each sensor, and then calculate an interpolated clearness map across the forecasting domain. The WRF models' predicted wind velocities at cloud height determine the speed, direction, and uncertainty of the clearness map propagation in time. Finally, the forecasted PV power is determined from the propagated clearness map. For details, see [8, 10].

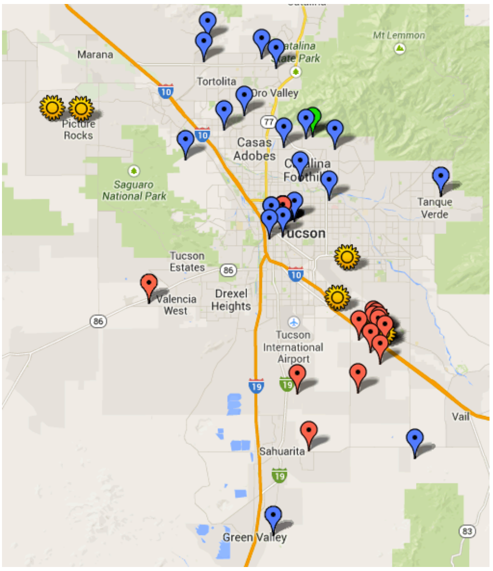

Fig. 4. Map of utility scale PV installations (suns), residential PV systems with data-monitoring hardware (blue and green pins), and custom-built irradiance sensors (red pins) used for PV power forecasting in the Tucson region.

III. Hybrid Forecasting

We combine the WRF models, satellite imagery, and sensor network data into a single "hybrid forecast" for Tucson Electric Power. Figure 5 shows a comparison of the individual forecasts across 4 orders of magnitude in time. Network and persistence forecasts perform well for time scales shorter than 30 minutes, and WRF models perform best at longer time horizons. We anticipate that expanding the sensor network will enable it to outperform WRF forecasts out to 1-2 hours. Additional work is needed to evaluate our GOES satellite-based forecasts and combine them with the network and WRF forecasts.

The forecasts and their confidence intervals are automatically refreshed every minute throughout the day as new model runs, satellite images, or network data becomes available. We currently supply these forecasts to TEP via a website for 13 utility-scale PV power plants and an aggregate, shown in Figure 6. The data from our network of rooftop PV installations also informs an estimate of real-time behind-the-meter PV generation. We are working with TEP to integrate these forecasts into their Energy Management System.

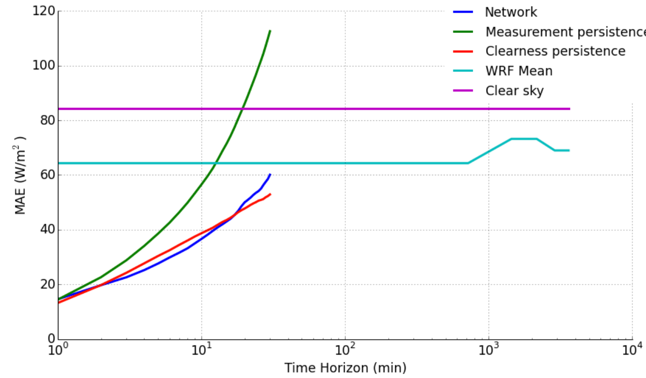

Fig. 5. Comparison of forecasted GHI MAE for 5 different forecasting techniques as a function of forecast time horizon. The WRF model forecast errors are daily averages.

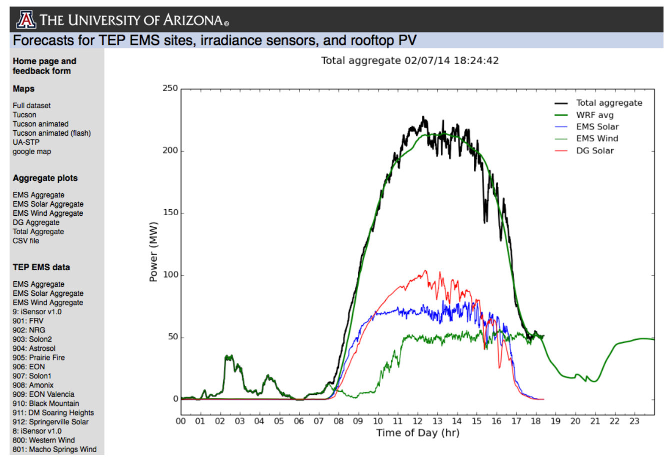

Fig. 6. Screenshot of website for delivering PV power forecasts to Tucson Electric Power. The day ahead forecasted total power production (thick green), measured utility scale solar (blue), measured distributed generation (red), and utility scale wind (thin green) is shown. Actual production is shown in black.

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