

# Inundation forecasts and coastal hazard analyses for low-lying islands in the Pacific



Pacific  
Community  
Communauté  
du Pacifique

**Moritz Wandres, Antonio Espejo, Herve Damlamian**



[moritzw@spc.int](mailto:moritzw@spc.int)



[@m\\_wandres](https://twitter.com/m_wandres)



GEM

Geoscience, Energy and Maritime Division



## 2021 Pacific Desk Webinar Series



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## The Pacific Community SPC

Pacific owned, Pacific led.



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Communauté  
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*SPC is the principal scientific and technical organisation in the Pacific region, proudly supporting development since 1947. We are owned and governed by our 26 country and territory members who we serve.*

Climate Change  
and Environmental  
Sustainability  
Programme (Noumea)

Fisheries,  
Aquaculture and  
Marine Ecosystems  
Division (Noumea)

Statistics for  
Development Division  
(Noumea)

Public Health Division  
(Noumea/Suva)

Social Development  
Programme (Gender,  
Culture, Youth) (Suva)

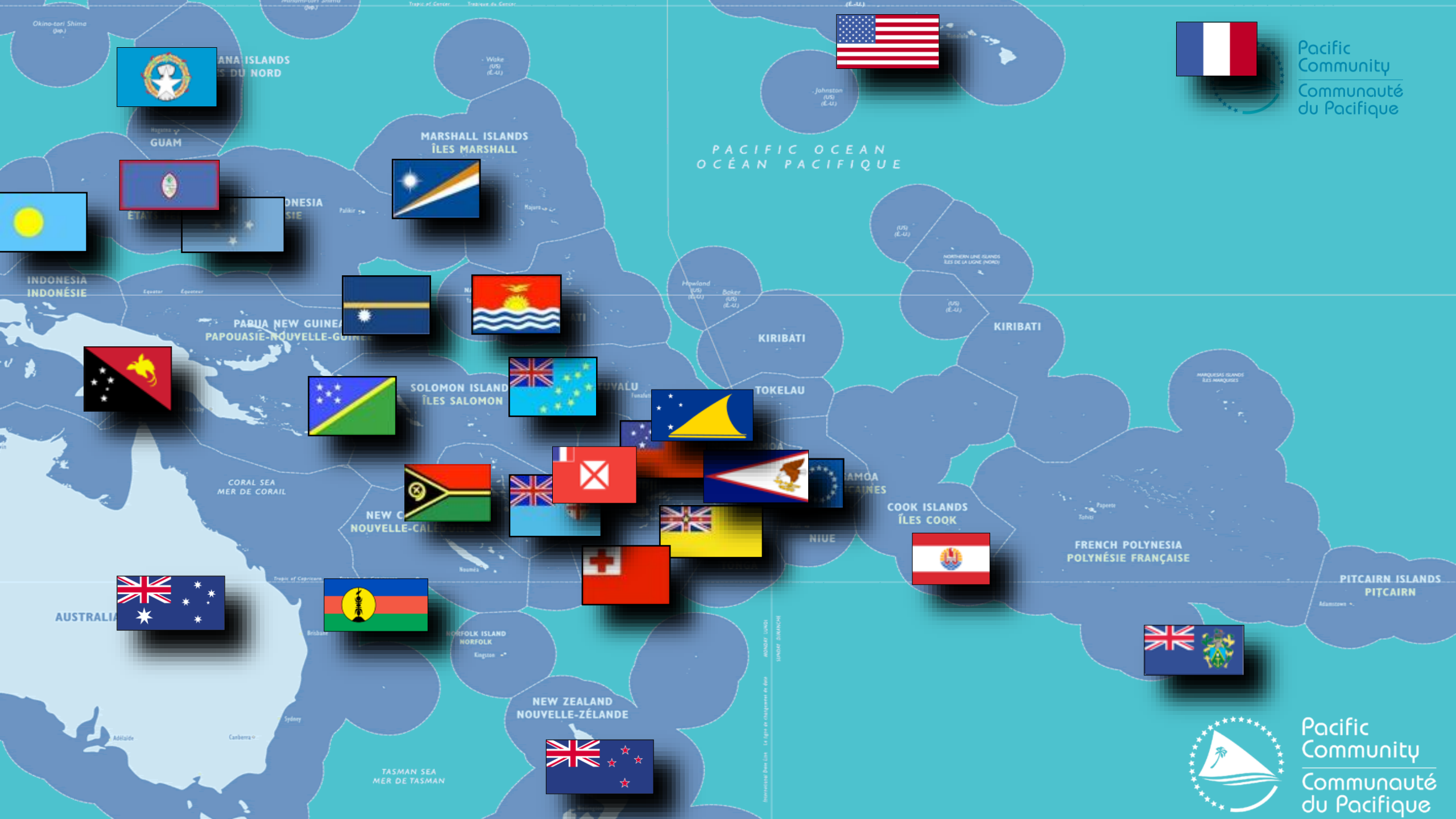
Regional Rights  
Resource Team (Suva)

Land Resources  
Division  
(Suva)

**Geoscience, Energy and Maritime  
Division (Suva)**

Education Quality  
and Assessment  
Programme (Suva)





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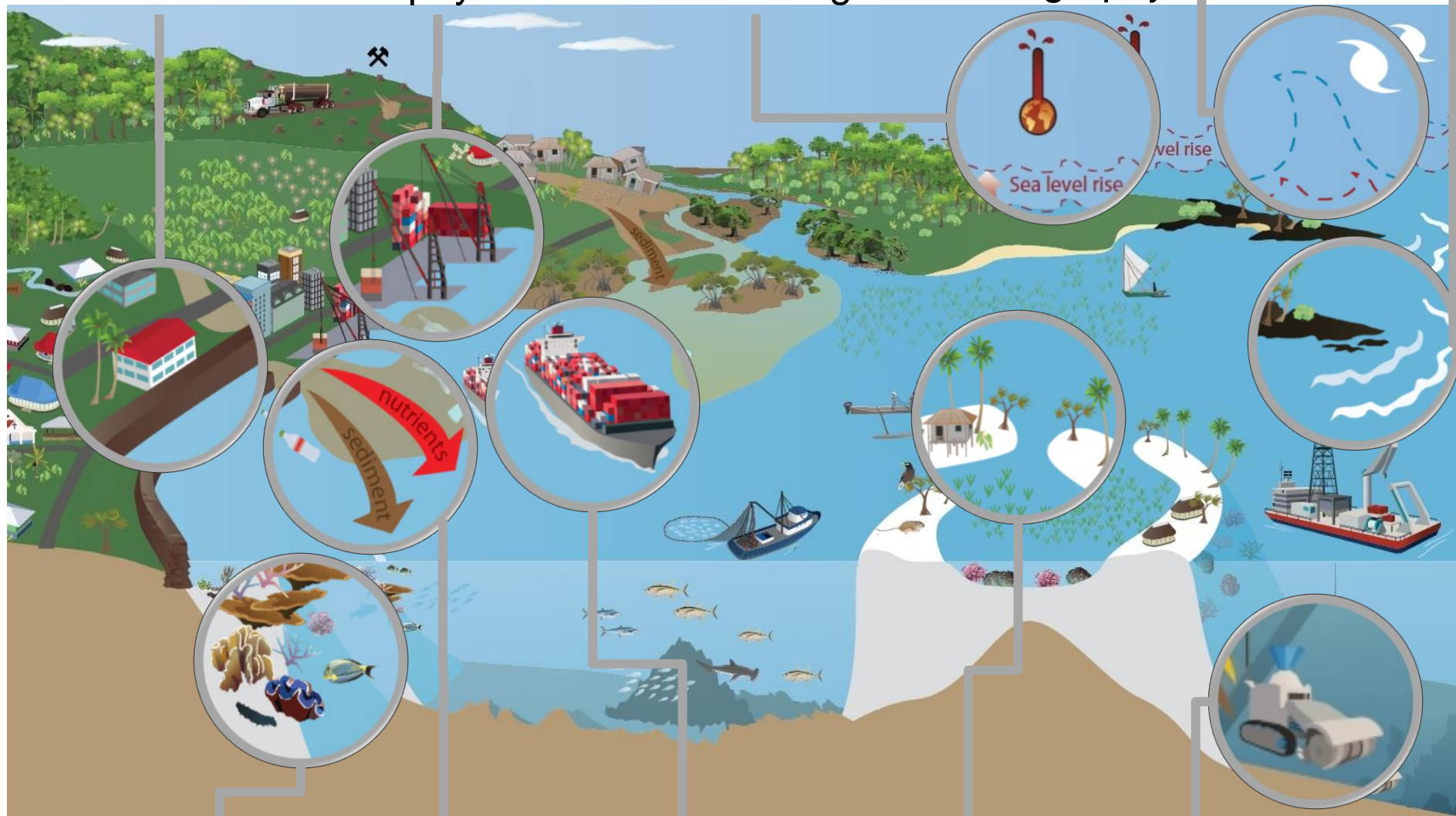
Coastal  
Hazards

Marine  
Geophysics

Ocean & Climate  
Monitoring

Oceanography

Maritime  
Boundaries



Habitat  
Mapping

Water  
Quality

Hydrographic  
Surveying

Resources  
Management

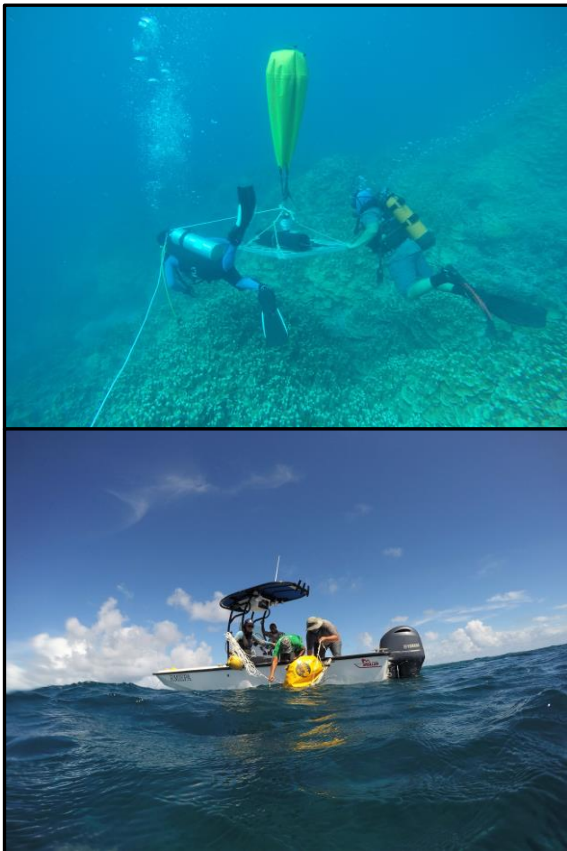
Deep Sea  
Minerals

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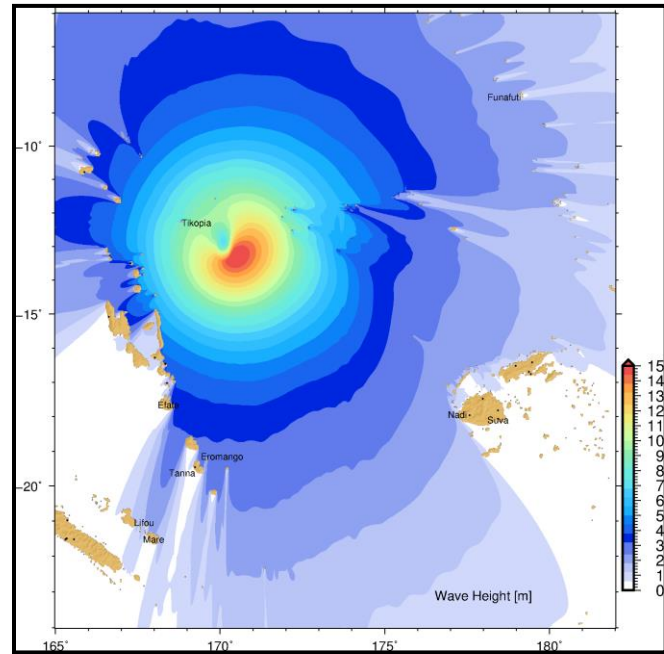


# Oceanography team

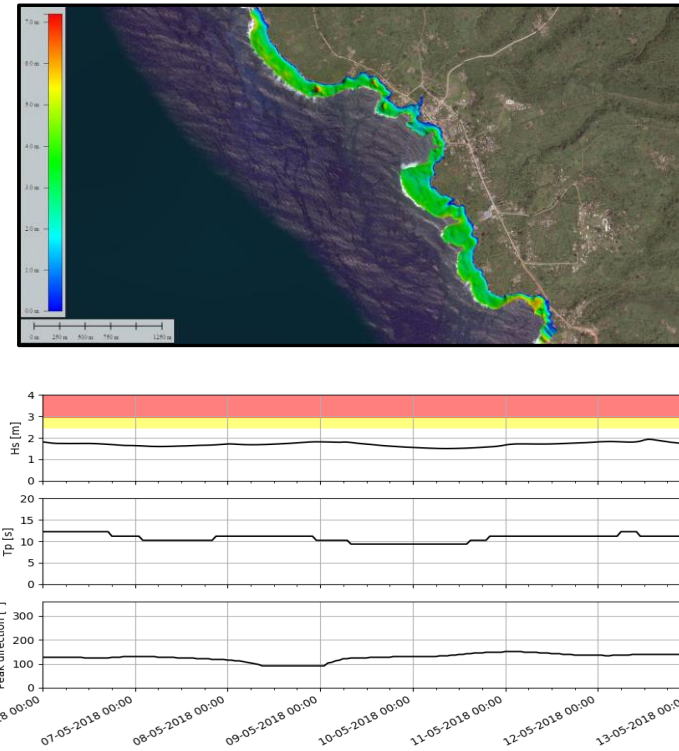
## Coastal monitoring



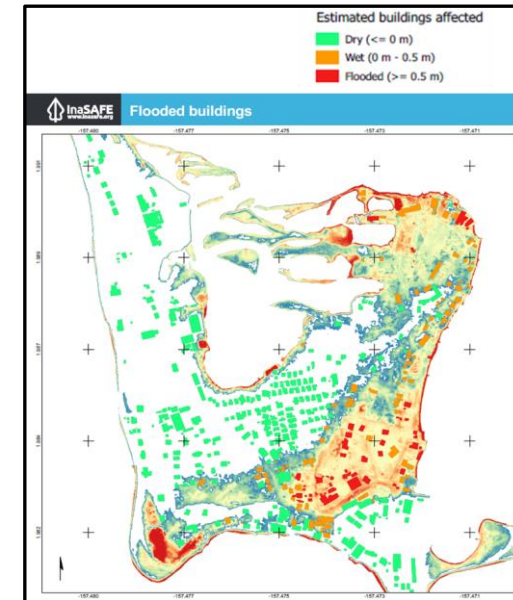
## Development of numerical models



## Coastal hazard assessments and early warning systems



## Risk assessments





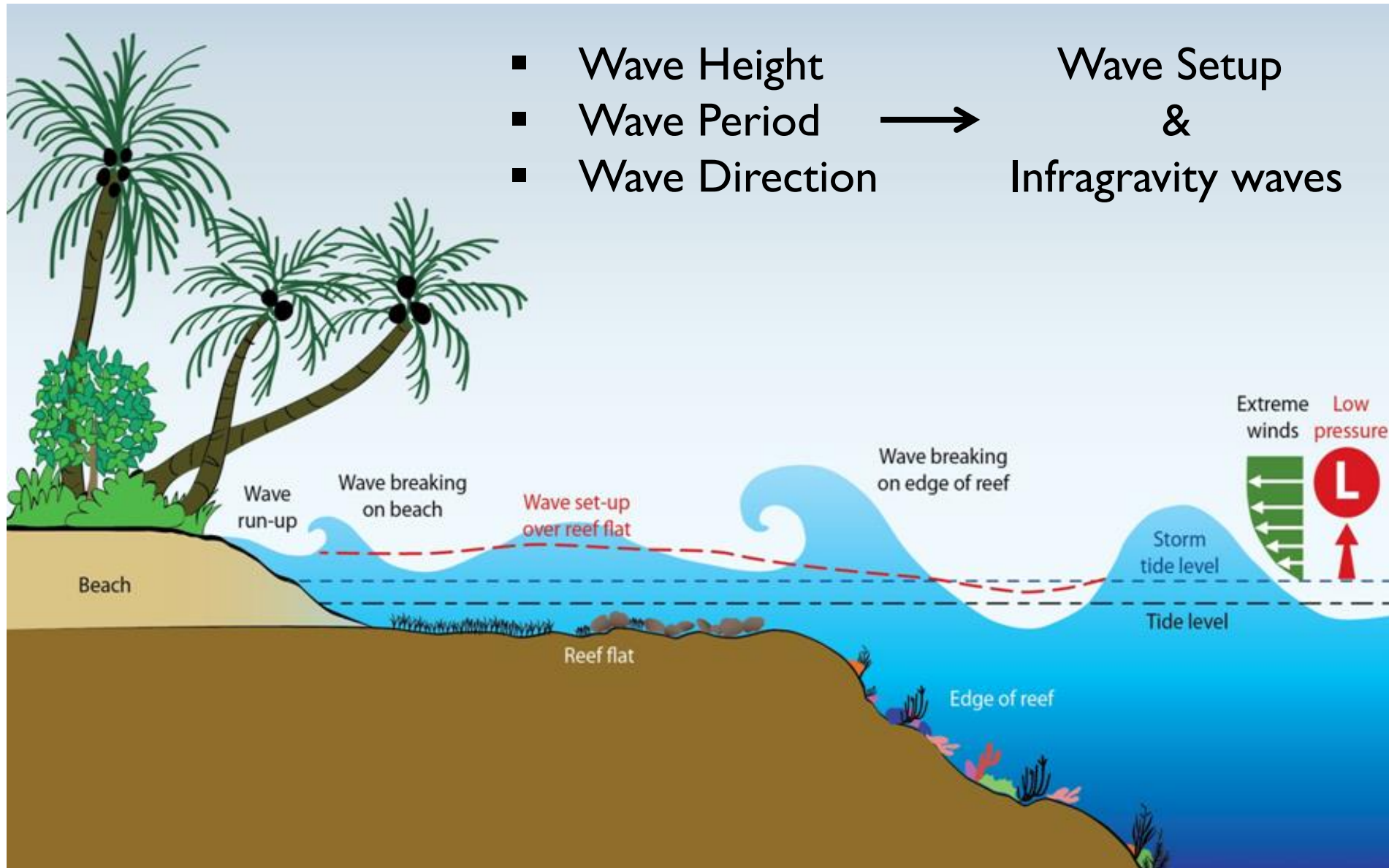


# Coastal Hazards



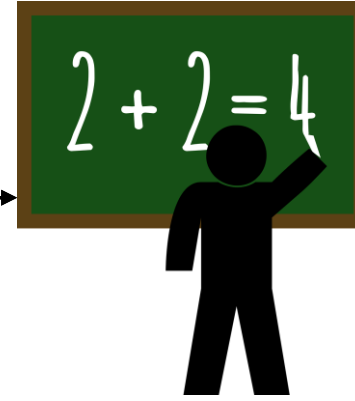


# Inundation drivers



# Informed decision making:

## Coastal vulnerability



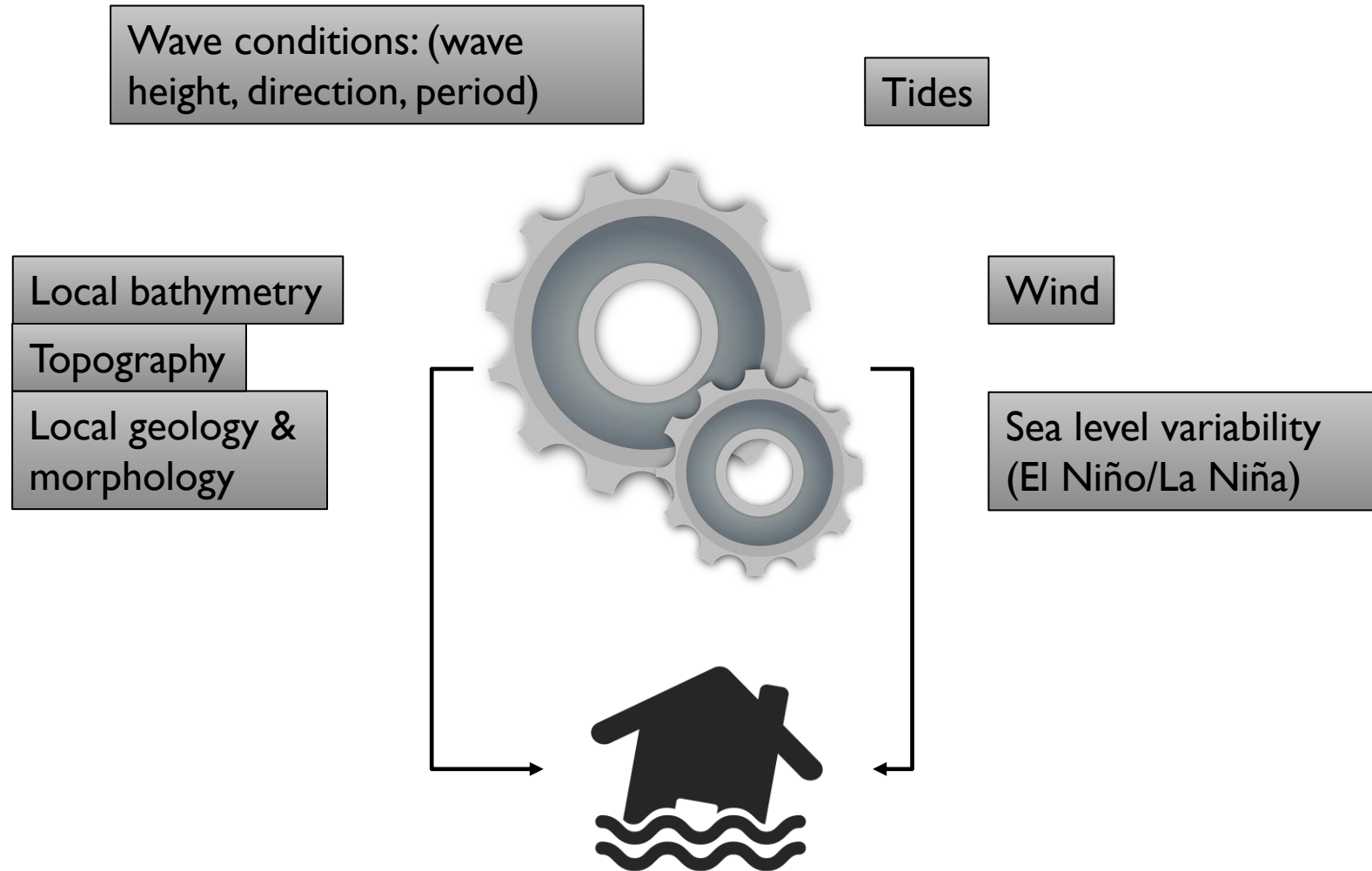
**Wave driven inundation**  
(Wave setup + infragravity waves)

Recorded by a resident of Nanumaga during TC Pam

- Local bathymetry
- Local geology & morphology
- Topography
- Tides
- Wind
- Wave conditions: (wave height, direction, period)
- Sea level variability (El Niño/La Niña)



# Wave-driven coastal inundation



# Operational coastal inundation forecasting system for distant-source swells



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- 1) **Altimetry data (Copernicus)**
- 2) **HYCOM (inc. altimetry assimilated)**

Mean Level of the Sea

Tide Predictions

Local tide gauge  
Tide model

Regional/Global Wave  
Forecast

Regional/Global Wind  
Forecast

- 1) **NOAA**
- 2) **BOM**
- 3) **ECMWF**

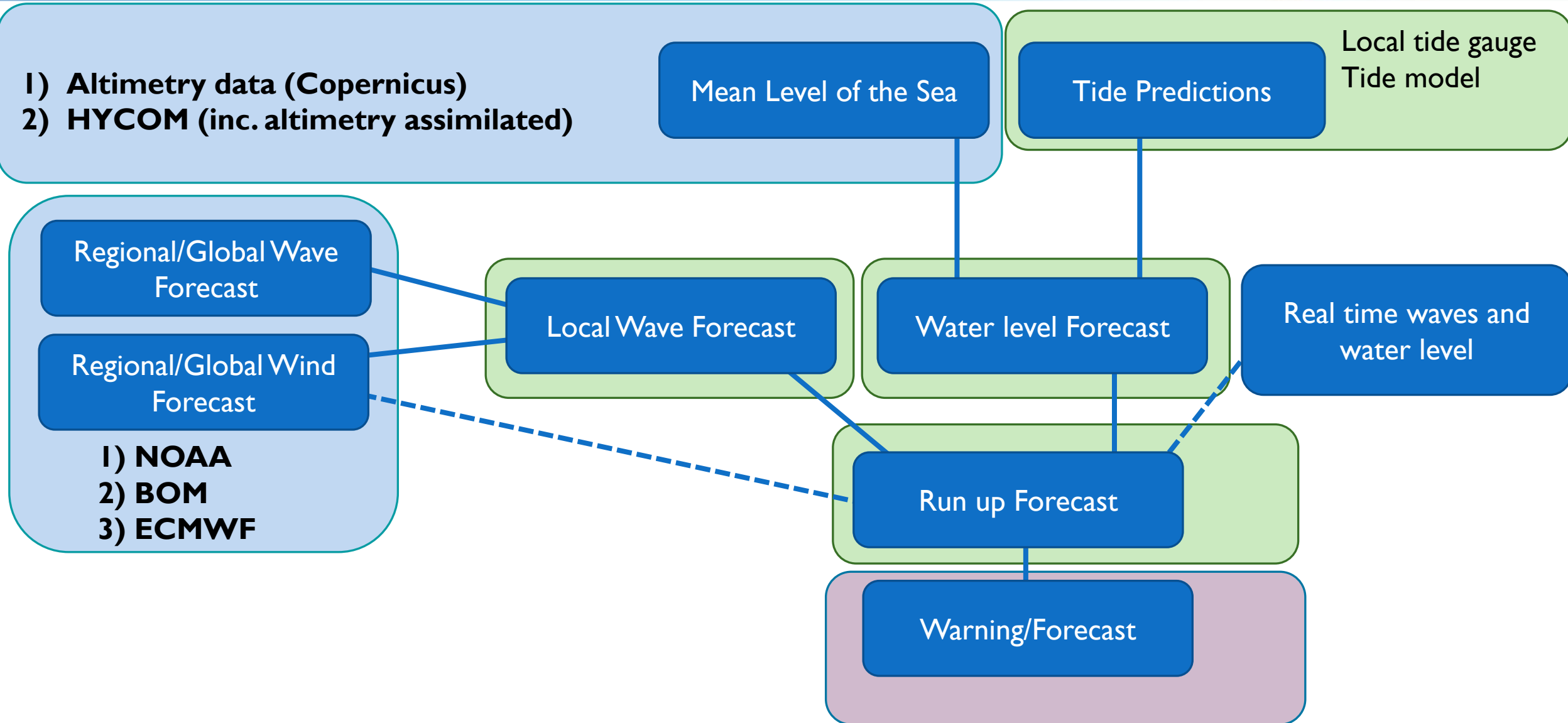
Local Wave Forecast

Water level Forecast

Real time waves and  
water level

Run up Forecast

Warning/Forecast





# Baseline data collection

- Geodetic data collection
  - Validate vertical reference datum
  - Calibrate topography and bathymetry data
- Oceanographic data collection
  - Calibrate models
  - Reduce uncertainties





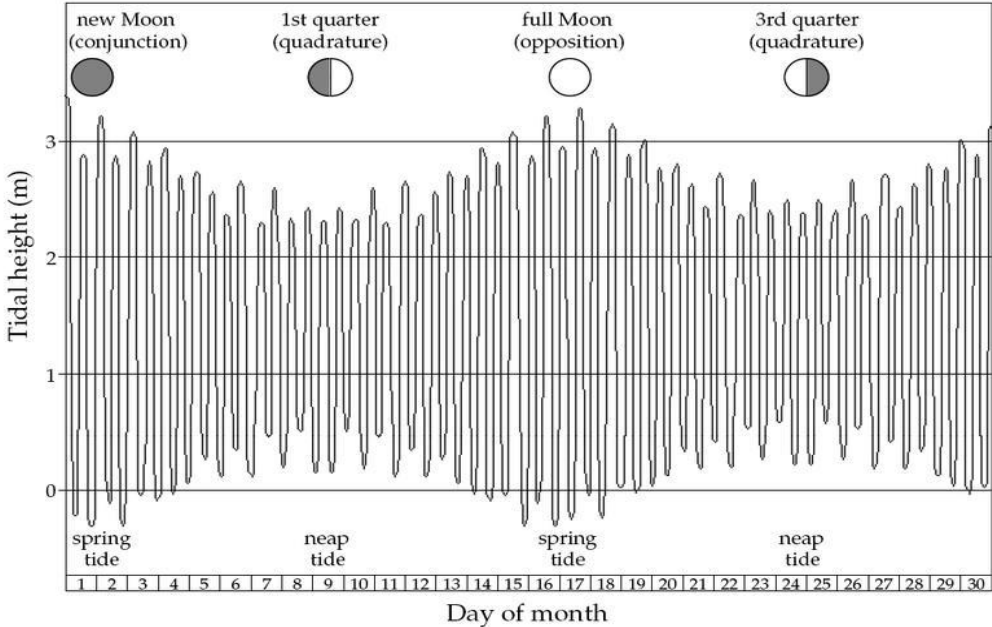
# Tides



## Spring Tides

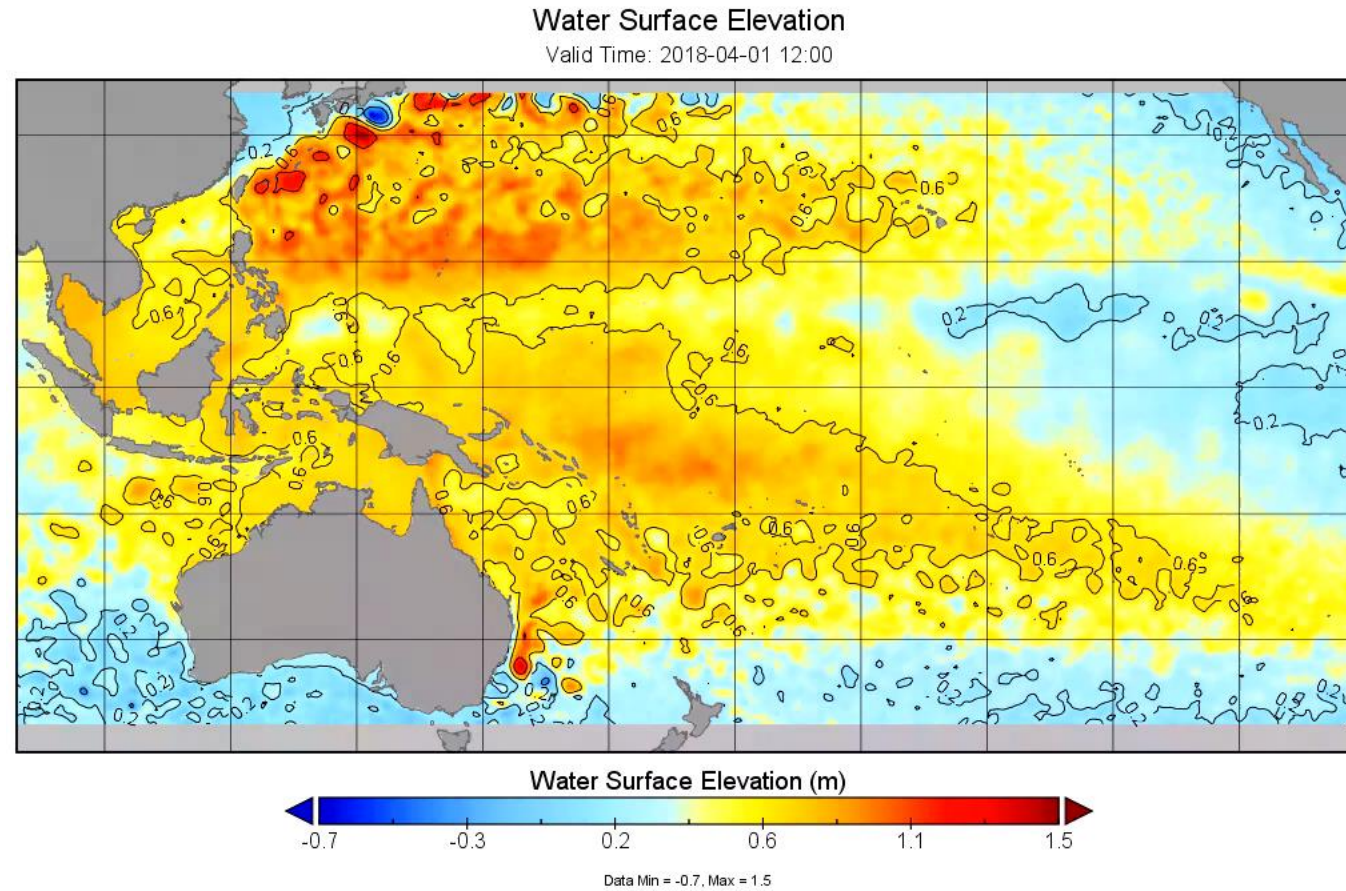


- Solar Tides
- Lunar Tides



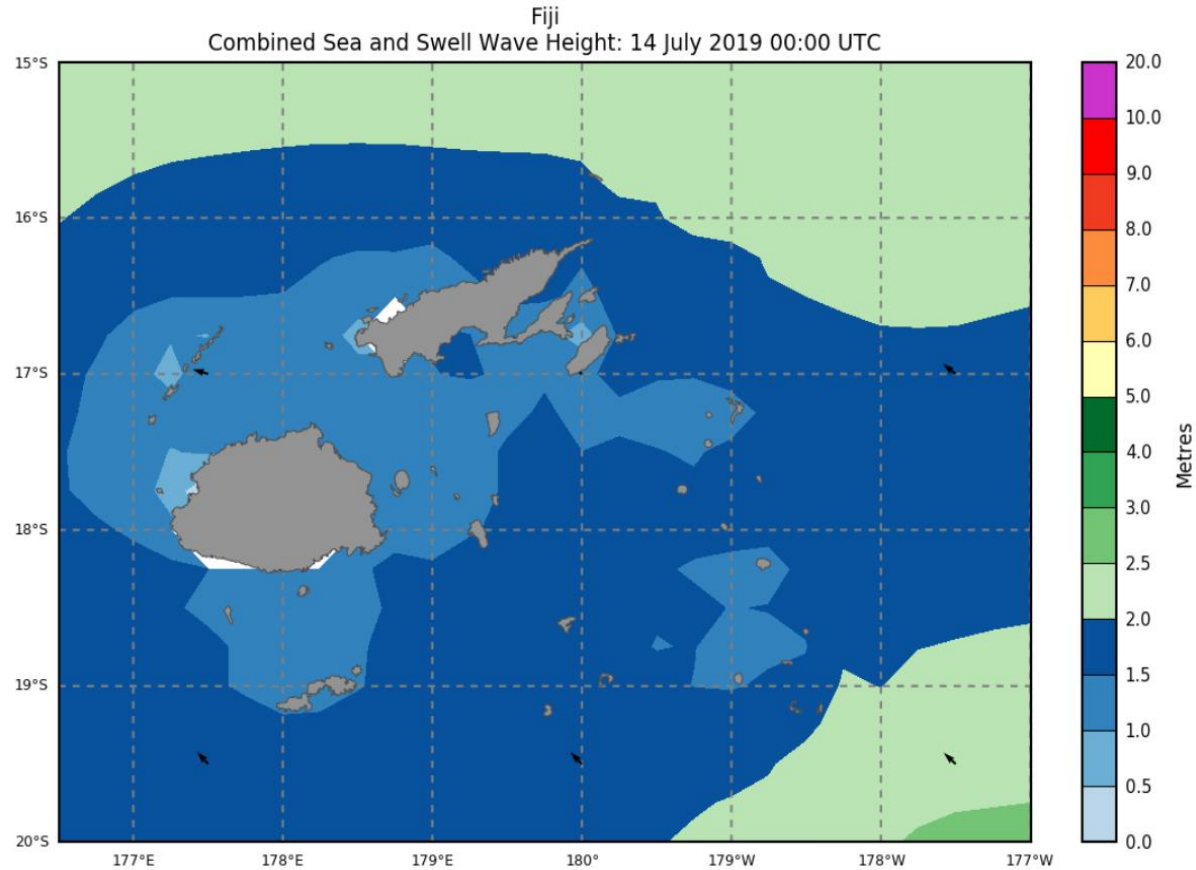


# Mean sea level anomaly

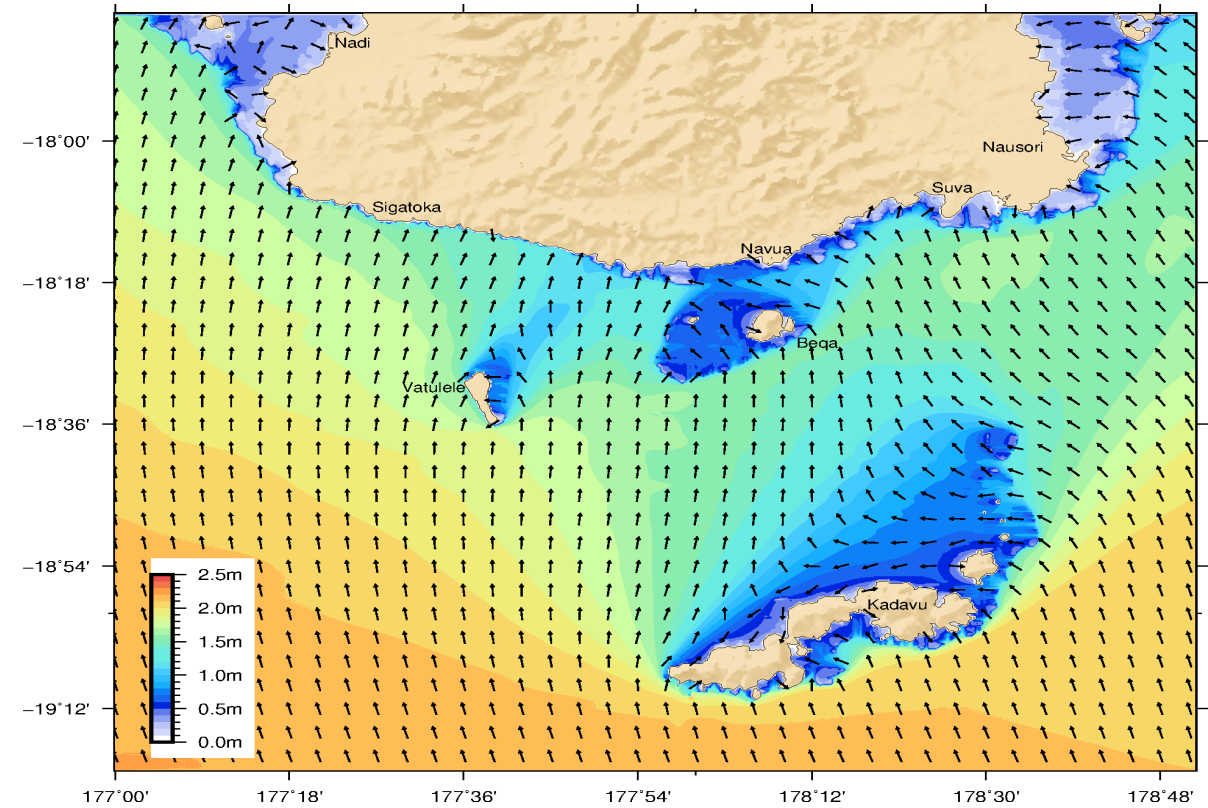


# Offshore wave conditions

## Global WW III wave forecast



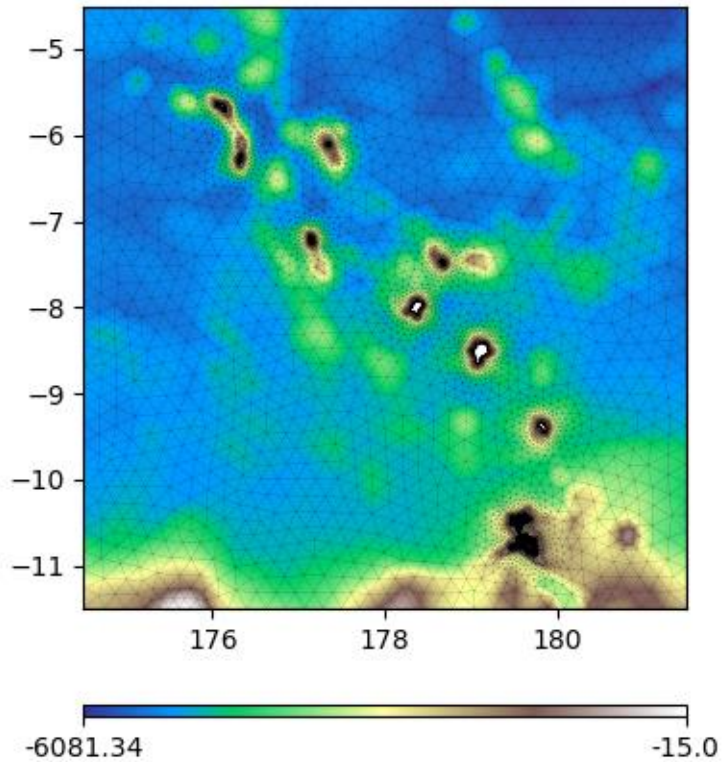
## Fiji's downscaled wave forecast



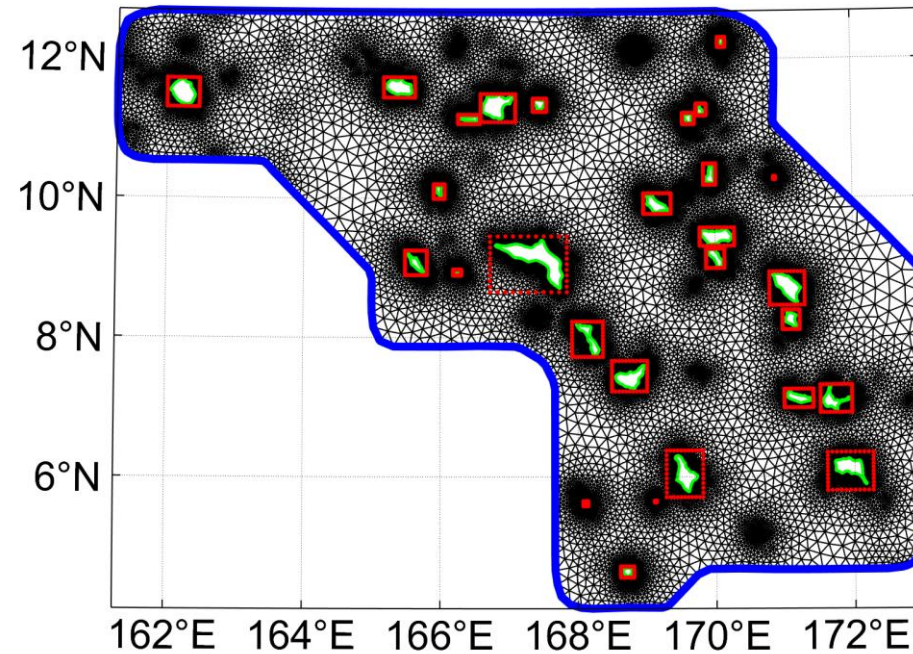


# Dynamical downscaling of global wave models (UnSWAN)

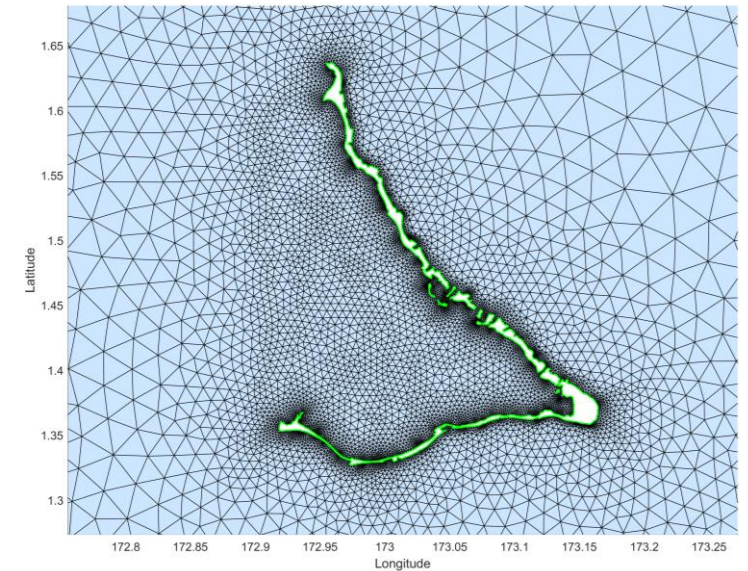
Tuvalu



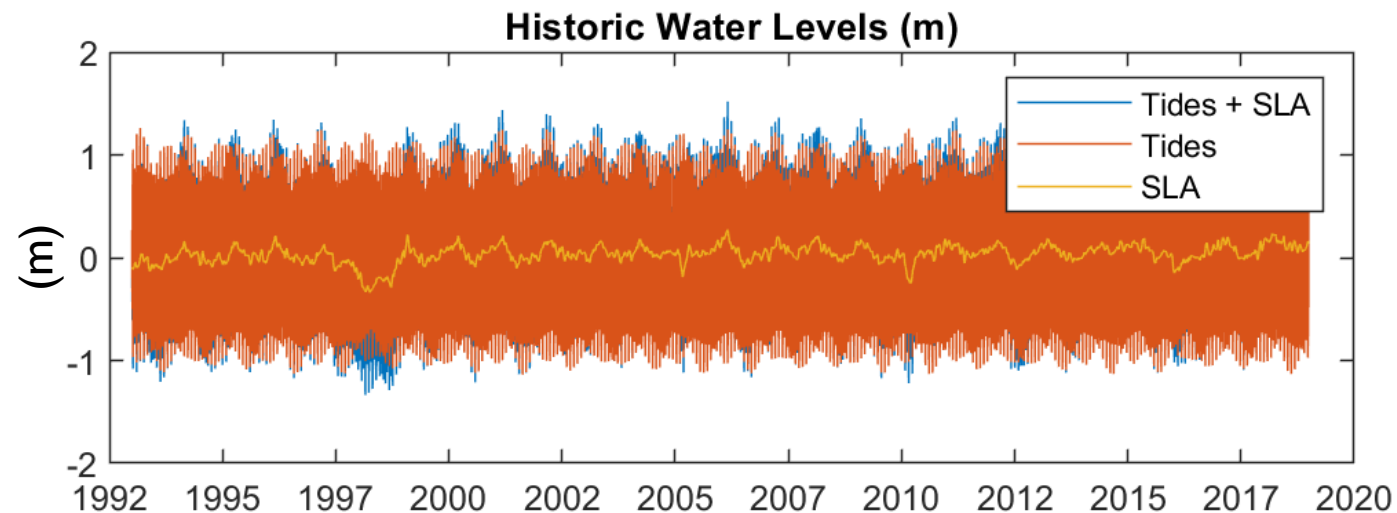
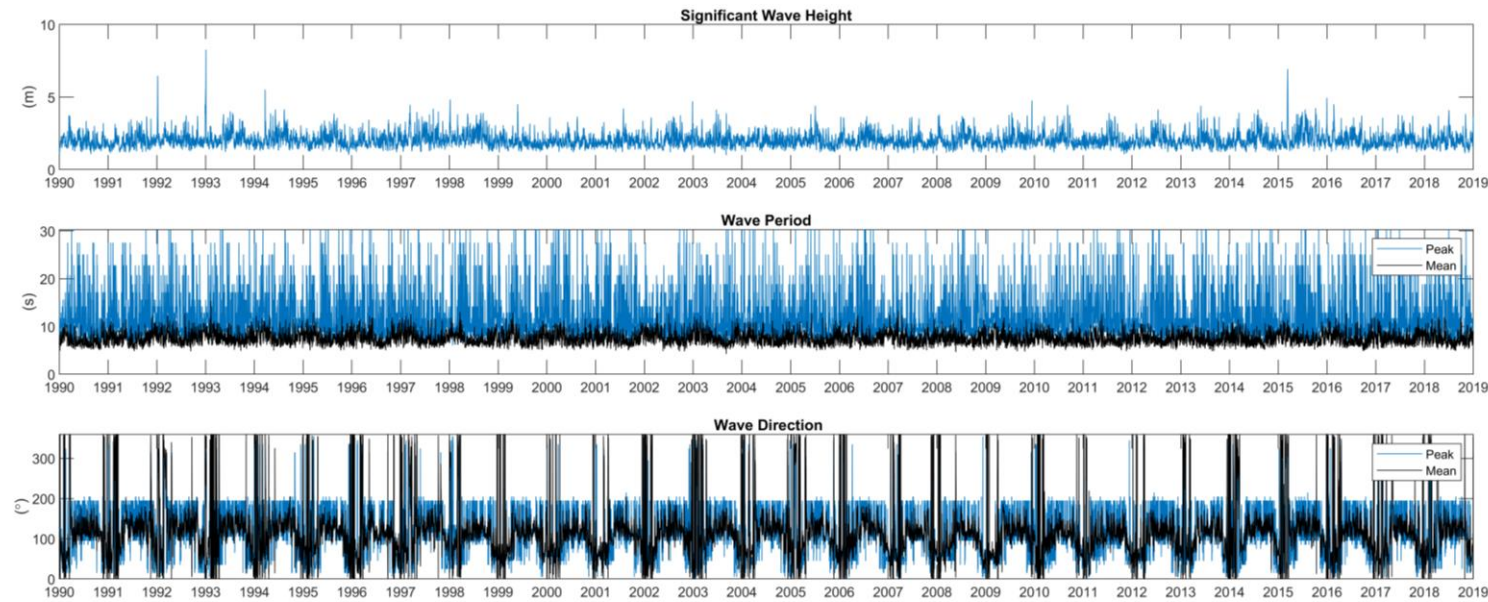
RMI



Tarawa, KI

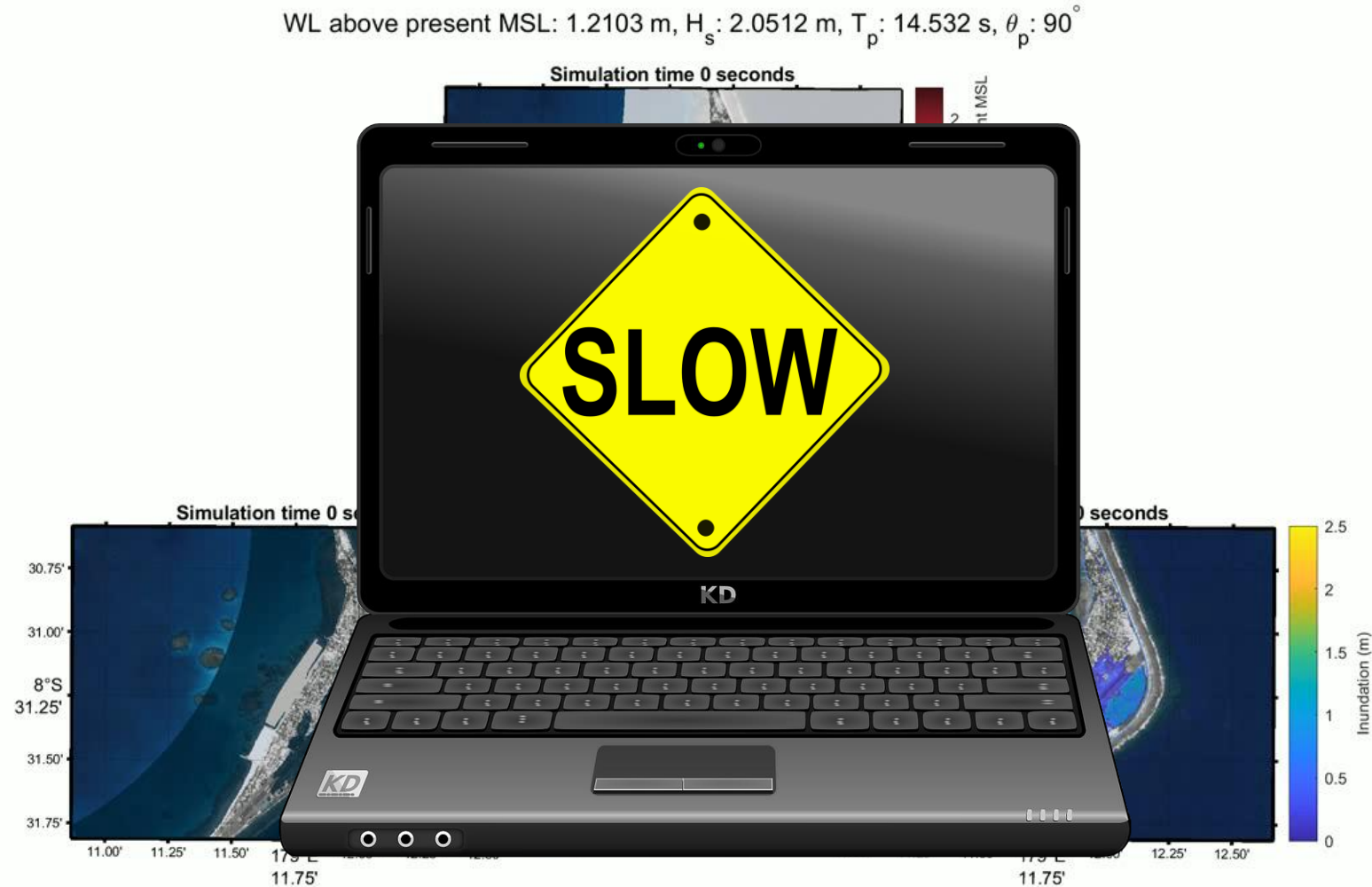


# Historical offshore wave and water level conditions

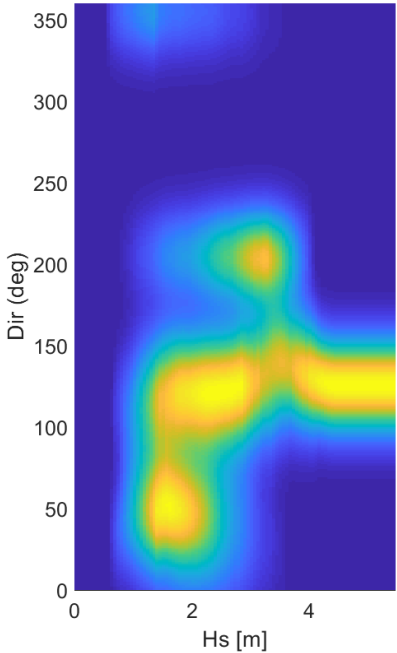
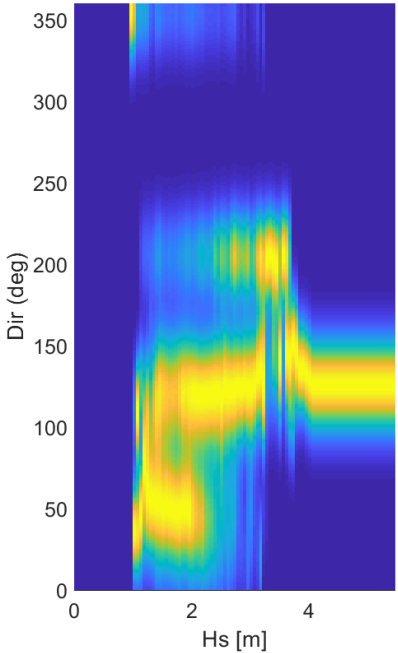
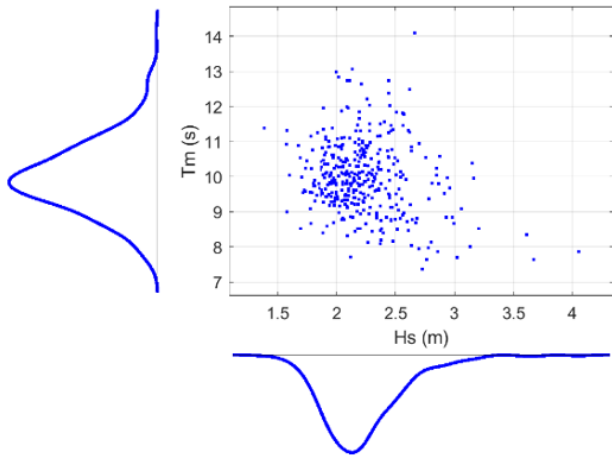
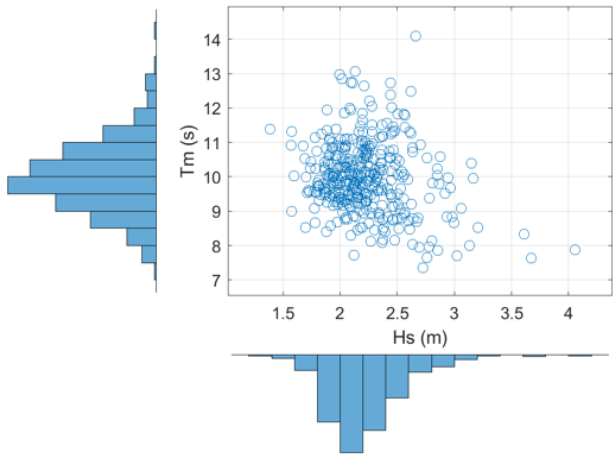




# Runup model (XBeach Non-hydrostatic)

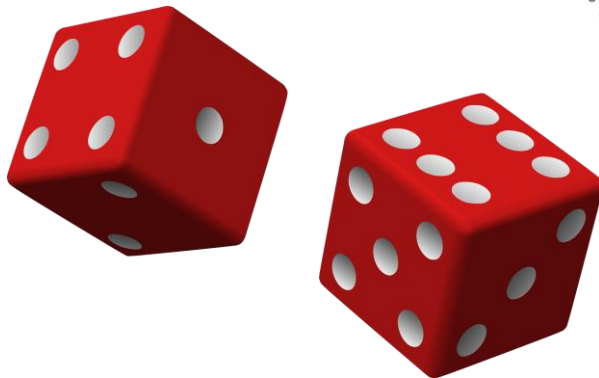
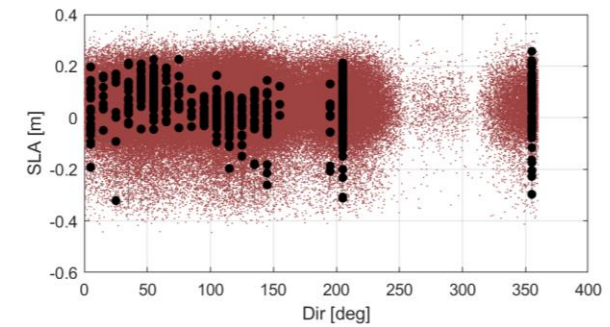
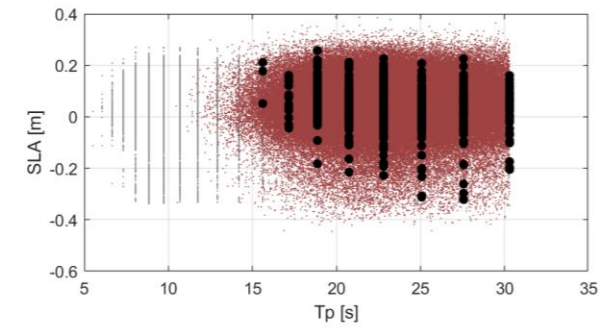
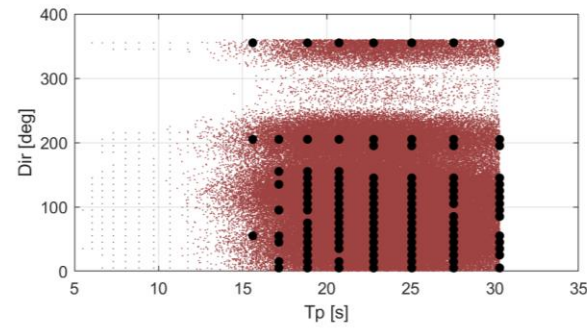
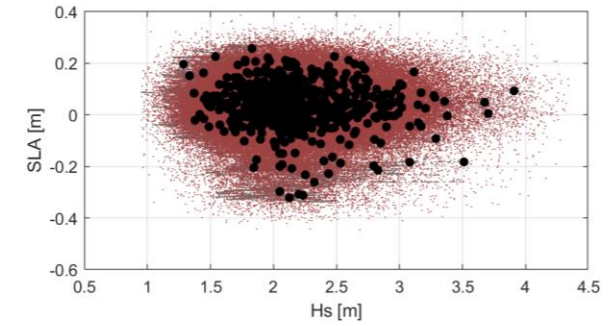
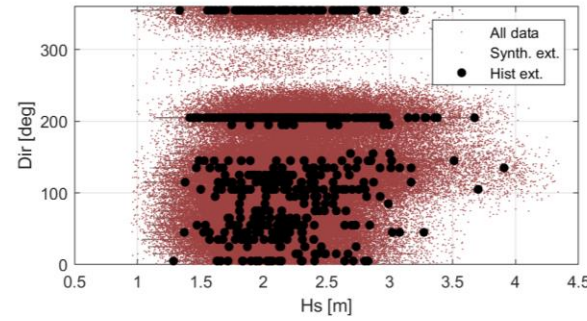
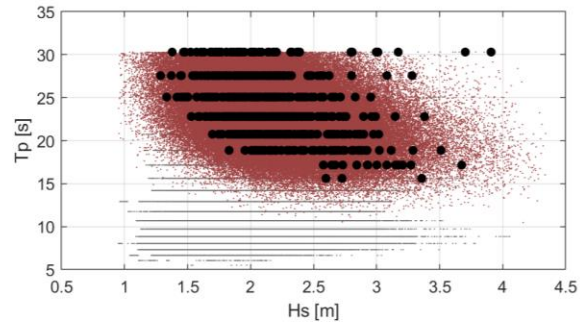


# Empirical and kernel distributions

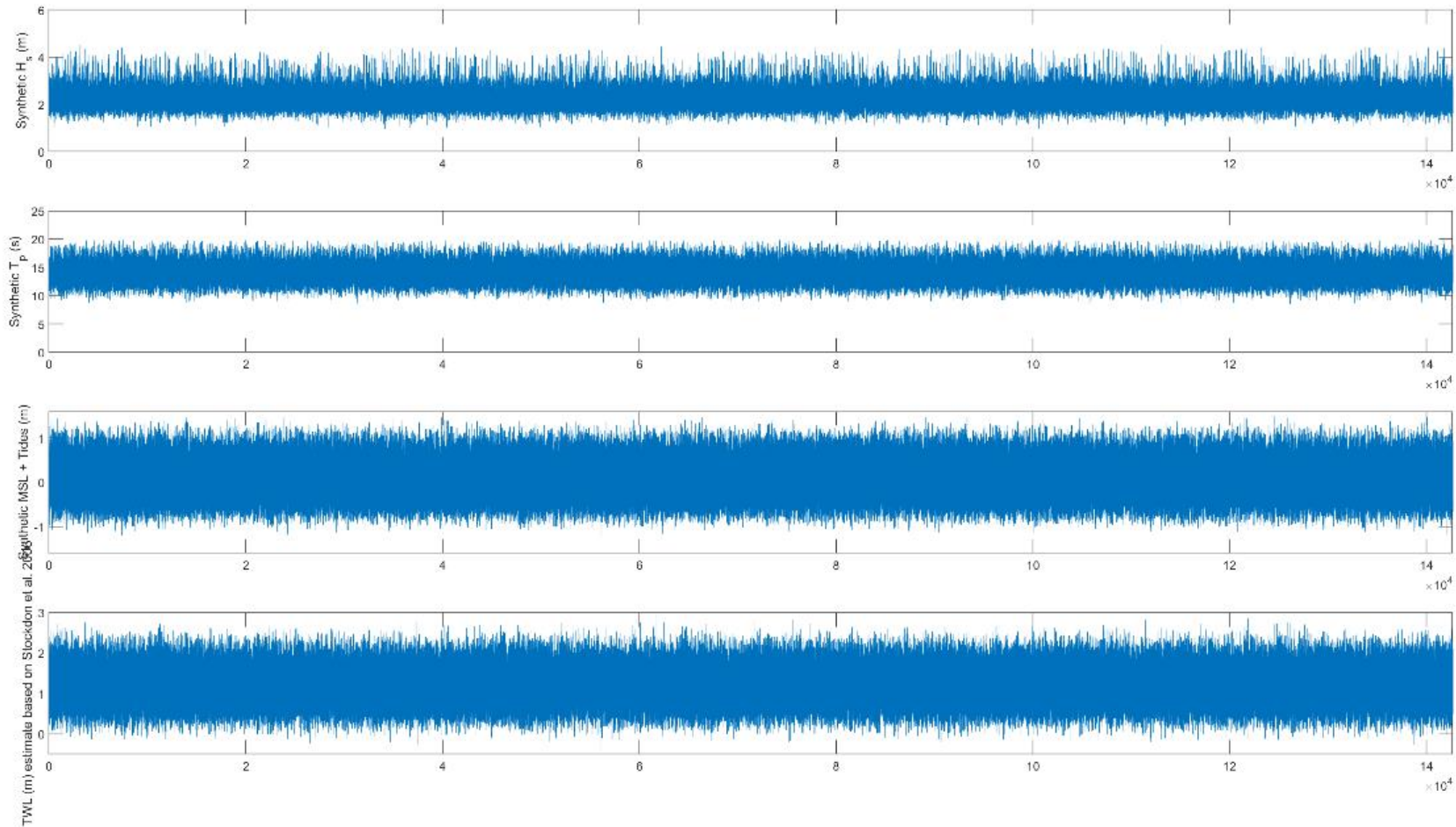




# Create 10,000 years of synthetic extremes

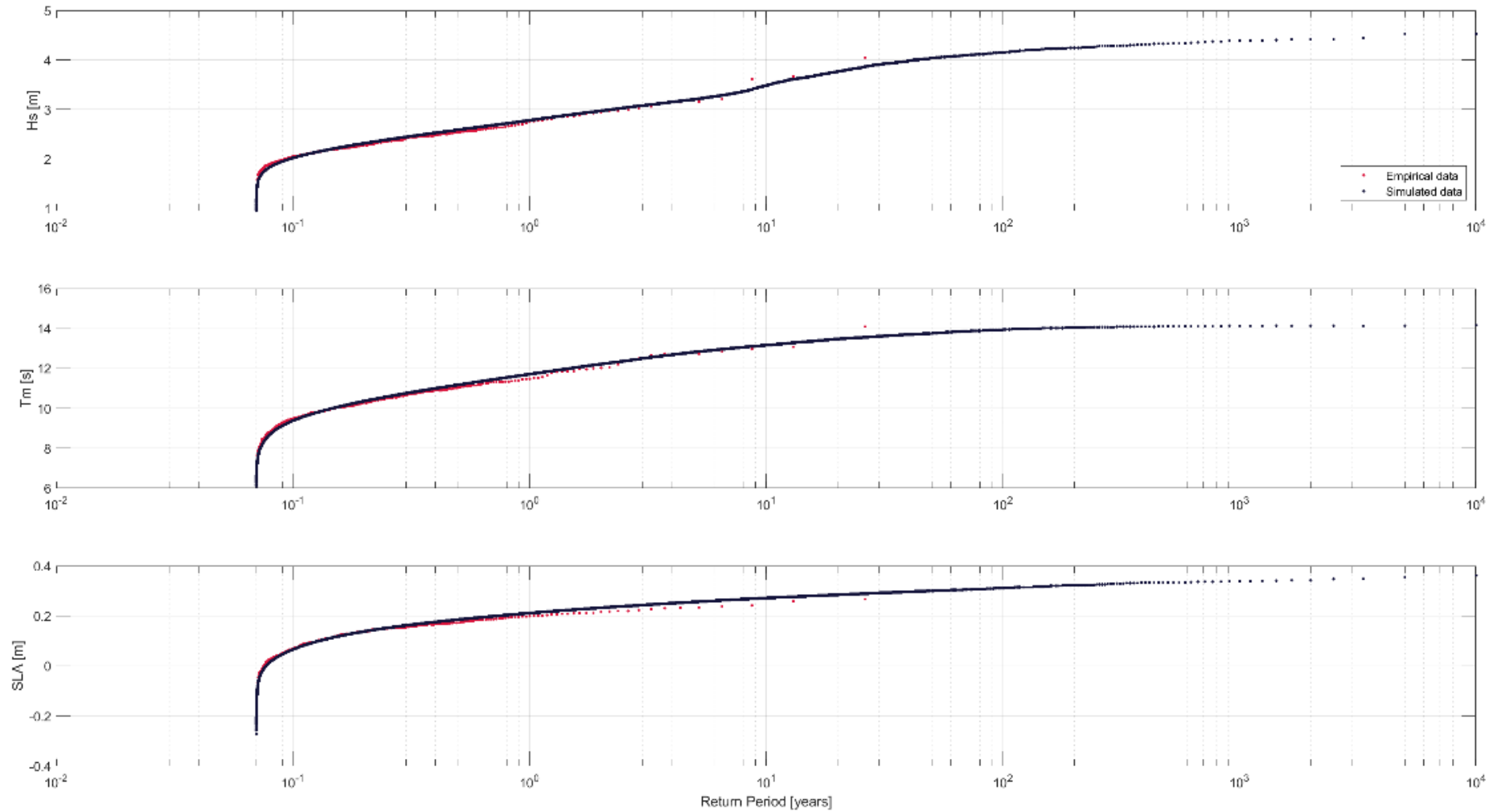


# Create 10,000 years of synthetic extremes

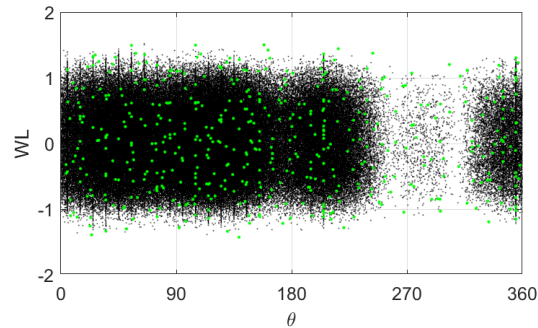
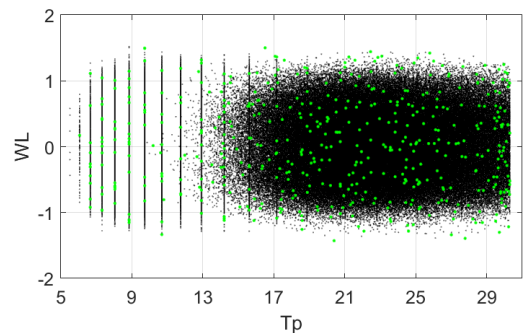
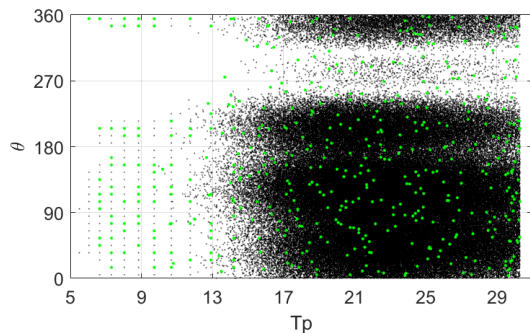
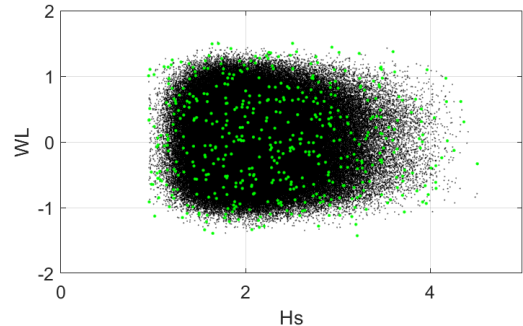
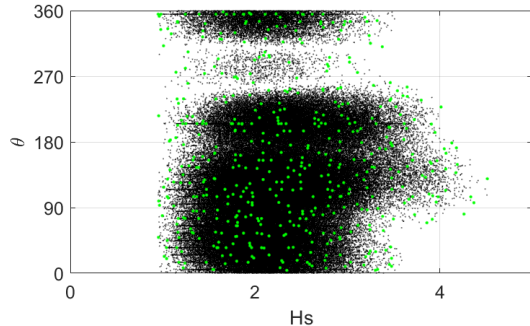
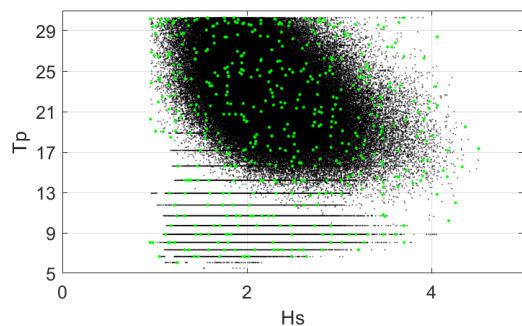




# Empirical extreme distributions



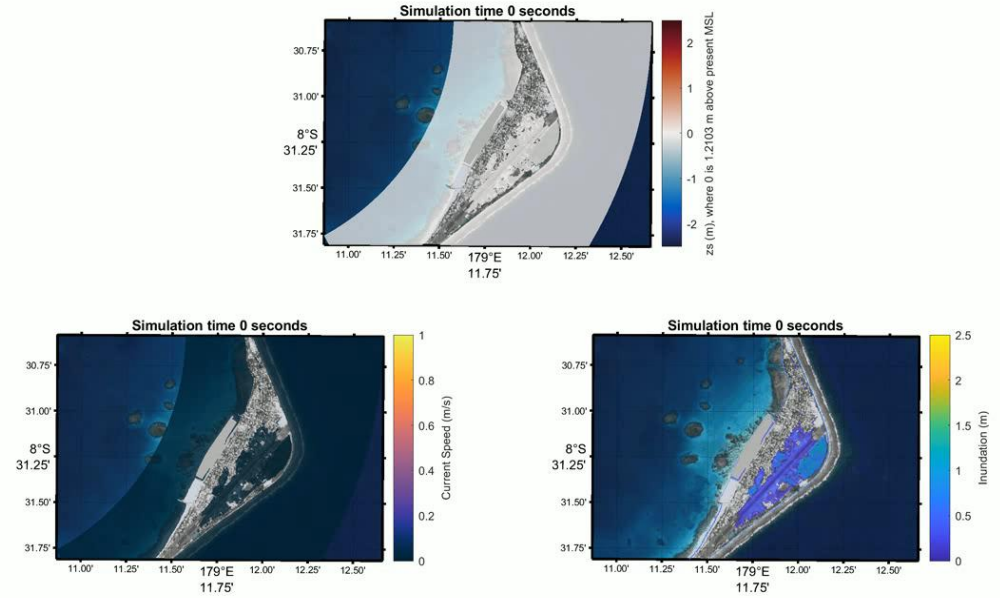
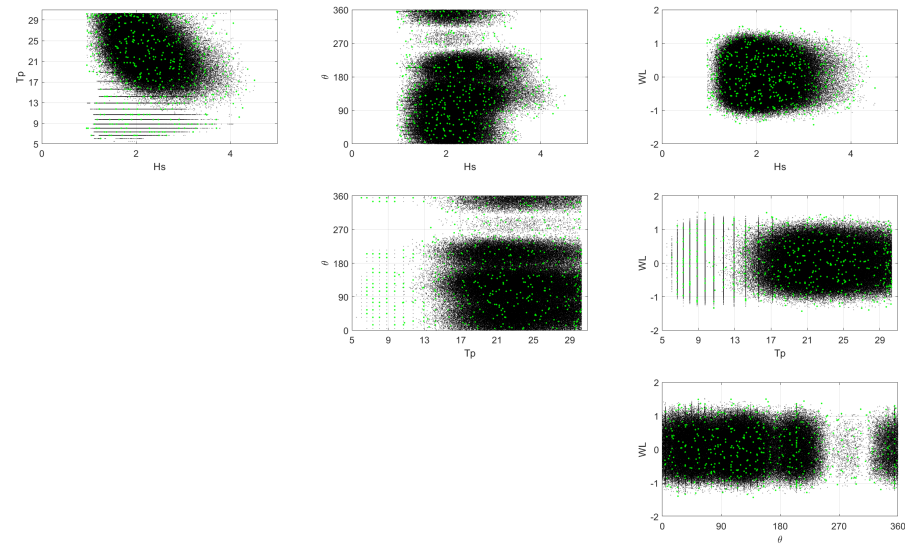
# Select 500 cases using MDA



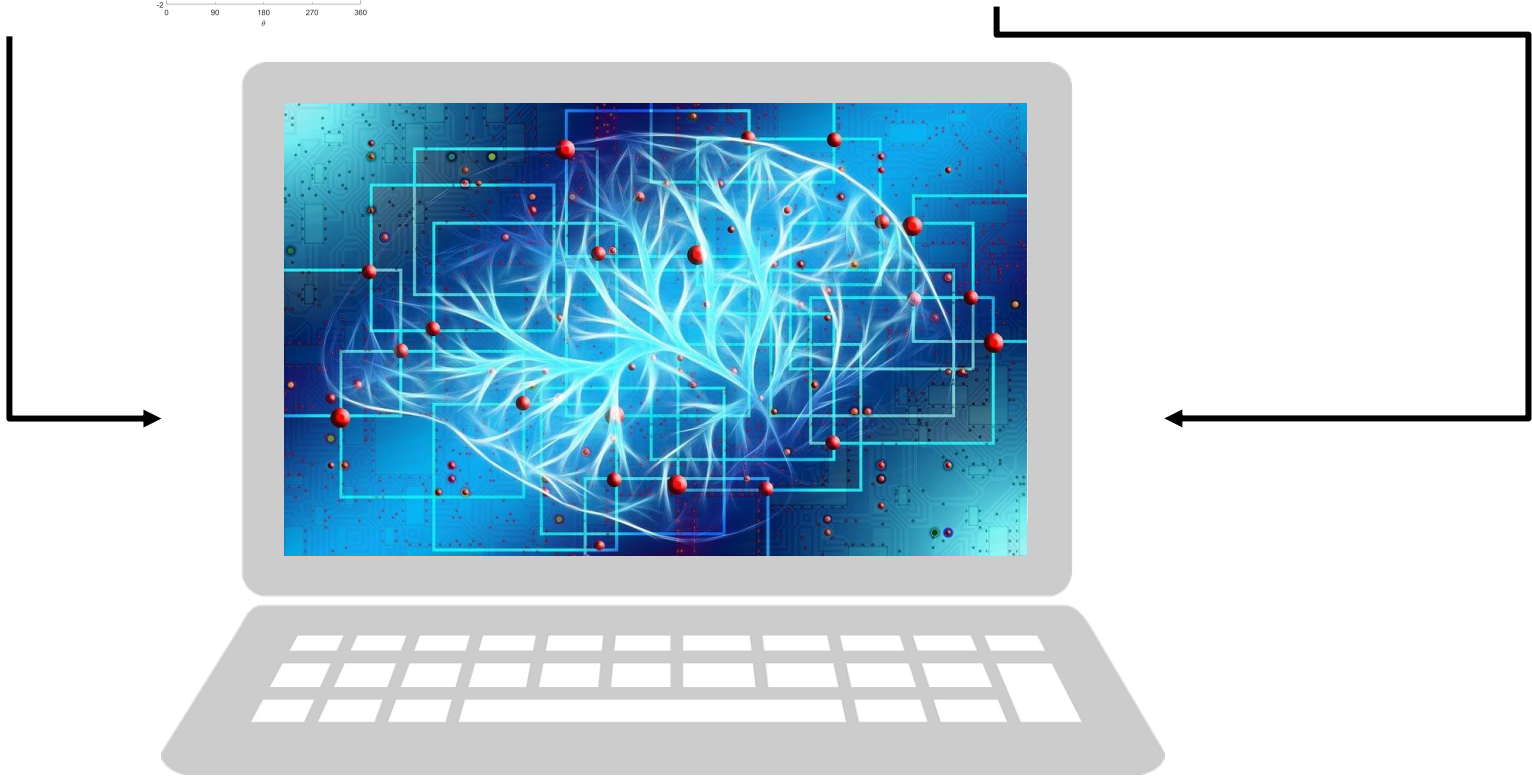
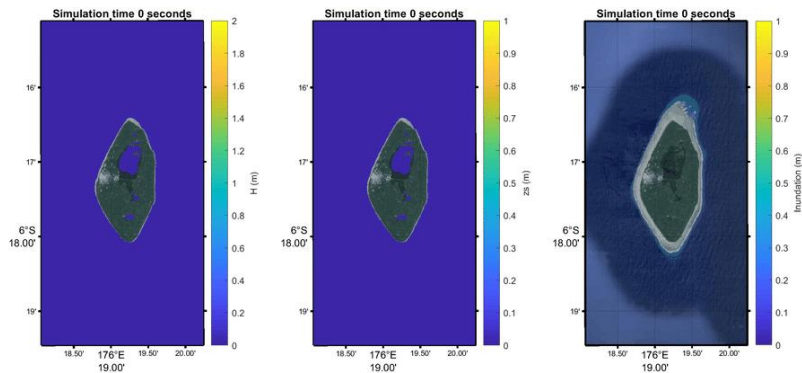
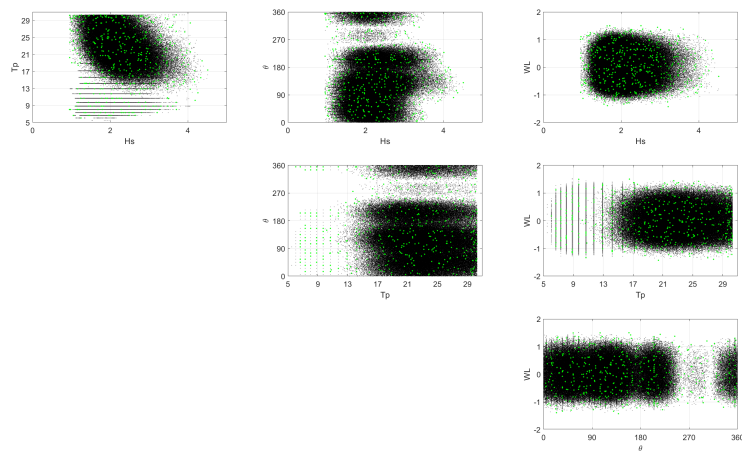


# Run 500 simulations with XBeach

WL above present MSL: 1.2103 m,  $H_s$  : 2.0512 m,  $T_p$  : 14.532 s,  $\theta_p$  : 90°



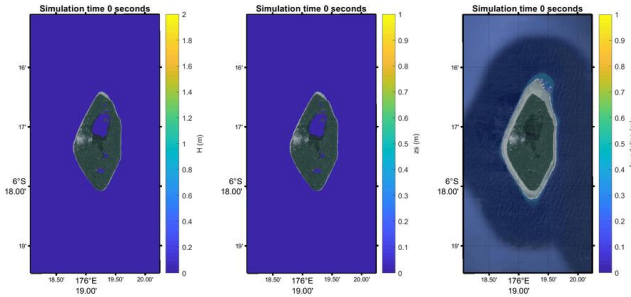
# Train RBF



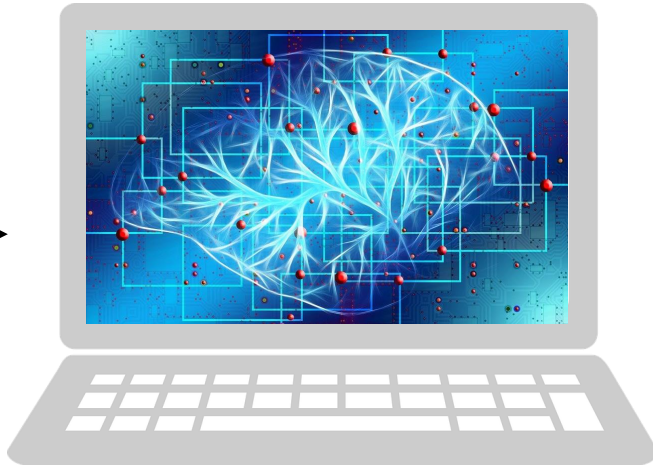


# Use RBF to reconstruct water levels

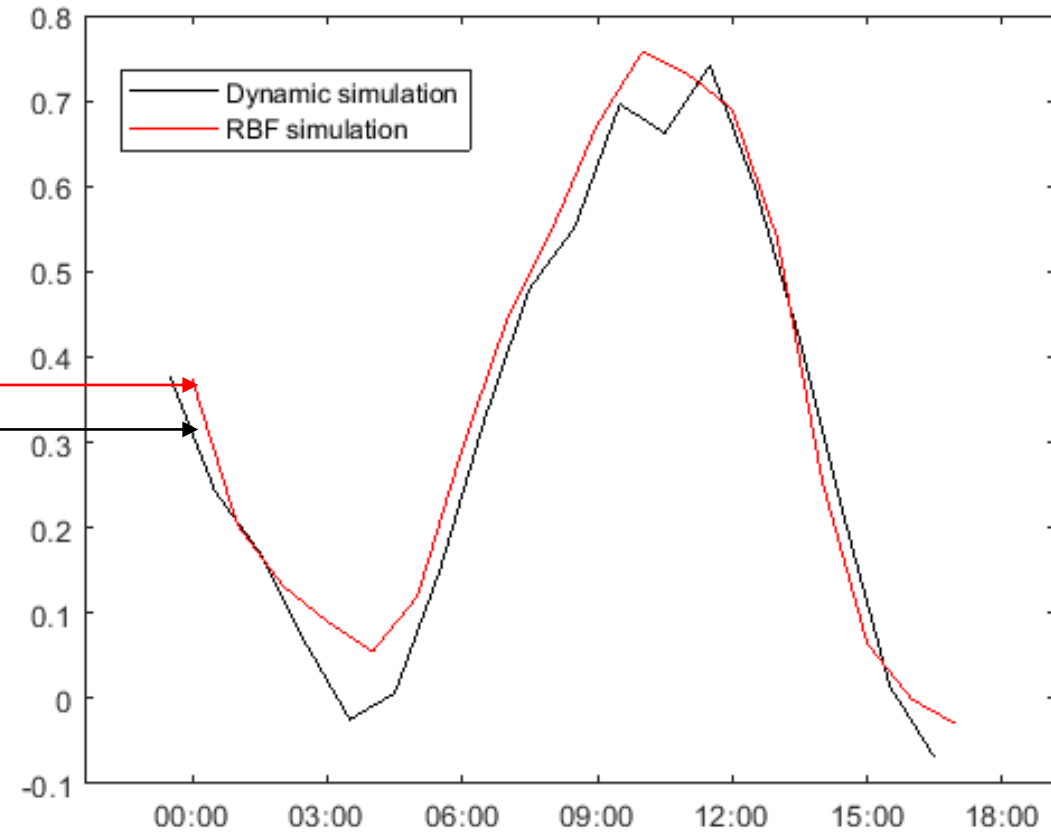
Hs, Tp, Dir, Sla+Tide



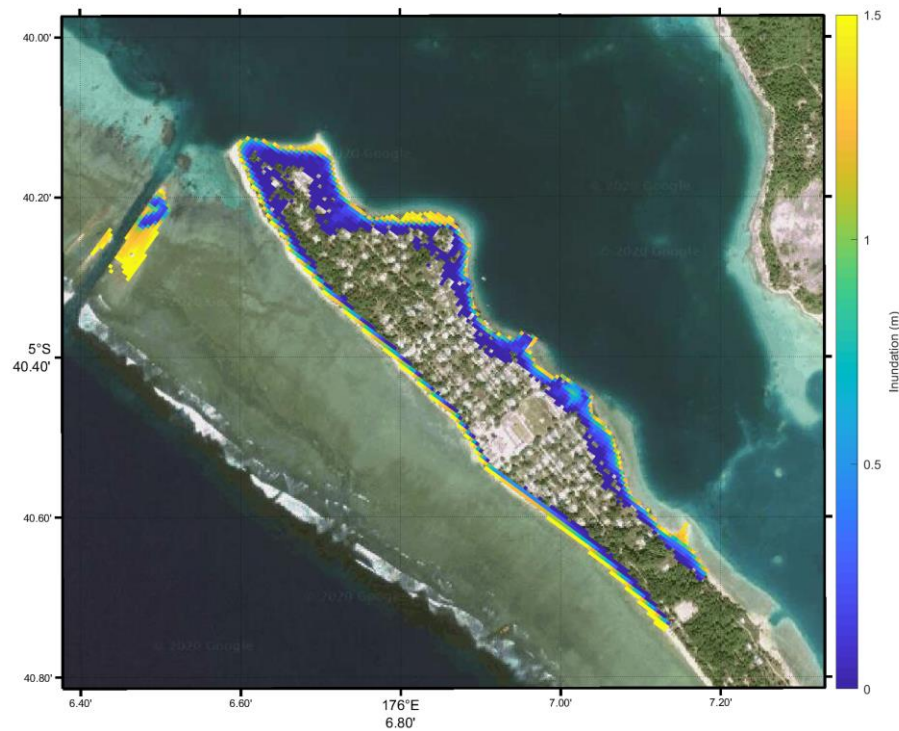
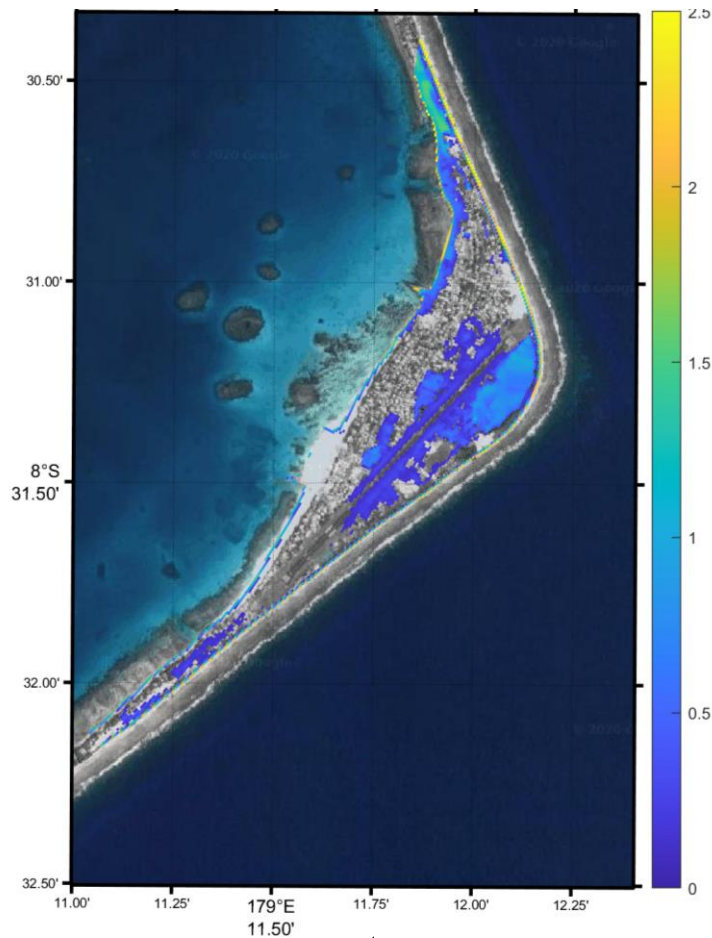
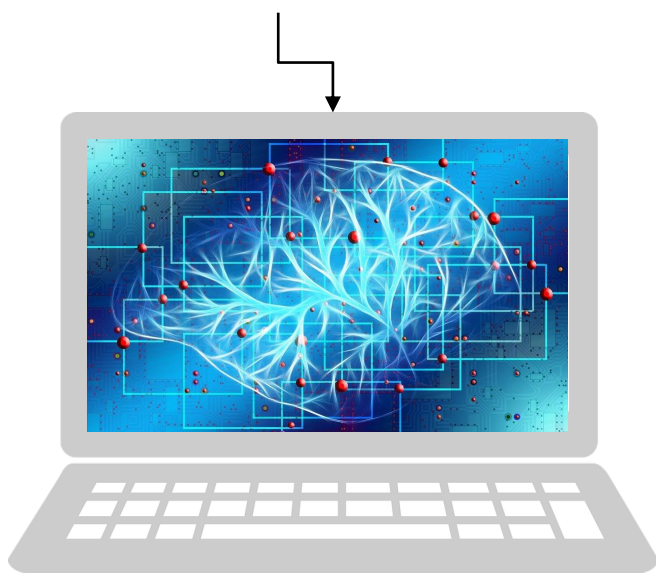
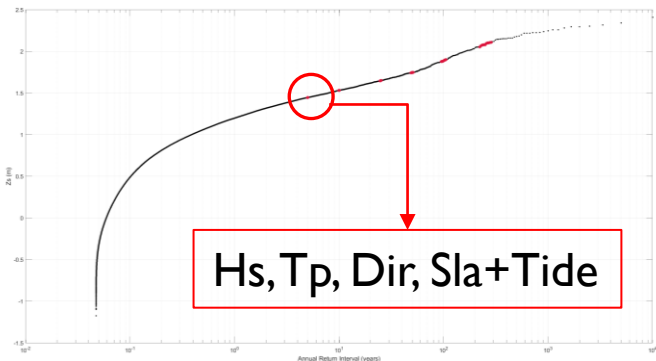
Computation time  
> 5 days



Computation time  
< 1 minute

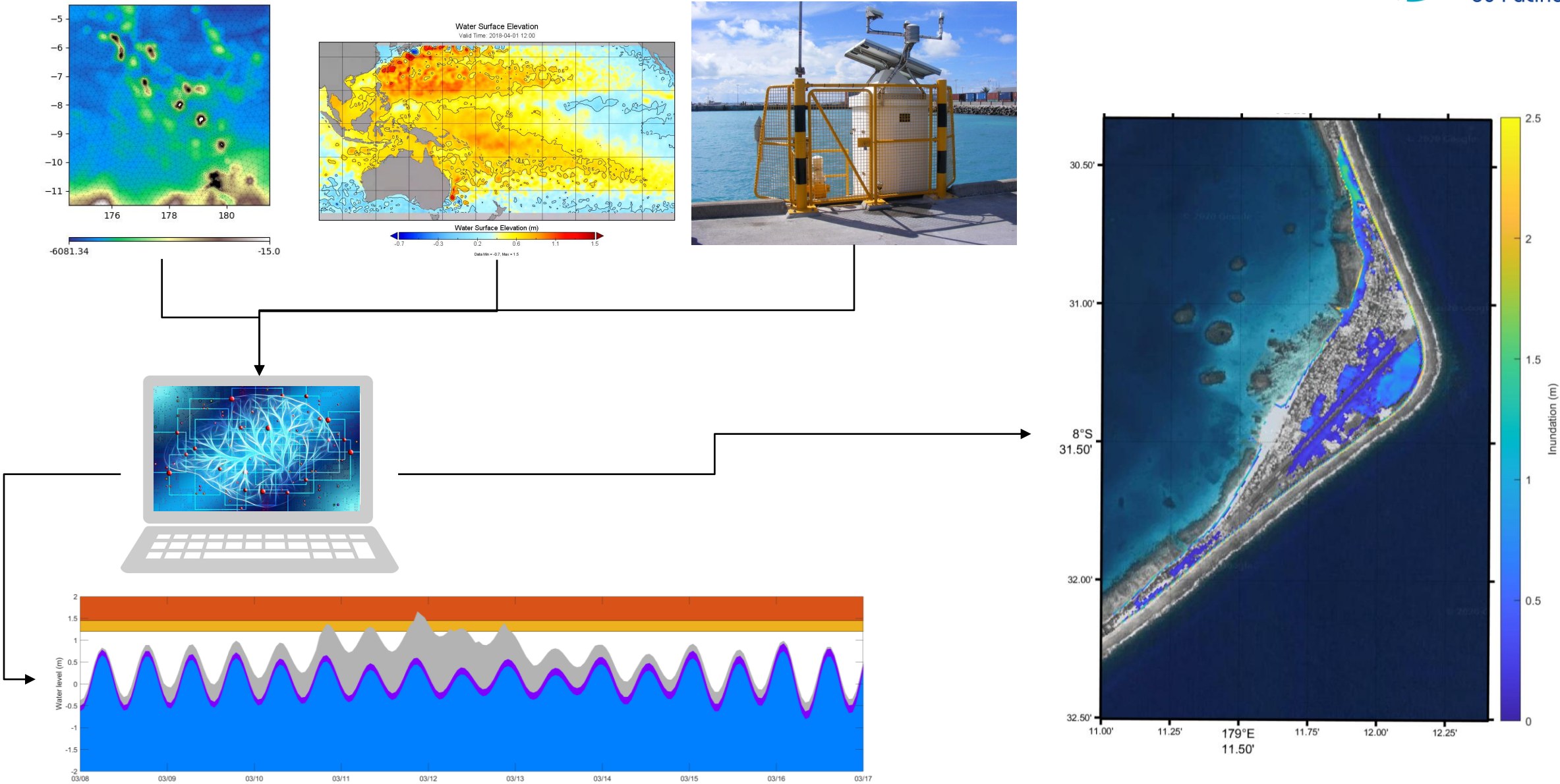


# Hazard assessment: Reconstruct 2D water level for different ARIs



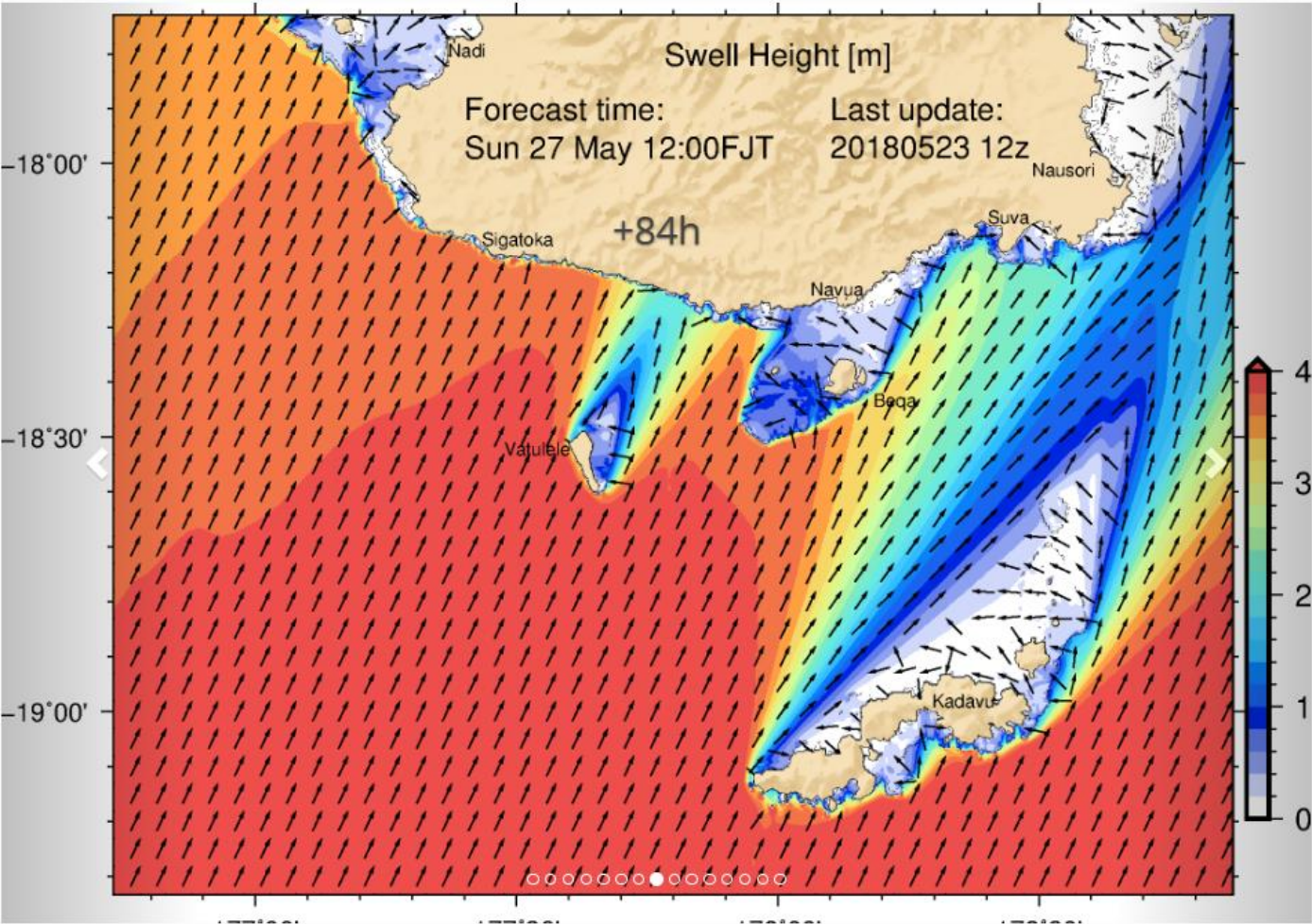


# Forecast system

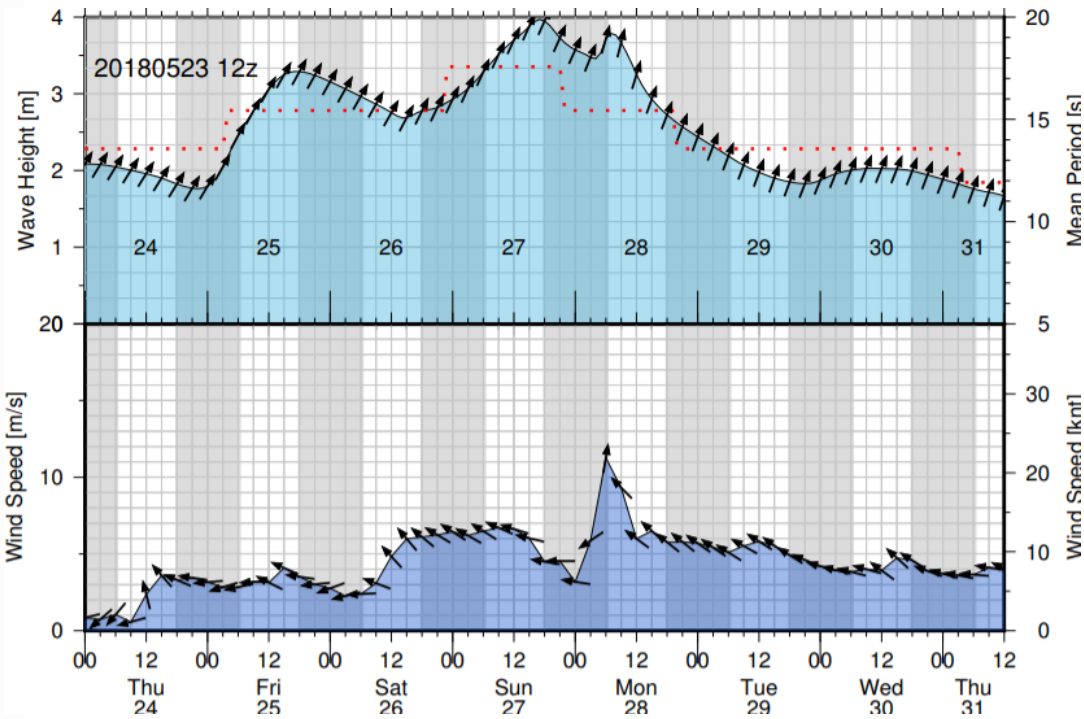


# Outcome: Inundation event May 2018

Long period swell waves with a height exceeding 4m from a SSW direction

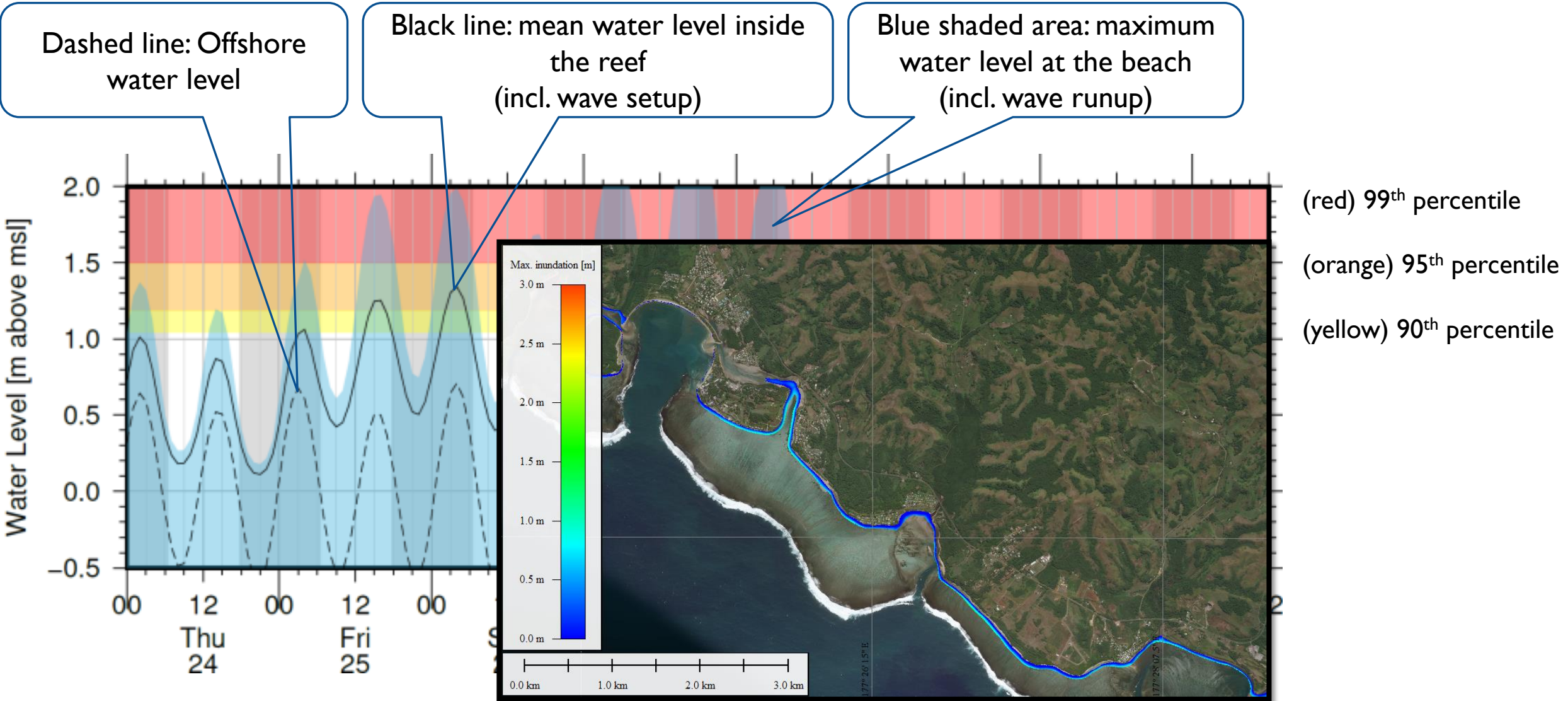


**Maui Bay forecast:**  
Wave period 18s  
Wave height 4m

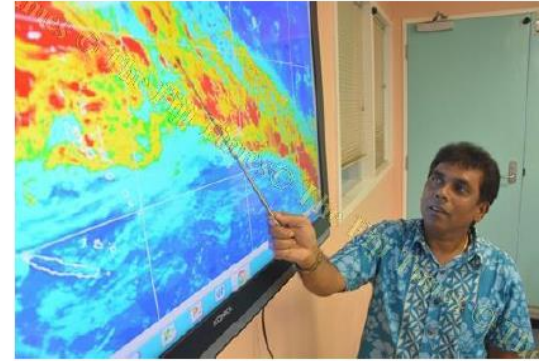
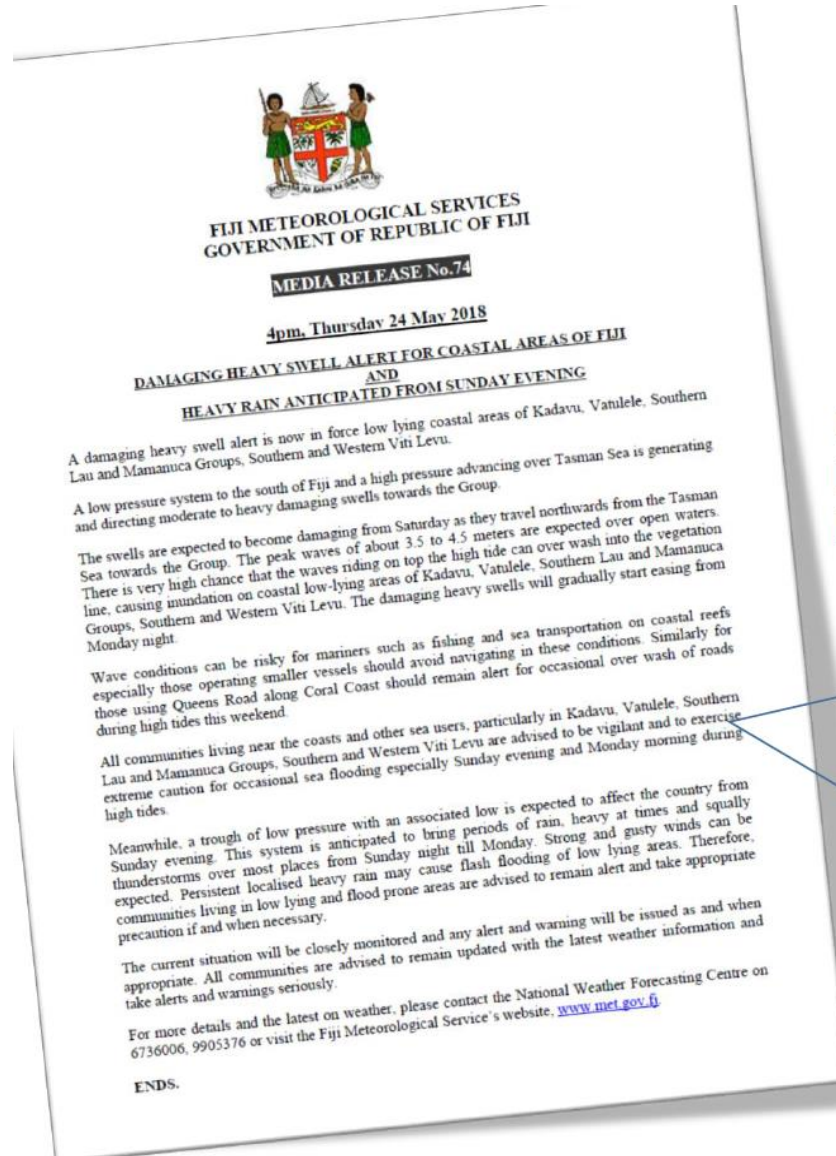




# Outcome: Inundation event May 2018



# Outcome: Inundation event May 2018



**User-focused communication, 24 May:**  
**Impact-based forecasting, that includes hazard and vulnerability information**

*“There is very high chance that the waves riding on top the high tide can **over wash into the vegetation line**, causing **inundation on coastal low-lying areas**”*

*“Similarly for those using Queens Road along Coral Coast should remain alert for occasional **over wash of roads during high tides this weekend.**”*



# Outcome: Inundation event May 2018





# Outcome: Inundation event 7<sup>th</sup> November 2018



FIJI METEOROLOGICAL SERVICE  
GOVERNMENT OF REPUBLIC OF FIJI

**MEDIA RELEASE No.100**

**4pm, Tuesday 06 November 2018**

## **MODERATE SWELLS MAY CAUSE INUNDATION OF LOW LYING COASTAL AREAS**

A high pressure system to the southwest of the Group has been directing a strong southeast wind flow over Fiji waters for the past few days. The sustained winds have caused moderate southerly swells to build up over open waters.

Strong winds coinciding with moderate swells of 2 to 3 metres over Fiji waters and high tide that is expected to be more than 2 metres near the coast pose a risk of inundation over low lying coastal areas especially during high tides today and tomorrow.

There is moderate chance that the waves riding on to the high tide reaching the coastline can over wash vegetation line and even on to the roads along the Coral Coast (especially Vatukarasa), Beqa, Vatulele, Kadavu and Southern Lau. The moderate swells will gradually ease from Thursday.

Wave conditions are risky for mariners using small watercrafts such as row boat, sailboat, canoe, rafts, and motorboat. Mariners are advised to avoid navigating in these conditions. Similarly, for those using Queens Road along Coral Coast should remain alert for occasional over wash of roads during high tides this evening, tomorrow morning and tomorrow evening.

Likewise, for those planning to spend the day at the beach and enjoy a picnic along the coral coast during the Diwali public holiday are advised to be very cautious and alert of big waves.

All communities living in the low coastal areas are cautioned to stay alert. Members of the public are requested to remain updated with the latest weather information and take alerts and warnings seriously.

For more details and the latest on weather, please contact the National Weather Forecasting Centre on 6736006, 9905376 or visit the Fiji Meteorological Service's website, [www.met.gov.fj](http://www.met.gov.fj). You can also visit the Fiji Meteorological Service official Facebook page for latest updates.

**R. KUMAR  
DMET**

**ENDS.**

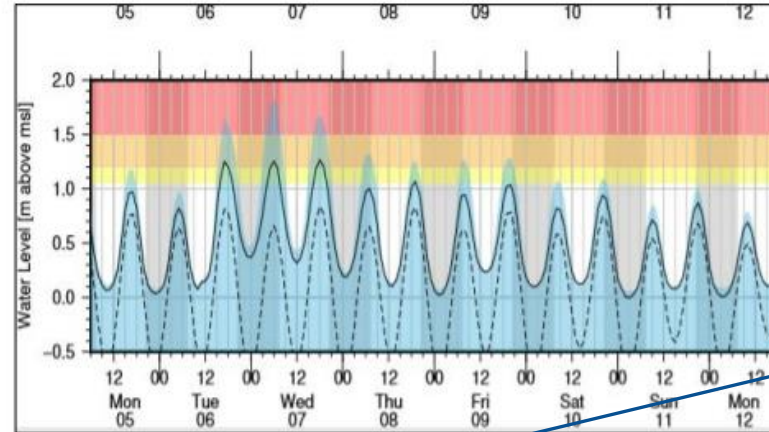


Figure 1: Predicted waves of about 1 to 2 meters for this afternoon, tomorrow morning and tomorrow evening coinciding with high tides. There is a possibility of waves overtopping the vegetation line and onto to the road along the Coral Coast.

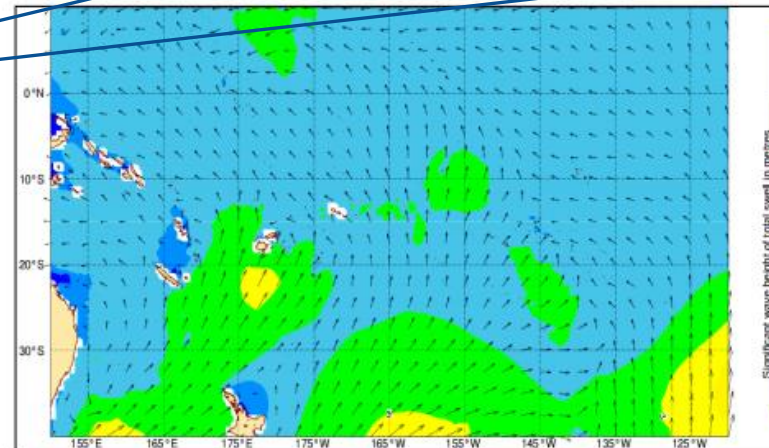


Figure 2: 2 to 3 meters (blue and green shades) of swells are predicted for today and tomorrow over open waters of Fiji and which may cause inundation of low lying areas along the Coral Coast, Beqa, Vatulele, Kadavu and Southern Lau during high tides.

There is a **moderate chance** that waves riding onto the high tide can over wash onto the vegetation line.... For those using the **Queen's Road** along the coral coast should **remain alert** for occasional **over wash of the roads during high tide**


- SPC collated witness account - Several villages and hotels along the coral coast experienced Inundation.
- Interestingly event was triggered by a 2.5m wave but at significantly higher high tide level.

# Conclusions

- Inundation events are compound events
- Wind generated waves are one of the main drivers for coastal inundation in the Pacific
- Meta-modelling provides a practical, computationally inexpensive way to assess inundation
- Forecast systems for Fiji, Tuvalu, and Kiribati are under development
- SPC is currently doing a detailed coastal hazard analysis in Majuro, which could be turned into a forecast system (talks with PacIOOS to do this are currently ongoing)

**Moritz Wandres**

 moritzw@spc.int

 @m\_wandres