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THE KJØREMSGRENDI SERIES. A COMPOSITE SERIES OF SUMMER TEMPERATURES (1813 - 1997)

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ABSTRACT

Farmers' diaries containing barley harvest data exist from the village Kjøremsgrendi in the Dovre area (Northern Gudbrandsdalen, Southern Norway) for the period 1813 - 1874. From the same area a series of instrumental observations is also available since 1864, called the Kjøremsgrendi series which is tested and judged to be homogeneous. Linear regression analysis during the overlapping period (1865-1874) shows that the first harvest day and the mean summer temperature May - August are well correlated (r = 0.97). Linear regression analysis is used to reconstruct summer temperature before 1865 so as to form a composite time series of summer temperature from 1813 to 1996.

This series is compared to the Norwegian classical 19th century instrumental series from Trondheim, Bergen and Oslo and the Swedish series from Uppsala and Stockholm. This comparison reveals some biases of the difference between the instrumental Trondheim and Oslo series during the period 1813 to about 1860, in which the Trondheim series is bias too warm compared to the later period, i.e. from about 1860 to present. The Kjøremsgrendi composite series does not support the high summer temperature at Trondheim during this early period. It is therefore likely that the bias of the Trondheim series is caused by overheating of the thermometer due to bad exposure.

In order to test this proxy data method, harvest data from three other diaries (one of them from the same village) have been correlated to mean summer temperature data from near by instrumental observations. Also these diaries correlate reasonably well to the instrumental series showing correlation coefficients of 0.78 (Kjøremsgrendi), 0.89 (Herøy), 0.91 (Snåsa). The residuals of the regression analysis varied from 0.3 to 0.6°C (0.1 to 0.3°C on decadal scale) and the biases in the mean value for the whole proxy series seemed to be ±0.3°C or less.

Provided that the harvest data are homogeneous (unchanged grain field and type of barley), they are a very useful tool for checking and eventually adjusting early instrumental records. Moreover, farmers' diaries might be used to extrapolate instrumental observations to pre-instrumental time. This requires however that the diary originates from the same climatic region as an available series of instrumental observations and that there exists a sufficient overlapping period for the two data sets.

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1 Introduction

Instrumental observations are sparse in Norway before the Norwegian Meteorological Institute was founded in 1866. It is therefore of crucial importance that also proxy data are used in order to amplify our knowledge of climate variations and trends. One such data source is farmers' diaries from a village called Kjøremsgrendi (62° 6' N, 9° 4' E) which is situated in a valley at an elevation of about 600 m near the Dovre Mountains, Fig. 1.

The diaries contain direct weather descriptions in addition to weather related information. This information could have been classified in an index system (Pfister 1992; Kastellet 1996) i.e. to convert written weather information to a relative scale.

One serious problem connected to the index method is the lack of an absolute scale. However, an absolute scale can be establish by use of some biological «constants» like the ripening time for rye (Tarand & Kuiv 1994). In the present paper barley is used, because this is the only cereal that ripens quite regularly in the village Kjøremsgrendi.

2 Description of the available data from Kjøremsgrendi/Dombås.

The diaries originate from two farms, Systugu Synstbø (1813 - 1874) and Simenrud (1874 - 1917). In the original material the years before 1820 and the years 1826 and1852 are lost, but transcripts exist except for 1826. However, the first years contain only a few notes and during the latest period, say after 1910, the diary writing was in decay. The first and last year containing harvest data was 1813 and 1917 respectively.

The original diaries were in 1997 archived by:
1820 - 1859: Oppland Fylke's archive, Lillehammer.
1860 - 1874: Arnfinn Sønstebø, at the farm Systugu Synstbø, Kjøremsgrendi.
1874 - 1917: Guri Søremgård, Kjøremsgrendi.

The author's sources have been transcripts 1812-1874 and 1874-1903 owned by Ola Jo Botheim and Guri Søremgård respectively, and original diaries (1904-1917). Some of the harvest data taken from the transcripts have been compared to the original data, and no discrepancies were detected.

The two series of diaries are strongly related to each other as they are written by the same family. The same arrangement of the books has been used for more than 100 years. Between the pages of almanacs additional pages were inserted on which the notes were written. The diaries contain information of the people from the cradle to the grave, of prices and economy and last but not least, of the weather and the work on the farm. Of special interest to this author are the dates of the start and finish of the spring work, the haymaking and the harvest.

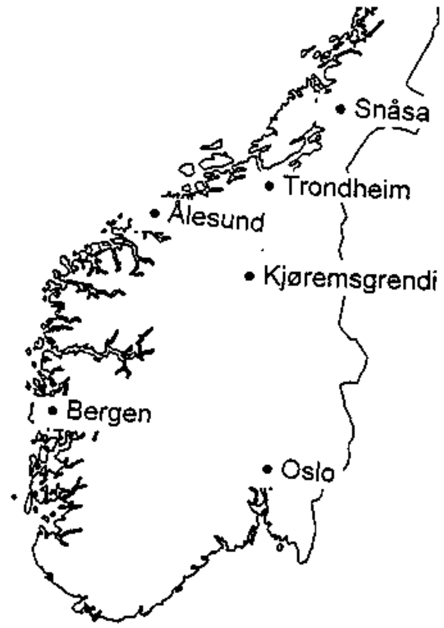

Fig.1 Map of Southern Norway

The oldest diary writer is Ola Jakobson Synstbø (Olle lachobssøn Sønstebøe) born in 1767. However, there are no doubt that his notes are rather few as he had an easily detectable handwriting (Høgåsen 1983). The great majorities of the notes are written by his oldest son, Jakob Olsson Synstbø (Jacob Olssøn Sønstebøe) born in 1788. His death in 1875 led to an end of the diary writing at the Systugu Synstbø farm.

Jakob's fifth son Torstein (Tosten) (1833 - 1922) moved from Synstbø to the farm Simenrud as he was married to Guri, a daughter of the owner of that farm. He brought with him the habit of writing diary to Simenrud. Some notes especially in the latest years, were however written by other members of the family.

The Systugu Synstbø farm. The name indicates that Synstbø is one of the oldest farms in Kjøremsgrendi, probably founded around 2000 BP (Kjelland 1996). It is situated in a rather steep south-facing valley side. The field, called Storåkeren (The large grain field), just beneath the farm houses is considered to be the oldest field for grain production. Storåkeren slopes 25% to the south and the elevation is 600 - 620 m a.s.l. Thus, the site is about 90 m higher than the valley floor. This site is probably optimal for grain production in the village. The southern slope gain excess of insolation compared to horizontal fields and its high elevation above the valley floor had prevented the farm from damages during many severe autumn frost events which hit less favourable fields, cf. the diaries. To the east and west the horizon is low and the farm has a favourable high number of potential sunshine hours.

The Simenrud farm. The farm originates from a field situated at an outskirt (Joramo) of Kjøremsgrendi. This field belonged to the Systugu Synstbø farm when Simen (1769 - 1839) settled down there in 1821 (Kjelland 1996) and established a farm named after him. Also Simenrud is situated at a south-facing valley side, but its main fields slope only about 10%. Simenrud is as Systugu Synstbø favourably situated concerning potential sunshine hours during the grain growing season. The farm houses is situated about 580 m a.s.l.

The Kjøremsgrendi series of instrumental observations. The series starts at the village Dombås in the summer of 1864 at the telegraph station where the measurements were taken until 1965. After two relocations within Dombås, the measuring site was moved about 5 km to the north-west at Kjøremsgrendi in 1977.

However, the elevation of the station and the height above the valley floor remained approximately unchanged. Parallel measurements at the two places indicate that the series is homogeneous (Nordli 1995a) during summer in spite of the relative large relocation. For simplicity the entire series is in this paper named the Kjøremsgrendi series.

3 The method used for calibration of proxy data

Simple regression analysis was used to establish relationships between 6 weather related events from the diaries and mean temperature during appropriate periods of the summer. The weather related events were: The start and finish of the spring work, the haymaking and the harvest. Best correlation was obtained between the harvest data and the mean temperature for the whole summer. Thus, the start of harvest was chosen as subject for further study.

The period 1865-1917 is the overlapping period of proxy data and instrumental observations. With some missing years subtracted, the material contains 49 years. As the proxy data originates from two farms, there is a risk of inhomogeneities in the harvest data due to different growing conditions. Therefore the two series of proxy data are separated in the regression analysis, Fig. 2. A test of significance, appendix II, shows that they are really different and it turns out that barley ripen earlier at Systugu Synstbø than at Simenrud with a possible exception of the warmest summers. This is also in agreement with the insolation conditions, see the descriptions of the farms. During the extraordinary warm summer 1997 parallel air temperature measurements were carried out at the grain fields of the two farms and the difference in favour of Synstbø was 0.12°C, see appendix III.

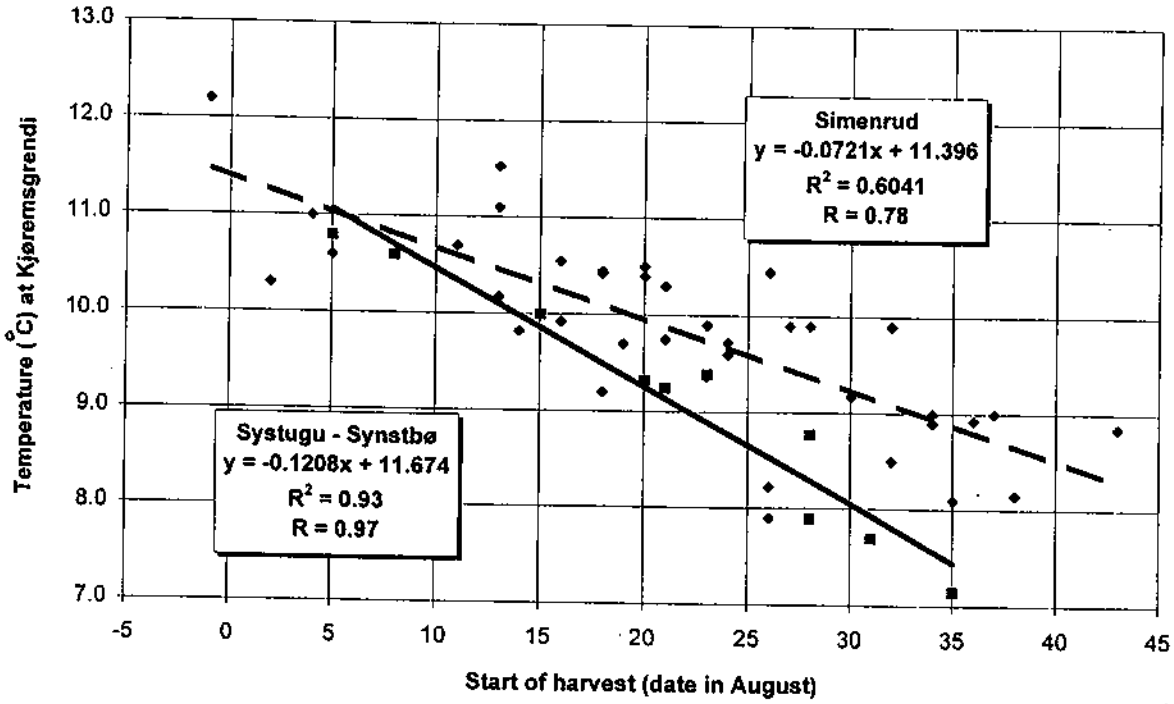

Fig. 2 The start of the harvest at the farms Systugu Synstbø (1865-1874) —— and Simenrud (1874-1917) ------- plotted against mean air temperature May - August from the Kjøremsgrendi instrumental series.

To make optimal use of the proxy data, the instrumental data for calibration should be chosen so as to obtain the highest possible correlation. However, as the entire Kjøremsgrendi series is available on monthly basis only, instrumental data were restricted to contain calendar months. It was readily seen that the end of the season should be 31 August. It was, however, more doubt about the optimal start of the season, whether 1 April or 1 May should be chosen. In Fig. 3 regression analyses are performed for both alternatives, showing correlation coefficients of 0.92 (April - August) and 0.97 (May - August). Thus, in this case the season May - August seems to be the optimal choice, that explains as much as 93% of the variance.

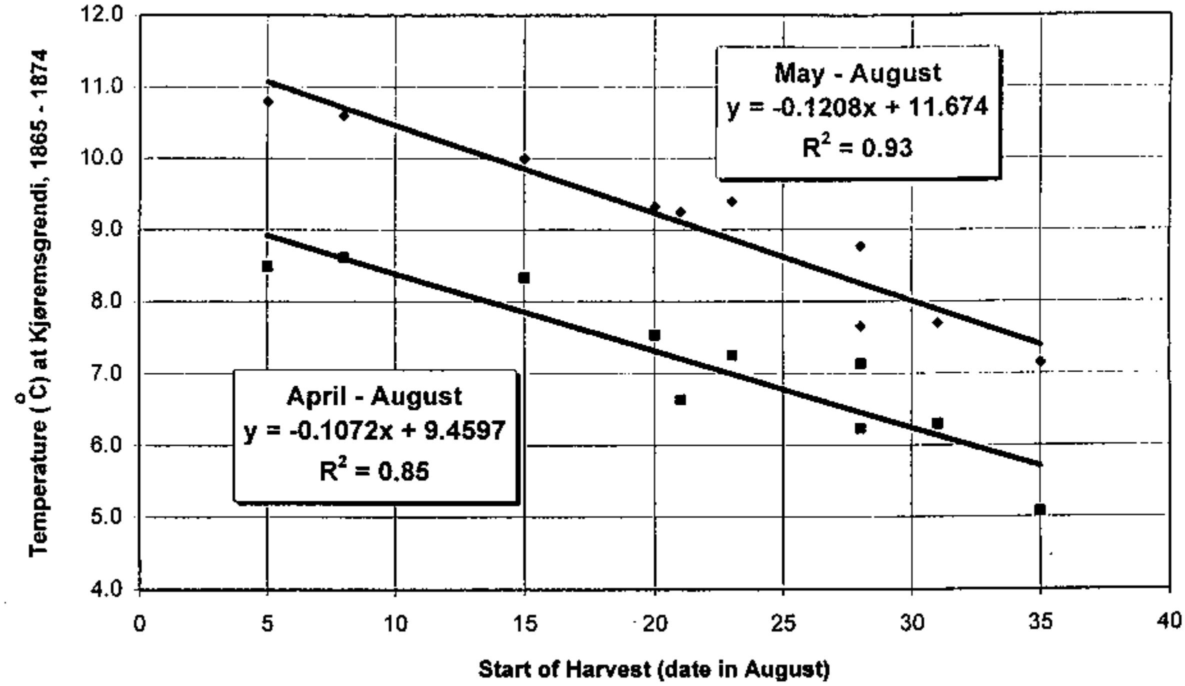

Fig. 3 Barley harvest at the farm Systugu Synstbø at Kjøremsgrendi plotted against mean air temperature May - August and April - August at Kjøremsgrendi in the period 1865 - 1874.

The obtained regression was used to reconstruct summer temperature May - August for the period 1813 - 1864 so as to form a composite series 1813 - 1997 together with the Kjøremsgrendi instrumental series. The missing year 1826 was interpolated by use of regression analysis with the Trondheim series as predictor. The same procedure was used for interpolation of the years 1836 and 1838, in which the grain was severely hit by frost in the autumn and no real harvest could be done. The composite series is shown in Fig. 6.

In order to test the method of proxy data, the entire composite series of Kjøremsgrendi was compared to the nearest instrumental series, see Fig. 8 in appendix I. However, normalising and filtering the instrumental series with a low pass filter revealed some very different temperature trends from 1813 to present. As the Oslo series has an increasing trend from the start to the 1930s, the Trondheim series has no such trend. In the Trondheim series the local maximum in the 1820s is even higher than the one in the 1930s. The other series reveal trends somewhat in between the Trondheim and Oslo series during this period. The Swedish series from Uppsala and Stockholm have maximum values in the 1850s, but the local maximum in the 1820s is appreciably lower than in the Trondheim series.

Despite the relatively short distance between Kjøremsgrendi and Trondheim (150 km) the high early 19th century temperatures are not found in the Kjøremsgrendi series, and it might be questioned whether this is a real difference in climate or an inhomogeneity in the Trondheim series. A possible climatic explanation could be different trends in the climates of Trondheim (situated near an open fjord) and Kjøremsgrendi (situated in an inland valley). To test this hypothesis the Kjøremsgrendi series was also compared to the Ålesund series (coastal climate), see appendix I for details. This is a composite series for the period 1843-1903 based upon instrumental observations at Ålesund and harvest data of barley and oat on the near by island Leinøya in Herøy municipality (Nordli 1997). Fig. 4 shows that the Ålesund series and the Kjøremsgrendi series are closely interrelated with approximately the same trends when adjusted for different variance. The different trends of the Trondheim and Kjøremsgrendi series can therefore not be interpreted as an coastal/ inland climate effect.

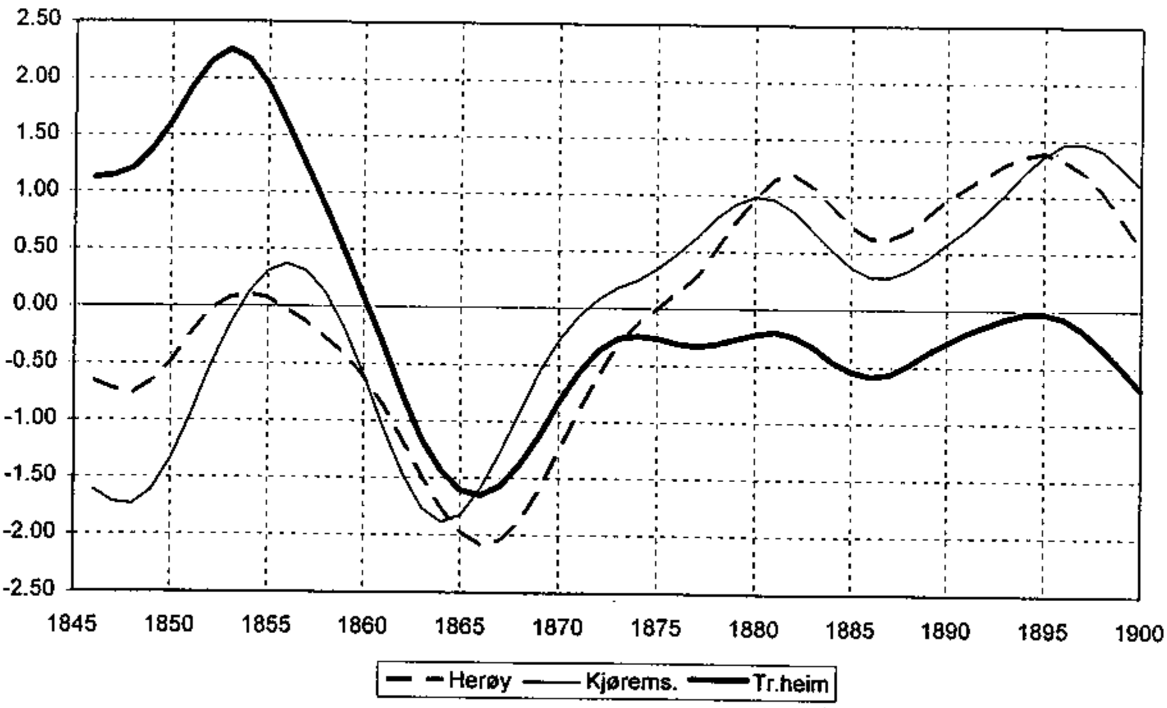

Fig. 4 The Kjøremsgrendi and Ålesund composite series of summer temperature (May - August) based on grain harvest data and instrumental observations. The values is filtered by a Gaussian filter with standard deviation 3 years in the distribution and normalised to zero mean and unit standard deviation. For comparison also the Trondheim series is shown.

The distance from Herøy/Ålesund to Trondheim is 250 km and the possibility of different spatial trends should not be excluded. Unfortunately this can not be checked directly on modern data, as the Ålesund series of instrumental observations is too short. However, in Fig. 5 a comparison between Ona (a lighthouse station to the northeast of Ålesund) and Trondheim is shown, during the period both stations were run by the Meteorological Institute, i.e. since 1870. The difference between the filtered values amounts to about 1 standard deviation during several time intervals, in the start of the comparison, in the 1920s and 1930s and also in the last part of the series. This is only one half of maximum difference between the Herøy and Trondheim series, see the 1850s in Fig. 4. Comparison of Figures 4 and 5 indicate a warm bias in the Trondheim series. The reason might have been an overheating of the thermometer, see discussion in appendix 1.

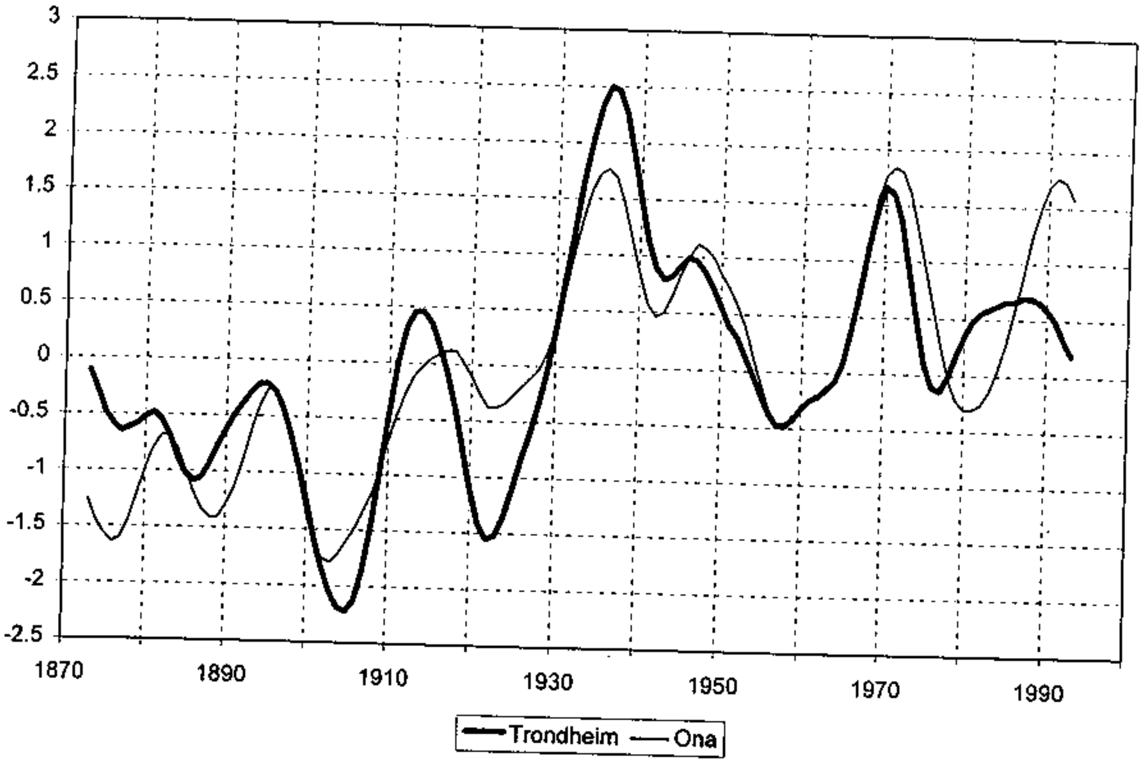

Fig. 5 The Trondheim and Ona series of summer temperature (May - August) based on instrumental observations. The filtering and normalisation are as in Fig. 4.

The overlapping period between the Systugu Synstbø series and the Kjøremsgrendi instrumental series is only 10 years, 1865-74. This might be too short for the regression coefficients to be determined with sufficient accuracy. To come closer to the problem the overlapping 39 years period of the Simenrud proxy series was divided into four groups containing 10 or 9 years and regression coefficients were determined within each period (see details in appendix I). Finally the four regression lines were applied to the data and the biases in the mean temperature in the periods 1813-74 and 1874-1917 were calculated. All biases were within the interval ± 0.3°C which is too small to explain the differences between the Trondheim and Kjøremsgrendi series. It can further be argued that proxy and instrument data were extremely well correlated during the overlapping period (1865-74) of Systugu Synstbø. The period is therefore not expected to contain any aberrant observations and biases in the mean value (1813-64) caused by inaccurately determined regression line, is likely to the less than ±0.3°C.

Possible inhomogeneities of the proxy data should also be examined. The diary itself ensure that the same grain field is used during the whole period, 1813-74. Another problem is connected to the barley itself, the question of different types. Barley has changed significantly with many new early-ripening varieties (Tarand & Kuiv 1994). This is probably not the case before 1874 as research on barley in Norway started around 1900 (Ringlund pers. comm.). And if the barley used before the overlapping period had been more early-ripening, the discrepancies with the Trondheim series should have been even larger. Moreover, on Herøy parallel series of barley and oat harvest data are available, and used as summer temperature proxies there is no significant difference between them (Nordli 1997).

Having analysed possible errors of the proxy data method, it seems likely that the different trends are caused by too high temperature in the Trondheim series in the period 1813 - 1869. During this period the Trondheim series is joined together of some private series, and very little is known of the quality and the exposure of the instruments (Birkeland 1949). Sources of errors in the Trondheim series might well be large enough to explain the discrepancies with the Kjøremsgrendi proxy data series, se discussion in appendix I.

The standard deviations of the residuals are for Kjøremsgrendi only 0.3°C and for Simenrud 0.6°C. These values are of the same order of magnitude as two series from Møre and Trøndelag, the earlier mentioned Herøy series and in addition a series from Snåsa, see Fig. 1 and -.

Table 1 The standard deviations of the residuals of proxy series of barley from four different farms.

District/village Farm	Kjøremsgrendi Systugu Synstbø	Kjøremsgrendi Simenrud	Herøy Frøystad	Snåsa Brunstad
No. of years	10	39	12	13
Standard dev.	0.3	0.6	0.4	0.5

Averaging over a decade the standard deviation of the residual (0.3 - 0.6°C) reduces to only 0.1 - 0.2°C.

4 Results

The composite series of Kjøremsgrendi is analysed by a low pass filter of Gaussian type. By choosing different standard deviations in the Gaussian distribution, climatic variations on different time scales may be studied. In Fig. 6 this is done by choosing standard deviations of 3 and 9 years corresponding to time scales of about 10 and 30 years.

Very low summer temperatures are revealed from the start of the series (1813) to about 1880 compared to those of the last 60 years and also compared to temperatures from the last part of the 19th century. Since 1930 the temperatures have been about one degree higher than during the period 1813 - 1880.

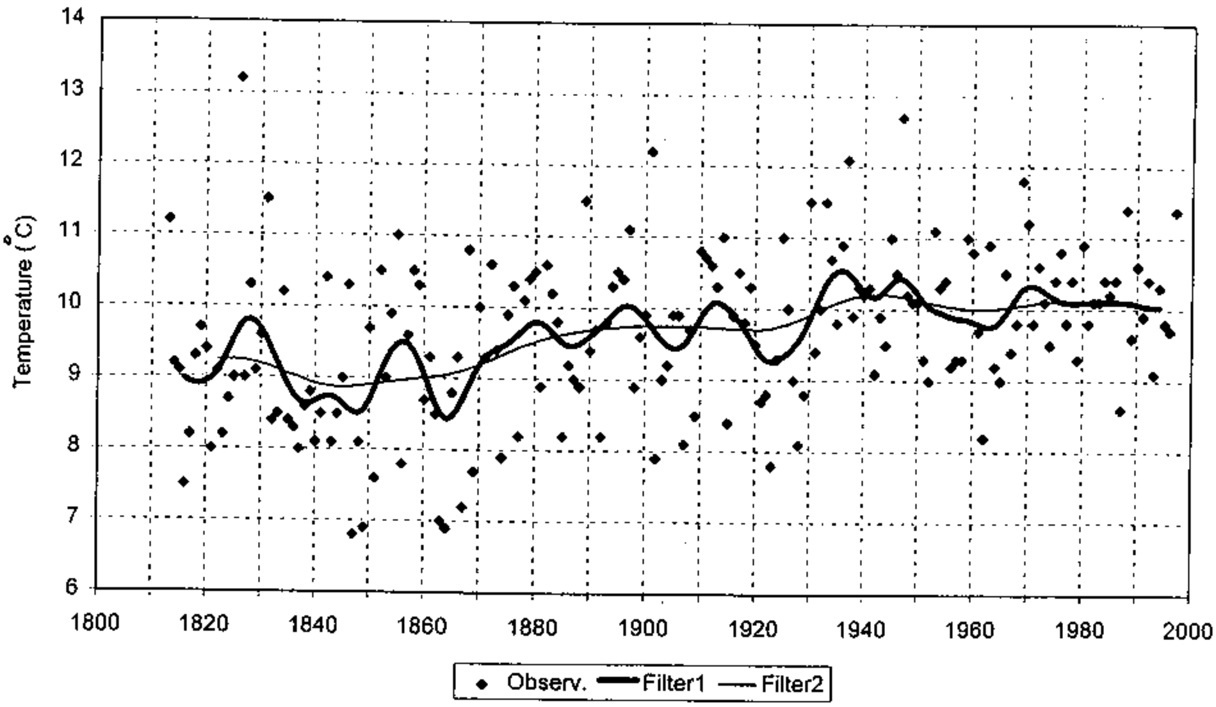

Fig. 6 The Kjøremsgrendi composite series of mean air summer temperature (1813 - 1997), actual values (dots) and long term variations (curves). Gaussian filters are used with standard deviations in the distributions of 3 (Filter 1) and 9 years (Filter 2).

The last part of the 1830s and the 1840s were especially cold periods. In particular the seven years 1835-1841 is still known as the seven bad years which led to starvation in the district (Høgåsen 1983). None of them was among the most extreme ones, but the period was not intersected by any summer temperature above the mean for the whole series (9.6°C) and in 1836 and 1838 the grain was totally damaged by early frosts. Also in the 1860s there is a cluster of bad harvests, especially some of the springs were extremely cold. However, in the 1850s there was a cluster of above normal years.

By analysis of time series of annual temperature in the period 1876 - 1990 by the Mann-Kendall test for trends and the Pettitt test for abrupt changes, Nordli (1995b) showed that temperature in Southern Norway had increased significantly until a breakpoint occurred in 1929 and the trend was followed by a steady state or decreasing trend. Similar results were obtained also for summer temperatures although trends before 1929 was not significant for all series, among these was Kjøremsgrendi. However, by using the entire composite series starting in 1813 the increasing trend up to 1929 is significant also during summer.

For a society dependent of grain production the variation of summer temperature must have had an enormous impact on the farmers' economy. In Table 2 the 10 warmest and 10 coldest summers are listed. The year 1826 turns out to be the warmest one, but the figure 13.2°C is probably not reliable as it is interpolated by the Trondheim series. The warmest well documented year is 1947, 0.5°C warmer than the next one on the list, 1901. The period before the start of the 1930s is represented on the top 10 list by the years 1826, 1831, 1889 and 1901. If it is accepted that an abrupt climatic change took place before the 1930s, the summer of 1901 was probably not less extreme than that of 1947 the prevailing climate of that time taken into account. People living before the climatic change had the opportunity to experience extremely warm summers also in the context of the present climate. The present generations, however, have had no experience of the extremely bad summers in the context of earlier climates. On the list of the 10 coldest summers no one but 1923 is represented from the present century. The coldest one is 1847, but the difference between the first four is so small that the ranking is not reliable.

Table 2 The 10 warmest and 10 coldest summers (May - August) at Kjøremsgrendi in the period 1813 - 1997. The summers 1813 - 1864 are reconstructed by barley harvest data. For individual years the standard error in the data is about ± 0.3°C. The year 1826 is interpolated by the Trondheim series.

Warmest summers		Coldest summers	
1826*	13.2	1847	6.8
1947	12.7	1849	6.9
1901	12.2	1864	6.9
1937	12.1	1863	7.0
1969	11.8	1867	7.2
1831	11.5	1816	7.5
1889	11.5	1851	7.6
1930	11.5	1869	7.7
1933	11.5	1856	7.8
1988	11.4	1923	7.8

The warmest and coldest periods of consecutive summers are listed in Table 3. It is readily seen that the 1930s is present in all of the warmest periods. The decade 1930-39 is still the warmest one in the entire series. The warmest possible 30 years period is 1930-59. Thus, the warmest 30 years period occurred only one year earlier than the official normal period 1931-60. With 10.3°C the old summer normal is third warmest among the 30 years periods of the series, while the present one, 1961-1990 with 10.1°C, is No. 32 of the 156 possibilities.

Table 3 The warmest and coldest summers during consecutive years of length 5, 10, 30, 50 and 100 years of the Kjøremsgrendi series, 1813 - 1997.

Length of periods (years)	Warmest periods		Coldest periods	
	Occurrence	Temp. (°C)	Occurrence	Temp. (°C)
5	1933/37	11.0	1847/51	7.8
10	1930/39	10.6	1860/69	8.4
30	1930/59	10.3	1835/64	8.8
50	1930/79	10.2	1816/65	9.0
100	1893/1992	10.0	1814/1913	9.3

In the 19th century the filter1 curve, Fig. 6, reveal two extremely cold periods, a distinct one in the 1860s and a somewhat longer period in the late 1830s continuing to the end of the 1840s. These periods are separated by a local maximum in the 1850s. The coldest 5 years period (1847-51) and the coldest 10 years period (1860-69) are located within each of these minima.

On the time scale of about 30 years (filter2 in Fig. 6) the minimum value is located in the middle of the 1840s with the lowest 30 years period in the years 1835-64. The period starts with the «7 years of starvation» (1835-41), continues with the bad years of the 1840s and ends in the first part of the cool 1860s. These 30 years are 1.5°C colder than the optimum 1930-59 and 1.3°C colder than the present normal.

5 Conclusions

A regression line was established with summer temperature (May - August) as predictand and the start of the barley harvest as predictor. The data originate from Northern Gudbrandsdalen in Southern Norway, the temperature data from the meteorological station Kjøremsgrendi and the harvest data from the near by farm Systugu Synstbø. The two data sets overlap in the period 1865-74 and the climate could be reconstructed back to 1813 by use of the regression. Together with the instrumental data a composite series were established for the period 1813 - 1997. The standard deviation of the residuals was 0.3°C which means that the standard deviation of the mean value of a decade is only 0.1°C.

The composite Kjøremsgrendi series was analysed for variations on time scales of 10 and 30 years by a Gaussian low pass filter and also by rectangular running mean filters of 5, 10, 30, 50 and 100 years. Trends were studied by Mann-Kendall test. A significant long term trend terminating before the 1930s was detected. Thus, the highest 5, 10, 30 and 50 years periods were all located after 1929, and the corresponding coldest periods were located before 1930. Before 1930 there was at least one extremely warm summer, 1901, and probably also 1826.

The Kjøremsgrendi series was compared to the nearest instrumental series, Trondheim about 150 km to the north. The results indicate that the Trondheim series was biased about 1°C too warm before the start of the official meteorological station in 1870. Also comparisons to other proxy and instrumental series indicate that the summer temperature of the Trondheim series is too warm in the period mentioned. However, compared to the Swedish series Uppsala and Stockholm only the period before 1830 seems to be too warm. Adjusting the Trondheim series at this stage seems to be premature because of the lack of a high quality proxy series to the north of the town. It is to hope, that such a series could be found.

On a farm, Simenrud also in the village of Kjøremsgrendi, there exist 39 years, 1874-1917, of overlapping proxy and instrumental data which were grouped into four subgroups. In each subgroup a regression line was calculated. By using the four regression lines, mean values of all the 39 years were calculated and the results compared to the result obtained by using all 39 years in establishing of the regression equation. This led to biases from -0.3°C to +0.3°C. In the decades where the largest biases were detected, there existed some aberrant observations. The overlapping period of proxy and instrumental data for the Kjøremsgrendi series was only 10 years, 1865-74. The regression explained 93% of the variance and in the overlapping period no aberrant observations were present. This indicates that a possible bias in the mean value was less than ±0.3°C.

Within the Kjøremsgrendi village the two south-facing grain fields had different sloping, 25% at Systugu Synstbø and only 10% at Simenrud. The ripening times for barley were different, and if there had not been any discrimination between the fields during the temperature reconstruction process, the resulting series would have been biased. Generally, this might be a pitfall in this proxy data method, but can in many cases be avoided by carefully reading of the farmer's notes. It is likely that if he writes when he harvests, he will also note which field he is harvesting. Different types of barley may also lead to biases in the reconstructed series. But this is probably restricted to the present century where intensive research on barley has been done in order to develop early ripening types.

Provided that the harvest data are homogeneous (unchanged grain field and type of barley), they are a very useful tool for checking and eventually adjusting early instrumental records. Moreover, farmers' diaries might be used to extrapolate instrumental observations to pre-instrumental time. This requires however that the diary originates from the same climatic region as an available series of instrumental observations and that there exists an overlapping period for the two data sets.

6 References

Birkeland, B.J. 1949. Old meteorological observations at Trondheim. Atmospheric Pressure and Temperature. *Geofysiske Publikasjoner* **XV**, 1-38.

Herøy sogelag 1978: *Ingebrigt Frøystad. En dagbok 1843 - 1875, 2nd edition.* 113 pp.

Høgåsen, S. 1983: Dagboksamling frå Lesja (1812) 1820 - 1859 (1874). *Årbok for Gudbrandsdalen 1983 (Yearbook for Gudbrandsdalen 1983)*, Dølaringen and Gudbrandsdal Historielag, Lillehammer, 14 - 43.

Kastellet, E. 1996: *Historiske klimadata som klide til rekonstruksjon av klima på Jæren i perioden 1821 - 1850.* Theses from the University in Bergen, 127 pp.

Kielland, A. 1996: *Bygdabok for Lesja 3.* Lesja kommune, N-2665 Lesja, 800 pp.

Middleton, W.E.K. 1966: *A history of the thermometer and its use in meteorology.* The John Hopkin Press, Baltimore, Maryland. 249 pp.

Nordli, P.Ø. 1995a: Adjustments of Temperature Time Series in winter Topo Climate. Results from Dombås Test Field. *DNMI-klima*, report No. 05/95, 20 p, Oslo.

Nordli, P.Ø. 1995b: Analysis of long Norwegian time series of temperature. In: Proc. of the international conference on climate dynamics and the global change perspective. Krakow, October 17-20 1995, 99-105.

Nordli, P.Ø. 1997: The Herøy series. A composite series of summer temperatures (1843- 1903). *DNMI-report*, No. 26/97Klima, 8 pp.

Pfister, C. 1992: Monthly temperature and precipitation in Central Europe 1525 - 1979: quantifying documentary evidence on weather and its effects. In *Climate since AD 1500.* red. by R.S. Bradly and P.D. Jones. Routledge, London 118-143.

Ringlund, K. 1997: Personal communication on scientific research on cereals in Norway. Agricultural University of Norway, Ås Norway.

Tarand A., Kuiv P. 1994: The beginning of the rye harvest - a proxy indicator of summer climate in the Baltic Area. *Paleoclimatic Research.* 13 (Special issue ESF project «European Palaeoclimate and man» 8 1994.), 61-72.

Appendix I. An evaluation of proxy data and instrumental observations

In the Kjøremsgrendi composite series proxy data is used during the period 1813 - 1864 during which there exist some instrumental series in Scandinavia. Among these the Trondheim series is the closest one to Kjøremsgrendi, the distance being 150 km. During the instrumental period (1865 - 1996) the correlation between the series is about 0.9. Both series are filtered and normalised to zero means Fig.7. As should be expected for well correlated series, local maxima and minima occur at almost the same years. However, before about 1870 the difference between the Trondheim and Kjøremsgrendi series is systematically higher than during the rest of the series. The two curves are crossing each other near the year 1865 when the source of the Kjøremsgrendi series changed from proxy data to instrumental observations.

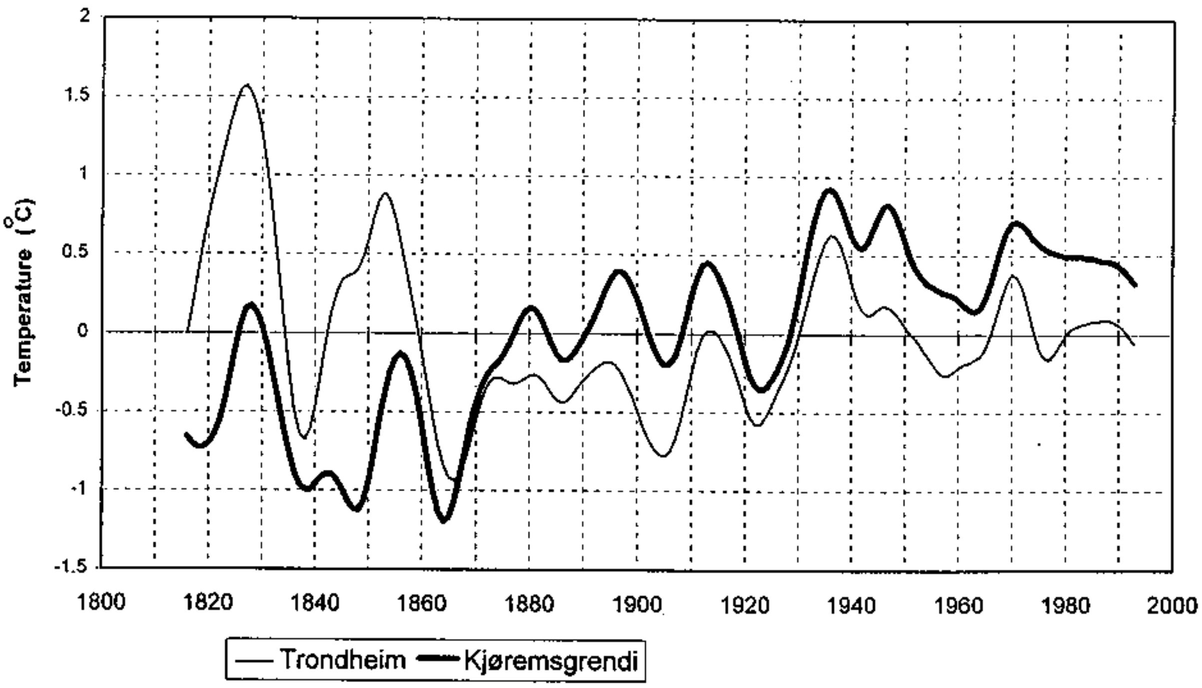

Fig. 7 The Kjøremsgrendi and Trondheim series of summer temperature (May - August) smoothed by a Gaussian filter with the standard deviation 3 years in the distribution and normalised to zero mean.

It is therefore possible that the discrepancy is caused by the proxy data method. However, other well known instrumental series also differ much in those years, Fig. 8. In the 1820s the Trondheim series is relatively warmer than all other series in Scandinavia and the Oslo series (250 km from Kjøremsgrendi) is even colder than the Kjøremsgrendi series. Since 1870 the difference between the Oslo and Trondheim series does not vary systematically. This indicates that the systematic change in 1870 is not caused by climate variation but by some biases in one or both of the Trondheim or Oslo/Kjøremsgrendi series.

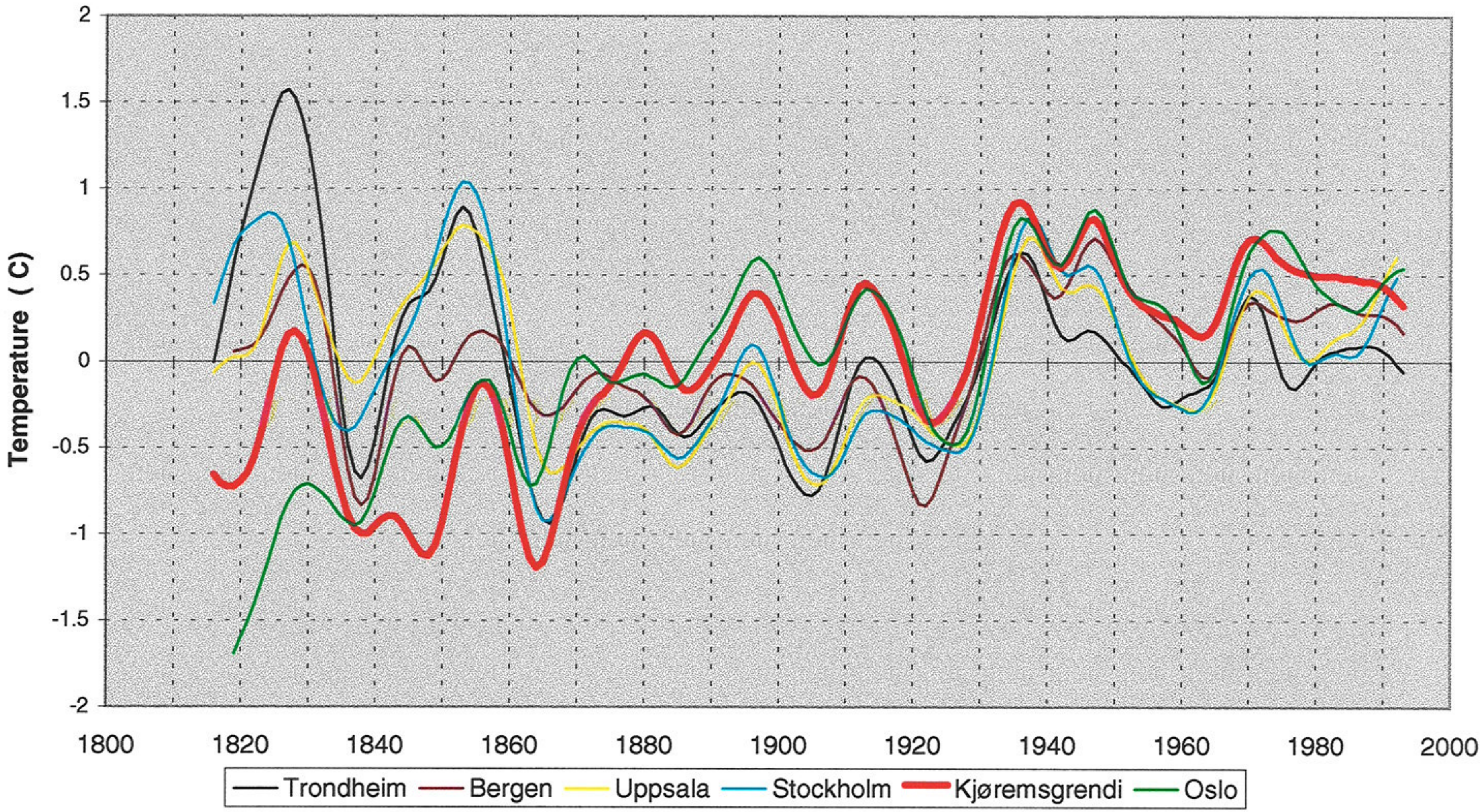

Fig.8 Summer temperature (May - August) for the longest series in Norway and Sweden, smoothed by a Gaussian filter and normalised to zero mean.

a) Trondheim instrumental series

The oldest Norwegian instrumental series is the classical Trondheim series, worked out and homogenised by Birkeland (1949). He made a composite series by joining many shorter instrumental series. The oldest of these started already in 1762 while it lasted more than 100 years before The Norwegian Meteorological Institute conducted its own observations in Trondheim (1870) with instrument maker Godager as the observer. In some periods there exist overlapping series while in other periods there are no observations at all. The gaps were filled by using Stockholm, Copenhagen and Edinburgh as reference stations for interpolations as well as for homogenisation of the series. According to Birkeland's calculations based on modern data, the standard deviation of the interpolated monthly mean values was about 1.1°C.

As our concern is the Kjøremsgrendi period of proxy data, the original series during this period (1813 - 1864) are as follows:
1813 - 1817 No observations, interpolation by Birkeland
1817 - 1834 War Commissioner Vibe's observations, 8^h (from 1827 also 22^h)
1835 - 1851 Pharmacist Møllerup's observations, 8^h, 14^h, 22^h.
1836 - 1884 Rosenvinge's observations 8^h, 14^h, 21^h (from 1843 8^h, 14^h, 22^h)

The greatest uncertainties of the series are expected to be the period 1813 - 1826 when the Trondheim series consists of either interpolated values or observations only once a day. Further more the measurements may have been hampered by bad exposure of the thermometers or by thermometers out of calibration. Often the thermometers showed too high values after some years of use caused by zero point attraction, i.e. shrinking of the thermometer glass (Middleton 1966). However, little is known of the accuracy of the thermometers and their exposure for the old part of the Trondheim series. Birkeland (1949) is aware of possible inaccuracies in some of the series. But, concerning Rosenvinge's observations, he states that they "convey a very reliable impression".

b) Kjøremsgrendi composite series.

Concerning the proxy data method, two possible features should be discussed which may cause biases in the series. These are:

1) The overlapping period of instrumental and proxy data is limited to only 10 years so that the regression line may not be well defined.

It is possible to come closer to this problem by using the data from Simenrud which contain the years 1874 - 1917, 39 years (there are some missing years). These were grouped into four subgroups comprising the years 1874-1885, 1886-1895, 1896-1906 and 1907-1917, the first three groups comprising 10 years of data and the last one 9 years. Regression lines for each group and for the entire dataset (1874 - 1917), was calculated, see table 4.

Table 4 Linear regression analysis for different periods with the start of harvest at Simenrud as predictor and summer temperature (May - Aug.) as predictand. Biases in mean temperature when regressions based upon different subsets of data are used for the whole period, are listed in the last column.

Period	y-value (°C)	r^2	r	Bias (°C)
1874 - 1885, 10 yr.	-0.0921x + 11.57	0.45	0.67	-0.3
1886 - 1895, 10 yr.	-0.0595x + 11.16	0.58	0.76	0.0
1896 - 1906, 10 yr.	-0.0800x + 11.83	0.75	0.87	0.3
1907 - 1917, 9yr.	-0.0841x + 11.51	0.81	0.90	-0.1
1874 - 1917, 39 yr.	-0.0721x + 11.40	0.60	0.78	

Each regression line was applied to the whole dataset and the biases in the mean values caused by each of the regressions were calculated. The bias, Δ, was defined as:

$$\Delta = \frac{1}{N}\sum_{i=1}^{N}(T_i^* - T_i) = \frac{1}{N}\sum_{i=1}^{N}(a^* P_i + b^* - aP_i - b) \quad \text{where:}$$

* denotes values for the sub groups.
T_i = the mean May - August temperature in year i obtained by the regression.
P_i = the first day of harvest in year i
a = the regression coefficient and b its constant term
N = number of years, for Simenrud 39 and for Systugu Synstbø 59 (there are missing proxy data).

The four regression lines of the subgroups had quite different fit to the observations. In the first period (1874-1885) under the half of the variance was explained, compared to over 80% in the last period (1907-1917). And when the regression line 1874-1885, was applied to the entire data set of 39 years, the mean value was biased by -0.3°C, based upon the period 1896-1906 it was bias 0.3°C, and based upon the two remaining periods the mean values were not biased at all or very little. Finally the regressions were applied to the independent data set of Systugu Synstbø (1813-1874) and just the same biases were found as in table 4 for Simenrud (shown in the last colomn).

The poor correlation between instrumental observation and harvest data at Simenrud in the period 1874-1885 is mostly due to the two cold summers 1874 and 1885, when the harvests despite of the cold weather, started relatively early (26 August). This lead to a too steep regression line and consequently negative bias in the mean value as already mentioned. However, the start of harvest data at Systugu Synstbø correlates very well with instrumental observations (r=0.97). This indicates that in the overlapping period there are no aberrant observations, and it is not likely that uncertainties in the regression line of Systugu Synstbø based on the years 1865-74 leads to so large biases as ±0.3°C. The bias between the Trondheim and the Systugu Synstbø series is about 1°C in the period 1813 - 1864 and it is very unlikely that such a large difference is due to insufficient overlapping period.

2) During history research has been done on the cereals, a.e. barley has changed significantly with many new early-ripening varieties (Tarand & Kuiv 1994).

In Norway systematic research aiming to improve the cereals started around 1900 (Ringlund pers. comm.). This means that the regression based on data from Systugu Synstbø in the years 1865-1874 is not influenced by research. The regressions 1896-1906 and 1907-1917 might have been influenced, but the results in table 4 do not indicate any systematic change. In the diaries it is noted that grain was bought after harvest failure. This might have had other ripening abilities than the grain that had been on the farm for a longer period. In a mountain village like Kjøremsgrendi with frequent frost damages, natural selection should favour early ripening grain so that the newly bought grain from lowland areas probably not ripened earlier than the traditional one. It could well be that the farmer was aware of this so that he if possible used his traditional grain even though he had the opportunity to use seed from outside the village.

c *The Ålesund composite series*

At Herøy (62°20'N, 5°40'E), an island municipality in the Sunnmøre county, there exists a farmer's diary for the period 1842 - 1875 from the farm Frøystad. The book is easily available as it is printed by Herøy sogelag (1978). During the period 1861 - 1875 it overlaps the instrumental observations from the nearby city Ålesund and by use of simple regression analysis summer temperatures (May - August) of the Ålesund series is extended back to the start in 1843 (Nordli, 1997). Thus, parts of the Kjøremsgrendi composite series and the Trondheim instrumental series may be checked by a coastal series from about the same latitude as Kjøremsgrendi. Filtered values of the three series are shown in Fig 4.

From Fig. 4 it is readily seen than the Ålesund proxy series is well correlated with the Kjøremsgrendi series. These series are significantly colder than the classical Trondheim series up to about 1860.

Appendix II Test of significance

At the farms Systugu Synstbø (1813 - 1874) and Simenrud (1874 - 1917), the mean day for the start of harvest is exactly the same, 22 August. This does not prove that the ripening conditions at the two farms are exactly the same as the periods of observation are different. When dealing with the ripening conditions, it should be taken into account that the climate might have changed during these 105 years. This is examined by using the relationship between the first date of harvest and summer mean temperature.

Thus, the summer temperature at Simenrud, T_{si}, is established by linear regression based on harvest data in the years 1874 - 1917, i.e. 39 years (four years are missing), Fig. 2. The equation is:

$$T_{si} = -0.0721P_{si} + 11.396,$$

where P_{si} is the date of harvest at Simenrud. This regression is also applied at the Systugu Synstbø data for the overlapping period with instrumental observations, 1865-1874. The standard deviation of the residuals was 0.6°C during the 39 years at Simenrud and 0.5°C during the 10 years overlapping period of instrumental observations at Systugu Synstbø. The difference of the mean values of the residuals was 0.8°C which is significant according to Student's T-test which gave critical values of 0.4°C and 0.6°C at significance levels 0.05 and 0.01 respectively.

Conclusion: There are statistical evidence for concluding that the growing condition at Simenrud is different from that at Systugu Synstbø and the harvest data from the two farms should be treated as separate series.

Appendix III Parallel measurements Systugu Synstbø and Simenrud during the summer of 1997

Initiated by the work with the diaries of Systugu Synstbø and Simenrud, automatic measurements of temperature were performed at the two farms every hour during the grain growing season 1997. The temperature sensors were both of the Aanderaa type 2812, set inside standard Aanderaa radiation screens. At Systugu Synstbø the measuring site, 610 m a.s.l., was in the Storåkeren field that slopes 25 % to the south, while at Simenrud the measuring site, 580 m a.s.l., was just to the south-west of the farmhouses in a south-facing 10 % slope.

By comparison of these series to the official series from Kjøremsgrendi meteorological station, which is situated 626 m a.s.l and only 1 km from Systugu Synstbø, it was readily detected that the automatic measurements led to unreliable monthly mean temperature. Further analysis of the data and discussion with the manufacturer revealed that this combination of radiation screen and sensor led to an overheating of the sensor under sunny weather conditions. However, as the equipment at Systugu Synstbø and Simenrud were identical, the overheating of the sensors most probably had not impeded the temperature difference between them. They were thoroughly calibrated at DNMI and as an extra precaution the equipment at one farm was moved to the other one and vice versa in the middle of each month. Thus, calibration errors if any, were expected to vanish when calculating the monthly mean difference between the sites, table 5.

Table 5 Monthly mean temperature difference (°C), Simenrud minus Systugu Synstbø during the grain growing season 1997.

May	June	July	August	May - August
-0.20	0.09	-0.10	-0.26	-0.12

The grain-growing season 1997 was the 11 warmest since the beginning of the composite series in 1813 in spite of an unusually cold May and a quite normal June. The warm weather in July and especially August was extraordinary with August as the warmest ever recorded. Frequent afternoon showers in July lowered the temperature already after 12^h compared to the other months, especially illustrative is the comparison with August in which the maximum temperature occurred at 16^h, Fig. 9. Except from May and August the monthly mean differences between the stations were smaller than expected sensor errors, table 5.

The temperature difference between the two stations varies during the day as shown in Fig. 10. It has an mean diurnal range during the grain-growing season of about 1°C. The temperature difference might be understood as a consequence of local differences in elevation, tilting of the slopes and heights above the valley floor. Simenrud is warmer than Synstbø in the morning after sunrise and before sunset. This is caused by lower elevation of the grain field at Simenrud compared to Storåkeren at Systugu Synstbø. Under dry adiabatic lapse rate this difference amounts to 0.3 °C in favour of Simenrud. At midday the effect of different elevation is more than compensated by the larger insolation at Systugu Synstbø due to the steep south-facing slope of Storåkeren.

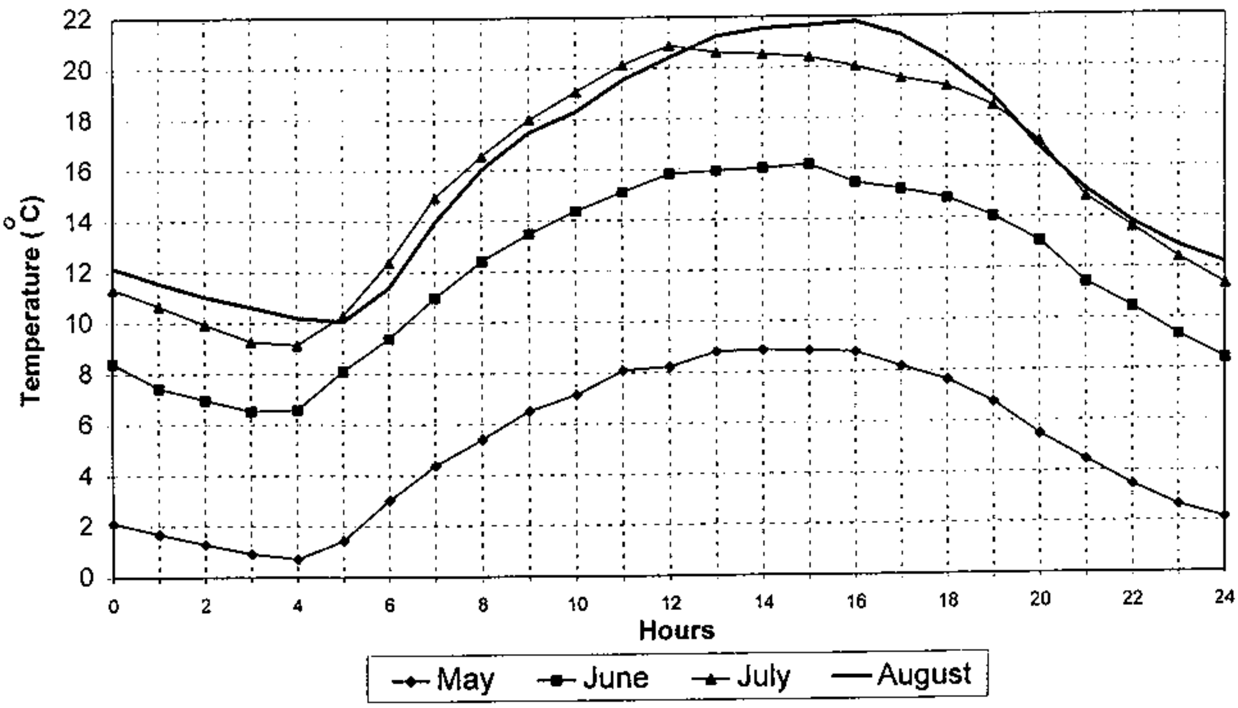

Fig. 9 The diurnal temperature range at Systugu Synstbø during the summer (May - August) 1997 (The temperature during daytime is probably too high due to badly screened sensor).

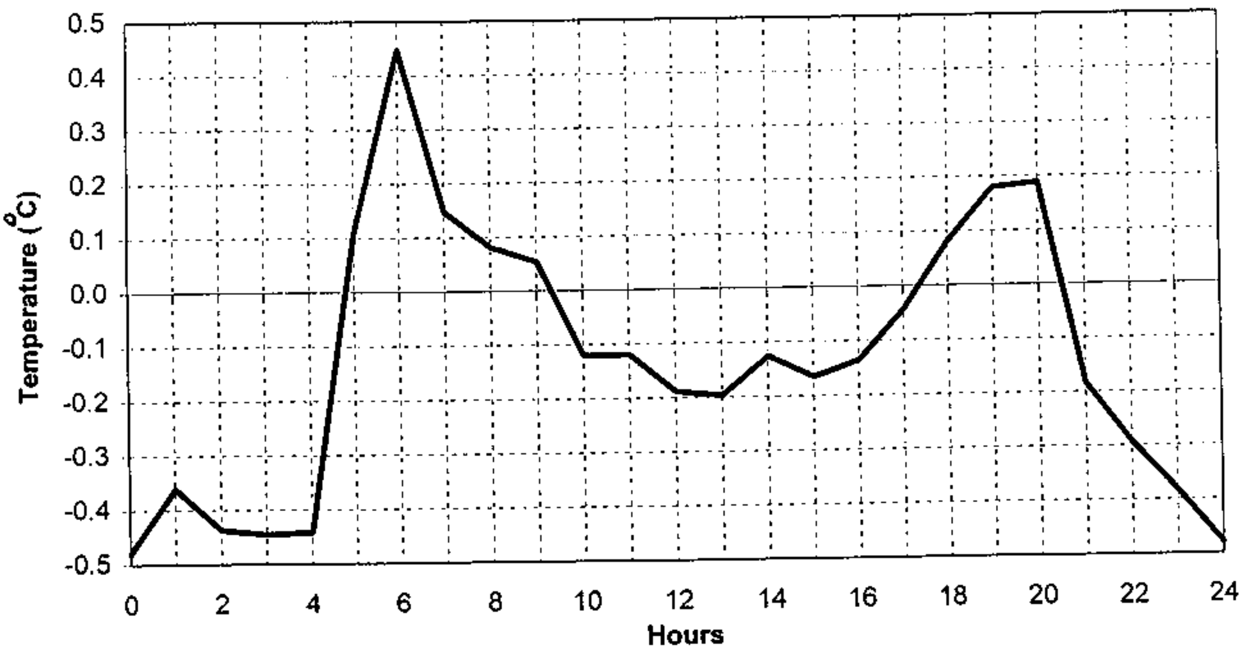

Fig. 10 The diurnal range of hourly temperature differences, Simenrud minus Systugu Synstbø, during the summer (May - August) 1997.

From 21^h Systugu Synstbø is warmer than Simenrud and this difference is increasing during the first part of the night, i.e. the nightly temperature inversion is established leading to lower temperature at Simenrud than at Systugu Synstbø. However, the inversion are not able to resist the insolation after 4^h and is abruptly broken.

The measurements state the suggestion that Systugu Synstbø is a more favourable site for grain production than Simenrud being more protected for frost damages by cold air, which is most predominated at the lower levels in the valley. The temperature difference between the farms in favour of Systugu Synstbø was only 0.12°C. However, for grain production the larger insolation at Synstbø might influence the grain to a larger extent than should be expected when only air temperature is considered.