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• Editorial Notes •

Preface to the Special Topic on Solar Energy Meteorology※

Dazhi YANG[1,2] and Xiang'ao XIA[3,4]

[1]*School of Electrical Engineering and Automation*, *Harbin Institute of Technology*, *Harbin* 150001, *China*

[2]*Chongqing Research Institute of Harbin Institute of Technology*, *Chongqing* 401151, *China*

[3]*Institute of Atmospheric Physics*, *Chinese Academy of Sciences*, *Beijing* 100029, *China*

[4]*University of Chinese Academy of Sciences*, *Beijing* 100049, *China*

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Advances in Atmospheric Sciences has long been a natural home for atmospheric scientists, but as the scope of the atmospheric sciences rapidly expands, it is logical and attractive to also broaden the scope of the journal. On this point, we are pleased to present this special topic on solar energy meteorology, a collection of five invited articles, addressing several important aspects including satellite remote sensing, solar system modeling, photovoltaic power forecasting, thermal balance of solar panels, and decarbonization strategy. All articles are contributed by established scientists, and readers can expect to enjoy the content of this special topic.

Within the field of solar energy meteorology, solar resource assessment and solar forecasting constitute the two main branches of learning. Whereas the former seeks to estimate the long-term (i.e., years to decades) resource availability, which is fundamental to energy planning, the latter focuses on the short-term (i.e., seconds to days) variability in irradiance and solar power, which is essential to power system scheduling. Needed by both topics is the omnichannel information of those so-called "energy meteorological variables," primarily including solar irradiance, ambient temperature, near-surface wind, and surface albedo. Like most other meteorological variables, these energy meteorological variables can be acquired via ground-based, satellite-based, and model-based techniques. Equally important is the meteorology-to-power mapping procedure, which is associated with a high level of uncertainty that can only be tamed with highly specialized knowledge and rich experience; in fact, three papers in this special topic discuss this mapping procedure. It is a common misconception, particularly within the meteorological community, that once granular and accurate meteorological data are obtained, producing high-quality solar power estimates becomes trivial. It is generally understandable that scientists in every discipline tend to focus on the traditional problems emphasized by their respective fields and rely on the techniques they are most familiar with. Therefore, we emphasize that solar meteorology, as an emerging discipline, results from the integration of atmospheric science and solar energy. Its development urgently requires both the atmospheric science community and the solar engineering field to set aside disciplinary biases and gain a deeper understanding of the key scientific and technological issues in interdisciplinary research. Only in this way can we effectively build bridges for disciplinary integration and collaboration.

As achieving planetary carbon neutrality and ensuring century-long energy security have already entered the sphere of concern of the general public, especially due to the success of the Paris Agreement, solar energy has taken center stage, and the need for better solar energy meteorology is implied. The overarching goal of this special topic is to share experts' perspectives and exemplify state-of-the-art research on solar energy meteorology, such that atmospheric scientists can be informed when developing techniques and methods that are intended for solar energy applications.

Solar energy applications may be new to some atmospheric scientists, but the history of solar technology can be traced back to the 7th century B.C. Solar energy meteorology blossomed into a standalone field at the turn of the 21st century, and the literature on solar resource assessment and forecasting is already fairly bulky. What this implies is a long learning curve for anyone who wishes to enter this field, let alone contribute to it. In what follows, we present a summary of each of the papers in this special topic, and slightly expand on the background information through other useful references.

• Xia et al. (2025) share the status of the Fengyun radiation service from a solar energy perspective. A central theme of

※ This paper is a contribution to the special topic on Solar Energy Meteorology.

this perspective article is that the potential of the new-generation Fengyun satellites has yet to be unleashed. The most iconic database for solar applications is the National Solar Radiation Database [NSRDB; Sengupta et al. (2018)], the development of which has spanned three decades. Hence, this perspective article presents an outlook, detailing 10 recommendations on future scientific and engineering efforts required to catch up with NSRDB. Satellite-retrieved irradiance is not just useful for resource assessment, it can also be used for intra-day forecasting. Interested readers may proceed from reading Miller et al. (2018).

• Yang et al. (2025) present a second tutorial review of the solar power curve, which is needed whenever solar energy meteorological variables are to be converted to photovoltaic power. Whereas the preceding tutorial review (Yang et al., 2024) elaborated on the two classes of solar power curves—namely, regressions and model chains—the current review focuses on the applications of solar power curves. The two reviews add up to more than 70 pages and serve as an all-in-one compendium of this topic. Worth noting is the series of papers from Mayer and coworkers, who formalized the modeling framework of the solar power curve, with a special focus on its forecasting applications (e.g., Mayer and Gróf, 2021; Mayer, 2022; Mayer and Yang, 2023).

• Horat et al. (2025) evaluate various strategies to apply post-processing in model-chain-based photovoltaic power forecasting. Traditional practices mandate correcting the irradiance forecasts before passing the forecasts through a model chain. However, it has been shown, in a probabilistic forecasting setting, that post-processing the irradiance forecasts has little to no value, insofar as the photovoltaic power forecasts are to be post-processed with power measurements. Their conclusion agrees with that of Mayer and Yang (2024), who formulated a sister study under a deterministic forecasting setting. Post-processing of irradiance and photovoltaic power forecasts has rich literature, which is best covered by the review by Yang and van der Meer (2021).

• Coimbra (2025) contributes a research article on the thermal effects of solar plants on the environment, and vice versa. Motivated by the diverse and often contradictory findings concerning the net thermal impact of large-scale power plants, detailed thermal balance models for PV power plants are derived. The thermal balances for the panels allow one to arrive at flow-dependent variables such as convective heat transfer coefficients through measurements or model estimates that are routinely available. Perhaps it is by virtue of shortwave irradiance being the power source of solar plants that solar energy meteorology places much more emphasis on the modeling of shortwave radiation than longwave radiation, but the importance of the latter goes beyond determining the cell temperature, and it is critically important for the evaluation of thermal impacts on local habitats. A good starting point for longwave radiation modeling is the work of Li et al. (2017).

• Peters (2025) shares his views on the global-scale strategy of photovoltaic deployment. The central argument is that there is currently a mismatch between countries with high economic capacity and those where PV installation would maximize global decarbonization benefits. By comparing two thought experiments on country-by-country decarbonization—one beginning with countries with high per capita GDP and the other with countries with high carbon emissions—the latter option is favored. As such, a globally coordinated photovoltaic deployment strategy is advocated. The catalytic effect of a growing renewable energy industry on decarbonization is often assumed *a priori*, but the most effective pathway of decarbonization is sometimes counterintuitive (Møller, 2024) and decarbonization efforts might be outpaced by the ever-increasing energy demand (Jackson et al., 2018).

To conclude these introductory pages for this special topic, we must first acknowledge that atmospheric science will always play an essential role in solar energy meteorology. However, it is crucial to recognize that solar energy meteorology is not merely a derivative problem that can be addressed using existing atmospheric science knowledge. The current transition in the energy mix—from one dominated by fossil fuels to one primarily reliant on renewables—is not solely the responsibility of energy engineers. We want to take this opportunity to emphasize that understanding the mechanisms and uncertainties involved in solar energy harvesting, as well as how this energy is delivered to users via the electricity grid, is very crucial. Scientists committed to contributing to the eventual widespread utilization of solar energy on a planetary scale must fully grasp this concept.

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