Chapter 3
East Timor (Timor-Leste)

3.1 Climate Summary

3.1.1 Current Climate

- Despite missing temperature records for Dili Airport, it is probable that over the past half century there has been a warming air temperature trend at Dili Airport in line with regional and global trends, partly due to the warming ocean temperatures around East Timor.
- Annual and seasonal rainfall trends show little change at Dili Airport since 1952.
- Seven tropical cyclones developed within or crossed the East Timor Exclusive Economic Zone (EEZ) between the 1969/70 and 2010/11 seasons. None of these cyclones became severe events (Category 3 or higher) within the Zone.
- Wind-waves around East Timor are quite small (typically less than 1 m high), and characterised by trade winds in June–September and westerly monsoon winds in December–March. Available data are not suitable for assessing long-term trends.

3.1.2 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*);
- There is a range of projections of average annual rainfall, from a decrease to increase (therefore *low confidence* in the model average projection), but with more extreme rain events *(high confidence*);
- Drought frequency is projected to remain similar to the current climate *(medium 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*
- A reduction of wave period in January is projected, with no other projected changes in the wave climate at East Timor *(low confidence)*.

3.2 Data Availability

There are currently five operational stations in the East Timor national meteorological network. The primary climate station is located at Dili Airport, near the nation's capital, on the northern side of the island of Timor. Monthly rainfall and air temperature data are available for Dili Airport from 1917 and 2003 to present respectively. More data will become available in the next few years as historical data are recovered from colonial archives and digitised. At the time of writing this chapter, sub-daily and daily rainfall and temperature data for 1980s and 1990s were being digitised at the Bureau of Meteorology in Melbourne.

Homogeneous monthly rainfall data for Dili Airport for 1952 to 2010 have been used in this report. There are insufficient data available at the current time for extreme daily rainfall and mean and extreme daily air temperature trend calculations. Additional information on historical climate trends in the East Timor 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.

3.3 Seasonal Cycles

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

3.3.1 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, wave lengths or wave periods, and directions.

The wind-wave climate of East Timor is strongly characterised by the West Pacific Monsoon (WPM) winds in December–March and south-easterly trade winds in June–September. At Dili on the north coast, waves are directed from the east-northeast during June–September, associated with trade winds, and are slightly larger (mean height around 0.3 m) (Table 3.1) than in other months. Waves are directed from the north-west and west during December–March, due to monsoon systems, with typically smaller than average heights (mean around 0.2 m) (Figure 3.1). Wave period does not vary significantly (Table 3.1). Waves larger than 0.6 m (99th percentile) occur predominantly during December–March, generated locally by monsoon storms from the west, and occur less often during the dry months from the east. The height of a 1-in-50 year wave event near Dili is calculated to be 1.8 m.

No suitable dataset is available to assess long-term historical trends in the East Timor wave climate. However, interannual variability may be assessed in the hindcast record. The wind-wave climate displays weak interannual variability near East Timor, varying slightly with the El Niño–Southern Oscillation (ENSO). During La Niña years, wave power is approximately 50% greater than during El Niño years during December–March and slightly more westerly, associated with an increase in monsoon winds. No relationship with the ENSO is apparent during June–September.

Table 3.1: Mean wave height, period and direction from which the waves are travelling in East Timor in December–March (wet season) and June–September (dry season). 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 3.5.6 and Table 3.5). A compass relating number of degrees to cardinal points (direction) is shown.

		Hindcast Reference Data (1979–2000) Dili	Climate Model Simulations (1986–2005)
Wave Height (metres)	December–March	0.2 (0.0–0.5)	0.4 (0.2–0.7)
	June–September	0.3 (0.1–0.5)	0.9 (0.5–1.4)
Wave Period (seconds)	December–March	4.6 (2.6–8.2)	5.6 (4.2–7.0)
	June–September	4.1 (2.9–5.5)	5.7 (5.0–6.3)
Wave direction (degrees clockwise from North)	December–March	310 (260–20)	240 (180–300)
	June–September	60 (0–80)	120 (100–140)

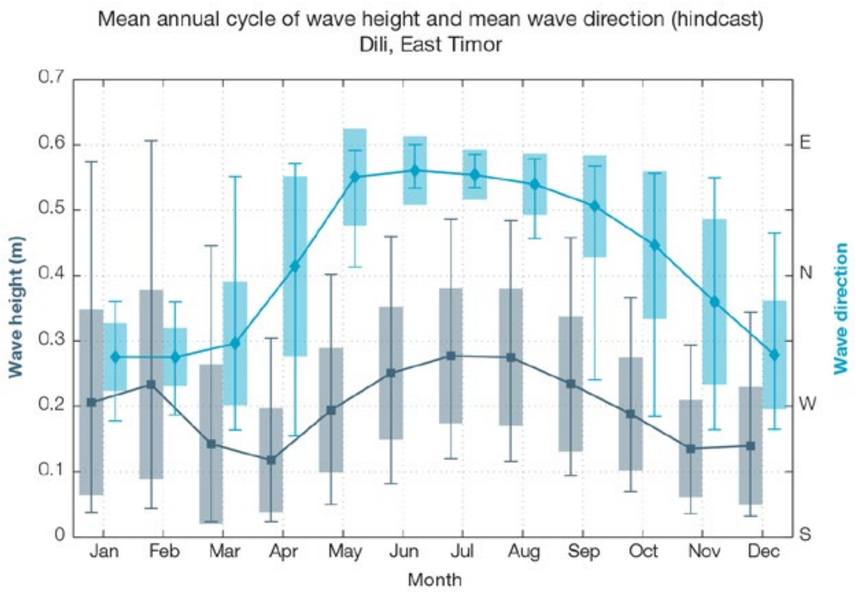

Figure 3.1: Mean annual cycle of wave height (grey) and mean wave direction (blue) at Dili, East Timor in hindcast data (1979–2009). To give an indication of interannual variability of the monthly means of the hindcast data, shaded boxes show 1 standard deviation around the monthly means, and error bars show the 5–95% range. The direction from which the waves are travelling is shown (not the direction towards which they are travelling).

3.4 Observed Trends

3.4.1 Air Temperature

Annual, Half-year and Extreme Mean Air Temperature

There is insufficient data available to provide mean and extreme air temperature trends. Over the past half century it is likely that there has been a warming air temperature trend at Dili in line with regional and global trends, partly due to the warming ocean temperatures around East Timor.

3.4.2 Rainfall

Annual and Half-year Total Rainfall

Notable interannual variability associated with the ENSO is evident in the observed rainfall record for Dili Airport since 1952 (Figure 3.2). Trends in annual and half-year rainfall shown in Figure 3.2 and Table 3.2 are not statistically significant at the 5% level. In other words, annual and half-year rainfall trends show little change at Dili Airport.

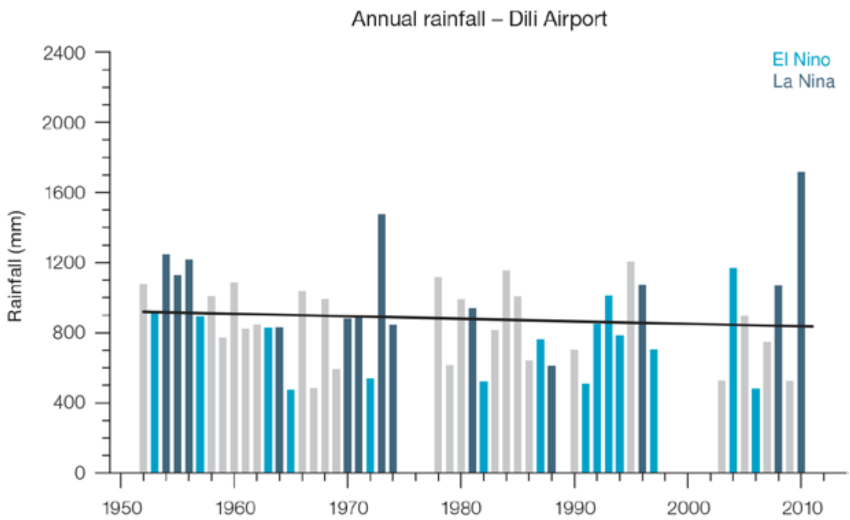

Figure 3.2: Observed annual average values of total rainfall (bars) at Dili Airport. Light blue, dark blue and grey bars denote El Niño, La Niña and neutral years respectively. Solid black trend line indicates a least squares fit.

Table 3.2: Annual and half-year trends in rainfall at Dili Airport for the period 1952–2010. The 95% confidence intervals are shown in brackets. None of the trends are significant at the 5% level.

	Dili Airport Total Rain (mm/10yrs) (1952–2010)
Annual	-29.3 (-77.9, +15.7)
Nov–Apr	-2.5 (-41.1, +45.4)
May–Oct	-20.2 (-45.2, +5.3)

Daily Rainfall

Due to insufficient historical daily rainfall records, observed extreme rainfall trends have not been calculated.

3.4.3 Tropical Cyclones

The tropical cyclone archive for the Southern Hemisphere indicates that between the 1969/70 and 2010/11 seasons, seven tropical cyclones developed within or crossed the East Timor EEZ between the months of November and April. None of these tropical cyclones became severe events (Category 3 or higher) within the East Timor EEZ. The low numbers and intensities are due to East Timor's proximity to the equator and small EEZ. Refer to Chapter 1, Section 1.4.2 (Tropical Cyclones) for an explanation of the difference in the number of tropical cyclones occurring in East Timor in this report (Australian Bureau of Meteorology and CSIRO, 2014) compared to Australian Bureau of Meteorology and CSIRO (2011). Available data are not suitable for assessing long-term trends.

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 East Timor region can be found at www.bom.gov.au/cyclone/history/tracks/index.shtml

3.5 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 East Timor 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 East Timor, the most important model bias is in the simulated wind and rainfall in the WPM. Rainfall is too strong in the present climate, especially in the November–April season, but the size of this bias depends on which observed dataset is used. This affects the confidence in the model projections. Out of 27 models assessed, one model was rejected for use in these projections due to biases in the mean climate. Climate projections have been derived from up to 26 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 East Timor, but rather a range of possible futures for each emission scenario. This range is described below.

3.5.1 Temperature

Further warming is expected over East Timor (Figure 3.3 and Table 3.4). Under all RCPs, the warming is up to 1.1°C by 2030, relative to 1995, but after 2030 there is a growing difference in warming between each RCP. For example, in East Timor by 2090 a warming of 2.4 to 4.2°C is projected for RCP8.5 (very high emissions) while a warming of 0.5 to 1.2°C is projected for RCP2.6 (very low emissions) gives a warming of 0.4 to 1.2°C. 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 0.4°C greater over land than over ocean in this area.

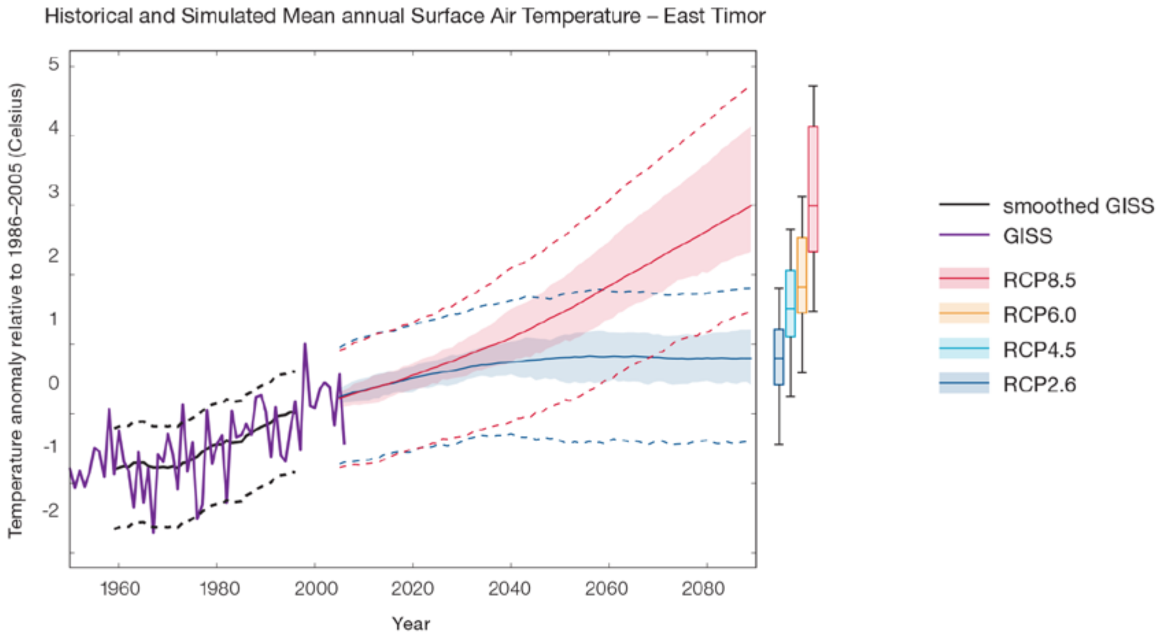

Figure 3.3: Historical and simulated surface air temperature time series for the region surrounding East Timor. The graph shows the anomaly (from the base period 1986–2005) in surface air temperature from observations (the GISS dataset, in purple), and for the CMIP5 models under the very high (RCP8.5, 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 *high confidence* in the model average temperature change shown in Table 3.4 because:

- The new models do a good job of simulating the rate of temperature change of the recent past; and
- There are no large model biases in sea-surface temperatures in the region.

3.5.2 Rainfall

The CMIP5 models show a range of projected rainfall change from an increase to a decrease, and the model average is near zero. The range is greater in the highest emissions scenarios (Figure 3.4, Table 3.4), and the pattern is similar for both dry season and wet season rainfall. There will still be wet and dry years and decades due to natural variability, and a wetter or drier future is possible in the long term. 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 rainfall changes may be greater over land than over ocean, and may be different on the north side of the island compared to the south side, including more rainfall on the north side than on the south side in May–October.

These results are different to those found in Australian Bureau of Meteorology and CSIRO (2011), which reported an increase in wet season and a decrease in dry season rainfall. The new model results and research into drivers of climate change have revealed more complesxity and a wider range of possible future climate than was found before.

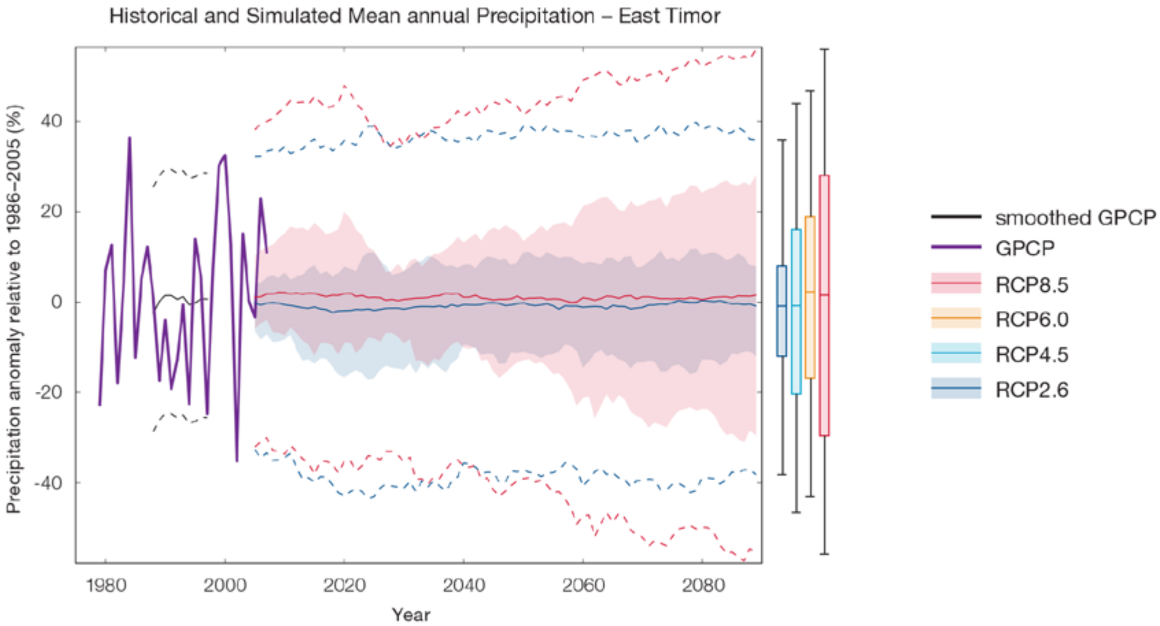

Figure 3.4: Historical and simulated annual average rainfall time series for the region surrounding East Timor. The graph shows the anomaly (from the base period 1986–2005) in rainfall from observations (the GPCP dataset, in purple), and for the CMIP5 models under the very high (RCP8.5, in red) and very 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.

There is no agreement in the direction of rainfall change in the models, and many models project little change in annual rainfall. 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 -8 to +8% by 2030 and -30 to +28% by 2090.

There is *medium confidence* that the long-term rainfall over East Timor will remain similar to the current climate because:

- The finding of little change is the average of a large number of models whose results range from a projected rainfall increase to a rainfall decrease, including many models that project little change; and
- Rainfall associated with the WPM is projected to generally increase, but the regional detail of change is uncertain. See Box in Chapter 1 for more details.

There is *low confidence* in the model average rainfall change for East Timor shown in Table 3.4 because:

- There is a large spread in model rainfall projections, which range from a projected rainfall increase to a rainfall 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;
- The new CMIP5 models broadly simulate the influence from the key features such as the WPM, but nevertheless have some uncertainty and biases, similar to the old CMIP3 models; and
- The future behaviour of the ENSO is unclear, and the ENSO strongly influences year-to-year rainfall variability.

3.5.3 Extremes

Extreme Temperature

The temperature of 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 0.7°C by 2030 under the RCP2.6 (very low) scenario and by 0.9°C under the RCP8.5 (very high emissions) scenario. By 2090 the projected increase is 0.9°C for RCP2.6 (very low) and 3°C for RCP8.5 (very high emissions).

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; 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 *medium 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 East Timor are currently unclear. Also, while all models project the same direction of change there is a 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 11 mm by 2030 for RCP2.6 and by 15 mm by 2030 for RCP8.5 (very high emissions). By 2090, it is projected to increase by approximately 18 mm for RCP2.6 and by 45 mm for RCP8.5 (very high emissions).The majority of models project the current 1-in-20-year daily rainfall event will become, on average, a 1-in-7-year event for RCP2.6 and a 1-in-5-year event for RCP8.5 (very high emissions) 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); and
- Increases in extreme rainfall in the Pacific are projected in all available climate models.

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

- Models generally underestimate the current intensity of local extreme events. The results in this region are influenced by the biases in the PM;
- 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 East Timor the overall proportion of time spent in drought is expected to decrease slightly under RCP8.5 and stay approximately the same under all other scenarios (Figure 3.5). Under RCP8.5 the frequency of moderate and severe drought is projected to decrease slightly while the frequency of events in other categories is projected to stay the same. The duration of events is projected to stay approximately the same in all categories under RCP8.5. Under RCP2.6 (very low emissions) the frequency and duration of events in all drought categories is projected to stay approximately the same from the present to 2090.

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

- There is only *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 frequency and duration 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.

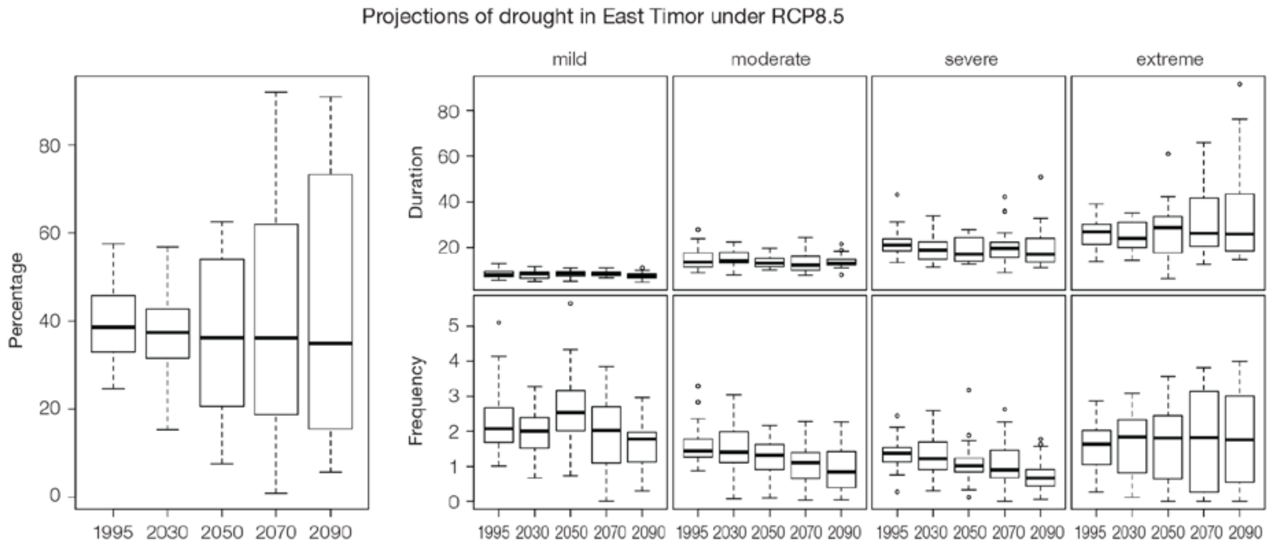

Figure 3.5: Box-plots showing percent of time in moderate, severe or extreme drought (left hand side), and average drought duration and frequency for the different categories of drought (mild, moderate, severe and extreme) for East Timor. These are shown for 20-year periods centred on 1995, 2030, 2050, 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.

3.5.4 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 East Timor, the aragonite saturation state has declined from about 4.5 in the late 18th century to an observed value of 4.0 by 2000. 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 3.6) 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.

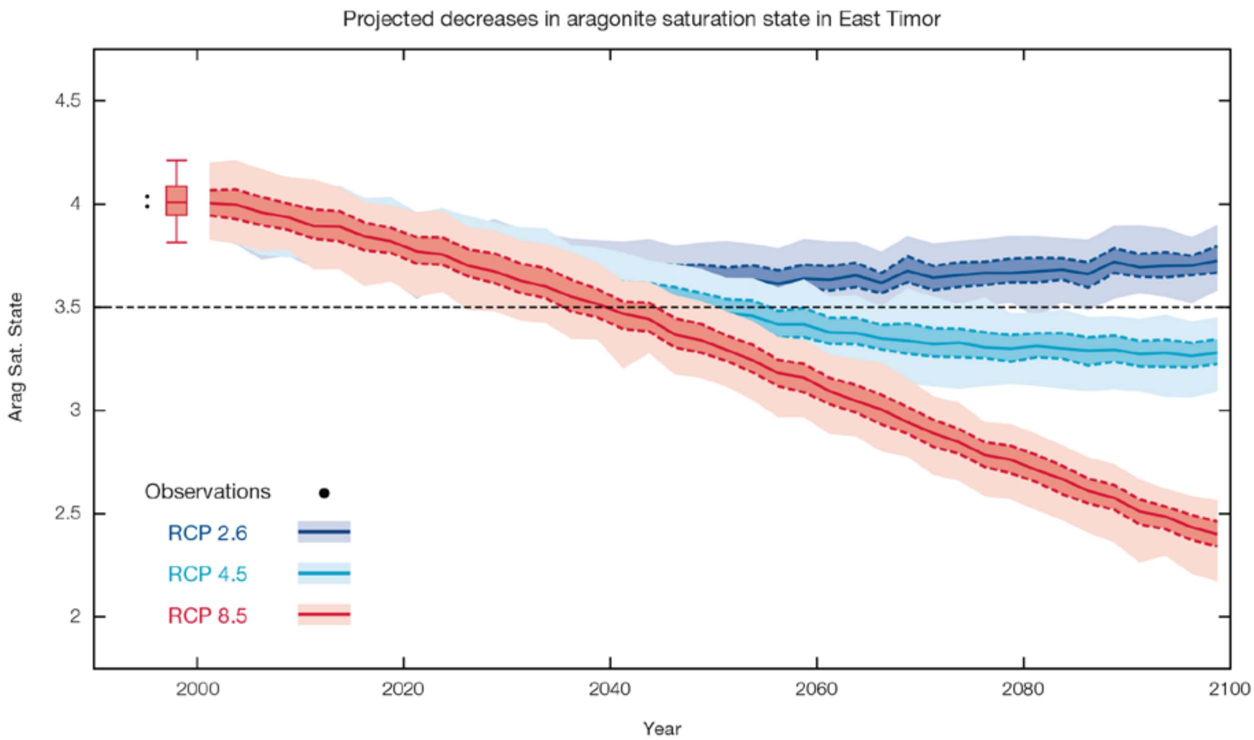

Figure 3.6: Projected decreases in aragonite saturation state in East Timor from CMIP5 models under RCP2.6, 4.5 and 8.5. Shown are the median values (solid lines), the interquartile range (dashed lines), and 5% and 95% percentiles (light shading). The horizontal line represents the transition to marginal conditions for coral reef health (from Guinotte et al., 2003).

Coral Bleaching Risk

As the oceans warm, the risk of coral bleaching increases (*very high confidence*). There is *medium confidence* in the projected rate of change for East Timor 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 3.3). 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 8.4 weeks (with a minimum duration of 3.0 weeks and a maximum duration of 3.1 months) and the average time between two risks will be 3.8 years (with the minimum recurrence of 7.8 months and a maximum recurrence of 10.7 years). If severe bleaching events occur more often than once every five years, the long-term viability of coral reef ecosystems becomes threatened.

We quantify the changes in the frequency (or recurrence) and duration of severe bleaching risk (Figure 3.6) for different projected SST changes (Table 3.3). For example, under a long-term mean increase of 1°C (relative to 1982–1999 period), the average severe bleaching risk event.

Table 3.3: Projected changes in severe coral bleaching risk for the East Timor 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	0	0
+0.25°C	0	0
+0.5°C	27.3 years (26.1 years – 28.5 years)	4.6 weeks (4.4 weeks – 4.8 weeks)
+0.75°C	13.6 years (8.2 years – 20.3 years)	6.3 weeks (4.6 weeks – 8.1 weeks)
+1°C	3.8 years (7.8 months – 10.7 years)	8.4 weeks (3.0 weeks – 3.1months)
+1.5°C	10.1 months (2.0 months – 2.3 years)	2.7 months (1.8 weeks – 5.3 months)
+2°C	6.1 months (1.2 months – 9.6 months)	4.7 months (2.4 weeks – 7.5 months)

[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

The impact of long-term ocean warming is a decrease of the time between two risk events and an increase in the period of the risk (Figure 3.6). If severe bleaching event occurs more often than once every five years, the long-term viability of coral reef ecosystems becomes threatened.

3.5.5 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 8–18 cm by 2030 (very similar values for different RCPs), with increases of 43–88 cm by 2090 under the RCP8.5 (Figure 3.7 and Table 3.4). 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 24 cm (5–95% range, after removal of the seasonal signal, see dashed lines in Fig. 3.7a) and it is likely that a similar range will continue through the 21st century.

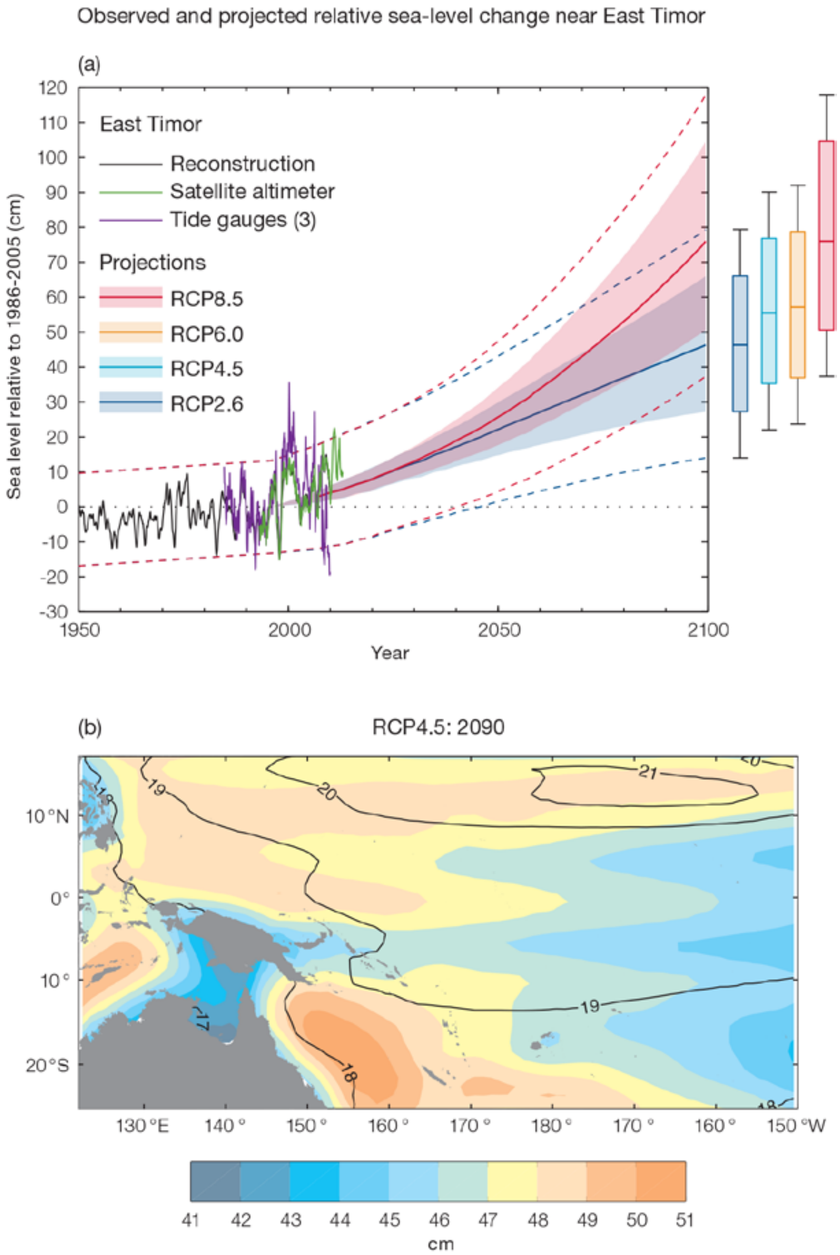

Figure 3.7 (a): The observed tide-gauge records of relative sea-level (since the late 1970s) are indicated in purple, and the satellite record (since 1993) in green. The gridded (reconstructed) sea level data at East Timor (since 1950) is shown in black. Multi-model mean projections from 1995–2100 are 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).

3.5.6 Wind-driven Waves

During December–March, the wet season in East Timor, there are no projected changes in wave properties (Figure 3.8, Table 3.5), except for a decrease in wave period in January, which is significant in 2035 under RCP4.5 and RCP8.5 (very high emissions), and in 2090 under RCP4.5 *(low confidence)*. This decrease is characteristic of an increase in the locally generated wind sea, or reduced swell. Wave direction is projected to be more variable in December–March (wet months) than June–September (dry months). There is a suggested decrease in the height of the larger waves *(low confidence)*.

In the dry season (represented here by June–September), there are no significant projected changes in wave properties *(low confidence)* (Table 3.5).

There is *low confidence* in projected changes in the East Timor wind-wave climate because:

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

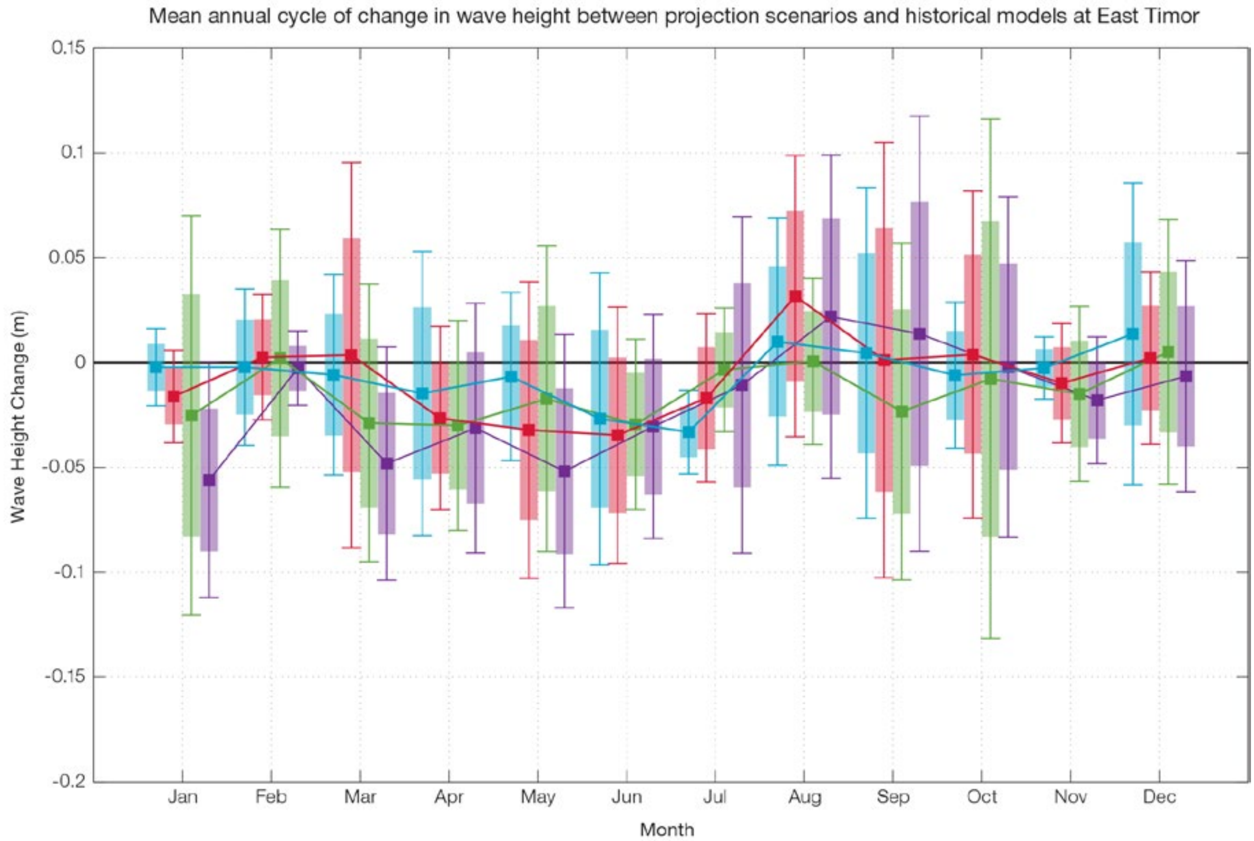

Figure 3.8: Mean annual cycle of change in wave height (m) between projection scenarios and historical models at East Timor. This plot shows no significant change in wave heights throughout the year. Shaded boxes show 1 standard deviation of models' means around the ensemble means, and error bars show 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).

3.5.7 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 *medium confidence* that mean rainfall and drought frequency will remain similar to the current climate.

Tables 3.4 and 3.5 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 3.4: Projected changes in the annual and seasonal mean climate for East Timor 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 (0.4–0.8)	0.8 (0.5–1.1)	0.8 (0.4–1.1)	0.8 (0.4–1.2)	*High*
		0.7 (0.4–1)	1.1 (0.8–1.5)	1.4 (0.9–1.9)	1.5 (1.1–2.1)	
		0.6 (0.4–1)	1 (0.7–1.5)	1.4 (1.1–1.9)	1.8 (1.5–2.6)	
		0.8 (0.5–1.1)	1.4 (1–2)	2.2 (1.7–3.1)	3 (2.4–4.2)	
Maximum temperature (°C)	1-in-20 year event	0.7 (0.4–1.1)	0.9 (0.4–1.1)	0.9 (0.4–1.2)	0.9 (0.4–1.4)	*Medium*
		0.7 (0–1.1)	1 (0.1–1.4)	1.3 (0.6–1.8)	1.5 (0.9–2)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.9 (0.3–1.2)	1.5 (0.4–2.2)	2.4 (1.2–3.3)	3.3 (1.9–4.3)	
Minimum temperature (°C)	1-in-20 year event	0.6 (0.2–0.9)	0.8 (0.3–1.2)	0.7 (0.3–1)	0.7 (0.1–1)	*Medium*
		0.6 (-0.2–0.9)	1 (0.4–1.3)	1.3 (0.4–1.6)	1.5 (0.6–2)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		0.8 (0.2–1.4)	1.6 (1–2.2)	2.4 (1.4–3.2)	3.2 (2.1–4.3)	
Total rainfall (%)	Annual	-1 (-15–6)	0 (-11–9)	-1 (-13–8)	-1 (-12–8)	*Low*
		0 (-15–11)	0 (-16–10)	-2 (-22–9)	-1 (-20–16)	
		1 (-11–8)	2 (-11–16)	1 (-9–11)	2 (-17–19)	
		0 (-8–8)	1 (-13–16)	1 (-25–21)	2 (-30–28)	
Total rainfall (%)	Nov-Apr	0 (-12–10)	1 (-7–8)	0 (-10–13)	1 (-8–12)	*Low*
		0 (-12–10)	1 (-16–9)	-1 (-16–9)	1 (-14–15)	
		2 (-5–10)	4 (-7–13)	3 (-7–13)	4 (-11–20)	
		1 (-12–10)	2 (-12–19)	2 (-19–20)	1 (-29–25)	
Total rainfall (%)	May-Oct	-4 (-24–14)	-3 (-28–11)	-4 (-22–19)	-5 (-25–14)	*Low*
		-1 (-23–32)	-1 (-27–24)	-5 (-34–20)	-4 (-31–24)	
		1 (-22–24)	1 (-23–26)	-2 (-18–17)	1 (-39–33)	
		0 (-19–29)	0 (-16–28)	-3 (-39–29)	2 (-60–54)	
Aragonite saturation state (Ωar)	Annual	-0.3 (-0.6–-0.1)	-0.4 (-0.6–-0.1)	-0.4 (-0.6–-0.1)	-0.3 (-0.6–-0.1)	*Medium*
		-0.3 (-0.5–-0.1	-0.5 (-0.7–-0.3)	-0.7 (-0.9–-0.5)	-0.7 (-0.9–-0.5)	
		NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	NA (NA–NA)	
		-0.4 (-0.6–-0.2)	-0.7 (-0.9–-0.5)	-1.1 (-1.2–-0.9)	-1.4 (-1.6–-1.3)	
Mean sea level (cm)	Annual	13 (8–17)	22 (15–30)	32 (21–45)	42 (26–59)	*Medium*
		13 (9–17)	23 (16–31)	36 (24–48)	49 (32–67)	
		12 (8–17)	23 (15–30)	35 (23–47)	50 (33–68)	
		13 (9–18)	26 (18–34)	43 (30–58)	64 (43–88)	

Waves Projections Summary

Table 3.5: Projected average changes in wave height, period and direction in East Timor for December–March and June–September for RCP4.5 (low emissions, in blue) and RCP8.5 (very high emissions, in red), over 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 (-0.2–0.2) 0.0 (-0.2–0.2)	0.0 (-0.2–0.2) -0.0 (-0.2–0.2)	*Low*
	June–September	0.0 (-0.4–0.5) 0.0 (-0.4–0.4)	0.0 (-0.4–0.5) 0.0 (-0.4–0.6)	*Low*
Wave period change (s)	December–March	-0.1(-1.0–0.9) -0.0 (-1.1–1.0)	-0.0 (-0.9–0.9) -0.0 (-1.1–1.0)	*Low*
	June–September	0.0 (-0.5–0.5) 0.0 (-0.5–0.5)	+0.0 (-0.5–0.7) +0.0 (-0.5–0.6)	*Low*
Wave direction change (° clockwise)	December–March	+0 (-40–50) 0 (-50–50)	0 (-40–40) -0 (-50–40)	*Low*
	June–September	0 (-10–10) 0 (-20–10)	0 (-20–20) -0 (-20–10)	*Low*

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