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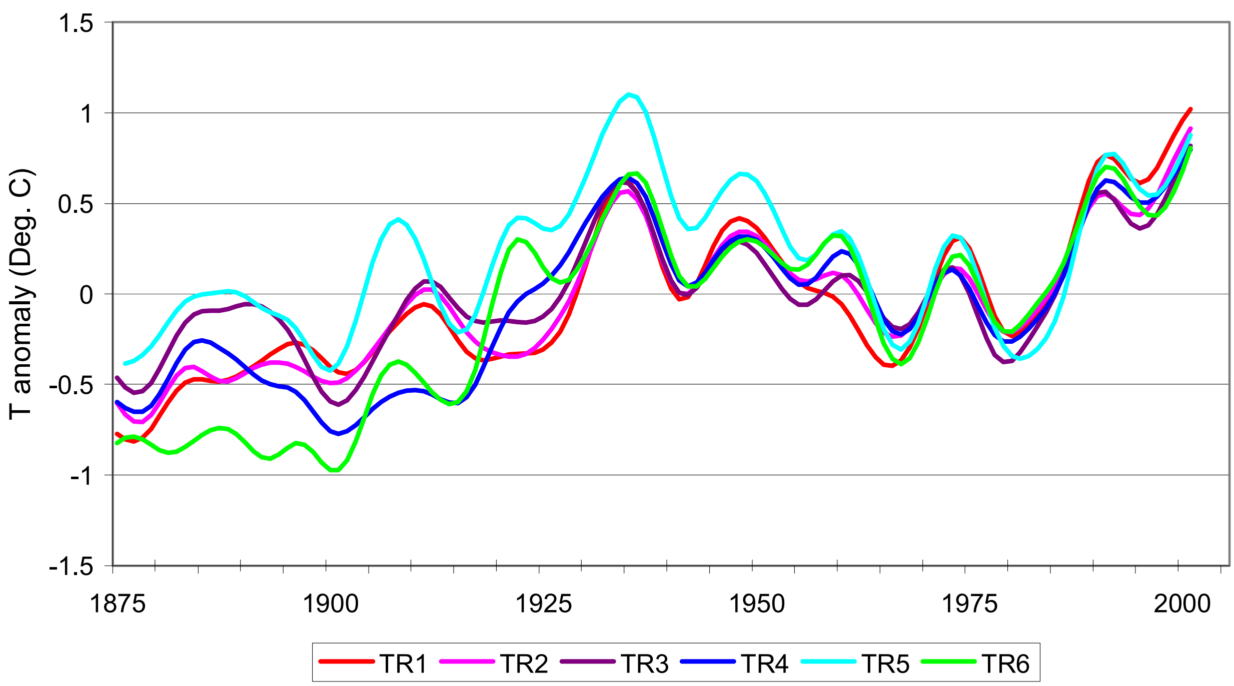
Regional temperature and precipitation series for Norway: Analyses of time-series updated to 2004

Inger Hanssen-Bauer



Filtered time-series of annual mean temperature from 6 Norwegian regions. The temperatures are given relative to the average over the period 1961-1990. Regions TR1 and TR2 cover southern Norway, TR3 covers mid-Norway while TR4, TR5 and TR6 cover northern Norway.

report

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Abstract

The annual mean temperature in Norway has during the period 1875-2004 increased by 0.5 to 1.5 °C. The increase in annual mean temperature is statistically significant at the 1% level everywhere except in the inland of Finnmark county. The winter temperature has increased significantly (at least 5% level) in 3 of the 6 temperature regions. Spring temperatures have increased significantly everywhere. Summer temperatures have increased significantly in northern regions, and autumn temperatures have increased significantly everywhere except in mid-Norway and the inland of Finnmark county. In spite of the linear trends: There have been substantial decadal and multi-decadal temperature variations during the last 130 years. After a rather cold period around 1900 followed "the early 20th century warming", which culminated in the 1930s. A period of cooling followed, before the recent period of warming which has dominated the whole country since the 1960s. In southern Norway, the warmest decade of the last 130 years occurred near the end of the series. In most parts of northern Norway, the warmest decade occurred around the 1930s.

Annual precipitation in Norway has during the last 110 years increased statistically significantly (5% level) in 9 of 13 regions. No region shows a negative trend. The largest increase (15-20% increase) is found in north-western regions. Autumn precipitation has increased significantly in most southern regions. Winter and spring precipitation has increased significantly in north-western, and to some degree in inland regions. Summer precipitation has increased significantly in most of the northern regions. The positive trends in temperature as well as in precipitation tend to be more statistically significant now than they were in similar analyses 7 years ago.

The connections between the winter NAO index and regional winter temperature and precipitation series have been investigated. Though the correlation between winter temperature and the NAOI is significant in all regions and the correlation between winter precipitation and the NAOI is significant at least in western regions, the correlation coefficients vary with time. One reason why these connections are not stationary may be that the atmospheric circulation over Norway is not only affected by the NAOI, but also by the position of the "Icelandic low". Further, local air temperature and precipitable water will not depend solely on atmospheric circulation, but also on e.g. sea surface temperatures.

Keywords

Temperature, precipitation, trends, variability, Norway, 20th century

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1. Introduction

Century long regional series of standardised temperature and precipitation in Norway up to 1997 have been reported earlier (Hanssen-Bauer and Nordli 1998, Hanssen-Bauer and Førland 1998). The present focus on climate variability and its possible impacts on human activities, infrastructure and biota has led to an increased demand for long, updated climate series. In the present report, updated regional Norwegian series of temperature and precipitation are analysed.

2. Temperature

2.1 Definition of temperature regions and standardised regional temperature series

The six Norwegian temperature regions (TR1-TR6) applied in the present analysis (Figure 1) were defined by Hanssen-Bauer and Nordli (1998) by using a combination of principal component analysis and cluster analysis of temperature series from Norwegian weather stations. For each region (*m*), a number (*n*) of temperature series were used to calculate the regional standardised temperature series in the following way:

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

Here $ST_{m,i}$ is the standardised temperature series from station number *i* in region *m*:

$$ST_{mi} = (T_{m,i} - \mu_{Tm,i})/\sigma_{Tm,i} \qquad (2),$$

where $T_{m,i}$ is the observed temperature series at station *i* in region *m*, and $\mu_{Tm,i}$ and $\sigma_{Tm,i}$ are mean value and standard deviation for the temperature at this station during the period 1961-1990. Standardised series were calculated on monthly, seasonal and annual basis. An overview of the stations applied in the various regions and some relevant information is given in the tables A1 and A2 in Appendix.

Figure 1. Temperature regions in Norway.

In order to calculate typical regional temperature variations in ^oC rather than relative to standard deviations, one may multiply the standardised series with typical regional standard deviations. The regional standard deviations given in Table 1 were calculated from grid-based regional temperature anomaly maps for the period 1961-1990 (Hanssen-Bauer et al. 2005).

Table 1. Typical regional standard deviations (^oC) for annual and seasonal temperature series, based upon gridded temperature maps for the period 1961-1990.

	TR 1	TR 2	TR 3	TR 4	TR 5	TR 6
Annual	0.96	0.70	0.80	0.82	1.16	0.99
Winter	2.96	2.11	2.56	2.00	2.43	1.53
Spring	1.03	0.76	0.85	1.07	1.63	1.40
Summer	0.85	0.79	0.94	1.14	1.31	1.24
Autumn	0.95	0.80	1.02	1.04	1.40	1.09

2.2 Long-term temperature trends

The regional series of annual and seasonal temperature are shown in Figure 2-6 together with 10-year running mean values and linear trends, all measured in standardised units. The linear trends for the period 1875-2004 are also given in Table 2, both in standardised units and in ^{o}C. (Note that the trend in ^{o}C will vary within a specific region, and that the given trends should be regarded as an average for the region.) The statistical significance of the trends was tested by the Mann-Kendall non-parametric test (Sneyers 1995). Comparison to the similar table based upon analyses 7 years ago (Hanssen-Bauer and Nordli 1998) show a tendency to increased statistical significance of the positive temperature trends. Temperature region 5 (TR5) is still the only region not showing statistically significant warming on an annual basis. All other regions now show a temperature increase significant at the 1% level.

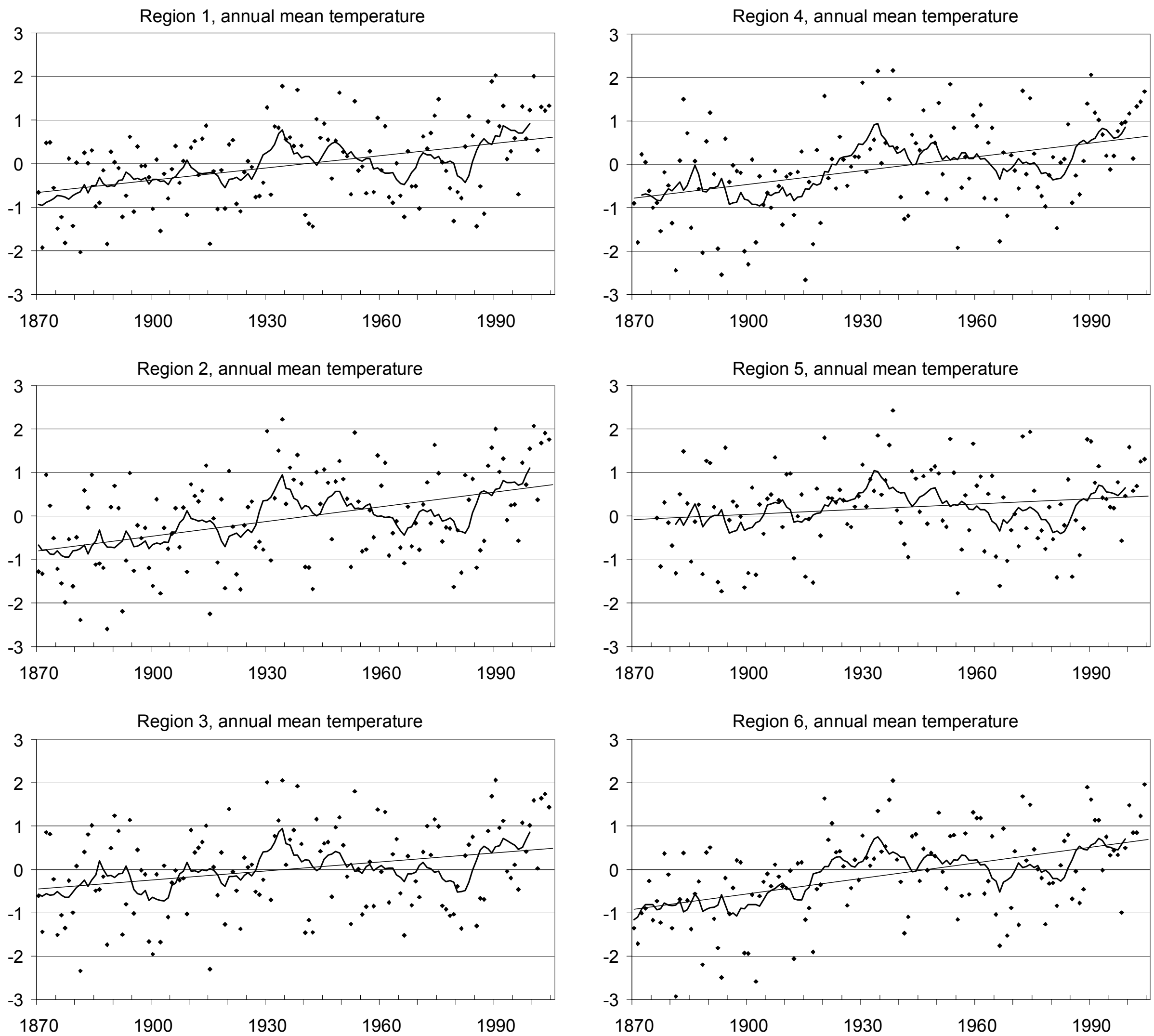


Figure 2. Standardised series of annual mean temperature anomalies in the temperature regions. *The anomalies are given in standard deviations relative to the 1961-1990 average. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

Table 2. Trends in annual and seasonal regional temperature series during the period 1875-2004. *Linear trends in regional temperature series given in standardised units (SU) per decade and in ^oC per decade . Trends significant at the 1% level according to the Mann-Kendall test are shown in* ***bold type****, while trends not significant at the 5% level are grey.*

	TR1		TR2		TR3		TR4		TR5		TR6	
	SU/dec	^{o}C/dec	SU/dec	^{o}C/dec	SU/dec	^{o}C/dec	SU/dec	^{o}C/dec	SU/dec	^{o}C/dec	SU/dec	^{o}C/dec
Annual	**+0.10**	**+0. 09**	**+0.12**	**+0.08**	**+0.08**	**+0.06**	**+0.11**	**+0.09**	+0.04	+0.05	**+0.12**	**+0.12**
Winter	+0.04	+0.12	+0.05	+0.11	+0.03	+0.08	+0.02	+0.04	-0.01	-0.02	+0.07	+0.11
Spring	**+0.13**	**+0.13**	**+0.13**	**+0.10**	**+0.10**	**+0.09**	**+0.13**	**+0.14**	+0.07	+0.11	**+0.11**	**+0.15**
Summer	+0.06	+0.05	+0.07	+0.06	+0.04	+0.04	**+0.08**	**+0.09**	+0.06	+0.08	**+0.10**	**+0.12**
Autumn	**+0.10**	**+0.10**	**+0.11**	**+0.09**	+0.04	+0.04	**+0.07**	**+0.07**	+0.03	+0.05	**+0.09**	**+0.10**

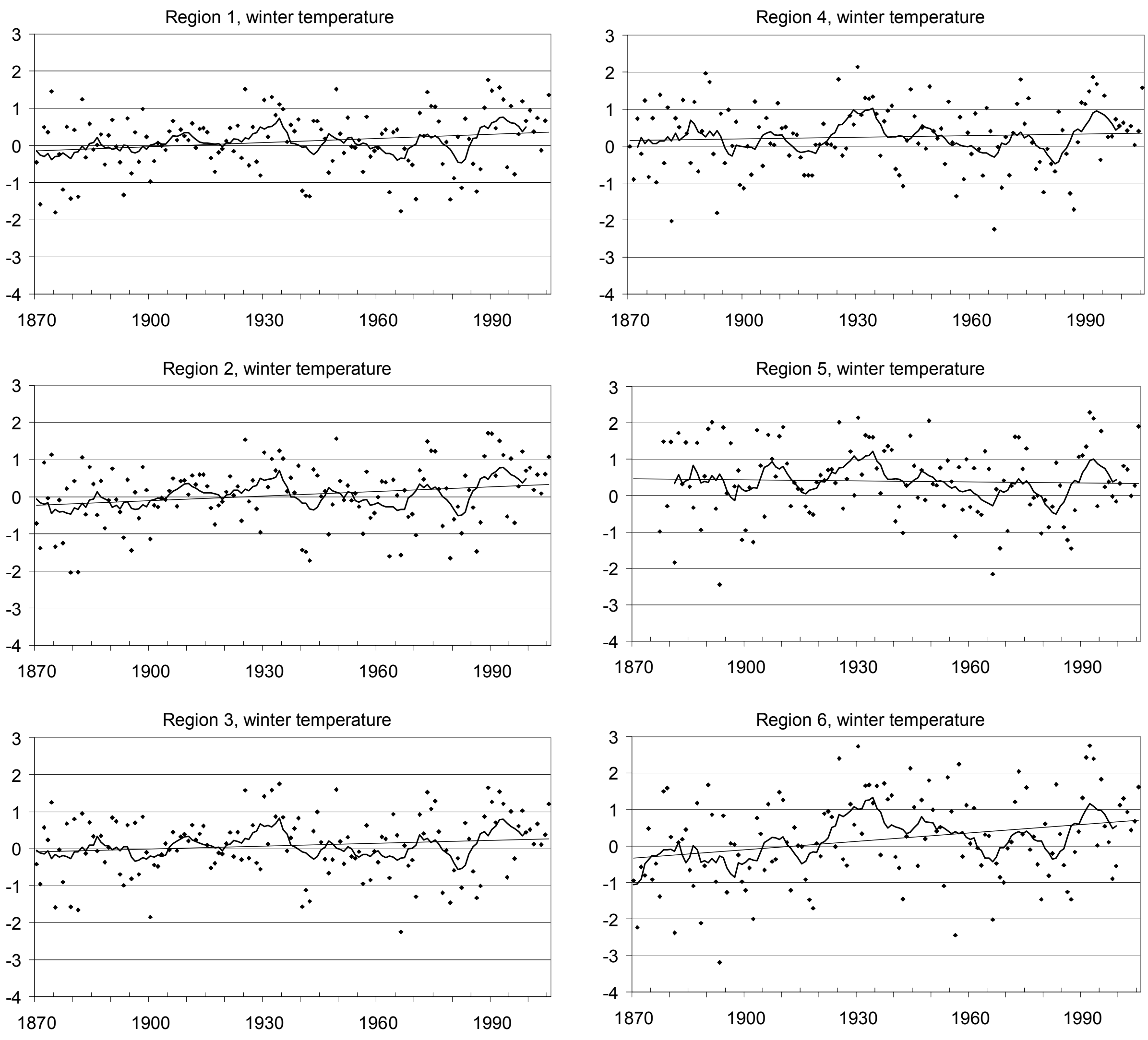


Figure 3. Standardised series of winter temperature anomalies in the 6 temperature regions. *The anomalies are given in standard deviations relative to the 1961-1990 average. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

A difference from the previous investigation is that the winter temperatures now show a statistically significant (5% level) increase in TR1, TR2 and TR6, while none of the regions showed significant trends in the winter temperature up to 1997. In TR5 there is still an insignificant negative trend in winter temperatures.

All regions now show an increase in spring temperatures significant at least at the 5% level. In the previous investigation, the spring warming was not statistically significant in TR5.

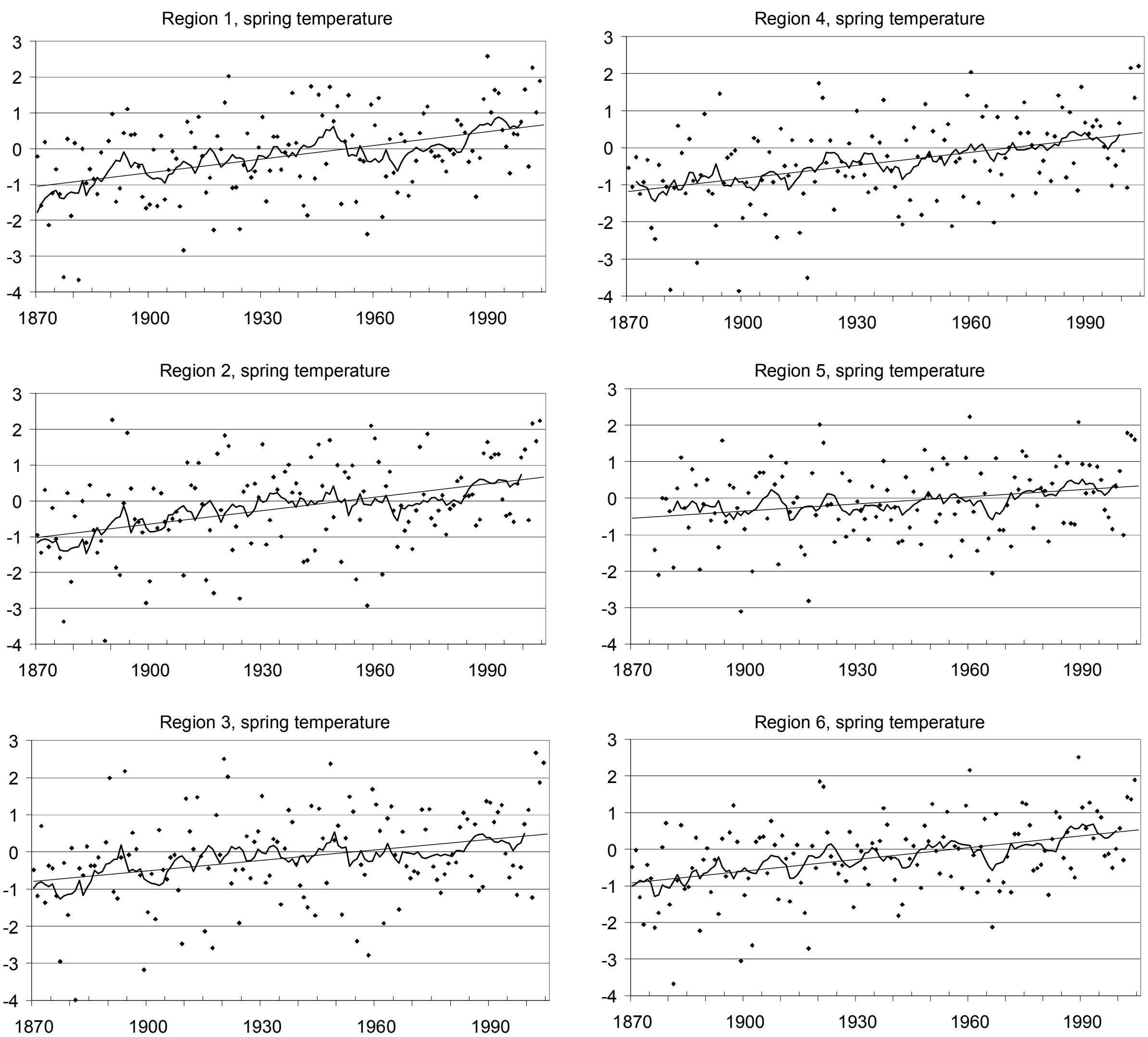


Figure 4. Standardised series of spring temperature anomalies in the 6 temperature regions. *The anomalies are given in standard deviations relative to the 1961-1990 average. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

In summer, the picture is mainly the same as seven years ago. The temperature increase is still not significant at the 5% level in the southern regions. In TR4, TR5 and TR6 on the other hand, the summer temperatures have increased significantly throughout the period.

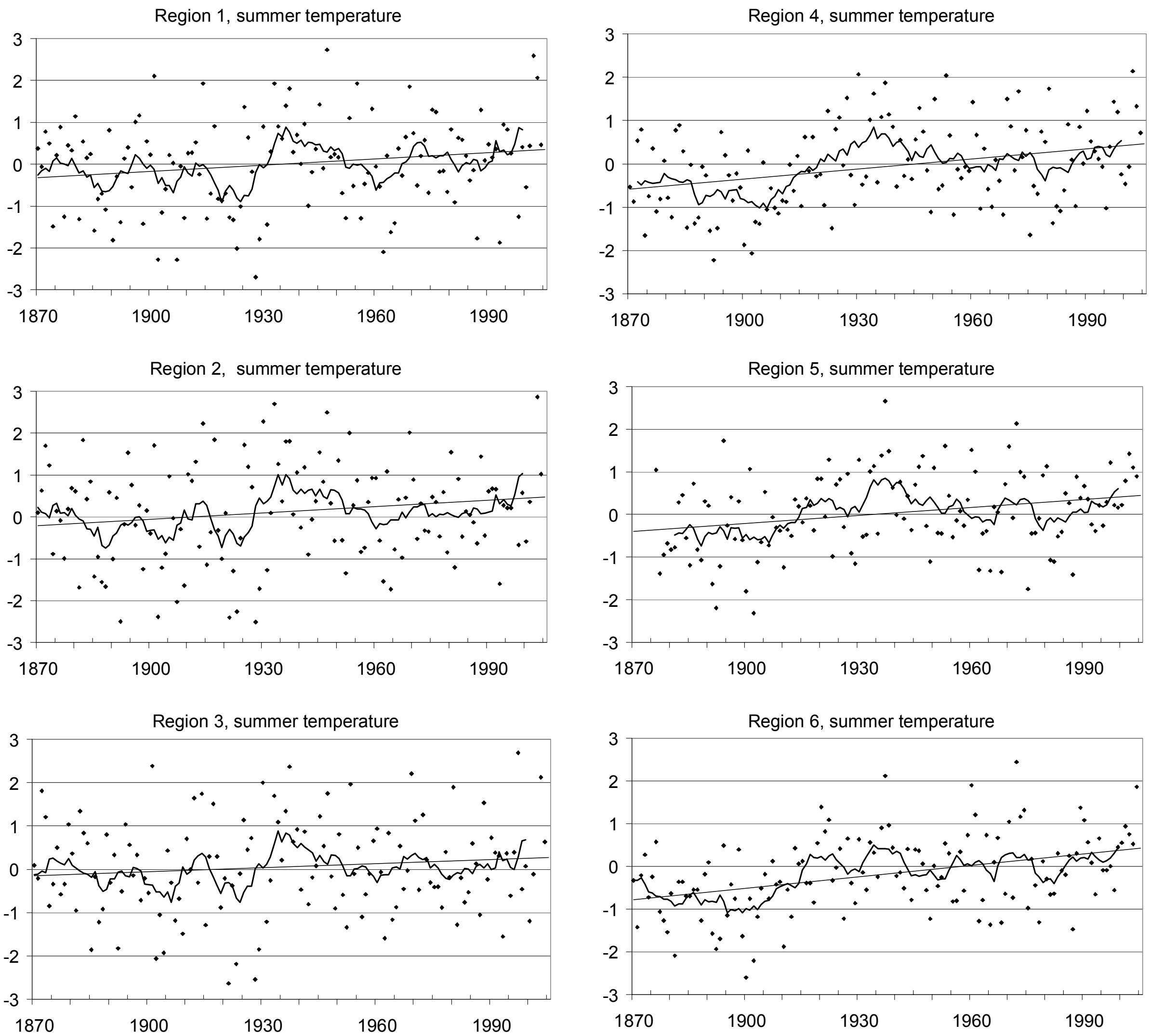


Figure 5. Standardised series of summer temperature anomalies in the 6 temperature regions. *The anomalies are given in standard deviations relative to the 1961-1990 average. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

In autumn, the linear temperature trends are larger now than seven years ago in most regions. The temperature increase is now significant at the 1% level in TR1, TR2, TR4 and TR6.
In the previous investigation, TR4 did not show a statistically significant increase.

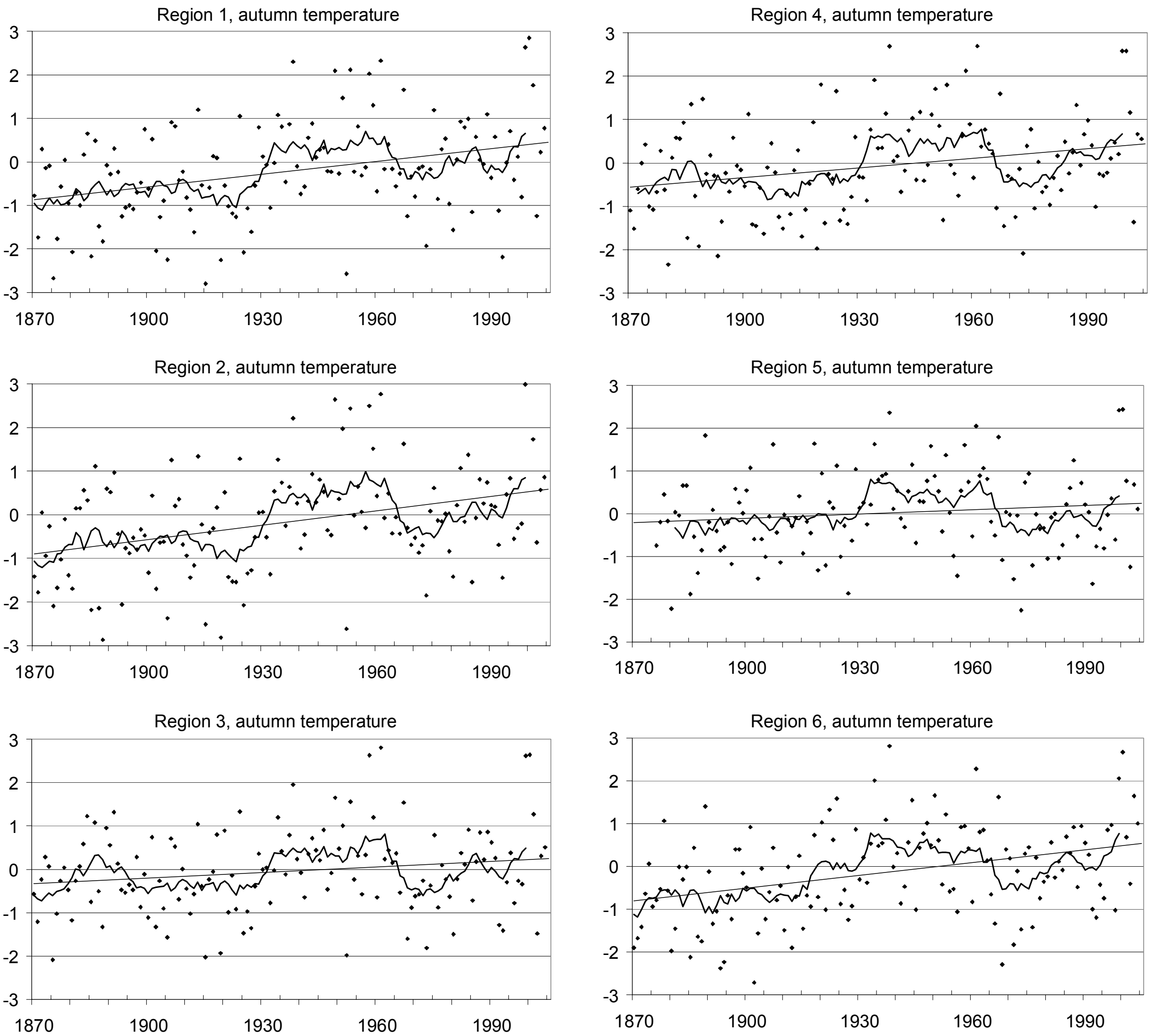


Figure 6. Standardised series of autumn temperature anomalies in the 6 temperature regions.
The anomalies are given in standard deviations relative to the 1961-1990 average. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.

2.3 Temperature variability

Figures 2 to 6 show that though a majority of the annual and seasonal regional temperature series show significant warming during the period 1875-2004, there is a substantial inter-annual variability. Typically, the warmest individual season or year is 2-3 standard deviations warmer than the 1961-1990 average while the coldest is 2-3 standard deviations colder than the average.

Extremely warm and cold years and seasons are not evenly distributed throughout the period. Table 3 lists the 3 coldest and warmest years and season in each region. Note that a majority of the cold events took place before 1920. However, there were several cool summers in southern Norway during the 1920s, and there were some cold winters and/or autumns in the period 1940-1980.

A majority of the warm events took place either in the 1930s or during the last 2 decades of the series. The winter 1949 was, however, warm in southern Norway, the spring 1960 was warm in northern Norway and the autumn 1961 was warm in most of the country.

Table 3. Coldest (a) and warmest (b) 3 years/seasons in TR1-6 during the period 1875-2004

a)

Region	Cold years	Cold winters	Cold springs	Cold summers	Cold autumns
1	1881, 1888, 1915	1875, 1966, 1979	1888, 1881, 1877	1928, 1907, 1902	1915, 1875,1952
2	1888, 1881, 1915	1879, 1881, 1942	1881, 1888, 1877	1928, 1892, 1921	1888, 1919, 1952
3	1881, 1915, 1900	1966, 1900, 1881	1888, 1881, 1899	1921, 1928, 1923	1875, 1915, 1952
4	1915, 1893, 1881	1966, 1881, 1893	1899, 1881, 1917	1892, 1902, 1900	1880, 1893, 1973
5	1955, 1893, 1899	1893, 1966, 1881	1899, 1917, 1877	1902, 1892, 1900	1973, 1880, 1885
6	1881, 1902, 1893	1893, 1956, 1881	1881, 1899, 1917	1900, 1902, 1881	1902, 1893, 1968

b)

Region	Warm years	Warm winters	Warm springs	Warm summers	Warm autumns
1	1990, 2000, 1989	1989, 1992, 1949	1990, 2002, 1921	2002, 1947, 1997	2000, 1999, 1961
2	1934, 2000, 1990	1989, 1990, 1949	1890, 2004, 2002	1997, 2002, 2003	2000, 1999, 1961
3	1990, 1934, 1930	1934, 1989, 1949	2002, 1920, 2004	2002, 1997, 1901	1961, 2000, 1958
4	1938, 1934, 1990	1930, 1890, 1992	2004, 2002, 1960	2002, 1930, 1953	1961, 1938, 1999
5	1938, 1974, 1934	1992, 1930, 1993	1960, 1989, 1920	1937, 1972, 1894	2000, 1999, 1938
6	1938, 2004, 1989	1992, 1930, 1991	1989, 1960, 2004	1972, 1937, 1960	1938, 2000, 1961

Table 3 as well as the individual values in Figures 2-6 illustrate the tendency of cold or warm years or seasons to be clustered in time. This tendency leads to temperature variations on decadal or multi-decadal timescales. Annual and seasonal temperature variability on decadal scale can be seen from the running means in Figures 2-6, but is also shown in Figure 7, where the series are smoothed with a “Gaussian filter” with a 3 year standard deviation (Hanssen-Bauer and Nordli 1998). Note that Figure 7 shows the standardised regional series, while the similar figure on the cover of this report shows the regional temperature anomalies in ^{o}C! The filtered series are cut 3 years from both ends because these values are too much influenced of the first or last few years. As all the regional series except TR5 start in the 1860s, they can nevertheless be plotted from 1875. The annual series show that the 1930s and the latest 10-15 years were the warmest periods in all regions (Figure 7, upper panel). When comparing 10-year averages (Figure 2), the 1930s tend to have been slightly warmer than the latest decade in the northern regions, while the tendency is opposite in the southern regions. All regions show cold periods during the first three decades, in the 1960s and the1980s. In TR5 the decade centred in the early 1980s was the coldest, while all other regions show colder decades during the first 30-40 years.

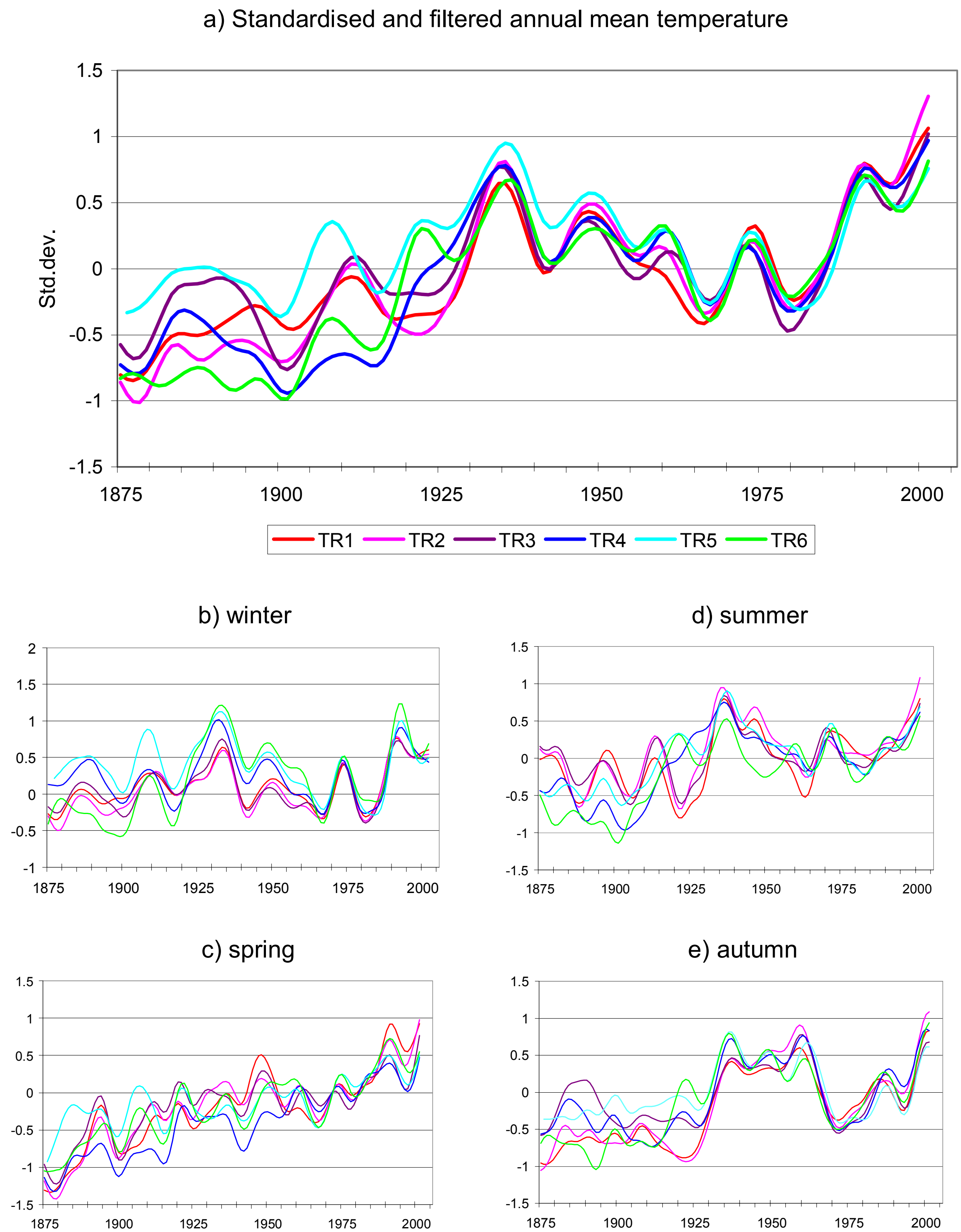


Figure 7. Standardised and low-pass filtered regional temperature series.
Panel a shows annual series, panels b-e show seasonal values. The low-pass filter includes a Gaussian weight function with standard deviation 3 years, and shows decadal scale variability. The filtered series are cut 3 years from the ends.

Based on variations in annual mean temperatures, the series can be split into 4 periods: a cold period in the beginning with small trends, a period referred to as "early 20th century warming" culminating in the 1930s, a period with cooling from the 1930s to the 1960s, and finally the "recent warming" from the 1960s to present. In order to calculate comparable trends, 4 partly overlapping 40-year periods were defined (Table 4). Both the early 20th century warming and the recent warming are statistically significant in all regions, though the former is dominating in northern regions TR4 and TR6 and the latter is dominating in southern regions TR1 and TR2. The cooling trend in the period 1932-1971 is of the same size as the warming trends only in region TR5.

Table 4. Trends in regional series of annual temperature during different time-slices.
Linear trends in standardised regional temperature series, given in ^oC per decade.
*Trends significant at the 1% level according to the Mann-Kendall test are **bold**.*
Trends which are not significant at the 5% level are grey.

	TR 1	TR 2	TR 3	TR 4	TR 5	TR 6
1866[1]-2004	**+0.09**	**+0.08**	**+0.06**	**+0.09**	+0.05	**+0.12**
1866[1]-1905	+0.19	+0.04	+0.02	-0.05	-0.04	+0.09
1900-1939	**+0.30**	**+0.27**	**+0.33**	**+0.48**	+0.38	**+0.50**
1932-1971	**-0.27**	-0.21	-0.22	-0.21	-0.39	-0.26
1965-2004	**+0.39**	**+0.34**	**+0.34**	**+0.36**	**+0.41**	**+0.40**

[1]: In region 4 the series start in 1868; in region 5 they start in 1875.

The decadal scale variability in regional winter temperatures shows mainly the same features as the annual temperatures (Figures 3 and 7b). In southern Norway, the highest winter-temperature level was observed near the end of the series, while in northern Norway the 1930s tend to show a slightly higher level. The cold spells in the 1960s and 1980s are even more pronounced for winter-temperatures than for annual means. In most regions, the coldest decade in entire time-series was centred in the 1980s (Figure 3).

The spring temperatures show in all regions decadal scale variability around a clear positive trend (Figures 4 and 7c). In all regions except TR5 the coldest decade is found near the beginning of the series, while the warmest is near the end. The spring-temperatures in the1930s were not particularly high.

The decadal scale variability in regional summer temperatures show similar features as the winter temperatures and annual temperatures with warm periods in the 1930s and the latest decade (Figures 5 and 7d). The coldest summers in northern Norway clearly occurred around 1900. In southern Norway, however, the summers in the 1920s were at least as cold.

The autumn temperatures were high not only in the 1930s and in the latest decade, but also around 1960 (Figures 6 and 7d). The southern regions (TR1 and TR2) generally show a low level of the autumn temperatures from the start of the series to the 1920s. Also the other regions show low autumn temperatures at least during parts of this period. In TR3 and TR5, however, the autumn temperature level of the 1970s was even lower.

3. Precipitation

3.1 Definition of precipitation regions and standardised regional precipitation series

The 13 Norwegian precipitation regions (RR01-RR13) applied in the present analysis (Figure 8) were defined by Hanssen-Bauer and Førland (1998) using "comparative trend analysis" (Hanssen-Bauer et al. 1997). For each region (*m*), a number (*n*) of precipitation series were used to calculate the regional standardised precipitation series (SR_m) in the following way:

$$SR_m = (1/n) \cdot \sum_{i=1}^{n} SR_{m,i} \qquad m=1\text{-}13 \qquad (3).$$

Here $SR_{m,i}$ is the precipitation series from station number *i* in region *m* given in percent of the average value for the period 1961-1990:

$$SR_{mi} = 100\, R_{m,i}/\mu_{R\,m,i} \qquad (2),$$

where $R_{m,i}$ is the observed precipitation series at station *i* in region *m*, and $\mu_{Rm,i}$ is the average precipitation at this station during the period 1961-1990. Standardised series were calculated on monthly, seasonal and annual basis. An overview of the 78 stations applied in the various regions and some relevant information is given in Table A3 in Appendix.

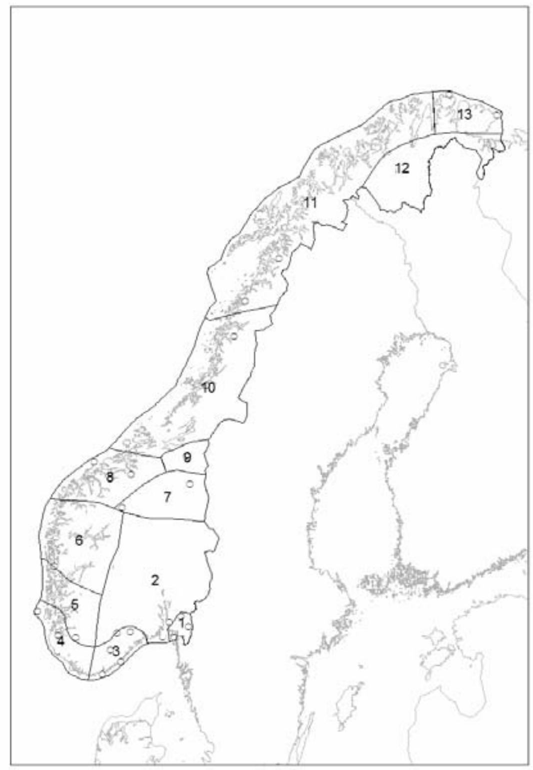


Figure 8. Precipitation regions in Norway.

3.2 Long-term precipitation trends

The regional series of annual and seasonal precipitation are shown in Figure 9-13 together with 10-year running mean values and linear trends. The linear trends for the period 1895-2004 are also given in Table 5. The statistical significance of these trends was tested by the Mann-Kendall non-parametric test (Sneyers 1990, 1995). Comparison to the similar table based upon analyses 7 years ago (Hanssen-Bauer and Nordli 1998), show a tendency to increased statistical significance of the long-term increase in annual precipitation. Of the 13 regions, 9 now show an increase in annual precipitation statistically significant at least at the 5% level. In the previous analysis, only 6 regions showed an increase of this significance. The northern regions RR10, RR11 and RR12 show an increase of between 15 and 20% of the annual average precipitation in 100 years.

Table 5. Trends in annual and seasonal regional precipitation series from 1895 to 2004. *Linear trends in standardised regional precipitation series, given in % of the average during the period 1961-1990. Trends significant at the 1% level according to the Mann-Kendall test are **bold**. Trends which are not significant at the 5% level are grey.*

	RR01	RR02	RR03	RR04	RR05	RR06	RR07	RR08	RR09	RR10	RR11	RR12	RR13
Annual	+1.3	+1.0	+0.5	+1.2	+1.4	+1.2	**+1.5**	+1.1	+1.2	**+1.6**	**+1.9**	**+1.8**	+0.3
Winter	+1.6	+0.8	-0.3	+0.5	+1.4	+0.7	+1.1	+1.5	+1.7	+2.1	+2.6	**+3.0**	-1.3
Spring	+0.8	+0.2	-0.9	+0.5	+1.8	+2.1	**+2.7**	+1.9	+2.0	**+2.7**	**+2.6**	**+2.4**	-1.6
Summer	+0.6	+0.1	-0.2	+0.7	+0.3	+1.0	+1.3	+1.0	+0.9	+1.5	**+2.4**	+1.4	**+3.2**
Autumn	+2.1	+2.5	+2.2	**+2.2**	**+1.7**	+1.1	+1.6	+0.3	+0.8	+0.7	+0.5	+1.2	+0.6

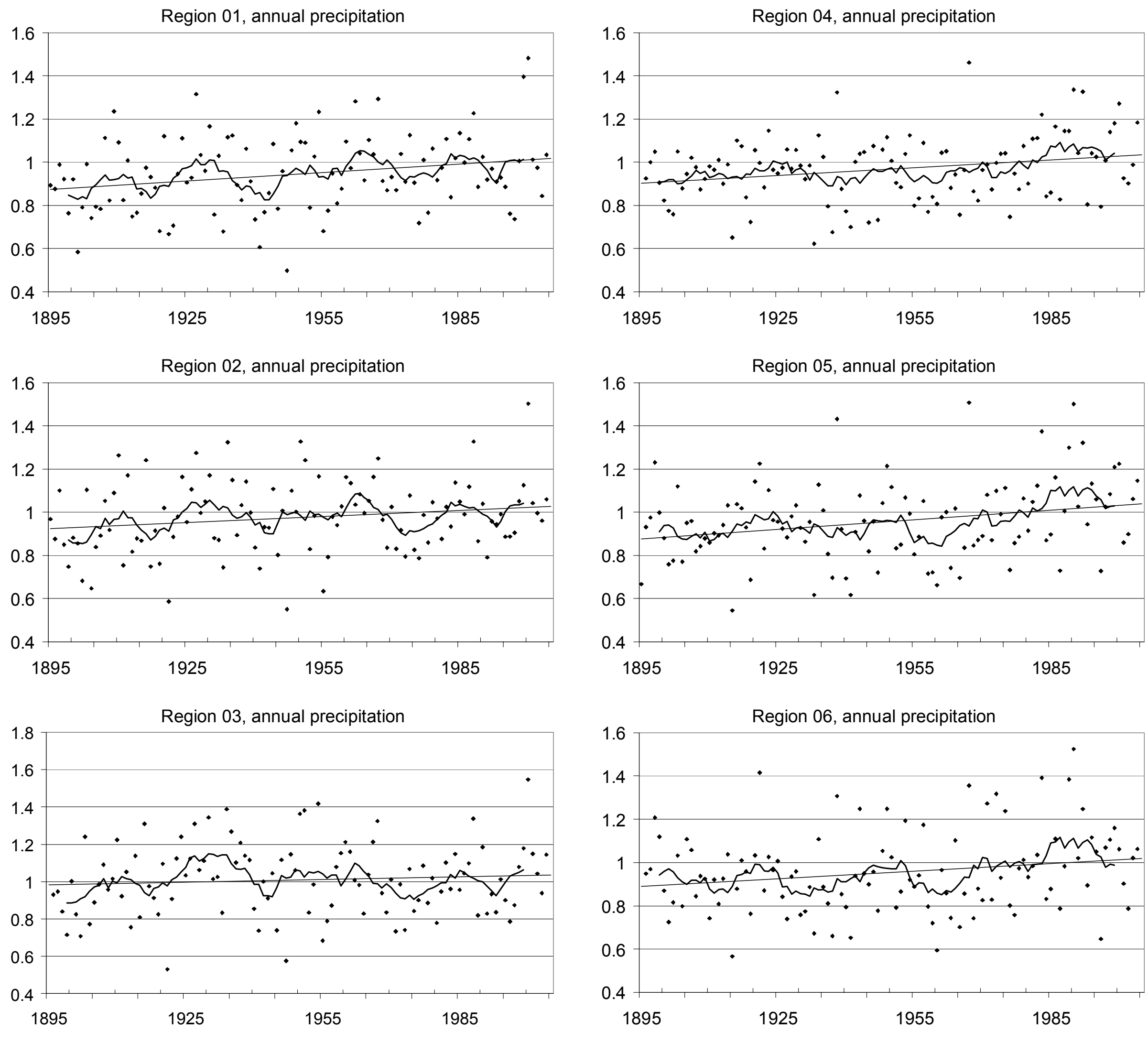


Figure 9. Standardised series of annual precipitation in precipitation regions RR01-RR06. *The precipitation is given as fraction of the 1961-1990 average. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

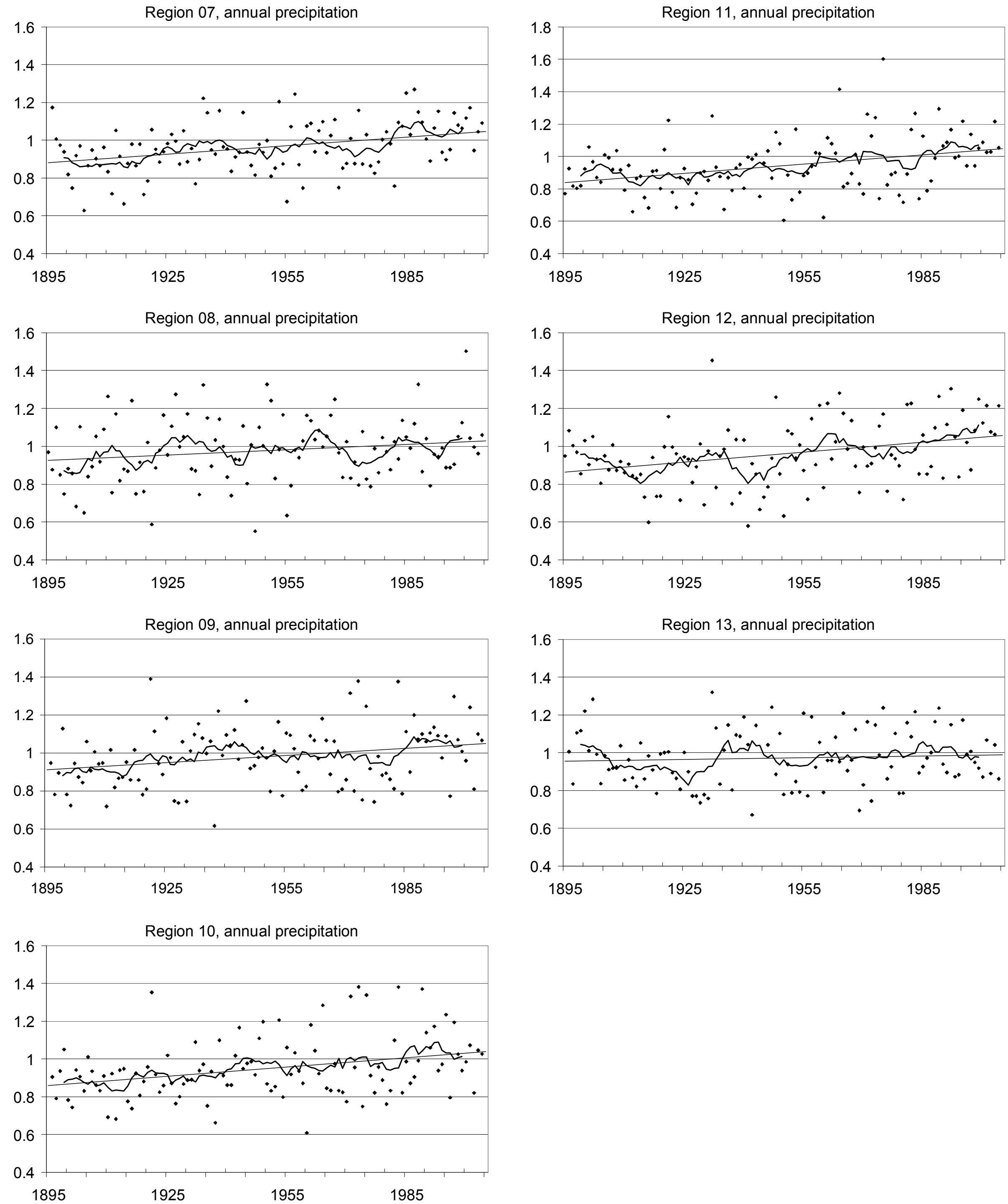


Figure 9 cont. Standardised series of annual precipitation in precipitation regions RR07-RR13. *The precipitation is given as fraction of the 1961-1990 average. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

The winter precipitation has increased in all regions except RR03 and RR13, but the trend is significant only in a couple of the northern regions.

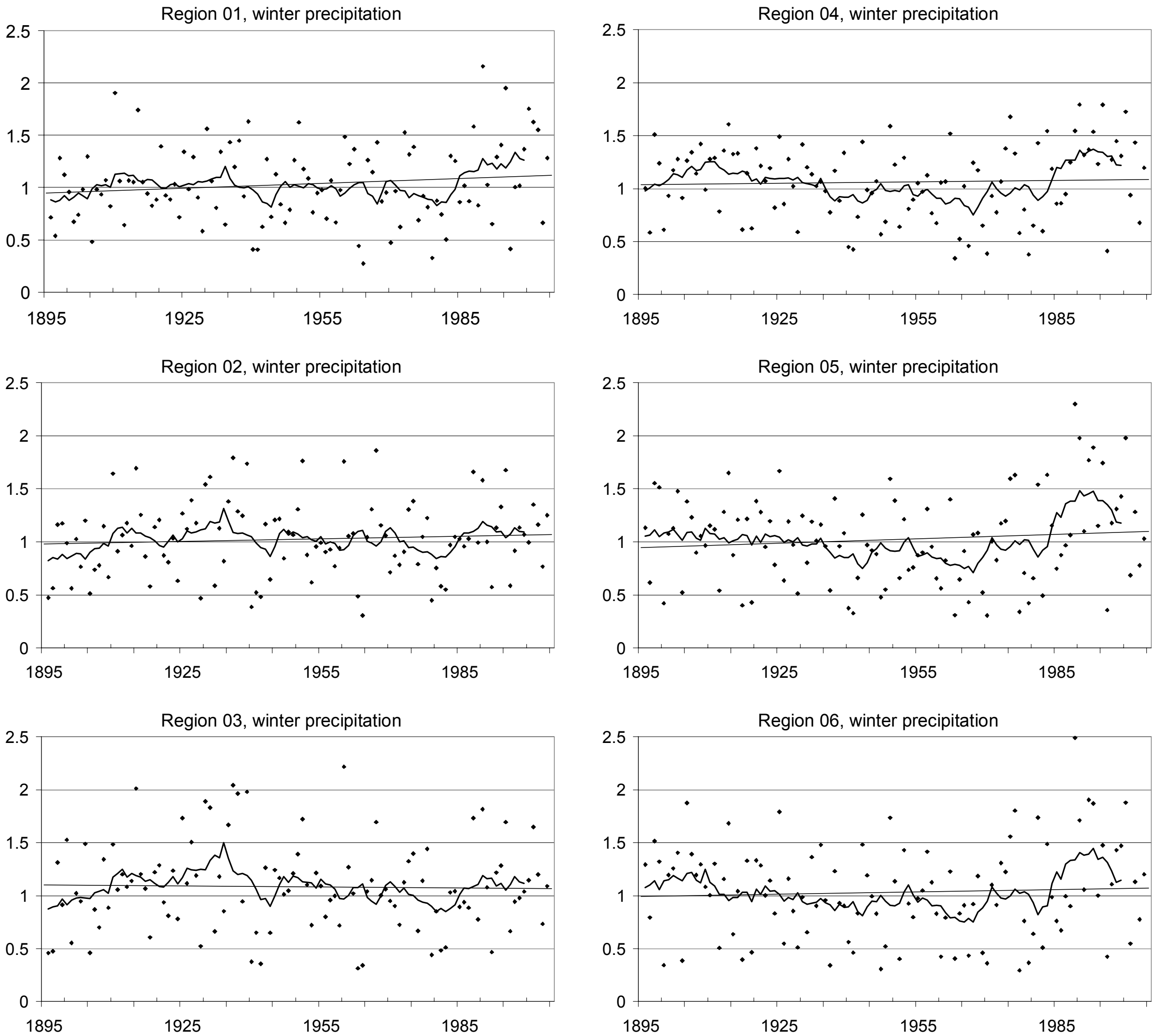


Figure 10. Standardised series of winter precipitation in precipitation regions RR01-RR06. *The precipitation is given as fraction of the 1961-1990 average winter precipitation. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

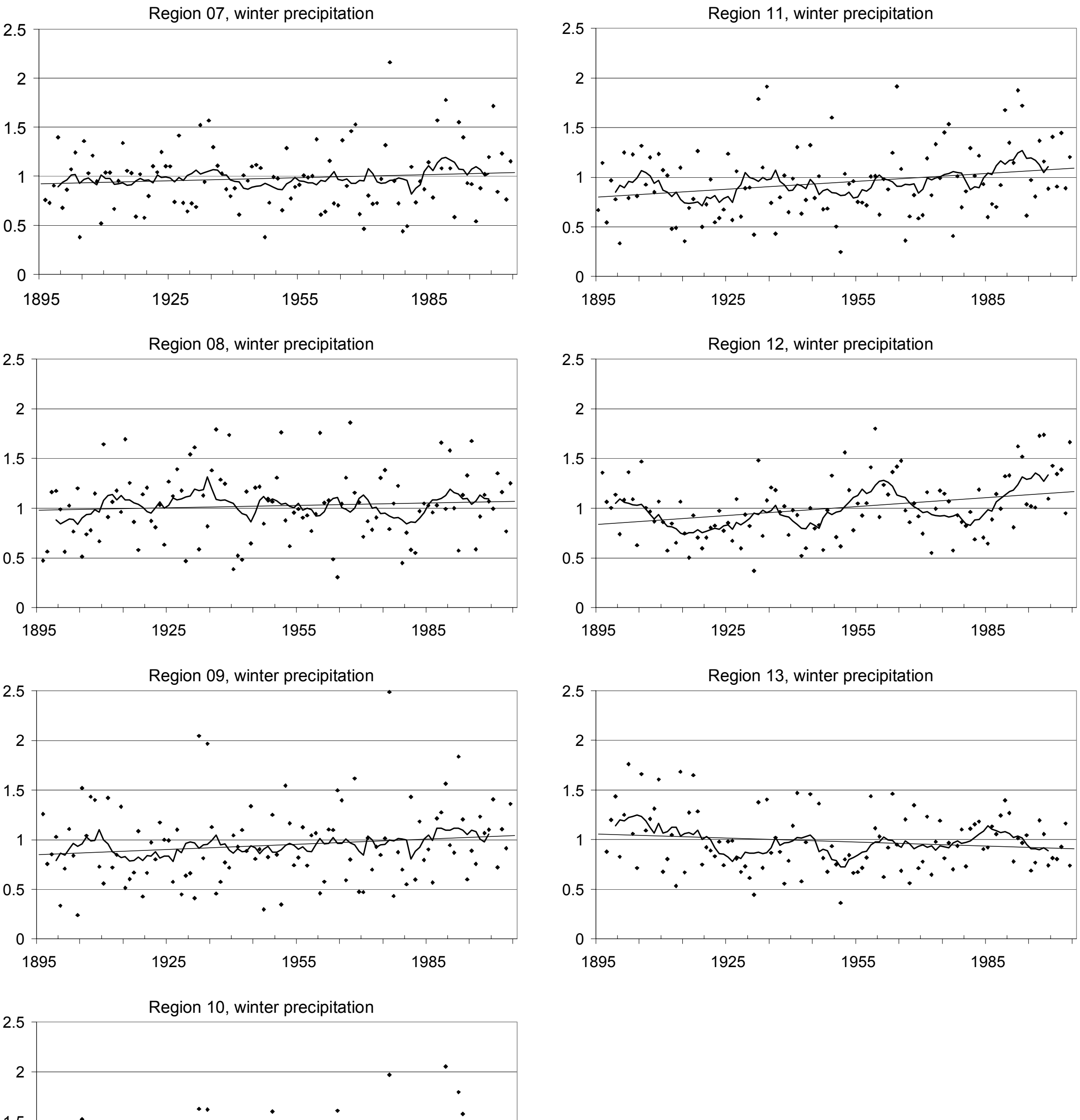


Figure 10 cont. Standardised series of winter precipitation in precipitation regions RR07-RR13. *The precipitation is given as fraction of the 1961-1990 average winter precipitation. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

Also the spring precipitation has increased in all regions except RR03 and RR13, and the trends are statistically significant in 5 regions: 3 northern regions and 2 in regions in central Norway.

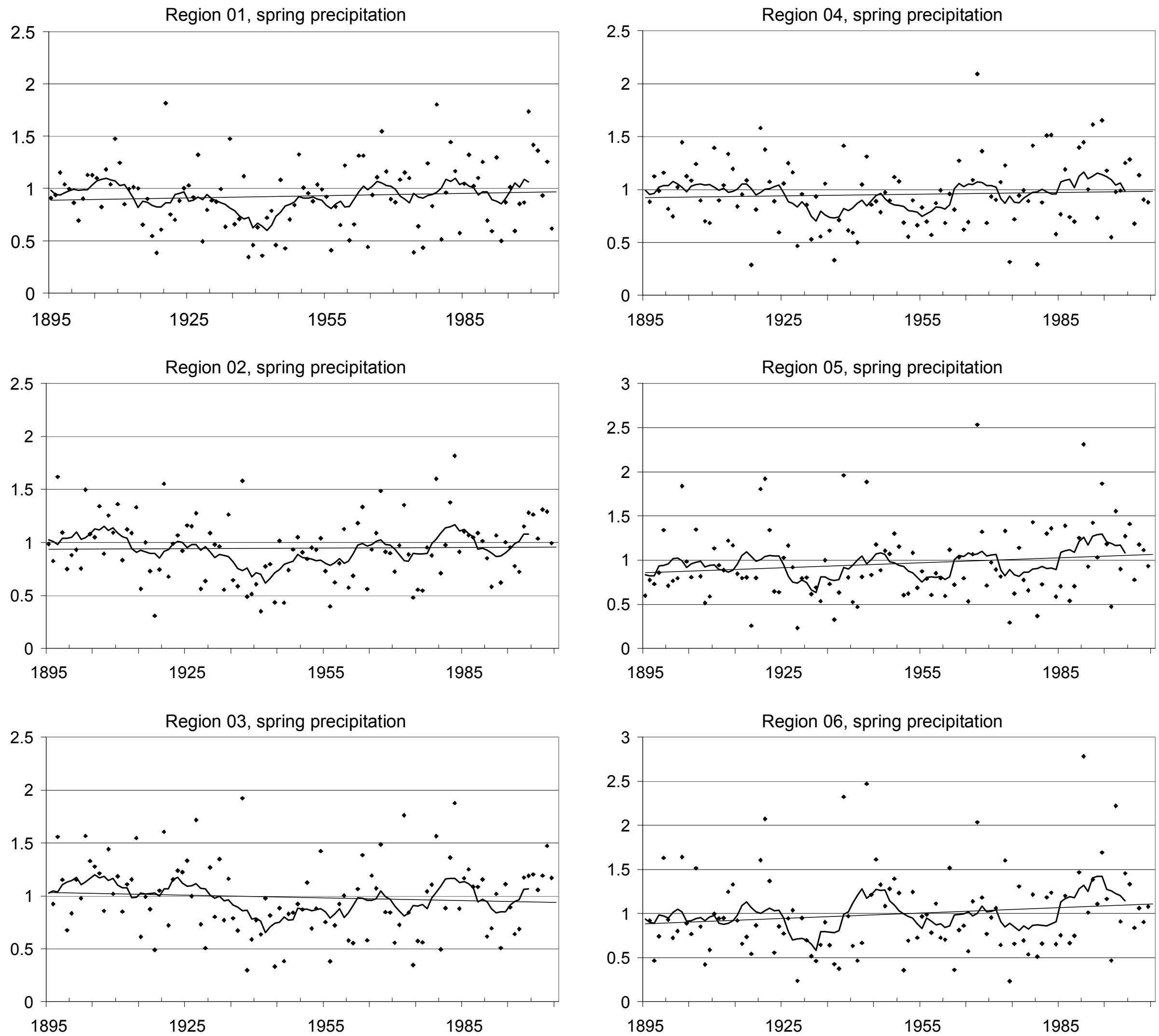


Figure 11. Standardised series of spring precipitation in precipitation regions RR01-RR06.
The precipitation is given as fraction of the 1961-1990 average spring precipitation. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.

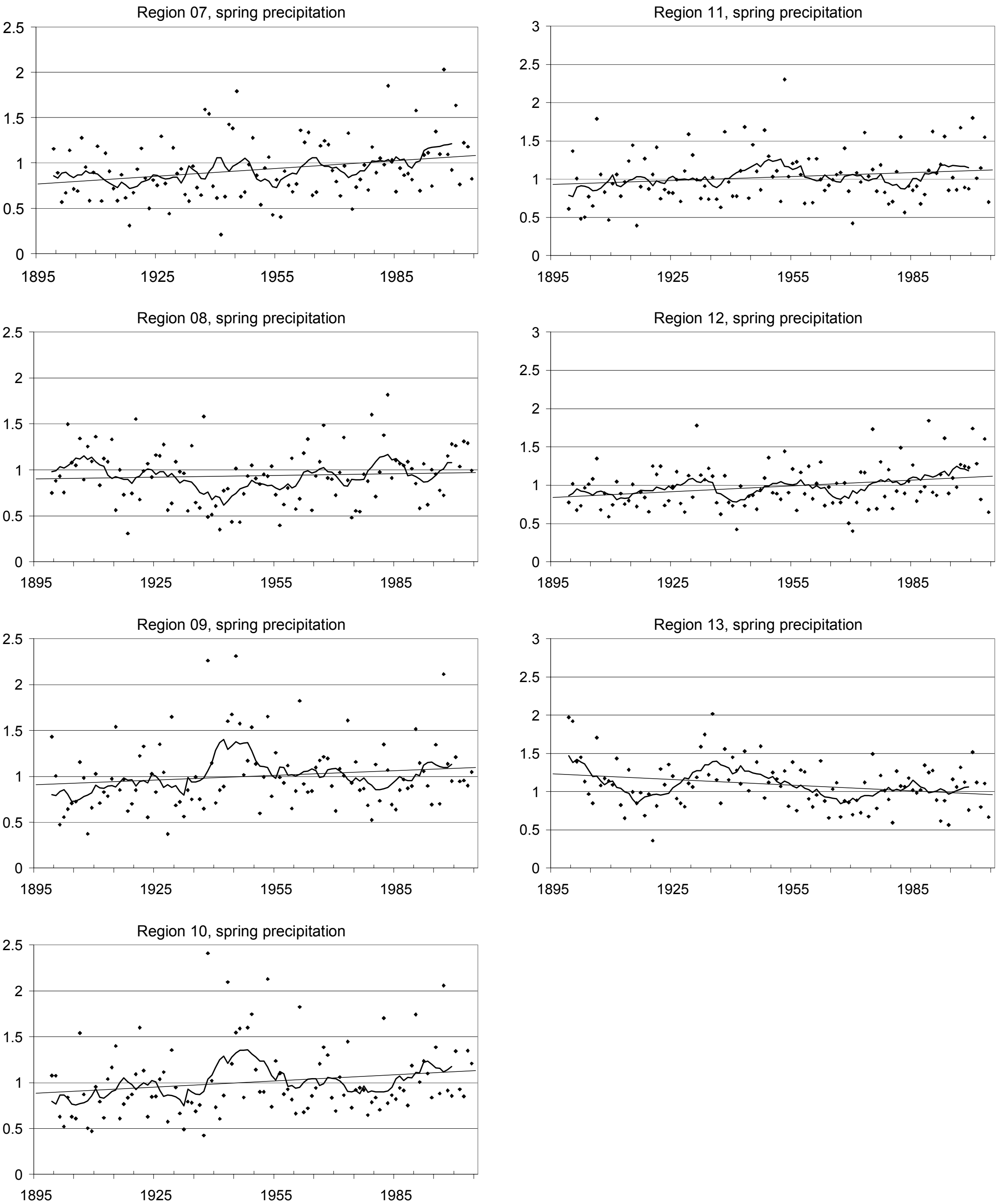


Figure 11 cont. Standardised series of spring precipitation in precipitation regions RR07-RR13. *The precipitation is given as fraction of the 1961-1990 average spring precipitation. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

The summer precipitation has increased in all regions except RR03, and the trends are statistically significant in 4 regions: 3 northern regions and 1 region in central Norway.

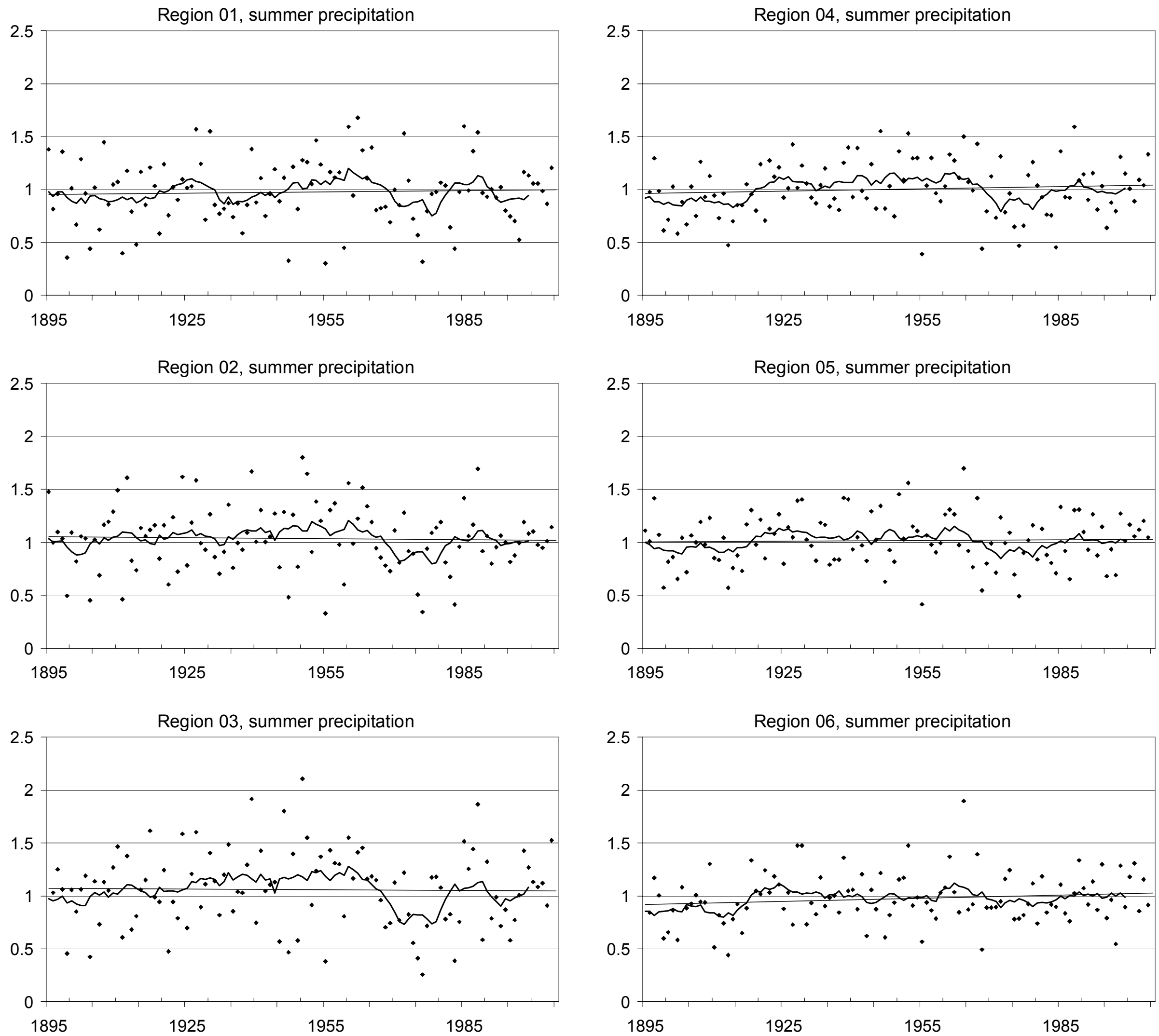


Figure 12. Standardised series of summer precipitation in precipitation regions RR01-RR06. *The precipitation is given as fraction of the 1961-1990 average summer precipitation. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

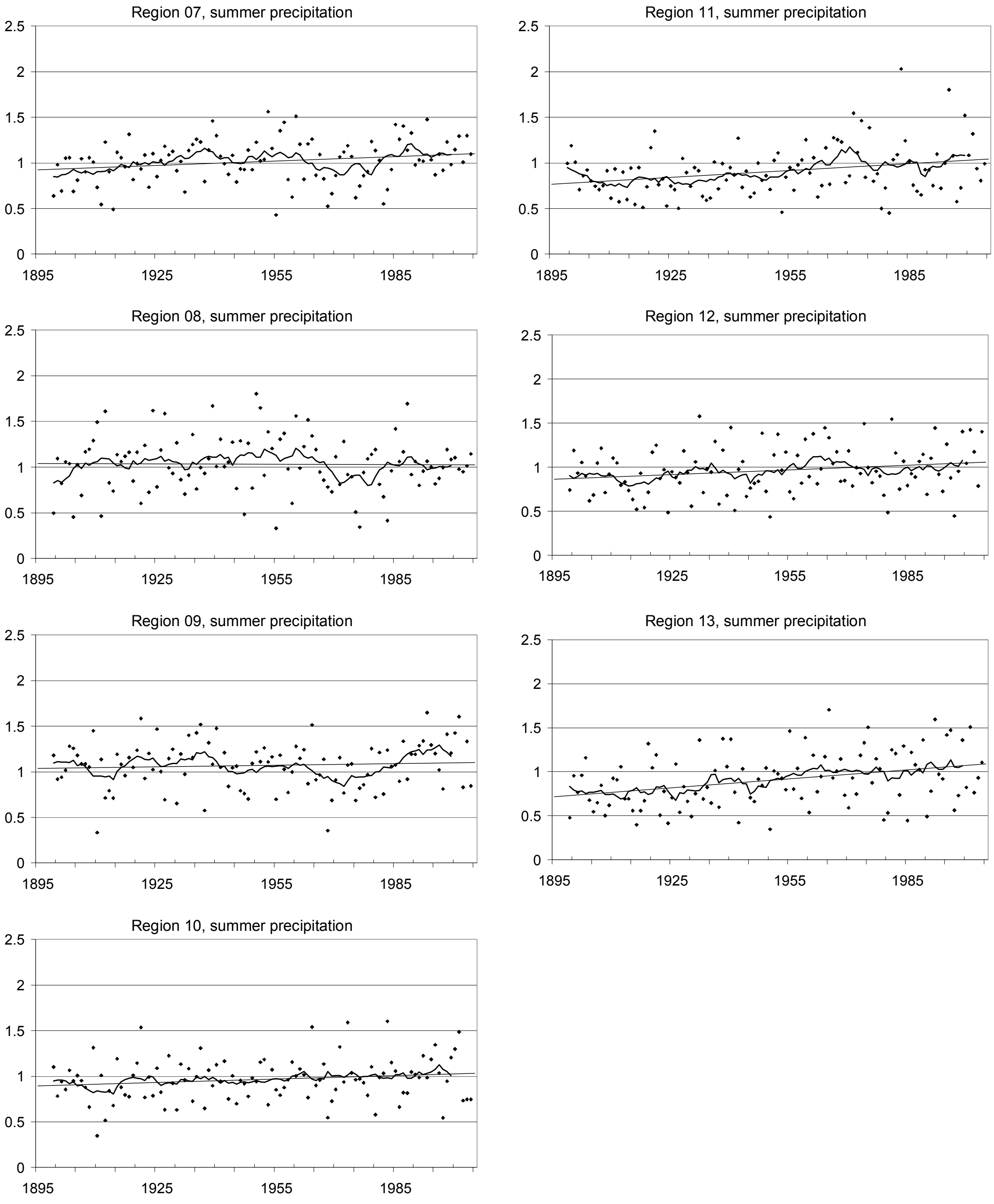


Figure 12 cont. Standardised series of summer precipitation in precipitation regions RR07-RR13. *The precipitation is given as fraction of the 1961-1990 average summer precipitation. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

The autumn precipitation has increased in all regions, and the trends are statistically significant in 6 regions: 5 southern regions and 1 in central Norway.

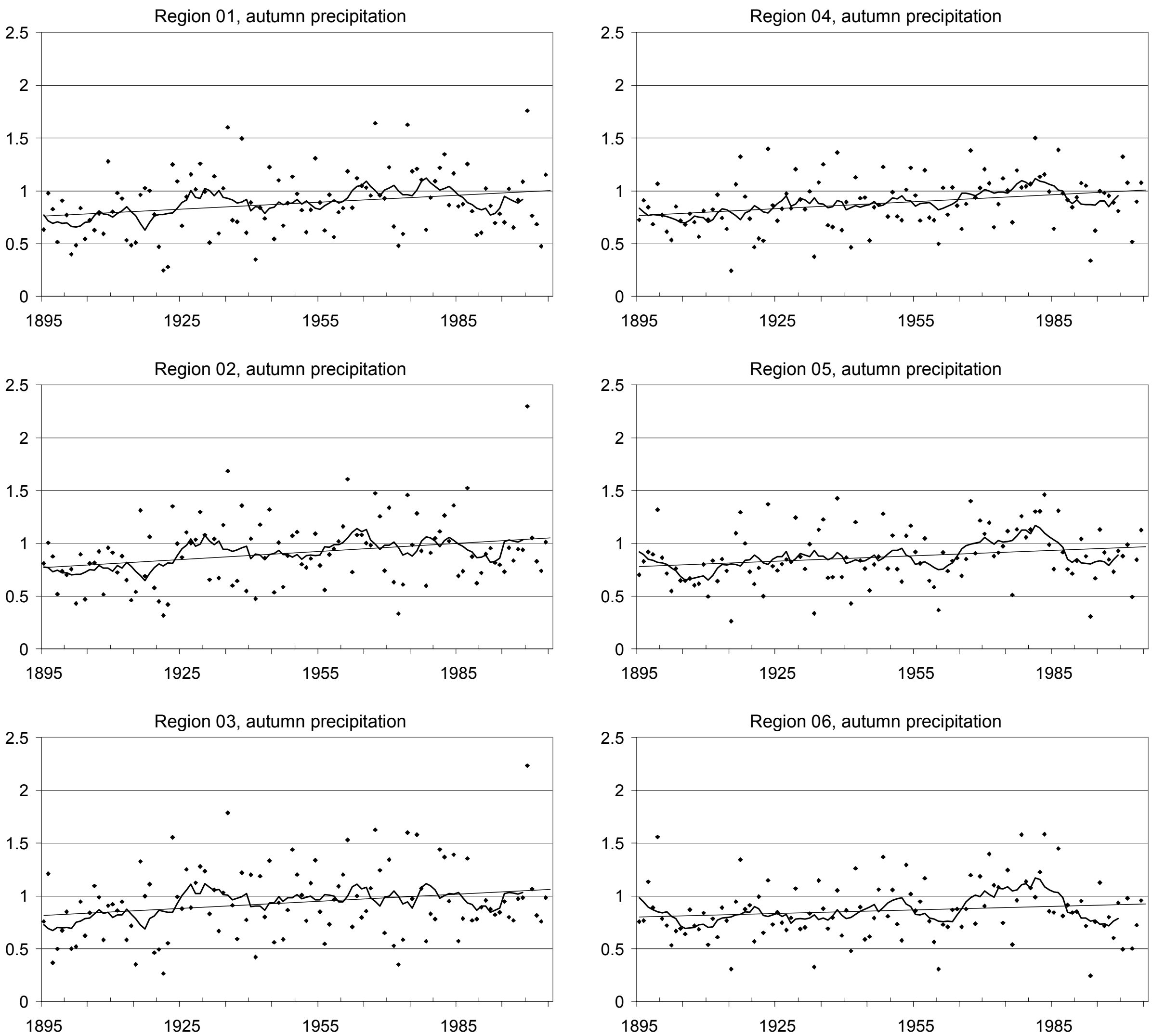


Figure 13. Standardised series of autumn precipitation in precipitation regions RR01-RR06. *The precipitation is given as fraction of the 1961-1990 average autumn precipitation. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

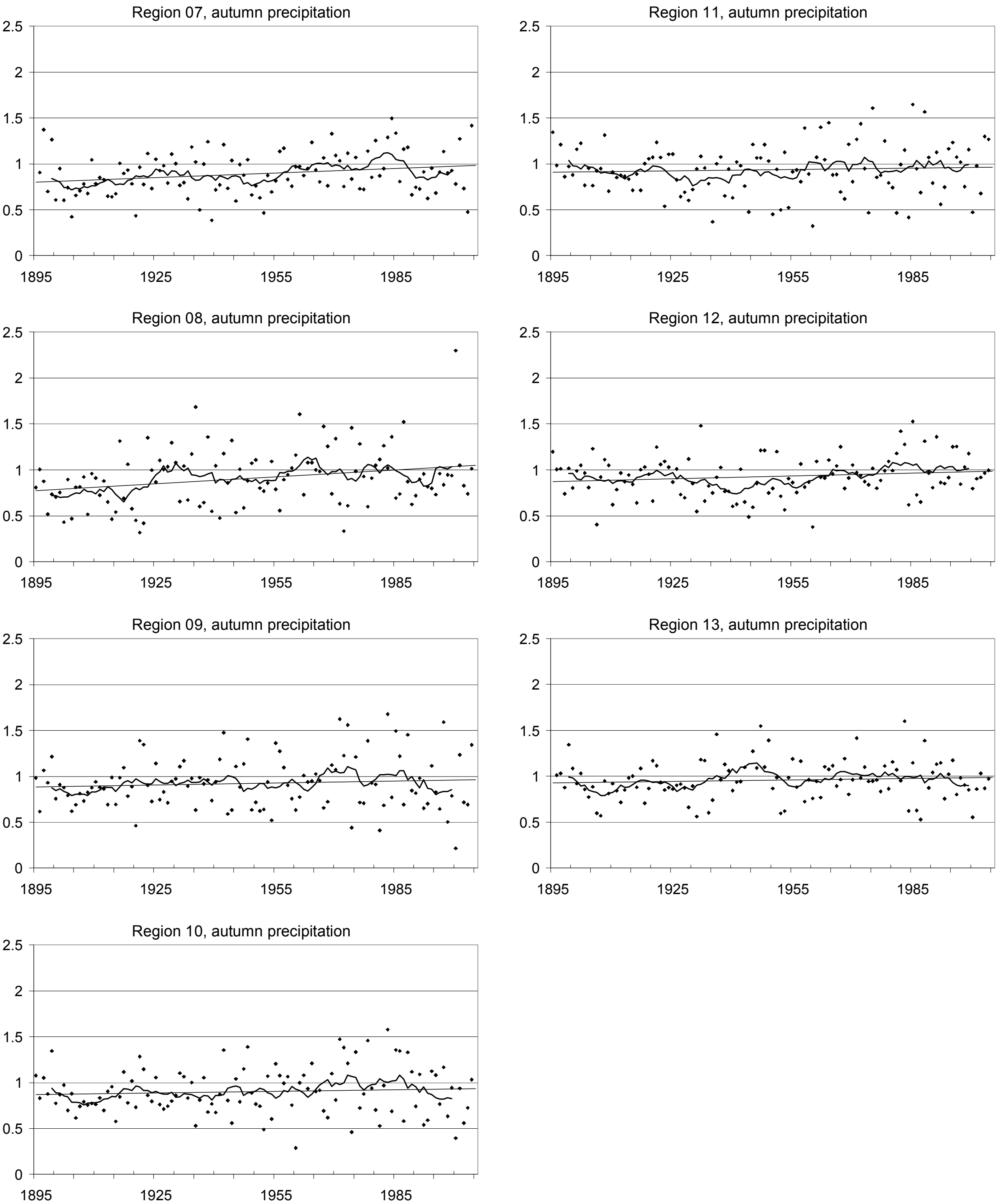


Figure 13 cont. Standardised series of autumn precipitation in precipitation regions RR07-RR13. *The precipitation is given as fraction of the 1961-1990 average autumn precipitation. The diamonds show individual values, while the curves show 10-year running means dated on the 5th year. The straight lines indicate the linear trends.*

3.3 Precipitation variability

Figures 9 to 13 show a substantial inter-annual variability in annual and seasonal precipitation series. Typically, the “driest” seasons get half the 1961-1990 precipitation average or less, while the “wettest” seasons typically gets 1.5 to 2.5 times the average.

Extremely “dry” or “wet” years and seasons are not evenly distributed throughout the period. Table 6 lists the 3 “driest” and “wettest” years and season in each region. Note that only one of the last 25 years were among the 3 driest in any region; namely 1996 which was “dry” in region 6 and 8. During the last 25 years, there were no “dry” winter or spring seasons in any region. However, several summers and autumns were “dry” in one or more regions during this period.

During the first 25 years, only one year was among the 3 “wettest” in any region, namely 1902 in region 13. On the other hand, 8 of the last 25 years were “wet” in one or more regions, some of them in 4 regions. Also for seasonal precipitation, Table 6 shows that the last 25 years are overrepresented among those classified as “wet”.

Table 6. Driest (a) and wettest (b) 3 years/seasons in RR01-13 during the period 1895-2004

a)

Region	Dry years	Dry winters	Dry springs	Dry summers	Dry autumns
1	1947,1901,1941	1964,1979,1941	1938,1941,1918	1955,1975,1947	1921,1922,1941
2	1947,1921,1955	1964,1940,1979	1918,1941,1956	1955,1976,1983	1921,1972,1922
3	1921,1947,1955	1963,1964,1942	1938,1944,1974	1976,1955,1983	1921,1972,1915
4	1933,1915,1937	1963,1979,1970	1918,1980,1974	1955,1968,1984	1915,1993,1933
5	1915,1933,1941	1970,1963,1941	1928,1918,1974	1955,1976,1968	1915,1993,1933
6	1915,1960,1996	1977,1947,1936	1974,1928,1951	1913,1968,1910	1993,1915,1960
7	1904,1914,1955	1904,1947,1979	1941,1918,1956	1955,1914,1968	1939,1904,1920
8	1996,1937,1977	1904,1947,1951	1908,1928,1897	1910,1968,1955	2000,1993,1920
9	1937,1910,1901	1904,1947,1900	1928,1908,1897	1910,1968,1937	2000,1981,1974
10	1960,1937,1912	1951,1900,1915	1897,1937,1909	1910,1912,1997	1960,2000,1974
11	1950,1960,1912	1951,1900,1915	1898,1916,1897	1980,1953,1978	1960,1935,1984
12	1941,1916,1950	1931,1916,1942	1970,1941,1895	1950,1997,1980	1960,1906,1944
13	1969,1942,1929	1951,1931,1913	1920,1898,1897	1950,1916,1942	1987,2000,1931

b)

Region	Wet years	Wet winters	Wet springs	Wet summers	Wet autumns
1	2000,1999,1927	1990,1995,1910	1920,1979,1999	1962,1985,1960	2000,1967,1974
2	2000,1988,1950	1967,1936,1951	1983,1897,1979	1950,1988,1939	2000,1935,1961
3	2000,1954,1934	1960,1936,1915	1937,1983,1972	1950,1939,1988	2000,1935,1967
4	1967,2000,1990	1990,1995,2000	1967,1994,1992	1988,1946,1952	1981,2000,1923
5	1967,1990,1938	1989,2000,1990	1967,1990,1938	1964,1952,1950	1983,1938,1967
6	1990,1921,1983	1989,1992,2000	1990,1943,1938	1964,1952,1928	1983,1978,1899
7	1987,1985,1957	1976,1989,2000	1997,1983,1945	1896,1953,1960	1984,2004,1897
8	1983,1973,1921	1976,1989,1905	1997,1990,1938	1964,1936,1909	1978,1983,1897
9	1921,1973,1983	1976,1932,1934	1945,1938,1997	1993,2001,1921	1983,1971,1997
10	1973,1983,1989	1989,1976,1992	1938,1953,1943	1983,1973,1964	1983,1971,1978
11	1975,1964,1989	1964,1934,1992	1953,2000,1906	1983,1995,1971	1985,1975,1988
12	1932,1992,1964	1959,1998,1997	1989,1931,2000	1932,1981,1974	1985,1932,1982
13	1902,1932,1947	1902,1914,1905	1899,1935,1900	1965,1992,1975	1947,1983,1936

In spite of this tendency for more “dry” seasons and years in the beginning of the series, and more “wet” seasons and years in the end, Table 6 as well as the individual values in Figures 9-13 illustrate that there is no monotonous trend in number of “dry” and “wet years. This is also seen from Figures 14 and 15, where the series are smoothed with a “Gaussian filter” with a 3 year standard deviation (Hanssen-Bauer and Nordli 1998). The filtered series are cut 3 years from both ends because these values are too much influenced of the first or last few years.

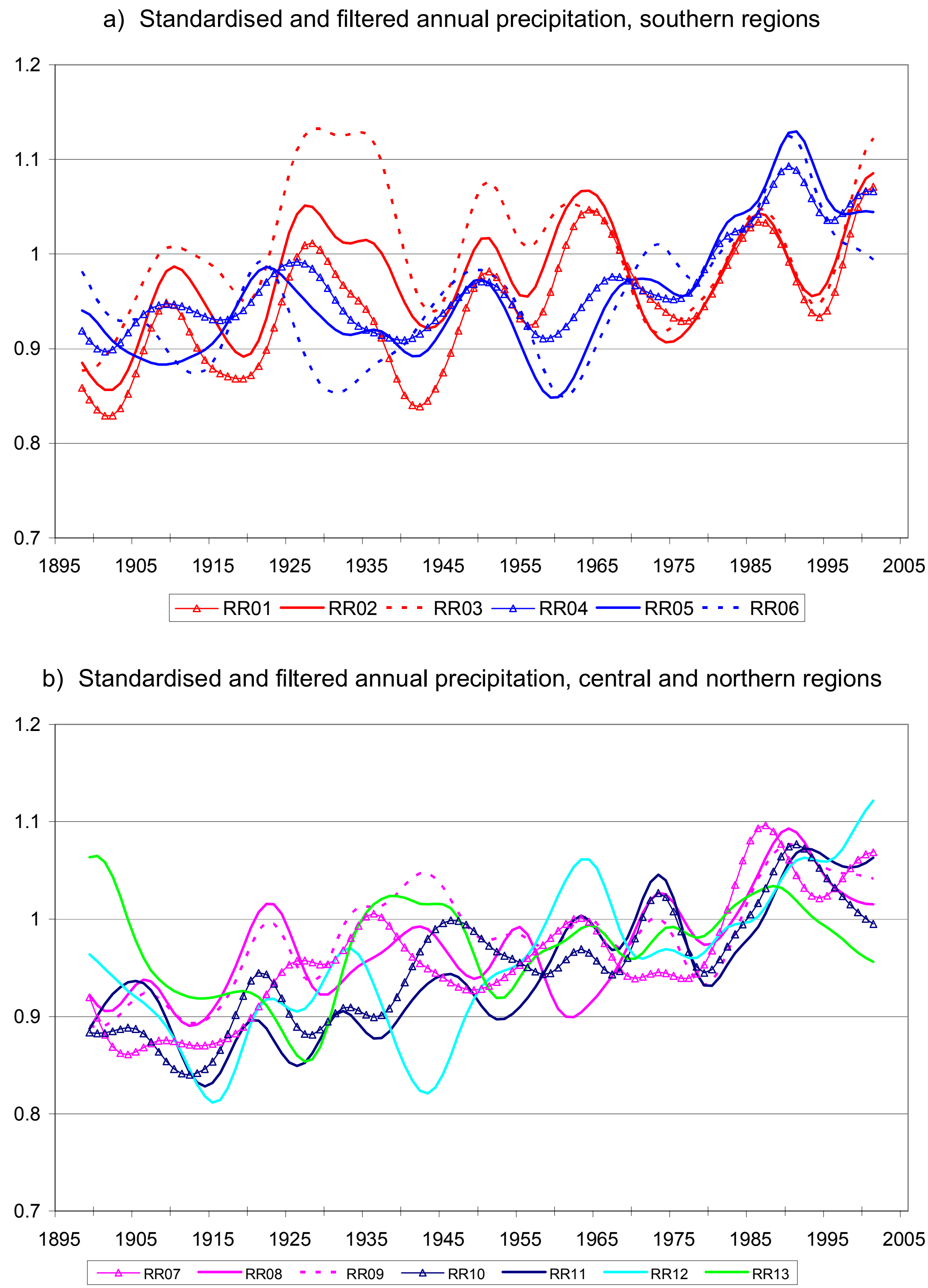
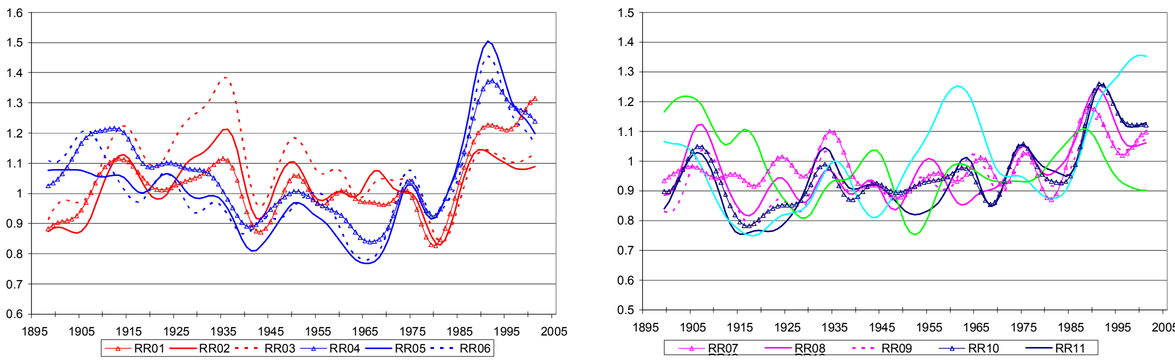
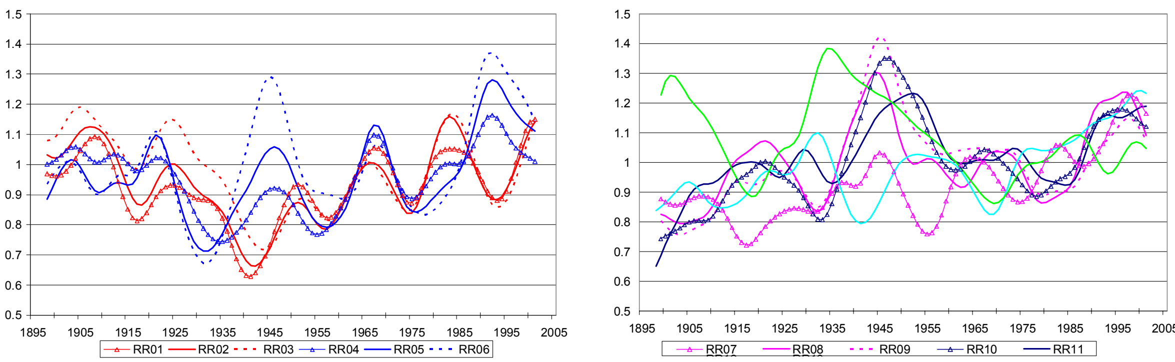


Figure 14. Standardised and low-pass filtered regional series of annual precipitation.
Panel a) shows the series from southern regions; panel b) shows central and northern series. The low-pass filter includes a Gaussian weight function with standard deviation 3 years, and shows decadal scale variability. The filtered series are cut 3 years from the ends. The precipitation is given as fraction of the 1961-1990 annual average.

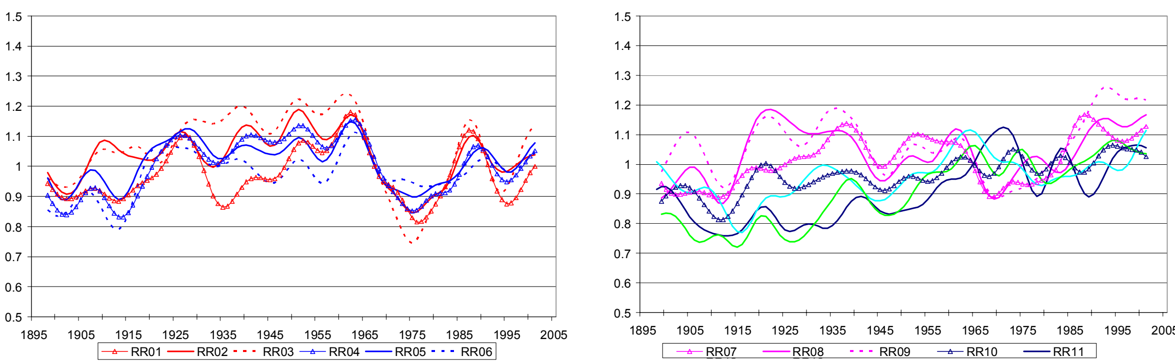
Winter



Spring



Summer



Autumn

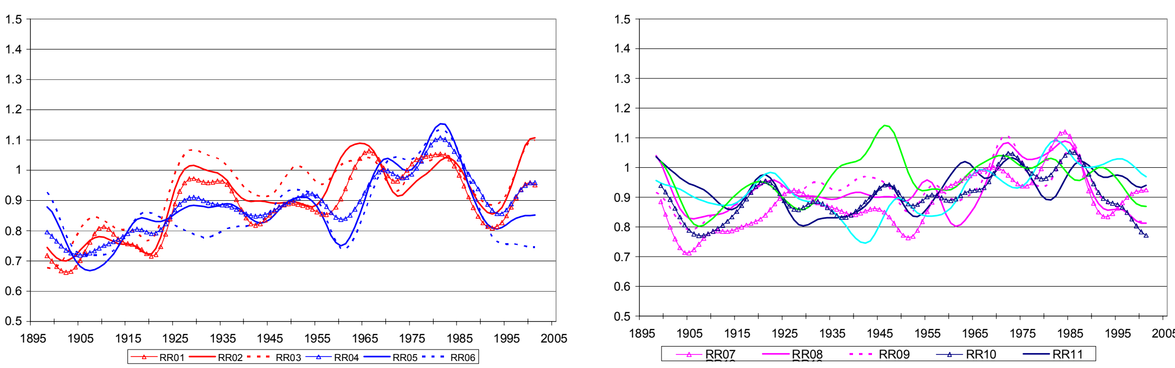


Figure 15. Standardised and low-pass filtered regional series of seasonal precipitation.
Left panels show the series from southern regions; right panel show central and northern series. The low-pass filter includes a Gaussian weight function with standard deviation 3 years, and shows decadal scale variability. The filtered series are cut 3 years from the ends. The precipitation is given as fraction of the 1961-1990 seasonal average.

4. Regional climate in Norway and the North Atlantic Oscillation

The North Atlantic Oscillation (NAO, Hurrell 1995) is an oscillation in the difference in sea level pressure between Iceland and the Azores, which highly affects the atmospheric circulation over the northern North Atlantic. The NAO index (NAOI) is a normalized measure for the NAO. During winter, positive correlations are found between the NAOI and the temperature and precipitation in northern Europe (Hurrell 1995, Thompson & Wallace 1998, Tuomenvirta et al. 2000). The reason is that positive (negative) values of the NAOI indicate increased (reduced) advection of warm humid air over the mid-latitude North Atlantic towards northern Europe. The winter NAOI (NAOI for the period December to April) has been found to correlate not only with local and regional climate, but also with hydrological and biological variables. Most of these studies are, however, based upon short time-series, and there has been some discussion about the stationarity of the correlation between the NAOI and other variables. In the present study, the correlation between the regional temperature or precipitation and the NAOI in moving 40-year windows has been studied. The analyses were performed both for December to April values and for annual values. The correlation coefficients were higher for the December to April values, and these results are presented here.

Figure 16 shows that the correlation between the winter NAOI and Norwegian winter temperature is best in south-western Norway (TR2), but it is statistically significant everywhere. In all regions, however, the correlation coefficient is highly variable in time. In TR2, the correlation coefficient is 0.84 in the period 1880-1919, 0.57 in the period 1900-1939, and 0.66 in the period 1965-2004. Thus the NAO accounts for about 70% of the variability in the winter temperatures in the period 1880-1919, but only 30% in the period 1900-1939! The rather sharp fall of the correlation coefficient indicate that the NAOI does not account for the “early 20th century warming”.

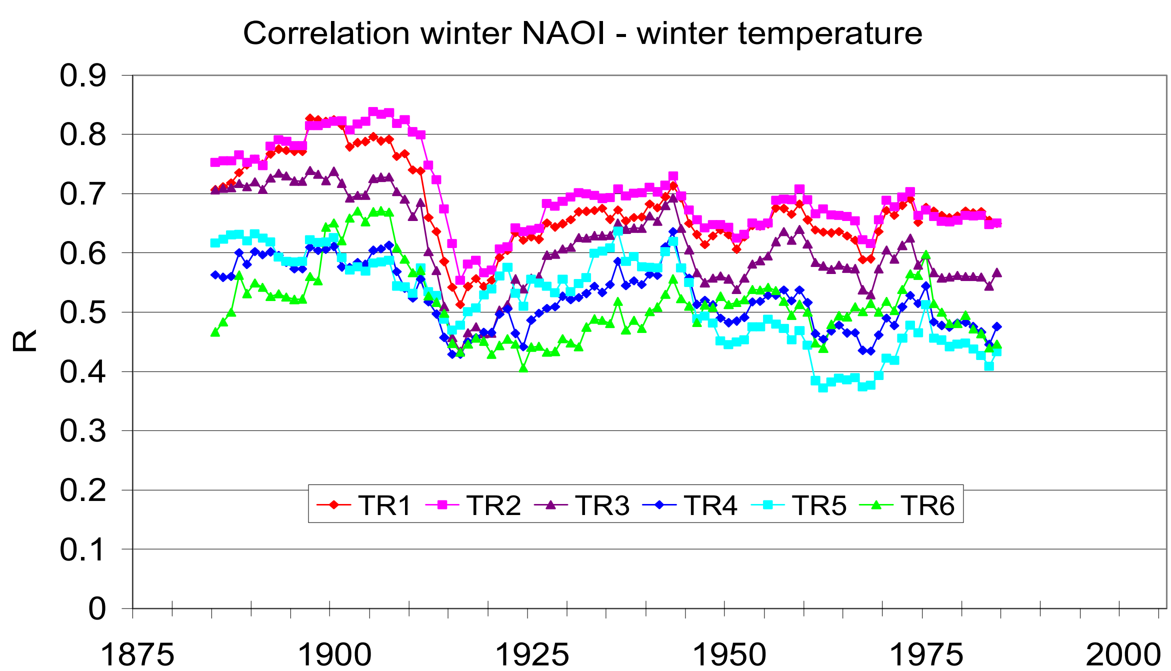
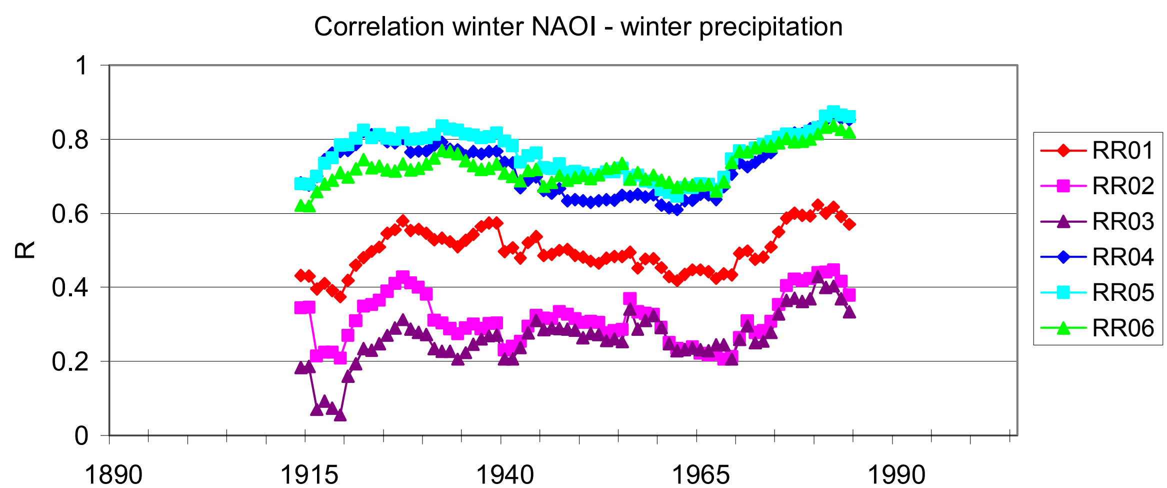


Figure 16. Correlation coefficient in moving 40-year windows between regional winter temperatures and the winter NAO index. The correlation coefficient for a 40-year period is plotted in at the 21st year in the period.

There is also significant correlation between the winter NAOI and winter precipitation, at least in western parts of Norway. The correlation is best in the south-western region RR05 where the correlation coefficient varies between 0.65 and 0.88 for different 40-year periods (Figure 17). Thus the NAOI accounts for between 40 and 75% of the variance in winter precipitation in this region. In the south-eastern regions, the NAOI usually accounts for less than 20% of the variance of winter precipitation. An exception is RR01, where the correlation coefficient in some periods is around 0.6.

Also in central and northern regions, the NAOI accounts for less than 20% of the variance in winter precipitation most of the time. The correlation between NAOI and winter precipitation in these regions has, however, increased during the 20th century, and especially from about 1960. Thus, the correlation coefficient exceeds 0.5 in some central and north-western regions for the last 40-year periods. The reason for this may be that the centre of the Icelandic low (which has the major influence on the NAOI) has migrated eastward during this period, and thus more directly influences the atmospheric circulation in these areas.

Hanssen-Bauer and Førland (2000) showed that more locally defined atmospheric circulation indices may account for a larger part of local variation in temperature and precipitation. But even these indices do not account for "the early 20th century warming".



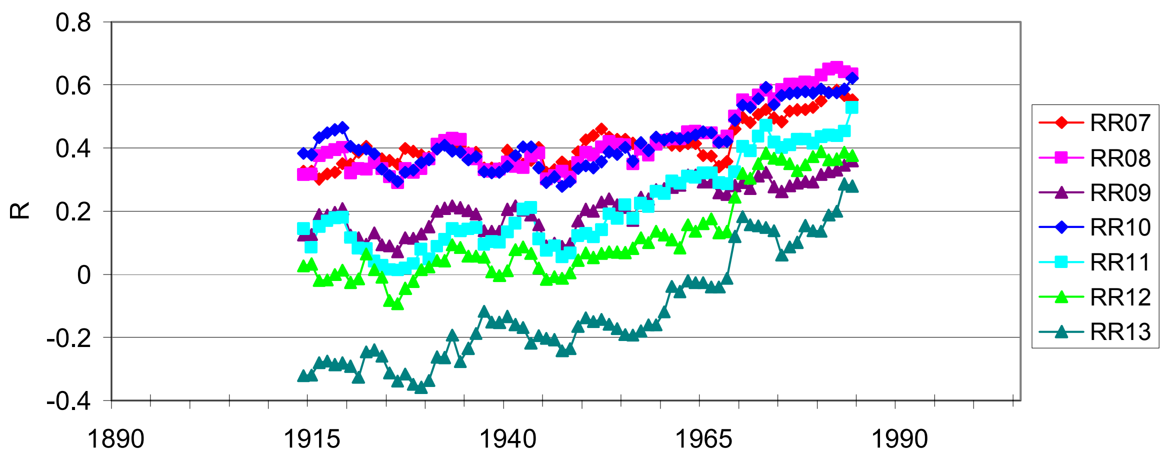


Figure 17. Correlation coefficient in moving 40-year windows between regional winter precipitation (Dec-Mar) and the winter NAO index. The correlation coefficient for a 40-year period is plotted in at the 21st year in the period.

5. Summary and conclusions

The annual mean temperature in Norway has during the latest 130 years increased by between 0.5 and 1.5 °C. The increase in annual mean temperature is statistically significant at the 1% level everywhere except in the inland of Finnmark county. The winter temperature has increased significantly (at least at the 5% level) in 3 of the 6 temperature regions. Spring temperatures have increased significantly everywhere. Summer temperatures have increased significantly in northern regions, and autumn temperatures have increased significantly everywhere except in mid-Norway and the inland of Finnmark county. In spite of the linear trends: There have been substantial decadal and multi-decadal temperature variations during the last 130 years. After a rather cold period around 1900 followed "the early 20th century warming", which culminated in the 1930s. A period of cooling followed, before the warming which has dominated the whole country since the 1960s. In southern Norway, the warmest decade of the last 130 years occurred near the end of the series. In most parts of northern Norway, the warmest decade occurred around the 1930s.

Annual precipitation in Norway has during the last 110 years increased statistically significantly (5% level) in 9 of 13 regions. No region shows a negative trend. The largest increase (15-20% increase) is found in north-western regions. Autumn precipitation has increased significantly in most southern regions. Winter and spring precipitations have increased significantly in north-western, and to some degree in inland regions. Summer precipitation has increased significantly in most of the northern regions. The positive trends in temperature as well as in precipitation tend to be more statistically significant now than they were 7 years ago.

The connections between the winter NAO index and regional winter temperature and precipitation series have been investigated. Though the correlation between winter temperature and the NAOI is significant in all regions and the correlation between winter precipitation and the NAOI is significant at least in western regions, the correlation coefficients vary with time. One reason why these connections are not stationary may be that the atmospheric circulation over Norway is not only affected by the NAOI, but also by the position of the "Icelandic low". Further, local air temperature and precipitable water will not depend solely on atmospheric circulation, but also on e.g. sea surface temperatures. An earlier investigation (Hanssen-Bauer and Førland 2000) has shown that though atmospheric circulation can account for a substantial part of the observed variability in precipitation and temperature in Norway, a marked phenomenon as "the early 20th century warming" is not accounted for by atmospheric circulation alone.

6. References

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Table A1. Information about temperature series used to produce regional series.
Average monthly, annual and seasonal temperature during the period 1961-1990

R	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	0.8	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	-3.6	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
3	16600	-10.3	-9.5	-7.0	-2.9	3.8	8.4	10.0	8.9	4.4	0.4	-5.7	-8.6	-0.7	-9.5	-2.0	9.1	-0.3
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	-4.7	-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
4	85950	1.1	0.9	1.5	2.9	5.7	8.3	10.5	11.0	9.0	6.6	3.8	1.8	5.3	1.3	3.4	9.9	6.5
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	98850	-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 A2. Information about temperature series used to produce regional series.
Standard deviation, monthly, annual and seasonal temperatures during the period 1961-1990

R	ST.NO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WIN	SPR	SUM	AUT
1	6040	5.2	4.9	2.9	1.3	1.1	1.6	1.1	1.2	1.2	1.5	2.8	3.8	1.2	3.7	1.2	0.9	1.2
1	10400	4.9	4.2	2.9	1.6	1.3	1.6	1.2	1.2	1.3	1.5	2.7	4.0	1.1	3.5	1.1	0.9	1.2
1	11500	4.3	4.3	2.8	1.4	1.2	1.5	1.2	1.3	1.1	1.3	2.2	2.9	1.1	3.2	1.2	0.9	1.0
1	16740	3.9	3.6	2.4	1.6	1.2	1.7	1.0	1.2	1.3	1.5	2.4	3.3	0.9	3.0	0.9	0.9	1.1
1	18700	3.5	3.5	2.2	1.3	1.2	1.5	1.2	1.4	1.1	1.3	1.8	2.7	0.9	2.6	1.1	0.9	0.8
1	23160	4.0	3.6	2.6	1.5	1.1	1.5	1.1	1.3	1.1	1.5	2.2	3.3	0.9	2.9	1.0	0.9	1.0
1	24880	4.9	4.4	2.9	1.3	1.1	1.5	1.2	1.3	1.2	1.5	3.0	3.8	1.2	3.4	1.2	0.9	1.2
1	27500	3.2	3.4	2.2	1.2	1.0	1.3	1.1	1.2	0.9	1.1	1.6	2.4	0.9	2.6	1.2	0.9	0.8
1	32100	4.2	4.0	2.4	1.3	1.0	1.2	1.1	1.2	1.2	1.3	2.0	2.9	1.0	3.7	1.1	0.8	0.9
1	37230	4.1	4.4	2.6	1.4	1.1	1.3	1.3	1.4	1.0	1.2	1.7	2.8	1.1	3.2	1.2	1.0	0.8
1	39100	3.1	3.0	2.0	1.1	1.0	1.1	1.0	1.1	0.8	1.0	1.5	2.3	0.9	2.4	1.1	0.8	0.7
1	42160	2.9	2.6	1.7	1.0	1.0	1.0	1.1	1.1	0.9	1.0	1.4	2.3	0.8	2.2	0.9	0.7	0.7
2	42920	3.8	3.1	2.4	1.2	1.2	1.5	1.2	1.5	1.2	1.3	1.7	3.1	0.9	2.6	1.1	0.9	0.8
2	46610	3.5	2.9	1.8	1.2	1.2	1.4	1.1	1.3	1.1	1.2	1.8	2.3	0.8	2.3	0.9	0.9	0.9
2	47300	2.0	1.9	1.3	0.8	0.9	1.0	1.0	1.1	1.0	0.8	1.2	1.6	0.6	1.6	0.7	0.7	0.6
2	50540	2.7	2.2	1.4	1.0	1.1	1.3	1.0	1.1	1.2	1.1	1.5	2.0	0.6	1.8	0.7	0.8	0.7
2	52530	2.0	1.8	1.2	0.8	0.9	0.9	0.9	1.1	1.1	0.9	1.3	1.7	0.6	1.5	0.7	0.7	0.6
2	54130	3.6	3.4	2.0	1.2	0.9	1.4	0.9	1.2	1.3	1.5	2.3	2.6	0.8	2.5	0.8	0.8	1.1
2	55780	2.8	2.4	1.6	1.2	1.0	1.5	1.0	1.2	1.2	1.3	1.9	2.1	0.6	1.9	0.7	0.8	0.9
2	55840	3.3	3.0	1.8	1.3	1.1	1.5	1.0	1.1	1.1	1.3	2.1	2.7	0.8	2.4	0.9	0.8	0.9
2	58700	2.4	2.3	1.7	1.4	1.3	1.7	1.1	1.3	1.5	1.5	1.9	1.8	0.6	1.6	0.9	1.0	1.0
2	59100	1.7	1.7	1.2	0.9	0.9	1.0	1.0	1.1	1.2	1.1	1.3	1.5	0.5	1.3	0.6	0.8	0.7
2	60500	2.6	2.5	1.7	1.4	1.1	1.3	0.9	1.1	1.5	1.6	1.9	2.1	0.6	1.7	0.8	0.9	1.0
2	62480	1.7	1.7	1.1	0.9	0.8	0.9	0.8	1.1	1.2	1.1	1.3	1.6	0.5	1.3	0.6	0.7	0.8
3	16610	3.1	3.1	2.2	1.7	1.2	1.7	1.2	1.3	1.4	1.5	1.9	2.7	0.8	2.4	0.9	0.9	0.9
3	69100	3.5	3.3	2.0	1.4	1.4	1.5	1.1	1.2	1.5	1.5	2.0	3.0	0.8	2.7	0.9	1.0	1.1
3	70850	4.0	3.6	2.3	1.3	1.4	1.8	1.2	1.3	1.4	1.5	2.4	3.6	0.9	3.0	0.9	1.0	1.2
3	71550	2.4	2.4	1.6	1.2	1.2	1.3	1.0	1.1	1.2	1.3	1.6	2.3	0.7	1.9	0.8	0.9	0.9
3	16600	3.0	3.8	3.0	1.6	1.6	1.7	1.3	1.5	1.4	1.8	1.9	2.2	0.9	2.1	1.5	1.0	1.2
4	75600	2.5	2.7	1.8	1.3	1.4	1.5	1.2	1.3	1.4	1.5	1.6	2.7	0.7	2.0	0.8	1.0	1.0
4	77420	4.1	4.2	2.7	1.5	1.0	1.8	1.3	1.4	1.5	1.8	2.5	4.3	1.0	3.2	1.1	1.1	1.4
4	80700	2.2	2.6	1.7	1.4	1.5	1.6	1.5	1.5	1.5	1.8	1.7	2.4	0.8	1.7	0.9	1.2	1.1
4	82290	2.1	2.6	1.7	1.3	1.5	1.6	1.5	1.3	1.3	1.7	1.6	2.5	0.7	1.7	0.9	1.2	1.0
4	85380	1.6	1.9	1.5	1.2	1.4	1.6	1.6	1.3	1.2	1.5	1.3	1.9	0.7	1.3	0.9	1.2	0.9
4	85910	1.5	1.7	1.3	1.0	0.8	1.0	1.0	1.0	1.0	1.3	1.2	1.7	0.6	1.2	0.7	0.9	0.9
4	90450	1.9	2.2	1.9	1.3	1.6	1.8	1.8	1.2	1.4	1.8	1.6	2.3	0.8	1.4	1.2	1.3	0.9
4	92700	1.5	1.9	1.8	1.3	1.5	1.6	1.8	1.2	1.3	1.6	1.5	1.9	0.8	1.2	1.2	1.2	0.9
4	85950	1.5	1.7	1.3	1.0	0.8	1.0	1.0	1.0	1.0	1.3	1.2	1.7	0.6	1.2	0.7	0.9	0.9
5	89950	3.1	3.5	2.6	1.6	1.8	1.9	1.7	1.3	1.5	2.1	2.3	3.7	1.0	2.3	1.3	1.3	1.2
5	93300	3.3	4.0	3.0	1.8	1.9	2.1	1.8	1.2	1.5	2.4	2.9	3.9	1.1	2.4	1.5	1.4	1.4
5	93900	3.8	4.4	3.4	2.0	2.1	2.0	1.7	1.2	1.5	2.7	3.0	4.5	1.2	2.7	1.7	1.3	1.6
5	97250	4.4	5.1	3.8	1.9	1.9	2.0	1.8	1.2	1.5	2.7	3.7	5.3	1.4	3.1	1.9	1.4	1.8
6	96400	1.5	1.9	2.0	1.4	1.3	1.4	1.4	1.1	1.2	1.6	1.3	1.8	0.8	1.0	1.2	1.1	0.9
6	98400	1.4	2.0	2.0	1.5	1.3	1.6	1.7	1.2	1.3	1.6	1.4	1.8	0.9	1.1	1.2	1.3	0.9
6	98850	1.4	2.1	2.0	1.4	1.2	1.3	1.4	1.1	1.1	1.5	1.5	1.7	0.8	1.1	1.2	1.1	0.9

Table A3. Information about precipitation series used to produce regional series.
Average monthly, annual and seasonal precipitation sums fore period 1961-1990

R	ST.NO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WIN	SPR	SUM	AUT
1	1230	54	45	48	42	52	70	75	80	87	100	88	60	802	160	142	225	276
1	1650	61	46	53	48	59	73	80	95	102	108	94	65	884	173	160	247	304
1	3450	54	42	51	42	55	72	76	88	92	100	85	59	815	155	148	235	277
2	5350	46	35	40	42	55	73	80	85	88	84	73	52	751	133	137	237	244
2	11900	45	34	38	37	56	71	87	91	86	89	70	49	753	128	132	249	245
2	13100	37	26	28	26	47	69	78	81	67	67	51	37	614	100	101	228	185
2	20520	56	43	46	43	54	66	81	86	80	93	79	62	790	161	143	234	252
2	22840	43	32	42	34	55	72	86	85	74	74	61	42	700	118	130	243	209
2	25640	57	38	50	32	51	67	75	76	77	85	74	64	746	160	134	217	236
2	27800	75	55	68	50	75	69	79	110	121	135	114	76	1027	206	193	259	370
2	18500	76	59	71	61	77	91	109	118	127	139	120	89	1136	224	209	317	386
2	28920	43	33	38	34	59	69	83	80	82	84	64	40	708	116	131	231	231
2	30370	84	64	79	62	86	86	104	132	137	154	123	90	1201	238	226	323	414
2	33250	67	49	55	37	61	74	81	89	90	95	78	66	842	183	153	243	263
2	37750	68	49	51	41	69	67	77	102	105	112	95	64	899	181	161	245	312

Table A3 cont. Information about precipitation series used to produce regional series.
Average monthly, annual and seasonal precipitation sums during the period 1961-1990

R	ST.NO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WIN	SPR	SUM	AUT
3	34600	65	46	54	46	71	66	85	101	108	116	101	64	923	175	171	252	325
3	38600	102	67	75	53	80	74	91	108	124	141	128	95	1137	264	208	273	392
3	39220	170	109	120	73	101	90	106	140	180	210	206	159	1662	437	294	336	595
4	42720	182	132	138	81	108	99	109	155	208	246	237	195	1890	508	327	364	691
4	43360	131	94	109	73	85	84	103	133	169	186	180	145	1492	370	268	319	535
4	44800	154	114	137	80	92	103	134	158	219	229	215	194	1827	462	309	395	662
4	47020	160	113	150	86	89	114	129	162	233	239	219	203	1895	476	324	405	691
5	40900	102	70	74	36	46	60	63	82	102	112	108	109	961	280	155	204	321
5	42890	216	148	168	87	117	121	122	169	248	287	259	238	2181	602	371	412	795
5	46050	222	159	189	94	95	120	138	171	267	286	277	281	2298	662	378	429	829
5	46450	174	119	124	63	66	84	89	121	190	213	191	193	1626	485	253	294	594
5	47500	176	128	150	74	92	113	123	158	241	251	229	214	1950	518	316	394	721
5	50540	191	148	169	111	107	127	147	183	292	285	265	236	2259	575	386	458	841
6	49550	133	87	110	50	52	66	82	95	154	169	156	165	1319	385	213	243	478
6	50350	329	238	288	151	147	192	214	257	428	424	375	399	3441	966	586	663	1227
6	52170	259	176	197	101	100	124	138	176	305	314	281	290	2461	725	398	438	901
6	52750	188	155	166	113	101	134	148	189	290	268	249	233	2235	576	381	471	807
6	53070	112	70	82	36	42	57	68	79	142	141	130	136	1095	318	160	204	413
6	55550	109	70	84	39	45	57	62	76	123	132	123	128	1046	307	167	195	377
6	56320	193	151	173	102	90	119	140	169	292	284	258	252	2224	596	365	428	835
6	56960	217	163	187	106	87	118	138	157	293	279	243	271	2259	651	380	412	815
6	57110	267	208	223	149	134	163	200	240	406	386	353	323	3052	798	506	603	1144
6	58880	168	121	132	69	55	71	85	99	194	196	200	218	1608	508	256	255	590
7	600	28	20	23	29	47	73	87	78	68	49	37	33	570	81	98	237	154
7	9100	17	13	12	13	26	51	70	53	37	28	23	20	363	50	51	175	88
7	10400	34	28	29	24	27	52	72	63	54	40	38	42	503	104	81	187	132
7	15660	25	15	15	7	16	30	44	35	34	36	29	31	316	70	38	109	99
7	66850	32	26	29	26	32	59	79	65	65	46	36	38	532	95	87	203	147
8	58960	198	151	159	93	68	88	110	124	225	230	214	247	1907	596	320	322	669
8	60400	95	74	81	49	35	44	63	62	112	113	111	127	965	296	164	169	336
8	60800	137	117	118	97	73	75	102	117	197	191	172	190	1585	443	288	294	560
8	61550	88	61	70	41	23	35	51	48	71	78	89	113	766	261	134	133	238
8	63100	107	81	96	62	54	69	99	97	141	132	120	137	1195	325	212	265	393
8	64800	116	95	99	83	64	86	117	119	174	157	131	153	1393	365	246	322	461
9	66250	55	49	50	46	40	66	92	79	93	79	65	71	783	175	136	236	236
9	68420	65	55	53	52	45	64	89	83	108	90	69	80	851	200	149	235	267
9	69550	103	86	85	74	68	83	109	108	143	129	96	121	1205	310	227	299	368
10	65220	161	129	127	96	68	79	98	100	190	190	163	208	1608	498	291	276	544
10	70360	70	57	58	57	56	71	100	89	121	108	74	89	950	216	171	260	303
10	70480	112	93	90	78	70	89	120	112	159	148	109	136	1314	340	237	320	416
10	72100	132	105	105	79	57	68	83	88	153	160	133	159	1321	395	242	239	446
10	72700	139	111	108	84	55	73	93	99	160	163	132	162	1376	411	247	265	454
10	75100	180	147	156	134	88	111	138	158	227	244	178	211	1973	539	378	407	649
10	78100	192	151	143	101	77	82	110	126	194	227	183	204	1790	548	320	319	604
10	79740	156	120	113	63	59	63	97	101	148	191	149	169	1429	446	235	261	487
10	80200	247	197	212	182	144	168	228	241	347	396	272	301	2933	745	537	637	1014
10	80400	209	162	169	135	112	120	168	180	265	319	223	248	2310	619	416	468	807
11	80700	194	163	148	117	90	99	143	153	237	283	212	230	2068	587	354	395	732
11	81100	121	107	94	66	51	57	83	92	140	179	134	151	1275	379	211	232	453
11	81900	99	93	83	59	45	61	85	77	106	143	99	117	1067	308	186	224	349
11	83500	161	138	108	80	67	72	91	99	142	206	137	183	1484	482	255	262	485
11	86850	143	128	115	98	73	77	93	97	152	211	157	162	1505	433	286	267	520
12	93300	31	25	24	22	26	44	69	63	45	42	34	30	455	85	72	176	122
12	93500	29	25	24	20	25	43	67	59	48	45	36	32	452	85	69	169	129
12	93700	9	7	9	11	19	38	69	59	43	33	18	10	325	26	39	166	94
12	93900	17	12	15	16	20	41	70	60	44	34	21	16	366	45	51	171	99
12	97250	18	12	14	15	23	42	71	58	40	33	22	17	365	47	51	171	96
12	99450	32	24	18	17	23	50	67	63	51	37	35	36	454	93	58	180	124
13	98400	55	44	41	38	35	41	55	66	68	65	56	56	618	155	114	162	188
13	98550	59	45	37	36	33	46	54	60	59	63	64	57	612	161	106	159	186