Abstract

Modeling electric grid vulnerability induced by natural events using Machine Learning and Geospatial analysis.

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The growing frequency of weather-induced power outages in recent decades has put the electric grid infrastructure of the United States at risk. Natural hazards, like hurricanes, floods, heat waves, and winter storms, can cause millions of dollars of loss to the grid infrastructure. Any damage to the electric grid can further impact other critical infrastructure, like water distribution and transportation. Past instances show that these events have more impact on low-income communities. Therefore, modeling the grid vulnerability to weather extremes is vital to protect these communities. This research involves the creation of a multi-step modeling method to predict the spatial extent and number of electric power outages for a case study in the Rio Grande Valley region of Texas. The study focuses on the impact of hydrologic flood events on the power grid using a step-wise workflow that scales geospatial analyses and applies a machine learning approach to inform prevention, mitigation, and restoration strategies.

The initial analysis generates a flood inundation model using the Height Above Nearest Drainage (HAND) method. This python workflow uses the Stampede2 supercomputer to produce the HAND flood extent for one input DEM tile in 16 seconds and was made scalable for 135,000 DEM tiles in the Rio Grande valley. The implementation presents ways to scale up and time-bound such hydrologic models on high performance computing systems. Combining the HAND data product with Precipitation Frequency Estimate generated a Flood Vulnerability Raster (FVR) to provide the base dataset for subsequent steps in the analysis.

The areas most prone to outages are identified using a spatial power outage model that combines information from the grid infrastructure maps, FVR, Social-Vulnerability Index (SVI) data, and the Weather Events dataset. The same set of input datasets with a total of 47 features for each of the 17 counties in the Rio Grande, along with their historical power outage data, is used to train a Random Forest model to predict the power outage expectation for a county. The Random Forest model performs well with a low normalized RMSE of 11.8%. Also, an analytical model for future outage prediction is developed based on linear regression. The simplified power-outage analytical model is created by using feature selection and utilizes only four important variables for an R-squared of 0.88. Furthermore, this research discusses possible practices that can improve power system resilience, such as deploying microgrids, expansion of transmission capacity and grid hardening. Research results show promise for use by urban planners, operators and decision-makers that make decisions related to resource allocation, critical infrastructure protection, investments, and manage emergency preparedness.