BART-Physical Damage Approach for Power Outages Forecast

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Objective

- The objective of this project is to develop a machine learning model that, by estimating damage to the power network and using simulated weather data, is able to predict power outages in the island of Puerto Rico.

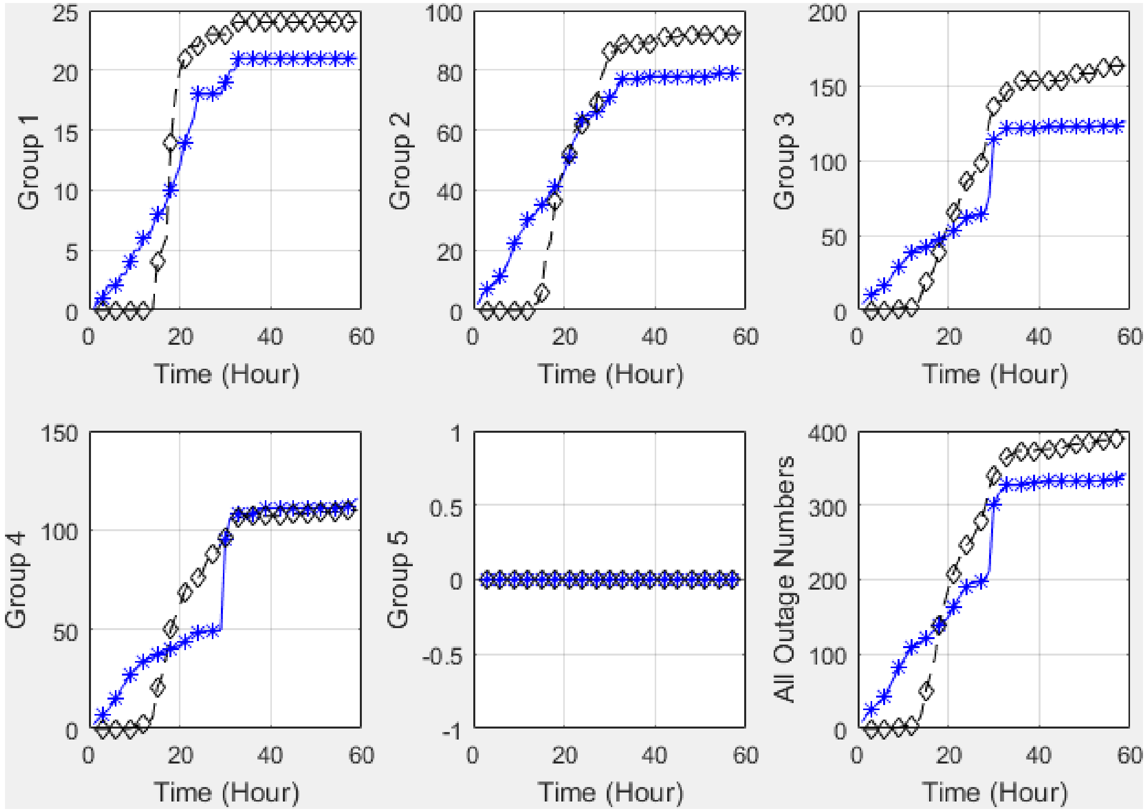
- This work is relevant because it will help us understand how the power grid stands to extreme weather events, and most important how it will behave in future events.

Background: Outage Calculation Using Radar Measurement Data

OH Cable Outage Hourly Estimation in a Storm August, 2011

* Actual Outages

◇ Failure Rate Model Calculated Outages



- The outage prediction was performed for five areas of the utility service territory;
  - Inputs: Hourly weather condition data and utility's component inventory.
  - Output: Hourly evolution of OH outages in different areas.

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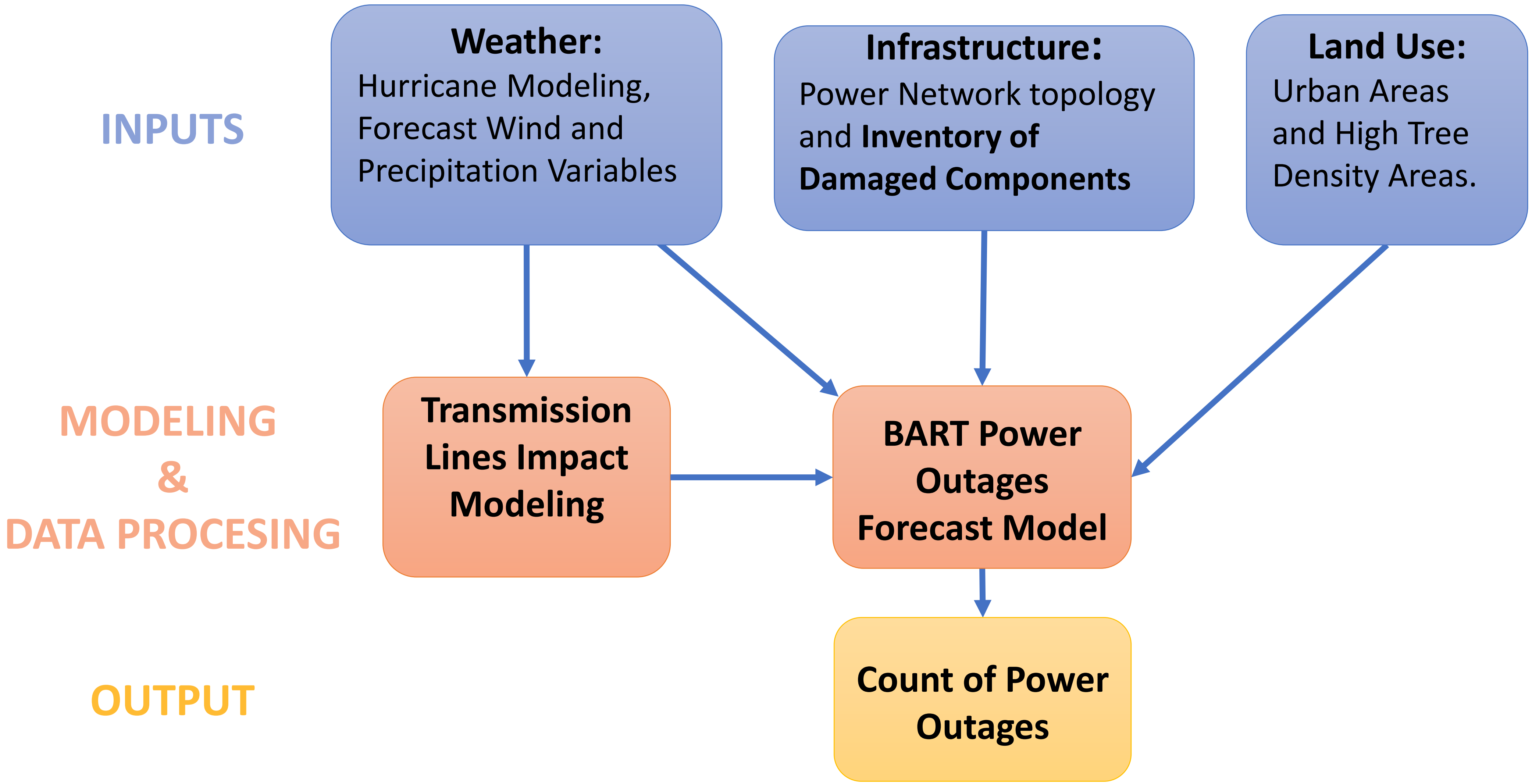
1. Yue, Meng, et al. "A Bayesian Approach-Based Outage Prediction in Electric Utility Systems Using Radar Measurement Data.“ *IEEE Transactions on Smart Grid* 9.6 (2017): 6149-6159.

Power Outage Forecast

- **Transmission Lines Impact Modeling** that estimate power towers failure due to extreme weather conditions, using mechanical stress analysis.

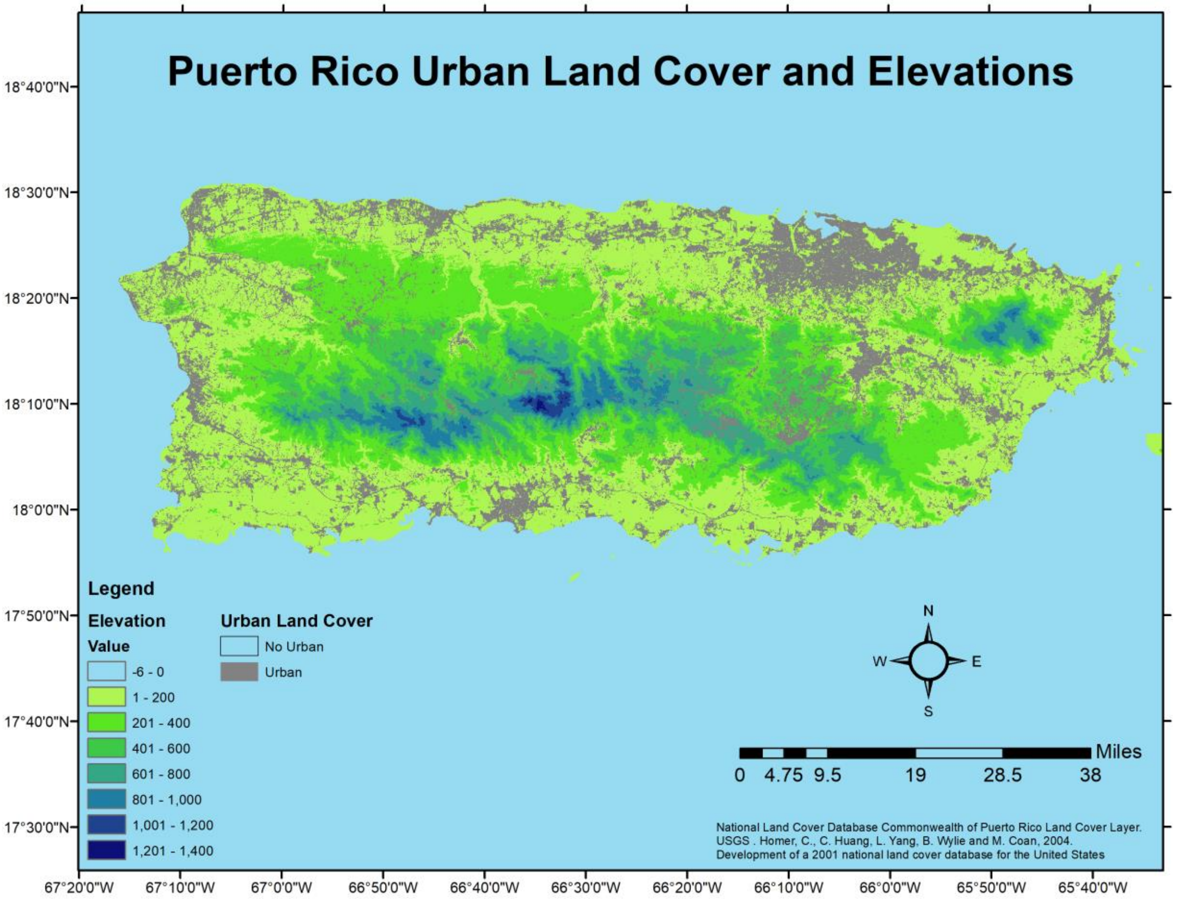
- **Machine Learning Model** of sample data (Weather, outage, etc) is used to predict the number of power outages caused by hurricanes. The model used is the Bayesian Additive Regression Trees (BART).

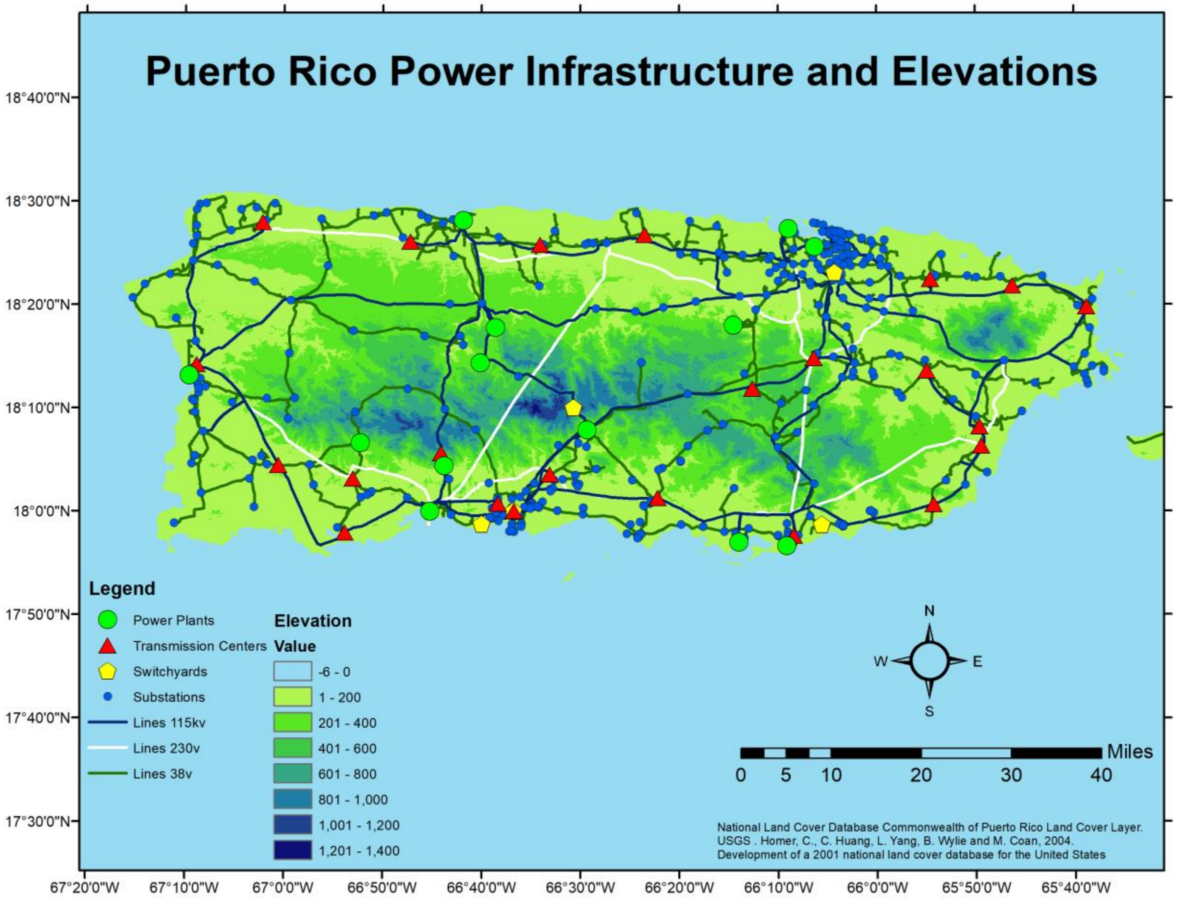
Power Outage Forecast - Approach



Input: Land Use and Power Infrastructure

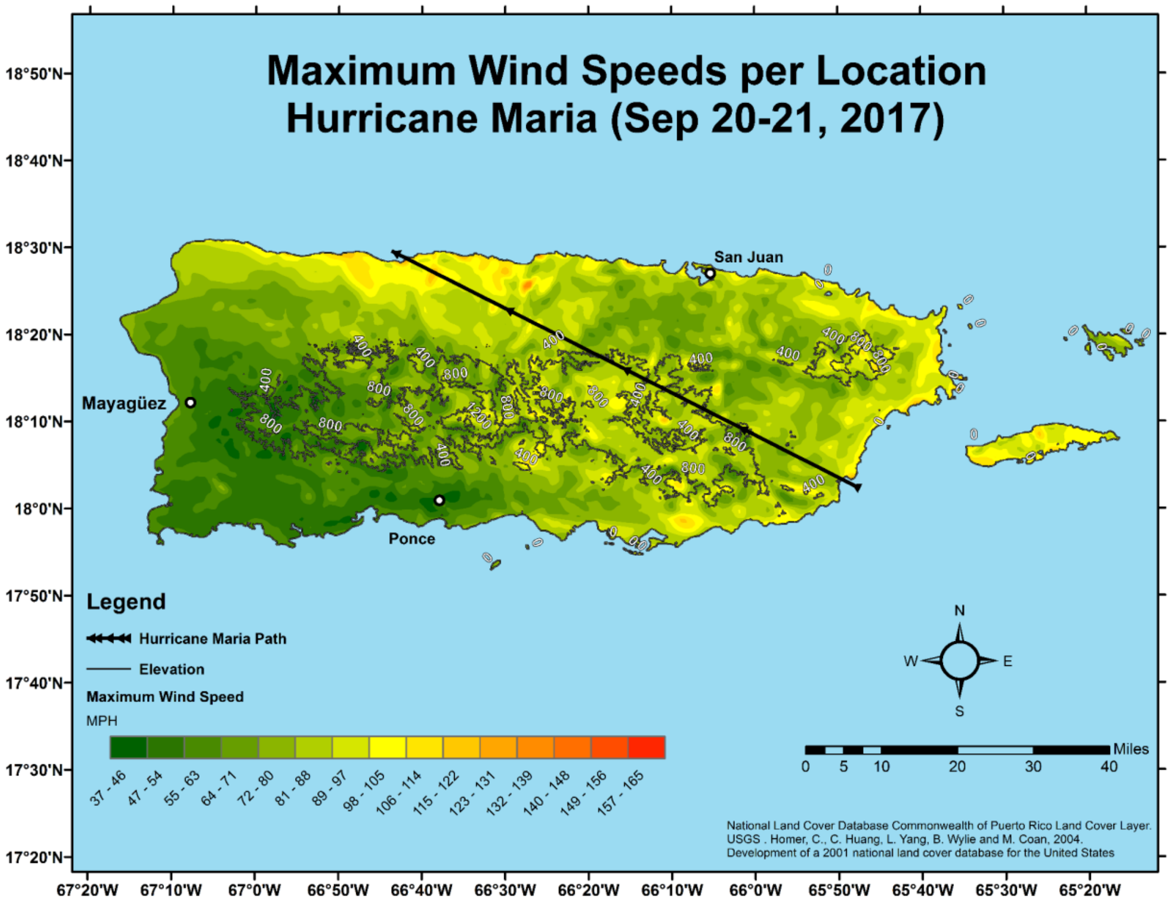
- The power infrastructure distribution as well as the urban land class in each grid cell will be an important predictor in our models.

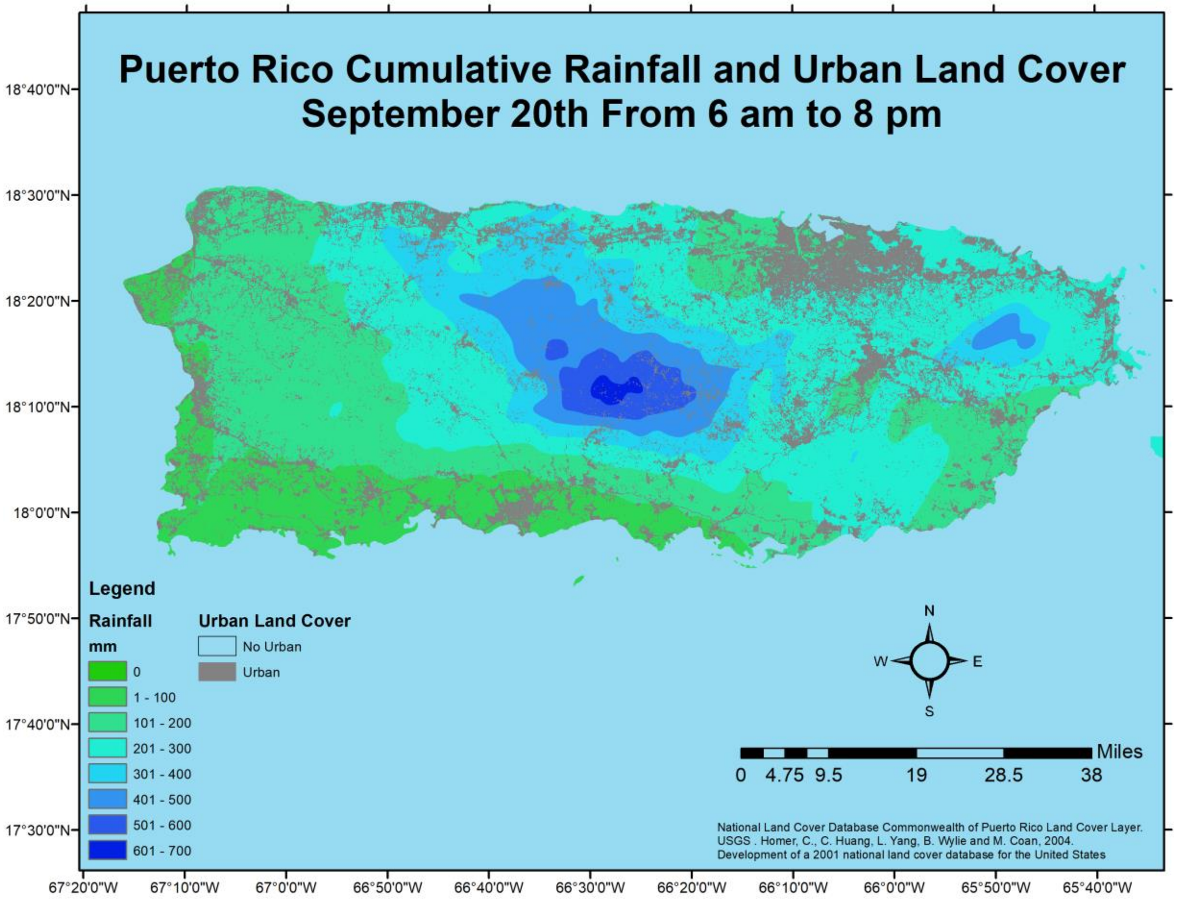




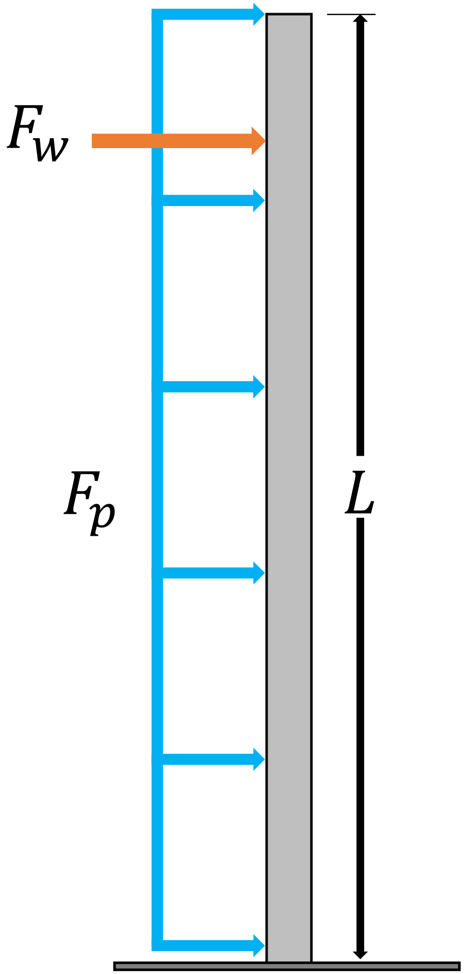
Input: Weather Variables

- The Weather Research and Forecasting Model (WRF) was devised to simulate the storm event used in our study.





Distribution Lines Impact Modeling

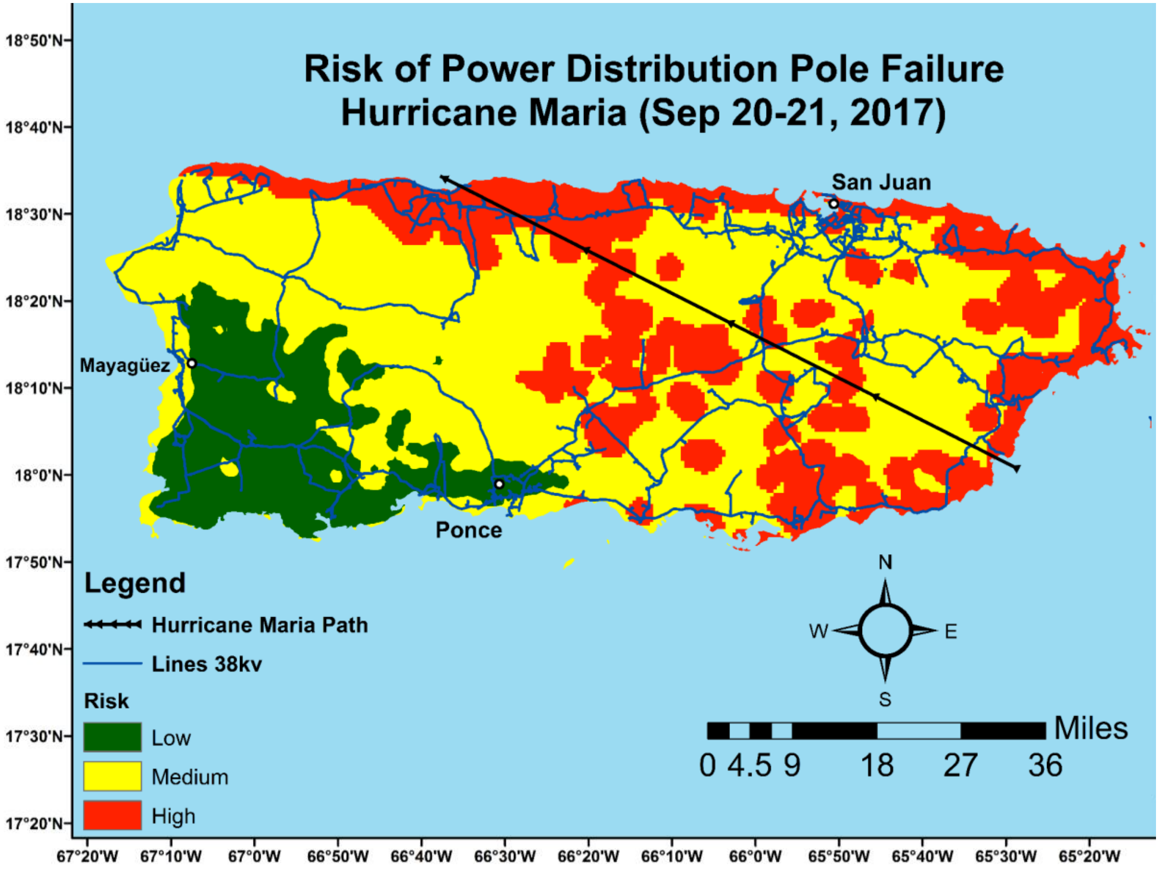


For this first approach we find the risk of a wood pole to fail due to extreme weather conditions and scale it to the whole island. The failure in the pole was given by the maximum Bending Moment:

$$\mathrm{M_{Max}} = \mathrm{M_P} + \sum (M_W * WS)$$

Where,
$\mathrm{M_P}$ = BM due to wind in the pole.
M_W = BM due to wind in the conductors.
WS = Length of the conductors

Distribution Lines Impact Modeling



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BART: Bayesian Additive Regression Trees

Is a Bayesian approach to nonparametric function estimation using regression trees.

Consist of two parts:

- Sum of trees model.
- Regularization prior on the parameters of tree model.

$$Y = \sum_{j=1}^{m} g\left(X_i; T_j, M_j\right)$$

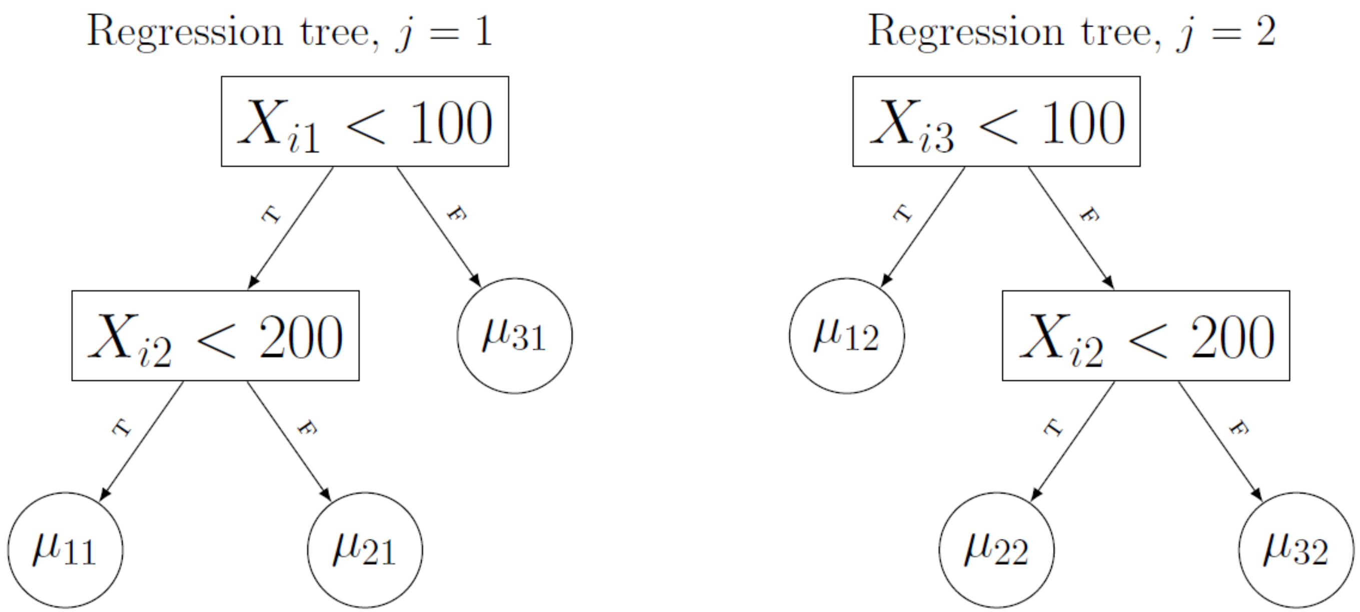
1. Chipmman HA, George EI, McColluch RE. BART: Bayesian Additive Regression Trees, arXive: 0806.3286v1. Available at: http:// arxiv.org/ abs/0806.3286, Accessed in June 2008.

Sum of Trees Model

$$Y = \sum_{j=1}^{m} g(X_i; T_j, M_j)$$

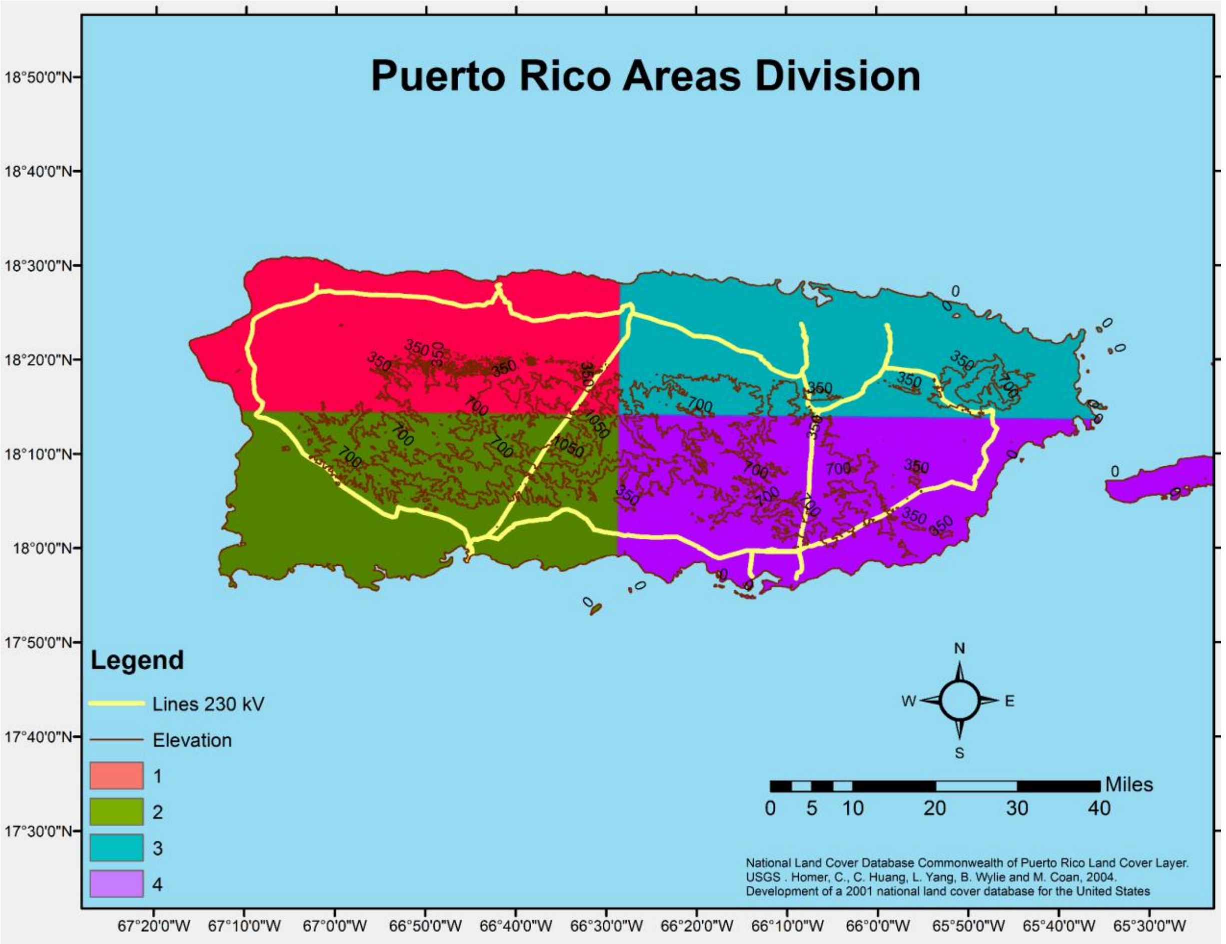
Where,

- Y: Response variable (i.e. Power Outages).
- X_i: Explanatory variables (e.g. Weather Variables).
- T_j: Contains the information of the splitting value and the nodes location.
- $M_j = \{\mu_{1j}, \ldots, \mu_{b_j j}\}$



1. Tan, Yaoyuan Vincent, and Jason Roy. "Bayesian additive regression trees and the General BART model." *arXiv preprint arXiv:1901.07504* (2019).

BART Preliminary Results

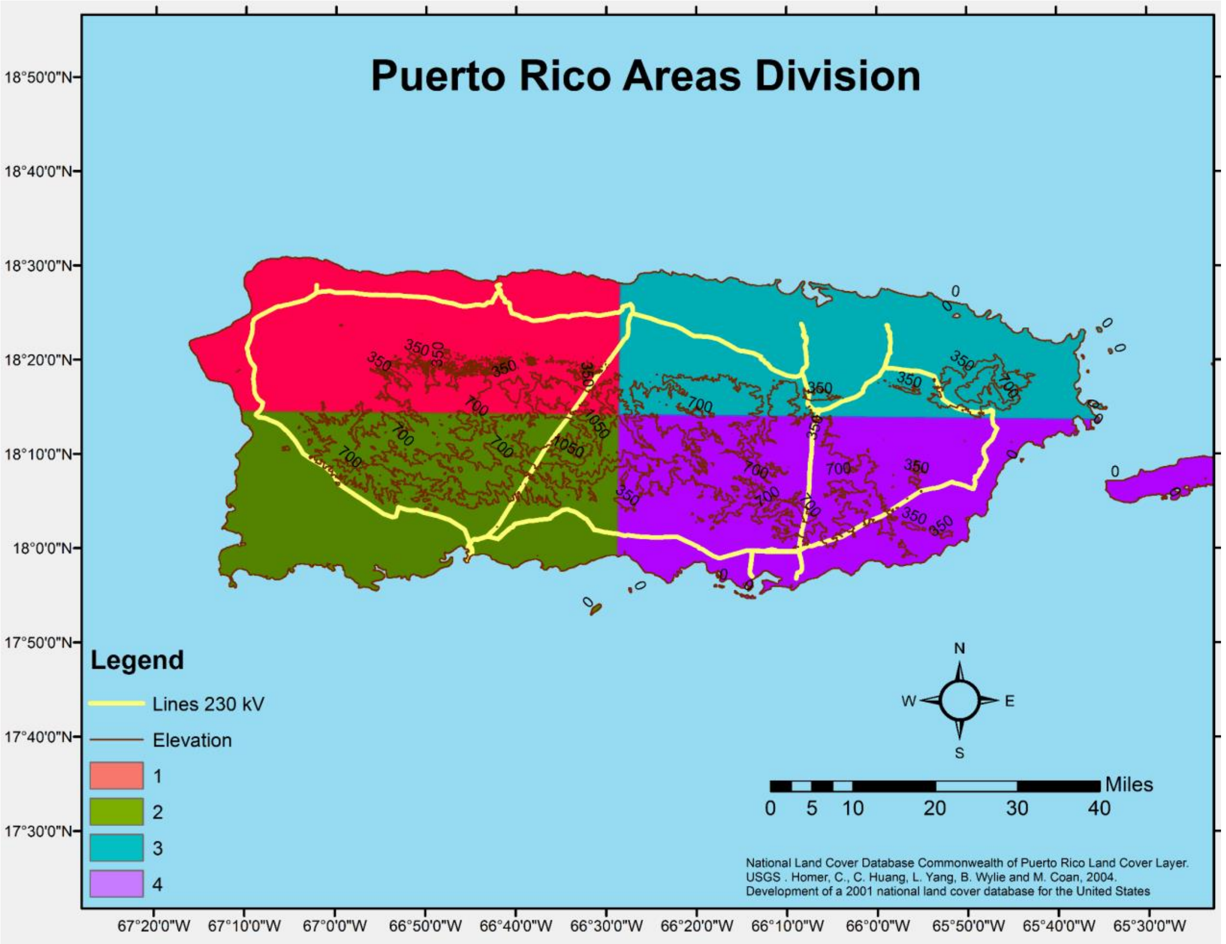


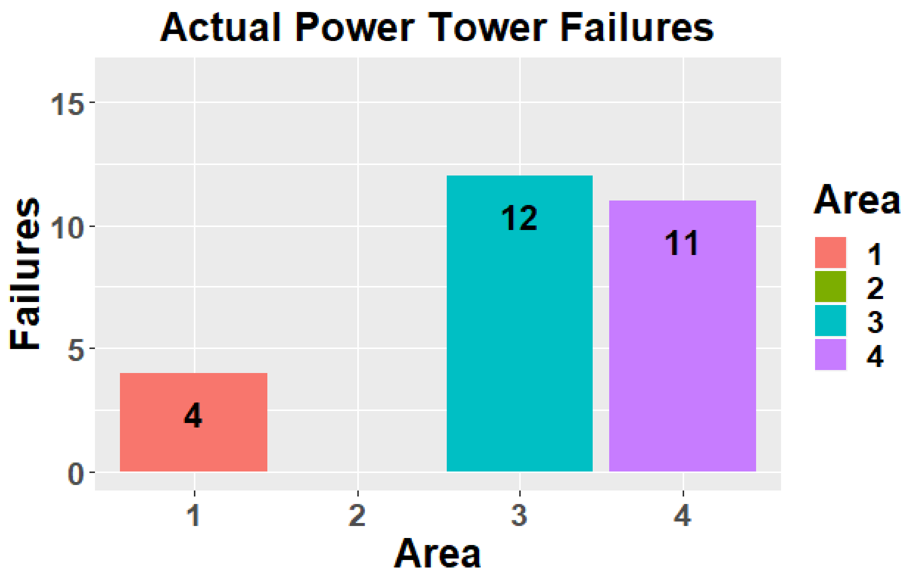
Explanatory Variables:
- Wind Speed.
- Elevation.

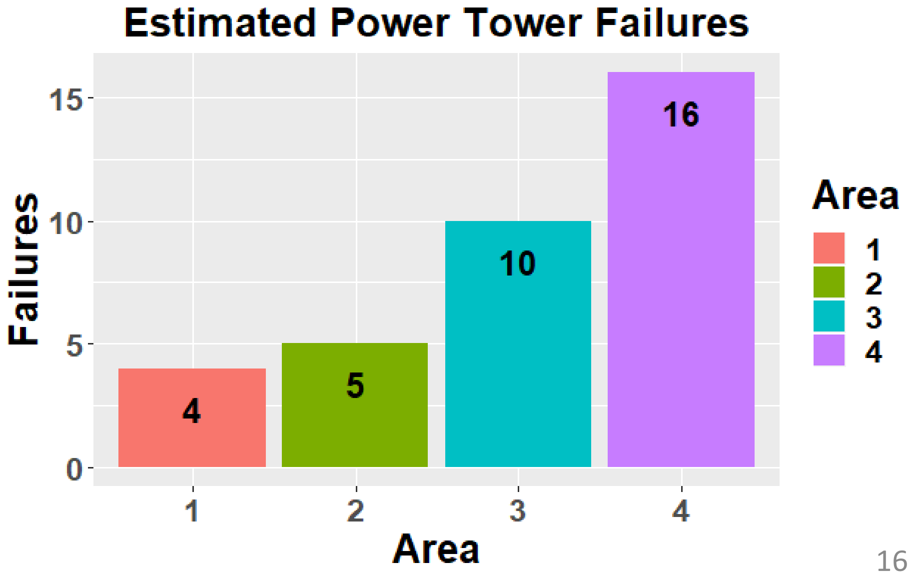
Response Variable:
- Google Earth data: 1270 power towers.

Zero – Inflation
- Under-Sampling

BART Preliminary Results

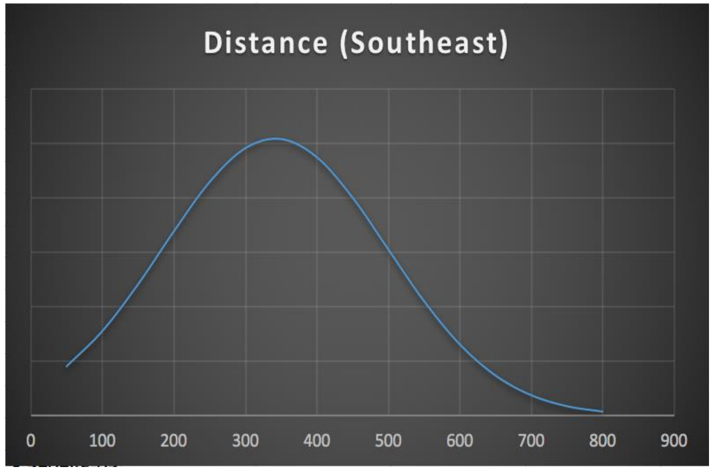






Next Steps: Wind Tunnel Experiment

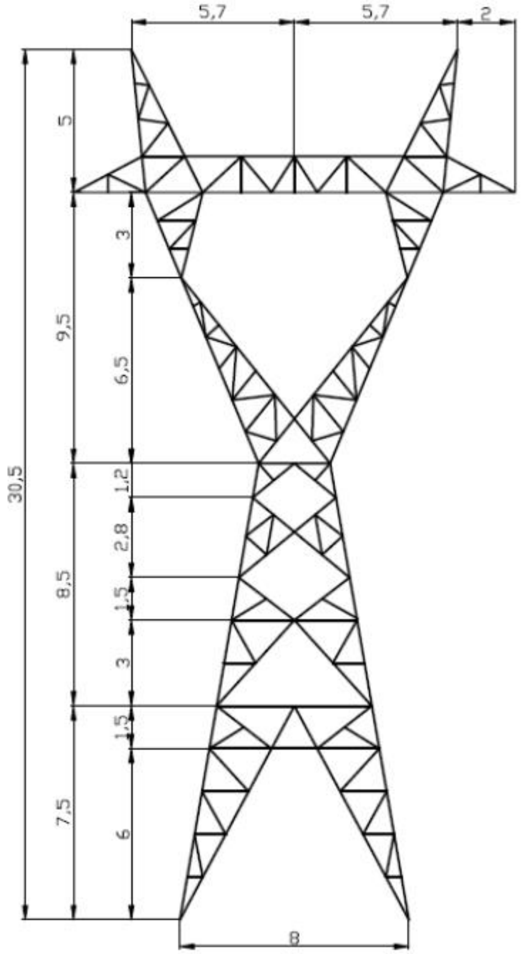
Source of data for the High-Voltage Transmission Lines Impact Modeling



Mean	341.71
Standard Dev	156.85
Max	766.59
Min	63.75

Meters

Horizontal Conf	82
Vertical Conf	18



Selected Tower Characteristics:

- Horizontal configuration Tower.
- 230 kV Voltage line
- Auto-supported.
- Wind span = 341m

Next Steps: Wind Tunnel Experiment

CAD model for 3D Printing

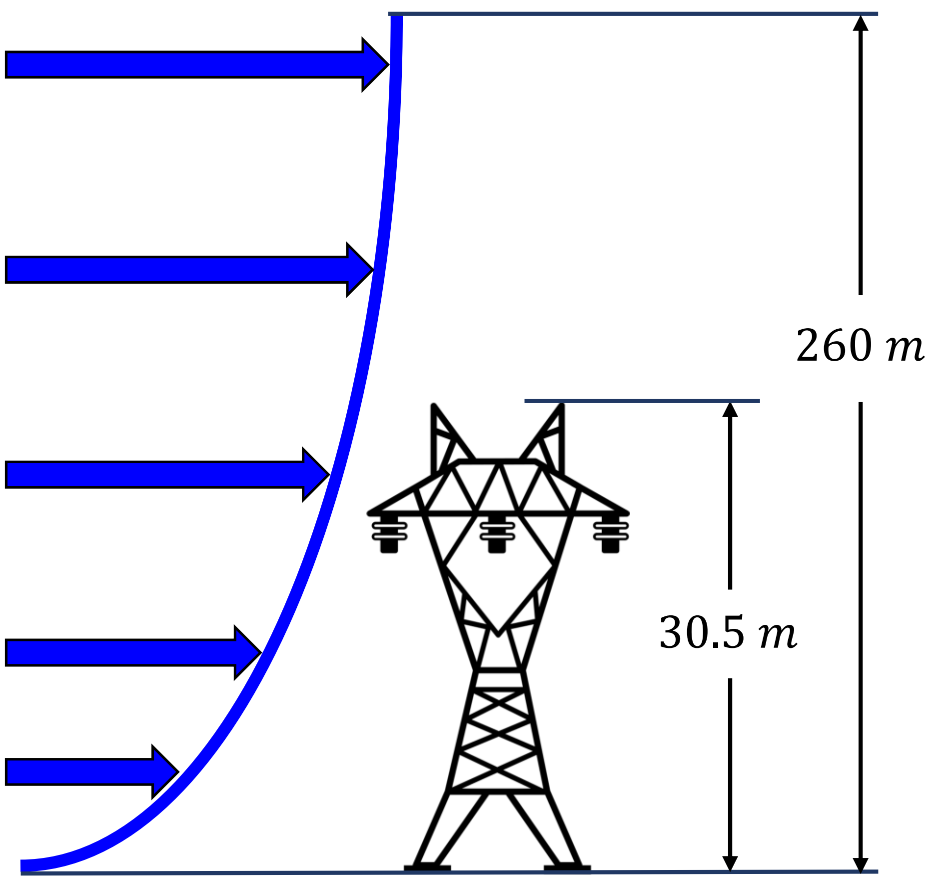
Geometric Scaling :

- H-Maria Boundary layer = 260 m
- Wind tunnel Boundary layer = 0.975 m
- Scaling Factor = 269.7
- Prototype tower height = 0.113 m

Expected Outcomes:

- **Drag coefficient** for different configurations of a power tower.
- **Maximum stress** in the base of the tower (Bending Moment) due to extreme wind speeds.
- **Maximum wind speed** a power tower can withstand in different configurations.

Next Steps: Transmission Lines Impact Modeling



When a high-voltage transmission line is damaged, it can generate a power outage in a large area. In general, these are very expensive and difficult to repair. Therefore, they take a long time to be repaired

Next Steps

- Use over-sampling to decrease the effect of the zero-inflation in the data.
- Incorporate new explanatory variables to the BART model.
- Incorporate transmission lines impact model as training cases for the BART model.
- Gather data from Hurricane Irene and Georges to use as rich training cases for the BART model.
- ***Expected outcome:*** **Power Outages Forecast model**, that uses weather forecast data as an input.

Deadlines

	Nov 2019	Dec 2019	Spring 2020	Summer 2020	Fall 2020
Transmission Lines Impact Model.	X				
Wind Tunnel Experiment.		X			
Incorporate transmission lines impact model with BART model.		X			
Train BART model with actual PREPA data.			X		
Expand BART model with different hurricanes events.				X	
Expand BART model to more transmission lines.					X

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Thank You!

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