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EVAULATION OF A METEOROLOGICAL RADIAL INTERPOLATION METHOD BY STATISTICAL EXPERIMENTS

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SUMMARY

An automated interpolation technique has been developed in order to enhance the interpolation procedures in the preliminary quality control routines at the Climatology Division.

The basis of the interpolation technique lies within the construction of statistical estimators applied to different meteorological elements such as air temperature, air pressure, relative humidity, cloud cover and precipitation. The estimator take advantage of a statistically updated correctional factor in order to reduce bias, but relies otherwise only on geographical information, using radial distance between stations as the central parameter.

The method has been tested by taking random samples of test stations and evaulating the results using same type of statistics as used for verifying forecasts. One such experiment is documentet in this report.

This particular experiments gives several score statistics for the estimation method and reveals certain difficulties with the method as it is applied today. Worst case examples are provided along with scatter plots that show general statistical characteristics of the simultaneous distribution of observed and estimated values for various meteorological elements.

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1. INTRODUCTION

In order to assure quality data for climatological applications, a systematic quality control must be applied to all meteorological observations collected and stored in the climatological databases.

One fundamental problem to consider is how to assure that observation series for vital meteorologigal elements such as air temperature, air pressure, precipitation etc. are complete. The word *interpolation*, as used in this document, refers exclusively to the procedure of inserting values in meteorological observation series in order to make the series complete based on knowledge of similar surrounding measurements within a short span of space and time.

This report documents an experiment using one such interpolation procedure. The quality control reseach at the Climatology Division at DNMI is internally conducted, and results are being presented internally. Development within the research concerning precipitation observations, however, is aligned with a Nordic precipitation quality control project FREYR (Vejen et al., 1997).

2. DATA SETS

A computer programme runs daily at DNMI pointing out missing observations in the datatable TELE which contains three terms of SYNOP data; 00, 06 and 18 hrs. UTC. For each missing observation, another programme makes estimates as to which numerical value one would have expected at these coordinates in given time and space.

For each missing value, an interpolated value is inserted into TELE and flagged in order to register it as an automatically generated value. The computer programmes made for this task is documented in a technical internal report (Øgland, 1997).

The same estimation method is used for all eight meteorological elements under consideration:

- air temperature (TT) in centigrades (°C)
- minimum air temperature (TN) in centigrades (°C)
- maximum air temperature (TX) in centigrades (°C)
- air pressure at station level (P0) in hecto Pascal (hPa)
- air pressure at sea level (P) in hecto Pascal (hPa)
- cloud cover (N) in octas (0-8)
- relative humidity (UU) in percentage (%)
- precipitation (RR) in millimeters (mm)

Interpolations are made from sets of observations with maximum recording frequency every three hours; 00, 03, 06, 09, 12, 15, 18, 21 hrs. UTC. Only observations recorded up to every six hours are interpolated; 00, 06, 12 and 18 hrs. UTC.

Observations have been taken from a selection of 15 weather stations from a list of 162 stations, where the selected stations were the ones missing data when the experiment was conducted. Test data were selected from the 3 day period October 17 1997 to October 19 1997.

3. THE RADIAL ESTIMATION METHOD

The estimation method used for interpolation and estimation of weather element x is based on a linear estimator $\overline{x}$ as described by the formula below, and is referred to, in this report, as the *radial* estimator

$$\overline{x}_i = C \sum_{j=1}^{10} w_j y_{i,j}$$

where $y_{i,j}$ is the observed value at reference station no. j, relative to the test station, recorded at time step no. i. The set w_j, $j = 1, 2, \ldots, 10$ is a set of empirically constructed values, called the *weights* for the estimator, computed from the radial distance between the test station and its reference station j with the property

$$\sum_{j=1}^{10} w_j = 1$$

More specifically, the weights w_j are constructed as functions of the following kind

$$w_j = \frac{\theta(r_j)}{\sum_{k=1}^{10} \theta(r_k)}$$

where

$$r_k^2 = (long_k - long_T)^2 + (lat_k - lat_T)^2 + (h_k - h_T)^2$$

where longitude and latitude are given in measures of 10000 * degrees + 100 * minutes + seconds, and height of station above sea level h is given in meters. The index T refers to the test station.

The function θ is defined as

$$\theta(r_k) = \exp\left(\frac{\lambda}{r_k^2}\right)$$

where the number λ at the moment is equal to 10000, chosen for numerical reasons.

The constant C is an emperically decided value. It is referred to as the *correctional factor* through out this text as it is introduced in order to reduce the bias of the estimator, and is constructed as

$$C = \frac{\sum_{i=1}^{N} x_i}{\sum_{i=1}^{N} \overline{x}_i}$$

summing through the complete period of the data set under consideration, using only occurences where both x_i and $\overline{x}_i$ have attainable values.

There are no physical understanding of the weather elements at hand programmed into the estimator. Each set of values, included code estimates for cloud cover and percentage estimates for relative humidity, are treated as floating numbers with no restrictions to range of allowable values.

4. SUMMARY STATISTICS

Statistics for evaluating the estimator are similar to statistics used at DNMI for verifying 2 meter temperature weather forecasts (Homleid, 1997). The statistical experiments have also been carried out in a similar way.

The statistics are calculated from n estimated values: $\overline{x}_i$, $i = 1, 2, \ldots, n$
and the corresponding observations: x_i, $i = 1, 2, \ldots, n$

The error e is defined as:

$$e_i = \bar{x}_i - x_i,\ i = 1, 2, \ldots, n$$

Mean error:

$$bias = \frac{1}{n}\sum_{i=1}^{n} e_i$$

Standard deviation of the errors:

$$stde = \sqrt{\frac{\sum_{i=1}^{n}(e_i - bias)^2}{n-1}}$$

Root mean square error:

$$rmse = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}$$

Mean absolute error:

$$mae = \frac{1}{n}\sum_{i=1}^{n} |e_i|$$

Min absolute error:

$$emin = \min(|e_i|),\ i = 1, 2, \ldots, n$$

Max absolute error:

$$emax = \max(|e_i|),\ i = 1, 2, \ldots, n$$

The result of the calculations is presented in Table 2 in Appendix 1.

Below is a series of tables, table 1.1, 1.2, 1.3 etc., giving summary statistics and description of worst case interpolation with complete description of all empirical data used for generating estimators along with plots of observed and estimated values.

The assumption of the radial method is that the closer a reference station is to the test station, the better it would be correlated. If all reference stations very perfectly correlated, the estimated values would, of course, be a perfect fit, provided a perfect correctional factor could be made.

As there is no guarantee that the closest reference stations, of a certain test station, would be best correlated, with respect to the weather element in question, correlation values have been calculated for all reference stations.

As the choice of reference stations is independent of which meteorological element one wants to estimate, there may be cases where a referece station is chosen that does not support measurements of this particular element. In such cases the correlation is by default assigned the value of zero.

Table 1.1. Statistics for air temperature (TT) in centigrades (°C) using the radial method.

TT at 15 stations	Sample size	Bias	Stde	Rmse	Mae	Emin	Emax
minimum	8 (V97350)	0.0 (V86760)	0.6 (V99720)	0.6 (V99720)	0.4 (V99720)	0.0 (V99720)	1.3 (V85910)
median	11 (V42920)	0.0 (V85910)	1.6 (V51670)	1.5 (V51670)	1.3 (V51670)	0.2 (V86780)	2.6 (V86780)
maximum	24 (V16610)	0.0 (A53101)	51.9 (V97350)	48.5 (V97350)	45.0 (V97350)	24.0 (V97350)	84.4 (V97350)
average	15	0.0	7.1	6.8	6.1	2.1	12.6
stddev	7	0.0	13.8	13.0	12.0	6.2	22.4

Weather station V97350 CUOVDDATMOHKKI has the greatest rmse.

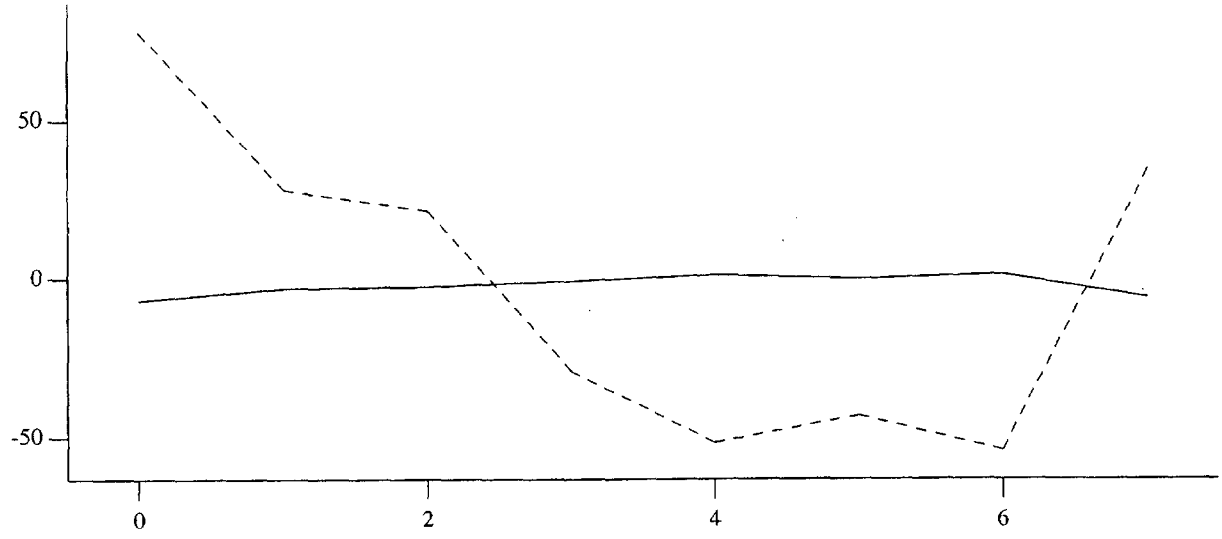
Sample size = 8 Bias = 0.0 Stde = 51.9 Rmse = 48.5 Mae = 45.0 Emin = 24.0 Emax = 84.4

Reference stations and weights for estimating:

Ref no. 1. 95350 BANAK at 70°03'60"N, 24°59'40"E, 5 m a.s.l.	Weight $w_1 = 31$	Corr = 0.98
Ref no. 2. 93300 SUOLOVUOPMI at 69°35'30"N, 23°31'90"E, 374 m a.s.l.	Weight $w_2 = 29$	Corr = 1.00
Ref no. 3. 97250 KARASJOK at 69°28'00"N, 25°30'60"E, 129 m a.s.l.	Weight $w_3 = 26$	Corr = 1.00
Ref no. 4. 93140 ALTA LUFTHAVN at 69°58'65"N, 23°21'49"E, 3 m a.s.l.	Weight $w_4 = 25$	Corr = 0.98
Ref no. 5. 93900 SIHCAJAVRI at 68°45'02"N, 23°32'02"E, 382 m a.s.l.	Weight $w_5 = 23$	Corr = 0.97
Ref no. 6. 93700 KAUTOKEINO at 68°59'81"N, 23°02'01"E, 306 m a.s.l.	Weight $w_6 = 21$	Corr = 0.98
Ref no. 7. 94500 FRUHOLMEN FYR at 71°05'60"N, 23°59'70"E, 13 m a.s.l.	Weight $w_7 = 17$	Corr = 0.73
Ref no. 8. 94700 HELNES FYR at 71°03'80"N, 26°13'80"E, 33 m a.s.l.	Weight $w_8 = 15$	Corr = 0.90
Ref no. 9. 92350 NORDSTRAUM I KVÆNANGEN at 69°50'02"N, 21°53'06"E, 6 m a.s.l.	Weight $w_9 = 14$	Corr = 0.99
Ref no. 10. 92700 LOPPA at 70°20'30"N, 21°28'00"E, 10 m a.s.l.	Weight $w_{10} = 14$	Corr = 1.00

Correctional factor C equals -21.018.

Figure 1.1. Observations TT and estimates $\overline{TT}$ at weather station CUOVDDATMOHKKI.



Solid curve represent observations of TT, dashed curve represent estimates using the radial method

Table 1.2. Statistics for minimum air temperature (TN) in centigrades (°C) using the radial method.

TN at 15 stations	Sample size	Bias	Stde	Rmse	Mae	Emin	Emax
minimum	4 (V95350)	0.0 (V86760)	0.8 (V18700)	0.7 (V18700)	0.6 (V18700)	0.0 (V85910)	1.3 (V95350)
median	6 (V99720)	0.0 (V85910)	1.7 (A53101)	1.5 (A53101)	1.3 (A53101)	0.2 (V99720)	2.4 (A53101)
maximum	6 (A53101)	0.0 (A53101)	22.9 (V86780)	20.5 (V86780)	15.4 (V86780)	3.1 (V32920)	38.4 (V86780)
average	6	0.0	4.6	4.1	3.3	0.7	7.2
stddev	1	0.0	6.1	5.5	4.2	1.1	10.2

Weather station V86780 LITLØY FYR has the greatest rmse.

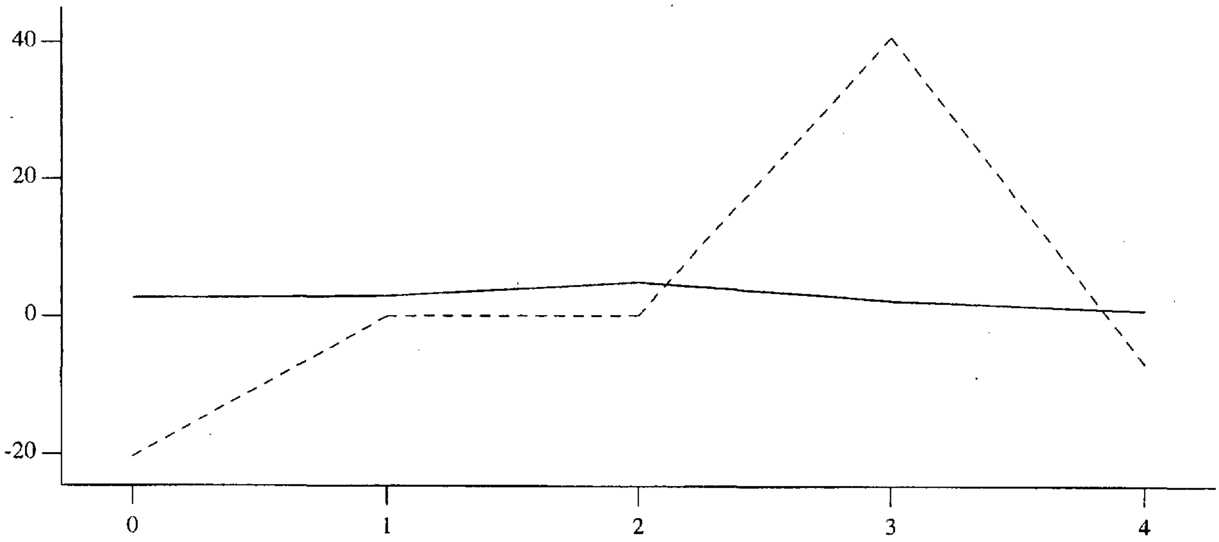
Sample size = 5 Bias = 0.0 Stde = 22.9 Rmse = 20.5 Mae = 15.4 Emin = 2.9 Emax = 38.4

Reference stations and weights for estimating:

Ref no. 1. 86760 BØ I VESTERÅLEN II at 68°37'93"N, 14°27'78"E, 12 m a.s.l.	Weight w_1 = 391609	Corr = 1.00
Ref no. 2. 85380 SKROVA FYR at 68°09'02"N, 14°39'05"E, 11 m a.s.l.	Weight w_2 = 198	Corr = 1.00
Ref no. 3. 86500 SORTLAND at 68°42'02"N, 15°25'01"E, 3 m a.s.l.	Weight w_3 = 26	Corr = 1.00
Ref no. 4. 82290 BODØ VI at 67°16'45"N, 14°26'01"E, 11 m a.s.l.	Weight w_4 = 23	Corr = 1.00
Ref no. 5. 83550 FINNØY I HAMARØY at 68°00'04"N, 15°36'59"E, 53 m a.s.l.	Weight w_5 = 23	Corr = 1.00
Ref no. 6. 80950 TENNHOLMEN FYR at 67°18'12"N, 13°29'94"E, 14 m a.s.l.	Weight w_6 = 20	Corr = 1.00
Ref no. 7. 81650 SALTDAL - NORDNES at 66°56'21"N, 15°18'83"E, 37 m a.s.l.	Weight w_7 = 16	Corr = 1.00
Ref no. 8. 87110 ANDØYA at 69°17'80"N, 16°08'80"E, 10 m a.s.l.	Weight w_8 = 16	Corr = 1.00
Ref no. 9. 79530 RANA - BÅSMOEN at 66°19'91"N, 14°06'14"E, 40 m a.s.l.	Weight w_9 = 16	Corr = 1.00
Ref no. 10. 85910 RØST II at 67°30'38"N, 12°04'57"E, 10 m a.s.l.	Weight w_{10} = 15	Corr = -1.00

Correctional factor C equals 67.892.

Figure 1.2. Observations TN and estimates $\overline{TN}$ at weather station LITLØY FYR.



Solid curve represent observations of TN, dashed curve represent estimates using the radial method

Table 1.3. Statistics for maximum air temperature (TX) in centigrades (°C) using the radial method.

TX at 15 stations	Sample size	Bias	Stde	Rmse	Mae	Emin	Emax
minimum	5 (V86780)	0.0 (V86760)	0.5 (V46910)	0.5 (V46910)	0.4 (V46910)	0.1 (V99720)	0.7 (V46910)
median	6 (V97350)	0.0 (V85910)	1.6 (V42920)	1.4 (V42920)	1.2 (V16610)	0.3 (V99840)	2.6 (V86760)
maximum	6 (A53101)	0.0 (A53101)	219.9 (V93140)	196.7 (V93140)	153.1 (V93140)	11.1 (V93140)	382.7 (V93140)
average	6	0.0	16.4	14.7	11.5	1.1	28.2
stddev	0	0.0	56.3	50.4	39.2	2.8	98.1

Weather station V93140 ALTA LUFTHAVN has the greatest rmse.

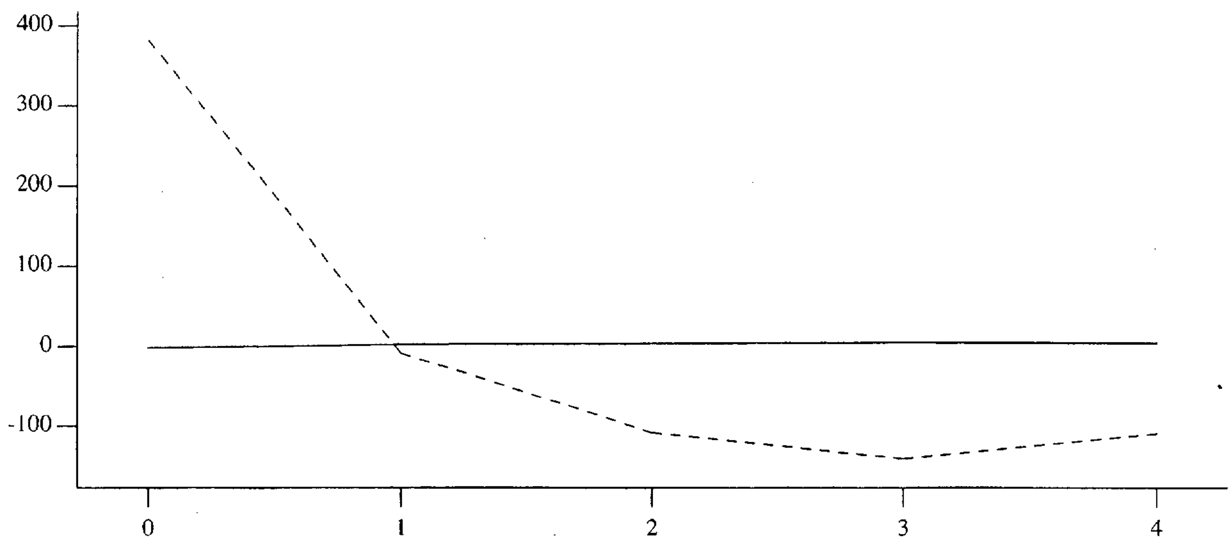
Sample size = 5 Bias = 0.0 Stde = 219.9 Rmse = 196.7 Mae = 153.1 Emin = 11.1 Emax = 382.7

Reference stations and weights for estimating:

Ref no. 1. 93300 SUOLOVUOPMI at 69°35'30"N, 23°31'90"E, 374 m a.s.l.	Weight $w_1 = 480$	Corr = 0.00
Ref no. 2. 93700 KAUTOKEINO at 68°59'81"N, 23°02'01"E, 306 m a.s.l.	Weight $w_2 = 27$	Corr = 0.00
Ref no. 3. 97350 CUOVDDATMOHKKI at 69°22'02"N, 24°26'00"E, 286 m a.s.l.	Weight $w_3 = 25$	Corr = 0.00
Ref no. 4. 93900 SIHCAJAVRI at 68°45'02"N, 23°32'02"E, 382 m a.s.l.	Weight $w_4 = 24$	Corr = 0.00
Ref no. 5. 95350 BANAK at 70°03'60"N, 24°59'40"E, 5 m a.s.l.	Weight $w_5 = 20$	Corr = 0.00
Ref no. 6. 94500 FRUHOLMEN FYR at 71°05'60"N, 23°59'70"E, 13 m a.s.l.	Weight $w_6 = 19$	Corr = 0.00
Ref no. 7. 92350 NORDSTRAUM I KVÆNANGEN at 69°50'02"N, 21°53'06"E, 6 m a.s.l.	Weight $w_7 = 18$	Corr = 0.00
Ref no. 8. 92700 LOPPA at 70°20'30"N, 21°28'00"E, 10 m a.s.l.	Weight $w_8 = 16$	Corr = 0.00
Ref no. 9. 97250 KARASJOK at 69°28'00"N, 25°30'60"E, 129 m a.s.l.	Weight $w_9 = 16$	Corr = 0.00
Ref no. 10. 91760 NORDREISA - ØYENG at 69°44'00"N, 21°01'00"E, 5 m a.s.l.	Weight $w_{10} = 16$	Corr = 0.00

Correctional factor C equals -86.353.

Figure 1.3. Observations TX and estimates $\overline{TX}$ at weather station ALTA LUFTHAVN.



Solid curve represent observations of TX, dashed curve represent estimates using the radial method

Table 1.4. Statistics for air pressure at station level (P0) in hecto Pascal (hPa) using the radial method.

P0 at 10 stations	Sample size	Bias	Stde	Rmse	Mae	Emin	Emax
minimum	8 (V86760)	0.0 (V86760)	0.3 (V18700)	0.3 (V18700)	0.2 (V18700)	0.0 (V18700)	0.6 (V18700)
median	21 (V99720)	0.0 (V16610)	5.5 (V93140)	5.4 (V93140)	3.7 (V93140)	0.2 (V86760)	10.6 (V99840)
maximum	24 (V16610)	0.0 (A53101)	49.4 (A53101)	48.4 (A53101)	46.5 (A53101)	21.6 (A53101)	61.8 (A53101)
average	17	0.0	8.4	8.2	7.2	2.4	13.6
stddev	7	0.0	14.7	14.4	14.0	6.7	18.4

Weather station A53101 VANGSNES has the greatest rmse.

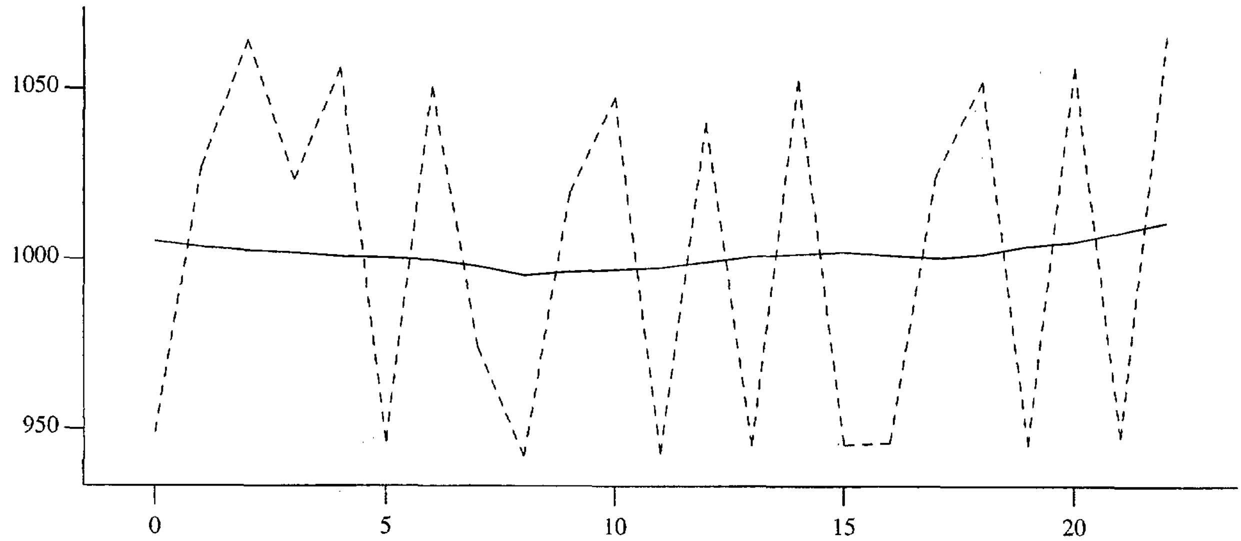
Sample size = 24 Bias = 0.0 Stde = 49.4 Rmse = 48.4 Mae = 46.5 Emin = 21.6 Emax = 61.8

Reference stations and weights for estimating:

Ref no. 1. 51670 REIMEGREND at 60°41'10"N, 06°44'60"E, 590 m a.s.l.	Weight $w_1 = 42$	Corr = 0.00
Ref no. 2. 51590 VOSS - BØ at 60°38'70"N, 06°29'70"E, 125 m a.s.l.	Weight $w_2 = 40$	Corr = 0.99
Ref no. 3. 49580 EIDFJORD - BU at 60°28'03"N, 06°51'63"E, 165 m a.s.l.	Weight $w_3 = 33$	Corr = 1.00
Ref no. 4. 57420 FØRDE - TEFRE at 61°27'89"N, 05°55'37"E, 64 m a.s.l.	Weight $w_4 = 32$	Corr = 0.97
Ref no. 5. 54120 LÆRDAL - MOLDO at 61°04'00"N, 07°31'00"E, 24 m a.s.l.	Weight $w_5 = 30$	Corr = 0.96
Ref no. 6. 52290 MODALEN II at 60°50'46"N, 05°57'20"E, 114 m a.s.l.	Weight $w_6 = 27$	Corr = 0.00
Ref no. 7. 52860 TAKLE at 61°01'60"N, 05°23'10"E, 38 m a.s.l.	Weight $w_7 = 24$	Corr = 0.00
Ref no. 8. 25830 FINSEVATN at 60°35'55"N, 07°31'83"E, 1210 m a.s.l.	Weight $w_8 = 23$	Corr = 0.98
Ref no. 9. 50300 KVAMSKOGEN at 60°23'60"N, 05°54'80"E, 408 m a.s.l.	Weight $w_9 = 23$	Corr = 0.00
Ref no. 10. 15720 BRÅTÅ at 61°54'40"N, 07°51'60"E, 712 m a.s.l.	Weight $w_{10} = 23$	Corr = 0.99

Correctional factor C equals 1.089.

Figure 1.4. Observations $P0$ and estimates $\overline{P0}$ at weather station VANGSNES.



Solid curve represent observations of P0, dashed curve represent estimates using the radial method

Table 1.5. Statistics for air pressure at sea level (P) in hecto Pascal (hPa) using the radial method.

P at 11 stations	Sample size	Bias	Stde	Rmse	Mae	Emin	Emax
minimum	8 (V86760)	0.0 (V86760)	0.3 (V18700)	0.3 (V18700)	0.2 (V18700)	0.0 (V93140)	0.7 (V18700)
median	17 (V93140)	0.0 (V85910)	1.3 (V85910)	1.2 (V85910)	0.9 (V86760)	0.1 (V46910)	2.7 (A53101)
maximum	24 (V16610)	0.0 (A53101)	5.9 (V99720)	5.7 (V99720)	4.7 (V99720)	0.4 (V99840)	10.6 (V99720)
average	17	0.0	2.0	1.9	1.6	0.1	3.8
stddev	7	0.0	1.8	1.8	1.6	0.1	3.0

Weather station V99720 HOPEN has the greatest rmse.

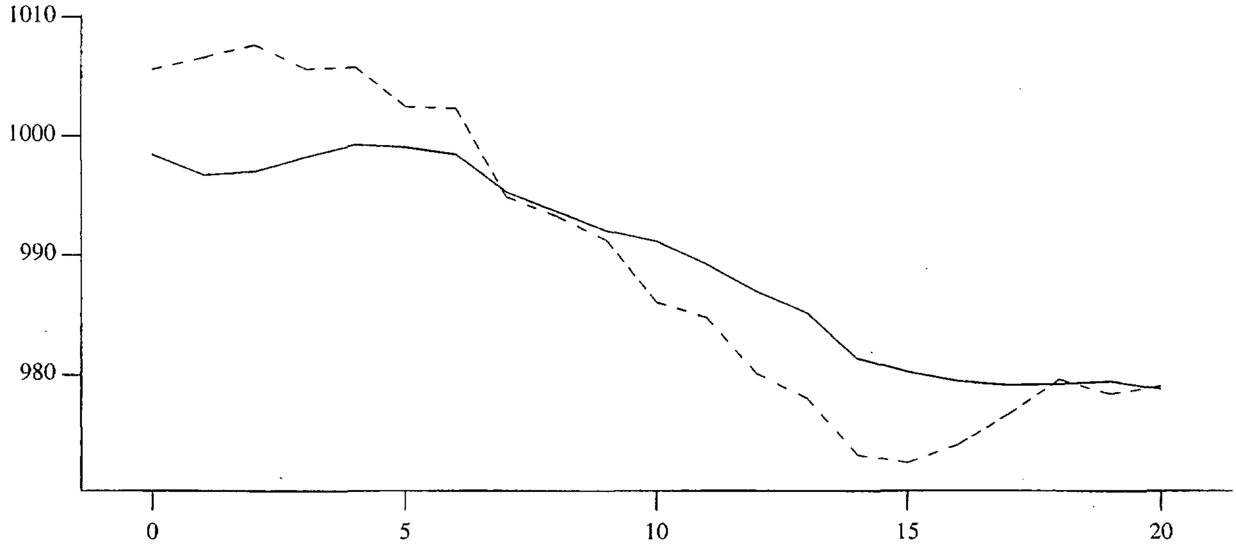
Sample size = 21 Bias = 0.0 Stde = 5.9 Rmse = 5.7 Mae = 4.7 Emin = 0.2 Emax = 10.6

Reference stations and weights for estimating:

Ref no. 1. 99735 EDGEØYA at 78°14'00"N, 22°47'00"E, 14 m a.s.l.	Weight $w_1 = 14$	Corr = 0.00
Ref no. 2. 94700 HELNES FYR at 71°03'80"N, 26°13'80"E, 33 m a.s.l.	Weight $w_2 = 12$	Corr = 0.00
Ref no. 3. 94500 FRUHOLMEN FYR at 71°05'60"N, 23°59'70"E, 13 m a.s.l.	Weight $w_3 = 12$	Corr = 0.43
Ref no. 4. 96400 SLETTNES FYR at 71°05'04"N, 28°13'07"E, 8 m a.s.l.	Weight $w_4 = 12$	Corr = 0.43
Ref no. 5. 95350 BANAK at 70°03'60"N, 24°59'40"E, 5 m a.s.l.	Weight $w_5 = 12$	Corr = -0.54
Ref no. 6. 99710 BJØRNØYA at 74°31'00"N, 19°01'00"E, 16 m a.s.l.	Weight $w_6 = 12$	Corr = 0.48
Ref no. 7. 96800 RUSTEFJELBMA at 70°24'02"N, 28°12'01"E, 9 m a.s.l.	Weight $w_7 = 12$	Corr = -0.64
Ref no. 8. 93140 ALTA LUFTHAVN at 69°58'65"N, 23°21'49"E, 3 m a.s.l.	Weight $w_8 = 12$	Corr = -0.62
Ref no. 9. 97250 KARASJOK at 69°28'00"N, 25°30'60"E, 129 m a.s.l.	Weight $w_9 = 12$	Corr = -0.53
Ref no. 10. 97350 CUOVDDATMOHKKI at 69°22'02"N, 24°26'00"E, 286 m a.s.l.	Weight $w_{10} = 12$	Corr = 0.00

Correctional factor C equals 0.996.

Figure 1.5. Observations P and estimates $\overline{P}$ at weather station HOPEN.



Solid curve represent observations of P, dashed curve represent estimates using the radial method

Table 1.6. Statistics for cloud cover (N) in octas (0-8) using the radial method.

N at 14 stations	Sample size	Bias	Stde	Rmse	Mae	Emin	Emax
minimum	8 (V51670)	0.0 (V86780)	0.6 (V85910)	0.6 (V85910)	0.4 (V85910)	0.0 (V85910)	1.6 (V51670)
median	11 (V86780)	0.0 (V16610)	1.2 (V86760)	1.1 (V86760)	0.9 (V97350)	0.1 (V93140)	2.2 (V86780)
maximum	24 (V18700)	0.0 (V85910)	2.1 (V16610)	2.0 (V16610)	1.5 (V16610)	0.3 (V32920)	4.4 (V42920)
average	13	0.0	1.3	1.2	1.0	0.1	2.6
stddev	6	0.0	0.5	0.5	0.4	0.1	1.0

Weather station V16610 FOKSTUA II has the greatest rmse.

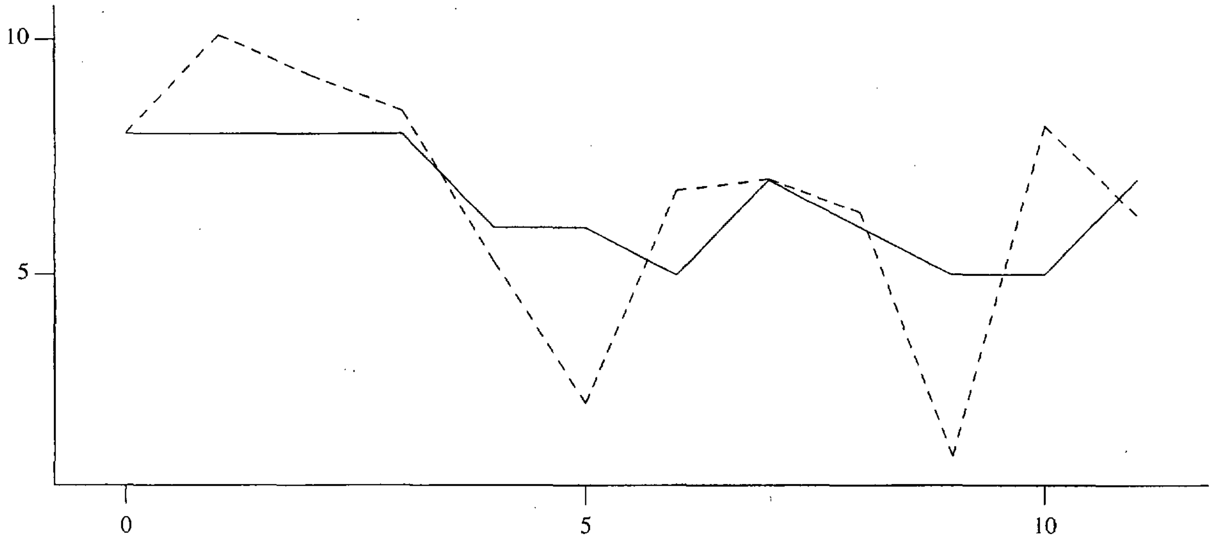
Sample size = 12 Bias = 0.0 Stde = 2.1 Rmse = 2.0 Mae = 1.5 Emin = 0.0 Emax = 3.9

Reference stations and weights for estimating:

Ref no. 1. 66770 OPPDAL - MAURHAUGEN at 62°39'73"N, 09°49'29"E, 668 m a.s.l. Weight $w_1 = 88$ Corr = 0.00
Ref no. 2. 13670 SKÅBU - STORSLÅEN at 61°30'91"N, 09°22'94"E, 890 m a.s.l. Weight $w_2 = 37$ Corr = 0.00
Ref no. 3. 13160 KVITFJELL at 61°29'00"N, 09°58'00"E, 1030 m a.s.l. Weight $w_3 = 31$ Corr = 0.00
Ref no. 4. 66730 BERKÅK - LYNGHOLT at 62°49'04"N, 10°01'03"E, 475 m a.s.l. Weight $w_4 = 29$ Corr = 0.00
Ref no. 5. 61770 LESJASKOG at 62°13'90"N, 08°22'40"E, 621 m a.s.l. Weight $w_5 = 29$ Corr = 0.00
Ref no. 6. 08710 SØRNESSET at 61°53'22"N, 10°09'21"E, 739 m a.s.l. Weight $w_6 = 26$ Corr = 0.00
Ref no. 7. 64550 TINGVOLL - HANEM at 62°50'43"N, 08°17'90"E, 69 m a.s.l. Weight $w_7 = 25$ Corr = 0.00
Ref no. 8. 13420 VENABU at 61°39'01"N, 10°06'65"E, 930 m a.s.l. Weight $w_8 = 24$ Corr = 0.00
Ref no. 9. 65110 VINJEØRA II at 63°12'45"N, 09°59'82"E, 47 m a.s.l. Weight $w_9 = 24$ Corr = 0.00
Ref no. 10. 10000 TYNSET II at 62°16'86"N, 10°47'97"E, 482 m a.s.l. Weight $w_{10} = 21$ Corr = 0.00

Correctional factor C equals 1.121.

Figure 1.6. Observations N and estimates $\overline{N}$ at weather station FOKSTUA II.



Solid curve represent observations of N, dashed curve represent estimates using the radial method

Table 1.7. Statistics for relative humidity (UU) in percentage (%) using the radial method.

UU at 15 stations	Sample size	Bias	Stde	Rmse	Mae	Emin	Emax
minimum	8 (V86760)	0.0 (V86760)	4.2 (V46910)	3.9 (V46910)	3.6 (V46910)	0.1 (V42920)	6.6 (V46910)
median	11 (V95350)	0.0 (V85910)	8.6 (V97350)	8.1 (V97350)	6.2 (V99720)	0.2 (V99840)	17.1 (V18700)
maximum	24 (V18700)	0.0 (A53101)	12.6 (V42920)	12.0 (V42920)	9.1 (V32920)	4.3 (V32920)	35.6 (V42920)
average	13	0.0	8.4	8.1	6.4	0.7	17.3
stddev	6	0.0	2.5	2.3	1.8	1.2	6.9

Weather station V42920 SIRDAL - TJØRHOM has the greatest rmse.

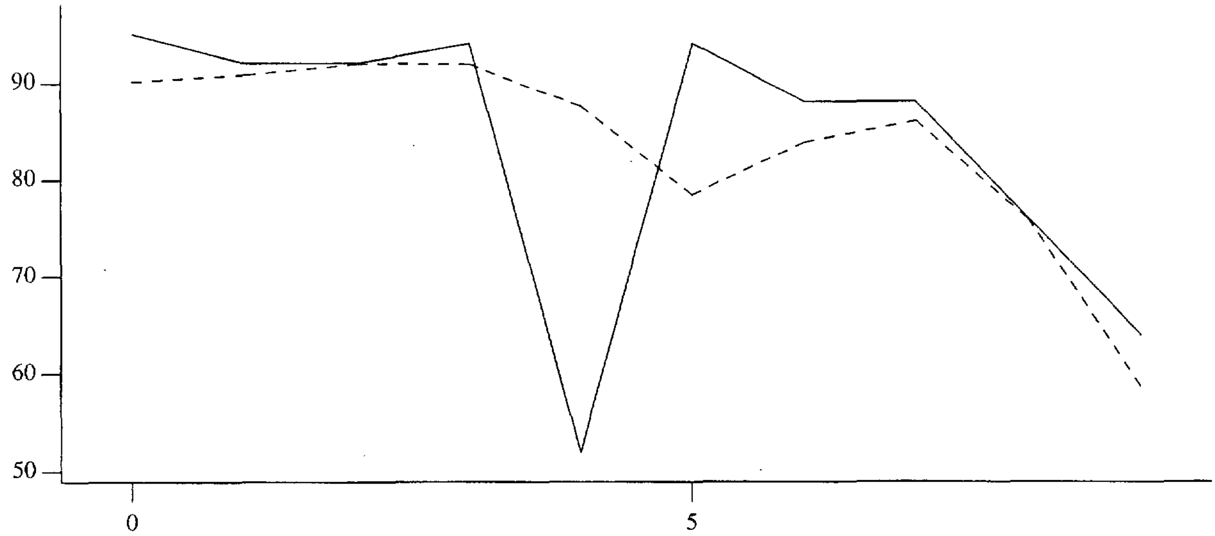
Sample size = 11 Bias = 0.0 Stde = 12.6 Rmse = 12.0 Mae = 6.5 Emin = 0.1 Emax = 35.6

Reference stations and weights for estimating:

Ref no. 1. 42160 LISTA FYR at 58°06'60"N, 06°34'10"E, 14 m a.s.l.	Weight $w_1 = 74$	Corr = 0.00
Ref no. 2. 42160 LISTA FYR at 58°06'60"N, 06°34'10"E, 14 m a.s.l.	Weight $w_2 = 74$	Corr = 0.00
Ref no. 3. 45880 FISTER - TØNNEVIK at 59°10'00"N, 06°03'16"E, 50 m a.s.l.	Weight $w_3 = 38$	Corr = 0.00
Ref no. 4. 41670 KONSMO - HØYLAND at 58°16'02"N, 07°22'84"E, 263 m a.s.l.	Weight $w_4 = 34$	Corr = -0.87
Ref no. 5. 46610 SAUDA at 59°38'92"N, 06°21'80"E, 5 m a.s.l.	Weight $w_5 = 30$	Corr = 0.00
Ref no. 6. 46510 MIDTLÆGER at 59°50'03"N, 06°59'49"E, 1079 m a.s.l.	Weight $w_6 = 28$	Corr = -0.63
Ref no. 7. 39690 BYGLANDSFJORD - SOLBAKKEN at 58°40'03"N, 07°48'06"E, 212 m a.s.l.	Weight $w_7 = 28$	Corr = 0.50
Ref no. 8. 41010 MANDAL - EIGEBREKK at 58°00'84"N, 07°36'52"E, 10 m a.s.l.	Weight $w_8 = 27$	Corr = 0.00
Ref no. 9. 41770 LINDESNES FYR at 57°59'00"N, 07°02'90"E, 13 m a.s.l.	Weight $w_9 = 25$	Corr = -1.00
Ref no. 10. 40880 HOVDEN - LUNDANE at 59°35'00"N, 07°23'00"E, 836 m a.s.l.	Weight $w_{10} = 25$	Corr = 0.00

Correctional factor C equals 0.937.

Figure 1.7. Observations UU and estimates $\overline{UU}$ at weather station SIRDAL - TJØRHOM.



Solid curve represent observations of UU, dashed curve represent estimates using the radial method

Table 1.8. Statistics for precipitation (RR) in millimeters (mm) using the radial method.

RR at 15 stations	Sample size	Bias	Stde	Rmse	Mae	Emin	Emax
minimum	4 (V95350)	0.0 (V86760)	0.1 (V99840)	0.1 (V99840)	0.1 (V99840)	0.0 (V97350)	0.1 (V99840)
median	6 (V97350)	0.0 (V85910)	1.2 (V95350)	1.0 (V95350)	0.8 (V95350)	0.0 (V95350)	1.8 (V99720)
maximum	12 (A53101)	0.0 (A53101)	5.4 (V42920)	4.9 (V42920)	3.2 (V42920)	0.6 (V46910)	9.5 (V42920)
average	7	0.0	1.6	1.5	1.1	0.1	2.7
stddev	2	0.0	1.5	1.4	1.0	0.2	2.6

Weather station V42920 SIRDAL - TJØRHOM has the greatest rmse.

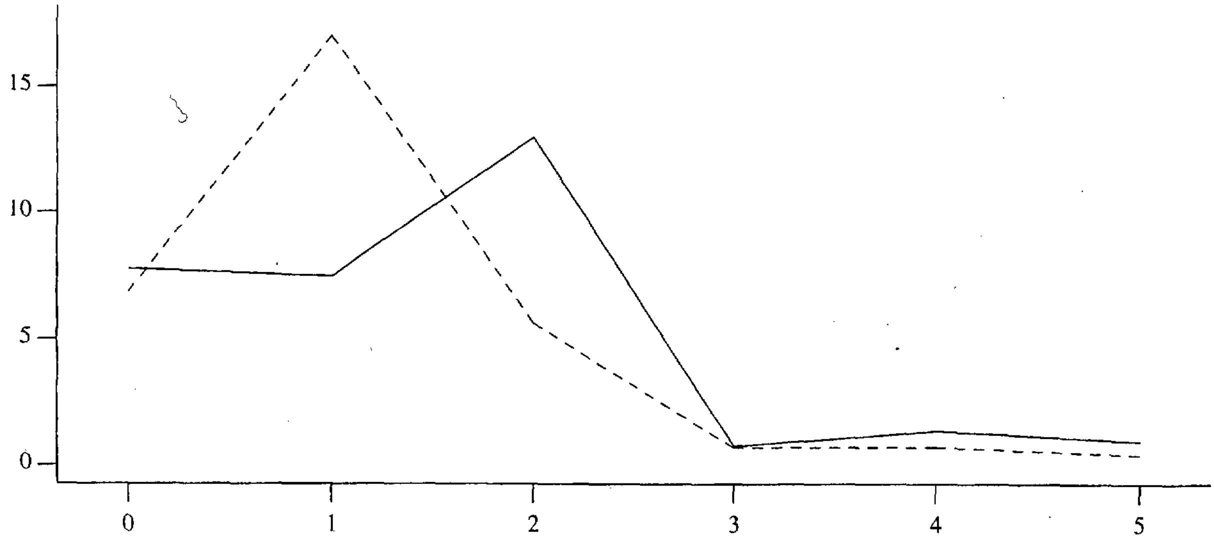
Sample size = 6 Bias = 0.0 Stde = 5.4 Rmse = 4.9 Mae = 3.2 Emin = 0.1 Emax = 9.5

Reference stations and weights for estimating:

Ref no. 1. 42160 LISTA FYR at 58°06'60"N, 06°34'10"E, 14 m a.s.l.	Weight $w_1 = 74$	Corr = 0.00
Ref no. 2. 42160 LISTA FYR at 58°06'60"N, 06°34'10"E, 14 m a.s.l.	Weight $w_2 = 74$	Corr = -1.00
Ref no. 3. 45880 FISTER - TØNNEVIK at 59°10'00"N, 06°03'16"E, 50 m a.s.l.	Weight $w_3 = 38$	Corr = -1.00
Ref no. 4. 41670 KONSMO - HØYLAND at 58°16'02"N, 07°22'84"E, 263 m a.s.l.	Weight $w_4 = 34$	Corr = 1.00
Ref no. 5. 46610 SAUDA at 59°38'92"N, 06°21'80"E, 5 m a.s.l.	Weight $w_5 = 30$	Corr = 0.00
Ref no. 6. 46510 MIDTLÆGER at 59°50'03"N, 06°59'49"E, 1079 m a.s.l.	Weight $w_6 = 28$	Corr = 0.00
Ref no. 7. 39690 BYGLANDSFJORD - SOLBAKKEN at 58°40'03"N, 07°48'06"E, 212 m a.s.l.	Weight $w_7 = 28$	Corr = -1.00
Ref no. 8. 41010 MANDAL - EIGEBREKK at 58°00'84"N, 07°36'52"E, 10 m a.s.l.	Weight $w_8 = 27$	Corr = 0.00
Ref no. 9. 41770 LINDESNES FYR at 57°59'00"N, 07°02'90"E, 13 m a.s.l.	Weight $w_9 = 25$	Corr = -1.00
Ref no. 10. 40880 HOVDEN - LUNDANE at 59°35'00"N, 07°23'00"E, 836 m a.s.l.	Weight $w_{10} = 25$	Corr = -1.00

Correctional factor C equals 0.701.

Figure 1.8. Observations RR and estimates $\overline{RR}$ at weather station SIRDAL - TJØRHOM.



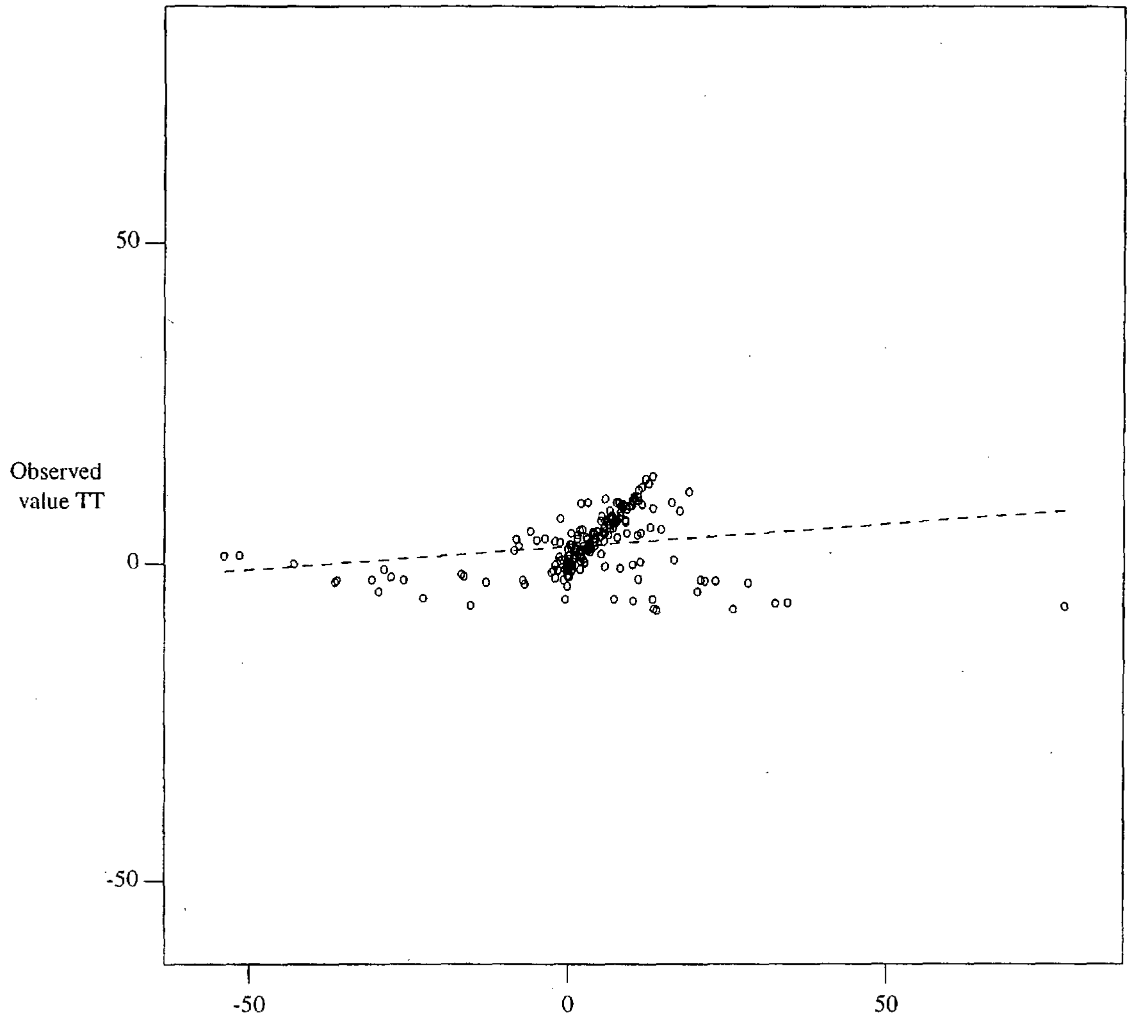
Solid curve represent observations of RR, dashed curve represent estimates using the radial method

5. SCATTER PLOTS

Scatter plots of estimated values against observed values give non-time dependent information about the simultaneous distribution of estimates and observations. In order to evaluate the estimators, on the following pages scatter plots and regression analysis has been applied to each of the meteorological elements without regard to location. In appendix two there are scatter plots for each weather element at each weather station.

Beneath each plot, there are given some general statistics characterizing the simultaneous distribution. Note that, as explained in chapter two above, all values, including cloud cover code and relative humidity, are treated as floating numbers not restricted by any limits of what would be physically or otherwise achievable. The estimator has no knowledge programmed into it of what kind of data it is processing.

Figure 2.1. Scatter plot for air temperature (TT) in centigrades (°C).



Min TT = -7.2	Max TT = 13.9	Average TT = 3.0	Stddev TT = 12.6	Cov($TT,\overline{TT}$) = 11.5
Min $\overline{TT}$ = -53.9	Max $\overline{TT}$ = 77.7	Average $\overline{TT}$ = 3.0	Stddev $\overline{TT}$ = 4.6	Corr($TT,\overline{TT}$) = 0.20

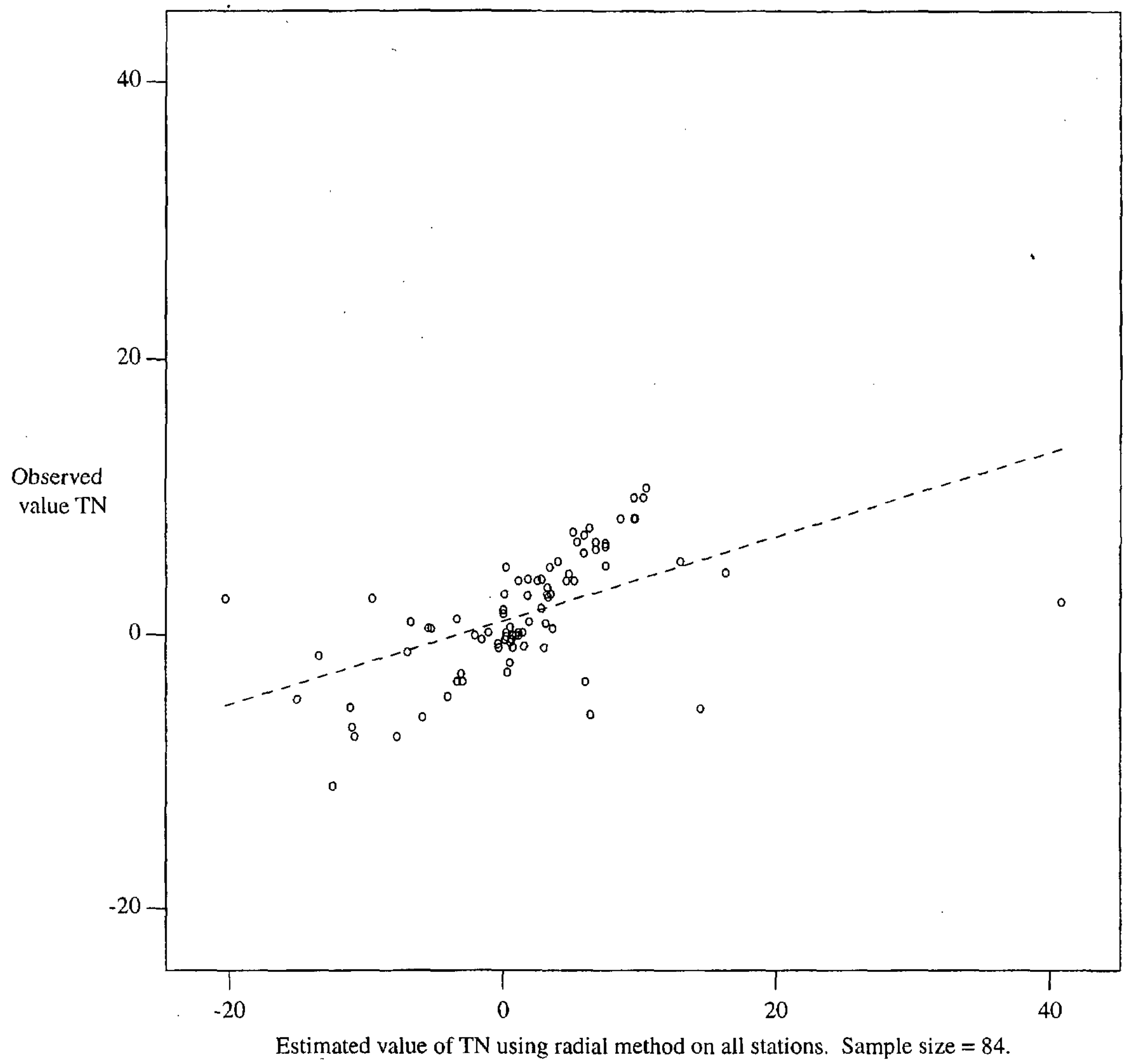
The diagonal of the plot represents the set $TT = \overline{TT}$, while dashed line represents the regression line

$$TT = \alpha + \beta\overline{TT}$$

with coeffecients:

$$\alpha=2.7603$$
$$\beta=0.0732$$

Figure 2.2. Scatter plot for minimum air temperature (TN) in centigrades (°C).



Min TN = -11.0	Max TN = 10.7	Average TN = 1.5	Stddev TN = 7.9	Cov(TN,$\overline{TN}$) = 18.8
Min $\overline{TN}$ = -20.3	Max $\overline{TN}$ = 40.8	Average $\overline{TN}$ = 1.5	Stddev $\overline{TN}$ = 4.4	Corr(TN,$\overline{TN}$) = 0.54

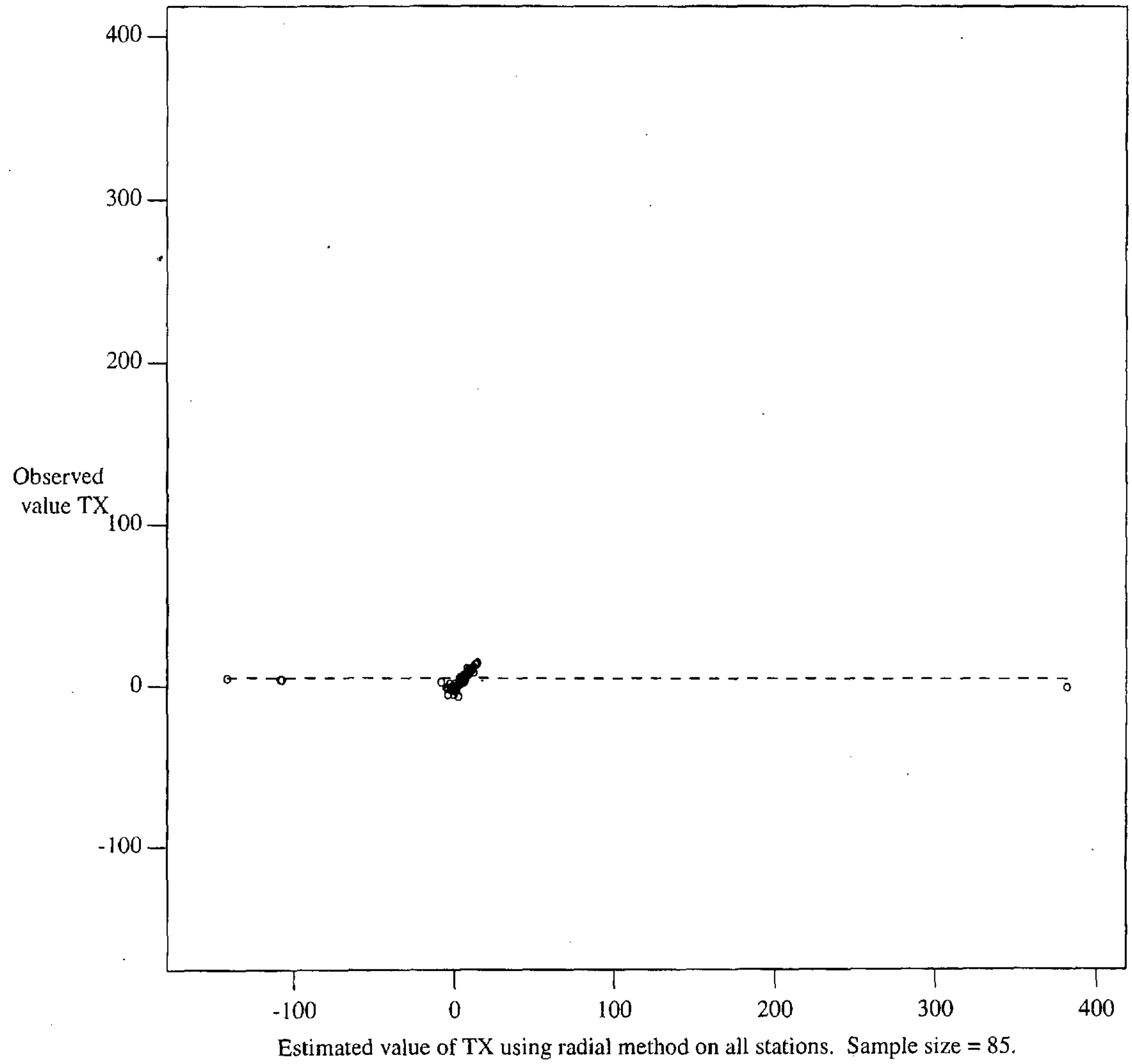
The diagonal of the plot represents the set $TN = \overline{TN}$, while dashed line represents the regression line

$$TN = \alpha + \beta\overline{TN}$$

with coeffecients:

$$\alpha=1.0360$$
$$\beta=0.3060$$

Figure 2.3. Scatter plot for maximum air temperature (TX) in centigrades (°C).



Min TX = -6.3	Max TX = 14.5	Average TX = 4.7	Stddev TX = 47.6	Cov(TX,$\overline{TX}$) = -7.2
Min $\overline{TX}$ = -141.4	Max $\overline{TX}$ = 381.4	Average $\overline{TX}$ = 4.7	Stddev $\overline{TX}$ = 4.7	Corr(TX,$\overline{TX}$) = -0.03

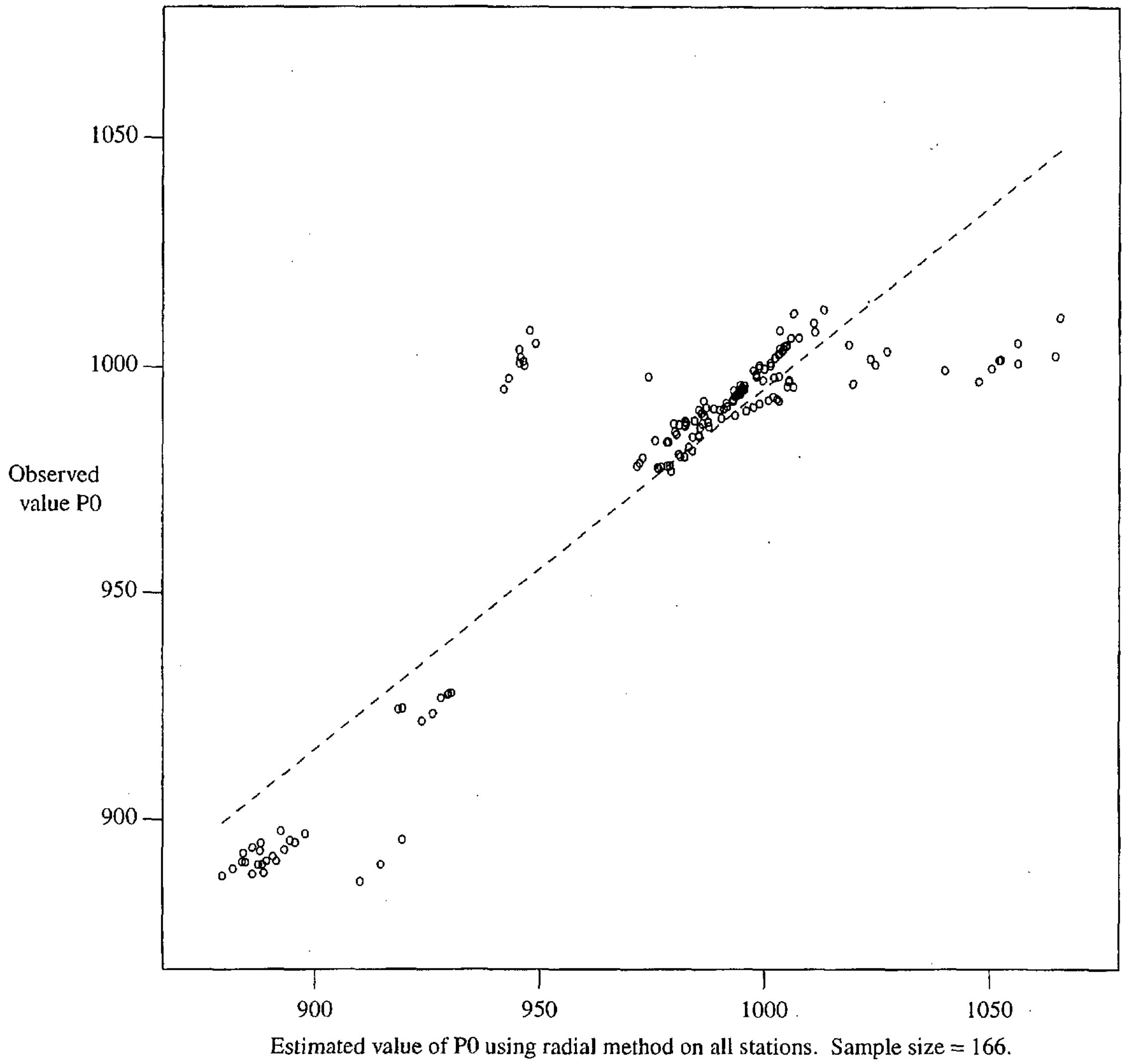
The diagonal of the plot represents the set $TX = \overline{TX}$, while dashed line represents the regression line

$$TX = \alpha + \beta\overline{TX}$$

with coeffecients:

$$\alpha = 4.6986$$
$$\beta = -0.0032$$

Figure 2.4. Scatter plot for air pressure at station level (P0) in hecto Pascal (hPa).



Min $P0$ = 886.4	Max $P0$ = 1012.6	Average $P0$ = 977.0	Stddev $P0$ = 42.7	Cov($P0,\overline{P0}$) = 1441.3
Min $\overline{P0}$ = 879.6	Max $\overline{P0}$ = 1065.4	Average $\overline{P0}$ = 976.9	Stddev $\overline{P0}$ = 38.0	Corr($P0,\overline{P0}$) = 0.90

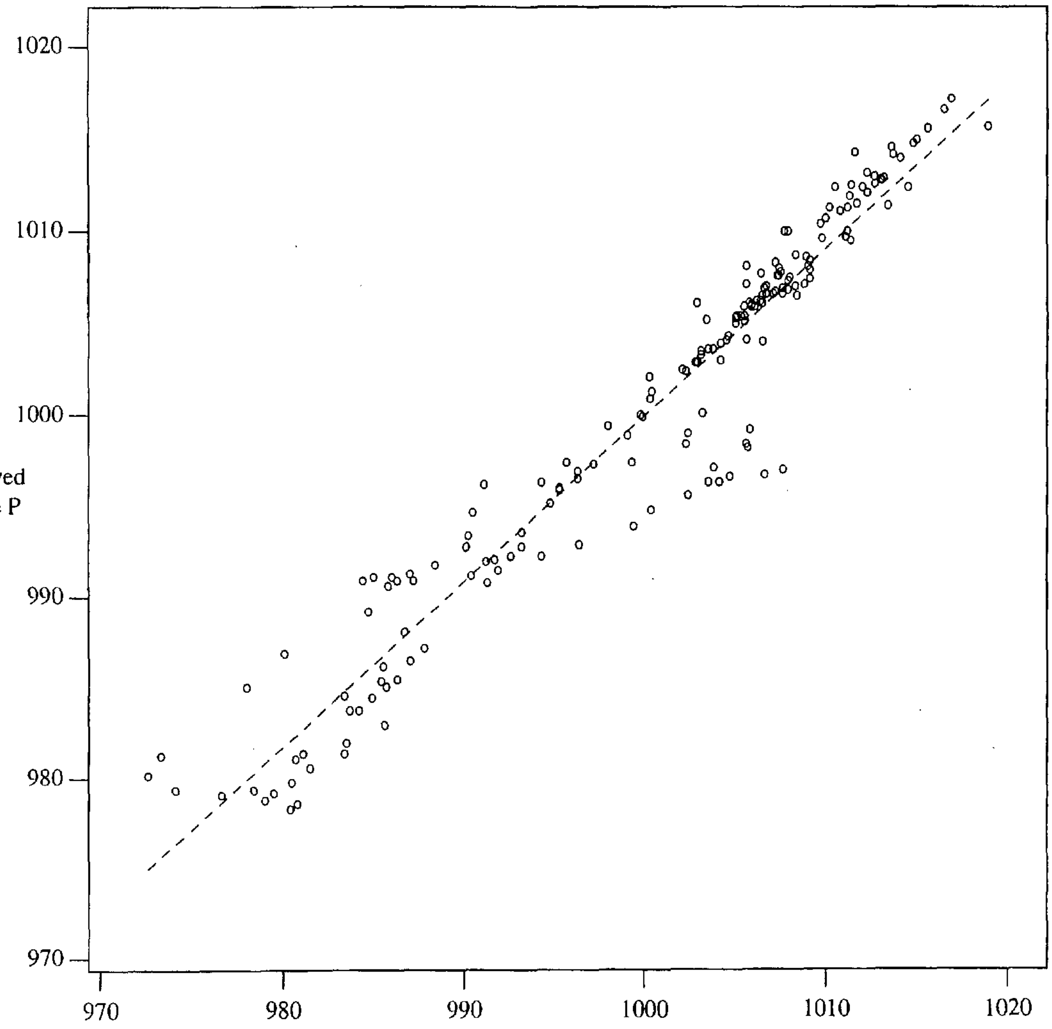
The diagonal of the plot represents the set $P0 = \overline{P0}$, while dashed line represents the regression line

$$P0 = \alpha + \beta\overline{P0}$$

with coeffecients:

$$\alpha=198.4601$$
$$\beta=0.7967$$

Figure 2.5. Scatter plot for air pressure at sea level (P) in hecto Pascal (hPa).



Min $P = 978.3$	Max $P = 1017.2$	Average $P = 1000.1$	Stddev $P = 11.0$	$\mathrm{Cov}(P,\overline{P}) = 110.2$
Min $\overline{P} = 972.6$	Max $\overline{P} = 1018.9$	Average $\overline{P} = 1000.1$	Stddev $\overline{P} = 10.4$	$\mathrm{Corr}(P,\overline{P}) = 0.97$

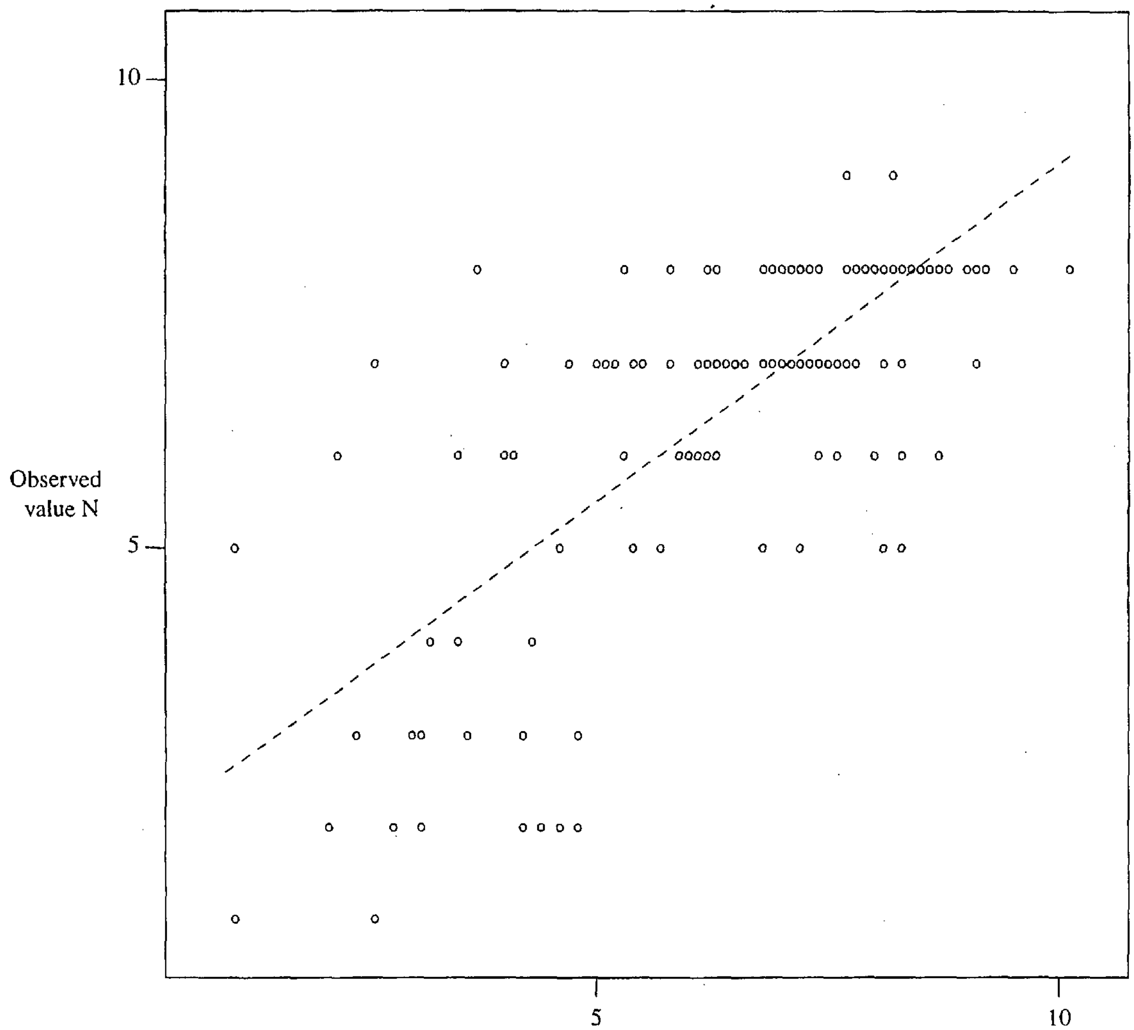
The diagonal of the plot represents the set $P = \overline{P}$, while dashed line represents the regression line

$$P = \alpha + \beta\overline{P}$$

with coeffecients:

$$\alpha = 89.5628$$
$$\beta = 0.9104$$

Figure 2.6. Scatter plot for cloud cover (N) in octas (0-8).



Estimated value of N using radial method on all stations. Sample size = 179.

Min $N = 1.0$	Max $N = 9.0$	Average $N = 6.7$	Stddev $N = 1.9$	$\mathrm{Cov}(N,\overline{N}) = 2.6$
Min $\overline{N} = 1.0$	Max $\overline{N} = 10.1$	Average $\overline{N} = 6.7$	Stddev $\overline{N} = 1.8$	$\mathrm{Corr}(N,\overline{N}) = 0.75$

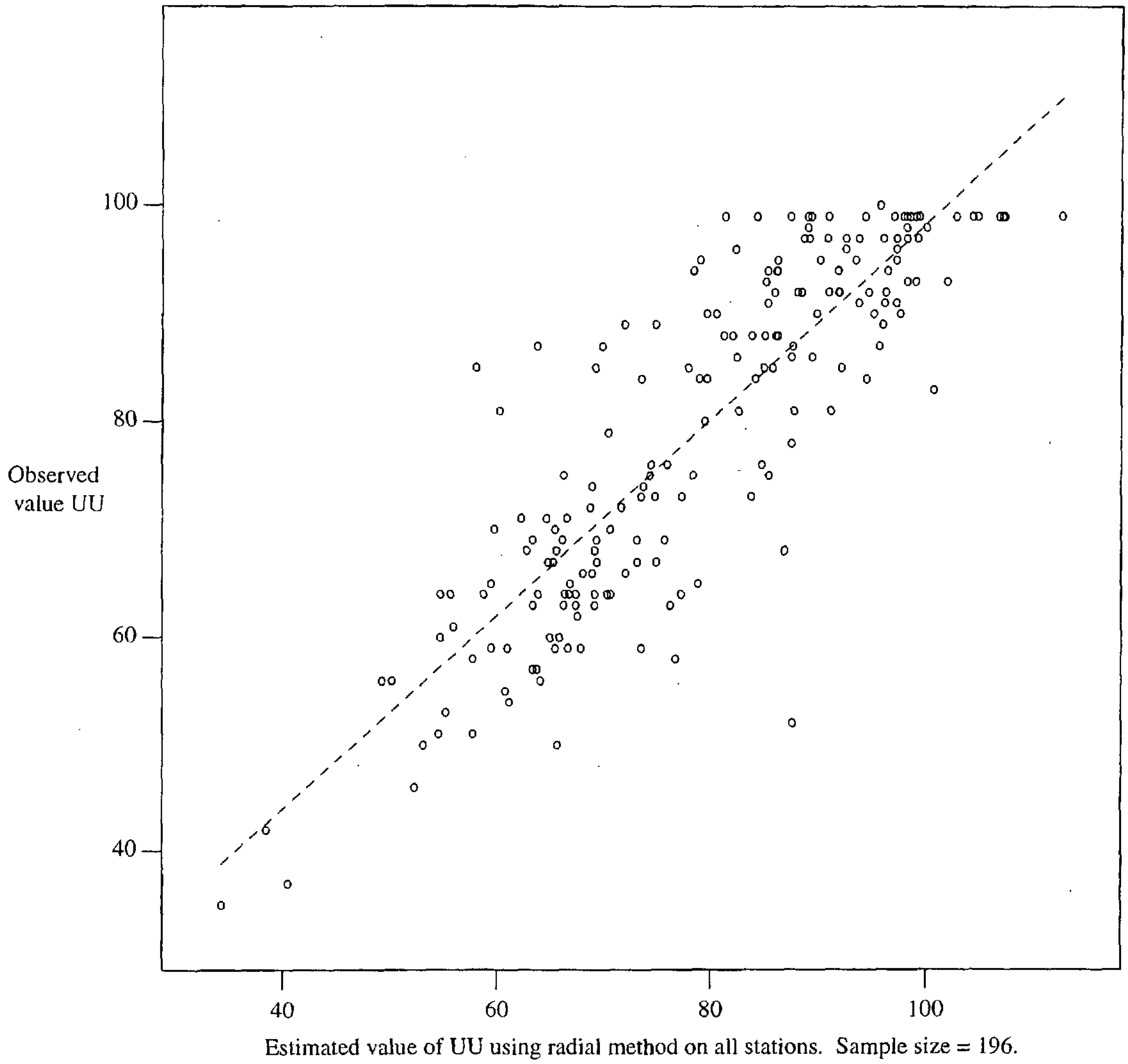
The diagonal of the plot represents the set $N = \overline{N}$, while dashed line represents the regression line

$$N = \alpha + \beta\overline{N}$$

with coeffecients:

$$\alpha=1.8827$$
$$\beta=0.7221$$

Figure 2.7. Scatter plot for relative humidity (UU) in percentage (%).



Min UU = 35.0	Max UU = 100.0	Average UU = 79.4	Stddev UU = 15.3	Cov(UU,$\overline{UU}$) = 210.4
Min $\overline{UU}$ = 34.4	Max $\overline{UU}$ = 112.6	Average $\overline{UU}$ = 79.5	Stddev $\overline{UU}$ = 16.0	Corr(UU,$\overline{UU}$) = 0.87

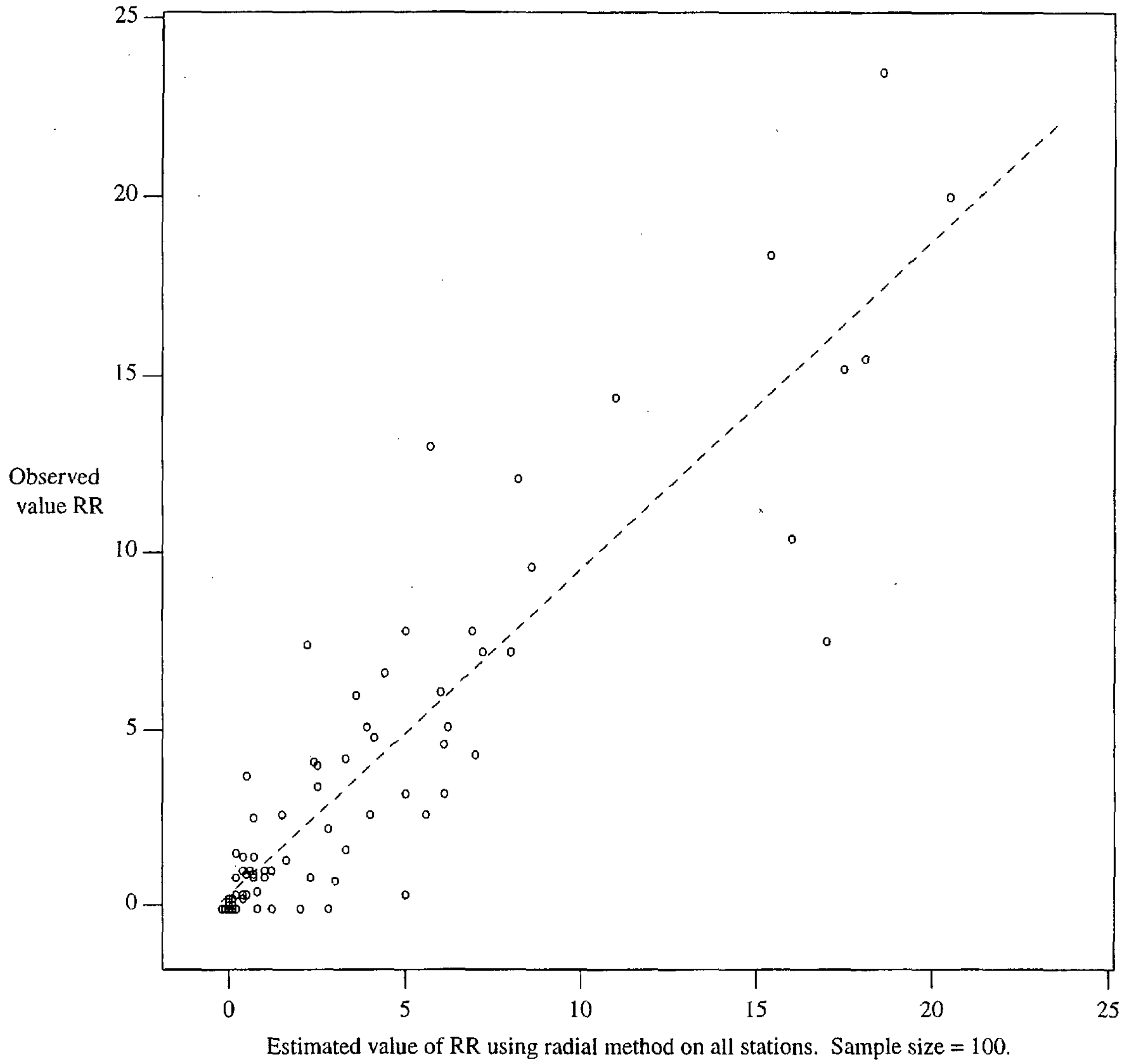
The diagonal of the plot represents the set $UU = \overline{UU}$, while dashed line represents the regression line

$$UU = \alpha + \beta\overline{UU}$$

with coeffecients:

α=7.5763
β=0.9065

Figure 2.8. Scatter plot for precipitation (RR) in millimeters (mm).



Min RR = -0.1	Max RR = 23.5	Average RR = 2.9	Stddev RR = 4.8	$\mathrm{Cov}(RR,\overline{RR})$ = 20.9
Min $\overline{RR}$ = -0.2	Max $\overline{RR}$ = 23.5	Average $\overline{RR}$ = 2.9	Stddev $\overline{RR}$ = 4.9	$\mathrm{Corr}(RR,\overline{RR})$ = 0.91

The diagonal of the plot represents the set $RR = \overline{RR}$, while dashed line represents the regression line

$$RR = \alpha + \beta\overline{RR}$$

with coeffecients:

$$\alpha=0.2115$$
$$\beta=0.9282$$

6. CONCLUSIONS

While the method described in this document and the experiment dealing with this method show that it is not perfect, in many cases the interpolation method works well. This has been verified by Barabara Toporowska and Stein Kristiansen, who are responsible for daily follow up and quality control of weather observations as stored in the datatable TELE.

In some cases, however, they have reported severe estimation errors, and as shown in this document, in some cases the estimators are very badly constructed indeed. Zbigniew Toporowski, responsible for interpolation and quality control in the weather station data storage routine, has also made valueable contributions by pointing out situations the interpolation programme has gone astray.

Automatic interpolation in the datatable TELE commenced on August 21 1997. There has ever since been a continuous interest to achieve better estimates. Bjørn Aune and Sofus L. Lystad have particularily contributed to this process by discussing ideas for improvements.

One idea that one hopes to investigate, is to estimate dew point temperature (TD), and to estimate relative humitidy from TT and TD instead of applying the estimation scheme directly to the UU parameter. There may be reason to believe that relative humidity is more difficult to estimate than temperature using the method under consideration and therefore could be better estimated by first estimating temperature.

Another problem that must be looked into is how the correctional factor *C*, as described in this document, can be estimated in situations where there are no data available. For the present *C* is set equal one when it cannot be constructed by fractions. This may introduce significant bias, and, as Eirik J. Førland (cf. Øgland & Førland, 1996) has suggested, precipitation normals, or other kinds of normals for other weather elements, should be applied to reduce this bias.

The first problem to consider, however, is how to improve the estimator by chosing weights that prevent badly correlated weather stations to influence on the estimate. Some work has already been done in this area, and systematic tests are on the agenda for further development.

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Øgland, P. (1997) *Automatic interpolation of SYNOP weather observations: Interpol1 and Interpol2*, DNMI Report No. 61/97 KLIBAS, Oslo, August 1997

APPENDIX 1.
Statistics below are generated by applying the radial estimation method.

Table 2.1. The radial method used for air temperature (TT) in centigrades (°C).

Station name	No.	Sample	Bias	Stde	Rmse	Mae	Emin	Emax
1. FOKSTUA II	V16610	24	0.0	2.4	2.4	1.9	0.0	5.3
2. OSLO - BLINDERN	V18700	24	0.0	0.9	0.8	0.7	0.0	2.0
3. ØYFJELL - TROVATN	V32920	8	0.0	2.2	2.0	1.6	0.2	4.2
4. SIRDAL - TJØRHOM	V42920	11	0.0	1.3	1.2	1.1	0.1	2.2
5. NEDRE VATS	V46910	8	0.0	1.1	1.1	0.8	0.2	2.6
6. REIMEGREND	V51670	8	0.0	1.6	1.5	1.3	0.3	2.6
7. VANGSNES	A53101	24	0.0	6.5	6.4	5.5	0.6	12.4
8. RØST II	V85910	14	0.0	0.7	0.7	0.6	0.0	1.3
9. BØ I VESTERÅLEN II	V86760	8	0.0	1.0	0.9	0.6	0.1	2.1
10. LITLØY FYR	V86780	11	0.0	0.9	0.9	0.6	0.2	2.6
11. ALTA LUFTHAVN	V93140	17	0.0	10.8	10.5	8.9	0.4	23.2
12. BANAK	V95350	11	0.0	2.0	1.9	1.5	0.0	3.8
13. CUOVDDATMOHKKI	V97350	8	0.0	51.9	48.5	45.0	24.0	84.4
14. HOPEN	V99720	21	0.0	0.6	0.6	0.4	0.0	1.4
15. SVALBARD LUFTHAVN	V99840	23	0.0	23.3	22.8	21.1	4.7	38.7

Table 2.2. The radial method used for minimum air temperature (TN) in centigrades (°C).

Station name	No.	Sample	Bias	Stde	Rmse	Mae	Emin	Emax
1. FOKSTUA II	V16610	6	0.0	9.6	8.8	8.0	2.5	12.3
2. OSLO - BLINDERN	V18700	6	0.0	0.8	0.7	0.6	0.1	1.4
3. ØYFJELL - TROVATN	V32920	6	0.0	9.0	8.2	7.5	3.1	12.0
4. SIRDAL - TJØRHOM	V42920	6	0.0	1.2	1.1	0.9	0.2	1.5
5. NEDRE VATS	V46910	6	0.0	1.3	1.2	0.9	0.3	2.4
6. REIMEGREND	V51670	6	0.0	1.7	1.6	1.5	0.9	2.3
7. VANGSNES	A53101	6	0.0	1.7	1.5	1.3	0.1	2.4
8. RØST II	V85910	4	0.0	1.0	0.8	0.7	0.0	1.3
9. BØ I VESTERÅLEN II	V86760	6	0.0	1.5	1.3	1.0	0.1	2.9
10. LITLØY FYR	V86780	5	0.0	22.9	20.5	15.4	2.9	38.4
11. ALTA LUFTHAVN	V93140	5	0.0	2.0	1.8	1.4	0.0	3.0
12. BANAK	V95350	4	0.0	0.9	0.8	0.6	0.0	1.3
13. CUOVDDATMOHKKI	V97350	6	0.0	2.9	2.6	2.1	0.1	4.4
14. HOPEN	V99720	6	0.0	1.4	1.3	1.1	0.2	2.1
15. SVALBARD LUFTHAVN	V99840	6	0.0	10.5	9.6	6.8	0.4	19.9

Table 2.3. The radial method used for maximum air temperature (TX) in centigrades (°C).

Station name	No.	Sample	Bias	Stde	Rmse	Mae	Emin	Emax
1. FOKSTUA II	V16610	6	0.0	1.4	1.3	1.2	0.6	1.9
2. OSLO - BLINDERN	V18700	6	0.0	0.9	0.8	0.7	0.1	1.2
3. ØYFJELL - TROVATN	V32920	6	0.0	1.0	0.9	0.8	0.1	1.4
4. SIRDAL - TJØRHOM	V42920	6	0.0	1.6	1.4	1.2	0.2	2.4
5. NEDRE VATS	V46910	6	0.0	0.5	0.5	0.4	0.1	0.7
6. REIMEGREND	V51670	6	0.0	1.9	1.8	1.3	0.1	3.6
7. VANGSNES	A53101	6	0.0	1.8	1.7	1.4	0.5	3.2
8. RØST II	V85910	5	0.0	0.8	0.7	0.7	0.5	1.1
9. BØ I VESTERÅLEN II	V86760	6	0.0	1.4	1.3	1.0	0.2	2.6
10. LITLØY FYR	V86780	5	0.0	1.7	1.5	1.3	0.4	2.8
11. ALTA LUFTHAVN	V93140	5	0.0	219.9	196.7	153.1	11.1	382.7
12. BANAK	V95350	5	0.0	3.2	2.9	2.7	1.1	4.6
13. CUOVDDATMOHKKI	V97350	6	0.0	5.1	4.7	3.9	1.2	8.5
14. HOPEN	V99720	5	0.0	1.1	1.0	0.7	0.1	1.8
15. SVALBARD LUFTHAVN	V99840	6	0.0	3.1	2.9	2.4	0.3	4.4

Table 2.4. The radial method used for air pressure at station level (P0) in hecto Pascal (hPa).

Station name	No.	Sample	Bias	Stde	Rmse	Mae	Emin	Emax
1. FOKSTUA II	V16610	24	0.0	9.7	9.5	6.1	0.3	24.5
2. OSLO - BLINDERN	V18700	24	0.0	0.3	0.3	0.2	0.0	0.6
3. ØYFJELL - TROVATN	V32920	8	0.0	3.5	3.3	2.8	1.0	6.0
4. NEDRE VATS	V46910	8	0.0	1.5	1.4	1.1	0.1	3.3
5. VANGSNES	A53101	24	0.0	49.4	48.4	46.5	21.6	61.8
6. RØST II	V85910	14	0.0	1.1	1.1	0.8	0.0	2.4
7. BØ I VESTERÅLEN II	V86760	8	0.0	1.2	1.1	0.9	0.2	2.2
8. ALTA LUFTHAVN	V93140	17	0.0	5.5	5.4	3.7	0.2	13.8
9. HOPEN	V99720	21	0.0	5.8	5.7	4.7	0.2	10.7
10. SVALBARD LUFTHAVN	V99840	23	0.0	6.1	5.9	5.4	0.5	10.6

Table 2.5. The radial method used for air pressure at sea level (P) in hecto Pascal (hPa).

Station name	No.	Sample	Bias	Stde	Rmse	Mae	Emin	Emax
1. FOKSTUA II	V16610	24	0.0	1.6	1.6	1.3	0.0	3.2
2. OSLO - BLINDERN	V18700	24	0.0	0.3	0.3	0.2	0.0	0.7
3. ØYFJELL - TROVATN	V32920	8	0.0	1.2	1.1	1.0	0.3	1.9
4. NEDRE VATS	V46910	8	0.0	1.5	1.4	1.1	0.1	3.2
5. VANGSNES	A53101	24	0.0	1.2	1.2	0.9	0.1	2.7
6. RØST II	V85910	14	0.0	1.3	1.2	0.9	0.0	2.6
7. BØ I VESTERÅLEN II	V86760	8	0.0	1.2	1.1	0.9	0.3	2.2
8. ALTA LUFTHAVN	V93140	17	0.0	1.4	1.3	0.9	0.0	4.5
9. BANAK	V95350	11	0.0	1.0	1.0	0.8	0.3	2.1
10. HOPEN	V99720	21	0.0	5.9	5.7	4.7	0.2	10.6
11. SVALBARD LUFTHAVN	V99840	23	0.0	5.2	5.1	4.7	0.4	8.1

Table 2.6. The radial method used for cloud cover (N) in octas (0-8).

Station name	No.	Sample	Bias	Stde	Rmse	Mae	Emin	Emax
1. FOKSTUA II	V16610	12	0.0	2.1	2.0	1.5	0.0	3.9
2. OSLO - BLINDERN	V18700	24	0.0	0.7	0.7	0.6	0.1	1.7
3. ØYFJELL - TROVATN	V32920	8	0.0	1.2	1.1	1.0	0.3	1.8
4. SIRDAL - TJØRHOM	V42920	9	0.0	2.0	1.9	1.5	0.2	4.4
5. NEDRE VATS	V46910	8	0.0	1.0	0.9	0.8	0.2	2.0
6. REIMEGREND	V51670	8	0.0	0.8	0.8	0.6	0.2	1.6
7. RØST II	V85910	14	0.0	0.6	0.6	0.4	0.0	1.7
8. BØ I VESTERÅLEN II	V86760	8	0.0	1.2	1.1	0.7	0.0	2.0
9. LITLØY FYR	V86780	11	0.0	1.0	0.9	0.6	0.1	2.2
10. ALTA LUFTHAVN	V93140	17	0.0	1.7	1.7	1.4	0.1	2.8
11. BANAK	V95350	11	0.0	1.1	1.1	0.9	0.1	2.2
12. CUOVDDATMOHKKI	V97350	8	0.0	1.3	1.2	0.9	0.0	2.3
13. HOPEN	V99720	21	0.0	1.7	1.7	1.4	0.2	4.3
14. SVALBARD LUFTHAVN	V99840	23	0.0	1.4	1.4	1.0	0.0	3.3

Table 2.7. The radial method used for relative humidity (UU) in percentage (%).

Station name	No.	Sample	Bias	Stde	Rmse	Mae	Emin	Emax
1. FOKSTUA II	V16610	20	0.0	6.5	6.3	5.3	0.2	13.7
2. OSLO - BLINDERN	V18700	24	0.0	5.4	5.3	3.8	0.2	17.1
3. ØYFJELL - TROVATN	V32920	8	0.0	10.3	9.6	9.1	4.3	15.6
4. SIRDAL - TJØRHOM	V42920	11	0.0	12.6	12.0	6.5	0.1	35.6
5. NEDRE VATS	V46910	8	0.0	4.2	3.9	3.6	1.0	6.6
6. REIMEGREND	V51670	8	0.0	10.1	9.4	8.0	0.4	14.2
7. VANGSNES	A53101	9	0.0	9.8	9.2	7.9	0.1	17.2
8. RØST II	V85910	14	0.0	10.0	9.7	7.7	0.3	20.8
9. BØ I VESTERÅLEN II	V86760	8	0.0	6.8	6.4	5.5	0.2	10.8
10. LITLØY FYR	V86780	11	0.0	10.2	9.7	8.4	3.1	18.8
11. ALTA LUFTHAVN	V93140	17	0.0	11.5	11.1	8.3	0.3	27.0
12. BANAK	V95350	11	0.0	7.5	7.1	5.5	0.4	16.0
13. CUOVDDATMOHKKI	V97350	8	0.0	8.6	8.1	6.2	0.1	17.7
14. HOPEN	V99720	21	0.0	8.1	7.9	6.2	0.1	17.7
15. SVALBARD LUFTHAVN	V99840	23	0.0	5.1	5.0	4.0	0.2	11.1

Table 2.8. The radial method used for precipitation (RR) in millimeters (mm).

Station name	No.	Sample	Bias	Stde	Rmse	Mae	Emin	Emax
1. FOKSTUA II	V16610	9	0.0	0.1	0.1	0.1	0.0	0.2
2. OSLO - BLINDERN	V18700	6	0.0	0.4	0.4	0.3	0.1	0.7
3. ØYFJELL - TROVATN	V32920	6	0.0	0.6	0.6	0.4	0.0	1.1
4. SIRDAL - TJØRHOM	V42920	6	0.0	5.4	4.9	3.2	0.1	9.5
5. NEDRE VATS	V46910	6	0.0	2.7	2.4	1.9	0.6	4.9
6. REIMEGREND	V51670	6	0.0	3.2	2.9	2.4	0.4	5.6
7. VANGSNES	A53101	12	0.0	3.0	2.9	2.4	0.3	5.2
8. RØST II	V85910	5	0.0	0.9	0.8	0.6	0.0	1.4
9. BØ I VESTERÅLEN II	V86760	6	0.0	2.6	2.3	1.9	0.0	3.4
10. LITLØY FYR	V86780	5	0.0	1.8	1.6	1.1	0.0	2.9
11. ALTA LUFTHAVN	V93140	6	0.0	1.5	1.4	0.8	0.0	2.4
12. BANAK	V95350	4	0.0	1.2	1.0	0.8	0.0	1.5
13. CUOVDDATMOHKKI	V97350	6	0.0	0.1	0.1	0.1	0.0	0.2
14. HOPEN	V99720	12	0.0	0.8	0.7	0.5	0.0	1.8
15. SVALBARD LUFTHAVN	V99840	5	0.0	0.1	0.1	0.1	0.0	0.1

APPENDIX 2.

Figure 3. Scatter plots for weather station FOKSTUA II.

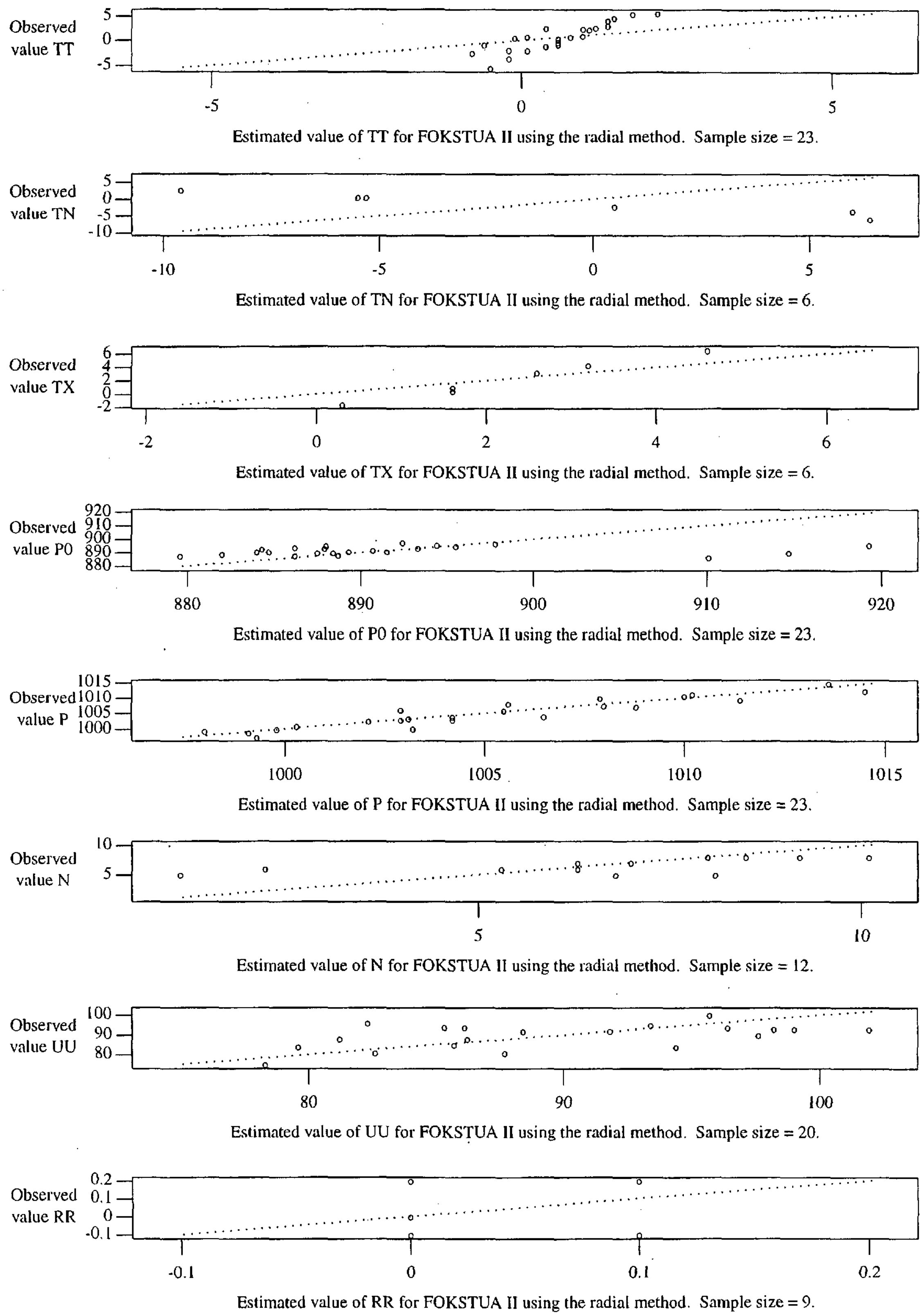
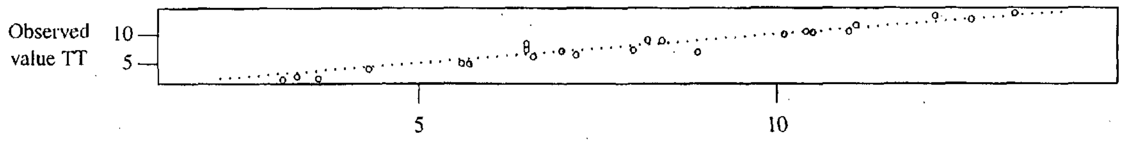
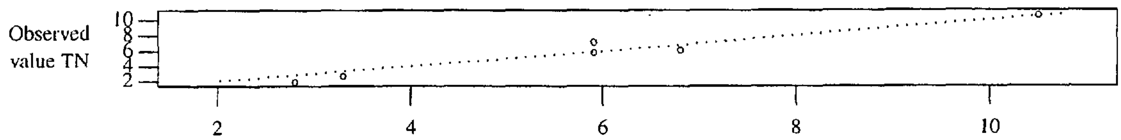


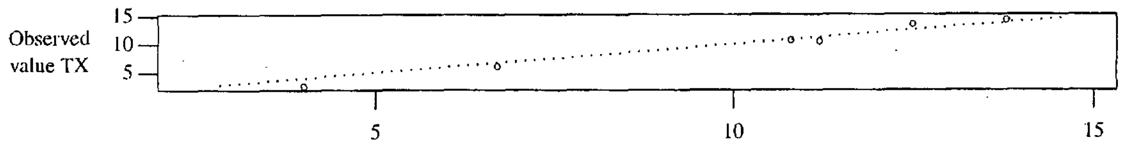
Figure 4. Scatter plots for weather station OSLO - BLINDERN.



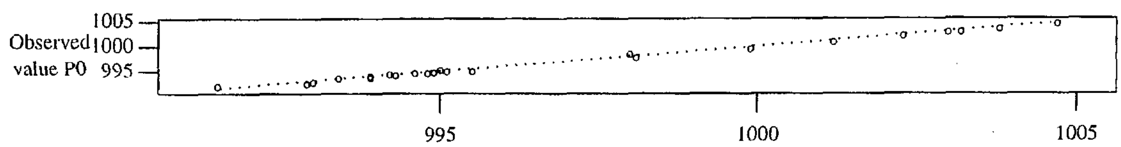
Estimated value of TT for OSLO - BLINDERN using the radial method. Sample size = 23.



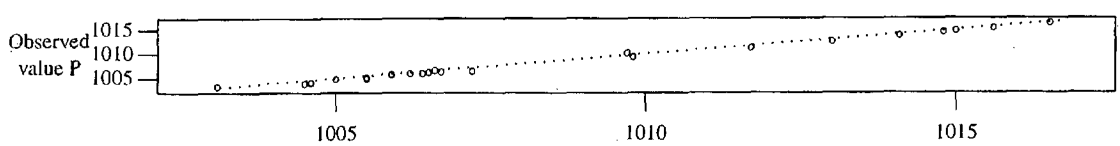
Estimated value of TN for OSLO - BLINDERN using the radial method. Sample size = 6.



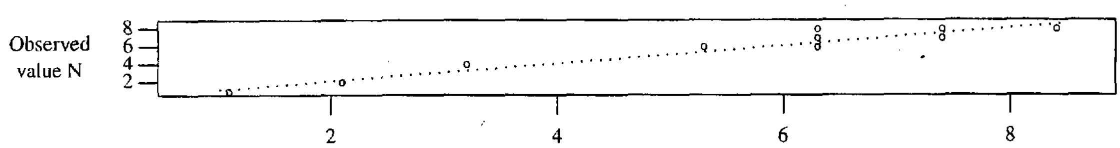
Estimated value of TX for OSLO - BLINDERN using the radial method. Sample size = 6.



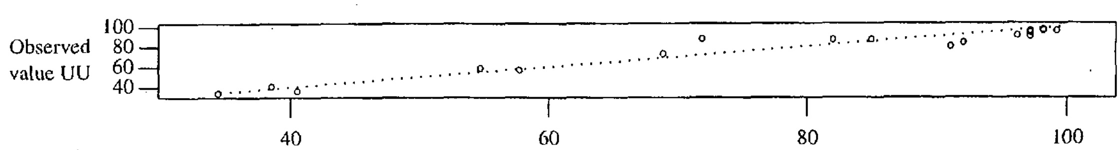
Estimated value of P0 for OSLO - BLINDERN using the radial method. Sample size = 23.



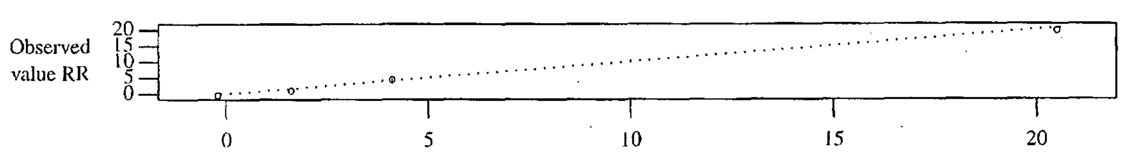
Estimated value of P for OSLO - BLINDERN using the radial method. Sample size = 23.



Estimated value of N for OSLO - BLINDERN using the radial method. Sample size = 23.

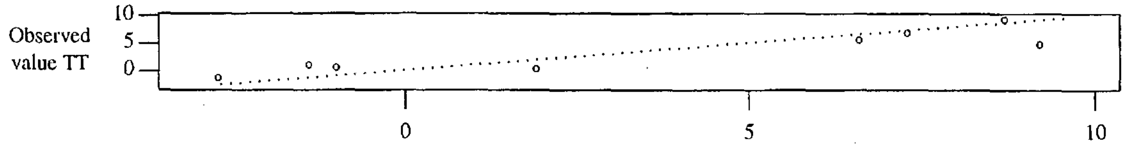


Estimated value of UU for OSLO - BLINDERN using the radial method. Sample size = 23.

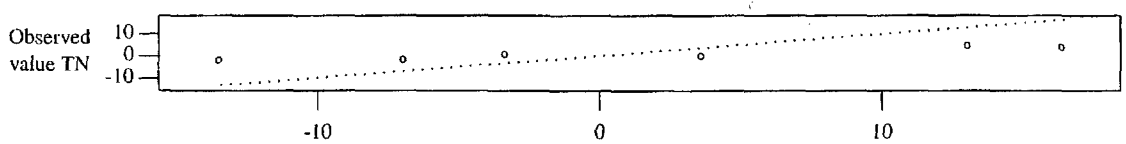


Estimated value of RR for OSLO - BLINDERN using the radial method. Sample size = 6.

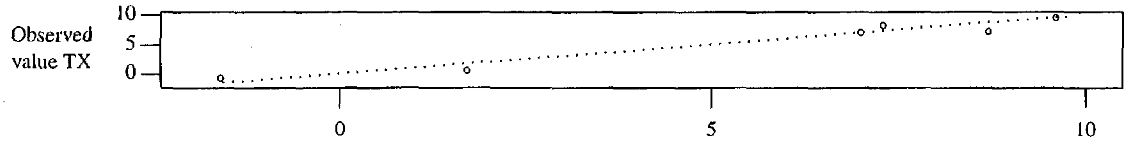
Figure 5. Scatter plots for weather station ØYFJELL - TROVATN.



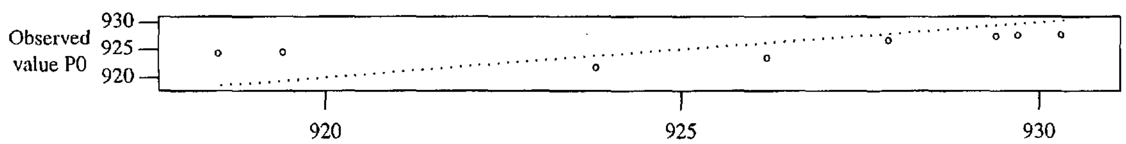
Estimated value of TT for ØYFJELL - TROVATN using the radial method. Sample size = 8.



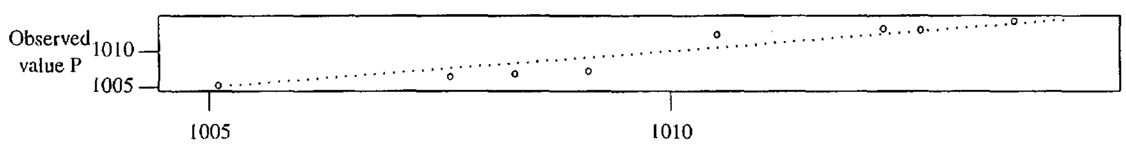
Estimated value of TN for ØYFJELL - TROVATN using the radial method. Sample size = 6.



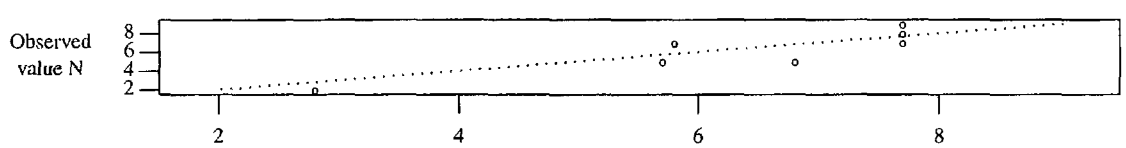
Estimated value of TX for ØYFJELL - TROVATN using the radial method. Sample size = 6.



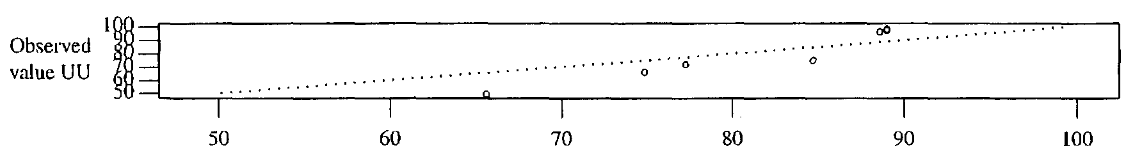
Estimated value of P0 for ØYFJELL - TROVATN using the radial method. Sample size = 8.



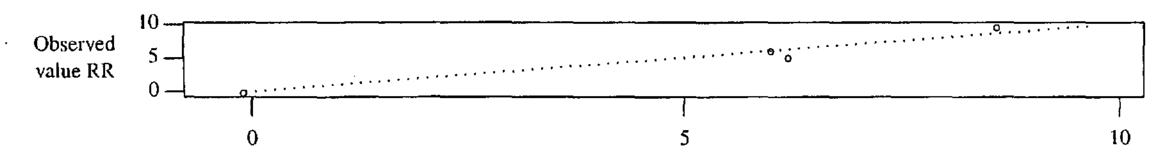
Estimated value of P for ØYFJELL - TROVATN using the radial method. Sample size = 8.



Estimated value of N for ØYFJELL - TROVATN using the radial method. Sample size = 8.



Estimated value of UU for ØYFJELL - TROVATN using the radial method. Sample size = 8.



Estimated value of RR for ØYFJELL - TROVATN using the radial method. Sample size = 6.

Figure 6. Scatter plots for weather station SIRDAL - TJØRHOM.

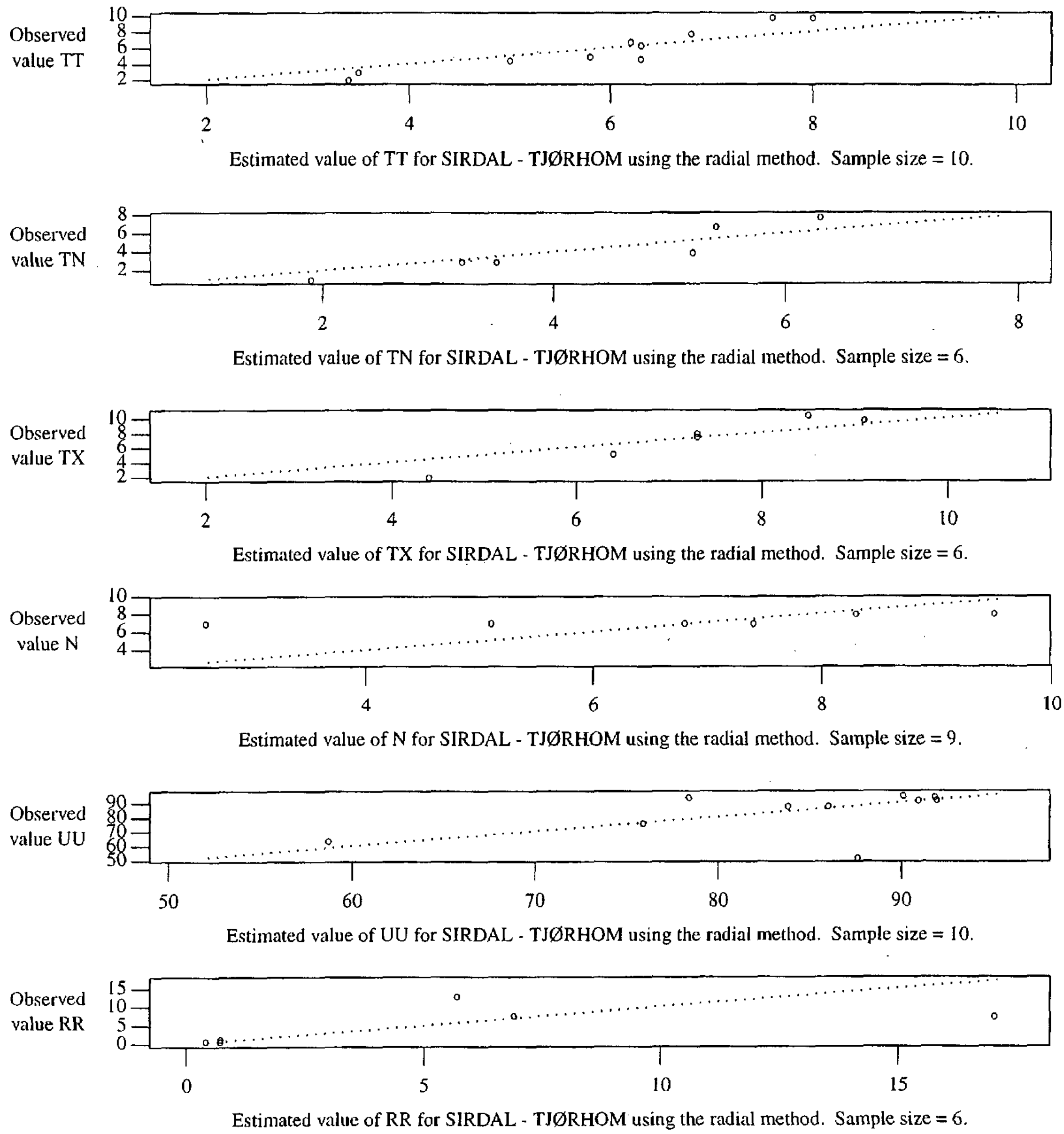
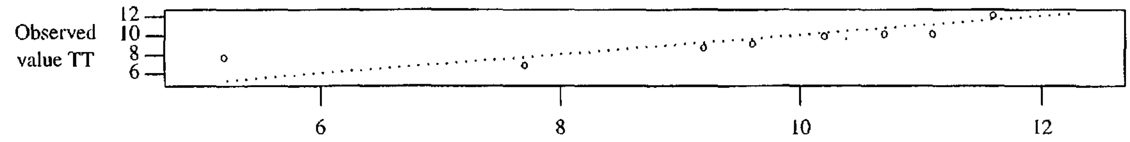
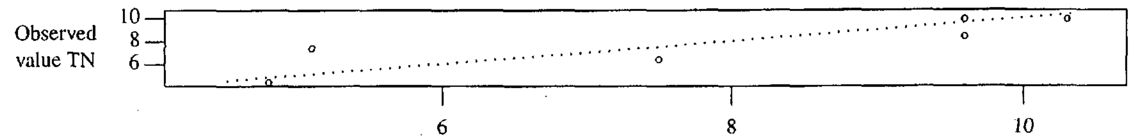


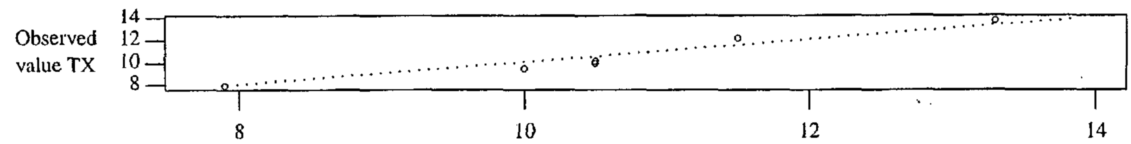
Figure 7. Scatter plots for weather station NEDRE VATS.



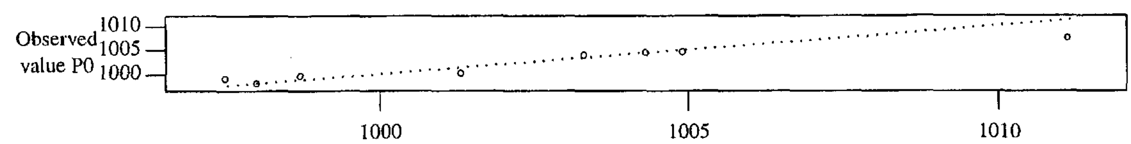
Estimated value of TT for NEDRE VATS using the radial method. Sample size = 8.



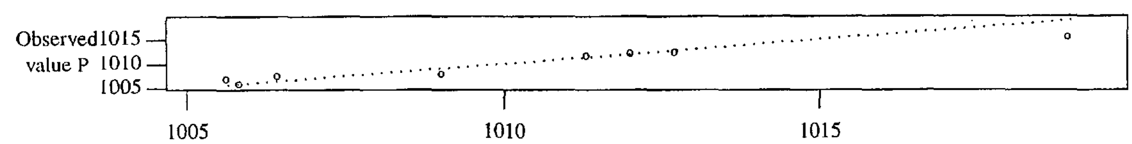
Estimated value of TN for NEDRE VATS using the radial method. Sample size = 6.



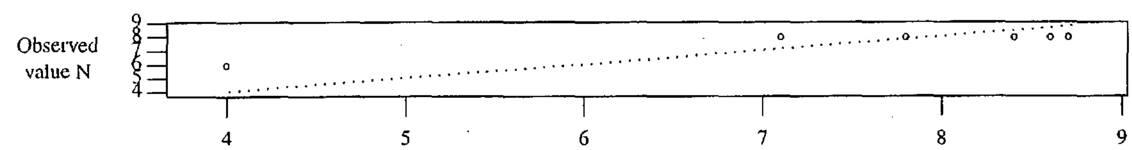
Estimated value of TX for NEDRE VATS using the radial method. Sample size = 6.



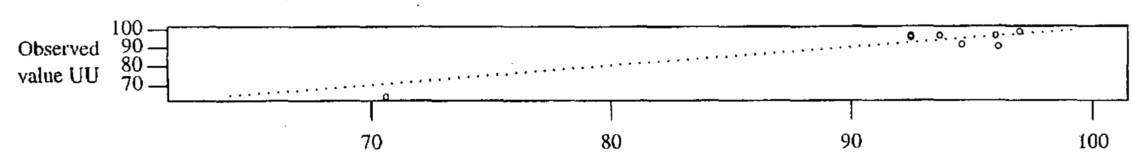
Estimated value of P0 for NEDRE VATS using the radial method. Sample size = 8.



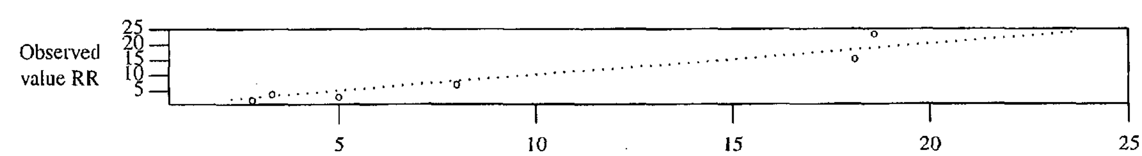
Estimated value of P for NEDRE VATS using the radial method. Sample size = 8.



Estimated value of N for NEDRE VATS using the radial method. Sample size = 8.

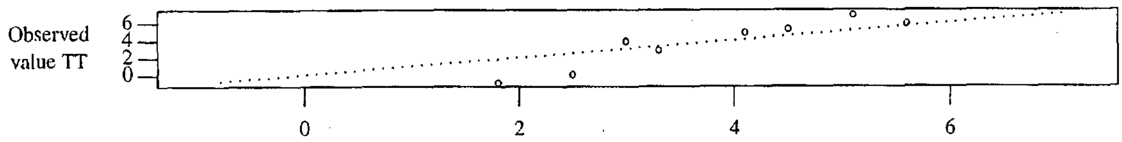


Estimated value of UU for NEDRE VATS using the radial method. Sample size = 8.

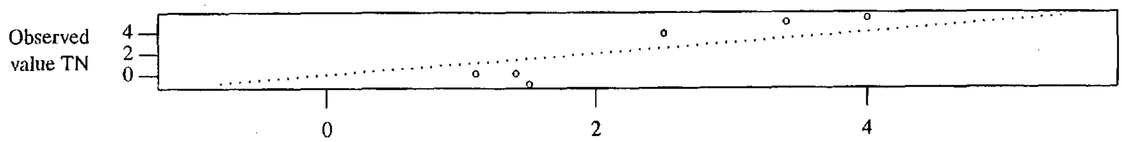


Estimated value of RR for NEDRE VATS using the radial method. Sample size = 6.

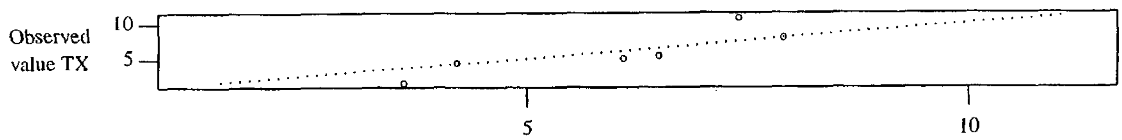
Figure 8. Scatter plots for weather station REIMEGREND.



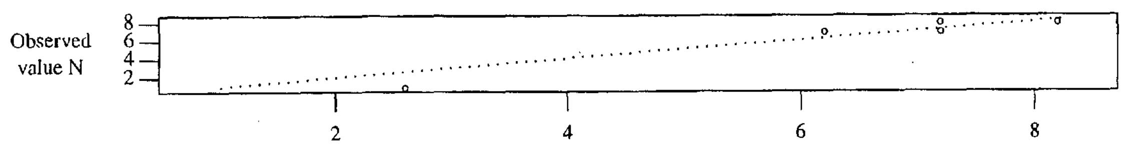
Estimated value of TT for REIMEGREND using the radial method. Sample size = 8.



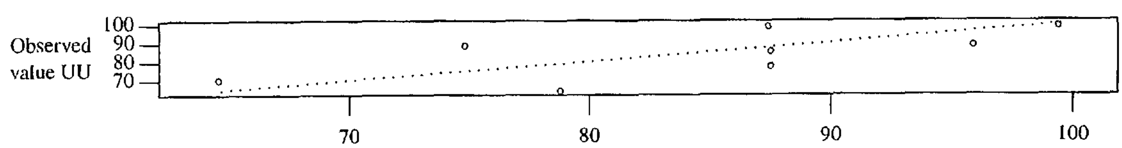
Estimated value of TN for REIMEGREND using the radial method. Sample size = 6.



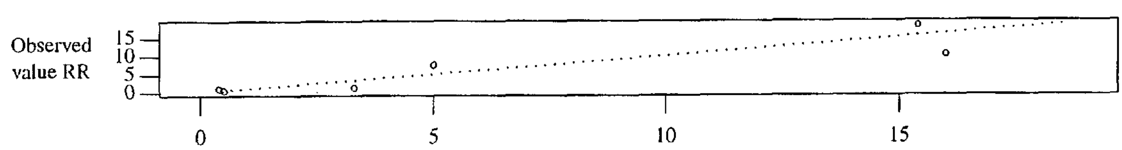
Estimated value of TX for REIMEGREND using the radial method. Sample size = 6.



Estimated value of N for REIMEGREND using the radial method. Sample size = 8.

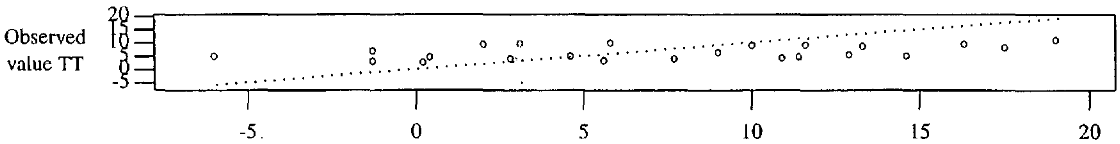


Estimated value of UU for REIMEGREND using the radial method. Sample size = 8.

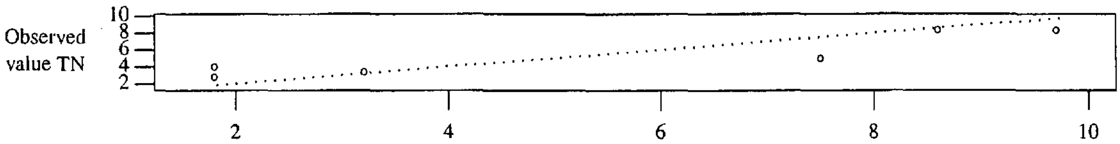


Estimated value of RR for REIMEGREND using the radial method. Sample size = 6.

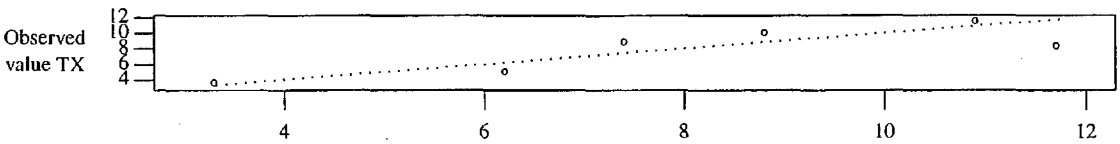
Figure 9. Scatter plots for weather station VANGSNES.



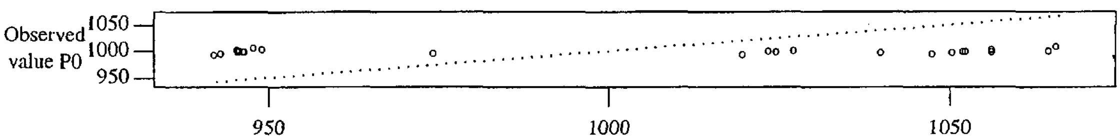
Estimated value of TT for VANGSNES using the radial method. Sample size = 23.



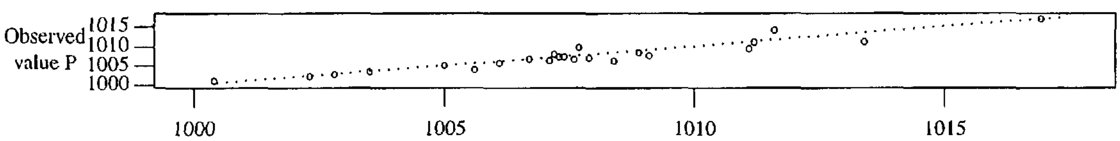
Estimated value of TN for VANGSNES using the radial method. Sample size = 6.



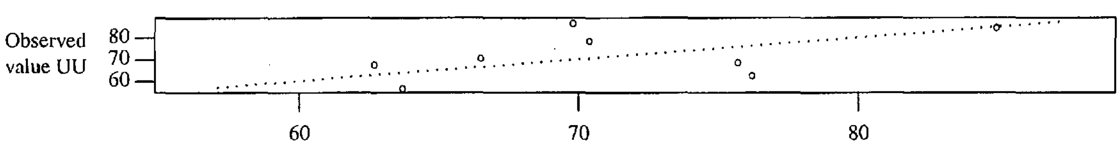
Estimated value of TX for VANGSNES using the radial method. Sample size = 6.



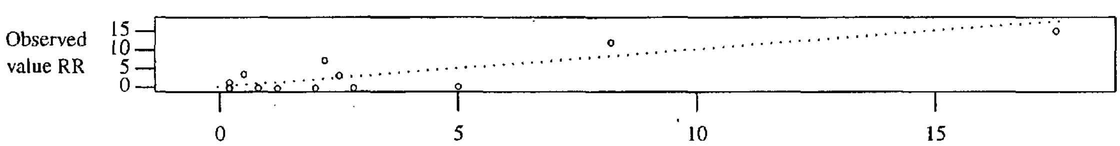
Estimated value of P0 for VANGSNES using the radial method. Sample size = 23.



Estimated value of P for VANGSNES using the radial method. Sample size = 23.



Estimated value of UU for VANGSNES using the radial method. Sample size = 8.



Estimated value of RR for VANGSNES using the radial method. Sample size = 12.

Figure 10. Scatter plots for weather station RØST II.

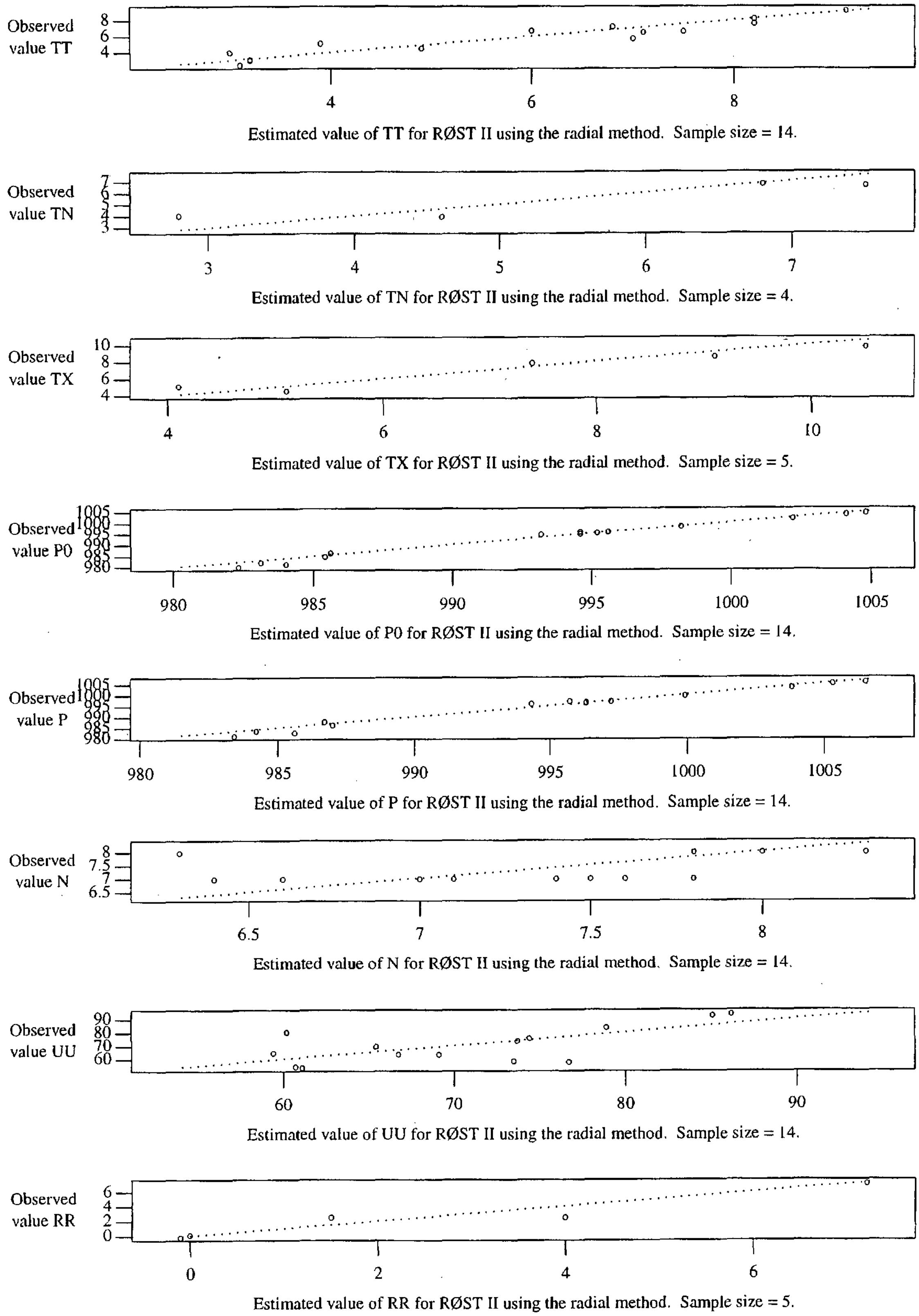
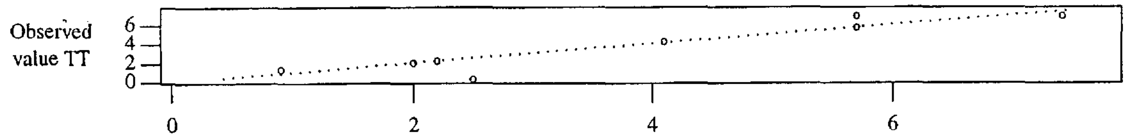
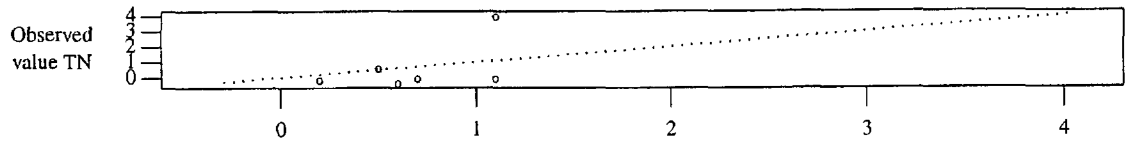


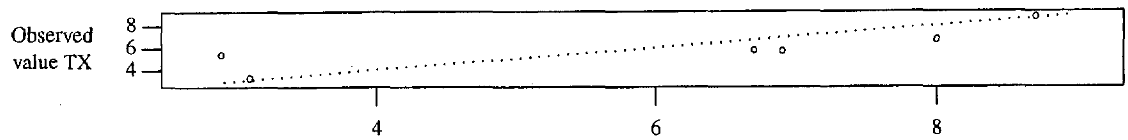
Figure 11. Scatter plots for weather station BØ I VESTERÅLEN II.



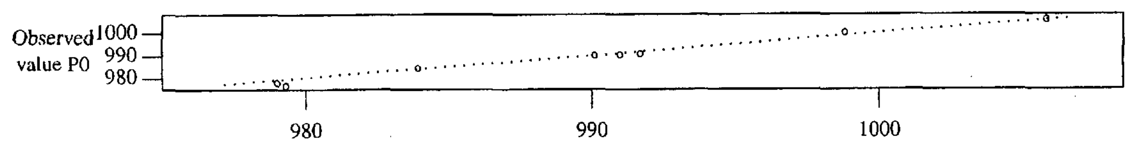
Estimated value of TT for BØ I VESTERÅLEN II using the radial method. Sample size = 8.



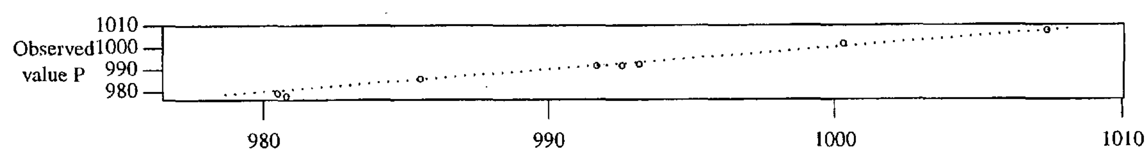
Estimated value of TN for BØ I VESTERÅLEN II using the radial method. Sample size = 6.



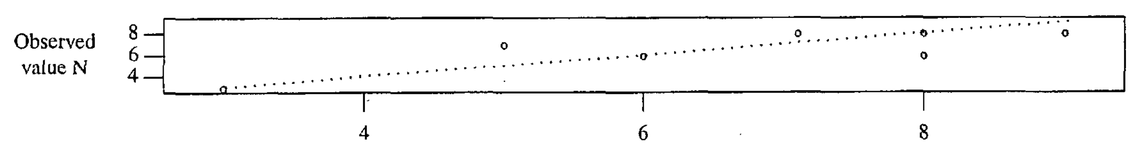
Estimated value of TX for BØ I VESTERÅLEN II using the radial method. Sample size = 6.



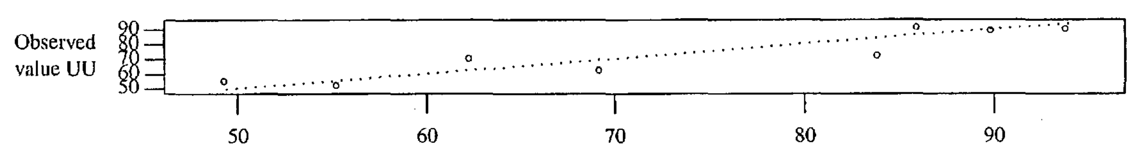
Estimated value of P0 for BØ I VESTERÅLEN II using the radial method. Sample size = 8.



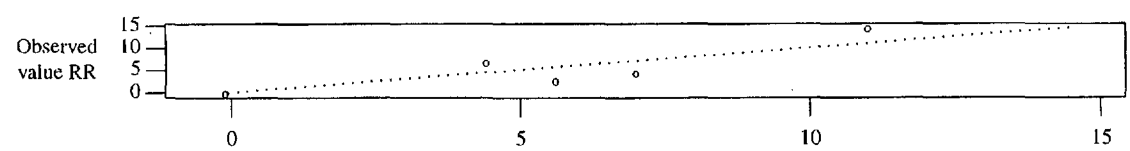
Estimated value of P for BØ I VESTERÅLEN II using the radial method. Sample size = 8.



Estimated value of N for BØ I VESTERÅLEN II using the radial method. Sample size = 8.



Estimated value of UU for BØ I VESTERÅLEN II using the radial method. Sample size = 8.



Estimated value of RR for BØ I VESTERÅLEN II using the radial method. Sample size = 6.

Figure 12. Scatter plots for weather station LITLØY FYR.

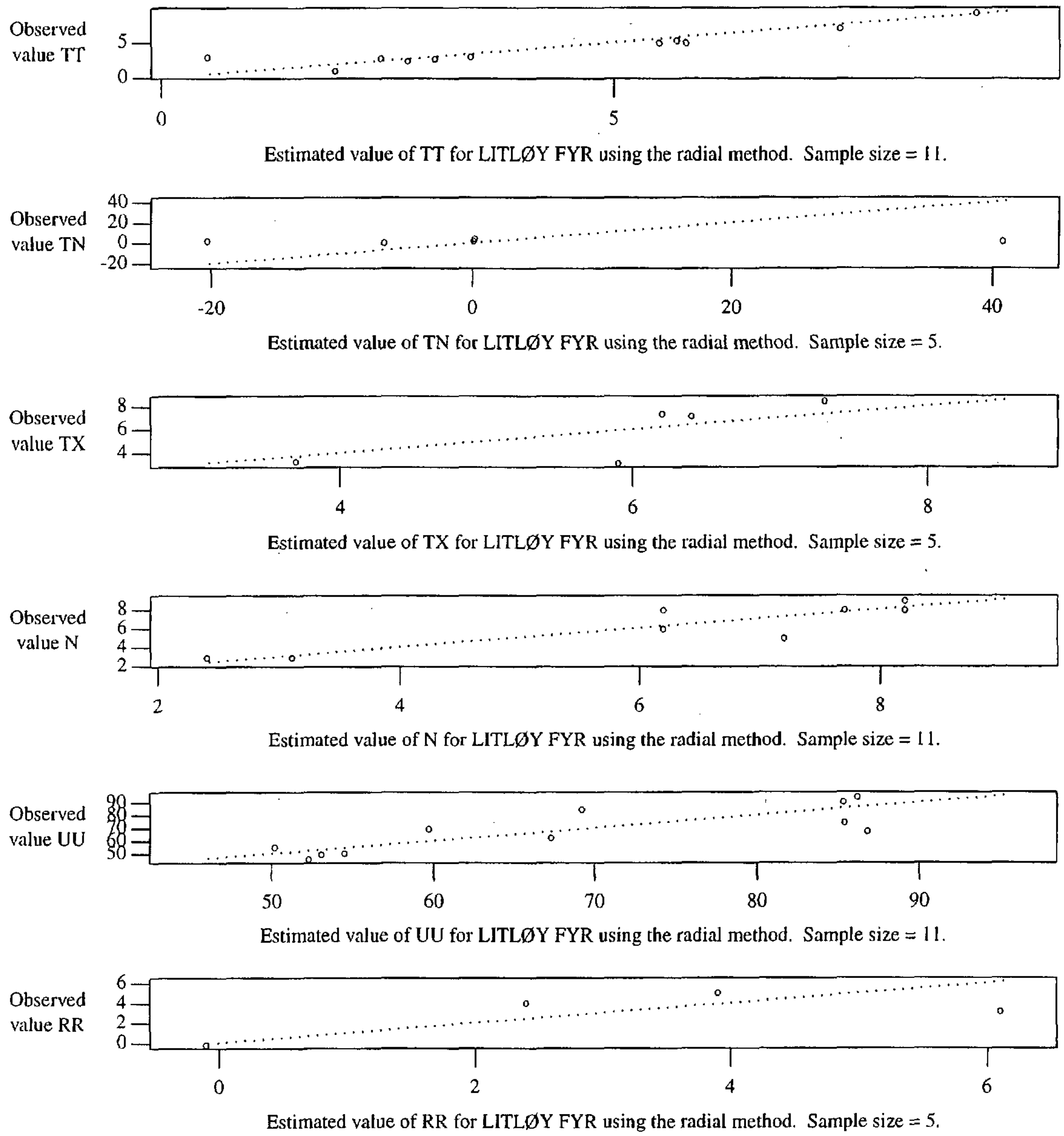


Figure 13. Scatter plots for weather station ALTA LUFTHAVN.

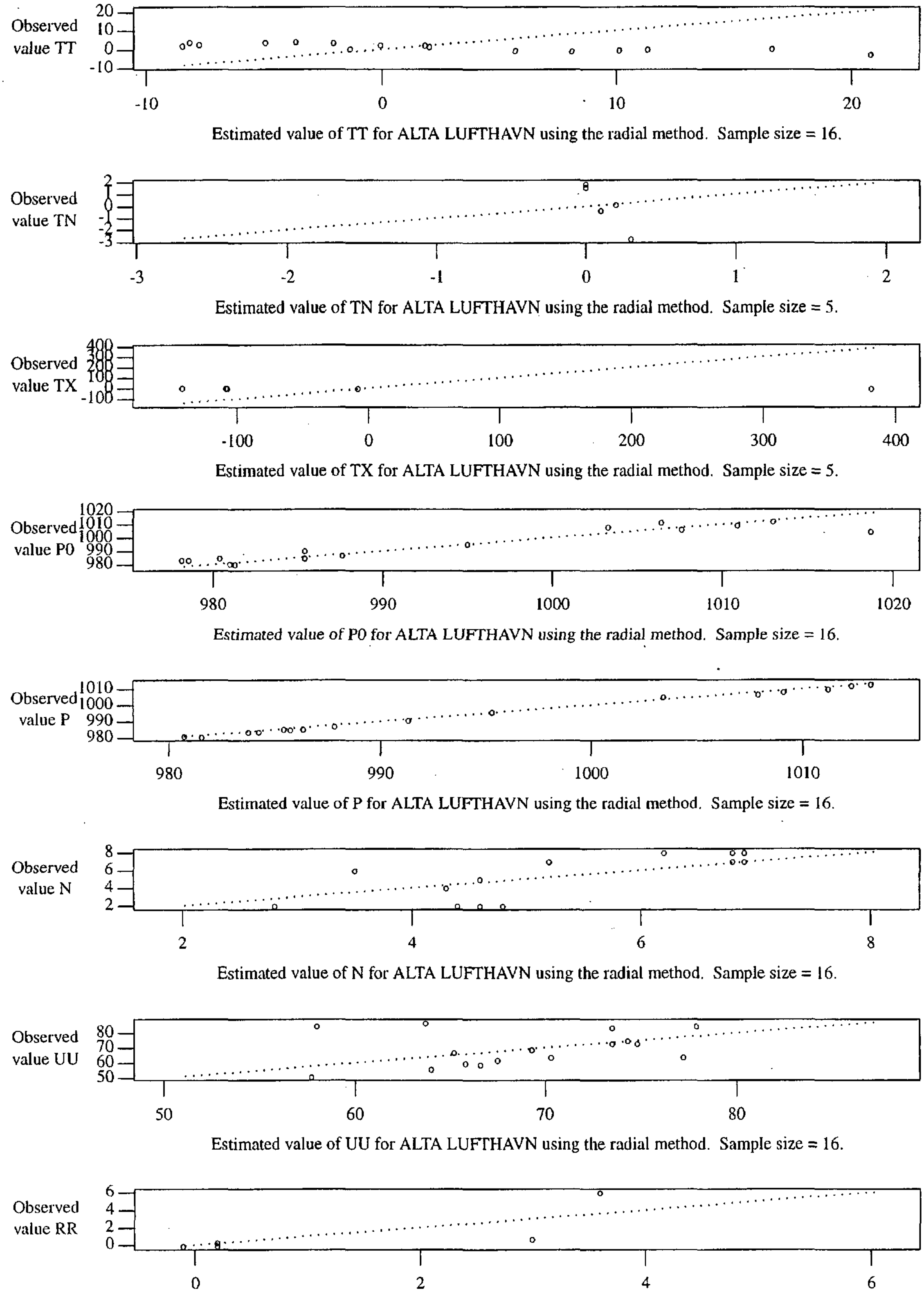


Figure 14. Scatter plots for weather station BANAK.

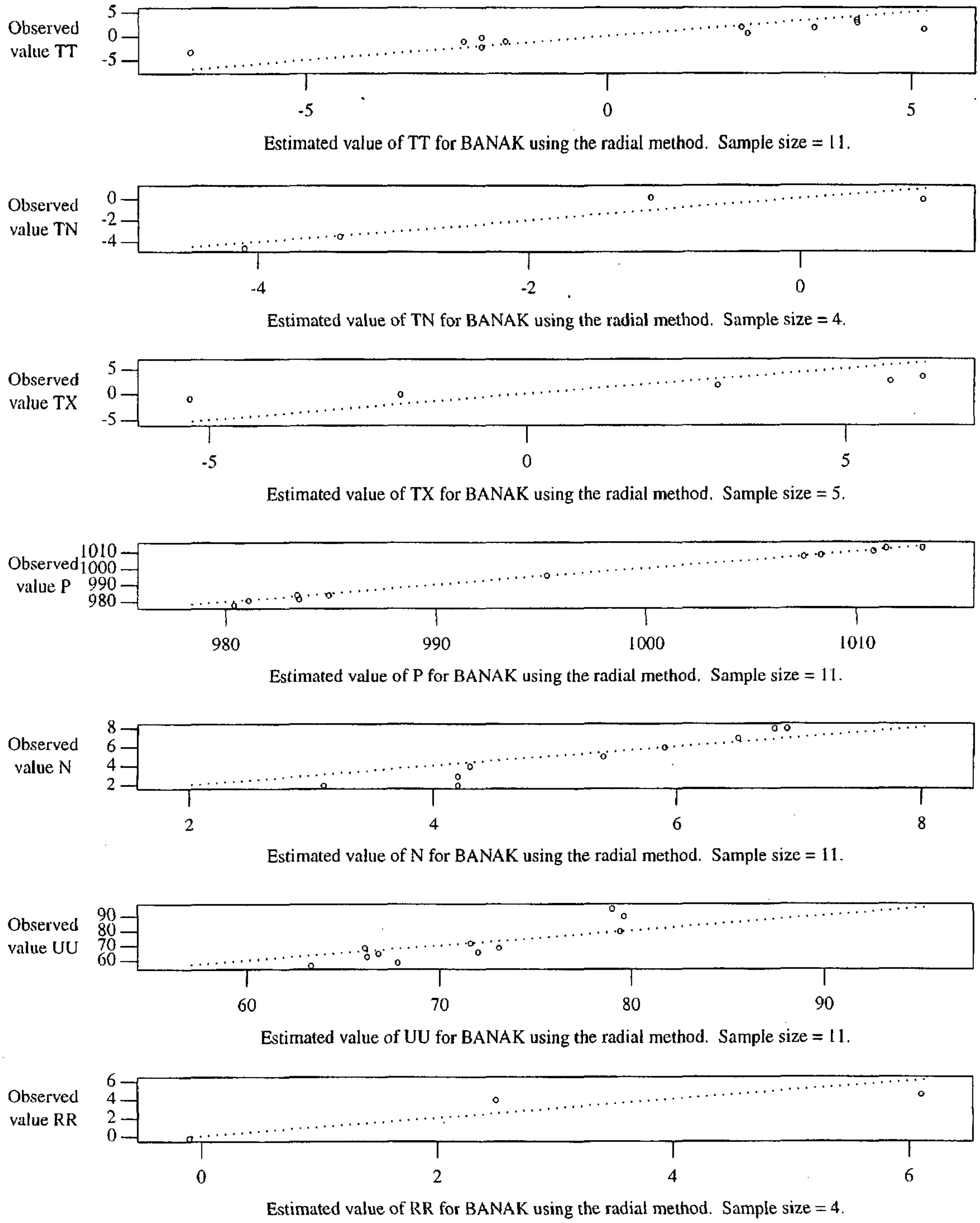


Figure 15. Scatter plots for weather station CUOVDDATMOHKKI.

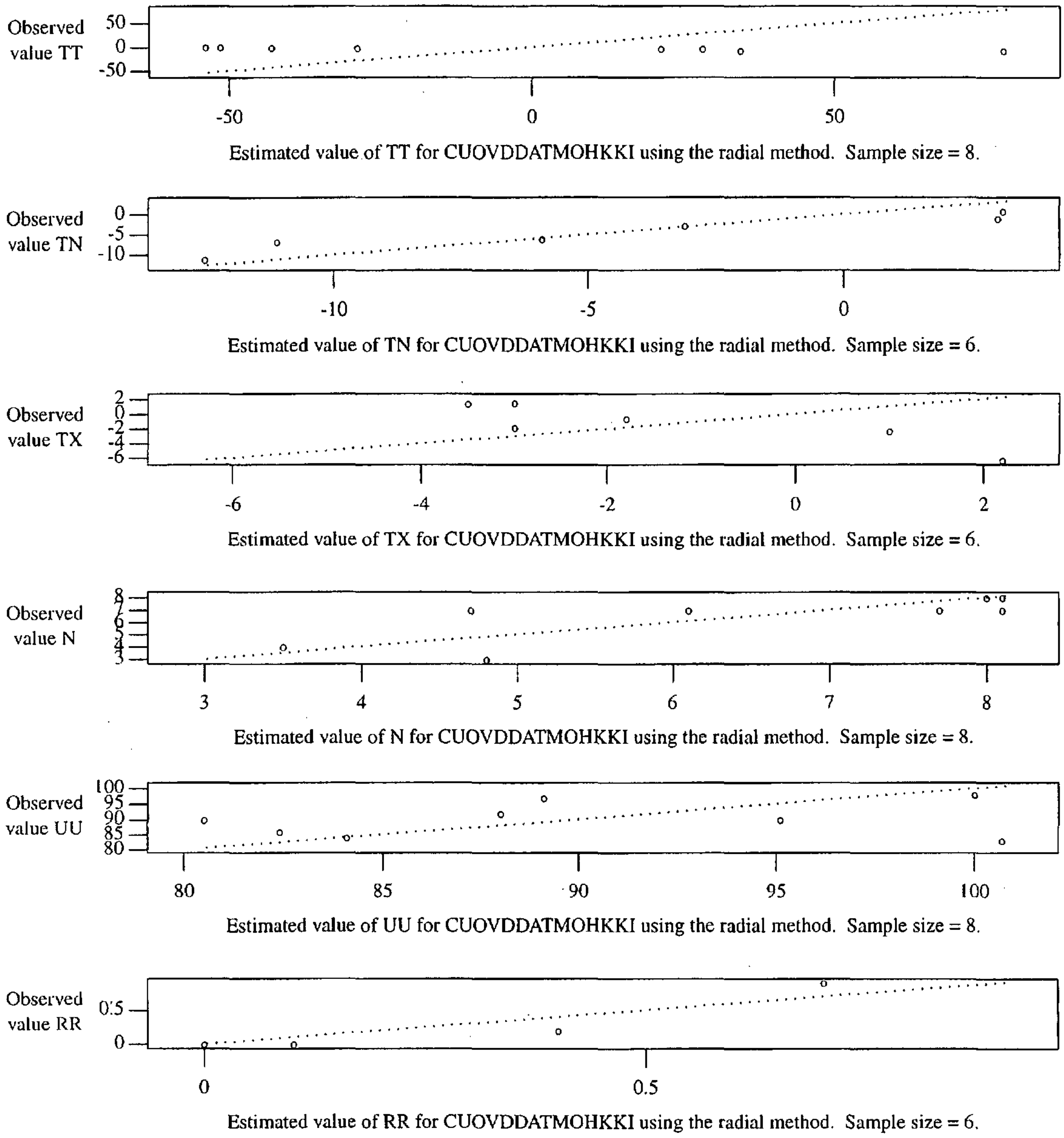


Figure 16. Scatter plots for weather station HOPEN.

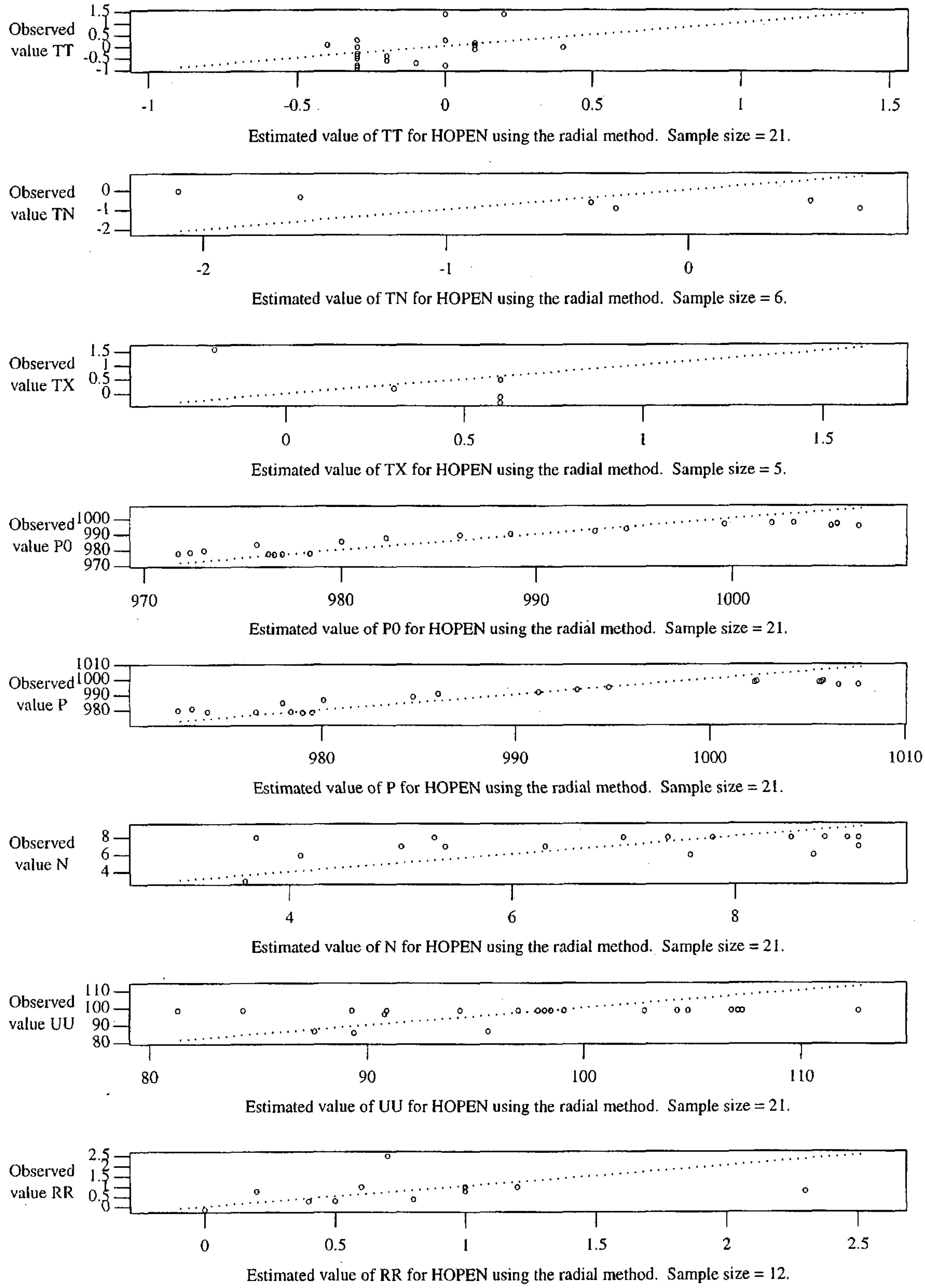


Figure 17. Scatter plots for weather station SVALBARD LUFTHAVN.