WEATHER TEST REFERENCE YEARS OF GREENLAND

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ABSTRACT

The purpose of this paper is to describe the construction of two test reference years of Greenland. The first test reference year is constructed using measurements of climatic parameters from the town Nuuk located in the southwestern part of Greenland. The second test reference year is constructed using measurements from the town Sisimiut located in the central part of Greenland on the west coast.
The construction of the test reference years fulfills the procedures described in the standard EN ISO 15927-4 using the following main weather parameters: Dry bulb temperature, global radiation, relative humidity and mean wind speed.
To construct the test reference years a program called REFYEAR was developed in MatLab. REFYEAR automatically constructs the test reference year using an input file containing the climatic measurements. The program REFYEAR is shortly described in this paper.
The two constructed test reference years, Nuuk.TRY and Sis.TRY, can be ordered by contacting AISAQ, Greenland.

1. INTRODUCTION

A test reference year is a data file containing hourly values of different climatic parameters such as temperature, solar radiation, humidity and wind speed. The data file is to be used in computer simulations where the weather influences the simulation model. An example could be the simulation of the annual heating demand of a house. In this case the outdoor temperature and solar radiation is used as an input to simulate the heating demand.

The test reference year is constructed by selecting the most typical months from all the years found by a statistic analysis of the data material. According to the standard EN ISO 15927-4 /1/, at least ten years of continuous (hourly) measurements of the climatic parameters should be used in the construction of a test reference year.
In computer simulation programs the fraction of diffuse solar radiation and direct normal radiation is often required as an input weather parameter. These two parameters are expensive and difficult to measure, though, and therefore seldom available, as is also the case in this work. The diffuse radiation and the direct normal radiation have therefore been calculated from the measured global radiation using the calculation procedures described in /2/.
The measured climatic data used for the construction of the test reference years are all delivered by ASIAQ /3/. The different climatic parameters in the final test reference year are shown in Table 1.

Table 1 Climatic parameters in the test reference year

Climatic parameter	Unit	Data origin
Dry bulb temperature	ºC	Measured
Global radiation	W/m²	Measured
Diffuse radiation	W/m²	Calculated
Direct beam normal radiation	W/m²	Calculated
Humidity	% RH	Measured
Wind velocity (10 min. mean)	m/s	Measured
Atmospheric pressure	hPa	Measured

The global radiation (short-wave) is 1 hour mean of 1 minute's measurements. The dry bulb temperature is measured in a radiation shield 2 metres above ground level.
The exact locations of the two weather stations in Nuuk and Sisimiut are shown in table 2:

Table 2 Locations of the weather stations

Town name	Station number	Altitude [m]	Latitude	Longitude
Nuuk	522	80	64°10' N	51°52 'W
Sisimiut	515	15	66°56' N	53°41' W

The data used in the construction of the two test reference years was measured over the following periods:
Nuuk: 1/11-1993 to 31/1-2004
Sisimiut: 1/10-1991 to 31/1-2004

2. QUALITY CONTROL OF DATA

A major part of the work to be done when constructing a test reference year is to handle the large quantity of data and check the quality of each climatic measurement. 10 years of hourly measurements of four climatic parameters gives 350,000 data values. These data should be checked for unrealistic values, dummy values or missing values. In this work the data material delivered from ASIAQ /3/ was of a very high quality.
In practice the measurement of the climatic parameters over 10 years or more will fail from time to time. In appendix A the percentage of missing data in each month and of each climatic parameter are shown for the data material used in this work.
According to the standard /1/ missing values should be generated by linear interpolation or by estimation. In this work missing values of the global radiation measurements are estimated using the values measured 24 hours before. This approach is chosen because of the 24 h periodicity of the solar radiation. Linear interpolation of missing values from 15:00 day 1 to 9:00 day 2 would give radiation all night which is obviously wrong.
Months missing more than 5 percent of the data are excluded from the data in the final reference year. Though months with interpolated values are included in the statistic analysis.
Also it should be mention that measurements from the intercalary day (29/2) 1992, 1996 and 2000 are excluded from the data.
In Figure 1 the raw data of the measured dry bulb temperature are shown for the two towns. It is seen that the temperature in Nuuk typically drops to – 20ºC in winter and rises to + 20ºC in the summer. In Sisimiut the lowest temperature is seen to be as low as –35ºC some years.

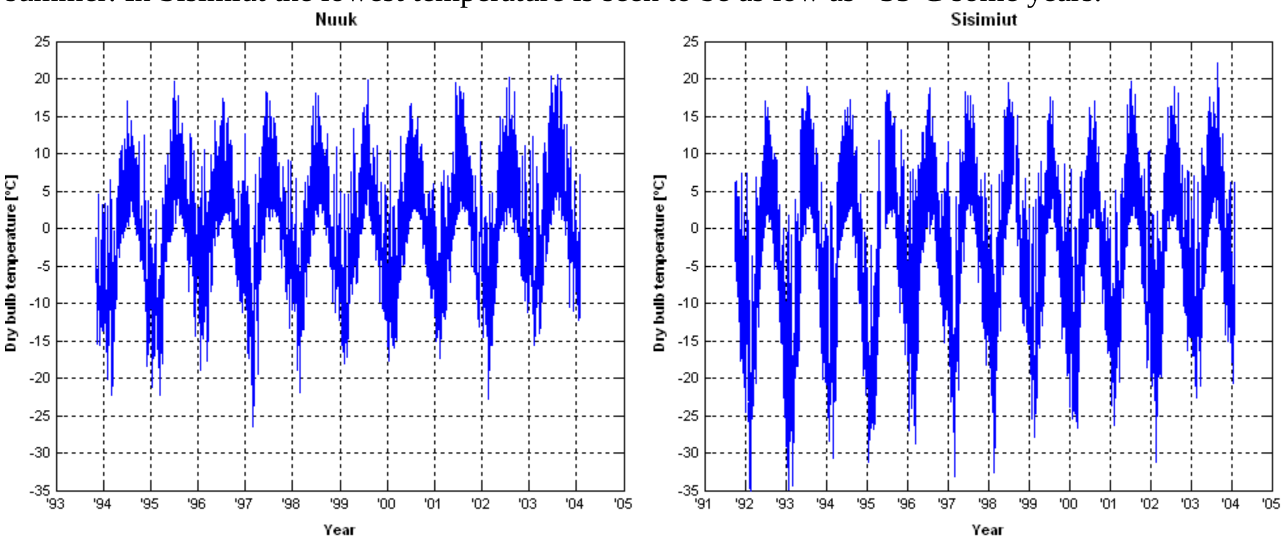

Figure 1 Yearly dry bulb temperature. Left Nuuk. Right Sisimiut

In Figure 2 the data of the measured global radiation is shown. In Nuuk and Sisimiut the maximum radiation on a horizontal surface is seen to be 800 W/m² and 750 W/m², respectively.

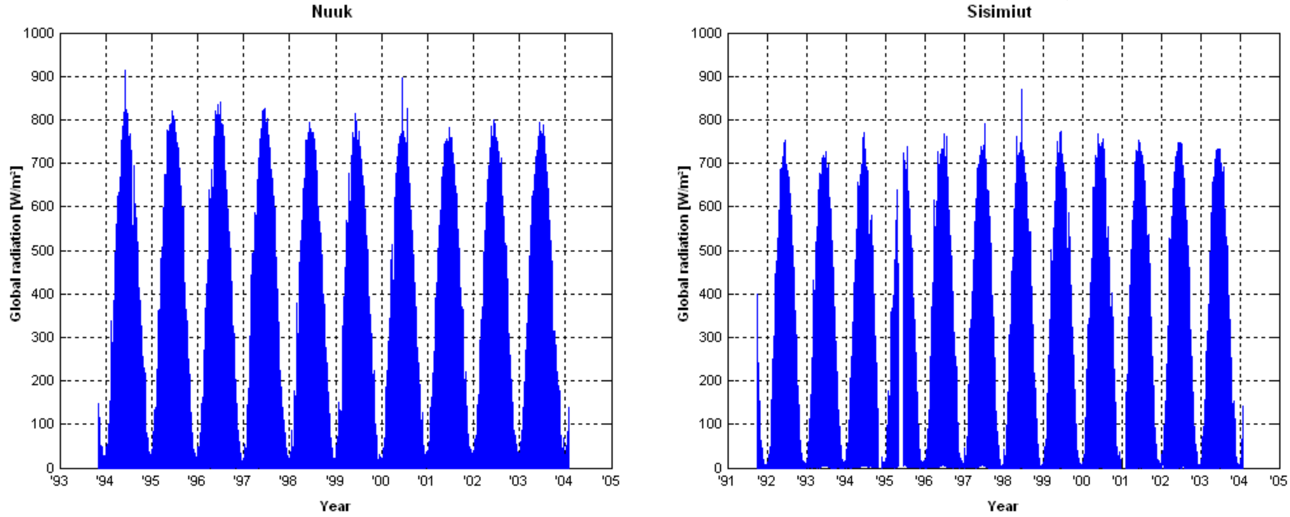

Figure 2 Measured global radiation. Left figure Nuuk and right figure Sisimiut

In Figure 3 the data of the measured relative humidity is shown. The relative humidity is seen to vary between 30 and 100%. No clear difference between the summer and winter seasons is evident. In Nuuk the relative humidity from 1995 to 1997 is seen to reach the 100% quite often, which is mostly explained by missing calibration of the measuring equipment.

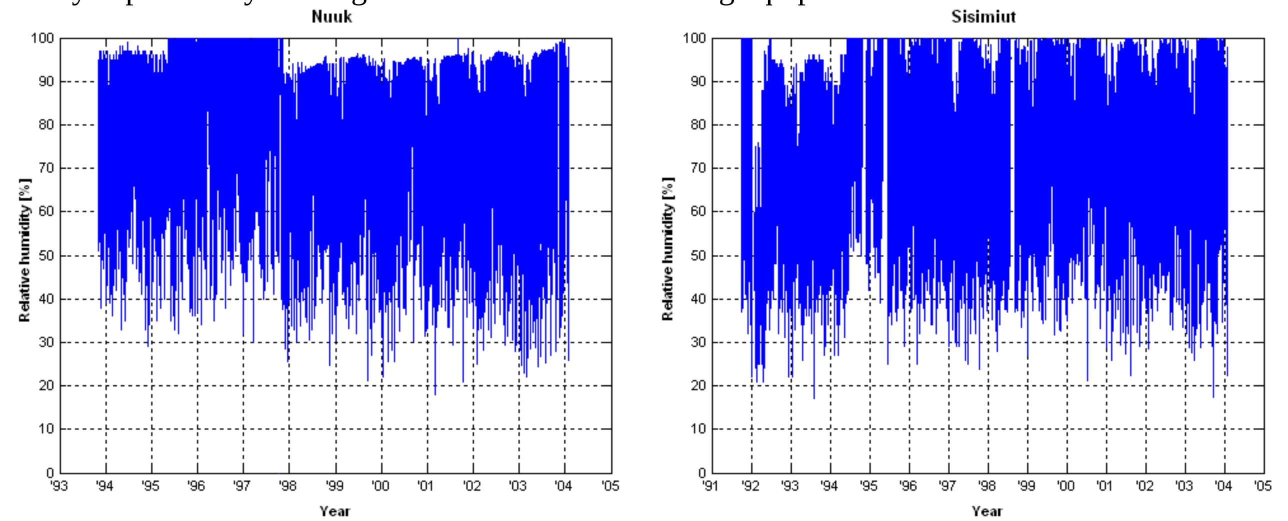

Figure 3 Measured relative humidity. Left figure Nuuk and right figure Sisimiut

In Figure 4 the data of the measured mean wind speed is presented.

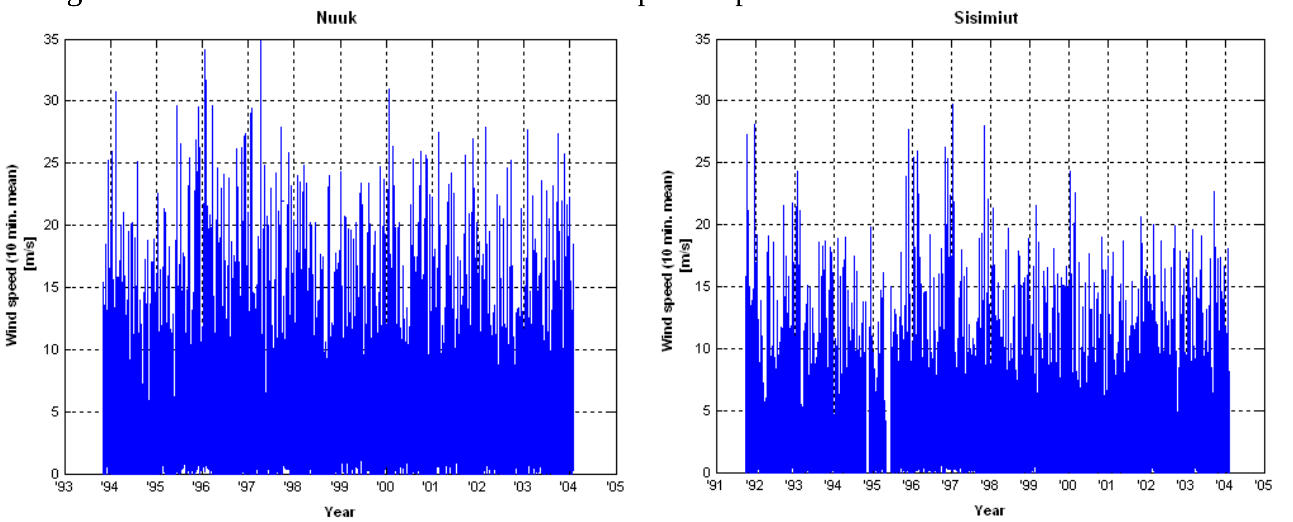

Figure 4 Measured wind speed (10 min. mean) Left figure Nuuk and right figure Sisimiut

3. STATISTIC ANALYSIS

In the following the construction of the test reference year is described according to the standard EN ISO 15927-4 /1/. The dry bulb temperature, the solar radiation (global), the air humidity and wind speed are taken as the primary climatic parameters used in the statistic selection of data to be in the final test reference year. To do the statistic analysis of the data material a program called REFYEAR was developed in MatLab /4/.
As the missing data were interpolated a complete list of hourly data from all the years was available. All the climatic data, p, mentioned above were arranged in a matrix, **A**, (See Figure 5).

$$A = \begin{bmatrix} \textit{date} & \textit{month} & \textit{year} & \textit{hour} & p_1 & p_2 & \cdot\ \cdot & p_i \\ 01 & 01 & 1993 & 00 & x_{1,1} & x_{1,2} & \cdot\ \cdot & x_{1,i} \\ 01 & 01 & 1993 & 01 & x_{2,1} & x_{2,2} & \cdot\ \cdot & x_{2,i} \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot\ \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot\ \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot & \cdot\ \cdot & \cdot \\ 31 & 12 & 2003 & 22 & x_{j-1,1} & x_{j-1,2} & \cdot\ \cdot & x_{j-1,i} \\ 31 & 12 & 2003 & 23 & x_{j,1} & x_{j,2} & \cdot\ \cdot & x_{j,i} \end{bmatrix}$$

Figure 5 The format of the input file to the program REFYEAR

Based on matrix **A,** a new matrix **B** containing daily mean values of the climatic parameters is then calculated. The daily mean values of the temperature, solar radiation and air humidity are then used to find the three most typical months of each calendar month. Of these three months, the month with the lowest deviation in wind speed is then selected for the test reference year.

To find the three most typical months of each calendar month, the following procedure has been performed according to the standard EN ISO 15927-4 /1/:

1. For each calendar month the cumulative distribution function of the daily means over all years is calculated in the data set, $\Phi(p,m,i)$, by sorting all the values in increasing order and then using equation (1).

   $$\Phi(p, m, i) = \frac{K(i)}{N+1} \tag{1}$$

   where K(i) is the rank order of the i^{th} value of the daily means within that calendar month in the whole data set.

2. For each year of the data set, the cumulative distribution function of the daily means within each month, F(p,y,m,i) is calculated, by sorting all the values for that month and that year in increasing order and then using equation (2).

   $$F(p, y, m, i) = \frac{J(i)}{n+1} \tag{2}$$

   where J(i) is the rank order of the i^{th} value of the daily means within that month and that year.

3. For each calendar month the Finkelstein-Schafer statistic FS(p,y,m) is then calculated using equation (3).

   $$FS(p, y, m) = \sum_{i=1}^{n} \left| F(p, y, m, i) - \Phi(p, m, i) \right| \tag{3}$$

4. For each calendar month, the individual months are then ranked from the multiyear record in order of increasing size of FS(p,y,m).

5. For each calendar month and each year, the separate ranks for the three climate parameters are added.

6. For each calendar month, for the three months with the lowest total ranking, the deviation of the monthly mean wind speed from the corresponding multi-year calendar month mean is calculated. The month with the lowest deviation in wind speed is selected as the 'best' month to be included in the reference year.

In Figure 6 the above-described procedure is shown. The calculation is to be repeated for each calendar month and for each climatic parameter p.

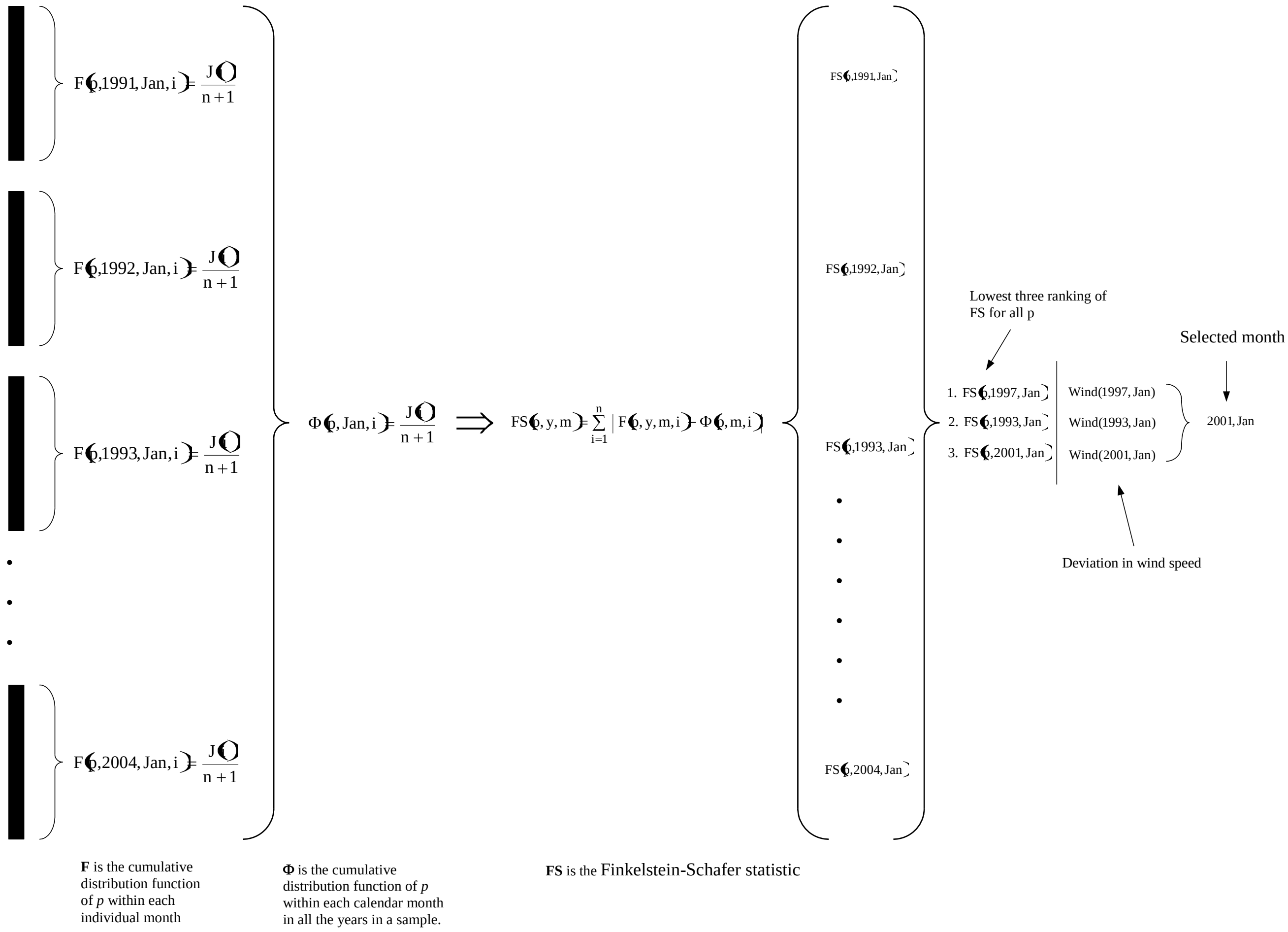

Figure 6 Principe of the data flow in the statistic analysis

4. RESULTS OF THE STATISTIC ANALYSIS

Using the procedure described above the three months (of each calendar month) with the lowest total ranking of Finkelstein-Schafer value were found as shown in Table 3 (Nuuk) and Table 5 (Sisimiut). Of these three months the month with the lowest deviation in wind speed was then selected for the test reference year. Though, as previously described a limit for acceptable percentage of missing data (5%) was also used in the final selection of months.

Nuuk:

Table 3 The three months with Lowest Total Ranking (LTR) in increasing order of the Finkelstein-Schafer statistic and the monthly mean wind deviation (W).

Jan		**Feb**		**Mar**		**Apr**		**May**		**Jun**	
LTR	W	LTR	W	LTR	W	LTR	W	LTR	W	LTR	W
1999	0.41	2002	0.33	2002	0.33	1994	0.03	1998	0.55	1998	0.94
1996	1.31	1997	0.56	1994	0.04	2002	0.12	2001	1.66	2001	0.19
2001	0.01	1994	0.53	1997	0.51	1995	0.37	1995	2.05	1996	0.08

Jul		**Aug**		**Sep**		**Oct**		**Nov**		**Dec**	
LTR	W	LTR	W	LTR	W	LTR	W	LTR	W	LTR	W
2003	0.22	2001	0.75	1997	0.17	2001	1.21	1994	1.61	2001	0.07
1995	0.14	2003	0.15	1999	0.18	1999	0.39	2001	0.95	1994	0.68
1999	0.80	1999	1.31	1995	0.28	1995	0.39	1999	0.08	1993	0.98

The final selection of the months to the test reference year of Nuuk is shown in Table 4.

Table 4 Selected months in the test reference year of Nuuk

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Nuuk	2001	2002	1994	1994	1998	1996	2003	2003	1997	1995	1999	2001

As it can be seen July 2003 has been selected though July 1995 has the lowest deviation in wind speed (see Table 3). The reason for the selection of July 2003 is that the percentage of missing data in July 1995 is 10 %, which is above the chosen limit of 5 percent (See appendix A).

Sisimiut:

Table 5 The three months with Lowest Total Ranking (LTR) in increasing order of the Finkelstein-Schafer statistic and the monthly mean wind deviation (W).

Jan		**Feb**		**Mar**		**Apr**		**May**		**Jun**	
LTR	W	LTR	W	LTR	W	LTR	W	LTR	W	LTR	W
1999	0.13	1992	1.43	2002	0.32	1994	0.19	1993	0.55	1996	0.07
2001	0.37	1995	0.71	1994	0.34	1997	0.14	2001	0.30	1999	0.25
2004	0.54	1999	0.55	1992	0.66	1995	0.30	1992	0.42	1997	0.15

Jul		**Aug**		**Sep**		**Oct**		**Nov**		**Dec**	
LTR	W	LTR	W	LTR	W	LTR	W	LTR	W	LTR	W
1993	0.45	1999	0.20	1993	0.21	1994	0.49	1995	0.62	1993	0.15
1995	0.31	2001	0.54	1998	0.77	2000	0.07	2000	0.78	1999	0.29
2000	0.05	1993	0.08	1995	0.83	2001	0.44	2001	1.14	1996	0.96

The final selection of the months for the test reference year of Sisimiut is presented in Table 6.

Table 6 Selected months in the test reference year of Sisimiut

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sisimiut	1999	1999	2002	1997	2001	1996	1995	1993	1993	2000	1995	1993

Again one of the months selected (July 2000) has more than 5 percent missing data. Instead July 1995 is selected to the reference year.

5. TRANSITION BETWEEN MONTHS

To ensure a continuous transition between the months when they are joined, the parameters are adjusted in the last eight hours of each month and the first eight hours of each month by linear interpolation. Also the transition between December and January is adjusted, so that the reference year can be used repeatedly in simulations. An example of why this is necessary is shown in Figure 7, where a discontinuity in the temperature appears in the transition from February 2002 to March 1994.

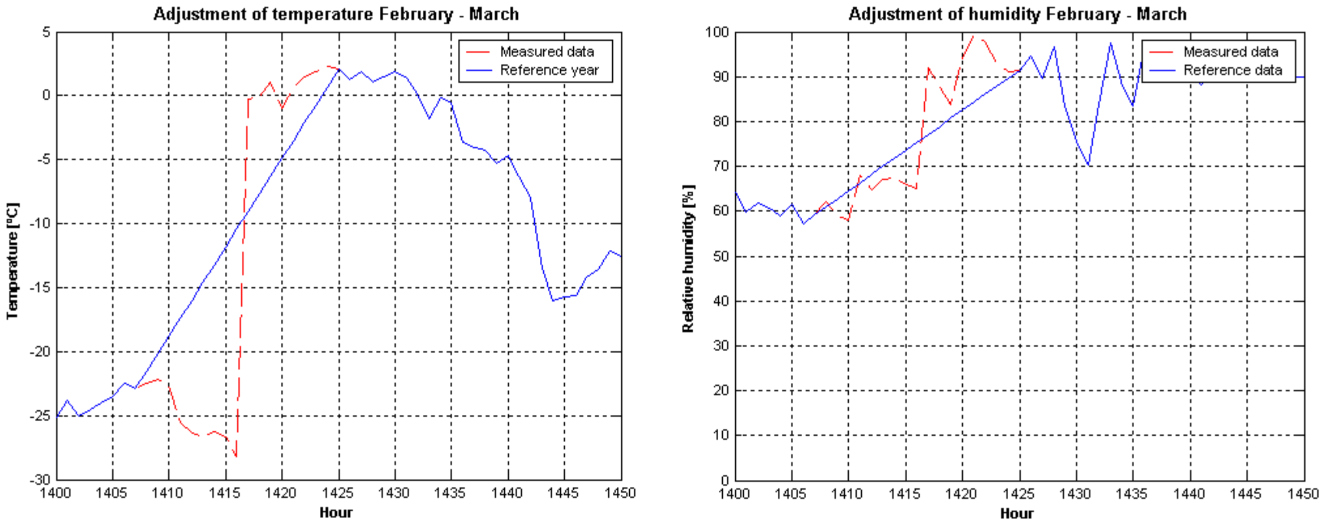

Figure 7 Example of transition between two months (February 2002 and March 1994). Left transition of temperature and right humidity

6. THE PROGRAM REFYEAR

Using the REFYEAR program requires that Matlab /4/ is installed on the computer and that the following data is saved in a *.mat file:

1. The climatic measurement (quality controlled)
2. Latitude of the weather station
3. Longitude of the weather station
4. Local standard time meridian

Starting the REFYEAR program from Matlab and using the input file the constructed test reference year is automatically generated as an output file. The test reference year has the format as shown in Table 7:

Table 7 Test reference year format

Position	Parameter	Number of characters
1	Station identifier (ASIAQ)	3
2	Time indicator for irradiation measurements (L or T)[1]	3
3	Dry bulb temperature in ºC	8
4	Mean hourly global radiance in W/m²	6
5	Mean hourly diffuse radiance in W/m²	6
6	Mean direct beam normal radiance in W/m²	6
7	Relative humidity in percent	7
8	Wind speed in m/s	6
9	Atmospheric pressure	8
10	Year (from original data)	6
11	Month	4
12	Day number	5
13	Hour, local standard time 01-24	4

[1] Original radiation measurements presented in local standard time (L) or true solar time (T). Radiation values are integrated over the preceding hour.

In appendix B an example of the test reference year format is shown.

7. THE TEST REFERENCE YEARS

In the following figures the data from the constructed test reference year (Nuuk.TRY and Sis.TRY) are presented.

In Figure 8 the dry bulb temperature from the test reference year is shown.

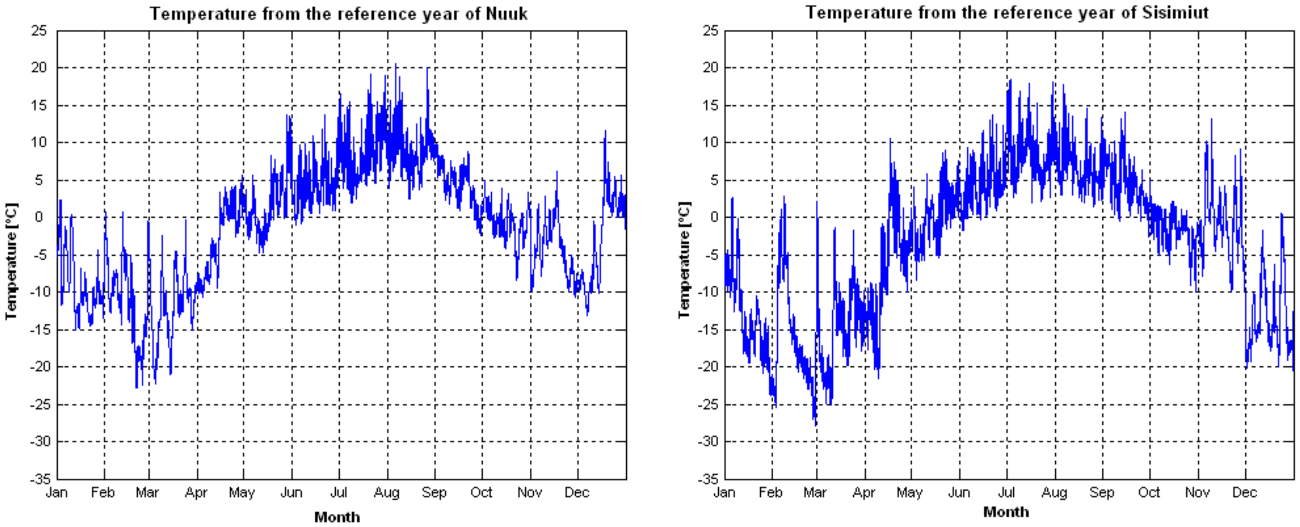

Figure 8 Dry bulb temperature from the reference years. Left Nuuk and Right Sisimiut

In Figure 9 the constructed global radiation from the test reference year is shown for both towns.

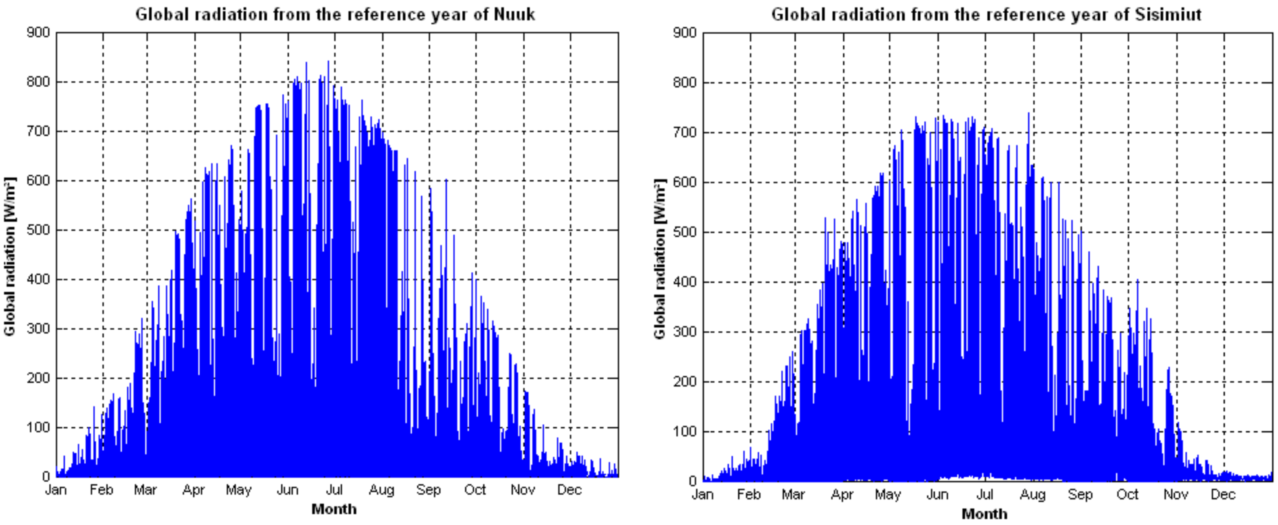

Figure 9 Global radiation from the reference years. Left Nuuk and right Sisimiut

Calculation of the diffuse and beam radiation

The calculation of the diffuse radiation is performed using the algorithms in /2/ and /5/. Using the global radiation measurement, G_h, and a calculation of the corresponding radiation outside the atmosphere, G_o, gives a clearness index, k_T.

$$k_T = \frac{G_h}{G_0} \tag{4}$$

The radiation outside the atmosphere is calculated using the following equation:

$$G_0 = I_0 \cdot \varepsilon \cdot \left(\frac{12}{\pi}\right) \cdot \left[\sin\phi \cdot \sin\delta \cdot (\omega_2 - \omega_1) + \cos\phi \cdot \cos\delta \cdot (\sin\omega_2 - \sin\omega_1)\right] \tag{5}$$

where

I_0	Solar constant	I_0 = 1367 W/m²
ϕ	Latitude	[°]
δ	Declination	[°]
ω_1	Hour angle at the start of the hour	[°]
ω_2	Hour angle at the end of the hour	[°]

ε is the correction for the distance between sun and the earth calculated as: $\varepsilon = 1 + 0{,}03344 \cdot \cos(j' - 0{,}048869)$, where
j' is the day angle given by:
$j' = \frac{2 \cdot \pi \cdot n}{365{,}25}$, where n is the day number

Determination of the hour angle is calculated using the formulary described in /2/. The Erbs et al. correlation /5/ is then used to find the fraction of diffuse radiation on a horizontal surface.

$$\frac{G_d}{G_h} = \begin{cases} 1.0 - 0.09 \cdot k_T & \text{for} \quad k_T \le 0.22 \\ 0.9511 - 0.1604 \cdot k_T + 4.388 \cdot k_T^2 - 16.638 \cdot k_T^3 + 12.336 \cdot k_T^4 & \text{for} \quad 0.22 < k_T \le 0.80 \\ 0.165 & \text{for} \quad k_T > 0.80 \end{cases} \tag{6}$$

where k_T is the clearness index.

In Figure 10 the calculated diffuse radiation is shown.

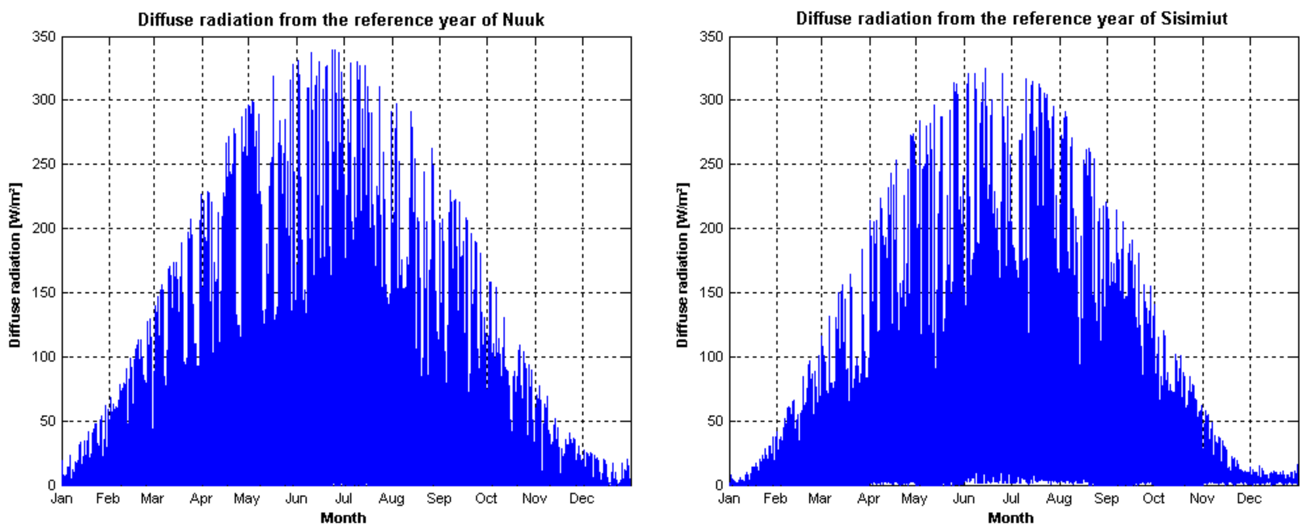

Figure 10 Diffuse radiation from the reference years. Left Nuuk and right Sisimiut.

Knowing that the global radiation, G_h, is the sum of beam radiation (direct horizontal radiation), G_b, and the diffuse radiation, G_d, the beam radiation (direct normal radiation), G_{bn} is calculated as:

$$G_{bn} = \frac{G_b}{\cos(\theta)} = \frac{G_h - G_d}{\cos(\theta)} \tag{7}$$

where θ is the angle of incidence of the beam radiation.

In Figure 11 the constructed relative humidity from the test reference year is shown for both towns.

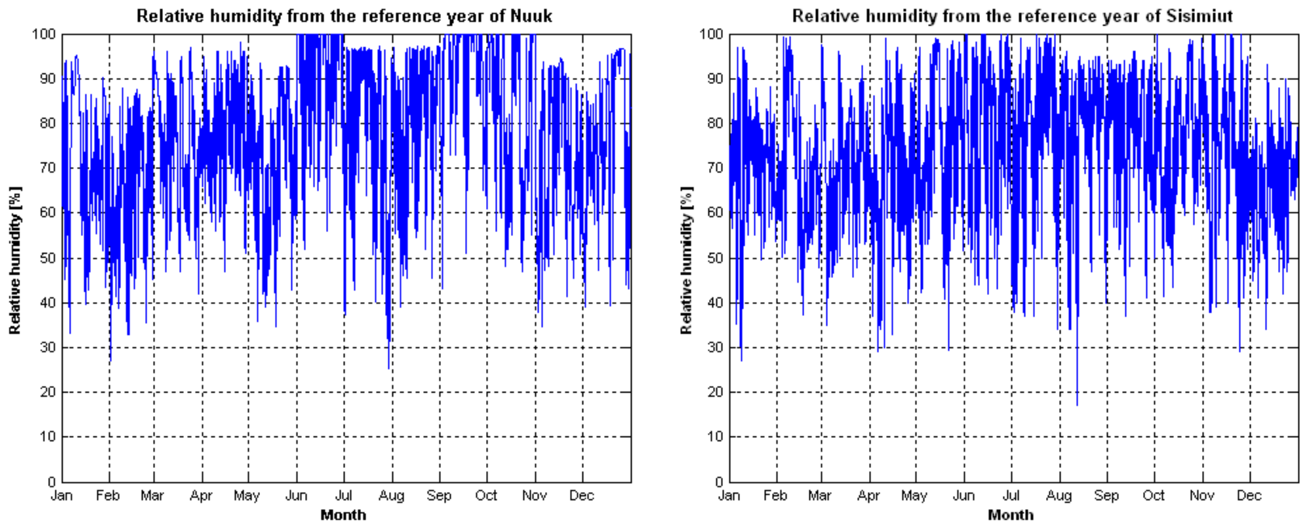

Figure 11 Relative humidity from the reference years. Left Nuuk and right Sisimiut

In Figure 12 the constructed relative humidity from the test reference year is shown for both towns.

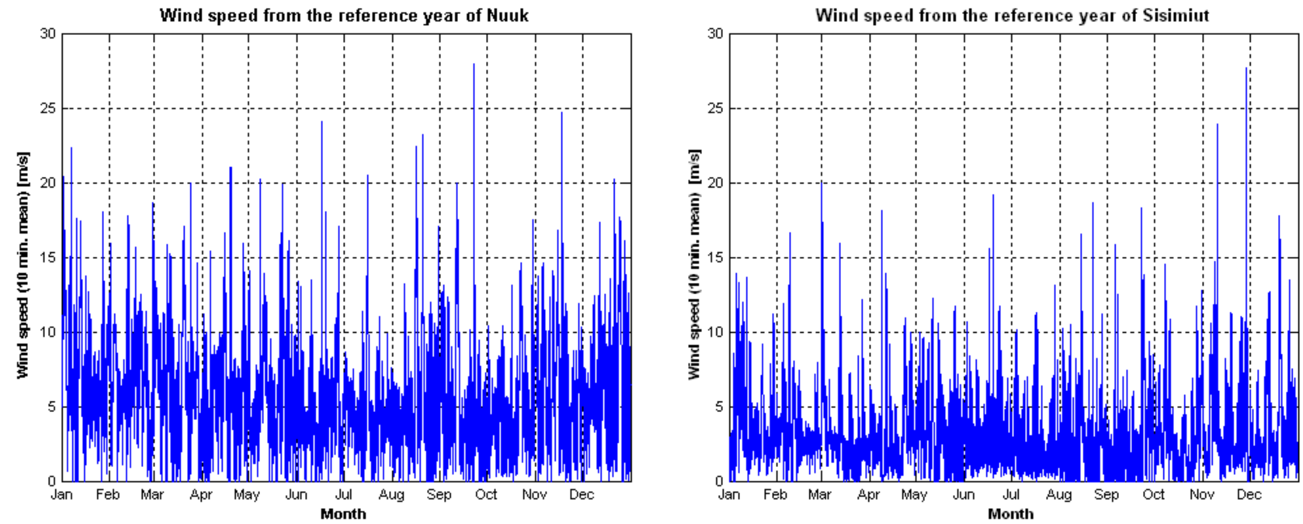

Figure 12 Wind speed from the reference years. Left Nuuk and right Sisimiut

In Figure 13 the constructed atmospheric pressure from the test reference year is shown for both towns.

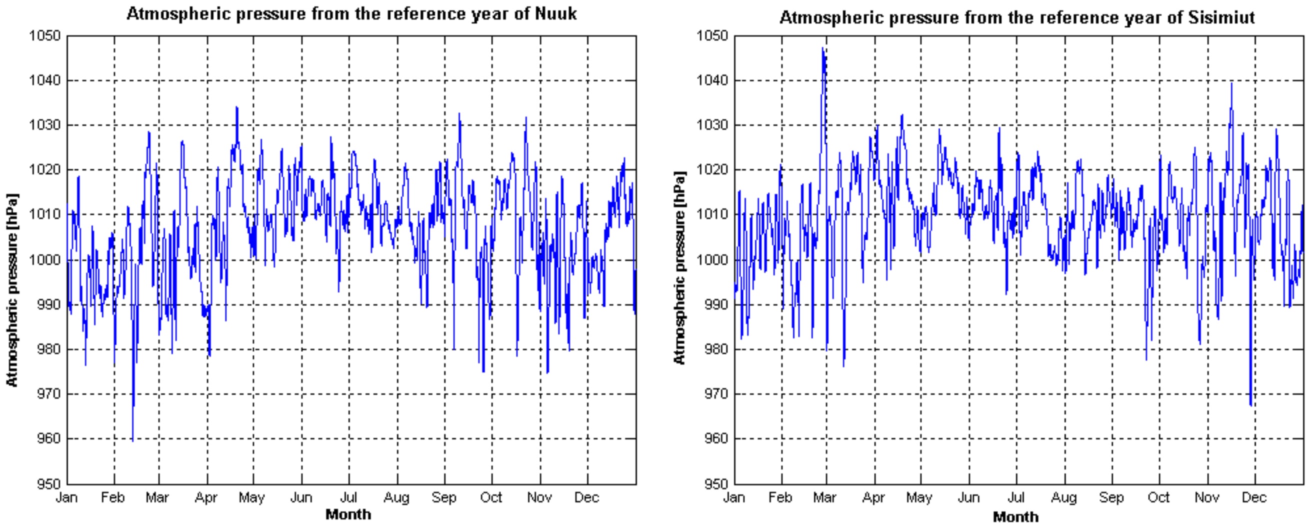

Figure 13 Atmospheric pressure from the reference year. Left Nuuk and right Sisimiut

8. COMPARING WITH OTHER REFERENCE YEARS

In the following different key values from the two constructed test reference years are compared with the similar values from the Danish design reference year. The Danish design reference year is constructed using another statistic analysis method. Though the weather reference years is still interesting to compare.

The key values of the dry bulb temperature are shown in Table 8. The yearly degree hour number, GD, is calculated as the difference between the dry bulb temperature, T_{Try}, and a base reference temperature, T_{base}, of 17ºC or 20ºC. The value of GD is calculated as:

$$GD = \sum_{i=1}^{8760} T_{base,i} - T_{Try,i} \qquad \text{for } T_{Try,i} < T_{base,i} \tag{8}$$

$$GD = 0 \qquad \text{for } T_{Try,i} \geq T_{base,i}$$

Table 8 Key values of the dry bulb temperature from the test reference years

Temperature	Unit	Nuuk	Sisimiut	Denmark
Mean temperature	ºC	-1.2	-3.8	7.8
Minimum temperature	ºC	-22.8	-32.6	-21.1
Maximum temperature	ºC	20.5	18.4	32.1
Degree hours (17ºC)	kKh	160	182	84
Degree hours (20ºC)	kKh	186	208	108

In Table 9 the yearly solar radiation on surfaces with different orientations and tilts is shown.

Table 9 Key values of the solar radiation on surfaces with different orientations and tilts

Radiation in kWh/m²	Nuuk	Sisimiut	Denmark
Tilt 90º			
South	954	954	909
West	691	688	654
East	631	613	671
North	385	383	338
Tilt 45º			
South	1158	1131	1217
West	863	843	899
East	803	766	916
North	467	450	524
Horizontal (0º)	900	858	1002

It is seen that the yearly radiation on vertically surfaces is higher in Greenland compared to Denmark, which must be explained by the lower incidence angle of the solar radiation. In Table 10 yearly mean values of the relative humidity, wind speed and atmospheric pressure are shown.

Table 10 Yearly mean values of the humidity, wind speed and atmospheric pressure

Mean values		Nuuk	Sisimiut	Denmark
Relative humidity	[%]	78	73	82
Wind speed	[m/s]	6.0	3.2	4.4
Atmospheric pressure	[hPa]	1007	1010	1013

9. DISCUSSION

In arctic climates the sun is below the horizon in the winter months. Therefore it could be discussed if the selection of the most typical winter months should be influenced by the very low radiation measurements of 0-5 W/m². The standard EN ISO 15927-4 does not recommend any adjustment of this problem. The purpose of this work was to construct the reference years fulfilling the standard and therefore this adjustment has not been made.
Also the standard EN ISO 15927-4 does not clearly explain the acceptable maximum of missing data in a month. In this work it was chosen to interpolate all missing values of temperature, humidity and wind, and for radiation the measurement 24 hours before was used. In the final selection of calendar months for the test reference year, it was then chosen to use the criterion that the percent of missing data in the original data should be below 5 percent. This criterion influenced the selection of one month in both reference years.

10. CONCLUSION

Two test reference years of Nuuk and Sisimiut have been constructed using the procedures described in the standard EN ISO 15927-4.
A program called REFYEAR was developed to do the statistic analysis. Using this program it is relatively simple to construct a test reference year. The major part of the work is then to create the input file with quality-controlled data.

11. AKNOWLEDGEMENT

The work is financed by The Commission for Scientific Research in Greenland, KVUG.

All climatic data used in this work were delivered by ASIAQ /3/. The constructed test reference years can be ordered by contacting AISAQ.

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/2/ The European Solar Radiation Atlas, Vol. 2: Database and exploitation software, Coordinators: K: Scharmer, J. Greif, Les Presses, de l'École des Mines, Paris, 2000.

/3/ ASIAQ, P.O Box 1003, DK-3900 Nuuk, Greenland, www.asiaq.gl
M.Sc. Håkon Gjessing Karlsen, Phone +299 34 88 00, hgk@asiaq.gl

/4/ Matlab™, Version 6.5, The MathWorks, Inc., 3 Apple Hill Drive, Natick MA 01760-2098, 2002.

/5/ Solar Engineering of Thermal Processes, Second Edition, John A. Duffie and William A. Beckman.

NOMENCLATURE

LATIN SYMBOLS:

FS	Finkelstein-Schafer statistic
F(p)	Cumulative distribution function of p within each individual month
GD	Degree hour number
G_{bn}	Beam radiation (direct normal radiation)
G_d	Diffuse radiation
G_h	Global (total) radiation on a horizontal surface
G_o	Radiation outside the atmosphere
I_0	Solar constant
J	Rank order of the daily means within a calendar month in one year
K	Rank order of the daily means within that calendar month in the whole data set
N	Number of days in any calendar month in the whole data set
T_{base}	Base reference temperature
T_{Try}	Dry bulb temperature from the test reference year
j'	Day angle
k_T	Clearness index
m	Month of the year
n	Number of days in an individual month
p	Climate parameter (temperature, solar radiation or humidity)
$\bar{p}$	Daily mean of any climate parameter
y	Year

GREEK SYMBOLS

$\Phi(p)$	Cumulative distribution function of p within each calendar month in all the years in a sample.
δ	Declination
ϕ	Latitude
θ	Angle of incidence
ε	Correction of distance between the earth and the sun
ω	Hour angle

APPENDIX A – Missing data from Sisimiut

Table explanations:
T: Dry Bulb temperature
R: Radiation
H: Humidity
W: Mean wind speed
S: The three statistically best months selected for the test reference year
_ : Finally-selected months for the test reference year fulfilling no more than 5% missing data.

Nuuk

Table 11: Percent of missing data from Nuuk

MONTH	JANUARY					FEBUARY					MARCH				
Parameter	T	R	H	W	S	T	R	H	W	S	T	R	H	W	S
1993	-	-	-	-		-	-	-	-		-	-	-	-	
1994	0	0.1	0	0		0	0	0	0	**3**	0	0	0	0	**1**
1995	0	0	0	0		0	0	0	0		0	0	0	0	
1996	0.1	0	0.1	0.3	**2**	0	0	0	6.5		0.4	0	0.4	17.7	
1997	0	0	0	1.3		0.1	0	0.1	0.3	**2**	0	0	0	0	**3**
1998	1.9	0	1.9	1.9		0.6	0	0.6	0.6		0	0	0	0.1	
1999	0	0	0	0	**3**	0	0	0	0		0	0	0	0	
2000	0	0	0	0.4		0	0	0	0		0.3	0	0.4	0.4	
2001	0.4	0	0.4	0.4	**1**	0.1	0	0.1	0.1		0	0	0.1	0	
2002	0	0	0	0.1		0	0	0.1	0.6	**1**	0	0	0	0.3	**2**
2003	0	0	0	0		0	0	0	0		15.2	15.0	16.0	15.0	
2004	0	0	0	0		-	-	-	-		-	-	-	-	

MONTH	APRIL					MAY					JUNE				
Parameter	T	R	H	W	S	T	R	H	W	S	T	R	H	W	S
1993	-	-	-	-		-	-	-	-		-	-	-	-	
1994	0	0	0	0	**1**	0	0	0	0		0	0	0	0	
1995	0	0	0	0	**3**	0.5	0.7	0.5	0.5	**3**	13.6	13,9	13.6	13.8	
1996	4.6	0	4.6	20.0		0.3	0	0.3	0.4		0	0	0	0	**1**
1997	0	0	0	0.4		0	0	0	0		0	0	0	0	
1998	0	0	0	0		0	0	0	0.3	**1**	0	0	0	1.0	**3**
1999	0.3	0	0.3	0.7		0	0	0	0		0.3	0	0.3	0.3	
2000	1.3	0	1.3	1.3		0	0	0	0		0.3	0	0.3	0.6	
2001	0	0	0	0		3.2	0	3.2	3.2	**2**	0.7	0	0.8	0.7	**2**
2002	0	0	0	5.1	**2**	0	0	0.1	0.9		0.4	0.4	0.4	0.4	
2003	0.1	0.1	0.1	0.1		0.3	0.3	0.3	0.3		0.6	0.6	0.6	0.6	
2004	-	-	-	-		-	-	-	-		-	-	-	-	

MONTH	JULY					AUGUST					SEPTEMBER				
Parameter	T	R	H	W	S	T	R	H	W	S	T	R	H	W	S
1993	-	-	-	-		-	-	-	-		-	-	-	-	
1994	0	0	0	0		3.6	3.6	3.6	16.8		0	0	0	0	
1995	9.7	9.7	9.7	9.4	**1**	0	0	0	0		0	0	0	0	**3**
1996	0.3	0	0.3	0.3		0	0	0	0		0	0	0	0.3	
1997	0	0	0	0		0	0	0	0		0	0	0	0.1	**1**
1998	3.2	0	3.2	3.5		0	0	0	0		0.4	0	0.4	0.3	
1999	0.7	0	0.4	0.7	**3**	0.3	0	0.3	0.3	**3**	0	0	0	0	**2**
2000	0.9	0	0.9	0.9		0.9	0	0.9	0.9		2.8	0	2.8	2.8	
2001	0.1	0	0.3	0.1		0	0	0	0	**2**	0	0	0	0	
2002	0	0	0	0		0	0	0	0		0.6	0.6	0.6	0.6	
2003	0	0	0	0	**2**	0	0	0	0	**1**	0.1	0.1	0.1	0.1	
2004	-	-	-	-		-	-	-	-		-	-	-	-	

MONTH	OCTOBER					NOVEMBER					DECEMBER				
Parameter	T	R	H	W	S	T	R	H	W	S	T	R	H	W	S
1993	-	-	-	-		0	0	0	0		0	0.1	0	0	**3**
1994	3.2	3.2	3.2	3.2		0.8	0.8	0.8	0.8	**3**	0	0	0	0	
1995	0	0	0	0	**1**	0	0	0	0		0	0	0	0	**2**
1996	0	0	0	3.2		0	0	0	0		0	0	0	0.4	
1997	39.5	13.8	62.4	54.4		0.4	0	11.7	0.1		0.3	0	0.3	1.1	
1998	0	0	0	11.4		0	0	0	0		0.5	0	0.5	0.8	
1999	0	0	0	0	**2**	0	0	0.1	0	**1**	0	0	0	0	
2000	1.2	0	1.2	1.2		0	0	0	0		0	0	0	0	
2001	0	0	0	0	**3**	2.1	1.8	2.2	1.8	**2**	0	0	0	0	**1**
2002	0.3	0.3	0.3	0.3		1.8	1.8	1.8	1.8		0	0	0	0	
2003	0.4	0.4	23.3	0.4		17.4	0.3	55.4	0.3		24.3	0.4	0.4	0.4	
2004	-	-	-	-		-	-	-	-		-	-	-	-	

Sisimiut

Table 12: Percent of missing data from Sisimiut

MONTH	JANUARY					FEBUARY					MARCH				
Parameter	T	R	H	W	S	T	R	H	W	S	T	R	H	W	S
1991	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1992	5.6	5.6	75.3	5.6		18.8	18.9	18.8	33.9	**3**	33.2	33.3	32.2	32.2	**3**
1993	0	0	0	0		0	0	0	0		0	0	0	0	
1994	0	0	0	0		0	0	0	0		0	0	0	0	**2**
1995	0	0.1	0	0		0	0	0	0	**2**	0	0	0	0	
1996	0.1	0.3	0	0		0	0	0	0		0.3	0.3	0.3	0.3	
1997	0	0	0	0		0	0	0	0		0	3.2	0	0	
1998	0.5	0	0.5	0.5		0	0	0	0		0	0	0	0	
1999	0	0	0	0	**1**	0	0	0	0	**1**	0	0	0.4	0	
2000	0.1	0	0.1	0		0	0	0	0		0	0	0	0	
2001	0	100	0	0	**2**	0	44.1	0	0		0.4	0.3	0.4	0.4	
2002	0	0	0	0		0	0	0	0		0	0	0	0	**1**
2003	0	0	0	0		0	0	0	0		0	0	0	0	
2004	0.3	6.5	0.3	0.3	**3**	-	-	-	-		-	-	-	-	

MONTH	APRIL					MAY					JUNE				
Parameter	T	R	H	W	S	T	R	H	W	S	T	R	H	W	S
1991	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1992	1.5	1.7	1.5	1.5		0	0	0	0	**2**	1.0	1.1	1.0	1.0	
1993	0	0	0	0		0	0	0	0	**3**	0	0	0	0	
1994	0	0	0	0	**2**	0	0	0	0		0.7	0.8	0.7	0.7	
1995	0	0	0	0	**3**	95.3	95.3	95.3	95.3		59.6	59.7	59.6	59.6	
1996	0	0	0	0		0.4	0.4	0.4	0.3		0	0	0	0	**1**
1997	0	0	0	3.5	**1**	0	0	0	0		0	0	0	0	**2**
1998	0.3	0.3	0.4	0.3		0	0	0.4	0		0	0	2.9	0	
1999	0.3	0.3	0.3	0.4		0	0	0.3	0		0.3	0.3	4.9	0.3	**3**
2000	1.3	0	3.1	1.3		0	0	0.3	0		0.3	0.3	7.8	0.3	
2001	0.1	0	0.1	0.3		0	0	0	0	**1**	0.3	0.3	0.3	0.3	
2002	0	0	0	0		0.1	0	0.1	0.1		0.4	0.3	0.4	0.3	
2003	0.3	0.3	0.3	0.3		0.1	0.1	0.1	0.1		1.1	1.1	1.1	1.1	
2004	-	-	-	-		-	-	-	-		-	-	-	-	

MONTH	JULY					AUGUST					SEPTEMBER				
Parameter	T	R	H	W	S	T	R	H	W	S	T	R	H	W	S
1991	-	-	-	-	-	-	-	-	-		-	-	-	-	-
1992	0	0	0	0		0.5	0.7	0.5	0.5		3.5	3.5	3.5	3.5	
1993	0	0	0	0	**3**	0.5	2.3	0.5	0.5	**1**	0.3	0	0	0	**1**
1994	0	0	0	0		3.9	3.9	3.9	3.9		0	0	0	0	
1995	0	0	0	0	**2**	0	0	0	0		0	0	0	0	**3**
1996	0.5	0.7	0.5	0.5		0	0.1	0	0		0	0	0	0.3	
1997	0	0	0	0		3.6	4.8	3.8	3.6		0	1.9	1.0	0.1	
1998	3.2	3.2	3.9	3.2		37.9	0.1	100	0.1		32.5	0.1	37.2	0.1	**2**
1999	0.3	0.3	8.2	0.4		0	0	1.8	0.3	**2**	0.1	0.1	0.1	0.1	
2000	0.9	1.2	20.0	0.9	**1**	17.2	15.1	30.8	17.2		13.2	8.9	30.7	13.2	
2001	0	0	0	0		0	0	0	0	**3**	0	0	0	0	
2002	0	0	0	0		0.3	0.3	0.3	0.3		0	0	0	0	
2003	22.0	22.0	22.2	22.0		0	0	0	0		0.1	0.1	0.1	0.1	
2004	-	-	-	-		-	-	-	-		-	-	-	-	

MONTH	OCTOBER					NOVEMBER					DECEMBER				
Parameter	T	R	H	W	S	T	R	H	W	S	T	R	H	W	S
1991	0	0	12.4	0		0	0	0	0		0	0	0	0.1	
1992	0	0	0	0		0	0.1	0	0		0	0	0	0	
1993	0	0	0	0		0	0	0	0.1		0	0	0	0	**1**
1994	3.2	3.2	3.2	3.2	**3**	1.0	100	100	100		0	0.9	0.9	0.9	
1995	0	0	0	0		0	0	0	0	**1**	0	0	0	0	
1996	8.2	0	0	0		18.1	0	0	0		0	0	0	0	**3**
1997	0.4	1.1	0.7	0.4		0	0	0	0		0	0	0	0	
1998	0	0	0.1	0		0.1	0.1	0.1	0.1		0	0.1	0	0	
1999	0.1	0.1	1.2	0.1		0	0	0	0		0	0	0.5	0	**2**
2000	1.5	1.6	1.5	1.5	**1**	0	0	0	0	**2**	0	0.1	0	0	
2001	0	0	0	0	**2**	0	0	0	0	**3**	0	0	0	0	
2002	0.3	0.3	0.3	0.3		1.9	1.9	1.9	1.9		0	0	0	0	
2003	0.1	0.1	0.1	0.1		0	0	0	0		0.1	0.1	0.1	0.1	
2004	-	-	-	-		-	-	-	-		-	-	-	-	

Appendix B – The format of the test reference years

TEST REFERENCE YEAR OF NUUK, GREENLAND
STATION: NUUK 522:
Location: Longitude -51.87 deg : Latitude 64.17 deg
Local standard time meridian -45 min.
Altitude: 80 m
Date of production of file: February 2004

Parameters:
St ASIAQ Station identifier
Time Time indicator for irradiation measurements L & T
(L for local standard time or T for true solar time)
T Dry bulb temperature, in °C
Gh Mean hourly global irradiance, in W/m²
Gd Mean hourly diffuse irradiance, in W/m²
Gb Mean hourly beam normal irradiance, in W/m²
RF Relative Humidity, in per cent
Ws Wind speed, in m/s
P Atmospheric pressure, in hPa
Y Year
M Month
D Day
H Hour

St Nr.	Time indc.	T °C	Ih W/m²	Id W/m²	Ib W/m²	RF %	Ws m/s	P hPa	Y	M	D	H
522	L	-5.1	0	0	0	66.7	6.0	1011.7	2001	1	1	1
522	L	-4.8	0	0	0	73.1	6.1	1010.8	2001	1	1	2
522	L	-4.5	0	0	0	68.6	5.8	1010.0	2001	1	1	3
522	L	-4.3	0	0	0	68.6	7.4	1009.4	2001	1	1	4
522	L	-4.2	0	0	0	68.6	6.8	1008.7	2001	1	1	5
522	L	-4.3	0	0	0	61.7	9.9	1007.3	2001	1	1	6
522	L	-4.1	0	0	0	66.3	9.3	1006.6	2001	1	1	7
522	L	-3.9	0	0	0	70.7	9.7	1006.0	2001	1	1	8
522	L	-4.2	0	0	0	71.5	11.0	1005.2	2001	1	1	9
522	L	-4.1	0	0	0	68.2	11.0	1004.9	2001	1	1	10
522	L	-4.4	4	4	0	70.6	8.0	1004.5	2001	1	1	11
522	L	-5.0	14	14	8	89.2	7.2	1004.3	2001	1	1	12
522	L	-5.2	20	19	26	89.3	6.7	1003.1	2001	1	1	13
522	L	-4.6	12	11	26	90.1	9.7	1002.1	2001	1	1	14
522	L	-4.7	4	4	0	88.4	11.1	1001.1	2001	1	1	15
522	L	-4.2	0	0	0	84.2	8.1	1001.5	2001	1	1	16
522	L	-4.4	0	0	0	87.7	10.9	1000.3	2001	1	1	17
522	L	-4.9	0	0	0	90.4	9.3	1000.3	2001	1	1	18
522	L	-4.6	0	0	0	90.6	9.2	1000.0	2001	1	1	19
522	L	-4.4	0	0	0	79.5	9.8	999.4	2001	1	1	20
522	L	-4.2	0	0	0	62.0	11.8	998.9	2001	1	1	21
522	L	-4.0	0	0	0	67.1	11.0	998.2	2001	1	1	22
522	L	-4.2	0	0	0	80.8	10.7	997.8	2001	1	1	23
522	L	-4.1	0	0	0	81.5	11.4	997.1	2001	1	1	24