ENERGY CENTER

1. Grid Resilience in a Warming Climate
2. Grid Reliability in a Changing Demand Environment
3. Renewable Energy Integration
4. Cyber-Physical System Security
5. Workforce training, outreach, and policy

Pillar 1 & 2
Grid Resilience & Reliability

For a resilient, equitable, and climate-adapted energy system

Work under this pillar will focus on:

- Storm forecasting & restoration modeling
- Development of grid resilience metrics
- Climate-focused load modeling
- Adapting vegetation management to climate change
- N-K contingency planning
- Resilience standards

For a reliable, secure and stable electric grid

Work under this pillar will focus on:

- Distribution system model quality & visibility improvement
- Frequency stability
- System vulnerability assessment
- Resource adequacy
- Predictive capabilities for system reliability assessment
- Integrated platforms for risk mitigations

Projects funded under Pillars 1 and 2: Reliability & Resilience

UCONN TECH PARK

Improving wind gusts and snow forecasting
Develop two operational products for improved wind gust and temperature/ snowfall forecasts. ***Prof. Astitha***

Assessing risk for substation flooding
Addressing the technical, financial, and societal issues that may arise from potential susceptibility of Eversource substations to compound flood events across the State of Connecticut, under the influence of climate change. ***Prof. Emmanouil***

Modeling tree risk on infrastructure
Combining remote sensing observations to monitor roadside tree structure and health condition and develop models to predict tree failure risk. ***Prof. Witharana***

Outage Prediction Model
Continuous improvements to the UConn OPM. ***Prof. Anagnostou***

Power system vulnerability assessment
Quantifying assets vulnerabilities and estimation of weather and outage return periods under current and future climate conditions. ***Prof. Zhang***

A model for estimating time to restoration
Complete the ABM for estimating time to restoration and use it to operationally predict ETR in advance of storms using OPM forecasts. ***Prof. Cerrai***

Integrating DERs in communities and development of resilience metrics
Development of a framework to integrate DERs and Effective Load Carrying Capability within energy communities, and development of resilience assessment metrics to evaluate system performance under extreme conditions. ***Prof Wang***

Resilience assessment and climate change
Improving the resilience system performance model to estimate benefits and costs of grid hardening improvements under changing climate conditions. ***Prof. Bagtzoglou***

Assessing roadside tree risk
Provide a forest disturbance and health monitoring framework for roadside utility risk assessment. ***Prof. Zhe***

Pillar 1 & 2 – Project 1

UCONN TECH PARK

The UConn OPM – Enhancing Prediction Accuracy & Supporting the Emergency Response Team with Real-Time Outage Forecasts

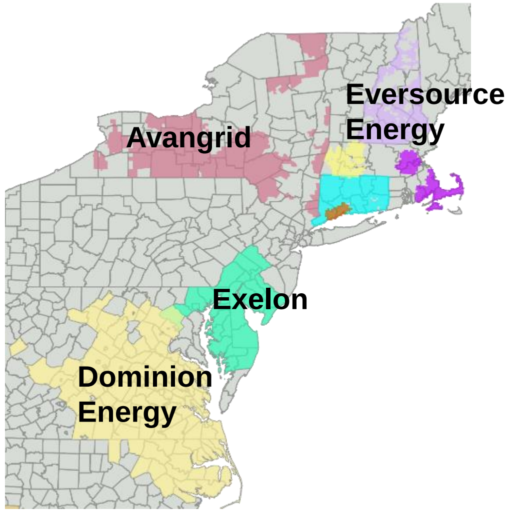
UConn OPM
OUTAGE PREDICTION MODEL

09 February 2024

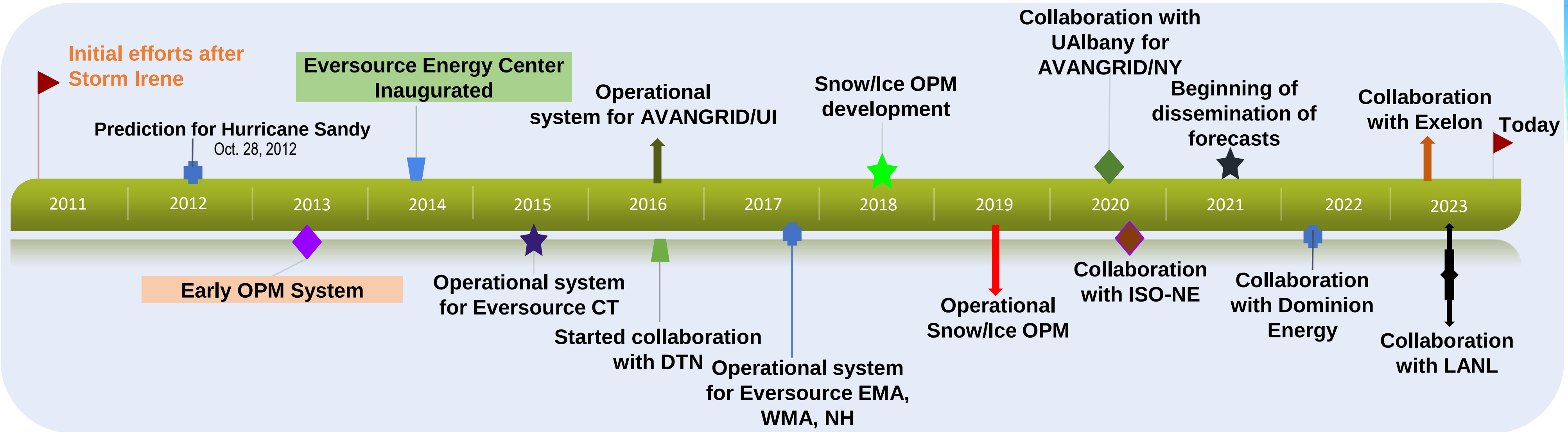
Prof. Emmanouil Anagnostou, *University of Connecticut*
Prof. Diego Cerrai, *University of Connecticut*

Industry Relevance & Need

UCONN TECH PARK



A growing number of utilities has been finding UConn's outage prediction capabilities useful for their operations.



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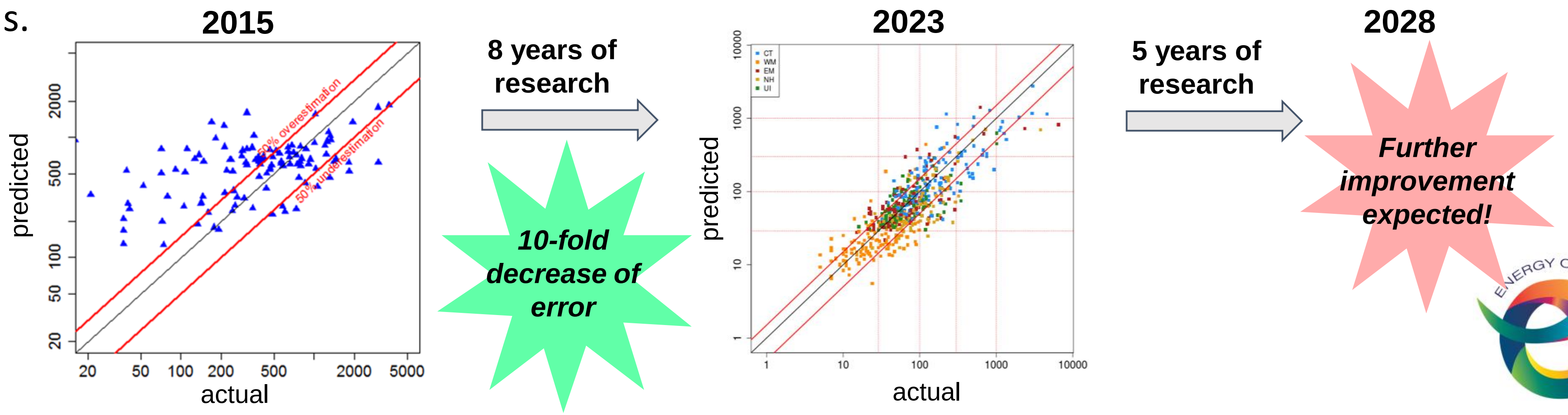
Project Goals and Objectives

Goal of this project is to continue the development and operation of the UConn Predictive Storm and Outage models for Eversource Connecticut service territory, by regularly updating and improving the model based on updated infrastructure and OMS data.

Specific objectives include:

- Continue the operational use of OPM for Eversource CT to support storm preparedness activities.
- Use enhanced variables from the new WRF 4.2 in the UConn Outage Prediction Model.
- Enhance OPM predictions based on improved rain/wind, snow, ice, thunderstorm and hurricane models.

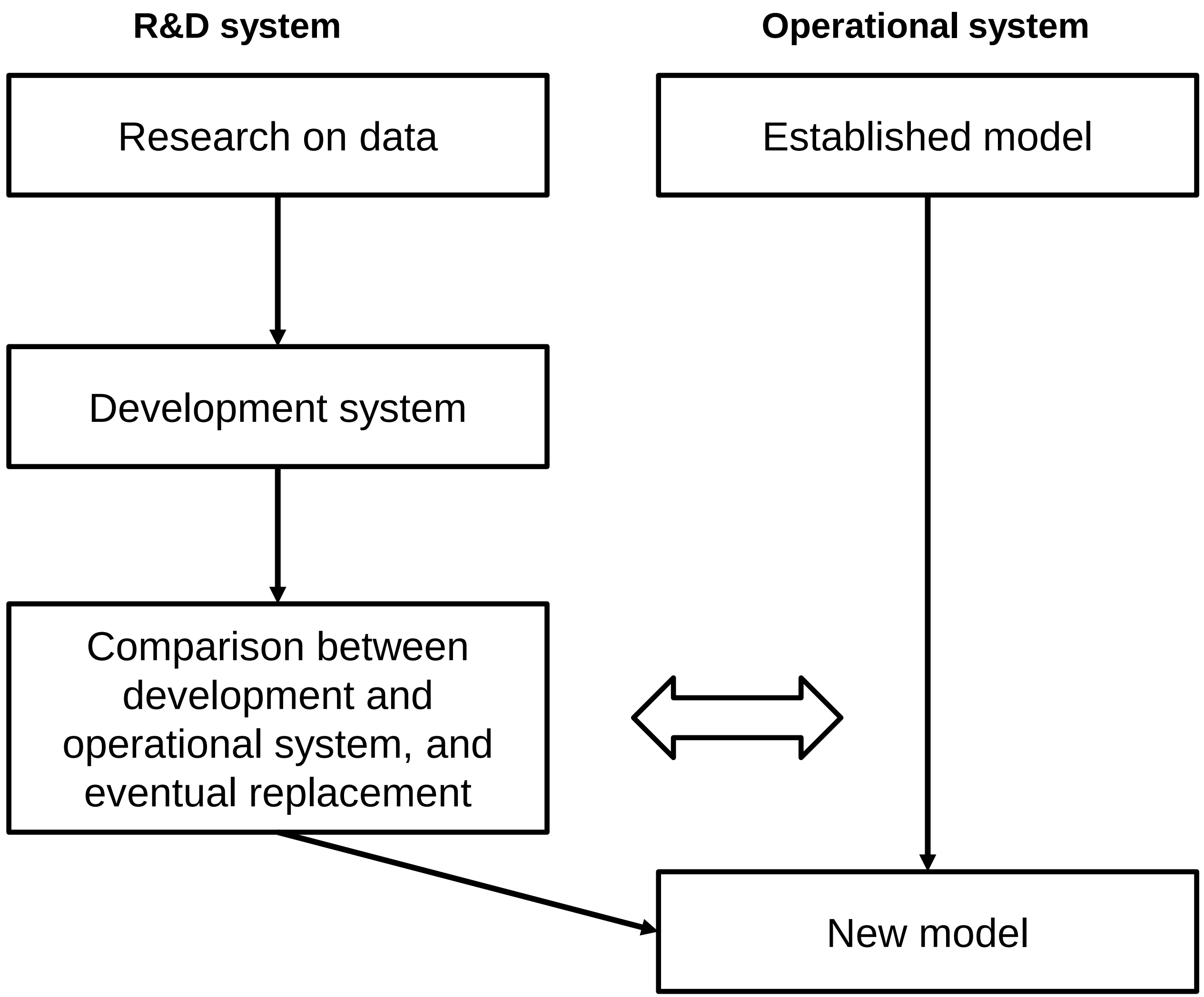


From Research to Operations

1st stage: 3-6 months

2nd stage: 3 months to 1 year

3rd stage: 1 month



Outcomes and Deliverables

Date	Activity Report	Deliverable
End of Q4 each year (2023-2027)	• Report on **Winter OPM** • Report on improvement of OPM from new snow variables developed by the weather team	• New OPM winter model version implemented annually
Q1 each year (2024-2028)	• Report on **Thunderstorm OPM** • Report on improvement of OPM from new gust variables developed by the weather team	• New OPM thunderstorm model implemented annually
Q2 each year (2023-2028)	• Report on **Extreme events OPM** • Report on improvement of OPM from new hurricane variables developed by the weather team	• New extreme events OPM implemented annually
Q3 each year (2023-2027)	• Report on **Rain/wind OPM** • Report on improvement of OPM from new rain/wind variables developed by the weather team	• New version of OPM for rain/wind events implemented annually
Annually/quarterly/ monthly	• **Performance evaluation of the operational OPM.** • Quarterly progress updates with project PIs	• Performance report presented at the annual meeting and in regular update meetings with Eversource managers.

Research Impact

The impact of this project will include, beyond Eversource, also many other stakeholders and the communities:

- The highly granular improved OPM system used to predict distribution grid outages will provide Eversource with critical and more accurate pre-storm data and situational awareness.
- The OPM forecasts can be used to support pre-storm crew allocation and deployment decisions, and ERP event level classifications.
- The communication of OPM forecasts to the NWS Office in Boston/Norton MA allows NWS to include quantitative wording related to outage threats into NWS guidance and severe weather watches/warnings.
- The enhanced situational awareness, the consequential reduction of outage duration, and the communication of outage threats to the population will improve the quality of life for the people living in the communities served by Eversource.

Pillar 1 & 2 – Project 2

UCONN TECH PARK

A Pathway to Enhance Grid Resilience: Zero-Carbon Energy Communities with DER-based ELCC Quantification

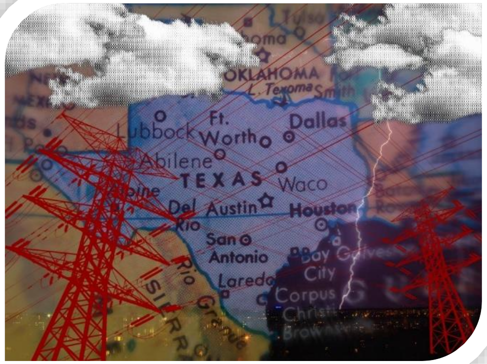
Zongjie Wang, Ph.D. (Single PI)

Assistant Professor, ECE Department, Eversource Energy Center, UConn

- **Research Interests:**
  - Power System Planning and Operation, Optimization,
  - Renewable Energy Integration, Grid Resilience.
- **Selected Awards (Lead-PI):**
  - **Eversource Energy**: Distribution system flexible load modeling;
  - **Eversource Energy:** Grid Resilience and ELCC Quantification;
  - **ISO-NE**: DER modeling and ISO-NE market dynamics;
  - **MISO:** Decomposition and coordination approach for Markov-based unit commitmen
  - **NSF:** Machine learning methods and microgrid control;
  - **BNL:** Grid dynamic behavior of solar integration at D levels;
  - **BNL:** Intra-day ahead unit commitment with wind and solar;
  - **DOE WPTO:** Hydropower Optimization Prize.

Project Period: 11/2023-11/2026

Industry Relevance & Need



01 Extreme Weather events

- Low-probability;
- Extensive socioeconomic costs and impacts;
- Address Eversource's need for enhanced grid resilience against events.

02 Critical grid components

- Reduce the likelihood outages;
- Analyze different event behaviors;
- Resilience metrics quantification;
- Provide solutions for future system planning and upgrading schemes.

03 Economic-Resilience Framework

- Find a trade-off between resilience and costs (economic);
- More resilience;
- More cost effective.

04 Resilience & Zero-Carbon Transition

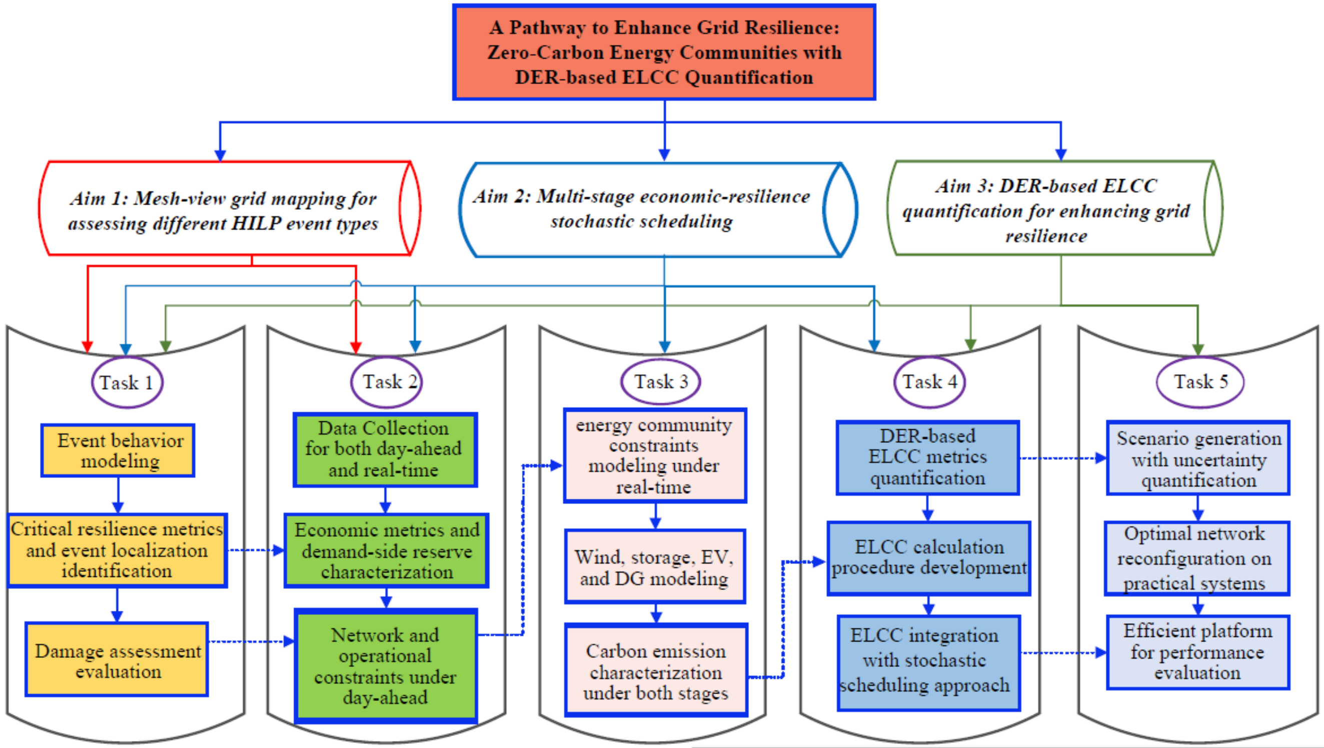
- Advanced tools and methodologies, reinforcing Eversource's leadership in sustainable energy transitions;
- Charts a progressive course towards the 2050 net-zero emission targets, catalyzing industry-wide adoption.

Project Goals and Objectives

Pillar 1 & 2 – Project 2

UCONN TECH PARK

Primary Goal is to increase the resilience of energy communities by leveraging innovative grid mapping techniques, detailed resilience assessments, and integrating DERs into planning and operations, aligning with Eversource's strategic direction towards a reliable, resilient, and sustainable energy future.



Project Objectives

Mesh-view Grid Mapping for HILP Events

Develop a mesh-view grid mapping tool to identify critical grid components and vulnerability areas and optimal resource allocation, for different types of HILP events.

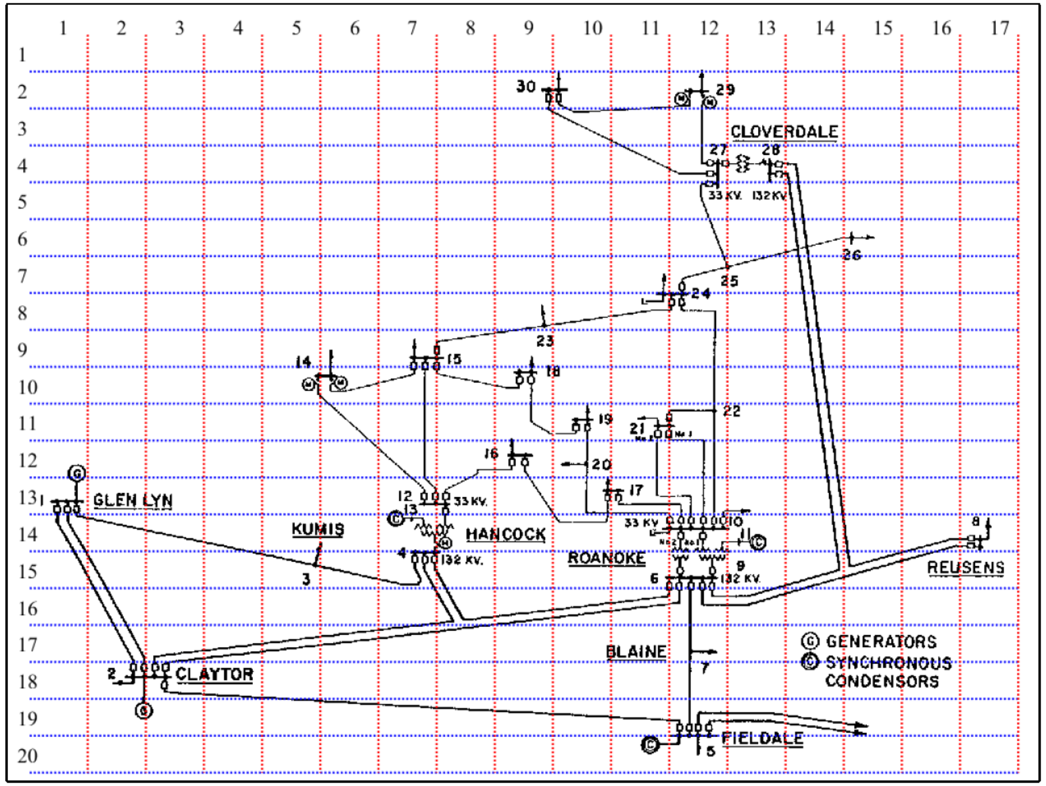
Quantitative Resilience Metrics

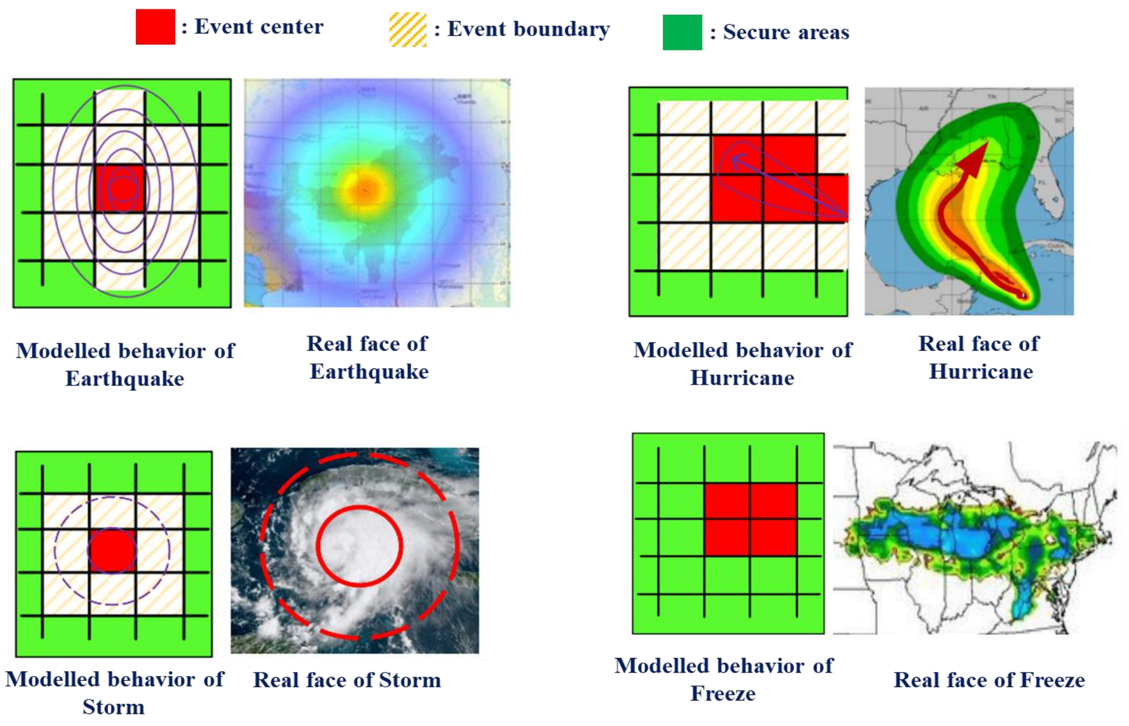
Establish innovative DER-based effective load carrying capability (ELCC) resilience metrics to expedite the restoration and ensure resilient operation of carbon-free energy communities.

DER-based ELCC for Resilient Energy Communities

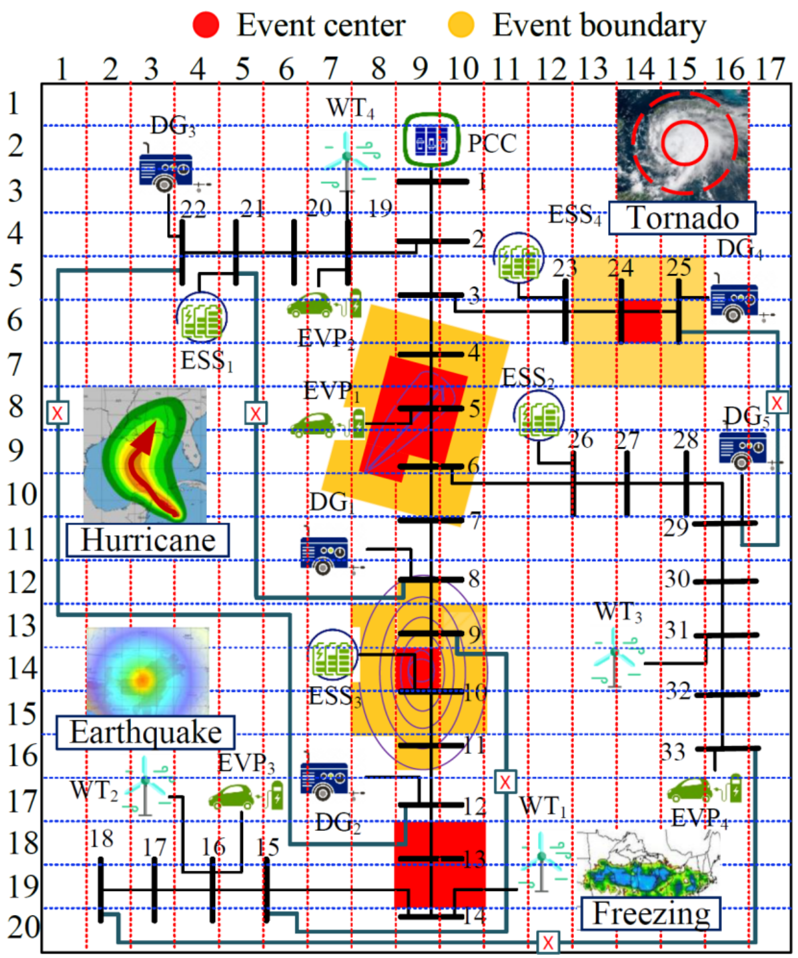
Incorporate a probabilistic vulnerability assessment strategy using ELCC metrics with the mesh-view mapping tool for precise event localization and grid components to enable effective resource deployment and improved decision-making for resilience enhancement.

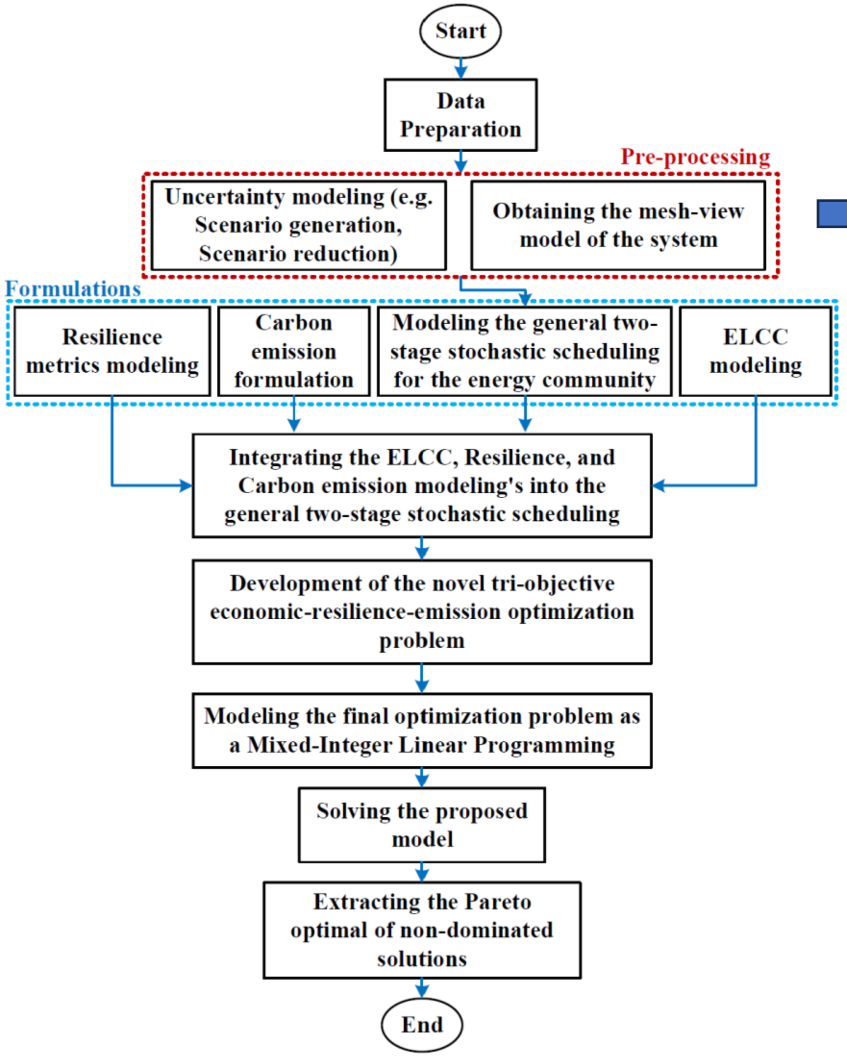
Research Approach

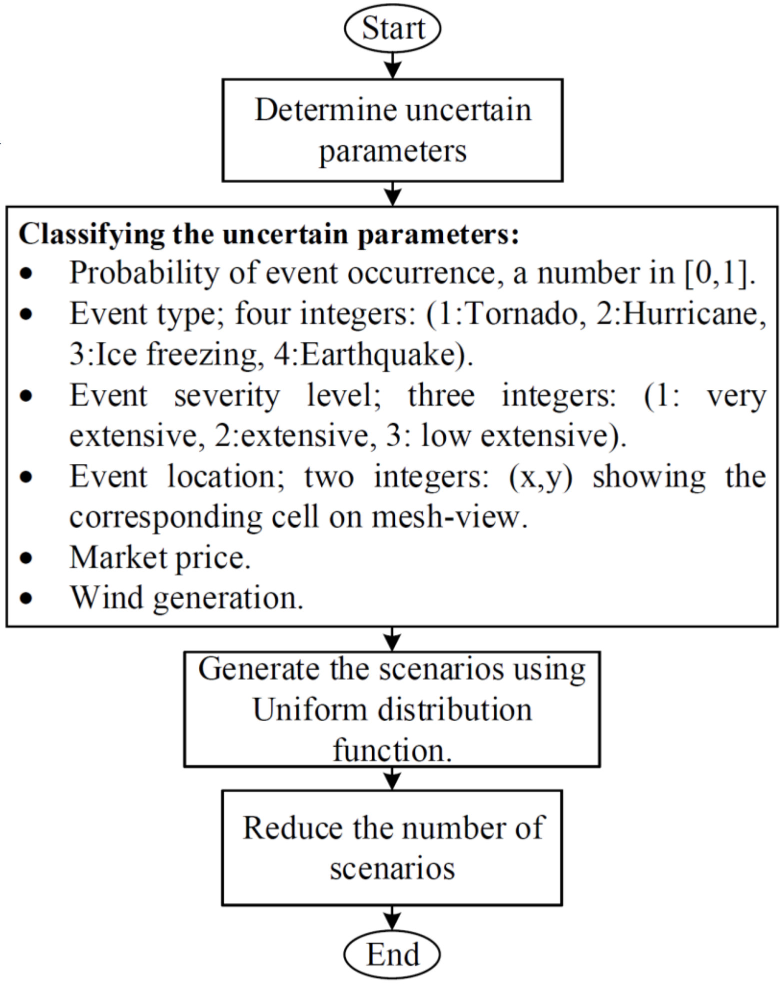




Research Approach







Outcomes and Research Impact

Pillar 1 & 2 – Project 2

UCONN TECH PARK

01

Mesh-view Grid Mapping

DER-based ELCC quantification;

Critical grid component identification for various events;

Resilience-economic framework with Markov stochastic optimization with network topology configuration.

02

Practical Framework Validation

Analyze the grid resilience against different natural disasters with different specific resilience criteria;

Practical distribution system validation with DER integration;

Provide solutions for future system planning and upgrading schemes.

03

Resilience Enhancement Tool

Implement specific resilience assessment matrix for utility needs;

Real-time adaptability;

Effective tool for utilities to enhance decision-making and resource allocation for improved resilience.

Long-term goal: ***Implement the mesh-view grid mapping tool across multi-regional utilities to be flexibly designed and meet specific state-defined information needs for a zero-carbon, resilient, and reliable energy communities.***

Project Relevant Publications:

- A. Younesi, **ZJ Wang***, etc. Enhancing the Resilience of Zero-Carbon Energy Communities: Leveraging Network Reconfiguration and Effective Load Carrying Capability Quantification [J]. *Journal of Cleaner Production*, 2023. (Accepted) Impact Factor: **11.07**
- A. Younesi, H. Shayeghi, **ZJ Wang***, etc. Trends in Modern Power Systems Resilience: Smart Grids Challenges and Opportunities [J]. *Renewable and Sustainable Energy Reviews*, 2022, (162), 112397. Impact Factor: **16.8**

A. Younesi, **ZJ Wang***, etc. DER Analysis with Effective Load Carrying Capability for Enhanced Carbon-Aware Active Distribution System Resilience [C]. *IEEE PES GM*, 2024.

A. Younesi, **ZJ Wang***, etc. A Pathway to Mitigate Climate Change Impacts on Energy Communities: Decarbonization-Based Cost-Effective Grid Resilience Enhancement [C]. *IEEE PES GM*, 2023.

A. Younesi, **ZJ Wang***, etc. Quantification of DERs Penetration Level in Microgrids: A Quest for Enhancing Short-Term Power Grid Resilience [C]. *IEEE PES GM*, 2023.

A. Younesi, **ZJ Wang***, etc. Investigating the Impacts of Climate Change and Natural Disasters on the Feasibility of Power System Resilience [C]. pp. 1-5, *IEEE PES GM*, 2022.

A. Younesi, **ZJ Wang***, etc. A Pathway to Enhance the Modern Distribution Systems Resilience: Flexible Behavior Investigations on Electric Vehicles [C]. pp. 1-5, *IEEE PES GM*, 2022.

Pillar 1 & 2 – Project 3

UCONN TECH PARK

Eversource Energy Center Annual Workshop

Innovation Partnership Building

University of Connecticut

Assessing compound risk for existing electrical substations over the State of Connecticut

Enhancing grid resilience in a changing climate

by

Stergios Emmanouil

Assistant Research Professor
Civil & Environmental Engineering and Eversource Energy Center
University of Connecticut

09-Feb-2024

Introduction

Industry Relevance and Need

Flood risk and early warnings

1. *Intensification of hydrometeorological extremes, poses an immediate threat to numerous substations lying close or within coastal and inland floodplains across Connecticut.*

2. *The vulnerability of critical infrastructure, and the associated flood risk, should be estimated as meticulously and accurately as possible, to determine how planning and operations may be affected.*

Address the technical, financial, and societal issues that may arise from the potential susceptibility of Eversource Energy substations to compound flood events across the State of Connecticut, under the influence of climate change.

2024 California floods (Source: CNN)

Project Goals & Objectives

Compound flood risk and climate change over CT

Pillar 1 & 2 – Project 3

UCONN TECH PARK

September 2023 – August 2026
(Initiated in Jan. 2024)

Assessing compound risk for existing electrical substations over the State of Connecticut, toward enhanced grid resilience in a changing climate

PI: *Stergios Emmanouil*

Across various temporal scales and return period levels!

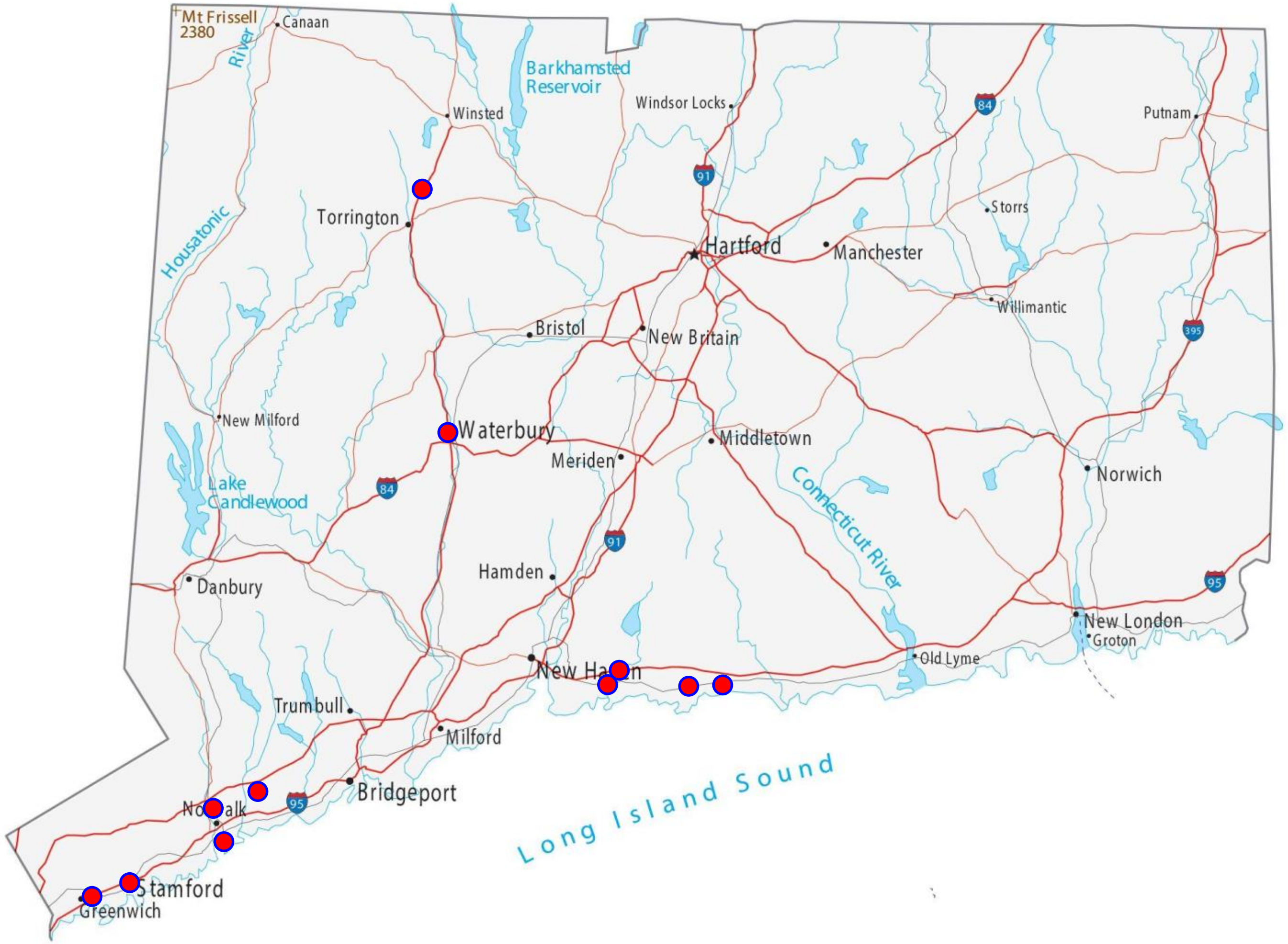
Goals

1. Robustly assess the susceptibility of existing substations against compound flood events.
2. Highlight the potential vulnerability of these critical facilities and reveal trends in the underlying flood risk induced by climate change.
3. Provide valuable information that supports decision making for future hazard mitigation projects and enhanced grid resilience.
4. Evaluate the future exposure of the system to hydrological hazards.

Research Approach

Study Domain

11 *locations in coastal and inland areas*

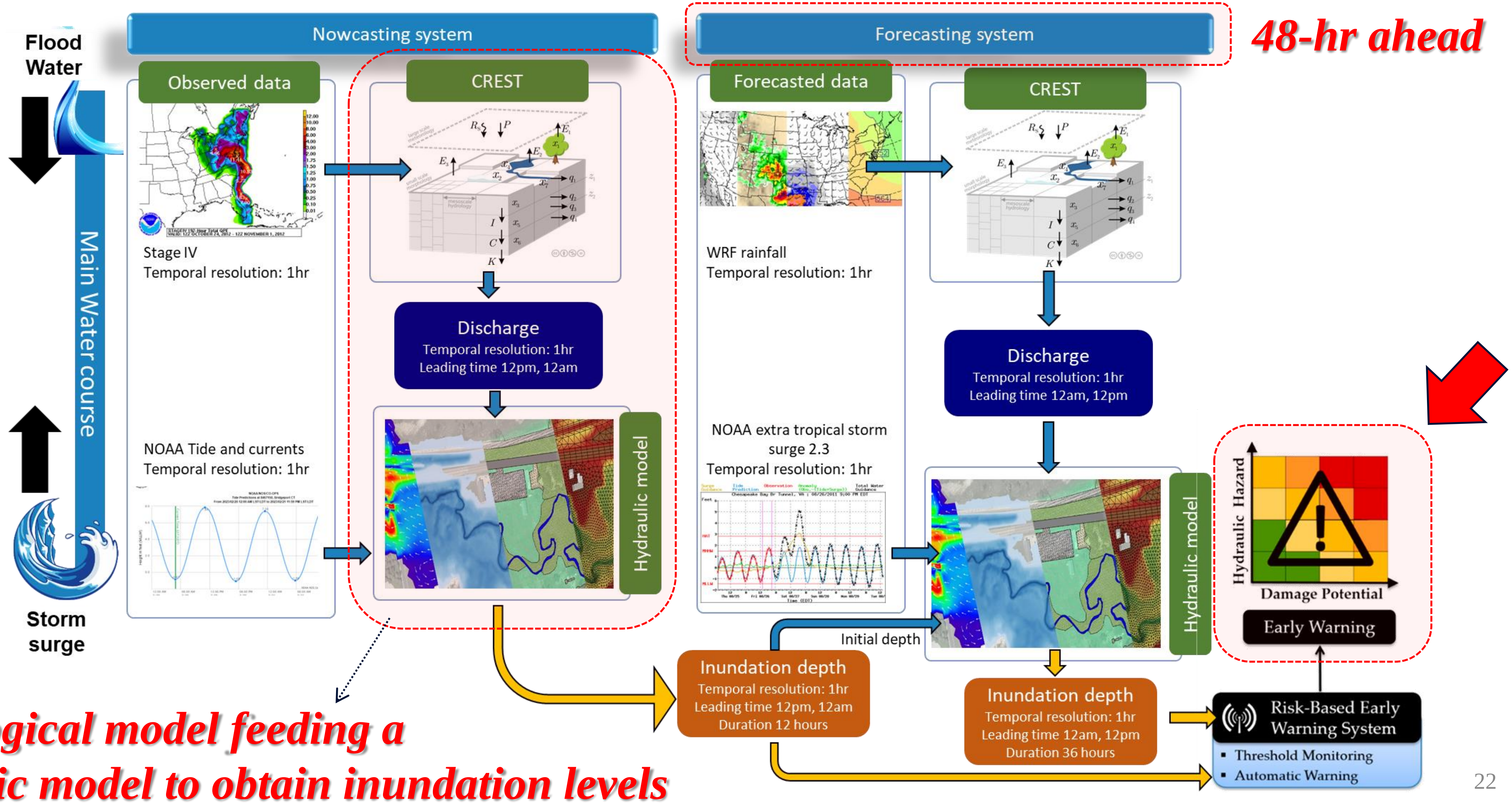


Research Approach

Real-time early warning system

Pillar 1 & 2 – Project 3

UCONN TECH PARK



Hydrological model feeding a hydraulic model to obtain inundation levels

Research Approach

Compound flood risk estimation

Parametric statistical models that account for nonstationarity

1 Return periods of hydrometeorological variables

Hydrodynamic model simulations

2 Acquired inundation levels

3 Climate simulations for various RCPs

Parametric linkage

Future flood risk and exposure

Compound flood risk estimation for existing substations

Project outcomes

Milestones and deliverables

- *Integrated and innovative tools for the statistical analysis of flood events and their driving mechanisms that account for climate change effects.*
- *A parametric linkage between the return periods of observed hydrometeorological extremes and the inundation levels.*
- *Estimates of exposure and flood risk for the remainder of the 21st century, based on future climate scenarios.*
- *Real-time early warnings for potentially hazardous conditions over existing Eversource Energy substations.*

Research Impact

Links to EEC research pillars

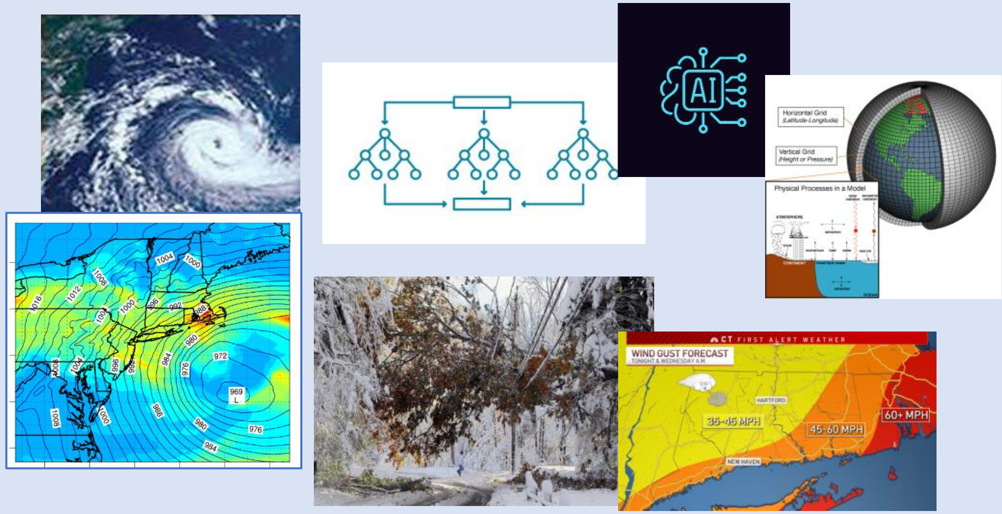
1 *Advances leading-edge research and technology to assure reliable power during extreme weather events and limit outages for substantial portions of the grid.*

2 *Identifies potential vulnerabilities of the system and highlights areas for design improvements toward enhanced resiliency.*

3 *Addresses existing needs, and provides useful and interpretable tools, while encompassing the effects of climate change on flood risk.*

4 *Supplies valuable information on potential future exposure of Eversource Energy critical infrastructure across the State of Connecticut.*

Improving Extreme Weather Forecasting Capabilities in support of Power Outage Prediction Activities: Phase II – wind gust and winter weather



09 February 2024

Prof. Marina Astitha, Civil and Environmental Engineering, *University of Connecticut*

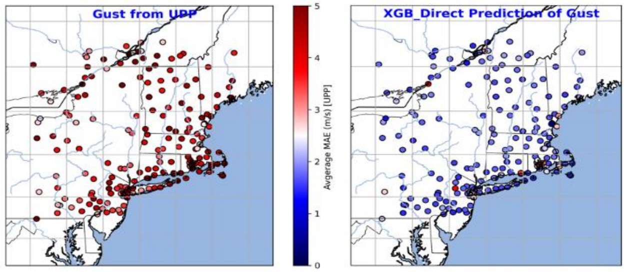
Industry Relevance & Need

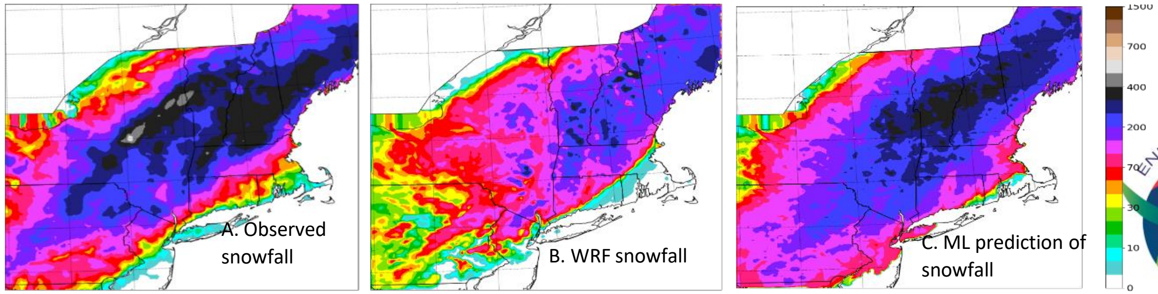
Phase II of the extreme weather forecasting project is the continuation of the 2020-2023 project and a long collaboration with EEC and Everource since 2013.

The project is essential to the OPM project activities. We work closely with the OPM team (research groups of Profs. Anagnostou and Cerrai) to ensure our improvements resonate with the future updates of the operational OPM.

The project is related to the first EEC pillar "*Grid Resilience during adverse weather and climate conditions*", since **advances and improvements in weather forecasting accuracy and reliability directly impact storm damage prediction and restoration modeling**.

Our work and expertise in extreme weather forecasting **have the potential to benefit other EEC projects related to grid reliability** under a changing climate.





Project Goals and Objectives

The **goals** for this second phase of the extreme weather forecasting improvements project are to:

- Develop two operational products for improved wind gust and temperature/snowfall forecasts based on the previous exploratory ML-based work, and
- Quantify the influence on OPM predictions

Research Approach

Task 1: Real-time forecast uncertainty quantification for wind, temperature and precipitation forecasting.

Task 1.1 Develop an automated operational system to investigate discrepancies from our WRF storm forecast through wind, precipitation, temperature maps and frequency distribution plots.

Task 1.2 Develop an automated system to download probabilistic winter forecast.

Task 2: Integration of ML-based gust with operational WRF

Task 2.1 Assess the ML-based gust approach at individual station locations to better understand the ML model's capabilities and generalization potential.

Task 2.2 The station-based approach will be transformed into a gridded product to be directly utilized by the OPMs.

Task 3: Improvements in forecasting snowfall

Task 3.1 Winter temperature bias correction.

Task 3.2 ML-based snowfall prediction.

Outcomes and Deliverables

Project deliverables

- Automated system for storm forecast uncertainty quantification (Jan/Jul 2024)
- ML-based wind gust prediction improvements and operational product (Jan 2025, Jan 2026)
- Correction of WRF temperature bias in winter weather forecasts (Jul 2025)
- ML-based snowfall prediction operational product (Jul 2026)

Project Activities	2023		2024				2025				2026		
	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Weather forecast uncertainty (T1.1)													
Winter forecast uncertainty (T1.2)													
ML-based gust improvements (T2.1)													
Operational ML-based gust (T2.2)													
Winter temp bias correction (T3.1)													
Operational ML-based snowfall (T3.2)													

Research Impact

We are specifically targeting improvement of gust and snowfall forecasts as their uncertainty and misrepresentation have significant impacts on power outage forecast accuracy.

The development of the two products, ML-based gust and snowfall prediction, will lead to extramural funding proposals to federal agencies.

Expected publications: ~3-4 peer-review papers, ~4-6 conference presentations.

Pillar 1 & 2 – Project 5

UCONN TECH PARK

Beta-testing of the Agent-Based Model for Estimating Time to Restoration and Development of Resilience Metrics

Image by Garry Killian on Freepik

09 February 2024

Prof. Diego Cerrai, *University of Connecticut*

Industry Relevance & Need

The UConn OPM allows to predict distributed weather-related power outages in advance of storms.

After estimating power outages, utilities need to estimate restoration needs, and specifically to:

- **Allocate crews** before the storm
- **Distribute resources** efficiently
- **Correctly handle the restoration** to avoid regulatory sanctions.

Outage restoration is a complex process which involves optimal crew deployment, travel path minimization and outage prioritization (e.g., emergency outages vs most customers affected).

An informed estimation of restoration time at the town level allows utilities to:

- **Meet state mandates**
- **Optimize crew deployment**
- **Devise optimal restoration strategies**


Image by macrovector on Freepik

Project Goals and Objectives

This project has two main goals:

- **Goal #1:** <u>Complete, improve, and operationalize the **Agent Based Model (ABM)** for **Estimating Time to Restoration (ETR)**.</u>
  The ABM will provide pre- and post-storm restoration information to Eversource emergency preparedness and response managers, in addition to the quantitative outage information provided by the OPM.

- **Goal #2:** <u>Develop new **resilience metrics** for damage duration and frequency.</u>
  The newly developed metrics will allow to assess historical damage duration by taking into account varying storm intensity and predict future improvements brought about by enhanced storm preparedness and response.

Research Approach

Modeling Restoration

The ABM, simulates ETR using geolocated information of road and electric distribution networks, area work centers, historical or predicted power outage locations, actual or proposed crew allocations, and decision rules.

Figure 2: Connecticut road network as modeled in the current version of the ABM.

We will *improve the ABM* by:

- Implementing varying crew travel speed on roads
- Including dynamic restoration time by damage type
- Shortening model runtime

Then, we will *develop an automated system* capable of delivering restoration time and scenarios predictions through a dedicated and secure website.

System Resilience Metrics

Based on preliminary metrics proposed to PURA in 2021, we will develop and test resilience metrics for system *damage duration and frequency* which will consider different levels of weather intensity and specifically: (i) **normalized trouble spots** numbers or duration for different **weather intensity levels**, (ii) **duration and intensity** of severe weather events.

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Outcomes and Deliverables

Date	Activity Reports
02/2024	• **Kick-off of the project.** • **Discussion of the project plan and deliverables.**
06/2024	• ABM improvements report: trucks travel speed & model runtime.
11/2024	• ABM improvements report: integration of different crew types & restoration time for each outage type. • Resilience metrics for duration and frequency developed
02/2025	• Presentation and discussion of the preliminary results at the EEC Annual Meeting • ABM system and website ready: beta-testing starts
09/2025	• Preliminary report after 6 months of beta-testing and plan to address issues • Historical assessment of damage duration reduction
02/2026	• Presentation and discussion of the results at the EEC Annual Meeting • End of beta-testing
04/2026	• Final beta-testing report and finalization of the model • Quantification of future damage duration reduction due to OPM and ABM
08/2026	• **Resilience metrics are published** • **ABM becomes operational**

Completed Activity

Research Impact

Modeling Restoration

- Interfacing the ABM for ETR with the OPM will create a unique decision support tool for storm preparedness and outage restoration management, which will allow for the simulation of crew and equipment allocation and deployment scenarios.
- Improvements in outage prediction and restoration allows utilities to gain enhanced situational awareness.
- Scientifically based and explainable models (compared against usual “black box” models) allows utilities to explain to the public, the regulators, and the press the reasons behind pre-storm decisions, and to be transparent throughout the entire process.

System Resilience Metrics

- The newly developed metrics will allow utilities, regulators, and any interested stakeholders to assess the effectiveness of resilience improvements by accounting for varying storm intensity and climate change trends across the years.

Pillar 1 & 2 – Project 6

UCONN TECH PARK

Power system vulnerability assessment under a changing climate

Xinxuan Zhang, Guiling Wang, Marina Astitha, Stergios Emmanouil

University of Connecticut

February 9th, 2024

xinxuan.zhang@uconn.edu

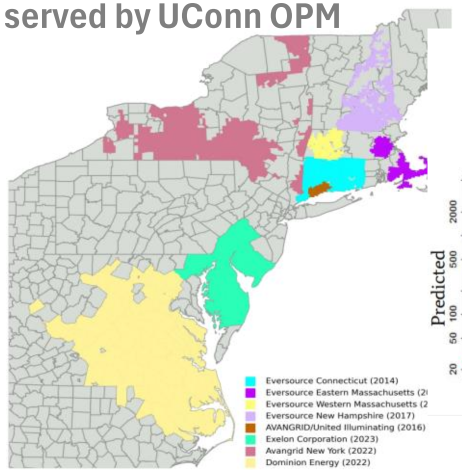
UCONN Eversource Energy Center EVERSOURCE

Industry Relevance & Need

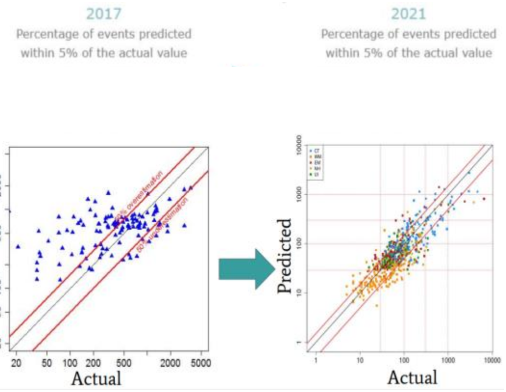
History

- Weather-related **power outages prediction models** (**OPM**) have been used to help pre-storm preparedness for utilities.
- The OPM performance keeps improving during the past decade.

The Expansion of Territories served by UConn OPM



OPM improvements



Challenge

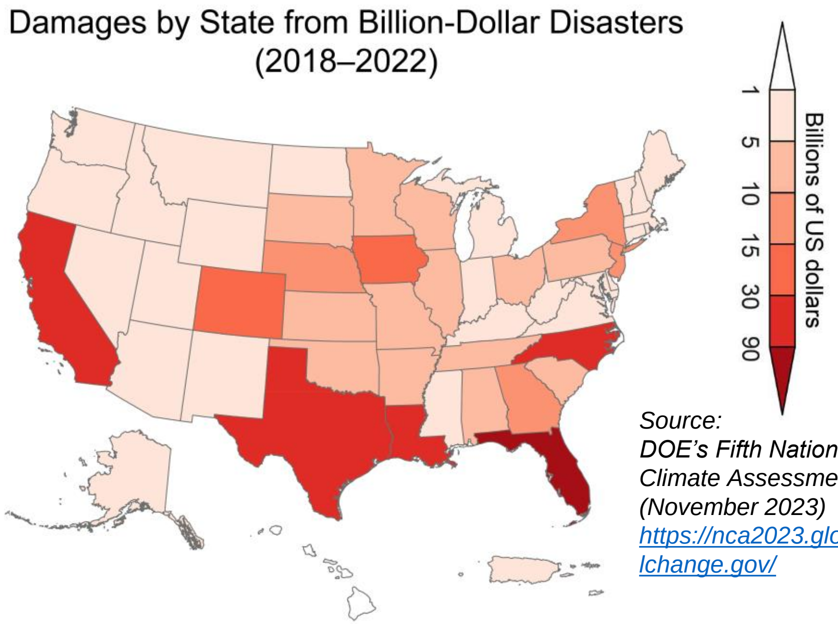
The current OPM requires a comprehensive list of high-resolution input parameters that are typically derived from the regional meso-scale atmospheric models with a high computational cost.

- **For climate studies, there are difficulties to adopt the current OPM framework due to limited data at climate scale.**
- We need to develop new approaches that make use of the limited parameters from climate datasets and consider the uncertainties of long-term climate projections.
- The project results will provide important information on how future climate change may affect the electric distribution planning, operations, and infrastructure.

Project Goals and Objectives

Pillar 1 & 2 – Project 6

UCONN TECH PARK



Source:
DOE's Fifth National Climate Assessment (November 2023)
https://nca2023.globalchange.gov/

The US now experiences, on average, a billion-dollar weather or climate disaster every three weeks.

- Billion-dollar weather and climate disasters are events where damages/costs reach or exceed $1 billion, including adjustments for inflation.
- Between 2018 and 2022, 89 such events affected the US, including 4 droughts, 6 floods, 52 severe storms, 18 tropical cyclones, 5 wildfires, and 4 winter storm events.

Research questions

1. How to effectively and accurately quantify the occurrence and intensity of weather events and their changes based on long-time climate projections?
2. How to quantitatively assess the relationship between the return periods of weather events and the corresponding power outages?
3. How to locate power asset vulnerabilities under a changing climate and when will be the turning point for different regions?

Objectives

- Analyzing the relationship between power outages and weather events during the historical period.
- Establish a framework that can estimate the likelihood of outage occurrences in future periods (e.g. 2040-2060, 2080-2100) based on the ensemble future climate datasets.

Overall, we will provide valuable insights into the frequency and severity of power outages under future climate, enabling more effective resilience improvement investments and resource allocation.

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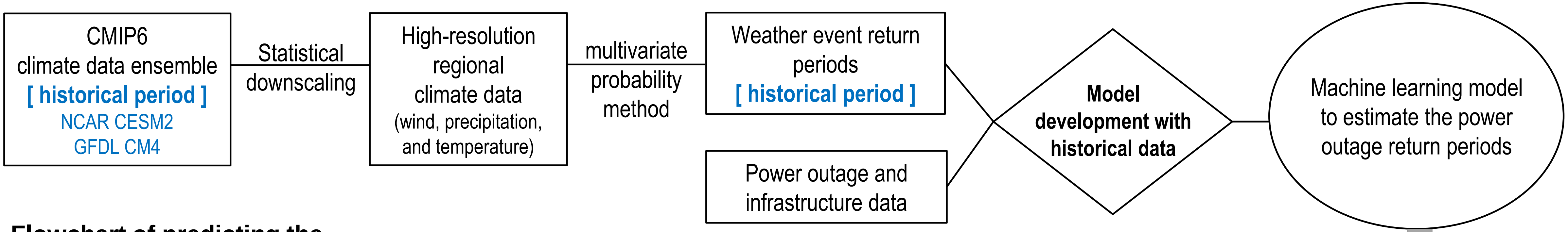
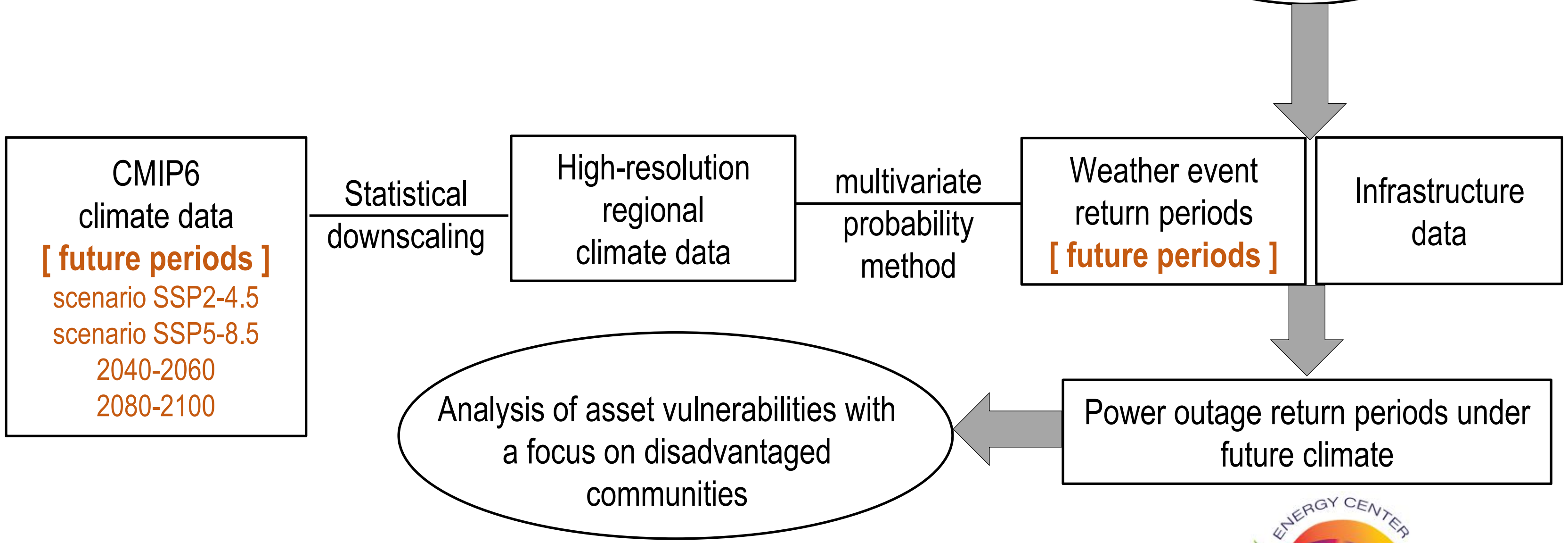
Research Approach



Flowchart of predicting the event outage return period under different future climate scenarios



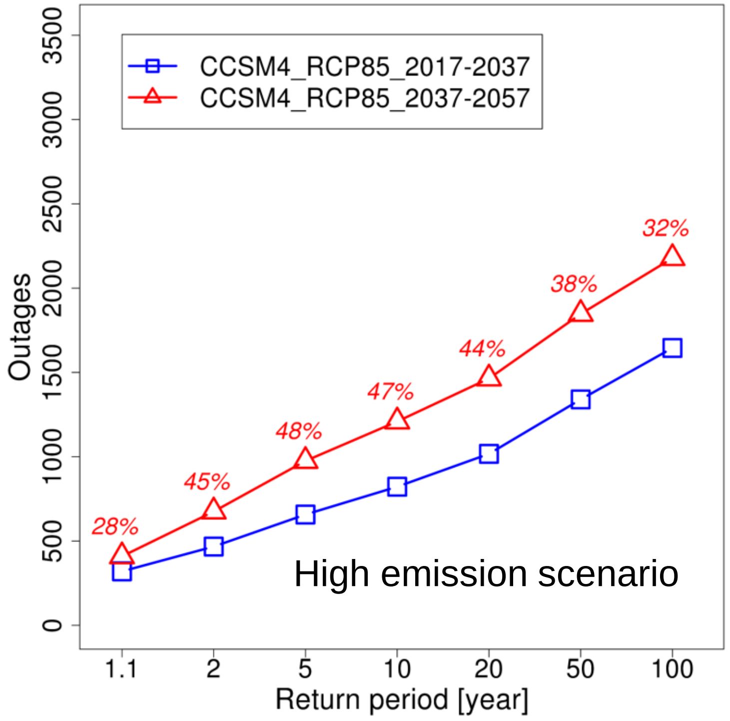
- **CMIP6**: the Coupled Model Intercomparison Project Phase 6 (CMIP6) is an international collaborative framework designed to improve knowledge of climate change, led by World Climate Research Programme (WCRP)
- **NCAR CESM2**: the latest version of Community Earth System Model (CESM) by National Center for Atmospheric Research (NCAR)
- **GFDL CM4**: the latest version of Global Climate Model (CM4) by NOAA's Geophysical Fluid Dynamics Laboratory (GFDL)
- **SSP**: Shared Socioeconomic Pathway
- **RCP**: Representative Concentration Pathway
- **Scenario SSP2-4.5**: Middle emission scenario for future climate
- **Scenario SSP5-8.5**: High emission scenario for future climate

Outcomes and Deliverables

Deliverables

1. Downscaled ensemble climate datasets over historical and future periods under scenarios SSP2-4.5 and SSP5-8.5
2. Return period estimates for weather events, as gridded products or at circuit/substation level in CT territory.
3. Machine learning model that provides return period estimates for the number of power outages, derived based on the historical weather data and power assets information.
4. Report on the evolving trends of power outage return periods under future climate projections.

Preliminary results based on CMIP5 product



Resilience System Performance Modeling in a Changing Climate

Team: Amvrossios (Ross) Bagtzoglou; Wei Zhang; Xinxuan Zhang

amvrossios.bagtzoglou@uconn.edu

Please email me for questions and paper requests

Proposed Work & Progress to date

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?

Pillar 1 & 2 – Project 7

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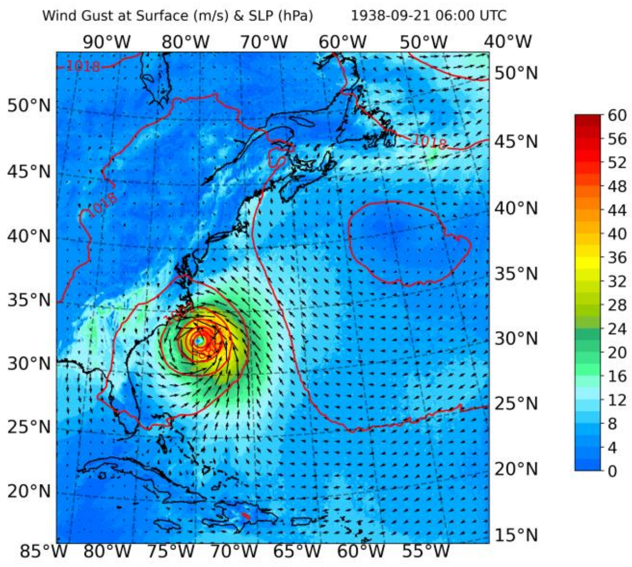
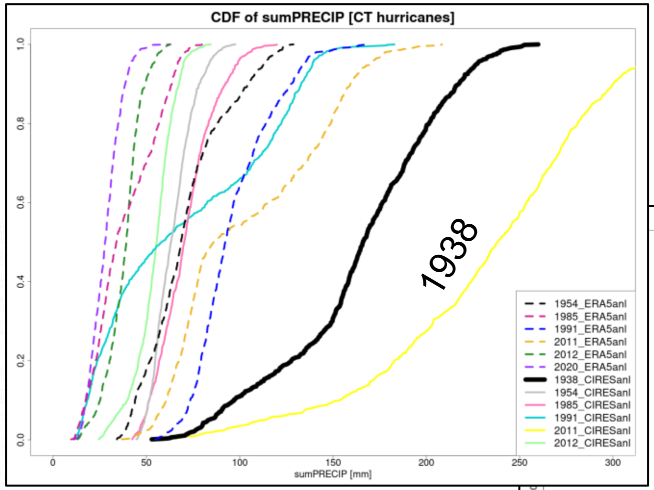
- Northeast region does not encounter hurricane often, but each occurrence brings catastrophic impact on power systems.
  - Assess the current power system resilience with historical extreme events [New England hurricane **1938**, Hurricane Carol **1954**, Hurricane Gloria **1985**, Hurricane Bob **1991**,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

New England 1938

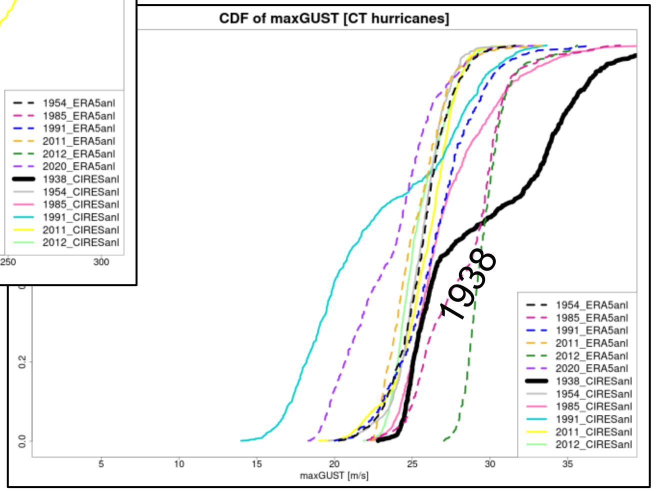
High-resolution weather data (Gust) from WRF-based dynamical downscaling



Comparison of weather data among hurricanes



Precipitation



Gust

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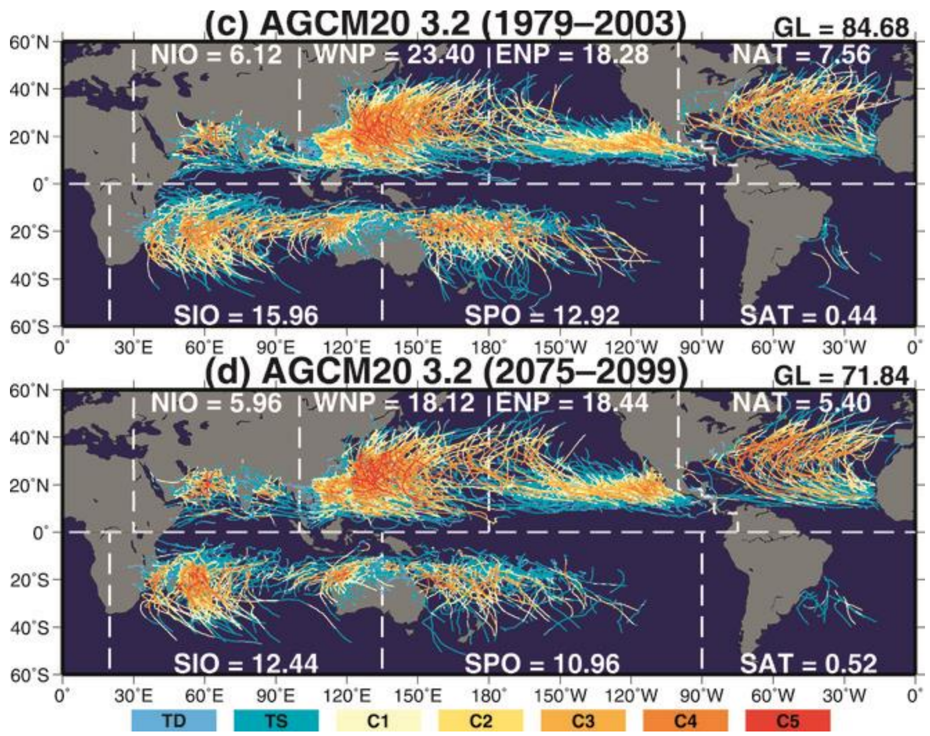
T4: Extreme events under future climate scenarios

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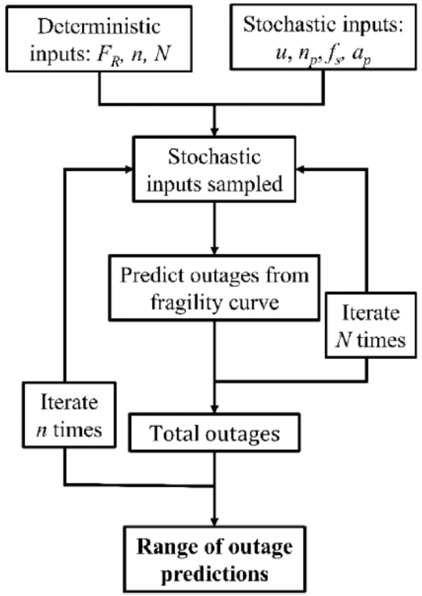
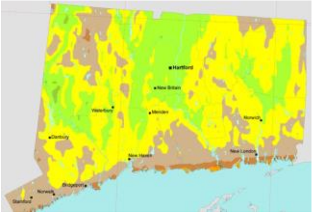
- Updating mechanistic fragility curves with the historic outage data.
- The hybrid model shows potential improvements of 25-50% in prediction accuracy over the purely data-driven approaches for high-impact storm events where the data-driven modeling is limited by lacking data.
- As more data become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

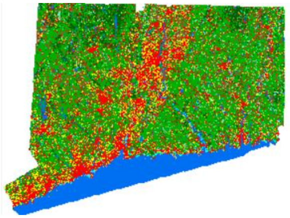


Input Data

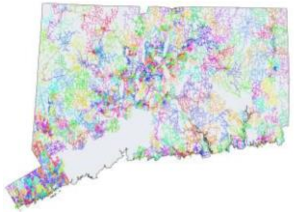


Weather

Vegetation



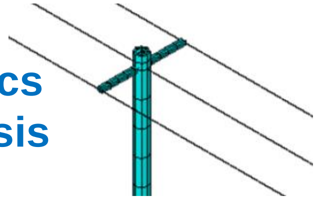
Land Cover



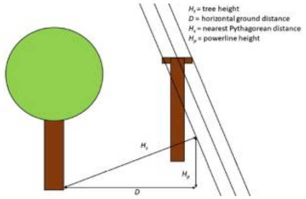
Infrastructure

Data-driven Model

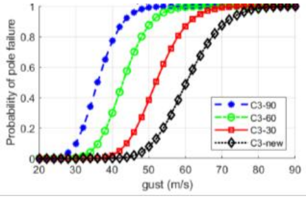
Physics Analysis



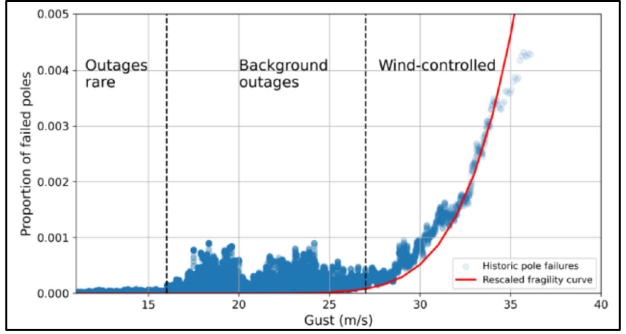
Structural Model



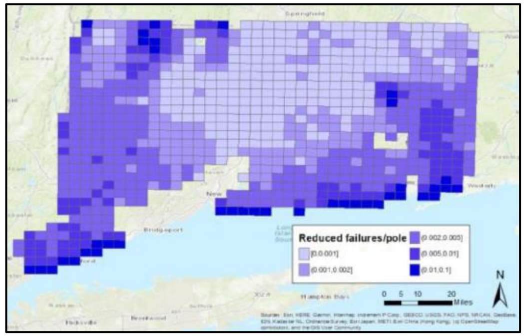
Tree Risk Model



Fragility Curve

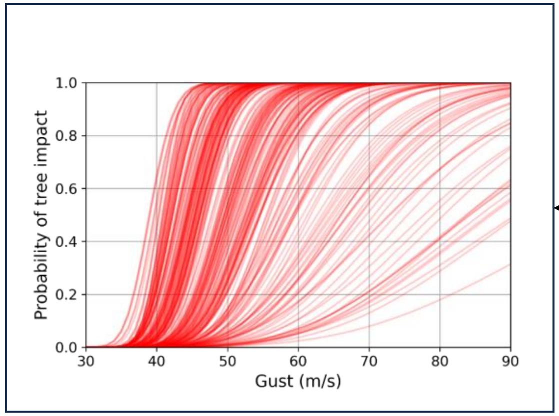


Outage Prediction

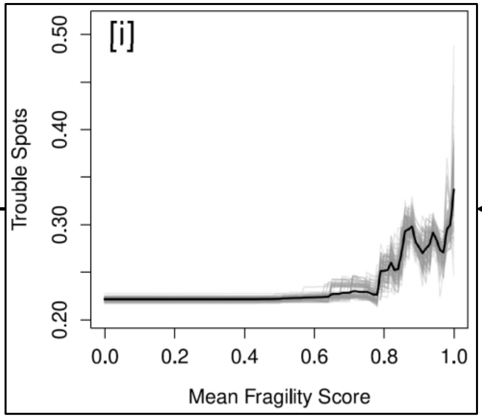


T3, T4: Assessment of Grid Hardening Strategies based on Hybrid Mechanistic-Machine Learning Outage Prediction Model

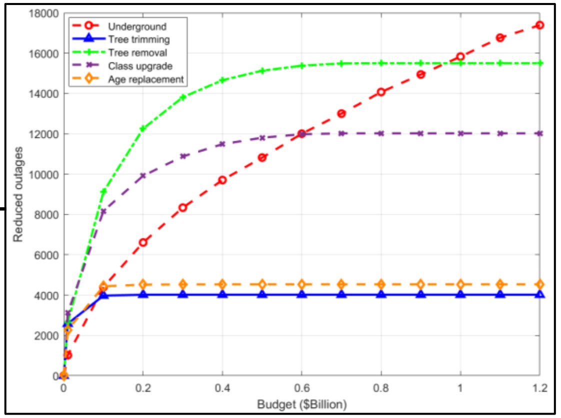
- Hybrid OPM model is sensitive both to changes in infrastructure and environmental/vegetation parameters.
- The efficacy of grid hardening strategies can be assessed based on predictions under different hypothetical scenarios.



Fragility Curves



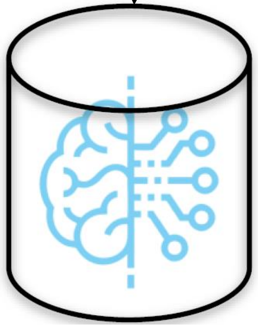
Hardening Simulation



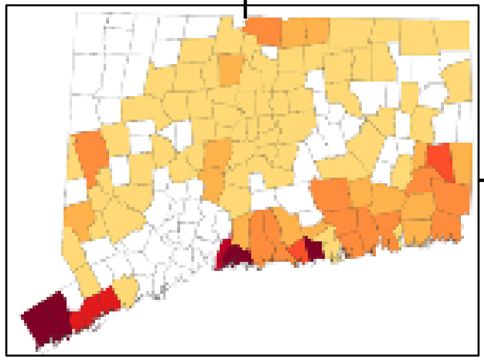
Optimization

Resilience Strategies & Fragility updates

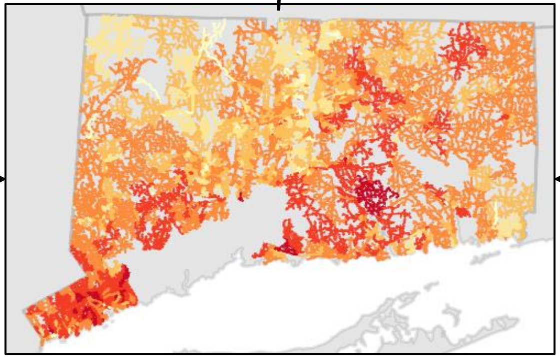
Underground
Tree trimming/removal
Class upgrade
Age replacement



Machine Learning Model



Outage Predictions



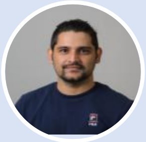
Cost-Benefit Analysis

Multi-source Remote Sensing Data for Modelling Tree Risk on Utility Infrastructure and Leveraging Climate Adapted Vegetation Management

09 February 2024

Prof. Chandi Witharana
University of Connecticut

PhD students | **Durga Joshi**



Harshana Wedegedara

University of Connecticut

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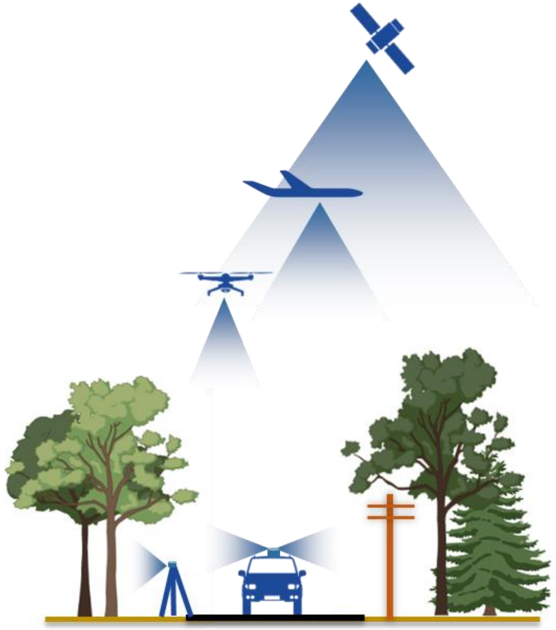
NATURAL RESOURCES AND THE ENVIRONMENT



Industry Relevance & Need

Characterization of roadside vegetation can assist utility industry to effectively allocate resources to implement vegetation management programs – tree trimming and removal operations, when & where needed basis.

The key **challenge** confronted in vegetation risk modelling is to obtain **tree structure and health** information over a **large area** - across different granularities from pole span, isolation device exposure zone, to circuit level - without compromising spatial details.

Project Goals and Objectives

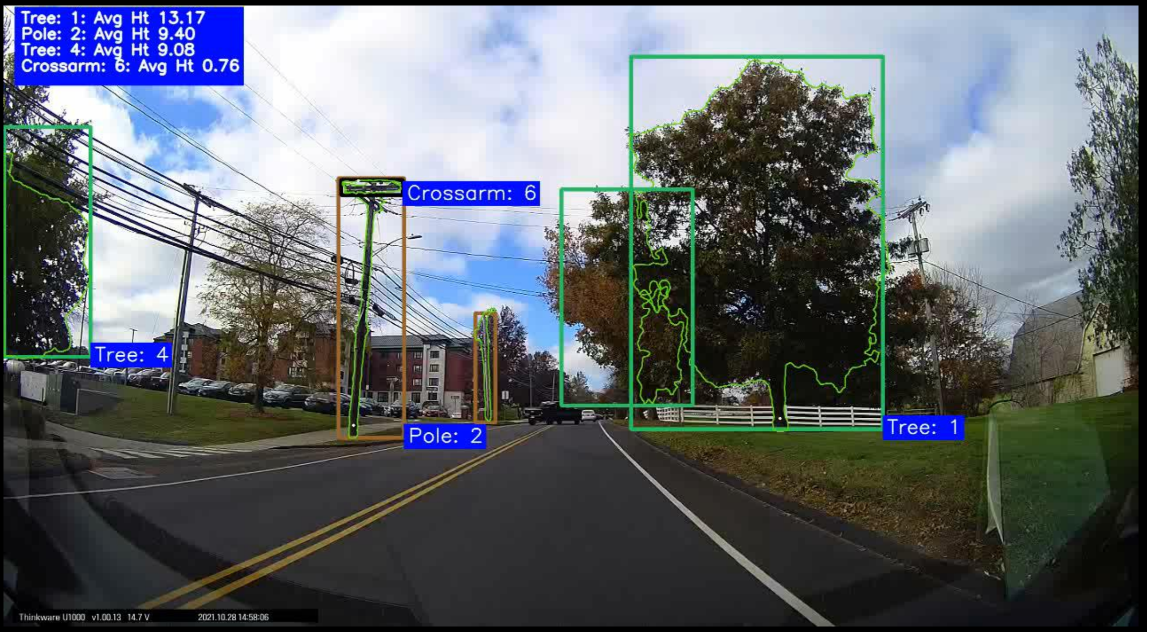
Goal

To combine **multi-modal** remote sensing observations to monitor and assess roadside **tree structure** and **health** condition and to develop **spatially explicit** models to predict tree failure risk.

Objectives

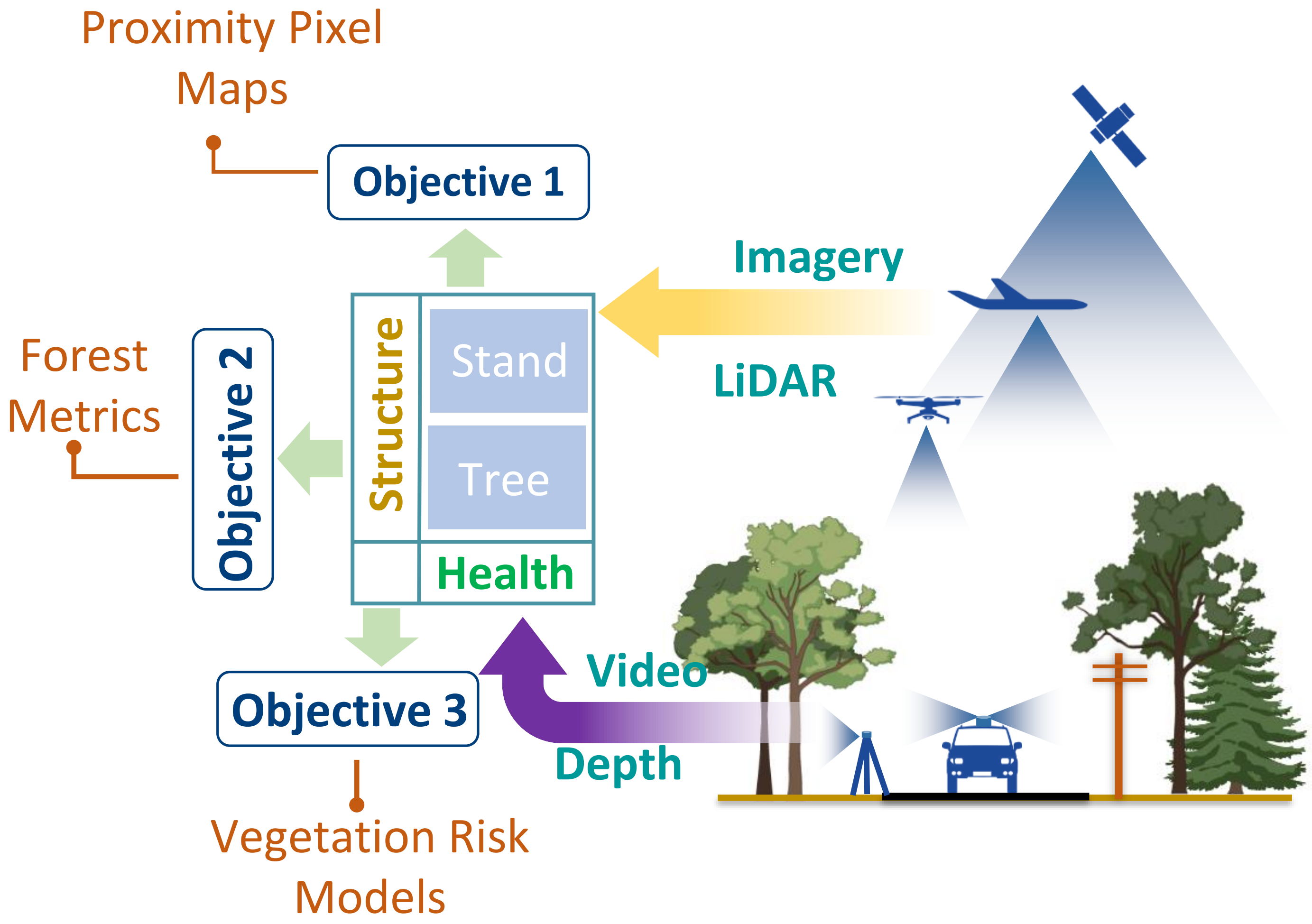
1. Develop a new statewide **proximity pixel map** (version 2.0) based on the 2023 LiDAR data to improve the outage prediction modelling
2. Derive LiDAR-based **forest metrics** that explain tree structural characteristics and relate to tree biomechanics modelling
3. Combine **mobile** and **overhead** remote sensing to inform vegetation risk modelling and optimal targeting of vegetation management programs

Research Approach

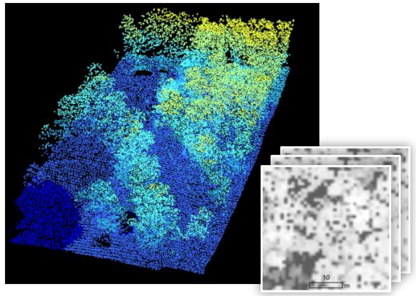


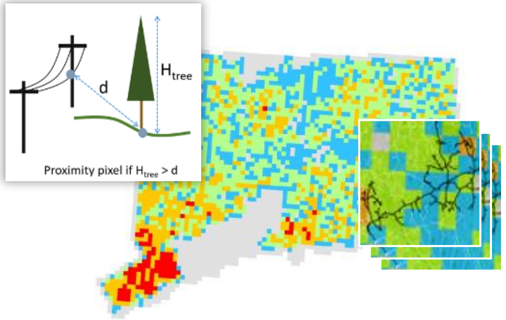
Vehicle-based Tree Assays

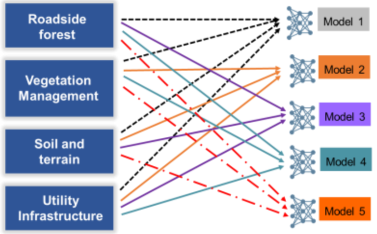
Remote Sensing of Forest-Infrastructure System



Outcomes and Deliverables







- Tree canopy height models
- LiDAR-based forest metrics
- New version of proximity pixel maps
- ML/AI models to integrate vehicle-based and overhead remote sensing data
- Improved vegetation risk models at multiple spatial scales

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Research Impact

Research outcomes will generate new **knowledge** and **tools** to leverage climate adapted vegetation management for;

- maximizing grid resilience
- optimizing management investment on roadside forest
- sustaining ecosystem benefits

Pillar 1 & 2 – Project 9

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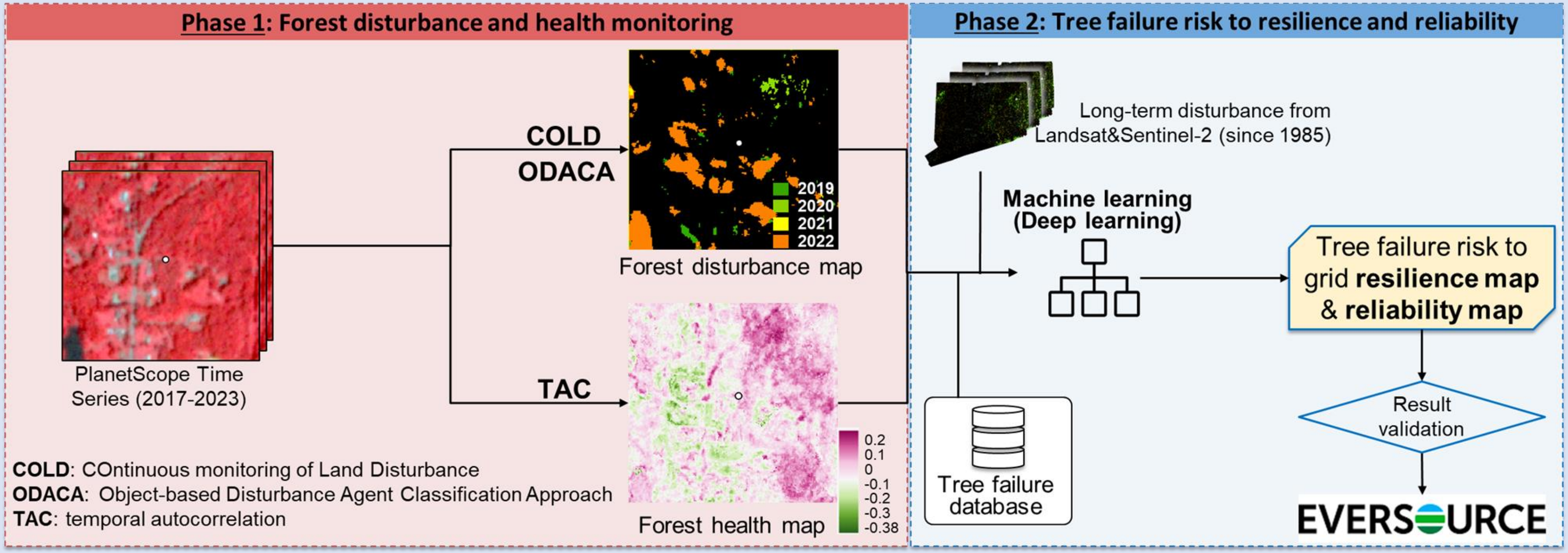
Estimating Roadside Tree Risk To Grid Resilience and Reliability Using PlanetScope Time Series



09 February 2024

Zhe Zhu, Shi Qiu, Kexin Song, *University of Connecticut*

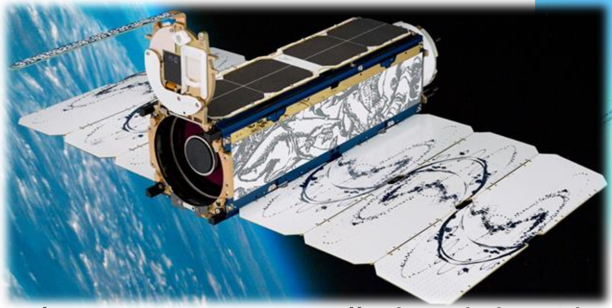
Industry Relevance & Need

- Mitigating **vegetation risk to infrastructure** is a major challenge in highly forested areas.
  - **43%** of CT tree-caused outages in **windy conditions**. → resilience
  - **39%** of incidents observed in **normal weather conditions**. → reliability

A fallen roadside tree in New Canaan in the aftermath of Tropical Storm Isaias (*Hearst Connecticut Media*).

- Two important factors influencing the risk are the **disturbance and health** the roadside and right-of-way (ROW) forests.

- **3 m PlanetScope time series** can provide regularly-update site-level vegetation risk information.
  - Help identify hazardous trees to **prevent tree fall events**.
  - Improve the predictive capability of **grid reliability and resilience**, such as the UConn Storm Outage Prediction Model (OPM).



PlanetScope constellation *(Planet).*

Project Goals and Objectives

The goal of this proposed project is to provide a **forest disturbance** and **health monitoring** framework for roadside **utility risk assessments**.

Objectives:

1. Monitor **forest disturbances** of the study site with 3-m PlanetScope time series and the COntinuous Land disturbance Detection (COLD) algorithm.
2. Monitor **forest health changes** with 3-m PlanetScope time series and the temporal autocorrelation (TAC).
3. Quantify **tree failure risks to grid resilience and reliability** using machine learning (deep learning).

Research Approach

Pillar 1 & 2 – Project 9

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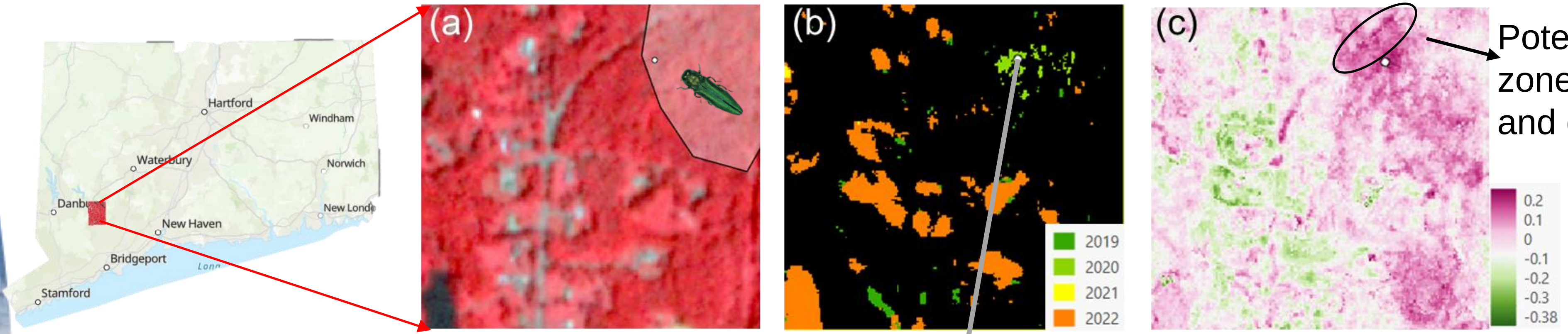
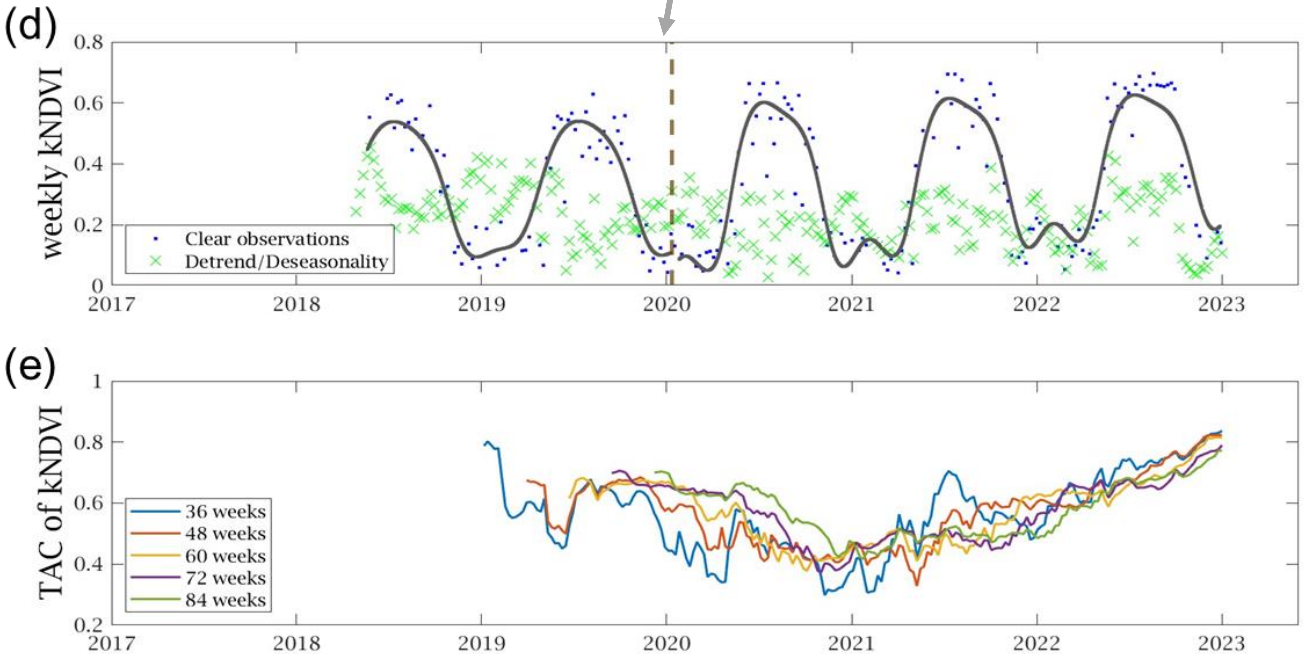


Potential high-risk zone of tree failure and outages

COntinuous monitoring of Land Disturbance (COLD)



Lag-1 temporal autocorrelation (TAC)

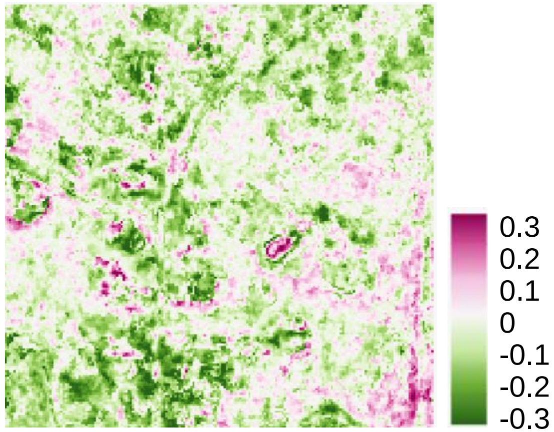
Outcomes and Deliverables

We will employ time series analysis and machine learning (deep learning) to provide:

- **Forest disturbance (annual),**
- **Forest health (weekly or bi-weekly),**
- **Forest risk products (same frequency as forest health)**.

These products would help modeling the effects of vegetation management on grid resilience and reliability.

Forest health change
(2020 – 2022)



Research Impact

- This project aligns tightly with the goal of **Eversource – UConn Partnership Research Pillars**.
  - Enabling quick and efficient prioritization of vegetation management efforts to prevent tree fall events and mitigate the risk of power outages.
  - Improving the predictive capability of grid reliability and informing decision-making.
- This project will likely lead to multiple extramural research supports, including the **NSF Humans, Disasters, and the Built Environment (HDBE)** program, and the **NASA Land-Cover and Land-Use Change (LCLUC), Future Investigators in NASA Earth and Space Science and Technology (FINESST)** programs.