centre								
Strat.	2024				2025			
	Mar	June	Aug	Oct	Mar	June	Aug	Oct
Strat.	0.35	2.0	4.1	1.7	0.04	1.5	3.3	2.0
0 m	31.1	30.4	29.9	30.7	31.7	31.0	30.7	30.8
10 m	31.2	30.6	29.9	30.6	31.7	31.2	30.8	30.9
20 m	31.4	31.0	30.8	30.6	31.7	31.5	31.2	31.1
30 m	31.5	31.2	31.4	30.9	31.7	31.7	31.7	31.6
50 m	31.6	31.6	31.8	31.7	31.7	31.9	32.0	32.0
75 m	31.7	31.9	32.1	32.1	31.9	32.2	32.3	32.3
100 m	32.2	32.3	32.5	32.4	32.7	32.6	32.7	32.6
150 m	33.5	33.2	33.4	33.3	33.8	33.5	33.5	33.4
200 m	34.34	34.07	34.18	34.13	34.38	34.20	34.21	34.17
250 m		34.56	34.62	34.58	34.62	34.59	34.59	34.53
300 m		34.80	34.82	34.81		34.76	34.74	34.71
350 m		34.91	34.89	34.88		34.84	34.83	34.82
400 m		34.93	34.91	34.92		34.86	34.87	34.86
450 m		34.93	34.91	34.91		34.88		34.88

Magdalen Shallows								
Strat.	2024				2025			
	Mar	June	Sep	Oct	Mar	June	Sep	Oct
Strat.	0.56	3.6	4.5	2.0	0.12	3.0	4.5	2.8
0 m	30.1	28.7	28.6	29.1	30.8	29.0	28.6	29.3
10 m	30.2	29.1	28.7	29.2	30.9	29.3	28.8	29.4
20 m	30.2	29.8	29.3	29.4	30.8	30.2	29.4	29.8
30 m	30.4	30.3	30.4	29.9	30.9	30.7	30.5	30.5
50 m	30.8	31.2	31.4	30.7	31.0	31.4	31.5	31.5
75 m	31.5	31.8	32.1	31.7	31.3	32.0	32.1	32.0
100 m	32.2	32.1	32.6	32.2	32.0	32.5	32.5	32.4
150 m	34.1	32.9	33.8	33.1	33.2	33.3	33.2	33.4

Cabot Strait								
Strat.	2024				2025			
	Mar	June	Aug	Oct	Mar	June	Aug	Oct
Strat.	0.39	1.7	3.7	1.3	0.38	1.1	3.3	1.7
0 m	31.2	30.7	30.4	31.2	31.4	31.2	31.0	31.4
10 m	31.3	30.8	30.5	31.0	31.6	31.3	31.0	31.6
20 m	31.6	31.0	30.9	31.3	31.6	31.5	31.6	31.7
30 m	31.6	31.3	31.5	31.5	31.8	31.6	31.9	31.9
50 m	31.7	31.8	32.0	31.9	31.9	31.9	32.1	32.2
75 m	32.0	32.1	32.2	32.2	32.0	32.3	32.3	32.4
100 m	32.3	32.4	32.4	32.4	32.5	32.6	32.5	32.5
150 m	33.0	33.3	33.4	33.1	33.8	33.5	33.1	32.9
200 m	33.80	34.24	34.29	34.09	34.47	34.22	34.01	33.78
250 m	34.21	34.66	34.61	34.56		34.59	34.51	34.42
300 m		34.82	34.73	34.72		34.74	34.72	34.70
350 m		34.89	34.82	34.83		34.86	34.80	34.78
400 m		34.93	34.91	34.90		34.89	34.87	34.88
450 m		34.93	34.92	34.91		34.90	34.89	34.90

Fig. 59. Depth-layer monthly average stratification (strat.) and salinity summary for months of the Gulf-wide oceanographic surveys in 2024 and 2025. Stratification is defined as the density difference at 50 m and the surface (kg m^{-3}) and its colour-coding is reversed (blue for positive anomaly because usually associated with low surface salinity).

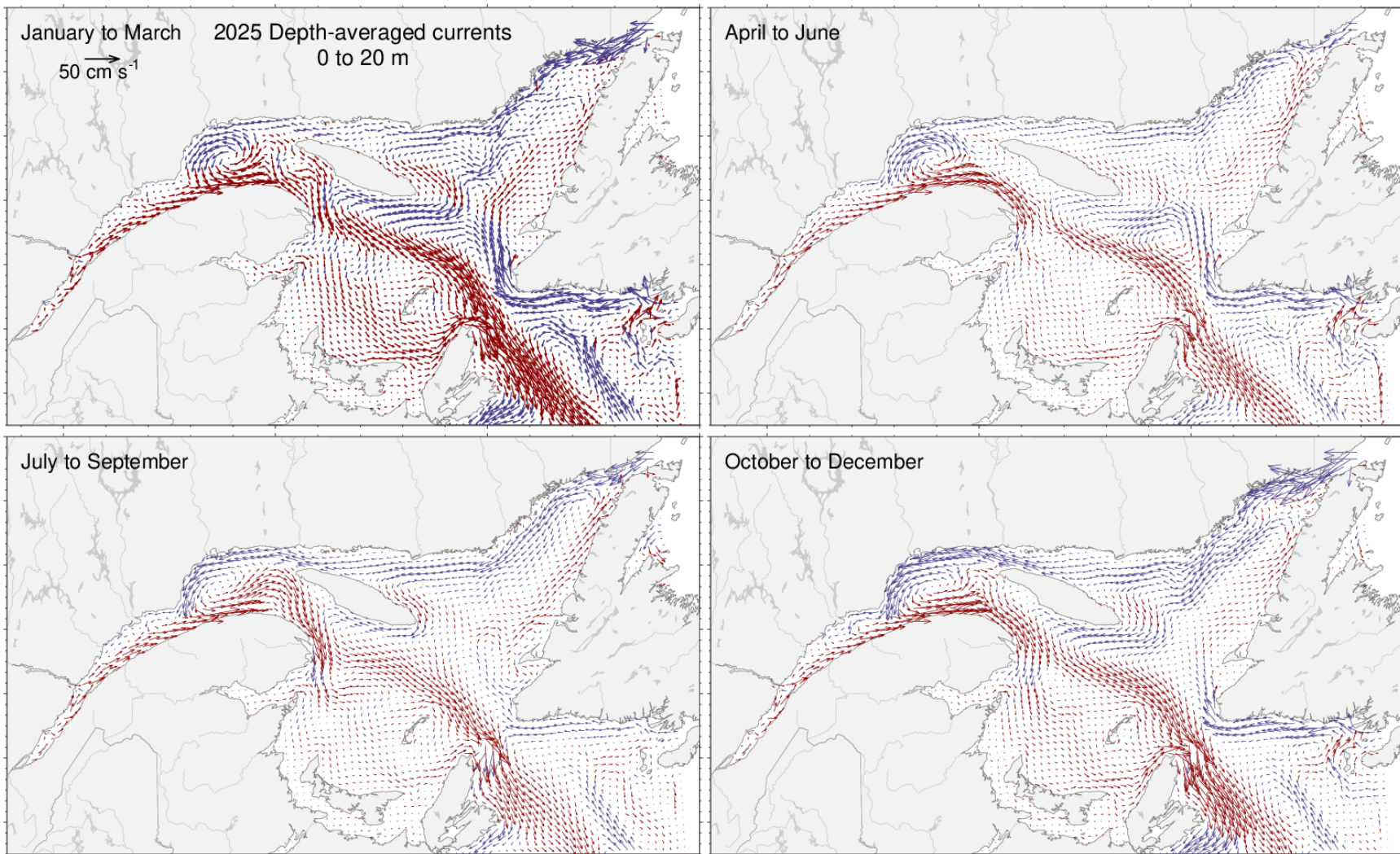


Fig. 60. Depth-averaged currents from 0 m to 20 m for each three-month period of 2025 derived from a NEMO (Nucleus for European Modelling of the Ocean) numerical model. Vectors drawn in blue are towards the west and those drawn in red are towards the east. Length of arrows is proportional to current amplitude (scale shown in upper-left panel).

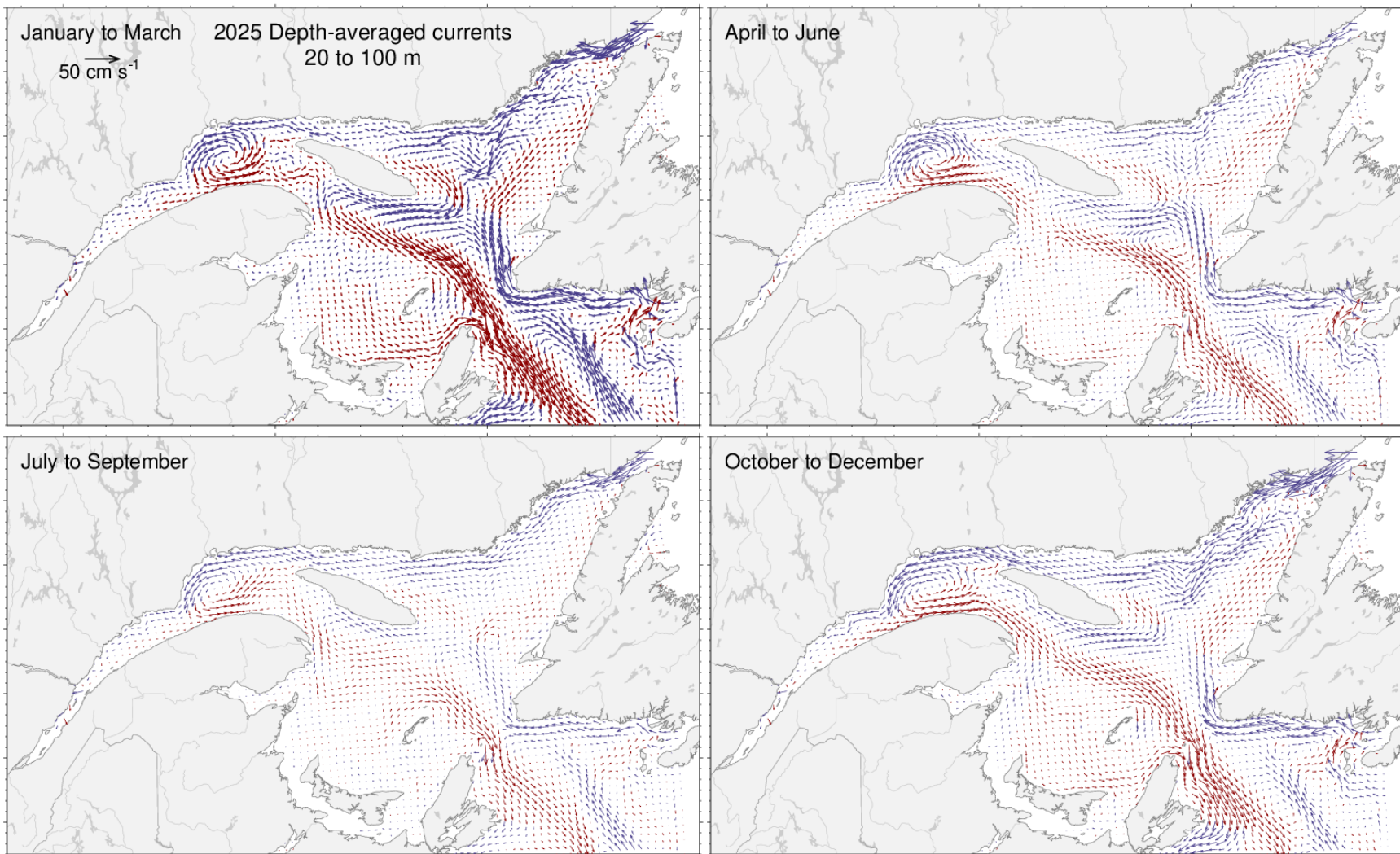


Fig. 61. Depth-averaged currents from 20 m to 100 m for each three-month period of 2025 derived from a NEMO (Nucleus for European Modelling of the Ocean) numerical model. Vectors drawn in blue are towards the west and those drawn in red are towards the east. Length of arrows is proportional to current amplitude (scale shown in upper-left panel).

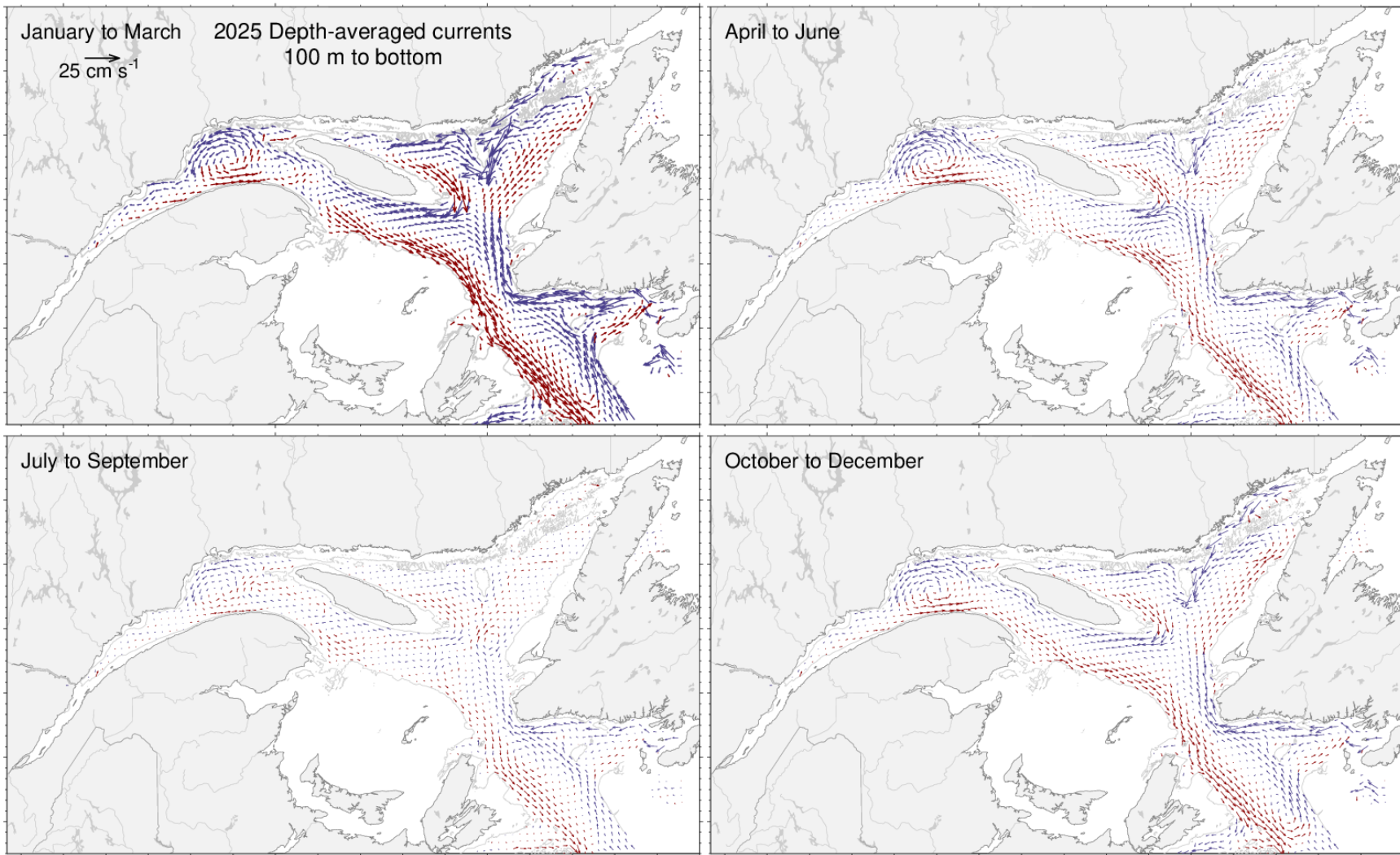


Fig. 62. Depth-averaged currents from 100 m to the bottom for each three-month period of 2025 derived from a NEMO (Nucleus for European Modelling of the Ocean) numerical model. Vectors drawn in blue are towards the west and those drawn in red are towards the east. Length of arrows is proportional to current amplitude (scale shown in upper-left panel; doubled from previous figures).

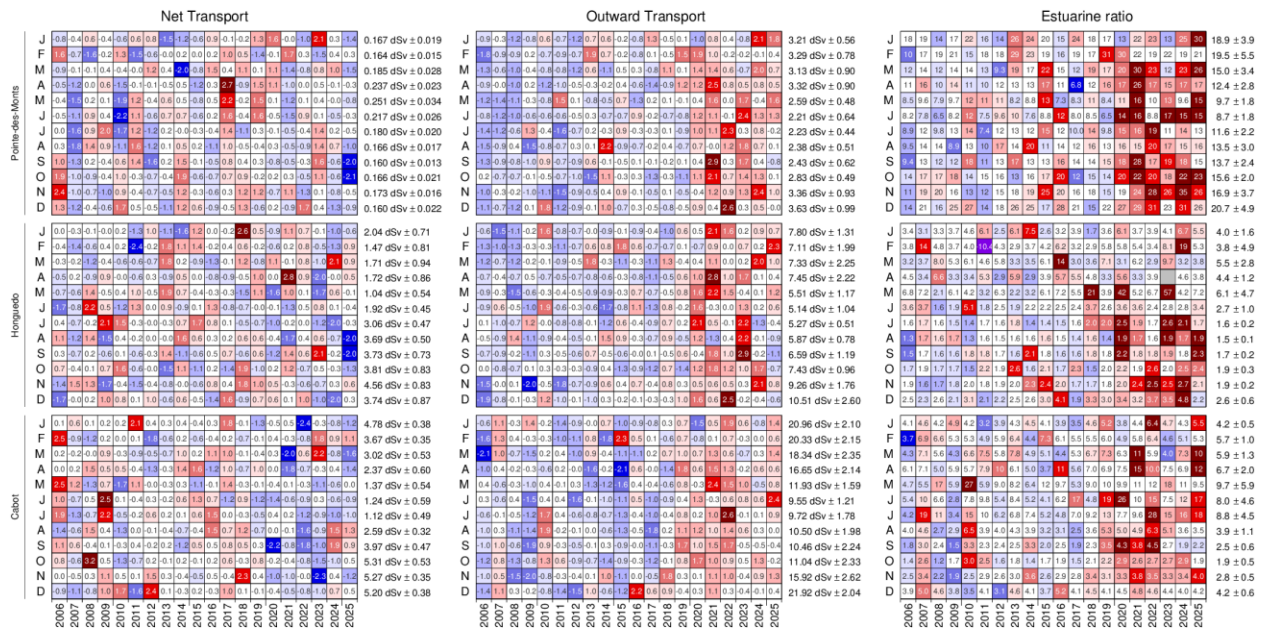
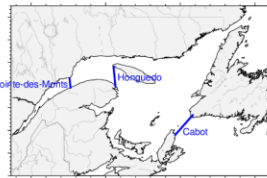


Fig. 63. Monthly averaged modelled transports (positive eastward) and estuarine ratio across sections of the Gulf of St. Lawrence since 2006. The numbers on the right are the 2006–2020 means and standard deviations. The numbers in the boxes are normalized anomalies for transport panels, but ratio values are indicated in the right panel. Colours indicate the magnitude of the anomaly. dSv (deci-Sverdrup) are units of transport equal to $10^5 \text{ m}^3 \text{ s}^{-1}$.



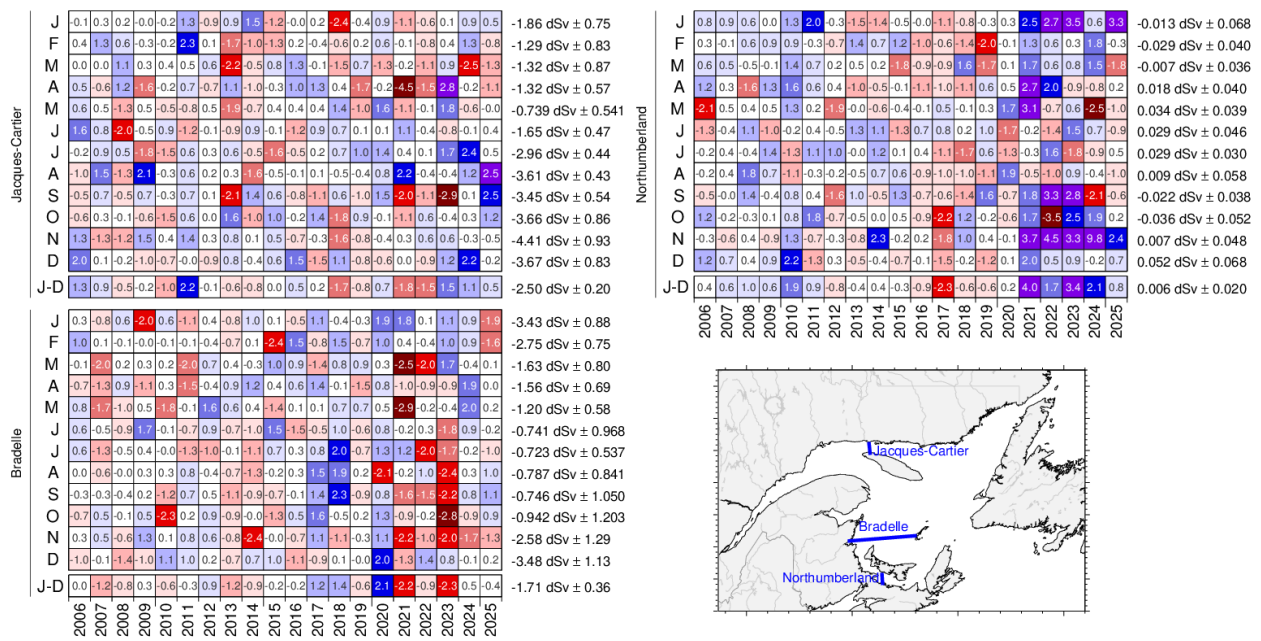


Fig. 64. Monthly and annual averaged modelled transports across sections of the Gulf of St. Lawrence since 2006. The numbers on the right are the 2006–2020 means and standard deviations, with positive values towards east and north. The numbers in the boxes are normalized anomalies. Since most mean transports are negative, negative anomalies are coded in red (e.g., negative anomalies are shown in red as stronger negative transport).

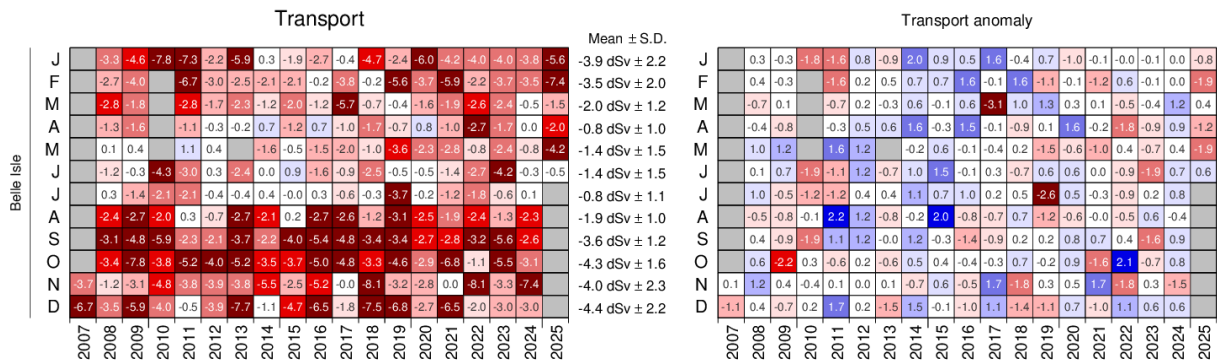


Fig. 65. Monthly-averaged transports estimates (right) and transport anomaly (left) across the Strait of Belle Isle section since 2007. The interannual means and standard deviations are shown to the right, with positive values towards the Labrador Shelf, and are calculated on the entire time series. The values are normalized anomalies in the left panel, and transport in units of deci-Sverdrups ($10^5 \text{ m}^3 \text{ s}^{-1}$) in the right panel. Colours indicate the magnitude of the anomaly or transport. Colours are reversed, red indicating a stronger (negative) transport towards the Gulf of St. Lawrence. See Fig. 13 for mooring location.

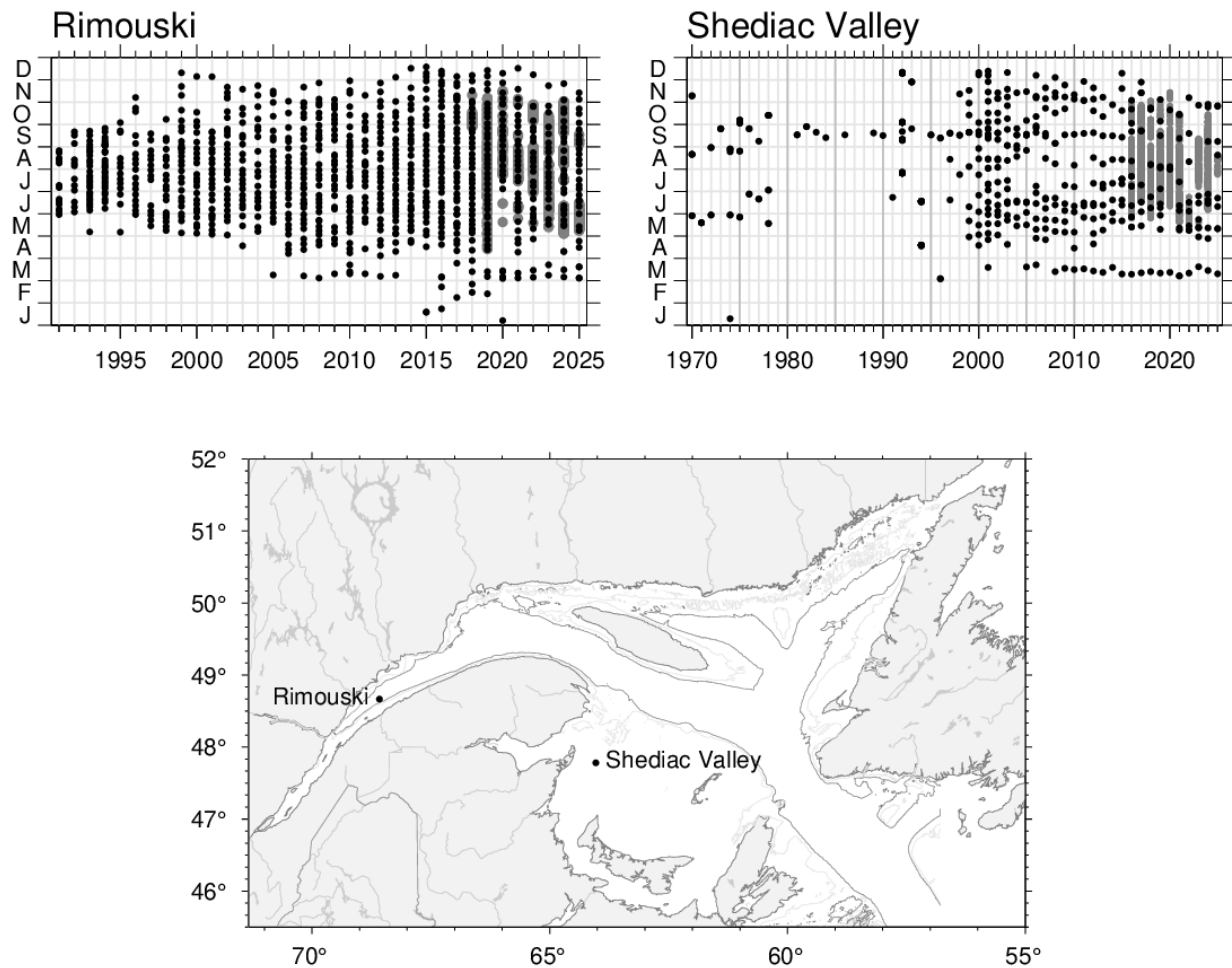


Fig. 66. Sampling frequency and positions of the AZMP stations Rimouski and Shediac Valley. Black dots show human occupations: 28 at Rimouski station and 8 at Shediac Valley station. Gray overlays show temperature and salinity casts made by oceanographic buoys. In 2025 at Shediac Valley, only 28 temperature and salinity profiles were made by the PMZA-VAS automatic oceanographic buoy between 2025-07-24 and 2025-08-19 and none to full depth; most were stopped around 30 to 40 m. At Rimouski station, 120 full depth temperature and salinity profiles made by the PMZA-RIKI automatic oceanographic buoy between 2025-05-07 and 2025-09-17.

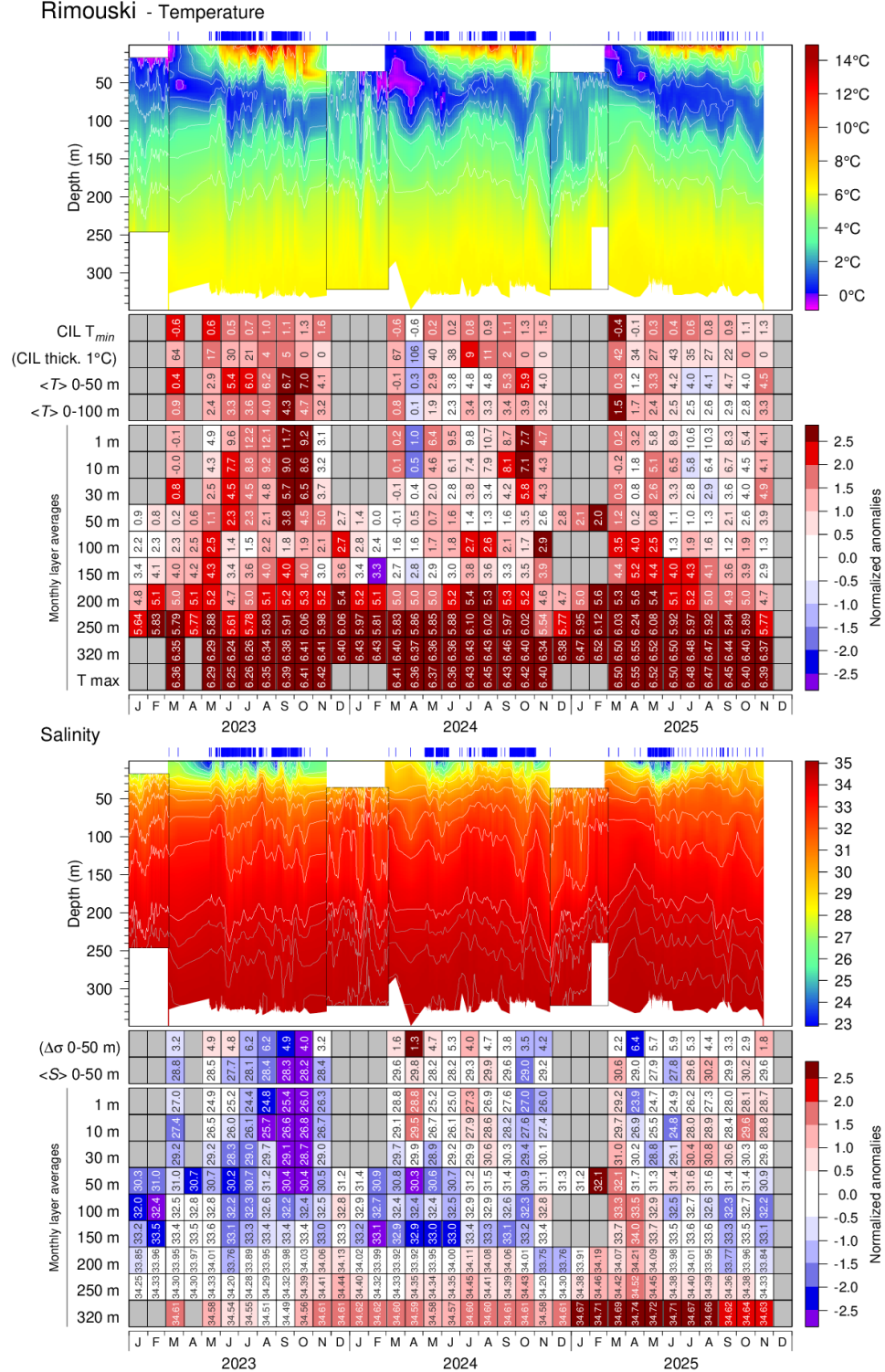


Fig. 67. Temperature (top) and salinity (bottom) time series at the Rimouski station, shown as isotherm and isohaline contour plots and scorecard tables; tick marks above indicate full-depth casts (mostly from an oceanographic buoy). The scorecard tables are monthly layer averages colour-coded according to the anomaly relative to the 1991–2020 monthly climatology for the station (yearly climatology for 200 m and deeper because of the absence of a seasonal cycle). Thickness of the CIL and stratification have reversed colour codes where blue indicates thicker CIL (associated with colder water) and more stratification (associated with low surface salinity). The box insets and some of the monthly averages are from mooring data.

Temperature Anomalies (ΔT)

The top panel displays depth profiles of temperature anomalies from 0 to 80 meters depth. The color scale ranges from 0°C (blue) to 18°C (red). Below the plot are two rows of monthly layer averages:

- <T> 0-50 m:** A row of values representing the average temperature anomaly in the upper 50 meters.
- <T> 0m-bottom:** A row of values representing the average temperature anomaly from the surface to the bottom.

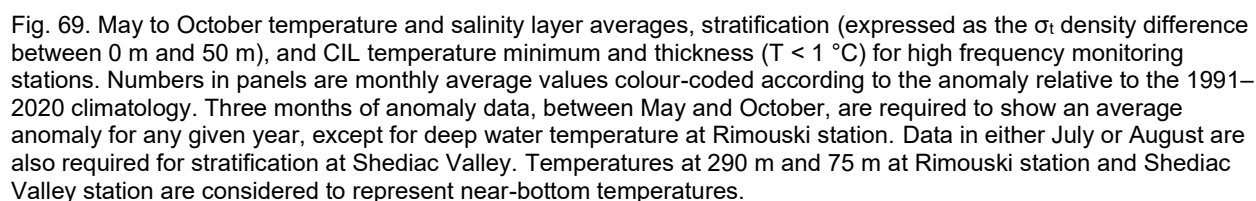
Salinity Anomalies ($\Delta \sigma$)

The bottom panel displays depth profiles of salinity anomalies from 0 to 80 meters depth. The color scale ranges from 23 (blue) to 35 (red). Below the plot are two rows of monthly layer averages:

- ($\Delta \sigma$ 0-50 m):** A row of values representing the average salinity anomaly in the upper 50 meters.
- < $\Delta \sigma$ > 0-50 m:** A row of values representing the average salinity anomaly from the surface to the bottom.

Both panels include a color bar for "Normalized anomalies" ranging from -2.5 to 2.5. The x-axis for both panels shows months from January (J) to December (D) for the years 2023, 2024, and 2025.

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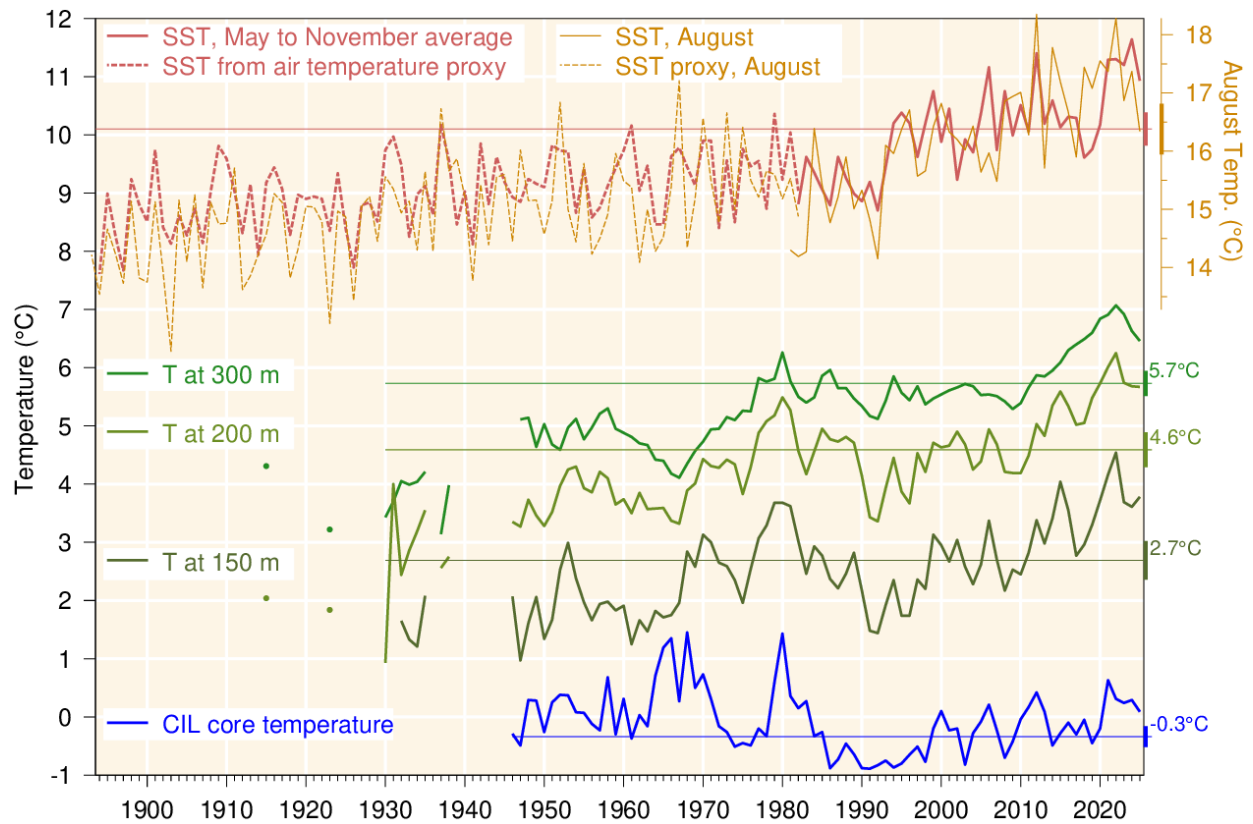


Fig. 70. Water temperatures in the Gulf of St. Lawrence. May–November SST averaged over the Gulf excluding the Estuary (1982–2025, red line), completed by a proxy based on April–November air temperature (1893–1982, red dashed line; average of available Adjusted and Homogenized Canadian Climate Data [AHCCD] stations shown in Fig. 4 but excluding Estuary stations at Baie Comeau and Mont-Joli). The combined proxy and SST data have a warming trend of 1.5 °C per century (1893–2025). August SST (orange line), the warmest month of the annual cycle, is shown using temperature scale offset by 6.3 °C; its proxy is based on the average air temperature in July and August. Layer-averaged temperatures for the Gulf of St. Lawrence at 150 m, 200 m and 300 m (green lines). Cold intermediate layer minimum temperature index in the Gulf of St. Lawrence (blue line). SST air temperature proxy is similar to that of Galbraith et al. (2012). Climatological averages based on the 1991–2020 period are indicated by thin lines labelled on the right side, and half the standard deviation is shown by vertical bars on the right side. Figure adapted from Benoit et al. (2012).

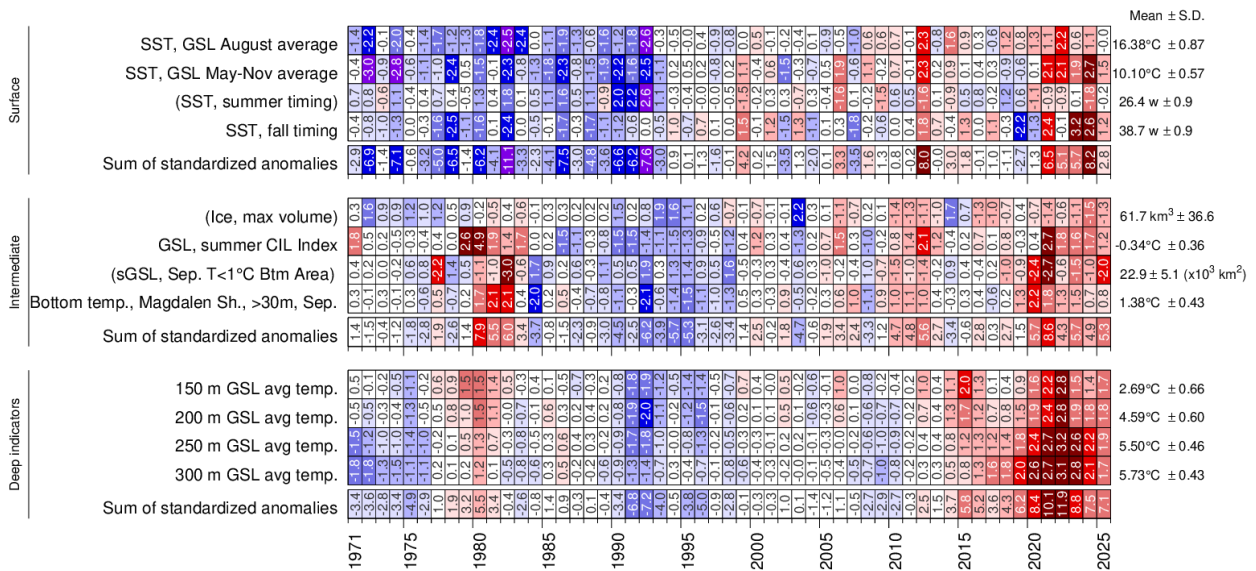


Fig. 71. Surface, intermediate (and sea-ice) and deep indicators used in the composite climate index (Fig. 72). The SST summer and fall timing are for 12 °C. Parameters in parentheses are reversed colour scale (to indicate warmer than normal as red).

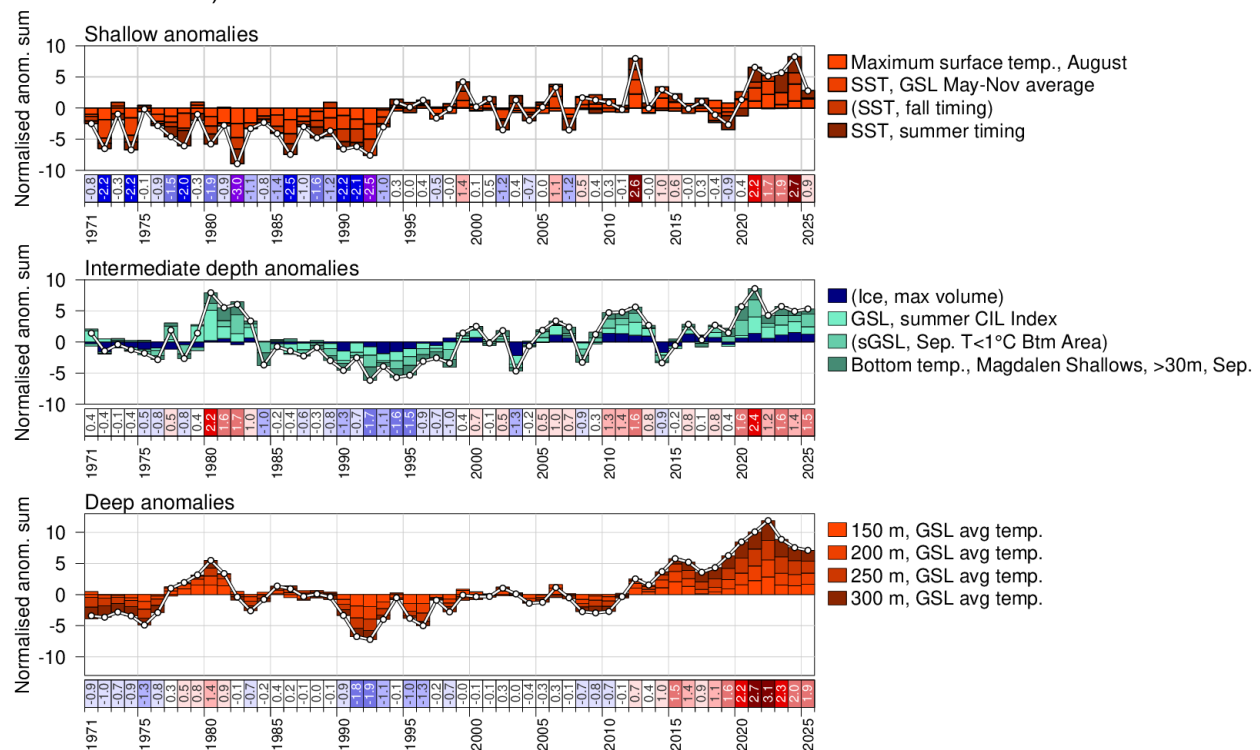


Fig. 72. Composite climate indices (white lines and dots) derived by summing various normalized anomalies from different parts of the environment (coloured boxes stacked above the abscissa are positive anomalies, and below are negative). Top panel sums anomalies representing shallow temperature anomalies, middle panel sums intermediate depth temperature anomalies and sea-ice (all related to winter formation), and bottom panel sums deep temperature anomalies. Each index is a sum of four normalized anomalies, and that time series is shown renormalized again at the bottom of each panel.

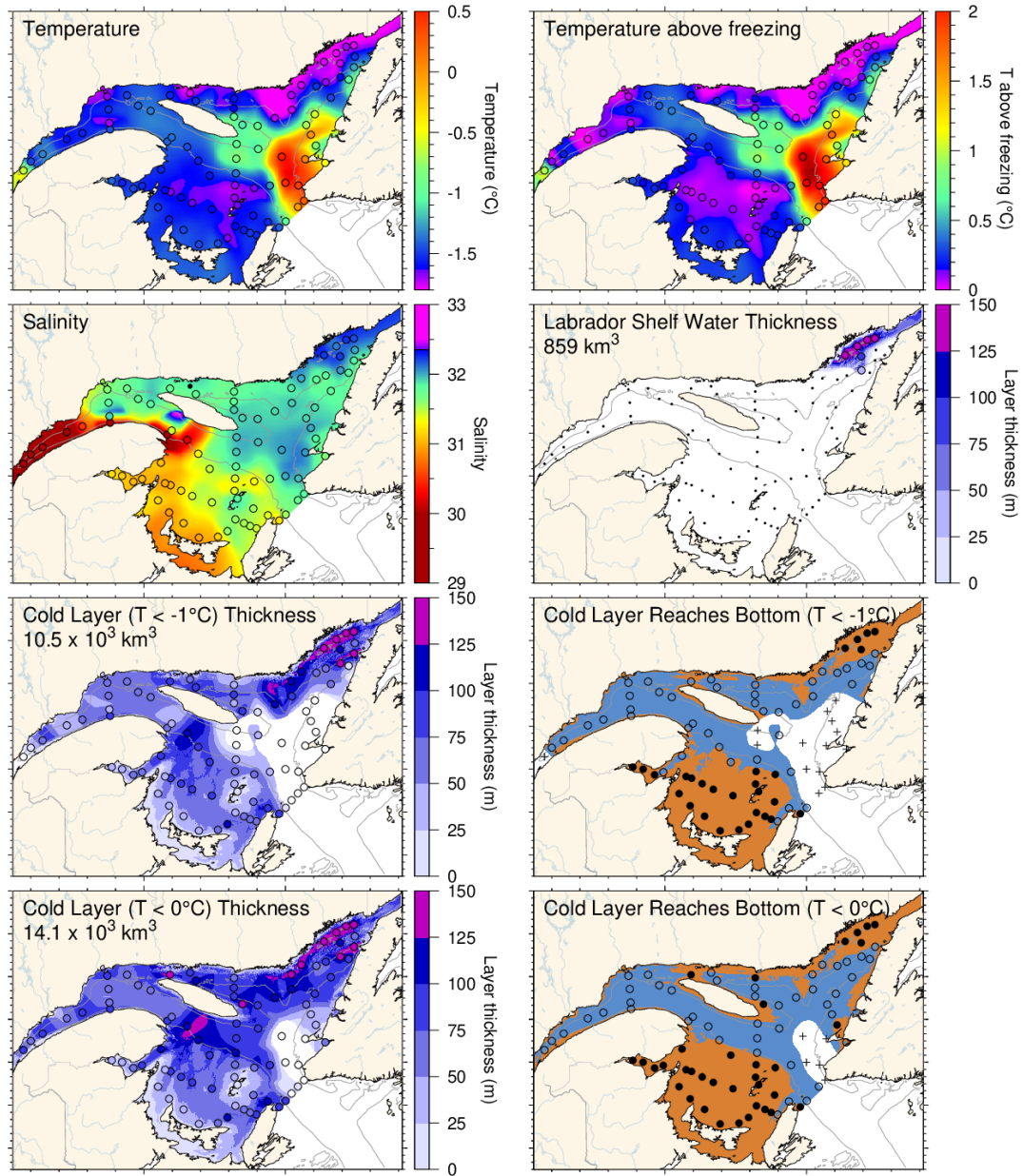


Fig. 73. March 2026 surface cold layer characteristics: surface water temperature (upper left), temperature difference with the freezing point (upper right), salinity (second row left), estimate of the thickness of the Labrador Shelf water intrusion (second row right), and cold layer (T < -1 °C and < 0 °C) thicknesses and where they reach bottom. 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.