

Ghanaian weather data for simulation purposes



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Preface

The present report on Ghanaian weather data is part of the project “Test and Research Project into the Drying of Food and Wood Products with Solar Heat” financed by Danida (Danish International development Assistance) via the Danish Embassy in Ghana. The project was established based on an initiative by the Energy Commission of Ghana.

The generated weather data are available on files - both as Excel97 and ASCII files.

The weather data are generated in a solar drying project. The weather data are, however, also valuable for other purposes like dimensioning of solar water heaters and pv systems and for prediction of the thermal performance of buildings.

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1. Introduction

When designing solar energy systems including solar dryers it is essential that the systems are designed to match the climate where they are going to be located. In order to be able to optimize the different components and the interaction of these components in a solar dryer it is important to know several climate parameters: Solar radiation (global (or direct) and diffuse radiation), ambient temperature, ambient humidity and wind speed. These data should preferably be on data files in the form of hourly data for a whole year.

Hourly data for a whole year is preferred in order to test the design under different weather conditions which it is likely to operate under and also to test the system under dynamic conditions where the climate change from hour to hour and from day to day.

Climate data from different locations in Ghana are available in (Akuffo, 1991). The following data are available:

- Global radiation: Hourly monthly mean values for the twelve months
- Diffuse radiation as a percentage of global radiation: Daily mean values for the twelve months
- Ambient dry bulb temperature: Three hourly monthly mean values for the twelve months
- Ambient relative humidity: Three hourly monthly mean values for the twelve months
- Wind speed: Daily mean values for the twelve months at a height of 2 m above the ground.

The above-mentioned data are available for the following locations:

Location	global radiation	diffuse radiation	dry bulb temperature	relative humidity	wind speed
Kumasi	x	x	x	x	x
Wenchi		x	x	x	x
Akim Oda		x	x	x	
Akuse		x	(x)	x	x
Koforidua		x	x	x	x
Accra	x	x	x	x	x
Tema			x	x	
Bole		x	(x)	x	x
Tamale	x	x	x	x	x
Yendi		x	x	x	x
Navrongo	x		x	x	x
Wa		x	x	x	x
Akatsi			x	x	x
Ho	x	x	x	x	
Kete Krachi		x	x	x	x
Axim		x	x	x	x
Sefwi-Bekwai	x	x	x	x	
Takoradi	x	x	x	x	x
Saltpond		x		x	x
Abetifi				(x)	
Ada		x		x	x
Sunyani					x

(x) means not all data are available

From the table it is seen that all data are only present for 4 locations. However, the wind speed is not the most important parameter, which means that sufficient data are available from 6 locations: Accra, Ho, Kumasi, Sefwi-Bekwai, Takoradi and Tamale. The locations of these six sites are shown in figure 1.



Figure 1. The location of five of the sites where all the climate data from the above-mentioned report are present – Sefwi-Bekwai which is not shown is located next to Kumasi.

The six locations are considered to well represent the different climate types in Ghana.

2. Generation of hourly mean monthly data files

In (Akuffo, 1991) only the global radiation exist as hourly data. The ambient dry bulb temperature and the ambient relative humidity are only present as a value for each third hour of the day, while the fraction of diffuse radiation and wind speed only is present as daily mean values.

The hourly data for the ambient dry bulb temperature, ambient relative humidity, diffuse radiation and wind speed is generated in the following way:

Ambient dry bulb temperature and ambient relative humidity

The missing data is found by linear interpolation between the three hourly data.

Diffuse radiation

In (Akuffo, 1991) the fraction of diffuse radiation of the global radiation is given as a mean daily value for each month. This fraction is hour by hour multiplied with the global radiation.

Wind speed

The wind speed is given as a mean daily value for each month. In the generated data files the wind speed is identical for all hours of the day.

2.1. Data files and graphs

The generated weather data for the six locations exist as an Excel97 file for each location including graphs showing the data and as an ASCII file for each location. The files are named after the location (for the ASCII file shortened) with an extension “xls” for the Excel97 file and “asc” for the ASCII files. The files contain the following data for each month of the year:

- Column 1: Month number
- Column 2: Day number of the 15th day of each month
- Column 3: Hour of the day
- Column 4: Global radiation [W/m²]
- Column 5: Diffuse radiation [W/m²]
- Column 6: Ambient dry bulb temperature [°C]
- Column 7: Ambient relative humidity [%]
- Column 8: Wind speed at 2 m height [m/s]

Appendix A-F show month by month graphs of the above weather data except for the wind speed which is constant over the day. The wind speed 2 m above the ground is given in the below table.

Month	Accra [m/s]	Ho [m/s]	Kumasi [m/s]	Sefwi- Bekwai [m/s]	Takoradi [m/s]	Tamale [m/s]
January	2.6	-	1.1	-	1.2	1.8
February	3.5	-	1.5	-	1.6	1.9
March	3.4	-	1.6	-	1.7	2.0
April	3.0	-	1.8	-	1.5	2.1
May	2.7	-	1.6	-	1.3	1.8
June	3.1	-	1.6	-	1.6	1.6
July	3.6	-	1.9	-	1.7	2.0
August	3.7	-	2.0	-	1.6	1.9
September	3.3	-	1.6	-	1.8	1.3
October	2.7	-	1.4	-	1.8	1.2
November	2.0	-	1.1	-	1.4	1.1
December	1.9	-	1.0	-	1.2	1.3

- means not available

3. Dynamic weather data

The above weather data are mean monthly data which means that it is possible to determine the average performance of the systems month by month. However, the data do not allow for parameter studies where e.g. the performance for a really good or really bad day may be investigated nor do the data allow for an investigation of the performance under dynamic conditions where the weather changes from day to day.

A weather station for detailed measuring of the necessary weather data is located at the Department of Mechanical Engineering, University of Science & Technology, Kumasi. Professor Fred O. Akuffo has kindly made samples of data from this weather station available for the project.

The data are collected in November 1999 and January 2000. The below tables show the average global and diffuse radiation and the ratio of diffuse radiation day by day for the two months.

Day in November 1999	G_{ave} W/m ²	D_{ave} W/m ²	D_{ave}/G_{ave}
1	518.09	194.36	0.38
2	532.20	204.00	0.38
3	343.36	251.82	0.73
4	540.55	203.73	0.38
5	356.91	195.27	0.55
6	400.33	201.33	0.50
7	474.09	175.18	0.37
8	511.64	187.82	0.37
9	431.64	186.09	0.43
10	324.18	187.55	0.58
11	535.27	165.18	0.31
12	475.75	151.75	0.32
13	426.82	214.73	0.50
14	458.36	206.36	0.45
15	409.18	167.64	0.41
16	511.73	151.91	0.30
17	499.64	168.36	0.34
18	427.55	224.64	0.53
19	324.09	195.73	0.60
20	465.55	182.91	0.39
21	390.36	212.64	0.54
22	440.64	227.91	0.52
23	346.18	175.27	0.51
24	449.73	195.45	0.43
25	454.91	197.09	0.43
26	394.90	237.80	0.60
27	438.55	258.55	0.59
28	422.73	239.82	0.57
29	367.18	190.36	0.52
30	473.09	253.09	0.53
monthly average	438.17	200.14	0.47

Day in January 2000	G_{ave} W/m ²	D_{ave} W/m ²	D_{ave}/G_{ave}
1	303.82	209.00	0.69
2	234.50	192.50	0.82
3	414.27	163.36	0.39
4	384.73	164.18	0.43
5	416.45	160.09	0.38
6	297.83	188.83	0.63
7	353.82	167.64	0.47
8	238.55	182.09	0.76
9	322.36	155.82	0.48
10	326.55	194.91	0.60
11	325.00	201.00	0.62
12	307.33	176.33	0.57
13	282.27	199.18	0.71
14	290.73	199.18	0.69
15	340.00	178.27	0.52
16	300.09	193.00	0.64
17	287.64	149.36	0.52
18	395.45	231.00	0.58
19	311.18	215.18	0.69
20	342.64	231.00	0.67
21	387.73	197.09	0.51
22	357.64	190.91	0.53
23	293.82	203.18	0.69
24	224.00	177.45	0.79
25	468.36	182.91	0.39
26	230.70	178.90	0.78
27	481.00	157.73	0.33
28	400.91	191.82	0.48
29	409.09	206.27	0.50
30	485.55	197.64	0.41
31	411.55	302.82	0.74
monthly average	342.76	191.57	0.58

Based on the two above tables three days has been selected for each month: the day with maximum average global radiation, a day with an average global radiation equal to the mean monthly global radiation and the day with minimum average global radiation. For these days detailed climate data are given hour by hour.

The data are shown graphical in appendix G and H. The graphs show the average values for global radiation, diffuse radiation, ambient temperature, ambient relative humidity, wind speed and wind direction. For the global radiation and diffuse radiation are further shown the maximum and minimum value within each hour. This data are also available as either Excel97 and ASCII files named November and January with the extension “xls” or “asc”.

The data files contain the following information:

- Column 1: Year
- Column 2: Day in the month
- Column 3: Month

- Column 4: Hour (times 100) where the number is the end of that particular hour
- Column 5: Average global radiation [W/m^2]
- Column 6: Average diffuse radiation [W/m^2]
- Column 7: Average ambient temperature [$^{\circ}\text{C}$]
- Column 8: Average ambient humidity [%]
- Column 9: Max global radiation within the hour [W/m^2]
- Column 10: Time (where the last two numbers are the minutes of the hour and the first on or first two numbers are the hour) when the max global radiation occurred
- Column 11: Max diffuse radiation within the hour [W/m^2]
- Column 12: Time (where the last two numbers are the minutes of the hour and the first on or first two numbers are the hour) when the max diffuse radiation occurred
- Column 13: Min global radiation within the hour [W/m^2]
- Column 14: Time (where the last two numbers are the minutes of the hour and the first on or first two numbers are the hour) when the min global radiation occurred
- Column 15: Min diffuse radiation within the hour [W/m^2]
- Column 16: Time (where the last two numbers are the minutes of the hour and the first on or first two numbers are the hour) when the min diffuse radiation occurred
- Column 17: Average wind speed [m/s] measured 1.1 m above the roof of a 7.4 m high building
- Column 18: Average wind direction [$^{\circ}$] - north being zero
- Column 19: Rain [mm]

The above-mentioned weather data are six particular days for Kumasi, however, it is believed that the data may be used to generate artificial weather data for other months and other locations so that it will be possible to perform simulation with varying weather conditions within a month.

3.1. Measurements from Pokuase

When comparing the measurements for Kumasi from Appendix G and H with the weather data for Kumasi given in Appendix C it is seen that the weather data for an average day in Appendix G and H is not identical to the data in Appendix C. This is of course not a surprise as the data of the appendixes are based on measurements from different years. However, especially the relative humidity for January is very different when comparing Appendix C and H. It is a major problem when considering solar drying if the assumed relative humidity of the ambient air is not correct

During the experiments on the solar crop dryer and the solar wood dryers major differences between the actual measured relative humidity and the humidity stated by (Akuffo, 1991) (Appendix C) was often observed. The experiments were performed in Pokuase (30 km North of Accra) and Mankoadze (65 km west-south-west of Accra) (Jensen et al, 2002) so it is natural to apply the weather data from Accra from Appendix A. In Appendix A the relative humidity only in January gets below 60 % (58%), while measurements at Pokuase showed relative humidities down to nearly 10% as seen in Appendix I.

Appendixes I-K show measurements of the ambient temperature and ambient relative humidity from days in February, September and October 2001. The first graphs show the mean values of the measurements from the actual month together with the data from (Akuffo, 1991),

while the two other graphs show the individual days. The actual measurements are in the form of 5 minutely values.

Appendix I shows a large discrepancy between (Akuffo, 1991) and the mean of the actual measurements: up to 5 K on the ambient temperature and 25% point on the relative humidity. The appendix shows some difference during daytime between the different days when the ambient temperature is considered, while major differences are observed for the relative humidity.

Appendix J shows some discrepancy between (Akuffo, 1991) and the mean of the actual measurements: up to 2.5 K on the ambient temperature and 10% point on the relative humidity. The appendix shows large difference during daytime between the different days when both the ambient temperature and the relative humidity are considered, the latter, however, less than for February, 2001.

Appendix K shows some discrepancy between (Akuffo, 1991) and the mean of the actual measurements: up to 5 K on the ambient temperature and 10% point on the relative humidity. The appendix shows less difference during daytime between the different days than Appendixes I and J when both the ambient temperature and the relative humidity are considered.

The discrepancy between (Akuffo, 1991) and the actual measurements has not been explained. It could be due to several reasons: different year is considered (temporary or permanent variations), measuring errors in one or both of the sources, location specific microclimate, etc. Appendixes I-K, however, illustrate that one should be very careful when choosing weather data as input for the simulation of drying devices as especially the relative humidity but also the ambient temperature may be very site specific.

Measurements at Monkoadze show same tendency as Appendixes I-K.

4. Conclusion

Based on available average weather data for Ghana data files for simulation purposes has been generated. The data files make it possible to chose weather data for design case studies among 6 locations each containing an average day for the 12 months. In order also to allow for more dynamical simulations where the weather not only change hour by hour but also day by day a set of measured weather data from Kumasi has been included. The weather data represent a clear day, an average day and an overcast day for two months - November 1999 and January 2000. These days may in combination with the data files containing average weather data be used to generate artificial weather data with a more dynamic behaviour.

One should, however, be very careful when choosing weather data as input for simulation purposes as several of the weather data may be very site specific.

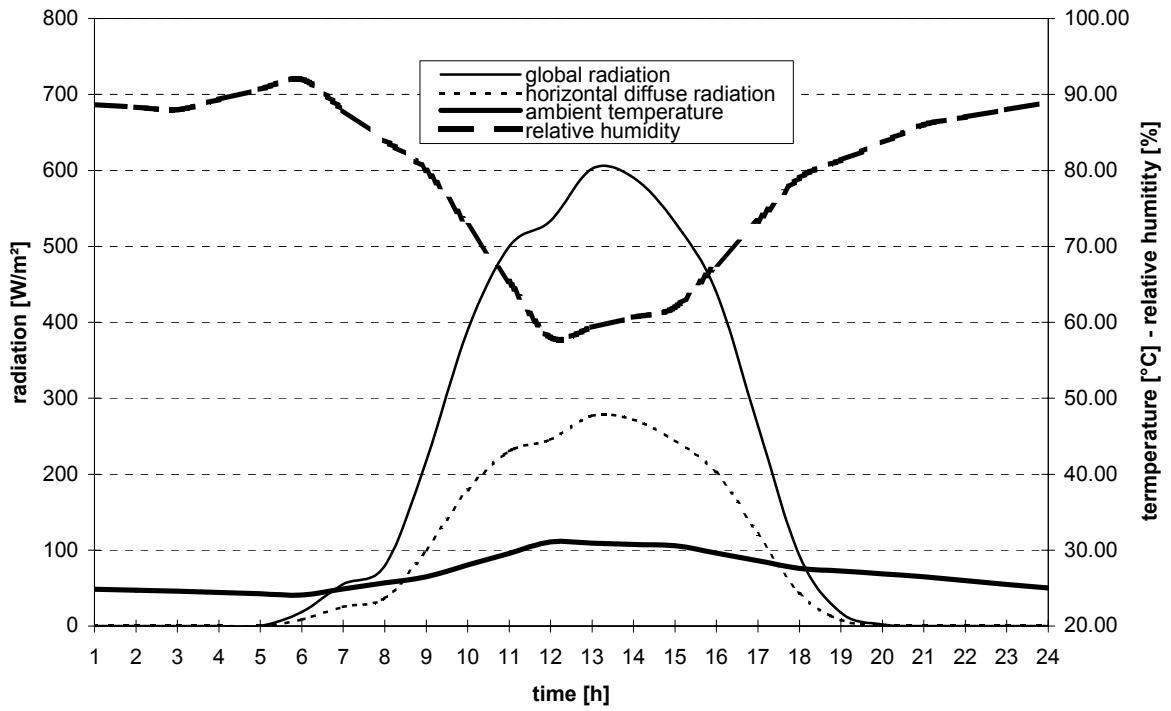
5. References

- Akuffo, F.O., 1991. Solar and Wind Energy Resources Assessment - Preliminary Data Analysis and Evaluation. Final report - Volume 2: Climate Data for Solar and Wind Energy Applications in Ghana. Solar Energy Laboratory, Department of Mechanical Engineering, University of Science and Technology, Kumasi, Ghana.
- Jensen et al, 2002. Test of solar dryers in Ghana, Solar Energy Centre Denmark. Danish Technological Institute. ISBN87-7756-658-0.

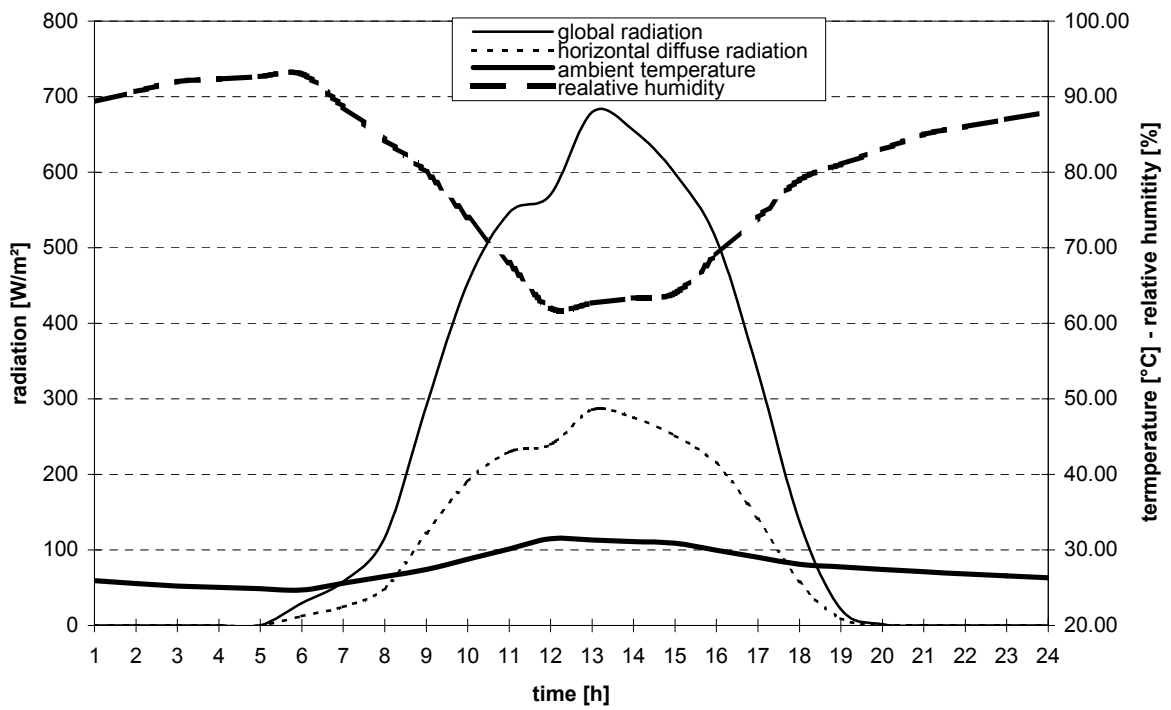
Appendix A

Weather data for Accra

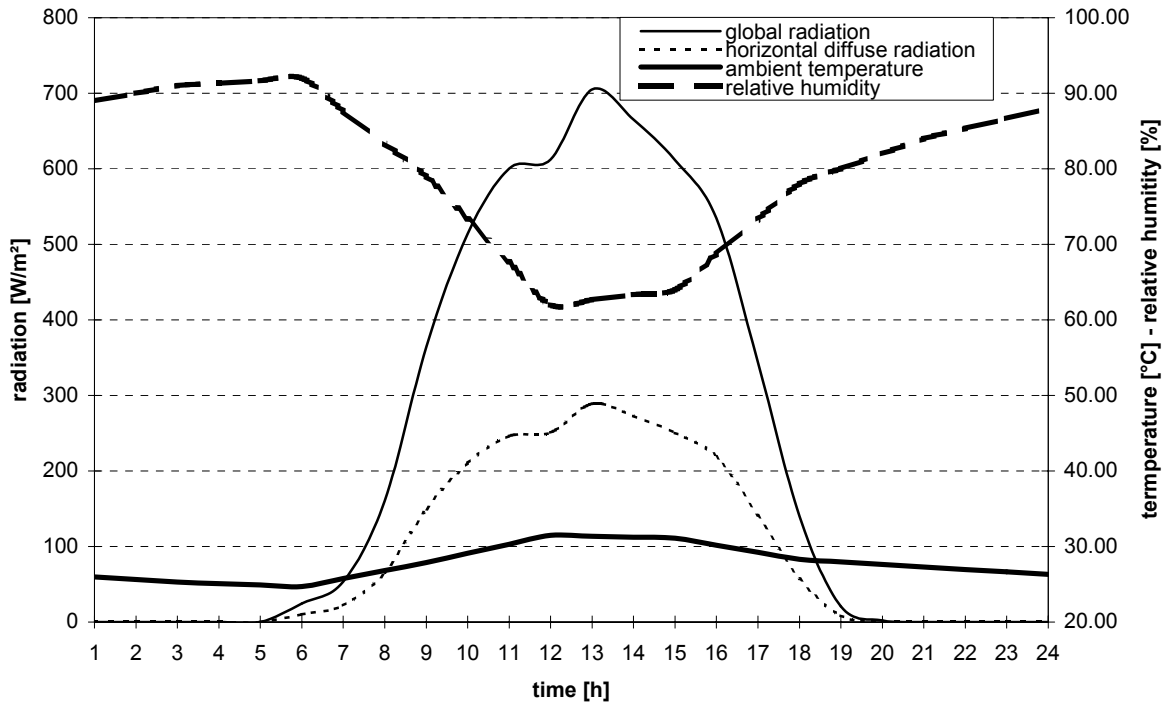
Accra - January



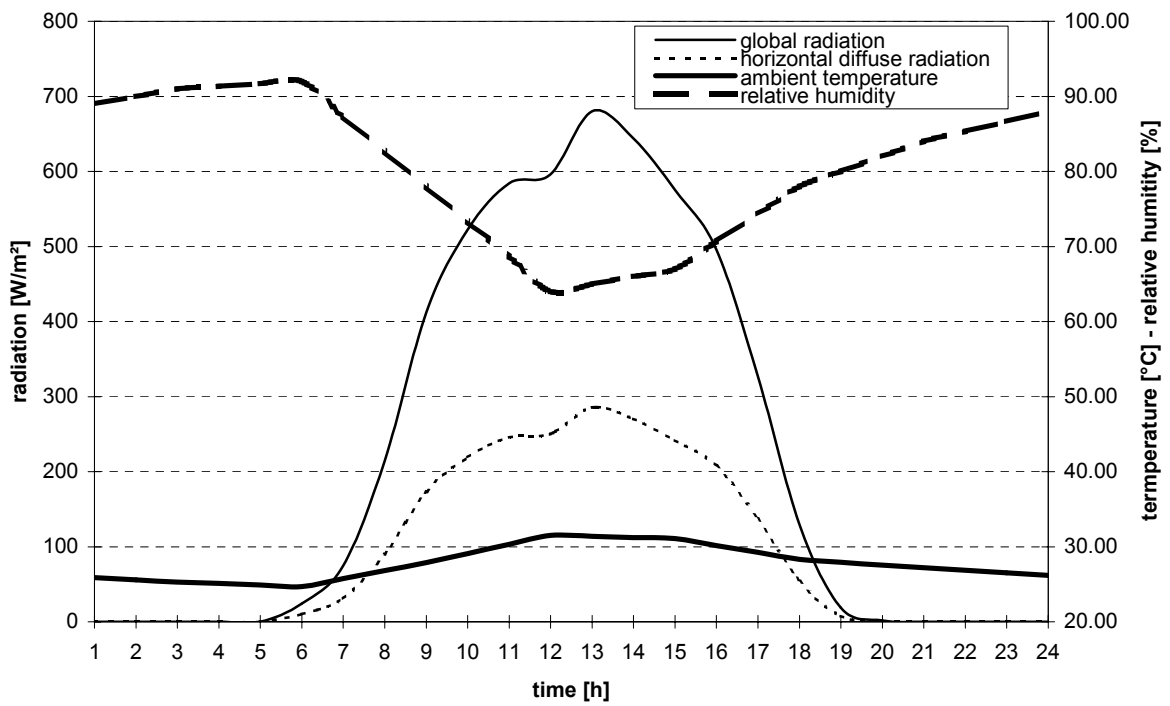
Accra - February



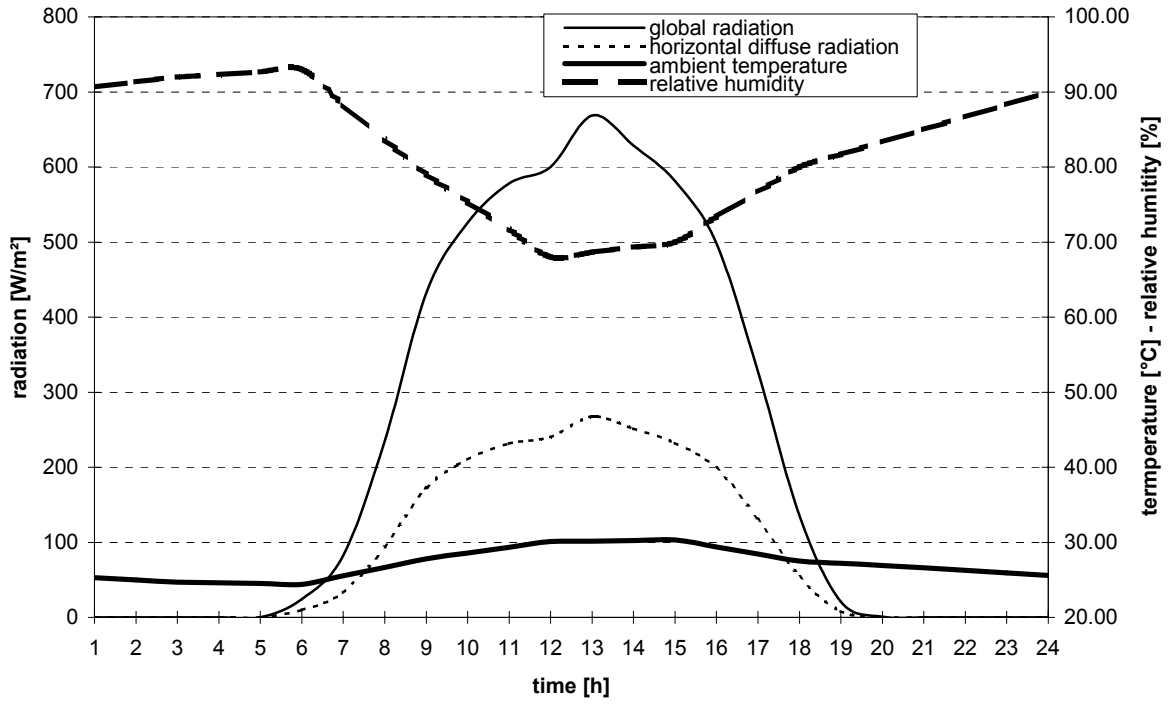
Accra - Marts



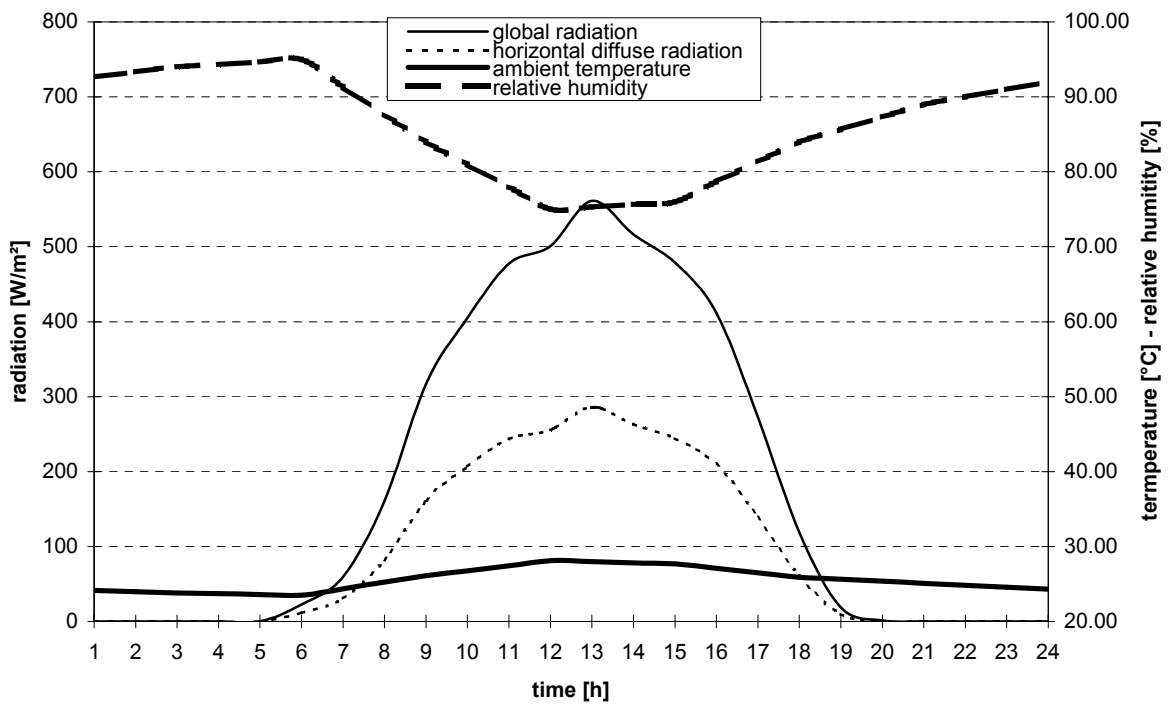
Accra - April



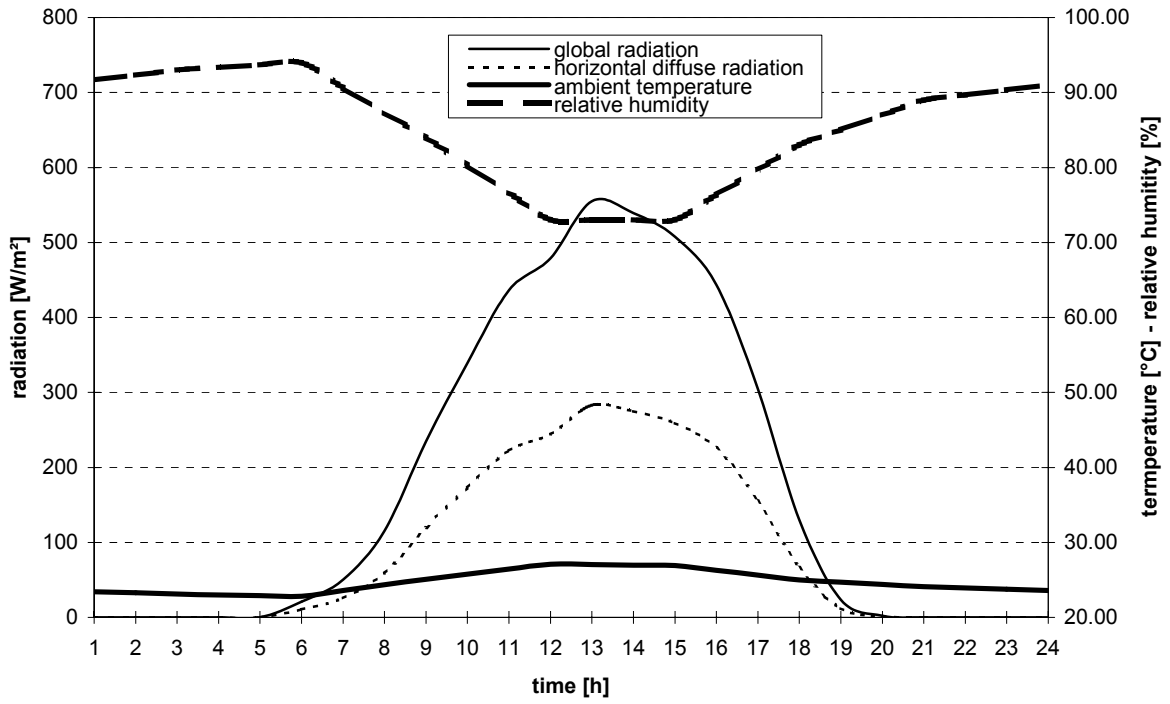
Accra - May



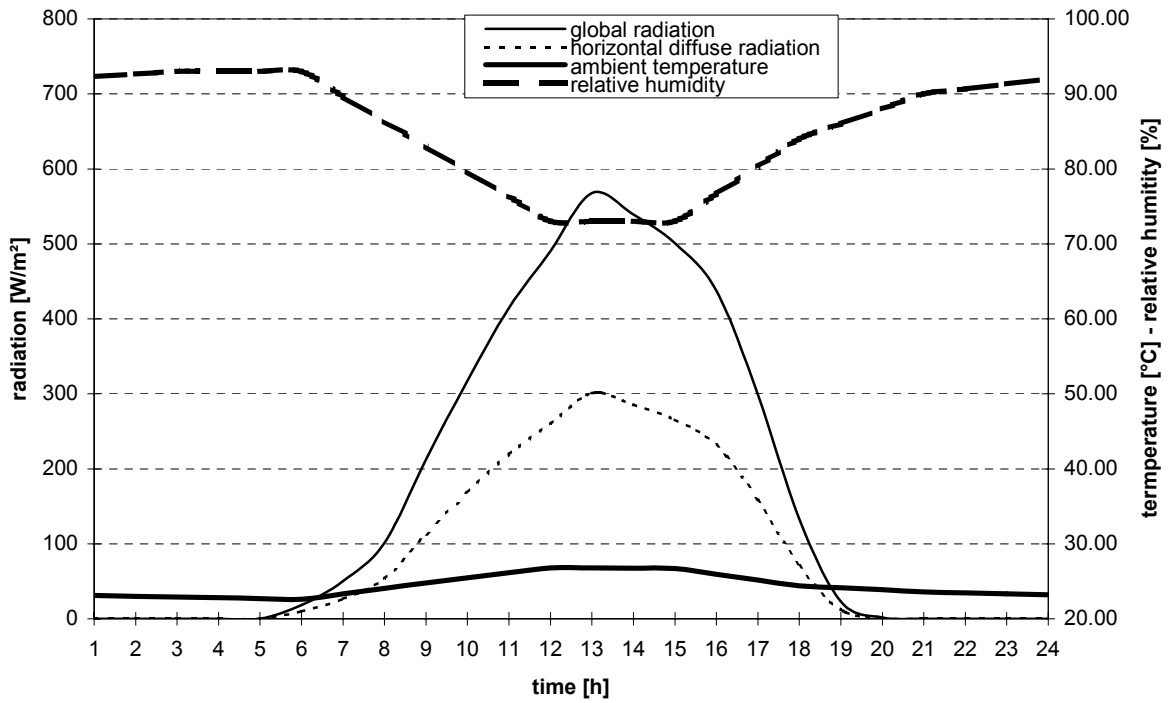
Accra - June



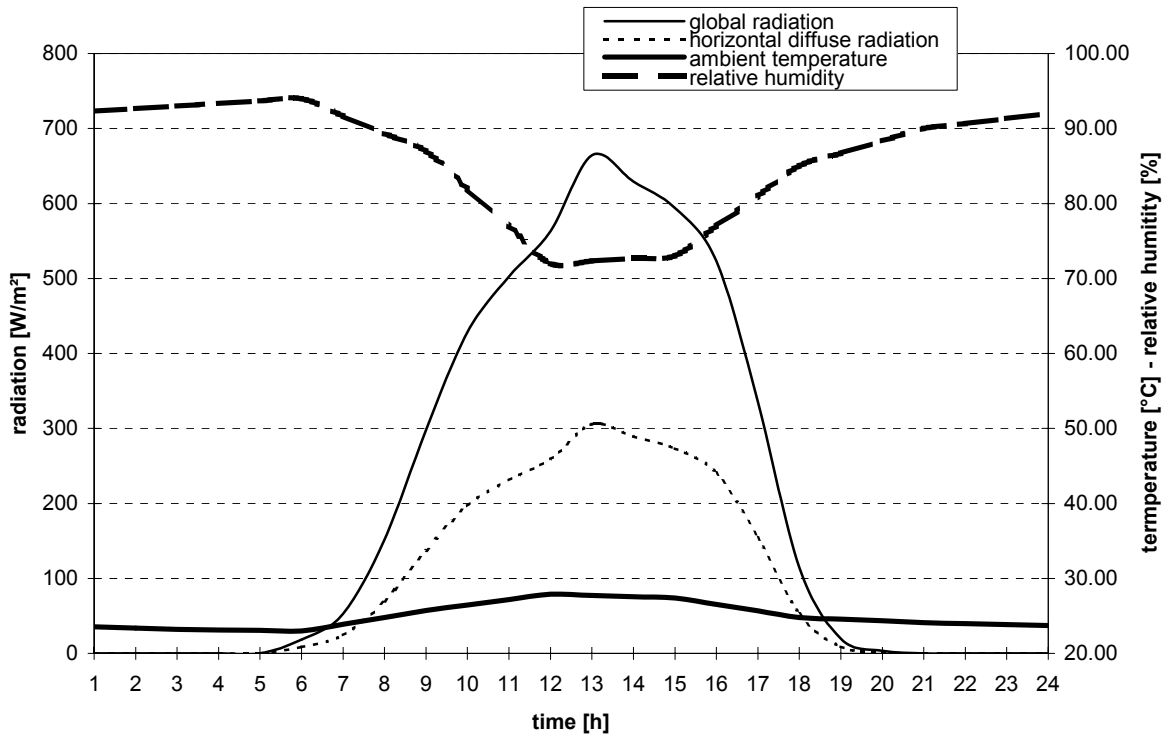
Accra - July



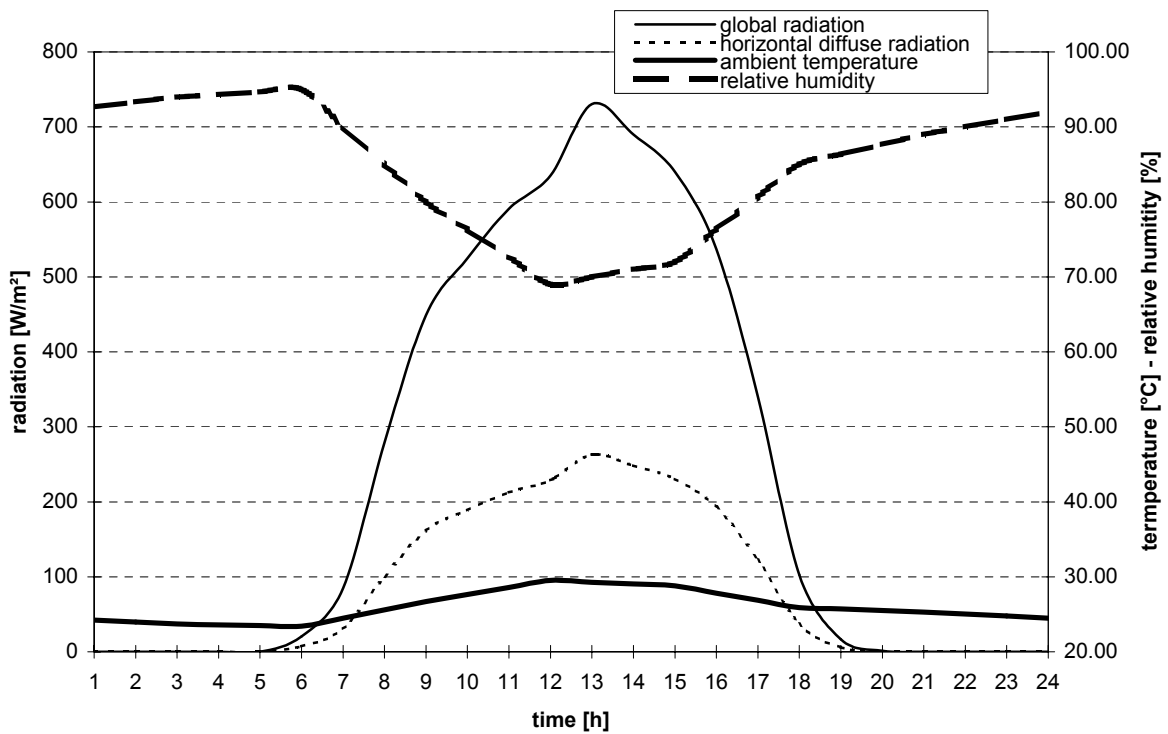
Accra - August



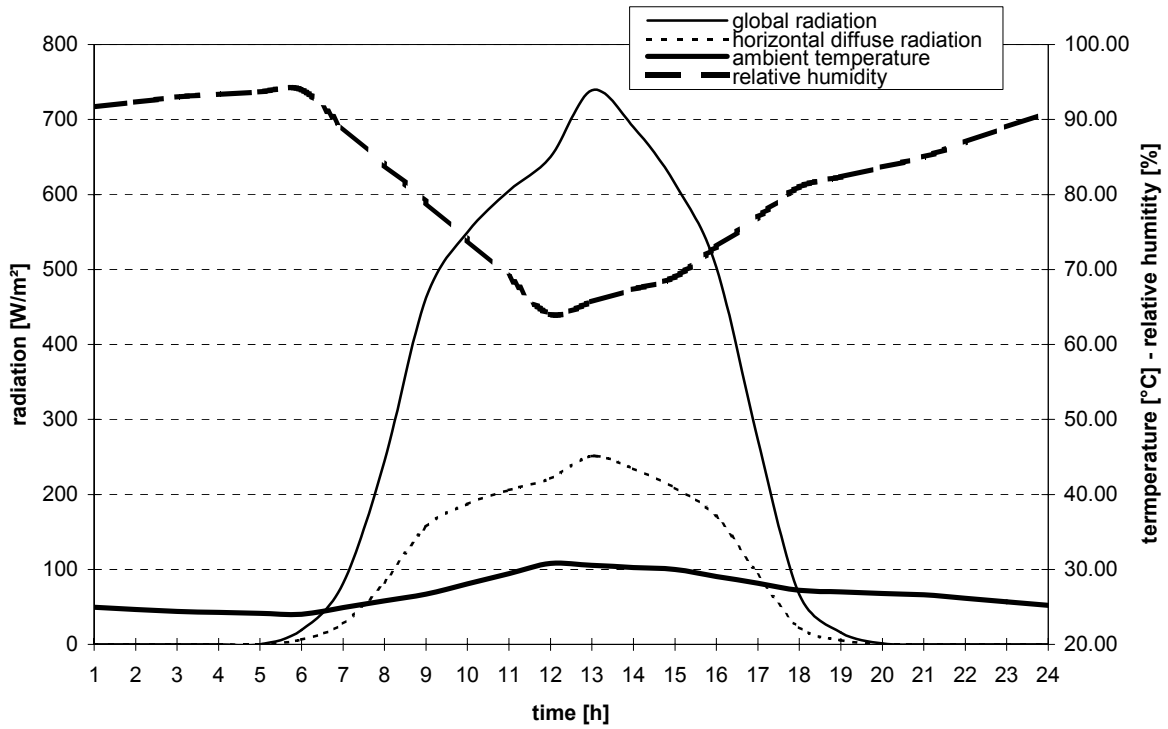
Accra - September



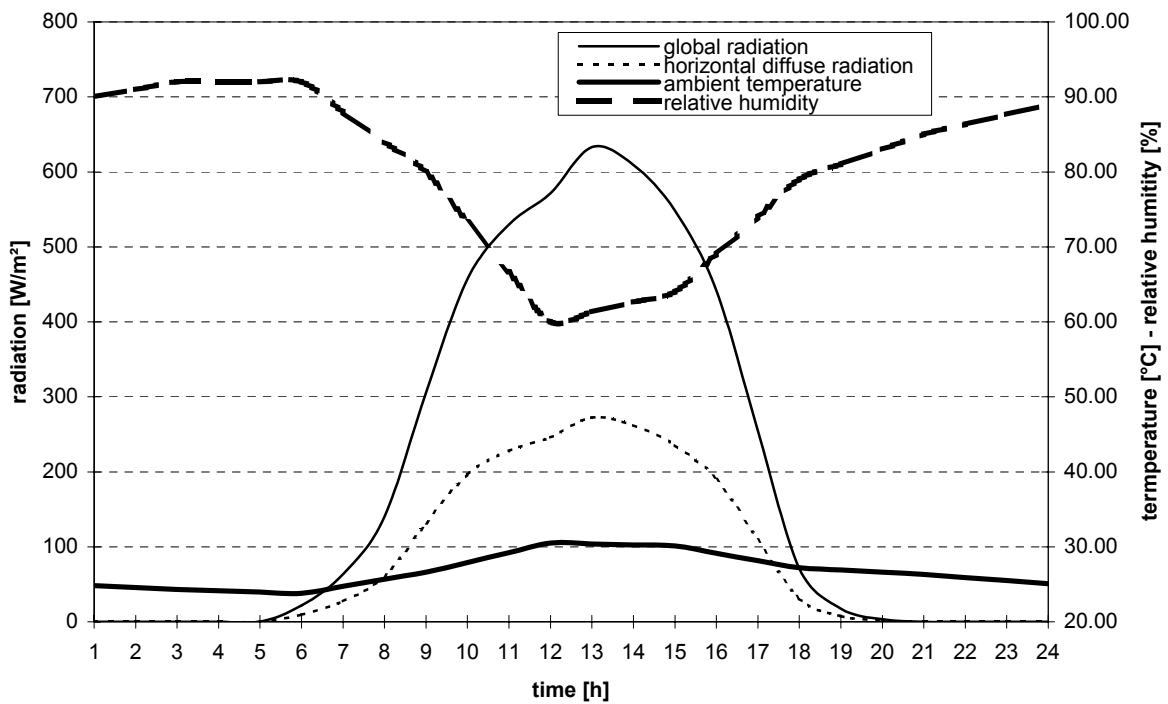
Accra - October



Accra - November



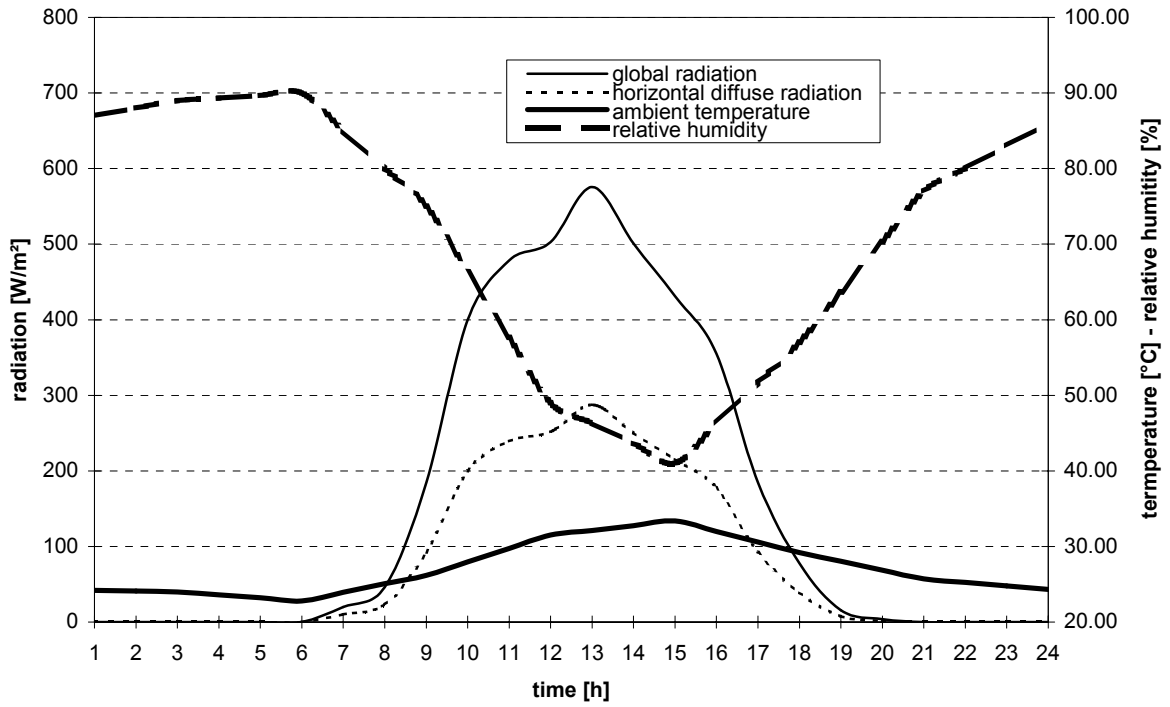
Accra - December



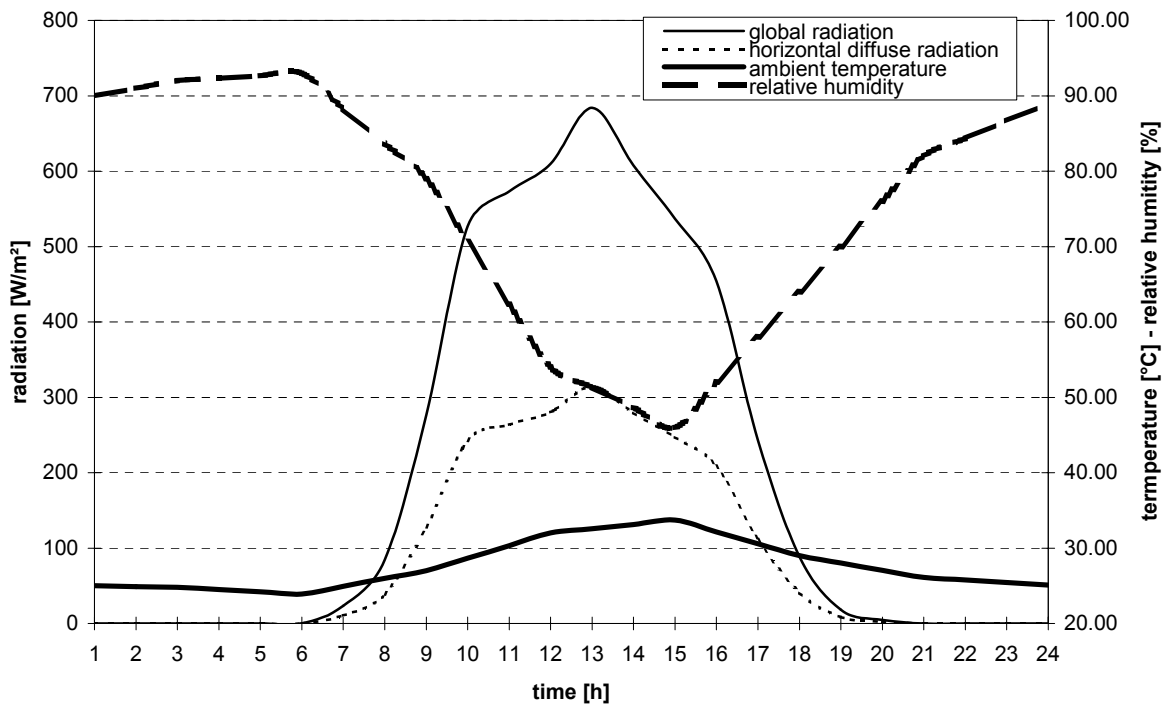
Appendix B

Weather data for Ho

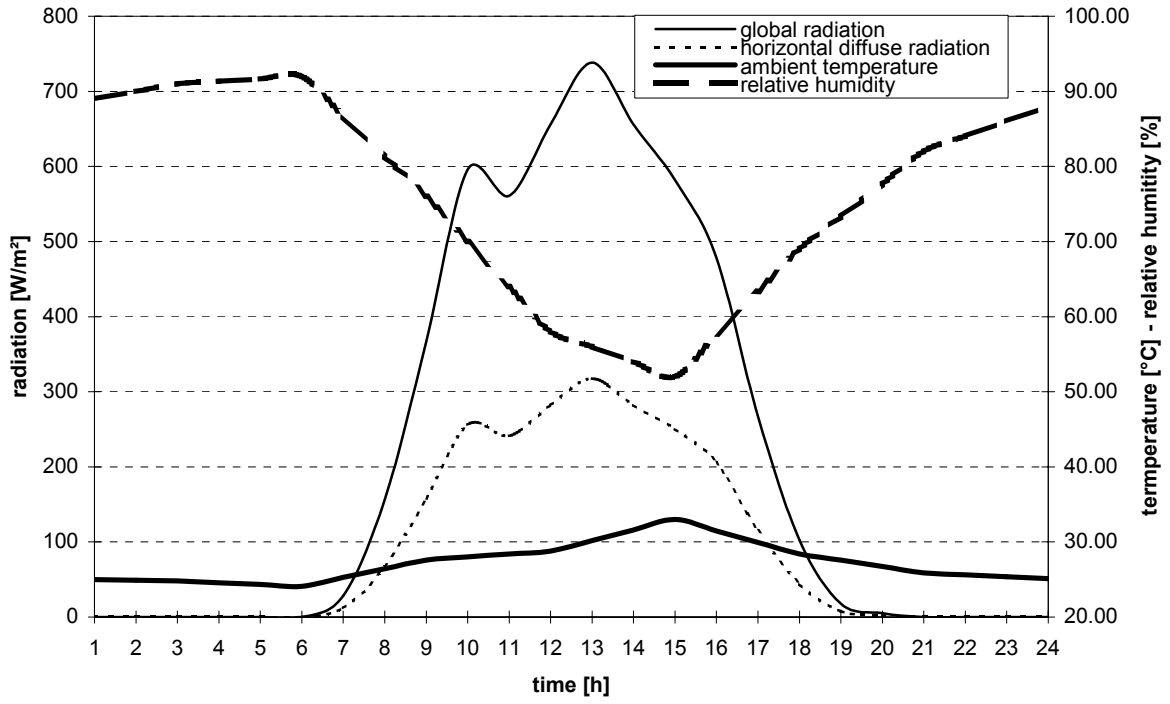
Ho - January



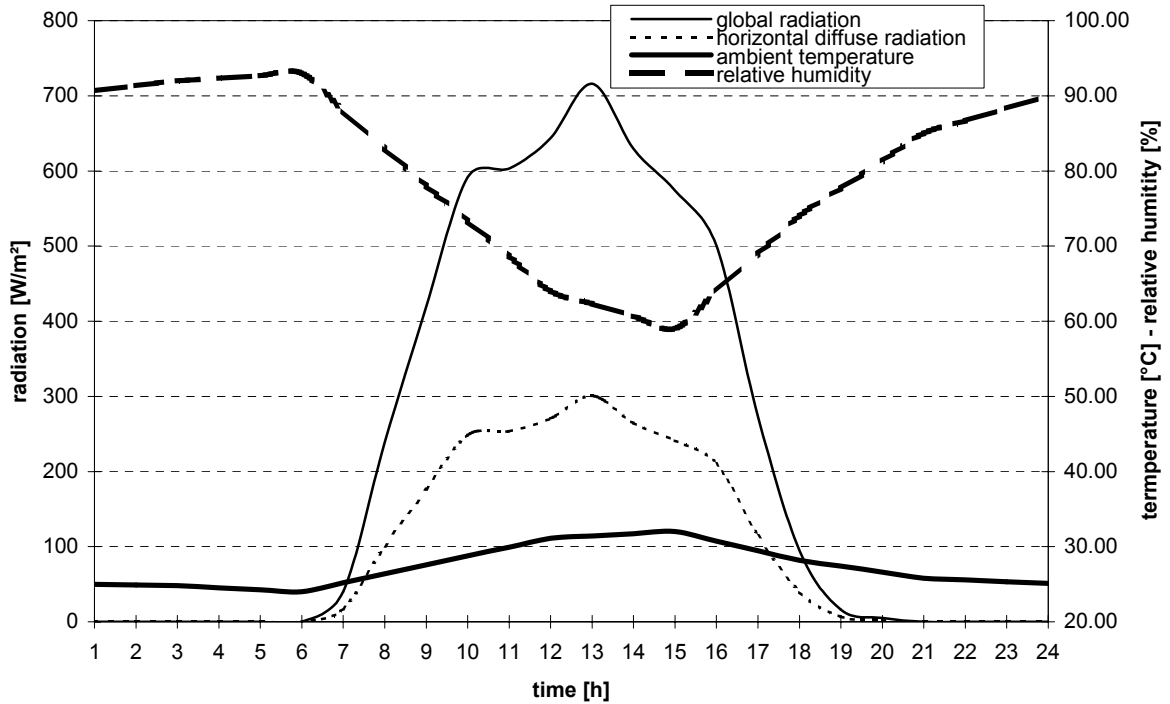
Ho - February



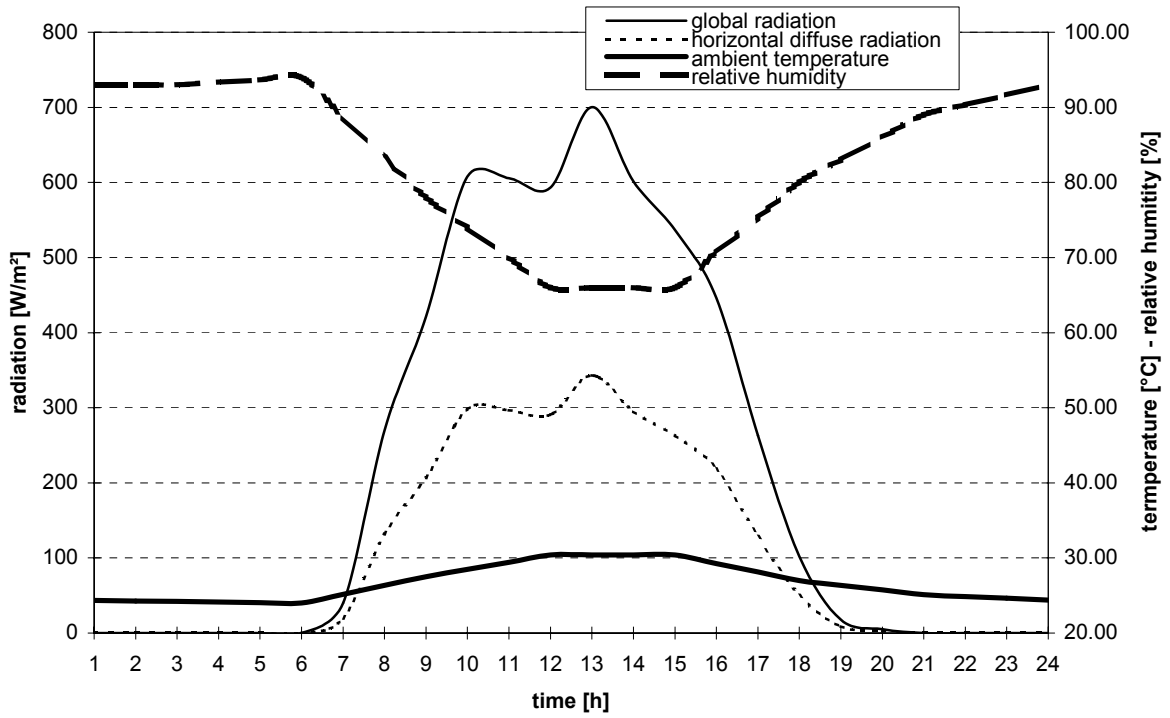
Ho - March



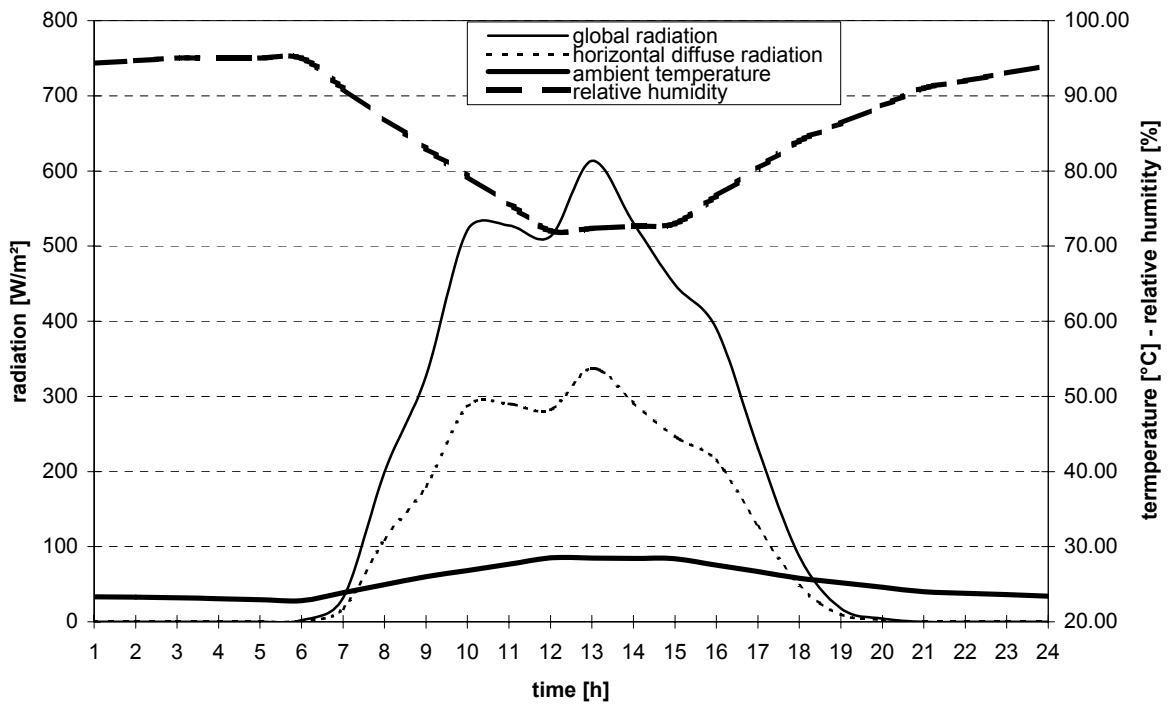
Ho - April



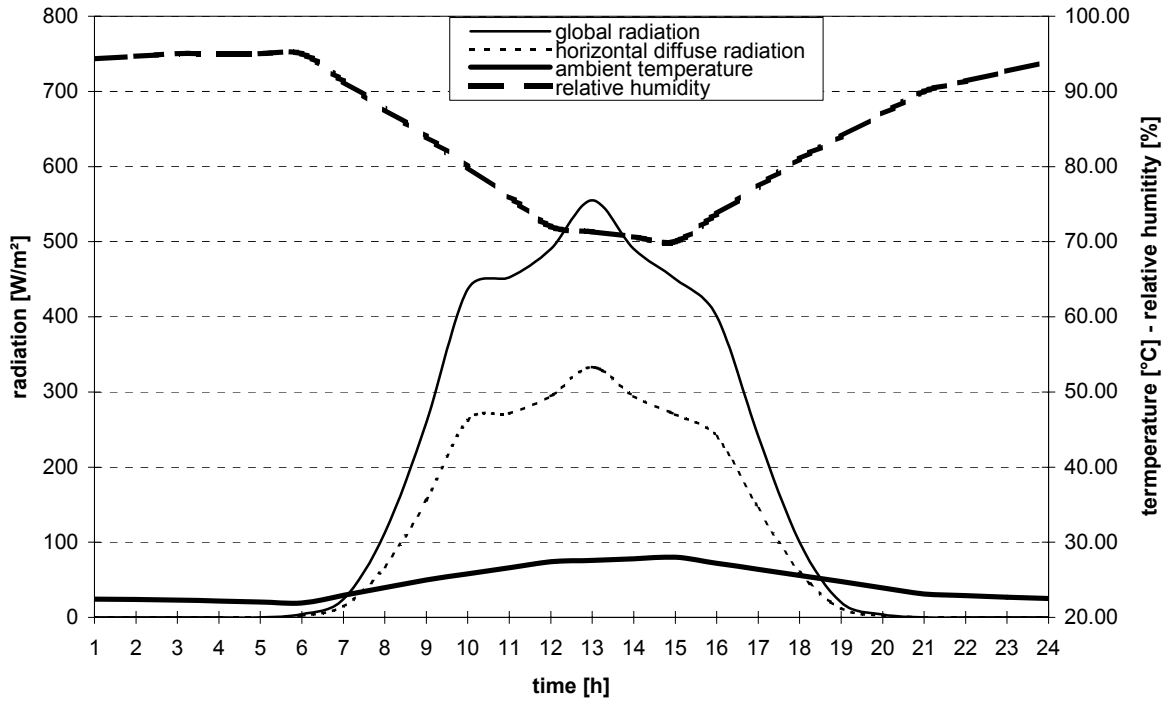
Ho - May



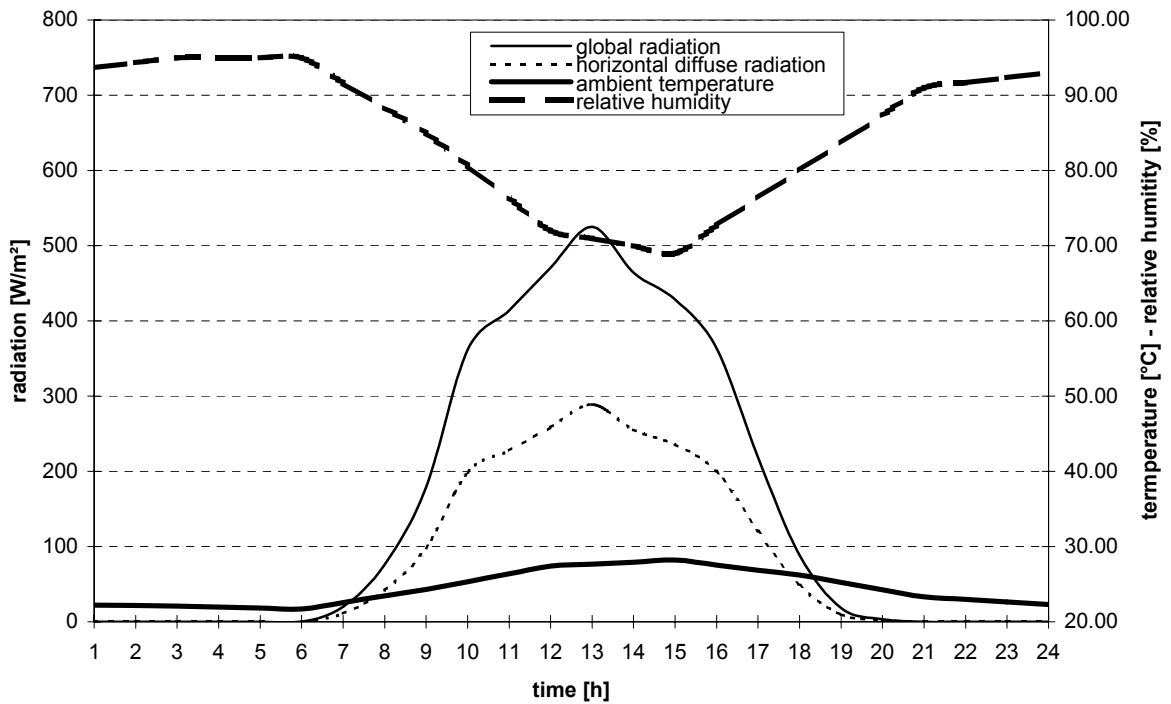
Ho - June



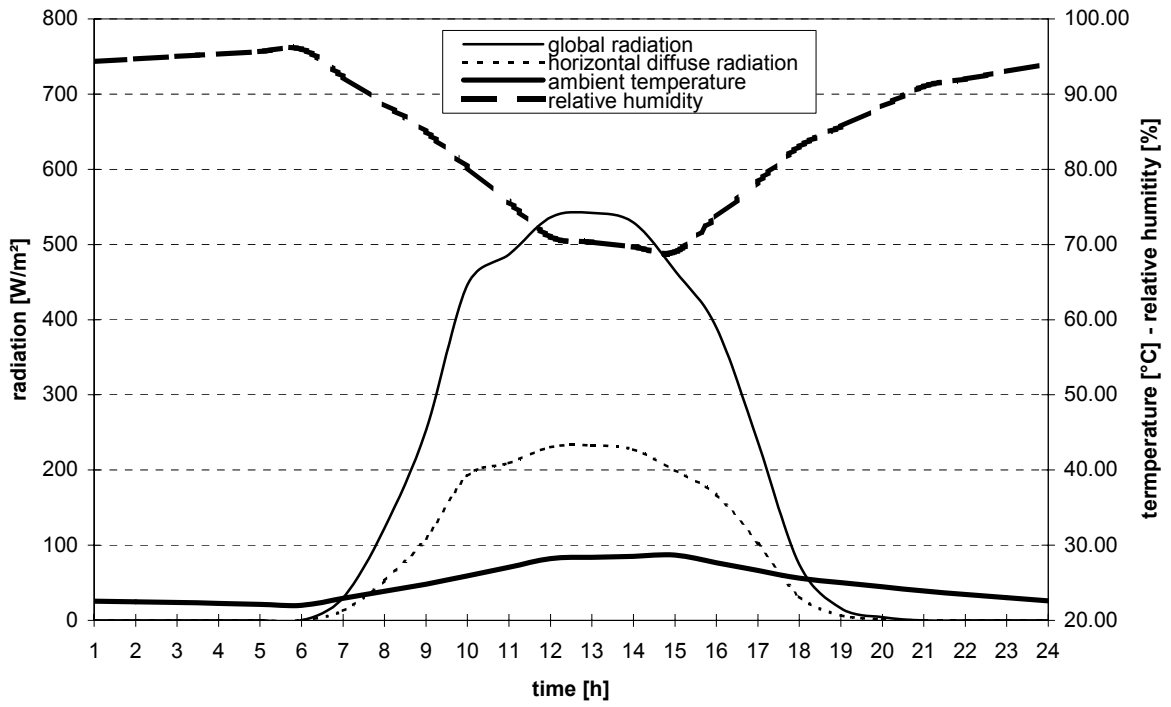
Ho - July



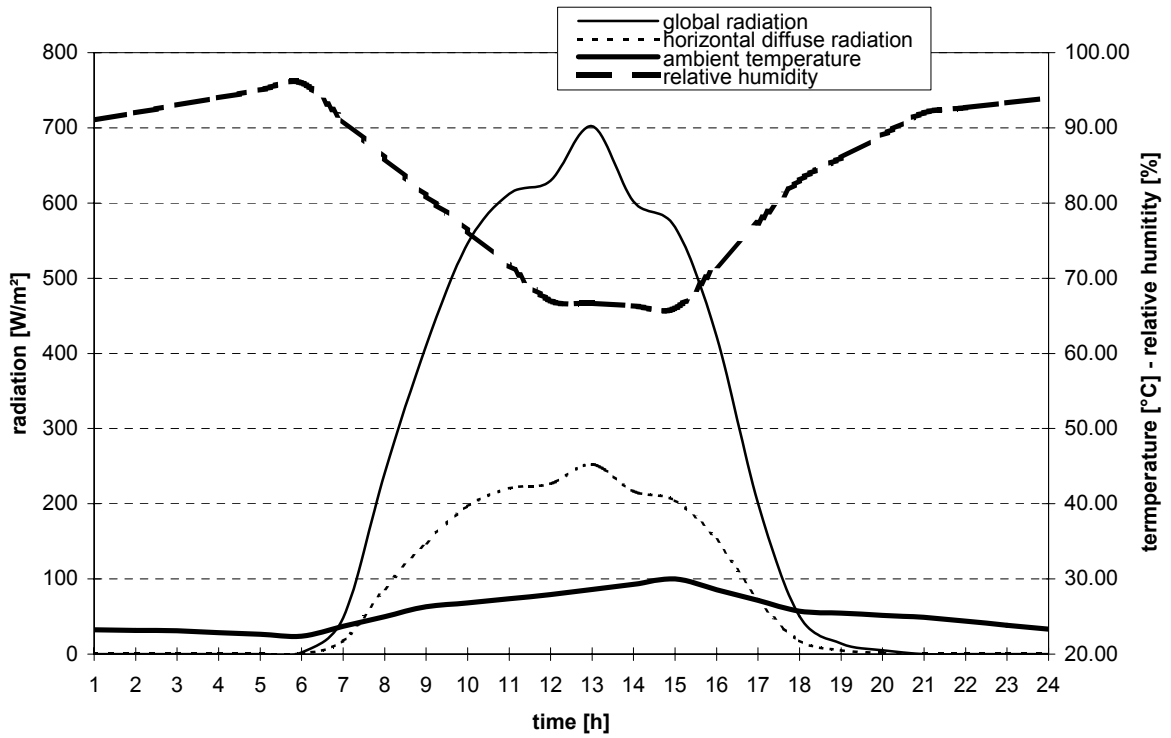
Ho - August



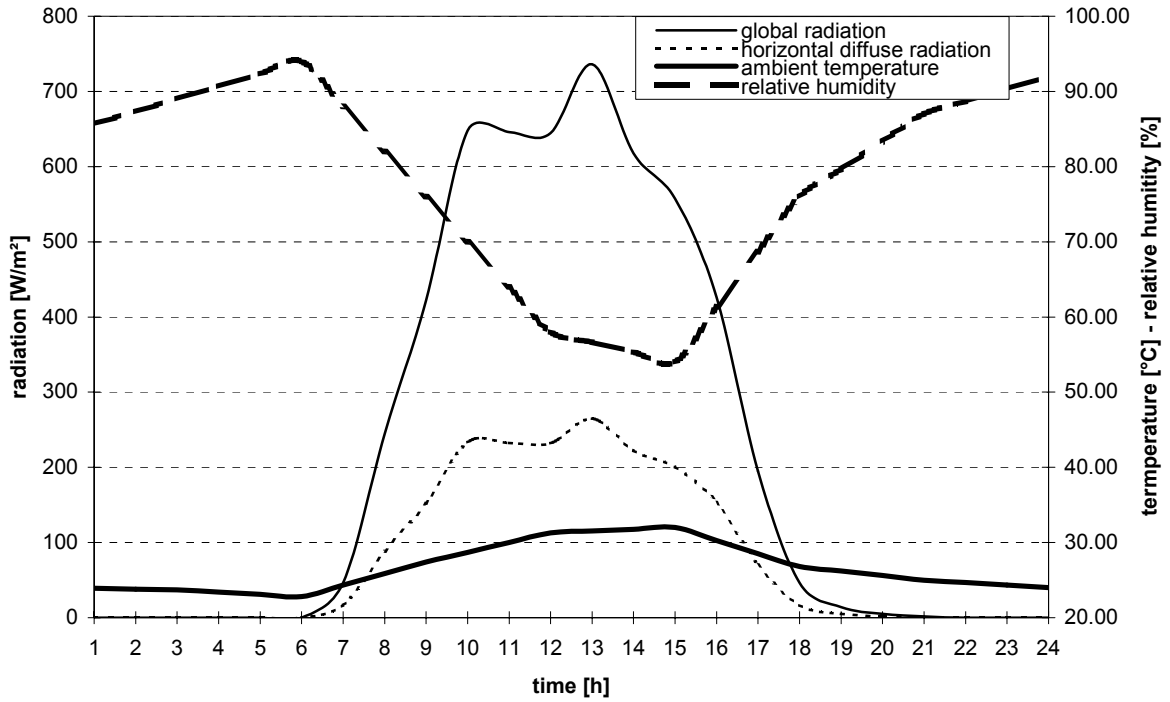
Ho - September



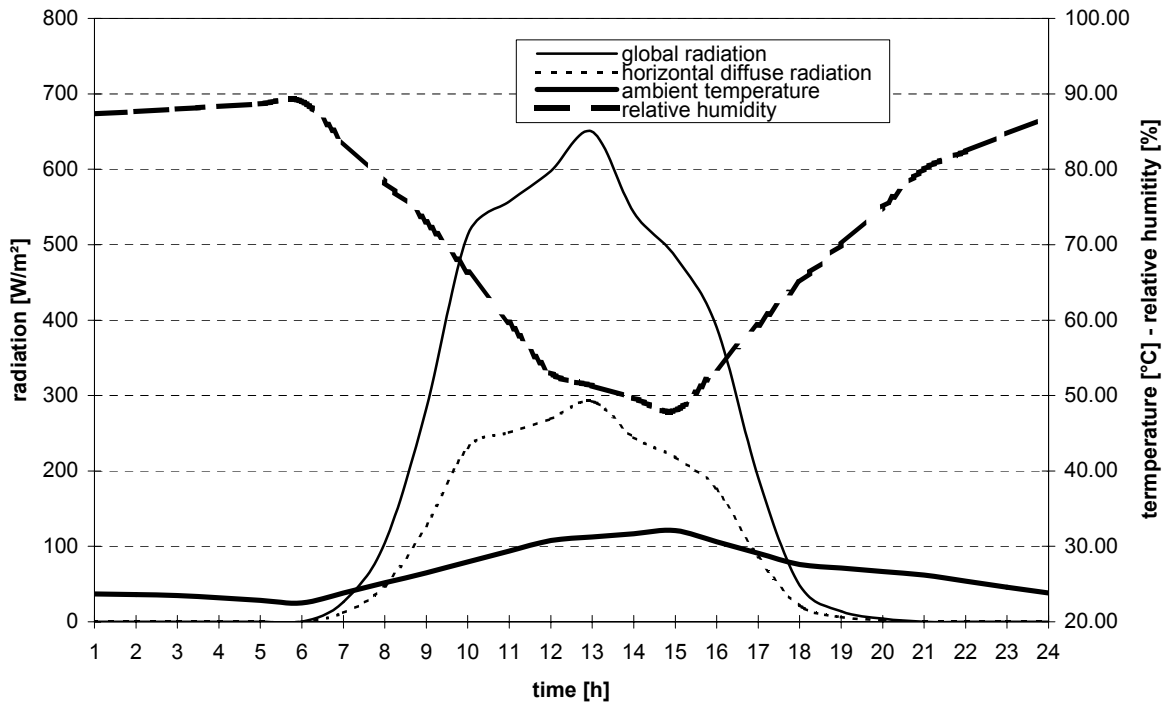
Ho - October



Ho - November



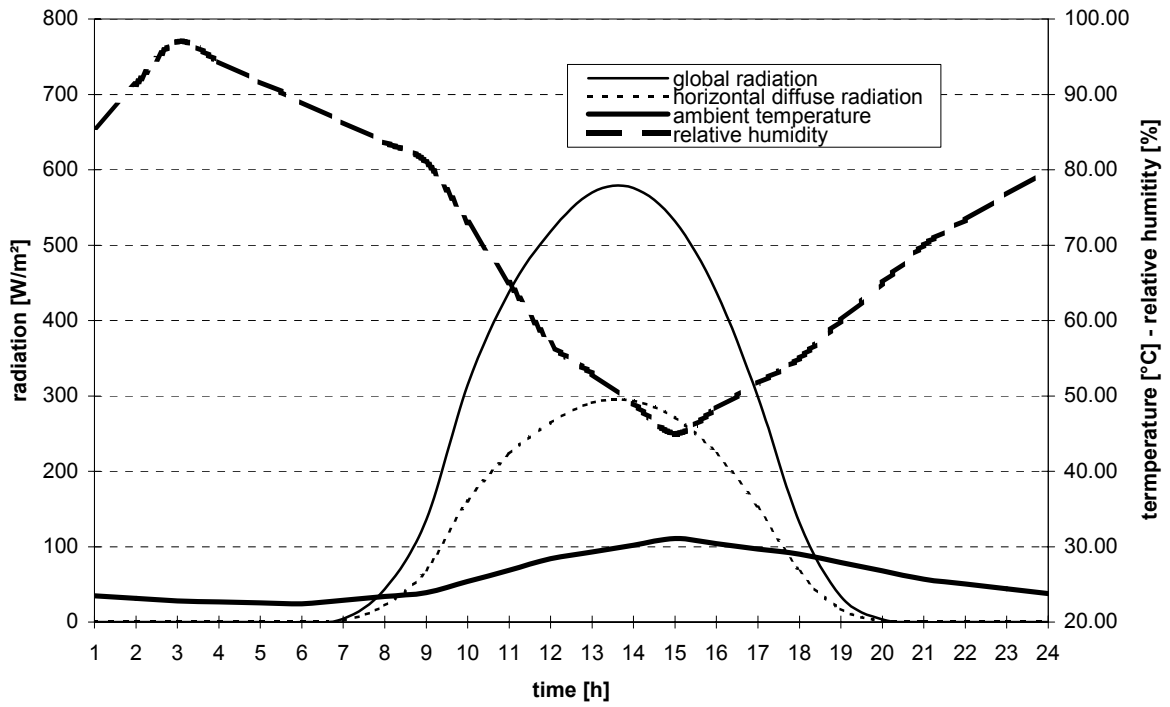
Ho - December



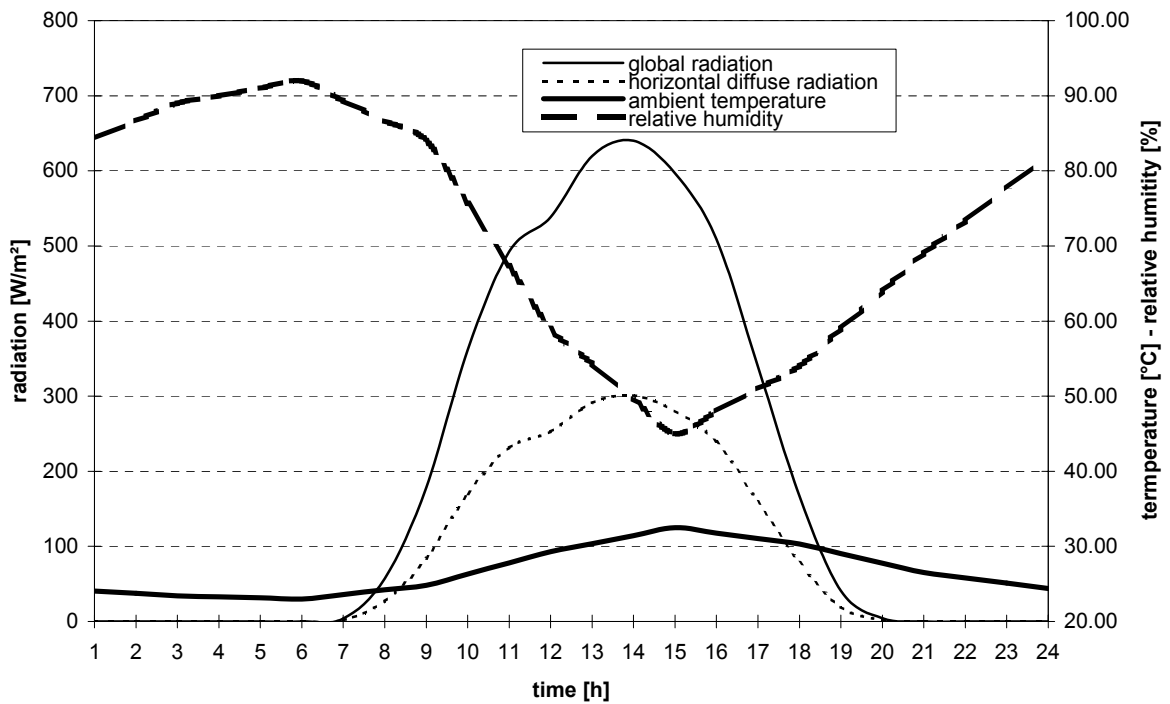
Appendix C

Weather data for Kumasi

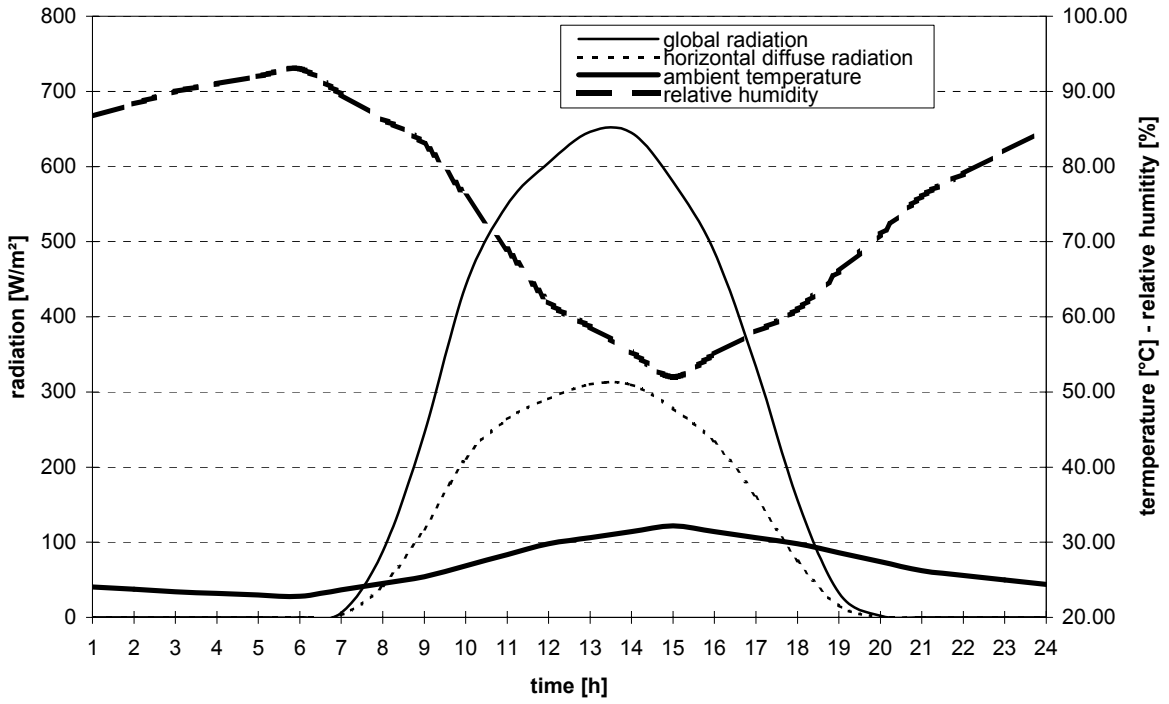
Kumasi - January



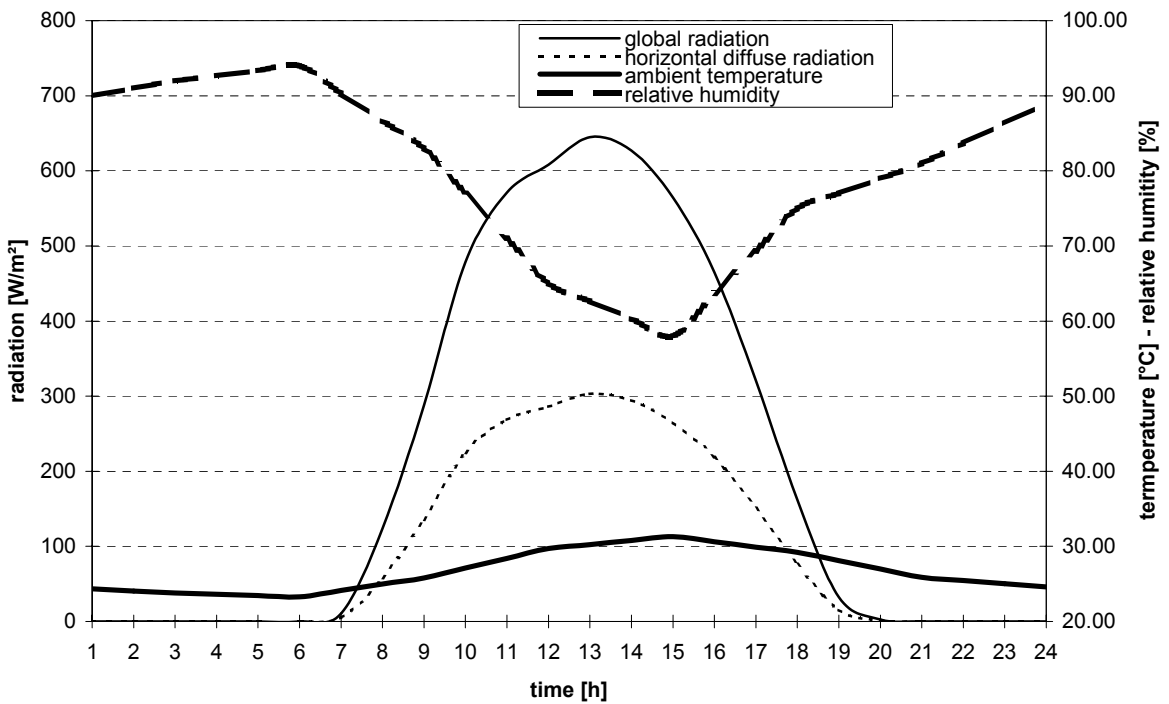
Kumasi - Febuary



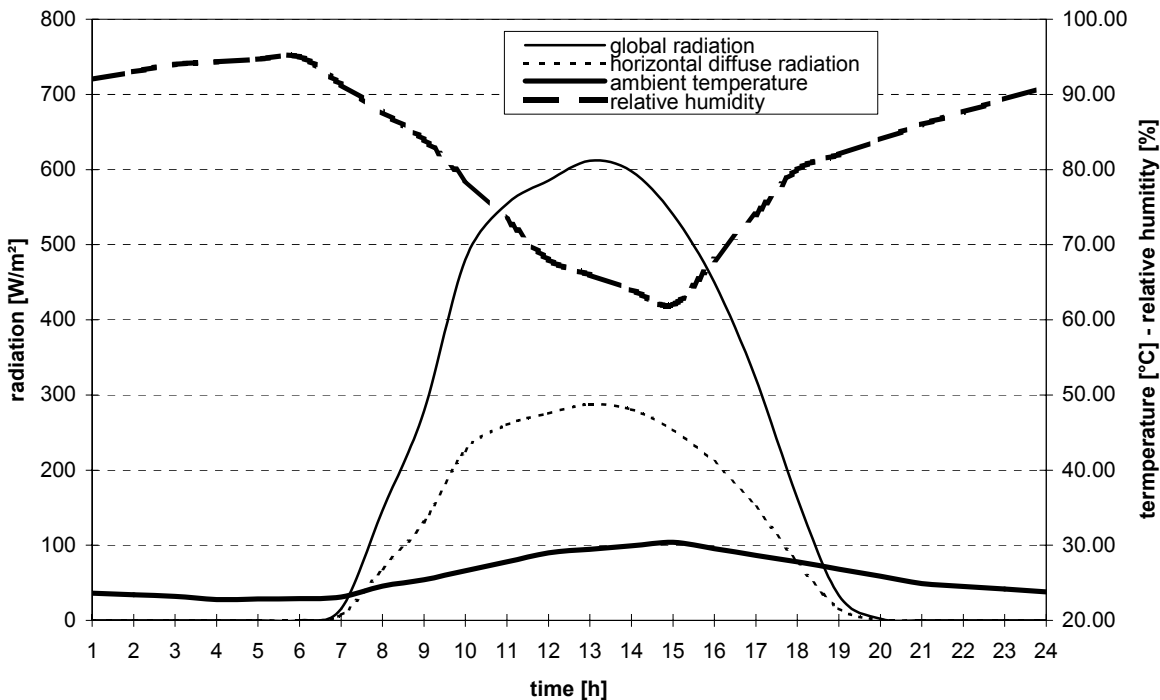
Kumasi - March



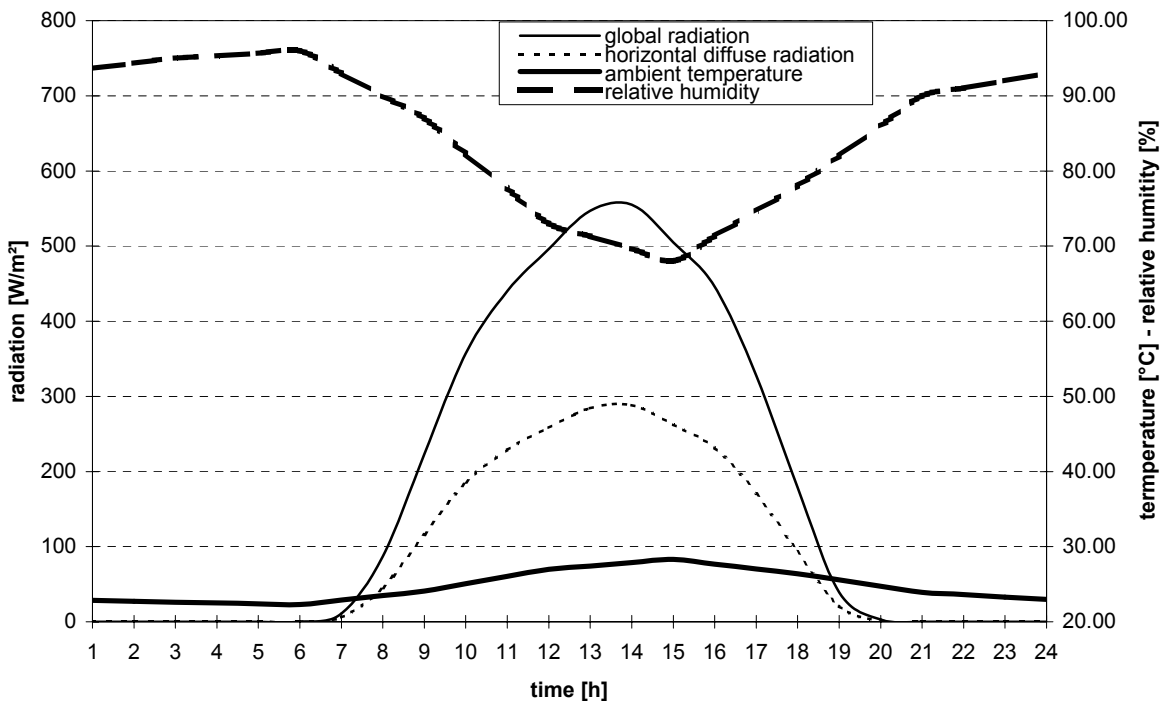
Kumasi - April



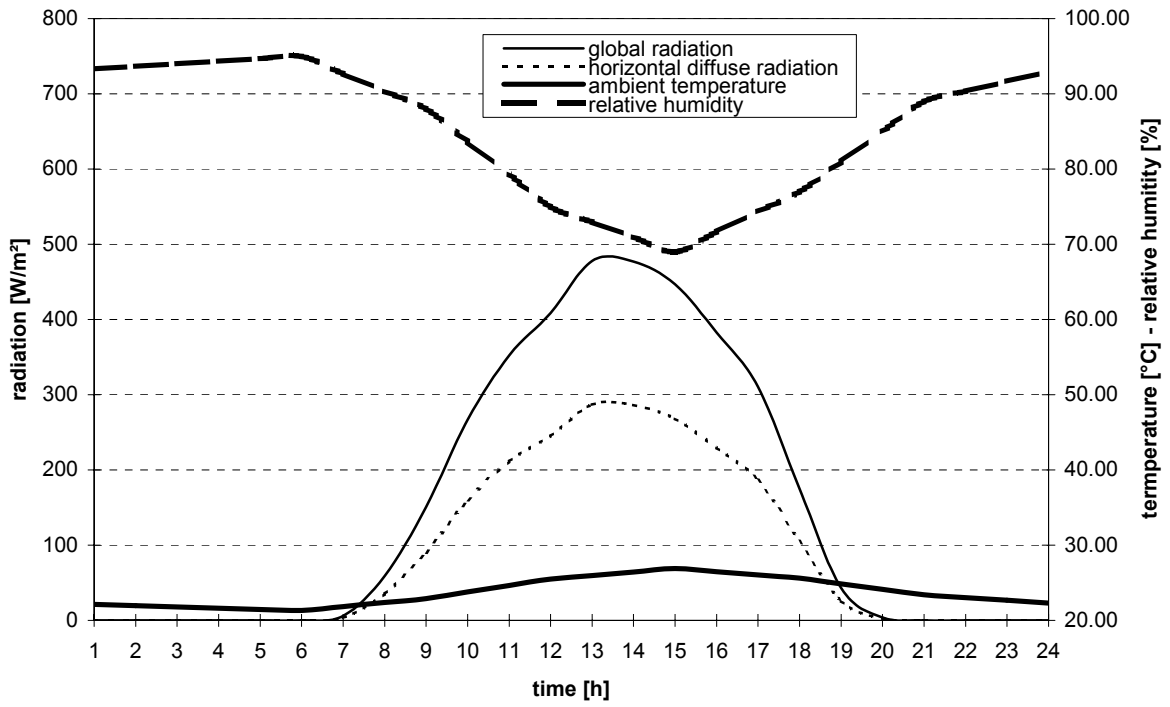
Kumasi - May



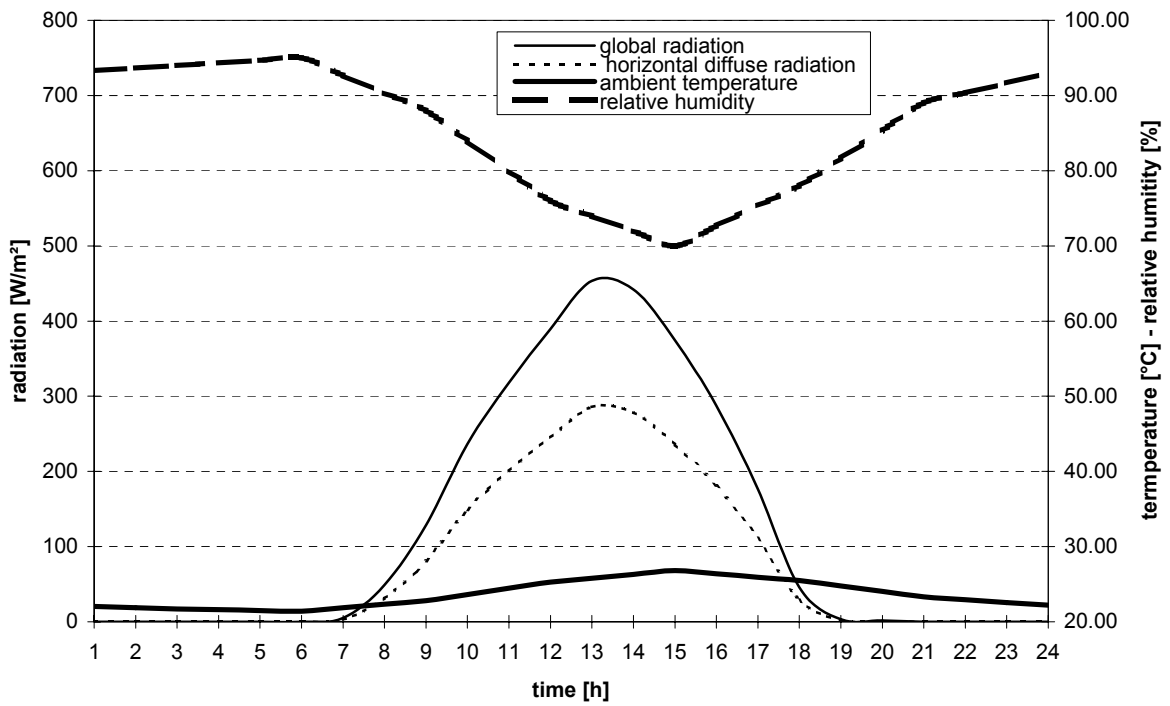
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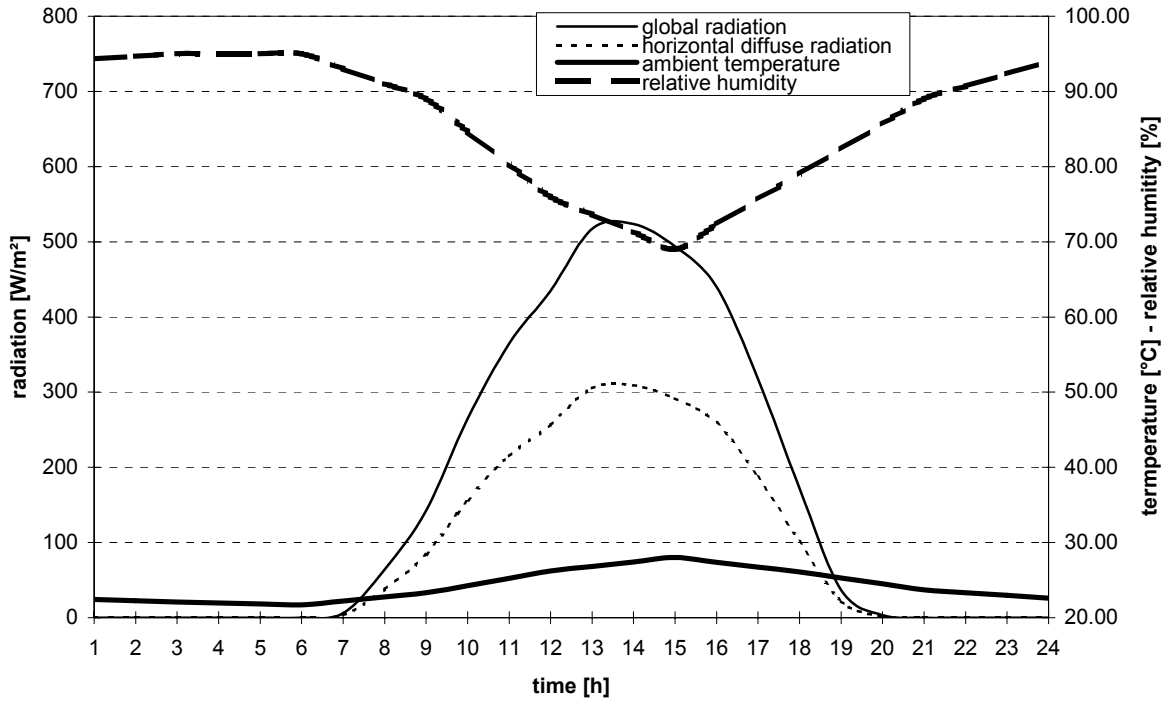
Kumasi - July



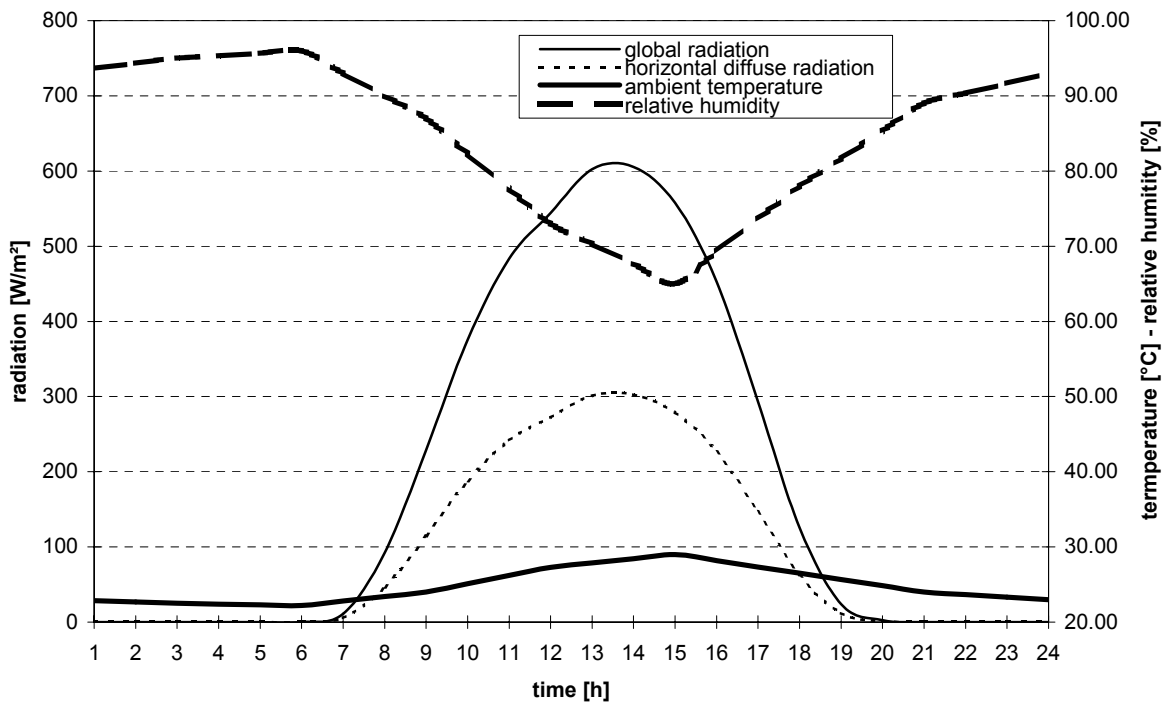
Kumasi - August



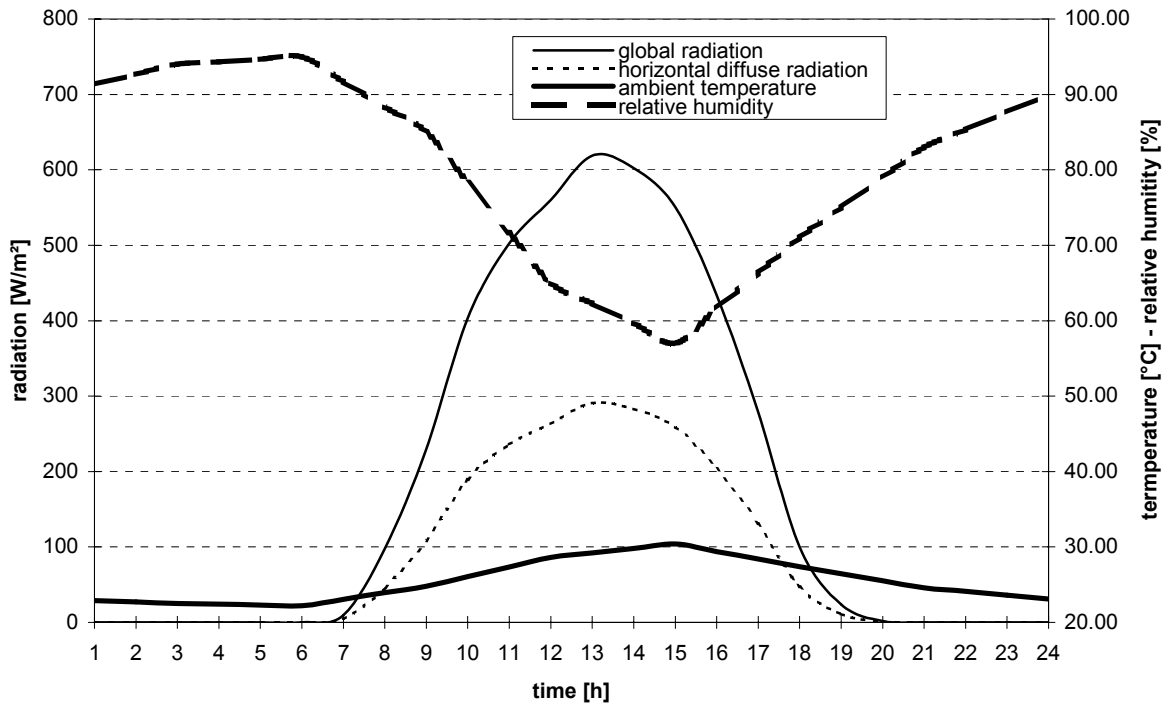
Kumasi - September



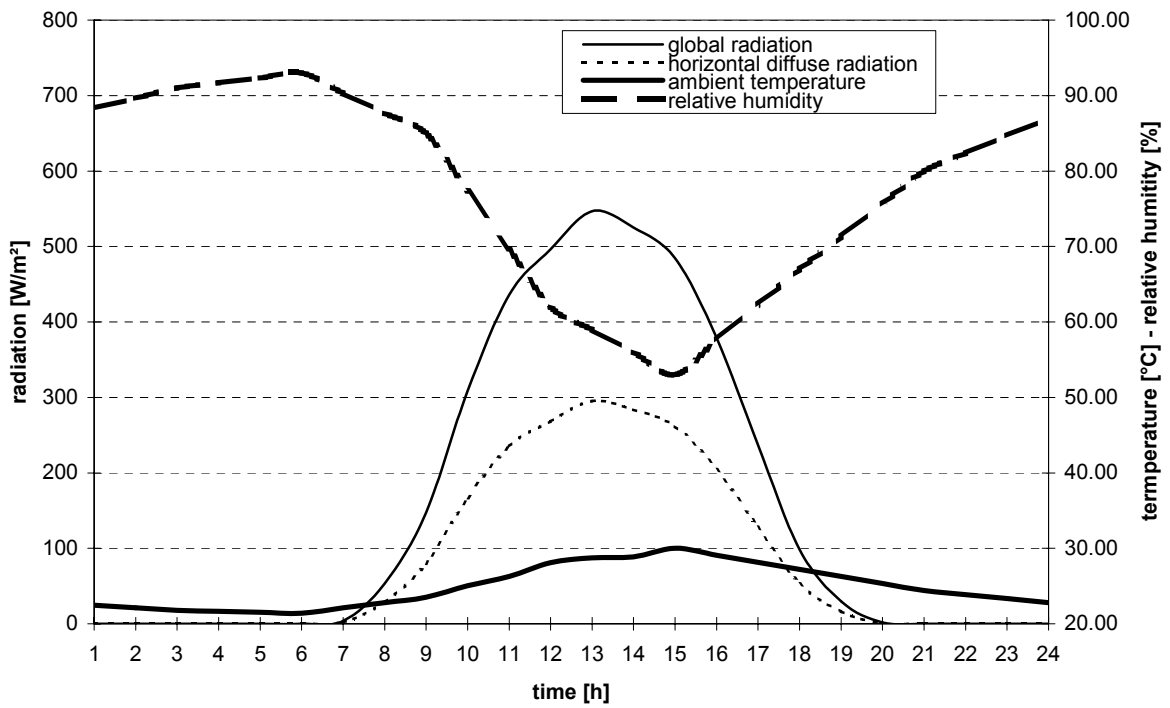
Kumasi - October



Kumasi - November



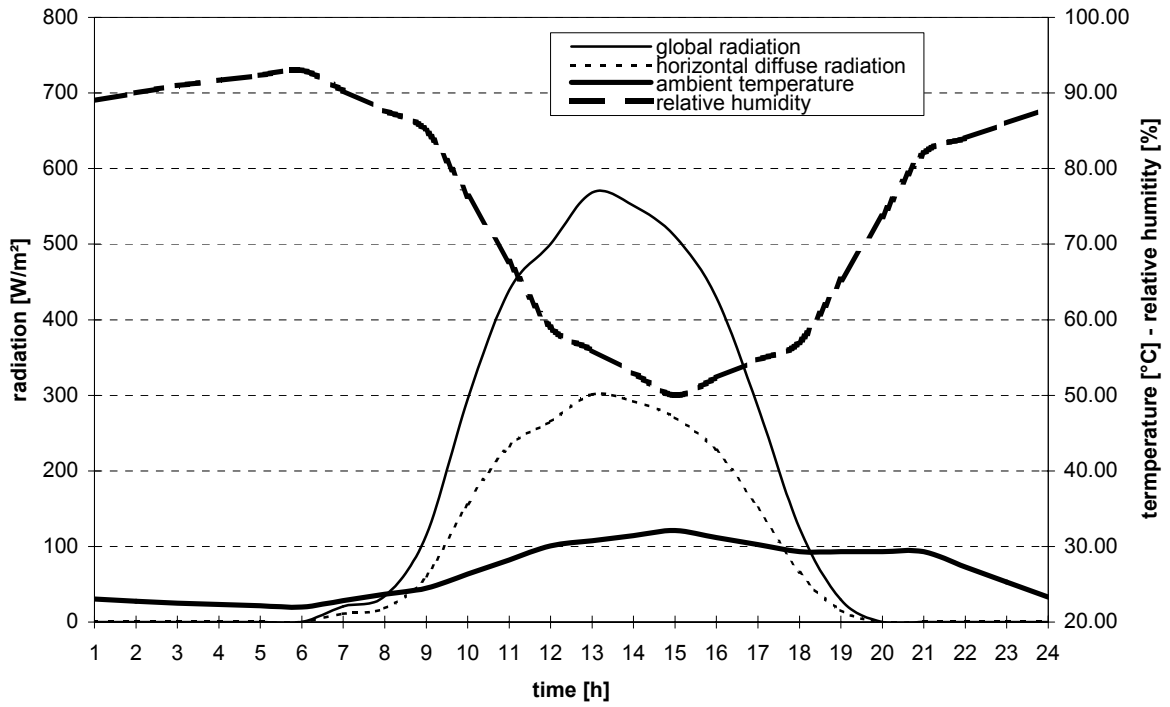
Kumasi - December



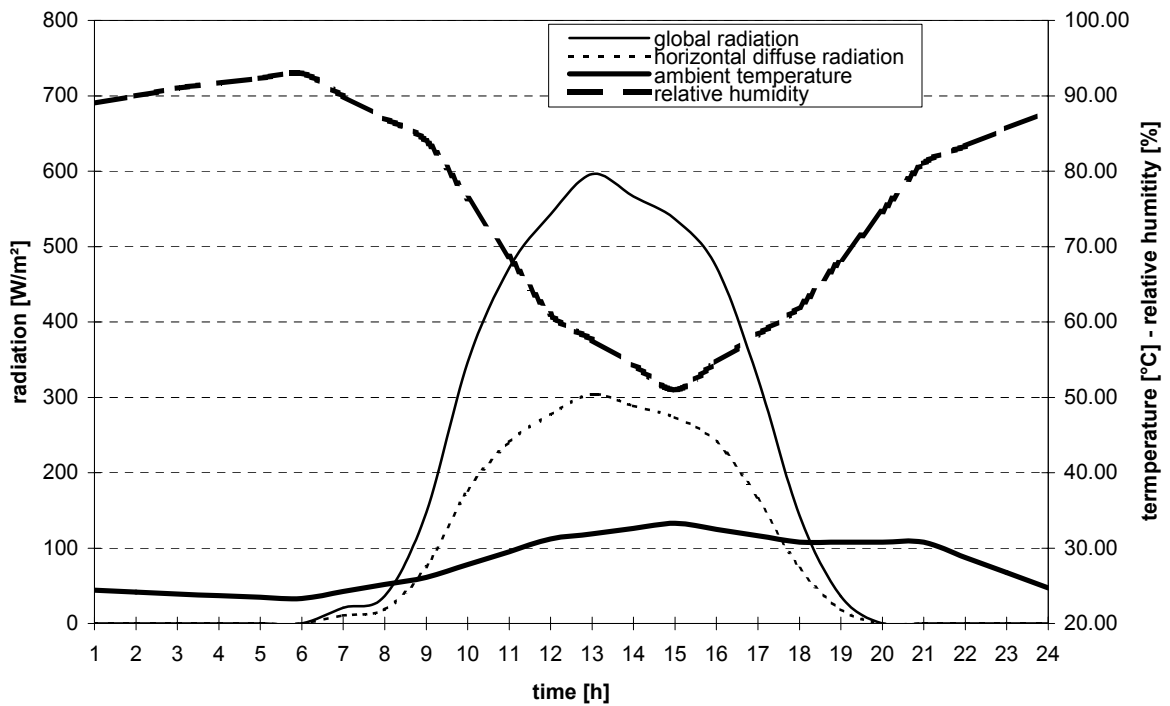
Appendix D

Weather data for Sefwi- Bekwai

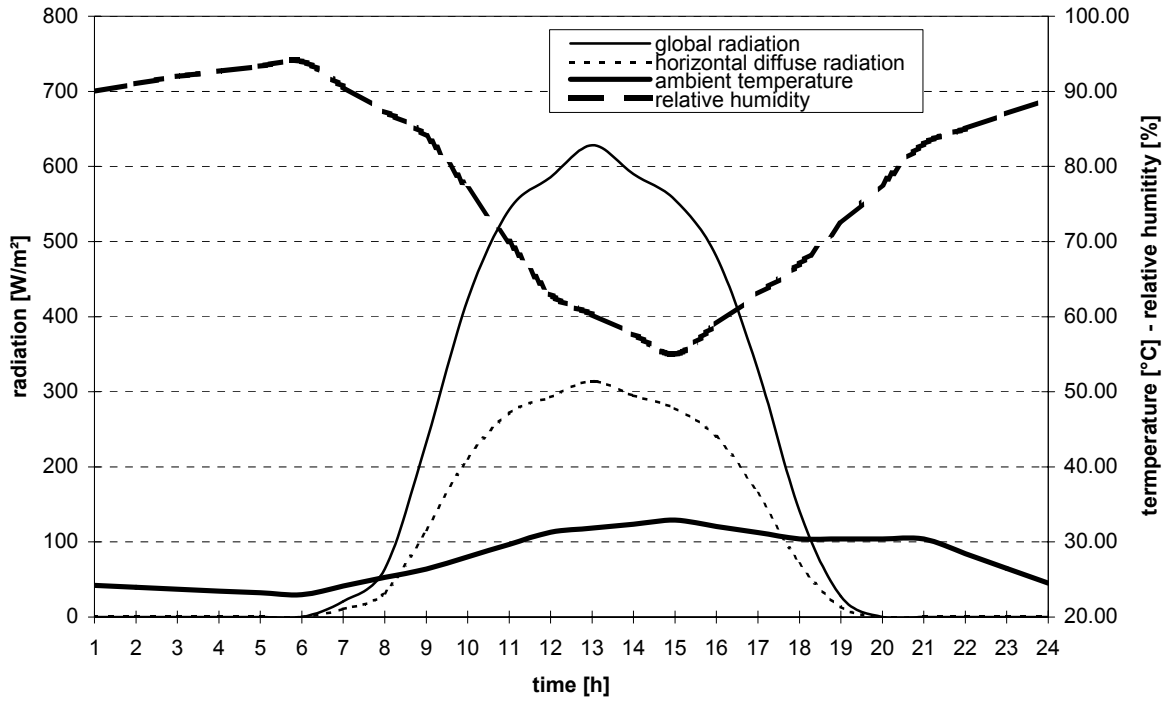
Sefwi-Bekwai - January



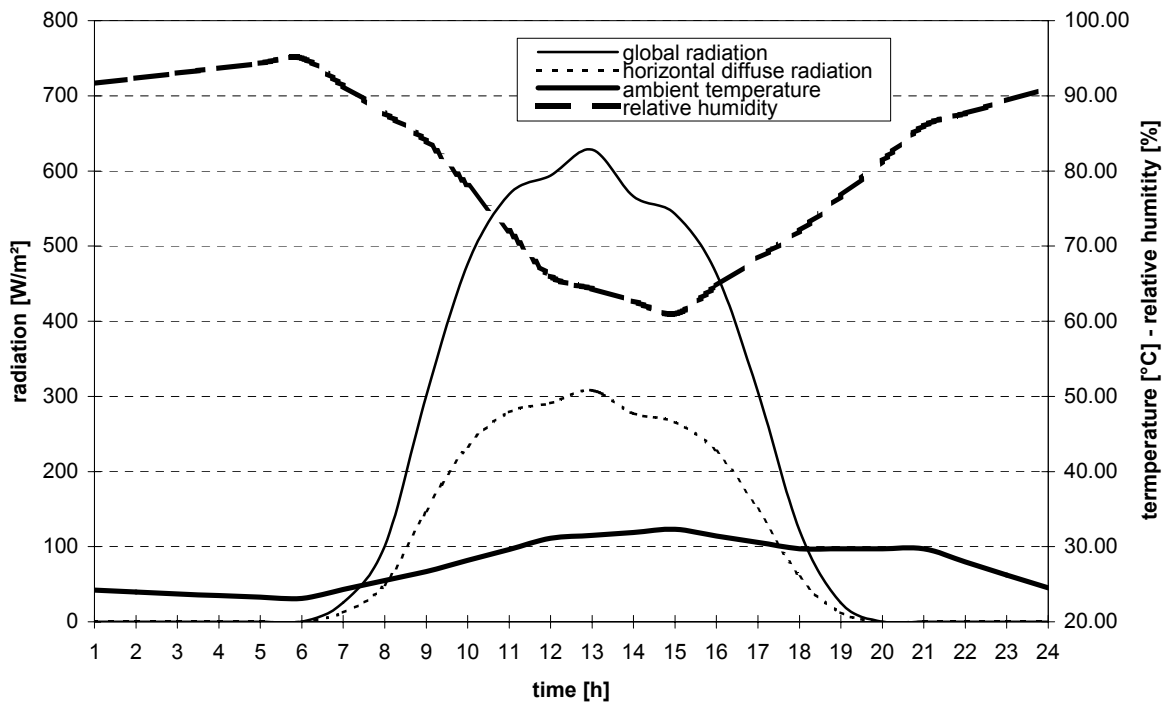
Sefwi-Bekwai - Febuary



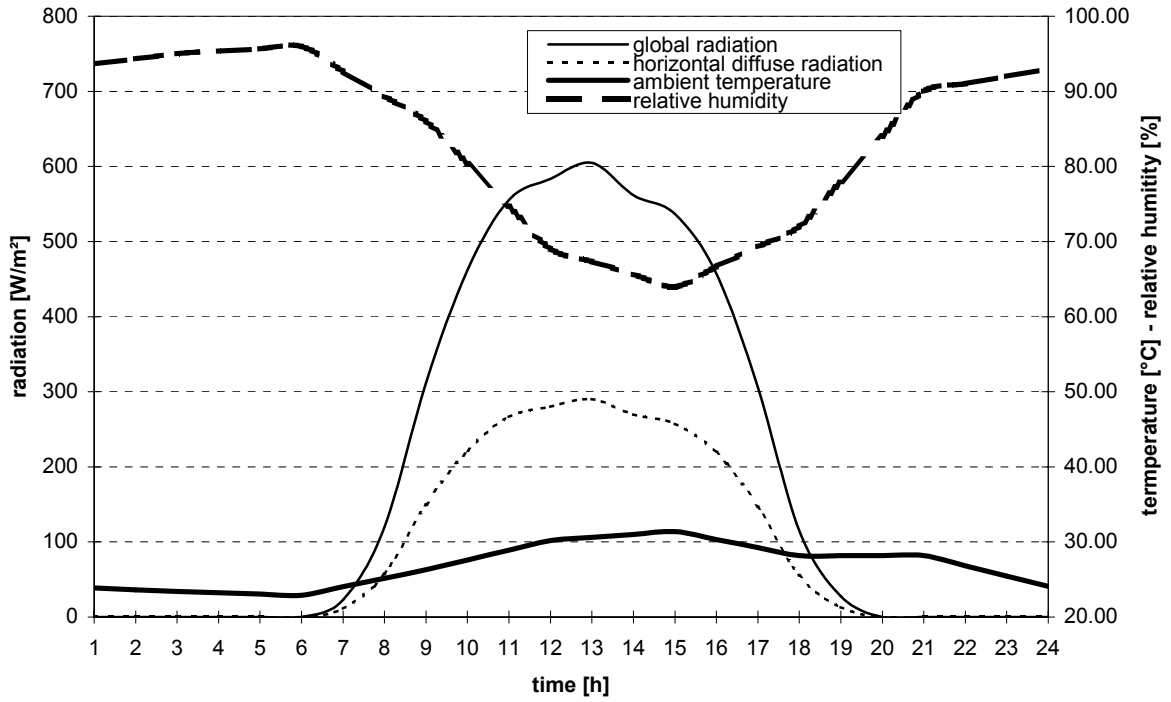
Sefwi-Bekwai - March



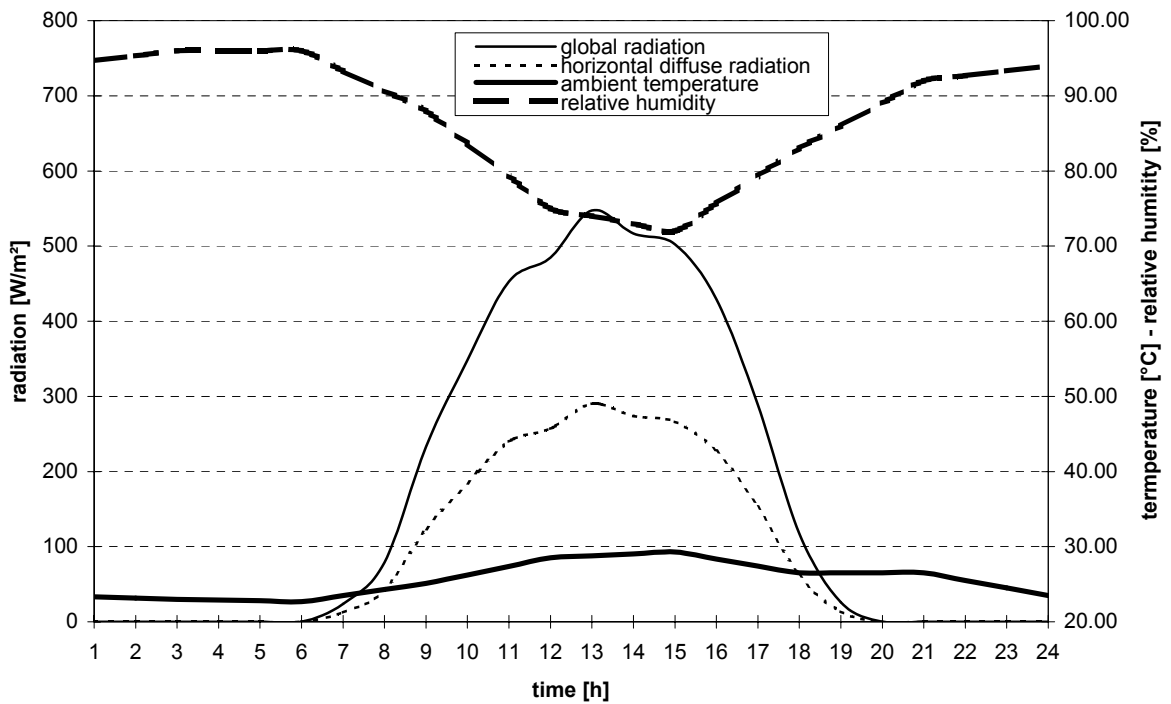
Sefwi-Bekwai - April



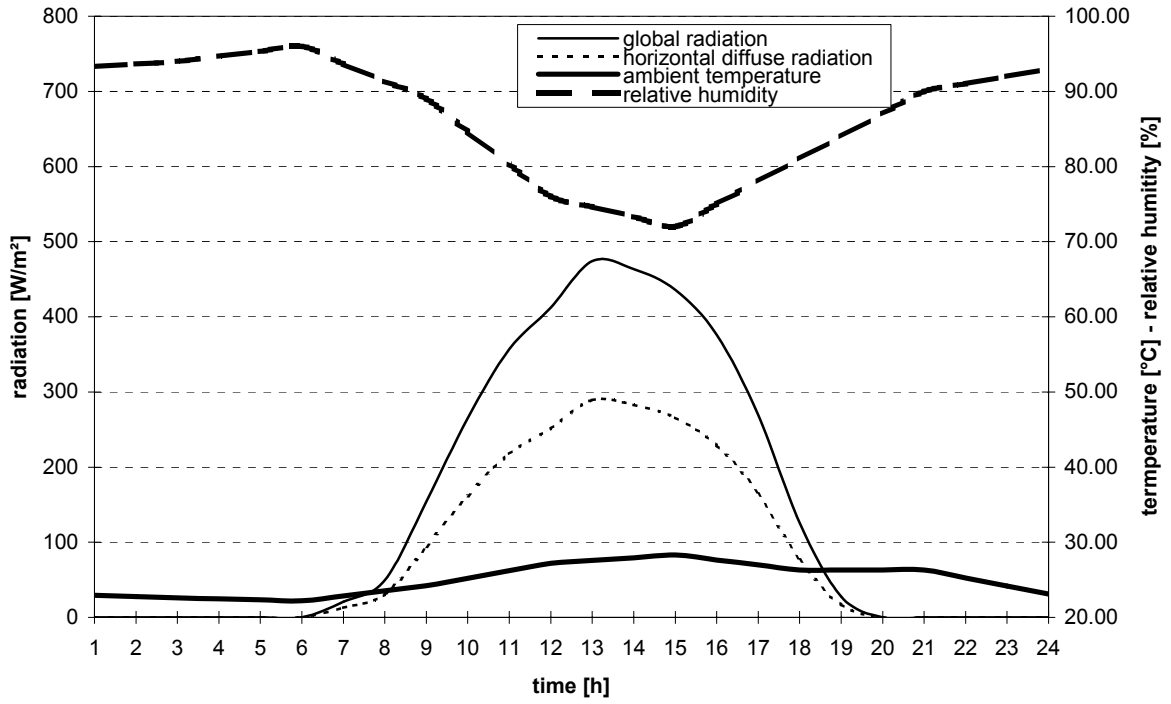
Sefwi-Bekwai - May



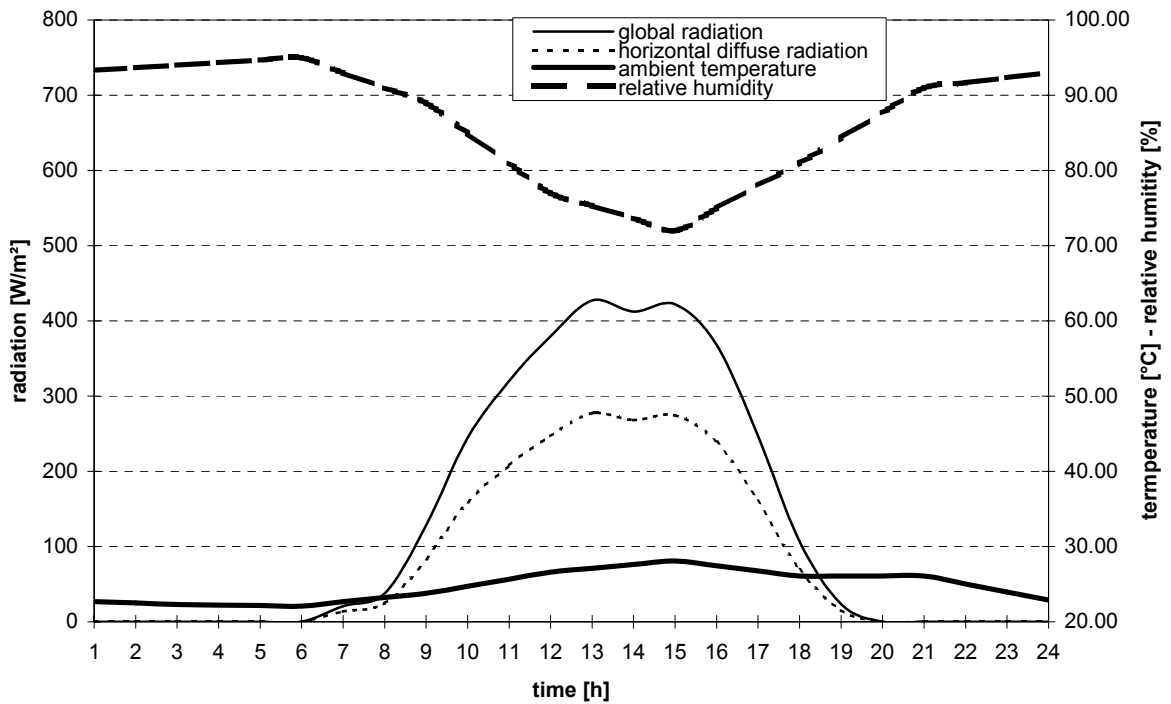
Sefwi-Bekwai - June



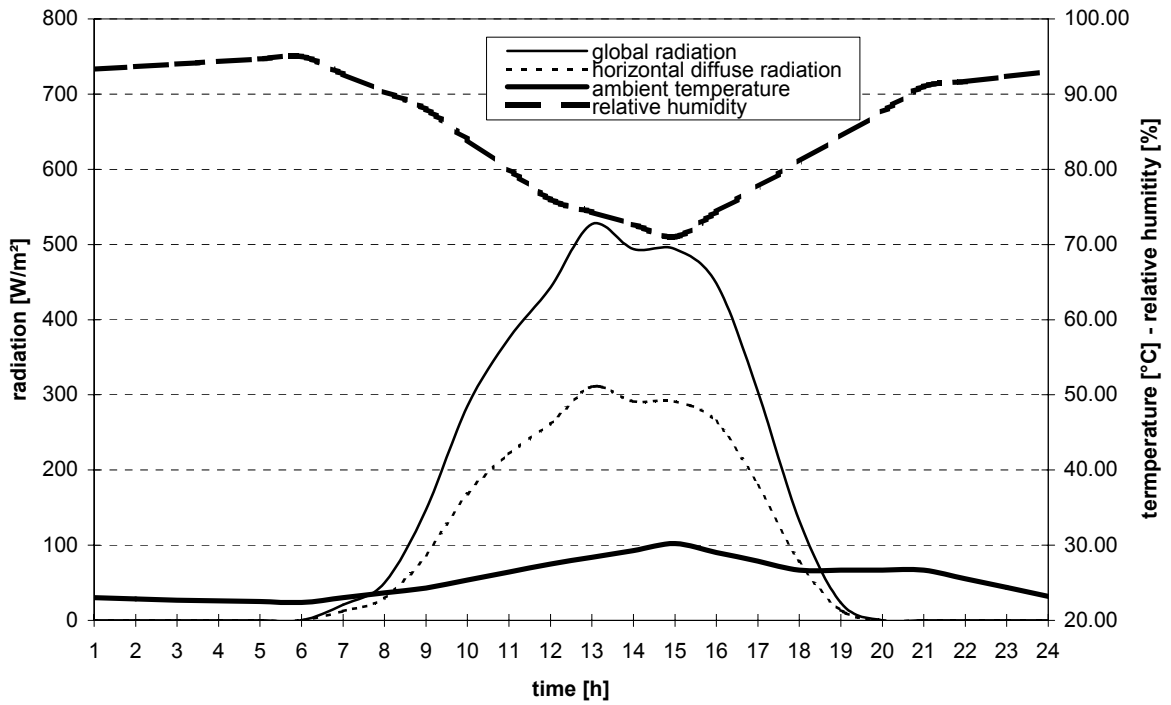
Sefwi-Bekwai - July



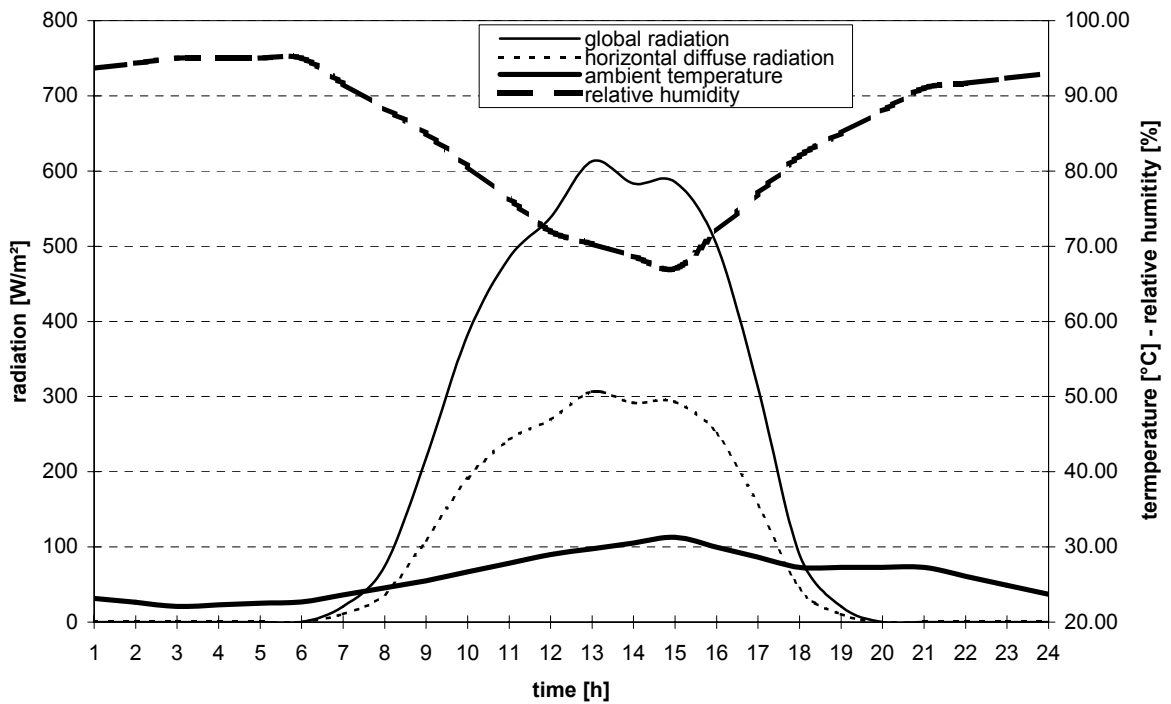
Sefwi-Bekwai - August



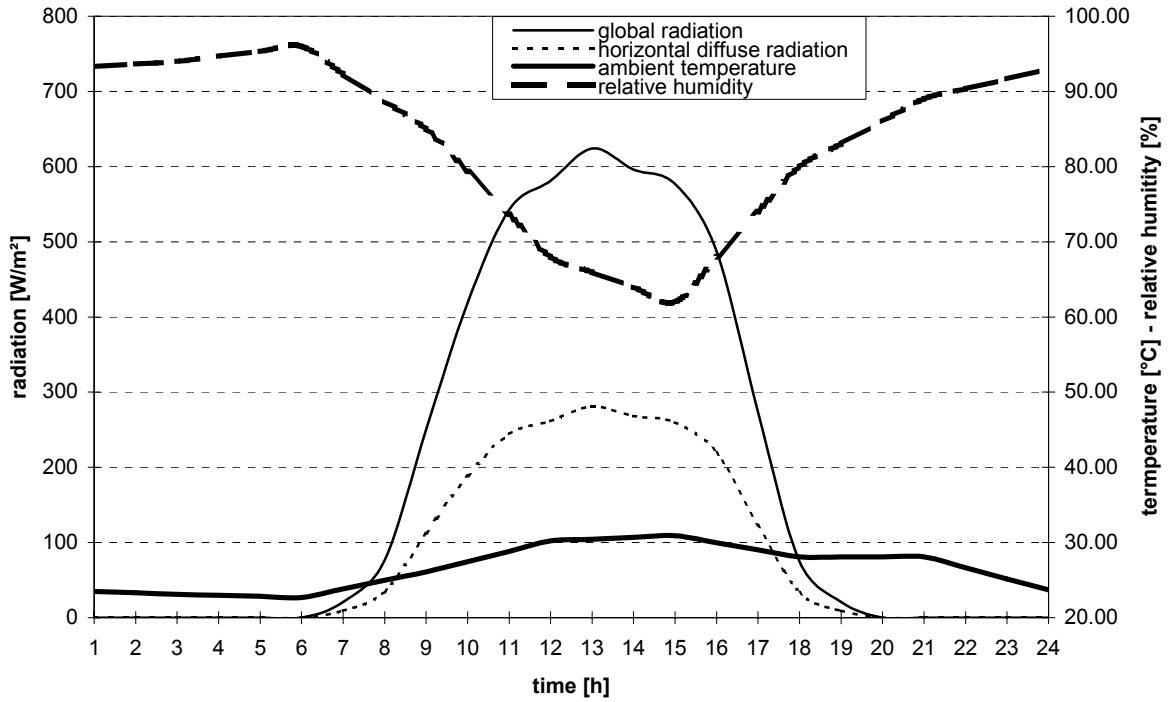
Sefwi-Bekwai - September



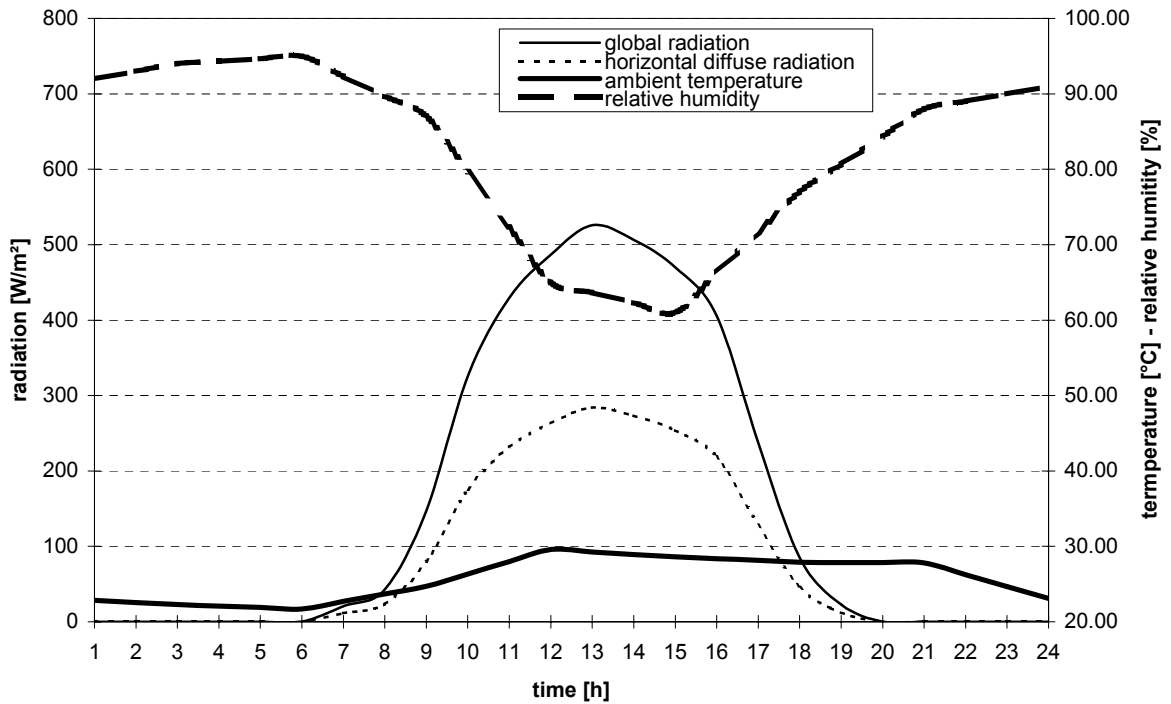
Sefwi-Bekwai - October



Sefwi-Bekwai - November



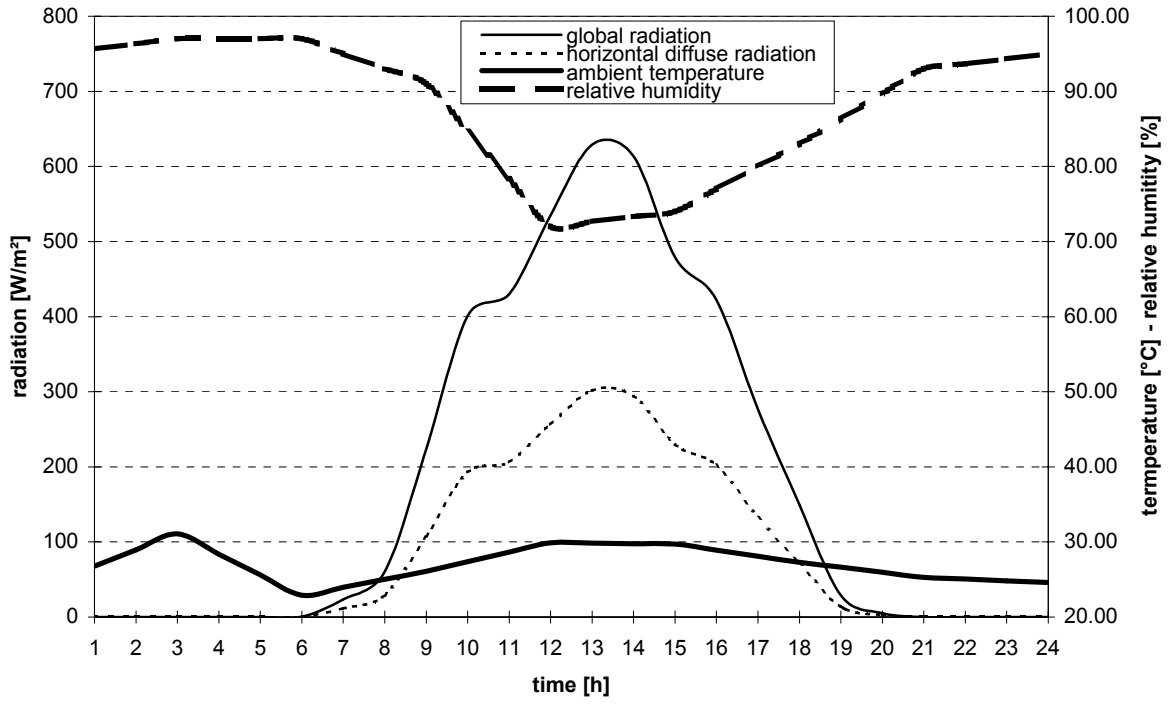
Sefwi-Bekwai - December



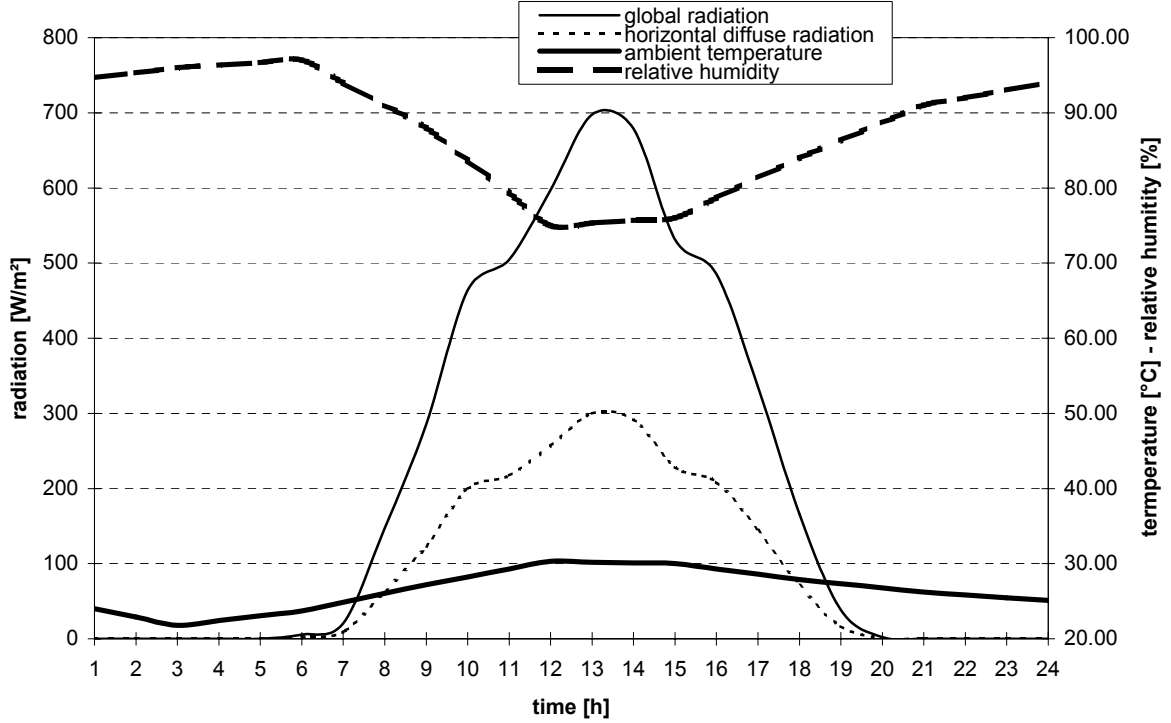
Appendix E

Weather data for Takardi

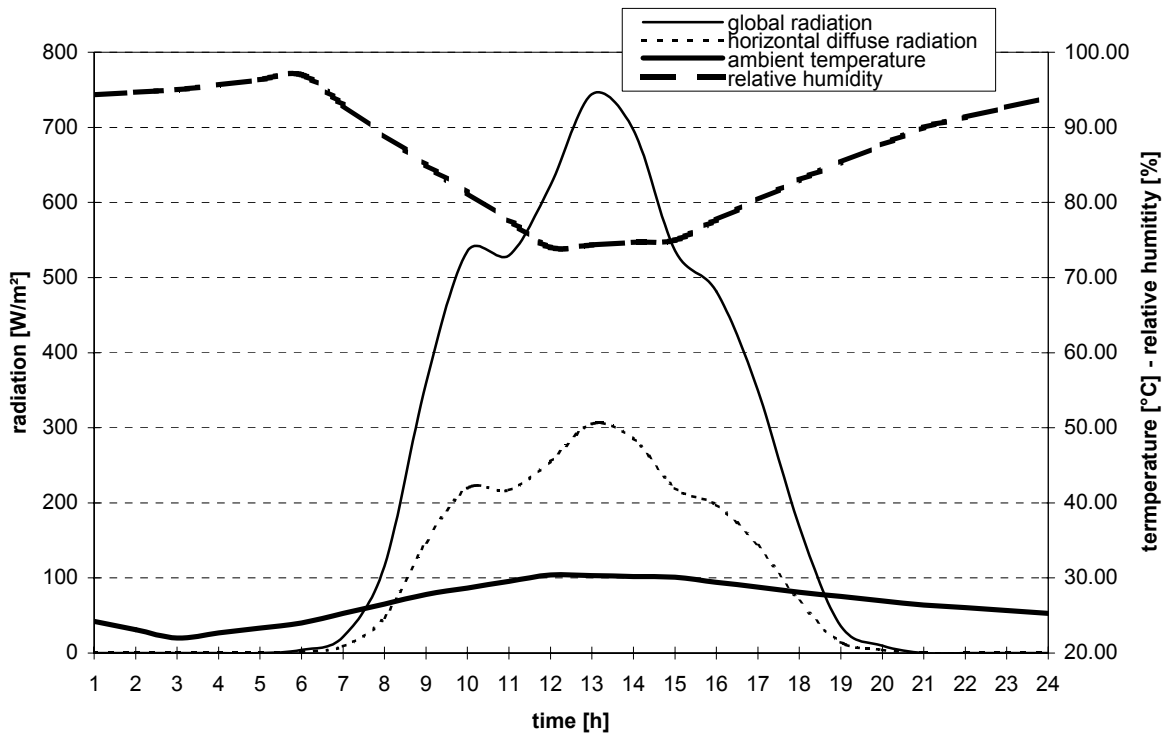
Takoradi - January



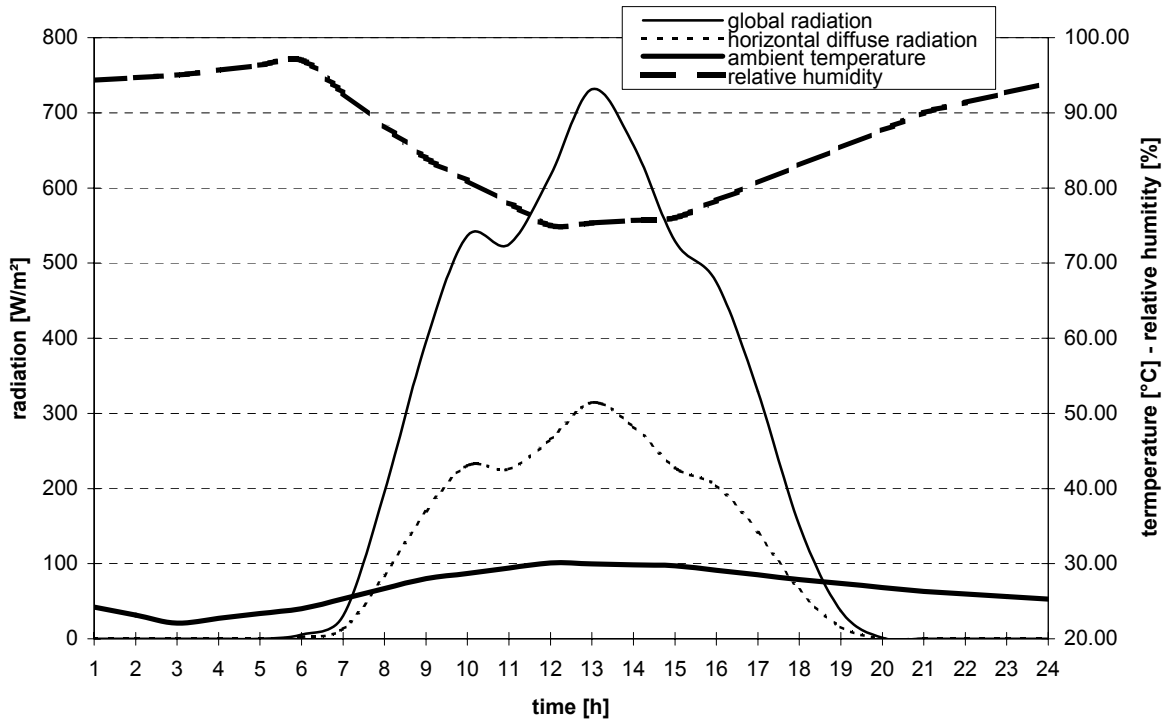
Takoradi - February



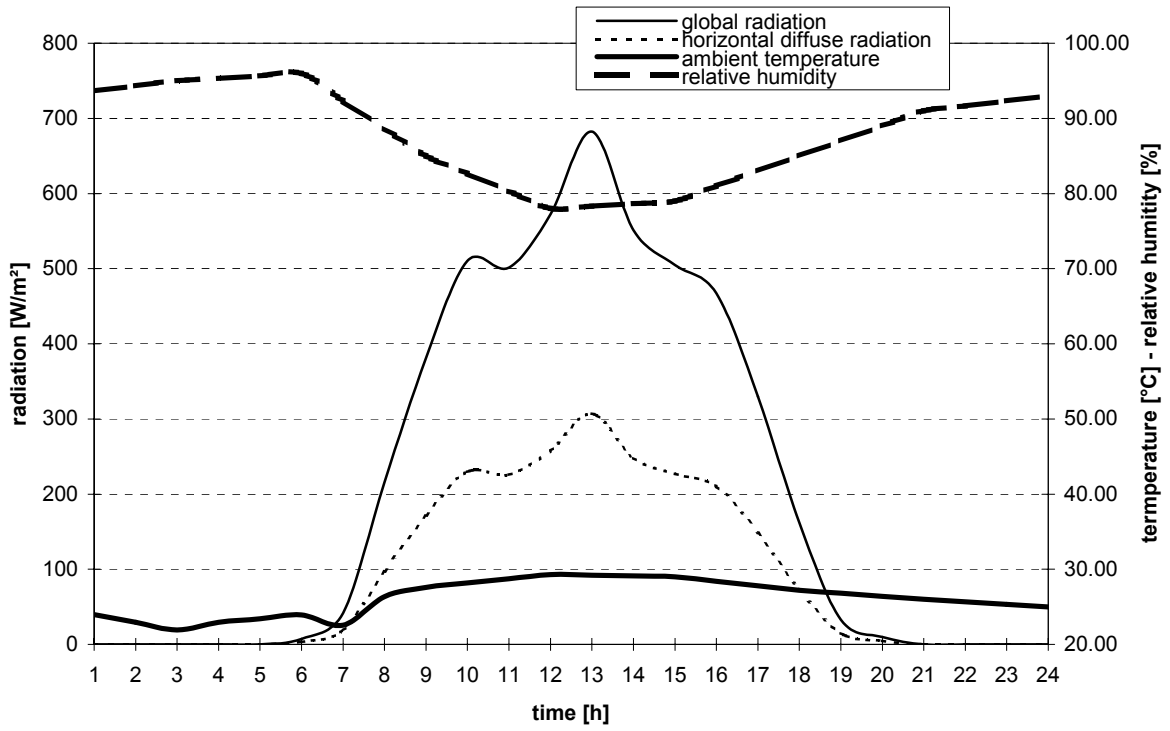
Takoradi - March



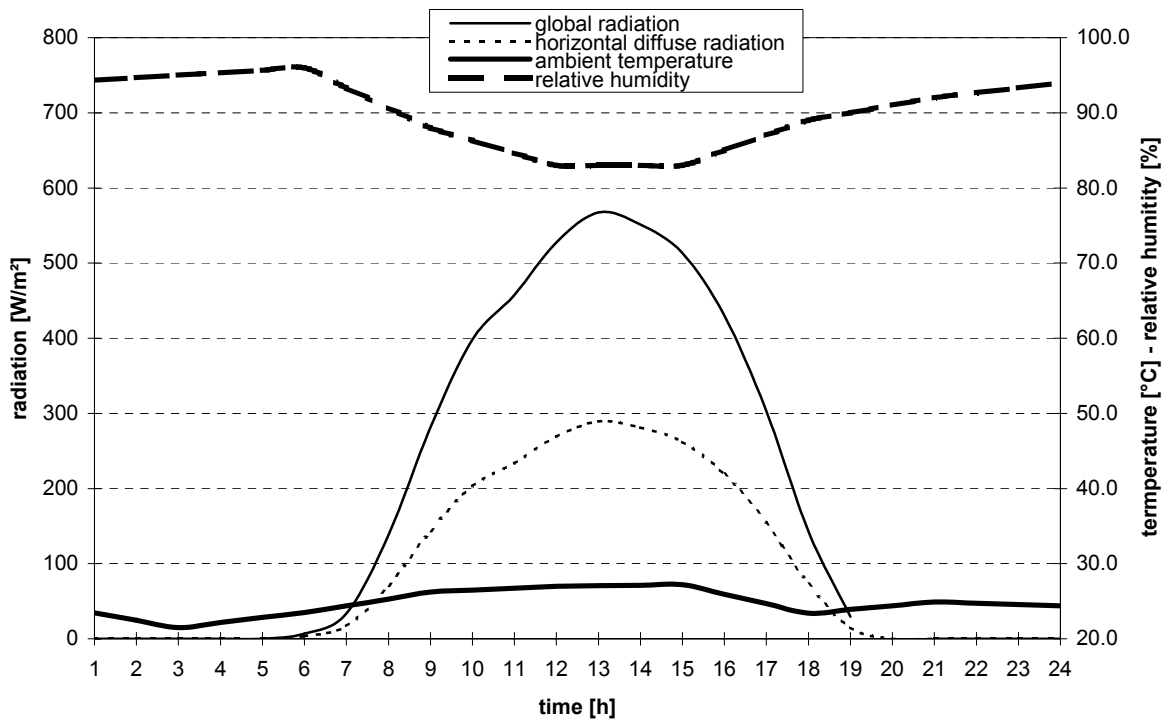
Takoradi - April



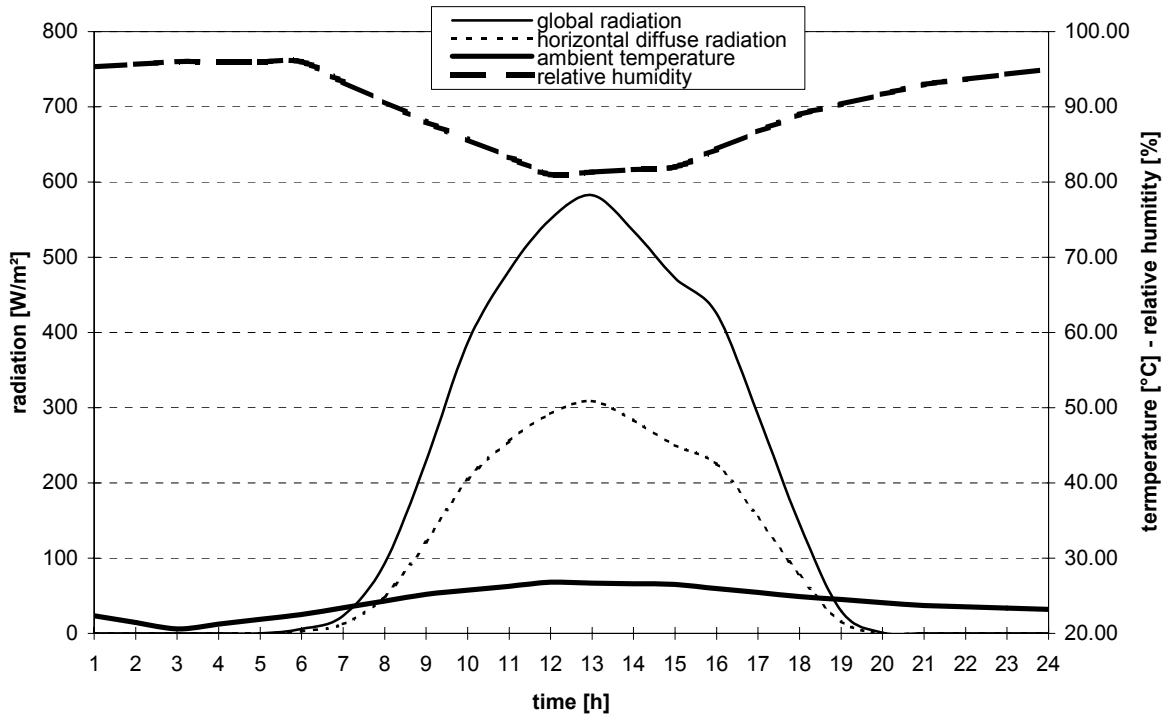
Takoradi - May



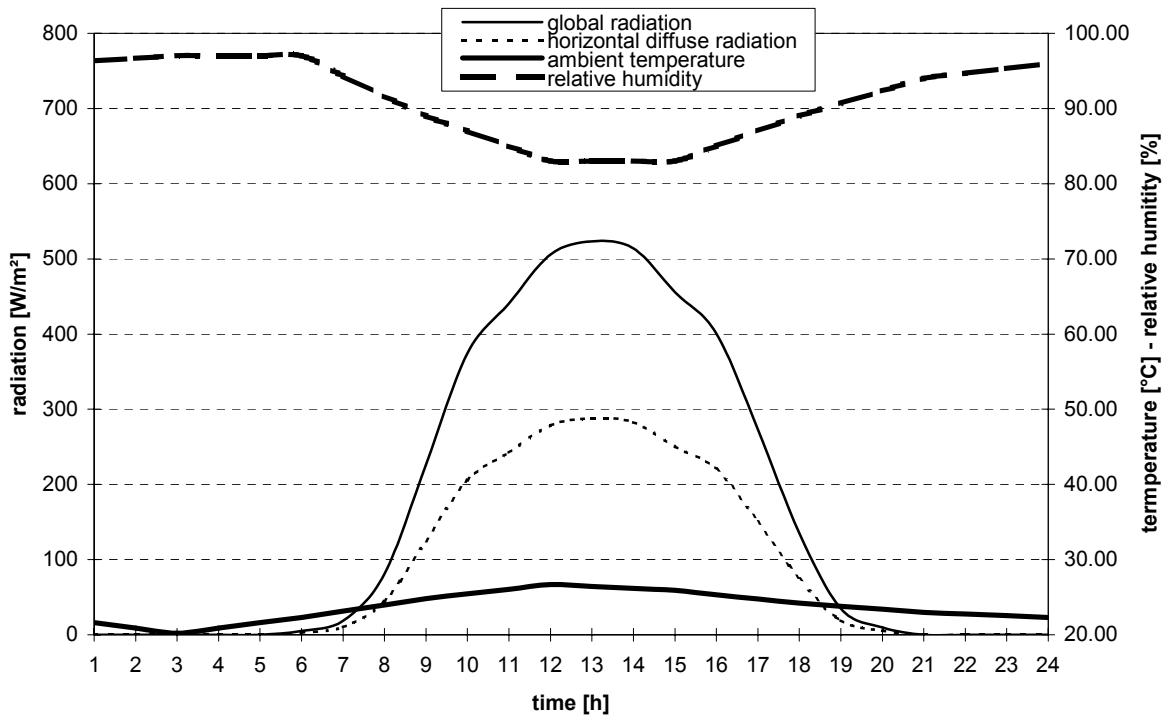
Takoradi - June



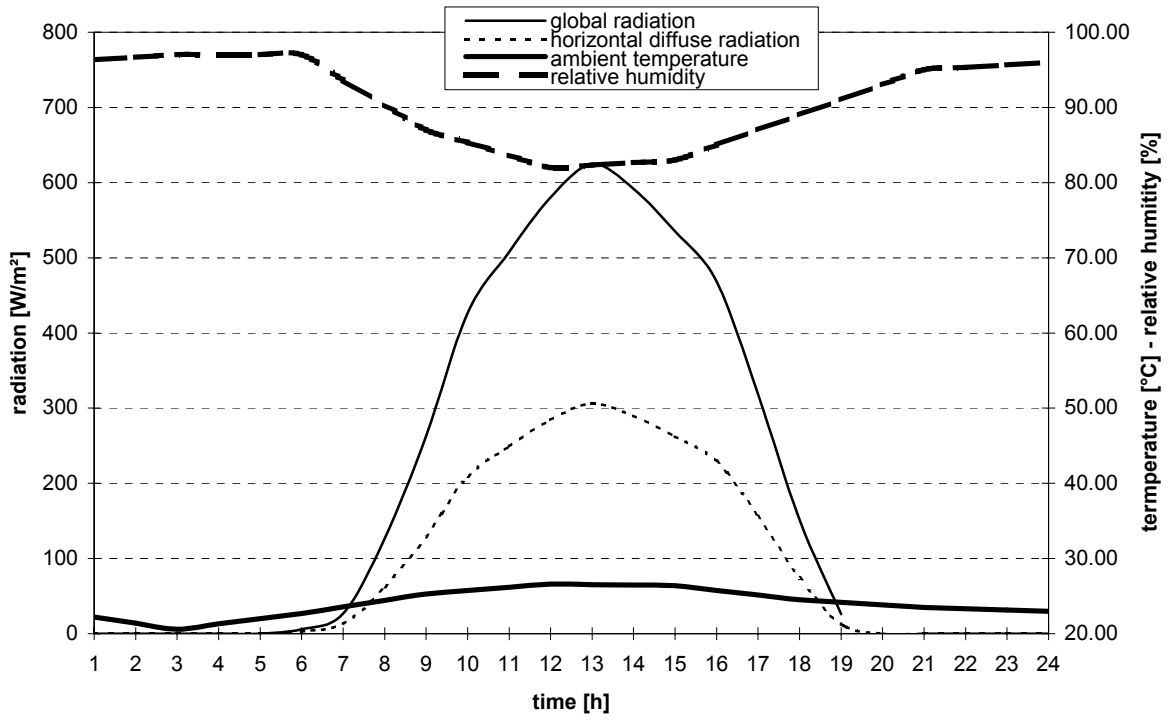
Takoradi - July



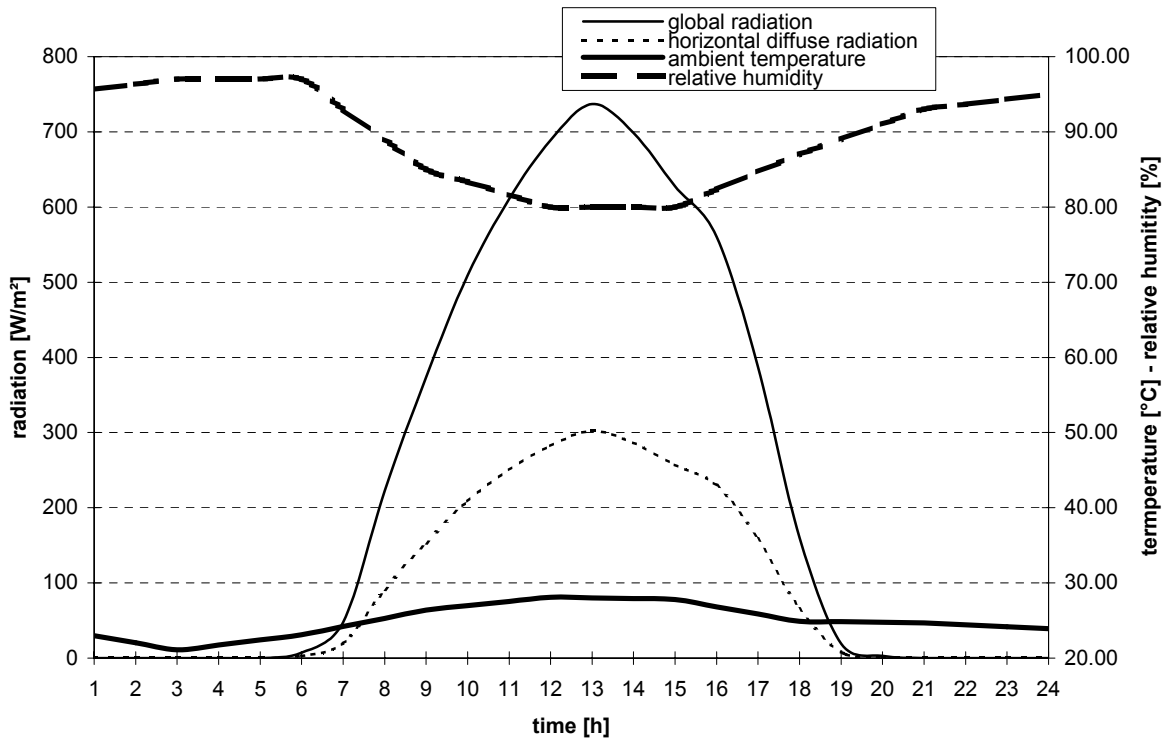
Takoradi - August



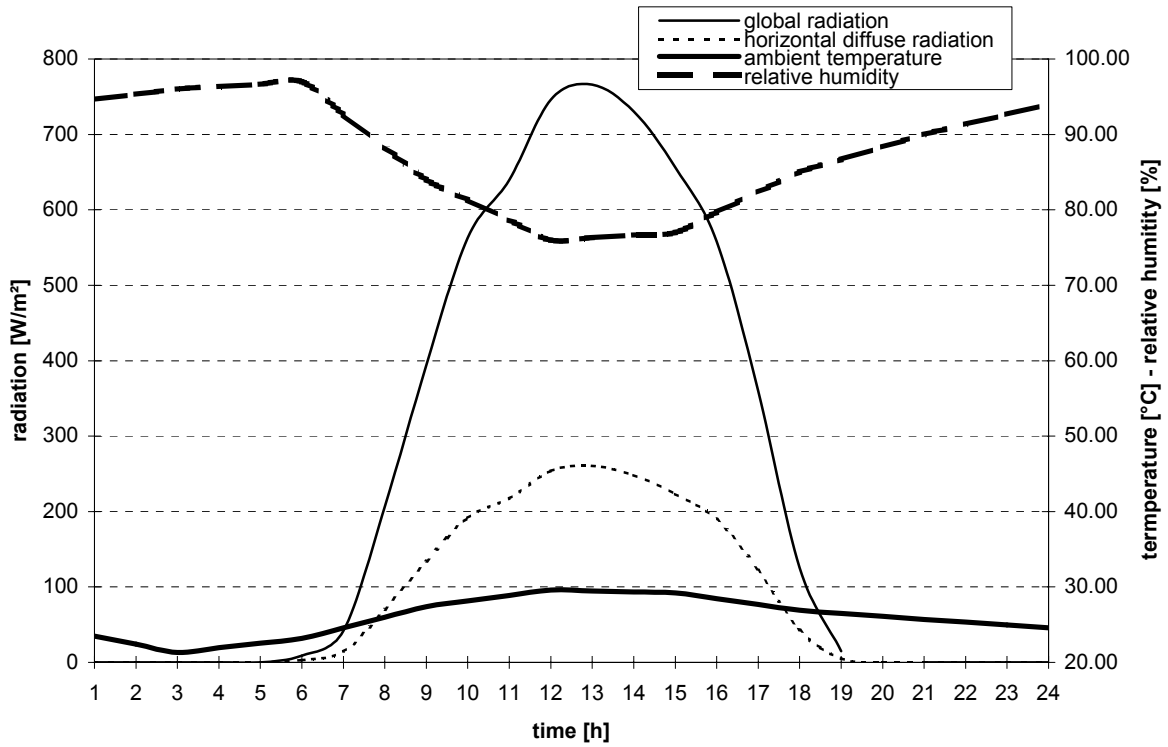
Takoradi - September



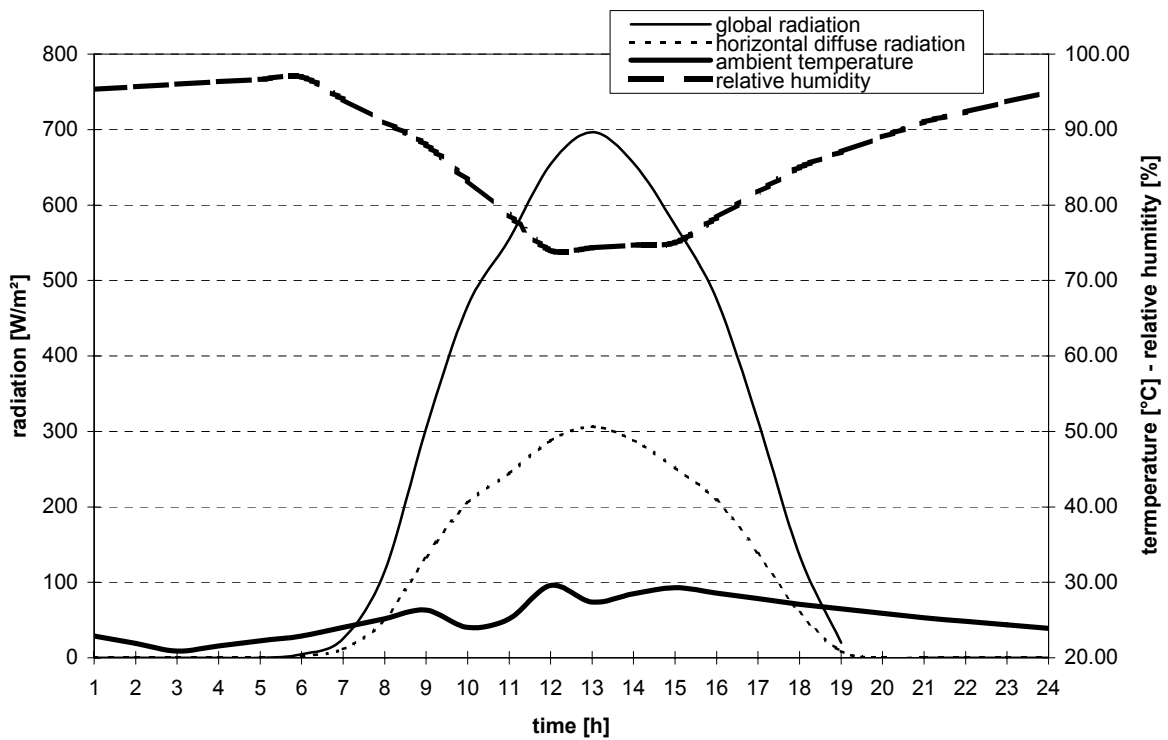
Takoradi - October



Takoradi - November



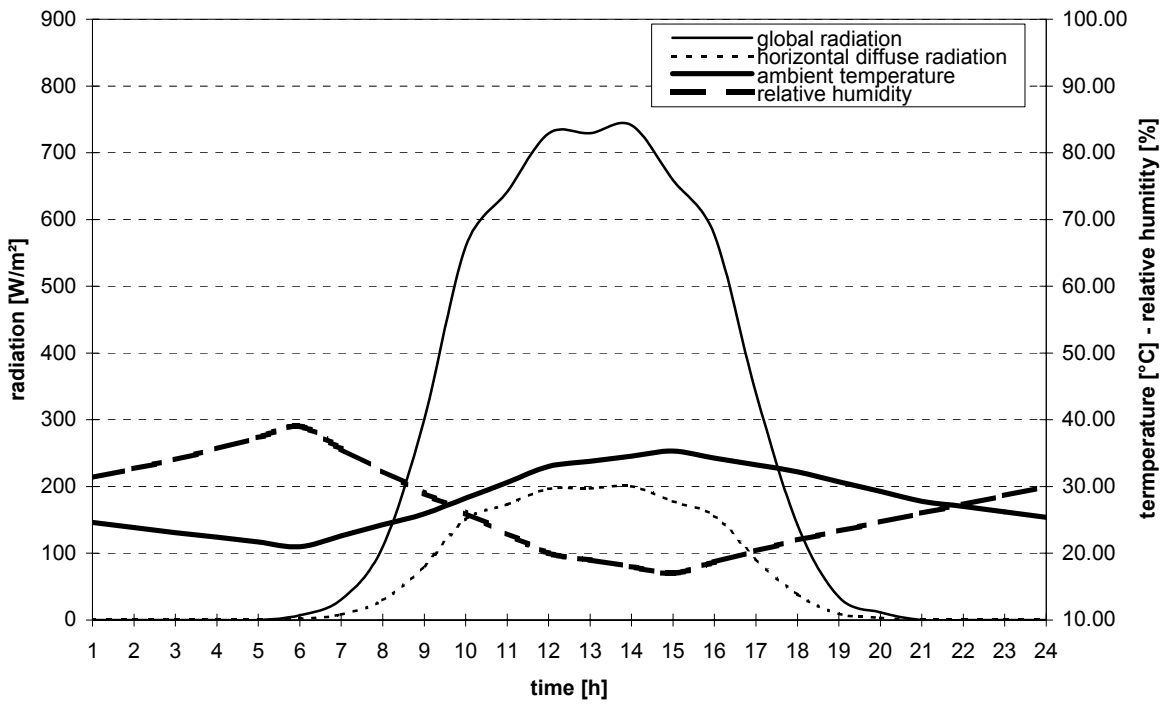
Takoradi - December



Appendix F

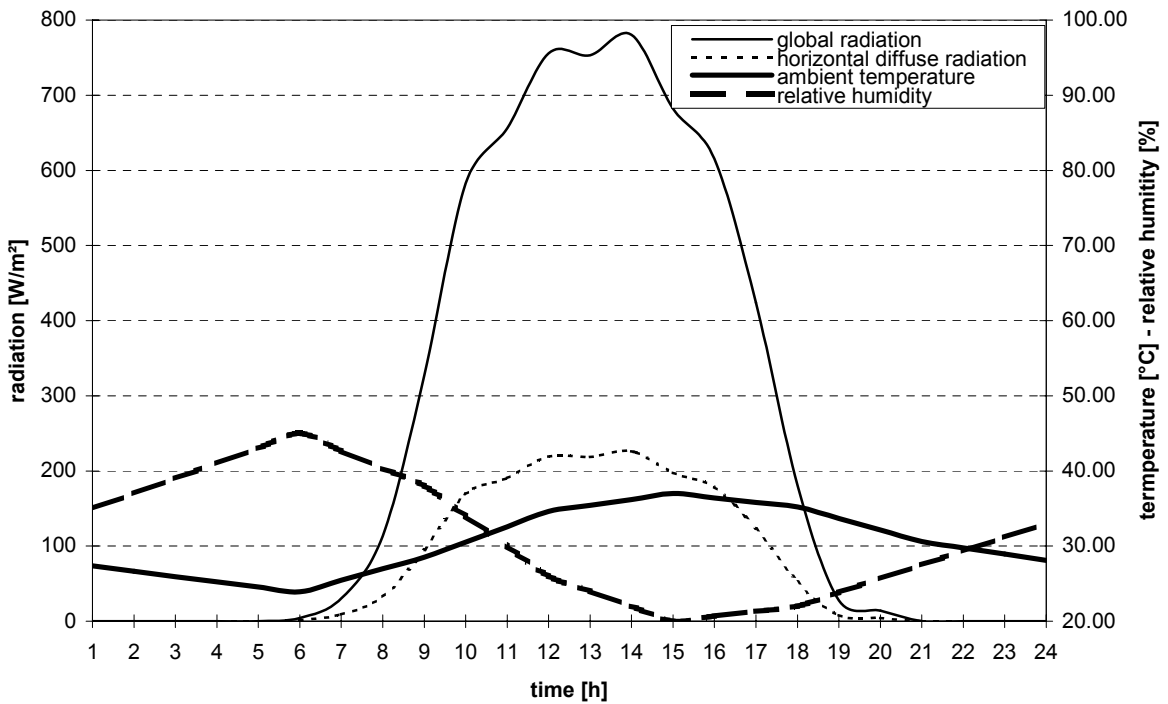
Weather data for Tamale

Tamale - January

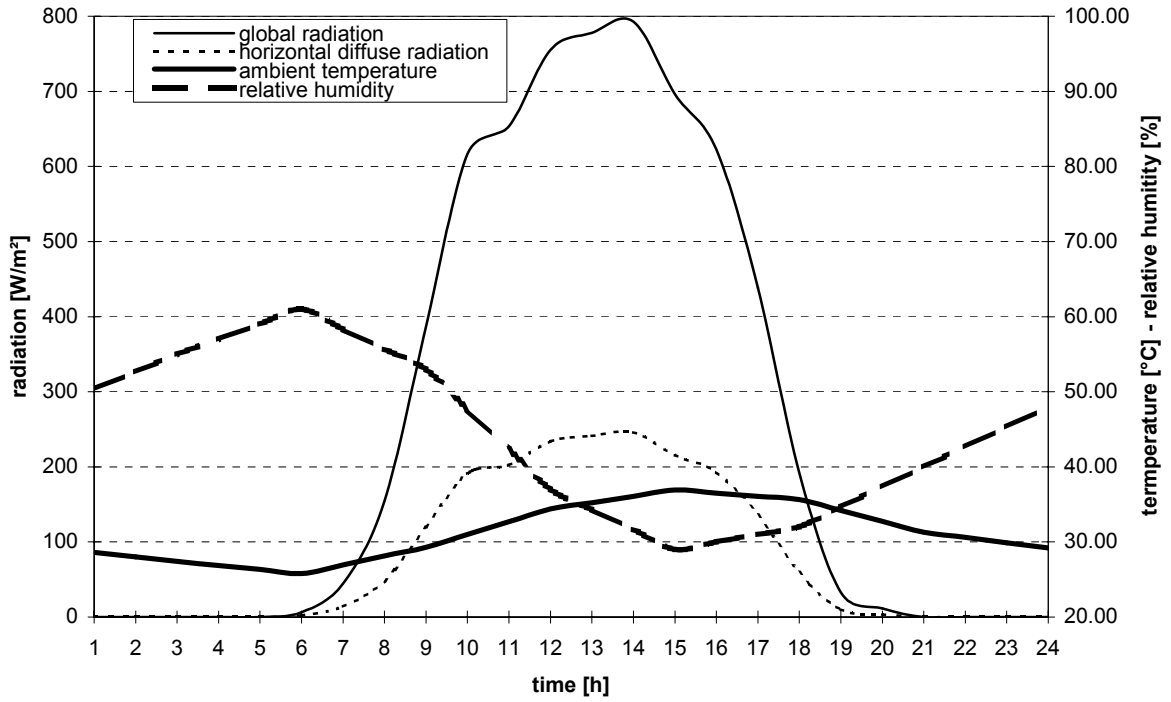


Please be aware of the changed scale on the two y-axis for Tamale – January.

Tamale - Fenuary



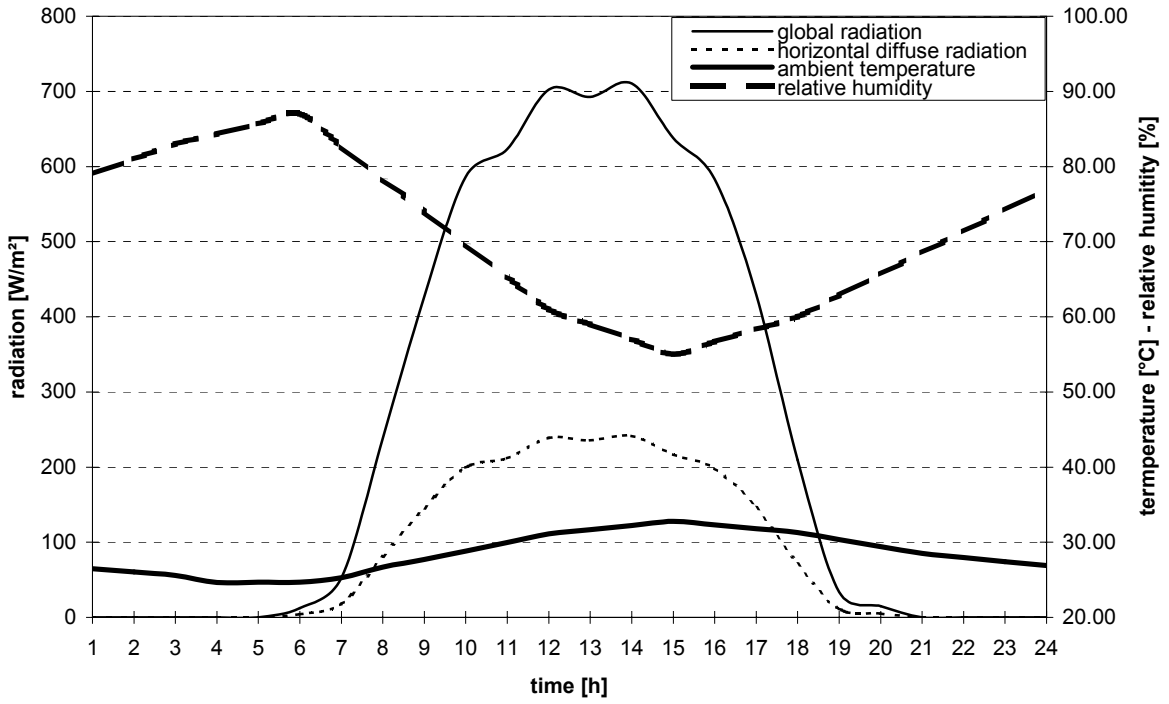
Tamale - March



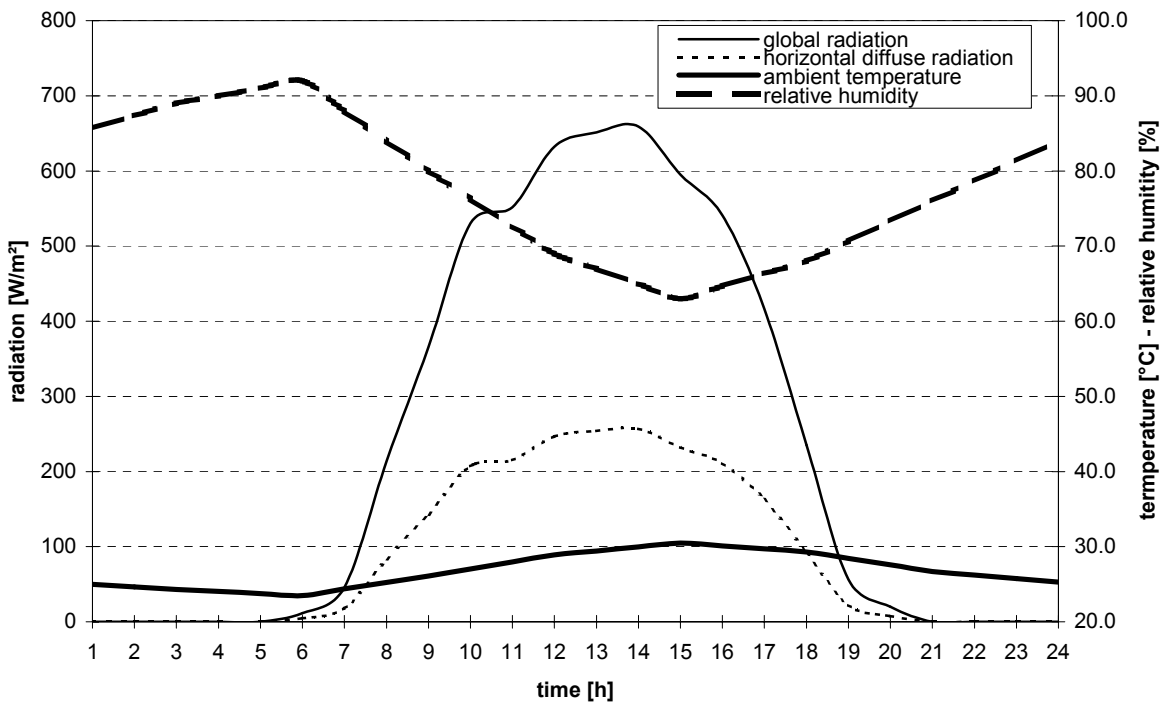
Tamale - April



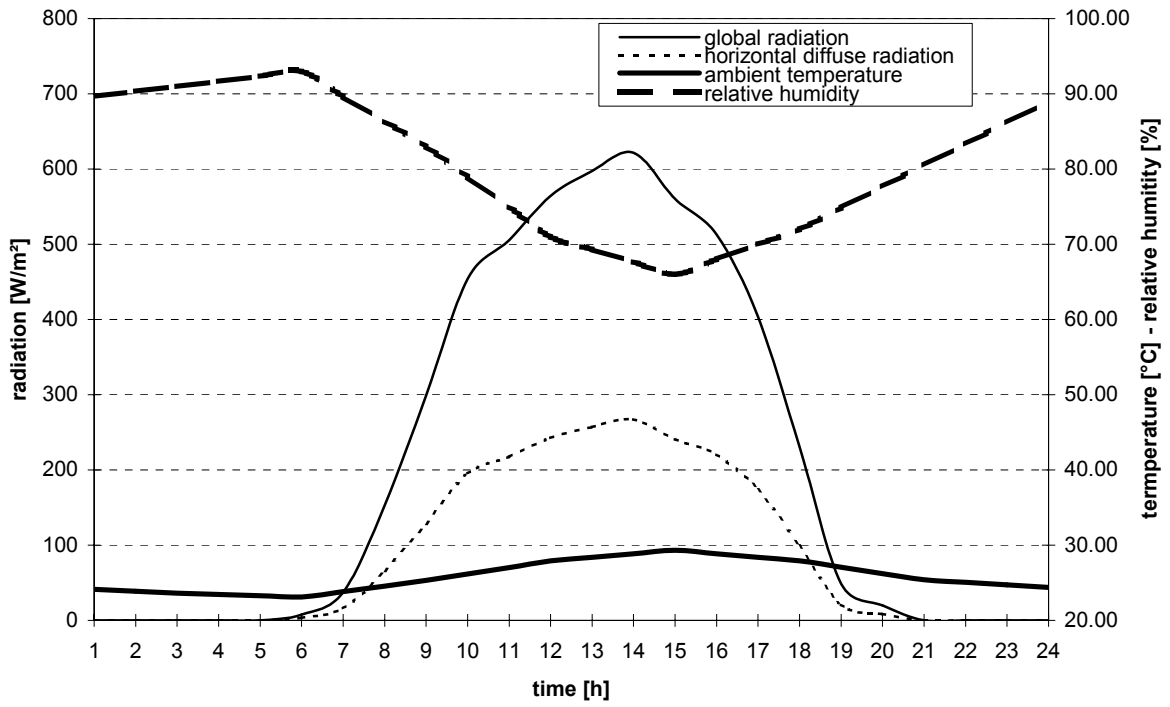
Tamale - May



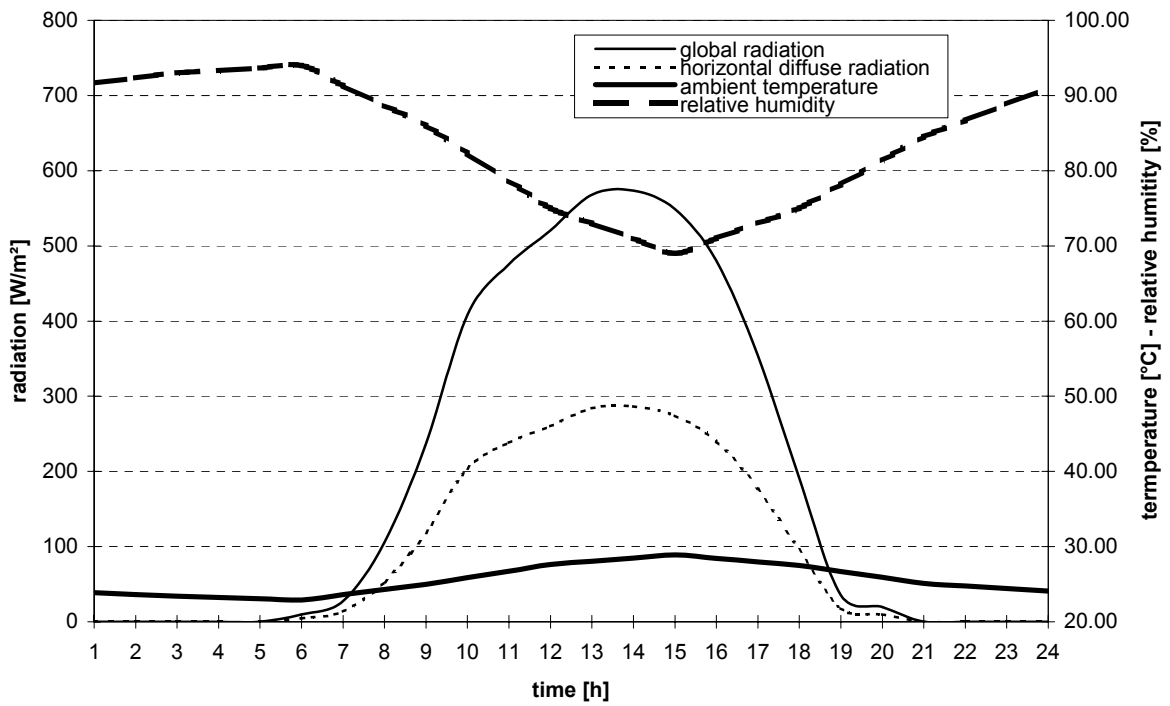
Tamale - June



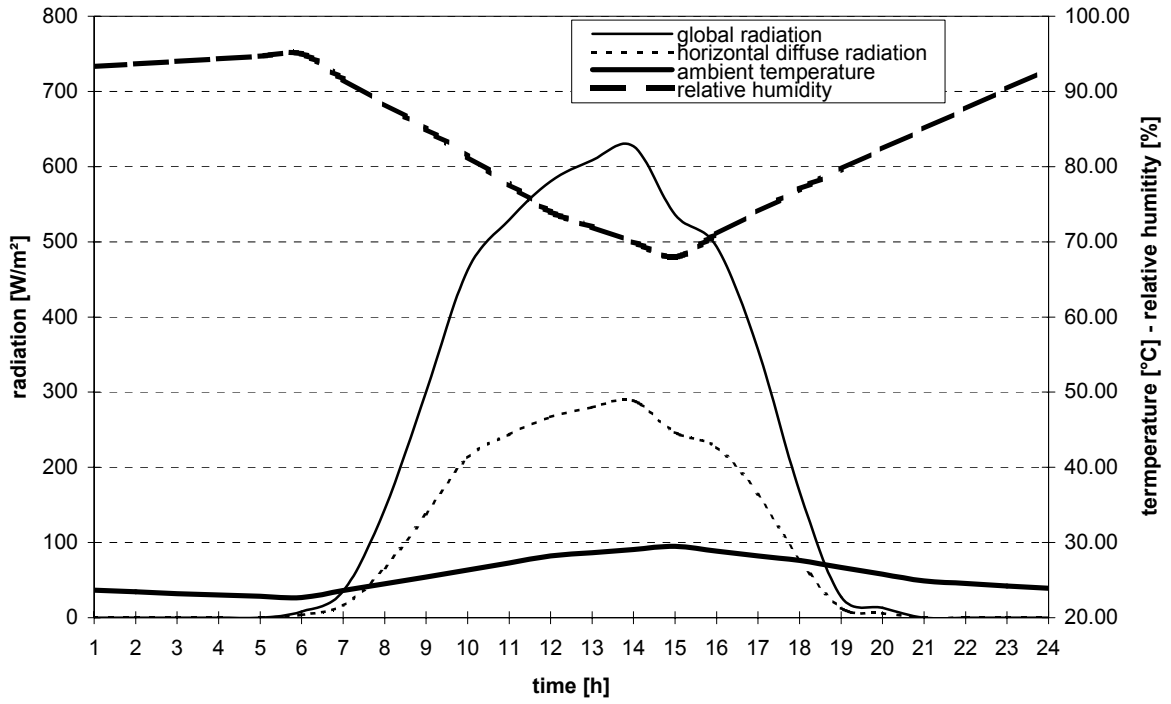
Tamale - July



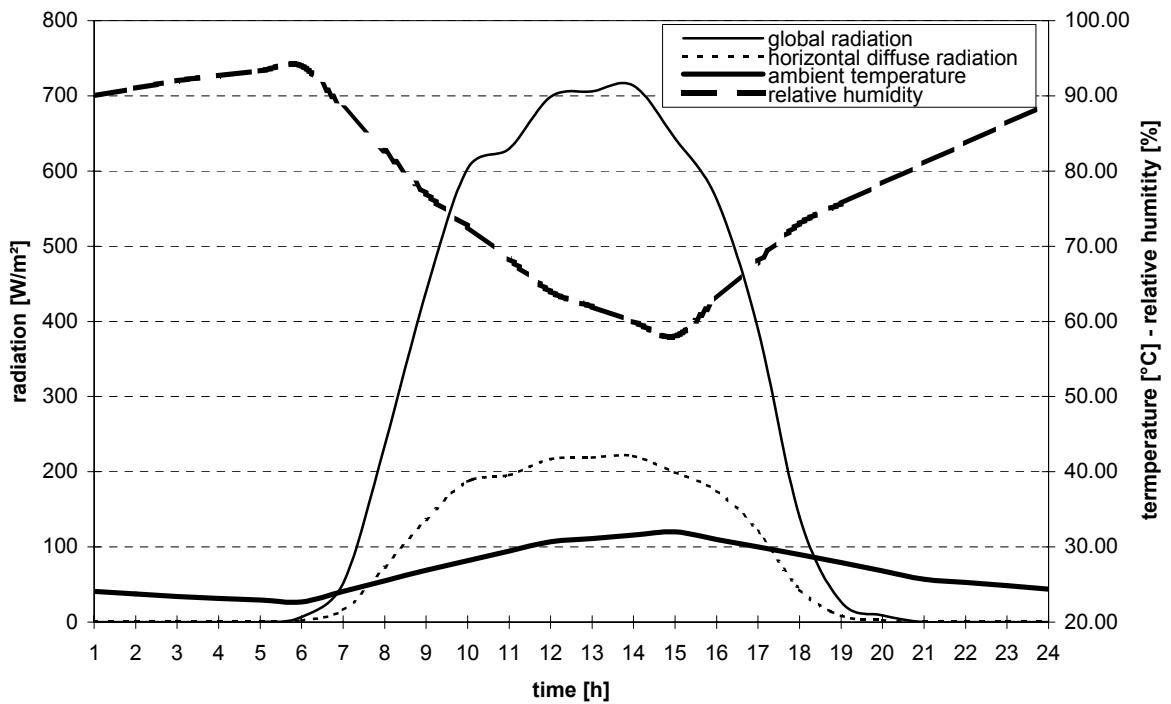
Tamale - August



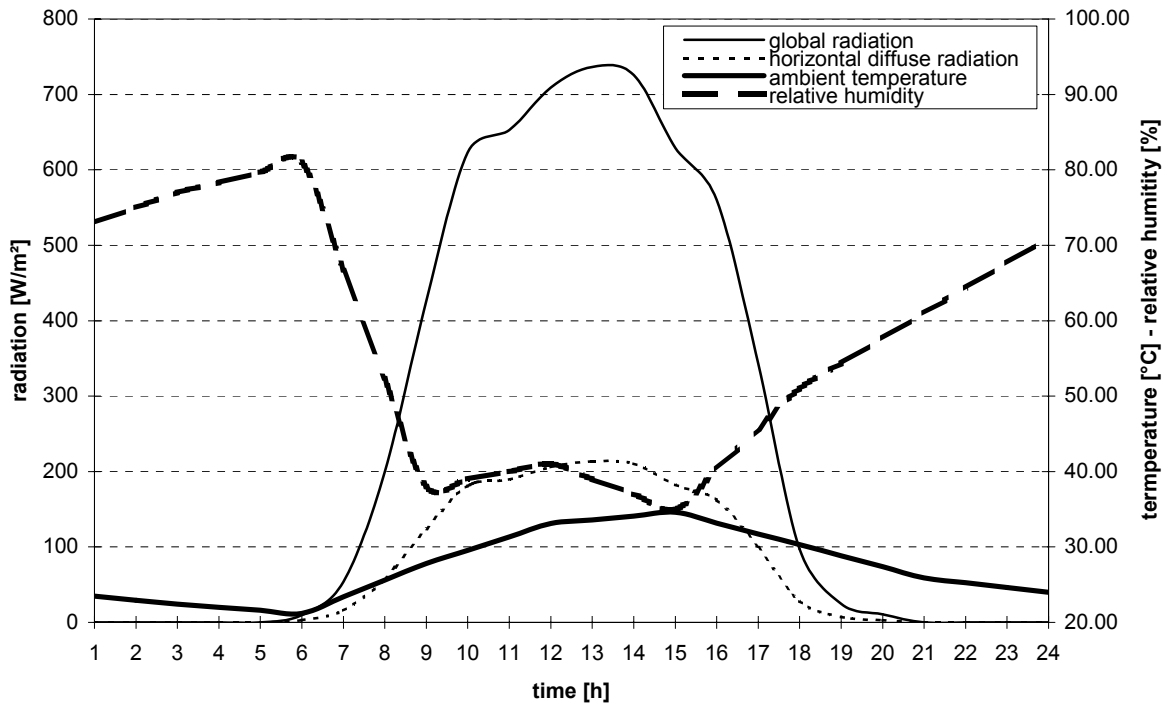
Tamale - September



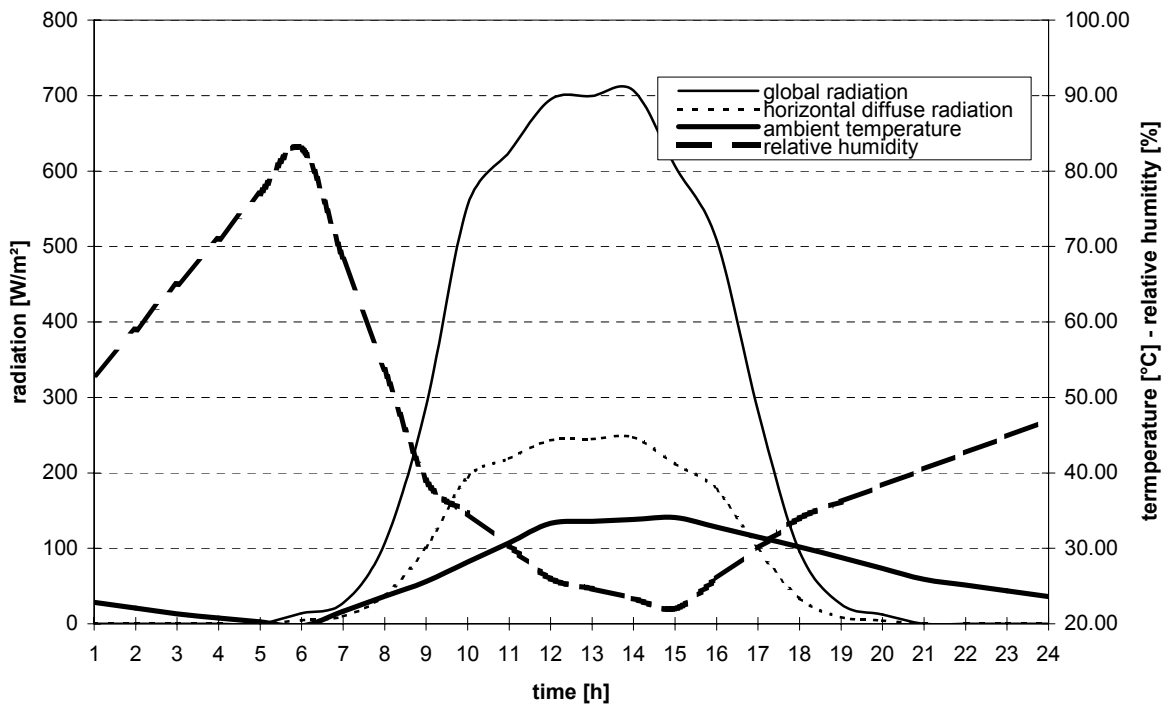
Tamale - October



Tamale - November

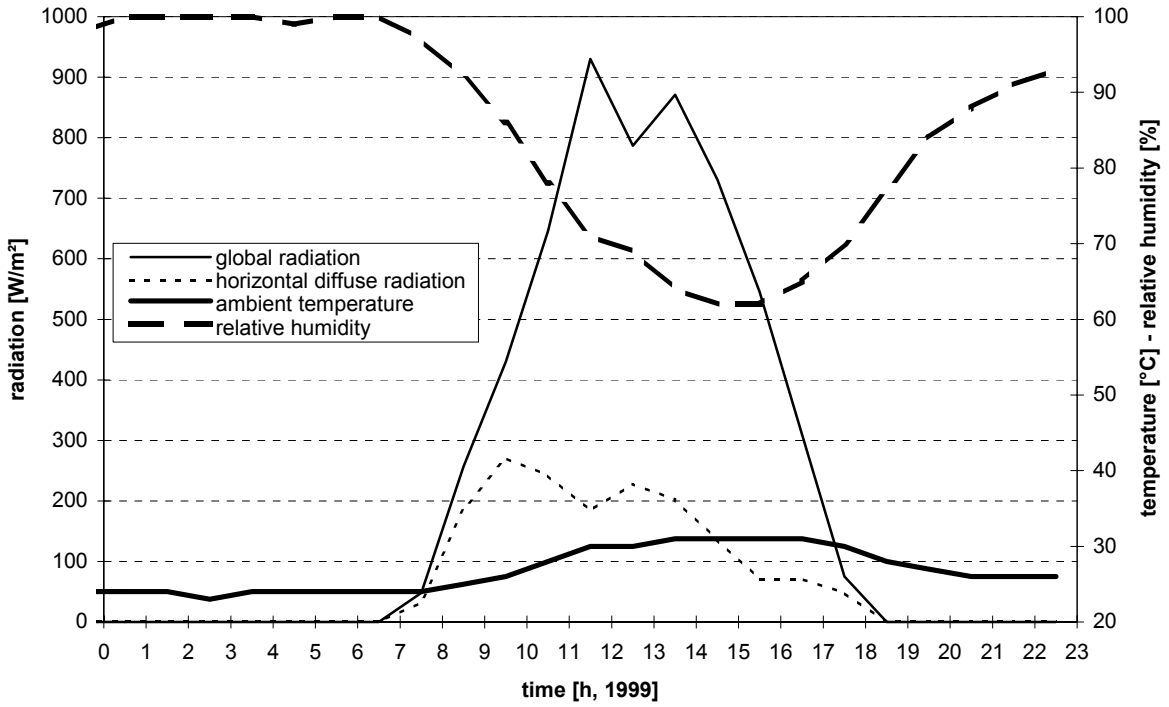


Tamale - December

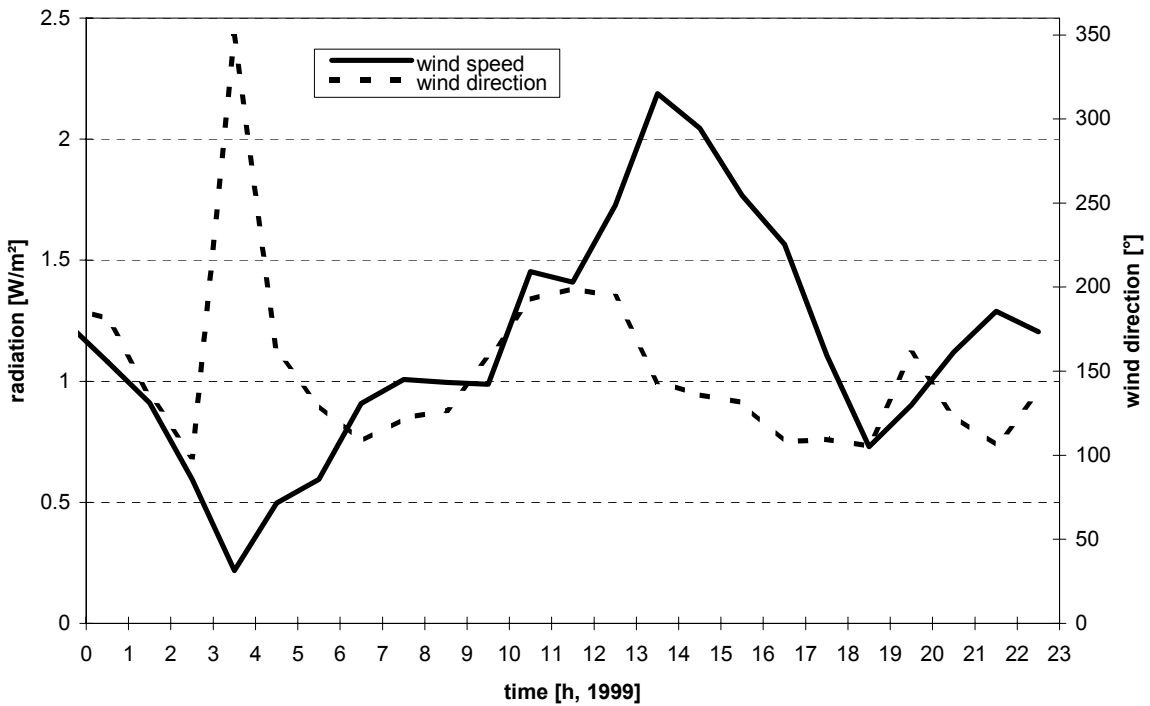


Appendix G
Measured weather data
for Kumasi
three days in November 1999

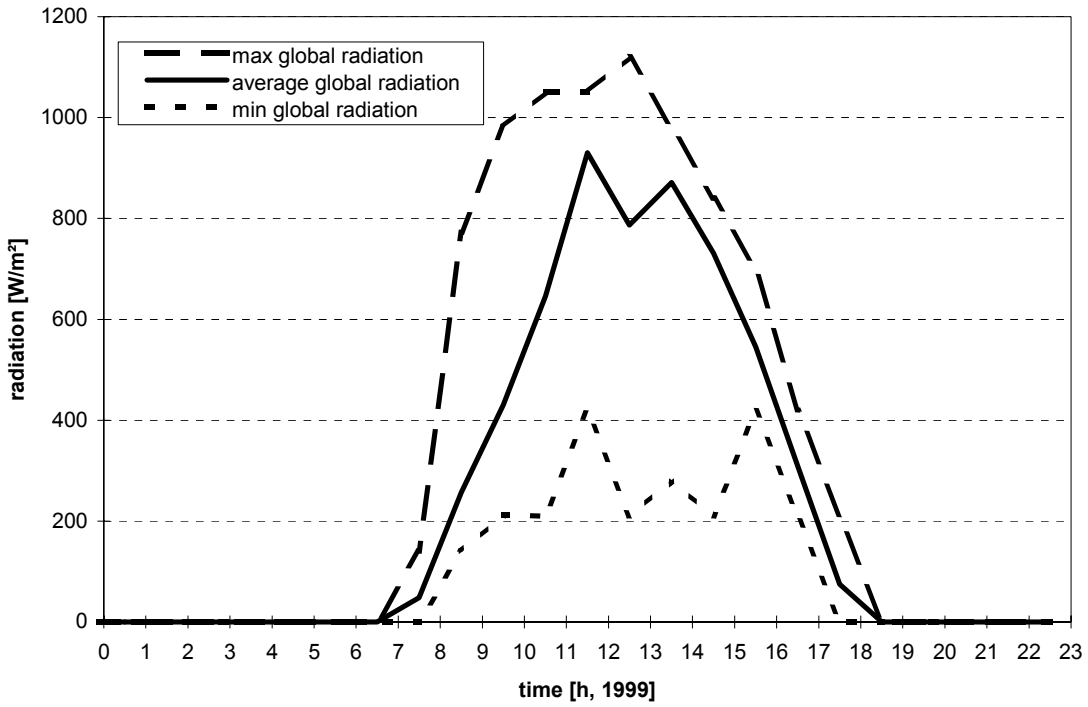
Kumasi - November
clear day



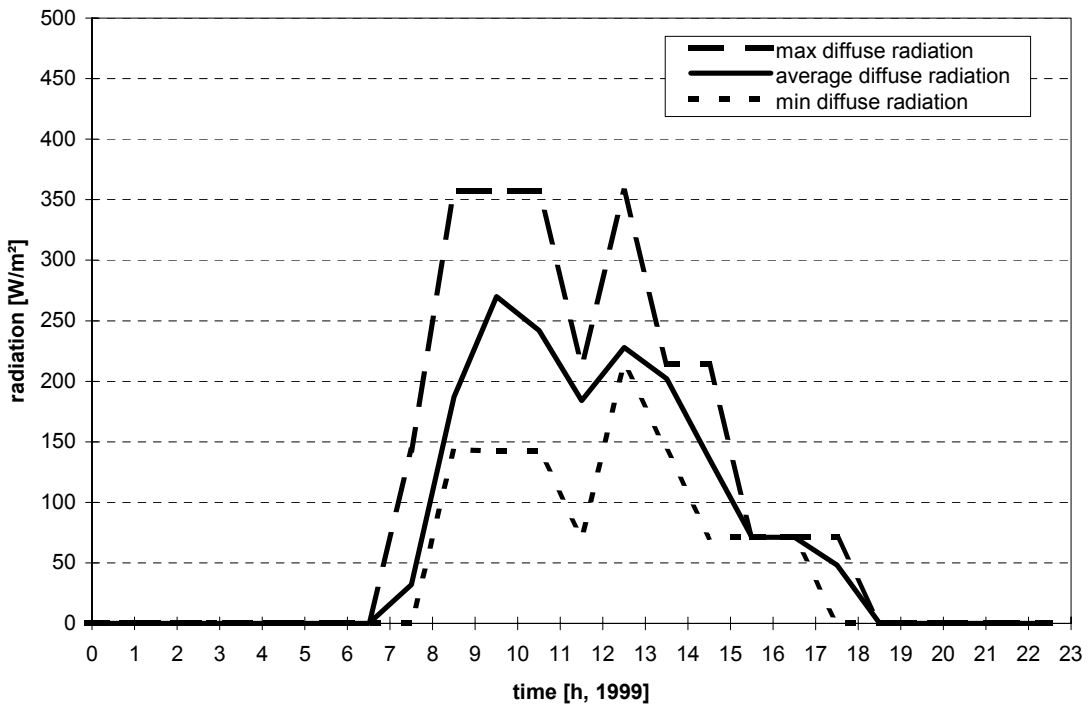
Kumasi - November
clear day



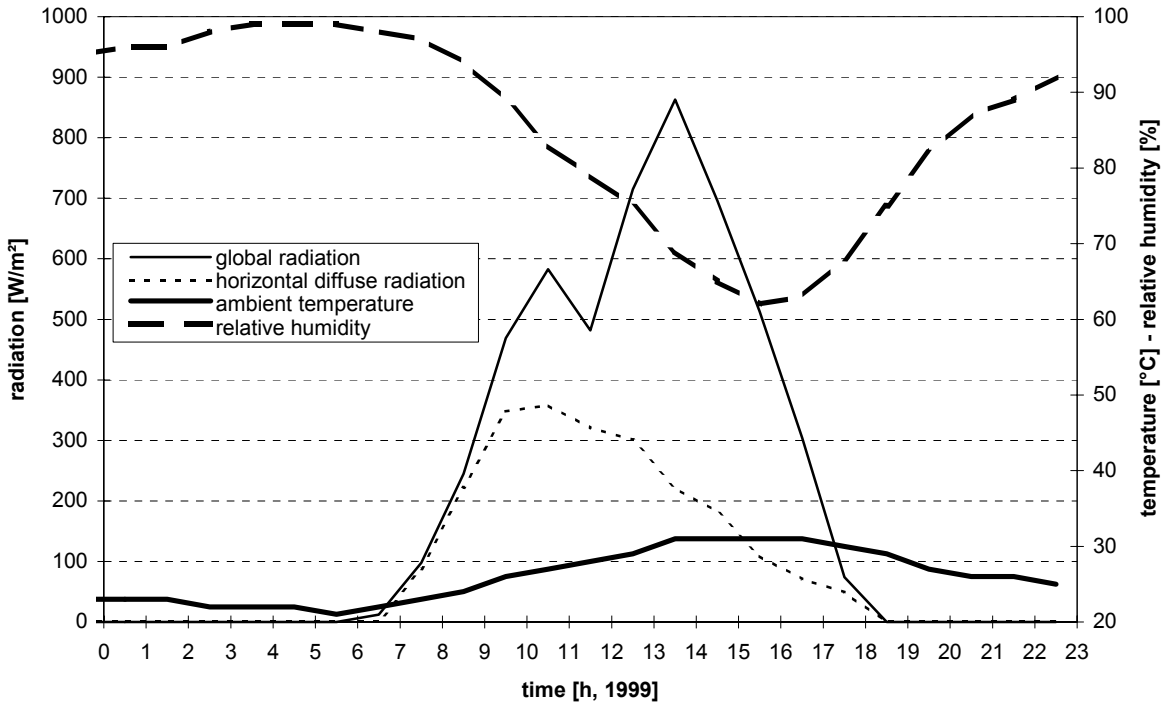
**Kumasi - November
clear day**



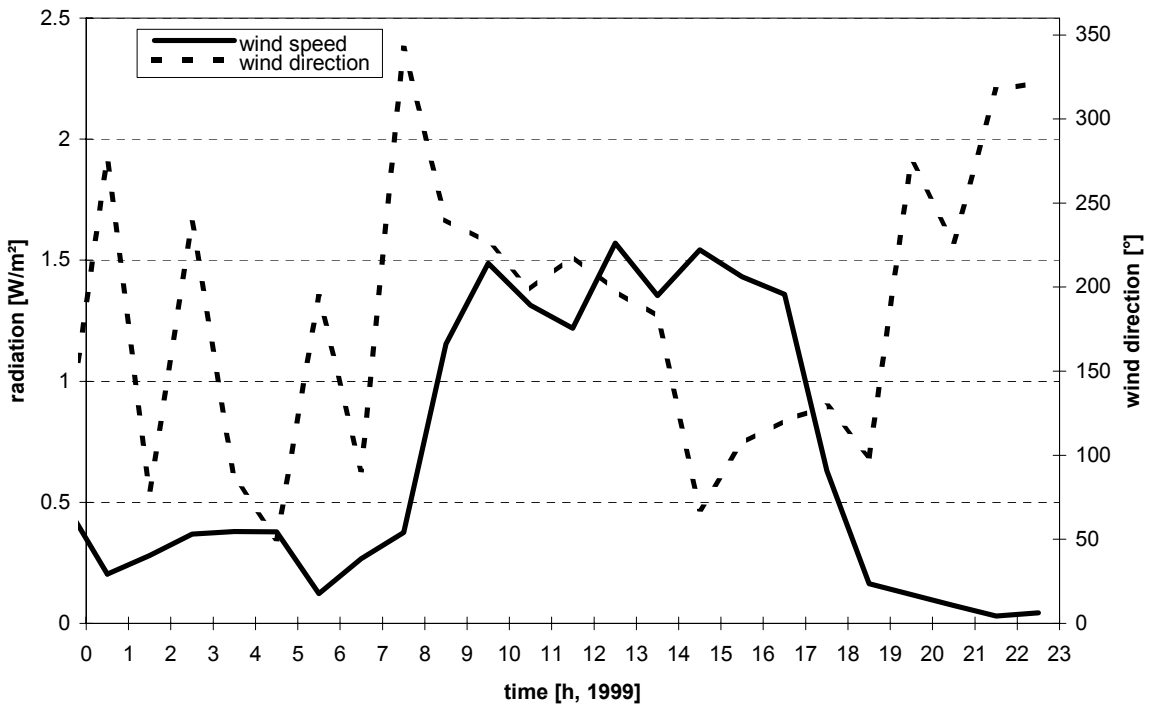
**Kumasi - November
clear day**



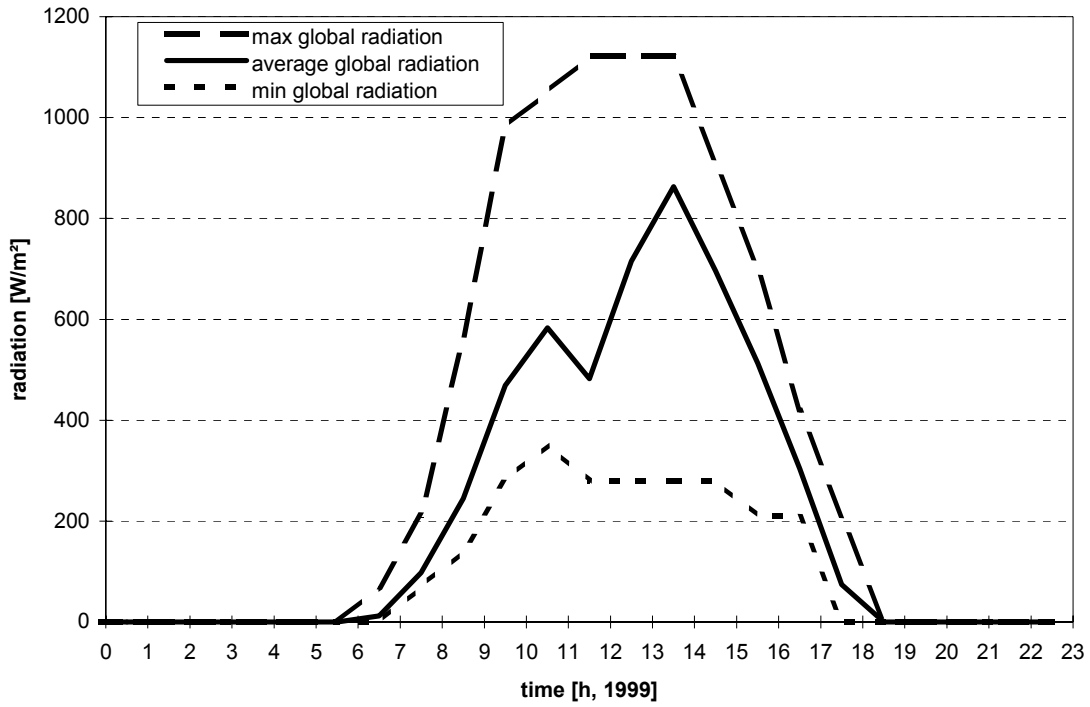
Kumasi - November
average day



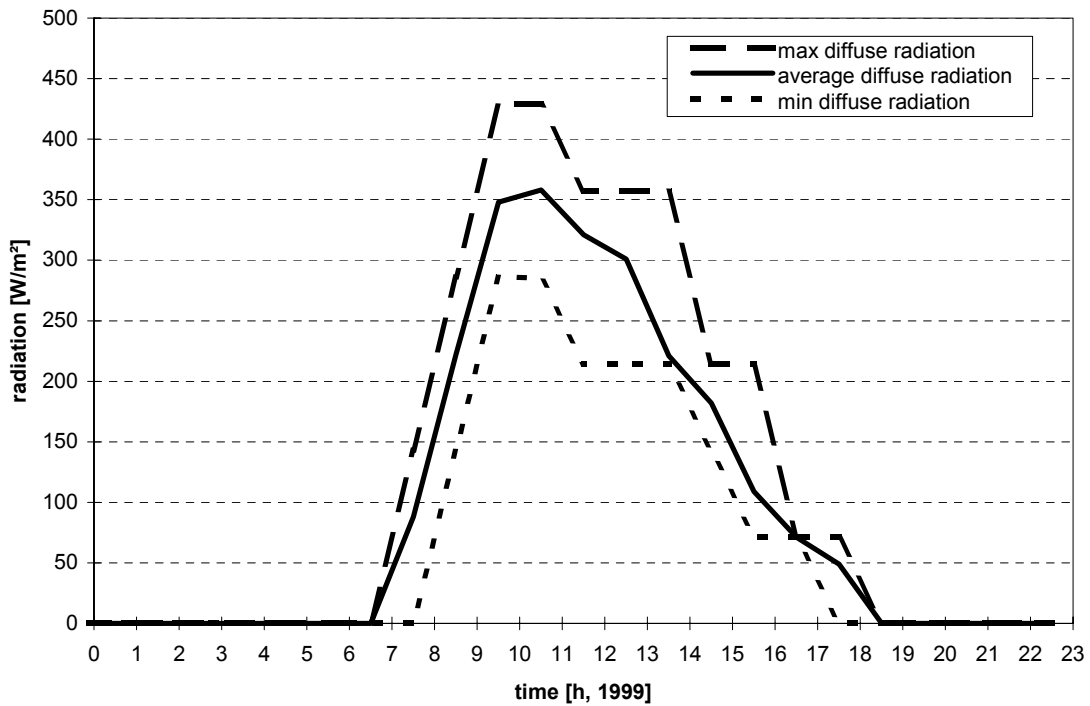
Kumasi - November
average day



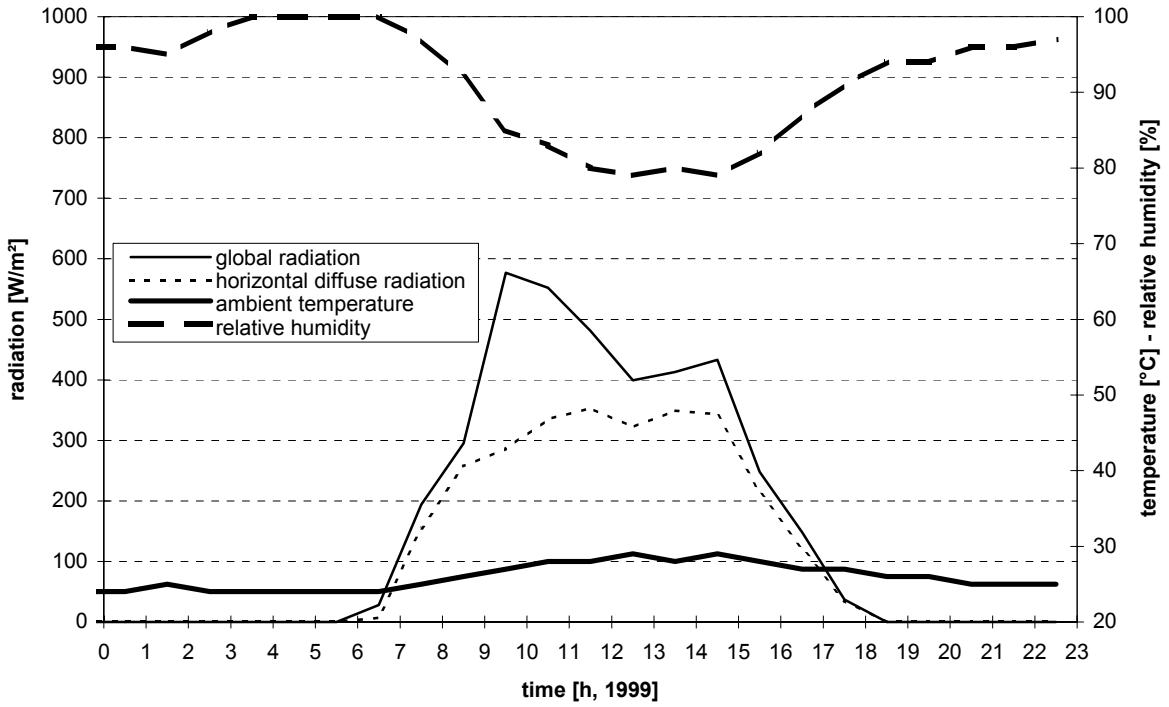
Kumasi - November
average day



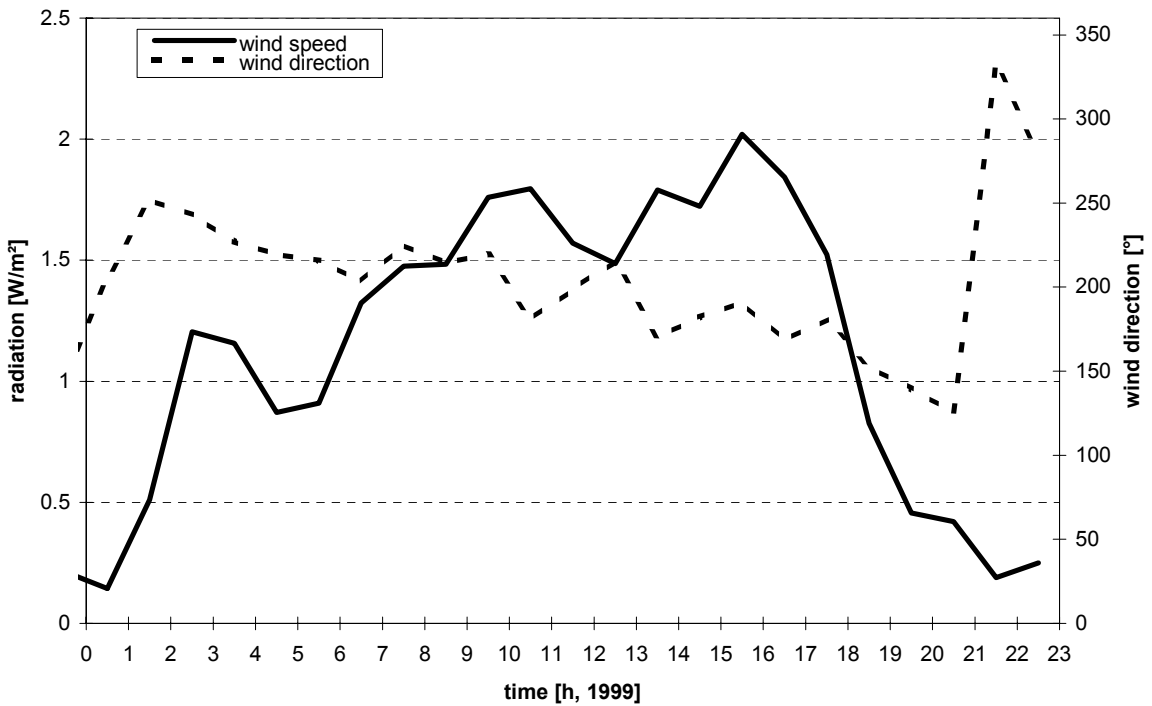
Kumasi - November
average day



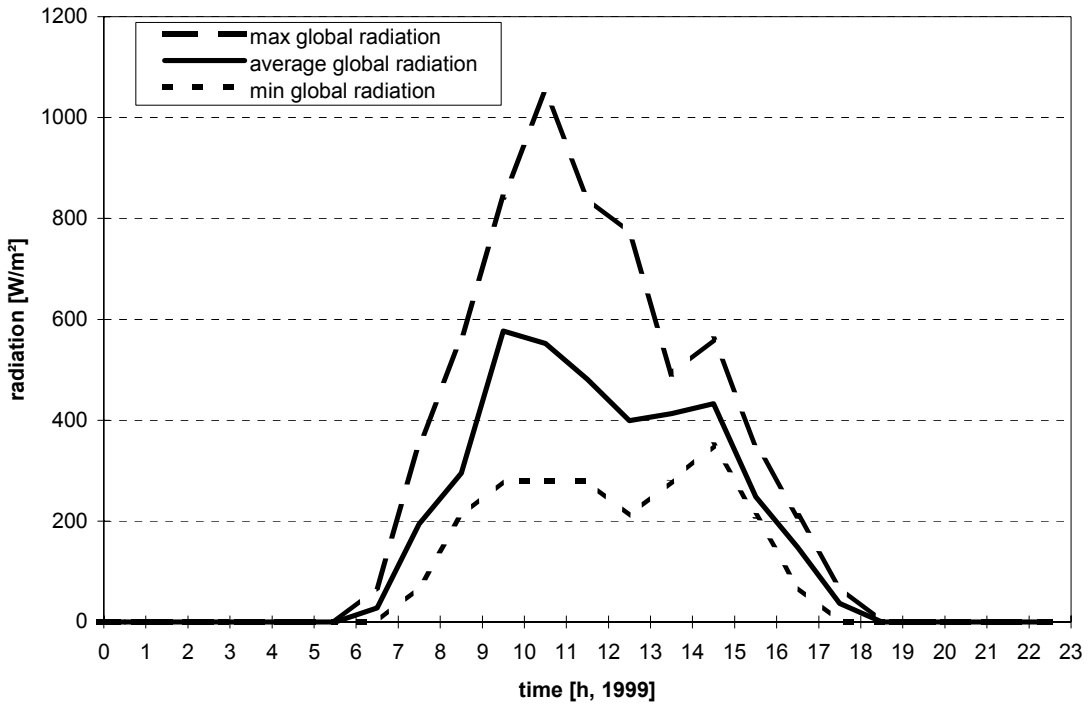
Kumasi - November
overcast day



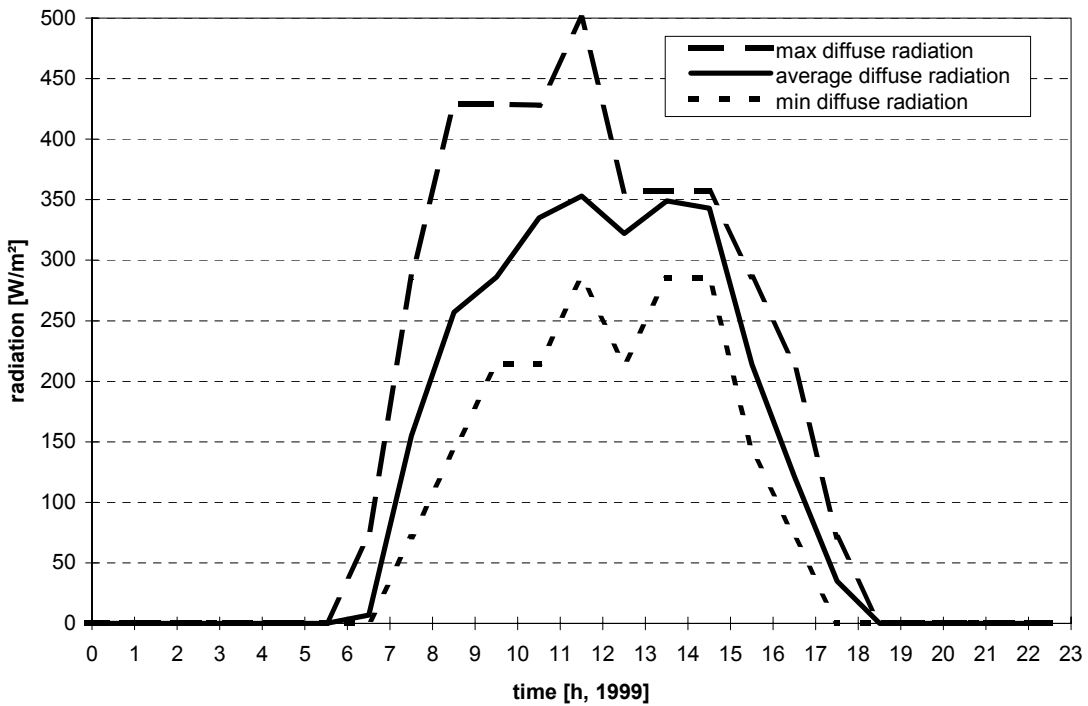
Kumasi - November
overcast day



Kumasi - November
overcast day

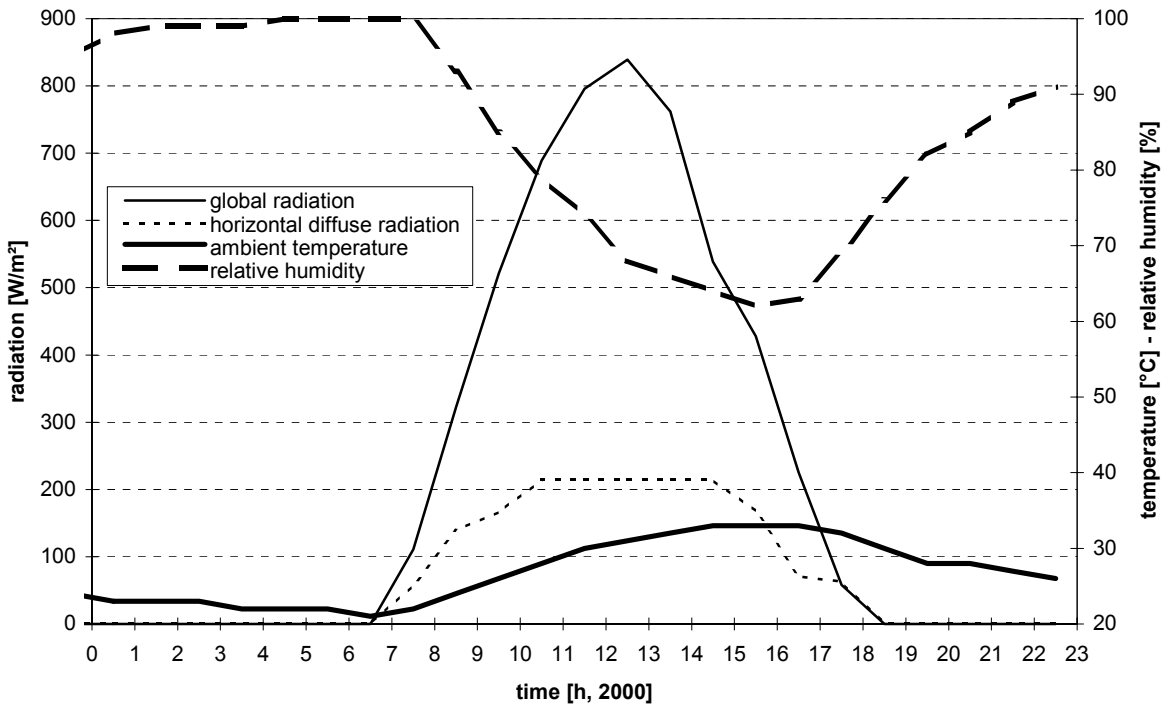


Kumasi - November
overcast day

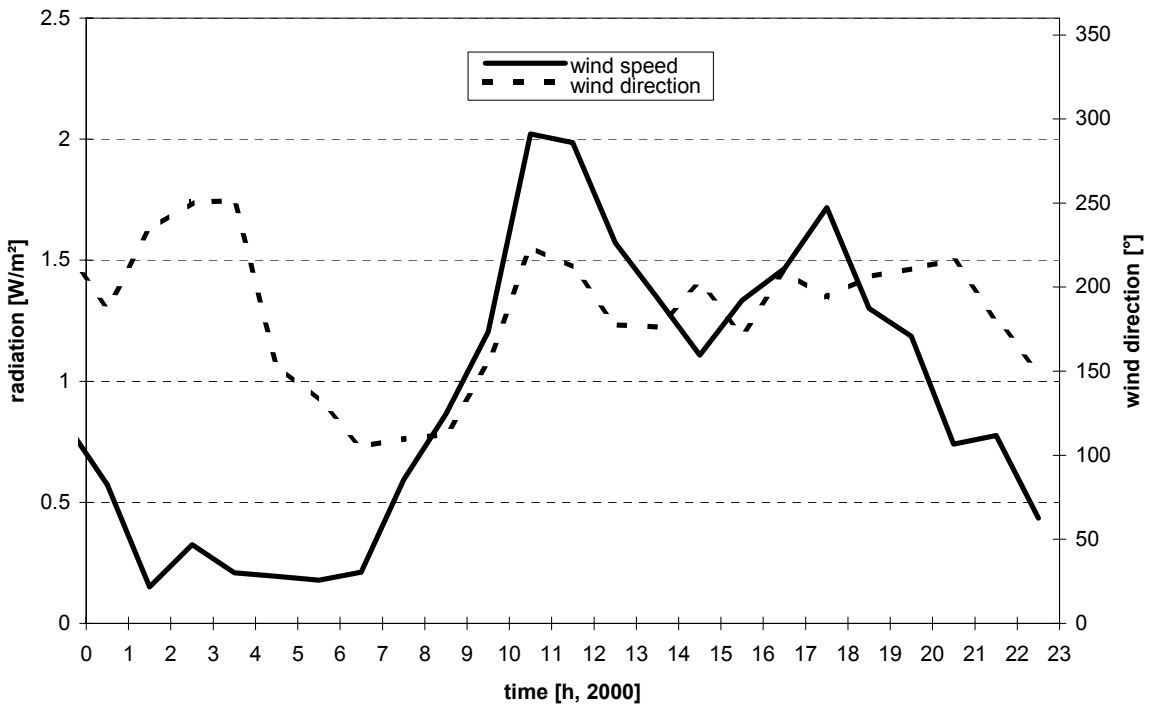


Appendix H
Measured weather data
for Kumasi
three days in January 2000

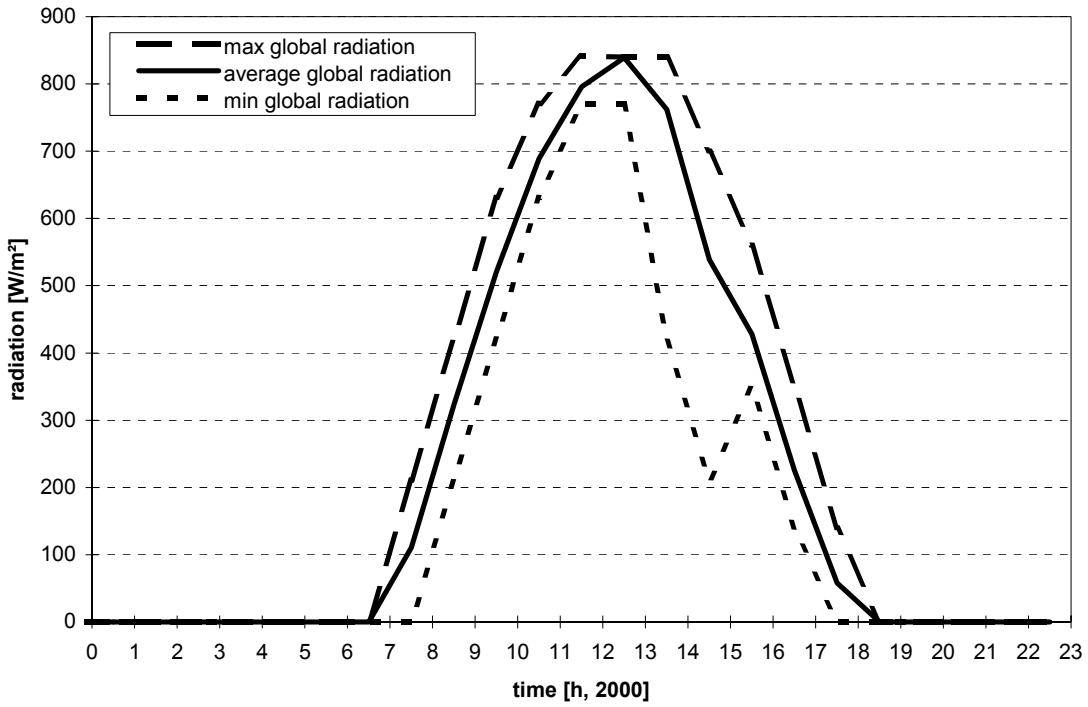
Kumasi - January
clear day



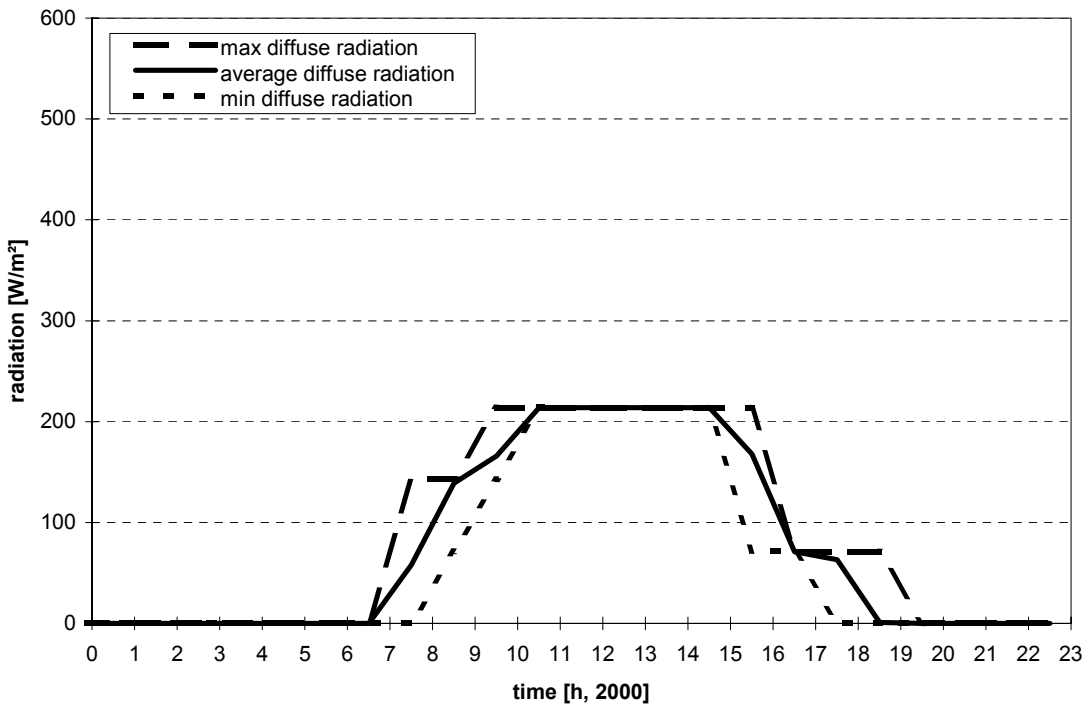
Kumasi - January
clear day



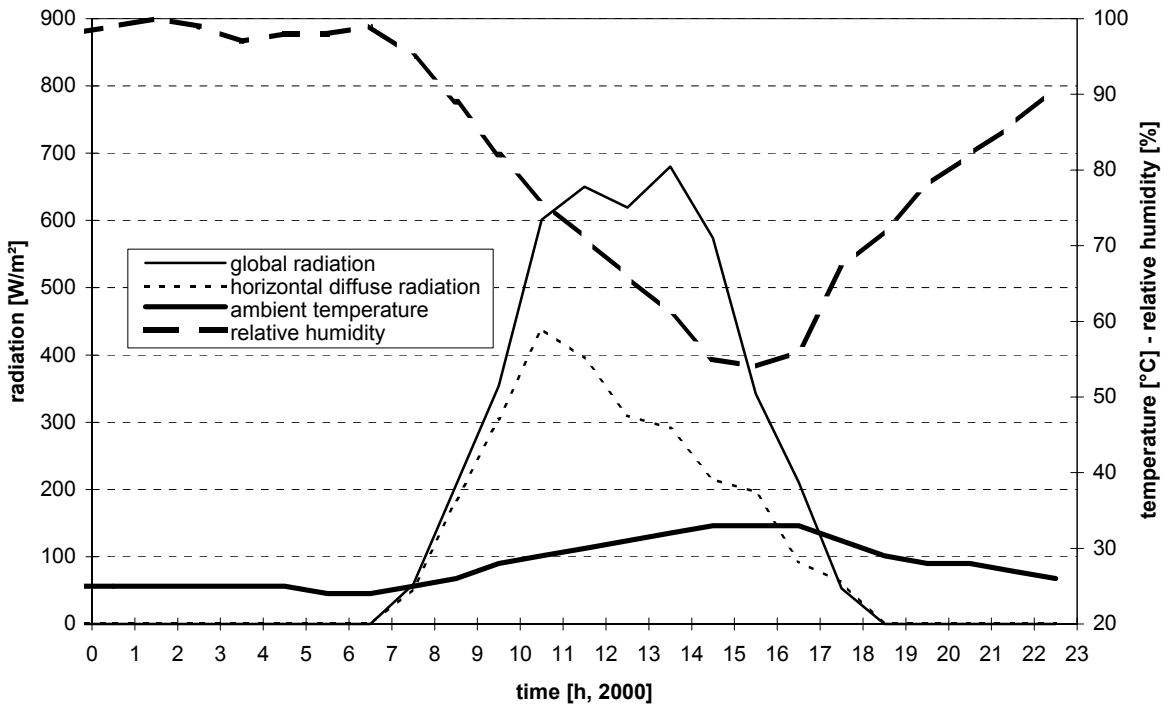
Kumasi - January
clear day



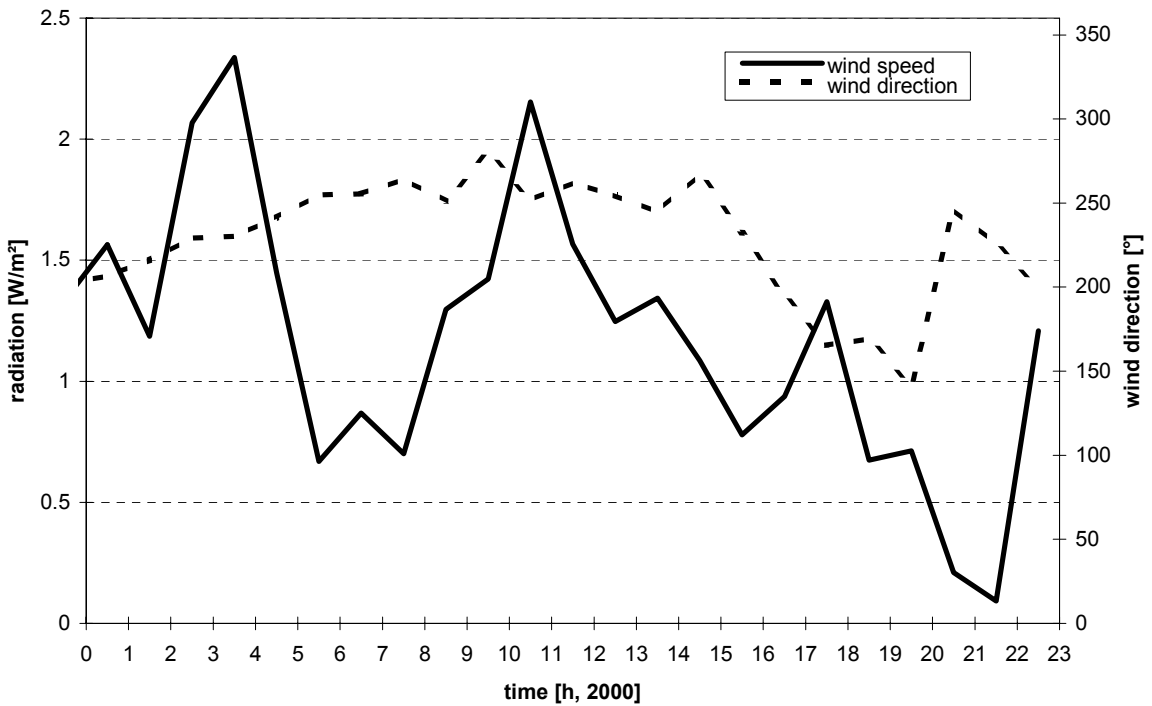
Kumasi - January
clear day



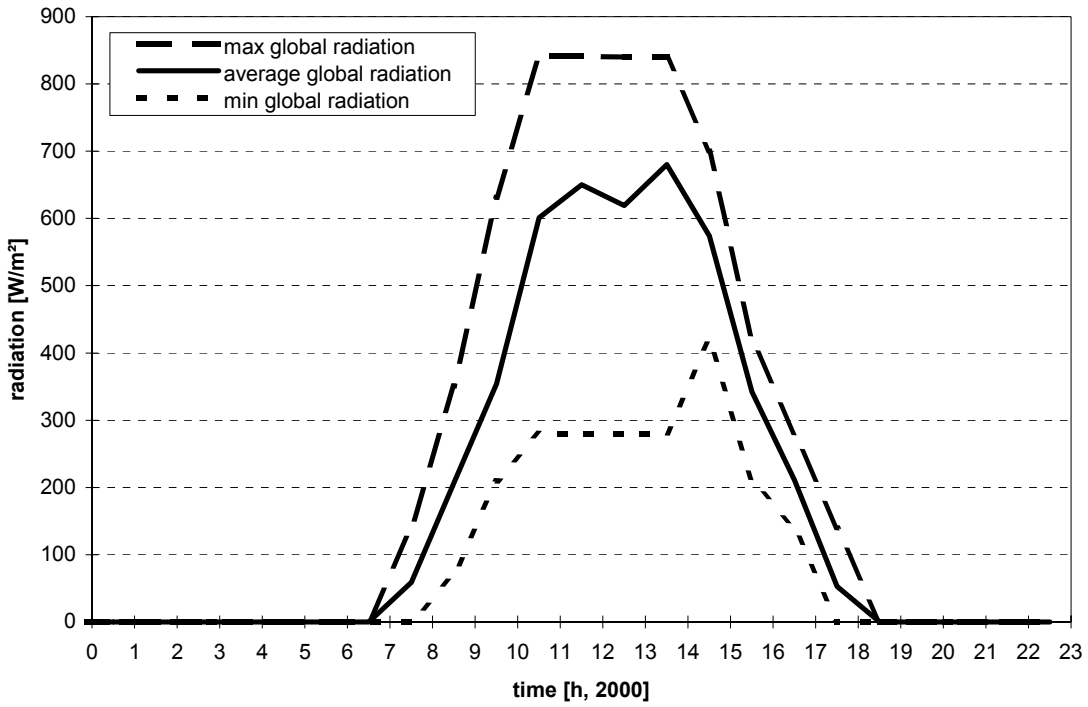
Kumasi - January
average day



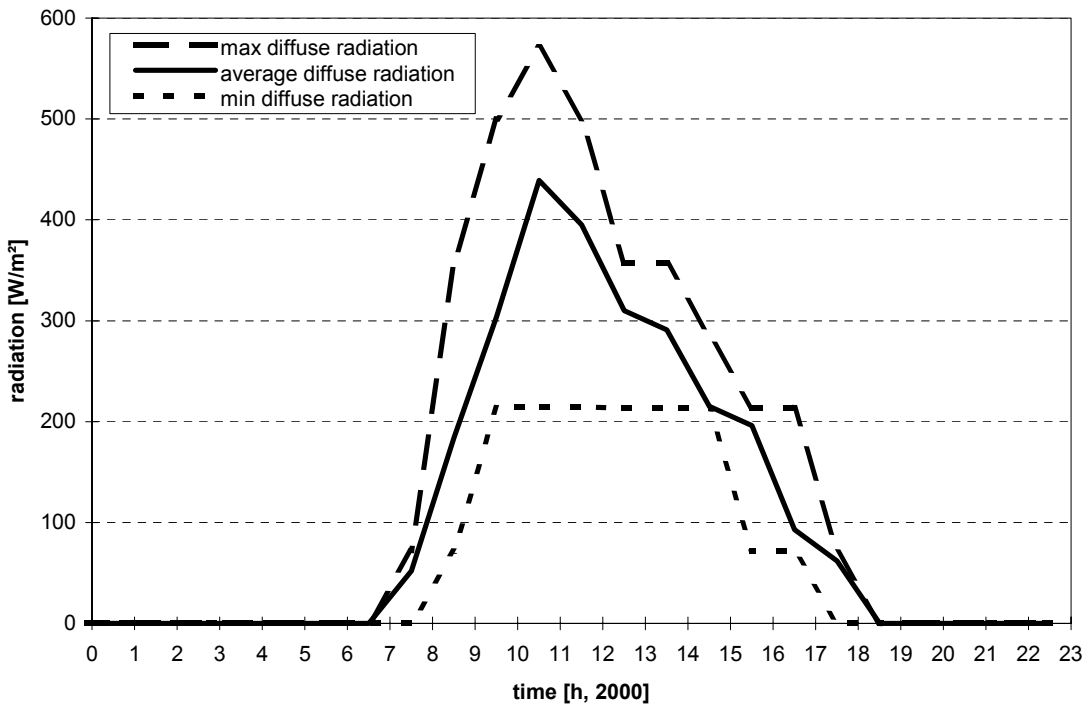
Kumasi - January
average day



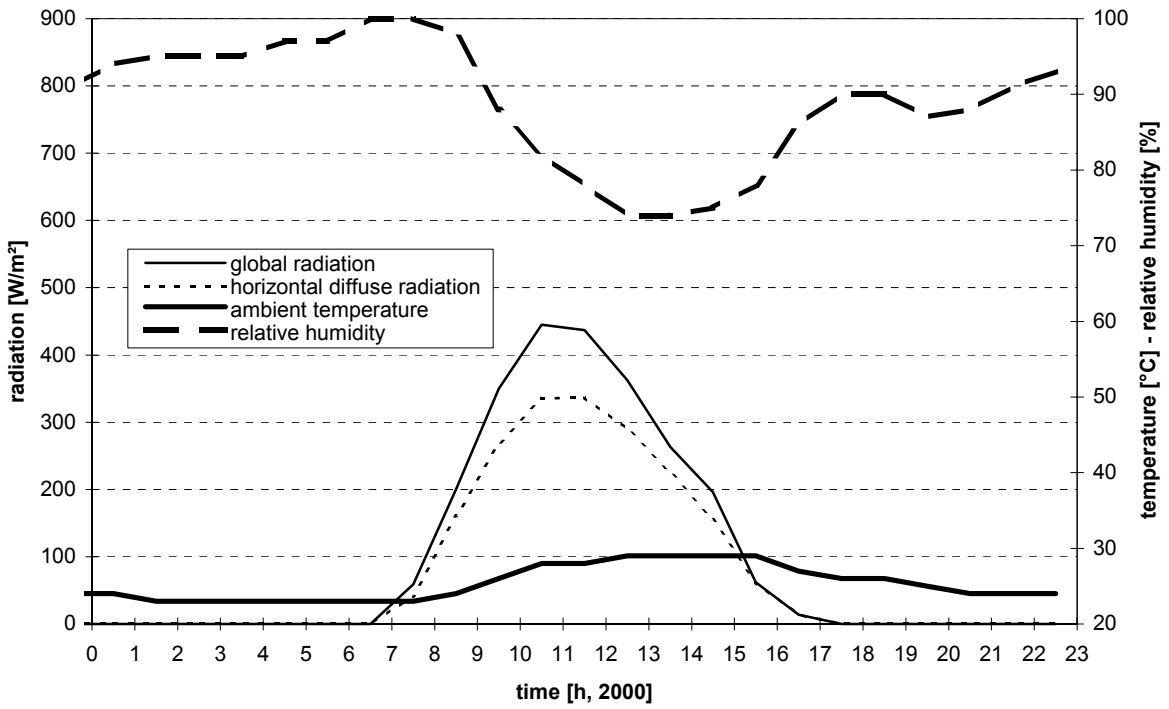
Kumasi - January
average day



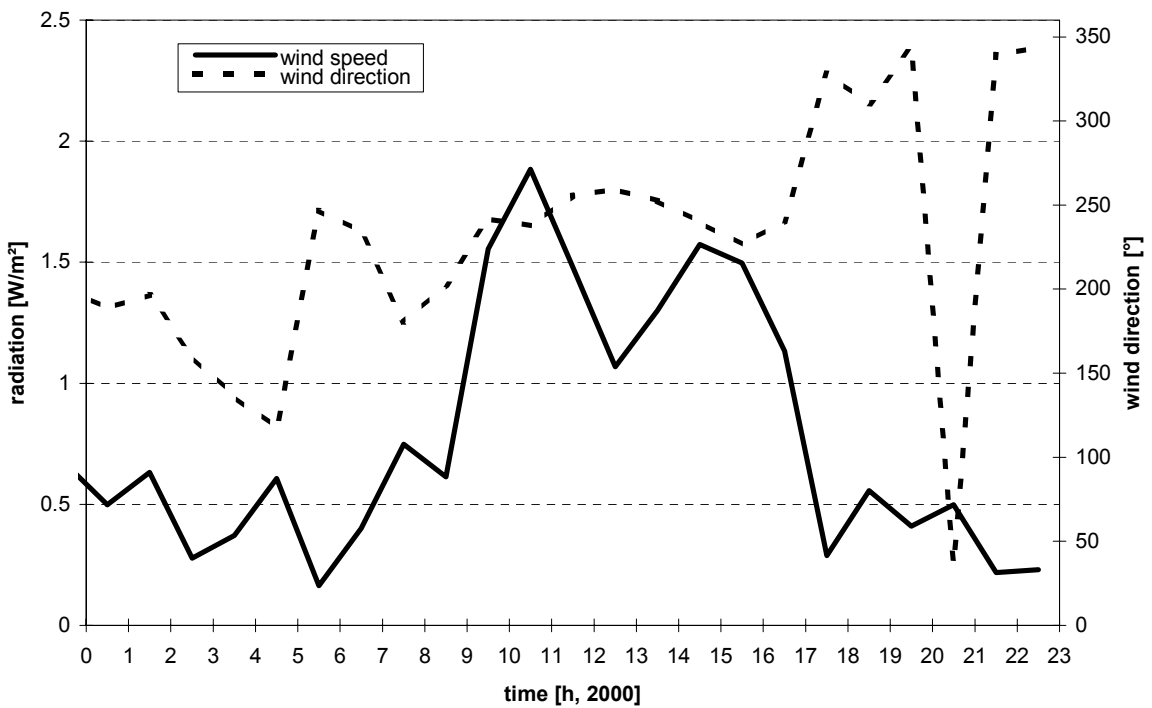
Kumasi - January
average day



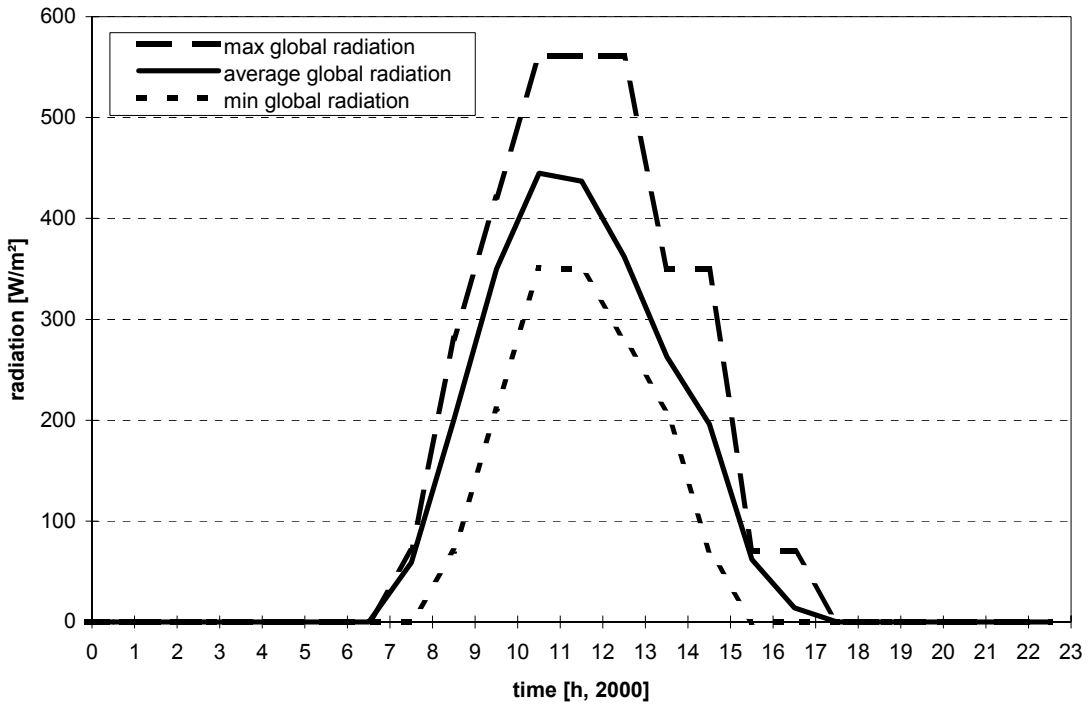
Kumasi - January
overcast day



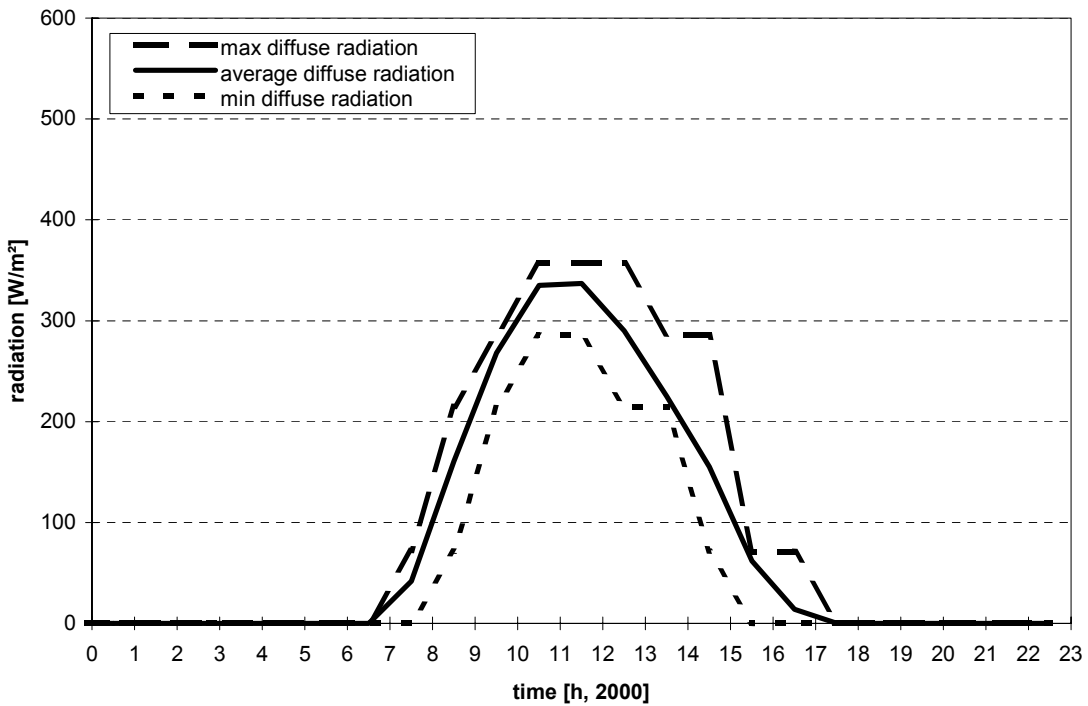
Kumasi - January
overcast day



Kumasi - January
overcast day

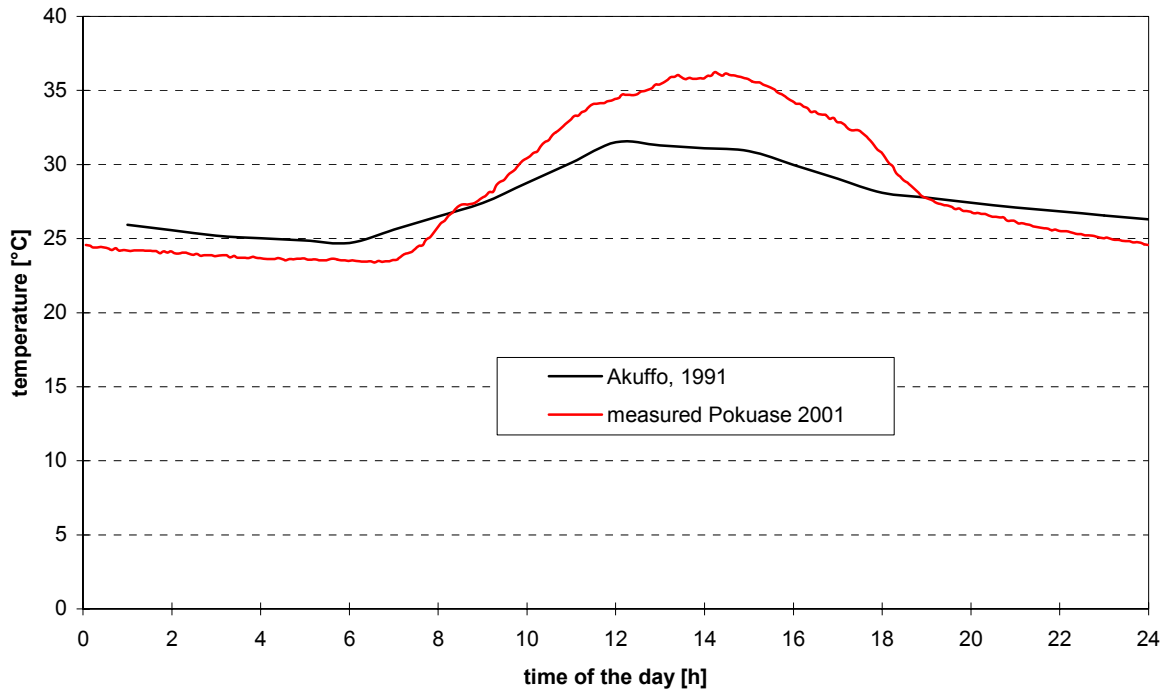


Kumasi - January
overcast day

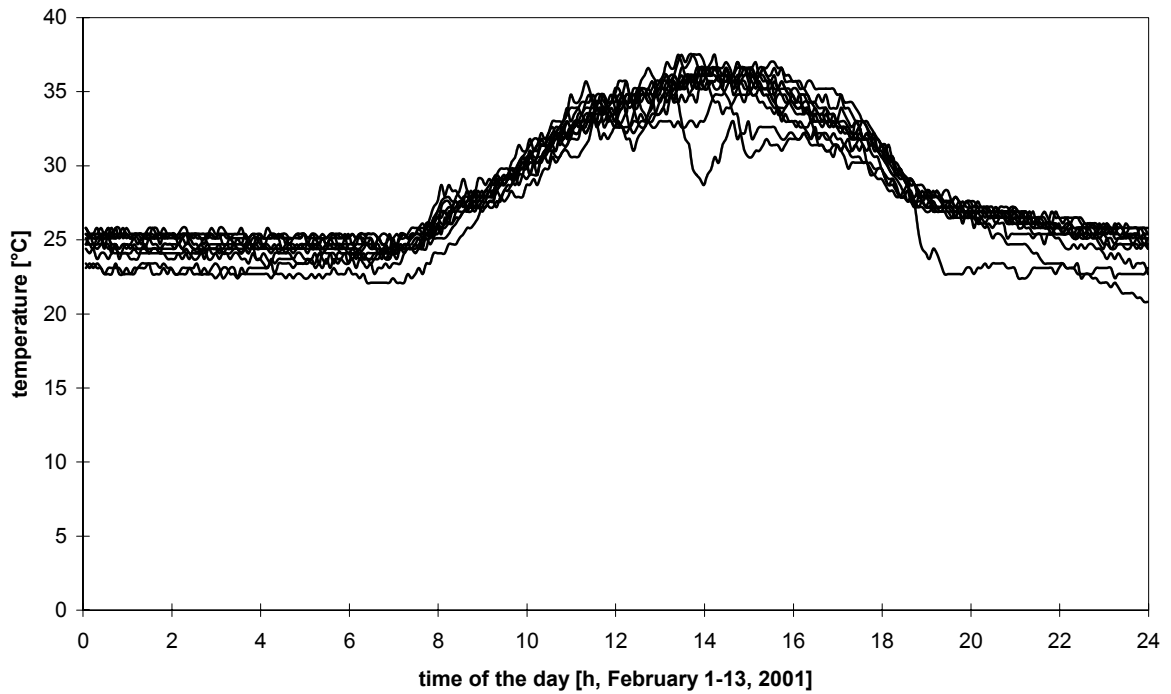


Appendix I
Measured weather data
for Pokuase
February 2001

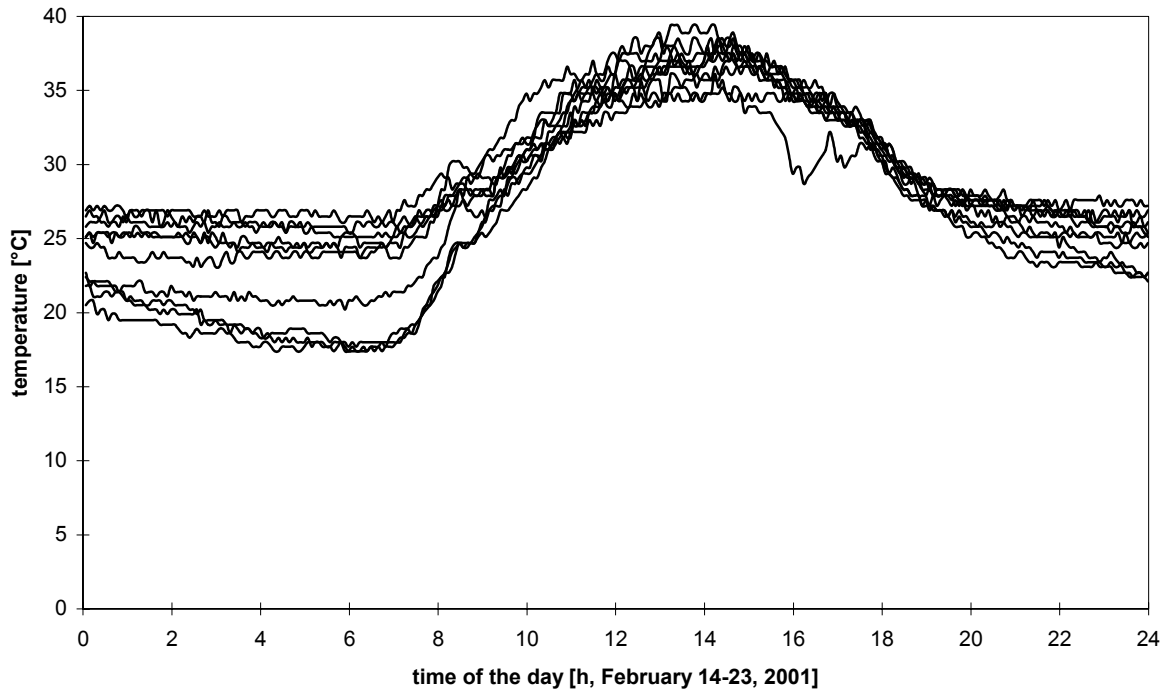
**Ambient temperature - Pokuase/Accra
Februar**



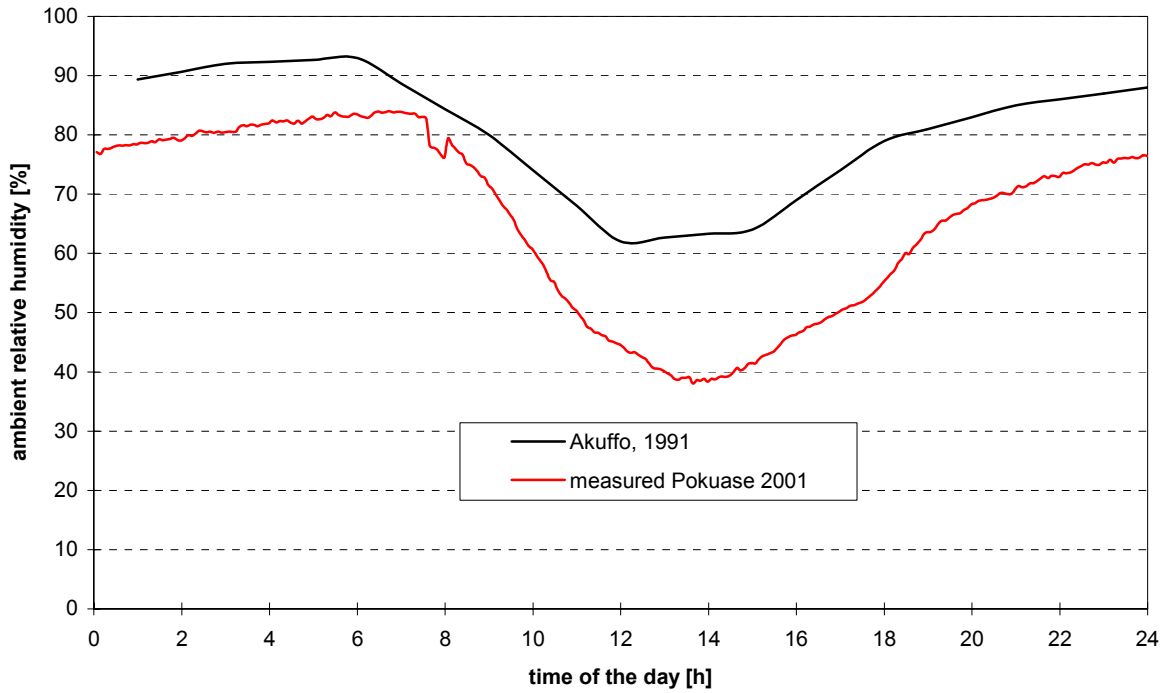
**Pokuase
ambient temperature over the day - Februar**



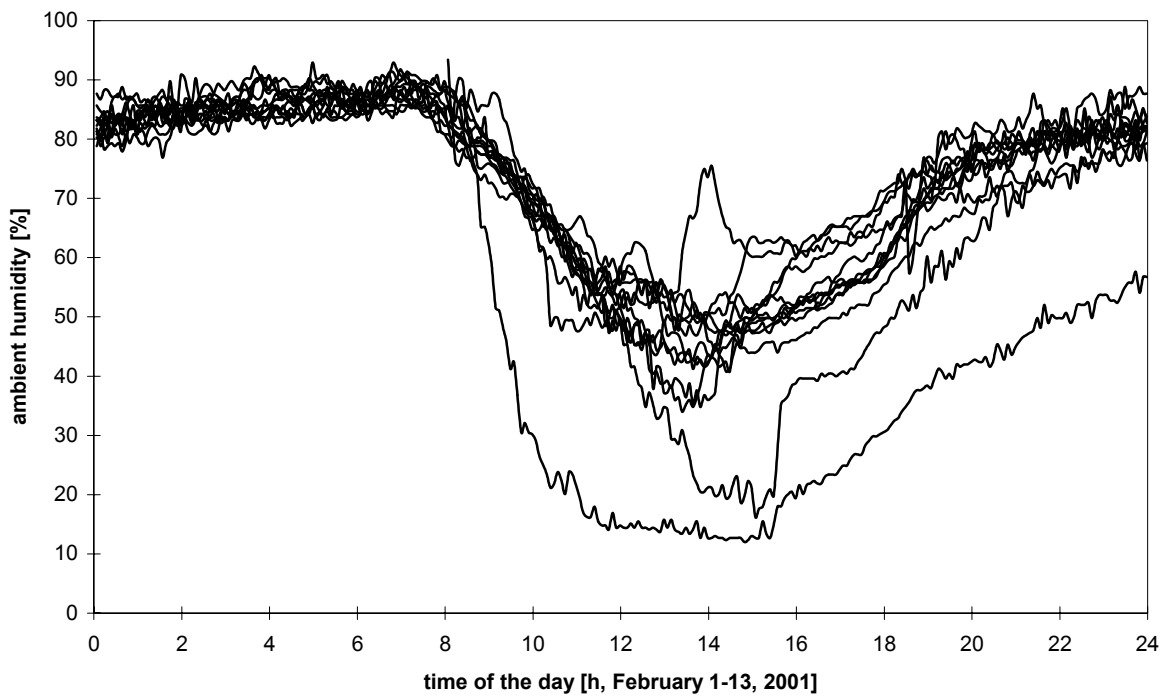
Pokuase
ambient temperature over the day - Februar



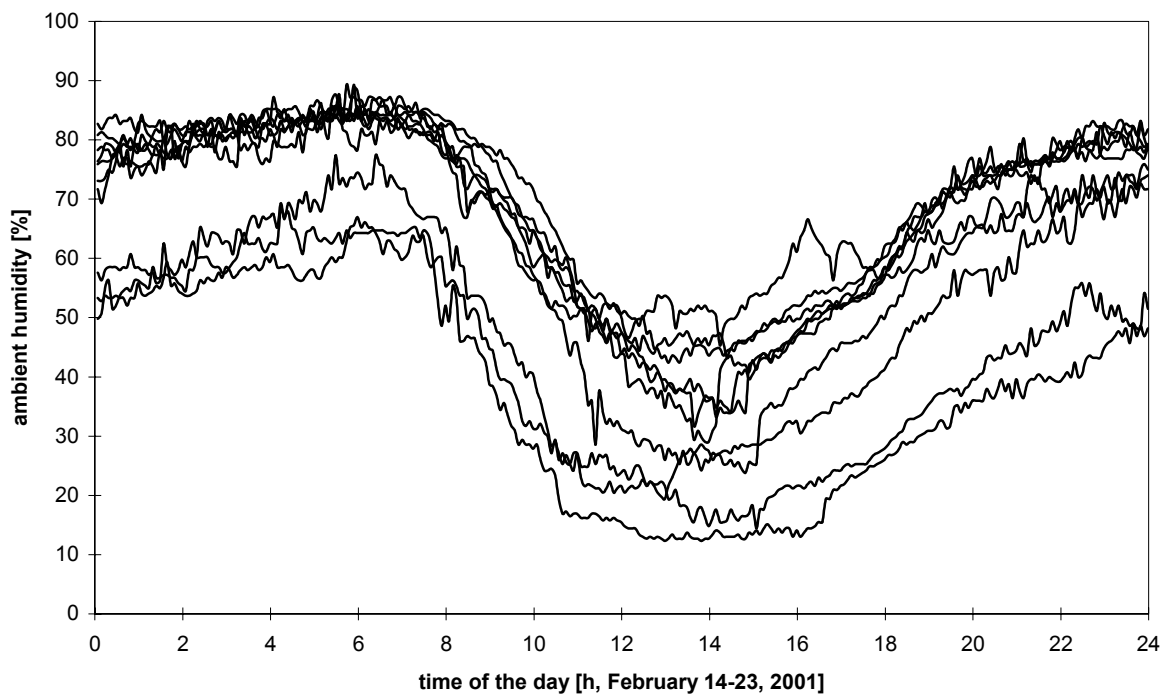
Relative humidity - Pokuase/Accra
Februar



Pokuase
ambient humidity over the day - Februar

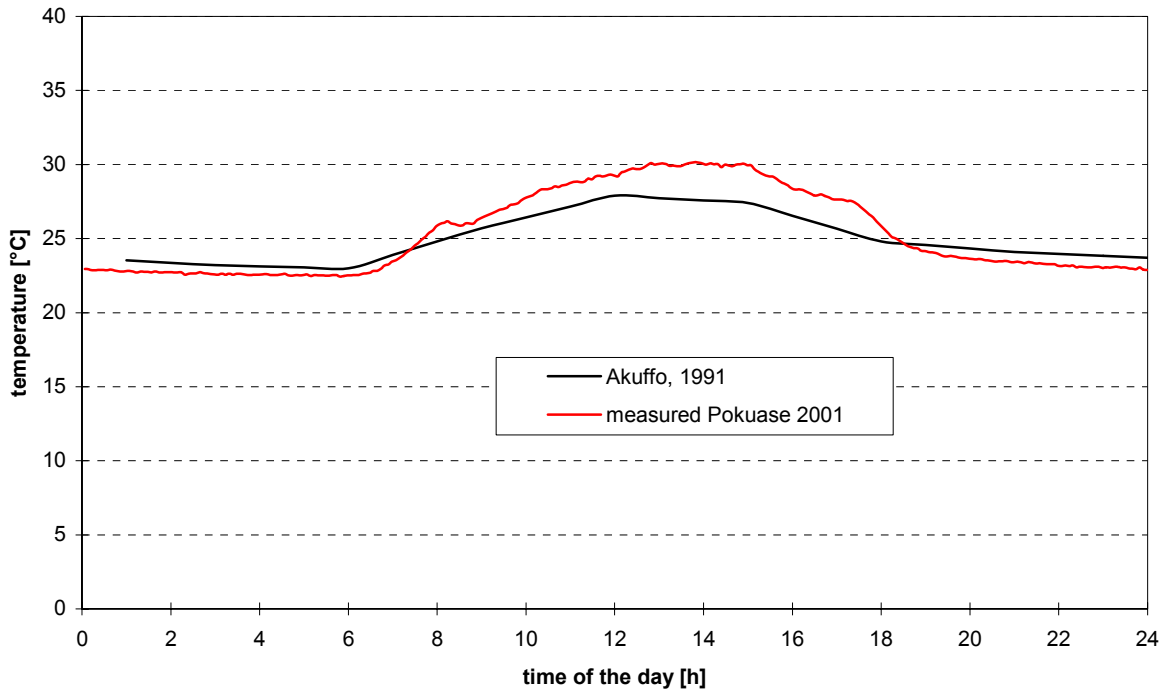


Pokuase
ambient humidity over the day - Februar

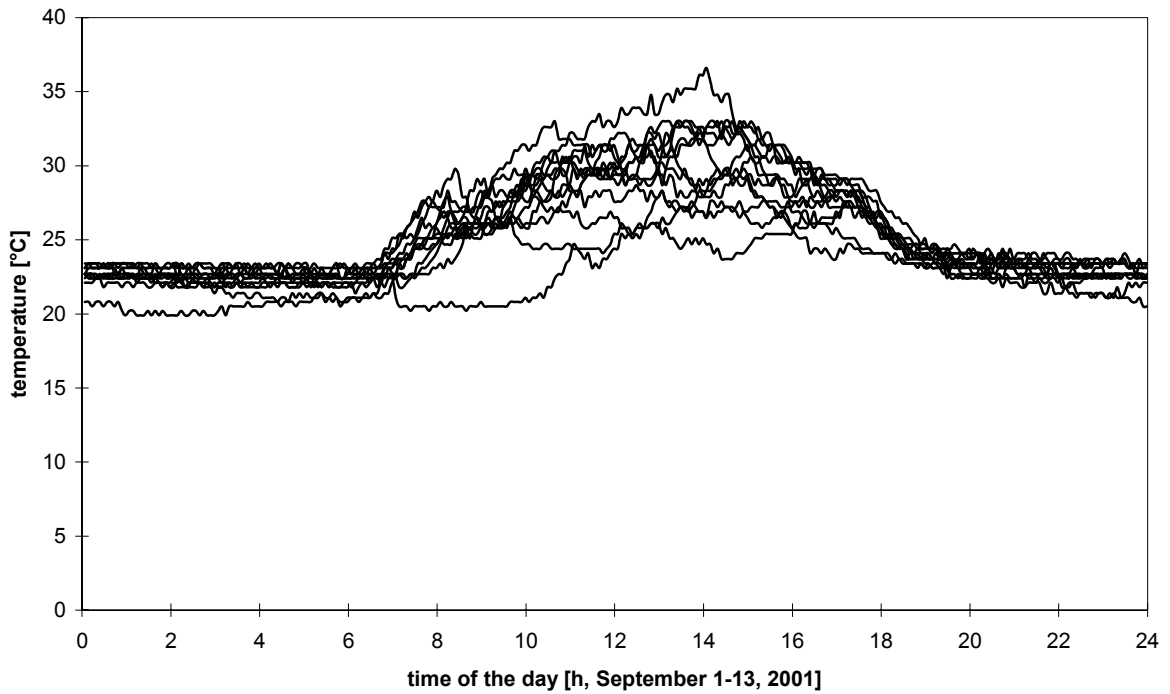


Appendix J
Measured weather data
for Pokuase
September 2001

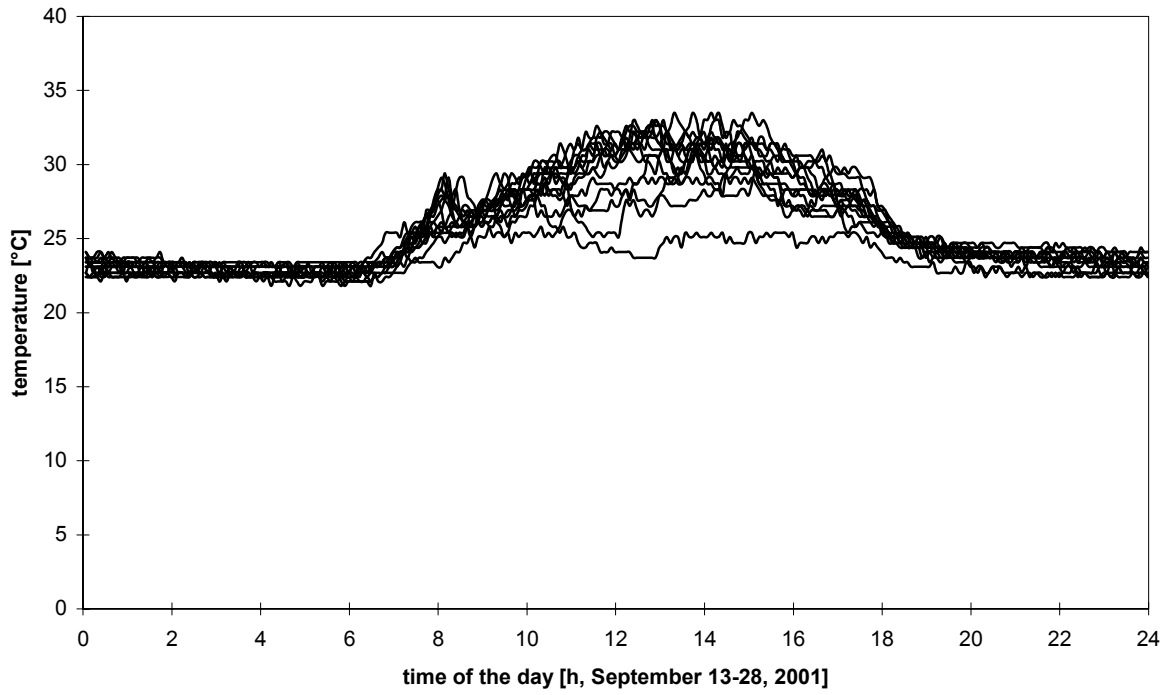
Ambient temperature - Pokuase/Accra September



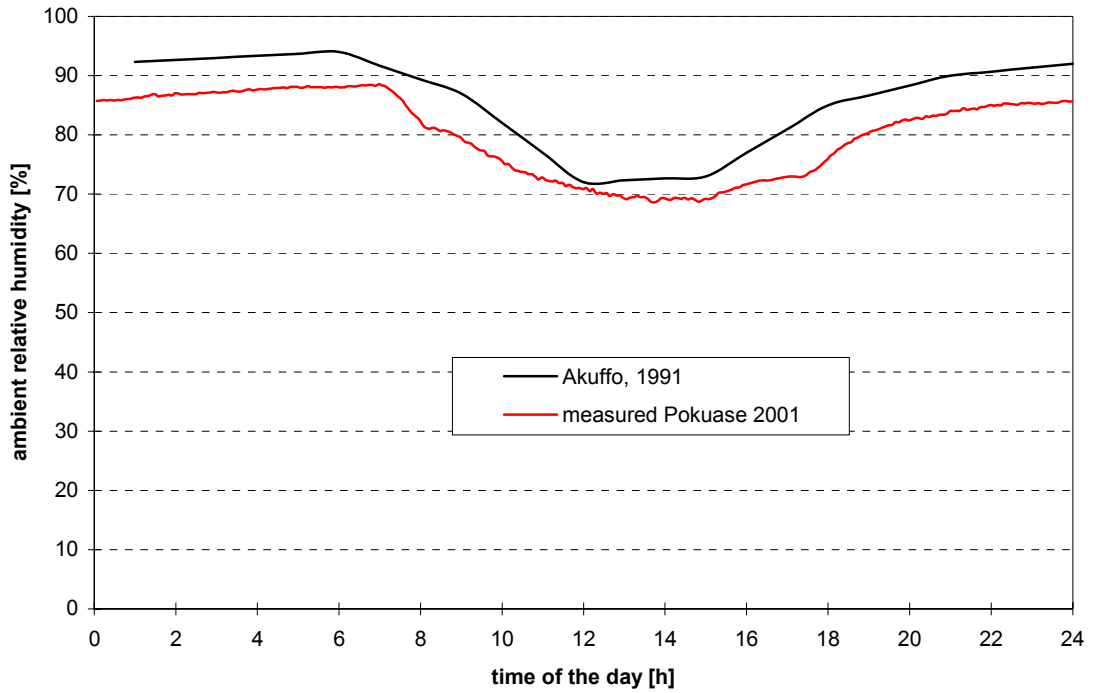
Pokuase ambient temperature over the day - September



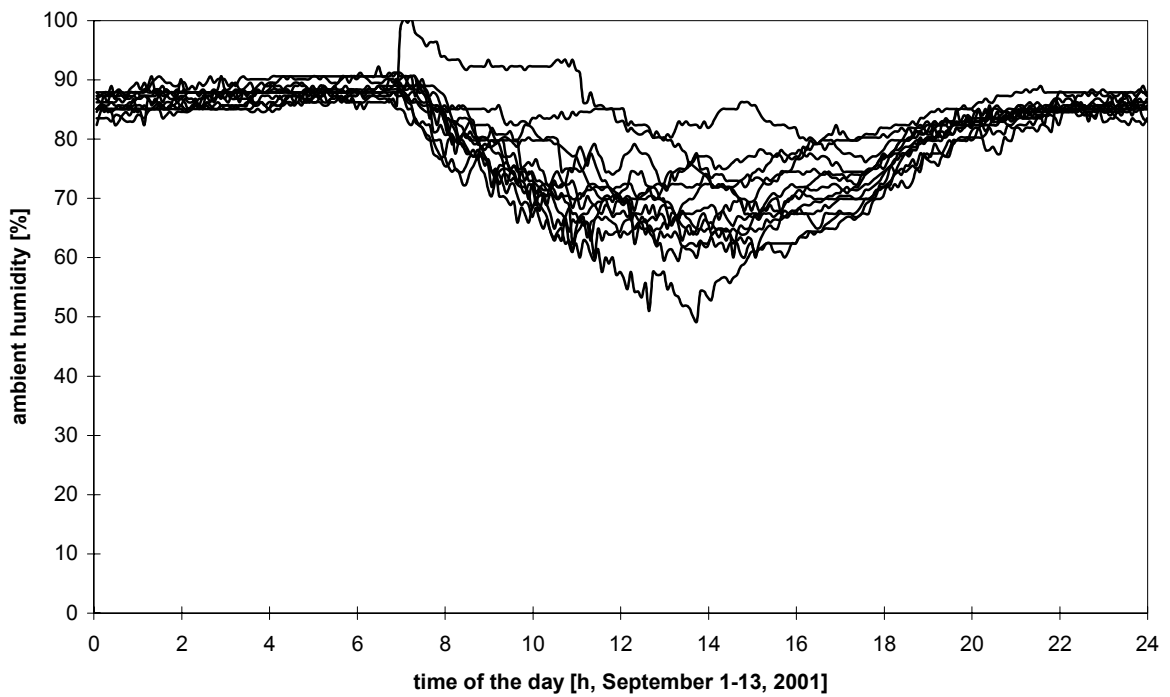
Pokuase
ambient temperature over the day - September



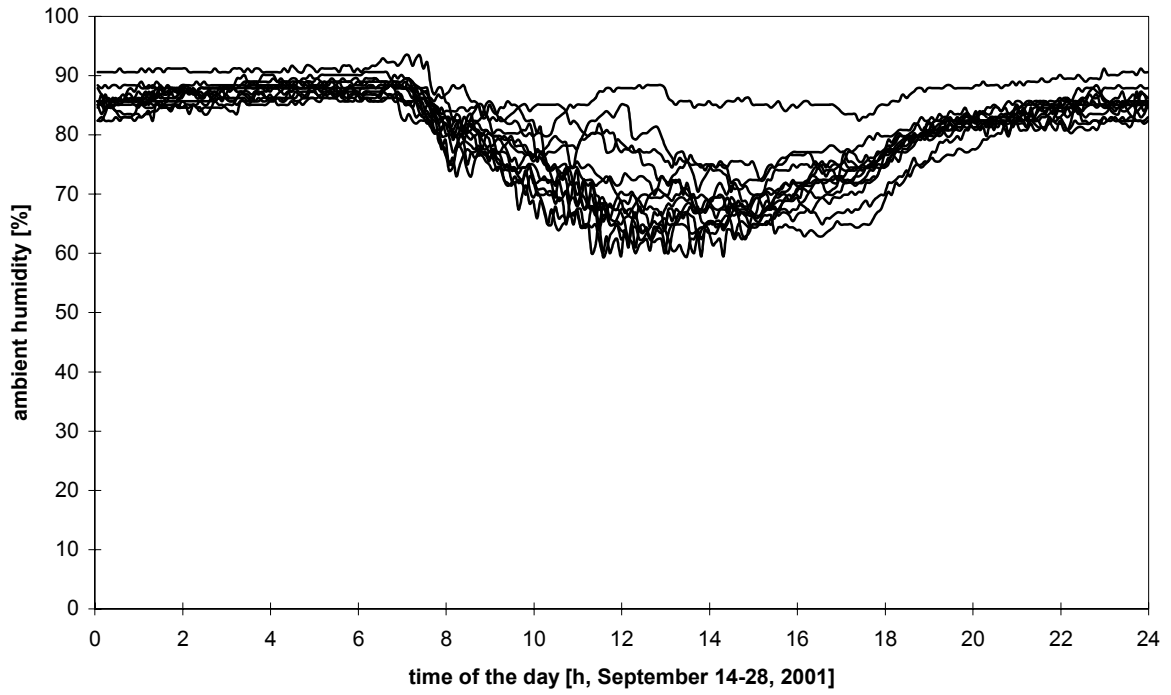
Relative humidity - Pokuase/Accra
September



Pokuase
ambient humidity over the day - September

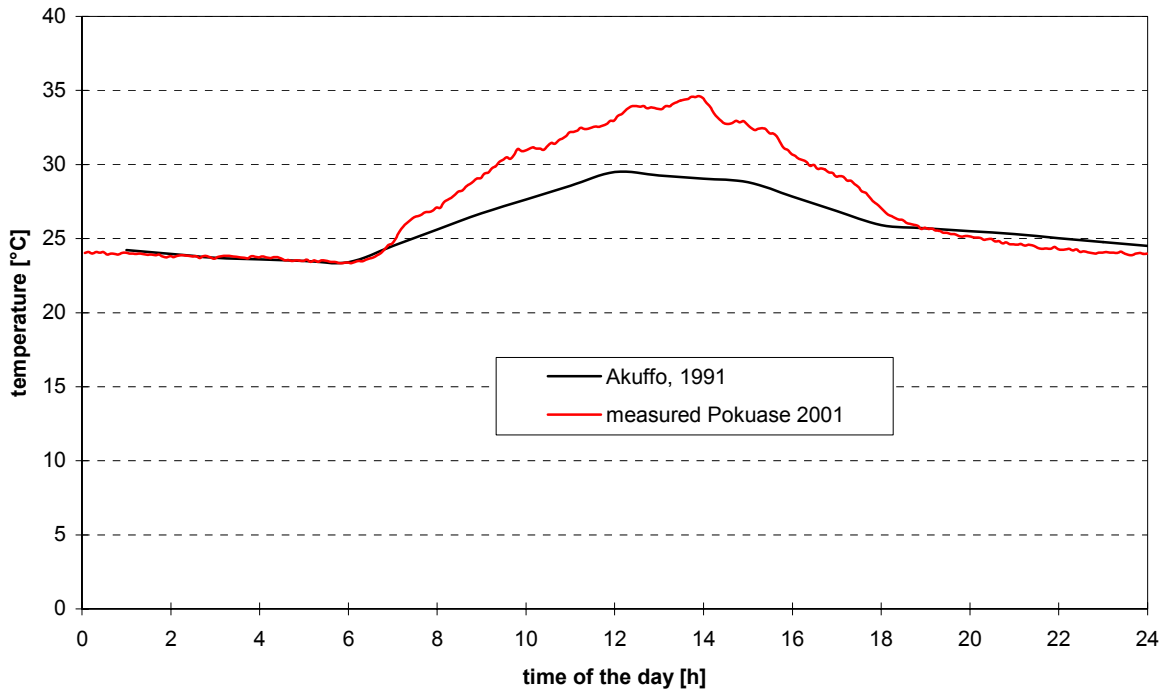


Pokuase
ambient humidity over the day - September

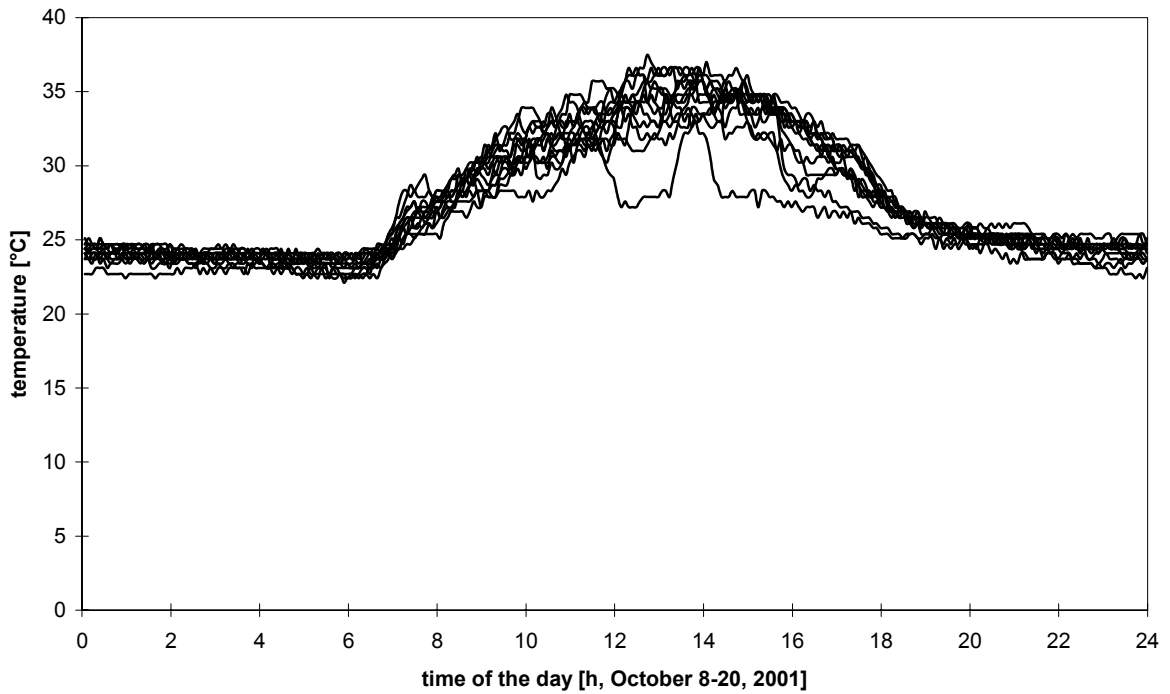


Appendix K
Measured weather data
for Pokuase
October 2001

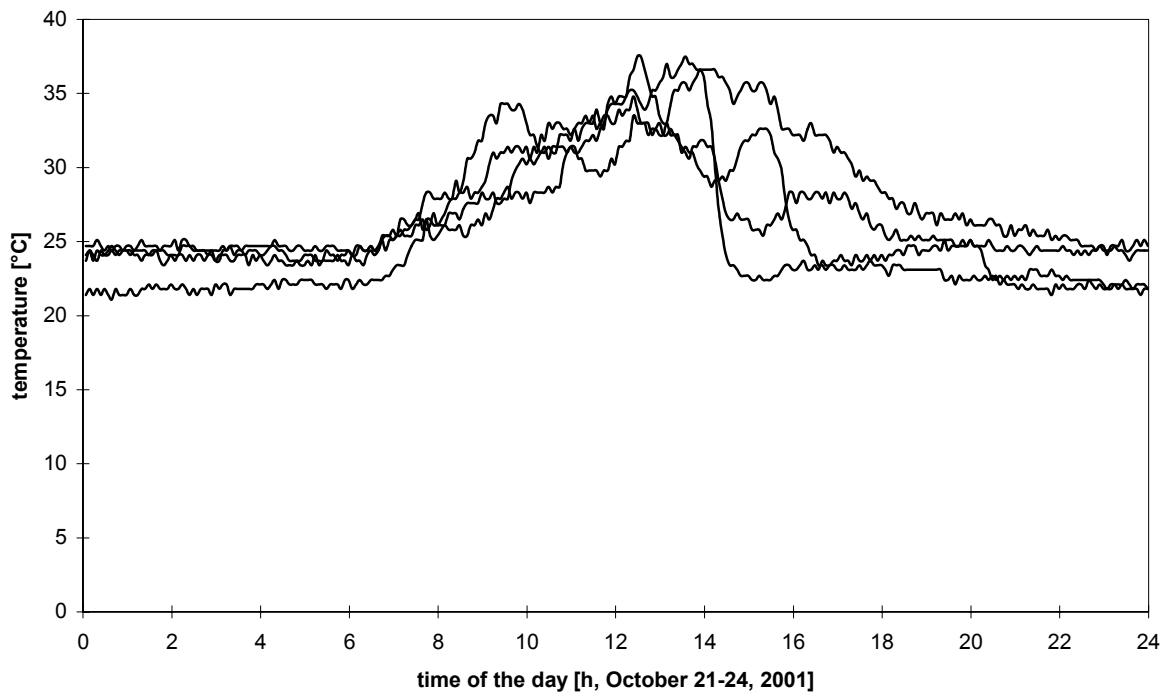
**Relative temperature - Pokuase/Accra
October**



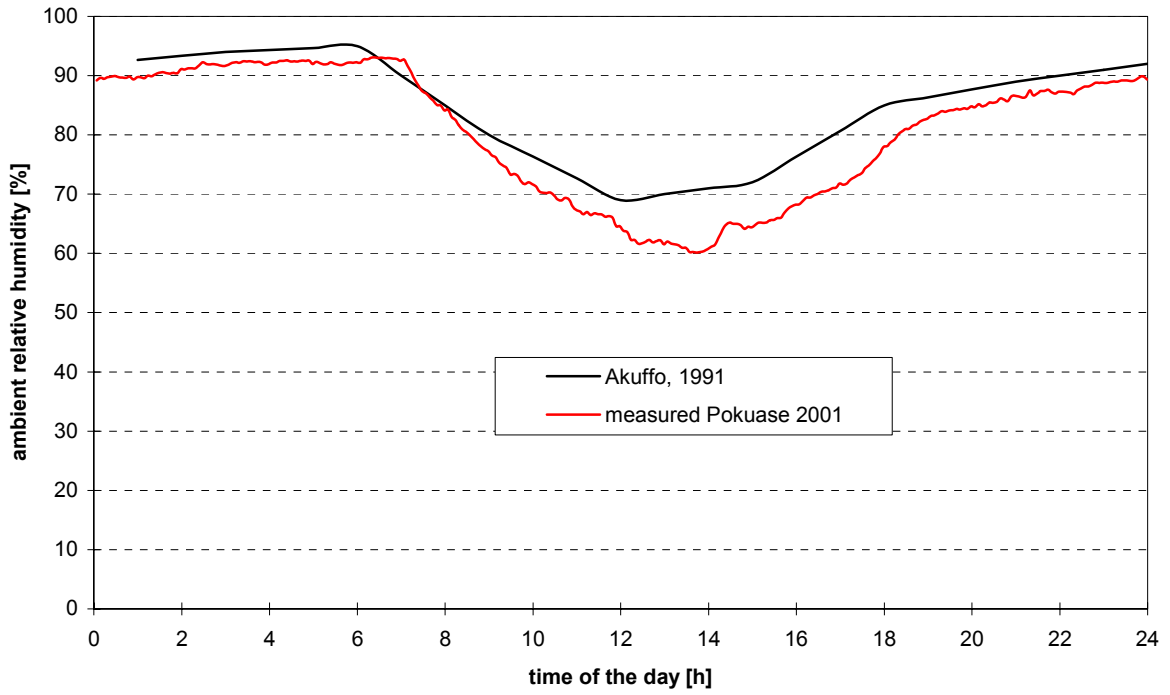
**Pokuase
ambient temperature over the day - October**



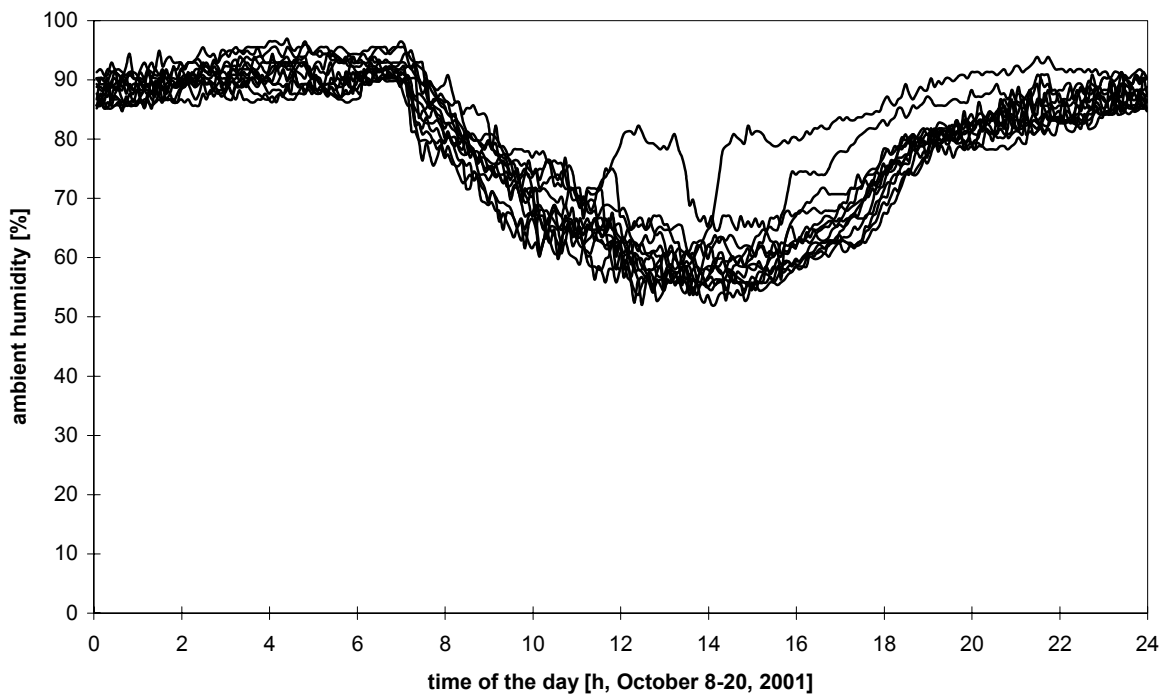
Pokuase
ambient temperature over the day - October



Relative humidity - Pokuase/Accra
October



Pokuase
ambient humidity over the day - October



Pokuase
ambient humidity over the day - October

