

Editorial

Climate Modeling for Renewable Energy Applications

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The exploration of environmentally friendly energy resources is one of the major challenges facing society today. The last decade has witnessed rapid developments in renewable energy engineering. Wind and solar power plants with increasing sizes and technological sophistication have been built. Amid this development, meteorological modeling plays an increasingly important role, not only in selecting the sites of wind and solar power plants but also in assessing the environmental impacts of those plants. The permanent land-use changes as a result of the construction of wind farms can potentially alter local climate (Keith et al. [1], Roy and Traiteur [2]). The reduction of wind speed by the presence of wind turbines could affect the preconstruction estimate of wind power potential (e.g., Adams and Keith [3]). Future anthropogenic greenhouse gas emissions are expected to induce changes in the surface wind and cloudiness, which would affect the power production of wind and solar power plants. To quantify these two-way relations between renewable energy production and regional climate change, mesoscale meteorological modeling remains one of the most efficient approaches for research and applications.

The construction of large-scale wind or solar power plants will change the physical properties of the surface such as surface roughness, albedo, and emissivity for longwave radiation. Wind turbines are momentum sinks for the atmospheric flow in the boundary layer. The physical basis for incorporating these processes in an atmospheric model is clear. Nevertheless, individual wind turbines, or even a wind farm as a whole, could be too small for a typical weather or climate model to resolve. A parameterization scheme for the subgrid-scale effect of wind farms on the velocity field is much needed

and has been actively developed. For example, a scheme developed by Fitch et al. [4] has recently been incorporated into the widely used weather research and forecasting (WRF) model (Skamarock et al. [5]). The scheme is formulated as an extension of the boundary layer parameterization scheme which is already implemented in many weather and climate models. The environmental impacts of wind farms and solar power plants can also be treated using the schemes for modeling the effects of land-use and land-cover changes. Such schemes have been actively developed especially in the form of urban canopy models (e.g., Kusaka et al. [6]). For example, if solar panels are classified as a distinctive surface type with specific surface albedo and emissivity, their effects can be calculated by using an existing urban parameterization scheme given the fractional area coverage of a solar power plant over a grid box of the model. Thus, the development of the parameterization schemes for the effects of wind and solar power plants is not an isolated activity but constitutes part of the important trend of incorporating multiscale physical processes into the framework of environmental prediction.

The large-scale jet streams in the global atmosphere that provide the reservoir of wind energy are projected to change on multidecadal and longer time scales under the influence of anthropogenic greenhouse gas emissions (e.g., Yin [7]). The shifts of jet streams and the accompanying changes in regional weather patterns (e.g., Seager et al. [8]) can lead to an increase or decrease of local cloud cover, thereby affecting the gain of solar power plants. Those large-scale climate changes have been systematically projected using global climate models with relatively coarse spatial resolutions (Taylor et al. [9]). Extensive efforts are underway to “downscale” the climate

information obtained by the global model to regional and urban scales. Nevertheless, only a few of the existing studies used the approach of climate downscaling to project the local changes in wind or solar power potential (e.g., Ren [10], Pryor and Barthelmie [11]). Progresses in this direction will not only help refine the estimate of global and regional wind and solar power potential but also aid the siting of wind and solar power plants, based on the premise that an optimal site today may not be optimal in one or two decades.

Climate modeling for renewable energy applications is an exciting emerging research topic for both climate scientists and renewable energy engineers. We conclude by suggesting the following four particularly promising directions for future research towards climate and energy applications: (1) further developments of the techniques for multiscale climate downscaling to transfer climate information from global to urban and wind-farm scales, (2) quantification of the mechanical and thermodynamic effects of wind or solar power plants on the microscale atmospheric environment and climate, (3) further developments of parameterization schemes for the subgrid-scale effects of wind and solar power plants in regional and global climate models, and (4) systematic classifications of wind farms and solar power plants as distinctive surface types for research of the impacts of land-use and land-cover changes on local climate.

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