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# Characterizing measurements campaigns for an innovative calibration approach of the global horizontal irradiation estimated by HelioClim-3

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ABSTRACT

This study explores the possibility to calibrate the estimation of the global horizontal irradiation provided by HelioClim-3, a satellite-based surface solar irradiation database (available at www.soda-is.com). The main objective of this work is to refine such an estimation whose performances differ from one site to another. A first processing of the long-term measurements provided by nine weather stations located in Provence-Alpes-Côte d'Azur Region (South France) leads to the characterization of the clearness index error variability for that Region: this parameter is made up of a bias, a drift and 3 sinusoids with periods respectively equal to the astronomical year, half a year and one third of a year. We show that the phase of the dominant frequency (365 days) is similar whatever the tested site. We propose a simple calibration procedure based on a linear regression whose performances, in terms of mean bias error and root mean square error, depend on the beginning and the duration of the measurement campaign; to illustrate this point, the mean bias error on the global horizontal irradiation for nine sites considered systematically goes below 3% when considering a 6-month measurement campaign starting in May. We also show that the performances of the proposed calibration are also applicable to another site in the same Region for which the initial error exceeds 13%. A graphical representation allows visualizing the characterization of these measurement campaigns depending on the expected accuracy.



## 1. Introduction

Strong attention is paid to the yearly yield production of photovoltaic (PV) projects whose economic constraints are becoming more stressing every day (higher investment for higher installed power). The reliability of this prediction depends on the accuracy of both the PV system modeling and the irradiation in the module plane.

Among other PV modeling software, PVsyst (available at www.pvsyst.com) allows constructing hourly meteorological data using monthly irradiation components as inputs: monthly global horizontal irradiation (GHI) and monthly diffuse horizontal irradiation (DHI) if available (otherwise a diffuse irradiance model is applied). Transposition in the collector plane is then performed using different models such as Hay's or Perez's [1,2]. Monthly GHI is, therefore, the minimum information regarding local irradiation which is mandatory for the yield assessment of any PV project. This would not have been the case for concentrated PV modeling whose constraints in terms of accuracy require the estimation of irradiation at a smaller timescale.

Different types of databases allow assessing the GHI of a specific site: databases based on ground stations, others based on satellite images and finally some others as a result of so-called reanalysis projects. Literature claims that it is better retrieving irradiation from satellite databases rather than interpolating measurements from surface stations 20–25 km apart [3–5]. This paper focuses on HelioClim-3 (HC3) database which is available through SoDa service (SOlar radiation DAta) and has been constructed since 2004 through the processing of Meteosat Second Generation satellite images by the Heliosat-2 method [6,7].

Even though the overall MBE (and its nMBE) is very low for all satellite databases, the inter-annual and inter-site variability is not

*Definition of symbols:* $GHI_X$, global horizontal irradiation (either daily or monthly) estimated by HelioClim-3 ($X = HC3$) or measured by a weather station ($X = ST$); $IRR_{TOA}$, daily horizontal irradiation at top of atmosphere; $KT_X$, clearness index corresponding to either HC3 estimation ($X = HC3$) or weather station measurement ($X = ST$); *j*, Julian date defined as the decimal number of the day starting at12 Universal Time on January 1, 4713 BC; MBE, mean bias error; nMBE, normalized MBE, with respect to the reference mean; RMSE, root mean square error; nRMSE, normalized RMSE with respect to the reference mean; CC, correlation coefficient.

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negligible for a given database [8]. When considering HC3 database, an earlier study [9] showed that for a given area (22 weather stations located in Provence-Alpes-Côte d'Azur Region – PACA, South France) the nMBE on the estimation of the monthly GHI is 5.3% for the overall sites (nRMSE = 10.2%). However, nMBEcan go up to 13.1% (nRMSE = 16.6%) for a coastal site without shading effect from orography and nMBE = 14.1% (nRMSE = 17.9%) for a site in the Alps.

Because the MBE is a systematic error that cannot be decreased with time step (*e.g.* month-to-year concatenation), it directly impacts the so-called typical irradiation (both monthly and yearly) that is used as an input to PV modeling software. It is, therefore, important to try and refine this satellite-based estimation through a calibration using on-site measurements. This is already the norm and latest practice in the field of wind energy for which a short campaign (6 months–1 year) usually measures the local wind distribution at the early stage of the project, as recommended by the International Energy Agency [10] that follows the best practice guidelines for wind energy. It is now appearing for large PV projects where local irradiation is measured every day by one or several pyranometers during a short period of time (typically lower than a year).

The two following challenges are addressed in the early stage of a PV project when considering such local measurement campaigns. The first challenge consists of defining a reliable calibration algorithm that corrects the long-term satellite-based estimation of the irradiation using the short-term local measurements. The second challenge consists of characterizing the measurement campaigns (start and duration) with respect to the expected gain (accuracy of the estimation); the double objective of this latest challenge is to optimize and limit the use of the physical weather station while remaining compliant with the project's milestones.

This paper addresses both challenges by considering the local calibration of HC3 daily GHI which is eventually used to decrease the MBE and the RMSE of the monthly GHI, as the irradiation is an input to PV modeling software along with the technical specification of the PV system (modules, inverters, electrical architecture…). This work only focuses on non-mountainous areas for which orography does not disturb the local measurements; a future work will be performed for mountainous areas.

Section 2 characterizes the error made by HC3 on the daily estimation of the GHI (through the clearness index) by processing the 5-year measurements of the daily GHI for nine sites located in PACA Region. This characterization leads to an analytic expression of the error made by HC3 which is applicable to long-term estimations.

Starting from this expression, Section 3 eventually characterizes the performance of the calibration algorithm depending on the start and the duration of the short-term measurement campaigns that have been simulated using the nine sites located in PACA.

We finally check the performances of this calibration be applicable to a site located in the PACA Region and presenting a stronger initial bias (nMBE = 13.1%).

## 2. Characterizing the error of the clearness index

### 2.1. Long-term performance of HC3 for nine sites in PACA

Such a characterization has been conducted with the use of nine weather stations belonging to Meteo France's network in PACA, whose latitude is suitable to PV projects and for which a solar atlas had been previously issued [9]. Fig. 1 locates these stations within PACA region.

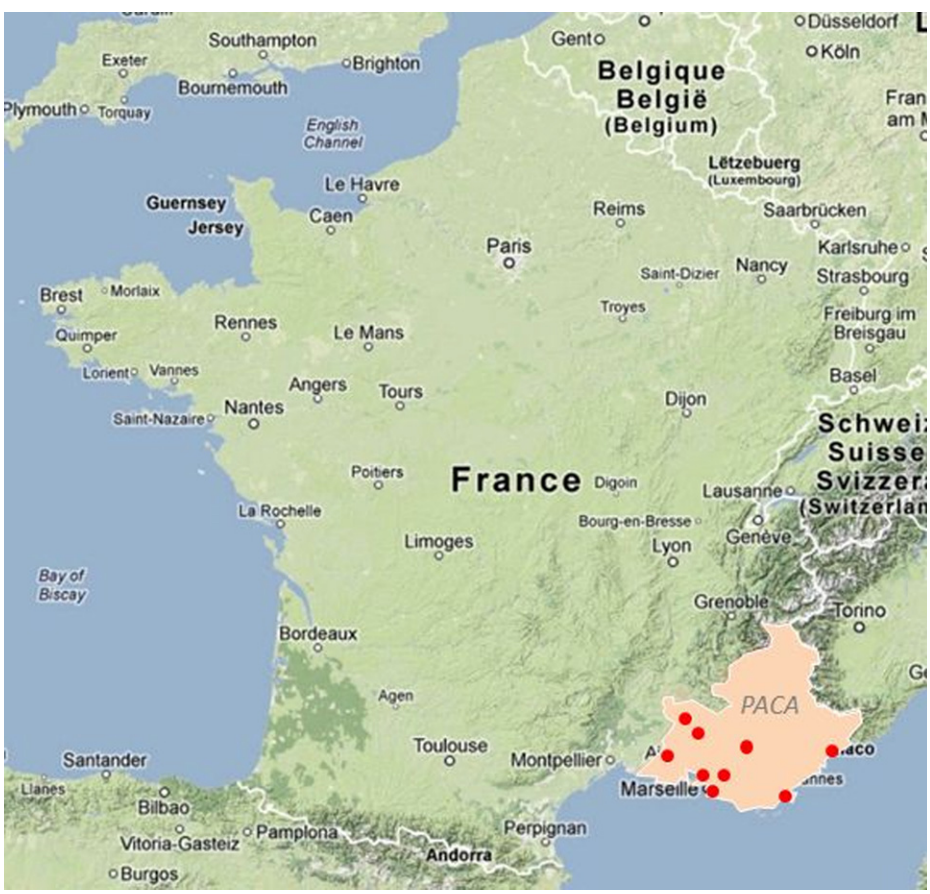


**Fig. 1.** Geographical location of the nine weather stations in non-mountainous areas of Provence-Alpes-Côte d'Azur (PACA), measuring the daily GHI over a 5-year period that is concomitant with HC3.