Pacific Climate Change Science Program

Understanding Storm Surge Risk in Fiji due to Climate Variability and Change

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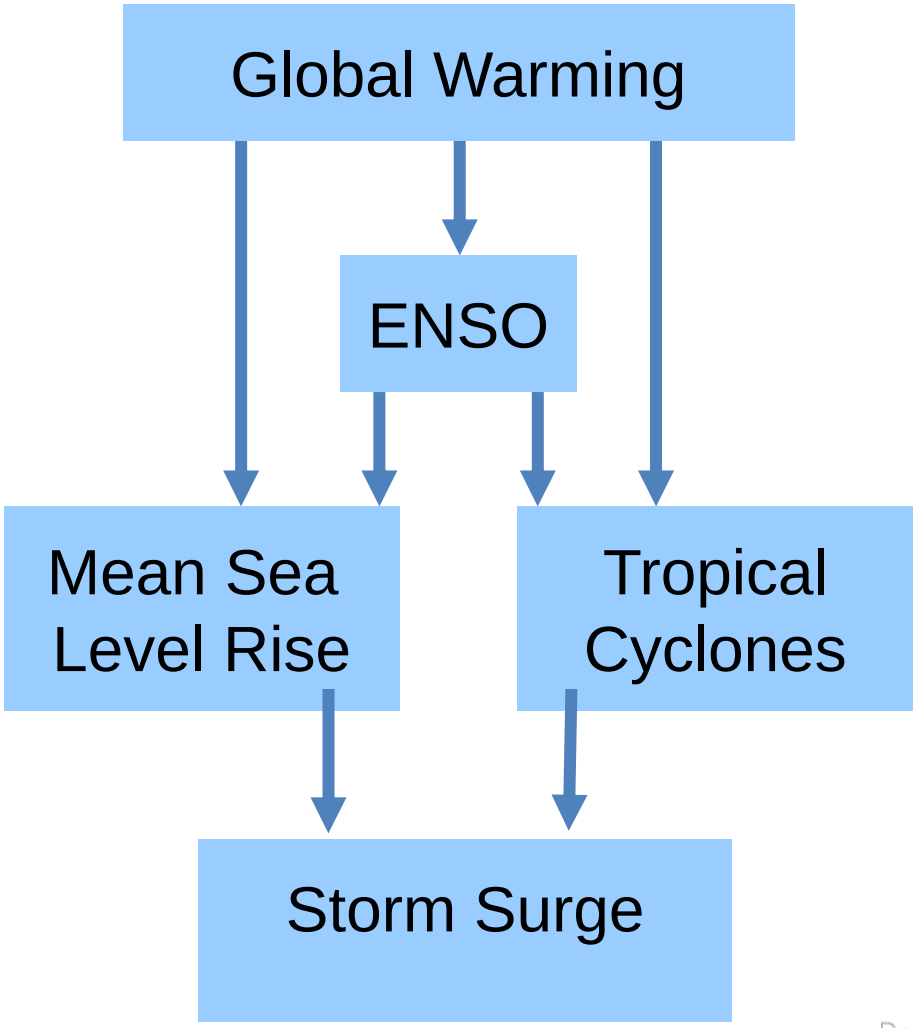
Australian Government

Outline

- Background and Motivation
- Models and Approach
- Stochastic model for cyclones
- Storm surge results
- Conclusions and Further work

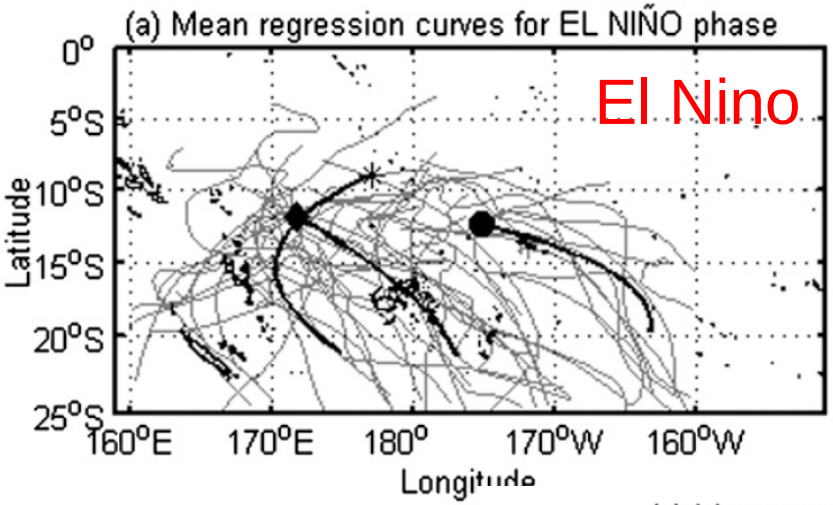
Storm surges and climate change

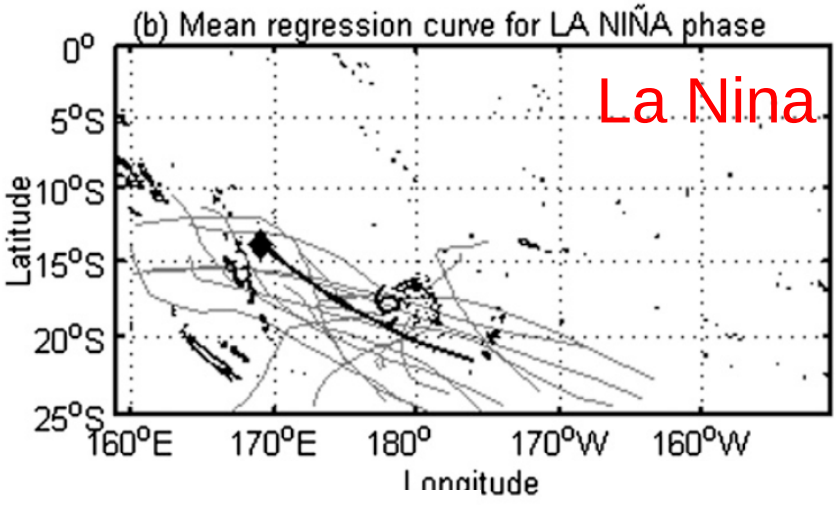


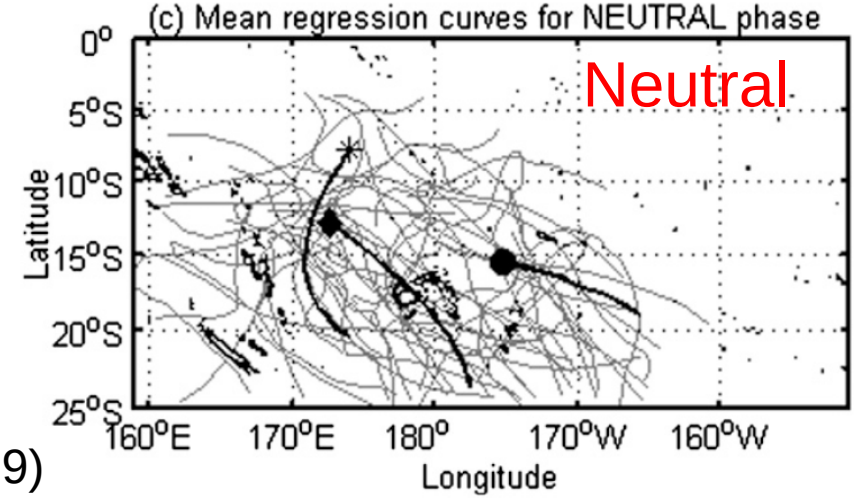
Objectives:

1. Use modelling to investigate storm surge risk around the Fiji coastline and provide a framework to understand large scale influences
2. Investigate the effect of ENSO on storm surge risk

Cyclone behaviour is linked to ENSO variability

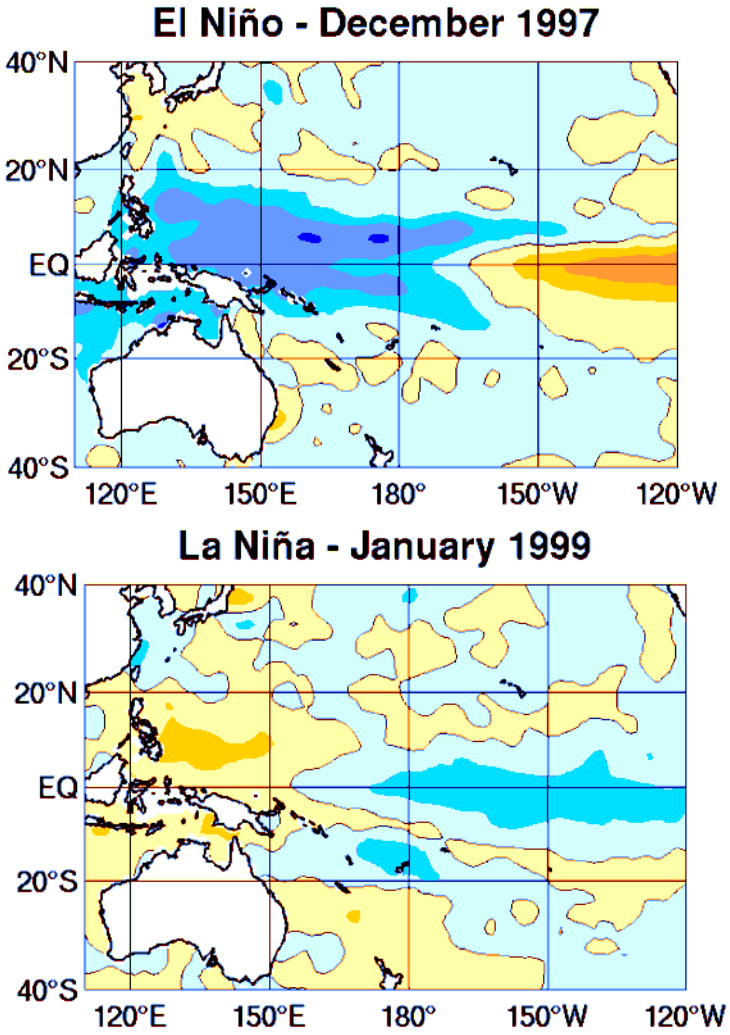


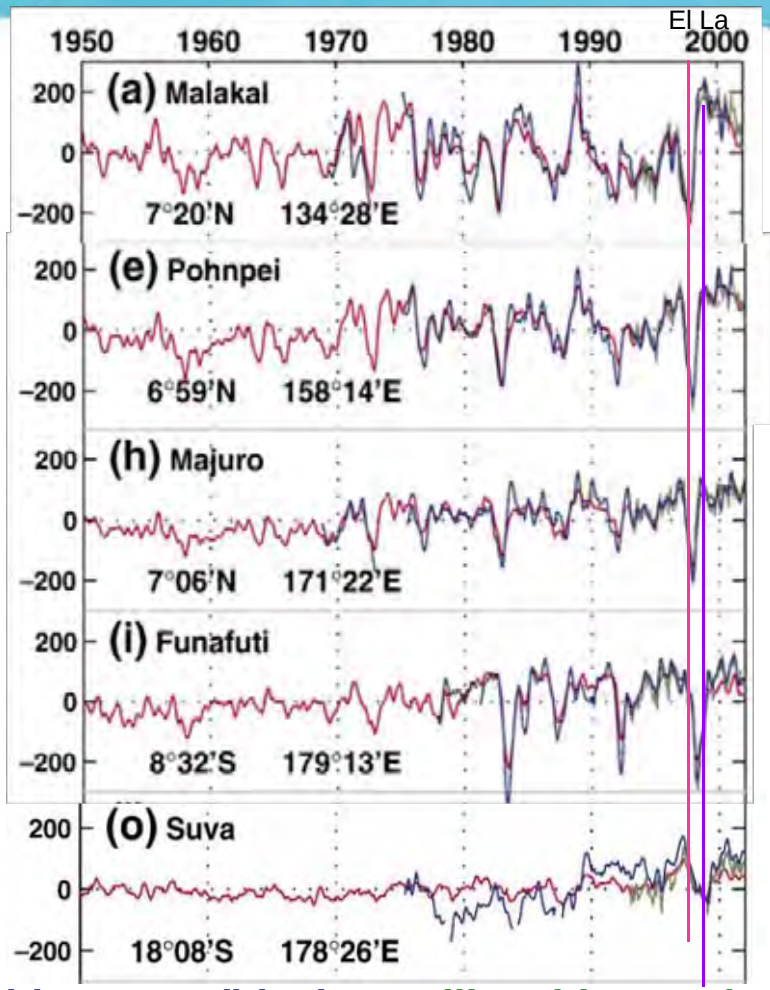




Source:
Chand and Walsh (2009)

Sea levels vary with ENSO





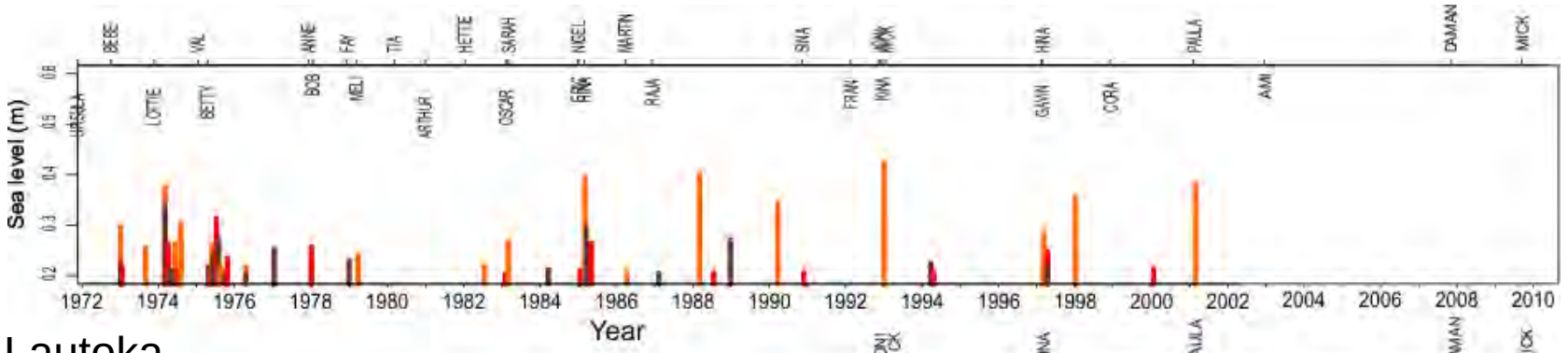
Tide gauge (blue), satellite altimeter (green)
Reconstructed sea levels (red)

Source: Church et al. (2006)

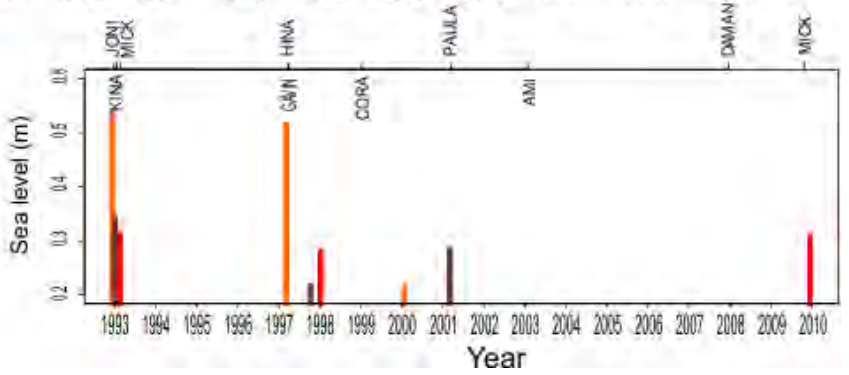
Courtesy: Neil White.

Tide gauge residuals

Suva

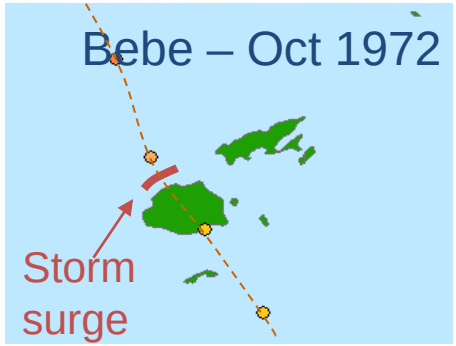


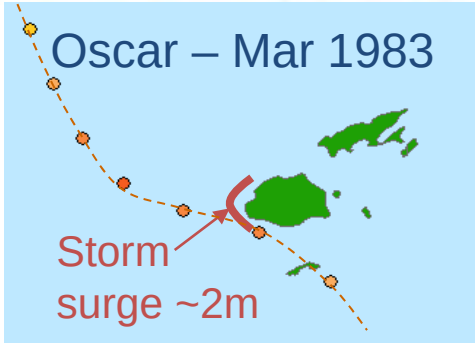
Lautoka

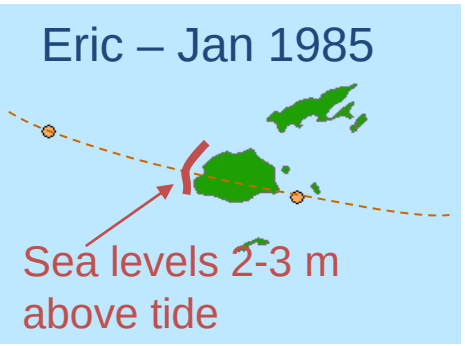


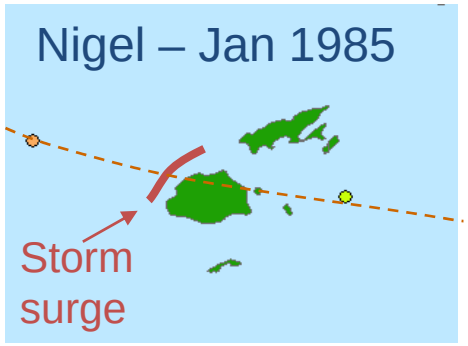
Historical storm surges and their impacts

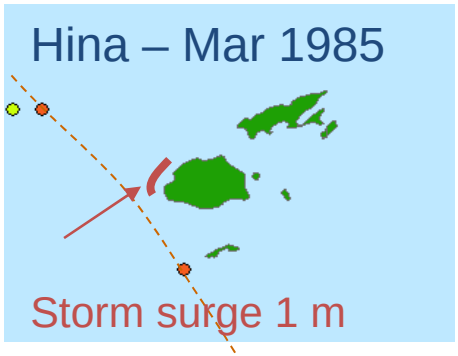
Anecdotal information indicates storm surges and impacts along Fiji coastline

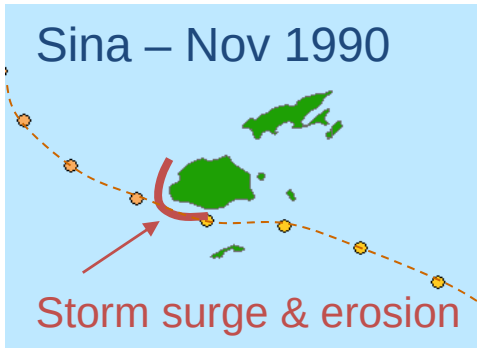


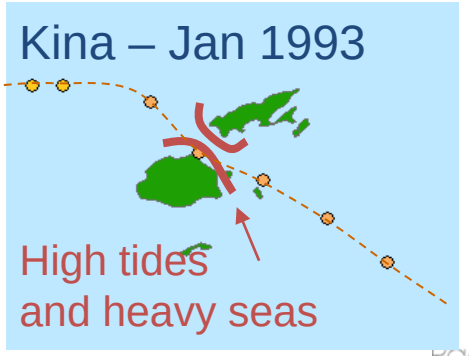


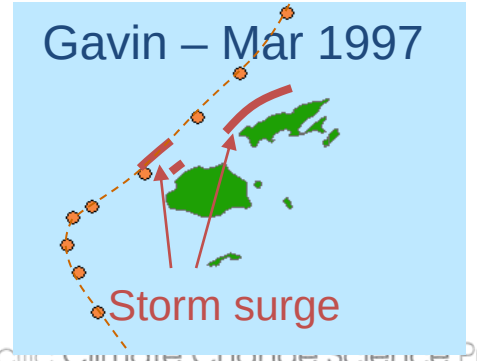


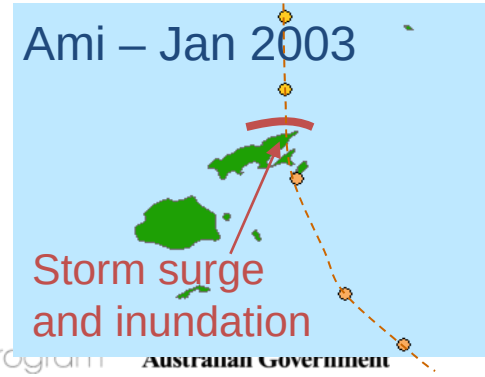








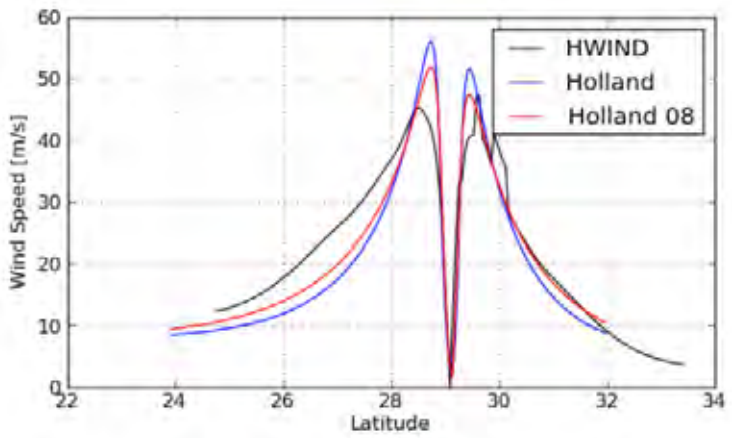


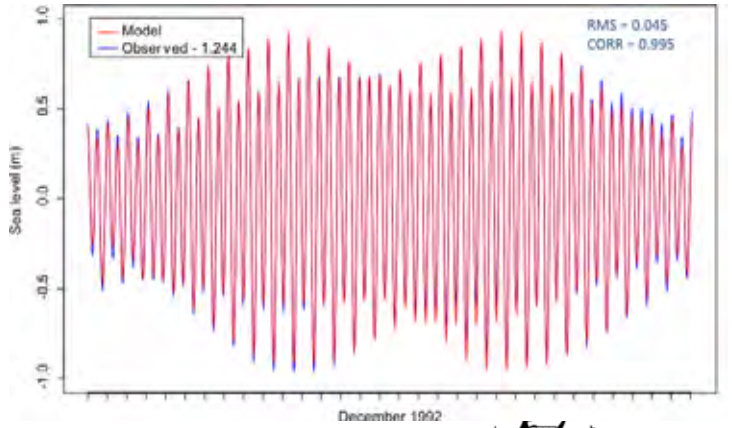


Source: McGree et al. 2010, Fiji Met Service TC country reports

Models

- Cyclone wind and pressure Holland (2008) vortex model (B parameter specified as a function of cyclone speed, latitude, pressure fall)
- Hydrodynamic model - GCOM2D (Hubbert and McInnes, 1999)





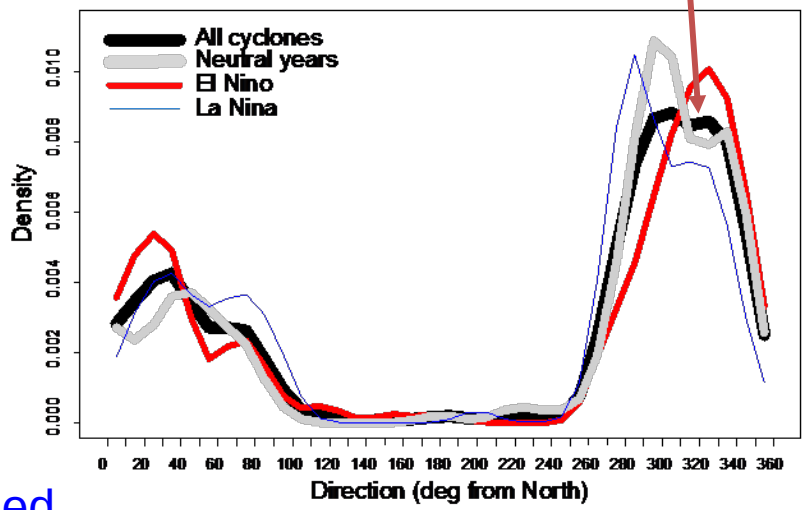
Method

- Modelling of storm surges based on stochastic modelling of cyclones
- Randomly sampled cyclones collectively fit the distributions of observed cyclones wrt
  - Direction
  - Speed of movement
  - Location
  - Central pressure
- Historical cyclones obtained from IBTrACS database (38 years)
- Based on cyclones within 6° Fiji

Cyclone tracks

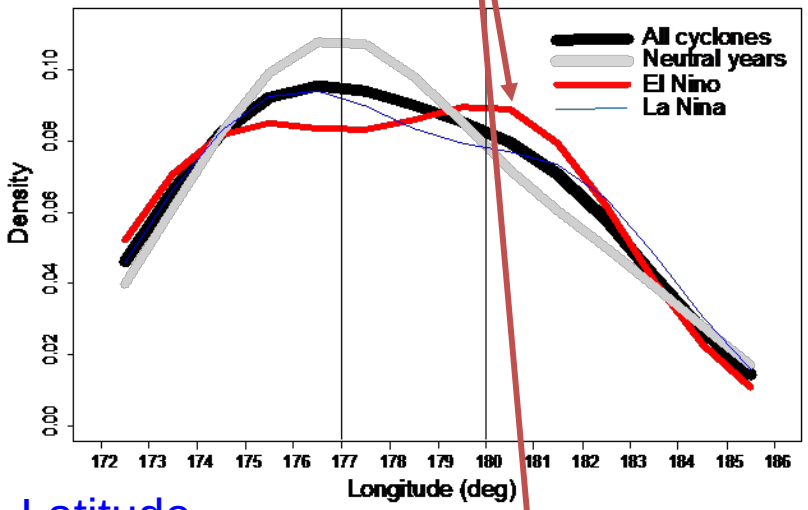
Direction

TCs most commonly approach from NW

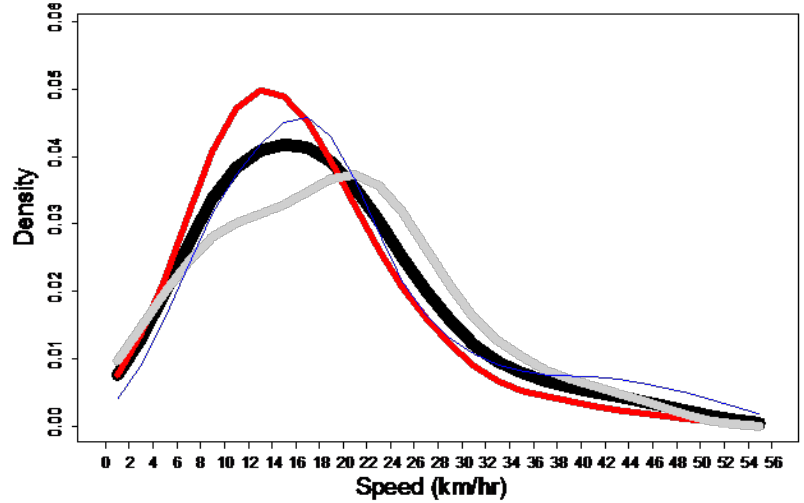


Longitude

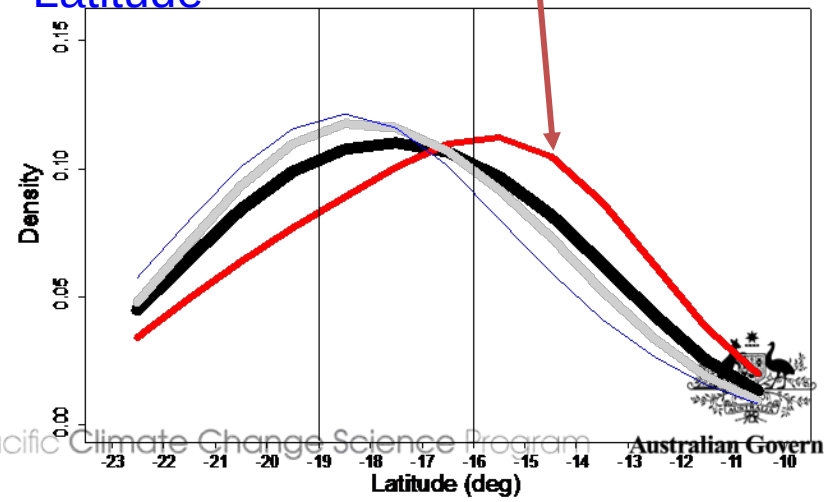
TC tracks are further north & east during El Nino



Speed



Latitude



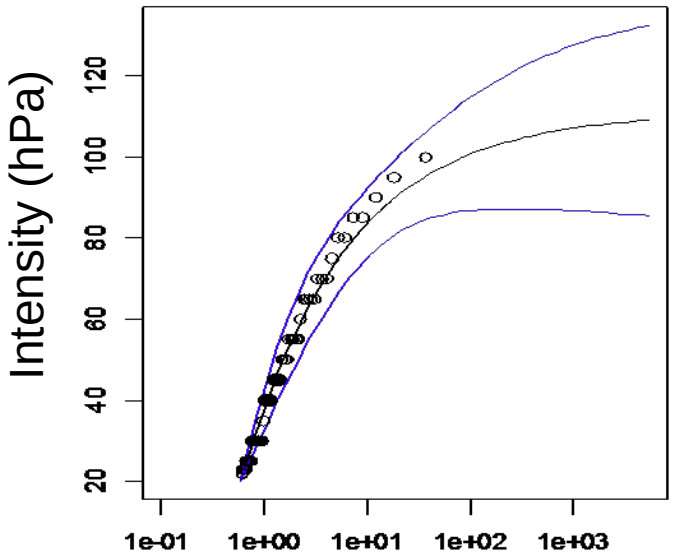
Cyclone intensity

- Generalised Pareto Distribution fit to cyclone central pressure

$$F(y) = 1 - \left(1 + \frac{\xi(y - \mu)}{\sigma}\right)^{-1/\xi}$$

- Threshold (μ) of 20hPa used was found to optimise the mle fit of the shape (ξ) and scale (σ) parameters based on QQ-plot and the stability of the parameters.

Pressure Deficit from 1010hPa



Radius to Maximum Winds

RMW modeled using a bivariate log-linear regression

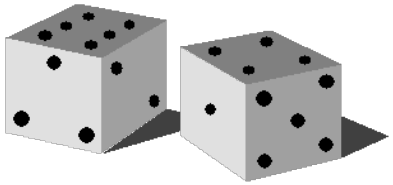
(Kossin et al, 2007)

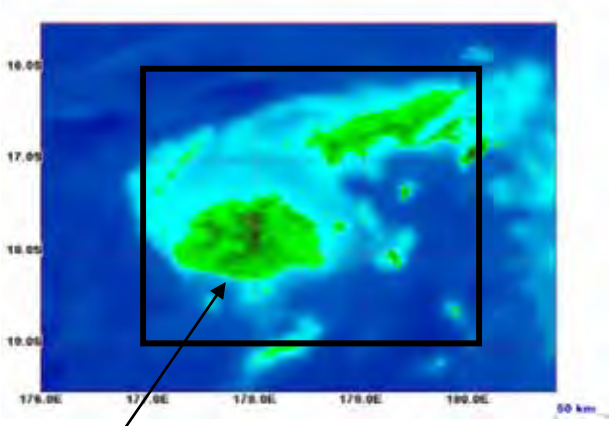
$RMW=a_0+a_1x_1+a_2x_2$

x_1=latitude (deg abs), x_2=minimum central pressure (in hPa)

$(a_0, a_1, a_2) = (-3.5115, 0.0264, 0.0068)$

Synthetic cyclones





Rate of cyclone occurrence:
1 per 3.9 years (Average)

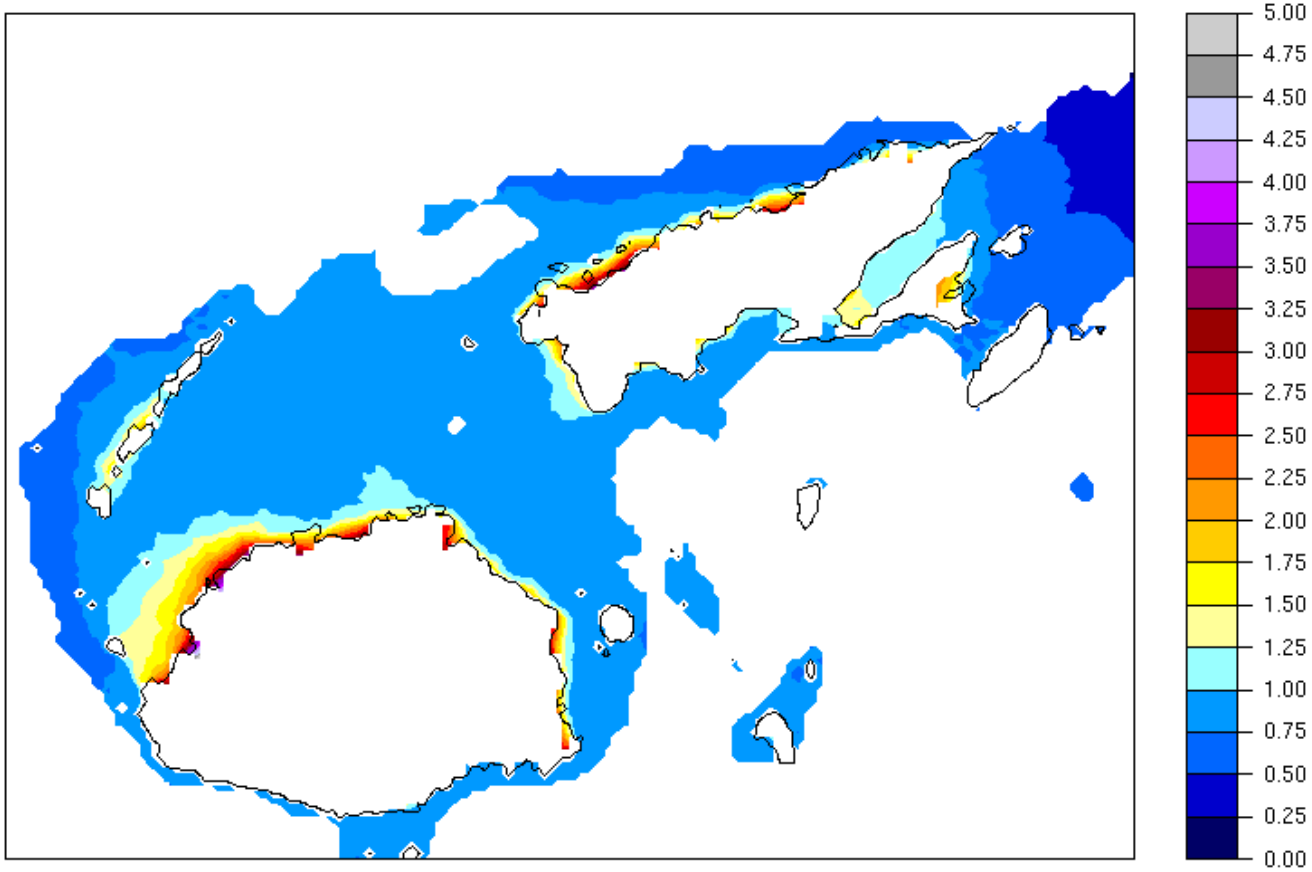
1 per 4.8 years (La Nina)
1 per 3.6 years (El Nino)
1 per 3.9 years (Neutral)

Procedure:

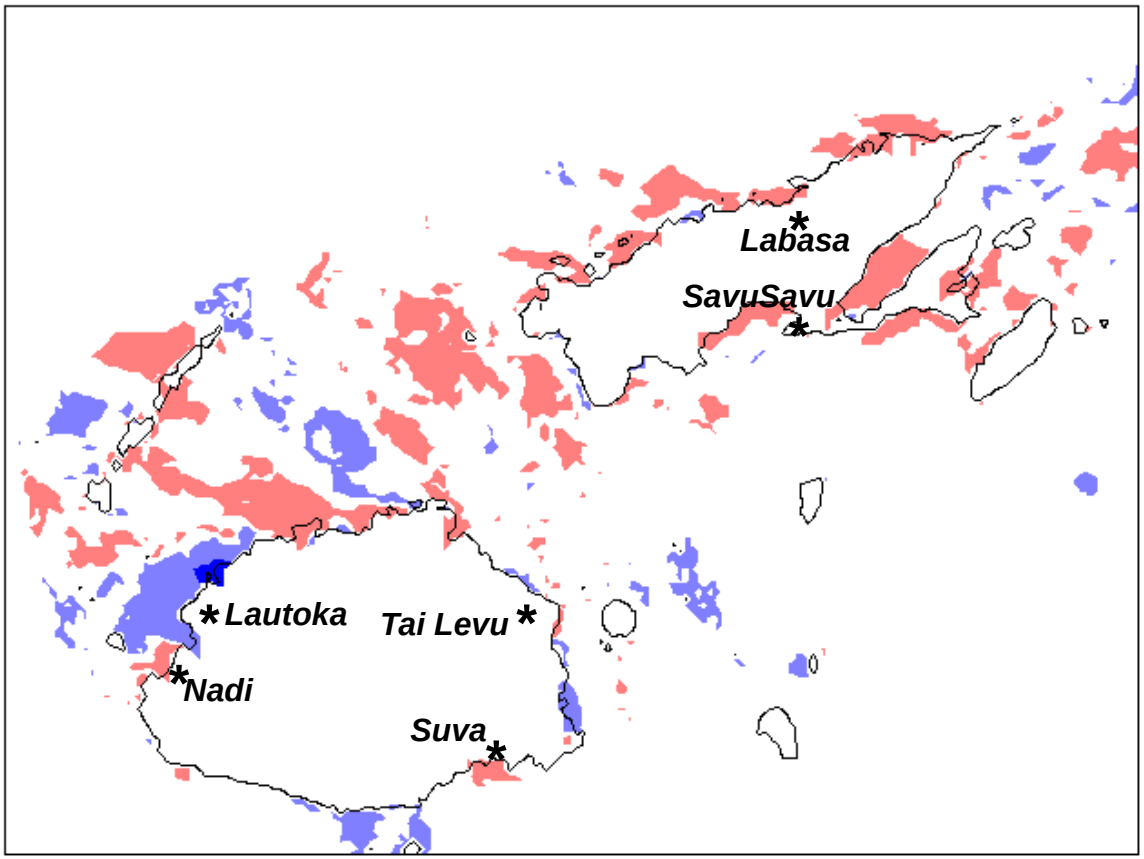
- Randomly select starting position
- From randomly selected direction and speed, cyclone track is calculated across model domain
- Holland vortex model run to calculate time varying wind and pressure field
- Hydrodynamic model run to simulate sea level heights
- Maximum heights stored for later analysis
- 1000 cyclones selected for average, La Nina, El Nino and Neutral seasons

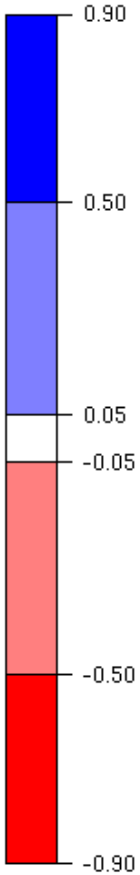
99th percentile surge heights

Average Conditions



La Nina – El Nino 99th percentile

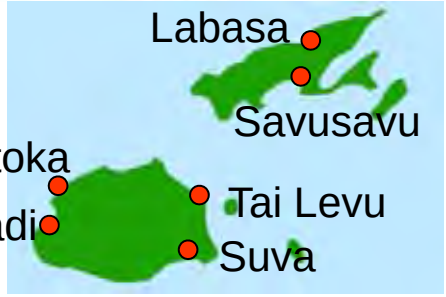




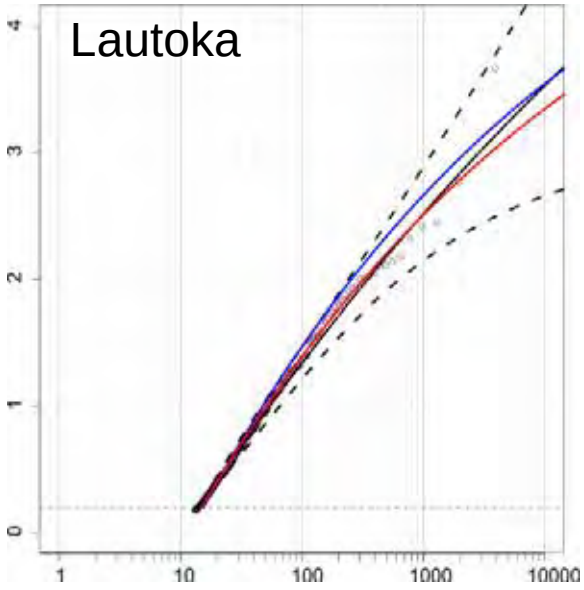
Storm surge risk is higher during La Nina

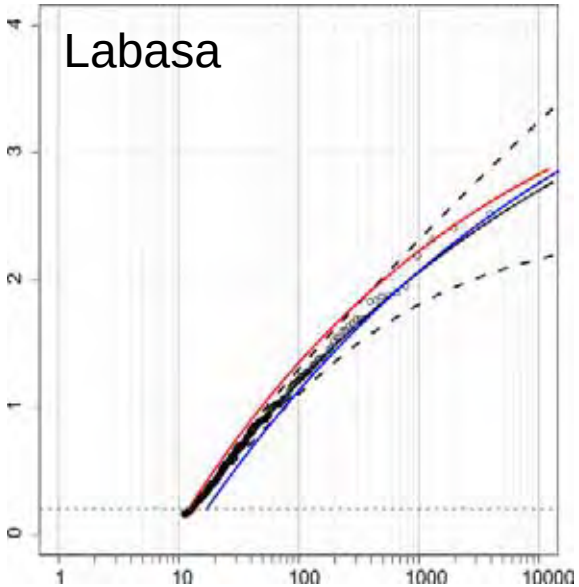
Storm surge risk is higher during El Nino

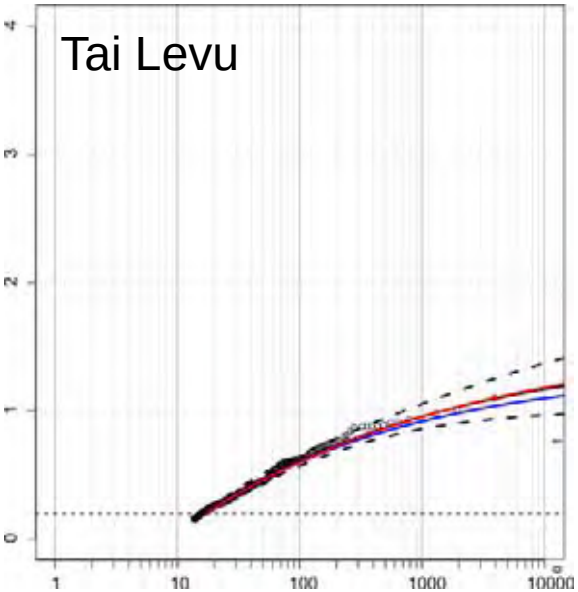
Return periods



All
La Nina
El Nino





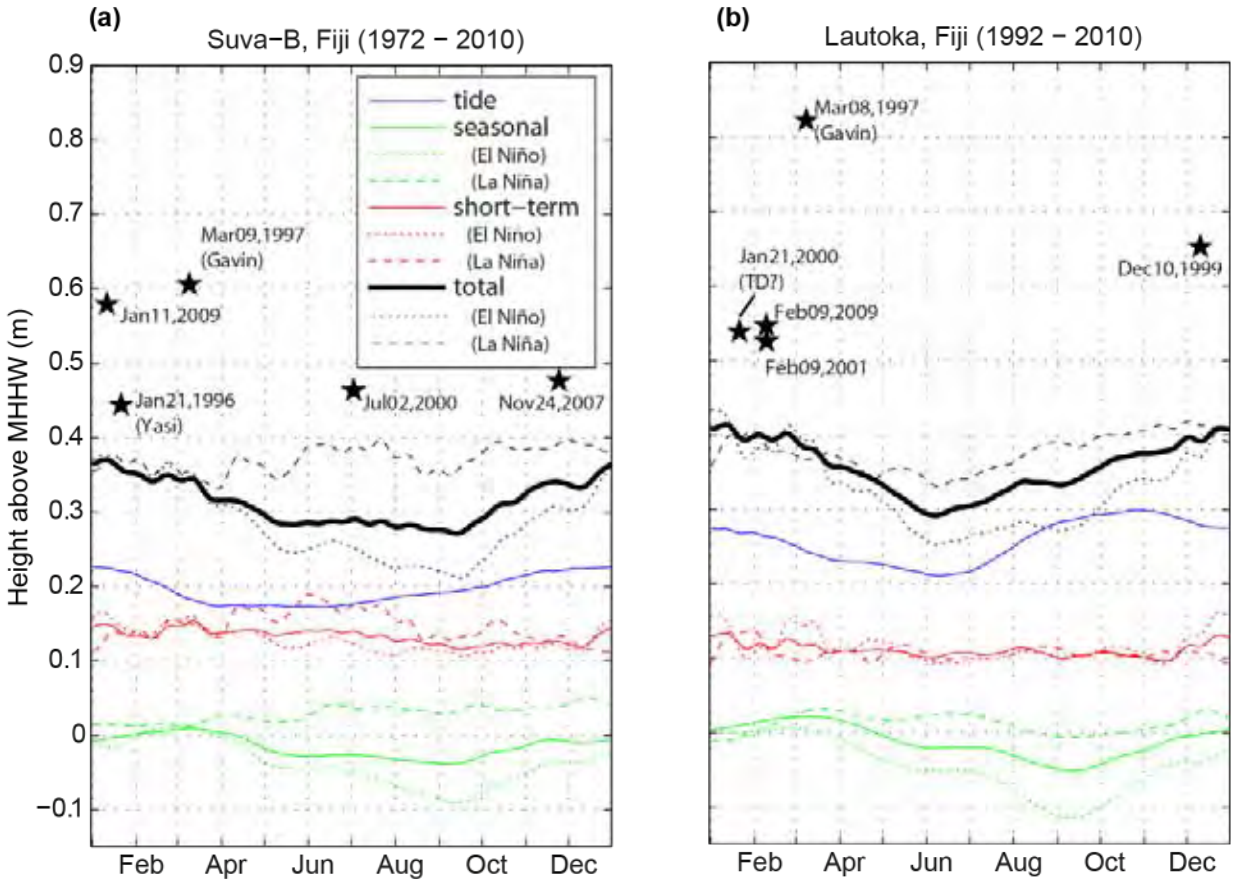


Changes in tracks and frequencies of cyclones between La Nina and El Nino seasons lead to small changes in return levels

Summary and further work

- Provides spatially varying information useful for impact studies along the coastline.
- Useful framework for investigating the effect of projected changes to TCs on storm surges
- 1 in 100 year storm surges on the western coastlines of Viti Levu and Vanua Levu tend to be around twice as large as those on the southeast coasts.
- Although during El Nino (La Nina), there is a greater tendency for higher storm surges to occur around Vanua Levu (Nadi and Lautoka on Viti Levu), the differences are small compared with the other uncertainties
- Incorporate tides and future climate projections

Extreme sea level climatology



Thank you

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Extreme sea levels from tropical cyclones