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Full Length Research Paper

Daily averages of solar radiation measured at Iju, Nigeria in 2008

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This work presents one year data of global solar radiation flux measured at a humid tropical location in West Africa (Iju, Nigeria; 7.15°N, 5.12°E) for the period 1st January to 31st December, 2008. The collected raw data were analyzed using Origin software and Excel spreadsheet to determine the daily means, daily minima and maxima for the period under consideration. The daily mean for the year was 143.66 ± 11.79 $Wm^{-2}day^{-1}$ while the mean of the daily maximum for the year was 653.42 ± 32.33 $Wm^{-2}day^{-1}$. The daily mean maximum of hourly global solar radiation flux was about 620 Wm^{-2} for the dry season and 430 Wm^{-2} for the wet season. The fluctuations in the daily averages were prominent during the wet season (April to October). The data set showed a double-peak daily mean average of about 200 $Wm^{-2}day^{-1}$ in March and November and a minimum of about 90 $Wm^{-2}day^{-1}$ in July and August.

Key words: Solar radiation, daily averages, Iju, Nigeria, humid tropical.

INTRODUCTION

Solar radiation is the radiant energy emitted by the sun from a nuclear fusion reaction that creates electromagnetic energy and travels through space to the earth surface in short-wave length. It is a major driver for many physical, chemical and biological processes on the earth's surface (Bulut and Buyukalaca, 2007; Sfetsos and Coonick, 2000). Thus, a complete and accurate solar radiation data at a particular location or region are very pertinent to developmental needs of any nation. It is required for many research and application fields such as meteorology, engineering, ecology, agrology, environmental, architecture and climate studies (Wu et al., 2007). Because of its significance, solar radiation data is expected to be measured continuously and accurately over time. However, in most part of the world especially in the developing nations like Nigeria, solar radiation measurements are not readily available due to the cost, technological, institutional limitations and government interests (Chiemeka, 2008). In order to meet the requirement of solar radiation data in the various field, practical methods have been developed for estimating the solar radiation with the help of astronomical and meteorological parameters routinely measured such as the solar elevation angle, sunshine duration hours, wind speed, cloudiness and relative humidity. Models such as remote sensing retrievals, single and multi-layer radiative transfer model and A-P models are also available. Unfortunately, as good as these approaches are, they rely on databases from geographical locations with different conditions to the tropical region. This is because there is a dearth of solar radiation databank more especially at the humid sub-tropics. The sparse radiation data available for the sub-region are from specific projects; for example, HAPEX-Sahel experiment (Goutorbe et al., 1994) and ARG-Ife experiment (Adedokun, 1992; Jegede, 1997) undertaken at very few stations and limited period.

In this paper therefore, efforts are made to make further contribution in the acquisition of solar radiation databank by *in-situ* measurement at a different location in the humid sub-tropical region at Iju, Nigeria (7.15°N, 5.12°E). A report of one year global solar radiation data obtained for the period 1 January to 31 December, 2008 is

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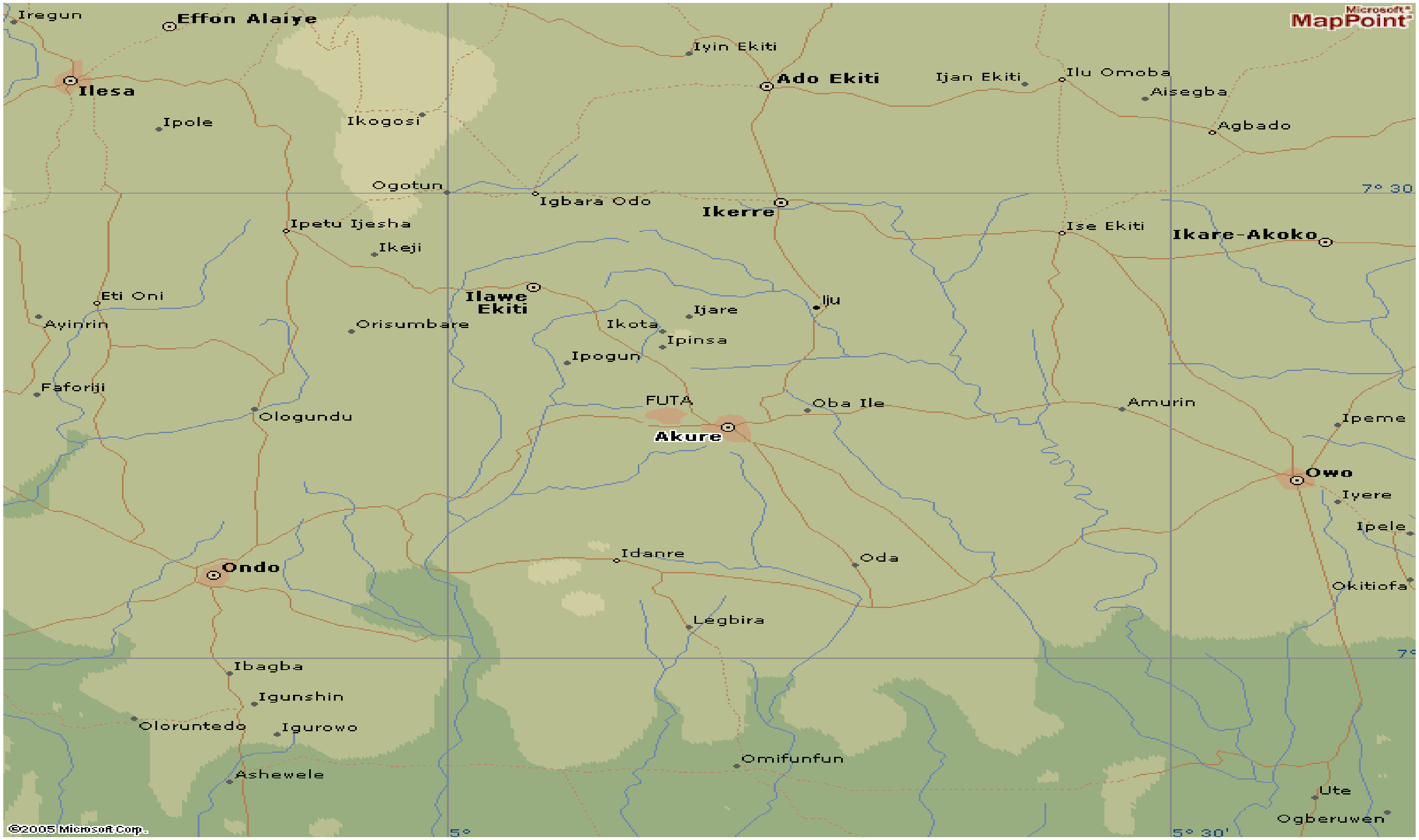

Figure 1. Map of the study location at Iju, Nigeria (7.15^{o}N, 5.12^{o}E).

therefore presented.

METHODOLOGY

The solar radiation data were obtained from the field measurement conducted by the Atmospheric Research Group of the Department of Physics, Federal University of Technology, Akure, at Iju, Nigeria between 10 December, 2007 and 10 January, 2009. The experimental site is located at the abandoned premises of the Nigerian Television Authority (NTA) at Iju in Akure North local government area of Ondo state. It is about 17 km by road away from the city of Akure (Figure 1).

The instrument used for this measurement is the Davis 6162 Wireless Vantage Pro2 (Figure 2), manufactured by Davis Instruments, Hayward, California, USA. The sensor is equipped with the Integrated Sensor Suite (ISS), a solar

Figure 2. Davis 6162 wireless vantage Pro2.

panel (with an alternative battery source) and the wireless console. The console is connected to a computer, through which the stored data are downloaded. The ISS houses the sensors for the solar radiation, atmospheric pressure, air temperature, and relative humidity including the sensor interface module (SIM). The SIM contains electronics that measure and store values of weather variables for transmission to the console via radio. The solar radiation measured (global solar radiation expressed in Wm^{-2}) is a measure of the intensity of the sun's radiation reaching a horizontal surface. This irradiance includes both the direct component from the sun and the reflected component from the sky. The measurement covers 24 h each day beginning from 00 h local time (LT) and for a time interval of 30 min. The data was then transmitted by wireless radio connection to the data logger. The data were then imported to Origin software and Excel spreadsheet to determine the mean, minima and maxima daily values for the radiation. A more detailed description of the experiment is contained in the study of Adediji et al. (2007).

RESULTS AND DISCUSSION

The daily mean, the maximum (daytime) and minimum (night-time) values of the global solar radiation measured at Iju station during January to December 2008 are presented in Table 1. The solar radiation data set has been processed with a great deal of care. Of the presented data for the year 2008, only seven days (April 7 to 10 and 19 to 21 December) data were missing of the 366 days. This gives us a data loss of less than 2%, so we have a consistent data-logging process. For the period, the mean of the daily averages was 143.66 ± 11.79 Wm^{-2} day^{-1}. The mean of the daily maximum in the year was 653.42 ± 32.33 $Wm^{-2}day^{-1}$. The night time minima were all zeros. This is obvious since there is no

Table 1. Daily mean and maximum values of solar radiation (Wm^{-2}) at Iju, Nigeria in 2008.

Day	Mean	Maximum	Day	Mean	Maximum
1	117.49	461	41	173	700
2	126.83	675	42	175.48	699
3	138.85	653	43	183.96	764
4	126.92	639	44	183.31	731
5	99.13	520	45	165.79	660
6	67.56	355	46	160.54	651
7	97.56	405	47	152.6	575
8	153.79	683	48	154.52	596
9	121.35	492	49	175.67	695
10	136.13	627	50	186.77	748
11	134.69	595	51	151.35	582
12	119.63	611	52	136.21	519
13	121.83	635	53	149.31	541
14	95.54	452	54	151.08	601
15	109.58	531	55	142.27	543
16	103.79	502	56	117.75	539
17	148.08	590	57	120.58	523
18	140.33	611	58	149.77	639
19	122	521	59	133.98	544
20	124.52	490	60	198.84	584
21	146.58	578	61	123.3	571
22	159.81	728	62	129.77	662
23	158.21	681	63	163.5	698
24	164.4	674	64	162.06	642
25	141.46	609	65	155.6	610
26	159.26	661	66	134.1	728
27	168.5	678	67	156.1	693
28	165.27	686	68	146.35	549
29	155.08	609	69	146.28	691
30	165.56	678	70	154.79	681
31	233.84	742	71	145.75	756
32	162.36	623	72	161.23	744
33	167.6	671	73	145.08	547
34	150.33	577	74	194.73	743
35	142.25	581	75	127.29	541
36	154.46	673	76	159.94	592
37	158.65	668	77	164.17	683
38	169.4	745	78	151.17	642
39	155.85	733	79	132.33	634
40	163.44	728	80	138.17	587
81	153.21	655	121	201.77	685
82	124.5	640	122	115.41	431
83	150.64	637	123	162.97	765
84	147.13	692	124	120.13	447
85	166.08	765	125	134.77	597
86	172.48	735	126	181.69	783
87	180.15	736	127	100.27	523
88	172.94	784	128	189.71	733
89	162.81	788	129	144.61	668
90	153.53	698	130	213.63	844
91	183.32	604	131	168.12	641

Table 1. Continued.

92	172.78	751	132	106.11	526
93	117.73	480	133	225.18	841
94	176.76	703	134	152.67	676
95	136.7	740	135	183.85	842
96	104.5	463	136	190.02	804
97	179.84	858	137	121.29	653
98	-	-	138	147.1	701
99	-	-	139	128.89	610
100	-	-	140	142.79	582
101	-	-	141	160.13	789
102	157.94	518	142	75.25	447
103	170.86	634	143	149.06	624
104	205.82	769	144	123.63	564
105	166.32	633	145	128.94	603
106	149.2	634	146	138.39	773
107	134.12	447	147	70.46	415
108	113.5	518	148	136.25	594
109	90.68	327	149	195.69	808
110	201.1	775	150	172.63	887
111	152.35	598	151	132.77	743
112	135.68	622	152	73.15	428
113	127.58	477	153	206.11	790
114	102.28	526	154	112.92	608
115	168.84	810	155	66.66	388
116	190.54	670	156	114.65	488
117	140.08	622	157	168.92	845
118	79.08	267	158	83.75	515
119	161.34	838	159	156.19	789
120	160.92	684	160	82.79	341
161	174.9	722	201	95.23	565
162	185.88	788	202	144.08	618
163	144.71	744	203	97.81	603
164	160.42	800	204	132.5	702
165	150.29	751	205	155.42	765
166	153.83	741	206	133.89	825
167	154.33	764	207	104.31	398
168	126.78	552	208	52.21	339
169	134.56	571	209	104.23	599
170	92.35	322	210	148.33	642
171	152.33	861	211	135.17	683
172	254.04	757	212	133.52	615
173	163.26	795	213	110.46	578
174	119.04	784	214	112.28	592
175	128.63	778	215	144.79	808
176	125.77	648	216	105.52	665
177	131.6	714	217	107.54	629
178	135.58	837	218	156.25	817
179	196.96	860	219	114	536
180	150.77	815	220	91.19	468
181	169.19	917	221	74.23	527
182	144.87	456	222	79.71	656
183	106.85	375	223	142.38	779

Table 1. Continued.

184	208.81	759	224	147.98	647
185	156.94	798	225	45.42	241
186	194.39	808	226	93.89	437
187	166.67	734	227	83.65	333
188	110.71	444	228	80.19	499
189	106.56	474	229	72.11	598
190	79.66	410	230	90.25	487
191	69.63	309	231	101.88	354
192	146.98	592	232	108.94	498
193	109.73	406	233	107.89	462
194	119.35	629	234	95.66	436
195	142.15	818	235	95.56	508
196	97.92	653	236	157.79	745
197	142.75	704	237	105.25	523
198	135.06	716	238	147.69	854
199	117.23	511	239	136.27	879
200	32.33	295	240	95.29	373
241	130	498	281	123.44	736
242	67.52	455	282	142.19	535
243	147.63	689	283	170.19	795
244	120.29	679	284	176.96	775
245	126.4	739	285	134.29	737
246	92.71	369	286	151.46	709
247	131.06	752	287	132.39	667
248	98.71	477	288	163.45	882
249	86.56	386	289	179.08	804
250	169.92	784	290	154.79	764
251	101.65	517	291	124.25	682
252	139.75	806	292	159.98	624
253	148.66	653	293	209.63	983
254	70.69	399	294	156.42	652
255	111.85	574	295	156.65	974
256	122.46	493	296	113.67	514
257	110.96	487	297	225.92	853
258	112.67	499	298	170.31	776
259	94.21	480	299	214.96	866
260	120.69	592	300	148.56	576
261	145.54	774	301	184.39	793
262	123.69	624	302	208.75	863
263	137.83	551	303	142.46	743
264	147.25	600	304	174.33	817
265	83.63	322	305	154.29	852
266	137.21	583	306	208.45	898
267	109.92	475	307	204.52	944
268	151.58	624	308	186.13	917
269	135.83	624	309	145.71	615
270	74.75	476	310	209.56	879
271	176.63	751	311	199.23	911
272	155.29	812	312	196.42	872
273	162.58	769	313	213.27	893
274	109.56	771	314	171.83	830
275	158.45	797	315	173.01	840

Table 1. Continued.

276	205.89	881	316	175.67	878
277	137.73	748	317	182.88	818
278	154.54	759	318	199.92	833
279	148.17	829	319	197.63	784
280	143.11	663	320	184.1	731
321	170.17	770	344	140.83	807
322	174.17	695	345	131.06	716
323	136.86	639	346	138.01	588
324	130.51	785	347	141.17	630
325	151.67	734	348	114.79	582
326	152.73	711	349	156.33	855
327	171.83	772	350	166.75	791
328	165.61	788	351	145.51	683
329	153.77	853	352	145.13	724
330	126.46	563	353	147.43	552
331	150.77	715	354	-----	------
332	183.97	847	355	------	-------
333	168.85	853	356	------	-------
334	129.08	573	357	157.67	664
335	143.69	813	358	172.17	741
336	164.87	863	359	157.45	654
337	133.65	530	360	142.96	581
338	159.11	811	361	150.25	628
339	143.85	720	362	173.15	719
340	89.44	374	363	181.58	764
341	81.35	460	364	166.13	699
342	172.04	778	365	147.96	564
343	167.79	744	366	141.77	613

Note: The minimum values were excluded from the table because it is all zeros.

direct beam at nights. The frequency distribution of daily averages of solar radiation (in 25 Wm^{-2} day^{-1}) is shown in Figure 3. It can be observed from Figure 3 that higher percentage of the daily mean distribution of solar radiation lies between 126 to 175 Wm^{-2}. This is an indication of the high global solar radiation input experienced in the region (Igbal, 1983; Balogun, 2002).

Figure 4 shows the daily mean averaged solar radiation flux from January to December 2008. It can be observed that the daily mean average of the solar radiation flux for the year has a double peak value of about 200 $Wm^{-2}day^{-1}$ around March and November and a minimum of about 90 $Wm^{-2}day^{-1}$ around July and August. July and August signifies the climax of the monsoon season. It can also be noticed from the plot that there were significant fluctuations in the daily averages, especially during the wet months (April to October). This effect can be attributed to the attenuating effects of clouds (and possibly aerosols) over the area (Jegede, 1997).

From Figure 5, the annual trend of the daily maximum global solar radiation is shown. It can be observed that the daily maxima occurred around March and November with peak values of between 800 to 950 Wm^{-2} day^{-1} respectively. It is also evident from the plot that there is significant fluctuation in the values and this is more pronounced in the wet season (April to October). This is because the signature of clouds is significantly prominent during this period.

Figure 6 shows the diurnal variation of the hourly global solar radiation flux over the two seasons peculiar to the study area that is: Dry (November to March) and wet (April to October). From the plot, though there is similarity in both patterns, there is significant difference in the magnitude of solar radiation values. The daily mean maximum of the hourly global solar radiation flux is about 620 Wm^{-2} for the dry and 430 Wm^{-2} for the wet season.

Conclusion

The daily averages solar radiation flux measured during a field campaign at Iju, Nigeria from January to

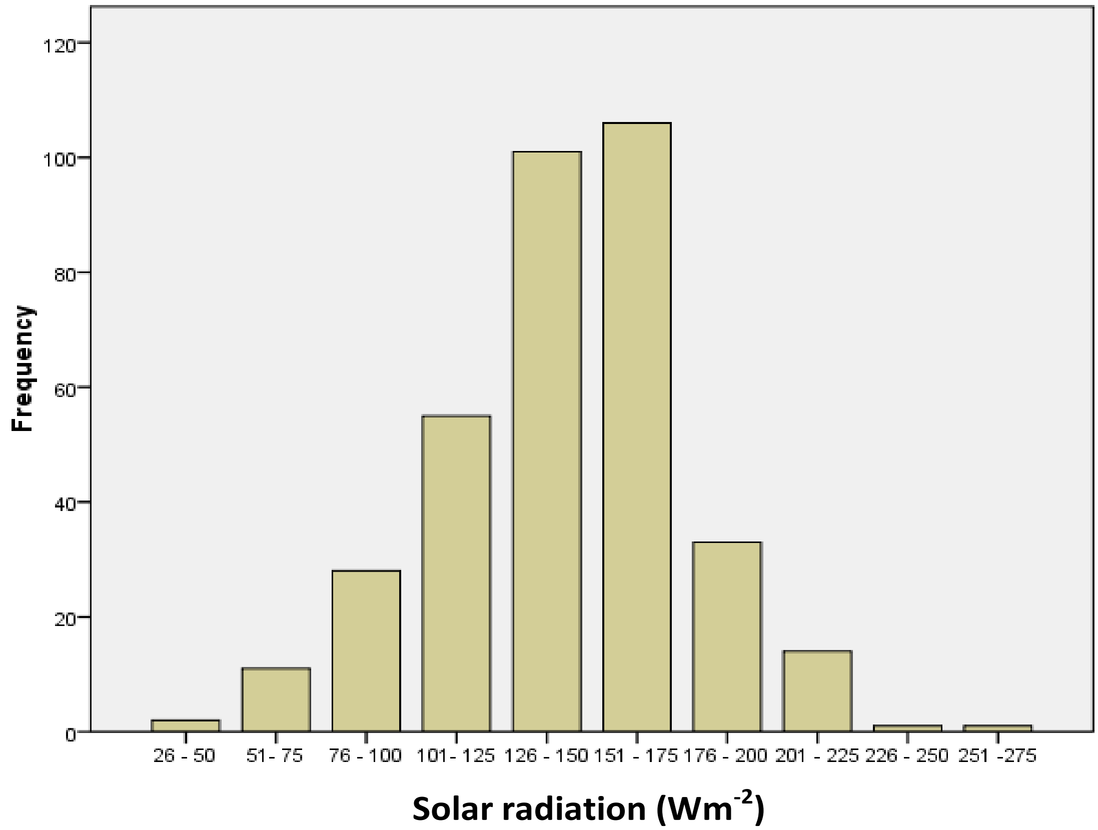

Figure 3. Bar chart of the daily mean solar radiation in (25 Wm^{-2}) classses at Iju for 2008.

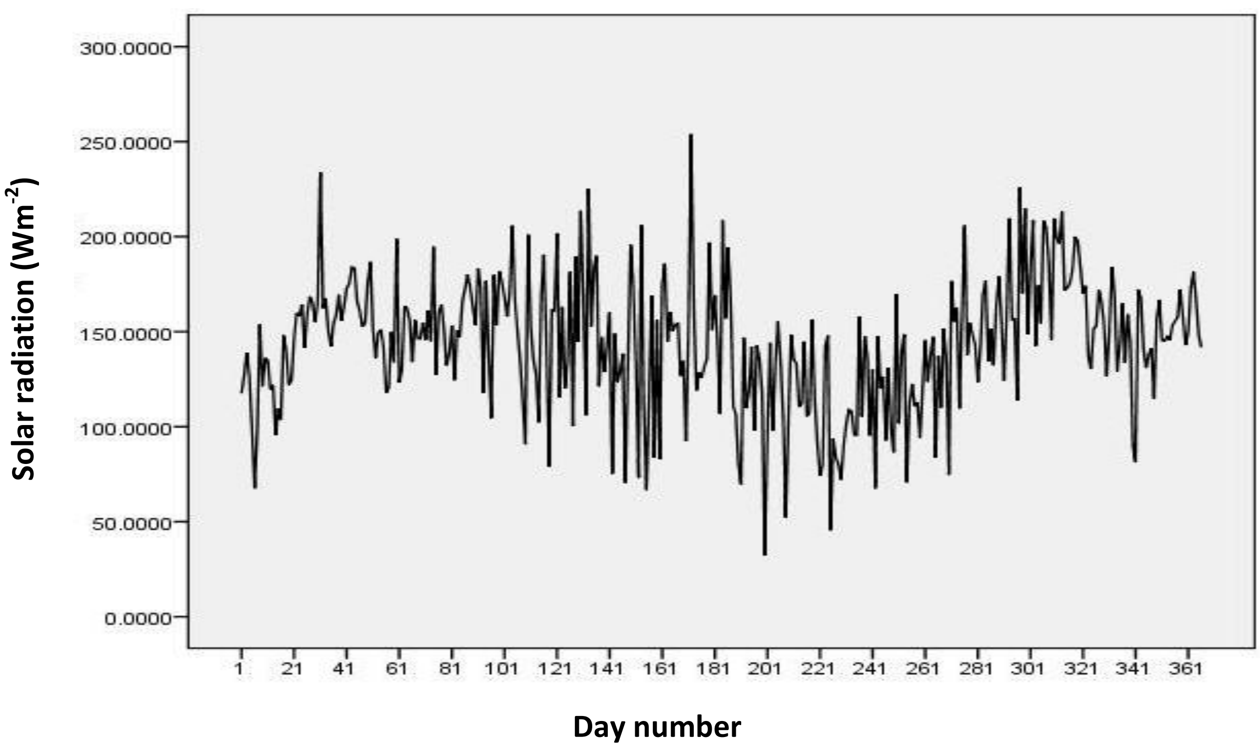

Figure 4. Daily averaged solar radiation at Iju, Nigeria, January to December, 2008.

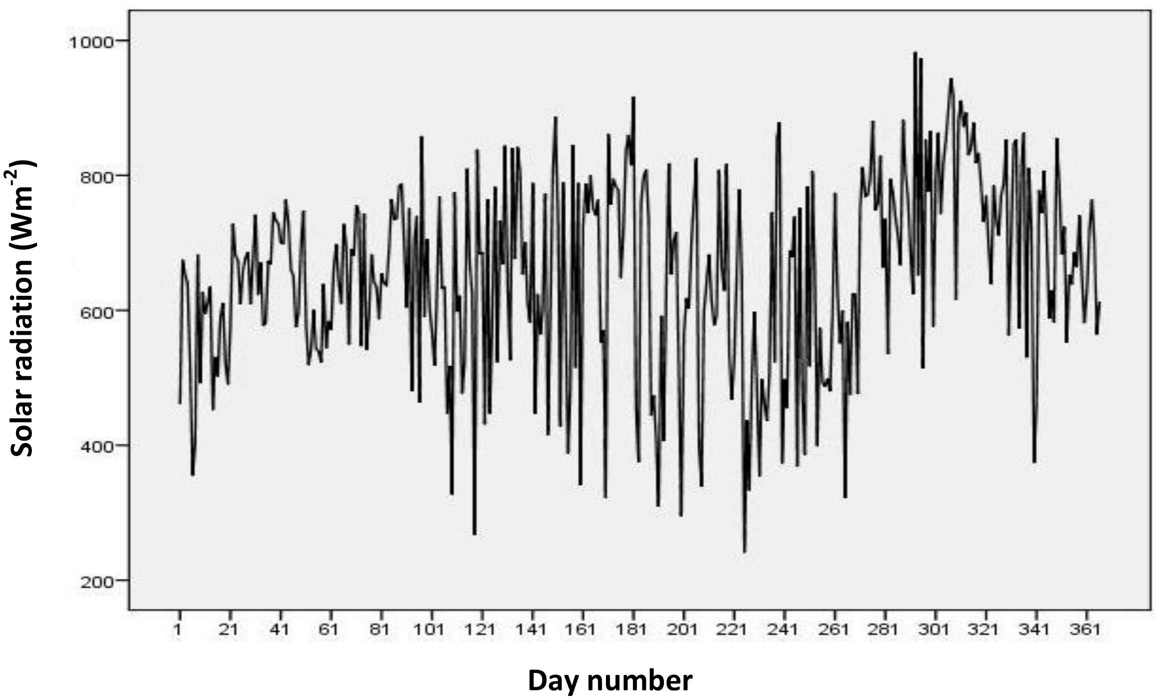

Figure 5. Daily maximum solar radiation at Iju, Nigeria, January to December, 2008.

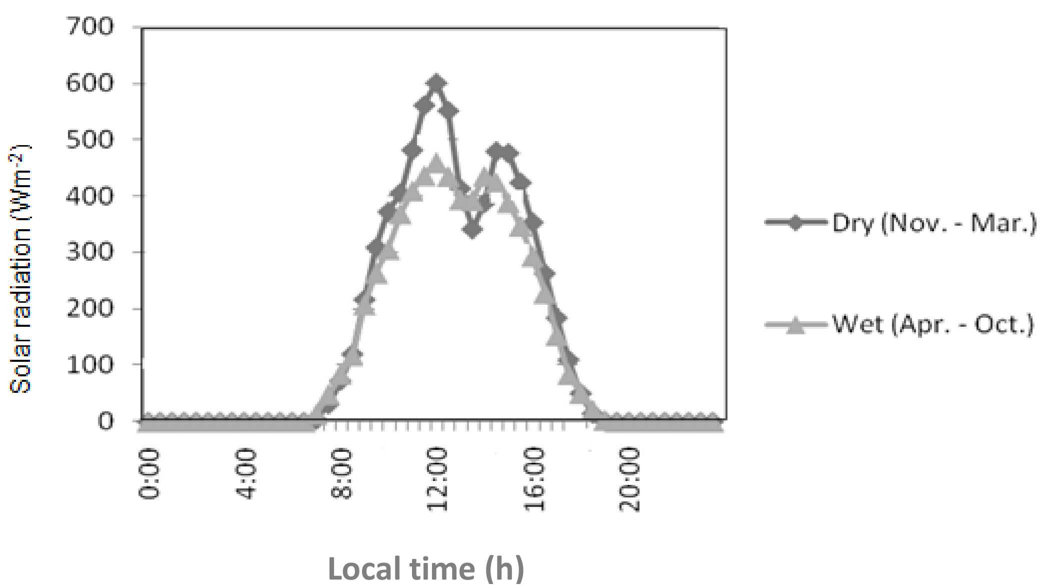

Figure 6. Diurnal variation of the solar radiation flux at Iju for both dry and wet seasons.

December 2008 have been presented in this work. The daily mean for the period was 143.66 ± 11.79 $Wm^{-2}day^{-1}$. The mean of the daily maximum in the year was 653.42 ± 32.*33* Wm^{-2} day^{-1}. The daily mean average has a double-peak value of about 200 $Wm^{-2}day^{-1}$, recorded in the month of March and November, and a minimum of about 90 Wm^{-2} day^{-1} around July and August. The variations in the global solar radiation flux between the two seasons were also shown. The differences in measured solar radiation flux in the two seasons can be attributed to the attenuating cloud effects on the solar radiation flux. The solar radiation databank is comprehensive. It is therefore believed that the databank (still continuous) would be useful to other researchers, especially to validate the numerous models available for the humid sub-tropical.

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