A High Resolution Photovoltaic Energy Production Simulator with A Probabilistic Approach

Weiming Hu*, Guido Cervone

Geoinformatics and Earth Observation Laboratory

Dept. of Geography and Institute for CyberScience, The Pennsylvania State University

*weiming@psu.edu**

PennState

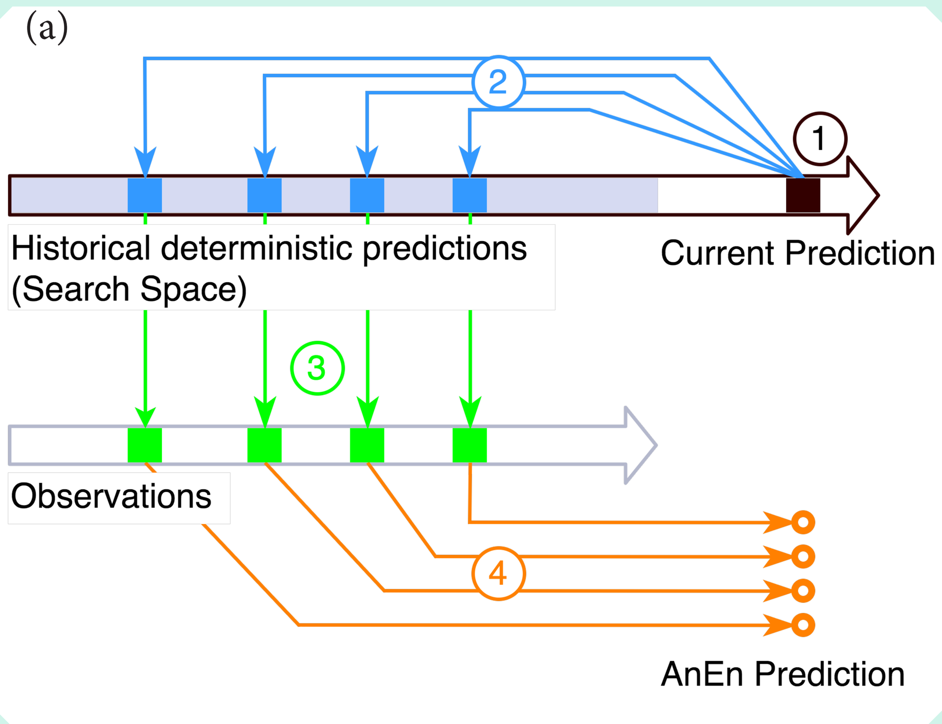
Introduction

According to the International Energy Agency's Renewables 2017 report, there are sharp cost reductions and improved policy support for continued growth in the renewable sector. A large amount of investment has already been directed in this direction and installation of solar panels has skyrocketed in the past decade which drastically drives down the price of this "green energy". As a result, distributed rooftop solar panels can now be commonly seen in modern communities. However there is growing concern of this renewable solution. For example, PV generation is directly linked with intermittency in meteorological phenomena of irradiance, air temperature, cloud cover, and wind speed. How accurate numerical weather models are for these parameters significantly influences the predictability of PV energy production at both a micro-scale and a synoptic scale.

This pilot study investigates a probabilistic PV energy production simulator. The simulator improves the temporal resolution of predictions and generates uncertainty information by providing an ensemble of predictions.

Analog Ensemble

1. Starts with a current deterministic prediction, a set of historical predictions, and the corresponding observations;
2. Finds the most similar historical predictions to the current prediction based on a multivariate metric;
3. Takes the observations associated with the historical predictions;
4. Generates the prediction ensemble for the current time.



Data

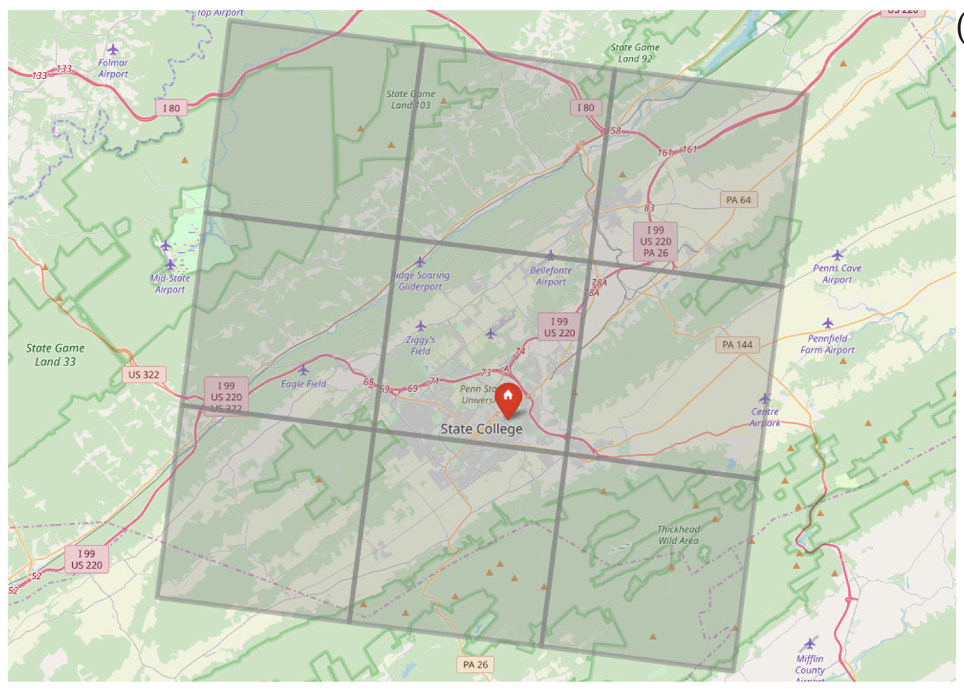
Distributed personal weather station, State College, PA

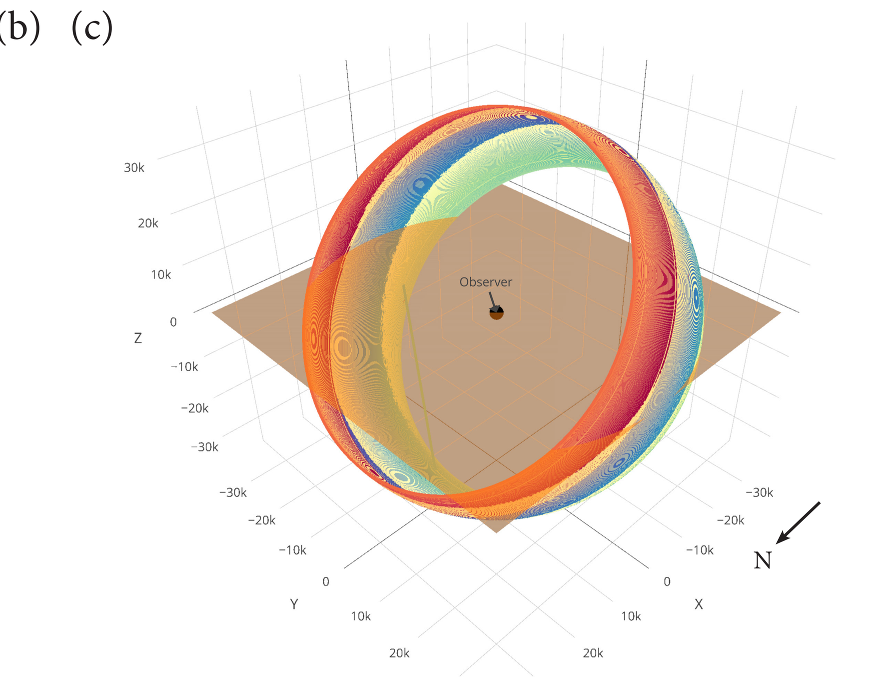
- Instrument: Ambient Weather WS-1002-WIFI model (~$270)
- Time period: April 8, 2017, to August 31, 2018
- Measurements: solar radiation
- Time interval: about 4 minutes

North American Mesoscale Forecast System

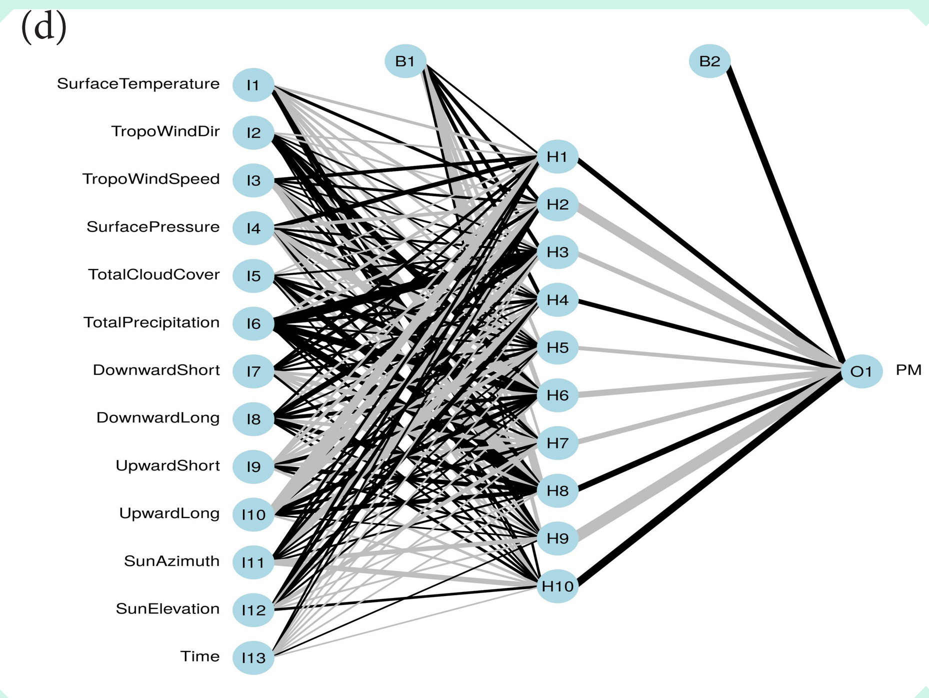
- Parameters: 10 variables including temperature, cloud cover and irradiance
- Forecast lead time: hourly forecasts until 84 hours
- Time period: January 2017 to August 2018
- Resolution: 11 km

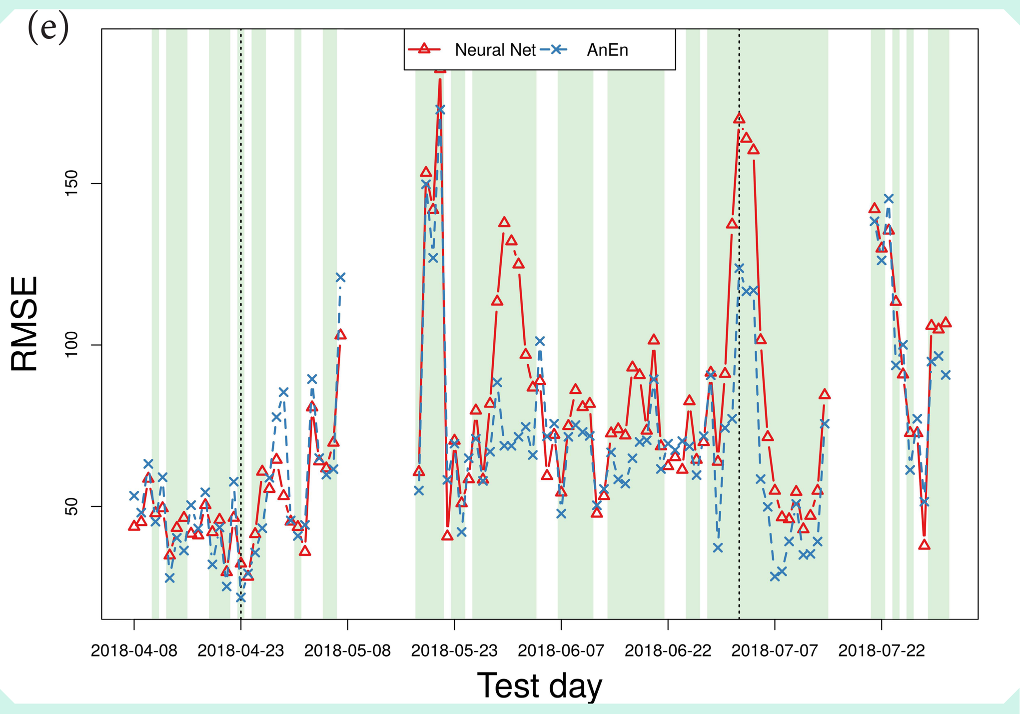
Fig. (b) shows the location of the weather station in NAM model. Sun positions are calculated. Fig. (c) visualizes sun trajectories from April 8, 2017, to April 8, 2018.





Results





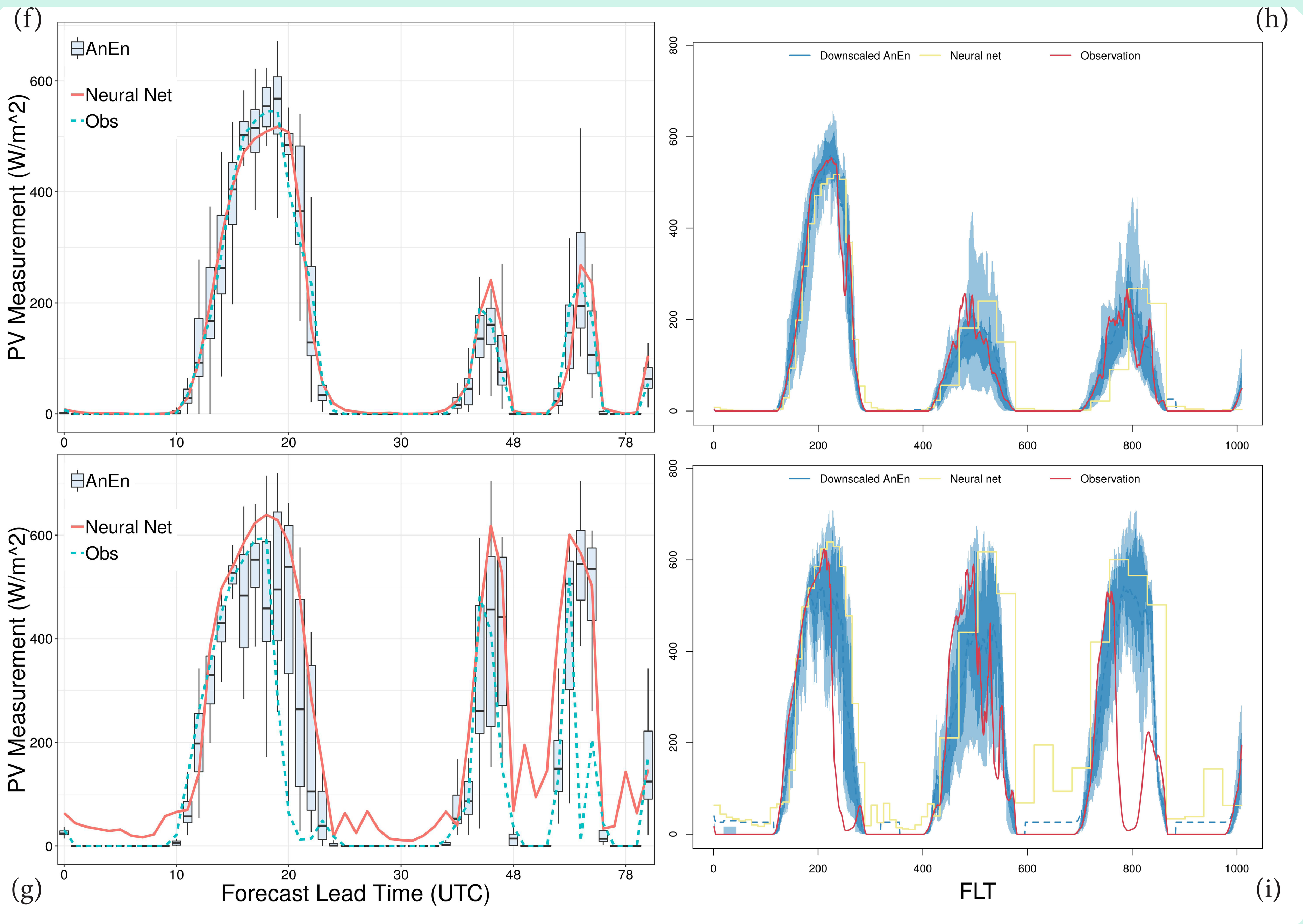
An Artificial Neural Network (ANN) is trained as a comparison to the AnEn predictions. Fig. (d) shows the network topology with 10 meteorological variables plus sun position and time information. Robust search experiments determined the best network size is 10.

Fig. (e) shows daily-averaged prediction RMSE from April 8 to July 31, 2018. Shaded area indicates days when AnEn is better than ANN. AnEn is superior to ANN for 67% of the days. The overall average RMSE for ANN and AnEn are 80.89 W/m² and 70.33 W/m² respectively.

Fig. (f) and (g) show examples for good and bad predictions as marked on Fig. (e) by the vertical dotted lines. ANN generates deterministic predictions and AnEn generates an ensemble of predictions which can be used to generate probabilistic information. AnEn tends to follow the ground truth closer than ANN.

Access AnEn

Fig. (h) and (i) show the temporal downscaling results of AnEn from hourly predictions to 5-minute predictions. Because ANN can only generates hourly predictions, flat lines are used to fill in time gaps within an hour. Two shaded colors show the 75th and 90th percentiles of the distribution.



Conclusions

A case study of using AnEn to forecast and downscale PV production at State College is carried out to investigate the potential of AnEn to generate higher-resolution probabilistic forecasts. Results from AnEn and ANN are compared. AnEn shows improved accuracy which is contrary to the literature. Cervone showed ANN outperformed AnEn at 3 sites in Italy. Potential causes could be the different weather regimes, the different spatial scales of the problem, and the different weather models used in the studies. A deeper understanding of ANN and AnEn performance is needed.

Alessandrini, S., et al. "A novel application of an analog ensemble for short-term wind power forecasting." Renewable Energy 76 (2015): 768-781; Delle Monache, Luca, et al. "Probabilistic weather prediction with an analog ensemble." Monthly Weather Review 141.10 (2013): 3498-3516; Cervone, Guido, et al. "Short-term photovoltaic power forecasting using Artificial Neural Networks and an Analog Ensemble." Renewable Energy 108 (2017): 274-286.