Pacific-Australia Climate Change Science and Adaptation Planning Program

Current and future climate of the **Cook Islands**

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

Australian Government

Current climate of the **Cook Islands**

Temperature

Seasonal temperatures differ between the northern and southern Cook Islands. The Northern Cook Islands' (Northern Group) position so close to the equator results in fairly constant temperatures throughout the year, while in the Southern Cook Islands (Southern Group) temperatures cool off during the dry season (May to October, Figure 1). Changes in temperatures are strongly tied to changes in the surrounding ocean temperature. The annual average temperature at Penrhyn in the Northern Group is 28°C and at Rarotonga in the Southern Group is 24.5°C.

Rainfall

Rainfall in the Cook Islands is strongly affected by the South Pacific Convergence Zone. This band of heavy rainfall is caused by air rising over warm waters where winds converge, resulting in thunderstorm activity. It extends across the South Pacific Ocean from the Solomon Islands to east of the Cook Islands (Figure 2). It is centred close to or over the Southern Group from November to May. This is when the South Pacific Convergence Zone is most active and furthest south. From November to March the South Pacific Convergence Zone is wide and strong enough for the Northern Group to also receive significant rainfall. The driest months of the year in the Cook Islands are from June to October.

Year-to-year variability

The Cook Islands' 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. The El Niño-Southern Oscillation has opposite effects on the Northern and Southern Groups. In Rarotonga, El Niño events tend to bring drier and cooler conditions than normal, while in the north El Niño usually brings wetter conditions. Ocean temperatures warm in the north during an El Niño event so air temperatures also warm.

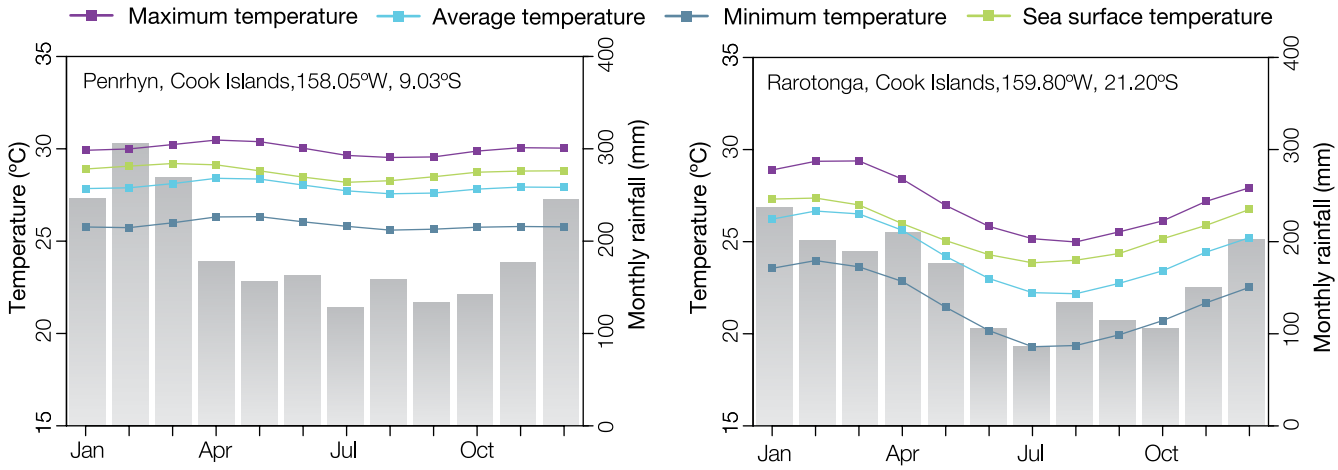


Figure 1: Seasonal rainfall and temperature at Penrhyn (in the north) and Rarotonga (in the south).

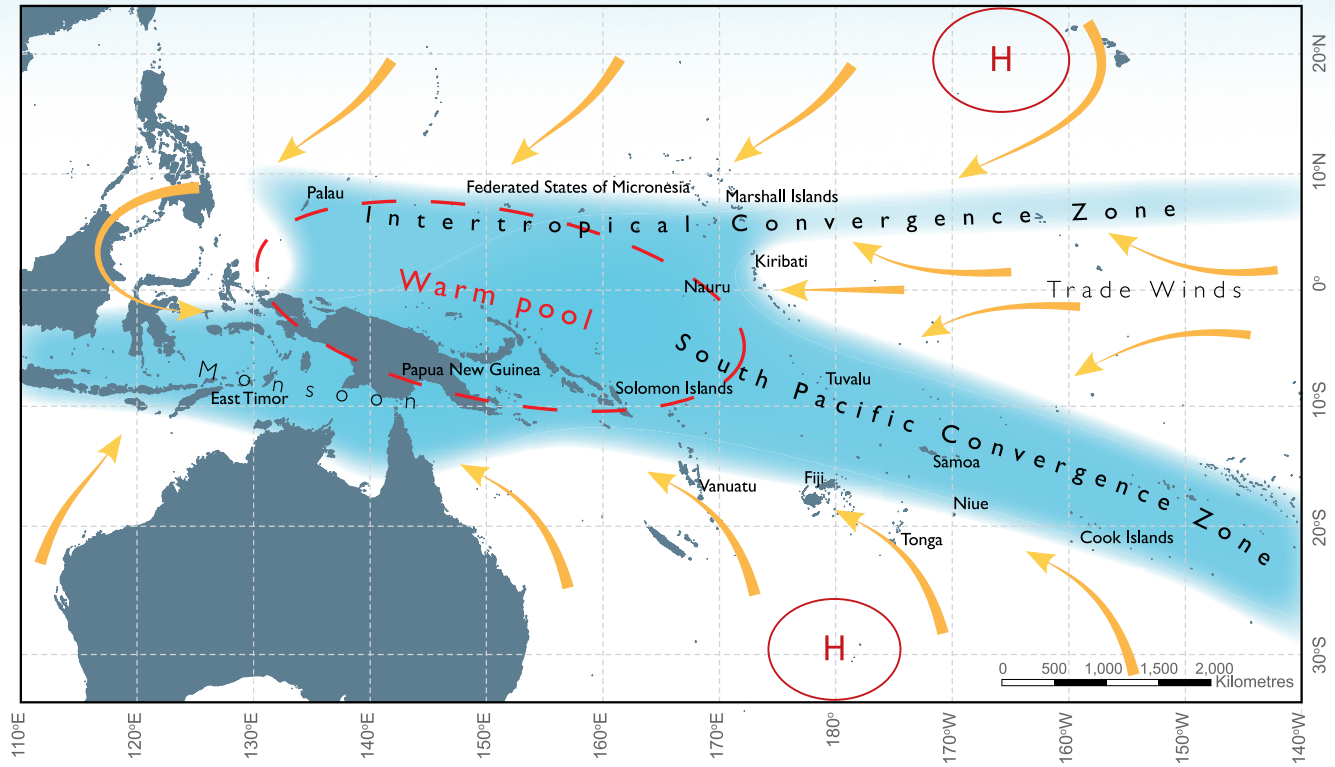


Figure 2: Average positions of the major climate features in November to April. The arrows show near surface winds, the blue shading represents the bands of rainfall convergence zones, the dashed oval shows the West Pacific Warm Pool and H represents typical positions of moving high pressure systems.

Tropical cyclones

Tropical cyclones tend to affect the Cook Islands between November and April. In the 42-year period between the 1969 and 2010 seasons, 74 tropical cyclones developed in or crossed into the Cook Island Exclusive Economic Zone, an average of 18 cyclones per decade (Figure 3). The number of cyclones varies widely from year to year, with none in some seasons but up to six in others. Over the period 1969 to 2010, cyclones occurred more frequently in El Niño years.

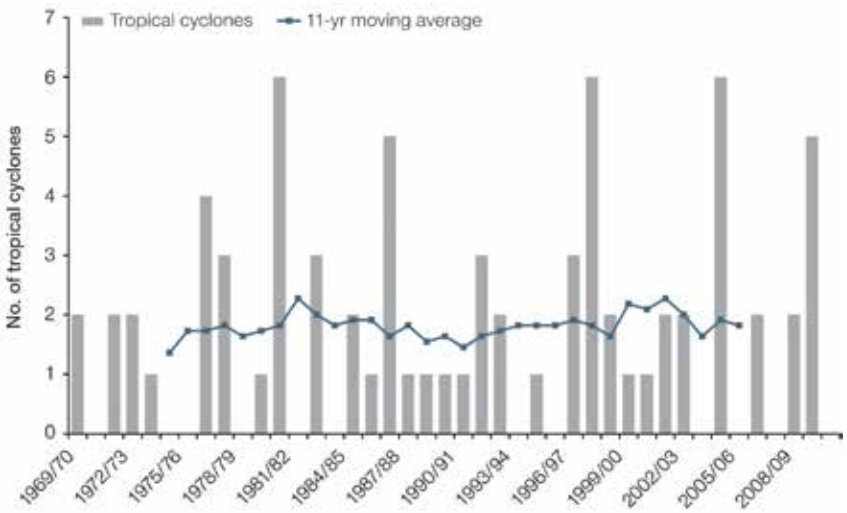


Figure 3: Number of tropical cyclones developing within and crossing the Cook Islands Exclusive Economic Zone per season. The 11-year moving average is in blue.

Wind-driven waves

Wind-waves in the Cook Islands are dominated by trade winds and the South Pacific Convergence Zone seasonally, and the El Niño–Southern Oscillation and Southern Annular Mode from year to year. Larger storm waves are seen in the Southern Cook Islands than in the Northern Cook Islands, usually associated with tropical cyclones.

In the Southern Group waves are predominantly from the south-east in May to September and from the north-east during December to March (Figure 4, top). In the Northern Group waves are predominantly from the south in June to September and from the north-west during December to March (Figure 4, bottom). Wave height remains stable throughout the year, with the largest waves occurring during December to March.

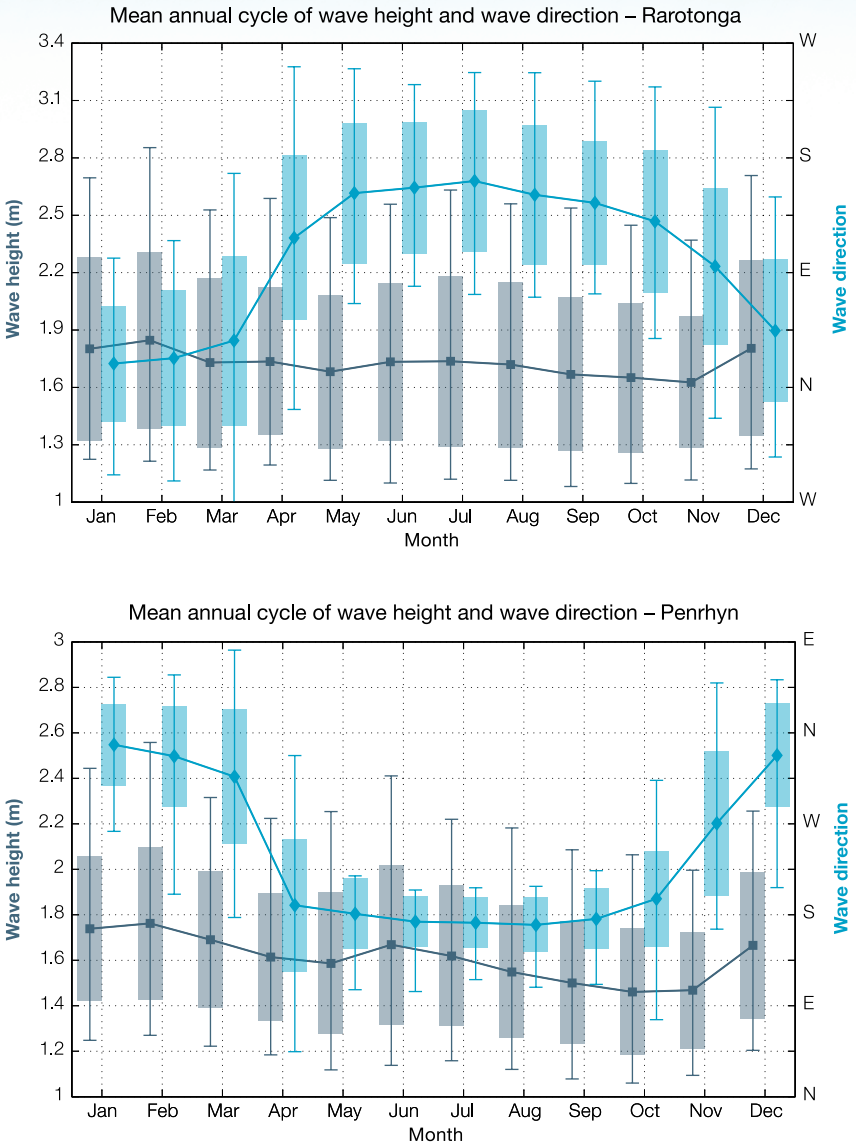


Figure 4: Annual cycle of wave height (grey) and wave direction (blue) at Rarotonga (top) and Penrhyn (bottom) based on data from 1979–2009. The shaded boxes represent one standard deviation around the monthly means, and the error bars indicate the 5–95% range, showing the year-to-year variability in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

Changing climate of the **Cook Islands**

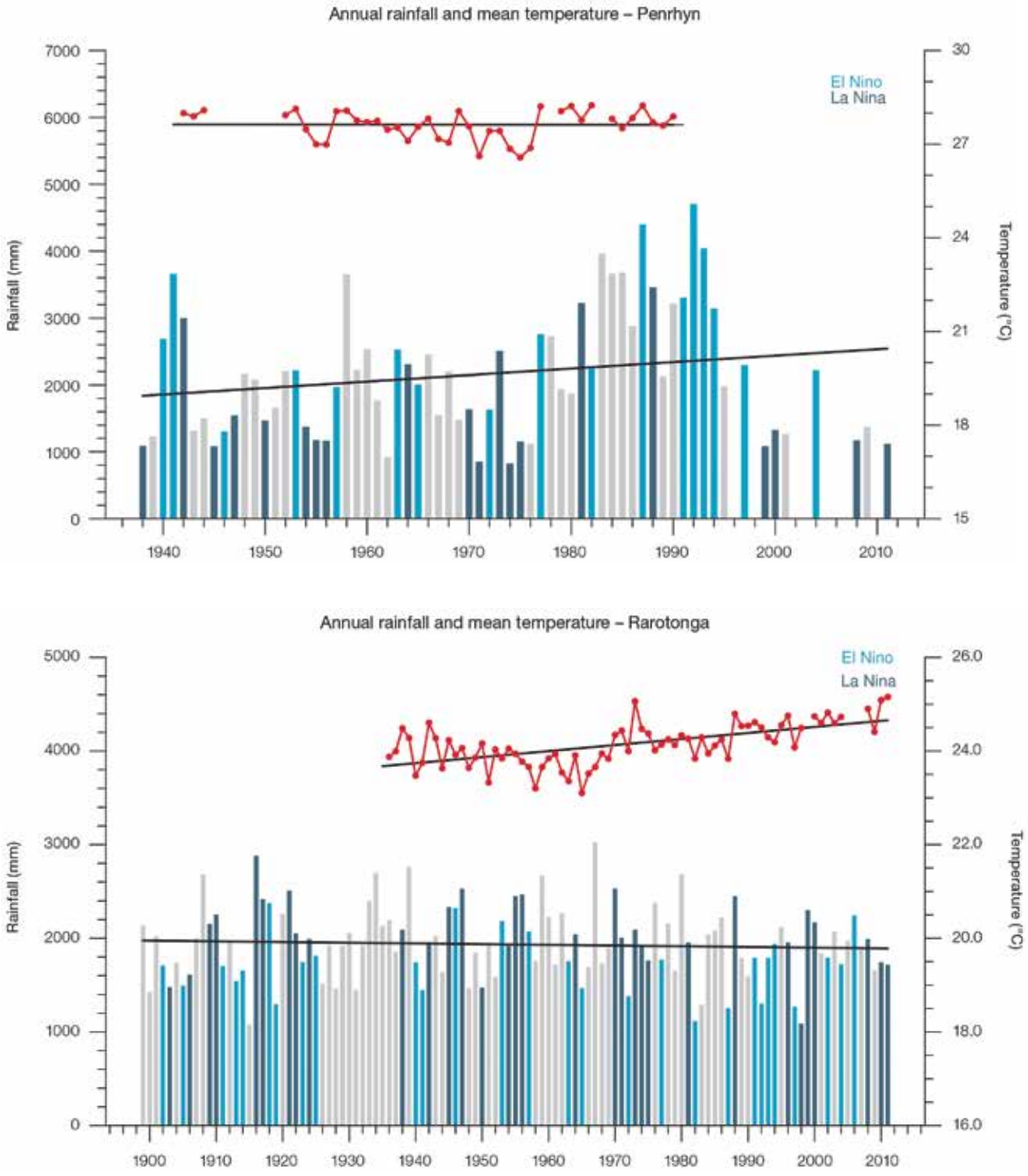


Figure 5 : Annual average air temperature (red dots and line) and total rainfall (bars) at Penrhyn (top) and Rarotonga (bottom). Light blue, dark blue and grey bars indicate El Niño, La Niña and neutral years respectively. No bars indicate that data is not available. Solid black lines show the trends.

Temperatures have increased

Annual temperatures have increased in Rarotonga since 1950 (Figure 5). In Rarotonga and Penhryn, maximum temperatures have increased at a rate of 0.09°C per decade, while minimum temperatures have increased faster at Rarotonga (0.19ºC) than at Penhryn (0.04ºC). These temperature increases are part of the global pattern of warming.

Daily temperature data for Rarotonga show clear increases in warm temperature extremes and decreases in cool temperature extremes. The numbers of warm days and warm nights at Rarotonga have increased, while the number of cool nights has decreased (Figure 6).

Rainfall varies from year to year

There are no clear trends in rainfall over the Cook Islands since 1899. There has been substantial variation in rainfall from year to year over this period. There has also been little change in extreme daily rainfall since the mid-1930s.

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 the Cook Islands by about 4 mm per year since 1993. This is slightly 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 since 1977 and the 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 the Cook Islands' waters.

National Environment Service, Government of the Cook Islands

Islet and coral microatolls in Penrhyn.

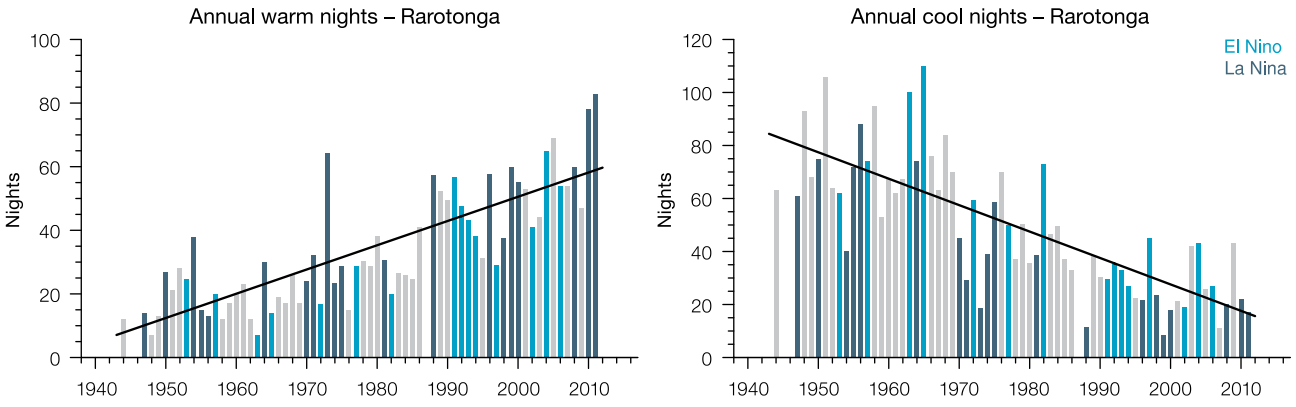


Figure 6: Annual total number of warm nights (left) and cool nights (right) at Rarotonga. Light blue, dark blue and grey bars indicate El Niño, La Niña and neutral years respectively. Solid black lines show the trends.

Future climate of the **Cook Islands**

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

At a glance

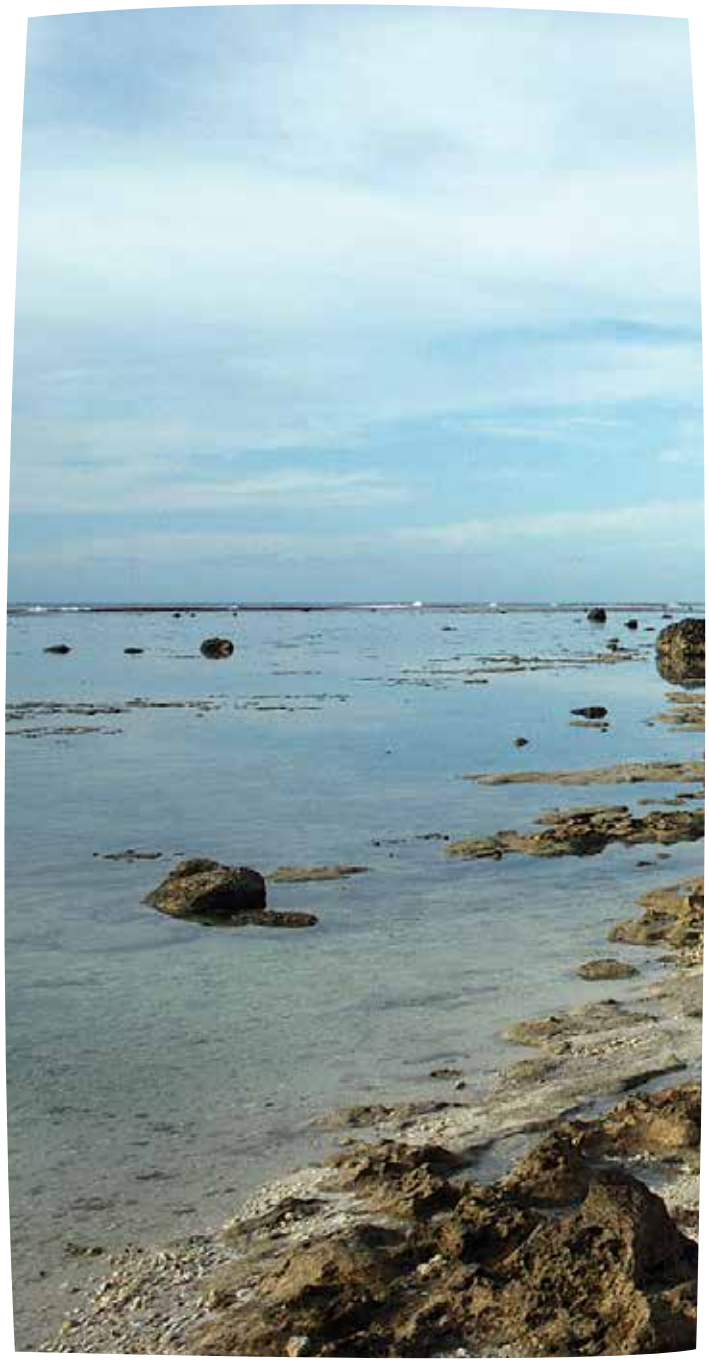
- El Niño and La Niña events will continue to occur in the future, but there is little consensus on whether these events will change in intensity or frequency.

- Annual mean temperatures and extremely high daily temperatures will continue to rise.
- Drought frequency is projected to remain similar to the current climate in the Southern Cook Islands, but increase slightly in the Northern Cook Islands under the high emission scenario.

- Average annual rainfall is projected to stay similar to the current climate, except for a small decrease in the dry season in the Northern Cook Islands under the high emission scenario, with more extreme rain events.
- Drought frequency is projected to decrease in the Southern Cook Islands, but increase slightly in the Northern Cook Islands under the high emission scenario.

- Sea level will continue to rise.
- Ocean acidification is expected to continue.
- The risk of coral bleaching is expected to increase.
- Wave climate is not projected to change significantly.

- 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 the Cook Islands (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 in the Northern Group and 0.4–1.0ºC in the Southern Group.

More very hot days

Increases in average temperatures will also result in a similar rise in the temperature on extremely hot days. The number of hot days is also expected to increase.

Changing rainfall patterns

There is uncertainty around projected changes in the South Pacific Convergence Zone, so there is only moderate confidence in rainfall changes for the Cook Islands. Projections indicate that the Northern Group is expected to get drier during the dry season. However, average annual rainfall is not projected to change significantly over the course of the 21st century.

Drought frequency is projected to remain similar to the current climate in the Southern Group, but increase slightly in the Northern Group under the high emissions scenario.

More extreme rainfall days

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

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

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

	2030 (°C)	2050 (°C)	2070 (°C)	2090 (°C)
Northern Cook Islands				
Very low emissions scenario	0.4–0.9	0.5–1.2	0.4–1.2	0.5–1.2
Low emissions scenario	0.4–1.0	0.6–1.3	0.8–1.8	0.9–2.1
Medium emissions scenario	0.4–0.9	0.6–1.4	0.8–1.8	1.0–2.4
Very high emissions scenario	0.5–1.0	0.9–1.8	1.5–2.9	2.0–3.8
Southern Cook Islands				
Very low emissions scenario	0.3–0.9	0.3–1.0	0.3–1.1	0.2–1.1
Low emissions scenario	0.3–0.9	0.6–1.5	0.7–1.8	0.7–2.1
Medium emissions scenario	0.3–0.9	0.5–1.4	0.8–1.9	1.1–2.4
Very high emissions scenario	0.4–1.0	0.8–2.0	1.3–3.0	1.7–4.2

Geoff Mackley

Rarotonga, Cyclone Meena, 2005.

Sea level will continue to rise

Sea level is expected to continue to rise in the Cook Islands (Table 2 and Figure 7). By 2030, this rise in sea level is projected to be in the range of 7–17 cm for all emissions scenarios. 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 the Cook Islands. Values represent 90% of the range of the models and changes are relative to the average of the period 1986-2005.

	2030 (cm)	2050 (cm)	2070 (cm)	2090 (cm)
Very low emissions scenario	7–17	13–29	18–43	22–57
Low emissions scenario	7–17	14–30	21–47	28–65
Medium emissions scenario	7–16	13–29	20–46	28–66
Very high emissions scenario	8–17	16–33	26–56	39–86

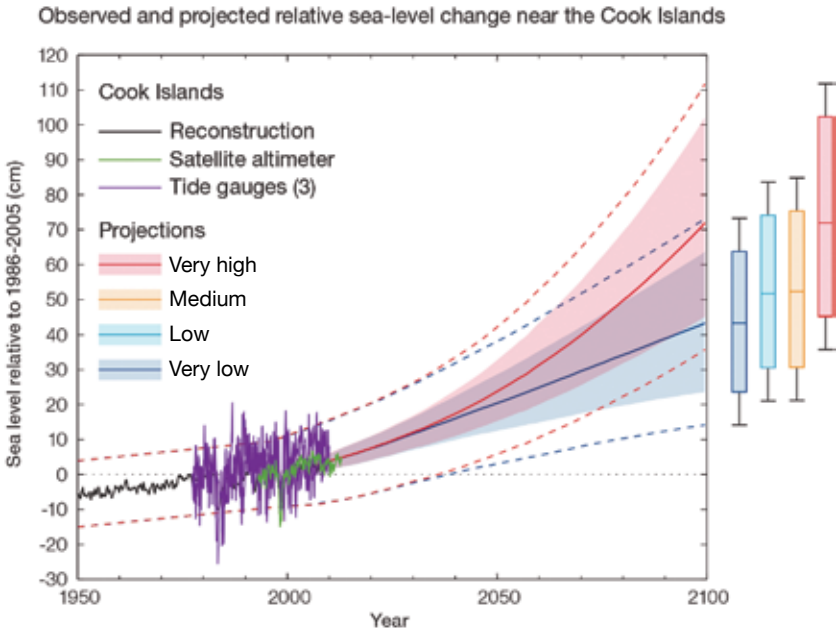


Figure 7: Tide-gauge records of relative sea-level (since the late 1970s) are indicated in purple, and the satellite record (since 1993) in green. The reconstructed sea level data at the Cook Islands (since 1950) is shown in black. Multi-model mean projections from 1995–2100 are given for the very high (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.

Ocean acidification will continue

Under all four emissions scenarios the acidity level of sea waters in the Cook Islands 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.

Little change in wave climate

The wind-wave climate of the Cook Islands is projected to show little change by the end of the century. Some models suggest a slight decrease in wave height during the wet season, however there is large year-to-year variability.

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-Australia 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 Cook Islands region of the western tropical Pacific. These 24 models have been used to develop climate projections for the Cook Islands.

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) 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 the Cook Islands are based on the four IPCC emissions scenarios: very low (RCP2.6), low (RCP4.5), medium (RCP6.0) and very high (RCP8.5), for 20-year time periods centred on 2030, 2050, 2070 and 2090, relative to a 20-year time period centred on 1995 (Figure 8). 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.

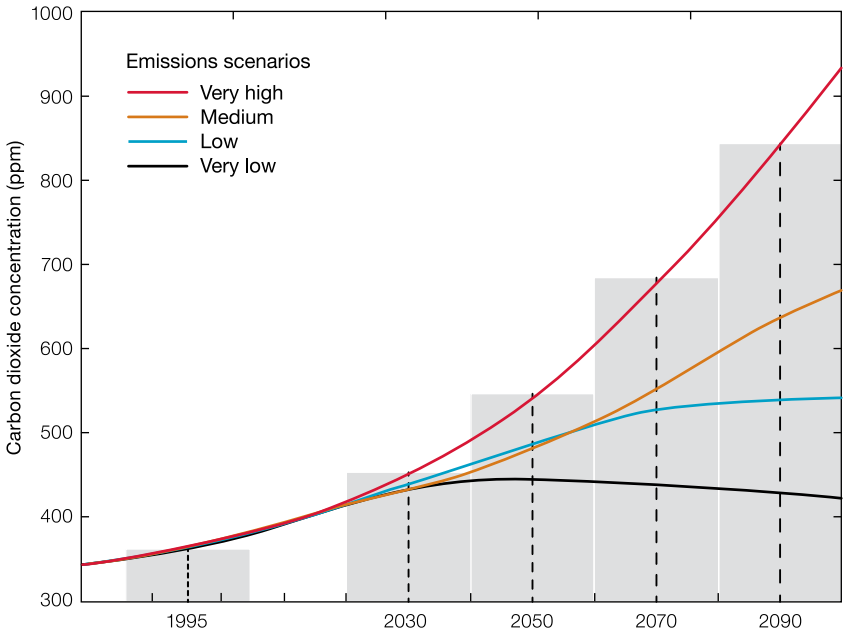


Figure 8: Carbon dioxide concentrations (parts per million, ppm) associated with the very low (RCP2.6), low (RCP4.5), medium (RCP6.0) and very high (RCP8.5) emissions scenarios for 20-year time periods (shaded) centred on 1995 (the reference period), 2030, 2050, 2070 and 2090.

This brochure contains a summary of climate projections for the Cook Islands. 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 the **Cook Islands' climate**

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

> Annual rainfall in the Cook Islands is not projected to change but rainfall may decrease in the dry season in the Northern Cook Islands. Rainfall patterns are projected to change over this century with more frequent and more intense extreme rainfall days.

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

> Sea level near the Cook Islands has risen and will continue to rise throughout this century.

> Wave climate is not projected to change by the end of the century.

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

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

The content of this brochure is the result of a collaborative effort between the Cook Islands 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. This 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 the Cook Islands 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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