Summer climatic data for Geneva: average and extreme conditions

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ABSTRACT: In the field of summer cooling by ventilation and/or evaporation, a good knowledge of the dry and wet bulb temperatures represents the basis of any simulation processes. The summer of the city of Geneva was analysed based on extracted from a large amount of climatic data obtained in downtown and its surroundings. The data study over the three summer months of the last decade shows that if the climate varies only very little from one summer to the other, there is nevertheless a considerable difference according to whether one is in urban or rural zones. In addition, summer 2003 is far apart from the average statistics.
This study aims to establish a representative database on average summer temperature conditions, downtown and in rural sites, as well as extreme conditions like in summer 2003.
A comparative study is also made with the Meteonorm software, which is the commonly used tool to generate data when no station is available.

Keywords: cooling, climatic database

1. INTRODUCTION

The share of energy consumption for the air-conditioning systems of buildings has become important. However, the use of a cooling system by means of ventilation or evaporation is an interesting alternative for summer comfort. The potential decision on using these systems requires a sound knowledge on the summer climate. A precise climatic database is therefore, essential for a correct evaluation of such systems [2].

This paper studies the summer climate in Geneva. On-sites variables are based on 15 years of temperature and radiation measurements in downtown Geneva and in its surroundings. Hence, enables to establish an average reference year and extreme values such as those measured during the 2003 summer.

2. DATA

Within the framework of the Centre Universitaire d'Etudes des Problèmes d'Energie (cuepe www.cuepe.ch), different projects have been conducted. A variety of data is obtained in the city of Geneva and in its surroundings.

In this study, the variables of two stations are used as reference: the Jonction station (located in the city of Geneva, at the Ernest-Ansermet Quay), with an IDMP station acquired since 1990 (IDMP, 1991, idmp.entpe.fr), and the Meteo Suisse (Swiss Weather Institute) at the Geneva-Cointrin Airport [www.meteosuisse.ch].

The Jonction is used as urban climate reference, whereas, the Geneva-Cointrin refers to the rural climate. Data from other stations are used to back up the obtained results.

The majority of the dry and wet temperature measurements were carried out by means of Rotronic probes (precision in temperature = ± 0.1°C, in relative humidity = ± 5%), the radiation acquisition was made with precision Kipp & Zonen CM10 pyranometers (precision of ± 2%).

3. AVERAGED AN INTERPOLATED DATA

To perform simulations, the lack of measurements often implies the use of data generation softwares or interpolations between stations. As such, it is possible to obtain data at any point of the globe, nevertheless the difficulty arrives from the fact that these data, by and large, do not differentiate the rural areas from urban, and take only little account of the climatic evolution.

Meteonorm is the software [www.meteotest.ch] most generally used for this purpose. It is based on more than ten years of measurements. It also allows data generation based on 12 measured monthly values on a given year, download from the Internet.

4. ANALYSIS METHOD

This study takes into consideration only the three summer months (June, July and August, days 152 to 243). Generally, these months are the hottest period of a year during which cooling down buildings become necessary to keep a certain comfort.

The main analysis relates the cumulated frequencies of the dry bulb temperature (or ambient temperature) over the measured period. Indeed, the characteristic of the summer climate is given by the number of hours during which a temperature threshold was exceeded. The curve is plotted on the basis of the sorted temperature according to the number of hours during which this temperature was exceeded, which in turn, gives directly the desired information (Figure 1).

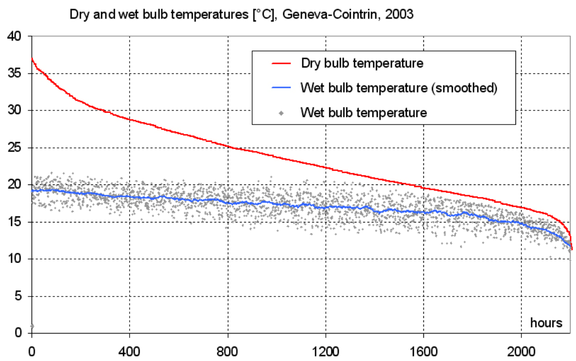

Figure 1 Dry and wet bulb temperature cumulated frequencies for the year 2003 acquired at Geneva-Cointrin.

A wet bulb temperature corresponds to each dry bulb temperature; it represents the content of condensable water vapour in the air. If one traces the corresponding values on Figure 1, one obtains a group of dots giving the various possible values of the associated wet bulb temperature to these dry bulb temperatures. By smoothing out these values on 60 values (± 30 values, Figure 1), one can obtain an average curve.

The analysis is carried out over a period of 16 years (1990 to 2005) at Geneva-Cointrin and four years (2002 to 2005) at the Jonction station (for technical reasons, temperatures were not measured at night at the Jonction until 2002). In order to simplify certain graphs, an average curve over several years is calculated, and it is surrounded by ± one standard deviation.

A comparative analysis is also carried out concerning the total radiation measured on a horizontal level. In this case, the graphs are expressed as a percentage time rather than in a number of hours on the abscissa. This comes from the fact that one considers only the hours when the total radiation exceeds 5 [W/m^2], and that the day length is variable during the year. In addition, they are the conventions used in the field of radiation and daylight [www.satel-light.com].

5. DRY BULB TEMPERATURE URBAN - RURAL COMPARISON

Jonction measurements are taken on the roof of a 15 floors building, in a rather dense urban zone. They are considered as representative of the urban climate, which is very heterogeneous by nature. The Geneva-Cointrin airport measurements are obtained on grass and are representative of the rural climate. The cumulated frequencies of the urban and rural summer temperatures are represented on Figure 2 for year 2004. It is noted that if the maxima are relatively close, there is a systematic difference of 2-3°C between the two sites, which is reproducible from year to year. This confirms results published in a previous paper [5]

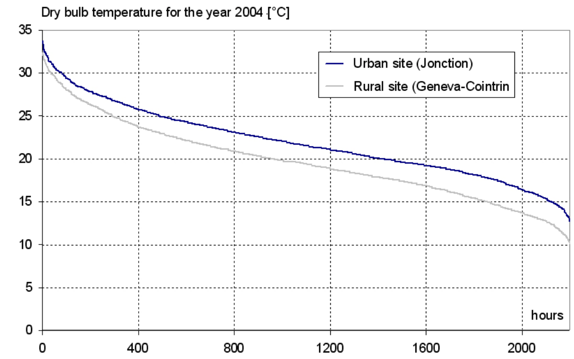

Figure 2 Rural and urban comparison of the bulb temperature cumulated frequencies for the year 2004.

6. INTERANNUAL VARIATION

This study also aims to establish standard summer periods, use as reference to fresh, average and hot summer. Over the recorded 16 years, summers are very similar from one to the other, with of course, the exception of year 2003 which is characterized by its high values. Figure 3 illustrates this tendency, with an average curve (1990 to 2005), surrounded by ± one standard deviation. It shows clearly the year 2003 is exceptional, largely apart from two standard deviations (95% of confidence). Temperatures obtained at the Jonction in urban climate have come to the same conclusions.

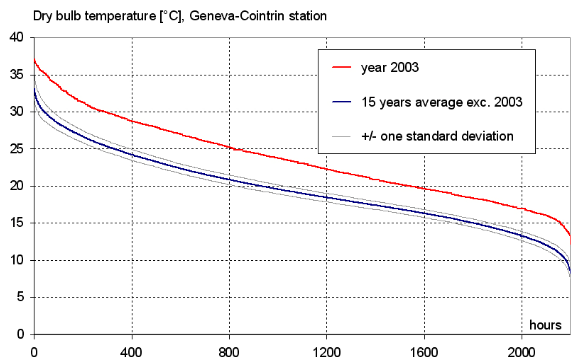

Figure 3 Interannuel variation of the 15 years average (exc. 2003) dry bulb temperature cumulated frequencies and for the year 2003.

Alternatively, it is very interesting to note that the interannual variations over the considered period are less significant than the urban-rural effect highlighted in the preceding section.

7. WET BULB TEMPERATURE

The wet bulb temperature is representative of the adiabatic potential of the evaporative cooling [7]. For the dry bulb temperature, the wet bulb temperature interannual variations are not very important and an average curve can be determined from the 15 years of measurements as illustrated on Figure 4.

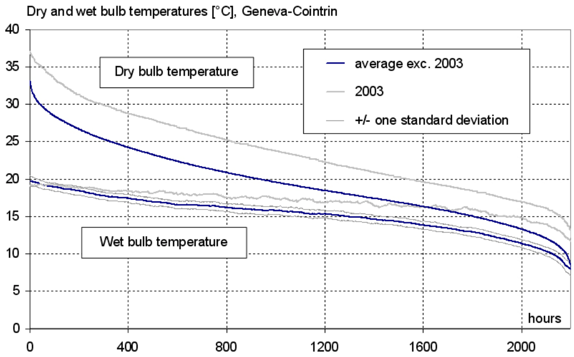

Figure 4 Interannuel variation of the 15 years average wet bulb temperature cumulated frequencies and for the year 2003.

The interesting point is the 2003 values considered over the 200 hottest hours do not deviate from the average of the other years. This shows that even with a particularly hot summer like 2003, the adiabatic cooling potential is preserved.

The on-site measurements obtained at Geneva-Cointrin are confirmed by the measurements from the Junction. Both sites take into account the urban-rural difference highlighted in section 5.

8. SOLAR RADIATION

The radiation is responsible for the overheating of buildings during the summer, thus justifies the analysis equally as the dry and wet bulb temperatures. As highlighted with the dry and wet bulb temperature, the interannual fluctuations are weak compared to the radiation values obtained during the summer 2003.

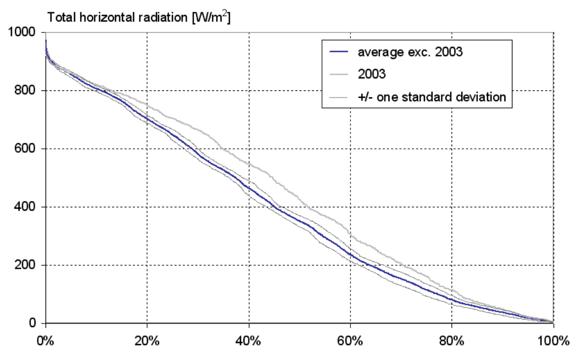

Figure 5 Interannuel variation of the 7 years average total horizontal solar radiation cumulated frequencies and for the year 2003.

Similarly, the temperatures, one can reduce the interannual fluctuations to an average curve surrounded by ± one standard deviation as illustrated on Figure 5.

Figure 6 illustrates the behaviour of the normal beam radiation. It is interesting to note that in summer 2003, because of a long period of high stable pressure, there was a persistent aerosols load in the atmosphere which resulted in a higher attenuation of the beam radiation. The maximum values of radiation are thus lower and the number of hours of average radiation more than the other years.

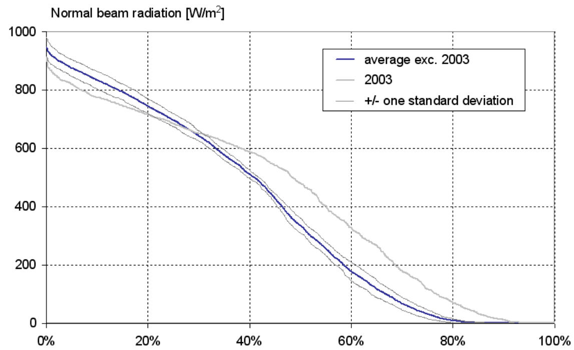

Figure 6 Interannuel variation of the 7 years average normal beam solar radiation cumulated frequencies and for the year 2003.

9. REFERENCE YEARS

Over the last 16 years, the analysis carried out has shown that only two reference years are necessary: an average and an extremely hot summer period. Indeed, the interannual variations over the considered period do not present an exceptionally fresh summer.

The preceding analysis leads to the choice on year 2004 as representative of the average climate over the considered period, except the year 2003. The year 2003 remains an exceptionally hot summer period reference. This choice is confirmed in regard to the radiation cumulated frequencies, as year 2004 measurements are not far from the average year, except 2003.

Simulation carried out over summer period, can determine temperatures higher or lower than the average. The summer 1994 is representative of the hottest summer (except 2003), and the year 1996 is the freshest summer.

10. OTHER SITES OF MEASUREMENTS

The results obtained from the Jonction and Geneva-Cointrin stations must be validated by means of measurements taken elsewhere in the Geneva region. Other stations in the Geneva region are also used to obtain a series of measurements limited in parameters and time. The above results are corroborated by these measurements.

- during the year 2003, a project required the acquisition of the dry bulb temperature in the Geneva countryside, in Bardonnex [1]. Measurements were taken in a tarred court; the dry bulb temperature cumulated frequencies are compared to those from the Jonction and Geneva-Cointrin. The curve is located between the urban and the rural curves. This is explained by the presence of buildings surrounding a tarred interior court,

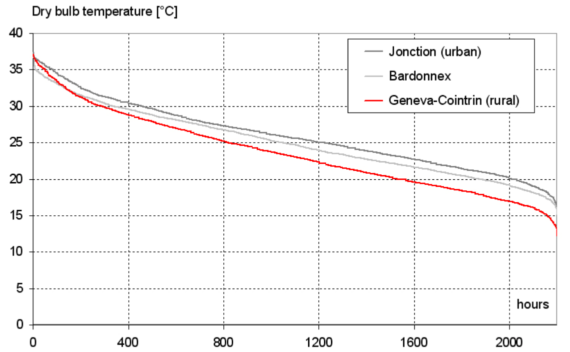

Figure 7 Dry bulb temperature cumulated frequencies for the year 2003 acquired at Jonction, Bardonnex and Geneva-Cointrin.

- The dry and wet bulb temperature measurements were taken in rue de la Corraterie [3], a street leads towards the lake during the year 2001. The result presents a temperature curve located between the downtown and the rural site, the urban values "are refreshed" by the draughts due to the proximity of the lake,
- a study undertaken in a housing estate in the countryside nearby Geneva-Cointrin airport since the end of 2004: the "Pommier" [8]. Measurements taken here are apart from the dense urban zone but similar to the situation of the countryside. The dry bulb temperature cumulated frequencies further confirm its similarity to those of Geneva-Cointrin. This effect had been highlighted by Lachal [6].
- the analysis of a cooling system in a building of Peney in the Geneva countryside during the year 2001 required the dry and wet bulb temperature measurements [4]. The corresponding cumulated frequencies are also close to those measured at Geneva-Cointrin.
- on the northern bank of the Lake of Geneva, a temperatures and wind measuring equipment make it possible for windsurfers to verify online information concerning the lake meteorological conditions. The access to these data (www.vengeron.net) enables to show that the lake moderates the measured values of the dry bulb temperature. Indeed, the variables of the dry and wet bulb temperature cumulated frequencies show a slightly weaker slope than those in Geneva-Cointrin, with nearly the same average value.

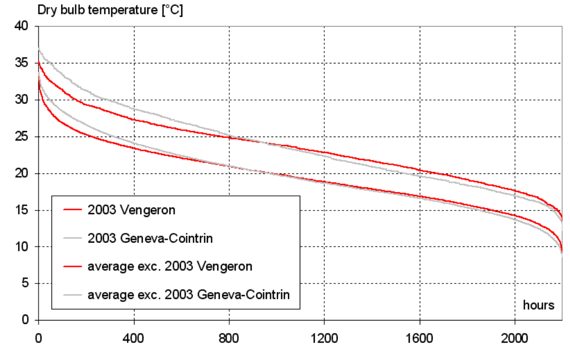

Figure 8 Dry bulb temperature cumulated frequencies for the year 2003 and the average exc 2003, acquired at Vengeron and Geneva-Cointrin.

These analyses show a good knowledge on the characteristics of the place to carry out a simulation enable decision on the type of data to use.

11. DATA GENERATED WITH METEONORM

The software Meteonorm enables climatic data generation when measurements are not available. It was developed for the particular conditions in Switzerland and takes relatively well into account the geographical characteristics of the country. It is based on well validated models and many data banks of several decades. It is thereafter, extended to the whole world.

To generate the various climatic parameters, the software enable the use of internal radiation and temperature values or real monthly mean values downloaded from the Internet. It also offers the possibility to import personal hourly or monthly data. In addition, it is also possible to specify the environment, such as, "open site", "urban conditions", etc. Analyses were carried out by means of the internal values for Geneva-Cointrin, and of real values from the years 1998 to 2005 in order to compare with the measurements from the Jonction.

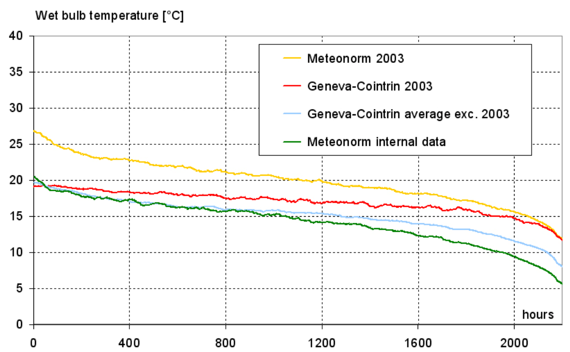

Figure 9 Comparison of the wet bulb temperature cumulated frequencies generated by Meteonorm and acquired at Geneva-Cointrin.

The comparison between the data measured in Geneva-Cointrin and those generated by Meteonorm without contribution of real data shows that the data the software provides are slightly underestimated, and that the use of the internal Meteonorm data for a summer period such as 2003 can lead to very important errors. In addition, in spite of the fact that it is possible to specify the site characteristics, the urban-rural variations is only about 0.7 °C, whereas a difference of about 2 °C is highlighted in section 5.

Likewise, for the wet bulb temperature, difference also becomes more important (Figure 9). Indeed, the software, on the basis of internal or real data, does not use measured data as parameter but produces values in a generic way. It is extremely important to be careful when using this type of software, and be very critical concerning the generated values. It is for example not possible to use such softwares to carry out an adiabatic cooling simulation.

Concerning the total horizontal radiation, even if Meteonorm is based on real data, the interannual distribution does not correspond to that carried out with the measurements of Geneva-Cointrin. There too, one need to be very critical when handling data generated for the evaluation of specific installations, as considering the horizontal diffuse radiation or the beam radiation on a tracking plane, the errors are then cumulated depending on the used algorithms.

12. CONCLUSIONS

The study carried out over the summer period between 1990 to 2005 shows that *the interannual variations of the dry bulb temperature are relatively weak*, except the summer 2003 which is particularly hot.

The temperature is a few degrees higher downtown than in rural sites (approximately 2 to 3°C). It is nevertheless necessary to modulate this difference according to the environment. Indeed, rural measurements taken in an interior gravel court can approach values generally more specific to urban sites and a well ventilated urban street data tend to approach rural values. These urban-rural effects are on the other hand definitely less important than the summer 2003 exceptional values.

The behaviour of the wet bulb temperature is relatively stable over the years, including the exceptional 2003 summer. Therefore, the wet bulb temperature is not higher in this case, which offers an interesting potential of adiabatic cooling.

These results obtained on the basis of two measuring site respectively located downtown and in the countryside are *corroborated by measurements of other stations located in the Geneva region*. It is nevertheless necessary to be careful when using data for a simulation, the situation of the place can be of high importance for the choice of the type of data to use.

With regard to the radiations, there are few interannual variations, and no urban-rural differentiation is necessary. On the other hand, it is necessary to differentiate the temperatures summer 2003 from the other years.

Precautions must be taken when using softwares such as Meteonorm for data generation. Although temperatures are underestimated, as a whole (in spite of use of real monthly mean values), they are relatively close to measurements; this is different for the wet bulb temperature and the radiation components.

In conclusion, the outcomes of this study show that *the year 2004 is perfect to represent the Geneva climate.* The year 2003 is used as reference for an exceptional hot summer period. 1994 and 1996 are respectively representative of slightly warmer or colder reference years. However, an extremely fresh year cannot be highlighted.

13. DATA AVAILABILITY

The data used in this study can be obtained under various conditions specific to the framework of the centres and institutes:

- the measurements taken at cuepe can be obtained from the centre, only during the time of extraction and work will be invoiced,
- the current measurements carried out at Geneva-Cointrin are accessible on line on the site www.meteosuisse.ch, the archives can be bought at Meteosuisse,
- the access to current measurements of Vengeron is free after inscription on the www.vengeron.net site,
- Meteotest sells the modelled values generated by Meteonorm software. All information is accessible on www.meteotest.ch

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