Climate Storyline to Evaluate Tropical Cyclone-Induced Marine Hazards in Naples, Florida

Presented by: Dana Pothier

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Dana Pothier[1], Melisa Menéndez[1], Marta Ramírez Pérez[1]

1: IHCantabria, Santander, Spain

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Introduction

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- Influence of **climate change** on TC-induced **storm surge** remains **uncertain** (Knutson et al., 2020)

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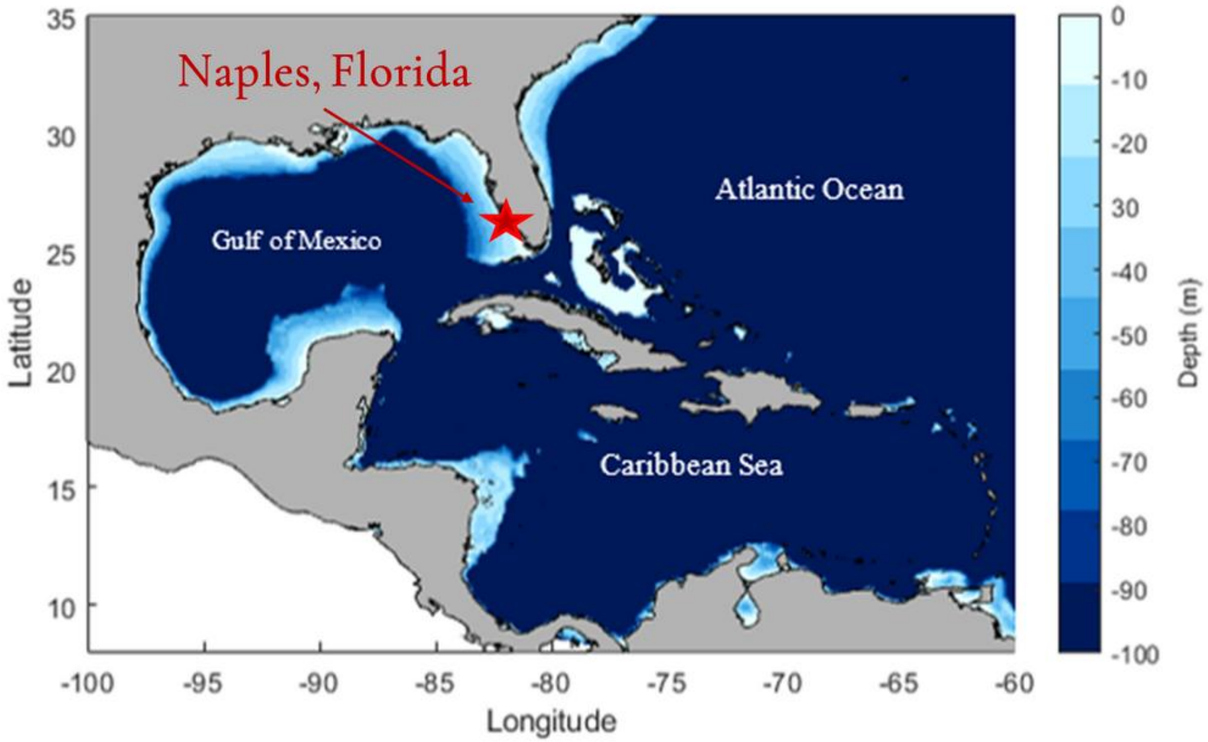
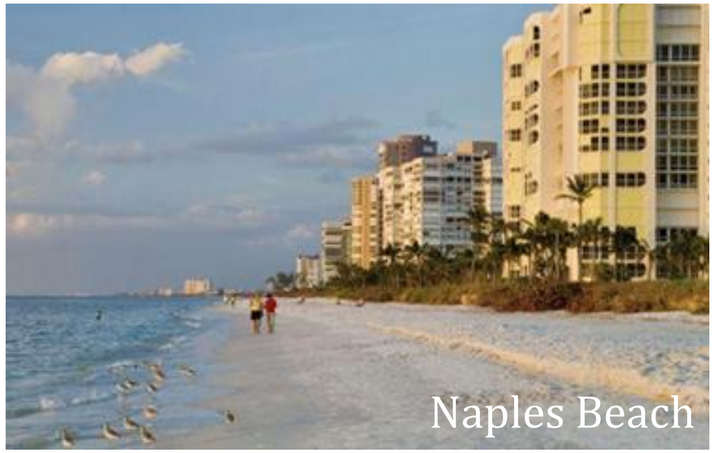


Study Site: Naples, Florida


Naples Beach


TC Ian (2022)

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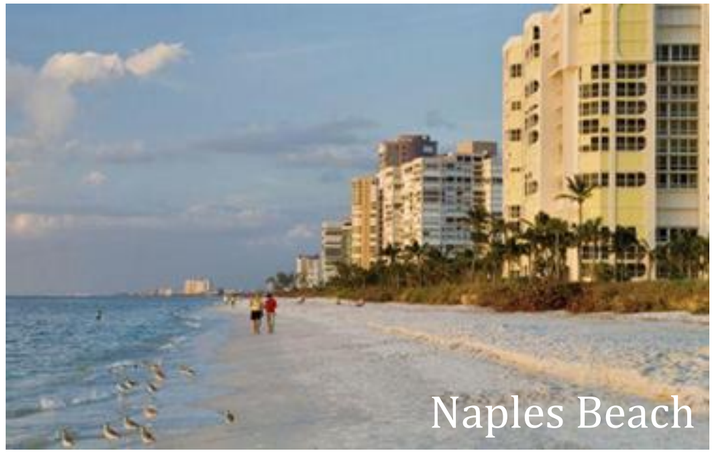

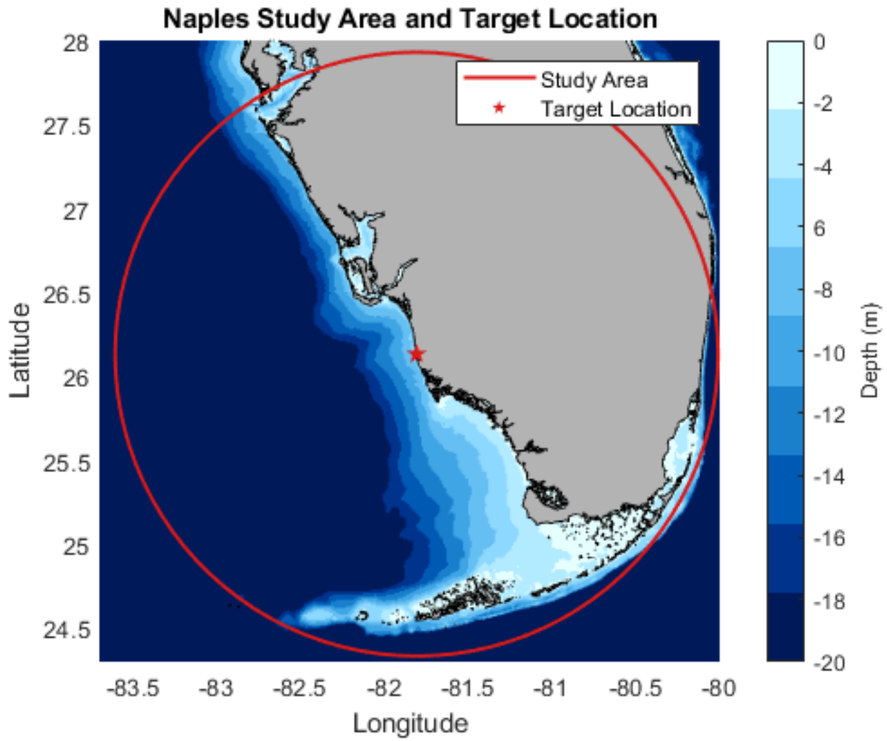

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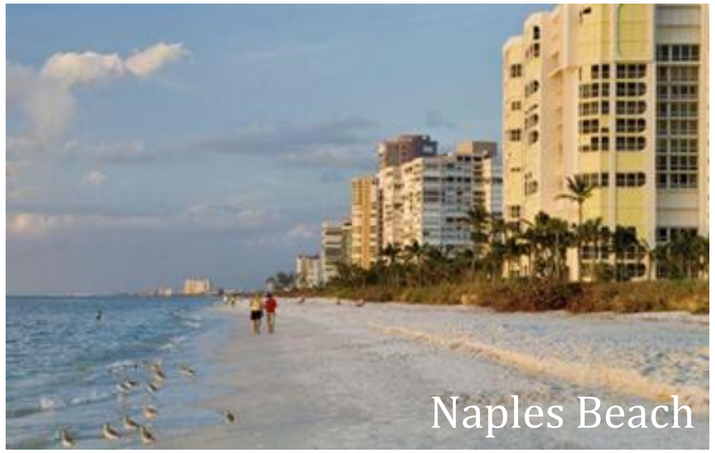
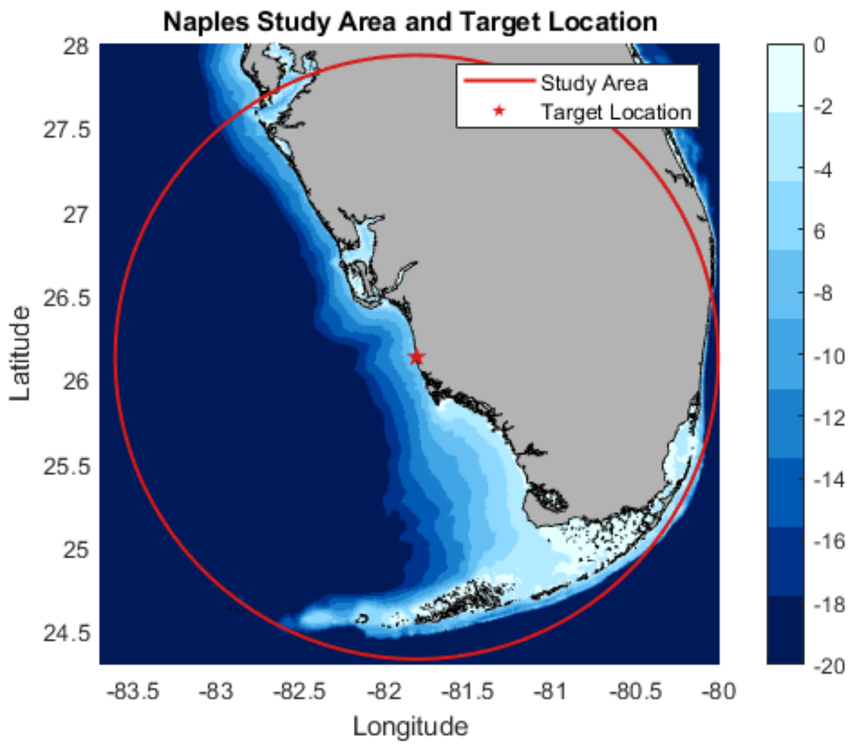
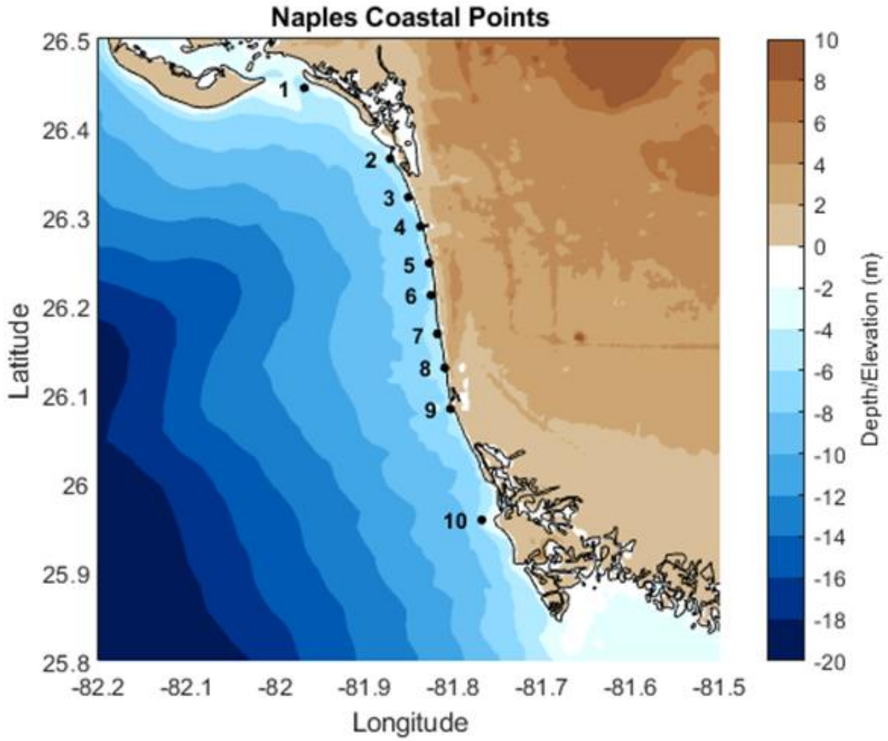






Methodology

1. TC Characterization

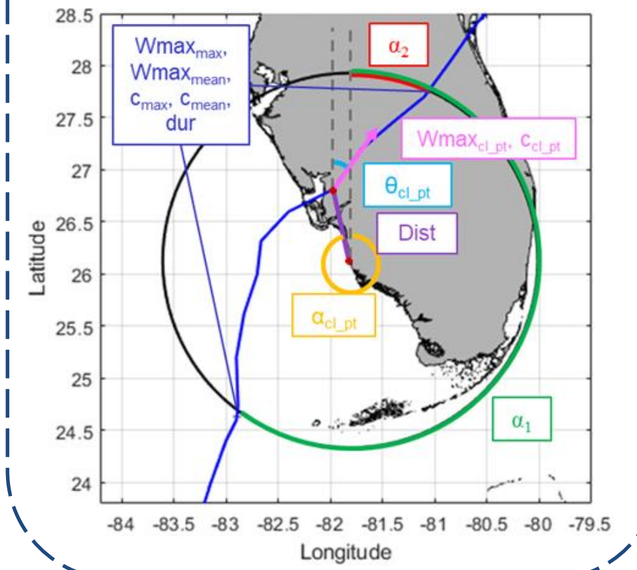
2. Statistical Methods

3. Modelling

Methodology

1. TC Characterization

- **TC datasets** (Bloemendaal et al., 2020, 2022)
  - Present climate synthetic tracks
  - Future climate (SSP-8.5, 2015-2050) synthetic tracks
- Calculated relevant **TC parameters**



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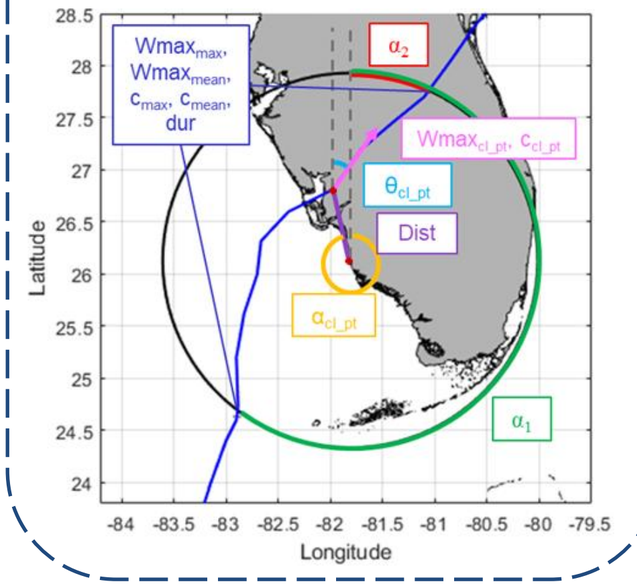
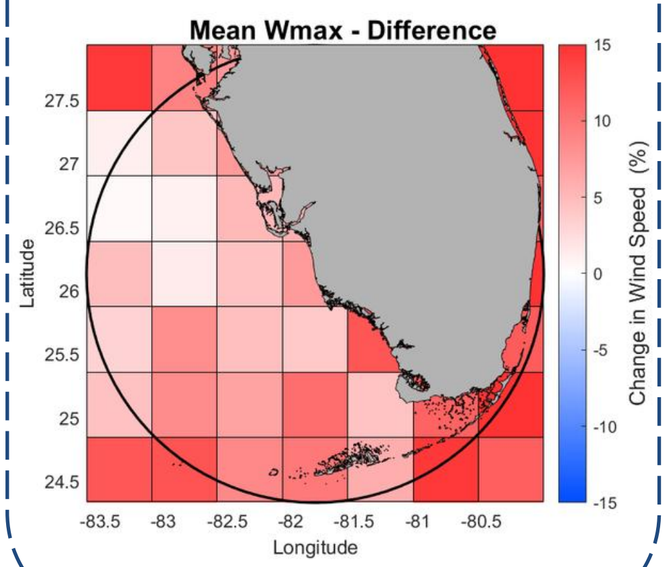


2. Statistical Methods

- Quantify **changes** in **TC parameters**
- Only parameter with **clear** and **significant** trend: **Wmax**
- Increase in future climate of **+8.5%**



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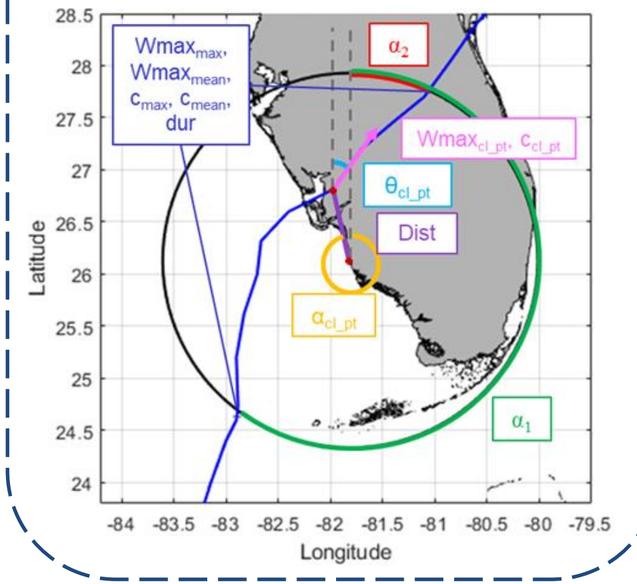

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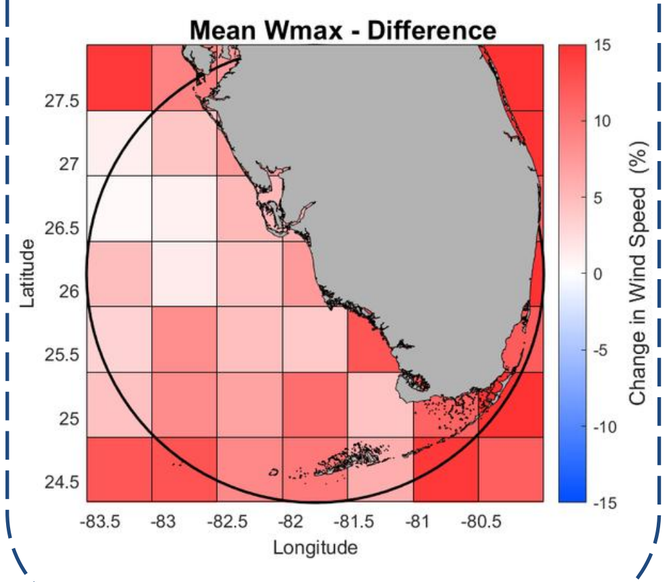
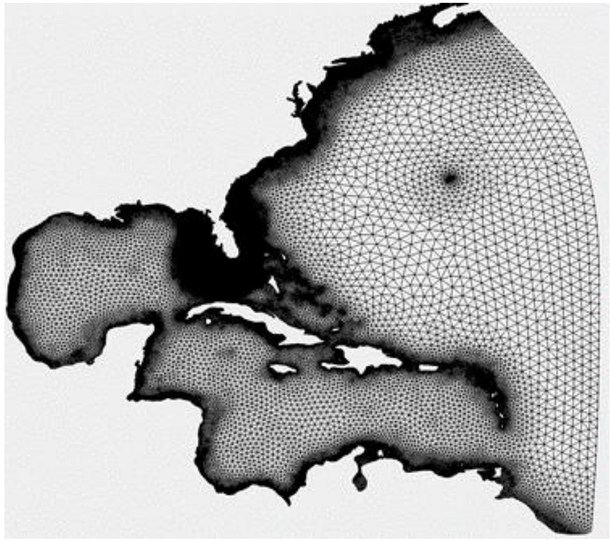
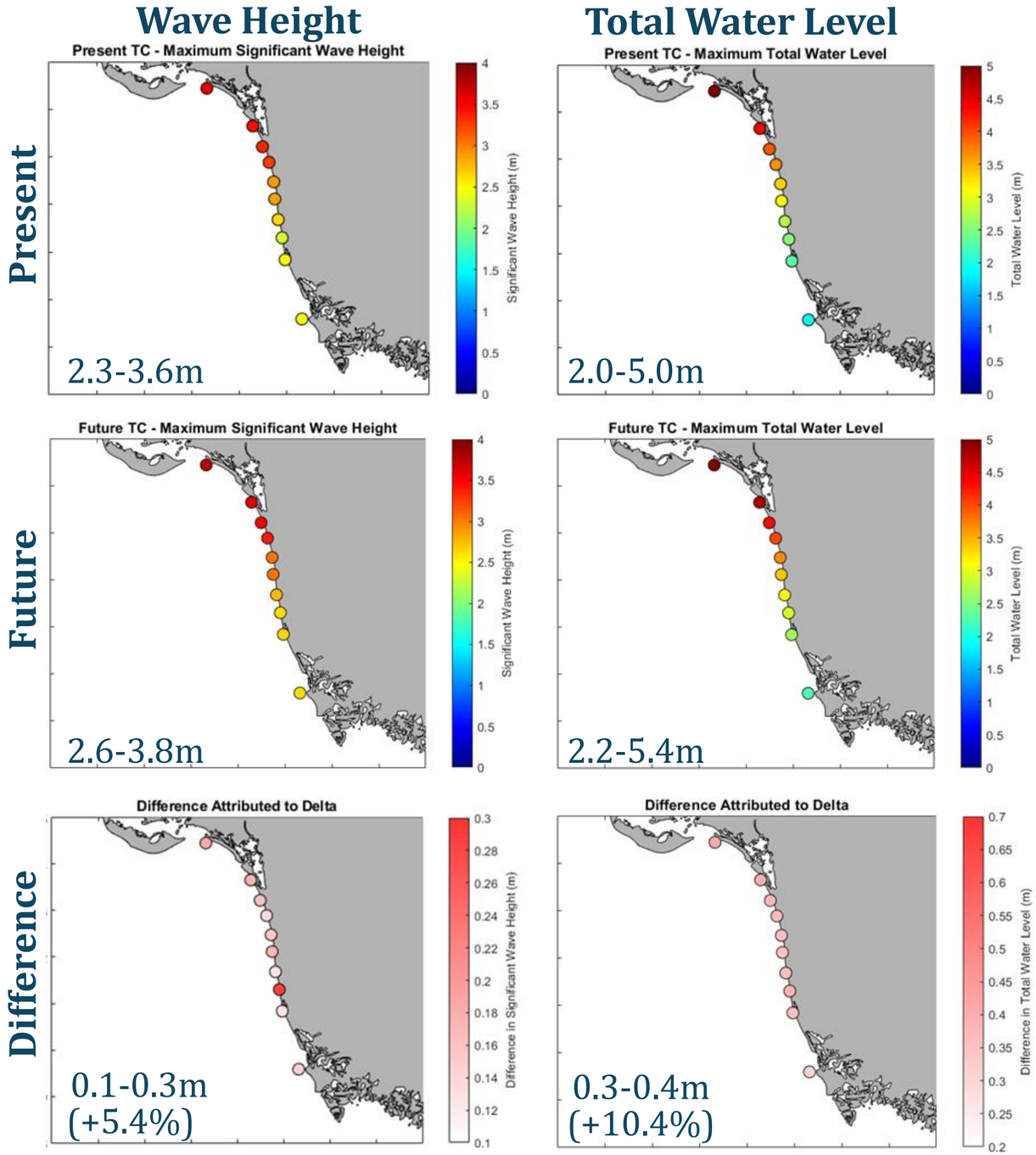


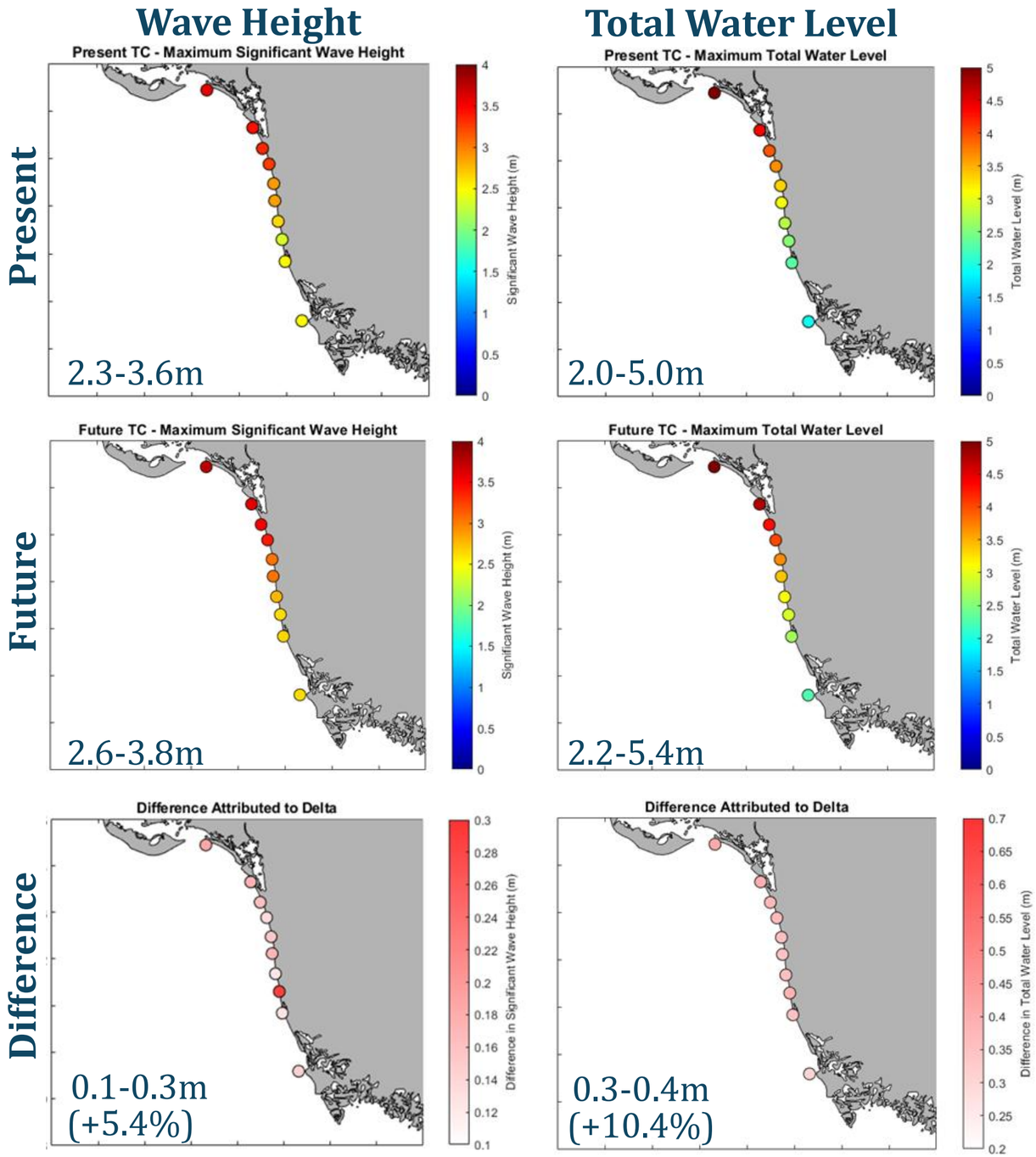
3. Modelling

- **Storyline:** TC Ian (2022) under **present** and **future climate** conditions
- Coupled **ADCIRC+SWAN**
- Unstructured **high-resolution** mesh, overland up to 10m



Results & Key Findings





Results & Key Findings

- **Magnitude** of coastal hazards and impacts **increase** due to changes in **TC characteristics**
  - Storm surge: +10.2%,
  - Significant wave height: +5.4%
  - TWL: +10.4%
  - Flood height: increases up to 0.5m
  - Flood extent: +7.5%
- Increase in **TWL** due to changes in **TC characteristics** (10.4%) **greater** than increase due to **SLR** (7.3%)
  - Important to consider changes in **TC characteristics** in hazard and risk assessment studies

Thank you!

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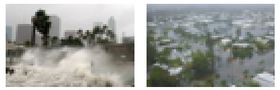
4th International Workshop on Waves, Storm Surges, and Coastal Hazards, Santander, Spain

IH cantabria

1. Introduction

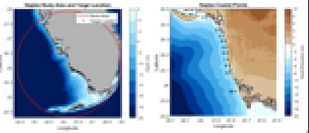
- Tropical Cyclones (TCs) are among the most costly and dangerous extreme weather events, affecting tropical coastal areas worldwide
- Induce coastal hazards: wind, storm surge, waves, total water levels (TWLs) & coastal impacts: flooding, erosion → causing $26 billion annual damages[1-3]
- Future changes in storm surge risk remain uncertain[4-5]



Study goal: Conduct a comprehensive local assessment in the Tropical Atlantic Region to evaluate the future changes in TC characteristics and the consequent effect on induced coastal hazards and impacts

2. Study Area: Naples, Florida

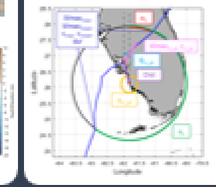
- 16 mile sandy beach backed by residential areas
- Numerous extreme historical TC events: Milton (2024), Ian (2022), Irma (2017)
- Study area selected with 200km radius[6]
- 50 km subsamed coastal segment identified with 100 coastal points



3. Methodology

1. TC Characterization

- Selection of TC tracks affecting the study area
- Calculation of relevant physical TC characteristics[7-8-9]



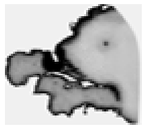
2. Statistical Methods

- Assessment of physical TC characteristics on induced storm surge
- Analysis of future changes in TC characteristics

Apply delta to historical track (storyline approach)

3. Numerical Modelling

- Selection of historical TC for climate change assessment
- Simulation of marine dynamics induced by present climate TC
- Simulation of marine dynamics induced by future climate TC

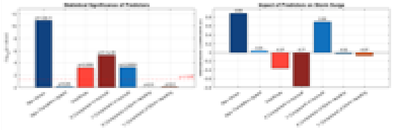


Scenario	Analyzed Marine Dynamic Output		
	Storm Surge	Significant Wave Height	Total Water Level
Present TC			
Future TC			
Future TC + SLR			

4. Results

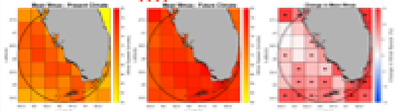
1. TC Characterization

- ANOVA analysis was conducted to determine contribution of different TC parameters to storm surge[10-11]
- 82% of variance in storm surge explained
- Statistically significant parameters: maximum wind speed, azimuth and normalized distance

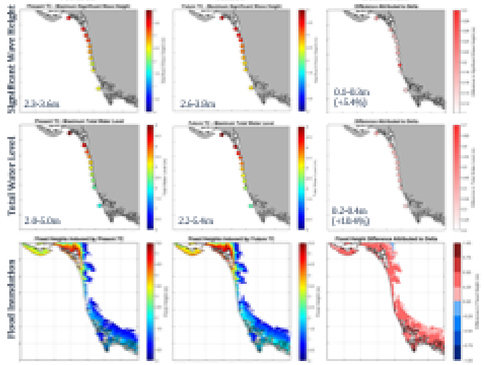


2. Statistical Methods

- Statistical analysis of present and future climate tracks
- Only TC parameter with a clear and significant trend: Maximum Wind Speed (Vmax)
- Median increase in Mean Vmax: +0.5%



3. Numerical Modelling: TC Ian under present & future climate conditions



5. Key Findings

- TC parameters with significant influence on storm surge:
  - Maximum wind speed, azimuth and novel normalized distance[10]
- TC parameters with significant and clear change in future:
  - Maximum wind speed (+0.5%)
  - Comparable results (-2% to +12 %) found in other studies[4-5-12]
- Magnitude of coastal hazards and related impacts increase due to changes in TC characteristics
  - Storm surge: +10.2%
  - Significant wave height: +5.4%
  - TWL: +10.4%
  - Flood depth: increases up to 0.5 m
  - Flood extent: +7.5%
- Increase in TWL due to changes in TC characteristics (10.4%) is higher than the increase due to SLR (7.3%)
  - Important to consider changes in TC characteristics in hazard and risk assessment studies, in addition to SLR component[13]
- Simulations show varying SLR magnitudes in the nearshore (0.2-0.3m)
  - Due to non-linear interactions in the nearshore
  - Important to include SLR component within a numerical simulation

6. Future Work

- ANOVA analysis using time of maximum induced storm surge instead of closest track position
- Applying delta using quantile mapping based on intensity[14]
- Storyline using analogous track from future dataset
- Applying probabilistic approach using clustering techniques
- Integrating hazard maps with exposure and vulnerability elements for complete risk mapping

References

[1] Mendelsohn et al. (2012)
[2] Knutson et al. (2020)
[3] Lin et al. (2012)
[4] Bakkar et al. (2023)
[5] Ortega et al. (2024)
[6] Toro et al. (2010)
[7] Esposito et al. (2019)
[8] Chang et al. (2020)
[9] Chaigneau et al. (2024)
[10] Scannilor et al. (2021)
[11] Bloemendaal et al. (2022)
[12] Dullaart et al. (2024)

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