

Generation of typical meteorological years for the Argentine Littoral Region



Facundo Bre^{a,b}, Víctor D. Fachinotti^{a,*}

^a Centro de Investigación de Métodos Computacionales (CIMEC), Universidad Nacional del Litoral (UNL)/Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Predio “Dr. Alberto Cassano”, Colectora Ruta Nacional 168, Paraje El Pozo, 3000 Santa Fe, Argentina

^b Grupo de Investigación en Mecánica Computacional y Estructuras (GIMCE), Facultad Regional Concepción del Uruguay, Universidad Tecnológica Nacional (UTN), Ing. Pereira 676, E3264BTD Concepción del Uruguay, Entre Ríos, Argentina

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ABSTRACT

This work describes the generation of the typical meteorological year (TMY) for 15 locations all around the Littoral Region in northeastern Argentina, southeastern South America. The originally available weather data at each location contain, among others, dry-bulb and dew-point temperatures, wind velocity, and total sky cover, hourly measured during the period 1994–2014 by the National Meteorological Service (SMN) of Argentina. From other sources, two of these locations have hourly measured solar radiation during a few years. These radiation measurements were used to calibrate an existing Zhang–Huang solar radiation model that was then used to calculate the hourly solar radiation for the entire weather data base.

Once we complete the long-term weather database at a given location, we define the typical meteorological year (TMY) at this location as the concatenation of 12 typical meteorological months (TMM). The typicality of a month is measured using Finkelstein–Schafer statistics based on nine daily indices (maximum, minimum and mean dry-bulb and dew-point temperatures, maximum and mean wind velocity, and global solar radiation).

We finally show an example of application of the current TMYs for building energy simulation in a location deep inside Littoral. Subsequently we show the importance of the newly developed local TMY above using original TMY from neighbouring locations.

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1. Introduction

This paper aims to define the typical weather for locations throughout the Argentine Littoral Region (hereinafter referred to as “Littoral”). Littoral is a region with an area of 0.5 million km² in northeastern Argentina, southeastern South America, see Fig. 1. Its climate is Cfa (C for warm temperate, f for fully humid, a for hot summer) according to the Köppen–Geiger classification [1]. In a finer classification [2], Littoral is divided into three bioclimatic zones (those ones separated by red dashed lines in Fig. 1): very hot in the north (I), hot in the center (II), and warm temperate in the south (III). Further, each zone is divided into two subzones (a and b), those ones separated by a green dashed line in Fig. 1, regarding the daily temperature range be larger or smaller than 14 °C.

Temperatures throughout Littoral are not only high to very high during summer, but also they will be 2–4.5 °C higher (throughout

southeastern South America) by 2100 according to the 2014 report of the Intergovernmental Panel on Climate Change (IPCC) [3]. Up to our knowledge, there is no information to quantify the concomitant increase in energy consumption for cooling in Littoral nor in South America, but studies in the USA indicates that the electricity used for residential cooling will increase by roughly 5–20% (depending on the location and customer class) per 1 °C warming [4].

In Littoral, the National Meteorological Service (SMN) of Argentina measures dry-bulb and dew-point temperatures, wind velocity, total sky cover, etc. on an hourly basis. For this work, they provided us these weather data for fifteen stations throughout Littoral (see Fig. 1) during the period 1994–2014.

SMN databases lack solar radiation, for which there are not long-term, continuous, frequent enough records in Argentina. Actually, the systematic record of solar radiation in Argentina began in 2010 [5] with the work of the GERSolar research group. GERSolar operates a series of solarimetric stations, one of them being located at Paraná (Littoral). For the current work, the available information on solar radiation include the data from GERSolar at Paraná (bioclimatic zone IIb, Fig. 1) during 2010–2014 and the data recorded at

* Corresponding author.

E-mail address: vfachino@intec.unl.edu.ar (V.D. Fachinotti).

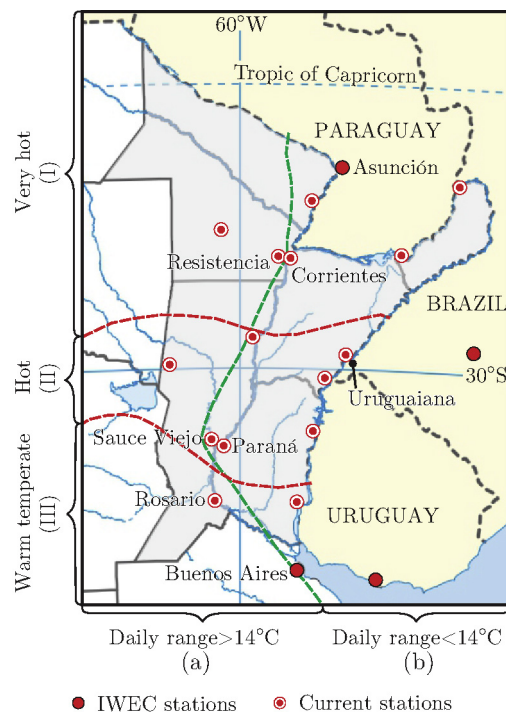


Fig. 1. Map of the Argentine Littoral Region (in light grey), showing the bioclimatic zones (I, II or III, a or b) and the location of weather stations. (For interpretation of reference to color in this figure legend, the reader is referred to the web version of this article.)

Corrientes (bioclimatic zone Ib, Fig. 1) by GER (research group on renewable energies) during 2010–2012.

One of the main goals of the current work is to overcome the lack of experimental solar radiation data by the use of accurate models. Following the ASHRAE development of IWEAC [6] and IWEAC2 [7], we evaluate two regression-based models: the Kasten model [8] and the Zhang–Huang model [9]. By fitting the available measurements as well as data from the IWEAC files of neighbour locations (Asunción–Paraguay and Buenos Aires–Argentina) and satellite-derived data from the Surface meteorological and Solar Energy (SSE) database [10], we will demonstrate that the Zhang–Huang model with coefficients calibrated to Paraná is very well suited to estimate the long-term solar radiation throughout Littoral.

With the aid of such solar model, we complete the available long-term databases for 15 locations in Littoral, opening the way to the definition of the typical weather at each location, which is the final goal of this work. For accurate energy calculations at a given location, we need to know the typical local weather at short intervals (usually, every hour) all along a year judged to be typical over a long period of time. There are two general approaches to define such typical year: (1) to select a continuous, 12-month period as typical; or (2) to select each typical calendar month separately, and then to concatenate the 12 typical months to build the typical year.

The first approach was introduced in the 1970s, with examples as the Test Reference Year (TRY) from the National Climatic Center (NCC) in USA [11], and the Example Weather Year (EWY) from the Chartered Institution of Building Services (CIBS) in UK [12]. This approach excludes the extreme conditions found in the long-term weather records, producing excessively moderate typical years.

To avoid this, we decided to use the second approach, following the pioneering work of Hall et al. [13] in Sandia National Laboratories (USA). In this work, appeared in 1978, Hall et al. introduced the concept of “typical meteorological year” (TMY) as a concatenation of typical meteorological months (TMMs). Later examples are the

TMY2 [14] and TMY3 [15] from the US National Renewable Energy Laboratory (NREL), the new Test Reference Year (TRY) from the Chartered Institution of Building Services Engineers (CIBSE, former CIBS, UK) [16], the International Weather for Energy Calculations (IWEAC [6,17] and IWEAC2 [7]) from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), etc. For reviews comparing these methods, we refer to the works of Crawley and Huang [18], Lhendup and Lhundup [19], and Chan [20].

Typical years from all around the world (1042 locations in the USA, 71 locations in Canada, and more than 1000 locations in 100 other countries) are given in the EnergyPlus weather data website [21]. There you can find files defining the typical year at each location, derived from 20 sources including Sandia’s TMY [13], NREL’s TMY2 [14] and TMY3 [15], and ASHRAE’s IWEAC [6,17]).

In this large database, there are very few locations in southeastern South America: Argentina, Paraguay, Uruguay, and Rio Grande do Sul (the Brazilian region neighboring Littoral) are represented by only one location each one. The shortage of information on the typical weather is a great obstacle for the development of energy simulation. Focusing on building energy simulation (BES), most of the works in Argentina [22–24] concerns short periods of time, using actual (not typical) weather data. In 2013, when we had to apply BES for Sauce Viejo (in Littoral, within the climatic zone IIb, see Fig. 1) [25], the local typical year was approximated by that one at Uruguaiana (southern Brazil). The typical years for Uruguaiana and other 410 Brazilian locations were defined by Roriz [26]. At this time, this seemed to be the best choice considering the similarity in weather conditions. However, Roriz [26] warned about the low representativeness of the typical years he defined due to the short length of historical records.

Then, we decided to generate the typical year for Sauce Viejo [27] based on the weather data measured by SMN at this location during the period 2000–2013, supplemented by solar radiation computed using the Zhang–Huang model [9] calibrated to tropical climate [28], as recommended by Kim et al. [29] for eastern Texas (USA), where the climate is Cfa like in Littoral.

Now, with the larger (in time and space) weather databases (including radiation) built at the beginning of this work, typical years are generated for the 15 locations throughout Littoral.

To this end, we follow the original method of Hall et al. [13] (the so-called “Sandia method”) for the Typical Meteorological Year (TMY). A TMY is a set of 12 typical meteorological months (TMMs). As first proposed by Hall et al. [13] and later picked up by Thevenard and Brunge [6] for IWEAC generation, the typicality of a month is measured using Finkelstein–Schafer statistics based on nine daily indices (maximum, minimum and mean dry-bulb and dew-point temperatures, maximum and mean wind velocity, and global solar radiation). Each variable is given a weight considering how determinant it is for the selection of the TMM. The Sandia and the IWEAC generation methods use different sets of weights, to be compared in this work.

After generating the TMYs, we give an insight of the typical weather for locations in different bioclimatic zones of Littoral (warm temperate, hot, and very hot). Finally, we develop an application to building energy simulation (BES) to highlight the importance of using the local TMY for a location deep inside Littoral.

2. Description of the weather data source

The meteorological database supporting this work was obtained by SMN during the period 1994–2014 at 15 weather stations located all around Littoral, those ones listed in Table 1 and shown in Fig. 1.

The available data include, among others, hourly measures of the following meteorological variables:

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