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GENERATION OF A TYPICAL METEOROLOGICAL YEAR FOR PORT HARCOURT ZONE

OKO C.O.C.*, OGOLOMA O.B.

Department of Mechanical Engineering, Faculty of Engineering,
University of Port Harcourt, Port Harcourt, Nigeria
*Corresponding Author: chimaoko@yahoo.com

Abstract

This paper presents data for the typical meteorological year (TMY) for the Port Harcourt climatic zone based on the hourly meteorological data recorded during the period 1983–2002, using the Finkelstein-Schafer statistical method. The data are the global solar radiation, wind velocity, dry bulb temperature, relative humidity, and others. The HVAC outside design conditions for the Port Harcourt climatic zone (latitude 4.44^{o}N, longitude 7.1^{o}E, elevation 20 m) were found to be 26.7^{o}C, 78.6% and 3.5 m/s for the dry bulb temperature, relative humidity and wind speed, respectively, and 13.5 MJ/m^2/day for the global solar radiation. The TMY data for the zone are shown to be sufficiently reliable for engineering practice.

Keywords: Typical meteorological year, Finkelstein-Schafer statistics, Outside design conditions, Solar energy.

1. Introduction

Energy generation, conversion and consumption are now becoming a subject of primary concern in many developing countries such as Nigeria as a result of their expanding economy and the rise in energy demands. The judicious utilization of the renewable energy resources such as the solar energy is also of prime concern. In Nigeria, for example, the Government and other reputable institutions are presently investing on projects that would harness solar and other renewable forms of energy to support life and industry, especially, in the riverine areas of the country. There is also a real need to optimize the design and operations of air-conditioning systems in the largely hot and humid coastal cities such as Port Harcourt (latitude 4.44^{o}N, longitude 7.1^{o}E and elevation 20 m) by appropriate choice of the outside design conditions: dry-and-wet-bulb temperatures, wind speed, etc.

Nomenclatures

DBT	Dry bulb temperature, °C
E_{vap}	Evaporation, mm
$F(X)$	Cumulative distribution function
FS_x	FS statistics on the parameter x
G	Global solar radiation, MJ/m²/day
M	Number of considered meteorological parameters
m	Specified month considered
n	Number of observations
RD	Relative difference between daily values of a specified year and their long-term average
RF	Rainfall, mm
RH	Relative humidity, %
$\overline{RH}$	Average monthly mean relative humidity for 20 years, %
RH_{max}	Maximum relative humidity, %
RH_{min}	Minimum relative humidity, %
S_d	Sunshine hours, h
T	Dry bulb temperature, °C
$\overline{T}$	Average monthly mean dry bulb temperature for 20 years, °C
T_{max}	Maximum dry bulb temperature, °C
T_{min}	Minimum dry bulb temperature, °C
W	Wind speed, km/h
WF_x	Weighting factors, $x = 1,2,\ldots, M$
WS	Weighted sum
$\overline{X}$	Average monthly mean value of X for 20 years
X_i	i^{th} ordered sample value of X
y	Specified year considered

Abbreviations

FS	Finkelstein-Schafer
HVAC	Heating, Ventilating, and Air Conditioning
IITA	International institute for tropical agriculture
TMM	Typical meteorological month
TMY	Typical meteorological year
TRY	Test reference year

The performance of active and passive solar energy based systems can be determined by detailed computer simulation which requires hourly data of global solar radiation and beam radiation as well as other meteorological parameters that may affect system response as key input parameters. The importance of such a condensed data set has led a number of authors to generate climatic data that would aid design and evaluation of HVAC and solar energy systems.

Computer simulation packages such as Energy plus, DOE-2 and TRNSY are now available for building energy simulations. The optimal outside design conditions for heating, ventilating, and air conditioning (HVAC) systems can be achieved by the method of averaging. For example, by applying the averaging method, Akpan [1] estimated the dry bulb temperature (*DBT*) and relative humidity (*RH*) for the Niger Delta Region of Nigeria, which includes the city of

Port Harcourt, to be 26.9°C and 84.12%, respectively. However, the data presented in [1] are not applicable to solar energy based systems, because they do not include the global solar radiation data. Fagbenle [2] generated a test reference year (TRY) for the city of Ibadan that is located in a different climatic zone in Nigeria, which contains data for the global solar radiation, but excludes other meteorological parameters.

In 1978, Hall et al. [3] created, for a network of stations in the United States, a representative database consisting of hourly global solar radiation and other weather data, which is called a "Typical Meteorological Year" (TMY). They employed the Finkelstein-Schafer (FS) statistical method to generate the data [4]. Hall's method has been used to successfully generate TMYs for a number of locations across the globe [5-8].

Therefore, the objective of this paper is to generate the TMY for the Port Harcourt climatic zone using the FS statistics and the procedure proposed by Hall et al. [3]. Port Harcourt is an oil rich city in the Niger Delta region of Nigeria with the following geographical data: latitude 4.44^{o}N; longitude 7.1^{o}E; and elevation 20 m. The data used in this study cover a period of 20 years (1983-2002), and were obtained from the station of the International Institute for Tropical Agriculture (IITA) at Onne on global solar radiation (G), minimum (T_{min}), maximum (T_{max}) and mean $(\overline{T})$ dry bulb temperatures, minimum (RH_{min}), maximum ($RH_{\max}$) and mean ($\overline{RH}$) relative humidity, wind speed (W), sunshine hours (S_d), evaporation (E_{VAP}) and rainfall (RF).

2. Theory

The procedure for selecting TMYs for a particular environment as proposed by Hall et al. [3] is as follows: A typical month for each of the 12 calendar months from the long term database is chosen. Then those chosen 12 months are concatenated to form the TMYs. The data sets generated to form the typical meteorological months (TMMs) are the eleven hourly-recorded data from IITA, Onne. Monthly statistics are calculated for each index. The month/year combination, which has statistics that are close to the long-term statistics, becomes candidate for the typical month. Final selection of a TMM is made based on statistics performed on five weather indices that are deemed most important for the objectives of this article. The procedure for selecting the TMM consisted of two steps: The first step is to select five candidate years, while the second step is to select the TMM from the candidate years.

2.1. Selection of five candidate years

For each of the twelve calendar months of the 20 years under consideration, the procedure involves selecting the five years that are "closest" to the composite of all the 20 years. This is done by comparing the cumulative distribution function (CDF) for each year with the CDF for the long-term composite of all the 20 years for each of the eleven parameters of interest. The statistics used for the comparison is the FS statistics.

For each month of the calendar year for the 20 years, five months are selected, which have the smallest weighted sum of the Finkelstein-Schafer (FS) statistics of the eleven weather parameters being investigated. Using the FS statistics as employed by Mosalam and Tadros [8], the FS statistics is given by:

$$FS_x = \max\{|F(X_i) - (i-1)/n|\},\ i = 1, 2, \ldots, n \tag{1}$$

and

$$F(X_i) = 1 - \exp(X_i / \overline{X}) \tag{2}$$

The weighted sum (WS) of the FS statistics is determined as

$$WS(y,m) = \frac{1}{M}\sum_{x=1}^{M} WF_x \cdot FS_x(y,m) \tag{3}$$

$$\sum_{x=1}^{M} WF_x = 1 \tag{4}$$

where WF_x, x = 1, 2, …, M, are the weighting factors, one for each daily parameter; $FS_x(y, m)$ is the FS statistics for the short term, year y and month m; M is the number of the considered meteorological parameters; X_i is an ordered sample value in a set of n observations sorted in an increasing order, X_1, X_2, X_3…,X_n. whose sample average is $\overline{X}$; thus, X is the average of the monthly means for the 20 years of observation for each X_i sample, where X_i, i = 1, 2,…, n, are arranged for each month as a monotonically increasing function. The weighting scheme used for the TMYs is presented in Table 1.

Table 1. Weighting Scheme for the TMYs.

T_{max}	T_{min}	$\overline{T}$	RH_{max}	RH_{min}	$\overline{RH}$	W	S_d	RF	E_{VAP}	G
0.04	0.05	0.09	0.04	0.04	0.08	0.08	0.04	0.01	0.04	0.50

2.2. Final selection of the TMM

The final selection of the TMM from the five candidate years involved examining statistics of the persistence structure associated with mean daily and monthly values of five meteorological parameters that are deemed most important in this research. The selection process also involves the comparison of the relative difference (RD) between the daily values of a particular year and the long-term average:

$$RD = \sum_{i=0}^{5} \delta_i \tag{5}$$

where

$$\delta_i = |X_i - \overline{X}| \tag{6}$$

A scoring method is introduced, for each month, m, and for each parameter x, a score, S_x, is calculated over all the candidate years. A composite score, S, is calculated as the sum of the scores of the five chosen parameters used, and the month with the highest score is selected. The five parameters used in the final selection stage are solar radiation, sunshine duration, relative humility, wind velocity and dry bulb temperature.

3. TMY Generation for Port Harcourt Zone

By applying the procedure described above for all months, the TMY for the Port Harcourt zone was finally formed, consisting of the selected most representative years for 12 months. Seven meteorological parameters were examined for a period of 20 years. These parameters were dry bulb temperature, relative humidity, wind velocity, evaporation, sunshine hours and global solar radiation intensity.

For each month, the FS statistics was estimated for every year and for all of the parameters that had been considered. In order to take into account the influence of the various meteorological parameters in the FS statistics and, accordingly, in the selection of the representative months, estimations were made by using the weighting factors tabulated in Table 1. The FS statistics were computed and a weighted sum was produced.

As illustrations, the global solar radiation and dry bulb temperature for the period under consideration are presented in Tables A-1 and A-2 (*Appendix A*), respectively; and their corresponding FS statistics are shown in Tables A-3 and A-4. Furthermore, a composite year was first formed consisting of the selected months with smallest values of the weighted sums (*WS*). For each month of the year, the cases corresponding to the five lower values of the FS statistics were selected and are presented in bold in Table A-5.

The final selection of the most representative year among the five selected for each month was done in the second stage by examining a number of statistics of the values of the adopted meteorological parameters. These statistics were the relative difference (*RD*) of the daily distribution of five of the meteorological parameters used for each month of each year with respect to the mean long-term daily distribution and the FS statistics. For the five selected cases, the *RD* was computed for each month. The *RD* result for global solar radiation for the selected years are shown in Table A-6 (*Appendix A*).

4. Results and Discussion

For the five selected cases, a composite *RD* and a score S_x were calculated for each month and for each parameter, x. The composite *RD* was calculated as the sum of *RDs* for the five parameters used, and the month with the highest score was selected to represent the TMY for that month. The selected month/year combinations from which the TMY was composed are shown in Table 2. Tabulated in Tables 3 and 4 are the monthly and annual values, respectively, of the pertinent design parameters produced by the TMY, while Figs. 1, 2 and 3 show the monthly variation of global solar radiation, dry bulb temperature and relative humidity, respectively.

The data for the TMY, for the average year (averaged over the 20 years), and for the worst year (for the most unfavourable monthly values) are plotted in each of the figures. The values produced by TMY are quite representative and do not differ appreciably from those obtained by Akpan [1]. However, they are dependent on the choice of the weighting scheme, Table 1, which is not unique as it is still based on trial and error.

Table 2. The Month/Year Combinations for the Composition of TMY.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year	1994	1987	1985	1984	1990	1997	1995	1988	1989	1991	1988	1987

Table 3. Monthly Values of the Meteorological Parameters obtained by TMY.

Parameter	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dry-Bulb Temp. (^oC)	26.60	28.32	28.38	27.69	27.06	26.20	25.40	25.16	25.72	25.46	26.81	27.43
Relative Humidity (%)	70.00	73.43	75.98	76.04	78.64	81.00	84.0	84.29	82.6	83.47	80.62	73.64
Solar (MJ/m^2-day)	14.03	14.41	14.67	14.77	14.54	14.76	11.45	11.25	12.31	12.62	12.61	14.58
Rainfall (mm)	13.80	59.00	183.2	97.40	277.7	340.90	312.2	423.7	183.40	127.00	69.50	19.20
Evaporation (mm)	128.10	113.80	122.70	143.0	83	82.80	74.40	68.5	62.80	85.10	82.60	94.10
Wind Velocity (km/h)	2.89	3.77	5.17	4.20	3.32	3.30	3.50	4.05	3.81	2.84	2.25	3.00
Sunshine Duration (h)	5.40	5.64	4.02	4.69	4.51	4.25	2.90	2.45	2.76	3.16	4.48	6.74

Table 4. Outside Design Conditions.

Parameter	Symbol	Units	Upper Limit	Lower Limit	Mean Value	STD Dev.
Dry-bulb Temperature	*DBT*	°C	27.32	26.05	26.69	0.64
Relative Humidity	*RH*	%	81.34	75.95	78.64	2.70
Solar Radiation	*G*	MJ/m^2day	14.27	12.73	13.50	0.77
Rainfall	*RF*	mm	252.27	98.90	175.58	76.69
Pan Evaporation	E_{VAP}	mm	109.58	80.57	95.07	14.51
Wind Velocity	*W*	km/h	3.94	3.08	3.51	0.43
Sunshine Duration	S_d	h	4.98	3.52	4.25	0.73

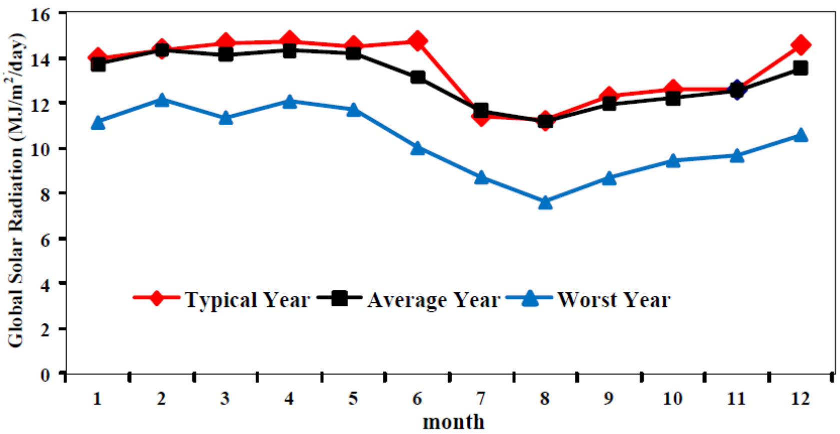

Fig. 1. Annual Variation of Monthly Mean Hourly Values of Global Solar Radiation for the whole Period of 20 Years, for the Selected TMY and for the Worst Year, composed of the Worst Months of the Period.

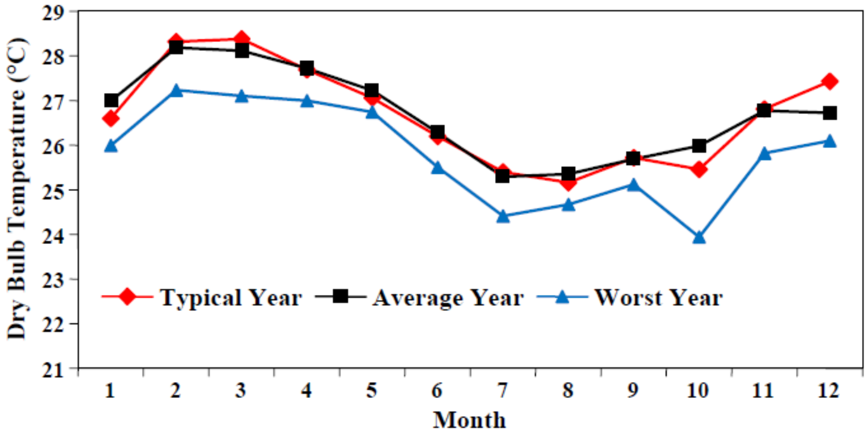

Fig. 2. Annual Variation of Monthly Mean Hourly Values of Dry Bulb Temperature for the whole Period of 20 Years, for the Selected TMY and for the Worst Year, composed of the Worst Months of the Period.

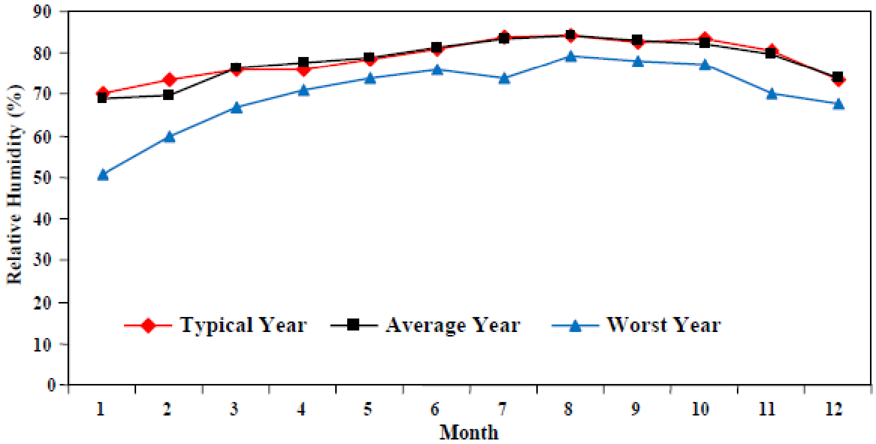

Fig. 3. Annual Variation of Monthly Mean Hourly Values of Relative Humidity for the whole Period of 20 Years, for the Selected TMY and for the Worst Year, composed of the Worst Months of the Period.

5. Conclusions

The generation of a typical meteorological year is very useful for optimal design and evaluation of solar energy and HVAC systems. This work, therefore, provides a reliable database for engineers who are engaged in design, installation and maintenance of thermo-fluid systems in the Port Harcourt climatic zone. It is hoped that the generation of TMYs will be extended to other climatic zones of Nigeria when adequate data are available.

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Appendix A

Tabulated Data

Table A-1. Global Solar Radiation [MJ/m^2/day].

	Month											
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1983	14.81	17.04	15.81	14.73	12.71	12.62	11.31	11.31	15.23	14.07	13.50	13.35
1984	14.86	16.04	16.19	14.77	16.02	16.03	15.13	16.08	14.81	14.66	14.58	13.05
1985	11.17	13.35	14.67	14.44	14.27	14.27	13.23	10.51	13.23	13.13	15.42	13.13
1986	15.97	15.01	11.99	13.94	16.60	15.73	12.14	13.38	12.95	13.60	14.58	16.33
1987	14.72	14.41	13.63	16.20	13.20	13.46	12.39	11.71	14.15	12.39	14.72	14.58
1988	13.83	13.71	15.21	16.10	15.86	13.79	11.25	11.25	12.65	12.37	12.61	14.16
1989	17.28	16.93	14.03	14.74	15.67	14.26	13.38	12.27	12.31	14.17	12.13	15.07
1990	13.62	15.20	16.91	16.00	14.54	13.54	9.20	11.11	10.93	12.37	13.36	11.80
1991	15.57	15.00	14.17	15.20	14.62	13.69	11.21	10.21	11.71	12.62	13.12	15.15
1992	16.55	17.64	15.01	14.43	15.26	11.22	9.37	9.45	11.64	11.98	13.86	15.10
1993	14.23	15.96	15.25	15.65	14.80	11.28	9.06	9.21	12.00	13.39	11.50	14.94
1994	14.03	13.18	12.74	15.54	14.71	14.99	14.48	10.22	12.73	12.78	13.97	14.97
1995	13.23	14.13	17.15	13.96	13.35	15.18	11.45	9.65	13.20	12.52	14.73	11.35
1996	12.25	13.94	12.74	15.54	14.71	11.63	14.85	13.73	10.32	11.36	13.97	14.97
1997	11.35	9.75	11.39	10.16	11.74	14.76	14.58	15.98	12.83	12.11	14.11	12.60
1998	13.23	14.22	13.59	13.66	14.55	13.04	11.06	11.27	9.72	10.96	11.34	11.79
1999	12.87	13.32	15.09	13.16	13.86	11.59	11.11	11.13	10.23	10.86	3.34	14.07
2000	12.09	13.45	14.21	13.81	12.78	10.90	9.47	8.58	8.71	10.39	10.57	12.27
2001	11.81	12.89	11.97	13.04	12.44	10.04	8.75	7.63	10.18	9.49	9.71	10.63
2002	11.72	12.17	11.68	12.1	12.92	11.58	10.3	9.3	10.1	9.59	10.90	12.3

Table A-2. Dry Bulb Temperature (°C).

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	26.61	29.54	30.14	28.31	27.28	26.30	25.34	25.01	25.62	25.74	26.65	26.30
1984	26.84	28.29	27.84	27.69	26.98	26.54	25.36	26.12	25.62	23.94	26.75	26.26
1985	27.54	28.31	28.38	27.40	27.33	26.18	25.03	25.05	25.42	25.86	26.66	26.13
1986	27.35	27.96	27.58	28.24	27.36	26.27	25.15	25.26	25.46	25.56	26.54	26.38
1987	27.76	28.32	27.78	28.78	27.93	26.86	26.31	26.08	26.56	26.86	27.73	27.43
1988	27.39	29.23	28.82	28.12	27.57	26.43	25.22	25.66	25.54	26.06	26.81	26.19
1989	25.66	27.99	27.54	27.23	26.74	26.18	25.40	25.26	25.72	26.54	27.40	27.24
1990	27.36	28.18	29.69	28.42	27.06	26.18	24.66	25.04	25.21	25.68	26.34	26.61
1991	27.12	27.80	27.71	27.10	26.98	26.31	25.08	24.67	25.12	25.46	26.56	26.26
1992	25.99	28.22	27.58	27.76	27.08	25.57	24.41	24.78	25.48	25.69	26.12	26.87
1993	27.00	27.80	27.10	27.00	26.80	25.80	24.80	25.30	26.10	26.30	26.90	26.70
1994	26.60	27.80	27.80	27.40	26.80	25.50	24.80	25.20	25.40	26.90	26.80	26.30
1995	27.00	28.30	27.70	28.00	26.80	26.30	25.40	25.40	25.90	25.80	27.10	26.80
1996	27.30	27.80	27.30	27.20	27.40	27.00	24.70	25.00	25.40	25.90	27.60	27.60
1997	27.30	27.90	28.40	27.30	27.00	26.20	25.60	25.70	26.60	26.90	27.00	27.50
1998	27.20	29.70	29.70	29.20	28.60	27.30	26.30	26.20	26.10	26.50	27.10	26.40
1999	27.00	27.60	27.90	27.50	27.10	26.60	25.90	26.10	25.70	25.70	26.30	27.30
2000	27.60	27.90	28.40	27.40	27.10	26.20	25.60	25.20	25.60	26.20	27.00	26.10
2001	26.60	27.90	27.80	27.20	27.00	25.70	25.10	25.00	25.40	25.90	26.30	27.20
2002	26.60	27.23	27.20	27.22	27.60	26.20	25.65	25.10	25.85	26.28	25.82	26.90

Table A-3. FS Statistics for Global Solar Radiation.

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983	0.091	0.249	0.178	0.142	0.491	0.266	0.118	0.058	0.281	0.217	0.148	0.177
1984	0.140	0.178	0.220	0.043	0.274	0.296	0.275	0.238	0.241	0.302	0.176	0.269
1985	0.556	0.355	0.094	0.184	0.234	0.089	0.073	0.208	0.181	0.091	0.306	0.221
1986	0.215	0.052	0.420	0.321	0.323	0.253	0.016	0.153	0.089	0.179	0.176	0.299
1987	0.007	0.083	0.267	0.324	0.355	0.190	0.053	0.102	0.207	0.137	0.222	0.010
1988	0.134	0.265	0.090	0.276	0.227	0.049	0.167	0.083	0.102	0.186	0.271	0.049
1989	0.285	0.208	0.228	0.092	0.182	0.011	0.119	0.135	0.142	0.264	0.307	0.178
1990	0.178	0.098	0.254	0.228	0.191	0.142	0.444	0.179	0.298	0.186	0.192	0.482
1991	0.173	0.048	0.182	0.003	0.093	0.096	0.216	0.298	0.224	0.043	0.235	0.276
1992	0.250	0.293	0.053	0.233	0.142	0.473	0.400	0.370	0.271	0.324	0.106	0.227
1993	0.045	0.130	0.135	0.186	0.103	0.425	0.488	0.460	0.183	0.135	0.337	0.133
1994	0.089	0.450	0.393	0.139	0.055	0.171	0.141	0.248	0.054	0.052	0.008	0.130
1995	0.268	0.176	0.299	0.272	0.309	0.216	0.074	0.327	0.132	0.090	0.272	0.518
1996	0.339	0.221	0.343	0.139	0.055	0.286	0.232	0.194	0.327	0.355	0.008	0.130
1997	0.512	0.492	0.552	0.507	0.562	0.126	0.188	0.190	0.007	0.278	0.088	0.306
1998	0.219	0.128	0.316	0.414	0.141	0.228	0.311	0.034	0.506	0.391	0.382	0.437
1999	0.308	0.404	0.005	0.450	0.273	0.335	0.262	0.130	0.374	0.438	0.382	0.097
2000	0.385	0.307	0.133	0.368	0.443	0.513	0.354	0.485	0.517	0.472	0.506	0.397
2001	0.426	0.492	0.470	0.497	0.533	0.533	0.526	0.494	0.422	0.539	0.526	0.544
2002	0.473	0.521	0.511	0.520	0.397	0.385	0.335	0.414	0.470	0.493	0.468	0.347

Table A-4. FS Statistics for Dry Bulb Temperature.

	Month											
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1983	0.377	0.301	0.342	0.210	0.033	0.032	0.133	0.427	0.081	0.329	0.280	0.326
1984	0.330	0.067	0.078	0.082	0.379	0.164	0.083	0.307	0.081	0.602	0.182	0.426
1985	0.260	0.166	0.064	0.178	0.066	0.331	0.378	0.328	0.378	0.230	0.231	0.574
1986	0.113	0.179	0.375	0.161	0.116	0.132	0.230	0.081	0.329	0.526	0.379	0.277
1987	0.358	0.216	0.228	0.304	0.308	0.260	0.353	0.208	0.306	0.256	0.355	0.258
1988	0.212	0.255	0.209	0.113	0.213	0.116	0.181	0.114	0.230	0.083	0.083	0.525
1989	0.614	0.130	0.474	0.376	0.626	0.331	0.066	0.081	0.067	0.210	0.259	0.161
1990	0.163	0.082	0.248	0.259	0.230	0.331	0.573	0.378	0.575	0.478	0.426	0.181
1991	0.134	0.377	0.277	0.574	0.379	0.067	0.329	0.622	0.624	0.575	0.329	0.426
1992	0.568	0.033	0.375	0.033	0.180	0.572	0.619	0.574	0.279	0.428	0.573	0.034
1993	0.182	0.377	0.619	0.622	0.476	0.475	0.425	0.031	0.262	0.113	0.034	0.132
1994	0.427	0.377	0.128	0.178	0.476	0.621	0.425	0.180	0.428	0.355	0.132	0.326
1995	0.182	0.116	0.327	0.064	0.476	0.032	0.066	0.067	0.165	0.279	0.213	0.083
1996	0.064	0.377	0.521	0.475	0.166	0.308	0.523	0.477	0.428	0.131	0.307	0.356
1997	0.064	0.228	0.164	0.326	0.279	0.181	0.163	0.163	0.355	0.355	0.115	0.307
1998	0.085	0.349	0.298	0.349	0.350	0.354	0.303	0.356	0.262	0.161	0.213	0.228
1999	0.182	0.574	0.029	0.129	0.080	0.213	0.259	0.257	0.032	0.378	0.476	0.210
2000	0.310	0.228	0.164	0.178	0.080	0.181	0.163	0.180	0.181	0.035	0.115	0.623
2001	0.427	0.228	0.128	0.475	0.279	0.524	0.279	0.477	0.428	0.131	0.476	0.111
2002	0.427	0.619	0.570	0.425	0.263	0.181	0.213	0.278	0.116	0.064	0.619	0.065

Table A-5. Weighted Sums (*WS*) of the FS Statistics*.

	Month											
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1983	0.0208	0.0258	0.0257	0.0206	0.0356	0.0252	0.0172	0.0194	0.0232	0.0232	0.0209	0.020
1984	0.0226	**0.017**	0.0205	**0.014**	**0.025**	0.0245	0.0225	0.0268	0.0213	0.0268	**0.017**	0.029
1985	0.0409	0.0262	**0.013**	0.0177	0.0201	**0.015**	**0.014**	0.0253	0.0228	**0.016**	0.0248	0.0262
1986	**0.016**	**0.015**	0.0292	0.0233	**0.025**	0.0205	**0.012**	0.0174	**0.015**	0.0208	0.0184	0.030
1987	**0.010**	**0.012**	0.0264	0.0276	**0.025**	0.0235	**0.015**	**0.017**	0.0232	0.0195	0.0242	**0.010**
1988	0.0163	0.0197	**0.016**	**0.017**	**0.018**	**0.010**	0.0151	**0.010**	**0.014**	**0.016**	**0.018**	0.0178
1989	0.0264	0.0209	0.0217	**0.017**	0.0218	**0.011**	**0.014**	**0.013**	**0.014**	0.024	0.0234	**0.018**
1990	0.0204	**0.015**	0.0243	0.0254	0.0184	0.0156	0.0341	0.0194	0.0251	0.0198	0.0191	0.0361
1991	**0.014**	**0.015**	0.0191	**0.012**	0.0166	**0.011**	0.0232	0.0318	0.0277	**0.015**	0.0241	0.0265
1992	0.0266	0.0239	**0.014**	0.02	0.0141	0.0377	0.0337	0.031	0.023	0.0276	0.0225	0.0218
1993	**0.014**	0.0172	0.0193	0.0268	0.0232	0.0357	0.0385	0.0295	0.0238	0.0215	0.0258	**0.0150**
1994	**0.015**	0.0297	0.0284	**0.017**	0.0202	0.0246	0.0216	0.0212	0.0178	**0.0120**	**0.015**	0.0180
1995	0.0272	0.0202	0.0254	0.0216	0.0307	0.0216	**0.007**	0.0225	**0.014**	**0.0170**	0.0278	0.0317
1996	0.0231	0.0229	0.0302	0.0227	**0.015**	0.0261	0.0258	0.021	0.0242	0.0270	**0.015**	**0.0160**
1997	0.0318	0.0391	0.0364	0.0365	0.0418	**0.014**	0.0205	0.020	**0.015**	0.0267	**0.013**	0.0277
1998	0.0227	0.0191	0.0273	0.0329	0.0229	0.0278	0.0281	**0.0140**	0.0393	0.0323	0.029	0.0340
1999	0.025	0.0361	**0.009**	0.0318	0.0215	0.0259	0.0234	**0.017**	0.0235	0.0307	0.0294	**0.0120**
2000	0.0274	0.0248	**0.015**	0.027	0.0293	0.0328	0.0267	0.0304	0.0353	0.0315	0.0334	0.03360
2001	0.0306	0.0352	0.0316	0.0331	0.0334	0.0377	0.0353	0.035	0.0307	0.0356	0.0376	0.03010
2002	0.0372	0.0367	0.0383	0.0367	0.0293	0.03	0.0266	0.0308	0.0356	0.0372	0.038	0.02430

**Bold numbers are for the 5 candidate years per month (per column).*

Table A-6. Relative Difference (*RD*) for the Monthly Values of the Solar Radiation for the Five Candidate Years.

	Month											
Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1983	-	-	-	-	-	-	-	-	-	-	-	-
1984	-	1.67	-	0.41	-	-	-	-	-	-	1.98	-
1985	-	-	0.50	-	-	1.09	1.54	-	-	0.89	-	-
1986	2.21	0.64	-	-	-	-	0.45	-	0.97	-	-	-
1987	0.96	0.04	-	-	-	-	0.7	0.51	-	-	-	1.00
1988	-	-	1.04	1.74	1.63	0.61	-	0.05	0.67	0.13	0.01	-
1989	-	-	-	0.38	-	1.08	1.69	1.07	0.33	-	-	1.49
1990	-	0.83	-	-	0.31	-	-	-	-	-	-	-
1991	1.81	0.63	-	0.84	0.39	0.51	-	-	-	0.38	-	-
1992	-	-	0.84	-	1.06	-	-	-	-	-	-	-
1993	0.47	-	-	-	-	-	-	-	-	-	-	1.36
1994	0.27	-	-	1.18	-	-	-	-	-	0.54	1.37	-
1995	-	-	-	-	-	-	0.24	-	1.22	0.28	-	-
1996	-	-	-	-	0.48	-	-	-	-	-	1.37	1.39
1997	-	-	-	-	-	1.58	-	-	0.85	-	1.51	-
1998	-	-	-	-	-	-	-	0.07	-	-	-	-
1999	-	-	0.92	-	-	-	-	0.07	-	-	-	0.49
2000	-	-	0.04	-	-	-	-	-	-	-	-	-
2001	-	-	-	-	-	-	-	-	-	-	-	-
2002	-	-	-	-	-	-	-	-	-	-	-	-