7 | Nauru

7.1 Summary

7.1.1 Climate

- There is little change in the seasonal cycle of air temperature through the year, and changes are strongly linked to changes in the surrounding ocean temperature. The Republic of Nauru wet season is between December and April and the dry season between May to November.
- The seasonal cycle of rainfall is strongly affected by both the Intertropical Convergence Zone (ITCZ) and the South Pacific Convergence Zone (SPCZ) as Nauru is located between the usual position of both zones of convection.
- Warming trends are evident in annual and seasonal air temperatures over the period 1979–2021. The number of hot days and warm nights has increased, while the number of cool days and cold nights has decreased. The energy required for cooling indoor environments has also increased.
- Annual and seasonal rainfall trends show little change.
- As the Nauru is located within a few degrees of the equator, tropical cyclones rarely form within or pass through Nauru waters.

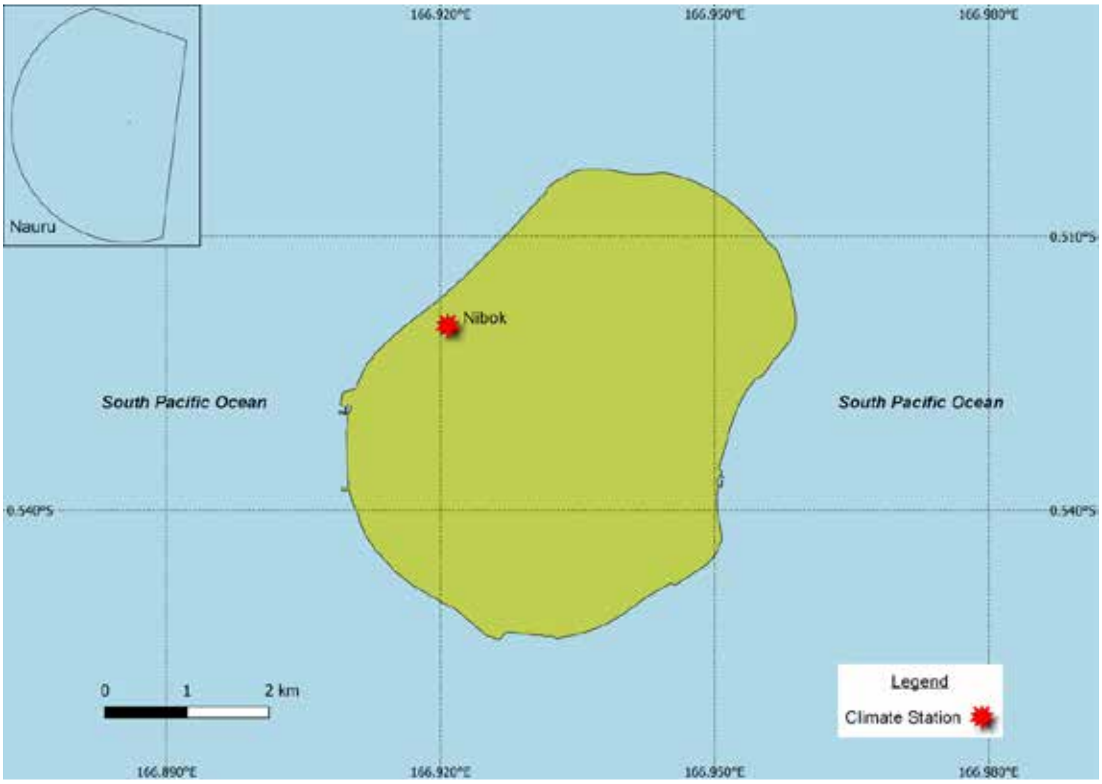
7.1.2 Ocean

- Highest sea levels typically occur in the months October–March.
- Sea-level rise at Nauru, measured by satellite altimeters from 1993 to mid-2020, ranges from 3.5 to 4.5 mm per year.
- Monthly average ocean temperature, as measured by the Nauru tide-gauge, ranges from 27.7 °C in February/March to 28.6 °C in July, with little difference between seasons. However, monthly temperatures in any given year can be ±4 °C of these averages due to variability from El Niño–Southern Oscillation (ENSO).
- The sea surface temperature (SST) trend across the Nauru exclusive economic zone (EEZ) is 0.22 °C per decade.
- Dominant wave direction is from 80° (east), with an average significant wave height of 1.31 m and average wave period of 10.54 s.
- Severe wave height was defined as 2.10 m, with an average of 3.4 severe events per year.
- Peak average wave activity in terms of significant wave height and period occurs from November to March.

7.2 Country description

Nauru is located in the equatorial Pacific Ocean, just south of the equator, between latitudes 0.5°S and 1°S, and longitudes 166.5°E and 167°E. Nauru is a single island country with a total land area of 21 km^2 and an EEZ of about 308,000 km^2. The capital of Nauru is Yaren, located on the west coast. The highest elevation is 65 m above sea level. Nauru has a population of approximately 10,000.

Figure 7.1:
Nauru and the location of the climate station used in this report



7.3 Data

Daily and monthly historical rainfall and air temperature records for Nauru from 1951 were obtained from The Bureau and Nauru Emergency Services Ministry. These records have undergone data quality and homogeneity assessment. While Nauru rainfall and temperature have been used to derive climatological information and rainfall trends in this report, there are insufficient maximum or minimum air temperature data to produce long-term trends. ERA5 reanalysis has been used to calculate temperature trends for 1979–2021 (further information is provided in Chapter 1). Additional information on historical climate trends for Nauru can be found in the Pacific Climate Change Data Portal http://www.bom.gov.au/climate/pccsp.

Tropical cyclone data and historical tracks starting from the 1969/70 season are available from the SHTC Data Portal http://www.bom.gov.au/cyclone/history/tracks/index.shtml.

SST covering the EEZ was obtained via the daily Optimum Interpolation SST version 2.1 (OISST v2.1) dataset from NOAA (Reynolds et al. 2007; Banzon et al. 2016). In situ ocean temperature data were obtained from the PSLGM Project tide-gauge located on Nauru, with data spanning from 1993 to 2021.

Wave data were obtained from the PACCSAP wave hindcast (Smith et al. 2021), available hourly from 1979 to present, with a grid resolution near Nauru of 7 km.

Regional sea level data were obtained from CSIRO satellite altimetry (updated by Benoit Legresy, Church and White 2011), with correction for seasonal signals, inverse barometer effect and glacial isostatic adjustment. Tide-gauge data were sourced from the Nauru tide-gauge station, spanning from 1993 to 2021 at hourly intervals.

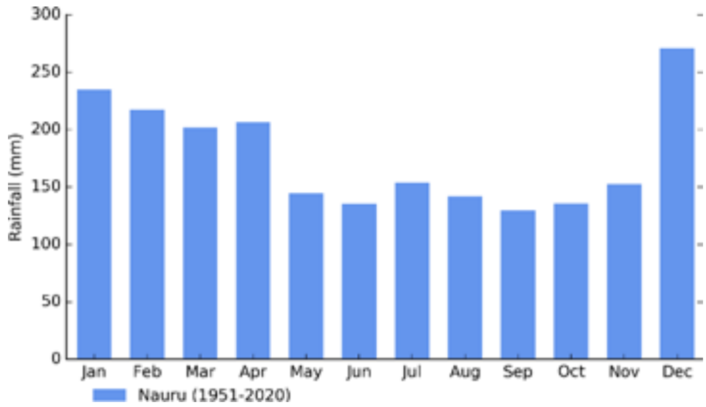
7.4 Rainfall

7.4.1 Seasonal cycle

Nauru's location on the edge of the Pacific Warm Pool leads to an average annual rainfall total of over 2100 mm. There is a distinct wet season between December and April with average monthly rainfall above 200 mm per month, and 60% of the annual rainfall occurs during this season (Figure 7.2). The wettest month of the year is December, which averages rainfall of 270 mm. In contrast, the driest month of the year is September, which averages 130 mm.

The highest rainfall during the year occurs when the ITCZ is furthest south and also when the SPCZ is at its strongest. Nauru is located between these two convergence zones, and this leads to a marked increase in rainfall at the end of the year.

Figure 7.2:
Mean annual rainfall at Nauru



7.4.2 Trends

Trends in annual and seasonal rainfall since 1951 are not statistically significant at Nauru (Figure 7.3, Table 7.1). Annual and seasonal rainfall trends indicate little change. Extremely large year-to-year variability associated with ENSO is evident, with El Niño years receiving significantly more rainfall than La Niña years. Annual rainfall since 1951 has varied from approximately 300 to 4400 mm. Limited daily precipitation is available for Nauru, so no trends in rainfall extremes have been calculated.

Figure 7.3:
Annual rainfall at Nauru. The straight line indicates the linear trend for annual rainfall (in black). The magnitude of this trend is presented in Table 7.1. Diamonds indicate years with insufficient data.

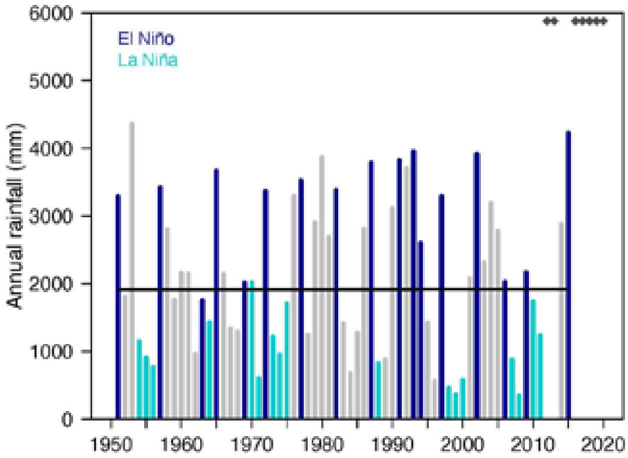


Table 7.1:
Trends in annual and seasonal rainfall at Nauru. The 95% confidence intervals are shown in parentheses, trends significant at the 95% level are shown in bold.

	Nauru
	1951–2015
Annual rainfall (mm/decade)	+1.52 (-198.67, +231.98)
November–April (mm/decade)	-58.33 (-179.3, +82.83)
May–October (mm/decade)	+19.81 (-36.57, +97.84)

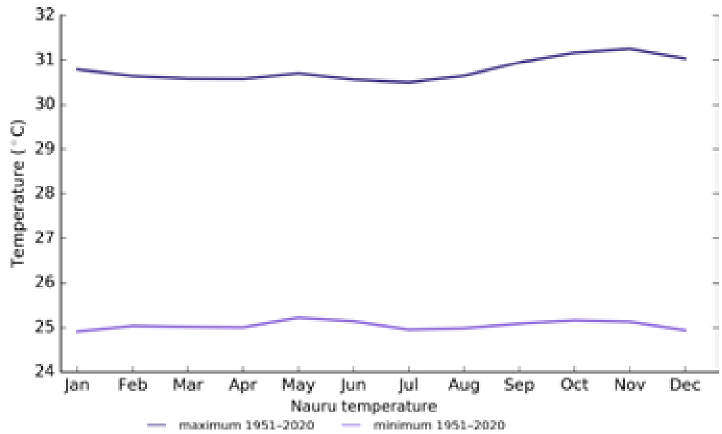
7.5 Air temperature

7.5.1 Seasonal cycle

Nauru has a hot and humid climate with highly consistent air temperatures throughout the year (Figure 7.4). There is a slight peak in maximum temperatures during November at the onset of the wet season. The average monthly minimum and maximum temperature range is less than 1 °C, with air temperatures very closely related to the surrounding SST due to Nauru's small size and low topography.

Note there is a large amount of missing air temperature observations from 1978 onwards.

Figure 7.4:
Maximum and minimum air temperature seasonal cycle for Nauru for the period 1951–2020.



7.5.2 Trends

Limited station temperature data for trend analysis is available for Nauru. Therefore, reanalysis data have been used to calculate temperature trends. Average annual and seasonal temperatures have increased since 1979 (Table 7.2). All temperature trends are statistically significant and there is little difference between minimum and maximum temperature trends or between seasons due to Nauru's tropical location.

Table 7.2:
Trends in annual and seasonal air temperatures at Nauru from ERA5 reanalysis data. A reanalysis is a global weather simulation merged with observations and represents the most complete picture of historical climate, but shares the same limitations as climate models. The 95% confidence intervals are shown in parentheses, and trends significant at the 95% level are shown in bold.

	Nauru-ERA5 Tmax (°C/decade)	Nauru-ERA5 Tmin (°C/decade)	Nauru-ERA5 Tmean (°C/decade)
	1979–2021		
Annual	**+0.19** (+0.07, +0.29)	**+0.17** (+0.12, +0.22)	**+0.16** (+0.09, +0.23)
November–April	**+0.21** (+0.08, +0.32)	**+0.19** (+0.12, +0.24)	**+0.19** (+0.11, +0.28)
May–October	**+0.17** (+0.08, +0.25)	**+0.18** (+0.11, +0.24)	**+0.17** (+0.10, +0.23)

The number of hot days and warm nights are increasing, and the number of cool days and cold nights are decreasing at Nauru (Table 7.3). The cooling degree days index provides a measure of the energy demand needed to cool a building down to 25 °C, with the assumption that air conditioners are generally turned on at this temperature. There has been an increase in the cooling degree index, suggesting the energy needed for cooling has increased significantly since 1979.

Table 7.3:
Trends in annual temperature extremes at Nauru from ERA5 reanalysis data. A reanalysis is a global weather simulation merged with observations and represents the most complete picture of historical climate but shares the same limitations as climate models. The 95% confidence intervals are shown in parentheses, and trends significant at the 95% level are shown in bold. Hot and cool days, and warm and cold nights are measured relative to 1981–2010 (see Chapter 1 for details).

	Nauru - ERA5
	1979–2021
Number of hot days (days/decade)	**+21.99** (+9.26, +35.01)
Number of warm nights (nights/decade)	**+12.90** (+7.93, +23.54)
Number of cool days (days/decade)	**-7.64** (-16.09, 1.13)
Number of cold nights (nights/decade)	**-12.93** (-16.58, 7.69)
Cooling degree days (degree days/decade)	**+55.11** (+31.15, +81.55)
Daily temperature range (°C/decade)	-0.02 (-0.12, +0.05)

7.6 Tropical cyclones

7.6.1 Seasonal cycle

No tropical cyclones passed within the EEZ between the 1969/70 and 2017/18 seasons.

7.6.2 Trends

Trends in total number of tropical cyclones (<995 hPa) and severe tropical cyclones (<970 hPa) are presented for the period 1981/82–2020/21 for the greater Southwest Pacific (135°E–120°W; 0–50°S). Trends are presented at a regional scale as the number of tropical cyclones occurring within Pacific Island EEZs is insufficient for reliable long-term trend analysis.

For the total number of tropical cyclones, the trend (and 95% confidence interval) is -0.92 (-1.85, 0.01) tropical cyclones/decade. There has been little change/marginal decline in the total number of tropical cyclones over the last 40 seasons. This trend is not statistically significant.

For the total number of severe tropical cyclones, the trend is -0.80 (-1.32, -0.29) tropical cyclones/decade. There is a negative trend in the number of severe tropical cyclones over the last 40 seasons. There has been little change/marginal decline in the proportion of tropical cyclones reaching severe status. The trend is -0.04 (-0.08, 0.00) tropical cyclones/decade. The negative trend is statistically significant.

Records of tropical cyclones exist from the late 1800s in some countries in the Southwest Pacific, but trends in tropical cyclones have only been presented from 1981/82. Satellite-based observations began in the Southwest Pacific in the early 1970s, but consistent coverage and reliable intensity estimates have only been available since the early 1980s. Confidence in tropical cyclone trends is moderate as the definition of a tropical cyclone has changed and satellite observation methods have continued to improve over the last 40 years.

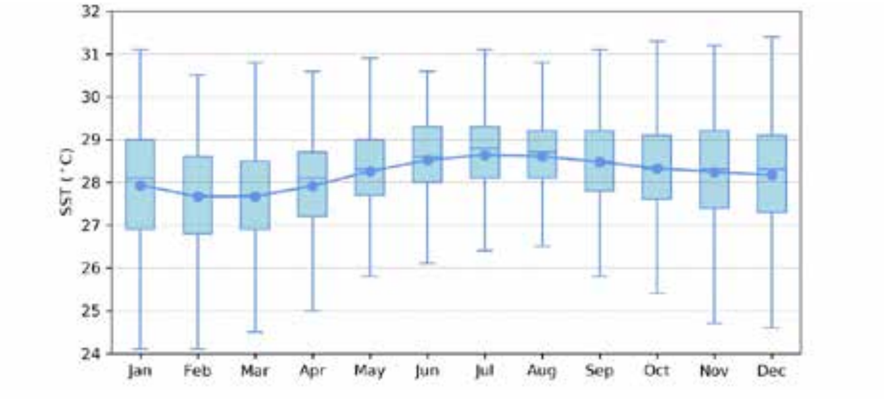
7.7 Sea surface temperature

7.7.1 Seasonal cycle

Ocean temperature, as measured by the Nauru tide-gauge, reaches on average a maximum of approximately 28.6 °C in July, but individual months can get as high as 31 °C (Figure 7.5). Minimum average temperature is 27.7 °C in February/March.

Temperatures can be up to 3 °C higher or 4 °C lower than these averages, although 50% of observations fall within 2 °C of the average. Equatorial locations typically have little average variation but can drastically change in a given year depending on the ENSO cycle. The variability in temperatures between October to March are reflective of peak months of ENSO.

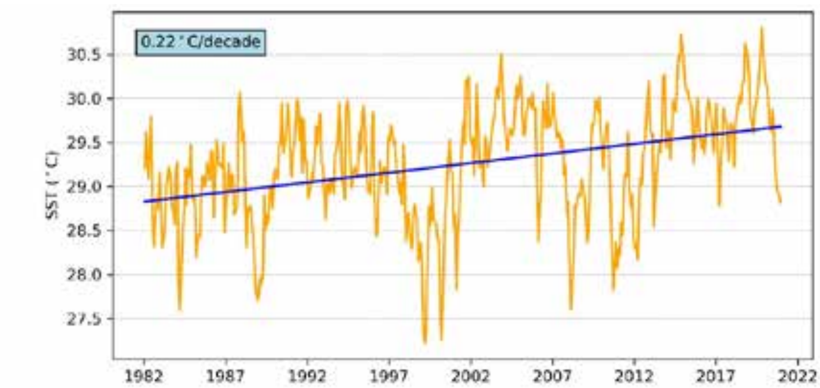
Figure 7.5:
Annual temperatures measured at the Nauru tide-gauge. Blue dots show the monthly average, and shaded boxes show the middle 50% of observations. Lines show the top and bottom 25% of observations.



7.7.2 Trends

Figure 7.6 shows the 1981–2021 SST from satellite observations averaged over the Nauru EEZ. The data show a trend of 0.22 °C per decade with a 95% confidence interval of ±0.05 °C.

Figure 7.6:
Sea surface temperature from satellite observations averaged across the Nauru EEZ, shown as the orange line. The blue line shows the linear regression trend.



7.8 Sea level

7.8.1 Seasonal cycle

Nauru experiences a semidiurnal tidal cycle, meaning two high and two low tides per day. During the last quarter moon, there is little difference between the high and low tides. The highest predicted tides of the year typically occur from November to February. Figure 7.7 shows the number of hours the 99th percentile (2.72 m) sea level threshold is exceeded per month across the entire sea level record at Nauru. Peak sea levels typically occur between October and March.

Figure 7.7:
Number of hours exceeding 99th percentile sea level threshold per month from 1993 to 2021 at the Nauru tide-gauge. Blue shading indicates the number of hours, and the final row provides a summary of all the years.

Number of hours exceeding 2.72 m (Aiwo, Nauru)

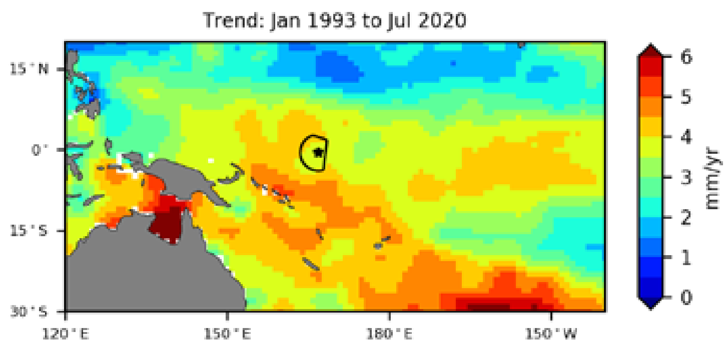
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1993	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	2	2
1995	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	1	0	0	0	0	0	0	0	0	0	0	0	1
1997	0	3	5	0	0	0	0	0	0	0	0	0	8
1998	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	11	11
2002	0	1	1	0	0	0	0	0	0	4	0	0	6
2003	0	0	0	0	0	0	0	0	0	1	5	0	6
2004	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	2	2	0	0	0	0	0	0	0	0	0	4
2006	0	0	0	0	0	0	0	1	1	3	1	0	6
2007	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	1	1	0	0	0	0	1	0	0	3
2013	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	10	11	23	3	0	0	0	0	2	5	0	4	58
2015	4	2	6	0	0	0	4	0	0	0	0	2	18
2016	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	1	1
2018	0	0	0	0	0	0	0	1	0	0	0	0	1
2019	2	1	0	0	0	0	0	3	3	0	6	0	15
2020	0	6	1	0	0	0	0	0	0	0	2	1	10
2021	0	1	0	2	0	0	0	0	0	0	2	2	7
Monthly Totals (%)	11	17	24	4	1	0	3	3	4	9	10	15	

7.8.2 Trends

Sea level at Nauru, measured by satellite altimeters (Figure 7.8) since 1993, has risen between 3.5 and 4.5 mm per year across the EEZ, with a confidence interval of ±0.6 to ±0.8 mm. These trend estimates are larger than the global average of 3.1 ± 0.4 mm per year (von Schuckmann et al. 2021). This rise is partly linked to a pattern related to climate variability from year to year and decade to decade.

Trend estimates at the Nauru tide-gauge over a similar time span to the altimetry observations (July 1993 to July 2020) are provided in the PSLGM Monthly Data Report for July 2020 (http://www.bom.gov.au/ntc/IDO60101/IDO60101.202007.pdf). For Nauru, the trend is reported as 5.5 mm per year, which is higher than the altimetry trends shown in Figure 7.8 (tide-gauge indicated by star symbol). This difference is most likely attributed to subsidence occurring at Nauru (Brown et al. 2020).

Figure 7.8:
Satellite altimetry annual trend for the Pacific from 1993 to 2020, with the Nauru EEZ highlighted. The star symbol indicates the location of the tide-gauge at Nauru.



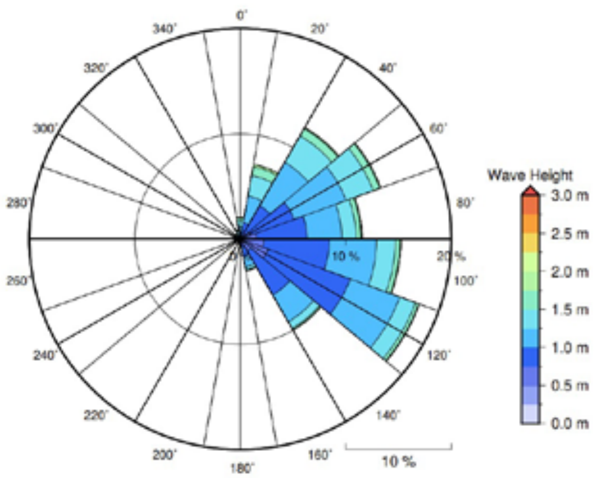
7.9 Waves

7.9.1 Seasonal cycle

The average wave climate at Nauru is defined by the significant wave height, peak period and peak direction. The significant wave height is the mean wave height (from trough to crest) of the highest one third of waves and corresponds to the wave height that would be reported by an experienced observer. Peak period is the time interval between two waves of the dominant wave period. Peak direction is the direction from which the dominant waves are coming.

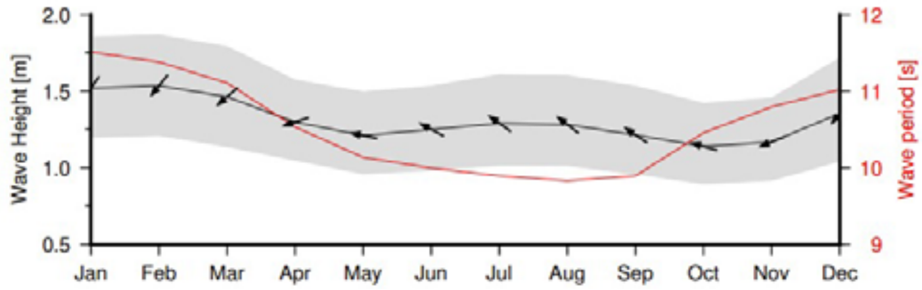
The average sea state is dominated by wind seas from the east. The annual mean wave height is 1.31 m, the annual mean wave direction is 80° and the annual mean wave period is 10.54 s. In the Pacific, waves often come from multiple directions and for different periods at a time. In Nauru, there are often more than eight different wave direction/period components coming from the southeast to southwest (Figure 7.9).

Figure 7.9:
Annual wave rose for Nauru. Note that direction is where the wave is coming from.



Seasonal wave activity peaks between November and March in terms of both wave height and period (Figure 7.10) due to North Pacific extra-tropical storm activity.

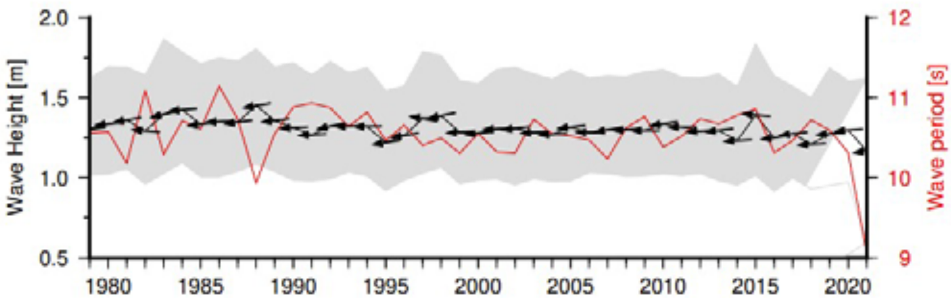
Figure 7.10:
Monthly wave height (black line), wave period (red line) and wave direction (arrows). The grey area represents the range of wave height between calm periods (10% of lowest wave height) and large wave events (10% of highest wave height).



7.9.2 Trends

Waves change from month to month with the seasons, but they also change from year to year with climate oscillations. Typically, these changes are smaller than the seasonal changes but can be important during phenomena such as ENSO. At Nauru, the mean annual wave height has remained unchanged since 1979 (Figure 7.11). The mean annual wave height in Nauru is not significantly correlated with the main climate indicators of the region.

Figure 7.11:
Annual wave height (black line), wave period (red line) and wave direction (arrows). The grey area represents the range of wave height between calm periods (10% of lowest wave height) and large wave events (10% of highest wave height).



7.9.3 Extreme waves

Extreme wave analysis for Nauru was done by defining a severe height threshold and fitting a generalized Pareto distribution (GPD). The optimum threshold selected was 2.10 m. In the 42-year wave hindcast, 142 wave events reached or exceeded this threshold, averaging 3.4 per year. The GPD was fitted to the largest wave height reached during each of these events (Figure 7.12, Table 7.3). Extreme wave analysis is a very useful tool but is not always accurate because the analysis is very sensitive to the data available, the type of distribution fitted and the threshold used. For example, this analysis does not accurately account for tropical cyclone waves. More in-depth analysis is required to obtain results appropriate for designing coastal infrastructure and coastal hazard planning.

Figure 7.12:
Extreme wave distribution for Nauru. The crosses represent the wave events that have occurred since 1979. The solid line is the statistical distribution that best fits past wave events. The dashed lines show the upper and lower confidence limits of the fit. There is a 95% chance that the fitted distribution lies between the two dashed lines. Note that the annual return interval is in logarithmic scale.

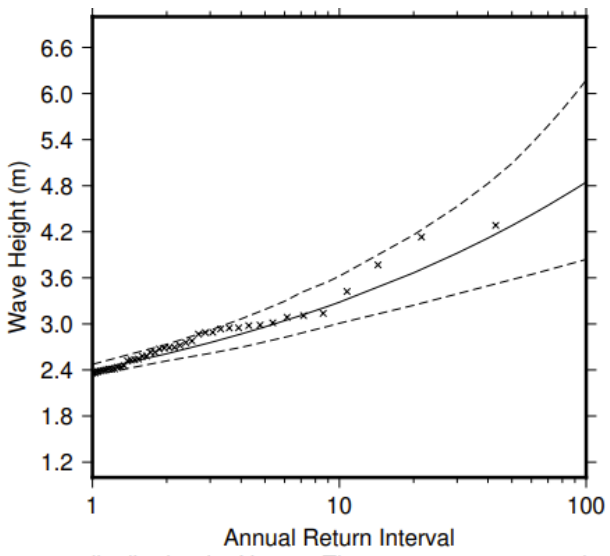


Table 7.3
Summary of the results from extreme wave analysis in Nauru

Large wave height (90th percentile)	1.67 m
Severe wave height (99th percentile)	2.12 m
1-year ARI wave height	2.39 m
10-year ARI wave height	3.28 m
20-year ARI wave height	3.66 m
50-year ARI wave height	4.28 m
100-year ARI wave height	4.85 m