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Integration of Physics and Observation-Driven Models to Advance Solar Forecast

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Abstract Solar energy has become an increasingly important source of renewable energies, calling for accurate forecast of solar irradiances over multiple time horizons (e.g., from minutes to days). The highly variable nature of clouds and their interactions with radiation poses daunting challenges to solar forecast that is based either on observations or numerical weather prediction (NWP) models. Observation-based models are often limited largely to forecasting global horizontal irradiance (GHI) or direct normal irradiance (DNI) over relatively short time horizons (e.g., <1 hour), and lack clear physics and clarity of interpretability. This study is focused on addressing these shortcomings by incorporating physics underlying cloud-radiation interactions into observation-based models to improve forecast accuracy, extend forecast time horizons, and develop clear interpretation of the improvements. I will first present a theoretical framework that links GHI and DNI with cloud properties. Then I will introduce a hierarchy of four physics-informed persistence models based on the theoretical framework that can be used to simultaneously forecast GHI, DNI and diffuse horizontal irradiance (DHI). Finally, I will discuss a hierarchy of more advanced statistical and machine learning models (ARIMA, LSTM, and XGBoost) that gradually introduce model predictors based on the theoretical framework. The ML models are compared with the four physics-informed persistence models, and with the simple and smart persistence models to assess the improvement of different models. The results demonstrate the value and feasibility of incorporating physics into observation-based models, and recommend the combined use of GHI and DNI, which significantly improves the forecast accuracy compared to using individual irradiances alone because the pair contains more information on cloud-radiation interactions.

Keyword(s)
Solar forecast, Clouds, Observation-based models, Cloud-radiation physics, Model interpretability

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