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Resilience System Performance Modeling in a Changing Climate

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Please email me for questions and paper requests

Proposed Work & Progress to date

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Project Objectives and Tasks

This project continues improving the UConn Resilience System Performance Model (RSPM) that integrates existing conditions (hardening options, infrastructure conditions, soil conditions, etc.) for a future changing climate. Future parameter interplays, such as high impact low probability extreme weather events, local wind and precipitation, and varied infrastructure conditions must be considered. Varied intervention techniques will be evaluated to optimize the resources and costs toward effective decision-making to system stability and resiliency in a future changing climate.

1. WRF-based dynamical downscaling of the NOAA-CIRES-DOE 20th Century Reanalysis data for historical extreme hurricane events that made landfall in Eversource territory and brought severe impact (T1)
2. Development of time-dependent fragility surfaces for different climate change pattern scenarios, including historical extreme event series and updated future extreme event series (T2)
3. Improve the RSPM to incorporate all parameter interplays (material and structural degradation, soil condition and variation, topographic relief, precipitation, wind, and vegetation status, etc.) (T3)
4. Analyze the changing trends of historical major events under different future climate scenarios (RCP4.5 and RCP8.5) by comparing the WRF-based downscaled future and historical climate projections, and apply benefit-cost estimates for the mitigation plans based on different future climate patterns (T4)

T1: What if the historical extreme events return?

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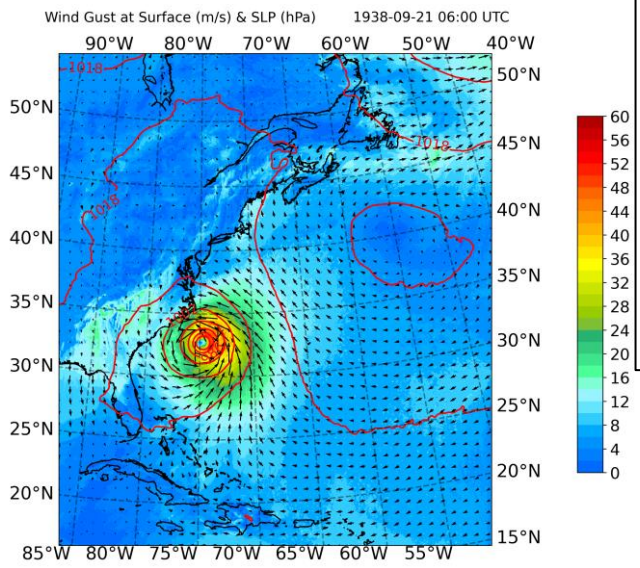
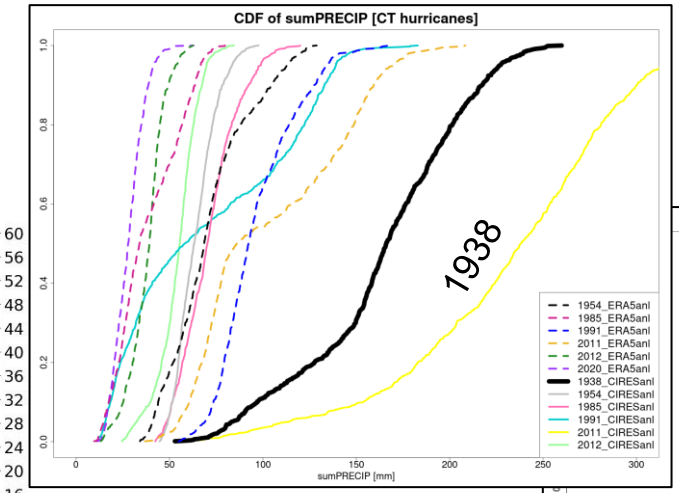
- Northeast region does not encounter hurricane often, but each occurrence brings catastrophic impact on power systems.
  - Assess the current power system resilience with historical extreme events
    [New England hurricane **1938**, Hurricane Carol **1954**, Hurricane Gloria **1985**, Hurricane Bob **1991**, Hurricane Irene **2011**, Hurricane Sandy **2012**, Hurricane Isaias **2020**]

New England 1938

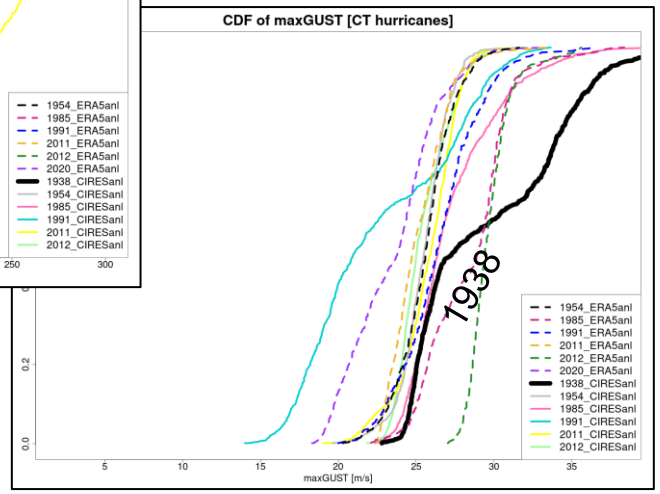
High-resolution weather data (Gust) from WRF-based dynamical downscaling





Precipitation

Comparison of weather data among hurricanes



Gust

T4: Extreme events under future climate scenarios

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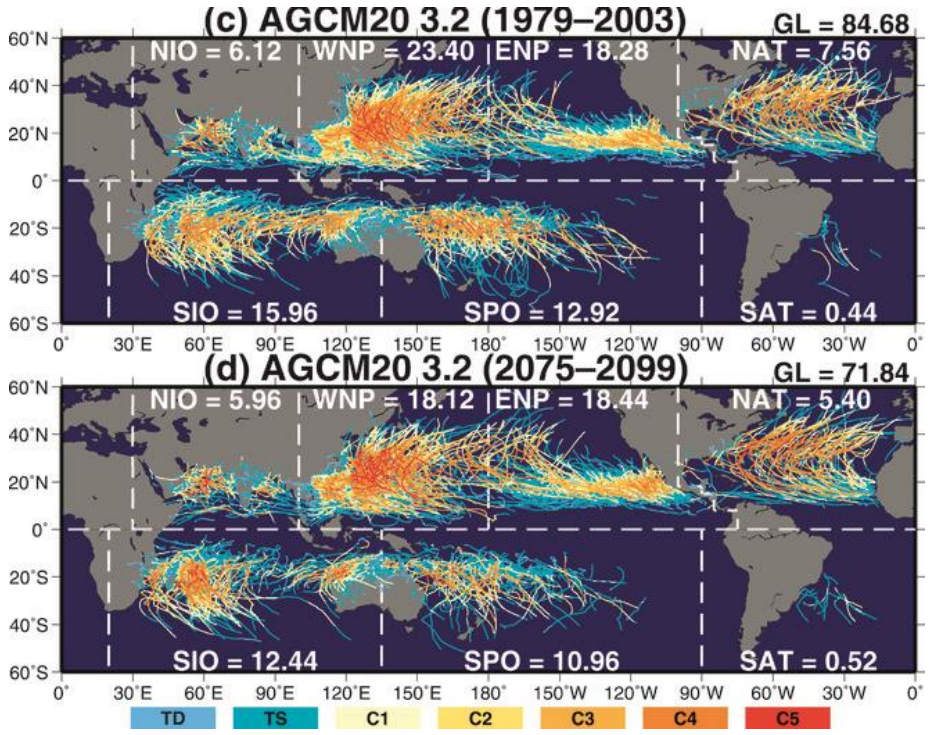
- Quantify the future extreme events
  - Evaluate the weather intensity
  - Estimate the possible physical damages of power system

- Identify potential tropical cyclones in selected global climate models (GCMs) under different future scenarios

- Track the storm as it travels and evolves

- Count the storms that affect northeast region



Source: **Journal of Climate 25, 9**; 10.1175/JCLI-D-11-00415.1

*Murakami, Hiroyuki, et al. "**Future changes in tropical cyclone activity projected by the new high-resolution MRI-AGCM**." Journal of Climate 25.9 (2012): 3237-3260.*

Global distribution of tropical cyclone (TC) tracks by the atmospheric general circulation model (AGCM)
- Top: present-day (1979–2003)
- Bottom: the end of 21st century (2075–99) under IPCC A1B scenario (similar to RCP 8.5 scenario at the mid-century)

The numbers for each basin show the annual mean number of TCs. TC tracks are colored according to the intensities of the TCs as categorized by the Saffir–Simpson hurricane wind scale [e.g., tropical depression (TD), tropical storms (TSs), and C1–C5].

T2: Hybrid Physics-Based and Data-Driven Model for Outage Prediction

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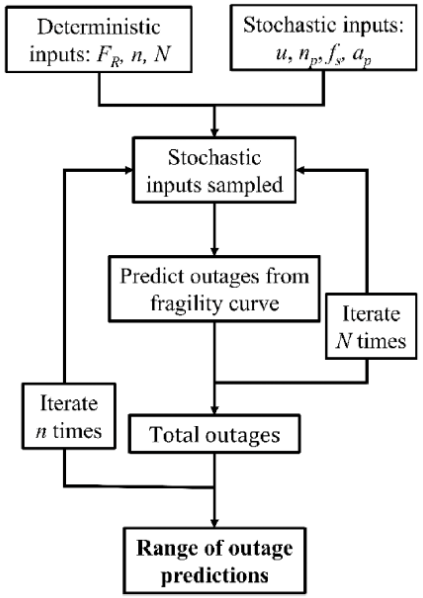
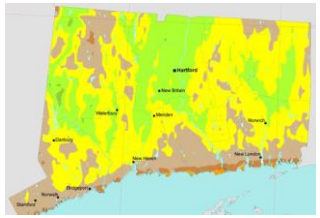
- Updating mechanistic fragility curves with the historic outage data.
- The hybrid model shows potential improvements of 25-50% in prediction accuracy over the purely data-driven approaches for high-impact storm events where the data-driven modeling is limited by lacking data.
- As more data become available, prediction accuracy can continue to improve.
- Refine fragility curves to fragility surfaces to consider correlations of parameters

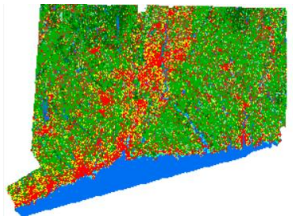


Input Data

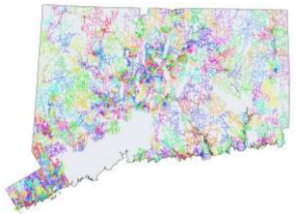


Weather

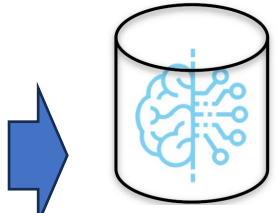
Vegetation



Land Cover

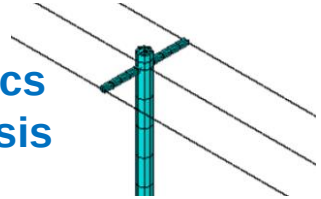


Infrastructure

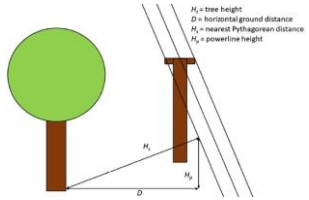


Data-driven Model

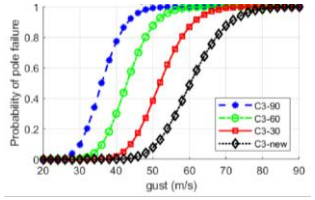
Physics Analysis



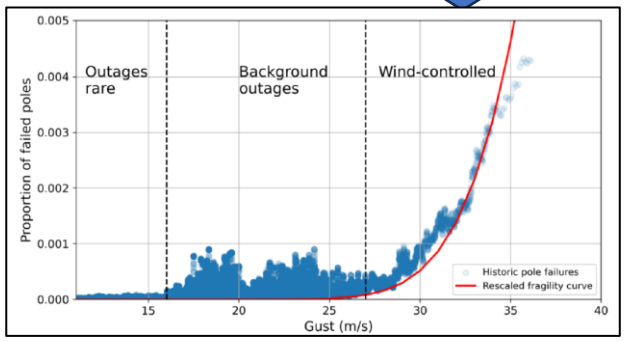
Structural Model



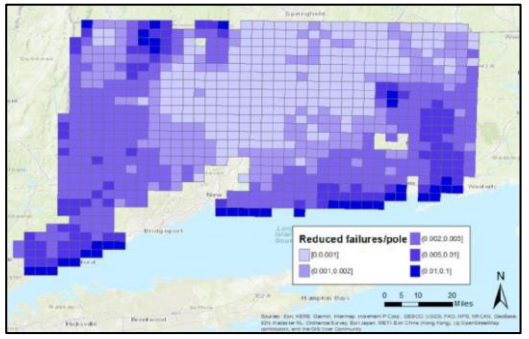
Tree Risk Model



Fragility Curve



Outage Prediction



T3, T4: Assessment of Grid Hardening Strategies based on Hybrid Mechanistic-Machine Learning Outage Prediction Model

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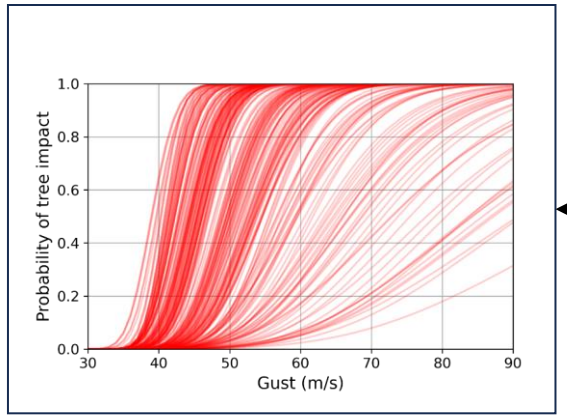
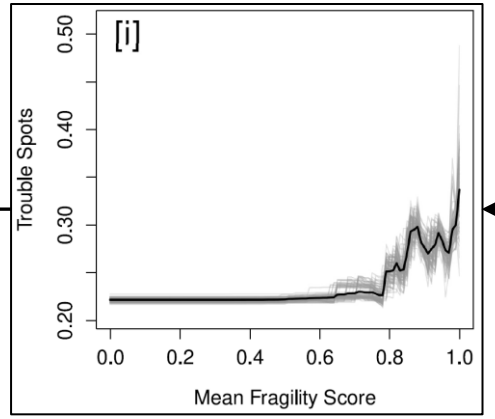
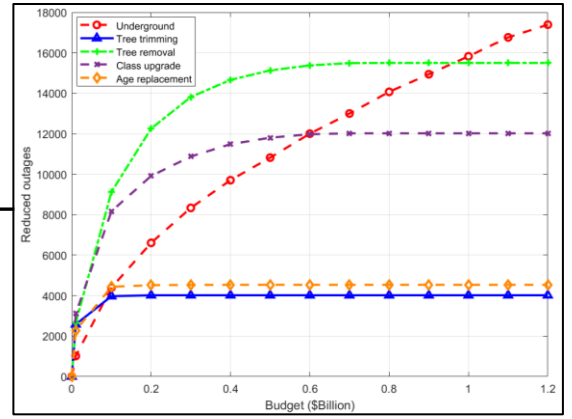
- Hybrid OPM model is sensitive both to changes in infrastructure and environmental/vegetation parameters.
- The efficacy of grid hardening strategies can be assessed based on predictions under different hypothetical scenarios.



Fragility Curves

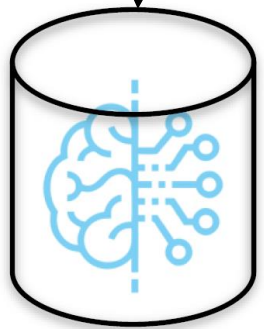


Hardening Simulation

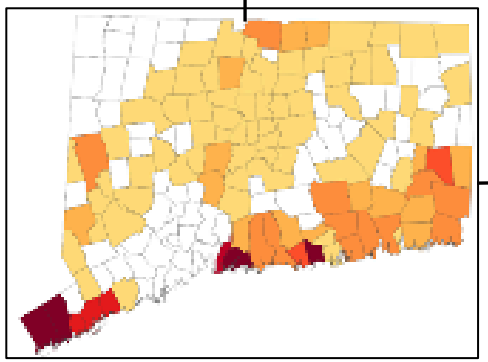


Optimization

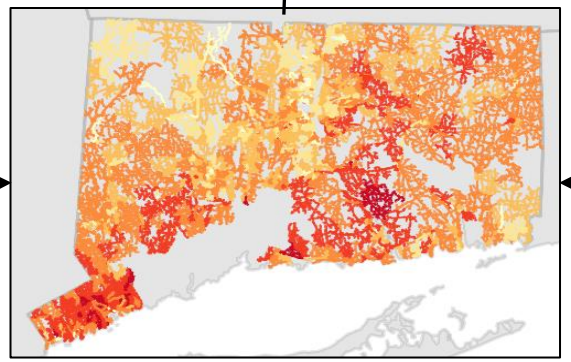
Resilience Strategies & Fragility updates



Machine Learning Model



Outage Predictions



Cost-Benefit Analysis

- Underground
- Tree trimming/removal
- Class upgrade
- Age replacement