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Assessment of alternative scenarios for tropical cyclone Yasi

P. Higuera[1,2], C. Thomas[1], S. Pandey[1]

[1]Moody's RMS, London, UK.

[2]Department of Civil and Environmental Engineering, The University of Auckland, New Zealand.

4TH INTERNATIONAL WORKSHOP ON WAVES, STORM SURGES, AND COASTAL HAZARDS

Incorporating the 18th International Waves Workshop

25/09/2025

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Assessment of alternative scenarios for tropical cyclone Yasi

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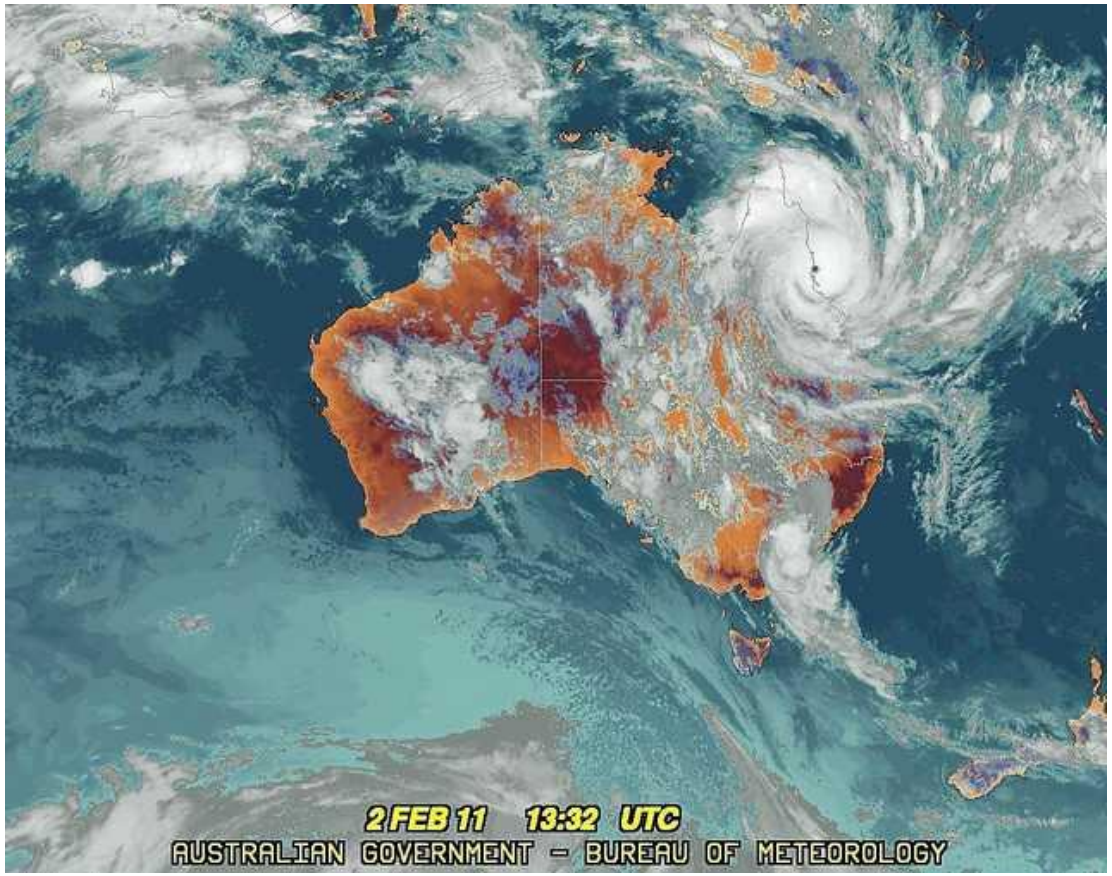

Image: www.bom.gov.au

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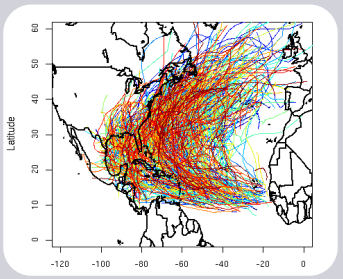
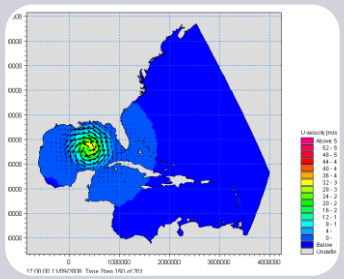
1) Motivation: Catastrophe Modelling

Within the (re)insurance industry

→ Quantify economic impact of Natural Catastrophes and make predictions about their future occurrence

→ Precise statements such as: “There is a **10% probability** that at any given year, the hurricane induced economic losses from ***wind***, ***inland flood*** and ***storm surge*** combined will be greater than **X Bn USD** in the state of **Florida**”


Stochastic Weather Module	**Hazard Module**	**Geocoding/ Exposure Module**	**Vulnerability Module**	**Financial Analysis Module**
Generate 50k years TC track set	Assess local hazard	Apply property characteristics	Calculate damage	Quantify financial loss

Climate perils model coverage

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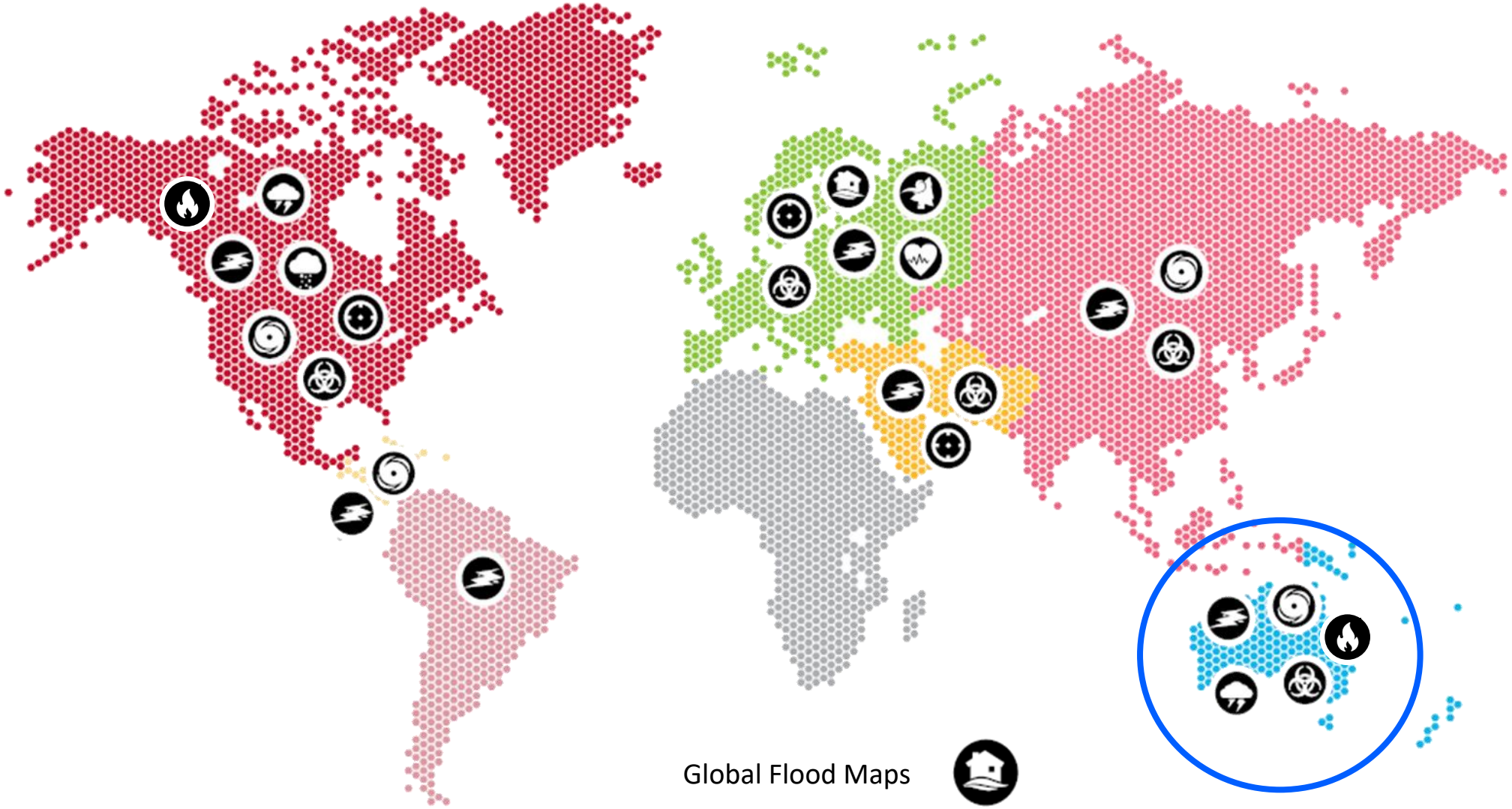
- Earthquake
- Tropical Cyclone
- Windstorm
- Severe Convective Storm (SCS)
- Winter Storm
- Flood
- Terrorism
- Pandemic
- Longevity
- Wildfire



Global Flood Maps

Australia new HD models

Hundreds of thousand stochastic events across a common timeline of 50k simulation years

BUSHFIRE

- All Sources of bushfire loss
- Accounting for ember and smoke

SEVERE CONVECTIVE STORM

- Complete nationwide model rebuild
- Hail, straight line winds, tornado

CYCLONE AND FLOOD

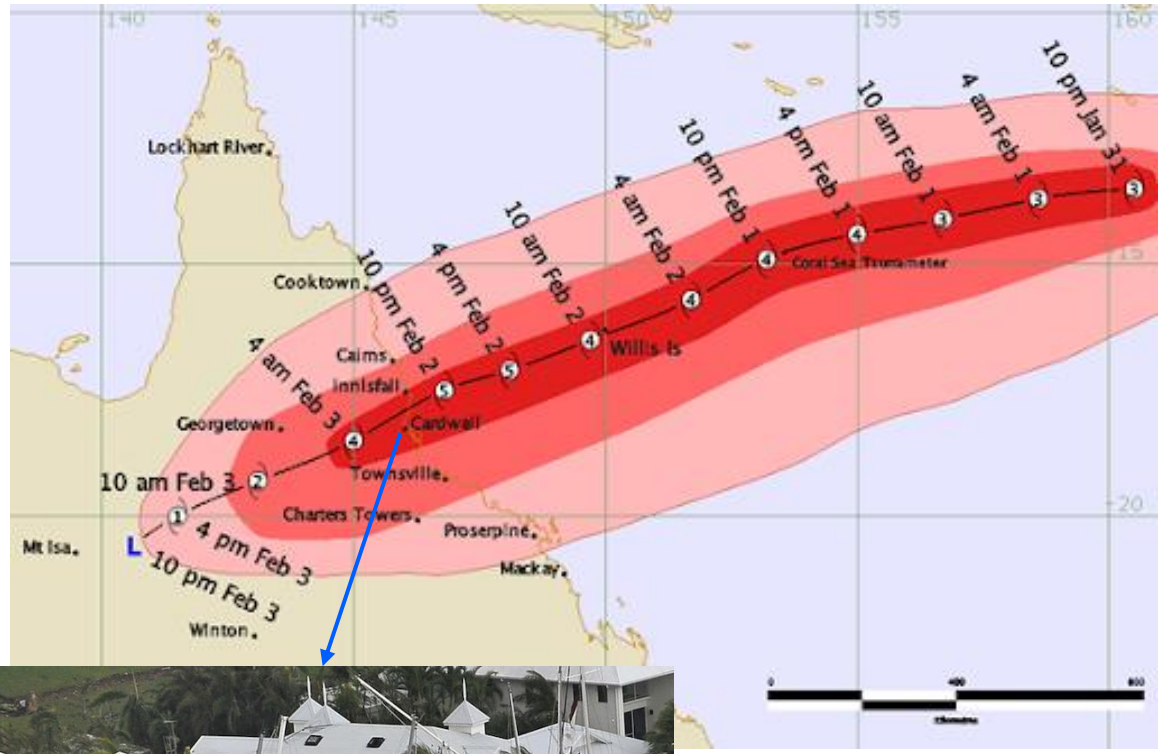
- All sources of flood (inland & coastal) and cyclone wind loss
- Explicit capture of cyclone pool

The first consistent suite of atmospheric peril models across the Australia and New Zealand Market.

TC Yasi [Landfall: 14:00 UTC on February 2nd 2011]

Importance

- Category 5 storm that hit northern Queensland (Australia)
- The costliest in Australian history
  - $3.6 billion in damages (wind, rain and surge combined)
- Produced significant storm surge and coastal inundation
  - Cardwell: storm tide level 2.3 m above the Highest Astronomical Tide (HAT)
  - Townsville: 0.6 m above HAT



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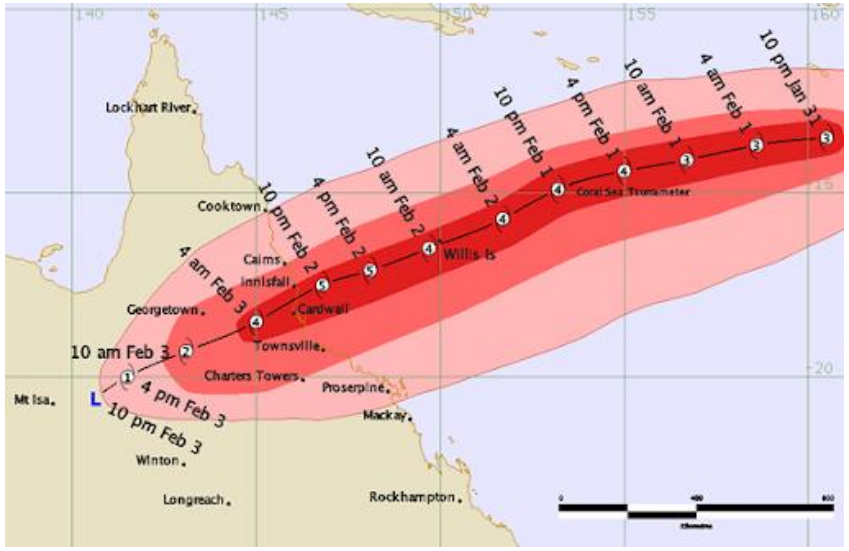
Images: www.bom.gov.au, www.abc.net.au

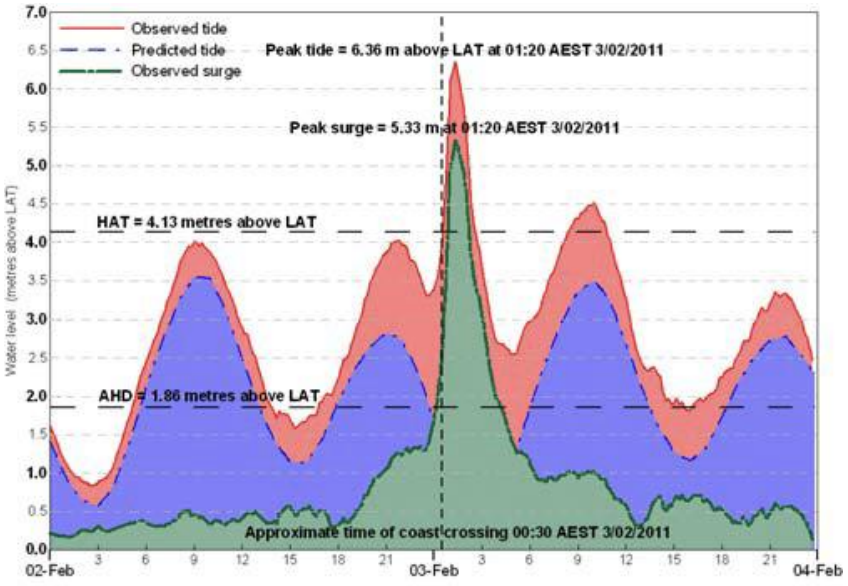
2) Methodology

Counterfactual analyses

- Two main circumstances mitigated the effects of TC Yasi
  - The TC made landfall far from densely populated areas
    - Landfall at Cardwell, far from Cairns and Townsville
  - The peak of storm surge happened when tide was falling
    - Reducing the maximum value it could have had at high tide
- Existing counterfactual analyses have focused on wind parameters (wind speed and radius of maximum winds), sea surface temperature or mean sea level

- We propose:
  - 1) Analysis on the impact of landfall time (i.e., tidal phase)
  - 2) Analysis on the impact of landfall location





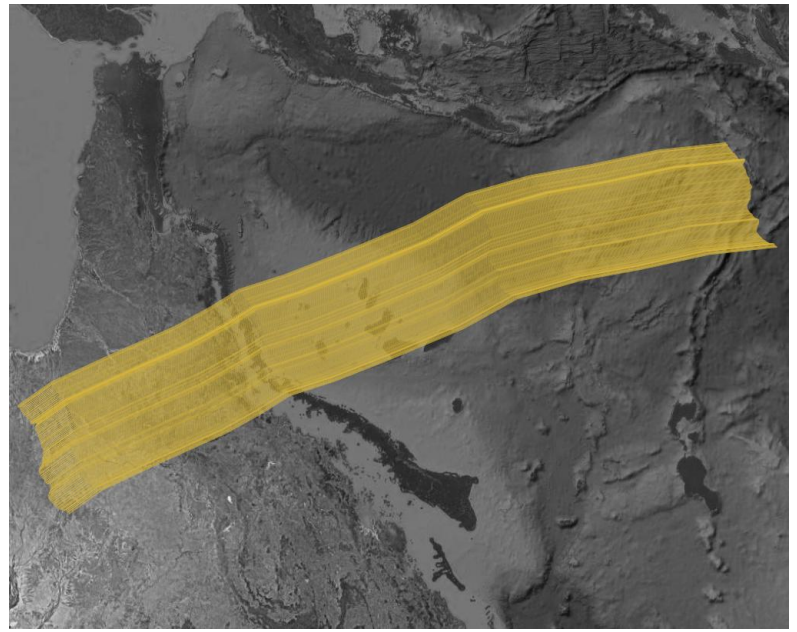
Images: www.bom.gov.au, Office of Climate Change QLD

2) Methodology

Counterfactual analyses – Plausible scenarios

- 1) Analysis on the impact of landfall time (i.e., tidal phase)
  - Modelling the same track, shifted in time
    - Landfall times from -14 to +14 days, every 15 minutes
  - Analyse the surge + tide interactions

- 2) Analysis on the impact of landfall location →
  - Modelling shifting track landfall point in space
    - Landfall locations along the coast from +150 km (north) to -150 km (south)
  - Analyse the surge level only (no tides)
  - Perform additional landfall time analyses for the worse potential landfall locations
    - I.e., highest levels at Cairns and Townsville



2) Methodology

Counterfactual analyses – Modelling

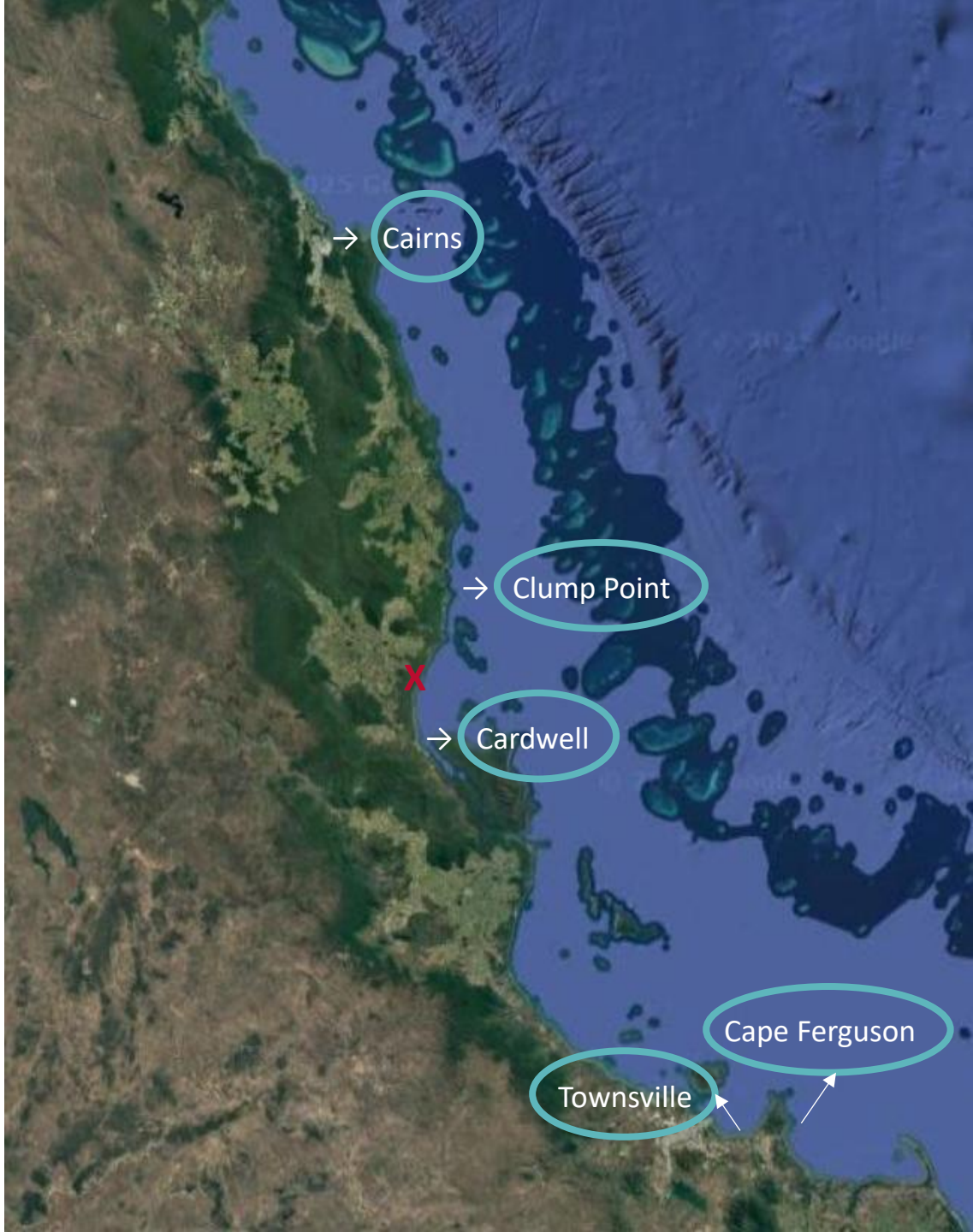
- Hydrodynamic modelling simulations with MIKE 21 (SWE)
  - Automatic mesh creation with seamsh
    - 2 km mesh resolution along the coast
  - Wind forcing: Yasi track provided by BOM
    - GAHM wind profile
  - Mesh and bottom roughness validated for tides
- Inundation simulations with in-house GPU Riemann solver (SWE)
  - 40 m resolution grid
  - Tide + surge hydrodynamic BCs (one-way coupling)
  - Wind forcing (same as above)
  - Bottom friction based on LULC

2) Methodology

Counterfactual analyses – Results

- Hydrodynamic modelling simulations
  - Time series at 5 main gauges
    - Total water level (storm tide, surge + tide)
    - Storm tide residual (surge only)

- Inundation simulations
  - Population affected (i.e., within the footprint)
    - High Resolution Population Density Maps, Meta – Data for Good (2019) https://data.humdata.org/
  - Buildings affected (i.e., within the footprint)
    - Global Building Atlas [Zhu et al. (2025), https://arxiv.org/abs/2506.04106]



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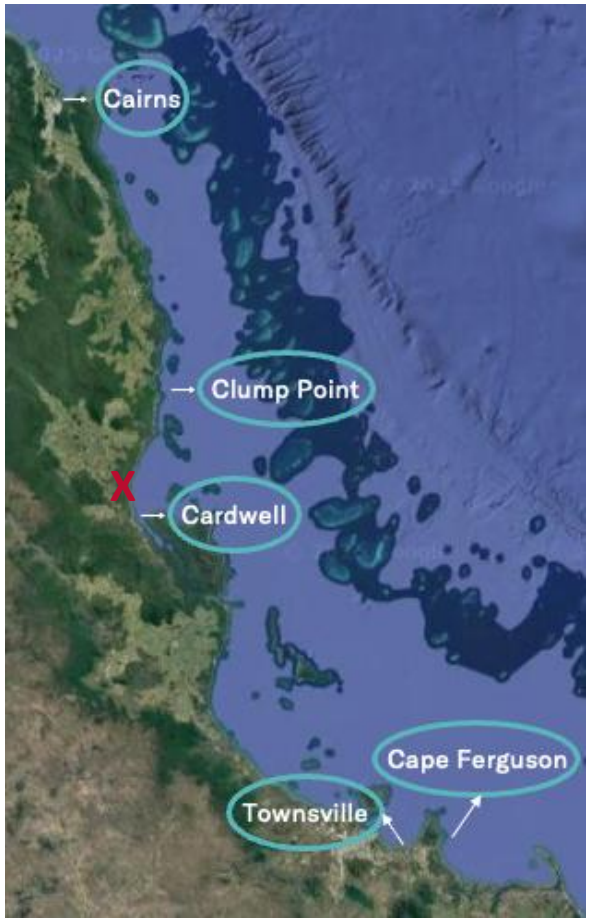
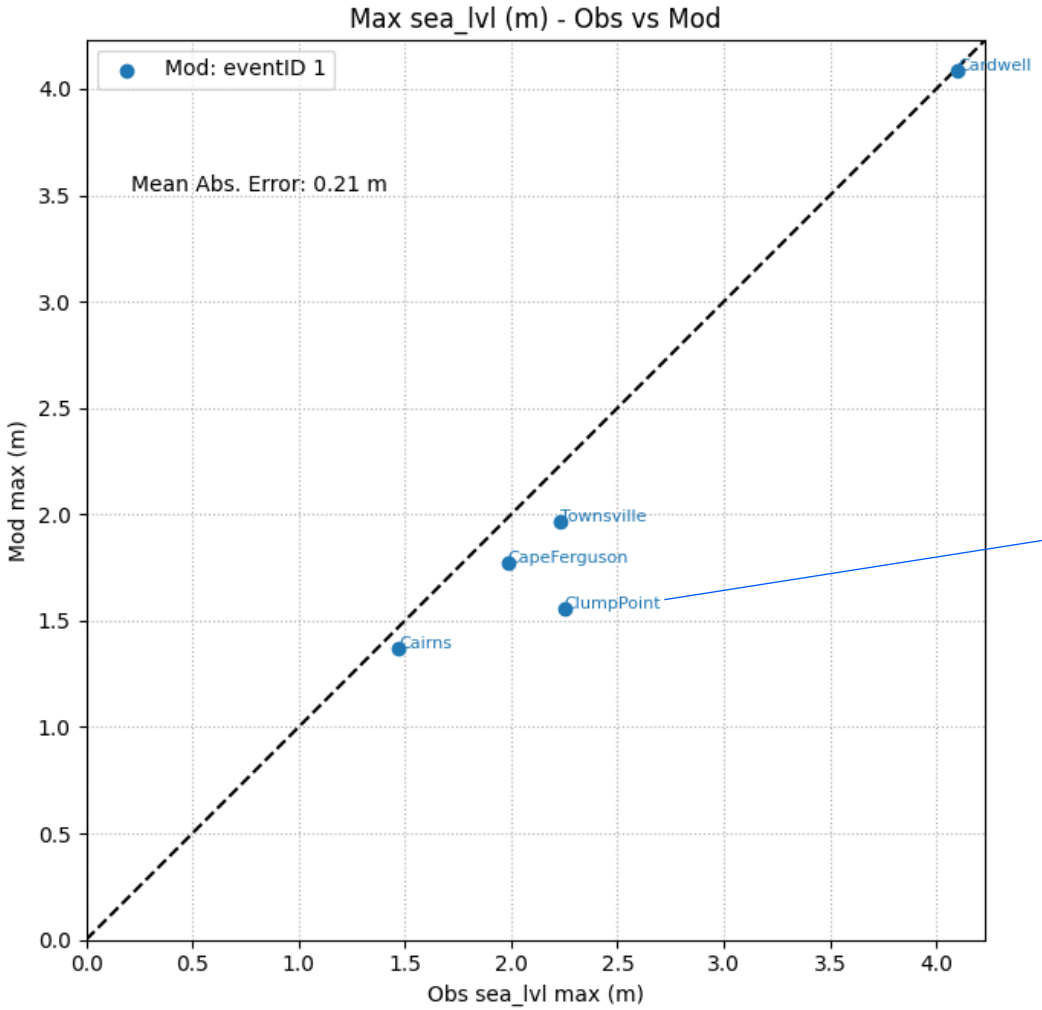
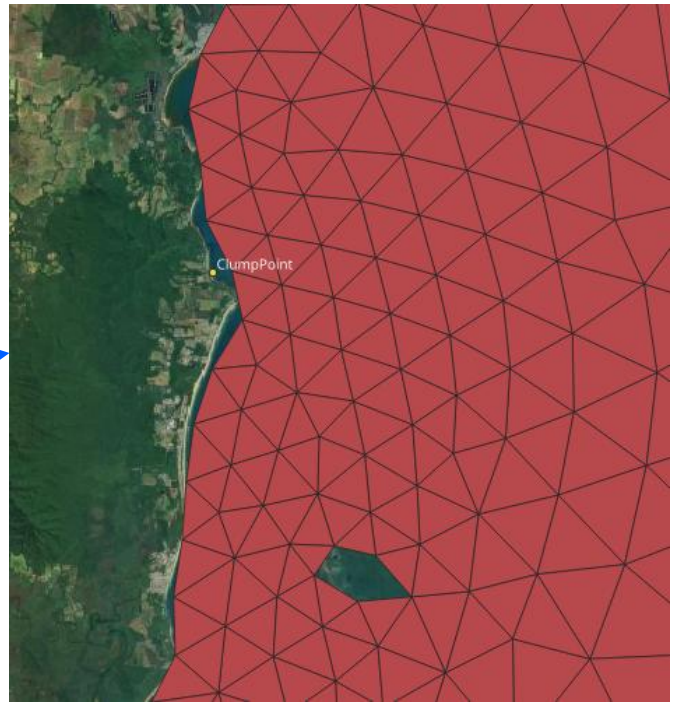
3) Results

Validation of “baseline” Yasi







3) Results

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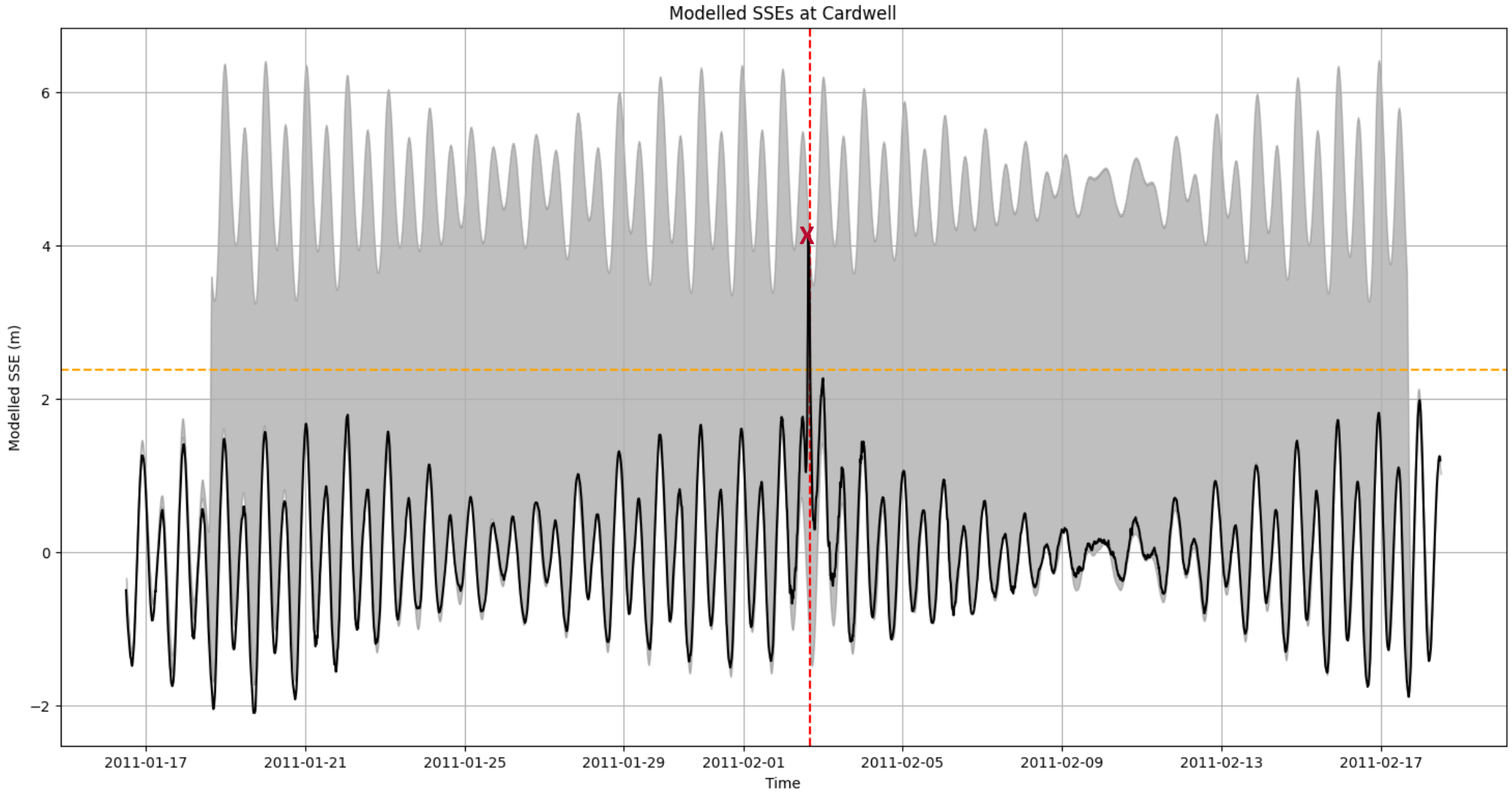

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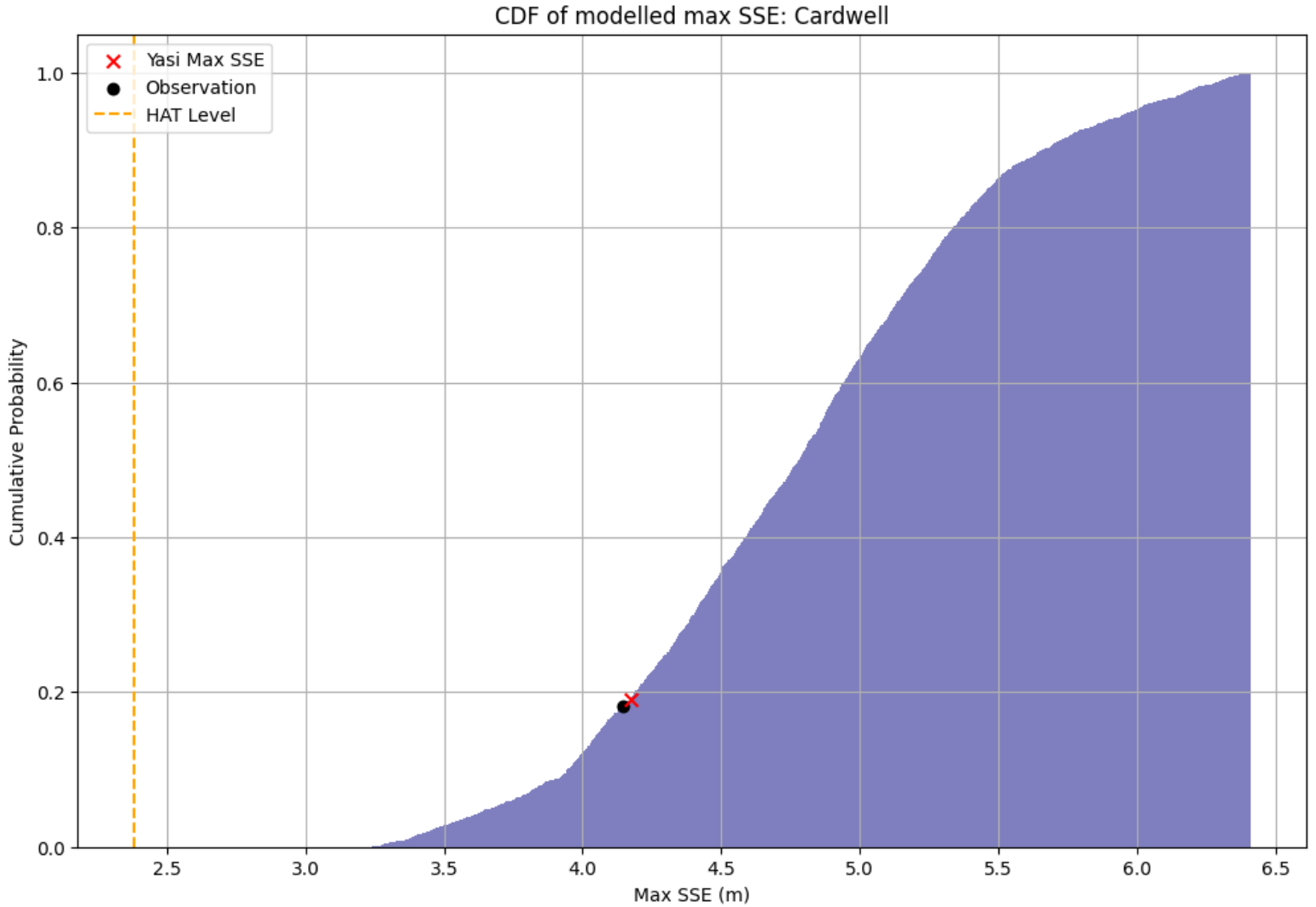

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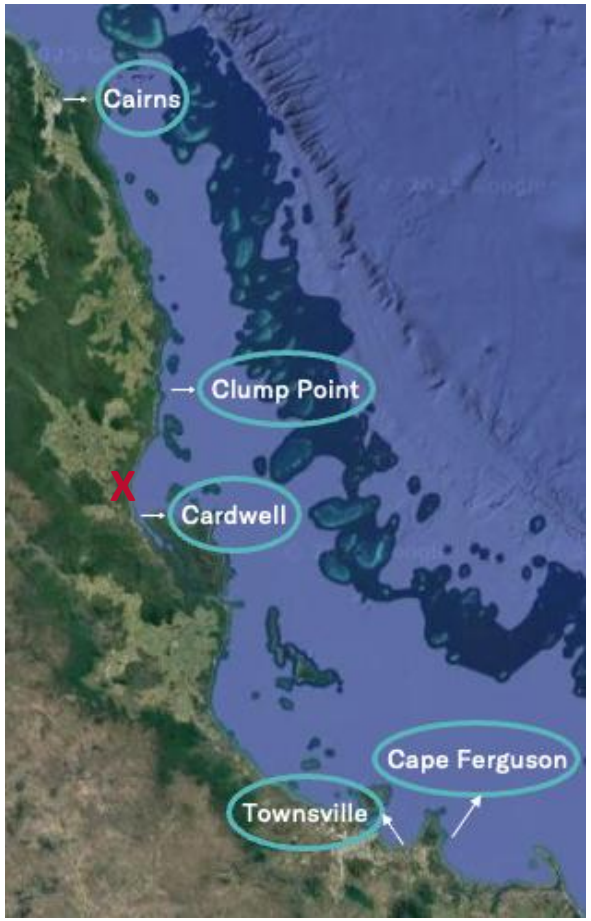
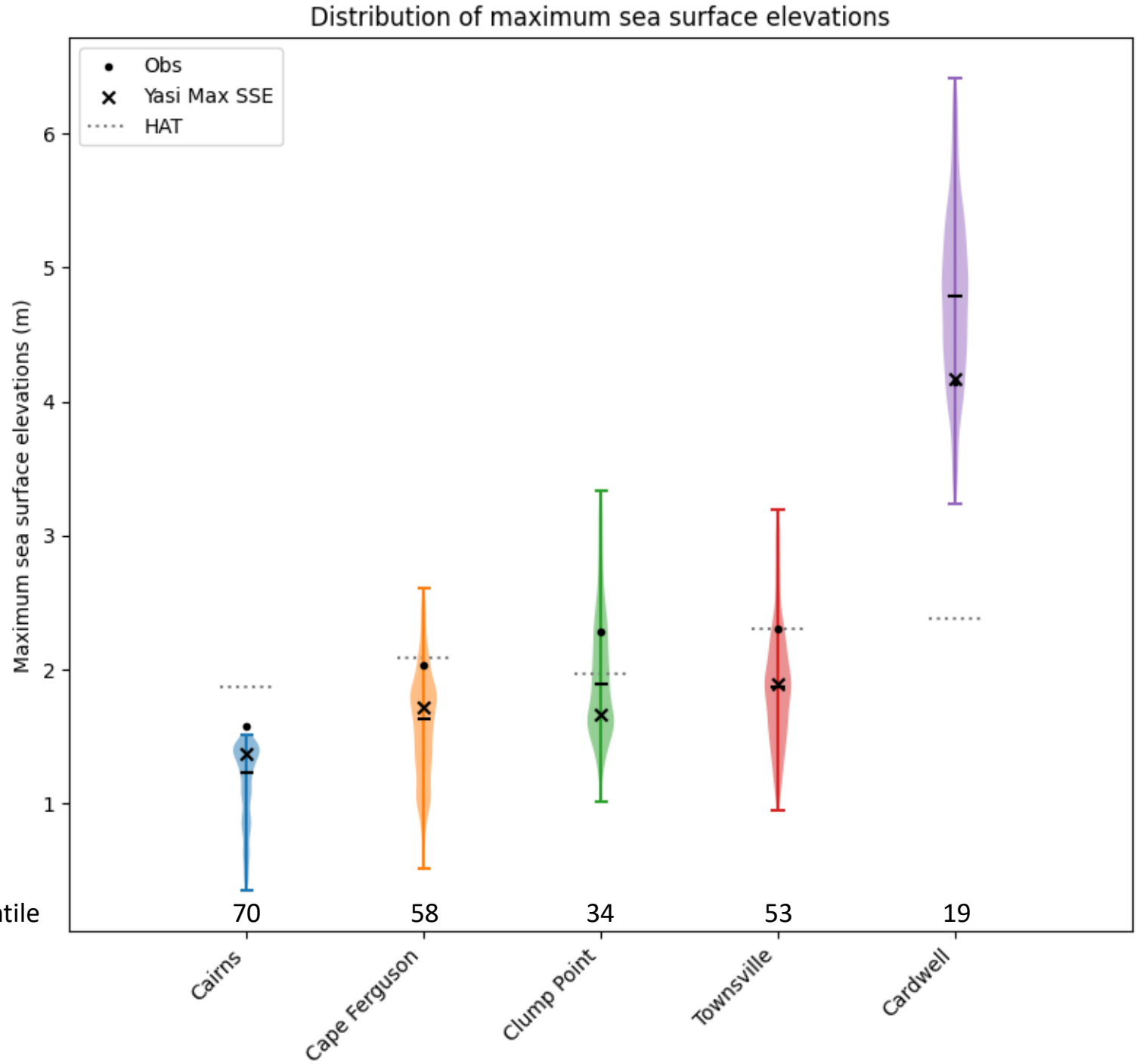


→ Percentile



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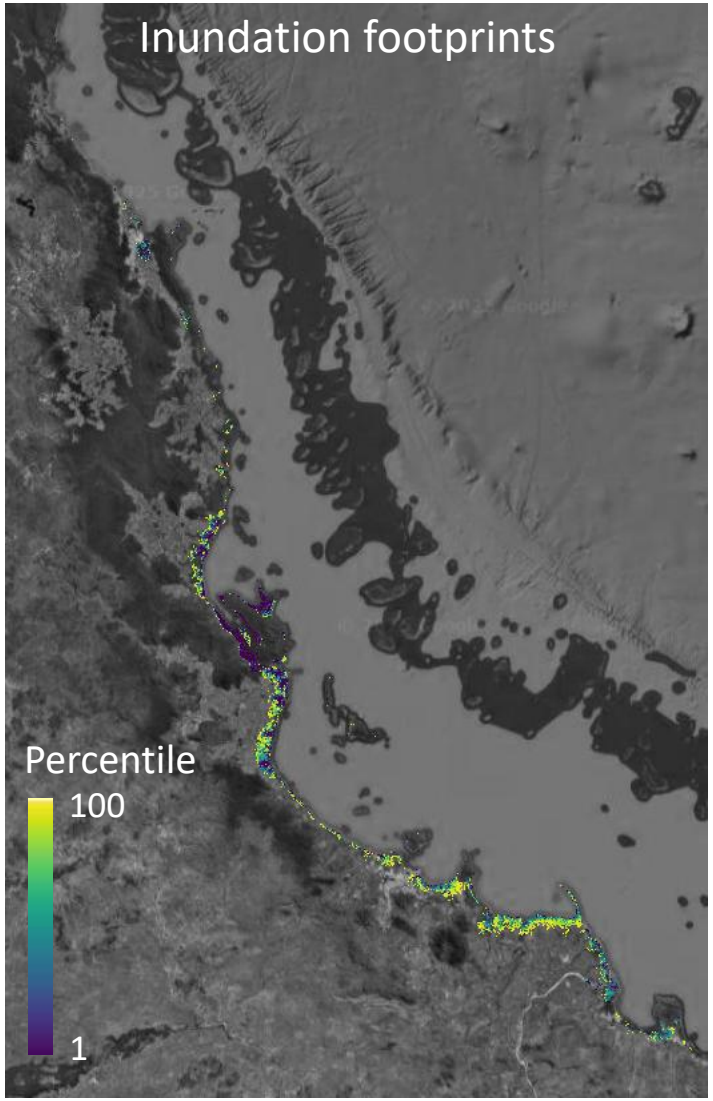
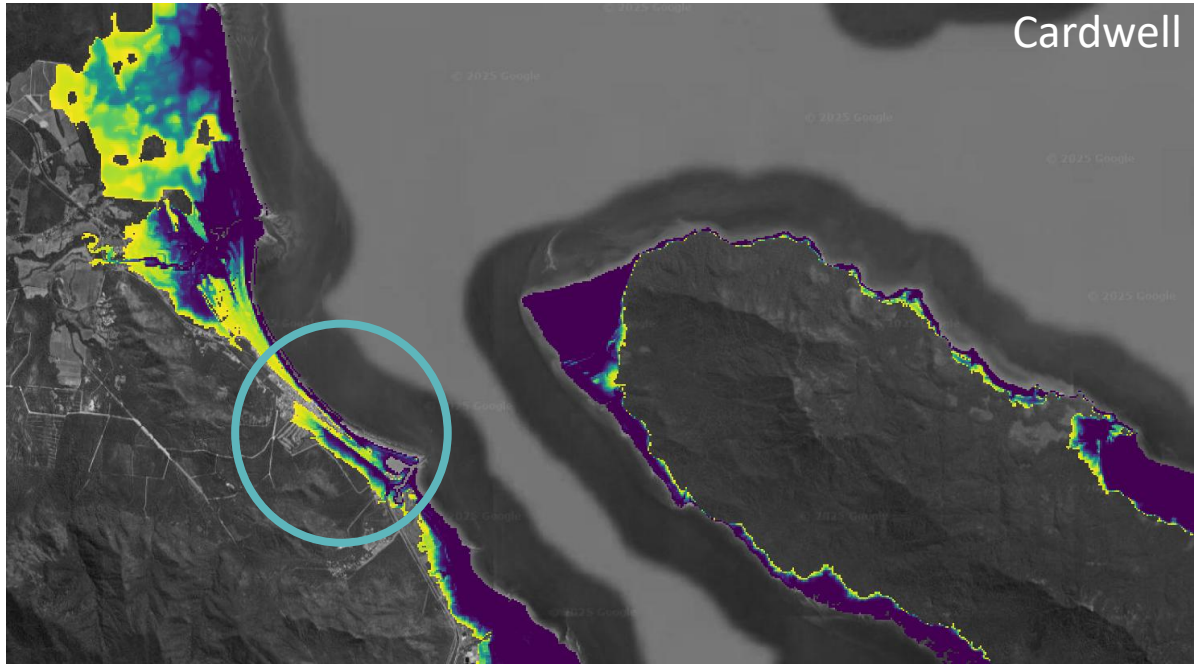
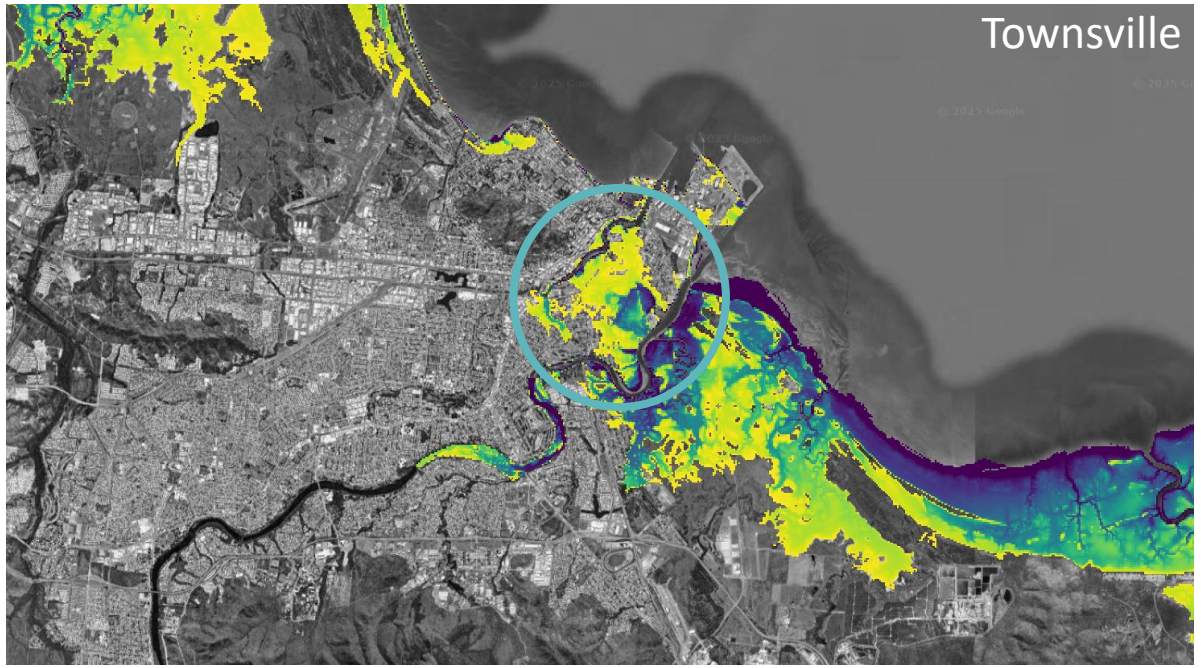
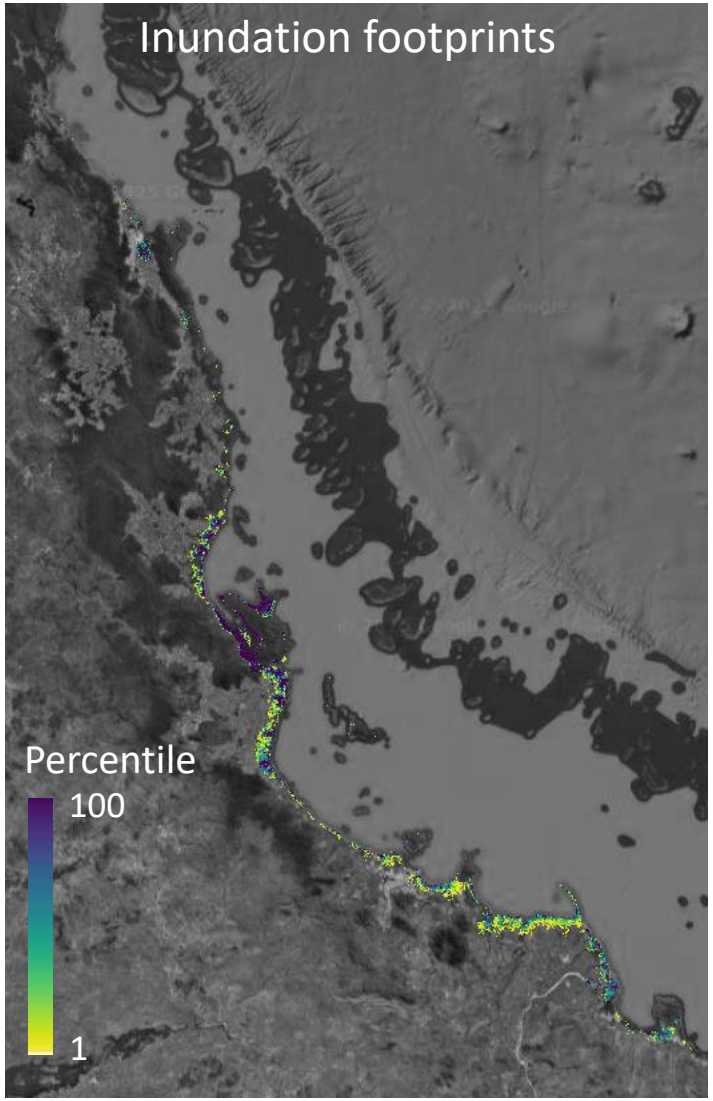
3) Results

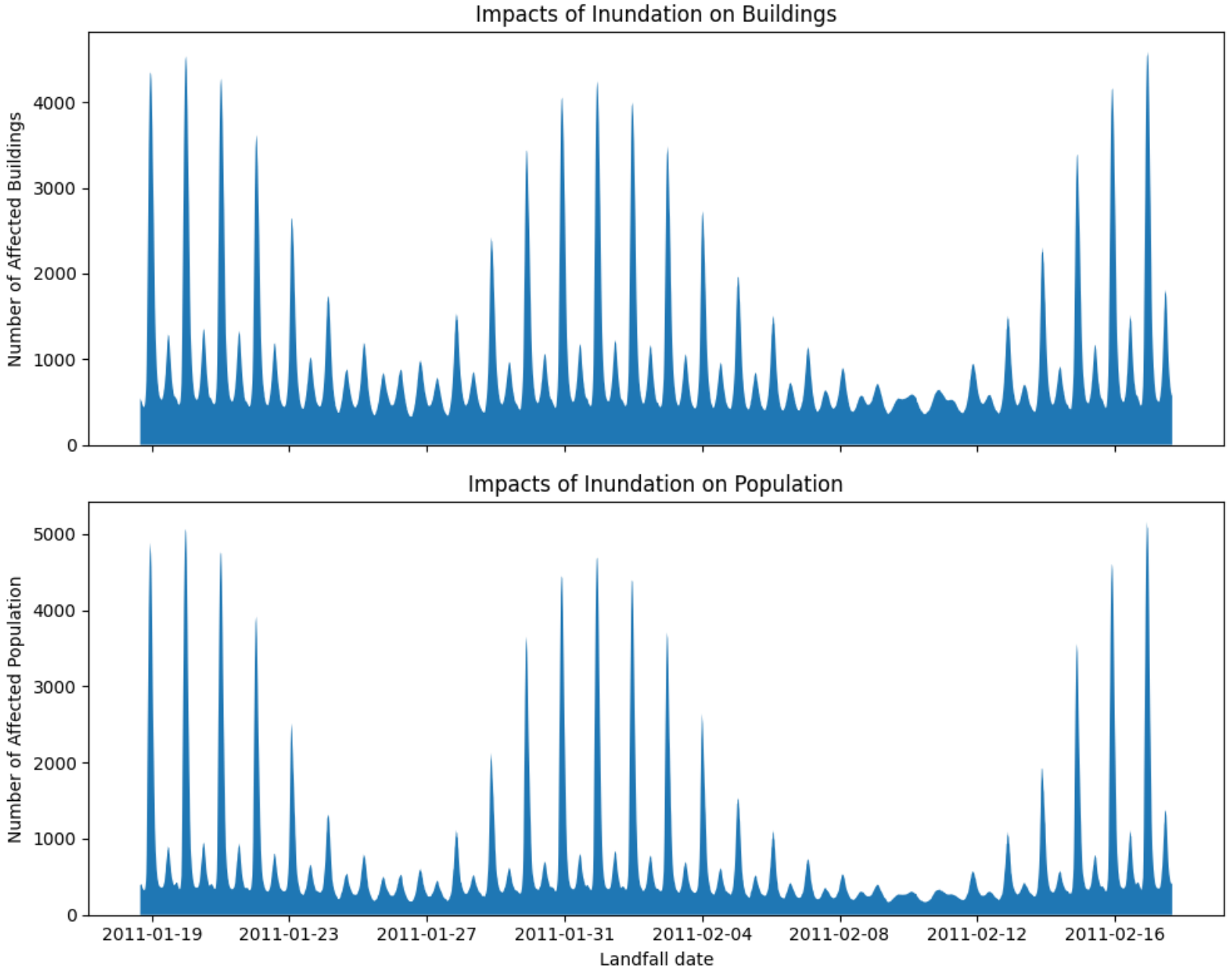

Inundation footprints
Percentile
100
1


Cardwell


Townsville

3) Results

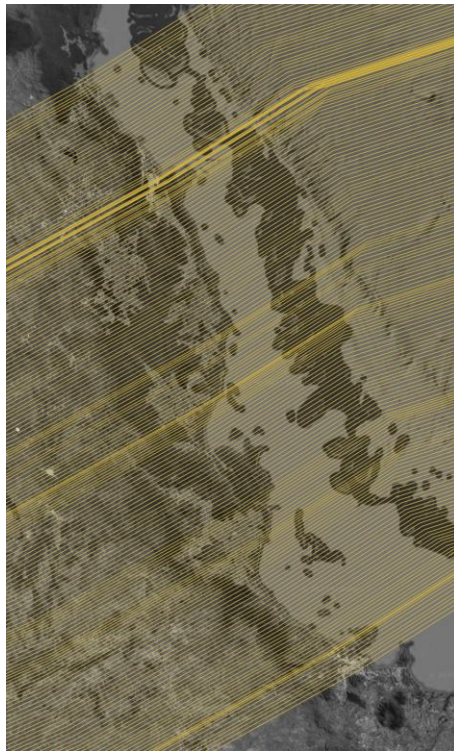


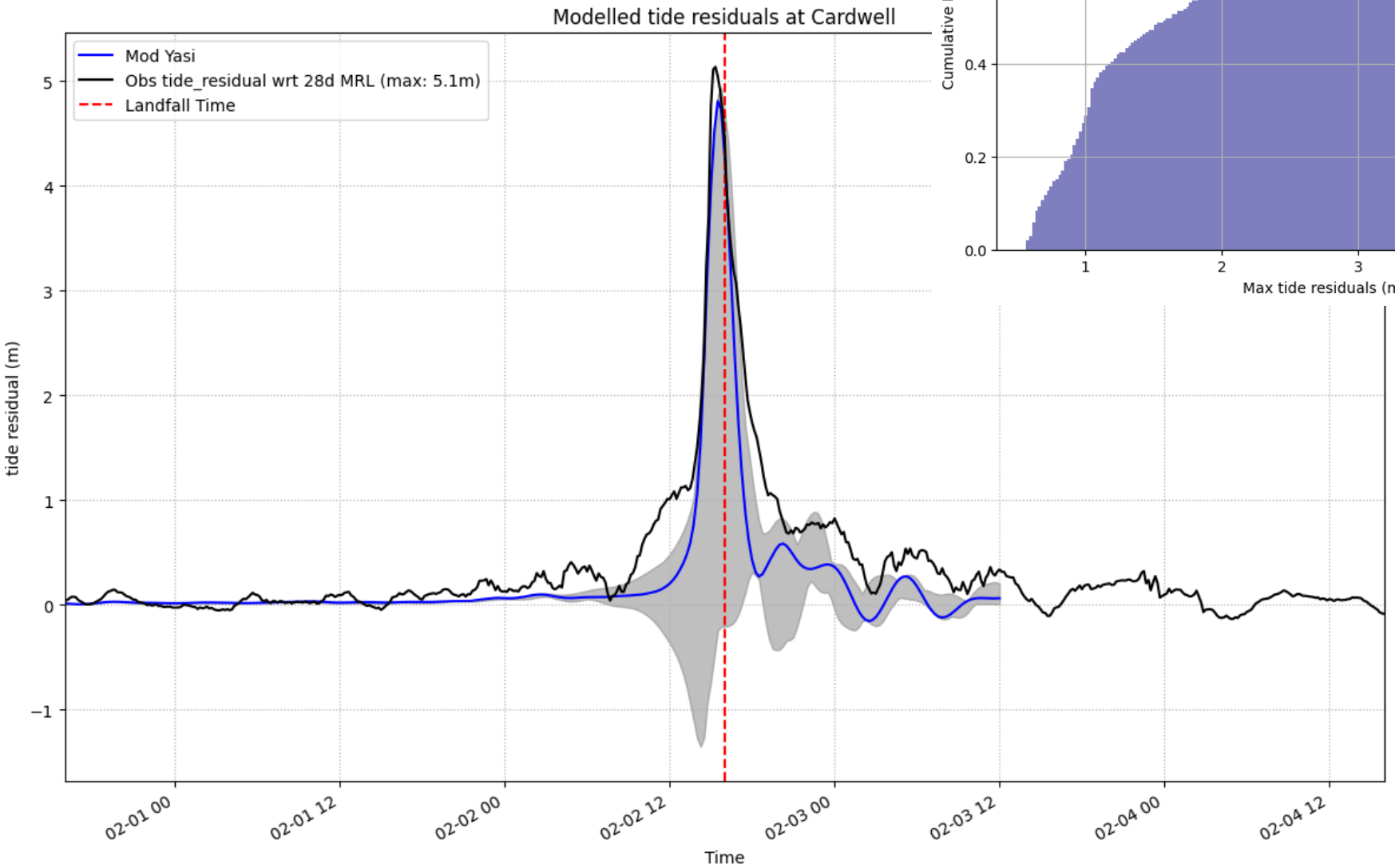


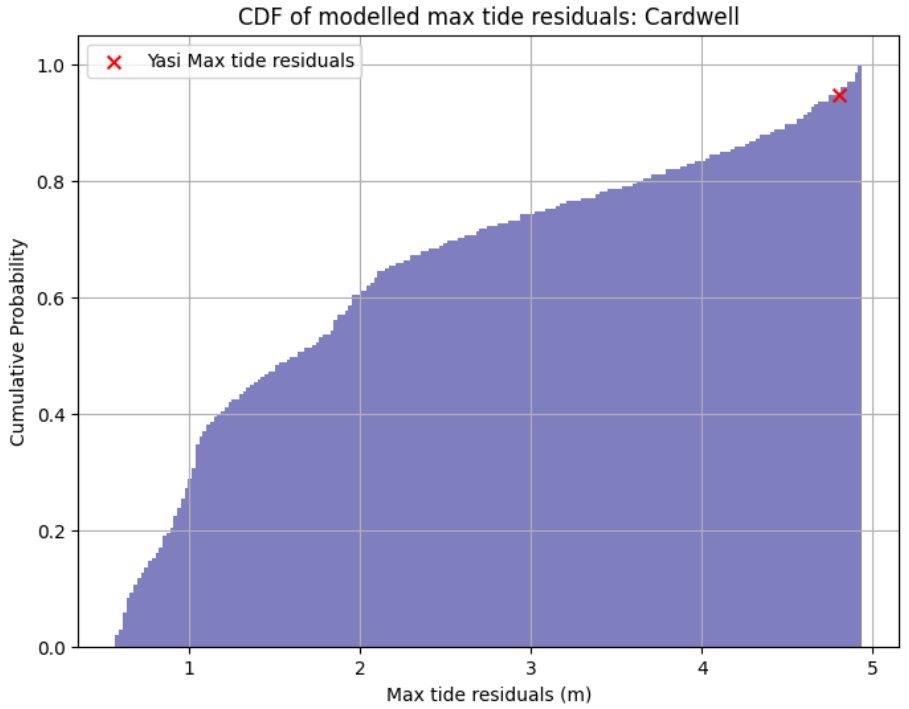
→ Yasi reconstruction: 572 buildings affected, 370 people affected

3) Results

2) Analysis on the impact of landfall location







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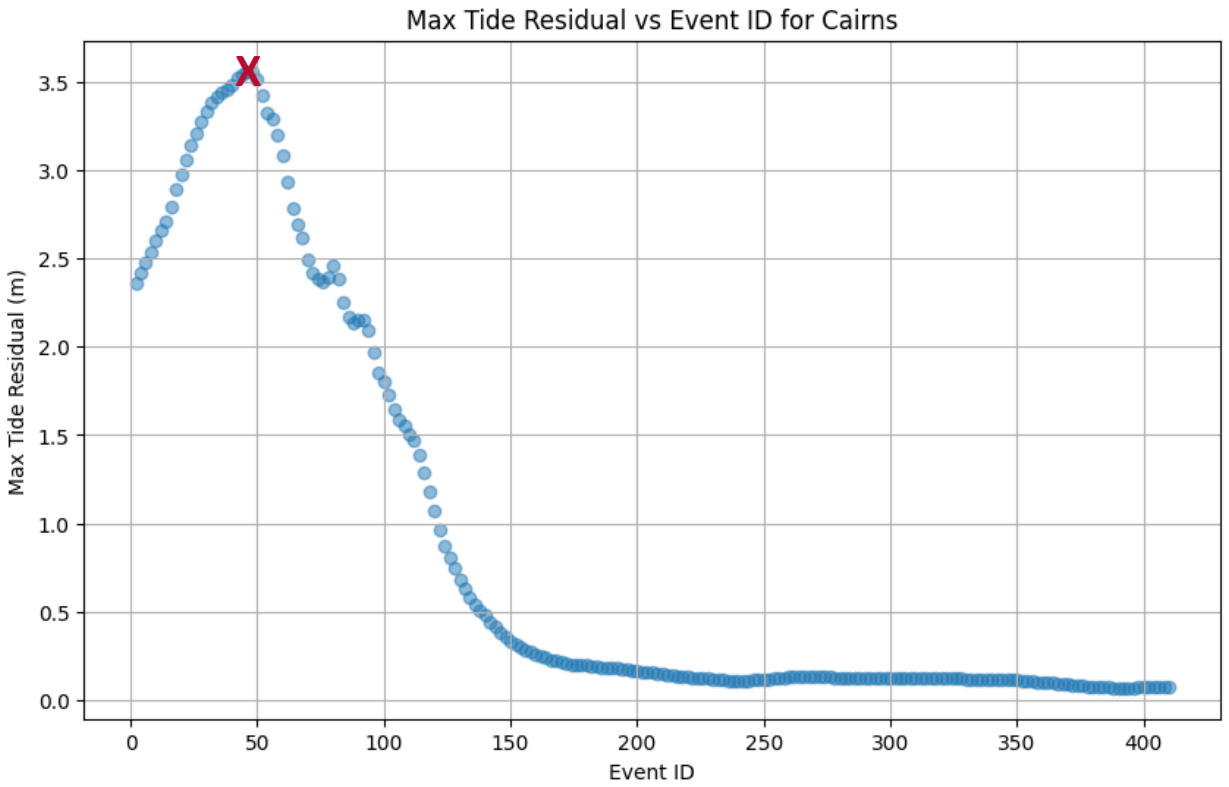
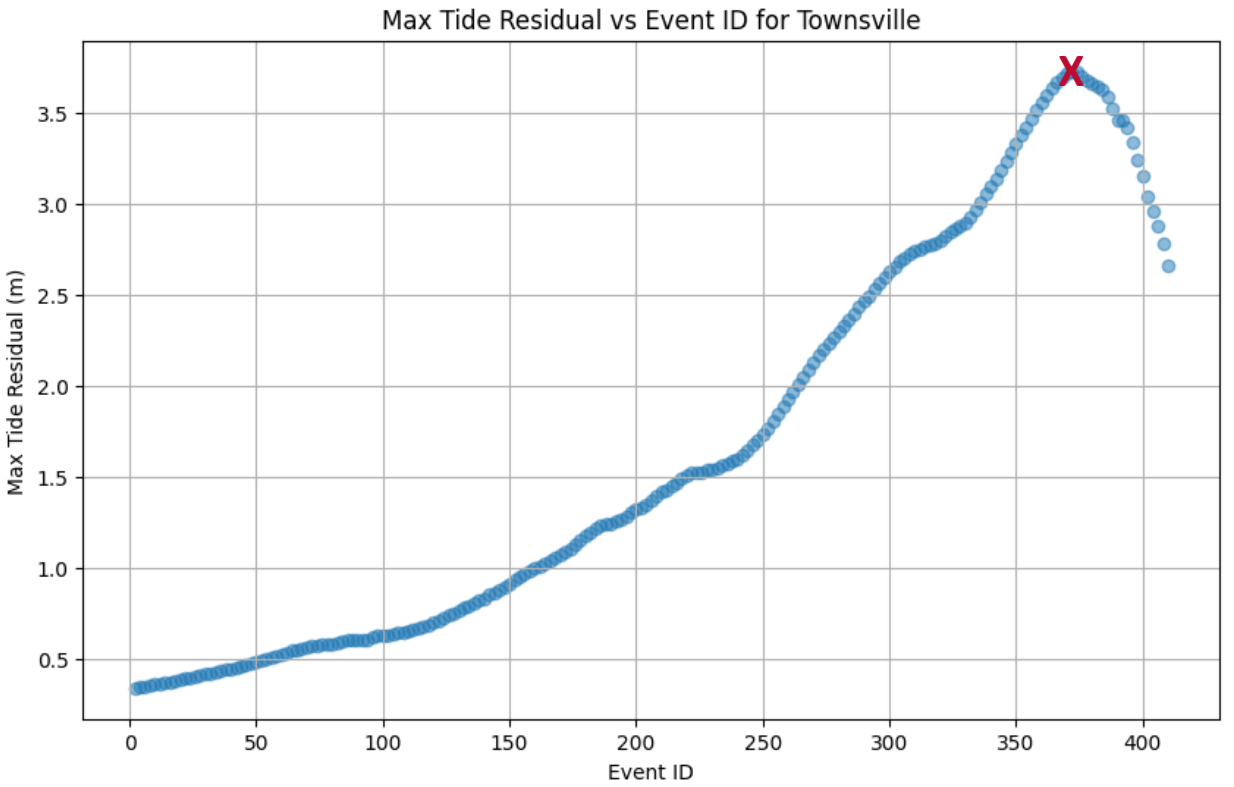
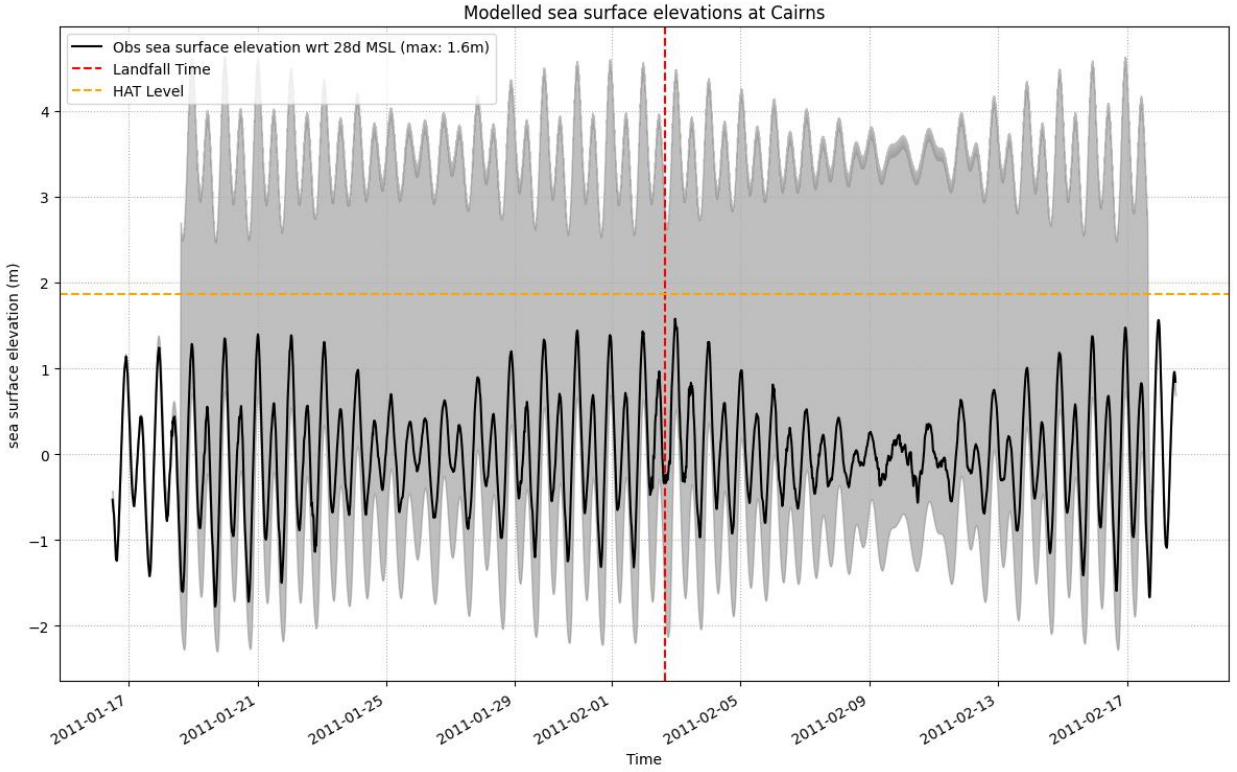
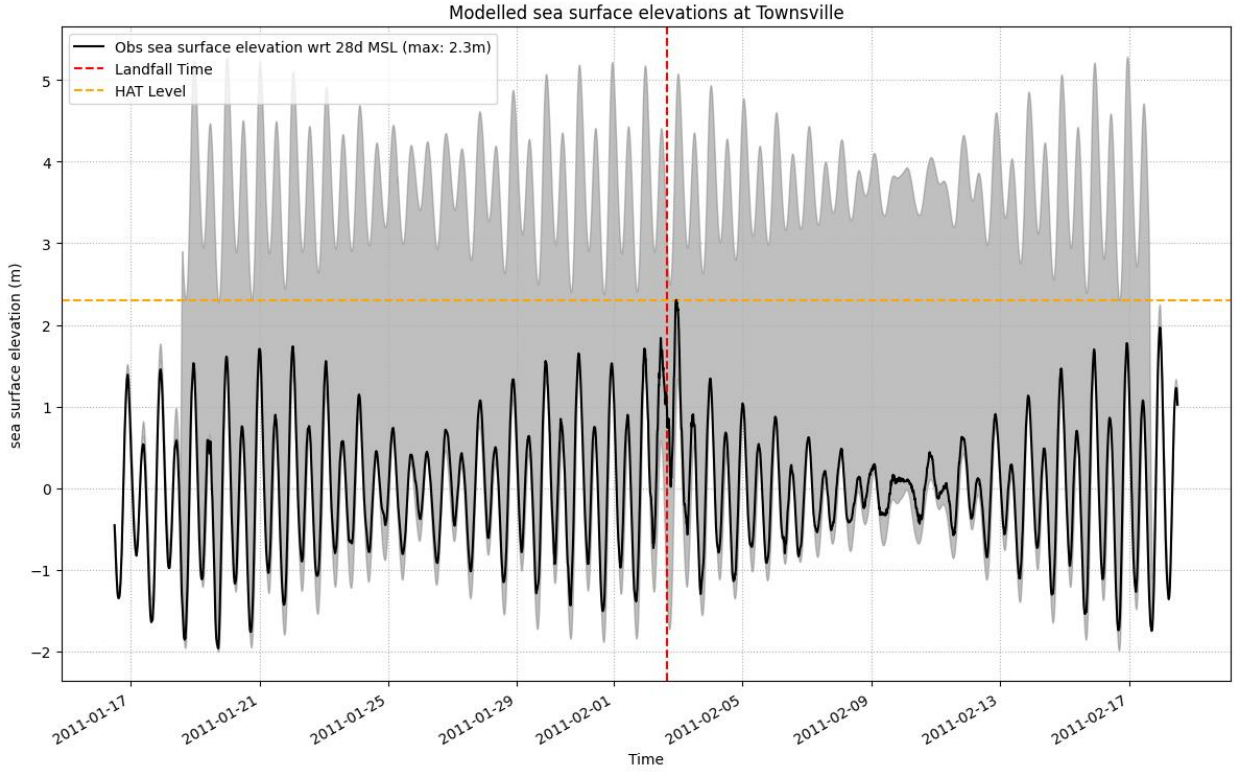




3) Results

2) Analysis on the impact of landfall location (+ landfall time analysis)





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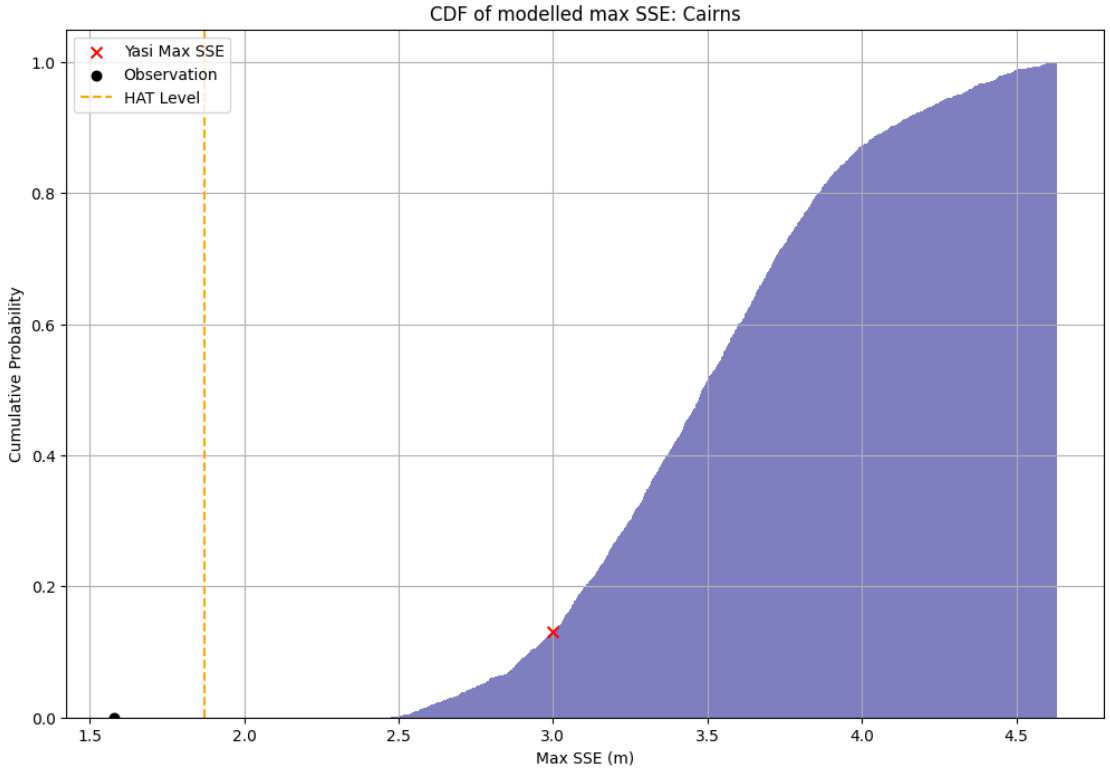

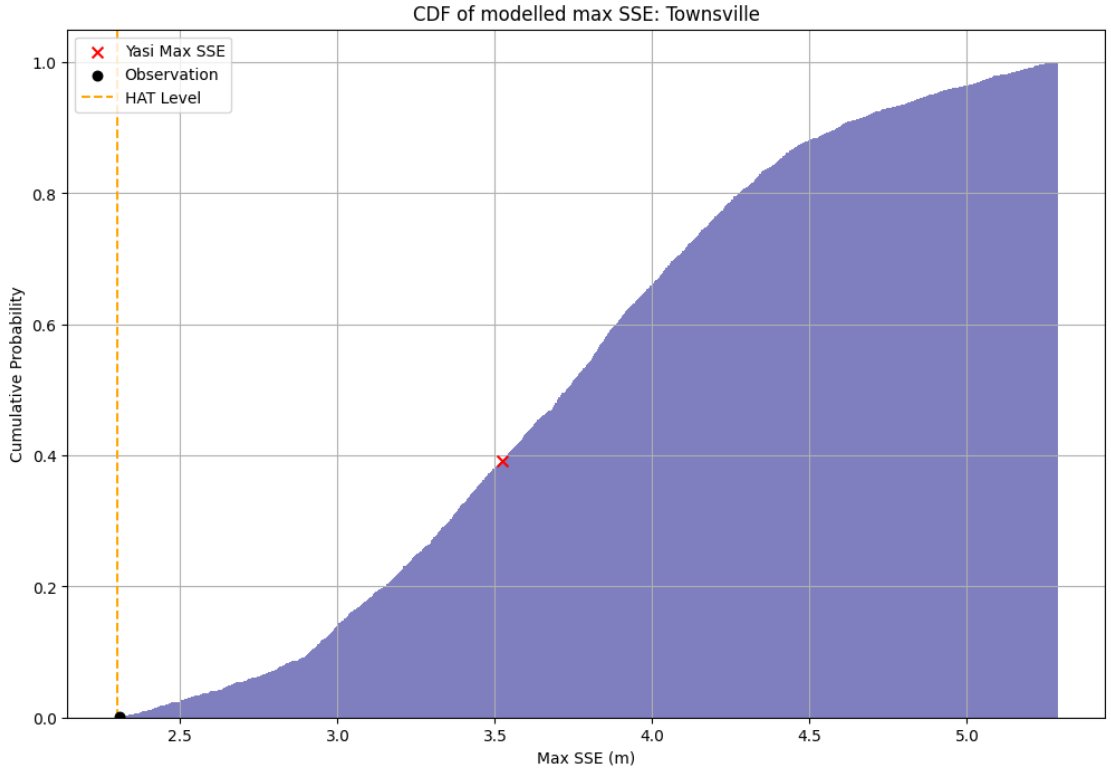

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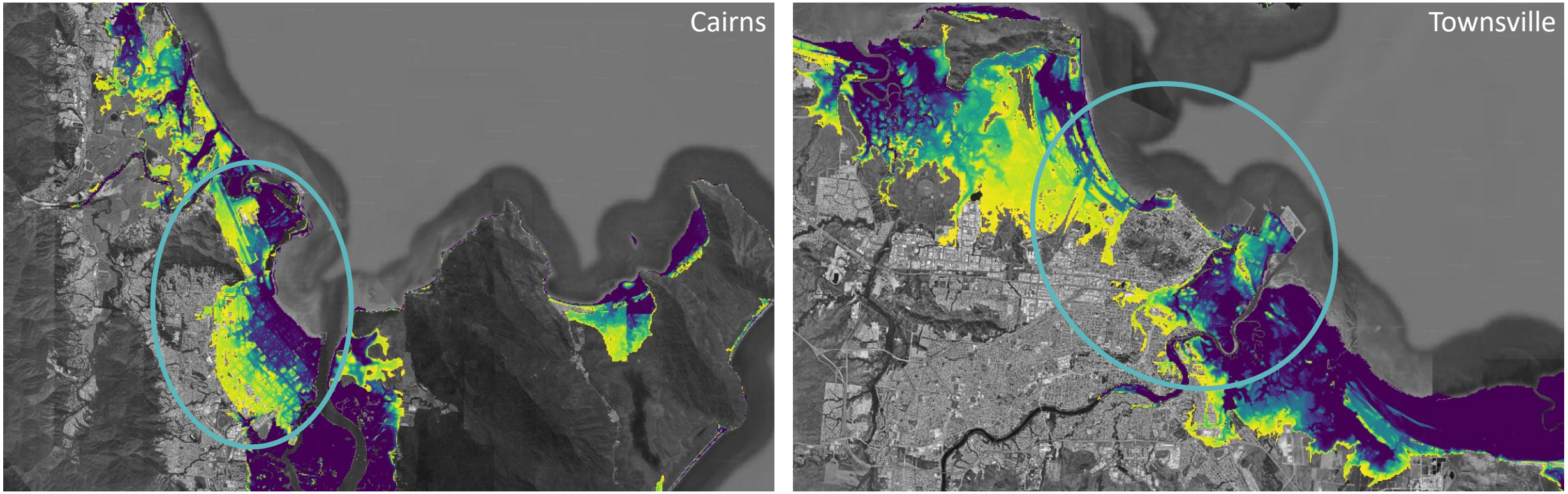


3) Results

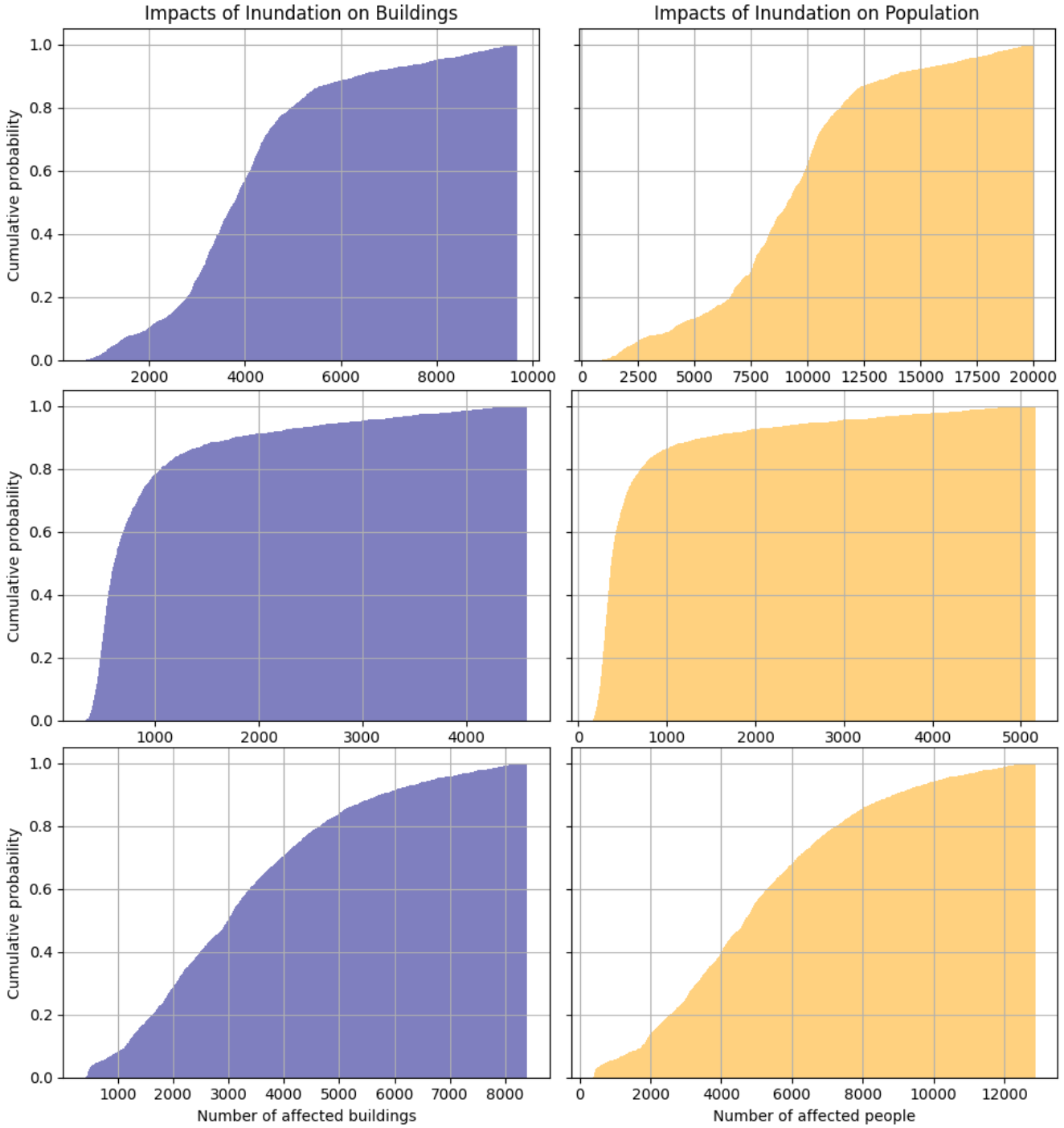
Final comparison

- → Yasi reconstruction:
  - → 572 buildings affected
  - → 370 people affected

Landfall location

Landfall location

Landfall location



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4) Conclusions

- Counterfactual analysis on TC Yasi's storm surge testing 3 locations in depth
  - Analysis based on tide phase for the original track at Cardwell
  - Analysis based on landfall location to identify worst potential effects
    - Analysis based on tide phase for Cairns and Townsville

- Comparisons in terms of population and buildings affected show
  - The worst impact in Cardwell is half or less than those in Cairns or Townsville
- Worst impact for landfall in Cairns
  - Despite Townsville having a larger population

- For a fuller picture, further analyses are needed in terms of
  - Including other perils [wind, inland flood]
  - Including vulnerability to compute losses

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