Method and System for Accessing PV Resource Data from the NSRDB

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Method and System for Accessing PV Resource Data from the NSRDB

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Abstract

This study developed a capability to provide spectrally resolved solar resource data from the National Solar Radiation Data Base (NSRDB), effectively providing 20 years of half-hourly data for all of the United States at a 4-km by 4-km spatial resolution. These data are now available freely to users directly through a geographic information system-based web interface (https://nsrdb.nrel.gov) as well as an application programming interface. Users of these data can conduct more accurate pre-feasibility studies and assess multiple photovoltaic (PV) technologies. It is expected that widely used models such as PVSyst, the National Renewable Energy Laboratory's (NREL's) System Advisor Model (SAM), and First Solar designed PlantPredict will develop the capabilities to use these spectral data.

Keywords: PV resource, radiative transfer, cloud, solar radiation

1. Introduction

Reducing uncertainty in the prediction and/or verification of photovoltaic (PV) plant output can directly increase the expected return on investment (ROI) for each party in a contract, likely leading to more favorable terms for the contract, including a possible reduction in interest rates. Note that a reduction of 1% in the interest rate is estimated to reduce the levelized cost of energy by ~0.5 cents/kWh. Solar resource is generally measured or modeled on the horizontal plane, whereas PV is mostly deployed at orientations that are tilted to optimize production. There have been significant efforts to develop models that can transform global horizontal irradiance (GHI) into a plane-of-array (POA) solar resource (Gueymard, 2009; Klucher, 1979; Liu and Jordan, 1961; Perez et al., 1987; Reindl et al., 1990). This conversion process has generally required two steps: (a) separation of GHI into direct normal irradiance (DNI) and diffuse horizontal irradiance (DHI) and (b) transposition of DHI, GHI and DHI into POA; both introduce uncertainties into the conversion process. More than 90 separation models (Step a) are currently available as documented in recent studies (Gueymard, 2010; Gueymard and Ruiz-Arias, 2014). These separation models are empirical and introduce similar levels of uncertainty in the GHI-to-POA process as Step b. A few transposition models, such as the Perez et al (1987) model, are also used to estimate POA from horizontal irradiance (Step b). All are empirical and location-specific in nature, with considerable uncertainty.

We reduced the uncertainty in (1) predicting future PV plant performance and (2) assessing existing PV plant performance. We accomplished this by modeling the spectrally weighted POA irradiance, which we refer to as the "PV resource," and creating and disseminating PV resource data sets to PV stakeholders. We also created more accurate satellite-based PV resource data than shown by the results from current methods, thereby leading to a reduced price of solar electricity and increasing the expected return on investment of PV projects.

2. Development of PV Resource

An important component of developing accurate PV resource data is the spectral distribution of solar radiation because all PV technologies are spectrally selective. We developed a high-resolution spectral distribution model using broadband irradiance measurements and satellite retrieved cloud properties from the National Solar Radiation Database (NSRDB). Previous models such as TMYSpec (Myers, 2012) and SEDES2 (Nann and Riordan, 1991) have a low resolution and are not compliant with the spectral resolution of current standard International Electrotechnical Commission (IEC) 60904 and ASTM G173 spectra, whereas radiative transfer models for meteorological applications are capable of computing spectral POA irradiances in a single step but require significant computing efforts in practice (Brown and Xie, 2012; Ding et al., 2009; Lawless et al., 2006; Minnis et al., 2011; Sengupta et al., 2018; Xie, 2010; Xie and Liu, 2013; Xie et al., 2014; Xie et al., 2016; Xie et al., 2006; Xie et al., 2011; Xie et al., 2009; Xie et al., 2012a; Xie et al., 2012b).

Figure 1 illustrates a flowchart of the algorithm to develop the PV resource. We developed a Fast All-sky Radiation Model for Solar applications with Narrowband Irradiances on Tilted surfaces (FARMS-NIT) to efficiently compute irradiances on inclined PV panels for 2002 narrow-wavelength bands from 0.28 to 4.0 µm (Xie and Sengupta, 2018; Xie et al., 2018; Xie et al., 2019). We analyze the benefit of combining aerosol optical depth (AOD) from Moderate Resolution Imaging Spectroradiometer (MODIS) and NASA Modern Era Retrospective Analysis for Research and Applications-2 (MERRA2). To accurately model surface impacts, a national climatology of surface albedo for the NSRDB 4 km grid is developed through the MODIS MCD43GF product and National Ice Center's Interactive Multisensor Snow and Ice Mapping System (IMS). The atmospheric and land surface properties are employed by the Simple Model of the Atmospheric Radiative Transfer of Sunshine (SMARTS) (Gueymard, 1995), the model used to develop the IEC 60904 and ASTM G173 clear-sky spectrum, to simulate high-resolution spectral atmospheric properties for the clear-sky atmosphere.

For cloudy-sky conditions, we develop the scattering properties of clouds for a set of relevant spectral bands and apply those properties to solve the radiative transfer equation to compute the spectral radiances in the whole hemisphere. Because solving the radiative transfer model is computationally expensive, a pre-computed database of cloud bidirectional transmittance distribution function (BTDF) is created as functions of cloud optical thicknesses, particle sizes, spectral bands, and solar and viewing geometries. This database enables fast extraction of spectral radiance given specific cloud properties and solar and viewing angles.

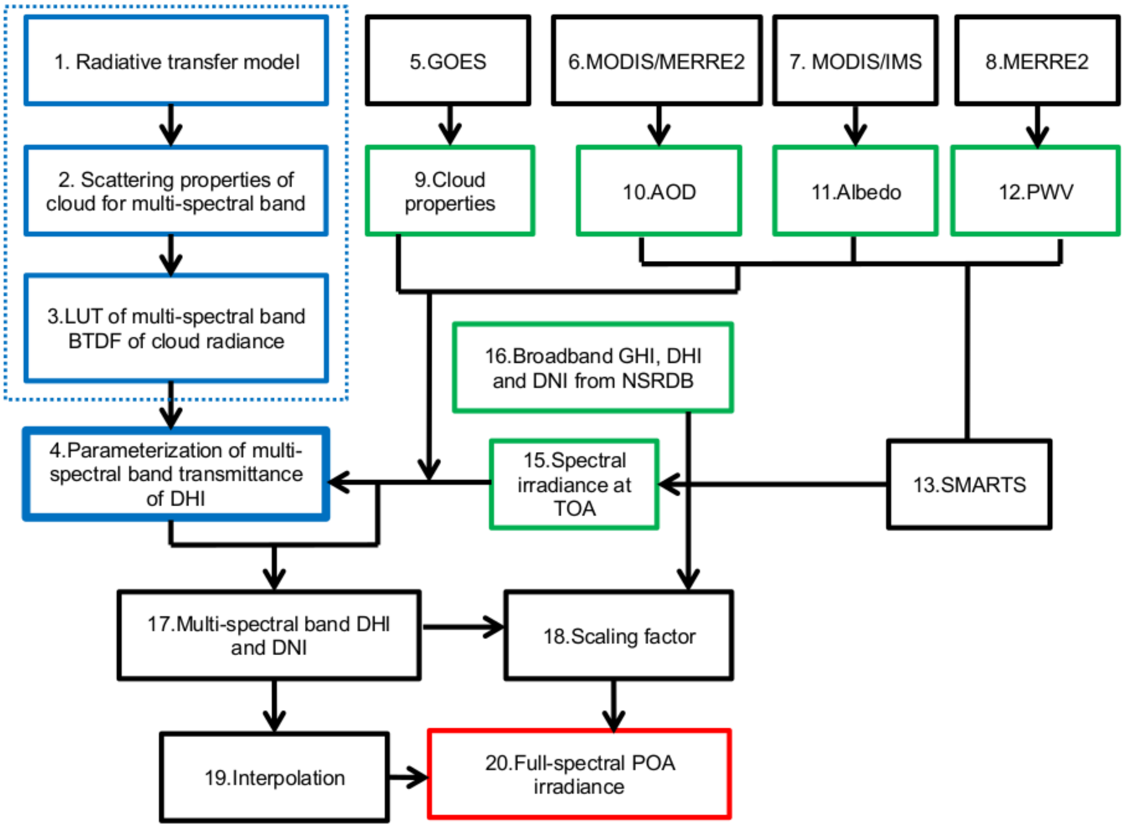

Figure 1 A flowchart of the algorithm to develop PV resource data.

3. Data Dissemination

The NSRDB Spectral Data On-Demand download tool provides users with access to the spectral solar radiation data via the NSRDB Viewer in an easy-to-use interface as well as via a download application programming interface (see Fig. 2). The viewer components provide access to a map tool for selecting the location as well as an input form for choosing the data year and download options. Options include calculating the spectral data for fixed and one-axis systems.

Once a request is submitted by a user, a spectral data generation job is placed into a job queue. A dedicated high-performance server consumes jobs in the order received and generates the requested data as quickly as possible. As soon as the data have been generated and are available for download, a signal is sent back up the job queue, which triggers an email to the user.

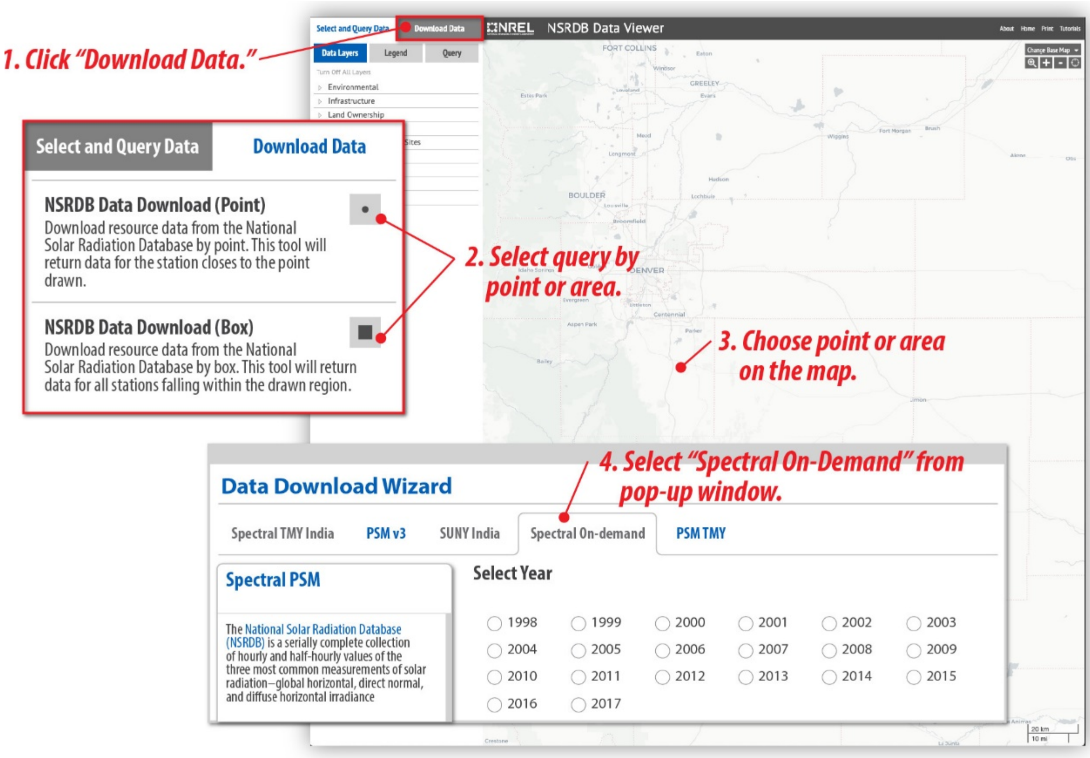

Figure 2 A diagram of the NSRDB viewer

4. Validation

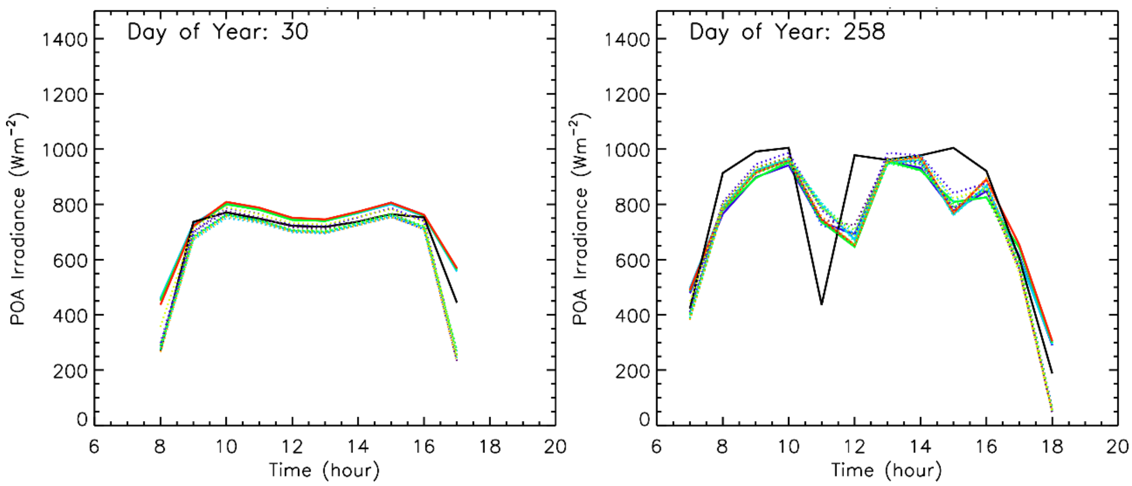

Figure 3 POA irradiances from the NSRDB (black line) compared with measurements from the thermopiles (solid color lines) and reference cells (dashed color lines) on the 30th and 258th day of 2017 for a site in Arizona.

To valid the PV resource data, we compared the model simulations to long-term surface observations of POA irradiances from First Solar. Figure 3 illustrates POA irradiances from the NSRDB compared with measurements from the thermopiles and reference cells on a single-axis tracker at a site in Arizona. The left panel is for a clear-sky day; measurements from thermopiles are slightly larger than reference cells, especially during the sunrise and sunset. The model simulations by FARMS-NIT show a very good accuracy, with most of the values between those from the thermopiles and reference cells. During a cloudy-sky day (the right panel of Fig. 3), the difference between the measurements from the thermopiles and reference cells are smaller than the clear-sky day. The model simulations from FARMS-NIT also show generally good accuracy in the cloudy-sky day, though more uncertainty is seen because of the error in cloud property retrievals.

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