1 Introduction to the country reports

1.1 Summary

Climate and ocean summaries presented at the beginning of each country chapter provide an overview of the climate and ocean observations for the relevant country.

1.2 Country description

The country description provides brief details for the relevant country. This includes location in the Pacific region, island type, land area, exclusive economic zone (EEZ) size, number of islands, provinces/administrative divisions, primary sources of foreign exchange and current population.

1.3 Data

This section provides details on the meteorological and oceanographic data used in this report.

Meteorological data length, completeness and quality differs from country to country. Where data are available, the analysis start date is 1 January 1951. While some station records have data for a much longer period, 1951 was selected as the start year, as the formalisation of meteorological operations for most Pacific countries and territories began during or just after the Second World War. A rapid increase in station numbers occurred in the late 1940s with a peak occurring around the early 1950s, which is the second reason for selecting 1951. For many observation sites there have been changes in station position, instrumentation and local environment that have produced inhomogeneities resulting in non-climatic step-changes in the data. For rainfall, only records or parts of records that have passed homogeneity tests are used in this report. For temperature, where possible, inhomogeneities have been identified and corrected using statistical techniques. Details on the quality control and homogenisation procedures for temperature and rainfall are presented in McGree et al. (2019). The raw and homogenised meteorological data used in this report is archived in the Pacific Climate Change Data Portal http://www.bom.gov.au/climate/pccsp.

Insufficient station daily rainfall and temperature data for Nauru and temperature data for Tokelau were available for this report. For both these countries it was determined that the European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis version 5 (ERA5) (Hersbach et al. 2020) was suitable for calculating temperature trends. Reanalysis products combine a global weather model with global ocean, land and atmospheric observations, and offer the most complete picture of historical climate. However, they also share the same limitations as models. ERA5 is a state-of-the-art reanalysis dataset providing global data at a resolution of approximately 30 km. Comparison with station data for a Pacific Island showed that ERA5 captures temperature trends well. Furthermore, temperatures do not typically vary by large amounts over small distances, particularly in oceanic environments, so grid cell temperatures from ERA5 are likely to be representative of any islands contained within them. Therefore, there is high confidence that trends from the ERA5 reanalysis are representative of station trends for small Pacific Islands.

Tropical cyclone data were provided by the Australian Tropical Cyclone Warning Centres (Brisbane, Darwin and Perth) for the Australian region (90–160°E) and by the meteorological services of Fiji and New Zealand for the eastern South Pacific Ocean (east of 160°E). Tropical cyclone tracks from these archives were merged into one archive, ensuring consistency of track data when tropical cyclones cross regional borders. For the Northwest Pacific, data were obtained from the Regional Specialised Meteorological Centre, Tokyo. These data are archived in the SHTC Data Portal http://www.bom.gov.au/cyclone/history/tracks/index.shtml and Western North Pacific Tropical Cyclone Data Portal http://www.bom.gov.au/cyclone/history/tracks/beta/?region=wnp.

Sea surface temperature (SST) data were obtained via the daily Optimum Interpolation SST version 2.1 (OISST v2.1) dataset from the National Oceanic and Atmospheric Administration (NOAA) (Reynolds et al. 2007; Banzon et al. 2016). In situ ocean temperature and sea level data were obtained from the COSPPac PSLGM project http://www.bom.gov.au/pacific/projects/pslm and are also available via the Pacific Ocean Portal http://oceanportal.spc.int/portal/ocean.html.

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

Regional sea level data were obtained from the Commonwealth Scientific and Industrial Research Organisation (CSIRO) satellite altimetry (updated by Benoit Legresy, Church and White 2011), with correction for seasonal signals, inverse barometer effect and glacial isostatic adjustment. In situ sea level data were obtained from local tide-gauges where available.

1.4 Rainfall

1.4.1 Seasonal cycle

Rainfall climatology for the selected locations is presented in this section. Influences of the main climate drivers and orography are also presented.

1.4.2 Trends

Where gaps in the daily timeseries exist and monthly values were available, these were used to extend and fill gaps in the monthly total timeseries (subject to passing quality control and homogeneity checks). Seasonal and annual totals are only presented where each month of the season/year is available. Trends in total rainfall have been calculated from monthly data.

Graphs in this section as well as the section on tropical cyclones are colour coded to differentiate El Niño, La Niña and El Niño–Southern Oscillation (ENSO) neutral years. These years are defined using the The Bureau official ENSO record http://www.bom.gov.au/climate/history/enso. Since this record ends in 2016, the status for subsequent years was obtained from the ENSO Outlook alert system http://www.bom.gov.au/climate/enso/outlook/#tabs=ENSO-Outlook-history.

The influence of ENSO on the climate of the partner countries is not always clear. This is because: (1) these events often start in the middle of one year and continue into the next; (2) the impact of ENSO on local rainfall and air temperature is not always simultaneous (that is, there can be a lag of a few months between ENSO development and impact at some locations); and (3) in some countries, ENSO does not have a major influence.

Eleven climate indices are used to characterise trends in annual and seasonal rainfall and temperature extremes. These indices are defined in Table 1.1 and are recommended by the World Meteorological Organization (WMO) Expert Team on Climate Information for Decision-Making (ET-CID) and calculated from daily data using Climpact software (University of New South Wales 2022). To maintain statistical robustness, any months with more than three missing days of data were not computed, and any years with more than 15 missing days were also not computed. Further, linear trends were not computed when there were insufficient years or months in the timeseries. Some temperature and rainfall indices involve a comparison of each year to a baseline period. This baseline period is 1961–1990 for station observations and 1981–2010 for reanalysis data, which was used in the case of Nauru, Samoa and Tokelau (see Section 1.3).

Table 1.1:
Temperature and rainfall extremes indices used in the following chapters. All indices are calculated yearly except for the standardised rainfall evapotranspiration index.

Variable	Index	Definition	Units
Rainfall	Number of wet days	The number of days each year with rainfall of at least 1 mm	Days
	Contribution to total rainfall from extreme events	The percentage of total annual wet day rainfall that occurs on days with rainfall above the 95th percentile for 1961–1990*	%
	Consecutive dry days	The longest stretch of consecutive days without rain	Days
	Maximum 1-day rainfall	The maximum rain that falls on a single day	mm
Temperature	Number of hot days	The number of days with maximum temperatures above the 90th percentile for 1961–1990*	Days
	Number of cool days	The number of days with maximum temperatures below the 10th percentile for 1961–1990*	Days
	Number of warm nights	The number of days with minimum temperatures above the 90th percentile for 1961–1990*	Nights
	Number of cold nights	The number of days with minimum temperatures below the 10th percentile for 1961–1990*	Nights
	Cooling degree days	The difference between daily mean temperature and 25 °C, summed over the entire year, with the assumption that air conditioners are generally turned on at this temperature. If daily mean temperature is below 25 °C, a value of zero is used for the corresponding day	Degree days
	Daily temperature range	The average difference between daily maximum and minimum temperatures	°C
Mixed	Standardised rainfall evapotranspiration index (SPEI)	SPEI is a drought index that uses both temperature and rainfall data, and can be calculated on a range of timescales from 1–48 months. It can be used for determining the onset, duration and magnitude of drought conditions with respect to normal conditions in a variety of natural and managed systems, such as crops, ecosystems, rivers, water resources, etc. The May–October and November–April periods are presented in this study. Negative values indicate drier conditions compared to 1961–1990*	Unitless

*This base period is 1981–2010 when using ERA5 reanalysis data for Nauru, Samoa and Tokelau.

Sen's slope was used to represent linear trends in annual, seasonal and extreme rainfall and temperature (Sen 1968). This method of linear trend analysis minimises the effect of outliers. Statistical significance of trends was determined using the Mann–Kendall test at a 95% significance level. Prewhitening of each timeseries using 'Zhang's method' (Bronaugh and Werner 2019) was conducted prior to trend analysis to remove the effect of autocorrelation. For statistical robustness, only station records with at least 20 valid data points and that are at least 70% complete after prewhitening have trends calculated.

1.5 Air temperature

1.5.1 Seasonal cycle

Air temperature climatology for the selected locations is presented in this section. Where possible, the long-term average is presented for the current WMO Normal period (1991–2020), which is compared with the long-term average for 1961–1990, the reference period for climate change assessment recommended by WMO at present.

1.5.2 Trends

This section provides revised and updated analyses of observed trends for mean and extreme annual and seasonal maximum and minimum temperatures. Methodological information is provided in Section 1.4.2.

1.6 Tropical cyclones

1.6.1 Seasonal cycle

This section provides the number of tropical cyclones that developed within or crossed a country or territory EEZ between the 1969/70 and 2017/18 seasons in the southern hemisphere, and 1969–2018 seasons in the northern hemisphere. Year-to-year changes in tropical cyclone occurrence are characterised by ENSO phases.

A graph with annual occurrences and an 11-year running mean shows the interannual and interdecadal behaviour of tropical cyclones. For most countries, the interannual variability in the number of tropical cyclones is large. For some, especially those close to the equator, only a small number of tropical cyclones occur within the EEZ boundary. Statistical analysis of such small numbers of tropical cyclone occurrences at a national scale cannot provide reliable estimates of long-term trends in tropical cyclone frequency and intensity (Kuleshov et al. 2010), and this information is therefore not presented in this report.

Some analysed tropical cyclone tracks include the tropical depression stage (sustained winds ≤34 knots) before and/or after tropical cyclone formation. For an event to be counted, it must become a 'tropical cyclone' within the respective country EEZ.

1.6.2 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 western North Pacific (125°E–180°W; 0–20°N) and Southwest Pacific (135°E–120°W; 0–50°S). In this report, 995 hPa and 970 hPa thresholds were used to define a tropical cyclone and a severe tropical cyclone, respectively, based on central pressure estimates as recommended in the literature (Nicholls et al. 1998; Kuleshov et al. 2010).

Records of tropical cyclones exist from the late 1800s in some countries. Satellite-based observations began in the Southwest Pacific in the early 1970s, with consistent coverage and reliable intensity estimates only 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. The trend is calculated using linear least-squares regression with a 95% confidence interval.

1.7 Sea surface temperature

1.7.1 Seasonal cycle

SST climatology for available in situ tide-gauges in the respective country or territory is presented in this section. Statistics are derived from hourly data over monthly timescales. In the absence of in situ data, daily satellite SST is used at the grid cell nearest to the country capital with a resolution of approximately 27 km and averaged monthly.

1.7.2 Trends

SST trends from satellite observations are provided for the country or territory EEZ from 1981 to 2021. The data temporal interval is daily and averaged across all grid cells in the EEZ prior to trend calculation. Grid cell spatial resolution is approximately 27 km. The trend is calculated using linear least-squares regression with a 95% confidence interval.

1.8 Sea level

1.8.1 Seasonal cycle

Sea level exceedance of the 99th percentile on a monthly basis is presented in this section for available tide-gauges in the respective country or territory. The 99th percentile threshold is calculated across all months and years. Exceedance values are presented as hours of exceedance split into years and a percentage of total hours exceedance for all years available.

1.8.2 Trends

Sea level trends from satellite altimeters are provided for the country or territory EEZ from 1993 to 2020 in the form of a thematic map and compared with the global average trend and tide-gauge trends (where available). Temporal interval of data is monthly and spatial resolution is 1° (approximately 110 km in the tropics). The trend is calculated using linear least-squares regression with a 95% confidence interval.

1.9 Waves

1.9.1 Seasonal cycle

The average wave climate for key locations in each country or territory 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 wave is coming. Annual wave roses categorise the directional wave data into 20° bins. Seasonal averages are presented monthly for wave height, peak period and direction.

1.9.2 Trends

Trends in wave height and period are presented for key locations in each country from 1979 to 2021 in the form of a timeseries plot to assess whether a trend can be observed.

1.9.3 Extreme waves

Extreme wave return periods are estimated by fitting a generalized Pareto distribution to the wave height data, which can then be used to calculate the average return (recurrence) interval (ARI) for 1-, 10-, 20-, 50- and 100-year return periods.