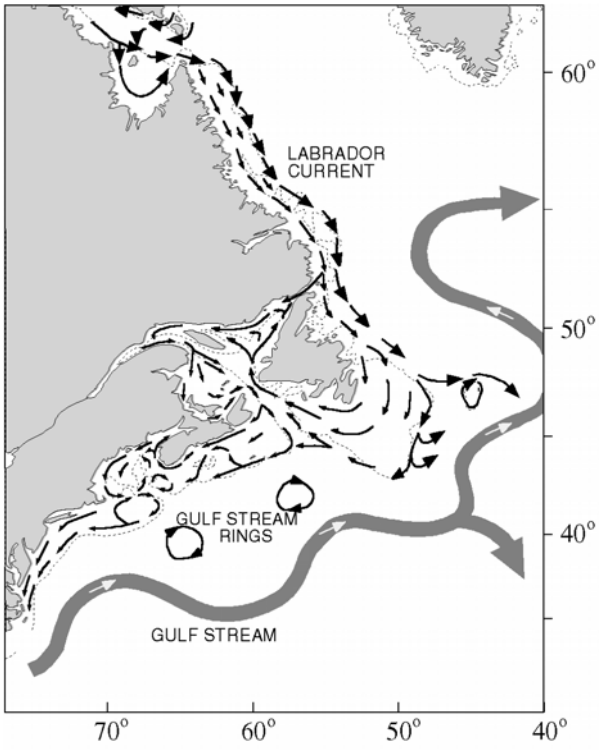
State of the Ocean: Northwest Atlantic

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 catadramous 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. Off the shelf, the major circulation feature is the eastward flowing Gulf

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Stream and its northward extension, the North Atlantic Current. Between the shelf and the Gulf Stream lay the "slope water" region. This region normally contains a few 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. They tend to be about 1000 m deep so they cannot move onto the shelf. They do, however, promote cross-shelf exchange, drawing shelf water into the slope water region and pushing slope water onto the shelf.

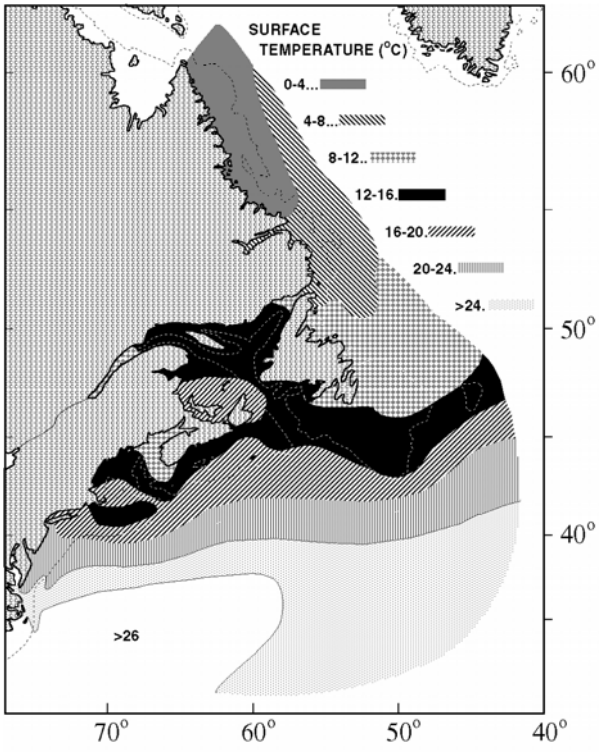
Seasonal sea ice forms off much of Canada's east coast. The Labrador Shelf, northern Newfoundland Shelf and the Gulf of St. Lawrence are typically ice covered during part of the winter with the southern-most limit of ice extending onto the southern Grand Bank and the central Scotian Shelf in heavy ice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

Large quantities of freshwater are discharged from Canadian rivers onto the continental shelves. Major contributors are the 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.

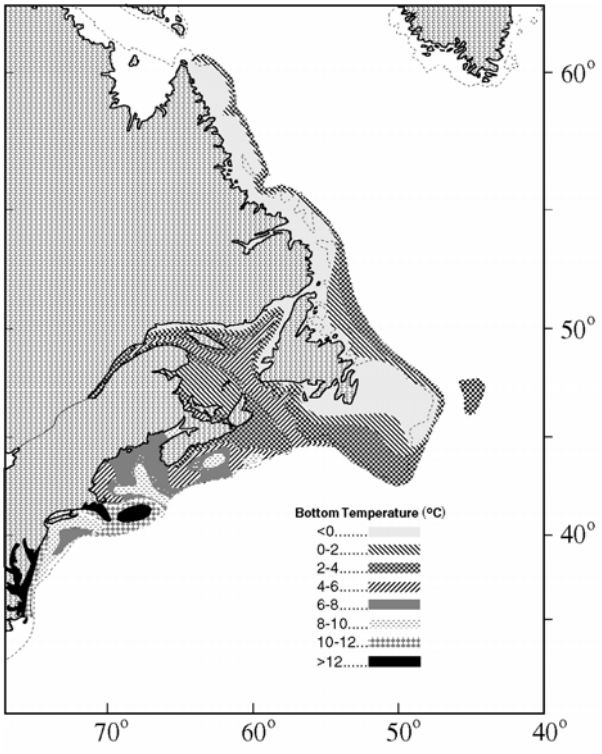
Temperature and salinity conditions of the waters within the Northwest Atlantic vary spatially due to differences in atmospheric heating and cooling, river discharge, vertical mixing and transport by ocean currents. The water properties are characterized by large seasonal cycles, depth differences, and horizontal gradients both north-south and inshore-offshore.

In deep areas of the shelf in winter, the water column consists of two layers. The upper layer (100 to 150 m) 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 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. 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, the CIL extends to the bottom. Also, where there are strong tidal currents, such as in the Gulf of Maine at depths less than 100 m, tidal mixing can result in the water being nearly homogeneous from top to bottom, even in summer.

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.

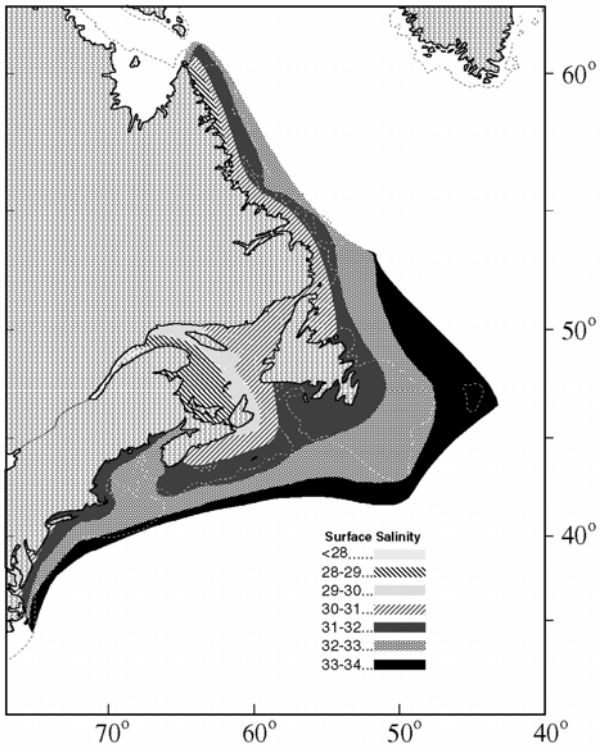


Surface Temperatures in August



Bottom Temperatures in August

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 (<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.



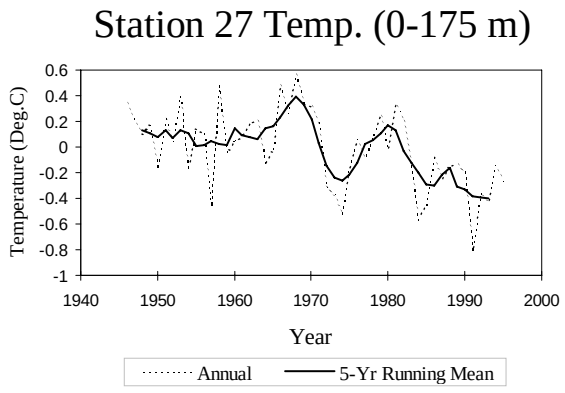
Surface salinities in August

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. Its effects can also be traced throughout the southern Gulf of St. Lawrence and onto the Scotian Shelf. Low salinities south of Hudson Strait and in the Gulf of Maine, reflect the influence of the Hudson Bay river discharge

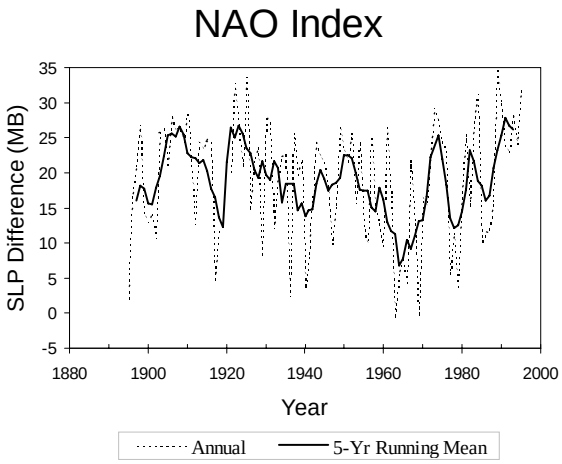
that exits from Hudson Strait and the Saint John River, respectively. Salinity undergoes seasonal changes that reflect the variability in the freshwater discharge and ice melt.

Time Trends

Long-term (1947-1995) 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 at all depths through the water column. The annual depth-averaged (0-175 m) temperature were near normal through the 1950s, rose to peak values in the 1960s and have declined since then. In addition, since 1960 there has been a near decadal oscillation with minima in the 1970s, the mid-1980s and in the 1990s. Similar trends are observed in the air temperatures along the Labrador coast.

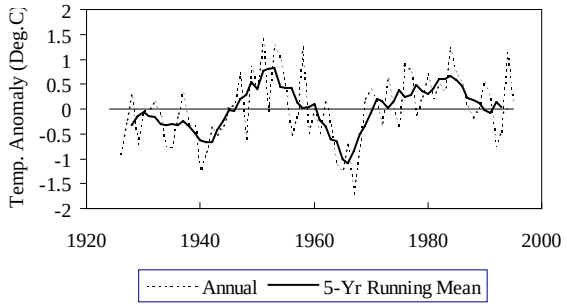


Accompanying the colder air and sea temperatures has been an increase in the area of ocean covered by ice including peaks in the areal ice extent during the times of temperature minima. These conditions are related to the large scale atmospheric circulation patterns and in particular the winter winds 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. The strength of the large-scale atmospheric circulation is related to the north-south air pressure difference over the North Atlantic Ocean, known as the North Atlantic Oscillation Index. When the index is high, the northwest winds over the Labrador 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, 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 trend 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, however, the bottom temperatures 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 the Scotian Shelf have been cold. In some areas the temperatures fell to levels as low or lower than the mid-1960s.

Prince 5 Sea Surface Temperature Anomaly



The temperature trends throughout the water column from the 1940s to the mid-1980s and near bottom since the mid-1980s 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 is transported 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, and which then is transported onto the Scotian Shelf and southward by the mean circulation. Local winter cooling and transport from the southern Newfoundland region may also play a role, however.

Conditions in 1995

Strong northwest winds resulted in colder-than-normal air temperatures off Labrador and Newfoundland during the winter of 1995. These conditions were associated with an intensification of the large-scale atmospheric circulation and reflected in a high North Atlantic Oscillation Index. The cold winter air temperatures and accompanying high winds caused ice to form early, be of greater areal extent than normal and last longer. In spite of these cold conditions, winter air temperatures and sea ice were less severe than in 1994 or the extremely cold years of the early 1990s. In contrast to Labrador and northern Newfoundland, winter air temperatures over the Gulf of St. Lawrence, Scotian Shelf and Gulf of Maine were slightly above average. Consequently, the first appearance of sea ice in the Gulf of St. Lawrence and the Scotian Shelf occurred later-than-normal or within a week of its usual arrival date. However, ice lasted longer-than-normal leading to a longer duration of ice especially in the northern Gulf.

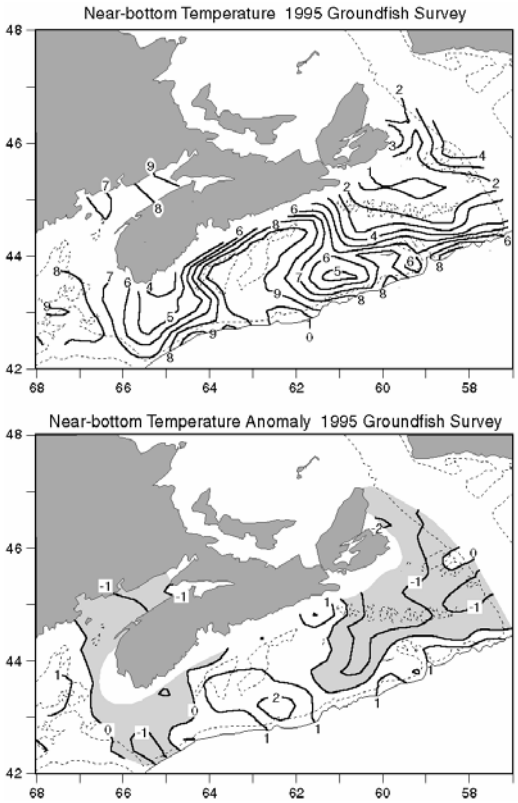
Annual air temperatures, even in the northern regions, were warmer-than-average due to above normal conditions during the spring, summer and especially the autumn. The extremely high autumn temperatures in the north were due to increased southerly winds associated with a high pressure system that developed over Greenland. The moderating conditions from the very cold period of the early 1990s that began last year continued through 1995.

Ocean temperatures off Labrador and Newfoundland remained colder-than-normal but similar to last year were not as severe as the early years of the 1990s. At Station 27, temperatures were typically below normal throughout the year with the coldest anomalies during the early spring and summer. By late autumn temperatures recovered to near normal conditions. The area of the cold intermediate layer (defined by temperatures <0°C) along the Bonavista Bay transect in summer was the smallest recorded in 10 years, being below the long-term average and reduced by 30% from that observed in 1994. However, on the Grand Banks the area of the cold intermediate layer area was 20% above normal and similar to last

year. During the autumn groundfish surveys, large areas of the continental shelf, including the Grand Bank, saw a significant increase in bottom temperatures (up to 0.5°C above the values experienced during 1991-94). South of Newfoundland, over St. Pierre Bank, the cold period which began around 1984, continued in 1995 with bottom temperatures of 1°C below the long-term mean.

In the Gulf of St. Lawrence, ocean temperatures generally remained cold or cooled. Core temperatures in the CIL waters were near the record low for the sixth consecutive year and have been below normal for the past 10 years. The area of the Magdallen Shallows covered by bottom waters with temperatures of less than 0°C was the maximum in the 25 year record and the area of waters less than 1°C was the third largest on record. Deep (200-300 m) waters of Cabot Strait were near their long-term mean value but fell relative to last year and the recent maxima recorded in 1993 of 1°C above normal. An exception to the cooling conditions within the Gulf was found in the upper 30 m of water during the summer with temperatures several degrees above last year, most notably along the Quebec north shore.

Ocean temperature trends over the Scotian Shelf and in the Gulf of Maine varied spatially in 1995 but the patterns were similar to last year. Colder-than-normal temperatures persisted in the bottom waters over the northeastern Scotian Shelf, along the Atlantic coast of Nova Scotia and off southwestern Nova Scotia. This continues a pattern of below normal temperatures established about the mid-1980s. In contrast, the waters in the central Scotian Shelf over Emerald Basin and along the continental slope 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 shore ward by cross-shelf exchange processes. In the Gulf of Maine, temperatures remained well above normal for the second year in a row. These conditions are believed to have been initiated by an influx of warm slope water through the Northeast Channel during late 1993.



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