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The Solar Energy Potential of Gaza Strip

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This paper summarizes the many years of data (1989-2002) that have been processed from the Solar Radiation Survey. Typical Meteorological Year files (TMY) based on the direct beam component, and the archived hourly data upon which they are based. The average annual direct beam total for all the stations is 2196 kWh m^{-2} $year^{-1}$. For example, during the 11 years of data that are discussed in the present paper, It is concluded that: (1) sufficient data probably now exist in order to enable one to identify the best places for locating solar power stations; (2) several more years of data will be necessary before a sufficiently reliable data base will exist for the purpose of simulating solar- concentrator power plant performance and determining their economic benefit.

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I. Introduction

A Typical Meteorological Year (TMY) consists of twelve monthly files of actual hourly meteorological data selected in a particular manner [1]. The months will not, in general, have come from the same year. Instead, each will have been chosen as being a "typical" representative of the month in question and,ideally, the choice for each will have been made from very many years of accumulated data.

The reason for taking actual months of data rather than averaged files is that the former preserve correlations (both known and unknown) that exist among the different measured parameters (e.g. solar radiation and ambient temperature) and also correlations that exist over a period of several days among values of any given parameter.

Design of active solar space-heating systems is usually based on selecting one type of collector system, usually a flat-plate collector, and designing the auxiliary components to fit that collector system. The type of climate at the location of utilization is not often considered when designing such a solar system. Therefore, a solar system may exhibit a high performance in some areas but low performance in others.Before making an investment decision, it is essential to investigate the solar energy characteristics of the particular location at which the solar energy system is to be used. This includes examination of the nature of the correlations between solar radiation and temperature, so that an optimal design of solar energy system can be established for the particular region [2].

The present study, however, is part of the Gaza Strip Survey, the aims of which are to provide data of relevance to the performance of solar power station. Clearly, therefore, the relevant criterion for this purpose is solar energy. There are in fact two solar radiation components that are measured: the global horizontal radiation and the normal direct beam component. For the given site the former is found to vary by approximately ± 5% from year to year. On the other hand, year to year variations of more than 30% have been observed in the direct beam component, over the comparatively few years that this study has been in progress.

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Fig. 1 : shows the locations of the meteorological stations involved in the Gaza Radiation Survey.

Figure1: Gaza Strip

II. Data Construction

When we have an odd number of years of data, then we "tried to choose" the year whose monthly direct beam average rendered it the median year of the available set. On the other hand, where an even number of years of data were available we "tried to choose" the year whose monthly mean was closest to the average taken over all of the years in the set. The words "tried to choose" have been used because sometimes this was not possible owing to large amounts of missing data in the desired file. In such cases a "second best" choice was made. Regarding small quantities of missing data, even relatively complete day files occasionally have a few hours when one or more instruments were not working properly. In such cases our practice is to look for a nearby qualitatively similar day, copy the relevant data sequence and use it to patch the hole [3]. Table 1 displays the monthly average values of direct beam radiation recorded by each of the stations during the fourteen-year period (1989-2002). Values in bold characters indicate the specific months that were ultimately chosen for each site as the basis for TMY.

The raw data provided by the Israel Meteorological Service include hourly average values of: direct beam radiation; global horizontal radiation; shadow-band pyranometer data; dry-bulb temperature; relative humidity (or alternatively, from some stations, the wet bulb temperature); wind speed and wind direction. Of the solar radiation data only direct beam and global horizontal are archived, the shadow-band data having been used for consistency checks only. Humidity data have been processed using algorithms given in the ASHRAE chapter on psychrometrics [4] in order to compute the humidity ratio. The present study employs a format which the University of Wisconsin originally established for the US SOLMET TMY. For each of the 12 monthly data files, the format allocates successive columns to: month, hour, direct beam, global horizontal, ambient temperature, humidity ratio, wind speed, wind direction, with units [5].

III. Some Observations

From Tables 1 one sees that Gaza station has provided 11 complete years of data. From table 4 we can see that the years 1995, 1998 and 2001 were relatively rich in direct beam solar radiation whereas 1990 was unusually poor.

Regarding a relative "ranking" of the station, in terms of annual direct beam radiation, at least two methods are available: one based on average data, the other on data from the TMY files. Table 1 includes an annual average daily radiation value. This average is the average of the annual averages over as many of the 11 years for which there were complete sets of data. The standard deviation has also been indicated. Fig. 2a plots these monthly average direct beam averages in the survey.

Table 2 lists the station ranked in order of descending annual average direct beam radiation, where the annual averages have been computed in the manner described, and multiplied by 365 for purposes of easy comparison with the corresponding TMY results (which are also shown in the table).

It is the annual direct beam totals from these tables that are shown in the last column of Table 2. The monthly mean direct beam values from the TMY files are plotted in Fig. 2b.

Comparison between the two methods of ranking the stations (Table 2) reveals only slight differences. The annual averages are quite similar and the overall ranking remains the same.

Another important use to which the TMY files will be put is in the simulation of non-concentrator systems (e.g. solar ponds [2], photovoltaic solar power plants [3], etc.). Here global radiation is more important than the direct beam component. However, unlike the situation for the direct beam component, the global horizontal radiation fluctuates relatively little from year to year [5].

We may also use the TMY files in order to rank for non-concentrator purposes. Table 3 shows the sites ranked according to the annual global horizontal radiation totals. Fig. 3 plots the monthly global horizontal TMY averages for Gaza site in the survey.

We note that the spread among stations is much "tighter" in Fig. 4 than is the case in Figs. 2 and 3, and the overall shape is much "smoother". These characteristics are symptomatic of smaller changes in the global horizontal insolation , `from year-to-year, compared with the corresponding direct beam insolation values.

Table 1: Gaza monthly direct beam averages [kWh m^{-2} day^{-1}]. Months indicated in bold print were used for TMY Underlined months excluded from consideration

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Mean	Sigma
JAN				2.83	2.83	2.92	3.97	2.85	3.64	3.48	3.63	3.08	4.49	**3.22**	3.36	0.54
FEB				2.26	2.94	4.50	3.53	2.98	4.89	**4.36**	3.96	4.99	4.37	4.92	3.97	0.92
MAR				2.52	4.01	3.72	5.02	4.65	4.40	3.30	5.39	4.54	5.57	**4.46**	4.33	0.90
APR					5.32	5.29	**5.14**	4.69	5.03	5.87	5.83	4.41	5.38	4.90	5.19	0.46
MAY					4.50	**6.45**	6.20	6.45	6.97	5.41	6.64	7.74	6.79	7.43	6.46	0.94
JUN				7.06	**7.69**	7.36	7.41	8.15	7.82	7.45	7.42	8.75	8.08	8.43	7.78	0.52
JUL		3.57		7.44	7.18	7.02	6.66	4.86	7.72	8.15	**7.41**	6.81	7.73	7.84	7.40	0.48
AUG				6.11	6.73	6.75	**6.76**	6.26	7.23	6.96	7.25	6.40	6.78	7.15	6.76	0.38
SEP				5.59	5.80	5.16	5.40	5.49	6.67	6.12	6.29	6.05	6.15	**6.01**	5.88	0.44
OCT					4.92	4.04	5.12	4.62	4.26	5.86	5.66	3.95	**4.67**	4.18	4.73	0.66
NOV		4.72			3.49	3.41	4.56	3.52	4.65	**4.36**	4.84	5.08	4.24	4.53	4.31	0.58
DEC		3.29			2.86	**3.51**	3.65	3.62	3.64	3.76	4.34	3.33	3.64	3.14	3.53	0.38
ANN					4.87	5.01	5.30	4.84	5.58	5.43	5.73	5.41	5.66	5.52	5.34	0.32

Table 2: Relative ranking of Gaza Radiation Survey according to average annual direct beam data (column 2). This ranking is relevant to solar-concentrator systems. Also shown is the slightly different ranking resulting from the corresponding TMY files (column 3)

Station	Average Annual Beam Total [kWh m^{-2} year^{-1}]	TMY Annual Beam Total [kWh m^{-2} year^{-1}]
Gaza	1949	1957

Table 3: Relative ranking of the Radiation Survey stations according to TMY annual global horizontal Totals. This ranking is relevant to non-concentrator systems.

Station	TMY annual global horizontal total [kWh m^{-2} year^{-1}]
Gaza	1905

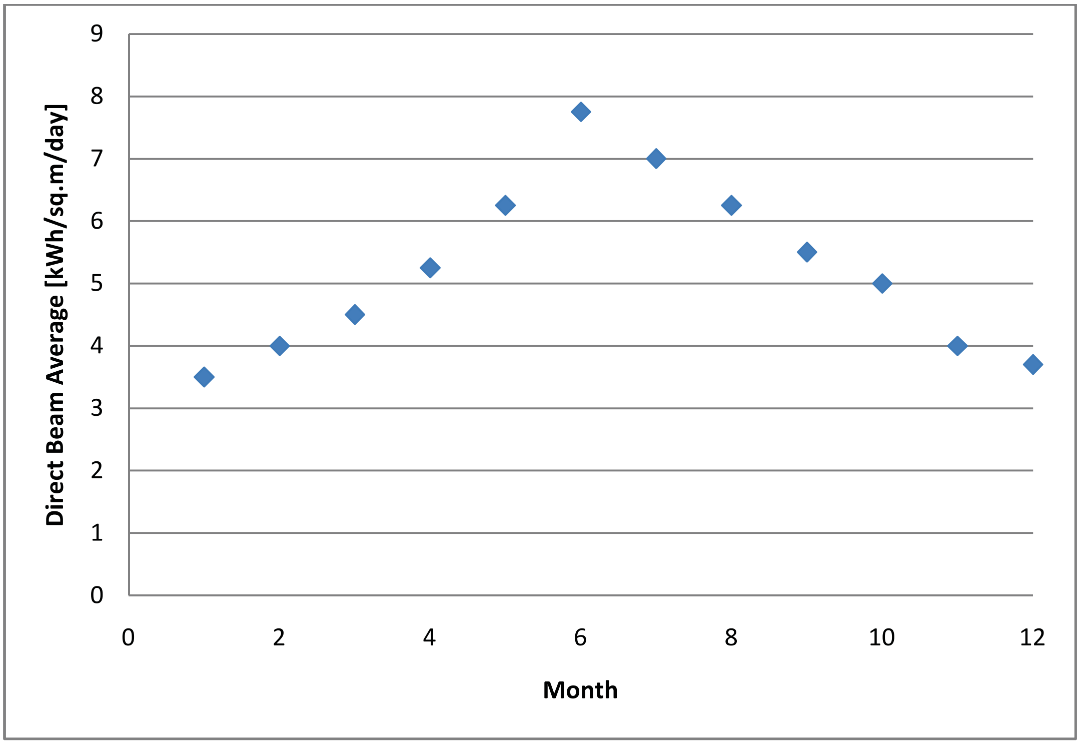

Figure 2: Mean monthly daily average direct beam insolation for Gaza in the Radiation Survey (1989-2002)

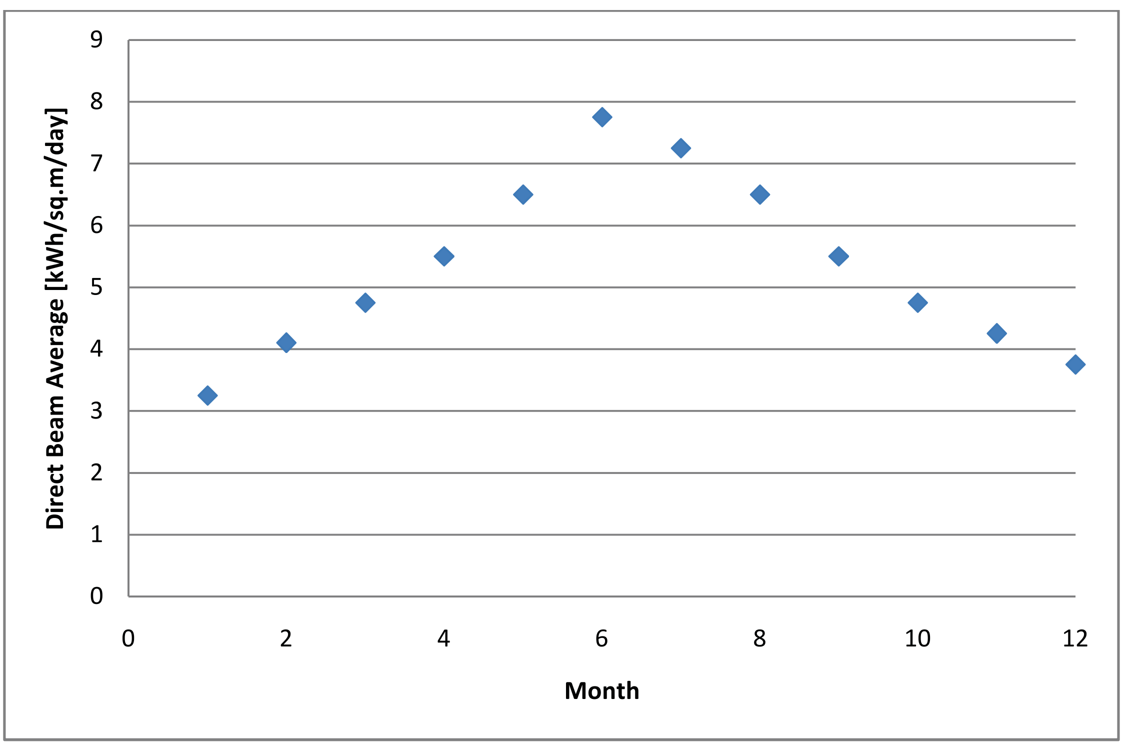

Figure 3: Monthly TMY daily average direct beam insolation for Gaza in the Radiation Survey (1989-2002)

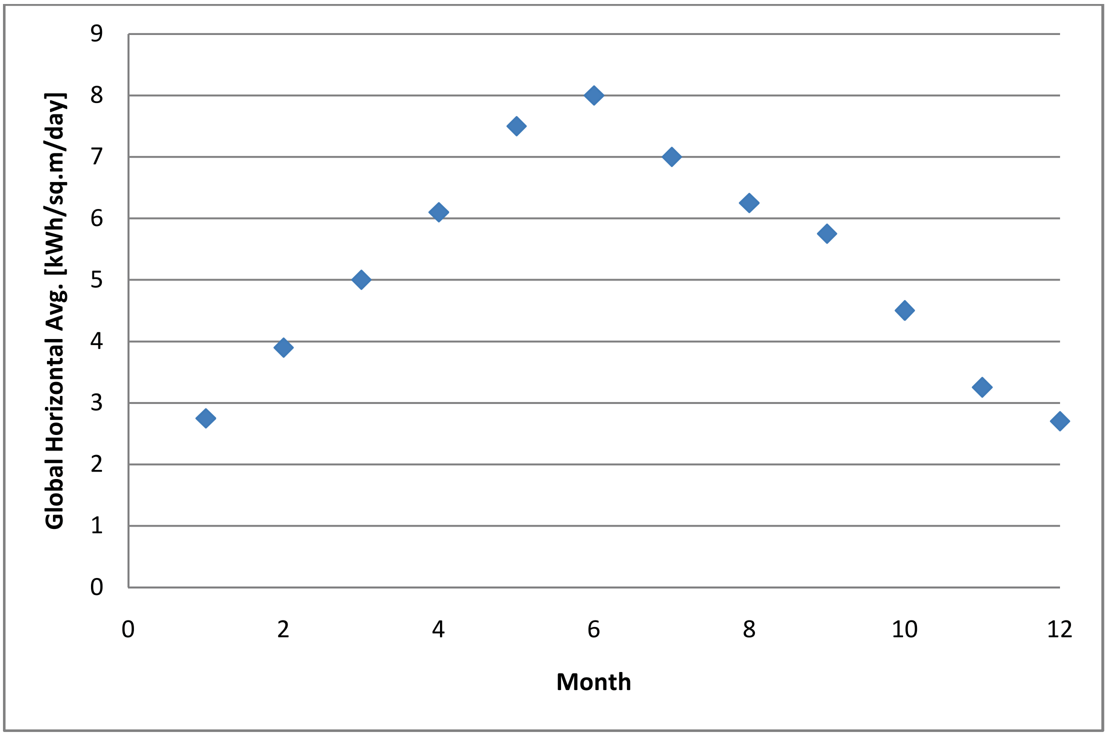

Figure 4: Monthly TMY daily average global horizontal insolation for Gaza in the Radiation Survey (1989-2002)

IV. Conclusions

This paper summarizes the first 11 years of data (1989 - 2002) that have been processed from the Gaza Radiation Survey. This survey of Typical Meteorological Year files (TMY) based on the direct beam component, and the archived hourly data upon which they are based.

For purposes of simulating the performance of solar-concentrator power plants Gaza station is introduced. Annual fluctuations in direct beam radiation may, however, be considerable. For example, during the 11 years of data that is discussed in the present paper. It is concluded that: (1) sufficient data probably now exist in order to enable one to identify the places for locating solar power stations; (2) several more years of data will be necessary before a sufficiently reliable data base will exist for the purpose of simulating solar- concentrator power plant performance and determining their economic benefit.

The average annual global horizontal radiation for Gaza is 2017 kWh m^{-2} $year^{-1}$. For purposes of simulating solar power plants of the non-concentrator variety Gaza station has global horizontal totals up to 6% lower than the mean normal global. We note also that the year-to-year fluctuations in global horizontal radiation are very much smaller than those among the direct beam components. We conclude, therefore, that for non- concentrator purposes Gaza probably now has enough data for reliable simulations.

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