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Coastal flooding: Local TCs





TC TINO, Photo taken at Sir Roberts Wharf on Saturday morning 18th January 2020. P.C – Coral Pasisi



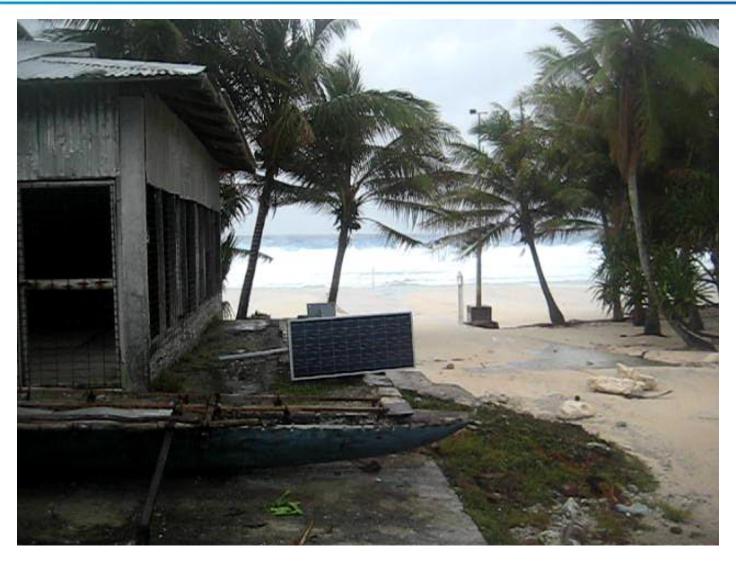
TC TINO, Photo taken at Avatele Beach on Saturday morning 18th January 2020. P.C – Tifaga Tupuiliu



Birdseye view of the destruction caused to the Huanaki Cultural Centre in Niue after Tropical Cyclone
Heta.



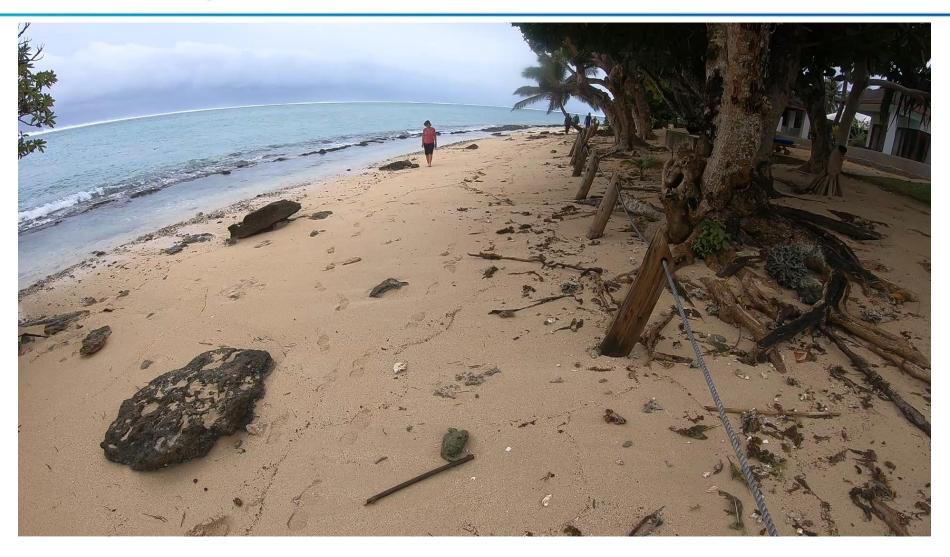
Coastal flooding: distant TCs



Recorded by a resident of Nanumaga, Tuvalu during TC Pam



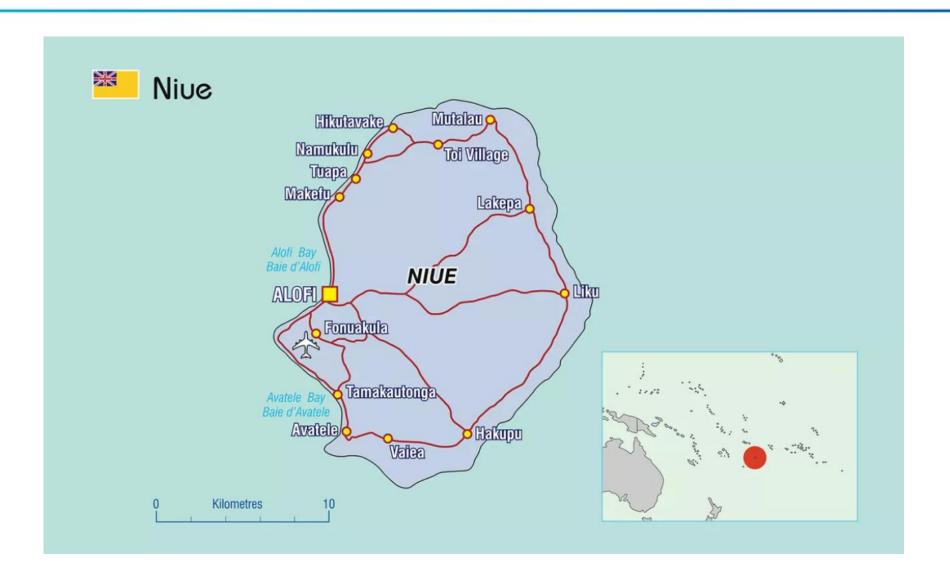
Coastal flooding: distant swells



Recorded by Jens Krueger on Fiji's Coral Coast in May 2018

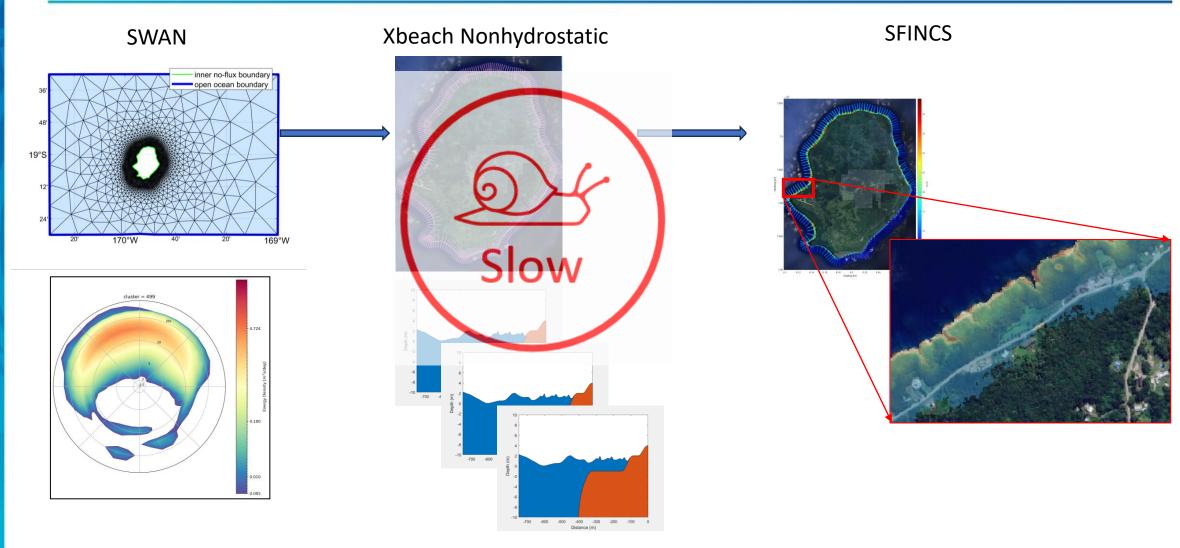
Niue







Inundation modelling



181 transects

Offshore ocean conditions



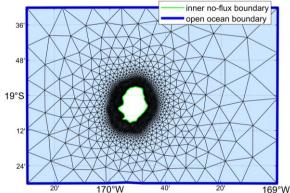
Baseline data





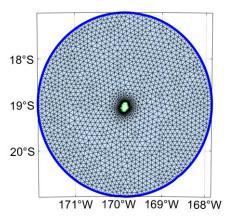
- Lidar bathy + topo
- Multibeam
- **GEBCO**

Distant storms



- Tides
- Sea level anomalies
- Waves
 - High-resolution (200 m) **UnSWAN** model

Local TCs

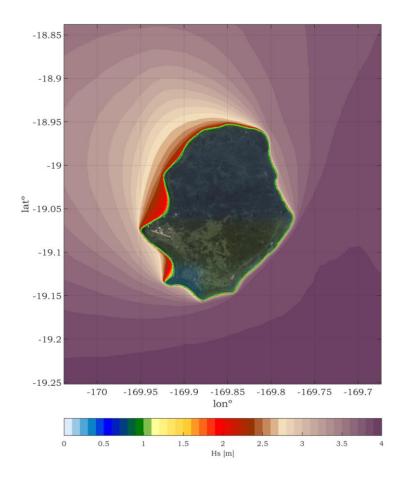


- Tides
- Sea level anomalies
- Waves and storm surge
 - High-resolution **UnSWAN** model coupled to ADCIRC

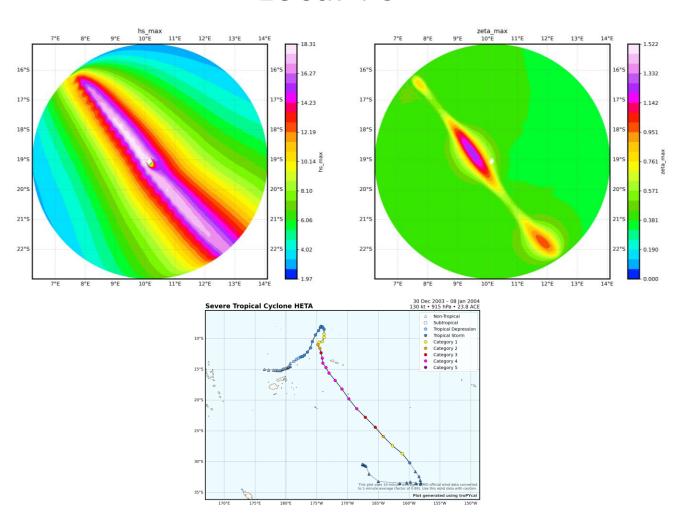
Offshore ocean conditions



Distant swell



Local TC





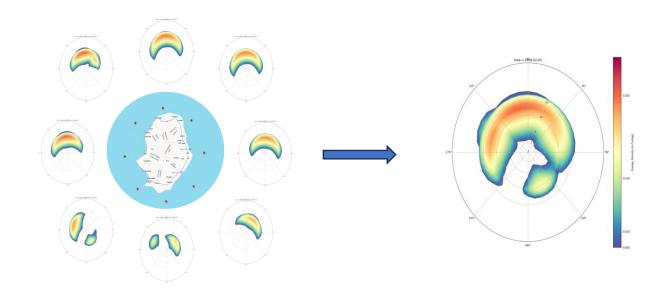
Machine learning

Input:

- Waves (Superpoint spectrum)
- Water level (tides/storm surge/MSLA)
- DEM

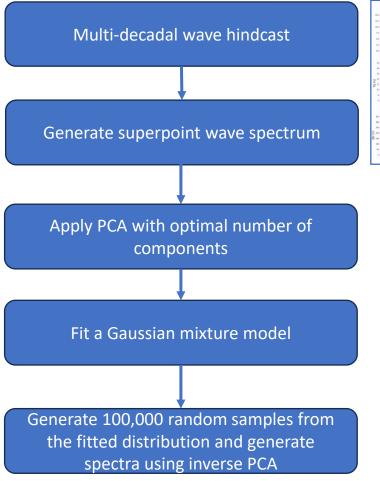
Output:

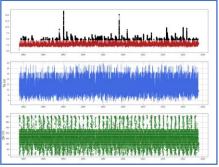
Inundation depth

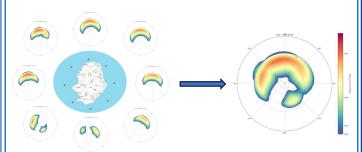


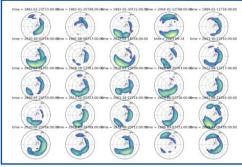


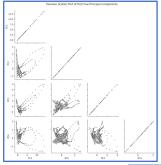
Spectral emulator



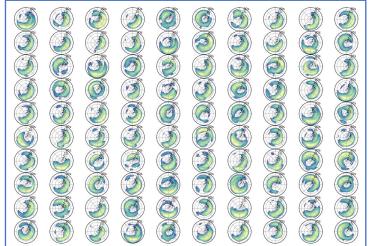






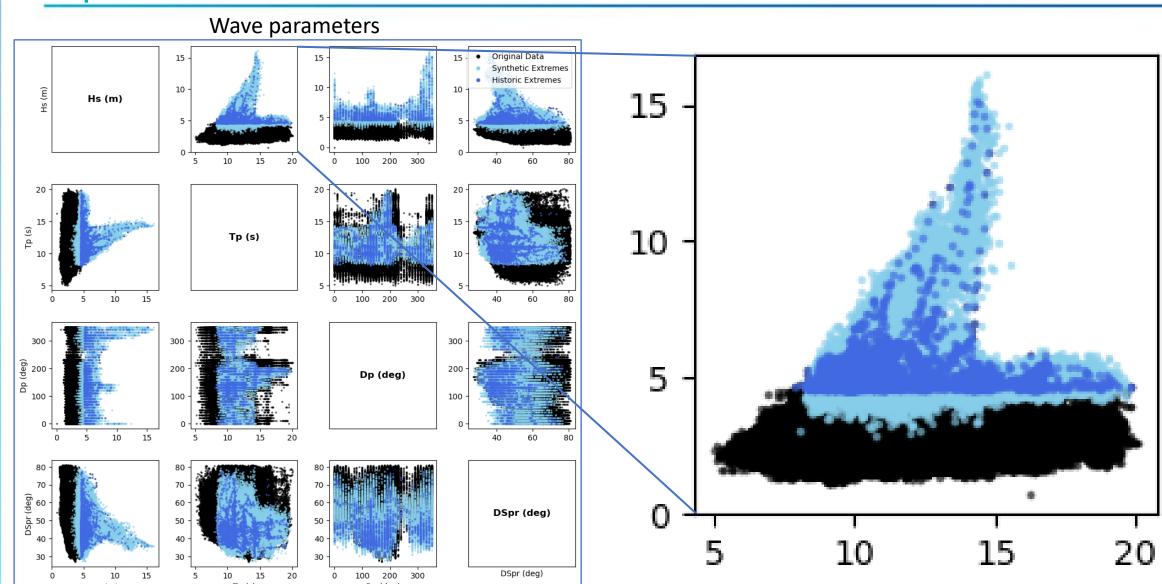


GMM is a probabilistic model that represents data as a weighted combination of several Gaussian (normal) distributions.





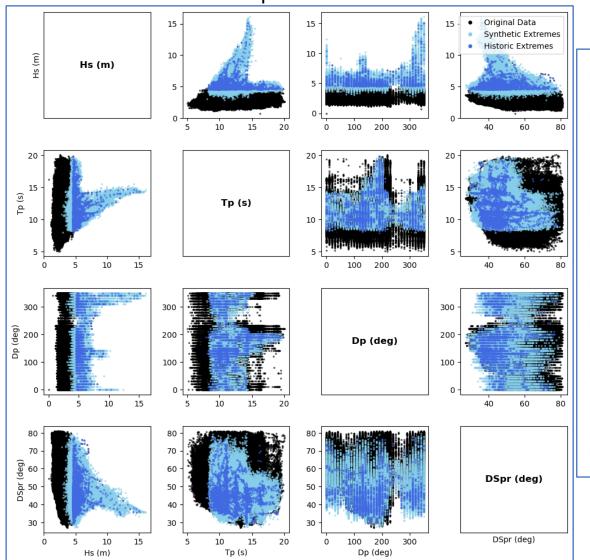
Spectral emulator - Results



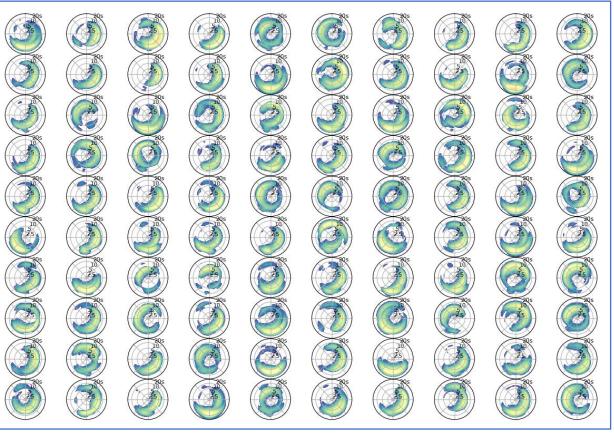


Spectral emulator - Results

Wave parameters

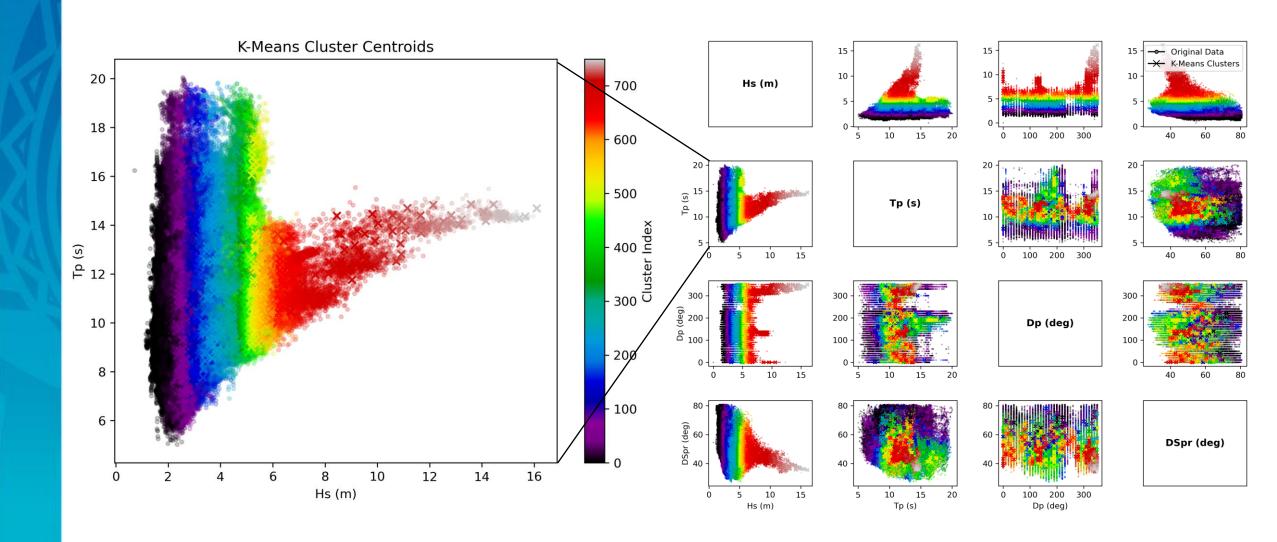


Example spectra

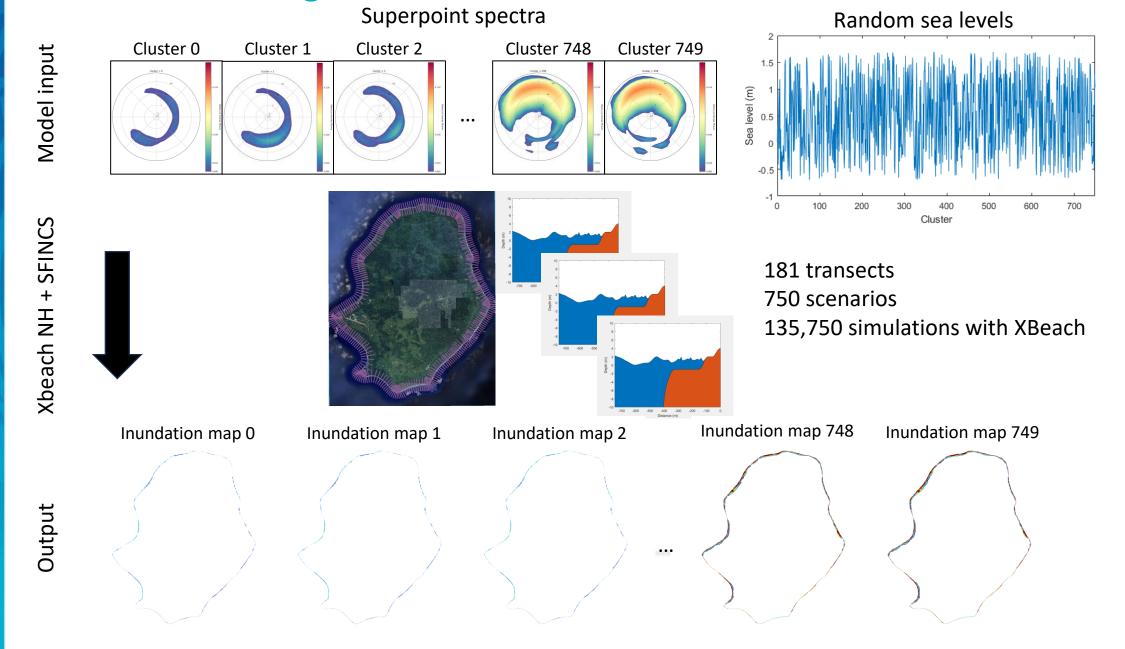




K-means clustering - Results

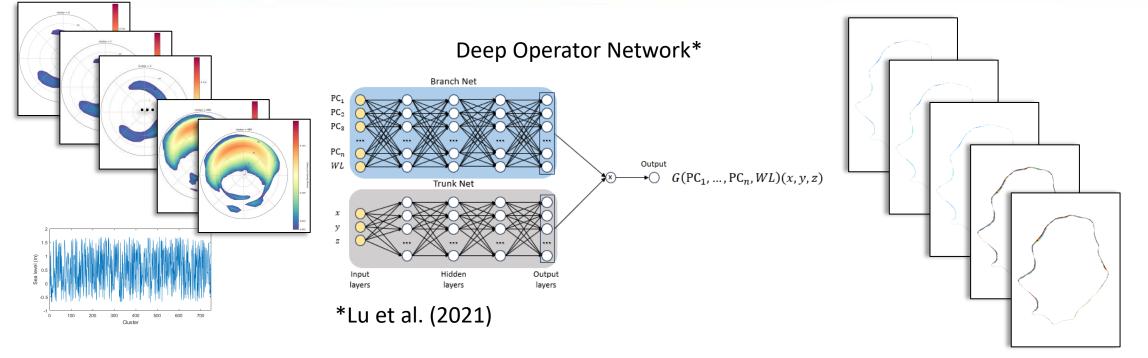


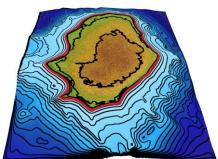
Generate training data











- Learns an operator that takes an *input function* and predicts a scalar output at
 each queried location, by combining the branch embedding of the input function
 with the trunk embedding of the location.
- DeepONet can reuse the same trained model to predict the scalar at *any* location by just changing the trunk coordinates.



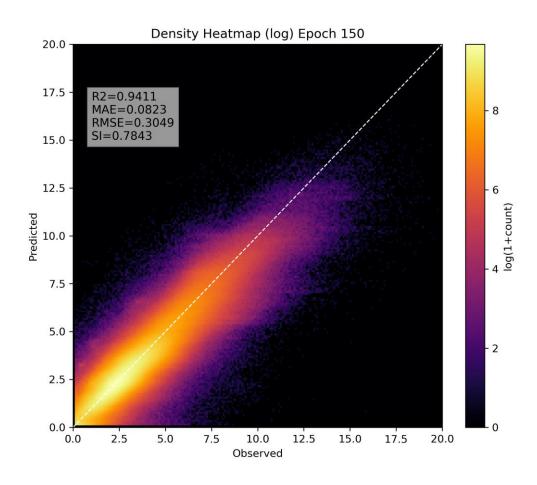
Historical events – TC Heta 2004







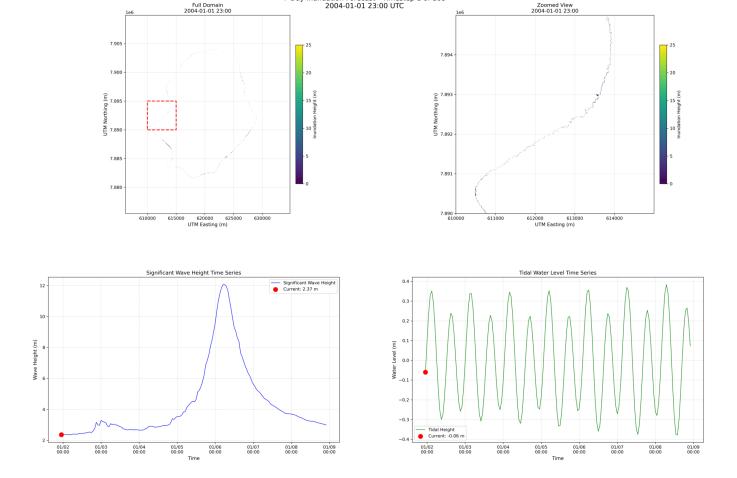
Numerical validation against 100 "unseen" scenarios



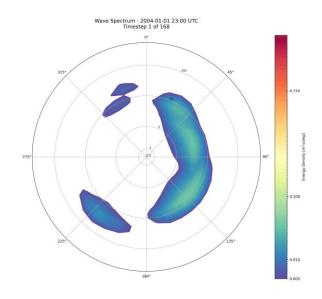


7-day "forecast" run

• 2.5-4 minutes for 7 days (168 time steps) with ~1 million grid points



7-Day Inundation Forecast - Timestep 1 of 168



Conclusion



- By plugging the system into a wave forecast (and storm surge in case of local TCs) we can efficiently predict coastal inundation.
- The methodology allows for domain-wide time-series prediction of inundation levels along with hourly inundation maps (as opposed to event-based maps) allowing for targeted response.
- Coupling the system to a risk model (RISKSCAPE) we can predict impact.
- Ensemble forecasting of inundation is possible (e.g., for TCs using multiple TC tracks).
- Method allows for hindcasting inundation (storage limited).
- System is currently being implemented/operationalized for TV and Niue with further countries in the pipeline.
- Method requires good baseline data to be effective.





- Population
- Buildings
- Roads
- Bridges
- Airports
- Port Facilities
- Power
- Water

- Evacuation Centres
- Health Facilities
- Schools
- Villages
- Infrastructure
- Telecommunication
- Crops
- Infrastructure Values

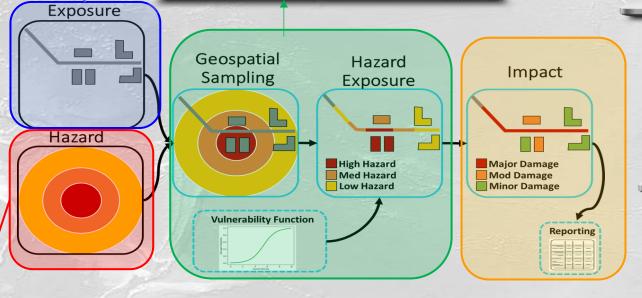
Hazards models Coastal inundation

Wave driven inundation

Tropical Cyclone

- Wind speed (incl. topography)
- Storm surge and wave driven flooding
- Rainfall and river flooding (not yet implemented)





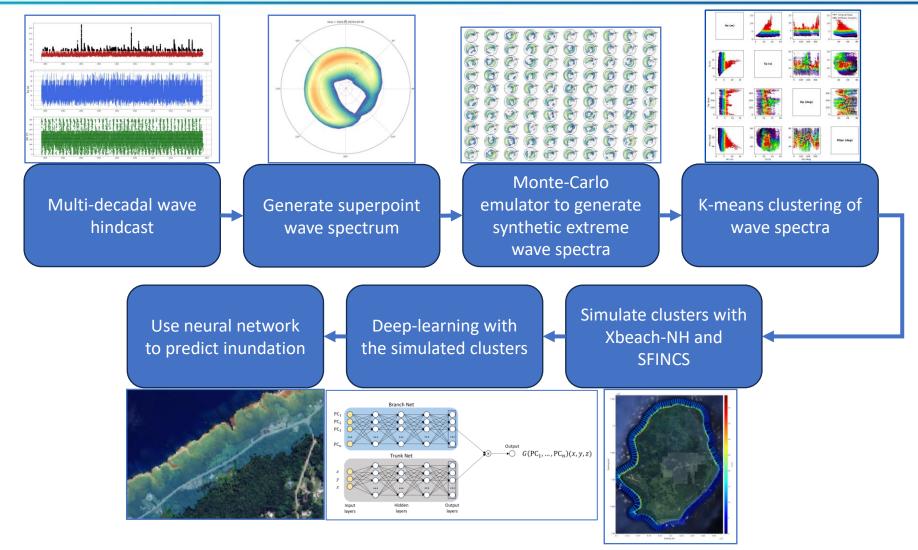






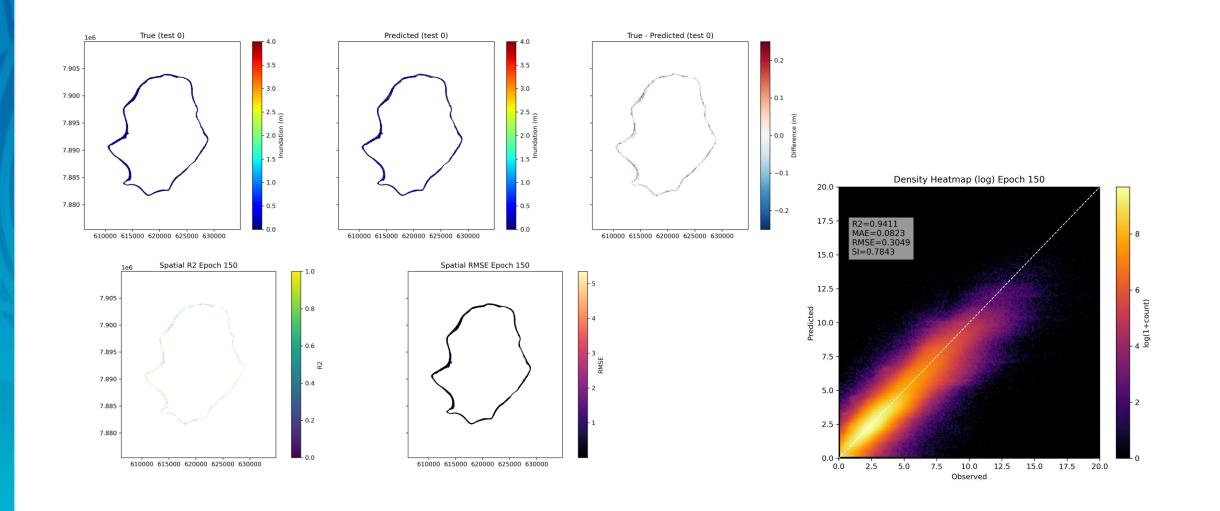


Inundation forecasting





Numerical validation against 100 "unseen" scenarios

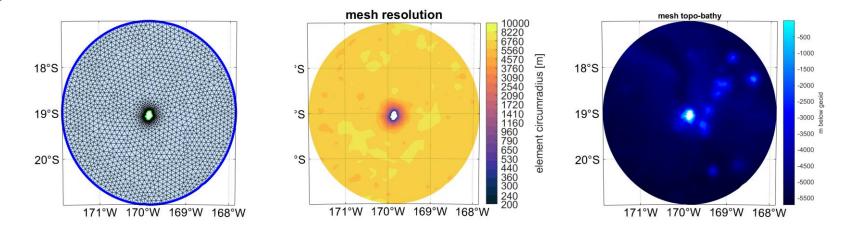


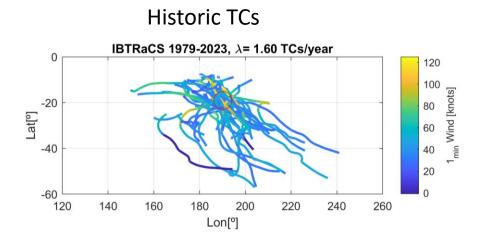


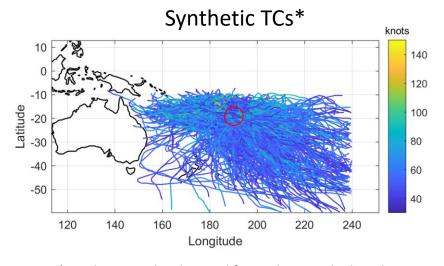




Adcirc + SWAN





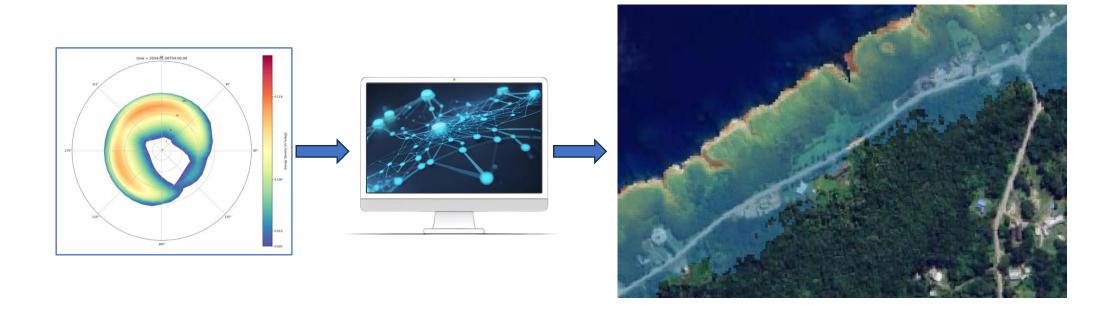


*Synthetic tracks obtained from Bloemendaal et al. 2020



Designing the forecast system

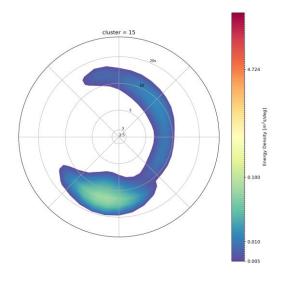
- Explicitly simulating inundation for each wave forecast cycle is computationally expensive
- Xbeach could become numerically unstable resulting in false predictions
- Surrogate models provide a computationally cheap solution
 - Generate 750 representative wave and water level conditions
 - Simulate 750 clustered spectra using Xbeach + SFINCS
 - Train neural network/ML algorithm using the 750 clusters as input and resulting inundation maps as output





K-means clustering - Results

Example centroid for cluster 15



Historic spectra belonging to cluster 15





K-means clustering - Results

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