TYPICAL METEOROLOGICAL YEAR FOR SOLAR ENERGY SYSTEMS IN URUGUAY BASED ON SOLAR SATELLITE ESTIMATES

Summary

Long-term solar radiation measurements are not available in Uruguay. A satellite-based solar irradiation model, adjusted with local high-quality, short-term (5 years) ground measurements, is used to complement existing long-term hourly records of humidity, temperature and wind speed and direction, and develop typical meteorological years (TMY) for the three climatic regions of the country. Hourly solar data is generated from GOES-East satellite images from January 2000 to date. The irradiation model is an improved version of Tarpley's model with very good performance in the relevant geographical region. With the resulting 15 year hourly datasets, NREL's TMY3 methodology is followed to obtain the TMY annual series.

Keywords: solar irradiance, satellite-based models, TMY, GOES images.

1. Introduction

A typical meteorological year (TMY) is a series of annual data which is representative of the typical weather condition of a site for a period of time. It is constructed by concatenating series of real data that is considered typical, and thus, the resulting annual series preserves the average, the typical variability and annual behavior of the variables involved. The TMY data series is suitable for simulations of solar energy devices or building's thermal behavior under realistic conditions. It should not be used for worst-case scenario assessment or to evaluate an actual output of a system. Using a base methodology originally proposed by Sandia National Laboratories (Hall et al., 1978), three types of TMYs have been developed in USA known as TMY, TMY2 (Marion and Urban, 1995) and TMY3 (Wilcox and Marion, 2008). These versions differ in the amount, quality and period of time of the input data used, and in few changes of implementation. In this work we use the TMY3 methodology to obtain hourly TMY datasets for three different locations in Uruguay.

2. Meteorological data and methodology

A TMY dataset is composed of typical values (in a precise statistical sense) of some meteorological variables. In this work, we select a group of variables useful to simulate solar energy conversion systems and thermal efficiency of buildings: global irradiation at an horizontal surface (GHI), direct normal irradiation (DNI), ambient temperature (TA), relative humidity (RH), wind velocity (WV) and wind direction (WD). Ideally, a TMY dataset should be derived from at least 30 years of hourly records. However, series of hourly ground measurements are scarce in Uruguay. In particular, solar irradiance is not recorded systematically at any of the national weather stations and the other variables (humidity, temperature and wind speed and direction) are recorded every three hours at most sites. As a result, long-term hourly ground measurements are only available for a few locations and solar irradiance is unavailable. Following UNIT 1026 national standard, the country has been divided in three climatic regions (North-West, Center and South-East). We select three stations, one in each of these regions, where hourly data are available for approximately 15 years.

In Uruguay, a TMY does not exist to date, essentially because there are no reliable long-term series of solar irradiation. Using satellite images it is possible to generate GHI estimates for arbitrary sites at an hourly basis. We use a local database of GOES-East images that account for the period 01/2000 to date. The irradiation model is based on a pre-existing statistical model (Justus et al., 1986). In (Alonso Suárez et al., 2012, 2014) a modified version of this model was introduced, which greatly improves the quality of the estimates. This improved model was adjusted for Uruguay and surrounding areas using 5 years of high quality ground data. These solar measurements are recorded by a measurement network with countrywide coverage, equipped with First Class or Secondary Standard pyranometers, which are calibrated every two years using a secondary standard (Kipp & Zonen CMP22). This pyranometer is periodically calibrated against the World Radiometric Reference at the World Radiation Center in Davos, Switzerland. A comparison with ground measurements (not used to adjust the model) shows that the performance of the model in the target territory is excellent: a relative Root Mean Squared Deviation of 14% and 7% was obtained for hourly and daily estimates, respectively. DNI measurements are much more scarce and recent. Thus, we derive DNI values from GHI using a diffuse fraction model. This model (Ruiz-Arias et al., 2010) was specifically adjusted for the region using both global and diffuse ground records from Uruguay and Argentina (Abal et al., 2013). The uncertainty of the satellite-derived DNI values is evaluated using indirect DNI measurements based on global and diffuse ground records from two Delta-T SPN1 pyranometers.

We follow the TMY3 methodology for each sites' dataset (Wilcox and Marion, 2008). A month of real hourly data must be selected for each month of the year, and thus, by concatenation and forcing continuity at night time, an annual dataset is constructed. To characterize the typical regime of a variable, the long-term Cumulative Distribution Function (CDF) for each month is computed from the 15 years of data. The actual typical month is the one with a CDF which is closer to the long-term CDF of the same variable. The distance between CDF's is measured using the normalized sum of the difference absolute values between them, which is known as the FS statistic (Finkelstein and Schafer, 1971). A unique FS statistic is obtained for each month by a weighted-average of the FS of each variable. The weights are chosen taking into account the relevance of each variable for the intended use. We select the weights in a similar manner as in (Wilcox and Marion, 2008). Then, each data-month is ranked based on its FS value, so that the month with lowest FS is the most typical. A series of persistence filters are applied to the best candidates in the list in order to detect and discard data-months with autocorrelations that are not typical of a meteorological time-series, since this is not necessarily preserved by the procedure. Finally, a set of 12 months is selected and a TMY is derived. This methodology is applied separately for the three climatic regions considered in this work.

3. Conclusion

A satellite-based approach is used to derive long-term solar data which is not available in Uruguay. The model to obtain solar hourly series was developed locally and adjusted to the target region using short-term hourly data from our solar measurement network. The satellite data allows us to complete meteorological datasets of about 15 years with hourly solar irradiation data. Using these data, three TMY datasets suitable for solar energy simulations are developed for the three climatic regions in the country, following the TMY procedure as recommended by NREL. The availability of TMYs datasets has a great impact in Uruguay, as it is required tool to evaluate devices which convert solar energy into useful energy, such as solar thermal or photovoltaic or to assess the thermal efficiency of buildings.

4. References

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