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Science | Sciences
Newfoundland and Labrador Region
Canadian Science Advisory Secretariat
Science Advisory Report 2009/057

2008 STATE OF THE OCEAN: PHYSICAL OCEANOGRAPHIC CONDITIONS IN THE NEWFOUNDLAND AND LABRADOR REGION

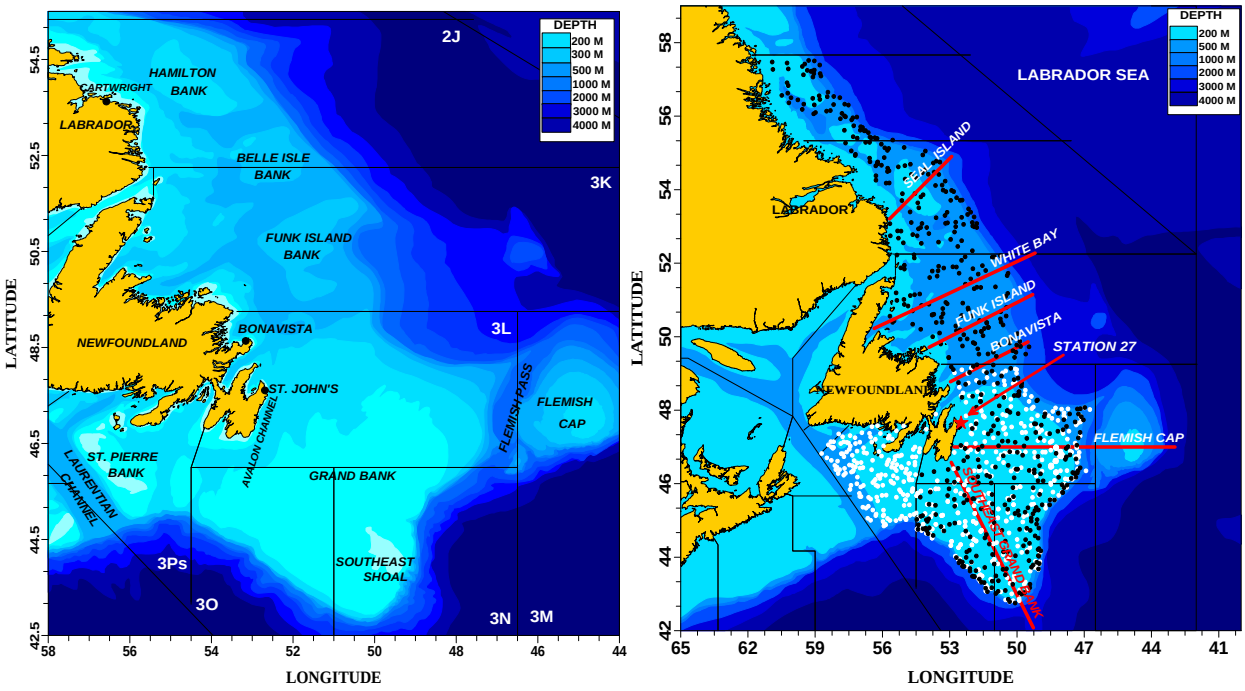

Fig. 1. Location maps showing bathymetric features, NAFO Areas, the positions of standard sections (red lines), the fixed AZMP monitoring site (Station 27, red star) and the positions of oceanographic observations made during spring (white dots) and fall (black dots) fisheries assessment surveys in the Newfoundland and Labrador Region during 2008.

Context

The physical oceanographic environment influences the yield (growth, reproduction, survival), and behaviour (distribution, catchability, availability) of marine organisms as well as the operations of the fishing industry. Changes in this environment may contribute directly to variations in food source (plankton), resource yield, reproductive potential, catchability, year-class size (recruitment) and spawning biomass as well as influencing the perception of the resource status and the efficiency and profitability of the industry.

Physical oceanographic conditions are therefore measured during research vessel resource surveys and regularly at fixed sites as part of the ***Atlantic Zonal Monitoring Program (AZMP)****. Additional hydrographic, meteorological and sea ice data are obtained from a variety of sources, research studies, ships-of-opportunity, fishing vessels and remote sensing (satellites). All of the hydrographic data are edited and archived in a database at Canada's National Integrated Scientific Data Management (ISDM) branch in Ottawa. A working copy is maintained in a regional database at the Northwest Atlantic Fisheries Centre (NAFC), St. John's, Newfoundland and Labrador.*

SUMMARY

- The North Atlantic oscillation index, during both 2007 and 2008, was slightly positive which likely contributed to a cooling in air and ocean temperatures relative to 2006 in most areas.

- Annual air temperatures were above normal in Newfoundland and Labrador by 0.8°C at Cartwright, 1°C at Bonavista and by 1°C at St. John's, a significant decrease over the record highs of 2006 but warmer than in 2007.

- The annual sea ice extent on the NL Shelf remained below normal for the 14th consecutive year. The winter ice extent was the highest since 1997 whereas the spring extent ranked 11th lowest since 1963.

- 976 icebergs were detected south of 48^{o}N on the Northern Grand Bank, up from 324 in 2007 and 0 in 2006.

- The Station 27 depth-averaged annual water temperature increased slightly over 2007 to 0.2°C above normal.

- Annual surface temperatures at Station 27 also increased over 2007 values to 1°C above normal.

- Bottom temperatures at Station 27 remained above normal for the 13th consecutive year. From 2004-06, they were about 0.8°C above normal but decreased to <0.5°C above normal in 2007-08.

- Near surface (0-50 m) summer salinities at Station 27 were above normal (by 0.35) for the 7th consecutive year.

- The average temperature and salinity along the Bonavista section has remained significantly above normal (by 2.8°C and 0.3, respectively) since 2002.

- The cross sectional area of <0°C cold-intermediate-layer (CIL) water mass on the eastern Newfoundland Shelf was below normal for the 14th consecutive year and the 5th lowest since 1948.

- Averaged spring bottom temperatures remained slightly above normal (by 0.3°C) in Divs. 3LNO but were below normal (by 0.6°C) in Sub-Div. 3Ps.

- Averaged fall bottom temperatures were above normal in Divs. 2J3K (by ~0.5°C) and slightly below normal in Divs. 3LNO. These represent a decrease over 2006 and 2007 values.

- The area of bottom habitat on the Grand Banks covered by <0°C water during the spring decreased from near 60% in 1991 to <5% in 2004 but increased to near-normal at about 30% in 2007-08.

INTRODUCTION

The ocean environment on the Newfoundland and Labrador Shelf is influenced by several factors including the Labrador Current, cross-shelf exchange with warmer continental slope water and by bottom topography. Superimposed on these oceanic processes are large seasonal and inter-annual variations in solar heat input, ice cover and storm-forced mixing. The resulting water mass on the shelf is characterised by large annual cycles with strong horizontal and vertical temperature and salinity gradients. Water properties are monitored extensively by fisheries assessment and oceanographic research surveys throughout the year (Fig. 1). Some of these observations are expressed as differences or anomalies from their long-term average values. Where possible, the long-term averages are standardized to a base period of 1971-2000, sometimes referred to as the normal.

2008 ASSESSMENT

Meteorological and Ice Conditions

The North Atlantic Oscillation index, a key indicator of climate conditions in the Northwest Atlantic, was slightly above normal (<0.5 standard deviations) for 2007 and 2008 and as a consequence, outflow of arctic air masses to the Northwest Atlantic was stronger than in 2006. Monthly air temperatures however at Cartwright Labrador and St. John's were above normal for 8 months of 2008 (Fig. 2). Annual air temperatures were above normal in both Newfoundland and Labrador by 0.8°C at Cartwright and 1°C at St. John's, but this was a significant decrease over the record highs observed in 2006. Since the 1960s, annual air temperature anomalies at Cartwright (Fig. 2) showed large variations, superimposed on a general downward trend to the early 1990s. This was followed by a general rise in air temperatures to the end of the 1990s and into the early 2000s. During 1999 for example, temperature anomalies of 1.9^{o}C above normal set an all time high at St. John's (126-year record); and in 2006 the annual anomaly of 2.9^{o}C at Cartwright was the highest in the 74-year record. Air temperatures at Cartwright have been above normal for the past 14 years and at St. John's for the past 11 years.

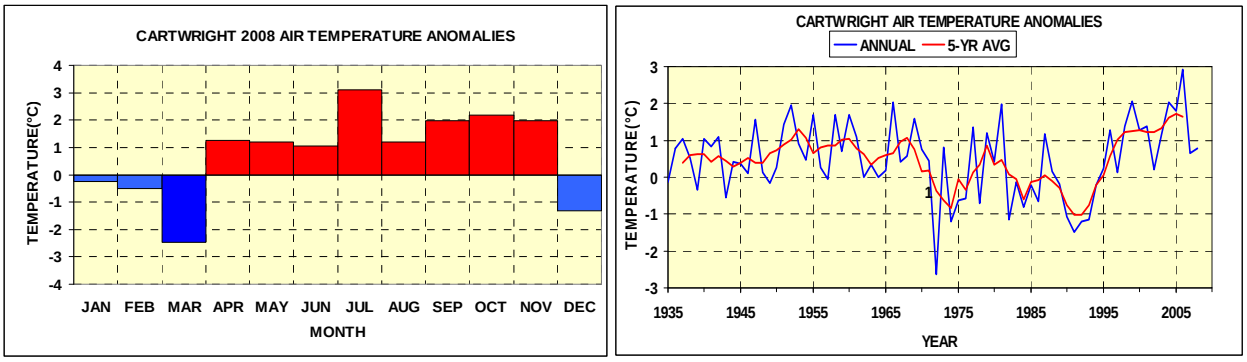

Fig 2. Departures from normal monthly mean air temperatures (left panel) at Cartwright for 2008 and departures from normal annual means (blue line) and the 5 year means (red line) (right panel).

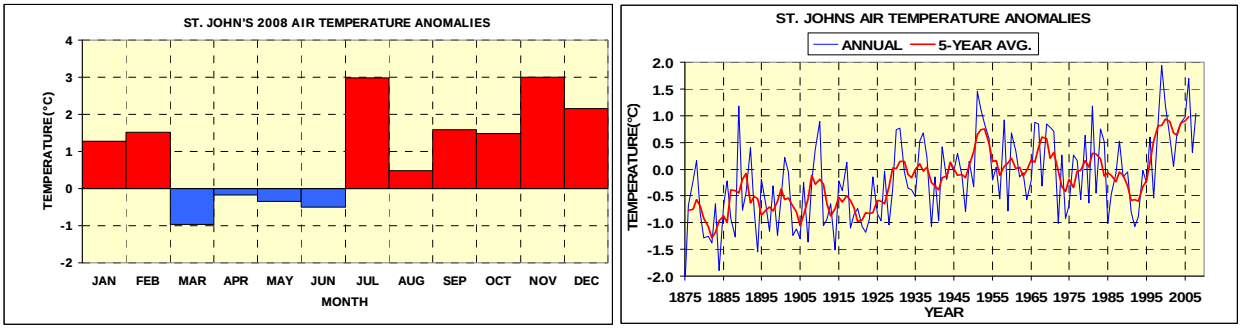

Fig 2 (cont). Departures from normal monthly mean air temperatures(left panel) at St. John's for 2008 and departures from normal annual means (blue line) and the 5 year means (red line) (right panel).

Monthly sea-ice extent on the Newfoundland and southern Labrador Shelf south of 55°N latitude was generally below normal during most of the year. Sea ice had disappeared by late-May and the annual and seasonal average extents were below normal for the 14th consecutive year (Fig. 3). In general, during the past several years, the sea ice season was shorter than normal in most areas of the NL Shelf; however, it extended into June in the inshore areas in 2007. The extent of sea ice during the winter of 2008 was the highest since 1997 yet still the 11th lowest during spring in the 45-year record.

In 2008 there were 976 icebergs detected south of 48°N on the Northern Grand Bank up from 324 in 2007 and 0 during 2006 compared with the 107-year average of 476 (Fig. 3). The highest number of icebergs normally occurs in May but just over 200 were seen in May 2008 and 712 (4 times the normal number) were detected in April. In some years of the early 1980s and 1990s, over 1500 icebergs drifted onto the northern Grand Bank with an all time record of 2202 in 1984.

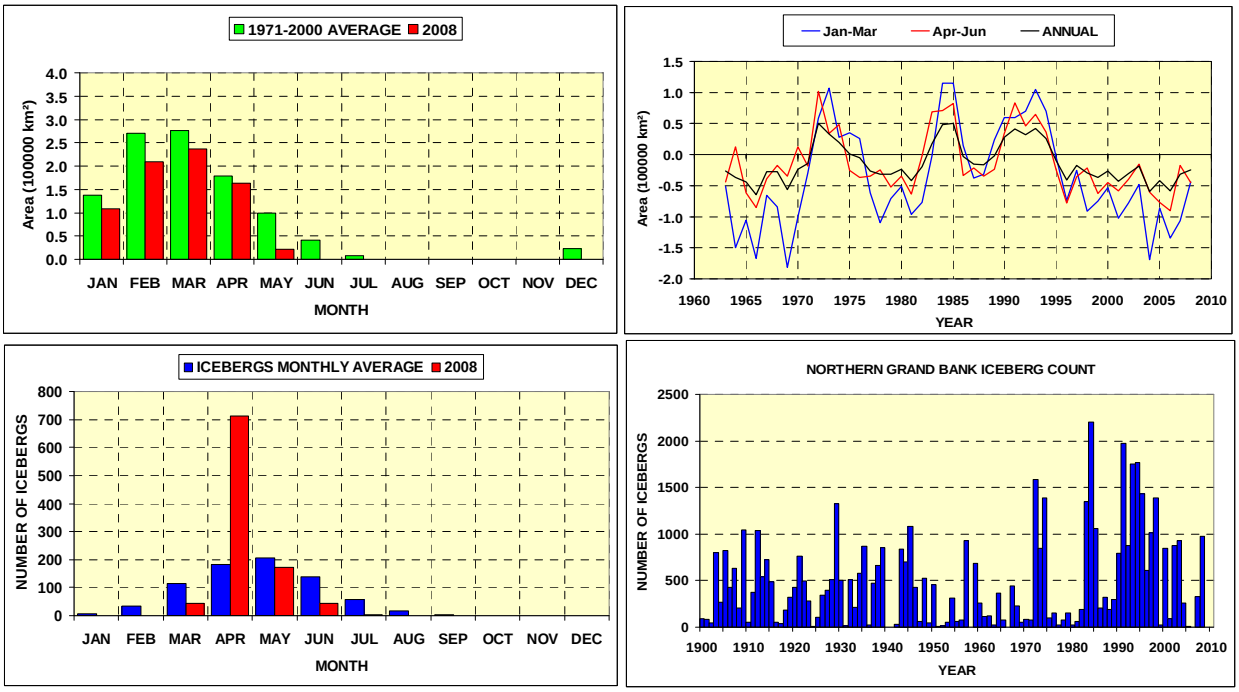

Fig. 3. Monthly and seasonal (winter, spring and annual) sea-ice extent anomalies off Newfoundland and southern Labrador (top panels) and monthly and annual iceberg counts for the northern Grand Banks (Bottom panels).

Temperature and Salinity Variability

AZMP Fixed Site (Station 27)

Temperature and salinity have been measured at a standard hydrographic monitoring station (Station 27, bottom depth 176 m) off Cape Spear, about 7 km from St. John's Harbour, since 1946 (Fig. 1). In 2008 the cold, near-isothermal water column during late January to May had temperatures ranging from near 0° to –1.5°C. These temperatures persisted throughout the year below 90 m. Upper layer temperatures warmed to >1°C by mid-May and to >14°C by late July and August, after which the fall cooling commenced with temperatures decreasing to 5°C by early December. The seasonally heated upper-layer was constrained to only about 30 m by the end of August due to increased salinity stratification but increased to about 75 m during the remainder of the year. This resulted in a sub-surface cold anomaly during the summer and late fall with temperatures reaching >0.5°C below normal (Fig. 4).

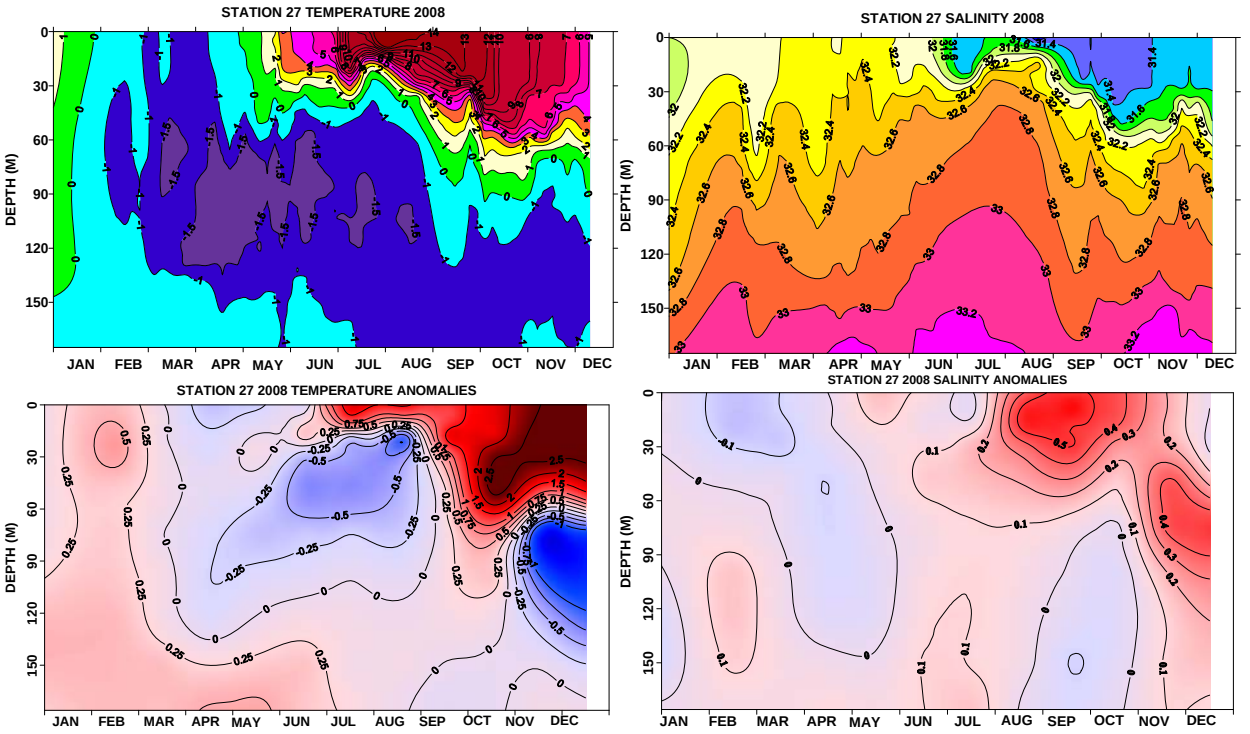

Fig. 4. Contours of temperature and salinity (top panels) and their monthly anomalies (bottom panels) at Station 27 as a function of depth for 2008.

Annual surface water temperatures increased over 2007 to 1°C above normal while bottom temperatures decreased slightly to 0.2°C above normal (Fig. 5). The Station 27 depth-averaged annual temperature (which is proportional to the total heat content) shows large annual and decadal fluctuations throughout the time series. From 1950 to the late 1960s, the total heat content was generally above the long-term mean. Recently, the heat content varied from a record low in 1991, to a record high during 2006, near-normal in 2007 and slightly above normal in 2008.

Maximum surface salinities (>32.2) occurred at Station 27 during late winter and early spring while minimum values of <31.4 occurred during late August (Fig. 4). At mid depths, salinities ranged from 32.4 to 33 and near the bottom were generally >33. The period of low salinity values at

shallow depths occurring from summer to late fall is a prominent feature of the salinity cycle on the Newfoundland Shelf and is due largely to melting sea-ice off Labrador earlier in the year followed by advection southward onto the Grand Banks. During 2008 this effect was slightly diminished as indicated by the positive salinity anomalies at shallower depths from August to December.

The 0-50 m depth-averaged summer salinity anomalies show similar patterns as the heat content with fresher-than-normal periods generally corresponding to the colder-than-normal conditions (Fig. 5). Since the fresh conditions of the early 1990s, salinities have fluctuated above and below normal. During 2002, summer salinities on the Newfoundland Shelf increased to the highest values in about 12 years. The 2003 to 2008 values remained above the long-term mean for the 7th consecutive year.

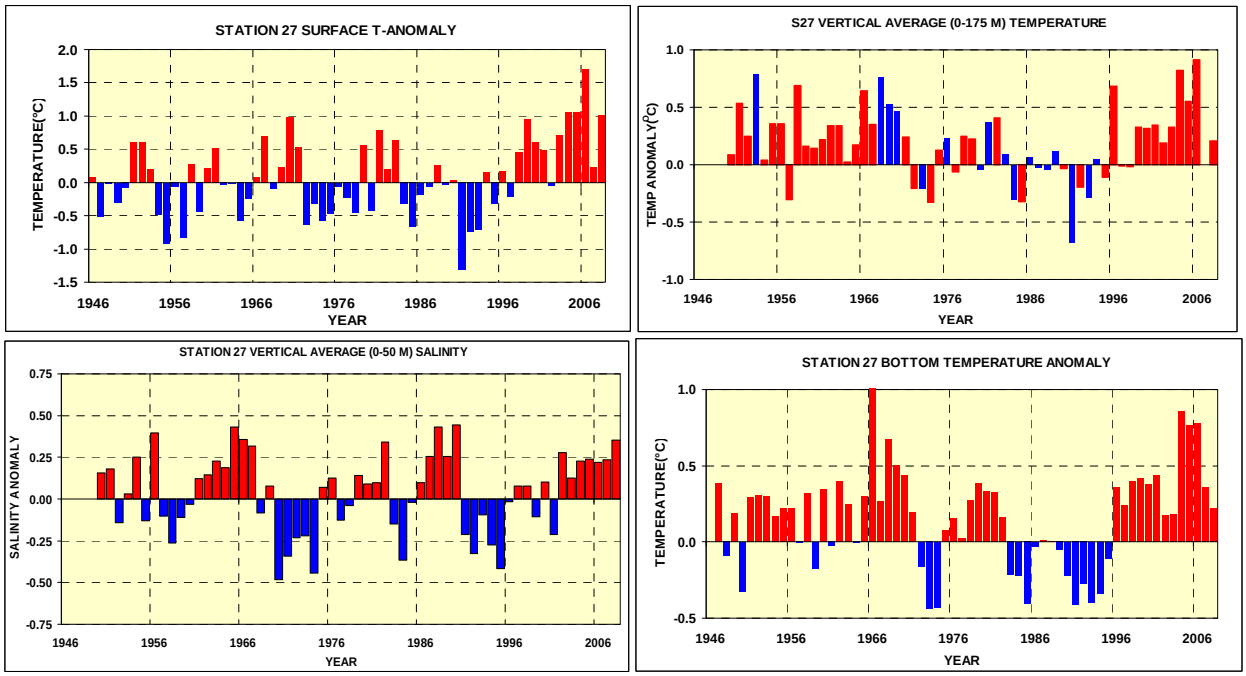

Fig. 5. Departures from normal surface, bottom and depth averaged (0-176 m) Station 27 temperature and upper layer depth averaged salinity.

AZMP Standard Sections

Summer monitoring of temperature and salinity along several standard sections across the Newfoundland and Labrador Shelf began in the late 1940s and early 1950s (Fig. 1). In 1998, under the Atlantic Zone Monitoring Program (AZMP), sampling along the sections was expanded to include biological and chemical measurements; several sections are now sampled seasonally except for the winter.

The water mass characteristics observed along the standard sections are typical of sub-polar waters with sub-surface temperatures ranging from -1º to 2ºC and salinities from 32 to 33.5. Labrador Slope Water flows southward along the shelf edge and into the Flemish Pass region. This water mass is warmer and saltier than the sub-polar shelf waters with temperatures ranging from 3º to 4ºC and salinities from 34 to 34.75. Surface temperatures generally increase to 10º to 14ºC during summer, while bottom temperatures over most of the shelf range from 1º to 4ºC. Throughout most of the year, the cold relatively fresh water overlying the shelf is separated from the warmer higher density water of the continental slope region by a strong temperature and

density front. In general, water properties along the standard sections undergo seasonal modification due to the seasonal cycles of air-sea heat flux, wind forced mixing and sea-ice formation and melting, which lead to intense vertical and horizontal changes or gradients (Fig. 6).

The dominant feature of the temperature structure on the Newfoundland and Labrador Shelf, particularly during the summer, is the layer of cold <0°C water, commonly referred to as the Cold Intermediate Layer (CIL). The winter-cooled water mass remains isolated during the summer and early fall months between the seasonally heated surface layer and warmer near bottom water originating from the continental slope region. Along the Bonavista section during the summer, the CIL normally extends offshore approximately 200 km, with a maximum vertical extent of about 200 m. In 2008, the cross sectional area of this water mass extended to the surface during spring, was smaller than normal in the summer, but increased significantly by late November. The seasonal cross sections of salinity show remarkable similarities from spring to fall with slightly fresher upper-layer inshore values occurring during the fall (Fig. 6).

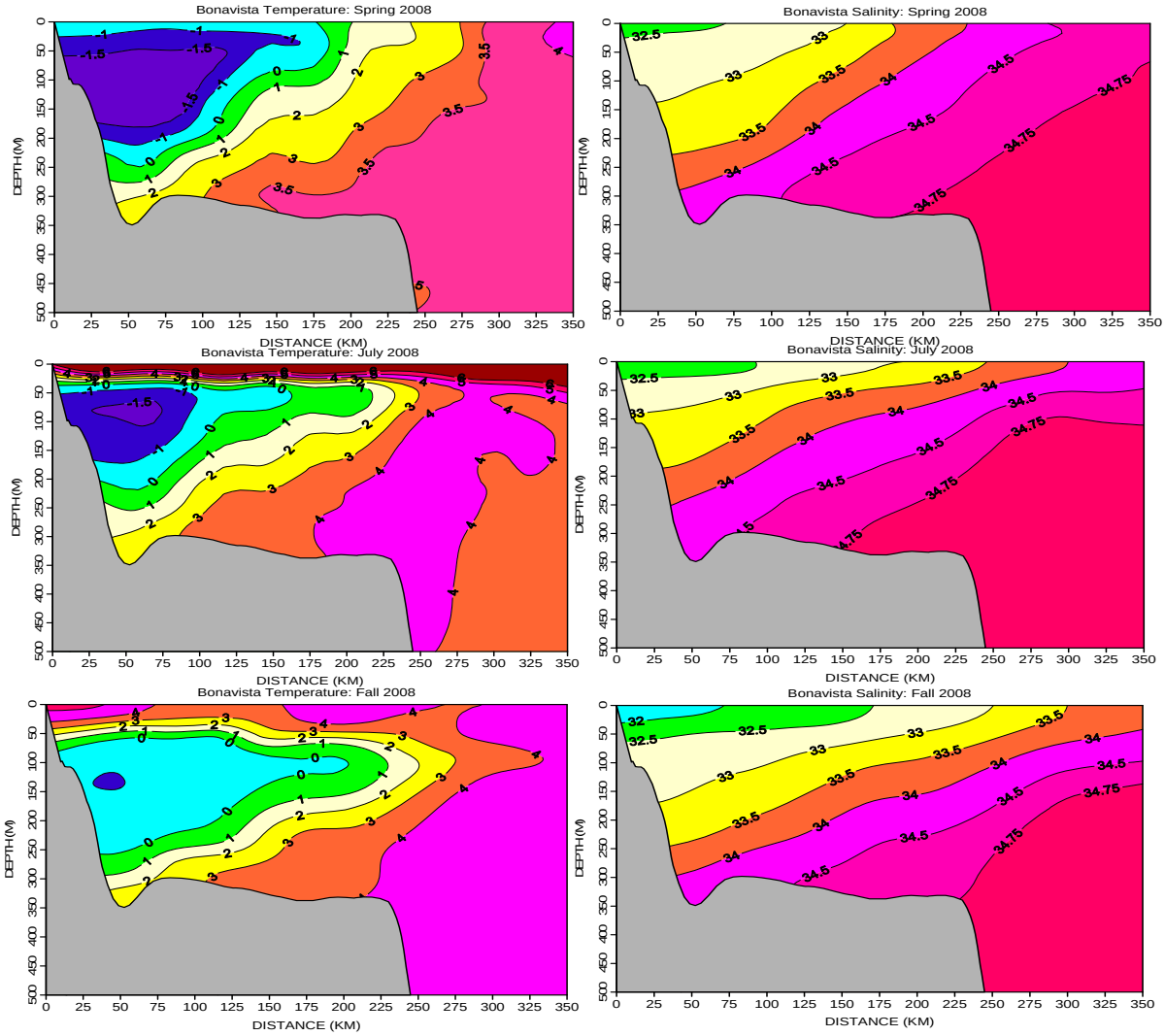

Fig. 6. Cross sectional contour maps of the temperature and salinity structure on the Eastern Newfoundland Shelf off Cape Bonavista during the spring, summer and fall of 2008.

The time series of CIL area and mean temperature for eastern Newfoundland (Bonavista section) and southern Labrador (Seal Island section) are displayed in Fig. 7. Small CIL cross sectional areas correspond to warm oceanographic conditions. The summer CIL area during 2008 was either near normal or smaller than the long-term mean for all sections sampled from Labrador to the Grand Banks. Along the Bonavista section, the CIL area was below normal for the 14th consecutive year (1995-2008), ranking the 5th lowest in 60 years of observations. These values are in sharp contrast to the near record high values measured during the extremely cold years of the early 1990s on the Newfoundland Shelf. The temperature time series for the eastern Newfoundland and southern Labrador sections show an increasing trend since the early 1990s with 2008 values among the highest since the mid-1960s (Fig. 7).

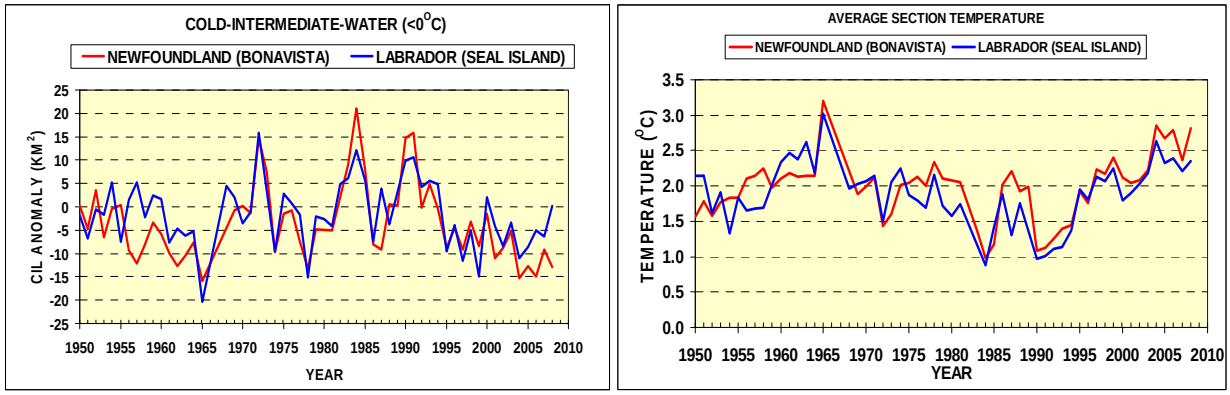

Fig. 7. Time series of the Cold-Intermediate Layer (CIL) areas and the average temperature along the Bonavista Section off eastern Newfoundland and the Seal Island Section of southern Labrador. See Fig. 1 for locations.

Multi-Species Survey Results

The collection of oceanographic data aboard fisheries resource assessment surveys was initiated in 1971. These data are routinely used by fisheries scientists and oceanographers to monitor changes in the near-bottom thermal habitat of many marine fish and invertebrate species. The data are also used to relate variations in the distribution and abundance of groundfish species to changes in the ocean environment. Two standardized trawl surveys are conducted each year, one in the spring in NAFO areas 3PLNO and one in the fall in areas 2J3KLNO (Fig. 1).

A bottom temperature map for NAFO Divisions 3PLNO based on the spring 2008 trawl surveys is displayed in Fig. 8 along with the percentage area of the bottom habitat covered with water in different temperature ranges. Spring bottom temperatures in Div. 3L ranged from <0° to 1°C in the inshore regions of the Avalon Channel and parts of the Grand Bank and from 1° to >3°C at the shelf edge. Over the central and southern areas of the Grand Banks and west of St. Pierre Bank, bottom temperatures ranged from 1° to 6°C. There was a significant increase in the area of St. Pierre Bank (3Ps) and the Grand Banks (3LNO) covered by water with temperatures <0°C during the spring of 2007 and 2008 compared to the previous 2-3 years (Fig. 8, right panels). In general, bottom temperature anomalies were highly variable with values ranging from 0.5° to 2°C above normal over most of the 3L region and in southern areas of 3O. In western areas of Div. 3Ps negative anomalies dominated, particularly in the deeper areas of the Laurentian Channel.

A bottom temperature map for the fall of 2008 in NAFO Divisions 2J, 3K and 3LNO along with time series of spatially averaged bottom temperatures is displayed in Fig. 9. Bottom temperatures in Div. 2J ranged from <1°C inshore, about 1°C over Hamilton Bank and >3.5°C offshore at the

shelf break. Most of the 3K region is deeper than 200 m, as a result relatively warm slope water floods through the deep troughs between the banks. Bottom temperatures in these areas during the fall of 2008 were generally warmer than normal between 2° to 3.5°C, with colder values <1°C along the northeast coast.

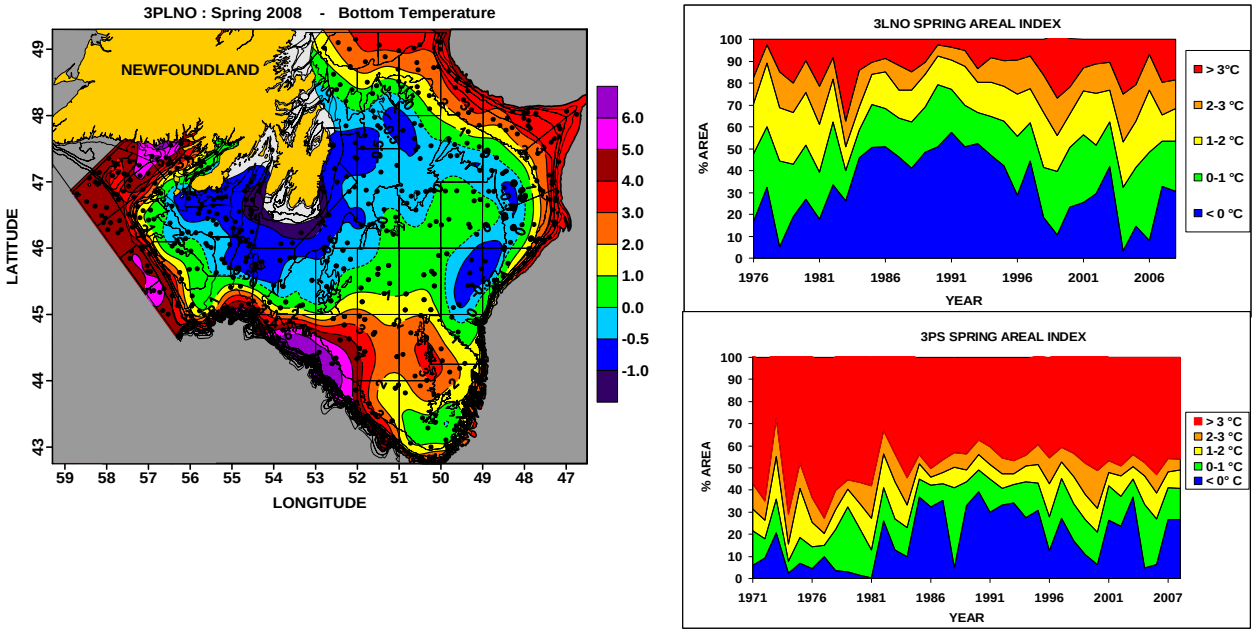

Fig. 8. Bottom temperature map (°C) for the spring of 2008 for NAFO Divisions 3PLNO and the percentage area of the bottom covered by water in different temperature ranges.

Fall bottom temperatures in northern areas of Div. 3L were generally above normal ranging from <0°C on the northern Grand Bank and in the Avalon Channel to >3.5°C along the shelf edge. Over the remainder of the Grand Banks, bottom temperatures were either near normal or slightly below normal. The area averaged bottom temperature in 2J and 3K decreased compared to 2007 values to about 2.5°C, whereas in 3LNO the average bottom temperature decreased only slightly from 1.8°C in 2006-07 to 1.7°C in 2008.

CONCLUSION

The North Atlantic Oscillation index, a key indicator of climate conditions in the Northwest Atlantic, was slightly above normal for 2007 and 2008 and as a consequence, outflow of arctic air masses to the Northwest Atlantic was stronger than in 2006. This most likely contributed to a broad-scale cooling of air temperatures throughout the Northwest Atlantic from West Greenland to Baffin Island to Labrador and Newfoundland, relative to 2006. Monthly sea-ice extent on the Newfoundland and southern Labrador Shelf however remained below normal during most months and near normal during April with the annual average below normal for the 14th consecutive year. In general, during the past several years, the sea ice season was shorter than normal in most areas of the NL Shelf, although it extended into June in the inshore areas during the spring of 2007. Water temperatures in 2007-08 on the Newfoundland and Labrador Shelf cooled from the record highs of 2006 but remained above normal in most areas, continuing the warm conditions experienced since the mid-to-late 1990s. Salinities on the NL Shelf, which were lower than normal throughout most of the 1990s, increased to the highest observed since the early 1990s during 2002 and have remained mostly above normal during the past 7 years.

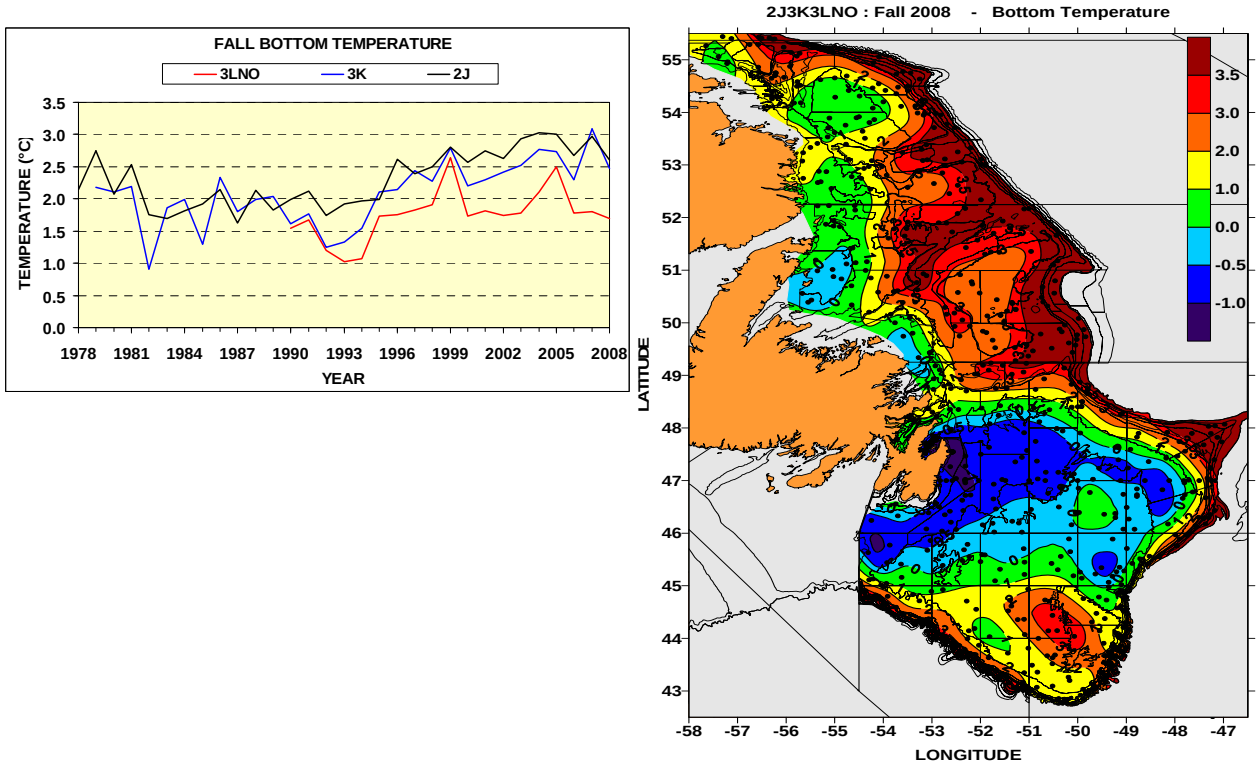

Fig. 9. Time series of spatially averaged bottom temperature and the bottom temperature map (°C) for the fall of 2008 for NAFO Divisions 2J and 3KLNO.

Outlook for 2009

Oceanographic conditions in the Newfoundland and Labrador region of the Northwest Atlantic are largely determined by the strength of the winter atmospheric circulation over the Northwest Atlantic, local air temperatures and the advection of sub-polar waters to the area from the north. An atmospheric pressure pattern that promotes the flow of cold Arctic air southward results in extensive sea-ice along the coast and generally cold and fresh ocean conditions during spring and summer. On the other hand, when the circulation is weak the reverse is generally true leading to warm-saline ocean conditions.

A large area of lower than normal sea level pressure (SLP) over the northwest Atlantic from the coast of Labrador to Greenland during December of 2008 and January of 2009 likely caused enhanced arctic air mass outflow to the region. However, air temperatures which were -1.3°C below normal in December on the Labrador coast were near normal farther south at St. John's. In January, air temperatures were slightly above normal in these areas. Sea ice extent by mid February was more extensive than normal on the east and northeast coast of Newfoundland but had decreased to less than its normal extent by the end of the month.

Temperature measurements at Station 27 in mid-February of 2009 indicate above normal water temperatures by >0.5°C at shallower depths and by 0.3°C near bottom. These were similar to values observed during mid-February of 2008. Therefore, the outlook based on limited and early information indicates a continuation of near-normal to above normal ocean temperatures throughout the Newfoundland and Labrador Region in 2009, similar to 2007 and 2008

conditions, and represents a significant cooling from the exceptionally warm period of 2004-2006.

SOURCES OF INFORMATION

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