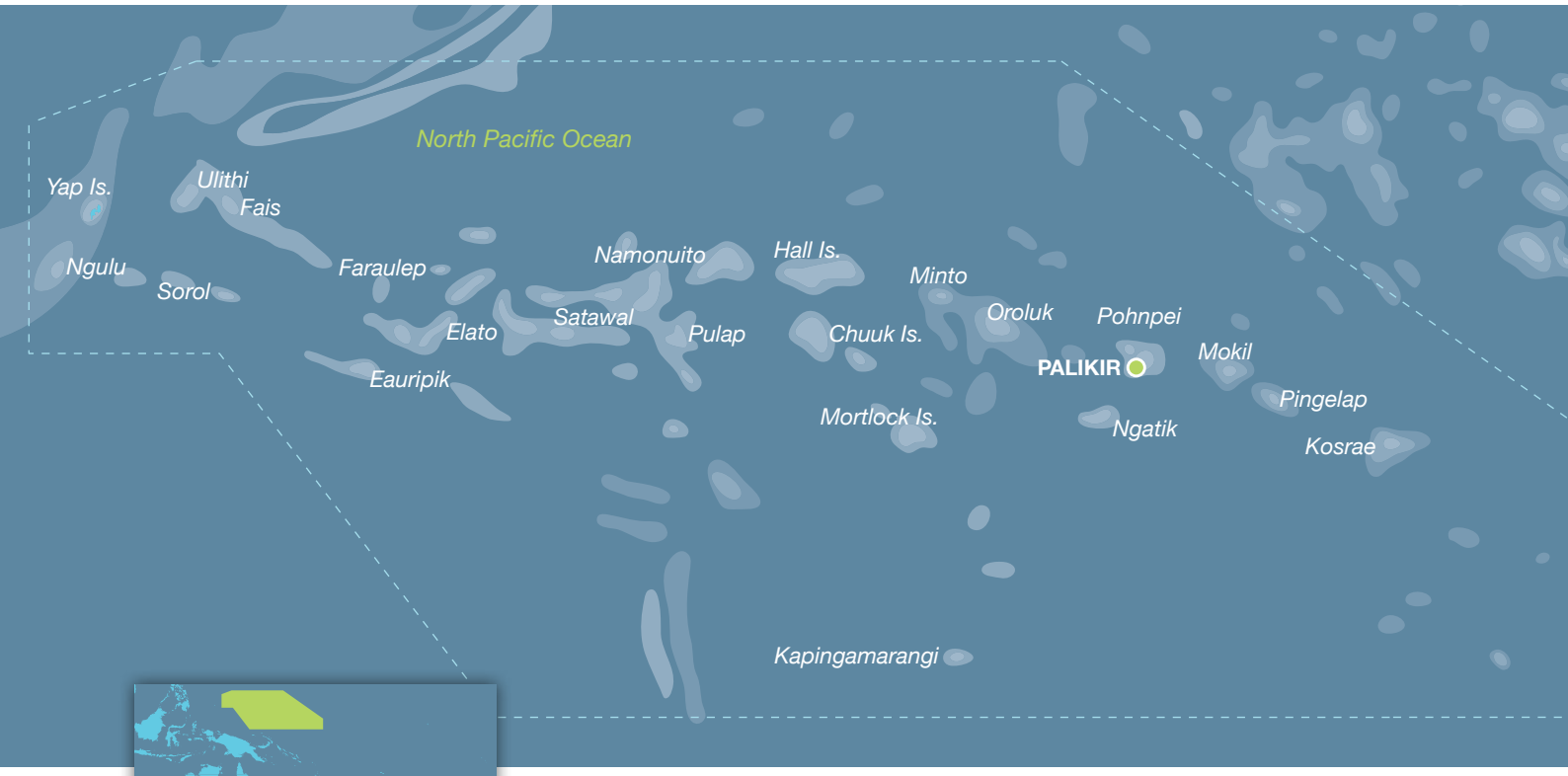
Pacific-Australia Climate Change Science and Adaptation Planning Program



Current and future climate of the **Federated States of Micronesia**

> Federated States of Micronesia National Weather Service Office
> Australian Bureau of Meteorology
> Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Australian Government

Current climate of the **Federated States of Micronesia**

Temperature

In the Federated States of Micronesia there is little seasonal variation in temperature, with less than 3ºF (1.5ºC) between the average hottest and coolest months. The country has two seasons – a dry season from November to April and a wet season from May to October (Figure 1).

Rainfall

Rainfall in the Federated States of Micronesia is affected by the movement of the Intertropical 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 Pacific just north of the equator (Figure 2). The wet season occurs when the Intertropical Convergence Zone strengthens and moves north close to the Federated States of Micronesia. The West Pacific Monsoon also impacts rainfall, bringing additional rain during the wet season. The Monsoon is driven by large differences in temperature between the land and the ocean, and its seasonal arrival usually brings a switch from very dry to very wet conditions.

Year-to-year variability

The Federated States of Micronesia'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 Pohnpei, El Niño tends to result in drier conditions during the dry season, but higher than average rainfall during the wet season. La Niña tends to bring above average rainfall in the dry season. The West Pacific Monsoon affects the western states of Chuuk and especially Yap more than the eastern states of Pohnpei and Kosrae. It tends to be farther east during El Niño, bringing higher rainfall, and in a more western position during La Niña, resulting in less rainfall. The Intertropical Convergence Zone results in less rainfall during El Niño events and more during La Niña.

Extreme weather events

Droughts, typhoons, storm waves, flooding and landslides all affect the Federated States of Micronesia. El Niño events are associated with drier conditions and occasional droughts. Fires, water shortages and food shortages have occurred during severe dry events. During El Niño events above-average numbers of tropical storms occur in the Federated States of Micronesia region.

Johannes Berdon, National Weather Service Office

Storm surge damage, Oneop, Chuuk.

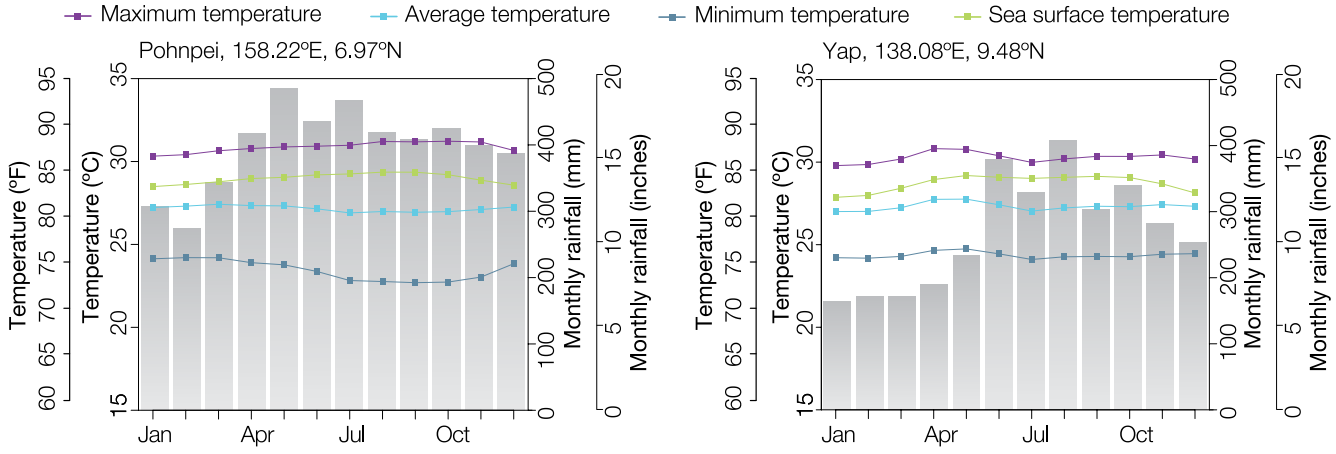


Figure 1: Seasonal rainfall and temperature at Pohnpei and Yap.

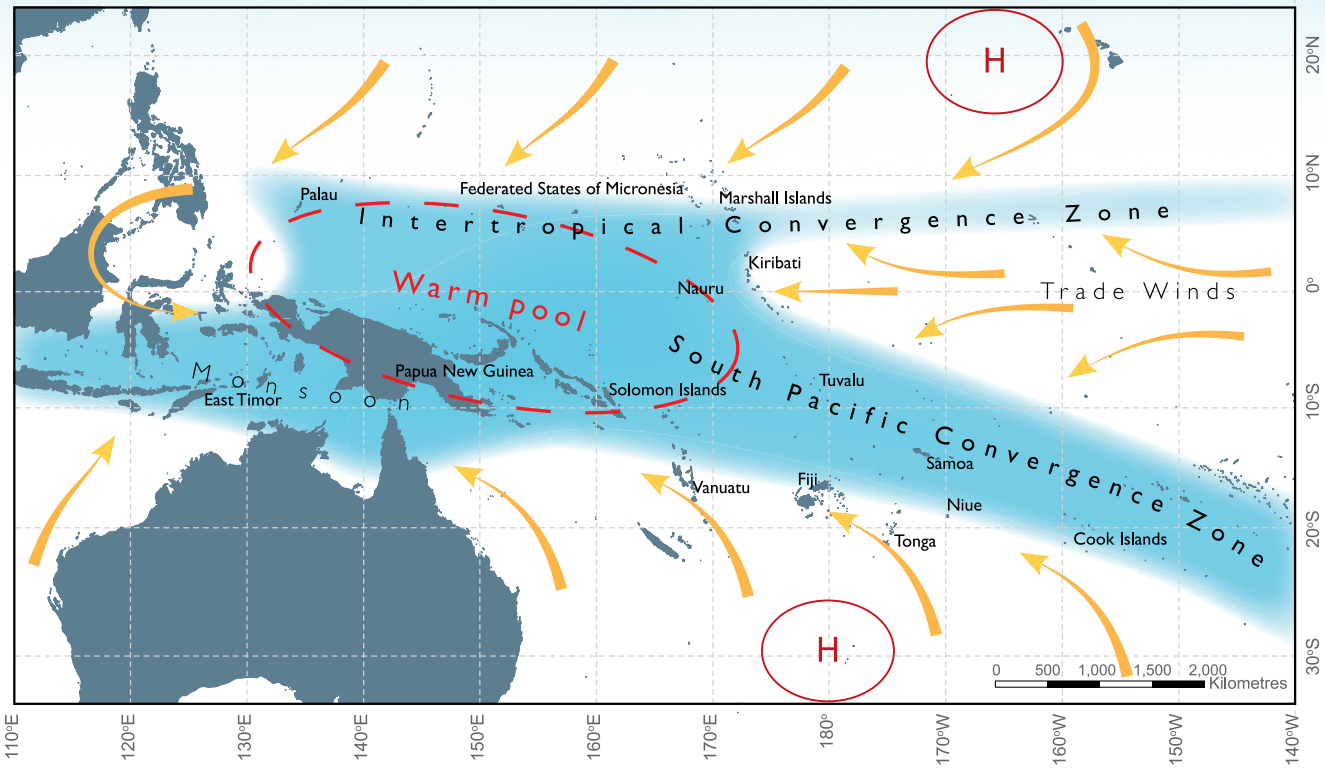


Figure 2: Average positions of the major climate features in November to April. The arrows show near surface winds, the blue shading represents the bands of rainfall convergence zones, the dashed oval shows the West Pacific Warm Pool and H represents typical positions of moving high pressure systems.

Typhoons

Typhoons can affect the Federated States of Micronesia between June and November. In the 34-year period between the 1977 and 2010 seasons, 248 typhoons developed within or passed through the Federated States of Micronesia Exclusive Economic Zone, an average of 71 per decade (Figure 3). The number of typhoons varies widely from year to year, with none in some seasons but up to 12 in others. Over the period 1977 to 2010 typhoons occurred more frequently during El Niño years.

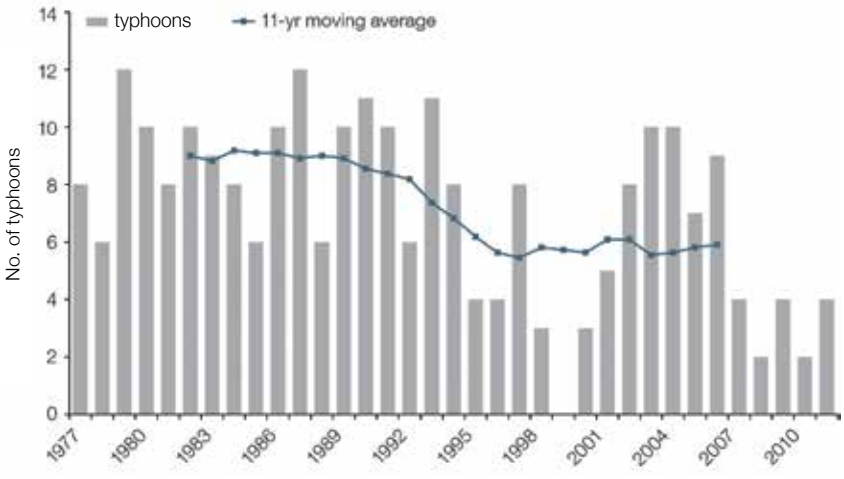


Figure 3: Number of typhoons developing within and crossing the Federated States of Micronesia Exclusive Economic Zone per season. The 11-year moving average is in blue.

Wind-driven waves

Wind-waves in the Federated States of Micronesia are dominated by north-easterly trade winds and westerly monsoon winds seasonally, and the El Niño–Southern Oscillation from year to year. There is little variation in wave climate between the eastern and western parts of the country; however Yap, in the west (Figure 4, bottom), has a more marked dependence on the El Niño–Southern Oscillation in June to September than Pohnpei, in the east (Figure 4, top). Wave power varies from year to year but is strongest during La Niña years.

Johannes Berdon, National Weather Service Office

Damage to taro crop from salt water inundation, Lekinioch, Chuuk.

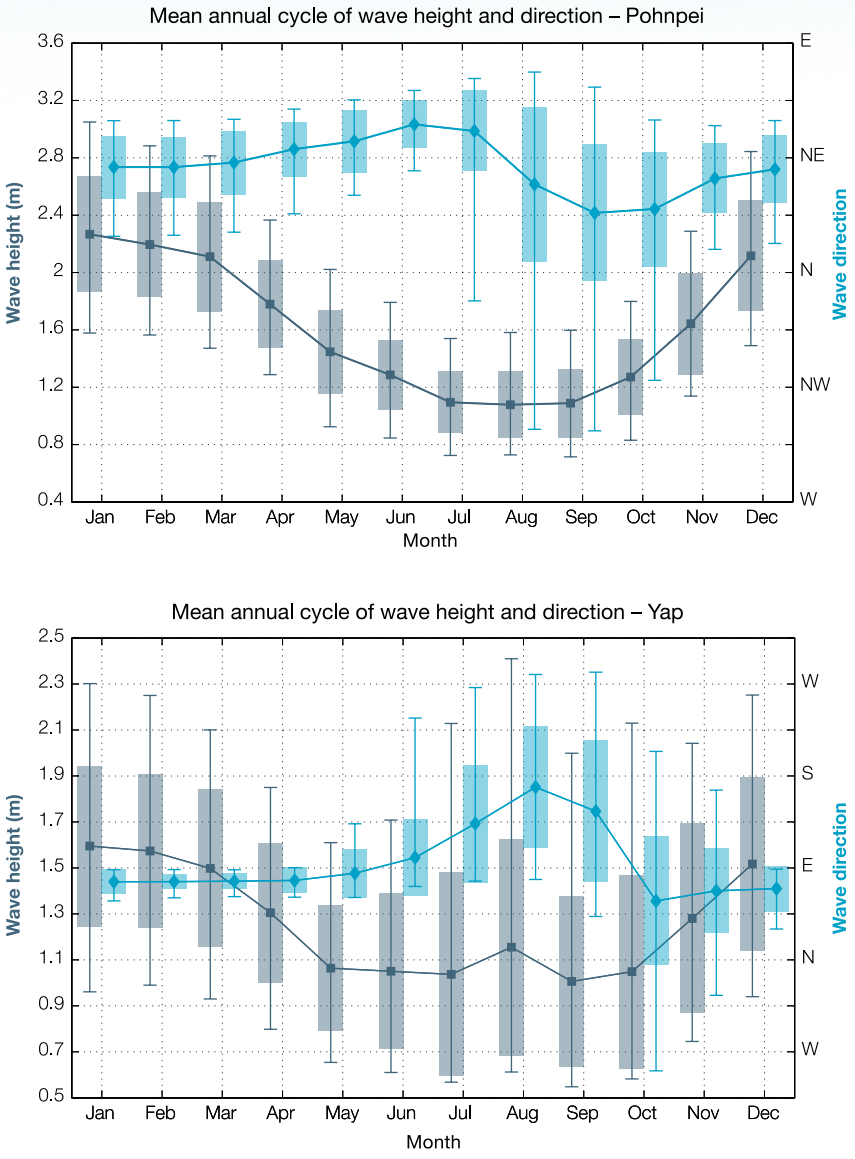


Figure 4: Annual cycle of wave height (grey) and wave direction (blue) at Pohnpei (top) and Yap (bottom) based on data from 1979–2009. The shaded boxes represent one standard deviation around the monthly means, and the error bars indicate the 5–95% range, showing the year-to-year variability in wave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

Changing climate of the **Federated States of Micronesia**

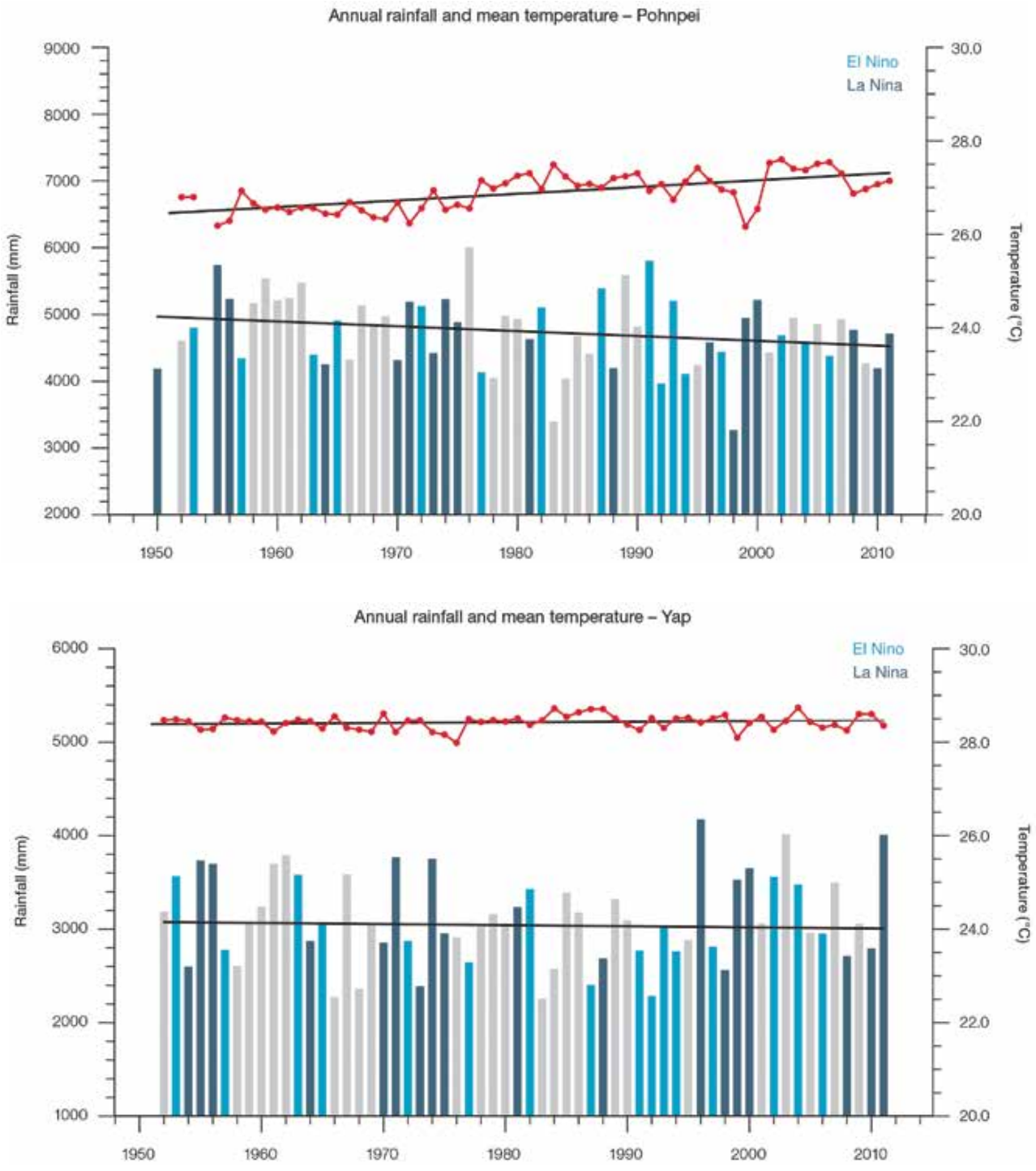


Figure 5: Annual average air temperature (red dots and line) and total rainfall (bars) at Pohnpei (top) and Yap (bottom). Light blue, dark blue and grey bars indicate El Niño, La Niña and neutral years respectively. No bars indicate that data is not available. Solid black lines show the trends.

Temperatures are changing

Annual and seasonal maximum temperatures have increased in Pohnpei and Yap since 1951. Maximum temperatures have increased at a rate of 0.32ºF (0.18°C) per decade at Pohnpei and at a rate of 0.41ºF (0.23ºC) per decade at Yap. Also at Pohnpei, annual and half-year trends in maximum air temperature are greater than those observed in minimum air temperature. These temperature increases are consistent with the global pattern of warming.

Annual and seasonal mean air temperature has also increased at Pohnpei during the ame period at a rate of 0.27ºF (0.15ºC) per decade (Figure 5). The Yap mean air temperature trend shows little change for the same period.

Pohnpei's annual rainfall has decreased

At Pohnpei, there has been a decreasing trend in wet season rainfall since 1950 (Figure 5). There are no clear rainfall trends at Yap.

There has also been a decreasing trend in very wet day rainfall at Pohnpei and annual consecutive dry days at Yap since 1952. The remaining annual, half-year and extreme daily rainfall trends show little change at both sites.

Sea level has risen

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

Instruments mounted on satellites and tide gauges are used to measure sea level. Satellite data indicate sea level has risen in the Federated States of Micronesia by over 0.39 inches (10 mm) per year since 1993. This is larger than the global average of 0.11–0.14 inches (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 year-to-year variation in sea level can be seen in Figure 6 which includes the tide gauge record since 1950 and the satellite data since 1993.

Taking temperature observations, Pohnpei Weather Service Office.

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 Federated State of Micronesia's waters.

Climate projections training, Pohnpei Weather Service Office.

Johannes Berdon, National Weather Service Office

Damage from high sea surge, Lekinioch, Chuuk.

Future climate of the **Federated States of Micronesia**

Climate impacts almost all aspects of life in the Federated States of Micronesia. Understanding the possible future climate of the Federated States of Micronesia 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.

- Average annual rainfall is projected to increase, with more extreme rain events.
- Drought frequency is projected to decrease.

- Sea level will continue to rise.
- Ocean acidification is expected to continue.
- The risk of coral bleaching is expected to increase.
- Wave height is projected to decrease in December–March, and waves may be more directed from the south in June–September.

- Typhoons are projected to be less frequent but more intense.

Kepirohi Falls, Pohnpei.

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 Federated States of Micronesia (Table 1). By 2030, under a very high emissions scenario, this increase in temperature is projected to be in the range of 1.1–2.0°F (0.6–1.1°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.

Changing rainfall patterns

Almost all the global climate models project an increase in average annual and seasonal rainfall over the course of the 21st century. However, there is some uncertainty in the rainfall projections and not all models show consistent results. Models generally suggest a greater increase in wet season rainfall over the Federated States of Micronesia. Wet and dry years will still occur in response to natural variability. Drought frequency is projected to decrease.

More extreme rainfall days

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

Less frequent typhoons

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

The Federated States of Micronesia is in a region where projections tend to show a decrease in typhoon frequency by the late 21st century.

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

	2030		2050		2070		2090	
	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)	(°F)	(°C)
FSM East								
Very low emissions scenario	0.7–1.6	0.4–0.9	1.1–2.2	0.6–1.2	0.9–2.2	0.5–1.2	0.9–2.2	0.5–1.2
Low emissions scenario	0.9–1.8	0.5–1.0	1.3–2.5	0.7–1.4	1.8–3.4	1.0–1.9	1.8–3.8	1.0–2.1
Medium emissions scenario	0.7–1.6	0.4–0.9	1.3–2.5	0.7–1.4	1.8–3.6	1.0–2.0	2.3–4.7	1.3–2.6
Very high emissions scenario	1.1–2.0	0.6–1.1	1.8–3.4	1.0–1.9	2.9–5.6	1.6–3.1	3.8–7.4	2.1–4.1
FSM East								
Very low emissions scenario	0.7–1.6	0.5–0.9	1.1–2.0	0.6–1.1	0.9–2.2	0.5–1.2	0.7–2.2	0.4–1.2
Low emissions scenario	0.9–1.8	0.5–1.0	1.4–2.5	0.8–1.4	1.8–3.2	1.0–1.8	1.8–3.8	1.0–2.1
Medium emissions scenario	0.7–1.6	0.4–0.9	1.3–2.5	0.7–1.4	2.0–3.4	1.1–1.9	2.5–4.7	1.4–2.6
Very high emissions scenario	1.1–2.0	0.6–1.1	2.0–3.4	1.1–1.9	2.9–5.6	1.6–3.1	3.8–7.2	2.1–4.0

Kolonia Harbour, Pohnpei.

Sea level will continue to rise

Sea level is expected to continue to rise in the Federated States of Micronesia (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 16.1–35.4 inches (41–90 cm). The sea-level rise combined with natural year-to-year changes will accentuate 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 Federated States of Micronesia 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 vary from year to year

Wave height is projected to decrease in December to March and waves may be more directed from the south in the June to September, however there is large year-to-year variability.

Table 2: Projected changes in the annual mean sea level rise (in inches and centimetres) for the Federated States of Micronesia. Values represent the 90% of the range of model results and are relative to the period 1986–2005.

	2030		2050		2070		2090	
	(in)	(cm)	(in)	(cm)	(in)	(cm)	(in)	(cm)
Very low emissions scenario	3.1–7.1	8–18	5.5–11.8	14–30	7.9–17.7	20–45	9.4–23.6	24–60
Low emissions scenario	3.1–6.7	8–17	5.5–12.2	14–31	8.7–19.3	22–49	11.8–26.8	30–68
Medium emissions scenario	2.8–6.7	7–17	5.5–11.8	14–30	8.7–18.9	22–48	12.2–27.2	31–69
Very high emissions scenario	3.1–7.1	8–18	6.7–13.8	17–35	11.0–23.2	28–59	16.1–35.4	41–90

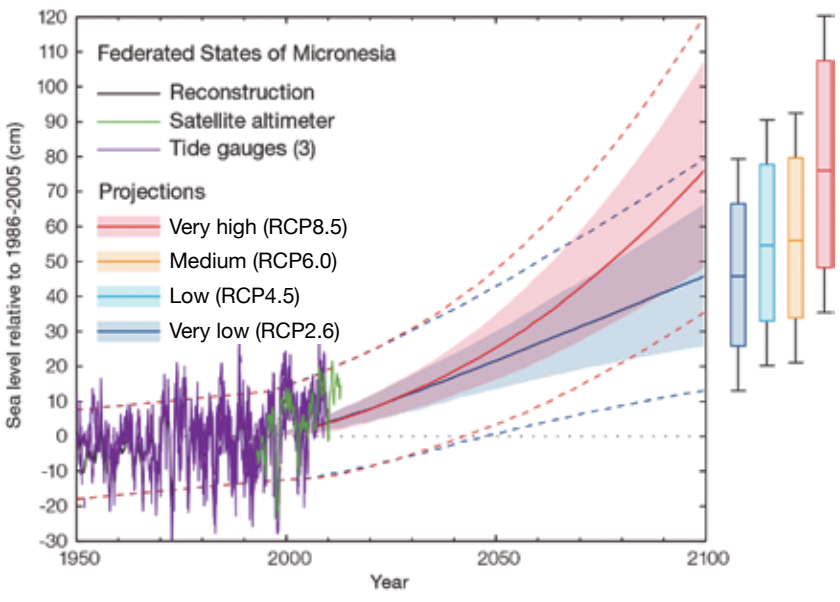


Figure 6: Tide-gauge records of relative sea level (since 1950) are indicated in purple, and the satellite record (since 1993) in green. The reconstructed sea-level data at the Federated States of Micronesia (since 1950) is shown in black. Multi-model mean projections from 1995–2100 are given for the 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 emission 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-Australia Climate Change Science and Adaptation Planning Program have evaluated models from around the world and found that 26 best represent the climate of the Federated States of Micronesia region of the western tropical Pacific. These 26 models have been used to develop climate projections for the Federated States of Micronesia.

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 Federated States of Micronesia 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 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.

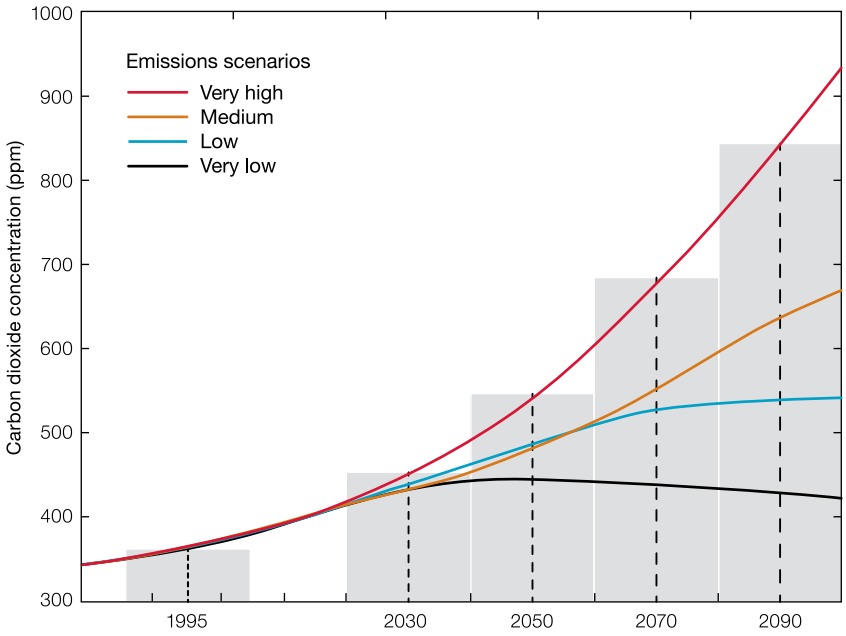


Figure 7: Carbon dioxide concentrations (parts per million, ppm) associated with the very low (RCP2.6), low (RCP4.5), medium (RCP6.0) and very high (RCP8.5) emissions scenarios for 20-year time periods (shaded) centred on 1995 (the reference period), 2030, 2050, 2070 and 2090.

This brochure contains a summary of climate projections for the Federated States of Micronesia. 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 climate of the **Federated States of Micronesia**

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

> Annual and wet season rainfall since 1950 has decreased at Pohnpei but at Yap there has been no clear change. Rainfall is generally projected to increase over this century with more extreme rainfall days. Drought frequency is projected to decrease.

> Sea level near the Federated States of Micronesia has risen and will continue to rise throughout this century.

> Ocean acidification has been increasing in the Federated States of Micronesia's waters. It will continue to increase and threaten coral reef ecosystems.

> Wave height is projected to decrease in December to March and waves may be more directed from the south in the June to September.

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

The content of this brochure is the result of a collaborative effort between the National Weather Service Offices of the Federated States of Micronesia 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 the Federated States of Micronesia 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).

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