Towards Multivariate Coastal Inundation Forecasting and Risk Analysis for the Pacific

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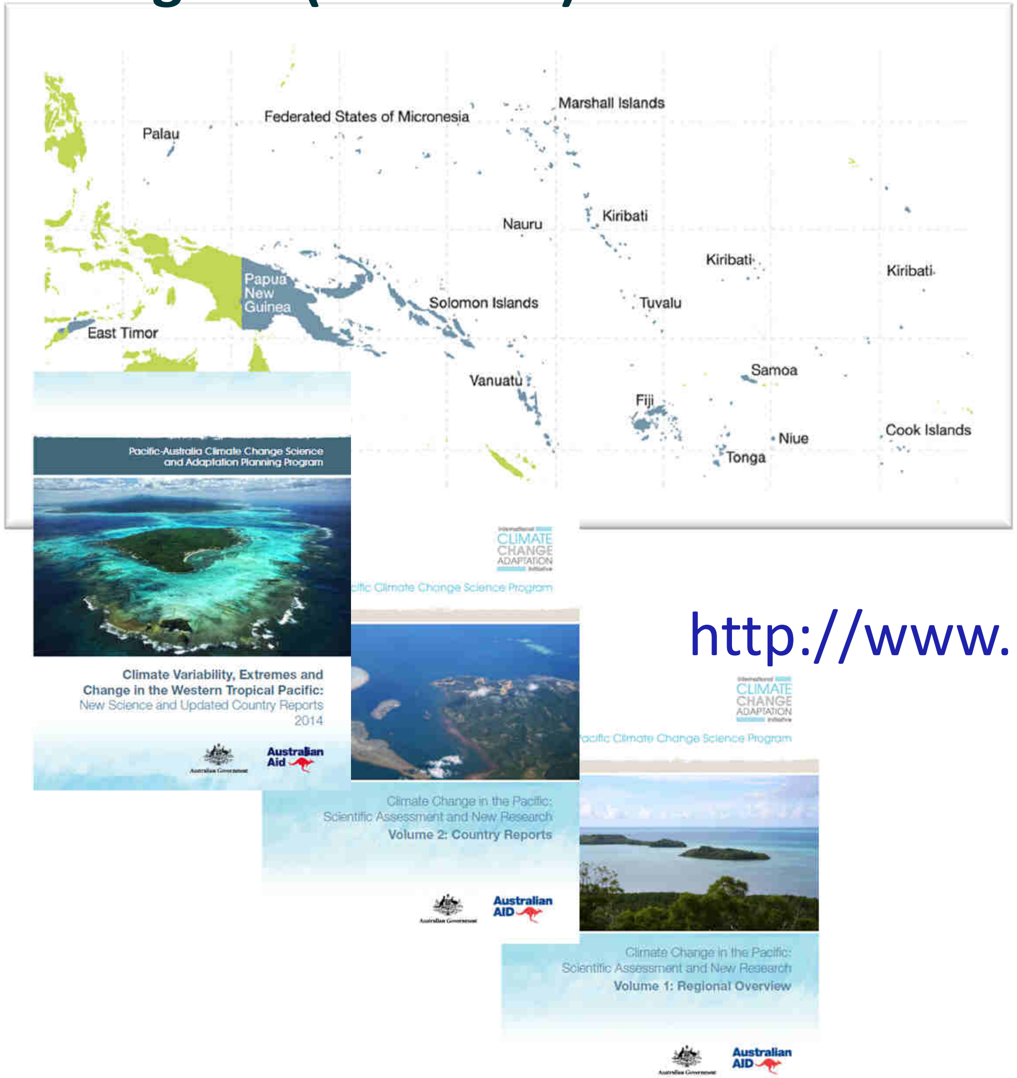
Pacific-Australia Climate Change Science and Adaptation Planning Program (PACCSAP)



1. Regional Sea Level Rise (IPCC-CMIP5)
2. Wind-wave Hindcast & Wave Climate Projections
3. Ocean Acidification (Aragonite saturation state)
4. Coral Bleaching Risk

http://www.pacificclimatechangescience.org/

5. Research on extreme sea levels in the Pacific was undertaken.

Extreme Sea Level Contributions:

- Wave Runup
- Wave Setup
- Storm Surge
- Astronomical Tides
- Variability (Seasonal / Interannual)

CAUSES	TIME SCALE	SPACE SCALE
swell/wind waves	seconds	wave shoaling zone 10s-100s of metres
Storms (pressure, wind stress)	hours	-----------
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	hours to days	continental shelf 10s-100s of kilometres
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lunar and solar gravity	hours to decades	
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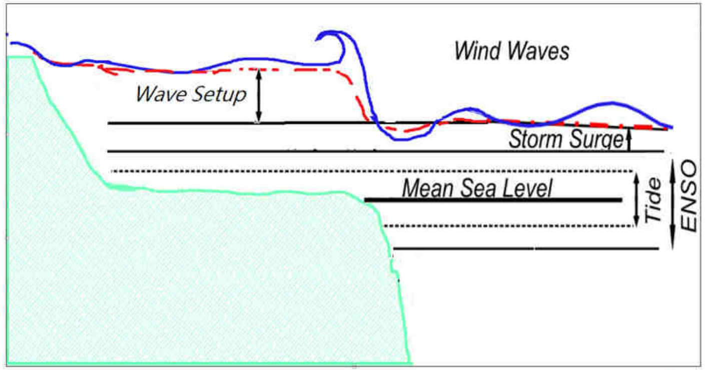
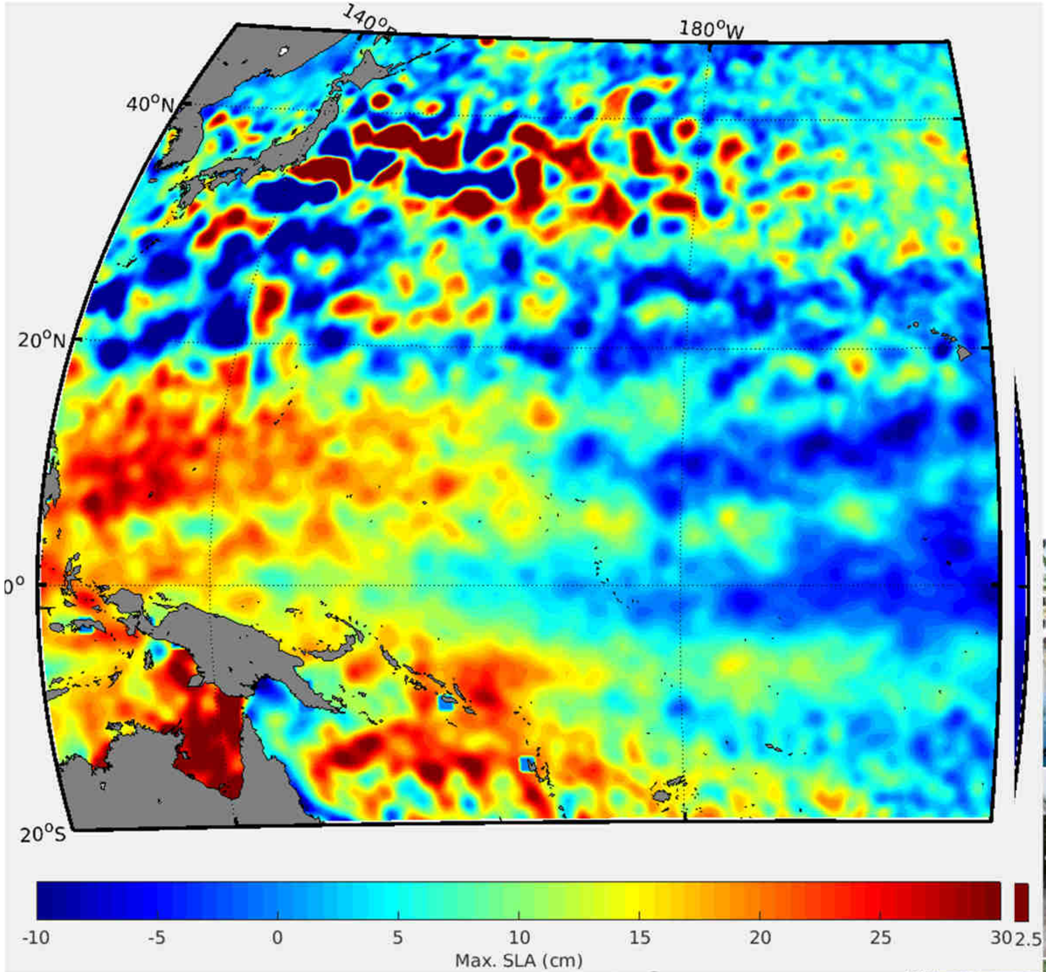
ocean/ atmosphere climate variability	months to years	ocean basin 1000s of kilometres



Mean Sea Level

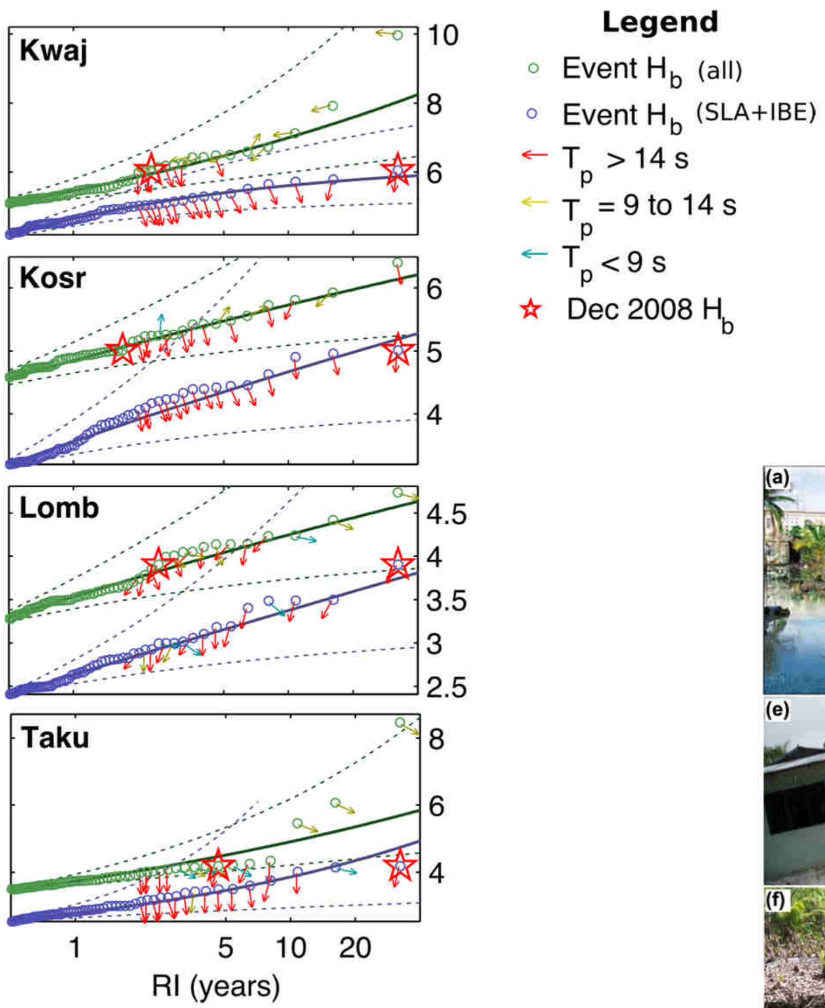
CSIRO



Extreme sea level drivers: swell from mid-latitude storms + SLA+tides = "compound event"

Examples of island inundation (right) triggered by exceptionally large waves from a north Pacific storm in December 2008 (above).

From: Hoeke, et al. (2013).



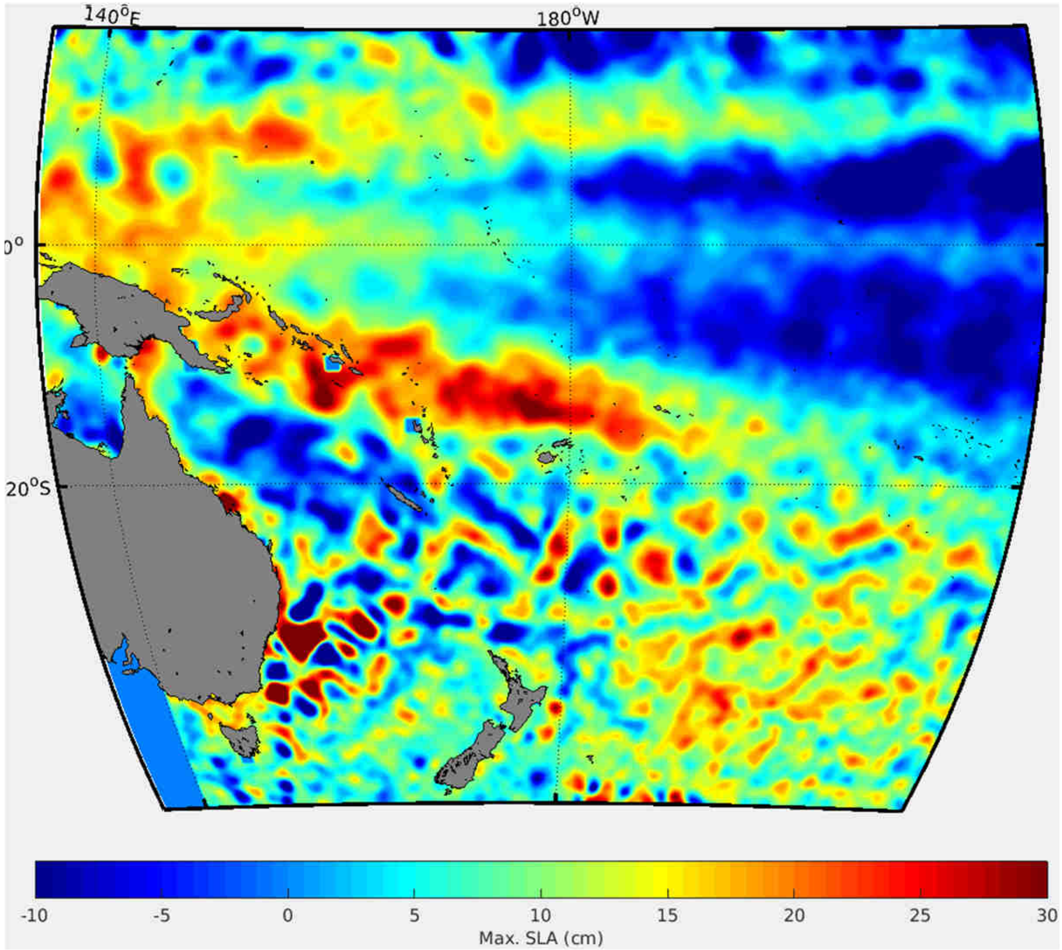
Extreme sea level drivers: swell from mid-latitude storms

+ SLA+tides

= "compound event"

From:

Hoeke, et al. (2013). *Global and Planetary Change*, *108*, 128-138.



Extreme sea level drivers: swell from mid-latitude storms

+ SLA+tides
= “compound event”?


Coast swamped

TIDAL SURGE Giant waves flood hotel rooms

Fiji Times, 21/05/2011

Examples of island inundation (right) triggered by exceptionally large waves from a Tasman sea storm in May 2011 (above).

From: Jens Kruger (SPC) pers. communication.

Inundation events in the RMI

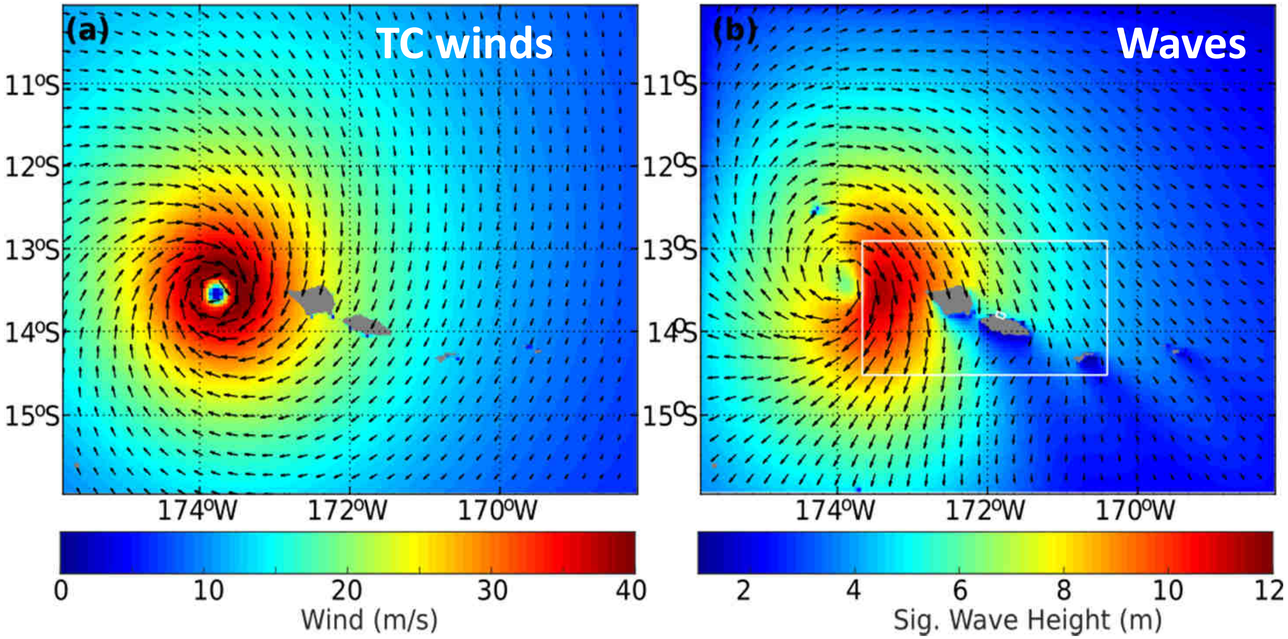
Years	Events	Areas (Affected)
1979	Sea Swell	Majuro
1988	Tropical Storm (Roy)	Kwajalein
1991	Tropical Storm (Zelda)	All of RMI
1992	Tropical Storm (Axel)	All of RMi
1994	High Surf/Wave Action	Majuro
1997	Typhoon (Paka)	Majuro, Ailinglaplap, and Namu
2008	Sea Swell/King Tide	Majuro, Arno, and Kili
2013	Sea Swell/Spring Tide	Majuro, Arno, and Kili
2014	Sea Swell/Wave Action	Majuro, Arno, and Kili
2015	Sea Swell/Wave Action	Ebeye, Kwajalein

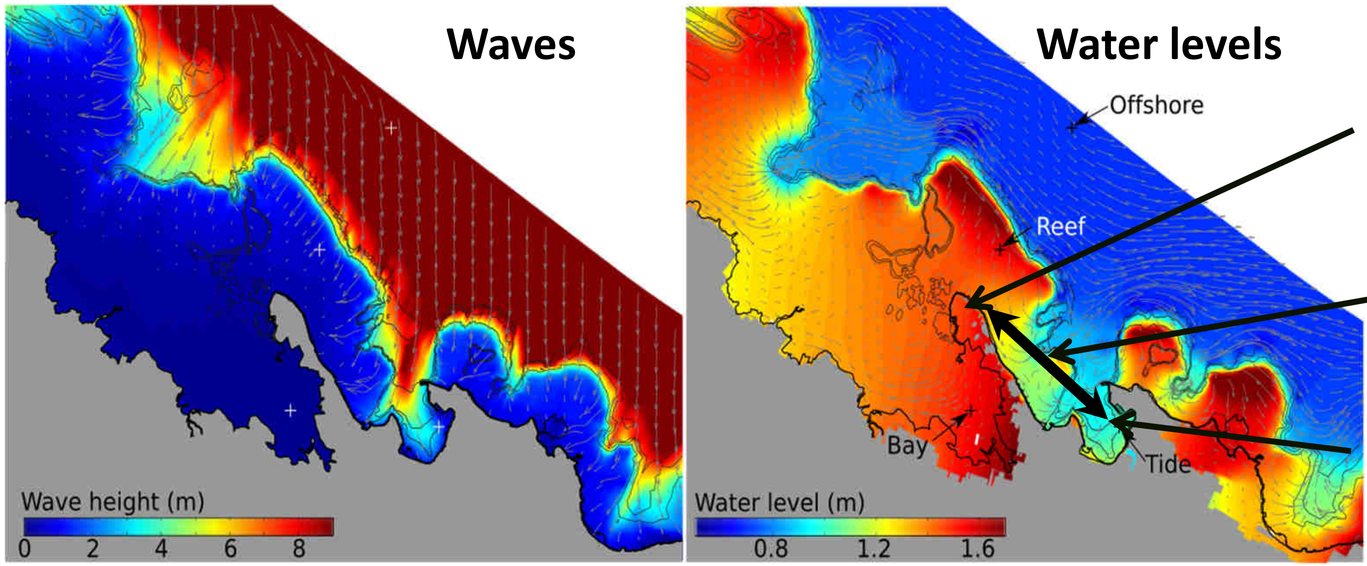
NOAA's National Weather Service

Credit: Reggie White (RMI NWS); Melissa Iwamoto (PacIOOS)

PACCSAP deliverables: Inundation hazards Samoa

Example for TC Ofa





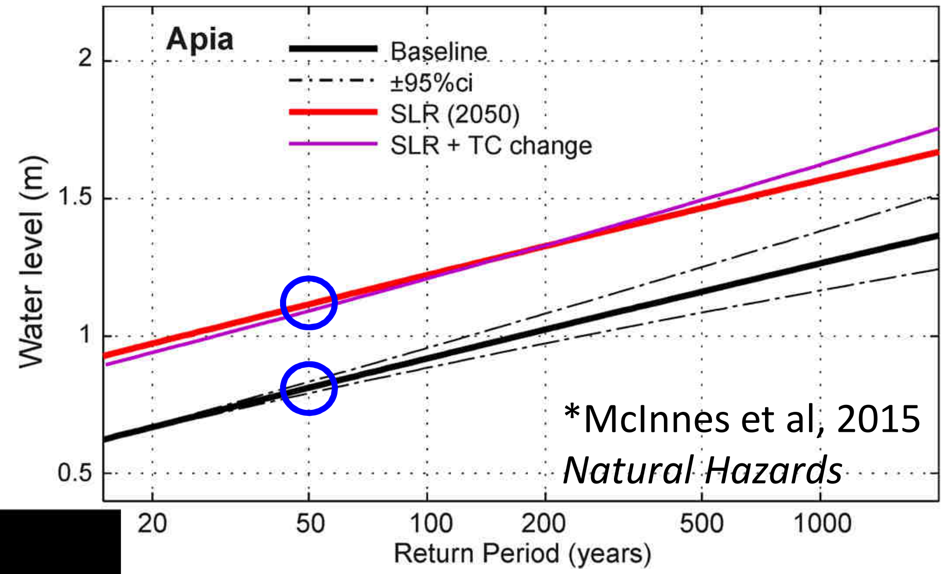
Water levels inshore of reef up to 1 m higher than tide gauge location

<2 km

Water levels at tide gauge Similar to the ‘stormtide only’ i.e. waves don’t increase sea levels through setup

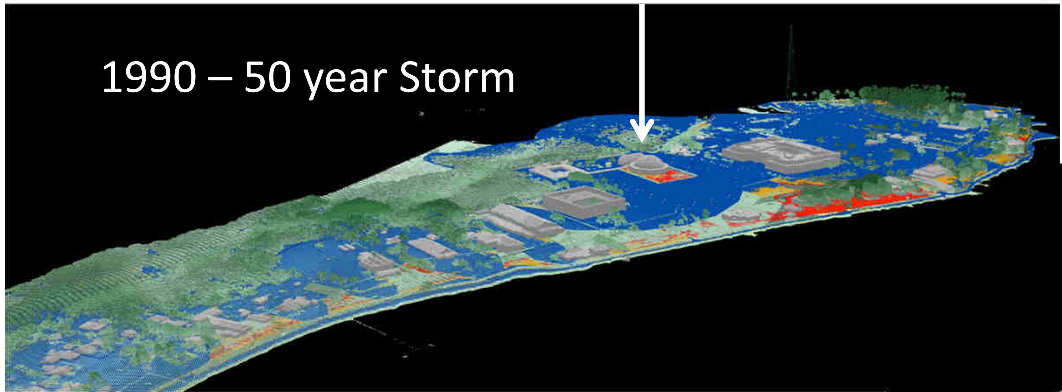
Source: McInnes et al., *Natural Hazards* (2016); Hoeke et al., *JMSE* (2015)

PACCSAP deliverables:
Engineering risk analysis



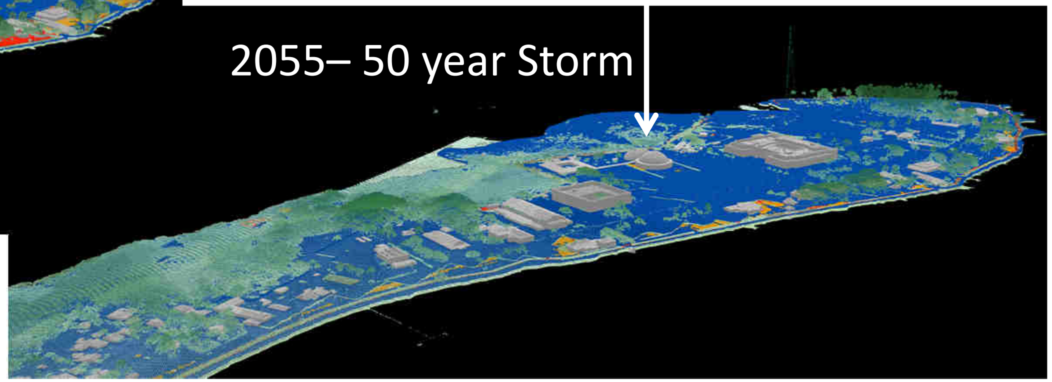
*McInnes et al, 2015 *Natural Hazards*

Samoan Parliament Building



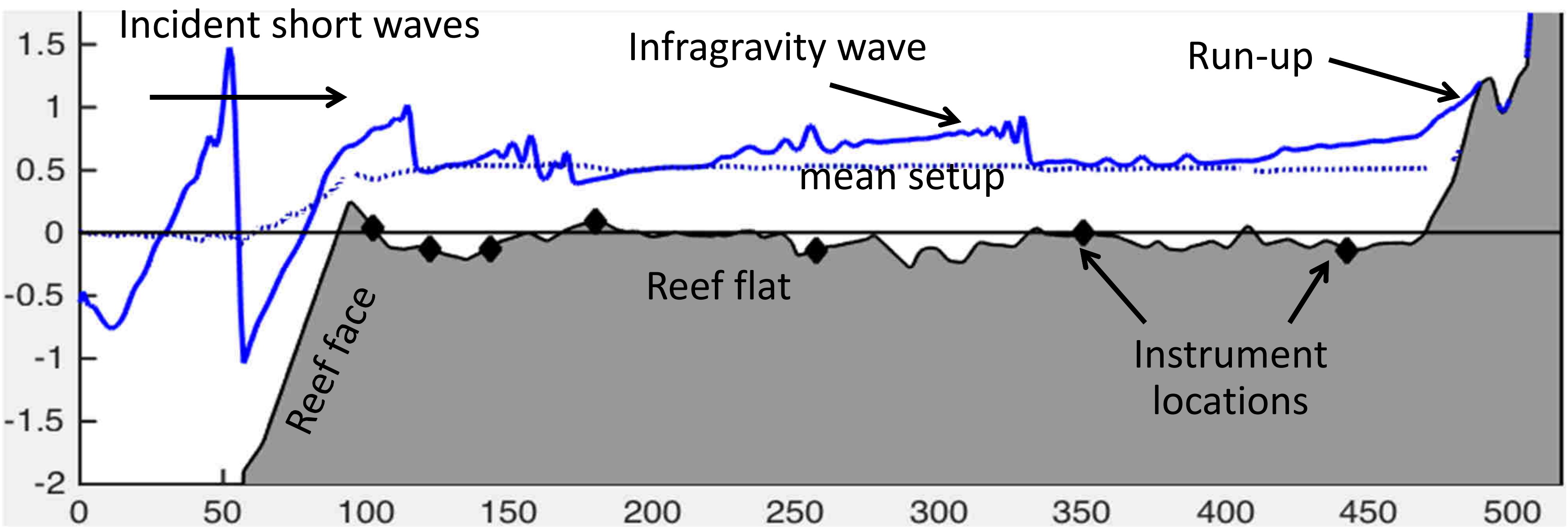
- Storm tide + Wave setup + Wave runup (maximum)
- Storm tide + Wave setup + Wave runup (median)
- Storm tide + Wave setup

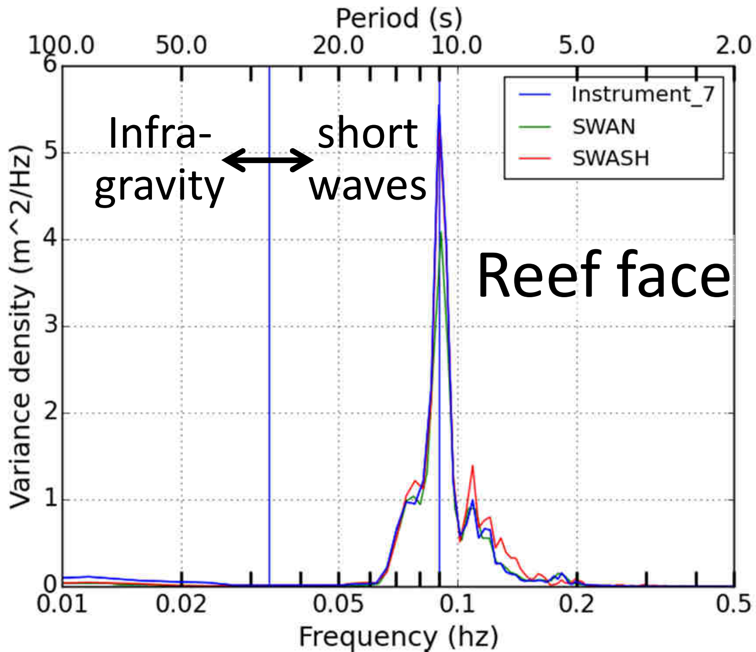
Samoan Parliament Building

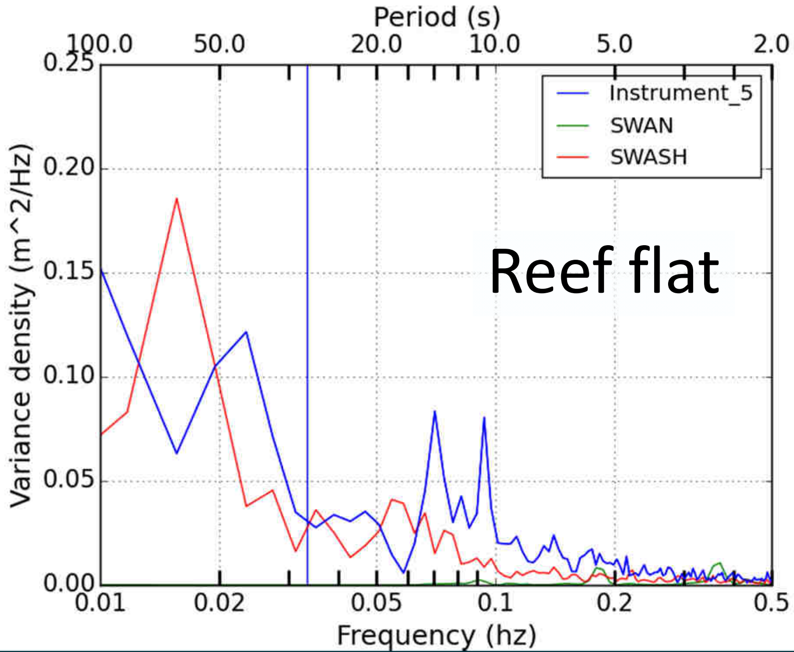


*Hoeke et al, CAWCR Technical Report 71 (2014); Hoeke et al., *JMSE* (2015)

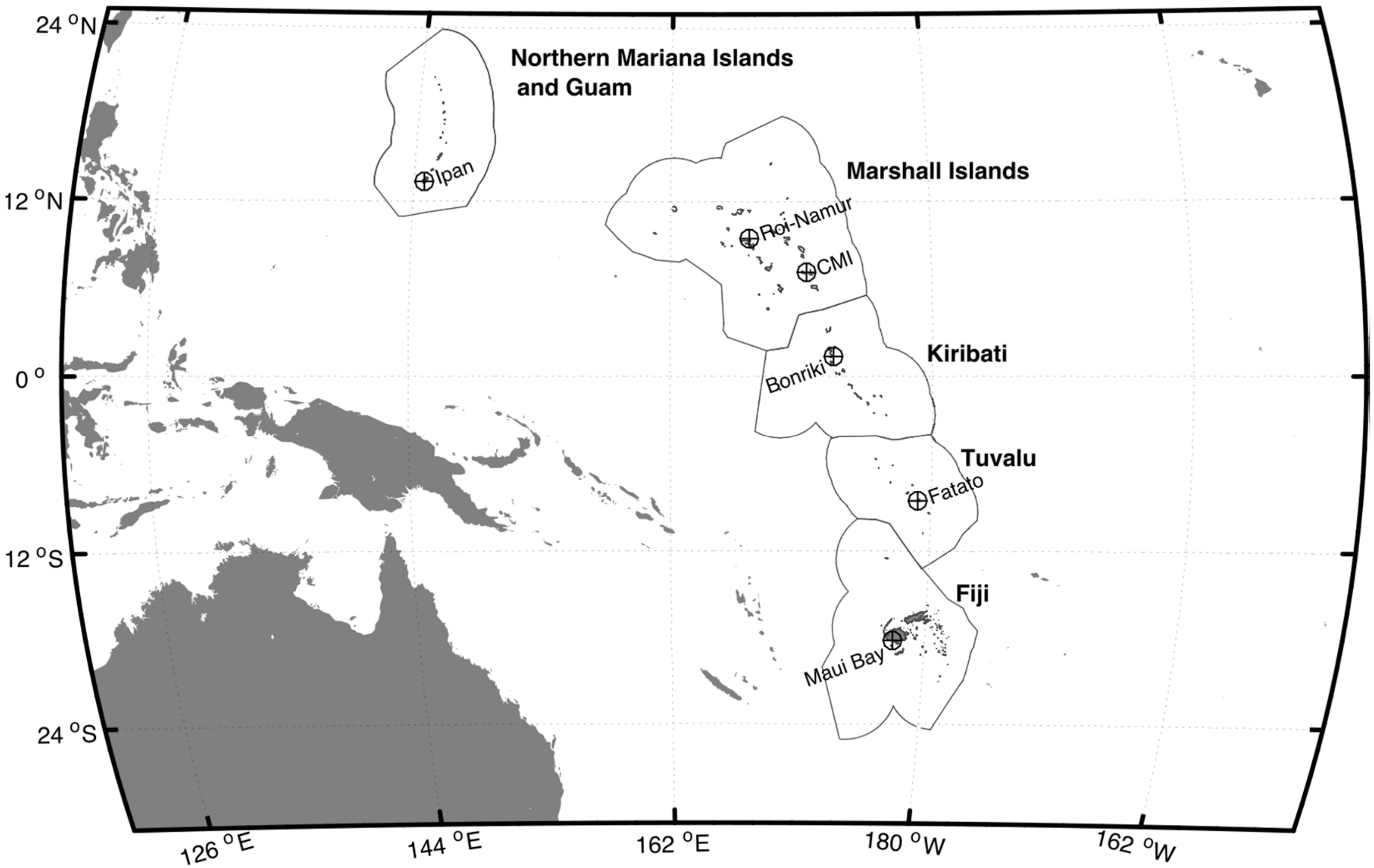
Details of littoral dynamics leading to inundation





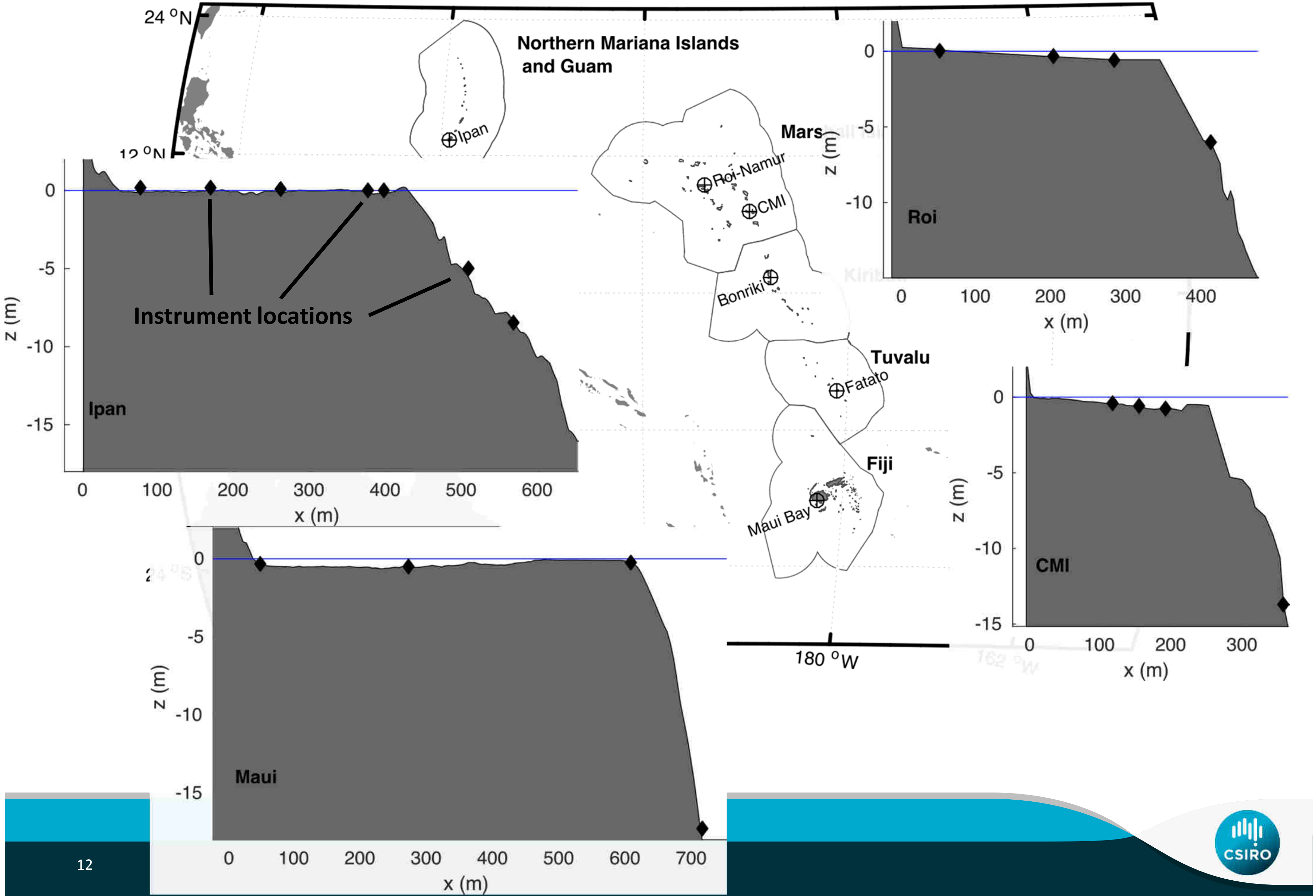


Pacific littoral model inter-comparison project



Partners: UNESCO-IHE, SPC, University of Hawai'i, University of Auckland

Pacific littoral model inter-comparison project



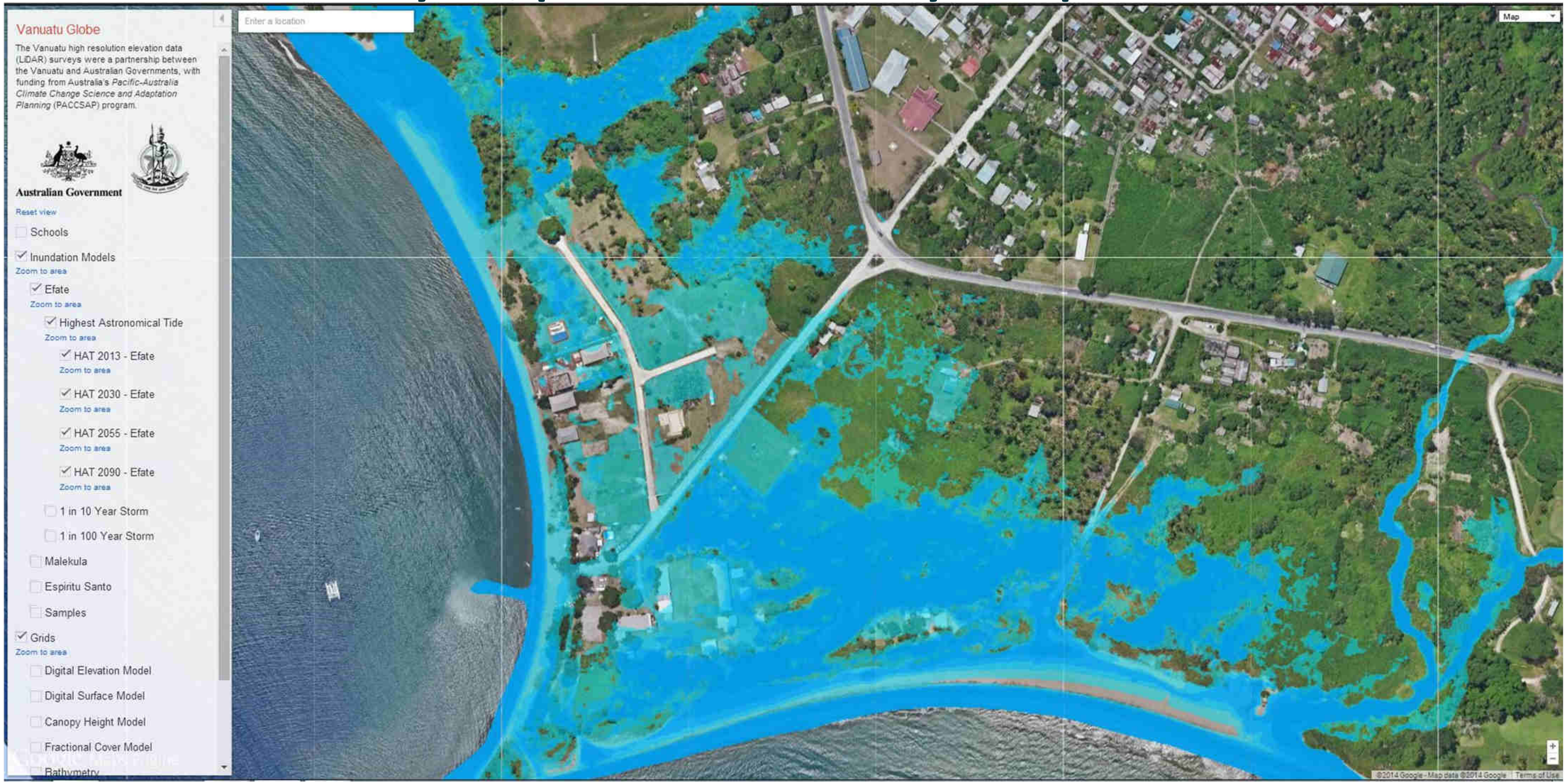
Pacific littoral model inter-comparison project

Empirical/analytic and numerical approaches considered

COMPLEXITY

	Wave statistics?	Wave breaking?	Nearshore water levels?
Merrifield, et. al (2014)[1*]		Empirical/analytic	
Blacka, et. al (2015)[2*]		Empirical/analytic	
SWAN[3*]	Phase-averaged spectral wave action balance.	Parameterised -fraction of breaking -dissipation of energy	Balances (phase-averaged) wave radiation stress gradient with pressure gradient.
XBeach[4*] **/ UnXBeach**	Phase –averaged representative frequency wave action balance (wave group time-space scale).	Parameterised -fraction of breaking -dissipation of energy	Balances time-varying wave stress with depth averaged circulation model. (infra-gravity and longer phases resolved).
SWASH[5*]	Simulates the free surface of individual waves (non-hydrostatic).	Identifies if the free surface is too steep, and turns off local pressure gradient to create a bore.	Time-averaged statistics of the modeled free surface. All frequencies phase resolved.

When the right model is coupled with the right spatial analytics, powerful risk analysis is possible.

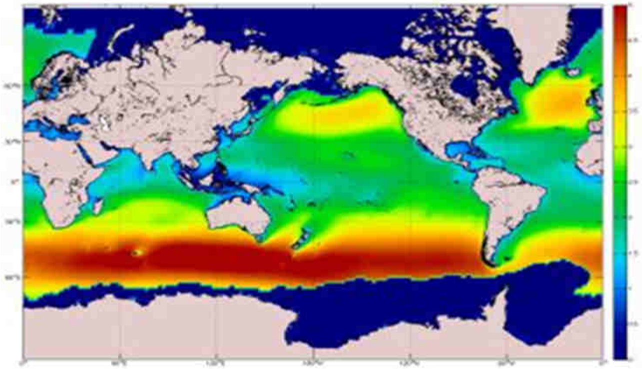


But high resolution bathymetric and topographic data is necessary.

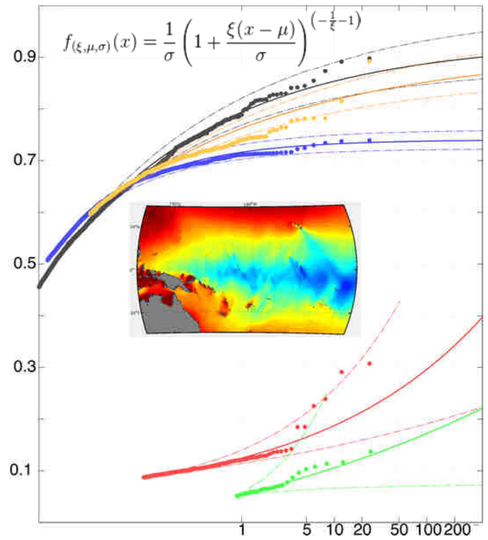
Credit: Nathan Quadros (CRCSI)

Coastal sea level extremes & waves analysis: early warning concept

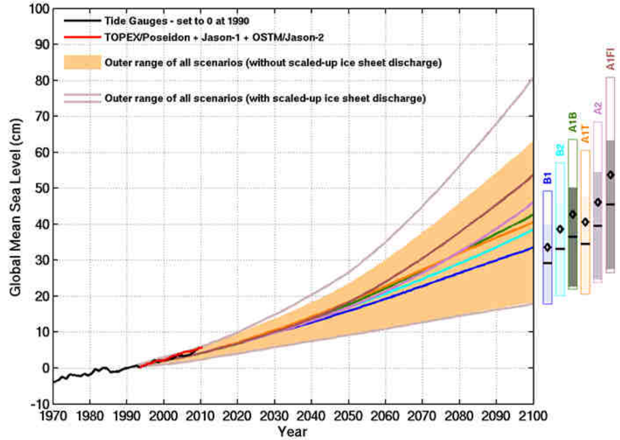
regional/global wave climate



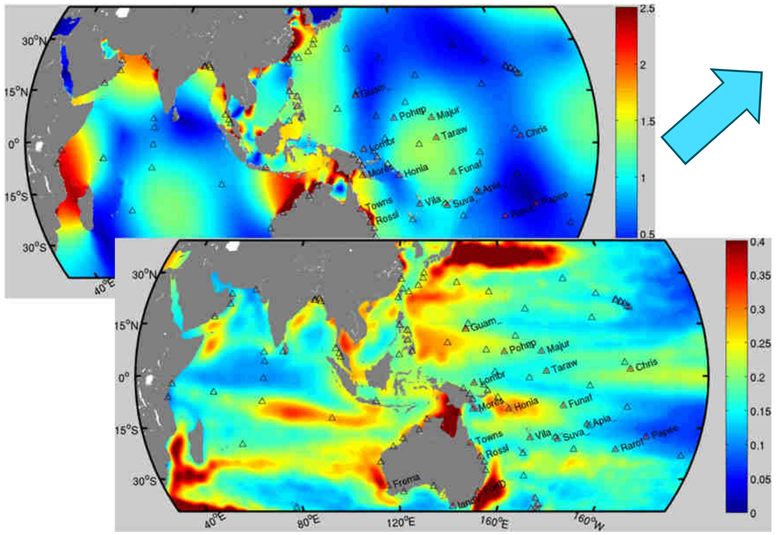
extreme value analysis

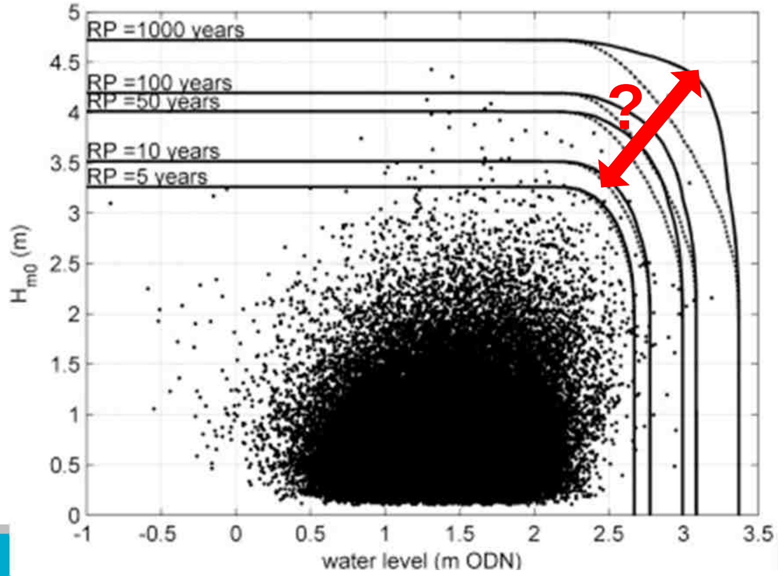


Sea level rise



regional/global tides and sea level variability





From: Chini, Stansby. (2012), Coastal Engineering 65: 27-37.

Summary

1. PACCSAP: Recent projections developed for Australia and the Pacific use the most up-to-date scenarios of marine variables such as sea levels and waves. The data, models and methods provide a basis for developing new products for early warning.
2. Sea level rise will increase (is already increasing?) the frequency of coastal inundation
3. Stochastic cyclone and dynamic modelling can enable extreme sea level likelihoods to be evaluated at high spatial resolution, BUT the computational overheads are high and data sources (e.g. high res bathymetry, hydrodynamic observations) are not widely available
4. Multivariate statistical analysis for wave, tide and sea level show promise of evaluating extreme sea level likelihoods at broad spatial scale with potential use in early warning of inundation events.

Thank you

For more information

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