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HOMOGENEITY TEST OF PRECIPITATION DATA
DESCRIPTION OF THE METHODS USED AT DNMI

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SAMMENDRAG

The report describes the methods for homogeneity testing of precipitation series which are used at the Norwegian Meteorological Institute (DNMI). The methods include double mass analysis and "standard normal homogeneity test". Correction factors are proposed for inhomogeneous series. Test results and data from the station history archives are used in the final evaluation of the precipitation series.

A summary of the results from testing of 151 precipitation series of 75 years or more are given. Of investigated series, 52 were classified as homogeneous, while 99 contained at least one inhomogeneity. Correction of inhomogeneous series is illustrated with an example.

UNDERSKRIFT

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1. INTRODUCTION

Homogeneous time series of meteorological parameters are essential for studies of climatic fluctuations and changes. A time series is homogeneous if the measurements have been consistently done by the same method, with the same instrumentation, at the same time and place, and in the same environment. This is seldom the case for long time series, and statistical methods should be used to detect possible inhomogeneities in the data. Inhomogeneities may mask or amplify real climatic variation. Inhomogeneous series therefore need to be corrected before being used in climate research.

Precipitation measurements usually contain systematic errors. Under conditions of snow and strong wind, a standard rain gauge catches less than half the "true precipitation" (NWGP, 1986). It is difficult to correct for such errors, but by homogenizing the precipitation series (i.e. testing and correcting for eventual inhomogeneities) one may avoid systematic variation of the errors throughout the series.

This report describes the method for homogenizing precipitation series used at the Norwegian Meteorological Institute (DNMI). The method is based upon the "standard normal homogeneity test" (Alexandersson 1986). The report also gives a summary of experience gained at DNMI using the method. A more extensive report on this is available in Norwegian (Førland et al. 1990).

2. METHODS FOR HOMOGENEITY TESTING

2.1 Computer programs.

The computer programs which are developed for homogeneity studies contain the following main functions:

1) Double mass curves. Accumulated precipitation at the station being tested (test station) is compared in a diagram with accumulated precipitation at one or more neighbouring stations (reference stations). Examples of such diagrams are shown in figures 2.3 (inhomogeneous station) and 2.5 (homogeneous station). The inhomogeneity in figure 2.3 is visualized as a change in the slope of the curve drawn between the points. The diagram, however, gives no measure for the significance level of the inhomogeneity.

2) Significance test of inhomogeneities. The test, which is described in section 2.2, decides by statistical means the probability that the precipitation measurements at the test station have changed relative to the neighbouring stations throughout the period of measure. The test has been applied earlier at the Swedish Meteorological and Hydrological Institute (Alexandersson, 1986).

3) Correction of inhomogeneous precipitation series. The program provides corrections for time series with only one inhomogeneity throughout the time of observation. Time series with more than one inhomogeneity must be divided into parts containing one inhomogeneity in each before this program can be applied.

2.2 Statistical methods.

Double mass analyses show that linear regression adequately describes precipitation at homogeneous neighbouring stations.

Consequently, for homogeneous time series, the ratio between precipitation at the test station and at a reference station may be expected to be fairly constant throughout the observation time. The time series $\mathbf{q}_i$ (index i denotes time step, i.e. year) of this ratio is therefore a suitable parameter for testing the significance of a suspected inhomogeneity.

A standardized series of the ratio, $\mathbf{z}_i$, is defined:

$$(2.1) \qquad z_i = (q_i - \bar{q}) / s_q$$

$\bar{\mathbf{q}}$ is the mean value and $\mathbf{s}_q$ the standard deviation of $\mathbf{q}_i$. The mean value of $\mathbf{z}_i$ is then 0, while the standard deviation is 1. Further, it is assumed that $\mathbf{z}$ has a normal distribution.

Two hypotheses are now defined:

H_0 <u>Null hypothesis</u>: The whole series is homogeneous. This implies that any part of the series is normally distributed with mean value = 0 and standard deviation = 1.

H_1 <u>Alternative hypothesis</u>: The series is inhomogeneous in the period of observation. There is an inhomogeneity at the end of year no. m such that the m first year of the series has mean value = μ_1 and the (n - m) last years has mean value = μ_2. The standard deviation is 1 in both parts of the series.

A test-parameter T is computed for each of the n years in the time series (Alexandersson, 1986):

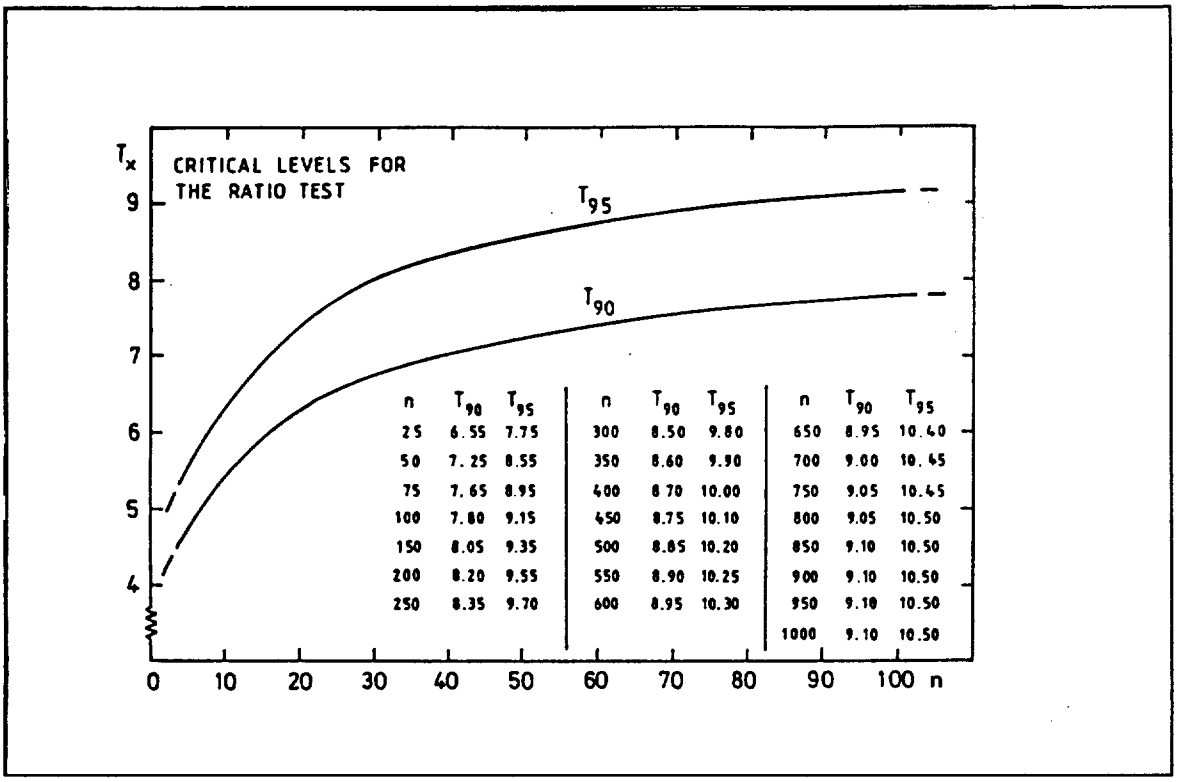
$$(2.2) \qquad T(m) = m\bar{z}_1^2 + (n - m)\bar{z}_2^2 \qquad , m=1,2,...,n$$

Here $\bar{z}_1$ is the mean value of z during the m first years and $\bar{z}_2$ is the mean value during the $(n - m)$ last years. A high T-value in the m'th year implies that the mean standardized ratios during the years before and after the m'th year depart significantly from 0, making H_0 unlikely.

The maximum T-value in the time series is denoted by T_x:

(2.3) $T_x = \max \langle T(m),\ m=1,2,\ldots,n \rangle$

The probability that T_x exceeds a certain value if H_0 is correct depends only on the length of the time series. Critical values of T_x connected to given confidence intervals may then be computed. The critical values for the 90%- and 95%-significance levels are denoted T_{90} and T_{95} respectively. These are shown in figure 2.1 as functions of number of years, n, in the time series. If H_0 is rejected for series for which $T_x > T_{90}$,



n	T_{90}	T_{95}	n	T_{90}	T_{95}	n	T_{90}	T_{95}
25	6.55	7.75	300	8.50	9.80	650	8.95	10.40
50	7.25	8.55	350	8.60	9.90	700	9.00	10.45
75	7.65	8.95	400	8 70	10.00	750	9.05	10.45
100	7.80	9.15	450	8.75	10.10	800	9.05	10.50
150	8.05	9.35	500	8.85	10.20	850	9.10	10.50
200	8.20	9.55	550	8.90	10.25	900	9.10	10.50
250	8.35	9.70	600	8.95	10.30	950	9.10	10.50
						1000	9.10	10.50

Figure 2.1 T_{90} and T_{95} as functions of number of years n in the time series (Alexandersson, 1986).

there will be a 10% risk of rejecting a homogeneous series because of random variation in the precipitation. If the 95%-level is chosen this risk decreases to 5%, but the risk of accepting an inhomogeneous series as homogeneous increases.

For time series that are classified as inhomogeneous, the test also gives the most probable year for the inhomogeneity. That is the year for which T is T_x. However, if the station history is known one should try to find the physical cause of the inhomogeneity, and in this way date the inhomogeneity more exactly.

2.3 Reference stations.

Ideally, only stations with homogeneous precipitation series should be used as reference stations. A general difficulty, however, is the initial choice of reference stations, before any stations in an area are tested. Homogeneous high-quality neighbouring stations with sufficiently long data series may be totally lacking, particularly when long time series are being tested. This problem is reduced by using several reference stations and redefining the ratio $\mathbf{q}_i$.

Choice of reference stations.

Because of the strong orographic influence on most Norwegian precipitation stations, it is not necessarily true that the nearest neighbouring stations are the best choices as reference stations. Therefore a correlation analysis is run on yearly and seasonal precipitation among all stations within a given distance (for instance 200-300 km) from the test station. During this analysis the stations which correlate best with the test station are chosen as reference stations. This is illustrated in tables 2.1 and 2.2, which also demonstrate that the correlation coefficient is not a mere linear function of the distance between stations.

Serious homogeneity breaks may influence the correlation coefficients, and thus the correlation analysis should be repeated after correcting inhomogeneous series (cf. figure 2.7).

General form of the ratio **q**.

The ratio for the **i**'th year of observation may be denoted:

$$(2.4)\quad q_i = f(P_i)\ /\ g(Q_i)$$

Here **f** is a function of the precipitation **P** at the test station, while **g** is a function of **Q**, which is either a weighted or unweighted mean value of the precipitation at the reference stations. The functions **f** and **g** may be defined in one of the following ways.

Simplest form.

$$(2.5)\quad f(P_i) = P_i \qquad (2.6)\quad g(Q_i) = \frac{1}{k}\cdot\sum_{j=1}^{k} Q_{ij}$$

Here **k** is the number of reference stations, and index **j** denotes the j'th reference station. Equation 2.6 may be used only if all reference stations have at least as long a time series as the test station. In the reference group, the stations count the same, independently of their correlation with the test-station. The reference station with the largest variation in precipitation amount will dominate eq. (2.6).

Scaling. The **f**-function is given by eq. (2.5), while the **g**-function now is given by eq. (2.7).

$$(2.7)\quad g(Q_i) = \frac{\sum_{j=1}^{k} Q_{ij}\, V_j}{\sum_{j=1}^{k} V_j}$$

Here V_j is a weight factor for reference station **j**, most commonly a function of the distance or the correlation between the test station and the j'th reference station. At DNMI, the square of the correlation coefficient is used as a weight:

$$(2.8) \quad v_j = r_j^2$$

Weighting the reference stations with their correlation coefficients relative to the test station, minimalizes the variance in q_i (Alexandersson, 1984). Also in this case, the reference stations must have at least as long time series as the test station.

Normalizing. The f- and g-functions are defined by equations (2.9) and (2.10).

$$(2.9) \quad f(P_i) = P_i \; / \; \overline{P} \qquad (2.10) \quad g(Q_i) = \frac{1}{k_i} \cdot \sum_{j=1}^{k_i} \frac{Q_{ij}}{\overline{Q}_j}$$

Here $\overline{P}$ and $\overline{Q}_j$ are mean precipitation throughout the observation periode for the test station and the j'th reference-station, respectively, while k_i is the number of reference stations in the i'th year of observation.

An advantage with using the normalized functions is that reference stations with shorter time series than the test station may be used, as the g-function is not dependent on the absolute precipitation at the reference stations. More reference stations are then available, and the variance in q_i may be minimized.

Normalizing and scaling. The f-function is given by eq. (2.9) while the g-function is defined by eq. (2.11).

$$(2.11) \quad g(Q_i) = \frac{\sum_{j=1}^{k_i} v_j \, (Q_{ij} \; / \; \overline{Q}_j)}{\sum_{j=1}^{k_i} v_j}$$

This equation permits use of reference stations with shorter periods of observation than the test station, at the same time as the reference values are scaled.

In the computer program at DNMI, any of the four above mentioned definitions of $g(Q_i)$ may be chosen. So far, however, both normalizing and scaling have been used in most of the homogeneity testing done at DNMI, including the testing referred to in the following sections.

2.4 Examples of homogeneity testing.

Inhomogeous precipitation series. The observation series from station 5848 Briksdal, which started in June 1895, was tested against 9 reference stations. Relevant information about the reference stations is found in table 2.1.

Figure 2.2 shows some of the output from the homogeneity test program. Station numbers for reference stations are shown in line 2 and 3. The numbers in brackets show the weight for each station (the square of the correlation coefficient between observed precipitation at the station and at 5848 Briksdal).

Table 2.1 Reference stations for testing homogeneity at station 5848 Briksdal (1895-1990). Correlation coefficients and distances are given relative to Briksdal.

STATION NO.	NAME	OBS.PERIOD FROM - TO	CORRELATION COEFFICIENT	DISTANCE (km)
5005	Nedre Ålvik	1918-1990	0.809	142
5307	Vik i Sogn	1895-1990	0.820	71
5578	Leikanger	1896-1990	0.825	57
5612	Høyangshåland	1907-1990	0.816	65
5680	Gaular	1881-1990	0.812	68
5748	Botnen i Førde	1895-1990	0.856	44
5787	Davik	1895-1970	0.809	70
5888	Sindre	1895-1990	0.821	28
5896	Hornindal	1895-1990	0.791	34

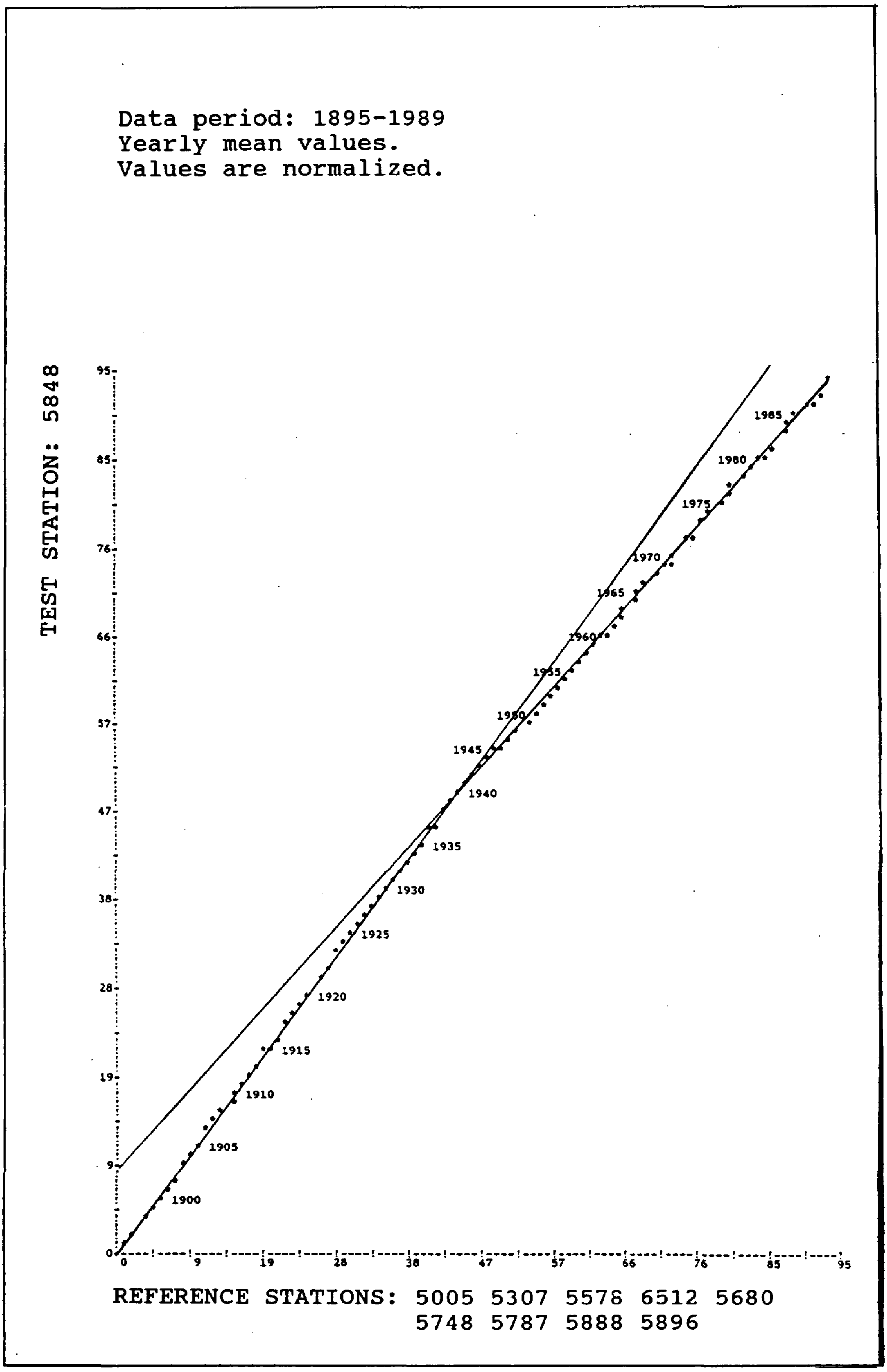
```
HOMOGENEITY TESTING OF YEARLY PRECIPITATION
Test station: 5848
Reference stations: 5005(.64) 5307(.67) 5578(.67) 5612(.66)
         5680(0.66) 5748(.72) 5787(.67) 5888(.67) 5896(.62)
Data periode 1895-1989
The values are normalized.

Max. T-value                :  62.4
Year for max. T-value       :  1939
Number of values (years)    :    94
Satisfies conf. (%)         :    95

Critical T-value (90%)      :   7.8
Critical T-value (95%)      :   9.1

Mean before inhomogeneity:    1.1110
Mean after inhomogeneity :    0.8998
Ratio after/before        :    0.8099

Relative change in cumulative sum:
Mean before inhomogeneity:    1.1056
Mean after inhomogeneity :    0.8968
Ratio after/before        :    0.8111
```

Figure 2.2 Output from testing homogeneity at 5848 Briksdal.

The output shows that the maximum T-value was 62.4, while the null hypothesis may be rejected on 90 and 95%-leve when $\mathbf{T_x}$ exceeds 7.8 and 9.1 respectively. Last line of the output shows that, compared with the reference stations, the precipitation was about 19% less after the inhomogeneity than before.

The computer program also gives some graphic output. Figure 2.3 shows the double mass curve. Figure 2.4 a,b and c shows time series of test parameter **T**, ratio $\mathbf{q_i}$ for each year, and 10-years running means of the ratios.

The inhomogenity in 1939 is visual as a change in the slope of the double mass curve (fig. 2.3), as a maximum point for the T-value (fig. 2.4a), and as a change in the ratios between the precipitation at the test station and at the reference stations (fig. 2.4c). Figure 2.4b shows the spread of the individual ratios. However, the inhomogeneity is also clearly visible in this figure, illustrating its high significance.



Figur 2.3 Double mass curve for 5848 Briksdal.

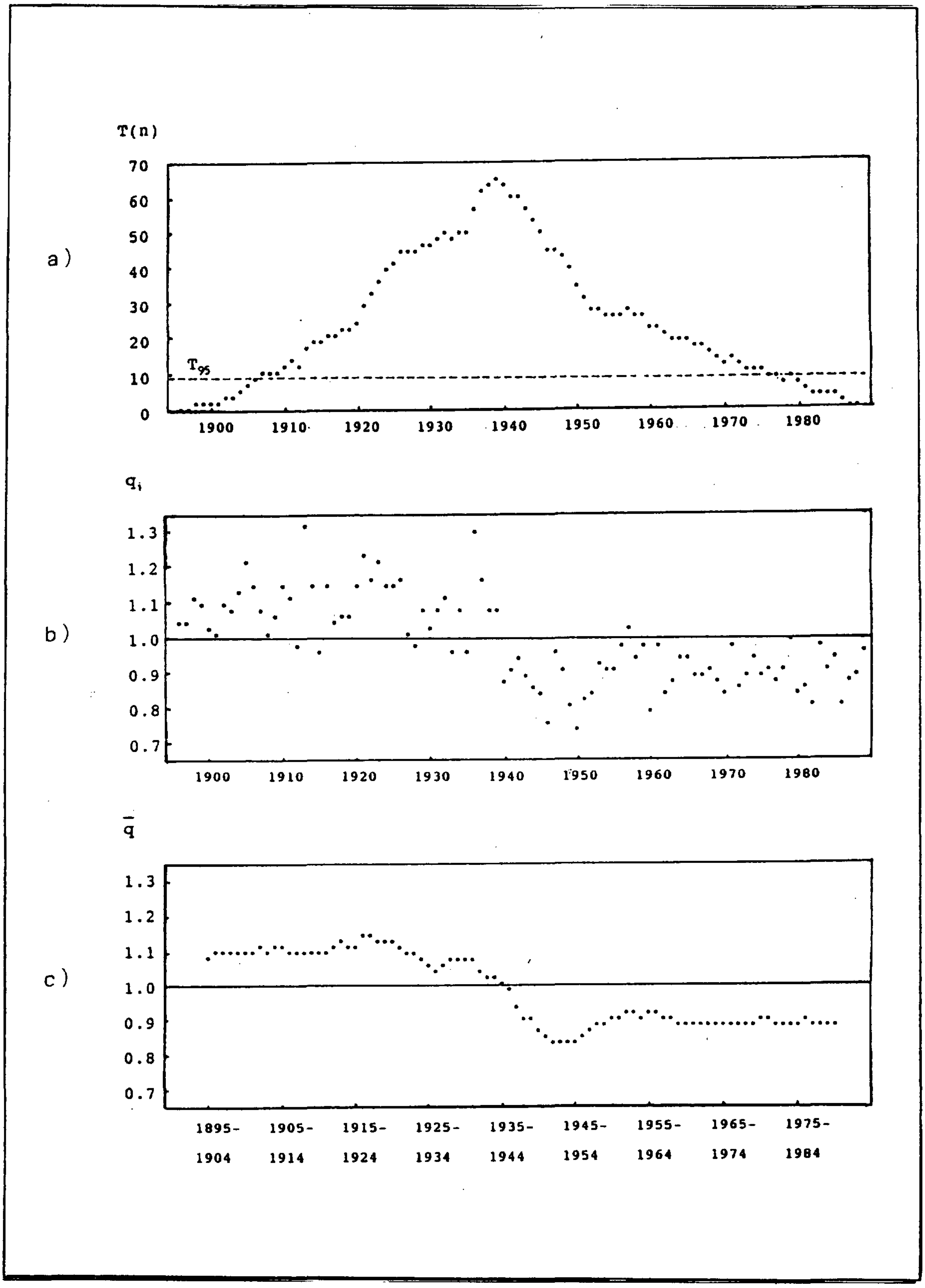


Figure 2.4 Plots for 5848 Briksdal; T-values (a), q-ratios (b) and running 10 year means of the ratios (c).

Table 2.2 Reference stations for testing homogeneity at station 3922 Mestad in Oddernes (1900-1990). Correlation coef- fisients and distances are given relative to Mestad.

STATION NO.	NAME	OBS.PERIOD FROM - TO	CORRELATION COEFFICIENT	DISTANCE (km)
3278	Høidalen/Solum	1897-1990	0.832	130
3460	Drangedal	1895-1990	0.827	119
3490	Postmyr/Dranged.	1895-1990	0.797	127
3508	Egelands verk	1889-1979	0.889	96
3845	Herefoss	1895-1990	0.918	42
3860	Mykland	1895-1990	0.886	51
3880	Tovdal	1895-1990	0.894	68
4148	Åseral	1895-1990	0.806	53
4272	Bakke	1895-1990	0.742	76

The reason for the inhomogeneity (found in the station history archive) is that the station was moved 4 km in January 1940.

Homogeneous precipitation series. The observation series from the station 3922 Mestad in Oddernes was tested against the 9 reference stations given in table 2.2.

The test gave T_x = 2,8 in year 1904. The value of T_x is far below the critical values T_{90} and T_{95}, which in this case are 7.7 and 9.1 respectively. Figure 2.5 shows the double mass curve for Mestad and the reference stations. Figure 2.6 a,b and c shows time series of T-values, ratios for each year, and 10-year running means of the ratios. Figure 2.6 b and c shows no systematic change in the ratios, and figure 2.5 shows no change in the slope of the double mass curve.

Information from the station history archive shows that the station has been situated at the same place from the beginning of registration, and that no major changes have occured in the environment of the precipitation gauge. Both station history and statistical test results thus indicate that the precipitation series from Mestad is homogegeous.

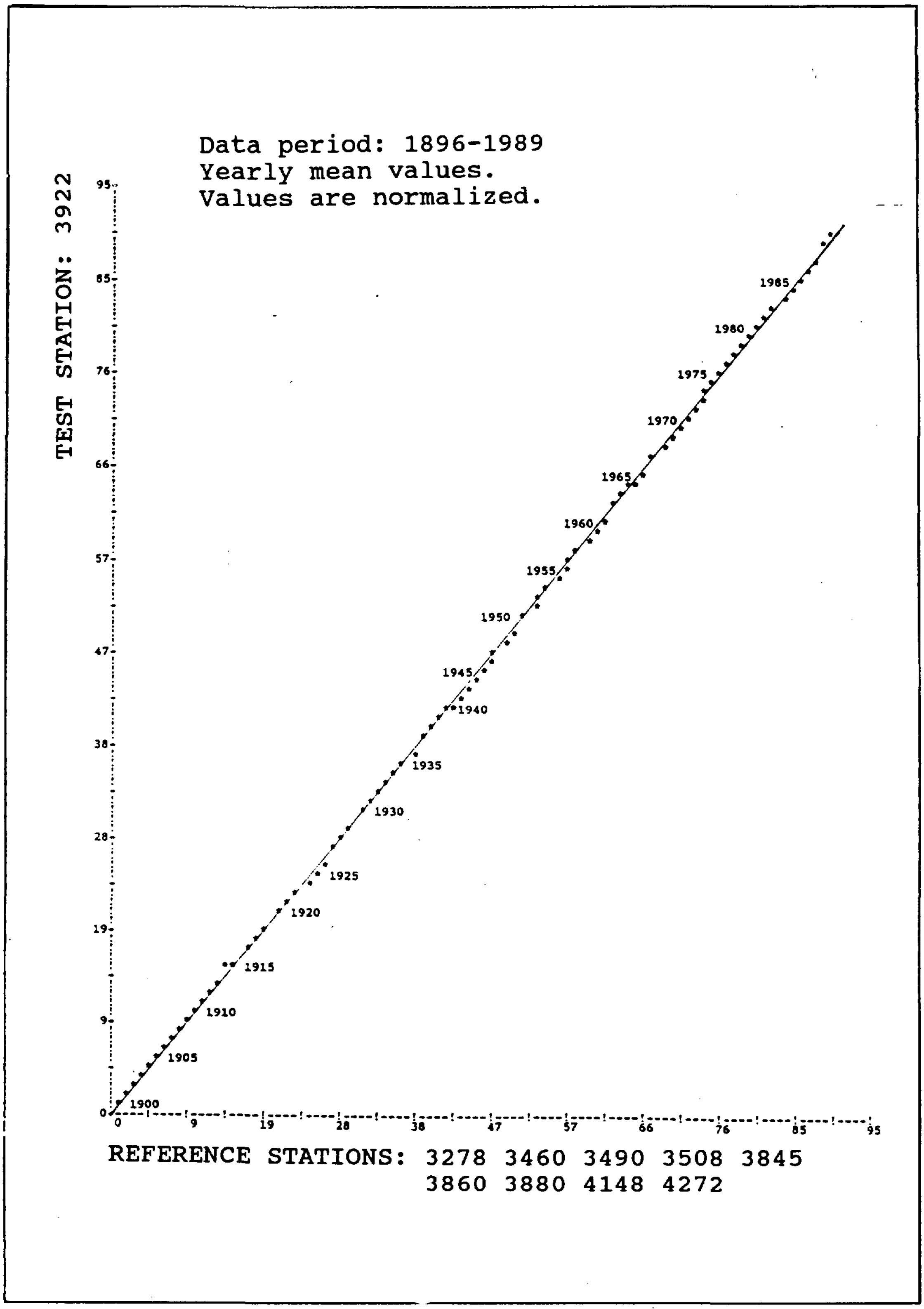


Figure 2.5 Double mass curves for 3922 Mestad.

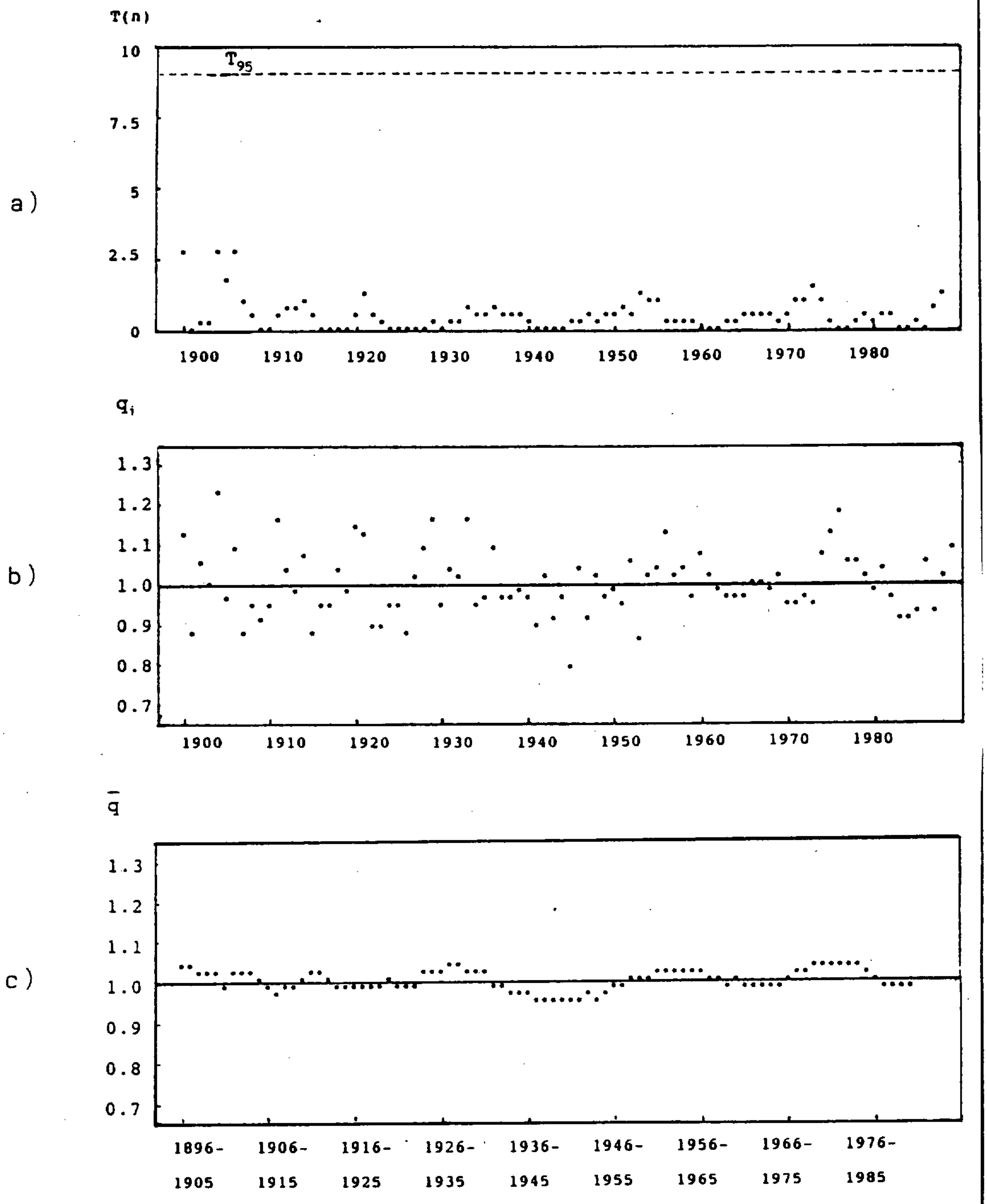


Figure 2.6 Plots for 3922 Mestad; T-values (a), q-ratios (b) and running 10-year means of the ratios (c).

2.5 Procedure for homogenizing precipitation series.

When homogeneity testing and eventual correction of inhomogeneities is to be applied on a group of stations, the test will have to be run more than once in most cases. A float diagram showing how this process is carried out at DNMI is shown in fig. 2.7. First, correlation coefficients between different time series are calculated. The correlation matrix is used to pick out reference stations for each of the test stations. The homogeneity test is then run, and the inhomogeneous series are corrected. The corrections change the basis for the correlation calculations, and the whole process has to be repeated.

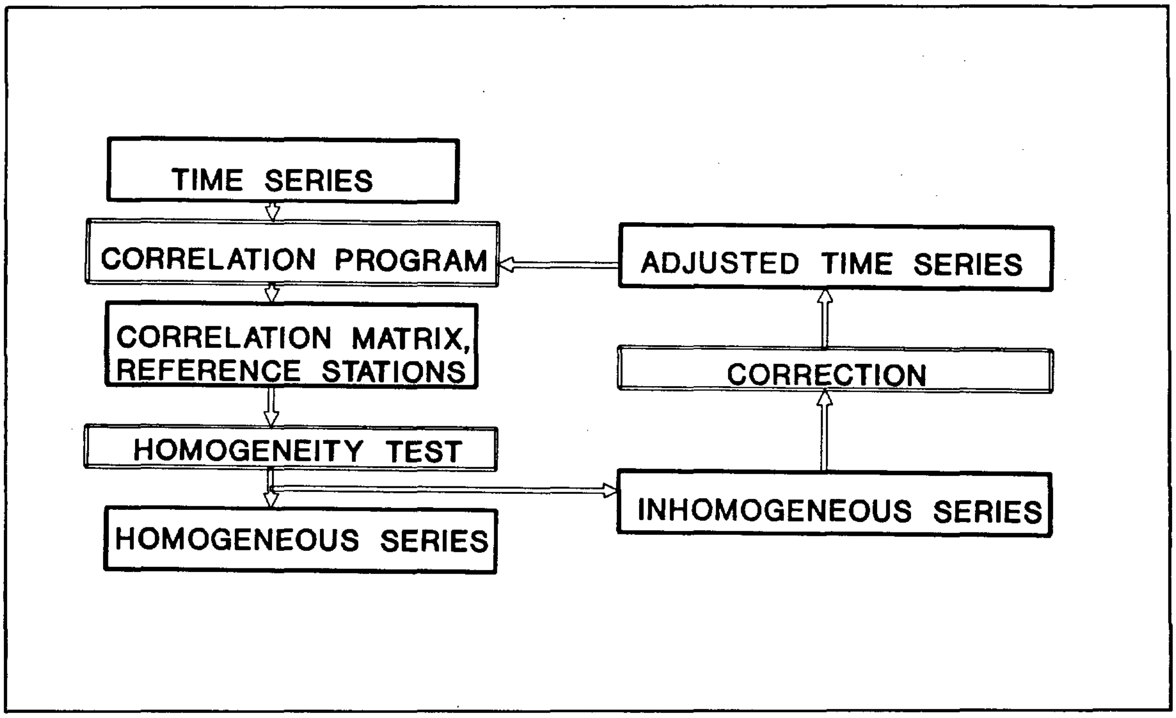


Figure 2.7 Float diagram for homogenizing.

3. APPLICATION OF THE TEST ON 151 PRECIPITATION SERIES

3.1 General description of the project.

The homogeneity test described in chapter 2 was applied on 151 of the longest Norwegian precipitation series. The map in figure 3.1 shows the position of the tested stations. The station history archives were used to find possible explanations for inhomogeneities which were detected by the test.

Before completion of this project, no network of homogeneous precipitation series existed. It was therefore impossible to satisfy the necessity of using only homogeneous reference stations. In order to reduce the effect of inhomogeneities in the reference stations, 5 - 9 reference stations were used for each test station. In cases where the test results indicated inhomogeneity (i.e. high values of T_x), tests were also run using different groups of reference stations. If the high T-value was caused by inhomogeneity in the test station, the different runs would give similar results. If, on the other hand, it was caused by inhomogeneity in one of the reference stations, the group which included the inhomogeneous series would differ considerably from other groups. In that case, test results from a run which did not include the inhomogeneous series were used in the further work. A summary of the main results of the project is given in table 3.1.

3.2 Criteria for homogeneity .

The tested precipitation series were classified as inhomogeneous if at least one of the following criteria were satisfied:

i) the series contained an inhomogeneity significant on the 95%-level;

ii) the series contained an inhomogeneity significant on the 90%-level, which was explainable by information in the station history archives.

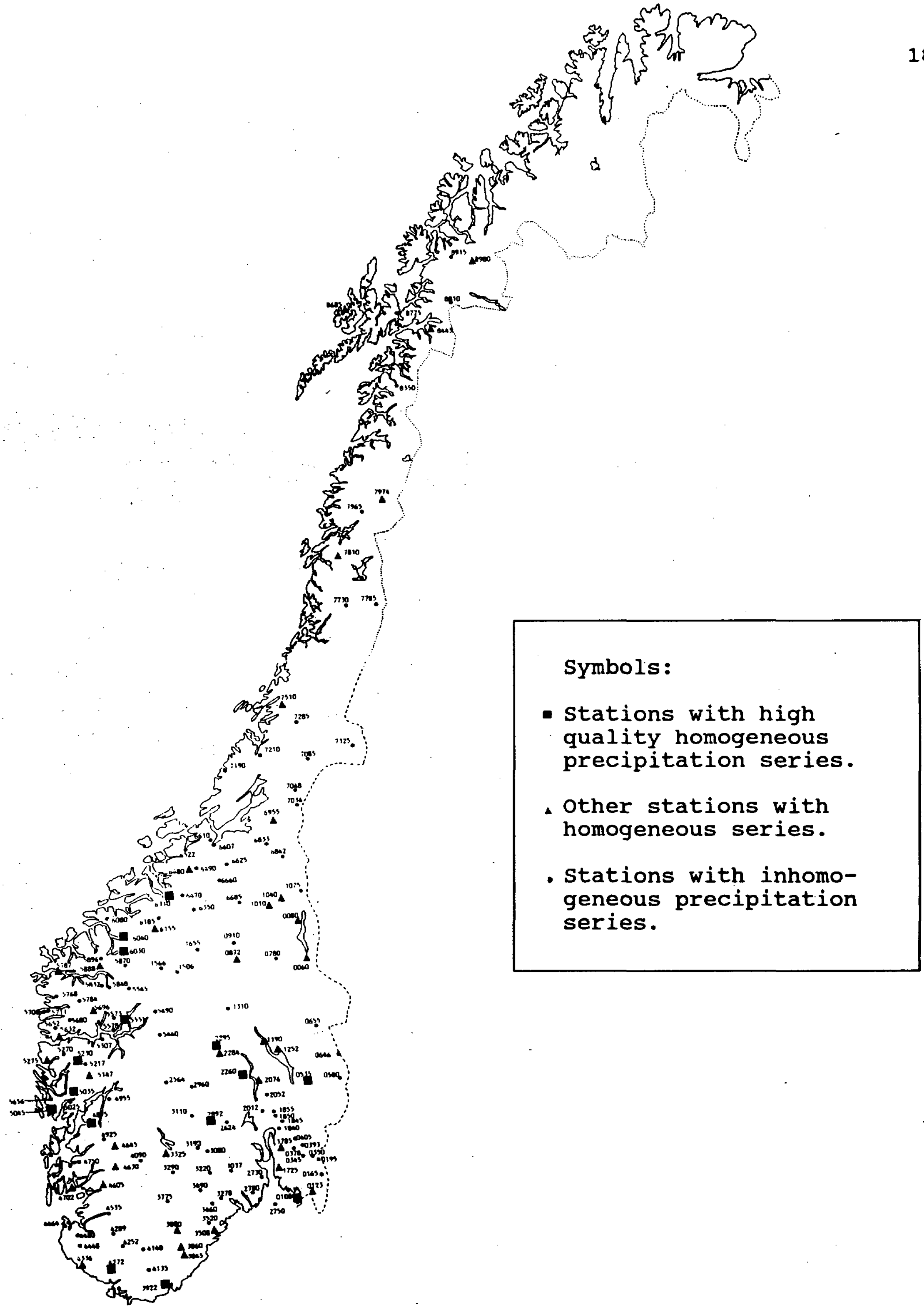


Figure 3.1 Map showing the tested precipitation stations.

Following these criteria, 52 of the tested series were homogeneous and 99 were inhomogeneous (fig. 3.1 and tab. 3.1a).

3.3 Homogeneous precipitation series.

The statistical handling of the problem implies that some of the 52 precipitation series which were classified as homogeneous after the chosen criteria, still contain inhomogeneities. These are too small to be distinguished from random variation in the distribution of precipitation, but test results indicate that they still may be considerable. In precipitation series from stations without significant inhomogeneities, relative changes in yearly precipitation compared with neighbouring stations of 7-8% may occur. Some of the stations which are here classified as homogeneous should therefore be investigated somewhat closer.

Table 3.1 Summary of test results.

a) Number of homogeneous and inhomogeneous stationes.
T is the test parameter (eq. 2.2).

Tested time series:			151	(100%)
Homogeneous:	High quality	- 15 (10%)		
	Others	- 37 (25%)		
	Total:		52	(34%)
Inhomogeneous:	One max in T	- 69 (46%)		
	More than one max in T	- 30 (20%)		
	Total:		99	(66%)

b) Reasons for break in the 99 inhomogeneous series:

Relocation of precipitation gauge:	46%
Changes in vegetation/buildings close to gauge:	20%
Installation/change of windshield:	7%
New observer:	5%
Change of gauge height above ground:	1%
Reason unknown:	20%

This may be done by testing the winter season separately, or by using data from neighbouring stations with shorter series as a supplement.

Quite a few of the series classified as homogeneous have their T_x either early or late in the series. This is in accordance with Hawkins (1977), who stated that for homogeneous series, the year of the most probable break tends to occur near either end of the series. This is a disadventage with the test (Alexandersson 1986), which may be reduced by suppressing the ends of the series (Alexandersson 1984) or by omitting the ends (Buishand,1984). Regardless, this is an argument for accepting quite high T-values close to the ends of homogeneous series without further investigation.

For 10% av of the tested stations (15 stations), a total evaluation of test results and station history indicates homogeneity so convincingly, that no further investigations are considered necessary. These stations are marked as "high quality homogeneous stations" in fig. 3.1, and are recommended for use in studies of time variation of precipitation and in further homogeneity studies.

3.4 Inhomogeneous series.

About 66% of the tested series were classified as inhomogeneous. In 20% of the series, the test parameter T had more than one clear maximum value, indicating more than one inhomogeneity. In 46% of the series, on the other hand, T had only one clear maximum. One should realize, however, that even these series may have several inhomogeneities, as a large break may "hide" a smaller break in the test. The smaller inhomogeneities will eventually be detectable when the larger one is corrected.

3.5 Main reasons for inhomogeneity.

Table 3.1b shows a summary of the reasons for the inhomogeneities found in this investigation. The most frequent reason is relocation of the precipitation gauge, which may explain almost every second inhomogeneity found by the the test. Relocation of only a few meters led to a break on several occasions. At station 5768 Eikefjord, for instance, the gauge was moved 6 m, leading to an increase in precipitation of 6% relative to the neighbouring stations.

Changes in vegetation or buildings within a radius of 20-30 m around the gauge may explain 20% of the inhomogeneities. Breaks caused by growing vegetation may be hard to detect because such changes happen gradually over long periods, and they are also difficult to make satisfactory corrections for.

Introduction/change of windshield explain only 7% of the inhomogeneities. This percentage would probably be somewhat larger for a more random group of Norwegian stations. To avoid unnecessary inhomogeneities in the long precipitation series, only 40% of the investigated stations have been equipped with a windshield (table 3.2), and in these cases, the windshields were often introduced in connection with other changes which broke the homogeneity anyway.

Table 3.2 Time intervals for introduction of windshield.

Stations:	Time intervals: 1900-1909	1910-1919	1920-1929	1930-1939	1940-1949	1950-1959	1960-1969	1970 1979	Total: 1900-1990
Number	37	7	0	11	3	1	2	1	62
%	25	5	0	7	2	1	1	1	41

Table 3.2 shows that 37 stations were equipped with wind shields during the first decade of this century (in 1906 at most stations). These stations thus may have a homogeneous record of more than 80 years after the shield was installed. (If all stations had been equipped with wind shields in the same year, it would have been very difficult to detect inhomogeneities caused by the shielding.)

New observer is given as "reason" for 5% of the inhomogeneities, in spite of the fact that the measurements ideally should be independent of the observer. Change of observer, however, occasionally leads to changes in routines which may cause inhomogeneities.

With the exception of one inhomogeneity, which was caused by a change of the height above ground of precipitation gauge, the rest of the inhomogeneous series (ca. 20%) had breaks which could not be satisfactorily explained by information from the station history archives. About half these series had more than one inhomogeneity, while the other half apparently had only one break. In the future, recommended corrections will be published for many of the inhomogeneous precipitation series. In that connection, the series with "unexplainable" inhomogeneities will be studied closer. One should be extremely cautious when making corrections for inhomogeneities whose causes are unknown.

3.6 Correction of inhomogeneous series.

The mean ratios between the normalized precipitation at the test station (eq. 2.9) and the nomalized and scaled value representative for the reference stations (eq. 2.11), valid for the periods before ($\bar{q}_b$) and after ($\bar{q}_a$) the year in which T_x appears, were calculated for all stations. The ratios between these, ($\bar{q}_a/\bar{q}_b$) are plotted against T_x in fig. 3.2, for all the inhomogeneous series.

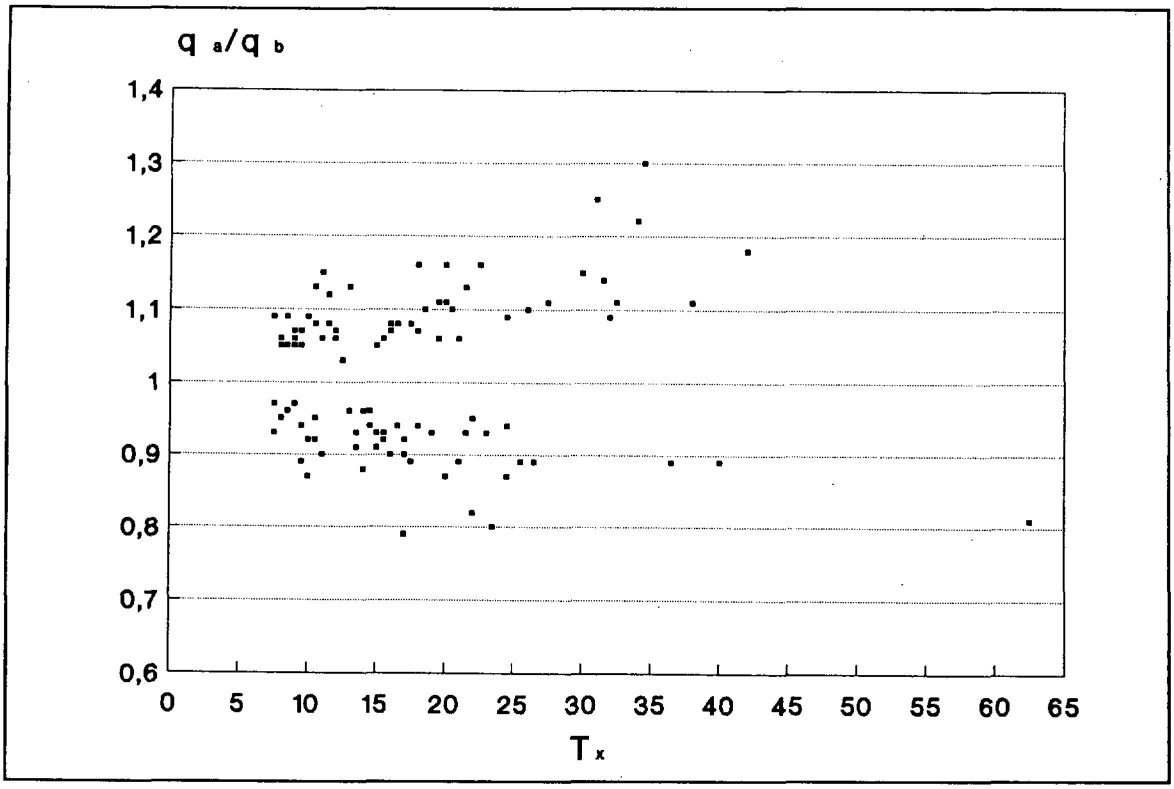


Figure 3.2 Ratio q_a/q_b plottet against testparameter T_x for each test stations.

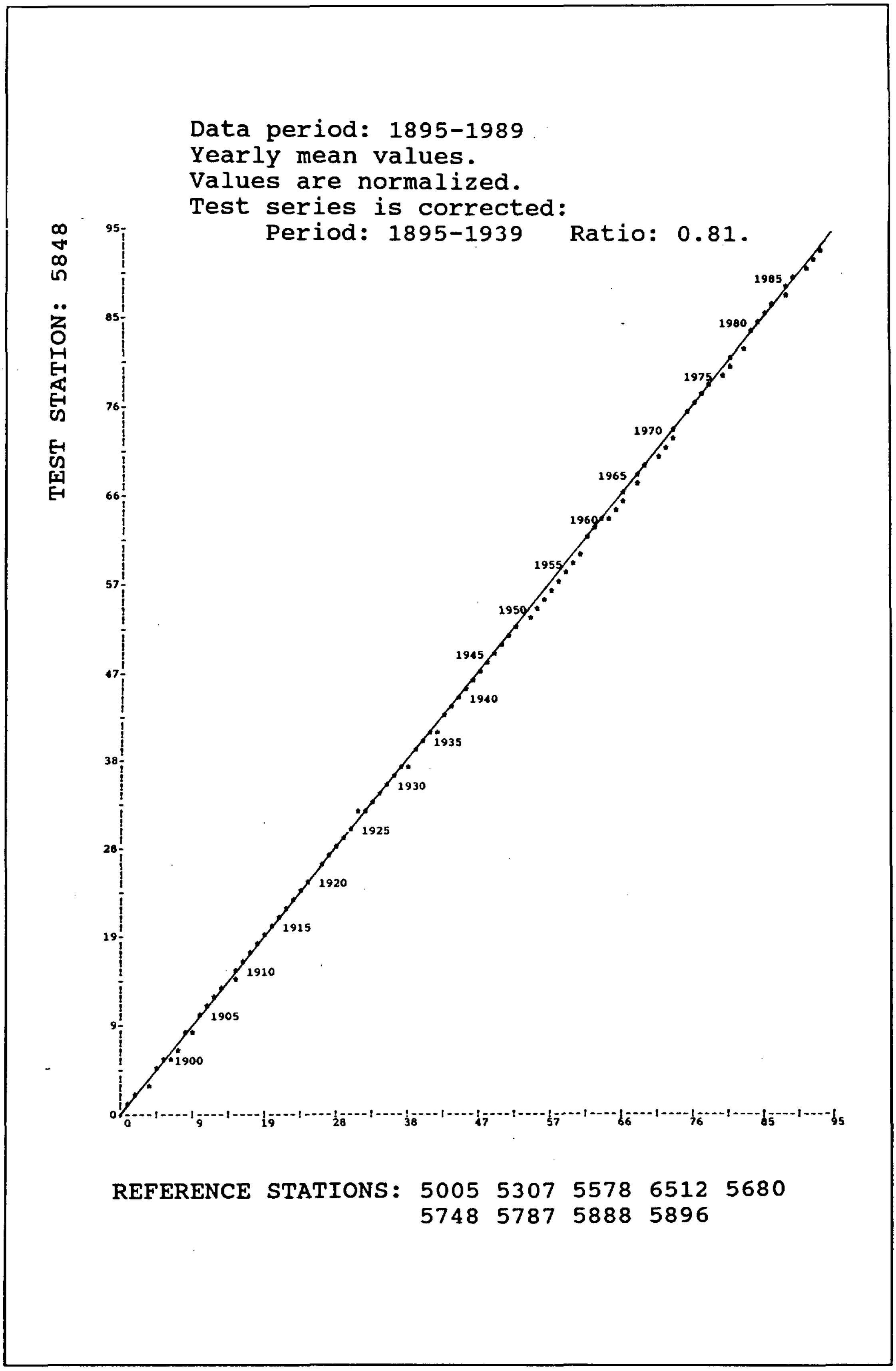
Precipitation series with one inhomogeneity only may be homogenized by multiplying mean yearly precipitation for the period before the break with $(\overline{q_a}/\overline{q_b})$. The series from 5848 Briksdal for instance, was corrected by multiplying the yearly precipitation for the period 1895-1939 with 0.81 (cf. figure 2.2). The corrected series was then homogeneity tested again using the same reference stations as were used in the first test (cf. table 2.1).

The test results, which are shown in figures 3.3, 3.4 and 3.5, should be compared with figures 2.2, 2.3 and 2.4. The value of T_x is now 1.8. This is far below the 90%-level, thus strongly indicating that the series from Briksdal contains no other inhomogeneities than the one that is already corrected.

```
HOMOGENEITY TESTING OF YEARLY PRECIPITATION
Test station: 5848
Reference stations: 5005(.64) 5307(.67) 5578(.67) 5612(.66)
         5680(0.66) 5748(.72) 5787(.67) 5888(.67) 5896(.62)
Data periode 1895-1989
The values are normalized.

Max. T-value                 :   1.8
Year for max. T-value        :  1952
Number of values (years) :    94
Does not satisfy the 90% conf.

Critical T-value (90%)       :   7.8
Critical T-value (95%)       :   9.1

Mean before inhomogeneity:   0.9891
Mean after inhomogeneity :   1.0114
Ratio after/before           :   1.0226

Relative change in cumulative sum:
Mean before inhomogeneity:   0.9863
Mean after inhomogeneity :   1.0065
Ratio after/before           :   1.0205
```

Figure 3.3 Output from testing homogeneity at the corrected series from 5848 Briksdal.

Series with more than one inhomogeneity must be divided into series containing one inhomogeneity only, before the final corrections are computed by running the test program on each part of the series. Corrections are thus found separately for each break, and they must be added up throughout the series. As every correction is uncertain, the quality of series with several corrections will never be as good as the quality of series without inhomogeneities. Examples of testing and adjusting precipitation series with several breaks are given earlier (Førland and Nordli, 1990). Some precipitation series with more than one inhomogeneity will probably be impossible to correct with a reasonable certainty.



Figur 3.4 Double mass curve for the corrected series from station 5848 Briksdal.

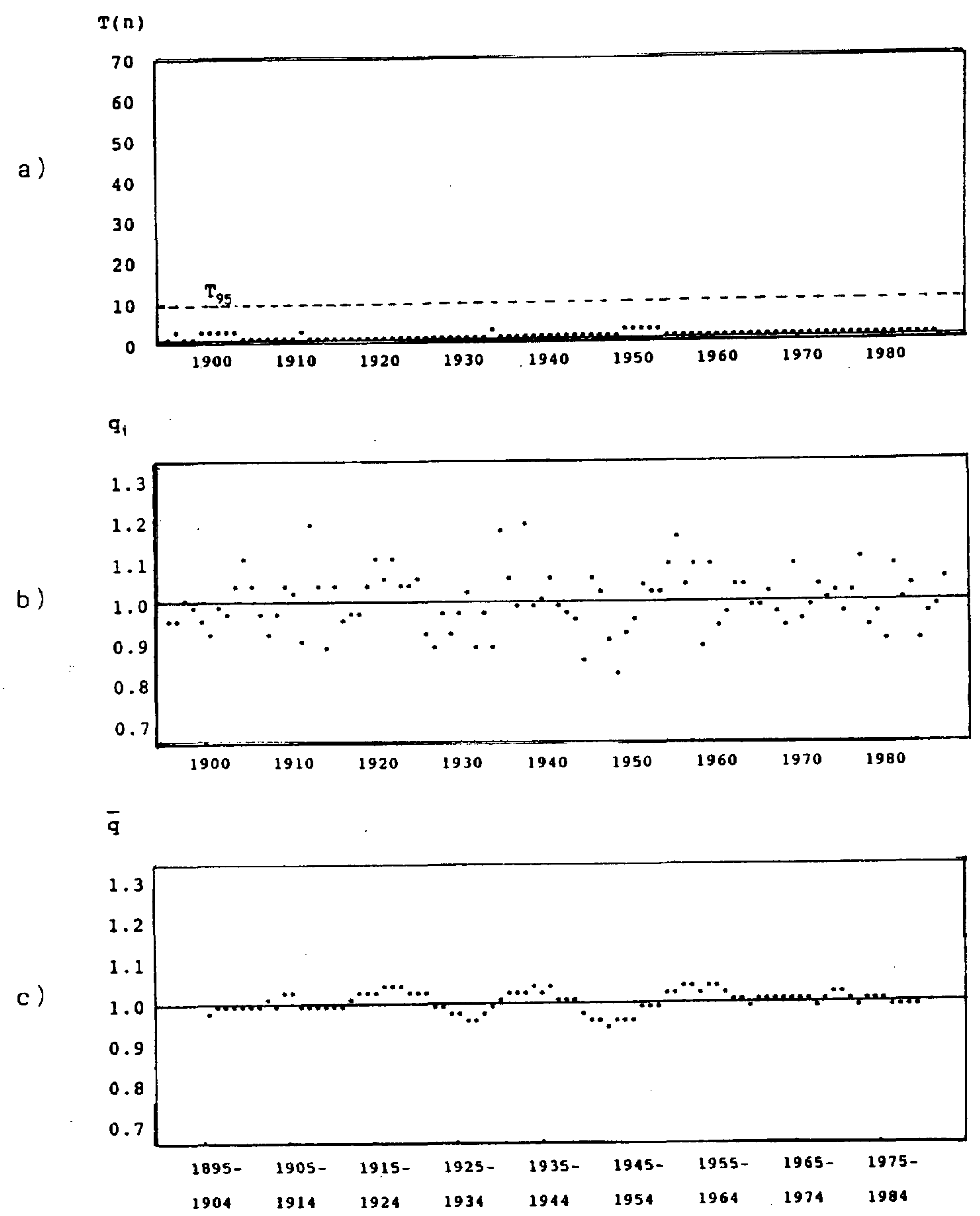


Figure 3.5 Plots for the corrected series from 5848 Briksdal; T-values (a), q-ratios (b) and running 10 year means of the ratios (c).

4. SUMMARY AND CONCLUSIONS

DNMI's system for homogeneity testing is mainly based on the "standard normal homogeneity test" (Alexanderson, 1986), but other test methods are also included. In the test procedure, it is possible to choose scaling (weigthing of reference stations) and/or normalizing (dividing the observed yearly precipitation values by the yearly mean value from the same station), and to use reference stations with shorter time series than the test station. Results from the test includes information of significant inhomogeneities, the most probable year for eventual inhomogeneities, and recommended corrections for stations with one inhomogeneity only.

The test was applied on 151 precipitation series of 75 years or more. Information about the stations from station history archives were used in addition to the test results, both to decide if series were homogeneous or not, and to decide the year for eventual inhomogeneities. The history archives were found to be an important supplement in the homogeneity studies, and a data base containing standardized information from the archives should be made in order to simplify the further work of homogeneity testing.

Of the investigated stations, 34% were classified as homogeneous, including 10% which were classified as "high quality homogeneous stations". Of the 64% of the stations which were classified as inhomogeneous, 80% had inhomogeneities that could be explained by information from the history archives. Relocation of the precipitation gauge was the most frequent explanation.

An important aim of the homogeneity testing program is to publish recommended corrections to inhomogeneous series, and in this way make them usable, for instance in trend studies. Caution should be taken to prevent real trends from being removed from the series by "corrections". In particular, one should be careful with recommending corrections for unexplained inhomogeneities. The combination of statistical methods and a historical data base is necessary to solve this problem.

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