Northwest Atlantic Fisheries Organization

Serial No. N489

NAFO SCR Doc. 82/VI/4

SCIENTIFIC COUNCIL MEETING - JUNE 1982

A Time-series Study of Sea-surface Temperature on the Flemish Cap, 1962-81

by

W. B. Bailey

Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography
Dartmouth, N.S., Canada B2Y 4A2

Introduction

The monitoring of oceanographic conditions is often cited as an honourable endeavour. This thesis was recently expounded upon at the September 1981 Meeting of the Scientific Council by Dunbar (1981). Our knowledge of the oceanography of a region is built-up from surveys of limited extent and duration. Added to these are a few "shore stations" from which observations have been made on a regular basis for many years. However, how far from the point of observation are these data representative? In some areas standard sections have been occupied at irregular intervals. As shown by Keeley (1981), all stations in a section are not necessarily observed during any particular cruise. Thus, in the ten-year period (1970-79), stations in the Flemish Cap regions were occupied on only 21 occasions. When it is demonstrated for a relatively stable area like the Bay of Fundy that, between the beginning and end of a cruise (45 days), there had been a complete exchange of water within the Bay (Bailey, 1953), one is forced to ponder to what transpires when he is not there to observe.

The use of synoptic sea-surface temperature data charts to develop a time series for specific locations is not new. Bailey (1975a) used data gathered at 11 locations for a climatic study of the Grand Banks. That study has been expanded to include some 38 positions in the Northeast Atlantic Ocean, and includes data to the end of 1981. This report focuses attention on a location on the Flemish Cap.

Data collection

Sea-surface temperatures observed by mariners have for many years formed the data base for a variety of research activities and atlas presentations. However, the inclusion of sea-surface temperatures in meteorological messages as part of the International Safety of Life at Sea Programme made these observations readily available for studies of synoptic oceanographic conditions.

In Canada, weekly analyses of sea-surface temperature data from merchant ships have been completed in chart form since the beginning of 1962. Now comprising over 1000 diagrams, these charts provide the data base on which statistical analysis may be carried out. The use of data extracted from charts has several distinct advantages; namely, a very large number of points may be examined, actual observations do not always have to be made, and the event surrounding a point can be reviewed at any time.

The more recent charts have the advantage of some injections of satellite infrared imagery into the contouring. However, due to the nature of the weather in the region, this practice is more fancy than fact and on the Flemish Cap nearly non-existent.

Results

Annual cycle

The waters of the Flemish Cap belong to a modified Arctic water type. although the Polar Front does not lie far from the Flemish Cap, the author's limited search of the literature has not indicated an occasion when that Front lay on or to the north of the Flemish Cap. Although considerable variations appear to take place, the oscillations are between Arctic waters and modified Atlantic water.

The annual cycle of sea-surface temperature during the period of 1962-81 shown in Fig. 1 illustrates a normal mean of 7.45°C with a minimum of 3.2°C in February and a maximum of 13.0°C in August. The distortion of the annual cycle, particularly in the spring months, is likely caused by an influx of winter-chilled waters from the Labrador coast as noted by Smith *et al.* (1937) and Bailey (1961).

In comparison with the analyses of data for other locations just off the Grand Bank and near the Flemish Cap, the annual cycle for the Flemish Cap is relatively regular. Common features are the waviness of the curves in the March-April period, the retarded spring temperature and elevated autumn temperatures.

Deviations of the annual mean from normal mean

Figure 1 shows the years in which maximum and minimum observed sea-surface temperature were observed for particular months. Although the years 1972 and 1973 were generally acknowledged as exceptionally cold years (Bailey, 1975b), an all-time record low temperature for the period was observed for only one month in 1972 and for two months in 1973, whereas the all-time maximum surface temperature was equalled in October 1972.

It is thus more informative to regard the deviation of the annual means from the normal mean. Figure 2 shows those deviations as multiplied by 12. In all probability, only those values exceeding ± 6°C are significant. Using this criterion, it can be seen in Fig. 2 that warm years are 1962, 1965, 1966, 1967, 1970 and 1979 and the cold years are 1968, 1972, 1973, 1974, 1975 and 1976.

As noted earlier, the waters on the Flemish Cap are close to a major oceanic water boundary and therefore some quite large changes in water conditions might be expected over faily short periods of time. Thus the deviations of the annual means from normal are not necessarily as instructive as they might be in another region. Since the interest of the Flemish Cap Working Group lies in the shorter time periods, seasonal departures from normal may be more instructive.

Seasonal departures from normal

Inspection of Fig. 3 shows that only in the years 1966, 1967 and 1981 were the seasonal departures from normal all of the same sign. In these cases, they were all positive. Therefore, a large deviation during a particular season coupled with near normal conditions throughout the remainder of the year would tilt the annual mean toward the larger departure, as was the case in 1965.

From Fig. 3 it can be seen that large deviations do take place from season to season. One now must speak of warm summers or cold springs, etc. Table 1 lists the years in which the seasonal departures from normal exceeded 1°C. Some interesting patterns are evident. Most obvious is that in the spring season there were no warm departures exceeding 1°C and a close inspection of Fig. 3 indicates that on only one occasion (1968) did the departure reach + 0.7°C. The reason for this is the small departures from normal in the spring which when averaged are smaller still. This flatens the curve of the annual cycle in the spring as seen in Fig. 4. The higher temperature of summer in both 1966 and in 1967 extended into the autumn and the departures from normal even increased.

On the cold side, the winter season was cold in four successive years, 1972-75 inclusive. These cold conditions appear to have had an impact on spring season conditions in 1972, 1974 and 1975, and lower temperatures extended even into the summer season in 1974. In 1968, the cold summer was followed by a cool autumn. Investigation by the author into the specific casual effect of these departures from normal has been planned.

Correlation analysis

It is desireable to measure the degree to which temperatures at two stations are related. This may be done using the yearly means for each location and calculating the coefficient of determination (r^2). By definition, the coefficient of determination is the proportion of the total variation in the temperature at one station explained by the regression line. Thus, r^2 signifies the percentage of the total variation or scatter of annual temperatures about their mean at one station that can be explained by the relationship between this variable and the corresponding annual temperature at a second station, as estimated by the regression line for the two sets of data.

In Fig. 5, the coefficient of determination, expressed as a percentage is shown for those stations in the vicinity of the Flemish Cap and the Grand Bank. It is seen that those stations with a strong Arctic influence have the higher percentages while station 11 (Ocean Station Delta) has the least at 3%. A warm water effect may be derived from station E which would be near the northward current of Atlantic water shown by Smith *et al.* (1937), Mann (1967) Reiniger and Clarke (1975) and Borovkov and Kudlo (1981).

General Conclusion

The sea-surface temperatures reported synoptically by merchant and other vessels can provide a unique data base for monitoring surface layer conditons. Comparisons with data gathered at "shore stations", hydrographic sections and by infrared satellite imagery show good agreement. However, one cannot depend upon a single observation. Synoptic observations must be sufficient to demonstrate both continuity and repeatability. This source of data, because of its continuity and larger number of observations than hydrographic stations, has a great potential for demonstrating changes in biological activity of marine animals due to changing environmental conditions.

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Table 1. Years in which the seasonal departures from normal exceeded 1°C.

	WINTER	SPRING	SUMMER	AUTUMN
WARM DEPARTURES	1962	-	1966	1966
	1965	-	1967	1967
	1970	-	1979	1974
	-	-	1981	-
COLD DEPARTURES	1972	1963	1968	1964
	1973	1972	1971	1968
	1974	1974	1974	-
	1975	1975	1976	-
	1977	-	1978	-
	1980	-	-	-

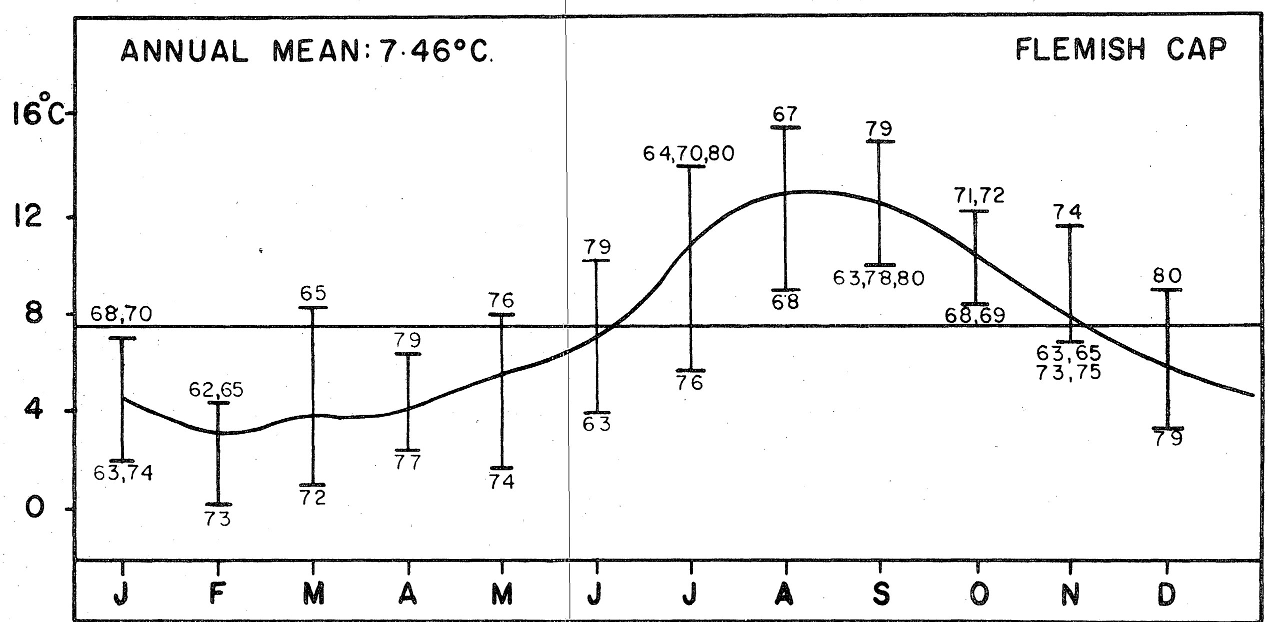

Fig. 1. Annual cycle of sea-surface temperature on the Flemish Cap, 1962-81. The monthly bars indicate the extreme variations and the numbers show the years in which the event occurred.

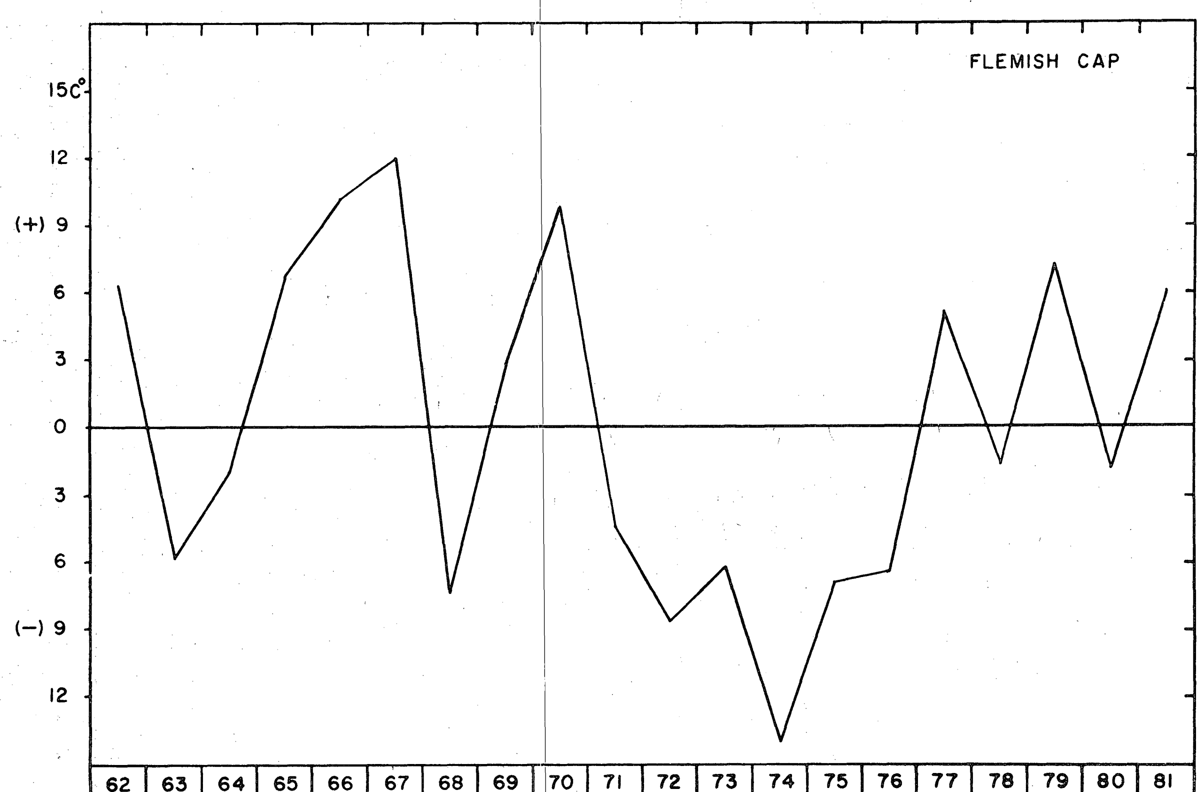

Fig. 2. Deviation (x 12) of the annual means of sea-surface temperature from normal for the Flemish Cap, 1962-81.

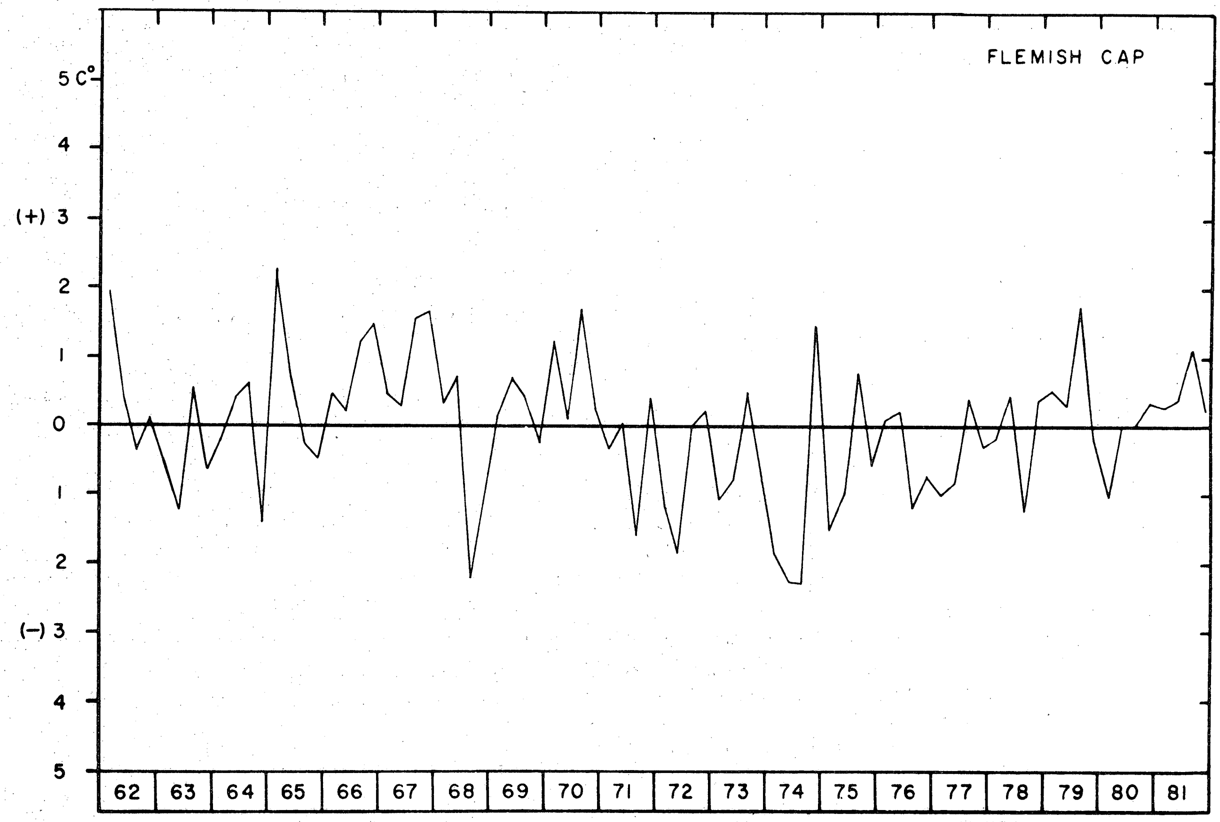

Fig. 3. Seasonal departures of sea-surface temperature from normal for the Flemish Cap, 1962-81.

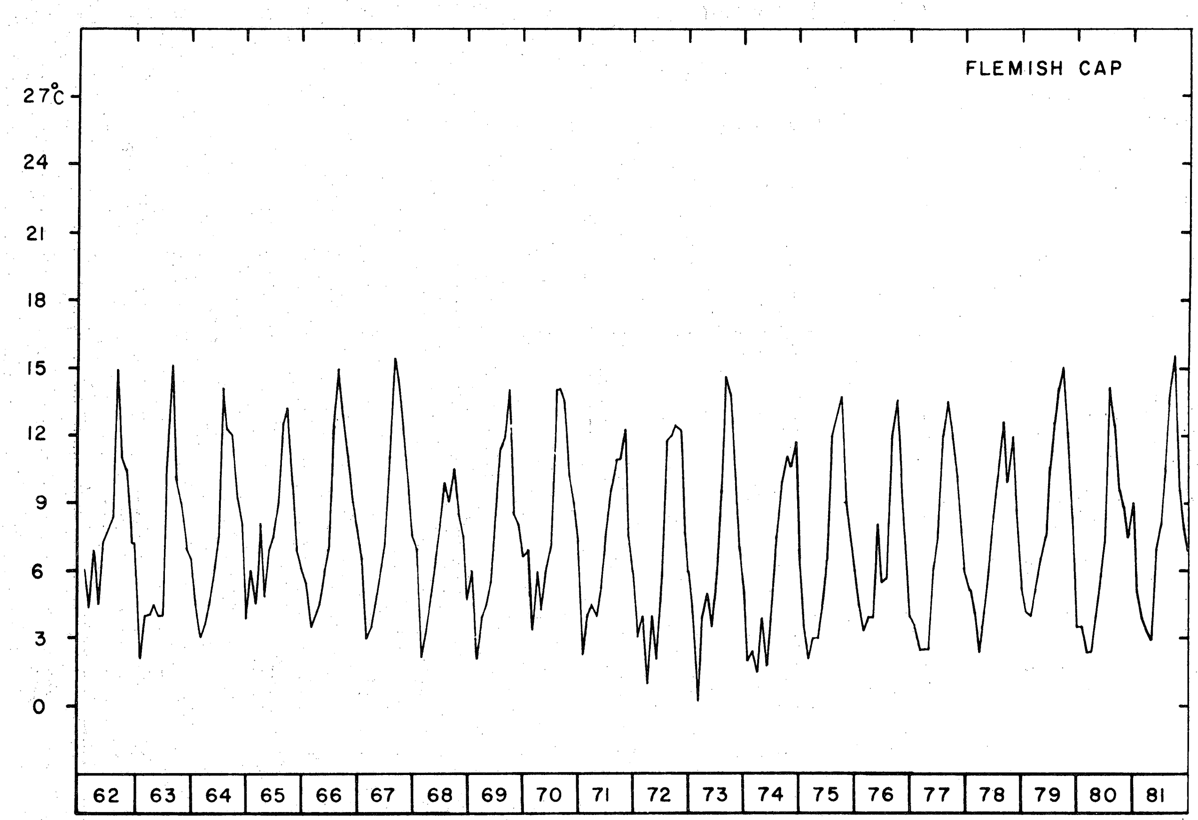

Fig. 4. Monthly mean sea-surface temperatures for the Flemish Cap, 1962-81.

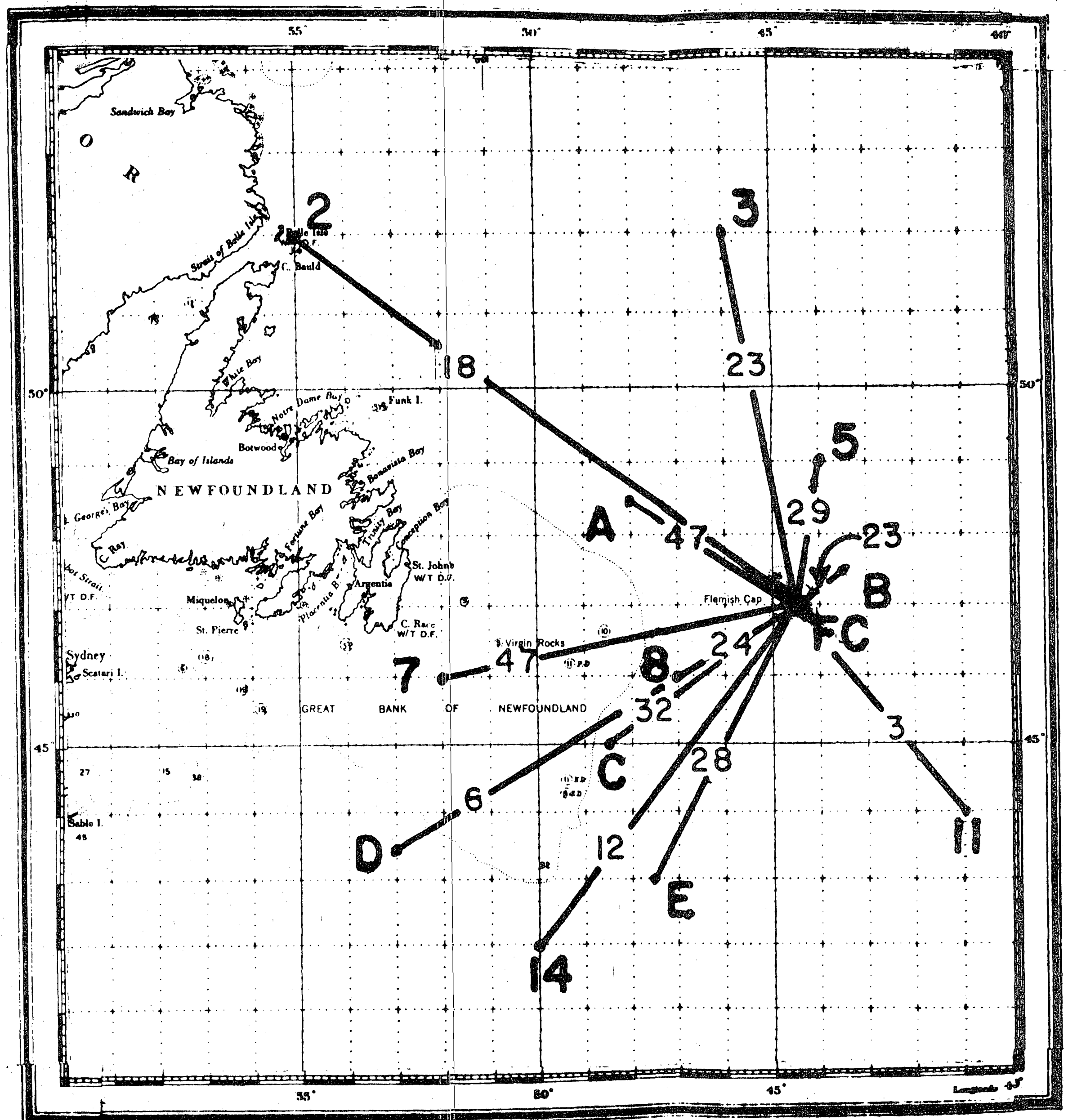

Fig. 5. The coefficient of determination expressed as a percentage between the station on the Flemish Cap and others in the Grand Bank area.