Climate variations in Fenno-

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FINSKEN Developing consistent global change scenarios for Finland

FIGARE 1999-2002

Scandia during the 20th century

INTRODUCTION

The 20th century was a period of increasing human influence on climate. Mankind, through emissions of greenhouse gases and aerosols, continued changing the composition of the global atmosphere. At regional and local scale the changes in land use modified surface characteristics. Although, knowing that it is difficult to attribute any of the climatic variations in Fennoscandia to specific anthropogenic actions, it is interesting to:

- Quantify the climatic variations in Finland and/or Fennoscandia.
- Determine their statistical significance in relation to natural variability, which is typically large in Fennoscandia.
- Compare trends in Fennoscandia to Global/Northern Hemisphere trends reported in the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report.
- Qualitatively compare observed trends to those simulated by climate models when forced with increasing levels of greenhouse gases.

MEAN TEMPERATURE

The annual mean temperatures show warming in Fennoscandia during the 20th century (Fig. 1). In the NORDKLIM data set roughly half of the stations show statistically significant trends (Tuomenvirta et al. 2001). In some of the capitals the warming has been further strengthened by local urbanisation. In general, the end of the 19th century was a cool period, which was followed by a warm period, peaking in the 1930s or in the 1940s (Fig. 2). The last ten years have been warm due to warm winters. This is linked to the positive phase of NAO (see the blue box) which causes warm, humid westerlies being the dominant airflow type over Fennoscandia.

The IPCC TAR breaks the 20th century mean temperature record into three periods. This characterisation fits reasonably well into Nordic temperature evolution, too. From Table 1 it can be seen that most of the trends of the period 1910-45 are positive, the period 1946-75 has many negative trends and all trends are positive during the most recent period. Due to large natural interannual variability, the magnitude of the linear trend is quite sensitive to the exact start and end years of the time periods. In some of the larger cities local urban warming probably has influenced the trends.

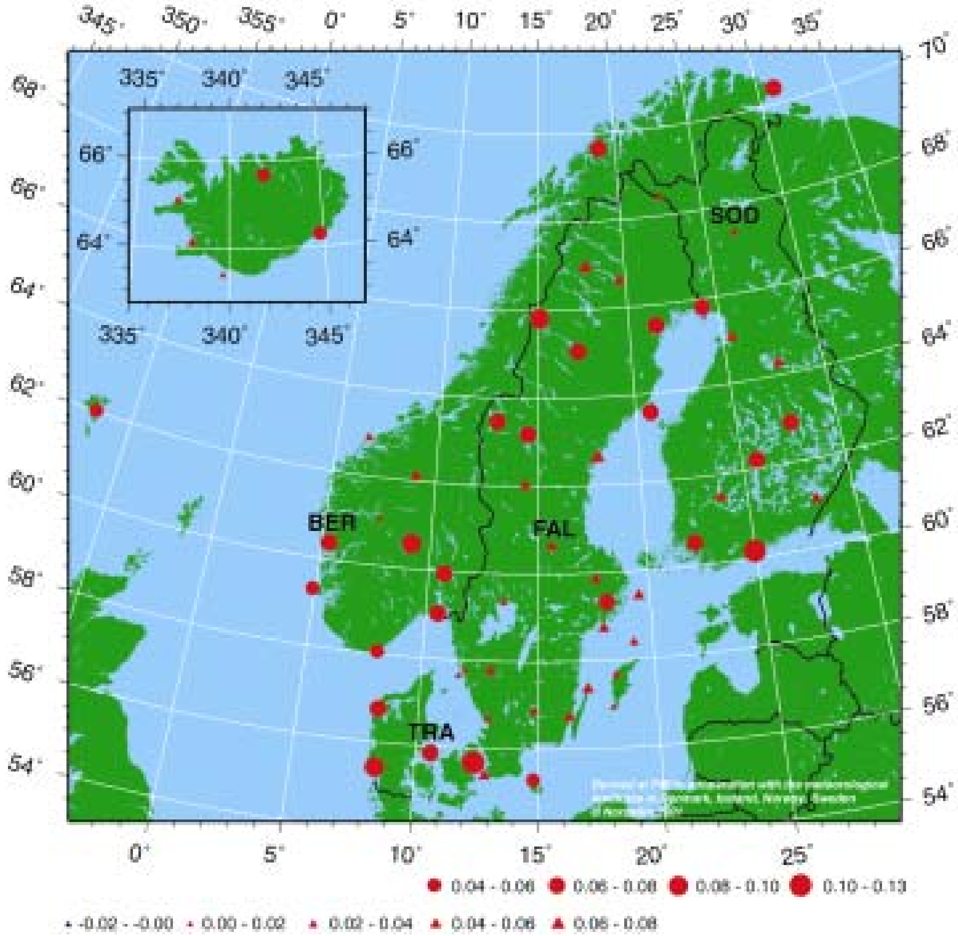

Figure 1. The 20th century temperature trends in the NORDKLIM data set (Unit: °C/decade). Annual mean temperature trends are determined using Sen's method for the period 1900-99. Statistically significant trends (Mann-Kendall test at the 5%-level) are marked with dots and non-significant trends with triangles. Only stations with more than 91 years of data are shown. Stations shown in Fig. 2 are marked.

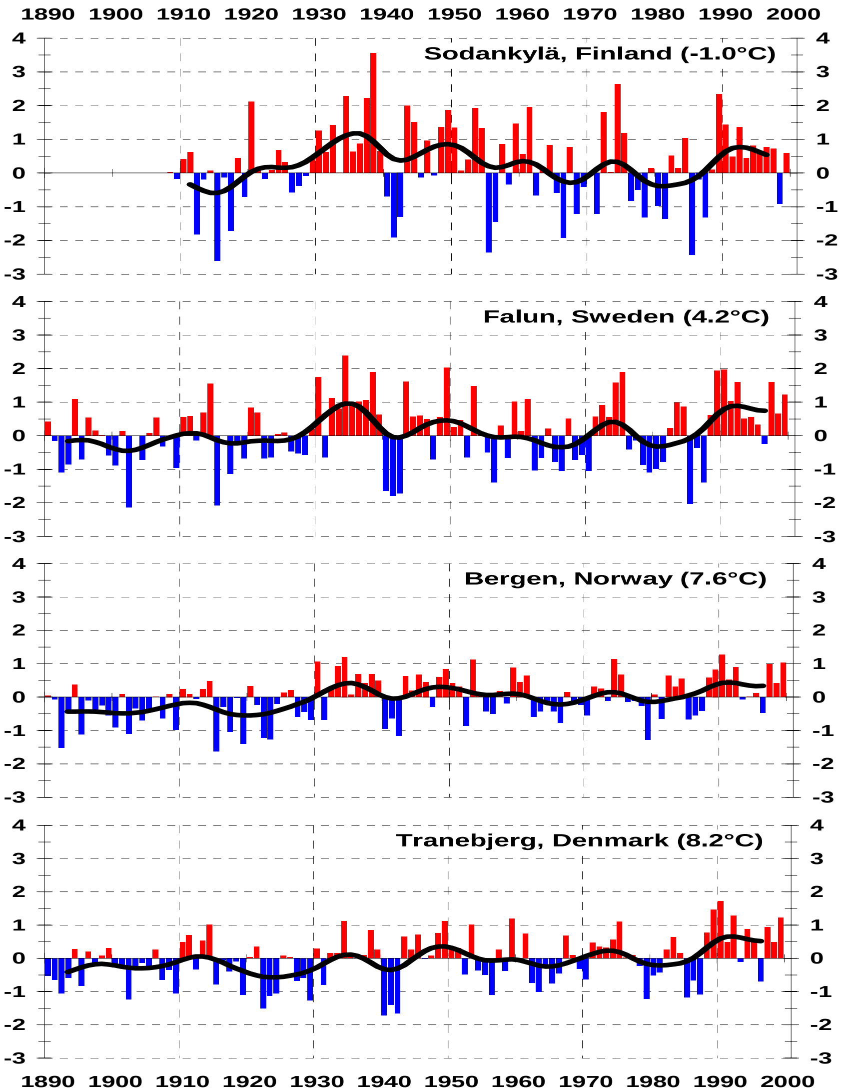

Figure 2. The annual anomalies of mean temperature for 4 stations marked in Fig. 1 (Unit: °C). The reference period 1961-90 mean value is given in the parenthesis. The black line obtained from yearly data by applying Gaussian filter (close to 10-year moving average).

Table 1. Linear trends (least squares method) in the annual average temperature (°C/10 years) at 17 NORDKLIM stations and Northern Hemisphere land surface air temperature (Jones et al. 1999 and updates).

Station	Country	1910-1945	1946-1975	1976-1999
Reykjavik	Iceland	0.45	-0.17	0.31
Akureyri	Iceland	0.52	-0.28	0.23
Bjoernoeya	Norway		-0.29	0.42
Jan Mayen	Norway		-0.71	0.51
Thorshavn	Faeroe Is.	0.26	-0.13	0.18
Tranebjerg	Denmark	-0.04	-0.01	0.55
Copenhagen	Denmark	0.11	0.15	0.42
Oslo	Norway	0.09	0.03	0.60
Bergen	Norway	0.17	-0.05	0.42
Tromsoe	Norway	0.34	-0.12	0.35
Gothenborg	Sweden	0.03	-0.01	0.42
Stockholm	Sweden	0.08	0.06	0.73
Falun	Sweden	0.13	0.05	0.83
Stensele	Sweden	0.32	0.02	0.80
Helsinki	Finland	0.17	0.08	0.70
Kajaani	Finland	0.20	-0.01	0.67
Sodankylä	Finland	0.40	-0.16	0.69
Northern Hemisphere		*0.14*	*-0.04*	*0.31*

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Tuomenvirta, H., A. Drebs, E. Førland, O-E Tveito, H. Alexandersson, E. Vaarby-Laursen, and T. Jónsson, 2001: NORDKLIM data set 1.0 – description and illustrations. DNMI-Report KLIMA. (in print)

Jones, P.D., M. New, D.E. Parker, S. Martin, and, I.G. Rigor, 1999: Surface air temperature and its changes over the past 150 years. *Reviews Geophysics* **37**, 173-199.

TEMPERATURE EXTREMES, THEIR RANGE AND CLOUD COVER

Tuomenvirta et al. (2000) analysed monthly mean daily maximum (Tx) and minimum (Tn) temperatures, and diurnal temperature range (DTR) trends in Fennoscandia. Temperature changes are not statistically significant except the springtime increase of mean daily minimum temperatures (Fig. 3) and the narrowing of annual mean DTR.

To a large extent the decrease of DTR can be explained by cloud cover increase and a strengthening of the westerly flow bringing more humid maritime air mass to Fennoscandia. Although changes in land use (urbanisation, de- and reforestation, etc.) may have a significant effect on Tx and/or Tn and modify DTR, they are mostly carried out at local or regional scale, thus, having only a minor contribution to DTR reduction at Fennoscandian scale.

According to Dai et al. (1999), the 20th century changes of DTR vary with cloud cover and precipitation changes in the USA, Australia, midlatitude Canada and the former U.S.S.R. During the last 5 decades, they report a decrease of DTR consistent with increasing trends of cloud cover and precipitation.

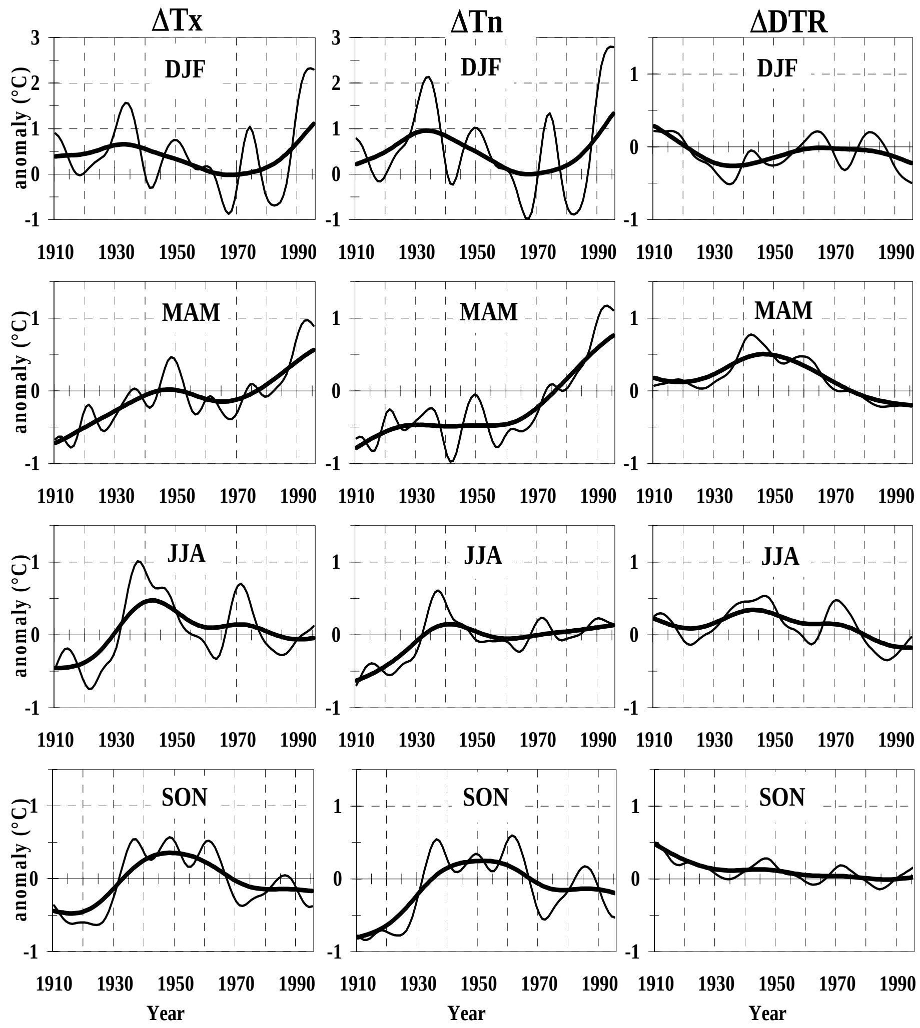

Figure 3. Seasonal anomalies of area-averaged Fenno-Scandian Tx, Tn, and DTR during 1910-95 smoothed with Gaussian filters (close to 10- and 30-year moving averages, thin and thick curve, respectively). Reference period is 1961-90. Note the different vertical scales of DJF ΔTx and ΔTn. (Notation: DJF=December-February, etc).

Based on analyses of Dai et al. (1999) and Tuomenvirta et al. (2000) it can be concluded that the direct effect of an increase of greenhouse gases and aerosols on DTR reduction must be small. The anthropogenic influence, if there is any, is likely to be manifested through clouds, due to their mainly asymmetric forcing of the diurnal cycle of temperature. The amount, properties and lifetime of clouds are affected by changes in atmospheric humidity and loadings of aerosols. Thus increased levels of greenhouse gases may have contributed to changes in the hydrological cycle and cloud cover. Similarly anthropogenic emission of aerosols may indirectly contribute to a narrowing of DTR.

The Fenno-Scandian cloud cover exhibited negative anomalies in spring, summer and autumn before the 1920s, which is also reflected in the annual mean (Fig. 4). The long-term increasing trend of annual mean cloudiness is 0.17 %/10 years during the period 1910-95.

Figure 4. Annual anomalies of Fennoscandian area-averaged cloud cover (CA) based on 36 *stations, 1910-95. Smoothed with Gaussian filter (close to 10-moving average, black curve). Reference period is 1961-90.* ➔

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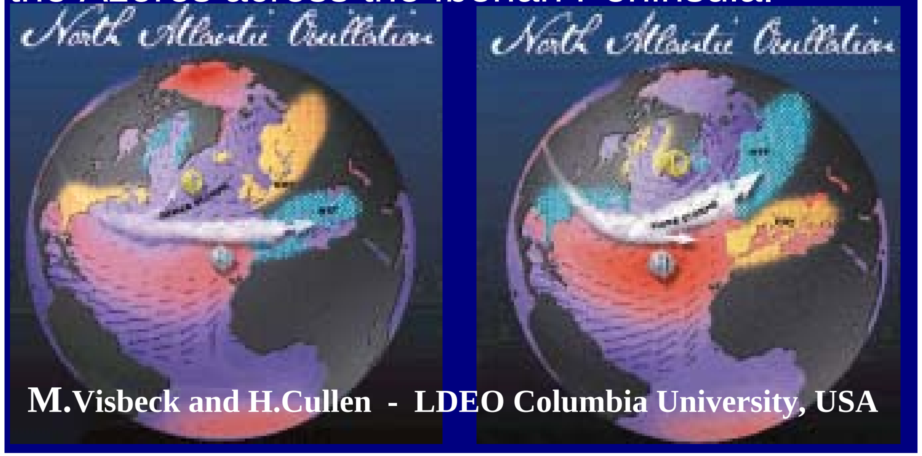
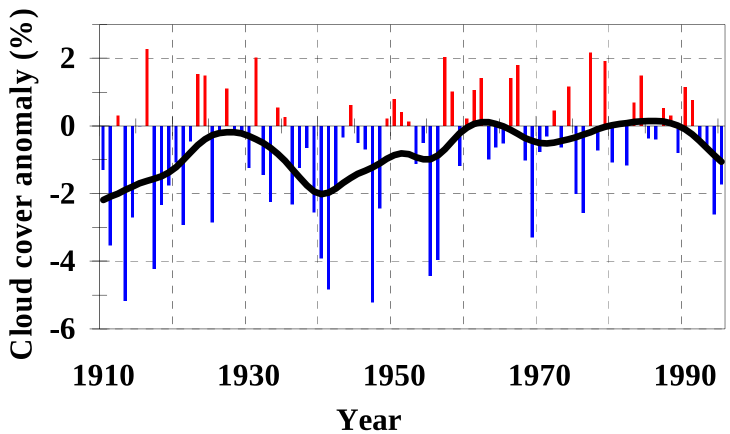
Tuomenvirta, H., Alexandersson, H., Drebs, A., Frich, P., and Nordli, P.O., 2000: Trends in Nordic and Arctic temperature extremes and ranges. *J. Climate* **13**, 977-990.

NAO (North Atlantic Oscillation) is a large-scale mode (pattern) of natural climate variability that has important impacts on the weather and climate of the North Atlantic region and surrounding continents, especially Europe. NAO refers to a meridional oscillation in atmospheric mass with centers of action near Iceland and over the subtropical Atlantic from the Azores across the Iberian Peninsula.





PRECIPITATION - TOTALS AND 1-DAY MAXIMUMS

Most of the stations in Fig. 5 are showing positive trends during the 20th century. Although precipitation amounts have large temporal and spatial variability, some regional patterns related to orography can be seen. There are statistically significant trends in the western parts of Norway, Denmark and Sweden, which are exposed to westerlies and receive large part of precipitation in winter season. Also in northern Fennoscandia the trends are mostly positive. Especially in Finland, the trends are mixed.

Førland et al. (1998) analysed maximum 1-day precipitation for the period 1880-1996 in the Nordic countries. Their main conclusions were (no figure):

1) Nordic countries comprise a complex region concerning geographical distribution of absolute values, seasons for extreme values, for long-term trends and for weather situations favourable for high 1-day precipitation.

2) The single station series are no ideal indicators for revealing trends. However, it is found that for all Nordic countries there is a maximum in the 1930s and a tendency of increasing values during the latest two decades in 1-day maximum precipitation. Only for Denmark there is a significant positive trend during the whole 100-year period.

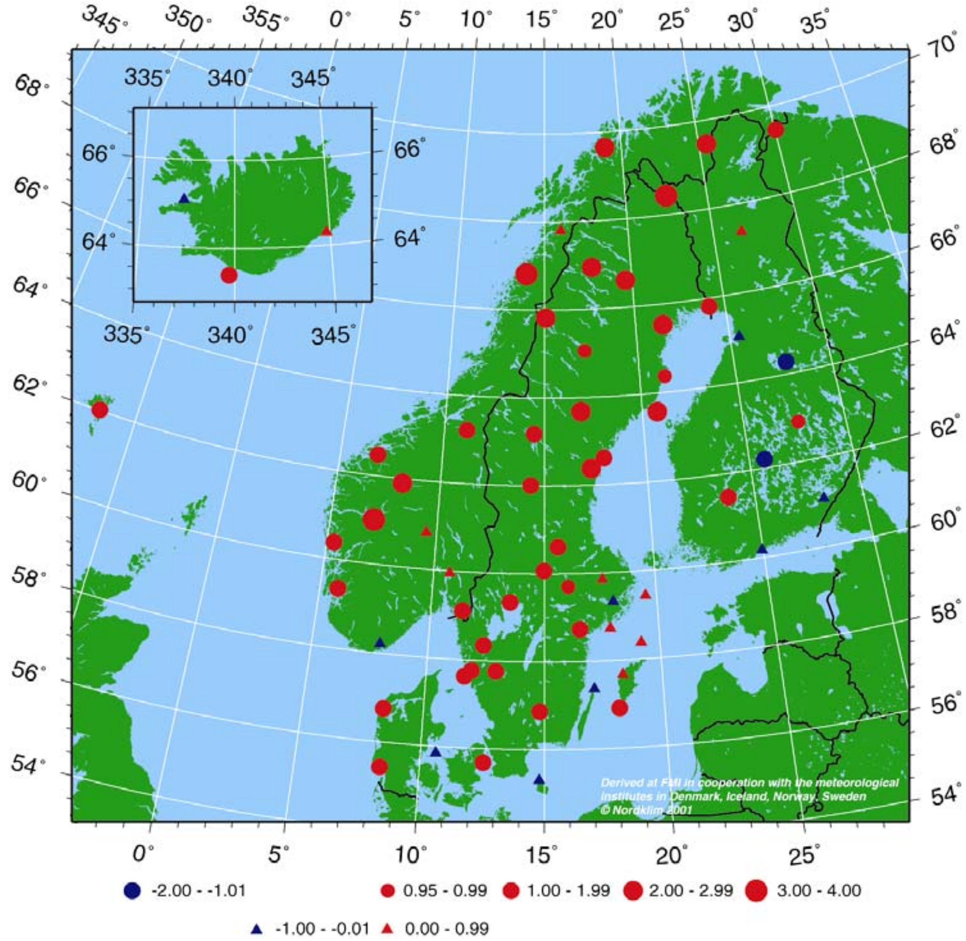


Figure 5. The 20th century precipitation trends in the NORDKLIM data set (Unit: %/decade). Calculations as in Fig. 1. (Tuomenvirta et al. 2001)

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Førland, E.J., H. Alexandersson, A. Drebs, I. Hanssen-Bauer, H. Vedin and O.E. Tveito, 1998: Trends in maximum 1-day Precipitation in the Nordic region. DNMI-Report 14/98 KLIMA, 55 pp.

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STORMINESS

Alexandersson et al. (2000) used high percentiles of geostrophic winds calculated from triangles of stations with air pressure observations as storm ("intense low pressure" system) indices. They show a weakening of strong winds from the late 19th century and the turn of the century until around the 1960s, but since then there has been some increase.

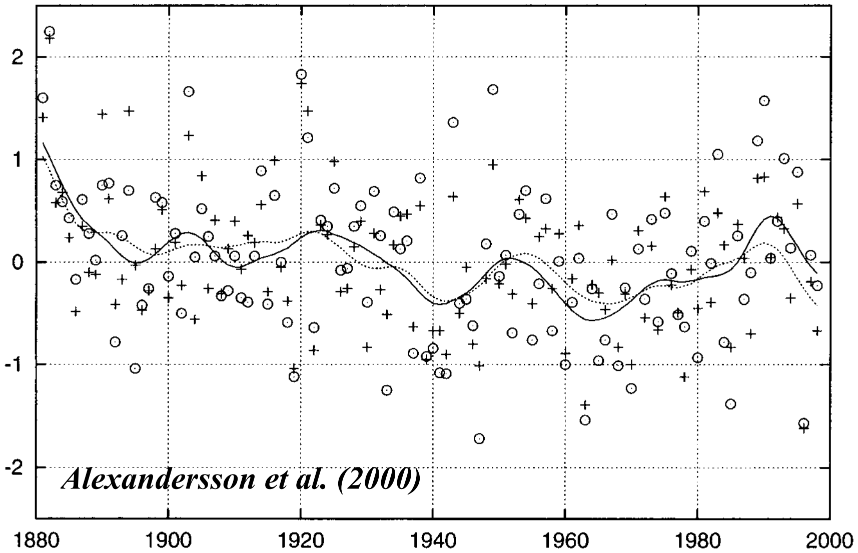

Figure 6. Standardized annual 95% (⊙ and solid line) and 99% (+ and dotted line) quantile time series from pressure triangles in Fennoscandian and Baltic Sea regions, 1881-1998. Yearly data smoothed with Gaussian filter (≈ 10-yr moving average). Dimensionless units.

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DISCUSSION

Fennoscandia vs. Northern Hemisphere

There are similarities in the climatic variations of Fennoscandia and Northern Hemisphere. Typically the variability is larger in the Nordic countries.

Role of the NAO

Most of the temperature and precipitation elements, showing statistically significant rising trends, have high correlation with the NAO. Therefore, many of the recent (the last 1-3 decades) changes are related to the wintertime increase of NAO index, i.e. the dominance of the westerly flow type over Fennoscandia. Notable exception is DTR. It shows a decreasing trend mainly due to increasing cloud cover, which is not directly related to the NAO.

Observed trends vs. climate model projections

In Fennoscandia, there are some similarities in the observed temperature and precipitation trends, and with trends projected by complex climate model simulations (forced with scenarios of atmospheric greenhouse gas and aerosol concentrations). However, the observed trends (increase of temperature, precipitation, cloud cover, NAO index) increase are mostly within the natural climatic variability.