High-Frequency Forecasting of Solar Radiation Using a Hybrid Numerical Weather Prediction and Stochastic Downscaling Model

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Introduction/Motivation

Forecasting the solar resource and power with high spatial and temporal resolutions has attracted the attention of electricity network operators and electricity generators because of its importance to managing the electric grid, market operations, and reducing the cost of solar energy. Compared to time-series analysis, stochastic models, and machine learning techniques, numerical weather prediction (NWP) models have unbeatable competitive advantages in the day-ahead forecasting of solar radiation because they manipulate vast data sets from satellites, radiosondes, and surface-based observing systems, and they perform comprehensive computations based on fundamental physics and chemistry. One downside to NWP models is their limited temporal resolution because of the large computational costs over a wide range of space and timescales.

This study introduces a hybrid model that combines NWP model output with a stochastic downscaling technique to produce high temporal frequency forecasts of solar radiation for the day-ahead time horizon. This hybrid model is evaluated using surface-based observations by the National Renewable Energy Laboratory's (NREL) Solar Radiation Research Laboratory (SRRL). The goal is to create an intraday solar forecast that requires minimal computational effort yet uses the best aspects of NWP and stochastic modeling.

Methods

NWP output from the High-Resolution Rapid Refresh (HRRR) model is used as the base forecast for solar radiation, which is available on a 3-km grid. The HRRR provides hourly data with a forecast horizon of 18 hours (more recently 36 hours). The HRRR model is initialized every hour, providing a frequently updated forecast. Despite this, higher frequency solar radiation data are often needed for grid operations.

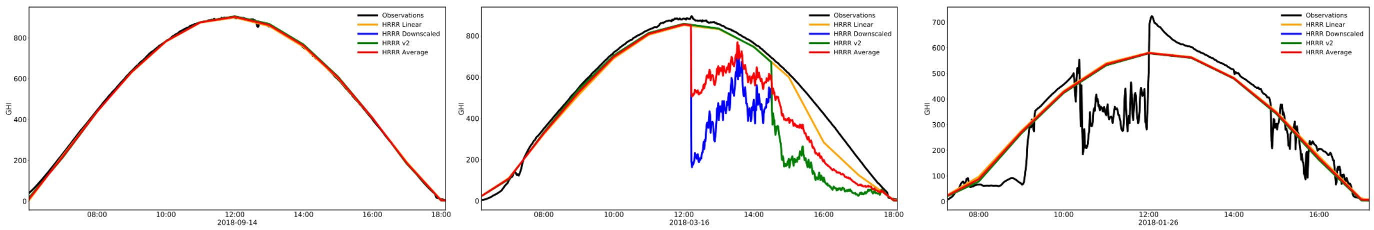
To help address this, we use methods introduced in similar research using solar radiation data from the National Solar Radiation Database (NSRDB) (Zhang et al. 2018). In this research, the NSRDB is downscaled to a minute resolution (originally 30 minutes) using a stochastic downscaling approach. Generally, this approach involves learning the relationship between observations and raw HRRR model output at a location of interest (SRRL), which creates seasonal coefficients that are applied to out-of-sample forecasts. This introduces a "learned" variability that is then applied to the HRRR forecast to create a more realistic solar profile. Specific details on this stochastic method can be found in Zhang et al. 2018.

After the stochastic forecast is applied to the HRRR, a variety of post-processing techniques are used to improve the forecast.

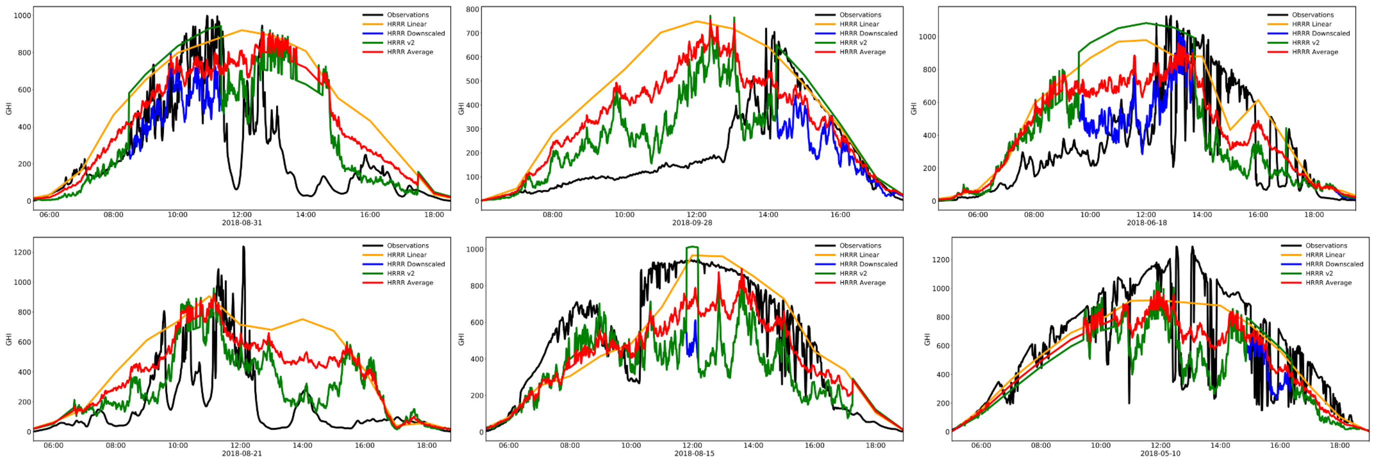
- Checking every 3-hour period for clear skies. If the HRRR is close to clear-sky global horizontal irradiance (GHI) in that window, the clear-sky GHI forecast is assumed true. If not, the downscaled method is taken.
- Creating alternate HRRR forecasts. This includes tracking variables such as cloud fraction ("HRRR v2" in plots) and the average of the downscaled HRRR and the linearly interpolated HRRR ("HRRR Average").

Results

Clear-Sky Testing



Performance Evaluation for Cloudy Conditions



Sample Statistics

Model	MBE (W/m²)	MAE (W/m²)	RMSE (W/m²)
HRRR Linear	50.61	103.59	178.95
HRRR Downscaled	6.56	114.76	183.23
HRRR v2	30.31	109.47	183.07
HRRR Average	28.59	105.56	171.39

Initial Conclusions

Initial iterations of this hybrid model show a lot of promise, and it succeeds when sky conditions are partly cloudy. These types of cloud conditions are the hardest to forecast and arguably the most difficult problem in solar forecasting research. Although the hybrid model does well in certain sky conditions, there is room for improvement, as illustrated in the plots. One improvement is the general accuracy of the HRRR model. There are instances when the HRRR model gets the forecast for the day entirely wrong, and the hybrid model in its current form cannot recognize this. The most difficult days to forecast are probably cloudy days in winter when solar radiation levels are already low as well as summer days when the morning begins with clear skies but afternoon thunderstorms create a chaotic solar profile.

Future work on this model will attempt to address current shortcomings. This will include using an ensemble of NWP models that are quickly and easily accessible so the hybrid model can make better decisions about how cloud conditions will evolve during the day. In addition, we hope to better understand the inherent bias in the HRRR model and track this bias on a seasonal basis so that adjustments can be made to the hybrid model throughout the year. With these adjustments, we hope to create an accurate and realistic high-resolution intraday solar radiation forecast.

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