DNMI

NORDKLIM – Nordic co-operation within Climate activities

Nordklim data set 1.0

- description and illustrations

Heikki Tuomenvirta, Achim Drebs, Eirik Førland, Ole Einar Tveito, Hans Alexandersson, Ellen Vaarby Laursen and Trausti Jónsson

Report no. 08/01

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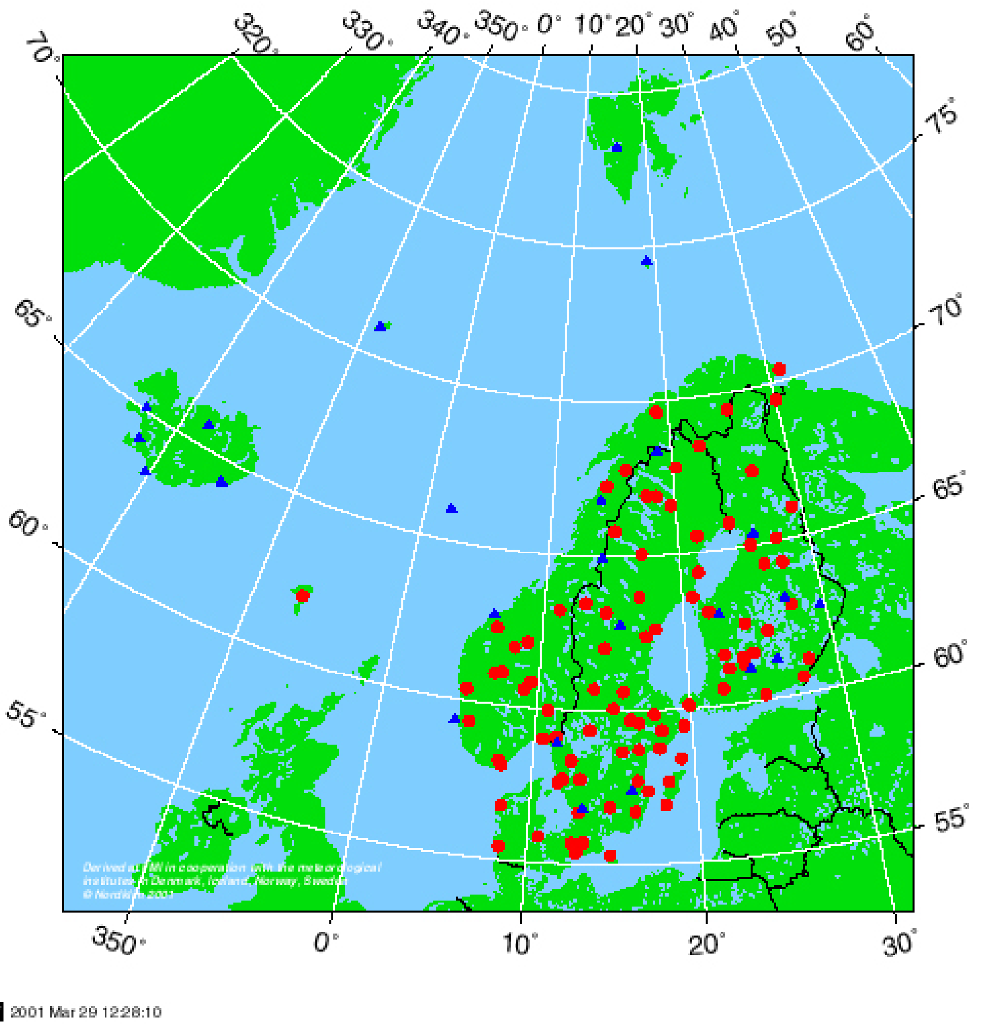

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Nordklim data set 1.0 - description and illustrations

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PROJECT CONTRACTORS:

NORDKLIM/NORDMET on behalf of the National meteorological services in Denmark (DMI), Finland (FMI), Iceland (VI), Norway (DNMI) and Sweden (SMHI)

SUMMARY:

The Nordklim dataset is a unique and useful achievement for climate analysis. It includes observations of twelve different climate elements from more than 100 stations in the Nordic region. It covers a time span for more than 100 years.

In this report the dataset is described, and some examples of analysis of the 20th century climate in the Nordic region is presented.

KEYWORDS:
Temperature, precipitation, cloud cover, air pressure, snow cover, Climate time series, Nordic

SIGNATURES:

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NORDKLIM Activity Manager

Bjørn Aune
Head of the DNMI Climatology Division

Foreword

This report is prepared under task 2 in the Nordic NORDKLIM project: *Nordic Co-Operation Within Climate Activities.* The NORDKLIM project is a part of the formalised collaboration between the NORDic METeorological institutes, NORDMET.

The main objectives of NORDKLIM are:
1). Strengthening the Nordic climate competence for coping with increased national and international competition
*2). Improving the cost-efficiency of the Nordic meteorological services (i.e. by i*mproving procedures for standardized quality control & more rational production of standard climate statistics)
3). Coordinating joint Nordic activities on climate analyses and studies on long-term climate variations

The NORDKLIM project has two main tasks:

1. Climate data (Network design, Quality control, long-term datasets).
2. Climate Applications (Time series analysis, use of GIS within climate applications, mesoscale climatological analysis, extreme values and return periods).

A detailed description of the project is given by Førland et al.(1998).

NORDKLIM is coordinated by an Advisory Committee, headed by an Activity Manager. Each of the main tasks is headed by a Task manager.

The Advisory Committee in NORDKLIM is presently consisting of:

Hasse Alexandersson, SMHI
Eirik J. Førland, DNMI (**Activity Manager**)
Raino Heino, FMI
Trausti Jónsson, VI
Lillian Wester Andersen, DMI

The present task managers are: Task 1: Pauli Rissanen (FMI), Task 2: Ole Einar Tveito (DNMI)

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CONTENTS

INTRODUCTION

The national meteorological institutes of Denmark, Finland, Iceland, Norway and Sweden have recognised the importance of compilation and analysis of long-term meteorological time series. In the context of anthropogenic climate change, it is of key importance to produce reliable information on climate and its variations. As holders of this unique information within their countries, the institutes have an obligation to produce the best available data and offer easy access to data for the international research community. Besides climate change research the long-term climatic data is needed in various applications. Climatic information is used in the management and planning, for example in construction, energy production and agriculture.

During the 1990s there were two major Nordic initiatives to compile and analyse long-term meteorological time series. Firstly, the NACD (North Atlantic Climatological Dataset) project which was a joint effort of the five Nordic countries, and Belgium, Netherlands, England and Ireland to cover the time period 1880-1990 (Frich et al. 1996; Dahlström et al. 1995). Secondly, the REWARD (Relating Extreme Weather to Atmospheric circulation using a Regionalised Dataset) project focused on the Nordic countries and on extreme climatic elements (Førland et al. 1998a). As one of the tasks of the NORDKLIM project is to coordinate joint Nordic activities of studies on long-term climate variations, the NORDKLIM project undertook the task of updating the Danish[1], Finnish, Icelandic, Norwegian and Swedish time series of NACD and REWARD, and merging them into NORDKLIM data set.

This report describes the NORDKLIM data set that is accessible via the NORDKLIM web site (http://www.smhi.se/hfa_coord/nordklim/). The aim of this report is not to provide comprehensive analysis of data but to present some maps and time series graphs as examples of different climatic elements included into the NORDKLIM data set.

1. THE NORDKLIM DATA SET

The NORDKLIM data set contains close to 70 000 years of monthly data from 114 stations. The station network covers all five Nordic countries, including data from the Faeroe Islands, Jan Mayen, Bjørnøya and Svalbard (Figure 1). There are seven monthly climatic elements describing temperature, two on precipitation and one on air pressure, cloud cover and snow cover (Table 1). The station catalogue can be found from Appendix 1.

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[1] Data from Greenland was not updated and is not included into the NORDKLIM data set.

Table 1. Monthly climatic elements in the NORDKLIM data set.

Element number	Climatic Element	Unit	Abbre-viation
101	Mean temperature	0.1 °C	T
111	Mean maximum temperature	0.1 °C	Tx
112	Highest maximum temperature	0.1 °C	Th
113	Day of Th	date	Thd
121	Mean minimum temperature	0.1 °C	Tn
122	Lowest minimum temperature	0.1 °C	Tl
123	Day of Tl	date	Tld
401	Mean Pressure	0.1 hPa	P
601	Precipitation Sum	0.1 mm	R
602	Maximum 1-day precipitation	0.1 mm	Rx
701	Number of days with snow cover (> 50% covered)	days	dsc
801	Mean cloud cover	%	N

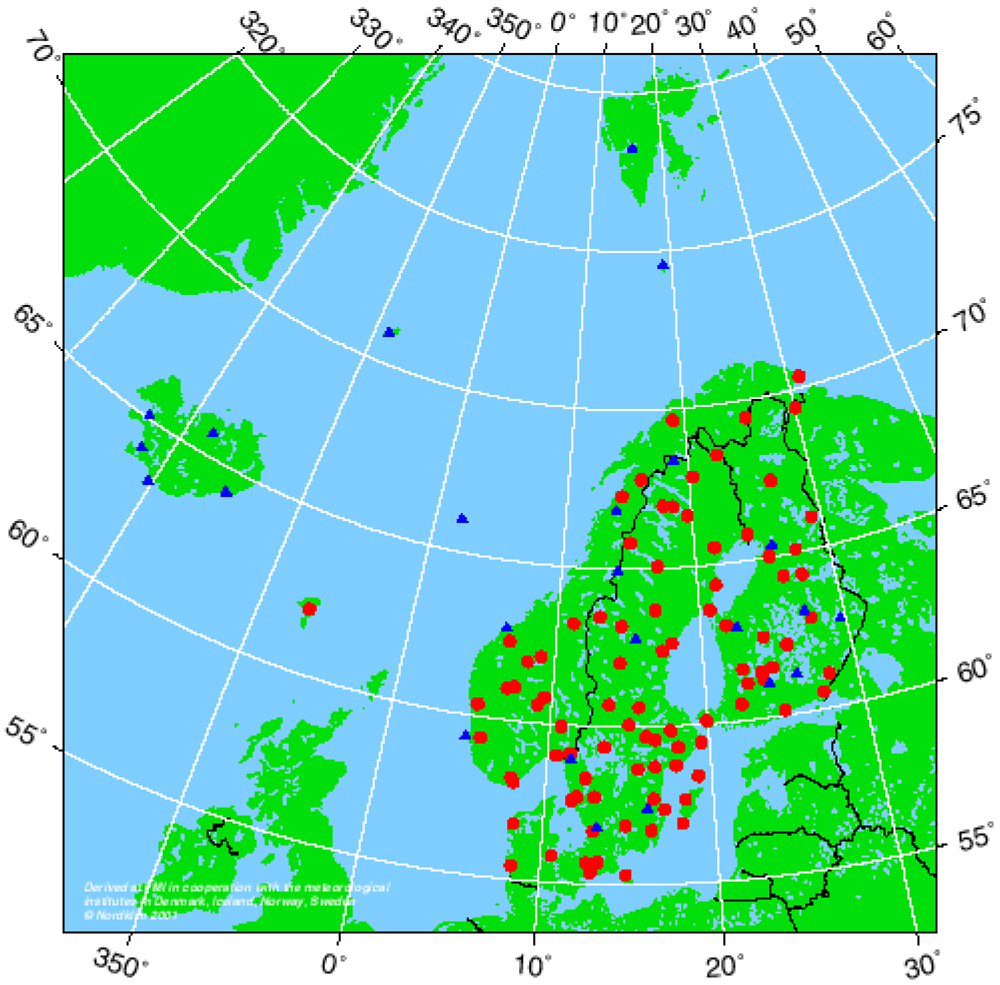

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Figure 1. Station map of the NORDKLIM data set. Stations with data series longer than 90 years are marked with red dots. Stations with shorter records are marked with black triangles.

NORDKLIM data set is built upon NACD (Frich et al. 1996) and REWARD (Drebs et al. 1998) data sets by updating them to year 1999. Because of its history NORDKLIM data set contains stations that have only a limited set of the elements listed in Table 1. Eleven stations have all twelve elements listed in Table 1 (Figure 2). About 40% of stations have nine or more elements. There are roughly equally many stations containing only one or two precipitation elements (Figure 2). More than half of the time series start during the 1890s or earlier (Figure 3). The shorter (less than 50 years) time series are mostly from the remote Arctic islands.

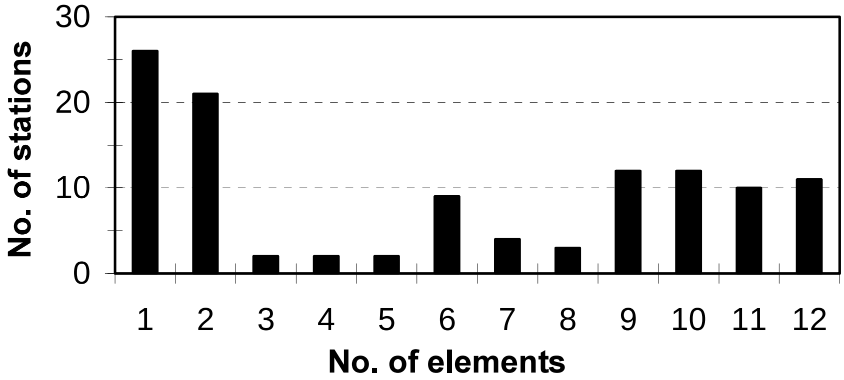

Figure 2. Number of stations as a function of number of climatic elements in the NORDKLIM data set.

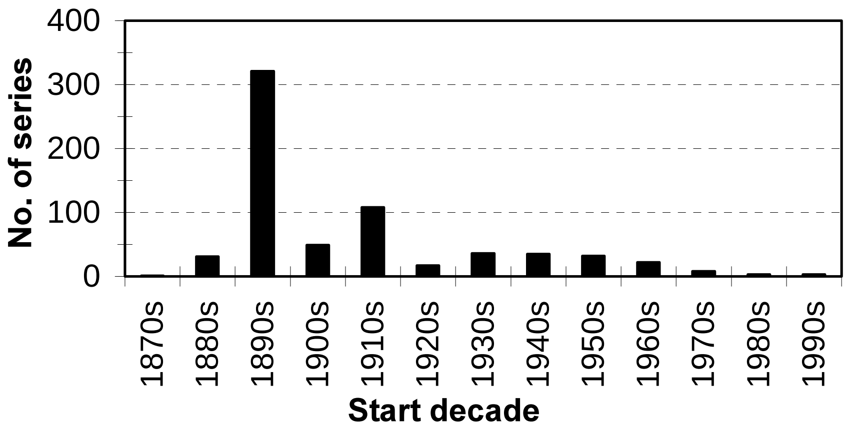

Figure 3. Number of time series as a function of the start year (decade) of the data in the NORDKLIM data set.

There have been several changes in the observing network during the 1990s, for example, some stations have been closed. Hence it was not always possible to update time series to the end of 20th century. The changes in the observing network may have also affected the homogeneity of time series. Therefore homogeneity classifications given in NACD (Frich et al. 1996) were dropped out.

2. MAPS AND GRAPHS

In this section some maps and time series graphs are presented to depict trends during the 20th century and to illustrate different climatic elements in the NORDKLIM data set. Location of stations shown in time series graphs is indicated in Figure 4. Also some subjective characterisations on reliability and homogeneity of data are presented. Heino (1994) discusses reliability and homogeneity questions of many climatic elements.

Figure 4. Location of stations shown in Section 3.

2.1 Mean temperature

There are 68 stations with data on monthly mean temperature in the NORDKLIM data set. Mean temperatures have usually gone through quality control. They have often been tested for homogeneity breaks and possible inhomogeneities have been adjusted. However, the data may still contain some homogeneity disturbances. Especially one should notice that stations represent local conditions, which may have been effected e.g. by urbanisation.

The annual mean temperature trends during the 20th century are shown in Figure 5. (The Sen's method for trend estimation and Mann-Kendall test of statistical significance are explained in Appendix 2). Almost all the stations are showing positive trends during the 20th century and roughly half of them are statistically significant at the 95%-level. The largest positive trends in annual mean temperature are more than 1°C in 100 years. It seems quite likely that in some of the capitals (Copenhagen, Stockholm and Helsinki) the warming has been further strengthened by local urbanisation. A more typical magnitude of the 20th century warming in Nordic region is about the same as that of the global mean temperature, i.e. 0.6°C (Jones et al. 1999).

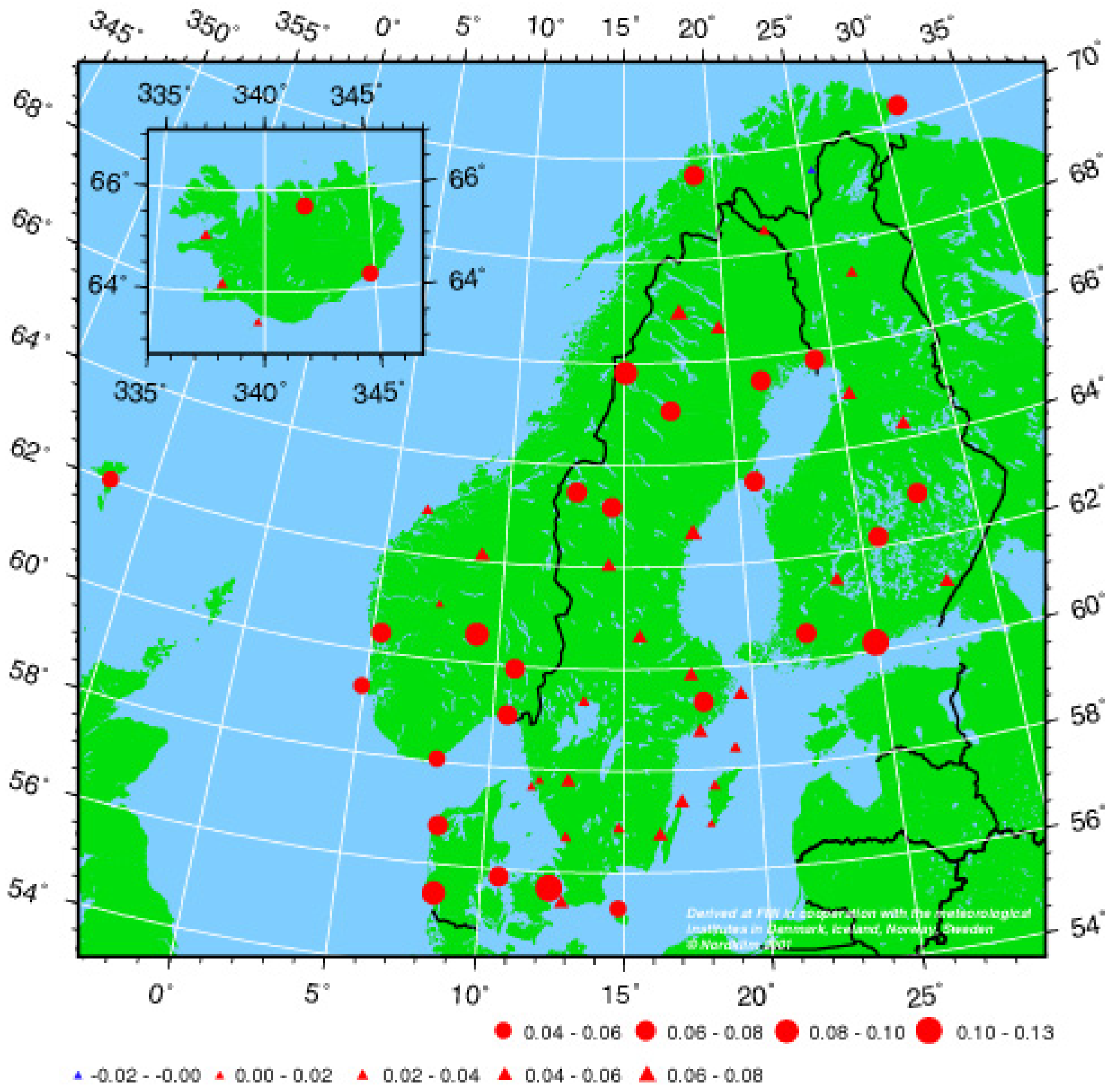

Figure 5. The 20th century temperature trends in the NORDKLIM data set (Unit: °C/decade). Annual mean temperature trends are determined using Sen's method for the period 1900-99. Statistically significant trends (Mann-Kendall test at the 5%-level) are marked with dots and non-significant trends with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

Figure 6 shows that there are many common features in the annual mean temperature series in the North Atlantic as well as in Fenno-Scandia. In general the end of the 19th century was a cool period, which was followed by a warmperiod, peaking in the 1930s or in the 1940s. The last ten years or so have been warm.

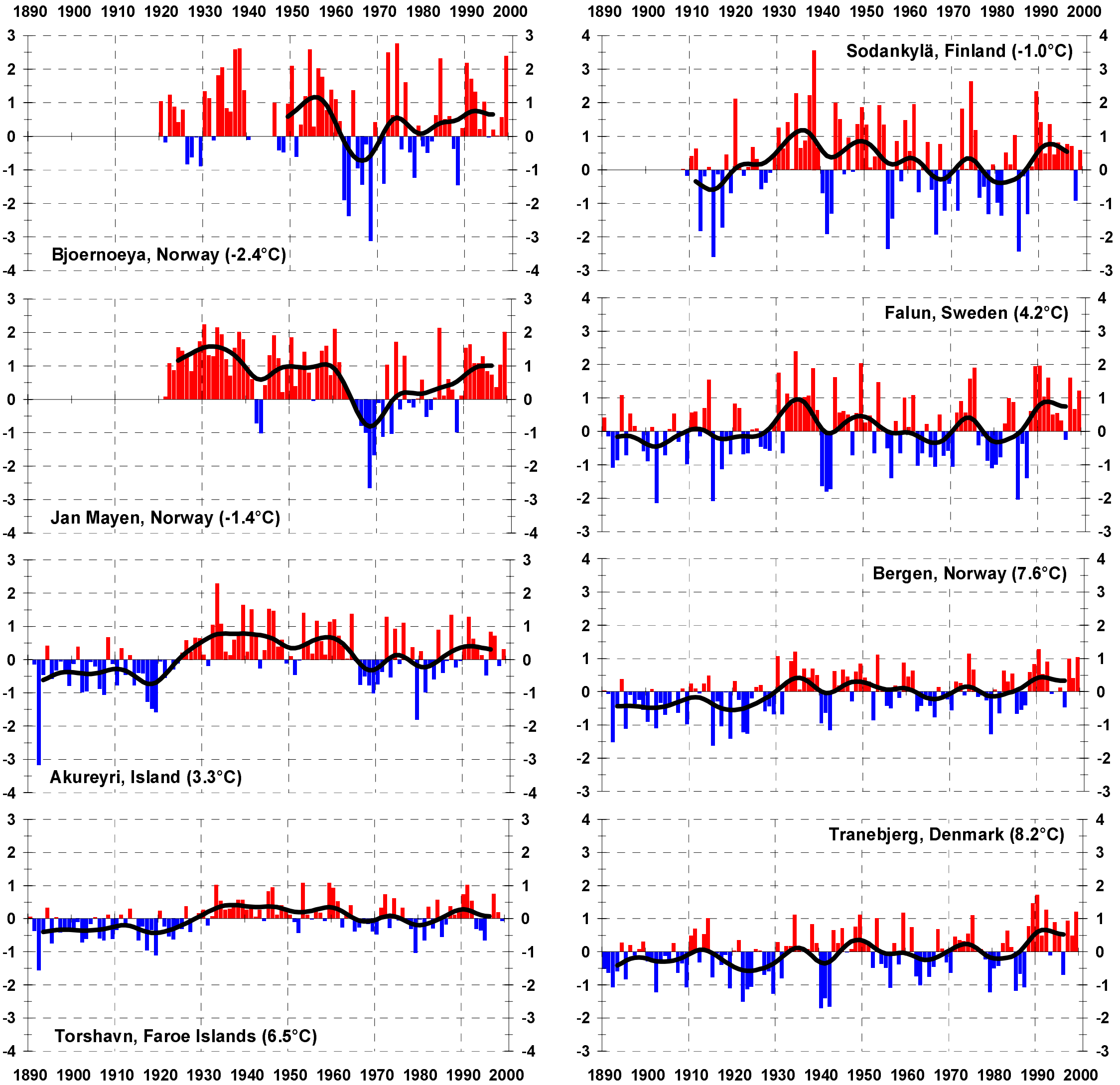

Figure 6. The annual anomalies of mean temperature for 8 stations of the NORDKLIM data set (Unit: °C). The reference period 1961-90 mean value is given in the parenthesis. The black line is smoothed with Gaussian filter (close to 10-year moving average).

The Intergovernmental Panel on Climate Change (IPCC) in its Third Assessment Report breaks the 20th century global mean temperature record into three periods: warming during the period 1910-45, no change or slight cooling from 1946 to 1975, and the recent warming period 1976-99. This characterisation fits reasonably well into Nordic temperature evolution, too. From Table 2 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.

Table 2. 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	1910-45	1946-75	1976-99
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 Island	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 (LSAT)		*0.14*	*-0.04*	*0.31*

2.2 Extreme temperatures

In the NORDKLIM data set there are about 60 stations with data on mean daily maximum and minimum temperatures, and on the highest maximum and the lowest minimum temperatures of each month. Besides quality control many of the mean daily maximum and minimum temperature series have been tested for homogeneity breaks and possible inhomogeneities have been adjusted. However the data may still contain some homogeneity discontinuities because the minimum and maximum temperatures are sensitive to station relocations, changes in the observing practices and changes in the environment of station (Tuomenvirta 2001). Only the Danish time series of the highest and lowest temperatures have been homogeneity tested.

Tuomenvirta et al. (2000) have analysed extreme temperature trends within the area covered by the NORDKLIM data set. The analysis focused on the time period 1950-95 in Fenno-Scandia and Nordic Seas and to a somewhat longer period 1910-95 in Fenno-Scandia. Their main conclusions were the following (Tuomenvirta et al. 2000):

- During the period 1950-95 mean daily maximum and minimum temperatures have increased in Fenno-Scandia as a result of the strengthening of the North Atlantic Oscillation (NAO). Trends in the Nordic Seas are minor. The far tails of the temperature distribution (highest and lowest monthly temperatures) have roughly followed the variations of mean maximums and minimums. At the same time the diurnal temperature range (DTR) has been statistically significantly decreasing.
- In Fenno-Scandia, the period 1910-95 shows smaller trends than the period 1950-95. Temperature changes are not statistically significant except the springtime increase of mean daily minimum temperatures. The narrowing of DTR is significant. To a large extent it can be explained by cloud cover increase and a strengthening of the westerly flow bringing more humid maritime air mass to Fenno-Scandia.

As an example of extreme temperature time series is shown data from Copenhagen (Figure 7). Mean minimum temperatures have increased faster than the mean maximum leading to a decrease of DTR. The highest annual temperatures have remained fairly stable while the lowest temperatures show an increase. All the above-mentioned features are typical for Fenno-Scandian area-average. However, they are probably exaggerated in the Copenhagen record due to gradual increase of the urban influence.

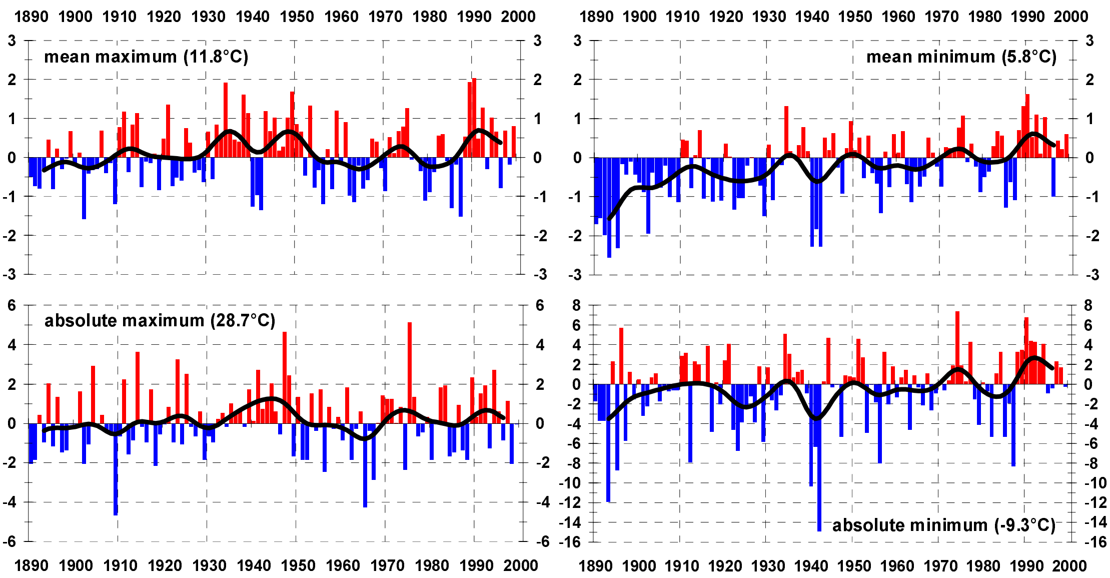

Figure 7. The annual anomalies of mean daily maximum and minimum temperatures (upper panels) and annual anomalies of the highest and lowest yearly temperatures (lower panels) in Copenhagen, Denmark (Unit: °C. N.B. The different scales in highest and lowest temperatures). The reference period 1961-90 mean value is given in the parenthesis. The black line is smoothed with Gaussian filter (close to 10-year moving average).

2.3 Precipitation sum

There are 82 stations with monthly time series of precipitation sum in the NORDKLIM data set. Precipitation data is routinely checked. The instrument changes in precipitation measurements in all countries cause some uncertainty although efforts have been taken to adjust them (Heino 1994; Hanssen-Bauer & Førland 1994). Many of the precipitation series have been homogeneity tested. Due to large temporal and spatial variability of precipitation testing is not as reliable as for temperature. For Norway the dataset (cf. Annex 1) is supplemented with some homogeneous series from stations measuring just precipitation.

The annual precipitation trends during the 20th century are shown in Figure 8. (The Sen's method for trend estimation and Mann-Kendall test of statistical significance are explained in Appendix 2.) In Fenno-Scandia, there are large differences in both annual precipitation totals (Tveito et al. 1997) as well as in long-term precipitation trends (Førland et al. 1996). To comfort comparison of stations, trends are given in percents. Most of the stations are showing positive trends during the 20th century. Some regional patterns can be seen. There are statistically significant trends in the western parts of Norway, Denmark and Sweden, which are exposed to the westerlies (Tveito 1996). Also in northern Fenno-Scandia the trends are mostly positive. In the leeward regions the trends are mixed, especially in Finland.

Figure 9 shows that the individual time series are quite different from each other and they reflect local fluctuations in precipitation. However, many of stations have experienced positive anomalies during the end of the 20th century.

2.4 Maximum 1-day precipitation

There are 76 stations with monthly time series of maximum 1-day precipitation in the NORDKLIM data set. The maximum 1-day precipitation time series have not been homogeneity tested, but it is quite likely that these data are not as sensitive to inhomogeneities as monthly precipitation sums (Førland et al. 1998b).

Førland et al. (1998b) analysed data for the period 1880-1996 covering the area of the NORDKLIM data set. Their main conclusions were:

- 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.

- The 100-year return period values of 1-day precipitation are in the interval 50-75 mm in large parts of the Nordic regions. Exceptions are a small area at the Baltic coast of Sweden, and stations in eastern Norway and southern Iceland with estimates exceeding 100 mm/day.
- The single station series are no ideal indicators for revealing trends. However, by grouping all national stations 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.

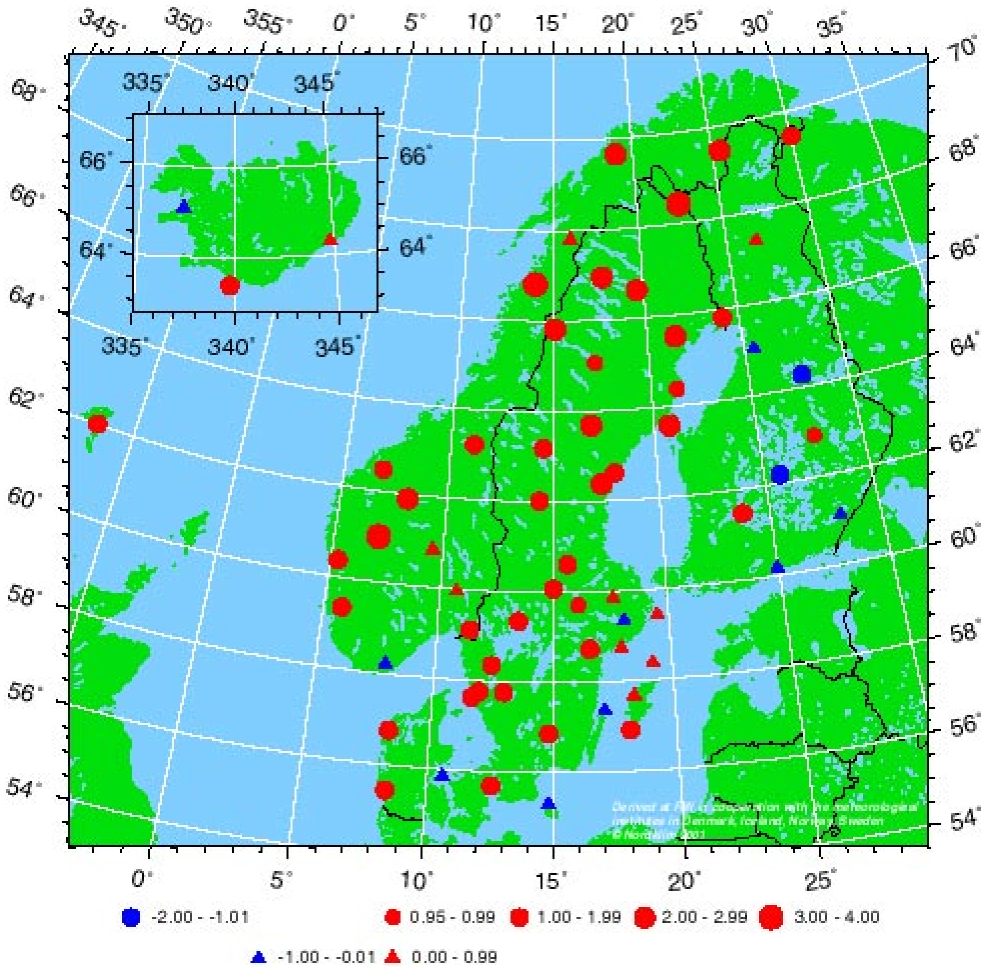

Figure 8. The 20th century precipitation trends in the NORDKLIM data set (Unit: %/decade). Annual precipitation trends are determined using Sen's method for the period 1900-99. The base period is 1961-90. Statistically significant trends (Mann-Kendall test at the 5%-level) are marked with dots and non-significant trends with triangles. Stations with more than 91 years of data are shown.

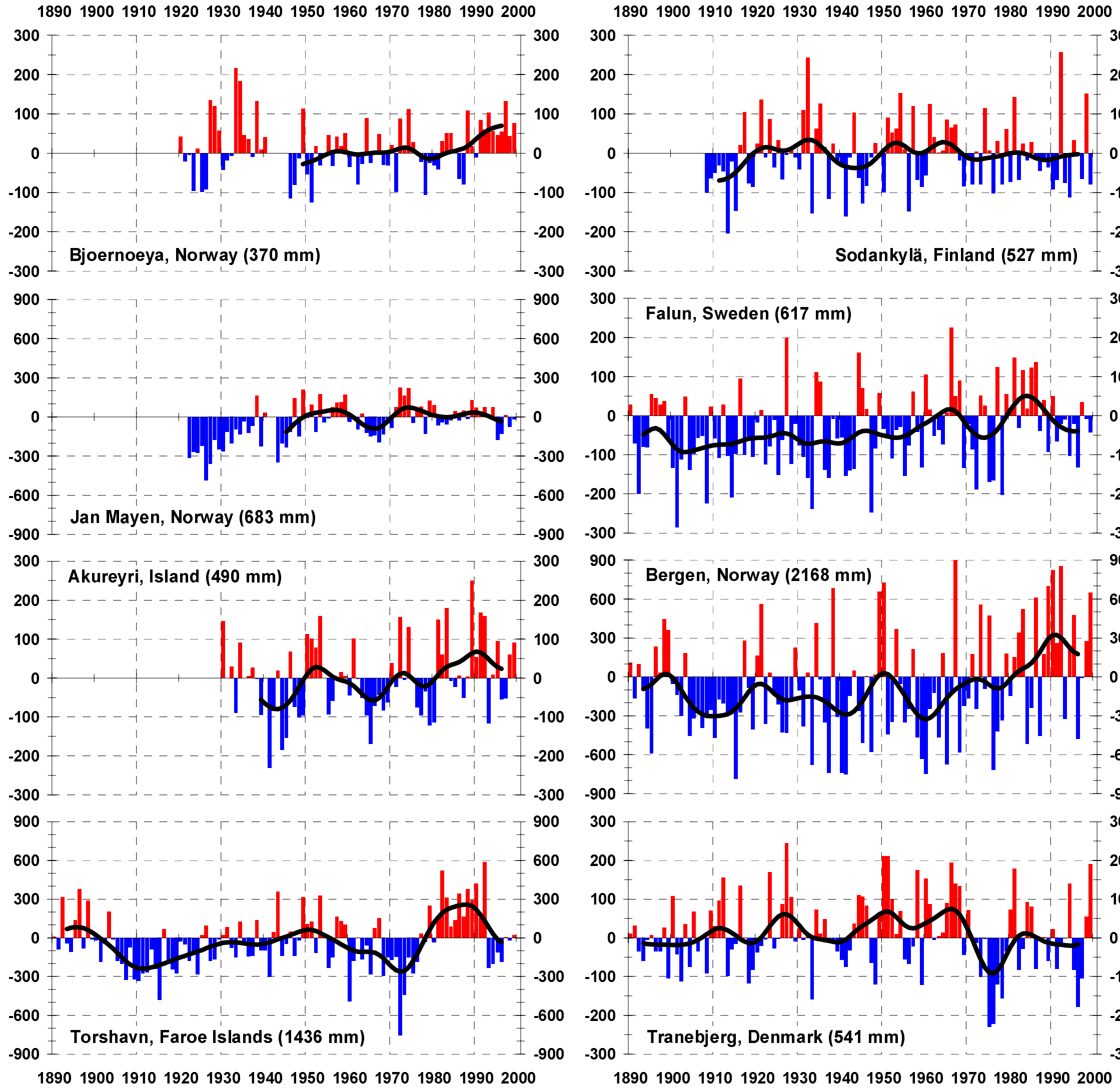

Figure 9. The annual anomalies of precipitation sum for 8 stations of the NORDKLIM data set (Unit: mm. N.B. The different scales on precipitation anomalies). The reference period 1961-90 mean value is given in the parenthesis. The black line is smoothed with Gaussian filter (close to 10-year moving average).

As an example, eight time series of the annual anomalies of the highest 1-day precipitation sum are shown in Figure 10. As the processes responsible for extreme heavy precipitation differ from region to region, it is hardly surprising that the single station series have quite little in common.

2.5 Snow cover

There are 43 stations with information on the number of days with snow cover (>50% of the ground covered by snow). In the NORDKLIM data set, the snow cover series are in general somewhat shorter than e.g. temperature series. Snow data has not been homogeneity tested. Changes of observing site or in the environment of the observing site may disturb homogeneity at single stations, but in general, snow cover time series are believed to be free of any systematic biases.

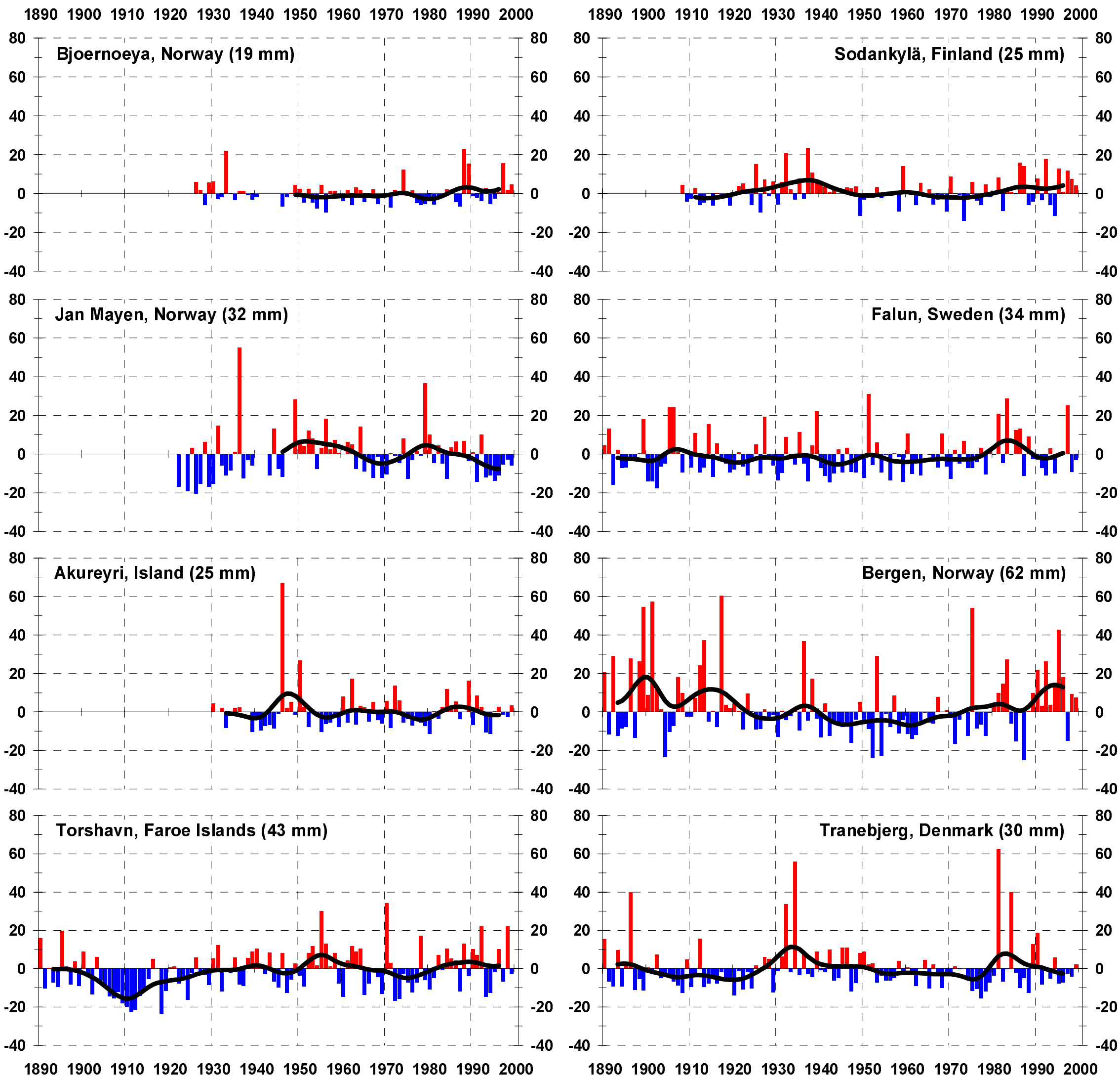

Figure 10. The annual anomalies of the highest 1-day precipitation sum for 8 stations of the NORDKLIM data set (Unit: mm). The reference period 1961-90 mean value is given in the parenthesis. The black line is smoothed with Gaussian filter (close to 10-year moving average).

There are large differences in the number of snow cover days within the NORDKLIM area. In the south and maritime locations there usually does not develop permanent snow cover while in the north and mountain regions the ground is covered by snow during the greater part of the year. The response of snow cover to temperature and precipitation changes is complex and varies from region to region.

The four stations shown in Figure 11 display quite different behaviour. In Denmark the number of snow cover days is sensitive to the temperature of mid-winter months. In Lapland it is the autumn and spring temperatures together with winter precipitation that control the length of the snow cover season.

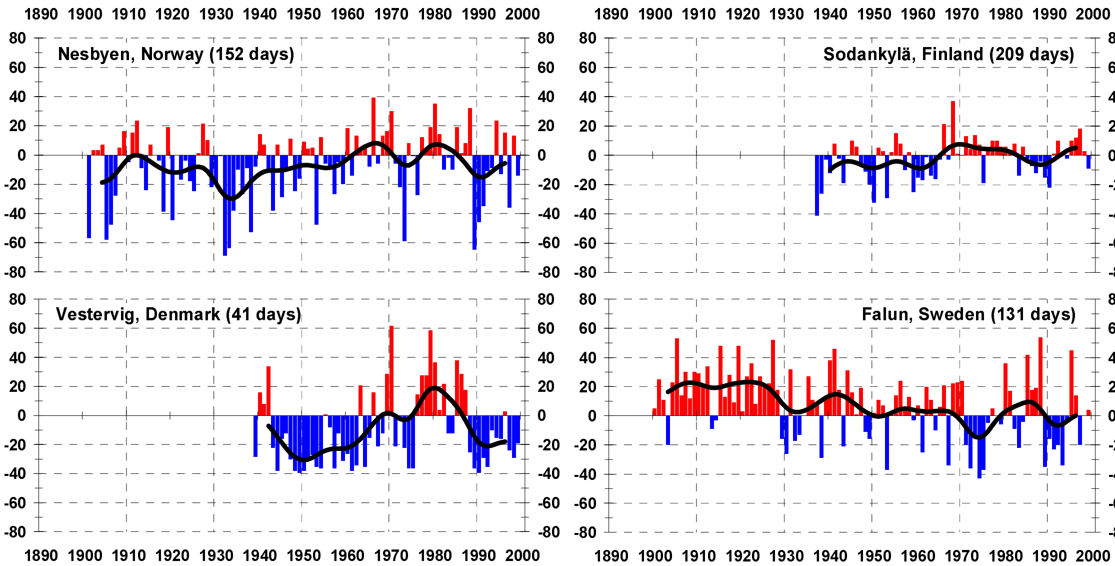

Figure 11. The annual anomalies of snow cover for 4 stations of the NORDKLIM data set (Unit: days). The reference period 1961-90 mean value is given in the parenthesis. The black line is smoothed with Gaussian filter (close to 10-year moving average).

2.6 Cloud cover

Monthly mean cloud cover data is compiled from 43 stations in the NORDKLIM data set. Cloud cover is based on visual observation by the observer. Therefore, it can be expected that single stations may contain susceptible values and inhomogeneities due to the subjective nature of the cloud cover observation. However, Tuomenvirta et al. (2000) found that the cloud cover quite successfully explains diurnal temperature variations (DTR) variations in Fenno-Scandian area-averages. This gives an indication that there are no systematic biases in the cloud cover data.

The four stations selected as examples in Figure 12 are far apart from each other and they show no common time evolution. Potentially, cloud cover is an interesting element because it controls both incoming short-wave radiative flux as well as outgoing long-wave flux.

There are 36 stations with time series of monthly mean air pressure at sea level. Most of the data have been homogeneity tested. Air pressure observations are regarded reliable and free from any systematic biases, on condition that the height of barometer above sea level is known.

Instead of single station time series, Figure 13 displays wintertime (November-March) pressure gradients in the south-north and west-east directions over Fenno-Scandia. The strength of the zonal and meridional geostrophic circulation is directly proportional to the pressure gradients. The mean meridional component of flow is usually from the south, but for a few years there is a component from the north.

Zonal flow is dominantly westerly. However, there are year-to-year and decadal scale variations and a rising trend due to the exceptionally strong westerly flow during the last ten winters or so. This increased advection of humid, relative warm air mass to a large extent "explains" some of the characteristics of the 1990s, i.e. the mild winters in Fenno-Scandia and abundant precipitation in regions experiencing orographic enhancement during westerlies.

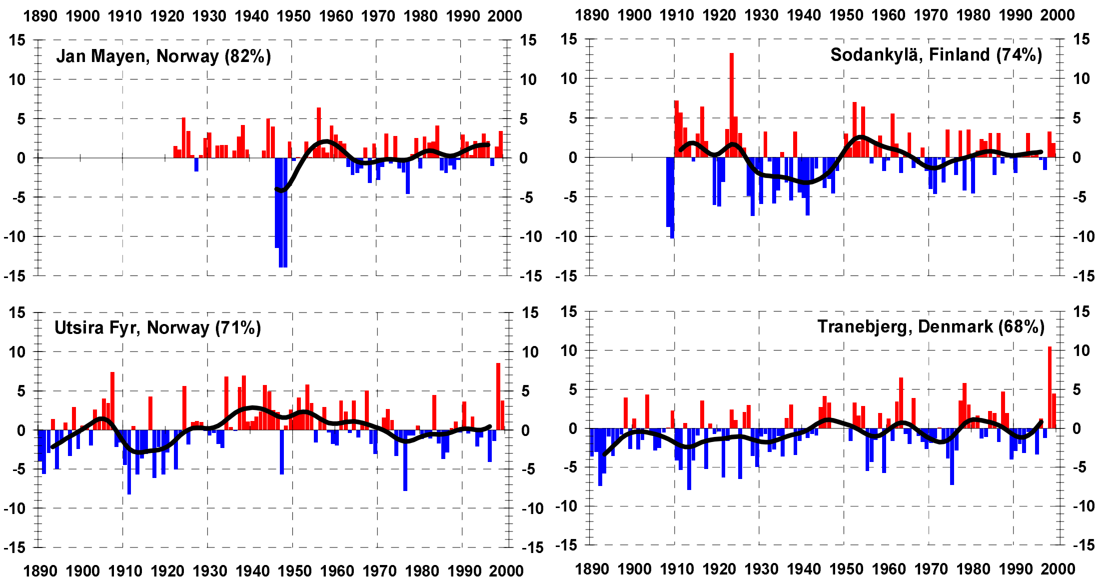

Figure 12. The annual anomalies of cloud cover for 4 stations of the NORDKLIM data set (Unit: percent). The reference period 1961-90 mean value is given in the parenthesis. The black line is smoothed with Gaussian filter (close to 10-year moving average).

2.7 Air pressure at sea level

The atmospheric circulation variability in Fenno-Scandia is connected to large-scale mode of natural climate variability, i.e. to the North Atlantic Oscillation (NAO) (Hurrell and van Loon 1997) or to the hemispheric pattern often called the Arctic Oscillation (Thompson and Wallace 1998). From Figure 14 can be seen that there are similarities between the regional (Fenno-Scandian) and large-scale (NAO) indices. Correlation coefficient between the two series is 0.68. Both series show rising trend from the 1970s, but it is not known what causes it.

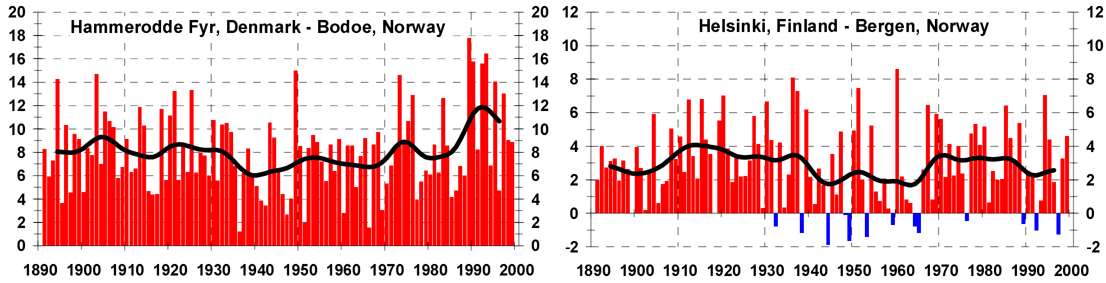

Figure 13. The wintertime (November-March) sea level pressure difference between Hammerodde, Denmark and Bodoe, Norway (left panel), and between Helsinki, Finland and Bergen, Norway (right panel) (Unit: hPa). The black line is smoothed with Gaussian filter (close to 10-year moving average).

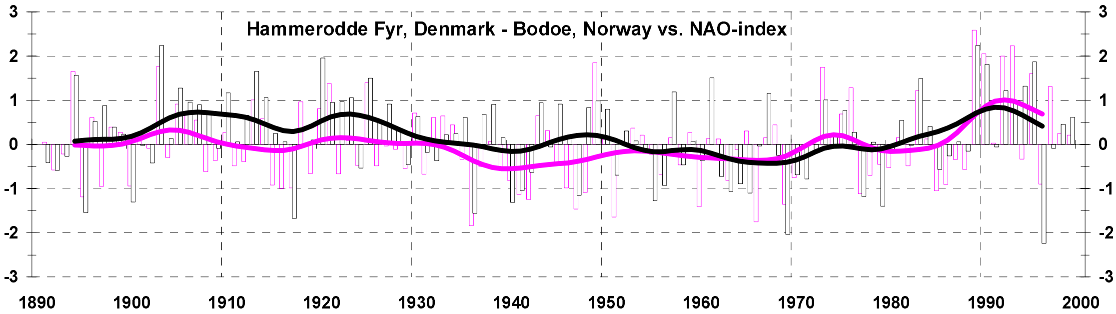

Figure 14. The wintertime (November-March) NAO index (black bars and curve) (Jones et al. 1997 and updates) and the sea level pressure difference between Hammerodde, Denmark and Bodoe, Norway (violet bars and curve). Both indices have been normalised and standardised using the normal period 1961-90 (the normal period mean value have been subtracted from the indices and they have been divided with the standard deviation). The lines are smoothed with Gaussian filter (close to 10-year moving average). (Unit: dimensionless).

3. CONCLUSIONS

The NORDKLIM data set is a unique and useful achievement for climate analysis, because of its many climatic elements and its multinational area coverage. It can be used for research on climatic variations and changes. The major climatic trends and variations within Nordic countries can be characterised with it. Also, many of the elements can be used in climate applications.

Further work is needed to improve the coverage and reliability of the data. As the station network is changing all the time, homogeneity testing needs to become an ongoing task with sufficient resources. There is some potential to extend some of the series even further back in time, and to add supplementary stations and elements to the data set .

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APPENDIX 1

The NORDKLIM Station Catalogue

Following information is given in the station catalogue:

Station name

Alt. Altitude of station in meters (above sea level)

Nat. Country of station

Num. NORDKLIM station number

Lat. Latitude of station in degrees and minutes

Lon. Longitude of station in degrees and minutes

Start year of each climatic element (see Table 1 for explanation)

Station name	**Alt.**	**Nat.**	**Num.**	**Lat.**	**Lon.**	**101**	**111**	**112**	**113**	**121**	**122**	**123**	**401**	**601**	**602**	**701**	**801**
Hammerodde Fyr	11	DK	6193	55 18 N	14 47 E	1890	1890	1890		1890	1890		1890	1890	1890	1890	1890
Vestervig	18	DK	21100	56 46 N	08 19 E	1890	1890	1890		1890	1890		1890	1890	1890	1939	1890
Nordby	5	DK	25140	55 26 N	08 24 E	1890	1890	1890		1890	1890		1890	1890	1890	1890	1890
Tranebjerg	11	DK	27080	55 51 N	10 36 E	1890	1890	1890		1890	1890			1890	1890	1948	1890
Koebenhavn	9	DK	30380	55 41 N	12 32 E	1890	1890	1890		1890	1890			1890	1890	1890	1890
Maarianhamina	4	FIN	00001	60 07 N	19 54 E		1908	1908	1908	1908	1908	1908					
Helsinki	4	FIN	00304	60 10 N	24 57 E	1890	1882	1882	1882	1882	1882	1882	1890	1890	1882	1937	1890
Turku	51	FIN	01101	60 31 N	22 16 E	1890	1903	1903	1903	1903	1903	1903		1909	1891	1937	1955
Huittinen	60	FIN	01103	61 10 N	22 47 E		1901	1901	1901	1901	1901	1901			1894		
Tampere	85	FIN	01202	61 28 N	23 45 E	1890	1902	1902	1902	1902	1902	1902		1890	1891	1950	
Hattula	88	FIN	01303	61 04 N	24 14 E		1925	1925	1925	1925	1925	1925					
Heinola	100	FIN	01506	61 13 N	26 03 E		1909	1909	1909	1909	1909	1909					
Virolahti	22	FIN	01601	60 32 N	27 33 E										1894		
Lappeenranta	105	FIN	01701	61 05 N	28 09 E	1890	1906	1906	1906	1906	1906	1906		1890	1886	1957	1958
Lavia	60	FIN	02104	61 37 N	22 33 E										1903		
Virrat	128	FIN	02211	61 13 N	23 50 E										1909		
Orivesi	89	FIN	02306	61 33 N	24 32 E										1891		
Jyvaeskylae	137	FIN	02425	62 12 N	25 43 E	1890	1902	1902	1902	1902	1902	1902		1890	1891		
Vaasa	4	FIN	03001	63 03 N	21 46 E		1908	1908	1908	1908	1908	1908					
Ylistaro	26	FIN	03101	62 56 N	22 30 E		1928	1928	1928	1928	1928	1928					
Aehtaeri	157	FIN	03301	62 32 N	24 13 E		1910	1910	1910	1910	1910	1910					
Kuopio	119	FIN	03602	62 54 N	27 41 E	1890	1902	1902	1902	1902	1902	1902		1890	1891	1957	
Maaninka	88	FIN	03603	63 09 N	27 19 E		1930	1930	1930	1930	1930	1930					
Joensuu	116	FIN	03801	62 40 N	29 38 E		1933	1933	1933	1933	1933	1933					
Kestilä	95	FIN	04509	64 21 N	26 17 E										1909		
Kajaani	132	FIN	04601	64 17 N	27 40 E	1890	1903	1903	1903	1903	1903	1903		1890	1886	1937	1957
Oulu	13	FIN	05404	65 02 N	25 29 E	1890	1905	1905	1905	1905	1905	1905	1890	1890	5404		
Yli-Ii	45	FIN	05407	65 22 N	25 51 E										1912		
Pudasjärvi	220	FIN	05605	65 06 N	27 32 E										1909		
Kuusamo	263	FIN	06801	65 59 N	29 13 E	1908	1908	1908	1908	1908	1908	1908		1908	1908	1937	
Sodankylae	179	FIN	07501	67 22 N	26 39 E	1908	1908	1908	1908	1908	1908	1908	1908	1908	1908	1937	1908
Torshavn	43	FR	06011	62 01 N	06 46 W	1890	1890	1890		1890	1890		1890	1890	1890	1939	1890
Stykkisholmur	8	IS	04013	65 05 N	22 44 W	1890	1952	1952	1952	1952	1952	1952	1890	1890	1890	1965	1890
Reykjavik	52	IS	04030	64 08 N	21 54 W	1870	1949	1949	1949	1949	1949	1949	1920	1920	1924	1965	1991

Station name	**Alt.**	**Nat.**	**Num.**	**Lat.**	**Lon.**	**101**	**111**	**112**	**113**	**121**	**122**	**123**	**401**	**601**	**602**	**701**	**801**
Vestmannaeyar	118	IS	04048	63 24 N	20 17 W	1878	1949	1949	1949	1949	1949	1949	1890	1890	1890	1924	1890
Akureyri	23	IS	04063	65 41 N	18 05 W	1882	1949	1949	1949	1949	1949	1949	1890	1928	1925	1924	1991
Teigarhorn	14	IS	04092	64 18 N	15 12 W	1890	1965	1965	1965	1965	1965	1965	1890	1890	1890	1924	1890
Halden	8	N	1230	59 07 N	11 23 E									1895	1895		
Skjaak	432	N	15660	61 54 N	08 10 E									1896	1896		
Kjoeremsgrendi	626	N	16740	62 06 N	09 03 E	1890	1931	1931		1876	1890		1890		1890	1931	1890
Oslo-Blindern	94	N	18700	59 57 N	10 43 E	1890	1937	1890		1876	1890		1890	1895	1890	1901	1890
Reinli	628	N	22840	60 50 N	09 30 E									1895	1895		
Nesbyen	167	N	24880	60 34 N	09 07 E	1897	1954	1954		1897	1897		1990		1897	1901	1895
Ferder Fyr	6	N	27500	59 02 N	10 32 E	1890	1931	1931		1885	1890		1890		1890		1890
Oksoey Fyr	9	N	39100	58 04 N	08 03 E	1890	1931	1931		1876	1890		1890		1890	1938	1890
Mestad	151	N	39220	58 13 N	07 54 E									1900	1900		
Nedstrand	10	N	47020	59 21 N	05 48 E									1895	1895		
Utsira Fyr	55	N	47300	59 18 N	04 53 E	1890	1931	1931		1876	1890		1921		1920	1945	1890
Bergen-Florida	12	N	50540	60 23 N	05 20 E	1890	1904	1890		1890	1890		1890	1895	1890	1906	1890
Laerdal	36	N	54120	61 04 N	07 31 E	1890	1953	1953		1876	1890		1890		1890	1945	1890
Vetti	329	N	54900	61 00 N	07 01 E									1895	1895		
Oerskog	4	N	60800	62 29 N	06 49 E									1895	1895		
Ona	13	N	62480	62 52 N	06 32 E	1890	1931	1931		1876	1890		1926		1919	1945	1890
Lien I Selbu	255	N	68330	63 13 N	11 07 E									1895	1895		
Vaernes/Trondheim	12	N	69100	63 28 N	12 56 E	1890		1890			1890		1890		1890		1890
Ship "M"	0	N	76900	66 00 N	02 00 E	1949	1949	1949		1949	1949		1949				1949
Glomfjord	39	N	80700	66 49 N	13 59 E	1890	1957	1957		1957	1957			1895	1990		1990
Bodoe	11	N	82290	67 16 N	14 26 E			1890			1890		1890				1890
Kraakmo	76	N	83500	67 48 N	15 59 E									1895	1895		
Tromsoe	100	N	90450	69 39 N	18 56 E	1890	1931	1931		1876	1890		1890	1890	1890	1901	1890
Karasjok	129	N	97250	69 28 N	25 31 E	1890	1950	1950		1877	1890		1890	1895	1890	1901	1890
Vardoe	14	N	98550	70 22 N	31 05 E	1890	1931	1931		1876	1890		1890		1893	1901	1890
Bjoernsund	28	N	99450	69 27 N	30 04 E									1895	1895		
Bjoernoeya	16	N	99710	74 31 N	19 01 E	1920	1937	1937		1921	1921		1920	1920	1926		1920
Svalbard Lufthavn	28	N	99840	78 15 N	15 28 E	1911		1957			1957		1934	1975	1957	1975	1975
Jan Mayen	10	N	99950	70 56 N	08 40 W	1921	1937	1937		1921	1921		1921	1921	1922		1921
Falsterbo	5	S	5223	55 23 N	12 49 E	1890											
Lund	50	S	5343	55 42 N	13 12 E										1885		
Halmstad	25	S	6240	56 40 N	12 55 E	1890								1890	1885		

Station name	**Alt.**	**Nat.**	**Num.**	**Lat.**	**Lon.**	**101**	**111**	**112**	**113**	**121**	**122**	**123**	**401**	**601**	**602**	**701**	**801**
Havraryd	185	S	6348	56 47 N	13 08 E									1912			
Vaexjoe	166	S	6452	56 52 N	14 48 E	1890	1873	1885	1885	1873	1885	1885		1890	1873	1900	1890
Kalmar	15	S	6641	56 43 N	16 17 E	1890							1890	1890	1885		
Hoburg	38	S	6855	56 55 N	18 08 E	1890								1890			
Vinga	19	S	7138	57 38 N	11 36 E	1890								1890			
Goeteborg	20	S	7147	57 46 N	11 53 E	1890	1881	1885	1885	1881	1885	1885	1890	1890	1881	1900	1890
Boraas	135	S	7245	57 46 N	12 56 E	1890								1890			
Krokshult	130	S	7623	57 23 N	16 05 E									1912			
Vaestervik	33	S	7647	57 43 N	16 28 E			1885	1885		1885	1885			1885		
Oelands Norra Udde	4	S	7722	57 22 N	17 06 E	1890								1890			
Visby	42	S	7840	57 40 N	18 20 E	1890	1879	1885	1885	1879	1885	1885	1890	1890	1879	1900	1890
Haavelund	100	S	8157	58 56 N	11 26 E									1911			
Vaenersborg	50	S	8223	58 21 N	12 22 E									1890			
Linköping	93	S	8524	58 40 N	15 32 E										1885		
Aalberga	25	S	8645	58 44 N	16 33 E									1890			
Landsort	13	S	8745	58 44 N	17 52 E	1890								1890			
Gotska Sandoen	12	S	8924	58 23 N	19 11 E	1890								1890			
Karlstad	46	S	9322	59 21 N	13 28 E	1890	1881	1885	1885	1881	1885	1885		1890	1881	1900	1890
Vaesteraas	6	S	9635	59 35 N	16 37 E										1885		
Lisjoe	60	S	9642	59 42 N	16 04 E									1890			
Uppsala	13	S	9752	59 51 N	17 37 E	1890							1890	1890		1890	1890
Stockholm	44	S	9821	59 20 N	18 03 E	1890	1873	1885	1885	1873	1885	1885		1890	1873	1900	1890
Svenksa Hoegarna	12	S	9927	59 26 N	19 30 E	1890								1890			
Malung	308	S	10341	60 42 N	13 41 E									1890			
Graengesberg	315	S	10505	60 04 N	14 59 E									1901			
Falun	160	S	10537	60 37 N	15 37 E	1890	1875	1885	1885	1875	1885	1885		1890	1875	1900	1890
Sveg	360	S	12402	62 01 N	14 21 E	1890		1885	1885		1885	1885		1890	1885		
Soesjoe	430	S	12546	62 46 N	15 29 E									1915			
Sidsjoe	60	S	12722	62 23 N	17 17 E									1890			
Haernoesand	8	S	12738	62 37 N	17 56 E	1890	1879	1885	1885	1879	1885	1885	1890	1890	1879	1900	1890
Oestersund	376	S	13411	63 11 N	14 29 E	1890	1875	1885	1885	1875	1885	1885		1890	1875	1900	1890
Junsele	210	S	13642	63 41 N	16 52 E									1890			
Holmoegadd	6	S	14036	63 35 N	20 45 E	1890								1890			
Leipikvattnet	475	S	14456	64 55 N	14 09 E									1914			
Loevaanger	21	S	15122	64 22 N	21 19 E									1890			

Station name	**Alt.**	**Nat.**	**Num.**	**Lat.**	**Lon.**	**101**	**111**	**112**	**113**	**121**	**122**	**123**	**401**	**601**	**602**	**701**	**801**
Taernaby/Hemavan	475	S	15594	65 49 N	15 05 E	1901								1890			
Stensele	325	S	15772	65 04 N	17 09 E	1890	1885	1885	1885	1885	1885	1885		1890	1885	1900	1890
Piteaa	6	S	16179	65 32 N	21 29 E	1890								1890	1885		
Haparanda	5	S	16395	65 49 N	24 08 E	1890	1873	1885	1885	1873	1885	1885	1890	1890	1873	1900	1890
Kvikkjokk	337	S	16798	66 57 N	17 44 E	1890								1890			
Tjaamotis	300	S	16897	66 55 N	18 32 E									1909			
Jokkmokk	260	S	16988	66 37 N	19 38 E	1890	1882	1885	1885	1882	1885	1885		1890	1882	1900	1890
Kiruna	442	S	18069	67 49 N	20 20 E									1898			
Abisko	388	S	18880	68 21 N	18 49 E	1913								1913			
Karesuando	327	S	19283	68 26 N	22 31 E	1890		1885	1885		1885	1885		1890	1885		

APPENDIX 2

Significance of trends and trend estimators

The non-parametric Mann-Kendall test was chosen for testing the significance of trends, as it can be used without knowing the exact distribution of the time series (Sneyers 1990). Test statistic, t, is defined by the equation

$$t = \sum_{i=1}^{n} n_i$$

where n is the number of elements and n_i is the number of smaller elements preceding element x_i (i= 1,2,.. n) that is being tested. Providing the number of elements in the series is more than 10, the test statistic, t, is nearly normally distributed under the hypothesis of randomness (the null hypothesis). Its expectation value, E(t), and variance, $D^2(t)$, are given by the equations

$$E(t) = \frac{n(n-1)}{4}$$

$$D^2(t) = \frac{n(n-1)(2n+5)}{72}$$

The normalised distribution of the test statistic is then

$$u(t) = \frac{t - E(t)}{\sqrt{D^2(t)}}$$

The cumulative distribution function for the standard normal distribution function may be used to decide whether the null hypothesis should be rejected or not.

Robust trend estimates can be calculated with Sen's non-parametric method (Gilbert 1987), where N' slope estimates, Q, are computed as

$$Q = \frac{x_{i'} - x_i}{i' - i}$$

where $x_{i'}$ and x_i are data values at times i' and i, respectively, and where i' > i. N' is the number of data pairs for which i' > i. If there is only one datum in each time period, then N' = n(n-1)/2, where n is the number of time periods. The median of these N' values of Q is Sen's estimator of slope. It is not sensitive to outliers or gross errors and allows for gaps in the data.