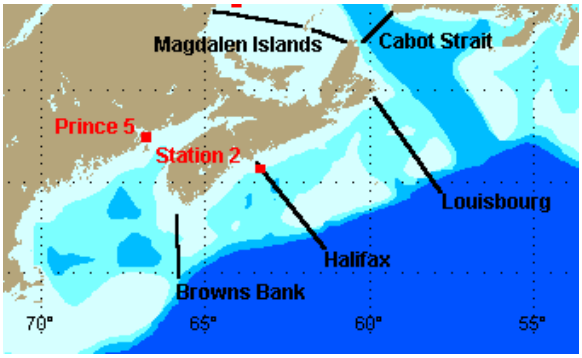
# State of the Ocean 2003: Physical Oceanographic Conditions on the Scotian Shelf, Bay of Fundy and Gulf of Maine




## Summary


- Annual air temperatures over the Scotian Shelf were slightly above normal; Bay of Fundy and eastern Gulf of Maine air temperatures were slightly below normal.
- Sea ice cover seaward of Cabot Strait was twice the normal cover for the Jan-May period, the 3rd greatest in 42 years; March saw the highest cover in 42 years, near the maximum extent for 1971-2000.
- Sea-surface temperatures were 0-0.5°C below normal for the Scotian Shelf and eastern Gulf of Maine; Boothbay Harbor, Maine, though was 2.4°C above normal.
- Colder, saltier than normal conditions prevailed over the Scotian Shelf and, to a lesser extent, eastern Gulf of Maine.
- Bottom temperatures were about 1°C below normal except for LaHave Basin and Bank where they were about 1°C above normal.
- Vertical stratification (0-50m) for the Scotian Shelf was higher-than-average, but with strong spatial differences.


## Background

*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 resource yield, reproductive potential, catchability, year-class size (recruitment) and spawning biomass as well as influence the perception of the resource status and the efficiency and profitability of the industry.*

*Physical oceanographic conditions (mainly water temperature and salinity) are therefore measured during research vessel resource surveys and regularly at fixed sites as part of the **Atlantic Zone Monitoring Program (AZMP)**. Additional hydrographic, meteorological and sea ice data are obtained from a variety of sources, including standard monitoring stations, research studies, ships-of-opportunity, fishing vessels, and remote sensing (satellites).*

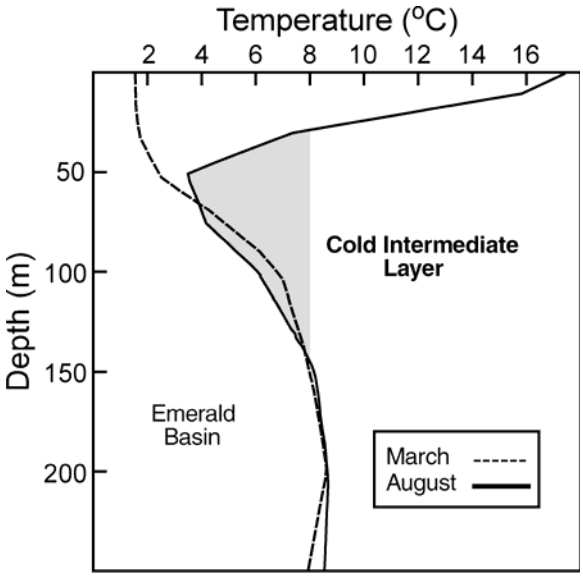
*All of the hydrographic data are edited and archived in Canada's national Marine Environmental Data Service (MEDS) database. A working copy is maintained in a Northwest Atlantic database at the Bedford Institute of Oceanography.*

## *Average Conditions*

Temperature and salinity conditions within the Scotian Shelf, Bay of Fundy and Gulf of Maine vary spatially due to complex bottom topography, transport from upstream sources such as the Gulf of St. Lawrence, melting of sea-ice in spring, and exchange with the adjacent, offshore slope waters. Water properties are also characterized by large seasonal cycles, depth differences and horizontal east-west and inshore-offshore gradients.

The seasonal temperature range of the waters over the Scotian Shelf decreases with depth. At the surface, the range is about 16°C; there is little or no seasonal change at depths greater than approximately 150 to 200 m. In the shallow regions of the Gulf of Maine, such as Lurcher Shoals, the Bay of Fundy and Georges Bank, the seasonal cycle changes less with depth due to vertical mixing by the strong tidal currents.

In the winter, the water column in deep regions of the Scotian Shelf consists of two layers separated by a transition zone, as can be seen in the plot of temperature as a function of depth in Emerald Basin.



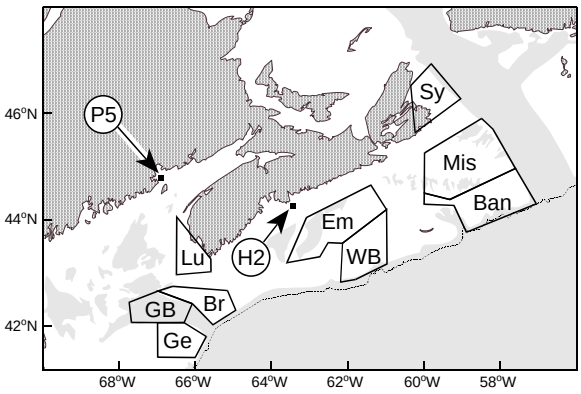

The upper layer is mixed by the winter winds and contains cold, low salinity water. The bottom layer has relatively warm and salty water. The latter comes from the offshore slope region and enters the Shelf through deep channels and gullies. In summer, seasonal heating forms a thin (30-40 m) warm upper layer. The winter-cooled waters form a cold intermediate layer (CIL; 40-150 m) and the warm bottom layer remains unchanged. Variation in this vertical structure occurs over the shelf. The warm offshore waters do not penetrate onto the eastern Scotian Shelf and hence waters typical of the CIL (temperatures less than 5°C) extend to the bottom. Throughout the Scotian Shelf where depths are shallower than 150 m, there is no warm bottom layer. In areas of strong tidal currents, such as off southwestern Nova Scotia, the waters are vertically well mixed even in summer.

Temperatures and salinities generally increase from east to west and from inshore to offshore due to the influences of the warmer, more saline offshore waters and the outflow of the fresher water from the Gulf of St. Lawrence. For example, in the summer within the CIL, the 50 m temperatures typically range from 0-3°C over the eastern Scotian Shelf, 3-8°C over much of the central shelf and 6-9°C over the western Scotian Shelf, eastern Gulf of Maine and Bay of Fundy. The one exception to this trend is the inner shelf surface temperatures in summer, which increase from west to east due to the warm surface outflow from the Gulf of St. Lawrence.

The near-bottom temperatures have similar ranges to those at 50 m, except over the central shelf where the range increases to 3-9°C, the slightly higher range being caused by the intrusion of the offshore waters.

## *Long-Term Time Trends*

Year-to-year, water temperatures on the Scotian Shelf and in the Gulf of Maine are among the most variable in the North Atlantic Ocean. This is based on: long-term coastal sea-surface temperatures at Halifax and St. Andrews; and, hydrographic monitoring sites Prince 5 (P5), located at the mouth of the Bay of Fundy, and station 2 on the Halifax Line (H2). Monthly temperature and salinity data have been collected at Prince 5 since the 1920s. The Atlantic Zone Monitoring Program (AZMP) has also resumed the occupation of standard sections including the Halifax Line. In addition to these data, temperature time series have been constructed for several areas from data collected during fisheries surveys and oceanographic studies.

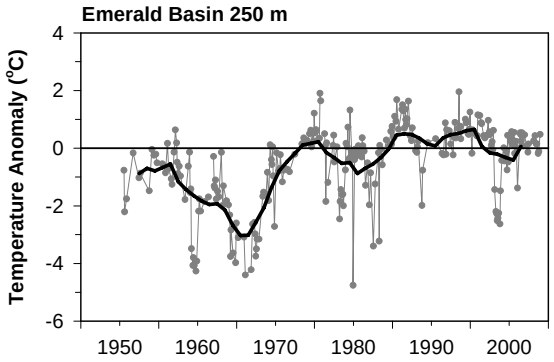



Sy -Sydney Bight
Ban-Banquereau
WB-Western Bank
Lu - Lurcher Shoals
GB - Georges Basin
P5 - Prince 5
Mis-Misaine Bank
Em -Emerald Basin
H2 - Halifax Stn 2
Br - Browns Bank
Ge - Georges Bank

In order to detect time trends in temperature, the seasonal cycle is removed by calculating deviations (anomalies) of temperatures from the long-term (1971-2000) monthly averages for each area. Inter-annual variability is also expressed as anomalies. With the exception of the Prince 5 series, the data from most areas are sparse prior to 1950.

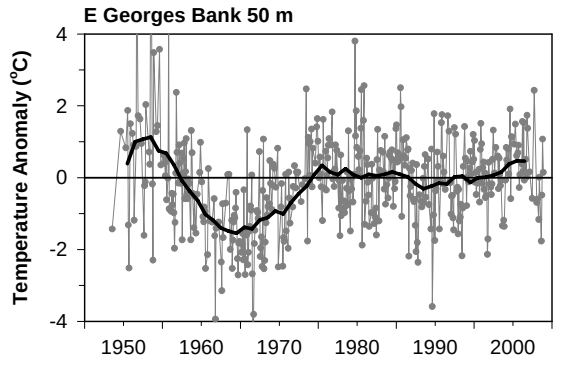
In general, the temperature records have short duration spikes, superimposed on longer (10-30 year) variations with amplitudes of 1-2°C. The spikes can be high frequency, localized variability and usually show little similarity from area to area. The long-period trends show strong similarity over much of the Scotian Shelf and the Gulf of Maine. In the time series plots, the thin, grey lines with dots are monthly averages and the thick, black lines are the 5-year running means of the annual averages.

The temperature pattern in Emerald Basin is representative of the long-period trends in the deep waters throughout the central and western shelf and in the Gulf of Maine. Temperatures were generally below average in the 1950s and declined further in the 1960s. The extended period with the lowest temperatures occurred during the mid-1960s. Temperatures rose rapidly in the late 1960s and from the 1970s to 1997 generally remained warmer-than-average. The highest sustained temperature anomalies in the approximate 50-year record were observed in the 1990s. In 1998 there was a rapid decline to levels not seen since the early 1980s and the 1960s. These cold waters were in turn replaced with waters of temperatures near their long-term average in 1999 and warmer in 2000, 2001 and 2003. Temperatures in 2003 are discussed in more detail in the next section.

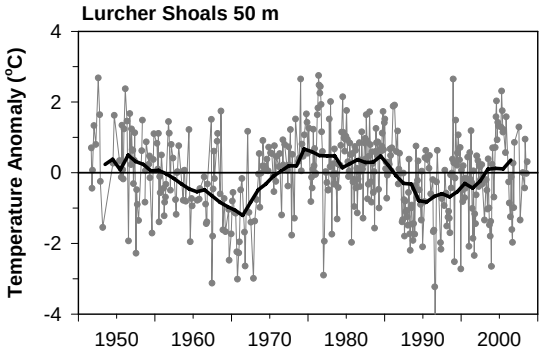



In shallower waters over the shelf, temperature trends were similar to those in the deep waters until the mid-1980s. Temperatures on eastern Georges Bank were near the long-term average throughout

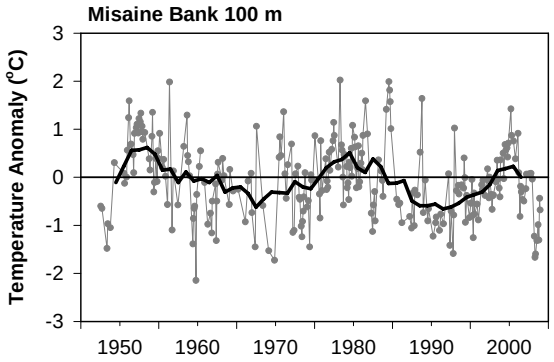
most of the 1970s, 1980s and 1990s. The 5-year running average has generally been above normal in the late 1990s.




Temperatures in the shallow inshore areas of southwestern Nova Scotia (Lurcher Shoals) show a clear decline from the mid-1980s to the early 1990s, reaching levels comparable to those in the cold period of the 1960s. Temperatures generally remained below average from the mid-1980s to the late 1990s. In 1999-2000 they were above normal, fell in 2001 and were slightly above normal in 2003.



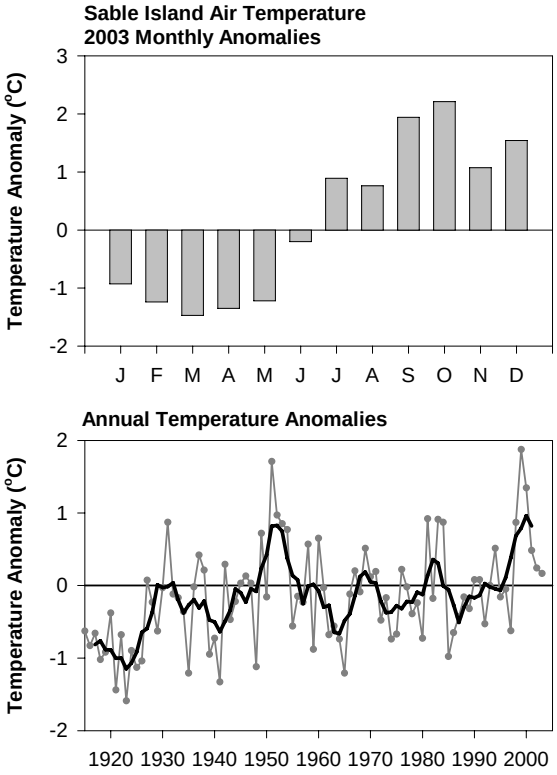

In intermediate and deep waters of the eastern shelf, as exemplified by Misaine Bank, the long-period temperature variations (~1°C) are smaller than for the rest of the shelf. The negative temperature anomalies of the 1960s were not as large as elsewhere on the Scotian Shelf. From the late-1960s to the mid-1970s, temperatures at Misaine Bank were near or above average. They rose above normal around 1980 but by the mid-1980s, temperatures dropped sharply. At all depths, temperatures were generally colder-than-normal until the late 1990s. The minimum temperatures were seen in the early 1990s, after which they rose. By 1999 and 2000, anomalies were above the long-term average but fell in 2001 to below average and remained below normal in 2003. The long-term temperature trends over the eastern inshore areas (e.g. Sydney Bight) and offshore banks (e.g. Banquereau) are similar to those in the Misaine area.




In the deep waters of Cabot Strait, temperatures were coldest during the 1960s but have been above or near average in recent years. In 2003 they were equal to the long term mean.

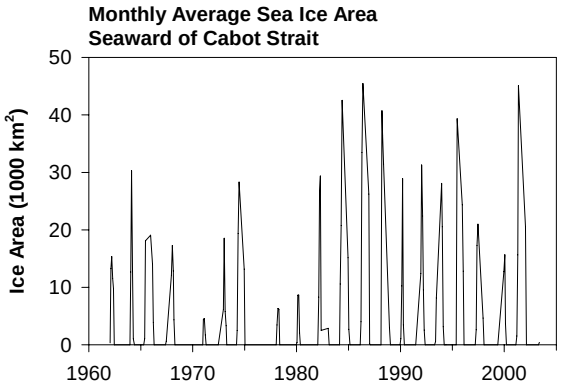
The general temperature trends described above are reflected in the time series of the summer research vessel stratified average near-bottom temperatures for the Bay of Fundy (NAFO Division 4X) as well as the western (4X), central (4W) and eastern (4Vs) Scotian Shelf.

## *Conditions in 2003*



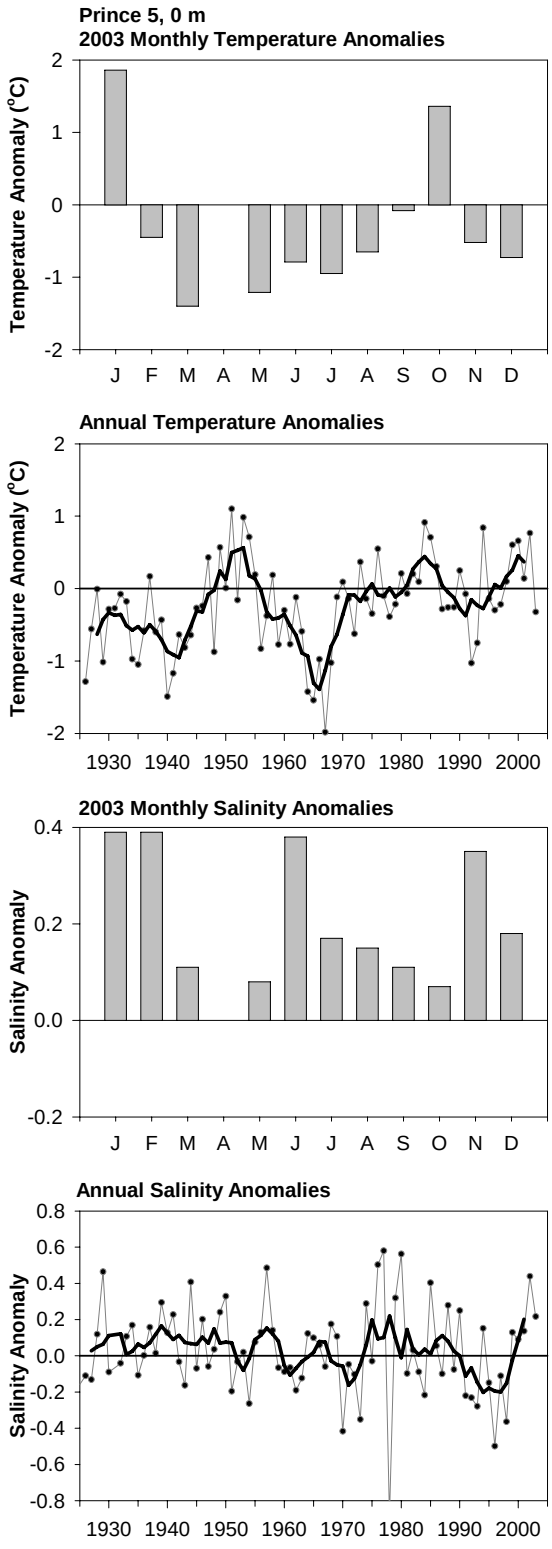

Annual air temperatures over the Scotian Shelf were about 0.1-0.2°C above normal in 2003. This was due to warm conditions in the second half of the year. The eastern Gulf of Maine monthly anomalies had the same pattern as Sable Island but the cold temperatures in the first half of 2003 dominated the warm values in the second half. This led to below normal annual temperatures of 0.1-0.4°C. Sable Island temperatures continued to decline since the long-term high of 1999.

The Jan-May 2003 sea ice cover seaward of Cabot Strait was twice the long-term mean and the 3rd greatest in 42 years. In March, ice reached Halifax and the shelf edge from Banquereau to Sable Island, exceeding or equalling the maximum extent of ice for the 1971-2000 period.



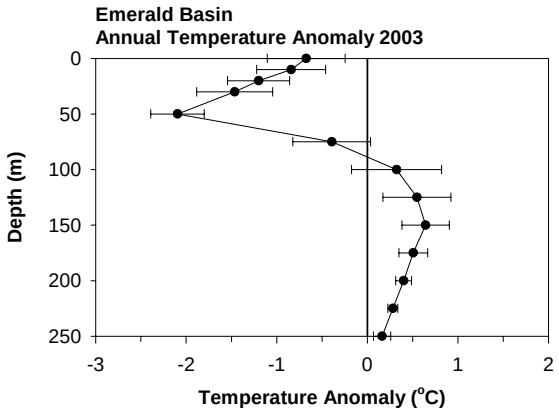

The annual average sea-surface temperature at Boothbay Harbor, Gulf of Maine, was 2.4°C above normal in 2003 continuing the trend of positive anomalies that persisted through the 1990s. It was the seventh warmest year in the 98-year record. In contrast, at St. Andrews, N.B., annual surface temperature was 0.6°C below normal while at Halifax, the annual anomaly was 1.8°C below normal, making 2003 the fourth coldest in 78 years.

At Prince 5, monthly average temperatures throughout the water column were dominated by colder-than-average values leading to annual anomalies 0.1-0.3°C below normal. At all depths temperatures decreased relative to 2002. The annual salinity anomalies at Prince 5 were saltier-than-normal by 0.15-0.25 but slightly less than in 2002.

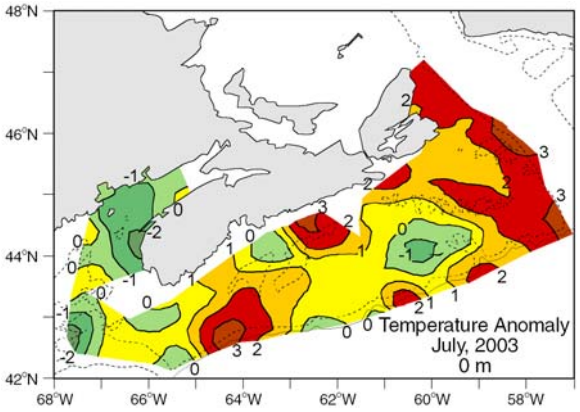


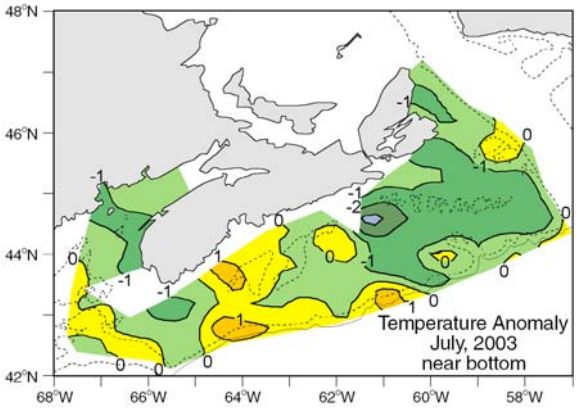

In the Laurentian Channel to the east of the Scotian Shelf, temperatures in the deep (200-300 m) waters at Cabot Strait were close to the long-term mean in 2003, slightly cooler than in 2002.

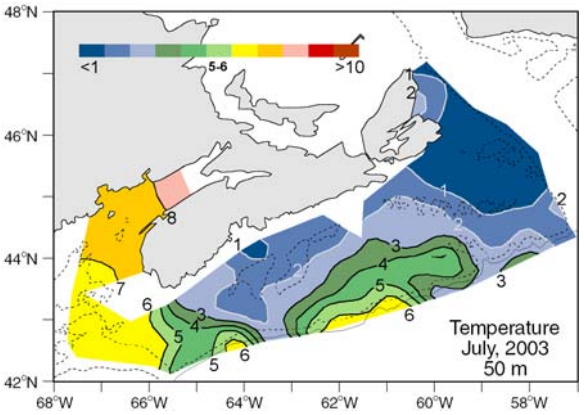
In 2003, the waters in Emerald Basin were colder-than-normal through most of the year from 0 to 75 m. The coldest water was at 50 m with an annual anomaly (dot) of 2°C below normal, usually by more than 1 standard error (horizontal bar). From 100 m to the bottom, temperatures were warmer than normal, typically by about 0.5°C. This transition from below to above normal temperatures marks the separation between two different water types: shallow, shelf waters flowing from the eastern shelf, and the deeper slope water that moves onto the shelf from the Scotian Slope.

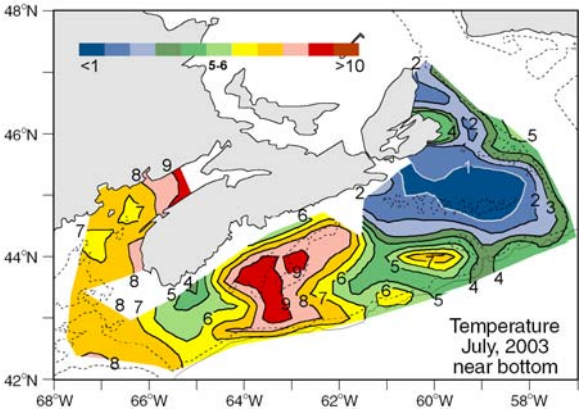



Temperature anomalies over the Scotian Shelf and eastern Gulf of Maine during the 2003 July groundfish survey varied with depth. At the surface, temperatures were above normal by 0-3°C except for the Bay of Fundy where they were below normal. Temperatures 1-3°C below normal prevailed at 50 and 100 m. Bottom temperatures were 0-1°C below normal for most of the shelf and the eastern Gulf of Maine. However, the shelf-wide area from Halifax west to Shelburne had bottom temperatures about 1°C above normal. At 50 m, temperatures less than 4°C extended about 150 km offshore as an exceptionally well-developed cold intermediate layer. The bottom temperatures of about 9°C in deep Emerald and LaHave Basins are characteristic of Warm Slope Water.

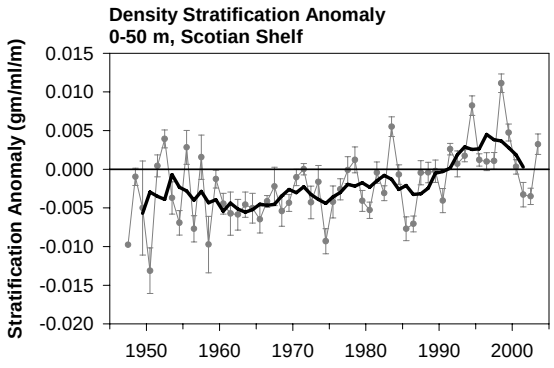



Ocean water density increases with depth and depends on temperature, salinity and pressure. The density difference between waters at two depths is referred to as the density stratification. In the 1990s, the average, 0 to 50 m density difference over the Scotian Shelf increased significantly. From the mid to late 1990s, this stratification index was at or near its maximum over the 50-year record. Little variation in density stratification was seen in the Gulf of Maine. The primary cause of recent changes in the Scotian Shelf stratification was a freshening of the near-surface waters through advection of low salinity waters from the Grand Banks. As the stratification increases at shallow depths, vertical mixing is inhibited; this can decrease nutrient replenishment to the surface waters and affect phytoplankton production. In 2003, stratification was slightly higher-than-average after 2 years of lower-than-average values. However, there was considerable spatial variability of the stratification over the Scotian Shelf with some areas, e.g. Sydney Bight and the Laurentian Channel, having very weak stratification.




The average positions of the temperature boundary between shelf and slope waters (Shelf/Slope front) and between slope and Gulf Stream waters in 2003 were seaward of their long-term means. Compared to 2002, the Shelf/Slope front moved onshore by 22 km; the Gulf Stream front move onshore by 32 km.

## For more Information

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## References

Petrie, B., R.G. Pettipas, W.M. Petrie, and K.F. Drinkwater. 2004. An overview of meteorological, sea ice and sea-surface temperature conditions off eastern Canada. DFO Can. Sci. Advisory Sec. Res. Doc. 2004/047.

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