Best practices in renewable energy resourcing and integration

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ABSTRACT

Renewable energy resourcing and forecasting are enabling technologies for low-cost integration of increasingly higher market penetration of low-carbon power generation into the grid. The “Best Practices in Renewable Energy Resourcing and Integration” Special Collection Issue in the Journal of Renewable and Sustainable Energy covers best practices in solar and wind forecasting for renewable energy integration and includes datasets for testing, development, and for the augmented reproducibility of methods and results. This Special Collection focuses on manuscripts containing methodologies that substantially advance the state-of-the-art in renewable resourcing and forecasting.

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INTRODUCTION

While solar and wind resources for meteorological and navigational purposes have been observed and studied for millennia, systematic recording of meteorological data for both land and sea weather applications goes back only a few hundred years (Soerensen, 1995). Even today, for most of the Earth’s surface, solar and wind resources have only been studied through remote sensing and numerical weather prediction (NWP) models. Until the 1970s, most solar resourcing models were tailored to low-temperature solar applications (Duffie et al., 2020) and therefore did not require the high temporal and spatial resolutions currently needed for effective solar power integration (Kaur et al., 2016). Similarly, wind measurements for power applications were not required at heights above 25 m until the 1980s, when most wind turbine blades measured 20 m or less (Kalogirou, 2009). The rapid market share growth of both wind and solar generation in the past two decades instigated the development of wind and solar forecasting methodologies with forecasting horizons ranging from minutes to several days ahead (see, e.g., the comprehensive reviews by Inman et al., 2013; Antonanzas et al., 2016; Yang et al., 2018; Chu et al., 2021). Much progress has been made in the relatively young research field of renewable energy forecasting in the last 10 years, but further progress requires the systematic evaluation of methodologies that are not easily compared with only a few agreed error metrics (Yang et al., 2020), given the diversity of conditions experienced around the globe. The objective of the Best Practices in Renewable Energy Resourcing and Integration Special Collection in the Journal of Renewable and Sustainable Energy is to curate a few selected manuscripts that shed light on the universality and portability of selected methodologies that advance the practice of renewable resourcing and forecasting beyond the incremental contributions that are generally available in standard research manuscripts.

SUMMARY OF AREAS COVERED

The Best Practices in Renewable Energy Resourcing and Integration Special Collection starts with an investigation on the impact of training diversity on data used for solar resourcing and forecasting. Bright (2019) discusses linear and Markov-Chain downscaling methodologies for downscaling data for a number of sites with diverse solar climatological characteristics and shows that measurable performance variations are observed if limited training exploration is conducted. This study complements perfectly previous studies that showed the importance of randomized training methods for maximum robustness and portability of solar forecasting training data when using advanced hybrid machine learning methods (see, e.g., Chu et al., 2013; Matsunobu et al., 2021).

Yang and collaborators contributed three important manuscripts to the collection. The first (Yang and Perez, 2019) covers the role that satellite-based irradiance resourcing and forecasting can play in assessing the quality of numerical weather prediction (NWP) forecasts.
While this manuscript shows that the National Solar Radiation Data Base (NSRDB) is suboptimal in comparison to the ground experimental data from the Surface Radiation Budget Network (SURFRAD) for verifying NWP forecasts, the manuscript concludes that more accurate remote sensing forecasts than the NRSDB could potentially be used as a replacement to the few ground stations currently used for verification due to the limitations caused by the lack of climatological diversity in ground measurements. The second contribution (Yang and Boland, 2019) proposes two new separation models for solar radiation based on multiple regressions that allow for the prediction of diffuse horizontal irradiance from standard meteorological inputs (obtained either directly from ground sensors or indirectly through remote sensing). Yang (2019a) exploits post-processing methodologies to correct Global Horizontal Irradiance (GHI) forecasts made by NWP models, and Yang (2019b) discusses the use of reference forecasts (perspective, climatology, and a combination of both) for the skill score comparisons across different locations and time periods, with a particular focus on day-ahead deterministic forecasts.

Next, Pedro et al. (2019a) describe a hybrid, smart image-based methodology for extracting the most important features from images captured by ground sky cameras, focusing on a Region of Interest (ROI) centered around the apparent position of the Sun. This simple methodology yields remarkably high forecasting skills for intra-hour forecasts, among the highest ever reported for such comprehensive datasets involving long periods of time. All other error metrics are also improved by the use of the ROI methodology. In recognition that comparisons between different forecasts made for different meteorological conditions require a large number of metrics beyond the standard error metrics used in the literature, Pedro et al. (2019b) released a comprehensive dataset including 1-min resolved ground data for both Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI), overlapping satellite imagery and numerical weather prediction results, sky images, and simple reference forecasts for a location in Folsom, CA during 3 years (2014–2016) of quality-controlled data collection by my own research group at the University of California San Diego. A main objective in releasing these datasets was to help accelerate the development of high-fidelity solar forecasting methods by other researchers that may not have access to high-quality experimental data collection.

Li et al. (2019) use Copula-based models to cluster wind sites according to their cross-correlations and then employ Gibbs sampling to generate scenarios for day-ahead markets for power system optimization. They show that the clustering approach outperforms existing methodologies while reducing computational costs.

Finally, Venugopal et al. (2019) discuss systematic methods of fusion (MoF) to input images and past values of PV power output as inputs to a deep learning method based on Convolution Neural Networks (CNNs) for 15-min ahead solar forecasts. The methodology results in substantial improvements in the forecasting skill score when compared to previous, nonoptimized results reported by the authors.

CONCLUSIONS

The nine manuscripts in the Special Collection on Best Practices in Renewable Energy Resourcing and Integration published in the Journal of Renewable and Sustainable Energy exemplify the type of research contribution that consolidates knowledge and impact across multiple areas that are relevant to renewable energy resourcing and forecasting, including the analysis and determination of metrics and benchmarks, the optimal use of statistical methods for the reduction of biases and spurious errors while acknowledging their inherent limitations, the systematic use of data to inform deficiencies in the current understanding of time-varying resources, and the discussion of relevant blind spots in the research literature. Based on early measures of impact caused by this collection on the recent literature, it is our hope that the research community will continue to benefit from the intellectual content and the datasets and codes provided by our contributing authors.

AUTHOR DECLARATIONS

Conflict of Interest

The authors have no conflicts to disclose.

REFERENCES


Yang, D., “Post-processing of NWP forecasts using ground or satellite-derived data through kernel conditional density estimation,” J. Renewable Sustainable Energy 11, 026101 (2019a).


