NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N6032 **NAFO SCR Doc. 12/008**

SCIENTIFIC COUNCIL MEETING – JUNE 2012

Hydrographic conditions off West Greenland in 2011.

by
A. Akimova and B. Cisewski

Institute of Sea Fisheries (vTI), Palmaille 9
D-22767 Hamburg, Germany
e-mail: anna.akimova@vti.bund.de, boris.cisewski@vti.bund.de

Abstract

Short overview of the atmospheric and hydrographic conditions off West Greenland in autumn 2011 is presented. Large scale atmospheric circulation is described in terms of the North Atlantic Oscillation Index, which was negative in 2011 (-1.57). This led to a positive air temperature anomaly over the study region. Mean air temperature at Nuuk Weather Station was -1.13°C, which shows, after the highest ever reported temperature had occurred in 2010, a decrease towards the temperature level of 2009. The water mass properties are monitored yearly at two standard NAFO/ICES sections, which span across the western shelf and the continental slope of Greenland. Two stations, namely Cape Desolation Station 3 and Fyllas Bank station 4 are historically used to analyze the interannual variability of the oceanic conditions. The uppermost layer of the Cape Desolation Station 3 in 2011 was occupied by relative fresh Surface Polar Water in contrast to the previous two years when no Polar Water was observed there. The water temperature between 100 and 700 m depth was warmer than its long-term mean, and thus continued the series of 'warmer than normal' years started in 1998. Fyllas Bank Station 4 was characterized in 2011 by a negative potential temperature anomaly within the uppermost 50 to 100 m and a positive temperature anomaly between 100 and 700 meter water depth. The salinity of Irminger Sea Water here was slightly above its long term mean.

Introduction

The water circulation pattern off Greenland comprises three main currents: Irminger current, West Greenland and East Greenland currents (Figure 1). The East Greenland current (EGC) transports fresh and cold Surface Polar Water (SPW) to the south along the eastern coast of Greenland. The Irminger current is a branch of the North Atlantic current. It makes a cyclonic loop in the Irminger Sea and transports salty and warm Irminger Sea Water (ISW) southward along the eastern continental slope of Greenland. South of Greenland both currents bifurcate, turn around the southern tip of Greenland and propagate northward along the west coast of Greenland in form of West Greenland current (WGC). The WGC transports water into the Labrador Sea, and hence is important for Labrador Sea Water formation, which is an essential element of the Atlantic Meridional Overturning Circulation (AMOC). Dynamically, this current has a single jet near the shelf break, but it is often divided into two components, based on the water properties (*Pickart et al.*, 2005). The variability of the cold and fresh inshore component is driven by the variability of the SPW and ice transport from the Arctic Ocean, atmospheric heat flux and ice melt (*Holfort et al.*, 2008). The temperature and salinity of the ISW offshore component follows those of the Irminger Current and is subject to variations within the Subpolar Gyre (SPG). During the northward propagation considerable mixing between two water masses takes place and ISW gradually increases its depth (Clarke and Gascard, 1983;

Myers et al., 2009). SPW and ISW components are monitored annually by the Institute of Sea Fisheries from board of R.V. 'Walter Herwig III' and reveals significant variability. Here we report on the atmospheric and hydrographic conditions during the autumn 2011 and put them in context of interannual and long-term variability.

Data

The German Institute of Sea Fisheries carries out autumn ground fish surveys on the western and eastern Greenland shelves since 1963 (*Stein*, 2010). In 2011, totally 91 hydrographic stations were sampled between October 9 and November 22, from R.V. Walther Herwig III (Figure 2). CTD (conductivity-temperature-depth) casts were conducted with a Sea-Bird 911plus profiler attached to a 12-bottle water sampler (www.seabird.com). For in situ calibration, temperatures were measured with reversing thermometers, and salinity samples were analyzed with a Guildline Autosal-8400A salinometer (www.osil.co.uk) immediately after the cruise. The obtained profiles were averaged into 1-m depth bins. If data was missing at the top of a profile, we assumed constant properties from the first measurement (normally 2 to 15 m depth) up to the surface.

The sea level pressure (SLP) and its anomalies during the winter months (December through March) were taken from NCEP/NCAR Reanalysis data available from the NOAA-CIRES Climate Diagnostics Centre (http://www.cdc.noaa.gov/). To describe the pattern of SLP over the North Atlantic we used Hurrell winter North-Atlantic Oscillation index (NAO; available at http://www.cgd.ucar.edu/cas/jhurrell/nao.stat.winter.html), which is based on the principal component (PC) time series of the leading EOF of seasonal (December through March) SLP anomalies over the Atlantic sector (20-80°N, 90W-40°E, *Hurrell*, 1995).

Air temperature at Nuuk station (Table 1) on the western coast of Greenland was used to characterize the atmospheric conditions in 2011. Monthly mean values were obtained from Goddard Institute for Space Studies of National Aeronautics and Space Administration (NASA), accompanied by the data from the Danish Meteorological Institute. The climatological mean of this timeseries were referenced to 1981-2010. Information about sea surface temperature anomalies was provided by NOAA/ESRL Physical Science Division, Boulder, Colorado, based on objective interpolation product (NOAA OI SST, *Reynolds et al.*, 2002).

Results and Discussion

Atmospheric Conditions and sea surface temperature.

The variability of the atmospheric conditions over Greenland and the Labrador Sea is driven by the large scale atmospheric circulation over the North Atlantic, which is normally described in terms of NAO. During positive NAO phase, strong northwest winds bring cold air from the North American continent and cause negative anomalies of air temperatures over Greenland, Labrador Sea, Baffin Bay (*Hurrell and Deser*, 2010). During negative NAO phase the westerlies slacken and the weather is normally milder over the whole region.

In 2011 the NAO index was negative (-1.57) (Figure 3). While the circulation cell reveals no shift in comparison with its long-term mean location (Figure 4), the Greenland High was stronger and the Icelandic Low pressure zone was weaker than the long-term mean, respectively. The mean air temperature at Nuuk Weather Station in West Greenland was -1.13°C in 2011 (Figure 5), which shows, after the highest ever reported temperature had occurred in 2010, a strong decrease towards the temperature level of 2009. The monthly temperatures were slightly higher than the corresponding long-term means during the summer 2011 and slightly lower in the winter months, respectively (Figure 6).

Following positive anomalies of the air temperature, the annual mean sea surface temperature for 2011 was higher than normal in Northwestern Atlantic and around Greenland (Figure 7). Negative anomalies were observed only along the eastern coast of Greenland and associated with the East Greenland current.

Water mass properties off West Greenland.

Two standard NAFO/ICES sections across the western shelf and the slope of Greenland are used to describe water mass properties in this region (Figure 2, Table 1). The first one, the Cape Desolation section, is situated 300 km northwest from the southern tip of Greenland. At this section the strong surface front separates

PSW on the shelf from ISW offshore (Figure 8). In autumn, the temperature of the upper layer is well above zero (Θ_{Min} = 0.89°C) due to the summer heat accumulation, and hence only the salinity can be used as a tracer of the SPW. A salinity of less than 32 was observed at station 874 (Figure 8). The most offshore station in 2011 (Station 872) corresponds to the standard Cape Desolation Station 3, which was reported to NAFO since 2001 (Stein, 2010). In 2011 the uppermost layer of this station consists of Surface Polar Water (SPW) in contrast to the previous two years when no SPW was apparent (Figure 9). Despite of a thin layer of negative temperature anomalies between 250 and 350 m, the water temperature was in most parts between 100 and 700 depth warmer than its long-term mean, and thus continued the series of 'warmer than normal' years started in 1998. While the salinity of the SPW layer was well below its long-term level, the warming of the ISW layer and the increase of its salinity further proceeded in 2011. Whether these processes exert a control on slowing down the Subpolar Gyre is still under debate (*Häkkinen and Rhines*, 2004; *Hátún et al.*, 2005; *Hátún et al.*, 2009)

The Fyllas Bank section (Figure 2, Table 1) is situated further to the north over the broad shallow Fyllas Bank that affects strongly the structure of the West Greenland Current (Myers et al., 2009). Fresh PSW was seen in top 100 m over the entire section (Figure 10) and it spread at least 100 km away from the shelf (Figure 10). In 2011, the core of ISW (θ >5 °C, S>34.9) was found between 300 and 450 m water depth at the station 906 (not shown). The Station 906 at the continental slope at 900 m depth corresponds to standard Fyllas Bank Station 4 (e.g. *Stein*, 2002; *Stein*, 2004). Similar to Cape Desolation Station 3, year 2011 can be characterized by a negative potential temperature anomaly within the uppermost 50 to 100 m and a positive temperature anomaly between 100 and 700 meter water depth. The salinity of ISW was slightly above its long term mean (Figure 11).

Acknowledgements

Authors would like to thank the ‚crew of RV "Walther Herwig 3", scientific group of Institute of Sea Fisheries and particular Dr. Heino Fock for gathering the data and presenting them during NAFO SC 2012 in Halifax, Canada.

References

Clarke, R. A., and J. C. Gascard (1983), The Formation of Labrador Sea Water. Part I: Large-Scale Processes, *J. Phys. Oceanogr.*, *13*, 1764–1778.

Häkkinen, S., and P. B. Rhines (2004), Decline of Subpolar North Atlantic Circulation During the 1990s, *Science*, *304*, 555-559.

Hátún, H., A. B. Sandø, H. Drange, B. Hansen, and H. Valdimarsson (2005), Influence of the Atlantic Subpolar Gyre on the Thermohaline Circulation, *Science*, *Vol. 309*, 1841-1844.

Hátún, H., M. R. Payne, G. Beaugrand, P. C. Reid, P. C. Sandø, H. Drange, B. Hansen, B. Jacobsen, and D. Bloch (2009), Large bio-geographical shifts in the north-eastern Atlantic Ocean: From the subpolar gyre, via plankton, to blue whiting and pilot whales, *Progress In Oceanography*, *80*(3-4), 149-162.

Holfort, J., E. Hansen, S. Østerhus, S. Dye, S. Jonsson, J. Meincke, J. Mortensen, and M. Meredith (2008), Freshwater fluxes east of Greenland, in *Arctic-Subarctic Ocean Fluxes*, edited by J. M. R. R. Dickson, and P. Rhines, pp. pp. 263– 288, Springer, New York.

Hurrell (1995), NAO Index Data provided by the Climate Analysis Section, edited, NCAR, Boulder, USA.

Hurrell, J. W., and C. Deser (2010), North Atlantic climate variability: The role of the North Atlantic Oscillation, *Journal of Marine Systems*, *79*(3-4), 231-244.

Myers, P. G., N. Kulan, and M. H. Ribergaard (2007), Irminger Water variability in the West Greenland Current, *Geophys. Res. Lett.*, *34*, L17601.

Myers, P. G., D. Chris, and M. H. Ribergaard (2009), Structure and variability of the West Greenland Current in Summer derived from 6 repeat standard sections, *Progress In Oceanography*, *80*(1-2), 93-112.

Pickart, R. S., T. D. J., and F. P. (2005), The East Greenland Spill Jet, *J. Phy. Oceanogr.*, *35*, 1037-1053.

Reynolds, R. W., N. A. Rayner, T. M. Smith, D. C. Stokes, and W. Wang (2002), An improved in situ and satellite SST analysis for climate, *Journal of Climate*, *15*, 1609-1625.

Stein, M. (2002), Area 1 - West Greenland*Rep.*, 7 pp, ICES Status Reports, 2001/2002 Annual ICES Ocean Climate Status Summary.

Stein, M. (2004), Climatic conditions off West Greenland - 2003 (Area 1)*Rep. 269*, 13-14 pp, The 2003/2004 ICES Annual Ocean Climate Status Summary. ICES Cooperative Research Report.

Stein, M. (2010), The oceanographic work of the Institute of Sea Fisheries in Greenland Waters, 1952-2008, *Journal of Applied Ichthyology*, *26*(C1), 19-31.

Table 1. Details on the times series, analysed in this study. Lat is used for the latitude, long is used for longitude.

Name	Lat (°N)	Lon (°W)	Type
Nuuk	64.36	-51.75	Weather station
Cape Desolation Station 3	60.45	-50.00	Oceanographic station
Fyllas Bank Station 4	63.88	-53.37	Oceanographic station

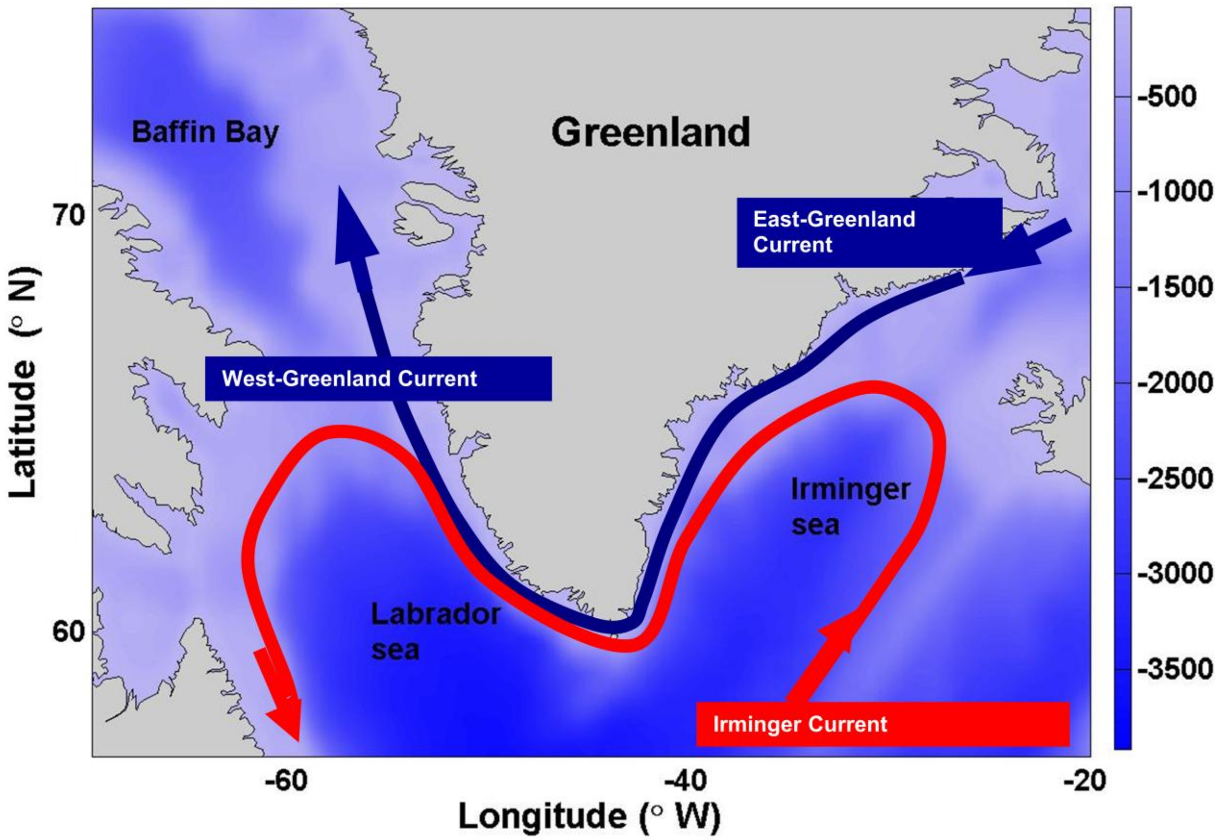


Figure 1. Scheme of the upper ocean circulation in the area of research. Red and blue curves show the trajectories of Irminger Sea Water and Surface Polar Water correspondingly.

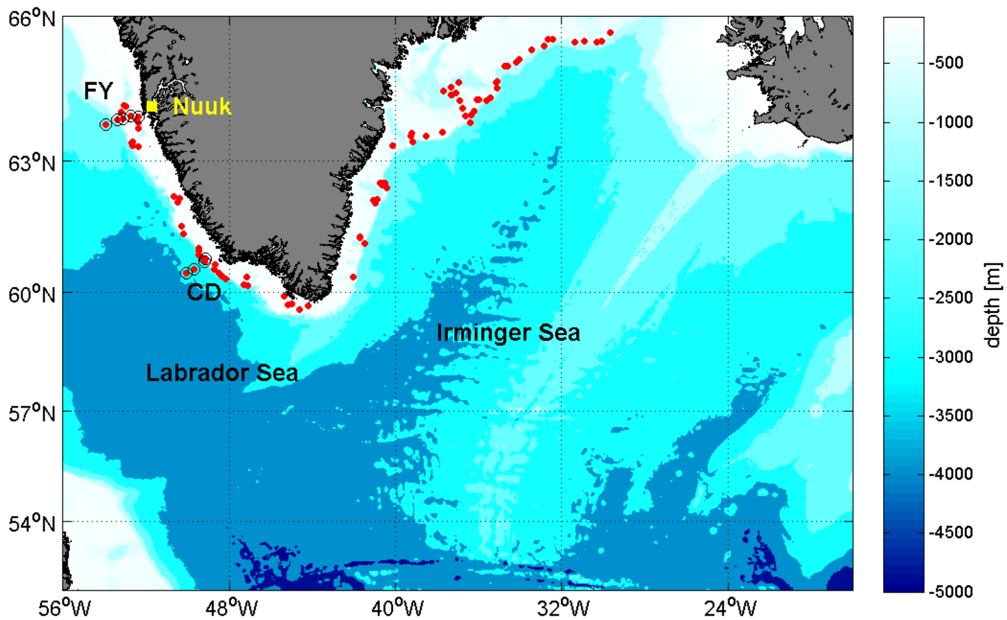


Figure 2. Map and bathymetry of the study region. Meteorological station location is shown in yellow. Red dots show the location of the fisheries stations, conducted during the survey in 2011. Gray edged dots show the two ICES/NAFO standard sections (CD – Cape Desolation section, FY – Fyllas Bank Section; geographic coordinates are given in table 1).

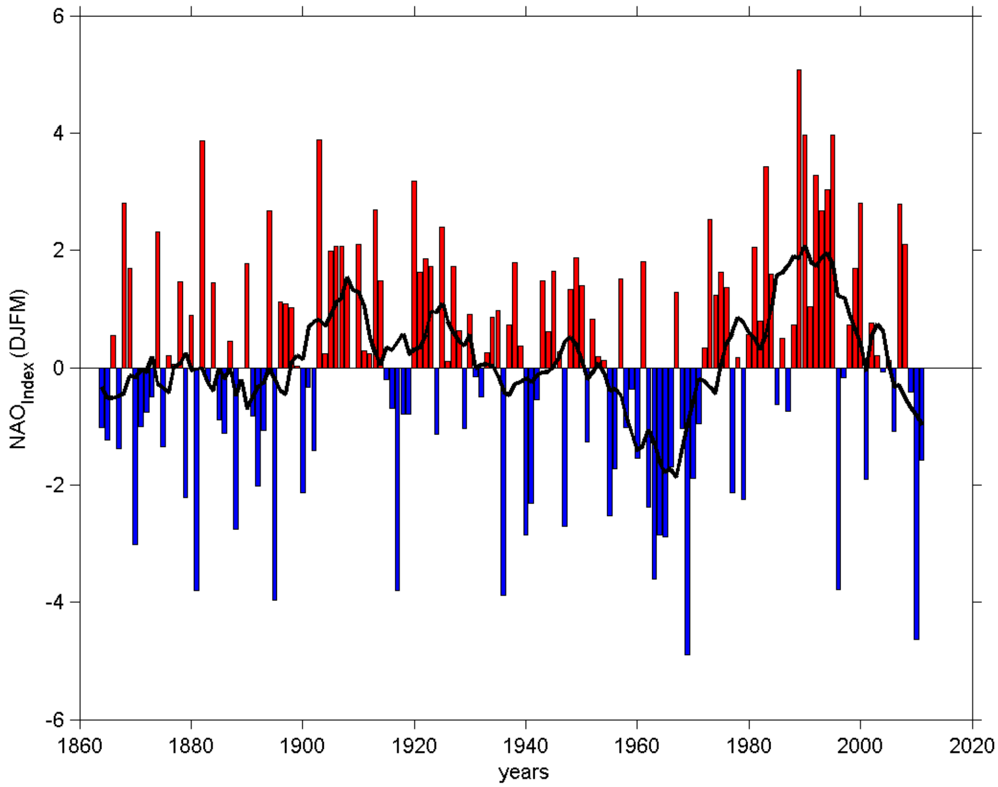
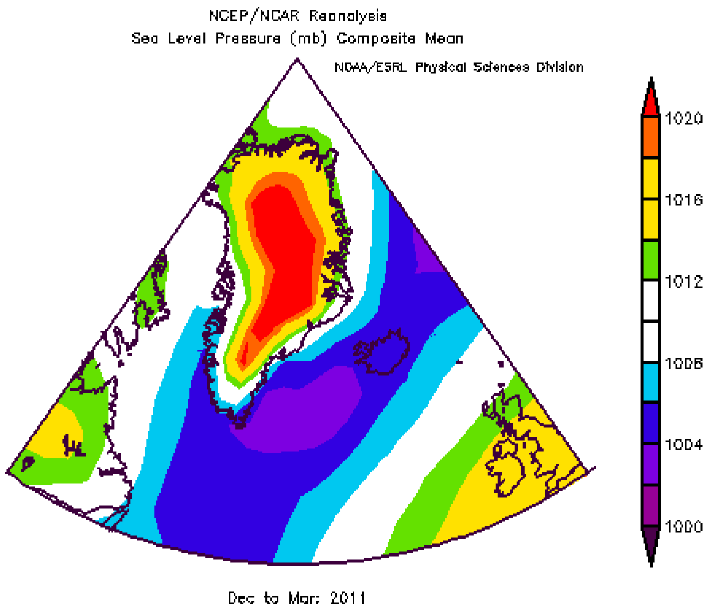


Figure 3. The Hurrell winter (DJFM) NAO index with a 5-year running mean (black curve). Data source: http://www.cgd.ucar.edu/cas/jhurrell/nao.stat.winter.html.



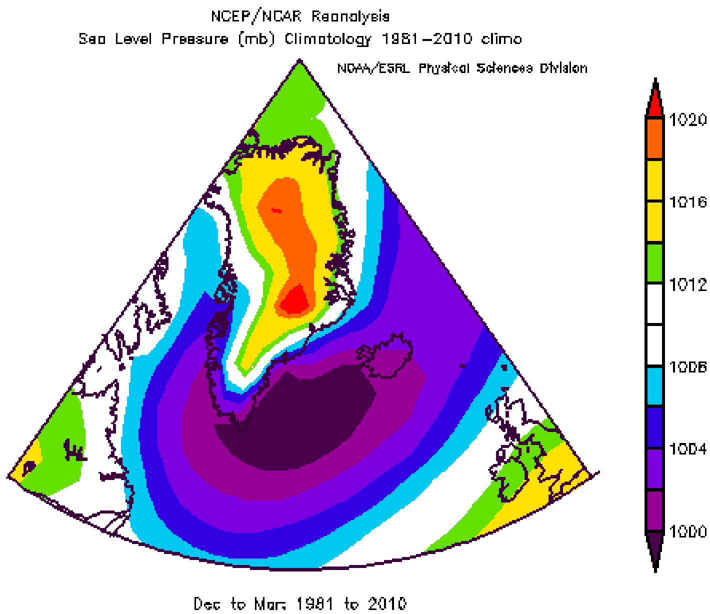


Figure 4. Sea level pressure in winter (December through March) 2011 and long-term (1981 to 2010) mean sea level pressure, as derived from NCEP/NCAR reanalyzes.

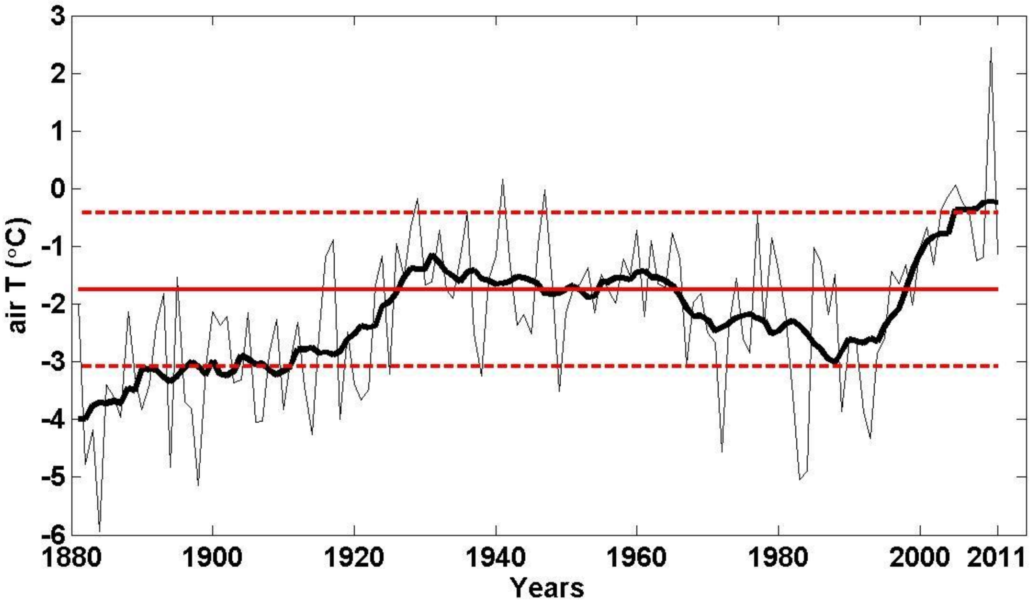


Figure 5. Annual mean air temperature at Nuuk station. Thick black line shows the 5-year smoothed data. Red solid line indicates the long-term mean temperature, referenced to 1981-2010. Dashed red lines mark corresponding standard deviations.

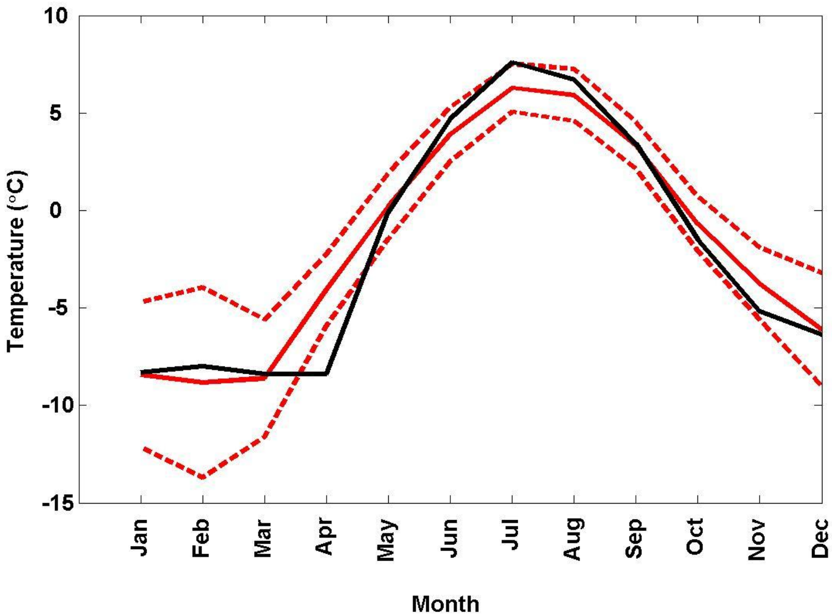


Figure 6. Monthly mean temperature at Nuuk station. Monthly mean temperature in 2011 (black line), long-term monthly mean temperature (red solid line) and one standard deviation (red dashed lines) are shown. Reference period is 1981 to 2010.

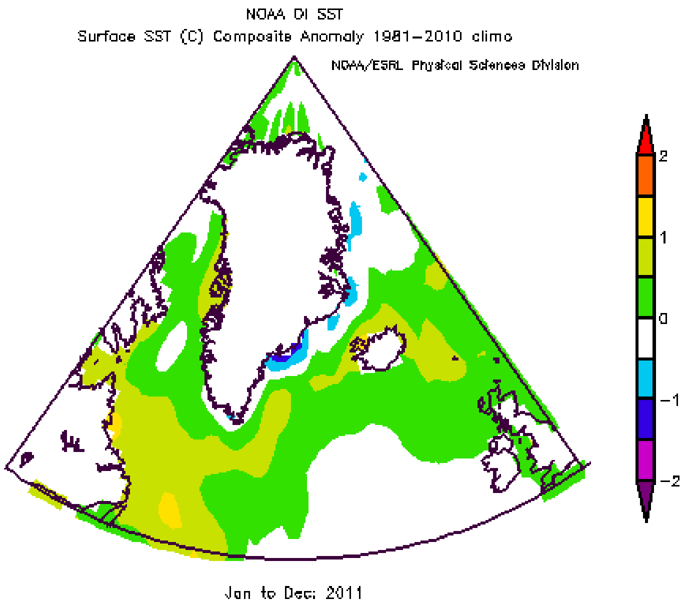


Figure 7. Map of 2011 annual sea surface temperature (NOAA OI SST) anomalies in the study region. The long-term mean corresponds to 1981-2010. Image is provided by the NOAA/ESRL Physical Science Division, Boulder, Colorado

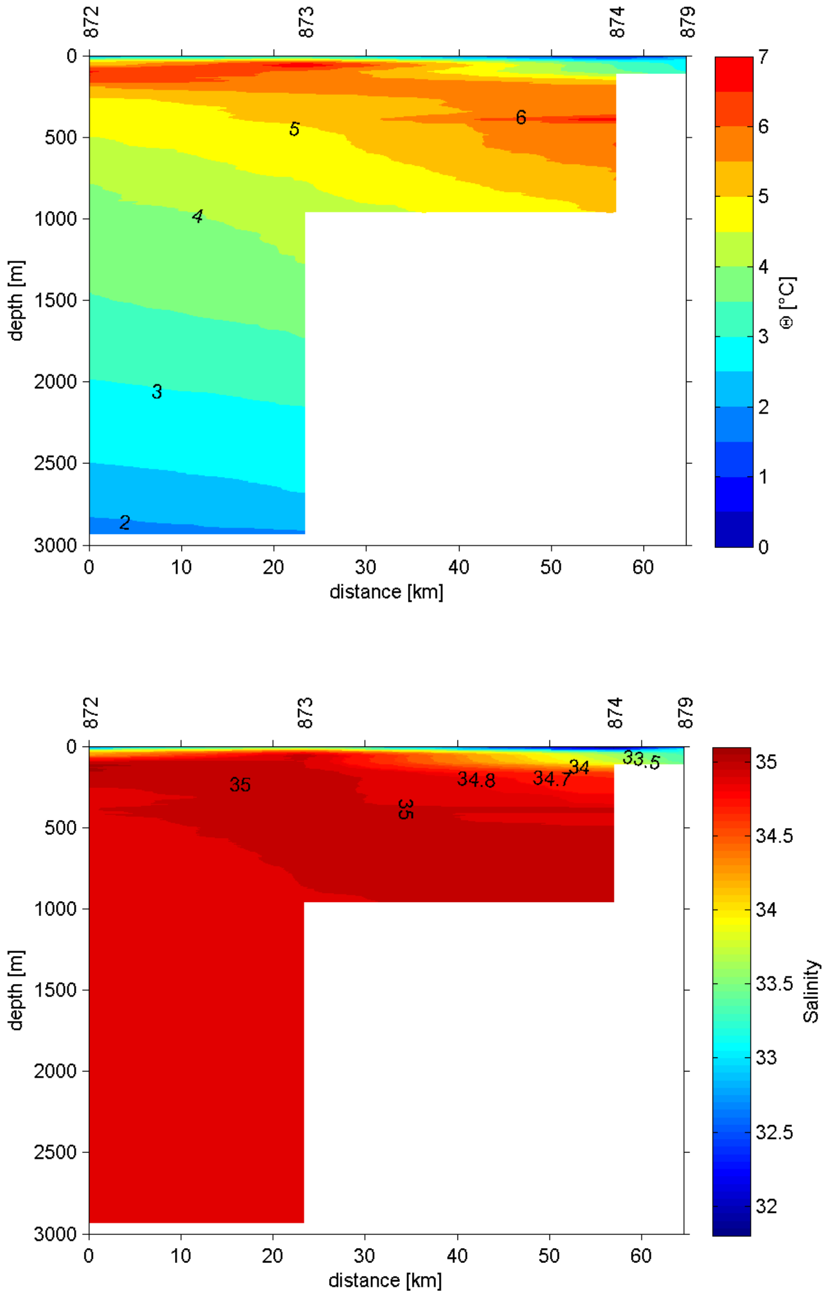


Figure 8. Vertical distribution of potential temperature (upper panel) and salinity (lower panel) along the Cape Desolation section in 2011.

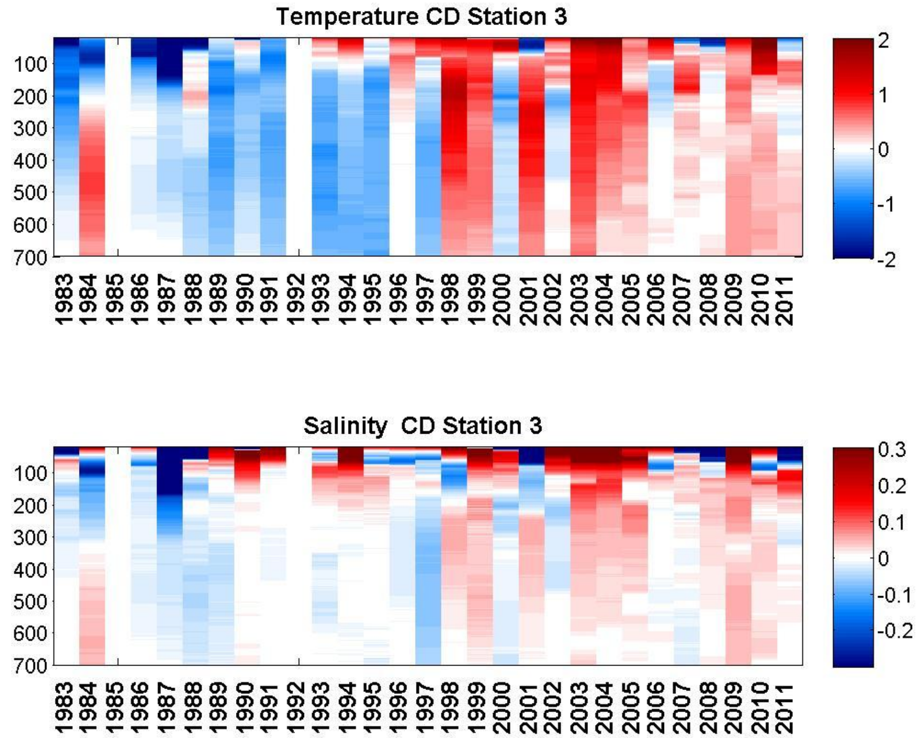
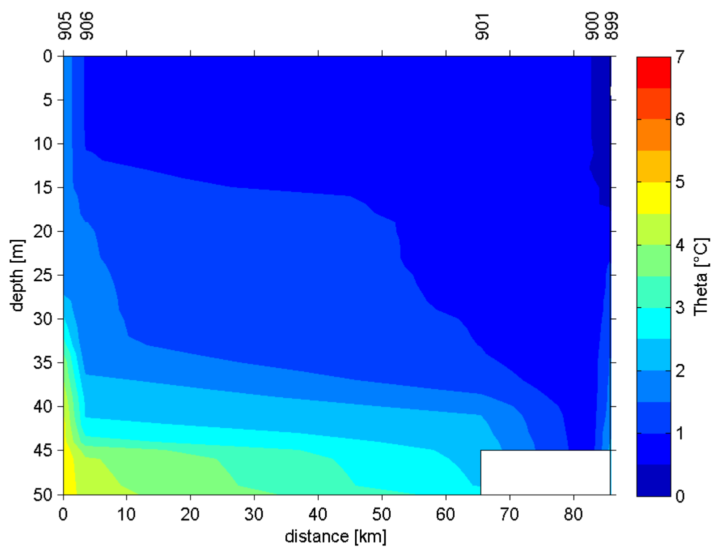


Figure 9. Hovmoeller diagram of the potential temperature anomalies (upper panel) and salinity anomalies (lower panel) in the upper 700 m at Cape Desolation Station 3. Reference period is 1983-2011.



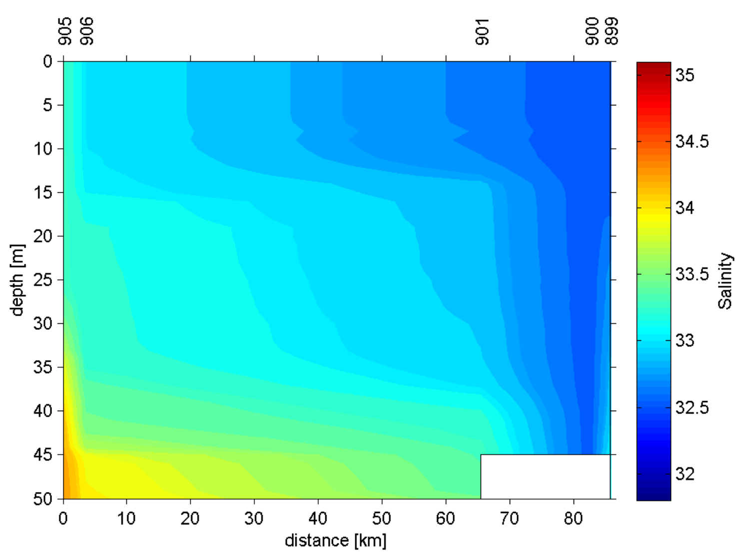
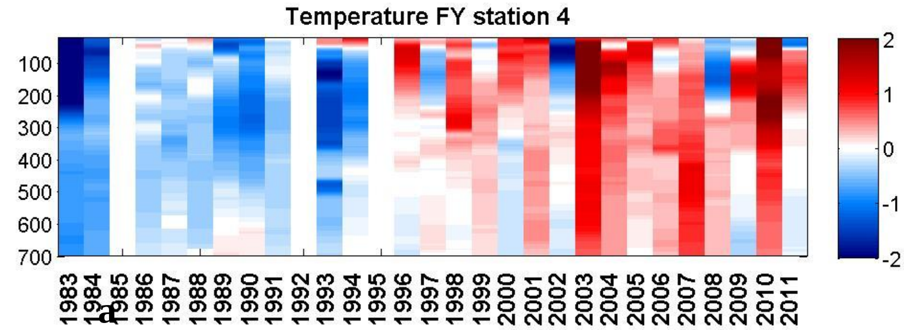


Figure 10. Vertical distribution of potential temperature (upper panel) and salinity (lower panel) along Fyllas Bank section in 2011. The upper 50 m are shown.



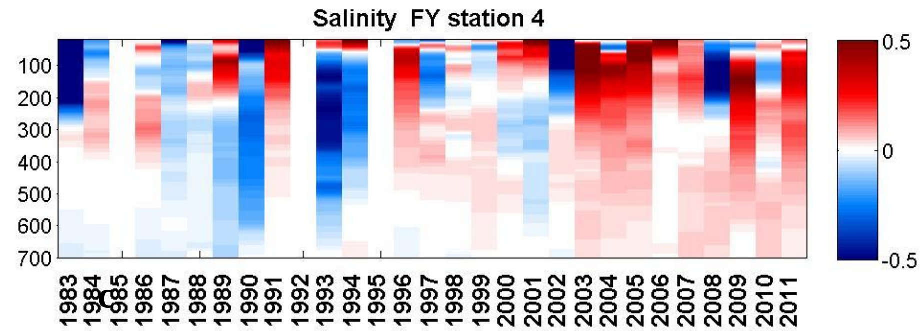


Figure 11. Hovmoeller diagram of the potential temperature anomalies (upper panel) and salinity anomalies (lower panel) in the upper 700 m at Fyllas Bank Station 4. Reference period is 1983-2011.