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Per Øyvind Nordli

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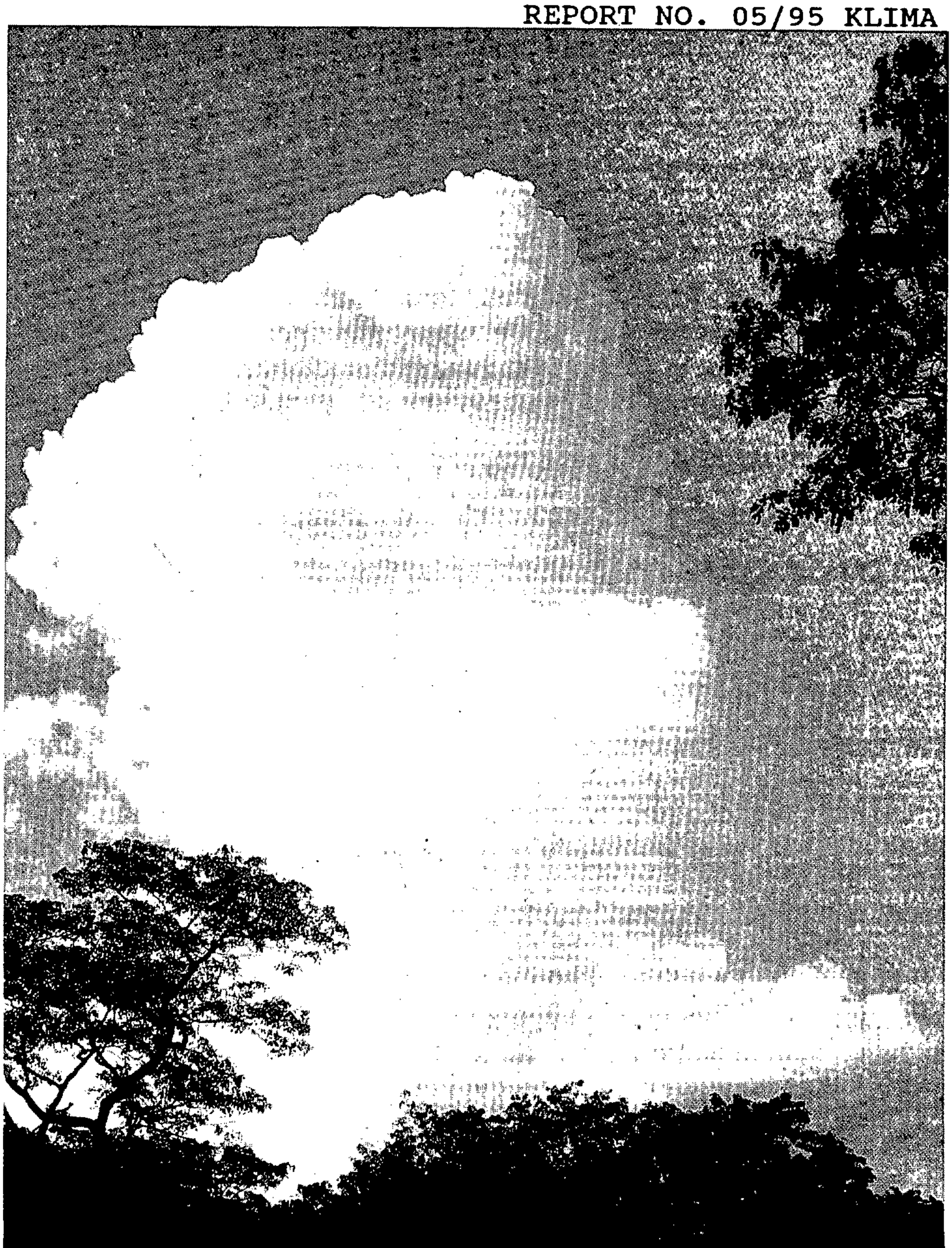

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UTARBEIDD AV

Per Øyvind Nordli

OPPDRAGSGJEVAR

DNMI - Climatological division, NACD-project

SAMANDRAG

If breaks are found in climatic time series parts of the series may be adjusted to obtain homogeneity. Adjustment terms only depending of the month have been in widely use. In a winter topo climate such adjustments may not only lead to intended changes of mean values but also to unintended changes of variability. On the basis of data from a test field at Dombås (62.05°N, 9.08°E), adjustment terms were calculated by regression analysis. This method will in a far better way maintain the variability of the time series also after adjustment.

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Per Øyvind Nordli
SAKSHANDSAMAR

Bjørn Aune
FAGSJEF

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Abstract

A test field for temperature has been in operation since 1988 at Dombås (62.05°N, 9.08°E) in the Gudbrandsdalen valley. The climate of Gudbrandsdalen is continental with frequent temperature inversions. The test field is near the former meteorological station Dombås (Old Site, 1864-1965) which is continued by Kjøremsgrendi at a distance of 5 km. The combined Dombås/Kjøremsgrendi data series is one of the 18 Norwegian series in The North Atlantic Climatic Dataset (NACD).

At Dombås three sites of temperature measurements are located within a distance of 200 m and within an elevation difference of 12 m or less. In winter substantial local differences of temperature were found. These were probably caused not only by the valley inversion but also by a local shallow inversion over the plateau at Dombås centre.

Adjustment terms were calculated by regression analysis. These were applied to monthly mean temperature at Kjøremsgrendi. The Kjøremsgrendi data could then fit into the old Dombås series without break in homogeneity. The adjustments ranged from 0.0°C to -0.5°C, were greatest in cold winter months.

If breaks are found in climatic time series parts of the series may be adjusted to obtain homogeneity. Adjustment terms only depending of the month have been in widely use. In a winter topo climate such adjustments may not only lead to intended changes of mean values but also to unintended changes of variability. The linear regression method, however, will in a far better way maintain the variability of the time series also after adjustment.

C O N T E N T

1 THE CONTINUATION OF THE DOMBÅS SERIES AT THE KJØREMSGRENDI METEOROLOGICAL STATION

1.1 Introduction.

As a Norwegian part of the NACD-project (The North Atlantic Climatic Dataset), 18 long time series from Norway and Arctic are chosen to be included in the dataset, (Frich, 1994). At one of these stations, Dombås, a test field for temperature has been in operation for six years. The test field is of private character. The winter 1993-94, however, it was supported by the NACD-project as will be the case also the winter 1994-95.

All stations in the NACD network will be tested for homogeneity and adjusted for possible breaks. In general this paper deals with the problem of adjusting temperature series in a winter topo climate where even small relocations may create substantial breaks in homogeneity. One special problem of interest is the closure of the Dombås station and its continuation at Kjøremsgrendi.

1.2 Description of the old (Dombås) and new (Kjøremsgrendi) sites

One of the most preferable conditions of the Dombås station is its location at the same site during a period of about 100 years. Since 1965, however, the station was relocated twice within the small centre of Dombås before it was finally closed in July 1976. In October 1977 the station was moved outside Dombås centre to Kjøremsgrendi, Fig 1, from the municipality of Dovre to another one, Lesja, where observations were resumed first on private basis (for the moment under digitization), then officially as a DNMI weather station from September 1978 (digitized).

The station 16740 Kjøremsgrendi is situated on a grass field near farm houses. Below the station is farm land, nowadays entirely in use for grass production. Above the station is a pine forest area. The station is situated 626 m a.s.l. about 100 m above the floor of Gudbrandsdalen valley. The slope of the valley side is oriented to the south. Some climatic data from the station are presented in table A1 in the appendix. Because of its elevation and northern position grain production is no longer economic favourable at this area.

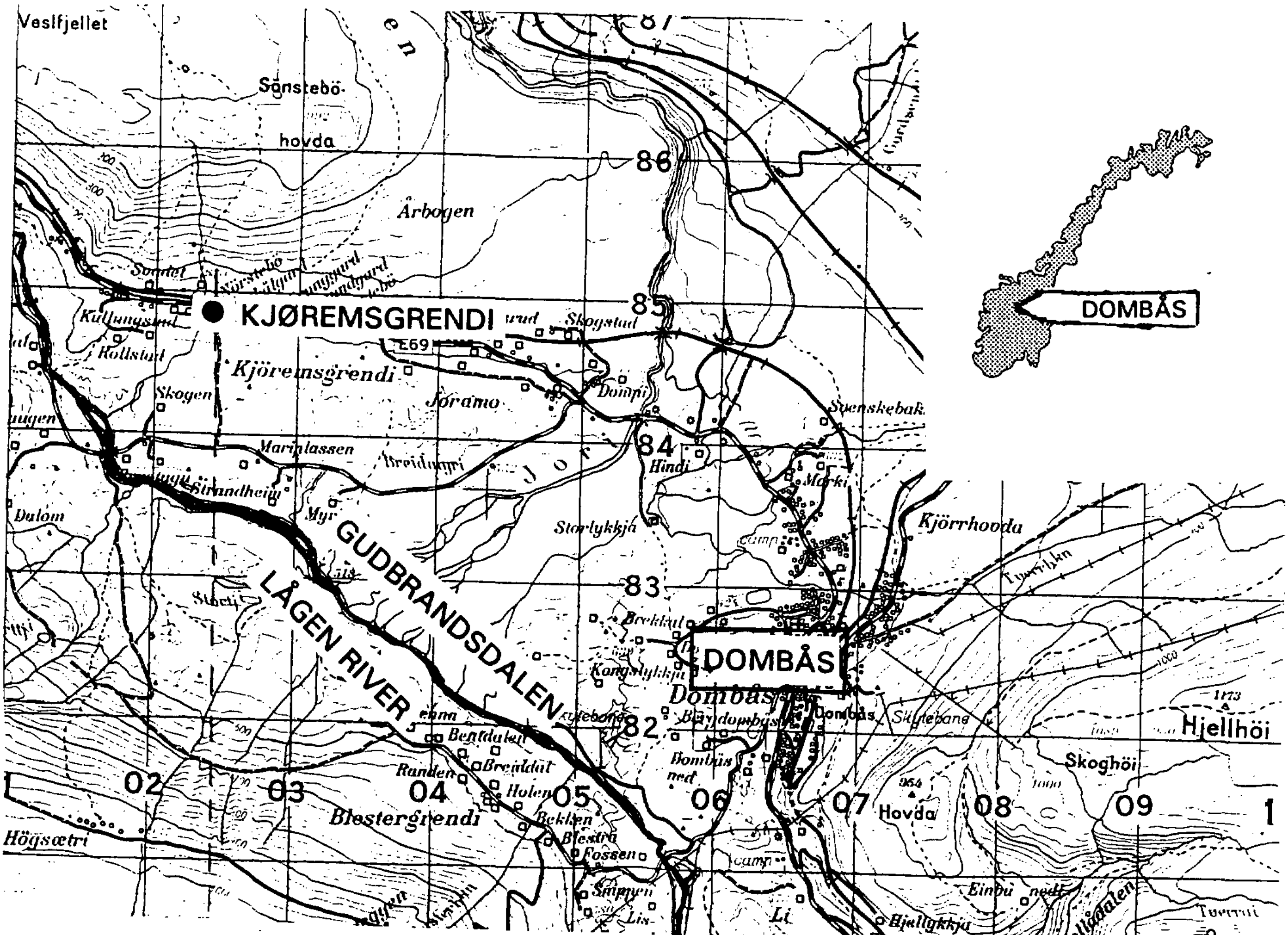


Fig. 1 Topographic map of the Dombås - Kjøremsgrendi district in the scale 1:50 000.

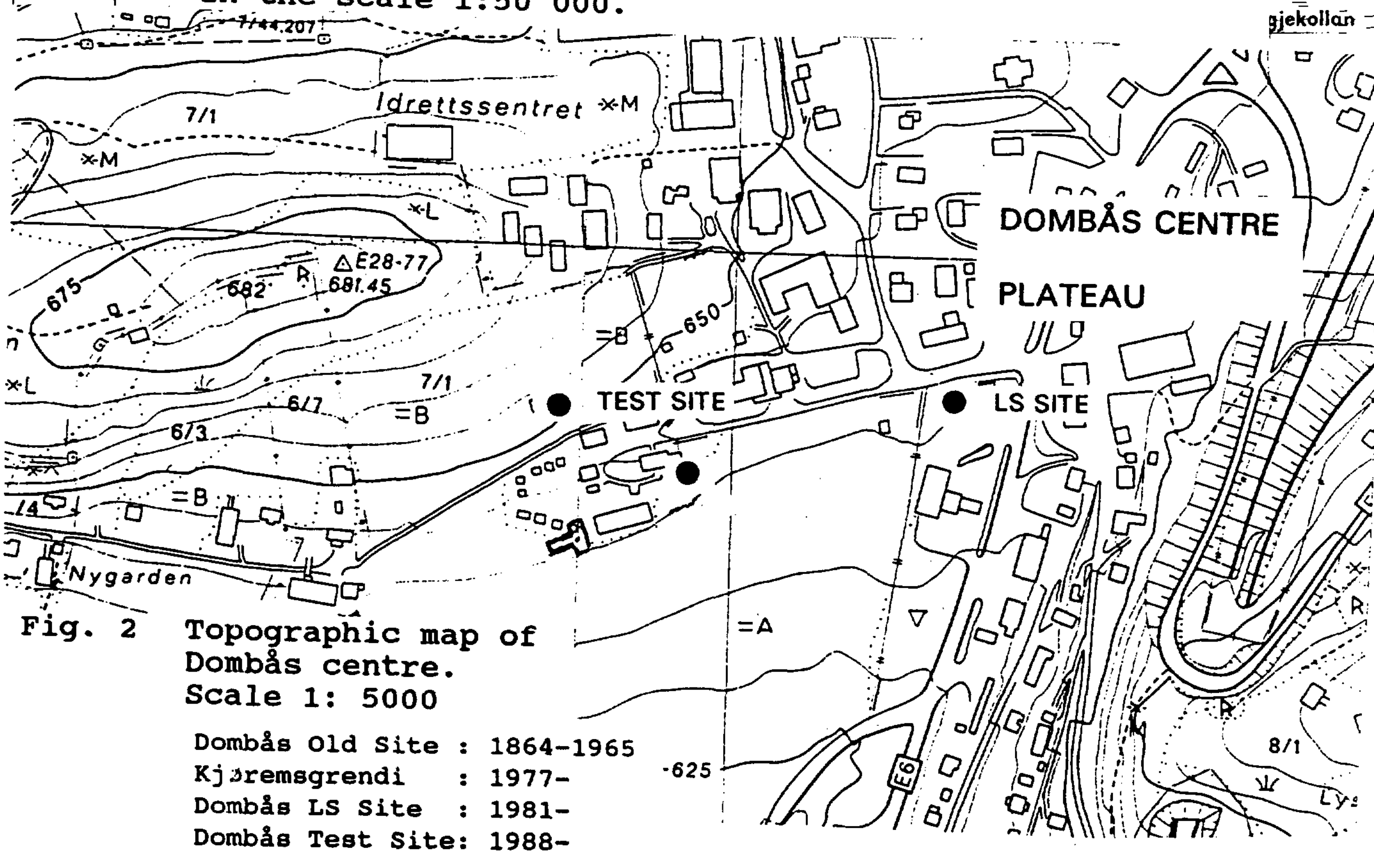


Fig. 2 Topographic map of Dombås centre.
Scale 1: 5000

Dombås Old Site : 1864-1965
Kjɔremsgrendi : 1977-
Dombås LS Site : 1981-
Dombås Test Site: 1988-

Earlier barley was cultivated in spite of frequent losses caused by frost damages in the autumn.

From the oldest site (until 1965) to the present one at Kjøremsgrendi the station height is reduced 17 m, from 643 m a.s.l. at Dombås. The old Dombås site was at the telegraph building situated at the outer border of Dombås centre, Fig. 2. Consequently no urban effect can be expected during the 100 years period. The centre has less than 1000 inhabitants spread over an area of 1 km^2. Kjøremsgrendi is purely a rural area.

1.3 Recent observations at the Old Site

Only 95 m from the Old Site, Dombås Test Field was establish in October 1988 and is still in operation, Fig 2. Its main purpose is to test an old Norwegian wall screen against screens of Stevenson type. Among the latter is the widely used MI-46 screen, almost of the same type which has been used at the station from 1933 to 1965 and which is still in use at Kjøremsgrendi.

In winter the temperature may vary considerably over short distances due to different terrain. At mid winter the valley temperature inversion may last the whole day without being broken up by solar radiation. Later in the winter the inversion breaks up in mid day but may be reestablished in the night. Another private measurement site at Dombås about 12 m lower than the test field shows lower winter temperature, table A6 in the appendix.

Due to different heights we suspect that the test field does not represents the Dombås Old Site in inversion situations. In the last part of October 1993 new observations were therefore started at the Old Site and terminated in the end of April 1994. The temperature was logged every hour. Our purpose was to connect the Kjøremsgrendi time series to the old series at Dombås.

2 TEMPERATURE COMPARISONS OF DIFFERENT SITES OF MEASUREMENTS

The observation hours at Kjøremsgrendi are 07^h, 13^h and 19^h CET with minimum and maximum temperature measured at the morning and evening observations only. Eventual systematic differences between the old Dombås site and Kjøremsgrendi are expected to be at maximum at night. The lack of night observations at Kjøremsgrendi and the short overlapping series at the Old Site, make it difficult to find realistic adjustments to be applied to the Kjøremsgrendi data. In our work we therefore found it necessary also to use the six years of measurements at the Test Site.

2.1 The Kjøremsgrendi series and the Test Site

The standard formula for computing the monthly mean temperature at Norwegian stations is a formula attributed to Köppen, (Birkeland, 1935).

$$T_{mk} = T_f - k(T_f - T_n) \qquad (1)$$

where T_f is the mean of the three observations at fixed hours, T_n is the daily minimum temperature and k is a constant. The magnitude of k depends on the station, the time of the year and the observation hours. The formula applied to the Kjøremsgrendi data during the observation period of the test field are shown in table 1:

Table 1 Mean temperature for 16740 Kjøremsgrendi during the period of the Dombås test field. In the bottom of the table the monthly mean temperature for the entire period and the official k-values are listed.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1988											-3.0	-5.3
1989	-1.2	-2.3	-1.0	0.9	6.0	10.4	12.1	9.7	7.6	2.6	-0.8	-7.2
1990	-5.0	0.2	0.0	1.8	7.4	11.5	11.9	11.6	5.8	2.7	-3.6	-4.5
1991	-6.1	-9.6	-0.7	1.8	4.7	7.7	14.6	12.6	6.5	1.4	-2.4	-3.3
1992	-2.5	-3.0	-1.2	-0.2	8.6	12.4	11.0	9.7	7.6	-2.5	-4.7	-4.5
1993	-4.4	-3.1	-3.3	2.1	7.9	8.2	11.1	9.0	5.0	0.9	-6.7	-10.4
1994	-9.0	-13.2	-3.9	1.9	5.6	8.4	16.0	11.2	6.0			
Mean	-4.70	-5.17	-1.68	1.38	6.70	9.77	12.78	10.63	6.42	1.02	-3.53	-5.87
k-val.	0.05	0.10	0.11	0.16	0.19	0.19	0.19	0.17	0.15	0.09	0.05	0.04

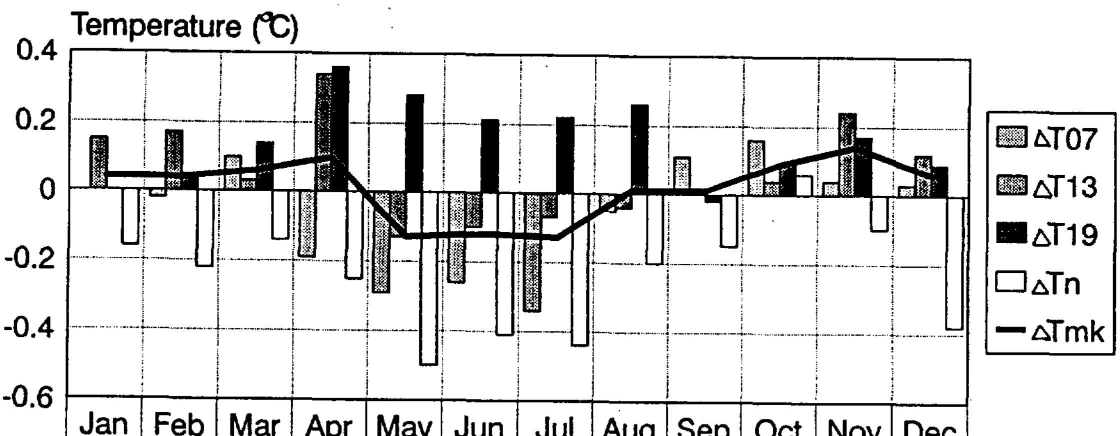
For the same period the monthly mean temperatures at Dombås test site (actually screen MI-46 of Stevenson type hereafter called the Test Site) are also calculated. As the Test Site contains hourly observations it was possible to calculate the monthly means in two different ways, from equation (1) , T_{mkT}, and also as mean values of the 24 observations at fixed hours,

T_{mT} (Notation: m - mean temperature, k - from Köppen's formula, T - Test Site). Some climatologists have used this last method as a definition of mean temperature. The official k-values of Dombås are the same as those of Kjøremsgrendi listed in table 1.

The mean differences Kjøremsgrendi - Dombås Test Site are listed in table 2, ΔT_m when 24 hours mean is used and ΔT_{mk} when Köppen's formula is used for the Test Site. The magnitude of most of the differences are of the same order as the calibration errors of the thermometers. We may therefore conclude that the differences between the two stations are so small that the combined series of monthly mean temperature is homogenous.

Table 2 Monthly mean temperature difference Kjøremsgrendi - Dombås Test Site screen MI-46. The differences noted, ΔT_m and ΔT_{mk} include T_{mT} and T_{mkT} for Dombås respectively.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ΔT_m	0.02	-0.12	-0.03	0.03	-0.12	-0.06	-0.14	0.00	-0.16	0.08	0.20	0.03
ΔT_{mk}	0.04	0.04	0.06	0.10	-0.13	-0.12	-0.13	0.01	0.01	0.09	0.14	0.06



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ΔT07	0	-0.02	0.1	-0.19	-0.29	-0.26	-0.34	-0.05	0.11	0.16	0.04	0.03
ΔT13	0.15	0.17	0.03	0.34	-0.13	-0.1	-0.07	-0.04	0.01	0.04	0.24	0.12
ΔT19	0	0.05	0.14	0.36	0.28	0.21	0.22	0.26	-0.02	0.09	0.17	0.09
ΔTn	-0.16	-0.22	-0.14	-0.25	-0.5	-0.41	-0.44	-0.2	-0.15	0.06	-0.1	-0.38
ΔTmk	0.04	0.04	0.06	0.1	-0.13	-0.12	-0.13	0.01	0.01	0.09	0.14	0.06

Fig. 3 Differences of monthly mean temperature at fixed hours Kjøremsgrendi - Dombås (MI-46).

The temperature differences of the two stations have also been analyzed for the observations at fixed hours, 07^h, 13^h and 19^h as well as the daily minimum temperature, Fig. 3. (The daily minimum temperature at the Test Site is not known, it has been approximated by the lowest value among the hourly observations).

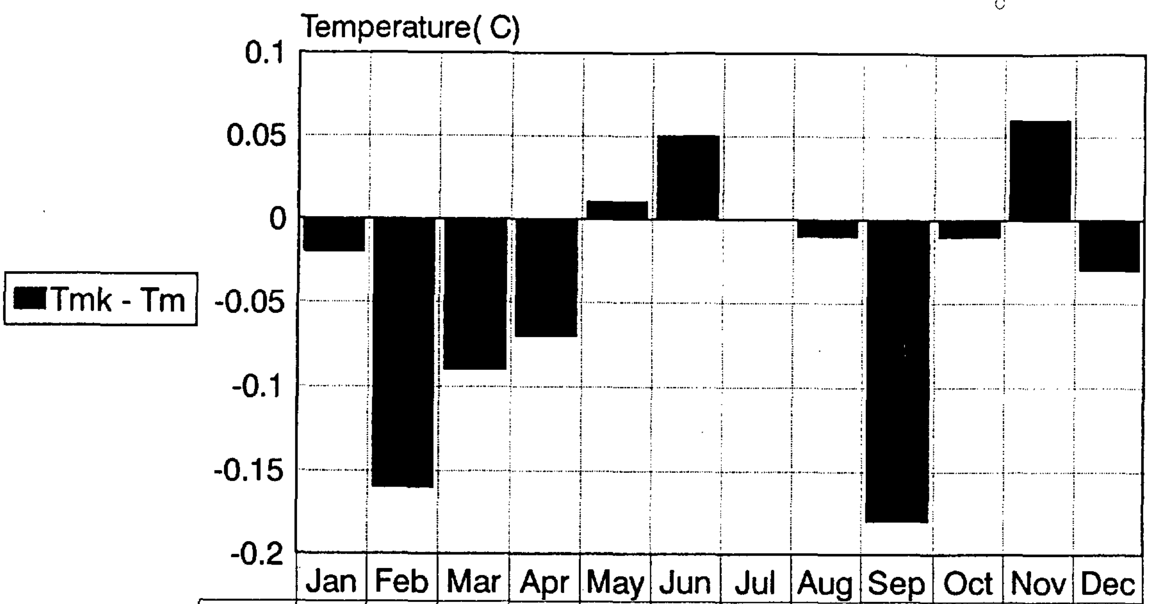
In the diagram of Fig. 3 the temperature differences at fixed hours are shown as bars and the differences in monthly mean temperature from Köppen's formula as a line. Köppen's formula can be applied also for the differences so that the line corresponds to the ΔT_{mk}-data in table 2.

The diagram reveals some systematic differences between the two sites. During the whole year (except October) the minimum temperature is lower at Kjøremsgrendi and the 19^h observation is higher in those months the stations are exposed to short wave radiation at that hour. In summer a higher temperature at Kjøremsgrendi 19^h is compensated by a lower 07^h observation. In winter the lower minimum temperature is compensated by a higher 13^h observation. The result being that in spite of practically equal monthly mean temperature, the two sites have different mean values at the observation hours and also different monthly means of daily minimum temperature.

From table 2 the fitness of Köppen's formula (1) can be tested by simply taking the difference $\Delta T_m - \Delta T_{mk} = (T_{mkK} - T_{mT}) - (T_{mkK} - T_{mkT}) = T_{mkT} - T_{mT}$, where K denotes Kjøremsgrendi and T the Test Site, Fig. 4. In 10 out of 12 months the difference is less than 0.1°C. The greatest difference being -0.18°C in September. None of the differences, however, are significant at the 0.95 level in Student's t-test. These results are in fairly agreement with earlier investigations of k-values, (Høgåsen, 1993).

2.2 The Test Site and the Dombås Old Site

The Old Site is located about 95 m southeast of and 10 m lower than the Test Site (screen MI-46), map Fig. 2. In the winter season Nov. 1993 to April 1994 the site was reactivated by automatic equipment, logging temperature every hour. From the start until January 12. there was a malfunction of the clock in the instrument, which led to an uncertainty of observation time of about half an hour. After that date another instrument without any malfunction was set up. The radiation screens at the Old Site and at the Test Site were of different types. It is therefore no point in comparing the two sites during daytime when the screens may have different effects on the temperature sensors.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tmk - Tm	-0.02	-0.16	-0.09	-0.07	0.01	0.05	0	-0.01	-0.18	-0.01	0.06	-0.03

Fig. 4 Differences (T_{mkT} - T_{mT}) of monthly mean temperature at Dombås Test Field, screen MI-46. T_{mkT} is calculated from Köppen's formula, T_{mT} is true mean. Nov.88-Sep.94

In inversion situations somewhat lower temperature at the Old Site is expected because of its lower elevation in the valley. Radiation at low solar angles may be insufficient to break up valley inversions (Nordli, 1990). The terrain around Dombås, however, is complicated with Dombås centre situated on a plateau on which cold air may stagnate thus forming a shallow local inversion over the plateau. A similar situation has been studied at the Olympic ski arena at Lillehammer (Nordli, 1994). This shallow inversion was easily broken down by solar radiation causing a drainage flow from the plateau to stop.

At night an adjustment term Δ on the observations at the Test Site should therefore be applied to simulate temperature at the Old Site. At daytime after the inversions are broken down this temperature difference is expected to vanish. The length of nights was estimated from the observations and coincide roughly with sunset/sunrise. The temperature at the Old Site can therefore be expressed as follows:

$$(2) \qquad T_{mD} = \frac{1}{24}[p(T_1+\Delta) + qT_2] = \frac{pT_1 + qT_2}{24} + \frac{p}{24}\Delta = T_{mT} + \frac{p}{24}\Delta$$

where

T_{mD}, T_{mT} Monthly mean temperature at the Dombås Old site and the Test Site respectively.

T_1 and T_2 Mean of night and day temperature respectively

p and q The length (hours) of night and day respectively (p + q = 24)

The adjustment term Δ reveals the strength of the inversions for each month during winter 1993/1994. In February fair weather was predominant, i.e. lower temperatures and less cloud cover than the normal. Lack of cloud cover leads to heat loss from the snow surface and accordingly an inversion is built up. The frequency and strength of inversions will vary during the different winters. Equation (2) used for other winters than 1993/94 may therefore give very crude estimates for the Old Site as long as the correction term Δ is a constant only depending on the month.

Table 3 Mean temperature difference, Δ, Old Site - Test Site, during the winter nights 1993-1994. The length, p, of the nights is used in formula 2.

Month 1993-94	Δ °C	Period From - To	p (hours)
November	-0.18	$17^h - 09^h$	17
December	-0.48	$16^h - 10^h$	19
January	-0.26	$17^h - 09^h$	17
February	-0.59	$18^h - 08^h$	15
March	-0.20	$20^h - 06^h$	11
April	-0.14	$21^h - 05^h$	9

To account for different strength and frequency of nightly inversions, regression analysis is carried out with Δ as predictand and nightly cloud cover as predictor. Cloud cover was represented by the mean cloud cover of the Kjøremsgrendi observations at 19^h and 07^h. The analysis was made on daily basis with complete months in the period November-March. In April the 4 last days were missing.

Regression equations with cloud cover as the only predictor is listed in table 4, equations 4, 6, 8, 10, 12 and 14. The correlation coefficient varies from month to month, strongest in the start of the season (2/3 of the variance is explained by the regression in November) less in April when the correlation almost vanishes. Figure 5 contains scatter diagrams for each month.

Table 4 Regression analyses of temperature difference, Δ, Old Site - Test Site, regression coefficients a and b for nightly mean cloud cover and minimum temperature respectively, the regression constant c and (multiple) correlation coefficient r.

Eq.No.	Months	a	b	c	r
1	November/	0.139		-1.07	0.76
2	February		0.064	0.40	0.72
3		0.092	0.035	-0.41	0.82
4	November	0.131		-0.95	0.80
5		0.123	0.012	-0.79	0.82
6	December	0.162		-1.24	0.73
7		0.051	0.059	0.05	0.82
8	January	0.107		-0.86	0.69
9		0.068	0.036	-0.22	0.77
10	February	0.125		-1.07	0.79
11		0.088	0.040	-0.30	0.82
12	March	0.064		-0.54	0.45
13		0.021	0.026	-0.11	0.60
14	April,	0.003		-0.35	0.24
15	01.26.	0.003	0.031	-0.11	0.34

In November cloud cover less than 4 oktas is represented by only three observations. This small sample makes the slope of the regression curve very uncertain. In other months little cloud cover is more common, especially in December (12 observations less than 4 oktas) and February (15).

The smallest difference, Δ, in April occurs under mean cloud cover 7.5 oktas. Analyses of the data show that the cloud cover must have broken up during night, but are reestablished

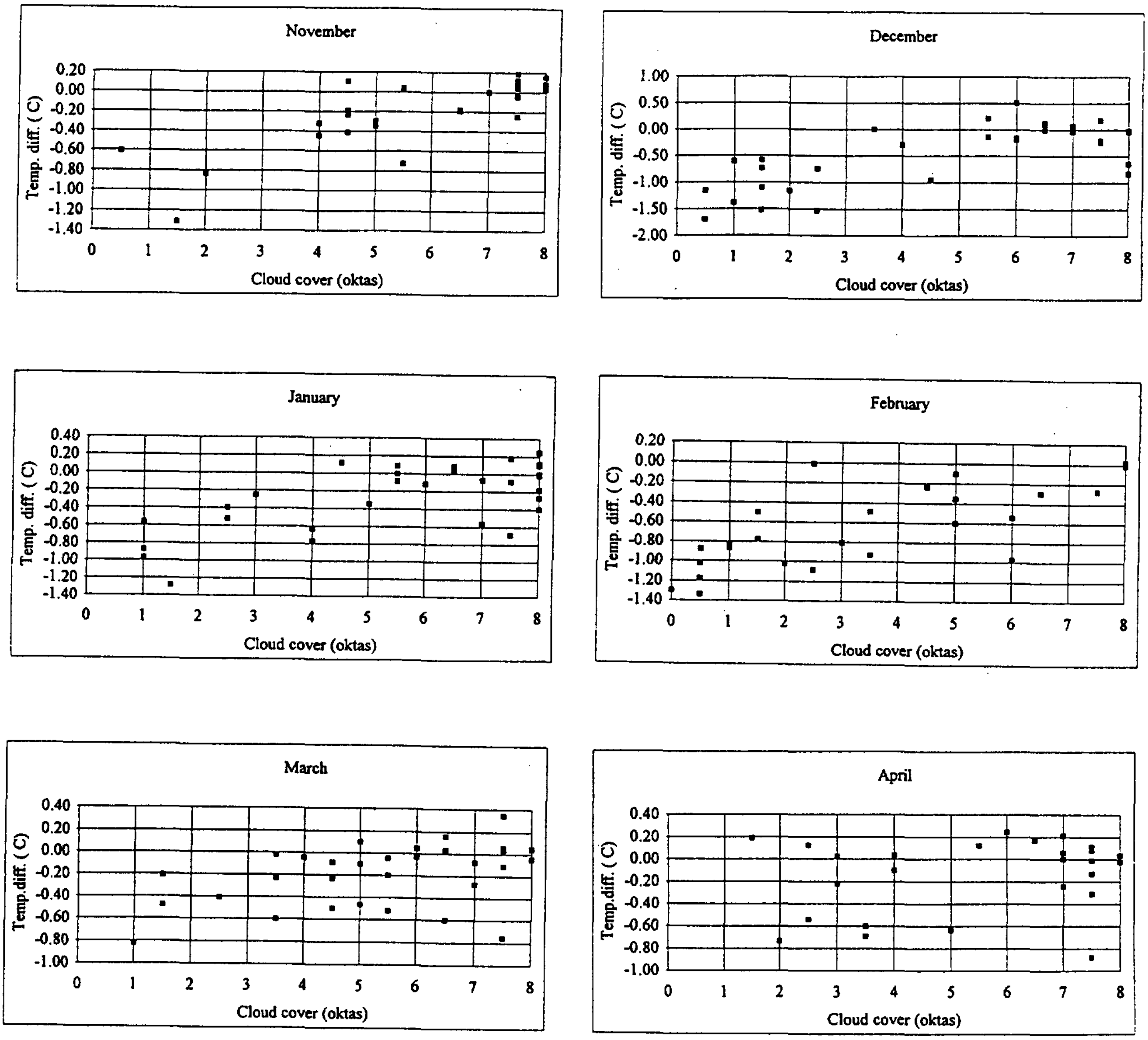


Fig. 5 Mean nightly difference Δ, Old Site - Test Site as a function of mean cloud cover at Kjøremsgrendi at the observations 19^h and 07^h during winter 1993-94.

before the morning observation. If more knowledge had been available of the cloud cover during nights, correlation would certainly have been stronger.

The analyses were extended from one to two predictors, cloud cover and nightly minimum temperature. The results are listed in equations 5, 7, 9, 11, 13 and 15 in table 4. In the months December, January and February the use of two predictors increases the correlation to about 0.8 and thus 2/3 of the variance is explained by the regression. In November the correlation had that magnitude already after the one predictor approach. In the months March and April correlation is still poor even when two predictors are used.

Regression analyses were also carried out during the season November - February, regressions 1-3 in table 4 and Fig. 6 and 7. When one predictor is used the regression explains about 1/2 of the variance which increases to 2/3 when two predictors are used.

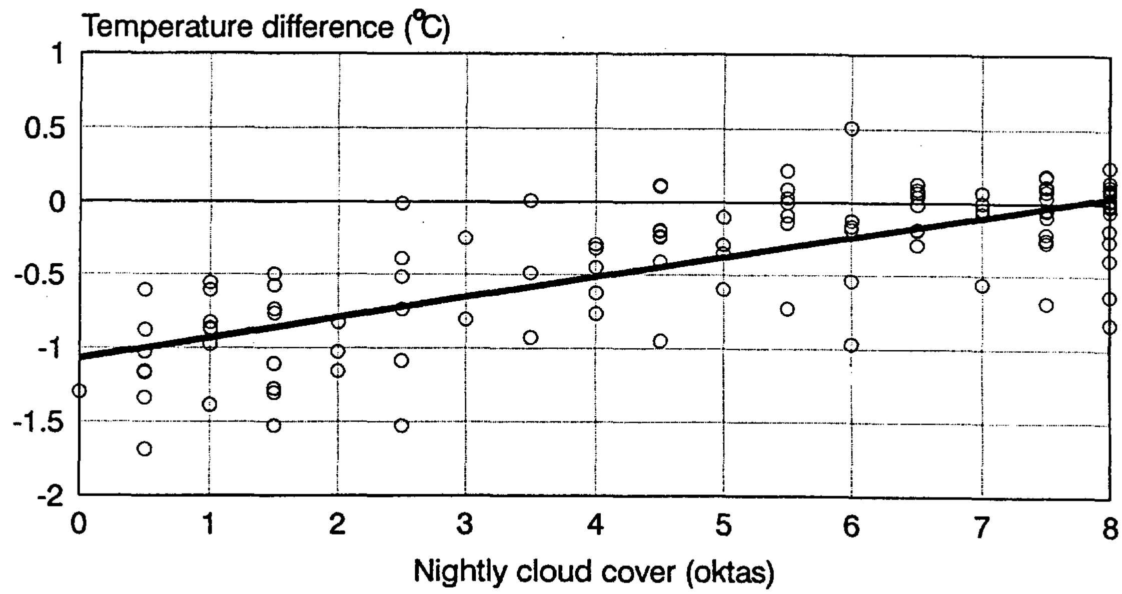


Fig 6 Mean nightly difference, Δ, Old Site - Test Site, as a function of mean cloud cover at Kjøremsgrendi at the observations 19^h and 07^h during the season November - February 1993-1994.

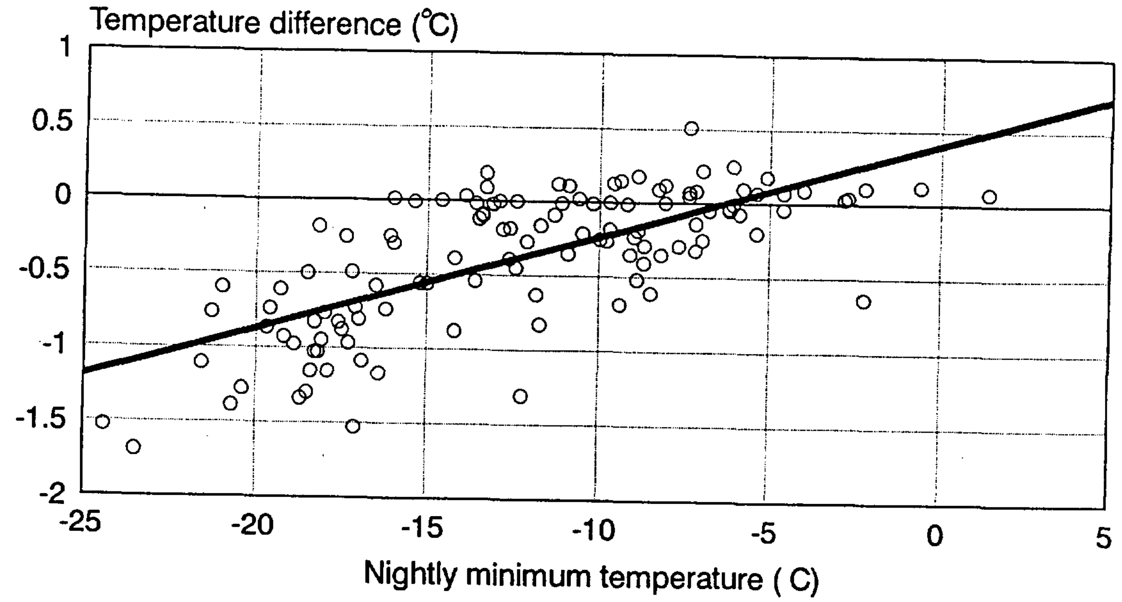


Fig 7 Mean nightly difference Δ, Old Site - Test Site as a function of mean nightly minimum temperature at Kjøremsgrendi during the season November - February 1993-1994.

2.3 Calculation of monthly mean temperature at the Old Site

Equation (2) may now be used to calculate the daily mean temperature at the Old Site. The correction term Δ was calculated from the regression equations in table 4 and extended back to the start of the Test Site, November 1988. Moreover for all practical purposes Kjøremsgrendi and Dombås Test Site have equal monthly mean temperatures. Mean temperature at the Test Site can therefore be replaced by mean temperature at Kjøremsgrendi, table A1. Thus the series of the Old Site can be extended back to the start of the Kjøremsgrendi series, for the moment September 1978 and after some digitization further back to October 1977.

Equation (2) may then be written with Kjøremsgrendi weather elements only on the right hand side:

(3) $$T_{mD} = T_{mkK} + \frac{p}{24}(a\frac{N_1+N_2}{2} + bT_n + c)$$

where

T_{mD}, T_{mkK} = mean temperature at Dombås Old Site and at Kjøremsgrendi respectively.

T_n = nightly minimum temperature at Kjøremsgrendi (19^h - 07^h)

N_1, N_2 = cloud cover at the evening and morning observations.

The results of the calculations are given in the appendix. In table A2 are listed the adjustment terms Δ applied to the Kjøremsgrendi data to get the monthly mean temperatures at the Dombås Old Site, table A4. The greatest adjustments (-0.5°C) occur in cold December or January months when even the shallow plateau inversion may be maintained most of the day. In mild cloudy weather the adjustment term vanishes as was the case at several occasions, for example in the winter 1991/92.

The mean correction in November was -0.1°C, in December, January and February -0.2°C. In March and April the correlation (table 6) is very poor, therefore a fixed correction term taken from table 6 is applied, Δ = 0,2°C in March and 0,14°C in April which yields -0,1°C and 0.0°C respectively when equation (2) is applied.

2.4 Discussion

The regression model is based upon nocturnal measurements of temperature differences Dombås Old Site - Dombås Test Site. In clear cold weather the lower Old Site is colder than the Test Site. Our suggestion is that the difference is caused not only by the valley inversion but also, and probably more important, by a shallow local inversion situated over the plateau at Dombås centre, Fig. 2. Shallow inversions over plateaus seem to disappear easily when exposed to solar radiation, (Nordli, 1994).

In daytime, difference between the Old Site and the Test Site is therefore estimated to zero in the model although this is not perfectly true at low solar angles. On the other hand the Old Site may experience somewhat higher temperatures according to the elevation difference, 0,07°C - 0,10°C when the air at daytime has neutral stability. This may compensate for the underestimation of inversions at daybreak.

Since December 1981 a private meteorological station (Dombås LS, see map Fig. 2) has been run by Sigmund Høgåsen and Olav

P. Amundgård. Its elevation is about 3 m lower than Dombås Old Site at a distance of 175 m, data table A6. In table A7 the difference Old Site - LS is given. The private station is colder than the Old Site in winter caused by its lower elevation and also probably by the fact that it is located close to Dombås centre in the drainage flow from the plateau. Drainage flows are of local character and may have scales less than the distances between the sites, (see for inst. Mahrt, 1986). Temperature differences between sites even at approx. same elevation may therefore occur at clear nights. Dombås LS is even more influenced by the local inversion than Dombås Old Site which again is more influenced than the Test Site.

At summer no systematic difference is seen between the Test Site and Dombås LS as is the case when Kjøremsgrendi is compared with the Test Site.

The terms used for adjustment of the Kjøremsgrendi data are listed in table A2 in the appendix. In December and January they varied from 0.0°C to -0.5°C during a period of 16 years. The magnitude of the adjustments were greatest in cold winter months. Dombås Old Site is more affected by inversions than Kjøremsgrendi and has therefore a greater variability in winter temperatures.

Inhomogeneous climatic time series may be adjusted to obtain homogeneity. Often the adjustment terms are constant from one year to the other only varying from month to month through the year. If then a temperature time series from the valley floor is adjusted by a series from the valley side, the adjustments do not only alter its mean value but also its variability. In this case the variability will be underestimated. The opposite is true if a series from the valley side is adjusted by one from the valley floor. The same arguments can be used adjusting coastal time series by those from inland and vice versa. The linear regression model, however, will in a far better way maintain the variability of the time series also after adjustment.

The use of time dependent adjustment terms are most beneficial for series from inland stations where inversion are frequent. Also in coastal regions frost pockets may exist, (Førland, 1984). Regression models rather than time independent adjustment terms may thus also be beneficial in coastal regions.

Used on individual days the model may render differences between the two sites which is impossible from a dynamical point of view. It is emphasized that the present regression lines should be used for monthly mean values only. However - it would certainly be possible to make a similar model for daily temperature.

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APPENDIX

Table A1 Monthly mean temperature at Kjøremsgrendi, mean values for the period of observation and the normal 1961-1990

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1978									4.9	2.8	-2.6	-14.5
1979	-15.4	-9.4	-3.9	0.7	4.7	11.8	10.6	9.9	6.0	1.1	-5.7	-10.2
1980	-10.7	-10.9	-5.6	1.9	7.0	12.1	13.3	11.2	7.7	-1.0	-8.0	-6.5
1981	-7.7	-9.2	-5.7	-0.2	8.1	8.6	11.9	10.4	8.4	0.8	-4.6	-15.0
1982	-11.7	-6.1	-1.1	1.0	6.0	8.7	13.4	12.2	7.1	2.5	-2.7	-6.3
1983	-4.5	-7.6	-3.3	0.6	6.7	9.4	12.8	11.3	7.4	2.3	-2.6	-5.0
1984	-11.7	-6.3	-6.0	2.9	8.1	10.0	11.6	11.8	6.1	3.0	-2.3	-4.0
1985	-11.1	-10.6	-4.3	-0.9	7.4	10.4	12.2	10.9	4.5	5.0	-8.1	-11.5
1986	-13.0	-12.2	-1.5	-1.5	7.5	13.0	11.9	9.3	4.4	3.1	-0.4	-7.1
1987	-15.0	-7.3	-7.7	2.3	5.0	8.3	11.8	9.4	5.5	3.9	-3.3	-5.3
1988	-5.1	-6.1	-6.0	-1.6	7.8	13.2	13.2	11.5	8.0	0.8	-3.0	-5.3
1989	-1.2	-2.3	-1.0	0.9	6.0	10.4	12.1	9.7	7.6	2.6	-0.8	-7.2
1990	-5.0	0.2	0.0	1.8	7.4	11.5	11.9	11.6	5.8	2.7	-3.6	-4.5
1991	-6.1	-9.6	-0.7	1.8	4.7	7.7	14.6	12.6	6.5	1.4	-2.4	-3.3
1992	-2.5	-3.0	-1.2	-0.2	8.6	12.4	11.0	9.7	7.6	-2.5	-4.7	-4.5
1993	-4.4	-3.1	-3.3	2.1	7.9	8.2	11.1	9.0	5.0	0.9	-6.7	-10.4
1994	-9.0	-13.2	-3.9	1.9	5.6	8.4	16.0	11.2	6.0	1.1		
Mean	-8.4	-7.3	-3.5	0.8	6.8	10.3	12.5	10.7	6.4	1.8	-3.8	-7.5
Normal	-8.9	-7.8	-4.0	0.3	6.5	10.7	12.0	11.1	6.6	2.3	-4.0	-7.3

Table A2 Corrections applied to Kjøremsgrendi monthly mean temperatures. representing the old site.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1978										0.0	-0.1	-0.5
1979	-0.5	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.3
1980	-0.3	-0.3	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.2
1981	-0.2	-0.3	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.5
1982	-0.3	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2
1983	-0.1	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
1984	-0.4	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	-0.2	-0.3	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	-0.4
1986	-0.4	-0.4	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
1987	-0.5	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
1988	0.0	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
1989	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2
1990	-0.1	0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
1991	-0.2	-0.3	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	0.0	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
1993	-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.3
1994	-0.2	-0.4	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Mean	-0.2	-0.2	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.2

Table A3 Monthly mean temperature at Dombås test field in screen MI-46 (24 hours mean).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1988											-3.2	-5.4
1989	-1.2	-2.0	-0.9	1.0	6.1	10.6	12.4	9.7	7.8	2.6	-0.9	-7.0
1990	-5.1	0.2	0.1	1.8	7.6	11.5	12.1	11.6	6.0	2.7	-3.8	-4.5
1991	-6.1	-9.5	-0.7	1.8	4.8	7.6	14.7	12.5	6.7	1.3	-2.7	-3.5
1992	-2.5	-3.0	-1.2	-0.3	8.6	12.6	11.1	9.8	7.5	-2.7	-4.7	-4.9
1993	-4.5	-3.0	-3.3	1.9	8.3	8.4	11.1	9.0	5.2	0.8	-7.1	-10.1
1994	-8.9	-13.0	-3.9	1.9	5.5	8.3	16.1	11.2	6.3			

Table A4 Monthly mean temperature at Dombås Old Site, corrections applied to Kjøremsgrendi mean temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1978									4.9	2.8	-2.7	-15.0
1979	-15.9	-9.6	-4.0	0.7	4.7	11.8	10.6	9.9	6.0	1.1	-5.8	-10.5
1980	-11.0	-11.2	-5.7	1.9	7.0	12.1	13.3	11.2	7.7	-1.0	-8.2	-6.7
1981	-7.9	-9.5	-5.8	-0.2	8.1	8.6	11.9	10.4	8.4	0.8	-4.7	-15.5
1982	-12.0	-6.3	-1.2	1.0	6.0	8.7	13.4	12.2	7.1	2.5	-2.8	-6.5
1983	-4.6	-7.8	-3.4	0.6	6.7	9.4	12.8	11.3	7.4	2.3	-2.6	-5.1
1984	-12.1	-6.4	-6.1	2.9	8.1	10.0	11.6	11.8	6.1	3.0	-2.3	-4.0
1985	-11.3	-10.9	-4.4	-0.9	7.4	10.4	12.2	10.9	4.5	5.0	-8.4	-11.9
1986	-13.4	-12.6	-1.6	-1.5	7.5	13.0	11.9	9.3	4.4	3.1	-0.4	-7.3
1987	-15.5	-7.5	-7.8	2.3	5.0	8.3	11.8	9.4	5.5	3.9	-3.3	-5.5
1988	-5.1	-6.2	-6.1	-1.6	7.8	13.2	13.2	11.5	8.0	0.8	-3.1	-5.4
1989	-1.2	-2.3	-1.1	0.9	6.0	10.4	12.1	9.7	7.6	2.6	-0.8	-7.4
1990	-5.1	0.3	-0.1	1.8	7.4	11.5	11.9	11.6	5.8	2.7	-3.7	-4.6
1991	-6.3	-9.9	-0.8	1.8	4.7	7.7	14.6	12.6	6.5	1.4	-2.4	-3.3
1992	-2.5	-3.0	-1.3	-0.2	8.6	12.4	11.0	9.7	7.6	-2.5	-4.8	-4.6
1993	-4.5	-3.2	-3.4	2.1	7.9	8.2	11.1	9.0	5.0	0.9	-6.8	-10.7
1994	-9.2	-13.6	-4.0	1.9	5.6	8.4	16.0	11.2	6.0			

Table A5 Monthly mean temperature at Dombås Old Site, corrections applied to the Dombås Test Field mean temperature (screen MI-46).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1988											-3.3	-5.5
1989	-1.2	-2.0	-1.0	1.0	6.1	10.6	12.4	9.7	7.8	2.6	-0.9	-7.2
1990	-5.2	0.3	0.0	1.8	7.6	11.5	12.1	11.6	6.0	2.7	-3.9	-4.6
1991	-6.3	-9.8	-0.8	1.8	4.8	7.6	14.7	12.5	6.7	1.3	-2.7	-3.5
1992	-2.5	-3.0	-1.3	-0.3	8.6	12.6	11.1	9.8	7.5	-2.7	-4.8	-5.0
1993	-4.6	-3.1	-3.4	1.9	8.3	8.4	11.1	9.0	5.2	0.8	-7.2	-10.4
1994	-9.1	-13.4	-4.0	1.9	5.5	8.3	16.1	11.2	6.3			

Table A6 Monthly mean temperature at Dombås LS
Private station run by S. Høgåsen and O.P.Amundgård

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981												-15.0
1982	-12.4	-6.7	-1.3	0.9	5.9	9.0				2.3	-3.2	-6.8
1983	-4.7	-8.0	-3.5	0.6	6.6	9.5	12.9	11.1	7.4	2.1	-5.7	-8.5
1984	-12.3	-6.5	-6.2	2.8	7.9	9.9				2.9	-2.8	-6.4
1985	-11.2	-11.2	-5.3	-1.6	7.3	10.3	12.2	10.9	4.5	4.9	-8.5	-12.0
1986	-13.4	-12.7	-1.5	-1.6	7.4	13.2	12.1	9.2	4.6			
1987	-16.1		-8.1	2.2	4.9	8.1						
1988	-5.3	-6.3	-6.5	-1.9	7.9	13.5	13.3	11.4	8.3	0.7	-3.3	-5.6
1989	-1.3	-2.2	-0.9	0.8	6.2	10.7	12.3	9.7				
1990	-5.4	0.2	0.1	1.8	7.5	11.5	12.0	11.5	5.9	2.4	-3.9	-4.8
1991	-6.6	-10.0	-0.8	1.7	4.8	7.6	14.6	12.5	6.5	1.3	-2.9	-3.7
1992	-2.8	-3.3	-1.3	-0.3	8.5	12.5	11.1	9.8	7.5	-2.9	-5.1	-5.1
1993	-4.5	-3.3	-3.5	1.7	8.1	8.3	11.1	9.0	5.0	0.7	-7.5	-10.8

Table A7 Monthly mean temperature diffference Dombås Old Site - Dombås LS
Difference A5 - A6

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1988											0.0	0.1
1989	0.1	0.2	-0.1	0.2	-0.1	-0.1	0.1	0.0				
1990	0.2	0.1	-0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.3	0.0	0.2
1991	0.3	0.2	0.0	0.1	0.0	0.0	0.1	0.0	0.2	0.0	0.2	0.2
1992	0.3	0.3	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.3	0.1
1993	-0.1	0.2	0.1	0.2	0.2	0.1	0.0	0.0	0.2	0.1	0.3	0.4
Mean	0.2	0.2	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.2	0.2	0.2