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Climate

Comparison of grid-based and station-based regional temperature and precipitation series

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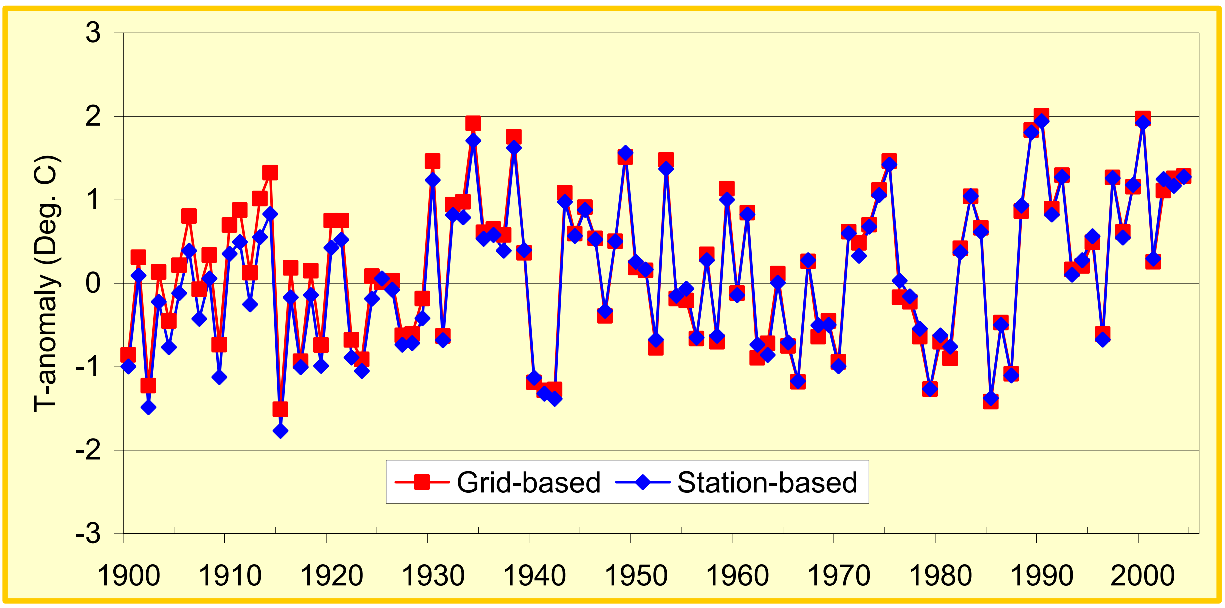

Average annual temperature anomaly in south-eastern Norway based upon gridded data (red) and selected station data (blue)

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Abstract

Regional series of annual and seasonal temperature and precipitation have been calculated by two different methods (one grid-based and one station-based) for 6 temperature regions and 13 precipitation regions in Norway. With few exceptions the series calculated by the two methods are very well correlated, but there are some differences in the estimated trends over the period 1900-2005. Differences between results from the two approaches are probably caused by poor spatial data coverage (major problem in the station-based approach), by inhomogeneity of the observational series or by variable station coverage (mainly a problem in the grid-based approach).

For temperature, the following features are found by both methods: On an annual basis, there has been a statistically significant (10% level) warming of between 0.04 and 0.10 ^{o}C per decade in all regions except the northern inland region. Neither method show significant trends in winter temperature, but both show a significant warming during spring all over the country. The trends in summer and autumn temperatures are positive in all regions, though they are not statistically significant everywhere. The trends in summer-temperatures tend to be significant in northern regions.

Both methods show a significant increase in annual precipitation in most regions. Also most of the seasonal trends are positive, but a majority of them are not statistically significant at the 10% level. Exceptions are that the increase in winter precipitation is significant in some of the northern regions, the spring precipitation has increased significantly in parts of central and northern Norway, and autumn precipitation has increased significantly in most southern regions. The methods agree that the only statistically significant negative trend is in spring precipitation in the north-easternmost region.

Keywords

Regional trends, temperature, precipitation, comparison of methods

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Contents

1. Introduction

Century long regional time-series of standardised temperature and precipitation in Norway based upon a limited number of high-quality series were reported by Hanssen-Bauer and Nordli (1998; temperature) and Hanssen-Bauer and Førland (1998; precipitation). During later years gridded data sets of monthly temperature and precipitation have been developed. These datasets are more flexible than the fixed regional series, as regions may be redefined according to the any specific need. Further, the gridded datasets include all available observations in Norway; not only a few selected series. The spatial data coverage is thus superior. On the other hand, the gridded datasets will include data from stations operative for short periods without reliable normal values for the period 1961-90, and also data of lower quality, and may thus be affected by inhomogeneities. In the present report temperature and precipitation series for the predefined regions for the period 1900-2004 calculated by the grid approach and by the selected station approach are compared, and the results are discussed.

2. Temperature and precipitation regions

The six Norwegian temperature regions (TR01-TR06) applied in the present analysis (Figure 1, left panel) were defined by Hanssen-Bauer et al. (1998) by using a combination of principal component analysis and cluster analysis of temperature series from Norwegian weather stations. The 13 Norwegian precipitation regions (RR01-RR13, Figure 1 right panel) were defined by Hanssen-Bauer and Førland (1998).

Figure 1. *Temperature (left) and precipitation regions (right) applied in the present analysis.*

3. Methods

3.1 Calculation of grid-based regional series

The gridded monthly datasets are established by spatial interpolation of monthly precipitation and temperature anomalies. Interpolation of anomalies is a robust approach, as the problems of biased station network and non-stationarity are reduced. Basically any spatial interpolation can be applied. For the development of gridded (2x2 km) maps of monthly mean temperature anomalies and monthly precipitation for Norway the TOPOGRID (Hutchinson 1989, 1993, Wahba 1990) algorithm implemented in the ArcINFO GIS software is applied. This is generally a discretized thin-plate spline method, having the effiency of local interpolators and at the same time it keeps the surface continuity of global interpolation methods.

The method ensures robust estimates, which also gives a smooth surface impression. The latter is important since the maps also are presented in the monthly climate bulletin of met.no, and therefore should give a "nice impression".

Monthly anomaly grids are established for the period 1900-present. The temperature anomalies are given in ^{o}C relative to the 1961-1990 average, while precipitation is given in percent of the 1961-1990 average. Examples of anomaly maps are given in Figure 2 for (left: temperature, right: precipitation). The regional values are obtained by using zonal functions implemented in the GIS-software. Absolute value maps for monthly temperature and precipitation can easily be obtained by combining the anomaly grids and the grids representing the mean monthly values 1961-90.

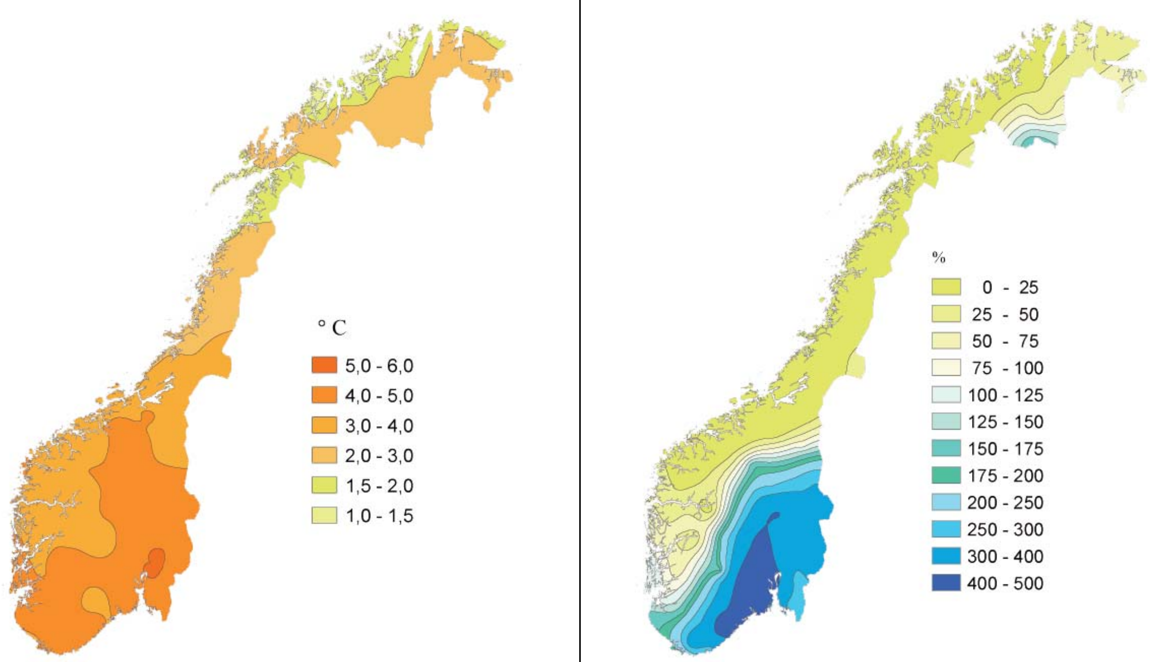

Figure 2 *Examples of gridded monthly anomaly maps*

a) *Temperature anomaly August 1997. The map shows the anomaly as the deviation from the mean 1961-1990 normal temperature.*

b) *Precipitation anomaly November 2000. The map shows the anomaly as the ratio (in %) the mean 1961-1990 normal temperature.*

In the present study, spatial averages were calculated for the regions given in Fig. 1. Series were calculated for all calendar months, and finally applied to calculate seasonal and annual values.

3.2 Calculation of regional series based on selected stations

For each temperature region in Fig. 1, a number (*nt*) of temperature series were used to calculate the regional standardised temperature series in the following way:

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

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

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

$T_{m,i}$ 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 their normal values is given in Table A1 in Appendix. In order to make these standardised regional temperature series comparable to the grid-based anomaly series, they have to be multiplied by annual or seasonal "effective regional standard deviations". These were calculated from the grid-based series, based upon the period 1961-1990 (Table 1).

Table 1.
Standard deviations (^oC) of the grid-based regional temperature series for the period 1961-1990.
The columns give results for the different temperature regions (Fig. 1, left panel).

	TR01	TR02	TR03	TR04	TR05	TR06
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

For the precipitation regions in Fig. 1, a number (*nr*) of precipitation series were used to calculate the regional standardised precipitation series (SR_m) in the following way:

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

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:

$SR_{mi} = 100\ R_{m,i}/\mu_{R\ m,i}$ (4),

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.

3.3 Methods for comparison of regional series

The comparison of the regional series is visualised by plots. Further, the correlation coefficients are given, and long-term trends are compared. The statistical significance of the trends is investigated by the Mann-Kendall non-parametric test (Sneyers 1995).

4. Temperature

4.1 Plots and correlation analyses

Correlation coefficients between regional temperature series calculated by the two methods described in sections 3.1 and 3.2 are presented in table 2. The correlation coefficients are in general very high.

The plots in Figures 2 to 4 visualise the excellent co-variation between series produced by the two methods on annual as well as on seasonal basis.

Table 2.
Correlation coefficients between grid-based and station-based regional temperature series.

	TR1	TR2	TR3	TR4	TR5	TR6
Annual	0.99	0.97	0.99	0.99	0.99	0.97
Winter	0.99	0.99	0.99	0.98	0.99	0.98
Spring	0.99	0.99	0.99	0.99	0.99	0.98
Summer	0.99	0.96	0.99	0.99	0.99	0.97
Autumn	0.98	0.98	0.99	0.98	0.99	0.97

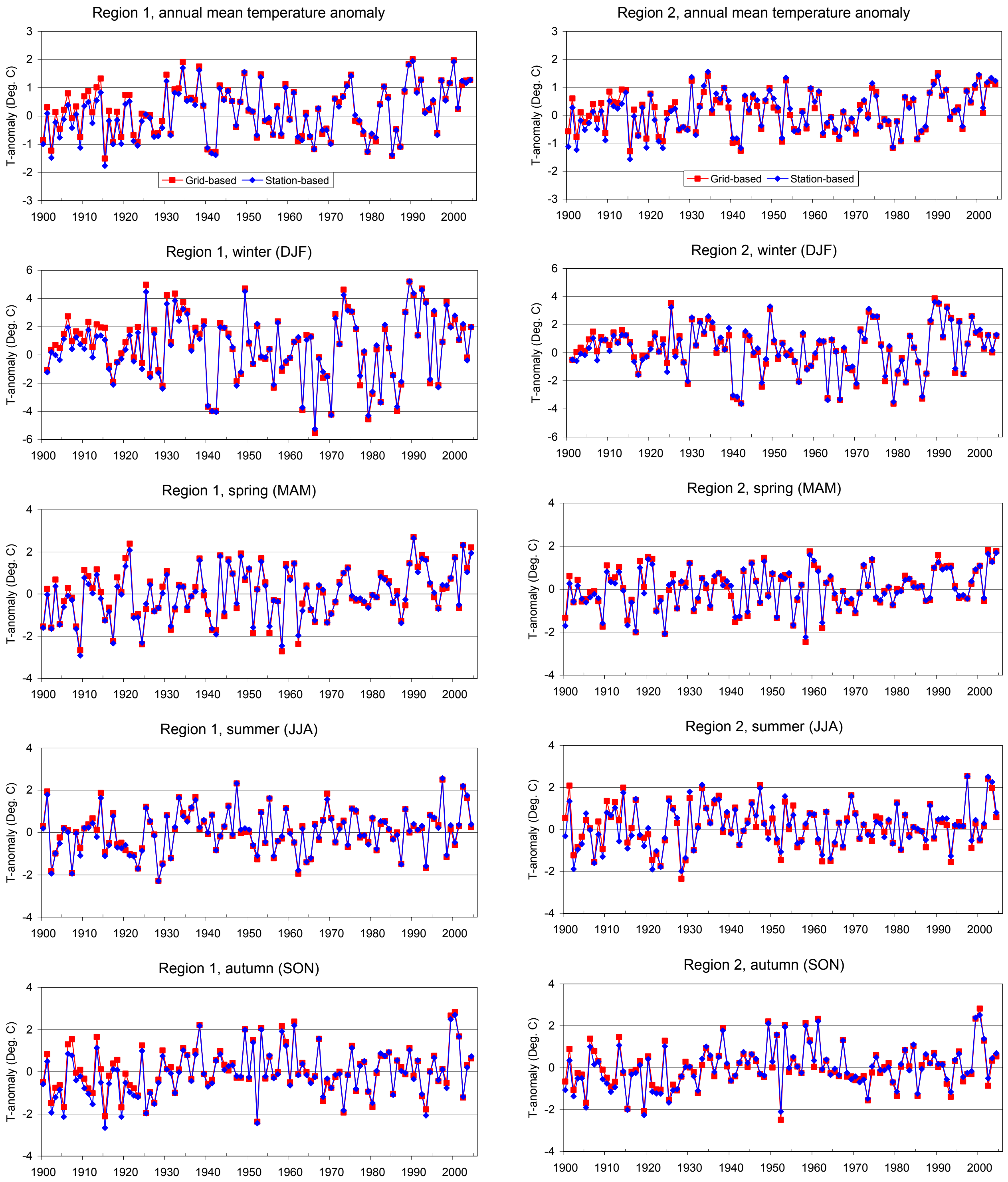

Figure 2. Grid-based (red) and station-based (blue) temperature anomaly series from regions 1 (left) and 2 (right). *The anomalies are given in ^{o}C relative to the 1961-1990 average. The upper panels show annual series, while the other panels show seasonal series.*

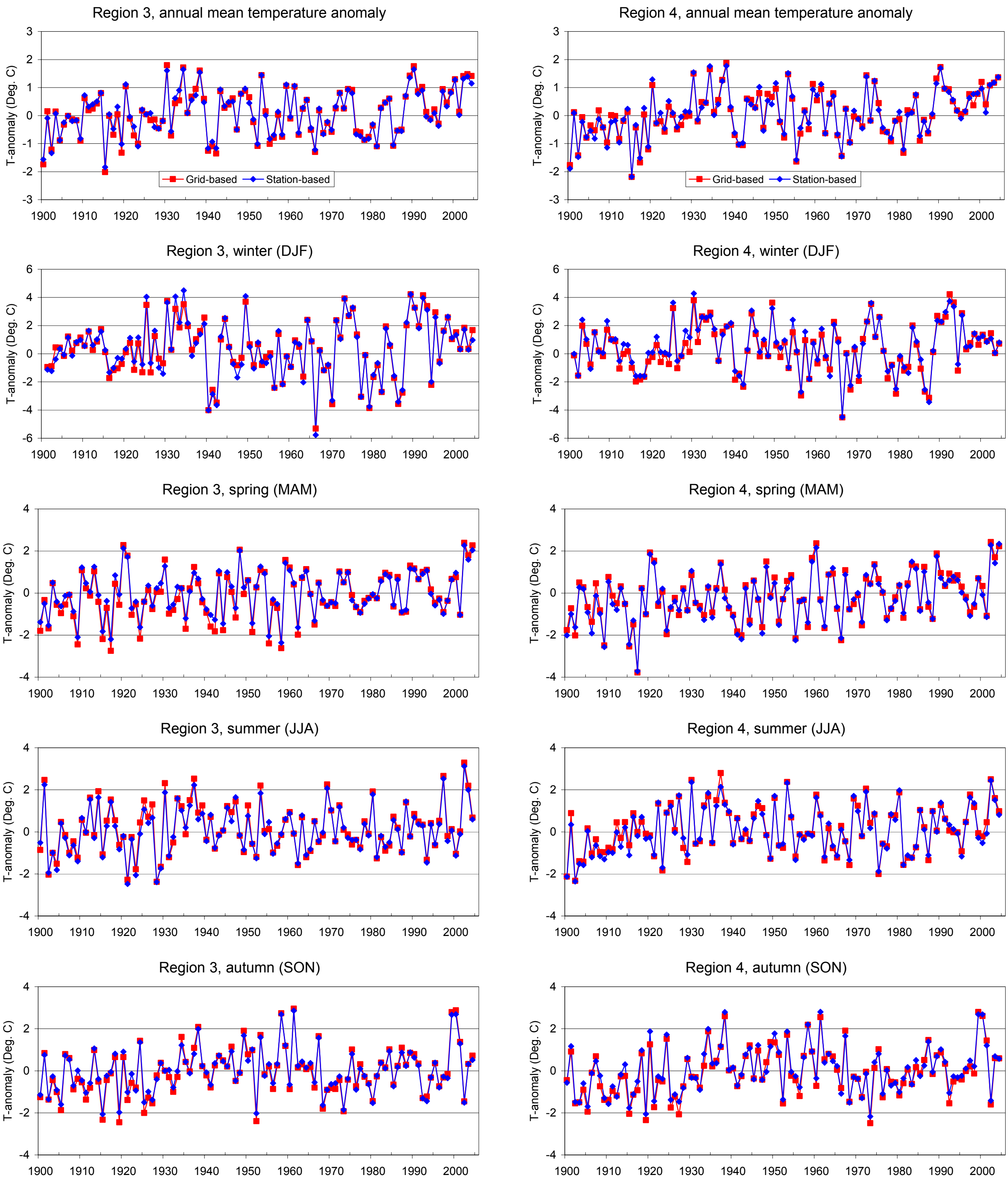

Figure 3. Grid-based (red) and station-based (blue) temperature anomaly series from regions 3 (left) and 4 (right). *The anomalies are given in ^{o}C relative to the 1961-1990 average. The upper panels show annual series, while the other panels show seasonal series.*

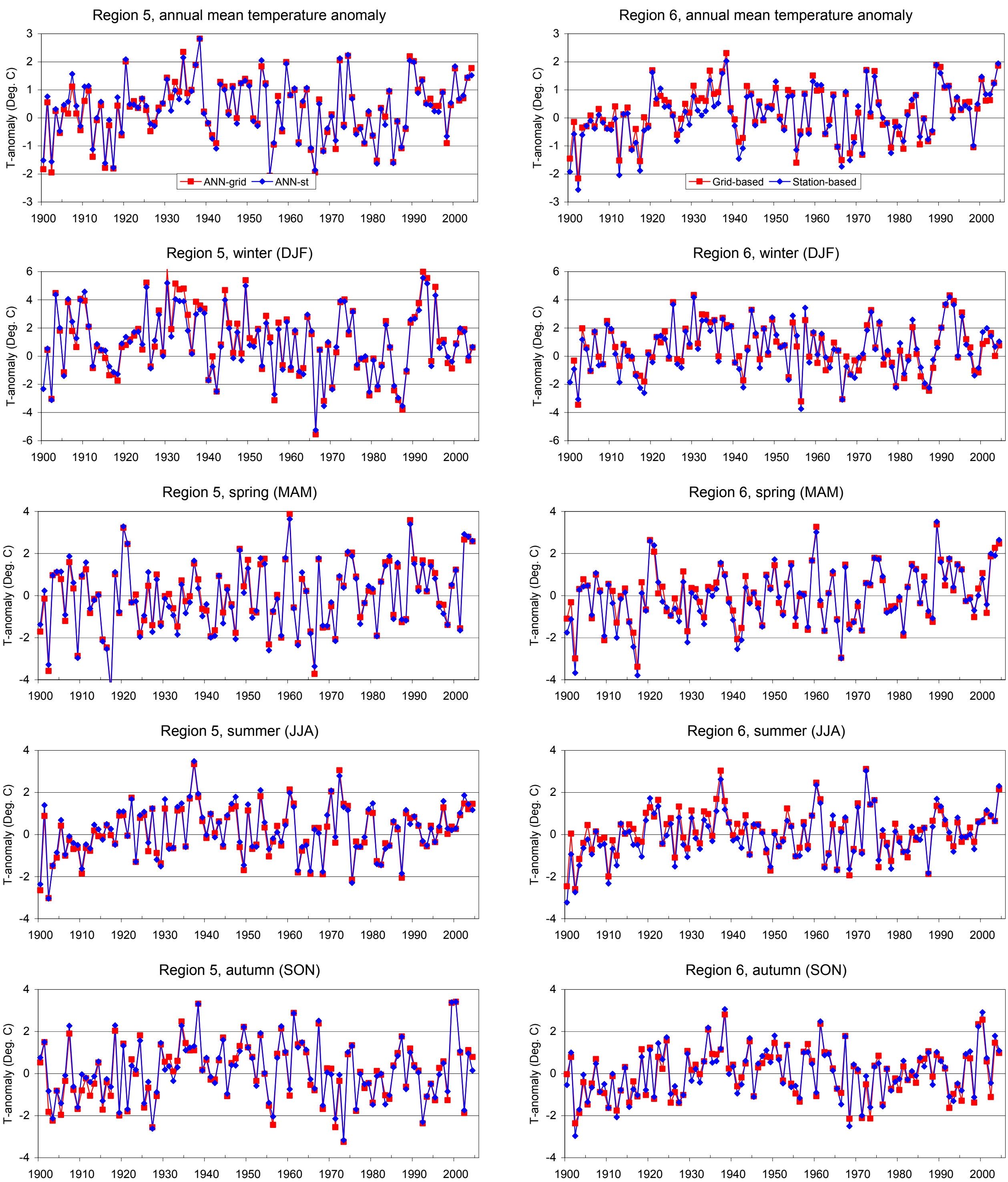

Figure 4. Grid-based (red) and station-based (blue) temperature anomaly series from regions 5 (left) and 6 (right). *The anomalies are given in ^{o}C relative to the 1961-1990 average. The upper panels show annual series, while the other panels show seasonal series.*

4.2 Trends

Though the correlation between regional temperature series calculated by the two different methods is high, there are some differences concerning long-term linear trends (Table 3). These differences are caused by errors in at least one of the estimates. Errors in the grid-based temperature series may be caused by inhomogeneities in individual series, or by variation in time of the representation of different parts of the region. Errors in the station-based series may also be caused by time variation of the data coverage within the region, though the standardisation of the individual series prior to the averaging reduces this problem somewhat. A general problem with the station-based series is, however, the poor spatial data coverage. One consequence of this is that the series may be representative for only parts of the region, while another is that the borders between different regions may be arbitrarily drawn. Another source for differences between the two methods, especially for small regions, is that the grid-based regional series will to some degree be affected by measurements from stations outside the region, while the station-based series are not.

Differences larger than 0.02 ^{o}C per decade for annual temperatures are found in regions 1, 2 and 6 (Table 3). Differences are found in all seasons, but they tend to be larger in winter. In regions 1 and 2, the difference is mainly due to inconsistence in the period 1900-1935 (Table 4). During this period, the number of stations included in the grid-based approach increased substantially. This may have led to a gradually better representation of areas with more "continental" climate. Thus, the trends in the first part of the series may be underestimated by the grid-method. One might reduce this problem by using standardised series. The problem would then be to estimate standard deviations for all stations over a common period (e.g. 1961-1990).

Poor data coverage in the station-based approach also contributes to the differences between the trends by the two methods. Note that only 3 stations represent region 6 (Appendix, A1). The main inconsistency between the grid-based and station-based series in this region is found in the period 1935-1970 (Table 4). It was investigated if this might be caused by inhomogeneity in the temperature series from Vardø, which is a key station in this region. However, though the series applied in the station-based approach has been adjusted, the long-term trend was hardly affected. The reason for the difference is most probably that while the station-based series is only representative for the coastal areas, the grid-based series represents a somewhat larger are.

Table 3. Trends in annual and seasonal temperature series during the period 1900-2004.
Linear trends in regional temperature series, given in ^{o}C per decade.
*Trends significant at least at the 10% level according to the Mann-Kendall test are written in red, and those significant at the 1% are given in **bold types**.*

	TR 1		TR 2		TR 3		TR 4		TR 5		TR 6	
	Grid	Station	Grid	Station	Grid	Station	Grid	Station	Grid	Station	Grid	Station
Annual	+0.05	**+0.09**	+0.04	**+0.07**	**+0.08**	+0.06	**+0.09**	**+0.09**	+0.04	+0.02	+0.06	**+0.09**
Winter	-0.02	+0.05	+0.01	+0.04	+0.05	+0.03	+0.05	+0.01	-0.09	-0.08	0.00	+0.06
Spring	**+0.11**	**+0.13**	+0.07	**+0.08**	**+0.11**	+0.07	**+0.13**	**+0.14**	+0.12	+0.11	+0.11	**+0.15**
Summer	+0.05	+0.07	+0.02	+0.05	+0.04	+0.05	+0.08	+0.09	+0.07	+0.06	+0.05	+0.10
Autumn	+0.05	+0.09	+0.06	+0.09	+0.08	+0.06	**+0.10**	**+0.09**	+0.04	+0.02	+0.06	+0.08

Table 4. Trends in annual temperature series during different sub-periods.
Linear trends in regional temperature series, given in ^{o}C per decade.

	TR 1		TR 2		TR 3		TR 4		TR 5		TR 6	
	Grid	Station	Grid	Station	Grid	Station	Grid	Station	Grid	Station	Grid	Station
1900-1935	+0.18	+0.25	+0.08	+0.21	+0.27	+0.29	+0.37	+0.45	+0.46	+0.30	+0.48	+0.45
1935-1970	-0.28	-0.26	-0.15	-0.17	-0.19	-0.17	-0.19	-0.16	-0.40	-0.35	-0.32	-0.23
1970-2004	+0.35	+0.35	+0.30	+0.33	+0.36	+0.32	+0.33	+0.32	+0.32	+0.31	+0.29	+0.29

In spite of some differences concerning long-term trends, the main features are clearly robust, in the sense that both methods agree: On an annual basis, both methods show a warming significant at least at the 10% level in all regions except for TR 5 (the northern inland region). Neither method show significant trends in winter temperature, but both show a significant warming during spring all over the country. The trends in summer and autumn temperatures are positive in all regions, though they are not statistically significant everywhere. The trends in summer-temperatures tend to be significant in northern regions.

5. Precipitation

5.1 Plots and correlation analyses

Correlation coefficients between regional precipitation series calculated by the two methods described in sections 3.1 and 3.2 are presented in table 5. The correlation coefficients are high (>0.9) except in region 13, which is a small region with no really long high quality precipitation series. The reason for the low correlation coefficient here is partly that the station-based series rely on only two series, and that the longest precipitation series in the region, Vardø, was adjusted for homogeneities before it was applied in this approach, while the unadjusted series is applied in the grid-based approach. It should be mentioned that the adjustment of this series is rather uncertain. The correlation coefficients in region 13 are better after 1950 except for the winter.

The plots in Figures 5 to 11 visualise the generally good co-variation between series produced by the two methods on annual as well as on seasonal basis.

Table 5.
Correlation coefficients between grid-based and station-based regional precipitation series.

	RR01	RR02	RR03	RR04	RR05	RR06	RR07	RR08	RR09	RR10	RR11	RR12	RR13
Annual	0.99	0.99	0.98	0.98	0.99	0.99	0.96	0.99	0.98	0.98	0.98	0.96	0.66
Winter	0.99	0.99	0.99	0.97	0.99	0.99	0.97	0.99	0.99	0.99	0.98	0.91	0.75
Spring	0.99	0.98	0.99	0.98	1.00	0.99	0.96	0.99	0.99	0.99	0.97	0.91	0.64
Summer	0.99	0.99	0.98	0.97	0.98	0.98	0.97	0.99	0.98	0.97	0.96	0.98	0.86
Autumn	0.99	0.99	0.99	0.98	0.99	0.99	0.96	0.99	0.99	0.99	0.98	0.95	0.68

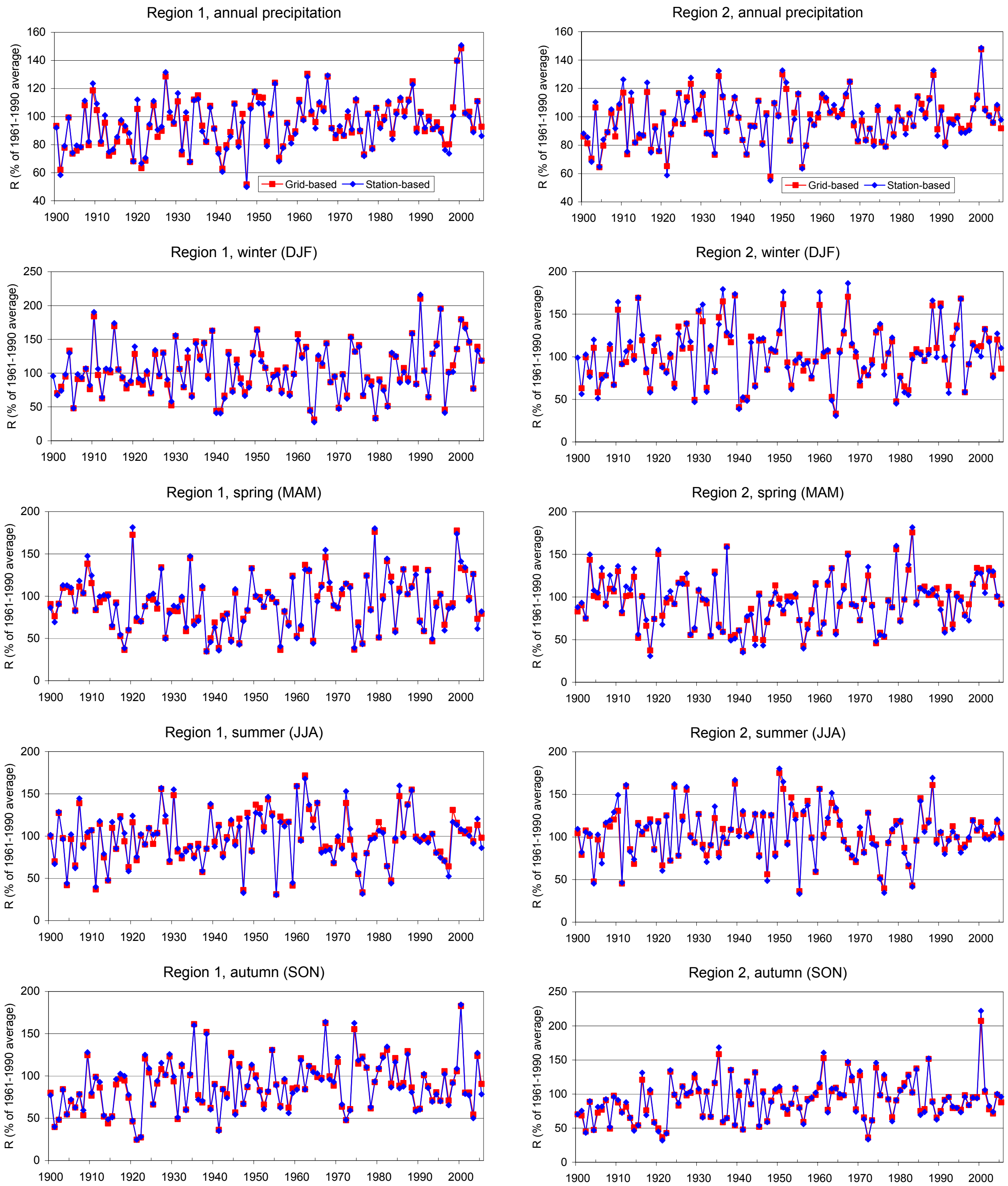

Figure 5. Grid-based (red) and station-based (blue) precipitation series from regions 1 (left) and 2 (right). *The anomalies are given in percent of the 1961-1990 average. The upper panels show annual series, while the other panels show seasonal series.*

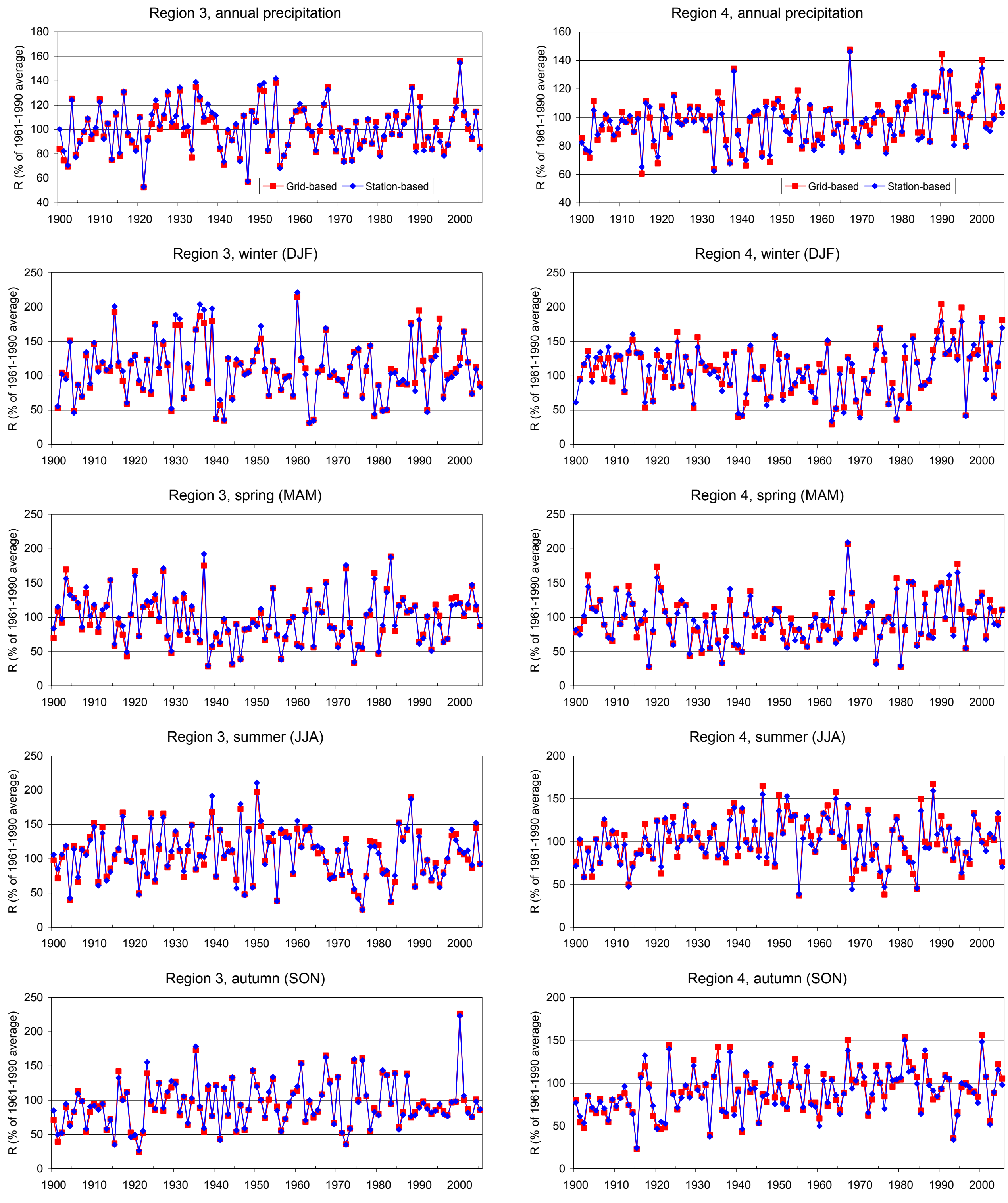

Figure 6. Grid-based (red) and station-based (blue) precipitation series from regions 3 (left) and 4 (right). *The anomalies are given in percent of the 1961-1990 average. The upper panels show annual series, while the other panels show seasonal series.*

Figure 7. Grid-based (red) and station-based (blue) precipitation series from regions 5 (left) and 6 (right). *The anomalies are given in percent of the 1961-1990 average. The upper panels show annual series, while the other panels show seasonal series.*

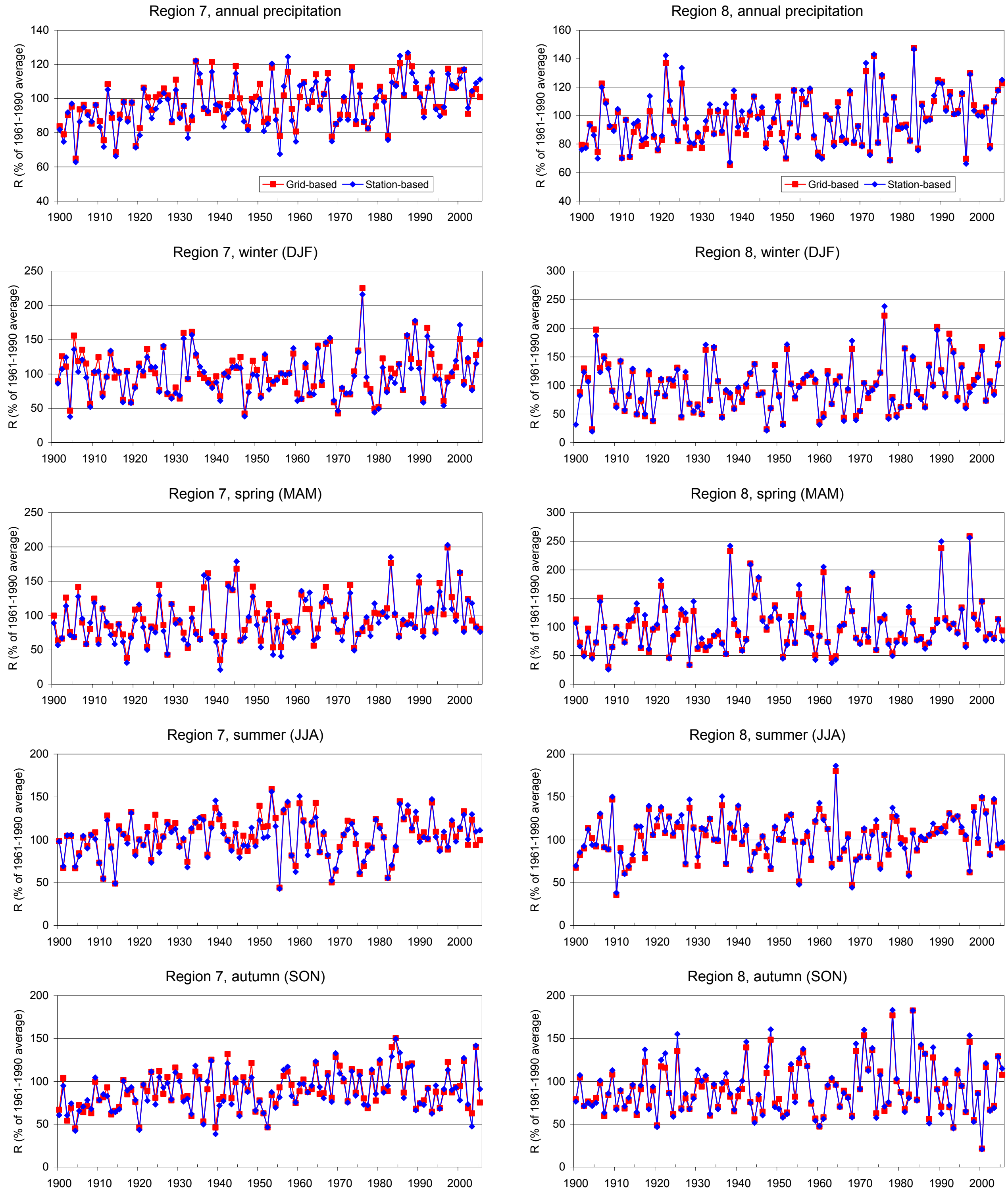

Figure 8. Grid-based (red) and station-based (blue) precipitation series from regions 7 (left) and 8 (right). *The anomalies are given in percent of the 1961-1990 average. The upper panels show annual series, while the other panels show seasonal series.*

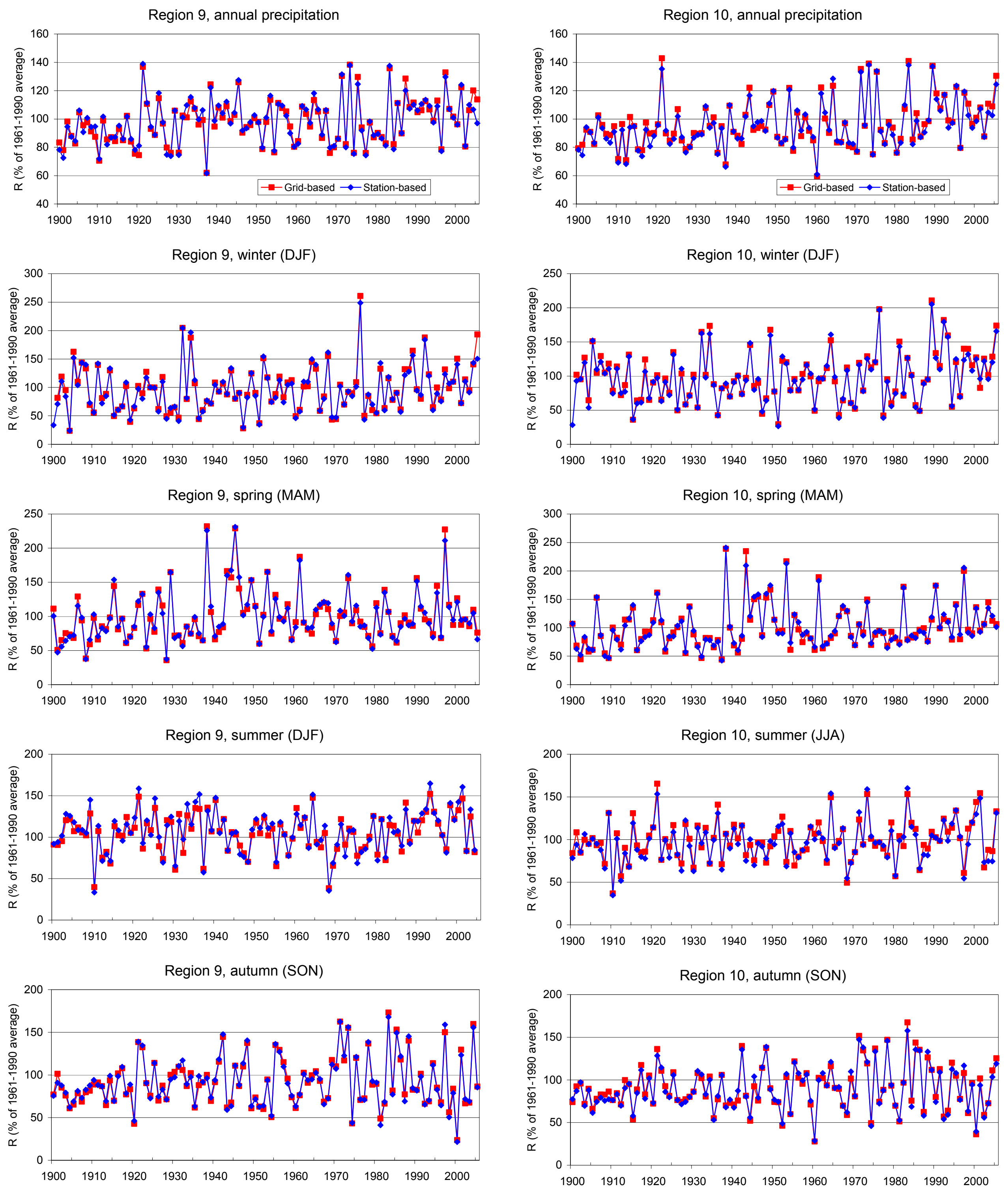

Figure 9. Grid-based (red) and station-based (blue) precipitation series from regions 9 (left) and 10 (right). *The anomalies are given in percent of the 1961-1990 average. The upper panels show annual series, while the other panels show seasonal series.*

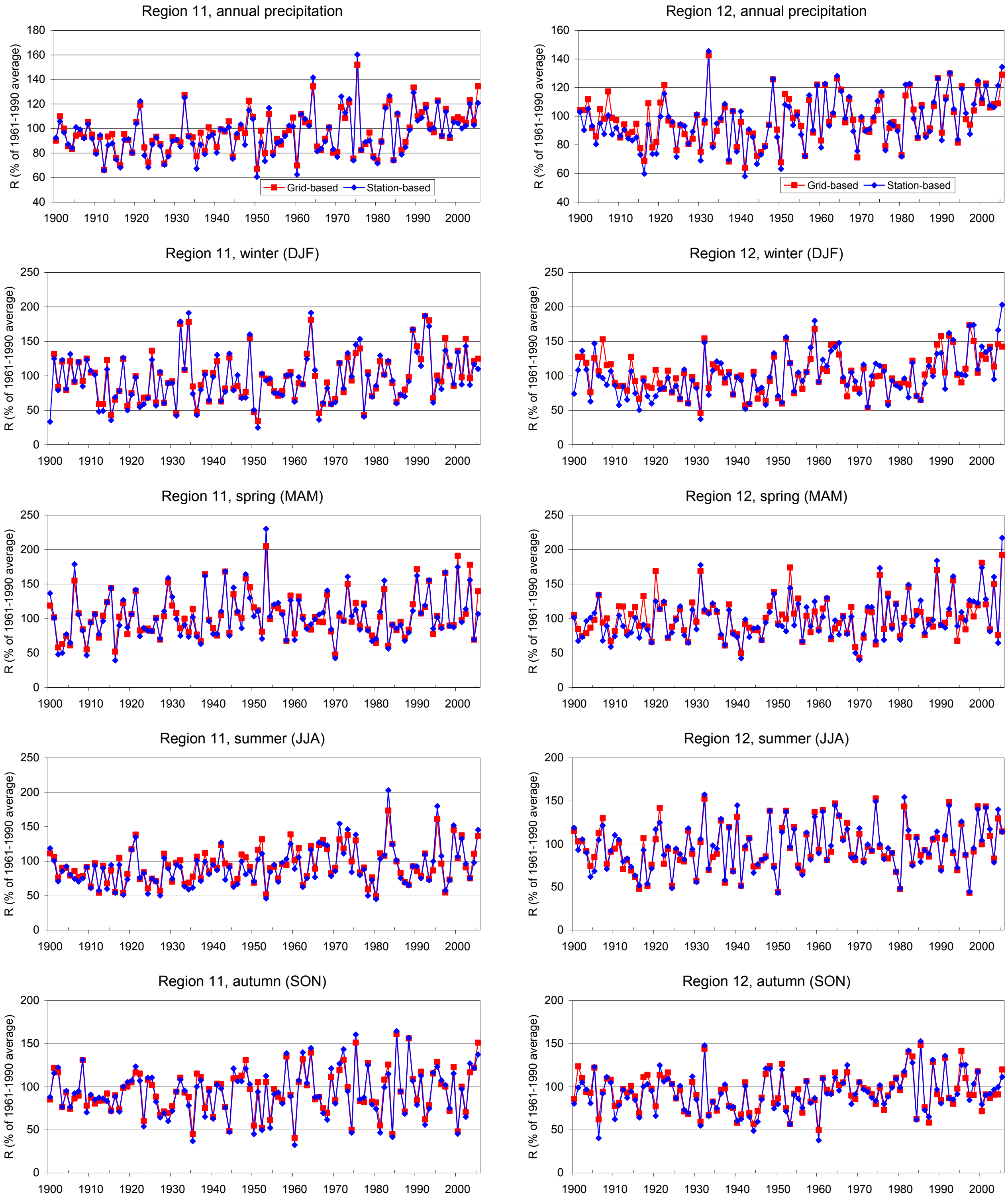

Figure 10. Grid-based (red) and station-based (blue) precipitation series from regions 11 (left) and 12 (right). *The anomalies are given in percent of the 1961-1990 average. The upper panels show annual series, while the other panels show seasonal series.*

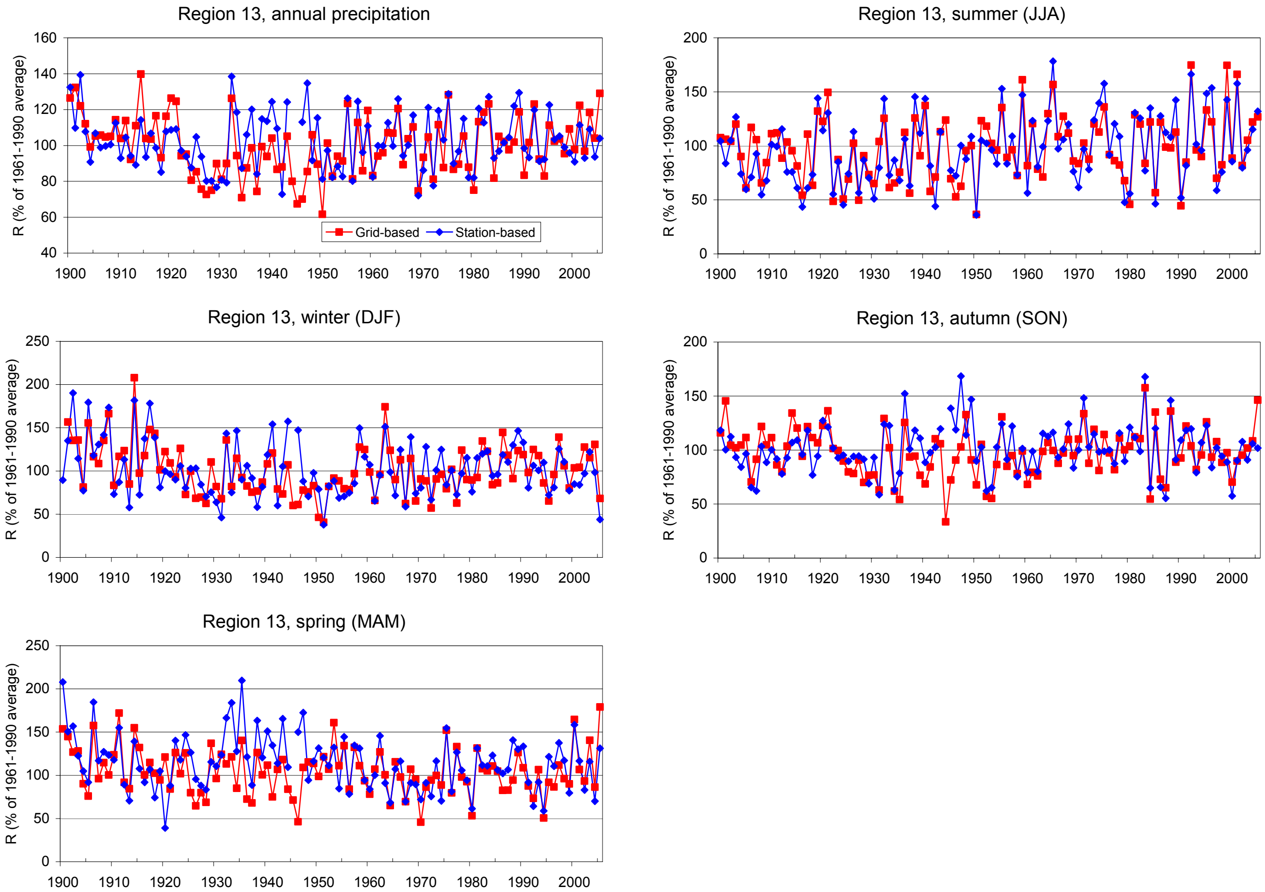

Figure 11. Grid-based (red) and station-based (blue) precipitation series from region 13. *The anomalies are given in percent of the 1961-1990 average. The upper panels show annual series, while the other panels show seasonal series.*

5.2 Trends

Table 5 shows that though the trends estimated by the two methods show some differences, there is in most cases agreement concerning which trends are significant at least at the 10% level. Both methods give statistically significant precipitation increase in 10 regions (RR01, 04, 05, 06, 07, 08, 09, 10, 11 and 12), and no significant change in two regions (RR03 and RR13). In RR02, the grid-method gives a significant trend, while the station-based method gives a slightly smaller positive trend, which is not statistically significant. This difference may partly be caused by the fact that the series applied in the latter approach were homogenised, and a majority of the inhomogeneous series were adjusted for increased catch efficiency, i.e. precipitation from the earlier years were multiplied by a factor larger than 1.0. This may also account for some of the discrepancy in region 1. The large differences in RR12 and, on seasonal basis, in RR13 are probably caused by poor spatial coverage in the station-based approach (see section 5.1), and the grid-based method are probably better.

Table 5. Trends in annual and seasonal precipitation series during the period 1900-2005. *Linear trends in regional temperature series, given in % of 1961-1990 value per decade. Trends significant at least at the 10% level according to the Mann-Kendall test are written in red, and those significant at the 1% are given in **bold types**.*

		RR01	RR02	RR03	RR04	RR05	RR06	RR07	RR08	RR09	RR10	RR011	RR12	RR13
An	Gr	**+1.8**	+1.2	+0.6	**+1.7**	**+1.8**	**+1.9**	**+1.6**	**+1.7**	**+1.5**	**+1.8**	**+1.9**	+1.5	-0.1
	St	+1.4	+0.9	+0.2	+1.4	**+1.8**	**+1.7**	**+1.9**	+1.4	+1.2	**+1.9**	**+1.9**	**+2.2**	+0.1
Wi	Gr	+2.1	+0.8	-0.1	+1.4	+1.8	+1.9	+0.9	+2.2	+2.3	+2.4	+2.5	+2.4	-1.4
	St	+1.6	+0.5	-0.9	+0.9	+2.1	+1.7	+1.2	+2.2	+2.3	+2.7	+2.5	**+4.0**	-1.7
Sp	Gr	+1.4	+1.2	-0.2	+1.1	+1.9	+2.4	**+2.4**	+2.2	+1.8	+2.4	+1.8	+1.6	-1.3
	St	+1.0	+0.5	-0.8	+0.8	+1.9	+2.2	**+2.9**	+1.6	+1.7	+2.4	+1.5	+3.0	-2.5
Su	Gr	+0.9	-0.1	-0.5	+0.5	+0.5	+0.9	+1.0	+1.0	+0.7	+1.4	+2.2	+1.5	+1.9
	St	+0.4	-0.3	-0.6	+0.6	+0.3	+0.9	+1.5	+0.8	+0.6	+1.5	**+2.8**	+1.7	**+3.1**
Au	Gr	**+2.7**	+2.6	+2.2	**+2.8**	**+2.4**	+2.0	**+2.1**	+1.2	+1.3	+1.1	+1.3	+0.7	0.0
	St	+2.3	+2.5	+1.8	**+2.5**	**+2.3**	+1.0	**+2.2**	+1.0	+1.0	+1.2	+1.1	+1.5	+0.5

In spite of differences between the results from the two methods, common features are found also concerning seasonal trends. Winter and spring precipitation tend to increase except in regions RR03 and 13, but significantly only in 2 to 5 regions, mainly in central and/or northern regions. Both methods show a significant negative trend in spring precipitation in RR13 (north-eastern Finnmark). In summer most regions tend to show positive trends, though the trends are significant only in 1-2 regions in northern Norway. Also in autumn there is a tendency to increased precipitation over most of the country according to both approaches. In most of the regions in southern Norway, the trends are significant at lest at the 10% level.

6. Conclusions

Regional series of annual and seasonal temperature and precipitation have been calculated by two different methods (one grid-based and one station-based) for six temperature regions and 13 precipitation regions in Norway. In general, the series calculated by the 2 methods are very well correlated, but there are some differences in the estimated trends over the period 1900-2004. These are caused by:

1) that the grid-based series are based on all available Norwegian data, while the station-based series are calculated from a few long-term key series;
2) that the grid-based series are calculated from original data, while the station-based is calculated from homogenised data;
3) the spatial station coverage varies during time (few stations during the earlier years);
4) the temperature and precipitation regions were defined from a sparse station network, and the borders between regions are probably not well defined everywhere.

For temperature, the following features are found by both methods: On an annual basis, both methods show a statistically significant (10% level) warming of between 0.04 and 0.10 ^{o}C per decade in all regions except for TR 5 (the northern inland region). Neither method show significant trends in winter temperature, but both show a significant warming during spring all over the country. The trends in summer and autumn temperatures are positive in all regions, though they are not statistically significant everywhere. The trends in summer-temperatures tend to be significant in northern regions.

The largest differences in estimated annual temperature trends were found in the southern regions TR01 and TR02, and the northern region TR06. In the southern regions, the grid-based method may underestimate the long-term trends because of variation in spatial station coverage during time. In the northern region, the station coverage in the station-based approach is probably only representative for parts of the region, and the grid-based method gives more representative results.

Both methods show a significant increase in annual precipitation in most regions, but not in the south-eastern region RR03 and the north-eastern RR13. Also most of the seasonal trends tend to be positive except in RR03 and RR13, but a majority of them are not statistically significant at the 10% level. Exceptions are that the increase in winter precipitation is significant in some of the northern regions, the spring precipitation has increased significantly in parts of central and northern Norway, and autumn precipitation has increased significantly in most southern regions. The methods agree that the only statistically significant negative trend is in spring precipitation in RR13.

The largest differences in annual precipitation trends were found in RR01 and 03 in south-eastern Norway and RR12 in northern Norway. On seasonal basis, the largest differences were found in regions 12 and 13. In all these regions, relatively few precipitation series were used in the station-based approach. Especially in northern Norway, limited data coverage and lack of high-quality series make the results uncertain. The grid-based results are probably best as they are based upon all available data. In southern Norway, the grid-based method may overestimate the trends somewhat because of inhomogeneous observational series are used.

7. References

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Table A1. Temperature series used to produce regional series.
The columns give: 1) temperature region no., 2) station no., 3-19) monthly, annual and seasonal temperature average (^oC) 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. Precipitation series used to produce regional series.
The columns give: 1) precipitation region no., 2) station no., 3-19) monthly, annual and seasonal average precipitation (in mm) 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	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
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

Table A2 cont. Precipitation series used to produce regional series.

R	ST.NO	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN	WIN	SPR	SUM	AUT
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
11	88100	76	71	51	44	35	47	76	81	87	112	85	82	846	229	130	204	284
11	89800	57	55	34	34	30	46	62	69	64	85	60	63	657	174	98	177	208
11	90450	95	87	72	64	48	59	77	82	102	131	108	106	1031	288	184	218	341
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