Northwest Atlantic Fisheries Organization

Serial No. N4943 **NAFO SCR Doc. 04/3**

SCIENTIFIC COUNCIL MEETING – JUNE 2004

Climatic Conditions Around Greenland - 2003

by

M. Stein

Institut für Seefischerei, Palmaille 9
D-22767 Hamburg, Federal Republic of Germany
e-mail: manfred.stein@ ish.bfa-fisch.de

Abstract

The pattern of sea level atmospheric pressure over the North Atlantic was anomalous during winter 2002/2003. In contrast to previous winters (1999-2001), the pressure anomaly fields during this winter differed considerably from a dipole pattern which is usually present in the North Atlantic region, with two pressure anomaly cells, one in the Icelandic Low area, the other in the Azores High area. As a consequence of this unusual anomaly pattern, the North Atlantic Oscillation (NAO) index for the winter 2002/2003 was weak and positive (0.07). Air temperature climatic conditions around Greenland continued to be warmer-than-normal and were record high. The climatic conditions at Nuuk are consistent with the NAO index (negative index = mild climate).

Warmer-than-normal conditions were observed around Greenland during most of the year 2003 with mean air temperatures at Nuuk indicating positive anomalies (+2.0K). Based on satellite derived ice charts for all months of 2003 it is shown that the distribution of sea ice in the waters around Greenland was favourable. Subsurface oceanographic data from Fyllas Bank performed from board the German RV "Walther Herwig III" revealed considerable warming in the upper 200 m of the water column during autumn 2003. It is shown that cold "polar events" during 1983, 1992 and 2002 characterize the long term ocean temperature time series. Irminger Water was found off Cape Desolation and at Fyllas Bank during autumn 2003. In the near-bottom water layer off Cape Desolation/West Greenland, at about 3 000 m depth, the Denmark Strait Overflow water mass was observed with salinities of 34.865, a value which was maintained since the year 2000.

Introduction

There are two annual Greenland surveys which are ongoing since decades in the waters adjacing this island: The Danish June survey (Buch, 2000), and the survey performed by Germany in autumn. During October/November 2003 FRV "Walther Herwig III" achieved oceanographic observations at NAFO Standard Oceanographic Sections Cape Desolation and Fyllas Bank as part of the annual autumn groundfish survey to East and West Greenland waters performed by Germany since 1963. The oceanographic data obtained during these surveys form the basis for interpretation of the oceanic climate on the fishing banks around Greenland and at selected NAFO Standard Oceanographic stations.

Starting in 1993 with a compilation of climatic conditions in the northwestern North Atlantic area (Stein, 1995), this paper is the eleventh in a series which provides an annual overview on environmental conditions around Greenland. Whereas the subsurface oceanographic data originate from FRV "Walther Herwig III" observations and from the World Ocean Database, the air pressure data, the air temperature data and the sea ice data are taken from sources given under data and methods.

Data and Methods

The pattern of sea level atmospheric pressure anomaly during the winter (December, January, February) of 2002/2003 (Fig. 1b) and of sea level atmospheric pressure (Fig. 1c) was taken from NCEP/NCAR Reanalysis data from the NOAA-CIRES Climate Diagnostics Centre: http://www.cdc.noaa.gov/Composites.

The NAO Index as given in Fig. 2 refers to the mean December, January, February (DJF) sea level pressure (SLP) from the Azores (Ponta Delgada, PD) and from Iceland (Akureyri, A). The individual SLP's are standardized to 1961-90 base period, and calculated using

$$\mathrm{NAO_i} = \frac{p_i - \bar{p}}{\sigma}\Big|PD - \frac{p_i - \bar{p}}{\sigma}\Big|A$$

with $_i$ = year, p_i = SLP of the given year from *PD* or *A*, p = mean SLP of the 1961-90 base period from *PD* or *A*, σ = standard deviation of the 1961-90 base period. DJF pressures for 1998/99 and 1999/2000 for Ponta Delgada were defined by regression (Loewe and Koslowski, 1998).

Data on the atmospheric climate of Greenland were sampled by the Danish Meteorological Institute at Nuuk (64°11'N, 51°44.5'W), Egedesminde (68°42.5'N, 52°53'W) and Angmagssalik (65°36'N, 37°40'W). Whereas the first data set was mutually supplied by the Danish Meteorological Institute in Copenhagen and the Seewetteramt, Hamburg, the latter data sets were given by the Seewetteramt, Hamburg. The climatic mean which the air temperature anomaly charts are referenced to is 1961-1990. Ice charts (Figs. 9-13) were taken from: http://www.natice.noaa.gov/pub/East_Arctic/Baffin_Bay/Davis_Strait/; http://www.natice.noaa.gov/pub/East_Arctic/Greenland_Sea/Greenland_Sea_southwest/; http://www.natice.noaa.gov/pub/East_Arctic/Greenland_Sea/Greenland_Sea_South/. They originate from NOAA satellite ice observations. Analysis of ice conditions is grouped in sub areas which are denoted in the above given internet links (Baffin Bay/Davis Strait, Greenland Sea southwest, Greenland Sea South).

During cruise WH257 of FRV "Walther Herwig III", CTD profiles were obtained at each fishing position of the surveyed area (Fig. 1a). Observations on Standard Oceanographic Stations (Stein, 1988) were done at the Cape Desolation Section and the Fyllas Bank Section (Fig. 14). Salinity readings of the CTD (SeaBird 911+) profiles were adjusted to water samples derived by Rosette water sampler. A mean salinity deviation of -0.002 was applied to all profiles. Data analysis and presentation was done using the most recent version of Ocean Data View (mp-Version 1.4-2003). θ/S sections of Cape Desolation Section and Fyllas Bank Section are displayed in Fig. 15 and 16, the θS-water mass diagram is given in Fig. 17. Time series of temperature anomaly at Fyllas Bank station 4 is given in Fig. 18 and 19, and the time series of salinity calibration samples at NAFO Cape Desolation Station 3 is given in Fig. 20.

Water mass analysis was done using the "patch" option in Ocean Data View for Irminger Water ($4°C < \theta < 6°C$, $34.95 < S < 35.1$) for the autumn observations (Fig. 21). Historic data for this analysis was taken from the World Ocean Database (WOD98, WOD01) and the World Ocean Atlas 1994. These historic data from Fyllas Bank Section station 4 were mainly sampled by Denmark and Germany. For this site there is also information available in the World Databases measured by vessels from Canada, USA, Norway, UK and Russia. The time period covered in this paper is 1946-2002.

Results and Discussion

The North Atlantic Oscillation (NAO)

Air pressure dipole patterns. The winter 2002/2003 situation indicates an east-west oriented dipole structure (Stein, 2003). The latter reflects the long-lasting flow of cold air masses from Scandinavia and Russia to western Europe during the winter of 2003.

The NAO index. The NAO index as given for the last and present decade shows mostly positive values (Fig. 2, upper panel). The index for winter 2002/2003 (December-February) is positive (0.07).

During the second half of the last century we see that the 1960s were generally "low-index" years while the 1990s were "high-index" years. There was a major exception to this pattern occurring between the winter preceding 1995 and the winter preceding 1996, when the index flipped from being one of its most positive values to its most negative value this century (Fig. 2 upper panel).

The direct influence of NAO on Nuuk winter mean air temperatures can be seen in Fig. 3: A "low-index" year corresponds with warmer-than-normal years. Colder-than-normal climatic conditions at Nuuk are linked to "high-index" years. This indicates a negative correlation of Nuuk winter air temperatures with the NAO. Correlation between both time series is significant ($r = -0.73$, $p << 0.001$).

Air Temperature and Climatic means

Similar to previous years conditions (Stein, 2001), February was the coldest month off West Greenland, and the warmer-than-normal air temperature conditions as observed during December 2002 at the West Greenland sites, were maintained through to January 2003.

The annual air temperature curves referenced to the climatic means at the three observation sites off West and East Greenland; are given in Fig. 4 to 6. Egedesminde's air temperatures during 2003 were above the climatic mean during all months (Fig. 4). Nuuk experienced colder than normal conditions only during February (Fig. 5). Air temperature anomalies (in brackets: mean temperature of the month) during February were +3.2K at Egedesminde (–12.8°C), and –1.2K Nuuk (–8.96°C). Angmagssalik (Fig. 6) experienced climatic conditions which were well above the climatic mean throughout the year. December was the coldest month when air temperature anomalies were +1.1K and monthly mean temperature was –6.1°C.

Climatic Variability off West Greenland

The annual mean air temperature anomaly calculated for 2003 is +2.0K (Fig. 7). This is a continuation of a series of warmer-than-normal years (0.2K to 1.3K) which started in 1996, with the exception of 1999 which was colder-than-normal (-0.3K). The presentation of decadal air temperature anomalies of Nuuk (Fig. 7) reveals much variability during the first years of each decade: whereas the years 1950 and 1960 were warmer-than-normal, 1970 about normal, the years 1980 and 1990 indicated considerable positive/negative anomalies, and the year 2000 conditions were similar to 1980. The year 2001 was the warmest "year 1" since the 1950s, and 2002 is the first warmer-than-normal "year 2" after three decades. 2003 is the warmest year on record for all decades. The long-term trend of Nuuk air temperature anomalies (the 13-year running mean) seems to point at warming, a feature similar to that observed during the 1880s (Fig. 8).

Ice Conditions around Greenland

Winter sea ice conditions were favourable during 2003 off West Greenland. The sea ice drift has a significant offshore component which is called the "West Ice". The southernmost location of the ice edge of "West Ice" was found around 20 March off Maniitsoq/Sukkertoppen (Fig. 9). Multi-year sea ice, coming from the Arctic Ocean via the East Greenland current to the Cape Farewell area, is called "Storis". During end-May, the East Greenland coast was surrounded by sea ice with concentrations ranging from 7-10 tenth (Fig. 11). There was also a tongue of newly formed ice in the Cape Farewell region (Fig. 10). Sea ice formed again in Baffin Bay in mid-November (Fig. 12) when 4-8 tenth of ice concentration was observed north off Baffin Island. Off East Greenland first sea ice formation was encountered in the Angmagssalik area during mid-November (Fig. 13). Due to these favourite ice conditions the cruise WH257 of FRV "Walther Herwig III" to East and West Greenland waters in October/November 2003 was not affected by any sea ice.

Sub-surface Observations off West Greenland

Vertical distribution of potential temperature and salinity at the NAFO Standard Oceanographic Sections Cape Desolation and Fyllas Bank (Fig. 14) are given in Fig. 15 and 16. They reveal the typical distribution of cold, low saline waters on the banks and warm saline waters at the slope region.

The water mass characteristics potential temperatureθ, potential density (σ_θ) and salinity (S) for these sections are given in Fig. 17. Starting in the lower left corner of the diagram, the cold, diluted surface waters emerge from the picture showing potential densities of $\sigma_\theta = 26$ to 26.5. In the deeper parts of the profiles, centered near $\sigma_\theta = 27.5$, the

domain of the warm Irminger Water is visible with temperatures exceeding 6°C and salinities near or above 35. Below the warm water the θ S-diagram is rather uniform showing temperatures less than 2°C at the lower end of the diagram. These θS-characteristics document the thermohaline conditions of the near-bottom water layer at about 3 000 m depth at station 3 of the Cape Desolation Section (CD3). This deep layer is influenced by the Denmark Strait Overflow water mass (Swift, 1984; Stein and Wegner, 1990).

Data on calibration samples taken at CD3, reveal freshening in deep water layers from 1984 onwards (Fig. 20, panel a). During the 2003 cruise, calibration samples were only obtained at 1 500 m and 3 00 0m depth. It would appear that the salinity measurements at 3000m depth (the Denmark Strait Overflow layer) reveal constant conditions since the year 2000 with a mean salinity of 34.865. At 1 500 m depth, salinity amounts to 34.911, a value similar to that observed during 1984 (34.915). A quadratic polynomial regression applied to the data (Fig. 20, panel b) observed at 1 500 m depth, yields significant correlation ($r^2 = 0.87$). It is suggested here that the values at 1 500 m depth represent climatic changes in the Labrador Sea throughout the time of the 1980s to 2003, whereas the Denmark Strait Overflow layer salinity (3 000 m depth) obtains it's characteristics north of the Denmark Strait in the Greenland Sea.

Time series of temperature measurements from Fyllas Bank Station 4 are given in Fig. 18 and 19. The data are referenced to the 1963-90 climatic mean. The surface layers 0-50m (Fig. 18) and 0-200 m (Fig. 19) indicate considerable warming during 2003. Both time series reveal cold "polar events" (1983, 1992 and 2002). During these years, cold and diluted waters from the West Greenland banks reached well out to the slope regions of e.g. Fyllas Bank where these waters cooled the upper layer of the water column.

The dashed curves in Fig. 18 and 19 denote the time series of the NAO winter index (1980-2003). There is ***no*** significant correlation between variations of water temperature anomalies and variations of NAO index. The correlation found is negative and the correlation coefficients are $r = -0.33$ for the 0-50 m layer, and $r = -0.35$ for the 0-200 m layer.

The major heat input to the water column off West Greenland is derived by advection, i.e. the warm Irminger component of the West Greenland Current. A total of 47 oceanographic stations were performed during the West Greenland part of cruise WH257 of FRV "Walther Herwig III". Among these there are profiles which were obtained along two NAFO Standard Oceanographic Sections, Cape Desolation and Fyllas Bank (Fig. 14). These temperature/salinity profiles show the presence of Irminger Water during autumn 2003 at stations 2 (from 616 m depth to 960 m depth) and 3 (259 m-505 m) of the Cape Desolation section. At Fyllas Bank, the characteristic parameters of Irminger Water ($4°C < \theta < 6°C$, $34.95 < S < 35.1$; Fig. 17) were met by the profiles obtained at stations 4 (609 m-822 m) and 5 (366m-699m). The depth data show that the layer of the warm water mass of Irminger Current origin slopes down from off-shore to in-shore of the sections.

An analysis on the presence of Irminger Water at Fyllas Bank station 4 during autumn, reveals that this water mass is mostly found at depths between 400 and 800 m (Fig. 21). The data indicate that Irminger Water was not found during all years at this site. There are some observations on the presence of Irminger Water at Fyllas Bank station 4 in the 1960s, in the second half of the 1980s, the early-1990s, during 1999, 2000 and 2003 (Fig. 21).

References

BUCH, E. 2000. Air-Sea-Ice Conditions off Southwest Greenland, 1981-97. *J. Northw. Atl. Fish. Sci.*, **26**: 123-136.

LOEWE, P., and G. KOSLOWSKI 1998. The Western Baltic sea ice season in terms of a mass-related severity index 1879-1992. *Tellus*, **50**A: 219-241.

STEIN, M. 1988. Revision of list of NAFO standard oceanographic sections and stations. *NAFO SCR Doc.,* No. 1, Serial No. N1432, 9 p.

STEIN, M. 1995. Climatic Conditions Around Greenland – 1992. *NAFO Sci. Coun. Studies*, **22**: 33-41.

STEIN, M. 2001. Climatic Conditions Around Greenland – 2000. *NAFO SCR Doc.*, No. 3: 1-21.

STEIN, M. 2003. Climatic Conditions Around Greenland – 2002. *NAFO SCR Doc.*, No. 4: 1-31.

STEIN, M., and G. WEGNER. 1990. Thermohaline Observations on the Deep Waters off West Greenland. *NAFO Sci. Coun. Studies,* **14**: 29-37.

SWIFT, J.H. 1984. The circulation of the Denmark Strait and Iceland-Scotland overflow waters in the North Atlantic. *Deep-Sea Res.*, **31**: 1339-1355.

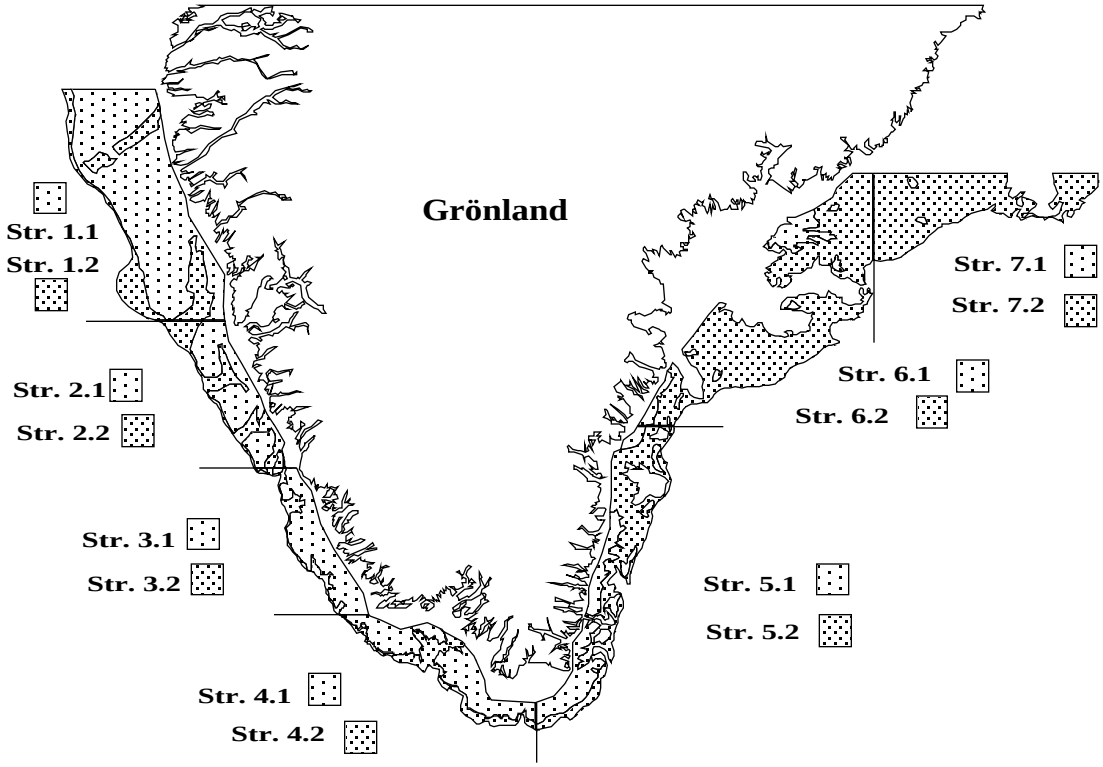

Fig. 1a. Area of investigation during WH 257 (20 October – 27 November 2003), and individual survey strata; strata 0-200 m: 1.1, 2.1, 3.1, 4.1, 5.1, 6.1 and 7.1, and 200-400 m: 1.2,2.2,3.2,4.2, 5.2, 6.2 and 7.2 around Greenland

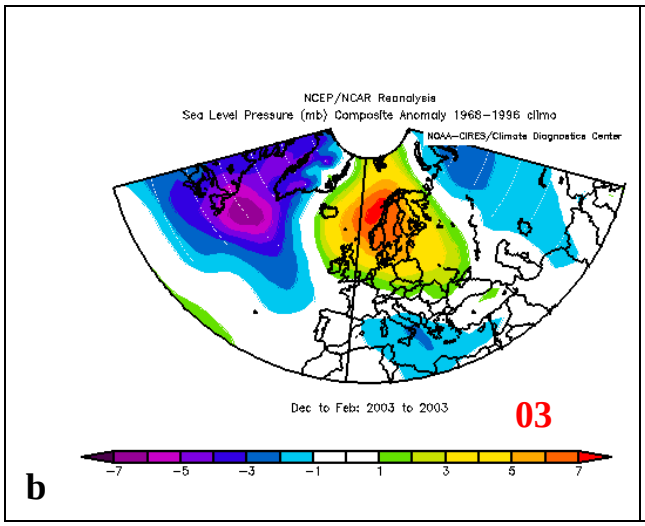

Fig. 1b. The pattern of sea level atmospheric pressure anomaly during the winters (December, January, February) of 2002/2003, red year label denotes positive NAO index.

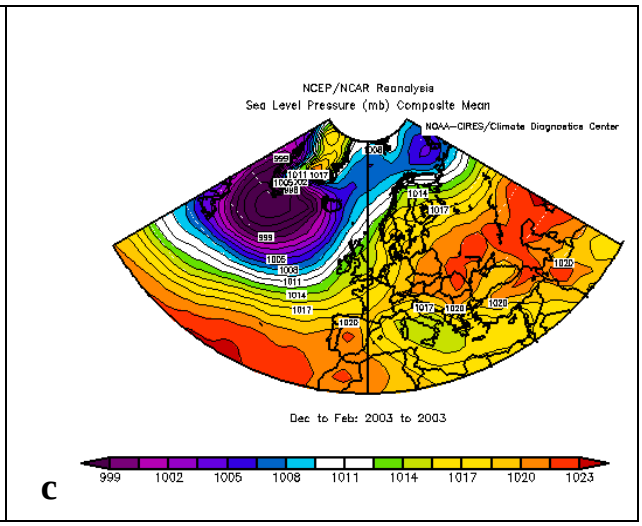

Fig. 1c. The pattern of sea level atmospheric pressure during the same winter as in Fig. 1b.

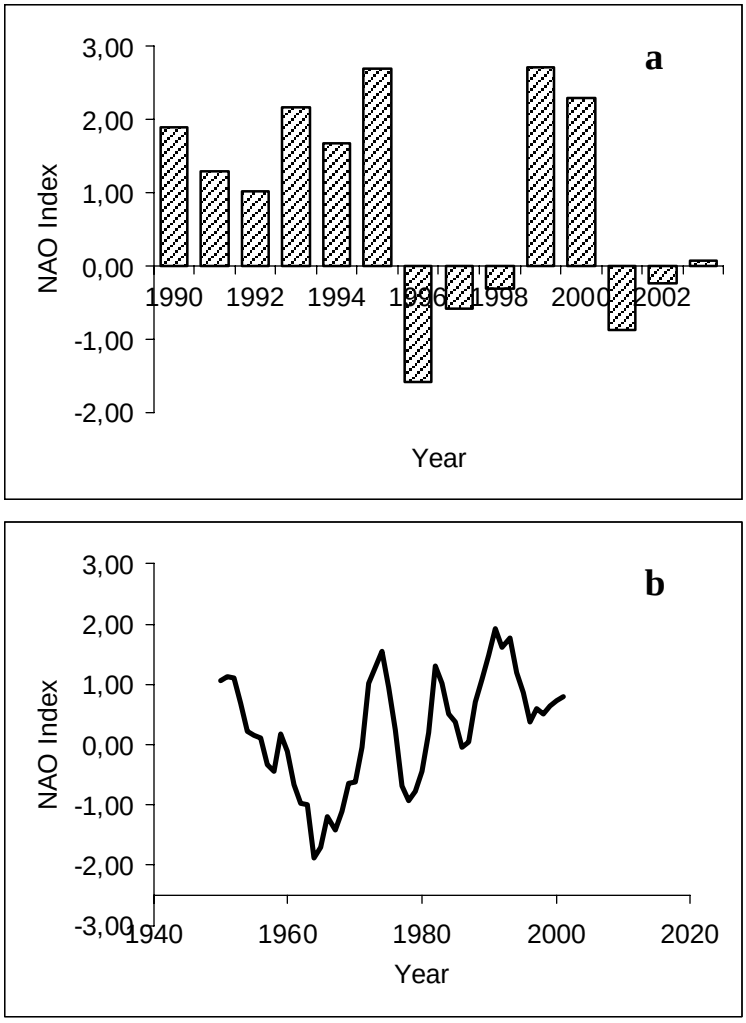

Fig. 2. The winter (DJF) NAO index in terms of the last and present decade (a) and the second half of the last century (lower figure b, a 5-year running mean has been applied)

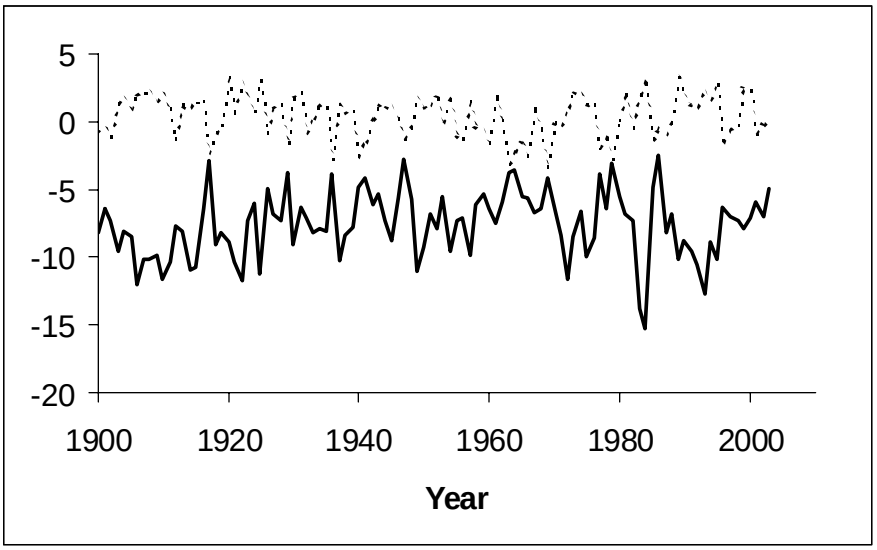

Fig. 3. The winter (DJF) NAO index in terms of the last century and during the first years of the 2000s decade (upper curve, dashed) and the winter (DJF) mean air temperatures at Nuuk (data: 1900-2003).

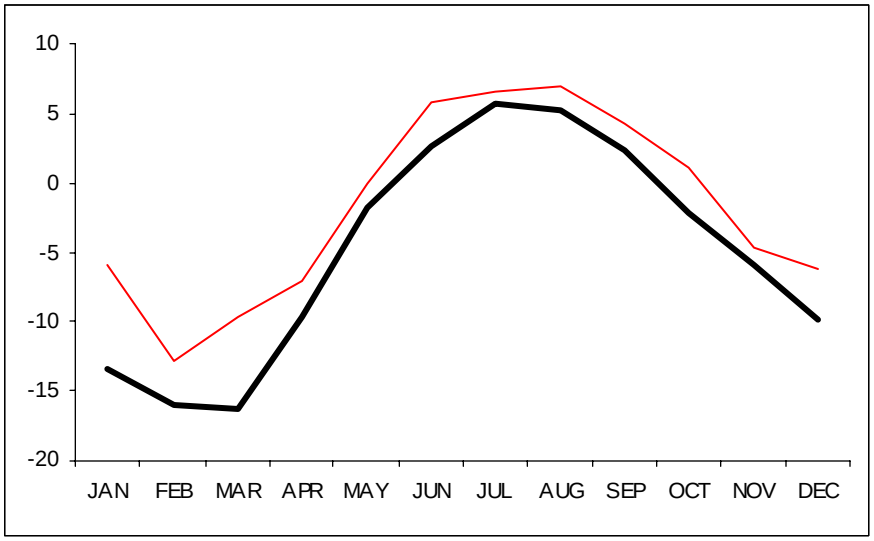

Fig. 4. Monthly mean air temperature (°C) at Egedesminde during 2003 (red, thin line) and climatic mean (1961-1990)

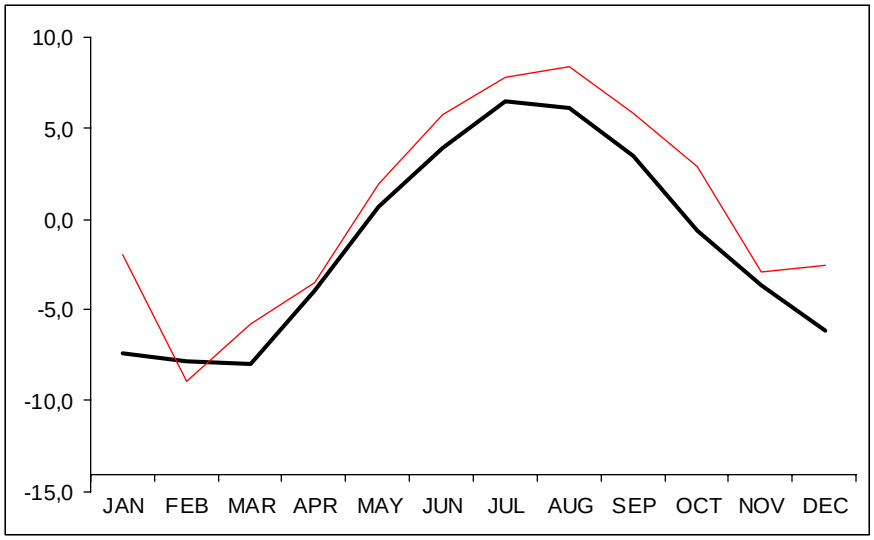

Fig. 5. Monthly mean air temperature (°C) at Nuuk during 2003 (red, thin line) and climatic mean (1961-1990)

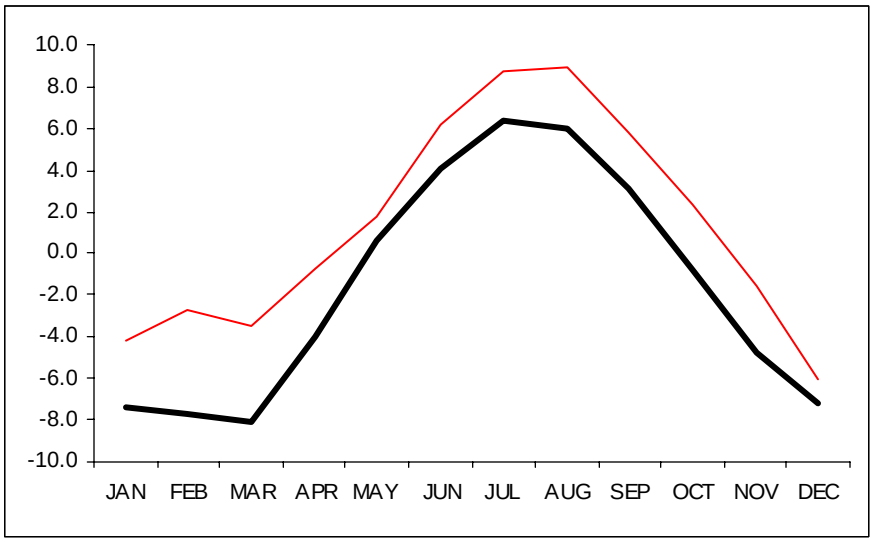

Fig. 6. Monthly mean air temperature (°C) at Angmagssalik during 2003 (red, thin line) and climatic mean (1961-1990)

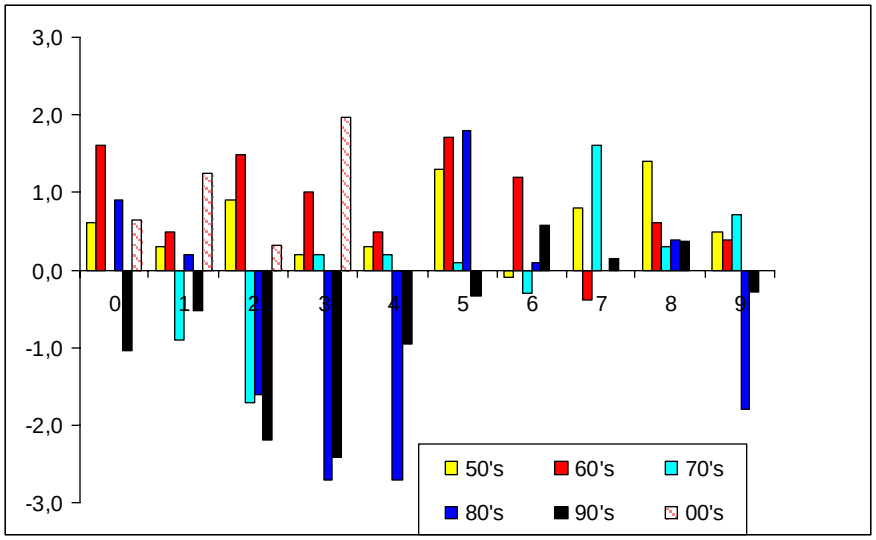

Fig. 7. Composite of decadal air temperature anomalies at Nuuk given relative to the climatic mean of 1961-90 for the decades of the 1950s - 1990s and 2000s (dashed column).

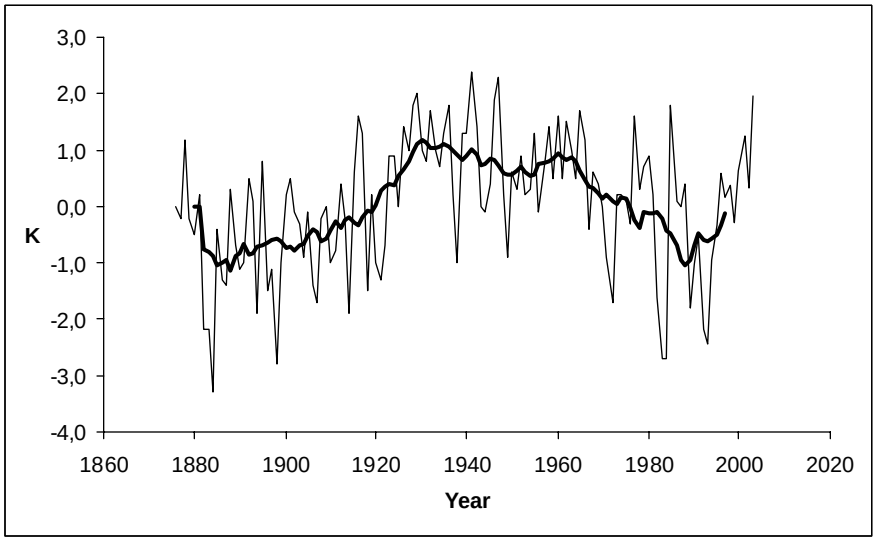

Fig. 8. Time series of annual mean air temperature anomalies at Nuuk (1876-2003, rel. 1961-90), and 13 year running mean.

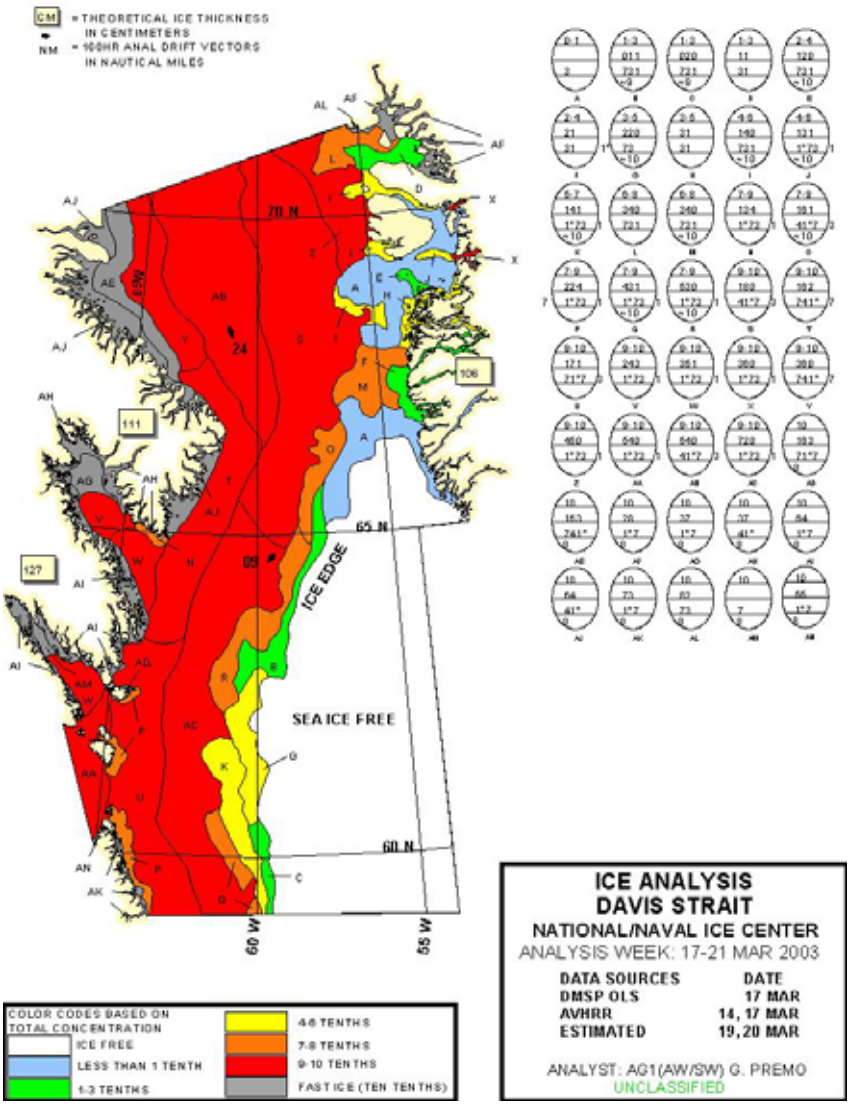

Fig. 9. Ice cover and ice edge during 17-21 March 2003 (Davis Strait).

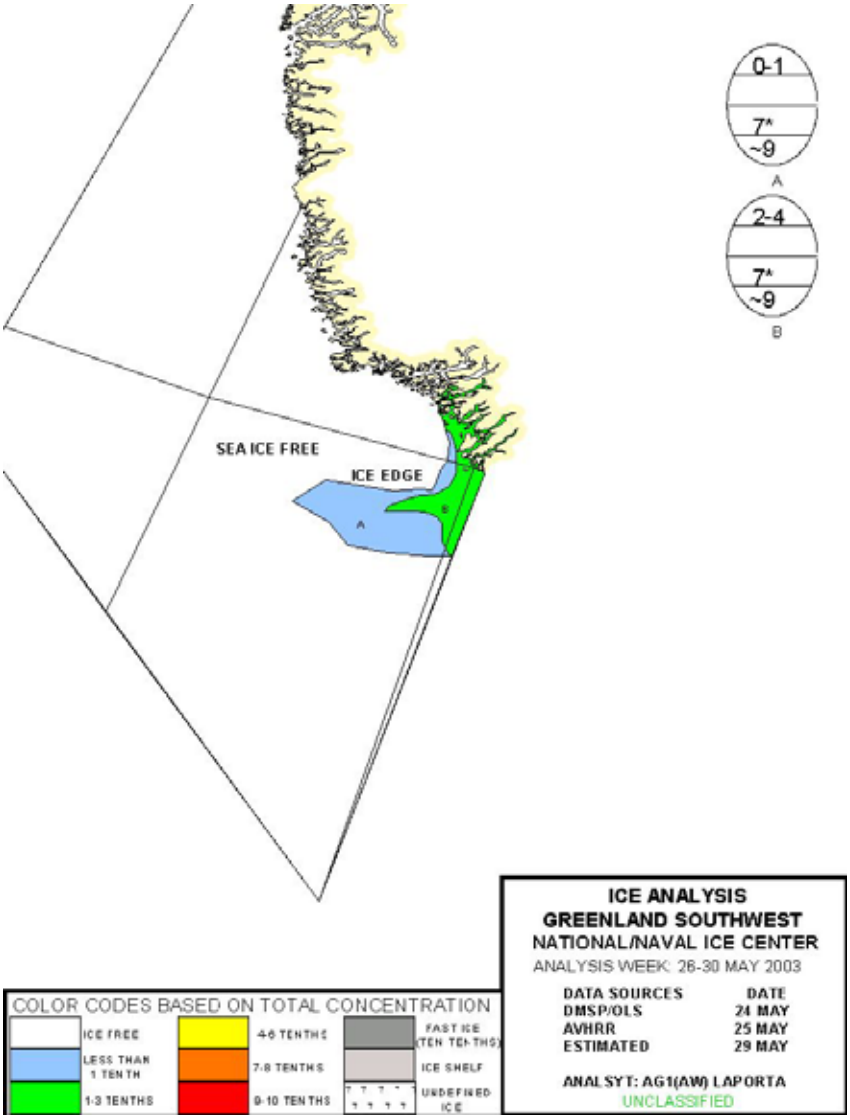

Fig. 10. Ice cover and ice edge during 26-30 May 2003 (Greenland Southwest).

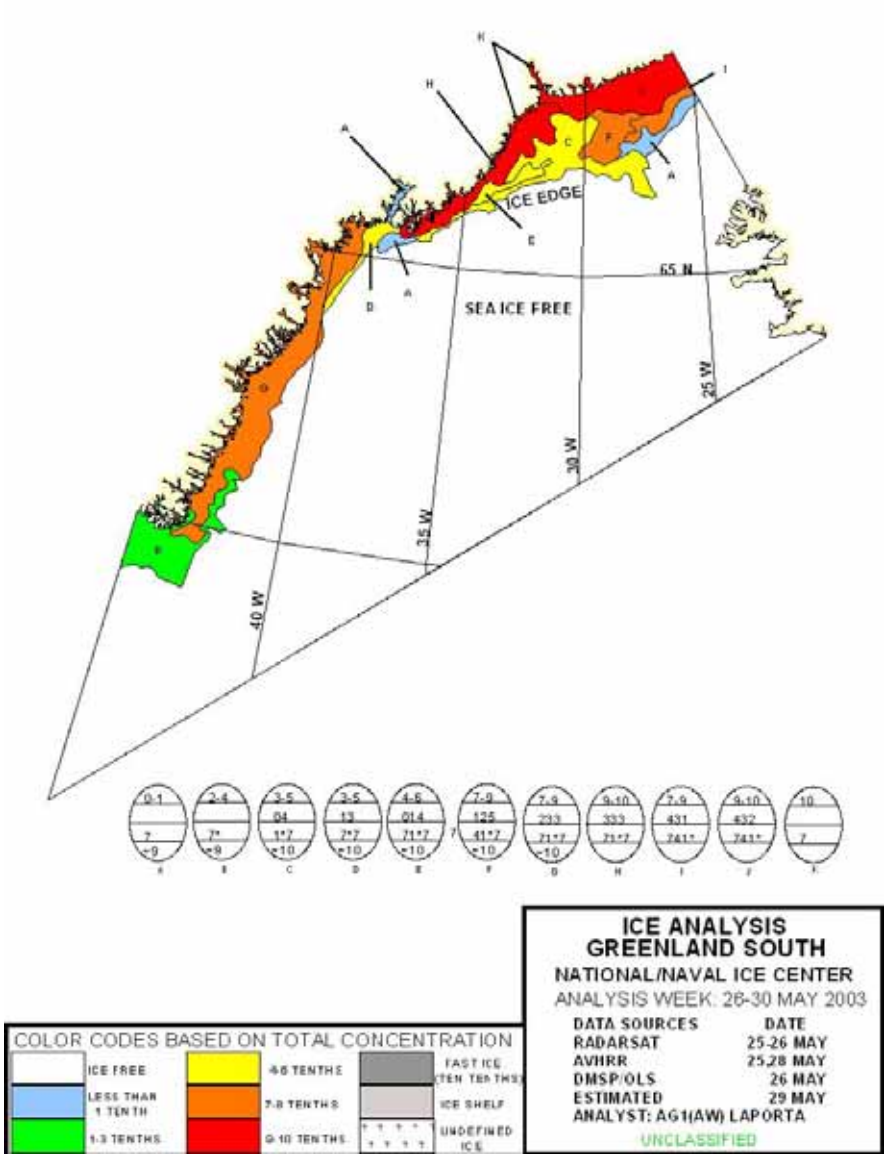

Fig. 11. Ice cover and ice edge during 26-30 May 2003 (Greenland South).

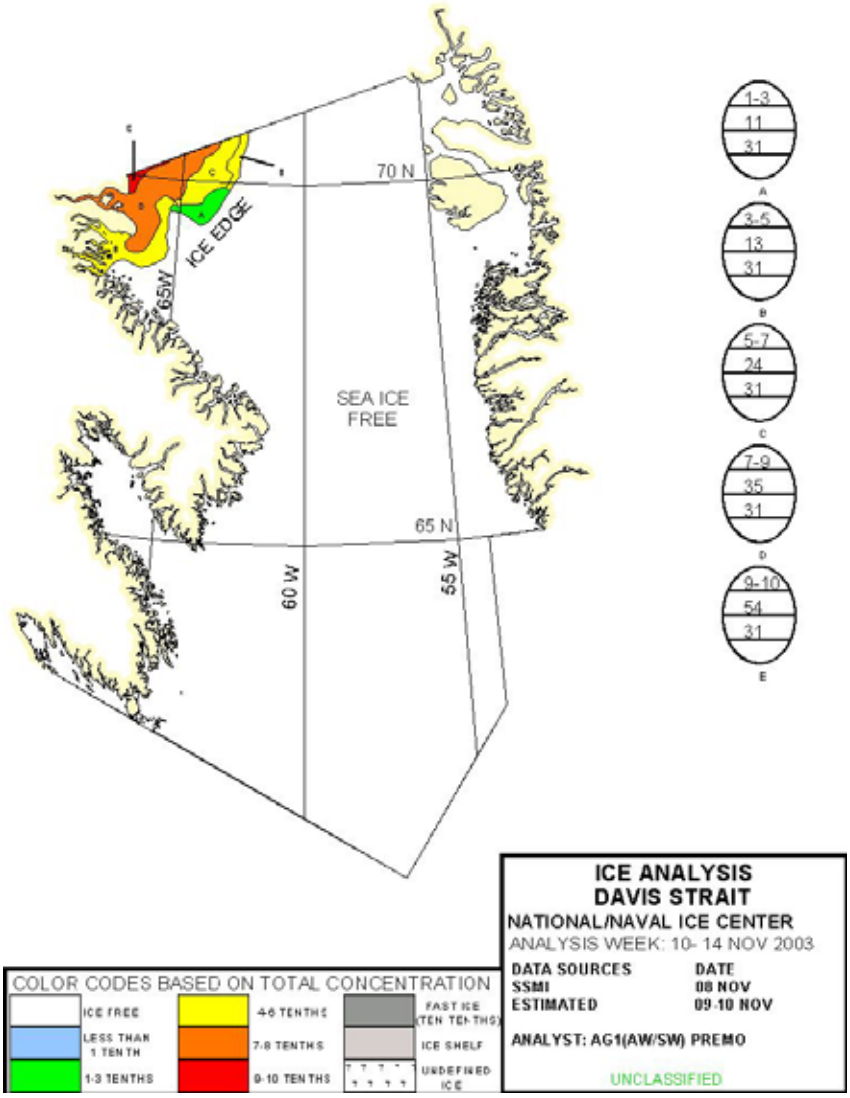

Fig. 12. Ice cover and ice edge during 10-14 November 2003 (Davis Strait).

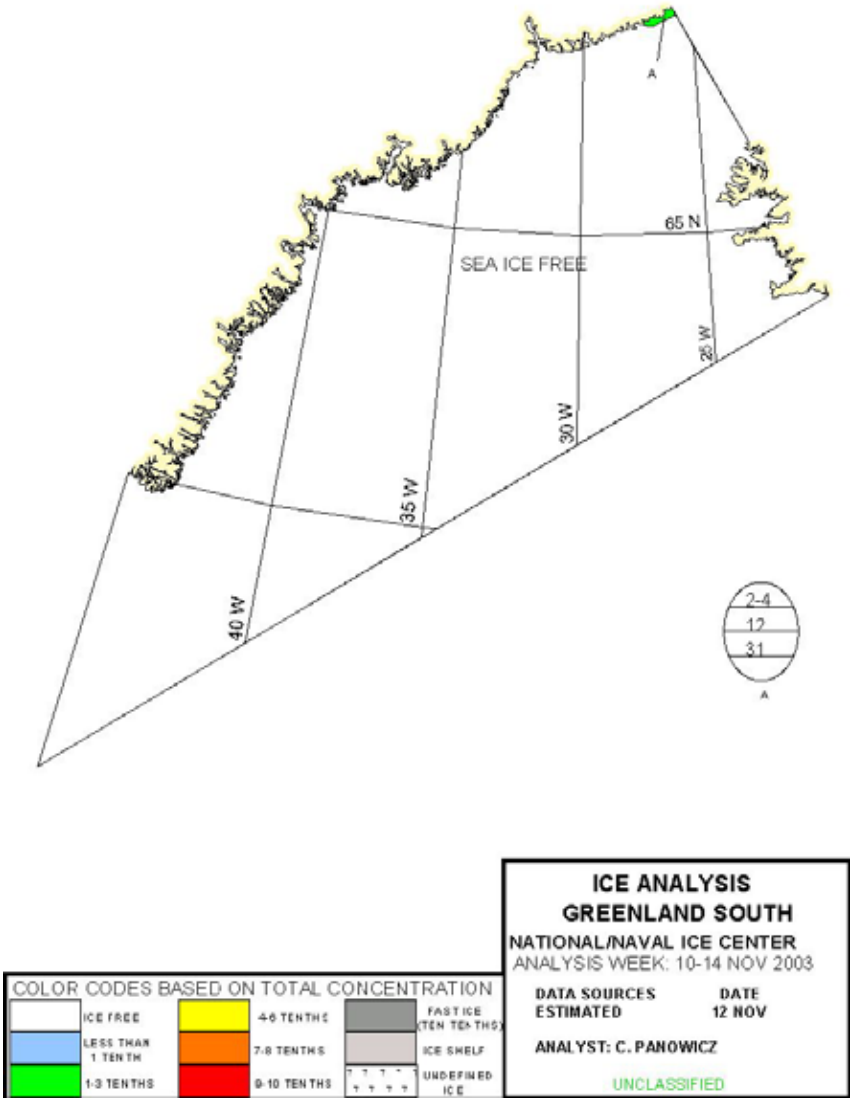

Fig. 13. Ice cover and ice edge during 10-14 November 2003 (Greenland South).

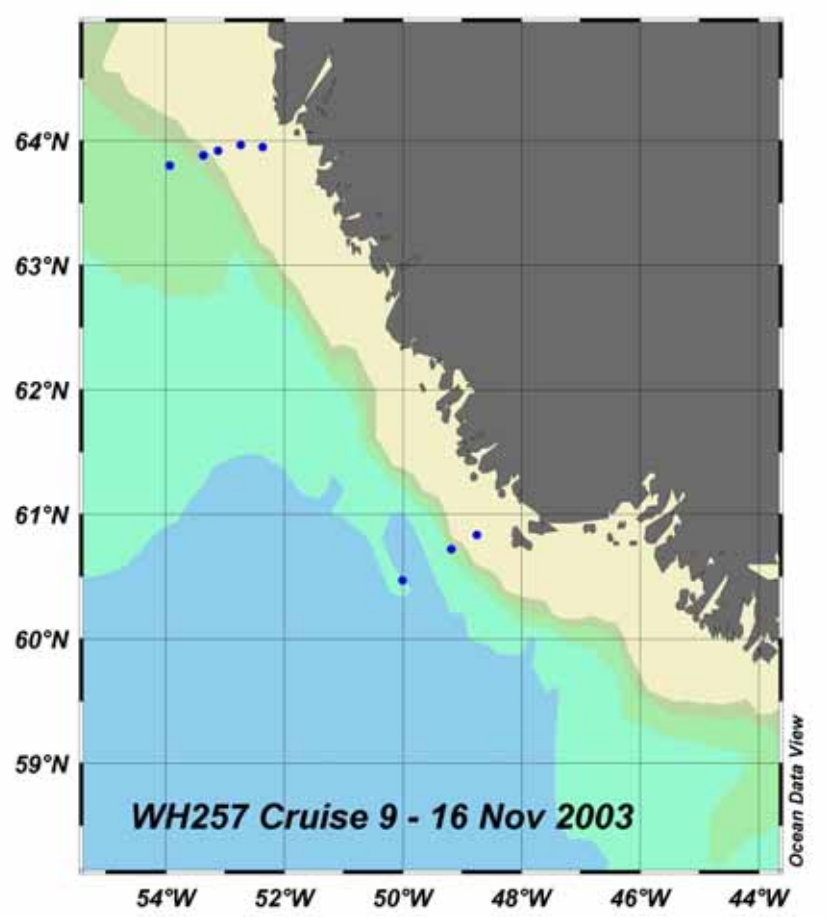

Fig. 14. Positions of sampled NAFO Standard Stations and Sections (9 - 16 November 2003).

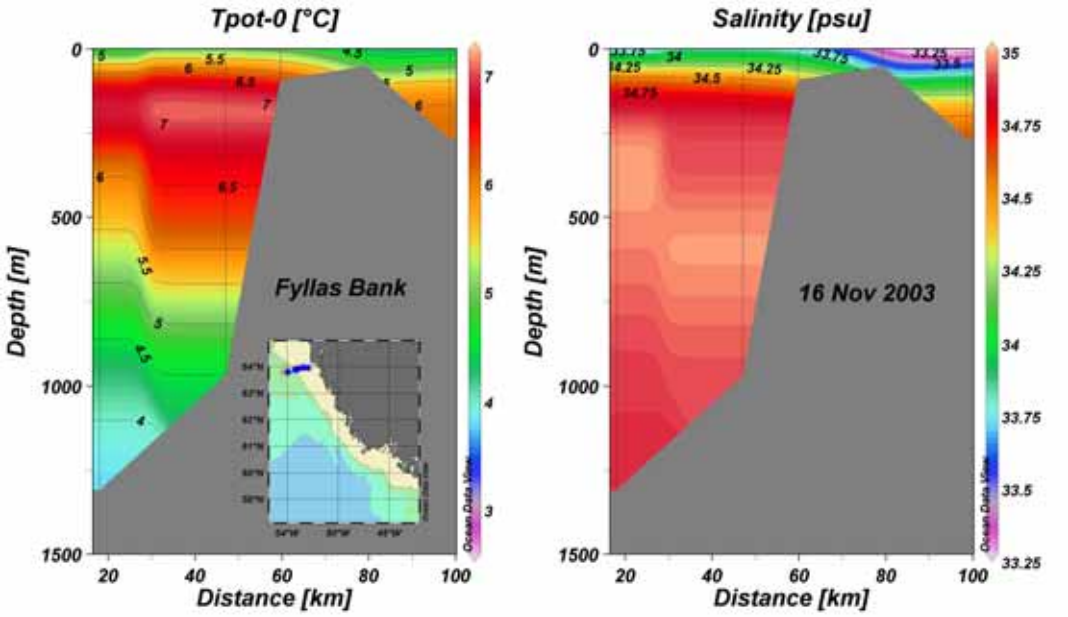

Fig. 15. Potential temperature and salinity along Fylla Bank Section (16 November 2003).

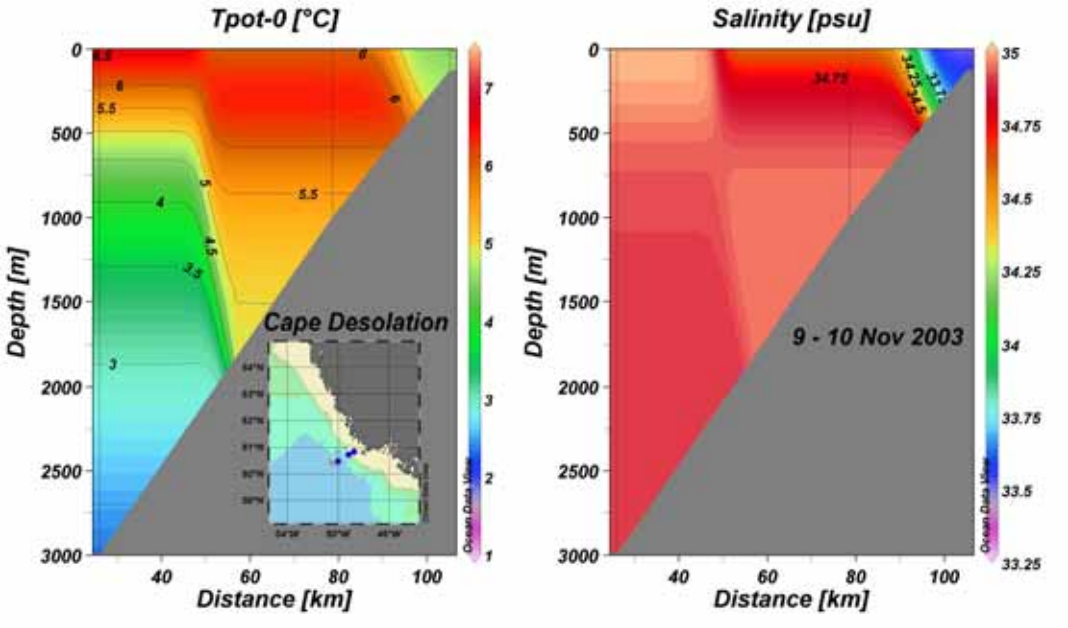

Fig. 16. Potential temperature and salinity along Cape Desolation Section (9-10 November 2003).

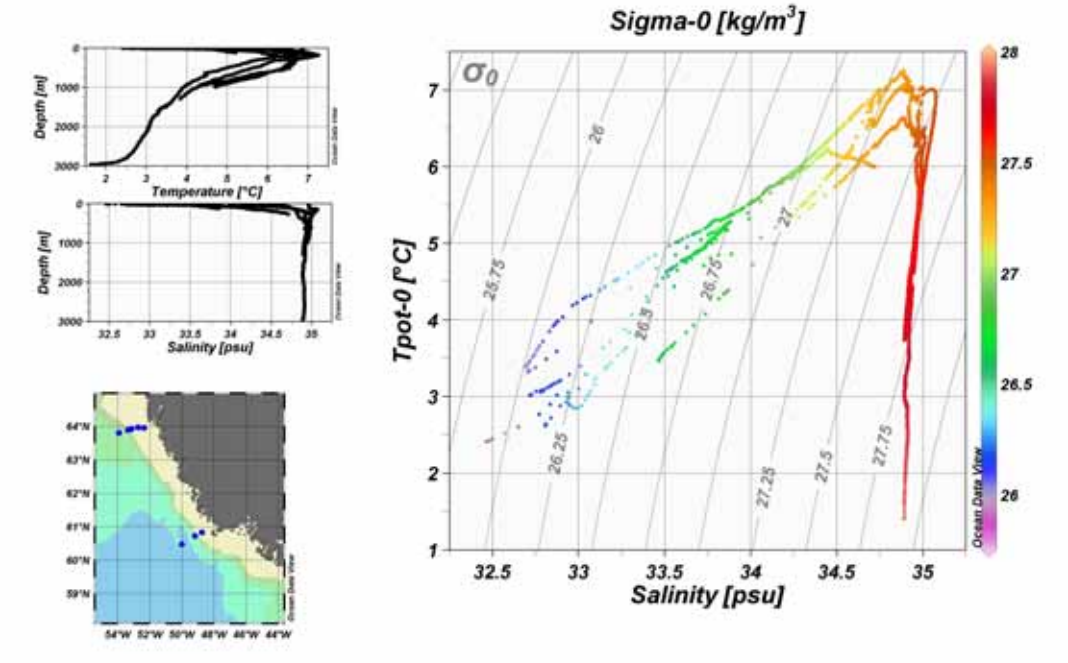

Fig. 17. Theta/S diagram of station profiles indicated in Fig. 14.

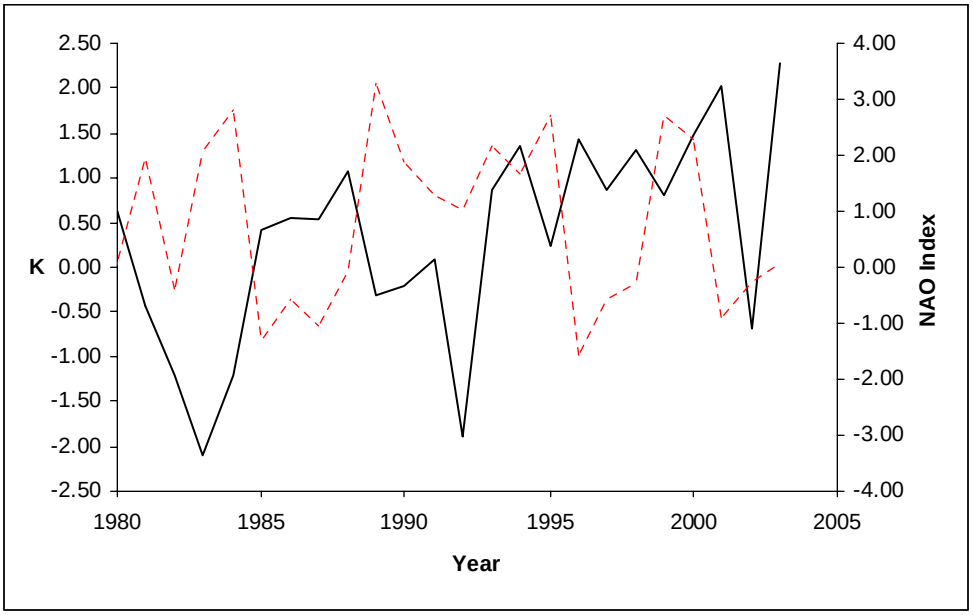

Fig. 18. Mean temperature anomalies of water layer 0-50.m at station 4 of the Fyllas Bank Section; data: 1980-2003 (dashed: NAO Index).

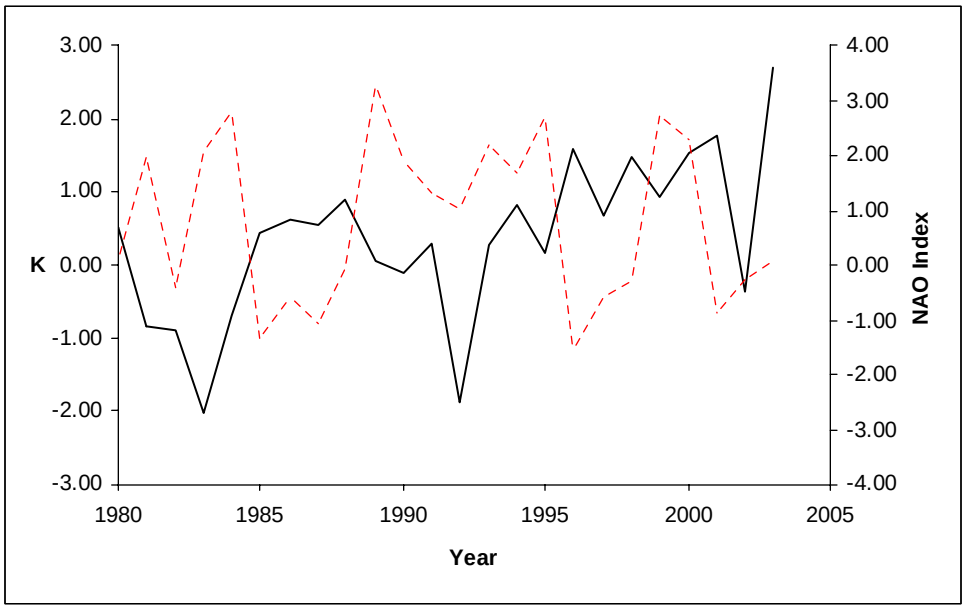

Fig. 19. Mean temperature anomalies of water layer 0-200 m at station 4 of the Fyllas Bank Section; data 1980-2003 (dashed: NAO Index).

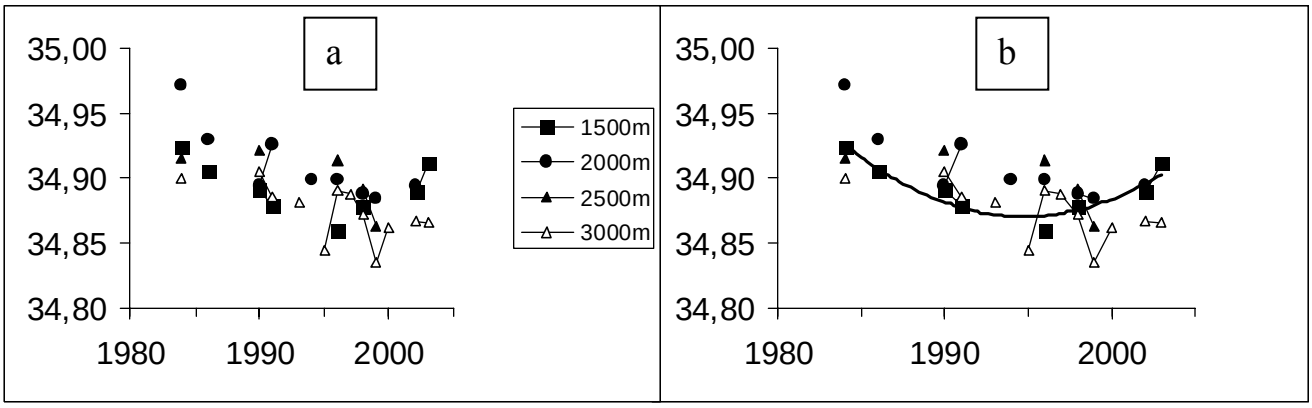

Fig. 20. (a) Salinity of calibration samples at Cape Desolation Section station 3 (60°28'N, 50°00'W; data: 1984-2003); (b) a quadratic polynome was applied to the calibration data at 1500m depth ($r^2 = 0.87$, $p < 0.05$).

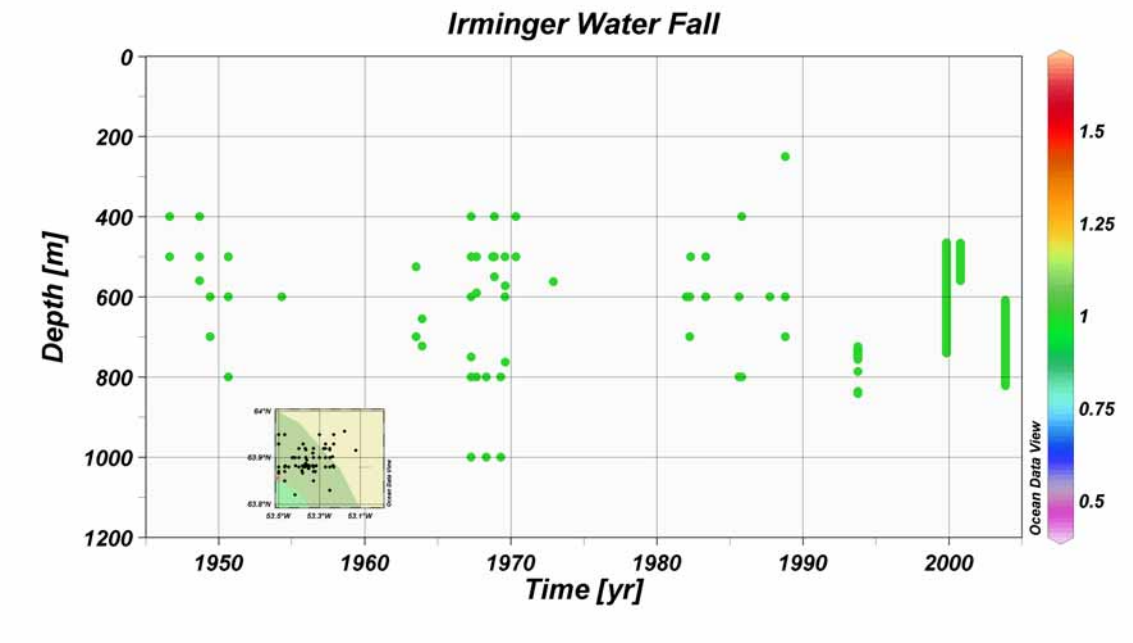

Fig. 21. Presence of Irminger Water at Fyllas Bank Station 4 during 1946-2003.