# CURRENT AND FUTURE TROPICAL CYCLONE RISK IN THE SOUTH PACIFIC


## COUNTRY RISK PROFILE: SOLOMON ISLANDS

JUNE 2013

- *The Solomon Islands have been affected by devastating cyclones on multiple occasions, e.g. 1986 Namu. The current climate average annual loss due to tropical cyclones represents about 0.85% of the country's GDP.*
- *End-of-century climate projections suggest a general decrease in losses from tropical cyclones compared to the current climate. Average annual losses are projected to decrease from 5.8 million USD to 5.7 million USD by mid-century and to 5.3 million USD by end-of-century, a decrease of 1.6% and 8.0%, respectively (2010 dollars).*
- *Larger reductions in losses are projected for more extreme events (> 100 year return period) by end-of-century.*
- *By 2100, losses from 1-in-250 year tropical cyclones are projected to decrease by 10.3%. However, in the worst case climate change scenario, losses could increase by 13.7%.*
- *The proportion of the population affected by future tropical cyclone risk is projected to decrease compared to the current climate.*
- *Maximum wind speeds produced by tropical cyclones in the Solomon Islands are projected to decrease slightly in the future climate.*

**Pacific Catastrophe Risk Assessment and Financing Initiative**
in collaboration with
**Pacific-Australia Climate Change Science and Adaptation Planning Program**

Australian AID

**BETTER RISK INFORMATION FOR SMARTER INVESTMENTS**

## PROJECT GOAL

Contributing to the third phase of the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), this project is supported by the Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Program with co-financing from the Global Fund for Disaster Risk Reduction. The primary goal of the project is to improve understanding of the risks posed by tropical cyclone hazards (winds, floods, and storm surge) to key assets in the Pacific region, under current and future climate scenarios. A clearer understanding of the current level of risk in financial terms - and the way that risk will change in the future - will aid decision makers in prioritising adaptation measures for issues such as land-use zoning, urban infrastructure planning, and ex-ante disaster planning.

## EXPOSURE AND POPULATION

The building assets considered in this study include residential, commercial, public and industrial buildings, while the infrastructure assets include major ports, airports, power plants, bridges and roads. The major crops in the Solomon Islands are coconut, oil palm, sweet potato and yam.

*Table 1: Summary of Population and Exposure in the Solomon Islands (2010)*

| | |
|---|---|
| Total Population | 547,500 |
| GDP Per Capita (USD) | 1,240 |
| Total GDP (million USD) | 678.6 |
| Total Number of Buildings | 169,112 |
| Number of Residential Buildings | 157,035 |
| Number of Public Buildings | 4,615 |
| Number of Commercial, Industrial, Other Buildings | 7,462 |
| Hectares of Major Crops | 83,955 |

As estimated and detailed in the previous phase of the project, the replacement value of all assets in the Solomon Islands is 3.5 billion USD of which about 87.5% represents buildings and 12% represents infrastructure. This study did not take into account future economic or population growth. Table 1 includes a summary of the population and exposure in the country.

## AIR TROPICAL CYCLONE MODEL

AIR has developed a South Pacific catastrophe parametric model to evaluate the tropical cyclone risk for 15 countries in the region. Historical data was used to build a stochastic catalogue of more than 400,000 simulated tropical cyclones, grouped in 10,000 potential realisations of the following year's activity in the basin. The catalogue provides a long-term view of tropical cyclone activity in the region. It was built to physically and statistically reflect the most credible view of current risk based on the historical record, including frequency, intensity and track evolution. The model estimates hazard (wind speeds and flooding levels) and damage (losses) for all events in the catalogue.

## CURRENT CLIMATE

The Solomon Islands are located south of the equator, just north of an area known for the frequent occurrence of tropical cyclones with damaging winds, rains and storm surge. The islands have been affected by devastating tropical cyclones on multiple occasions during the past few decades. For example, tropical cyclone Namu in 1986 claimed more than 100 lives and tens of thousands were left homeless. The storm caused massive landslides and flooding with severe damage to buildings, infrastructure and crops. Total losses amounted to between 30 and 60 million USD, which considerably set back the country's economic development.

The country's current tropical cyclone risk profile has been derived from an estimation of the direct losses to buildings, infrastructure and major crops, as caused by wind and flooding due to rain and storm surge. 'Losses' in this report refers to the direct costs needed to repair or replace damaged assets *plus* the emergency costs that governments may sustain as a result of providing necessary relief and recovery efforts (e.g. debris removal, setting up shelters for those made homeless, or supplying medicine and food). The average expected losses per calendar year are referred to as the *Average Annual Loss* or *AAL* (see Appendix). The current climate AAL value is 5.8 million USD. The percentage distribution for the different assets considered is shown in Figure 1.

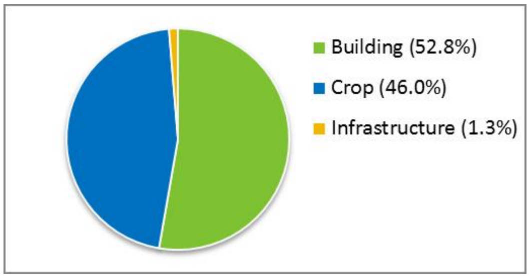


*Figure 1: Contribution to total Average Annual Loss (AAL) from the three types of assets considered*

The model also estimates losses from stronger and more damaging tropical cyclones that are such as 50, 100 and 250 year return period (RP) events. The current losses from such events are: 44.5 million USD (50 year RP), 63.9 million USD (100 year RP) and 101.5 million USD (250 year RP), respectively.

## FUTURE CLIMATE

As part of the project, Geoscience Australia (GA) analysed general circulation model outputs from a total of 11 different Global Climate Models (GCMs), from two successive generations of GCM experiments referred to as CMIP3 and CMIP5. The models in the two frameworks are forced by different emission scenarios: the A2 scenario[1] for CMIP3 models and the RCP 8.5 scenario[2] for CMIP5 models. Both A2 and RCP 8.5 represent high emission scenarios.

Results from the latest generation CMIP5 models, for which no dynamical downscaling was required, indicate these models tend to perform better at replicating tropical cyclone behaviour in the current climate, especially in the Southern Hemisphere. More confidence should be placed in the results from the CMIP5 framework. The results outlined in the following sections are based on the CMIP5 models.

The Mean Estimate reflects results obtained after averaging output over all five models under the same climate framework. Figure 2 displays the relative frequencies for different storm categories, for both current and Mean Estimate future climates.

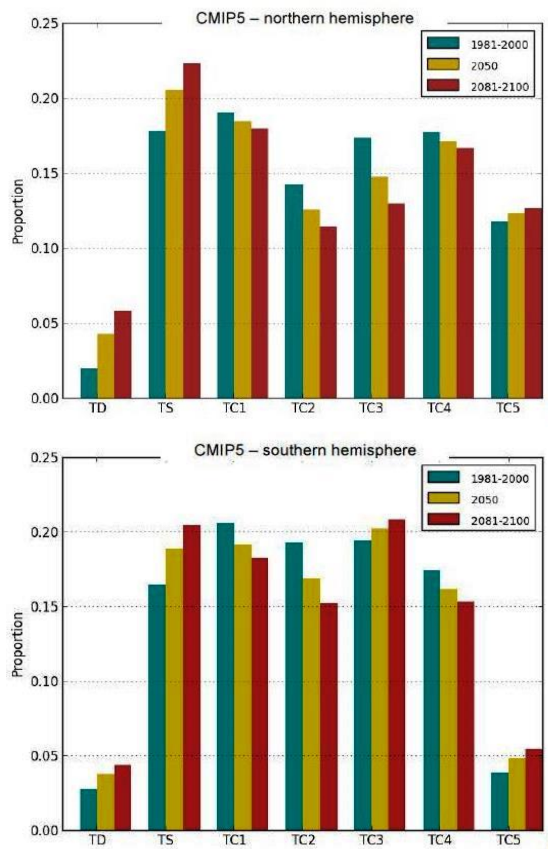


*Figure 2: Mean Estimate relative proportion of TC intensity – multi model ensemble for CMIP5 models in the Northern and Southern Hemispheres. Classification is based on central pressure using a Cp-based Saffir-Simpson Hurricane Intensity Scale*

[1] http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=98
[2] http://link.springer.com/content/pdf/10.1007%2Fs10584-011-0148-z.pdf

For both hemispheres, there is an expected future increase in the relative frequency of tropical depressions, tropical storms, and category 5 storms and a general decrease in the number of storms in the other categories. Most notable is the increase in category 5 storms (and category 3 storms in the southern hemisphere) which may have a measurable impact on observed losses in the region. There is also a slight equatorward movement of tropical cyclone tracks in the northern hemisphere and poleward movement of tropical cyclone tracks in the southern hemisphere.

### *Future loss projections*

Of the five individual models analysed, generally three models suggest increases in losses and two models suggest decreases. The significant divergence in the individual model results indicates a large range of model estimates.

Figure 3 shows end-of-century individual model projections for Exceedance Probability (EP – see Appendix) (blue) along with the current climate EP (green).

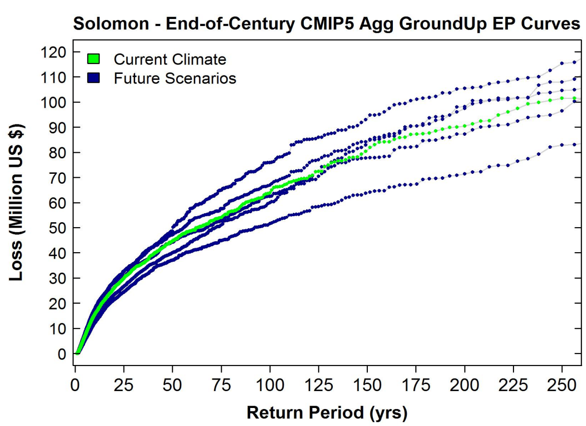


*Figure 3: End-of-century EP-curves for individual CMIP5 models compared to the current climate EP-curve (green curve)*

Any analysis of future model projections should consider estimates of the ensemble mean (the 'Mean Estimate' of all models), the full range of model results, and the worst case climate change scenario. The individual model that projects the greatest increase in losses as compared to the current climate defines the worst case scenario for the country.

There is a consistent decrease in projected losses from tropical cyclones across all return periods. Figure 4 contrasts end-of-century Mean Estimate projections with current climate. Larger loss decreases are observed for high and low frequency events.

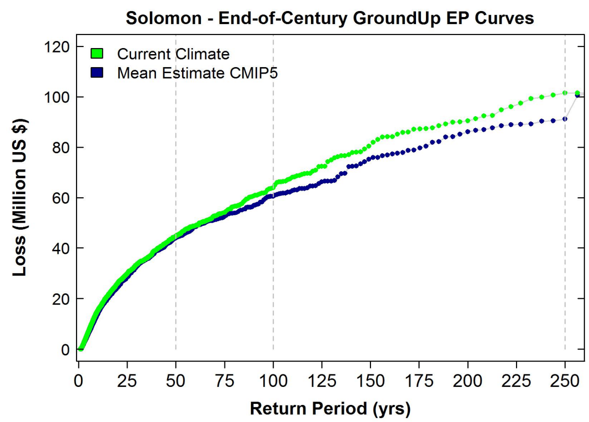


*Figure 4: End-of-century EP-curve for the future Mean Estimate (blue curve) compared to the current climate EP-curve (green curve)*

The 250-year return period future Mean Estimate suggests a decrease in losses of 0.3% compared to the current climate. One in-50 and 1-in-100 year events are also projected to experience reduced losses by 2100. However, the worst case climate change scenario (most upper curve in Figure 3) for the most extreme (250-year return period) tropical cyclones suggests an increase of 13.7%.

*Table 2: Loss estimates (USD) for current climate and future end-of-century Mean Estimate and worst case scenario*

| CMIP5 (Total Loss) | AAL | 50yr RP | 100yr RP | 250yr RP |
|---|---|---|---|---|
| Current Climate | 5,787,335 | 44,470,128 | 63,889,725 | 101,527,242 |
| Future Mean Estimate | 5,326,316 | 43,971,496 | 60,612,589 | 91,121,590 |
| Future Worst Case | 6,540,290 | 48,553,154 | 75,982,885 | 115,424,118 |

Table 2 contrasts current climate losses with the future Mean Estimate and worst case climate change scenario estimate across different return periods. The worst case scenario consistently projects significant loss increases when compared to the current climate across all return periods considered as well as the AAL.

### *Mid-century v End-of-century future loss projections by different assets*

Projected future losses from tropical cyclones were examined for mid-century and end-of-century across different assets (buildings, infrastructure, crops and population). The modeling of tropical cyclones under a future climate generally indicates a decrease in Mean Estimate future losses compared to the current climate. The total AAL decreases from 5.8 million USD to 5.7 million USD by mid-century, and to 5.3 million USD by end-of-century, a reduction of 1.6% and 8.0%, respectively.

Table 3 contrasts the AAL and the 50, 100 and 250 year RP losses from the current and future climates, for both 2050 and 2100 time periods, across the different assets at risk. The total loss represents the sum of the building, infrastructure and crop AALs.

All assets generally observe decreases in losses. The largest decreases tend to occur for infrastructure while the smallest changes are observed for crops, across different return periods. Slightly fewer people are likely to be affected (in terms of fatalities and casualties) by future tropical cyclone risk than under the current climate.

Note that no adjustment to account for future economic or population growth was considered for any of the assets.

*Table 3: Percent changes between future climate loss projections for mid-century and end-of-century, and the baseline, for different return periods, by different assets. Baseline loss numbers are expressed in USD*

| Mean Estimate | | AAL | 50yr RP | 100yr RP | 250yr RP |
|---|---|---|---|---|---|
| Total Loss | Current Climate | 5,787,335 | 44,470,128 | 63,889,725 | 101,527,242 |
| | Future 2050 (%) | -1.6 | -4.6 | -5.6 | -5.3 |
| | Future 2100 (%) | -8.0 | -1.1 | -5.1 | -10.2 |
| Building | Current Climate | 3,053,304 | 25,552,151 | 42,551,000 | 75,042,824 |
| | Future 2050 (%) | -2.3 | -8.3 | -10.5 | -3.3 |
| | Future 2100 (%) | -8.7 | -2.6 | -7.0 | -12.0 |
| Infra-structure | Current Climate | 72,524 | 423,641 | 1,240,795 | 3,632,290 |
| | Future 2050 (%) | +0.1 | -26.7 | -13.8 | -6.9 |
| | Future 2100 (%) | -12.1 | -18.7 | -8.4 | -0.8 |
| Crop | Current Climate | 2,661,507 | 21,184,878 | 26,636,139 | 34,585,774 |
| | Future 2050 (%) | -0.8 | +2.8 | +0.1 | -3.7 |
| | Future 2100 (%) | -7.1 | -1.9 | -4.9 | -2.4 |
| Population Affected | Current Climate | 63 | 489 | 691 | 1,019 |
| | Future 2050 (%) | -1.9 | -4.9 | -6.4 | -2.6 |
| | Future 2100 (%) | -7.5 | -1.4 | -6.1 | -3.4 |

### *Wind, flood and surge contributions to total loss estimates*

The analysis captures the effects of three hazards associated with tropical cyclones: strong winds, precipitation-induced flooding and coastal flooding due to storm surge. Tropical cyclone winds can be very destructive and in most cases they are the main cause of damage and subsequent losses.

Unlike the wind, which decreases in intensity as the storm moves inland, the intensity of storm-related precipitation and accumulated runoff can increase in inland regions and consequently also lead to significant damage to property.

The storm surge represents the sea water forced ashore due to the rise in sea level accompanying any approaching storm of intensity. A significant storm surge event can have devastating effects on-shore. Both sea level and precipitation changes under future climates are not considered in this study.

The main contributors to building loss are wind and flood with a minor contribution from storm surge. Conversely, the main contributor to the infrastructure total loss is wind, with a minor storm surge contribution and no flood contribution.

Figure 5 explores the *relative changes* in contributions to total loss split by hazard between the current and the Mean Estimate future climates.

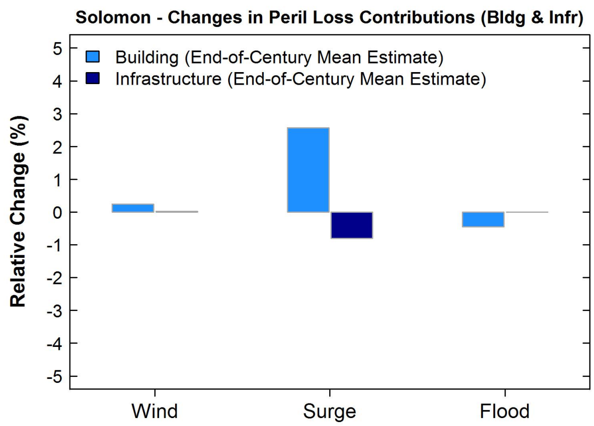


*Figure 5: Percent changes between the end-of-century future climate and the current climate for Wind, Surge and Flood loss contributions to total loss, for buildings (light blue) and infrastructure (dark blue)*

There are no notable changes in the loss contributions across all hazards. Wind remains the main contributor to infrastructure loss, while wind and flood remain the dominant sources of loss for buildings.

### *Wind hazard maps for end-of-century climate compared to current climate*

The wind hazard decreases slightly for the 100 year return period under future climate, as shown in Figure 6. The 100-year return period winds, which represent an event that has a 40% chance of being equalled or exceeded once in 50 years, are capable of generating severe damage to buildings, infrastructure, and crops with consequent large economic losses.

Figure 6 depicts the end-of-century 100 year mean RP wind speed, expressed as maximum 1-minute sustained winds in km/h, for the current climate (top panel) and future projection (bottom panel). For example, for Honaira, the 100 year RP wind speed decreases from 111.2 km/hr to 110.6 km/hr by the end of century. The wind level changes are less dramatic than the changes in total losses, because a small change in wind speed can result in significantly larger damage costs.

The current climate wind patterns in the Solomon Islands are generally maintained under future climate projections (e.g. higher winds are exhibited on the islands to the south-east).

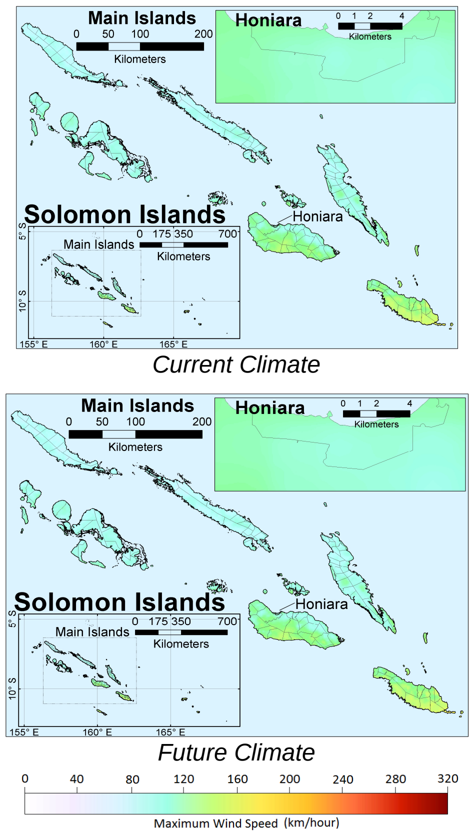


*Figure 6: 100 year mean return period winds (maximum 1-minute sustained winds in km/h) for the current climate (top panel) and the future climate (bottom panel)*

## SUMMARY

The evaluation of the current and future climate tropical cyclone risk in the South Pacific region was carried out using Geoscience Australia's analysis of tropical cyclone activity along with AIR's catastrophe model developed specifically for the region. The risk model allows for the translation of the climate change induced effects observed in the frequency, intensity and path of tropical cyclones into direct loss results for the region and individual countries.

For both hemispheres, numerical models predict a future increase in the relative frequency of tropical depressions, tropical storms, and category 5 storms and a general decrease in the number of storms in the other categories (Figure 2). Most notable is the regional increase in category 5 storms.

The financial impacts are measured using metrics such as the Average Annual Loss (AAL) or the 100 year return period loss. For planning purposes, it is useful to understand both average annual losses as well as possible losses from extreme events.

The Mean Estimate (Table 3) suggests decreased future losses compared to the current climate. Larger decreases in losses are projected for high and low frequency events (Figure 4).

At high return periods (250 RP) the future Mean Estimate suggests a reduction in losses from tropical cyclones of 10.3% compared with the current climate, while the worst case scenario suggests an increase in loss of 13.7% (Table 2).

The proportion of the population affected by future tropical cyclone risk decreases compared to the current climate.

The main contributors to total losses to buildings are wind and flood with a minor contribution from storm surge. Conversely, the main contributor to infrastructure loss is wind. There are reported minimal future changes in different hazards' contributions to total loss (Figure 5). Hence, wind remains the main contributor to infrastructure loss, while wind and flood remain the dominant sources of loss for buildings.

The end-of-century Mean Estimate projects slightly lower winds compared to the current climate (Figure 6). The current climate general wind hazard patterns are maintained across the country.

Models from both the CMIP3 and CMIP5 global climate model runs were analysed in this project. The CMIP5 models demonstrated greater skill and performance in replicating current climate conditions, and reporting of damage and loss has therefore focused on results from the CMIP5 framework.

There is consistent divergence, in the resulting EP-curves for individual models under the same framework (Figure 3) indicative of significant model uncertainty. The mean changes in future losses compared to the baseline are too small to be considered statistically significant when measured against the range of model estimates.

There is also the uncertainty associated with the risk model itself that needs to be accounted for. A statistical quantification of the uncertainty around each estimated EP-curve reveals that the separation between the baseline and the future projection is not large enough to be considered statistically significant.

## APPENDIX

### *Classification of tropical cyclones*

A tropical cyclone represents an atmospheric low-pressure system with a spiral arrangement of thunderstorms that produce strong winds and heavy rain. The table below describes the categorisation of storms based on maximum sustained winds and minimum central pressure as used in this study.

| Classification | 1-minute sustained wind speed (km/h) | Minimum central pressure (hPa) |
|---|---|---|
| Tropical Depression (TD) | <=62 | >=1005 |
| Tropical storm (TS) | 63-118 | 1005-995 |
| Category 1 (TC1) | 119-153 | 995-980 |
| Category 2 (TC2) | 154-177 | 980-965 |
| Category 3 (TC3) | 178-208 | 965-945 |
| Category 4 (TC4) | 209-251 | 945-920 |
| Category 5 (TC5) | >=252 | <920 |

### *Definition of key metrics used to describe future risk changes*

Several key metrics are utilised in order to evaluate the change in losses/risk between the current climate and the future climate: Average Annual Loss (AAL), Return Period (RP) Loss, Exceedance Probability (EP) curve.

- Average Annual Loss (AAL). AAL represents the sum of all losses observed in the domain divided by all realisations of next-year activity (10,000 years); AAL thus refers to the average loss that can be expected to occur per year.
- Return period (RP) loss. The X-year return period loss is the loss that can be expected to occur or be exceeded on average once every X years. Highlighted for this analysis are the 50 year (2.0% exceedance probability), 100 year (1.0% exceedance probability) and 250 year (0.4% exceedance probability).
- Exceedance Probability curve (EP-curve). An EP-curve represents the probability curve that various levels of loss will be exceeded. By inverting the exceedance probability to obtain corresponding return periods, the EP-curve then represents the various levels of loss associated with different return period events. An EP-curve is obtained by sorting all losses largest to smallest observed over a domain, assigning a rank to all entries (1 being the largest loss, 2 being the second largest loss etc.), and then dividing the ranking by the total number of years (10,000).

### *Loss and damage*

The 'losses' referred to in this report represent the 'damages'; (i.e., the direct ground up-losses before the application of insurance (zero deductible)), plus an estimation of the emergency losses (i.e., debris removal, setting up shelters for those made homeless, or supplying medicine and food). All estimates of current and future losses in this report are in 2010 dollars.

Australian Government

With financial support from the European Union
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