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COMPUTED GLOBAL RADIATION USING INTERPOLATED, GRIDDED CLOUDINESS FROM THE MESO-BETA ANALYSIS COMPARED TO MEASURED GLOBAL RADIATION

WEINE JOSEFSSON

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FROM THE MESO-BETA ANALYSIS COMPARED TO MEASURED GLOBAL RADIATION

Weine Josefsson, SMHI, S-601 76 Norrköping

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1 Data sets

A method of computing global radiation using dense, gridded information of cloudiness together with sparse information of measured solar radiation has been tested. It will also be compared to other methods e.g. interpolation. To do this two data sets have been compiled. The first data set contains global radiation from a dense network around Norrköping. It includes the first fourteen stations in the list below. The period is April to September 1988. It has been distributed to the subtask D members.

The second data set includes the same stations plus six others belonging to the Swedish national solar radiation network. It also contains the cloud information from the meso-beta analysis. The period of this second data set is 28 April to 31 October 1989.

Name	N:o	lat	long	(m)	site	horizon	instrument
Norrköping	2071	5835	1609	43	roof	very good	CM 11
Grundbro	2703	5919	1707	30	airfield	suff.	CM 5
Örebro	2705	5916	1517	23	suburban	very good	CM 5
Katrineholm	2708	5859	1614	62	suburban	bad	CM 5
Västerljung	2710	5856	1726	34	field	good	CM 5
Jönåker	2717	5845	1646	30	field	good	CM 5
Örberga	2721	5826	1450	105	field	good	CM 5
Herrberga	2723	5824	1513	85	field	good	CM 5
Vreta Kloster	2724	5829	1531	52	field	good	CM 5
Söderköping	2725	5828	1621	27	suburban	bad	CM 5
Östermem	2726	5830	1637	30	field	good	CM 5
Thorönsborg	2728	5821	1645	4	coast	suff.	CM 5
Harstena	2734	5815	1700	17	island	bad	CM 5
Vimmerby	2740	5740	1551	107	indust.	suff.	CM 5
Lund	2627	5543	1313	73	roof	very good	CM 11
Växjö	2641	5656	1444	182	airfield	good	CM 11
Göteborg	2513	5742	1200	5	roof	good	CM 11
Visby	2091	5740	1821	51	airfield	very good	CM 11
Stockholm	2483	5921	1804	30	urban	very good	CM 11
Karlstad	2415	5922	1328	46	airfield	very good	CM 11
Borlänge	2749	6029	1526	140	roof	very good	CM 11

Table 1. The name and location of the measuring sites. WMO station number. Latitude and longitude in degrees and minutes. Height above the mean sea level. A rough description of the surroundings is added. The type of Kipp and Zonen instrument is noted.

The following procedure and corrections have been applied to the measured data. All stations belong to the SMHI automatic weather station network. Therefore, data are automatically transferred to a central computer and to a file. From this file the stations of interest have been extracted. The data at this level are 6-minute averages of global radiation.

Mainly due to the used data acquisition system there is a large offset in the signal from the pyranometer. The values during night (sun below -5 degrees) are used to compute a correction that is applied to the values during the day. The night values as well as negative values during the morning/evening are set to zero.

All instruments are calibrated at SMHI in Norrköping but some of the CM-5's seem to have changed since the calibration. Using a set of clear days and clear parts of days the stations have been compared to SMHI-Norrköping Only hours close to noon have been used for days that seem to be clear at both sites. In the table below correction factors are given. If the factor has changed during the period the first date for the new factor is given. Otherwise the same factor has been applied to the whole period. The specified date is connected with the date of service and replacement of the pyranometer.

Name	N:o	CF1	DATE	CF2	Dataset 2
Norrköping	2071	no corrections needed			
Grundbro	2703	1.01	880525	0.98	0.99
Örebro	2705	1.025	880428	1.	1.
Katrineholm	2708	1.01	880505	1.	0.98
Västerljung	2710	1.03	880526	0.98	1.
Jönåker	2717	1.01	880831	0.99	1.01
Örberga	2721	1.01		1.01	1.03
Herrberga	2723	1.		1.	1.
Vreta Kloster	2724	1.		1.	1.
Söderköping	2725	1.05		1.05	1.01
Östermem	2726	1.04		1.04	1.
Thorönsborg	2728	1.		1.	1.02
Harstena	2734	1.		1.	1.01
Vimmerby	2740	1.03	880907	1.	1.
Stockholm	2483	no corrections needed			
Lund	2627	no corrections needed			
Växjö	2641	no corrections needed			
Göteborg	2513	no corrections needed			
Visby	2091	no corrections needed			
Karlstad	2415	no corrections needed			
Borlänge	2749	no corrections needed			

Table 2. Correction factors applied to the datasets and date of change of the correction factor. Factor 1. denotes no correction.

The information about the cloudiness is achieved from the meso-beta analysis fields that is available for each third hour of the day. The cloudiness is given in octas for three levels (low, middle and high) in a grid of 22 * 22 km. Data have been compiled for 64 gridpoints (8 * 8) in the surroundings of Norrköping where the dense radiation network is situated. The other stations have been 'connected' to one gridpoint each.

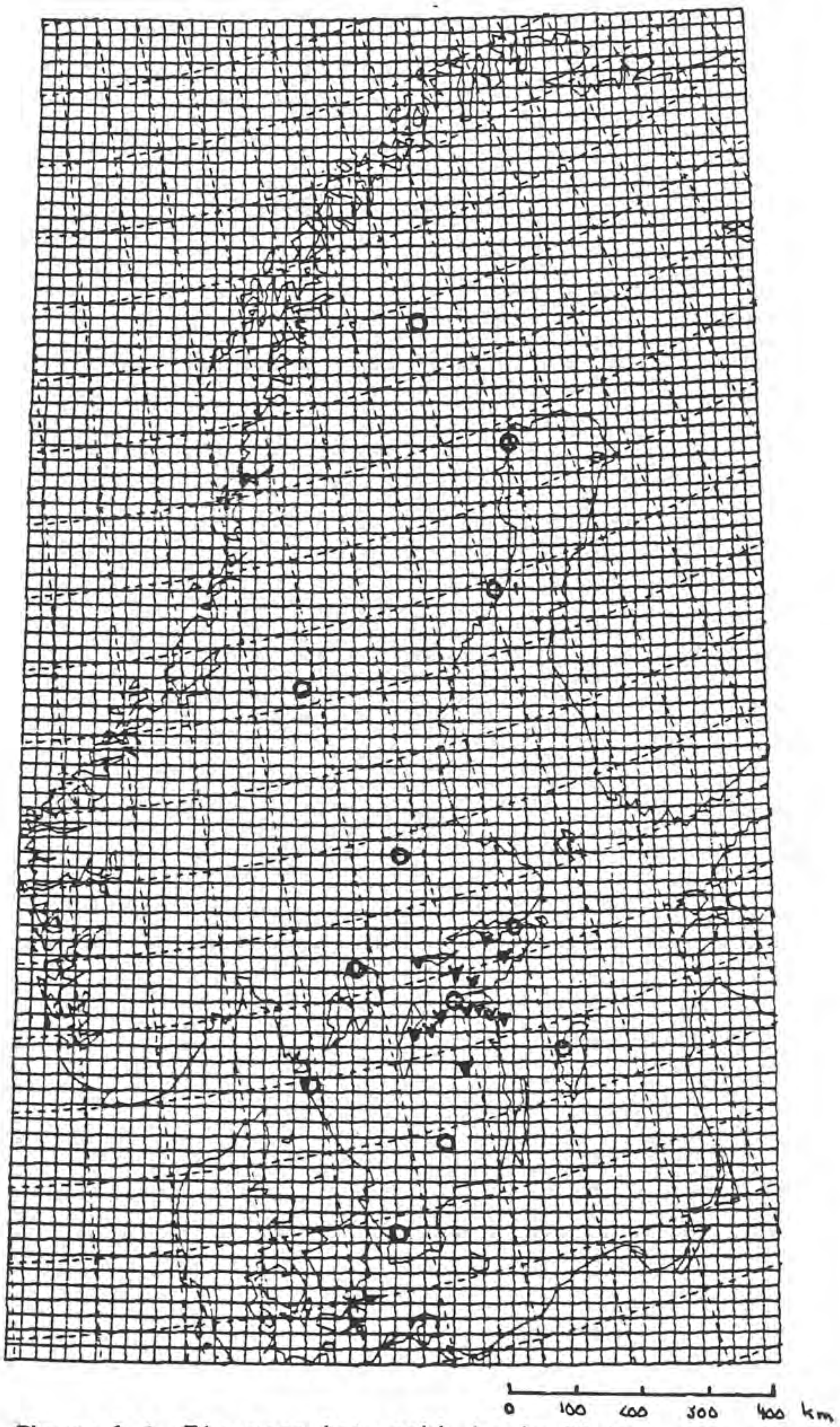


Figure 1.1 The meso-beta grid $\Delta x = \Delta y = 22$ km
National solar radiation network circles, dense network v-shaped indication. Data set 1 includes v-stations. Data set 2 also includes the eight souternmost stations from the national network.

2 Model description

To compute global radiation using this cloud information a simple (non-complex) model have been used. Details of the model may be found in the Appendix where a computer program printout can be found. It includes several comments. However, the principal approaches and important points will be discussed in the following paragraphs. At the end some preliminary results will be given.

Using time, latitude and longitude as input hourly values of the global extraterrestrial radiation, (gex), can be computed. To compute the 'clear' day global irradiance a simple relation between the 'clear' day transmittance, (xt), and the solar height, (solh), is used. It includes correction terms for snowcovered ground and a rough seasonal variation. This type of relation could easily be adopted to any climate using local empirical relations. An important improvement should be to have some information of the clearness (turbidity) of the atmosphere as input-parameter.

xt = 0.50 + 0.30 * sin(solh)Ü0.75 + seas + snow

The Meso-beta cloud amount for each level (low=cl, middle=cm and high=ch) is used to compute the total cloud transmittance, (tc), for each third hour including the effect of multiple reflection, (gmult). The screening effect between the different cloudlayers is taken into account and also the over-estimation of cloudiness by the observer. A large simplification is the use of a constant transmittance for each cloud level. A simple method to improve the model in this respect is to include information on the occurence of precipitation or not. This will be discussed below.

```
th = 0.9       high cloud transmittance
tm = 0.37      middle cloud transmittance
tl = 0.28      low cloud transmittance

tc = ((1-ch) + ch*th)*
     ((1-cm) + cm*tm)*
     ((1-cl) + cl*tl) * gmult
```

The transmittance for the other hours is found by interpolation. The reflectance of the ground is very important. Especially if snowcover will be present. The data set used in this test does not include snow covered ground.

Applying the transmittance of the clouds on the 'clear' day global radiation will give hourly values of the global radiation for each grid point.

glo = gex * xt * tc

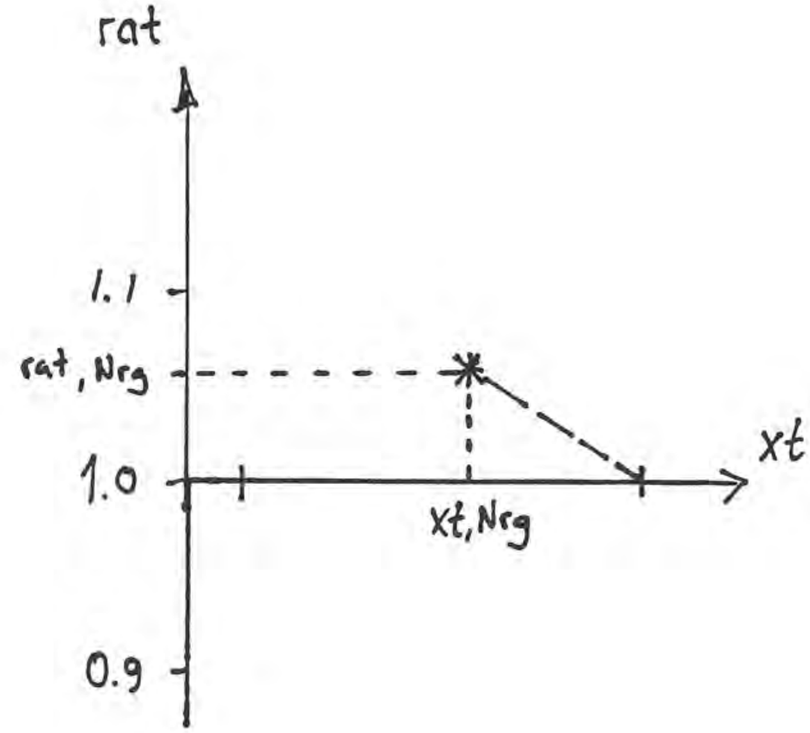
3 Correction of computed values using 'ground truth'

The next step was to investigate if the use of a reference station or a 'ground truth' station would improve the calculated field of radiation. Therefore, daily values were summed up and for the station in Norrköping the ratio between the measured and the computed value was determined.

rat,Nrg = meas / comp

xt,Nrg = comp / gex

The other stations were corrected according to this ratio in such way that all stations having a daily total transmittance of global radiation equal or lower than the one in Norrköping were corrected by the same ratio. The global radiation at stations with higher total transmittance were corrected by a smaller factor. It was determined by a linear equation between the the ratio found for Norrköping and the ratio equal one for the total daily global transmittance equal to 0.85, which roughly corresponds to an almost perfectly clear day. To avoid unreliable results the corrected total global transmittance was limited between 0.05 and 0.77. One must note that all these manipulations are applied on daily values.



4 Testresults

Because of problems with the measured data, mainly incompleteness, a short period was used for testing; viz. 89 Apr 28 to 89 Jun 06. All the presented results refer to this period and includes all stations regardless of distance from the reference-station (Norrköping).

Plotting the modelcomputed global radiation versus the measured is presented in Figure 4.1. The model overestimates the overcast days and underestimates the intermidiate days. The 'clear' days seems to be well formulated. These larger discrepancies have been studied and they seem not be correlated to e.g. cloud amount or the 'clear' day relation. It is not especially sensitive to moderate changes in the cloud transmittances of the three layers.

Taking a closer look at the specific days will give a hint why the point deviate. The main reason for the regular discrepancies seems to be that the model uses a climatological average value for cloud transmittance. Therefore, it is not able to describe for example the two very different transmittances when it is raining or not. This is illustrated in Figure 4.2. For example only cloud-amount as input gives the same computed global radiation for overcast. In reality the scatter is large. Using an extra variable, precipitation or not, combined with two different transmittances should improve the model.

Using a reference station, in this case Norrköping, naturally corrected some of the previously mentioned discrepancies. The result is plotted in Figure 4.3. This figure also includes the data from Norrköping itself, which is incorrectly. It also includes stations so far away (>200 km) that the correction applied, using Norrköping as reference, should not be done. However, it is illustative and it will be further discussed below.

In table 4.1 are the mean bias and the root-mean squared errors presented for all stations for the whole test period. The first line for each station gives the computed vs the measured global radiation. The second line gives the corrected computed vs the measured value. The large deviation of the last station nr. 21 is not yet explained. The last column gives the distance from Norrköping.

In Figure 4.4 and 4.5 are the absolute values of the MBE for each station given before and after correction as a function of the distance from. The present model underestimates the global radiation on average. As shown before it is mainly dependant on cloudtransmittance and of course on the frequency of this 'two' types.

More interesting is perhaps the behaviour of the RMSE as a function of the distance. In Figure 4.6 and 4.7 the uncorrected and the corrected result can be studied respectively. The first figure gives a hint of the model performance, which should be undependant of the distance. There seems to be two groups one close to RMSE =10-15 % and another 15-20%.

Applying the correction gives an interesting result. One would expect a clear reduction of the RMSE close to the reference station. There is such a reduction but it is not uncontradictable. A clear conclusion will not be possible at this moment. Maybe is a correction, as used in this test, not valid for daily values at distances over 30 km.

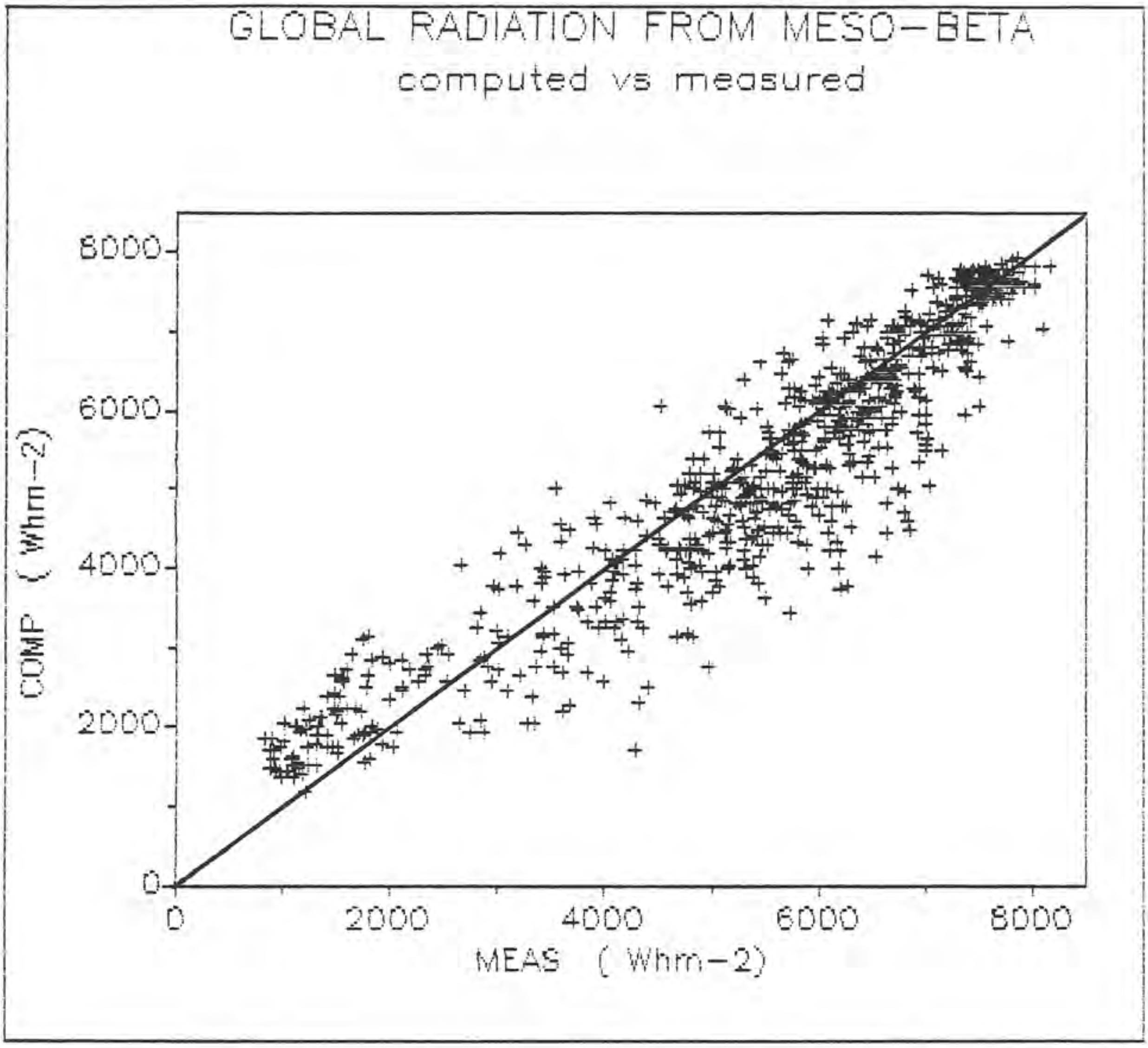


Figure 4.1 Model computed versus measured daily global radiation for all stations during the test period.

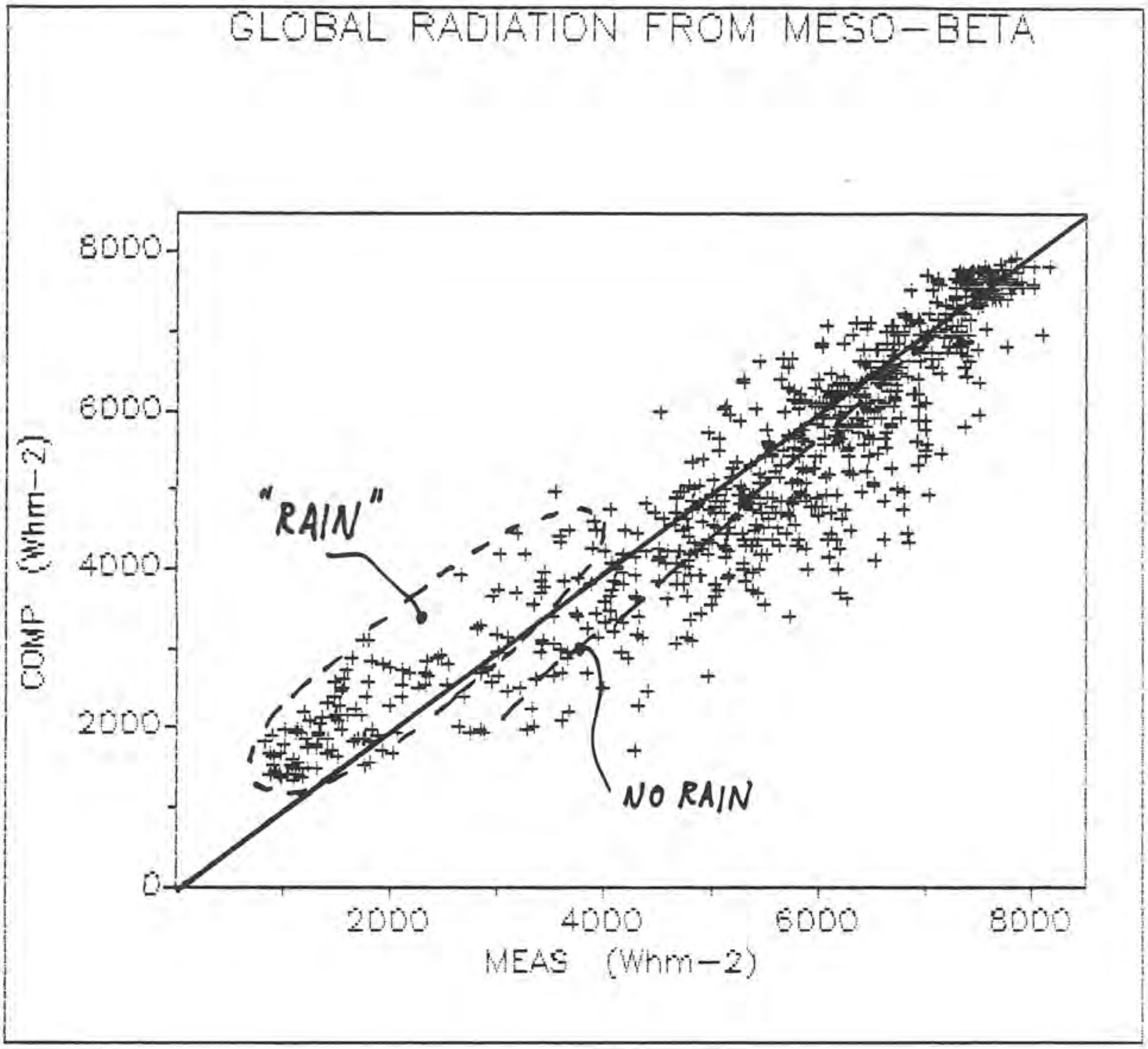


Figure 4.2 Model computed versus measured daily global radiation for all stations during the test period. Probable explanations for some of the scatter is indicated.

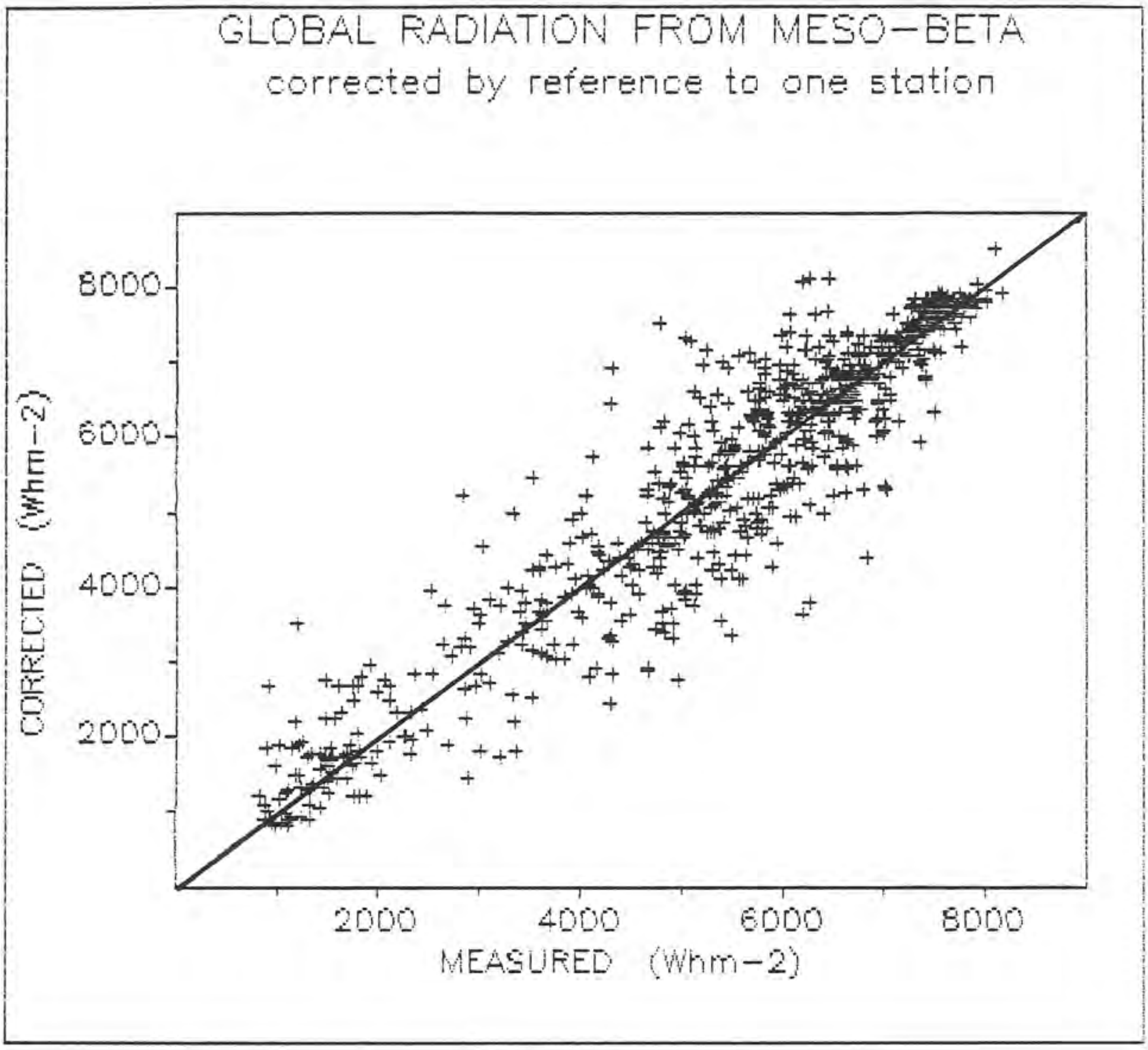


Figure 4.3 Corrected, using Norrköping as reference, model computed versus measured daily global radiation for all stations during the test period.

FIRST LINE COMPUTED VS MEASURED SECOND LINE CORRECTED VS MEASURED

STN	GLOBAL RAD (Whm-2)	MBE (Whm-2)	MBE (%)	RMSE (Whm-2)	RMSE (%)	N:O	DIST. (km)
1	5439.	-235.2	-4.3	727.8	13.4	40.	0
1	5439.	0.0	0.0	0.0	0.0	40.	0
2	5374.	-170.9	-3.2	586.3	10.9	39.	99
2	5374.	93.7	1.7	743.4	13.8	39.	99
3	5278.	-351.6	-6.7	871.4	16.5	39.	91
3	5278.	-103.6	-2.0	756.8	14.3	39.	91
4	5366.	-204.3	-3.8	606.1	11.3	36.	45
4	5366.	76.4	1.4	504.4	9.4	36.	45
5	5639.	-260.6	-4.6	657.2	11.7	39.	84
5	5639.	-0.3	0.0	657.9	11.7	39.	84
6	5274.	-166.9	-3.2	644.0	12.2	33.	40
6	5274.	108.2	2.1	590.2	11.2	33.	40
7	5616.	-558.9	-10.0	921.3	16.4	38.	78
7	5616.	-299.4	-5.3	631.6	11.2	38.	78
8	5537.	-472.7	-8.5	863.9	15.6	38.	58
8	5537.	-207.1	-3.7	553.6	10.0	38.	58
9	5433.	-248.8	-4.6	646.6	11.9	38.	38
9	5433.	27.3	0.5	515.3	9.5	38.	38
10	5387.	-93.8	-1.7	667.2	12.4	38.	17
10	5387.	180.2	3.3	418.3	7.8	38.	17
11	5433.	-54.4	-1.0	585.7	10.8	38.	29
11	5433	218.9	4.0	512.1	9.4	38.	29
12	5548.	-3.1	-0.1	569.2	10.3	37.	43
12	5548.	275.1	5.0	684.4	12.3	37.	43
13	5858.	-135.6	-2.3	657.8	11.2	38.	62
13	5858.	130.6	2.2	631.8	10.8	38.	62
14	5510.	-78.5	-1.4	592.5	10.8	38.	103
14	5510	204.1	3.7	645.9	11.7	38.	103
15	5840.	-238.6	-4.1	693.4	11.9	40.	364
15	5840.	-26.9	-0.5	804.5	13.8	40.	364
16	5330.	138.0	2.6	519.2	9.7	39.	202
16	5330.	353.4	6.6	705.1	13.2	39.	202
17	5201.	71.6	1.4	558.5	10.7	39.	262
17	5201	255.2	4.9	698.6	13.4	39.	262
18	6214.	-209.5	-3.4	573.4	9.2	39.	164
18	6214.	-47.8	-0.8	612.5	9.9	39.	164
19	5494.	-83.7	-1.5	524.9	9.6	39.	139
19	5494.	126.2	2.3	812.0	14.8	39.	139
20	5372.	-459.1	-8.5	846.6	15.8	39.	177
20	5372.	-278.8	-5.2	878.2	16.3	39.	177
21	5326.	-693.6	-13.0	1068.5	20.1	38.	215
21	5326.	-536.2	-10.1	1059.3	19.9	38.	215

Table 4.1 Mean bias and root mean squared errors for all stations and the whole testperiod. First line of each station shows computed versus measured and the second line gives the 'corrected' versus the measured global radiation. The two last columns give the number of days included for each station and the distance from the reference station. The stations are numbered in the same order as in Table 1 and 2.

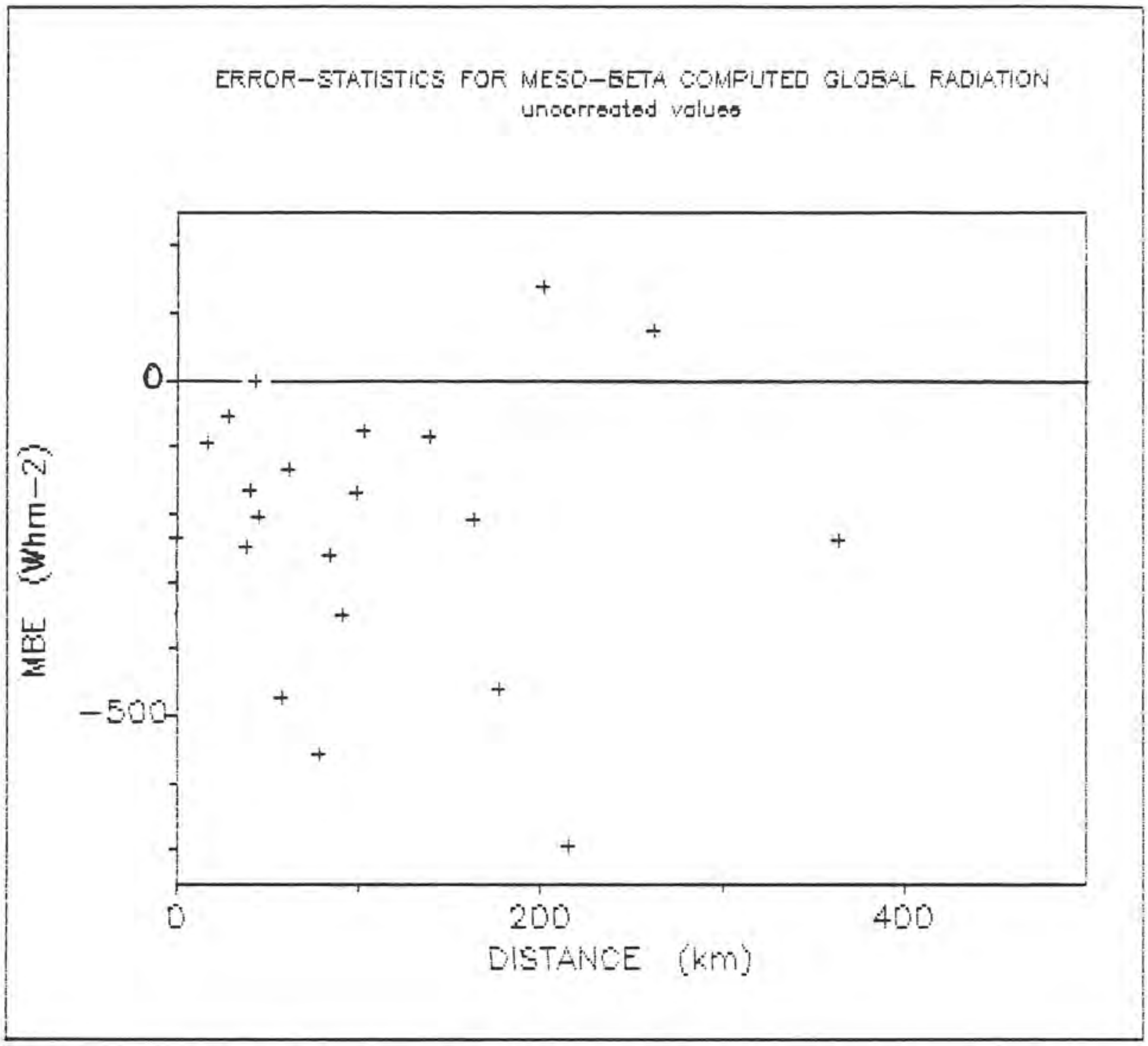


Figure 4.4 The Mean Bias Error in Whm-2 computed value minus the measured global radiation for the testperiod and for all stations plotted versus the distance in km from Norrköping.

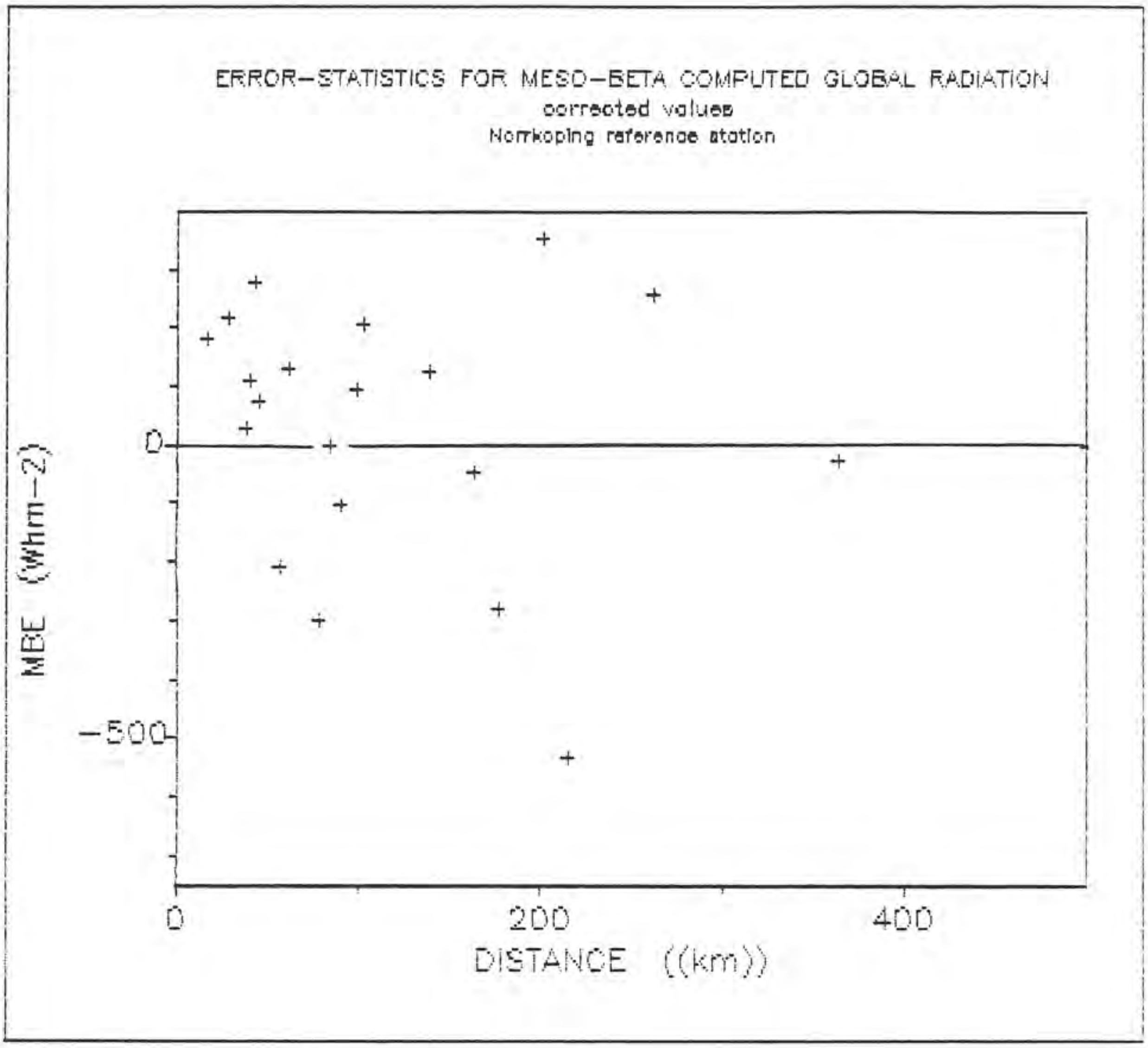


Figure 4.5 The Mean Bias Error in Whm-2 after correction using Norrköping as referens, for the testperiod and for all stations plotted versus the distance in km from Norrköping.

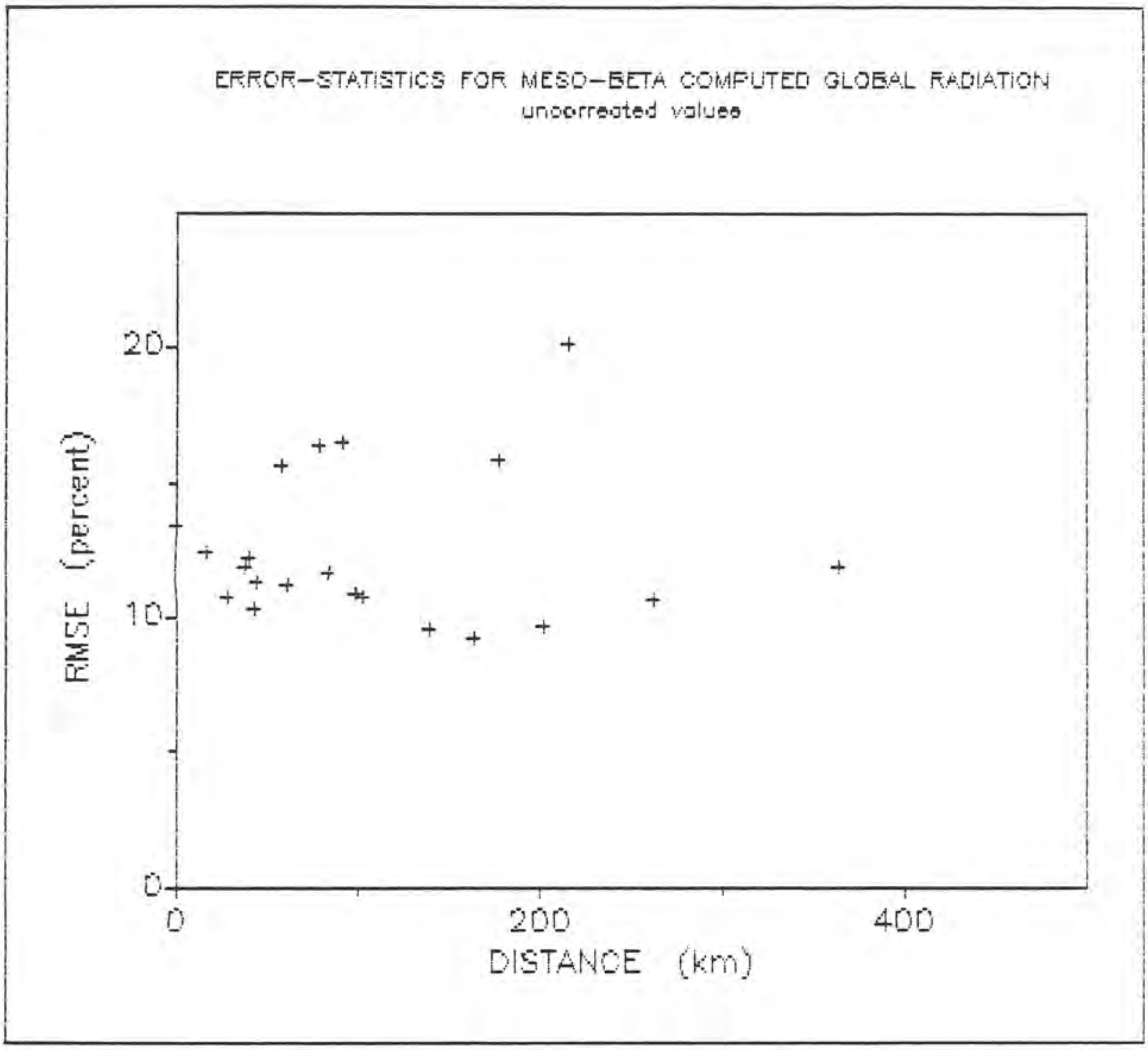


Figure 4.6 The Root-Mean-Squared Error in percent computed related to measured global radiation for the testperiod and for all stations plotted versus the distance in km from Norrköping.

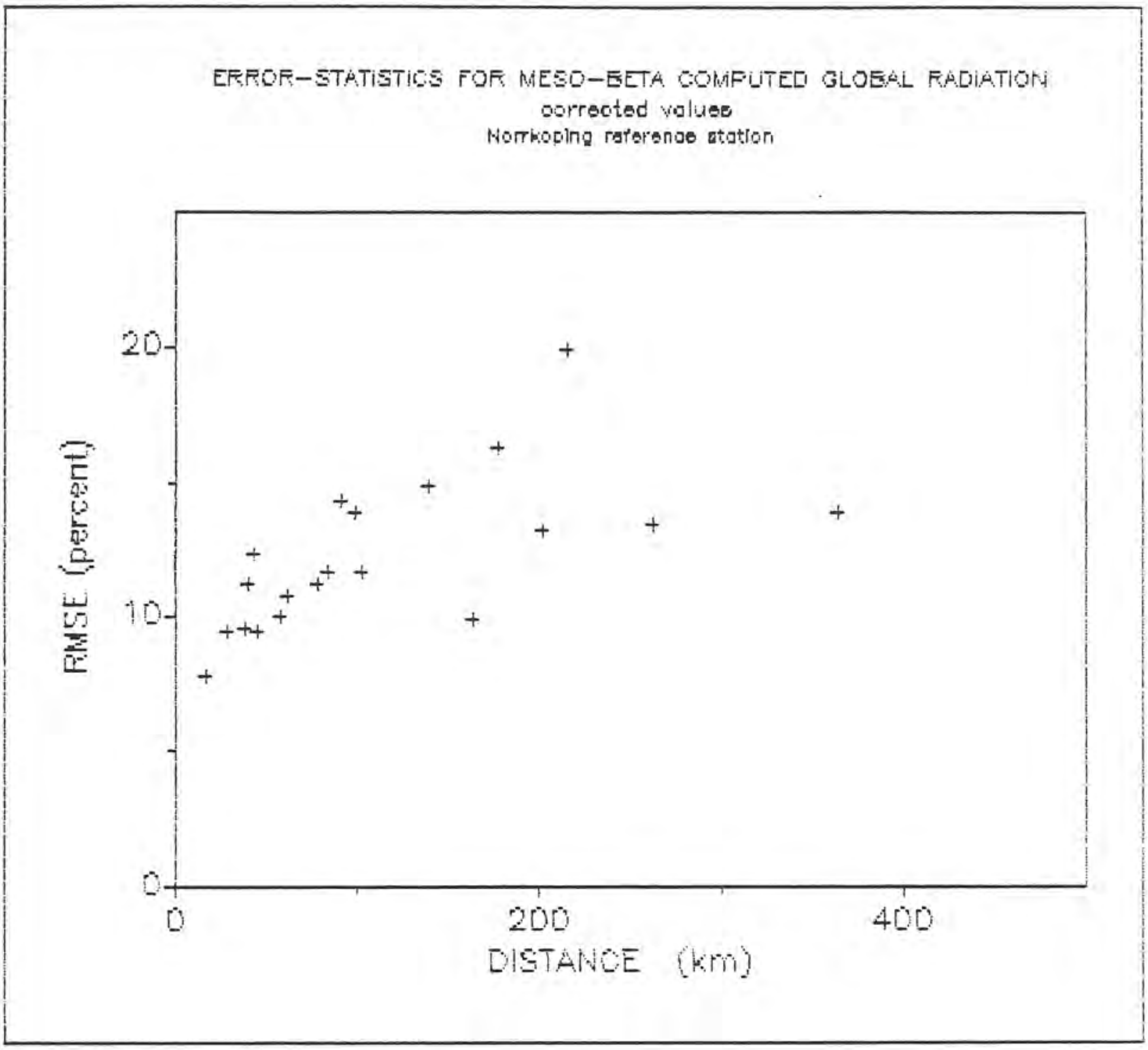


Figure 4.7 The Root-Mean-Squared Error in percent after correction using Norrköping as referens, for the testperiod and for all stations plotted versus the distance in km from Norrköping.

APPENDIX

```
C 1989 10 30 last change 1989 11 30
C                               use the MESO-BETA info to compute
c                               global radiation for selected sites
C
        INTEGER YY, MM, DD, LDATE, DATE
        INTEGER ILAT(21), ILONG(21), ELEMENT(21), ISUMG(21)
        REAL  dhojd(24), GEX(24), BLAT, BLONG, SUMG(21)
        INTEGER IC,Y,M,D,HOUR, HH
        REAL PDATA(72),CLOUD(3,8,21),TC(24),GLO(24)

        pi=3.1415925
        KUT=0
        KREAD=0
C
 1001   FORMAT(1X,5I3)
 1002   FORMAT(1X,8F5.2)
 1000   FORMAT(1X,8F5.2)
C 1050   FORMAT(1X,5I5)
C                       READ STN INFORMATION
C                       stn-nr latitude longitude height element-nr in MESO beta fie
         DO 2 ID=1,21
        READ(15,*) ISTN, ILAT(ID), ILONG(ID), IHOJD, ELEMENT(ID)
 2       CONTINUE
C
C                       read MESO-BETA cloud amount three layers
C
 1      READ(16,1001,END=999) IC,Y,M,D,HOUR
        READ(16,1000) (PDATA(K),K=1,8)
        READ(16,1000) (PDATA(K),K=9,16)
        READ(16,1000) (PDATA(K),K=17,24)
        READ(16,1000) (PDATA(K),K=25,32)
        READ(16,1000) (PDATA(K),K=33,40)
        READ(16,1000) (PDATA(K),K=41,48)
        READ(16,1000) (PDATA(K),K=49,56)
        READ(16,1000) (PDATA(K),K=57,64)
        READ(16,1000) (PDATA(K),K=65,72)
        KREAD=KREAD+1
C
C                       put info in matrix for each hour HH
        HH=HOUR/3+1
C                       and each station IS
C                       and cloudlayer IC
         DO IS=1,21
                CLOUD(IC,HH,IS)=PDATA(ELEMENT(IS))
         ENDDO

        IF((HOUR+IC).LT.24) GOTO 1

        DATE= 10000*Y +100*M +D
C                       BREAK-DATE for the test period ******* NOTE ****
        IF(DATE.GT.890610) GOTO 999
C
C============================================================
C
C               CALCULATE GLOBAL RADIATION FOR EACH STATION
C               FOR THIS DAY

        DO 4 IS=1,21


C               DETERMINE EXTRATERR. RAD. AND SOLAR HEIGHTS FOR EACH HOUR
C               using subroutine HAZ input is latitude and longitude
C               in degrees, not degrees and minutes
C
                BLAT=ILAT(IS)/100.
                        BLAT=BLAT+(ILAT(IS)-BLAT*100)/60
                BLONG=ILONG(IS)/100.
```

```
                           BLONG=BLONG+(ILONG(IS)-BLONG*100)/60

          call HAZ(Y, M, D, INR, dhojd, GEX, BLAT, BLONG)
CCC
CCC               compute for each hour ID
      DO 62 ID=1,24
c                 set ZERO if sun below 0.1 degree
        GLO(ID)=0
        IF(DHOJD(ID).LT.0.1) GOTO62
C
        SINH=SIN(PI*DHOJD(ID)/180.)
CC
CC                compute clear sky value
CC                NOTE: the relation is related to season by a very rough corr. SEAS
CC                      and also to the presence of snowcover SNOW
CC                      the REFLectance is preset in this test
CC                      the daynumber INR (1-366)

        SEAS = 0.02 + 0.02 * COS(2*PI*INR/365.25)

        REFL = 0.2
        SNOW = (1-0.07*0.2) / (1-0.07*REFL) - 1

        IF(SINH.GT.0.08)THEN

CC                'clear' sky could be described by different relations
CC                depending on different conditions e.g.
CC turbid      GLO(ID)=GEX(ID)*( 0.35 + 0.45*SINH**0.75 + SEAS + SNOW)
CC high        GLO(ID)=GEX(ID)*( 0.43 + 0.37*SINH**0.75 + SEAS + SNOW)

cc low clouds and clear
           GLO(ID)=GEX(ID)*( 0.50 + 0.30*SINH**0.75 + SEAS + SNOW)
        ELSE
          GLO(ID)=GEX(ID)*(1.0-6.*SINH + SEAS + SNOW)
        ENDIF

 62   CONTINUE


C=================================================================
CCC               COMPUTE TRANSMITTANCE THR CLOUDS AND MULTIPLE SCATTERING
CC                init
        DO 64 ID=1,24
                  TC(ID)=-1
 64     CONTINUE
C                         every third hour
        DO 63 ID=1,8
C                         octas to fractional cloudiness
                  CL=CLOUD(1,ID,IS)/8.
                  CM=CLOUD(2,ID,IS)/8.
                  CH=CLOUD(3,ID,IS)/8.

C                         correct low and middle cloud amount
C                         NOTE: if satellite data is used
C                               this should be different
C                               it's only for data based on ground observ.
                  IF(CL.GT.0) CL=CL**1.6
                  IF(CM.GT.0) CM=CM**1.6
C                         total amount of low and middle clouds due to screen effects
                  CTLM= CL+(1-CL)*CM
C                         total cloudamount due to screen effects
                  CTOT= CTLM + (1-CTLM)*CH
C                         set a value for the cloud reflectance by interpolation
C                         low and middle clouds 0.6 high clouds 0.3
                  IF( CTOT.GT.0 )THEN
                   RC= (0.6*CTLM + 0.3*(CTOT-CTLM)) / CTOT
                  ENDIF
```

```
C                   ground reflectance
C                   NOTE: this should be changed if snow is present
c                         it's only preset in this TEST
            RG= REFL
c                   sky reflectance, where clear sky reflectance is 0.07
            RS= CTOT*RC+0.07*(1-CTOT)
C                   multiple reflection factor
            GMULT=1/(1-RG*RS)

C                   average cloud transmittance for each layer corrected
c                   for mult.refl. because GMULT is applied for actual condition
C                   Canadian, Davies et.al. (1985) Monthly Weater Review
C                   exept for HIGH clouds where 0.9 is used.
c                   The model is actually not so sensitive for variation in
c                   these values.
c                   However, a large improvement could be achieved by
c                   differencing between cloud-transmittances (low and
c                   middle) for situations with or without precipitation
c                   see attended figure
              TH= 0.9
              TM= 0.37
              TL= 0.28

            IDD=(ID-1)*3+1
C                   every third hour
C                   total transmittance through all three layers
C                   and corrected for mult. refl.
            TC(IDD)=((1-CH)+CH*TH)*
     *              ((1-CM)+CM*TM)*
     *              ((1-CL)+CL*TL) * GMULT

  63    CONTINUE

C                   interpolate (extrapolate) the transmittance
C                   to get one value for each hour during the day
        DO 66 ID=1,22,3

           IF(TC(ID).GT.0.) TIN=TC(ID)
           IF(TC(ID).GT.0. .AND. ID.NE.22 )THEN
                TC(ID+1)=TC(ID)+(TC(ID+3)-TC(ID))/3
                TC(ID+2)=TC(ID)+2*(TC(ID+3)-TC(ID))/3
           ELSEIF(TC(ID).GT.0)THEN
                TC(ID+1)=TC(ID)
                TC(ID+2)=TC(ID)
           ELSE
                TC(ID)=TIN
                TC(ID+1)=TC(ID)
                TC(ID+2)=TC(ID)
           ENDIF
 66     CONTINUE

C                   global radiation = clear value * cloud trans
C                   make daily sums
        SUMG(IS)=0
        DO 70 ID=1,24
        IF(GLO(ID).GE.0. .AND. TC(ID).GE.0.)THEN
                GLO(ID)=GLO(ID)*TC(ID)
        ELSE
                GLO(ID)=0
        ENDIF
                SUMG(IS)=SUMG(IS)+GLO(ID)
 70     CONTINUE
C                   put in integer vector for outprint
        ISUMG(IS)=SUMG(IS)+0.5

 4      CONTINUE
```

```
C===============================END OF THE COMPUTATION FOR THAT DAY=========

C                       outprint date and daily values for all sites

        WRITE(10,1111) DATE,ISUMG
         KUT=KUT+1
        GOTO1

 1111   FORMAT(1X,I7,21I5)

 999    WRITE(6,*)'KUT=  ',KUT
        STOP
        END
C
      SUBROUTINE HAZ(iy, im, id, inr, dhojd, GEX, BLAT, BLONG)
***      PROGRAM HAZ
***   ----------------------------------------------------------
***   This subroutine use date and time for input
***   to compute solar heights (degrees) and global extra-
***   terrestrial radiation (Wm-2). The daynumber is also avail.
***   ----------------------------------------------------------
***

      INTEGER  dw,  di, ddek
      INTEGER iy, im, id, kd, il, inr, mfas
      INTEGER itim, datum, tid
      REAL a, b, pi, y, m, x, p, dnr, tnr, tekv, gamma
      REAL blat, blong, daz, GEX(24),dhojd(24)

        pi=3.1415925
        DO 75 ITIM=1,24
      snt = itim-.5

***
***   ----------------------------------------------------------
***   Compute julian daynumber -  inr
***   ----------------------------------------------------------
***
      a  = 1.0
      b  = 0.5
          kd = 0
***
      y  = FLOAT(iy)
      m  = FLOAT(im)
      IF (m .LT. 2.99) THEN
         GOTO 9
      ENDIF
      a  = 3.0
      b  = 59.5
      x  = y/4.0
      kd = INT(x-INT(x-0.1))
9     p  = m-a
      il = INT(p*30.6+b)
***
      inr = id+kd+il
***
***
***   *** LATITUDE IN RADIANS ***
***
      b = blat*pi/180
***
***   *** TIME DIFFERECE IN HOURS ***
***
      tsk = 24.0/360.0*(15.0-blong)
***
      mfas = MOD(iyear, 4)
      IF (mfas .EQ. 0) THEN
```

```
         dfas = 0.0
      ELSE
         dfas = (4.0 - FLOAT(mfas))*0.25
      ENDIF
***
***
***   --------------------------------------------------------
***   This part computes the equation of time (UNIT= hours) as
***   a function of julian daynumber during the leap year cycle
***   --------------------------------------------------------
***
      dnr = FLOAT(inr)
      mfas = MOD(iyear,4)
      IF (mfas .EQ. 0) THEN
         tnr = dnr
      ELSE IF (mfas .EQ. 1) THEN
         tnr = dnr+366
      ELSE IF (mfas .EQ. 2) THEN
         tnr = dnr+731
      ELSE
         tnr = dnr+1096
      ENDIF
***
      tnr = 2*pi*tnr/365.25
      tekv = 0.00020870+0.0092869*COS(tnr)-0.12229*SIN(tnr)
     --0.052258*COS(2*tnr)-0.15698*SIN(2*tnr)
     --0.0013077*COS(3*tnr)-0.0051602*SIN(3*tnr)
     --0.0021867*COS(4*tnr)-0.0029823*SIN(4*tnr)
     --0.0001510*COS(5*tnr)-0.00023463*SIN(5*tnr)
***
***
***
***   --------------------------------------------------------
***   Compute the declination
***   y = SIN(declination)
***   --------------------------------------------------------
***
      gamma = (2*pi*(dnr+283.33+dfas))/365.2422
      y = 0.39795*SIN(gamma+0.007133*SIN(gamma)+0.032680*COS(gamma)
     --0.000318*SIN(2.0*gamma)+0.000145*COS(2.0*gamma))
      dek = ASIN(y)
      ddek = INT(dek*180/pi)
***
***
***
***   --------------------------------------------------------
***   Computations
***   --------------------------------------------------------
***
***   ** true solar time **
      snst = snt - tsk + tekv
***
***   ** hour angle **
      w = (pi - ((snst*2*pi)/24))
      dw = INT(w*180/pi)              ! to degrres
***
***   ** SOLar height **
      hojd = ASIN(SIN(dek)*SIN(b)+COS(dek)*COS(b)*COS(w))
      dhojd(ITIM) = hojd*180/pi       ! to degrees
***
***   ** EXTRATERR RADIATION WM-2**

      RAD=1.+0.033*COS(2.*PI*DNR/365.24)
        GEX(ITIM) = 1370. *SIN(HOJD) *RAD


***
```

```
***    ** AZIMUTH **
C       qq = (SIN(hojd)*SIN(b)-SIN(dek))/(COS(hojd)*COS(b))
C       IF (qq .GT. 0.99999) qq = 1
C       az = ACOS(qq)
C       daz = az*1800/pi                ! to degrees*10
C
C       IF (w .GE. 0.0) THEN
C          daz = 1800-daz
C       ELSE
C          daz = 1800+daz
C       ENDIF
***
 75      CONTINUE
***
***    ------------------------------------------------------
***    Finale Ende Finish Stop Slut
***    ------------------------------------------------------
***
       RETURN
       END
```