Renewables

TOWARDS A CONSISTENT MACHINE LEARNING-BASED PREDICTION SYSTEM FOR RENEWABLE GENERATION AND LOAD

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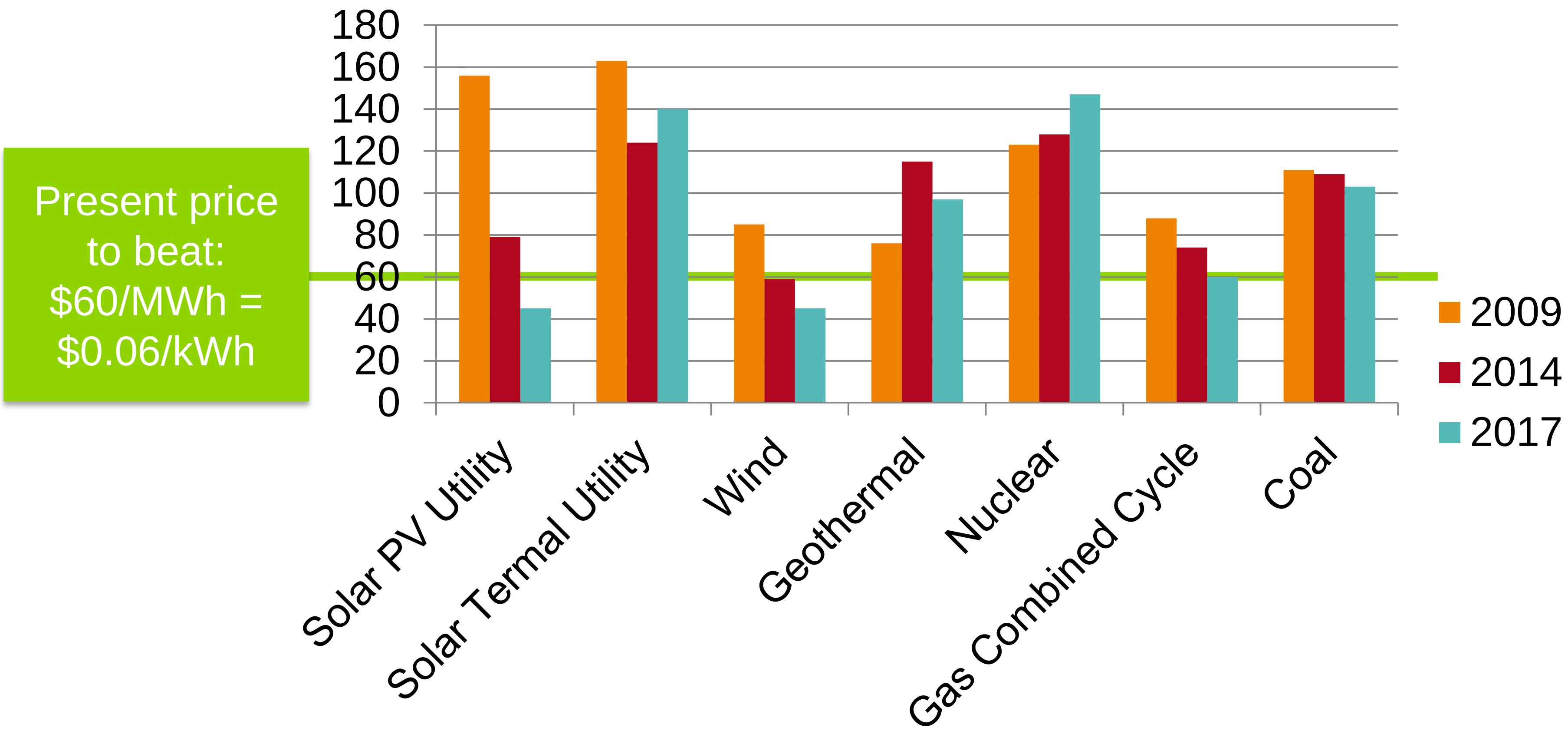
April 10, 2019

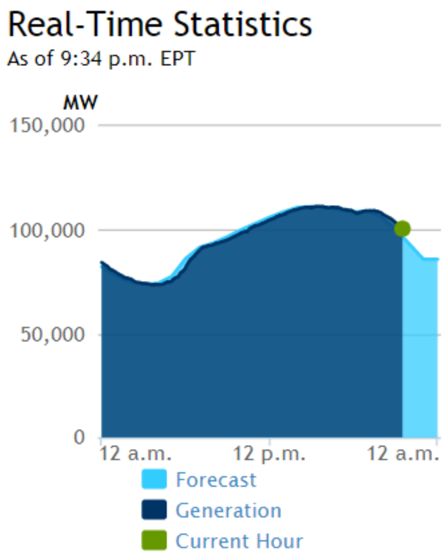
AN ELECTRICAL GRID IN TRANSITION

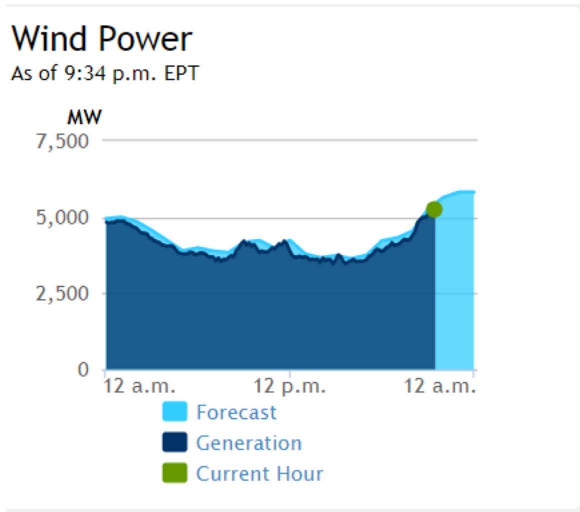


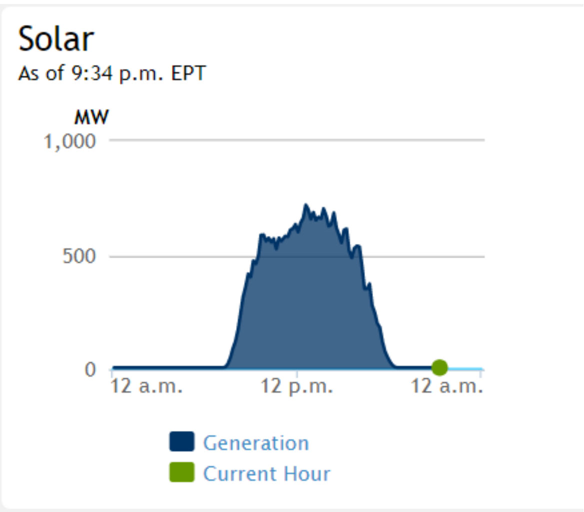
Sources: https://www.lazard.com/perspective/levelized-cost-of-energy-2017/
http://blog.cleanenergy.org/files/2009/04/lazard2009_levelizedcostofenergy.pdf
https://www.lazard.com/media/1777/levelized_cost_of_energy_-_version_80.pdf

RENEWABLES ARE MAINSTREAM

In the past, the forecast of electrical load was the main basis for decision making about tomorrows electrical supply…







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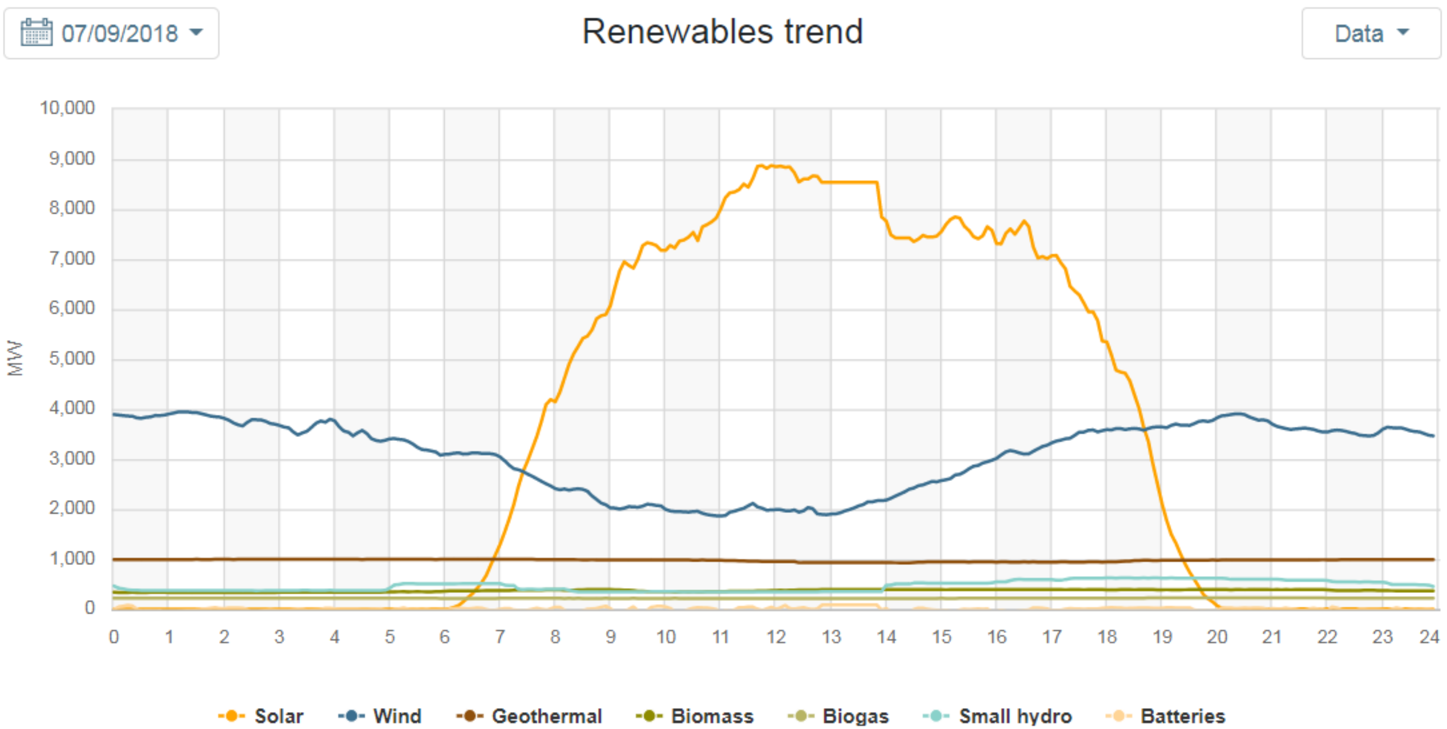

California ISO | 20 YEARS 1998-2018

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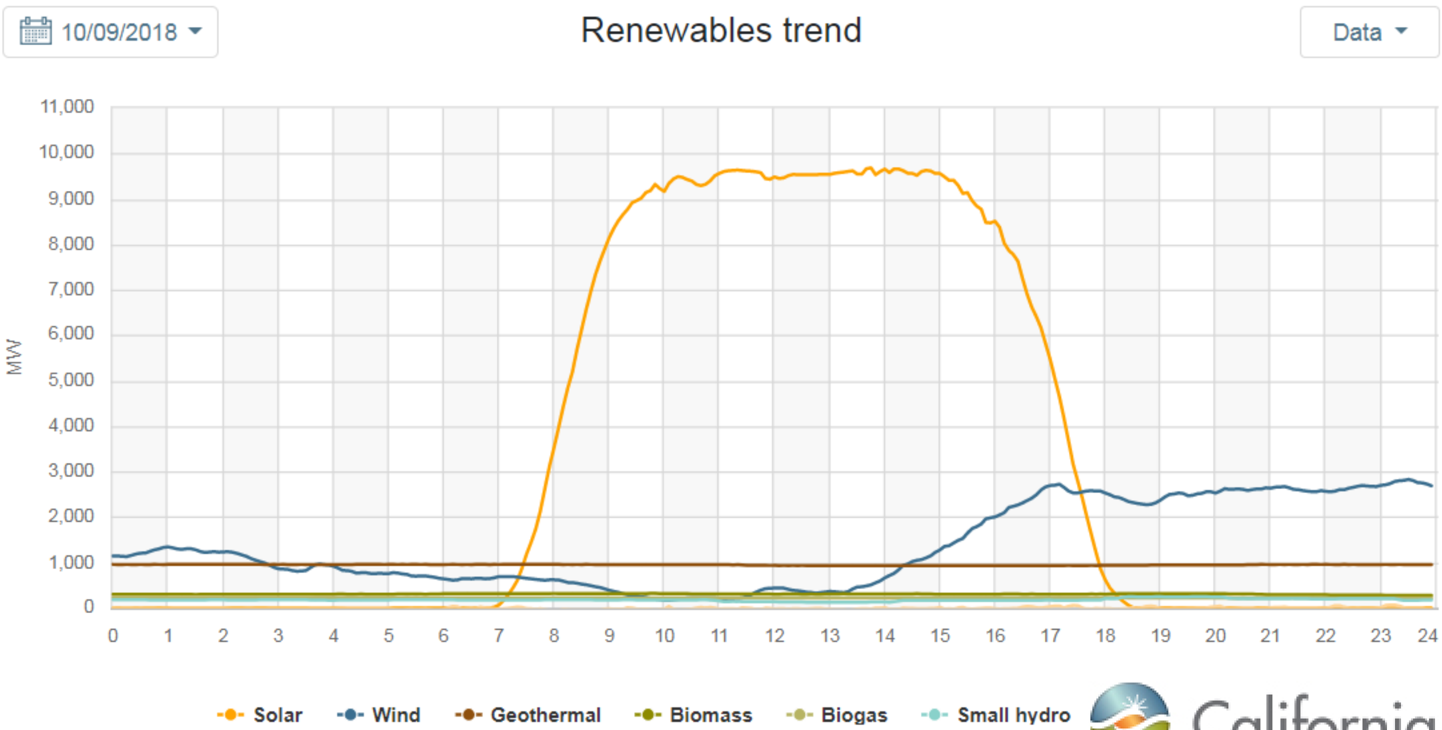

California ISO | 20
1998-2018 YEARS

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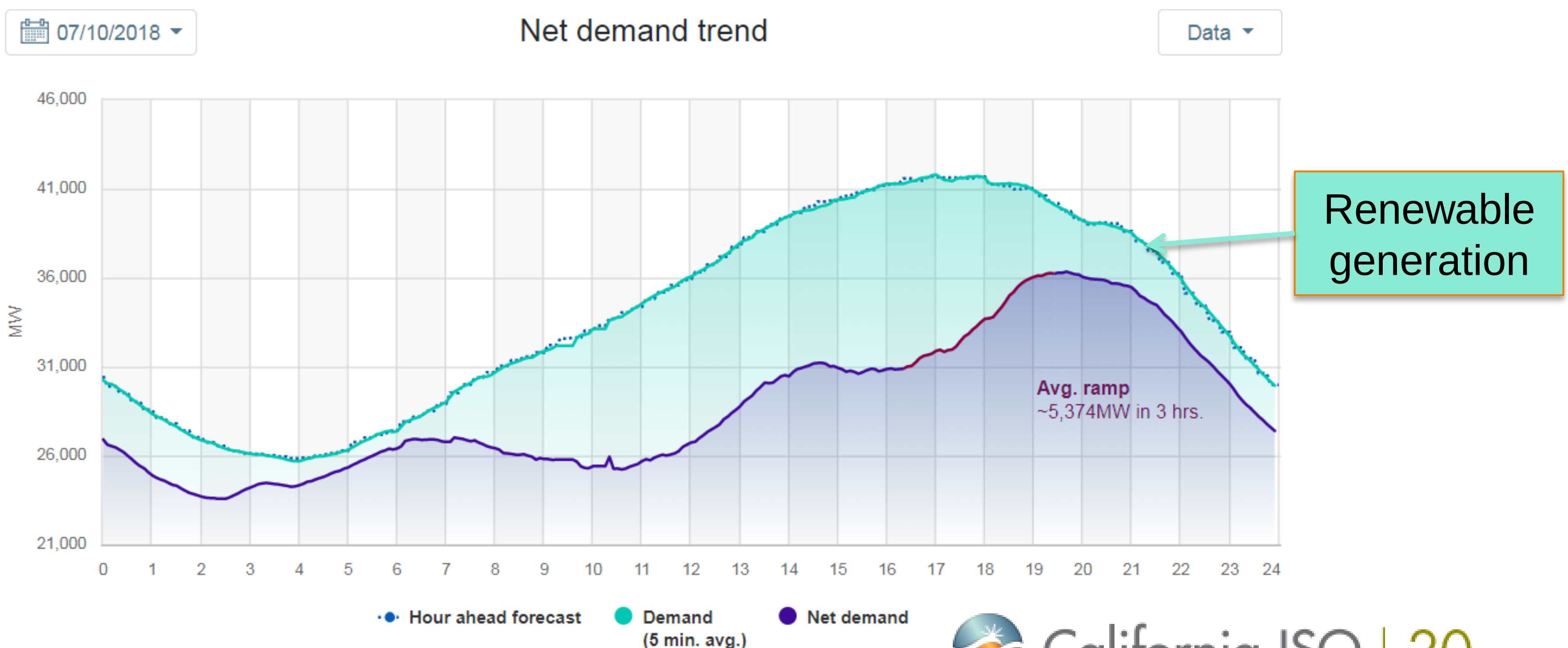

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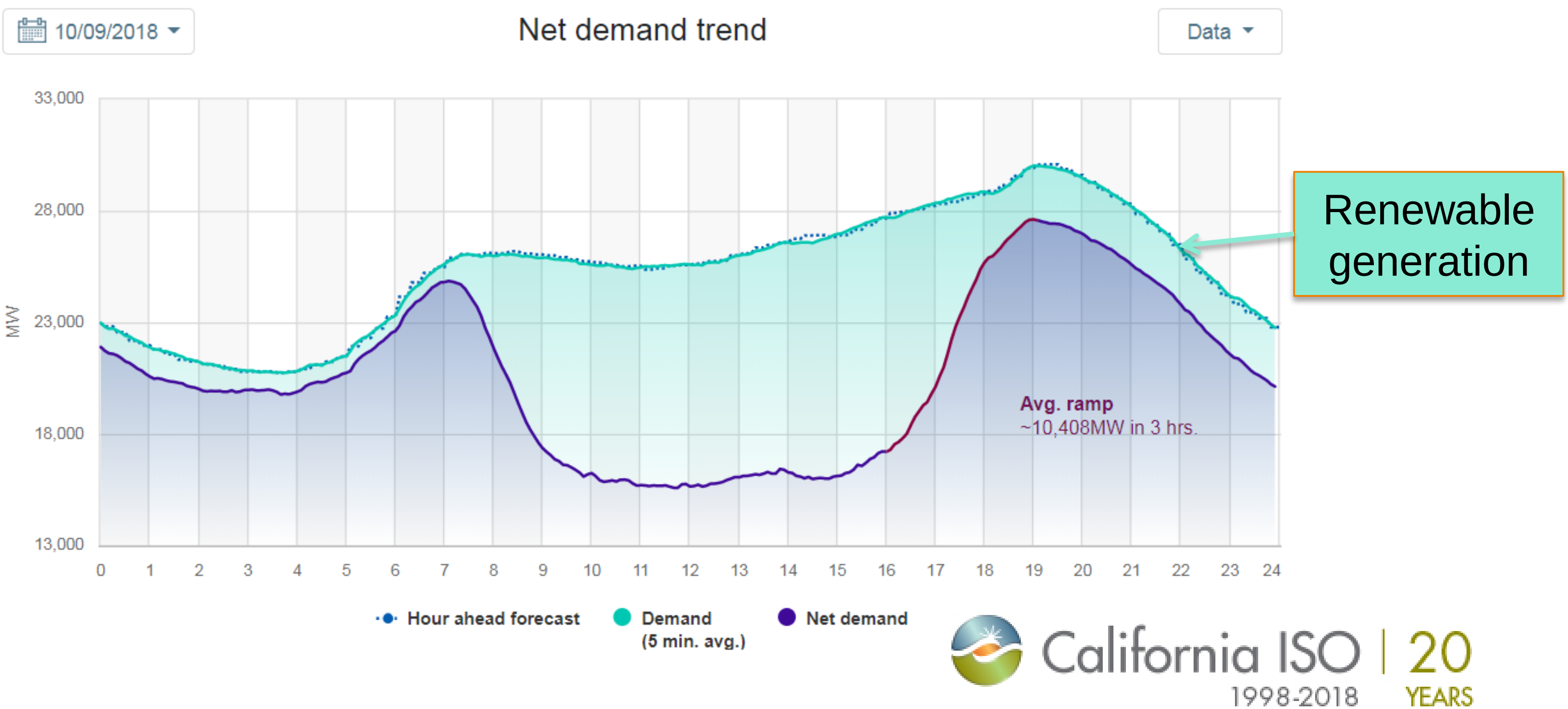
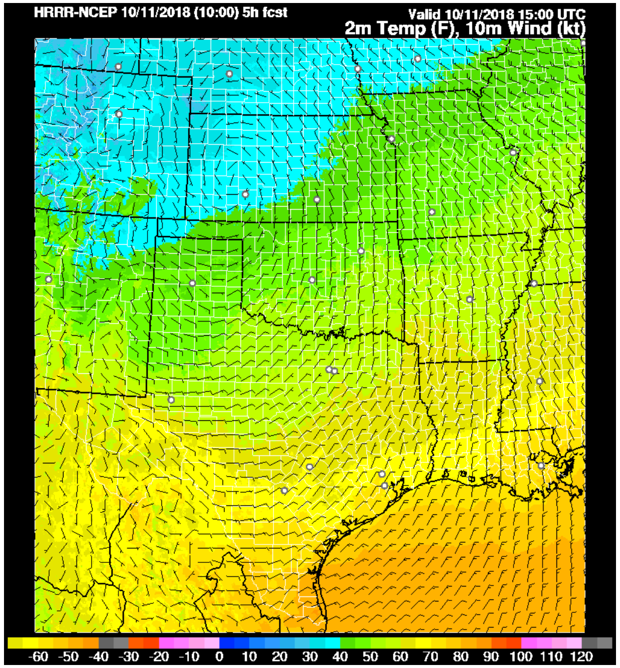
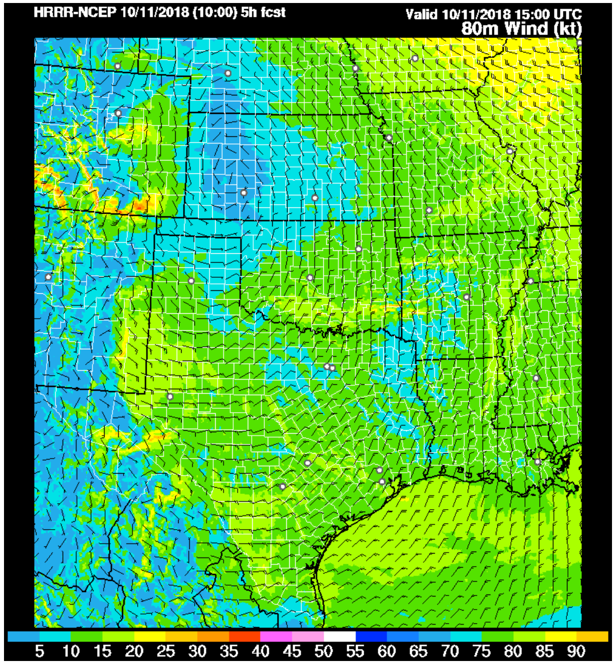
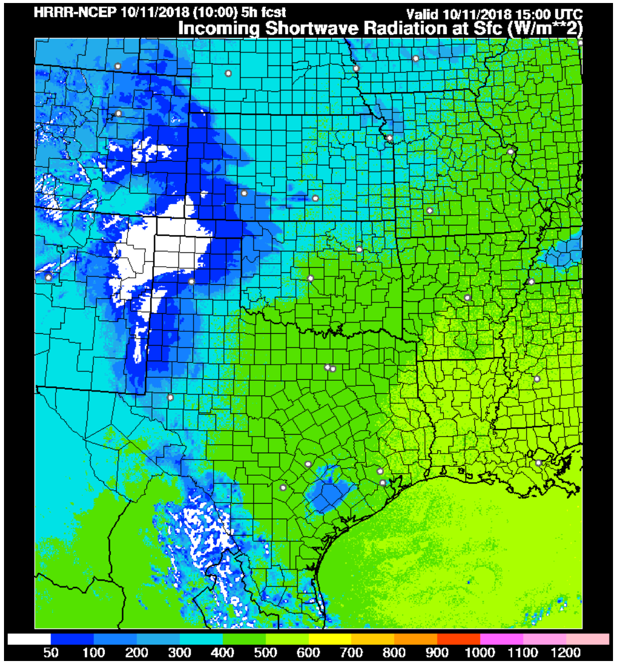


WEATHER'S MULIT-FACETED INFLUENCE ON THE GRID







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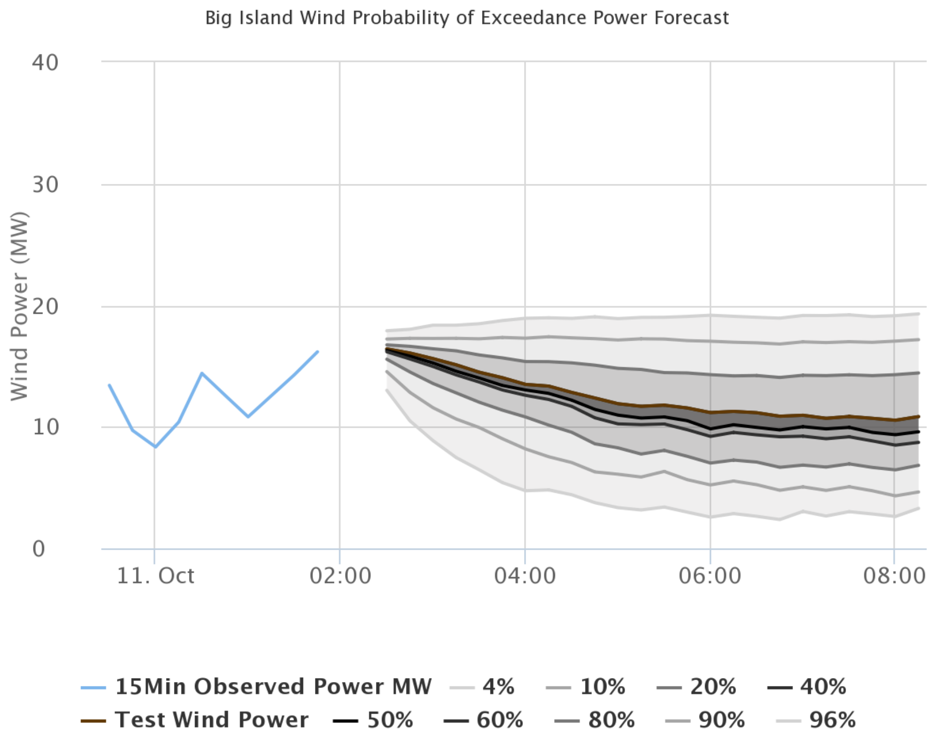
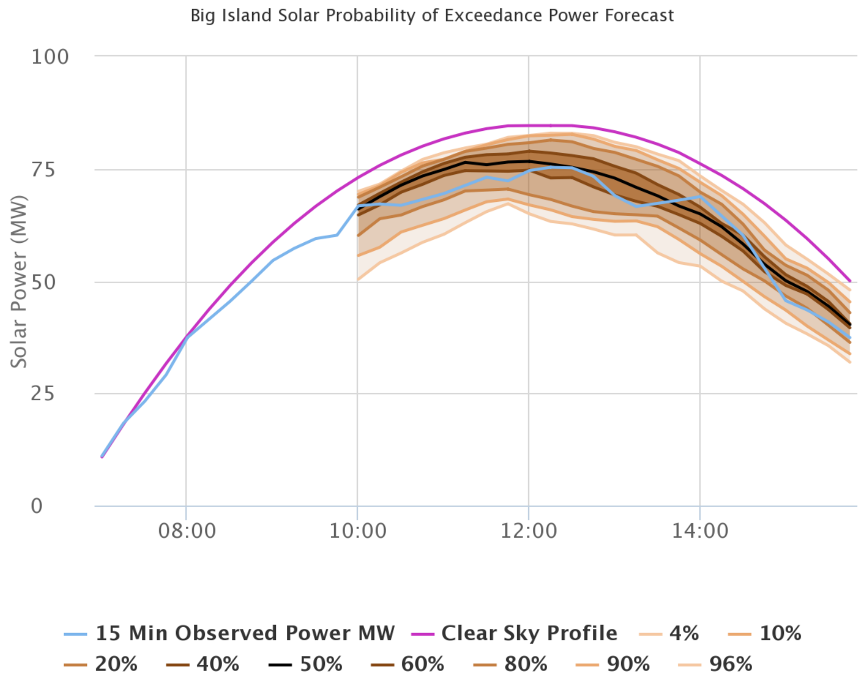
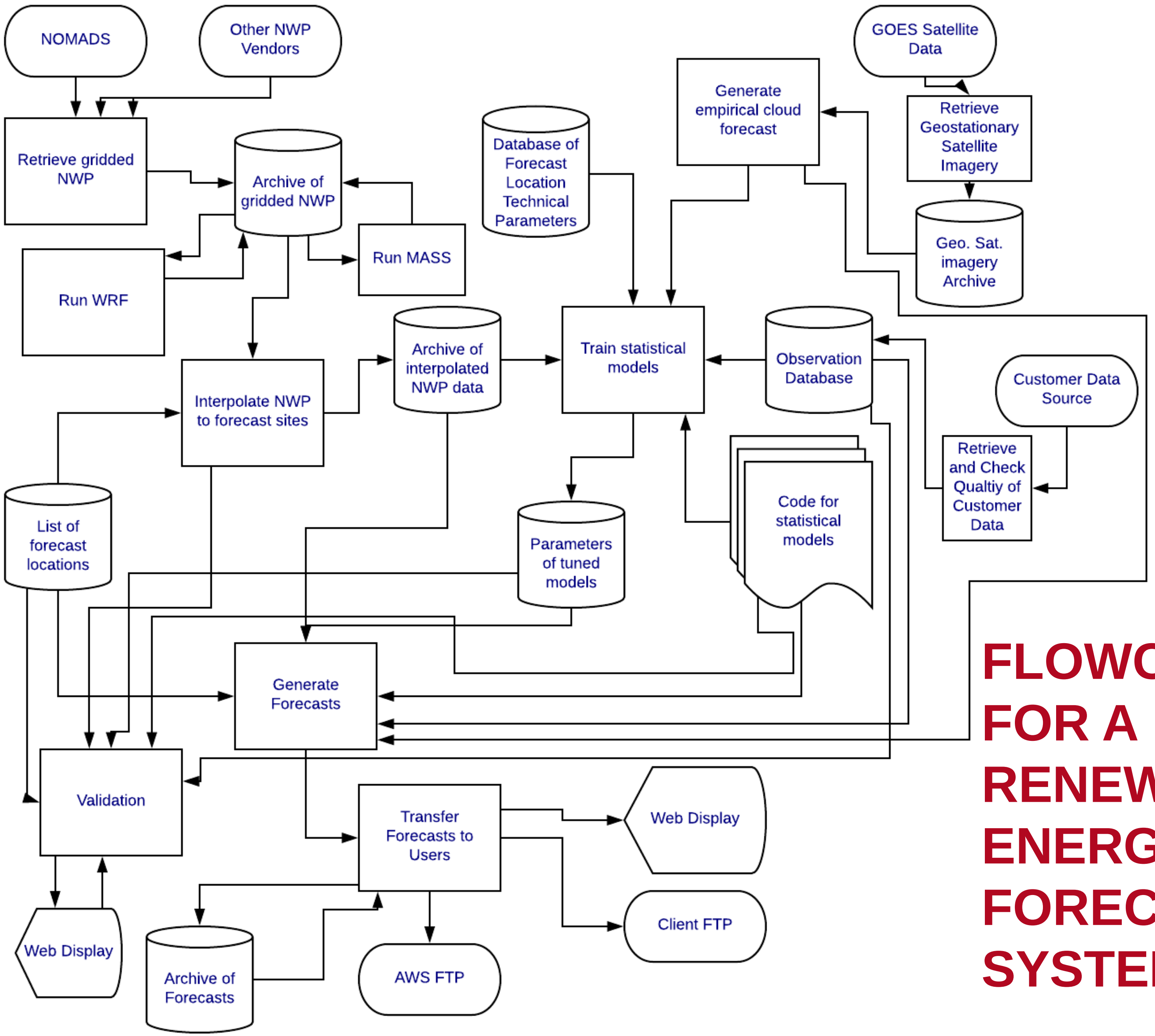






FLOWCHART FOR A RENEWABLE ENERGY FORECAST SYSTEM

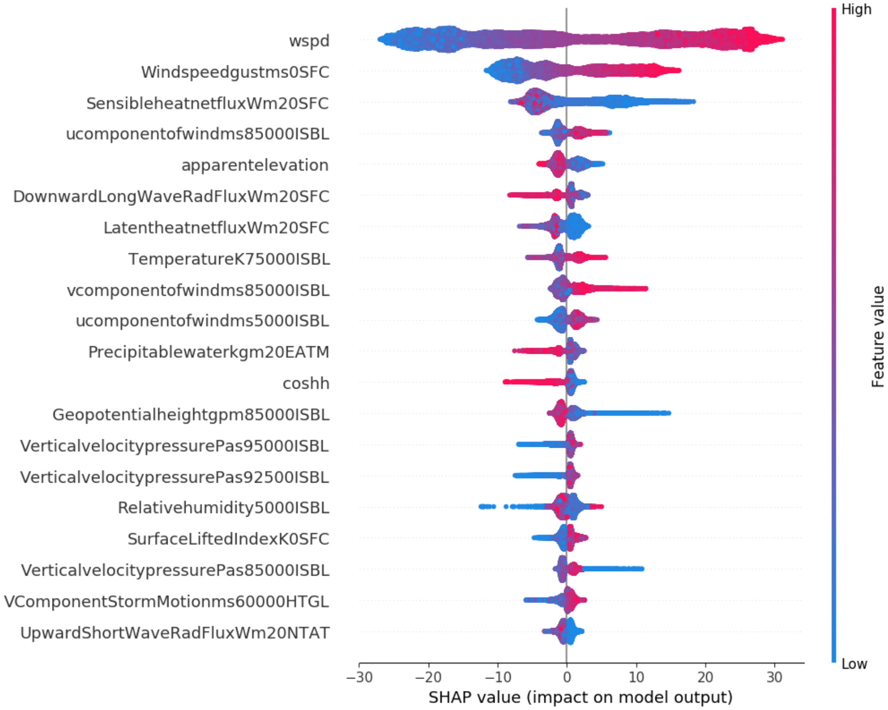
PATHWAYS TO FORECAST IMPROVEMENT

- Improving NWP
  - Additional models
  - Additional ensemble members
  - Improving existing models
    - Data assimilation
    - Parameterizations
    - Resolution
- Improved post-processing
  - Progress in AI/machine-learning algorithms
  - Better treatment of probabilistic forecasting
- Longer timeseries for training

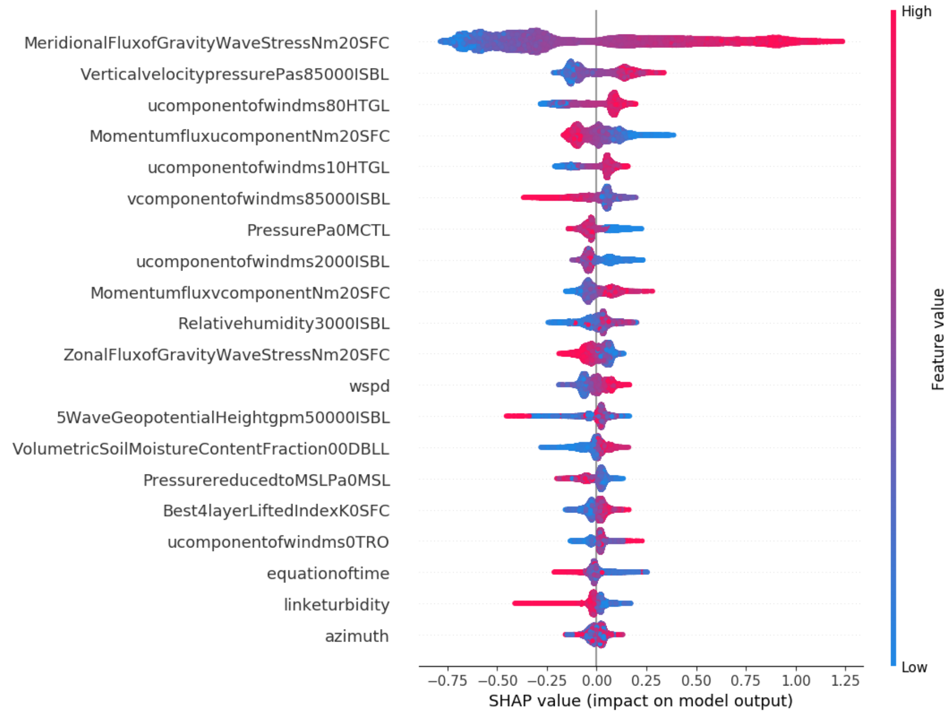
MAKING AI METHODS MORE TRANSPARENT

New methods of displaying feature importance

Plains wind farm

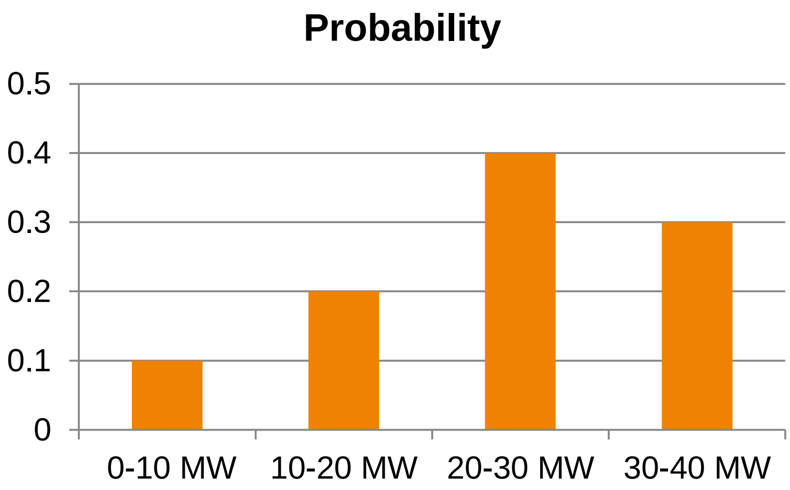


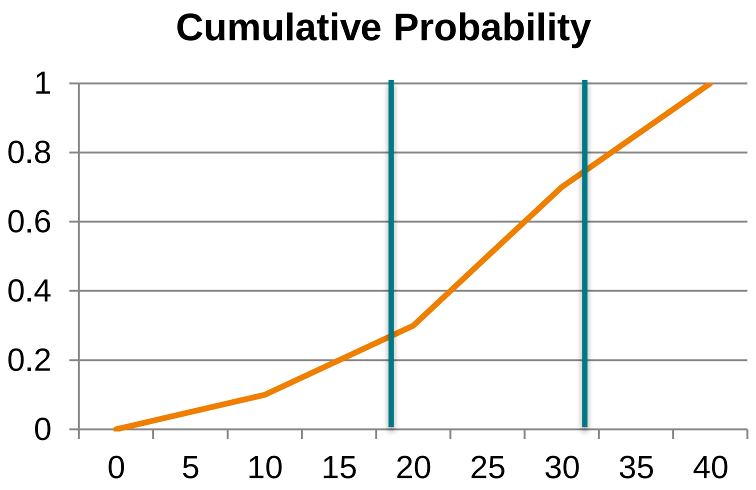
Valley wind farm



UNCERTAINTY FORECASTING USING MACHINE LEARNING (DOE SOLAR FORECAST IMPROVEMENT)

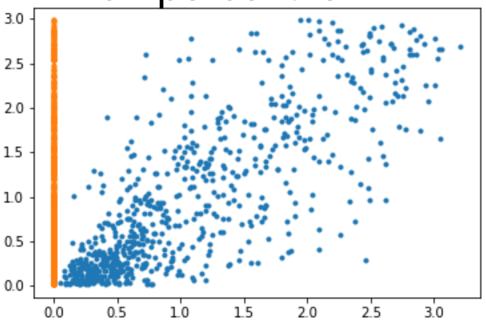
A lot of the heritage of machine learning techniques involves categorical prediction (is the image more likely of a cat or a dog)? This means that many of the popular techniques are well-suited to probabilistic forecasts.



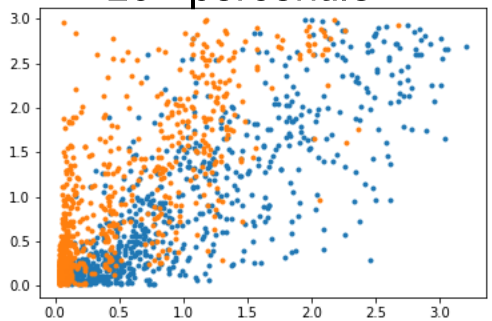


EXAMPLE OF PROBABILISTIC FORECASTS

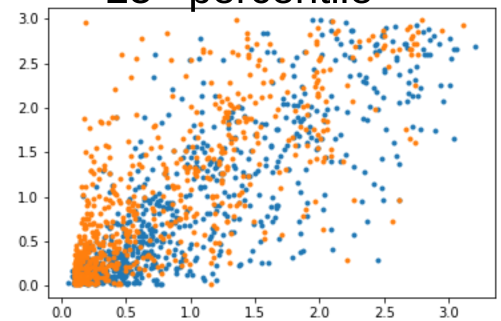
0th percentile



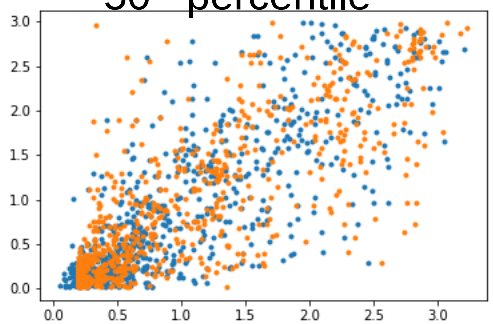
10th percentile



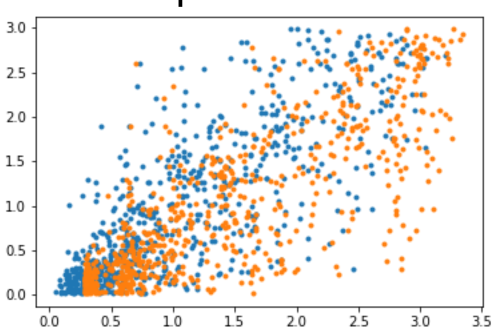
25th percentile



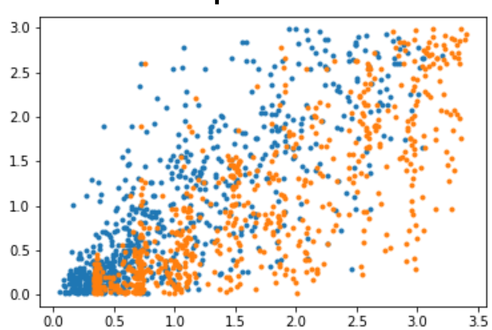
50th percentile



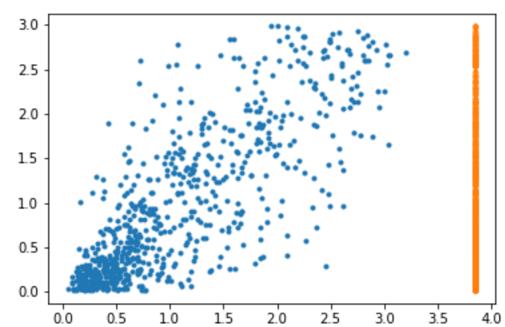
75th percentile



90th percentile



100th percentile



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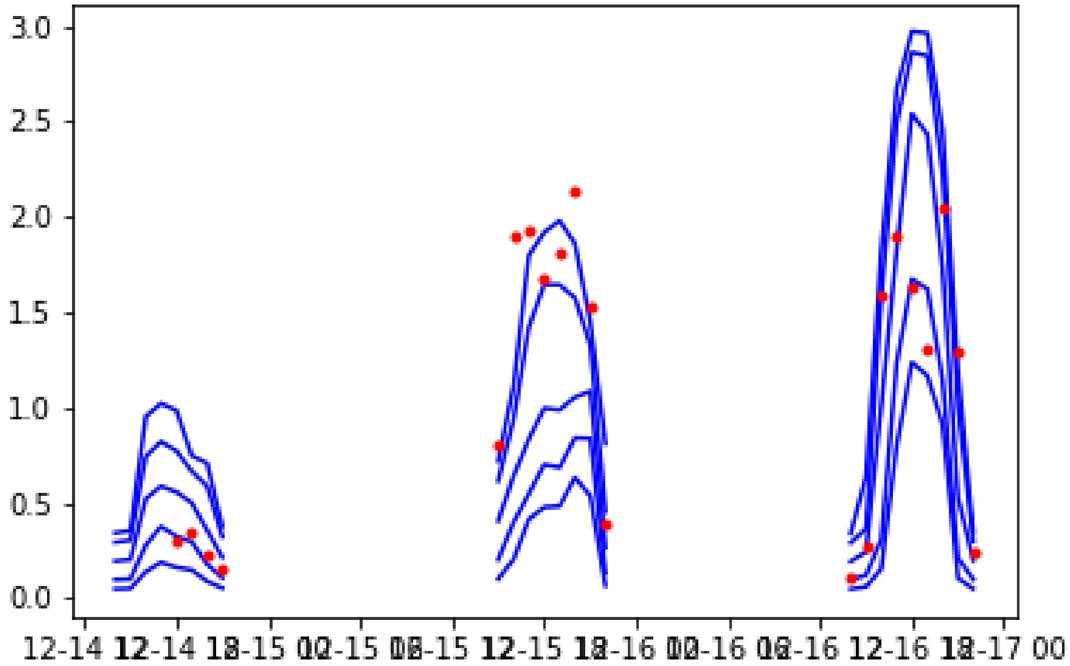
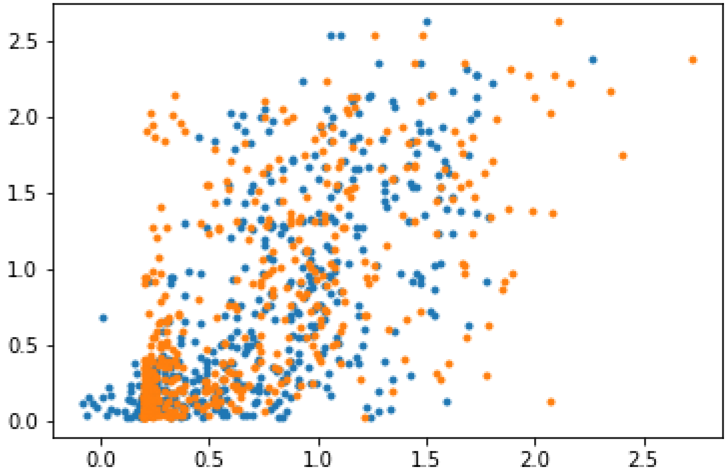
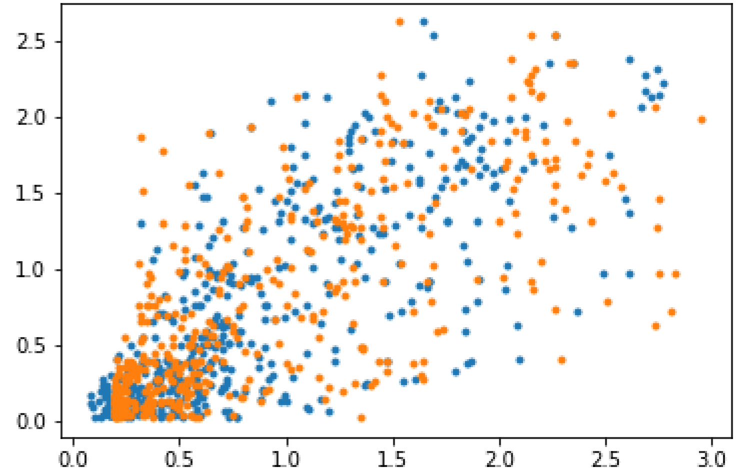


EXAMPLE OF PROBABILISTIC FORECASTS

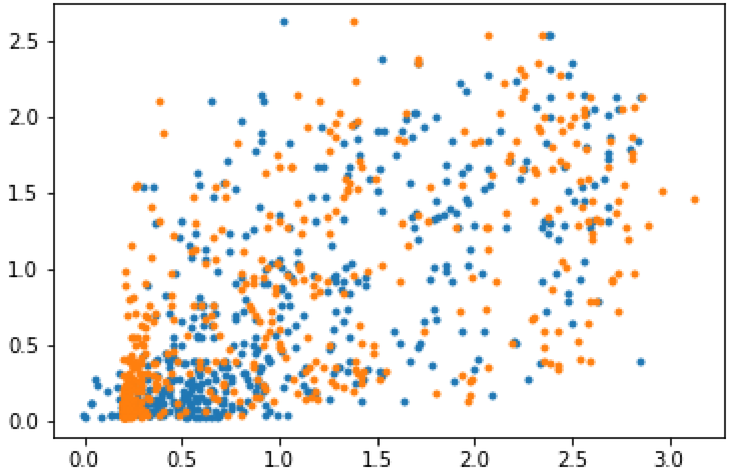
UKM



ICON

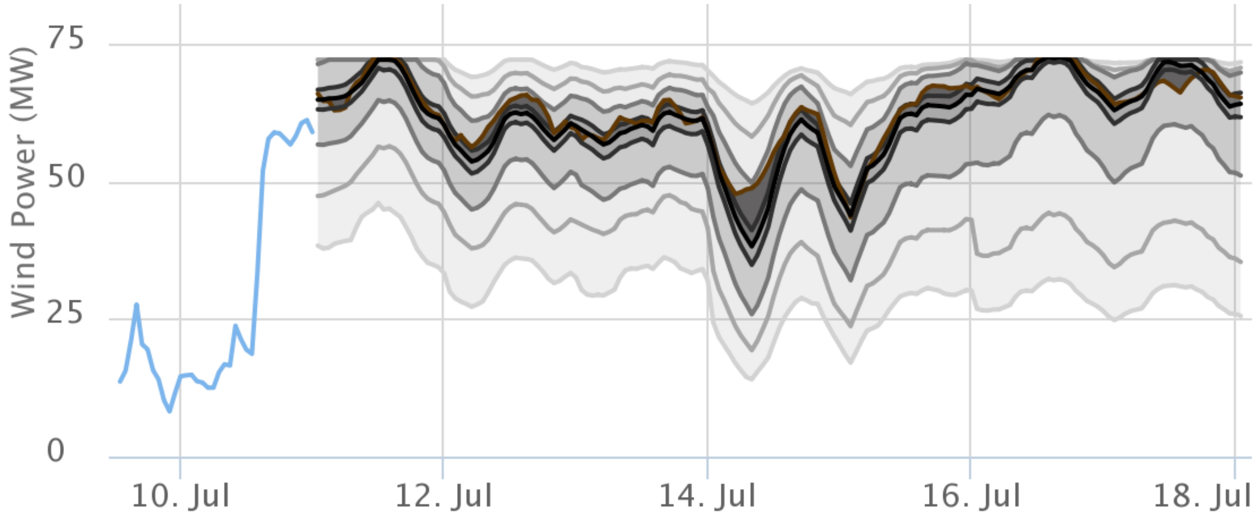


GFS



CURRENT PRACTICE IN PROBABILISTIC FORECASTING

We forecast wind and solar generation for utilities and grid operators, providing various percentiles of the cumulative probability distribution. Operators tend to pay by far the most attention to the 50th percentile. To convince them to pay attention to the full distribution we need to do a better job clarifying the reliability and usefulness of the full distribution.



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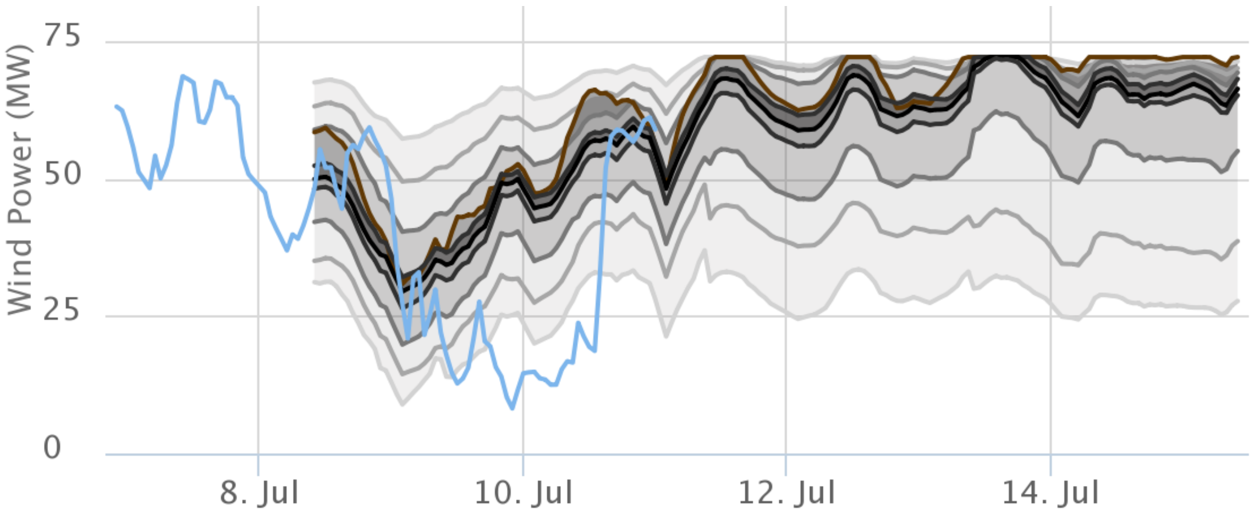
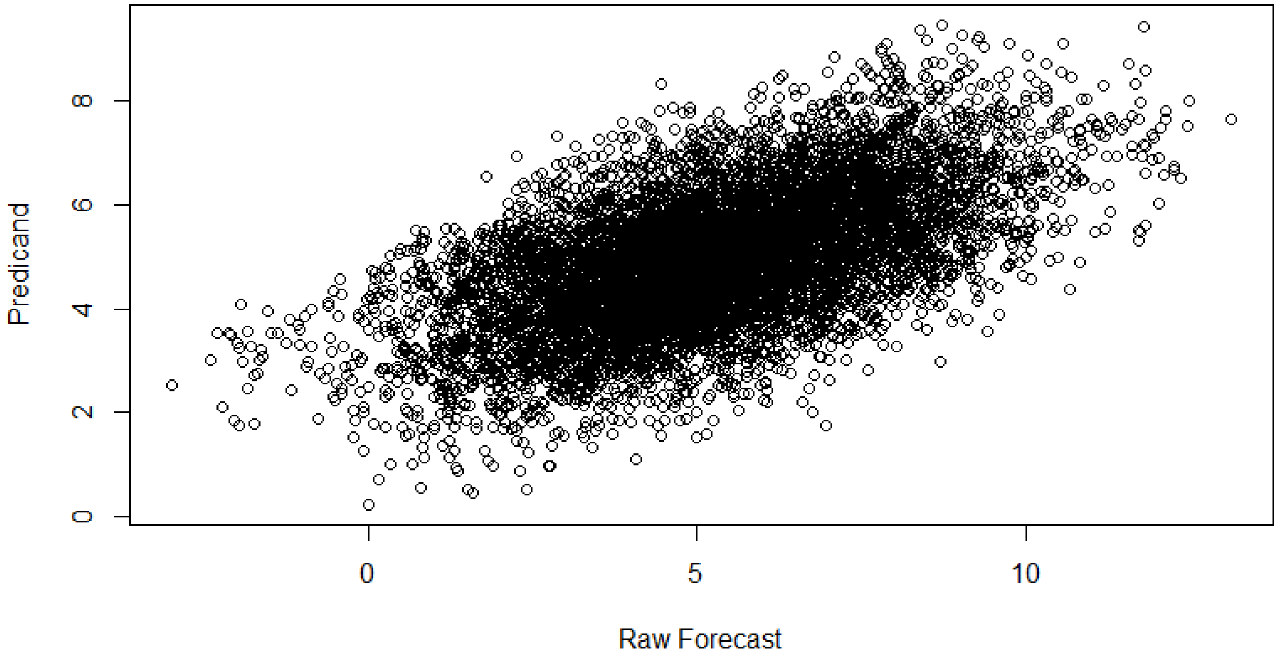


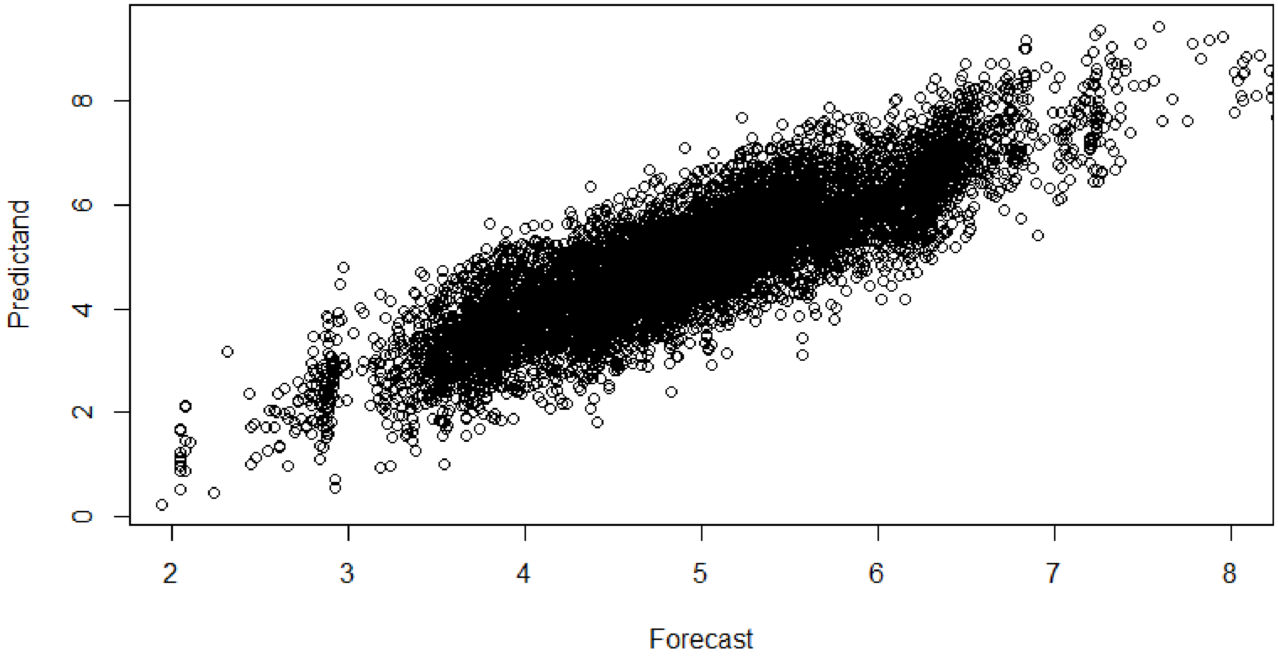
IMPROVING THE PDF CAN BE ASSOCIATED WITH A BETTER FORECAST

Original Forecast (50th percentile)

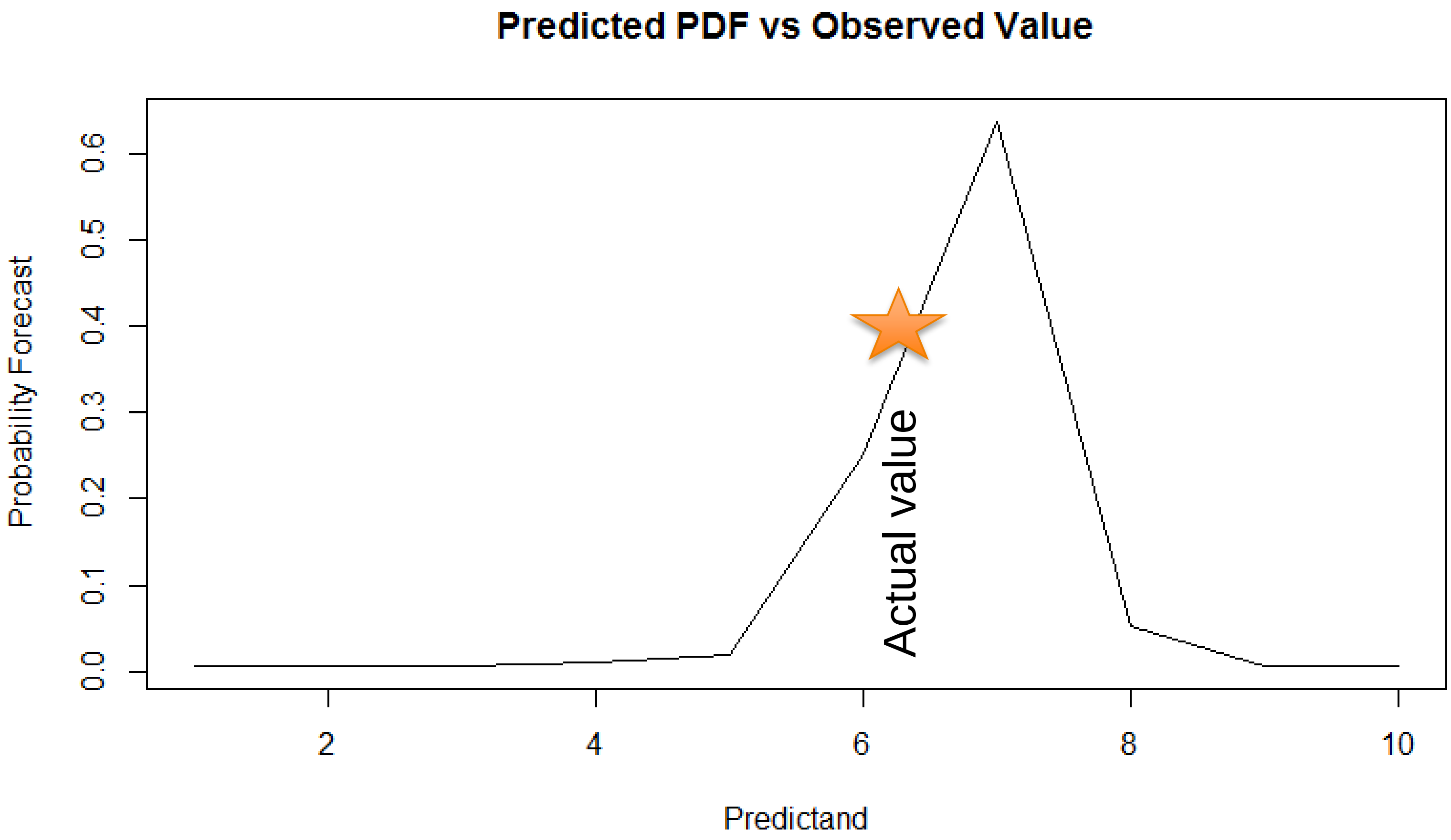


IMPROVING THE PDF CAN BE ASSOCIATED WITH A BETTER FORECAST

Machine-learning improved forecast (50th percentile)



WE NEED A MEASURE OF FORECAST SKILL THAT COMBINES PDF ACCURACY AND PRECISION



WE NEED A MEASURE OF FORECAST SKILL THAT COMBINES PDF ACCURACY AND PRECISION

S: Score (calculated for each observation, can be averaged over a range of observations)

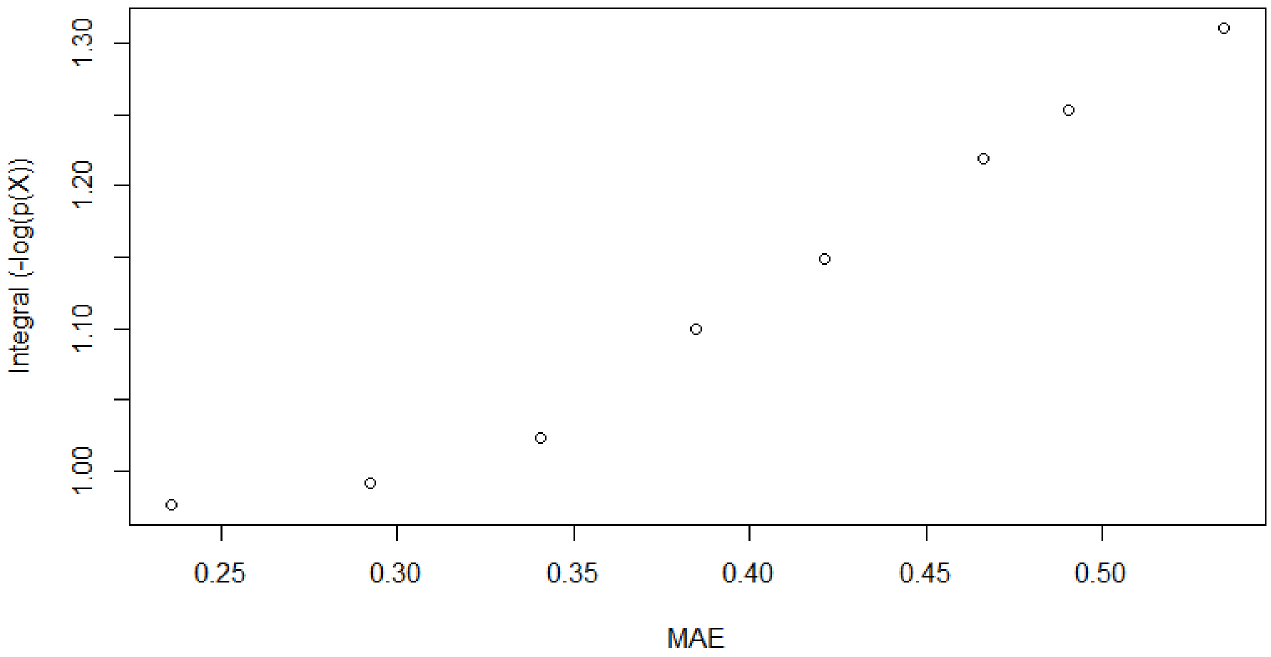
$p(x)$: predicted probability that the predictand will have the value *x*

X: actual observed value of the predictand at the time in question

Ignorance: $S[p(x), X] = -\log p(X)$

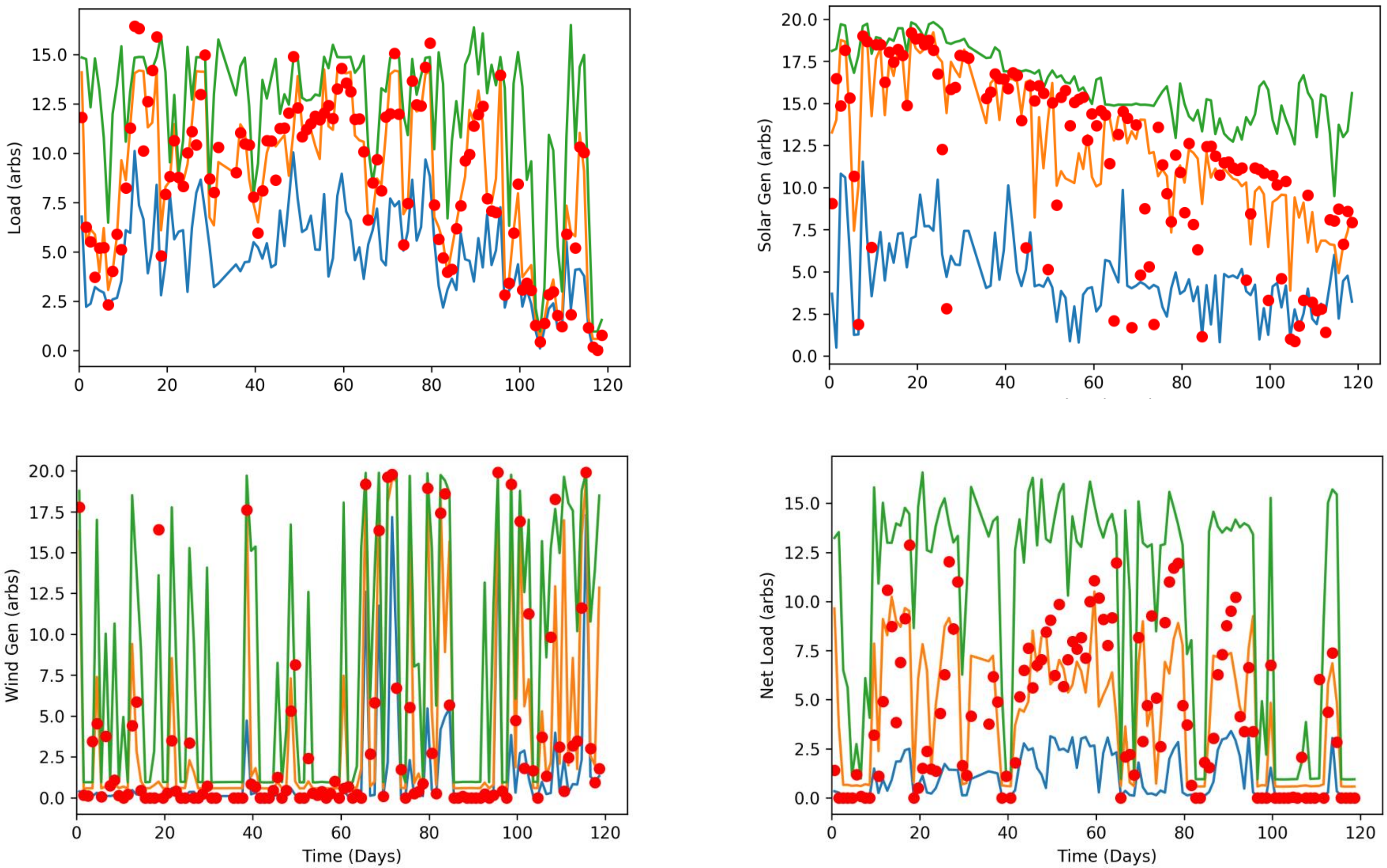
Proper linear score: $S[p(x), X] = \int p^2(z)dz - 2p(X)$

IGNORANCE VS MEAN ABSOLUTE ERROR OF 50TH PERCENTILE FORECAST

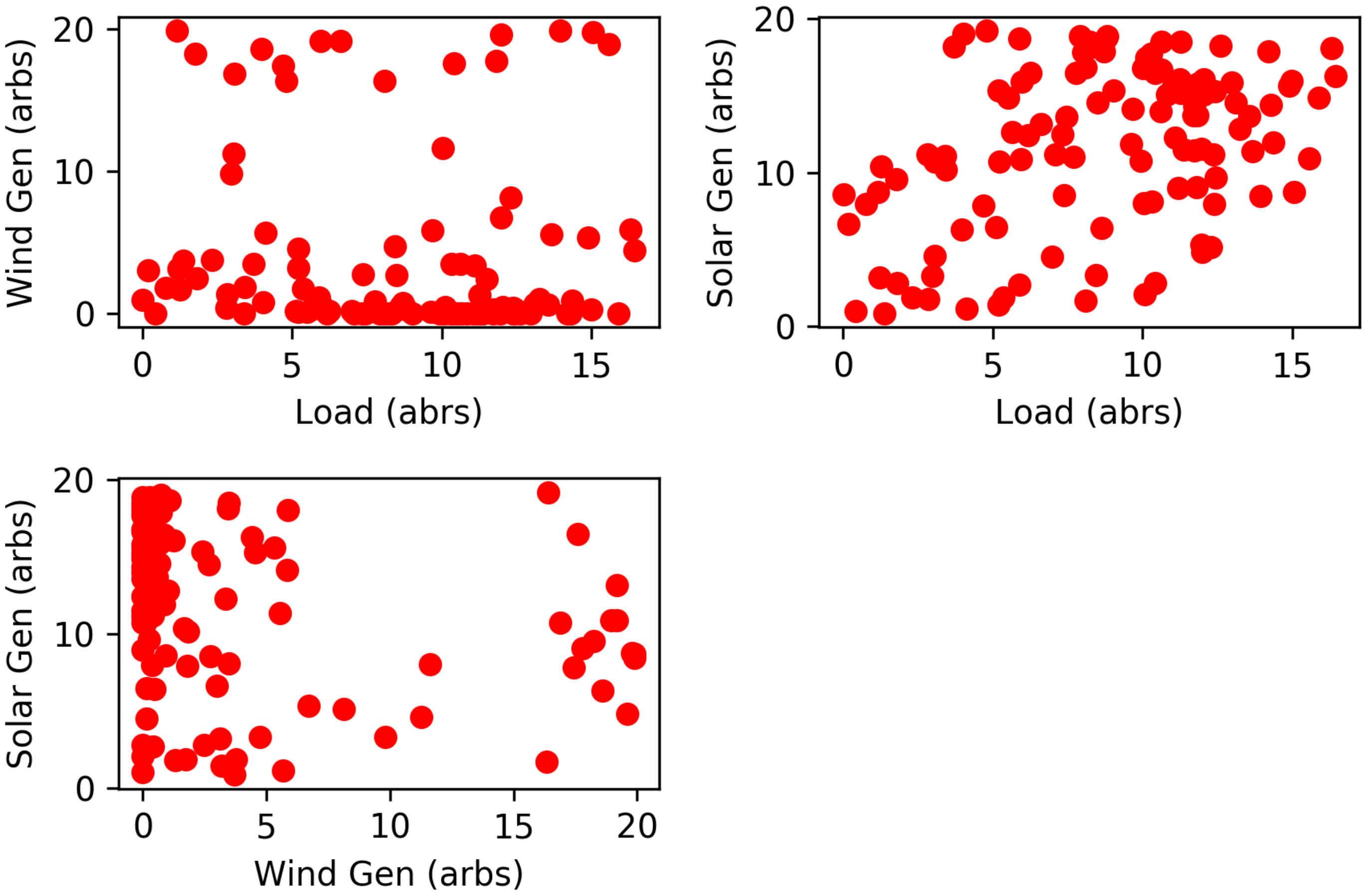


At low values of MAE, Ignorance is not falling off with continued improvements in MAE because the predicted probability distribution is getting very sharp, but biases are not decreasing: this is a forecast problem that can be addressed to improve performance.

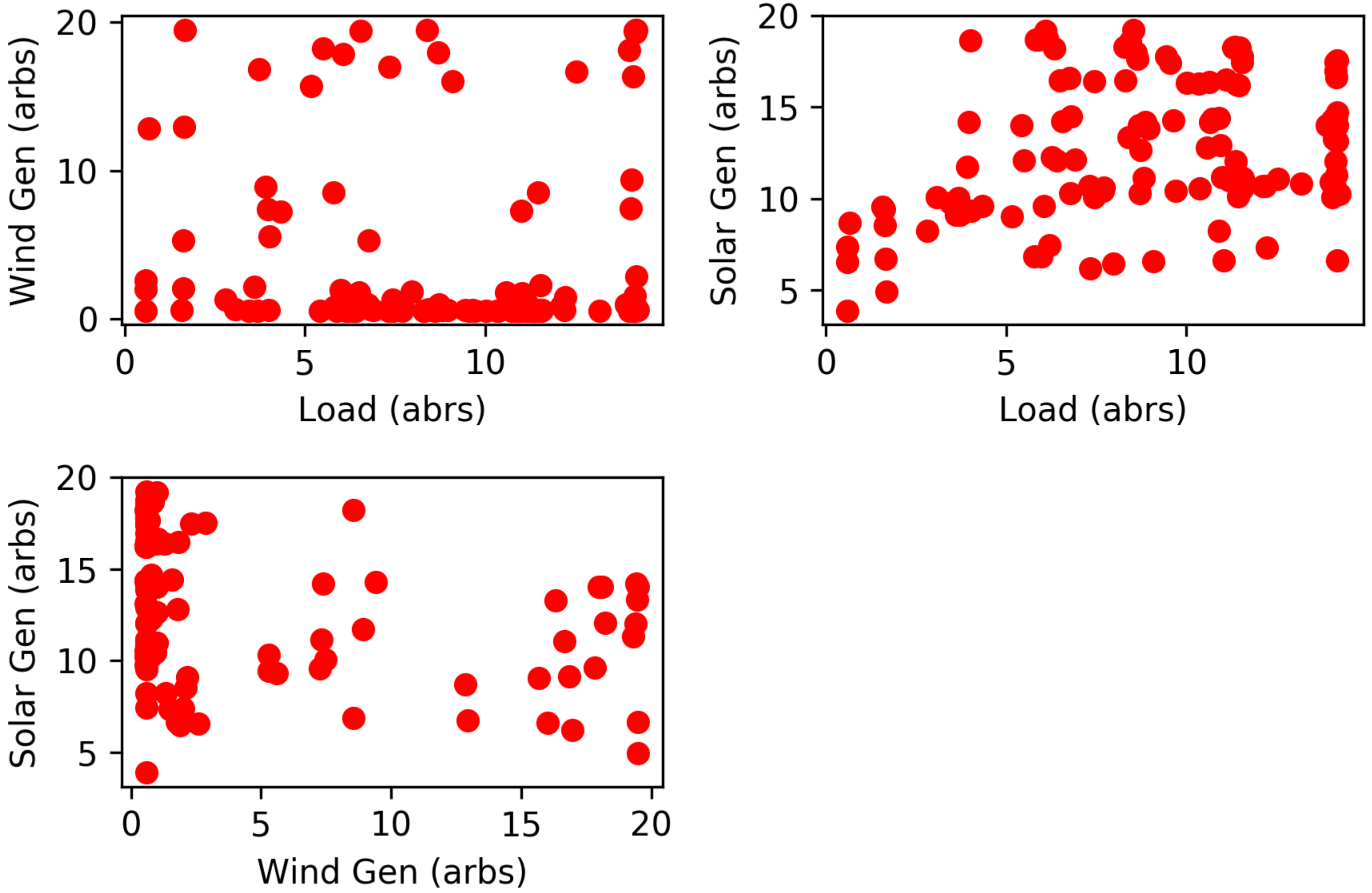
COMBINED RENEWABLES AND LOAD FORECAST



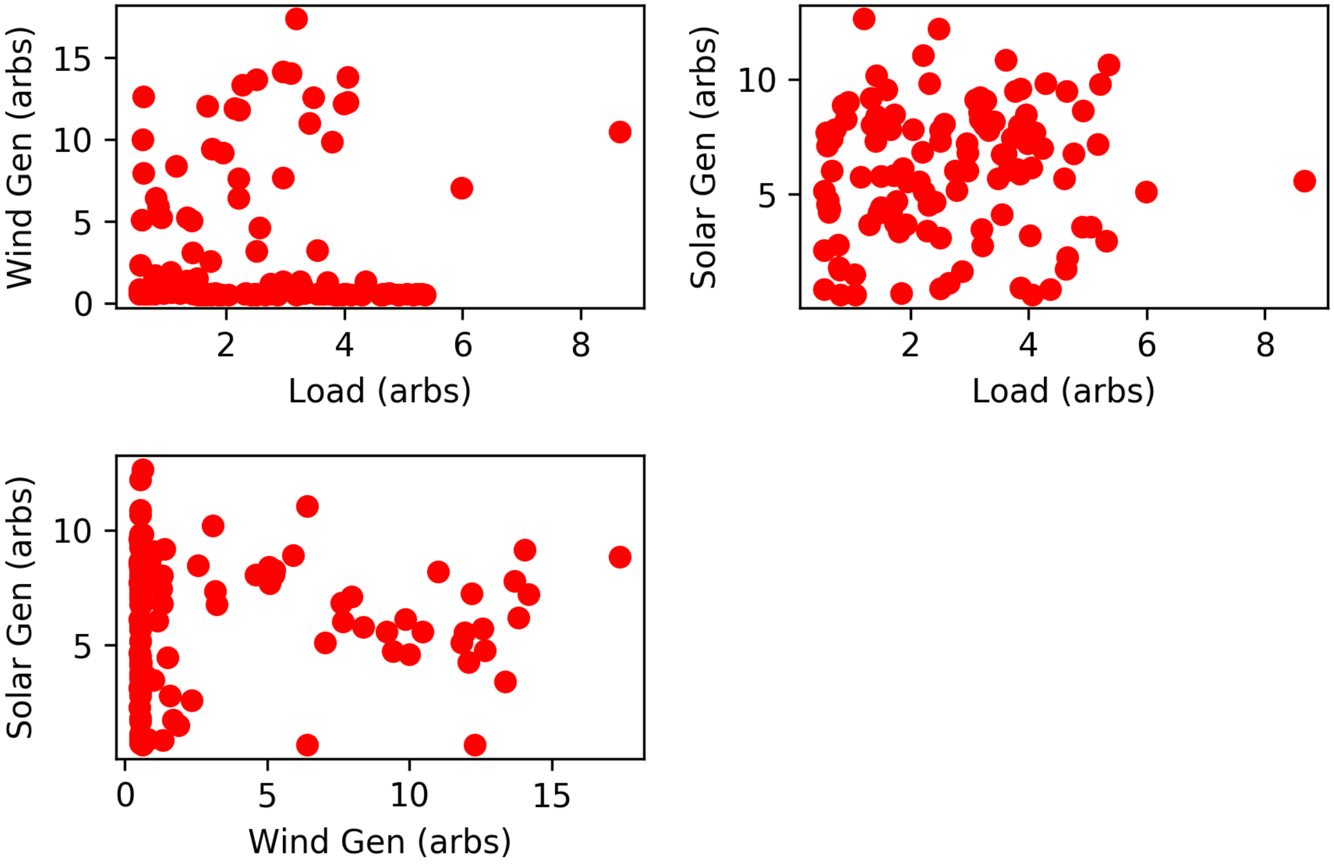
COVARIANCE OF LOAD AND GENERATION



COVARIANCE OF LOAD AND GENERATION FORECASTS



COVARIANCE OF ERROR SPREAD (75TH-25TH PERCENTILES)



CONCLUSIONS

- Machine Learning Techniques allow unified treatment of load and renewable generation
- This allows forecast errors to be combined in a physically consistent way
- Improve error propagation should yield better results when probabilistic forecast are propagated through to decision support

Questions?

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