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# HurriCast: Synthetic Tropical Cyclone Track Generation for Hurricane Forecasting

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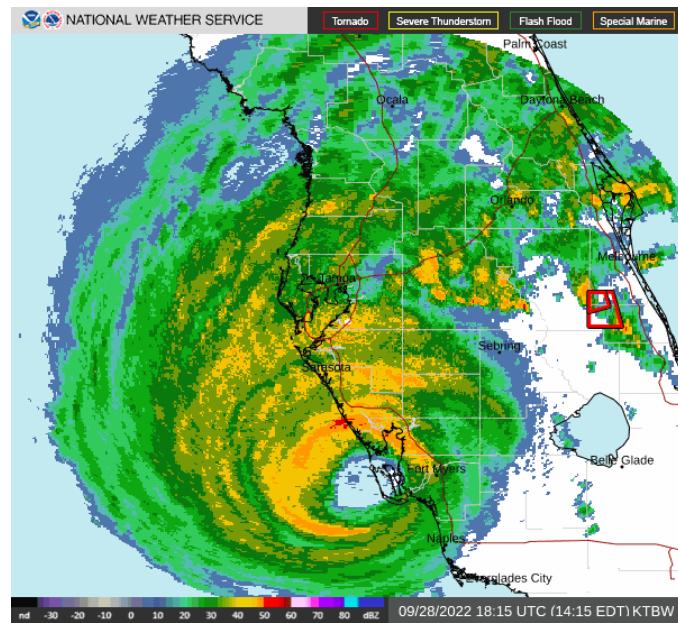
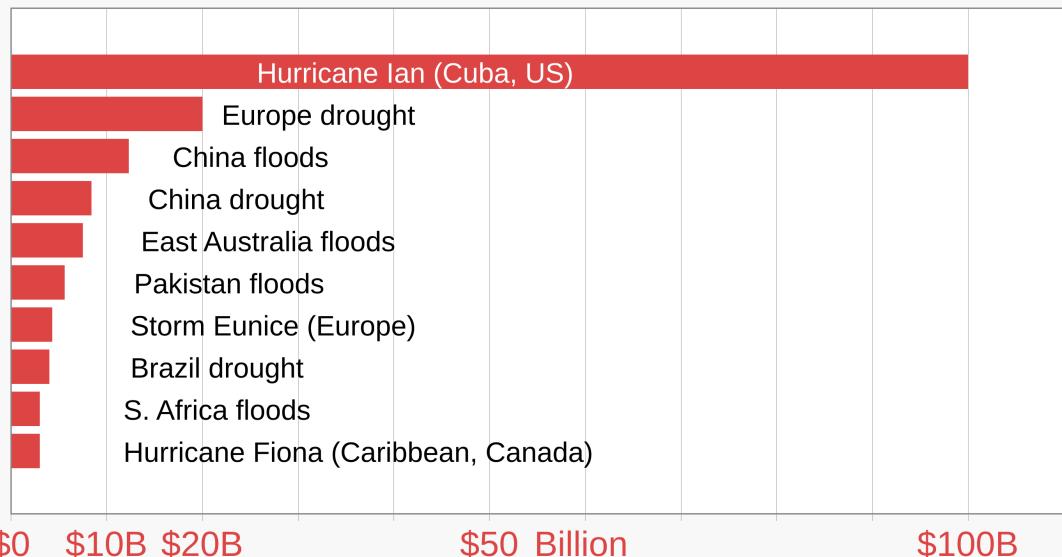
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# Outline

- Introduction
- FPHLM
- Methodology
- Result
- Summery
- Future Steps

## Costs of 2022 climate-related disasters



## Introduction

## FPHLM

## Methodology

## Result

## Summary



- Florida ranks #1 in total insured property value exposed to hurricane wind and #1 in coastal property exposed to storm surge.
- Florida has \$3.6 trillion in insured properties of which about \$2 trillion are residential, and all are exposed to hurricane risk.
- About 79% is coastal property which is particularly vulnerable to hurricane risk.
- Of this \$400 billion in properties may be particularly vulnerable to storm surge.

- Florida ranks #1 in auto insurance, 55% higher than the national average.
- After hurricane Ian, many insurance companies went out of business and 200,000 claims could not be paid.

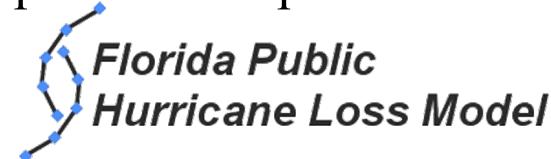
# FPHLM

- The Florida Public Hurricane Loss Model (FPHLM) is a hurricane catastrophe model developed by a multi-disciplinary team of experts in the fields of meteorology, oceanography, hydrology, wind, structural engineering, computer science, GIS, statistics, finance, and actuarial science.
- The model consists of five major components: wind hazard (meteorology), coastal flooding (oceanography), inland flooding (hydrology), vulnerability (engineering), and insured loss cost (actuarial). It has over a dozen sub-components.
- The FPHLM estimates loss costs and probable maximum loss levels from hurricane events for personal lines and commercial lines of residential property. The losses are estimated for building, appurtenant structure, contents, and additional living expenses.



# Participating Institutions

- Florida International University/ IHRC (lead institution)
- Florida State University
- Florida Institute of Technology
- Hurricane Research Division, NOAA
- University of Florida
- University of Miami
- Notre Dame University
- Oregon State University
- About 2 dozen professors and experts and over 4 dozen graduate and undergraduate students have been involved in the development and operation of the model.



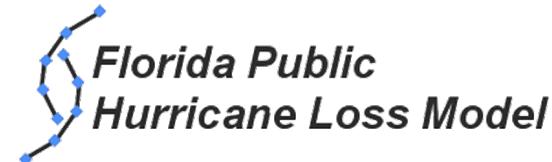
# FPHLM

- The FPHLM is a complex collection of computer programs that simulate and predict
  - **where and when hurricanes form,**
  - **their wind speeds, intensity and sizes, their tracks,**
  - **storm surge and wave induced by hurricane wind, their height and extension,**
  - **inland flooding caused by hurricane rainfall, their height and range,**
  - **how they are affected by the terrain after landfall,**
  - **how the winds interact with different types of structures,**
  - **how the flooding interact with different types of structures,**
  - **how much damage they can cause to house roofs, windows, doors, and interiors,**
  - **how much it will cost to rebuild the damaged parts,**
  - **how much of the loss will be paid by insurers.**



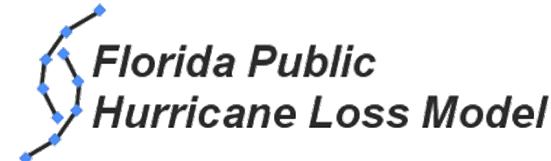
# FPHLM

- The Goal is:
  - how much damage they can cause to house roofs, windows, doors, and interiors,
  - how much it will cost to rebuild the damaged parts,
  - how much of the loss will be paid by insurers.
- The First Step is:
  - where and when hurricanes form,
  - their wind speeds, intensity and sizes, their tracks.

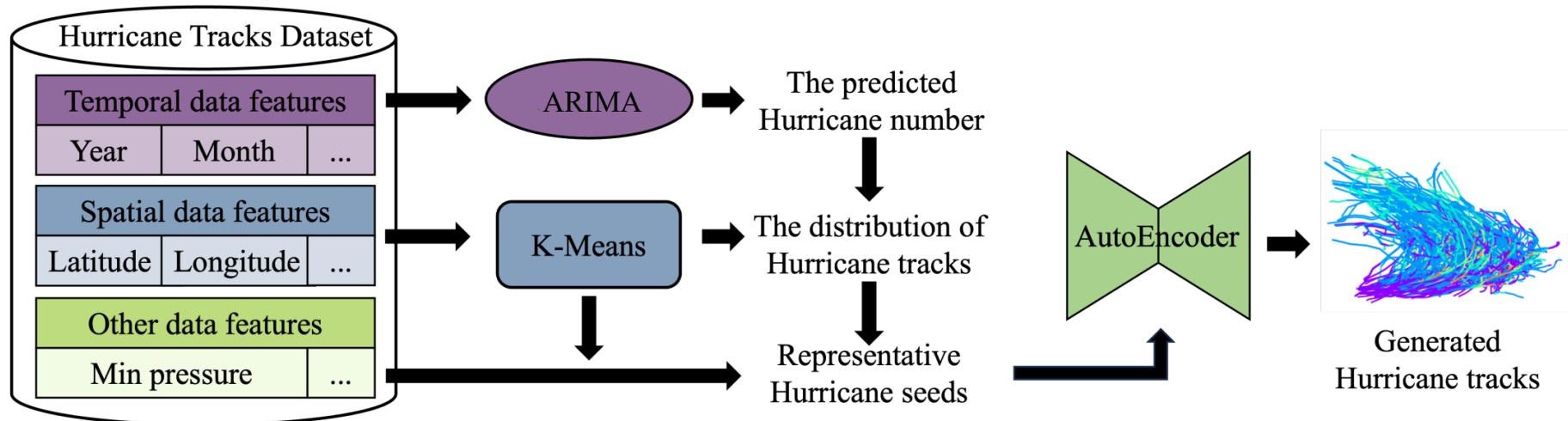


# FPHLM

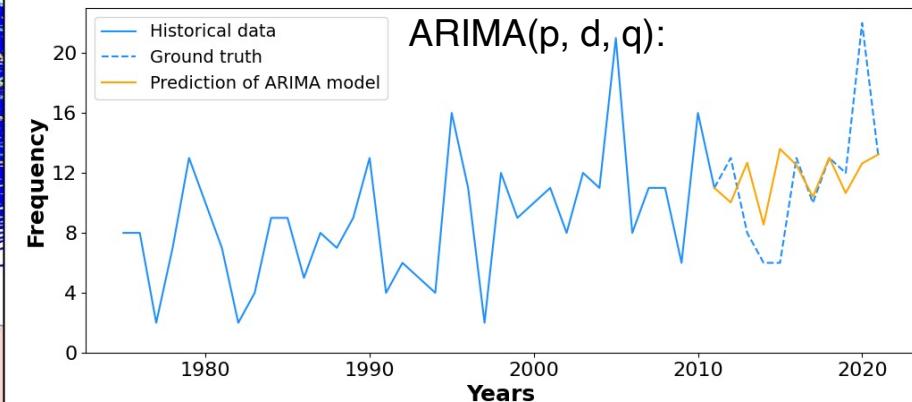
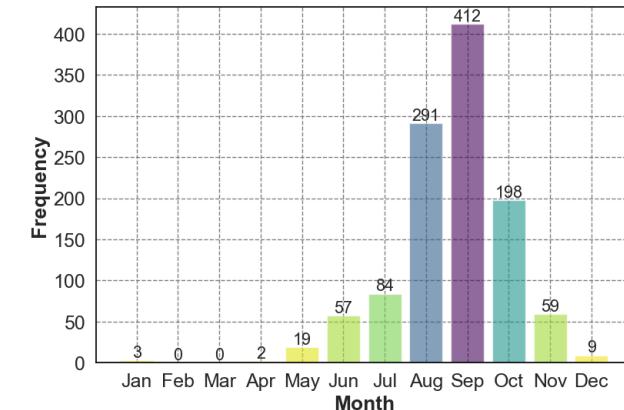
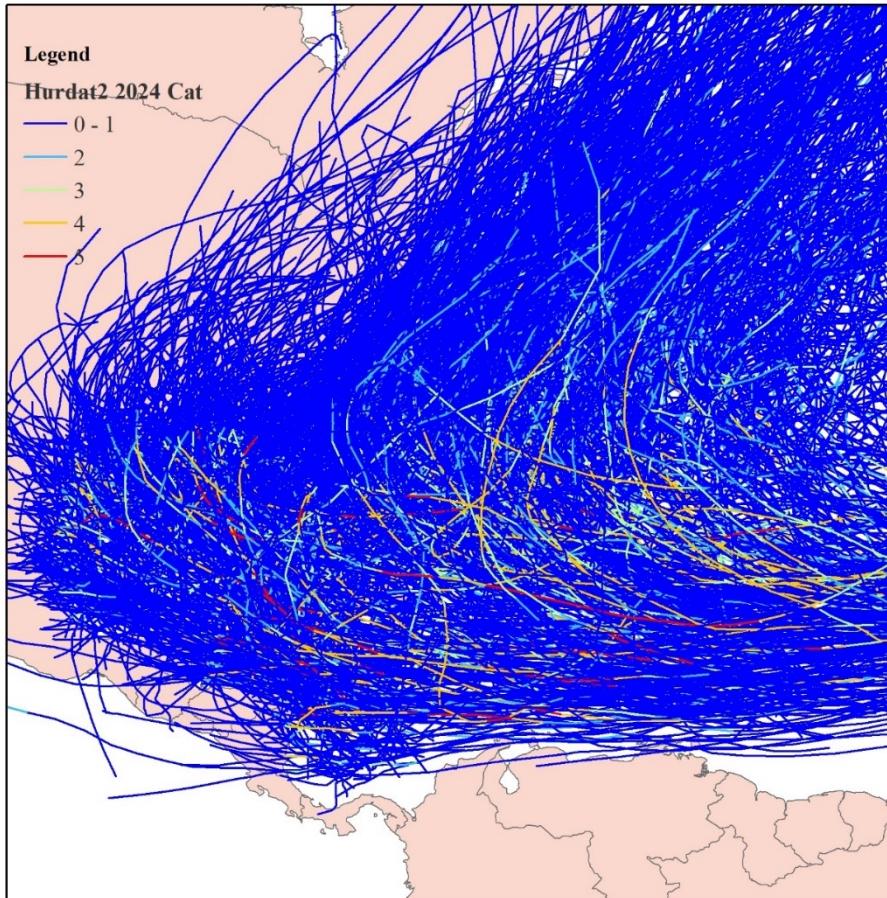
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  - how much it will cost to rebuild the damaged parts,
  - how much of the loss will be paid by insurers.
- The First Step is:
  - where and when hurricanes form,
  - their wind speeds, intensity and sizes, their tracks.
- The Problem is:
  - Data is all you need!
  - Historical hurricane data:
    - Hurricane best track database (HURDAT2),
    - Atlantic basin 1851-2024,
    - 1284 historical hurricane data.



# Flowchart of the hurricane track simulator



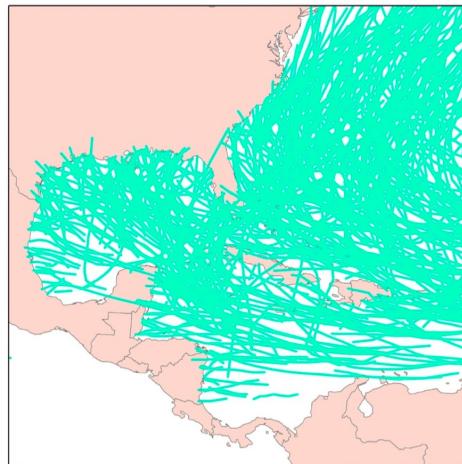
# Historical Hurricane on Atlantic Ocean



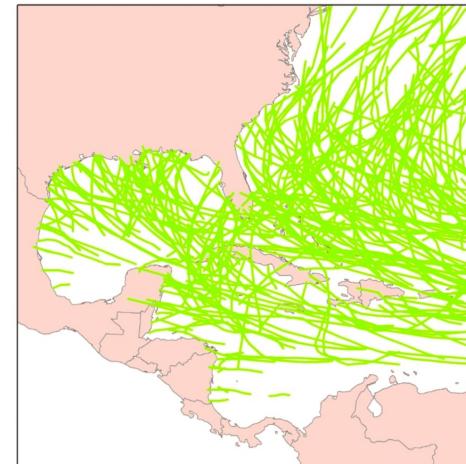
# Distribution of Historical Hurricane on Atlantic Ocean

## K-Means:

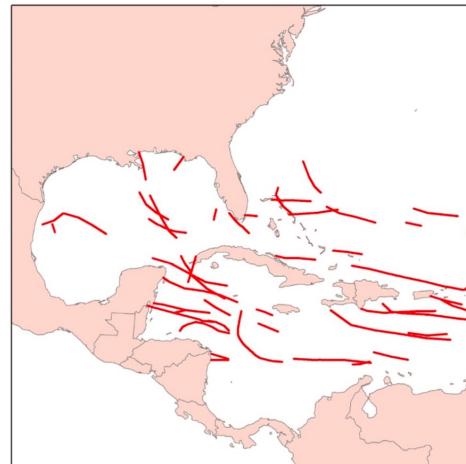
- Category
- Trajectory
- Start points
- Time



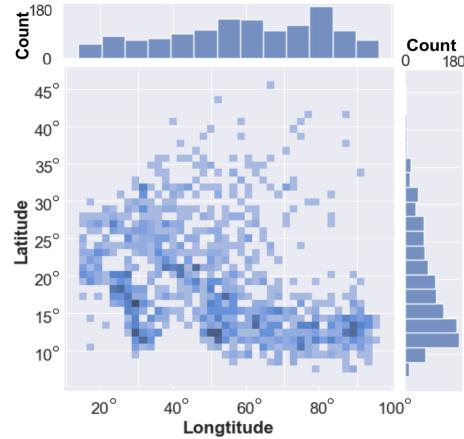
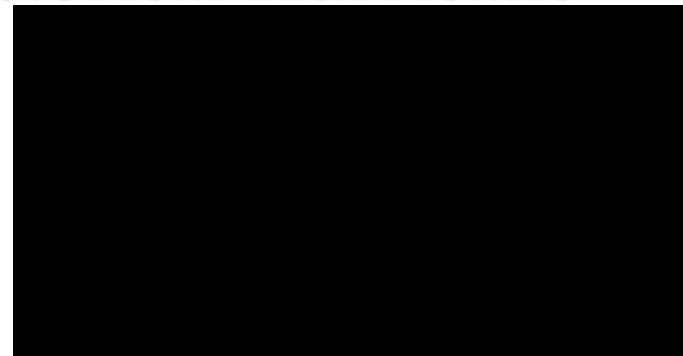
(a) Historical tropical cyclone  
(CAT $\geq$ 2)



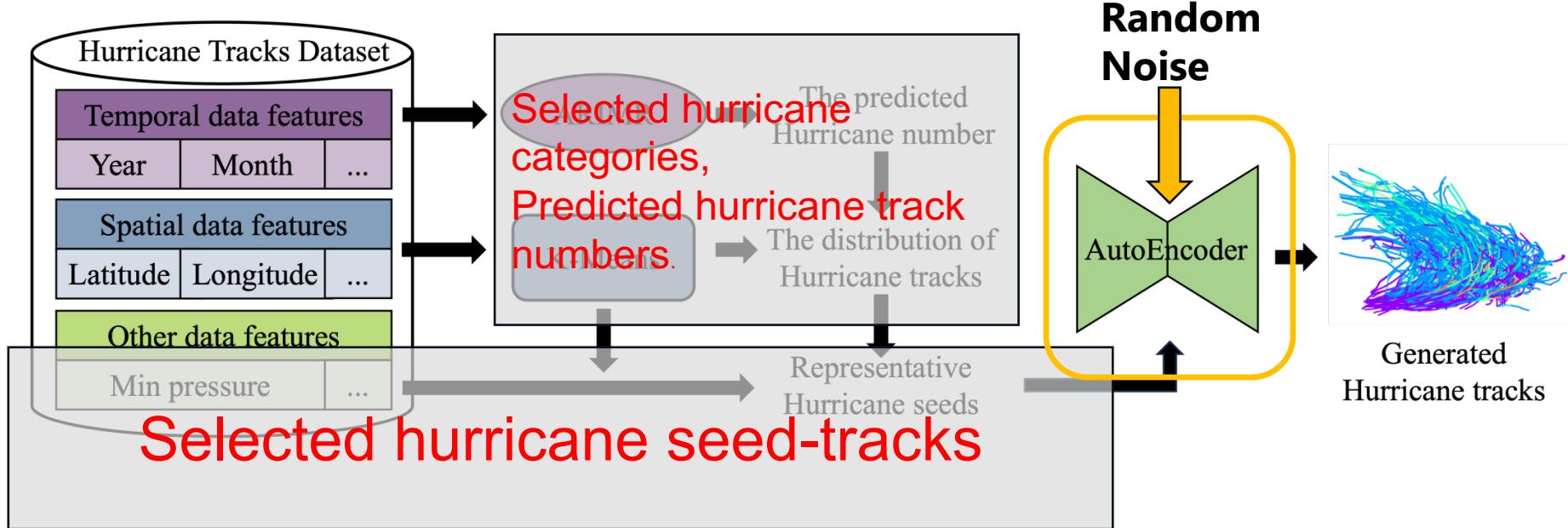
(b) Historical tropical cyclone  
(CAT $\geq$ 3)



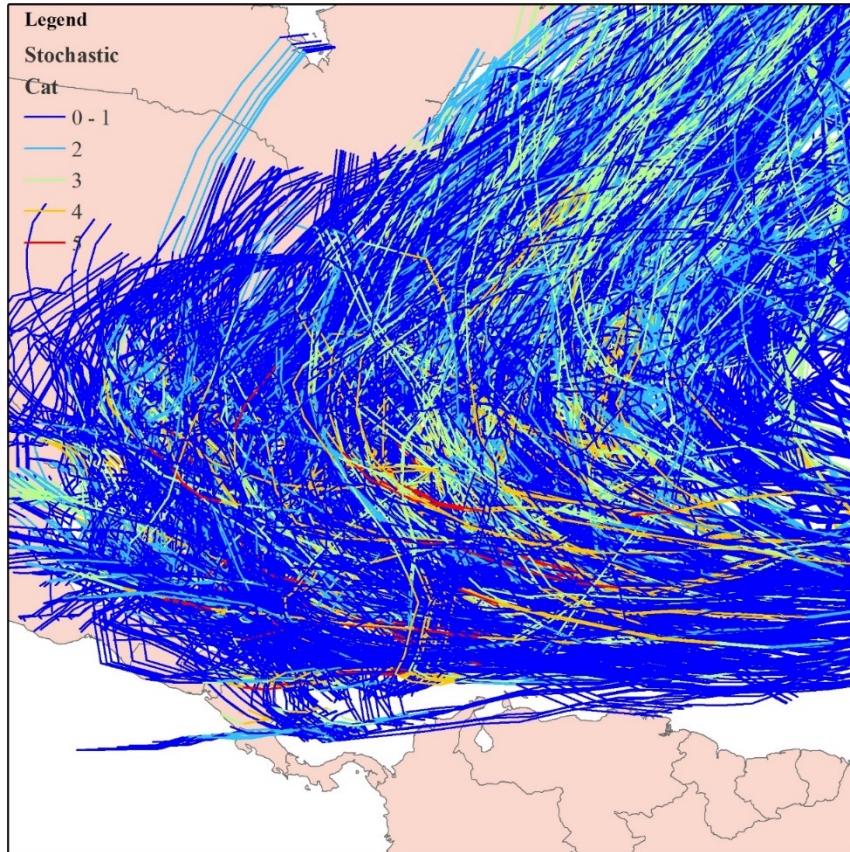
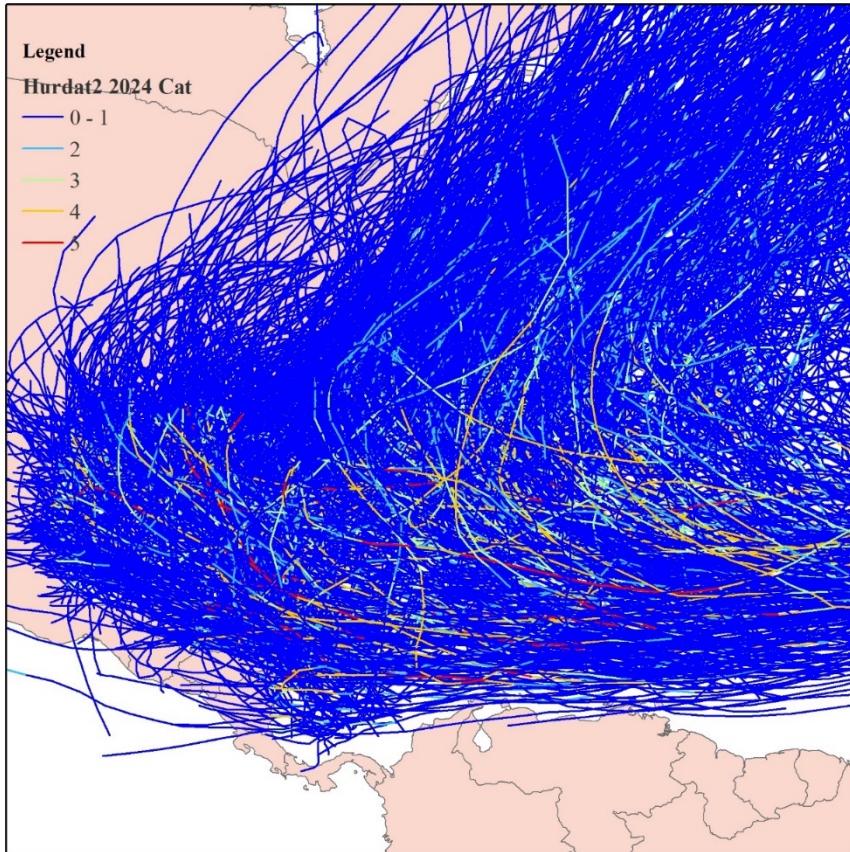
(c) Historical tropical cyclone  
(CAT $\geq$ 5)



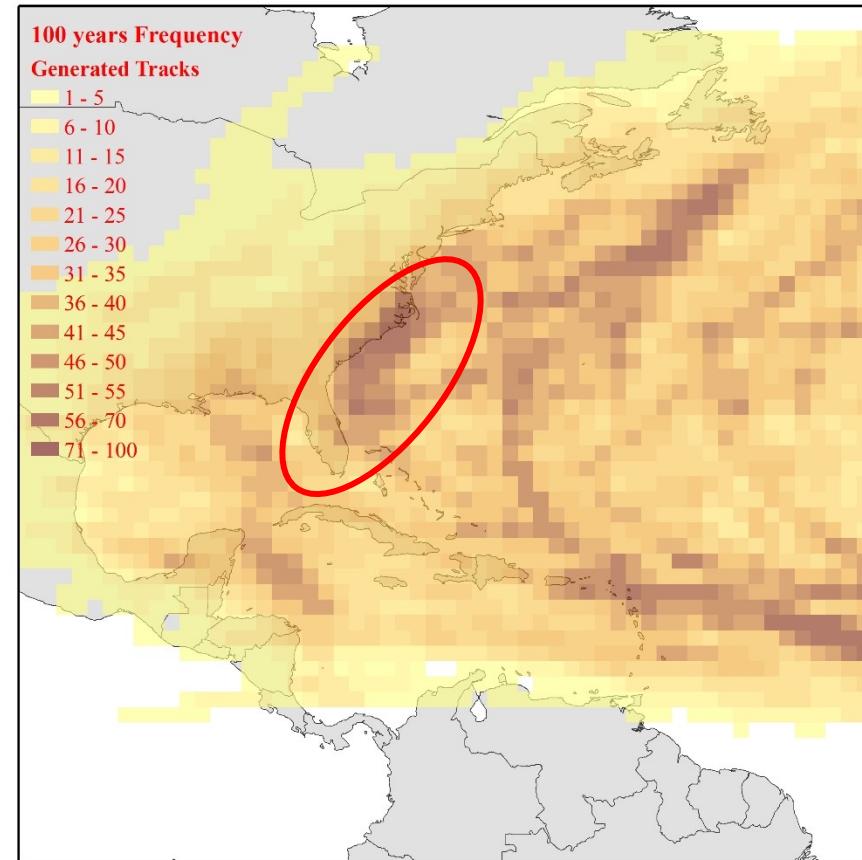
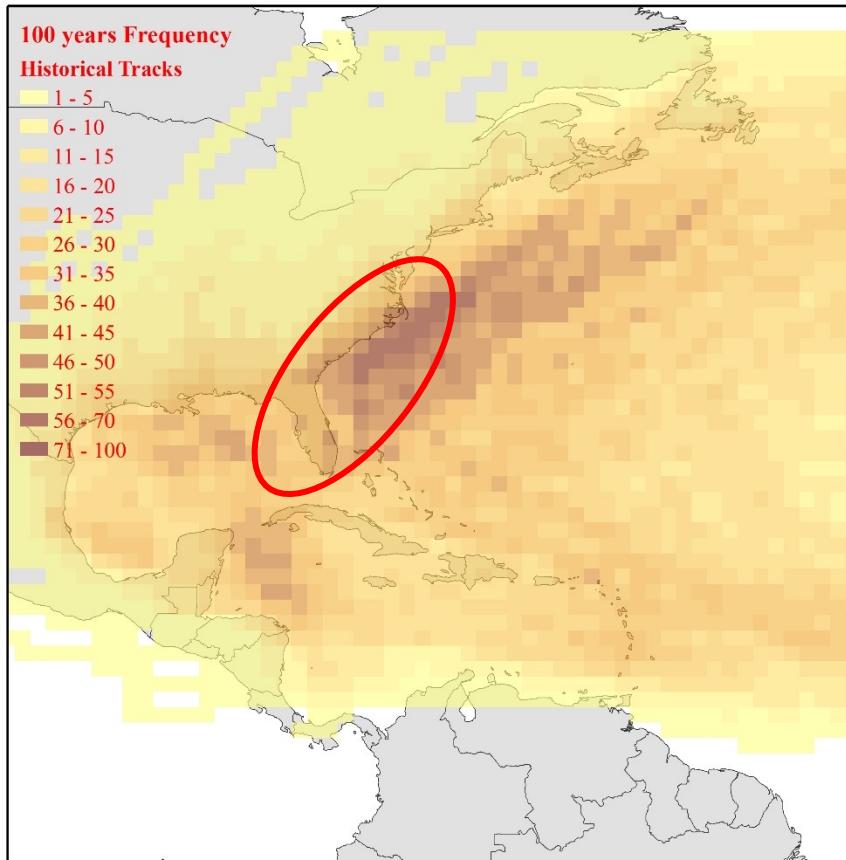
# Generate Hurricane Tracks on Atlantic Ocean



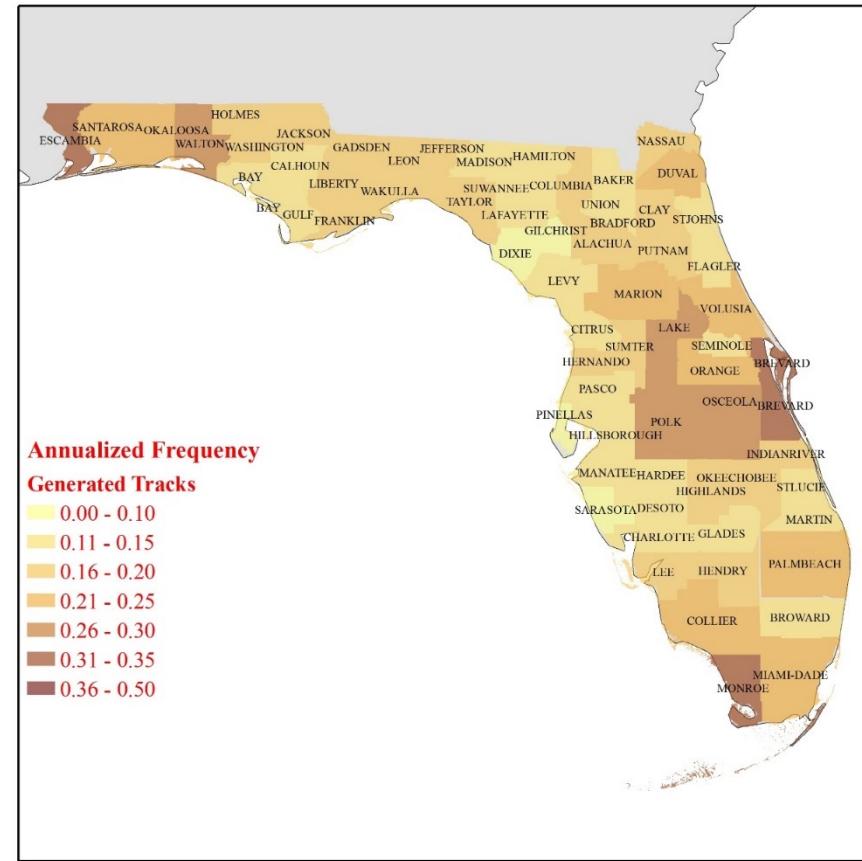
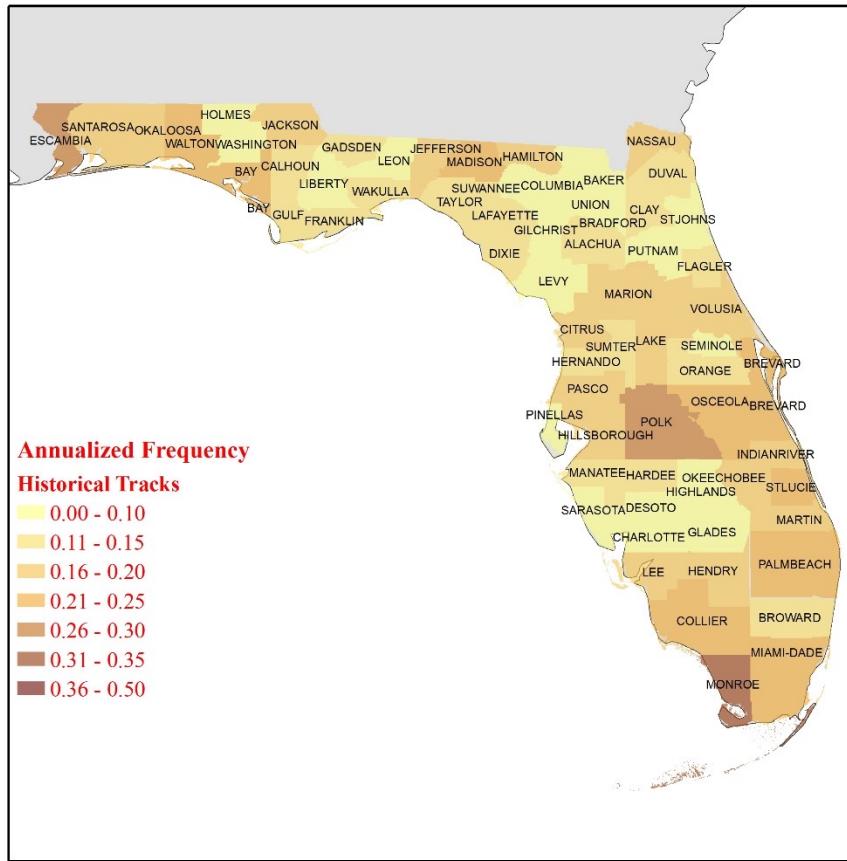
# Historical vs. generated tropical cyclone



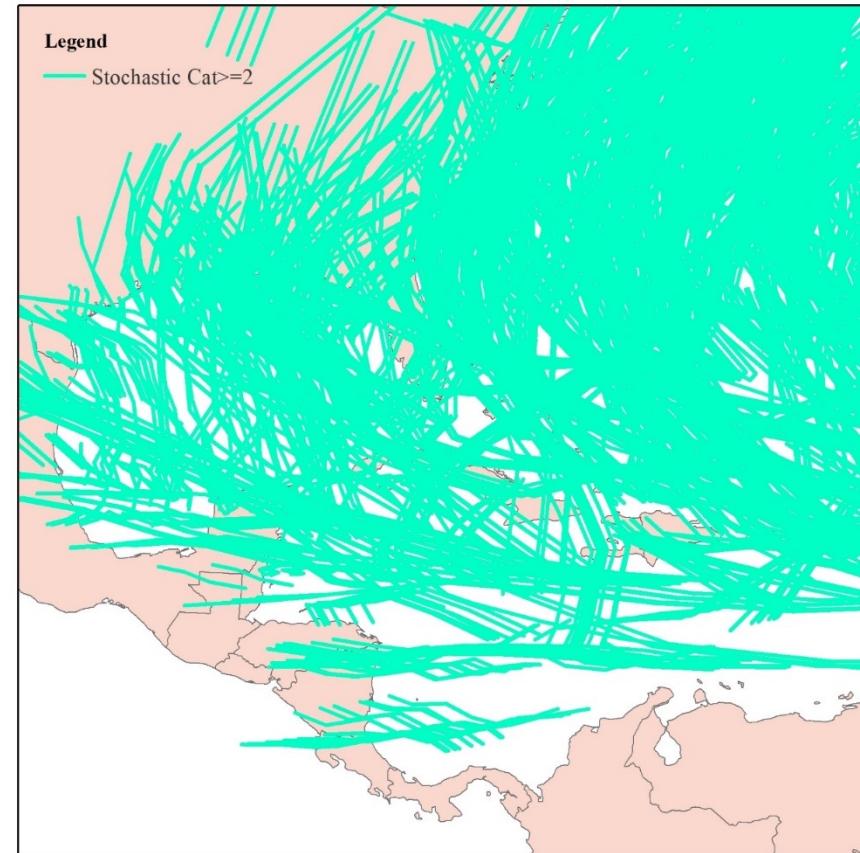
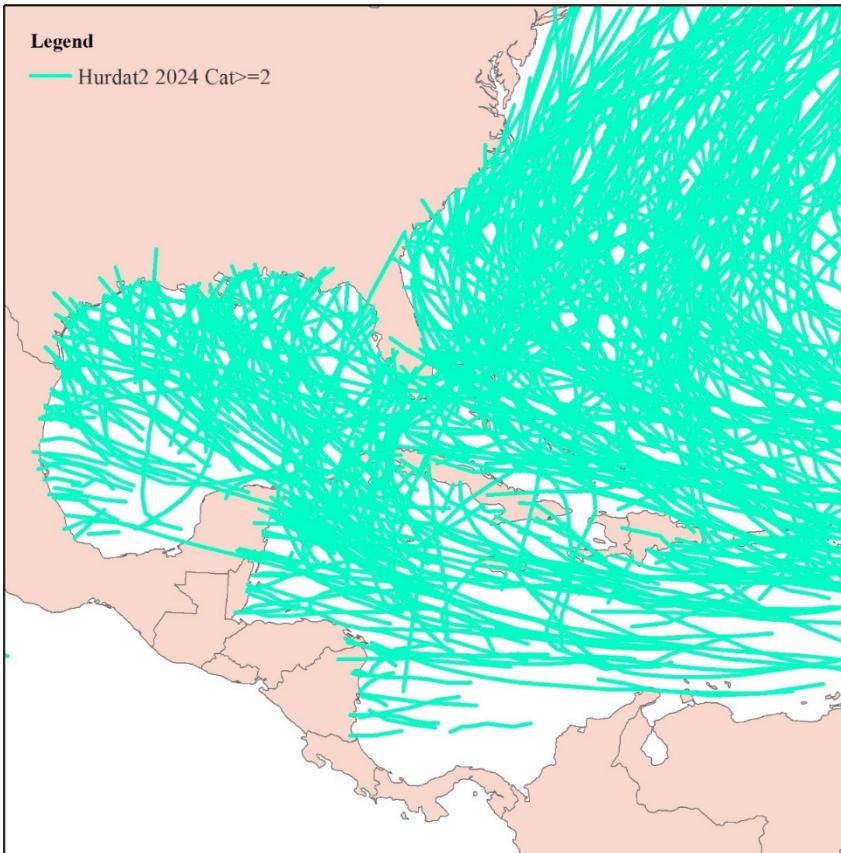
# Historical vs. generated 100 years frequency



# Historical vs. generated annualized frequency at Florida

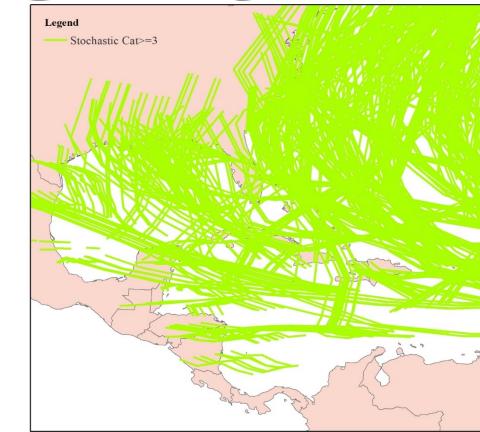
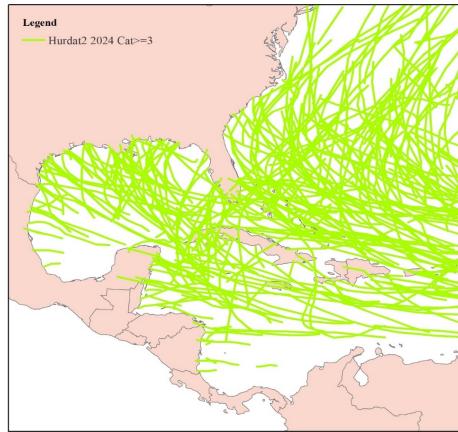


# Historical vs. Simulated tropical cyclone (CAT $\geq$ 2)

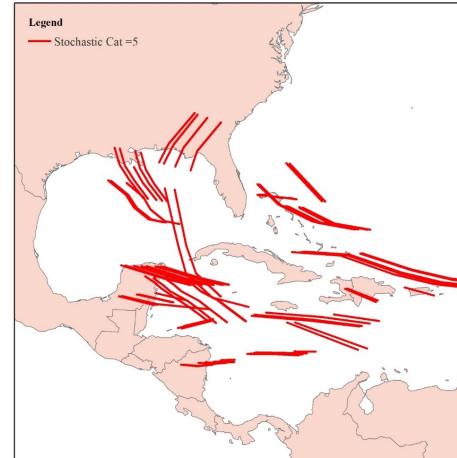
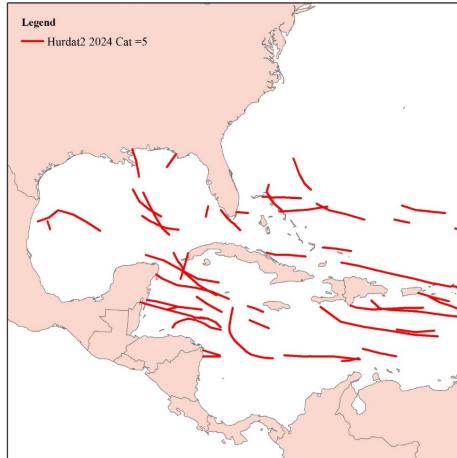


# Historical vs. Simulated tropical cyclone

(CAT $\geq 3$ )



(CAT=5)



- This study presents an AI framework designed to generate stochastic tropical cyclone tracks in North America. It integrates three methods: ARIMA, K-Means clustering, and Auto-encoder.
- The comparison between historical and generated hurricane tracks indicates that they follow similar spatial trends.
- The 100 years frequency in North American at each latitude-longitude degree tile are produced.
- The annualized frequency of hurricanes making landfall at Florida is 2, derived from historical and generated tracks.

## Future Work

- Other machine learning tools are investigated to generate stochastic hurricane tracks, such as Generative Adversarial Networks (GANs) and Long Short-Term Memory (LSTM) networks.
- Other hurricane characteristics, like storm size and moving speed, will be incorporated in this study, to achieve more refined and accurate hurricane track simulation results.
- Damage control using edge devices.
  - a) Disaster response
  - b) Policy making
  - c) Resource allocation



# Thanks