Probabilistic tropical cyclone inundation hazard assessment, Lenakel, Tanna Island, Vanuatu

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CASE STUDY: CYCLONE WINSTON 2016

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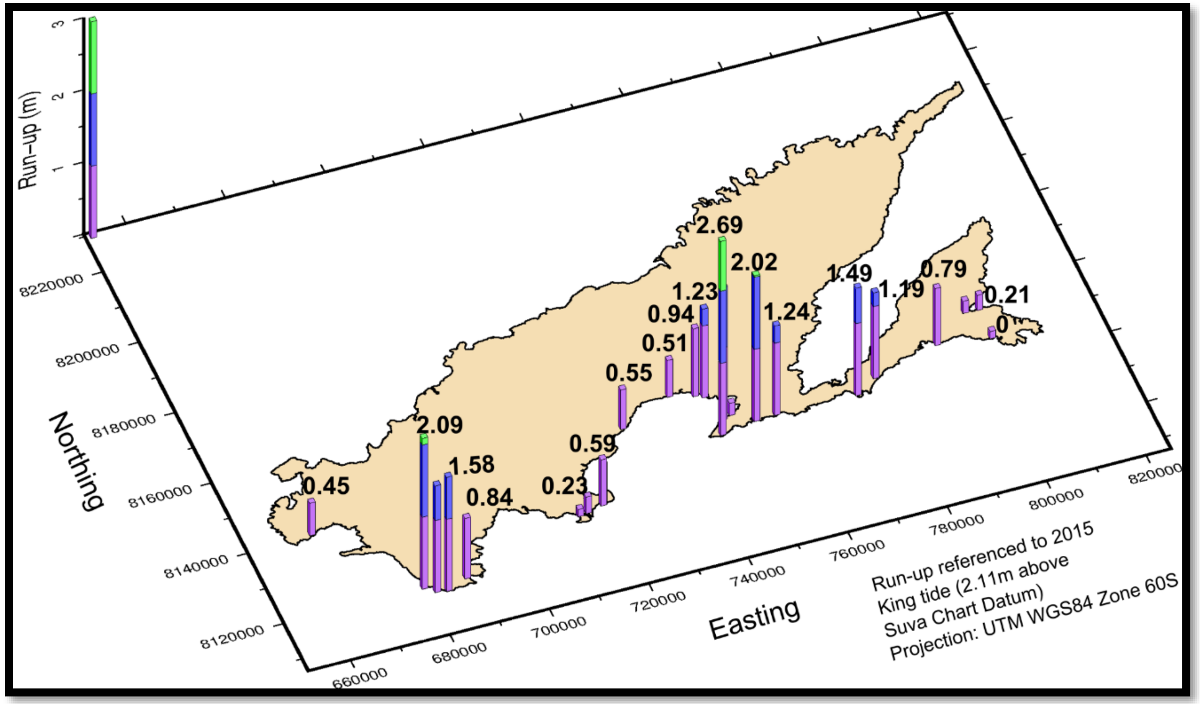
2016, TC Winston - Impact

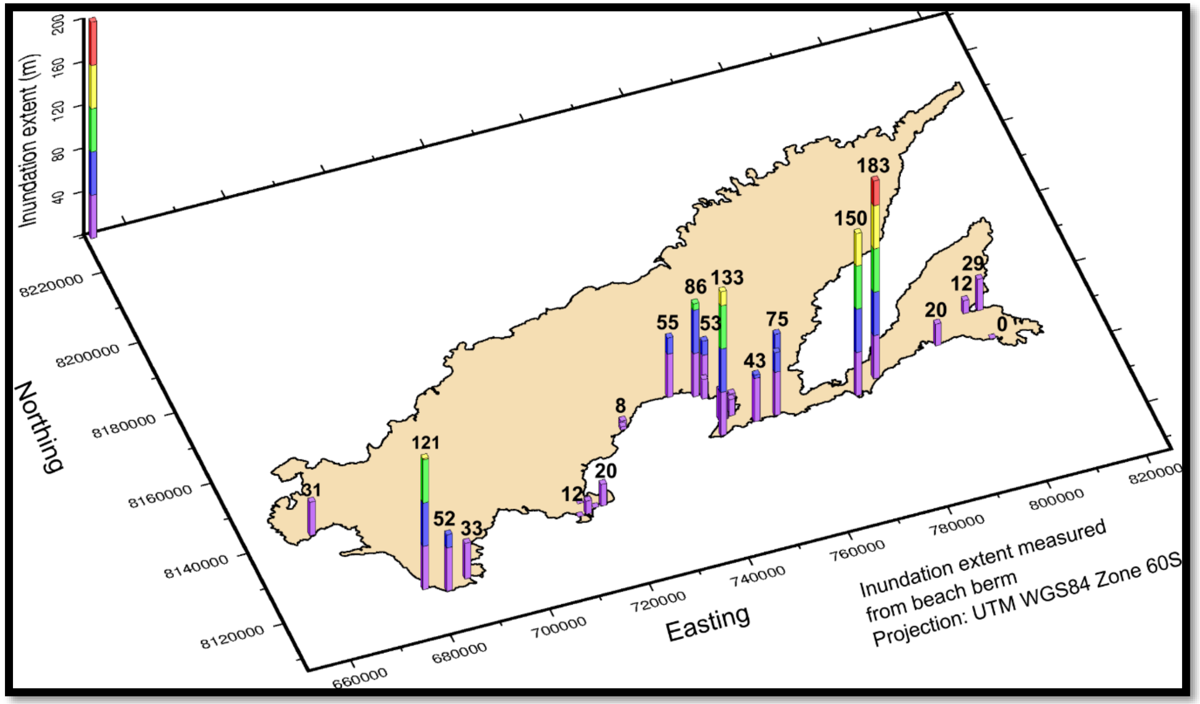
Fiji:

- **44** death
- **>40%** population affected (350,000)
- **17,000** buildings affected
- **FJD$ ~2,500M** – Damage & Loss
- 240 schools severely damaged/destroyed

WINSTON



Wave Run-up in Vanua Levu



Inundation Extent in Vanua Levu

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Case study: Cyclone Winston

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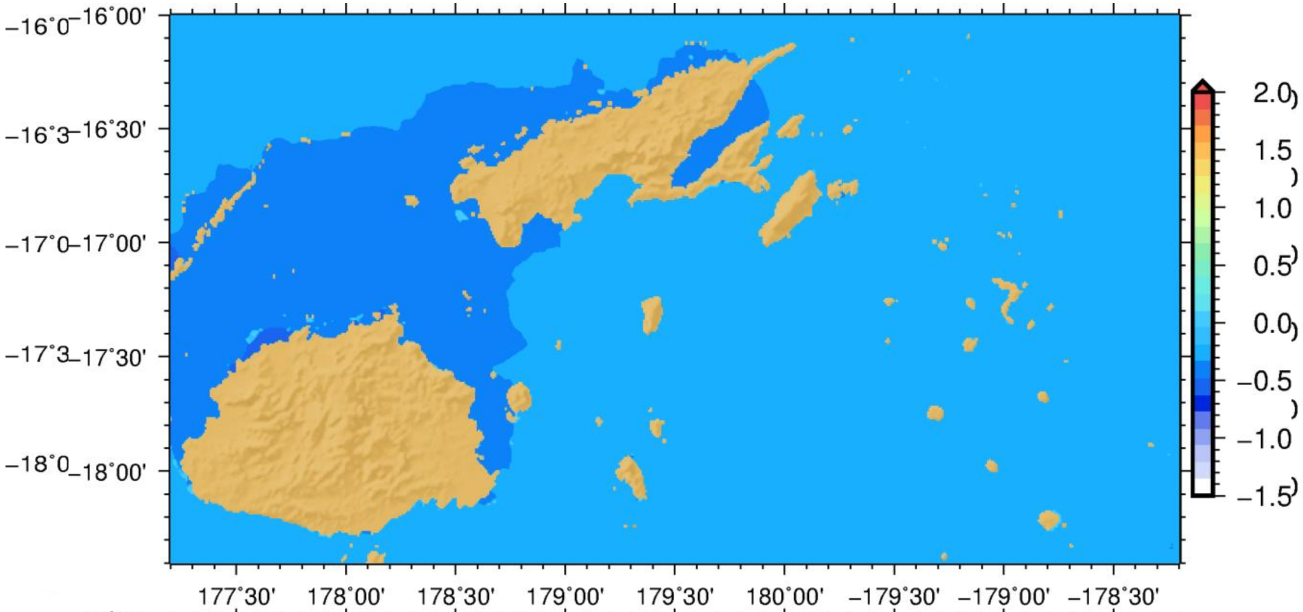
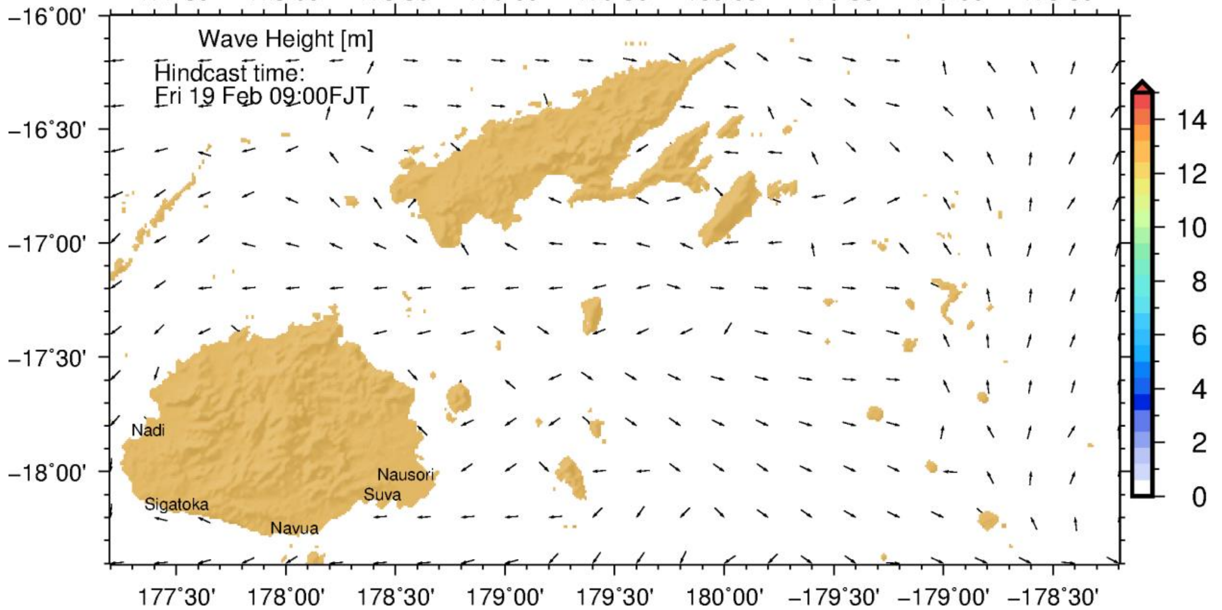
Storm Tide Model
Wind speed



Wave Model



CASE STUDY: CYCLONE WINSTON

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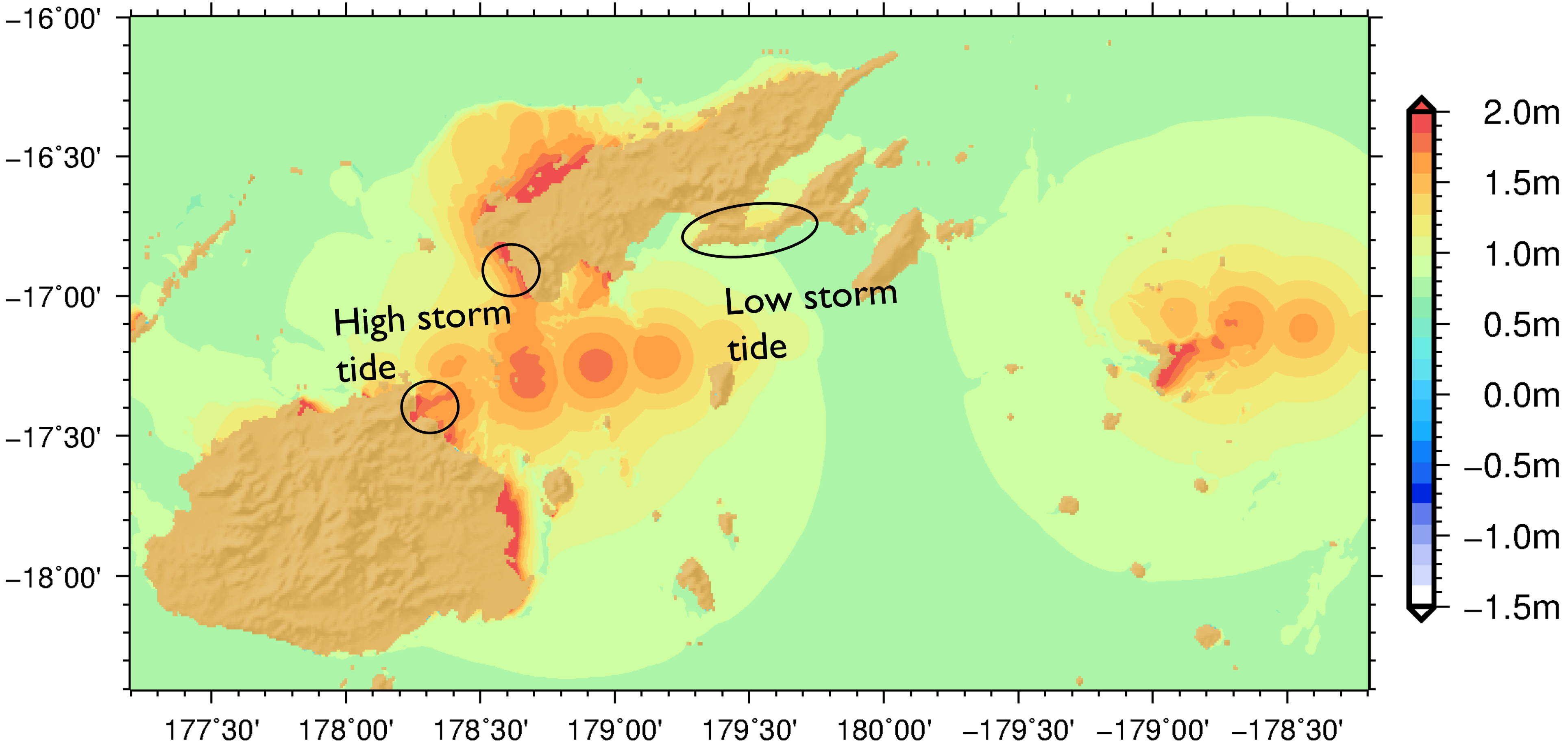
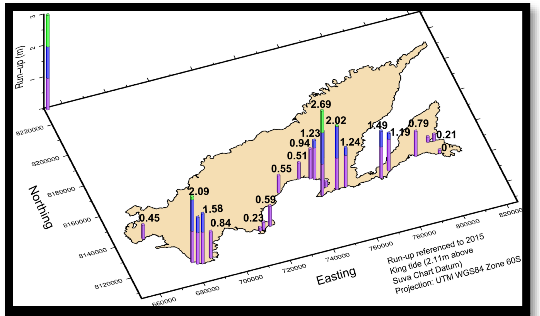
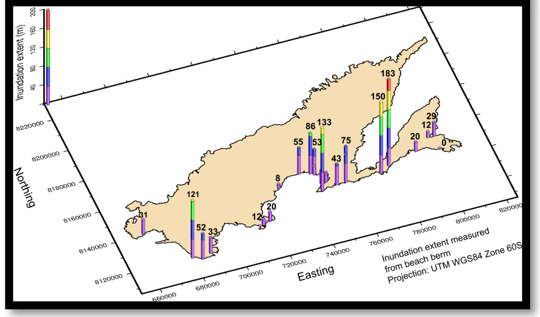
Maximum Storm Tide

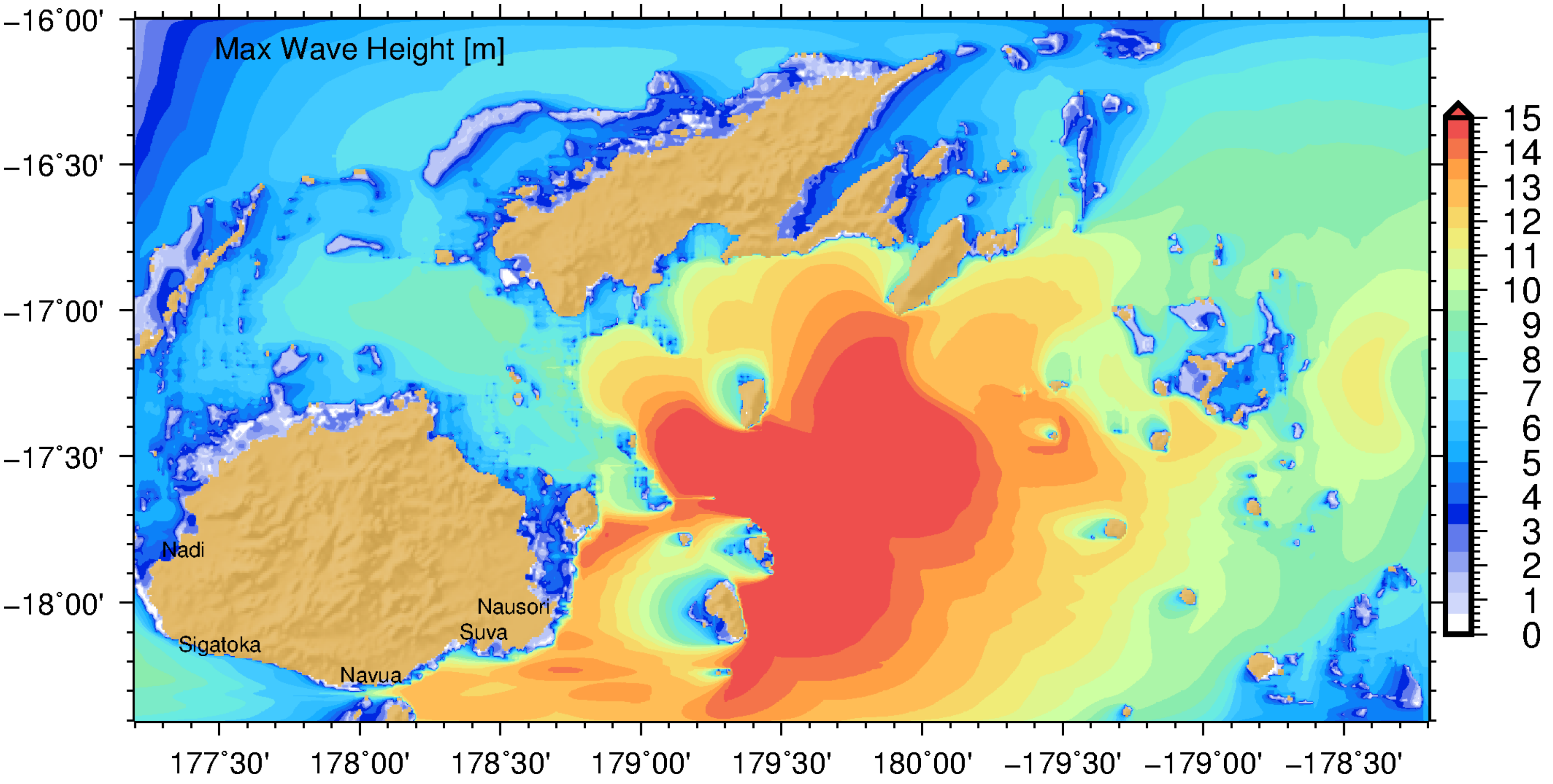


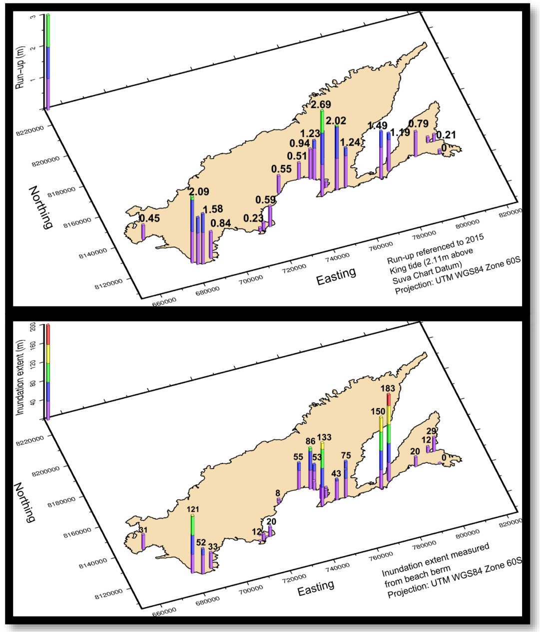




CASE STUDY: CYCLONE WINSTON

Maximum Wave Height





Lenakel, Tanna

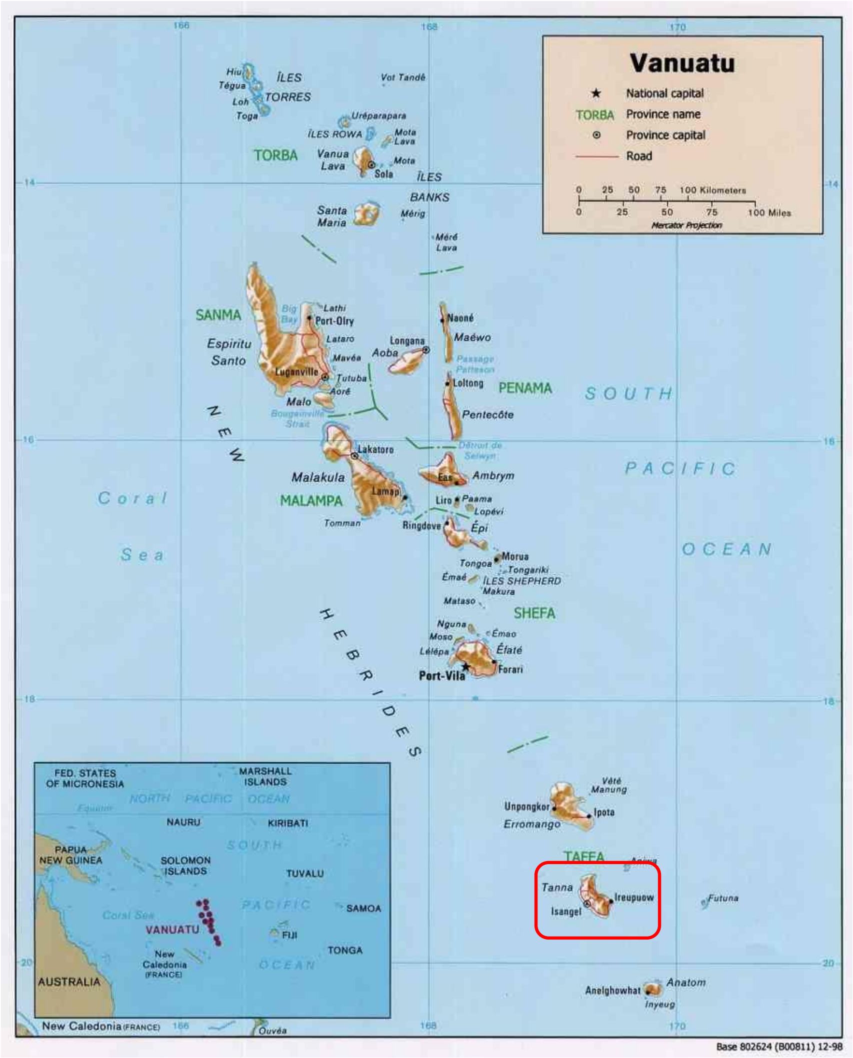
Declared a town in 2015

Population: *14,000*

Goal: *Provide likelihood of hazard to inform urban planning and evacuation road*

Hazards:

- Swell
- TC Wind & Inundation
- Tsunami



Improved Tropical Cyclone EWS
A regional priority

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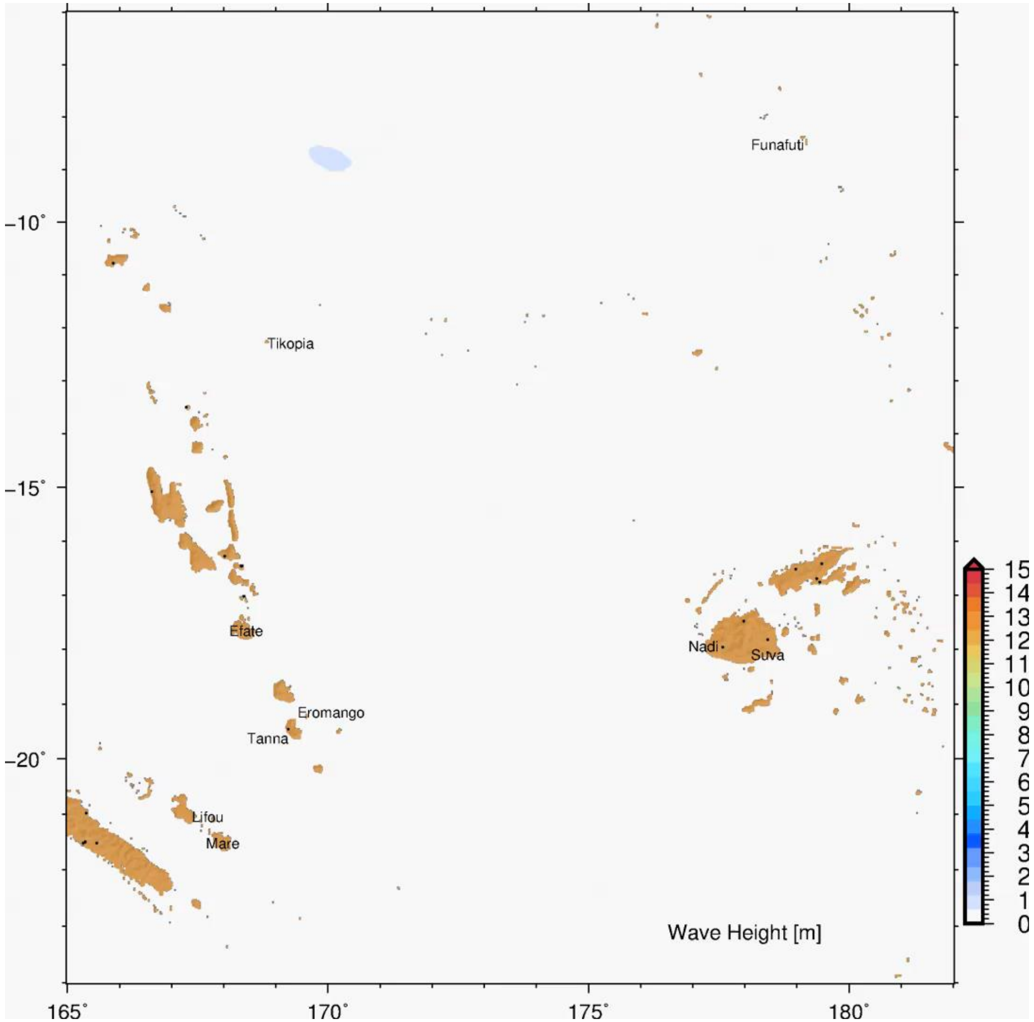
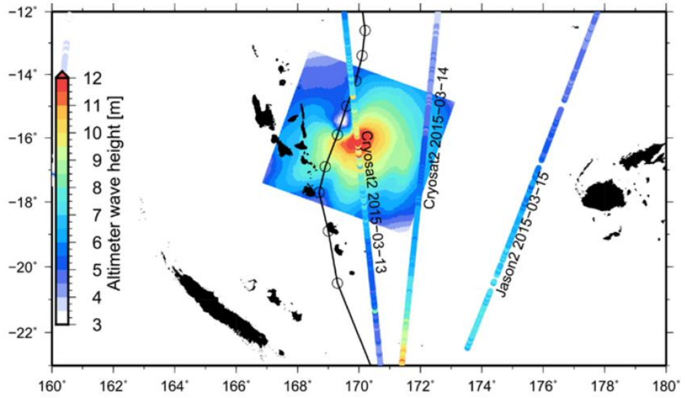
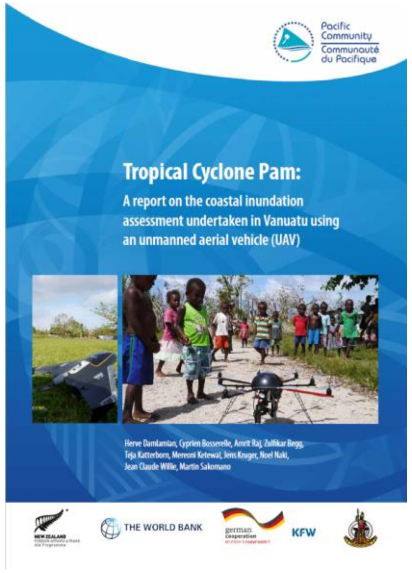
TC Pam wave model







2015, TC PAM - IMPACT

Tuvalu:

- AU$ ~14M
- **25% of TV 2013 GDP**
- **41% population affected**

Vanuatu:

- **16** death
- **>50%** population affected (166,000)
- **17,000** buildings affected
- **AU$ ~619M** – Damage and Loss
- **64.1%** of GDP

Other countries affected: New Caledonia, Solomon Island, Kiribati, New-Zealand.

TC PAM : BEFORE / AFTER

USING AERIAL PHOTOGRAPH TAKEN DURING LIDAR CAMPAIGN (2012)

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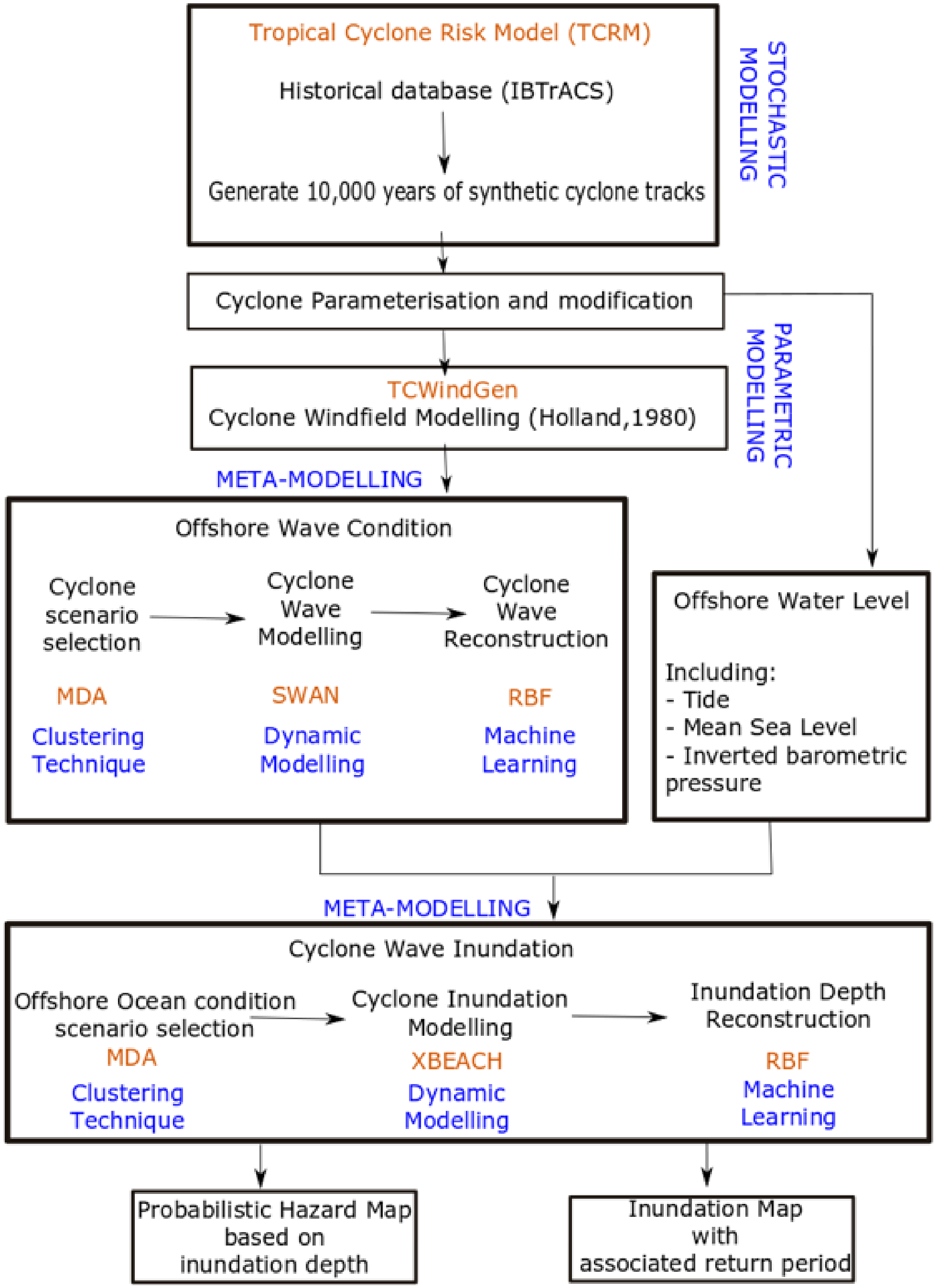
TC PAM : Before / After

using Aerial photograph taken during LiDAR campaign (2012)

EXTREME TC WAVE RUN-UP, TC PAM

Epau, run-up between 6.0 - 7.0m

Epike, run-up between 6.0 - 7.2m



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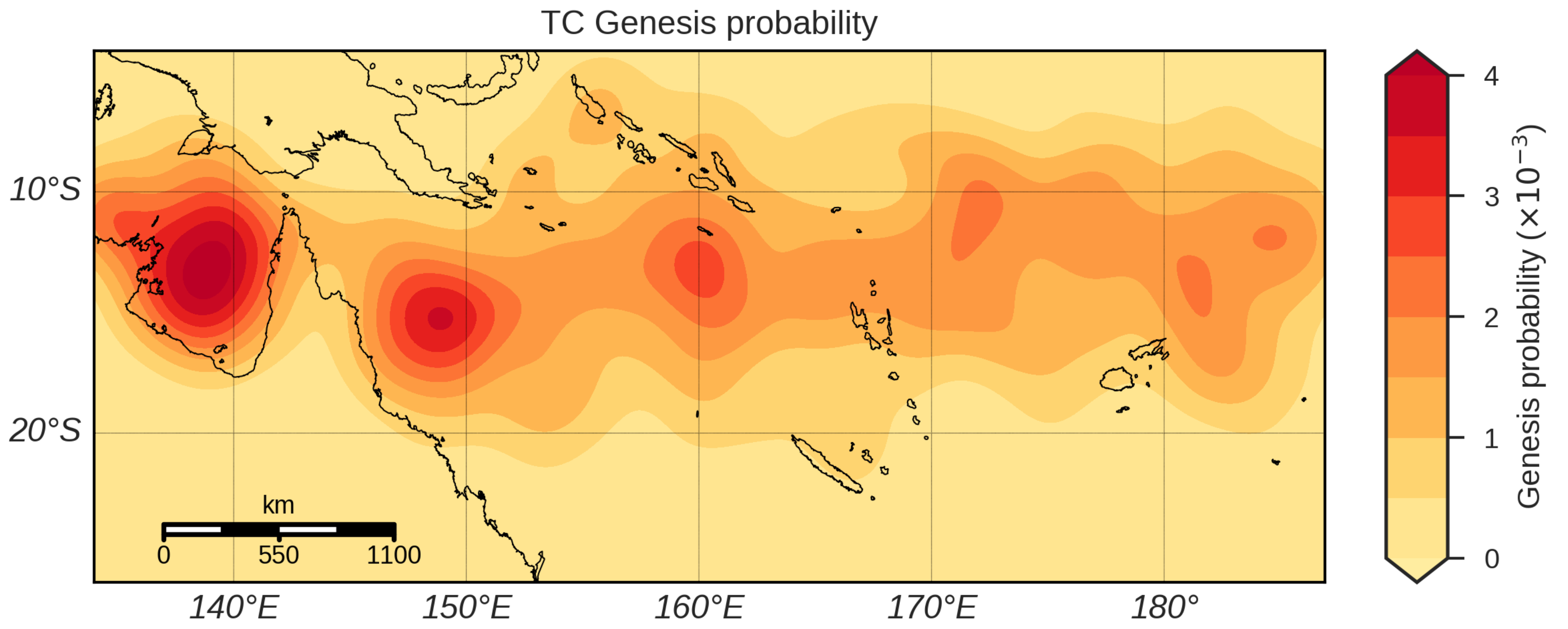
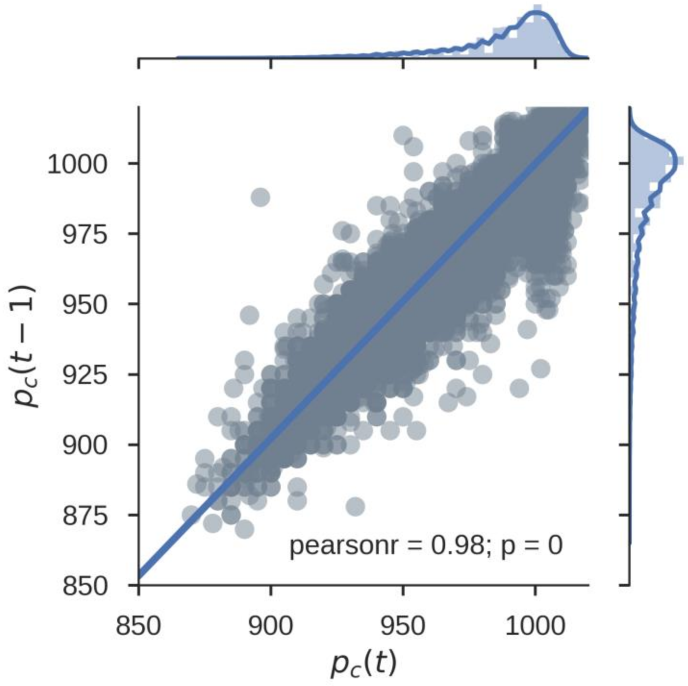
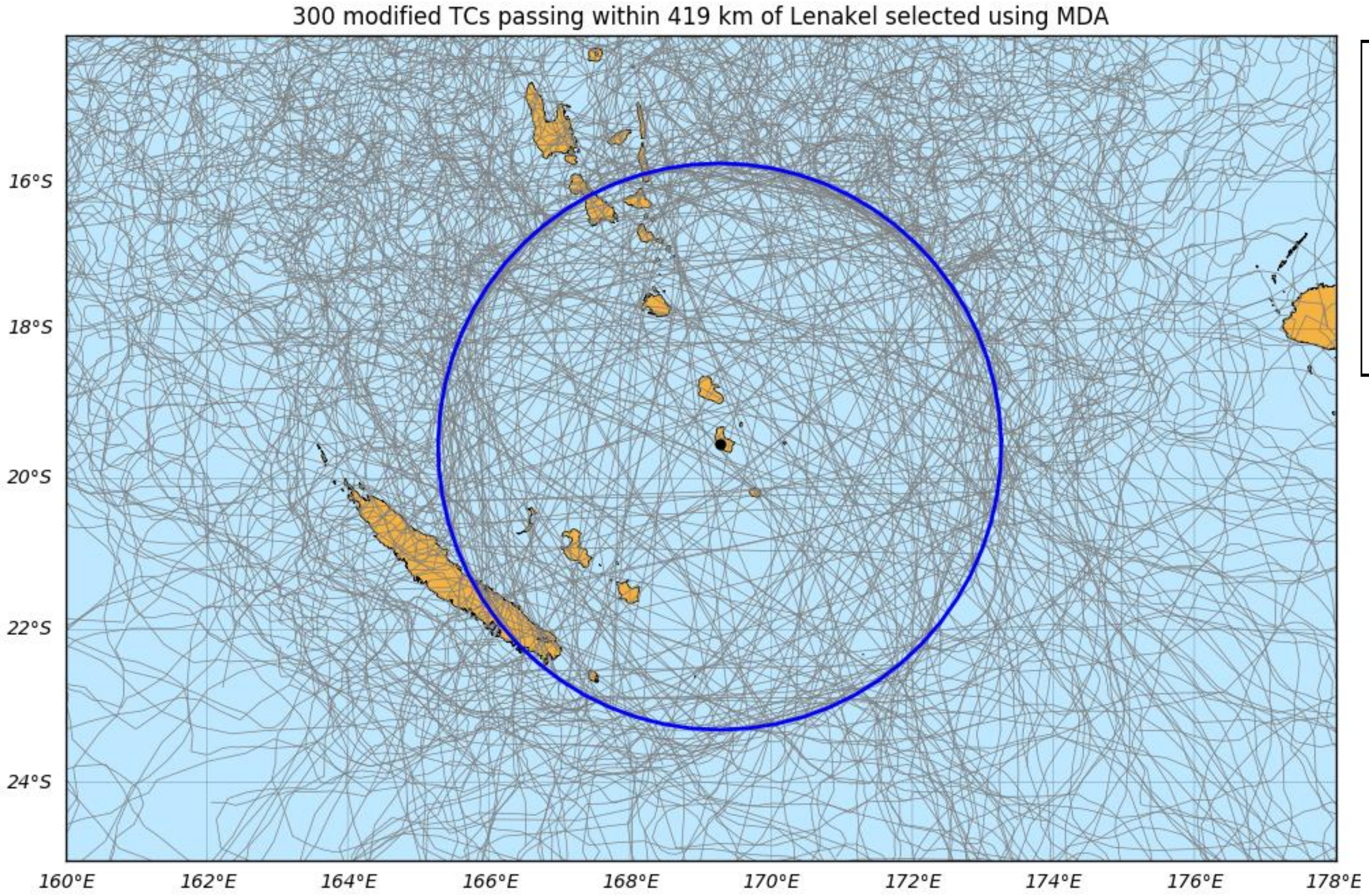
CREATE DATABASE OF 10,000 YEARS OF CYCLONE TRACK FOR LENAKEL

- Using Open Source Tropical Cyclone Risk Model (TCRM) from Geoscience Australia
- Stochastic approach based on Historical Cyclone Track Database (IBTRACS)
- ~16000 cyclone generated over a 10,000 year period

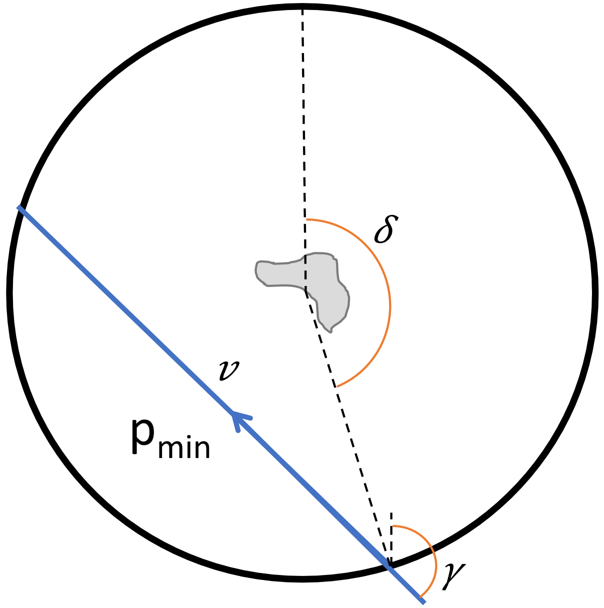




CYCLONE PARAMETERIZATION



- Cyclone Parameters:
  - Pmin, Min. Central Pressure
  - Fw, Forward Speed
  - δ, Angle of Entrance
  - γ, Azimuth



TC TRACK MODIFICATION

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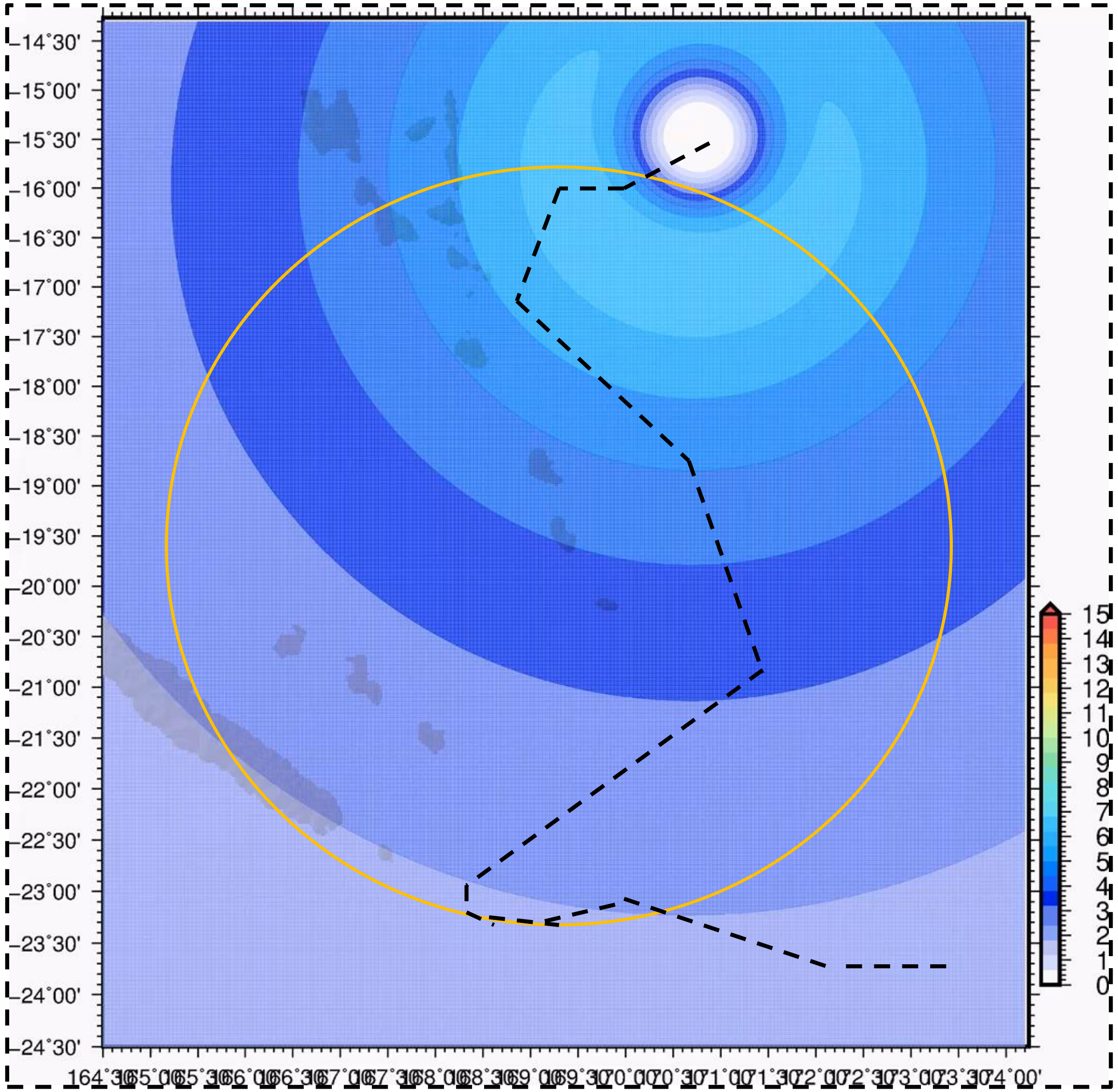
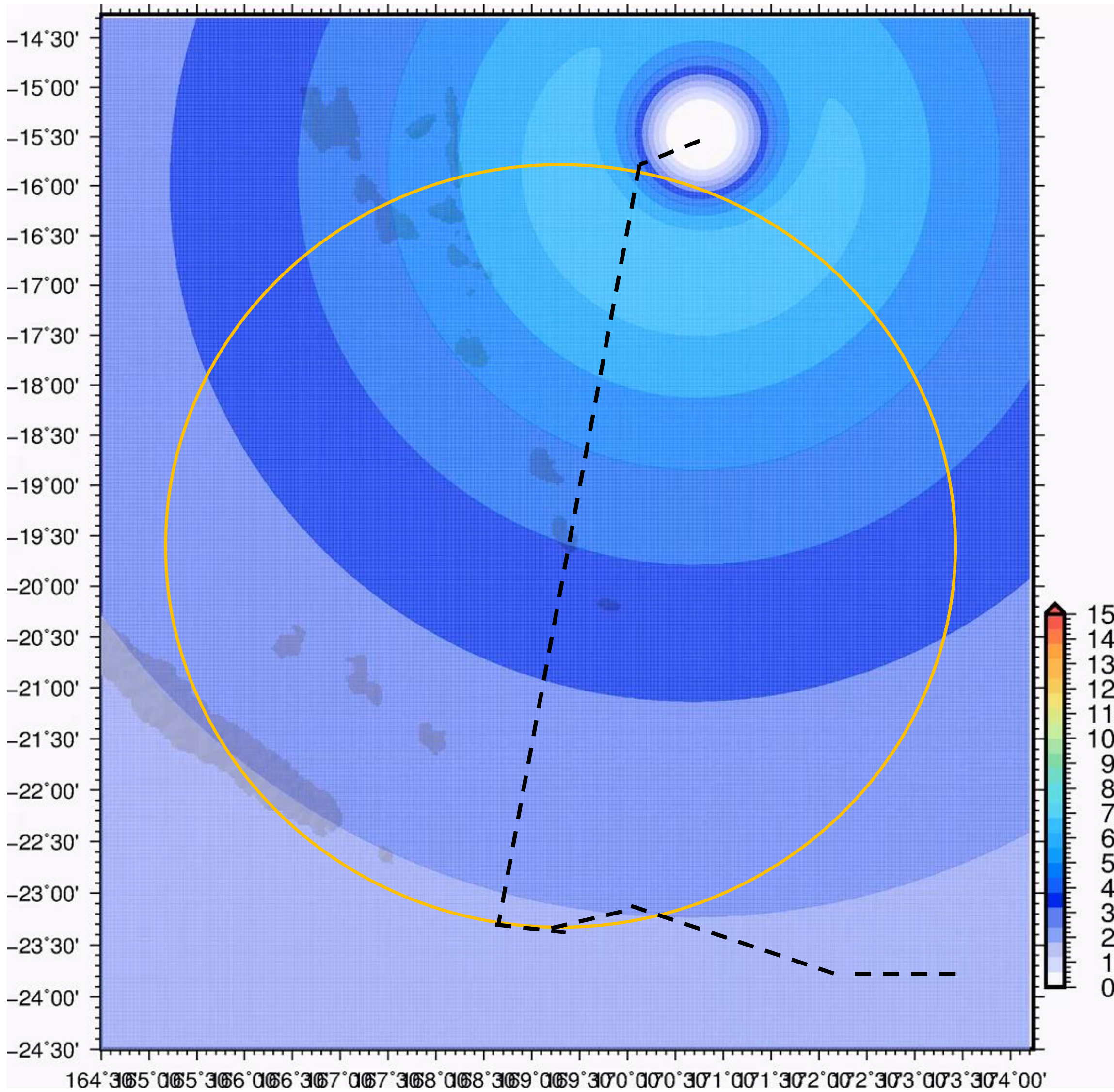
Wind field from synthetic track (TCRM track)



Wind field from modified track



META-MODELLING OF EXTREMES

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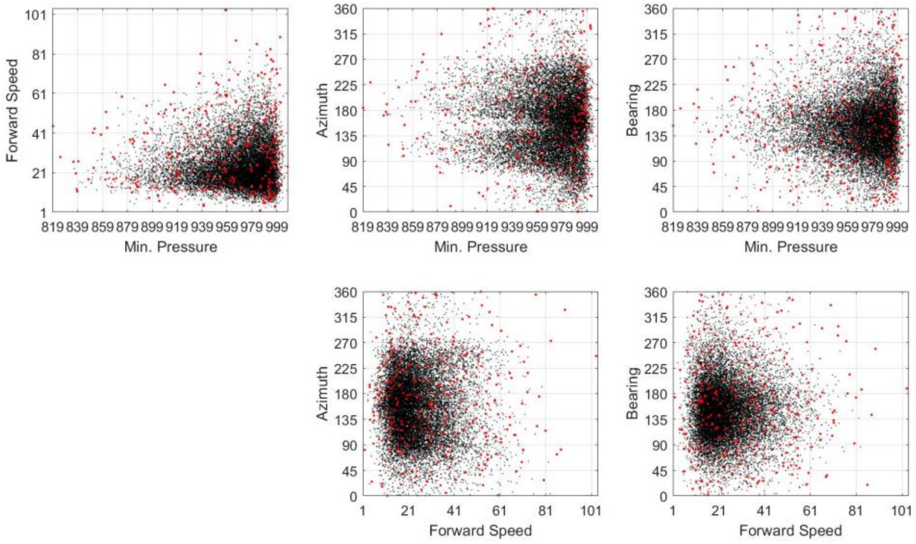
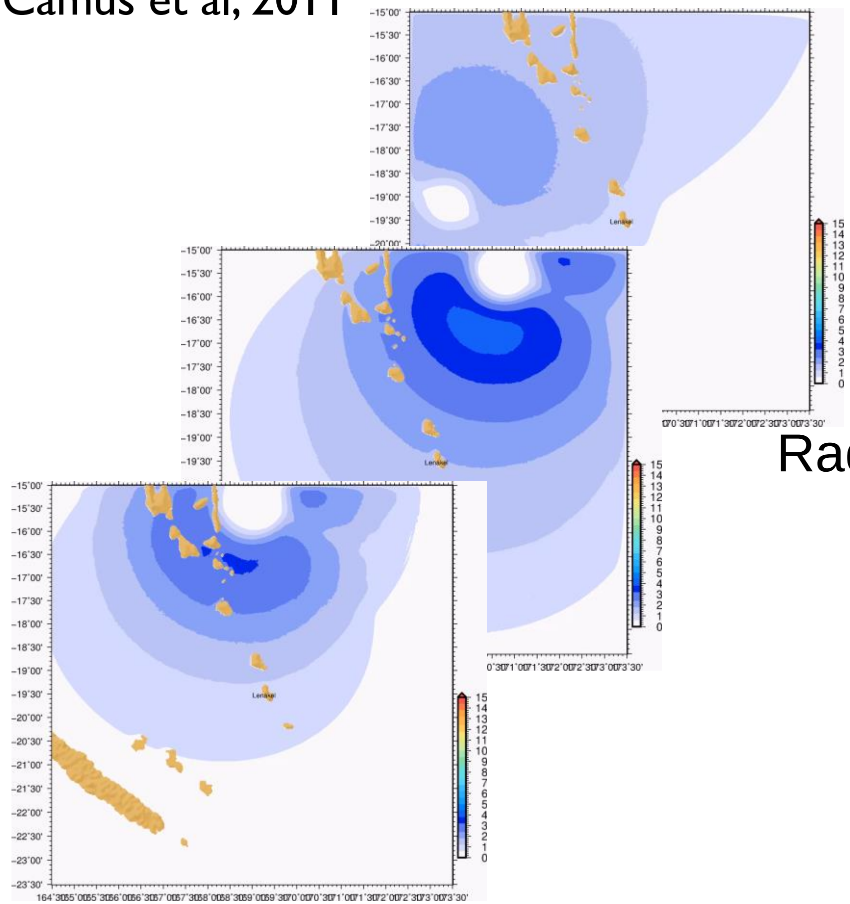
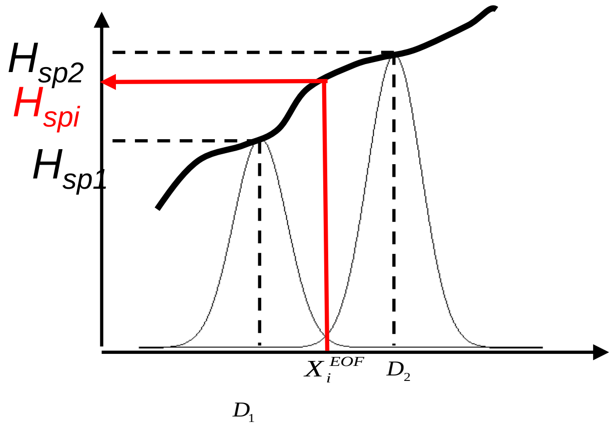
Based on Camus et al, 2011

Maximum Dissimilarity Algorithm





Radial Basis Functions (RBF)

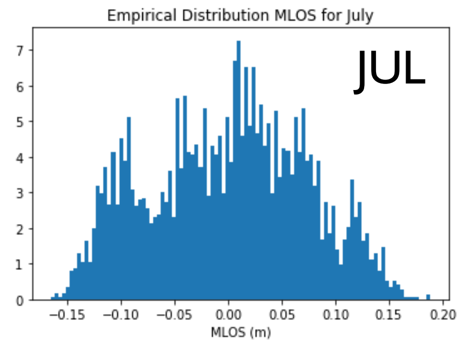


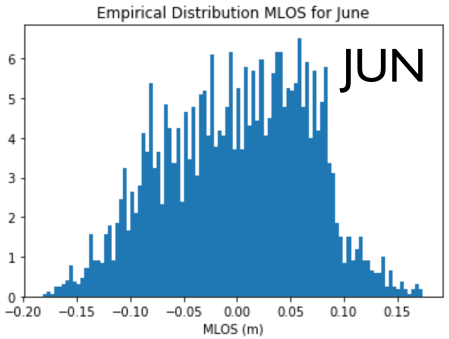
Select representative cases (500) → Simulate TC wave for each selected cases → Reconstruct of 10,000 years of TC offshore condition

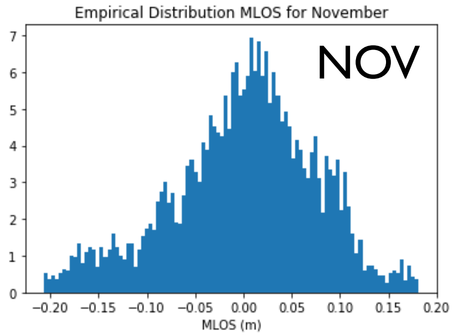
WATER LEVEL CONDITIONS

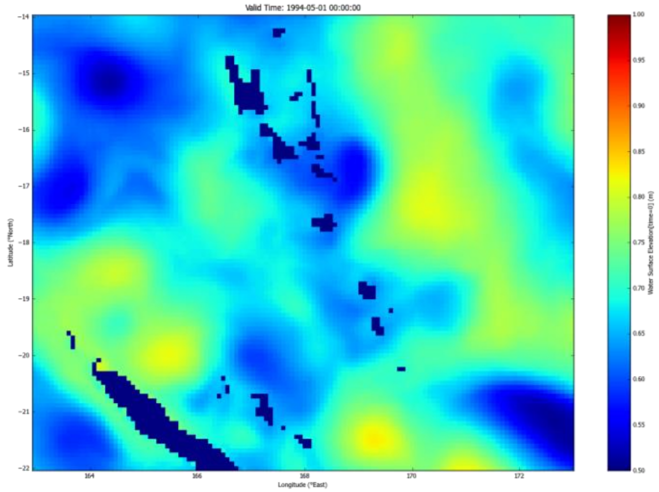
Mean Level of the Sea (MLS):

- 20 years HYCOM Reanalysis (1992-2012)
- Map monthly behavior (probabilistic distribution)



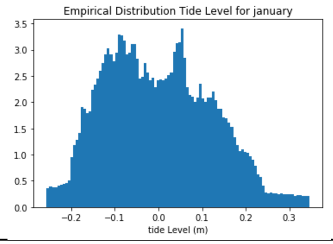






Tide:

- Harmonic Analysis on the JICA Tide gauge in Lenakel (2015-)
- Map monthly behaviour (probabilistic Distribution)



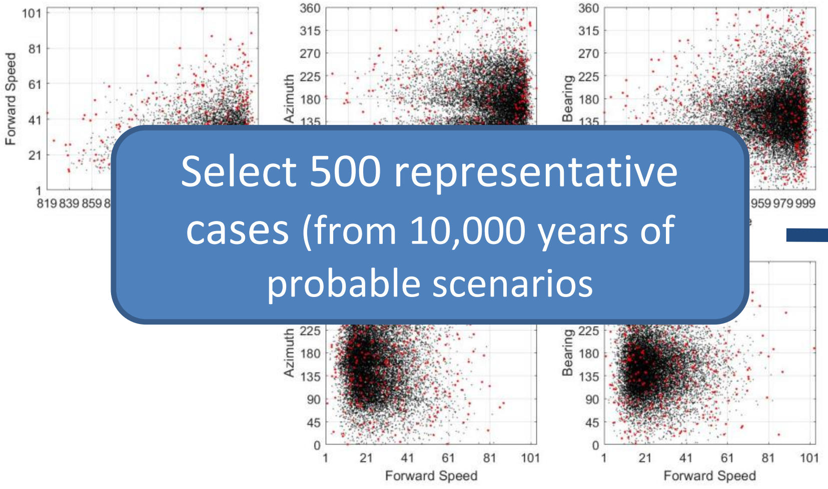
Storm Surge:

- Inverted barometric pressure: from Cyclone Central Pressure
- Wind Setup: Include Wspd and Wdir as part of Cyclone Inundation Scenario

META-MODELS FOR PROBABILISTIC INUNDATION SCENARIOS

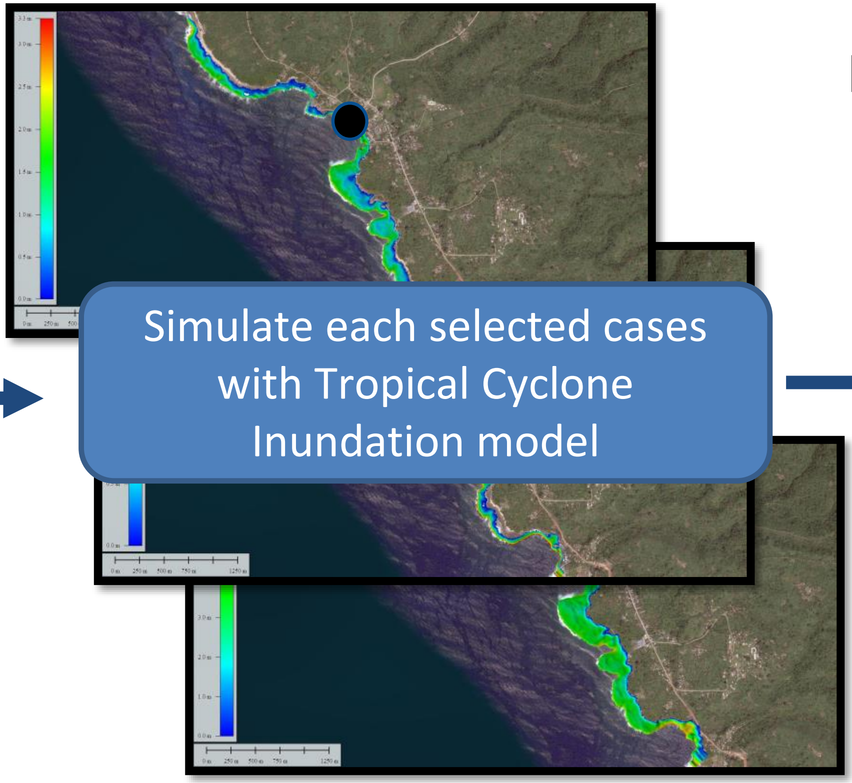
Based on Camus et al, 2011

Maximum Dissimilarity Algorithm



Select 500 representative cases (from 10,000 years of probable scenarios

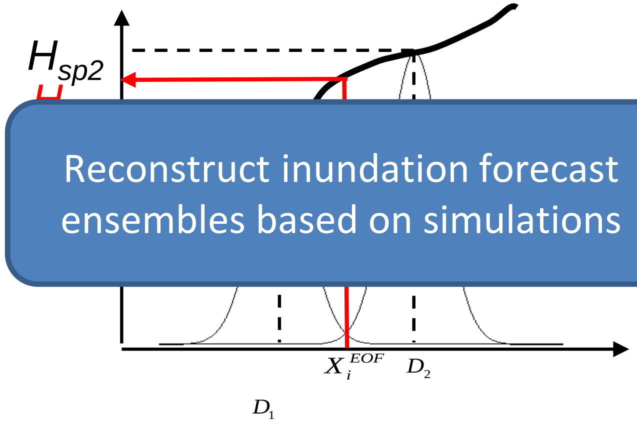
Scenarios characterized by 6 variables:
Hs, Tp, Dp, Tide, SS, MLOS



Simulate each selected cases with Tropical Cyclone Inundation model

Dynamic Modelling (Xbeach-GPU)

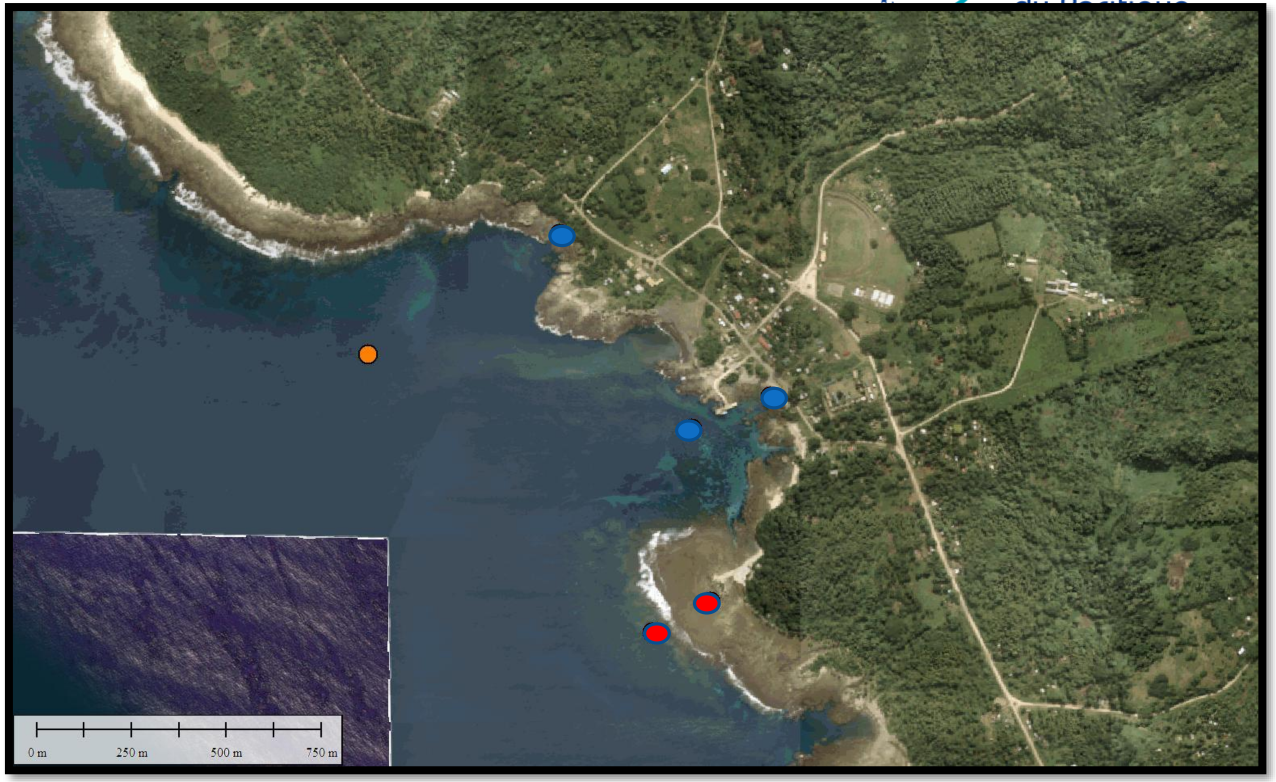
Radial Basis Functions (RBF)



Reconstruct inundation forecast ensembles based on simulations

INUNDATION MODELLING ON REEF FRONTED ISLAND

- XBEACH_GPU : (https://github.com/CyprienBosserelle/xbeach_gpu).
  - Fast – especially with high end graphic cards
  - Provides suitable platform to model extreme wave height condition (using very low CFL calculation i.e. down to CFL=0.0001)

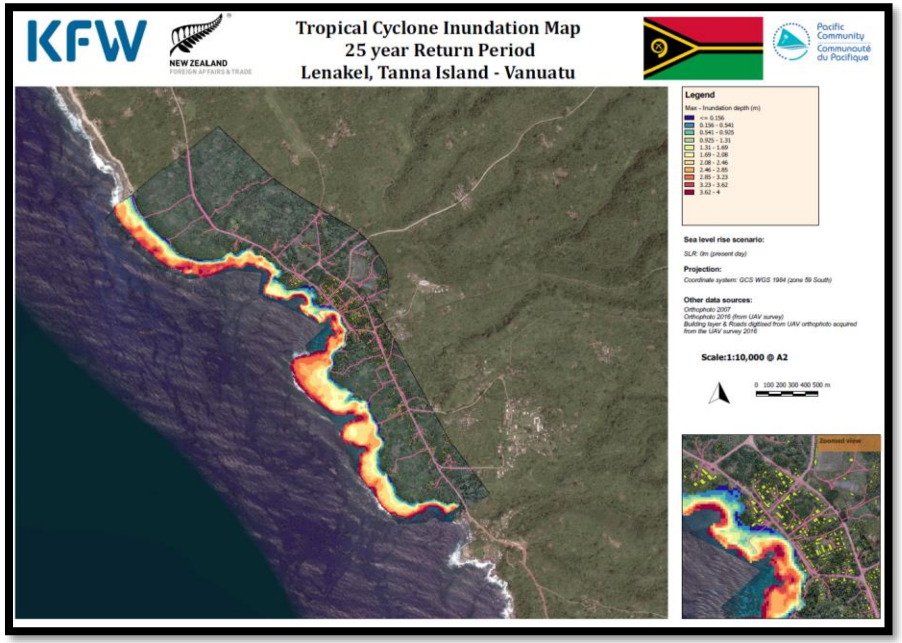


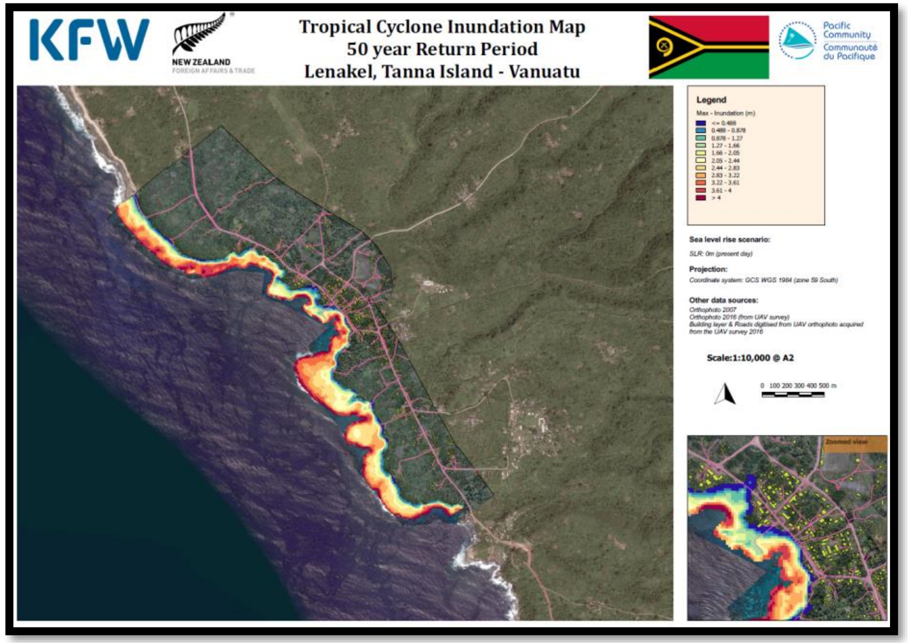
- Calibration
  - 6 month deployment
  - 4 wave events with Hs>3m used in calibration
  - 350 runs

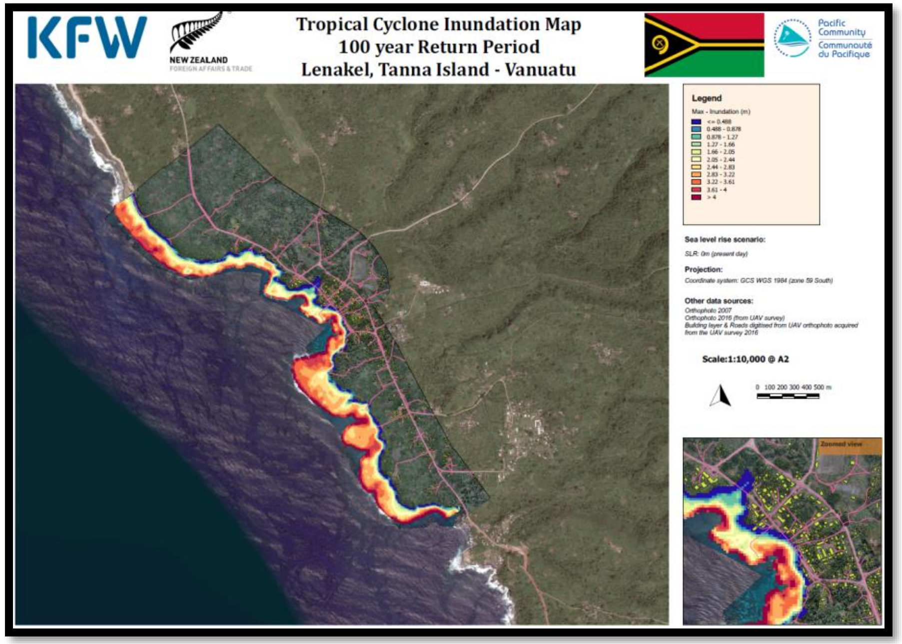
- Obs.Vs Sim at the shore for Hs>3m:
  Wave Setup error: 0.07m
  IG error: 0.02m
  Short Wave error: 0.06m

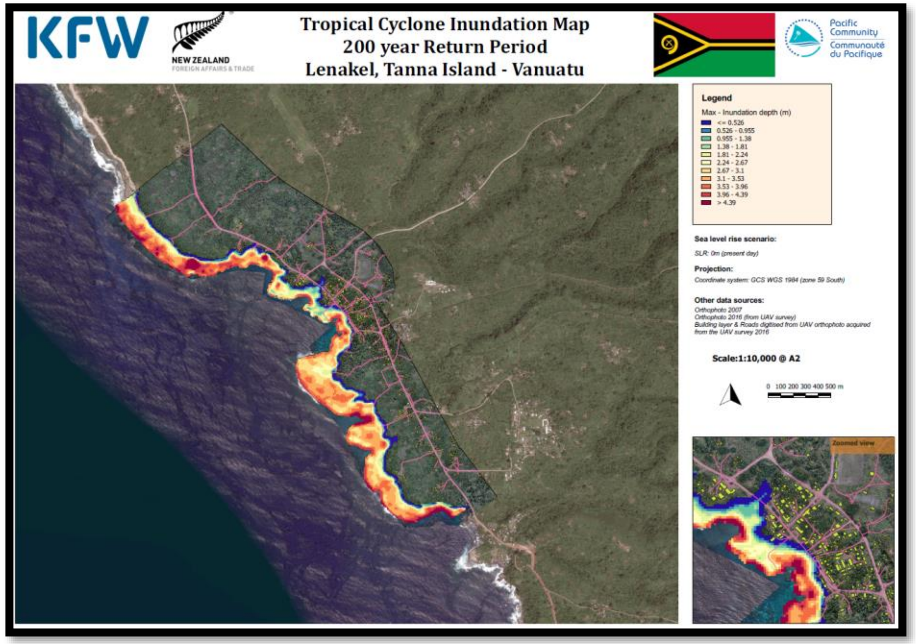
- VIRTUOSO – 1Hz / continuous
- TWR – 1Hz / 2048s burst / 3hrs
- AWAC

TC INUNDATION HAZARD MAPPING









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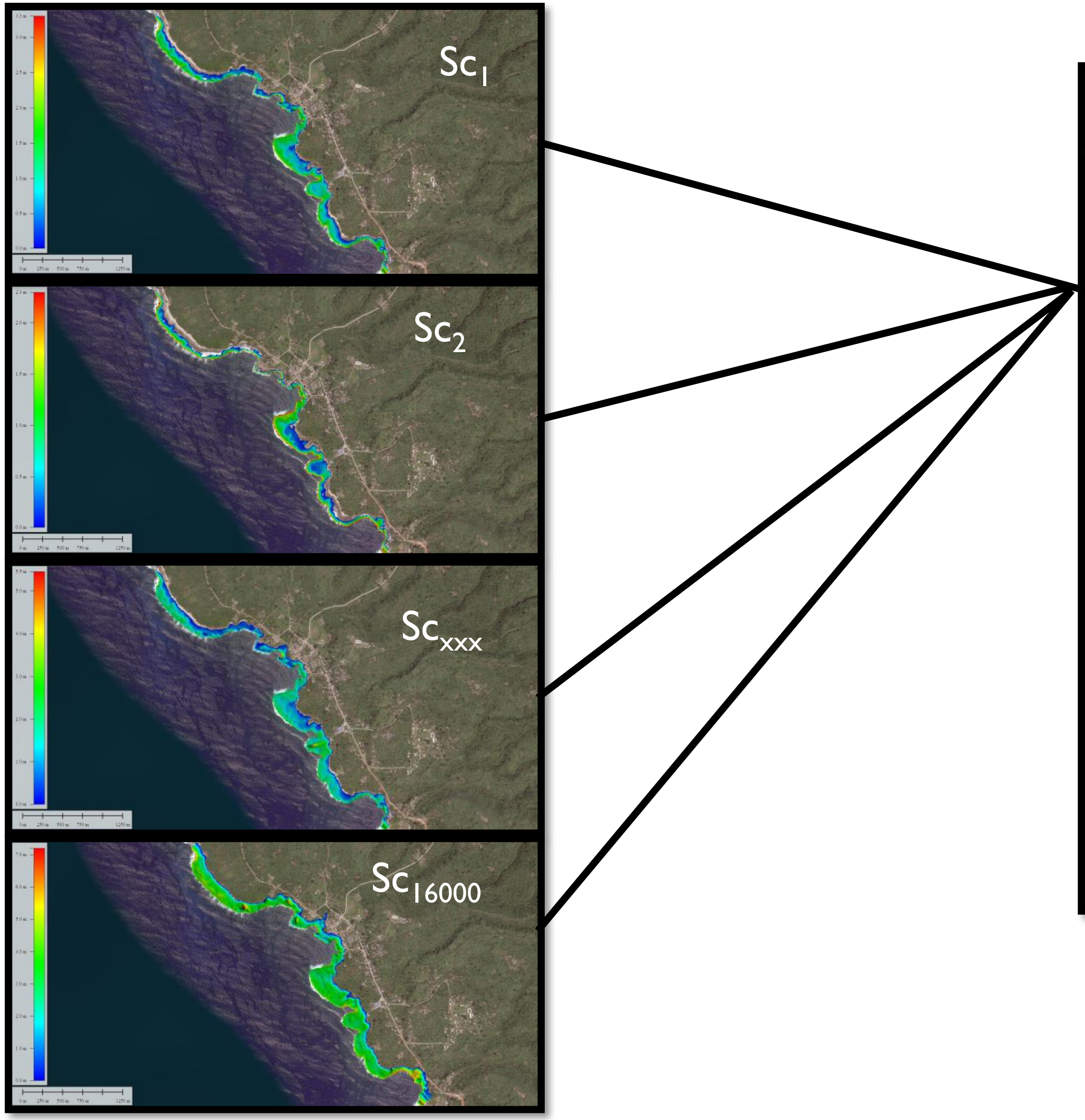
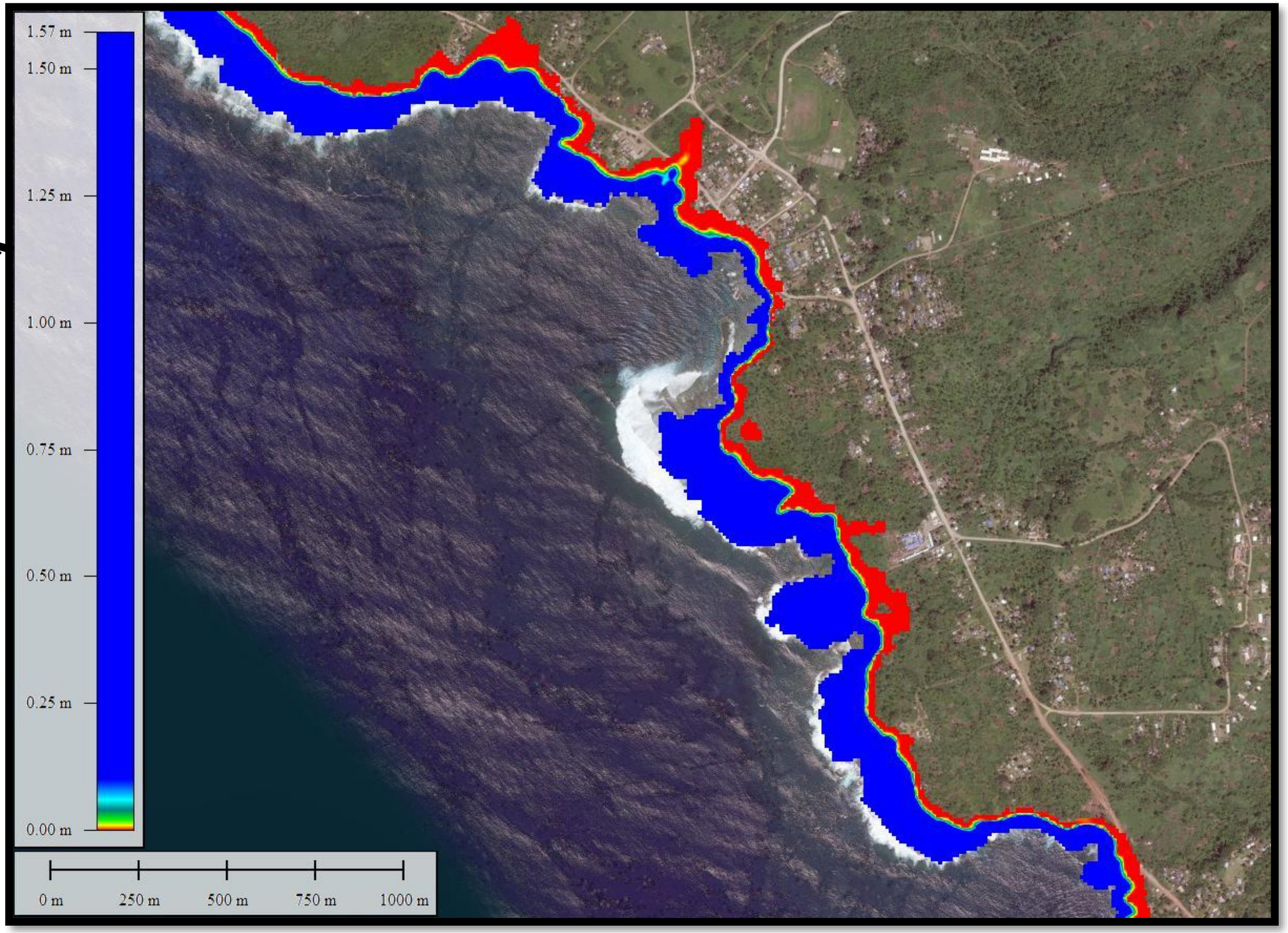
- Aggregated Inundation Map (~10 scenarios)

8 TC Inundation Hazard map:

- RP: 25,50,100,200 years
- SLR: Present & RCP8.5 (2090)

PROBABILISTIC INUNDATION MAPS





Map showing probability for Lenakel to experience more than 50cm flow depth

RISK ASSESSMENT TO SUPPORT DECISION MAKING

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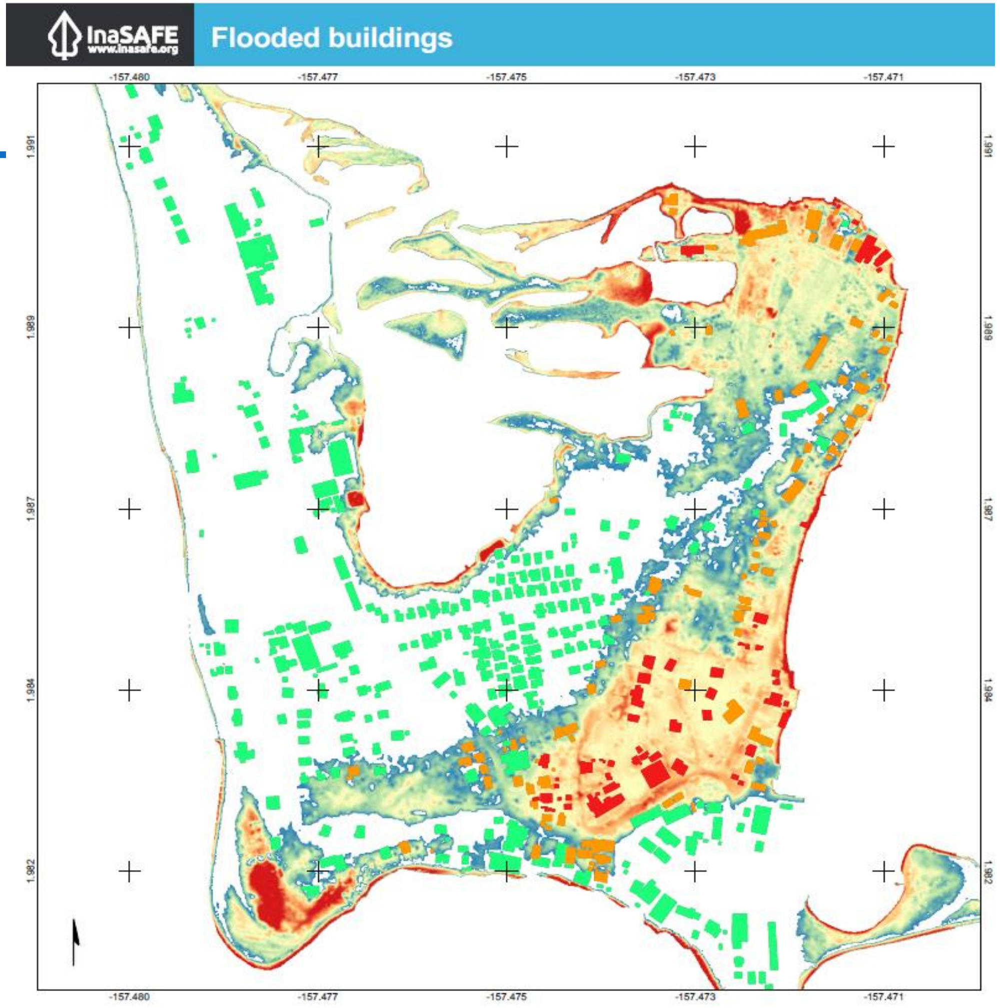
RISK = LIKELIHOOD x CONSEQUENCE

		CONSEQUENCE				
		Insignificant	*Minor*	*Moderate*	*Major*	*Catastrophic*
LIKELIHOOD	Almost Certain	Low	Medium	High	Extreme	Extreme
	Possible	Low	Low	Medium	High	Extreme
	Rare	Low	Low	Low	Medium	High

LONDON, KIRITIMATI, KIRIBATI



Future Improvements

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- Include **Radius of Max. Wind** as a 5th cyclone parameter

- Map **dependency** between **TCs & Mean Level of the Sea**
- Include **Climate Change** impact on TC

Tesla-flood framework
based on Annual, monthly and daily predictor
(Mendez,F & Rueda,A University of Cantabria)

- Investigate its application as a TC **inundation forecast** system
- Photogrammetry vs **LiDAR** topography data

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