Projection of Evacuation Zones under Storm and climate change Scenarios

New York University
Prof. Kaan Ozbay
Hong Yang
Kun Xie
Yuan Zhu
Dr. Dilruba Ozmen-Ertekin

Stony Brook University
Prof. Minghua Zhang
Prof. Henry Bokuniewicz
Wuyin Lin
Sung-gheel Jang
Ping Liu

March 15, 2015

NYS RISE

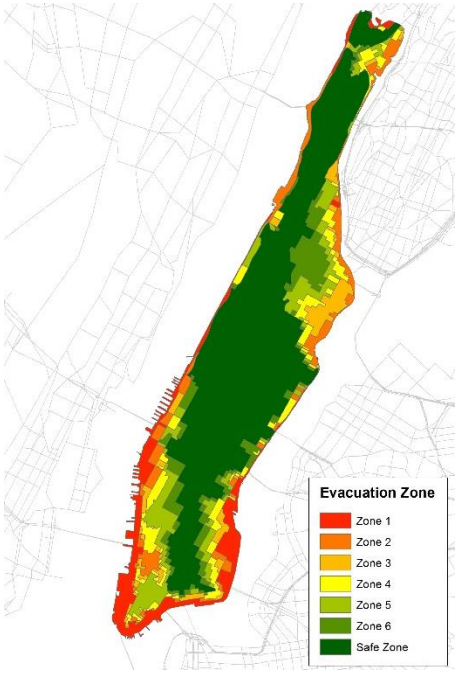
Resiliency Institute for Storms & Emergencies

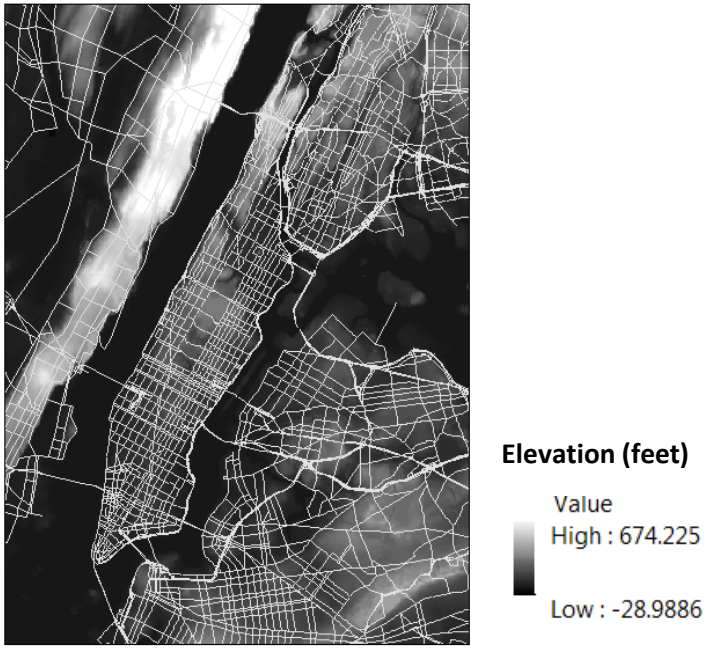
Introduction

- Background
  - Evacuation zone division will be changed in the future due to the climate variability
  - Lack of a robust quantitative methods to project future evacuation zones
- Objective
  - Develop a data-oriented methodology to project future evacuation zones in response to storms and climate change
  - Predict climate change in the future (from SBU team)
  - Provide useful insights for evacuation planning and management
- Study Scope
  - Study area: Manhattan
  - Target years: 2050s and 2090s

Current Conditions

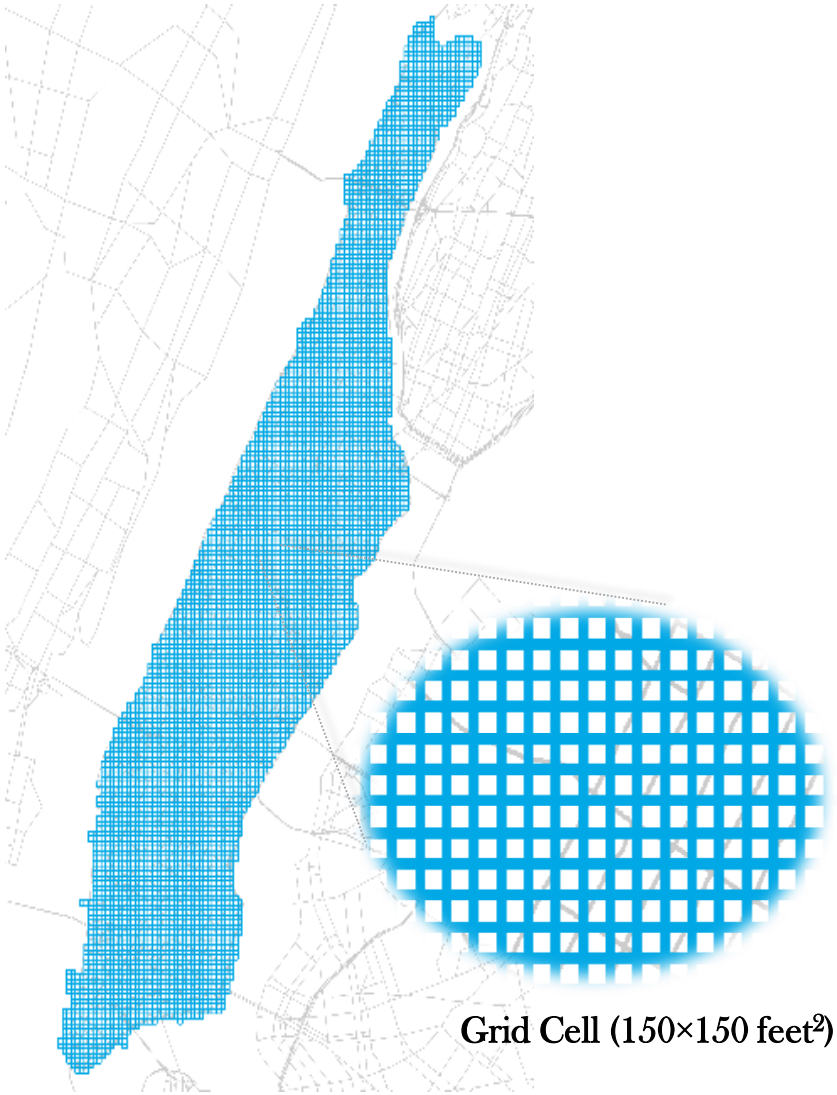
- NYC 2013 Evacuation Zone
  - Zone categories could reflect the risk levels during storms
- Geographic Features
  - Average elevation above sea level
    - Areas which have lower elevation have more chance to be flooded
  - Distance to the coast
    - Areas closer to the coast are more likely to be affected by the storm surges.





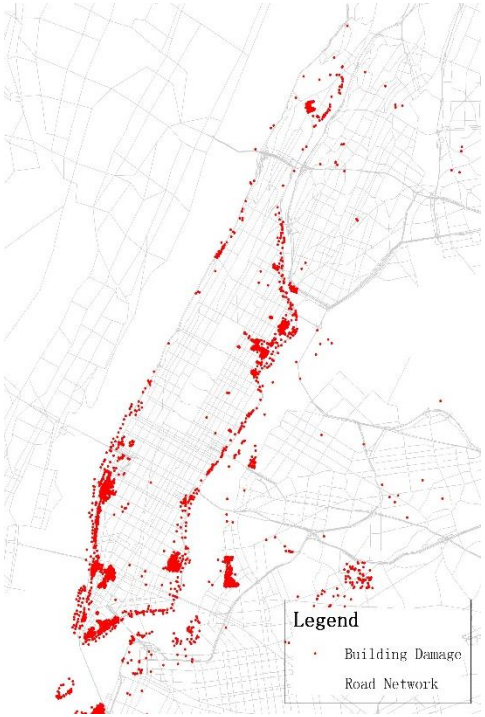
DATA

- Geographical Units of Analysis
  - Grid cells
    - Cell number: 25440
    - Size: 150×150 feet^2
  - Advantage
    - Capture individual geographic features precisely
    - Provide street-by-street resolution for evacuation modeling



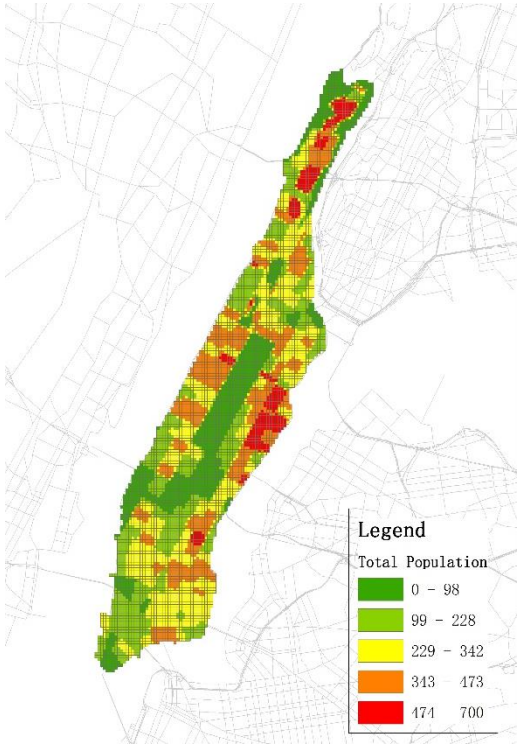
DATA

- Additional Data
  - Historical storm data: e.g. building damage data during Sandy
  - Evacuation ability: e.g. the distance to an evacuation center, subway station etc.
  - Demographic features: e.g. total population, population over 65 etc.



Building Damage During Sandy

Evacuation Centers



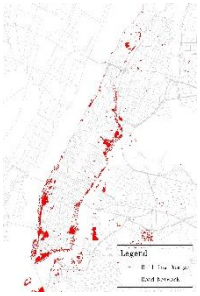
Population Distribution

Methodology

- Objective: Predict evacuation zone categories using collected features as inputs
  - Response variable: zone category
    - E1 (corresponding to NYC 2013 evacuation zone 1)
    - E2 (corresponding to NYC 2013 evacuation zone 2 and 3)
    - E3 (corresponding to NYC 2013 evacuation zone 4, 5 and 6)
    - S (safe zone outside of the evacuation areas)
  - Potential predictors
    - Geographic features: average elevation above sea level (feet), distance to coast (feet)
    - Historical storm data: building damage in Sandy
    - Evacuation ability: distance to evacuation center (feet), distance to the nearest subway station (feet), distance to the nearest bus stop (feet), distance to the nearest highway (feet)
    - Demographic features: total population, population over 65, total population under 14

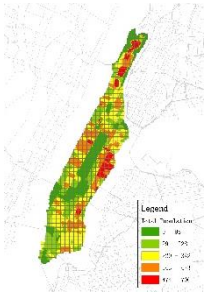
METHODOLOGY

Geographic features

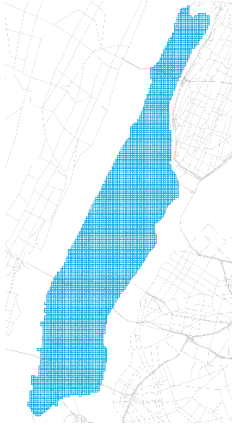


Historical storm data

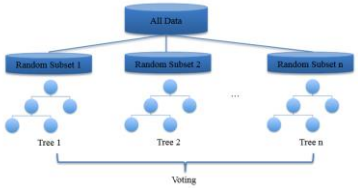
Evacuation ability



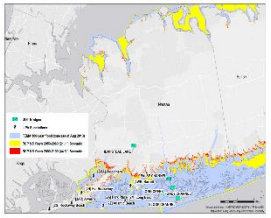
Demographic features



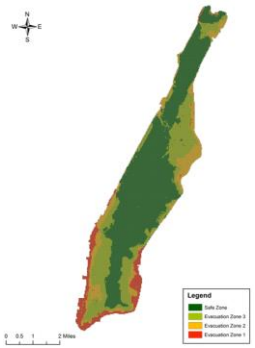
Capture features using grid cells



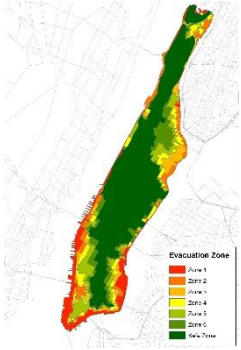
Develop zoning models



SBU Climate change prediction

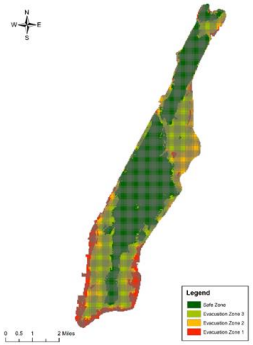


Predict current zone division



Current zone division

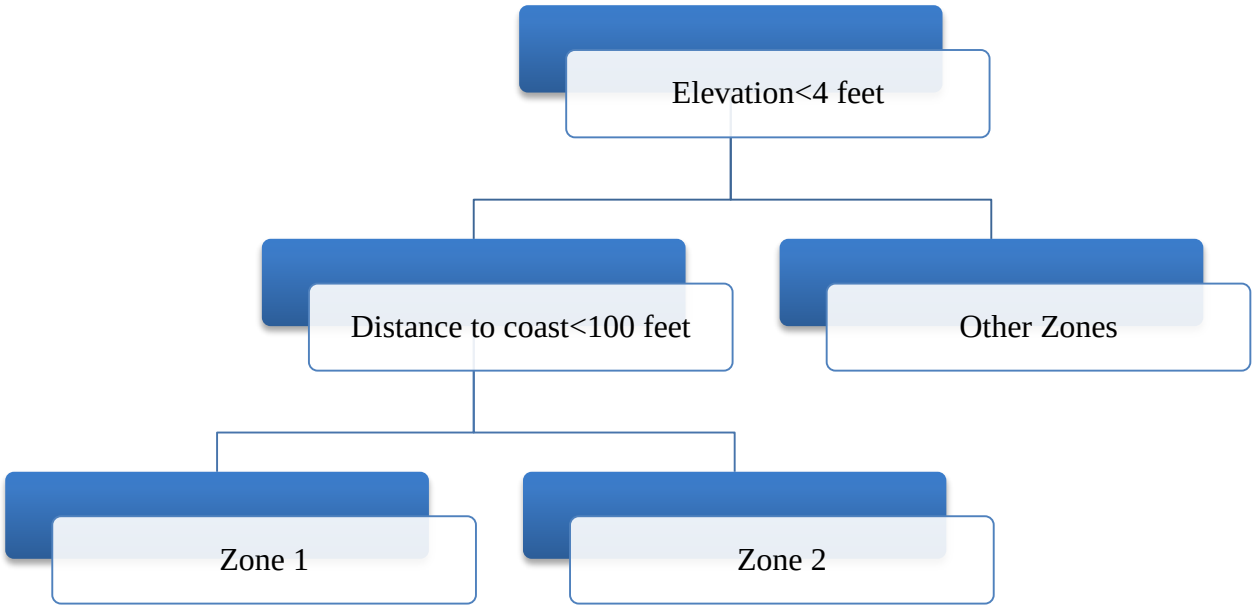
Compare



Predict future zone division

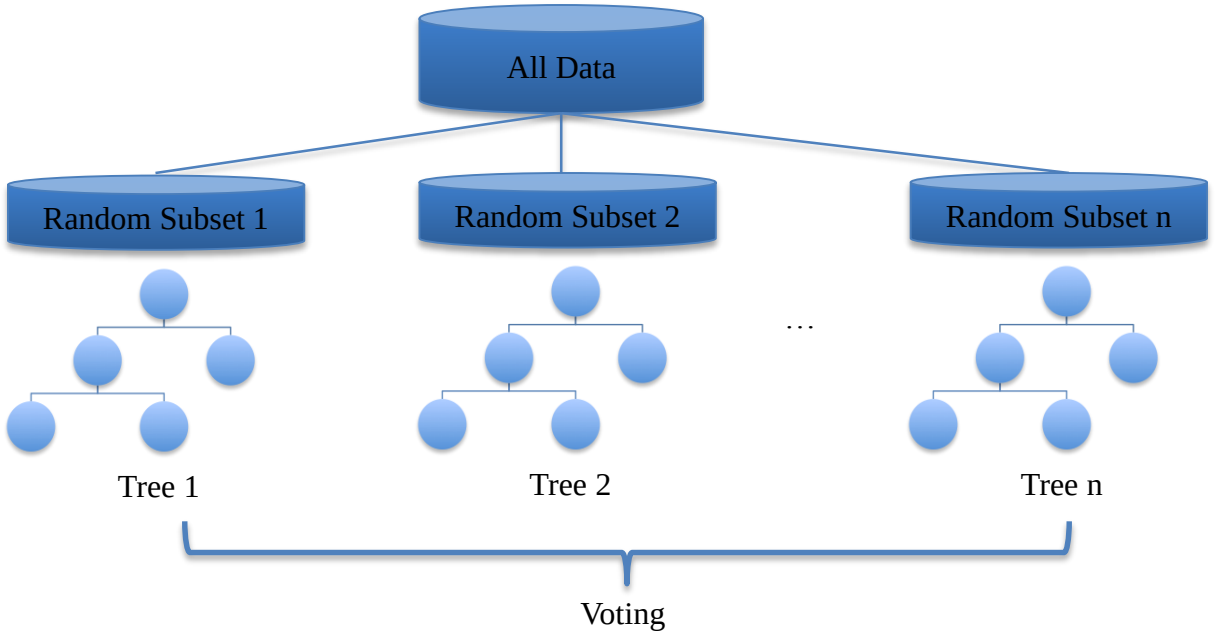
METHODOLOGY

- Decision Tree
  - Capture the nonlinear relationship between the evacuation zone categories and relevant features
  - Perform feature selection automatically
- A simplified demonstration of decision tree



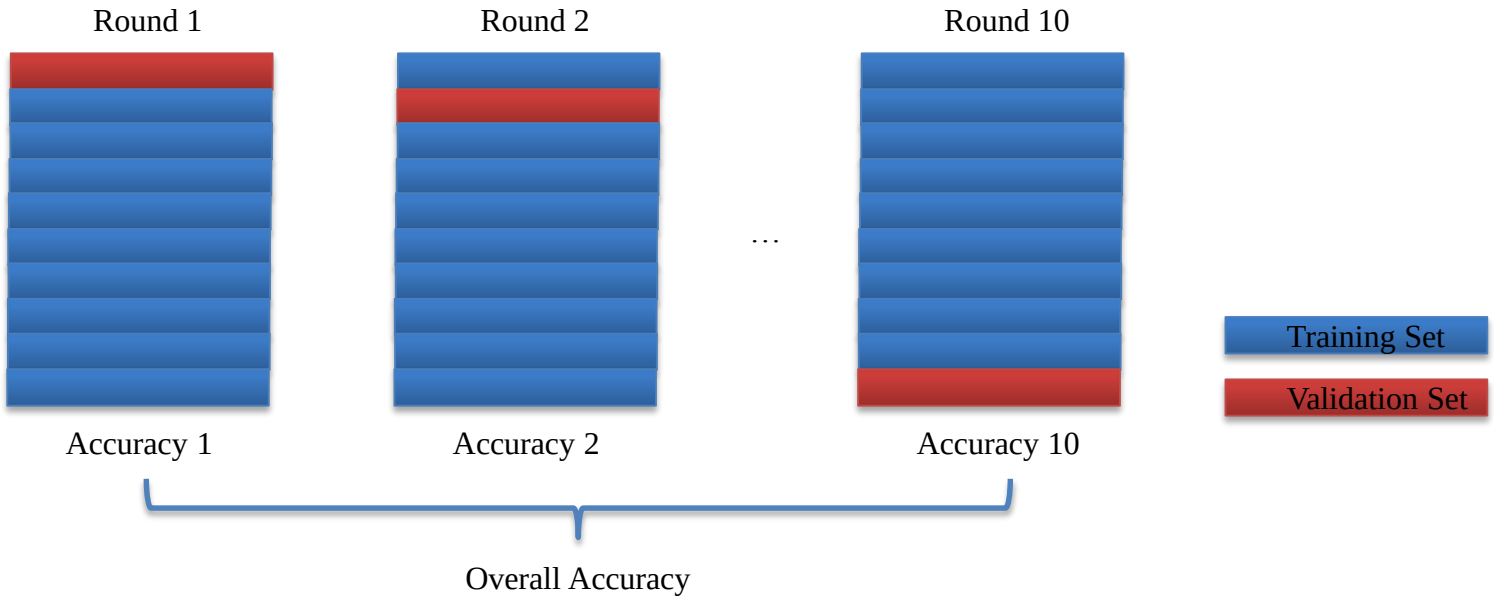
METHODOLOGY

- Random Forest
  - Construct multiple decision trees and use the mode of the categories estimated by individual trees as the output
  - Repeatedly select a portion of the training set (with replacement) to develop individual trees
  - Produce a more accurate classifier



Methodology

- Model Assessment
  - 10 fold cross-validation
    - All Observations are used for both training and validation
    - Address the over-fitting issue



Modeling Results

- Model Comparison: Decision Tree vs Random Forest
  - Overview

	Decision Tree	Random Forest
Correctly Classified Instances	22965	23947
Incorrectly Classified Instances	2475	1493
Total Number of Instances	25440	25440
Accuracy	90.27%	**94.13%**
Kappa statistic	0.8420	**0.9049**

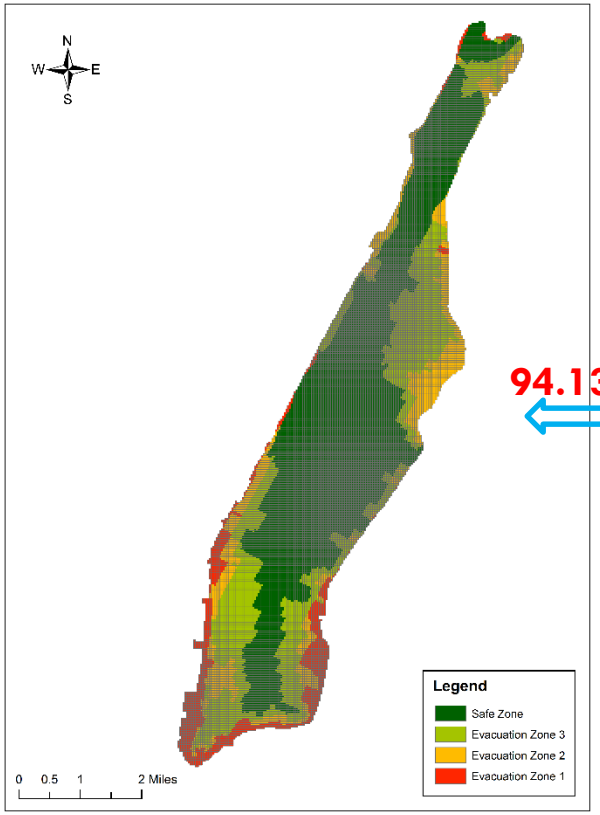
  - Confusion matrix

Decision Tree		Classified as			
		E1	E2	E3	S
Actual Class	E1	1704	187	53	44
	E2	195	2376	377	50
	E3	48	374	5641	568
	S	28	59	492	13244

Random Forest		Classified as			
		E1	E2	E3	S
Actual Class	E1	**1824**	116	36	12
	E2	129	**2619**	220	30
	E3	24	253	**6052**	302
	S	14	29	328	**13452**

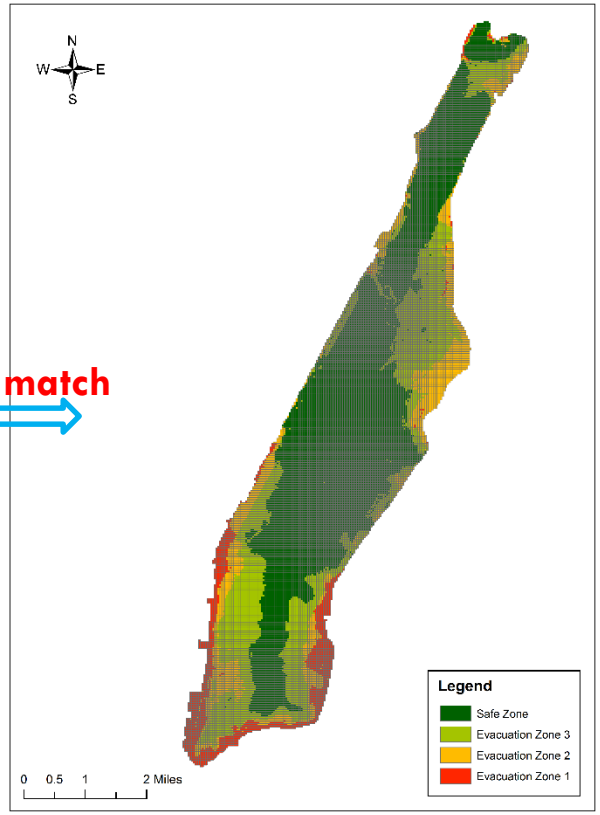
Modeling Results

- Current Evacuation Zones vs Estimated Evacuation Zones
  - The random forest model is selected to estimate the current evacuation zones
  - The outcome is quite similar to the current zone divisions



Current Evacuation Zones

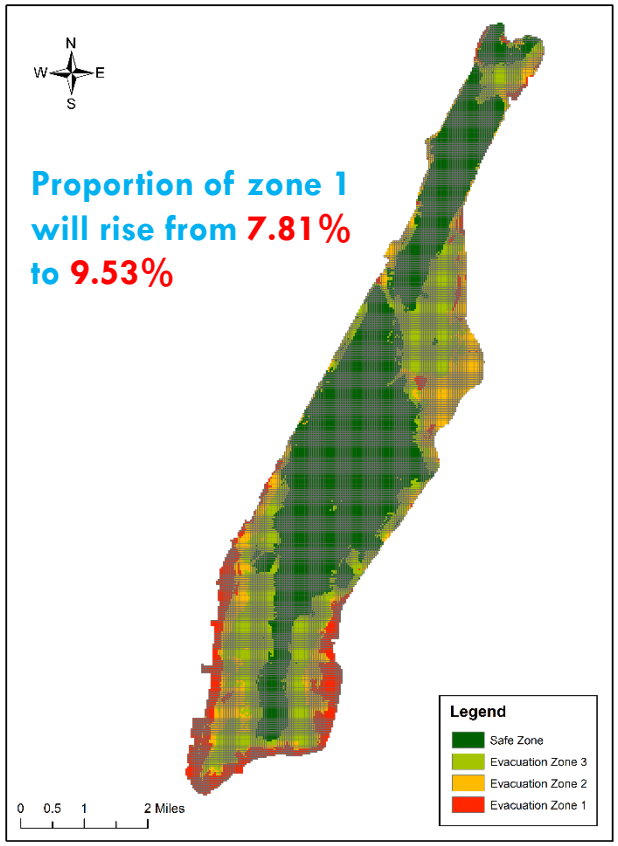
94.13 % match



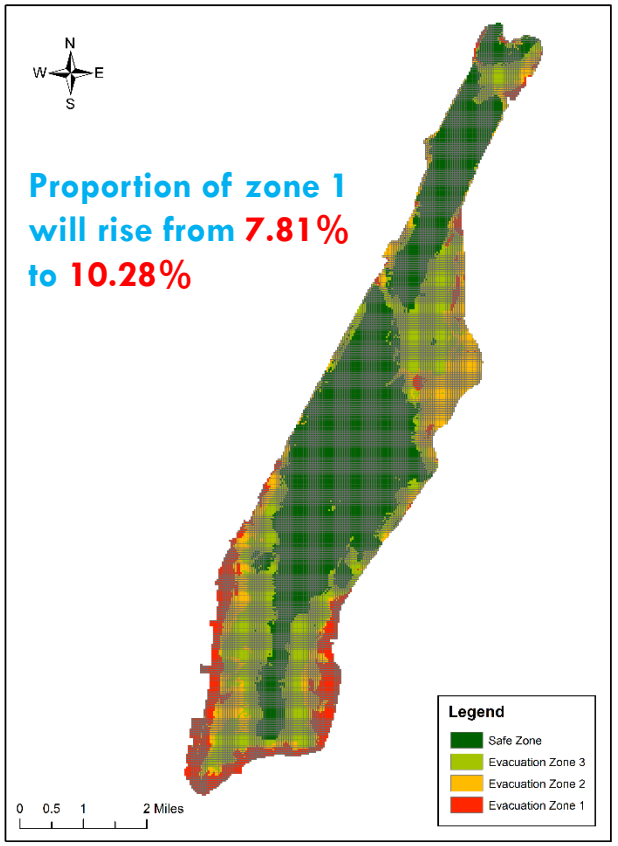
Estimated Evacuation Zones

PROJECT FUTURE EVACUATION ZONES

- SBU team predicts future sea level rises under the RCP 8.5 scenario
  - 2050s: sea level rise by 36.3 inches
  - 2090s: sea level rise by 45.1 inches
- Zones with higher risk are expected to increase in the 2050s and 2090s



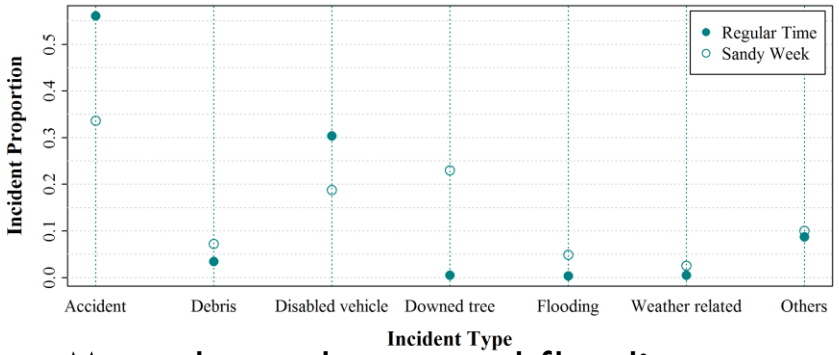
Forecasted Evacuation Zones in 2050s



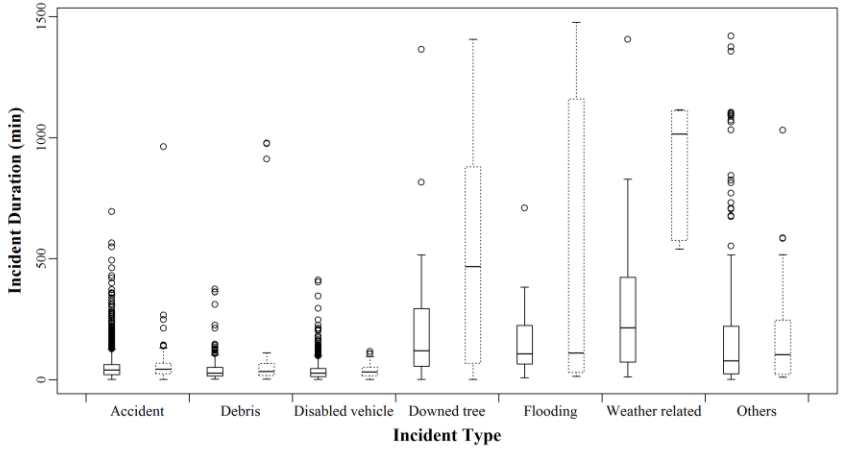
Forecasted Evacuation Zones in 2090s

Other Sandy Related Analysis

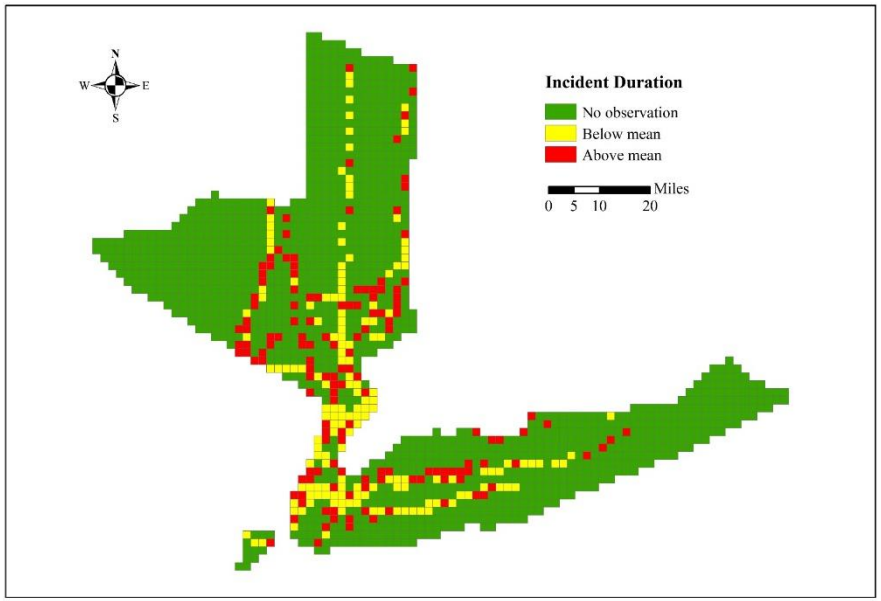
- Traffic Incident Analysis During Sandy



More downed trees and flooding occurred during Sandy



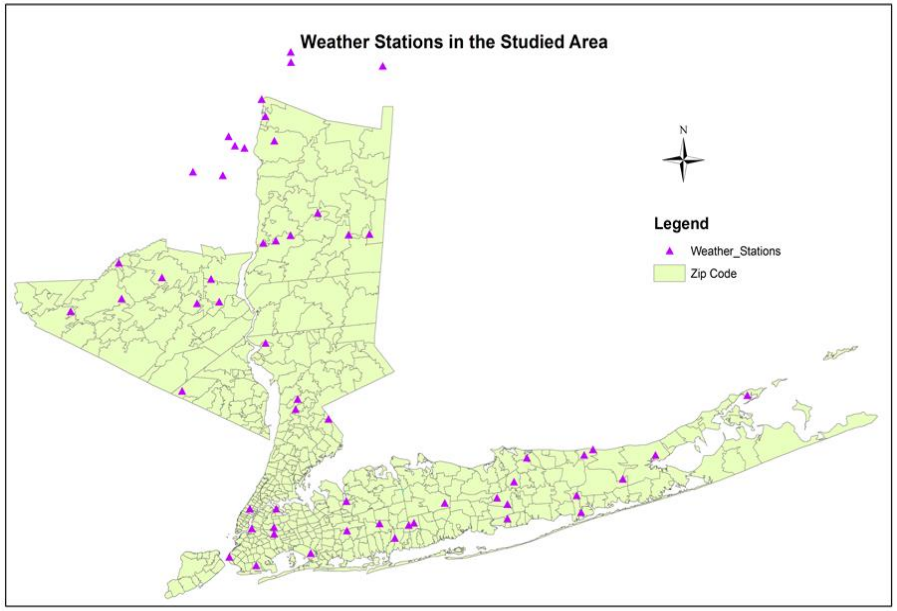
Incident duration got extended during Sandy

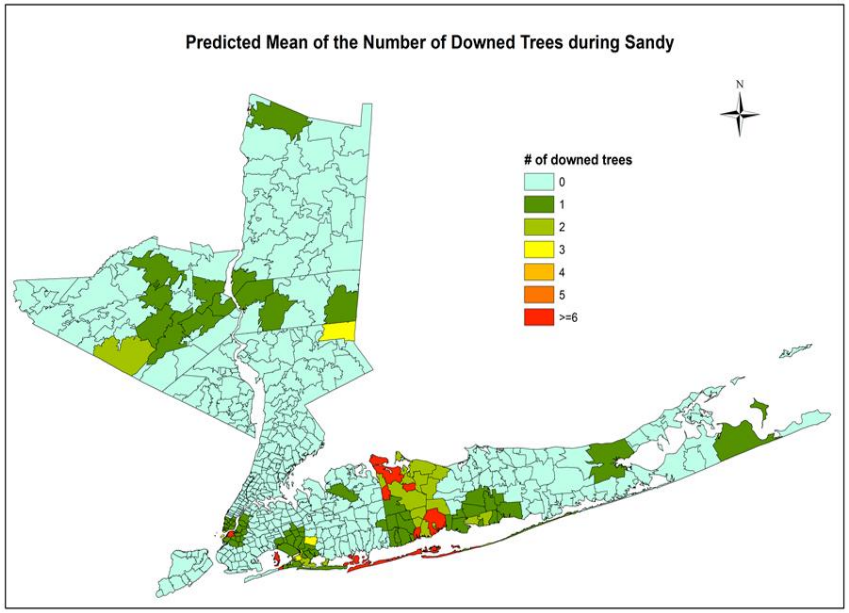


Spatial clustering of areas with high incident duration

Other Sandy Related Analysis

- Modeling the Risk of Downed Trees
  - Strong correlation between the risk of tree down and the weather condition (wind speed and precipitation)
  - The proposed model can be used to estimate tree down risk in advance with projected weather data





Summary

- Proposed a data-oriented methodology to project future evacuation zones in response to future storms and climate change
- Tested and demonstrated the use of the proposed approach with sea-level rise data obtained from SBU
- The projection of future evacuation zones can be used to estimate the evacuation demand under different scenarios
- Incident analysis provides useful insights into the evacuation planning and emergency management given the evacuation zones
- Future work
  - Expand the study area to its neighboring regions
  - Additional work is needed to predict the future demographic and mobility features
  - Combine these results with Task 1.2 (Evacuation Modeling)