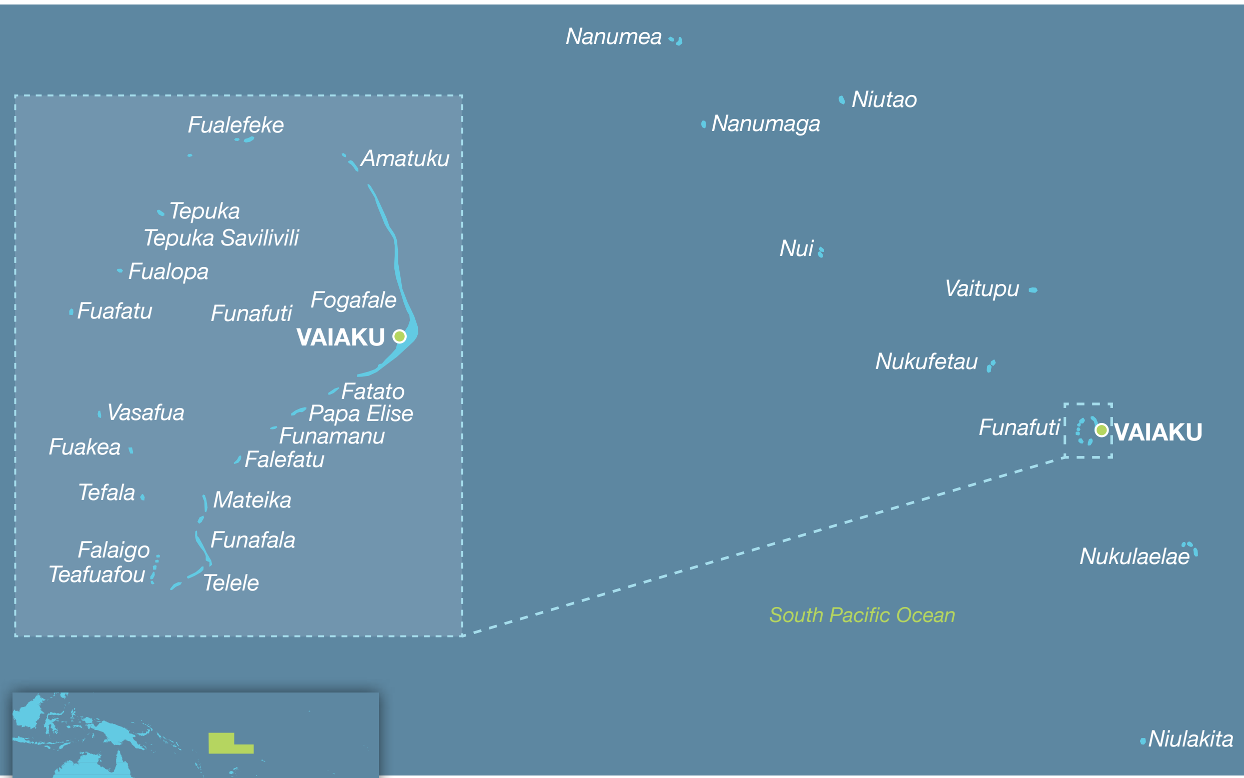
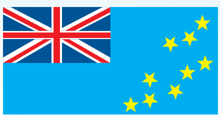
Pacific-Australia Climate Change Science and Adaptation Planning Program



Current and future climate of **Tuvalu**



> Tuvalu Meterological Service
> Australian Bureau of Meteorology
> Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Australian Government

Tuvalu's current climate

Temperature

In Funafuti, the capital of Tuvalu, there is little variation in temperature throughout the year. The maximum temperature is between 31–32°C and the minimum temperature between 25–26°C all year round. Air temperatures are strongly tied to the ocean temperatures surrounding the islands and atolls of the country.

Rainfall

The country has two distinct seasons – a wet season from November to April and a dry season from May to October (Figure 1), however rainfall averages more than 200 mm each month of the year in Funafuti and more than 160 mm in Nanumea. This is due to the location of Tuvalu near the West Pacific Warm Pool (Figure 2), where thunderstorm activity occurs year round.

Tuvalu's wet season is affected by the movement and strength of the South Pacific Convergence Zone (Figure 2). 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 the Cook Islands and is most intense during Tuvalu's wet season.

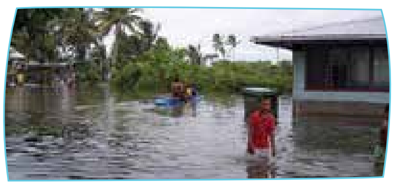
The West Pacific Monsoon can also bring heavy rainfall to Tuvalu during the wet season. The Monsoon is driven by large differences in temperature between the land and the ocean, and its arrival usually brings a switch from very dry to very wet conditions.

Year-to-year variability

Tuvalu'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 Funafuti, El Niño events tend to bring wetter, warmer conditions than normal, while La Niña events usually bring drier, cooler than normal conditions. This is likely due to the warmer ocean temperatures around Tuvalu in El Niño years.

Extreme weather events

Spring tides and tropical cyclones are among the main extreme events that affect Funafuti. As well as high winds and rainfall, tropical cyclones also cause storm surges and swells. The resulting flooding causes agricultural losses, particularly of taro crops and damage to buildings and roads along the coast.



Tuvalu Meteorological Service

Flooding in front of the Meeting Place (Lotonui Falekaupule), Tuvalu.

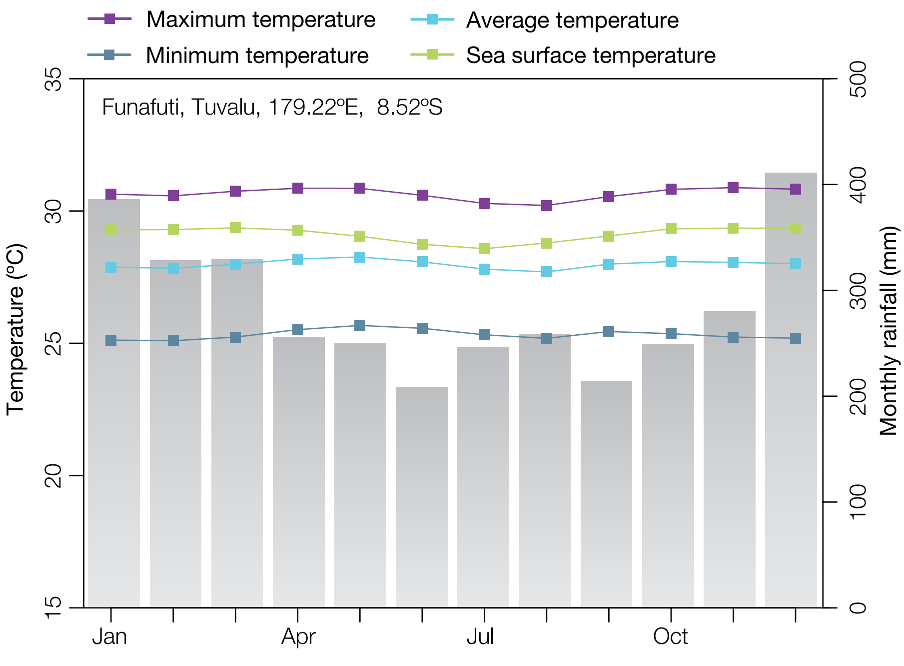


Figure 1: Seasonal rainfall and temperature at Funafuti.

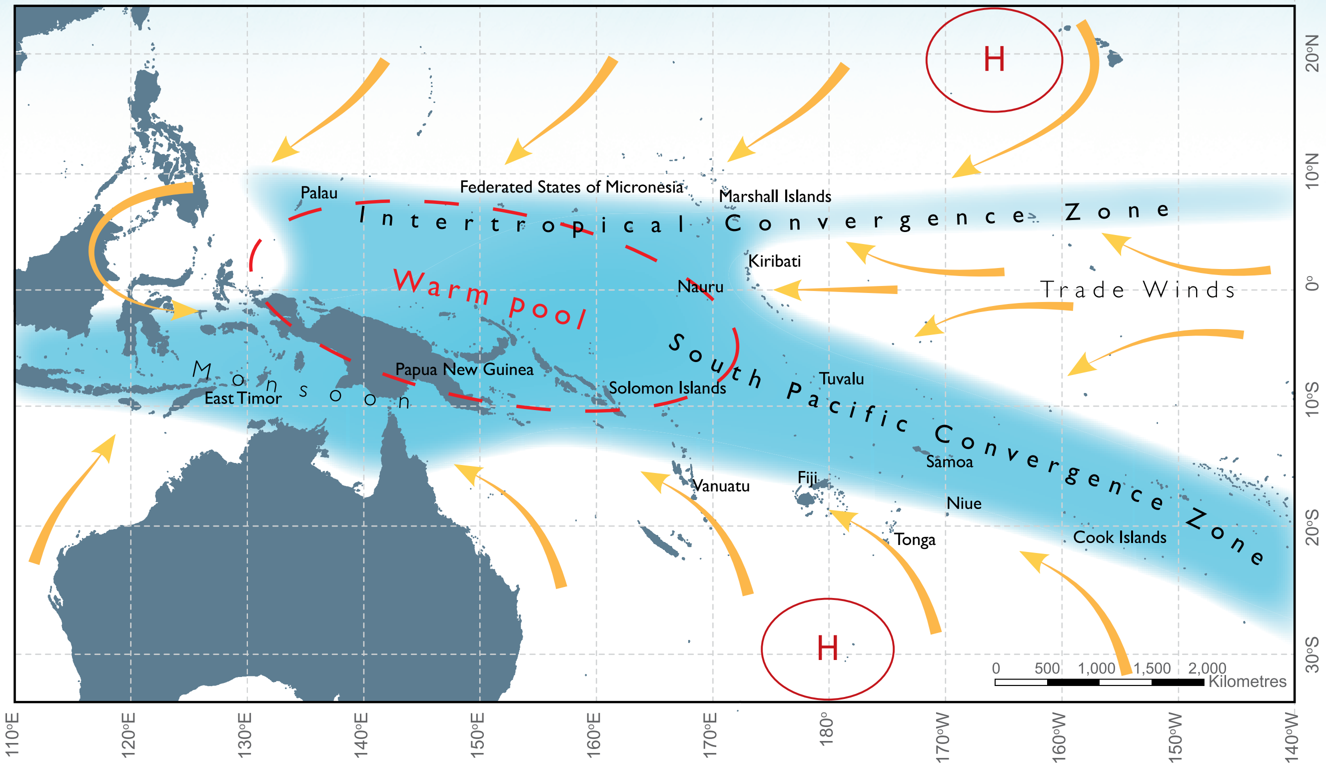


Figure 2: Average positions of the major climate features in November to April. The arrows show near surface winds, the blue shading represents the bands of rainfall convergence zones, the dashed oval shows the West Pacific Warm Pool and H represents typical positions of moving high pressure systems.

Tropical cyclones

Tropical cyclones tend to affect Tuvalu between November and April. In the 42-year period between the 1969 and 2010 seasons, 35 tropical cyclones developed in or crossed onto the Tuvalu Exclusive Economic Zone, an average of eight cyclones per decade (Figure 3). The number of cyclones varies widely from year to year, with none in some seasons but up to three in others. Over this period, cyclones occurred most frequently in El Niño years.

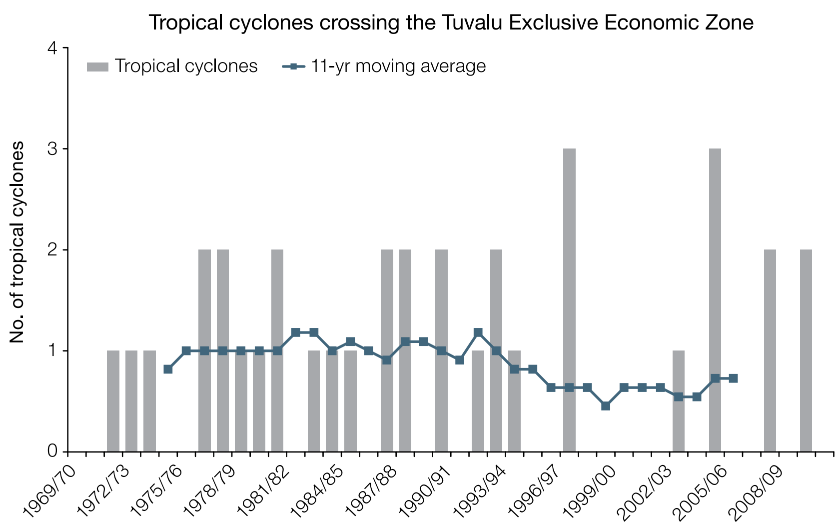


Figure 3: Number of tropical cyclones developing within and crossing the Tuvalu Exclusive Economic Zone per season. The 11-year moving average is in blue.

Wind-driven waves

Wind-waves around Tuvalu do not vary significantly in height during the year. Seasonally, waves are influenced by the trade winds, extra-tropical storms and cyclones. From year to year they vary with the El Niño–Southern Oscillation and the strength and location of the South Pacific Convergence Zone. At Funafuti maximum wave height occurs during June to September (Figure 4, top). Wave direction at Nanumea is north-easterly from December to March and south-easterly from May to October, associated with variability of the trade winds (Figure 4, bottom).

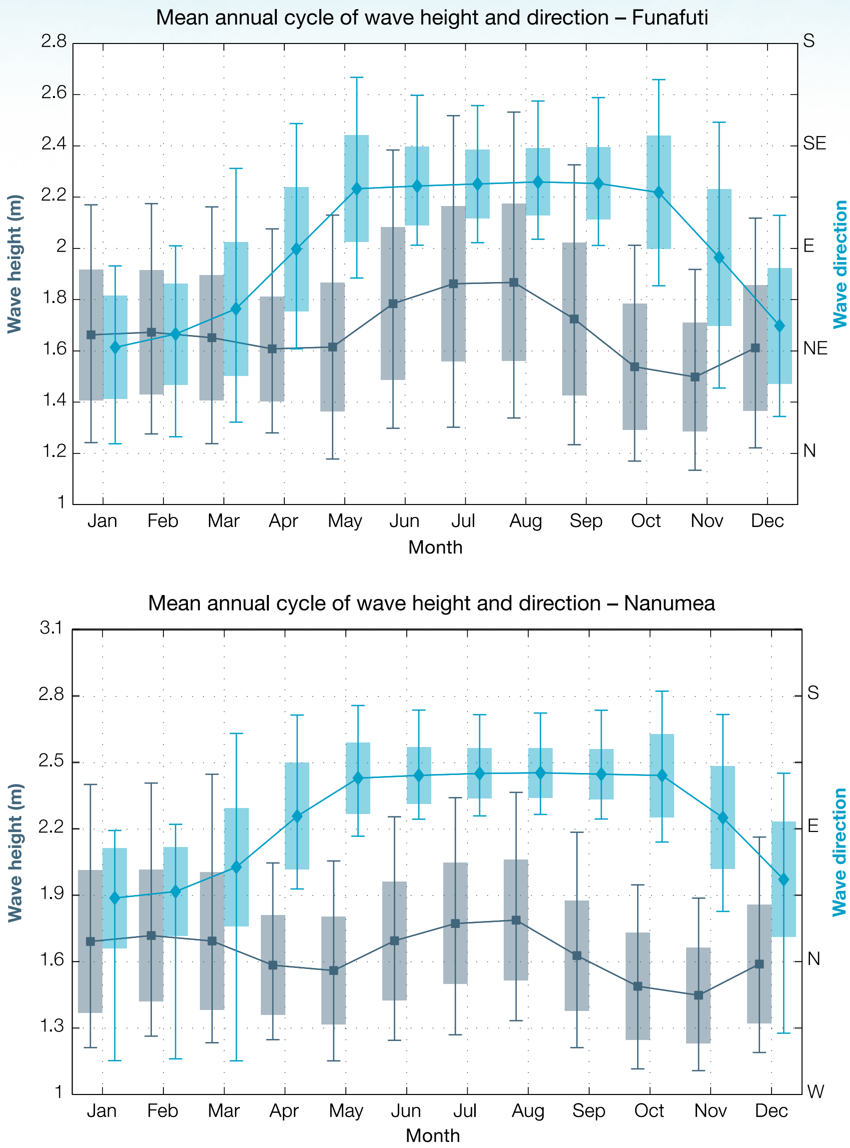


Figure 4: Annual cycle of wave height (grey) and wave direction (blue) at Funafuti (top) and Nanumea (bottom) based on data from 1979–2009. The shaded boxes represent one standard deviation around the monthly means, and the error bars indicate the 5–95% range, showing the year-to-year variability in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

Coral reef, Funafuti.

Tuvalu's changing climate

Temperatures have increased

Annual and dry season mean and maximum temperatures have increased at Funafuti since 1933 (Figure 5). Dry season maximum temperatures have increased at a rate of 0.11°C per decade and annual and dry season mean temperatures have increased at a rate of 0.10°C per decade over the same period. These temperature increases are consistent with the global pattern of warming. The number of warm nights has increased and the number of cool nights has decreased since 1961.

Aerial view of Funafuti Airport, Vaiaku.

Rainfall varies from year to year

There are no clear trends in wet season or annual rainfall over Tuvalu since 1927 (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.

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 Tuvalu by about 5 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 6 which includes the tide gauge record since 1977 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 Tuvalu's waters.

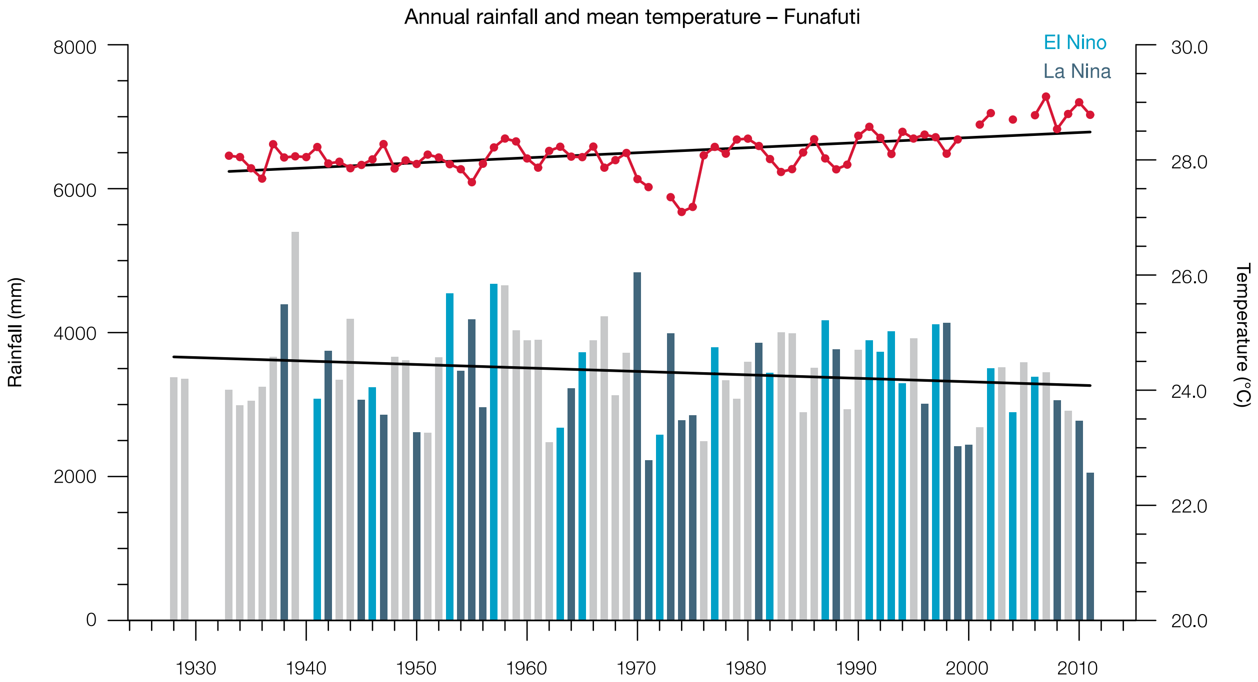


Figure 5: Annual average air temperature (red dots and line) and total rainfall (bars) at Funafuti. Light blue, dark blue and grey bars indicate El Niño, La Niña and neutral years respectively. No bars indicate that data is not available. The solid black lines show the trends.

Tuvalu's future climate

Climate impacts almost all aspects of life in Tuvalu. Understanding the possible future climate of Tuvalu 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, the model average indicating little change, with more extreme rain events.
- Incidence of drought 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.

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 Tuvalu (Table 1). By 2030, under a very high emissions scenario, this increase in temperature is projected to be in the range of 0.5–1.0°C. Later in the century the range of the projected temperature increase under the different scenarios broadens.

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 rainfall projections for Tuvalu as model results are not consistent. 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.

Table 1: Projected changes in the annual average surface air temperature for Tuvalu. 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	0.5–0.9	0.5–1.2	0.5–1.2	0.4–1.3
Low emissions scenario	0.5–1.0	0.7–1.4	0.9–1.8	1.0–2.1
Medium emissions scenario	0.4–0.9	0.6–1.4	0.9–2.0	1.1–2.6
Very high emissions scenario	0.5–1.0	1.0–1.9	1.5–3.1	2.0–4.0

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 also 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 Tuvalu region, projections tend to show a decrease in the frequency of tropical cyclones by the late 21st century.

Inundation during spring tide in front of Tuvalu Meteorological Service.

Taking temperature observations, Tuvalu Meteorological Service.

Sea level will continue to rise

Sea level is expected to continue to rise in Tuvalu (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 7–18 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

Under all four emissions scenarios the acidity level of sea waters in the Tuvalu 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 Tuvalu. Values represent 90% of the range of the model results and are relative to the period 1986–2005.

	2030 (cm)	2050 (cm)	2070 (cm)	2090 (cm)
Very low emissions scenario	7–17	13–30	19–44	23–59
Low emissions scenario	7–17	13–31	20–48	28–67
Medium emissions scenario	7–16	13–29	20–47	28–67
Very high emissions scenario	7–18	16–34	26–57	39–87

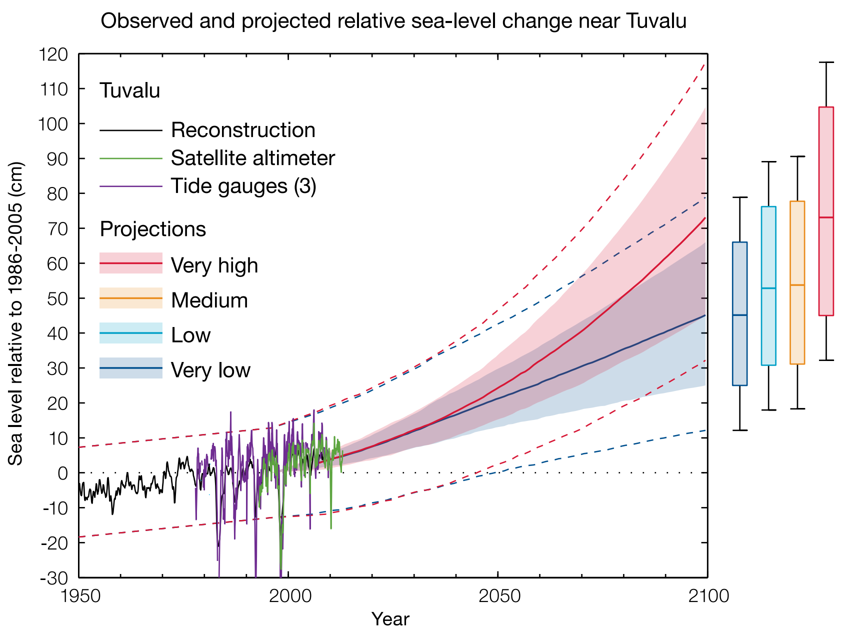


Figure 6: Tide-gauge records of relative sea level (since the late 1970s) are indicated in purple, and the satellite record (since 1993) in green. The reconstructed sea level data at Tuvalu (since 1950) is shown in black. Multi-model mean projections from 1995–2100 are given for the very high (red solid 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 Tuvalu region of the western tropical Pacific. These 24 models have been used to develop climate projections for Tuvalu.

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 Tuvalu 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.

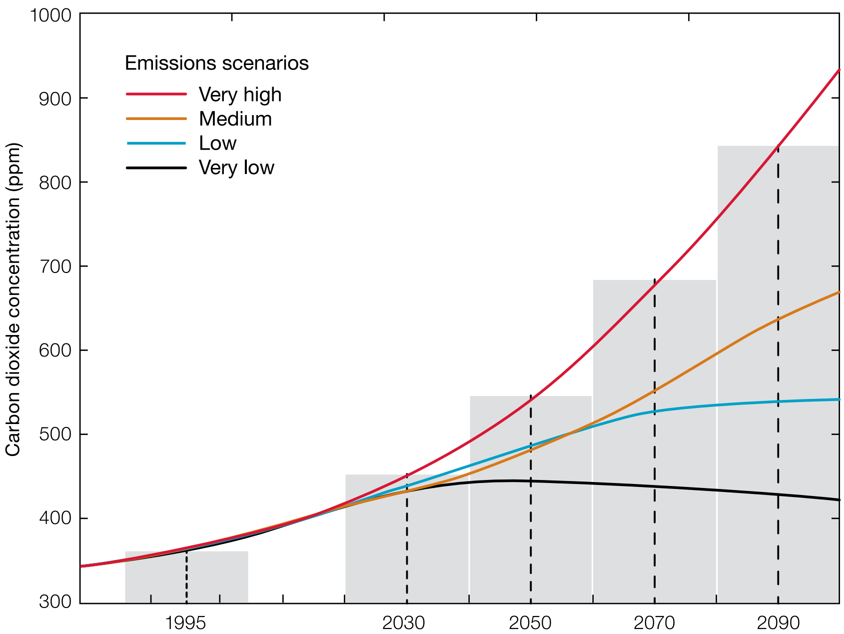


Figure 7: Carbon dioxide concentrations (parts per million, ppm) associated with the very low (RCP2.6), low (RCP4.5), medium (RCP6.0) and very high (RCP8.5) emissions scenarios for 20-year time periods (shaded) centred on 1995 (the reference period), 2030, 2050, 2070 and 2090.

This brochure contains a summary of climate projections for Tuvalu. 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 Tuvalu's climate

- Temperatures have warmed and will continue to warm with more very hot days in the future.
- Rainfall shows no clear trend since 1927. Projections of annual rainfall are unclear, with models indicating little change. Wet and dry years will still occur as a result of natural variability. Extreme rainfall events are projected to become more frequent and more intense. Drought frequency is projected to decrease by the end of the century.
- By the end of this century projections suggest decreasing numbers of tropical cyclones but a possible shift towards more intense categories.
- Sea level near Tuvalu has risen and will continue to rise throughout this century.
- Ocean acidification has been increasing in Tuvalu'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 Tuvalu* brochure published in 2011.

The content of this brochure is the result of a collaborative effort between the Tuvalu 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 Tuvalu 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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