# Forecasting Damage on Power Infrastructure

Emmanouil Anagnostou

Center Director

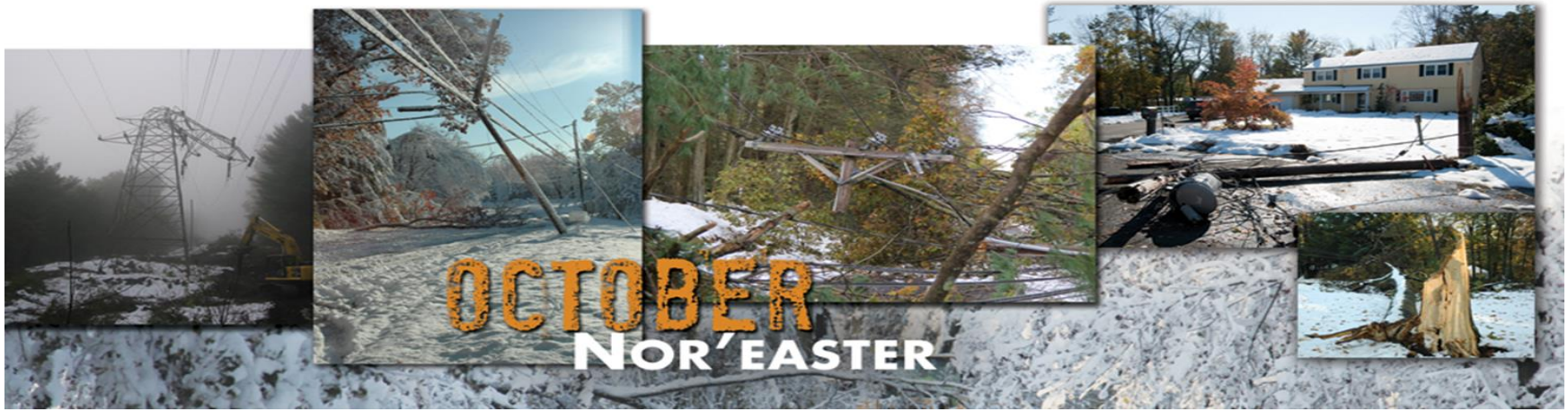
Board of Trustees Distinguished Professor

Endowed Chair in Environmental Engineering

NSF CRISP (ERIC) SYMPOSIUM - October 24-25

# 2011 & 2012 Storms Revealed Information Gaps in Decision Making

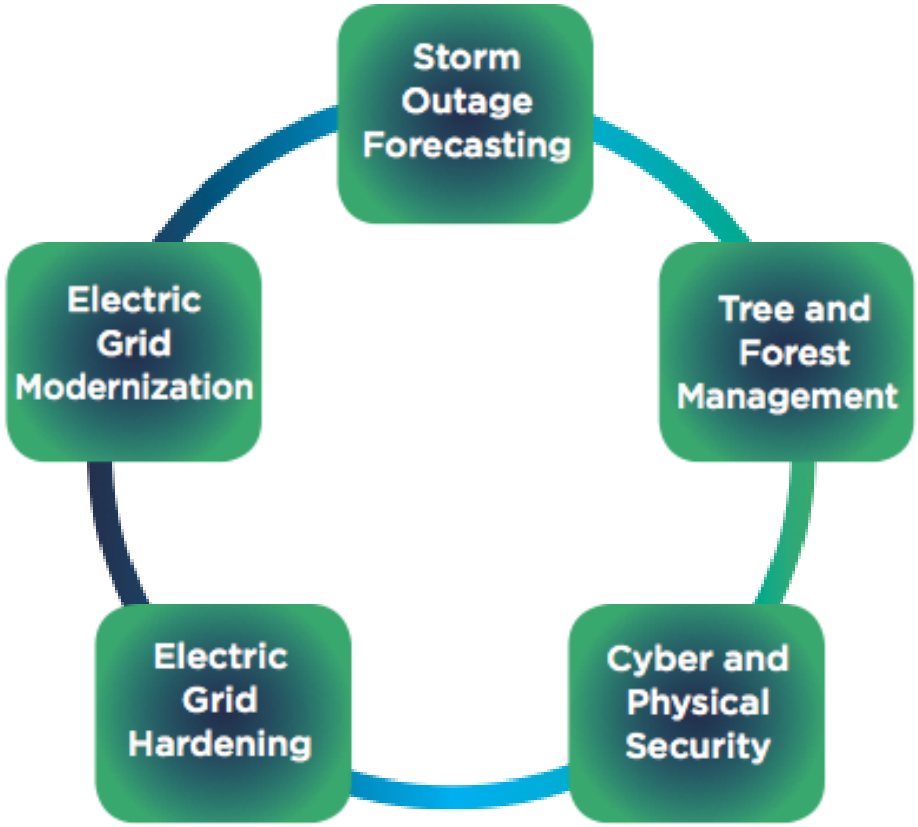

Irene ($20B), October Nor'easter ($3B), Sandy ($62B)

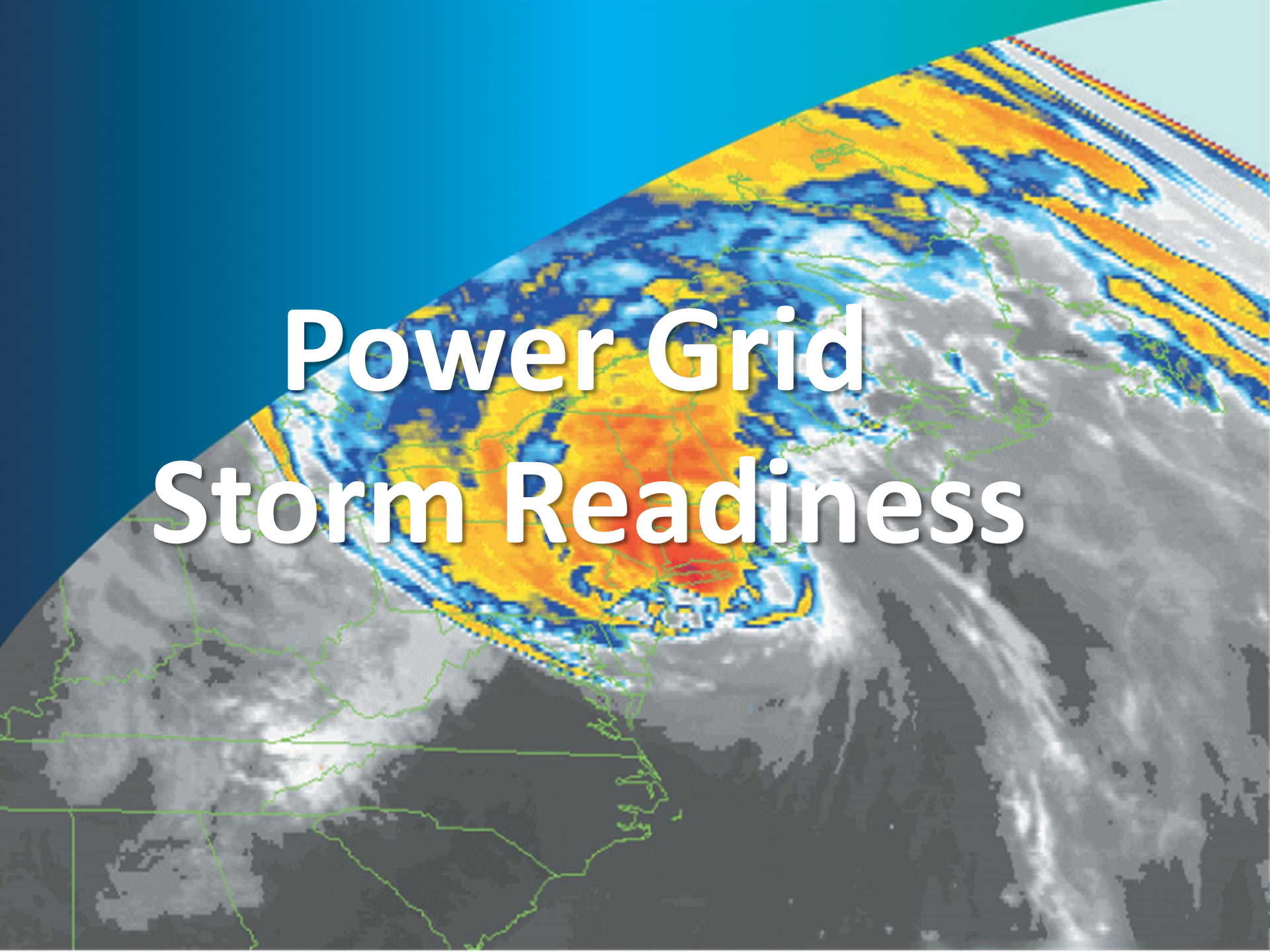


# Eversource Energy Center

*mission and goals*

*"Advance leading-edge interdisciplinary research and technology to assure reliable power during extreme weather and security events"*




Power Grid
Storm Readiness

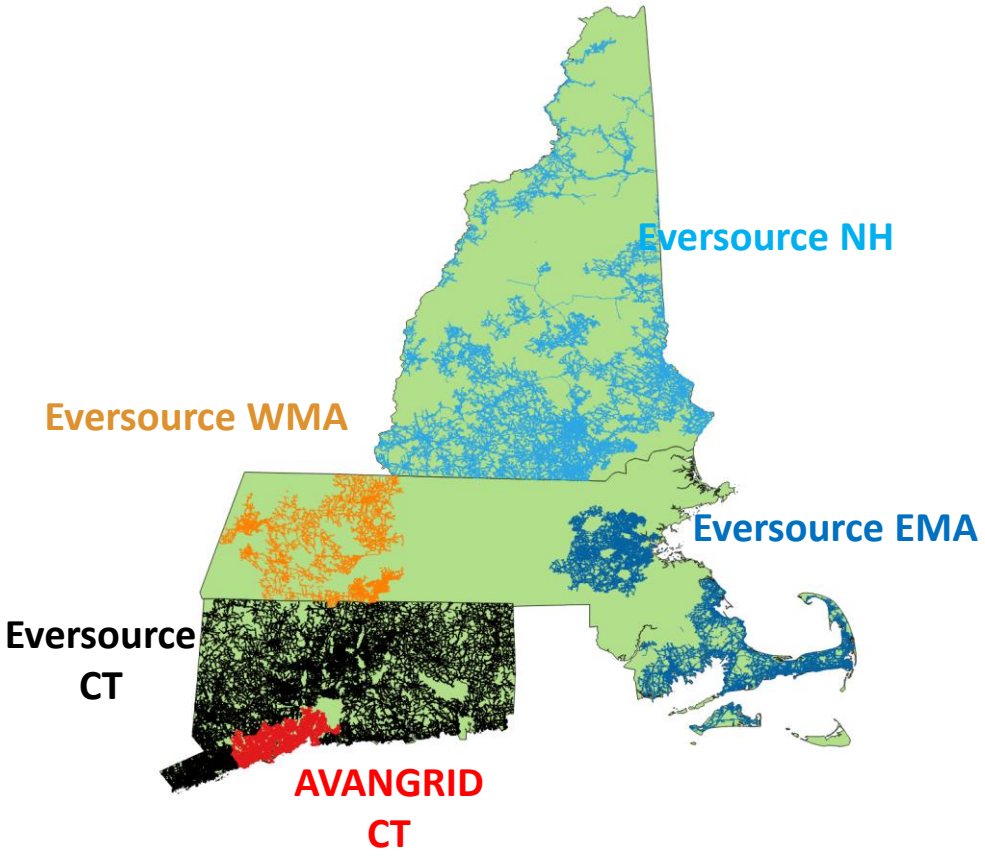
# Storm Outage Forecasting

UConn OPM
OUTAGE PREDICTION MODEL

***Informed decision making for securing and prepositioning of crews & resources***

*A computerized intelligence system that combines infrastructure, tree and varying storm characteristics to:*

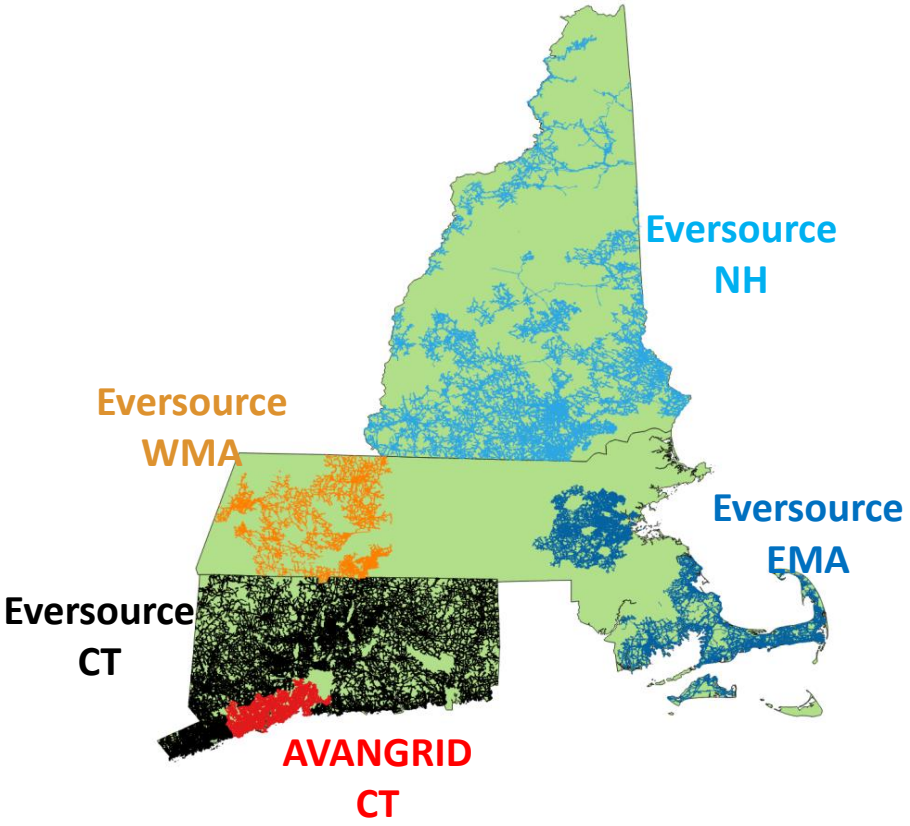
- predict the likely storm impact and a visualization of where outages are likely to occur.
- provide resiliency insights, such as quantifying the value of vegetation management and other network hardening investments.



# OPM Coverage

UConn OPM
OUTAGE PREDICTION MODEL

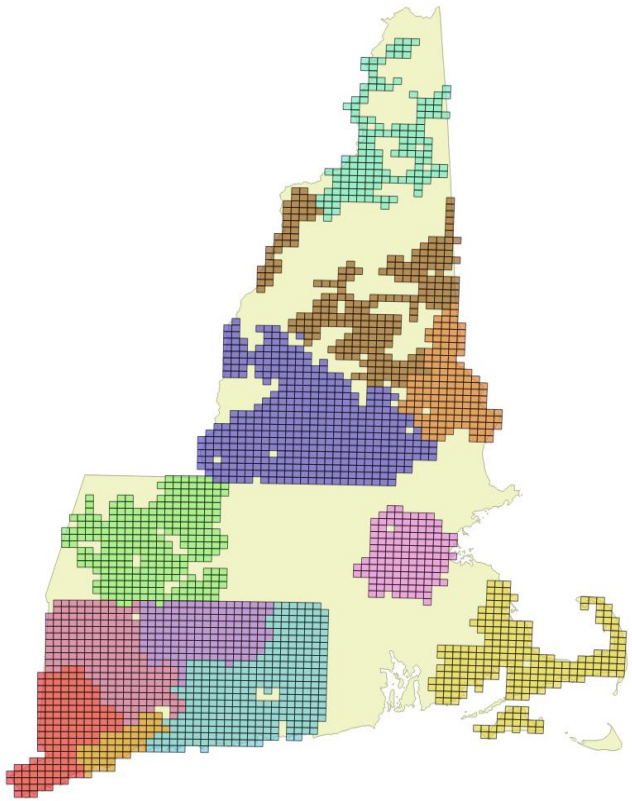
- We have a different OPM for different types of weather: Rain/Wind, Snow/Ice, Thunderstorms, and Extreme Events.
- The OPM is run independently for each service territory.
- We classify each storm at the service territory level: a storm can be classified as Rain/Wind in Connecticut and as Snow/Ice in New Hampshire.



# How it Works

UConn OPM
OUTAGE PREDICTION MODEL

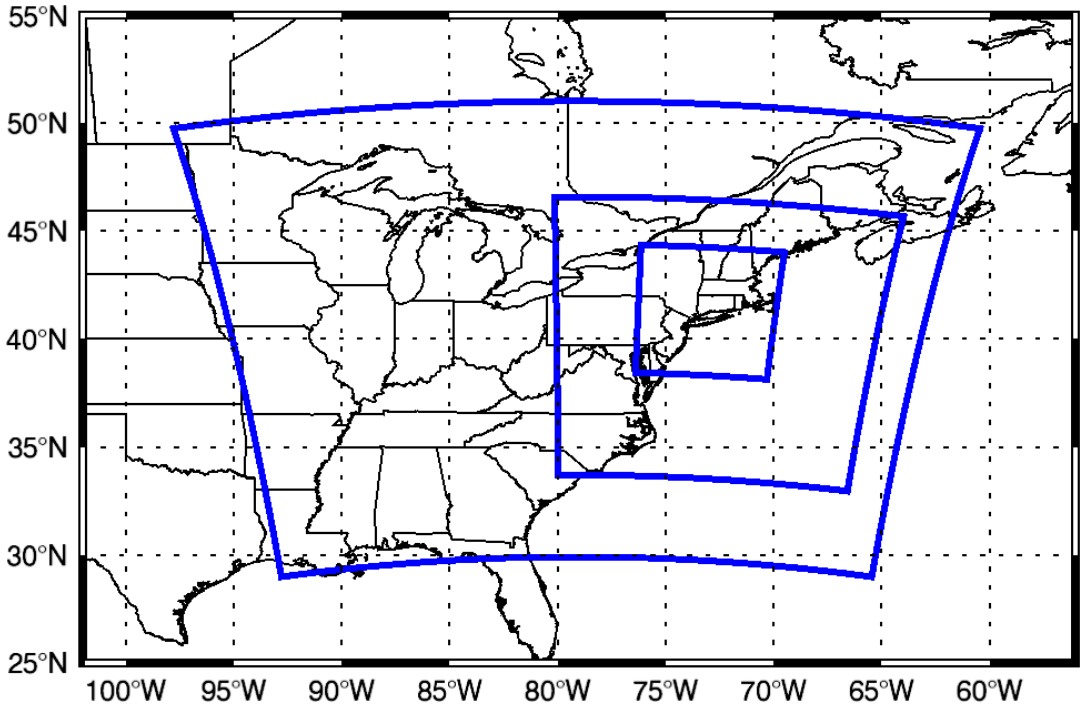
1. We identify and develop a database of weather events of interest, and analyze these events with our weather models.
2. For every grid cell in our system, we aggregate information about outages, infrastructure, the environment, and weather.
3. We use the aggregated information to train a Machine Learning model so that it understands the non-linear patterns between weather, infrastructure, environment, and outages.
4. Using this Machine Learning model, we can predict expected outages based on a weather forecasts.



# Weather Input

UConn OPM
OUTAGE PREDICTION MODEL

- We run our own weather models to generate the weather data for the OPM
- We currently run three different models at different resolutions:
  - WRF 3.8 (4 km) or (2km for T-storms)
  - WRF 3.7 (2 km)
  - RAMS/ICLAMS (2 km)

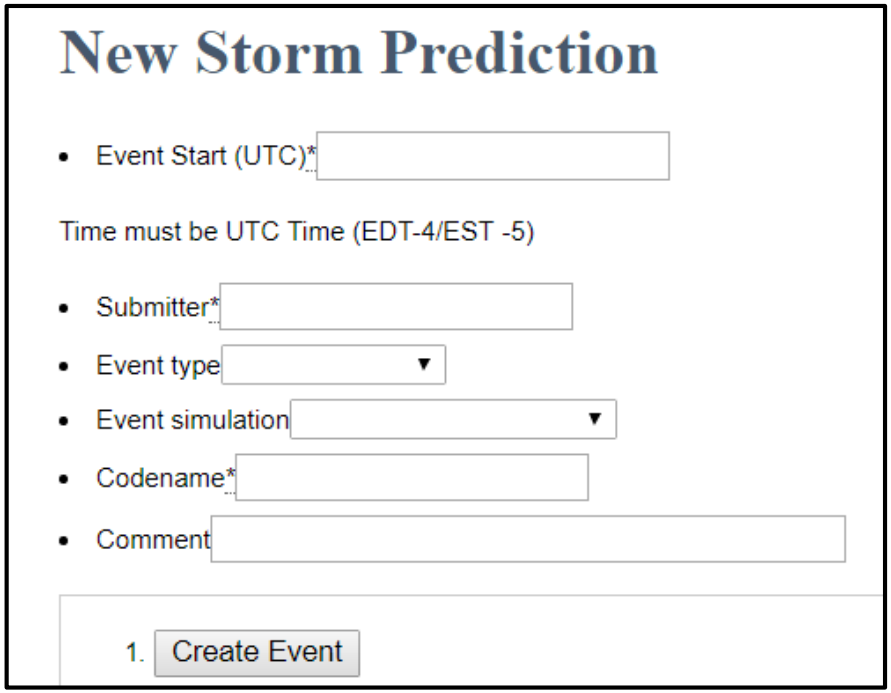



The Nested Domains of our WRF 3.7 Weather Model

# Operations

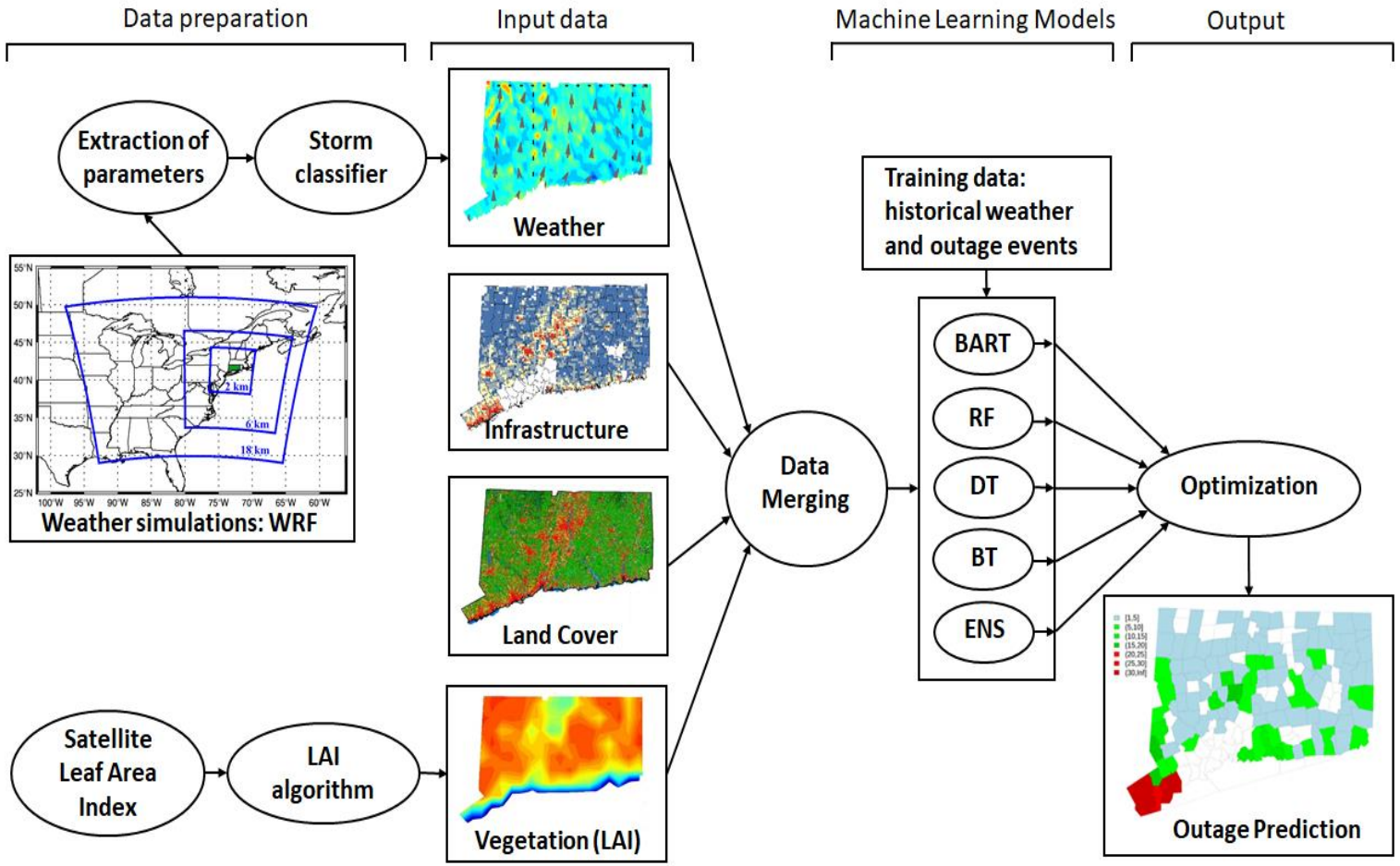
UConn OPM
OUTAGE PREDICTION MODEL

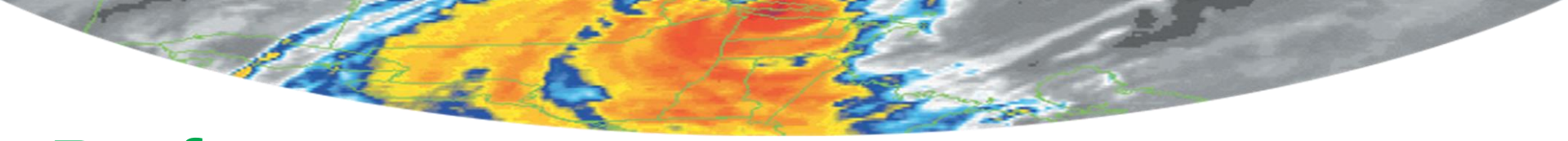
1. The system is triggered on-line, via a password protected webpage;
2. We identify weather events that might affect the electric grid in 3 to 5 days;
3. We determine, for each territory, a time window (up to 48 hours) and an event type (rain and wind, thunderstorm, snow and ice, hurricane);
4. We choose the weather forecasting model to run (WRF3.8, WRF3.7, RAMS/ICLAMS);



# Architecture

UConn OPM
OUTAGE PREDICTION MODEL

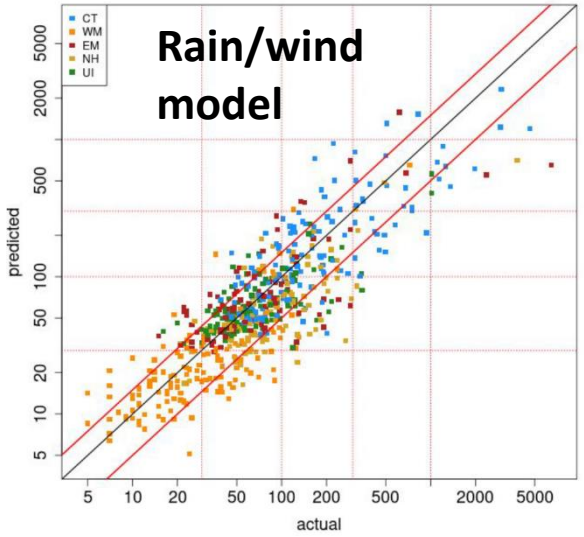


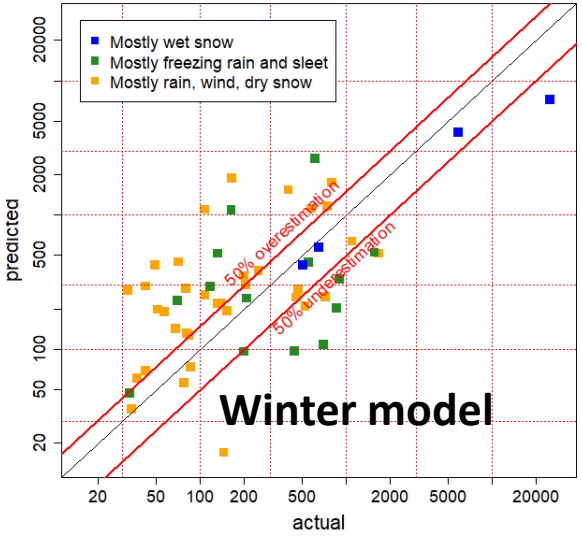


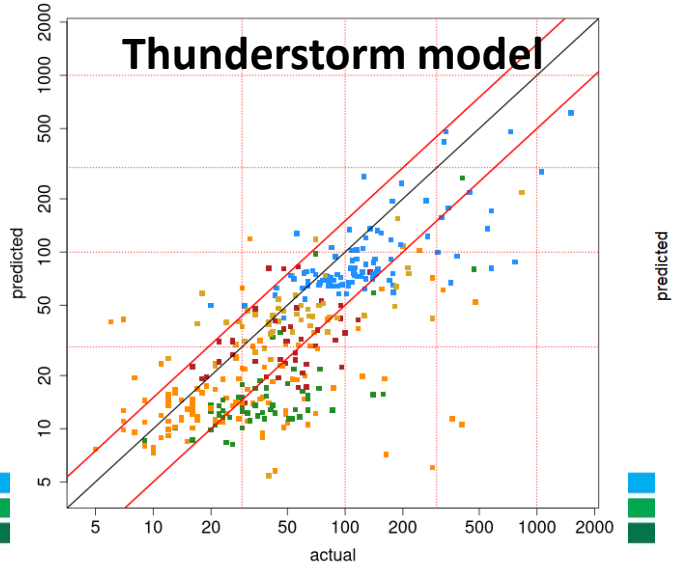
# Performance

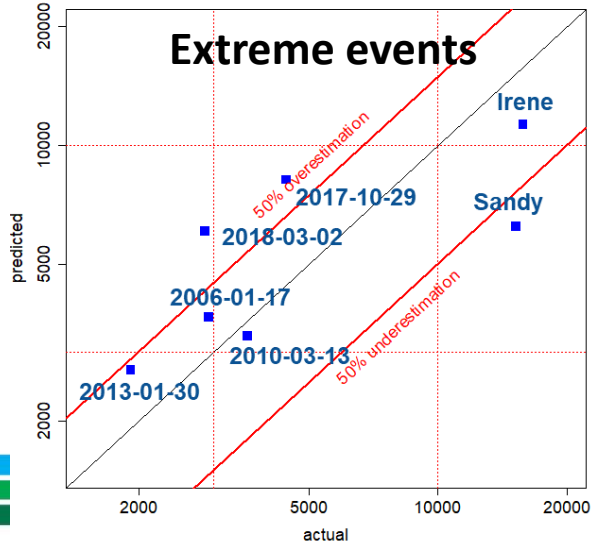
UConn OPM
OUTAGE PREDICTION MODEL

500 rain/wind, T-storm, winter and extreme events

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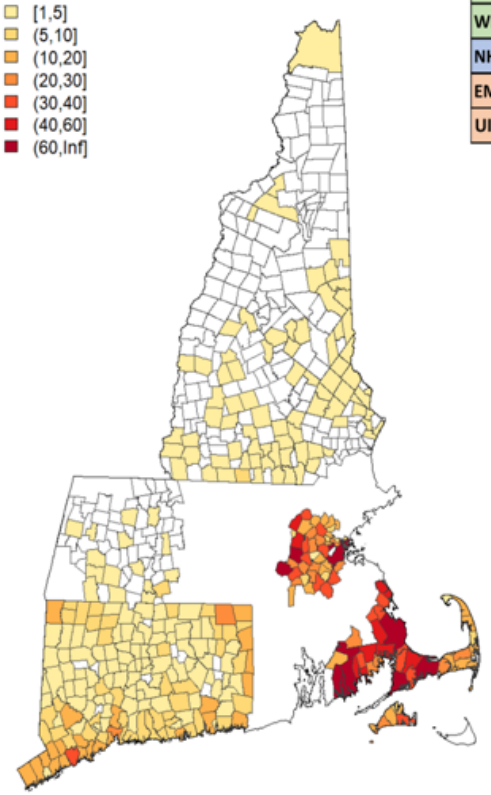
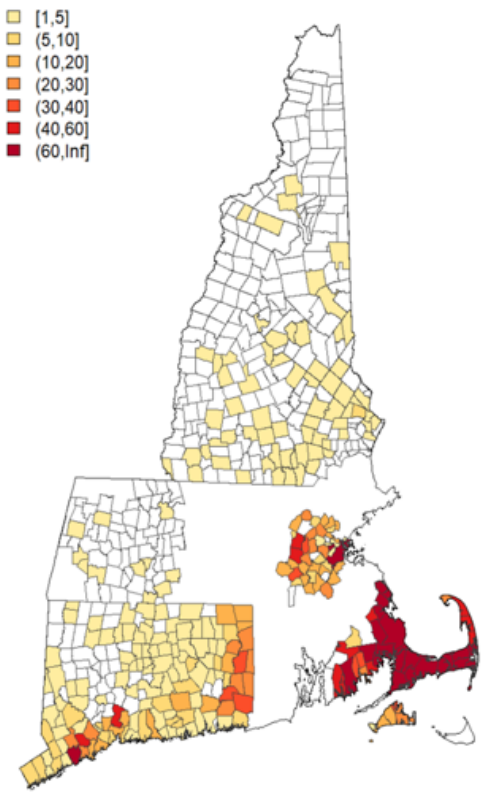
# Performance

Case study

## Eversource Energy Center OPM Performance for March 13th 2018 Nor'Easter

| | OPM | Actual |
|---|---|---|
| CT | 500-1000 | 646 |
| WMA | 20-40 | 22 |
| NH | 200-400 | 78 |
| EMA | 2000-3500+ | 4874 |
| UI | 120-250 | 360 |

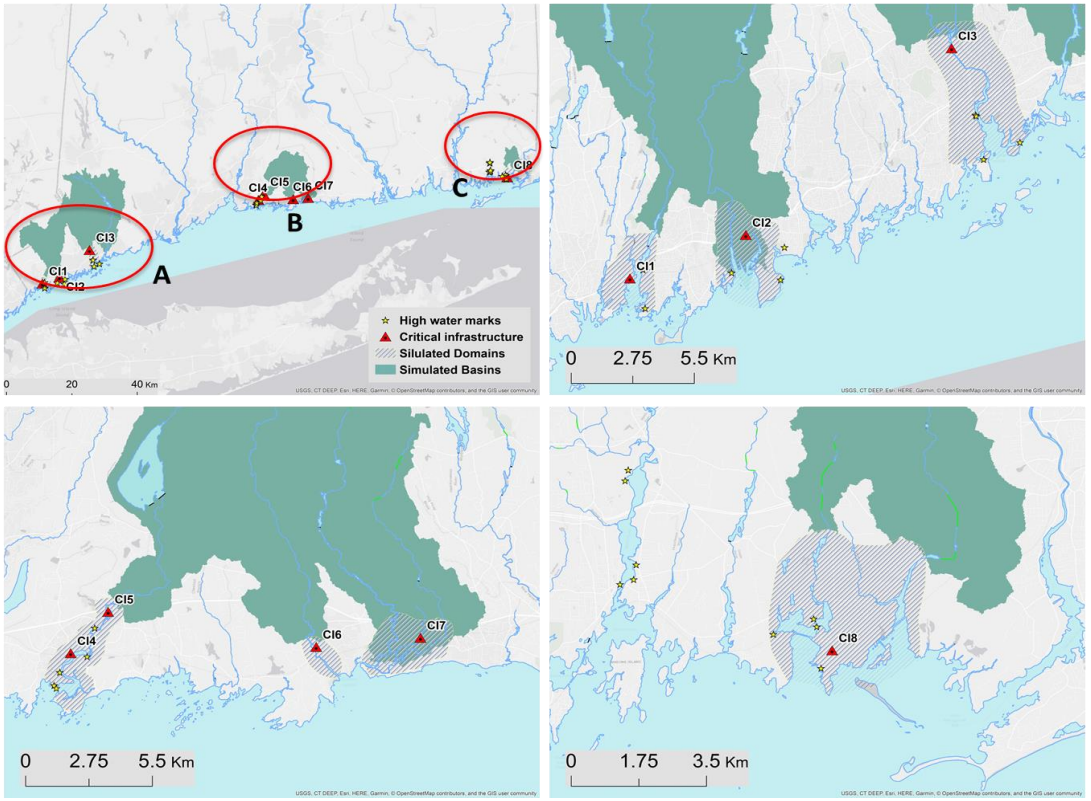


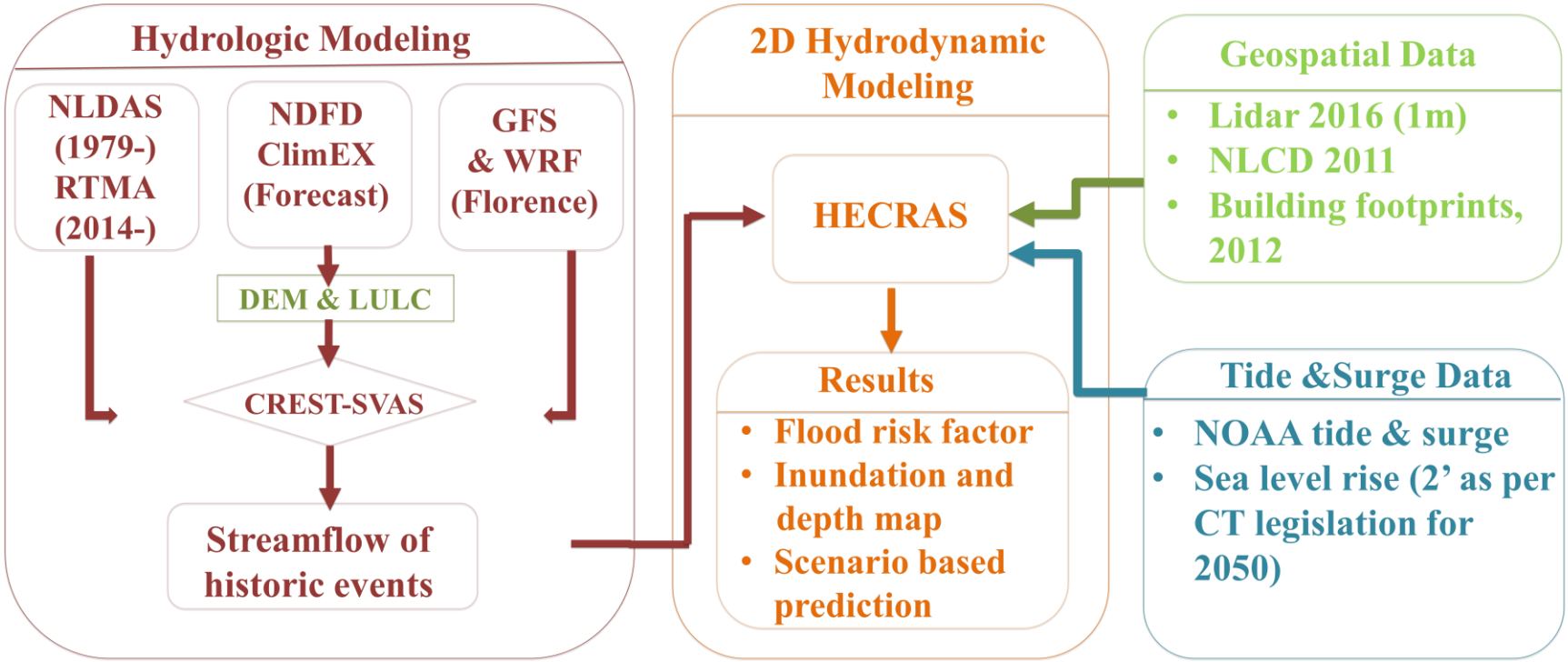

Vulnerability
Assessment

# Substations Vulnerability to Compound Flood Events

- Derive inundation maps for potential hurricane landfalls in New England: compound hazards from riverine flooding, coastal surge and tide, and SLR (sea level rise) due to climate change effects.
- Pilot a real-time flood forecasting system for early warning flood inundation at the selected substations.



# Simulation Framework



# Substations Vulnerability to Compound Flood Events

**IRENE, 2011**

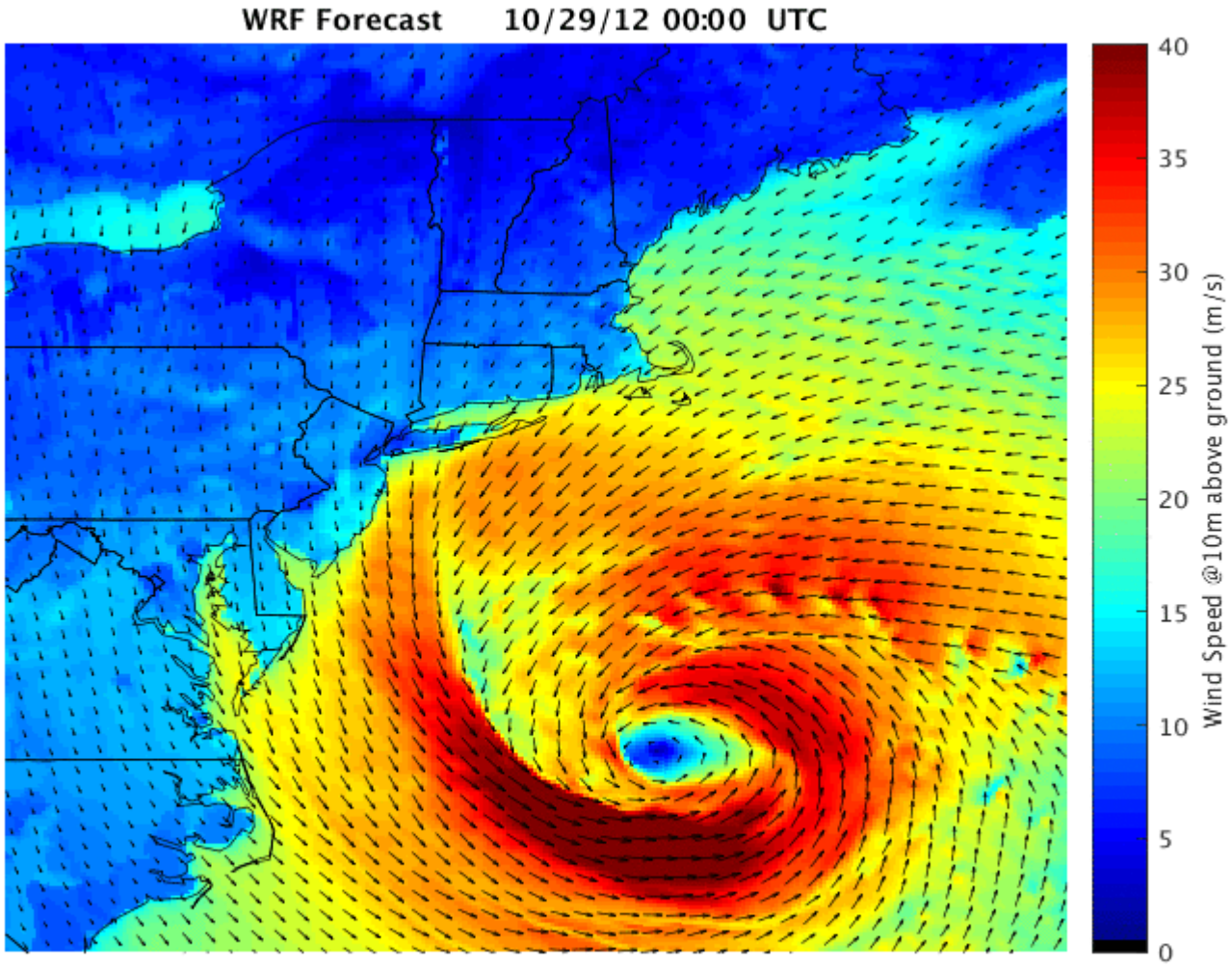
- **IR (NOAA WL & Simulated streamflow actual Irene)**
- **IR+SLR (NOAA WL + SLR & Simulated streamflow for actual**

| Stations | Basin averaged accumulated precipitation (mm) | | | | Peak flow of simulated event, $m^3/s$ | | | |
|---|---|---|---|---|---|---|---|---|
| | Irene | Actual Sandy | Future Sandy | Florence | Irene | Actual Sandy | Future Sandy | Florence |
| Norwalk 9S | 173.5 | 21.5 | 526.8 | 165.1 | 126.7 | 3.3 | 201.7 | 74.9 |
| Branford & Meadow | 98.1 | 17.0 | 338.2 | 192.0 | 93.9 | 4.7 | 178.3 | 106.1 |
| Southend | 177.8 | 24.7 | 546.9 | 147.5 | 201.1 | 9.3 | 319.1 | 87.3 |
| Bostonpost | 86.1 | 15.1 | 316.6 | 200.7 | 93.5 | 0.9 | 197.0 | 143.2 |
| Coscob | 187.8 | 24.8 | 555.3 | 128.5 | 158.5 | 3.4 | 242.4 | 51.3 |
| Guilford | 91.6 | 17.7 | 330.2 | 203.9 | 85.7 | 1.3 | 168.4 | 113.3 |
| Stonington | 58.5 | 8.9 | 323.7 | 289.2 | 30.8 | 0.03 | 94.7 | 93.1 |

**Florence, 2018**

- **Florence)**
- **FL+SLR (NOAA WL + SLR & Simulated streamflow for synthetic Florence)**

# Future Sandy scenario

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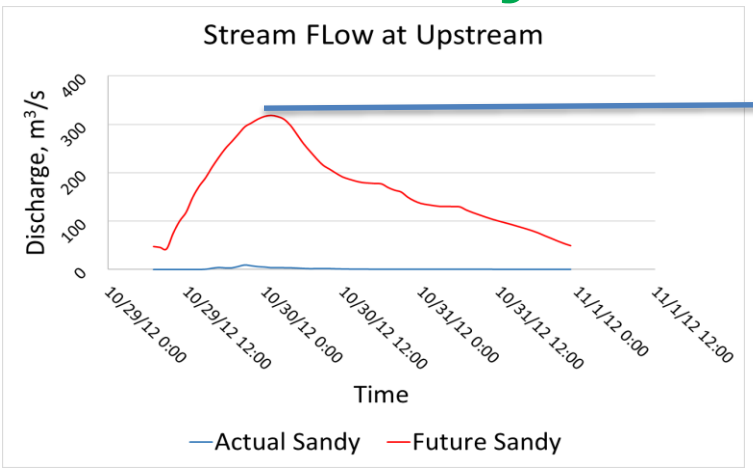
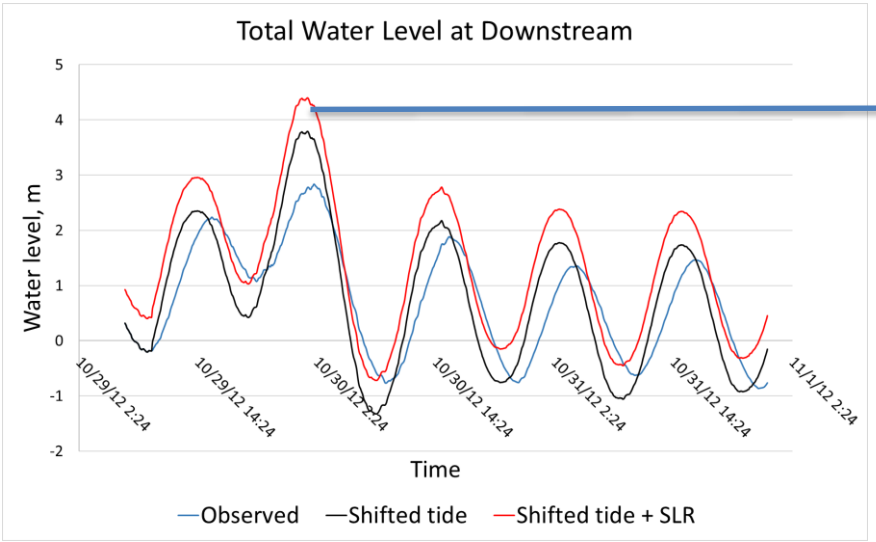
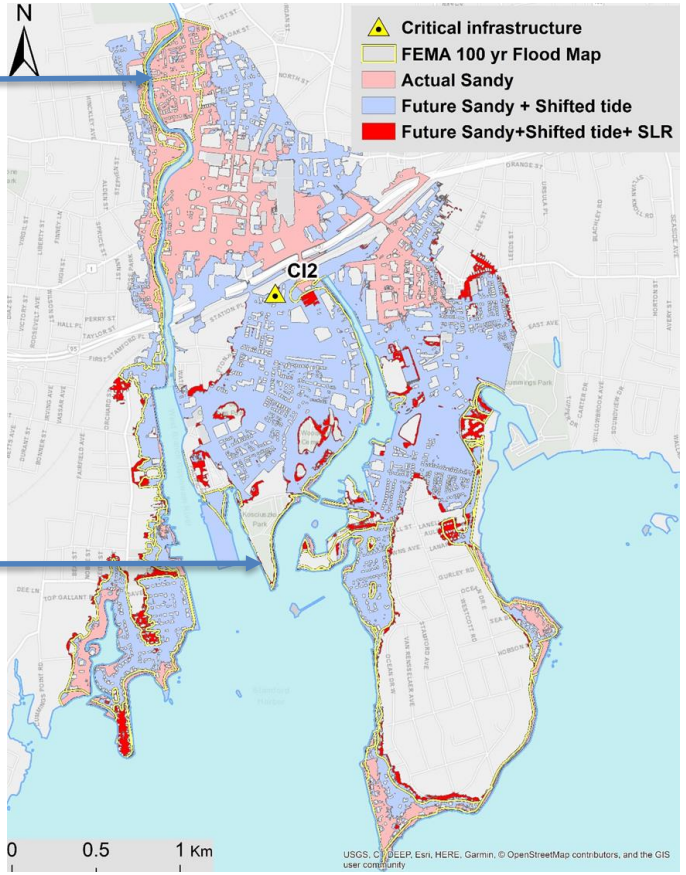
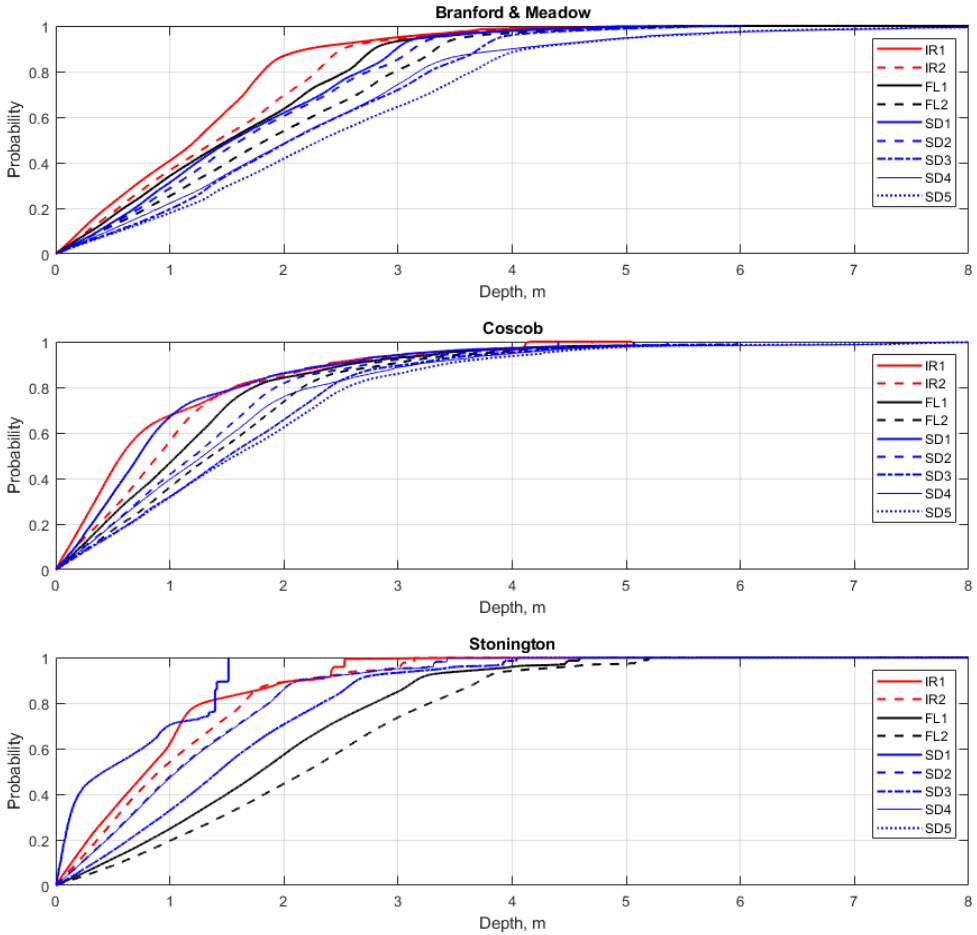
# Future Sandy scenario - Southend substation



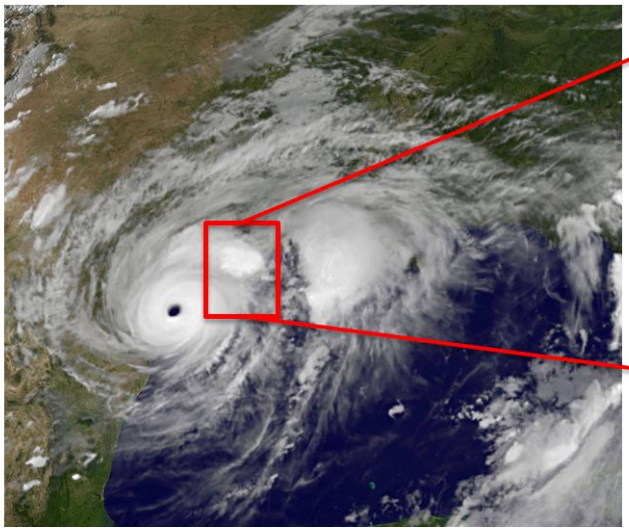
# Flood depth probabilities in the vicinity of substations

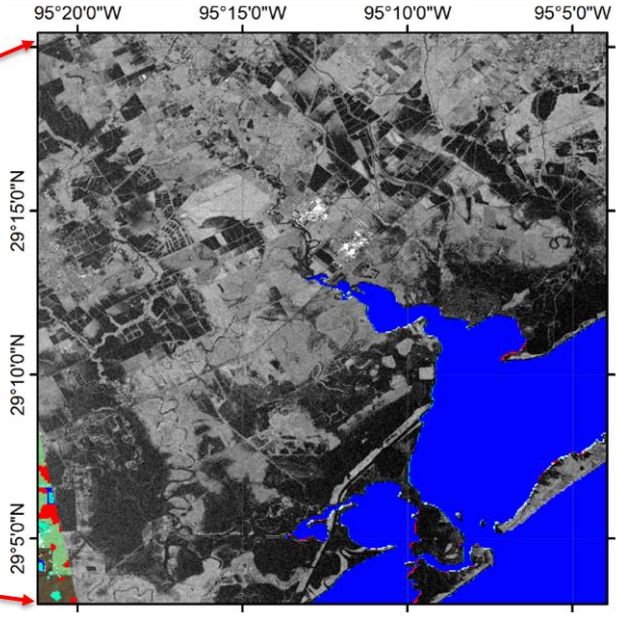


# Monitoring Flooding from Space

- Microwave penetration

Landsat image during Harvey





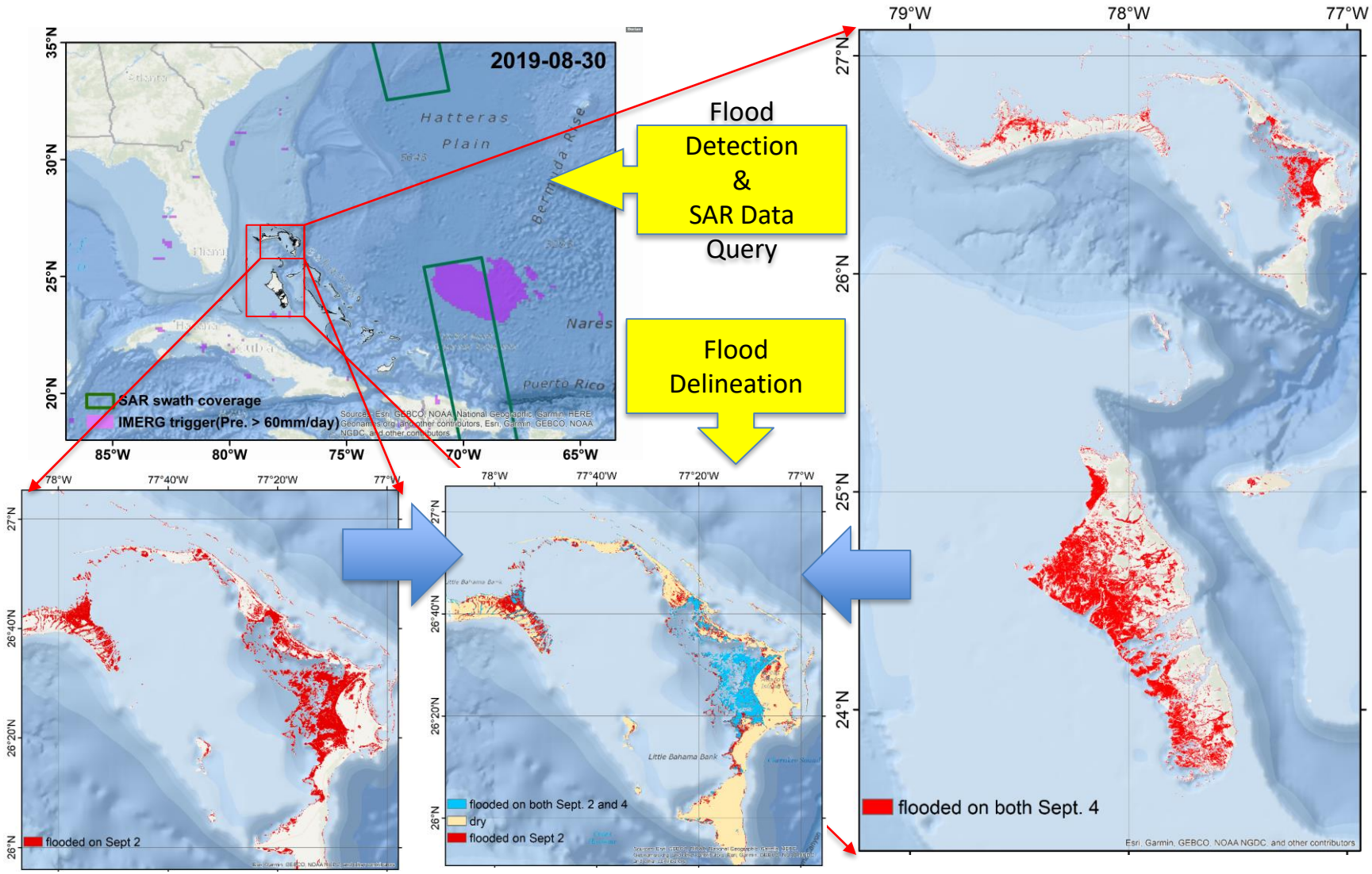
# RAdar Produced Inundation Diary (RAPID)

The globally unique near-real-time (NRT) flood mapping system using Synthetic Aperture Radar (SAR)

- 10-m resolution
- 1-2-day interval during major events


Shen and Anagnostou et al., 2019: Near-real-time non-obstructed flood inundation mapping using synthetic aperture radar. *Remote Sensing of environment*

# Case-Study Hurricane Dorian



# What's next

- Establish RAPID system as an operational near-real-time flood mapping system. Potentially integrate commercial SAR observations.
- Assign probabilities (occurrence frequencies) to the synthetic storm impact simulations.
- Extend our OPM model to support regional outage predictions and provide resilience analysis to utility industry.