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Variation of Climatic Indices Around Greenland During 1991-2000

by

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Abstract

Based on climatology data as provided by the Climate Diagnostics Centre of NOAA, and on air temperature data measured at Greenland coastal stations Egedesminde, Nuuk and Angmagssalik the variability of the atmospheric climate is outlined for the decade of the 1990s. Oceanographic data on sea surface temperature anomalies, sub-surface measurements of temperature and salinity, and a water mass analysis elucidate the variability in the ocean off West Greenland during the last decade.

Atmospheric as well as oceanographic data indicate significant warming which took place during the second part of the decade, in particular during the last two years. Concurrent with this observed warming, Irminger Water travelled further north along the West Greenland slope region during the later years of the decade. In autumn 1999 this water mass was found as far north as Lille Hellefiske Bank (65°06'N).

The assumption that Greenland normally experiences warm conditions when the NAO index is negative, works if we consider the first half of the 1990s. For the remainder of the decade, however, in particular for the years 1999 and 2000, this assumption does not fit .

Keywords: NAO index, water masses, temperature, salinity, ice, wind

Introduction

Monitoring environmental data leads after a considerable time of systematic sampling to understanding environmental variability. Following this philosophy, meteorologists arrived at time-series of e.g. air temperatures, which cover periods of more than 100 years, after starting observations in the middle of the 19^{th} century. Oceanographers have followed long time-series of data collection at Oceanographic Standard Stations, where measurements were performed at the same position, during the same season of the year.

NAFO through its Standing Committee on Fisheries and Environment (STACFEN) encouraged research scientists to continue sampling of oceanographic data whenever there is research activity in the NAFO Convention Area. This led to the existence of some really long-term time-series of NAFO Oceanographic Standard Stations (**Stein, 1988**).

Following **Latif (1998)**, the climate system exhibits considerable natural variability on time scales of the order of decades. Decadal climate variability is an important issue for three reasons:

- A better understanding of the mechanisms generating decadal climate variability might open the possibility to make predictions at decadal time scales.
- The detection of anthropogenic climate change requires information about natural variability to separate the anthropogenic signal from the natural background noise.

- Long-term changes in the climate state might influence short-term climate fluctuations. A better knowledge of the slowly evolving background state can improve the prediction of the faster climate variations substantially.

After completion of the decade of the 1990s the author of this contribution feels that it is timely to collate some results on environmental changes around Greenland, which outline the relevant changes during the past decade.

Data and Methods

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. Sea surface temperature anomaly data for the region between Greenland and Labrador were taken from the IGOSS Data Base http://ingrid.ldgo.columbia.edu/SOURCES/.IGOSS .

To assess the annual climatic variation in certain key-areas, boxes were formed which cover areas of Standard Sections off West Greenland, as well as areas off East Greenland (Fig. 1: Lille Hellefiske Bank 65N-66N, 56W-53W; Fylla Bank 63N-64N, 54W-52W; Cape Desolation 60N-61N, 50W-48W; Tordenskjoeld Bank 61.5N-62.5N, 42W-40W; Angmagssalik 65N-66N, 38W-37W). Data on air temperatures, wind and ice for these boxes around Greenland were extracted from the Climate Diagnostics Centre (CDC) of NOAA.

http://sgi62.wwb.noaa.gov:8080/cgi-bin/disp_mf_cdas.sh . Monthly mean air temperatures as downloaded for these boxes were reduced to annual mean temperature time series to better compare climatic data with adjacing station data time-series.

Observations on Standard Oceanographic Stations (**Stein, 1988**) were done at the Cape Desolation Section, the Frederikshaab Bank Section, the Fyllas Bank Section, the Lille Hellefiske Bank Section, and the Holsteinsborg Section (Fig. 28). Salinity readings of the CTD profiles were adjusted to water samples derived by Rosette water sampler. Water mass analysis was done using the “patch” option in Ocean Data View (Version 5.4) for Irminger Water (4°C < Theta < 6°C, 34.95 < S < 35.1) (Fig. 28).

The NAO Index as given in Fig. 29 refers to the mean December, January, February (DJF) Sea Level Pressure (SLP) from the Azores (Ponta Delgada) and from Iceland (Akureyri). The individual SLP's are standardized to 1961-90 base period, and calculated using

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

DJF pressures for 1998/99, 1999/2000 and 2000/2001 for Ponta Delgada were defined by regression (**Stein, 2000**).

Results

Air temperatures

During the decade of the 1990s there is significant increase of mean annual air temperatures at the coastal stations Egedesminde and Angmagssalik (Fig. 2 and 4). The upward trend as given in Fig. 3 for the Nuuk time series is **not** significant. The West Greenland sites indicate 1993 as the coldest year during the decade. 1998 is warmest at Egedesminde, 1996 at Nuuk. Angmagssalik air temperature time series reveals a completely different shape compared to the West Greenland stations. 1996 is the warmest year during the decade.

The climatology of the West Greenland boxes Lille Hellefiske Bank (Fig. 5), Fylla Bank (Fig. 6) and Cape Desolation (Fig. 7) indicate time series of similar shape as the Nuuk time series. This reflects obviously the influence of the data measured at Nuuk, on the gridded set of data available from CDC of NOAA. Air temperatures for the East Greenland boxes reveal a different thermal regime for Tordenskjoeld Bank and for the Angmagssalik box. Coldest conditions were encountered during 1994 in the Tordenskjoeld Bank region (Fig. 8), and during 1995 in the Angmagssalik box (Fig. 9). The climatic time-series have **no** significant trends.

Ice concentrations

Figures 10 to 14 give estimates of mean monthly ice concentrations in boxes H, F, D, T and A (c.f. Fig. 1 for location of boxes). The scaling ranges from 1=ice to 0=no ice. Accordingly, 1993 was an ice year for boxes H, F and D. The Lille Hellefiske Bank box indicates ice concentrations during all years of the decade 1991 to 2000, mostly for the period January to April. The 1993 ice concentrations reveal ice from December 1992 until May 1993 (Fig. 10). The Cape Desolation box was mostly free of ice during the last decade. Off East Greenland ice concentrations were maximum during 1995 for the Tordenskjoeld Bank box (Fig. 13). There was always ice present in the Angmagssalik box (Fig. 14).

Wind directions

Amplitudes of variation of wind directions decrease from north to south off West Greenland (Fig. 15 to 17). For the Lille Hellefiske box there is a distinct difference between mean winter (NE winds) and summer conditions (SE winds). From mid-1995 to mid-1996 the changes between winter and summer wind directions were reduced, especially at the Fyllas Box (Fig. 16) when winds came mostly from easterly directions. Off East Greenland variation in wind direction is much less expressed, and the smoothed time series indicate mostly SE winds (Fig. 18, 19).

Sea-surface temperatures

Sea surface temperature (SST) anomalies between 50°N-70°N, 60°W-40°W for the month of August 1991-2000 are displayed in Fig. 20 and 21. Coldest conditions were observed during 1992. From 1996 onwards there was considerable warming which affected mostly the region off Labrador and Newfoundland (lower right panel of Fig. 20). Warmer than normal SSTs were encountered during August 1998 and 2000 (Fig. 21) when SSTs rose by +2.5K. While this warming was seen mostly at the Canadian side of the Labrador Sea in August 2000, off South and West Greenland cooling took place (lower right panel of Fig. 21).

Sub-surface observations

Temperature

Oceanographic observations at the Fylla Bank Section were taken to demonstrate decadal changes in the water column off West Greenland (Fig. 22-27). The year 1992 clearly emerges as coldest year during the 1990s (Fig. 22; c.f. SST anomalies). The results obtained for the 0-200m water layer confirms 1992 as being the coldest year, however there is a significant positive trend of warming during the decade of the 1990s at Fylla Bank station 4 (Fig. 23). Also the so-called "Irminger Water Layer" (Fig. 24, 200-300m) reveals a significant positive trend of warming. At this water layer 1993 was found to be the coldest year.

Salinity

Salinity fluctuations indicated no significant trend during the decade of the 1990s (Fig. 25-27). During 1993 there was a negative deviation of salinity, which amounted to nearly –0.4 psu in the Irminger Water Layer (Fig. 27).

Irminger Water Mass

The distribution of Irminger Water Mass along the West Greenland slope area is given in Fig. 28 for a swath of 60km in width. Data presentation is done with standard depth data (0, 10, 20, 30, 50m, ….). If the observed temperature and salinity data meet the T,S-characteristics of the Irminger Water Mass (4°C < Theta < 6°C, 34.95 < S < 35.1) a green dot marks the position in depth and geographic latitude. The position of NAFO Standard Oceanographic Sections (**Stein, 1988**) is indicated by section name.

At Cape Desolation section there was each year Irminger Water except for 1992, which was the coldest year as shown above. Northernmost location of this water mass was found during 1999 when T,S-properties at Hellefiske Bank Section indicated the presence of Irminger Water (Fig. 28, lower left panel).

The North Atlantic Oscillation (NAO) Index

The NAO index as given for the decade of the 1990s shows mostly positive values (Fig. 29). 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 during last century.

Discussion

Climatology data as well as air temperatures measured at West and East Greenland sites indicate warming during the decade of the 1990s. This is concurrent with SST anomalies, which show warming for the second part of the decade (Fig. 20, 21). Also sub-surface data show a clear warming trend in water temperatures down to 300m depth. As a result of this warming it would appear that the extension of the warm water mass component in the West Greenland Current system, the Irminger component, was found further north in the later years of the 1990s than in the beginning of the decade.

With regard to hemispheric climatic conditions, the North Atlantic Oscillation (NAO) index was mostly positive during the 1990s with a major exception to this pattern occurring between December 1995 and January, February 1996 (Fig. 29). Greenland lies within the area, which normally experiences warm conditions when the NAO index is negative. As concerns the first half of the 1990s this model assumption works. For the remainder of the decade, however, the years 1999 and 2000 do not fit this model.

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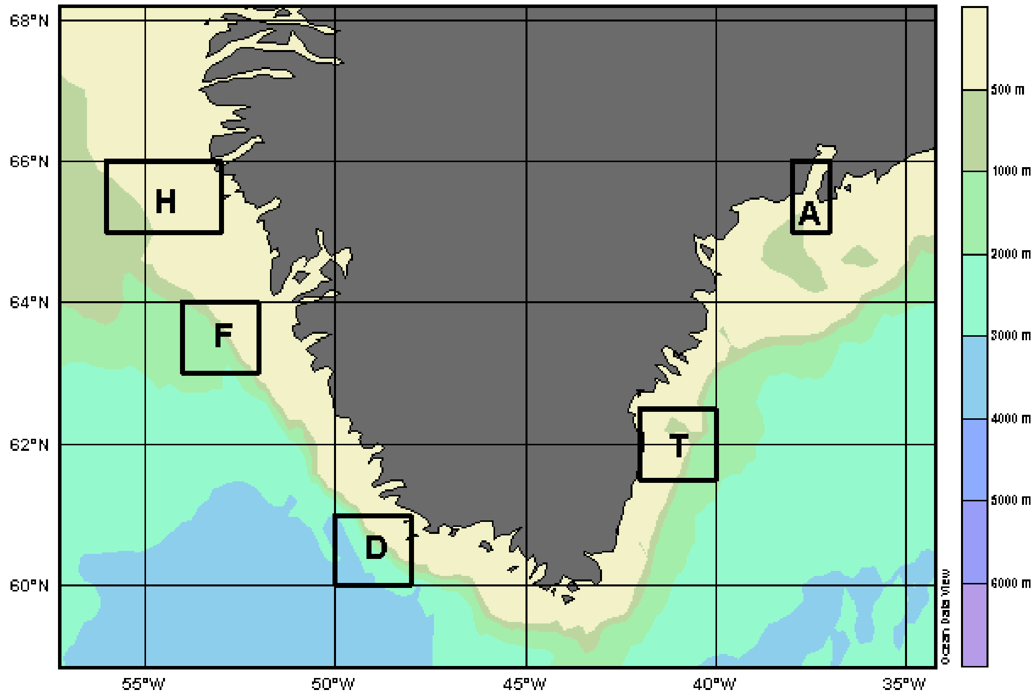

Fig. 1. Location of boxes for climatic time series around Greenland.

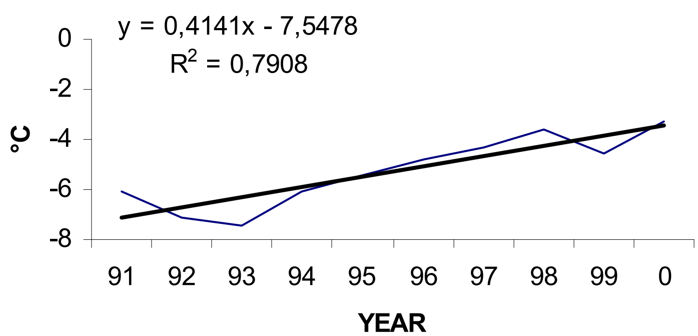

Fig. 2. Air temperatures at Egedesminde.

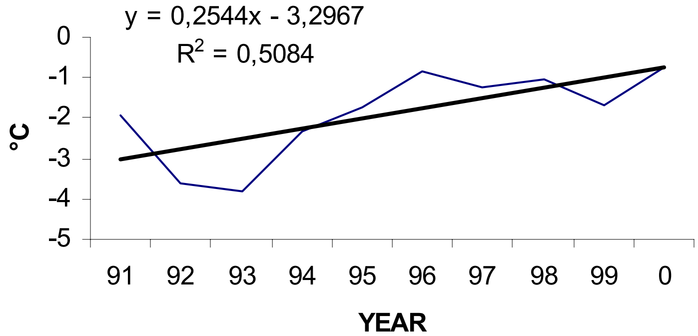

Fig. 3. Air temperatures at Nuuk.

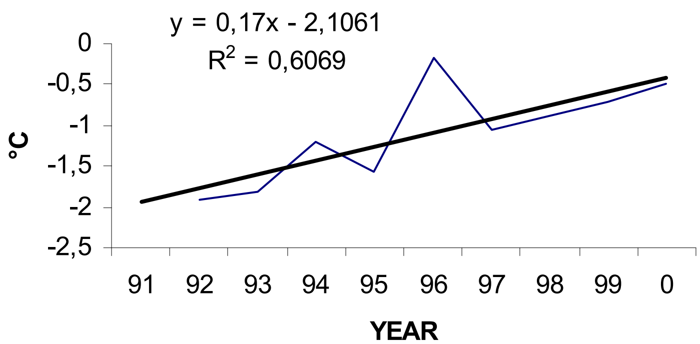

Fig. 4. Air temperatures at Angmagssalik.

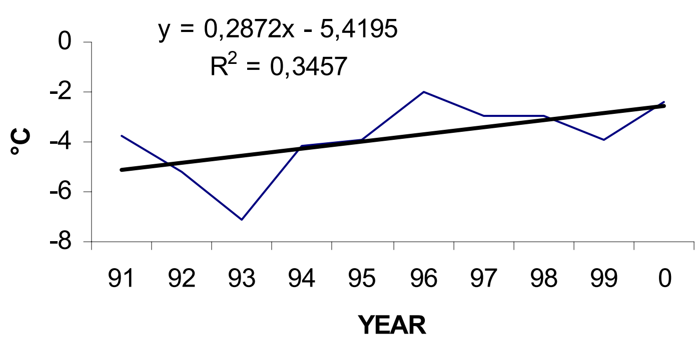

Fig. 5. Air temperatures (2 m) for Hellefiske Bank Box.

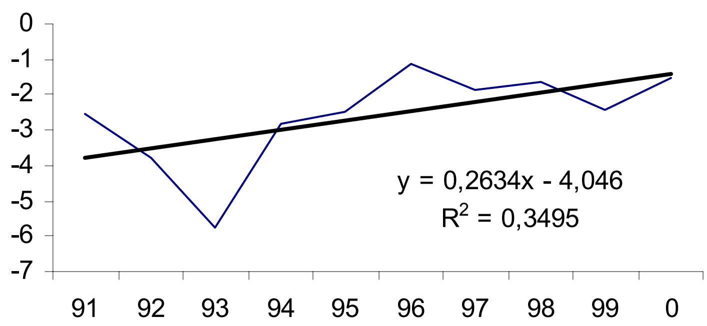

Fig. 6. Air temperatures (2 m) for Fylla Bank Box.

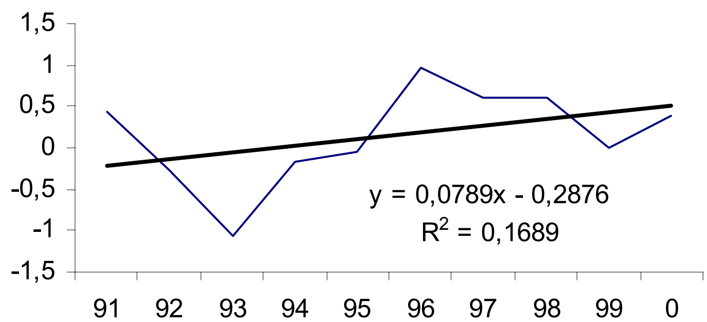

Fig. 7. Air temperatures (2 m) for Cape Desolation Box.

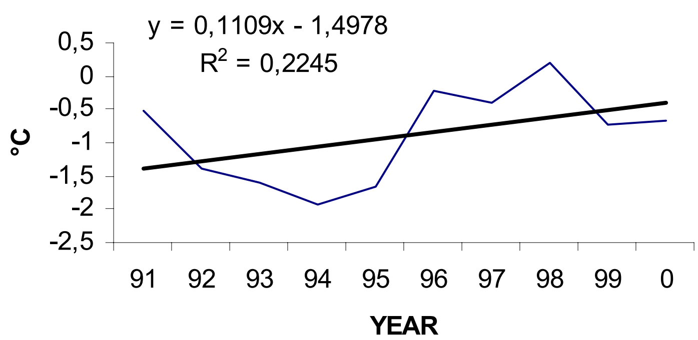

Fig. 8. Air temperatures (2 m) for Tordenskjoeld Bank Box.

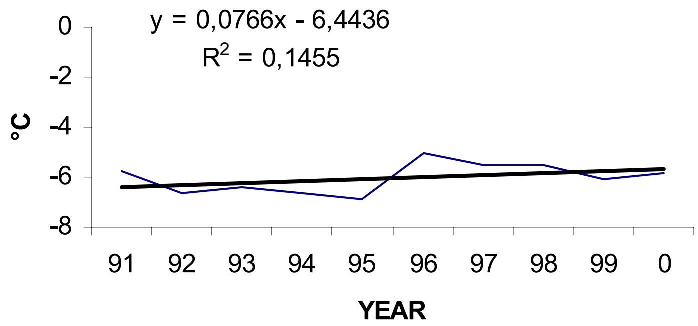

Fig. 9. Air temperatures (2 m) for Angmagssalik Box.

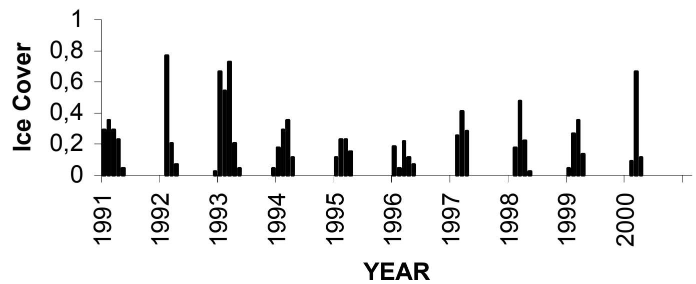

Fig. 10. Ice cover for Hellefiske Bank Box.

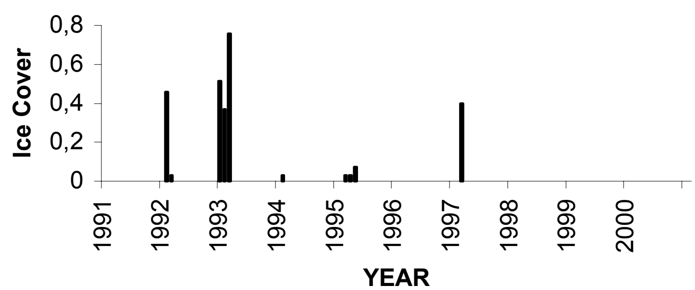

Fig. 11. Ice cover for Fylla Box.

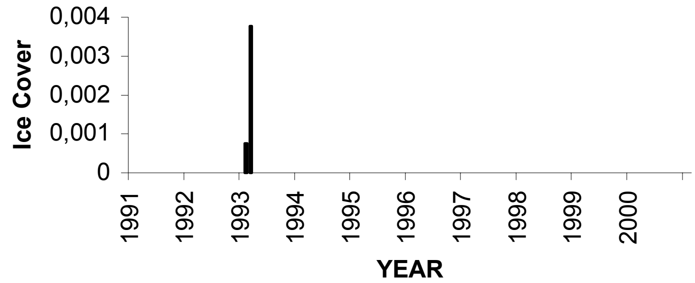

Fig. 12. Ice cover for Cape Desolation Box.

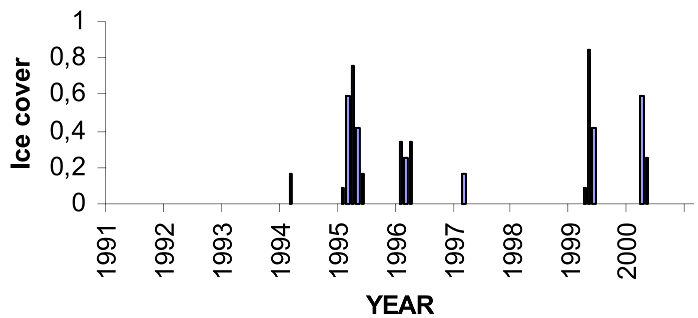

Fig. 13. Ice cover for Tordenskjoeld Bank Box.

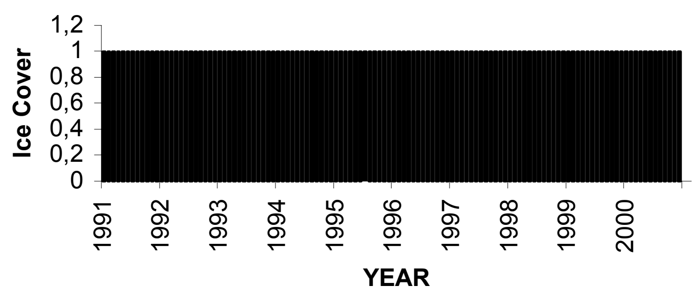

Fig. 14. Ice cover for Angmagssalik Box.

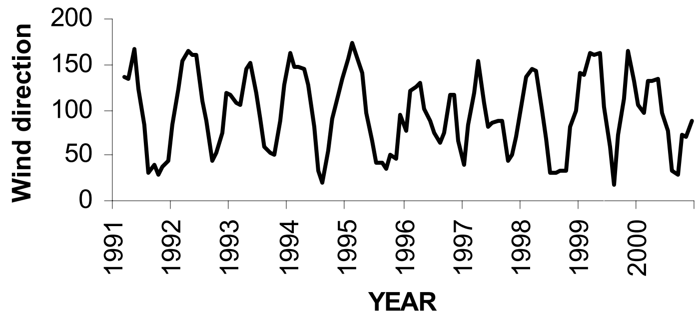

Fig. 15. Wind direction Hellefiske Box (3-fold overlapping mean)

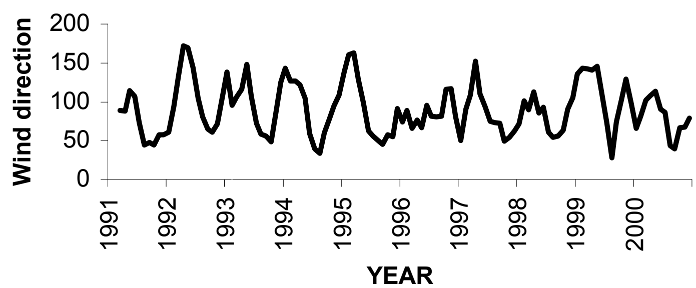

Fig. 16. Wind direction Fyllas Box (3-fold overlapping mean).

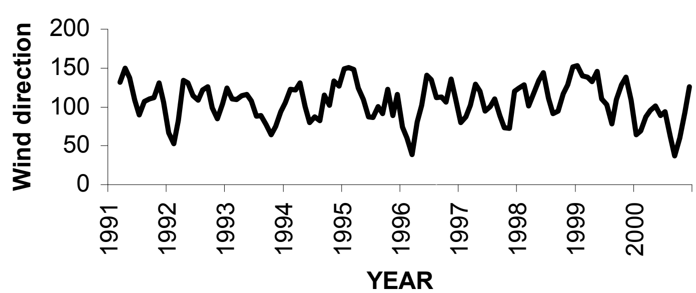

Fig. 17. Wind direction Cape Desolation Box (3-fold overlapping mean).

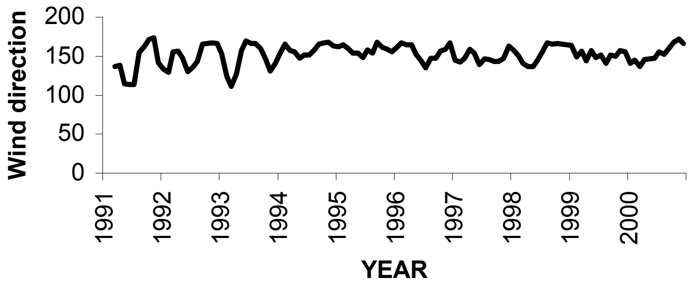

Fig. 18. Wind direction Tordenskjoeld Box (3-fold overlapping mean).

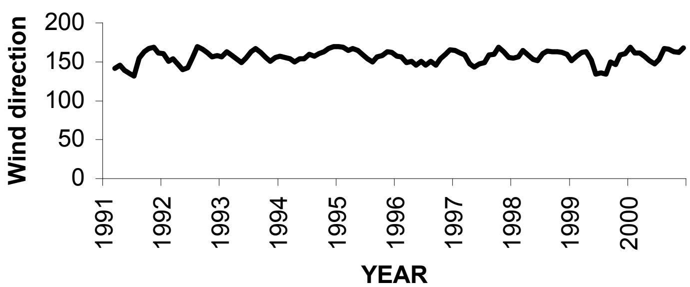

Fig. 19. Wind direction Angmagssalik Box (3-fold overlapping mean).

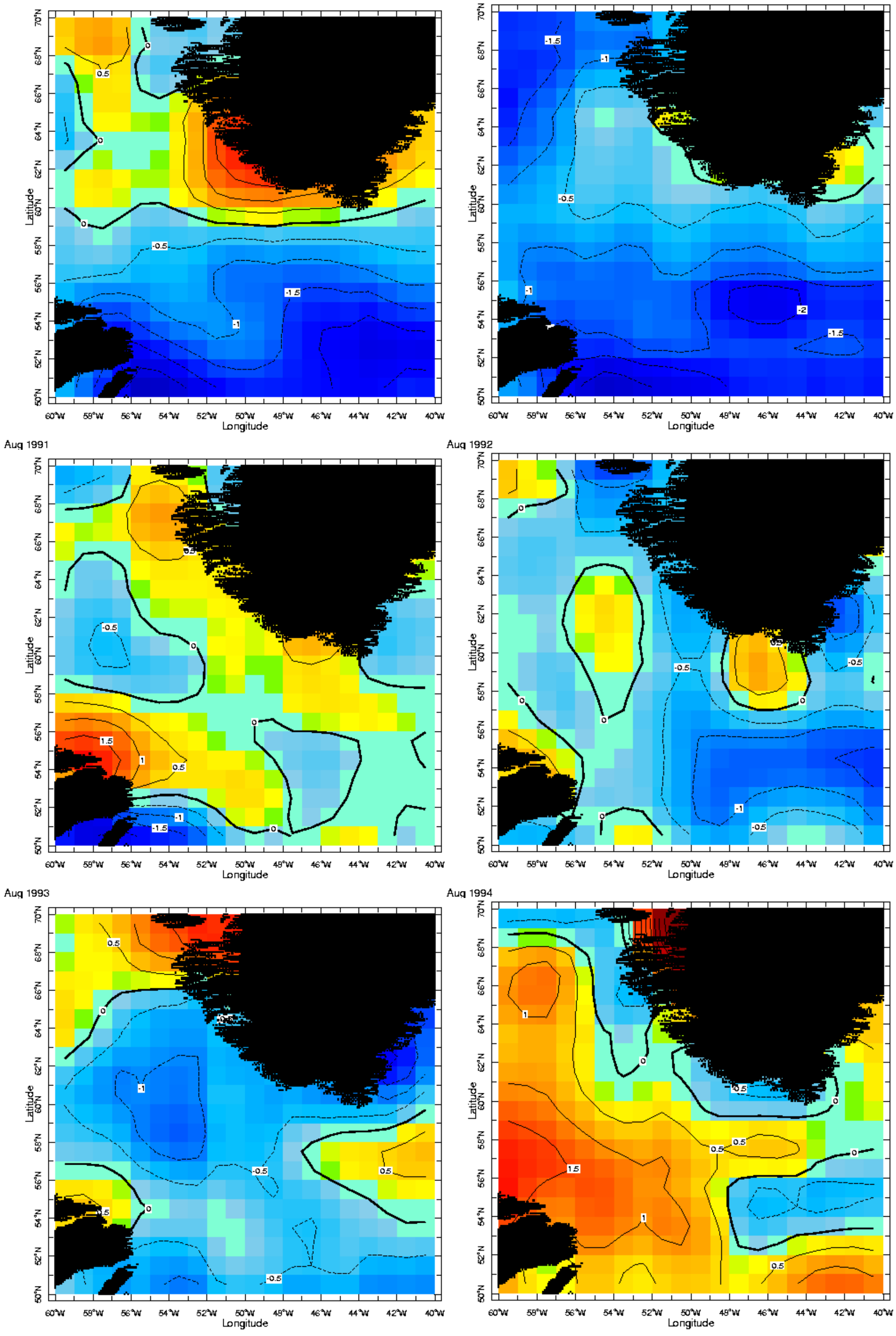

Fig. 20. Sea-Surface Temperature Anomalies during August 1991-1996.

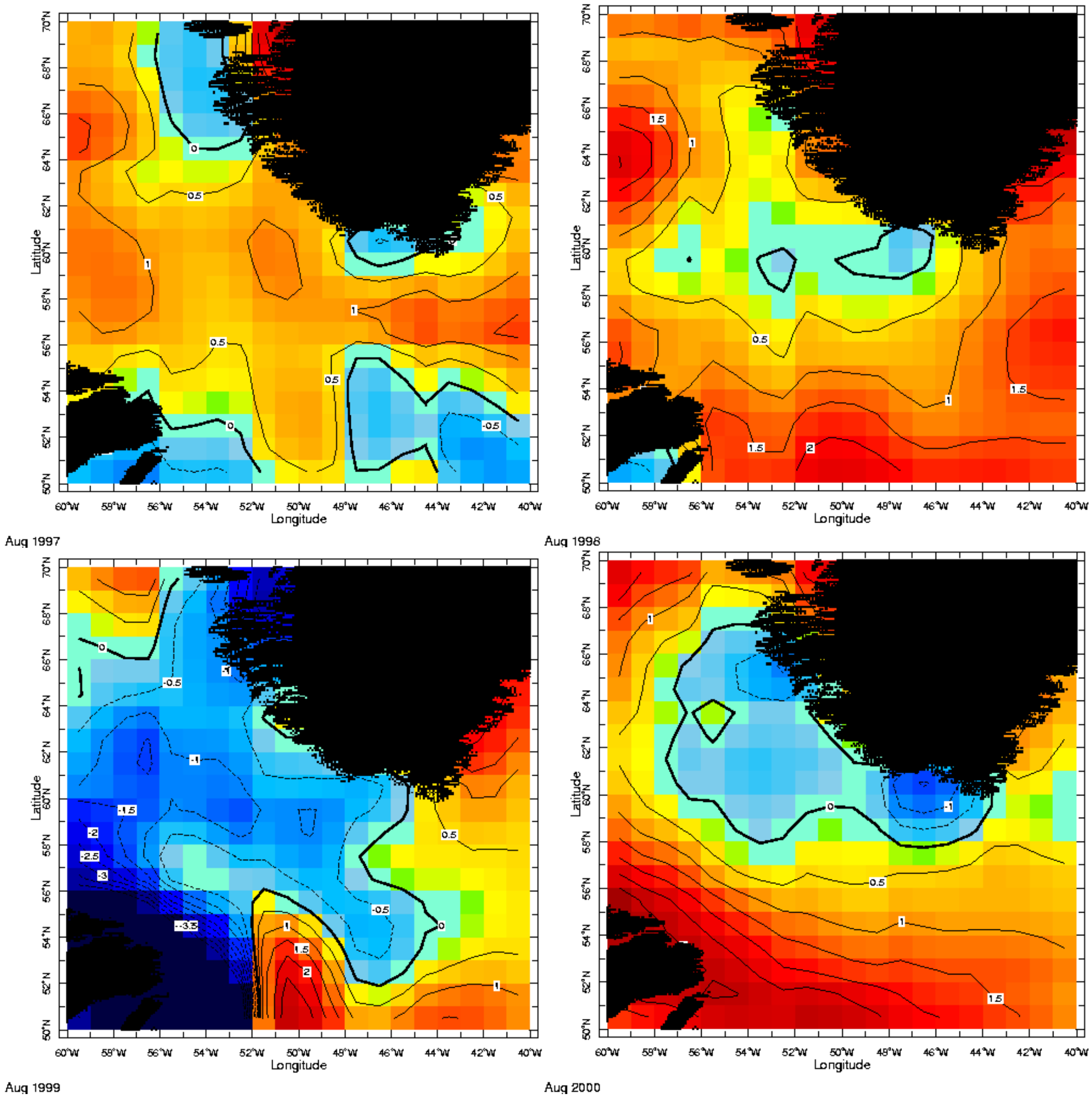

Fig. 21. Sea-Surface Temperature Anomalies during August 1997-2000.

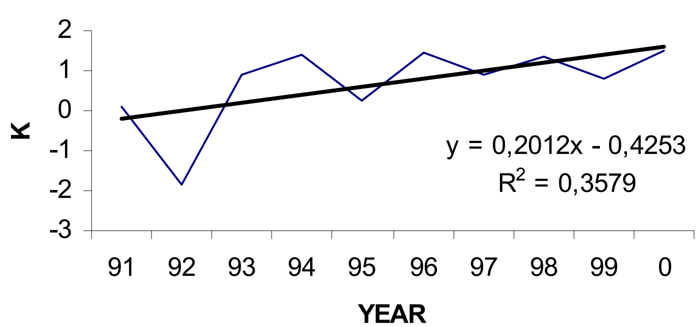

Fig. 22. Temperature Anomaly Fylla Bank 0-50 m.

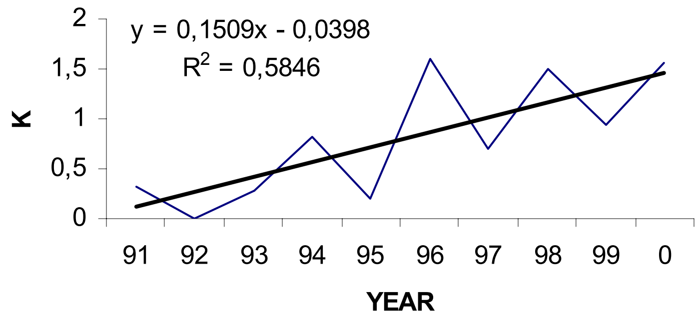

Fig. 23. Temperature Anomaly Fylla Bank 0-200 m.

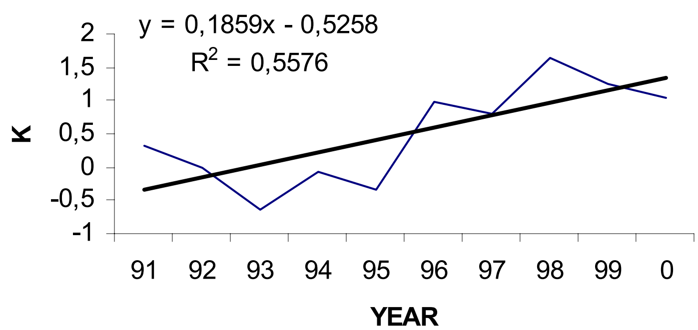

Fig. 24. Temperature Anomaly Fylla Bank 200-300 m.

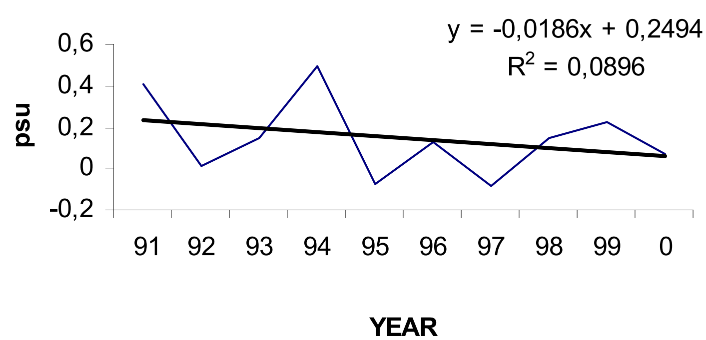

Fig. 25. Salinity Anomaly Fylla Bank 0-50 m.

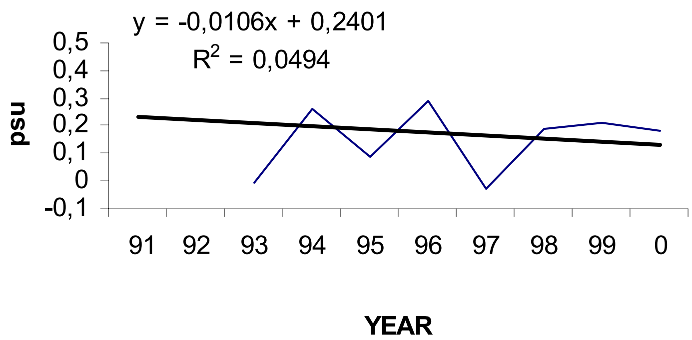

Fig. 26. Salinity Anomaly Fylla Bank 0-200 m.

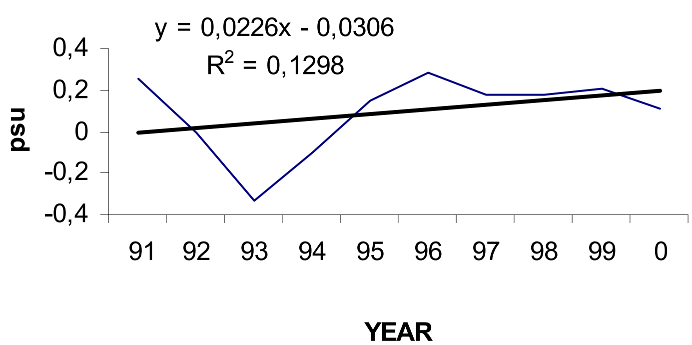

Fig. 27. Salinity Anomaly Fylla Bank 200-300 m.

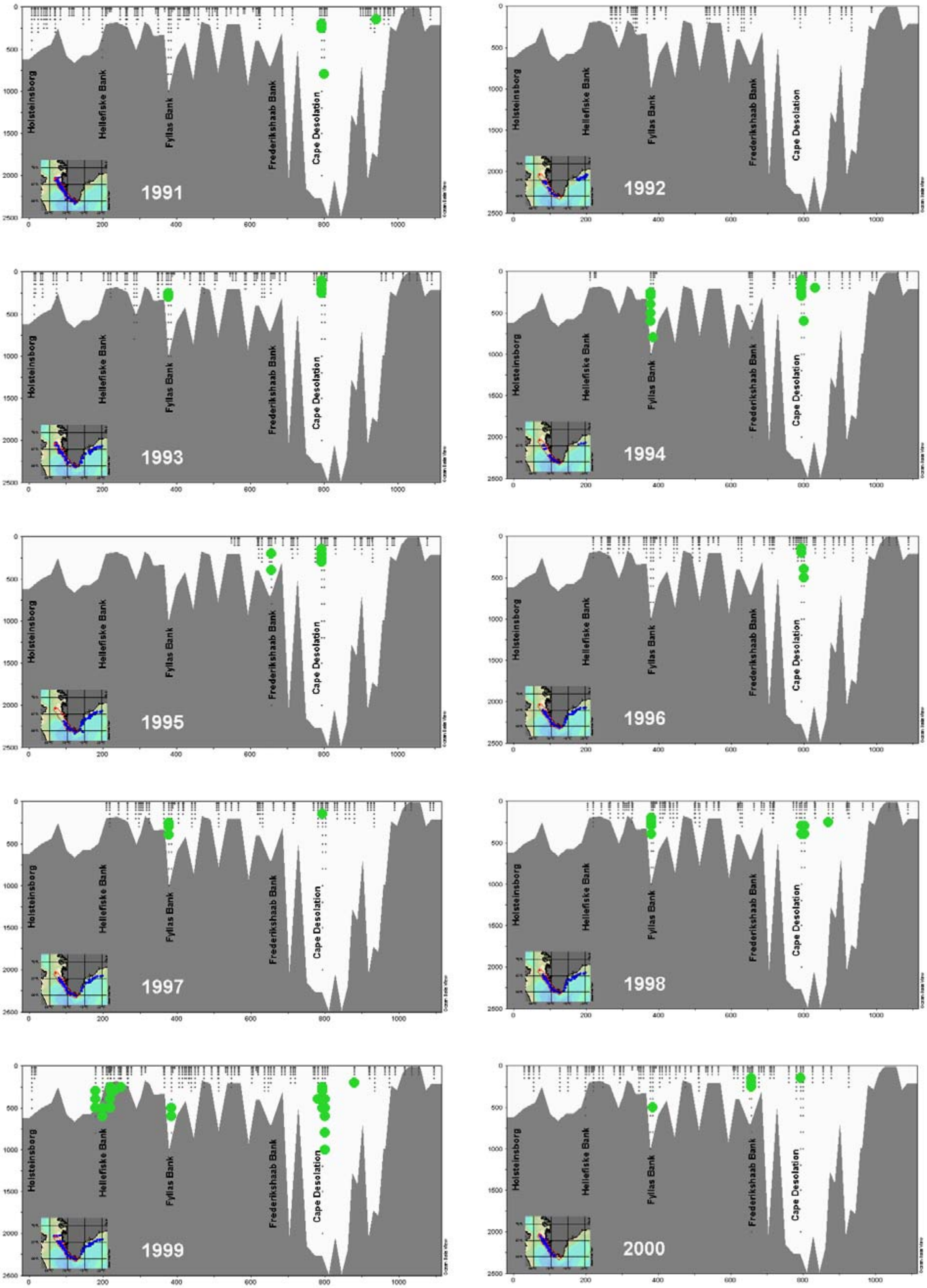

Fig. 28. Distribution of Irminger Water Mass along West Greenland, 1991-2000

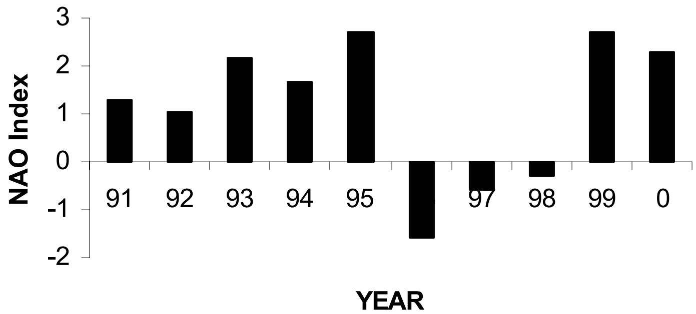

Fig. 29. NAO Index, 1991-2000 (rel. 1961-1990).