



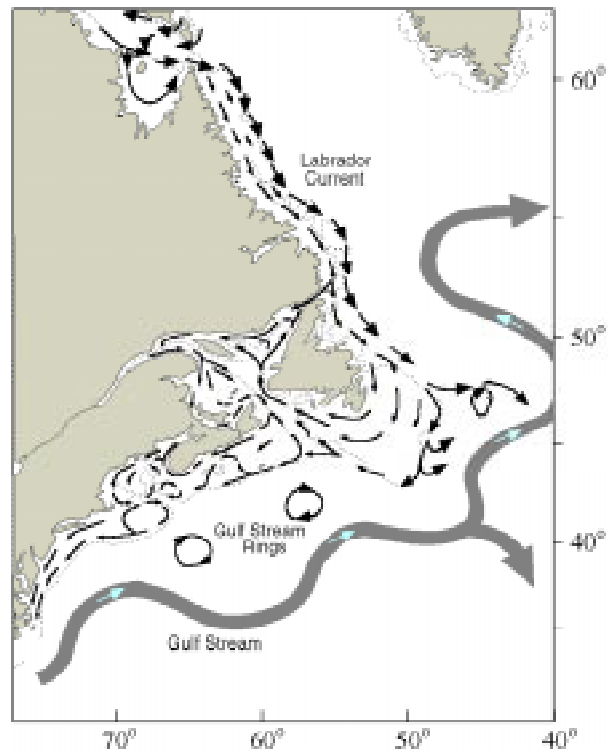
State of the Ocean: Northwest Atlantic

Background

The abundance, growth, catchability and geographic distribution of many fish and shellfish stocks vary in response to environmental change. Therefore, to help understand the cause of observed fluctuations in fish and shellfish resources and eventually predict future changes, we seek to describe and understand the ocean climate and its variability.

Catches of most major fish and shellfish species off eastern Canada have centered on offshore banks but most of the continental shelf, including estuaries and embayments, from Hudson Strait to the Gulf of Maine are commercially exploited. In addition, the habitat of anadromous (e.g. salmon) and catadromous species (e.g. eels) extend from the inland river systems to the deep open ocean at different times of the year. Climate summaries of the physical oceanographic conditions (mainly water temperature and salinity) within this broad geographic area are gathered from standard monitoring stations, regional resource surveys, process-oriented research studies, ships-of-opportunity, fishing vessels, and satellite imagery. Additional data on hydrological, meteorological and sea ice conditions are collected or gathered from various government departments.

All of the hydrographic data are edited and archived in Canada's national Marine Environmental Data Service (MEDS) data base. A working copy is maintained in a zonal data base at the Bedford Institute of Oceanography.



Mean Conditions

The circulation of the continental shelf waters off eastern Canadian is dominated by general southward flow. From Hudson Strait to the Grand Bank, the waters are transported south by the Labrador Current. Some of the surface flow continues into the Gulf of St. Lawrence, circulates anticlockwise within the Gulf and exits on the south side of Cabot Strait off the northern tip of Cape Breton Island. The water flows onto the Scotian Shelf and is transported south by the Nova Scotian Current. From there, it moves into and around the Gulf of Maine before continuing its southward journey on the Middle Atlantic Bight. In the deep

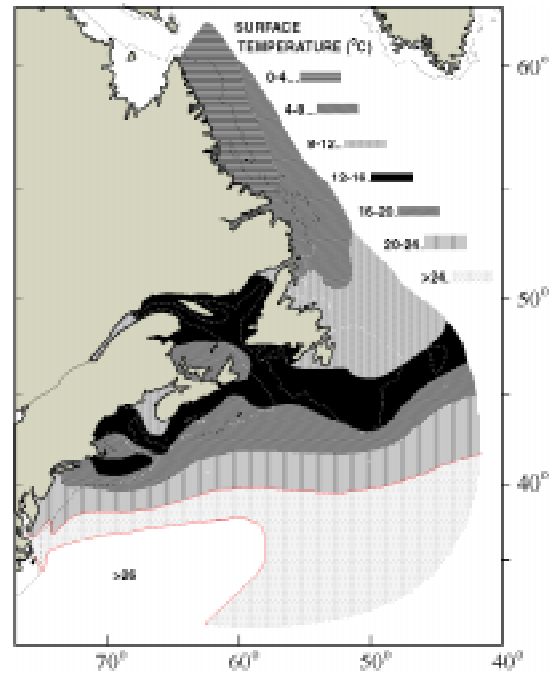
waters off the continental shelf, the major circulation feature is the eastward flowing Gulf Stream and its northward extension, the North Atlantic Current. The waters that lay off the shelf over the continental slope and extend seaward out to the Gulf Stream are known as “slope waters”. The slope water region normally contains one or more Gulf Stream rings or eddies. They form from Gulf Stream meanders which break off from the Stream and will last anywhere from a few days to over a year. These eddies tend to be about 1000 m deep which prevents them from moving onto the shallower continental shelf. As the eddies approach the shelf, they do promote cross-shelf exchange, drawing water off the continental shelf into the slope water region and pushing slope water onto the shelf.

Sea ice forms in winter off much of Canada’s east coast. The Labrador Shelf, northern Newfoundland Shelf and the Gulf of St. Lawrence are typically ice covered during part of the year with the southern-most limit of ice extending onto the southern Grand Bank and the central Scotian Shelf in heavy ice years.

Large quantities of freshwater are discharged from Canadian rivers onto the continental shelves. Major contributors are the Churchill River on the Labrador coast, the numerous rivers flowing into the Gulf of St. Lawrence (of which the largest runoff comes from the St. Lawrence River), and the Saint John River which empties into the Gulf of Maine. The many rivers flowing into Hudson and Ungava bays provide freshwater to the Labrador Shelf through Hudson Strait. All of the rivers exhibit large seasonal variations with the maximum runoff in spring, when the snow melts, and a minimum in summer.

Temperature and salinity conditions of the waters within the Northwest Atlantic vary spatially due to these differences in river discharge and ice formation and melting as well

as differences in atmospheric heating and cooling, vertical mixing and advection by ocean currents. The water properties are characterized by large seasonal cycles, depth differences, and horizontal gradients both north-south and inshore-offshore.

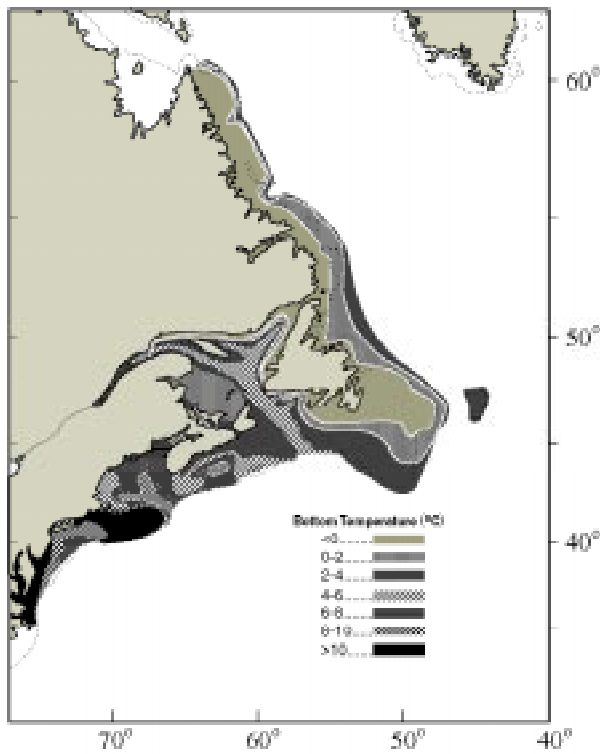


Surface Temperatures in August

During winter, the water column over the deep regions of the shelf consists of two layers. The upper layer (top 50 to 150 m depending upon location) contains relatively cold, low salinity water and sits above a bottom layer of warm, salty water that originates offshore and penetrates the shelf through deep channels or gullies. In summer, there are usually three layers. Seasonal heating forms a thin (30-40 m) warm upper layer. The deeper winter-cooled waters form a cold intermediate layer (CIL) and the warm bottom layer remains unchanged. The coldest CIL waters (0°C) are found on the Labrador Shelf and off Newfoundland and the warmest (3°-6°C) in the western Gulf of Maine. The CIL extends to the bottom except in shallow areas (less than 150 m) or where the warm offshore waters cannot penetrate the shelf,

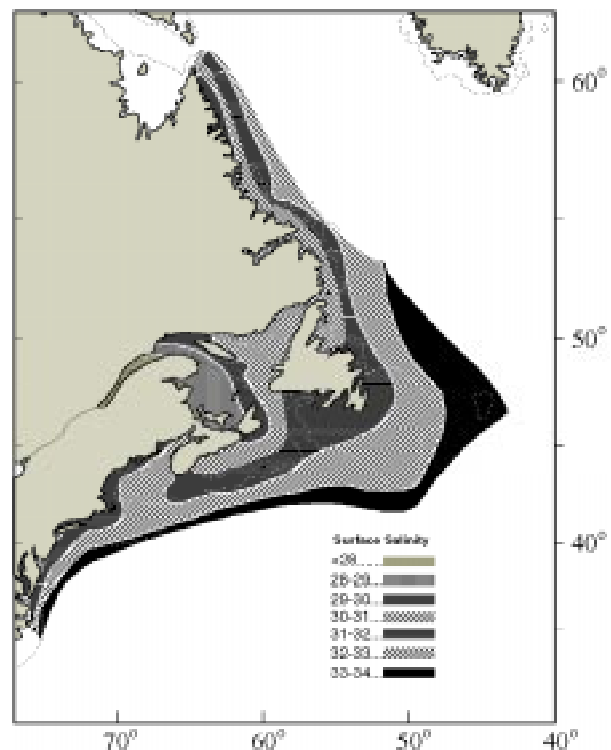
as on the Grand Bank or the eastern Scotian Shelf. Also, where there are strong tidal currents, such as in the Gulf of Maine, and depths are less than approximately 100 m, tidal mixing results in the water being nearly homogeneous from top to bottom of the water column, even in summer.

Near-bottom temperatures exhibit much less seasonal variability. Throughout most of the year, near-bottom temperatures from Labrador to the Grand Banks are typically less than 2°C. They are also relatively cold (less than 4°C) in the Gulf of St. Lawrence (except in the deep Laurentian Channel) and on the northeastern Scotian Shelf. Bottom temperatures increase over the southwestern Scotian Shelf and Gulf of Maine to 6°-12°C with the highest temperatures in the deep basins or very shallow areas.



Bottom Temperatures in August

The seasonal range of the surface waters over much of the continental shelf from the Gulf of Maine to the southern Gulf of St. Lawrence (15°-20°C) is among the highest in the Atlantic Ocean. In winter, the minimum surface temperatures in these areas vary geographically from below -1°C to 5°C while in summer most of the region is covered with waters of 15° to greater than 20°C. The temperature and its seasonal range both decrease on the Grand Banks and Labrador Shelf with surface waters on the northern Labrador Shelf reaching only 4°C in summer and falling to almost -2°C in winter.



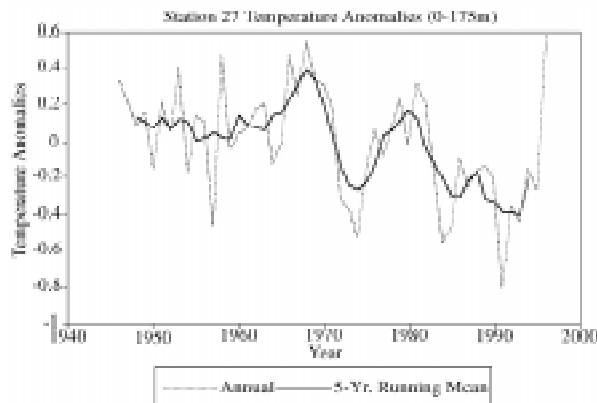
Surface salinities in August

Salinities show a strong inshore to offshore gradient due to the influences of the warmer, more saline offshore waters and freshwater discharge along the coast. The lowest salinities are found in the St. Lawrence Estuary due to the influence of the St. Lawrence River system. The effects of the St. Lawrence runoff can be traced throughout the southern Gulf of St. Lawrence and onto the Scotian Shelf. Low salinities south of Hudson Strait reflect the influence of the Hudson Bay river discharge that exits from

Hudson Strait whereas those in the Gulf of Maine are due to the discharge from the Saint John River. Near surface salinity undergoes seasonal changes on account of the variability in the freshwater discharge and ice melt.

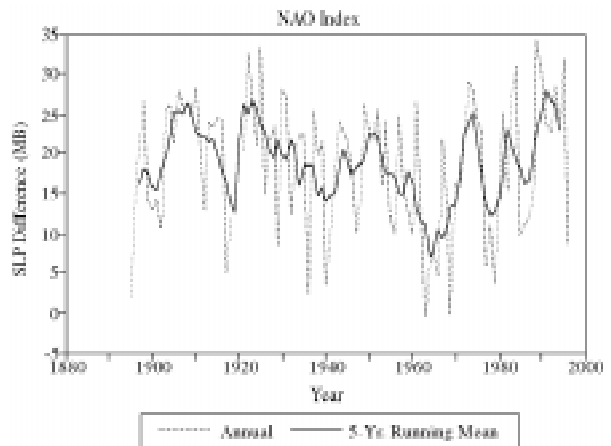
Time Trends

Long-term (1947-1996) hydrographic measurements representative of the Labrador and Newfoundland shelves are available from Station 27 located just off St. John’s Harbour. The long period temperature trends show high similarity through the water column. The annual depth-averaged (0-175 m) temperature was near normal through the 1950s and rose to peak values in the 1960s, after which it declined. (Events in 1996 are discussed in the next section.) In addition to this declining trend, temperatures fluctuated with a period of approximately 10 years resulting in minima in the 1970s, the mid-1980s and the early 1990s. Similar trends are observed in the air temperatures along the Labrador coast.



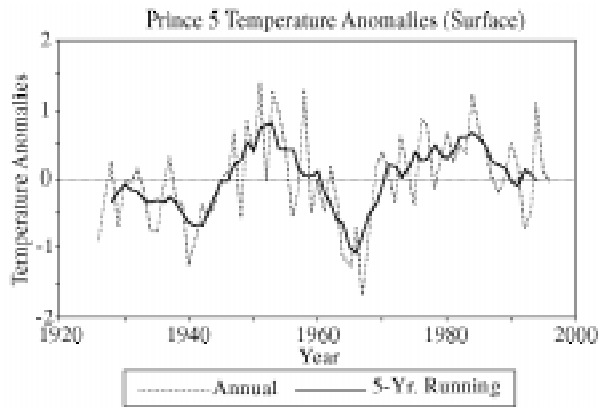
Accompanying the trend towards colder air and sea temperatures during the past 30 years was an increase in the area of ocean covered by ice. Also, peaks in the areal ice extent occur during temperature minima. These conditions are related to the large scale atmospheric circulation patterns, in particular the winter winds over the Labrador Sea. When the northwest winds

increase, they push cold Arctic air farther south, leading to more ice formation and increased cooling of the shelf waters. One index of the strength of the large-scale atmospheric circulation is the north-south air pressure difference over the North Atlantic Ocean, known as the North Atlantic Oscillation (NAO) Index. When the index is high, the northwest winds over the Labrador Sea are strong, the air temperatures are cold, there is more ice and sea temperatures are cold. When the index is low, the northwest winds are weak, air temperatures are relatively warm, ice coverage is reduced and sea temperatures are warmer-than-usual.



Temperature trends on the Scotian Shelf, in the Gulf of Maine and Gulf of St. Lawrence (Prince 5), have also been dominated by long period fluctuations. These differ from those off Labrador and Newfoundland with a gradual decline from warm temperatures in the early 1950s to very cold temperatures in the mid-1960s, a sharp rise in the late 1960s and above normal temperatures through the 1970s to the mid-1980s. This temperature pattern was generally observed at all depths and throughout the entire region although the exact timing of the minima and maxima varied slightly. Since the mid-1980s, near-bottom temperatures in the deep basins have generally remained warm (with a short cold spell in the early 1990s) while the cold intermediate layer waters in the Gulf of St. Lawrence and on the Scotian Shelf have

been cold. Water temperatures in some areas fell to levels as low or lower than observed during the mid-1960s.



Temperature trends in the deep basins originate within the slope waters and are transported onto the shelf through cross-shelf exchange processes. Changes in the slope water characteristics are in turn dependent upon the amount of deep Labrador Current that flows into the slope water region. In years when the transport is large, the slope waters are colder.

The cooling of the cold intermediate layer waters since the mid-1980s is believed to be due to enhanced winter cooling, most likely within the Gulf of St. Lawrence. These waters are then advected onto the Scotian Shelf and southward by the mean circulation. Local winter cooling and advection from off southern Newfoundland may also play a role, however.

Conditions in 1996

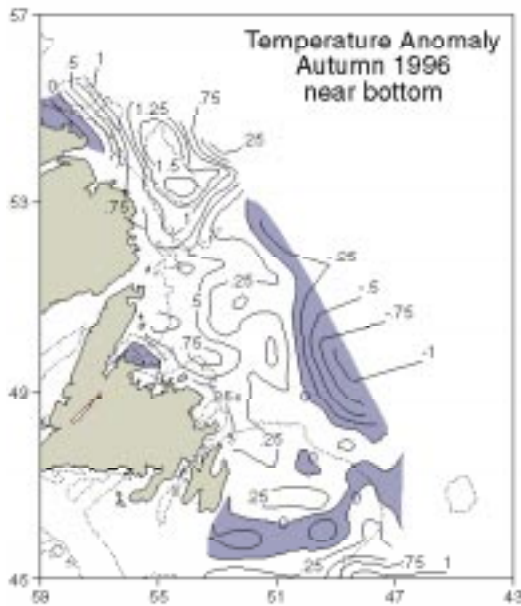
During 1996 a significant change in the atmospheric circulation resulted in above normal air temperatures over the Labrador Sea region for the first time in over a decade. Weak northwest winds carried less cold Arctic air southward resulting in the relatively warm conditions off Labrador and Newfoundland during the winter. This was associated with a

weakening of the large-scale atmospheric circulation and was reflected in the lowest NAO index since the late 1970s. The decrease in the NAO index from 1995 to 1996 was the single largest annual decline in over 100 years of record. The relatively warm winter air temperatures and accompanying lower winds caused less sea ice to form off Labrador and Newfoundland and that which did form appeared later and lasted for a shorter time than normal. Air temperatures were generally higher and sea ice was less severe during the winter of 1996 than in 1995 or the extremely cold years of the early 1990s. As usual, sea ice covered the Gulf of St. Lawrence during the winter of 1996 but the ice was thinner and looser-than-normal due to several severe winter storms which broke-up the ice. Warmer-than-normal air temperatures in winter over the Gulf contributed to a shorter ice season. A light sea ice year was also experienced on the Scotian Shelf with less ice and a shorter season than normal.

Over the Scotian Shelf and Gulf of Maine, annual air temperatures tended to be about average, consistent with recent years.

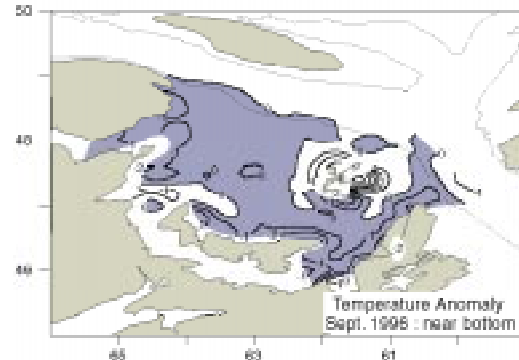
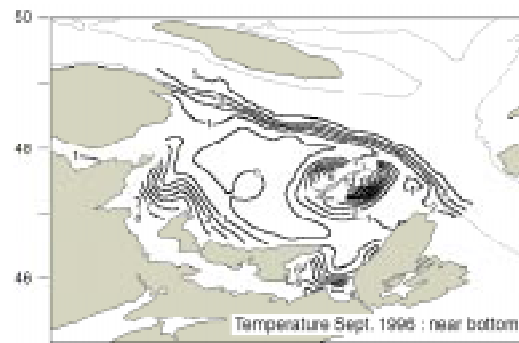
Ocean temperatures off Labrador and Newfoundland were above average for the first time since the early 1980s. At Station 27, temperatures were warmer-than-normal throughout most of the year with the peak anomalies during July. The depth-averaged (0-175 m) temperatures were equal to those recorded in the late-1960s. Also, the amount of CIL water along the Bonavista Bay transect in summer (defined by temperatures less than 0°C) was less-than-normal, but slightly greater than in 1995. On the Grand Banks, the CIL area decreased slightly and dropped below normal for the first time since 1981. During the autumn groundfish surveys, near-bottom temperatures over most of the continental shelf, including the Grand Bank, were similar to 1995 and up to 0.5°C above the values experienced during 1991-94. South of Newfoundland over St.

Pierre Bank, bottom temperatures were still below normal but rose significantly compared to 1995.



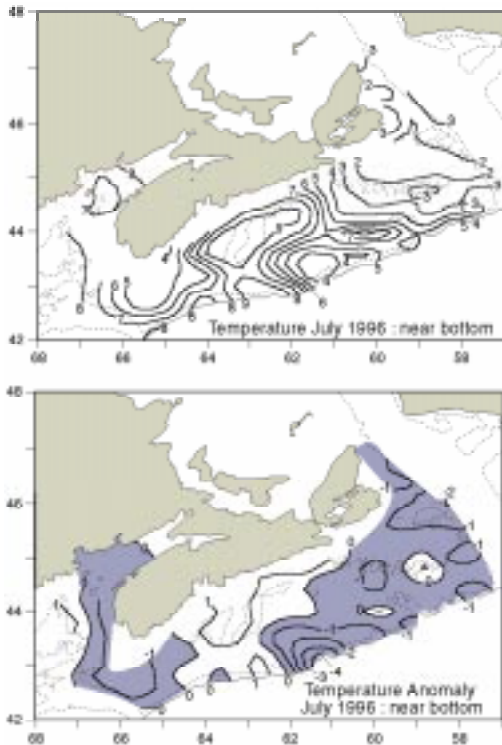
In the Gulf of St. Lawrence, ocean temperatures generally remained cold. Core temperatures in the CIL waters have been below normal for the past 11 years but did increase slightly in 1996 for the second year in a row from the extreme lows observed in the early 1990s. During the September groundfish survey, most of the Magdalen Shallows was covered by near bottom

waters with below normal temperatures. The only exceptions were in shallow regions, for example around the Magdalen Islands. The area of the Magdalen Shallows covered by bottom waters with temperatures less than 0°C decreased slightly compared to 1995, but remained well above normal. Deep (200-300 m) waters of Cabot Strait were near their long-term mean value, similar to last year and down from the maxima recorded in 1993 of 1°C above normal.



Ocean temperature trends over the Scotian Shelf and in the Gulf of Maine varied spatially in 1996 but the patterns were similar to last year. Colder-than-normal temperatures persisted in subsurface waters over the northeastern Scotian Shelf and off southwestern Nova Scotia continuing a pattern established in the mid-1980s. In contrast, the waters in the central Scotian Shelf over Emerald Basin and vicinity were warmer-than-normal. These conditions are related to the presence of warm slope water offshore which intrudes upon the shelf and is intermittently transported shoreward by cross-

shelf exchange processes. Similarly, warm waters covered much of the central Gulf of Maine, with temperatures remaining above normal for the third successive year. These conditions are believed to have been initiated by an influx of warm slope water through the Northeast Channel during late 1993.



In summary, 1996 saw warming of the waters off northern and eastern Newfoundland and Labrador to levels not seen since the mid-1980s. The waters off southern Newfoundland, in the Gulf of St. Lawrence and on parts of the Scotian Shelf remained cold but with signs of warming. In the deep basins of the Scotian Shelf and the Gulf of Maine, water temperatures continued to be warmer than normal but conditions cooled slightly relative to 1995. Based upon past temperature variability and recent temperature trends, the waters on the Grand Banks and off northern Newfoundland and Labrador are expected to remain well above the temperatures recorded in the early 1990s during the next year or two. Off southern Newfoundland, in the Gulf of St. Lawrence, on

the northeastern Scotian Shelf, and off southwestern Nova Scotia subsurface temperatures will likely continue to rise gradually in 1997 whereas the warm deep waters in the basins of the Scotian Shelf and in the Gulf of Maine will cool slightly.

For more Information

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