Proceedings of the 33rd European Safety and Reliability Conference (ESREL 2023)
Edited by Mário P. Brito, Terje Aven, Piero Baraldi, Marko Čepin and Enrico Zio
 Published by Research Publishing, Singapore.
doi: 10.3850/978-981-18-8071-1_P322-cd

Estimating Tropical Cyclone induced Power Outages in Future Climate Scenarios

Zaira Pagan-Cajigas

Industrial and Operations Engineering, University of Michigan, MI, United States. E-mail: zpagan@umich.edu

Seth Guikema

Industrial and Operations Engineering, University of Michigan, MI, United States. E-mail: sguikema@umich.edu

Charles Fant

Industrial Economics Inc., MA, United States. E-mail: cfant@indecon.com

Brent Boehlert

Industrial Economics Inc., MA, United States. E-mail: bboehlert@indecon.com

This study investigates the impact of tropical cyclones on power outages at the census tract level, considering climate change's impact on the hazard's intensity and frequency. For this analysis, we use seven climate models to generate the synthetic tropical cyclones corresponding to historical data and future scenarios as well as a power outage model to predict the fraction of outages at each census tract. Our main objective is to evaluate if future climate scenarios will increase the frequency or produce longer-lasting outages for the Gulf and East Coast of the US.

Keywords: Power outage predictions, outage model, climate models, data analysis, climate change projections.

1. Introduction

The energy system is one of the most critical services, enabling communities to meet their most basic needs. Nevertheless, the occurrence of natural disasters, such as tropical cyclones, floods, and tsunamis, frequently disrupts this system, leading to power outages. Simultaneously, climate change projections indicate that these hazards will become more frequent and severe (Knutson et al. 2010), thereby prolonging the duration of outages. As the duration of an outage increases, it results in greater economic and societal losses while simultaneously disrupting dependent critical infrastructures such as water and communications systems.

Although many hazards can inflict significant damage on energy systems, tropical cyclones are particularly dangerous as they can severely damage critical components of the system, (e.g., substations and distribution lines). Climate change projections indicate that future tropical cyclones are likely to exhibit slower movements and prolonged lifespans. This prolonged exposure to stronger winds increases the likelihood of extensive damage to the energy system's infrastructure.

One of the main approaches for estimating power outages are statistical analysis models. Statistical outage forecasting models use weather forecasting information as well as information on the infrastructure exposed to the hazard to predict the number of outages at an aggregated spatial level, such as the census tracts or county level.

2. Methods and Results

This research uses a power outage model to examine how tropical cyclones could affect power outages at the census tract level using seven climate models. For each model, 4000 synthetic tropical cyclones were generated for the Atlantic and Gulf Coasts regions, 2000 corresponding to historical conditions and 2000 based on the SSP5-8.5 socioeconomic pathway projection, which assumes high levels of greenhouse emission and a 4.5-degree Celsius temperature increase by 2100.

The power outage model builds from McRoberts et al. (2018). This two-step model predicts power outage by first using a binary random forest classification model to determine whether an outage will occur at the census track level. If the binary model indicates an outage, the second step of the model predicts the number of outages at each location using a random forest regression model. We reduced the set of predictor variables utilizing only publicly available and accessible information, including hurricane-related characteristics, socio-demographic and environmental variables. We conducted statistical analysis to ensure the fraction of outages generated with the reduced dataset did not significantly differ from the original results. For this analysis, we used an alpha level of 0.1.

Our final set of variables includes the maximum 3-sec wind gust, the duration of sustained winds exceeding 20 m/s, the census tract population density, and three land cover variables: forest, grassland, and wetlands. To estimate the maximum 3-sec wind gust and the duration of sustained winds exceeding 20 meters per second, we utilized a parametric wind field model that has been validated in previous studies (Nateghi et al. 2014; Guikema et al. 2014). Population density data were obtained from the 2020 US decennial census, while land cover data was sourced from the National Land Cover Database.

Our analysis focused on 24 states along the Gulf and East Coasts of the United States. Fig.1 displays the average annual fraction of outage difference between the historical data and the SSP5-8.5 projection for the CNRM-CM6-1 climate model. The graph colors indicate whether the projection presented a greater (red) or lower (blue) fraction of outages compared to the historical data. Results indicates that for the CNRM-CM6-1 climate model, there is an increase on the average annual fraction of outages for all the Gulf and East Coast states.

In the final analysis, which will be presented at the conference, we compare the average annual fraction of outages difference between the historical data and the SSP5-8.5 projection, for all seven climate models as well as an ensembled at the census tract level.

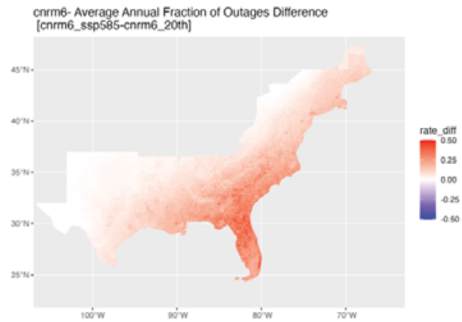

Fig. 1. Average annual fraction of outages difference between the historical data and the SSP5-8.5 projection, for the CNRM-CM6-1 climate model.

3. Conclusion

This study provides a basis for understanding if future climate scenarios will increase the frequency of outages for the Gulf and East Coast of the US. The findings can be used to inform the development of strategies to mitigate the climate change risks and ensure the resilience of the energy system. Furthermore, it provides a basis for additional economic and societal impact analysis of future climate projections.

References

Guikema, Seth David, Roshanak Nateghi, Steven M. Quiring, Andrea Staid, Allison C. Reilly, and Michael Gao. 2014. "Predicting Hurricane Power Outages to Support Storm Response Planning." *IEEE Access* 2: 1364–73.

Knutson, Thomas R., John L. McBride, Johnny Chan, Kerry Emanuel, Greg Holland, Chris Landsea, Isaac Held, James Kossin, A. K. Srivastava, and Masato Sugi. 2010. "Tropical Cyclones and Climate Change." *Nature Geoscience* 3 (3): 157–63.

McRoberts, D. Brent, Steven M. Quiring, and Seth D. Guikema. 2018. "Improving Hurricane Power Outage Prediction Models Through the Inclusion of Local Environmental Factors." *Risk Analysis* 38 (12): 2722–37.

Nateghi, Roshanak, Seth Guikema, and Steven M. Quiring. 2014. "Power Outage Estimation for Tropical Cyclones: Improved Accuracy with Simpler Models." *Risk Analysis* 34 (6): 1069–78.