Spatial and Temporal Variability of Solar Energy

Richard Perez
University at Albany, SUNY, Albany, USA, rperez@albany.edu

Mathieu David
University of La Réunion, La Réunion, France,
mathieu.david@univ-reunion.fr

Thomas E. Hoff
Clean Power Research, Napa, California, USA,
tomhoff@cleanpower.com

Mohammad Jamaly
University of California, San Diego, California, USA,
smjamaly@ucsd.edu

Sergey Kivalov
University at Albany, SUNY, Albany, USA, skivalov@albany.edu

Jan Kleissl
University of California, San Diego, California, USA,
jkleissl@ucsd.edu

Philippe Lauret
University of La Réunion, La Réunion, France,
philippe.lauret@univ-reunion.fr

Marc Perez
MGH-Energy, Montpellier, France, mjp2167@columbia.edu

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philippe.lauret@univ-reunion.fr

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MGH-Energy, Montpellier, France, mjp2167@columbia.edu

Contents

Abstract

This monograph summarizes and analyzes recent research by the authors and others to understand, characterize, and model solar resource variability. This research shows that understanding solar energy variability requires a definition of the temporal and spatial context for which variability is assessed; and describes a predictable, quantifiable variability-smoothing space–time continuum from a single point to thousands of kilometers and from seconds to days. Implications for solar penetration on the power grid and variability mitigation strategies are discussed.

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Introduction

Unlike conventional electrical power generation (e.g., fossil or nuclear), solar energy is intermittent. The output of a solar power plant is driven by weather and by the cycle of days and seasons. It varies from zero to full power outside the control of plant operators.

The intermittency, or better termed, variability, of the solar resource has two causes. One is precisely predictable and traceable to the apparent motion of the sun in the sky and the earth's distance from the sun. The other is much less predictable and traceable to the motion of clouds and weather systems.

In order to fully understand the issue and develop intelligent mitigation solutions, both solar geometry-induced variability and cloud-induced variability should be examined in an appropriate spatial and temporal context. Taking an intuitive example for the temporal context, a single location on a given partly cloudy day will experience a high degree of variability due to changes in solar geometry and the passing of clouds. However, solar energy integrated over several days at that same location will exhibit less variability and variability will become insignificant as the temporal integration increases to one year or more (Figure 1.1) — e.g., see Gueymard and Wilcox (2011). Likewise

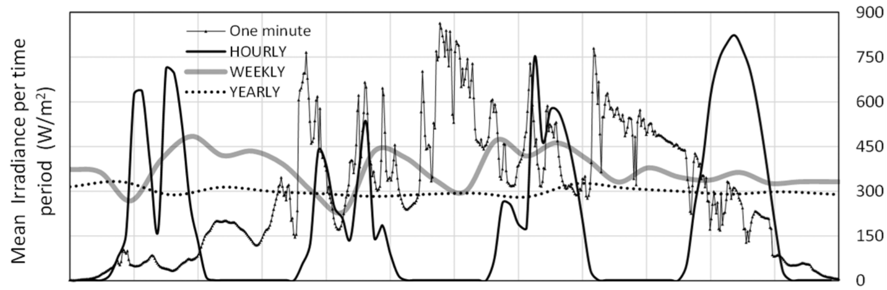

Figure 1.1: Comparing the variability of global irradiance time series in a North-American location, as a function of integration time. The figure includes 1 day's worth of one-minute data, 4 days' worth of hourly data, 26 weeks' worth of weekly data, and 16 years' worth of yearly-integrated data.

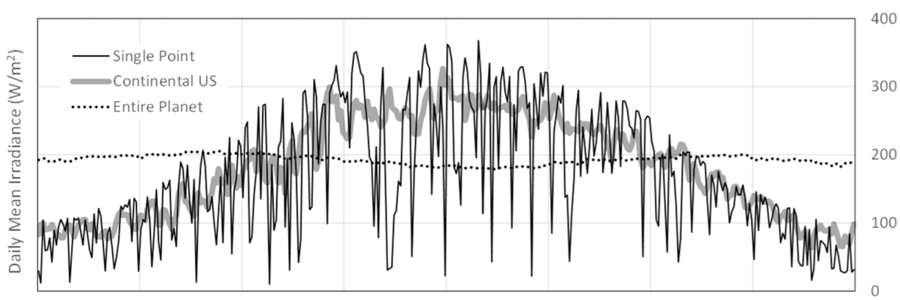

Figure 1.2: Comparing the variability of daily global irradiance time series for one year as a function of the considered footprint.

in the spatial realm, increasing the solar generation footprint from a single location to a resource dispersed over an entire region or a continent will reduce intermittency considerably. Increasing this footprint to the entire planet will eliminate it almost entirely (Figure 1.2).

The focus of this article is placed on understanding, characterizing, and modeling the interplay between intermittency and the considered spatial and temporal scales. Implications for the power grid and appropriate intermittency mitigation strategies are discussed.

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