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Climatic Conditions around Greenland - 2008

by

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Abstract

The pattern of sea level atmospheric pressure over the North Atlantic during winter 2007/2008 indicated one distinct negative pressure anomaly cell, located off East Greenland. A weak positive anomaly cell was located in the western Atlantic area, a strong positive anomaly cell stretched from the Tyrrhenian Sea in the west, to the Caspian Sea in the east. As a consequence of this pattern, the North Atlantic Oscillation (NAO) index for the winter 2007/2008 was positive (+0.65).

Air temperature climatic conditions around Greenland are still warmer-than-normal, although the mean annual temperature anomaly amounted to only +0.3K. The climatic conditions at Nuuk are inconsistent with the NAO index (positive index = cold climate).

Warmer-than-normal conditions were observed around Greenland during most of the year 2008, except for January and February.

During the end of January, Greenland was surrounded by sea ice.

Based on satellite derived ice charts for all months of 2008 it is shown that winter sea ice conditions were less favourable during 2008 off West Greenland than during 2006 and 2007.

At Fyllas Bank, the trend of the water temperature data during recent years points at another "polar event" off Fyllas Bank. Thermohaline conditions in the near-surface layer reveal cold diluted water masses stretching from the coast to the offshore parts of the section.

Calibration samples from the deep water station Cape Desolation 3 (3000m depth) off southwest Greenland reveal harmonic oscillation signals which are most expressed at the 1500m depth level ($r^2 = 0.85$). At 3000m depth, in the domain of the Denmark Strait Overflow water mass, the harmonic signal is weaker, and it explains 48% of variation in the calibration data.

Introduction

Since decades, Denmark and Germany perform annual surveys in Greenland waters: The Danish June survey which was initiated in 1950 (Buch, 2000), and the German autumn survey starting in 1963 (Stein, 2004). During October/November 2008 FRV "Walther Herwig III" achieved oceanographic observations at NAFO Standard Oceanographic Sections Cape Desolation and Fyllas Bank

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 seventeenth 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, 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 2007/2008 (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/cgi-bin/data/composites/printpage.pl .

The NAO Index as given in Fig. 2, refers to the mean December, January, February (DJF) index. It is taken from

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao_index.html.

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 (Figs. 3–7). The climatic mean which the air temperature anomaly charts are referenced to is 1961-1990.

Ice charts (Figs. 8-14) 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).

Sea surface temperature data for the region between Greenland and Labrador were taken from the IGOSS Data Base

http://ingrid.ldgo.columbia.edu/SOURCES/.IGOSS. The climatology is referenced to 1971-2000 (Figs. 15, 16).

During cruise WH316 of FRV “Walther Herwig III”, CTD profiles were obtained at each fishing position of the surveyed area (Figs. 1 and 17). Observations on Standard Oceanographic Stations (Stein, 1988) were done at the Cape Desolation Section and the Fyllas Bank Section (Figs. 18, 20). Salinity readings of the CTD (SeaBird 911+) profiles were adjusted to water samples derived by Rosette water sampler. Time series of temperature anomaly at Fyllas Bank station 4 is given in Fig. 19. The data comprise observations done during September-November at the station site. Data gaps in our own data base, due to e.g. December observations, were filled with data from the World Data Base. This is the case for 1972, 1978, 1980 and 1981.The time series of salinity calibration samples at NAFO Cape Desolation Station 3 is given in Figs. 21 - 23. Data analysis and presentation (Figs. 17, 18, 20) was done using the most recent version of Ocean Data View (Version 3.4.2, 2008; Schlitzer, 2008).

Results and Discussion

Fig. 1 shows the area of investigation during cruise WH316. Starting off East Greenland in the Dohrn Bank region (stratum 7) on 15 October 2008, FRV “Walther Herwig III” went southwards along the East Greenland shelf and slope to complete bottom trawl fishing and CTD/Rosette work in stratum 6. From 27 October onwards, the ship worked in West Greenland waters, doing bottom trawl fishing and CTD/Rosette work, as well as CTD/Rosette observations along oceanographic sections. On 11 November 2008, FRV “Walther Herwig III” left Nuuk and made her way back to Bremerhaven where the cruise was finished on 20 November 2008.

The North Atlantic Oscillation (NAO)

Fig. 1b shows the pattern of sea level pressure anomalies over the North Atlantic during the winter of 2007/2008 (DJF). There was no similar pressure pattern recorded during past winters from 1989/90 onwards (Stein, 2003). During winter 2007/2008, there was one distinct negative pressure anomaly cell, located off East Greenland. A weak positive anomaly cell was located in the western Atlantic area, a strong positive anomaly cell stretched from the Tyrrhenian Sea in the west, to the Caspian Sea in the east. As a consequence of this pattern, the North Atlantic Oscillation (NAO) index for the winter 2007/2008 was positive (+0.65).

The sea level atmospheric pressure over the North Atlantic during winter 2007/2008 is given in Fig. 1c. NAO *positive* winters, like 1999, 2000 and 2005, outline a deeper-than-normal Icelandic Low and a stronger-than-normal subtropical Azores High. NAO *negative* winters, like 1998, 2001, 2002, 2003 and 2004 show a weak subtropical high and a weak Icelandic low (for winters prior to 2003/2004, see: Stein, 2003).

The NAO index

The NAO index, as given for the last and present decade shows mostly positive values (Fig. 2a, upper panel). The index for winter 2007/2008 (December-February) is positive (+0.65). As can be seen from Fig. 2a, this index is among the stronger positive indices, encountered since 1990.

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 (Fig. 2b). 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. 2a, upper panel).

The direct influence of NAO on Nuuk winter mean air temperatures is as follows: 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 ($r = -0.73$, $p << 0.001$; Stein, 2004). The 2008 mean annual air temperature anomalies at Nuuk (0.3K) reveal, however, that statistical significance being valid for the entire time series of 130 years, must not necessarily mean that this model fits with every year of observation. The NAO index for winter 2007/2008 is among the stronger positive values during the past 19 years (Fig. 2a), and the annual mean air temperatures are near the mean value observed during 1876-2008 (see below).

Air Temperature and Climatic means

During 2008, February was the coldest month off West and East Greenland. While at Egedesminde (Fig. 3) temperatures were above normal from March onwards, the Nuuk air temperatures reveal colder-than-normal conditions during January, February and December (Fig. 4).

With the exception of February, Angmagssalik (Fig. 5) experienced climatic conditions which were above the climatic mean throughout the year.

Climatic Variability off West Greenland

The annual mean air temperature anomaly calculated for 2008 is 0.3K (Fig. 6). This is a continuation of a series of warmer-than-normal years (0.2K to 2.0K) which started in 1996, with the exception of 1999 which was colder-than- normal (-0.3K). During recent times, 2003 was the warmest year with +2.0K. We have to go back to the 1940s to find similar warm years, like 1947 with +2.3K.

Warming in arctic regions has become a more and more frightening scenario in past years (http://cires.colorado.edu/science/groups/steffen/greenland/melt2005/).

Warming as observed in our data on West Greenland Current properties (e.g. Stein, 2005), in the climatic data of Nuuk, as indicated above, and in subsurface oceanographic data off West Greenland’s fishing banks (see below) support this scenario.

The presentation of decadal air temperature anomalies at Nuuk (Fig. 7) reveals much variability during the first year 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, and 2004 is the warmest “year 4”. The year 2005 (+1.6K) is in a similar range as the years 1955 (+1.3K), 1965 (+1.7K) and 1985 (+1.8K). The year 2006 (+1.2K) is in the same range as the year 1966 (+1.2K) and thus another warmer-than-normal year at Nuuk. The same trend can be seen for the year 2007 (+ 0.8K) which is the same as in 1957. The year 1977 was the warmest “year 7”, and the anomaly amounted to + 1.6K. The year 2008 mean air temperature is in a similar range as the temperatures of the “year 8” of the previous four decades.

Ice Conditions around Greenland

Winter sea ice conditions were not as favourable during 2008 off West Greenland than during the previous year. The sea ice drift has a significant offshore component which is called the "West Ice". During the end of January, Greenland was surrounded by sea ice (Figs. 8-10). Multi-year sea ice, coming from the Arctic Ocean via the East Greenland current to the Cape Farewell area, is called "Storis". During 21-25 April, the East Greenland coast was surrounded by sea ice with concentrations ranging from 9-10 tenth (Fig. 11). There was also a tongue of newly formed ice in the Cape Farewell/Julianehaab Bight region which extended up off Paamiut (Fig. 12). Sea ice formed again in Baffin Bay in the early-November (Fig. 13) when up to 9-10 tenth of ice concentration was observed north off Baffin Island. This was similar to the sea ice conditions during 2007. Off East Greenland, first sea ice formation was encountered in the Angmagssalik area and to the north at Storfjord Deep during early-November (Fig. 14).

Sea Surface Temperature (SST) Observations off Greenland and in the Labrador Sea

The SST anomaly data as given in Figs. 15 and 16 reveal anomalous warm conditions off Greenland and in the Labrador Sea throughout all months of 2008. Maximum warming exceeded 3 K during July and August (Fig. 16), least warming occurred in December when SSTs were 0.5 K warmer-than-normal. Compared to the previous year, December SSTs cooled by about 0.5 K. During all months, there are colder-than-normal surface waters at the Greenland coast. This points at the influence of the sea ice on the SSTs.

Subsurface Observations off West Greenland

There are two salient features in the vertical distribution of temperature which characterize the hydrographic properties between Greenland and arctic Canada (Stein, 2005): The Baffin Island Current and the core of the West Greenland Current (WGC). The Baffin Island Current is a broad current band which exports cold water from Baffin Bay southwards. On the eastern side of the section, the West Greenland Current flows along the shelf break and transports heat into the Baffin Bay.

Vertical distribution of potential temperature and salinity at the NAFO Standard Oceanographic Sections Cape Desolation, and Fyllas Bank are given in Figs. 18 to 20.

Cape Desolation Section

The Cape Desolation Section station 3 is in the domain of the WGC-core and reveals maximum temperatures of 6.20°C at 86m depth during 29 October 2008 (Fig. 18). The salinity maximum (35.001psu) is found deeper, at 213m depth. At depths of 2989m potential temperature of 1.50°C was calculated (*in situ* temperature / salinity: 1.73°C / 34.908 psu).

Fyllas Bank Section

Based on autumn measurements (September-November) at station 4 of the Fyllas Bank section, the temperature anomaly time series reveals a warming trend which is persistent since 1993 (Fig. 19). Since station 4 of the Fyllas Bank section is situated at the bank slope, it happened in the past decades that cold surface waters from Fyllas Bank were moved westward and influenced the upper 200m of the water column. This happened during autumn 1983, 1992 and 2002, and these events will be called here "polar events". Mean temperature of the upper layer 0-200m again indicates cooling after 2003 which was the record warm year in the entire time series. The 2008 observations indicate slightly positive anomalies of the 0-200m layer (0.26K). The trend of the data obtained since 2003 (Fig. 19) points at another "polar event" off Fyllas Bank. This is corroborated by the information obtained from the entire Fyllas Bank section (Fig. 20): The thermohaline conditions in the near-surface layer off Fyllas Bank reveal cold diluted water masses stretching from the coast to the offshore parts of the section. At depths, the warm and saline signal of the WGC dominates the hydrographic conditions off-slope the Fyllas Bank.

Calibration samples

Data on calibration samples taken at CD3, reveal freshening in deep water layers from 1984 onwards (Figs. 21 to 23). During the 2008 cruise, calibration samples were obtained at 500m, 1000m, 1500m, 2000m, 2500m and 3000m depth. Model (1) adjusted to the data of 1500m, 2000m and 3000m depth, reveals significant harmonic trends.

(1) $\zeta(t)=A*\sin(2\pi/\tau + \varphi)$ + lin trend

They explain 85% of variation at 1500m depth (Fig. 21), 80% at 2000m depth (Fig. 22) and 48% at 3000m depth (Fig. 23). It is suggested here that the values at 1500m depth represent climatic changes in the Labrador Sea throughout the time of the 1980s to 2008. At 2000m depth, which is the approximate depth of the upper boundary of the saline, low-oxygen layers of the North Atlantic Deep Water (NADW) the model suggests climatic changes which might be forced by the Labrador Sea Water layer, sitting above the NADW (Stein and Wegner, 1990). The bottom water layer at Cape Desolation Station 3 is influenced by the Denmark Strait Overflow Water (DSOW). It would appear that the salinity at this depth (3000m) points at freshening of this water mass, which obtains its characteristics north of the Denmark Strait in the Greenland Sea. Since 2003, data suggest increasing salinities in the bottom water layer at Cape Desolation Station 3. This might be a consequence of previous warming and increasing salinities upstream in the Greenland Sea (Osterhus and Gammelsrod, 1999; Walter, 2004).

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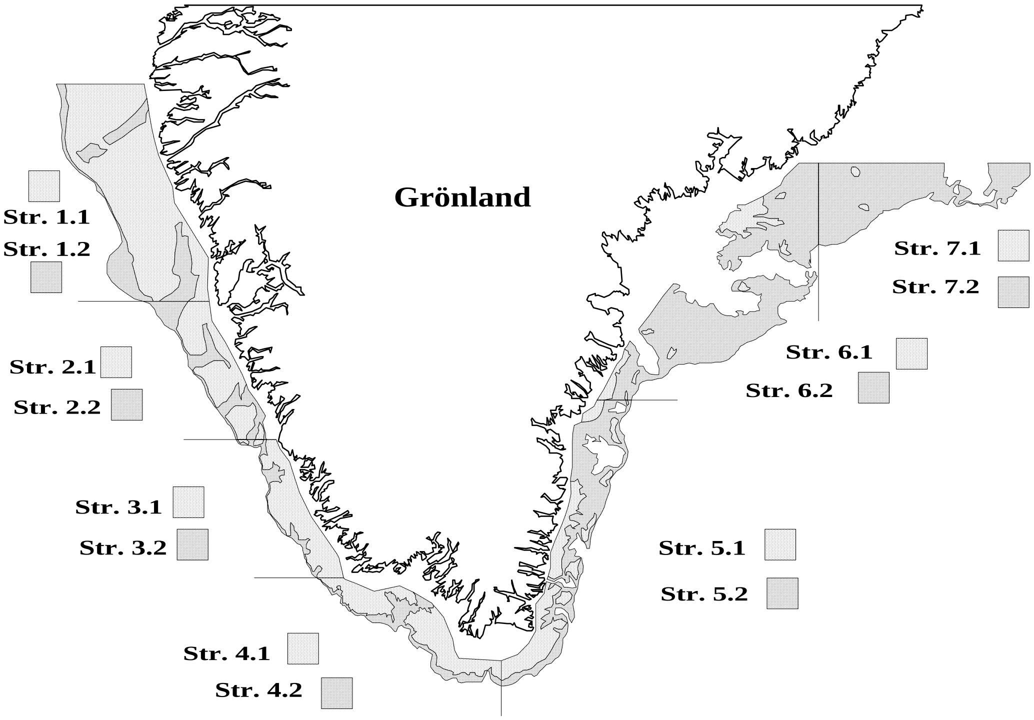


Fig. 1a Area of investigation during WH 305 (2 October – 21 November 2008), and individual survey strata; strata 0-200m: 1.1, 2.1, 3.1, 4.1, 5.1, 6.1 and 7.1, and 200-400m: 1.2, 2.2, 3.2, 4.2, 5.2, 6.2 and 7.2 around Greenland

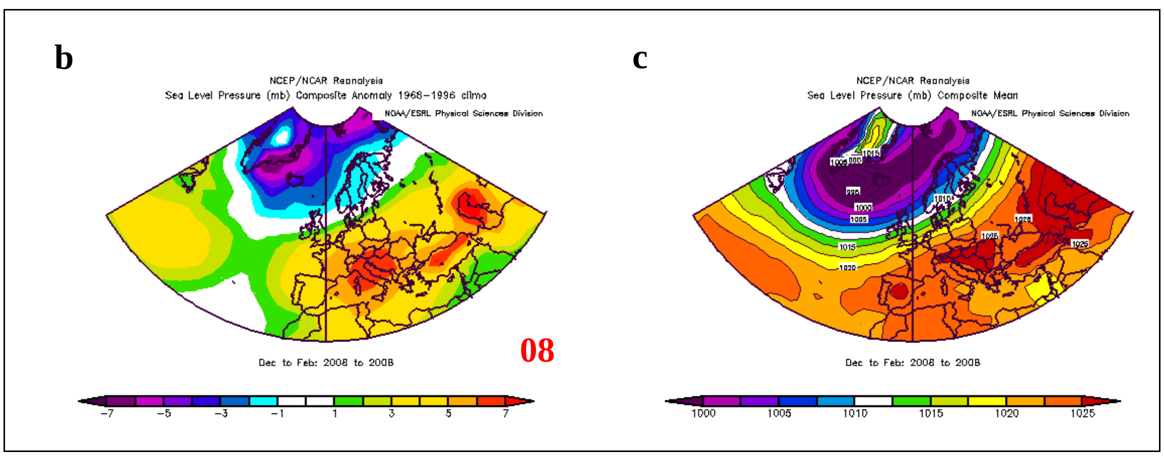
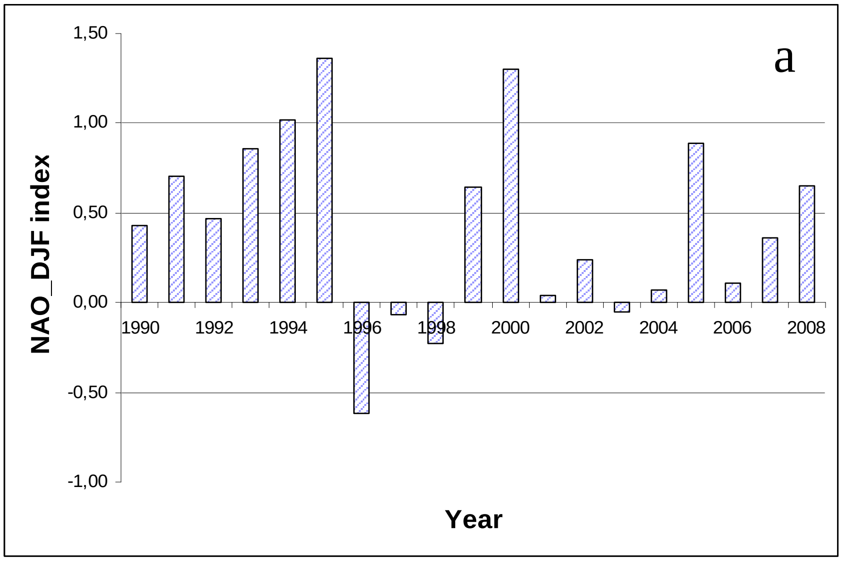


Fig. 1b Pattern of sea level atmospheric pressure anomaly during the winters (December, January, February) of 2007/2008, *red year label denotes positive NAO index.*

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



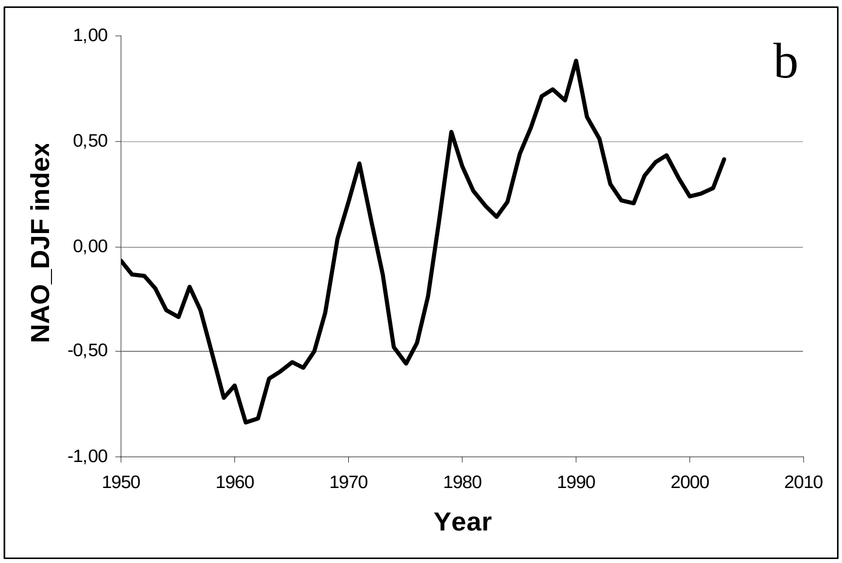


Fig. 2 The winter (DJF) NAO index in terms of the last and present decade (a), and the second half of the last century (lower figure b, a 5 year running mean has been applied)

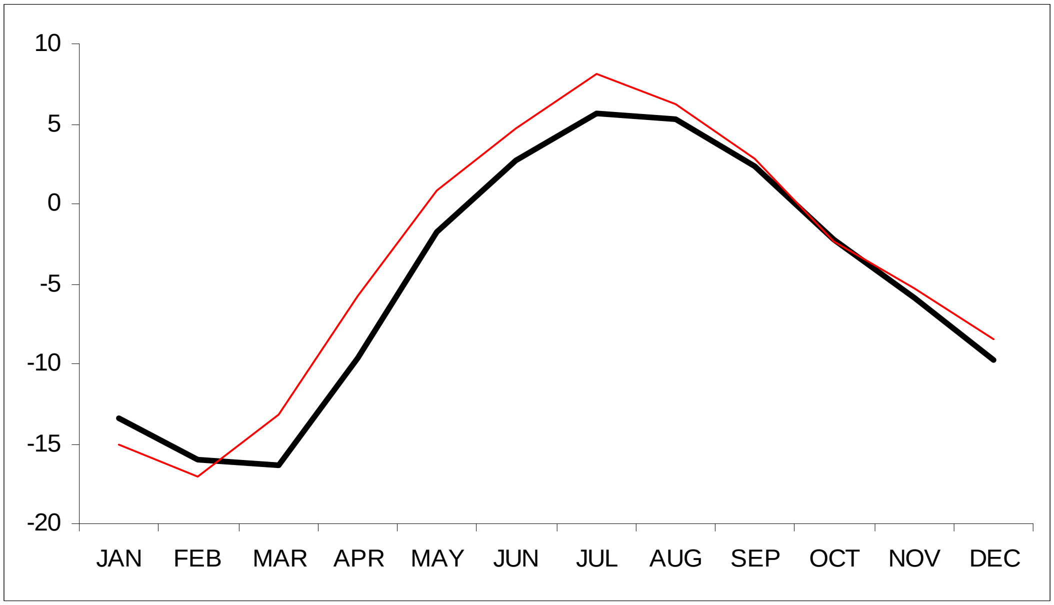


Fig. 3 Monthly mean air temperature [°C] at Egedesminde during 2008 (red, thin line) and climatic mean (1961-1990)

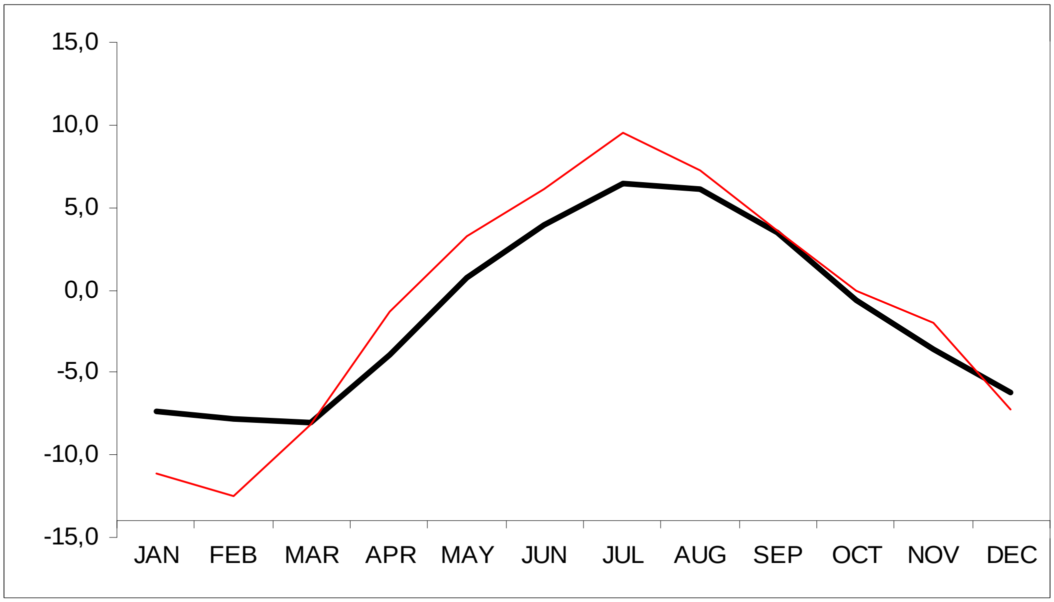


Fig. 4 Monthly mean air temperature [°C] at Nuuk during 2008 (red, thin line) and climatic mean (1961-1990)

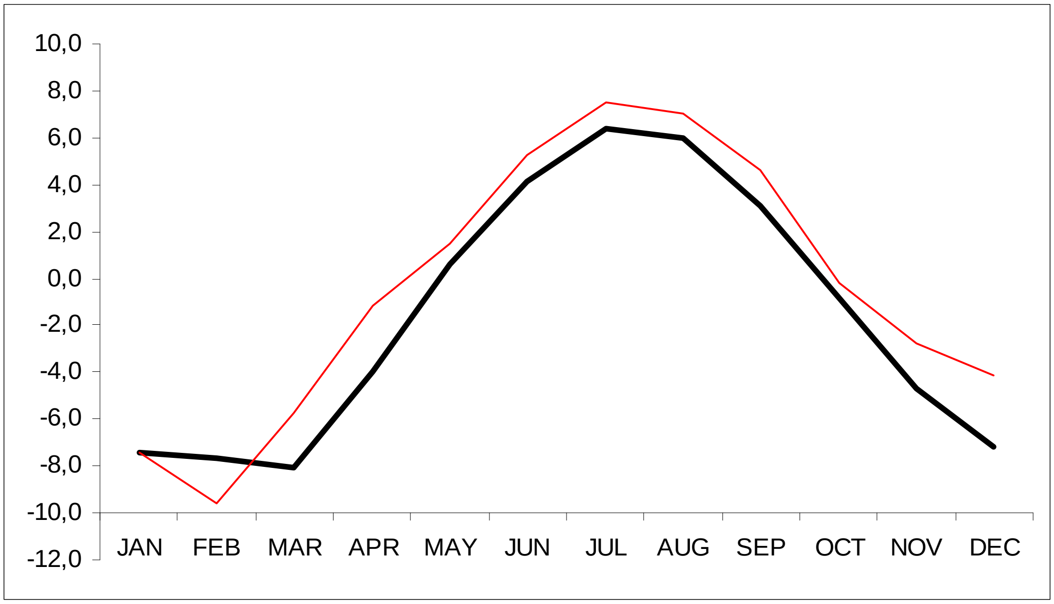


Fig. 5 Monthly mean air temperature [°C] at Angmagssalik during 2008 (red, thin line) and climatic mean (1961-1990)

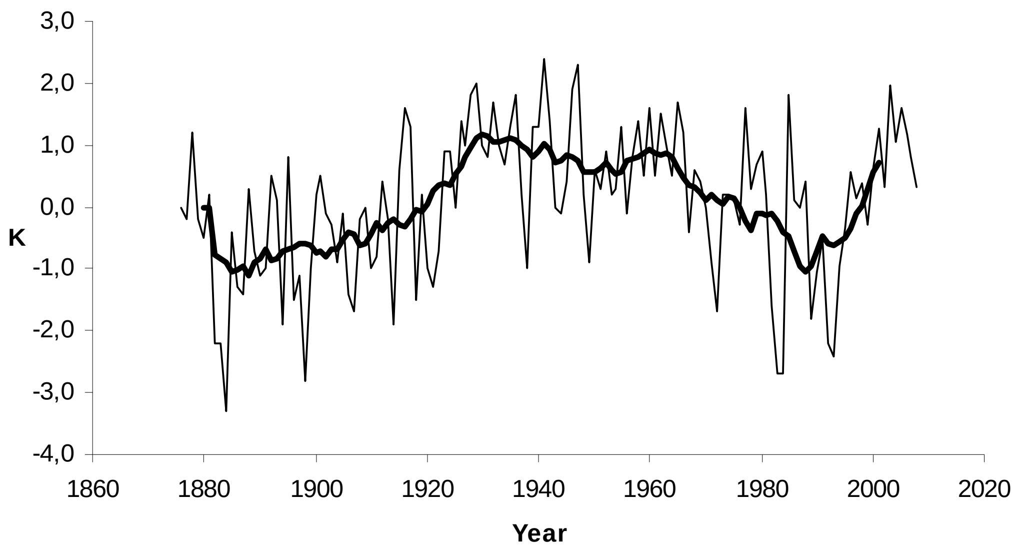


Fig. 6 Time series of annual mean air temperature anomalies at Nuuk (1876-2008, rel. 1961-1990), and 13 year running mean

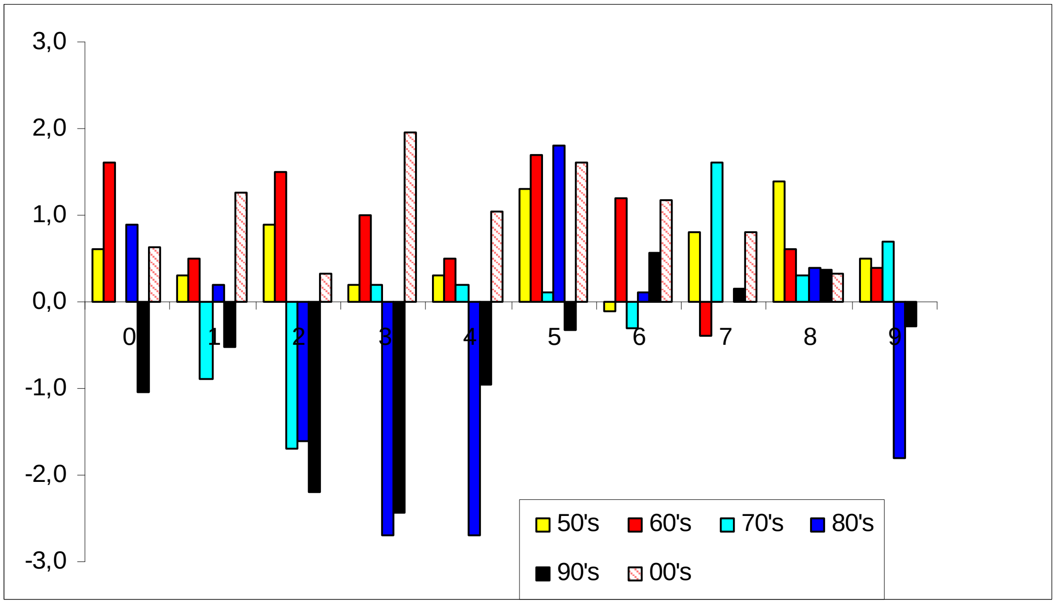


Fig. 7 Composite of decadal air temperature anomalies at Nuuk given relative to the climatic mean of 1961-1990 for the decades of the 1950s - 1990s and 2000s (dashed column)

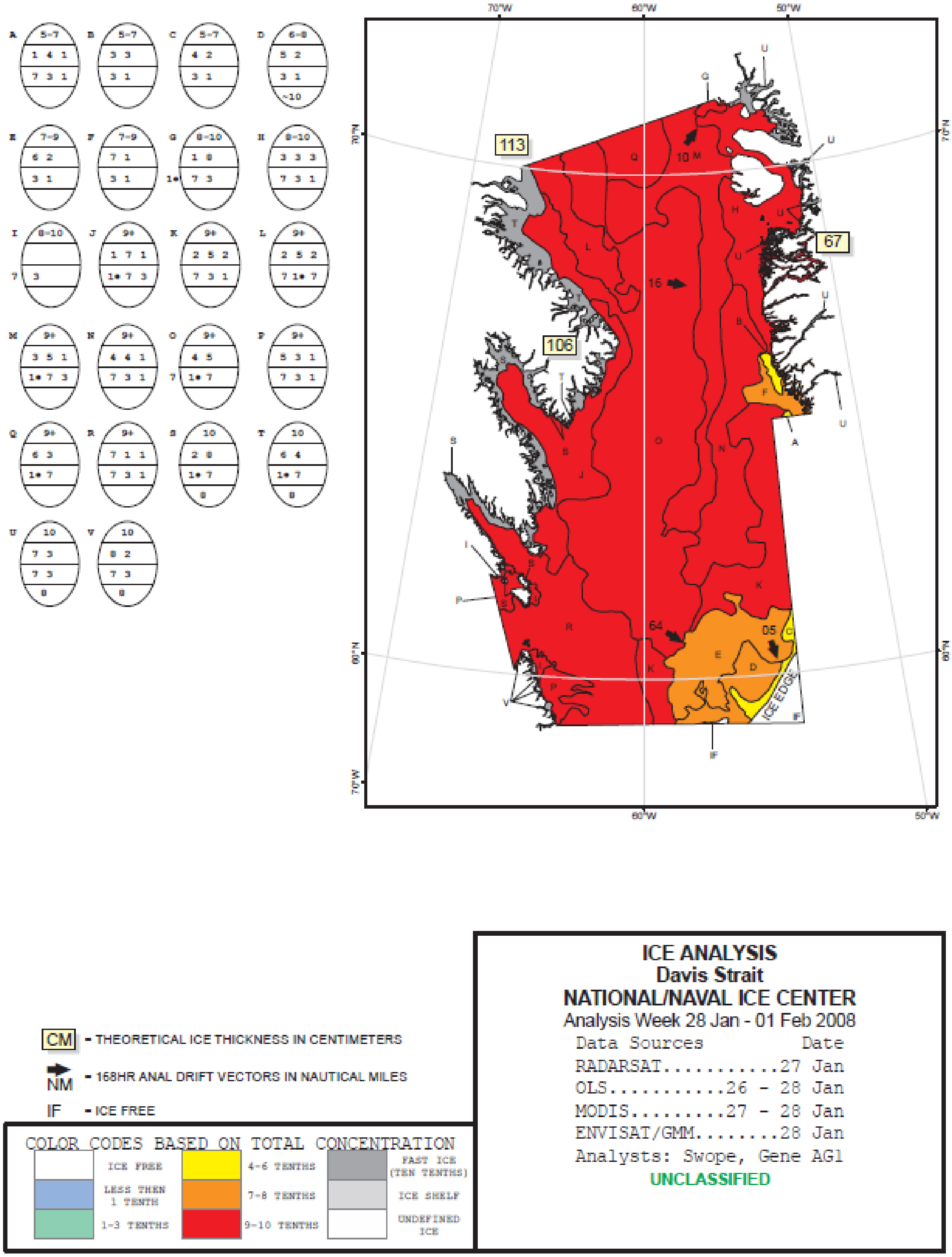


Fig. 8 Ice cover and ice edge during 28 January - 01 February 2008 (Davis Strait)

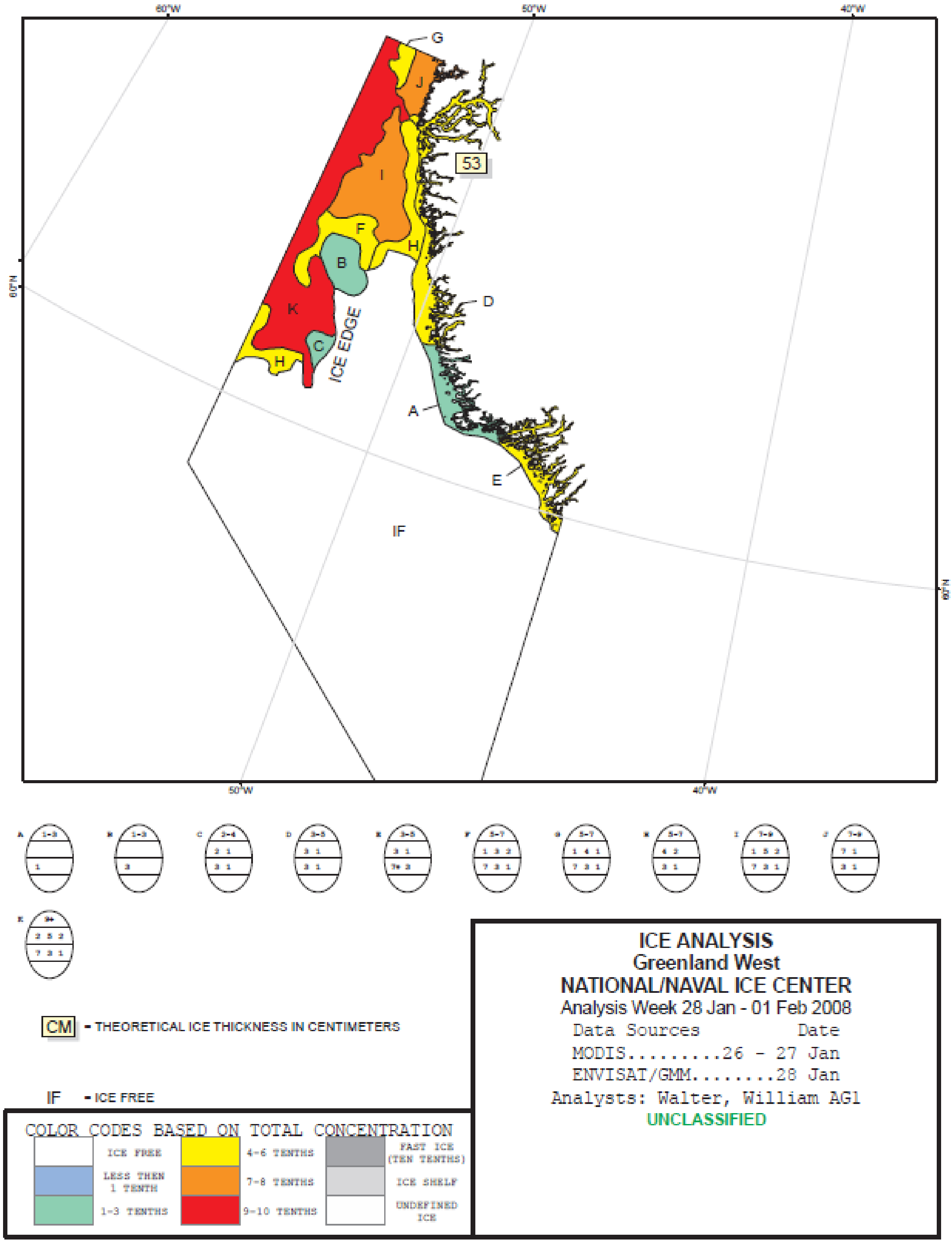


Fig. 9 Ice cover and ice edge during 28 January - 01 February 2008 (Greenland Southwest)

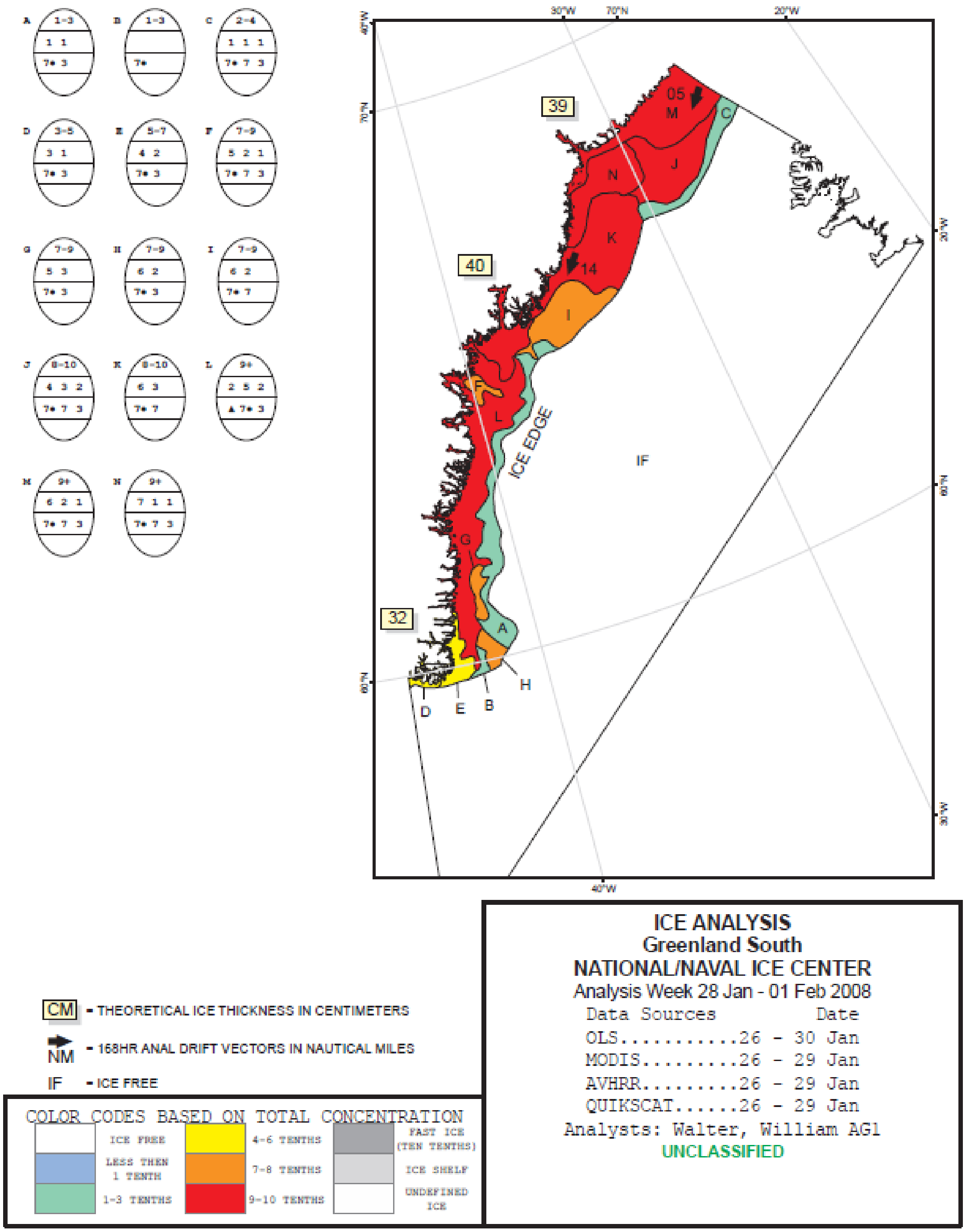


Fig. 10 Ice cover and ice edge during 28 January - 01 February 2008 (Greenland South)

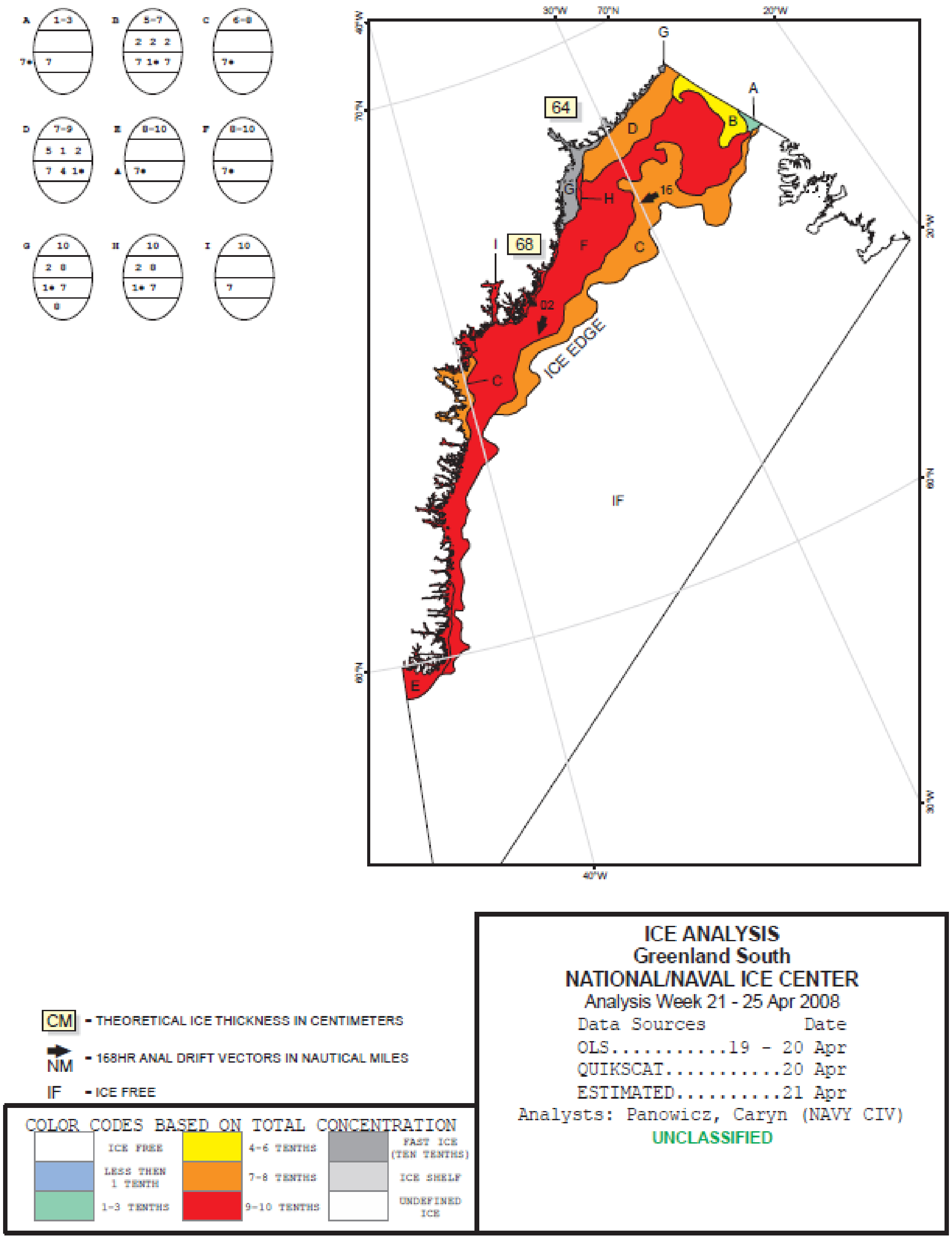


Fig. 11 Ice cover and ice edge during 21 - 25 April 2008 (Greenland South)

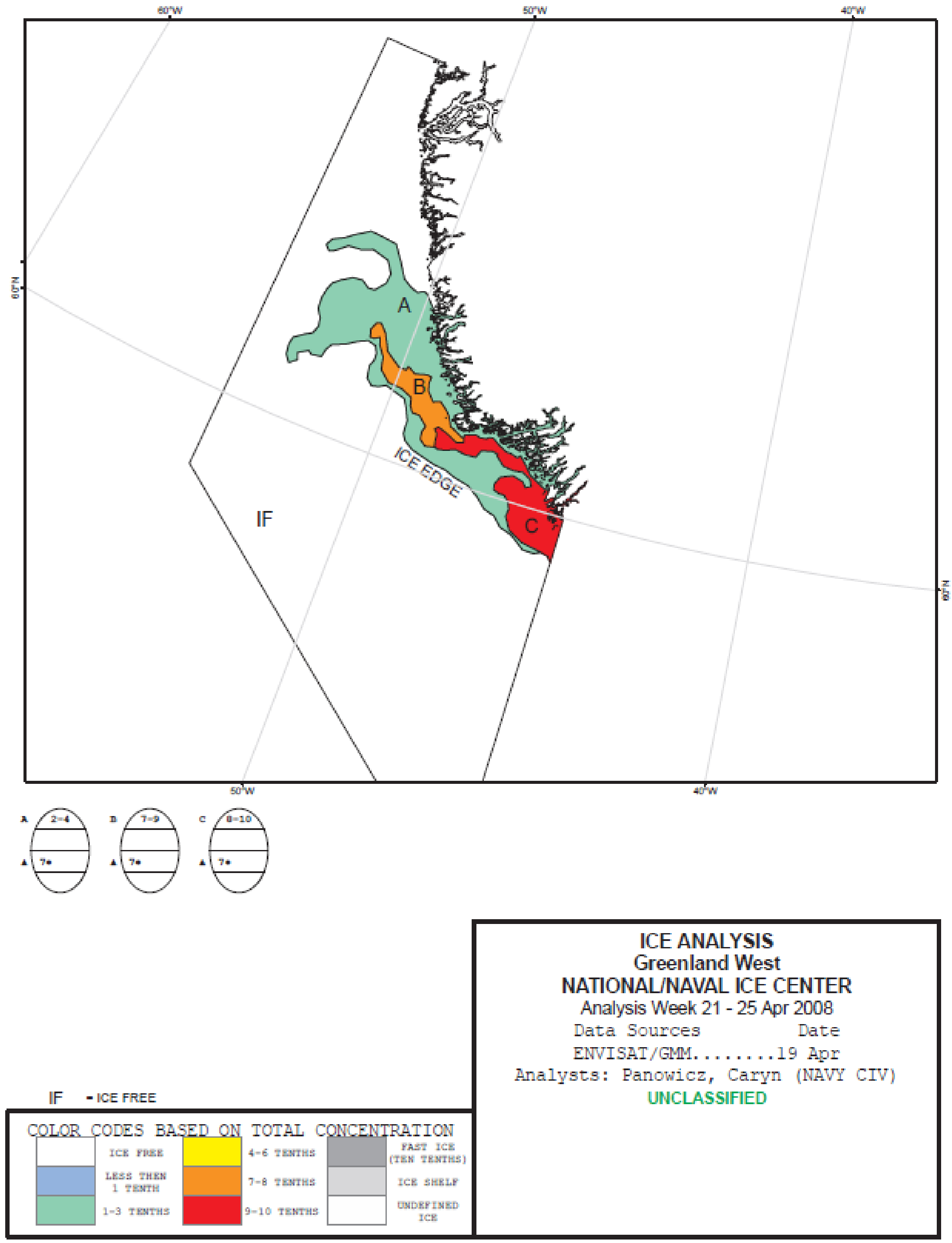


Fig. 12 Ice cover and ice edge during 21 - 25 April 2008 (Greenland Southwest)

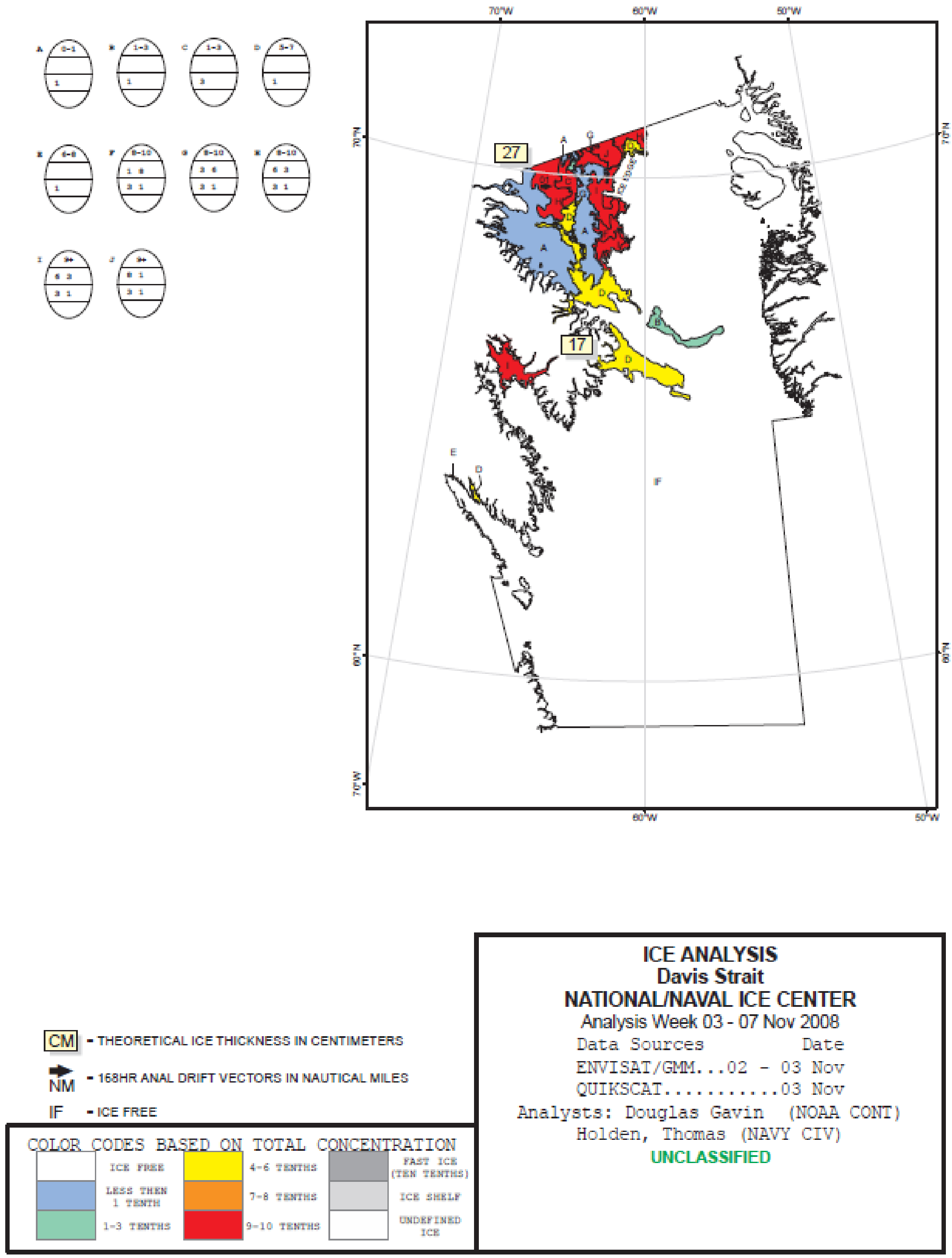


Fig. 13 Ice cover and ice edge during 03 - 07 November 2008 (Davis Strait)

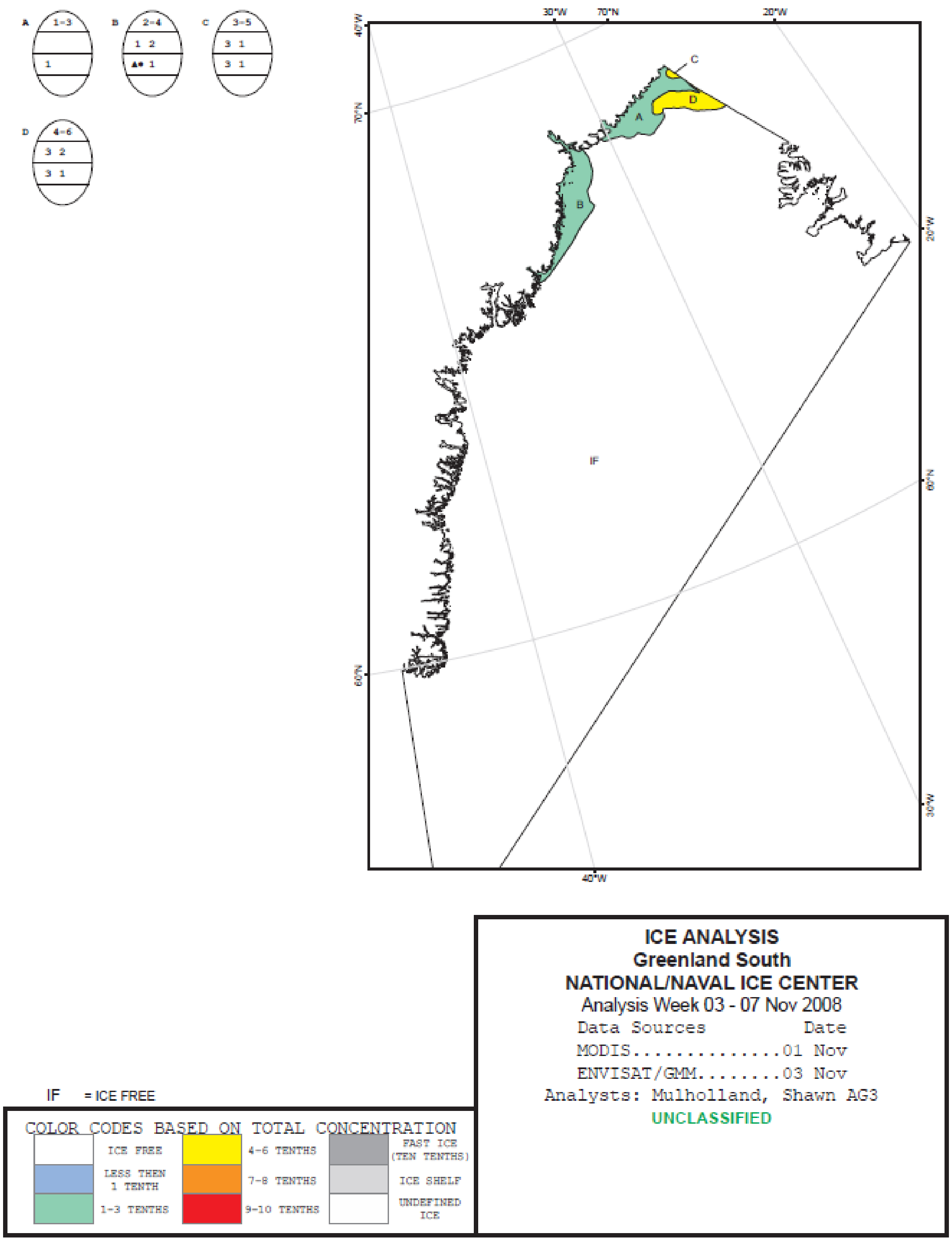


Fig. 14 Ice cover and ice edge during 03 -07 November 2008 (Greenland South)

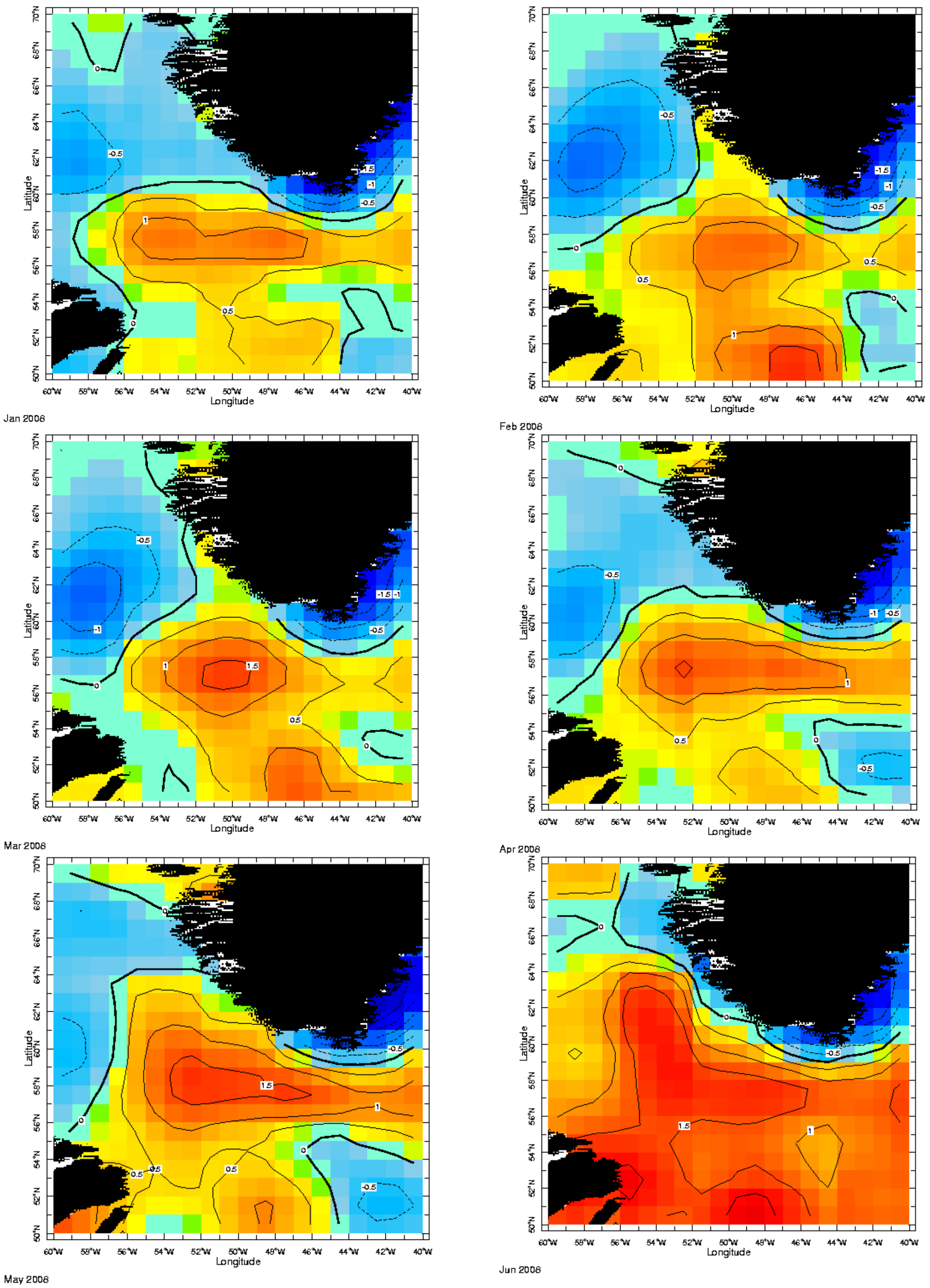


Fig. 15 Sea Surface Temperature Anomalies (K) off Greenland and in the Labrador Sea, January-June 2008

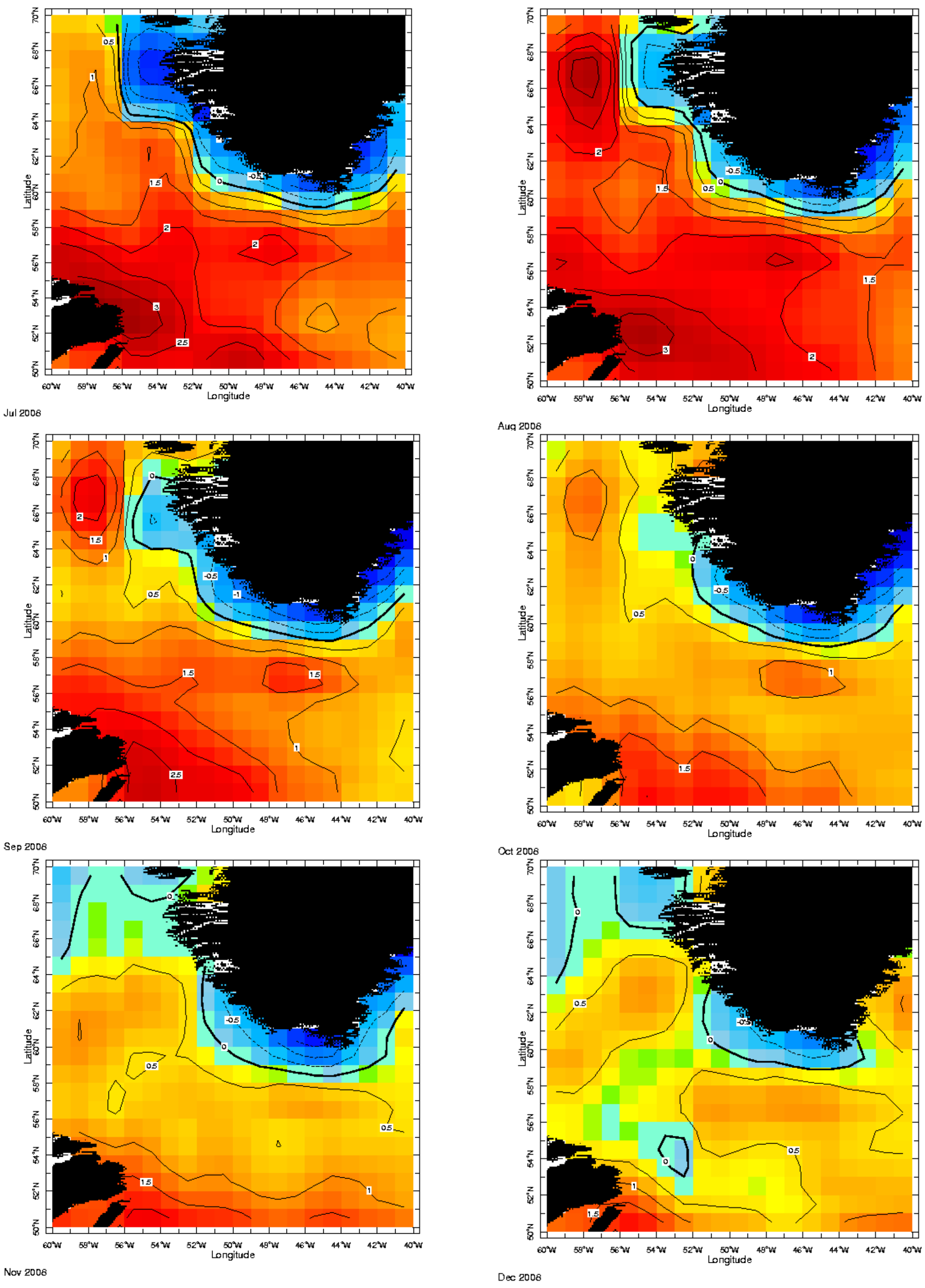


Fig. 16 Sea Surface Temperature Anomalies (K) off Greenland and in the Labrador Sea, July- December 2008

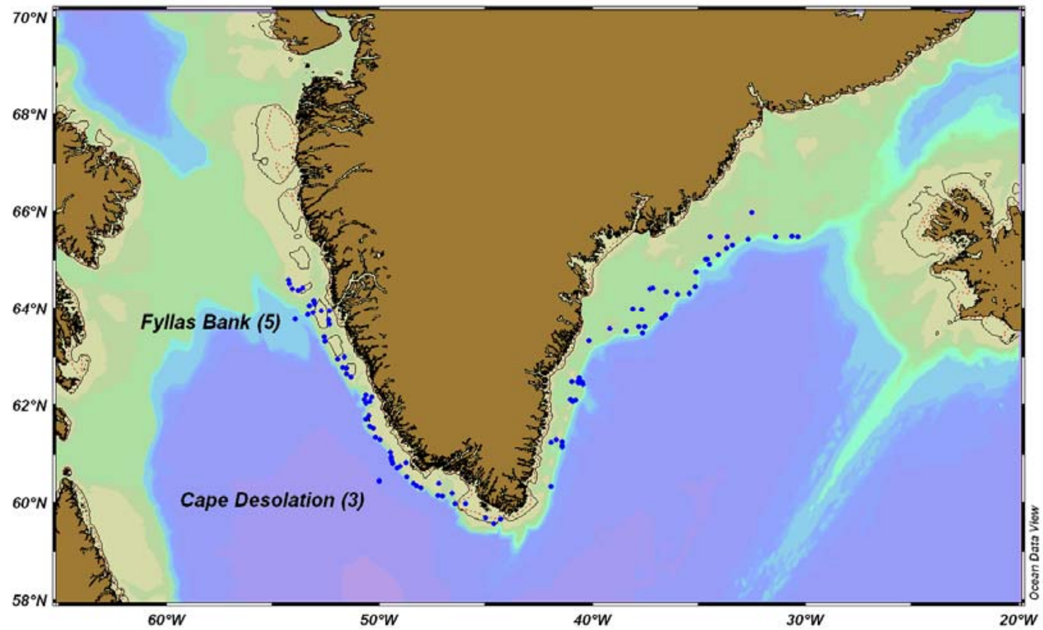


Fig. 17 Positions of fishing stations off East and West Greenland (104) during WH316_2008, sampled NAFO Standard Sections: Fyllas Bank, Cape Desolation; in brackets: No. of stations;

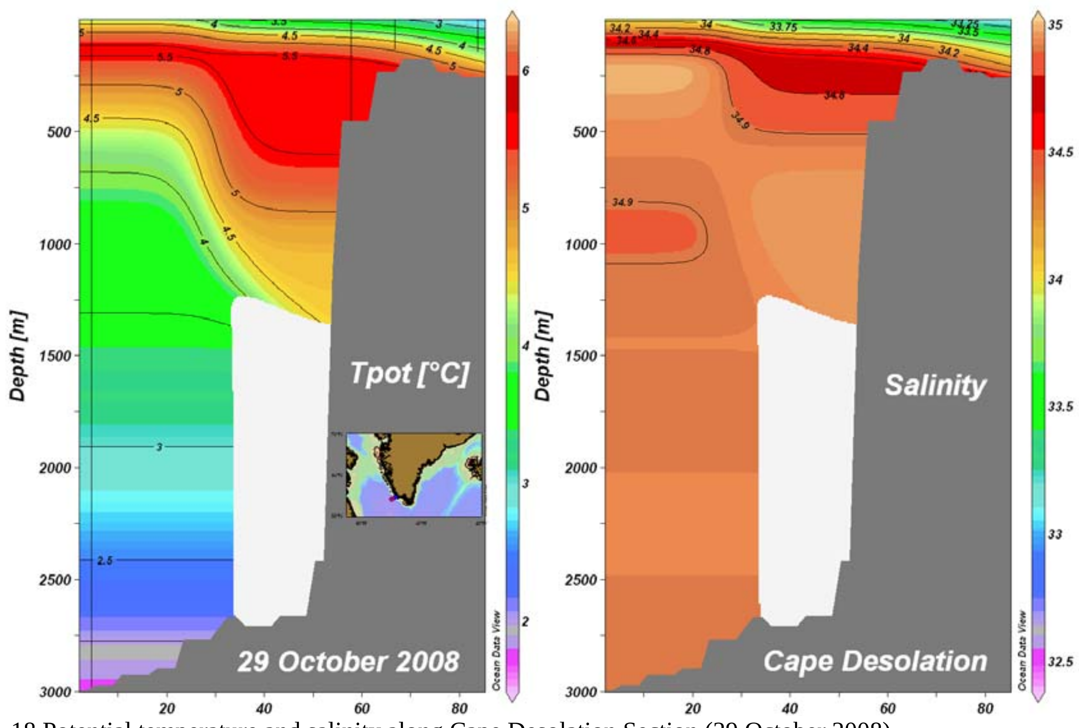


Fig. 18 Potential temperature and salinity along Cape Desolation Section (29 October 2008)

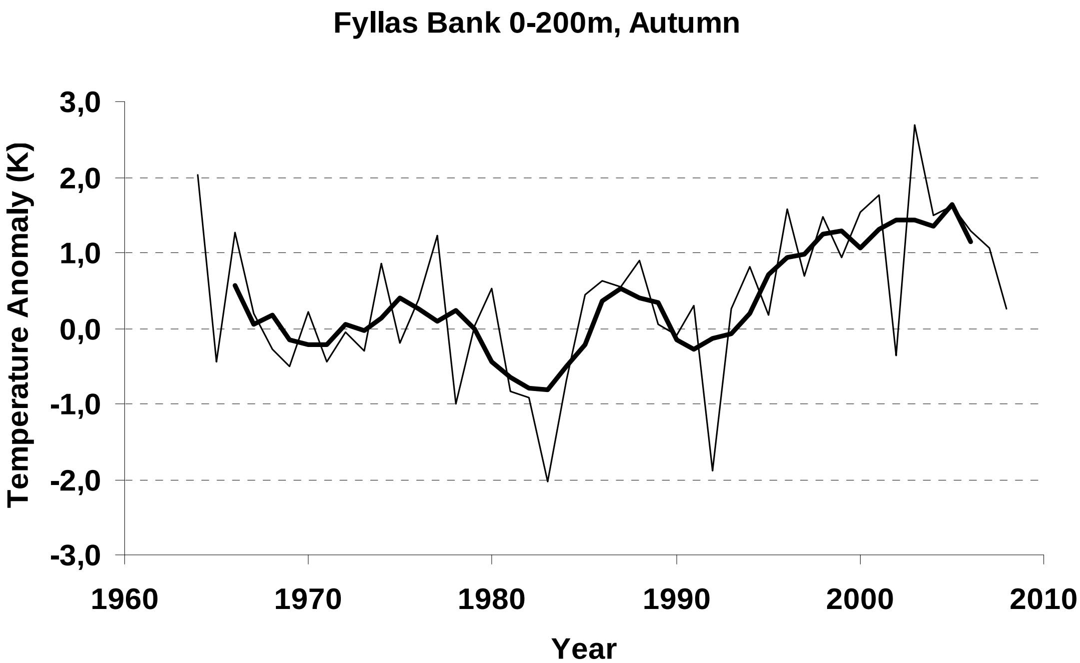


Fig. 19 Mean water temperature anomalies of layer 0-200m at station 4 of the Fyllas Bank Section during autumn; data: 1964-2008 (thin), 5 yr r.m. (bold); (base period: 1964-1990)

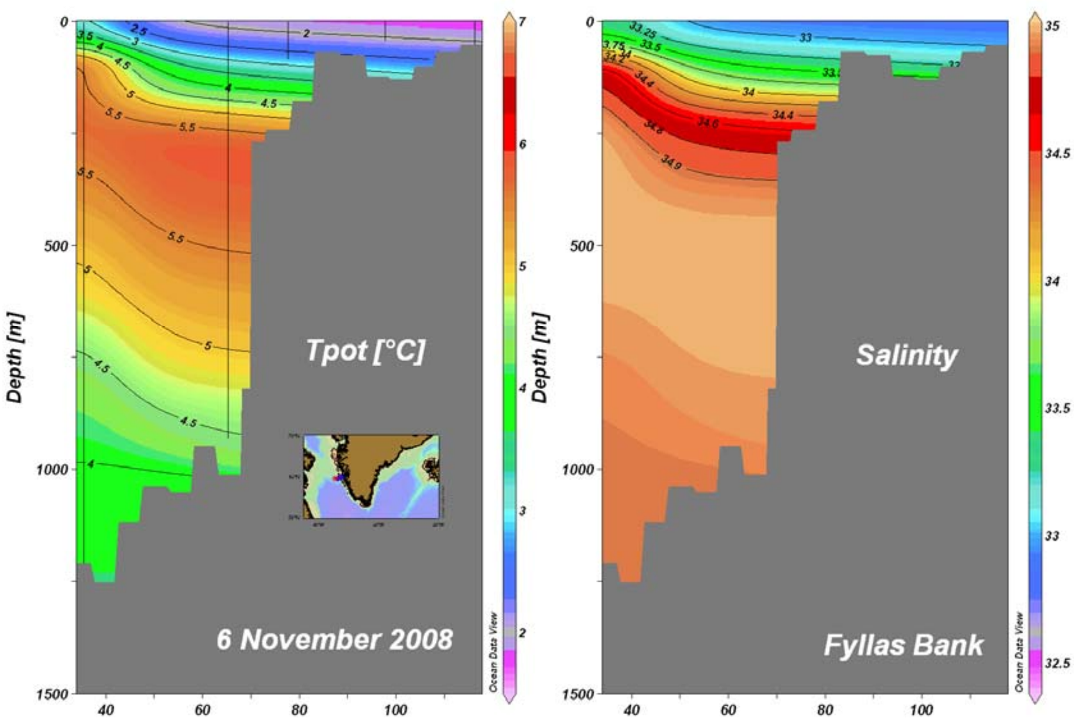


Fig. 20 Potential temperature and salinity along Fyllas Bank Section (1 November 2007)

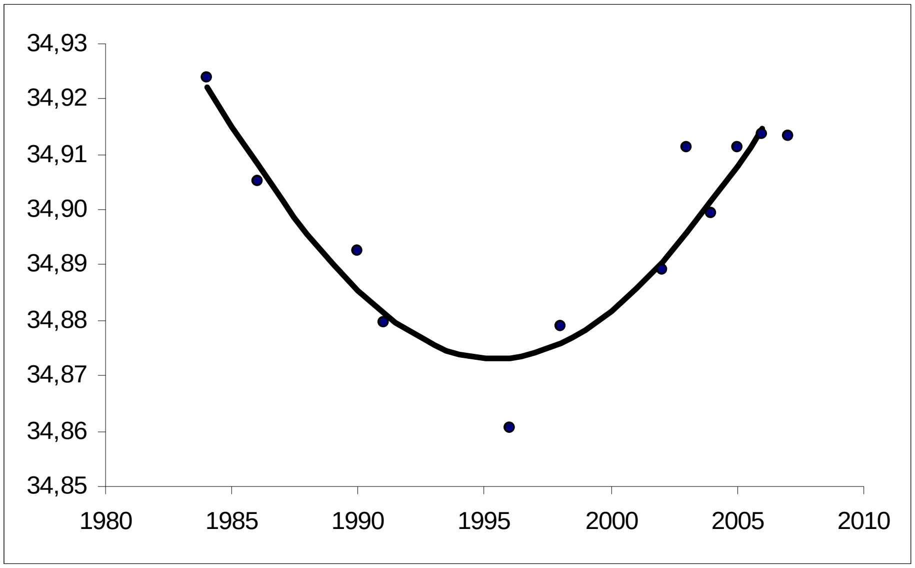


Fig. 21 Salinity of **calibration samples** at Cape Desolation Section station 3, **1500m** depth (60°28'N, 50° 00'W; data: 1984 – 2008; harmonic model adjusted to the data; $r^2 = 0.85$)

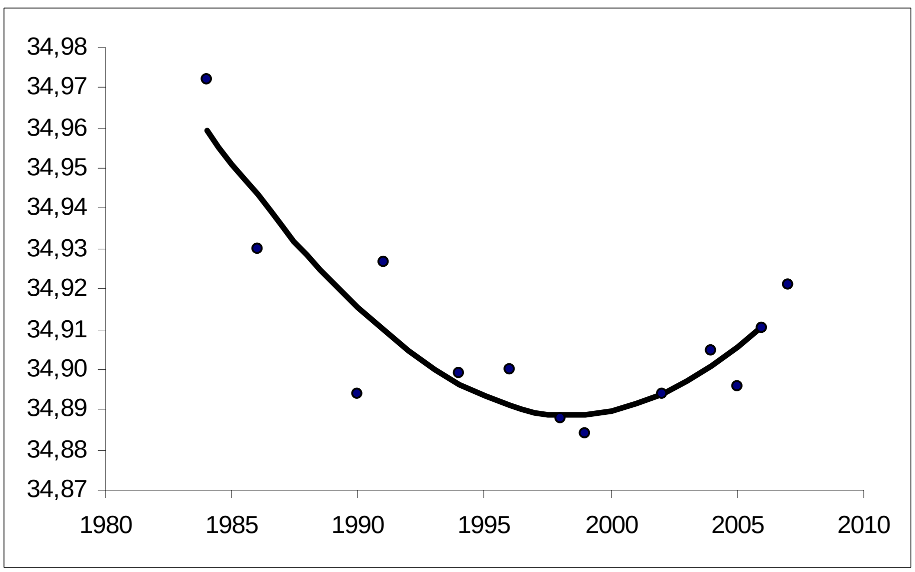


Fig. 22 Salinity of **calibration samples** at Cape Desolation Section station 3, **2000m** depth (60°28'N, 50° 00'W; data: 1984 – 2008; harmonic model adjusted to the data; $r^2 = 0.80$)

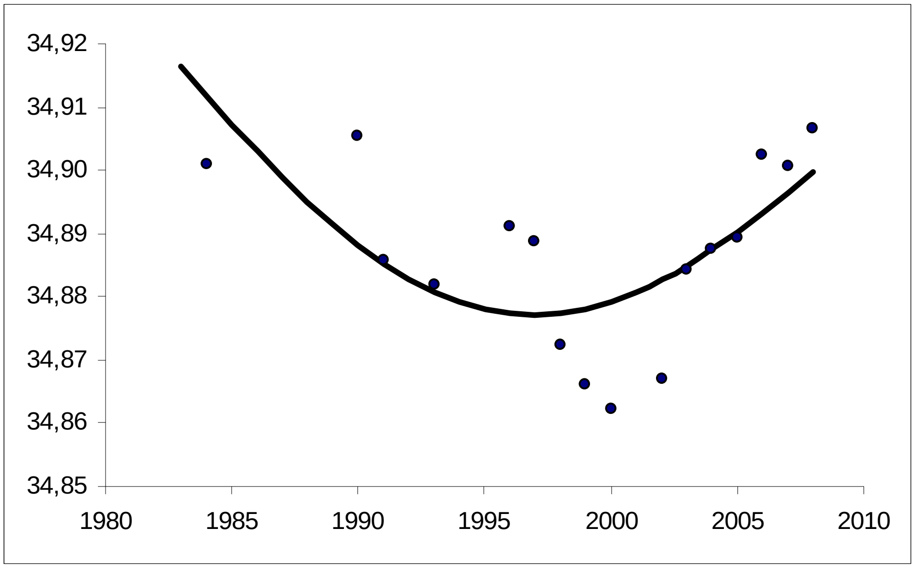


Fig. 23 Salinity of **calibration samples** at Cape Desolation Section station 3, **3000m** depth (60°28'N, 50° 00'W; data: 1984 – 2008; harmonic model adjusted to the data; $r^2 = 0.48$)