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Preliminary survey on site-adaptation techniques for satellite-derived and reanalysis solar radiation datasets

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Abstract

At any site, the bankability of a projected solar power plant largely depends on the accuracy and general quality of the solar radiation data generated during the solar resource assessment phase. The term "site adaptation" has recently started to be used in the framework of solar energy projects to refer to the improvement that can be achieved in satellite-derived solar irradiance and model data when short-term local ground measurements are used to correct systematic errors and bias in the original dataset. This contribution presents a preliminary survey of different possible techniques that can improve long-term satellite-derived and model-derived solar radiation data through the use of short-term on-site ground measurements. The possible approaches that are reported here may be applied in different

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ways, depending on the origin and characteristics of the uncertainties in the modeled data. This work, which is the first step of a forthcoming in-depth assessment of methodologies for site adaptation, has been done within the framework of the International Energy Agency Solar Heating and Cooling Programme Task 46 "Solar Resource Assessment and Forecasting".

Keywords: Satellite-derived solar radiation; Site adaptation; Bankability of data for solar projects; Solar radiation model-derived data

1. Introduction

Accurate and precise knowledge of the local solar resource is a prerequisite for the successful deployment of any solar energy system. For instance, reliable and accurate data of different components of solar radiation are needed for concentrating solar power (CSP) projects, which are primarily interested in direct normal irradiance (DNI), and flat-plate collectors (PV or thermal) which require good predictions of the incident global horizontal (GHI) or global tilted irradiance (GTI), also referred to as "plane of array" (POA). From the initial site selection stage to the plant's design and financing the solar resource assessment plays a major role in the success of the project whenever monthly or annual plant predictions are needed (Stoffel et al., 2010; Sengupta et al., 2015).

High-quality solar resource measurements at the target site are usually not available to ensure proper solar resource assessment and thus to secure the final acceptance of the project. Additionally, the inter-annual variability of solar radiation components plays an important role in the uncertainty associated with the energy yield prediction of solar plants. As a consequence, long-term, typically multi-decadal, time series of the key solar radiation components are required at various stages of any solar plant project (Meyer et al., 2006; Stoffel et al., 2010). Since multi-decadal measurements are hardly available at any potential solar power plant site, long-term time series of solar irradiance must generally be supplied from modeled data, typically using satellite imagery to derive the influence of clouds on solar radiation at the Earth's surface.

Solar radiation components at the Earth's surface can be determined from several methods and different approaches. The most widely known ones are those based upon the use of meteorological satellites (Hammer et al., 2003; Mueller et al., 2003; Rigollier et al., 2004; Janjai et al., 2005; Polo et al., 2008; Perez et al., 2013). The underlying methodologies have been evolving during the last 30 years, following advances in remote sensing and computational techniques. The literature documents this trend that started with simple methods based on a crude atmospheric energy balance (Gautier et al., 1980; Moser and Raschke, 1983; Cano et al., 1986) and has progressed to the more intricate methods currently in use (Perez et al., 2002; Rigollier et al., 2004; Mueller et al., 2004; Schillings et al., 2004; Viana et al., 2011). For solar applications, most developments follow an empirical or semi-empirical approach, also referred to as the cloud-index method. The common approach to determine DNI with the cloud-index method is the use of a GHI-to-DNI separation method (Gueymard and Ruiz-Arias, 2014). In recent years, a convergence between the physical and the semi-empirical approach has started to manifest, with semi-empirical models tending to include more physical descriptions. Physical methods (using retrievals of cloud optical properties from satellite observations) can now provide appropriate datasets for solar applications (Sengupta et al., 2015).

Satellite based methods are able to provide long-term hourly or even sub-hourly time series of solar radiation components. A thorough validation exercise of most of the current satellite-based databases has been performed within the International Energy Agency (IEA) Solar Heating and Cooling (SHC) Programme Task 46 "Solar Resource Assessment and Forecasting" activities (Ineichen, 2014). Different comparative and evaluation studies have shown that despite the high accuracy and reliability of satellite-derived data, significant differences from ground data may result (e.g., Gueymard, 2011; Ineichen, 2014). This is a consequence of several sources of error, whose complex causes typically affect GHI, GTI and DNI differently (Cebecauer et al., 2011). For instance, satellite-derived methods usually require external atmospheric information on the most important attenuating components under cloudless conditions, namely aerosols and precipitable water vapor, with an important impact on the final uncertainty (Gueymard and Thevenard, 2009; Gueymard, 2012, 2014). In addition, site-specific information (albedo or topography) is also needed and can affect the final uncertainty. A complete list of known issues and potential uncertainty sources in satellite-based solar models is outlined in previous works (Suri and Cebecauer, 2014).

For sound solar resource assessments, all model-derived estimates must be validated and qualified as much as possible using locally available ground measurements. Moreover, all large solar power projects must respond to stringent bankability criteria, following the regular practice of financial institutions. In this context, detailed and accurate knowledge of the seasonal and inter-annual variability in the solar resource is of crucial importance. Therefore, bankable energy production scenarios must be based on a statistical analysis of long-term time series. Since a large inter-annual variability of the solar resource means a larger risk, this variability must be thoroughly assessed. Current studies demonstrate that the inter-annual variability in