

April 1, 2026

NOAA Mission Goal:
A Weather-Ready Nation

Developing an AI Forecast Model for Power Outage Prediction

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National Hurricane Center





No communication!

No AC!

Dangerous!

Is it possible to predict the location/severity of power outages prior to a TC landfall?

Metric

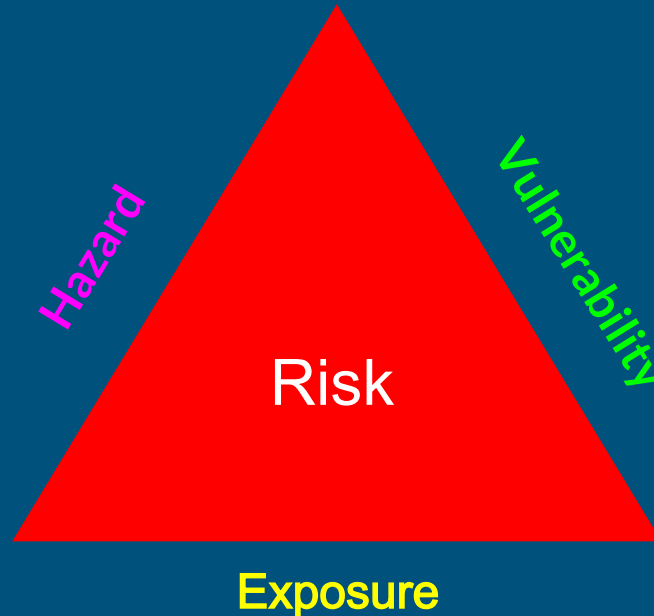
% of customers who lose power in the 120 hours following a forecast time, county level

Source

EAGLE-I Outage Data, compiled from real-time outages



HEV Framework (IPCC)



Physical Risk of Actual
Danger
(Meteorological Metrics)

- Wind Speed
- Rainfall
- Storm Surge

Susceptibility to
Damage

- Mobile Homes
- Poverty

Who/What is at Risk

- Population
- Tree Cover

$$\begin{array}{r} \text{Hazard} \\ \times \text{ Exposure} \\ \times \text{ Vulnerability} \\ \hline \text{Risk} \end{array}$$

Input Variables

Hazard

34-knot Wind Probabilities
 50-knot Wind Probabilities
 64-knot Wind Probabilities
 100-knot Wind Probabilities
 Duration of Winds
 Arrival Time of Winds
 Storm Surge
 Extreme Rainfall Risk
 Severe Weather Risk

Exposure

Population
 Population Density
 Number of Businesses
 Total Length of Roads
 Total Length of Transmission Lines
 Dominant Land Cover Type
 Median Tree Canopy Cover
 Average Tree Canopy Height

Vulnerability

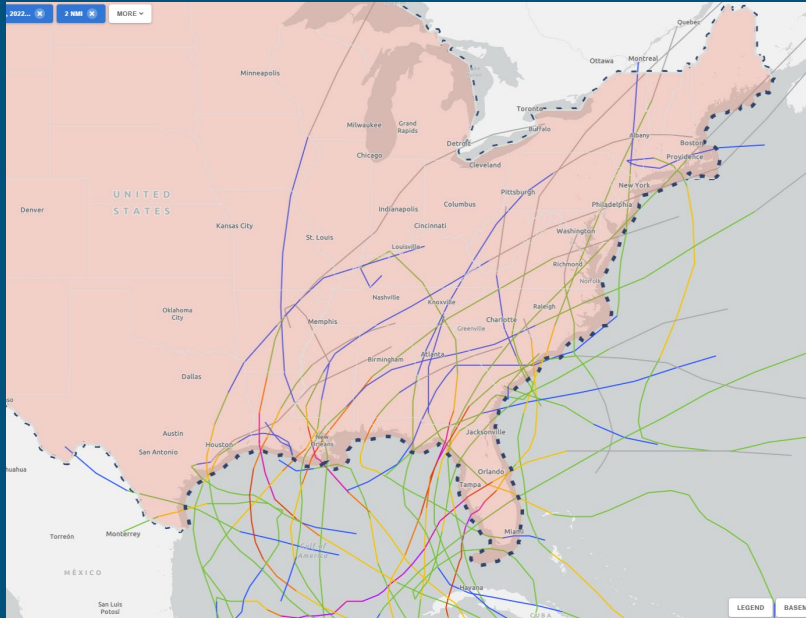
Overall Vulnerability		Y
Overall Vulnerability	Socioeconomic Status	Below 150% Poverty Unemployed Housing Cost Burden No High School Diploma No Health Insurance Aged 65 & Older
	Household Characteristics	Aged 17 & Younger Civilian with a Disability Single-Parent Households English Language Proficiency
	Racial & Ethnic Minority Status	Hispanic or Latino (of any race) Black or African American, Not Hispanic or Latino Asian, Not Hispanic or Latino American Indian or Alaska Native, Not Hispanic or Latino Native Hawaiian or Pacific Islander, Not Hispanic or Latino Two or More Races, Not Hispanic or Latino Other Races, Not Hispanic or Latino
	Housing Type & Transportation	Multi-Unit Structures Mobile Homes Crowding No Vehicle Group Quarters

Household Age
 Median Household Income
 GDP
 Rural/Urban Characteristics



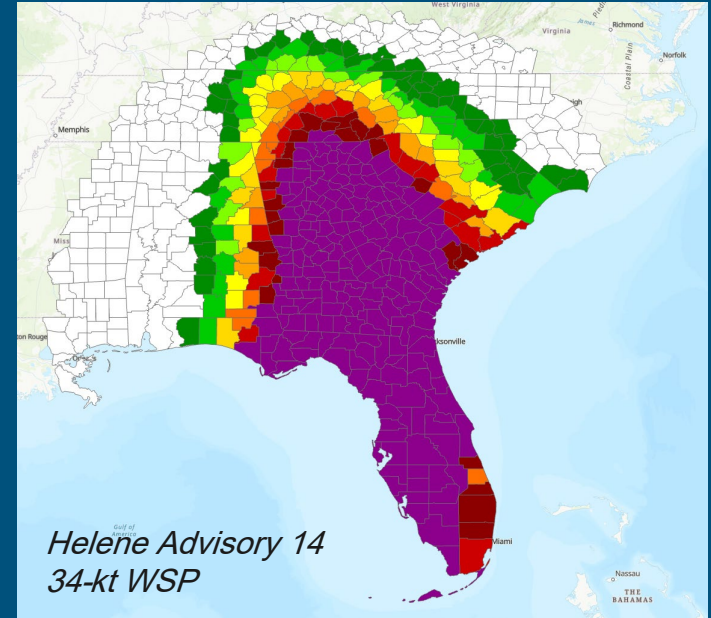
Compiling Training Data

Source



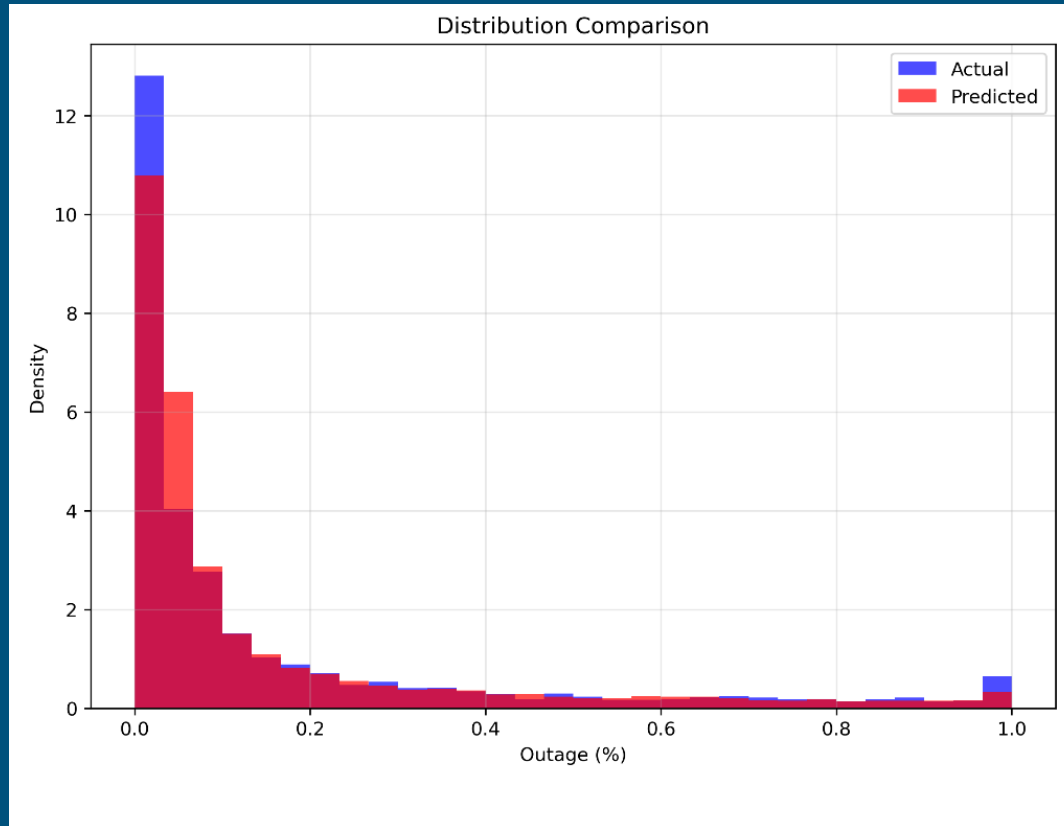
36 tropical cyclones landfalling in the contiguous US 2020-2024.

Method



Gathered hazard data for each forecast advisory by county.

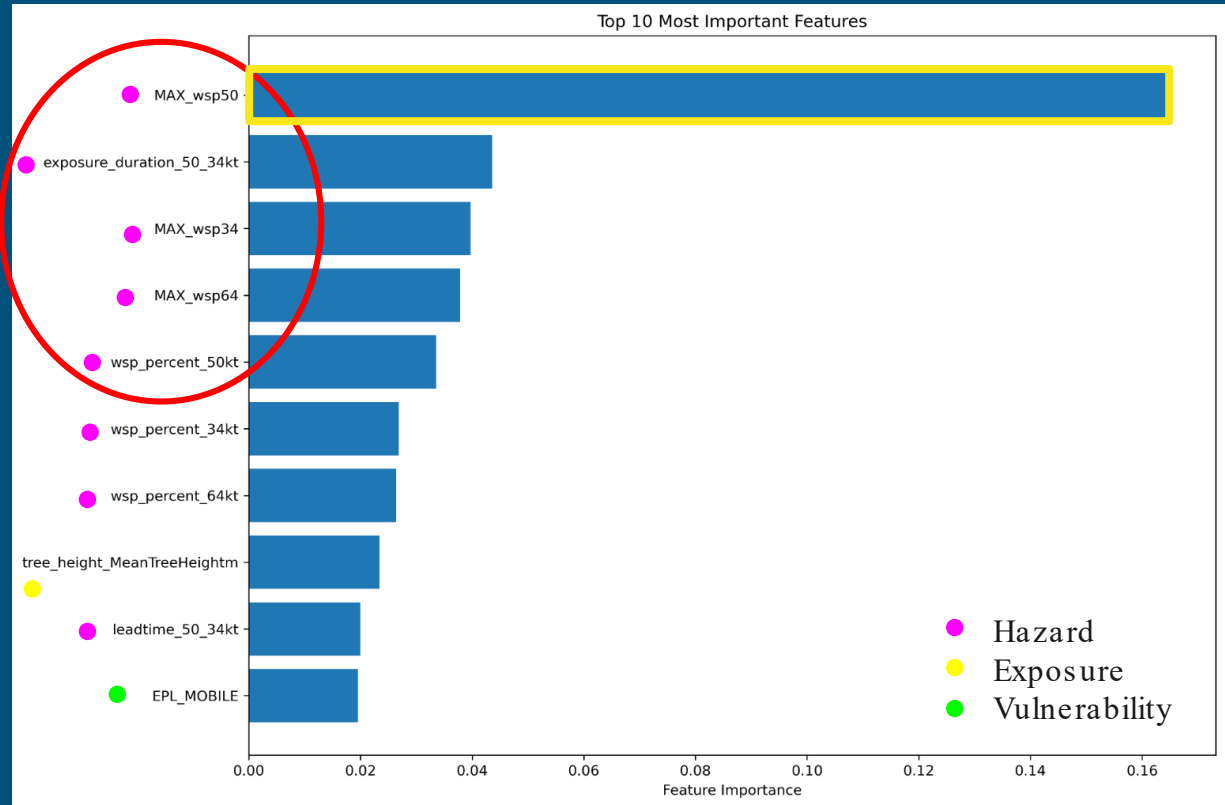
“All Storms” Model Results



$R^2: 0.739$

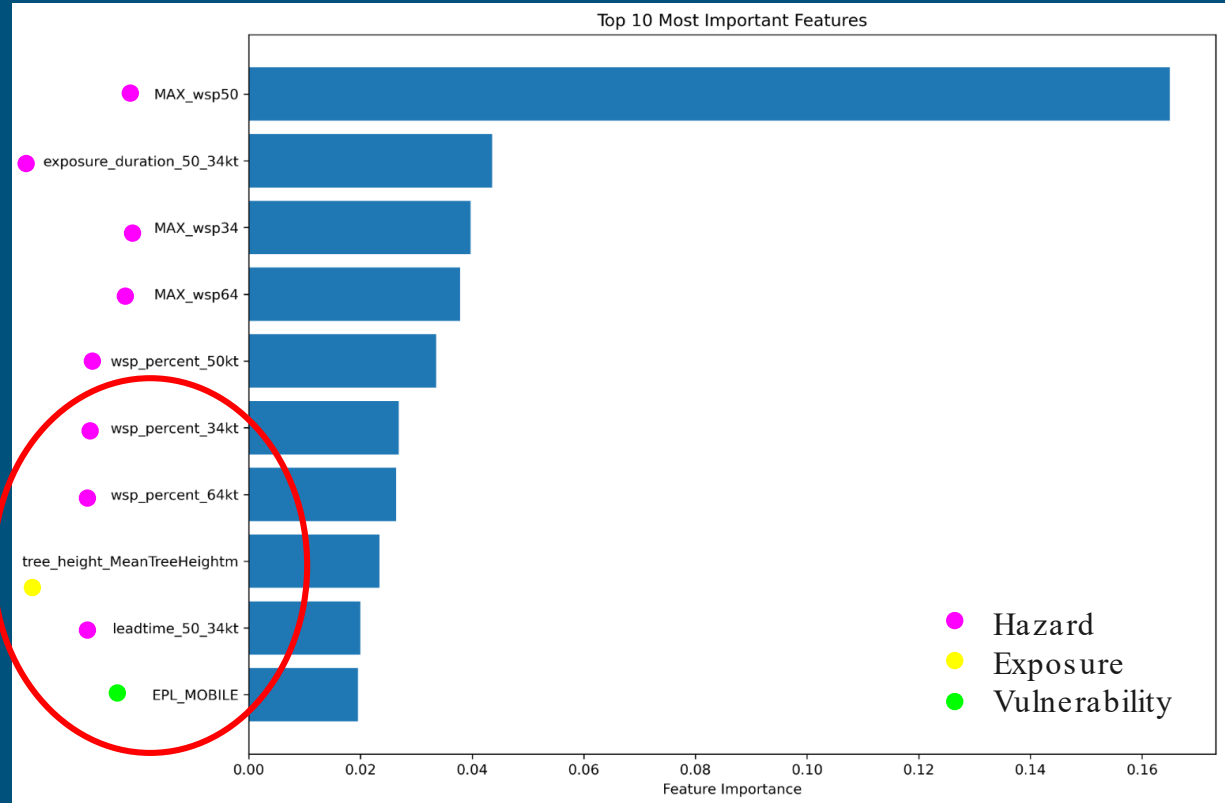
“All Storms” Model Results

1. 50-knot Wind Probabilities (point)
2. Duration of 34-knot Winds
3. 34-knot Wind Probabilities (point)
4. 64-knot Wind Probabilities (point)
5. 50-knot Wind Probabilities (areal)



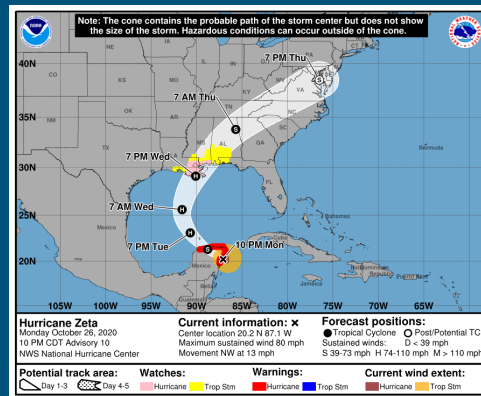
“All Storms” Model Results

- 6. 34-knot Wind Speed Probabilities (areal)
- 7. 64-knot Wind Speed Probabilities (areal)
- 8. Mean Tree Height
- 9. Hours Before Arrival of 34-Knot Winds
- 10. % Mobile Home Residents

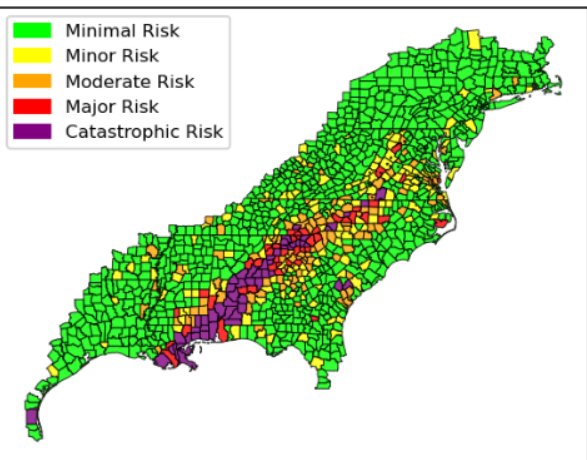


Zeta

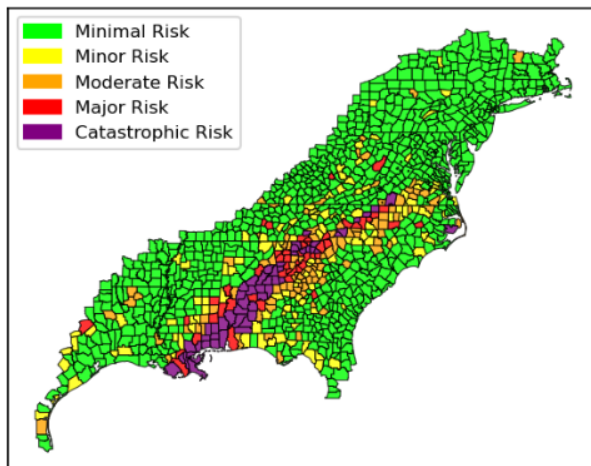
Extremely accurate predictions near landfall



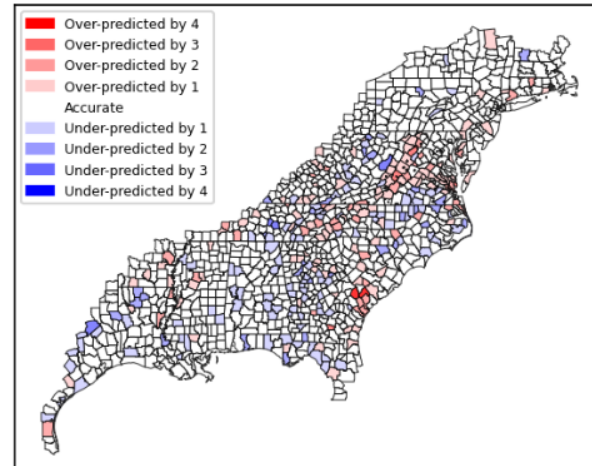
Predicted Power Outages
AL282020 Advisory 10



Actual Power Outages
AL282020 Advisory 10

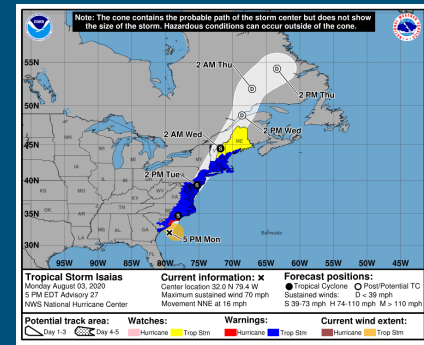


Categorical Prediction Accuracy
AL282020 Advisory 10

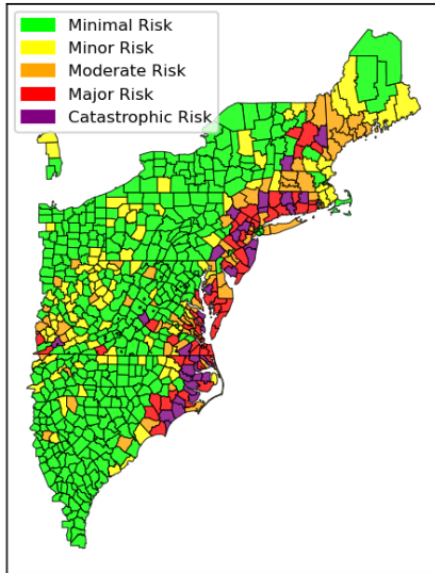


Isaias

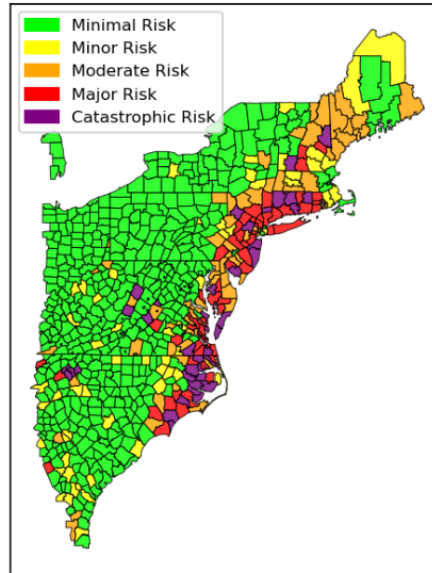
Predictions accurate even in New England



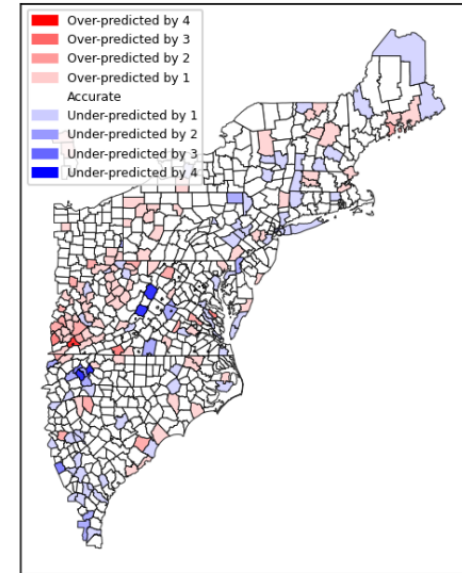
Predicted Power Outages
AL092020 Advisory 27



Actual Power Outages
AL092020 Advisory 27

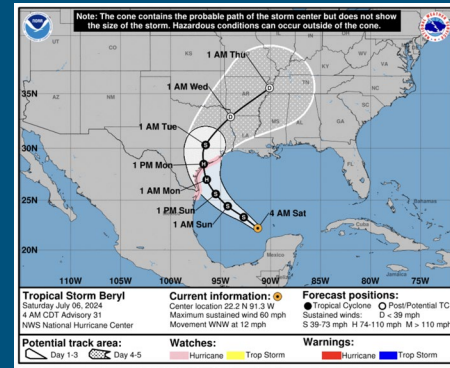


Categorical Prediction Accuracy
AL092020 Advisory 27

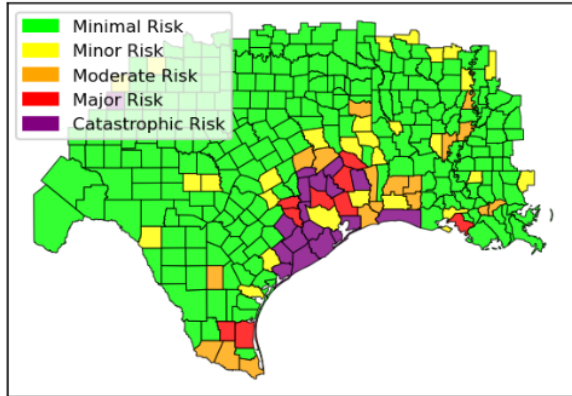


Beryl

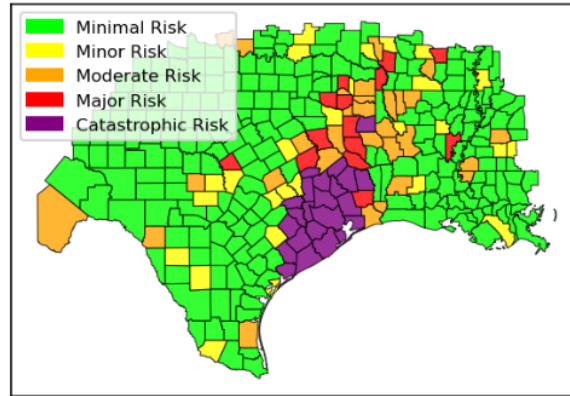
Accurate predictions in Texas



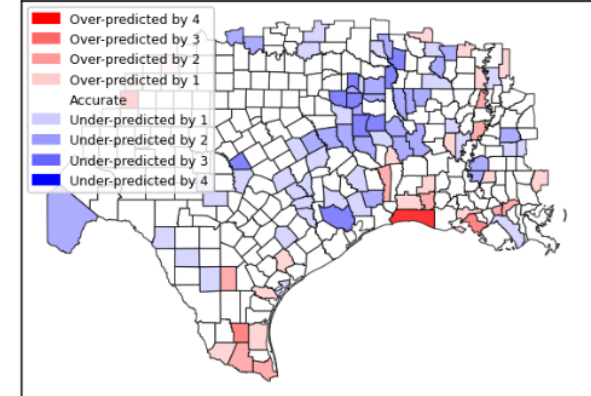
**Predicted Power Outages
AL022024 Advisory 31**



**Actual Power Outages
AL022024 Advisory 31**

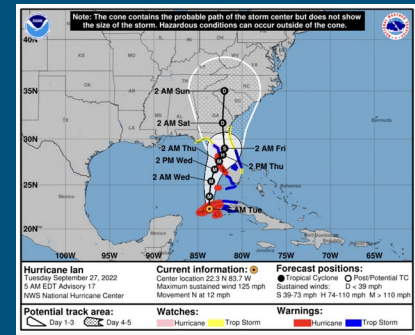


**Categorical Prediction Accuracy
AL022024 Advisory 31**

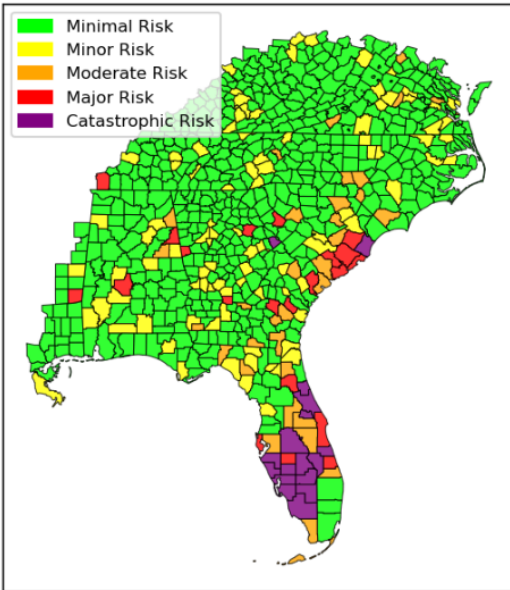


Ian

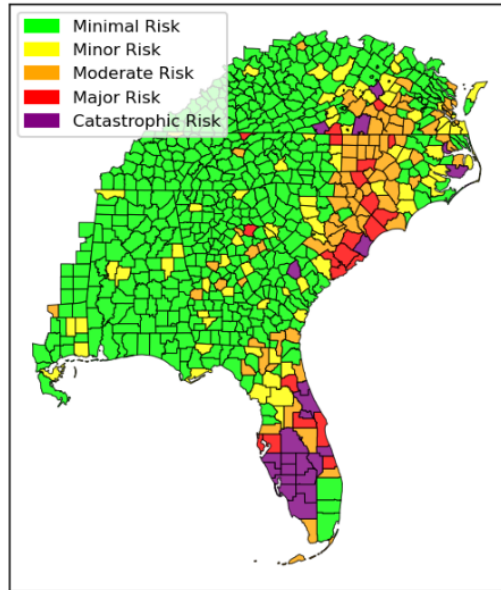
Excels at first landfall, misses inland extent of second



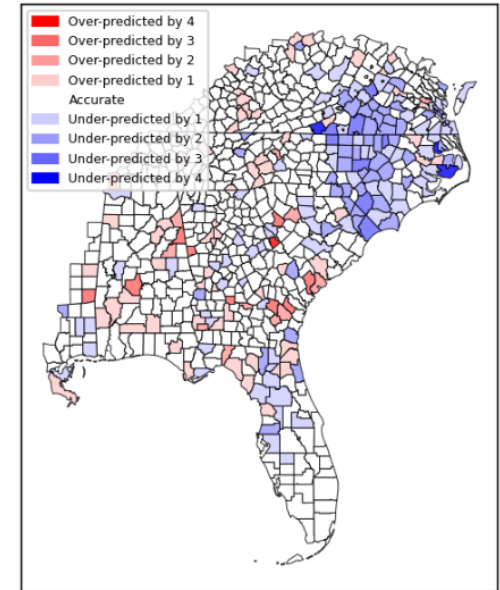
**Predicted Power Outages
AL092022 Advisory 17**



**Actual Power Outages
AL092022 Advisory 17**

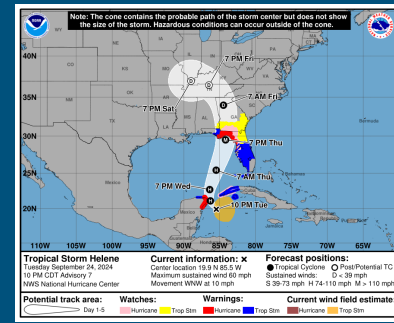


**Categorical Prediction Accuracy
AL092022 Advisory 17**

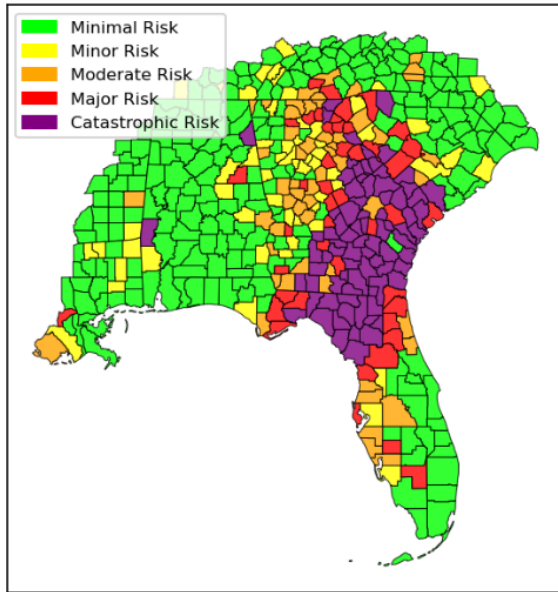


Helene

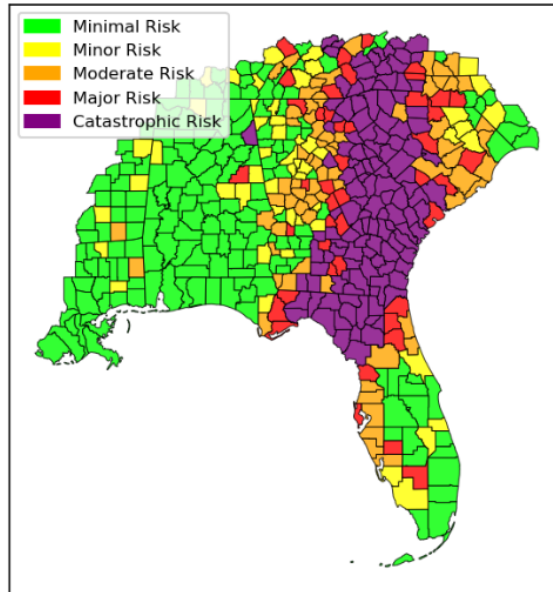
Excels in FL/GA, severe under-prediction in NC



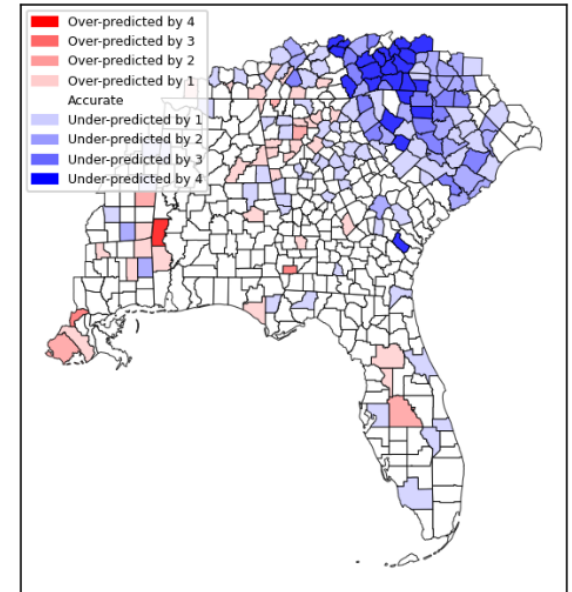
Predicted Power Outages
AL092024 Advisory 7



Actual Power Outages
AL092024 Advisory 7



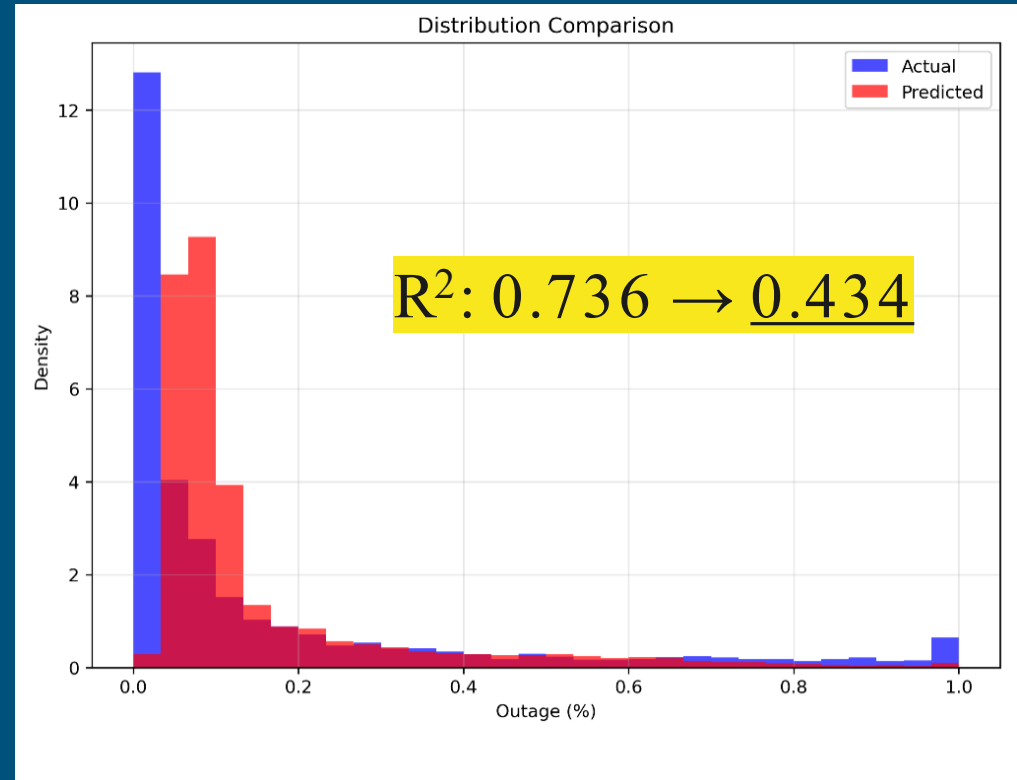
Categorical Prediction Accuracy
AL092024 Advisory 7



“Only Hazards” Model

Exposure and vulnerability variables removed: only hazard variables included

Exposure and vulnerability variables are critical to accurately assess location and severity of power outages.





“Only Major/Catastrophic” Power Outages

- PROBLEM: Training data largely “zero-inflated”: many inputs of 0% outage
 - Difficult for model to accurately predict cases of severe outages
- SOLUTION: Ran model only including training data with a 30%+ outage
 - Will the model be able to predict the severity of major outages with accuracy?

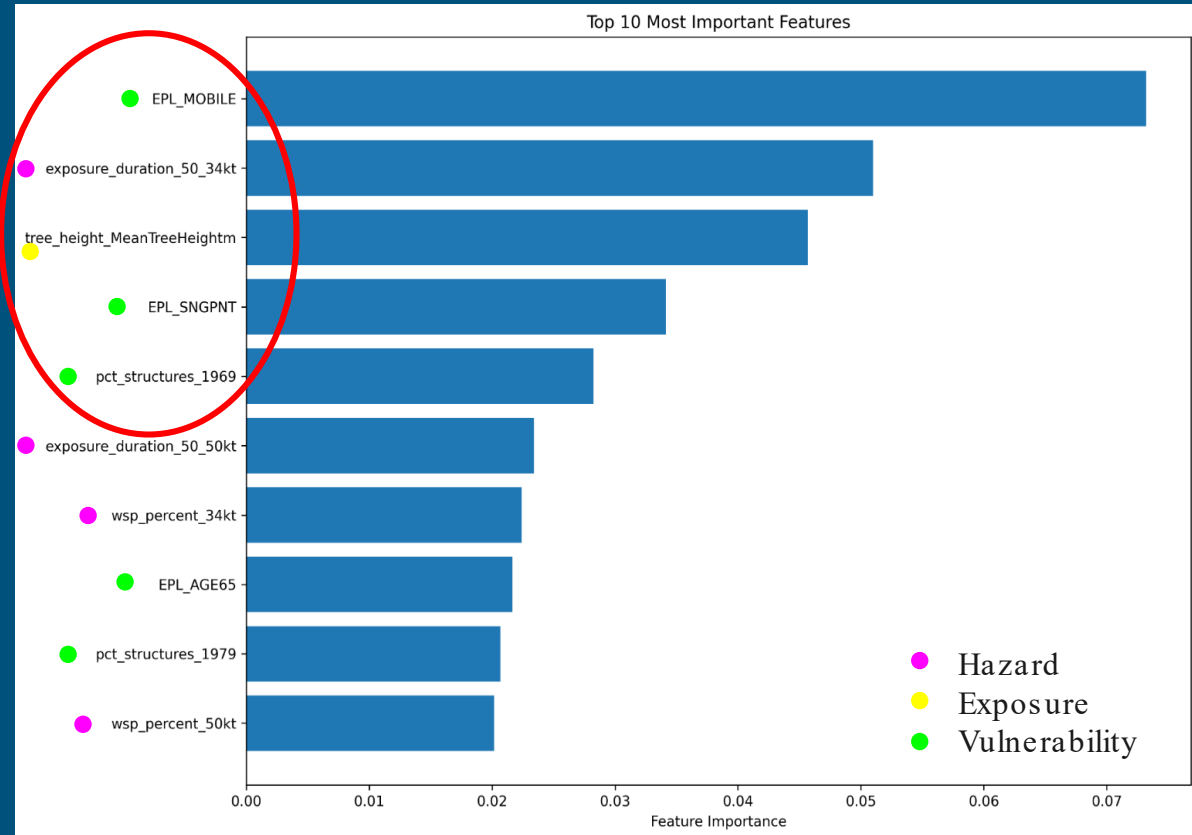
Yes!

$R^2: 0.879$

- PITFALL: This model is not applicable to any outage under 30%

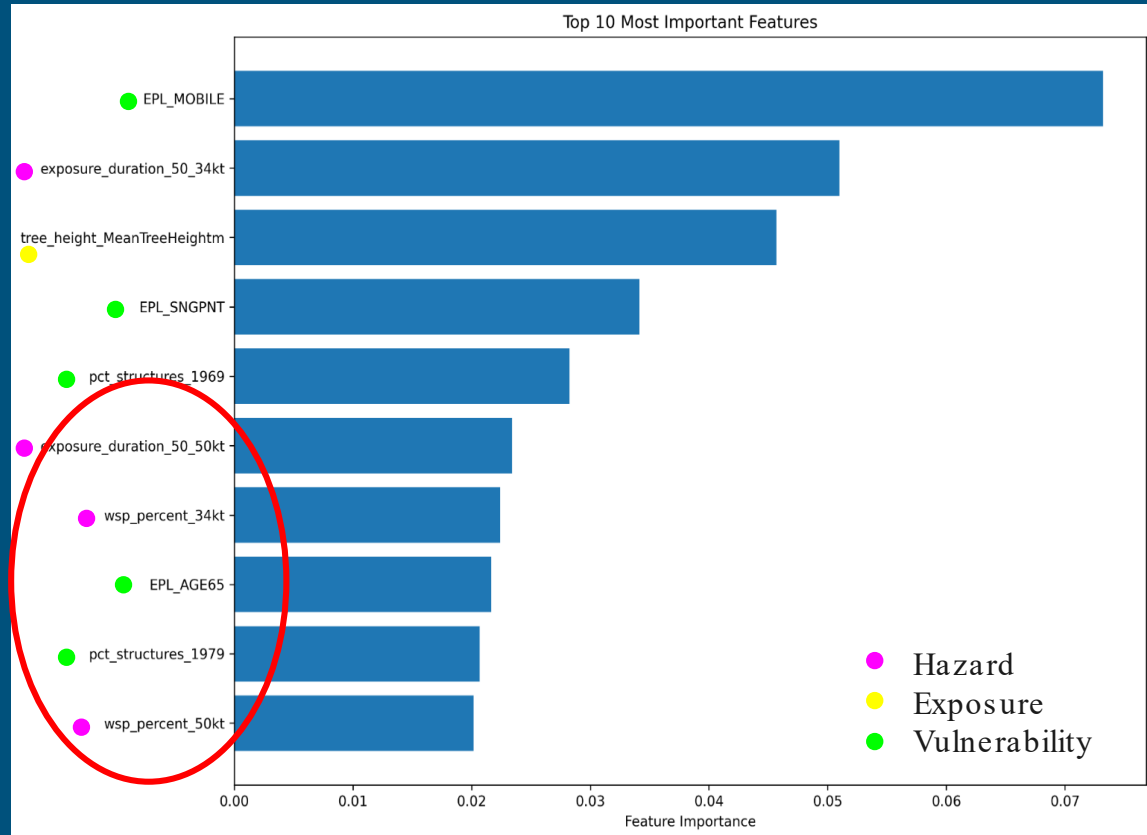
“Only Major/Catastrophic” Power Outages

1. % Mobile Home Residents
2. Duration of 34-knot Winds
3. Mean Tree Height
4. % Homes with Child and Single Parent
5. % Households Built Between 1960-1969

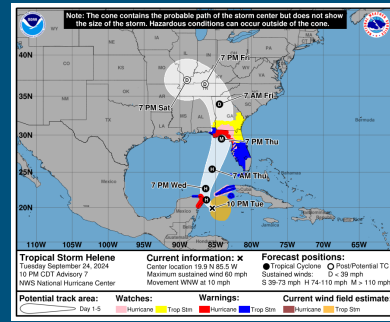


“Only Major/Catastrophic” Power Outages

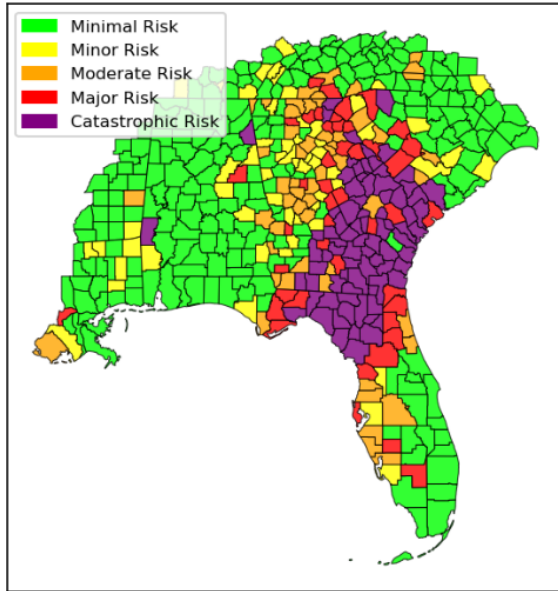
6. Duration of 50-knot Winds
7. 34-knot Wind Probabilities
8. %Elderly Population (65+)
9. %Households Built Between 1970-1979
10. 50-knot Wind Probabilities



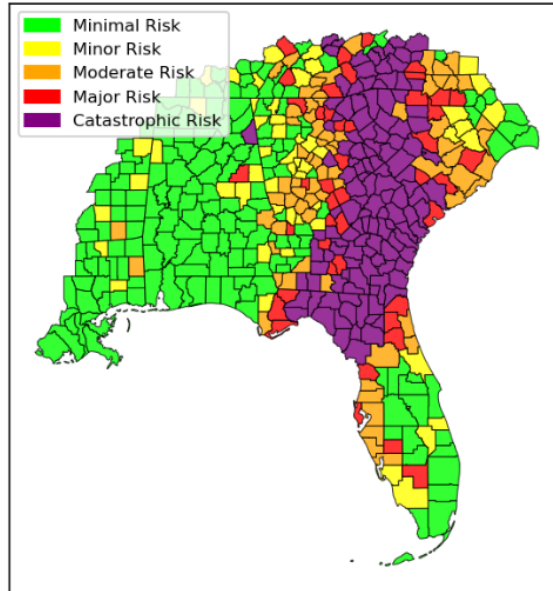
Helene



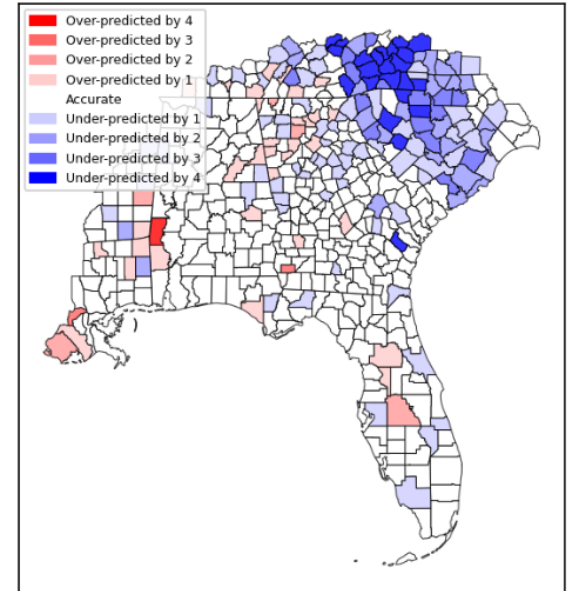
Predicted Power Outages
AL092024 Advisory 7



Actual Power Outages
AL092024 Advisory 7



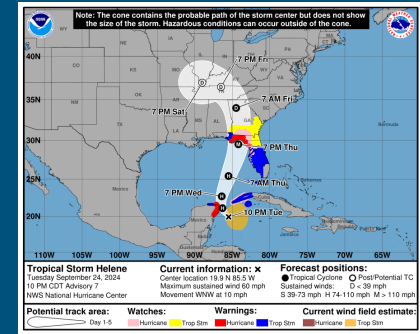
Categorical Prediction Accuracy
AL092024 Advisory 7



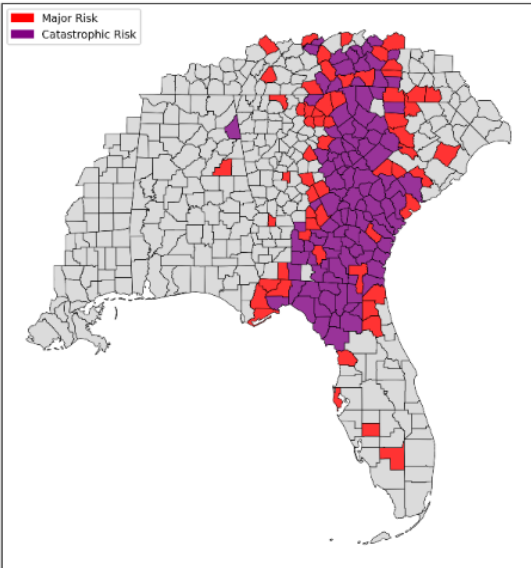


Helene (Severe Outage Model)

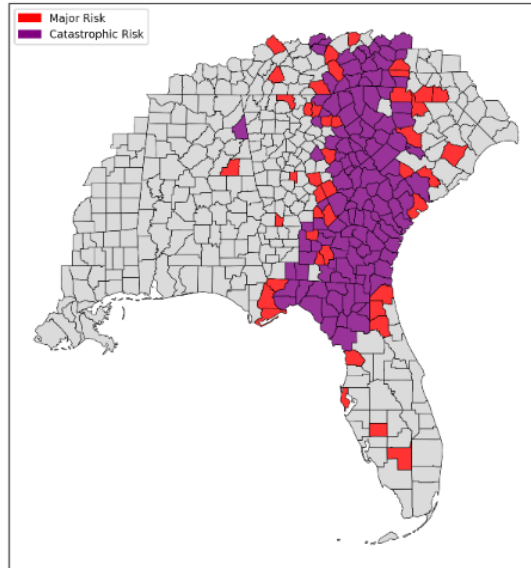
Improved predictions in NC/SC



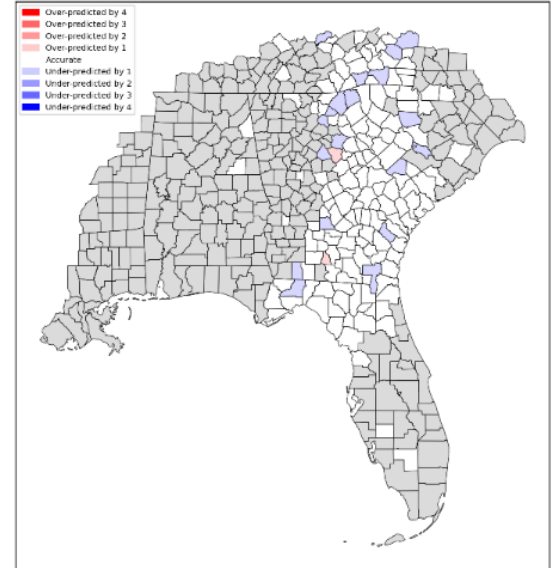
Predicted Power Outages AL092024 Advisory 7



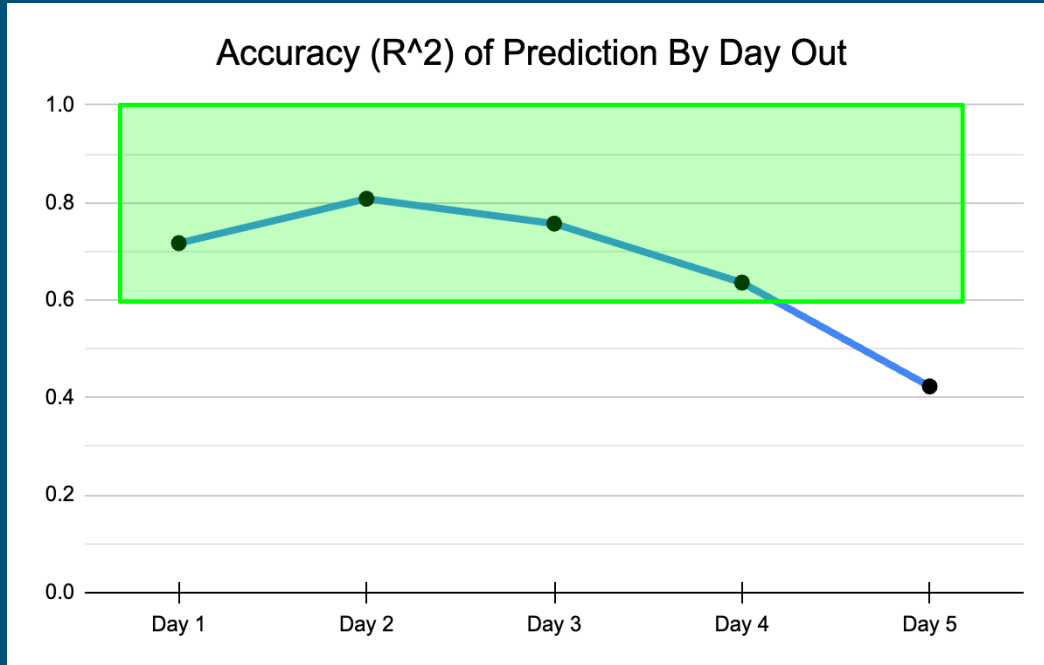
Actual Power Outages AL092024 Advisory 7



Categorical Prediction Accuracy AL092024 Advisory 7

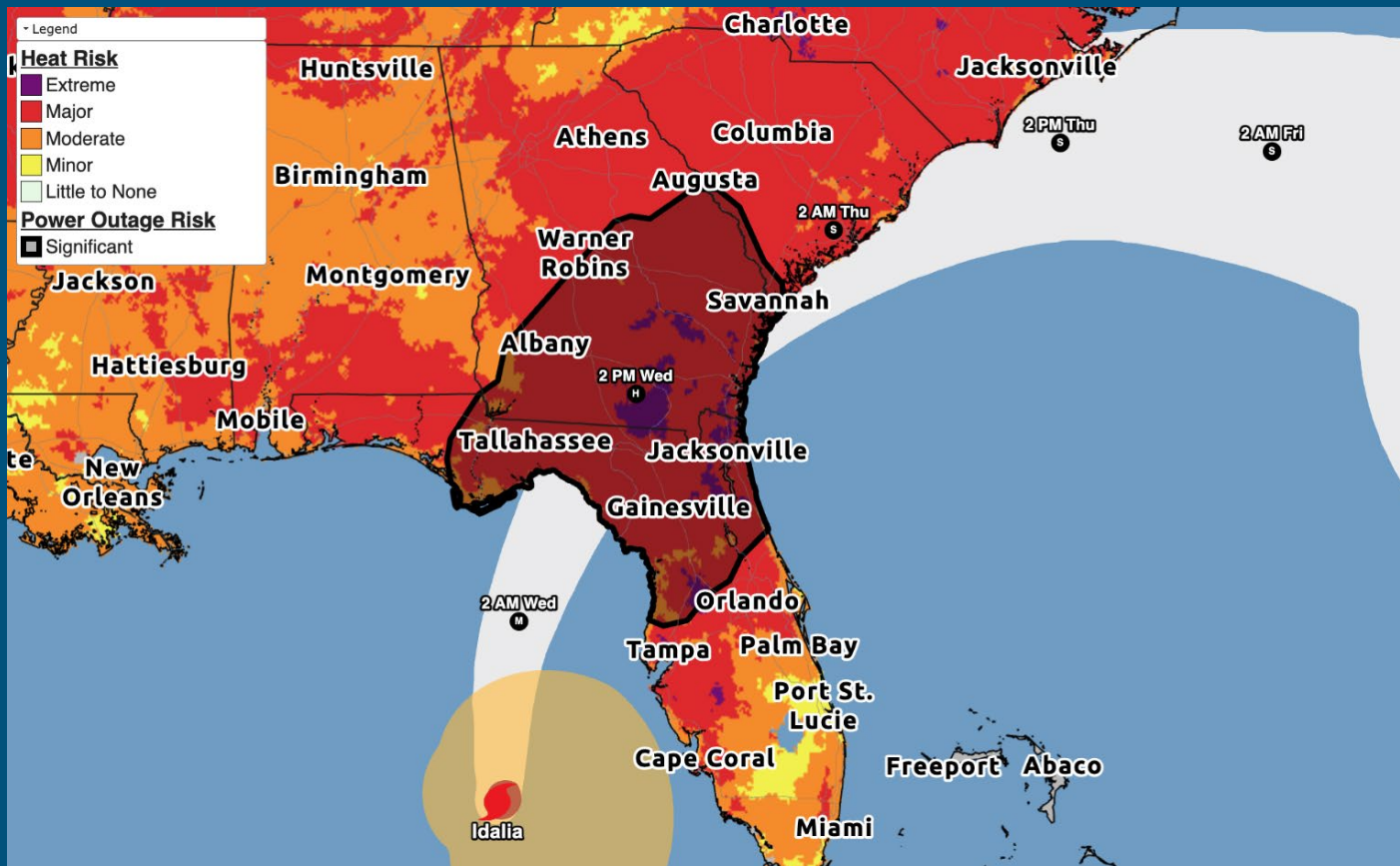


Time Accuracy of Product



- Accuracy between the predicted & actual values by days before landfall
- Model maintains accuracy through Day 4!

Communication: Heat Risk and Power Outages



A Framework for the Future

- Model can be tailored to add new input/output variables
 - Inputs: Elevation, Tree Species, Soil Moisture, Power Infrastructure Data
 - Outputs: Duration of Outages, Damage
 - New Storm Data
- Accuracy and feature importance for different geographic regions of US
- A real-time internal tool at NHC
- Apply this model to US territories (Puerto Rico, Virgin Islands, etc.) and Caribbean nations





Takeaways

- Damaging winds best determine power outage severity
 - Pay attention to when the NHC communicates this metric!
- Exposure/vulnerability metrics are critical to accurately assess risk
- Exposure/vulnerability metrics determine if a major outage will be catastrophic
- Know your local population and area!
- This product paves the way towards impact-based probabilistic forecasting for IDSS

Acknowledgements

Joshua Alland

Associate Scientist at the National Hurricane Center

Jamie Rhome

Deputy Director of the National Hurricane Center

Wallace Hogsett

Science & Operations Officer at the National Hurricane Center

National Hurricane Center Staff

NOAA Ernest F. Hollings Scholarship
Program

