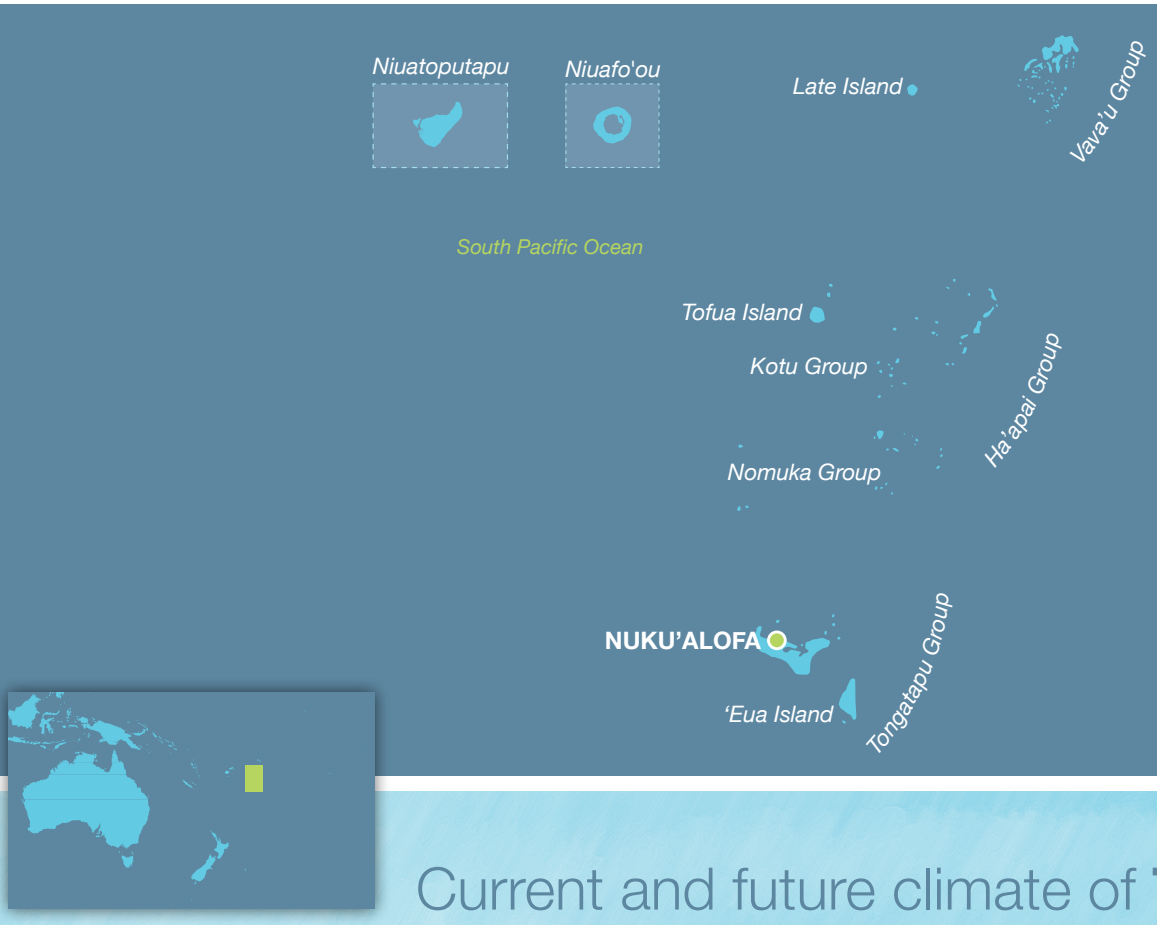
International CLIMATE CHANGE ADAPTATION Initiative

Pacific Climate Change Science Program



Current and future climate of **Tonga**

> Tonga Meteorological Service
> Australian Bureau of Meteorology
> Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Australian Government

Tonga's **current climate**

Tonga has two distinct seasons – a warm wet season from November to April and a cooler dry season from May to October (Figure 1). Almost two thirds of the annual rainfall comes during the wet season.

Tonga's rainfall is affected by the South Pacific Convergence Zone. This band of heavy rainfall is caused by air rising over warm water where winds converge, resulting in thunderstorm activity. It extends across the South Pacific Ocean from the Solomon Islands to east of the Cook Islands and is most intense during Tonga's wet season (Figure 2).

Temperatures in Tonga change from season to season and are strongly tied to changes in the surrounding ocean temperature (Figure 1). The larger differences occur in the south, with about 5ºC difference between the warmest month (February) and coolest month (July) at Nuku'alofa. Temperatures in the winter months are also affected by sub-tropical high pressure systems that bring cooler air from the south.

Tonga's climate varies considerably from year to year due to the El Niño-Southern Oscillation. This is a natural climate pattern that occurs across the tropical Pacific Ocean and affects weather around the world. There are two extreme phases of the El Niño-Southern Oscillation: El Niño and La Niña. There is also a neutral phase. In Nuku'alofa and Lupepau'u, El Niño events tend to bring cooler dry seasons and drier wet seasons than normal, while La Niña events usually bring wetter than normal conditions.

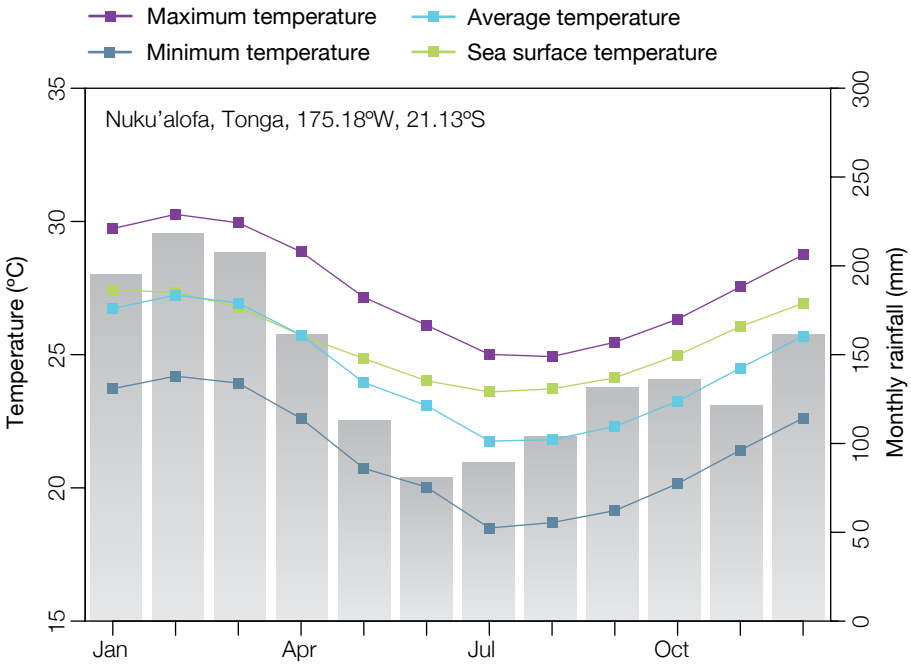


Figure 1: Seasonal rainfall and temperature at Nuku'alofa.

Beach at Kala'au, Tongatapu.

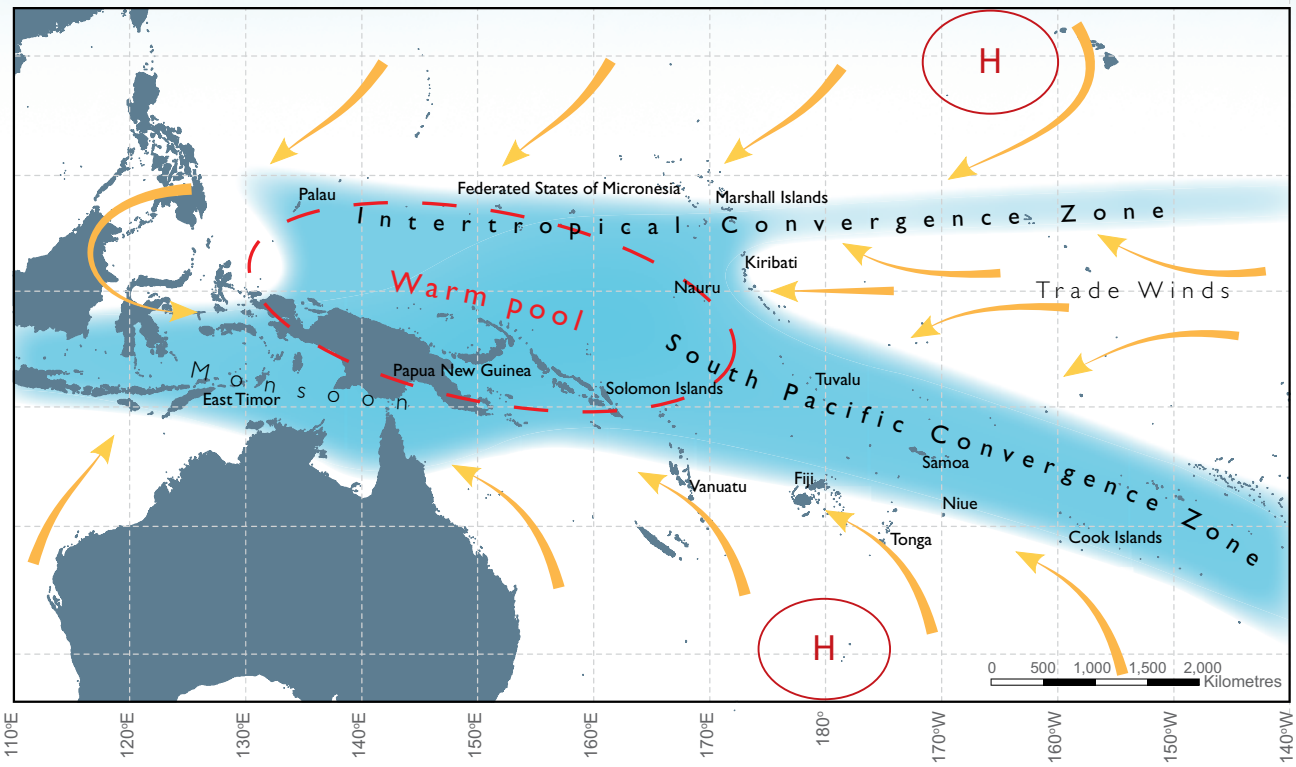


Figure 2: The average positions of the major climate features in November to April. The arrows show near surface winds, the blue shading represents the bands of rainfall convergence zones, the dashed oval shows the West Pacific Warm Pool and H represents typical positions of moving high pressure systems.

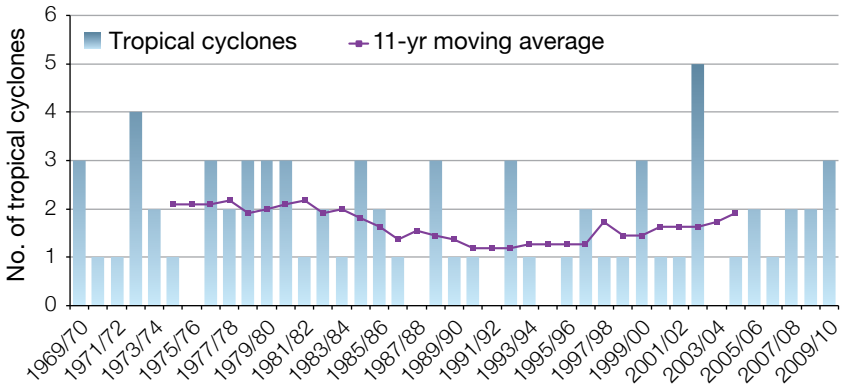


Figure 3: Number of tropical cyclones passing within 400 km of Nuku'alofa. Eleven-year moving average in purple.

Tropical cyclones

Tropical cyclones affect Tonga between November and April. In the 41-year period between 1969 and 2010, 71 tropical cyclones passed within 400 km of Nuku'alofa, an average of one to two cyclones per season (Figure 3). The number of cyclones varies widely from year to year, with none in some seasons but up to five in others. Over the period 1969–2010 cyclones occured more frequently in El Niño years.

Tonga's **changing climate**

Temperatures have increased

Annual and seasonal maximum and minimum temperatures have increased in Nuku'alofa since 1950 (Figure 4). Maximum temperatures have increased at a rate of 0.10°C per decade. These temperature increases are consistent with the global pattern of warming.

Nuku'alofa's annual rainfall has decreased

Data since 1950 show a clear decreasing trend in the annual and wet season rainfall at Nuku'alofa (Figure 5) but no clear trend in dry season rainfall. There are no clear rainfall trends at Lupepau'u. Over this period, there has been substantial variation in rainfall from year to year at both sites.

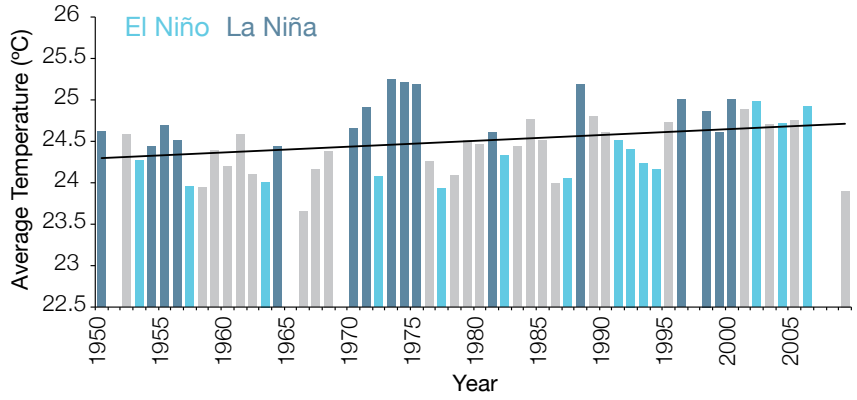


Figure 4: Annual average temperature for Nuku'alofa. Light blue bars indicate El Niño years, dark blue bars indicate La Niña years and the grey bars indicate neutral years.

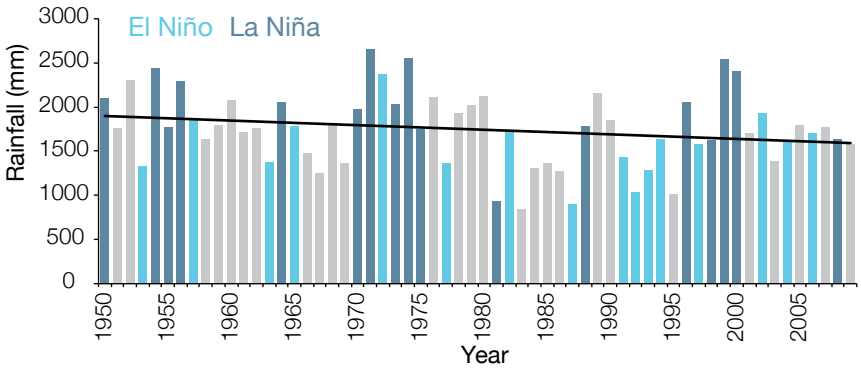


Figure 5: Annual rainfall for Nuku'alofa. Light blue bars indicate El Niño years, dark blue bars indicate La Niña years and the grey bars indicate neutral years.

Sea level has risen

As ocean water warms it expands causing the sea level to rise. The melting of glaciers and ice sheets also contributes to sea-level rise.

Instruments mounted on satellites and tide gauges are used to measure sea level. Satellite data indicate the sea level has risen near Tonga by about 6 mm per year since 1993. This is larger than the global average of 2.8–3.6 mm per year. This higher rate of rise may be partly related to natural fluctuations that take place year to year or decade to decade caused by phenomena such as the El Niño-Southern Oscillation. This variation in sea level can be seen in Figure 7 which includes the tide gauge record and satellite data since 1993.

Ocean acidification has been increasing

About one quarter of the carbon dioxide emitted from human activities each year is absorbed by the oceans. As the extra carbon dioxide reacts with sea water it causes the ocean to become slightly more acidic. This impacts the growth of corals and organisms that construct their skeletons from carbonate minerals. These species are critical to the balance of tropical reef ecosystems. Data show that since the 18th century the level of ocean acidification has been slowly increasing in Tonga's waters.

Taking weather observations, Tonga Meteorological Service.

Tonga's **future climate**

Climate impacts almost all aspects of life in Tonga. Understanding the possible future climate of Tonga is important so people and the government can plan for changes.

How do scientists develop climate projections?

Global climate models are the best tools for understanding future climate change. Climate models are mathematical representations of the climate system that require very powerful computers. They are based on the laws of physics and include information about the atmosphere, ocean, land and ice.

There are many different global climate models and they all represent the climate slightly differently. Scientists from the Pacific Climate Change Science Program (PCCSP) have evaluated 24 models from around the world and found that 18 best represent the climate of the western tropical Pacific region. These 18 models have been used to develop climate projections for Tonga.

The future climate will be determined by a combination of natural and human factors. As we do not know what the future holds, we need to consider a range of possible future conditions, or scenarios, in climate models. The Intergovernmental Panel on Climate Change (IPCC) developed a series of plausible scenarios based on a set of assumptions about future population changes, economic development and technological advances. For example, the A1B (or medium) emissions scenario envisages global population peaking mid-century and declining thereafter, very rapid economic growth, and rapid introduction of new and more efficient technologies. Greenhouse gas and aerosol emissions scenarios are used in climate modelling to provide projections that represent a range of possible futures.

The climate projections for Tonga are based on three IPCC emissions scenarios: low (B1), medium (A1B) and high (A2), for time periods around 2030, 2055 and 2090 (Figure 6). Since individual models give different results, the projections are presented as a range of values.

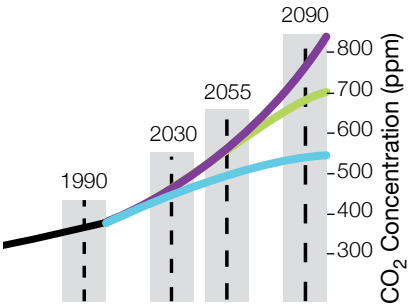


Figure 6: Carbon dioxide (CO_2) concentrations (parts per million, ppm) associated with three IPCC emissions scenarios: low emissions (B1 – blue), medium emissions (A1B – green) and high emissions (A2 – purple). The PCCSP has analysed climate model results for periods centred on 1990, 2030, 2055 and 2090 (shaded).

Taro crops.

Inundation event.

Tonga Meteorological Service

Tonga's **future climate**

This is a summary of climate projections for Tonga. For further information refer to Volume 2 of *Climate Change in the Pacific: Scientific Assessment and New Research*, and the web-based climate projections tool – *Pacific Climate Futures* (available at www.pacificclimatefutures.net).

Temperatures will continue to increase

Projections for all emissions scenarios indicate that the annual average air temperature and sea surface temperature will increase in the future in Tonga (Table 1). By 2030, under a high emissions scenario, this increase in temperature is projected to be in the range of 0.3–1.1°C.

More very hot days

Increases in average temperatures will also result in a rise in the number of hot days and warm nights and a decline in cooler weather.

Table 1: Projected annual average air temperature changes for Tonga for three emissions scenarios and three time periods. Values represent 90% of the range of the models and changes are relative to the average of the period 1980-1999.

	2030 (°C)	2055 (°C)	2090 (°C)
Low emissions scenario	0.2–1.0	0.5–1.5	0.8–2.0
Medium emissions scenario	0.2–1.2	0.7–1.9	1.3–2.9
High emissions scenario	0.3–1.1	1.0–1.8	1.9–3.3

Changing rainfall patterns

There is uncertainty around rainfall projections for Tonga as model results are not consistent. However, projections generally suggest a decrease in dry season rainfall and an increase in wet season rainfall over the course of the 21st century. Wet season increases are consistent with the expected intensification of the South Pacific Convergence Zone. Drought projections are inconsistent across Tonga.

More extreme rainfall days

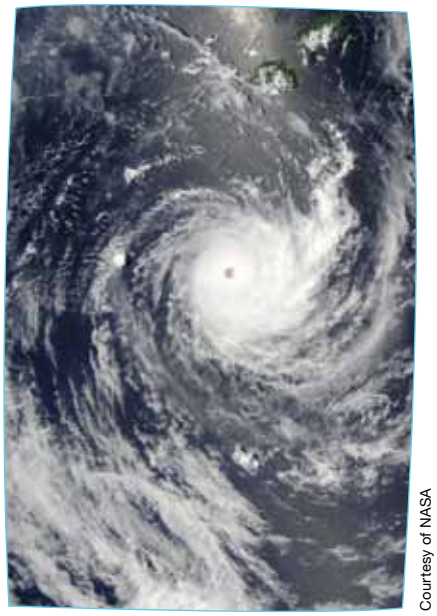
Model projections show extreme rainfall days are likely to occur more often.

Gathering seafood at low tide in Nuku'alofa.

Less frequent but more intense tropical cyclones

On a global scale, the projections indicate there is likely to be a decrease in the number of tropical cyclones by the end of the 21st century. But there is likely to be an increase in the average maximum wind speed of cyclones by between 2% and 11% and an increase in rainfall intensity of about 20% within 100 km of the cyclone centre.

In the Tonga region, projections tend to show a decrease in the frequency of tropical cyclones by the late 21st century and an increase in the proportion of the more intense storms.



Courtesy of NASA

Cyclone Wilma caused substantial damage in Tonga in January 2011.

Sea level will continue to rise

Sea level is expected to continue to rise in Tonga (Table 2 and Figure 7). By 2030, under a high emissions scenario, this rise in sea level is projected to be in the range of 3-17 cm. The sea-level rise combined with natural year-to-year changes will increase the impact of storm surges and coastal flooding. As there is still much to learn, particularly how large ice sheets such as Antarctica and Greenland contribute to sea-level rise, scientists warn larger rises than currently predicted could be possible.

Table 2: Sea-level rise projections for Tonga for three emissions scenarios and three time periods. Values represent 90% of the range of the models and changes are relative to the average of the period 1980-1999.

	2030 (cm)	2055 (cm)	2090 (cm)
Low emissions scenario	5–16	10–27	16–47
Medium emissions scenario	4–16	10–31	20–59
High emissions scenario	3–17	9–31	21–62

Ocean acidification will continue

Under all three emissions scenarios (low, medium and high) the acidity level of sea waters in the Tonga region will continue to increase over the 21st century, with the greatest change under the high emissions scenario. The impact of increased acidification on the health of reef ecosystems is likely to be compounded by other stressors including coral bleaching, storm damage and fishing pressure.

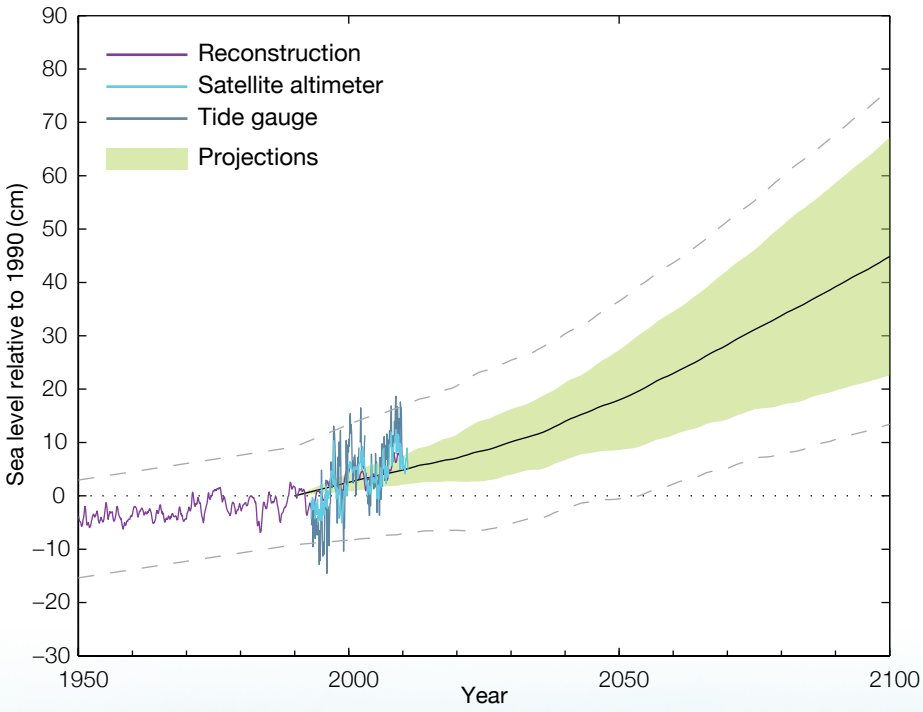


Figure 7: Observed and projected relative sea-level change near Tonga. The observed sea-level records are indicated in dark blue (relative tide-gauge observations) and light blue (the satellite record since 1993). Reconstructed estimates of sea level near Tonga (since 1950) are shown in purple. The projections for the A1B (medium) emissions scenario (representing 90% of the range of models) are shown by the shaded green region from 1990 to 2100. The dashed lines are an estimate of 90% of the range of natural year-to-year variability in sea level.

Changes in Tonga's climate

> Temperatures have warmed and will continue to warm with more very hot days in the future.

> Annual and wet season rainfall at Nuku'alofa has decreased since 1950. Rainfall patterns are projected to change over this century with more extreme rainfall days expected.

> By the end of this century projections suggest decreasing numbers of tropical cyclones but a possible shift towards more intense categories.

> Sea level near Tonga has risen and will continue to rise throughout this century.

> Ocean acidification has been increasing in Tonga's waters. It will continue to increase and threaten coral reef ecosystems.

The content of this brochure is the result of a collaborative effort between the Tonga Meteorological Service and the Pacific Climate Change Science Program – a component of the Australian Government's International Climate Change Adaptation Initiative. This information and research conducted by the Pacific Climate Change Science Program builds on the findings of the 2007 IPCC Fourth Assessment Report. For more detailed information on the climate of Tonga and the Pacific see: *Climate Change in the Pacific: Scientific Assessment and New Research. Volume 1: Regional Overview. Volume 2: Country Reports*. Available from November 2011.

www.pacificclimatechangescience.org

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