A New Era In Outage Modeling: Towards Ensemble Multi-Model Outage Prediction

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Abstract: Severe weather events create power outages affecting human activities and causing economic losses for the electric companies and the society. Prediction of outages and forecast divulgation to the interested utilities and population is basic for a correct emergency management. The UCONN OPM is the tool developed for fulfilling this need and for improving outage prediction performances. The model is going towards multi-weather and multi-statistical model forecasts for the Eversource Energy power grid, and the experience acquired in outage prediction for Connecticut is applied for creating an outage model for the New Hampshire territory.

Introduction

The UCONN OPM is an operational framework focused on the prediction of the number of outages, "trouble spots", in Eversource Energy power lines caused by adverse atmospheric conditions.
The operational model uses the WRF 3.4.1 weather model.
In this poster will be presented the outage prediction comparison for rain and wind events between 3 different weather models:

- **WRF 3.4.1**
- **WRF 3.8.1**
- **ICLAMS**

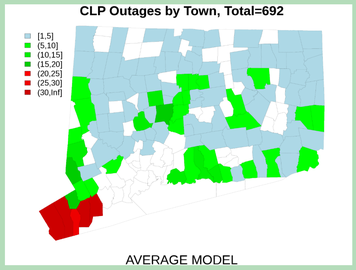


Figure 1: Example of operational map of predicted trouble spots by town, using the WRF 3.4.1 weather model for January 23rd 2017.

OPM Architecture

The outage prediction model input is extended from a single weather model to three models.

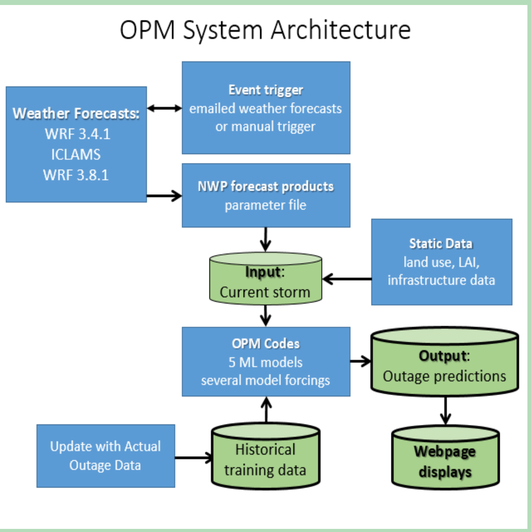


Figure 2: Outage Prediction Model architecture.

Comparing Different Weather Models

The outage predictions, obtained through a Leave-One-Storm-Out-Cross-Validation (LOSOCV) on the rain and wind events in Connecticut are compared for three different weather models, using two different forcings:

- **Base** configuration: it uses 23 variables related to weather, land cover, infrastructure and tree conditions;
- **Wind** configuration: it uses 19 variables, by excluding gust related variables.

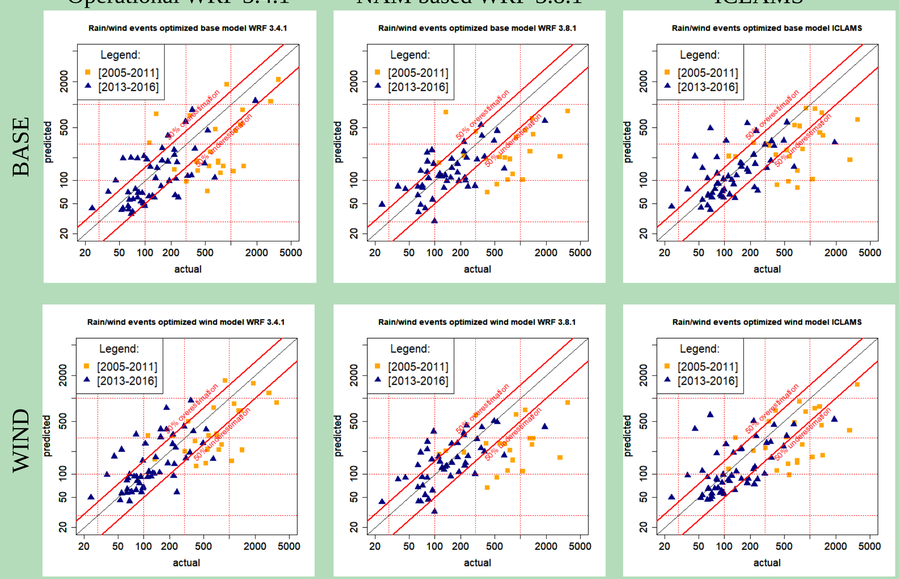


Figure 3: Leave-One-Storm-Out-Cross-Validation for: WRF 3.4.1 (left), NAM based WRF 3.8.1 (center) and ICLAMS (right) using base (top) and wind (bottom) forcings.

Ensemble Multi-Model Outage Prediction

The blended products has the low absolute error typical of the ICLAMS model and the high correlation and low CRMSE and MAPE typical of the WRF models.

Base Models:	WRF 3.4.1	ICLAMS	WRF 3.8.1	BLENDED
AE q25	21	10	20	17
AE q50	53	30	45	35
AE q75	115	92	106	83
APE q25	18%	7%	15%	14%
APE q50	45%	25%	39%	28%
APE q75	69%	55%	66%	50%
MAPE	53%	58%	48%	46%
CRMSE	188	268	218	210
R2	0.57	0.14	0.5	0.54
NASH	0.55	0.11	0.4	0.45

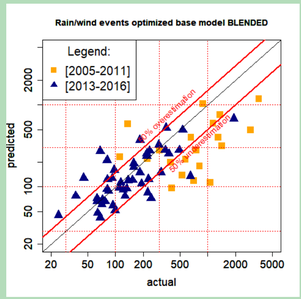
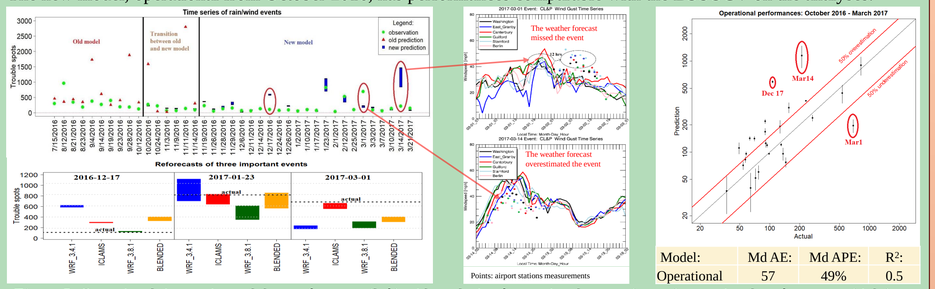


Figure 4: Comparison between three single models performances and the blended product for the base model.

Operational Performances

The new model, operational from October 2016, has performances comparable with the LOSOCV on the analyses.

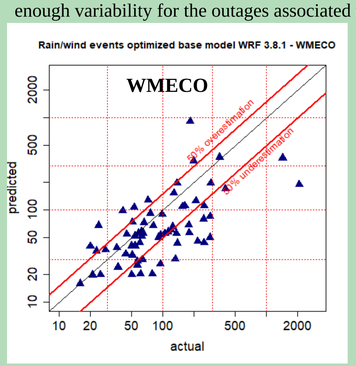


Model:	Md AE:	Md APE:	R^2:
Operational	57	49%	0.5

Figure 5: Operational time series and three reforecasts (left) with analysis of two missed events (center) operational performances (right).

WMECO And New Hampshire Territories

New OPMs, based on WRF 3.8.1 weather model, have been developed for Western Massachusetts and New Hampshire territories for events exhibiting mainly rain and wind conditions. It should be noted for New Hampshire the limited data set in terms of geolocated outages (data are available only since 2016) and the lack of enough variability for the outages associated to these events.



Territory:	WMECO
Base Model:	WRF 3.8.1
Md AE	41
Md APE	47%
MAPE	54%

Territory:	NH
Base Model:	WRF 3.8.1
Md AE	26
Md APE	31%
MAPE	33%

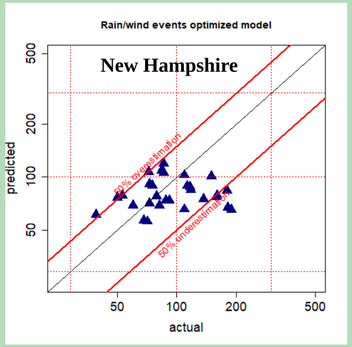


Figure 6: Performances of the new OPM for Western Massachusetts New Hampshire for rain and wind storms.

Future Research: Let's Keep Improving

- The **ensemble multi-model** outage prediction will be operational soon for Connecticut, and will be available for Massachusetts and New Hampshire in 2017.
- Research on the **winter model** is also performed in order to find the best combination of variables which allows to improve the prediction of outages caused by nor'easters and ice storms for the Eversource territories.
- These outage prediction models will input other useful decision-support tools - such as **crew allocation** models and **estimated time until restoration** models.
- Accurate outage prediction models for electric utilities encourage **coordination of emergency response** activities across the region and support interdependence research topics.

Acknowledgments: This work is supported by Eversource Energy and by the University of Connecticut, in a collaborative effort for achieving the goal of reliable energy power in the State of Connecticut and to ensure people's safety and primary needs in emergency situations, through a risk prediction and management.

References: Wanik, D. W., E. N. Anagnostou, B. M. Hartman, M. Frediani, M. Astitha, 2015: Storm Outage Modeling for an Electric Distribution Network in Northeastern US, *Natural Hazards*,**79(2)**, 1359-1384, doi 10.1007/s11069-015-1908-2.
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