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A software tool for the creation of a typical meteorological year

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ABSTRACT

The generation of a typical meteorological year is of great importance for calculations concerning many applications in the field of thermal engineering. In this context, a method has been proposed by Hall et al. focusing on the generating of typical data, and improving the criterion for final selection of typical meteorological month (TMM). The final selection of the most representative year was done by examining a composite score *S*, which was calculated as the weighed sum of the scores for the four used meteorological parameters. These parameters were air dry-bulb temperature, relative humidity, wind velocity and global solar radiation intensity.
This work reports a new modern software tool using Delphi 6.0 utilizing the Filkenstein–Schafer statistical method for the creation of a typical meteorological year for any site of concern. Whereas, an improved criterion for final selection of typical meteorological month was employed. Such tool allows the user to perform this task without an intimate knowledge of all of the computational details. Using this software tool, a typical meteorological year was generated for Damascus, capital of Syria, as a test run for example. The data processed used were obtained from the Department of Meteorology and cover a period of 10 years (1991–2000).

1. Introduction

A climatological and solar database is very important for the calculation of energy efficiency and must be representative of the area of interest. A representative database for year duration is known as a typical meteorological year (TMY), a term mainly used in the USA, or a test reference year (TRY) or design reference year (DRY), terms mainly used in Europe. TMY, TRY or DRY consists of individual months of meteorological data sets selected from different years over the available data period which is called long-term measured data series.

The question of "typicality" appears to be sidestepped by most users of solar and building energy simulations. Some have selected weather, which appears to them to be typical of an appropriate portion of the year. Others have selected a year, which appears to be typical from several years of solar radiation data, and some investigators have run long periods of observational data in an attempt to simulate typical weather for the calculation. The best address to the question of typicality thus far appears to be that taken by the solar group at the University of Wisconsin [1,2]. This group had selected each month of a typical year from a total of 10 years of data on the basis that the month selected had the same mean radiation as the mean for that month calculated from the entire 10 years of data. Nevertheless, even this approach leaves many unanswered questions whether the sequence of days within the month selected is typical.

Several methods for generating typical data have been developed. Typical meteorological year methodologies have been proposed by many investigators [2–18]. The primary objective of these methods is to select single year or single month from the multi-year database, preserving a statistical correspondence. This means that the occurrence and the persistence of the weather should be as similar as possible in TMY to all available years. These different TMY methodologies have been developed with selection criteria based on only solar radiation or on solar radiation together with other meteorological variables. Eventually, the above mentioned methods often seem rather convoluted and complex. For description of performance comparison between different methods for generating TMYs, the reader is adviced to refer to Argiriou et al. [19] and Julia et al. [20].

The literature review conducted in this work shows that one of the most common methodologies for generating a TMY is the one proposed by Hall et al. using the Filkenstein–Schafer (FS) statistical method [21] "Sandia method". The other methodologies cited above for generating TMY use a modified version of Hall et al. This method is an empirical approach that selects individual months from different recorded years from. The selection criteria was based on 13 meteorological parameters. These parameters were the daily mean, maximum and minimum values and ranges of temperature,

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dew-point and wind velocity and the daily values of global solar radiation. However, four of 13 parameters were considered to be less effective, and therefore, are given zero weight. These variables are the ranges of daily dry-bulb temperature, wet-bulb temperature and wind speed, and daily minimum wind speed. Except for a few changes to the weighting criteria, which account for the relative importance of the solar radiation and meteorological elements, there has been no change in the original methodology which has been adopted by different countries. For example, by the date of publication, Siurna et al. for Canadian cities [22], Pissimanis et al. for Athens [8], Shaltout and Tadros for Egypt [23], Marion and Urban for 239 meteorological stations of USA [10], Lund for Denmark [24], Fagbenle for Ibadan, Nigeria [25], Chow and Fong for Hong Kong [26], Petrakis et al. for Nicosia, Cyprus [12], Merter and Arif for main Turkish cities [27], Somsak and Khemmachart for Bangkok [28], Zhang et al. for main Chinese cities [31], Soteris for Nicosia, Cyprus [32], Husamettin for Istanbul, Turkey [33], Kamal for Damascus, Syria [34], Lin and Huang for Taiwan [35], Husamettin and Buyukalaca et al. for southeastern Anatolia, Turkey [36,37], Naseem et al. for different locations in Oman [38], and Apple et al. for Hong Kong [39].

Recently, ASHRAE has been started an international project to develop TMY data throughout the world and international weather year for energy calculations (IWEC) [29,30]. Most recently, using the Sandia method Kalogirou developed TMYs for the city of Nicosia, Cyprus. The study of Kalogirou included additional variables such as illuminance, visibility, precipitation, and snow fall data [17].

The method proposed by Hall et al. is selected in this work as the most suitable one, and an improved criterion for final selection of typical meteorological month (TMM) was demonstrated. The final selection of the most representative year was done by examining a composite score *S*. The composite score was calculated as the weighed sum of the scores of the four used meteorological parameters. These parameters are air dry-bulb temperature, relative humidity, wind velocity and global solar radiation intensity. One can see that the methodology implemented leads to acceptable results. It finds the TMM, which would seem to include the following sensible properties:

- The meteorological measures of the TMM, i.e., temperature, relative humidity, wind and solar radiation should have frequency distribution, which are "close" to the long-term distributions.
- The sequences of the daily measures of the TMM should in some sense be "like" the sequences often registered at a given location.
- The relationships among the different measures of the TMM should be "like" the relationships observed in nature.

Since we deal with large sets of data, performing the relevant rather complex statistical calculations are time consuming. So far, development of computer programs for performing such specific statistical calculations was the object of very few studies [40]. In the frame of this work, an attempt is made to develop a software tool for the implementation of this method. This software tool was named "TMY Generation" and includes a number of data filtering and processing utilities. It also includes the graphical outlay of the results. All kinds of tests and successes have been demonstrated. This software tends to be usable for the researcher and designers, by means of interactivity, user friendly and easy communication. The conceptual basis of this tool was exposed and one example of application was demonstrated.

The "TMY Generation" program was used to generate a TMY for Damascus province. Damascus is located in the southwestern corner of Syria and cover 18 100 km^2 of built up area. About 3.5 million people live and work in this area. It has a pleasant and varied Mediterranean climate with four distinct seasons. Average temperatures in the summer, winter, spring and autumn are 32 °C, 10 °C and 22 °C, respectively. The time zone for November–February is GMT + 2 h and for March–October is GMT + 3 h.

The meteorological and global solar radiation data that were used in this work are from the measurements of meteorological stations in Damascus International Airport and in Kharabo site and cover a period of 10 years (1981–1990). The Damascus International Airport Station is located at 36° 30′ east longitude, 33° 24′ north latitude and at an elevation of 608 m above sea level. The Kharabo station is located at 36° 28′ east longitude, 33° 30′ north latitude and at an elevation of 620 m above sea level. A variety of routine meteorological data as well as irradiance data have been collected for a great number of years and archived in the database of the Meteorology Department.

2. Method used

The approach adopted for selecting TMYs for a given zone is as follows: a typical month for each of the 12 calendar months from the long term database was chosen and then those 12 months TMMs are catenated to form TMYs. The data set generated to form the basis for the selection of a typical month consisted of nine daily indices calculated from the hourly values of air dry-bulb temperature, relative humidity, wind velocity and global solar radiation intensity. Monthly statistics were calculated for each index. Month/year combinations, which had statistics that were 'close' to the long-term statistics, were candidates for typical months. Final selection of a typical month included consideration of persistence of the weather patterns.

The procedure for selecting a TMM consisted of two steps. The first step was to select five candidate years. The second step was to select the TMM from the candidate years.

2.1. Selection of five candidate years

For each of the 12 calendar months, the procedure involved selecting the five years that were 'closest' to the composite of all 10 years. This was done by comparing the cumulative distribution function (CDF) for each year with the CDF for the long term composite of all 10 years for each of the nine indices. The statistic selected to measure the closeness of each year's CDF to the long term composite for a given index was the FS statistic.

For each month of the calendar year, five months are selected, having the smallest weighed sum of the FS statistics of the nine daily indices, namely, maximum, minimum and mean air dry-bulb temperature (T_{max}, T_{min}, $\overline{T}$) and relative humidity (RH_{max}, RH_{min}, $\overline{RH}$), maximum and mean wind velocity (W_{max}, $\overline{W}$) and daily global solar radiation (G). The weighed sum WS of the FS statistic is calculated according to

$$FS_x(y,m) = \frac{1}{N}\sum_{i=1}^{N}\left|CDF_m(x_i) - CDF_{y,m}(x_i)\right| \quad (1)$$

$$WS(y,m) = \frac{1}{M}\sum_{x=1}^{M} WF_x FS_x(y,m) \quad (2)$$

$$\sum_{x=1}^{M} WF_x = 1 \quad (3)$$

where CDF_m is the long term (10 years) and $CDF_{y,m}$ is the short term (for the year y) cumulative distribution function of the daily index x for month m, and WF_x are the weighting factors, one for each daily index. N is the number of bins and M is the number of considered