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Estimating the Spatial Distribution of Power Outages during Hurricanes for Risk Management

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EPRI GIS Interest Group

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Project Summary

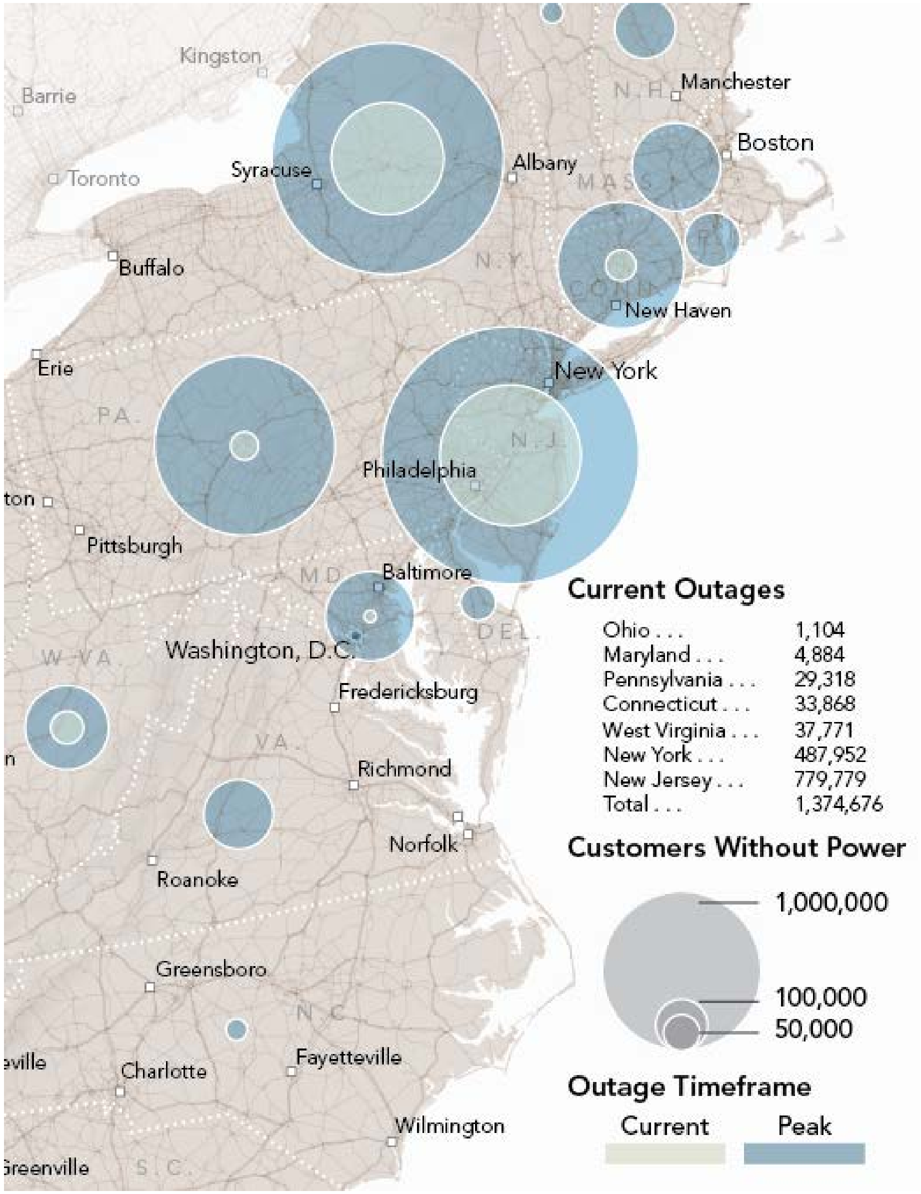
- Build a model to estimate the spatial distribution of power outages using GIS and statistical analysis techniques
- Use comprehensive and transparent methods – Clear understanding of all variables
- Fill gaps in previous research
- Focus on US Northeast / Tri-State area

Northeast US Major Storms

- Frequency of storms causing major outages is increasing.
  - **Isabel** 2003 (4.3 million customers)
  - **Irene** 2011 (5 million customers)
  - **Sandy** 2012 (8 million customers)
  - Nor'easter of Feb 2013 (650,000 customers)

Goals

- Inform response planning
- Reduce outage durations
- Assess grid resilience and plan mitigation measures



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What's Been Done?

IBM Deep Thunder

A Statistical Model for Risk Management of Electric Outage Forecasts

- Typical weather forecasts are based on continental-scale weather models with a spatial resolution on the order of 10 km and temporal resolution of 3-hour intervals.
  - This not sufficient detail for a utility service territory.
  - Does not incorporate surface features that effect mesoscale meteorology.
- Utilizes numerical prediction model for local, high-resolution weather predictions
- No discussion of variables beyond weather (wind gusts and rainfall)

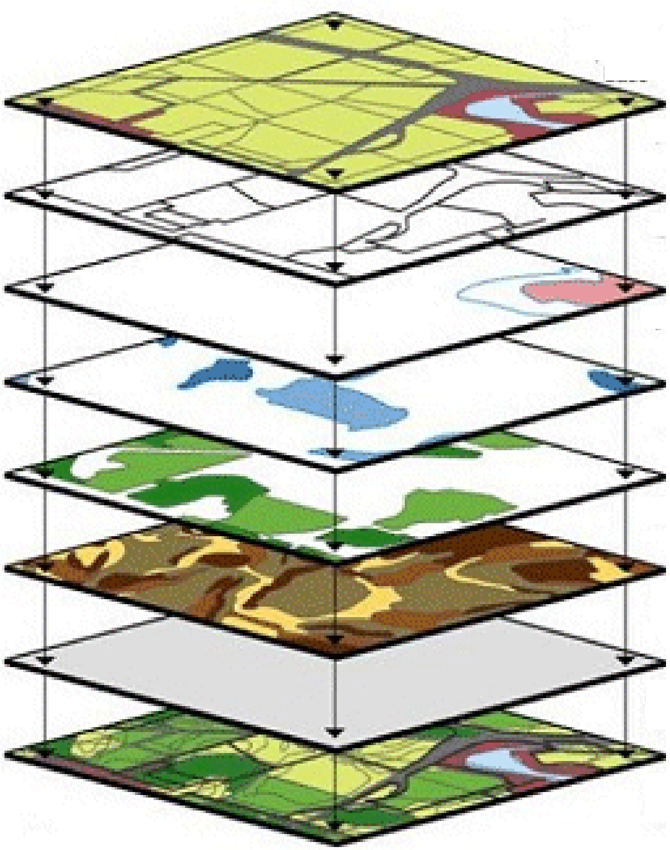
Academic Research

- H. Liu, R.A. Davidson, T.V. Apanasovich. **Spatial generalized linear mixed models of electric power outages due to hurricanes and ice storms.** Reliability Engineering & System Safety, Volume 93, Issue 6, June 2008, Pages 897–912
- S. Han, S.D. Guikema, S.M. Quiring, K. Leed, D. Rosowsky, R.A. Davidson. **Estimating the spatial distribution of power outages during hurricanes in the Gulf coast region**
- H. Liu, R.A. Davidson, D.V. Rosowsky, J.R. Stedinger. **Negative binomial regression of electric power outages in hurricanes.** Journal of Infrastructure Systems, 11 (4) (2005), pp. 258–267

- Look at several geographic variables
- Can benefit from industry collaboration and more sophisticated GIS analysis

General Concept

GIS: Vulnerability



Base Topography

Power Grid

Land Cover / Vegetation

Soils

Weather: Wind Gusts / Rainfall

Composite Vulnerability

Model Training:

Historical Data for Outages and Corresponding Conditions

Historical Data

- Utilize historical power outage data from electric utility companies

Occurrence:

Equipment Effected

Weather conditions
- Synoptic conditions
- Mesoscale conditions
- Gusts / rainfall

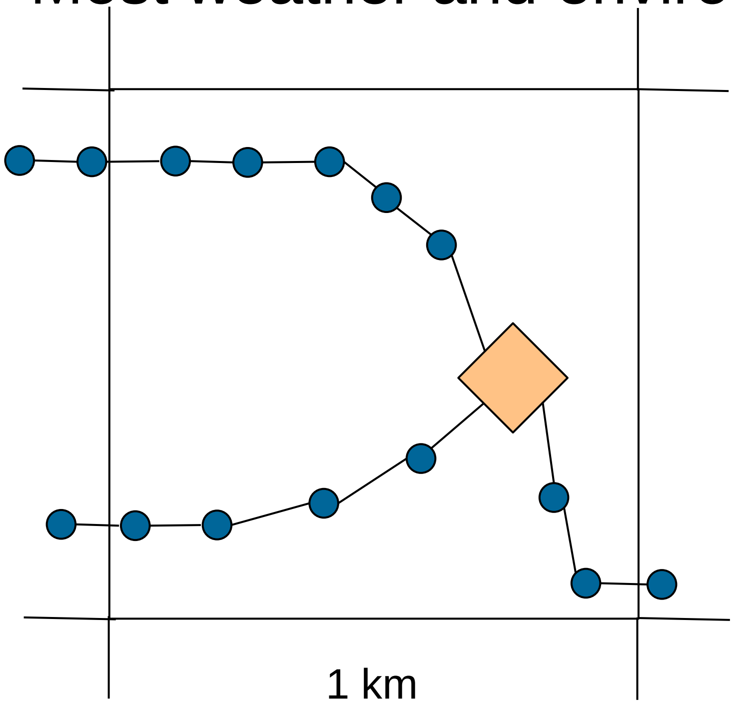
Environmental conditions
- Soil characteristics
- Land cover / vegetation
- Topography

Model Variables: Environmental

- Soil drainage and soil depth – from STATSGO
- Topography – from USGS
  - Can be used to predict flooding
- Land cover (forested vs. non-forested) – NLCD
  - This could also be classified from high resolution aerial photos.
- Detailed vegetation data
  - Was not included in academic research due to lack of available data.
  - Useful GIS data may exist with T&D ROW management

Model Variables: Power Grid

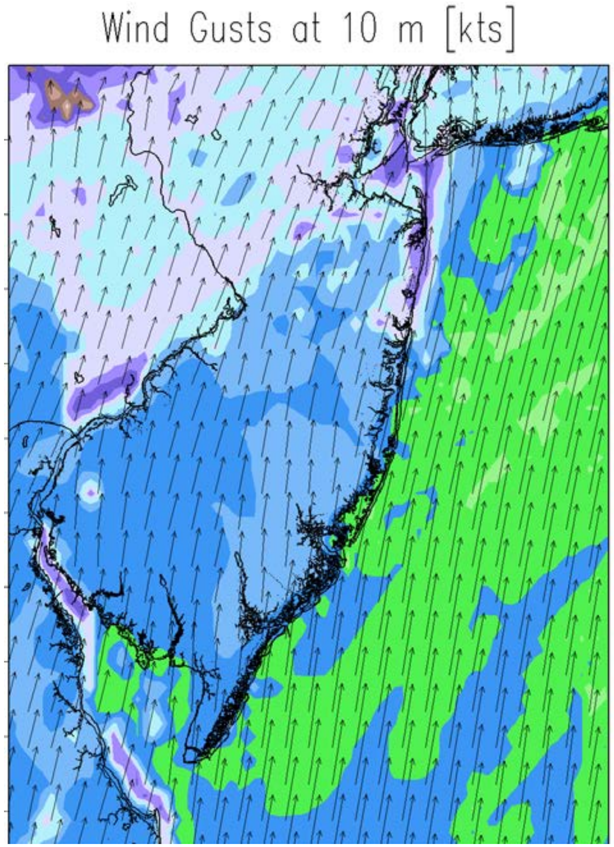
- Raster or vector?
  - Raster may be adequate for response planning
  - Most weather and environmental data will be raster

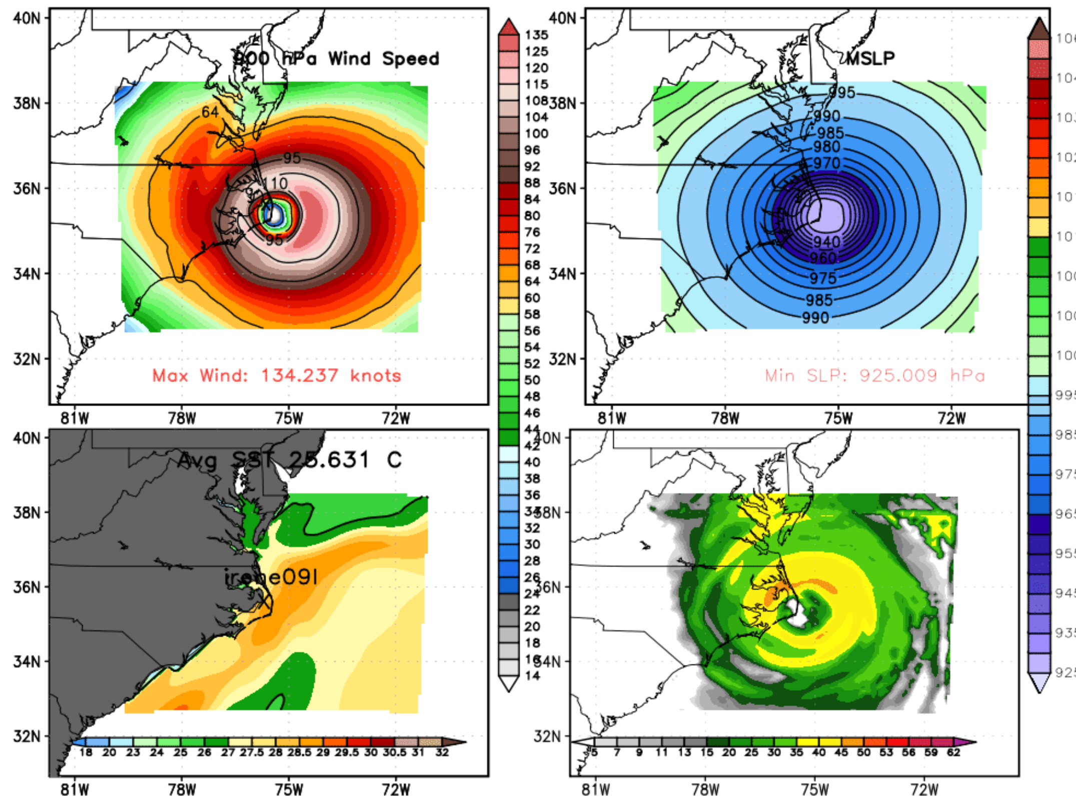


- Summarize
  - Number of poles
  - Number of substations
    - Number of switches
    - Number of transformers

Model Variables: Weather

Existing studies show that wind gust speeds and rainfall have the strongest correlations to outages.





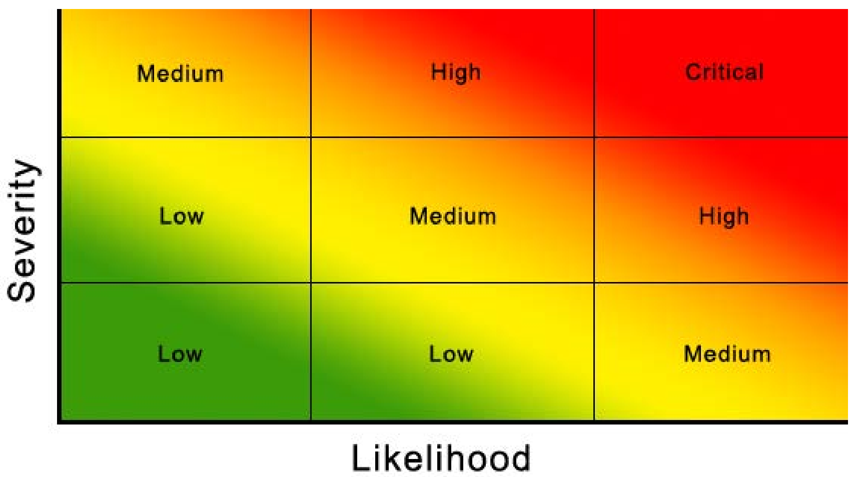
Model Variables: Weather (continued)

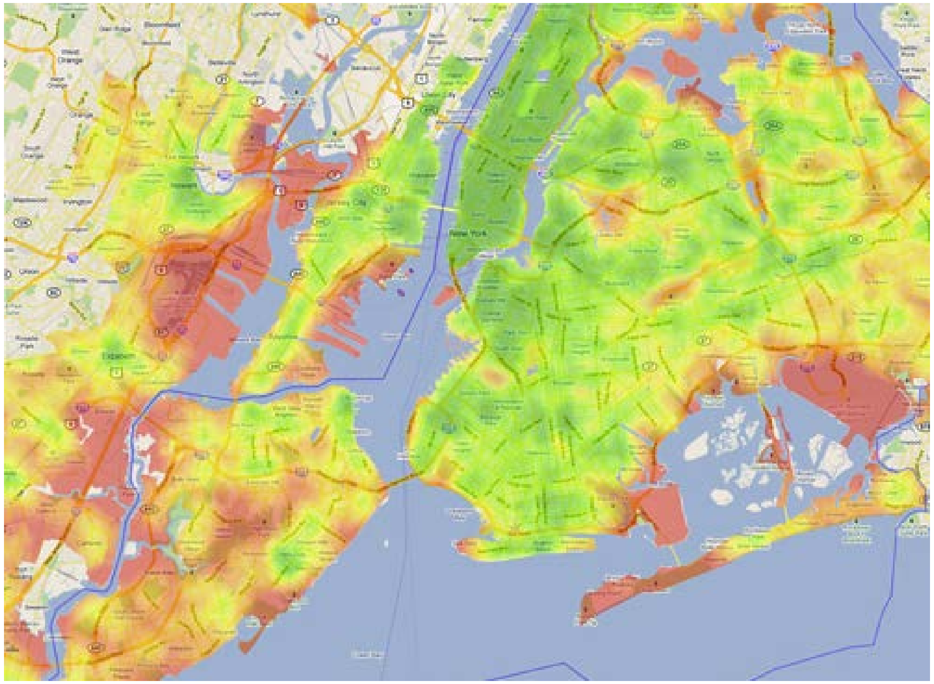
- **The Weather Research and Forecasting (WRF) Model** is a next-generation mesoscale numerical weather prediction system designed to serve both atmospheric research and operational forecasting needs.
  - Supported by NOAA and NCAR
  - Latest model to be adopted by the National Weather Service and the US Military
  - Can produce mesoscale wind forecasts down to 3km resolution up to 72 hours into the future.
  - Hurricane WRF (HWRF) is a specialized model run while a hurricane is present

Risk Assessment: Final Results

Likelihood (determined by GIS/statistical model) +

Severity (number of customers effected or repair time)





Conclusions

- Industry collaboration can help build a better model
  - Historical outage data
  - Detailed grid data
  - Knowledge base

- Transparent methods (no “black boxes”)

- This project can help fill gaps in previous research