Modelling extreme sea levels due to tropical cyclones
Examples for Fiji and Samoa

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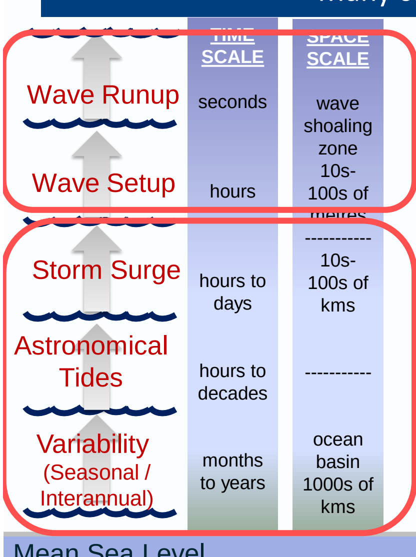
Delta's in times of Change - 25 September 2014

Centre for Australian Climate and Weather Research

Extreme Sea Levels

Many contributing factors



2:

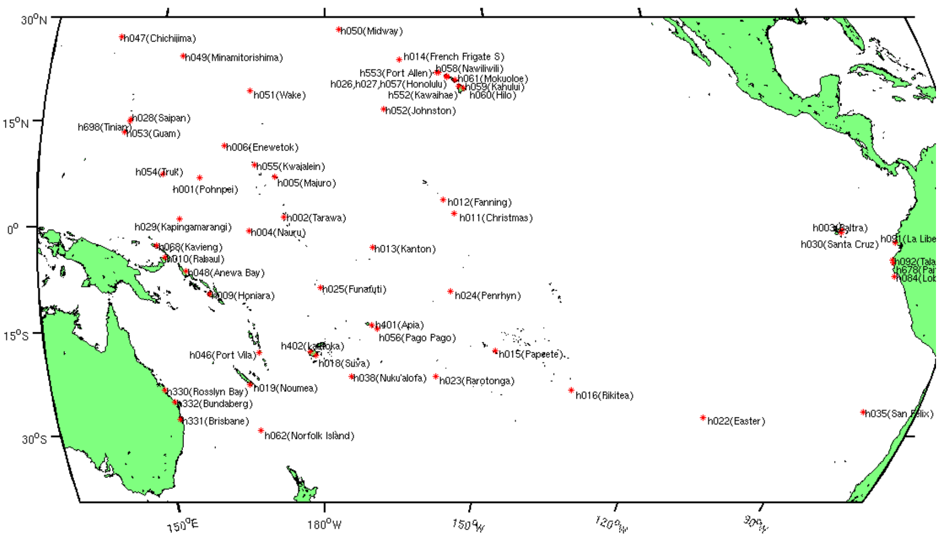
- **Estimate contributions from waves from a 'Limited Ensemble' of events**
- **Modelling at local scale ~10 m resolution**

1:

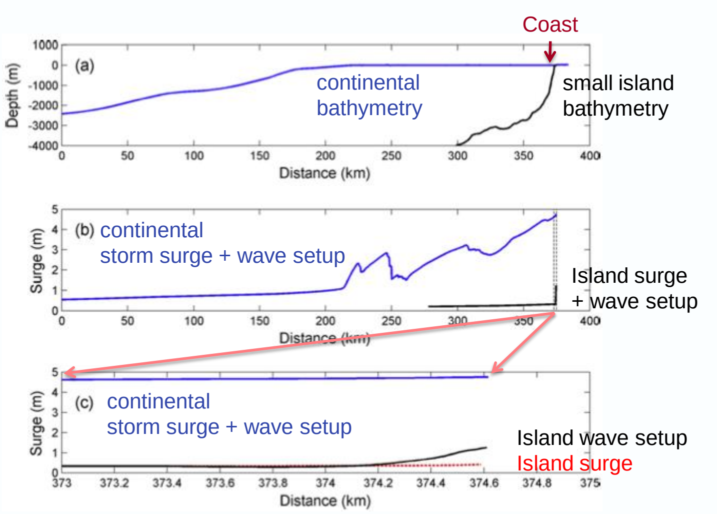
- **Use 'synthetic cyclone' + hydrodynamic model to simulate storm tides and estimate storm tide risk**
- **Modelling at national scale ~ 1 km resolution**

Extreme sea levels in small islands: Challenges

1. Tide gauge records are short in time and spatially sparse



Continent vs Island SL extremes



Source: Kennedy, et al. 2012, Oc. Mod.

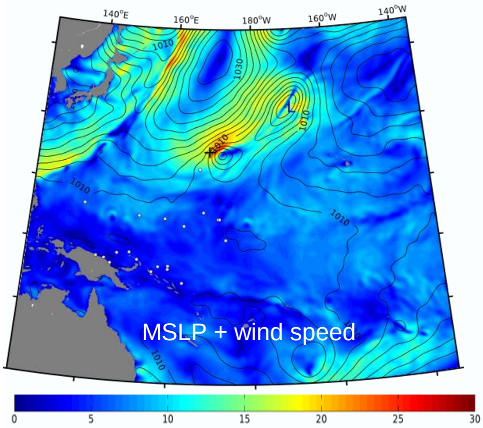
Extreme sea levels in small islands: Challenges

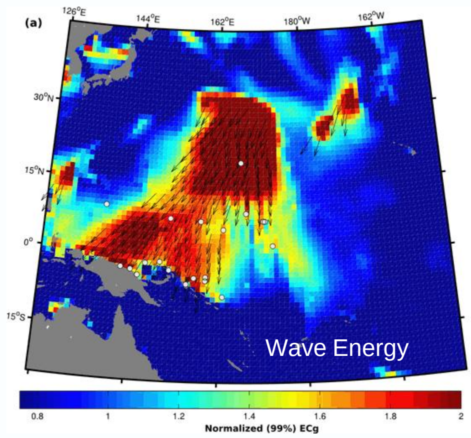
1. Tide gauge records are short in time and spatially sparse
2. Wind waves and swell can be a significant cause of extreme sea level inundation for steep shelved islands
3. Extreme waves are not necessarily caused by local storms

Swell wave-induced flooding affected islands across 6 Pacific nations in Dec 2008

Source: Hoeke et al, 2013:. Glob. Plan. Change

The cause was swell waves from a north Pacific storm ~4000 km away





Wave energy is about twice 99th percentile levels

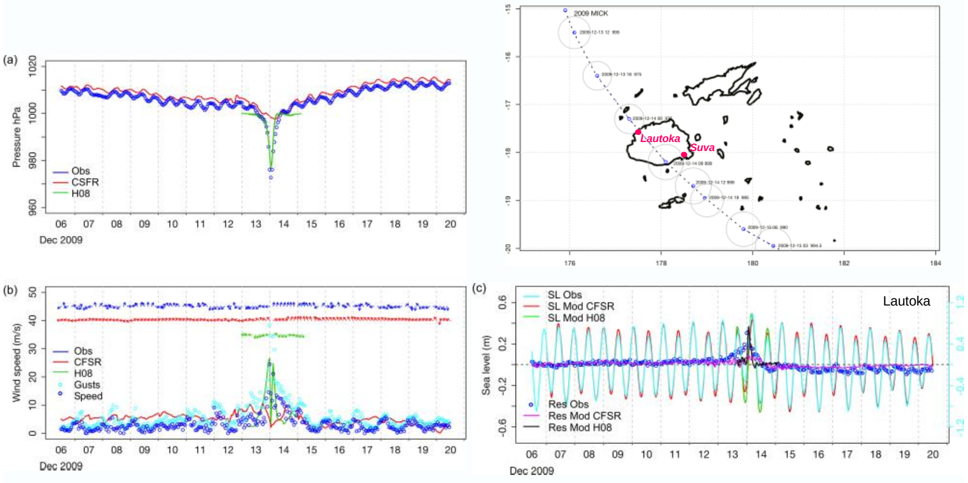
Extreme sea levels in small islands: Challenges

1. Tide gauge records are short in time and spatially sparse
2. Wind waves and swell can be a significant cause of extreme sea level inundation for steep shelved islands
3. Extreme waves are not necessarily caused by local storms
4. Wave extremes are rarely captured by tide gauges

In the context of tropical cyclone storm surges, we need methods to generate long records of extreme sea levels to estimate risk
$\Rightarrow$ synthetic cyclone generation

analytic cyclone models + hydrodynamic models

Modelling a coastal crossing cyclone using CFSR reanalysis and Cyclone Vortex Model-TC Mike, Fiji



Source: McInnes et al, Glob. Plan. Ch. 2014

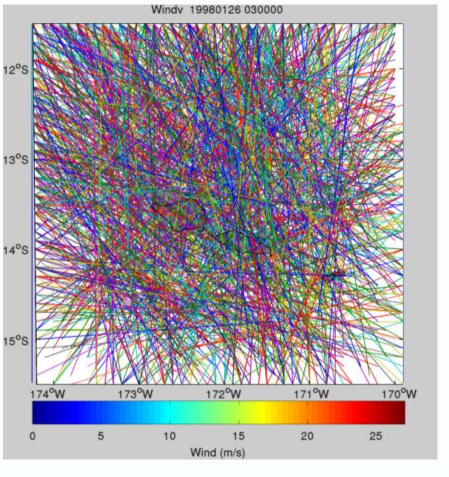
Synthetic cyclones are used for estimating storm tide risk from tropical cyclones

Use idealized wind and pressure fields from cyclone vortex model as forcing for hydrodynamic model

Develop PDFs of cyclone characteristics from historical cyclones in region

Generate 1000’s of plausible tropical cyclones for location of interest

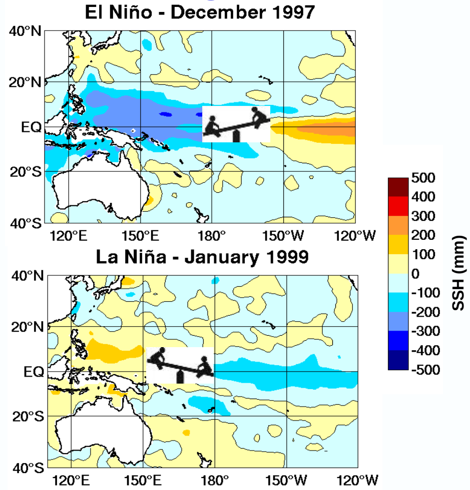
Use simulated storm tides to estimate extreme sea level return periods



Source: McInnes et al, Glob. Plan. Ch. 2014

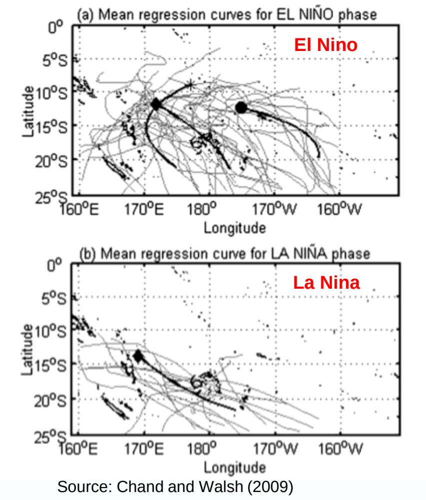
Synthetic cyclones used to investigate role of ENSO on extreme sea level risk

ENSO effect on regional sea levels



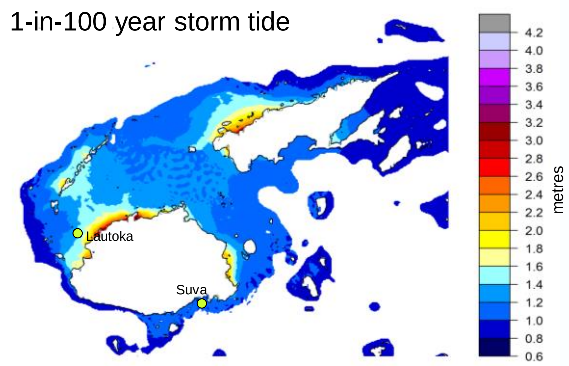
Courtesy: Neil White.

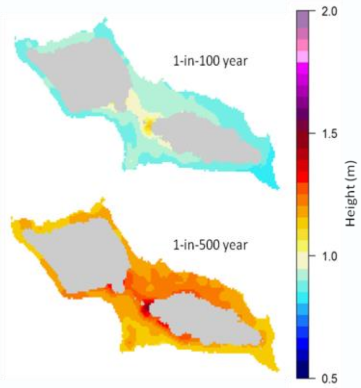
ENSO effect on tropical cyclones



Source: Chand and Walsh (2009)

Spatial maps of storm tide for Fiji and Samoa

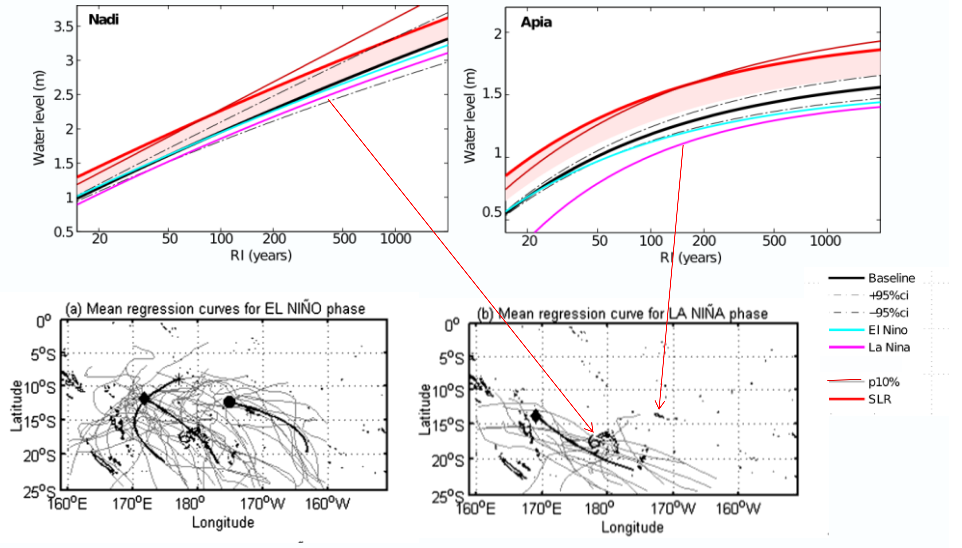




- Storm tide risk greater on northwest coastlines of the Fiji Islands
- Storm tide risk is more uniform around the coastline of Samoa

Source: McInnes et al, Glob. Plan. Ch. 2014

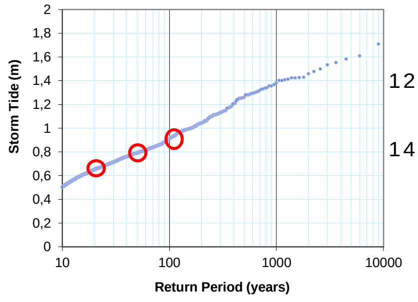
Storm tide return period curves – Fiji vs. Samoa

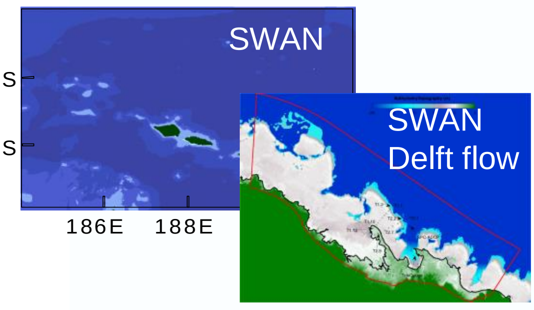


The Problem:
Assessing Design Heights for Coastal Infrastructure due to storm tides, waves and rising sea level

Example:
Redesign of the Samoa Parliament Complex Redevelopment Project (SPCRP).

'Limited Ensemble Approach'

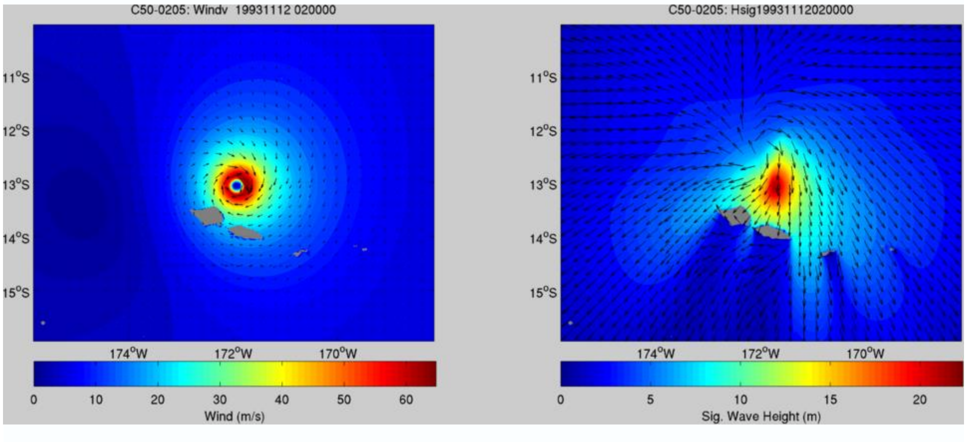




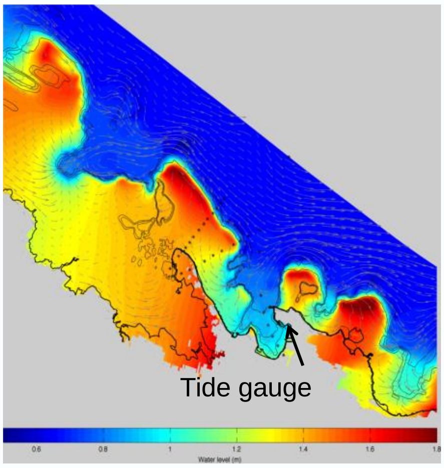
- From ranked storm tide events select a sample of events around the return periods of interest (100-y, 50-y, 20-y)
- Simulate at high resolution with wave and hydrodynamic models
- Models used: SWAN, Delft3D hydrodynamic model

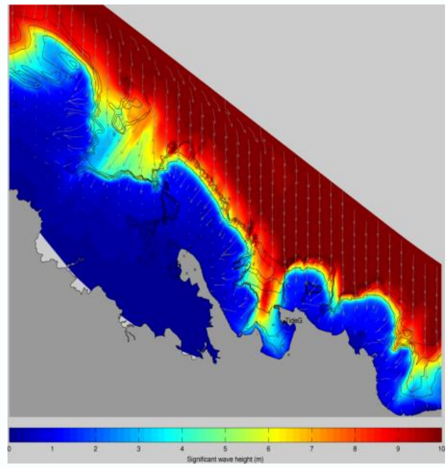
Source: Hoeke et al, 2014: CAWCR tech. rep.

Simulated wind fields → Simulated waves



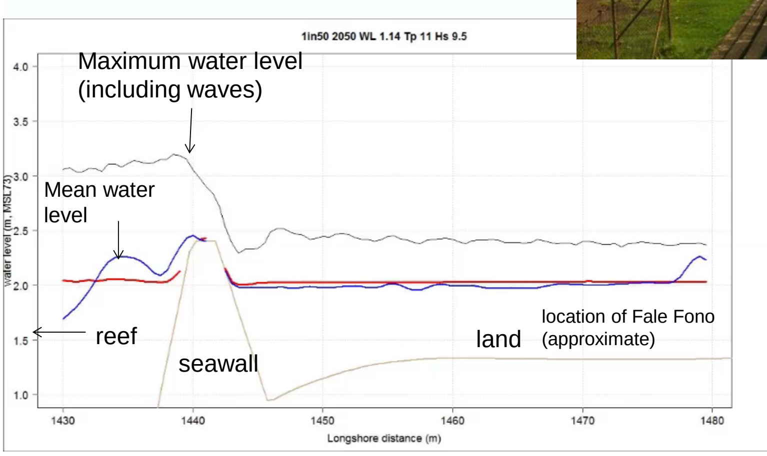
Simulated water levels ⟷ Simulated waves





- Offshore reefs strongly influence the total sea levels at the Peninsula due to wave setup. These are about 1 m higher than at the tide gauge

Wave runup and overtopping of the seawall is estimated using a phase resolving wave model (SWASH)



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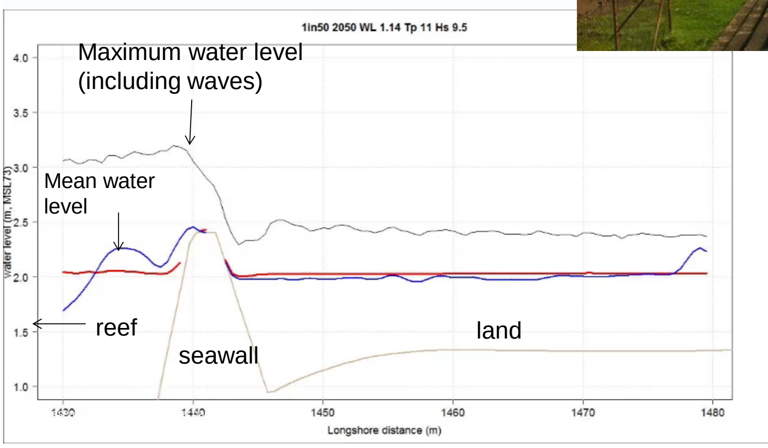
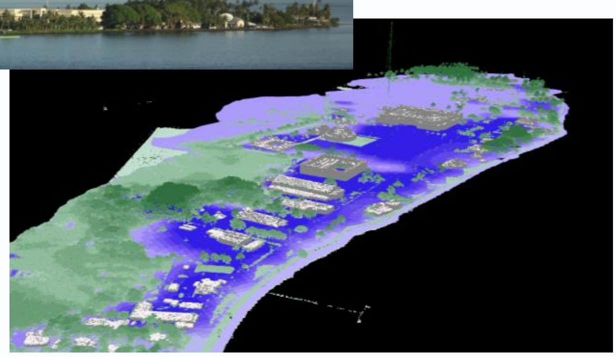


Peninsula - 1 in 100 year levels



Tide+surge (IBE+wind setup)+wave setup+ runup
best estimate of sea level is ~ 2.5 m in 1990
upper estimate of sea level is ~ 3.2 m in 1990
Compares with a 1-in-100 year tide+surge value (i.e. no waves) of 0.93 m

General points:

- Steep shelfed islands are extremely vulnerable to inundation from waves (both local storm- and remote swell-generated)
- Tide gauges rarely measure the occurrence of these events because they are typically located where wave effects are minimal (e.g. harbours)
- Therefore reliance on tide gauges for extreme sea level risk analysis may under-represent an important cause of inundation in small island nations
- Synthetic cyclone techniques combined with wave and hydrodynamic modelling provide a useful method for investigating extreme sea level risk and the effect of climate variability and change

Thank you

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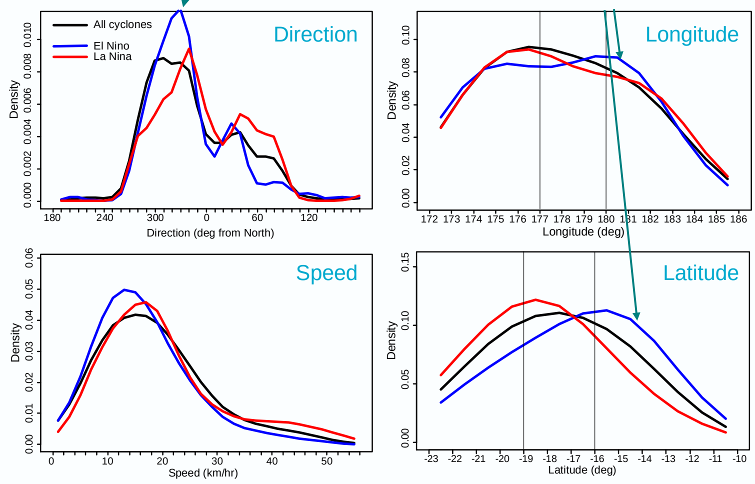
Cyclone tracks

TCs most commonly approach from NW

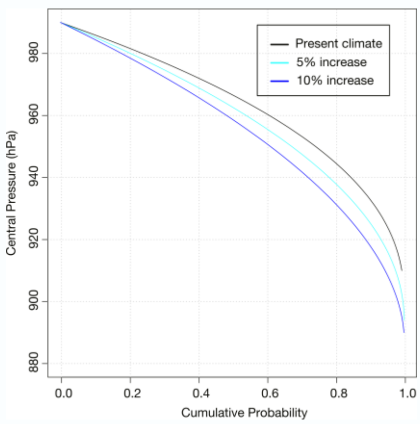
TC tracks are further north & east during El Nino



Cyclone intensity

Present: Lowest central pressure attained by each cyclone track while within 6° of Fiji was fitted to a Generalised Pareto Distribution.

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



Future:

Increase in wind speed	Mean/max pressure deficit change (hPa)
5%	4/6
10%	8/12