



NREL HOME

ABOUT NREL ENERGY ANALYSIS SCIENCE & TECHNOLOGY TECHNOLOGY TRANSFER TECHNOLOGY DEPLOYMENT ENERGY SYSTEMS INTEGRATION

Transmission Grid Integration

More Search Options SEARCH Site Map

Printable Version

Transmission Grid Integration Home

Issues

Projects

Research Staff

Working with Us

Publications

Webinars

Data & Resources

Wind Integration Datasets

Solar Integration Datasets

Technical Review Committee Principles for Integration Studies

Glossary

News

Solar Power Data for Integration Studies

The Solar Power Data for Integration Studies are synthetic solar photovoltaic (PV) power plant data points for the United States for the year 2006. The data are intended for use by energy professionals such as transmission planners, utility planners, project developers, and university researchers who perform solar integration studies and need to estimate power production from hypothetical solar plants.

The Solar Power Data for Integration Studies consist of one year (2006) of 5-minute solar power and hourly day-ahead forecasts for approximately 6,000 simulated PV plants. Solar plant locations were determined based on the capacity expansion plan for high-penetration renewables in the [Western Wind and Solar Integration Study Phase 2](#) and the [Eastern Renewable Generation Integration Study](#). The 5-minute dataset was generated by NREL using the [Sub-Hour Irradiance Algorithm](#). The day-ahead solar forecast data for locations in the western United States were generated by 3TIER based on numerical weather prediction simulations for the Western Wind and Solar Integration Study Phase 1 (3TIER 2010). The day-ahead solar forecast data in eastern U.S. locations were generated by NREL using the Weather Research and Forecasting (WRF) model.

Alert! The solar power datasets are modeled data, not actual measured data. They are meant to be used to study the operational impacts of integrating solar power resources on the electric power grid.

[Obtain the Solar Power Datasets](#)

The data are for specific years and should not be assumed to be representative of typical radiation levels for a site. These data should not generally be used for site-specific project development work.

Sub-Hour Irradiance Algorithm

Modeled sub-hour irradiance and photovoltaic power is produced from hourly irradiance data derived from satellite images using the semi-empirical model developed by Perez et al. and implemented by Clean Power Research in the [SolarAnywhere](#) dataset. The Sub-Hour Irradiance Algorithm predicts the temporal variability from a spatial "patch" of satellite data points. Global horizontal irradiance (GHI) values are converted to a fraction of the clear sky global horizontal irradiance value, called the clearness index (ci), to remove the diurnal effects of the solar zenith angle. Figure 1 shows the "patch" of ci values at a location that also has measured 1-minute data (also converted to ci values).

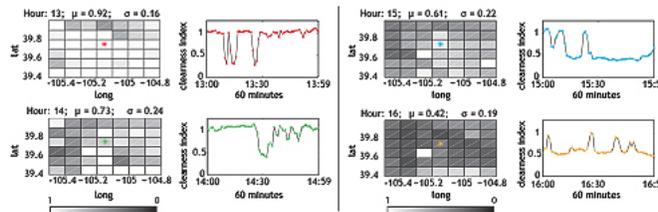


Figure 1. Spatial ci patch (a) and time series measured at the starred location for the same hour of time (b). Data shown are from the Measurement and Data Instrumentation Center at NREL in Golden, Colorado.

Each set of 60-minute ci values can be classified according to variability, as shown in Figure 2. Classes I, II, and III show relatively low variability, while classes IV and V demonstrate distinct, sharp shifts in ci. Class V represents clear sky conditions with intermittent clouds, while Class IV irradiance variability is characterized by multiple ci states.

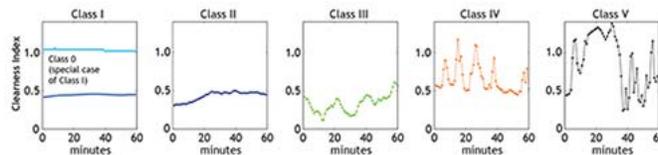


Figure 2. Classes of temporal variability (from the Sub-Hour Irradiance Algorithm)

Figure 3 shows the workflow for modeling 1-minute ci values at a single location. First, the clear sky global horizontal irradiance is calculated for every location within 40 km of the location of interest. Second, the mean and standard deviation of the patch data, for a given hour, selects a temporal classification probability distribution. The third step is to synthesize ci values for each minute based on the probabilistically selected temporal classification of that hour. Each temporal class has a separate algorithm to produce the synthetic 1-minute interval solar values. The fourth step is to reassemble the time series of ci values. Next, a temporal filter is applied based on the estimated footprint of the plant (~40 MW/km²). The last two steps convert the 1-minute-interval ci values back to global horizontal irradiance, combine the irradiance and meteorological data, and run the [PVWatts](#)® calculator to determine the AC power output of the plant during each 1-minute interval.

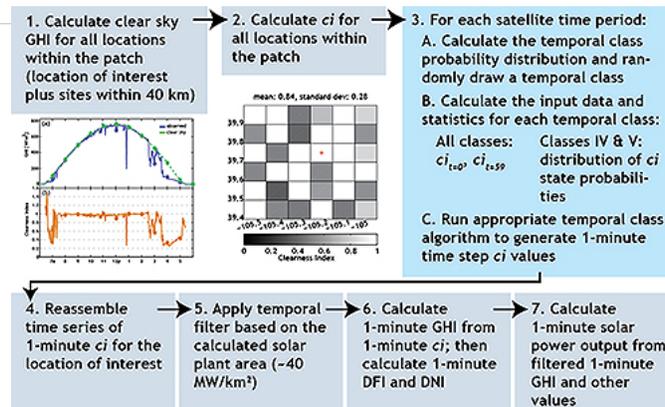


Figure 3. Workflow for producing modeled, 1-minute-interval ci values at a single location

Day-Ahead Forecasts Using the Weather Research and Forecasting Model

The WRF model (Wang et al. 2010) was used to mimic operational solar irradiance forecasts over the eastern U.S. for one year, January–December 2006. WRF was set up in operational mode with the aim of having a 4-hour and day-ahead forecast for global horizontal irradiance, direct normal irradiance (DNI), and diffuse irradiance (DFI) ready at 12 p.m. EST. The forecasts were thus initialized at 16 UTC each day (11 a.m. EST) and run for 38 hours to make a 4-hour and day-ahead forecast for midnight the next day available. The 4-hour forecast is five to six hours, depending on the time zone, from the simulation start, which is desired to avoid model spin-up. Simulated irradiance, temperature, and pressure values were input into PVWatts to create power forecasts.

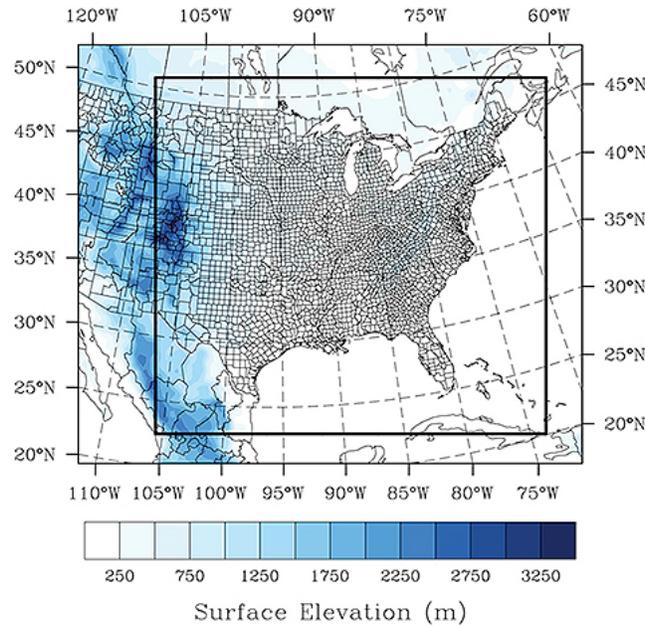


Figure 4. WRF model setup

The WRF model setup (Advanced Research WRF, Version 3.5.1) consists of a main grid with horizontal grid spacing of 30 km and one nested domain with 10-km grid spacing (Figure 4). Only the forecasts of the 10-km grid were used. The model was initialized and forced at the boundaries by 1°×1° U.S. National Center for Environmental Prediction Global Forecast System forecasts that were initialized at 12 UTC each day. For 24 days during the year 2006, Global Forecast System forecast data were missing; therefore, Global Forecast System analyses were used as boundary conditions for these 24 days instead. The sea surface temperature fields are also obtained from National Center for Environmental Prediction analyses at 00 UTC each day at a horizontal resolution of 1/12°. Land use categories come from the United States Geological Service. Forty-one vertical levels are used, and the model physics options include: NOAA land surface model, Kain-Fritsch cumulus parameterization, WRF Single-Moment 5-class scheme for microphysics, the Yonsei University atmospheric boundary layer scheme with topographic correction for surface winds (Jimenez and Dudhia 2012), the rapid radiative transfer model for long-wave radiation, and for short-wave radiation, the Dudhia scheme with simple downward integration, which is efficient for calculating clouds and clear-sky absorption and scattering. Climatological ozone and aerosol data were used for the rapid radiative transfer model. The aerosol data are based on Tegen et al. (1997) and have six types: organic carbon, black carbon, sulfate, sea salt, dust, and stratospheric aerosol. The data also have spatial and temporal (monthly) variations.

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