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Under Global Warming

Annual and seasonal precipitation variations in Norway 1896-1997

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Abstract

Norway was divided into 13 regions, using comparative trend analysis (CTA) of precipitation series from more than 100 stations. Time-series of normalised precipitation are quite similar for all stations within a certain region. The precipitation evolution within a region can thus be described by one normalised series. Consequently, the regions are convenient spatial units for describing precipitation variations in the past, as well as for estimating future precipitation scenarios.

Normalised precipitation series from the 13 regions during the period 1896-1997 were analysed using the Mann-Kendall trend test and low-pass filtering. Positive trends were found in annual precipitation during the period 1896-1997 in all regions except in one of the south-eastern regions, R3, where there is no trend. The annual precipitation increase, which varies from 5 to 18 %, is statistically significant at least at the 5% level in 6 regions. The largest and most significant precipitation increase is found in the north-western regions R10 and R11. There are regional differences concerning the time interval in which the precipitation increased, as well as in which seasons the increase occurred. In south-eastern Norway the precipitation increased mainly before 1940, in south-western regions the increase occurred mainly after 1960, while the increase in northern Norway occurred from around 1920 to present. In most southern regions, autumn is the only season in which precipitation has increased significantly during the present century. In northern regions, on the other hand, spring precipitation as well as summer- and/or winter precipitation have increased.

Comparison of long-term trends in precipitation and temperature, indicates that even regionally and within a specific season, there is no general relationship between these trends, though both temperature and precipitation changes to some extent are connected to variations in dominating atmospheric circulation patterns.

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Annual and seasonal precipitation variations in Norway 1896 - 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

During the present century, an increase in annual precipitation has been observed at higher northern latitudes (Hulme, 1995, Dai et al.,1997, Karl et al.,1993). Recent studies of homogenised precipitation series indicate an increase also in Norway; - in most parts of Norway the annual precipitation increased by 8 - 14 % during the period 1896-1994, though the increase did not occur simultaneously all over the country (Hanssen-Bauer et al., 1997).

Global climate models project substantial increase of temperature and precipitation in high northern latitudes as the greenhouse gas concentrations increase (Kattenberg et al. 1996). The project «Regional climate development under global warming» (Reg Clim) (Iversen et al., 1997) aims to predict the regional climate development in Norway if the major features in these models are correct. Both dynamical and statistical downscaling approaches will be used in these regional predictions.

Traditionally the predictands used in statistical downscaling are climate series from single stations. For the Nordic region, the series from Bergen and Tromsø have been used in earlier climate change estimates (Kaas, 1993, Kaas & Frich, 1995). However, climate change projections based on single series may be influenced by inhomogeneities in the series and local anomalies, and also they give no information on the regional representativity of the scenarios. In the estimation of future changes in precipitation in the Nordic countries, Jóhanneson et al (1995) divided Norway into two regions, - one western and one eastern. Hanssen-Bauer et al. (1997), however, concluded that there are differences between precipitation evolution in time also between southern and northern parts of the country. In the Reg Clim project we therefore plan to use a finer regionalisation.

In the present study, homogenised precipitation series are used to define regions with similar long-term variations. Precipitation series valid for 13 regions which cover the Norwegian mainland (Figure 1) are updated to 1997 and analysed for trends and variability on annual and seasonal basis. The regional precipitation series can easily be updated further by using data from a limited number of stations. In addition to describing the long-term precipitation variations in different parts of Norway, the resulting series from these 13 regions will form an excellent basis for statistical downscaling of precipitation scenarios in Principal Task 3 in the Reg Clim project.

2. Calculation of regional precipitation series

2.1 Definition of precipitation regions

Hanssen-Bauer et al. (1997) defined 12 precipitation regions on the Norwegian mainland using comparative trend analysis (CTA) of precipitation data from 142 stations. Within each region, long-term trends and decadal scale variability of standardised precipitation are quite uniform. In the present analysis, some additional data from northern Norway has led to the definition of one more region: The eastern part of the northern coast region 11 is defined as a separate region, R13. Except from this change, the precipitation regions which are used in the following analyses (Figure 1), are identical to those defined by Hanssen-Bauer et al. (1997).

2.2 Calculation of regional series

The station network used for calculation of regional precipitation series (Figure 2), consists of 78 stations of which 71 are still operative. Data from the period 1896 - 1997 were used. The series were homogeneity tested by Hanssen-Bauer and Førland (1994a), and in case of inhomogeneities, the series were adjusted. Basic information about the stations is given in Table A.1 in Appendix. Average precipitation during the period 1961-1990, i.e. the standard normals (PN), on monthly, annual and seasonal basis are given in Table A.2 in Appendix, for each station.

The standardised precipitation at station i in region m ($SP_{m,i}$) is defined as the observed precipitation ($P_{m,i}$) divided by the standard normal 1961-90 for the station ($PN_{m,i}$):

$$SP_{m,i} = P_{m,i} / PN_{m,i} \qquad (2.1)$$

This definition is applied on annual, seasonal and monthly precipitation series. This way of standardising makes it easy to reverse the process and extrapolate time series in mm. Hanssen-Bauer and Førland (1994b) demonstrated that within each region, different series of normalised precipitation are very similar. The precipitation evolution within region m can thus be described by one «regional standardised precipitation series» SP_m , which is defined as the average of n standardised series from region m:

$$SP_m = 1/n \cdot \sum_{i=1}^{n} SP_{m,i} \qquad m = 1,2,..,13 \qquad (2.2)$$

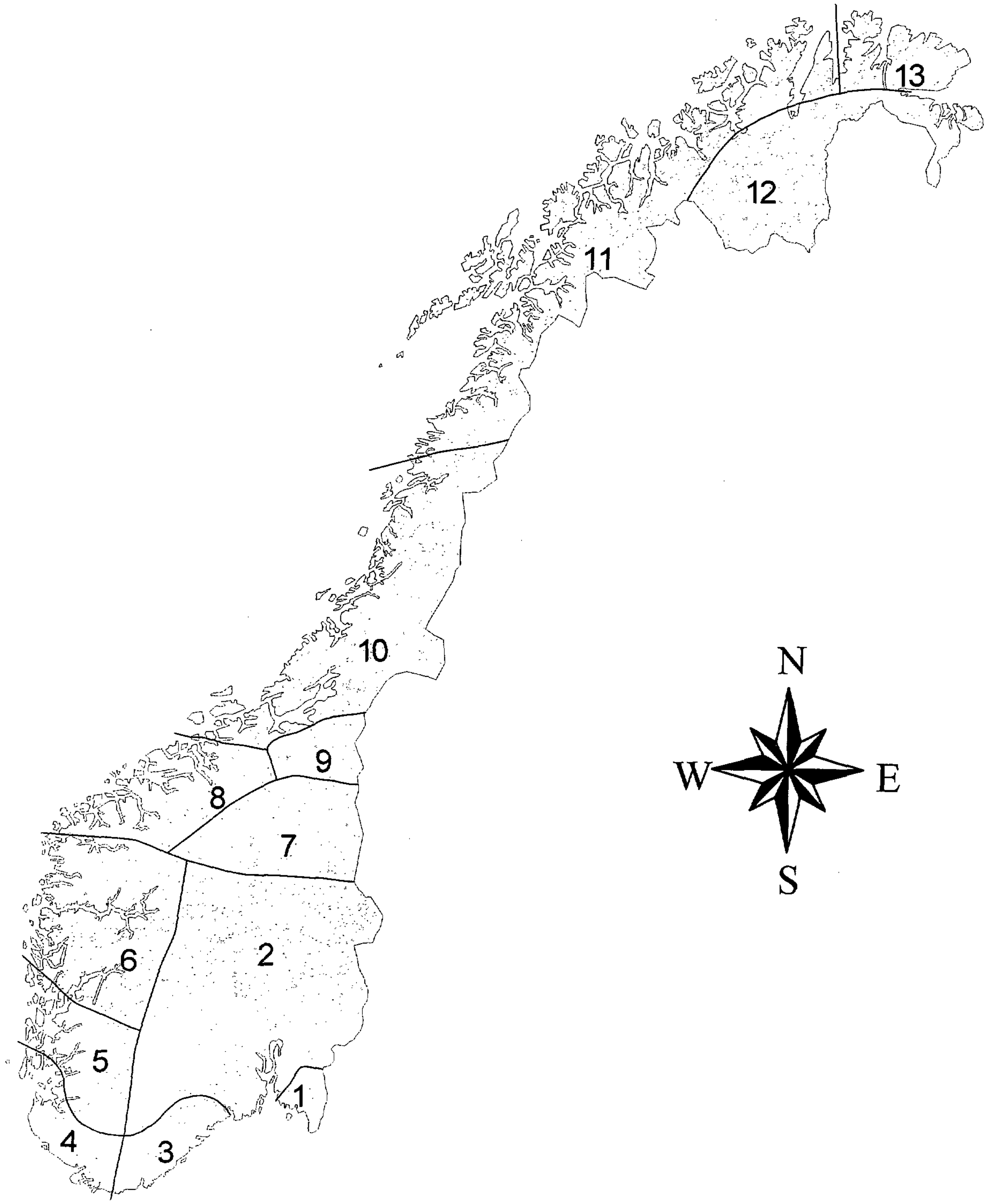


Figure 1. The 13 precipitation regions for which regional precipitation series are analysed.

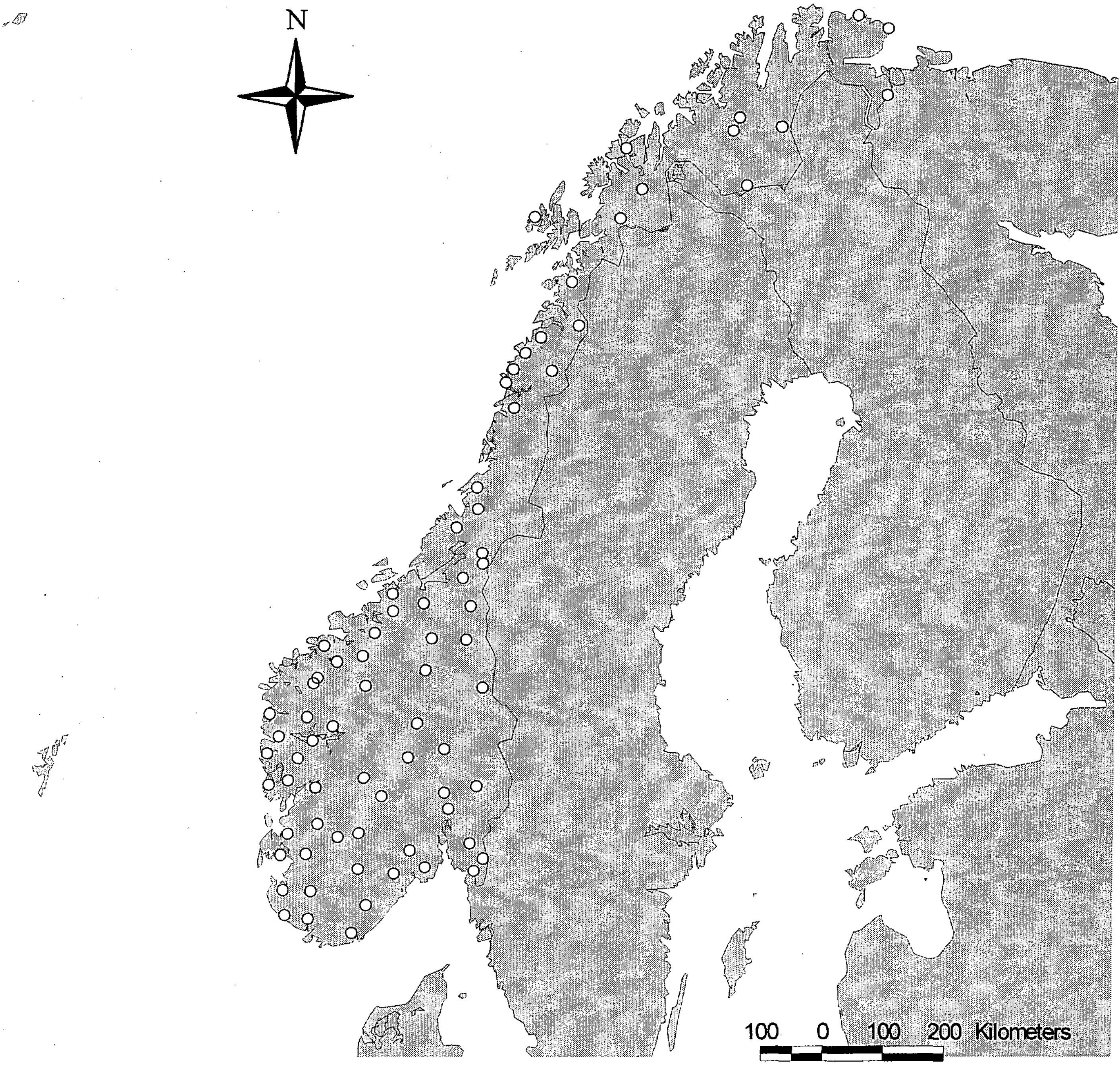


Figure 2. Stations used for calculating regional precipitation series.

The standardised regional series may be used to estimate the temperature series in mm on annual seasonal or monthly basis at an arbitrary site x in region m:

$$P_{m,x} = SP_m \cdot PN_{m,x} \qquad (2.3)$$

Here, $PN_{m,x}$ is the standard normal of precipitation during the period 1961-90 valid for the site x. This can be estimated for any site by using normal maps (Førland, 1993). Series of regionally averaged precipitation valid for region m, P_m, can be calculated by substituting the regional averaged standard normal value in equation 2.3.

2.3 Results

Standardised precipitation series for regions R1-R13 on annual, seasonal and monthly basis were calculated. The correlation coefficients between the annual regional series range from -0.36 to 0.91 (Table 2.1). The correlation between the regions are depicting the same main spatial pattern as found by correlation analysis of 129 homogeneous precipitation series (Hanssen-Bauer & Førland, 1994b). Relatively high correlation is found internally between the south-eastern regions R1, R2 and R3, between the south-western regions R4, R5 and R6, between the central regions R8 and R9, and between the north-western regions R10 and R11. The central region R7, the northern inland region R12 and the north-eastern region R13, are rather different from all other regions. Negative correlation is mainly found between the south-eastern regions R1-R3 and the central and north-western regions R8-R11.

Table 2.1 Correlation coefficients between standardised regional series of annual precipitation.

	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13
R01	1	0.81	0.73	0.52	0.35	0.11	0.33	-0.15	-0.17	-0.09	-0.11	0.19	-0.17
R02	0.81	1	0.88	0.42	0.22	-0.04	0.38	-0.29	-0.28	-0.27	-0.28	0.01	-0.31
R03	0.73	0.88	1	0.41	0.19	-0.08	0.12	-0.34	-0.36	-0.31	-0.32	-0.01	-0.30
R04	0.52	0.42	0.41	1	0.90	0.74	0.33	0.38	0.19	0.38	0.19	0.33	0.04
R05	0.35	0.22	0.19	0.90	1	0.91	0.36	0.55	0.34	0.56	0.33	0.30	0.13
R06	0.11	-0.04	-0.08	0.74	0.91	1	0.37	0.75	0.54	0.75	0.49	0.29	0.25
R07	0.33	0.38	0.12	0.33	0.36	0.37	1	0.41	0.47	0.29	0.11	0.13	-0.02
R08	-0.15	-0.29	-0.34	0.38	0.55	0.75	0.41	1	0.84	0.80	0.54	0.27	0.38
R09	-0.17	-0.28	-0.36	0.19	0.34	0.54	0.47	0.84	1	0.76	0.53	0.27	0.37
R10	-0.09	-0.27	-0.31	0.38	0.56	0.75	0.29	0.80	0.76	1	0.83	0.42	0.45
R11	-0.11	-0.28	-0.32	0.19	0.33	0.49	0.11	0.54	0.53	0.83	1	0.48	0.43
R12	0.19	0.01	-0.01	0.33	0.30	0.29	0.13	0.27	0.27	0.42	0.48	1	0.41
R13	-0.17	-0.31	-0.30	0.04	0.13	0.25	-0.02	0.38	0.37	0.45	0.43	0.41	1

Correlation coefficient   < 0.0   0.0 - 0.49   0.50 - 0.74   ≥ 0.75

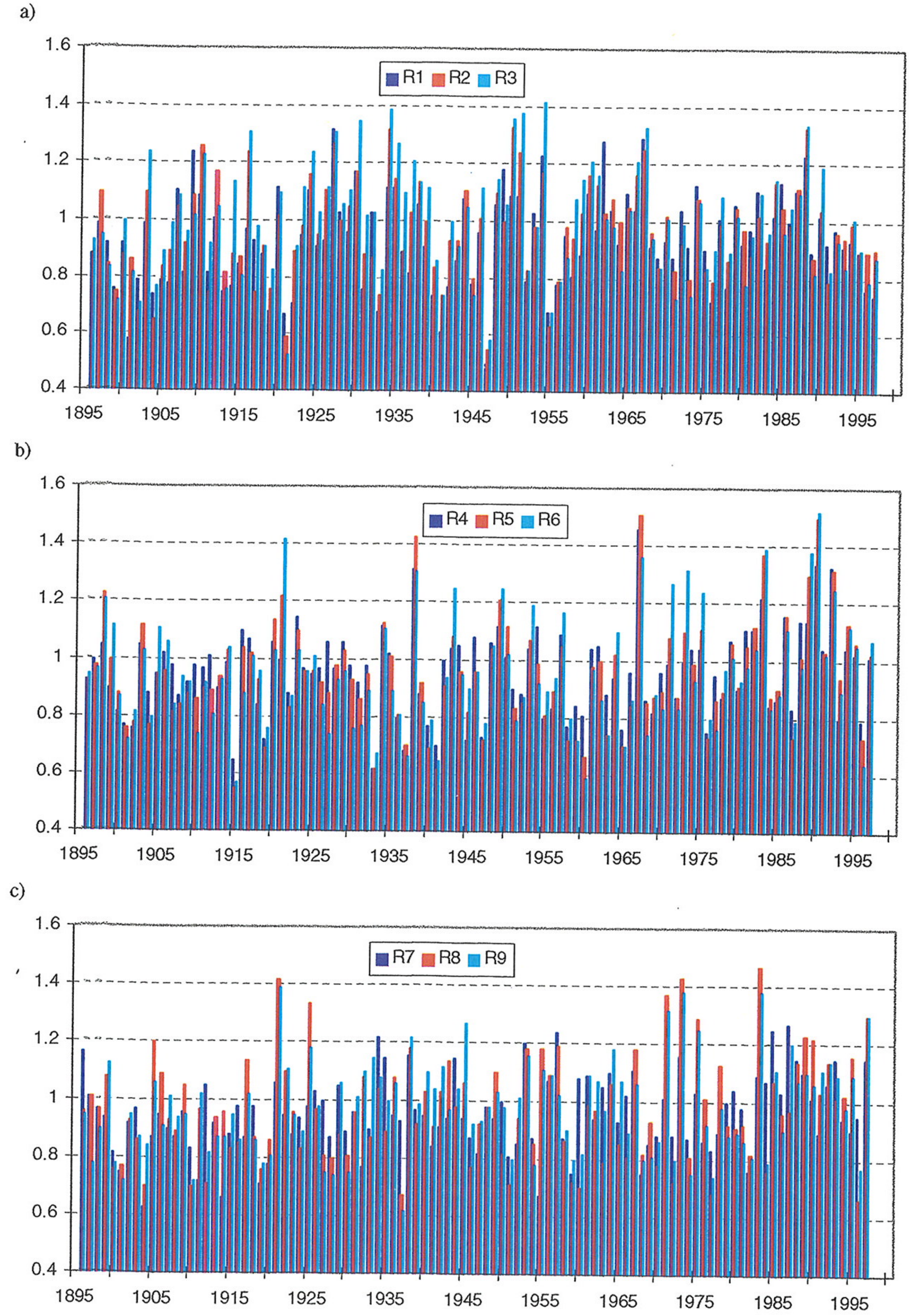
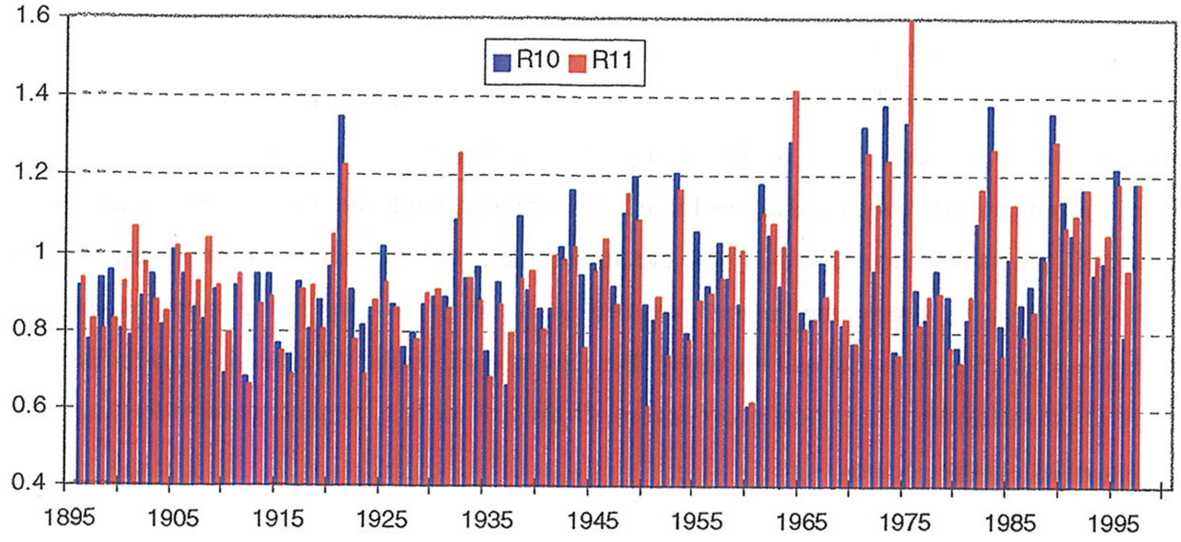


Figure 3. Standardised annual precipitation in (a) south-eastern regions R1-R3, (b) south-western regions R4-R6, and (c) central regions R7-R9.

d)



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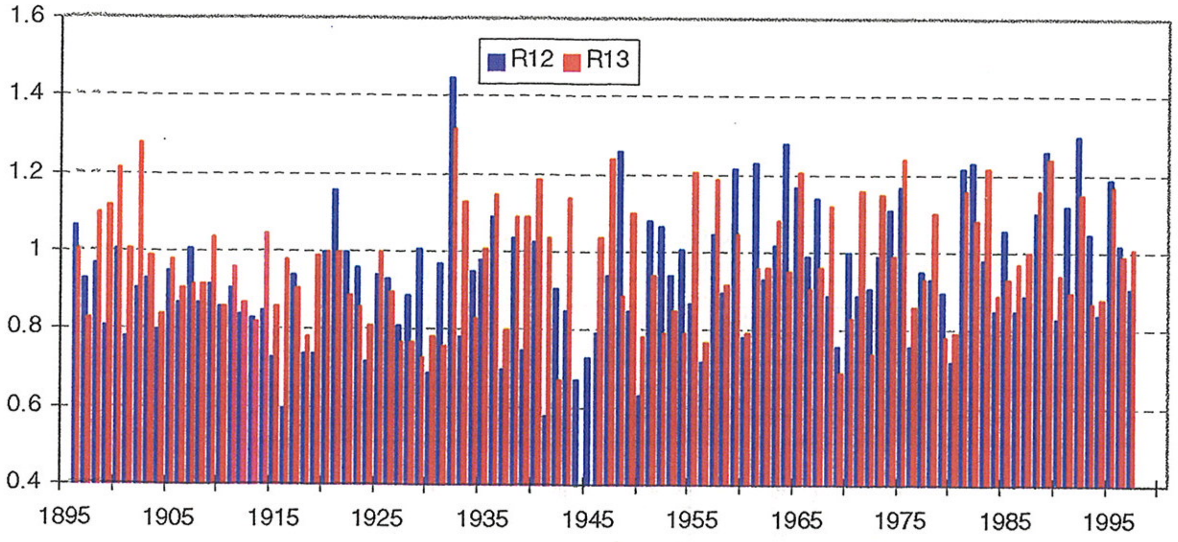


Figure 3, continued. Standardised annual precipitation in (d) north-western regions R10 and R11, and (e) northern inland region R12 and north-eastern region R13.
Note: Values for region R13 are missing for the years 1944-1946

Figure 3 shows standardised regional series of annual precipitation for the south-eastern regions R1-R3 (a), the south-western regions R4-R5 (b), the central regions R7-R9 (c), the north-western regions R10-R11 (d) and the northern inland and north-eastern regions R12-R13 (e). The inter-annual variation is large, and in order to investigate long-term variability and trends, it is necessary to use statistical methods and filtering techniques. This is done in chapter 3, where the regional series are analysed and presented on annual and seasonal basis. In the present chapter, we will have a closer look at extremely dry or wet years in different regions.

In order to study the seasonal characteristics of dry and wet years, annual and seasonal precipitation was ranked in each region. Figure 3 shows that there is a fair agreement between regions in the same part of the country concerning years of extremely high or low precipitation. Thus, the examination of dry and wet years is presented for 3 regions only: R2 from the south-east, R5 from the south-west, and R11 from the north-western part of the country. For these regions, seasonal characteristics of the 8 lowest ranked (driest) years are given in Table 2.2. Similarly, the 8 wettest years are characterised in Table 2.3. The tables show that 1-2 years are among the extremes both in the south-east and in the south-west, while 1-3 are among the extremes both in the south-west and in the north, but there is no overlap between the south-east and the north. For temperature, on the other hand, Hanssen-Bauer and Nordli (1998) showed that at least every second of the coldest and warmest years were found to be «extreme» all over the country.

Table 2.2 Seasonal characteristics of the 8 driest years during the period 1896-1997.

The 4 driest seasons are characterised as «very dry», No. 5 to 12 as «dry», No. 13-25 as «slightly dry», No. 26 -77 are characterised as «medium», and No. 78-90 as «slightly wet».

Rank numbers are given except for the «medium» seasons.

a) Region 2

YEAR	RANK N	WINTER	SPRING	SUMMER	AUTUMN
1899	8	medium	medium	dry (7)	medium
1902	5	medium	medium	medium	very dry (4)
1904	4	medium	medium	very dry (4)	dry (7)
1921	2	medium	slightly dry (23)	dry (9)	very dry (1)
1933	7	medium	dry (9)	medium	slightly dry (25)
1941	6	dry (9)	very dry (2)	slightly wet (87)	dry (8)
1947	1	medium	medium	dry (6)	slightly dry (16)
1955	3	medium	medium	very dry (1)	medium

b) Region 5

YEAR	RANK S	WINTER	SPRING	SUMMER	AUTUMN
1915	1	medium	medium	medium	very dry (1)
1919	5	dry (9)	medium	medium	medium
1933	2	medium	dry (9)	slightly wet (78)	very dry (3)
1937	7	slightly wet (87)	slightly dry (21)	medium	slightly dry (23)
1940	6	dry (6)	dry (10)	medium	medium
1941	3	very dry (3)	dry (6)	medium	medium
1960	4	medium	medium	slightly wet (83)	very dry (4)
1965	8	medium	dry (11)	medium	slightly dry (25)

c) Region 11

YEAR	RANK S	WINTER	SPRING	SUMMER	AUTUMN
1912	3	dry (7)	medium	dry (10)	medium
1916	5	medium	very dry (4)	dry (6)	medium
1923	6	slightly dry (13)	medium	medium	dry (11)
1927	7	medium	medium	dry (7)	dry (12)
1935	4	slightly dry (24)	medium	slightly dry (14)	very dry (2)
1950	1	dry (6)	medium	medium	very dry (4)
1960	2	slightly dry (21)	slightly dry (15)	medium	very dry (1)
1980	8	medium	slightly dry (20)	very dry (3)	slightly dry (19)

Table 2.3 Seasonal characteristics of the 8 wettest years during the period 1896-1997.

The 4 wettest seasons are characterised as «very wet», No. 5 to 12 as «wet», No. 13-25 as «slightly wet», No. 26 -77 are characterised as «medium», and No. 78-90 as «slightly dry».

Rank numbers are given except for the «medium» seasons.

a) Region 2

YEAR	RANK N	WINTER	SPRING	SUMMER	AUTUMN
1910	5	wet (9)	wet (9)	wet (10)	medium
1916	8	slightly wet (22)	medium	medium	wet (11)
1927	4	slightly wet (14)	slightly wet (14)	wet (7)	medium
1934	3	medium	slightly wet (15)	slightly wet (14)	slightly wet (17)
1950	1	slightly wet (19)	medium	very wet (1)	slightly wet (20)
1951	7	very wet (4)	medium	very wet (4)	medium
1967	6	very wet (1)	wet (7)	medium	very wet (4)
1988	2	wet (8)	slightly wet (23)	very wet (2)	medium

b) Region 5

YEAR	RANK S	WINTER	SPRING	SUMMER	AUTUMN
1898	7	wet (12)	medium	medium	very wet (4)
1921	8	slightly wet (22)	very wet (4)	medium	medium
1938	3	medium	very wet (3)	wet (5)	very wet (2)
1967	1	medium	very wet (1)	very wet (4)	very wet (3)
1983	4	wet (8)	slightly wet (13)	slightly dry (82)	very wet (1)
1989	6	very wet (1)	slightly wet (21)	wet (12)	medium
1990	2	very wet (2)	very wet (2)	medium	medium
1992	5	very wet (3)	wet (11)	slightly wet (17)	medium

c) Region 11

YEAR	RANK S	WINTER	SPRING	SUMMER	AUTUMN
1921	8	medium	slightly wet (14)	wet (6)	wet (9)
1932	6	wet (5)	medium	medium	medium
1964	2	very wet (2)	medium	slightly wet (18)	very wet (4)
1971	5	slightly wet (25)	medium	very wet (3)	wet (8)
1973	7	slightly wet (16)	wet (7)	very wet (4)	medium
1975	1	wet (8)	medium	wet (5)	very wet (2)
1983	4	medium	medium	very wet (1)	medium
1989	3	very wet (4)	medium	medium	medium

In Table 2.2 and 2.3, seasons are characterised as «very dry» («very wet»), «dry» («wet»), or «slightly dry» («slightly wet»), if they are among the 4%, 12%, or 25% driest (wettest) seasons. The rest of the seasons (50%) are characterised as «medium». About every second «dry» year is characterised by only one «very dry» or «dry» season, while the other seasons are characterised as «slightly dry», «medium» of even «slightly wet». For the wet years, it is more usual that 2 or 3 seasons are characterised as «wet» or «very wet».

It should be noted that there are large regional differences in the seasonal contributions to the annual precipitation in Norway. In some areas (e.g. parts of region 2) almost 50% of the annual precipitation is falling during the three summer months, and less than 15% during the three winter months (Tveito et al., 1997). In other areas (e.g. parts of region 5 and 11) autumn or winter are the seasons with highest precipitation, and summer the season with lowest (15-20%) contribution to the annual precipitation. As a consequence of these differences in seasonal contributions, the anomalies in the annual precipitation will tend to be dominated by the anomalies in one or two seasons.

Table 2.2 shows that most of the «dry» years in R2 and R11 are characterised by dry summers and/or autumns. In region 5, on the other hand, dry years are characterised by dry autumns, winters and/or springs. Table 2.3 shows that «wet» years can be characterised by much precipitation in any season, though wet years in northern Norway seldom are caused by much precipitation during spring.

Tables 2.2 and 2.3 show that 5-6 of the 8 driest years in regions R2, R5 and R11 occur in the first half of the series (1896-1946), while 2-4 of the 8 wettest years occur during this period. This tendency is in accordance with Hanssen-Bauer at al. (1997) who showed that when the precipitation regions were grouped together in 4 regional groups (eastern, western, central and northern groups), one could conclude that these experienced a precipitation increase of 8-14% during the period 1896-1994. However, it was not tested whether the positive trends were statistically significant. Neither were differences within the large regional groups investigated. This will be done in chapter 4, where also the seasonal series will be analysed.

3. Trends and variability in precipitation

3.1 Methods

3.1.1 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:

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

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 analyses in the present chapter, 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.

3.1.2 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

$$t = \sum_{i=1}^{n} n_i \qquad (4.2)$$

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

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

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

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 (1991).

3.2 Long-term trends and decadal scale variability

Results from Mann-Kendall tests of the standardised annual and seasonal precipitation series for the period 1896 - 1997 are summarised in Table 3.1, where also the linear trends of the series are given. Though all regions except the south-eastern region R3 have experienced an increase in annual precipitation during this period, the positive trends are statistically significant at the 5% level in only 6 of the 13 regions. The precipitation increase tends to be largest and most significant in the north-western regions, where the annual precipitation has increased by more than 15% during the period.

Table 3.1 Trends in annual and seasonal precipitation series during the period 1896-1997.
Linear trends in the standardised regional series given in % of normal value 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	(+ 1.0)	(+ 0.7)	(- 0.1)	(+ 0.1)	+ 2.3 s
2	(+ 0.6)	(+ 0.7)	(- 0.8)	(- 0.6)	+ 2.3 s
3	(0.0)	(- 0.5)	- 2.1 s	(- 0.9)	(+ 2.0)
4	(+ 0.9)	(- 0.2)	(+ 0.4)	(+ 0.4)	+ 2.4 ss
5	+ 1.2 s	(+ 0.9)	(+ 1.8)	(- 0.2)	+ 2.2 ss
6	(+ 1.2)	(+ 0.3)	(+ 2.2)	(+ 0.7)	+ 1.8 s
7	+ 1.4 ss	(+ 0.5)	+ 2.6 s	(+ 1.0)	+ 1.8 s
8	(+ 1.2)	(+ 1.3)	(+ 2.4)	(+ 0.5)	(+ 1.0)
9	+ 1.3 s	(+ 1.5)	+ 2.3 s	(+ 0.4)	(+ 1.4)
10	+ 1.8 ss	(+ 2.0)	+ 3.0 ss	+1.8 s	(+ 1.2)
11	+ 1.7 ss	+ 2.4 s	+ 2.5 ss	+ 2.0 ss	(+ 0.6)
12	+ 1.6 ss	+ 2.3 ss	+ 2.3 ss	(+ 1.3)	(+ 1.1)
13	(+ 0.5)	(- 1.5)	(- 1.6)	+ 3.3 ss	(+ 1.1)

Førland et al. (1997) reported that further north, in the Norwegian Arctic, annual precipitation has increased by 25% during the last 80 years, and that there was a statistically significant increase in the precipitation in all seasons except in winter. Table 3.1 shows that the regions with maximum precipitation increase at the Norwegian mainland, R10-R12, have experienced a statistical significant increase in the spring precipitation, as well as in winter and/or summer precipitation.

Autumn precipitation increased in all regions, but the increase is statistically significant only in southern Norway, in the regions in R1, R2 and R4 through R7. In all southern regions except R3, autumn is the only season in which the precipitation has changed significantly during the period 1896-1997. In summer and winter, only minor positive or negative changes are found during the period as a whole. Spring precipitation decreased significantly in R3. This is the only statistical significant negative value in Table 3.1.

The Mann - Kendall tests were run successively, both forwards and backwards (Figure 4). 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 (cf. section 3.1.2). Figure 4, together with Figure 5, which shows low pass filtered (cf. section 3.1.1) series of standardised regional precipitation on annual basis, give a more complete picture of long-term variation in annual precipitation than Table 3.1. In contrast to regional temperature series from Norway (Hanssen-Bauer and Nordli 1998) which show some common features for all regions, there are distinct differences between precipitation regions in different parts of the country. In the south-eastern regions R1-R3, there was a statistically significant increase in the annual precipitation during the period 1896-1939 and/or 1896-1967. However more stable conditions, or even a decrease in annual precipitation during the later decades, makes the total change during the period 1896-1997 insignificant. Annual precipitation increased significantly in the south-western regions R4-R6 from about 1960 to 1997, while the precipitation level was fairly constant in these regions from 1896 to 1960. In the northern regions, the increase in annual precipitation is clearly significant during the period 1910 to 1997. In the north-eastern region R13, there was a statistically significant negative trend during the first couple of decades, making the increase during the whole 102 year long period insignificant. In north-western regions, on the other hand, the conditions before 1910 were rather stable, and the positive trends are thus highly significant also for the total period. The central regions R7-R9 form a «transition zone» between south-eastern, south-western and north-western regions, where R7 has most in common with the south-eastern regions, R8 has most in common with the south-western regions and R9 has most in common with the north-western regions.

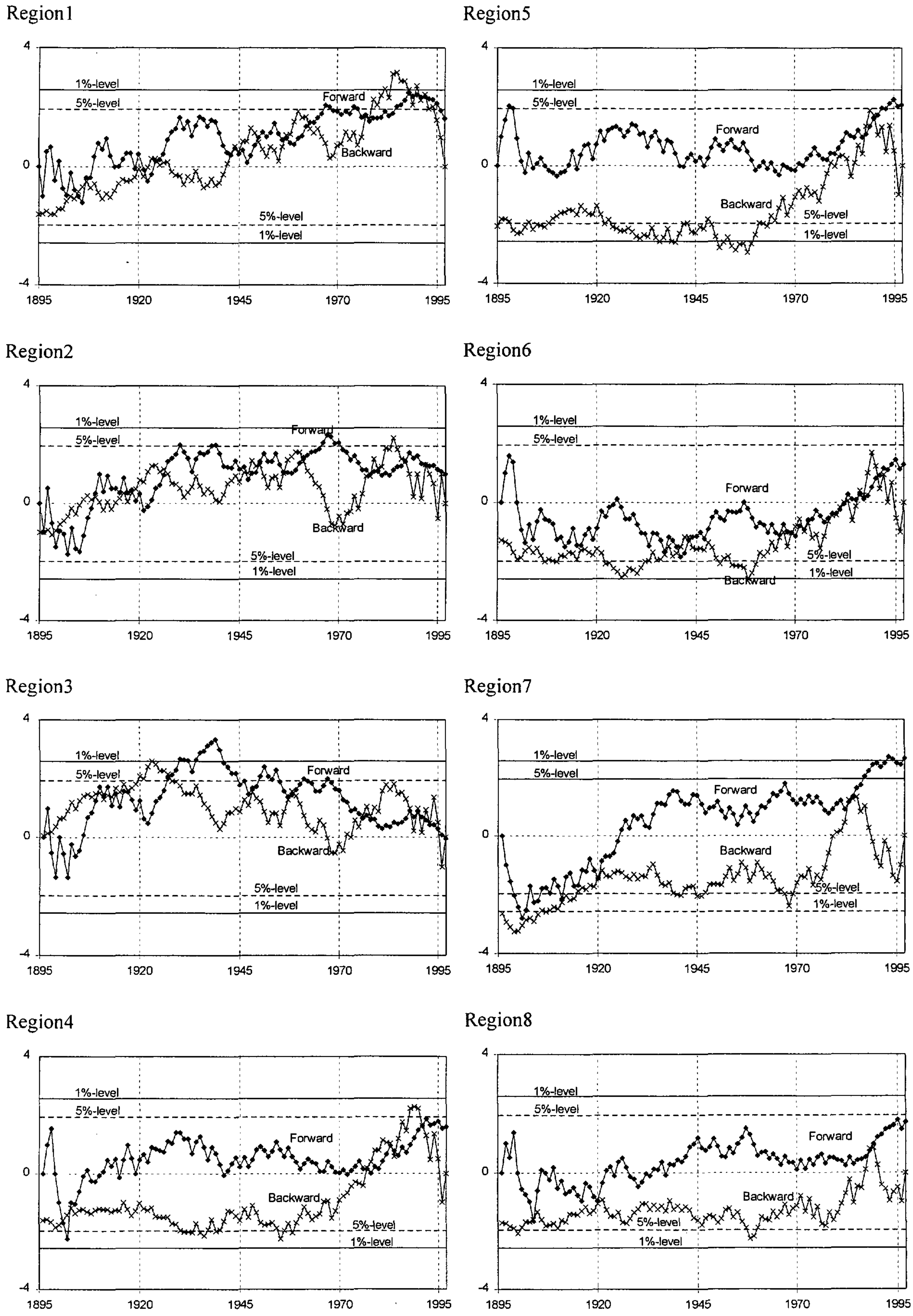
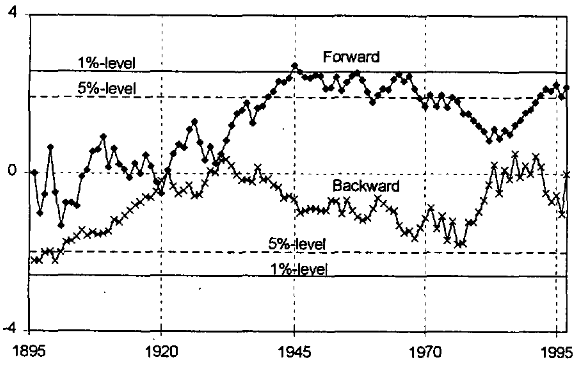
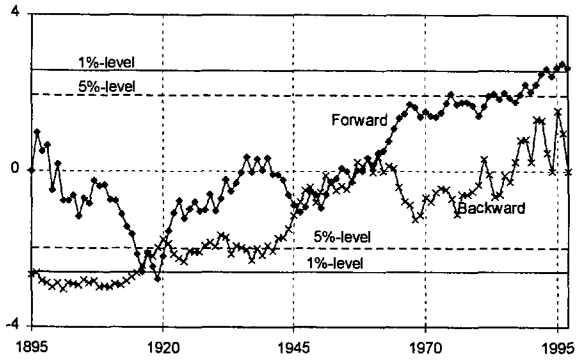


Figure 4. Mann-Kendall test statistics for regional series of annual precipitation. The «forward» series give the test result for the period from 1895 to the actual year. The «backward» series give the test result for the period from the actual year to 1997. The given significance levels are not valid for tests of 10 years or less.

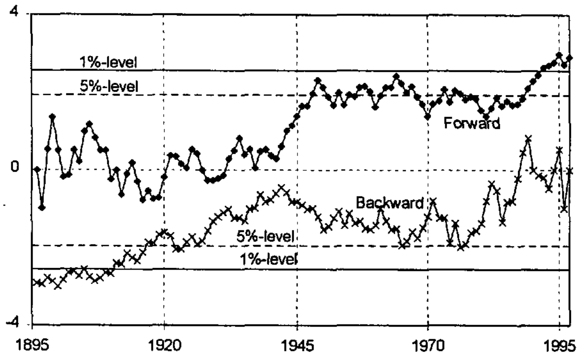
Region9



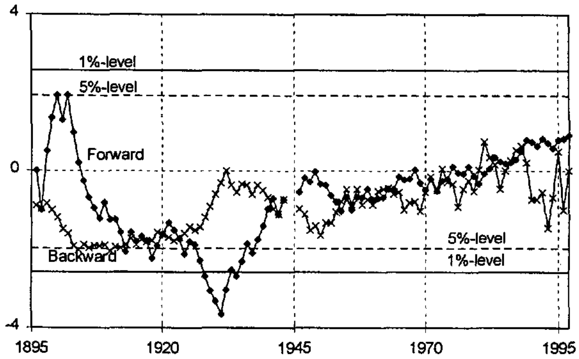
Region12



Region10



Region13



Region11

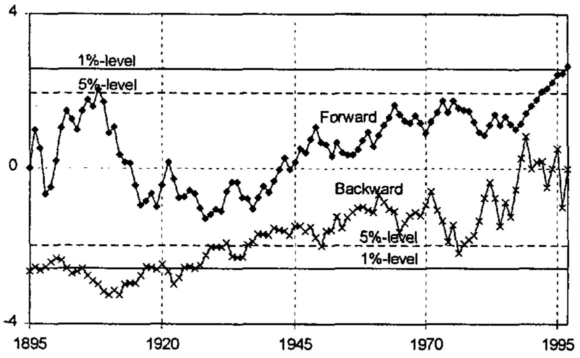
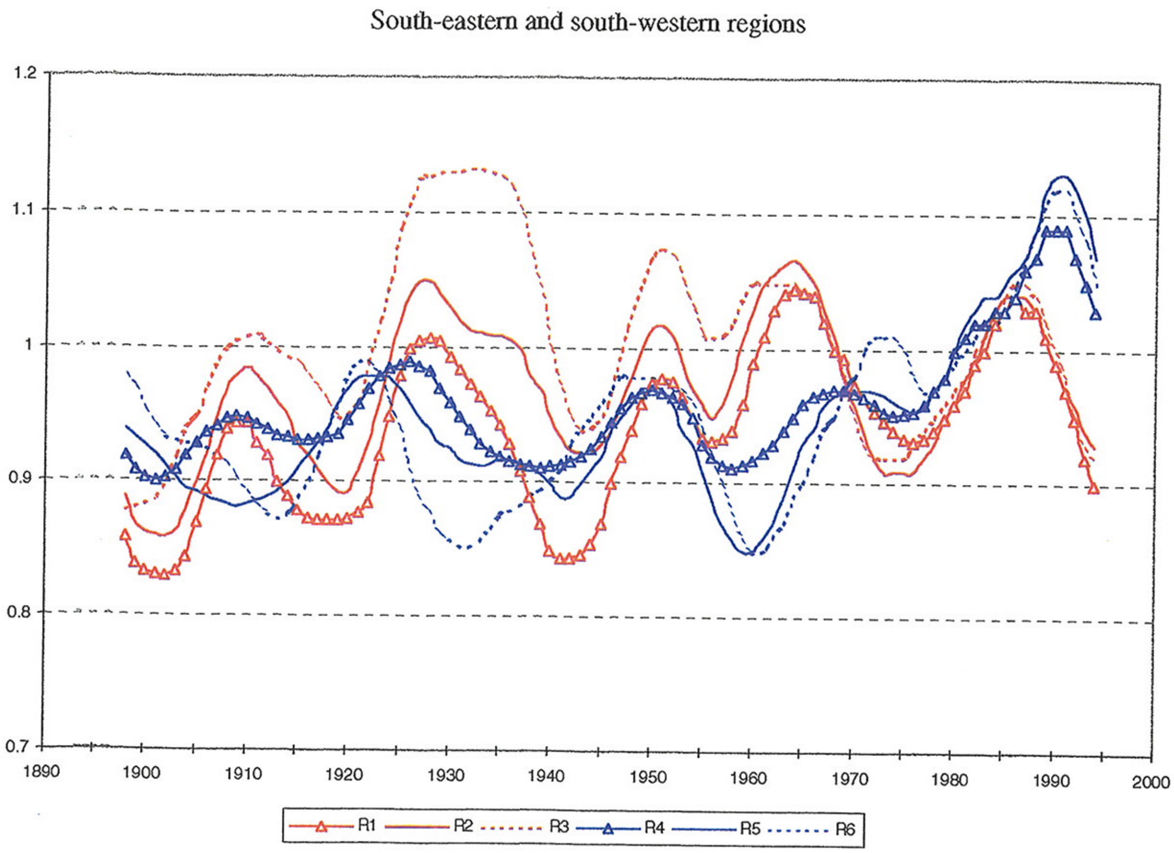


Figure 4 continued. Mann-Kendall test statistics for regional series of annual precipitation. The «forward» series give the test result for the period from 1895 to the actual year. The «backward» series give the test result for the period from the actual year to 1997. The given significance levels are not valid for tests of 10 years or less.


South-eastern and south-western regions

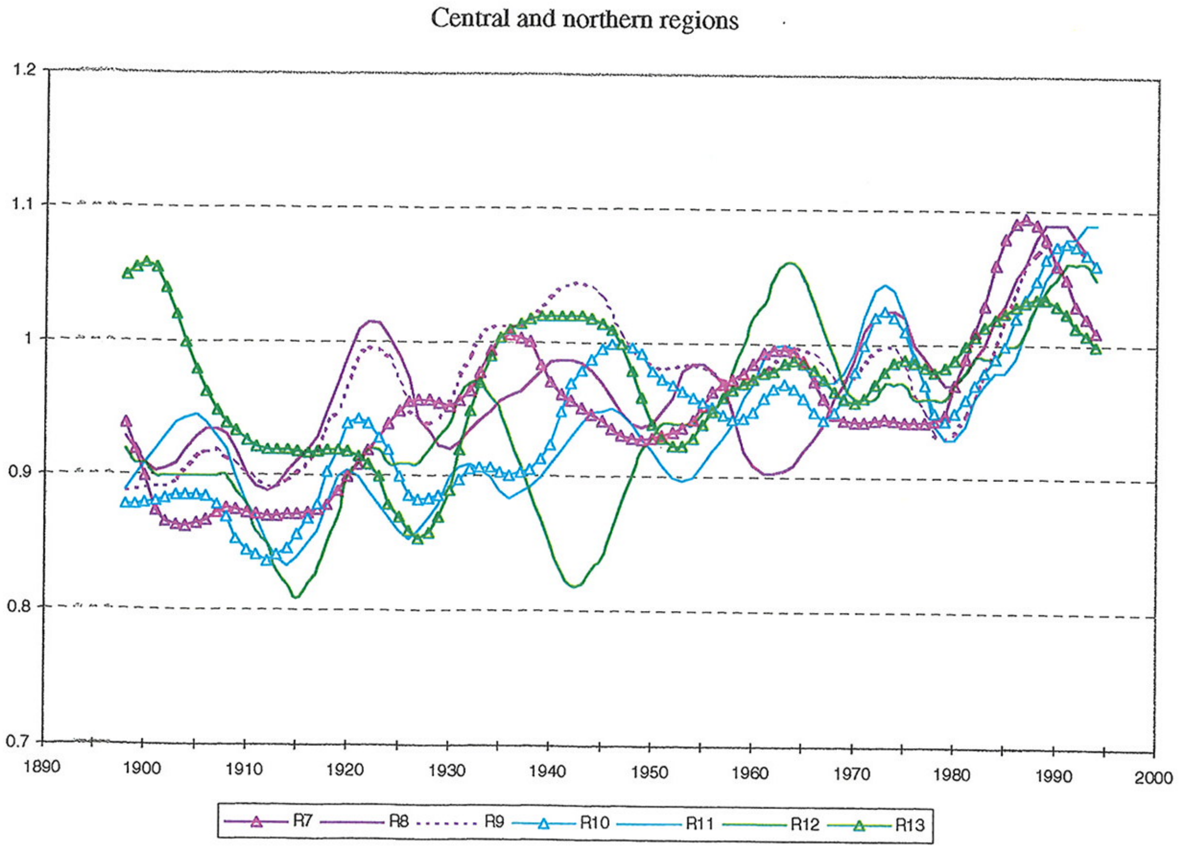

Central and northern regions

Figure 5. Low pass filtered regional series of standardised annual precipitation for regions 1-6 (upper panel) and regions 7-13 (lower panel). Values are given relative to the 1961-1990 average.

Figures 6 shows low-pass filtered seasonal series. Note the dramatic increase in **winter precipitation** in R4-R6 from its minimum level around 1965 to its maximum level around 1990 (Figure 6a). Successive Mann-Kendall tests of winter precipitation (not shown) revealed that the south-western regions experienced a statistically significant increase in winter precipitation from around 1960 to 1997, but that a negative trend from 1896 to the 1960s prevents the trend for the entire period from being significant. In the south-eastern regions R1-R3, the increase from the winter precipitation minimum around 1980 to the end of the series is not statistically significant. However, in R2 and R3, there was a significant increase in winter precipitation from 1896 to the absolute maximum in the early 1930s. Negative trends in winter precipitation in these regions from the 1930s to around 1980 give no significant trend from 1896 to 1997. In R9-R12, successive Mann-Kendall tests revealed that winter precipitation increased significantly from around 1915 to 1997. Decreasing winter precipitation during the first decades, however, prevents the positive trend during 1896-1997 from being significant in R9 and R10. The north-eastern region R13 shows a highly significant decrease from maximum winter precipitation in the beginning of the series to a dry spell around 1930. Still, the negative trend from 1896 to 1997 is not significant, as there is a positive trend from the absolute minimum in the early 1950s to 1997.

Førland et al. (1996) found that the **spring precipitation** in south-eastern Norway was up to 35% higher during the recent standard normal period (1961-90) than during the previous (1931-60). North-west of the mountain divide, on the other hand, the spring precipitation was lower (up to 15%) than in the previous normal period. In spite of these dramatic variations in spring precipitation, the filtered series (Figure 6b) and the Mann-Kendall tests on seasonal basis demonstrates that the spring precipitation shows no significant increase in southern Norway during the period 1896-1997. Though the spring precipitation increased significantly in most of the southern regions from the 1930s to 1997, particularly the eastern regions experienced a significant decrease in spring precipitation during the period 1896-1940. The south-eastern regions also tend to show a negative trend from the 1980s to 1997.

The features found in the south-eastern regions are quite contrary to those which are found in the regions R9-R11: Here, the average spring precipitation was lower during 1961-1990 than during 1931-1960. Still, the all over trend is positive, because there was a precipitation increase significant at the 1% level during the first 5 decades or so. The spring precipitation also tends to increase during the last 2 decades in these regions. The tendency for opposite trends in spring precipitation in regions R1-R3 and regions R9-R11 is clearly seen in Figure 6b. Table 2.1 shows that also annual precipitation tends to be negatively correlated between south-eastern and north-western regions.

The decadal scale variability in **summer precipitation** (Figure 6c) is rather similar in the southern regions R1-R6: Maximum summer precipitation occurred in the early 1960s, while the summers were rather dry around 1900, 1915, 1975, and towards the end of the series. The former minima tend to be the lowest in west, while the latter tend to be the absolute minima in the east. Dry periods close to both ends of the series, make linear trends for the entire period small in all these regions. In the northern regions, on the other hand, summer precipitation tends to increase from a minimum around 1910 or 1915 at least to the 1960s. In the northern inland region R12, summer precipitation decreased somewhat during the last decades. In regions R10, R11 and R13, on the other hand, the positive trend in summer precipitation is significant also for the entire period (Table 2.1).

Autumn precipitation has increased in all regions, though not statistically significant everywhere (Figure 6d). In the southern regions R1-R6, the driest periods occurred around 1900 and/or 1905, while the wettest periods mainly occurred around 1965 and/or 1980. After 1980, autumn precipitation has decreased in southern Norway. Still, the positive trends during 1896-1997 are statistically significant in all southern regions except R3, and even in this region, it is significant during the period 1896-1993. In the northern regions, autumn precipitation tends to decrease in the very beginning of the series, and the increase during later decades is not sufficient to make the trend statistically significant during the entire period.

4. Covariation between precipitation and temperature

There are 3 main reasons for covariation between air temperature and precipitation:

I) Generally, a warmer climate will include an intensified hydrological cycle, and thus an increase in the precipitable water in the atmosphere. This effect implies a positive correlation between temperature and precipitation.

II) Precipitation is connected to cloudy sky, which locally affects the radiation budget at the surface. This connection contributes to a positive correlation between temperature and precipitation in winter (when the average radiation budget at the surface is negative), and a negative correlation in summer. The connection is expected to be stronger for frontal precipitation, which is associated with extensive cloud systems, than for scattered showers, which are coming from clouds of limited horizontal size. As scattered showers probably account for a larger percentage of summer precipitation than of winter precipitation in most parts of Norway, the connection is expected to be weaker in summer than in winter.

III) For a given atmospheric circulation pattern, a certain geographical region will be exposed to air-masses of a specific origin, i.e. with characteristic values of climate elements like temperature and water content. A shift between different circulation patterns will thus lead to changes in temperature and precipitation which are characteristic for the difference between the air-masses which were advected into the area before and after this shift. There is no general rule as to the structure of the resulting connection between temperature and precipitation, which may certainly vary in space as well as in time. Systematic changes between dry, cold and humid, warm air-masses would contribute to a positive correlation, while changes between dry, warm and humid, cold air-masses would contribute to a negative correlation. In most parts of Norway, the major contrast is between maritime, humid air-masses advected in from the North-Atlantic ocean, and continental, dry air-masses advected from inland areas. Thus, the correlation is expected to be mostly positive in winter, when sea is warmer than land, and negative during summer.

It should be noted that the above connections strictly are valid only for short-time values of precipitation and temperature. Averaging over months, seasons or years may affect precipitation and temperature differently, as temperature variation may be described as a continuous process, while precipitation is discontinuous. E.g. large amounts of precipitation may fall on a day or two when the temperature conditions are quite untypical for the month or season. The averaging will then create some uncertainty, and the connection between e.g. seasonal precipitation and temperature is expected to express weaker signals than one would find from analysing daily values.

Table 4.1 Correlation coefficients between regional series of precipitation and temperature.

P-REGION	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	R11	R12	R13
WINTER	+0.50	+0.31	+0.32	+0.75	+0.73	+0.68	+0.36	+0.48	+0.43	+0.48	+0.50	+0.22	-0.28
SPRING	-0.02	+0.01	-0.12	+0.12	+0.18	+0.10	+0.23	+0.12	+0.10	+0.12	+0.13	+0.20	-0.38
SUMMER	-0.40	-0.21	-0.14	-0.04	-0.19	-0.40	-0.02	-0.31	-0.42	-0.20	-0.34	-0.21	-0.05
AUTUMN	+0.28	+0.30	+0.33	+.020	+0.17	+0.11	+0.11	-0.09	-0.09	-0.03	+0.11	-0.05	-0.08

Temperature evolution with time in Norway is expressed by 6 regional series of standardised temperature (Hanssen-Bauer and Nordli 1998). Table 4.1 shows the correlation between the regional standardised precipitation series and the standardised temperature series from the temperature region which includes the major part of the actual precipitation region. Correlation coefficients are given for all seasons.

As correlation between temperature and precipitation is the result of several effects, the physical interpretation of Table 4.1 is not obvious. However, the negative correlation coefficients during summer indicate that direct temperature effect on precipitable water (effect I) is not the most important one on the inter-annual time-scale. The connection via the cloud cover (effect II) is consistent with most of the seasonal pattern which is seen in the table (negative correlation in summer and mainly positive correlation in winter). Still, the connection via circulation patterns (effect III) is suggested to be a main key to the correlations given in Table 4.1. Circulation indices have earlier been shown to influence inter-annual as well as inter-decadal variation in local precipitation and temperature considerably (e.g. Hurrell 1995, Tveito 1996, Hanssen-Bauer & Førland 1998). Besides, effect III seems to be the only effect which may be able to account for some of the details in Table 4.1, e.g. the negative correlation in winter in region R13. As stated above, effect III would contribute to a positive correlation between temperature and precipitation in winter in most parts of Norway, as precipitation commonly is associated with moist and mild onshore advection from west and/or south. Region R13, however, is mainly exposed for precipitation from east and north-east. Air-masses coming from these directions may very well be produced over cold ice or snow surfaces in polar oceans or Siberia, and only be slightly affected by a short path over open sea.

The correlation coefficients are at maximum in winter in the south-western regions R4 and R5, where more than 50% of the variance in precipitation is accounted for by temperature variations. In winter in these regions, all the mentioned effects which may lead to covariation between temperature and precipitation work in the same direction. The regression coefficients between winter precipitation and temperature for regions R4-R6 were found to be 33-38% precipitation change per standard deviation temperature change. Using typical values for standard deviation of winter temperature, gives an average «precipitation sensitivity to temperature» of 15-25% per °C in these regions. These numbers are valid for the present century, but we will warn strongly against using them directly to make precipitation scenarios for the future, based only upon temperature scenarios. As the ratio between precipitation- and temperature-anomalies depends strongly on the average atmospheric circulation conditions, precipitation scenarios must be based also on scenarios for changes in these conditions.

The fact that the direct temperature effect on precipitable water (effect I) seems to be less important than effect III for interpretation of inter-annual variation of temperature and precipitation does not imply that it is insignificant when it comes to long-term trends. Hulme (1995) plotted a low-pass filtered series of annual global land surface precipitation for the period 1900-1992 against a similar temperature series. Even though the filter suppresses variability of time-scales shorter than about 30 years, the resulting scatter-plot expresses an undulating curve, rather than a straight line, moving against warmer and wetter climate. One interpretation of the figure, is that the undulations are mainly due to different states or modes of the global circulation systems, while the long-term average «precipitation sensitivity to global warming», which was found to be 3.2% per °C for land areas, mainly is a result of the intensified hydrological cycle in a warmer climate. It is difficult to assess if there also is a net positive effect from clouds (effect II). The observed global warming seems to be caused more by increasing minimum temperatures than by increased maximum temperatures (Easterling et al. 1997). This may be caused by a positive trend in the cloud cover (e.g. Kaas & Frich, 1995), which certainly also might give a potential for more precipitation. However, the net effect of cloud cover on temperature depends on types of clouds as well as their distribution in space and time.

Regional series are certainly far more affected by circulation effects than global averages, even on long time-scales. A comparison of long-term trends in precipitation and temperature may still reveal features which are masked by the large inter-annual variability. Figures 7 and 8 show low-pass filtered series of regional precipitation plotted against similar temperature series. The filter described in section 3.1.1 was used with a standard deviation of 9 years, which suppresses variability of time-scales less than 30 years, and is thus comparable to the filter used by Hulme (1995). The first and last 5 years of the series were skipped in order to avoid the uncertain values at each end of the series (cf. section 3.1.1). Figures 7 and 8 show the results on seasonal basis for one of the south-eastern regions (R2), one south-western region (R5), one north-western region (R11) and the northern inland region (R12).

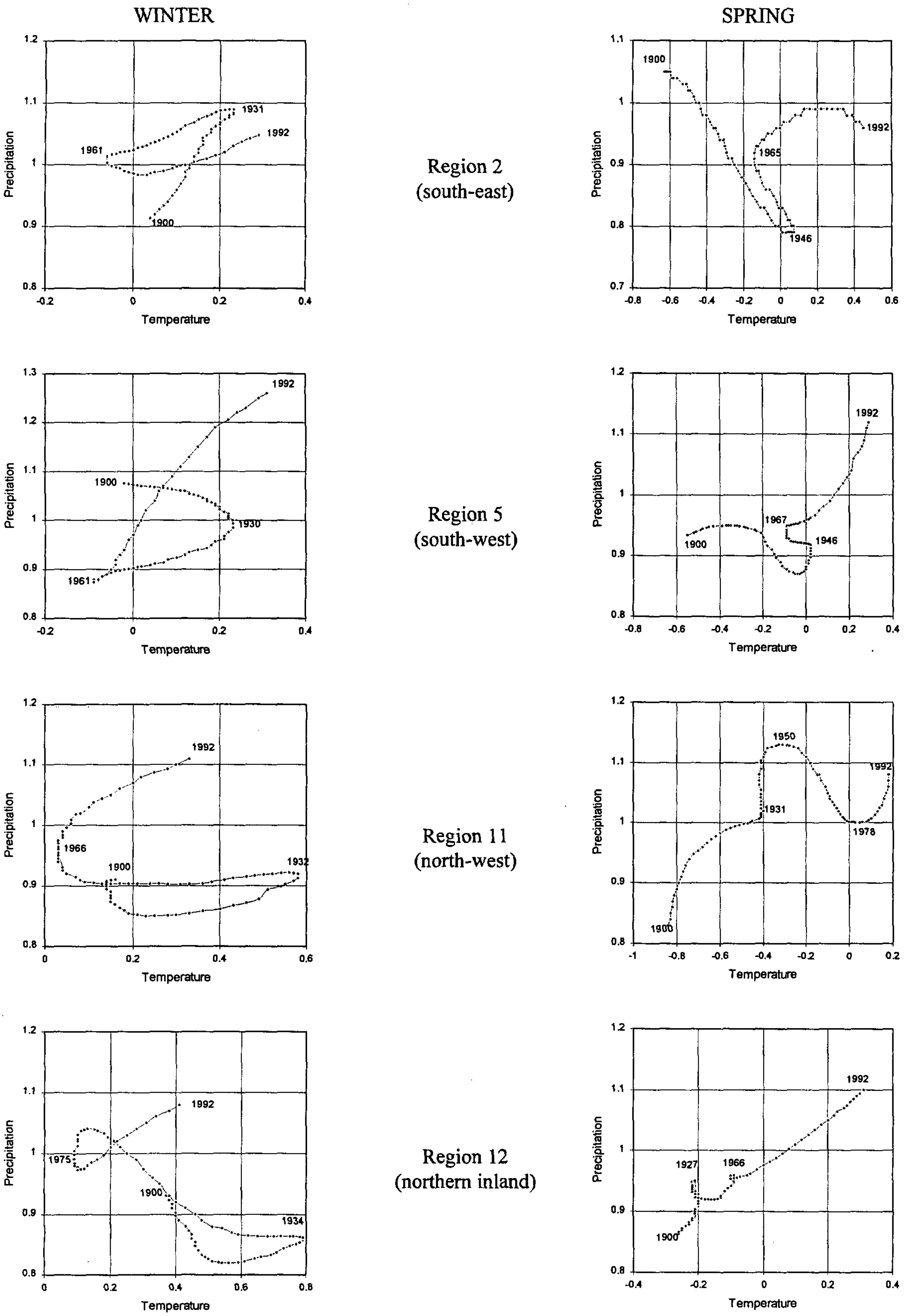


Figure 7. Temperature trends vs.precipitation trends in regions R2, R5, R11 and R12 during winter (left) and spring (right). Precipitation is given as proportion of the 1961-1990 average. Temperature anomaly is given in number of standard deviations relative to the 1961-1990 average.

The **winter** plots (Figure 7, left) show some interesting differences between south-eastern and south-western regions: In R2, precipitation increased by about 10% per 0.1 standard deviation increase in temperature before the temperature optimum in the 1930s. This is almost 3 times the average ratio for the whole series. After this optimum, the ratio between changes in precipitation and temperature was considerably smaller, both during the following 3 decades, when temperature and precipitation decreased, and during the latest decades when temperature and precipitation increased once again. In the south-western region R5, on the other hand, the precipitation increased by about 10% per 0.1 standard deviation increase in temperature after 1960, while the ratio between precipitation change and temperature change was smaller in the period 1930-1960, and even negative before 1930. The north-western region R11 reminds of R5 in the winter, with little covariation between temperature and precipitation trends before the 1960s, and a clear positive connection between the trends during the last 3 decades. In the northern inland region R12, precipitation trends and temperature trends were mainly negatively correlated up to the 1960s. During the last couple of decades, also this region shows a positive ratio.

In south-western Norway, it has been shown that the increase in winter precipitation and winter temperature after 1960 both are highly correlated to a strengthening in the average zonal (on-shore) wind component (Hurrell 1995, Tveito 1996). Such a strengthening in the average zonal wind field (increased NAO index) can explain why increasing winter temperatures are found all over the country, while increased precipitation mainly is found in the western parts of the country. Variation in circulation patterns thus seems able to explain the winter plots from the 1960s to present. But why is the connection between atmospheric circulation, temperature and precipitation different before 1960 ? The winter plot from R2 may suggest an explanation: It is reasonable that this region, which is partly in the «rain shadow» under westerly winds, experienced a smaller relative precipitation increase than westerly regions in the period from 1960 to the 1990s, when the average zonal wind-field was intensified. On the other hand, it also seems reasonable that the large ratio between precipitation changes and temperature changes before the 1930s was caused by changes in the wind component which is most important for the precipitation conditions in this region, namely the meridional wind component. A probable hypothesis is that the increase in Norwegian winter temperatures before the 1930s (at least to some degree) was caused by an increase in the frequency and/or intensity of southerly winds, which also led to increased precipitation in south-easterly regions, while the precipitation in western and northern parts of the country was less affected. This hypothesis has to be tested against circulation data, as there may also be other explanations for the different conditions before and after 1960.

Hanssen-Bauer & Førland (1998) concluded that variations in the atmospheric circulation system could explain most of the long-term variations in temperature at Svalbard during the period 1960-1995. However, the temperature variations before 1960 (a temperature increase up to the 1930s and a cooling from the 1930s to the 1960s) could not be explained solely by variations in circulation pattern: Other factors (SST, sea ice, cloudiness, etc.) are needed to model long-term variations in temperature in the Norwegian Arctic. It is interesting to note that even simulations of global annual warming during 1860-1990 allowing for increase in greenhouse gases and sulphate aerosols (Kattenberg et al., 1996) fail to reproduce the warming in the 1930s and 40s, while the global warming since 1960 is modelled satisfactorily. Thus other factors may be responsible for parts of the temperature increase in Norway, and also affect the ratio between temperature trends and precipitation trends.

The **spring** plots of long-term trends in precipitation against temperature (Figure 7, right), illustrates very well the differences between south-eastern and north-western regions: In R2, the spring precipitation decreased considerably with increasing temperature up to the 1940s. After this, there has been a net increase in temperature as well as in precipitation. In R11, on the other hand, the spring precipitation increased considerably with increasing temperature up to about 1950. Since then, there has been a small net reduction in precipitation, while the temperature has increased further. These rather systematic contrasts between precipitation trends in regions situated south-east and north-west of the mountain divide, respectively, make us suspect that variation in circulation indices which have an opposite effect on the orographic precipitation in these regions can explain at least most of the observed precipitation trends. It is still a question how much of the temperature increase which might be explained in this way. The surprisingly constant ratio between long-term trends in spring precipitation and spring temperature in region R12 makes it tempting to try to explain also these trends by orographic effects. However, a constant ratio between temperature and precipitation trends seems to be an exception rather than the rule.

The **summer** plots of long-term trends in precipitation against temperature (Figure 8, left), show that the main differences in this season are between south and north rather than between east and west. The general connection between temperature trends and precipitation trends is apparently weaker: Large temperature changes occur in periods with minor precipitation changes and vice versa. The tendency for negative correlation between temperature and precipitation, which is found between single values (Table 4.1), not are reflected in general negative ratios between the long-term trends.

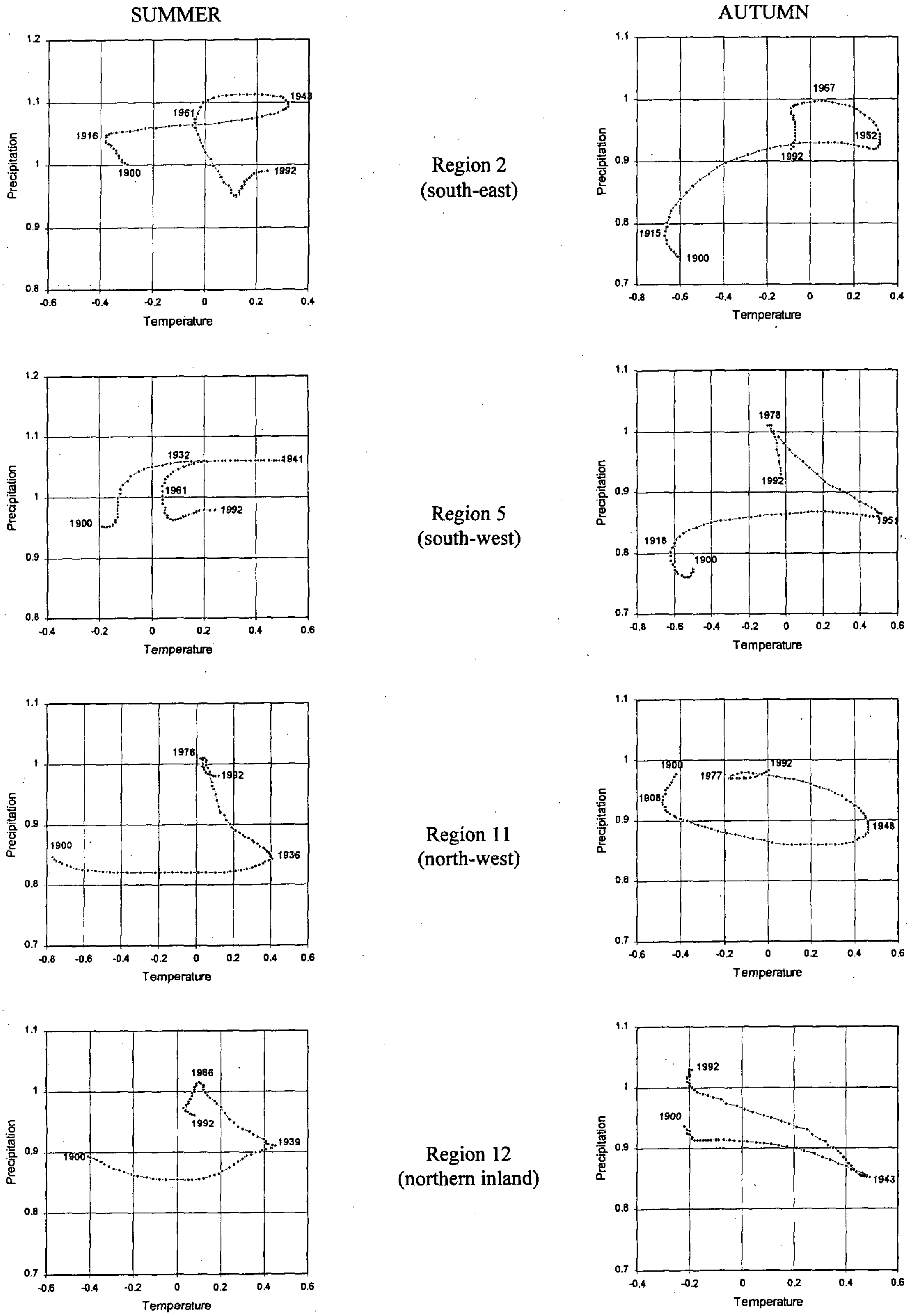


Figure 8. Temperature trends vs.precipitation trends in regions R2, R5, R11 and R12 during summer (left) and autumn (right). Precipitation is given as proportion of the 1961-1990 average. Temperature anomaly is given in number of standard deviations relative to the 1961-1990 average.

In **autumn** (Figure 8, right), both temperature and precipitation has increased in southern Norway during the last 100 years. Still, there is no clear connection between these trends. In the south-western region one of the most striking features is actually that the negative temperature trend from around 1950 to around 1980 was accompanied by a positive trend in precipitation. In northern Norway, the connection between trends in autumn precipitation and temperature generally seems to be weak. In the inland region R12 there seems to be a weak negative connection, as the precipitation decreased slightly when the temperature increased up to the 1940s, while it increased slightly when the temperature decreased after the 1940s.

5. Summary and conclusions

Norway was divided into 13 precipitation regions. Time-series of standardised precipitation are quite similar for all stations within a certain region. The precipitation evolution within a region can thus be described reasonably well by one standardised series. Consequently, the regions are convenient spatial units for describing precipitation variations in the past, as well as for estimating future precipitation scenarios. The regions will later be used as spatial units for statistical downscaling of precipitation within the frame of the Reg Clim project (Iversen et al. 1997).

Studies of standardised precipitation from the 13 Norwegian precipitation regions show that there is a positive trend in annual precipitation during the period 1896-1997 in all regions except the south-eastern region R3, where there is no trend. The precipitation increase, which varies from 5 to 18 %, is statistically significant at least at the 5% level in 6 regions. The largest and most significant precipitation increase is found in north-western regions R10 and R11. There are regional differences concerning the time interval in which the precipitation increased, as well as in which seasons the increase occurred. In south-eastern Norway the precipitation increased mainly before 1940, in south-western regions the increase occurred mainly after 1960, while the increase in northern Norway was more evenly distributed from around 1920 to present. In southern Norway, the net increase in annual precipitation is mainly caused by increased autumn precipitation. In northern regions, on the other hand, spring precipitation as well as summer precipitation and/or winter precipitation have increased significantly.

Comparison of simultaneous long-term trends in precipitation and temperature, shows that even regionally and within a specific season, there is no general relationship between these trends. In some periods and seasons, both precipitation- and temperature changes seem to be rather closely associated with systematic changes in the atmospheric circulation, and the ratio between precipitation- and temperature changes is fairly constant. In other periods and/or seasons, there is no obvious connection, neither between precipitation- and temperature changes, nor between the temperature changes and changes in the atmospheric circulation. However, the analyses we have seen so far of the connection between atmospheric circulation and Norwegian temperature and precipitation conditions, are based upon rather simple circulation indices (NAO-index or other surface pressure gradients). One of the tasks within the frames of the Reg Clim project is to study these connections further, using more detailed circulation indices, and more advanced techniques.

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Appendix

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

R: Region number, STNR: Station number, NAME: Station name, LAT: Latitude, LONG: Longitude, PERIOD: Period of observations

R	STNR	NAME	LAT	LONG	PERIOD	R	STNR	NAME	LAT	LONG	PERIOD
1	1230	HALDEN	590735	112332	1896 - 1997	7	9100	FOLDAL	620759	100290	1896 - 1997
1	1650	STRØMSFOSS S.	591798	113993	1896 - 1997	7	10400	RØROS	623404	112302	1896 - 1997
1	3450	HAGA	593197	111787	1896 - 1997	7	15660	SKJÅK	615411	81034	1896 - 1997
2	5350	NORD-ODAL	602304	113306	1896 - 1997	7	66850	KVIKNE	623580	101629	1895 - 1997
2	11900	BIRI	605705	103598	1896 - 1997	8	58960	HORNINDAL	620019	63907	1899 - 1997
2	13100	VESTRE GAUSD.	612069	94639	1896 - 1997	8	60400	NORDDAL	621486	71449	1895 - 1997
2	18500	BJØRNHOLT	600306	104119	1896 - 1997	8	60800	ØRSKOG	622873	64920	1898 - 1994
2	20520	LUNNER	601766	103482	1896 - 1997	8	61550	VERMA	622052	80326	1895 - 1997
2	22840	REINLI	605011	92960	1896 - 1997	8	63100	ØKSENDAL	624113	82547	1895 - 1997
2	25640	GEILO	603189	80951	1896 - 1997	8	64800	SURNADAL	630030	90068	1895 - 1997
2	27800	HEDRUM	591174	95809	1895 - 1997	9	66250	HØLONDA	630693	100112	1895 - 1997
2	28920	VEGGLI	601532	84201	1896 - 1997	9	68420	AUNET	630337	113417	1895 - 1997
2	30370	BESSTUL	592682	93231	1896 - 1997	9	69550	ØSTÅS I HEGRA	632924	112136	1895 - 1997
2	33250	RAULAND	594228	80219	1895 - 1997	10	65220	HEMNE	631553	90023	1895 - 1997
2	37750	FYRESDAL	591022	80232	1902 - 1997	10	70360	SULSTUA	634099	120199	1895 - 1981
3	34600	DRANGEDAL	590588	90428	1896 - 1997	10	70480	SKJÆKERFOSSEN	635035	120139	1906 - 1997
3	38600	MYKLAND	583800	81698	1896 - 1997	10	72100	NAMDALSEID	641501	111200	1900 - 1997
3	39220	MESTAD	581297	75355	1900 - 1997	10	72700	OVERHALLA	643099	115699	1896 - 1977
4	42720	BAKKE	582473	63959	1896 - 1997	10	75100	LIAFOSS	645032	115741	1909 - 1997
4	43360	EGERSUND	582716	60018	1896 - 1997	10	78100	DREVJA	655992	132500	1906 - 1997
4	44800	SVILAND	584911	55521	1901 - 1997	10	79740	DUNDERLANDSD.	663041	145445	1896 - 1997
4	47020	NEDSTRAND	592065	54790	1895 - 1997	10	80200	LURØY	662338	131123	1923 - 1997
5	40900	BJÅEN	593830	72625	1896 - 1997	10	80400	NORDFJORDNES	663499	132999	1906 - 1973
5	42890	SKREÅDALEN	584929	64292	1896 - 1997	11	80700	GLOMFJORD	664860	135888	1916 - 1997
5	46050	ULLA	592276	63166	1895 - 1997	11	81100	BEIARN	670099	143599	1900 - 1978
5	46450	RØLDAL	594986	64954	1902 - 1997	11	81900	SULITJELMA	670809	160427	1905 - 1997
5	47500	ETNE	593960	55801	1895 - 1997	11	83500	KRÅKMO	674758	155924	1895 - 1997
5	50540	BERGEN	602300	52002	1895 - 1997	11	86850	BARKESTAD	684904	144812	1896 - 1997
6	49550	KINSARVIK	602235	64429	1895 - 1997	11	88100	BONES I BARDU	683874	181473	1907 - 1997
6	50350	SAMNANGER	602774	55390	1901 - 1997	11	89800	ØVERBYGD	690107	191682	1895 - 1996
6	52170	EKSINGEDAL	604800	60942	1895 - 1997	11	90450	TROMSØ	693925	185581	1873 - 1997
6	52750	FRØYSET	605088	51304	1899 - 1997	12	93300	SUOLOVUOPMI	693530	233190	1908 - 1997
6	53070	VIK I SOGN III	610432	63511	1895 - 1997	12	93500	JOTKAJAVRE	694527	235605	1923 - 1997
6	55550	HAFSLO	611758	71146	1895 - 1997	12	93700	KAUTEKEINO	690099	230299	1889 - 1972
6	56320	LAVIK	610673	53282	1895 - 1997	12	93900	SIHCAJAVRI	684502	233202	1912 - 1997
6	56960	HAUKEDAL	612535	62274	1895 - 1997	12	97250	KARASJOK	692800	253060	1877 - 1997
6	57110	OSLAND	612632	51316	1907 - 1997	12	99450	BJØRNSUND	692704	300415	1895 - 1997
6	58880	SINDRE	615543	63251	1895 - 1997	13	98400	MAKKAUR FYR	704203	300408	1924 - 1997
7	600	GLØTVOLA	615064	115107	1896 - 1997	13	98550	VARDØ	702203	310509	1867 - 1997

Table A.2 Precipitation normals 1961-1990 on monthly, seasonal and annual basis. Unit: 0.1mm

STNO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WIN	SPR	SUM	AUT
600	276	196	225	294	465	725	873	775	683	489	368	333	5700	805	983	2372	1540
1230	545	446	481	416	519	699	747	802	874	1005	885	602	8019	1605	1415	2248	2764
1650	608	462	535	483	587	726	796	946	1023	1082	938	649	8835	1732	1604	2468	3043
3450	536	421	508	424	551	716	757	876	924	998	846	590	8147	1553	1484	2348	2768
5350	461	354	400	417	548	725	798	845	876	840	727	516	7505	1337	1364	2368	2443
9100	171	126	123	125	260	511	702	534	367	280	229	198	3627	496	507	1747	877
10400	342	279	290	242	274	522	717	626	536	401	382	417	5025	1036	806	1864	1318
11900	449	344	378	373	564	712	866	909	860	888	704	485	7532	1275	1315	2486	2453
13100	370	261	284	255	471	685	784	808	670	666	513	371	6138	1002	1010	2277	1849
15660	246	151	149	68	160	303	435	351	339	359	293	307	3162	701	377	1089	991
18500	759	591	707	614	766	906	1086	1181	1274	1391	1195	889	11359	2231	2087	3173	3860
20520	555	430	456	431	542	664	814	862	803	933	786	622	7895	1606	1429	2340	2521
22840	429	323	420	338	546	721	863	849	736	741	609	424	6998	1173	1303	2432	2086
25640	573	384	502	324	511	667	748	759	769	845	741	641	7465	1598	1337	2174	2355
27800	750	548	682	497	751	693	792	1100	1210	1347	1141	758	10269	2041	1930	2585	3698
28920	428	327	382	337	586	689	826	797	822	841	642	404	7079	1156	1305	2312	2304
30370	842	635	785	617	862	862	1044	1324	1370	1538	1228	899	12004	2372	2264	3229	4136
33250	674	490	554	373	606	736	808	887	896	951	781	661	8418	1823	1533	2431	2629
34600	647	454	540	455	708	656	848	1012	1078	1161	1009	639	9205	1741	1703	2516	3246
37750	678	487	513	410	686	671	767	1015	1046	1124	952	644	8994	1816	1609	2454	3123
38600	1015	673	746	529	802	744	905	1084	1239	1407	1277	953	11373	2642	2077	2733	3923
39220	1695	1090	1197	728	1012	902	1062	1400	1795	2095	2062	1585	16622	4374	2937	3364	5952
40900	1016	697	735	360	458	598	626	818	1017	1116	1079	1091	9611	2782	1554	2041	3212
42720	1815	1317	1378	812	1078	993	1094	1551	2084	2460	2369	1945	18896	5063	3268	3638	6912
42890	2162	1481	1680	869	1165	1212	1224	1687	2478	2873	2594	2381	21806	6005	3714	4123	7945
43360	1310	935	1093	733	849	840	1026	1327	1693	1861	1797	1454	14916	3713	2675	3192	5351
44800	1535	1138	1366	803	920	1032	1339	1579	2185	2286	2145	1942	18269	4608	3089	3949	6616
46050	2222	1591	1892	939	953	1200	1382	1707	2668	2858	2766	2805	22983	6589	3784	4289	8293
46450	1737	1187	1236	626	664	842	892	1207	1900	2133	1907	1930	16260	4829	2526	2941	5939
47020	1597	1130	1497	860	885	1136	1291	1620	2330	2385	2194	2029	18953	4742	3242	4047	6909
47500	1756	1284	1500	743	921	1126	1232	1584	2411	2509	2293	2138	19496	5145	3164	3942	7213
49550	1332	873	1100	502	523	658	822	953	1535	1687	1557	1646	13187	3820	2125	2433	4778
50350	3293	2375	2882	1511	1469	1921	2137	2568	4278	4239	3751	3989	34413	9572	5863	6626	12268
50540	1906	1483	1685	1109	1065	1272	1471	1832	2920	2845	2648	2357	22595	5700	3859	4575	8414
52170	2591	1756	1974	1010	1000	1240	1379	1757	3053	3144	2810	2900	24613	7199	3984	4376	9006
52750	1882	1548	1663	1129	1014	1344	1475	1893	2899	2675	2493	2332	22346	5710	3806	4712	8066
53070	1116	703	824	362	417	565	684	789	1421	1409	1297	1360	10945	3156	1603	2037	4126
55550	1088	702	839	390	445	565	620	762	1225	1321	1228	1278	10463	3056	1674	1947	3775

Table A.2 continued. Precipitation normals 1961-1990 on monthly, seasonal and annual basis
Unit: 0.1mm

STNO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WIN	SPR	SUM	AUT
56320	1932	1506	1732	1022	896	1186	1403	1692	2924	2842	2579	2524	22238	5883	3650	4281	8344
56960	2170	1626	1871	1061	871	1180	1379	1565	2932	2792	2428	2714	22589	6436	3802	4124	8153
57110	2670	2079	2231	1494	1339	1631	2000	2400	4059	3856	3525	3234	30519	7918	5064	6031	11440
58880	1684	1213	1321	689	545	706	846	993	1944	1960	1995	2180	16076	5039	2555	2545	5899
58960	1976	1505	1588	934	680	879	1097	1244	2254	2295	2141	2474	19069	5899	3202	3220	6691
60400	951	742	806	486	346	435	629	624	1120	1134	1109	1271	9654	2929	1638	1687	3363
60800	1365	1167	1183	965	727	752	1019	1168	1971	1914	1716	1898	15845	4363	2874	2939	5601
61550	875	605	703	406	234	348	508	475	710	777	889	1126	7655	2580	1343	1331	2375
63100	1065	812	964	621	536	688	993	965	1413	1323	1196	1374	11951	3217	2121	2646	3932
64800	1159	952	993	826	640	863	1167	1188	1735	1569	1308	1534	13933	3601	2459	3219	4611
65220	1607	1294	1268	963	678	789	976	997	1899	1904	1632	2076	16082	4918	2909	2762	5434
66250	553	486	498	457	401	656	921	785	927	789	647	706	7826	1729	1357	2362	2362
66850	316	257	286	262	319	589	786	651	647	464	358	380	5315	946	867	2026	1469
68420	646	551	530	516	447	638	888	825	1079	901	692	801	8513	1973	1493	2350	2672
69550	1026	864	846	738	684	827	1088	1078	1430	1290	963	1211	12046	3062	2268	2994	3683
70360	700	570	580	570	560	710	1000	890	1210	1080	740	890	9500	2160	1710	2600	3030
70480	1118	926	899	777	697	890	1195	1118	1593	1478	1088	1356	13136	3350	2373	3203	4160
72100	1316	1045	1051	790	574	678	834	878	1534	1600	1329	1585	13213	3904	2415	2390	4463
72700	1390	1105	1075	840	550	730	930	985	1595	1625	1320	1615	13760	4110	2465	2645	4540
75100	1800	1471	1561	1339	882	1106	1384	1583	2270	2437	1778	2114	19725	5301	3782	4073	6485
78100	1923	1513	1427	1007	767	822	1104	1260	1936	2274	1828	2039	17897	5425	3201	3185	6037
79740	1564	1197	1132	627	587	628	973	1013	1476	1905	1490	1694	14287	4417	2345	2614	4871
80200	2469	1971	2120	1817	1436	1677	2277	2412	3467	3956	2721	3007	29330	7367	5373	6366	10143
80400	2090	1620	1690	1350	1120	1200	1680	1800	2650	3190	2230	2480	23100	6190	4160	4680	8070
80700	1938	1631	1476	1165	899	990	1426	1532	2373	2834	2115	2298	20677	5811	3540	3948	7322
81100	1210	1070	940	660	510	570	830	920	1400	1790	1340	1510	12750	3790	2110	2320	4530
81900	986	927	825	592	446	610	852	774	1064	1434	988	1170	10667	3058	1863	2236	3486
83500	1610	1384	1080	799	669	721	914	987	1419	2058	1373	1825	14840	4762	2549	2622	4851
86850	1428	1279	1147	983	729	769	932	968	1519	2111	1569	1618	15053	4277	2859	2669	5199
88100	762	714	509	441	349	471	759	806	869	1123	845	815	8464	2256	1300	2036	2837
89800	565	547	343	340	296	460	618	694	635	847	597	629	6572	1721	980	1772	2079
90450	949	867	620	552	415	504	653	704	1017	1306	1078	1060	9725	2853	1587	1861	3401
93300	310	246	236	217	264	439	690	634	450	423	342	295	4546	848	718	1763	1215
93500	288	249	239	204	248	425	673	594	477	450	360	315	4522	851	691	1692	1287
93700	90	70	90	110	190	380	690	590	430	330	180	100	3250	260	390	1660	940
93900	170	120	150	160	200	410	700	600	440	340	210	160	3660	450	510	1710	990
97250	179	124	138	147	229	416	714	576	404	329	224	167	3647	478	513	1706	957
98400	547	442	407	382	348	408	554	655	680	646	555	557	6181	1539	1137	1618	1880
98550	593	446	373	356	327	463	535	596	592	627	640	568	6118	1607	1057	1595	1859
99450	322	243	177	168	232	497	673	633	508	374	354	360	4541	925	577	1803	1236