Chapter 13

Solomon Islands

13.1 Climate Summary

13.1.1 Current Climate

- Annual and half-year minimum temperatures have been increasing at Honiara since 1953 and Munda since 1962. Minimum temperature trends are generally stronger than maximum temperature trends.
- There have been significant increases in Warm Nights and decreases in Cool Nights at Honiara and Munda. Cool Days have decreased at Munda. These temperature trends are consistent with global warming.
- Annual and half-year rainfall trends show little change at Honiara since 1950 and Munda since 1962. At Honiara, there is a decreasing trend in the number of rain days since 1955 and at Munda there is an increasing trend in annual maximum 1-day rainfall since 1962.
- Tropical cyclones affect Solomon Islands mainly between November and April. An average of 29 cyclones per decade developed within or crossed the Solomon Islands Exclusive Economic Zone (EEZ) between the 1969/70 to 2010/11 seasons. Tropical cyclones were most frequent in El Niño years (39 cyclones per decade) and least frequent in La Niña and neutral years (21 cyclones per decade). Twenty-two of the 82 tropical cyclones (27%) between the 1981/82 and 2010/11 seasons were severe events (Category 3 or stronger) in the Solomon Islands EEZ. Fifteen of the 22 intense events occurred in seasons when an El Niño was present. Available data are not suitable for assessing long-term trends.
- Wind-waves around the Solomon Islands vary across the country, being small at Honiara, while at the outlying islands such as Santa Cruz waves are much larger. Seasonally, waves are influenced by the trade winds and the West Pacific Monsoon (WPM), and display variability on interannual time scales with the El Niño–Southern Oscillation (ENSO). Available data are not suitable for assessing long-term trends.

13.1.2 Climate Projections

For the period to 2100, the latest global climate model (GCM) projections and climate science findings indicate:

- El Niño and La Niña events will continue to occur in the future (*very high confidence*), 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 (*very high confidence*);
- Annual rainfall is projected to increase slightly (*low confidence*), with more extreme rain events *(high confidence*);
- Incidence of drought is projected to decrease slightly (*low confidence*);
- Ocean acidification is expected to continue *(very high confidence);*
- The risk of coral bleaching will increase in the future (*very high confidence);*
- Sea level will continue to rise *(very high confidence); and*
- December–March wave heights are projected to decrease *(low confidence)*, while there are no significant changes projected in June–September waves *(low confidence)*.

13.2 Data Availability

There are currently six operational meteorological stations in the Solomon Islands. Multiple observations over a 24-hour period are taken at Taro, Munda, Auki, Honiara, Henderson and Santa Cruz (also known as Lata). A single rainfall observation per day is taken at Kirakira (previously multiple observations). More than 60 volunteer single observation rainfall-only stations have closed in recent years. The primary climate station is located in Honiara on the northern side of Guadalcanal Island. Several stations, including Auki and Kirakira, have rainfall data from the late 1910s. Honiara has air temperature data from the early 1950s.

Honiara monthly rainfall from 1950 (Honiara-Henderson composite; daily values from 1955) and monthly air temperature data from 1953, and Munda rainfall and air temperature data from 1962 have been used in this report. The Honiara and Munda records are homogeneous. Additional information on historical climate trends in the Solomon Islands region can be found in the Pacific Climate Change Data Portal www.bom.gov.au/climate/pccsp/.

Wind-wave data from buoys are particularly sparse in the Pacific region, with very short records. Model and reanalysis data are therefore required to detail the wind-wave climate of the region. Reanalysis surface wind data have been used to drive a wave model over the period 1979–2009 to generate a hindcast of the historical wind-wave climate.

13.3 Seasonal Cycles

Information on temperature and rainfall seasonal cycles can be found in Australian Bureau of Meteorology and CSIRO (2011).

13.3.1 Wind-driven Waves

Surface wind-wave driven processes can impact on many aspects of Pacific Island coastal environments, including: coastal flooding during storm wave events; coastal erosion, both during episodic storm events and due to long-term changes in integrated wave climate; characterisation of reef morphology and marine habitat/species distribution; flushing and circulation of lagoons; and potential shipping and renewable wave energy solutions. The surface offshore wind-wave climate can be described by characteristic wave heights, lengths or periods, and directions.

The wind-wave climate of the Solomon Islands shows strong spatial variability across the region. At the capital Honiara, which is sheltered from easterly trade winds by the island chain, waves are small (mean height around 0.15 m). They vary little in height throughout the year, but display strong seasonal variability of direction characterised by trade winds, monsoons and cyclones (Figure 13.1). During June–September, waves are directed from the east, generated locally by prevailing trade winds, and have shorter periods (seasonal mean around 4.6 s) than in December–March, with a small component of south-easterly trade wind swell. During December–March, mean waves reach an annual maximum period (seasonal mean period around 8.1 s) (Table 13.1) and are directed from the north-west as locally generated monsoon waves and from the north as swell from extra-tropical storms in the North Pacific. Waves larger than 0.8 m (99th percentile) at Honiara occur predominantly during December–March, directed from the north-west through to north-east as the wet season progresses, and are associated with monsoons and cyclones. The height of a 1-in-50 year wave event is calculated to be 3.0 m.

On the outlying easterly islands (e.g. to the north of Santa Cruz), waves are characterised by variability of the Southern Hemisphere trade winds and westerly monsoon winds. During the southern trade wind season, June–September, waves at Santa Cruz are easterly and have a shorter than annual average period (around 7.1 s) (Table 13.1). These waves consist primarily of local trade wind generated waves, with some south-westerly swell from extra-tropical storms. During December–March, waves are mostly north-easterly swell from the northern trade winds with a longer than annual average period (mean around 9.2s) (Figure 13.2), with some locally generated easterly trade wind waves and north-westerly monsoon waves, and a northerly component of swell propagating from extra-tropical storms in the Northern Hemisphere. Waves larger than 2.5 m (99th percentile) occur during December–March from the north-west through to north-east associated with tropical cyclones and extra-tropical storms, with some large easterly waves in July-October. The height of a 1-in-50 year wave event on the north coast of Santa Cruz is calculated to be 8.0 m, much greater than at Honiara.

No suitable dataset is available to assess long-term historical trends in the Solomon Islands wave climate. However, interannual variability may be assessed in the hindcast record.

The wind-wave climate displays strong interannual variability at Honiara and Santa Cruz, varying with the El Niño–Southern Oscillation (ENSO). During La Niña years, a rotation of north-westerly waves toward the east during December–March is observed at Honiara, with June–September waves more strongly directed from the east. At Santa Cruz, there is a reversal from north-westerly to north-easterly waves during La Niña years in December–March, while in June–September wave power increases slightly with waves more strongly directed from the east, both associated with a strengthening in trade winds.

Table 13.1: Mean wave height, period and direction from which the waves are travelling around the Solomon Islands in December–March and June–September. Observation (hindcast) and climate model simulation mean values are given with the 5–95th percentile range (in brackets). Historical model simulation values are given for comparison with projections (see Section 13.5.6 – Wind-driven waves, and Table 13.7). A compass relating number of degrees to cardinal points (direction) is shown.

		**Hindcast Reference Data (1979–2009) – Honiara**	**Hindcast Reference Data (1979–2009) – Santa Cruz**	**Climate Model Simulations (1986–2005) – Solomon Islands**
Wave Height (metres)	December–March	0.2 (0.1–0.6)	1.2 (0.8–2.1)	1.3 (1.1–1.6)
	June–September	0.1 (0.0–0.3)	1.2 (0.8–1.9)	1.4 (1.1–1.7)
Wave Period (seconds)	December–March	8.1 (3.5–12.9)	9.2 (6.8–11.6)	8.2 (7.4–9.0)
	June–September	4.6 (2.6–8.5)	7.1 (5.9–8.8)	6.8 (6.2–7.7)
Wave direction (degrees clockwise from North)	December–March	350 (300–30)	10 (310–60)	50 (0–80)
	June–September	80 (20–110)	100 (80–120)	120 (110–130)

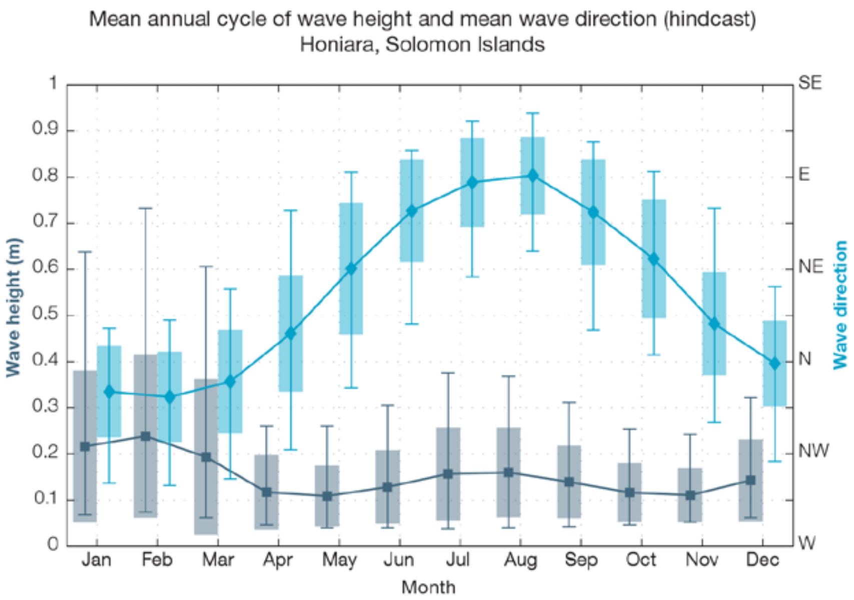

Figure 13.1: Mean annual cycle of wave height (grey) and mean wave direction (blue) at Honiara in hindcast data (1979–2009). To give an indication of interannual variability of the monthly means of the hindcast data, shaded boxes show 1 standard deviation around the monthly means, and error bars show the 5–95% range. The direction from which the waves are travelling is shown (not the direction towards which they are travelling).

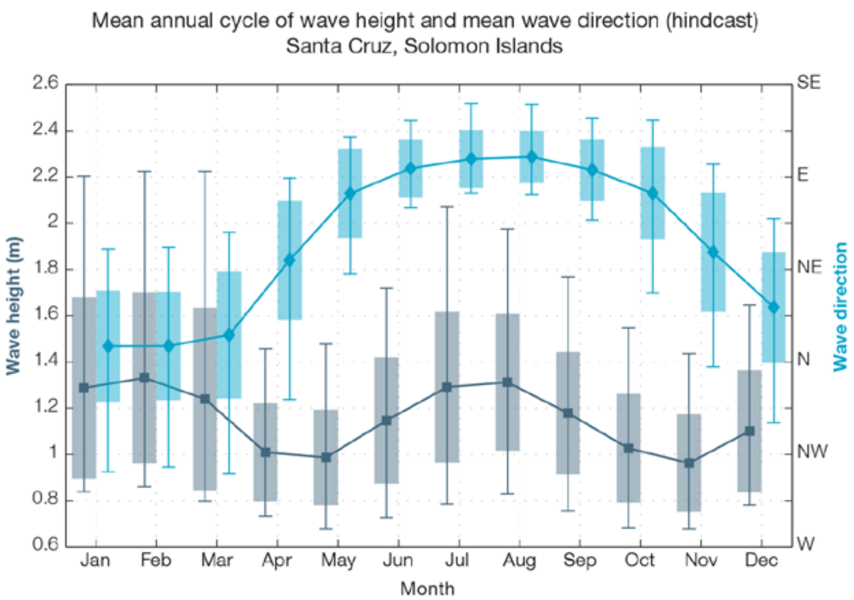

Figure 13.2: Mean annual cycle of wave height (grey) and mean wave direction (blue) near Santa Cruz in hindcast data (1979–2009). To give an indication of interannual variability of the monthly means of the hindcast data, shaded boxes show 1 standard deviation around the monthly means, and error bars show the 5–95% range. The direction from which the waves are travelling is shown (not the direction towards which they are travelling).

13.4 Observed Trends

13.4.1 Air Temperature

Annual and Half-year Mean Air Temperature

Annual and half-year minimum temperatures increased at Honiara and Munda from 1953 and 1962 respectively (Figure 13.3, Figure 13.4 and Table 13.2). These trends and the positive annual and November–April maximum temperature trends at Munda are statistically significant at the 5% level. Minimum temperature trends are generally stronger than maximum temperature trends.

Extreme Daily Air Temperature

- Trends in night-time extreme daily temperatures were were stronger than day-time extreme temperatures (Table 13.3 and Figure 13.5). At both Honiara and Munda there have been significant increases in annual Warm Nights and decreases in Cool Nights. Cool Days have decreased at Munda.

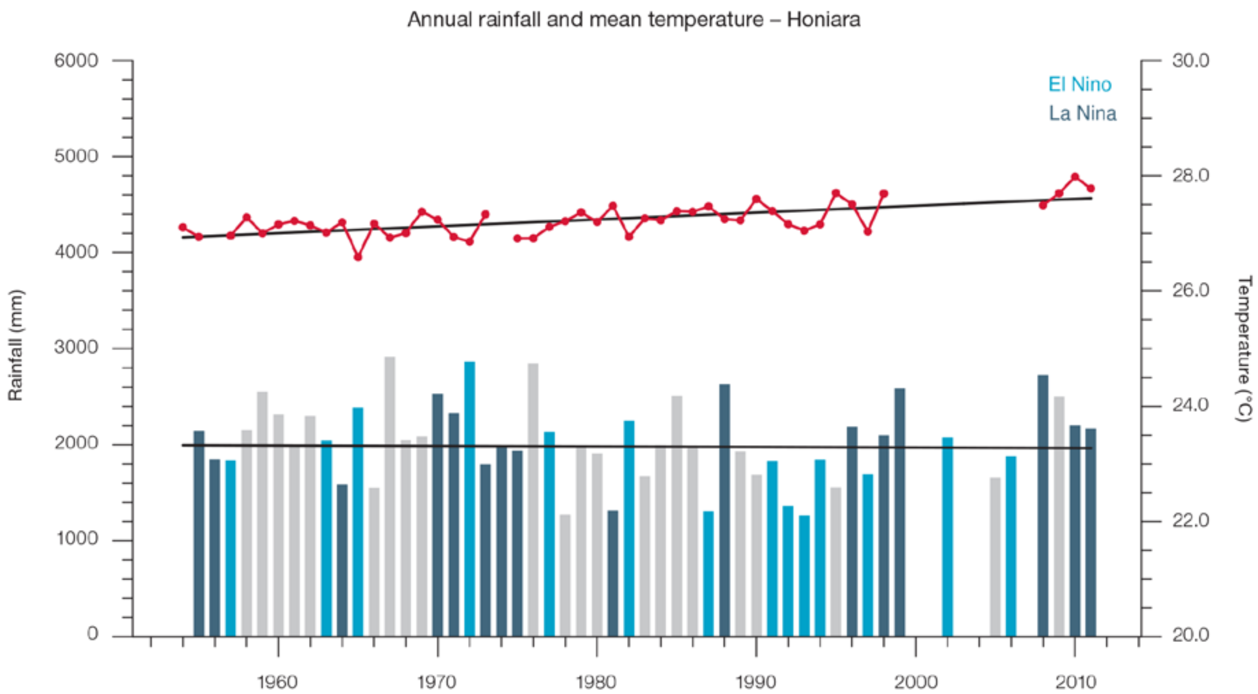

Figure 13.3: Observed time series of annual average values of mean air temperature (red dots and line) and total rainfall (bars) at Honiara. Light blue, dark blue and grey bars denote El Niño, La Niña and neutral years respectively. Solid black trend lines indicate a least squares fit.

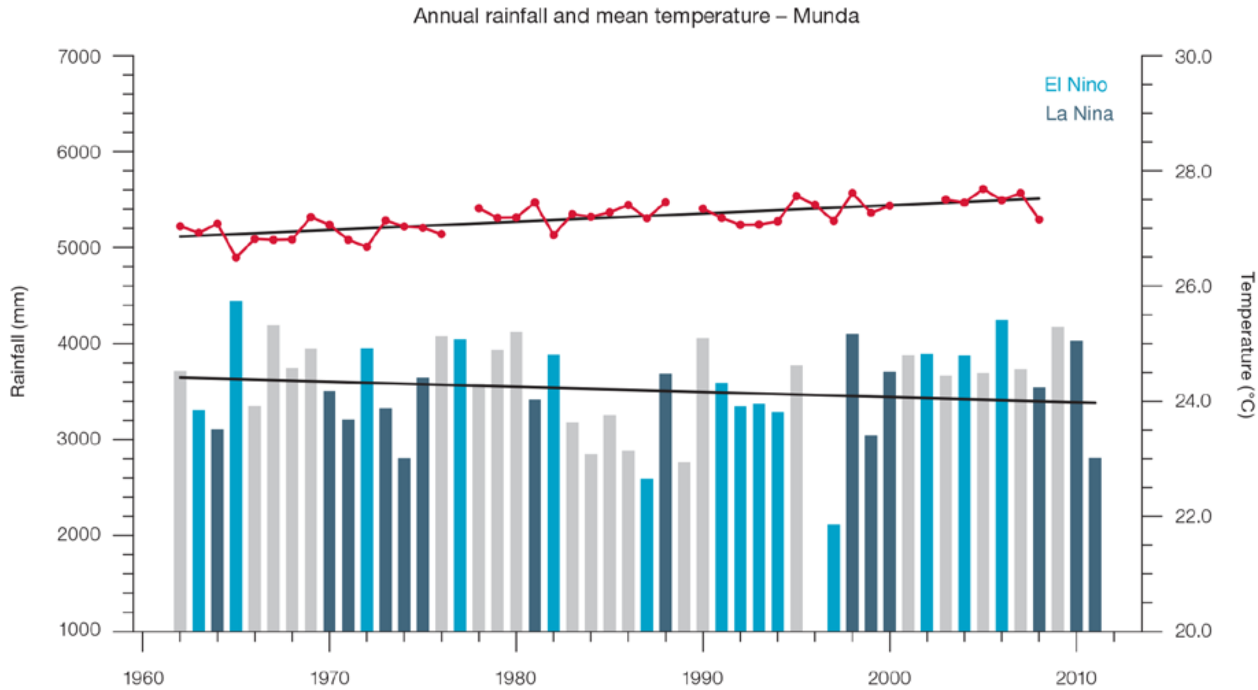

Figure 13.4: Observed time series of annual average values of mean air temperature (red dots and line) and total rainfall (bars) at Munda. Light blue, dark blue and grey bars denote El Niño, La Niña and neutral years respectively. Solid black trend lines indicate a least squares fit.

Table 13.2: Annual and half-year trends in air temperature (Tmax, Tmin, Tmean) and rainfall at Honiara (top) and Munda (bottom). The 95% confidence intervals are shown in brackets. Values for trends significant at the 5% level are shown in **boldface**.

Honiara	Tmax (°C/10yrs)	Tmin (°C/10yrs)	Tmean (°C/10yrs)	Total Rain (mm/10yrs)
		1953–2011		1950–2011
Annual	+0.05 (-0.03, +0.12)	**+0.17** (+0.12, +0.21)	**+0.12** (+0.04, +0.21)	-32.4 (-103.9, +46.5)
Nov–Apr	+0.04 (-0.02, +0.09)	**+0.17** (+0.12, +0.22)	**+0.10** (+0.05, +0.16)	-27.9 (-85.4, +28.9)
May–Oct	+0.06 (-0.03, +0.14)	**+0.15** (+0.04, +0.28)	**+0.12** (+0.03, +0.20)	-9.4 (-35.4, +21.6)

Munda	Tmax (°C /10yrs)	Tmin (°C/10yrs)	Tmean (°C/10yrs)	Total Rain (mm/10yrs)
		1962–2008		
Annual	**+0.09** (+0.03, +0.17)	**+0.18** (+0.08, +0.27)	**+0.14** (+0.03, +0.25)	+13.3 (-91.8, +112.5)
Nov–Apr	**+0.16** (+0.08, +0.24)	**+0.18** (+0.06, +0.28)	**+0.18** (+0.12, +0.22)	-0.3 (-82.6, +91.9)
May–Oct	**+0.07** (0.00, +0.16)	**+0.16** (+0.08, +0.24)	**+0.13** (+0.02, +0.23)	+35.9 (-53.2, +95.3)

Table 13.3: Annual trends in air temperature and rainfall extremes at Honiara (left) and Munda (right). The 95% confidence intervals are shown in brackets. Values for trends significant at the 5% level are shown in **boldface**.

	Honiara	Munda
TEMPERATURE	**(1953–2011)**	**(1962–2011)**
Warm Days (days/decade)	+5.11 (-1.19, +11.25)	+3.91 (-2.53, +10.92)
Warm Nights (days/decade)	**+11.70** (+8.44, +16.16)	**+10.37** (+4.58, +17.26)
Cool Days (days/decade)	-1.54 (-3.65, +0.50)	**-3.80** (-6.71, -1.40)
Cool Nights (days/decade)	**-12.44** (-16.04, -7.89)	**-11.95** (-19.19, -4.12)
RAINFALL	**(1955–2011)**	**(1962–2011)**
Rain Days ≥ 1 mm (days/decade)	**-3.75** (-8.06, -0.27)	+0.49 (-2.92, +3.33)
Very Wet Day rainfall (mm/decade)	+2.19 (-44.53, +53.81)	+55.40 (-43.00, +119.55)
Consecutive Dry Days (days/decade)	+0.51 (-0.69, +1.69)	+0.03 (-0.71, +0.85)
Max 1-day rainfall (mm/decade)	+1.42 (-5.68, +9.22)	**+9.82** (+2.75, +18.12)

Warm Days: Number of days with maximum temperature greater than the 90th percentile for the base period 1971–2000
Warm Nights: Number of days with minimum temperature greater than the 90th percentile for the base period 1971–2000
Cool Days: Number of days with maximum temperature less than the 10th percentile for the base period 1971–2000
Cool Nights: Number of days with minimum temperature less than the 10th percentile for the base period 1971–2000
Rain Days ≥ 1 mm: Annual count of days where rainfall is greater or equal to 1 mm (0.039 inches)
Very Wet Day rainfall: Amount of rain in a year where daily rainfall is greater than the 95th percentile for the reference period 1971–2000
Consecutive Dry Days: Maximum number of consecutive days in a year with rainfall less than 1 mm (0.039 inches)
Max 1-day rainfall: Annual maximum 1-day rainfall

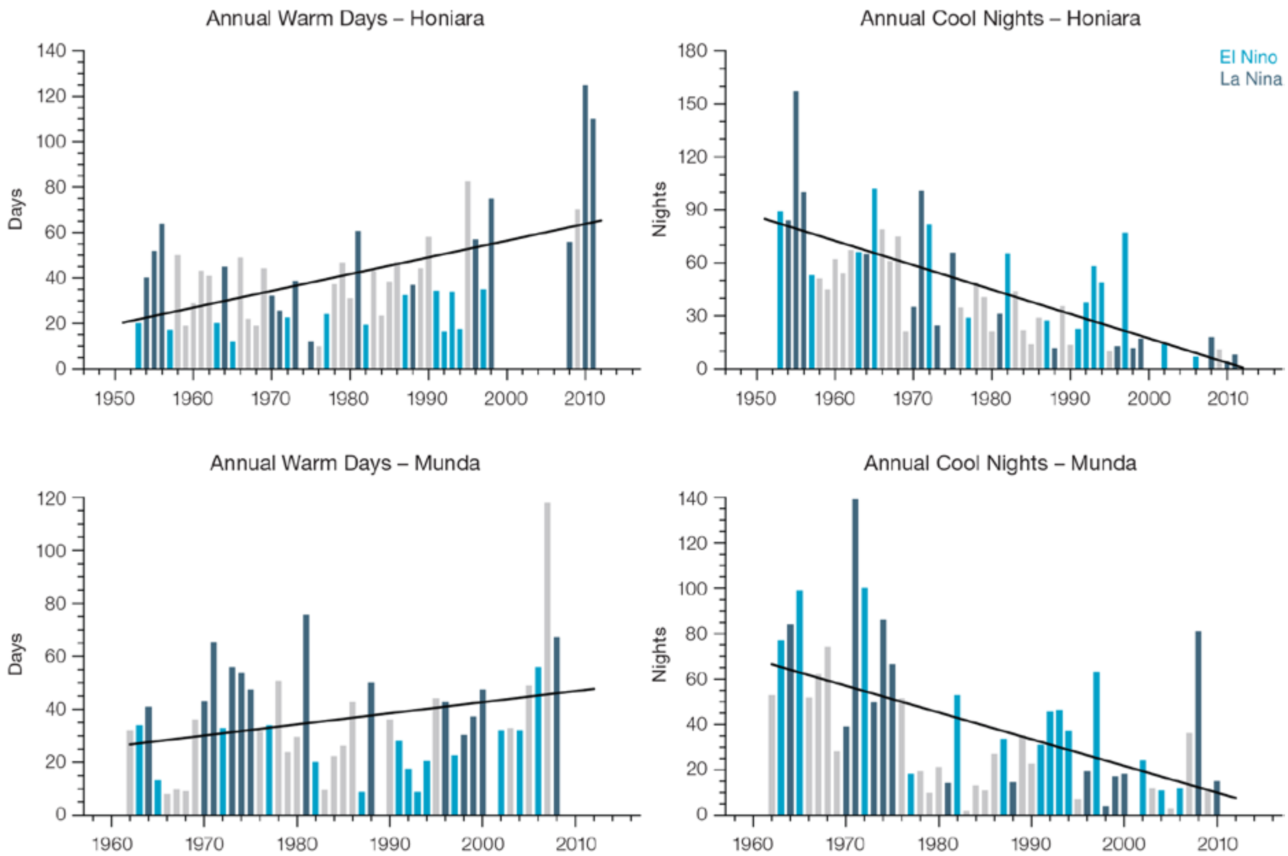

Figure 13.5: Observed time series of annual total number of Warm Days at Honiara (top left) and Munda (bottom left), and annual Cool Nights at Honiara (top right) and Munda (right bottom). Solid black trend lines indicate a least squares fit.

13.4.2 Rainfall

Annual and Half-year Total Rainfall

Notable interannual variability associated with the ENSO is evident in the observed rainfall records for Honiara since 1950 (Figure 13.6) and Munda since 1962 (Figure 13.6). Trends in annual and seasonal rainfall presented in Table 13.2 and Figure 13.6 are not statistically significant at the 5% level. In other words, annual and half-year rainfall trends show little change at Honiara and Munda.

Daily Rainfall

Daily rainfall trends for Honiara and Munda are presented in Table 13.3. Figure 13.6 shows trends in annual Max 1-day rainfall and Rain Days ≥ 1 mm (days with rainfall) at both sites. The Honiara negative annual Rain Days ≥ 1 mm trend and Munda positive Max 1-day rainfall trend are statistically significant (regardless of the large positive outlier in Munda 1-day rainfall). Both these trends occur even though there is no significant trend in annual or seasonal rainfall. The remaining daily rainfall trends are not statistically significant.

13.4.3 Tropical Cyclones

When tropical cyclones affect the Solomon Islands they tend to do so between November and April. Occurrences outside this period are rare. The tropical cyclone archive for the Southern Hemisphere indicates that between the 1969/70 and 2010/11 cyclone seasons, 120 tropical cyclones developed within or crossed the Solomon Islands EEZ. This represents an average of 29 cyclones per decade. Refer to Chapter 1, Section 1.4.2 (Tropical Cyclones) for an explanation of the difference in the number of tropical cyclones occurring in the Solomon Islands in this report (Australian Bureau of Meteorology and CSIRO, 2014) compared to Australian Bureau of Meteorology and CSIRO (2011).

The interannual variability in the number of tropical cyclones in the Solomon Islands EEZ is large, ranging from zero in some seasons to eight in 1997/98 (Figure 13.7). Tropical cyclones were most frequent in El Niño years (39 cyclones per decade). The La Niña and neutral year averages are 21 cyclones per decade. Twenty-two of the 82 tropical cyclones (27%) between the 1981/82 and 2010/11 seasons were severe events (Category 3 or stronger) in the Solomon Islands EEZ.

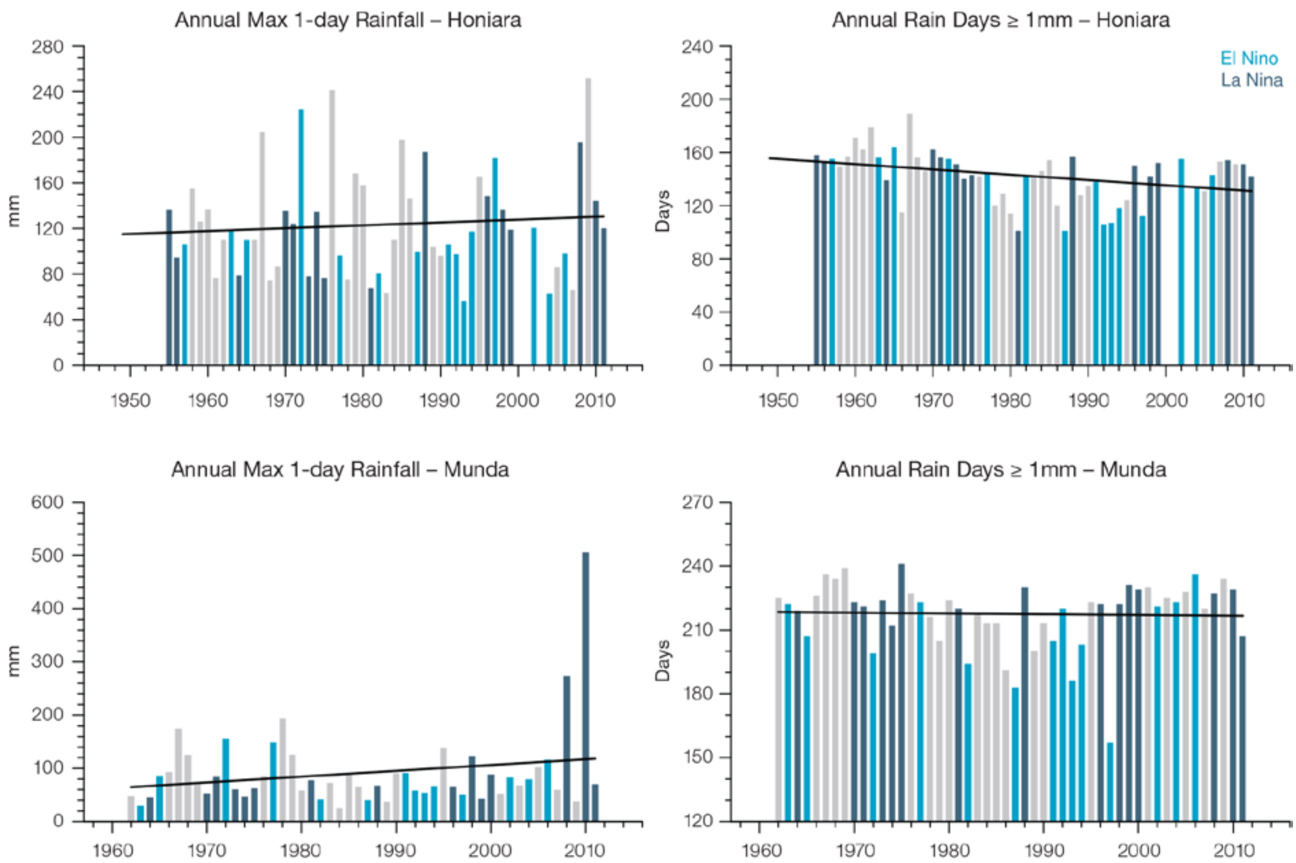

Figure 13.6: Observed time series of annual Max 1-day rainfall at Honiara (top left panel) and Munda (bottom left panel). Annual Rain Days ≥ 1 mm at Honiara (top right panel) and Munda (bottom right panel). Solid black trend lines indicate a least squares fit.

Long-term trends in frequency and intensity have not been presented as country scale assessment is not recommended. Some tropical cyclone tracks analysed in this subsection include the tropical depression stage (sustained winds less than or equal to 34 knots) before and/or after tropical cyclone formation.

Additional information on historical tropical cyclones in the Solomon Islands region can be found at www.bom.gov.au/cyclone/history/tracks/index.shtml

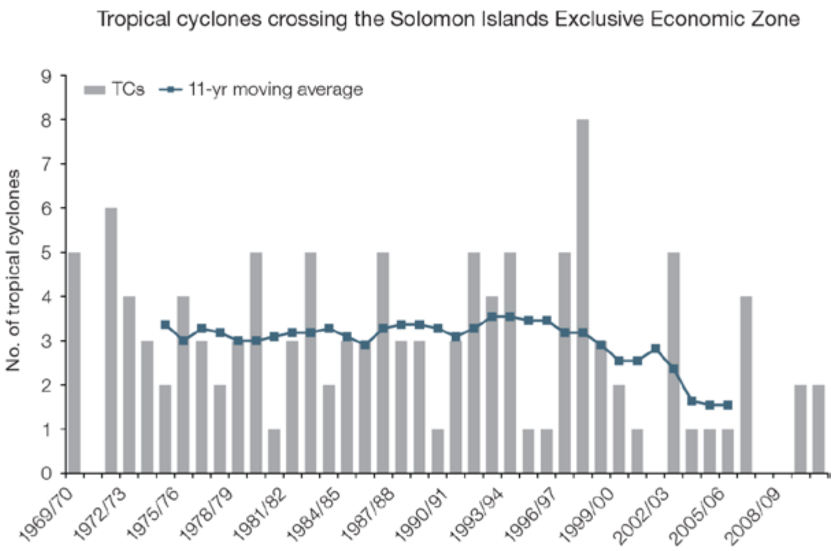

Figure 13.7: Time series of the observed number of tropical cyclones developing within and crossing the Solomon Islands EEZ per season. The 11-year moving average is in blue.

13.5 Climate Projections

The performance of the available Coupled Model Intercomparison Project (Phase 5) (CMIP5) climate models over the Pacific has been rigorously assessed (Brown et al., 2013a, b; Grose et al., 2014; Widlansky et al., 2013). The simulation of the key processes and features for the Solomon Islands region is similar to the previous generation of CMIP3 models, with all the same strengths and many of the same weaknesses. The best-performing CMIP5 models used here have lower biases (differences between the simulated and observed climate data) than the best CMIP3 models, and there are fewer poorly-performing models. For the Solomon Islands the most important model bias is that the rainfall maximum of the the South Pacific Convergence Zone (SPCZ) is too zonally (east-west) oriented. The region directly to the north is too dry due to overly cold sea-surface temperatures near the equator. Also, the WPM westerly winds do not extend far enough east in many models. This lowers confidence in the model projections. Out of 27 models assessed, three models were rejected for use in these projections due to biases in the mean climate and in the simulation of SPCZ. Climate projections have been derived from up to 24 new GCMs in the CMIP5 database (the exact number is different for each scenario, Appendix A), compared with up to 18 models in the CMIP3 database reported in Australian Bureau of Meteorology and CSIRO (2011).

It is important to realise that the models used give different projections under the same scenario. This means there is not a single projected future for the Solomon Islands, but rather a range of possible futures for each emission scenario. This range is described below.

13.5.1 Temperature

Further warming is expected over the Solomon Islands (Figure 13.8, Table 13.6). Under all RCPs, the warming is up to 1.0°C by 2030, relative to 1995, but after 2030 there is a growing difference in warming between each RCP. For example, in the Solomon Islands by 2090, a warming of 2.0–4.0°C is projected for RCP8.5 while a warming of 0.4–1.2°C is projected for RCP2.6. This range is broader than that presented in Australian Bureau of Meteorology and CSIRO (2011) because a wider range of emissions scenarios is considered. While relatively warm and cool years and decades will still occur due to natural variability, there is projected to be more warm years and decades on average in a warmer climate. Dynamical downscaling of climate models (Australian Bureau of Meteorology and CSIRO, 2011, Volume 1, Chapter 7) suggests that temperature rises may be about 0.2°C greater over land than over ocean in this area.

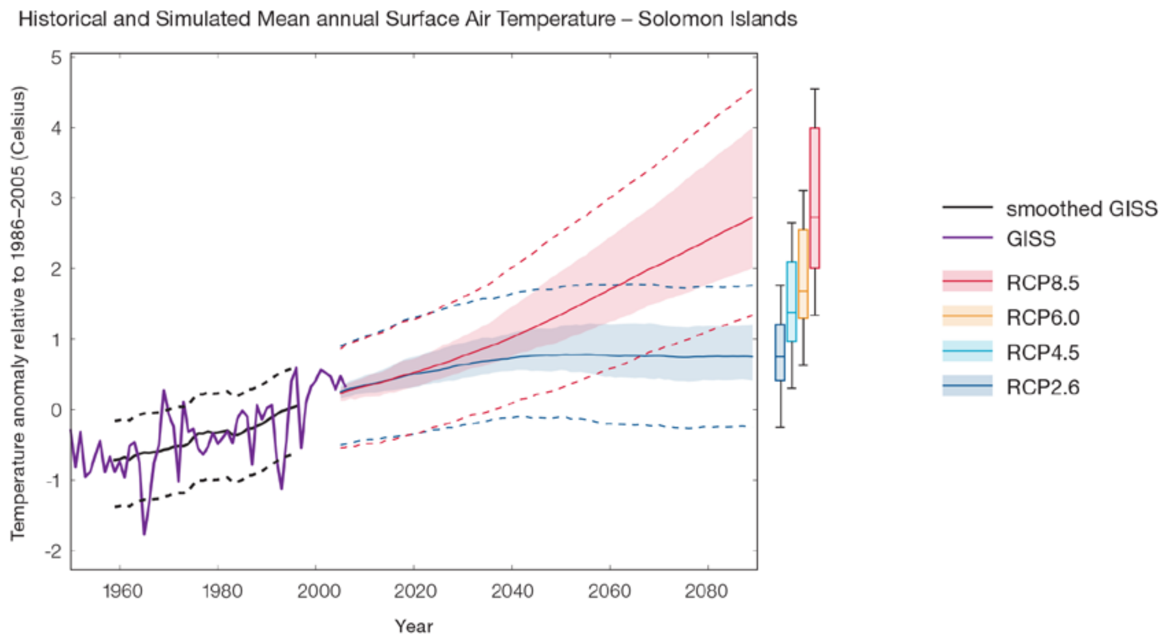

Figure 13.8: Historical and simulated surface air temperature time series for the region surrounding the Solomon Islands. The graph shows the anomaly (from the base period 1986–2005) in surface air temperature from observations (the GISS dataset, in purple), and for the CMIP5 models under the very high (RCP8.5, in red) and very low (RCP2.6, in blue) emissions scenarios. The solid red and blue lines show the smoothed (20-year running average) multi-model mean anomaly in surface air temperature, while shading represents the spread of model values (5–95th percentile). The dashed lines show the 5–95th percentile of the observed interannual variability for the observed period (in black) and added to the projections as a visual guide (in red and blue). This indicates that future surface air temperature could be above or below the projected long-term averages due to interannual variability. The ranges of projections for a 20-year period centred on 2090 are shown by the bars on the right for RCP8.5, 6.0, 4.5 and 2.6.

There is *very high confidence* that temperatures will rise because:

- It is known from theory and observations that an increase in greenhouse gases will lead to a warming of the atmosphere; and
- Climate models agree that the long-term average temperature will rise.

There is *medium confidence* in the model average temperature change shown in Table 13.6 because:

- The new models do a good job of simulating the temperature change of the recent past in the Solomon Islands.

13.5.2 Rainfall

The CMIP5 models show a range of projected annual rainfall change from an increase to a decrease, and the model average is for a slight increase. The range is greater in the highest emissions scenarios (Figure 13.9, Table 13.6). There is a similar range of results in both November–April and May–October rainfall, with a slight increase in the model average in both seasons. These results are different to those found in Australian Bureau of Meteorology and CSIRO (2011), which reported an increase in mean rainfall in all seasons with *high confidence.* The range of new model results and new research into the drivers of change suggest that there is less certainty in the direction of projected change than found previously.

The year-to-year rainfall variability over the Solomon Islands is generally larger than the projected change, except for the models with the largest projected change in rainfall later in the century. The effect of climate change on average rainfall may not be obvious in the short or medium term due to natural variability. Dynamical downscaling of climate models (Australian Bureau of Meteorology and CSIRO, 2011, Volume 1, Chapter 7) suggests that there may be some difference in the rainfall change over land compared to over ocean and on the western side of each island compared to the east side of the island.

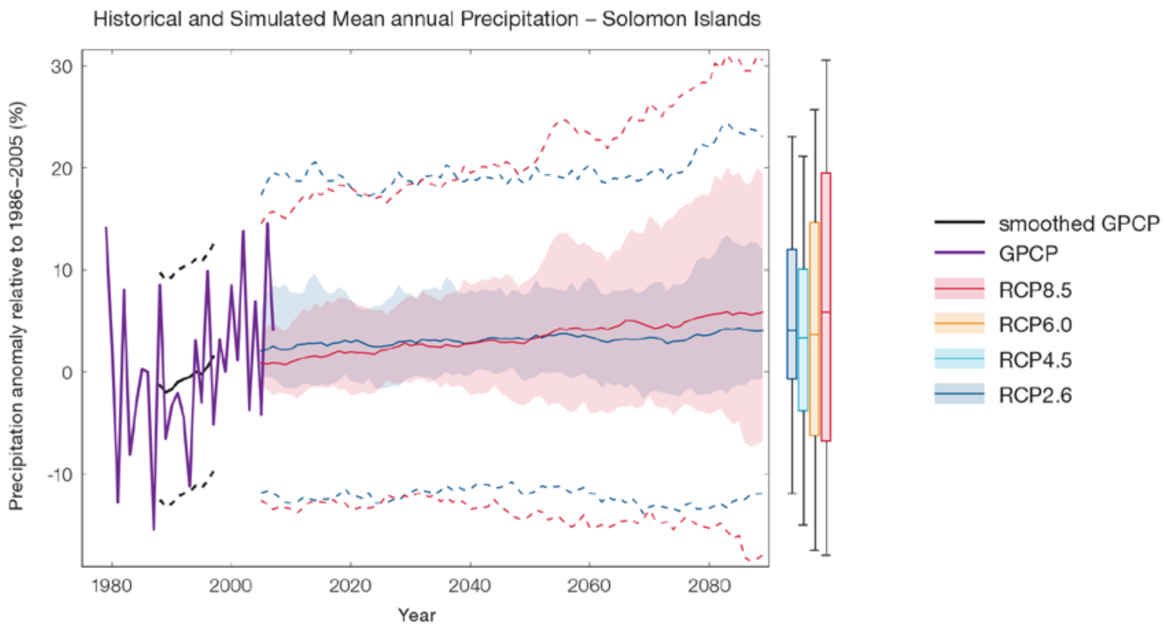

Figure 13.9: Historical and simulated annual average rainfall time series for the region surrounding the Solomon Islands. The graph shows the anomaly (from the base period 1986–2005) in rainfall from observations (the GPCP dataset, in purple), and for the CMIP5 models under the very high (RCP8.5, in red) and very low (RCP2.6, in blue) emissions scenarios. The solid red and blue lines show the smoothed (20-year running average) multi-model mean anomaly in rainfall, while shading represents the spread of model values (5–95th percentile). The dashed lines show the 5–95th percentile of the observed interannual variability for the observed period (in black) and added to the projections as a visual guide (in red and blue). This indicates that future rainfall could be above or below the projected long-term averages due to interannual variability. The ranges of projections for a 20-year period centred on 2090 are shown by the bars on the right for RCP8.5, 6.0, 4.5 and 2.6.

Although the average of models shows a slight increase in rainfall, there is no strong agreement as to the direction of change in the models. This lowers the confidence that we can determine the most likely direction of change in annual rainfall, and makes the amount difficult to determine. The 5–95th percentile range of projected values from CMIP5 climate models is large, e.g. for RCP8.5 (very high emissions) the range is -1 to +7% by 2030 and -7 to +20% by 2090.

There is *low confidence* that rainfall will slightly increase for the Solomon Islands because:

- There is a model spread from a projected rainfall increase to a decrease; and
- The future of the SPCZ is not clear due to model biases in the current climate, and likewise the future of the ENSO is unclear (see Box in Chapter 1).

There is *low confidence* in the model average rainfall change shown in Table 13.6 because:

- There is a large spread in rainfall projections, which range from a projected rainfall increase to a decrease;
- The complex set of processes involved in tropical rainfall is challenging to simulate in models. This means that the confidence in the projection of rainfall is generally lower than for other variables such as temperature;
- There is a different magnitude of change in the SPCZ rainfall projected by models that have reduced sea-surface temperature biases (Australian Bureau of Meteorology and CSIRO, 2011, Chapter 7 (downscaling); Widlanksy et al.,2012) compared to the CMIP5 models; and
- The future behaviour of the ENSO is unclear, and the ENSO strongly influences year-to-year rainfall variability.

13.5.3 Extremes

Extreme Temperature

The temperature on extremely hot days is projected to increase by about the same amount as average temperature. This conclusion is based on analysis of daily temperature data from a subset of CMIP5 models (Chapter 1). The frequency of extremely hot days is also expected to increase.

The temperature of the 1-in-20-year hot day is projected to increase by approximately 0.6°C by 2030 under the RCP2.6 scenario and by 0.8°C under the RCP8.5 scenario. By 2090 the projected increase is 0.8°C for RCP2.6 and 2.9°C for RCP8.5.

There is *very high confidence* that the temperature of extremely hot days and the temperature of extremely cool days will increase, because:

- A change in the range of temperatures, including the extremes, is physically consistent with rising greenhouse gas concentrations;
- This is consistent with observed changes in extreme temperatures around the world over recent decades (IPCC, 2012); and
- All the CMIP5 models agree on an increase in the frequency and intensity of extremely hot days and a decrease in the frequency and intensity of cool days.

There is *low confidence* in the magnitude of projected change in extreme temperature because models generally underestimate the current intensity and frequency of extreme events. Changes to the particular driver of extreme temperatures affect whether the change to extremes is more or less than the change in the average temperature, and the changes to the drivers of extreme temperatures in the Solomon Islands are currently unclear. Also, while all models project the same direction of change there is a wide range in the projected magnitude of change among the models.

Extreme Rainfall

The frequency and intensity of extreme rainfall events are projected to increase. This conclusion is based on analysis of daily rainfall data from a subset of CMIP5 models using a similar method to that in Australian Bureau of Meteorology and CSIRO (2011) with some improvements (Chapter 1), so the results are slightly different to those in Australian Bureau of Meteorology and CSIRO (2011). The current 1-in-20-year daily rainfall amount is projected to increase by approximately 9 mm by 2030 for RCP2.6 and by 9 mm by 2030 for RCP8.5. By 2090, it is projected to increase by approximately 6 mm for RCP2.6 and by 43 mm for RCP8.5.The majority of models project the current 1-in-20-year daily rainfall event will become, on average, a 1-in-9-year event for RCP2.6 and a 1-in-4-year event for RCP8.5 by 2090. These results are different to those found in Australian Bureau of Meteorology and CSIRO (2011) because of different methods used (Chapter 1).

There is *high confidence* that the frequency and intensity of extreme rainfall events will increase because:

- A warmer atmosphere can hold more moisture, so there is greater potential for extreme rainfall (IPCC, 2012);
- Consistent with the mixed changes in mean and extreme rainfall indices, the pattern of change in the extreme rainfalls shows considerable variation from station to station. For the lower recurrence intervals (2 and 5 years) there is little systematic change in rainfall intensity. In some contrast the very most extreme rainfall being that occurring with an average recurrence interval of 20 years shows a mean increase of 3.5%, (significant at the 10% level);
- Increases in extreme rainfall in the Pacific are projected in all available climate models; and
- An increase in extreme rainfall events within the SPCZ region was found by an in-depth study of extreme rainfall events in the SPCZ (Cai et al., 2012).

There is *low confidence* in the magnitude of projected change in extreme rainfall because:

- Models generally underestimate the current intensity of local extreme events, especially in this area due to the 'cold-tongue bias' (Chapter 1);
- Changes in extreme rainfall projected by models may be underestimated because models seem to underestimate the observed increase in heavy rainfall with warming (Min et al., 2011);
- GCMs have a coarse spatial resolution, so they do not adequately capture some of the processes involved in extreme rainfall events; and
- The Conformal Cubic Atmospheric Model (CCAM) downscaling model has finer spatial resolution and the CCAM results presented in Australian Bureau of Meteorology and CSIRO (2011) indicates a smaller increase in the number of extreme rainfall days, and there is no clear reason to accept one set of models over another.

Drought

Drought projections (defined in Chapter 1) are described in terms of changes in proportion of time in drought, frequency and duration by 2090 for very low and very high emissions (RCP2.6 and 8.5).

For the Solomon Islands the overall proportion of time spent in drought is expected to decrease under all scenarios. Under RCP8.5 the frequency of mild, moderate and severe drought events is expected to decrease while the frequency of extreme drought events is expected to remain stable (Figure 13.10). The duration of mild, moderate and severe drought events is expected to decrease while the duration of extreme drought events is expected to remain stable under RCP8.5. Under RCP2.6 the frequency of moderate, severe and extreme drought events are expected to decrease slightly while the frequency of mild drought events is expected to remain stable. The duration of events in all categories is projected to remain stable under RCP2.6 (very low emissions).

There is *low confidence* in this direction of change because:

- There is *low confidence* in the direction of mean rainfall change;
- These drought projections are based upon a subset of models; and
- Like the CMIP3 models, the majority of the CMIP5 models agree on this direction of change.

There is *low confidence* in the projections of drought duration and frequency because there is *low confidence* in the magnitude of rainfall projections, and no consensus about projected changes in the ENSO, which directly influence the projection of drought.

Tropical Cyclones

Global Picture

There is a growing level of consistency between models that on a global basis the frequency of tropical cyclones is likely to decrease by the end of the 21st century. The magnitude of the decrease varies from 6%–35% depending on the modelling study. There is also a general agreement between models that there will be an increase in the mean maximum wind speed of cyclones by between 2% and 11% globally, and an increase in rainfall rates of the order of 20% within 100 km of the cyclone centre (Knutson et al., 2010). Thus, the scientific community has a *medium* level of confidence in these global projections.

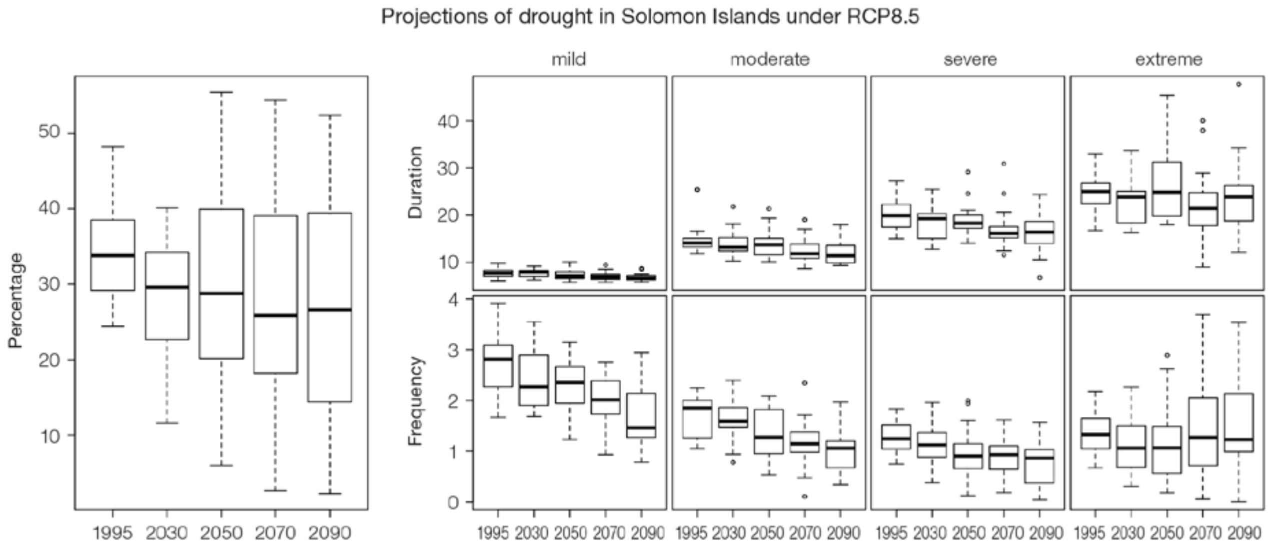

Figure 13.10: Box-plots showing percent of time in moderate, severe or extreme drought (left hand side), and average drought duration and frequency for the different categories of drought (mild, moderate, severe and extreme) for the Solomon Islands. These are shown for 20-year periods centred on 1995, 2030, 2050, 2070 and 2090 for the RCP8.5 (very high emissions) scenario. The thick dark lines show the median of all models, the box shows the interquartile (25–75%) range, the dashed lines show 1.5 times the interquartile range and circles show outlier results.

Solomon Islands

The projection is for a decrease in cyclone genesis (formation) frequency for the south-west basin (see Figure 13.11 and Table 13.4). However the confidence level for this projection is medium. The GCMs show inconsistent results across models for changes in cyclone frequency for the south-west basin, using the direct detection methodologies (OWZ or CDD) described in Chapter 1 with a little over a half of projected changes being for a decrease in genesis frequency. About half of the projected changes, based on these methods, vary between a 15–35% decrease in genesis frequency. The three empirical techniques assess changes in the main atmospheric ingredients known to be necessary for cyclone formation. About two-thirds of models suggest the conditions for cyclone formation will become less favourable in this region with about one third of projected changes being for a decrease in genesis frequency of between 5 and 30%. These projections are consistent with those of Australian Bureau of Meteorology and CSIRO (2011).

Table 13.4: Projected percentage change in cyclone frequency in the south-west basin (0–40°S; 130°E–170°E) for 22 CMIP5 climate models, based on five methods, for 2080–2099 relative to 1980–1999 for RCP8.5 (very high emissions). The 22 CMIP5 climate models were selected based upon the availability of data or on their ability to reproduce a current-climate tropical cyclone climatology (See Section 1.5.3 – Detailed Projection Methods, Tropical Cyclones). Blue numbers indicate projected decreases in tropical cyclone frequency, red numbers an increase. MMM is the multi-model mean change. N increase is the proportion of models (for the individual projection method) projecting an increase in cyclone formation.

Model	GPI change	GPI-M change	Tippett	CDD	OWZ
access10	-11	-11	-62	-17	
access13	11	2	-36	24	
bcccsm11	1	-2	-28		-21
canesm2	24	13	-51	28	
ccsm4				-86	4
cnrm_cm5	-3	-5	-26	-4	-26
csiro_mk36	0	-9	-29	-21	12
fgoals_g2	13	8	-5		
fgoals_s2	3	-3	-40		
gfdl-esm2m				17	26
gfdl_cm3	24	17	-4		-19
gfdl_esm2g				-21	3
gisse2r	4	-2	-30		
hadgem2_es	2	-4	-63		
inm	3	3	-16		
ipslcm5alr	4	-1	-29		
ipslcm5blr				-35	
miroc5				-27	-24
mirocesm	-44	-50	-30		
mpim	-4	-7	-47		
mricgcm3	-5	-9	-38		
noresm1m	0	-6	-30	-39	
MMM	1	-4	-33	-16	-6
N increase	0.7	0.3	0.0	0.3	0.5

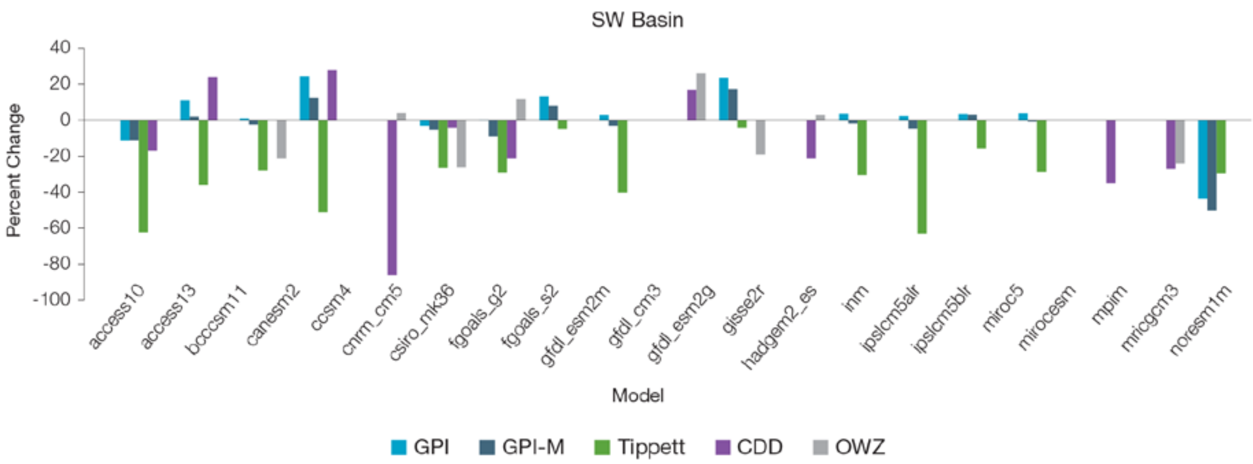

Figure 13.11: Projected percentage change in cyclone frequency in the south-west basin (data from Table 13.4).

13.5.4 Coral Reefs and Ocean Acidification

As atmospheric CO_2 concentrations continue to rise, oceans will warm and continue to acidify. These changes will impact the health and viability of marine ecosystems, including coral reefs that provide many key ecosystem services (*high confidence*). These impacts are also likely to be compounded by other stressors such as storm damage, fishing pressure and other human impacts.

The projections for future ocean acidification and coral bleaching use three RCPs (2.6, 4.5, and 8.5).

Ocean Acidification

Ocean acidification is expressed in terms of aragonite saturation state (Chapter 1). In the Solomon Islands the aragonite saturation state has declined from about 4.5 in the late 18th century to an observed value of about 3.9±0.1 by 2000 (Kuchinke et al., 2014). All models show that the aragonite saturation state, a proxy for coral reef growth rate, will continue to decrease as atmospheric CO_2 concentrations increase (*very high confidence*). Projections from CMIP5 models indicate that under RCPs 8.5 (very high emissions) and 4.5 (low emissions) the median aragonite saturation state will transition to marginal conditions (3.5) around 2030. In RCP8.5 (very high emissions) the aragonite saturation state continues to strongly decline thereafter to values where coral reefs have not historically been found (< 3.0). Under RCP4.5 (low emissions) the aragonite saturation plateaus around 3.2 i.e. marginal conditions for healthy coral reefs. While under RCP2.6 (very low emissions) the median aragonite saturation state never falls below 3.5, and increases slightly toward the end of the century (Figure 13.12) suggesting that the conditions remains adequate for healthy corals reefs. There is *medium confidence* in this range and distribution of possible futures because the projections are based on climate models that do not resolve the reef scale that can play a role in modulating large-scale changes. The impacts of ocean acidification are also likely to affect the entire marine ecosystem impacting the key ecosystem services provided by reefs.

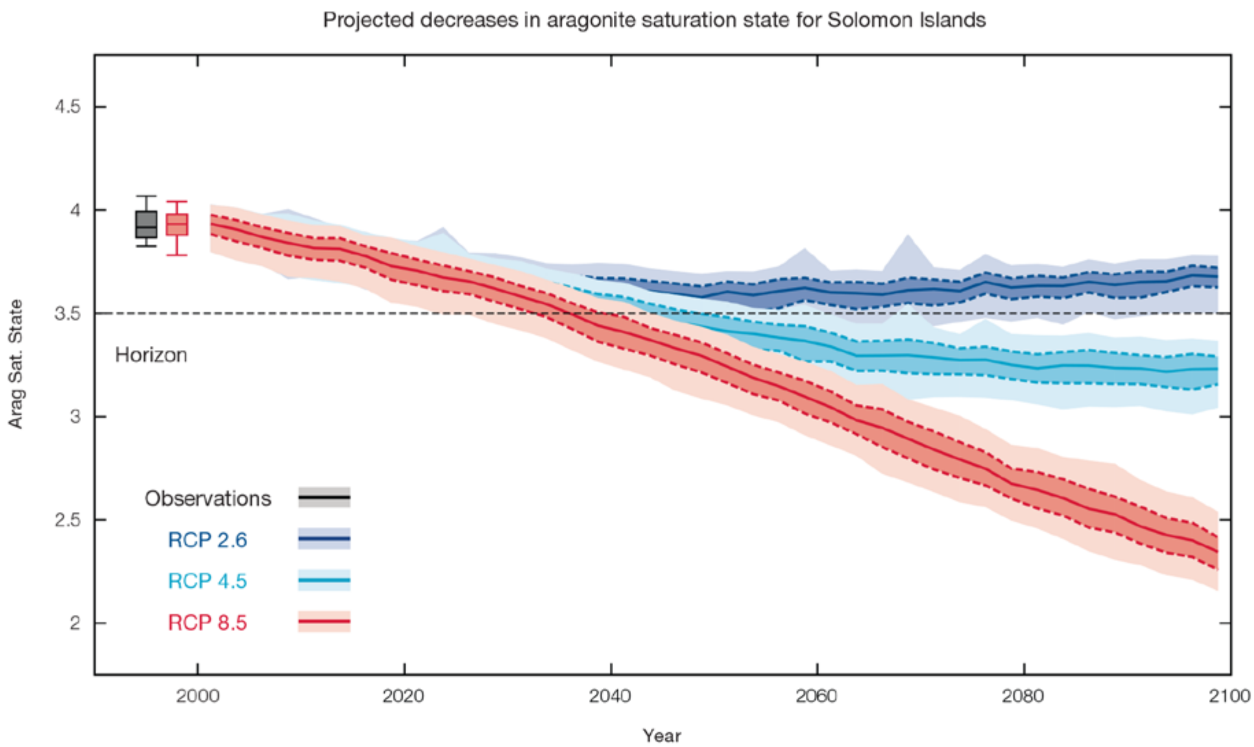

Figure 13.12: Projected decreases in aragonite saturation state in the Solomon Islands from CMIP5 models under RCP2.6, 4.5 and 8.5. Shown are the median values (solid lines), the interquartile range (dashed lines), and 5% and 95% percentiles (light shading). The horizontal line represents the transition to marginal conditions for coral reef health (from Guinotte et al., 2003).

Coral Bleaching Risk

As the ocean warms, the risk of coral bleaching increases (*very high confidence*). There is *medium confidence* in the projected rate of change for the Solomon Islands because there is *medium confidence* in the rate of change of sea-surface temperature (SST), and the changes at the reef scale (which can play a role in modulating large-scale changes) are not adequately resolved. Importantly, the coral bleaching risk calculation does not account the impact of other potential stressors (Chapter 1).

The changes in the frequency (or recurrence) and duration of severe bleaching risk are quantified for different projected SST changes (Table 13.5). Overall there is a decrease in the time between two periods of elevated risk and an increase in the duration of the elevated risk. For example, under a long-term mean increase of 1˚C (relative to 1982–1999 period), the average period of severe bleaching risk (referred to as a risk event) will last 8.2 weeks (with a minimum duration of 1.8 weeks and a maximum duration of 4.5 months) and the average time between two risks will be 2.6 years (with the minimum recurrence of 4.3 months and a maximum recurrence of 7.4 years). If severe bleaching events occur more often than once every five years, the long-term viability of coral reef ecosystems becomes threatened.

13.5.5 Sea Level

Mean sea level is projected to continue to rise over the course of the 21st century. There is very *high confidence* in the direction of change. The CMIP5 models simulate a rise of between approximately 7–18cm by 2030 (very similar values for different RCPs), with increases of 40–89 cm by 2090 under the RCP8.5 (Figure 13.13 and Table 13.6). There is *medium confidence* in the range mainly because there is still uncertainty associated with projections of the Antarctic ice sheet contribution. Interannual variability of sea level will lead to periods of lower and higher regional sea levels. In the past, this interannual variability has been about 31 cm (5–95% range, after removal of the seasonal signal, see dashed lines in Figure 13.13 (a) and it is likely that a similar range will continue through the 21st century.

Table 13.5: Projected changes in severe coral bleaching risk for the Solomon Islands EEZ for increases in SST relative to 1982–1999.

Temperature change [1]	Recurrence interval [2]	Duration of the risk event [3]
Change in observed mean	30 years	5.4 weeks
+0.25°C	30 years	6.5 weeks
+0.5°C	26.7 years (24.2 years – 29.1 years)	6.8 weeks (6.4 weeks – 7.2 weeks)
+0.75°C	9.7 years (3.5 years – 17.4 years)	6.9 weeks (3.6 weeks – 2.6 months)
+1°C	2.6 years (4.3 months – 7.4 years)	8.2 weeks (1.8 weeks – 4.5 months)
+1.5°C	7.5 months (1.4 months – 2.2 years)	3.8 months (1.6 weeks –10.3 months)
+2°C	4.4 months (1.6 months – 8.7 months)	10.2 months (5.1 weeks – 3.3 years)

[1] This refers to projected SST anomalies above the mean for 1982–1999.
[2] Recurrence is the mean time between severe coral bleaching risk events. Range (min – max) shown in brackets.
[3] Duration refers to the period of time where coral are exposed to the risk of severe bleaching. Range (min – max) shown in brackets.

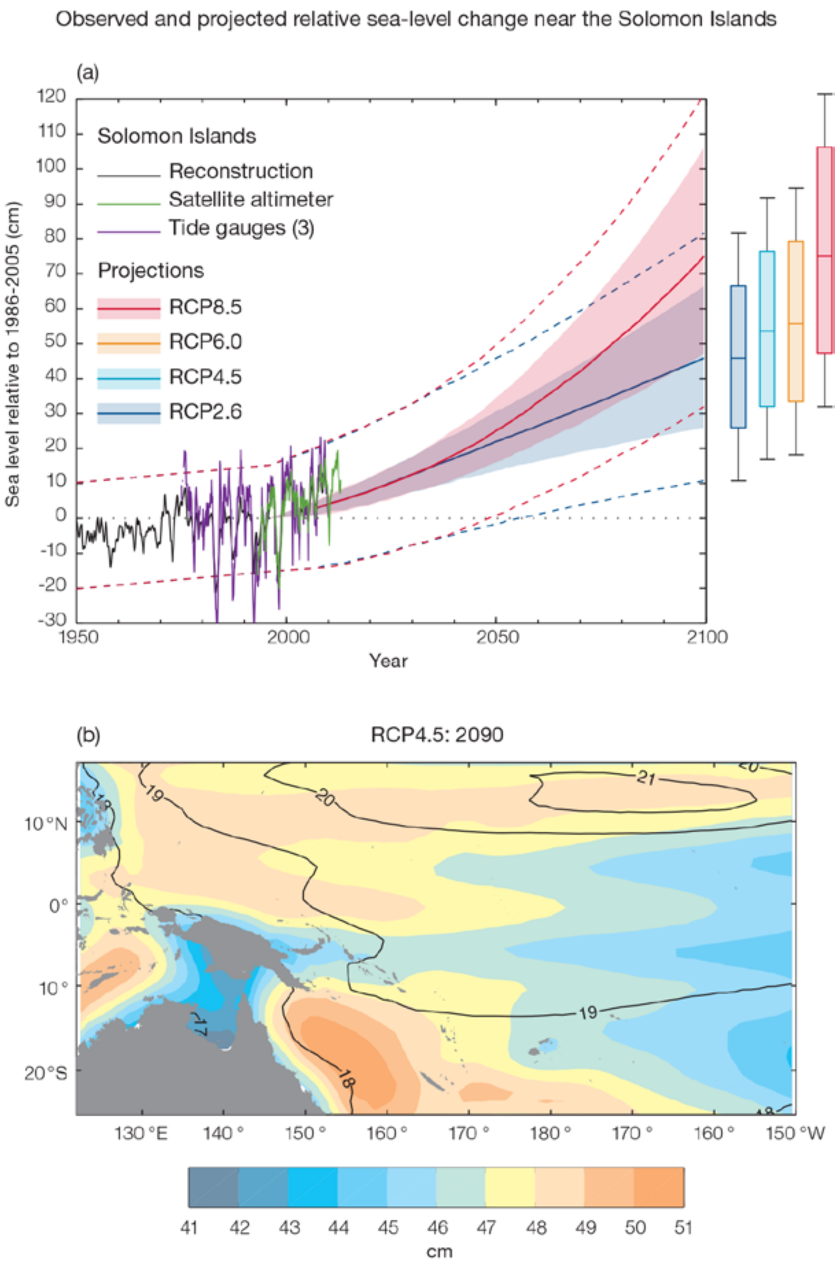

Figure 13.13: (a) The observed tide-gauge records of relative sea-level (since the late 1970s) are indicated in purple, and the satellite record (since 1993) in green. The gridded (reconstructed) sea level data at the Solomon Islands (since 1950) is shown in black. Multi-model mean projections from 1995–2100 are given for the RCP8.5 (red solid line) and RCP2.6 emissions scenarios (blue solid line), with the 5–95% uncertainty range shown by the red and blue shaded regions. The ranges of projections for four emission scenarios (RCPs 2.6, 4.5, 6.0 and 8.5) by 2100 are also shown by the bars on the right. The dashed lines are an estimate of interannual 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.

(b) The regional distribution of projected sea level rise under the RCP4.5 emissions scenario for 2081–2100 relative to 1986–2005. Mean projected changes are indicated by the shading, and the estimated uncertainty in the projections is indicated by the contours (in cm).

13.5.6 Wind-driven Waves

During December–March, projected changes in Solomon Islands wave properties include a decrease in mean wave height (significant under the very high emission RCP8.5 scenario in 2090) (Figure 13.14), accompanied by a decrease in wave period, with no significant change in direction, which is variable in the wet season *(low confidence)* (Table 13.7). These features are characteristic of a decrease in the strength of prevailing winds. No change is projected in the height of larger storm waves *(low confidence)*.

In June–September, there are no statistically significant projected changes in wave properties *(low confidence)* (Table 13.7). Non-significant changes include a suggested increase in wave height and a possible decrease in period. A slight increase in the heights of larger waves is suggested *(low confidence)*.

There is *low confidence* in projected changes in the Solomon Islands wind-wave climate because:

- Projected changes in wave climate are dependent on confidence of projected changes in the ENSO, which is low; and
- The difference between simulated and observed (hindcast) wave data are larger than the projected wave changes, which further reduces our confidence in projections.

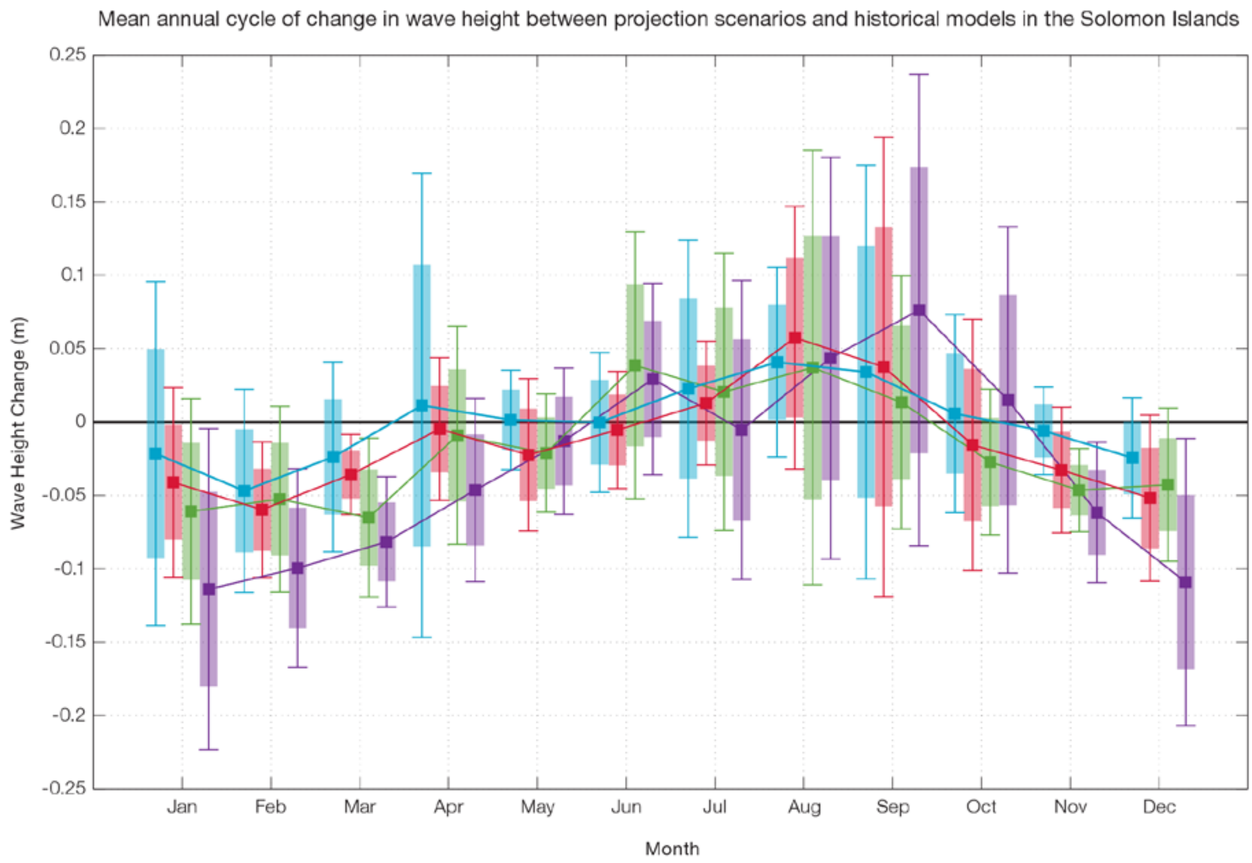

Figure 13.14: Mean annual cycle of change in wave height between projection scenarios and mean of historical models in the Solomon Islands. This panel shows a small decrease in wave heights in the wet season months (which is statistically significant in 2090 RCP8.5, very high emissions, and in February and March in 2035 RCP8.5 and in March in 2090 RCP4.5), with no significant change in the dry season months. Shaded boxes show 1 standard deviation of models' means around the ensemble means, and error bars show the 5–95% range inferred from the standard deviation. Colours represent RCP scenarios and time periods: blue 2035 RCP4.5 (low emissions), red 2035 RCP8.5 (very high emissions), green 2090 RCP4.5 (low emissions), purple 2090 RCP8.5 (very high emissions).

13.5.7 Projections Summary

There is *very high confidence* in the direction of long-term change in a number of key climate variables, namely an increase in mean and extremely high temperatures, sea level and ocean acidification. There is *high confidence* that the frequency and intensity of extreme rainfall will increase. There is *low confidence* that annual rainfall will increase slightly and the incidence of drought will decrease slightly.

Tables 13.6 and 13.7 quantify the mean changes and ranges of uncertainty for a number of variables, years and emissions scenarios. A number of factors are considered in assessing confidence, i.e. the type, amount, quality and consistency of evidence (e.g. mechanistic understanding, theory, data, models, expert judgment) and the degree of agreement, following the IPCC guidelines (Mastrandrea et al., 2010).

Confidence ratings in the projected magnitude of mean change are generally lower than those for the direction of change (see paragraph above) because magnitude of change is more difficult to assess. For example, there is *very high confidence* that temperature will increase, but *medium confidence* in the magnitude of mean change.

Table 13.6: Projected changes in the annual and seasonal mean climate for the Solomon Islands under four emissions scenarios; RCP2.6 (very low emissions, in dark blue), RCP4.5 (low emissions, in light blue), RCP6 (medium emissions, in orange) and RCP8.5 (very high emissions, in red). Projected changes are given for four 20-year periods centred on 2030, 2050, 2070 and 2090, relative to a 20-year period centred on 1995. Values represent the multi-model mean change, with the 5–95% range of uncertainty in brackets. Confidence in the magnitude of change is expressed as *high*, *medium* or *low*. Surface air temperatures in the Pacific are closely related to sea-surface temperatures (SST), so the projected changes to air temperature given in this table can be used as a guide to the expected changes to SST. (See also Section 1.5.2). 'NA' indicates where data are not available.

Variable	Season	2030	2050	2070	2090	Confidence (magnitude of change)
Surface air temperature (°C)	Annual	0.6 (0.4–0.9)	0.8 (0.6–1.2)	0.8 (0.4–1.2)	0.7 (0.4–1.2)	*Medium*
		0.7 (0.4–1)	1 (0.7–1.4)	1.2 (0.9–1.8)	1.4 (1–2.1)	
		0.6 (0.5–0.9)	0.9 (0.7–1.4)	1.3 (1–2)	1.7 (1.3–2.6)	
		0.7 (0.5–1)	1.3 (1–1.9)	2.1 (1.5–3)	2.8 (2–4)	
Maximum temperature (°C)	1-in-20 year event	0.6 (0.2–0.8)	0.7 (0.4–1)	0.7 (0.3–1)	0.8 (0.4–1.1)	*Medium*
		0.6 (0.3–0.8)	0.9 (0.4–1.3)	1.2 (0.7–1.8)	1.3 (0.9–2)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.8 (0.4–1.2)	1.4 (0.9–2.1)	2.2 (1.5–3.2)	2.9 (2–4.1)	
Minimum temperature (°C)	1-in-20 year event	0.6 (0.2–0.9)	0.7 (0.4–1)	0.7 (0.3–1)	0.7 (0.1–0.9)	*Medium*
		0.6 (0.3–0.9)	0.9 (0.5–1.3)	1.1 (0.6–1.5)	1.3 (0.8–1.9)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.7 (0.5–1.2)	1.5 (1–2.1)	2.2 (1.5–3.3)	3 (2.2–4.4)	
Total rainfall (%)	Annual	3 (-1–8)	3 (-1–7)	3 (-3–8)	4 (-1–12)	*Low*
		3 (-2–9)	3 (-4–9)	4 (-2–12)	3 (-4–10)	
		4 (-1–9)	3 (-3–8)	5 (-3–14)	4 (-6–15)	
		3 (-1–7)	3 (-3–9)	5 (-3–14)	6 (-7–20)	
Total rainfall (%)	Nov-Apr	3 (-2–9)	3 (-1–9)	3 (-3–9)	4 (0–10)	*Low*
		2 (-2–9)	2 (-4–7)	4 (-2–13)	4 (-1–10)	
		3 (-2–9)	2 (-4–9)	4 (-3–11)	4 (-5–14)	
		3 (-2–9)	3 (-5–10)	5 (-4–13)	6 (-6–20)	
Total rainfall (%)	May-Oct	3 (-4–8)	3 (-4–12)	3 (-5–11)	4 (-4–15)	*Low*
		3 (-4–11)	4 (-3–11)	4 (-3–11)	3 (-8–12)	
		4 (-3–13)	5 (-4–13)	5 (-8–16)	4 (-8–16)	
		3 (-2–8)	3 (-6–9)	5 (-7–15)	5 (-11–22)	
Aragonite saturation state (Ωar)	Annual	-0.3 (-0.6–0.0)	-0.4 (-0.7–0.0)	-0.4 (-0.7–0.0)	-0.3 (-0.7–0.0)	*Medium*
		-0.3 (-0.7–0.0)	-0.5 (-0.9–-0.2)	-0.7 (-1.0–-0.4)	-0.7 (-1.1–-0.4)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		-0.4 (-0.7–-0.1)	-0.7 (-1.0–-0.4)	-1.1 (-1.4–-0.8)	-1.5 (-1.8–-1.2)	
Mean sea level (cm)	Annual	13 (8–18)	22 (14–31)	32 (19–45)	42 (24–60)	*Medium*
		12 (7–17)	22 (14–31)	35 (21–48)	47 (29–67)	
		12 (7–17)	22 (14–30)	34 (21–47)	49 (30–69)	
		13 (8–18)	25 (16–35)	42 (28–58)	63 (40–89)	

Waves Projections Summary

Table 13.7: Projected average changes in wave height, period and direction in the Solomon Islands for December–March and June–September for RCP4.5 (low emissions, in blue) and RCP8.5 (very high emissions, in red), for two 20-year periods (2026–2045 and 2081–2100), relative to a 1986–2005 historical period. The values in brackets represent the 5th to 95th percentile range of uncertainty.

Variable	Season	2035	2090	Confidence (range)
Wave height change (m)	December–March	-0.0 (-0.2–0.1) -0.0 (-0.2–0.1)	-0.1 (-0.2–0.1) -0 1 (-0.2–0.0)	*Low*
	June–September	+0.0 (-0.3–0.3) +0.0 (-0.3–0.3)	+0.0 (-0.3–0.3) +0.0 (-0.3–0.3)	*Low*
Wave period change (s)	December–March	-0.0 (-0.7–0.7) -0.0 (-0.7–0.7)	-0.1 (-1.0–0.7) -0.2 (-1.1–0.8)	*Low*
	June–September	-0.0 (-0.6–0.5) -0.0 (-0.6–0.5)	-0.1 (-0.7–0.6) -0.1 (-0.7–0.7)	*Low*
Wave direction change (° clockwise)	December–March	+0 (-30–30) +0 (-30–30)	0 (-30–30) -0 (-30–30)	*Low*
	June–September	0 (-5–5) 0 (-5–5)	0 (-5–10) 0 (-5–10)	*Low*

Wind-wave variables parameters are calculated for a 20-year period centred on 2035.