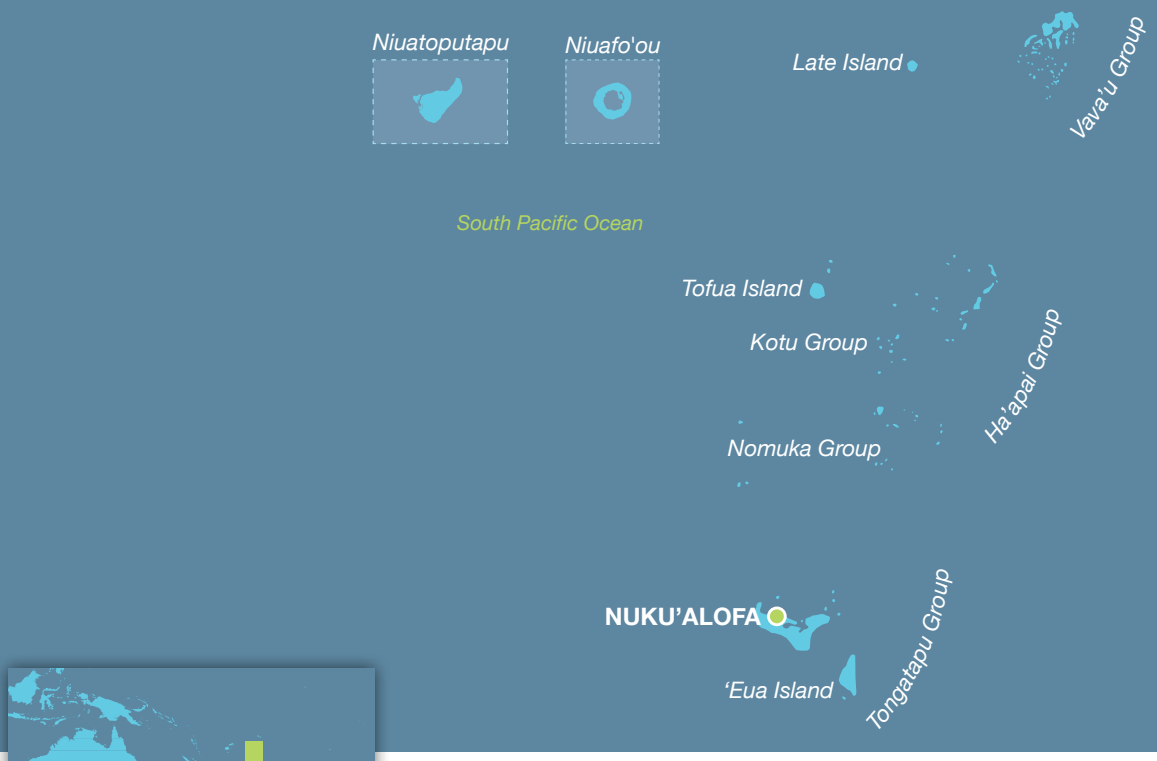
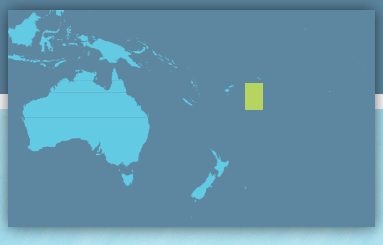
Pacific-Australia Climate Change Science and Adaptation Planning Program





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.

Temperature

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.

Rainfall

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).

Year-to-year variability

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.

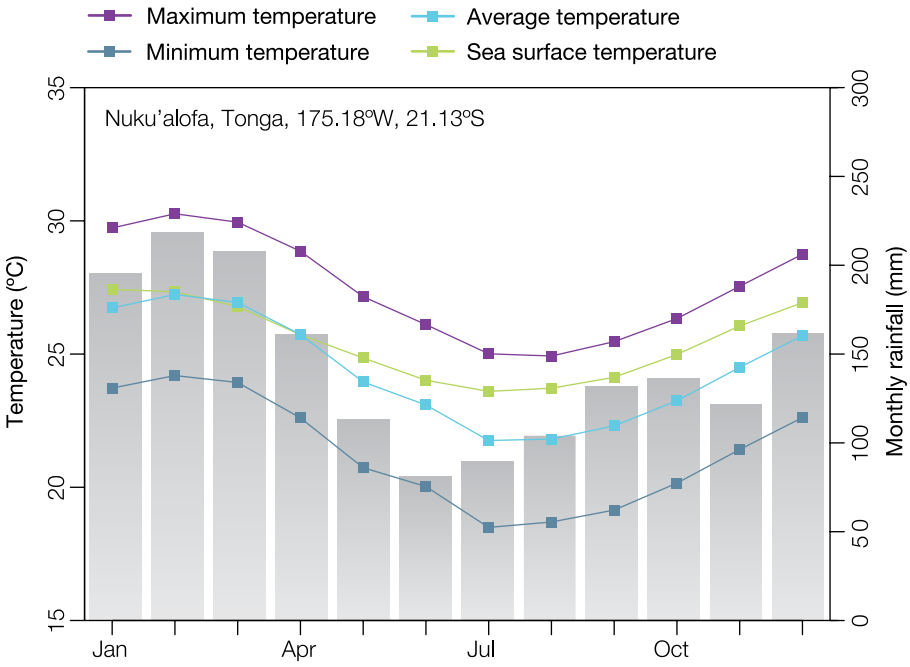


Figure 1: Seasonal rainfall and temperature at Nuku'alofa.

Beach at Kala'au, Tongatapu.

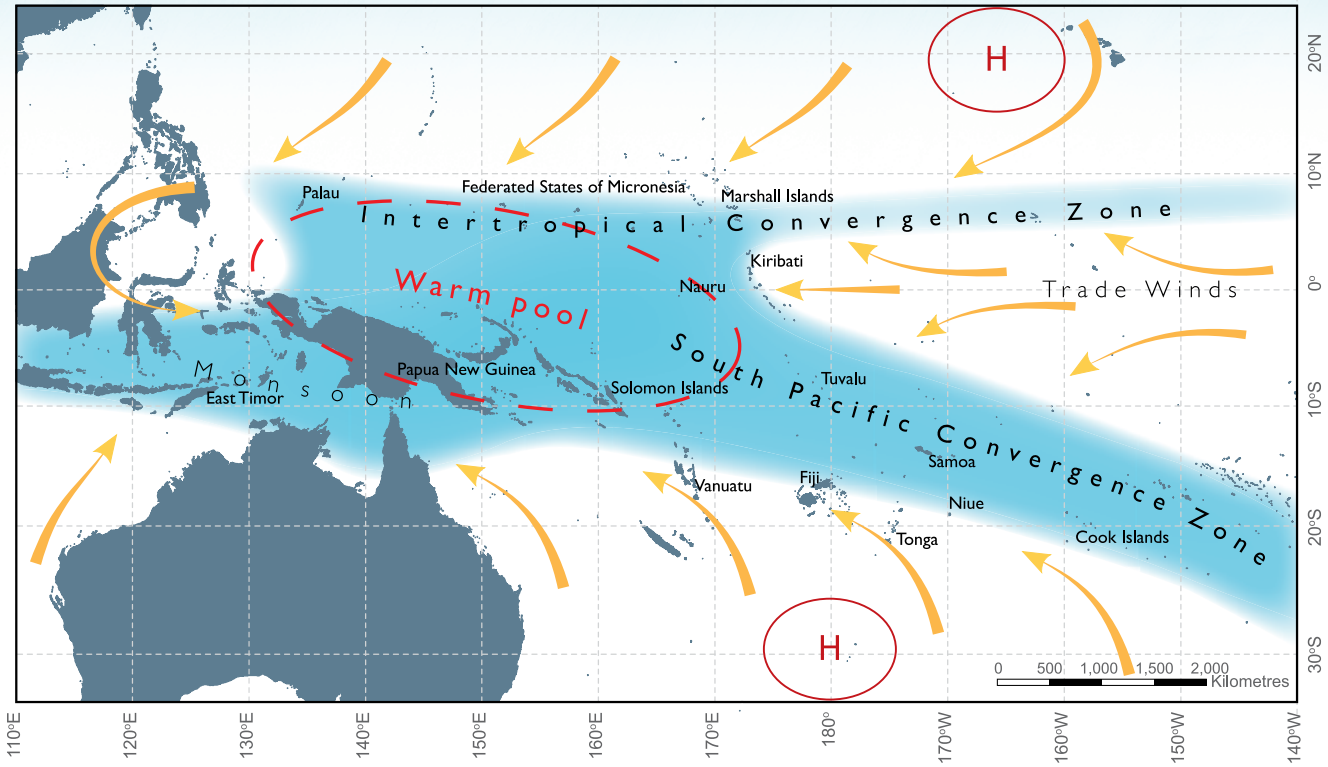


Figure 2: Average positions of the major climate features in November to April. The arrows show near surface winds, the blue shading represents the bands of rainfall convergence zones, the dashed oval shows the West Pacific Warm Pool and H represents typical positions of moving high pressure systems.

Tropical cyclones

Tropical cyclones tend to affect Tonga between November and April. In the 42-year period between the 1969 and 2010 seasons, 85 tropical cyclones developed or crossed into the Tonga Exclusive Economic Zone, an average of 20 cyclones per decade (Figure 3). The number of cyclones varies widely from year to year, with none in some seasons but up to five in others. Over this period cyclones occurred in El Niño, La Niña and neutral years.

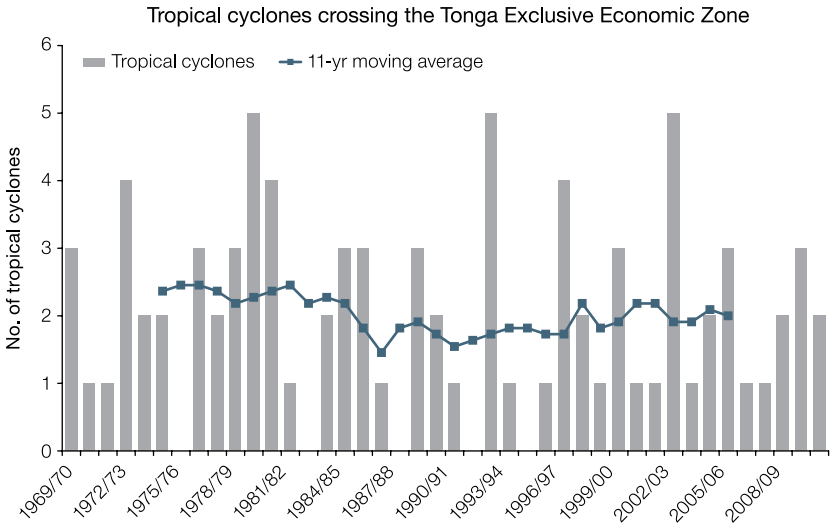
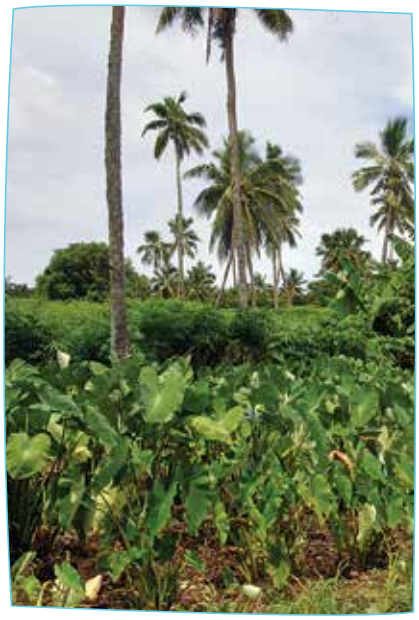


Figure 3: Number of tropical cyclones developing within and crossing the Tonga Exclusive Economic Zone per season. The 11-year moving average is in blue.

Wind-driven waves

Wind-waves around Tonga do not vary substantially in height throughout the year. Seasonally, waves are influenced by the trade winds and tropical storms, while from year to year they vary with the El Niño–Southern Oscillation and Southern Annular Mode. Near Nuku'alofa wave period is shorter during June to September and waves are directed from the east (Figure 4, top). From December to March, wave period increases slightly and waves are directed mostly from the north-east. To the north waves are characterised by variability of the Southern Hemisphere trade winds (Figure 4, bottom).



Taro crops.

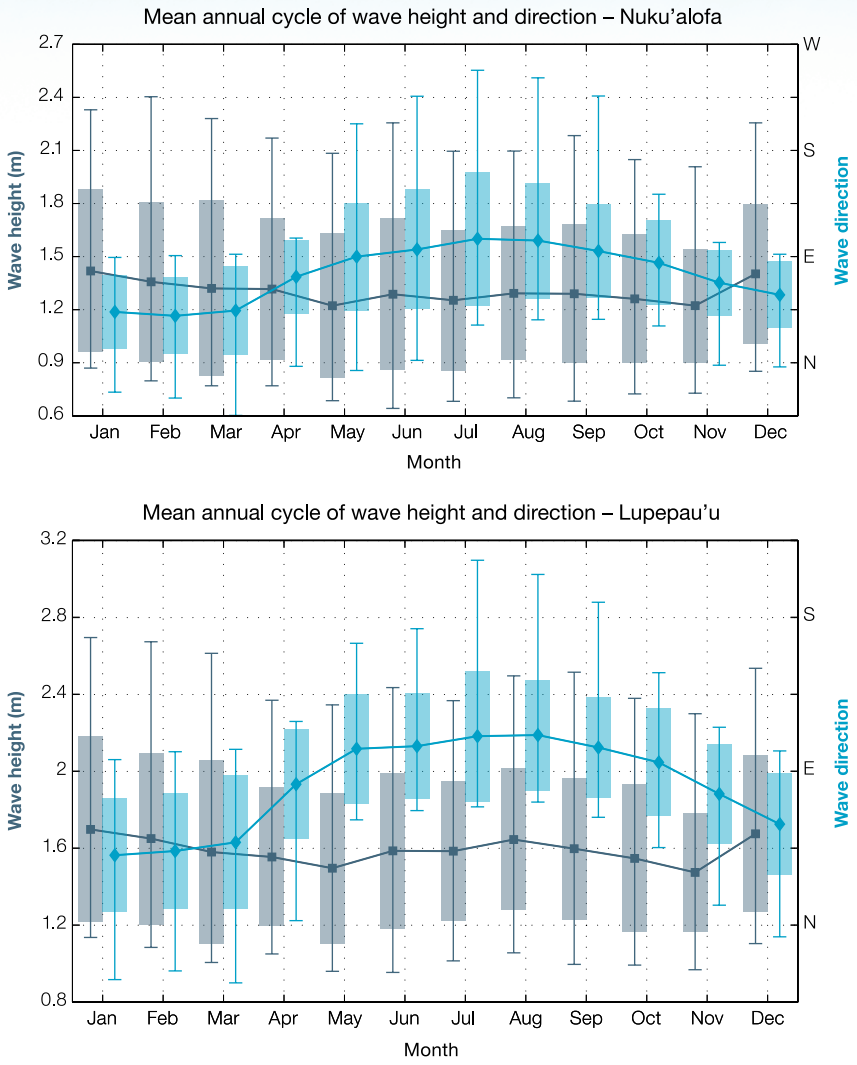


Figure 4: Annual cycle of wave height (grey) and wave direction (blue) at Nuku'alofa (top) and Lupepau'u (bottom) based on data from 1979–2009. The shaded boxes represent one standard deviation around the monthly means, and the error bars indicate the 5–95% range, showing the year-to-year variability in wave climate. The direction from which the waves are travelling is shown (not the direction towards which they are travelling).

Tonga's changing climate

Temperatures have increased

Annual and wet season mean and minimum temperatures have increased in Nuku'alofa since 1949 (Figure 5). Wet season maximum temperatures have increased at a rate of 0.15°C per decade and dry season minimum temperatures have increased at a rate of 0.13ºC per decade over the same period. Data at Lupepau'u are insufficient to evaluate temperature trends. These temperature increases are consistent with the global pattern of warming.

Rainfall varies from year to year

Dry season rainfall at Lupepau'u has increased since 1947 but there are no clear trends in wet season or annual rainfall over Tonga since the 1940s (Figure 5). Over this period there has been substantial variation in rainfall from year to year. There has been little change in extreme daily rainfall over the same period.

Taking weather observations, Tonga Meteorological Service.

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.

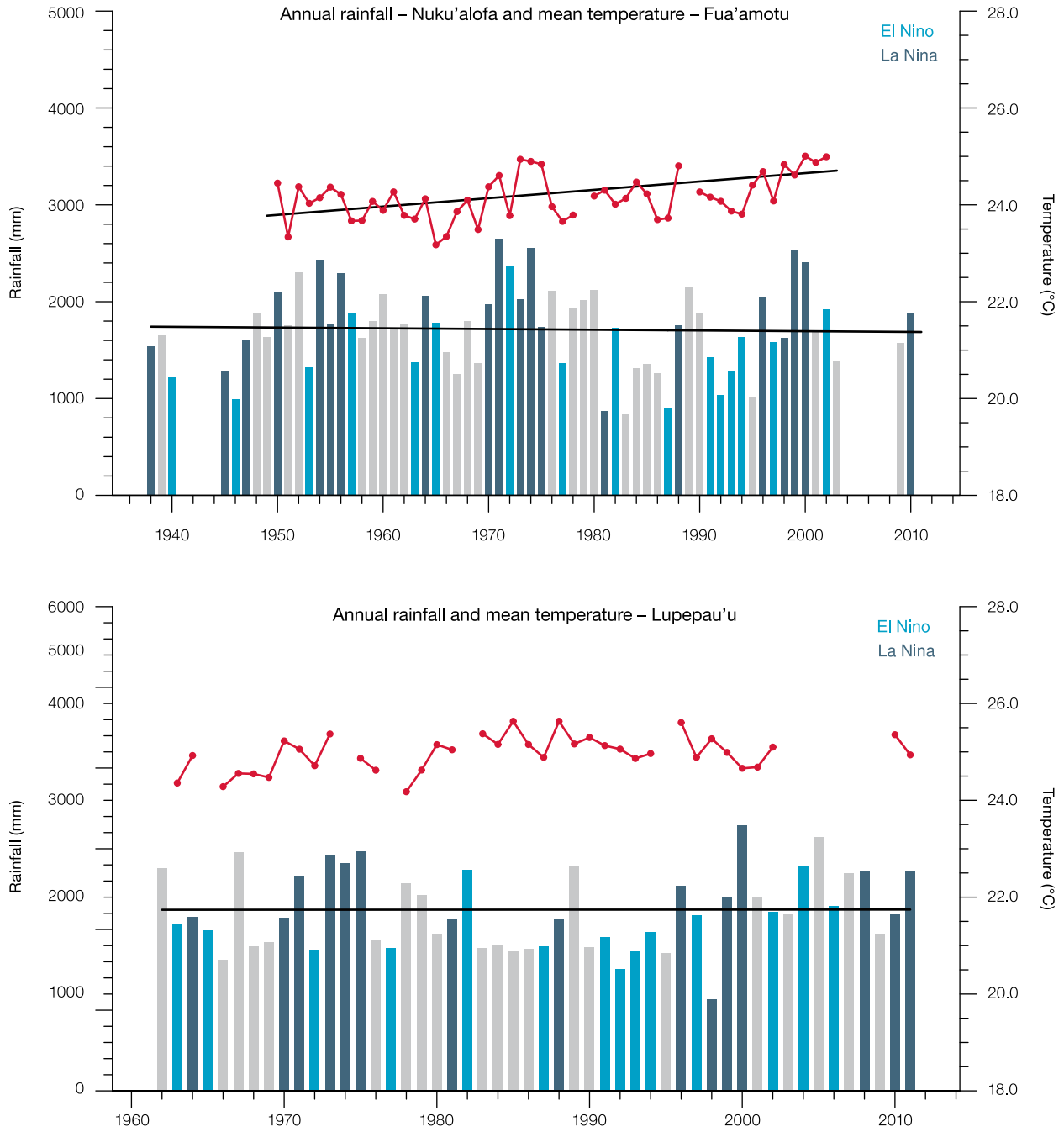


Figure 5: Annual average air temperature (red dots and line) and total rainfall (bars) at Nuku'alofa (top) and Lupepau'u (bottom). Light blue, dark blue and grey bars indicate El Niño, La Niña and neutral years respectively. No bars indicate that data is not available. The solid black lines show the trends.

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.

At a glance

- El Niño and La Niña events will continue to occur in the future, but there is little consensus on whether these events will change in intensity or frequency.

- Annual mean temperatures and extremely high daily temperatures will continue to rise.

- It is not clear whether mean annual rainfall will increase or decrease and the model average indicates little change with more extreme rain events.
- Drought frequency is projected to decrease slightly.

- Sea level will continue to rise.
- Ocean acidification is expected to continue.
- The risk of coral bleaching is expected to increase.
- December–March wave heights and periods are projected to decrease slightly.

- Tropical cyclones are projected to be less frequent but more intense.

Gathering seafood at low tide in Nuku'alofa.

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 very high emissions scenario, this increase in temperature is projected to be in the range of 0.4–1.0°C. Later in the century the range of the projected temperature increase under the different scenarios broadens.

Table 1: Projected changes in the annual average surface air temperature for Tonga. Values represent 90% of the range of the models and are relative to the period 1986–2005.

	2030 (°C)	2050 (°C)	2070 (°C)	2090 (°C)
Very low emissions scenario	0.3–0.9	0.4–1.0	0.3–1.0	0.2–1.1
Low emissions scenario	0.3–1.0	0.6–1.4	0.7–1.8	0.8–2.1
Medium emissions scenario	0.3–0.8	0.6–1.3	0.8–1.8	1.2–2.4
Very high emissions scenario	0.4–1.0	0.8–2.0	1.4–2.9	1.8–4.1

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.

Changing rainfall patterns

There is uncertainty around annual rainfall projections for Tonga as model results are not consistent. However, projections generally suggest 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. Wet and dry years will still occur in response to natural variability. Drought frequency is expected to decrease slightly by the end of the century.

More extreme rainfall days

Projections show extreme rainfall days are likely to occur more often and be more intense.

Less frequent 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.

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 6). By 2030, under a very high emissions scenario, this rise in sea level is projected to be in the range of 8–18 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.

Ocean acidification will continue

Under all four emissions scenarios the acidity level of sea waters in the Tonga region will continue to increase over the 21st century, with the greatest change under the very 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.

Wave climate will change

December to March wave heights and periods are projected to decrease slightly. There are no significant changes projected during June to September.

Table 2: Sea-level rise projections for Tonga. Values represent 90% of the range of model results and are relative to the period 1986–2005.

	2030 (cm)	2050 (cm)	2070 (cm)	2090 (cm)
Very low emissions scenario	8–18	14–30	19–43	23–58
Low emissions scenario	8–18	15–31	22–48	29–66
Medium emissions scenario	7–17	14–31	21–47	30–67
Very high emissions scenario	8–18	17–35	28–58	41–88

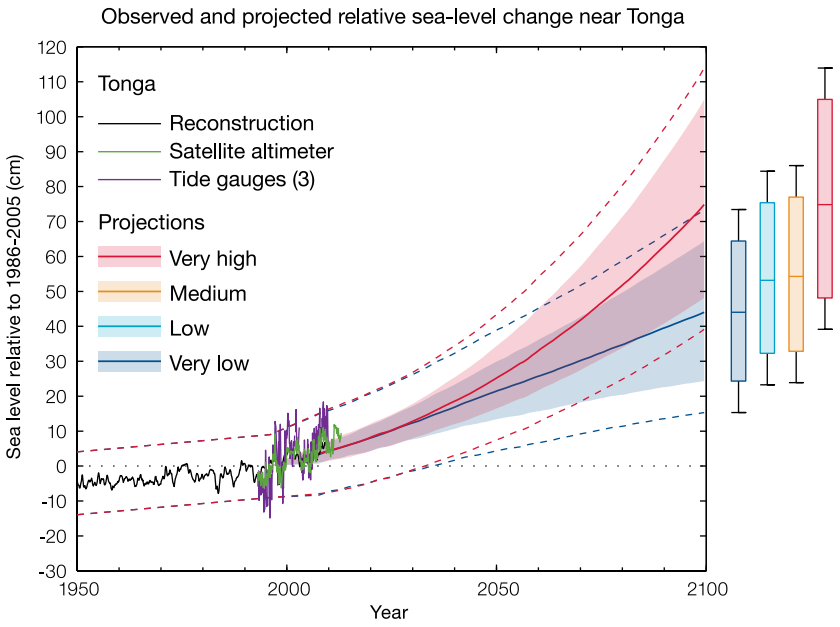


Figure 6: Tide-gauge records (purple) of relative sea level and the satellite record (green) since 1993. The reconstructed sea level data at Tonga (since 1950) is shown in black. Multi-model mean projections from 1995–2100 are given for the very high (red solid line) and very low emissions scenarios (blue solid line), with the 5–95% uncertainty range shown by the red and blue shaded regions. The ranges of projections for the four emissions scenarios by 2100 are also shown by the bars on the right. The dashed lines are an estimate of year-to-year variability in sea level (5–95% uncertainty range about the projections) and indicate that individual monthly averages of sea level can be above or below longer-term averages.

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 and Adaptation Planning Program have evaluated 26 models from around the world and found that 24 best represent the climate of the Tonga region of the western tropical Pacific. These 24 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. Greenhouse gas and aerosol emissions scenarios are used in climate modelling to provide projections that represent a range of possible futures. The Intergovernmental Panel on Climate Change (IPCC) has developed four greenhouse gas and emissions scenarios, called Representative Concentration Pathways (RCPs). These scenarios cover a broad range of possibilities. For example, the lowest scenario shows the likely outcome if global emissions are significantly reduced, while the highest scenario shows the impact of a pathway with no policy of reducing emissions.

The climate projections for Tonga are based on the four IPCC RCPs: very low emissions (RCP2.6), low emissions (RCP4.5), medium emissions (RCP6.0) and very high emissions (RCP8.5), for four 20-year time periods centred on 2030, 2050, 2070 and 2090, relative to a 20-year period centred on 1995 (Figure 7). Since individual models give different results, the projections are presented as a range of values. When interpreting projected changes in the mean climate in the Pacific, it is important to keep in mind that natural climate variability, such as the state of the El Niño-Southern Oscillation, strongly affects the climate from one year to the next.

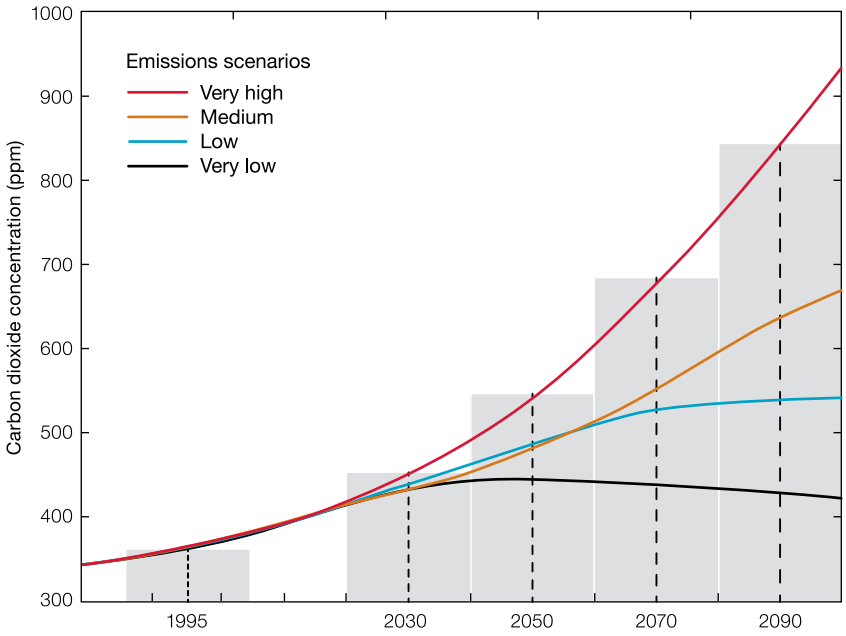


Figure 7: Carbon dioxide concentrations (parts per million, ppm) associated with the very low (RCP2.6), low (RCP4.5), medium (RCP6.0) and very high (RCP8.5) emissions scenarios for 20-year time periods (shaded) centred on 1995 (the reference period), 2030, 2050, 2070 and 2090.

This brochure contains a summary of climate projections for Tonga. For more information refer to the technical reports *Climate Change in the Pacific: Scientific Assessment and New Research (Volume 2)* and *Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports.*

These reports are available at **www.pacificclimatechangescience.org**.

Climate projections are also available through the web-based Pacific Climate Futures tool at **www.pacificclimatefutures.net**.

Changes in Tonga's climate

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

> Rainfall shows no clear trend since the 1940s. Projections of annual rainfall are unclear with some models suggesting a slight increase by the end of the century. Extreme rainfall events are projected to become more frequent and more intense. Drought frequency is projected to decrease slightly by the end of the century.

> By the end of this century projections suggest tropical cyclones will become less frequent.

> 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.

> December to March wave heights and periods are projected to decrease slightly.

This publication updates the original *Current and future climate of Tonga* brochure published in 2011.

The content of this brochure is the result of a collaborative effort between the Tonga Meteorological Service and the Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Program – a component of the Australian Government's International Climate Change Adaptation Initiative. The information in this publication, and research conducted by PACCSAP, builds on the findings of the 2013 IPCC Fifth Assessment Report, and uses new emissions scenarios and climate models.

For more detailed information on the climate of Tonga and the Pacific see *Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports* (2014) and *Climate Change in the Pacific: Scientific Assessment and New Research. Volume 1: Regional Overview. Volume 2: Country Reports* (2011).

www.pacificclimatechangescience.org

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