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A method to generate Typical Meteorological Years from raw hourly climatic databases

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ABSTRACT

In order to assess the efficiency of buildings or renewable energy systems, simulation software needs relevant meteorological files. These weather data are generated thanks to statistical methods. Actually, these methods are derived to treat high quality hourly databases or monthly average of the weather parameters. When only inconsistent hourly database is available for a site, the meteorological file used for the energy simulations must be generated from the monthly averages.

This paper deals with a new weather data generation tool, Runeole, that is capable of generating a set of Typical Meteorological Year (TMY) data directly from inconsistent hourly databases. This C++ software is based on typical weather sequence analysis. It deals with the analysis and the generation process of stochastic continuous multivariable phenomena with frequency properties applied to a climatic database. The method is able to reproduce the time dependencies and the cross-correlations between different weather parameters. To do so, five weather parameters at least must be taken into account: air temperature, humidity, global solar radiation, wind speed and wind direction.

This paper introduces the methodology used and the analysis of the results given by the meteorological databases from different worldwide climates.

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1. Introduction

The design of buildings, in terms of energy consumption and thermal comfort, is directly influenced by the climatic context. The design rules of construction must meet precisely the external local weather conditions. Moreover the forecasting of energy efficiency of buildings also needs an accurate and a simultaneous knowledge of a wide range of climatic parameters [5,10]. These weather parameters are solar irradiation, dry bulb temperature, humidity, wind speed and wind direction [7,8]. We also need to take into account the time dependency of these parameters. The current best way of taking into account the dynamic behaviour of the weather without being time consuming in terms of calculation time is the use of Typical Meteorological Years (TMYs). In order to size systems properly and to assess the energy demand of buildings, these TMYs should gather the long term trend and the daily fluctuations with an hourly time step.

The first means of investigation to derived TMY or Test Reference Year (TRY) data files is the selection of typical month through the Sandia's method [4,11]. But to get accurate TRY, this method requires long term and consistent hourly weather databases that exhibit a minimum of gaps in the data. To select a month, CIBSE and ASHRAE agree on a maximum of 15% of erroneous and missing data for any single parameter [15]. So this method cannot be applied to most parts of the world where automatic weather stations that record hourly data are recent or where the climatic databases are inconsistent.

When only monthly means are available, TMY can be obtained by using a weather generator such as METEONORM [20] or TRNSYS Type 54 [12,23]. For METEONORM and TRNSYS Type 54, which are the most used, the deterministic part is commonly generated from the long term means associated with mean profiles or trigonometric functions. The way the weather data are generated has reduced significantly their accuracy for two reasons. First, these methods use some parameters that are site dependent. Second, the stochastic part is obtained by autoregressive functions. According to these methods, each parameter is split and studied independently from the others. The drawback of this split is that the estimation of the cross-correlations between some of the generated weather variables could not be realistic.

The aim of the method presented here is to generate TMY from inconsistent hourly weather databases. Such databases presenting too much missing data can't be used for the selection of typical month by the Sandia's method [11]. The method is able to reproduce

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Nomenclature

ε, ε'	uniformly distributed random numbers
ρ_0	lag 0 correlation coefficient
ρ_1	lag 1 correlation coefficient
σ	standard deviation
C	weather state
C_0	lag 0 correlation matrix
C_1	lag 1 correlation matrix
d	daily index
DBT	dry bulb temperature (°C)
Fp	repartition function of probabilities
G	hourly global horizontal irradiation (W m^{-2})
G_d	daily global horizontal irradiation (Wh m^{-2})
H	hourly index
i, j	weather state indices
k, l	weather parameter index
K	number of weather parameters
k_t	clearness index
N	number of weather states
p_i	marginal probabilities
p_{ij}	conditional probabilities
r'	residual part
r	residual part
RH	relative humidity (%)
Ws	wind speed (m s^{-1})
Wd	wind direction (°, north = 0°)
X_k	value of the weather parameter k
$\overline{X_k}$	average value of the weather parameter k

correlations between the artificial and measured weather data that cannot be obtained with the actual weather generators Meteonorm and TRNSYS Type 154. In our approach, the typical weather sequences and their probabilities of transition obtained through long term measurements [18] are the deterministic parts of the climate. The stochastic part is obtained thanks to a correlative and autoregressive matrix function [16]. This process treats simultaneously all the weather variables under consideration. Therefore the time dependencies and the correlations between the climatic parameters are well reproduced. This method has been implemented in the C++ software named Runeole [6].

The approach used for the development of this synthetical outdoor climate is quite similar to that of common weather generators. The mathematical model generates new hourly data which have the same statistical properties as the measured data. In order to reproduce these statistical properties, the climate is divided into a deterministic part and a stochastic part.

In the following section, the mathematical model of outdoor climate will be presented. Then, we will focus on the accuracy of the generated data for a set of weather stations (Table 1) in Section 3. The interest of this new method of TMY generation will be discussed in Section 4.

2. Mathematical model of the weather generator

The main algorithm is described in Fig. 1. In the following subsections, we will explain in detail each step, beginning with the verification process.

2.1. Step 1: verification of the raw data

In order to detect simultaneously missing data and erroneous values, we first check whether the value of the different recorded weather parameters matches with their interval of definition

Table 1
Description of the meteorological weather stations.

City	Country	Period of record	Percentage of available days	Altitude (m)	Latitude	Longitude
Tropical						
Avirons	Reunion	2002–2006	95.59	180	21°14′24″S	55°19′36″E
Dzaoudzi	Mayotte	1991–2006	40.65	7	12°48′18″S	45°16′54″E
FAAA	Tahiti	1991–2006	55.53	2	17°33′12″S	149°36′30″W
Gillot	Reunion	1991–2006	86.58	8	20°53′30″S	55°31′42″E
Le Raizet	Caraïbes	1991–2006	49.74	13	16°51′48″N	61°30′54″W
Ligne Paradis	Reunion	1997–2006	41.59	156	21°19′06″S	55°29′06″E
Matoury	Guyana	1991–2006	62.27	4	4°49′18″N	52°21′54″W
Piton Saint-Leu	Reunion	2000–2006	77.58	565	21°12′42″S	55°19′36″E
Saint-Paul	Reunion	1997–2006	57.94	186	20°58′30″S	55°19′30″E
Petit-Canal	Caraïbes	1996–2006	29.55	35	16°24′18″N	61°28′54″W
Temperate						
Ajaccio	Corsica	1991–2006	85.24	5	41°55′00″N	8°47′30″E
Belfast	Ireland	1991–2005	87.92	63	54°39′51″N	6°13′28″W
Camborne	Cornwall (UK)	1991–2006	67.50	87	50°13′04″N	5°19′43″W
London	England	1991–2004	80.14	43	51°31′15″N	0°06′35″W
Corte	Corsica	1991–2006	55.15	362	42°17′54″N	9°10′24″E
Spezet	France	1994–2006	58.60	138	48°10′24″N	3°43′42″W
Altitude > 1000 m						
Bellecombe	Reunion	1998–2006	84.48	2245	21°13′00″S	55°41′12″E
Petite France	Reunion	1999–2006	62.85	1200	21°02′42″S	55°20′30″E
Cold						
Aviemore	England	1996–2006	86.92	228	57°34′33″N	3°49′06″W
Dumont D'Urville	Antarctica	1991–2006	48.56	43	66°36′42″S	140°00′00″E
Lerwick	Shetland (UK)	1991–2006	86.77	82	60°08′03″N	1°11′10″W
Port-Aux-Français	Kerguelen	1991–2006	39.02	29	49°21′06″S	70°14′36″E
Saint-Pierre	Saint-Pierre et Miquelon	1991–2006	28.19	21	46°45′54″N	56°10′42″W

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