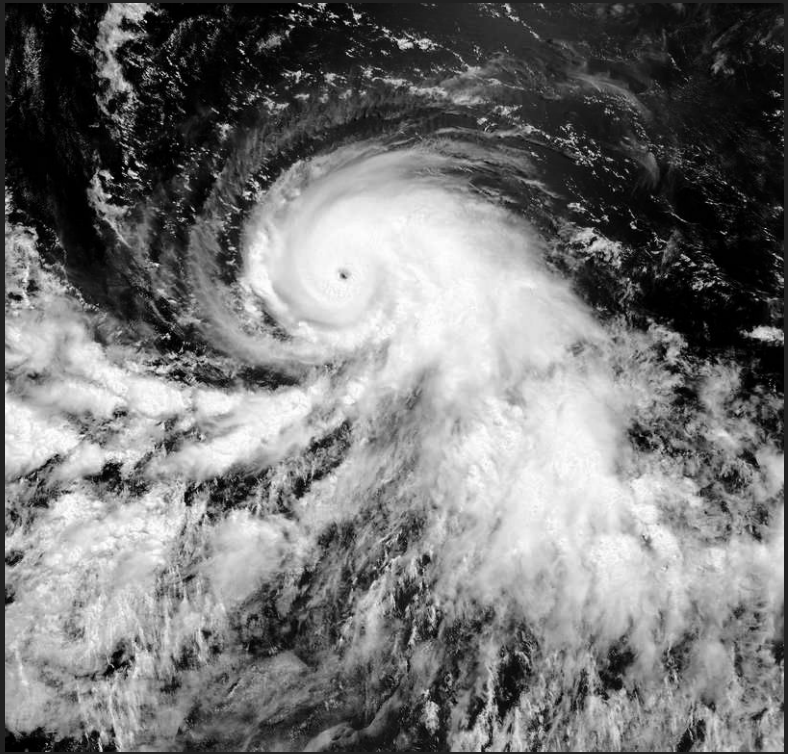
Paper presentation

Self-organizing maps of typhoon tracks allow for flood forecasts up to two days in advance

Maximilian Barth, Philipp Weber, Li Ting Luong

Schedule

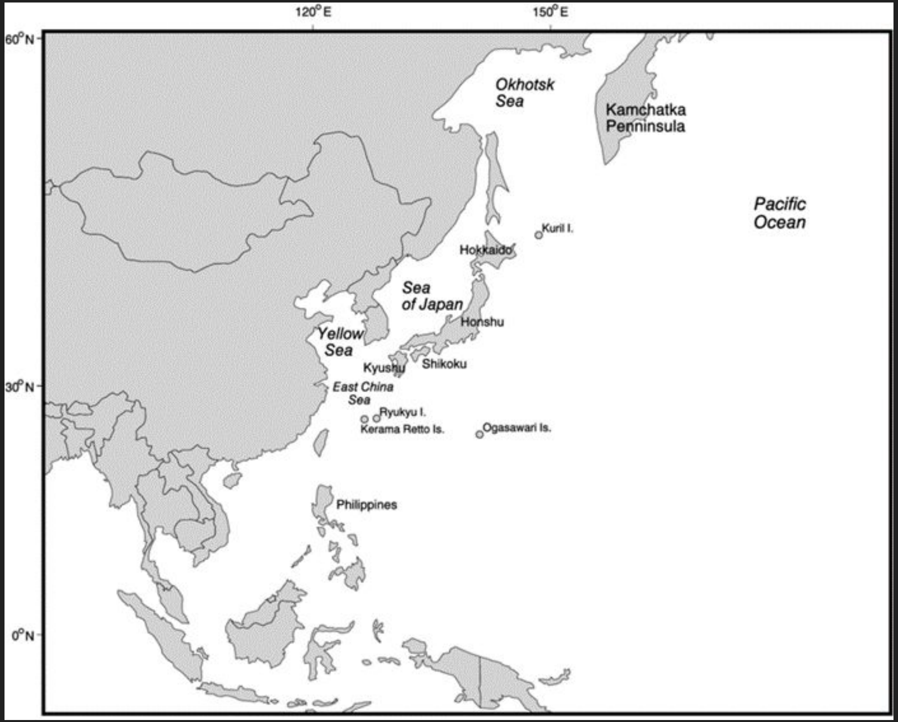
- What is a typhoon?
- Background
- Short overview and methods used
- Results they achieved with the research
- Critique and own opinion
- Comparison to other papers



What is a typhoon?

What is a typhoon?

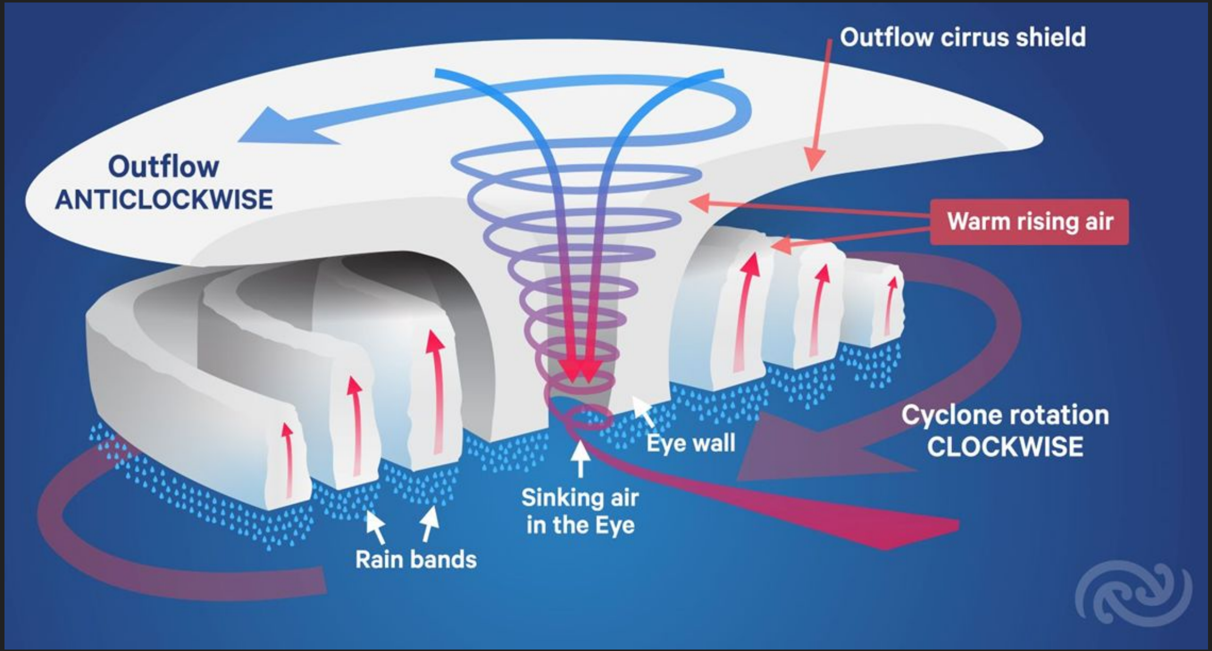
- Natural disaster
- Tropical cyclone
- Western North Pacific



Western North Pacific region

https://www.researchgate.net/figure/Western-North-Pacific-region_fig4_237471675

Formation of a Typhoon



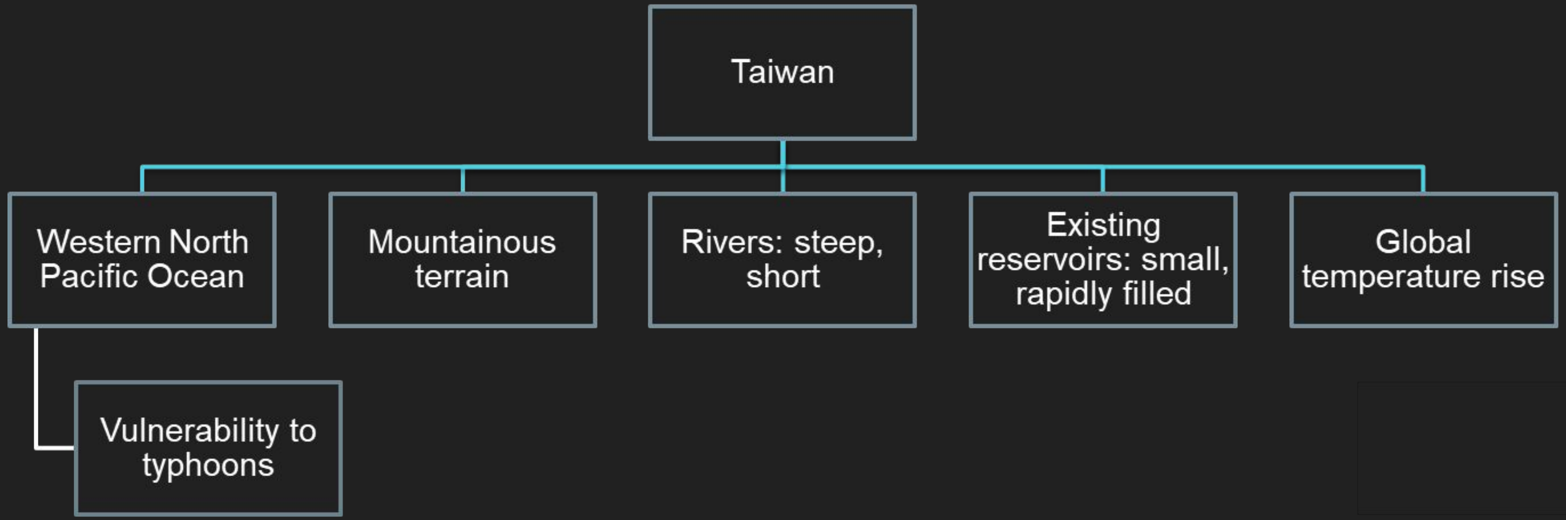
Typhoon Structure (Southern Hemisphere)

https://about.metservice.com/our-company/national-weather-services/tropical-cyclones/

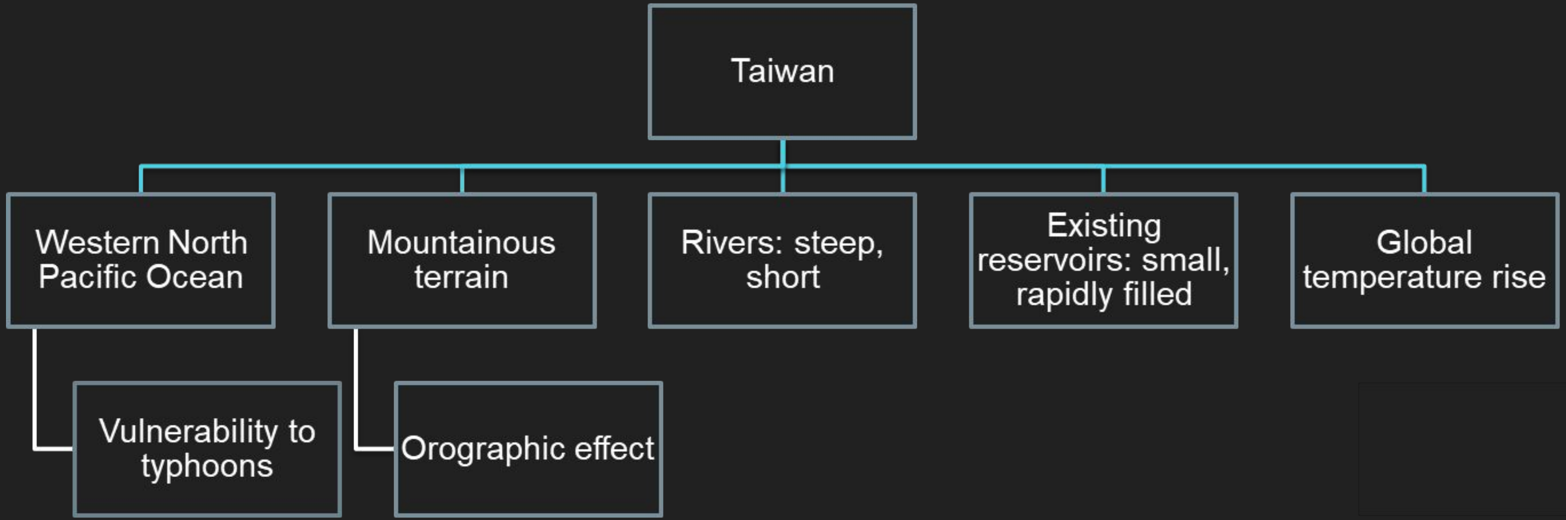
Background

- Taiwan
  - Western North Pacific Ocean
  - Mountainous terrain
  - Rivers: steep, short
  - Existing reservoirs: small, rapidly filled
  - Global temperature rise

Background


Taiwan
Western North Pacific Ocean
Mountainous terrain
Rivers: steep, short
Existing reservoirs: small, rapidly filled
Global temperature rise
Vulnerability to typhoons

Background


Taiwan
Western North Pacific Ocean
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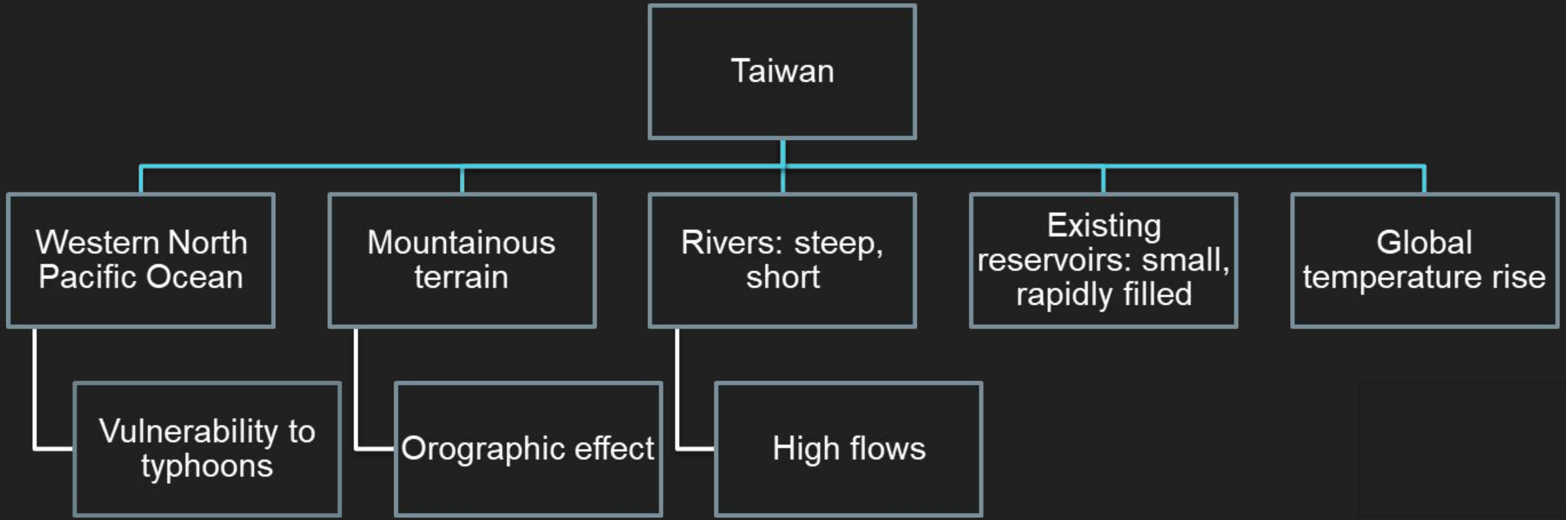
Vulnerability to typhoons
Orographic effect

Background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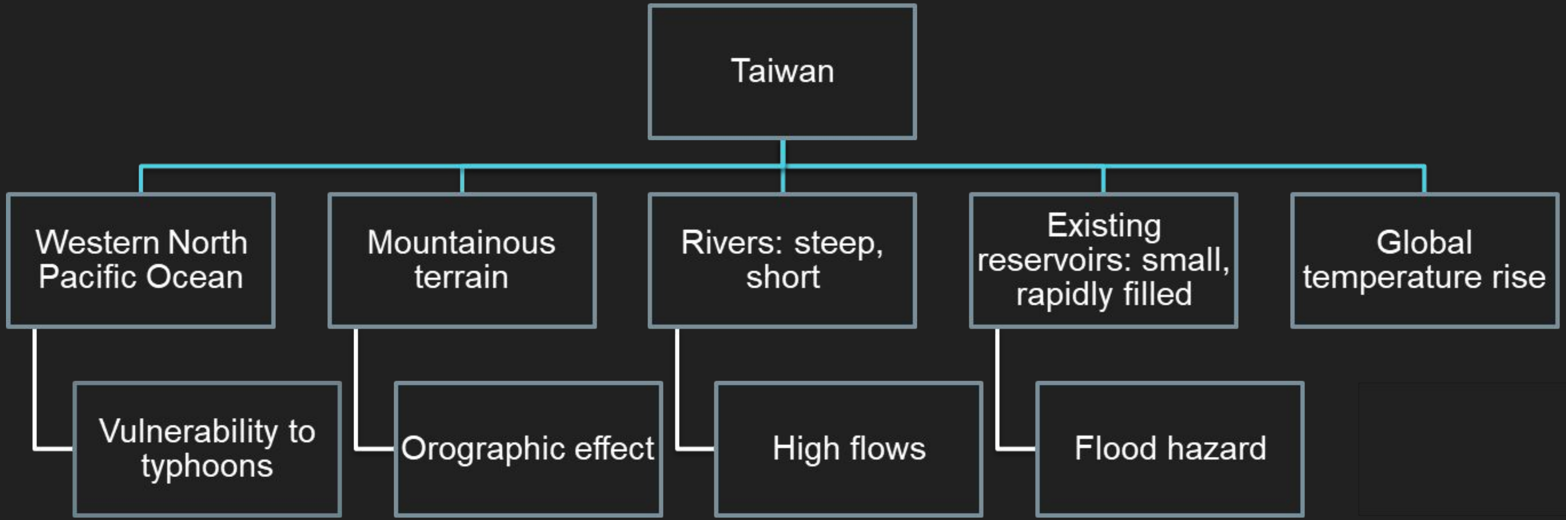
Vulnerability to typhoons
Orographic effect
High flows

Background


Taiwan
Western North Pacific Ocean
Mountainous terrain
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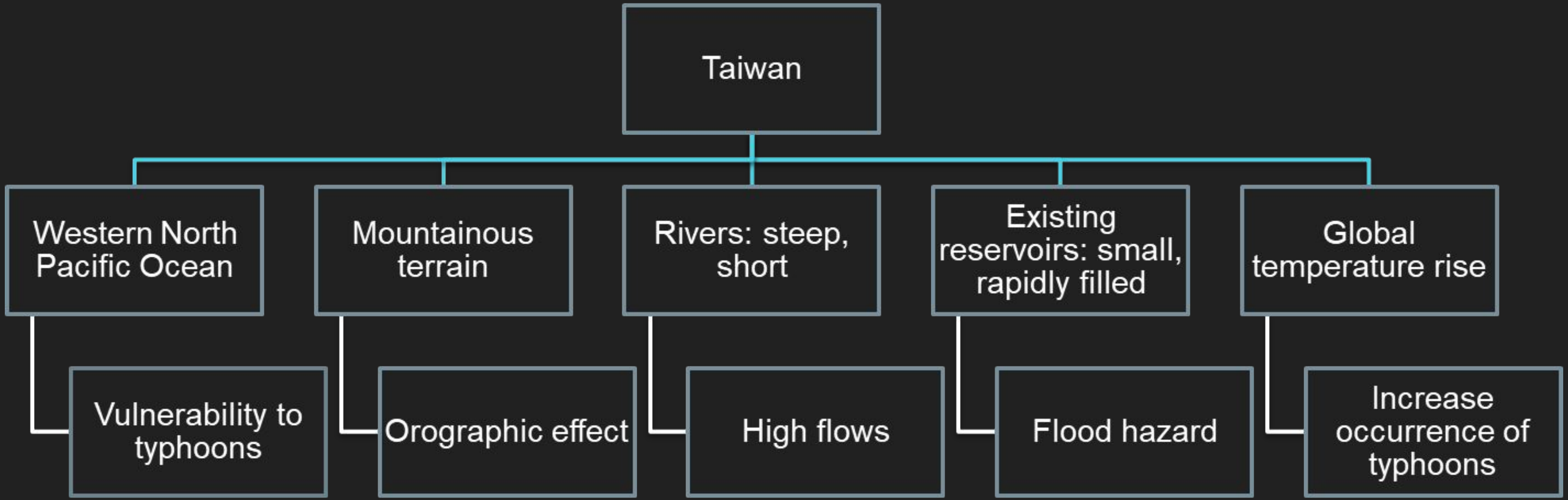
Vulnerability to typhoons
Orographic effect
High flows
Flood hazard

Background


Taiwan
Western North Pacific Ocean
Mountainous terrain
Rivers: steep, short
Existing reservoirs: small, rapidly filled
Global temperature rise
Vulnerability to typhoons
Orographic effect
High flows
Flood hazard
Increase occurrence of typhoons

Short overview and methods used

COMMUNICATIONS

ARTICLE

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Self-organizing maps of typhoon tracks allow for flood forecasts up to two days in advance

Li-Chiu Chang[1✉], Fi-John Chang[2✉], Shun-Nien Yang[1], Fong-He Tsai[2], Ting-Hua Chang[3] & Edwin E. Herricks[4]

Typhoons are among the greatest natural hazards along East Asian coasts. Typhoon-related precipitation can produce flooding that is often only predictable a few hours in advance. Here, we present a machine-learning method comparing projected typhoon tracks with past trajectories, then using the information to predict flood hydrographs for a watershed on Taiwan. The hydrographs provide early warning of possible flooding prior to typhoon landfall, and then real-time updates of expected flooding along the typhoon's path. The method associates different types of typhoon tracks with landscape topography and runoff data to estimate the water inflow into a reservoir, allowing prediction of flood hydrographs up to two days in advance with continual updates. Modelling involves identifying typhoon track vectors, clustering vectors using a self-organizing map, extracting flow characteristic curves, and predicting flood hydrographs. This machine learning approach can significantly improve existing flood warning systems and provide early warnings to reservoir management.

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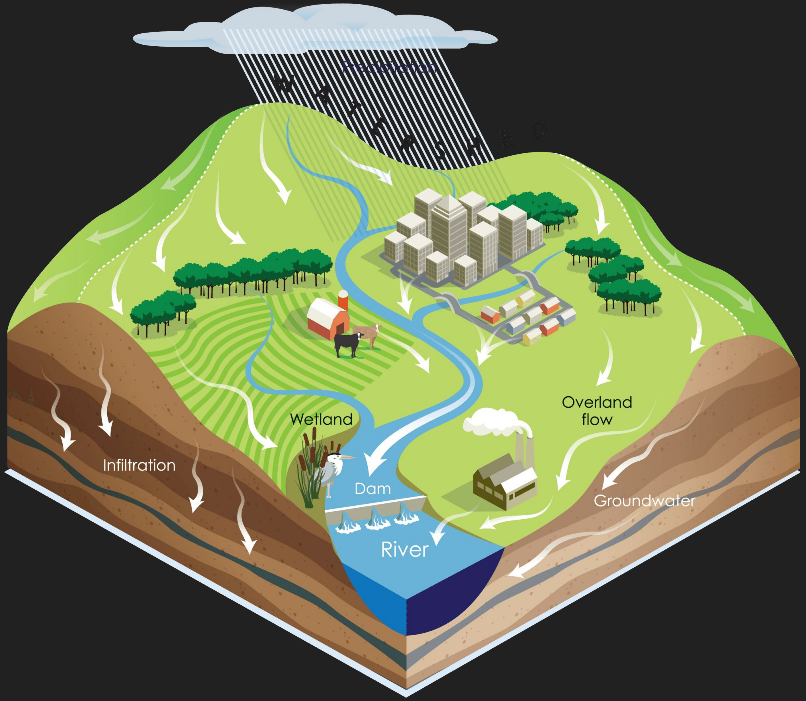
Short overview of the paper

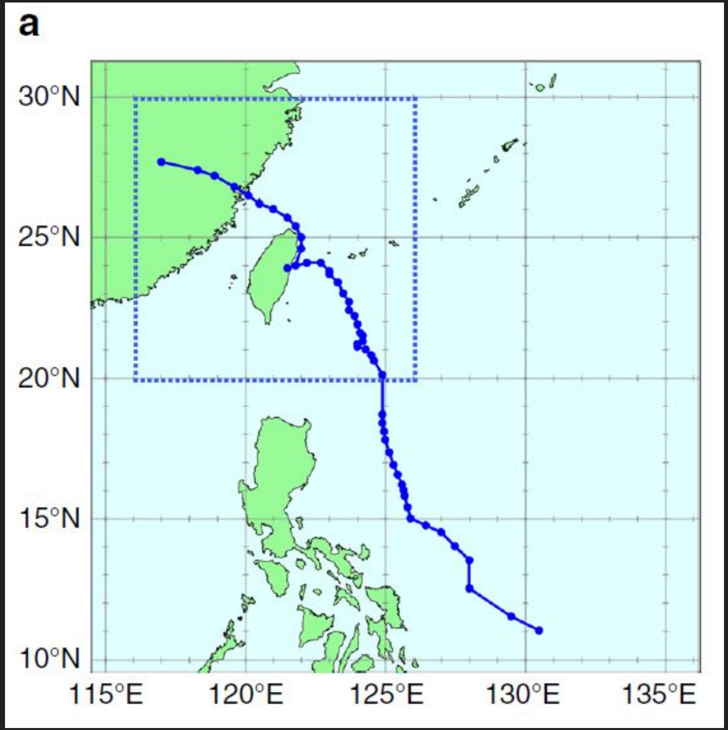
- Used data from 97 typhoons (87 + 10)
- Shihmen reservoir watershed near Taipei



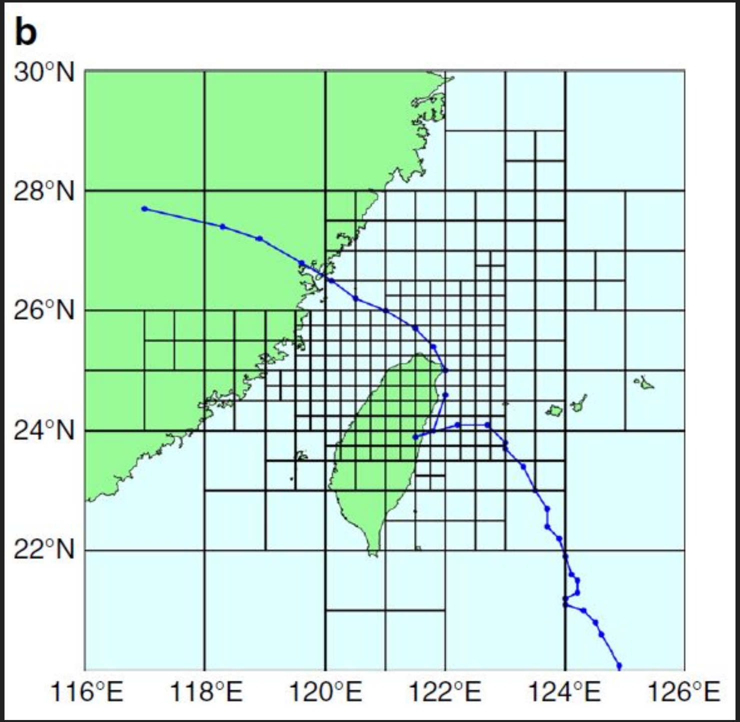
Example of a watershed

https://www.lakecountyil.gov/ImageRepository/Document?documentID=23634

Vectorization of typhoon tracks

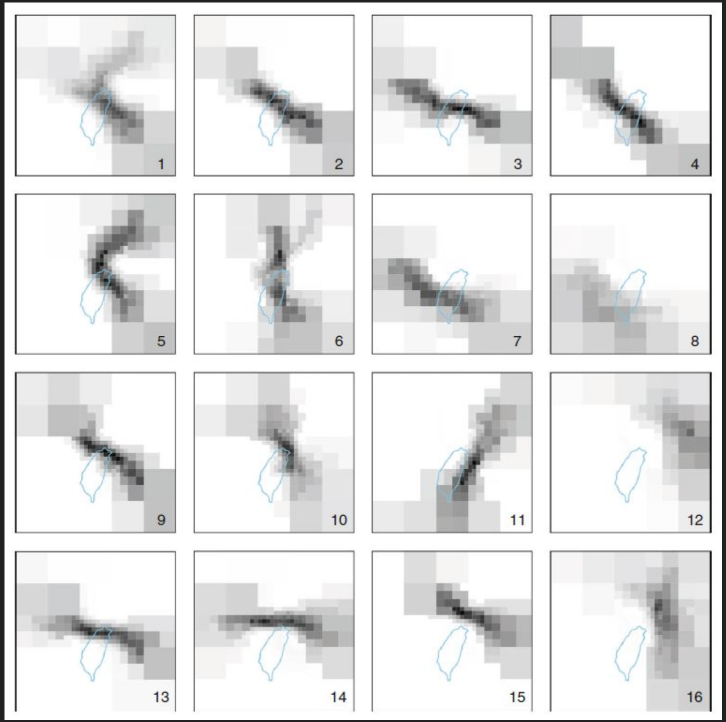


Example of a typhoon track passing over Taiwan

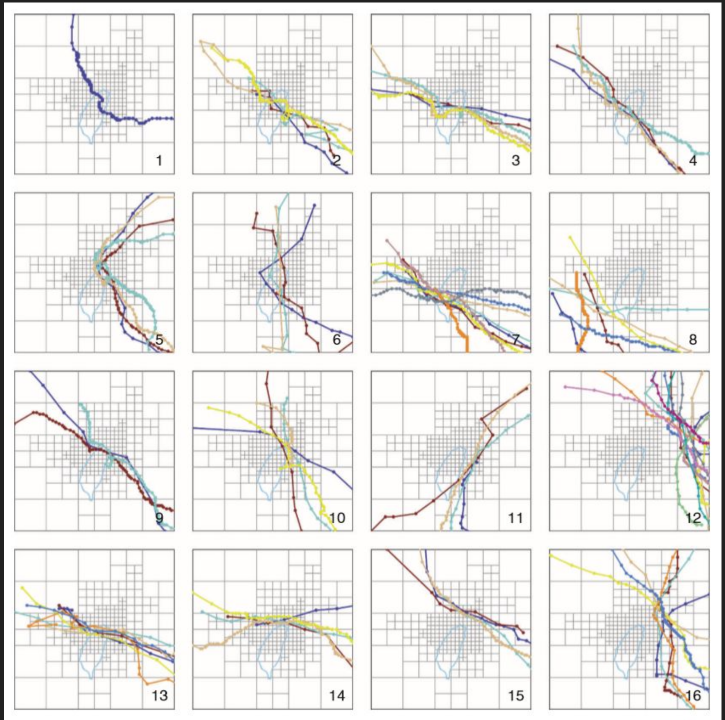


Typhoon track with the grid used to vectorize tracks

Using self-organizing maps for clustering

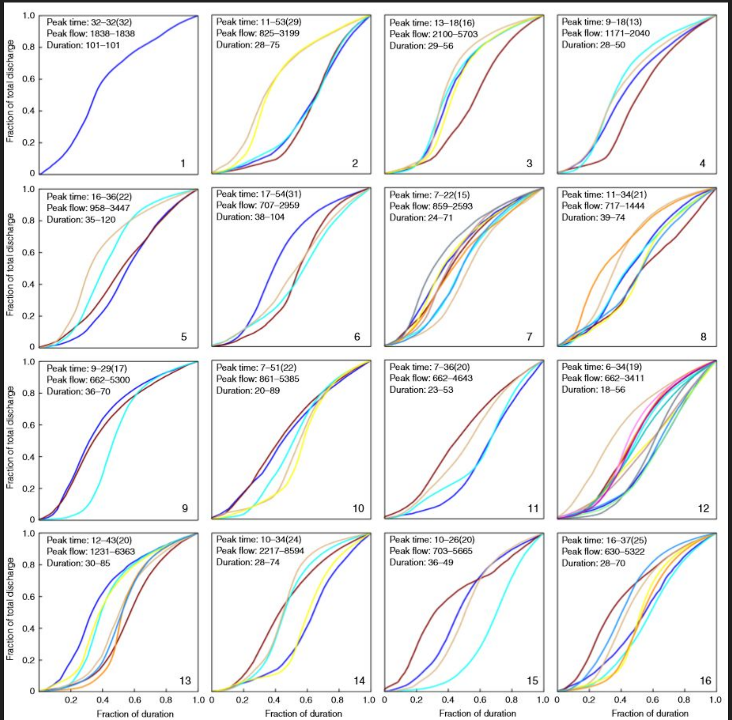


4x4 self-organizing map

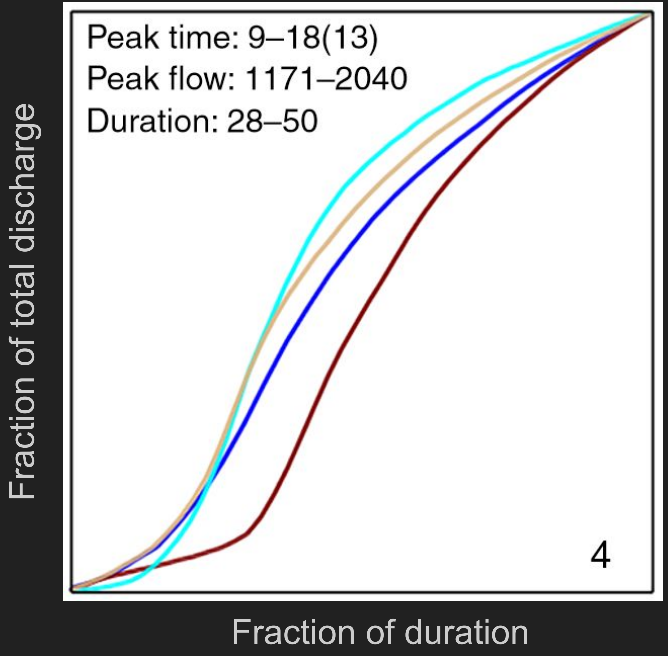


Clustered tracks

determining the FCC

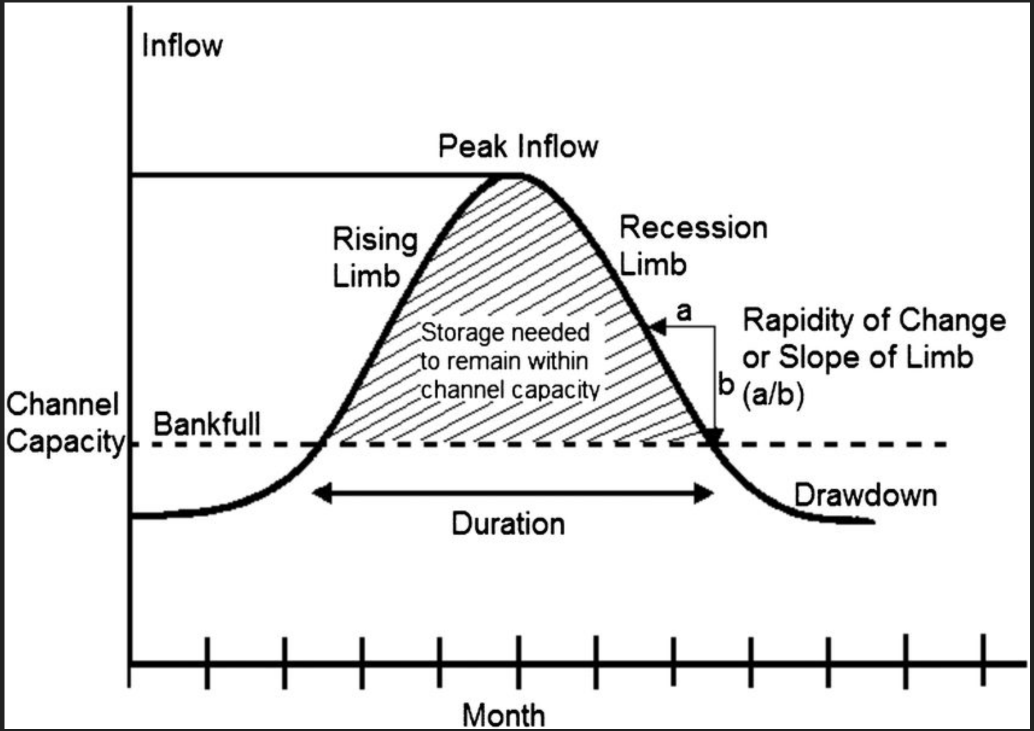


FCCs of the different clusters



FCCs of cluster 4

Hydrograph prediction

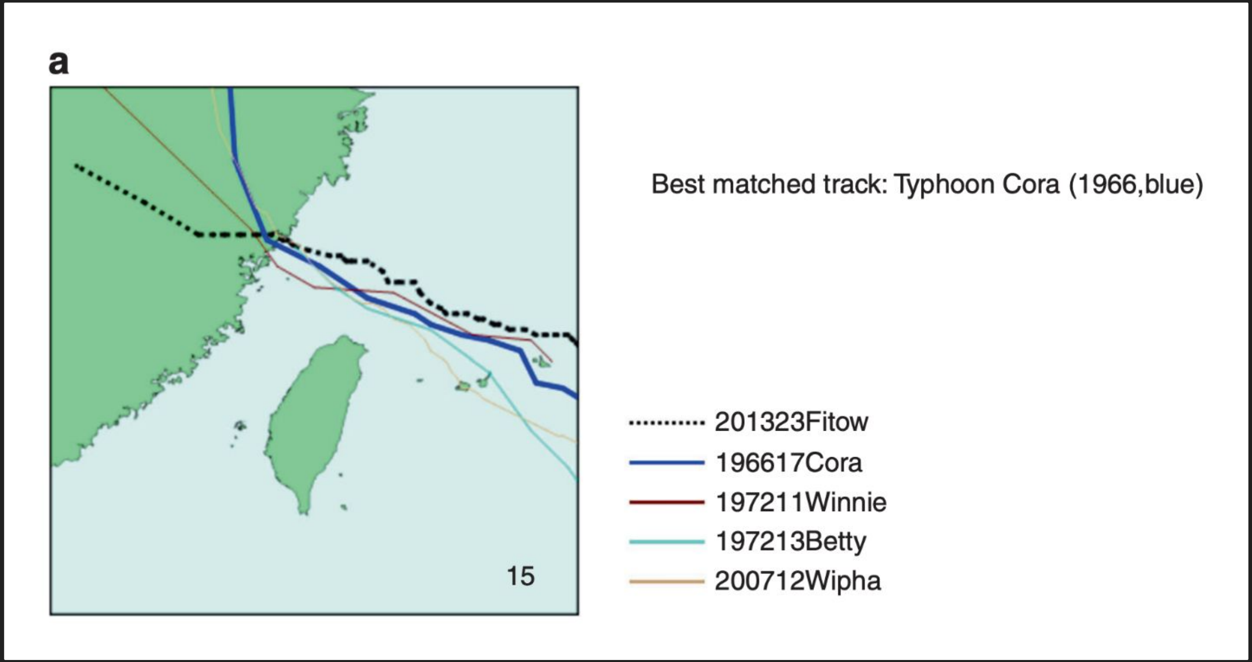


Example of a hydrograph

- identify best matched cluster / best matched track
- get the FCC
- FCC + forecasted rainfall = flood hydrograph

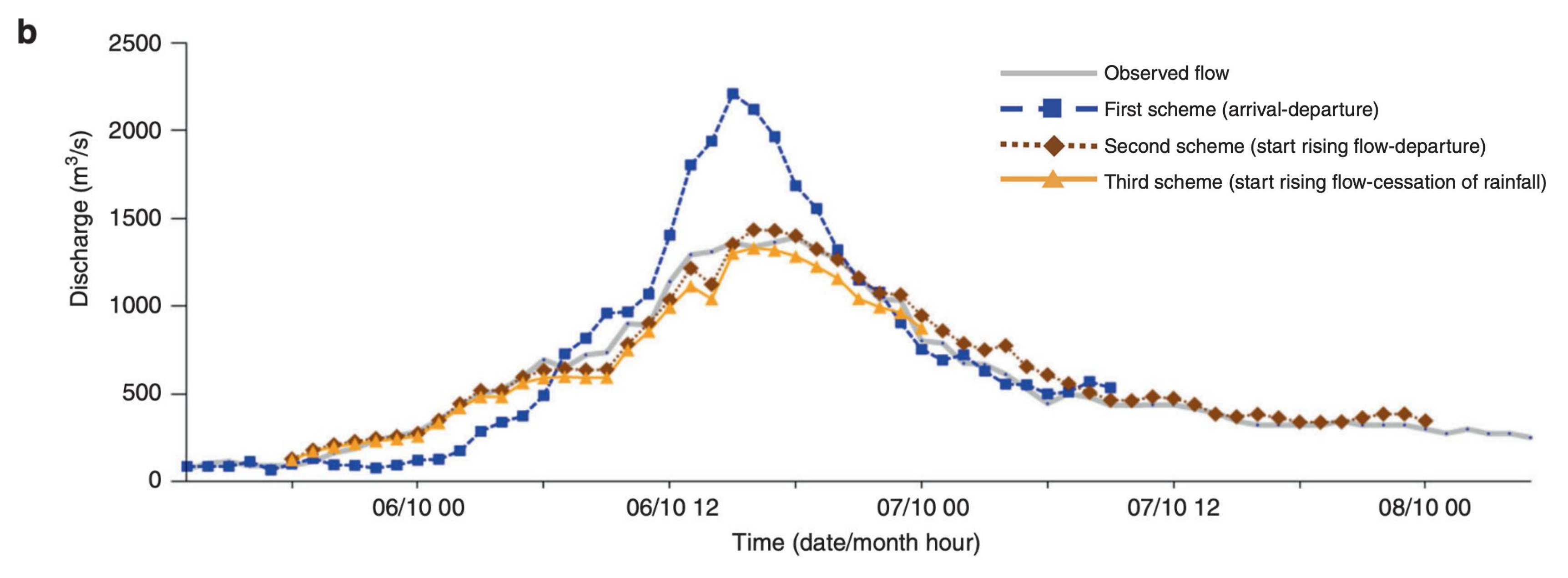
https://www.researchgate.net/profile/Rui-Hui-2/publication/271374977/figure/fig1/AS:403439948451840@1473198987470/Simple-flood-hydrograph.png

Test case: Typhoon Fitow



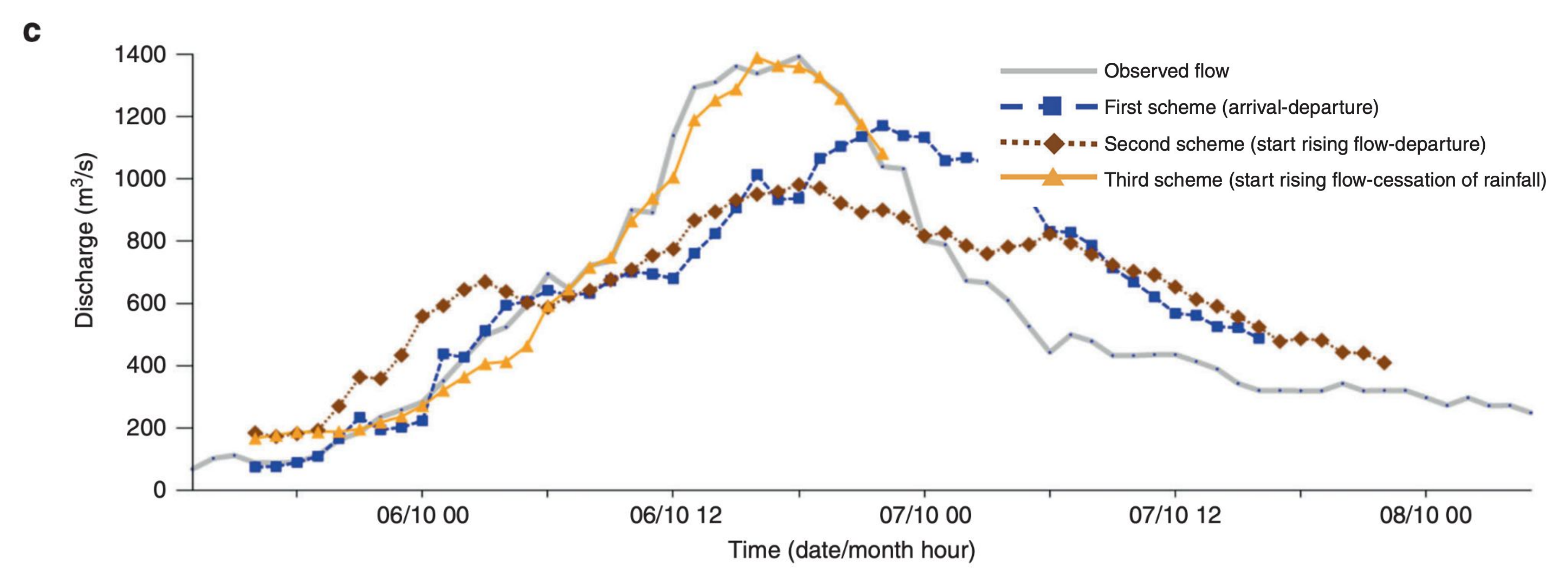
Plot of TC Fitow track and associated cluster

Results: Best matched track



Results of the three schemes using the best matched track

Results: Average of best matched cluster



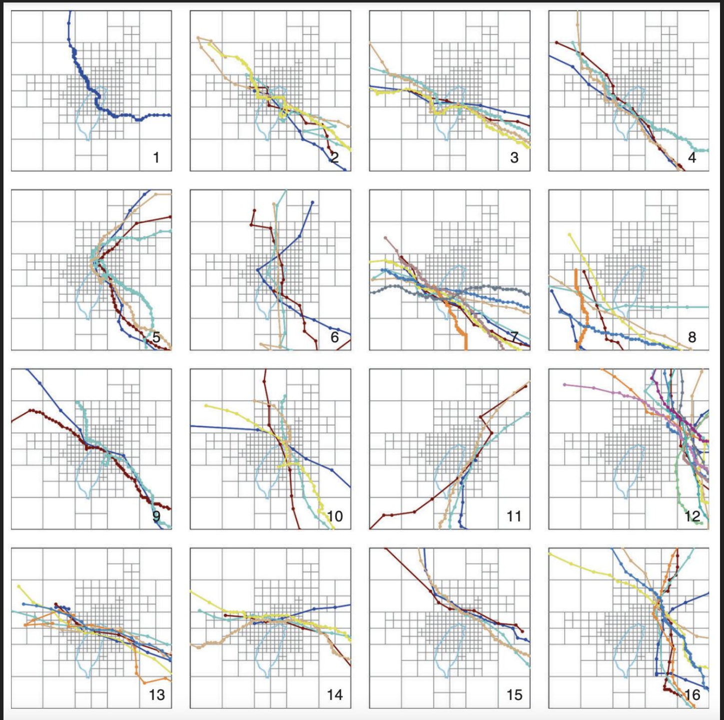
Results of the three schemes using the average of the cluster

Results

- Generally matched actual flow characteristic curves
- AI approach better than commonly used prediction model
- More accurate results with best matched track
- BUT: reliant on track prediction

Shihmen Reservoir
https://travel.tycg.gov.tw/image/7554/1024x768

What happens in case of a mispredicted track?



SOM with the 16 clusters

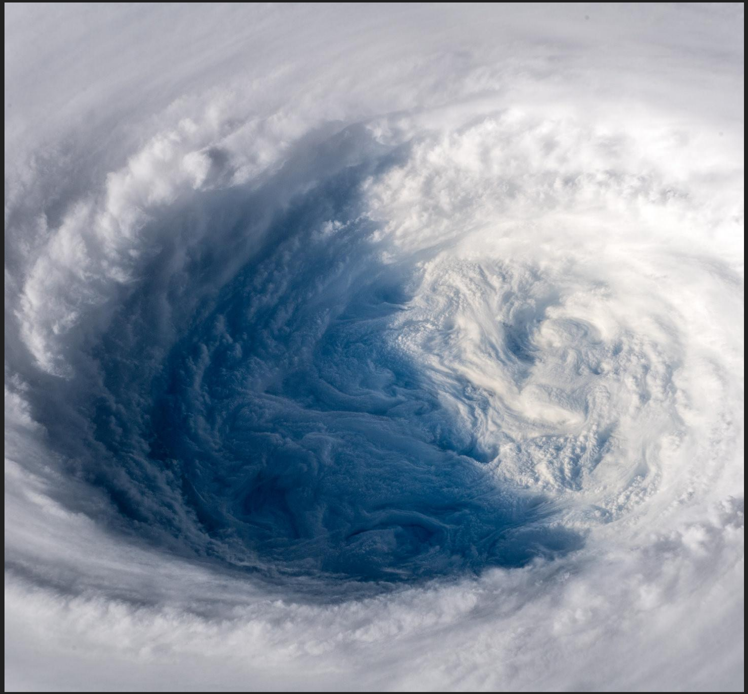
- SOM deals with false tracks
- Relatively good predictions
- Track prediction accuracy is steadily increasing
- ML approaches

Critique and own opinion

https://www.communitycare.co.uk/2021/04/23/case-promoting-free-speech-debate-enquiry-social-work-classroom/

Room for improvement?

- Dependant on other models
  - Track prediction
  - Rainfall prediction
  - tropical cyclone velocity prediction
- Small sample size
  - Cluster with only one track

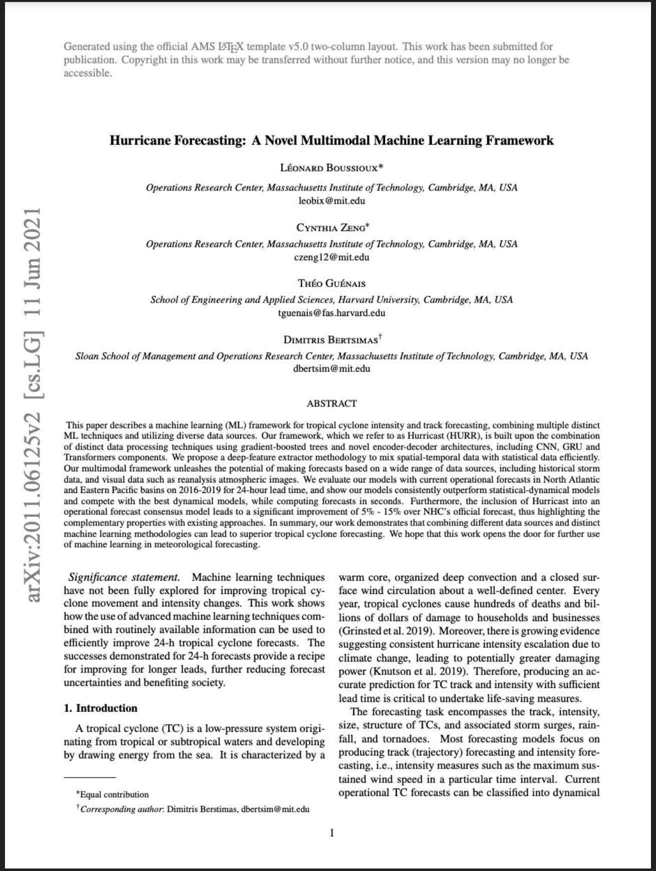


https://cdn.mos.cms.futurecdn.net/wB5fx8w5RuMiHS8NNw5B3j.jpg

Related paper: Hurricane Forecasting

- New development in 2021
- ML approach to tropical cyclone prediction
- Competitive results

➡ Could be used to improve flood forecasts



arXiv:2011.06125v2 [cs.LG] 11 Jun 2021

Hurricane Forecasting: A Novel Multimodal Machine Learning Framework

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ABSTRACT

This paper describes a machine learning (ML) framework for tropical cyclone intensity and track forecasting, combining multiple distinct ML techniques and utilizing diverse data sources. Our framework, which we refer to as Hurricast (HURR), is built upon the combination of distinct data processing techniques using gradient-boosted trees and novel encoder-decoder architectures, including CNN, GRU and Transformers components. We propose a deep-feature extractor methodology to mix spatial-temporal data with statistical data efficiently. Our multimodal framework unleashes the potential of making forecasts based on a wide range of data sources, including historical storm data, and visual data such as reanalysis atmospheric images. We evaluate our models with current operational forecasts in North Atlantic and Eastern Pacific basins on 2016-2019 for 24-hour lead time, and show our models consistently outperform statistical-dynamical models and compete with the best dynamical models, while computing forecasts in seconds. Furthermore, the inclusion of Hurricast into an operational forecast consensus model leads to a significant improvement of 5% - 15% over NHC's official forecast, thus highlighting the complementary properties with existing approaches. In summary, our work demonstrates that combining different data sources and distinct machine learning methodologies can lead to superior tropical cyclone forecasting. We hope that this work opens the door for further use of machine learning in meteorological forecasting.

Significance statement. Machine learning techniques have not been fully explored for improving tropical cyclone movement and intensity changes. This work shows how the use of advanced machine learning techniques combined with routinely available information can be used to efficiently improve 24-h tropical cyclone forecasts. The successes demonstrated for 24-h forecasts provide a recipe for improving for longer leads, further reducing forecast uncertainties and benefiting society.

1. Introduction

A tropical cyclone (TC) is a low-pressure system originating from tropical or subtropical waters and developing by drawing energy from the sea. It is characterized by a warm core, organized deep convection and a closed surface wind circulation about a well-defined center. Every year, tropical cyclones cause hundreds of deaths and billions of dollars of damage to households and businesses (Grinsted et al. 2019). Moreover, there is growing evidence suggesting consistent hurricane intensity escalation due to climate change, leading to potentially greater damaging power (Knutson et al. 2019). Therefore, producing an accurate prediction for TC track and intensity with sufficient lead time is critical to undertake life-saving measures.

The forecasting task encompasses the track, intensity, size, structure of TCs, and associated storm surges, rainfall, and tornadoes. Most forecasting models focus on producing track (trajectory) forecasting and intensity forecasting, i.e., intensity measures such as the maximum sustained wind speed in a particular time interval. Current operational TC forecasts can be classified into dynamical

*Equal contribution

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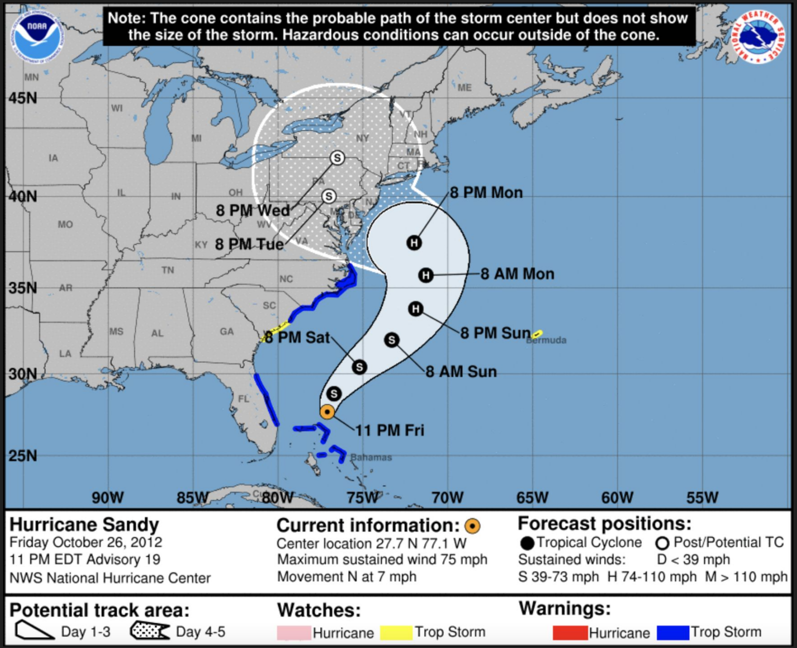
TC track predictions

1. Dynamical models: use physical equations and measured initial conditions
2. Statistical models: use historic data
3. Ensemble models: combination of multiple models
4. NEW: Neural Network based approaches



Official track prediction of the NOAA and the National Weather Service

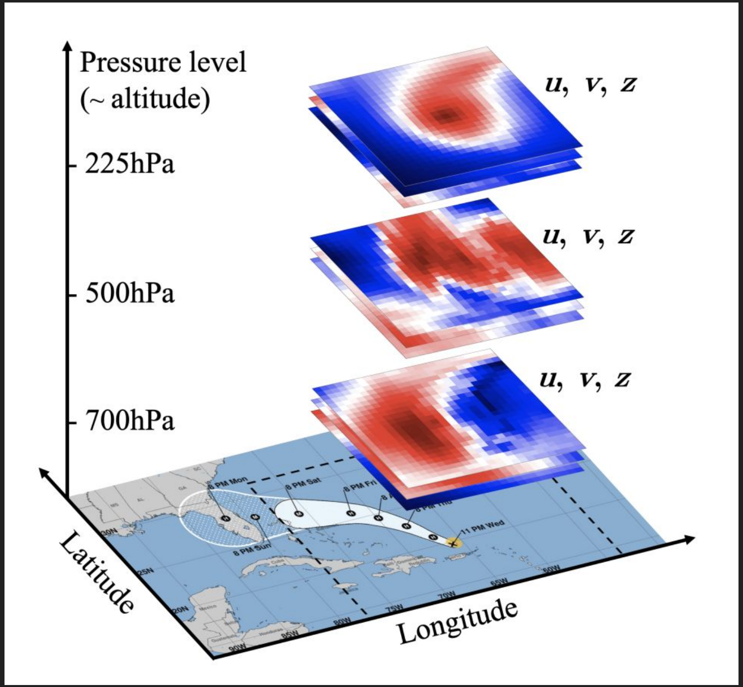
https://www.nhc.noaa.gov/tc-graphics/images/cone_5day_no_wind.png

Track prediction using ML

Two approaches:

1. CNNs used on satellite images
2. Recurrent neural networks
    - recognize sequential patterns

- Maximum of 48h forecast
- Produce competitive results
- Improve multimodal approaches



CNN approach to TC track prediction

AI for Social Good

- Important step for tropical cyclone predictions
- The model is an improvement over conventional methods
- It has a positive impact on people's lives
- Can be applied in other parts of the world

https://d3t3ozftmdmh3i.cloudfront.net/production/podcast_uploaded_episode400/13570443/13570443-1616270981262-7eb6c82571e66.jpg