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Under Global Warming

Annual and seasonal temperature variations in Norway 1876-1997

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Abstract

Norway was divided into 6 temperature regions, using a combination of principal component analysis and clusteranalysis of series of annual mean temperature. Within each region there are only minor differences between different time-series of standardised temperature. The temperature evolution within a region can thus be described by one standardised series. Consequently, the regions are convenient spatial units for describing temperature variations in the past, as well as for estimating future temperature scenarios.

Standardised regional temperature series from the 6 Norwegian temperature regions during the period 1876-1997 were analysed using linear trends, Mann-Kendall test statistics and low-pass filtering. There are positive trends in the series of annual mean temperature during this 122 year period. The temperature increase, which at most places lies between 0.4 and 1.2 °C, is statistically significant, at least at the 5% level, in all regions except the northern inland region. In all regions, the temperature increased significantly from 1876 to the 1930s and from the late 1960s and/or the 1970s to 1997. There was a temperature decrease between the 1930s and 1970 and/or 1980. In all regions, the periods of highest annual mean temperatures are found around 1935 and around 1990. The lowest annual mean temperatures are found in the very beginning of the series and/or around 1900.

In all regions except the northern inland region, there has been a statistically significant increase of the spring temperature during the period 1876-1997. In northern Norway, there was also a significant increase of summer temperatures, while the autumn temperature increased significantly in the two southernmost regions. The high annual mean temperatures around 1935 were caused by high winter-, summer- and autumn-temperatures. Around 1990, it was mainly warm winters and springs which led to high annual mean temperatures.

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Annual and seasonal temperature variations in Norway 1876 - 1997.

FOREWORD

The present report is a result from the project «Regional climate development under global warming» (Reg Clim) (Iversen et al. 1997), which is supported by the Norwegian Research Council Programme (NRC Contract No 120656/720). The work is done within the frames of Principal Task 3 «Statistical downscaling», subtask 3.1 «Establishing datasets for statistical downscaling».

1. Introduction

Nicholls et al. (1996) conclude that the global mean temperature increased by 0.3 to 0.6 °C from the late 19th century to 1995, and by 0.2 to 0.3 °C during the period 1940-1995, but that the warming has not been globally uniform. A previous analysis (Hanssen-Bauer et al. 1996) showed that Norway is in an area where the increase in annual mean temperatures during the period 1890-1990 was not statistically significant even on the 5% level. Large inter-annual variability in this area results in a high noise level which an eventual signal has to overcome.

In the present report, the long-term temperature variations and trends in Norway are investigated further. Regions which are fairly homogeneous concerning temperature variations are defined, and typical temperature series (updated to 1997) are calculated for each region, on annual, seasonal and monthly basis. The regional temperature series, which are tested for linear trends, can easily be updated by using data from a limited number of stations. The defined temperature regions will later be used for statistical downscaling of temperature scenarios in the project «RegClim» (Iversen et al. 1997).

2. Definition of temperature regions

2.1 Data

Choice of station network for definition of temperature regions is a compromise between having as many stations as possible (good spatial coverage) and as long a period as possible. Figure 1 shows the station network which was used in the present analyses. The main analyses were based on a network consisting of 46 stations (including 6 Swedish and 1 Finnish station), which all have data during the 50-year period 1931-1980. As this network is quite sparse in some areas, additional analyses were run over shorter periods, using denser station networks in such areas. In this way it was possible to define the borders between the final regions more exactly than the basic network would allow. Figure 1 shows the basic network as well as the additional stations. Some information about the stations is given in Table A.1 in Appendix. As far as possible, homogeneity tested series from the North Atlantic Climatological Dataset (Frich et al. 1996) were used.

2.2 Methods

The temperature regions are defined by using a combination of principal component analysis (PCA) and cluster analysis (Singleton and Spackman 1984). This method has earlier been applied in an evaluation of the Norwegian network of weather stations (Hanssen-Bauer and Andresen 1997). It was then used to define areas which are homogeneous concerning variations in daily minimum temperature. In the present analysis the aim is to define regions which are fairly homogeneous concerning temperature variability on longer time-scales (inter-annual and more). The method is therefore applied on annual mean temperatures. In order to investigate the stability of these regions concerning seasonal variation, analyses were also performed on seasonal mean temperatures.

The PCA (e.g. Preissendorfer 1988) was applied on the correlation matrix rather than on the covariance matrix in order to avoid dominance of inland stations with large standard deviations of temperature. The first n principal components were used in the cluster analysis. The eigenvectors were weighted by multiplying with the square root of the respective eigenvalues. For each station, the loadings could then be interpreted as its position in the n-dimensional space which is defined by the first n principal components. Cluster analysis was performed in this space by a method called «nearest centroid sorting» (Anderberg 1973). The analyses were performed using the SAS software procedures PRINCOMP and FASTCLUS (SAS Institute Inc. 1988).

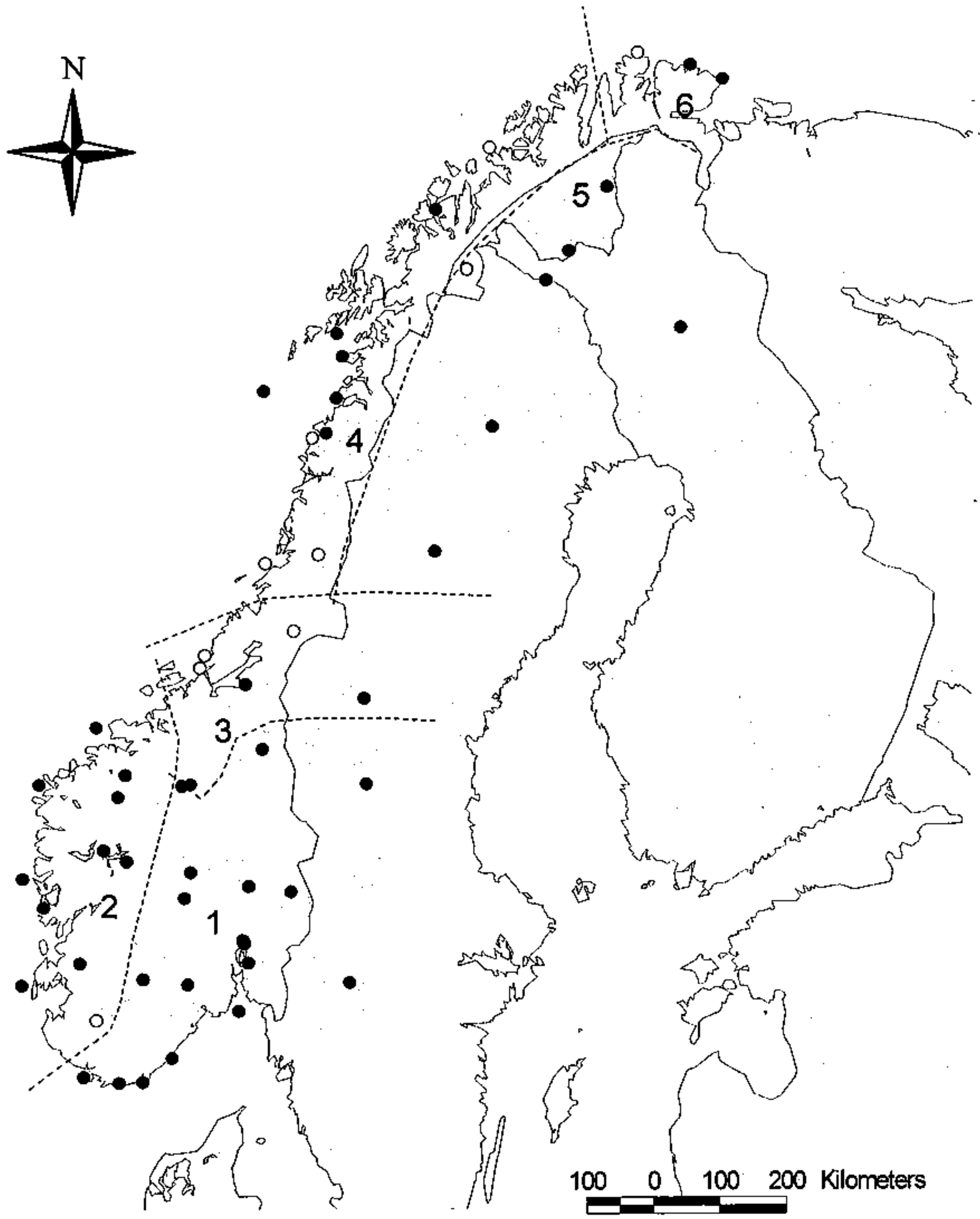


Figure 1. Stations used in the regionalisation, and the resulting 6 temperature regions. Black dots show stations used in the main analyses, while white dots show additional stations used in supplementary analyses. Dotted lines show the borders between the temperature regions.

2.3 Results

The main analyses were performed on annual mean temperatures. Ten principal components, which together account for more than 98% of the variance in the standardised dataset (Table 2.1), were used in the cluster analysis. The 46 stations were then clustered in 6 groups, for which some basic information is given in Table 2.2. The regions R1-R6 defined by the clusters are shown in Figure 1. The final borders between the regions were defined after making supplementary analyses including all stations shown in this figure.

Table 2.1. Eigenvalues of the Correlation Matrix

PC no.	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10
Eigenvalue	37.8865	4.0108	1.0895	0.6488	0.4391	0.3689	0.2373	0.1971	0.1820	0.1375
Proportion	0.8236	0.0872	0.0237	0.0141	0.0095	0.0080	0.0052	0.0043	0.0040	0.0030
Cumulative	0.8236	0.9108	0.9345	0.9486	0.9581	0.9662	0.9713	0.9756	0.9796	0.9826

Table 2.2. Basic information of the 6 clusters defined from annual mean temperatures.

Cluster no.	Frequ-ency	RMS Std. Dev.	Max. Distance Seed-Observation	Nearest Cluster	Distance Between ClusterCentroids
1	18	0.0687	0.2806	2	0.3873
4	7	0.0542	0.1922	5	0.3990
2	10	0.0799	0.2733	1	0.3873
6	2	0.0341	0.0763	5	0.4356
3	3	0.0764	0.2327	1	0.4094
5	6	0.0687	0.2490	4	0.3990

In addition to the analyses based upon annual temperatures, analyses were also made on seasonal basis in order to investigate to which degree the seasonal time series for the stations within a region would show similar features also on seasonal basis. The results are given in Table 2.3. On seasonal basis, the clusters are denoted A through F in order to distinguish them from the main clusters 1 through 6, which are based upon annual mean temperature.

In winter, the clusters are rather similar to the clusters which were found on an annual basis, with cluster A corresponding to cluster 1 etc., except for 2 features. The Mid-Norway cluster C extends further south than cluster 3, and the inland cluster F is considerably smaller than cluster 5. In spring, the entire pattern of clusters seems to be rotated compared to the annual pattern. Cluster A includes the southern parts of cluster 1 and cluster 2. Cluster B includes the rest of cluster 2, while the rest of

Table 2.3 Results from cluster analysis on seasonal and annual basis

The columns show which cluster the stations belong to in winter, spring, summer, autumn, and on annual basis. Key stations are written in bold types.

STATION	WINTER	SPRING	SUMMER	AUTUMN	ANNUAL
06040	**A**	**C**	**C**	**A**	**1**
10400	C	C	C	A	1
11500	A	C	A	A	1
16610	C	C	C	A	3
16740	C	C	C	A	1
17850	A	A	A	A	1
18700	A	A	A	A	1
18950	C	A	A	A	1
23160	C	C	A	A	1
24880	A	C	A	C	1
27500	**A**	**A**	**A**	**A**	**1**
32100	A	A	A	C	1
33060	A	A	A	C	1
36200	A	A	A	A	1
39100	B	A	A	A	1
41110	A	A	A	A	1
42160	B	A	C	B	1
46610	B	B	B	C	2
47300	**B**	**A**	**D**	**B**	**2**
50540	B	B	B	B	2
52530	B	B	D	B	2
54130	**B**	**B**	**B**	**C**	**2**
55780	B	B	B	C	2
58700	B	B	B	C	2
59100	C	B	D	B	2
60500	B	B	B	C	2
62480	C	B	D	B	2
69100	**C**	**D**	**D**	**D**	**3**
80610	D	D	E	F	4
80700	**D**	**D**	**E**	**D**	**4**
82290	D	D	E	D	4
83120	D	D	E	F	4
85380	D	F	E	F	4
85950	D	F	E	F	4
90450	**D**	**F**	**E**	**F**	**4**
93900	D	E	E	E	5
97250	**D**	**F**	**E**	**E**	**5**
98400	F	F	F	F	6
98550	**F**	**F**	**F**	**F**	**6**
S-09322	A	A	A	A	1
S-12402	E	C	C	A	1
S-13411	E	C	C	D	3
S-15772	E	E	E	D	5
S-16988	E	E	E	D	5
S-19283	D	E	E	E	5
F-07501	D	E	E	E	5

cluster 1 is included in cluster C together with most of cluster 3. In northern Norway, cluster F is larger than cluster 6, and it includes parts of cluster 4 and 5. In summer, the pattern is more similar to the annual pattern. The main difference is that an additional cluster, D, is found along the west-coast of southern Norway. Thus only two clusters are left to northern Norway, and cluster E includes major parts of both cluster 4 and 5. In autumn, the mountain areas in southern Norway form a separate cluster, while cluster 3 is included in cluster D together with southern parts of cluster 4 and 5. Cluster E includes northern part of cluster 5 while cluster F is rather similar to the one found in spring.

In spite of the fact that the analyses differ from season to season, the regions R1-R6 defined from the analyses based upon annual values are used for describing typical regional variability and trend both for annual and for seasonal mean temperatures. Results from the seasonal analyses are, however, used when choosing **key stations**, which can be recommended for use in connections when original series are preferred to regional series. Key stations should be representative for their region on annual as well as on seasonal basis. At least one key station is chosen from each cluster-defined region. In the larger regions, 2 key stations are chosen, and they are chosen in order to reveal typical features in different parts of the region.

The key stations are written with bold types in Table 2.3. Two key stations are chosen in regions 1, 2 and 4. In region 1, they are chosen to represent southern and northern parts of the region, respectively, as these show some differences concerning spring and summer temperatures. In region 2, one key station is chosen at the coast and one further inland, because some differences are found in summer and autumn. Also the differences between southern and northern parts of the region concerning spring temperatures, should be covered by these key stations. In region 4, differences between south and north seem to manifest themselves mainly in spring and autumn. Thus one key station is chosen from the northern part, and one from the southern part of this region. The final choices of key stations were also based upon earlier homogeneity studies (Nordli, 1997) and on the length of the series.

3. Calculation of regional temperature series

3.1 Stations

The station network used for calculation of regional temperature series (Figure 2 and Table 3.1), consists of 43 stations of which 36 are still operative. The network is not identical to the one used in the cluster analysis. For the present purpose, it is more important that the network is evenly distributed in space, at least within each region. On the other hand, there are no problems with

Table 3.1 Stations used to calculate standardised regional series.

STATION		PERIOD		ANNUAL MEAN TEMPERATURE (°C)		RESULTS FROM PRESENT ANALYSES	
NUMBER	NAME	FROM	TO	MEAN 1961-90	STD DEV 1961-90	REGION	CORR. WITH REGION SERIES
6040	FLISA	1919	dd	3.3	1.22	R1	0.957
10400	RØROS	1871	dd	0.3	1.05	R1	0.959
11500	ØSTRE TOTEN	1930	dd	3.6	1.06	R1	0.990
16740	KJØREMSGRENDE	1864	dd	1.5	0.87	R1	0.946
18700	OSLO BLINDERN	1874	dd	5.7	0.93	R1	0.986
23160	ÅBJØRSBRÅTEN	1923	dd	1.3	0.94	R1	0.960
24880	NESBYEN SKOGLUND	1897	dd	2.7	1.18	R1	0.987
27500	FÆRDER FYR	1885	dd	7.4	0.95	R1	0.991
32100	GVARV	1919	1989	4.8	1.00	R1	0.978
37230	TVEITSUND	1944	dd	5.0	1.07	R1	0.982
39100	OKSØY FYR	1875	dd	7.3	0.90	R1	0.982
42160	LISTA FYR	1926	dd	7.4	0.78	R1	0.980
42920	SIRDAL TJØRHOM	1974	dd	3.2	0.90	R2	0.983
46610	SAUDA	1928	dd	6.2	0.80	R2	0.955
47300	UTSIRA FYR	1900	dd	7.4	0.60	R2	0.951
50540	BERGEN FLORIDA	1860	dd	7.6	0.60	R2	0.977
52530	HELLISØY FYR	1867	1992	7.4	0.56	R2	0.973
54130	LÆRDAL TØNJUM	1869	1996	5.9	0.75	R2	0.973
55780	LEIKANGER	1929	1990	6.6	0.62	R2	0.961
55840	FJÆRLAND SKARESTAD	1952	dd	5.1	0.79	R2	0.974
58700	OPPSTRYN	1897	1991	5.7	0.61	R2	0.933
59100	KRÅKENES FYR	1926	dd	7.2	0.52	R2	0.964
60500	TAFJORD	1930	dd	6.9	0.63	R2	0.920
62480	ONA	1870	dd	7.1	0.55	R2	0.936
16610	FOKSTUA	1923	dd	0.0	0.76	R3	0.979
69100	VÆRNES	1870	dd	5.0	0.82	R3	0.982
70850	KJØBLI I SNÅSA	1939	dd	3.1	0.89	R3	0.988
71550	ØRLAND	1921	dd	5.8	0.68	R3	0.984
75600	LEKA	1940	dd	5.2	0.73	R4	0.947
77420	MAJAVATN	1967	1996	1.4	1.00	R4	0.904
80700	GLOMFJORD	1916	dd	5.0	0.75	R4	0.990
82290	BODØ	1868	dd	4.5	0.69	R4	0.976
85380	SKROVA FYR	1933	dd	5.0	0.67	R4	0.978
85910	RØST	1890	1996	5.4	0.64	R4	0.986
90450	TROMSØ	1867	dd	2.5	0.77	R4	0.969
92700	LOPPA	1920	dd	3.6	0.77	R4	0.940
89950	DIVIDALEN	1936	dd	0.8	0.96	R5	0.983
93300	SUOLOVUOPMI	1963	dd	-2.4	1.09	R5	0.993
93900	SIHCAJAVRI	1913	dd	-3.1	1.19	R5	0.995
97250	KARASJOK	1876	dd	-2.4	1.36	R5	0.988
96400	SLETNES FYR	1927	dd	1.7	0.83	R6	0.998
98400	MAKKAUR FYR	1924	dd	1.6	0.87	R6	0.996
98550	VARDØ	1867	dd	1.3	0.84	R6	0.996

handling missing values. Data from the period 1876 - 1997 were used, though only 10 series cover the entire period. Additional information about the stations is given in Table A.1 in Appendix.

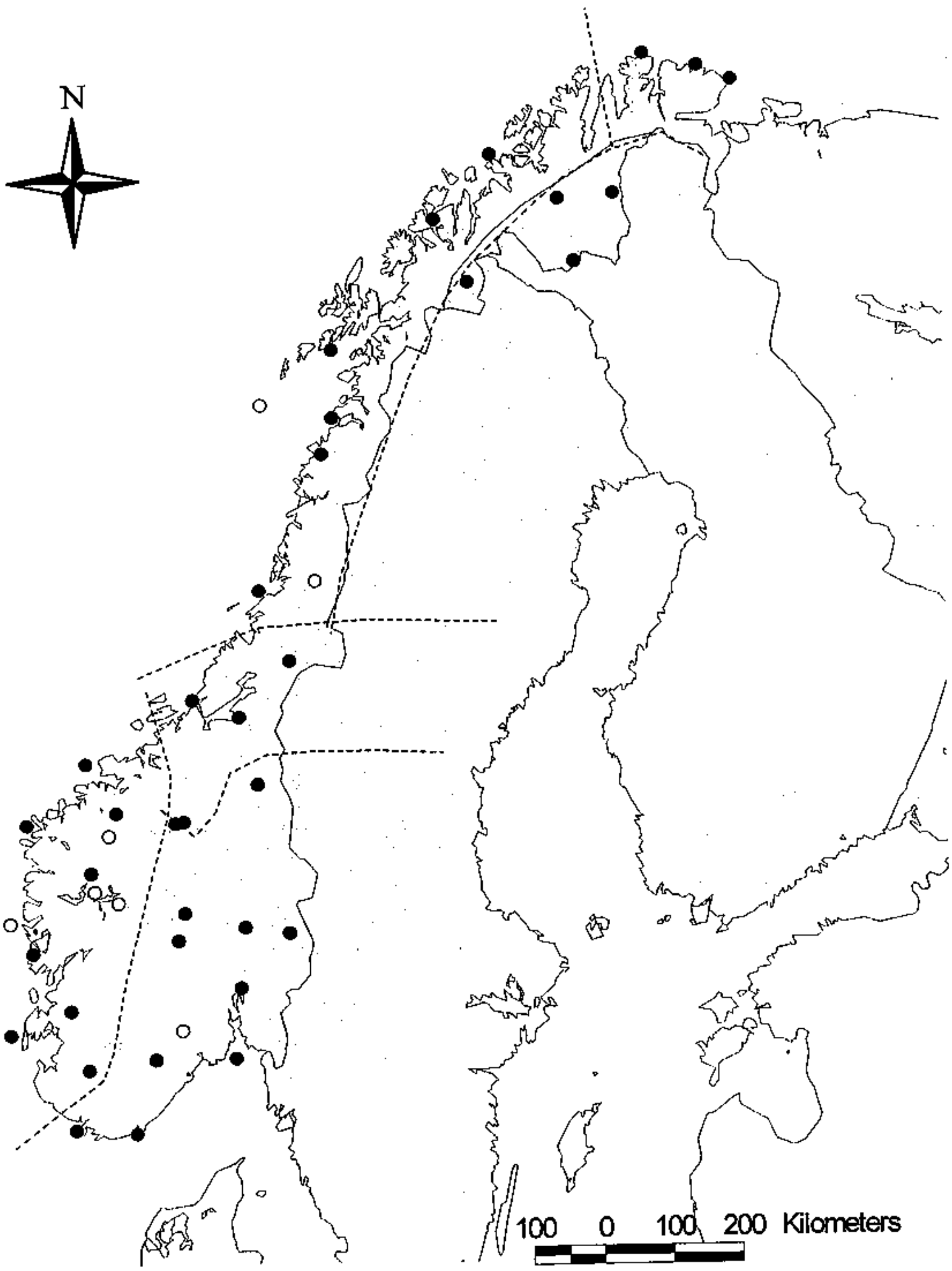


Figure 2. Stations used for calculating regional temperature series. Black dots show stations which were operative in 1997. White dots show stations which closed down before 1997.

3.2 Methods

The regionalisation was based on the correlation matrix rather than covariance. Consequently, the standardised series rather than the original ones are representative for the region. The «regional standardised temperature series» ST_m for region m, is thus defined as the average of n standardised series from region m:

$$ST_m = 1/n \cdot \sum_{i=1}^{n} ST_{m,i} \qquad m = 1,2,..,6 \qquad (3.1)$$

Here $ST_{m,i}$ is the standardised temperature series from the i'th station in region m. Series are defined based on annual, seasonal and monthly values. In order to allow the inclusion of series covering different periods, all series were standardised by subtracting the 1961-1990 average («standard normals») and dividing by the standard deviation during the same period:

$$ST_{m,i} = (T_{m,i} - \mu_{m,i}) / \sigma_{m,i} \qquad (3.2)$$

$T_{m,i}$ is the temperature series from station i in region m. Standard normals $\mu_{m,i}$ exist even for stations which were not running throughout the entire period 1961-1990 (Aune 1993). Standard deviations $\sigma_{m,i}$ for the same period were calculated or estimated in connection with the present work. Table A.2 in Appendix shows, for all stations used in the present calculations, the averages and standard deviations on monthly, seasonal and annual basis.

An advantage of the above defined standardised regional series, is that it is possible to include shorter series in addition to the very few long-term series which exist. However, even if the averaging between standardised series will preserve the zero mean value during 1961-1990, one should be aware that the standard deviation is reduced somewhat (on annual basis 0-4%) from unity. This reduction is the result of averaging out variance connected to the geographical variation within the regions, as well as random errors, and in practice it depends, to some degree, on the number of stations which is included in the calculations. Ideally, the number of stations should therefore be constant during the period which is studied, but keeping strictly to this ideal would decrease either the data coverage or the time period seriously. It is thus accepted that the number of stations included in the averages is increased from 1875 to about 1930 in order to get a reasonable geographical representation within the region. However, from the 1930s, new series are included mainly to replace series from stations which are closed down. In these cases, we try to find a new station in the same part of the region, and overlap of the series is avoided.

The increasing number of stations during the first decades is likely to affect the variance of the regional series, which would tend to be slightly higher in the beginning of the series than after 1930. One should thus be very cautious with using the regional series for studying changes with time in extremes and inter-annual variance. On the other hand, the regional series are well suited or studies of long-term trends and variability.

The standardised regional series may be used to estimate the temperature series (in $^{\circ}$ C) on annual seasonal or monthly basis in an arbitrary area x in region m:

$$T_{m,x} = ST_m \, \sigma_{m,x} + \mu_{m,x} \qquad (3.3)$$

Here, $\sigma_{m,x}$ is the standard deviation of temperature during the period 1961-90 in the area x, while $\mu_{m,x}$ is the mean value during the same period. The latter can be estimated from normal maps (Aune 1993). Similar maps with standard deviations will also be published by the Norwegian Meteorological Institute. Note that the variance of estimated series will be somewhat reduced compared to real measurements. Series of regionally averaged temperature valid for region m, T_m, can be calculated by substituting the regional averaged standard deviation and mean value, σ_m and μ_m, in equation 3.3.

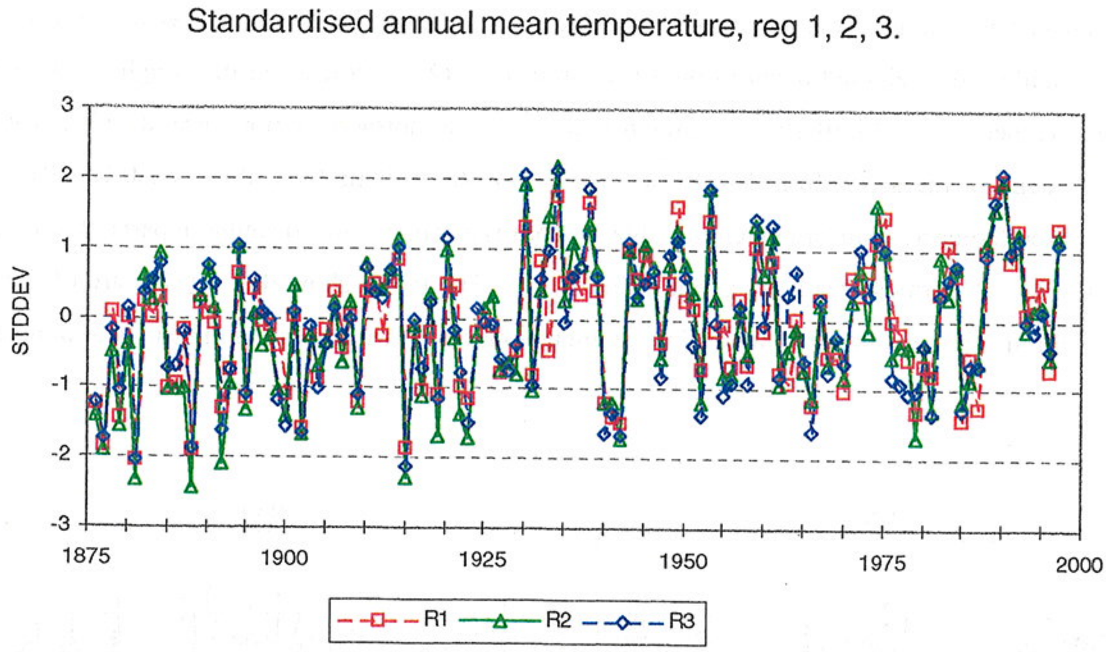
3.3 Results

Standardised temperature series for regions R1-R6 on annual, seasonal and monthly basis were calculated. Correlation coefficients between single series and the regional series on annual basis range from 0.90 to 1.00 (Table 3.1, last column). The annual series are shown in Figure 3 for the southern regions R1-R3, and the northern regions R4-R6. The correlation coefficients between northern and southern regions range from 0.66 - 0.85, while those between regions in the same part of the country range from 0.86 - 0.95 (Table 3.2).

Table 3.2 Correlation coefficients between standardised regional series (annual).

REGION	R1	R2	R3	R4	R5	R6
R1	1	0.92	0.91	0.74	0.71	0.67
R2	0.92	1	0.95	0.81	0.76	0.66
R3	0.91	0.95	1	0.85	0.84	0.69
R4	0.74	0.81	0.85	1	0.91	0.87
R5	0.71	0.76	0.84	0.91	1	0.86
R6	0.67	0.66	0.69	0.87	0.86	1

Correlation matrixes for seasonal series (not shown) are very similar to Table 3.2, except for the summer, when the correlation coefficients are lower, especially between northern and southern regions (0.20 - 0.70). Because the main differences are between southern and northern regions, seasonal series are shown only for the southern region R2 and the northern region R4 (Figure 4).



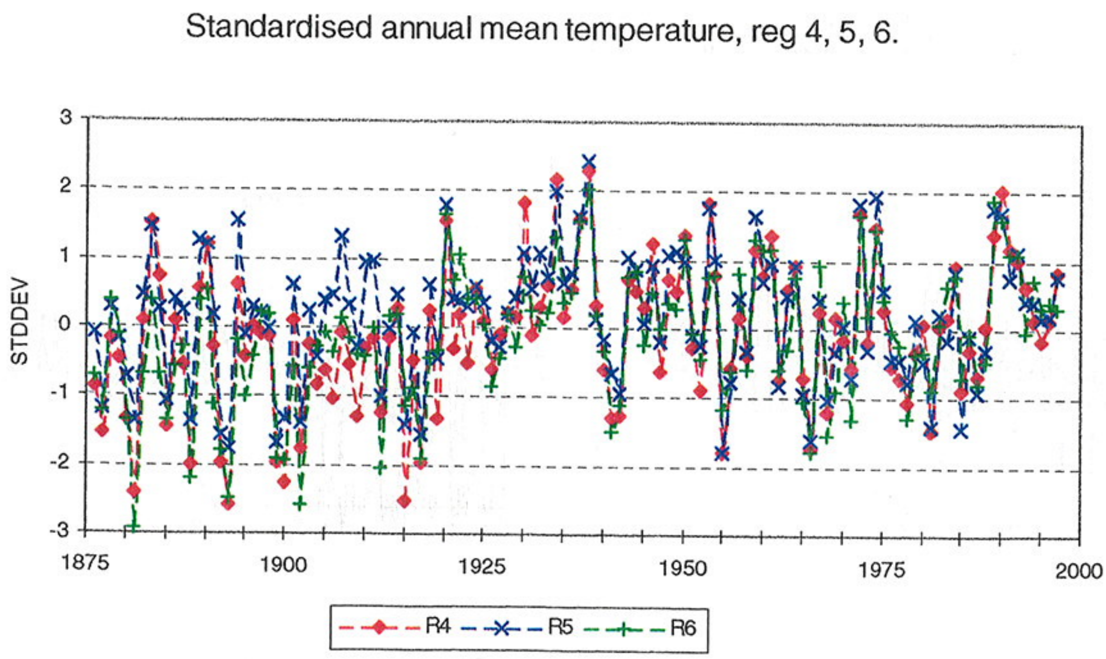
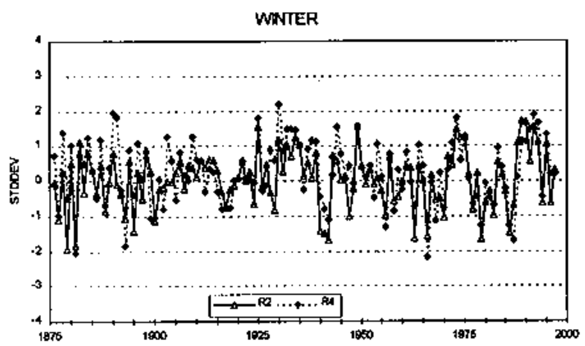


Figure 3. Standardised regional series of annual mean temperature in southern regions R1, R2 and R3 (upper panel), and northern regions R4, R5 and R6 (lower panel).

Figure 4 might give the false impression that the inter-annual variation is at minimum in winter. Note that the unity along the y-axis is standard deviation during the period 1961-1990 which, especially in southern Norway, is larger for the winter than for the other seasons (Table A.2b Appendix).

The coldest and warmest years in each region were investigated somewhat closer concerning seasonal temperature variations. Because of the similarities between regions R1-R3, a common ranking of the annual mean temperatures was made for the southern regions. The rank of each year was decided from a roughly area weighted mean of the series from R1, R2 and R3, using the weights 0.42, 0.42 and 0.16, respectively. Similarly, a common ranking of the northern regions was decided from a weighted mean of the series from R4, R5 and R6, using the weights 0.66, 0.17 and 0.17. The 10 lowest ranked (coldest) years are given in Table 3.3 for (a) northern and (b) southern parts of Norway. Similarly, the 10 warmest years are given in Table 3.4. The tables show that 5 years are of the 10 coldest both in south and in north, while 7 years are among the 10 warmest both in south and in north.

a)



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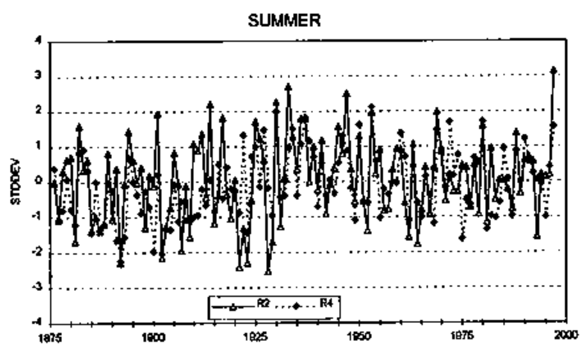
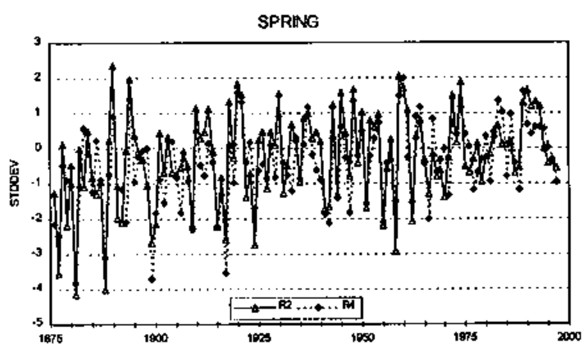


b)



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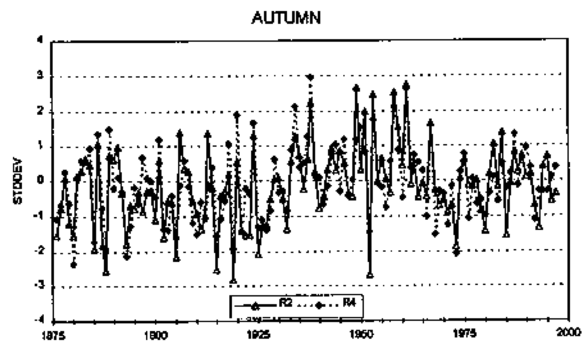


Figure 4. Standardised seasonal temperature series for regions R2 and R4.
a) winter (DJF), b) spring (MAM), c) summer (JJA), d) autumn (SON).

Table 3.3 Seasonal characteristics of the 10 coldest years during the period 1876-1997.

The 5 coldest seasons are characterised as «very cold», No. 6 to 15 as «cold», No. 16-30 as «chilly», and No. 31 -92 are characterised as «medium». Rank numbers are given except for the «medium» seasons.

a) Northern regions

YEAR	RANK N	WINTER	SPRING	SUMMER	AUTUMN
1881	2	very cold (3)	very cold (2)	cold (8)	medium
1888	5	cold (14)	very cold (4)	cold (11)	very cold (4)
1892	8	medium	medium	very cold (1)	medium
1893	1	very cold (1)	cold (9)	cold (5)	very cold (3)
1899	6	cold (10)	very cold (1)	chilly (29)	medium
1900	4	cold (12)	chilly (16)	very cold (3)	medium
1902	3	cold (11)	cold (12)	very cold (2)	cold (7)
1915	9	medium	cold (10)	medium	cold (12)
1917	7	chilly (16)	very cold (3)	medium	medium
1966	10	very cold (2)	cold (8)	medium	chilly (24)

b) Southern regions

YEAR	RANK S	WINTER	SPRING	SUMMER	AUTUMN
1877	4	cold (13)	very cold (3)	chilly (23)	medium
1879	9	very cold (2)	cold (10)	medium	chilly (25)
1881	1	very cold (3)	very cold (2)	cold (13)	medium
1888	2	chilly (16)	very cold (1)	chilly (22)	very cold (5)
1892	5	chilly (28)	chilly (18)	cold (6)	medium
1902	6	medium	chilly (22)	very cold (2)	cold (9)
1915	3	medium	cold (15)	chilly (19)	very cold (2)
1923	8	medium	medium	very cold (3)	chilly (17)
1942	7	very cold (4)	cold (13)	chilly (28)	medium
1979	10	very cold (5)	medium	medium	chilly (30)

Table 3.4 Seasonal characteristics of the 10 warmest years during the period 1876-1997.

The 5 warmest seasons are characterised as «very warm», No. 6 to 15 as «warm», No 16-30 as «mild», No. 31 -92 as «medium», and No. 93-107 as «chilly». Rank numbers are given except for the «medium» seasons.

a) Northern regions

YEAR	RANK N	WINTER	SPRING	SUMMER	AUTUMN
1920	6	medium	very warm (3)	medium	warm (7)
1930	10	very warm (1)	mild (25)	very warm (4)	medium
1934	2	varm (14)	medium	warm (11)	very warm (3)
1937	7	mild (27)	warm (10)	very warm (1)	warm (12)
1938	1	mild (21)	medium	warm (12)	very warm (1)
1953	5	medium	mild (29)	very warm (3)	warm (6)
1972	4	mild (20)	mild (24)	very warm (2)	medium
1974	8	medium	warm (8)	mild (20)	medium
1989	9	medium	very warm (2)	medium	mild (28)
1990	3	mild (24)	mild (16)	warm (15)	mild (21)

b) Southern regions

YEAR	RANK S	WINTER	SPRING	SUMMER	AUTUMN
1930	4	warm (8)	warm (14)	warm (8)	medium
1934	2	warm (7)	medium	mild (17)	warm (11)
1938	6	medium	mild(23)	medium	very warm (4)
1949	7	very warm (3)	medium	medium	very warm (3)
1953	5	medium	mild(17)	warm (9)	very warm (5)
1959	10	medium	warm (9)	mild (19)	warm (8)
1974	8	warm (13)	warm (6)	medium	medium
1989	3	very warm (1)	warm (13)	medium	warm (14)
1990	1	very warm (2)	very warm (1)	medium	medium
1992	9	very warm (4)	warm (11)	normal	chilly (97)

The seasonal mean temperatures were ranked in the same way as the annual mean temperatures, and in Tables 3.3 and 3.4, the seasons are characterised as «very cold» («very warm»), «cold» («warm»), or «chilly» («mild), if they are among the 4%, 12%, or 25% coldest (warmest) seasons. The rest of the seasons (50%) are characterised as «medium». Usually, the coldest (warmest) years include more than one «below medium» («above medium») season, and no «above medium» («below medium») season .

Table 3.3 shows that many of the coldest years are characterised by cold winter and/or spring. This is the case for the coldest years during the last half of the series, and also for many of the coldest years during the first decades. However, from the 1890s to the 1920s, several of the coldest years had cold summer and/or autumn.

Table 3.4 shows that the warmest years in northern Norway tend to have warm summers, while the warmest years in southern Norway tend to have warm winters. There also seems to be some systematic changes with time: In southern Norway, the warm years 1934, 1938,1949 and 1953 were characterised by warm winters and/or autumns, while the warmest years during the later decades have been characterised by warm winters and/or springs. In northern Norway there seems to be a similar shift from warm summers and/or autumns, to warm summers and/or springs in the warmest years.

Tables 3.3 and 3.4 show that 9 (8) of the 10 coldest years in northern (southern) Norway occur in the first half of the series (1876-1936), while only 3 (2) of the 10 warmest years occur during this period. This makes it tempting to suggest that there are positive trends in the series. Linear trend curves (not shown) based on the 6 regional series in Figure 3 also suggest that the annual mean temperatures were increasing by 0.03 to 0.09 standard deviations pr. decade during the period 1876 to 1997. Using typical values of the standard deviations in different parts of Norway, the total temperature increase during the 122 years is estimated to be between 0.4 and 1.2 ^{o}C. Values around 0.5^{o}C are found in region R5 (northern inland region), where the relative temperature increase has been small, and also at some lighthouse stations along the west coast of Norway, where the relative temperature increase has been larger, but the standard deviation of temperature is generally small. Values above 1 ^{o}C are found in inland areas (except from R5), especially in valleys and lowland. Figure 3 illustrates, however, that the inter-annual variation is considerable, and it is thus not obvious that the observed trends are statistically significant. This will be investigated in chapter 4.

4. Trends and variability in temperature

4.1 Methods

4.1.1 Filtering Techniques.

Time series of scattered individual values often give a rather chaotic impression. To identify local maxima and minima as well as trends, the series may be smoothed by a low pass Gaussian filter. The weighting coefficient in year j, G_j is given by:

$$G_j = \frac{\sum_{i=1}^{n} w_{ij} \cdot x_i}{\sum_{i=1}^{n} w_{ij}} \qquad w_{ij} = e^{\frac{-(i-j)^2}{2\sigma^2}} \tag{4.1}$$

where the x_i is the original series which consists of n years, and σ is the standard deviation in the Gaussian distribution. For the present paper, a filter with $\sigma = 3$ is chosen, which is favourable for studying variations on decal time scales. The ends of filtered curves are very dependent on the first or last few values, which may influence the trends seriously. Thus, three years on either ends of the curves are cut.

4.1.2 Test for trend.

The non-parametric Mann-Kendall test is chosen for testing the significance of trends. It can be used without knowing the exact distribution of the time series, and its test statistic t is defined by the equation

$$t = \sum_{i=1}^{n} n_i \tag{4.2}$$

where n is the number of elements and n_i is the number of smaller elements preceding element x_i (i = 1,2,.. n) (Sneyers 1990). Providing that n > 10 (Sneyers 1995) the test statistic is very nearly normally distributed under the hypothesis of randomness (the null hypothesis). Moreover, its expectation, E(t), and variance, var t, are given by the equations

$$E(t) = \frac{n(n-1)}{4} \tag{4.3}$$

$$var\ t = \frac{n(n-1)(2n+5)}{72} \tag{4.4}$$

The standardised distribution of the test statistic is then

$$u(t) = \frac{t - E(t)}{\sqrt{var\ t}} \qquad (4.5)$$

A percent table of the normal distribution function may be used to decide whether the null hypothesis should be rejected or not.

Time series may be successively tested by adding one by one year reapplying the test for each year added. Using graphical representation of the standardised test statistic, the development of trends in the series may easily be traced. It has also proved to be valuable to apply the test by starting with the last year going backward in time Demarée (1990).

4.2 Trends

Results from Mann-Kendall tests of the standardised annual and seasonal temperature series for the period 1876 - 1997 are summarised in Table 4.1, where also the linear trends of the series are given. All regions except the northern inland region R5 have experienced a statistically significant temperature increase during the period. The spring temperatures in these regions have increased significantly. Also the summer has become significantly warmer in northern Norway, while autumn has warmed significantly in the two southernmost regions. In winter, no significant trends are found. The winter temperature increase in R6 is close to the 5% significance level, while the others changes are far from being significant.

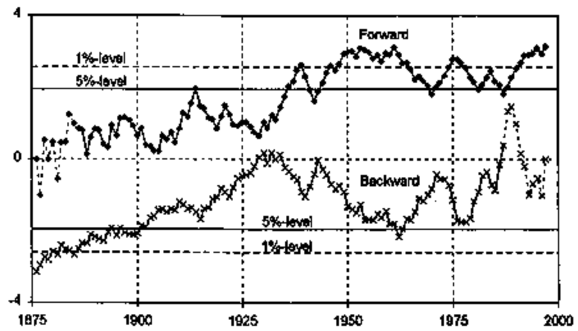
Analyses on monthly basis (not shown) reveale that the positive trend in spring temperature is mainly caused by temperature increase in March and May. The positive trend in summer temperature in northern Norway is due to warming in both June, July and August, while the warming in autumn in southern Norway mainly is caused by warming in October.

Table 4.1 Trends in annual and seasonal temperature series during the period 1876-1997.
Linear trends in the standardised regional series given in the unit «standard deviations pr. decade».
Trends significant at the 1% level according to the Mann-Kendall trend test are marked with ss, while trends significant only at the 5% level are marked with s. Trends which are not significant are given within brackets.

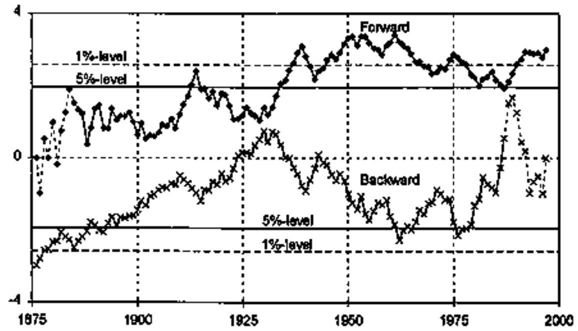
Region	Annual	Winter	Spring	Summer	Autumn
1	+0.08 ss	(+0.02)	+0.12 ss	(+0.06)	+0.07 ss
2	+0.08 ss	(+0.02)	+0.11 ss	(+0.04)	+0.07 s
3	+0.06 s	(+0.01)	+0.10 s	(+0.03)	(+0.04)
4	+0.09 ss	(0.00)	+0.12 ss	+0.08 ss	(+0.05)
5	(+0.03)	(-0.02)	(+0.06)	+0.06 s	(+0.02)
6	+0.10 ss	(+0.07)	+0.10 ss	+0.09 ss	+0.08 ss

The Mann - Kendall tests were run successively, both forwards and backwards. The results from testing the annual series are given in Figure 5. Note that the significance levels given in the figure are not valid for first 10 t-values of the «forward» series and the last 10 values of the «backward» series (see section 4.1.2).

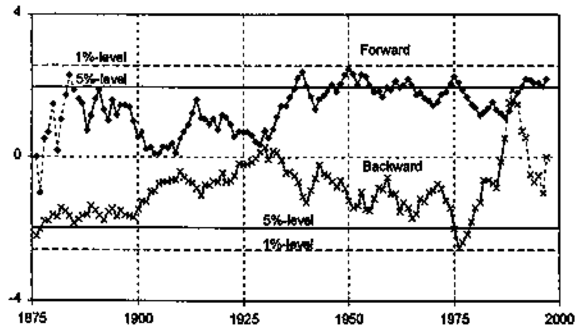
Region 1



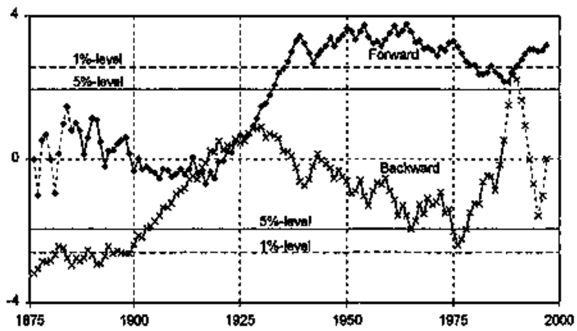
Region 2



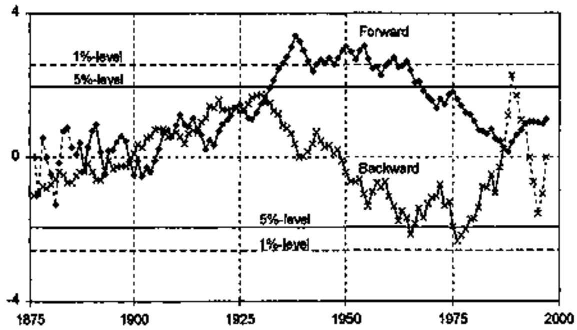
Region 3



Region 4



Region 5



Region 6

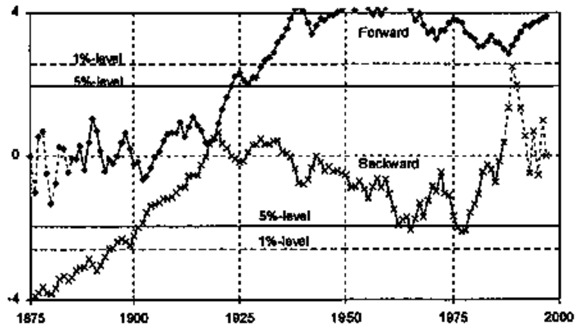


Figure 5. Mann-Kendall test statistics for regional series of annual mean temperatures.
The «forward» series give the test results for the period from 1876 to the actual year.
The «backward» series give the test results for the period from the actual year to 1997.
The 1 and 5% significance levels which are given, are not valid for the first 10 years of the «forward» series and the last 10 years of the «backward» series, which thus are dotted.

Figure 5 shows that all regions (R5 included) experienced a warming, statistically significant at least at the 5% level, from 1876 to the end of the 1930s. Similarly, all regions experienced a statistically significant warming from the end of the 1960s and/or the 1970s to 1997. From the 1930s to around 1970 and/or 1980, on the other hand, the temperature trends were negative. Mann-Kendall tests starting in 1930 (not shown) revealed that these trends are statistically significant, at least at the 5% level, in all regions except R3.

4.3 Decadal scale and long-term variability

Figure 6 shows low pass filtered (cf. section 4.1.1) series of standardised regional temperature for all temperature regions, on annual as well as on seasonal basis. Some common features are seen in all regions: Compared to the standard normal temperatures 1961-1990, the period before 1920 was relatively cold in all regions except in northern inland region R5. The period 1930-1960, on the other hand, was relatively warm. The last decade of the series was also a relatively warm period.

The similarities between the 3 southernmost regions concerning decadal scale variability are striking. On the decadal scale, 7-8 more or less pronounced local temperature minima and maxima are found. The absolute minimum is in the beginning of the series, 0.5 - 1.0 standard deviations below the 1961-1990 average, while the highest maxima, 0.5 - 1.0 standard deviations above the 1961-1990 average, are found in the 1930s and around 1990. In the regions R2 and R3 these maxima are of similar size. In the south-eastern region R1, however, the absolute maximum is found around 1990.

The standardised temperature curves from regions R4, R5 and R6 are somewhat different from those from the southern regions, especially before 1930: The absolute temperature minimum in the northern regions occurred around 1900, mainly because of very low summer and winter temperatures. The northern curves also show a local temperature maximum around 1922 which is not seen in the southern regions, and which is mainly cause by local maxima in summer and autumn temperatures. There are also differences internally between the northern regions during the first decades: Regions R4 and R6 are at average about 0.5 standard deviation colder than R5 during the first 4 decades. After 1930, the curves for the northern regions are more similar to eachother, as well as to the southern curves: The warmest periods are found around 1935 and 1990 also in regions R4, R5 and R6. However, in these regions, the 1935 maximum is similar to or higher than the 1990 maximum.

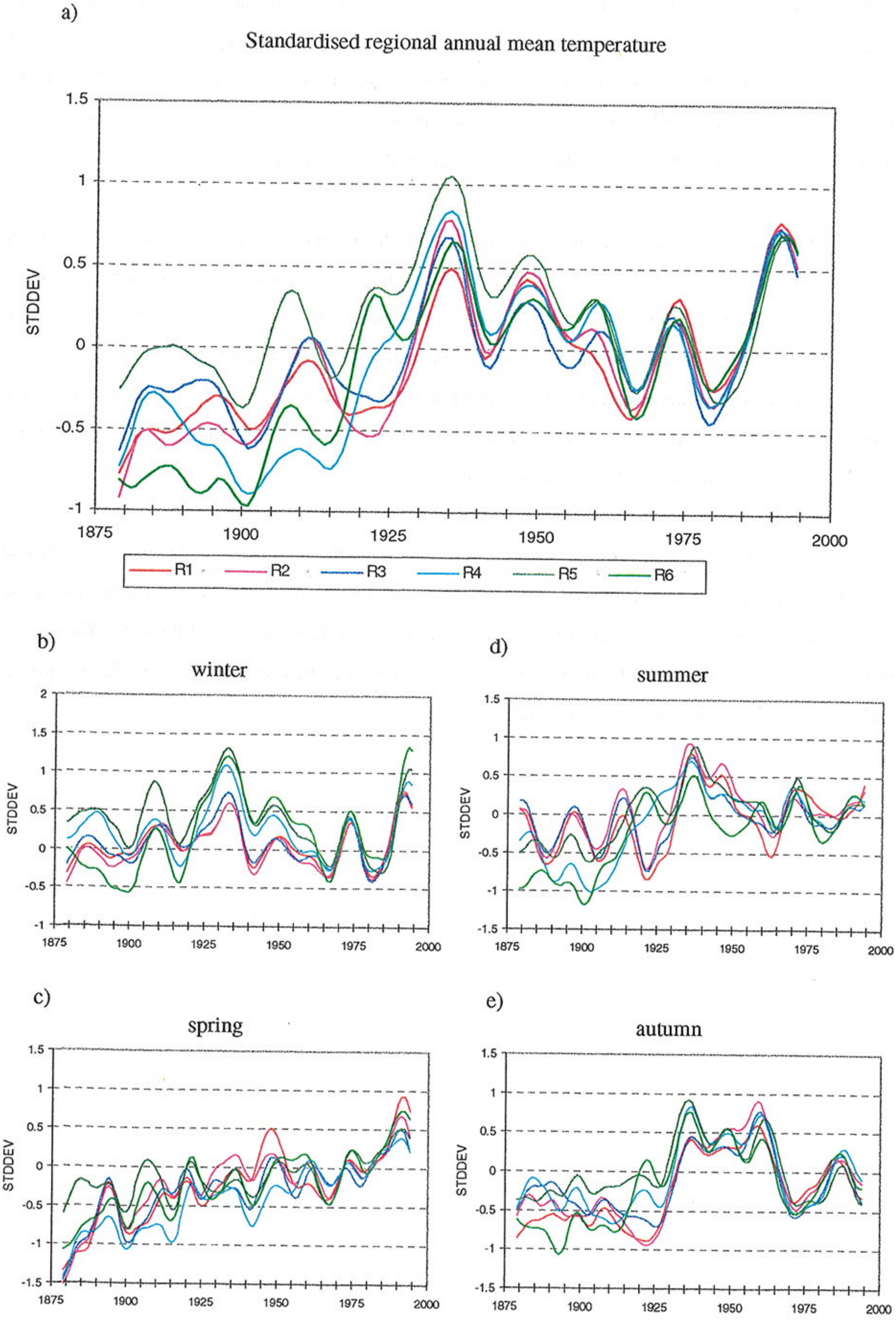


Figure 6. Lowpass filtered series of standardised temperature for regions 1 - 6.
a) Aannual mean temperature, b-e) Seasonal mean temperature

Some of the discrepancies between the regional curves during the first decades may be caused by the fact that the regional series are based upon a sparse station network in the beginning (cf. section 3.1). One should, however, be aware the fact that the series are standardised using the period 1961-1990. The curves are thus «forced» into the same level during this period, and the visual impression of agreement especially in this period is thus to some degree the result of this choice.

Figure 5 b)-e) shows that the local maxima and minima in the seasonal curves coincide, to a large degree, with those of the annual curves. However, there are major differences concerning the relative sizes of the maxima and minima. Note that the warm period in the 1930s was caused by warm autumns, winters and summers, while the warm period around 1990s was caused by warm winters and springs. The highest winter maxima are, as the annual temperature maxima, found in the 1930s and around 1990. In northern Norway the former tends to be the absolute highest, while the 1990 maximum tends to be the highest in southern Norway.

The lowest winter minima in southern Norway are found in the beginning of the series and around 1980. In northern Norway, the lowest winter minima are found around 1900 and 1966. Thus, the reason why the annual mean temperatures generally are lower in the beginning of the series than in the 1960s and 1980s is not a lack of cold winters, but rather that the other seasons (especially the spring) usually are warmer during these later decades.

5. Summary and conclusions

Norway was divided into 6 temperature regions, using a combination of PCA and clusteranalysis of annual mean temperature series. Within each region there are only minor differences between different timeseries of standardised temperature. The temperature evolution within a region can thus be described reasonably well by one standardised series. Consequently, the regions are convenient spatial units for describing temperature variations in the past, as well as for estimating future temperature scenarios. The temperature regions will later be used for statistical downscaling of temperature within the frame of the Reg. Clim. project (Iversen et al. 1997).

Studies of standardised temperature from the 6 Norwegian temperature regions show that there is a positive trend in annual mean temperature during the period 1876-1997 everywhere. The temperature increase, which at most places lies between 0.4 and 1.2 °C, is statistically significant at least at the 5% level in all regions except the northern inland region R5. In all regions (including R5), the temperature increased significantly both from 1876 to the 1930s and from the 1960s and/or the 1970s to 1997. However, there was a significant temperature decrease between the 1930s and about 1970 and/or 1980 in all regions except R3.

In all regions, the periods of highest annual mean temperatures are found around 1935 and/or around 1990. In northern Norway, the 1935-maximum was similar to or higher than the 1990-maximum. In southern Norway, the 1990-maximum was similar to or higher than the 1935-maximum. The period with lowest annual mean temperatures in southern Norway is the very beginning of the series. In northern Norway, the period around 1900 was coldest.

In all regions except R5, there has been a statistically significant increase of the spring temperature during the period 1876-1997. In northern Norway, there was also a significant increase of summer temperatures, while the autumn temperature increased significantly in the two southernmost regions R1 and R2. In the 1930s, above average winter-, summer- and autumn-temperatures contributed to the high annual mean temperatures. Around 1990, it was mainly high winter- and spring-temperatures which led to high annual mean temperatures.

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Appendix

Table A.1 Some basic information about stations used in the present report.

STATION NUMBER	LAT (° min N)	LONG (° min E)	PERIOD	COMMENT	USED IN CLUSTER ANALYSES ?	USED TO COMPUTE REGIONAL SERIES ?
06040	60° 37,04	12° 01,02	1919- dd		YES	YES
10400	62° 34,04	11° 23,02	1871- dd		YES	YES
11500	60° 42,99	10° 52,99	1930- dd	automat. from 1988	YES	YES
16610	62° 06,87	09° 17,24	1923- dd	COMBINED	YES	YES
16740	62° 05,63	09° 02,76	1864- dd	COMBINED	YES	YES
17850	59° 40,99	10° 47,99	1874-1988		YES	NO
18700	59° 56,56	10° 43,24	1874- dd	COMBINED	YES	YES
18950	59° 59,00	10° 41,00	1927- dd		YES	NO
23160	60° 55,10	09° 17,41	1922- dd		YES	YES
24880	60° 34,11	09° 07,32	1897- dd	COMBINED	YES	YES
27500	59° 01,60	10° 31,80	1885- dd		YES	YES
32100	59° 23,99	09° 11,99	1919- dd		YES	YES
33060	59° 27,99	08° 00,99	1928- dd		YES	NO
36200	58° 23,99	08° 47,51	1944- dd		YES	NO
37230	59° 01,63	08° 31,24	1944- dd		NO	YES
39100	58° 04,02	08° 03,05	1875- dd		YES	YES
41100	58° 02,80	07° 27,40	1949- dd		YES	NO
42160	58° 06,60	06° 34,10	1926- dd		YES	YES
42920	58° 53,25	06° 50,91	1974- dd		in additional analyses only	YES
46610	59° 38,92	06° 21,80	1928- dd		YES	YES
47300	59° 18,46	04° 52,70	1926- dd		YES	YES
50540	60° 23,00	05° 20,02	1860- dd	COMBINED	YES	YES
52530	60° 45,16	04° 42,73	1924-1992		YES	YES
54130	61° 03,70	07° 31,00	1869-1996	COMBINED	YES	YES
55780	61° 11,99	06° 52,99	1896-1990		YES	YES
55840	61° 26,12	06° 46,35	1952- dd		NO	YES
58700	61° 56,00	07° 13,60	1895-1991		YES	YES
59100	62° 02,10	04° 59,20	1926- dd	automat. from 1996	YES	YES
60500	62° 14,01	07° 25,00	1930- dd		YES	YES
62480	62° 51,58	06° 32,37	1870- dd	COMBINED	YES	YES
69100	63° 27,55	10° 56,11	1870- dd	COMBINED	YES	YES
70850	64° 09,50	12° 28,70	1939- dd		in additional analyses only	YES
71550	63° 42,02	09° 36,08	1921- dd	COMBINED	in additional analyses only	YES
71650	63° 51,99	09° 44,99	1921-1974		in additional analyses only	NO
75600	65° 05,85	11° 42,13	1940- dd		in additional analyses only	YES
77420	65° 10,80	13° 25,20	1967- dd		in additional analyses only	YES
80610	66° 45,80	12° 29,30	1972- dd		in additional analyses only	NO
80700	66° 48,60	13° 58,88	1916- dd		YES	YES
82290	67° 16,45	14° 26,01	1868- dd	COMBINED	YES	YES
83120	67° 50,00	14° 47,00	1920-1978		YES	NO
85380	68° 09,02	14° 39,05	1933- dd		YES	YES
85910	67° 30,38	12° 04,57	1890- dd	COMBINED	NO	YES
85950	67° 25,99	11° 53,99	1890-1978		YES	NO
89950	68° 46,70	19° 42,60	1921- dd		in additional analyses only	YES
90450	69° 39,25	18° 55,81	1867- dd	COMBINED	YES	YES
92700	70° 20,30	21° 28,00	1920- dd		in additional analyses only	YES
93300	69° 35,30	23° 31,90	1963- dd		NO	YES
93900	68° 45,02	23° 32,02	1913- dd		YES	YES
96400	71° 05,04	28° 13,07	1927- dd		in additional analyses only	YES
97250	69° 28,00	25° 30,60	1876- dd		YES	YES
98400	70° 42,03	30° 04,08	1924- dd		YES	YES
98550	70° 22,03	31° 05,09	1867- dd		YES	YES
S-09322	59° 21,00	13° 28,00	1859- dd		YES	NO
S-12402	62° 01,00	14° 21,00	1875- dd		YES	NO
S-13411	63° 11,00	14° 29,00	1860- dd		YES	NO
S-15772	65° 04,00	17° 09,00	1861- dd		YES	NO
S-16988	66° 37,00	19° 38,00	1890- dd		YES	NO
S-19283	68° 26,00	22° 29,00	1890- dd		YES	NO
F-07501	67° 22,00	26° 39,00	1908- dd		YES	NO

Table A.2 Some additional information about stations used to compute regional series.

a) Temperature normals 1961-1990, monthly, seasonal and annual

REG	ST.NO.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WIN	SPR	SUM	AUT
1	6040	-8.6	-7.8	-2.5	2.8	9.4	14.2	15.2	13.8	8.9	4.3	-2.3	-7.1	3.3	-7.9	3.2	14.4	3.6
1	10400	-11.2	-9.7	-5.6	-0.7	5.6	10.1	11.4	10.4	6.1	1.7	-5.2	-9.1	0.3	-10.0	-0.3	10.6	0.9
1	11500	-7.3	-7.0	-2.5	2.3	9.0	13.7	14.9	13.5	9.1	4.7	-1.4	-5.3	3.6	-6.6	2.9	14.0	4.1
1	16740	-8.8	-7.6	-3.9	0.3	6.5	10.7	12.0	11.1	6.6	2.4	-3.9	-7.2	1.5	-7.9	1.0	11.3	1.7
1	18700	-4.3	-4.0	-0.2	4.5	10.8	15.2	16.4	15.2	10.8	6.3	0.7	-3.1	5.7	-3.8	5.0	15.6	5.9
1	23160	-9.1	-7.9	-4.8	0.0	5.9	10.7	12.1	11.0	6.6	2.4	-4.1	-7.4	1.3	-8.2	0.4	11.2	1.6
1	24880	-10.5	-8.6	-2.3	3.0	9.1	14.1	15.2	13.5	8.6	3.6	-4.0	-8.6	2.7	-9.3	3.3	14.3	2.7
1	27500	-0.7	-1.5	0.9	4.5	10.0	14.8	16.5	16.2	12.9	9.2	4.6	1.4	7.4	-0.3	5.1	15.8	8.9
1	32100	-6.6	-5.7	-0.7	4.3	10.2	14.8	16.0	14.6	10.0	5.6	-0.4	-5.0	4.8	-6.2	4.6	15.1	5.1
1	37230	-4.0	-4.8	-0.9	3.2	8.9	13.6	15.1	14.0	9.9	6.0	1.0	-2.0	5.0	-4.4	3.7	14.2	5.6
1	39100	0.3	-0.3	1.6	4.5	9.3	13.3	15.2	15.2	12.5	9.3	5.0	2.1	7.3	0.7	5.2	14.6	8.9
1	42160	1.0	0.5	2.2	4.9	9.2	12.4	13.9	14.6	12.2	9.4	5.5	2.7	7.4	1.4	5.4	13.6	9.0
2	42920	-5.2	-5.4	-2.2	0.9	6.6	11.2	12.4	11.6	8.1	4.7	-0.2	-3.8	3.2	-5.3	1.8	11.7	4.2
2	46610	-2.0	-1.7	1.4	4.8	10.2	13.7	14.9	14.2	10.6	7.1	2.2	-0.7	6.2	-1.5	5.5	14.2	6.6
2	47300	2.3	1.7	2.7	4.6	8.3	11.4	13.0	13.6	11.7	9.3	5.9	3.9	7.4	2.6	5.2	12.7	9.0
2	50540	1.3	1.5	3.3	5.9	10.5	13.3	14.3	14.1	11.2	8.6	4.6	2.4	7.6	1.7	6.5	13.9	8.1
2	52530	2.5	2.1	3.0	4.9	8.5	11.2	12.8	13.4	11.4	9.1	5.7	3.7	7.4	2.7	5.5	12.5	8.7
2	54130	-2.5	-2.2	1.3	5.2	10.3	13.5	14.7	13.9	9.9	6.1	1.4	-1.2	5.9	-2.0	5.6	14.1	5.8
2	55780	-0.8	-0.4	1.6	5.0	10.3	13.8	14.9	14.2	10.3	6.9	2.6	0.3	6.6	-0.3	5.6	14.3	6.6
2	55840	-3.3	-3.0	-0.1	3.6	9.6	13.3	14.3	13.3	9.4	5.7	0.6	-2.1	5.1	-2.8	4.4	13.7	5.2
2	58700	-1.0	-1.0	0.9	3.7	9.2	12.4	13.5	12.9	9.4	6.5	2.1	-0.2	5.7	-0.7	4.6	12.9	6.0
2	59100	2.8	2.6	3.2	4.7	8.2	10.8	12.2	13.0	11.1	9.0	5.6	3.8	7.2	3.0	5.4	12.0	8.5
2	60500	0.5	0.7	2.7	5.2	10.1	12.7	13.8	13.7	10.5	8.0	3.6	1.3	6.9	0.8	6.0	13.4	7.4
2	62480	2.6	2.5	3.2	4.5	7.8	10.3	12.1	12.9	10.9	8.8	5.4	3.6	7.1	2.9	5.2	11.8	8.4
3	16610	-8.8	-8.3	-6.0	-2.3	4.1	8.5	9.8	9.1	4.6	0.9	-4.7	-7.3	0.0	-8.1	-1.4	9.1	0.3
3	69100	-3.4	-2.5	0.1	3.6	9.1	12.5	13.7	13.3	9.5	5.7	0.5	-1.7	5.0	-2.6	4.3	13.2	5.3
3	70850	-6.3	-5.4	-2.3	1.5	7.4	11.6	12.9	12.0	8.1	4.2	-1.9	-4.5	3.1	-5.5	2.2	12.2	3.5
3	71550	-0.7	-0.3	1.4	4.1	8.7	11.4	12.7	12.9	9.9	6.9	2.6	0.5	5.8	-0.2	4.7	12.4	6.5
4	75600	-1.5	-1.2	0.4	3.3	8.0	11.0	12.7	12.7	9.5	6.2	1.9	-0.5	5.2	-1.1	3.9	12.1	5.9
4	77420	-8.4	-7.7	-4.5	-0.6	4.8	10.0	12.2	11.2	6.9	2.8	-3.4	-6.7	1.4	-7.6	-0.1	11.1	2.1
4	80700	-1.3	-1.1	0.3	2.9	7.5	10.7	12.5	12.2	8.9	5.8	1.7	-0.4	5.0	-1.0	3.6	11.8	5.5
4	82290	-2.2	-2.0	-0.6	2.5	7.2	10.4	12.5	12.3	9.0	5.3	1.2	-1.2	4.5	-1.8	3.0	11.7	5.2
4	85380	-0.5	-0.8	-0.1	2.1	6.4	9.9	12.5	12.5	9.2	5.8	2.5	0.3	5.0	-0.4	2.8	11.6	5.8
4	85910	1.1	0.9	1.5	3.0	6.0	8.6	10.8	11.5	9.1	6.5	3.8	1.9	5.4	1.3	3.5	10.3	6.5
4	90450	-4.4	-4.2	-2.7	0.3	4.8	9.1	11.8	10.8	6.7	2.7	-1.1	-3.3	2.5	-4.0	0.8	10.5	2.7
4	92700	-2.0	-2.0	-1.1	1.1	4.8	8.5	11.6	11.0	7.8	4.1	0.9	-1.1	3.6	-1.7	1.6	10.4	4.3
5	89950	-9.3	-8.2	-5.4	-0.8	5.0	10.2	12.7	10.9	6.2	1.0	-4.7	-7.9	0.8	-8.5	-0.4	11.3	0.8
5	93300	-14.4	-13.2	-10.0	-4.4	2.0	8.2	11.5	9.5	4.4	-2.0	-8.3	-12.6	-2.4	-13.5	-4.1	9.7	-2.0
5	93900	-15.9	-14.9	-11.3	-5.3	1.9	8.9	11.8	9.7	4.2	-2.5	-9.4	-14.1	-3.1	-15.1	-4.9	10.1	-2.6
5	97250	-17.1	-15.4	-10.3	-3.1	3.8	10.1	13.1	10.7	5.3	-1.3	-9.4	-15.3	-2.4	-16.0	-3.2	11.3	-1.8
6	96400	-4.4	-4.5	-3.1	-0.8	2.8	6.3	9.3	9.2	6.7	2.5	-0.9	-3.2	1.7	-4.1	-0.4	8.3	2.8
6	98400	-5.0	-5.2	-3.6	-1.0	2.8	6.7	10.1	9.6	7.0	2.4	-1.3	-3.6	1.6	-4.6	-0.6	8.8	2.7
6	98550	-5.1	-5.4	-3.6	-1.1	2.5	6.2	9.2	9.1	6.6	2.4	-1.3	-3.7	1.3	-4.8	-0.7	8.2	2.6

Table A.2 cont. Some additional information about stations used to compute regional series.

b) Temperature standard deviations 1961-1990, monthly, seasonal and annual

REG	ST.NO.	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WIN	SPR	SUM	AUT
1	6040	5.17	4.87	2.87	1.33	1.12	1.56	1.13	1.23	1.21	1.48	2.78	3.84	1.22	3.67	1.16	0.89	1.24
1	10400	4.87	4.21	2.94	1.62	1.31	1.62	1.21	1.16	1.33	1.46	2.71	4.01	1.05	3.50	1.13	0.90	1.23
1	11500	4.29	4.32	2.79	1.43	1.16	1.53	1.21	1.32	1.10	1.29	2.16	2.92	1.06	3.21	1.18	0.92	0.99
1	16740	3.94	3.59	2.39	1.55	1.16	1.66	1.00	1.23	1.30	1.49	2.35	3.25	0.87	2.99	0.92	0.89	1.07
1	18700	3.49	3.52	2.24	1.34	1.16	1.52	1.16	1.40	1.09	1.25	1.83	2.65	0.93	2.63	1.07	0.94	0.84
1	23160	3.99	3.60	2.61	1.52	1.13	1.49	1.14	1.30	1.13	1.47	2.24	3.27	0.94	2.92	1.01	0.86	1.00
1	24880	4.93	4.41	2.92	1.27	1.11	1.48	1.25	1.31	1.20	1.49	2.95	3.83	1.18	3.43	1.20	0.91	1.21
1	27500	3.23	3.41	2.21	1.23	0.99	1.25	1.07	1.21	0.92	1.15	1.60	2.43	0.95	2.59	1.16	0.85	0.77
1	32100	4.18	3.99	2.43	1.27	1.03	1.24	1.09	1.18	1.17	1.25	1.98	2.85	1.00	3.71	1.12	0.82	0.94
1	37230	4.08	4.38	2.63	1.38	1.11	1.34	1.28	1.39	1.02	1.22	1.71	2.79	1.07	3.94	1.20	0.95	0.79
1	39100	3.09	3.02	2.03	1.14	1.03	1.12	1.02	1.06	0.85	0.96	1.47	2.34	0.90	2.41	1.06	0.77	0.67
1	42160	2.93	2.63	1.71	1.02	1.03	0.99	1.07	1.08	0.94	1.00	1.44	2.28	0.78	2.22	0.89	0.72	0.65
2	42920	3.78	3.06	2.41	1.23	1.18	1.48	1.16	1.46	1.19	1.31	1.70	3.05	0.90	2.62	1.08	0.85	0.77
2	46610	3.47	2.88	1.79	1.19	1.18	1.41	1.12	1.26	1.15	1.23	1.85	2.30	0.80	2.29	0.91	0.87	0.86
2	47300	2.05	1.90	1.31	0.81	0.90	0.98	0.96	1.07	1.01	0.81	1.16	1.61	0.60	1.55	0.75	0.69	0.57
2	50540	2.65	2.18	1.40	1.03	1.05	1.32	0.98	1.13	1.20	1.06	1.54	1.98	0.60	1.77	0.67	0.79	0.69
2	52530	1.99	1.81	1.22	0.80	0.90	0.93	0.94	1.07	1.06	0.91	1.29	1.66	0.56	1.47	0.67	0.67	0.63
2	54130	3.57	3.35	2.03	1.17	0.90	1.42	0.92	1.16	1.28	1.48	2.28	2.56	0.75	2.50	0.75	0.83	1.08
2	55780	2.76	2.41	1.63	1.21	0.98	1.47	0.99	1.17	1.18	1.26	1.86	2.05	0.62	1.88	0.70	0.84	0.90
2	55840	3.29	3.04	1.76	1.32	1.12	1.49	1.00	1.05	1.13	1.34	2.05	2.66	0.79	2.38	0.89	0.83	0.94
2	58700	2.41	2.35	1.67	1.37	1.26	1.70	1.14	1.29	1.50	1.53	1.87	1.83	0.61	1.63	0.88	1.04	1.03
2	59100	1.68	1.66	1.20	0.89	0.94	1.02	0.98	1.10	1.15	1.11	1.29	1.53	0.52	1.27	0.59	0.75	0.70
2	60500	2.59	2.49	1.70	1.38	1.08	1.31	0.91	1.10	1.55	1.60	1.90	2.07	0.63	1.74	0.78	0.86	1.04
2	62480	1.74	1.67	1.12	0.89	0.81	0.85	0.76	1.05	1.18	1.09	1.29	1.58	0.55	1.32	0.58	0.70	0.78
3	16610	3.11	3.08	2.16	1.67	1.24	1.73	1.16	1.28	1.39	1.48	1.93	2.70	0.76	2.38	0.91	0.92	0.93
3	69100	3.48	3.29	2.02	1.36	1.38	1.54	1.08	1.16	1.49	1.46	2.02	3.02	0.82	2.66	0.90	0.99	1.10
3	70850	3.96	3.63	2.27	1.33	1.42	1.75	1.24	1.31	1.45	1.53	2.42	3.58	0.89	2.95	0.93	1.04	1.23
3	71550	2.43	2.38	1.62	1.22	1.22	1.28	0.99	1.14	1.25	1.32	1.57	2.32	0.68	1.90	0.77	0.88	0.90
4	75600	2.51	2.68	1.75	1.31	1.40	1.50	1.18	1.25	1.35	1.51	1.64	2.66	0.73	2.00	0.84	1.00	1.00
4	77420	4.10	4.20	2.70	1.50	1.00	1.80	1.30	1.40	1.50	1.80	2.50	4.30	1.00	3.15	1.05	1.12	1.37
4	80700	2.20	2.58	1.74	1.41	1.54	1.64	1.52	1.51	1.47	1.81	1.68	2.41	0.75	1.73	0.92	1.22	1.09
4	82290	2.09	2.60	1.73	1.34	1.47	1.57	1.50	1.35	1.33	1.71	1.60	2.55	0.69	1.74	0.92	1.18	0.95
4	85380	1.56	1.86	1.48	1.19	1.41	1.61	1.65	1.34	1.24	1.52	1.31	1.92	0.67	1.28	0.92	1.25	0.90
4	85910	1.45	1.72	1.31	0.97	0.83	1.01	1.04	1.04	1.03	1.31	1.21	1.69	0.64	1.15	0.74	0.89	0.85
4	90450	1.87	2.21	1.88	1.29	1.60	1.76	1.77	1.20	1.37	1.76	1.56	2.28	0.77	1.44	1.16	1.28	0.94
4	92700	1.50	1.88	1.82	1.33	1.46	1.59	1.75	1.20	1.32	1.64	1.49	1.91	0.77	1.19	1.15	1.24	0.93
5	89950	3.09	3.49	2.61	1.59	1.82	1.90	1.68	1.30	1.54	2.12	2.34	3.69	0.96	2.30	1.29	1.31	1.20
5	93300	3.33	3.99	2.98	1.77	1.88	2.07	1.79	1.19	1.46	2.41	2.89	3.94	1.09	2.38	1.51	1.39	1.42
5	93900	3.77	4.36	3.43	2.02	2.05	2.00	1.67	1.23	1.53	2.68	2.99	4.54	1.19	2.73	1.71	1.31	1.58
5	97250	4.44	5.13	3.83	1.90	1.89	1.97	1.82	1.17	1.51	2.70	3.74	5.30	1.36	3.09	1.85	1.36	1.76
6	96400	1.48	1.88	1.98	1.44	1.27	1.42	1.39	1.08	1.23	1.56	1.34	1.78	0.83	1.02	1.20	1.11	0.88
6	98400	1.44	2.04	2.05	1.51	1.34	1.58	1.70	1.19	1.26	1.61	1.41	1.78	0.87	1.06	1.22	1.27	0.91
6	98550	1.40	2.08	1.99	1.40	1.20	1.32	1.39	1.09	1.10	1.53	1.46	1.68	0.84	1.14	1.17	1.10	0.90