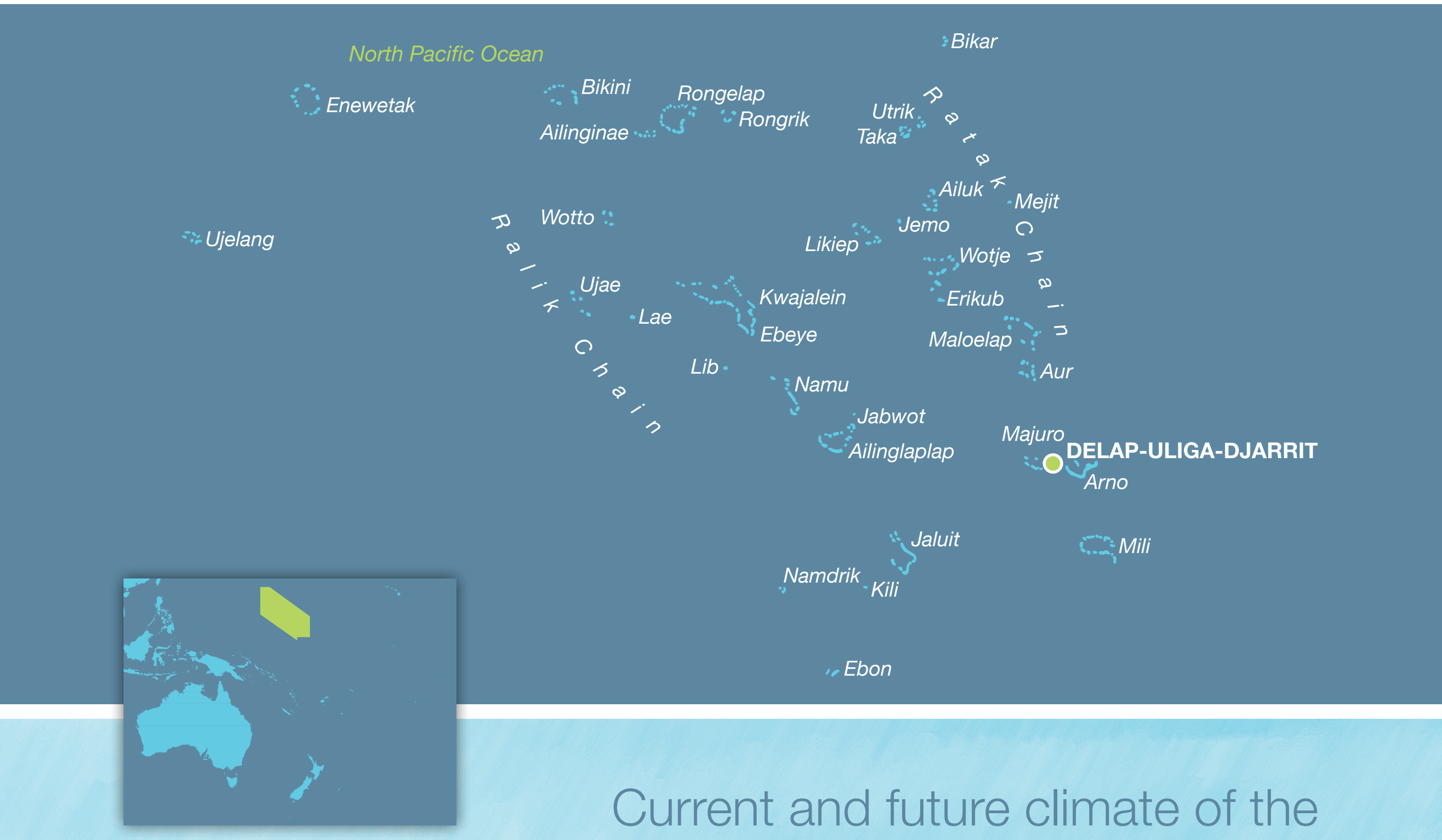
International
CLIMATE
CHANGE
ADAPTATION
Initiative

Pacific Climate Change Science Program



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

> Marshall Islands National Weather Service Office
> Australian Bureau of Meteorology
> Commonwealth Scientific and Industrial Research Organisation (CSIRO)

Australian Government

Current climate
of the Marshall Islands

Across the Marshall Islands the average temperature is relatively constant year round. Changes in the temperature from season to season are relatively small around 2°F (1°C) and strongly tied to changes in the surrounding ocean temperature (Figure 1).

Both Majuro and Kwajalein have a dry season from around December to April and a wet season from May to November, however rainfall varies greatly from north to south. The atolls to the north receive less than 50 inches (1250 mm) of rain each year and are very dry in the dry season, while atolls closer to the equator receive more than 100 inches (2500 mm) of rain each year.

The Intertropical Convergence Zone brings rainfall to the Marshall Islands throughout the year. 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) and is most intense and closer to the Marshall Islands during the wet season. Rainfall is also sometimes influenced by the West Pacific Monsoon, which brings wetter conditions when it is active over the Marshall Islands.

The climate of the Marshall Islands 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. Conditions during La Niña years are generally wetter than normal. El Niño events tend to bring warmer than normal wet seasons and warmer, drier dry seasons.

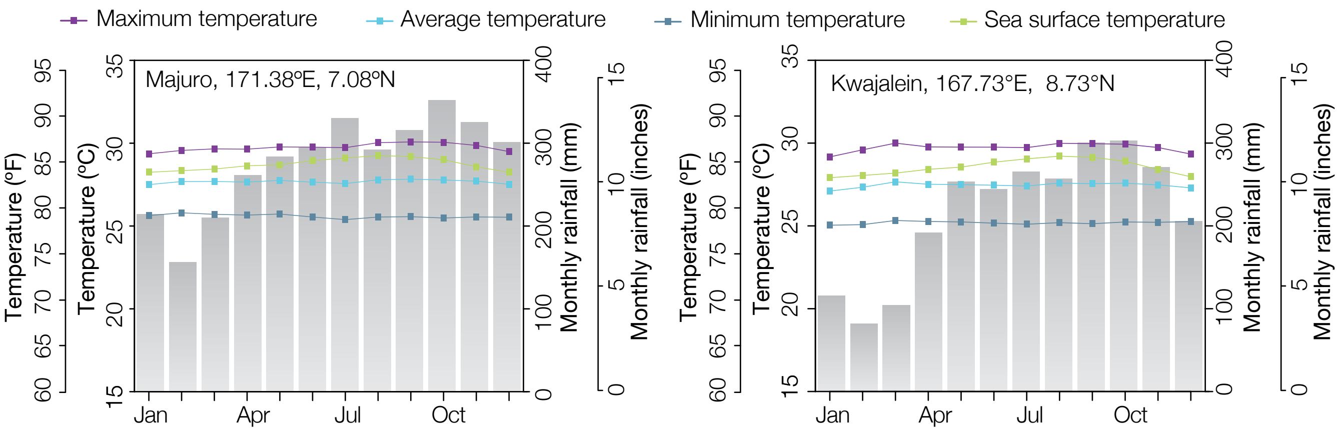


Figure 1: Seasonal rainfall and temperature at Majuro and Kwajalein.

Majuro Lagoon.

Courtesy of Lee Jacklick, National Weather Service Office

Ujae atoll.

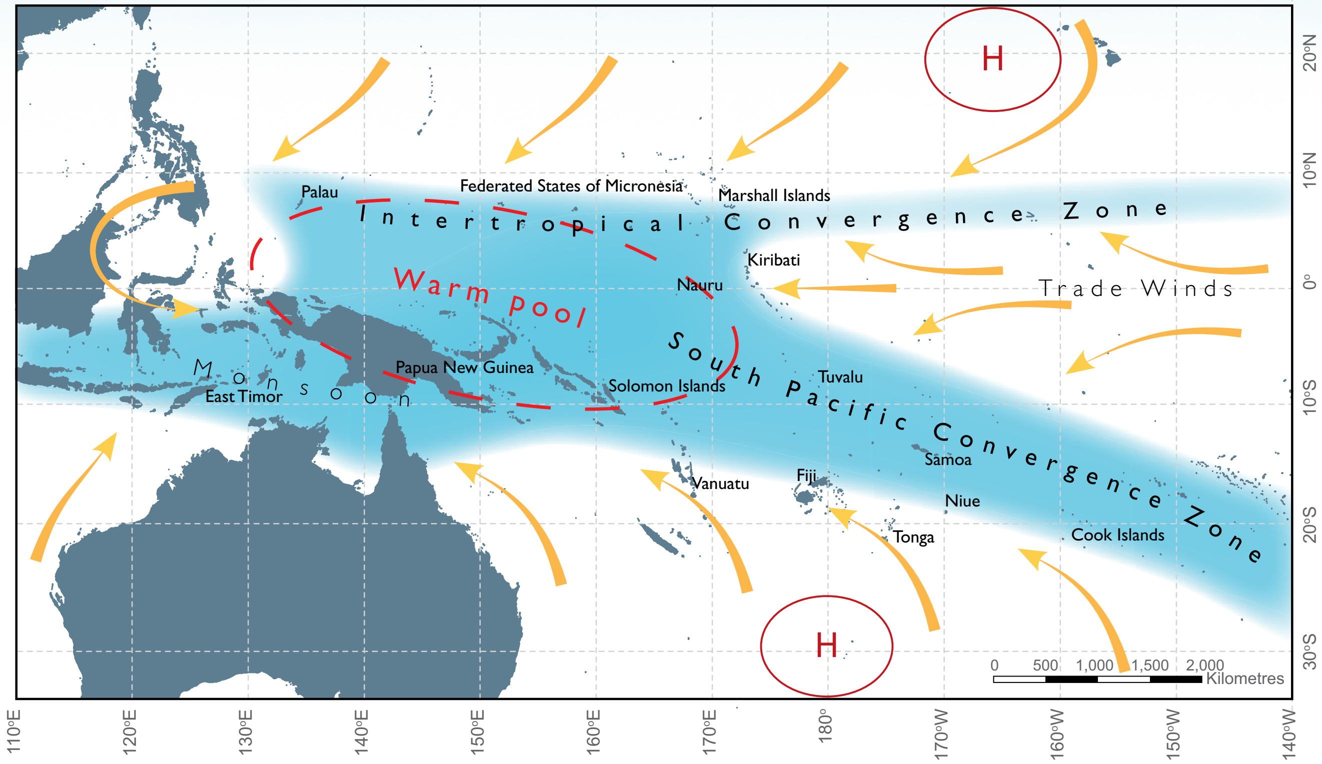


Figure 2: The average positions of the major climate features in November to April. The arrows show near surface winds, the blue shading represents the bands of rainfall convergence zones, the dashed oval shows the West Pacific Warm Pool and H represents typical positions of moving high pressure systems.

extreme weather events

Typhoons, droughts and storm waves are the main extreme events that impact the Marshall Islands. Typhoons affect the Marshall Islands late in the typhoon season, between September and November. They are usually weak when they pass through the region, but are more intense in El Niño years. During an El Niño event the sea surface temperatures increase in and to the east of the Marshall Islands. This allows more intense typhoons to form.

Droughts generally occur in the first four to six months of the year following an El Niño. Following severe El Niño events, rainfall can be reduced by as much as 80%. The dry season begins earlier and ends much later than normal during an El Niño.

Reginald White, National Weather Service Office

High surf event, Majuro, December 2008.

Changing climate
of the Marshall Islands

Temperatures have increased

Annual maximum and minimum temperatures have increased in both Majuro (Figure 3) and Kwajalein since 1956 and 1960 respectively. In Majuro, maximum temperatures have increased at a rate of 0.22ºF (0.12°C) per decade and at Kwajalein the rate of increase has been 0.36ºF (0.20°C) per decade. These temperature increases are consistent with the global pattern of warming.

Annual rainfall has decreased

Rainfall data since 1950 for Kwajalein (Figure 4) show a decreasing trend in annual and seasonal rainfall. At Majuro, since 1950, there has also been a decreasing trend in annual and dry season rainfall but no trend in wet season rainfall. Over this period, there has been substantial variation in rainfall from year to year at both sites.

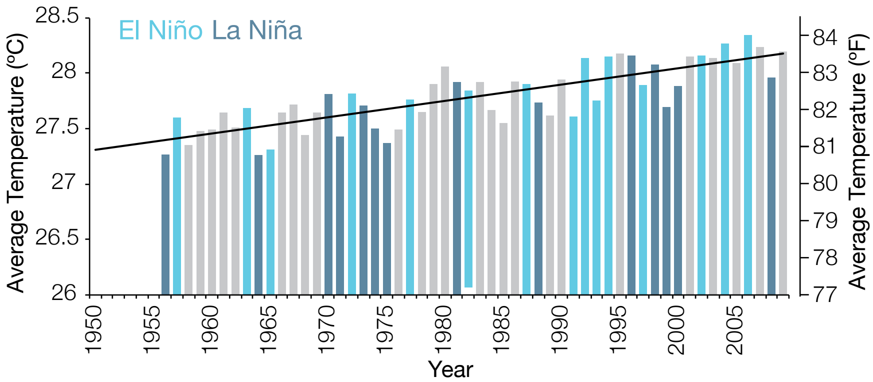


Figure 3: Annual average temperature for Majuro. Light blue bars indicate El Niño years, dark blue bars indicate La Niña years and the grey bars indicate neutral years.

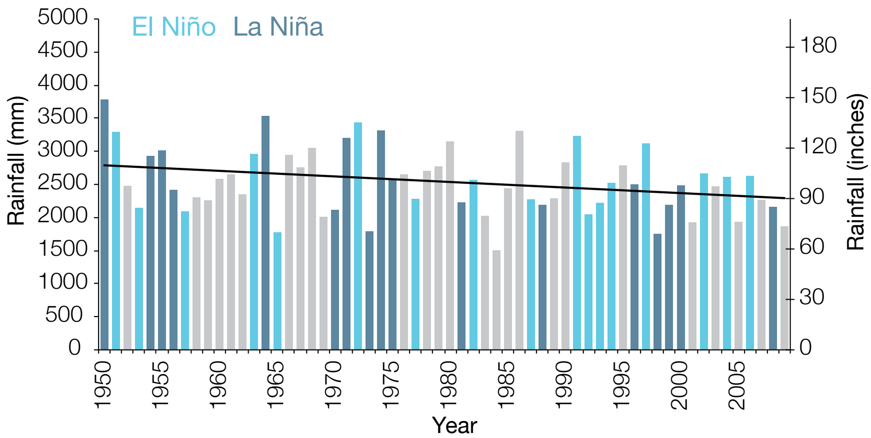


Figure 4: Annual rainfall for Kwajalein. Light blue bars indicate El Niño years, dark blue bars indicate La Niña years and the grey bars indicate neutral years.

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 the Marshall Islands by about 0.3 inches (7 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 variation in sea level can be seen in Figure 6 which includes the tide gauge record since 1950 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 Marshall Islands' waters.

Lee Jacklick, National Weather Service Office

Flooding during extreme high tide.

Future climate
of the Marshall Islands

Climate impacts almost all aspects of life in the Marshall Islands. Understanding the possible future climate of the Marshall Islands 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 the Marshall 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. 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 the Marshall Islands are based on three IPCC emissions scenarios: low (B1), medium (A1B) and high (A2), for time periods around 2030, 2055 and 2090 (Figure 5). Since individual models give different results, the projections are presented as a range of values.

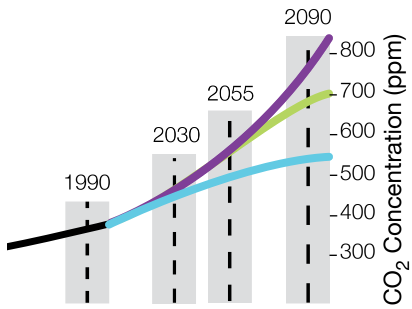


Figure 5: Carbon dioxide (CO_2) concentrations (parts per million, ppm) associated with three IPCC emissions scenarios: low emissions (B1 – blue), medium emissions (A1B – green) and high emissions (A2 – purple). The PCCSP has analysed climate model results for periods centred on 1990, 2030, 2055 and 2090 (shaded).

Lee Jacklick, National Weather Service Office

Ujae Atoll.

Mr. Jiti Samuel from Namdrik Atoll, Marshall Islands

Flooding during extreme high tide, Namdrik Atoll.

Future climate of the Marshall Islands

This is a summary of climate projections for the Marshall Islands. 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 the Marshall Islands (Table 1). By 2030, under a high emissions scenario, this increase in temperature is projected to be in the range of 0.8–1.8ºF (0.4–1.0°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 of the global climate models project an increase in average annual and seasonal rainfall over the course of the 21st century. Wet season increases are particularly due to the expected intensification of the West Pacific Monsoon and the Intertropical Convergence Zone. However, there is some uncertainty in the rainfall projections and not all models show consistent results. Droughts are projected to become less frequent throughout this century.

More extreme rainfall days

Model 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. But there is 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 Marshall Islands is in a region where projections tend to show a decrease in typhoon frequency by the late 21st century, and a decrease in the proportion of the more intense storms.

Table 1: Projected annual average air temperature changes for the Marshall Islands 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		2055		2090	
	(°F)	(ºC)	(°F)	(ºC)	(°F)	(ºC)
Northern Marshall Islands						
Low emissions scenario	0.4–2.0	0.3–1.1	0.9–3.1	0.5–1.7	1.3–4.3	0.6–2.4
Medium emissions scenario	0.5–2.3	0.3–1.3	1.7–3.9	0.9–2.1	2.6–6.0	1.4–3.4
High emissions scenario	0.8–1.8	0.4–1.0	1.8–3.4	1.0–1.8	3.9–6.3	2.1–3.5
Southern Marshall Islands						
Low emissions scenario	0.4–2.0	0.2–1.2	1.0–3.0	0.5–1.7	1.4–4.2	0.8–2.4
Medium emissions scenario	0.5–2.3	0.3–1.3	1.5–3.9	0.9–2.1	2.6–6.0	1.5–3.3
High emissions scenario	0.8–1.8	0.4–1.0	1.8–3.4	1.0–1.8	3.9–6.3	2.1–3.5

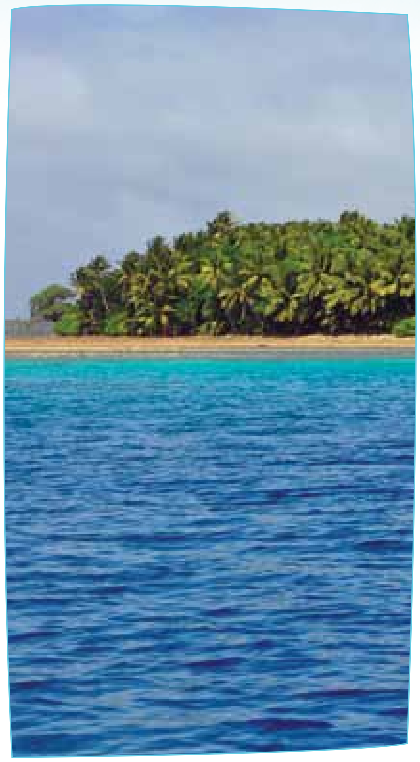
Weather balloon launch, Majuro Weather Service Office.

Sea level will continue to rise

Sea level is expected to continue to rise in the Marshall Islands (Table 2 and Figure 6). By 2030, under a high emissions scenario, this rise in sea level is projected to be in the range of 1.2–6.3 inches (3-16 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 three emissions scenarios (low, medium and high) the acidity level of sea waters in the Marshall Islands 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.



Majuro Atoll.

Table 2: Sea-level rise projections for the Marshall Islands 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		2055		2090	
	(in)	(cm)	(in)	(cm)	(in)	(cm)
Low emissions scenario	1.6–5.9	4-15	3.9–10.6	10-27	7.1–18.5	18-47
Medium emissions scenario	1.6–5.9	4-15	4.3–12.6	11-32	8.3–23.6	21-60
High emissions scenario	1.2–6.3	3-16	4.3–11.8	11-30	8.7–24.4	22-62

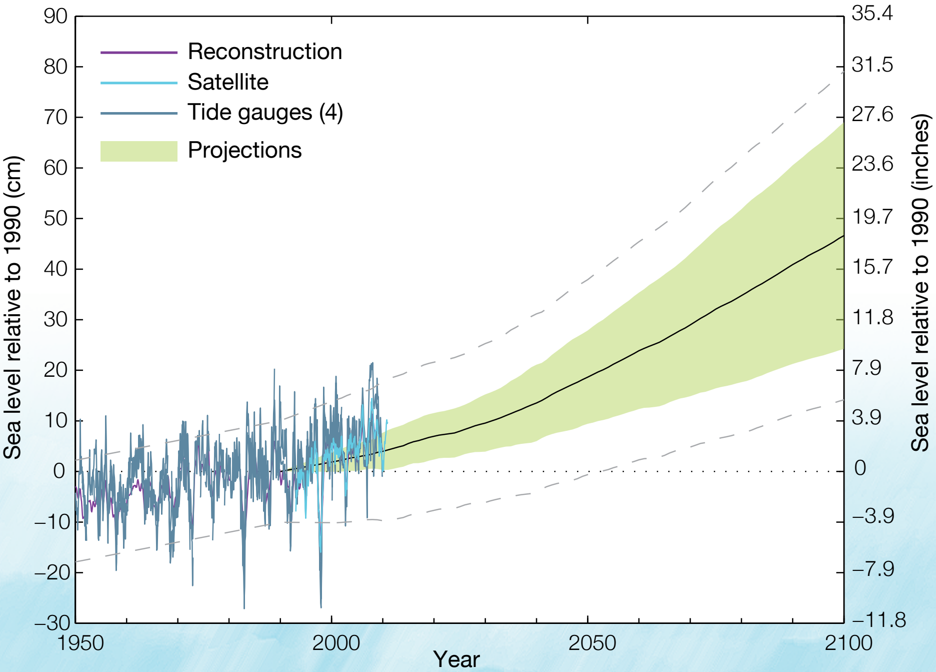


Figure 6: Observed and projected relative sea-level change near the Marshall Islands. The observed sea-level records are indicated in dark blue (relative tide-gauge observations) and light blue (the satellite record since 1993). Reconstructed estimates of sea level near the Marshall Islands (since 1950) 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 the Marshall Islands' climate

- > Temperatures have warmed and will continue to warm with more very hot days in the future.
- > Annual rainfall at Majuro and Kwajalein has decreased since the 1950s. Rainfall is generally projected to increase over this century with more extreme rainfall days and less droughts.
- > By the end of this century projections suggest decreasing numbers of typhoons and a possible shift towards less intense categories.
- > Sea level near the Marshall Islands has risen and will continue to rise throughout this century.
- > Ocean acidification has been increasing in the Marshall Islands' 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 Marshall Islands National Weather Service Office 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 the Marshall Islands 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

Contact the Marshall Islands National Weather Service Office:

web: www.prh.noaa.gov/majuro
phone: +692 247 5705

Australian AID

Australian Government
Bureau of Meteorology

Australian Government
Department of Climate Change and Energy Efficiency

CSIRO