



# 2005 STATE OF THE OCEAN: PHYSICAL OCEANOGRAPHIC CONDITIONS IN THE NEWFOUNDLAND AND LABRADOR REGION

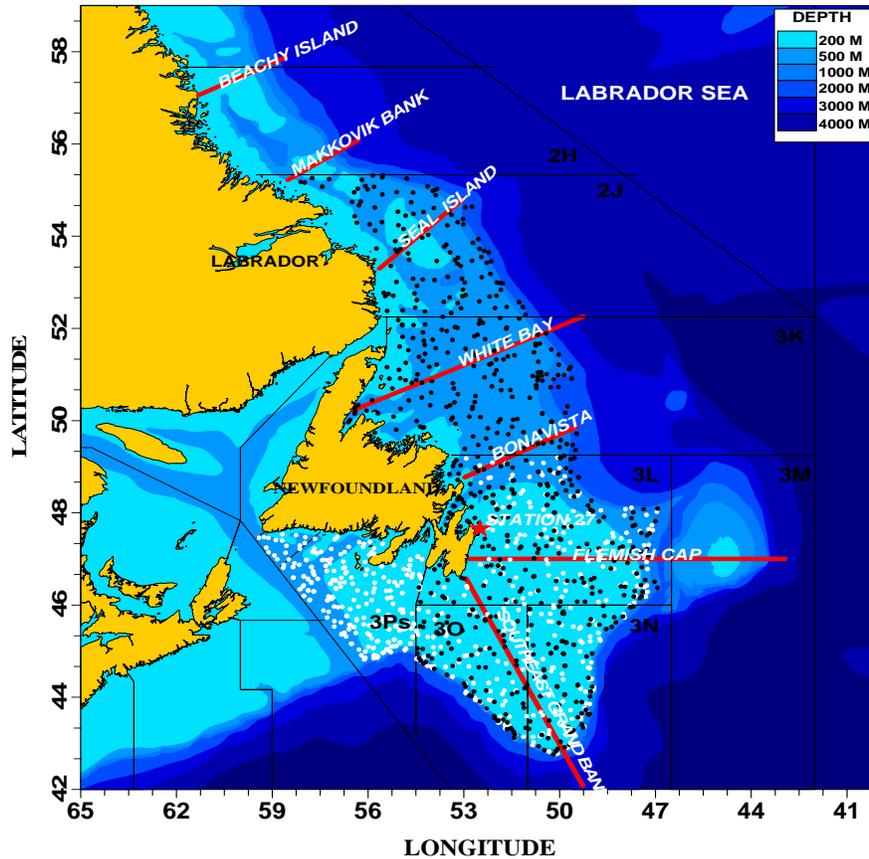


Fig. 1. Location Map showing the positions of standard sections, the fixed AZMP monitoring site (Station 27) and the positions of oceanographic observations made during spring (white dots) and fall (black dots) fisheries assessment surveys in the Newfoundland and Labrador Region during 2005.

## 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 Canada's national Marine Environmental Data Service (MEDS) database. A working copy is maintained in a zonal database at the Northwest Atlantic Fisheries Centre in St. John's Newfoundland.

## SUMMARY

- Annual air temperatures were above normal in Newfoundland and Labrador during 2005 by 1.8°C at Cartwright and by nearly 1°C at St. John's.
- Annually sea-ice extent on the Newfoundland and Labrador Shelf remained below normal for the 11<sup>th</sup> consecutive year.
- Only 11 icebergs drifted south of 48°N onto the Northern Grand Bank during 2005; this was the lowest number since 1966 and well below the 106 year average of 477.
- The Station 27 annual depth-averaged water temperature off St. John's decreased from the record high of 2004 to just over 0.5°C above normal, the 7<sup>th</sup> highest on record.
- Annual surface temperatures at Station 27 remained at the 60 year record high value of 2004 at 1°C above normal.
- Annual bottom temperatures at Station 27 were also above normal by 0.8°C, the 3<sup>rd</sup> highest in the 60-year record.
- Near surface annual salinities off St. John's at Station 27 were above normal for the 4<sup>th</sup> consecutive year.
- The area of <0°C (CIL) water mass on the eastern Newfoundland Shelf during 2005 was below normal for the 11<sup>th</sup> consecutive year and the 5<sup>th</sup> lowest since 1948.
- Bottom temperatures on St. Pierre Bank were above normal during the spring of 2005, the highest since 2000 and the 6<sup>th</sup> highest in 36 years of observations.
- Bottom temperatures during the fall of 2005 on the Newfoundland and Labrador Shelf were above normal in almost all areas, reaching a record of 2°C above average off southern Labrador.
- The area of bottom habitat on the Grand Banks covered by sub-zero water has decreased from >50% during the first half of the 1990s to approximately 15% during 2004 and 2005.

## 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 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 standardised to a base period of 1971-2000, sometimes referred to as the normal.

## 2005 ASSESSMENT

### Meteorological and Ice Conditions

Monthly air temperatures at Cartwright Labrador were above normal during all months of 2005 except in January whereas at St. John's they were above normal in all months except March, May and June (Fig. 2). Annually, air temperatures were very similar to 2004 values which were above normal in both Newfoundland and Labrador by nearly 2°C at Cartwright and 1°C at St. John's. Since the 1960s, annual air temperature anomalies at Cartwright (Fig. 2) showed large variations, superimposed on a general downward trend through to the early 1990s. This was followed by a general rise in air temperatures through to the end of the 1990s and into the early 2000s. During 1999 for example, temperature anomalies of 1.9°C above normal set all time highs at St. John's (126-year record) and Cartwright (65-year record). Air temperatures at Cartwright have been above normal for the past 11 years and at St. John's for the past 8 years.

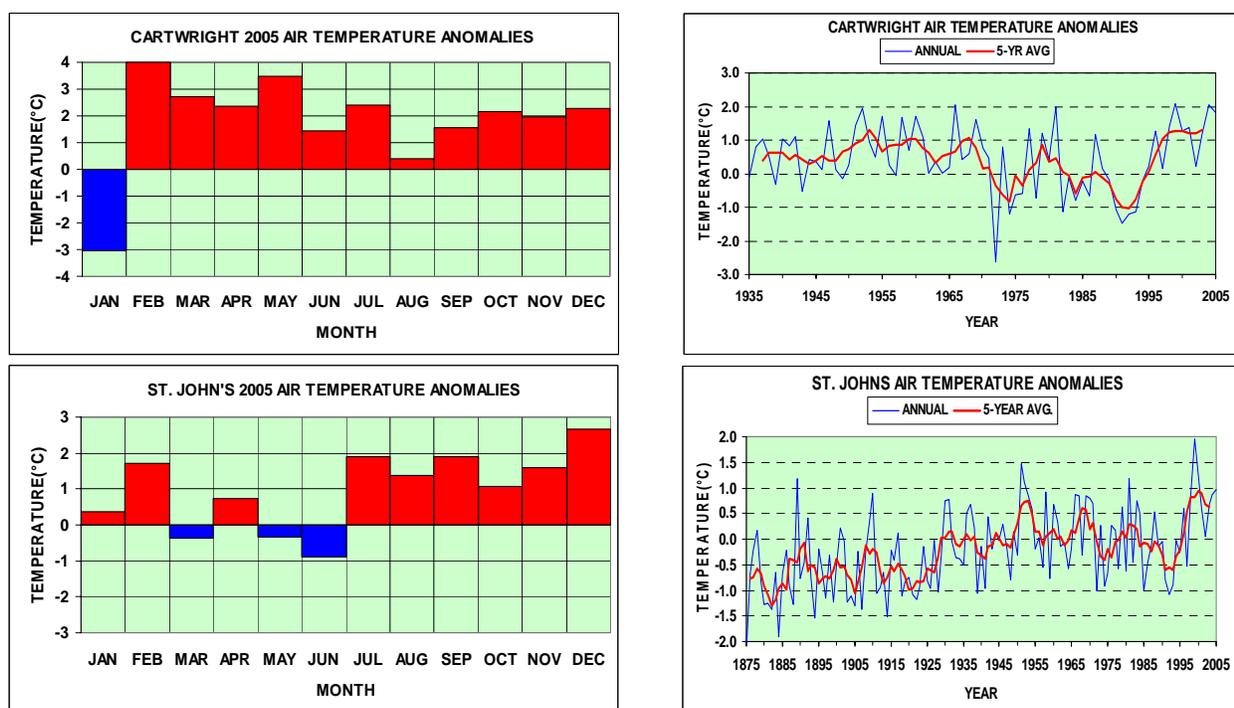


Fig 2. Departures from normal monthly mean air temperatures at Cartwright and St. John's for 2005 (left panels) and departures from normal annual means (blue line) and the 5 year means (red line) at Cartwright and St. John's (right panels).

Monthly sea-ice areas on the Newfoundland and southern Labrador Shelf south of 55°N latitude were well below normal with the largest coverage in February (Fig. 3). By May the ice areas had decreased to very low values and by June sea-ice had disappeared completely. The duration of the sea ice season was shorter than normal during 2005. Sea-ice extent increased slightly compared to 2004, but remained below normal for the 11<sup>th</sup> consecutive year. The area of sea ice during the winter of 2004 decreased to the lowest in the 42-year record. Winter sea-ice extent on the Newfoundland and Labrador Shelf during 2005 increased slightly compared to that of 2004, whereas spring ice cover decreased in 2005 to the 3<sup>rd</sup> lowest in the time series.

A total of 11 icebergs drifted south of 48°N onto the Northern Grand Bank during 2005, 9 in March and one in April and one in May (Fig. 3). These were the lowest numbers since 1966, well below the 106 year average of 477. The highest number of icebergs normally occurs in May with just over 200. In 2004 there were 262 icebergs observed on the Northern Grand Bank and in some years of the early 1990s over 1500 icebergs drifted onto the northern Grand Bank.

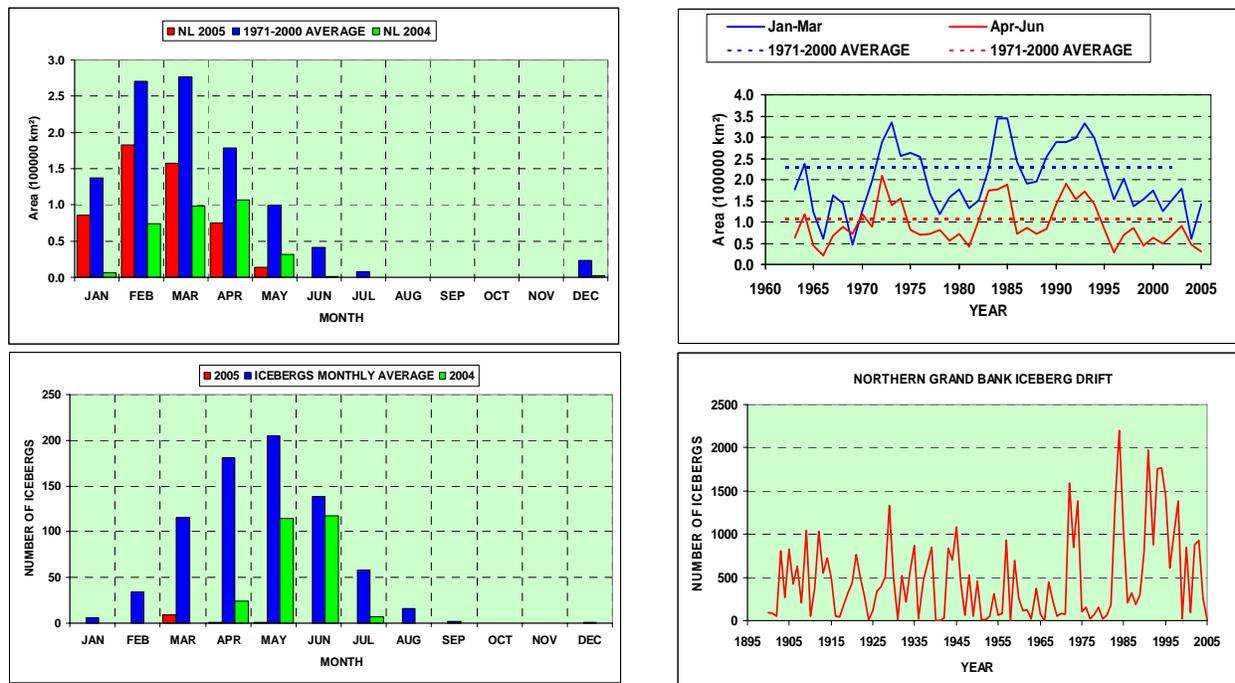


Fig. 3. Monthly and seasonal (winter and spring) sea-ice areas off Newfoundland and southern Labrador (top panels) and monthly and annual icebergs counts for the northern Grand Banks (Bottom panels).

## Temperature and Salinity Variability

### AZMP Fixed Site (Station 27)

Temperature and salinity conditions 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 2005 upper layer temperatures at this site, which is located in the inshore branch of the Labrador Current, were generally less than 0°C from February to mid-April and from approximately 0°C to -1°C throughout the year near the bottom. By early-May upper layer temperatures had warmed to 2°C and to above 15°C by August, after which the fall cooling commenced.

Temperatures were about 0.5°-1.5°C above normal during the winter months over most depths and throughout the year at the surface and near bottom. A colder than normal anomaly occurred at intermediate depths during mid-summer with temperatures dropping to 1°C below average at 30 m depth due to upwelling of cold sub-surface water (Fig. 4).

Annual surface water temperatures off St. John's were 1°C above normal, identical to 2004, the highest in the 60 year record; bottom temperatures were above normal by 0.8°C, the 3<sup>rd</sup> highest in the 60-year record (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 (Fig. 5). 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 very high during 1996 and to a record high during 2004. The 2005 value decreased over the record high of 2004 to just over  $0.5^{\circ}\text{C}$  above normal, the 7<sup>th</sup> highest on record.

Maximum surface salinities at Station 27 (Fig. 4) were  $>32$  during March while minimum values of  $<31.2$  occurred by September. Below the surface layer, salinities ranged from 32.4 to 33 near the bottom throughout the year. Salinity values were near normal during January, generally below normal from February to June and above normal from August to the end of the year at shallow depths.

The 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 2005 values remained above the long-term mean.

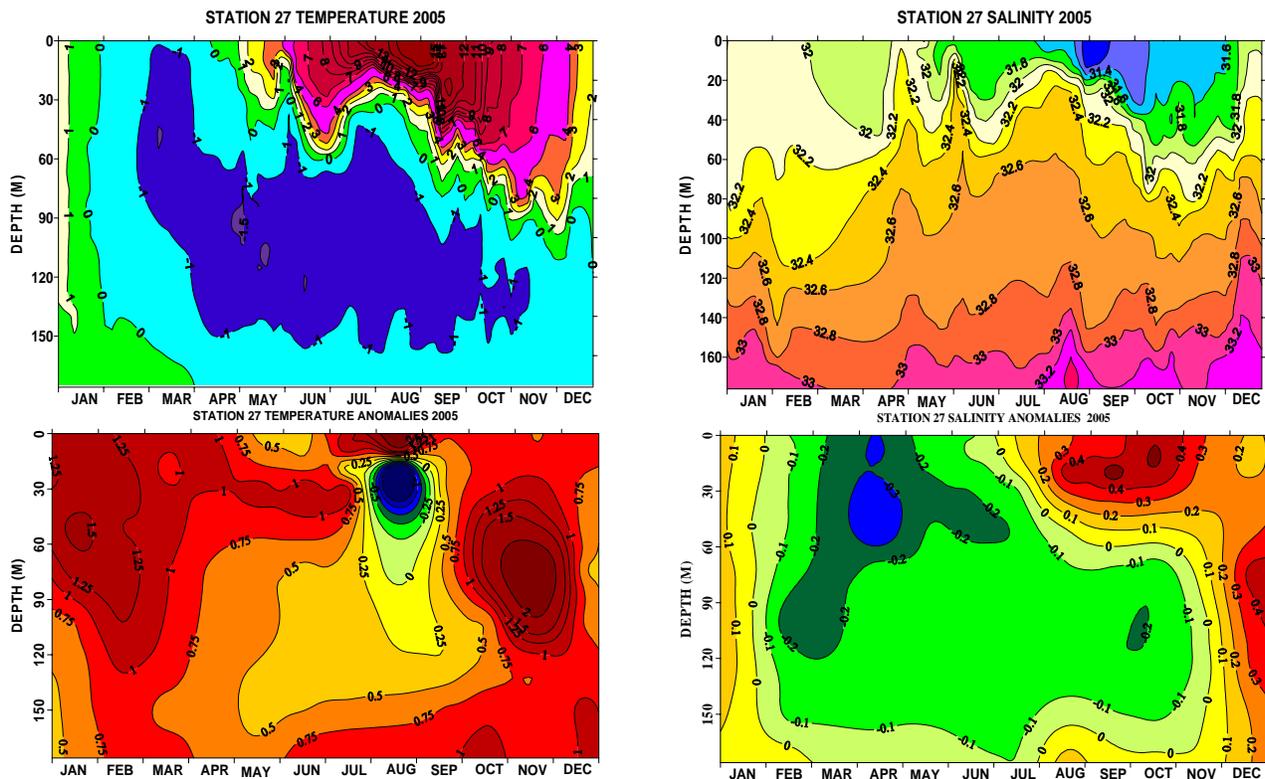


Fig. 4. Contours of temperature and salinity (top panels) and their anomalies (bottom panels) at Station 27 as a function of depth for 2005.

### 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.

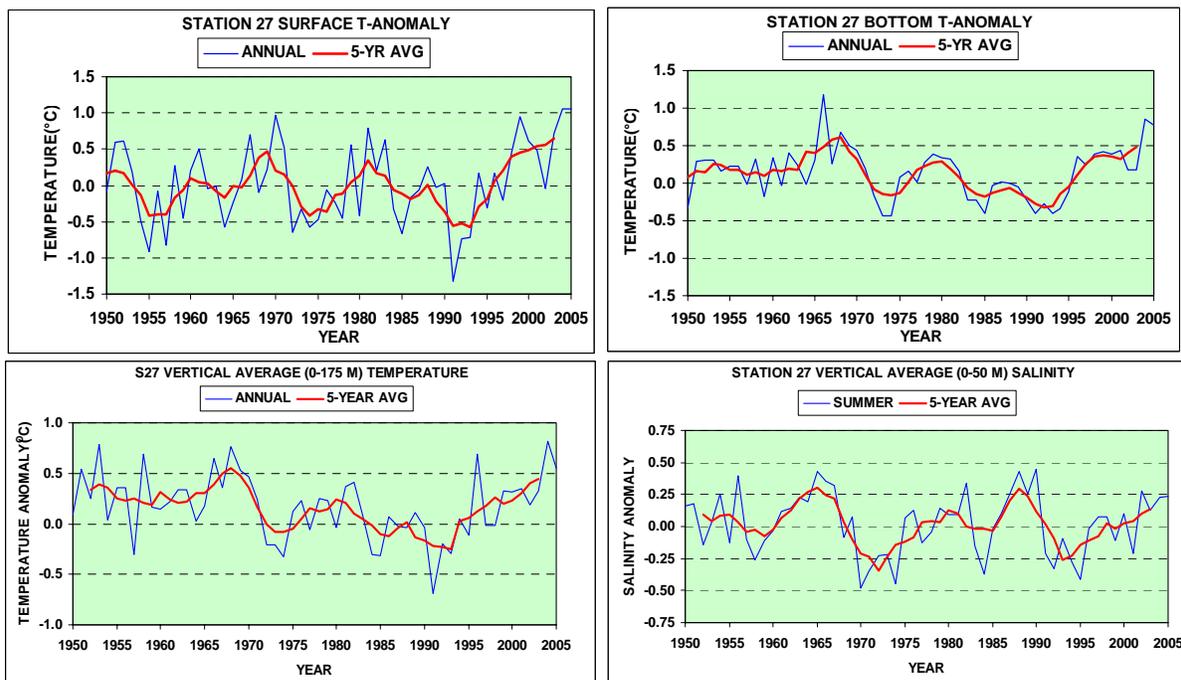


Fig. 5. Departures from normal surface, bottom and depth averaged (0-176 m) Station 27 temperature and upper layer depth averaged salinity.

The water mass characteristics observed along the standard sections are typical of sub-polar waters with sub-surface temperatures ranging from  $-1^{\circ}$  to  $2^{\circ}\text{C}$  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  $3^{\circ}$  to  $4^{\circ}\text{C}$  and salinities from 34 to 34.75. Surface temperatures warm to  $10^{\circ}$  to  $12^{\circ}\text{C}$  during summer, while bottom temperature over most of the shelf range from  $1^{\circ}\text{C}$  to  $4^{\circ}\text{C}$ . 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 ice formation and melt leading to intense vertical and horizontal changes or gradients (Fig. 6).

The most revealing feature of the temperature structure on the Newfoundland and Labrador Shelf, particularly during the summer, is the layer of cold  $<0^{\circ}\text{C}$  water, commonly referred to as the Cold Intermediate Layer (CIL). This 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 by over 200 km, with a maximum vertical extent of about 200 m. In 2005, this water mass extended to near the surface during spring, was the 5<sup>th</sup> smallest since 1948 in the summer and was nearly gone by late autumn (Fig. 6).

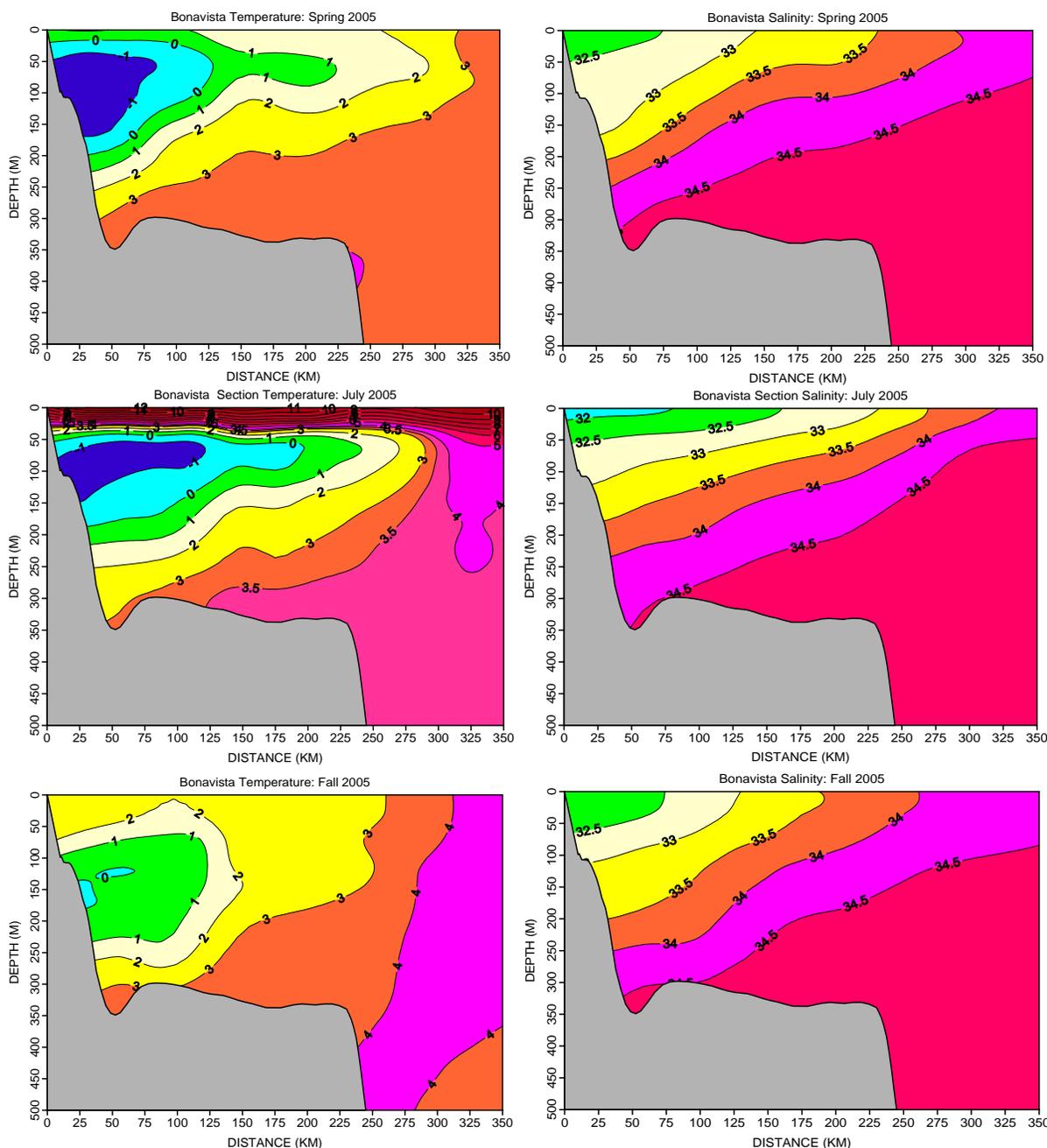


Fig. 6. Cross sectional contour maps of the temperature structure on the Eastern Newfoundland Shelf off Cape Bonavista during the spring, summer and fall of 2005.

Seasonal cross sections of salinity for 2005 show remarkable similarities from spring to fall with slightly fresher upper-layer shelf values occurring during the summer (Fig. 6). The time series of CIL area, mean temperature and salinity for eastern Newfoundland (Bonavista section) and southern Labrador (Seal Island) are displayed in Fig. 7. In these plots, low CIL areas correspond to warm oceanographic conditions. The CIL area during 2005 was below the long-term mean along all sections sampled from Labrador to southern Newfoundland. Along the Bonavista section the CIL was below normal for the 11<sup>th</sup> consecutive year. 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 both Newfoundland and Labrador show a continuation of the increasing trend since the early 1990s with the 2005 value the 3<sup>rd</sup> highest off

eastern Newfoundland and the 7<sup>th</sup> highest off southern Labrador. The salinity time series show inter-annual fluctuations of the order of 0.1 to 0.2 with no significant trend (Fig. 7).

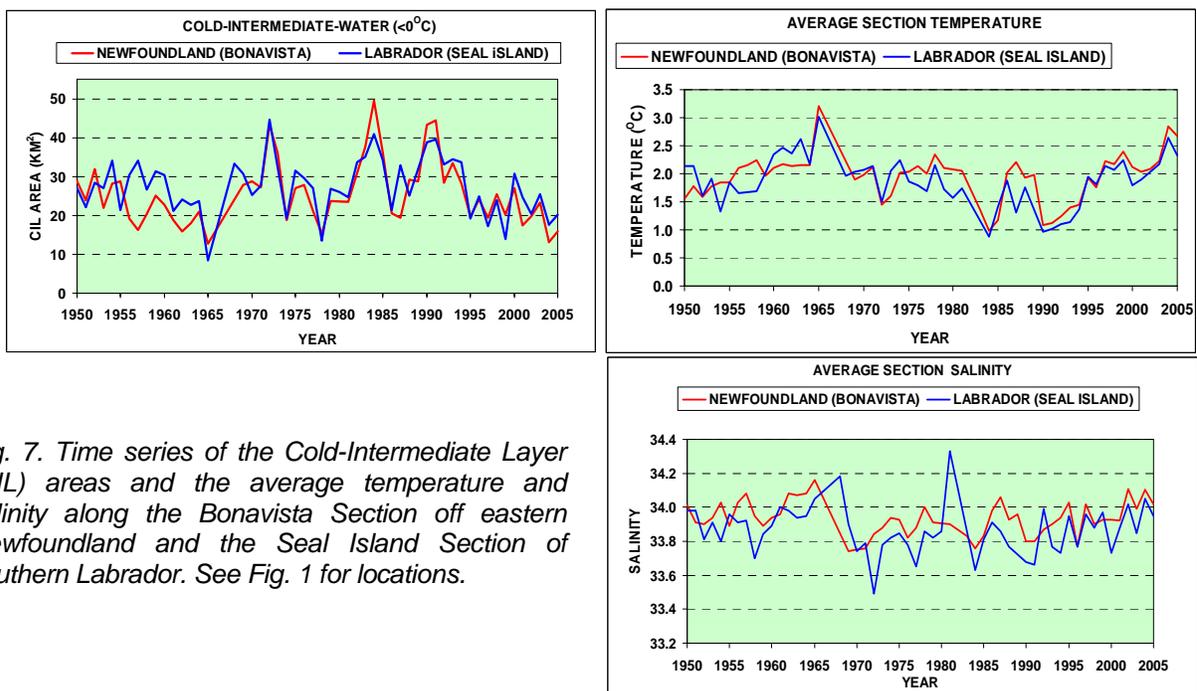


Fig. 7. Time series of the Cold-Intermediate Layer (CIL) areas and the average temperature and salinity along the Bonavista Section off eastern Newfoundland and the Seal Island Section of southern Labrador. See Fig. 1 for locations.

### Multi-Species Survey Results

The collection of oceanographic data aboard fisheries resource assessment surveys was initiated in 1971 in the Newfoundland and Labrador Region. 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 by Fisheries and Oceans in the Newfoundland and Labrador Region, one in the spring in NAFO areas 3PLNO and one in the fall in areas 2J3KLNO (Fig. 1).

Bottom temperature maps for NAFO Divisions 3P and 3LNO during the spring of 2005 are displayed in Fig. 8. Bottom temperatures over most of St. Pierre Bank ranged from  $<1^{\circ}$  to  $3^{\circ}\text{C}$ , which were above the long-term mean and a significant increase over 2003 values in this area. The area of the bottom covered by water with temperatures  $<0^{\circ}\text{C}$  was very similar to 2004 which was the lowest since 1988. In the deeper regions, (Laurentian and Hermitage Channels) temperatures were mostly below the long-term average but still generally  $>3^{\circ}\text{C}$  (Fig. 8). The averaged bottom temperature of the surveyed area in Division 3P ranged between  $2^{\circ}$  to  $4^{\circ}\text{C}$  from 1970 to 1984 decreased to between  $2^{\circ}$  to  $2.5^{\circ}\text{C}$  from 1985 to 1997. During 1999 and 2000 the average bottom temperature increased to over  $3^{\circ}\text{C}$  but decreased to near  $2^{\circ}\text{C}$  from 2001 to 2003. During the spring of 2004 and 2005 the mean bottom temperature had once again increased to  $3^{\circ}\text{C}$ .

Spring bottom temperatures in Div. 3L ranged from  $<0^{\circ}\text{C}$  to  $1^{\circ}\text{C}$  in the inshore regions of the Avalon Channel and parts of the Grand Bank and from  $1^{\circ}$  to  $>3^{\circ}\text{C}$  at the shelf edge. Over the central and southern areas bottom temperatures ranged from  $1^{\circ}\text{C}$  to  $3.5^{\circ}\text{C}$  and generally  $>3.5^{\circ}\text{C}$

along the southwest slopes of the Grand Bank in Div. 3O. The spring of 2005 had the 4<sup>th</sup> lowest area of  $<0^{\circ}\text{C}$  water in Division 3L since the surveys began in the early 1970s (Fig. 8). In general, temperatures were above normal in most areas of the Grand Banks by  $0.5^{\circ}\text{C}$  to  $2^{\circ}\text{C}$ . From 1998 to 2000 the 3LNO spatially averaged bottom temperature increased significantly over the lows of the early 1990s. The mean bottom temperature during the spring of 1999 and 2000 reached  $2^{\circ}\text{C}$  but decreased to just over  $1^{\circ}\text{C}$  from the spring of 2001 to 2003. In 2004 it increased by  $1^{\circ}\text{C}$  to near  $2.5^{\circ}\text{C}$ , the highest since 1983 but decreased again by almost  $0.5^{\circ}\text{C}$  in 2005 (Fig. 8).

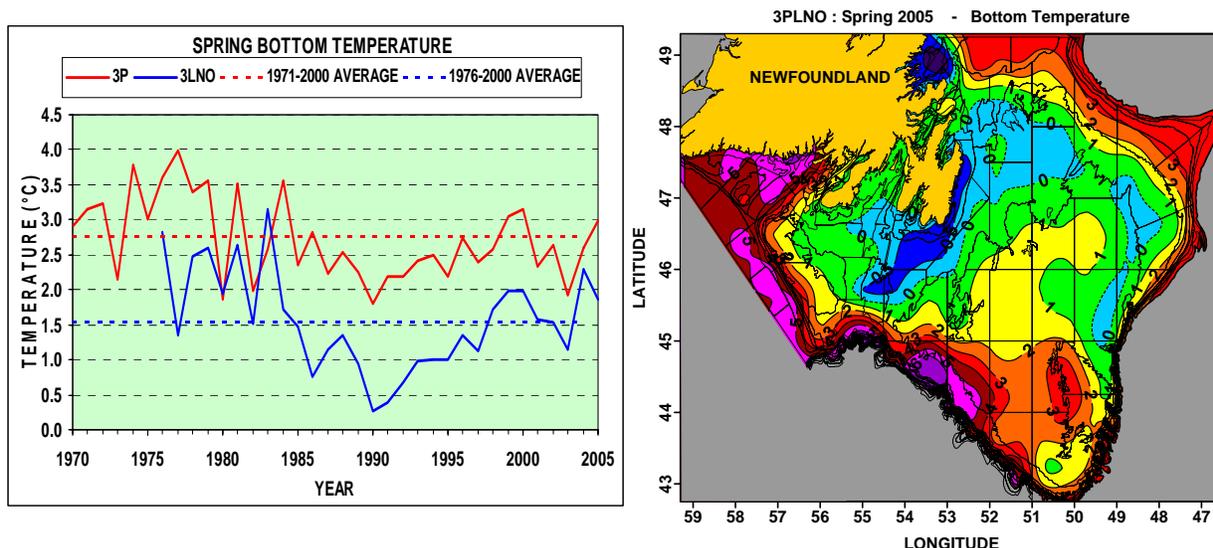


Fig. 8. Time series of spatially averaged bottom temperature and the bottom temperature map ( $^{\circ}\text{C}$ ) for the spring of 2005 for NAFO Divisions 3PLNO.

Bottom temperature maps for the fall of 2005 in NAFO Divisions 2J, 3K and 3LNO are displayed in Fig. 9. Bottom temperatures in Div. 2J ranged from  $<2^{\circ}\text{C}$  inshore, to  $>3.5^{\circ}\text{C}$  offshore at the shelf break. Over Hamilton Bank they ranged from  $2^{\circ}\text{C}$  to  $3^{\circ}\text{C}$ , about  $1.5^{\circ}$  to  $2^{\circ}\text{C}$  above the long-term average. The spatially averaged bottom temperatures during the fall in Div. 2J was slightly over  $2^{\circ}\text{C}$  but during the latter half of the 1990s they increased to about  $2.5^{\circ}\text{C}$ . During the fall of 2003 mean bottom temperatures increased over 2002 values to a record value of near  $3.0^{\circ}\text{C}$  and have remained steady during 2004 and 2005 (Fig. 9).

Most of the 3K region is deeper than 200-m, as a result relatively warm slope water floods through the deep troughs between the northern Grand Bank and southern Funk Island Bank and between northern Funk Island Bank and southern Belle Isle Bank. Bottom temperatures on these banks during the fall of 2005 ranged between  $2^{\circ}$  to  $3.5^{\circ}\text{C}$ , which were about  $0.5^{\circ}$  to  $1.5^{\circ}\text{C}$  above their long-term means. In the near-shore areas temperatures were  $<2^{\circ}\text{C}$  which were also above normal by  $1^{\circ}\text{C}$  to  $2^{\circ}\text{C}$ . Near the edge of the continental shelf in water depths below 500 m, temperatures were generally near normal around  $3.5^{\circ}\text{C}$ . The time series of the average bottom temperature in Div. 3K (Fig. 9) during the fall ranged from  $1^{\circ}\text{C}$  in 1982 to  $2.3^{\circ}\text{C}$  in 1986 with an overall average of slightly  $<2^{\circ}\text{C}$ . From 1995 to 1999 they increased to above-average values reaching a maximum of  $2.7^{\circ}\text{C}$  during 1999. After decreasing by about  $0.5^{\circ}\text{C}$  in 2000, bottom temperatures have again increased to near-record highs in 2004 and 2005.

Fall bottom temperatures in Div. 3LNO generally ranged from  $<0^{\circ}\text{C}$  on the northern Grand Bank and in the Avalon Channel to  $3.5^{\circ}\text{C}$  along the shelf edge. Over the southern areas, bottom temperatures ranged from  $1^{\circ}$  to  $3.5^{\circ}\text{C}$  during 2005 and to  $>3.5^{\circ}\text{C}$  along the edge of the Grand Bank. During 2005 bottom temperatures were predominately above normal on the northern Grand

Bank but varied about the mean in southern areas. The spatially averaged bottom temperature in Divs. 3LNO during the fall decreased from approximately 1.5°C during 1990 to 1°C during 1993 and 1994 then increased to approximately 1.8°C during 1995. These remained relatively constant up to 1998 but then increased to >2.5°C during 1999, the highest in the 10 year record. During the fall of 2000 to 2003 the mean bottom temperature decreased by nearly 1°C over the 1999 value, but was still above the cold condition of the early 1990s. In 2004 and 2005 temperatures again increased by about 0.5°C reaching 2.5°C, the 2<sup>nd</sup> highest in the time series (Fig. 9).

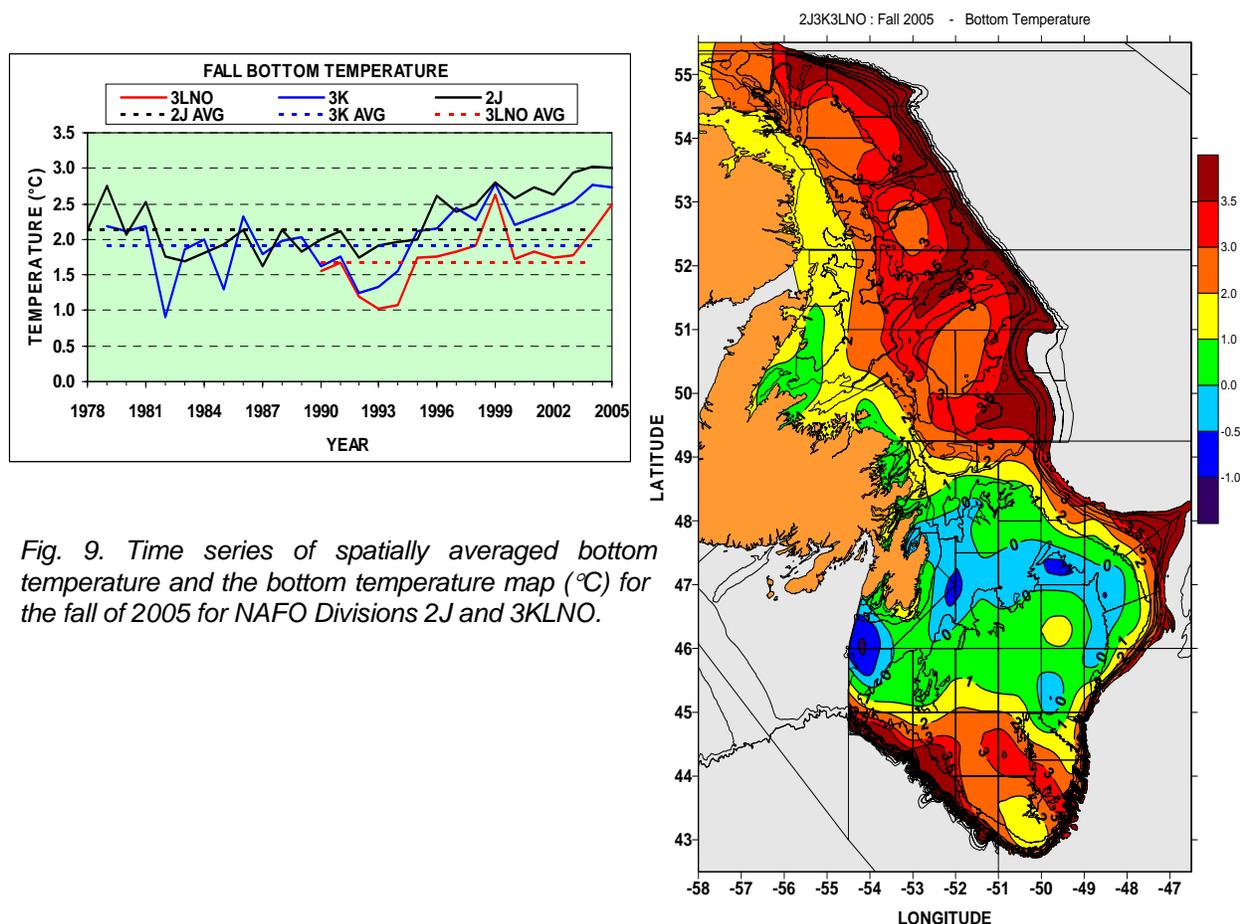


Fig. 9. Time series of spatially averaged bottom temperature and the bottom temperature map (°C) for the fall of 2005 for NAFO Divisions 2J and 3KLNO.

## Outlook for 2006

Oceanographic conditions in the Newfoundland and Labrador region of the Northwest Atlantic are to a large degree determined by the strength of the winter atmospheric circulation over the Northwest Atlantic and local air temperatures. A circulation 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. Early indications during the winter of 2005/2006 show significant positive anomalies in air temperatures over Labrador (+4.5°C in January and +1°C in February at Cartwright) and Newfoundland (+3.3°C in January and +1.5°C in February at St. John's). This has led to delayed sea-ice formation on the Newfoundland and Labrador Shelf with generally lower than average coverage continuing into the winter of 2006. In addition, the atmospheric pressure fields during the December-February 2006 period indicating very weak arctic outflow during the winter with sea-level pressures above normal over a wide area of the North Atlantic. These conditions have resulted in warmer than

normal water temperatures at Station 27 over all depths into the second week of February 2006. Therefore, unless conditions cold significantly during the spring months, we can expect a continuation of the warming trend in ocean temperatures throughout the Newfoundland and Labrador Region during 2006.

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