Climate Risk Profile for Samoa

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Summary

The likelihood (i.e. probability) components of climate-related risks in Samoa are evaluated for both present day and future conditions. Present day conditions are described using data for Apia and, for some parameters, Afiamalu. Anticipated changes over time reflect the influence of global warming.

The risks evaluated are extreme rainfall events (both six-hourly and daily), drought, high sea levels, extreme winds and extreme high air and water temperatures.

Projections of future climate-related risk are based on the output of global climate models, for a range of emission scenarios. All the likelihood components of the climate-related risks show increases as a result of global warming, though for some the increases are small relative to the uncertainties.

Best estimates of long term, systematic changes in the average climate for Samoa indicate that by 2050 sea level is likely to have increased by 36 cm, rainfall by 1.2%, extreme wind gusts by 7% and maximum temperatures by 0.7 C.

The observed long term trend in relative sea level for Apia is 5.2 mm/yr. But maximum hourly sea level is increasing by approximately 8 mm/yr, a rate far in excess of the observed local and global trends in mean sea level. For Apia an hourly sea level of 1.8 m above mean sea level is currently a 100-year event. It will likely be at least a four-year event by 2025.

No significant long term trends are evident in the observed daily, monthly, annual or maximum daily rainfall. Currently a daily rainfall of at least 300 mm is a relatively rare event in Apia, with a return period of 10 years. There is large uncertainty in the rainfall projections, with two models suggesting substantial increases in rainfall, one model suggesting only small increases, and one model indicating a large decrease in rainfall into the future. An extreme daily rainfall of 400 mm is currently a 41-year event. It will likely be a 38-year event by 2050. An extreme six-hourly rainfall of 200 mm is currently a 30-year event. It will likely become a 20-year event by around 2050.

A monthly rainfall below the ten percentile is used as an indicator of drought. Drought frequency is strongly linked to the occurrence of El Niño events. Six global climate models that were best out of 19 at simulating present day ENSO conditions show no significant changes toward El Niño-like conditions in the latter part of the current century. Therefore it is not yet possible to make any predictions about the future nature of El Niño events and the implications for the frequency, duration and intensity of droughts in Samoa.

Currently an extreme wind gust of 70 kt at Apia has a return period of 75 years. This will reduce to approximately 40 years by 2050.

There is relatively high confidence in projections of maximum air temperature. A maximum air temperature of at least 35 C is a relatively rare event at Apia, with a return period of approximately 20 years. By 2050 it will likely have a return period of 9 years

Introduction

Formally, risk is the product of the likelihood (i.e. probability) of an event or happening, normally referred to as a "hazard", and the consequence of that hazard.

While the consequence component of a climate-related risk will be site or sector specific, in general the likelihood component of a climate-related risk will be applicable over a larger geographical area, and to many sectors. This is due to the spatial scale and pervasive nature of weather and climate. Thus the likelihood of, say, an extreme climate event or anomaly, is often evaluated for a country, state, small island or similar geographical unit. While the likelihood may well vary within a given unit, there is often insufficient information to assess this spatial variability, or the variations are judged to be of low practical significance.

This climate risk profile (CRP) is based on observed data for Apia (Latitude 13 80 S; Longitude 171 77 W) and, for some variables, Afiamalu (Latitude 13 90 S; Longitude 171 77 W). The cooperation and assistance of other staff of the Meteorology Division, Ministry of Natural Resources, Environment and Meteorology, Government of Samoa, and of the National Tidal Centre, Australian Bureau of Meteorology is acknowledged with gratitude. While data for Apia and Afiamalu cannot characterize the climate conditions for all of Samoa, they do provide a general indication of current climate risks facing the country. The CRP can also be extended by analysing data from additional locations in Samoa.

Future changes in climate are based on the output of GCMs, and are for a grid square covering a large portion of Upolu and adjacent areas. The climate projections are therefore more reflective of changes for the country as a whole, rather than just the Apia and adjacent areas.

The following hazards are considered to be among the potential sources of climate-related risk:

- extreme high rainfall events;
- drought;
- high sea levels;
- damaging winds; and
- extreme high air temperatures.

Methods

Preparation of a CRP for a given geographical unit involves an evaluation of current likelihoods of all relevant climate-related risks, based on observed and other pertinent data.

Future changes in risk are estimated using the outputs of selected GCMs[1] run for a range of greenhouse gas emission scenarios (Figure 1). Table 1 lists the combination of models and emission scenarios on which the CRP is based.

Differences in the climate projections give rise to uncertainties in the estimated values of future climate risks. There are numerous sources of uncertainty in projections of the likelihood components of climate-related risks. These include uncertainties in greenhouse gas emissions as well as in modelling the complex interactions and responses of the atmospheric and ocean systems. Policy and decision makers need to be cognizant of uncertainties in projections of the likelihood components of extreme events.

Best estimates of future risk levels are based on an average of the estimates using a multi model and emission scenario ensemble. The range in uncertainty is determined using a model and emission scenario combination that produces the maximum and minimum rate of change in future risk levels.

Estimates of future changes in the frequency of drought use the daily data generated by the Canadian Climate Centre GCM (CGCM).

[1] Hadley Centre (United Kingdom) , Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO), Japan’s National Institute for Environmental Science (NIES), the Canadian Climate Centre GCM (CGCM) and the Goddard Fluid Dynamics Laboratory (GFDL).

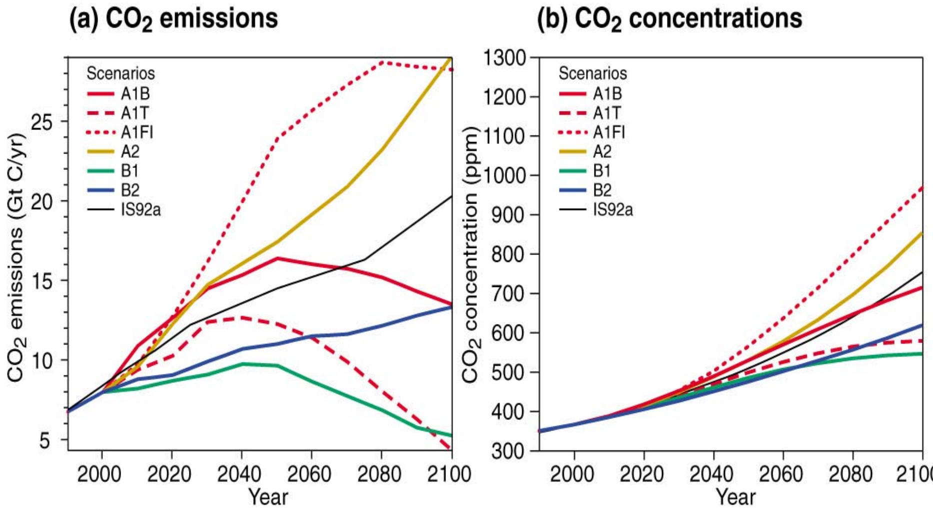

Figure 1 Scenarios of CO_2 gas emissions and consequential atmospheric concentrations of CO_2 (from IPCC, 2001).

Table 1

Available Combinations of Global Climate Models and Emission Scenarios[1]

	CGCM[2]	CSIRO	Hadley	NIES	GFDL	See Text
A1B	T, P, S	T, P, S	T, P, S	T, P	S	W
A1F	T, P, S	T, P, S	T, P, S	T, P	S	W
A1T	T, P, S	T, P, S	T, P, S	T, P	S	W
A2	T, P, S	T, P, S	T, P, S	T, P	S	W
B1	T, P, S	T, P, S	T, P, S	T, P	S	W
B2	T, P, S	T, P, S	T, P, S	T, P	S	W

[1] T = temperature, P = precipitation, S = sea level, W = wind
[2] In addition to monthly data, daily data are available for this model, but for the A2 and B2 emissions scenarios only.

Data Specifications and Terminology

The *return period* (sometimes referred to as the *recurrence interval*) is used as a measure of the likelihood of an extreme event. The *return period* is a statistical estimate of how often an extreme event of a given magnitude is likely to be equalled or exceeded. Thus the "hundred-year event" is one which will, on average, be equalled or exceeded once in any hundred-year period. It does not mean that that the event occurs every hundred years. In fact, in every year there is a 1 percent chance that an event with a 100 year return period will occur.

Sea Level

a) Current Risks Levels

Figure 2 shows daily mean values of sea level for Apia, relative to mean sea level. There are large interannual variability and extremes (both high and low) in sea level, as well as a long term trend of increasing sea level. The observed long term trend in sea level for Apia is

5.2 mm/yr. This is greater than the estimated range of global sea-level rise over the past century, namely 1 to 2 mm/yr.

The National Tidal Centre, Australian Bureau of Meteorology reports a 3.7 mm/yr increase in relative sea level at Apia for the period of record, after vertical movements in the observing platform and the inverted barometric pressure effect have been taken into account.

Even more extreme high sea levels are evident in the mean hourly sea level data. Figure 3 presents the maximum mean hourly sea level, by year, for Apia. Such exceptionally high sea levels are associated with flooding, accelerated coastal erosion and salt water intrusion into groundwater. Extreme high sea levels associated with El Niño events are clearly evident. The long term trend in the extreme hourly sea levels is 8.2 mm/yr. This is substantially greater than the trend for the daily mean sea level. An hourly sea level of 1.7 m above mean sea level is a relatively rare event for Apia, with a return period of approximately 40 yr (Figure 4 and Table 2).

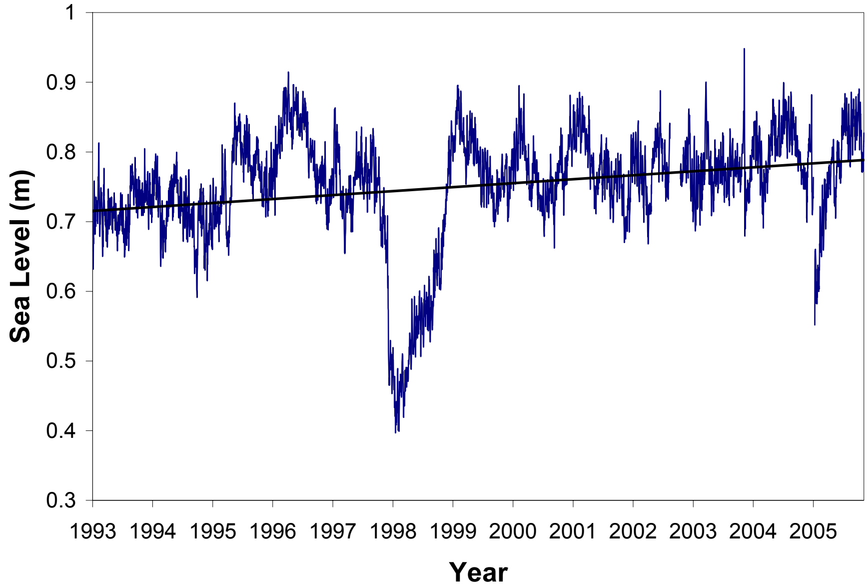

Figure 2 Daily sea level for Apia (1993 to 2005), relative to mean sea level. Also shown is the linear trend in sea level over the same period (5.2 mm/yr).

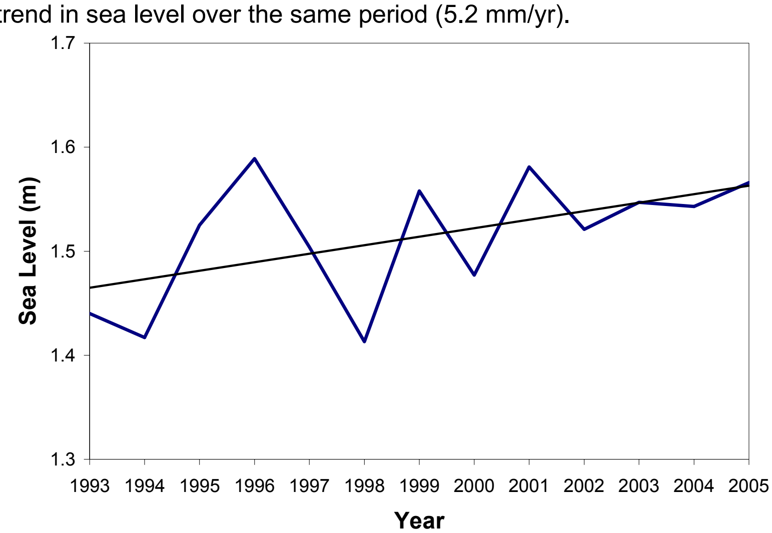

Figure 3 Maximum hourly sea level, by year, for Apia (1993 to 2005). Also shown is the linear trend in sea level over the same period (8.2 mm/yr).

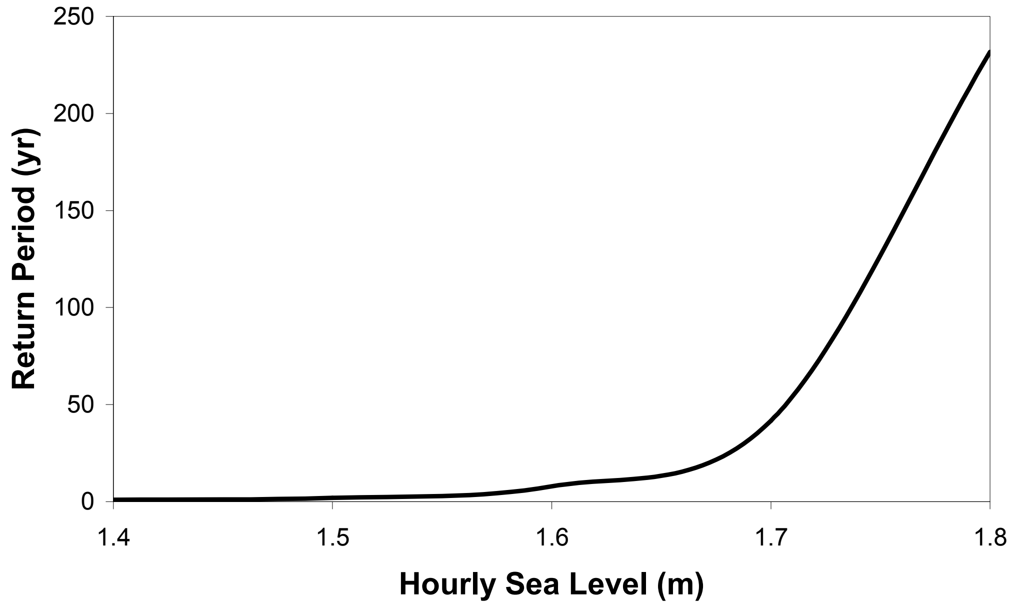

Figure 4 Relationship between hourly sea level and return period for Apia, based on observed hourly sea level for 1993 to 2005.

Table 2

Return Periods (yr), for Hourly Sea Level (m) at Apia

Sea Level (m) of at Least	Observed	2025	2050	2075	2100
1.4	1	1	1	1	1
1.5	1.9	1	1	1	1
1.6	7.8	1	1	1	1
1.7	42	2	1	1	1
1.8	232	8.6	1.1	1	1
1.9	1300	46	3	1	1
2.0	7300	254	14	1.2	1

b) Projected Risk Levels

Best estimates of future sea-level rise are based on an average of the estimates using a multi model and emission scenario ensemble (see Table 1). Figure 5 shows the best estimate of mean sea level out to 2100, as well as the band of extreme uncertainty. The latter is estimated using the highest and lowest estimates of sea-level rise for all model and emission scenario combinations.

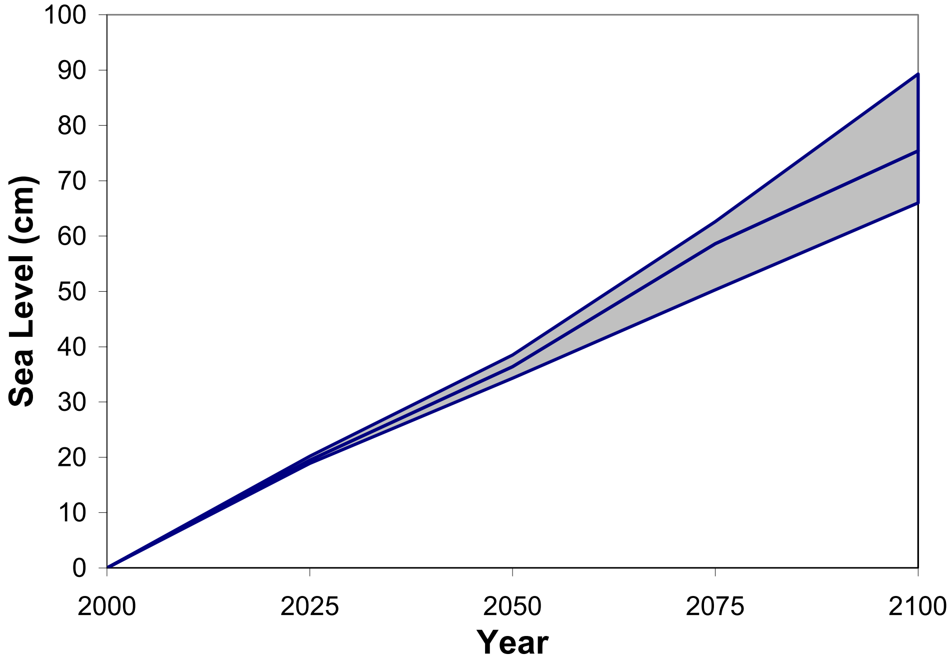

Figure 5 Best estimate of projected increase in mean sea level for Apia, along with the uncertainty envelope as given by the maximum and minimum estimates using all possible combinations of the available global climate models and emission scenarios.

As indicated in Figure 6 and Table 2, global warming will also have a significant impact on the return periods of extreme high sea levels that persist for at least an hour. For example a sea level 175 cm is currently a 100-year event. It will likely be a 4-year event by 2025. Figure 6 also shows the low level of uncertainty in future projections of sea level extremes.

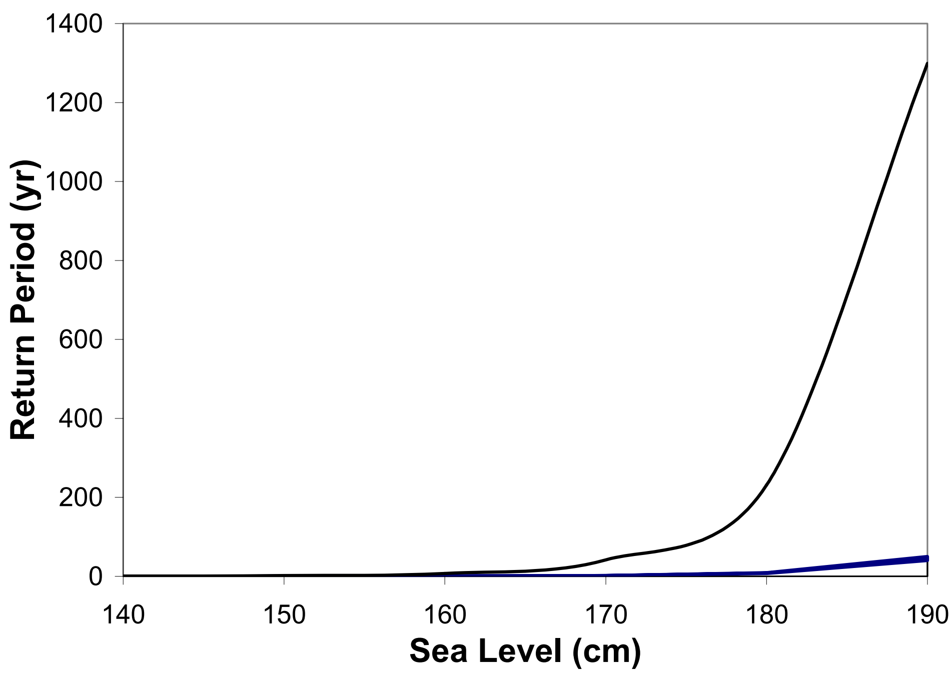

Figure 6 Relationship between hourly sea level and return period for Apia, for present day (black line) and 2025 (blue lines). The uncertainty envelope shows the maximum and minimum estimates of return periods for 2025, based on all possible combinations of the available global climate models and emission scenarios.

Daily Rainfall

a) Current Risks Levels

Figure 7 shows daily rainfall for Apia. High variability, including extremes, is readily apparent. This is also the case for the longer term monthly and annual rainfall data (Figures 8 and 9, respectively). No significant long term trends are evident in any of the three time series.

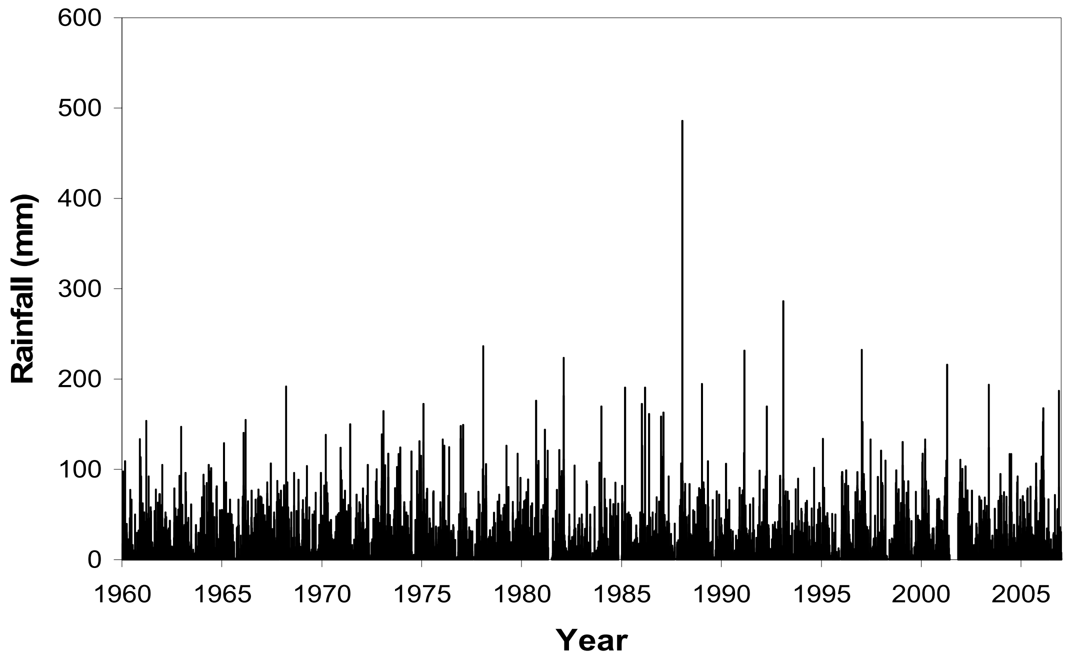

Figure 7 Daily rainfall for Apia (1960 to 2006).

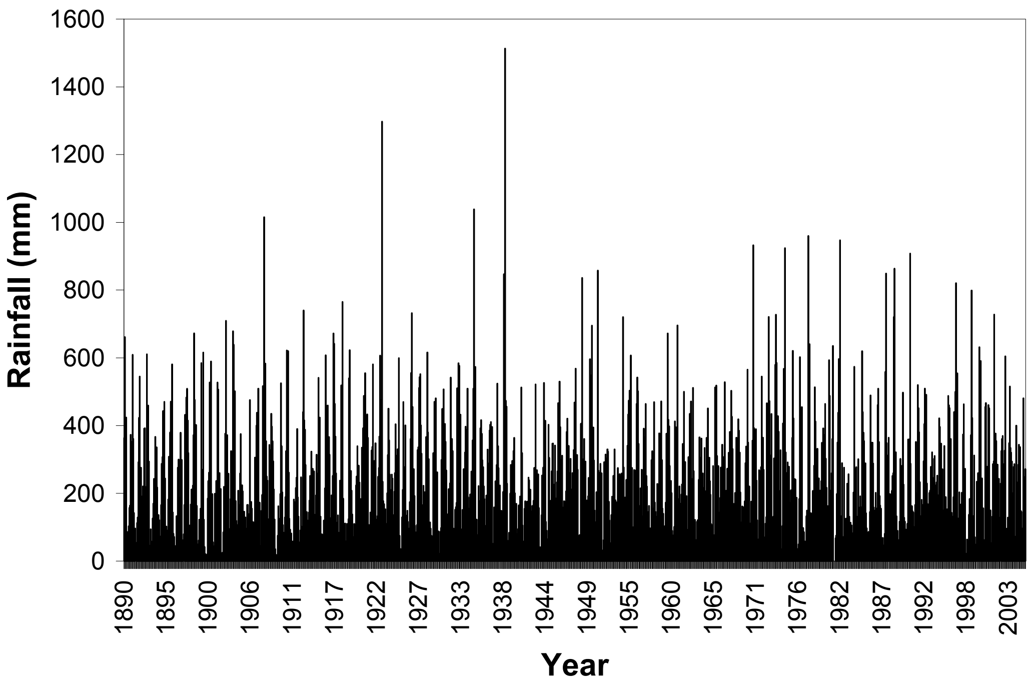

Figure 8 Total monthly rainfall for Apia (1890 to 2005).

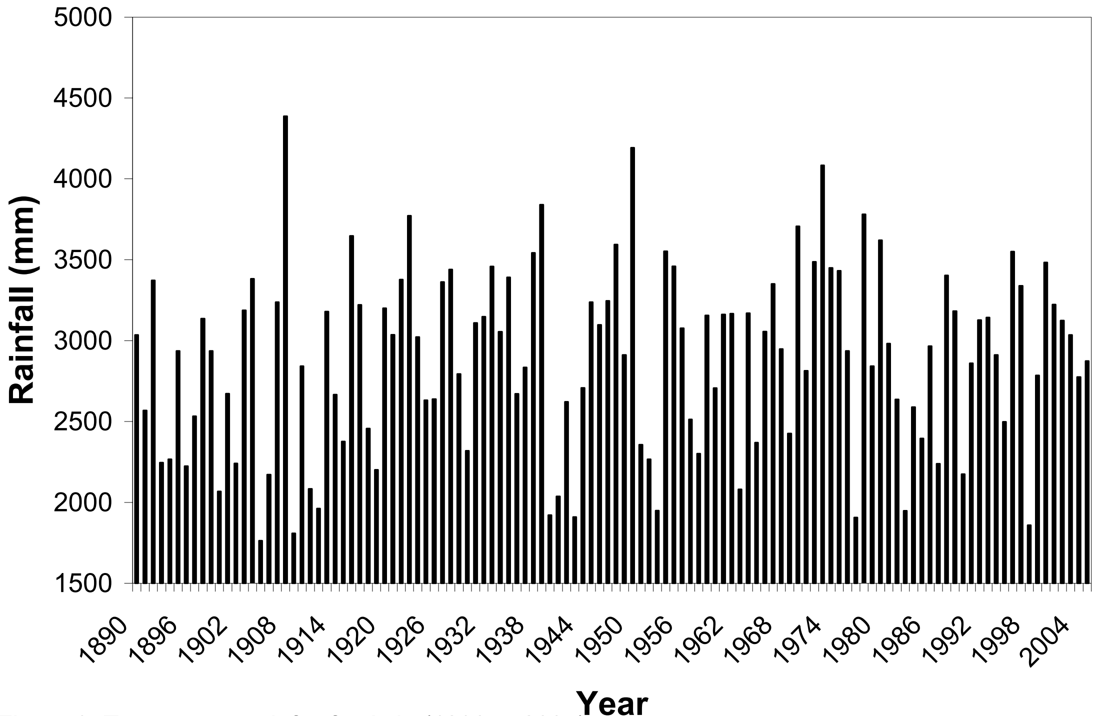

Figure 9 Total annual rainfall for Apia (1890 to 2005).

Figure 10a presents the annual maximum daily rainfall for Apia. Again, considerable interannual variability in extreme rainfall occurrences is evident. A similar trend is shown in Figure 10b for Afiamalu. A daily rainfall of at least 300 mm is becoming increasingly common in Apia, with a current return period of approximately 10 years (Table 3a and Figure 11a). It is even more common in Afiamalu with a return period of about 5 years (Figure 11b and Table 3b).

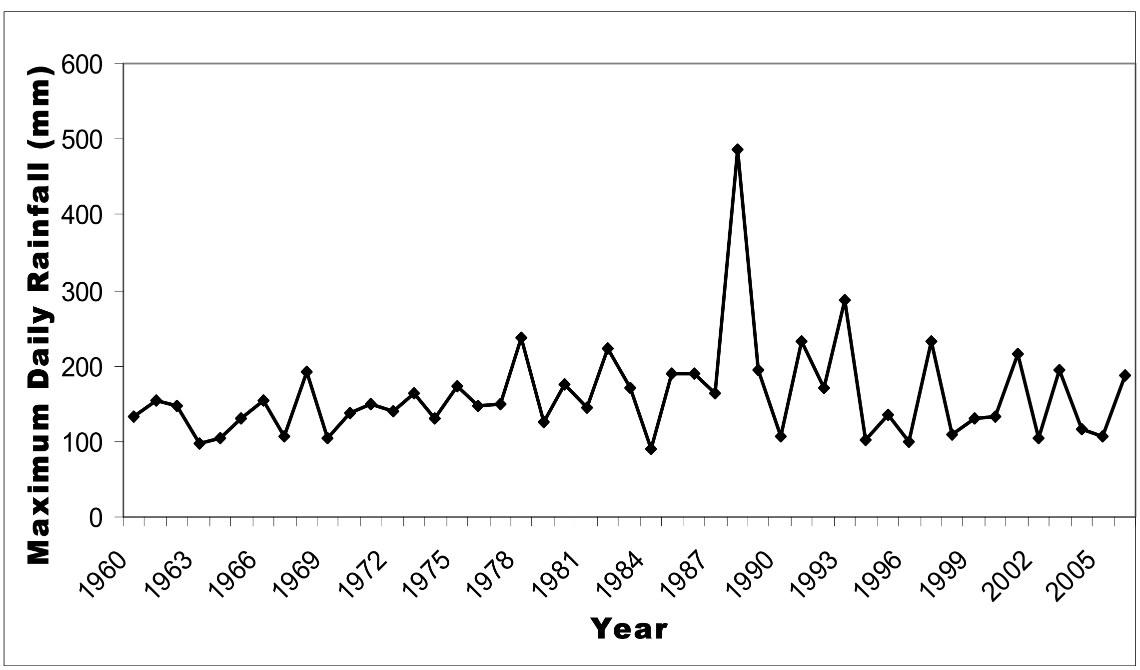

Figure 10a Maximum daily rainfall, by year, for Apia (1960 to 2006).

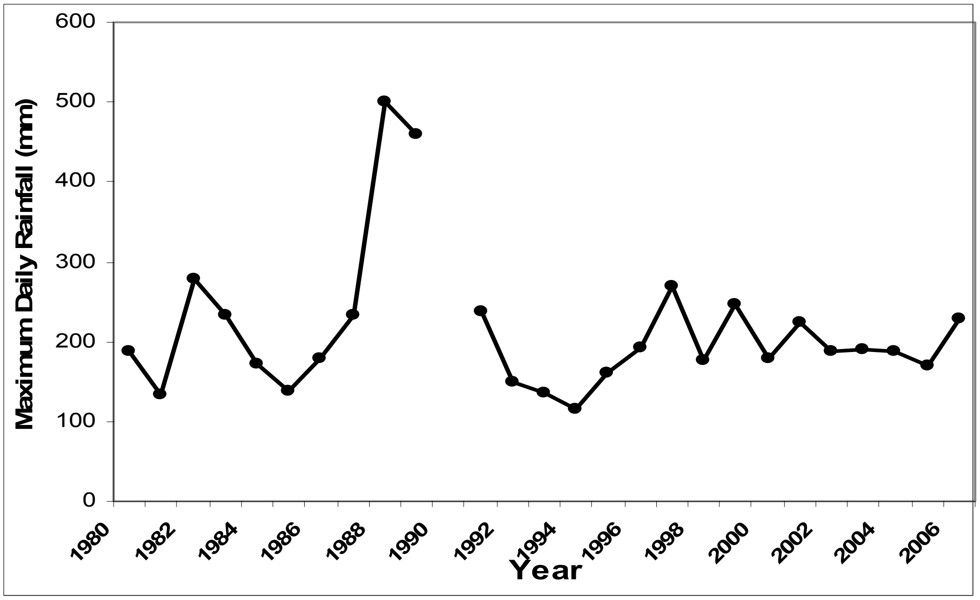

Figure 10b Maximum daily rainfall, by year, for Afiamalu (1980 to 2006).

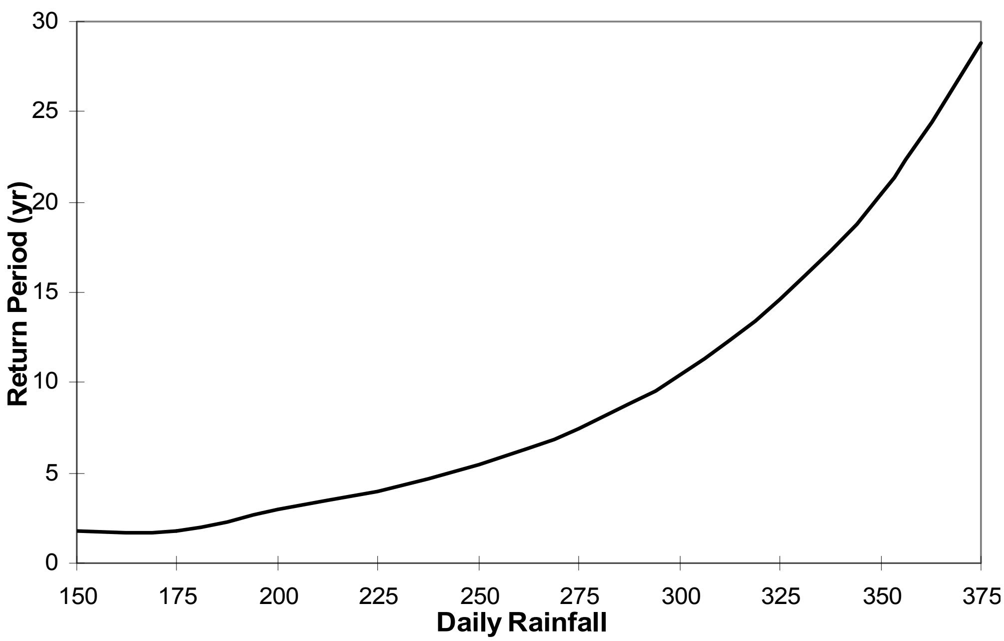

Figure 11a Relationship between daily rainfall and return period for Apia, based on observed daily rainfall for 1980 to 2006.

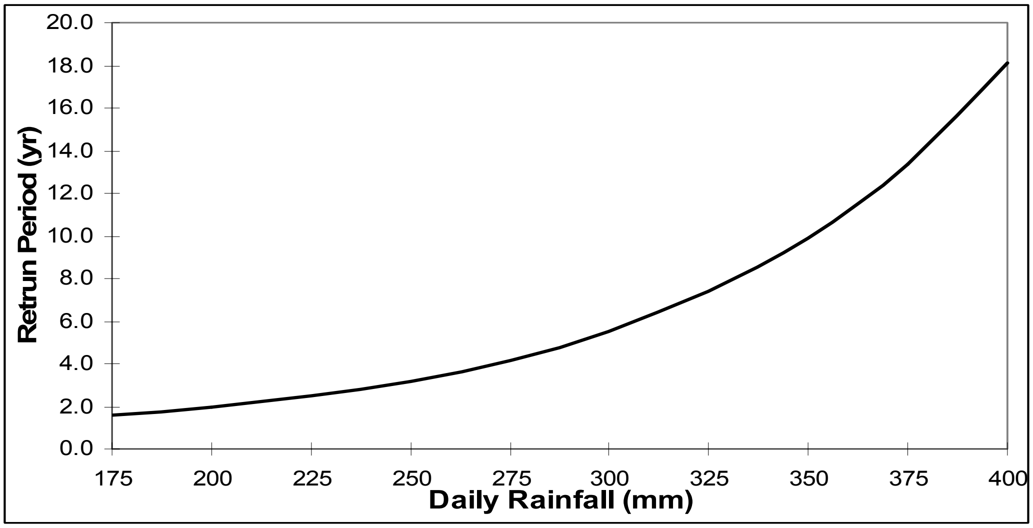

Figure 11b Relationship between daily rainfall and return period for Afiamalu, based on observed daily rainfall for 1980 to 2006.

Table 3a
Return Periods (yr), for Daily Rainfall (mm) at Apia

Daily Rainfall of at least	1960-1979	1980-2006	2025	2050	2075	2100
175	5.3	1.8	1.8	1.8	1.8	1.7
200	11.6	3	3	2.9	2.9	2.8
225	26.1	4	3.9	3.9	3.8	3.8
250	59.8	5.5	5.4	5.3	5.2	5.1
275	137.7	7.5	7.4	7.2	7.1	6.9
300	318.4	10.4	10.2	10	9.7	9.6
325	736.7	14.6	14.2	13.9	13.5	13.2
350	1705.6	20.5	19.9	19.4	18.8	18.4
375	3949.7	28.8	27.9	27.1	26.3	25.7
400	9149.2	40.6	39.3	38.1	36.9	35.9

Table 3b
Return Periods (yr) for Daily Rainfall (mm) at Afiamalu

Daily Rainfall of at least	1980-2006	2025	2050	2075	2100
175	1.6	1.6	1.6	1.6	1.6
200	2.0	2.0	1.9	1.9	1.9
225	2.5	2.5	2.4	2.4	2.4
250	3.2	3.2	3.1	3.1	3.0
275	4.2	4.1	4.0	4.0	3.9
300	5.5	5.4	5.3	5.2	5.1
325	7.4	7.2	7.1	6.9	6.8
350	9.9	9.7	9.5	9.2	9.0
375	13.4	13.0	12.7	12.4	12.1
400	18.1	17.6	17.1	16.6	16.3

b) Projected Risk Levels

Best estimates of changes in daily rainfall are based on an average of the estimates using a multi model and emission scenario ensemble (see Table 1). Figure 12 shows the best estimate of mean annual rainfall out to 2100, as well as the band of extreme uncertainty. The latter is estimated using the highest and lowest estimates of daily rainfall, for all model and emission scenario combinations. It is clear that there is large uncertainty in the rainfall projections, with two models suggesting substantial increases in rainfall, one model suggesting only small increases, and one model indicating a large decrease in rainfall into the future.

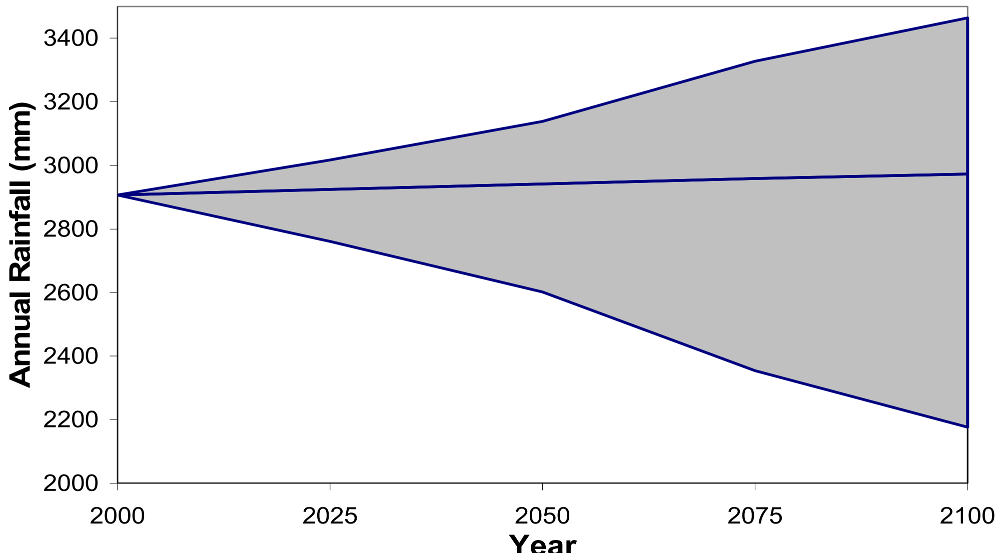

Figure 12a Best estimate of projected change in mean annual rainfall for Apia, along with the uncertainty envelope as given by the maximum and minimum estimates using all possible combinations of the available global climate models and emission scenarios.

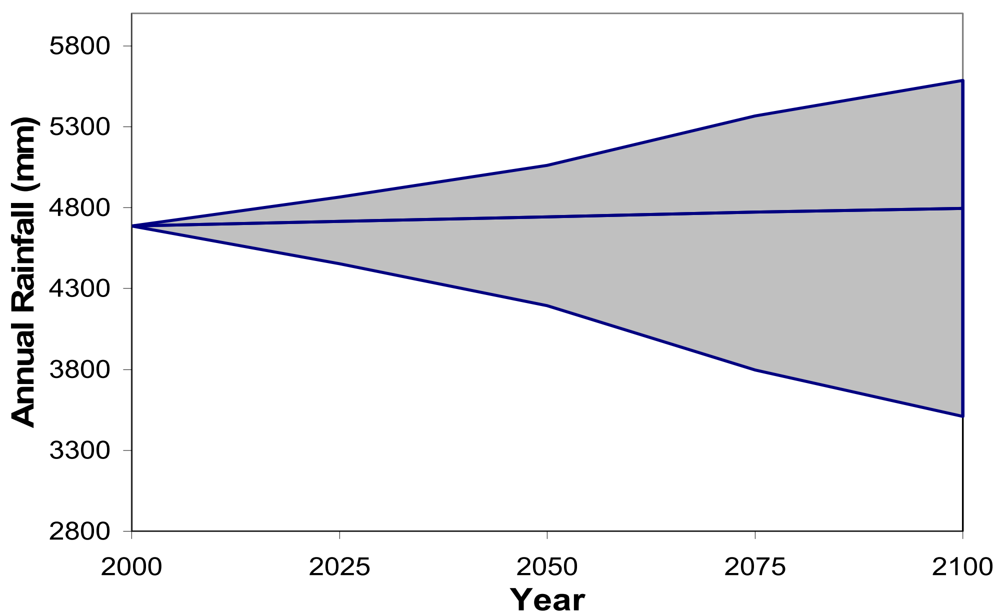

Figure 12b Best estimate of projected change in mean annual rainfall for Afiamalu, along with the uncertainty envelope as given by the maximum and minimum estimates using all possible combinations of the available global climate models and emission scenarios

As indicated in Table 3 and Figure 13, global warming may reduce the return periods of extreme daily rainfall events, despite the small change anticipated for the mean rainfall. But both Figures also show that again there is large uncertainty.

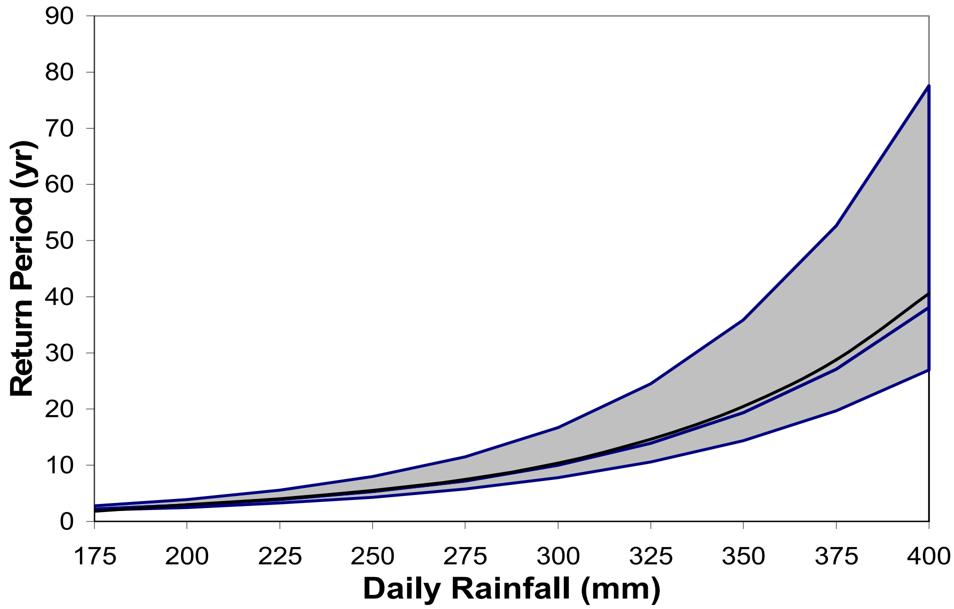

Figure 13a Relationship between daily rainfall and return period for Apia, for present day (black line) and 2050 (blue lines). The uncertainty envelope shows the maximum and minimum estimates of return periods for 2050, based on all possible combinations of the available global climate models and emission scenarios.

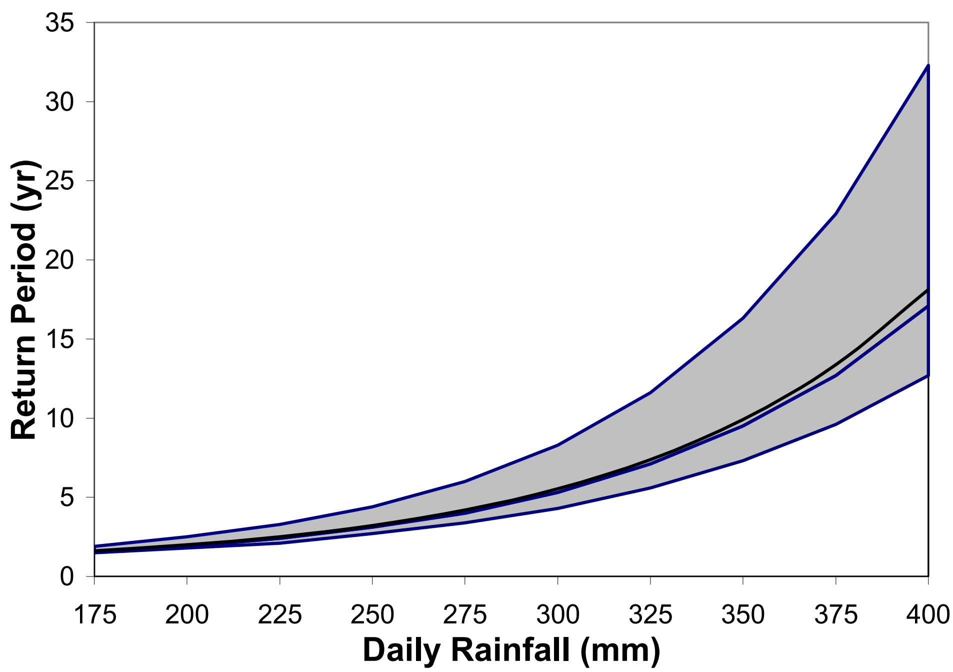

Figure 13b Relationship between daily rainfall and return period for Afiamalu, for present day (black line) and 2050 (blue lines). The uncertainty envelope shows the maximum and minimum estimates of return periods for 2050, based on all possible combinations of the available global climate models and emission scenarios.

Six-hourly Rainfall

a) Current Risks Levels

Figure 14 presents the annual maximum six-hour rainfall for Apia. The data covers the period 1969 to 2005, but with a large break between 1975 and 1990. Substantial interannual variability in extreme six-hourly rainfall occurrences is evident. A six-hour rainfall of at least 200 mm is a relatively rare event at Apia, with a return period of approximately 30 yr (Figure 15 and Table 4).

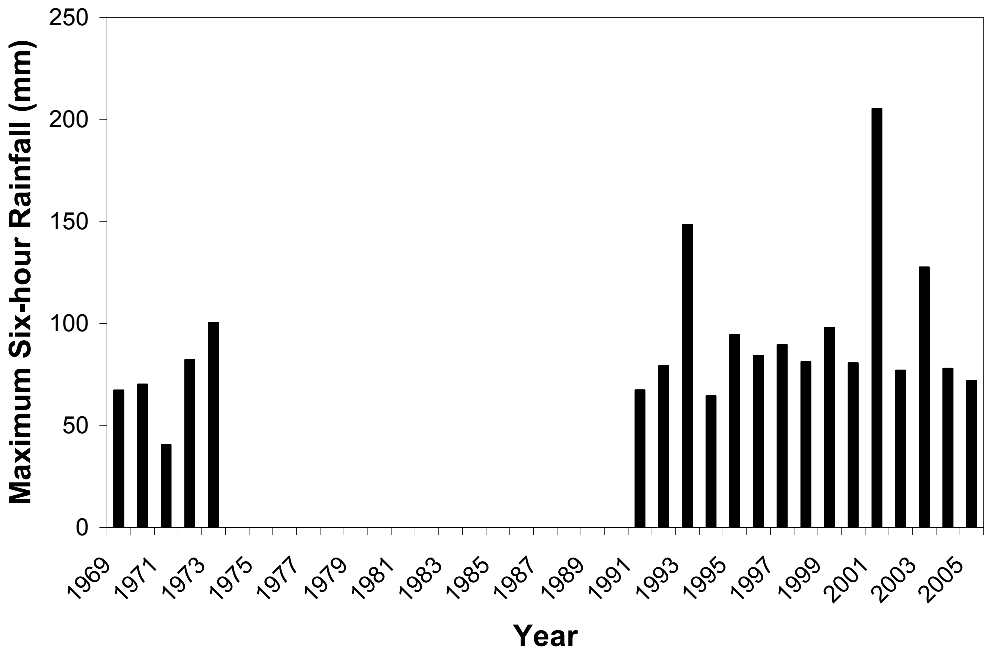

Figure 14 Maximum six-hourly rainfall, by year, for Apia (1969 to 1974 and 1991 to 2005).

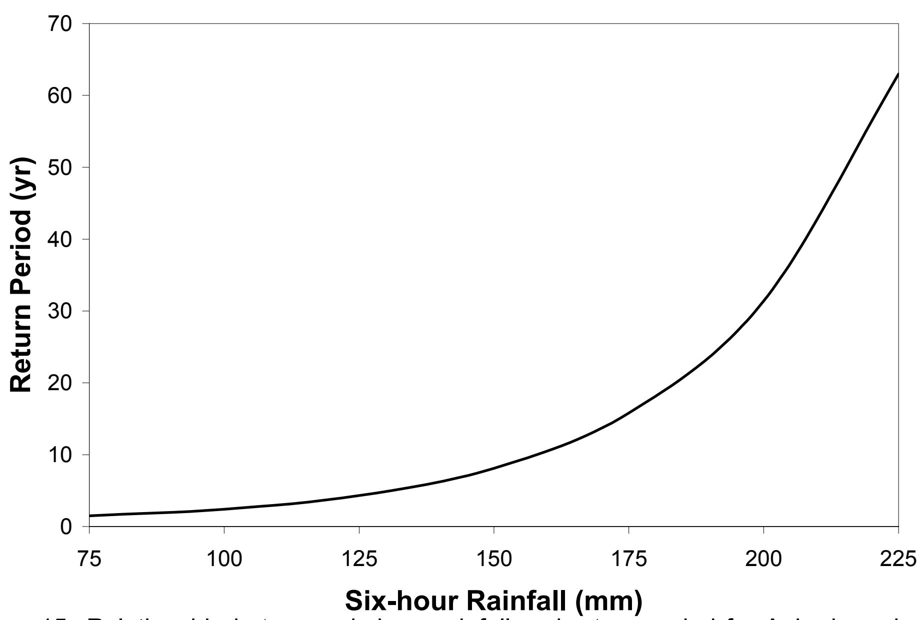

Figure 15 Relationship between six-hour rainfall and return period for Apia, based on observed six-hourly rainfall for 1969 to 1974 and 1991 to 2005.

Table 4

Return Periods (yr), for Six-hourly Rainfall (mm) at Apia

Daily Rainfall (mm) of at Least	1969-1974 & 1991-2005	2025	2050	2075	2100
75	1.5	1.5	1.5	1.5	1.5
100	2.4	2.3	2.3	2.2	2.1
125	4.3	4.0	3.8	3.5	3.4
150	8.1	7.3	6.7	6.1	5.6
175	16	14	12	11	9.5
200	31	27	23	19	17
225	63	52	43	35	29

b) Projected Risk Levels

Best estimates of changes in six-hour rainfall extremes are based on an average of the estimates using a multi model and emission scenario ensemble (see Table 1). As indicated in Table 4 and Figure 16, global warming will likely reduce the return periods of extreme hourly rainfall events, although Figure 16 also shows there is considerable uncertainty in the projections.

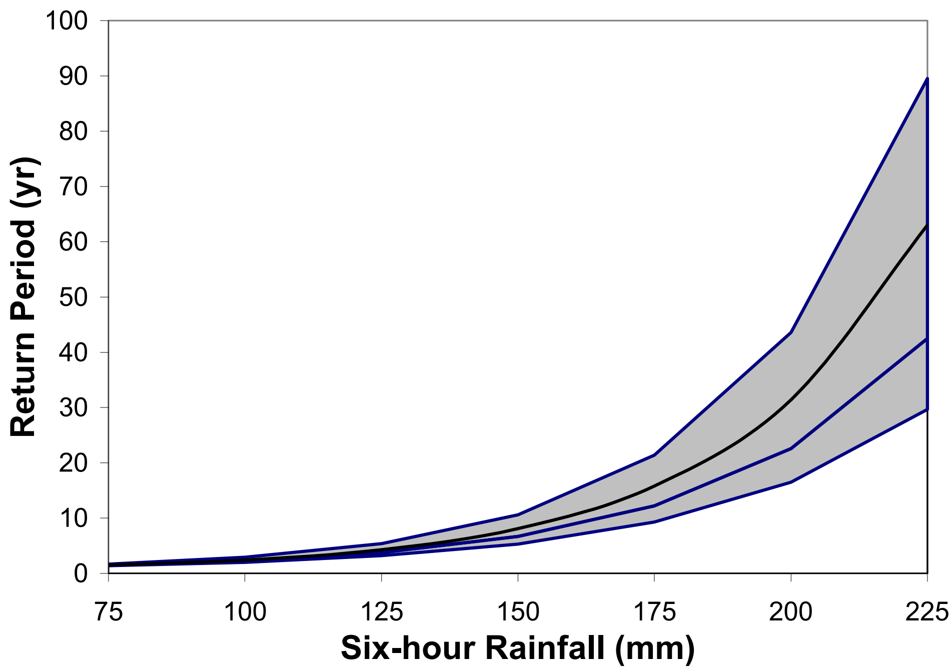

Figure 16 Relationship between six-hour rainfall and return period for Apia, for present day (black line) and 2050 (blue lines). The uncertainty envelope shows the maximum and minimum estimates of return periods for 2050, for all possible combinations of the available global climate models and emission scenarios.

Drought

Figure 17 presents, for Apia, the number of months in each year (1961 to 2005), and each decade, for which the observed precipitation was below the ten percentile. A monthly rainfall below the ten percentile is used here as an indicator of drought.

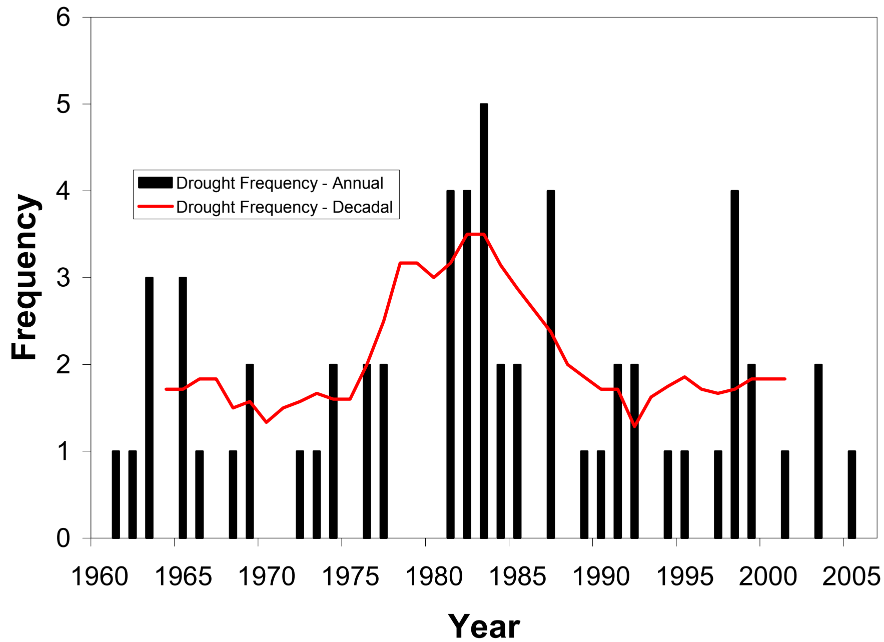

Figure 17 Number of months in each year for which the precipitation was below the ten percentile. Also shown is the average over ten years. Data for Apia (1942 to 2005).

There is considerable inter-annual and inter-decadal variability in this indicator of drought, with no obvious long term trend. However, the droughts associated with the El Niño events of the early and late 1980s and late 1990s are clearly evident.

Figure 18 shows the results of a similar analysis, but for rainfall estimates (1961 to 1990) and projections (1991 to 2100) based on the Canadian GCM and the A2 and B2 emission scenarios. It is clear that the model data does not capture the increased incidence of drought associated with El Niño conditions. More robust results might be obtained using a GCM that is able to simulate El Niño events. Most recent global climate modelling studies (e.g. Yamaguchi and Noda, 2005) indicate that, in a warmer world, the pattern of tropical Pacific sea surface temperatures becomes more El Niño-like – sea surface temperatures in the Easter tropical Pacific increase faster than those in the west, with an associated eastward migration in the tropical Pacific rainfall pattern. But for the six (out of 19 studied) models that were best at simulating present day ENSO conditions, van Oldenborgh and Philip (2005) found no significant changes toward El Niño-like conditions in the latter part of the current century. Therefore it is not yet possible to make any predictions about the future nature of El Niño events, or of the opposite cool event, the La Niña. Figure 18 does indicate that drought frequency is likely to increase in the second half of the present century, under the B2 emissions scenario.

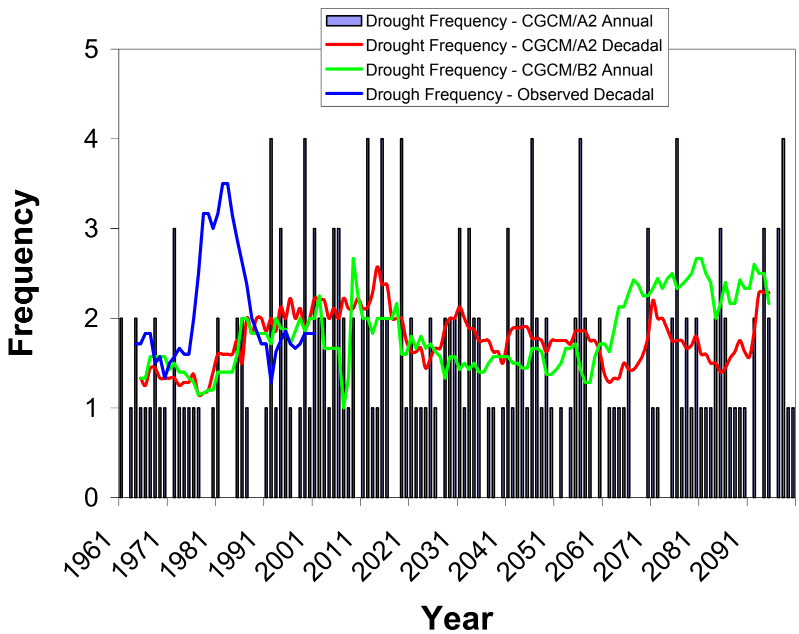

Figure 18 The number of months per year for which the precipitation for Apia is projected to be below the 1961-1999 ten percentile for the relevant month. Also shown are the averages over ten years, based on the observed (1957 to 2005) and modelled (1961 to 2100) data. Modelled data are from the Canadian GCM, with an A2 and B2 emission scenarios and best estimates for GCM sensitivity.

Extreme Winds

a) Current Risk Levels

Figure 19 shows the annual maximum wind gust recorded at Apia over the period 2001 to 2005. There is large interannual variability and no trend in the data. The maximum gust of 61 knots. (31.2 ms^{-1}) was recorded in January 2004, during Cyclone Heta.

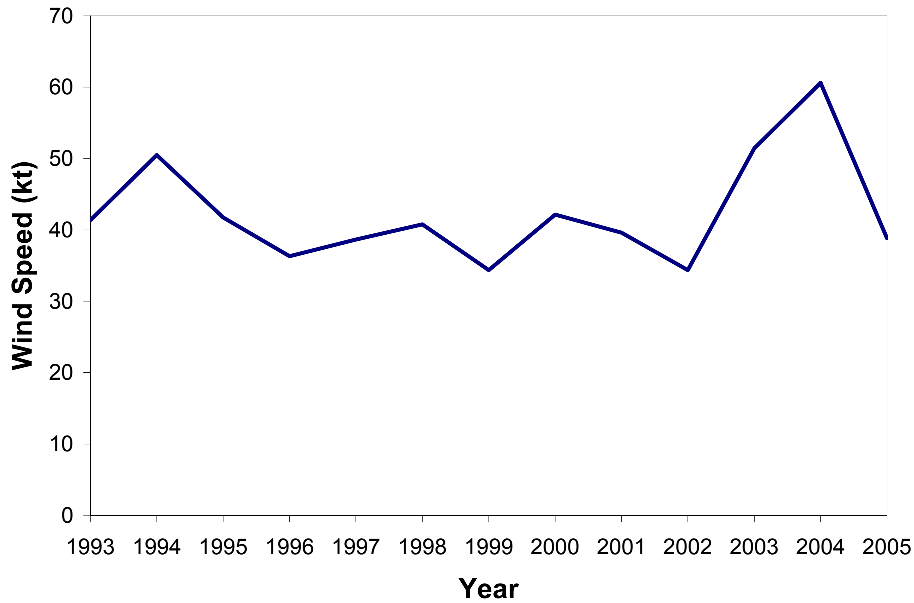

Figure 19 Annual maximum wind gust recorded at Apia for the period from 1993 to 2005.

A peak gust of at least 60 knots can be considered a relatively rare event, with a return period of approximately 19 yr (Table 5 and Figure 20).

Table 5

Return Periods (yr), for Peak Gust (knots) at Apia

Peak Gust of at Least (kt)	Observed	2025	2050	2075	2100
40	1.8	1.6	1.4	1.3	1.3
50	5.3	4.3	3.6	3.0	2.6
60	19	15	12	8.9	7.6
70	75	55	41	30	24
80	295	206	146	101	81

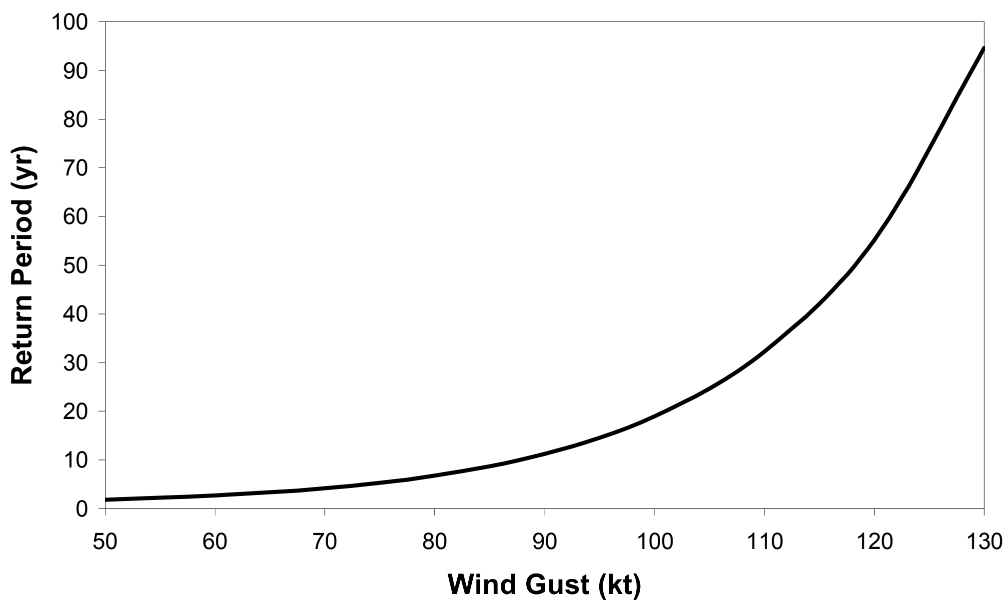

Figure 20 Relationship between maximum wind gust and return period for Apia, based on observed peak gust data for 1962 to 2005.

The maximum wind gusts associated with cyclones occurring in the Fiji area (Fiji Meteorological Service, 2002) have been used in order to compare estimates of return periods for an extreme wind occurring at a specific location and anywhere in the country (Hay, 2006). Figure 21 shows that, as is to be expected, the return periods for all of Fiji are considerably lower than those for Nadi. Based on these findings, the risk of a damaging wind occurring somewhere in Samoa is some three times higher than the estimates derived for a specific location. Thus the return period for an 80 kt gust occurring anywhere in Samoa may be closer to 100 years, rather than the 300 years for Apia alone.

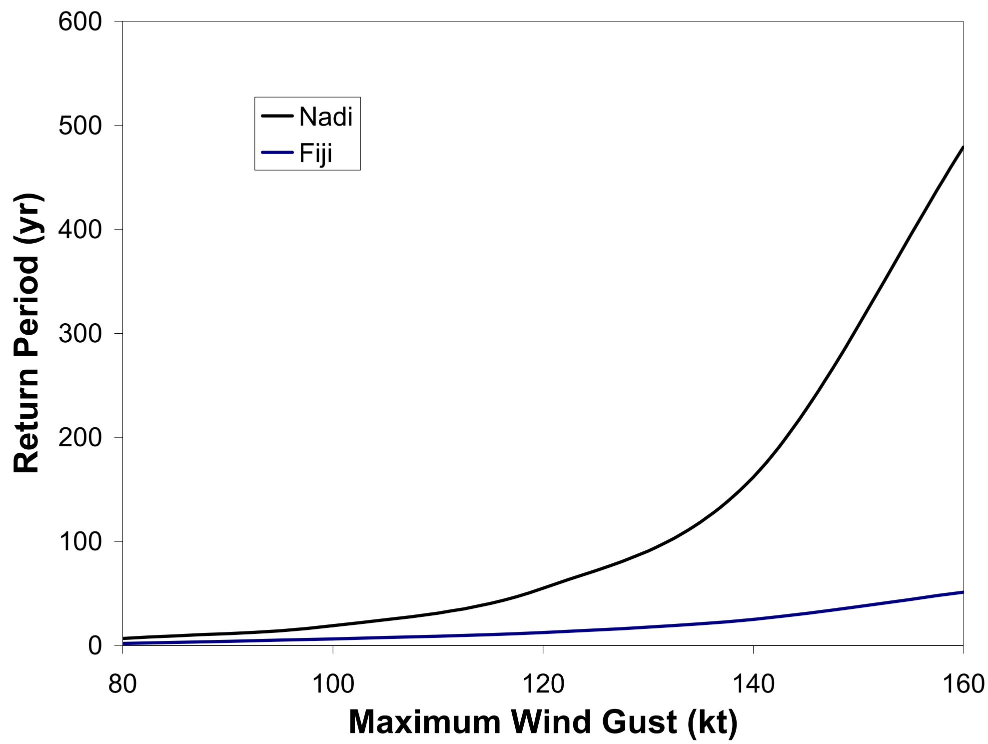

Figure 21 Return periods for extreme wind gusts at Nadi (based on observed data for 1962 to 2005) and for Fiji (based on observed and estimated extreme wind gusts associated with tropical cyclones, 1968 to 2005). Source: Hay (2006).

b) Projected Risk Levels

Estimates of changes in extreme wind gusts are based on the assumption that maximum wind gusts will increase by between 2.5 and 10 per cent per degree of global warming, with a best estimate of 10 per cent. The emission scenarios listed in Table 1 are still explicitly included in the wind gust projections. The best estimate of the increase in extreme wind gusts is determined by averaging the ensemble of estimates for all combinations of percentage increase and emission scenarios.

Figure 22 shows the best estimate of extreme wind gust out to 2100, as well as the band of maximum uncertainty. The latter is estimated using the highest and lowest estimates of extreme wind gust, for all three percentage increases and emission scenario combinations. It is clear that there is substantial uncertainty in the maximum wind gust projections.

As indicated in Table 5 and Figure 23, global warming will influence the return periods of extreme wind gusts. For example, currently an extreme wind gust of 70 kt has a return period of 75 years. This will reduce to approximately 40 years by 2050.

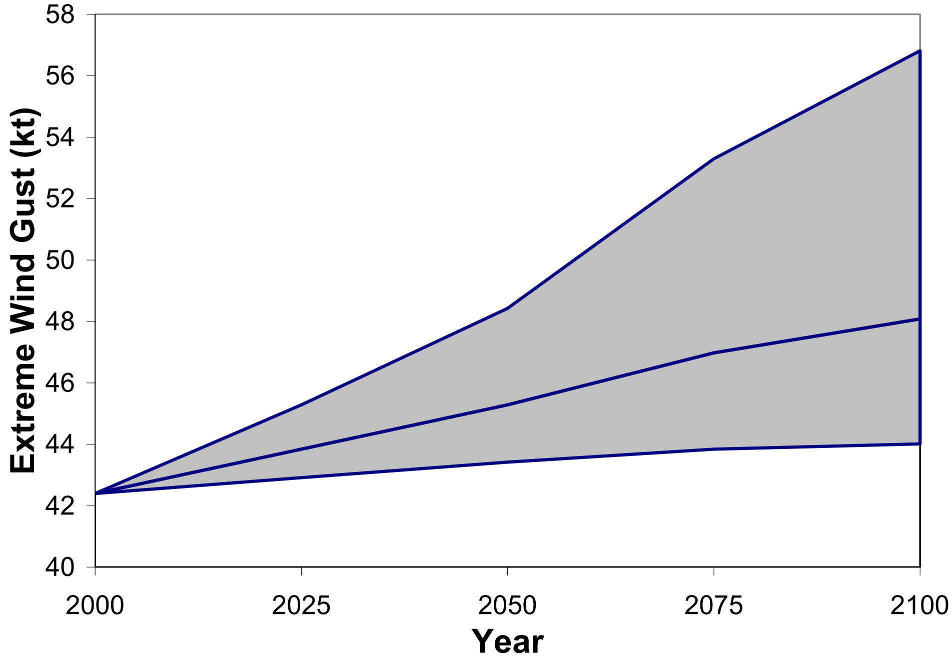

Figure 22 Best estimate of projected increase in extreme wind gust for Apia, along with the uncertainty envelope as given by the maximum and minimum estimates provided by all possible combinations of the percentage increases and the emission scenarios.

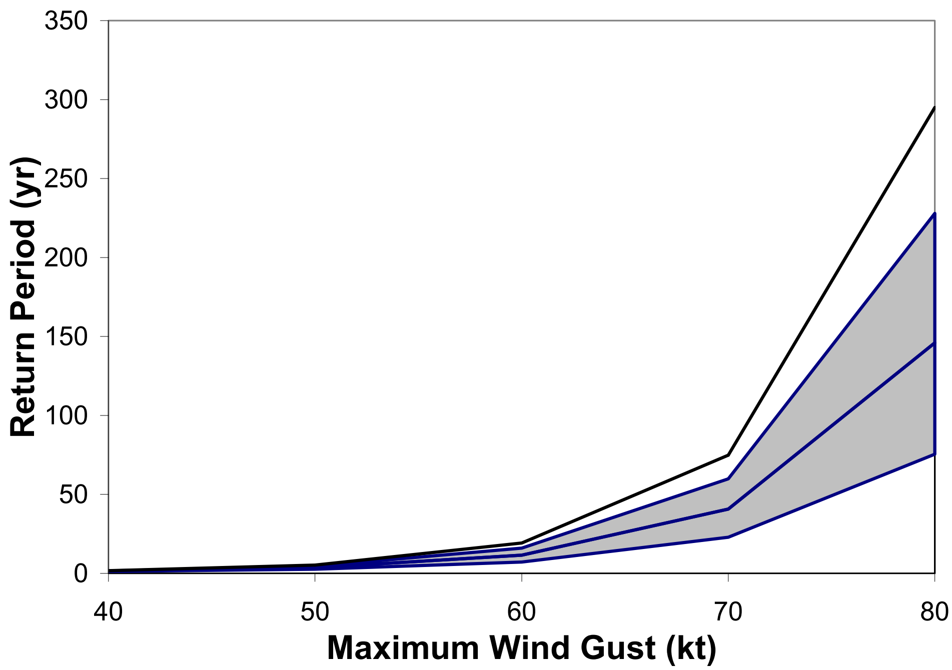

Figure 23 Relationship between peak wind gust and return period for Apia, for present day (black line) and 2050 (blue lines). The uncertainty envelope shows the maximum and minimum estimates of return periods for 2050, based on all possible combinations of the percentage increases and emission scenarios.

Extreme High Air Temperatures

a) Current Risks Levels

Figures 24a and 24b present the annual maximum air temperature for Apia and Afiamalu. Considerable interannual variability in the extreme air temperature is evident, and there is an indication of a rising trend in the maximum air temperature for both locations. A maximum air temperature of at least 35 C is a relatively rare event at Apia, with a return period of approximately 20 years (Figure 25a and Table 6a). Afiamalu has a return period of 35 years for the same maximum temperature.

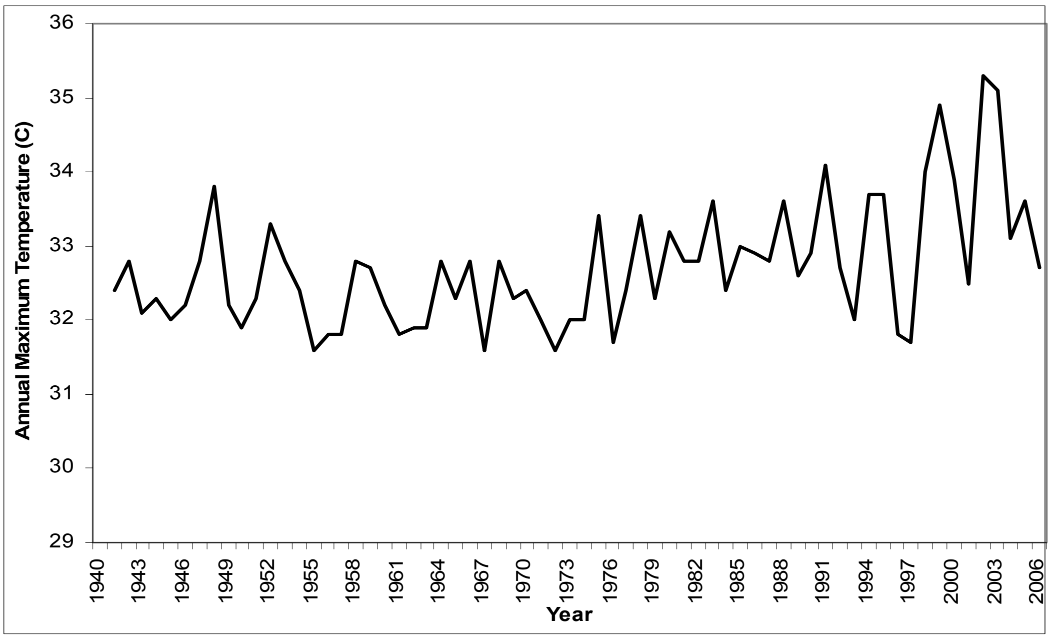

Figure 24a Maximum air temperatures, by year, for Apia (1941 to 2006).

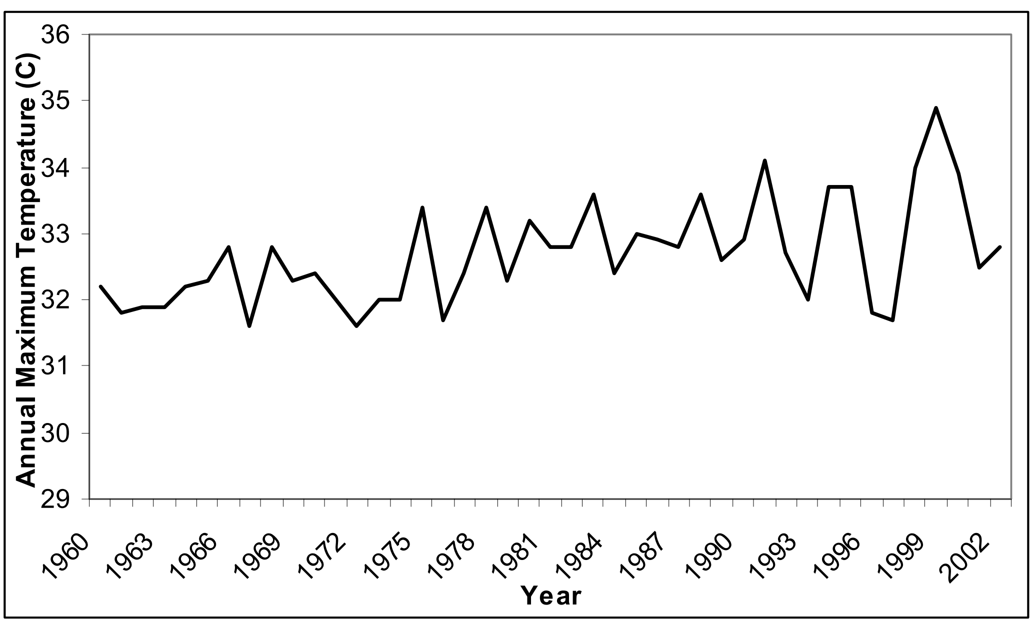

Figure 24b Maximum air temperatures, by year, for Afiamalu (1960 to 2002).

b) Projected Risk Levels

Best estimates of changes in maximum air temperature are based on an average of the estimates using a multi model and emission scenario ensemble (see Table 1). Figure 26 shows the best estimate of maximum air temperature out to 2100, as well as the band of extreme uncertainty. The latter is estimated using the highest and lowest estimates of extreme daily rainfall, for all model and emission scenario combinations. It is clear that there is low uncertainty in the maximum temperature projections, at least in an absolute sense.

As indicated in Tables 6a,6b and Figures 27a and 27b, global warming will influence the return periods of maximum air temperatures. For example, in recent decades the return period for maximum air temperature of 34 C for Apia has declined from over 60 years to around seven years. By 2050 this event will likely have a return period of three years. Return periods for Afiamalu are 9 years for maximum air temperature of 34 C while a 35 C maximum has a return period of around 35 years.

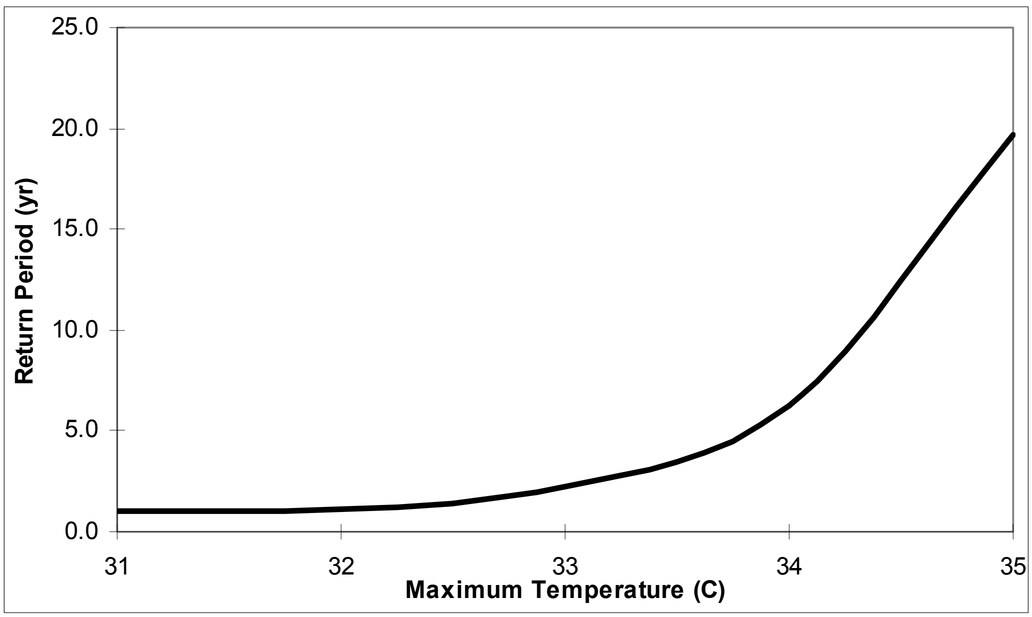

Figure 25a Relationship between maximum air temperature and return period for Apia, based on observed daily maximum temperature for 1971 to 2006.

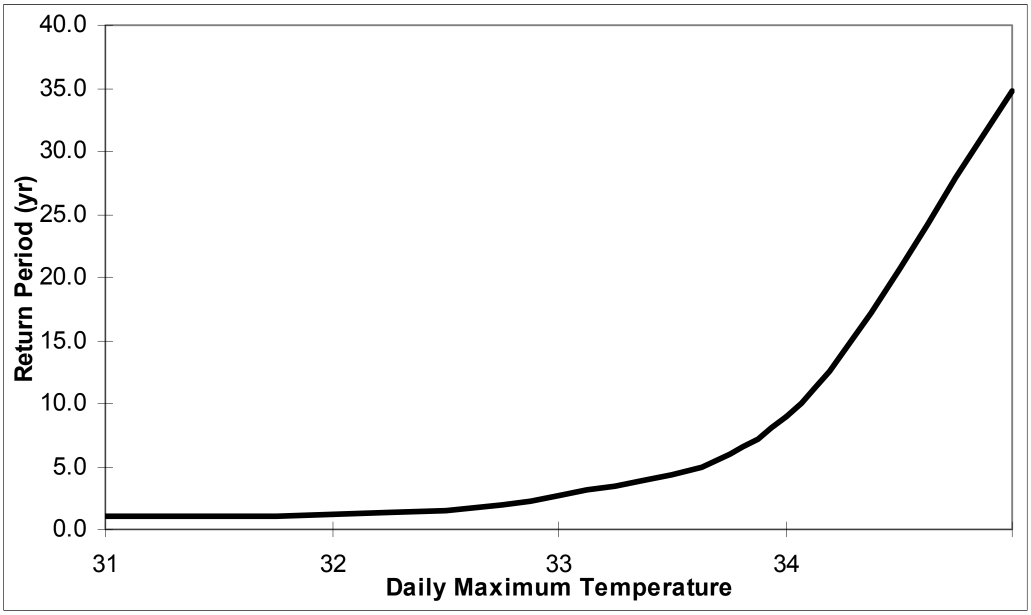

Figure 25b Relationship between maximum air temperature and return period for Afiamalu, based on observed daily maximum temperature for 1971 to 2002.

Table 6a

Return Periods (yr), for Maximum Air Temperature (C) at Apia

Maximum Temperature (C) of at least	**1941-1970**	**1971-2006**	**2025**	**2050**	**2075**	**2100**
31	1	1.0	1.0	1.0	1.0	1.0
32	1.4	1.2	1.1	1.0	1.0	1.0
33	7.6	2.3	1.7	1.4	1.1	1.0
34	67	6.2	4.4	3.0	2.1	1.6
35	619.7	19.7	13.5	8.9	5.7	4.1
36	5770	64.8	44.1	28.6	17.9	12.4

Table 6b

Return Periods (yr) for Maximum Air Temperature (C) at Afiamalu

Maximum Temperature (C) of at Least	**1971-2002**	**2025**	**2050**	**2075**	**2100**
31	1.0	1.0	1.0	1.0	1.0
32	1.2	1.1	1.0	1.0	1.0
33	2.7	1.9	1.4	1.1	1.0
34	9.0	6.0	3.8	2.4	1.8
35	34.8	22.4	13.7	8.1	5.4
36	138.6	88.8	53.8	31.2	20.4

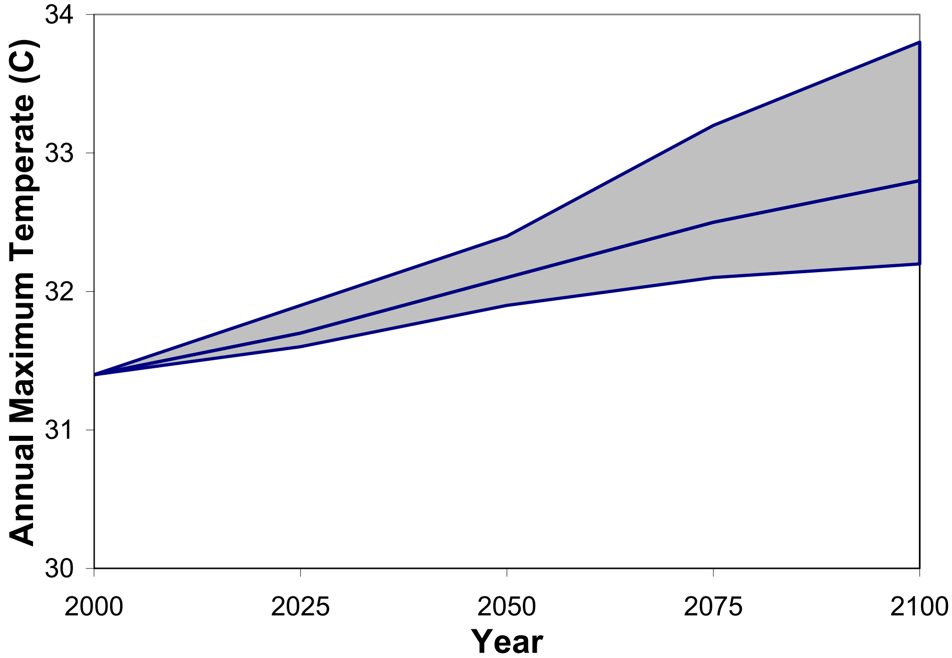

Figure 26a Best estimate of projected increase in annual maximum air temperature for Apia, along with the uncertainty envelope as given by the maximum and minimum estimates provided by all possible combinations of the available global climate models and emission scenarios.

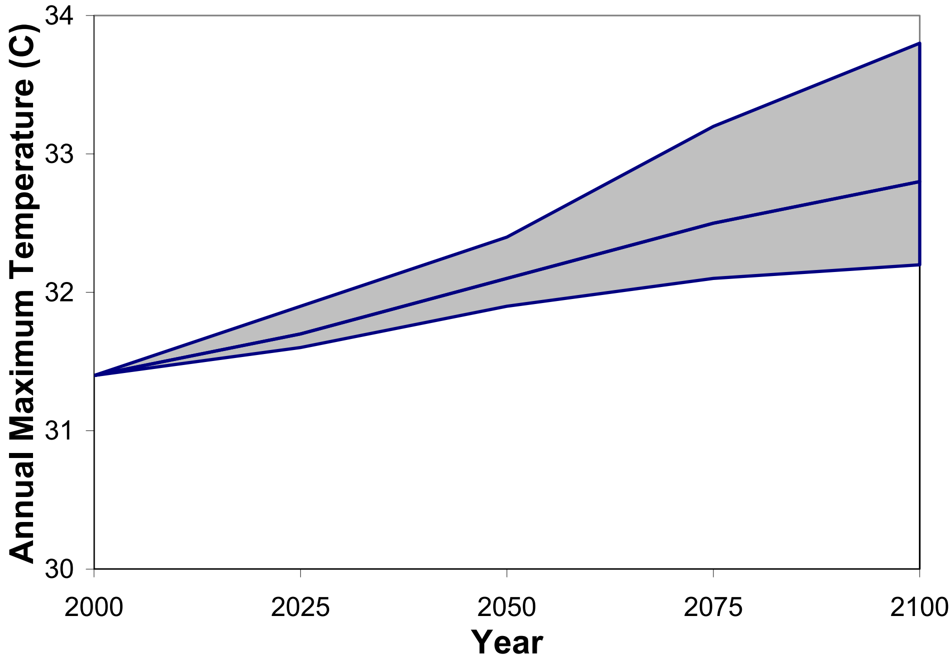

Figure 26a Best estimate of projected increase in annual maximum air temperature for Afiamalu, along with the uncertainty envelope as given by the maximum and minimum estimates provided by all possible combinations of the available global climate models and emission scenarios.

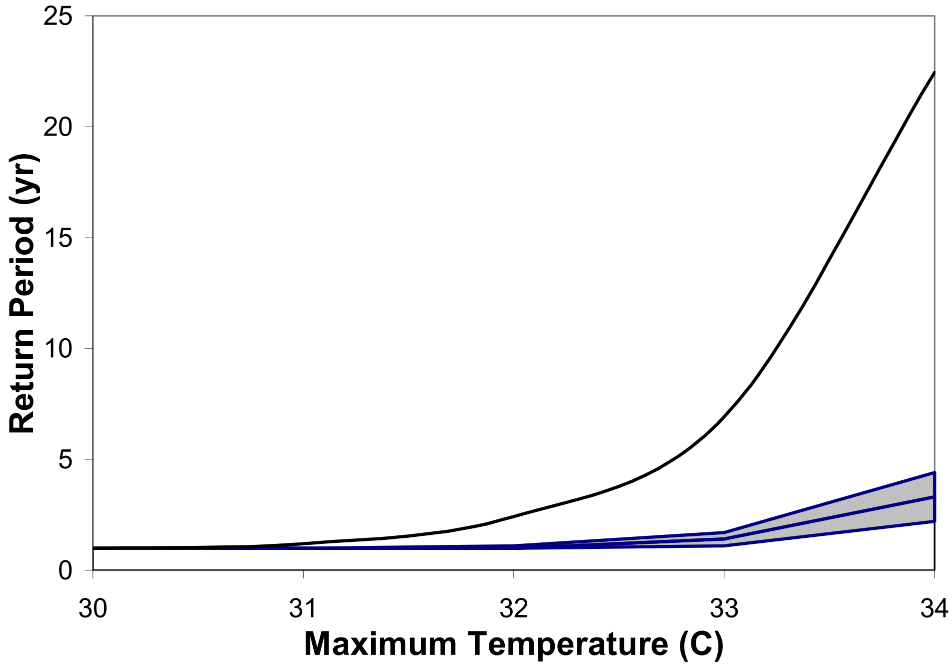

Figure 27a Relationship between maximum air temperature and return period for Apia, for present day (black line) and 2050 (blue lines). The uncertainty envelope shows the maximum and minimum estimates of return periods for 2050, based on all possible combinations of the available global climate models and emission scenarios.

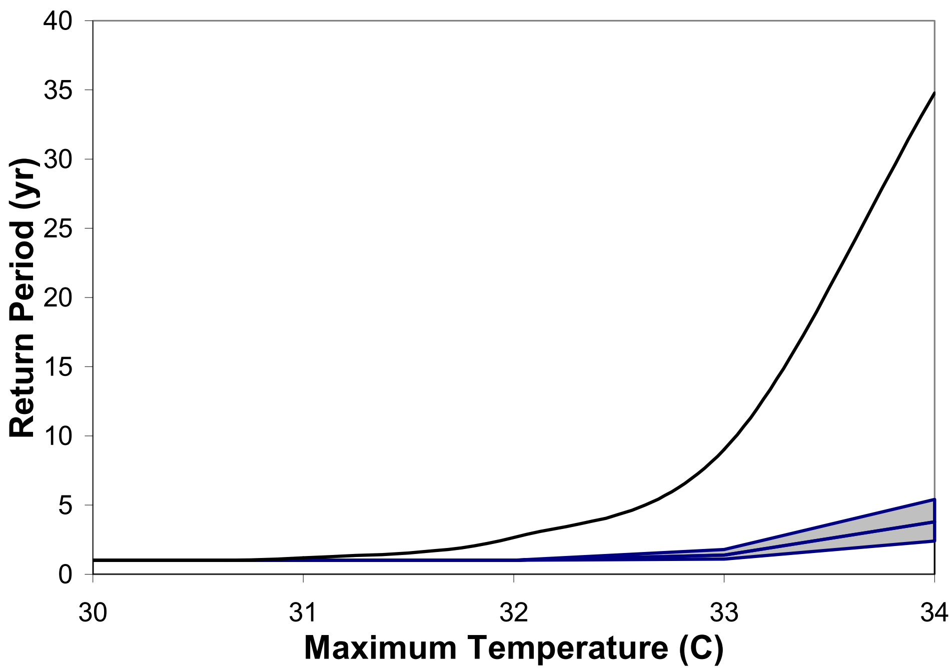

Figure 27b Relationship between maximum air temperature and return period for Afiamalu, for present day (black line) and 2050 (blue lines). The uncertainty envelope shows the maximum and minimum estimates of return periods for 2050, based on all possible combinations of the available global climate models and emission scenarios.

Extreme High Water Temperatures

a) Current Risks Levels

Figure 28 presents the annual maximum water temperature for Apia. The data are from the SEAFRAME gauge and hence the exposure will not be representative of lagoon or open water temperatures. Considerable interannual variability in extreme water temperatures is evident, and there an indication of a rising trend in the maximum water temperature. A maximum temperature of at least 32 C is a relatively rare event at Apia, with a return period of approximately 13 yr (Figure 25 and Table 6).

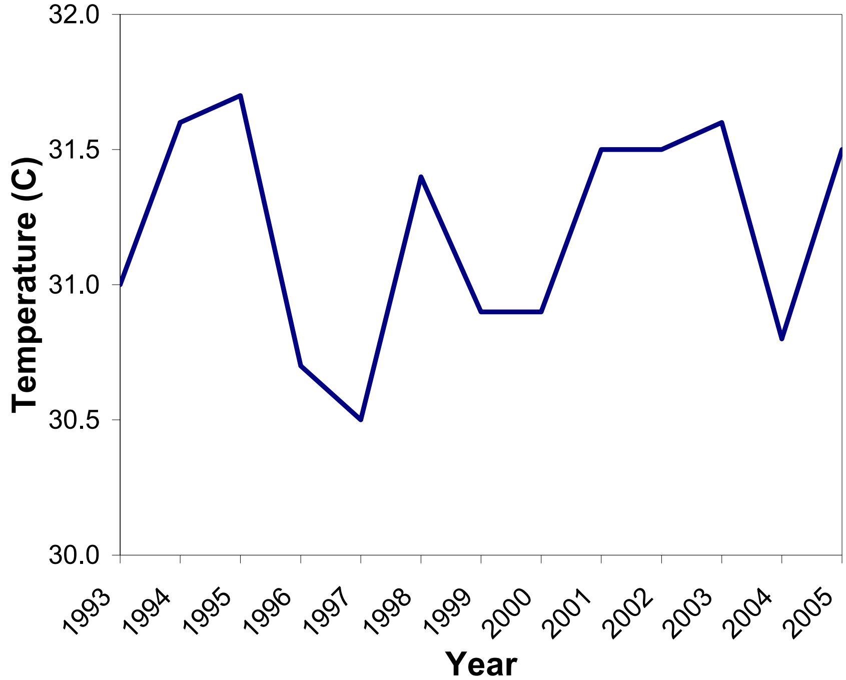

Figure 24 Maximum water temperature, by year, for Apia (1993 to 2005).

Table 6

Return Periods (yr), for Maximum Water Temperature (C) at Apia

Maximum Temperature (C) of at Least	Observed
30	1
31	1.6
32	13
33	162
34	2049

Future Work

The present CRP is the first step in analysing the climate-related risks facing Samoa. Additional data for Apia should be analysed, with both the current and additional data being subjected to rigorous quality control. For example, the rainfall records used in the present analyses had gaps during Cyclones Val and Ofa.

Data for other locations should also be included in a future climate risk profile, as Apia and Afiamalu are not representative of the entire country.

A future climate risk profile might also include assessments of the consequence components of the climate-related risks, for relevant sectors and social groups.

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