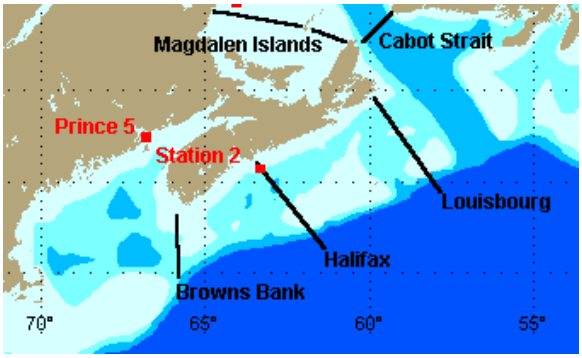
2001 State of the Ocean: Physical Oceanographic Conditions on the Scotian Shelf, Bay of Fundy and Gulf of Maine



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 Zonal 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.

Summary

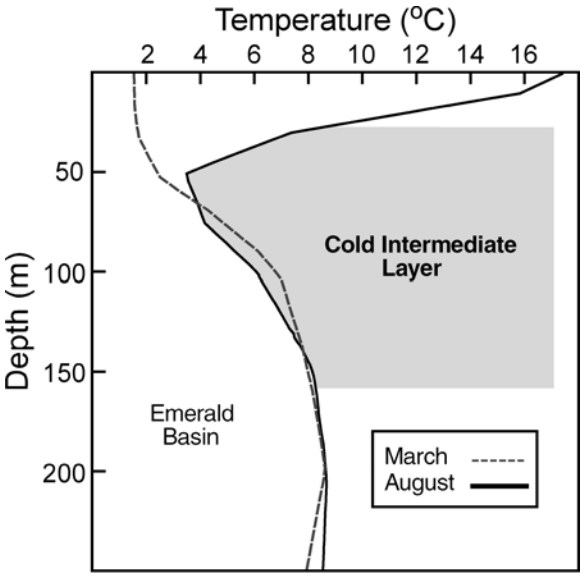
- Annual mean air temperature over the Scotian Shelf, Bay of Fundy and eastern Gulf of Maine were warmer-than-normal in 2001.
- The area of the Scotian Shelf covered by sea-ice in the winter was less than normal although the ice that was present lasted longer than usual.
- Sea surface temperatures were generally warmer-than-normal during 2001.
- The subsurface waters over the northeastern Scotian Shelf declined to below normal temperatures after two years of warmer-than-normal conditions.
- Near-bottom temperatures over most of the Scotian Shelf during the July groundfish survey in 2001 were below normal.
- Since the mid-1990s, vertical stratification in the upper layers has been at or near its maximum in the approximately 50-year record.

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 but 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 shows much less change 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 originates from the offshore slope region and enters the Shelf through deep channels or 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. Further, 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 southwest Nova Scotia, the waters even in summer are vertically well mixed.

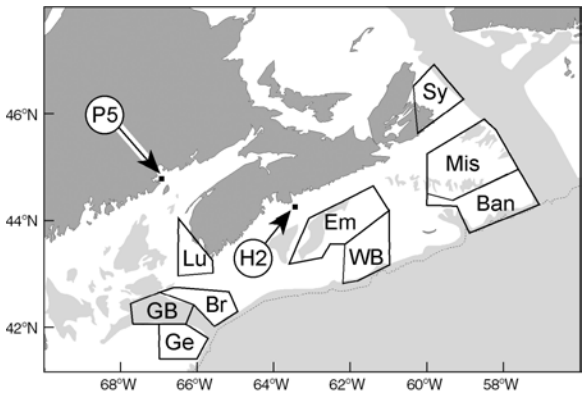
Temperatures and salinities generally increase from east to west and from inshore to offshore due to the influences of the warmer, more saline offshore waters and the outflow of the fresher water from the Gulf of St. Lawrence. For

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 the general trend in horizontal distributions is the surface temperatures in summer, when they increase from west to east due to the warm surface outflow from the Gulf of St. Lawrence.

The near-bottom temperatures display 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. Information on this variability is derived from several sources. Long-term coastal sea surface temperatures are available at Halifax and St. Andrews. Hydrographic monitoring sites within the region include Prince 5 (P5), located at the mouth of the Bay of Fundy, and a new monitoring site established in 1998 at the location of standard station 2 on the Halifax Line (H2). Monthly temperature and salinity data have been collected at Prince 5 since the 1920s. The Atlantic Zonal Monitoring Program (AZMP) has also reinstituted the occupation of standard sections including the Halifax Line. In addition to these data from the monitoring sites and sections, 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

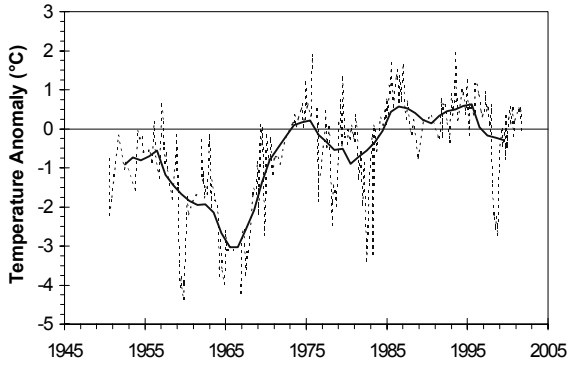
In order to detect time trends in temperature, the seasonal cycle is removed by calculating deviations (anomalies) of temperatures from the long-term (1971-2000) monthly means for each area. Inter-annual variability is also expressed as anomalies. With the exception of the Prince 5 series, the data from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

In general, the temperature records are characterized by short period spikes, superimposed on long period (10-30 year) trends with amplitudes of 1-2°C. The spikes often represent “noise” due in large part to limited amounts of data 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 dashed lines indicate monthly means and the solid 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 near or above average in the 1950s and declined

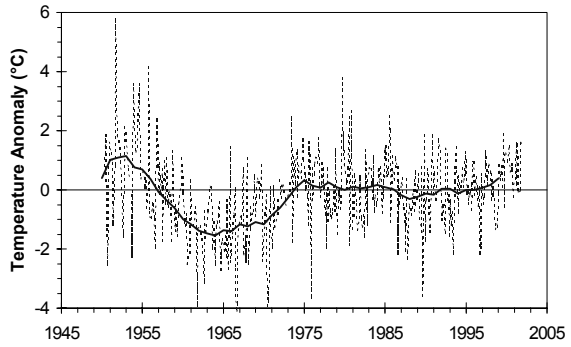
to below average in the 1960s. The extended period with the lowest temperatures occurred during the mid-1960s. Temperatures rose rapidly in the late 1960s and from the 1970s to 1997 generally remained warmer-than-average. Indeed, the highest sustained temperature anomalies in the approximate 50-year 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 to their long-term mean in 1999 and warmer in 2000. Temperatures events in 2001 are discussed in more detail in the next section.

Emerald Basin – 250 m



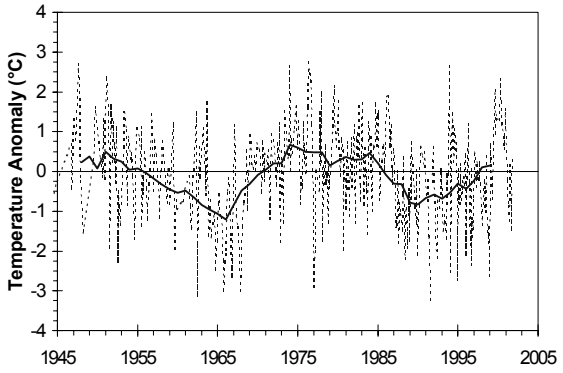
In shallower waters over the shelf, temperature trends were similar to those in the deep waters until the mid-1980s. Temperatures on eastern Georges Bank, which are representative of the offshore banks including Browns and Western, tended to be above average through most of the 1970s and 1980s but declined slightly in the late 1980s. Through the 1990s, temperatures have varied above and below the mean but their average (using 5-year running means) has generally remained above the long-term mean.

Eastern Georges Bank – 50 m



Temperatures in the shallow inshore areas of southwest 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 and 2000 they rose to above normal.

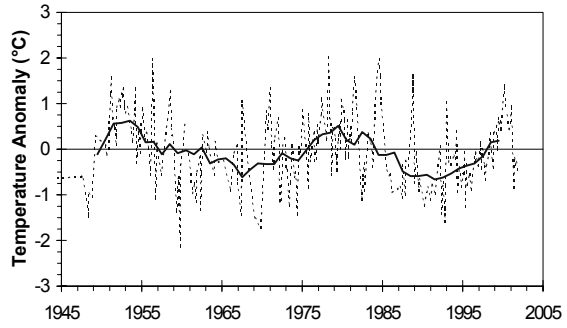
Lurcher Shoals – 50 m



In intermediate and deep waters of the eastern shelf, as exemplified by Misaine Bank, the amplitude of the long-period temperature trend is smaller (order 1°C) than for the rest of the shelf. Also, the low temperature anomalies during the 1960s were not as cold as elsewhere on the Scotian Shelf such as in Emerald Basin or over Lurcher Shoals. From the late-1960s to the mid-1970s, temperatures at Misaine Bank oscillated near or above average. They rose above normal around 1980 but by the mid-1980s, temperatures fell sharply.

Throughout most of the water column, temperatures were generally colder-than-normal until the late 1990s. The minimum temperature was recorded in the early 1990s, after which temperature anomalies rose. By 1999 and 2000 anomalies were above the long-term average. 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.

Misaine Bank – 100 m

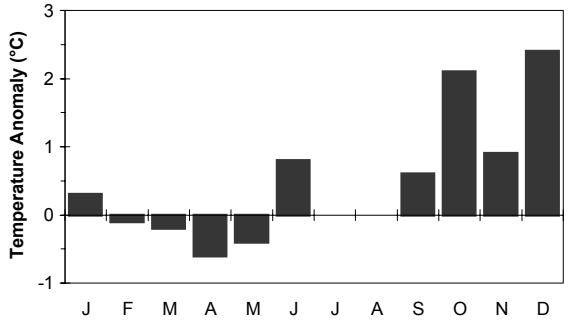


In the deep waters of Cabot Strait, temperatures were coldest during the 1960s but have been above or near average in recent years.

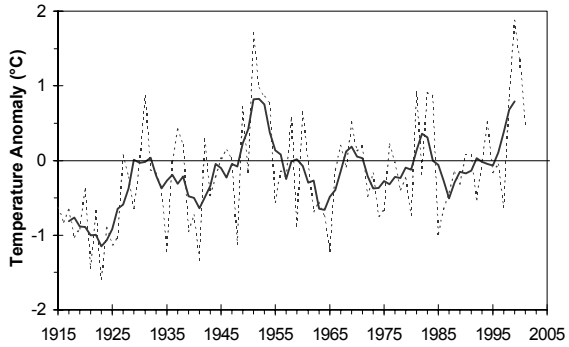
The general temperature trends described above are reflected in the time series of the summer research vessel stratified mean near-bottom temperatures for the Bay of Fundy (NAFO Division 4X) as well as the western (4X), central (4W) and eastern (4Vs) Scotian Shelf.

Conditions in 2001

Sable Island Air Temperatures
2001 Monthly Anomalies



Annual Time Series

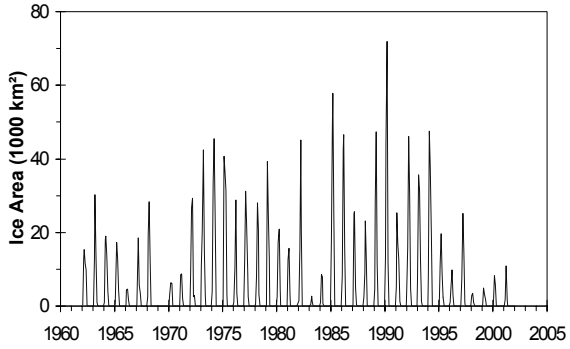


Annual mean air temperature over the Scotian Shelf, Bay of Fundy and eastern Gulf of Maine were warmer-than-normal in 2001. This was due mostly to warm conditions in June and the last four months of the year. The maximum monthly anomaly was in December (>2°C). July and August matched their long-term averages (zero anomalies) while February through May was slightly below normal. Although 2001 was warm, the annual mean temperature declined for the second consecutive year after the record setting high in 1999.

The area of sea ice that was observed seaward of Cabot Strait in 2001 was less than normal and remained low for the fourth consecutive year. While most of the ice was located in the Sydney Bight region, ice did reach the Scotian Shelf proper. The ice coverage seaward of

Cabot in 2001 was the seventh lowest in the 39-year record. On the other hand, the ice that was present lasted longer than usual.

Monthly Mean Area of Sea Ice Seaward of Cabot Strait

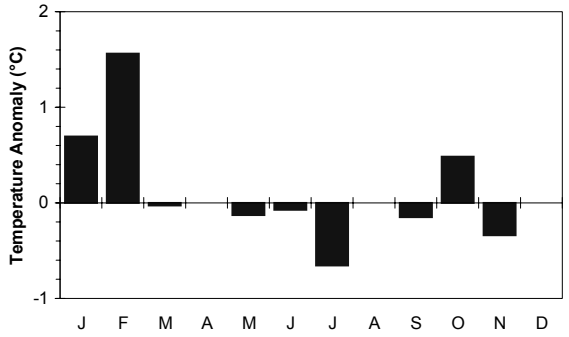


Monthly mean coastal sea surface temperatures in the Gulf of Maine during 2001 were warmer-than-normal continuing the general trend of positive temperature anomalies that persisted through the 1990s. At Halifax, monthly mean temperatures were mostly colder-than-normal reversing the warming trend of the past decade and the warmer-than-normal conditions of 1999 and 2000.

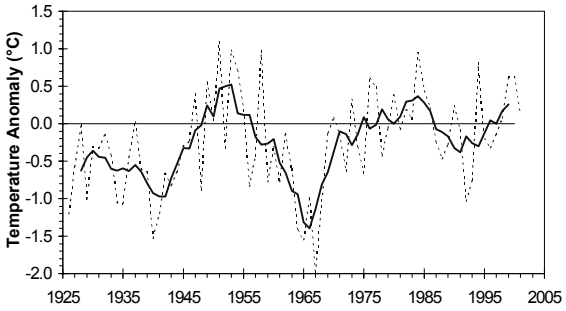
At Prince 5, monthly mean temperatures varied from above normal during the beginning of the year to below normal in much of the second half of the year. These conditions persisted throughout the water column. Annual mean temperatures were near normal although with a tendency for being slightly above normal in the upper half of the water column and below in the bottom half. At all depths temperatures declined relative to 2000 values. The annual salinity anomalies at Prince 5 were saltier-than-normal, near 1999 and 2000 values, and well above the fresh conditions of the 1990s.

In the Laurentian Channel to the east of the Scotian Shelf, temperatures in the deep (200-300 m) waters at Cabot Strait were above normal in 2001 and similar to 2000 values. They are at levels not observed since the late 1970s.

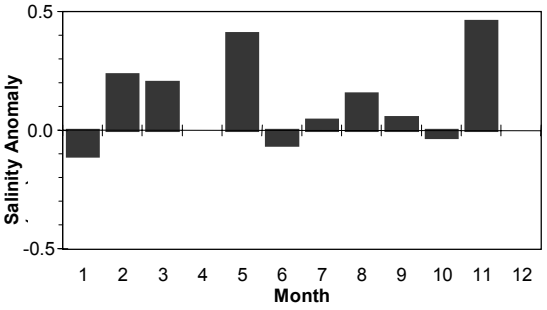
Prince 5 – 0 m
2001 Monthly Temperature Anomalies



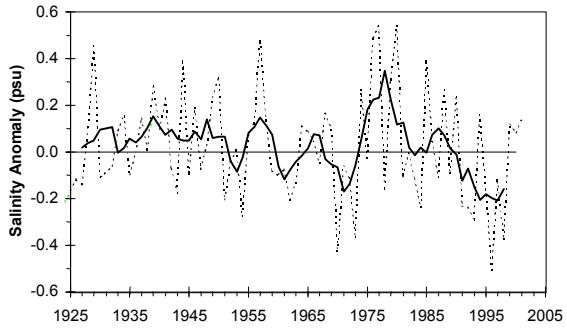
Annual Temperature Time Series



2001 Monthly Salinity Anomalies

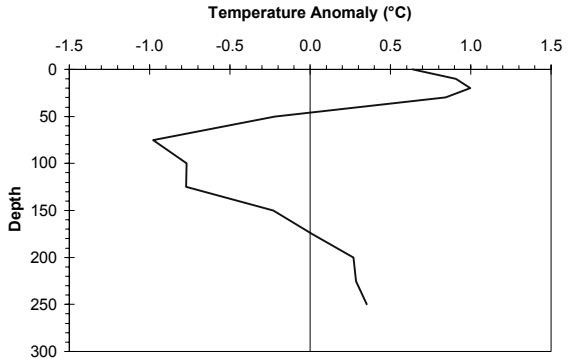


Annual SalinityTime Series

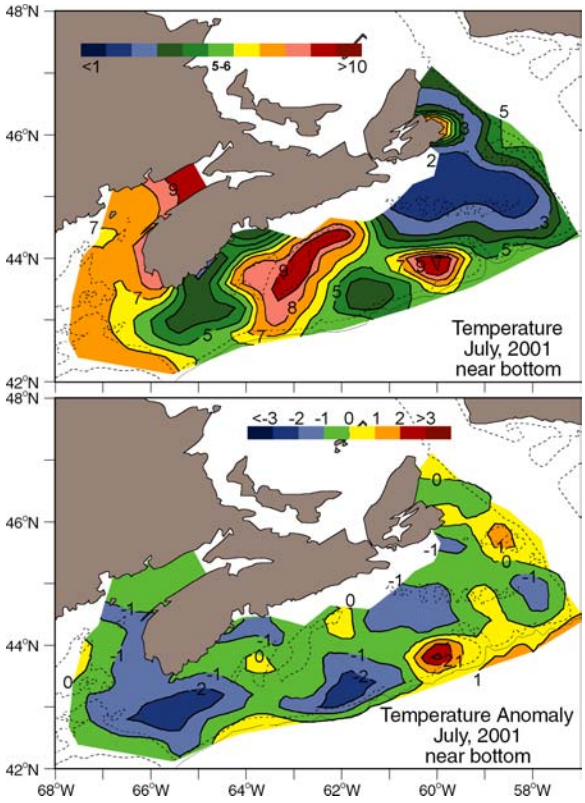


In 2001, the waters in Emerald Basin were warmer-than-normal at the surface and near bottom (250 m) throughout the year resulting in positive annual temperature anomalies. At mid-depth (50 to 175 m), however, negative annual temperature anomalies were observed due principally to cold conditions in the second half of 2001.

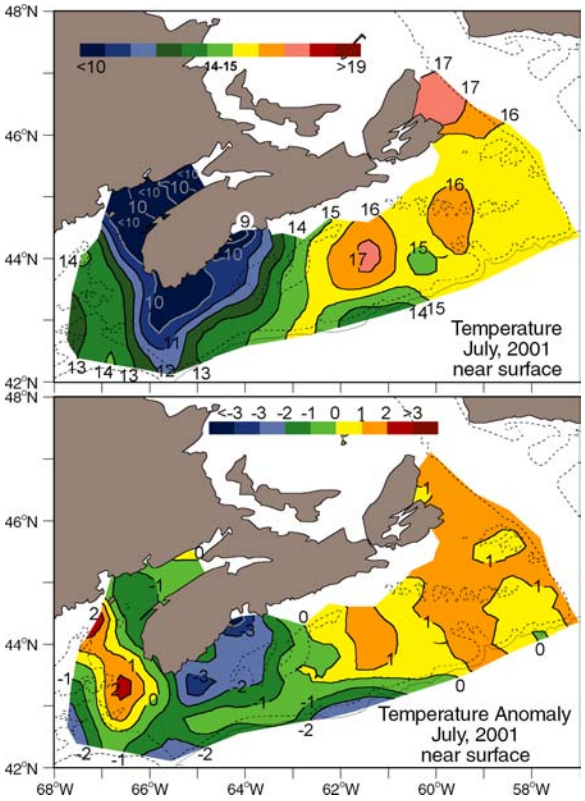
Emerald Basin
2001 Annual Temperature Anomalies



Near-bottom temperatures over most of the Scotian Shelf during the July groundfish survey in 2001 were below normal, in some regions by more than 2°C. In the northeast, most of the bottom was covered by temperatures ranging from >1° to 4°C. These represented cooling relative to 2000. Emerald and LaHave Basins in the central shelf were covered by near-bottom temperatures >8°C, indicative of the influence of Warm Slope Water from offshore. Temperatures at 50 m and 100 m from the July survey also showed colder-than-normal temperatures, similar to the pattern observed near-bottom. This is consistent with the data from 100 m at Misaine Bank. They suggest the subsurface waters over the northeastern Scotian Shelf declined to below normal temperatures after two years of warmer-than-normal conditions.

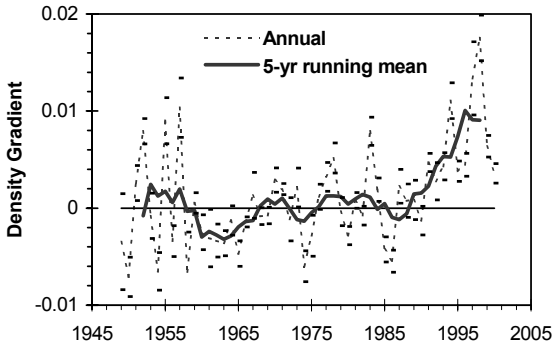


The temperatures at the surface during the July groundfish survey ranged from over 17°C in the northeast to <10°C in the Bay of Fundy. Over the northeastern shelf these were 0° to over 1°C above normal. Above normal temperatures were also observed in the Gulf of Maine off southern Nova Scotia. In contrast to these areas, the southwestern Scotian Shelf and the Bay of Fundy had surface temperatures that were colder-than-normal by up to 2° to 3°C.



In the ocean, lighter water lays over top of denser waters due to differences in the temperature and salinity characteristics. The difference in density with depth is referred to as density stratification. Through the 1990s, the density difference over the top 50 m averaged throughout the Scotian Shelf increased significantly. Since the mid-1990s, this stratification index has been at or near its maximum in the approximately 50-year record. However, no increase in density stratification has been observed in the Gulf of Maine. The primary cause of changes in the Scotian Shelf stratification has been a freshening of the near surface waters. This low salinity water originates upstream off Newfoundland. As the stratification increases in the upper layers, vertical mixing tends to be reduced, which in turn can decrease nutrient replenishment to the surface waters. In 2001, stratification remained stronger-than-normal although it has been decreasing during the past three years.

Density Stratification in upper 50 m over the Scotian Shelf



In 2001, the thermal boundaries between the shelf waters and the slope waters (the Shelf/Slope front) as well as the slope waters and Gulf Stream (the north wall of the Gulf Stream) moved further offshore by approximately 20 km relative to their mean annual positions in 2000. For the Shelf/Slope front, it moved to a location seaward of its long-term mean position whereas the Gulf Stream front remained shoreward of its long-term mean.

For more Information

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