Annex B

Installation of the solar measuring station and calibration of sensors

1 – 8 July 2003

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1. Installation of the solar measuring station

The solar measuring station is installed at the meteorological station at Male Airport, Hulhule – 4°11'28" North, 73°31'52" East. The solar measuring station is located on a concrete platform on the campus of the meteorological station next to other instruments for measuring solar radiation as seen in figure 1.

Figure 1. The concrete platform (to the left) with the solar measuring station.

The solar measuring station was installed during the period 1 – 6 July 2003. The long installation period was due to necessary calibration of the instruments as described later.

1.1. Instrumentation of the solar measuring station

The solar measuring consists of a Symphonie datalogger from NRG, two pyranometers from LI-COR, one shielded ambient temperature sensor from NRG and a relative humidity sensor also from NRG. The components of the solar measuring station will briefly be described in the following.

The Symphonie data logger from NRG is a special purpose data logger developed for wind measurement. The data logger was chosen because the project also comprised the installation of three wind measuring stations where it was natural to use the Symphonie data logger. In order to ease the maintenance of the measuring stations it was decided to use equipment from only one supplier. As NRG also supply instruments necessary for solar measurements it was decided to use their system also for the solar measuring station. However, it was necessary to calibrate the sensors in order to insure the quality of the measurements. The result of the calibration of the sensors is described later.

1.1.1. Symphonie data logger

The Symphonie data logger is as mentioned a special purpose data logger. Many of the normal settings of the data logger are, therefore, fixed. The scan rate is e.g. fixed to each second sec. The scans are averaged into 10 minutely data which is stored on a memory card. The data can either be downloaded from the memory card using a card reader or if the data logger is connected to an iPack with a mobile phone the data may be send from the logger as e-mails. The latter was chosen in the present project due to the remote location of two of the wind measuring stations. The data are send to the Ministry of Communication, Science and Technology and to the meteorological station at the Airport of Male, Hulhule.

A complete description of the Symphonie data logger and the iPack may be found in the Symphonie manual (www.nrgsystems.com). Figure 2 shows a picture of the Symphonie data logger. The iPack is powered by a small 15 V, 5 W PV-panel also seen in figure 1.

Figure 2.   The Symphonie data logger.

1.1.2. Pyranometers

In order to access the potential for utilization of solar energy it is import that it is possible to calculate the solar radiation at any give plane. In order to facilitate this is it necessary to obtain the two components of the solar radiation: direct (or beam) radiation and diffuse radiation. The direct radiation is very difficult and expensive to measure. The global radiation and the diffuse radiation on horizontal are instead measured. Based on these two measurements it is possible to calculated the direct radiation in the following way:

$$G_b = (G_g - G_d)/\cos(v)$$

where: G_b is the direct radiation
G_g is the global radiation on horizontal
G_d is the diffuse radiation on horizontal
v is the incidence angle of the direct radiation on horizontal

Figure 3 shows the instrumentation for measuring global and diffuse radiation. The instruments are mounted on a horizontal concrete slap with the dimension 60 x 100 cm² with one of the 60 cm sites facing almost south – 2° toward west.

Figure 3 The instrumentation for measuring global and diffuse horizontal radiation.

Figure 4 shows pictures of the surroundings of the solar measuring station. The pictures are taken from the concrete slap. Figure 1 shows that the platform is located higher than the top of the fence around the campus. The top of the platform is approx. in the horizontal middle of the pictures in figure 4. Figure 4 shows that there are nearly no obstructions, which may shade the platform with the instrumentation for measuring solar radiation – except a little toward west and southwest. It is, however, judged that this will have minor influence on the obtained data.

The applied pyranometers for measuring the solar radiation are both LI-200SA pyranometers from LI-COR, which are based on PV technology. The manufacture state the uncertainty to be below ±5% at indigence angles below 80°. For further information please refer to www.licor.com or "LI-COR Radiation Sensors – Instruction Manual", LI-COR, 1986.

Both pyranometers were calibrated by the manufacture and were each supplied with a calibration certificate and have the following serial numbers and calibration factors:

Serial number	Calibration factor mA per 1000 W/m²	Used for measuring of:
PY43858	101.9	global radiation
PY43859	98.2	diffuse radiation

Table 1. Calibration factors for the two applied pyranometers.


South


Southeast


East


Northeast


North


Northwest


West


Southwest

Figure 4. View – 360° round - from the platform with the pyranometers with the direction stated below the pictures.

In the data logger the pyranometers are programmed with an offset and a scaling factor. The offset is zero while the offset is found in the following way:

$$\text{scaling factor} = 119.04/\text{calibration factor} \qquad [1]$$

In order to measure the diffuse radiation the direct solar radiation has to be shades of for the pyranometer measuring the diffuse radiation. This is done using a movable shading ring as seen in figure 3 - with a radius of 0.275 m and a width of 0.07 m. The pyranometer is located in the centre of the half circle of the shading ring. The shading ring is parallel to south and tilted slightly towards south: a tilt equal to the latitude in order to always be able to screen off direct radiation.

However, the shading ring shades of more than the direct radiation. It also shades off part of the diffuse radiation. This has to be corrected for. For this correction is used the equation in "An introduction to meteorological measurements and data handling for solar energy applications", IEA, DOE, USA, October 1980:

$$\Delta G_d = 2w / (\pi \cdot r) \cos^3\delta \, (\Psi_o \cdot \sin\phi \cdot \cos\delta + \cos\phi \cdot \cos\delta \cdot \sin\Psi_o) \qquad [2]$$

where: ΔG_d is the faction of the diffuse radiation screened off by the shading ring
w is the width of the shading ring (here 0.07 m)
r is the radius of the shading ring (here 0.275 m)
δ is the solar declination
Ψ_o is the azimut angle of the sun at sunset
ϕ is the latitude of the installation (here approx. 4.5°)

The solar declination may be found as (from "A European Transient Simulation Model for Thermal Solar Systems – EMGP2. Solar Energy R&D in the European Community. Series A, volume 5. The Commission of the European Communities"):

$$\delta = 0.4092797 \sin(0.0172142\,(n + 284)) \qquad [3]$$

where: n is the number of the day (1, 2, 3, ….., 365)

The azimut angle of the sun at sunset has been found using the program Almanak 1.0b VisualSoft Nakskov 1998 (in Danish) with the result shown in figure 5. A regression line is also shown in the figure:

$$\Psi_o = 4.88 \cdot 10^8 n^4 - 3.37 \cdot 10^5 n^3 + 5.734 \cdot 10^3 n^2 + 0.02999n + 67.165 \ [°] \qquad [4]$$

where: n is the number of the day (1, 2, 3, ….., 365)

Figure 6 shows the faction of the diffuse radiation screened off by the shading ring.

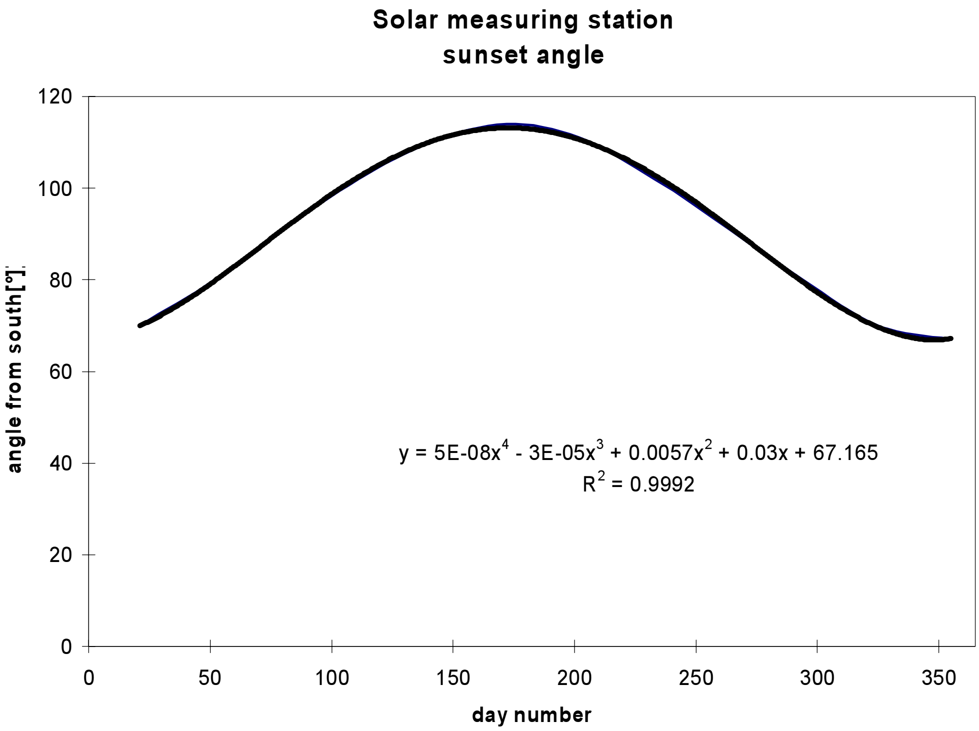

Figure 5. The sunset angle over the year for the solar measuring station.

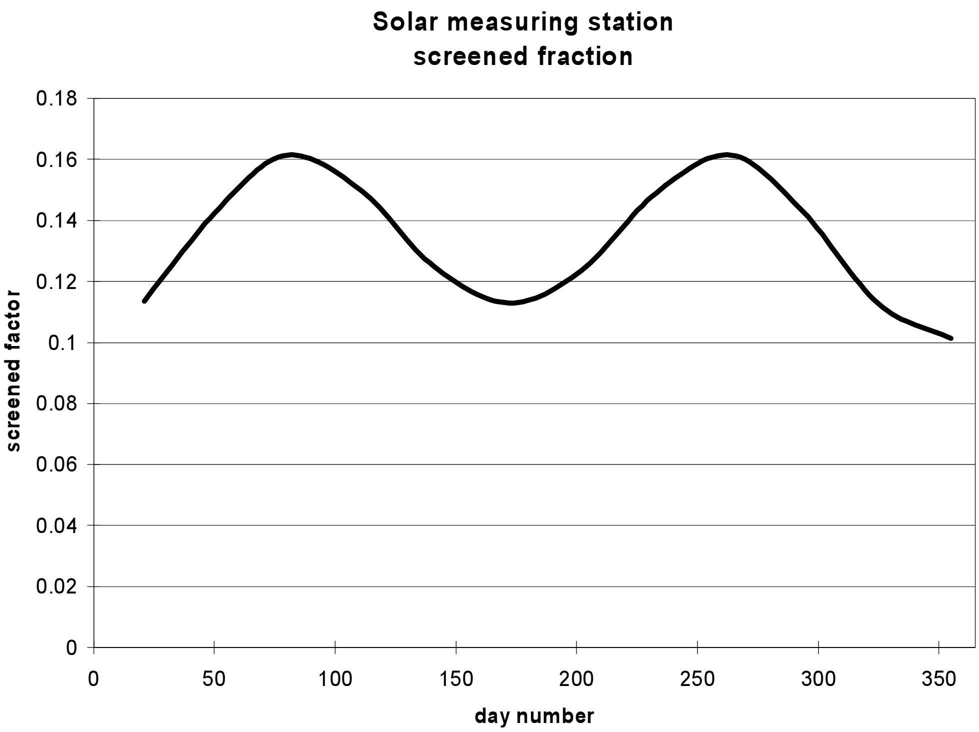

Figure 6. The faction of the diffuse radiation screened off by the shading ring

The measured diffuse radiation should be corrected due to ΔG_d in the following was:

$$G_d = G_{dm} / (1- \Delta G_d) \qquad [5]$$

where: G_d is the diffuse radiation
G_{dm} is the measured diffuse radiation not corrected for the shading ring
ΔG_d is the faction of the diffuse radiation screened off by the shading ring

The above correction for the shading ring is under the assumption that the sky is isotropic. However, there is a brighter area just around the sun called circum solar. In order to correct for this the following equation from "The SERC meteorological data base – volume II : algorithm manual. 2nd edition", Department of Building Sceince, University of Sheffield, UK, 1988 may be used:

$$f = 1.148 - 0.142\,(G_{di} / G_g)^3 - 0.00118\delta \qquad [6]$$

where: f is the correction factor for a non isotropic sky
G_{di} is the diffuse radiation with isotropic shading ring correction - eqn. [5]
G_g is the global radiation
δ is the solar declination

The shading factor for non isotropic sky is used in the following way:

$$G_d = f \cdot G_{di} \qquad [7]$$

The above equations for correction of the measured diffuse radiation due to the shading ring has been implemented in a small program which automatically will make the correction to the measured diffuse radiation.

1.1.3. Ambient air temperature sensor

The ambient air temperature is measured using a shielded temperature sensor supplied by NRG: #1105. Figure 7 shows the shielding of the ambient temperature sensor.

The ambient temperature sensor is located on the beam carrying the platform for the pyranometers and is shaded by the platform.

The manufacture states the uncertainty of the sensor to be ±1.1°C.

For further information on the shielded ambient temperature sensor please refer to www.nrgsystems.com.

1.1.4. Ambient relative humidity sensor

The ambient relative humidity is measured using a sensor supplied by NRG: #2047. Figure 7 shows the relative humidity sensor.

The sensor is located on the beam carrying the platform for the pyranometers and is shaded by the platform.

Figure 7. The shielded ambient temperature sensor (to the right) and the sensor for measuring relative humidity (to the left).

The manufacture states the uncertainty of the sensor to be ±5% RH from 5 to 95% RH at 25°C.

For further information on the relative humidity sensor please refer to www.nrgsystems.com.

2. Calibration of the sensors at the solar measuring station

In order to obtain measured data of high quality it is outmost important that the sensors give correct readings. Therefore, it is important to calibrate the sensors in order to insure that they give correct values or if not to obtain correction equation for the sensors so that readings from the sensors may be corrected.

2.1. Calibration of the pyranometers

The pyranometers were calibrated in two steps: first a side by side comparison in order to determine if they are performing identically and secondly to calibrate the pyranometers using a high precision calibrated pyranometer.

Figure 8 shows the set up for the calibration of the pyranometers.

Figure 8.   Set up for calibration of the pyranometers.

2.1.1. Side by side comparison of the pyranometers

The side by side comparison of the pyranometers were performed during the period July 1, 12:00 – July 6: 10:50. Figures 9-11 show the result from the comparison. Figure 9 shows the measured solar irradiation during the period for both pyranometers. Measurements is lacking for July 2, 10:20-12:30 due to work being performed on the platform causing shading on the pyranometers. Figure 9 shows almost complete agreement.

Figure 10 shows the correlation between the measurements from the two pyranometers.

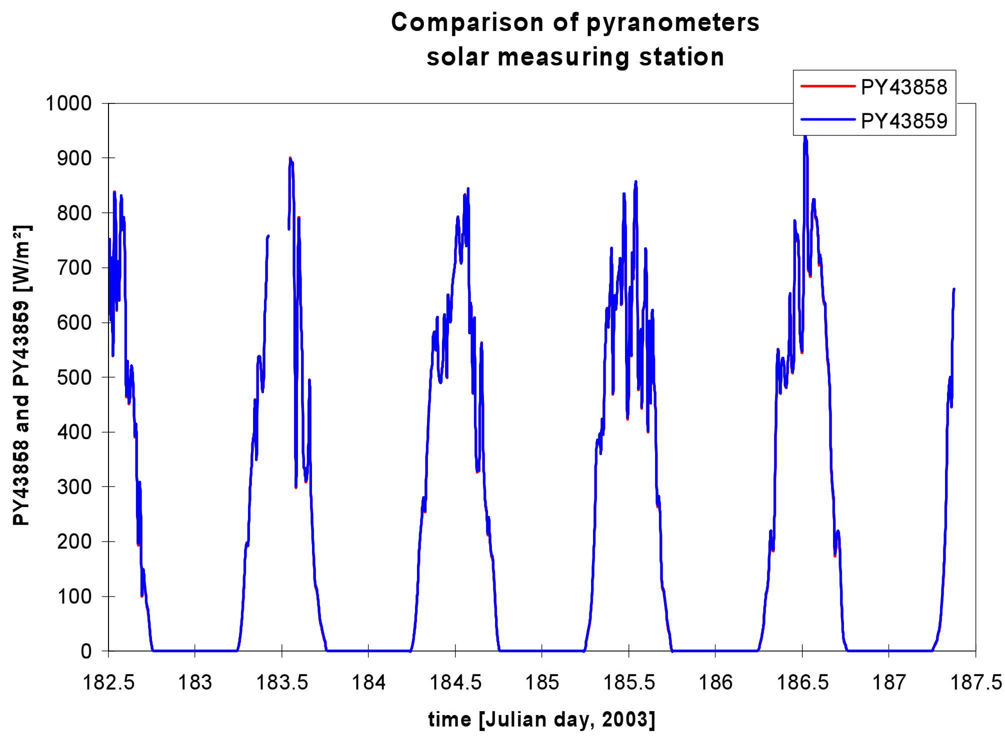

Figure 9. The result of the side by side comparison shown over the considered period.

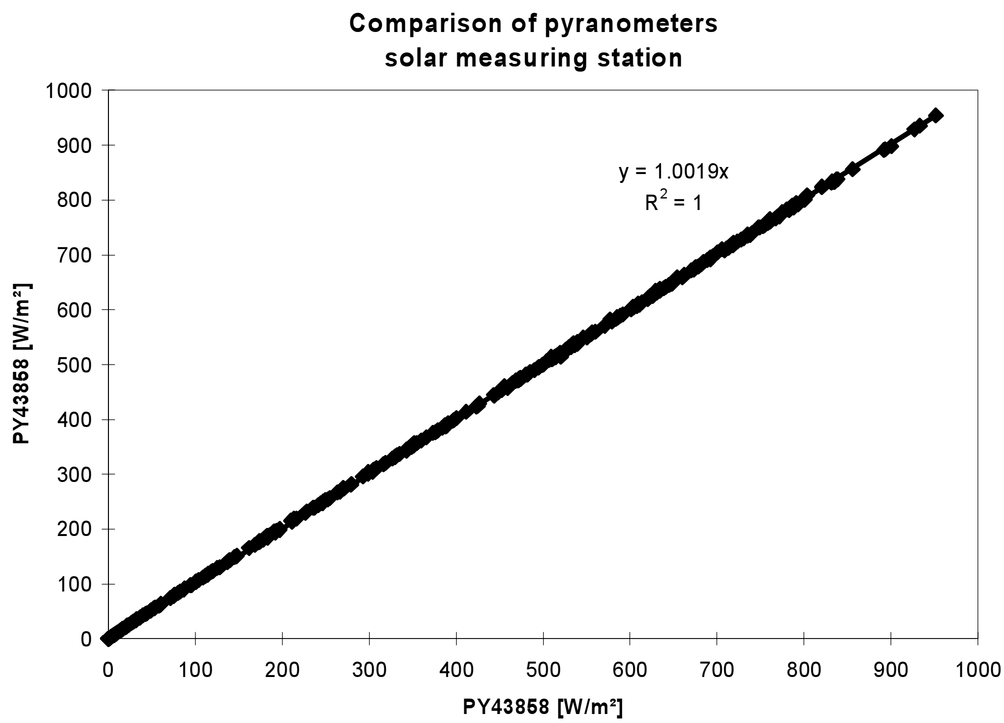

Figure 10. The correlation between the measurements from the two pyranometers.

Figure 10 also shows an almost perfect agreement between the measurements of the two sensors.

Figure 11 shows the absolute difference between the measurements of the two pyranometers (PY43858 minus PY43859) as a function of the measurements of PY43858. The relative uncertainty increases with decreasing solar radiation – at 100 W/m² the difference is around 3%, which still is good, but the higher relative difference at this low radiation level has only minor influence on the daily sum of radiation as only little energy is contained in the radiation below 100 W/m²,

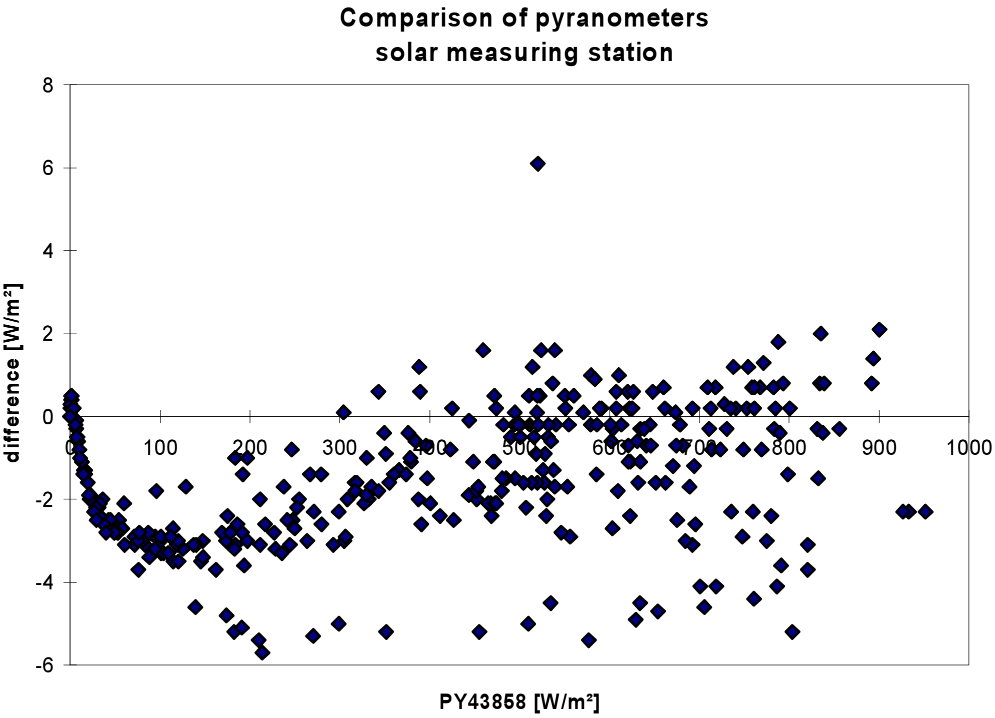

Figure 11. The absolute difference between the measurements for the two sensors.

It may thus be concluded that the two pyranometers performs almost identically.

2.1.2. Calibration of the pyranometers

As the two pyranometers performs identically only PY43858 was calibrated against a high precision pyranometer from Kipp&Zonen type CM11.

The calibration was performed manually – i.e. with the CM11 connected to a high precision multimeter with display - see figure 12. The readings of the multimeter were compared with the readings from the display of the Symphony data logger for PY43858. In this way not only PY43858 was calibrated but the combination of pyranomter and data logger, which means that no additional uncertainty of the data logger should be added to the reading from the sensor.

The calibration was carried out on July 4 and 7, 2003.

Figure 12. Manually calibration of the pyranometers.

Figures 13-14 show the result of the calibration. Figure 13 shows the correlation between the two pyranometers together with a regression line and regression equation. There is a very good fit between measured data and the regression line.

Figure 14 further show the uncertainty on the measurements. The uncertainty on the PY43858 is set to the uncertainty given by the manufacture: ±5%. The uncertainty on the Kipp&Zonen is set to ±3% (it is very difficult to obtain a lower uncertainty even with an extremely well calibrated instrument). The uncertainty on the multimeter is determined by the resolution on the display, which is 0.1 mV – it is thus possible to read the values with and uncertainty of ±0.5 V.

On figure 14 it is seen that the regression line is within the uncertainty of the PY43858 and also just inside the uncertainty of the Kipp&Zonen incl. multimeter. The figure, therefore, shows that the two pyranometers in fact may perform identically. However, figures 13-14 always show a higher reading from PY43858 than from Kipp&Zonen. So in order not later to be accused to boosting the solar potential at the Maldives it is suggested that the readings of both pyranometers of the measuring station are divided by a factor of 1.045. This suggestion is also based on a laboratory calibration of another LI200 pyranometer in the report "Control of the EDS Measuring Equipmant for Measurements of Irradiance in Swaziland", Danish Solar Energy Centre, Danish Technological Institute, 2000, were a 6-7% higher reading for the LI200 pyranometer was found. In this later calibration the signal from the pyranometer was mV and not at here mA. This may have caused the bit higher offset of the LI200 pyranometer in the 2000 study.

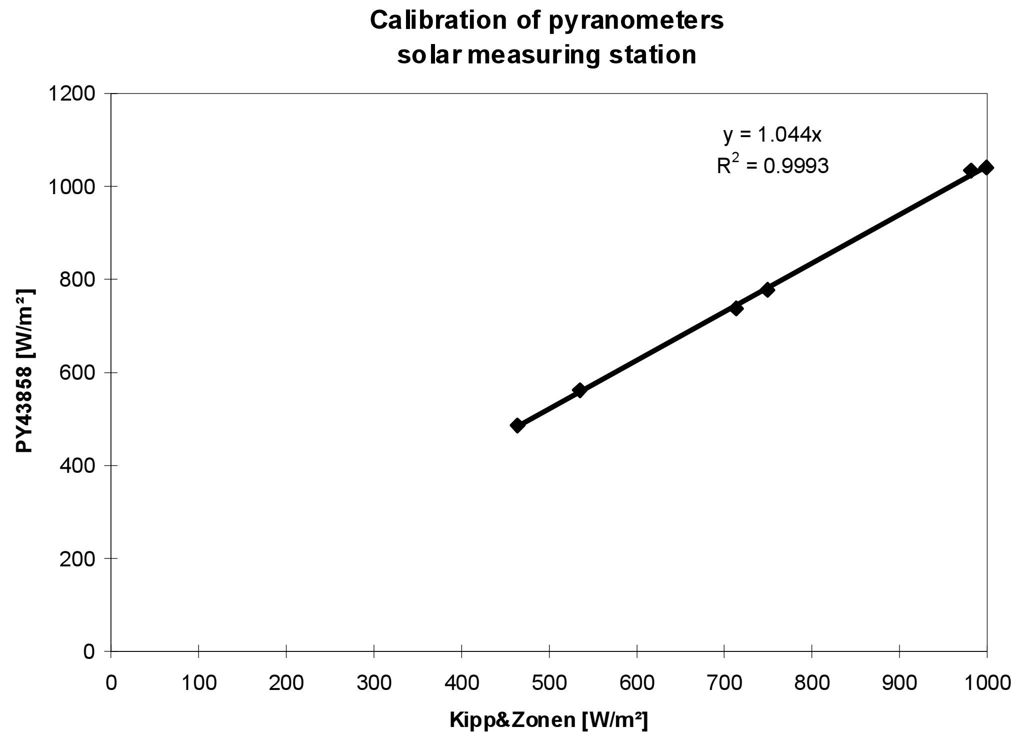

Figure 13. Result from calibration of the PY43858 pyranometer.

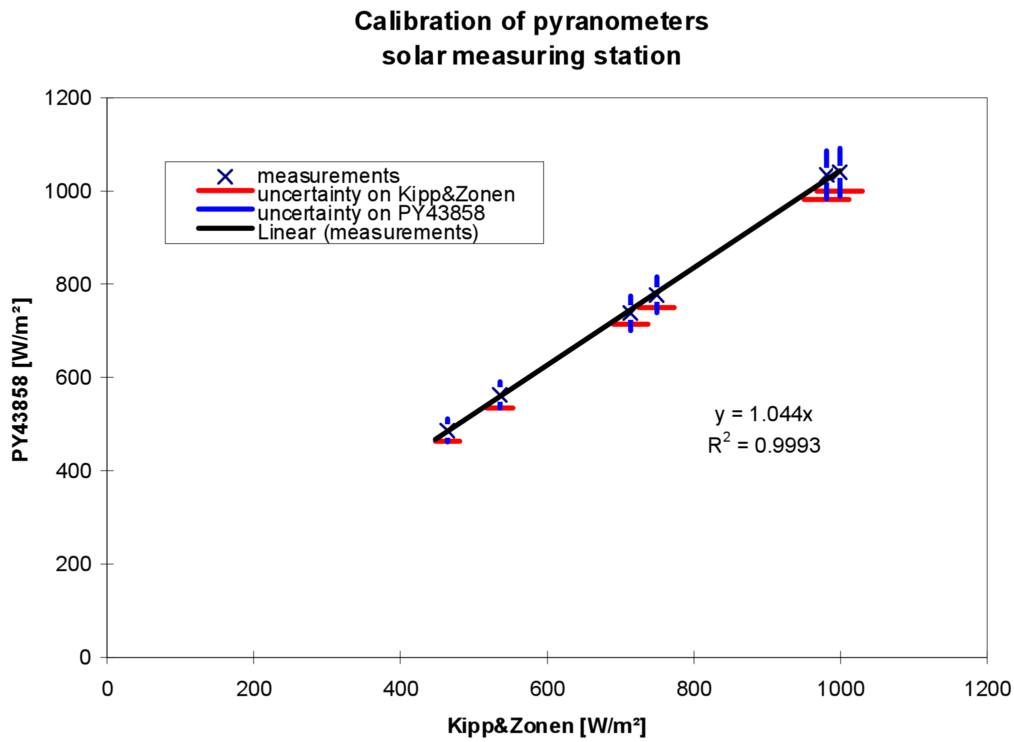

Figure 14. Result from calibration of the PY43858 pyranometer including uncertainties.

2.2. Calibration of the ambient temperature and the relative humidity sensor

The calibration of the ambient temperature and relative humidity sensor was carried out in three steps:

step 1: comparison of the readings from the two sensors with the readings from two Tinytag data loggers
step 2: comparison of the readings from the two sensors with the measurements obtained from the sensors at the meteorological station
step 3: comparison of the readings from the two Tinytag data loggers with the measurements obtained from the sensors at the meteorological station

The successive approach was adopted as differences were obtain in both step 1 and step 2

2.2.1. Step 1

Two small special purpose data loggers (Tinytag data loggers) were brought with from Denmark. One Tinytag with external probe for measuring of the ambient temperature and one Tynytag for measuring of relative humidity (this data logger also includes an internal temperature sensor). The Tinytag with external probe was calibrated in Denmark prior to this mission using a calibrated and certified Jofra model D 50 RC temperature sensor calibration instrument. The Tinytag for relative humidity has former with good results been compared with at calibrated high precision comfort meter from Brüel&Kjær type 1213.

Figure 15 shows the external temperature probe located inside the shield besides the ambient temperature sensor of the solar measuring station. The external temperature probe is ø3 mm and 90 mm long and could be installed through one of the drain holes of the shield of the ambient temperature sensor. Figure 15 also show the Tinytag for measuring of relative humidity.

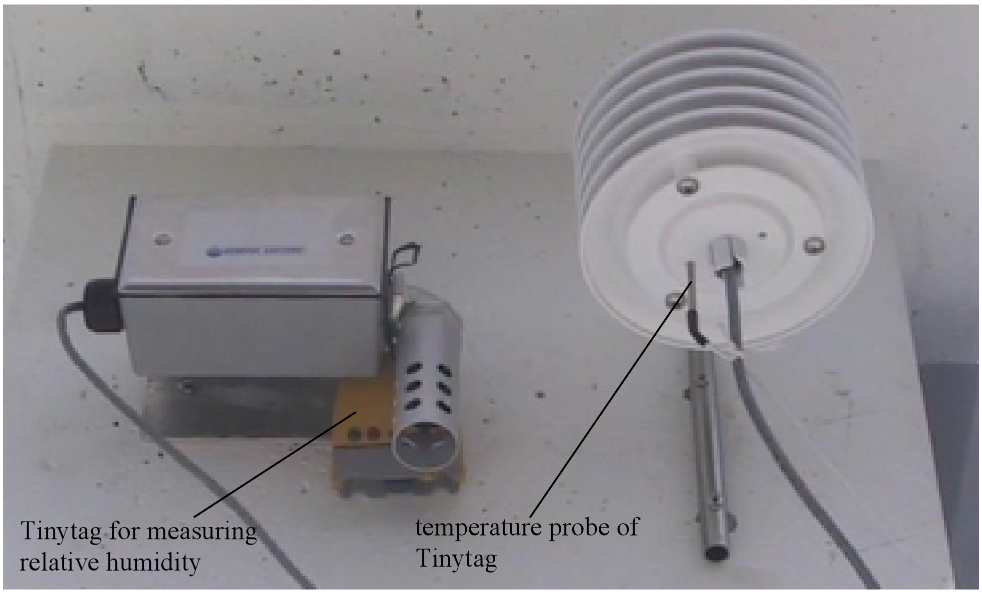

Figure 15. Tinytag data loggers for comparison with the readings of the ambient temperature and relative humidity sensor of the solar measuring station.

Figure 16 shows the result of the comparison between the ambient temperature sensor of the solar measuring station and the calibrated Tinytag temperature sensor for the period July 1, 12:00 – July 6, 10:50 using 10 minutely data.

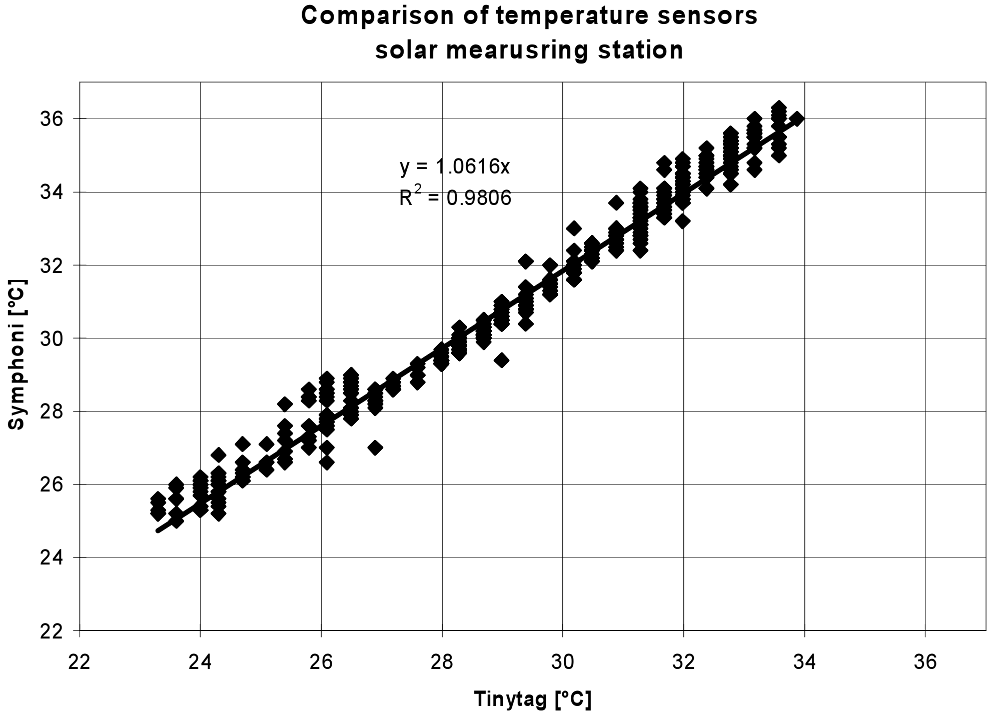

Figure 16. Comparison of the ambient temperature measured with the sensor of the solar measuring station (Symphonie) and the Tinytag data logger.

Figure 16 shows that the temperature sensor of the solar measuring station overpredicts the temperature by about 6 %. The readings from the ambient temperature sensor should thus be divided by 1.0616.

Figures 17-18 show the relative humidity measured with the sensor for the solar measuring station and the Tinytag. Figure 17 shows a rather scattered picture with a tendency of the relative humidity sensor of the solar measuring station to give too high readings. However, measuring of relative humidity is a rather difficult task. The actual measured relative humidity is further very dependent on the actual air temperature at the sensor. Figure 18 shows, however, same trend for the two sensors. Figure 19 shows a comparison of the readings from the temperature sensor of the two Tinytag data loggers. Figure 19 shows also a rather large scattering and that the temperature measured with the Tinytag for measuring relative humidity was higher that the temperature measured by the Tinytag with the external temperature sensor located in the shielding of the ambient temperature sensor of the solar measuring station. The scattering and higher temperature measured with the Tinytag for measuring relative humidity may very well be responsible for the difference shown in figure 17.

No conclusion can thus be obtained regarding the correctness of the relative humidity sensor of the solar measuring station. Further investigation was necessary.

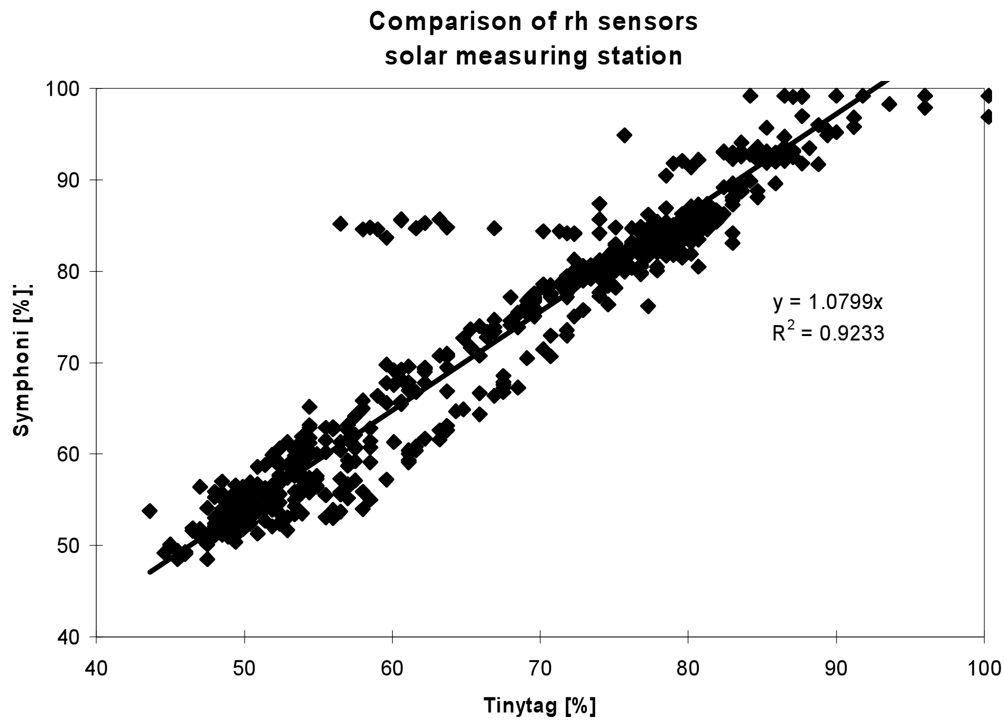

Figure 17. Comparison of the relative humidity measured with the sensor of the solar measuring station (Symphonie) and the Tinytag data logger.

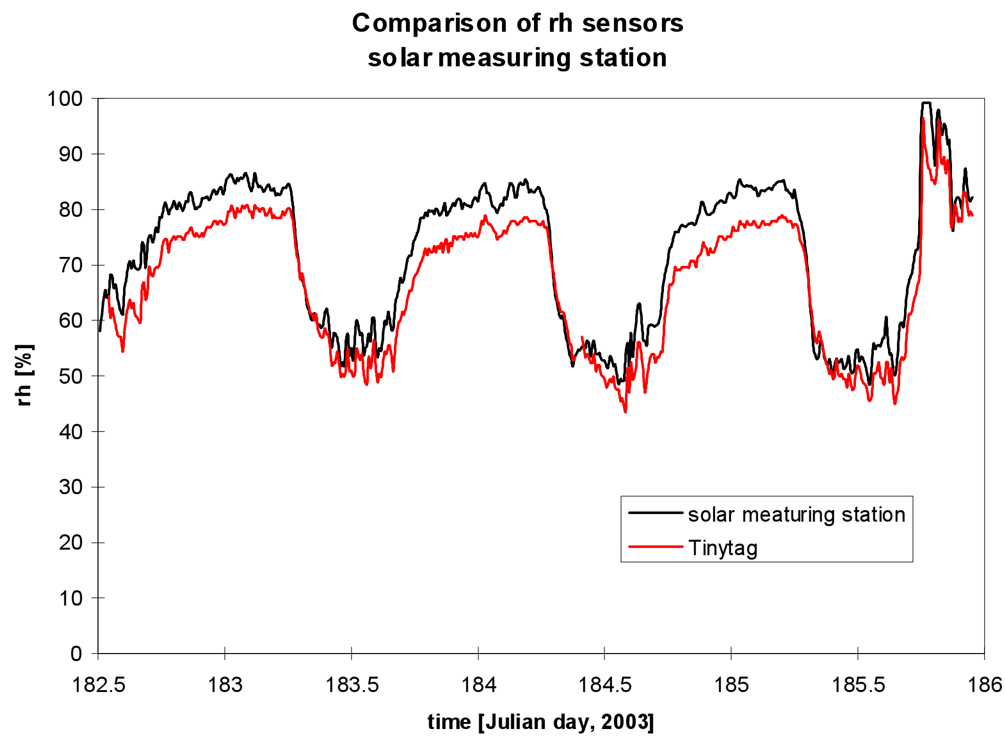

Figure 18. Comparison of the relative humidity measured with the sensor of the solar measuring station (Symphonie) and the Tinytag data logger.

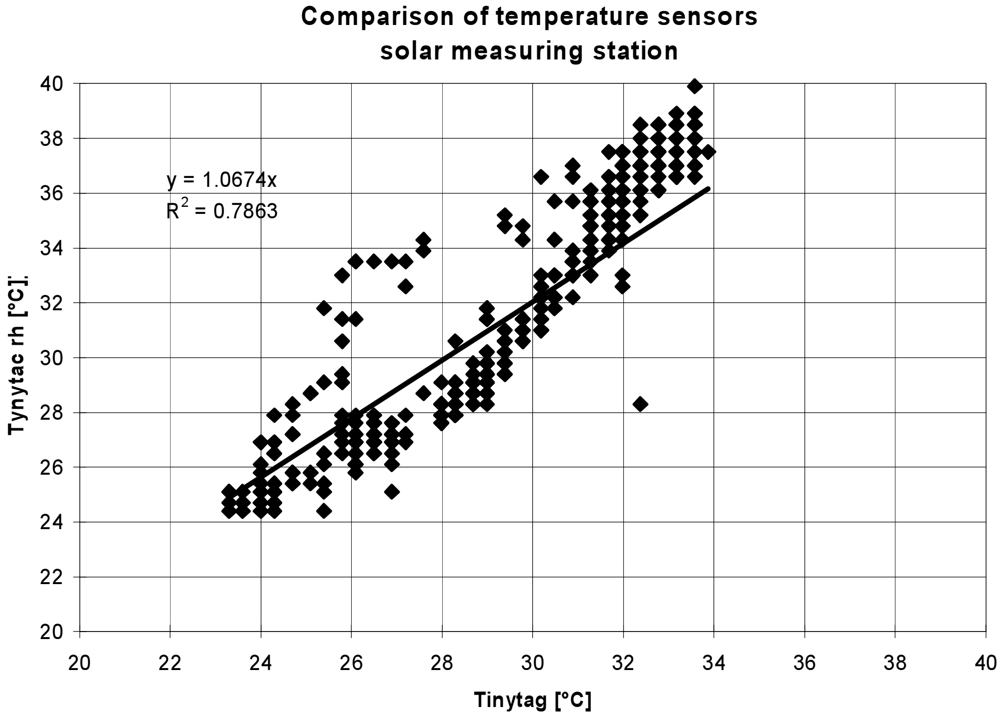

Figure 19. Comparison of the ambient temperature measured with the sensors of the two Tinytag data loggers.

2.2.2. Step 2

In this step the measured date from the ambient temperature and relative humidity sensor of the solar measuring station were compared with measurements obtained with the sensors of the meteorological station hosting the solar measuring station for the same period as above – but now using hourly data. The values obtained from the solar measuring station are averaged second secondly values over the hour, while the values from the meteorological station are hourly spot values. This of course introduces an uncertainty on the comparison – however, not large enough to explain the large discrepancies shown in the following.

The sensors of the meteorological station are calibrated yearly and are located in traditional English huts in order to shield them from the sun. One of the English huts is shown in figure 20 (also seen in figure 4 in the picture South). The English huts of the meteorological station are located few meters from the solar measuring station.

Figure 21 shows a comparison between the ambient temperature measured with the ambient temperature sensor of the solar measuring station and the meteorological station. The figure also shows a curve for the ambient temperature sensor of the solar measuring station after corrected using the calibration factor found in figure 16.

Figure 20. One of the English huts at the meteorological station for shielding the ambient temperature and relative humidity sensor.

Figure 21 shows bad agreement between the measurements even when the temperature sensor of the solar measuring station is corrected. The temperature of the solar measuring station before correction shows a difference compared to the sensor of the meteorological station of about 1 K during the night and up to 5 K during the day. Correcting the reading of the sensor using the findings in figure 15 leads to minor but still to high differences: -1 K during the night and up to 3 K during the day.

This indicates that the concrete platform has another micro climate than in the English huts of the meteorological station. This suggests that the location of the sensor should be changed.

Figure 22 shows a comparison of the measured relative humidity from the solar measuring station and the meteorological station. Figure 22 shows a rather good agreement during the night while a poor agreement during the day. During the night mostly below 5 % point while during the day down to 30 % point less than measured at the meteorological station.

This again suggests that the location of the sensor at the platform for the solar measuring station may be a wrong choice.

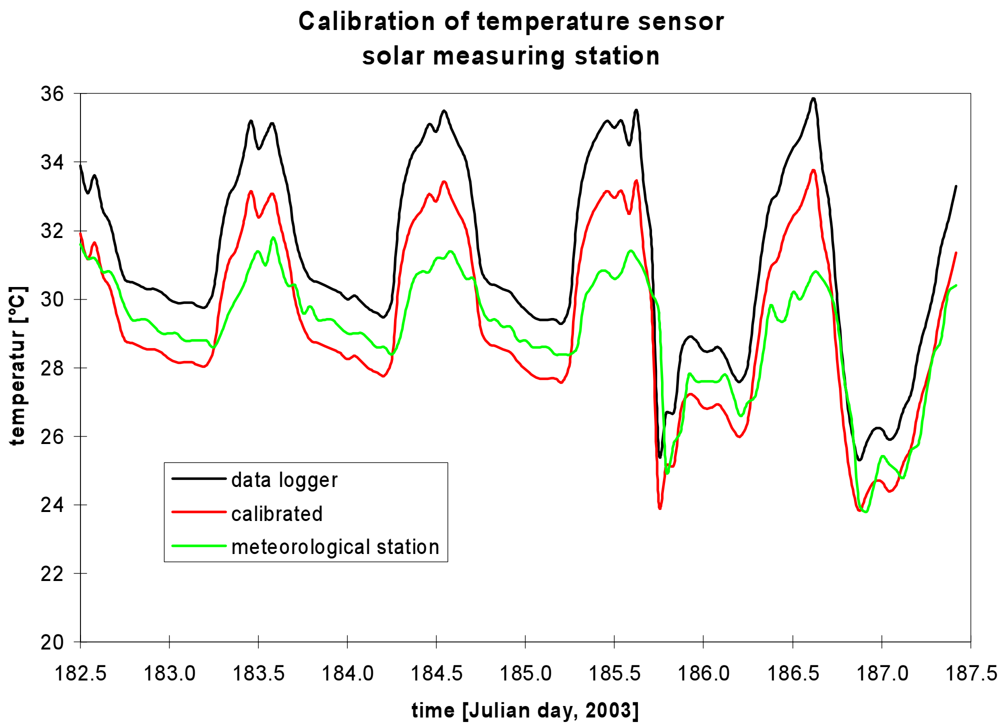

Figure 21. Comparison of the readings of ambient temperature from the solar measuring station (uncorrected and corrected) and from the meteorological station.

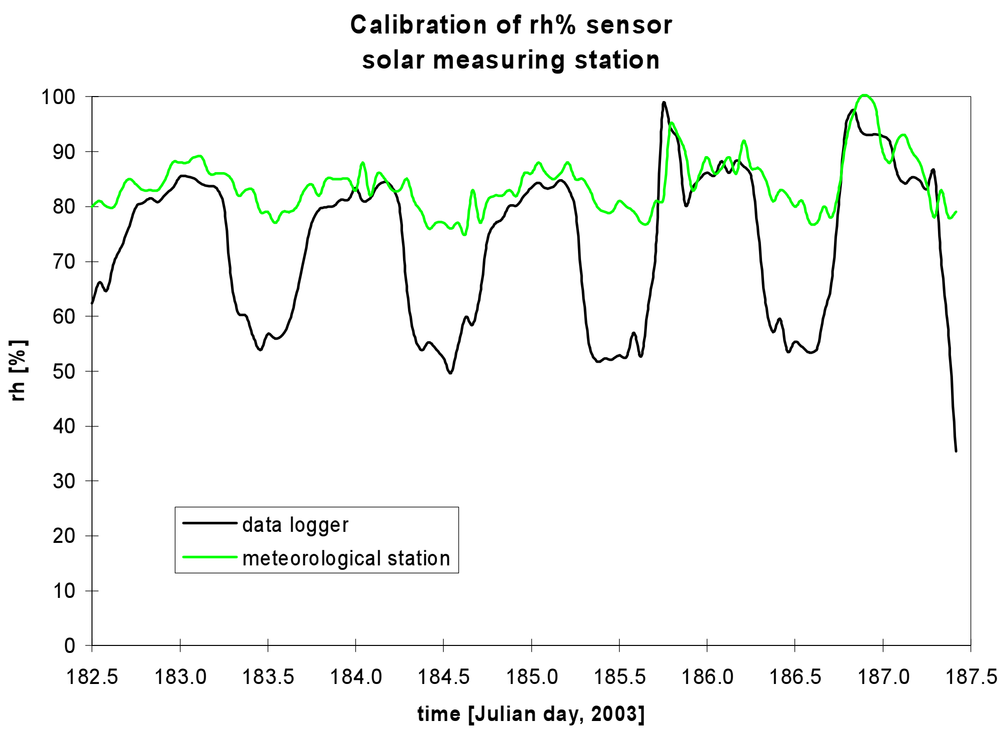

Figure 22. Comparison of the readings of relative humidity from the solar measuring station and from the meteorological station.

2.2.3. Step 3

However, before finally stating that the sensors for measuring of ambient temperature and relative humidity should be relocated a final comparison were performed. The Tinytag data loggers were relocated from at the solar measuring station (figure 15) to within one of the English huts of the meteorological station as shown in figure 23. The used data is hourly data from the period July 6, 12:00 – July 8, 8:00.

Figure 23. The two Tinytag data loggers located in one of the English huts of the meteorological station.

The comparison of the two sensor sets is shown in figures 24 and 25. The two figures show that the two sensor sets perform very identically meaning that the readings of the Tinytag data loggers are correct. Figure 26 further shows that the two temperature sensors of the Tinytags also perform very similar.

The above underlines the former finding that the concrete of the solar measuring station leads to changes in micro climate.

The conclusion is, therefore, that the sensors for measuring ambient temperature and relative humidity at the solar measuring station should be relocated – preferably to an English hut – e.g. to one of the English huts of the meteorological station.

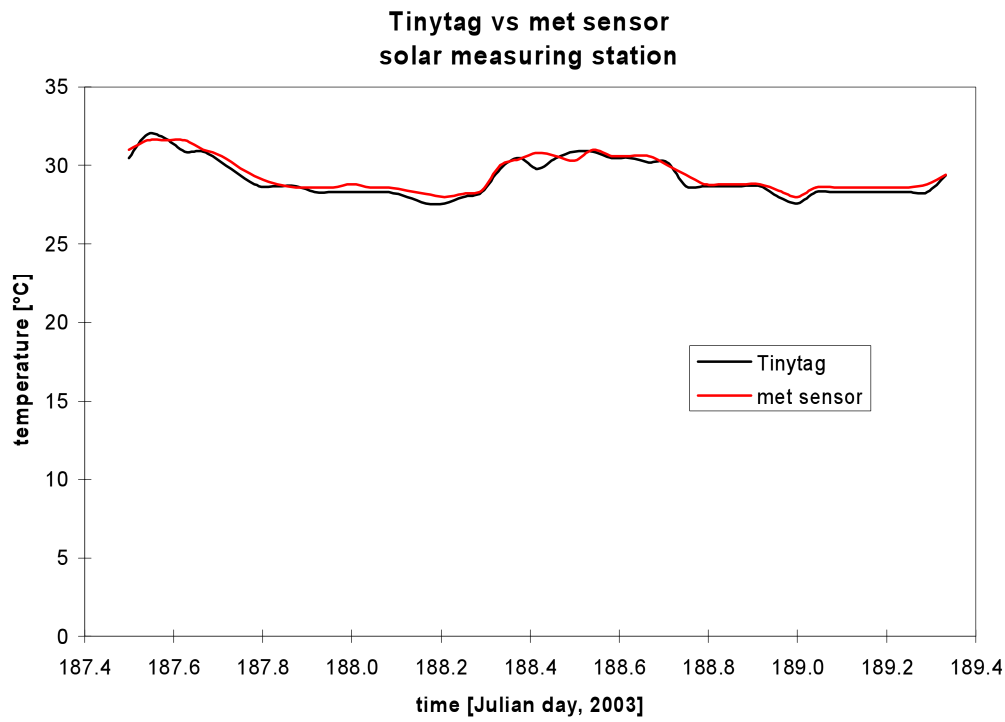

Figure 24. Comparison of the readings of ambient temperature from the Tinytag and from the meteorological station.

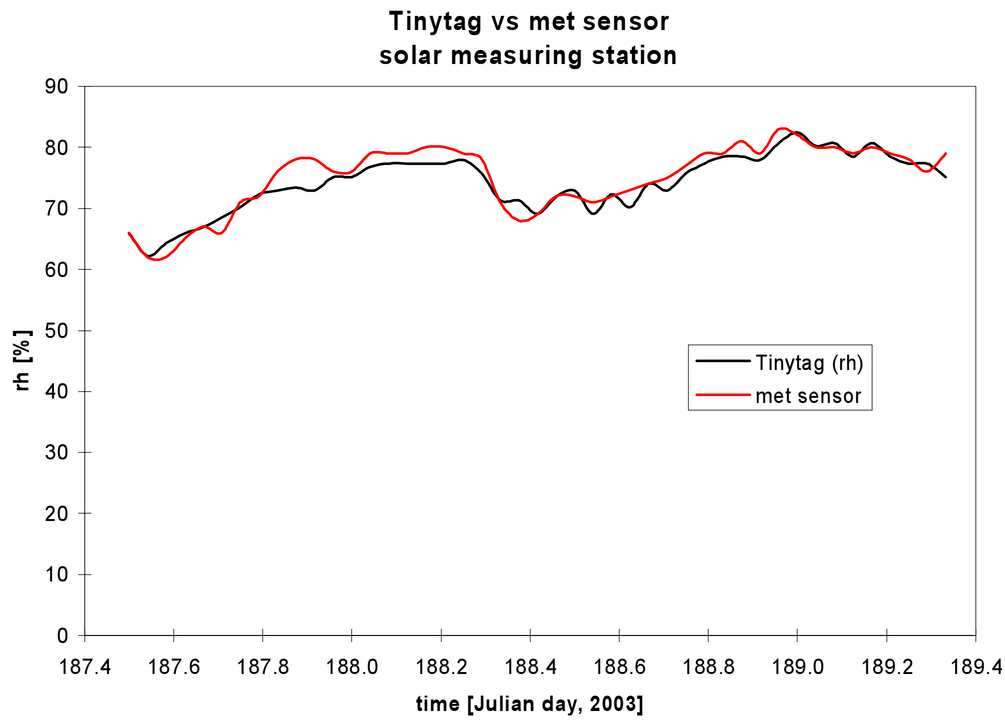

Figure 25. Comparison of the readings of relative humidity from the Tinytag and from the meteorological station.

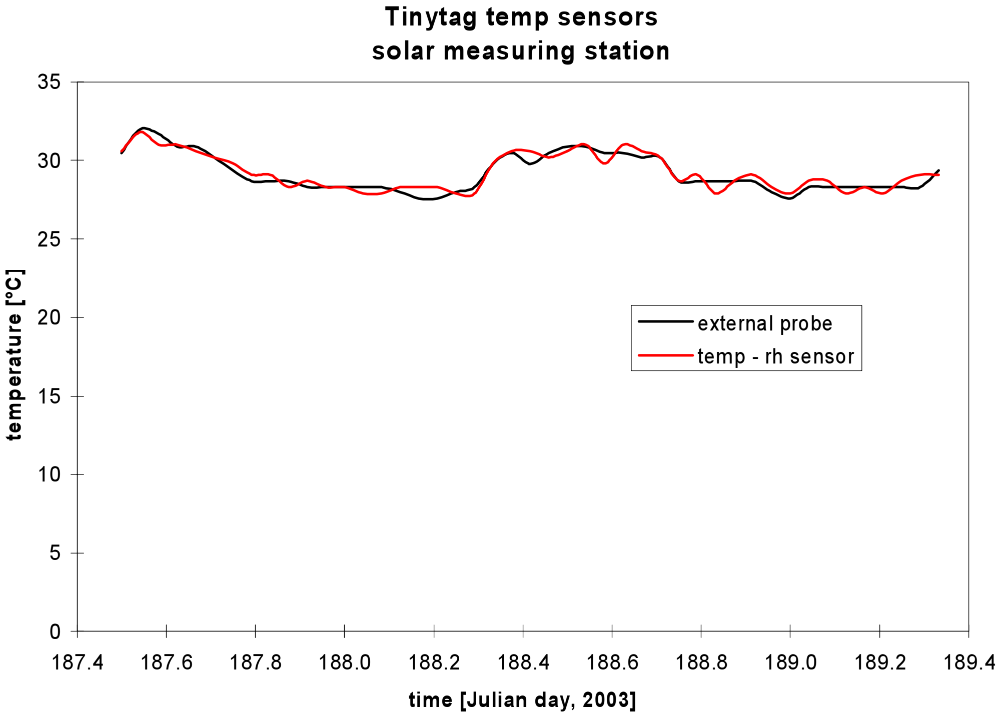

Figure 26. Comparison of the readings of ambient temperature from the two Tinytags.

2.3. Conclusion

2.3.1. Pyranometers

The two pyranometers give almost identical readings when exposed to identical solar radiation.

The two pyranometers give a slightly higher reading than a calibrated high precision pyranomter from Kipp&Zonen – 4.5 %. But as the uncertainty of the instrument overlap the reading of the two pyranometers at the solar measuring station is satisfactory and within the uncertainty given by the manufacture.

However, in order not to be accused of trying to boost the potential for utilization of solar energy at the Maldives it is proposed to decrease the readings of the pyranometers of the solar measuring station by the above mentioned 4.5 %.

2.3.2. Ambient temperature and relative humidity sensors

The reading of the ambient temperature sensor should be divided by 1.0616 in order to obtain the correct value.

The original location of these two sensors at the platform for the solar measuring station is not good due to the special micro climate created by the concrete of the platform.

There are three alternatives:

- the sensors are left where they are and measurements from the meteorological station are used instead
- the two sensors are located in a new English hut next to the solar measuring station
- the two sensors are located in one of the existing English huts of the meteorological station

The latter alternative is preferred. However, in order to do this the length of the cables of the two sensors should be extended, which is no problem according to NRG as long as a shielded three wire cable with low resistance is used.

After the relocation of the two sensors the readings of the sensors should once more be compared with the readings of the instruments of the meteorological station in order to verify that the two sensors then as expected give correct readings.

3. Maintenance

The main task of the physical maintenance is the cleaning of the pyranometers and the mowing of the shading ring.

3.1. Important

If it is necessary to enter the construction avoid direct shading of the pyranometers. The pyranometers measure the radiation from the whole hemisphere so even if direct shading is avoided stay at the construction will still influence the measurements. Traffic on the construction of the solar measuring station should, therefore, be limited as much as possible. When the platform is enteret this should be stated in the logbook as seen later

3.2. Cleaning of the pyranometers

The pyranometers are mounted horizontally, which means that e.g. dirty may build up on the sensors leading to a too low measured solar radiation. It is, therefore, important that the sensor is cleaned at regular intervals (a weekly cleaning may be necessary, however, the interval should be determined by trial) – especially during the dry season. The following recommendations are found in "LI-COR Radiation Sensors – Instruction Manual", LI-COR, 1986:

"CLEANING INFORMATION

***DO NOT** use alcohol, organic solvents, abrasives or strong detergents to clean the diffusor element on LI-COR light sensor.*

The acrylic material used in LI-COR light sensors can be crazed by exposure to alcohol or organic solvents, which will adversely affect the cosine response of the sensor.

*Clean the sensor **only** with water and/or a mild detergent such as dishwashing soap. LI-COR has found that vinegar can also be used to remove hard water deposit from the diffusor element, if necessary."*

Also the vertical edges of the diffusor element must be kept clean in order for the sensors to measure correctly at high incidence angles.

Figure 27 shows a picture of a LI200 pyranometer, where the diffusor element is pointed out. Around the diffusor element is a ditch with a drain hole. The ditch and the drain hole should be keep free of deposits.

The cleaning of the pyranometers should be performed at early dawn or late dusk in order not to influence the measured solar radiation.

The exact time of cleaning of the pyranometers should be stated in the logbook of the solar measuring station.

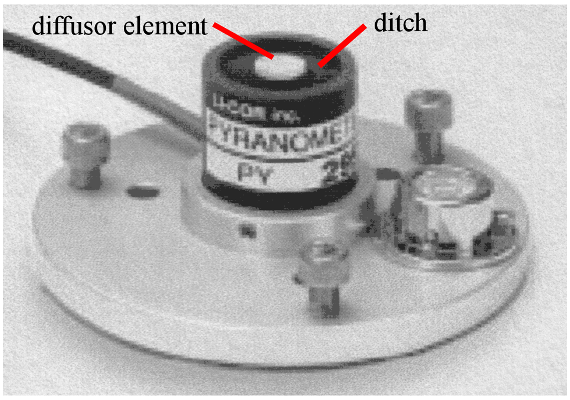

Figure 27. The LI200 pyranometer.

3.3. Moving the shading ring

Due to the changing declination of the sun over the year the shading ring should be moved at regular intervals in order to ensure that the pyranometer for measuring diffuse radiation always are shaded by the shading ring.

During sunshine it is easy to locate the shading ring correctly. However, it may be necessary to operate the shading ring during overcast conditions. The position of the shading ring is calculated in the following.

The position of the shading ring is calculated using basic trigonometry and the solar height at noon found using the program Almanak 1.0b VisualSoft Nakskov 1998 (in Danish).

The obtained distance is the distance from the front (pointing towards south) of the profiles carrying the shading ring to the front (pointing towards south) of the shading ring as seen in figure 28.

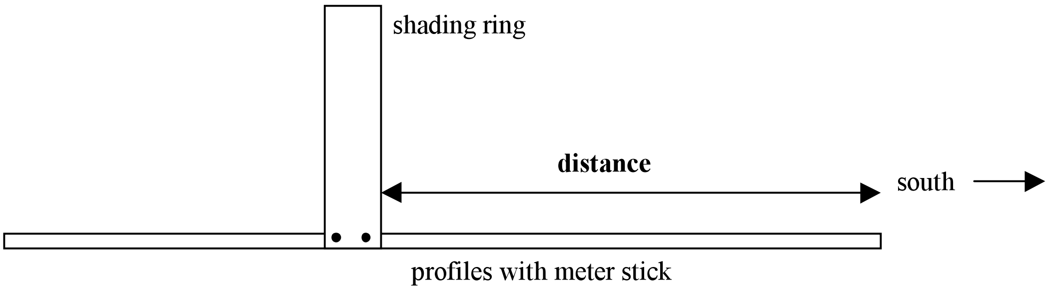

Figure 28. The distance for locating the shading ring which is given in the following

Table 2 shows the location of the shading ring on a fortnightly basis. The same is shown graphically in figure 29. Figure 29 also gives a regression equation for the location of the shading ring:

$$\text{distance} = 0.0014\, n^4 - 0.0684\, n^3 + 0.8997\, n^2 - 1.3049\, n + 18.565 \qquad [8]$$

where: n is the number of the day – found in table 3

The uncertainty on the **distance** is judged to be ±1 cm. But as the shading ring has a width of 7 cm, this should not cause any problems. It is, however, advised that if the shading ring is moved during overcast the position should be checked at the fist available sunshine.

The shading ring should be moved on a weekly basis. The movement is between 0.5-1.5 cm per week except at high summer and winter, with a movement of 1 mm.

<u>The exact time of moving the shading ring should be stated in the logbook of the solar measuring station.</u>

Date	**distance** cm
jan-01	17.8
jan-15	19.1
feb-01	21.5
feb-15	24.1
mar-01	27.0
mar-15	29.6
apr-01	32.8
apr-15	36.2
maj-01	38.7
maj-15	40.8
jun-01	43.0
jun-15	43.2

Date	**distance** cm
jul-01	43.1
jul-15	42.2
aug-01	40.3
aug-15	38.2
sep-01	35.3
sep-15	32.1
okt-01	29.1
okt-15	26.3
nov-01	23.1
nov-15	20.7
dec-01	18.7
dec-15	17.7

Table 2. The location (distance from figure 28) of the shading ring on a fortnightly basis.

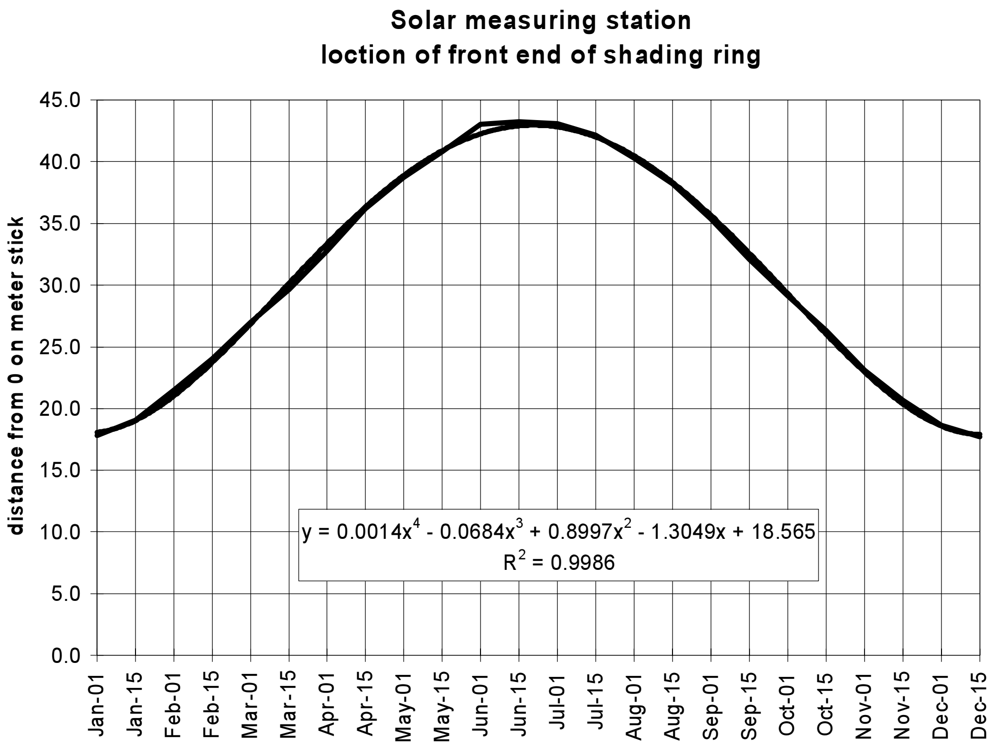

Figure 29. The location (distance from figure 28) of the shading ring over the year.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Okt	Nov	Dec
1	1	32	60	91	121	152	182	213	244	274	305	335
2	2	33	61	92	122	153	183	214	245	275	306	336
3	3	34	62	93	123	154	184	215	246	276	307	337
4	4	35	63	94	124	155	185	216	247	277	308	338
5	5	36	64	95	125	156	186	217	248	278	309	339
6	6	37	65	96	126	157	187	218	249	279	310	340
7	7	38	66	97	127	158	188	219	250	280	311	341
8	8	39	67	98	128	159	189	220	251	281	312	342
9	9	40	68	99	129	160	190	221	252	282	313	343
10	10	41	69	100	130	161	191	222	253	283	314	344
11	11	42	70	101	131	162	192	223	254	284	315	345
12	12	43	71	102	132	163	193	224	255	285	316	346
13	13	44	72	103	133	164	194	225	256	286	317	347
14	14	45	73	104	134	165	195	226	257	287	318	348
15	15	46	74	105	135	166	196	227	258	288	319	349
16	16	47	75	106	136	167	197	228	259	289	320	350
17	17	48	76	107	137	168	198	229	260	290	321	351
18	18	49	77	108	138	169	199	230	261	291	322	352
19	19	50	78	109	139	170	200	231	262	292	323	353
20	20	51	79	110	140	171	201	232	263	293	324	354
21	21	52	80	111	141	172	202	233	264	294	325	355
22	22	53	81	112	142	173	203	234	265	295	326	356
23	23	54	82	113	143	174	204	235	266	296	327	357
24	24	55	83	114	144	175	205	236	267	297	328	358
25	25	56	84	115	145	176	206	237	268	298	329	359
26	26	57	85	116	146	177	207	238	269	299	330	360
27	27	58	86	117	147	178	208	239	270	300	331	361
28	28	59	87	118	148	179	209	240	271	301	332	362
29	29		88	119	149	180	210	241	272	302	333	363
30	30		89	120	150	181	211	242	273	303	334	364
31	31		90		151		212	243		304		365

Table 3. Day number.

3.4. Calibration

The instruments of the solar measuring station should be calibrated once a year.

The ambient temperature and relative humidity sensor may easily be calibrated by comparing the readings with the readings from the instruments at the meteorological station, which are calibrated each year.

The calibration of the pyranometers are more difficult. There are two alternatives:

- a calibrated pyranometer is brought to the Maldives for calibration of the pyranometers as done by the Danish solar expert in the present project.
- one of the pyranometers is shipped to a certified calibration institute for calibration. The pyranometers should be calibrated in a set-up equal to the set-up at the solar

measuring platform – i.e. measuring of mA. On return the other pyranometer should be calibrated against the calibrated pyranometer.

By the end of the present project the Danish expert may calibrate the pyranometers.

3.5. Logbook

A detailed log should be kept on all events regarding the solar measuring station – i.e. cleaning of pyranometers, moving of the shading ring, visits to the solar measuring station, etc. For each event the following should be written in the logbook: data, time (period), name/initials of the person writing in the logbook and a description of the event.