SWC 2019
SATELLITE-BASED INTERANNUAL VARIABILITY OF GLOBAL HORIZONTAL AND DIRECT NORMAL SOLAR IRRADIATION IN URUGUAY

Summary

This is the first study which aims to characterize the interannual and intermonth variability for solar radiation in the territory of Uruguay. Both global horizontal irradiation (GHI) and direct normal irradiation (DNI) are considered. Satellite-based hourly estimates validated with good quality ground data are the basis for the analysis. The satellite information consists of the complete set of GOES-East images (visible channel) from 2000 to 2017 (18 years). As expected, DNI variability is larger than GHI. The number of years necessary for a solar radiation average with given confidence level is also determined.

1 Introduction

The interannual variability of the solar resource must be taken into account when estimating the probable energy yield of a medium or large scale solar power plant. A good knowledge of the local variability is required in order to reduce the financial risk of the project and increase its financial viability (Gueymard and Wilcox 2011; Fernández Peruchena et al. 2016).

The variability of solar radiation has an important local component determined by the cloudiness regimes and by daily or seasonal variations in atmospheric composition and aerosol type and content. In the area of interest of this study there are no previous studies on internanual variability of the solar resource. Aerosol density is low (except for a few small isolated burn events related to agriculture) and the main contribution to variability comes from water vapor and clouds. Records of global horizontal irradiance (GHI) measurements suitable for climatological characterization (ideally spanning several decades) are nonexistent at most places and the situation is even worse for direct normal irradiance (DNI). For this reason, long-term satellite estimates have frequently been used for this purpose (Krakauer and Cohan 2017; Wainana and Sato 2018).

In this work, the 18-year database of GOES-East satellite images (visible range) maintained by NOAA is used to estimate hourly GHI from a locally adjusted and well validated satellite model (Alonso Suárez et al. 2012; Alonso-Suárez et al. 2014). Regularly, an image is available every 30 minutes approximately. A simple interpolation scheme is used to compensate for missing images when only tri-hourly images are available. The DNI hourly estimates are obtained from a locally adjusted diffuse fraction model (Abal et al. 2017). Both GHI and DNI estimates are validated against three years of local BSRN-quality ground data in order to assess the uncertainty in the hourly, daily and monthly mean estimates. The yearly totals are calculated for each year and their variability is investigated. This is the first systematic study on interannual variability in this region.

2 Results

2.1 Validation

Validation of the satellite-based estimates of GHI and DNI is done against 2 years (2016 and 2017) of good quality ground-based data for a single location (LE site, latitude = $-31.28°$, longitude = $-57.92°$, elevation = 56 m). GHI is measured with a secondary-standard CMP10 Kipp & Zonen pyranometer. DNI is measured by a Kipp & Zonen CHP1 pyrheliometer mounted on a SOLYS2 tracker fitted with a fine alignment Sun sensor. Instruments are polled every 10 seconds and the average is recorded at 1 minute intervals. The station is cleaned and maintained on a daily basis. The data is filtered using the extremely rare BSRN limits and by solar altitude larger than $7°$ to avoid low-sun error-prone data. The commonly used indicators, rRMSD (Root

Table 1: Relative indicators for satellite-based GHI and DNI as compared to ground data. The last row is the ground data averages. The hourly comparison is based on 41213 hours from 2016-2017 and the daily comparison on 751 days from the period 2015-2017.

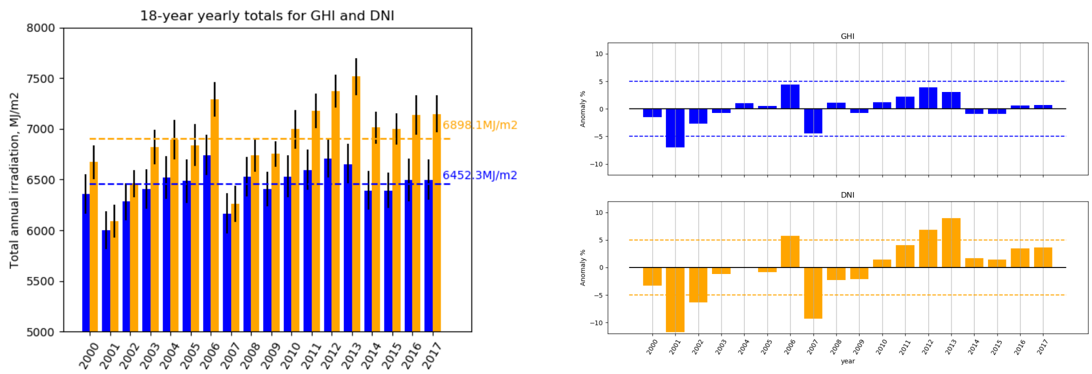
Hourly	GHI	DNI	Daily	GHI	DNI
rMBD (%)	-0.8	-1.3	rMBD (%)	-0.5	-2.4
rRMSD (%)	10.0	22.7	rRMSD (%)	5.3	13.3
average $(\mathrm{Wh/m^2})$	556.2	594.0	average $(\mathrm{MJ/m^2})$	19.0	21.9

Mean Squared Deviation) and rMBD (Mean Bias Deviation), expressed as a % of the measurement average, are used to evaluate the satellite-based estimates for DNI and GHI against the ground data. The validation is conducted both at the hourly level and at the daily total level and the results are summarized in Tab. 1. A small underestimation (negative bias) is observed in both variables, but the stated parameters show a good performance, consistent with the time scale and methodology used to obtain the satellite-based estimates.

2.2 *Yearly totals*

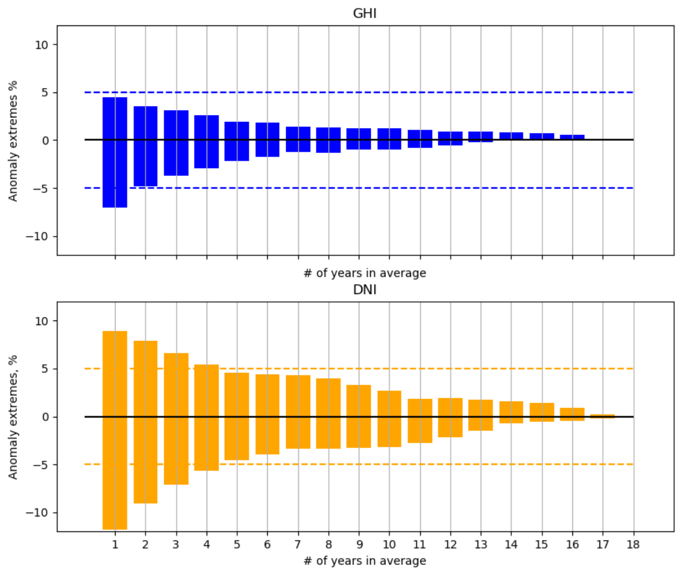
Monthly averages for GHI and DNI are computed for the 18 year data base. Inter-month variability can be analyzed from this data. Given the space limitations for the abstract, we describe here only the inter-annual variability results. Yearly totals are calculated for each year using the monthly averages and the number of days in each month. The long-term average for yearly total GHI is $6452\,\mathrm{MJ/m^2}$ and for DNI $6898\,\mathrm{MJ/m^2}$. The anomaly of a given year is defined as the difference between the year's total irradiation and these long term average. The anomalies are shown in Fig. 1, where the thin vertical bars represent the uncertainty in the satellite-based yearly totals.

Figure 1: Yearly total and anomalies for the LE site. Blue is GHI and orange is DNI.



A similar analysis can be repeated at any other point in the territory to study the spatial variations, since the satellite model has a spatial resolution of about 3 km. There is another form to present the variability information (Wainana and Sato 2018; Fernández Peruchena et al. 2016; Lohmann et al. 2008). This is done by averaging the yearly anomalies using a variable window of $L_w = 1, 2, \ldots 18$ years. For each window size, only the extreme anomalies (maximum and minimum) are preserved. When these extreme anomalies (expressed as a % of the long term mean) are plotted vs the window size, a figure like Fig. 2 results. Of course, for $L_w = 18$ the anomalies are zero. This implies that at least three years of GHI daily data are required if an average with a level of confidence of 95 % is desired. For DNI, at least 5 years of data are required for the same confidence level.

Figure 2: Extreme yearly anomalies for the LE site with variable moving average (1 to 18 year) windows.



3 Conclusion

A database of 18 years (2000-2017) of GOES-East satellite images and a locally adjusted model (BD-JPT) are used to obtain hourly estimates for GHI irradiation. Hourly DNI is obtained from them, using a locally adjusted diffuse fraction separation model. A validation against two years of good quality ground data shows that daily GHI is estimated with 5% uncertainty and daily DNI with 13 % uncertainty from this methodology. A preliminary analysis for one site shows that DNI has larger variability than GHI and at least 5 years are required for a 95% confidence level average.

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