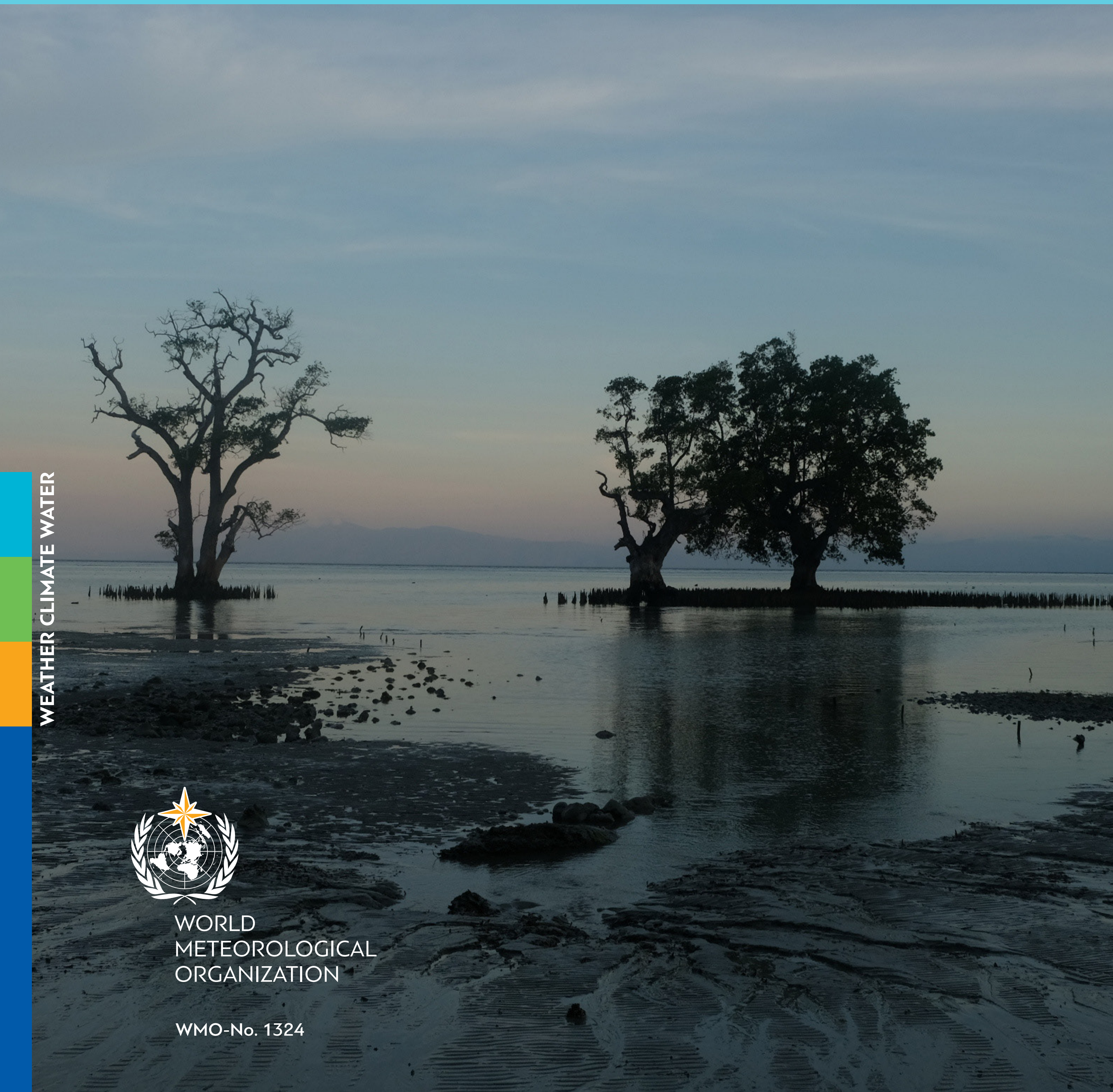
State of the Climate in the South-West Pacific

2022



WEATHER CLIMATE WATER

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Contents

Key messages

The moderate La Niña event contributed to significant rainfall anomalies, namely particularly dry conditions in much of the equatorial Pacific, including Kiribati, Tuvalu, Nauru, Tokelau (some locations received totals more than 80% below the long-term average), and wet conditions over the Maritime Continent[1] and eastern Australia.

The year 2022 was still a warm year for the region, despite temporary cooling associated with the La Niña event. The mean temperature over the South-West Pacific region was 0.13 °C [0.05 °C–0.15 °C] above the 1991–2020 average, and 0.46 °C [0.27 °C–0.52 °C] above the average for the WMO 1961–1990 reference period. Although lower than the temperatures over the 2015 to 2020 period just prior to the multi-year La Niña event, average temperatures in 2022 were 0.2 °C to 0.3 °C higher than during the last strong La Niña event in 2011, and the year still ranks within the top ten warmest years for the region.

Marine heatwaves occurred in various parts of the region. The most prominent and persistent marine heatwaves occurred in a large area north-east of Australia and south of Papua New Guinea in the Solomon and Coral Seas, over a period of more than six months.

Sea-level rise rates were, in general, slightly higher than the global mean rate, reaching approximately 4 mm per year in several areas, except in southern Australia and part of the equatorial Pacific.

In Indonesia, measurements of glacier ice thickness show a reduction of 24 m from June 2010 to the beginning of 2021, and the estimated remaining ice thickness in December 2022 was just 6 m.

The South-West Pacific region is prone to disasters, especially storms and floods. Overall, more than 8 million people were directly affected by these hazards in 2022, leading to total economic damage of close to US$ 9 billion.

Flooding was experienced in eastern Australia. The most severe floods were in late February and early March. Significant loss of lives and economic impacts of the order of US$ 6.6 billion were reported in association with these severe floods.

The Philippines experienced a number of significant tropical cyclone landfalls during the year. The two most significant storms were *Megi* in April and *Nalgae* in October. Both caused significant loss of life and socioeconomic damage, particularly to the agricultural sector.

Comparing the reported economic loss from disasters in 2022 to the average over the past 20 years (2002–2021), economic loss from floods in 2022 was more than 4 times the 2002–2021 average, but damage from storms was less than 10% of the 2002–2021 average.

Enhancing the resilience of food systems is a high priority in the South-West Pacific region, as was emphasized in the nationally determined contributions (NDCs) of most of WMO Members in the region. Monitoring the past and current climate and providing forecasts on weather and climate timescales are fundamental activities underpinning effective early warning services for agriculture and food security.

Foreword

Following last year's successful publication of the WMO report on the *State of the Climate in the South-West Pacific 2021* (WMO-No. 1302), I am pleased to see the timely publication of this third edition in the series. This third report has involved National Meteorological and Hydrological Services (NMHSs) and several research institutions, as well as an increased number of contributing United Nations agencies and international and regional organizations.

The report summarizes the state of the climate, extreme events and their socioeconomic impacts in the South-West Pacific in 2022. Despite temporary cooling associated with the La Niña event, the year 2022 was still a warm year for the region. The mean temperature in 2022 was 0.2 °C to 0.3 °C higher than during the last strong La Niña event in 2011, and the year still ranks within the top ten warmest years for the region. Ocean heat content, sea level, ice thickness and extreme events are also assessed and described, along with the most recent data and analyses, and trends and impacts of concern in the region are identified.

The La Niña condition during 2022 contributed to significant rainfall anomalies in the region. Most of the equatorial Pacific islands experienced drier-than-normal conditions, and Kiribati and Tuvalu suffered from significant water shortages at times during the year. At the other extreme, Australia suffered significant economic loss in association with severe floods.

Early warning is one of the most effective ways of reducing damage from disasters, as it empowers people to make risk-informed decisions for food security, as well as other sectors. Despite continuous efforts to strengthen multi-hazard early warning systems, the present report clearly shows that there are still significant gaps to be addressed to strengthen these systems to reduce the adverse impacts of hydrometeorological hazards in the region.

WMO and the United Nations Office for Disaster Risk Reduction (UNDRR) are co-leading the Early Warnings for All initiative, and its Executive Action Plan was launched by United Nations Secretary-General António Guterres at the twenty-seventh session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP27) last year. To ensure the mainstreaming of this initiative in the region, the WMO Regional Conference of Regional Association V (South-West Pacific) held in September 2022 recommended that consideration be given to establishing a Special Task Group to analyse the current status and critical gaps regarding early warning systems and develop an initial action plan for the Regional Association to move forward.

I take this opportunity to congratulate the experts from the region and around the world for leading the scientific coordination and authorship of this report and thank WMO Members and sister United Nations agencies for their continuous commitment to supporting this publication, through providing input and contributing to the report review process.

Prof. Petteri Taalas
Secretary-General, WMO

Preface

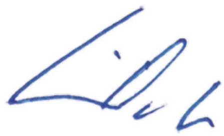
The year 2022 marked another year characterized by climate change impacts of increasing intensity which cascaded with and compounded a series of disasters. The devasting impacts of Tropical Storms *Megi* and *Nalgae* experienced by the Philippines are but two examples.

Compared to 2021, the number of reported disaster events decreased; however, economic losses increased. Economic damage due to flooding was US$ 8.5 billion, almost triple compared to the previous year, with most of the damage attributable to a series of flooding events in Australia, especially in New South Wales. Evacuations and disruption of power for many hampered rescue efforts and access to basic amenities. Likewise, storm events were considered to be responsible for over 70% of disaster fatalities reported in the region, and most can be linked to the two storms experienced by the Philippines.

These impacts raise the urgency of implementing transformative adaptation if development gains are to be protected and sustainable development achieved. In this regard, food system resilience is fundamental to protecting both lives and livelihoods, especially for the most at-risk populations. This report emphasizes that the agriculture sector is one of the most critical sectors affected by climate-related disasters, echoing the national adaptation plans of many countries in the South-West Pacific. Impact-based forecasting and early warnings for all that lead to anticipatory actions are examples of the transformative adaptation needed to strengthen the resilience of food systems and food security in the South-West Pacific. Investments in data-driven observations and forecasting, supported by regional policy coordination and regional cooperation through the exchange of cross-sectoral expertise, are critical.

The Early Warnings for All Executive Action Plan, launched by the United Nations Secretary-General and co-led in implementation by WMO and UNDRR at the global level, is critical in the Pacific, which is characterized by distinct disaster risk hotspots that are intensifying and expanding as climate-related hydrometeorological disasters intensify. Working through a network of partnerships that includes the lead United Nations organizations at the global level, the ESCAP secretariat stands ready to mobilize and facilitate the necessary regional implementation.

In this context, the *State of the Climate in the South-West Pacific 2022* is timely, as it presents the important climate indicators showing change over time as well as the impacts and measures needed to make risk-informed decisions. ESCAP and WMO, working in partnership, will continue to invest in raising climate ambition and accelerating the implementation of policy actions, which includes bringing early warnings to all in the region so that no one is left behind as our climate change crisis continues to evolve.



Armida Salsiah Alisjahbana
Under-Secretary-General of the United Nations and Executive Secretary of ESCAP

Global climate context

The global annual mean near-surface temperature in 2022 was 1.15 °C [1.02 °C to 1.28 °C] above the 1850–1900 pre-industrial average. The year 2022 was either the fifth or the sixth warmest year on record according to six data sets,[2] despite the cooling effect of La Niña. The years 2015 to 2022 are the eight warmest years on record in all data sets.[3]

Atmospheric concentrations of the three major greenhouse gases reached new record observed highs in 2021, the latest year for which consolidated global figures are available, with levels of carbon dioxide (CO_2) at 415.7 ± 0.2 parts per million (ppm), methane (CH_4) at 1 908 ± 2 parts per billion (ppb) and nitrous oxide (N_2O) at 334.5 ± 0.1 ppb – respectively 149%, 262% and 124% of pre-industrial (before 1750) levels (Figure 1). Real-time data from specific locations, including Mauna Loa[4] (Hawaii, United States of America) and Kennaook/Cape Grim[5] (Tasmania, Australia) indicate that levels of CO_2, CH_4 and N_2O continued to increase in 2022.

Over the past two decades, the ocean warming rate has increased, and the ocean heat content in 2022 was the highest on record. Ocean warming and accelerated loss of ice mass from the ice sheets contributed to the rise of the global mean sea level by 4.62 mm per year between 2013 and 2022, reaching a new record high in 2022. Between 1960 and 2021, the ocean absorbed about 25% of annual anthropogenic emissions of CO_2 into the atmosphere,[6] and CO_2 reacts with seawater and lowers its pH. The limited number of long-term observations in the open ocean have shown a decline in pH, with a reduction of the average global surface ocean pH of 0.017–0.027 pH units per decade since the late 1980s. This process, known as ocean acidification, affects many organisms and ecosystem services,[7] and threatens food security by endangering fisheries and aquaculture.

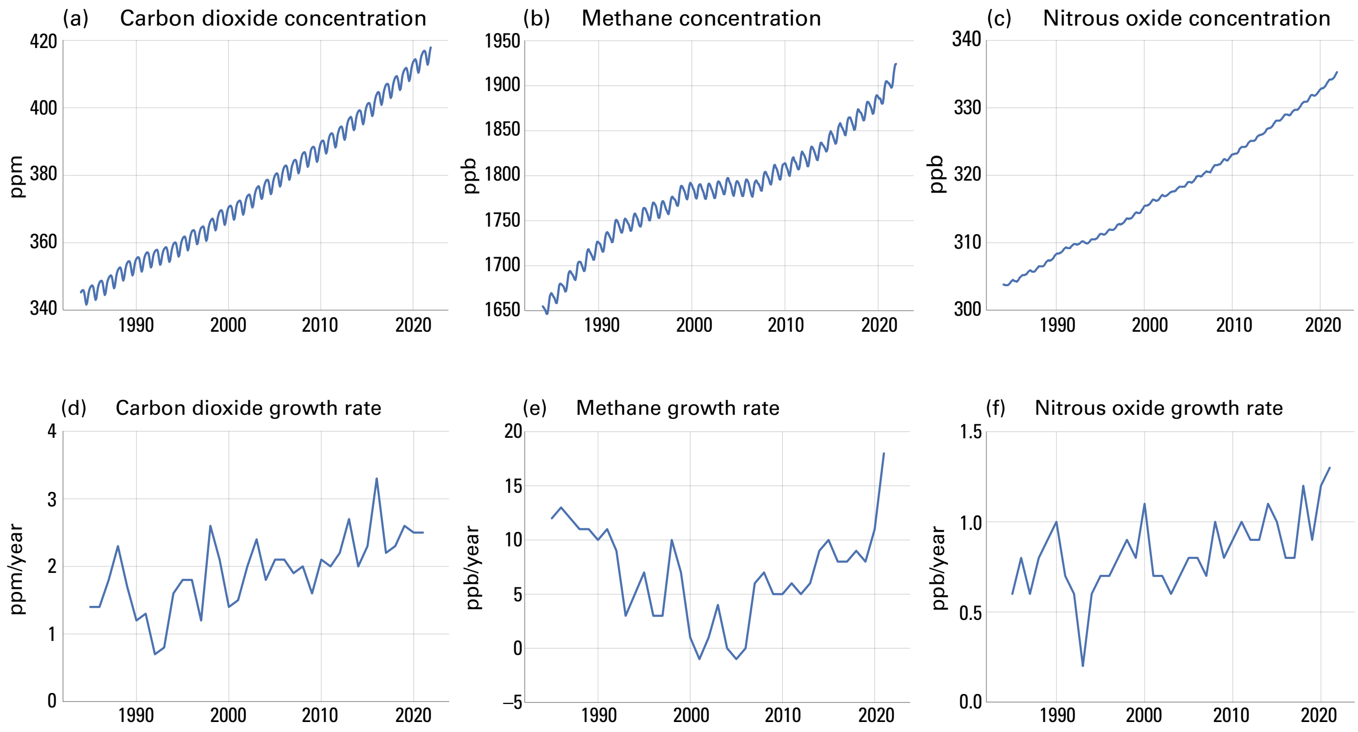


Figure 1. Top row: Monthly globally averaged mole fraction (measure of atmospheric concentration), from 1984 to 2021, of (a) CO_2 in parts per million, (b) CH_4 in parts per billion and (c) N_2O in parts per billion. Bottom row: Growth rates representing increases in successive annual means of mole fractions for (d) CO_2 in parts per million per year, (e) CH_4 in parts per billion per year and (f) N_2O in parts per billion per year.

Regional climate

The following sections analyse key indicators of the state of the climate in the South-West Pacific (WMO Region V – South-West Pacific; see the domain map in the Region domain subsection under Data sets and methods at the end of the report). One important such indicator, temperature, is described in terms of anomalies, or departures from a reference period. For global mean temperature, the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC)[8] uses the reference period 1850–1900 for calculating anomalies in relation to pre-industrial levels. However, this pre-industrial reference period cannot be used in all regions as a baseline for calculating regional anomalies, due to insufficient data for calculating region-specific averages prior to 1900. Instead, the 1991–2020 climatological standard normal reference period is used for computing anomalies in temperature and other indicators. Regional temperature anomalies can also be expressed relative to the reference period 1961–1990. This is a fixed reference period recommended by WMO for assessing long-term temperature change. In the present report, exceptions to the use of these baseline periods for the calculation of anomalies, where they occur, are explicitly noted.

MAJOR CLIMATE DRIVERS

The climate in the South-West Pacific region[9] is influenced by a number of drivers of regional climate variability,[10] including the El Niño-Southern Oscillation (ENSO). ENSO strongly influences the climate over most of the tropical Pacific, along with many other parts of the world. The Indian Ocean Dipole (IOD) strongly influences the climate over the tropical Indian Ocean and adjacent countries, particularly Australia and Indonesia. The Madden–Julian Oscillation (MJO) influences intraseasonal climate variability in tropical areas, with active phases increasing the chances of heavy rainfall and tropical cyclone formation in the affected longitudes, while the Southern Annular Mode (SAM) impacts the southern hemisphere extratropics.

The year 2022 was the third consecutive year with La Niña conditions. The La Niña event began in late 2020 and continued for most of 2021, with a short break in June–August 2021. Moderate La Niña conditions prevailed throughout 2022.

The IOD was in a negative phase in the second half of 2022. A negative IOD was also present in the second half of 2021, making 2022 the second consecutive year with a negative IOD.

The SAM was predominantly positive during the year 2022.

The La Niña event contributed to above-average rainfall over the Maritime Continent and eastern Australia, as well as to below-average rainfall over much of the equatorial Pacific. The impacts of La Niña on rainfall in eastern Australia were further exacerbated in the second half of the year by the negative IOD, as well as the positive SAM, particularly in New South Wales.

There were a number of active phases of the MJO, which are associated with increased rainfall and a higher risk of tropical cyclone formation. In April, when the MJO was in its active phase in the western Pacific region and the Maritime Continent, two tropical cyclones formed in the western North Pacific, namely Typhoon *Malakas* and Tropical Storm *Megi*. In September, the MJO was in its active phase in the western North Pacific, and this coincided with seven tropical cyclone formations, including Typhoon *Nanmadol*, the most intense tropical cyclone in 2022 in the western North Pacific basin.

TEMPERATURE

The mean surface temperature in 2022 in the South-West Pacific region ranked between the eighth and tenth warmest on record, depending on the data set considered. It was 0.13 °C [0.05 °C –0.15 °C] above the 1991–2020 average and 0.46 °C [0.27 °C –0.52 °C] above the 1961–1990 average[11] (Figure 2). The years 2021 and 2022 were substantially cooler than the previous few years in the region, largely as a result of the La Niña conditions which prevailed throughout most of these two years. La Niña years are typically

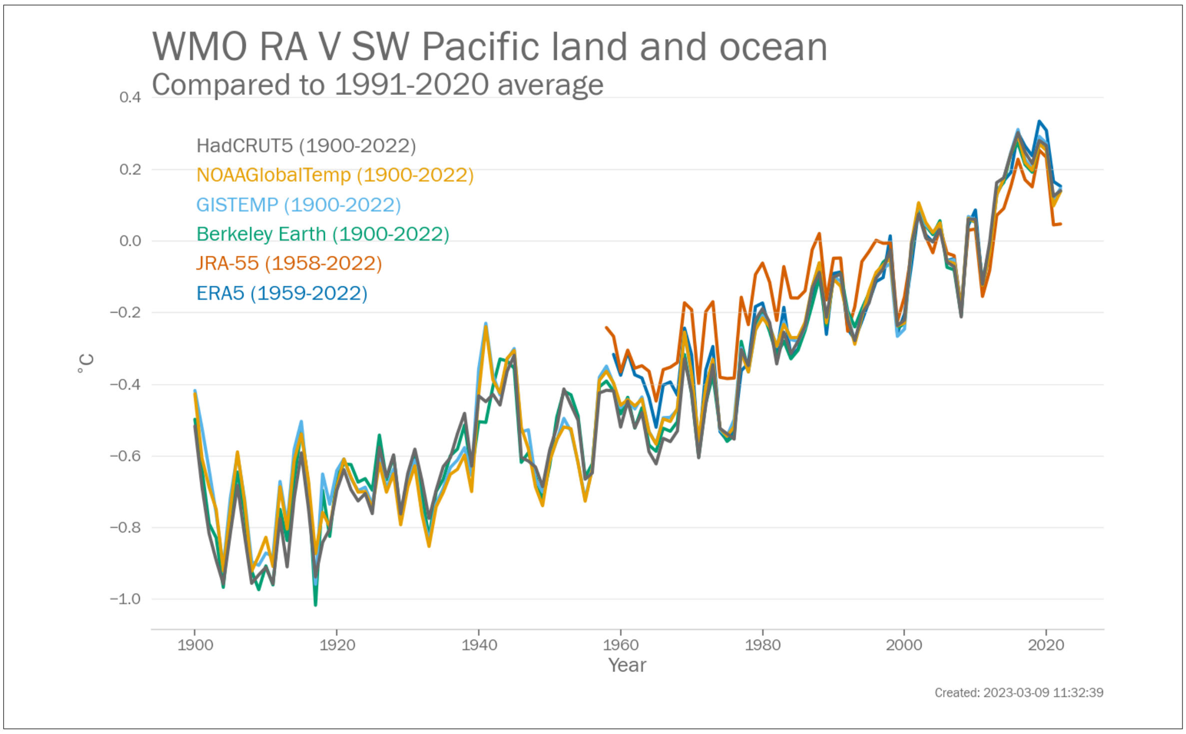


Figure 2. Annual regional mean land and ocean temperature for WMO Region V, South-West Pacific (°C, difference from the 1991–2020 average) from 1900 to 2022. Data are from six data sets. For details on the data sets and processing, see Data sets and methods.

substantially cooler than other years in the South-West Pacific region. Temperatures in 2022, although lower than those over the 2015 to 2020 period that was just prior to the multi-year La Niña event, were 0.2 °C to 0.3 °C higher than those during the last strong La Niña period in 2011, and similar to those in 2021.

The most significant warmth was in the South Pacific, over a region extending from Melanesia to French Polynesia, as well as New Zealand (Figure 3). Over these regions, temperatures were generally 0.5 °C to 1.0 °C above the 1991–2020 average. New Zealand had its warmest year on record, with an average temperature 1.02 °C above the 1991–2020 average.

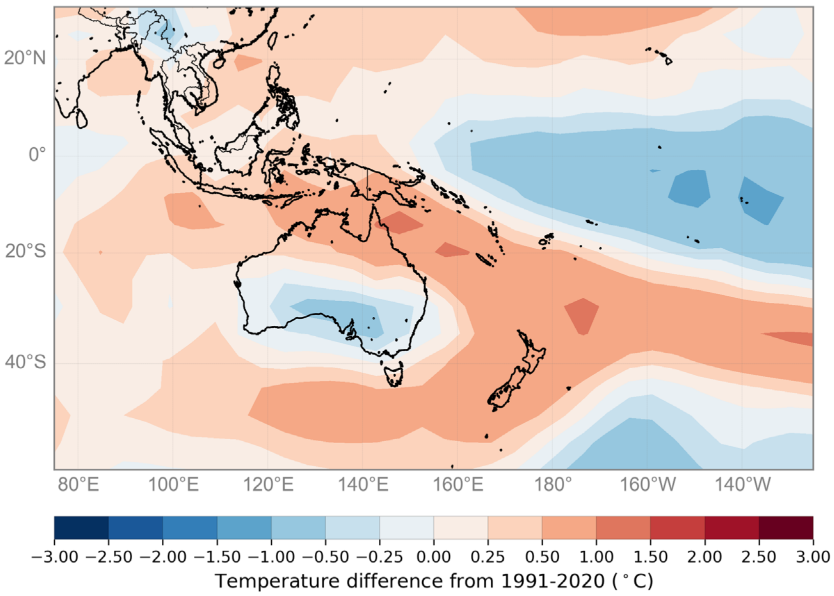


Figure 3. Annual temperature anomalies for 2022, relative to the 1991–2020 average, using the HadCRUT5 dataset
Source: Derived from the HadCRUT5 dataset, downloaded from https://www.metoffice.gov.uk/hadobs/hadcrut5/data/current/analysis/HadCRUT.5.0.1.0.analysis.anomalies.ensemble_mean.nc

Negative temperature anomalies were seen over much of the equatorial Pacific and over many parts of southern Australia, with parts of the equatorial Pacific more than 1 °C below average in association with La Niña conditions.

PRECIPITATION

Precipitation is a key climate parameter, closely related to indispensable resources for human activities such as water for drinking and domestic purposes, agriculture and hydropower. It also drives major climatic events such as droughts and floods.

Rainfall patterns over many parts of the region were consistent with the La Niña conditions that prevailed in 2022. In general, annual precipitation amounts were above normal in the western parts of the region and below usual across the central Pacific islands. An exception is northern Australia, which was drier than usual, but usually receives more rainfall than normal during La Niña episodes.

In 2022, the largest precipitation deficits (measured as percentage of normal) were observed in Kiribati, the Hawaiian Islands, the northern and western parts of the Bismarck Archipelago and southern Luzon (Figure 4). Other regions with below-average rainfall amounts were the Mariana Islands, parts of northern and south-west Australia, western Tasmania, the southern South Island of New Zealand, some regions in the Greater Sunda Islands (Indonesia), French Polynesia and Tuvalu. Based on time series analyses (not shown), it was unusually dry (below the 10th percentile) in Kiribati, French Polynesia, the Hawaiian Islands, the Bismarck Archipelago, south-west Tasmania and the southern coast of New Zealand's South Island.

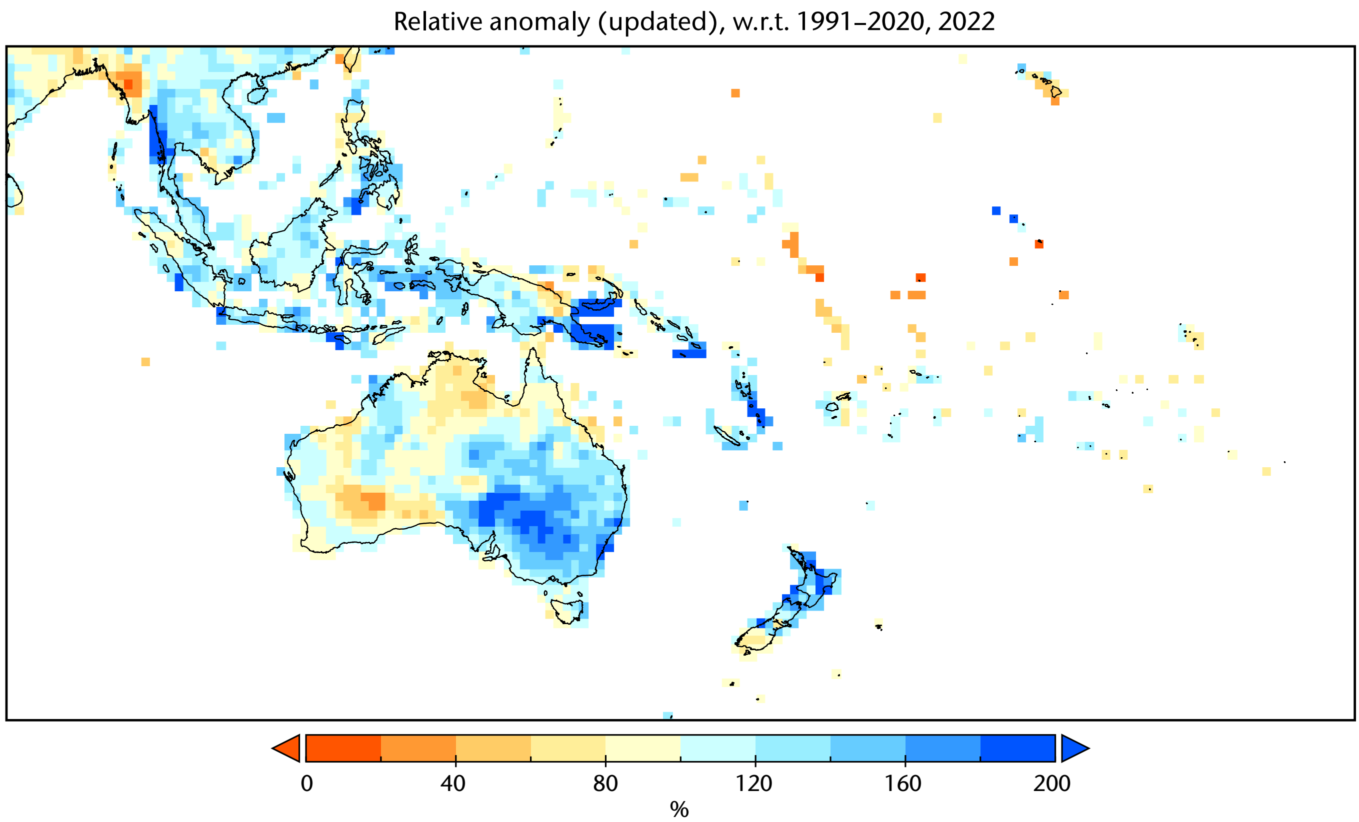


Figure 4. Precipitation anomalies for 2022, expressed as a percentage of the 1991–2020 average
Source: Global Precipitation Climatology Centre (GPCC), Deutscher Wetterdienst (DWD), Germany

At the other extreme, the largest rainfall excesses were measured in the majority of the Malay Archipelago, the Solomon Islands and Vanuatu. Other regions that received above-normal rainfall amounts include eastern Australia, central and northern New Zealand, New Caledonia, Fiji, Niue and the southern Cook Islands. Time series analyses indicate unusually wet conditions in south-east Australia, central and northern New Zealand, Vanuatu, New Caledonia and many locations in the Malay Archipelago. Some parts of eastern Australia had their wettest year on record, including Sydney, which received 2 530 mm of rain, more than 300 mm above its previous record. It was the wettest year on record for New Caledonia, and records were also set at a number of locations in the southern North Island of New Zealand. In February, Niue received 594.7 mm, which is the highest recorded rainfall to date for that month.

CRYOSPHERE

Snow is rare or unknown at low elevations over most of the region, however snow and ice occur in some mountain regions. There are glaciers in the mountains of New Zealand, mostly on the South Island, and on the highest peaks of the western part of the island of New Guinea. There is significant seasonal snow cover in the highland regions of New Zealand and southern Australia.

New Zealand's seasonal snow is monitored via ten National Institute of Water and Atmospheric Research (NIWA) snow and ice monitoring sites. Data from these sites show that snow depths were largely above average[12] through June and July, before dropping to well below average at eight sites in the second half of August due to warm weather and a considerable rain-on-snow event. Snow was absent from many sites on or to the west of the Main Divide and at lower elevations (<1 500 m) at the period of usual peak accumulation (mid-September). The average snow depth for the year was as low as 23% of average at Ivory Glacier (West Coast, 1 390 m elevation). However, average annual snow depths were above average at five of the sites, while the median value across all ten sites was 99% of annual average snow depth. Peak snow depths for 2022 ranged from 0.44 m (37% of average) at Ivory Glacier to 2.95 m (103% of average) at Mueller Hut (Canterbury, 1 818 m elevation).

In Australia, mountain snowpacks were above average and unusually persistent at higher elevations. At the longest-running snow depth measurement site, Spencers Creek (near Perisher Valley in New South Wales, 1 830 m elevation), the snow depth reached 1.18 m on 15 June, the greatest depth so early in the year since 1968, and remained above 1.0 m until 12 October, the longest duration of snow depth above 1.0 m since at least 1981. The seasonal peak depth, reached on 20 September, was 2.32 m, which is above the long-term (1954–2022) average. Sites at 1 600 m elevation or below recorded snow depths near or below average, though an unusually cold spell in November resulted in late-season snow at elevations of 900 m or lower both in Victoria and on the New South Wales Central Tablelands.

On 19 December, a kona low system (subtropical cyclone that occurs during the cool season in the north central Pacific) brought blizzard-like conditions to the higher elevations of Hawaii. The summit of Mauna Kea reported 3 m snow drifts and gusts over 160 km per hour.

In Indonesia, satellite estimates of the area of a glacier in the western part of the island of New Guinea showed a total ice area in April 2022 of 0.23 km^2, a decrease of about 15% from the previous assessment of 0.27 km^2 in July 2021. From 2016 to 2022, the average reduction in ice area was approximately 0.07 km^2 per year. Measurements of ice thickness via a single stake show a reduction in thickness of 24 m from June 2010 to the beginning of 2021, and the estimated remaining ice thickness in December 2022 was just 6 m.

SEA-SURFACE TEMPERATURE

Sea-surface temperature (SST) is an important physical indicator for Earth's climate system. Changes in SST play a critical role for the coupling between the ocean and the atmosphere, as they can trigger the transfer of energy, momentum and gases (including water vapour evaporating and ocean uptake/release of greenhouse gases) between the two Earth system components.[13] SST is an essential parameter in weather and climate prediction, and is also important for the study of marine ecosystems.[14] While the global mean SST is increasing, there is variability around this average, with different regions and locations experiencing different responses. These responses vary both in terms of the trend and variance on different timescales, and are also linked to climate modes (such as ENSO) and ocean dynamics such as ocean fronts, eddies, coastal upwelling and exchanges between the coastal shelf and open ocean.[15]

Over the period 1981–2022 for which observation data from satellites are available, the SST trend in part of the central tropical Pacific shows a cooling pattern. This area is strongly affected by year-to-year variability from varying ENSO conditions (Figure 5(a), Box 2) superposed on the long-term warming. Anomalous cold conditions are observed on average in this area in 2022, which are linked to prevailing La Niña conditions in this area (Figure 5(b), Box 2). Over most remaining parts of the South-West Pacific region, surface ocean warming is observed, reaching record rates of more than 0.4 °C per decade north-east of New Zealand and at the northern margin of this area (Figure 5(a)). This is about three times faster than the global surface ocean warming rate. For comparison, global mean SST has increased over recent decades at a rate of 0.15 ± 0.01 °C per decade.[16]

In 2022, SST again reached near-record-high values of almost +0.5 °C in the Philippine Sea. The year had the third highest average surface ocean temperature on record in this sub-area, ranked directly behind 2020[17] and 2021[18] (Figure 5(b), Box 1). Similar conditions prevailed in 2022 in the ocean area around New Zealand, including in the Tasman Sea, with average temperatures reaching the third highest value on record at 0.5 °C above the average (Figure 5(b), Box 4). In the Indian Ocean, surface ocean warming prevailed over the period 1982–2022 at rates higher than the global average.

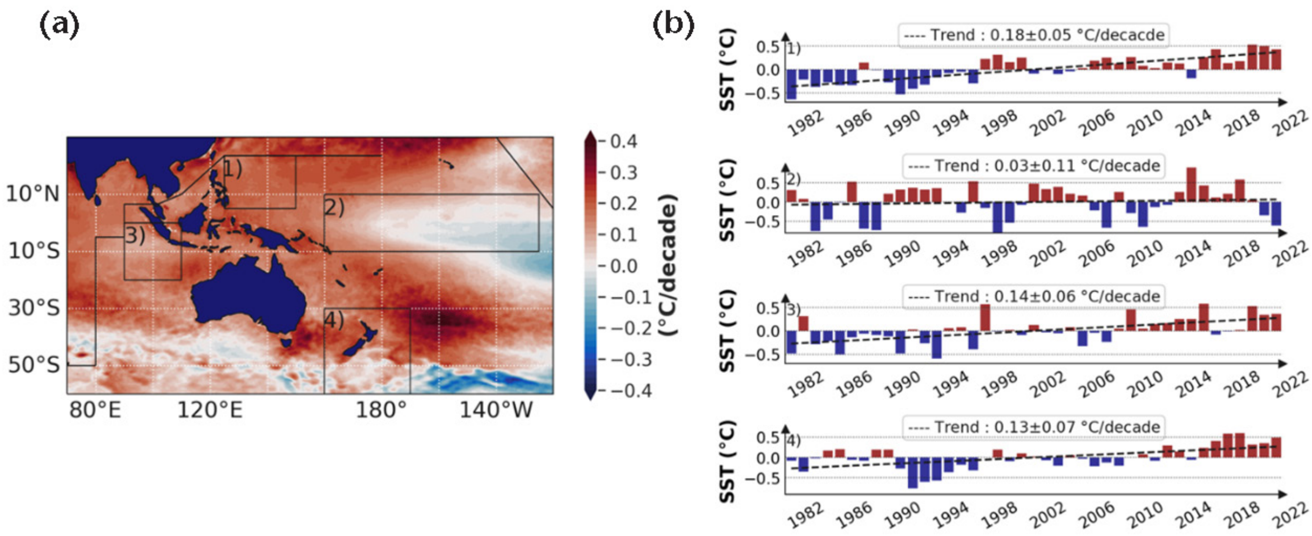


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Figure 5. (a) Linear trends in SST (°C per decade) over the period 1982–2022. (b) Area-averaged time series of SST anomalies (°C) relative to the 1982–2022 reference period for the areas indicated in grey dashed lines in 5(a).
Source: Derived from the Copernicus Marine Service remote sensing products available at https://doi.org/10.48670/moi-00168 (for 1982–2021) and https://doi.org/10.48670/moi-00165 (for 2022)

OCEAN HEAT CONTENT

Due to emissions of heat-trapping greenhouse gases resulting from human activities, the global ocean has warmed. It has taken up more than 90% of the excess heat in the climate system, making climate change irreversible on centennial to millennial timescales.[19] Ocean warming contributes about 40% of the observed global mean sea-level rise through thermal expansion of seawater. It is altering ocean currents, indirectly altering storm tracks[20] and increasing ocean stratification,[21] which can lead to changes in marine ecosystems.

Most of the regions in the South-West Pacific show upper-ocean (0–700 m) warming since 1993. Warming is particularly strong, with rates exceeding 2–3 times the global average warming rates, in the Solomon Sea and east of the Solomon Islands; in the Arafura, Banda and Timor Seas; east of the Philippines; along the southern coast of Indonesia and in the Tasman Sea (Figure 6(a)). The latter sub-areas witnessed the highest upper ocean heat content on record during the year 2022 (Figure 6(b), Boxes 3, 4). In addition, upper-ocean warming in the region is strongly affected by natural variability. For example, in the tropical Pacific, the average upper-ocean warming is dominated by natural variability (for example, ENSO) whereby large amounts of heat are redistributed from the surface down to deeper layers, and from the tropics to the subtropics.[22]

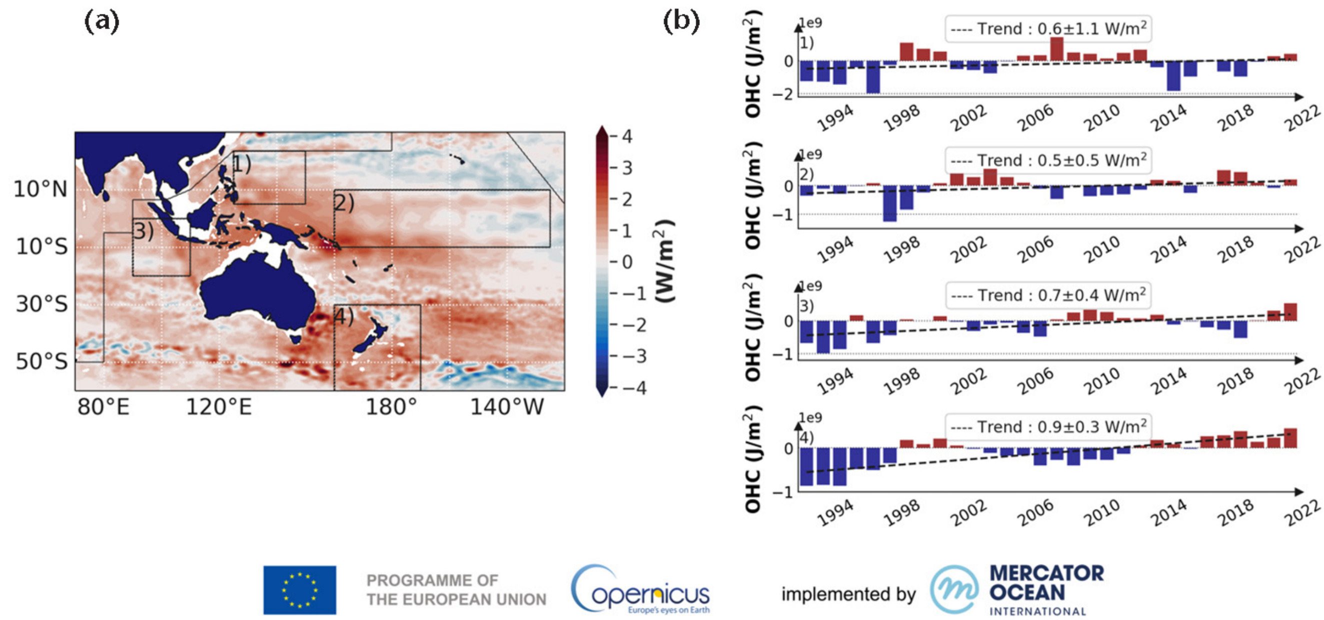


Figure 6. (a) Linear trends in ocean heat content (OHC) (in W/m²) over the period 1993–2022, integrated from the surface down to 700 m depth. Ocean warming rates in areas with water shallower than 300 m have been masked in grey owing to product limitations. (b) Area-averaged time series of upper 700 m OHC anomalies (joules per square meter (J/m²)) for the four areas indicated in grey dashed lines in 6(a). For each area, the linear trend over the full period is provided. Since the unit W has a dimension of J divided by time, the trend (changes with time) in ocean heat content per unit surface (J/m²) is shown in the unit W/m².
Source: Derived from the in situ-based Copernicus Marine Service product available at https://doi.org/10.48670/moi-00052

SEA LEVEL

Sea level at the coast has been measured by tide gauges in the South-West Pacific region for more than 100 years. In recent years, the number of tide gauges in operation has grown, and records from these newer gauges have been complemented by data from high-precision altimeter satellites to provide much better spatial coverage.[23] Since the early 1990s, these satellites indicate that the global mean sea level has risen at an average rate of 3.4 ± 0.3 mm per year in response to ocean warming and land-ice melt.

Figure 7 shows the sea-level trend over the January 1993–June 2022 period as measured by satellite altimeters. The map shows that rates of sea-level rise in the eastern Indian Ocean, western tropical Pacific, and south and north mid-latitude Pacific are higher than the global mean. The regional sea-level time series (Figure 7, bottom left and right) display strong inter-annual variability. This is mostly driven by ENSO, especially in the western tropical Pacific, where a temporary strong sea-level drop of about 15 cm occurred during the 1997/1998 El Niño event, and another drop of nearly 10 cm occurred during the 2015/2016 El Niño event.

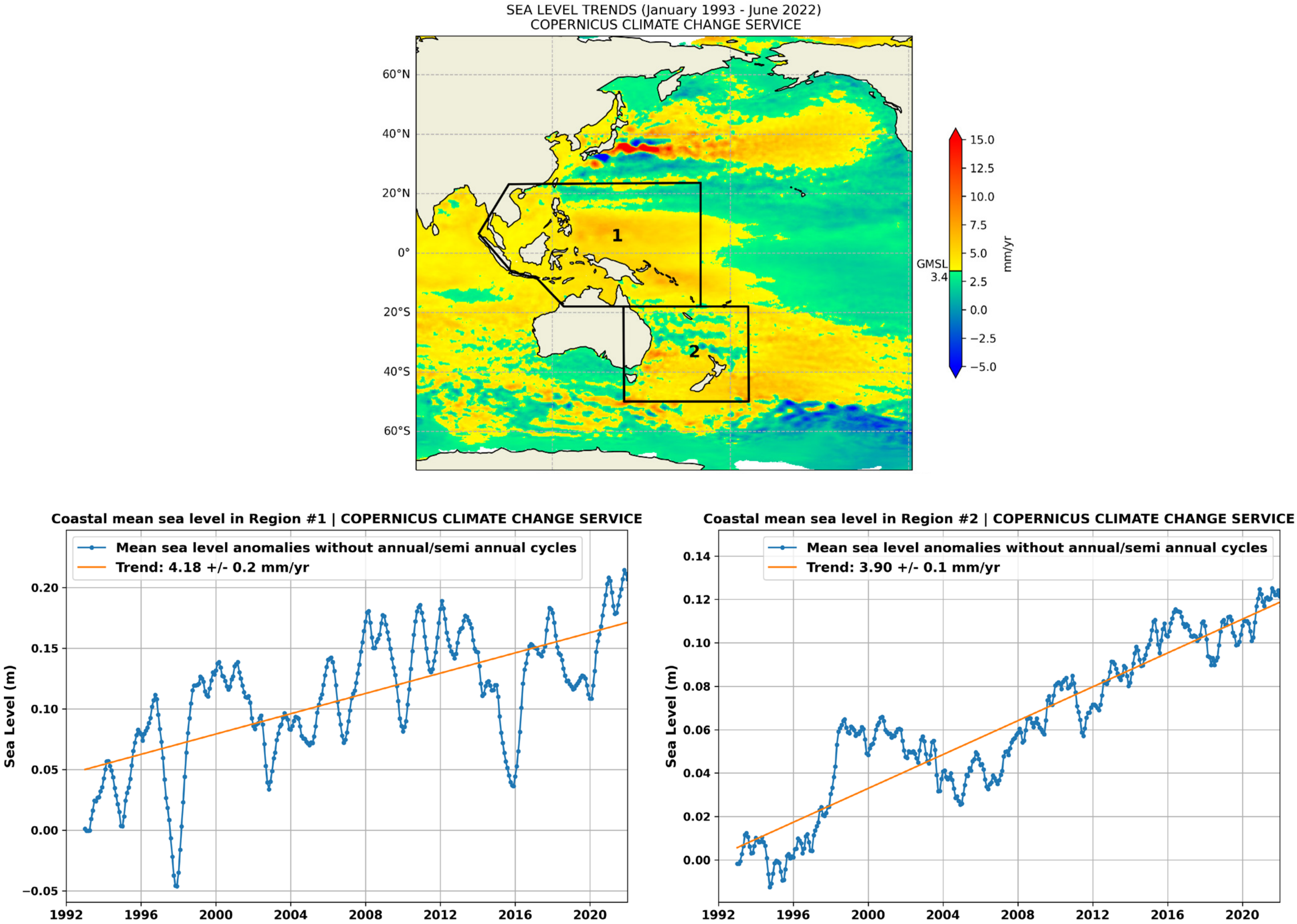


Figure 7. Altimetry-based coastal sea-level time series (m) from January 1993 to June 2022 for the western Pacific and eastern Indian Ocean. The map (top) shows annual mean sea-level trend and location of regions summarized in the plots at the bottom left and right, and the transition from green to yellow colour corresponds to the 3.4 mm per year overall trend in the global mean sea-level rise. The plots (bottom left and right) show mean sea-level anomalies (blue) and estimated trend (orange line) for the South-East Asia and southern Oceania regions, respectively.
Source: Copernicus Climate Change Service (C3S) – https://climate.copernicus.eu/sea-level, and Laboratory of Space Geophysical and Oceanographic Studies (LEGOS), France

Extreme events

TROPICAL CYCLONES

The South-West Pacific encompasses the Australian and South Pacific tropical cyclone regions (covering the southern hemisphere from 90°E eastward to 120°W, up to the equator) as well as part of the western and central North Pacific regions. It is an active region for tropical cyclones, with most countries affected. The South Pacific and Australian tropical cyclone season of 2021/2022 coincided with a second year of active La Niña in the tropical Pacific. La Niña typically acts to shift tropical cyclone genesis farther west in the South Pacific towards Australia, along with the shift in warmer sea-surface temperatures westward that is associated with La Niña. La Niña also often increases tropical cyclone numbers in the eastern Indian Ocean off the Australian coast when compared to either an El Niño or ENSO-neutral[24] condition, although there is a high level of variability from year to year.

During the 2021/2022 tropical cyclone season, ten tropical cyclones formed in the Australian region, which is close to the long-term average. Two of these were considered severe tropical cyclones (category 3 or above); Tropical Cyclones *Vernon* and *Charlotte* reached category 4 status during February 2022 and March 2022 respectively. In the South Pacific region there were a total of six tropical cyclones, which was also close to the long-term average, with Tropical Cyclone *Cody* reaching category 3 in January 2022 and Tropical Cyclone *Dovi* reaching category 4 in early February 2022. It was also the first season since 2018/2019 in which there was no Category 5 tropical cyclone in the South Pacific. Along its track *Dovi* led to heavy rainfall and flooding, including in Vanuatu and New Caledonia. *Cody* brought significant flooding in Fiji, with 525 mm of rain in 24 hours on 9 January at Nadarivatu and over 200 mm at numerous other sites.

In the western North Pacific basin, a total of 25 tropical cyclones with maximum sustained wind speeds of ≥34 knots formed over the western North Pacific Ocean and the South China Sea, which was equal to the 1991–2020 average. The Philippines, however, experienced a number of significant landfalls affecting in total nearly 7 million people, leading to over 500 deaths and more than US$ 140 million in reported damage. The two most significant were *Megi*, from 10 to 12 April, and *Nalgae*, on 27 and 28 October. Tropical Cyclone *Megi* brought heavy rainfall leading to flooding in the same areas (Leyte province in the central Philippines, for example) which had been severely affected by the recent Typhoon *Rai* in 2021.[25] The passage of the tropical storm on 10–11 April left 346 dead or missing, mostly due to rain-induced landslides, affected close to 2.3 million people, and caused economic damage of over US$ 41 million, including a significant portion attributable to lost agricultural produce from damaged crops in agricultural areas.[26] Tropical Storm *Nalgae* brought heavy rains and strong winds to the Philippines, affecting all 17 regions of the country. Flooding and landslides caused by heavy rainfall damaged over 11 000 houses, 140 buildings and 57 000 hectares of cropland.[27] Associated with the storm, more than 150 deaths were reported, over 3.3 million were affected, and there was estimated economic damage of over US$ 45 million.[28]

In addition, on 25 September, Typhoon *Noru*, which first made landfall in the Philippines, brought violent winds and torrential rains, leaving 17 dead or missing and affecting over 900 000 people. Impact to lifeline services, such as power, communications and water was minimal, with only parts of Nueva Ecija and Aurora provinces, and island villages in Quezon province remaining without power four days after the passage of the typhoon.[29] Economic damage from the disaster is estimated to have been close to US$ 57 million.[30]

HEAVY PRECIPITATION AND FLOODING

There was flooding in eastern Australia on numerous occasions during the year. The most severe floods were in late February and early March, affecting eastern coastal areas in south-east Queensland, northern New South Wales and around Sydney. The Wilsons River (northern New South Wales) exceeded previous record levels by about 2 m, and much of the Lismore town centre was inundated. In western Sydney the Hawkesbury-Nepean Rivers reached their highest level since 1978. Queensland and New South Wales suffered from flooding between late February and early March which led to 22 deaths, affected over 54 000 people, and caused an estimated US$ 6.6 billion in economic damage.[31] Thousands of people in south-western Sydney were ordered to evacuate due to the rising floodwaters, and the extreme rain cut off power for tens of thousands of people across the region, limiting their access to basic amenities and hampering rescue efforts.[32]

New Zealand also experienced a number of flood events during the year. The most significant was in August, when prolonged heavy rain occurred in northern and western parts of the South Island. This event was the most intense atmospheric river[33] to make landfall in the country during the month of August since at least 1959. North Egmont received 692 mm of rain in 24 hours on 18 August, and Upper Takaka (93 m above sea level) recorded 245 mm on 17 August. The most significant flooding was in the northern South Island, particularly in the Nelson area. A March system which affected the North Island brought 103 mm of rain in one hour to Maungatapere (near Whangarei), a national record for a low-elevation (500 m or less above sea level) site, and went on to cause flooding in the Gisborne area.

Between late February and early March, heavy rainfall caused flooding in Banten, the westernmost province of Indonesia's island of Java, killing 13 people and affecting over 31 000. In West Java province, heavy rainfall, the overflowing of rivers and a tornado displaced people and damaged over 3 000 houses.[34] The estimated total economic damage from the flooding is over US$ 62 million. In December 2022, as a result of persistent rainy conditions, about two-thirds of Peninsular Malaysia was affected by flooding. The associated floods damaged roads and bridges in the states of Johor, Kelantan, Pahang, Perak and Terengganu. The estimated total economic damage from the flooding was about US$ 140 million.[35] A landslide which occurred in a steeply sloped area of Batang Kali in the state of Selangor killed 31 people. This is the second-largest landslide recorded in Peninsular Malaysia, after the Highland Towers tragedy which occurred in 1993. The nearest station recorded continuous rainfall for 20 days around the time of the landslide, amounting to 300 mm.

Strong south-easterly swells associated with an intense low in the far southern Pacific, combined with tides near their astronomical maximum, resulted in coastal inundation in a number of Pacific island regions from 11 to 16 July. The most significant impacts were in the Cook Islands, where a number of villages were inundated. The water level at Penrhyn was the highest observed outside of tropical cyclones. French Polynesia and Teraina island (Kiribati) were also affected.

DROUGHT

The La Niña conditions which prevailed throughout 2022 resulted in abnormally low rainfall through much of the equatorial Pacific, for the second successive year in many cases. Most areas between the equator and 10°S, and east of 150°E, had annual rainfall below the 5th percentile, with some locations receiving totals more than 80% below the long-term average (Figure 8). Areas affected by the dry conditions included Kiribati, Nauru, Papua New Guinea (particularly the east), Tokelau, Tuvalu, the southern Federated States of Micronesia and the Marquesas islands (French Polynesia). The Kiribati Government declared a state of disaster due to drought in June. The entire country was affected, with the most critical situation occurring on Tarawa island, where the capital is located. Widespread contamination of drinking water was reported.[36] Shorter-term dry conditions also extended at times during 2022 to other areas, including American Samoa, the Republic of the Marshall Islands and Samoa. Kiribati and Tuvalu were particularly badly affected, with both countries experiencing significant water shortages at times during the year.

It was also a very dry year in much of Hawaii. Annual rainfall was below the 10th percentile at numerous locations, and at the drought's peak in October, 93% of the state was assessed as being in drought. Parts of New Zealand had a dry start to the year, with Auckland having its second-longest dry spell on record, a period of 37 days from 17 December to 22 January. It was also abnormally dry in western Tasmania, resulting in low levels in water storage reservoirs used for hydroelectricity generation.

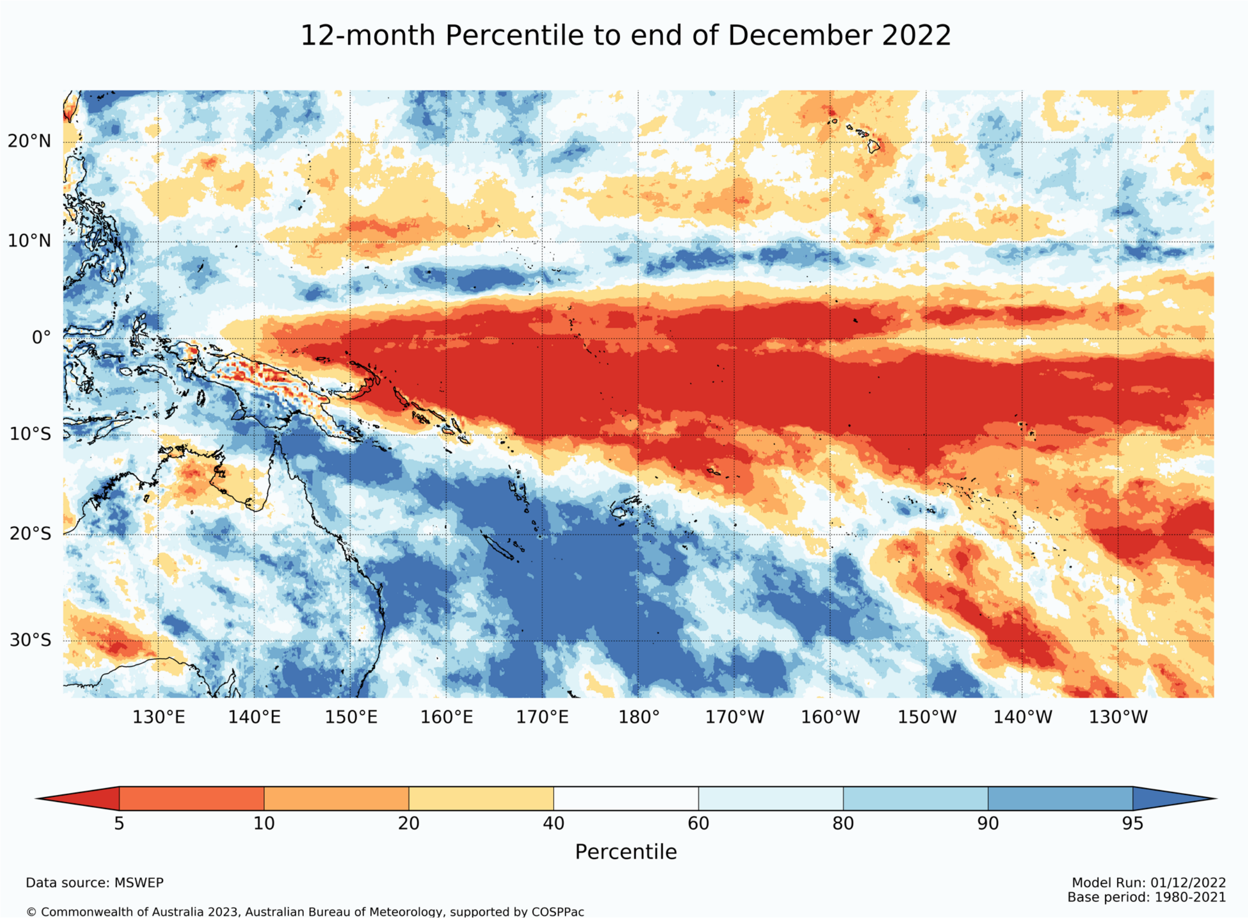


Figure 8. Rainfall in 2022 expressed as a percentile, from the satellite-based Multi-Source Weighted-Ensemble Precipitation (MSWEP v2.8) data set, showing the abnormally dry conditions over much of the equatorial Pacific. Note: There are some localized differences between the maps in Figures 4 and 8. These result primarily from differences in baseline periods and grid resolution, along with local data quality issues.

EXTREME HEAT

There were a number of significant heatwaves in Western Australia, although it was a mild summer farther east. Onslow in the state's north-west reached 50.7 °C on 13 January, equalling the national record, while Perth set a record with six consecutive days above 40 °C from 18 to 23 January and a total of 13 days during the summer above 40 °C, almost double the previous record. Daytime temperatures for the 2021/2022 summer were the highest on record in many areas near the west coast south of the tropics.

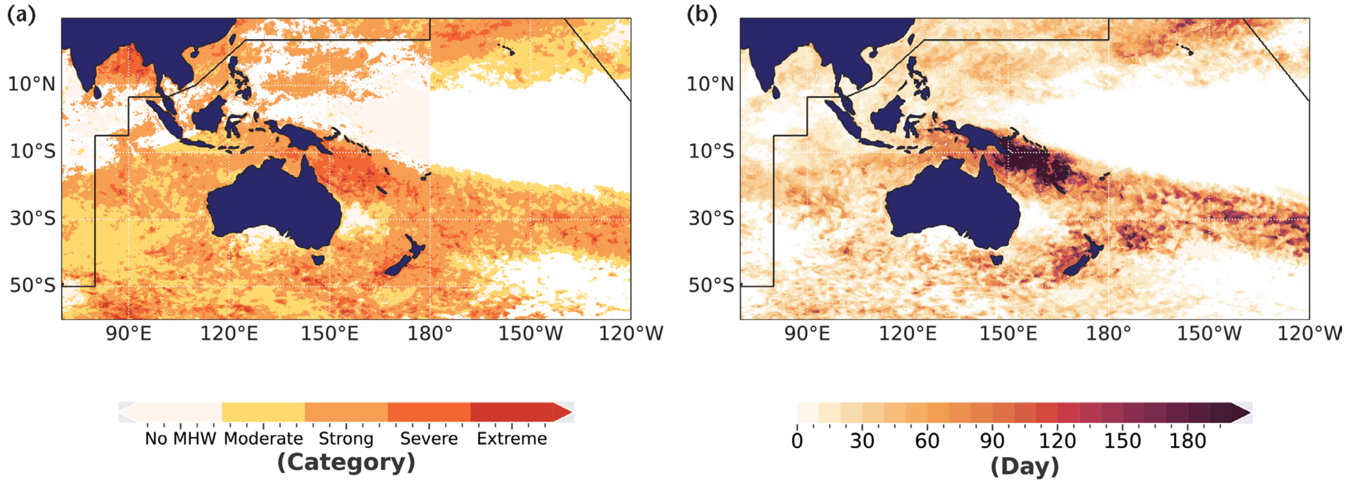
Many locations on the North Island of New Zealand had their warmest night on record in the period from 8 to 13 February as a result of a moist tropical airstream, with Whanganui (32.7 °C) and Greymouth (29.8 °C) also having their hottest days on record during this period.

In April and May unusually hot days were recorded in Singapore. On 1 April, 36.8 °C was recorded at Admiralty, which was the second-highest temperature on record for the country. On 13 May, 36.7 °C was recorded at Admiralty, which was the warmest temperature ever recorded in Singapore in May.

MARINE HEATWAVES

Analogous to heatwaves on land, marine heatwaves are prolonged periods of extreme heat that affect the ocean and can have a range of consequences for marine life and dependent communities. Marine heatwaves have become more frequent over the twentieth and twenty-first centuries. Satellite retrievals of sea-surface temperature (SST) are used to monitor marine heatwaves. They are categorized as moderate when SST is above the 90th percentile of the climatological distribution for five days or longer; the subsequent categories are defined with respect to the difference between the SST and the climatological distribution average: strong, severe or extreme, if that difference is, respectively, more than two, three or four times the difference between the 90th percentile and the climatological distribution average.[37]

In 2022, the most prominent and persistent marine heatwaves occurred in a large area north-east of Australia and south of Papua New Guinea in the Solomon and Coral Seas, lasting over a period of more than six months (Figure 9). Other areas that experienced severe to extreme marine heatwaves lasting 2–4 months included the Tasman Sea along the western coast of New Zealand; the tropical Pacific between about 15°S and 40°S, including marine areas of several Pacific small island developing States (SIDS); the central Pacific between 20°N and 30°N; and the Arafura and Banda Seas. Similar events occurred along the southern coast of Indonesia, but these were in the moderate category.



MERCATOR OCEAN INTERNATIONAL

Figure 9. (a) Maximum categories of marine heatwaves, and (b) the maximum duration over the year 2022
Source: Mercator Ocean international, France; derived from the Copernicus Marine Service remote sensing products available at https://doi.org/10.48670/moi-00168 (for 1982–2021) and https://doi.org/10.48670/moi-00165 (for 2022)

Observational basis for climate monitoring

Climate monitoring is performed by a system of observing systems covering the atmosphere, the ocean, hydrology, the cryosphere and the biosphere. Each of these areas is monitored in different ways by a range of organizations. Cutting across all these areas, satellite observations provide major contributions to global climate monitoring.

In 1992, the Global Climate Observing System (GCOS) was established by WMO, the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP) and the International Science Council (ISC) to coordinate and facilitate the development and improvement of global climate observations. GCOS has identified a set of Essential Climate Variables (ECVs) that together provide the information necessary to understand, model and predict the trajectory of the climate as well as plan mitigation and adaptation strategies (Figure 10). The status of the observational basis for these ECVs is published in regular status reports. GCOS also identifies what is needed to improve the system in implementation reports.

In 2022, GCOS released its latest Implementation Plan[38] in response to the findings of the 2021 GCOS Status Report, implications arising from the IPCC Sixth Assessment Report and recent scientific studies on the climate cycles. The publication provides recommendations for a sustained and fit for purpose Global Climate Observing System.

In addition to observations provided by the GCOS-coordinated Global Surface Network (GSN) and Global Upper-Air Network (GUAN), National Meteorological and Hydrological Services (NMHSs) of WMO Members provide a more comprehensive and widespread network of observations, acquired primarily for operational weather prediction. WMO's Global Basic Observing Network (GBON), a globally-designed network with prescribed capabilities and observing schedules and for which international data exchange is mandatory, will provide critically needed observations for numerical weather prediction and will help substantially strengthen climate reanalysis.

In order to provide the necessary financial and technical assistance for the implementation and operation of GBON in the poorest and most poorly observed areas of the globe, WMO, the United Nations Development Programme (UNDP) and UNEP have established the Systematic Observations Financing Facility (SOFF). SOFF has raised significant funds for supporting observations in least developed countries and small island developing States and commenced its implementation phase in 2023.

Complementing the observations of the physical and dynamic properties of the atmosphere, WMO's Global Atmospheric Watch (GAW) coordinates atmospheric composition measurements, ensuring that reliable and accurate data are obtained from measurements made by WMO Members, research institutions and/or agencies and other contributing networks.

Ocean observations of ocean physics, biogeochemistry, biology and ecosystems are coordinated through the Global Ocean Observing System (GOOS). The GOOS Observations Coordination Group (OCG) monitors the performance of these observations[39] and produces an annual Ocean Observing System Report Card. Ocean observations are generally made widely available to international users.

In the terrestrial domain, there is a wider group of observing networks. Hydrological observations are generally operated by NMHSs and coordinated through WMO. A number of specialized Global Terrestrial Networks (GTNs), for example, on hydrology, permafrost, glaciers, land use, and biomass, also contribute to GCOS. Data exchange agreements are generally less developed for the terrestrial networks, and many important observations are not made available to international users.

The Committee on Earth Observation Satellites/Coordination Group for Meteorological Satellites (CEOS/CGMS) Joint Working Group on Climate (WGClimate) bases the development of satellite observations for climate on the ECV requirements established by GCOS. It has produced an ECV Inventory that includes records for 766 climate data records for 33 ECVs covering 72 separate ECV products, with more planned. WGClimate is also working on actions arising from the Implementation Plan. Satellite observations have near-global coverage. Used with ground-based observations, either as complementary data sets or for validation and calibration, they form an invaluable part of the global observing system.

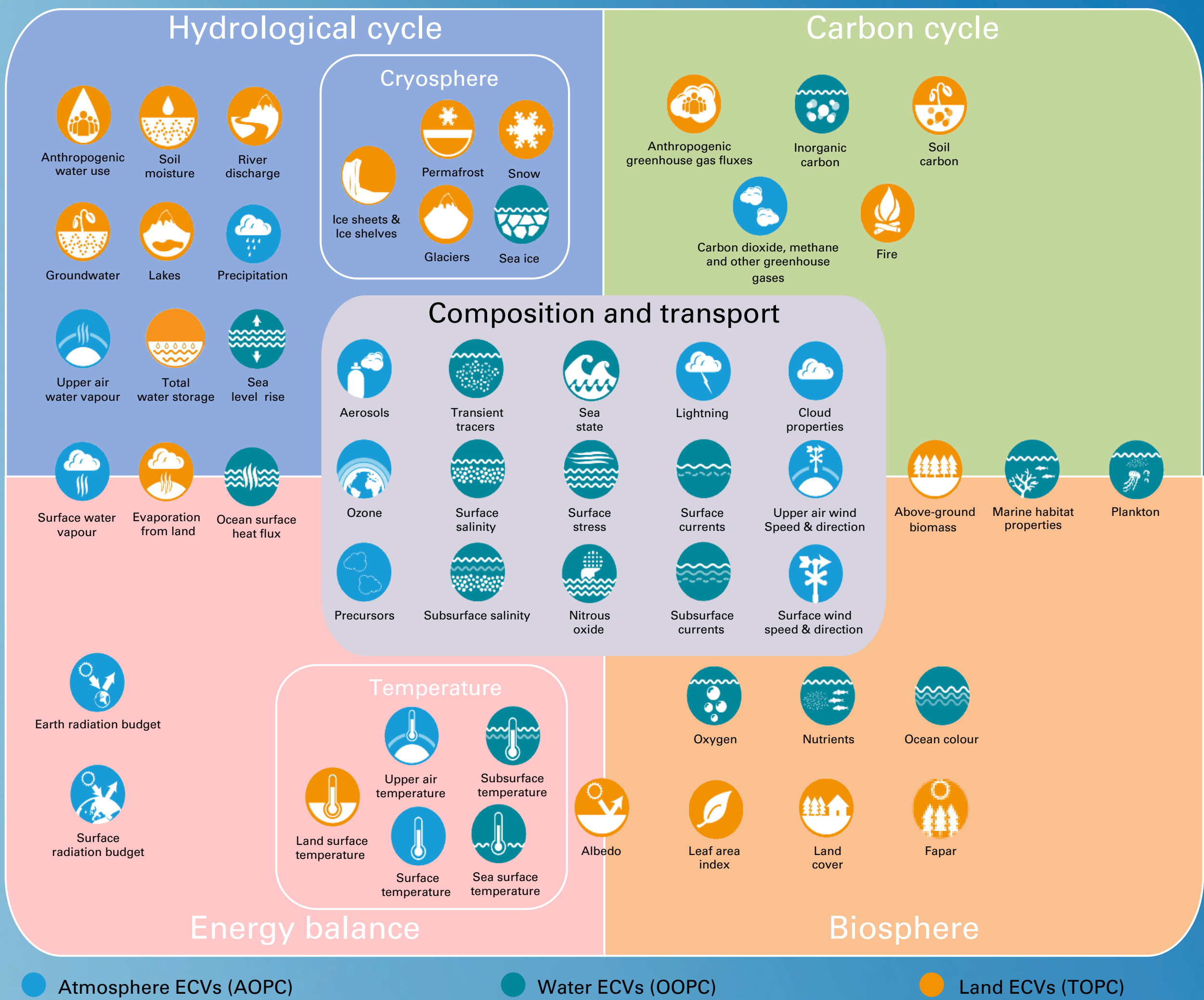


Figure 10. Essential Climate Variables (ECVs) identified by GCOS and the climate cycles. Many ECVs contribute to understanding several different cycles; this figure only indicates the main links.

Climate-related impacts and risks

AFFECTED POPULATION AND DAMAGE

In 2022, a total of 35 natural hazard events were reported in the South-West Pacific according to the International Disaster Database (EM-DAT),[40] of which over 70% were flood events. These reported natural hazard events resulted in over 700 fatalities, of which over 70% were associated with storms. Over 8 million people were directly affected by these hazards, and they caused total economic damage of close to US$ 9 billion. Storms were the leading cause of death and affected the greatest number of people in 2022, followed by floods, which were the second highest cause of death and affected the second highest number of people during the year (Figure 11). In 2022, storms in the Philippines and Fiji caused the greatest number of fatalities, highlighting the continuing high level of vulnerability of the South-West Pacific region, especially to storms.

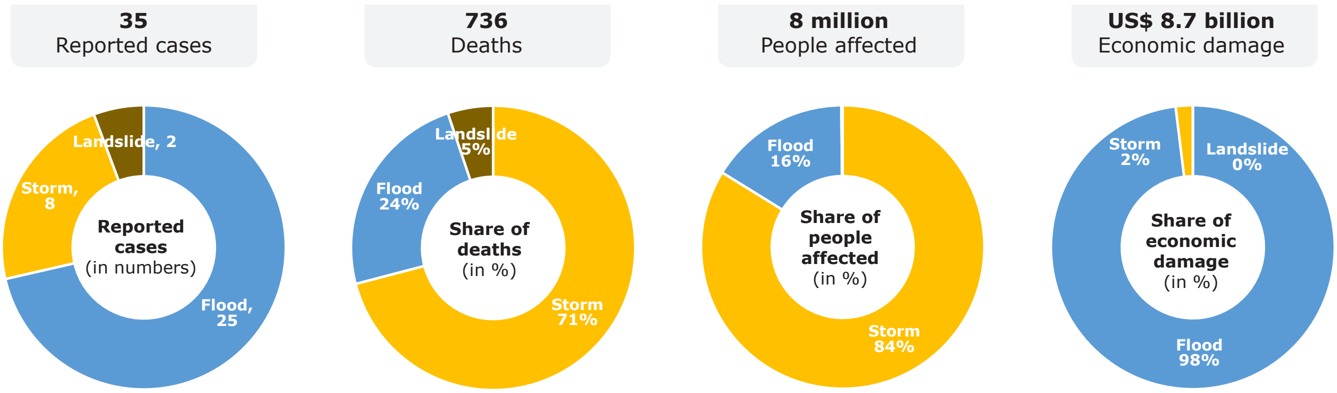


Figure 11. Overview of 2022 disasters in the South-West Pacific region. Note: The economic damages resulting from some disasters are not presented in the diagram due to data unavailability. Only cases reported in EM-DAT are considered in the diagram.
Source: United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) calculations based on EM-DAT data

IMPACT ON THE ECONOMY

A comparison of the economic losses from disasters in the South-West Pacific region in 2022 with the average over the past 20 years (2002–2021) (Figure 12) shows that the losses associated with flooding in 2022 (an estimated US$ 8.5 billion) were more than 4 times the average, while damage associated with storms (estimated at US$ 0.2 billion) was well under one tenth of the average. In 2022, as an aggregate, flooding caused the highest economic losses in Australia, where the total was over US$ 8 billion, followed by Indonesia (over US$ 74 million) and the Philippines (over US$ 11 million). Storms also caused significant economic damage, especially in the Philippines (over US$ 144 million[41]) and Fiji (over US$ 25 million).

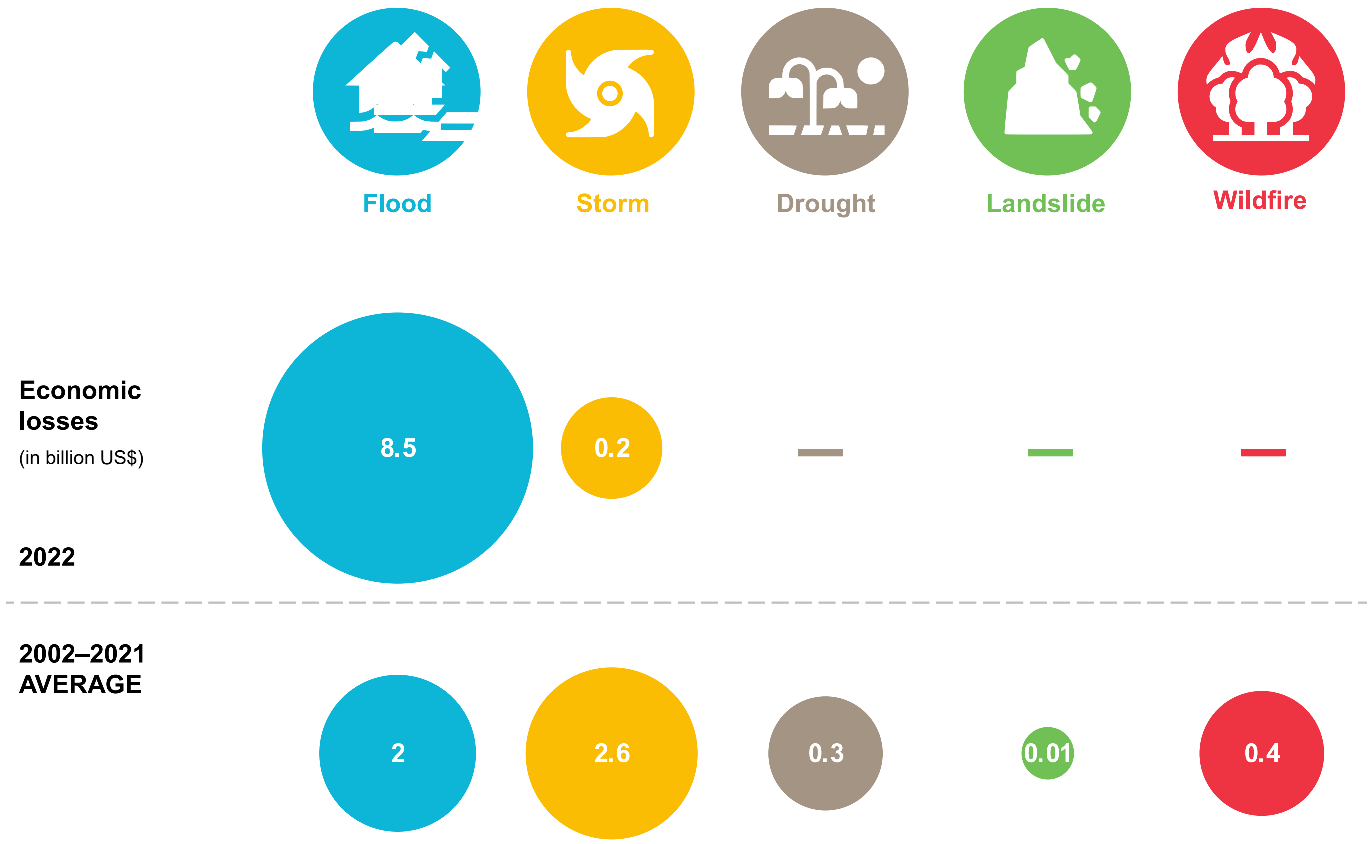


Figure 12. Economic losses in the South-West Pacific in 2022 from disasters, compared to the 20-year average (2002–2021). Note: The economic damages resulting from some disasters are not presented in the diagram due to data unavailability.
Source: ESCAP calculations based on EM-DAT data

Enhancing climate resilience and adaptation policies

FOOD SYSTEM RESILIENCE: THE NECESSITY

In many respects, 2022 was a year marked not only by compounding and cascading disasters, but also by underlying socioeconomic vulnerabilities, exposure and complex major disasters and global geopolitical events. The major disasters of 2022 fell across the development spectrum, from floods in Australia to drought in Kiribati and Tuvalu, impact of typhoons *Megi* and *Nalgae* in the Philippines, and earthquakes in Fiji and Indonesia.[42]

Looking at the sectoral impacts of disasters in 2022, agriculture continued to be the most heavily impacted sector, and this is especially visible in countries where the sector is important to the economy. The agriculture sector employs over 30% of the labour force in developing countries such as Indonesia and the Philippines. Disasters have a direct impact on the livelihoods of millions of small farmers and rural communities in developing countries. In Timor Leste, the floods in 2022 significantly aggravated existing challenges for a vulnerable population, creating long-lasting effects on food security for the affected population.[43] In Kiribati, the drought impacted access to drinking water and food crops. Some 119 000 people residing in Kiribati were affected, with people on Tarawa island most severely affected.[44] Disasters can change agricultural trade flows and cause losses in agriculture-dependent manufacturing subsectors such as the textile and food processing industries.[45] The 2021 report by the Food and Agriculture Organization of the United Nations (FAO) on the impact of disasters and crises on agriculture and food security[46] states that the agriculture sector absorbed 26% of the overall impact from medium- to large-scale disasters in low- and lower-middle-income countries. For climate-related disasters such as floods, droughts and tropical storms, more than 25% of all damages and losses are in the agriculture sector. Agriculture is the sector most affected by droughts, accounting on average for about 84% of all the economic impact.

Comprehensive risk management is a critical means for making food systems – and agri-food production in particular – more resilient. Risk reduction can protect development investments in agriculture as well as markets and transportation, ecosystems and child and maternal health. The sectors and systems that support and connect food systems and food security are highly interrelated. If risks at the producer level are not effectively managed, there can be cascading effects across all components of the food value chain, potentially leading to overall food system failures.

Adopting a comprehensive risk management approach is key to maintaining resilient food systems. The importance of food system resilience is also emphasized in the Nationally Determined Contributions (NDCs) submitted by Parties to the Paris Agreement. As of February 2023, 194 Parties, of which 20 are from the South-West Pacific, had submitted NDCs, and at least 15 of those 20 highlighted agriculture as their focus sector area for climate adaptation, followed by environment and water (Figure 13).

According to the Global Commission on Adaptation, without adaptation, climate change may depress growth in global agriculture yields by up to 30% by 2050.[47] According to the Indonesia's NDC, the Government considers climate adaptation and mitigation efforts to be integrated and essential for building resilience in safeguarding food, water and energy resources.[48] Globally, few small-scale farmers have adaptation mechanisms, such as access to resilient crops, drought-proof water supplies and the financing needed when disaster comes.

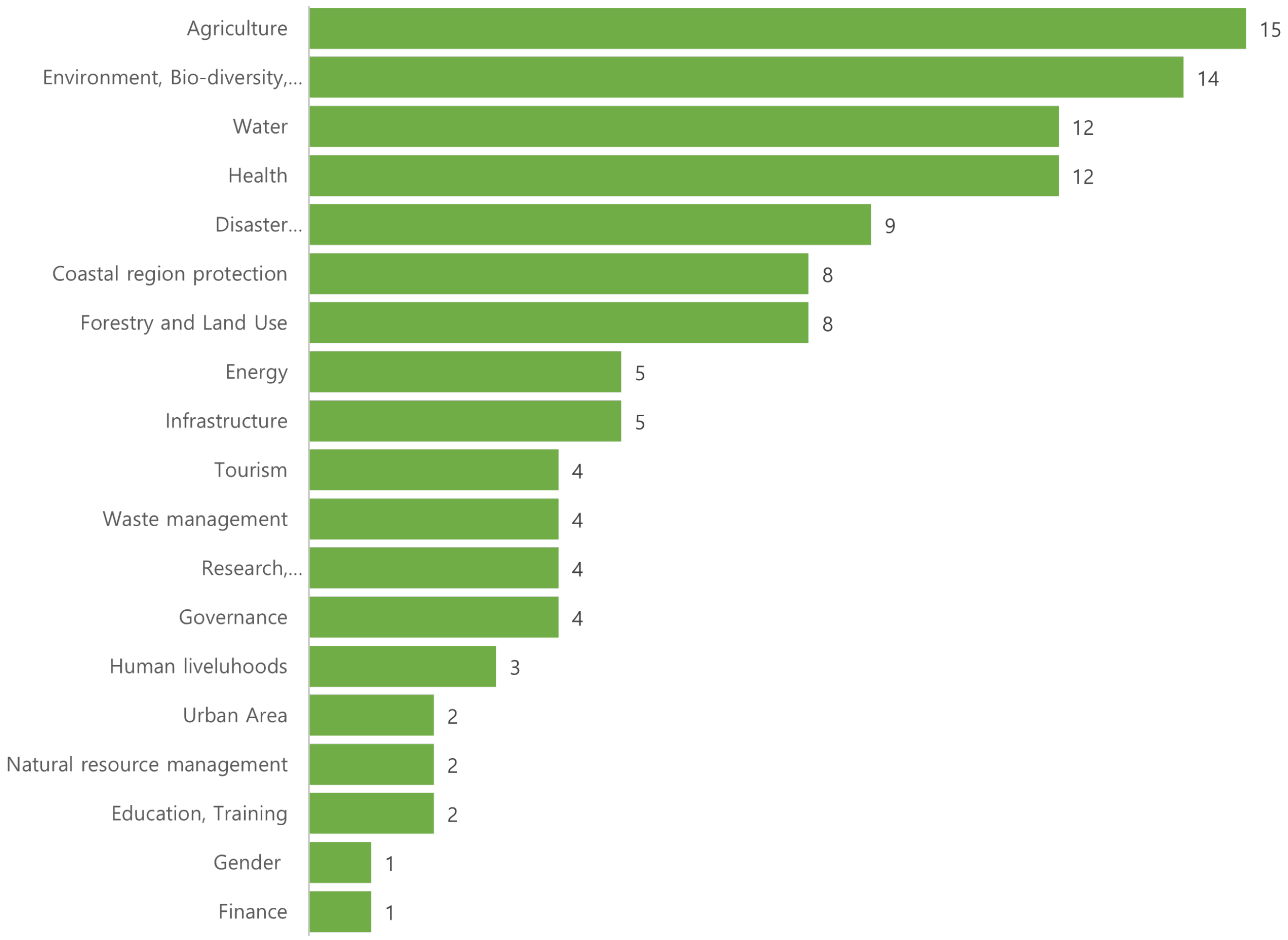


Figure 13. Priority areas for adaptation in the South-West Pacific region
Source: NDC registry, United Nations Framework Convention on Climate Change (UNFCCC)

RESILIENT FOOD SYSTEM: IMPACT-BASED FORECASTING AND ANTICIPATORY ACTIONS

Impact-based forecasting adopts the viewpoint of "what the weather will do" instead of "what the weather will be". By adding socioeconomic layers (such as age, gender and income level) as well as exposed assets (such as infrastructure and agricultural production quantity) to hazard layers (such as weather observations and climate projection data), it is possible to identify potential exposure and vulnerability in advance. For example, in subregional climate outlook forums, such as in the ASEAN Climate Outlook Forum (ASEANCOF), impact-based forecasting is presented using the consensus-based seasonal climate information along with critical exposure data, such as vegetation health condition indices, to estimate the potential exposure and the risk hotspots for agricultural crops attributable to abnormal precipitation levels. In this regard, impact-based forecasting has a potential to give sufficient lead time for farmers and other relevant stakeholders (actors in the supply chain and governments) to take adaptation measures, as can be shown in Figure 14.

Anticipatory action is an adaptation method which takes impact-based forecasting to the next level whereby early action precedes a disaster by systematically linking early warnings to early actions carried out before a disaster occurs. In food system resilience, this includes climate-informed food and land use systems planning, and early warning in advance of weather extremes to advise of potential damage to crops, food shocks, and global transport and trade disruptions.[49] Anticipatory actions in agriculture and food for slow-onset disasters, such as drought, include commercial animal destocking, animal health interventions and pre-positioning of emergency relief at the first early warning of the onset of dry conditions.

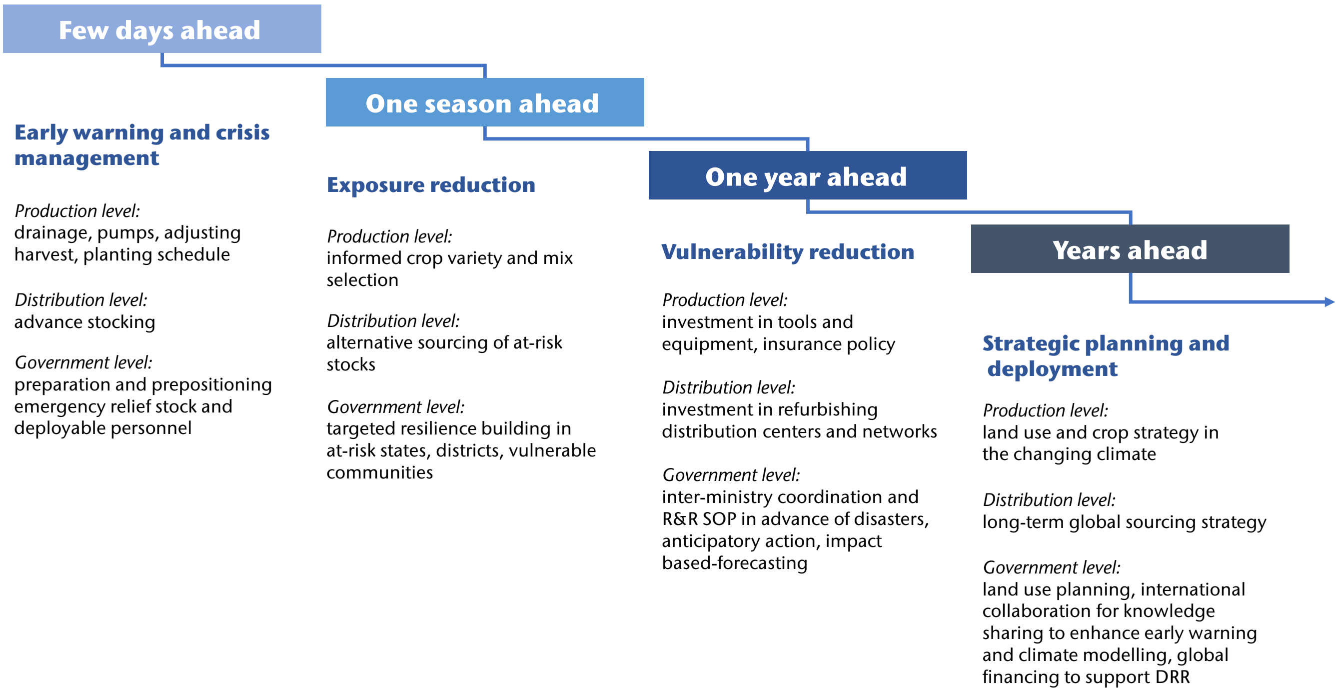


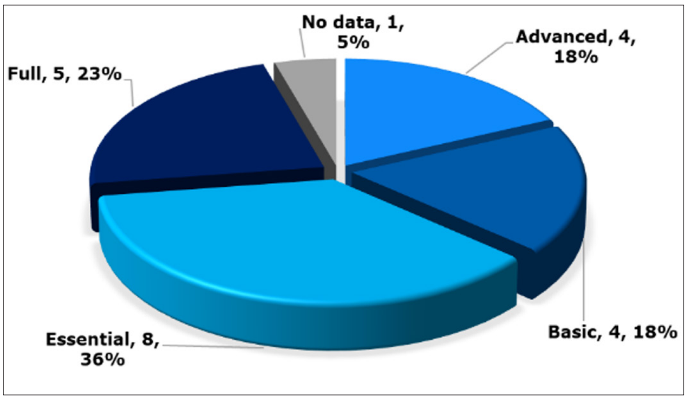
Figure 14. Examples of risk-management policy mix for food system resilience. Note: DRR – disaster risk reduction.
Source: ESCAP

OBSERVATIONS AND FORECASTING: INVESTING IN CLIMATE AND WEATHER SERVICES

Early warning is one of the most effective ways of reducing damage from disasters, as it empowers people to make risk-informed decisions. Early warning systems are estimated to provide more than a tenfold return on investment,[50] and a dependable multi-hazard early warning system serves as a backbone of a comprehensive risk-management policy mix to prevent and mitigate the effects of extreme weather on the food security and nutrition of highly vulnerable people. Unfortunately, hydrometeorological infrastructure, which is key to the early warning information value chain, is costly and underfunded, especially in developing countries. According to data from National Meteorological and Hydrological Services (NMHSs) in the South-West Pacific collected by WMO, only 18% of NMHSs in the region are providing climate services at an advanced level (according to WMO's guidelines,[51] this level involves providing customized climate products and climate application tools), while the majority (36%) are providing those services at an essential level (which involves providing seasonal climate outlooks and climate monitoring products) (Figure 15). Furthermore, monitoring and evaluation of the socioeconomic benefits of climate services and capacity development are lagging, as the available data show in the graph on the right side of Figure 15.

With respect to specific sector information, 94% of Members in the region reported providing climate services for the agriculture and food security sector; however, gaps in climate projections and tailored products still exist (Figure 16).

There are numerous existing initiatives on international and regional levels with aims to increase the capacity of climate and weather services. On a regional level, regional climate outlook forums, such as ASEANCOF and the Pacific Islands Online Climate Outlook Forum (PICOF), bring together climate experts and sector representatives to produce consensus-based forecasts and build mutual understanding between climate service providers and beneficiaries.



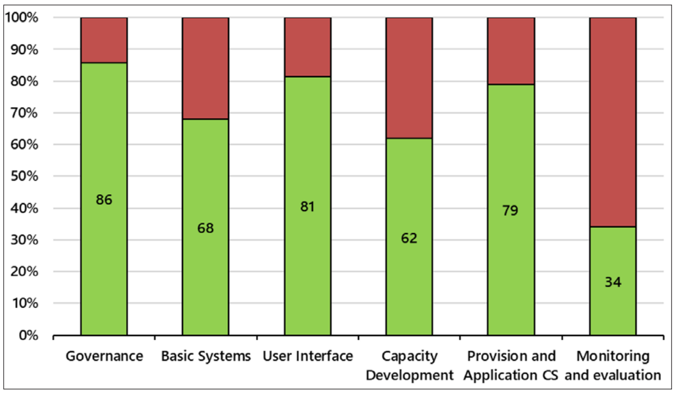


Figure 15. Percentage/number of Members in the South-West Pacific with the capacity to provide basic, essential, full and advanced climate services (left); overview of climate services, by value chain component: percentages of functionalities satisfied in value chain components based on data from WMO Region V (right). Note: CS – climate services.
Source: WMO climate service checklist data as of February 2023

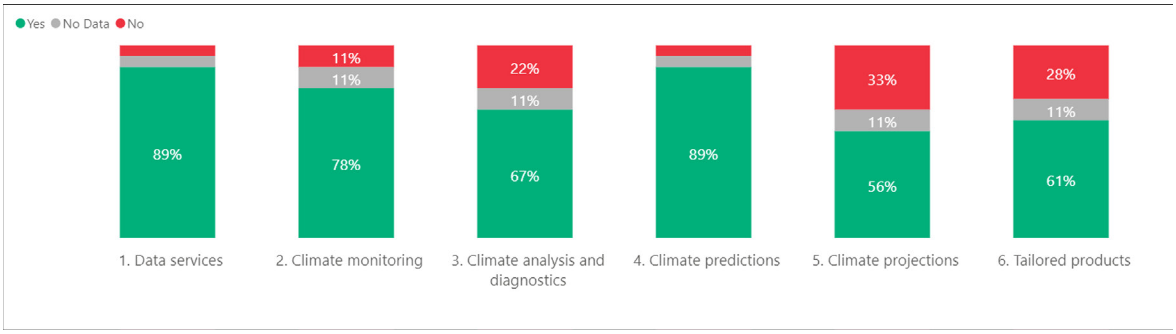


Figure 16. Percentage of National Meteorological and Hydrological Services providing specific services for the agriculture and food security sector
Source: WMO Climate services dashboard

Climate monitoring and predictions on multiple time scales, like climate watches and seasonal forecasts, can help with decisions, such as which variety of crops to plant and when, how much water will be needed for irrigation, whether any disease outbreaks are likely to occur or whether to reduce numbers of livestock in case of drought. Highly variable seasonal rainfall, increases in temperature and frequency of extreme climate events due to climate change together with growing demand for food and energy place significant stress on food system resilience. The necessity of early warning and climate services and their application are growing in this context.

WMO and the United Nations Office for Disaster Risk Reduction (UNDRR) are co-leading the Early Warnings for All initiative to ensure that everyone on Earth is protected by early warnings in the next five years. The Early Warnings for All Executive Action Plan[52] was launched by United Nations Secretary-General António Guterres at the twenty-seventh session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP27) in Sharm el-Sheikh, Egypt. To ensure the success of this initiative in the region, the WMO Regional Conference of Regional Association V (South-West Pacific) held in September 2022 recommended that consideration be given to establishing a Special Task Group to analyse the current status and critical gaps regarding early warning systems and develop an initial action plan for the Regional Association to move forward.

Data sets and methods

REGION DOMAIN

The focus of this report is WMO Region V, the extent of which can be seen in the map in Figure 17.

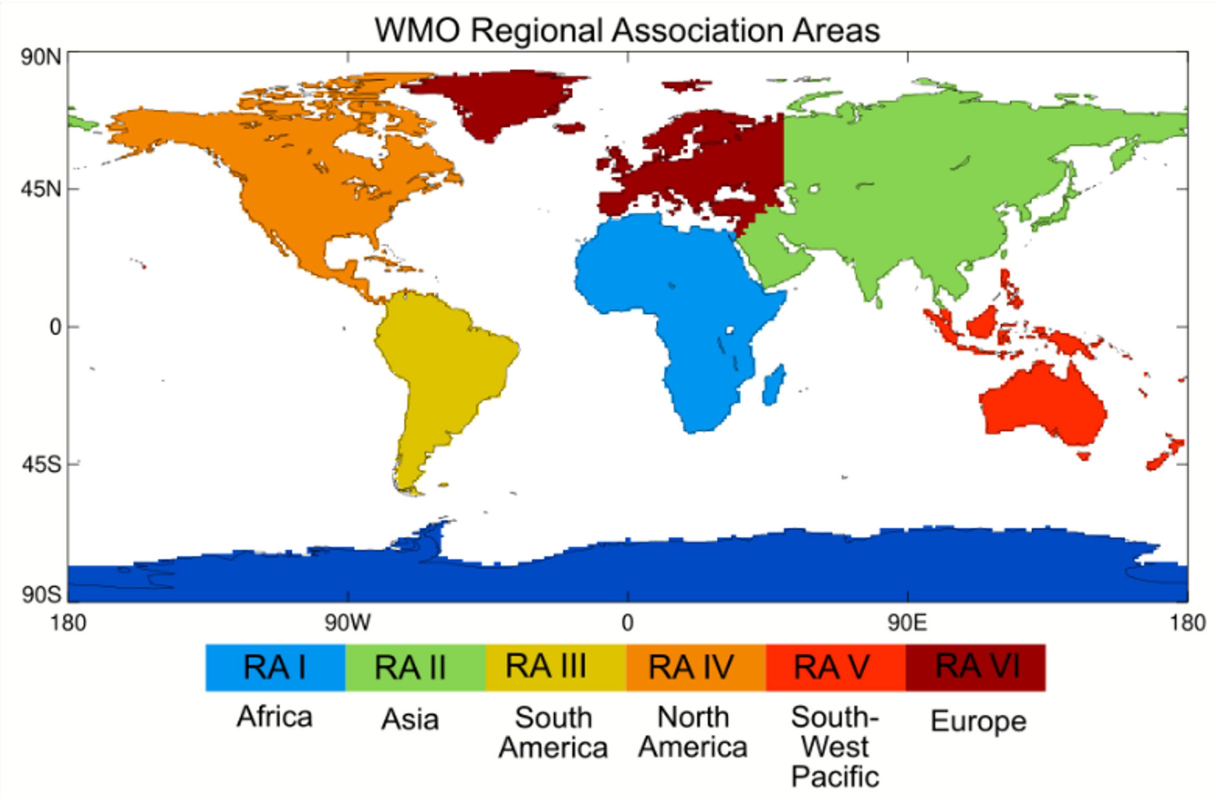


Figure 17. Map of WMO Regional Association (RA) areas. WMO Region V is the focus of this report.

TEMPERATURE

Six data sets (cited below) were used in the calculation of regional temperature.

Regional mean temperature anomalies were calculated relative to 1961–1990 and 1991–2020 baselines using the following steps:

1. Read the gridded data set;
2. Regrid the data to 1° latitude × 1° longitude resolution. If the gridded data are higher resolution, then take a mean of grid boxes within each 1°×1° grid box. If the gridded data are lower resolution, then copy the low-resolution grid box value into each 1°×1° grid box that falls inside the low-resolution grid box;
3. For each month, calculate the regional area average using only those 1°×1° grid boxes whose centres fall within the region;
4. For each year, take the mean of the monthly area averages to obtain an annual area average;
5. Calculate the mean of the annual area averages over the periods 1961–1990 and 1991–2020;
6. Subtract the 30-year period average from each year.

The following six data sets were used:

Berkeley Earth – Rohde, R. A.; Hausfather, Z. The Berkeley Earth Land/Ocean Temperature Record. *Earth System Science Data* **2020**, *12* (4), 3469–3479. https://doi.org/10.5194/essd-12-3469-2020.

ERA5 — Hersbach, H.; Bell, B.; Berrisford, P. et al. *ERA5 Monthly Averaged Data on Single Levels from 1940 to Present*; Copernicus Climate Change Service (C3S) Climate Data Store (CDS), 2023. https://doi.org/10.24381/cds.f17050d7.

GISTEMP v4 — GISTEMP Team, 2022: GISS Surface Temperature Analysis (GISTEMP), version 4. NASA Goddard Institute for Space Studies, https://data.giss.nasa.gov/gistemp/. Lenssen, N.; Schmidt, G.; Hansen, J. et al. Improvements in the GISTEMP Uncertainty Model. *Journal of Geophysical Research: Atmospheres* **2019**, *124* (12), 6307–6326. https://doi.org/10.1029/2018JD029522.

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GLACIERS

The description of glaciers in Indonesia is based on the contribution from the Badan Meteorologi, Klimatologi, dan Geofisika (BMKG, Indonesia).

OCEAN HEAT CONTENT

Data are from the in situ-based product https://doi.org/10.48670/moi-00052, downloaded from Copernicus Marine Service.

SEA-SURFACE TEMPERATURE

Data are from the Copernicus Marine Service remote sensing products available at https://doi.org/10.48670/moi-00168 (for 1982–2021) and https://doi.org/10.48670/moi-00165 (for 2022).

SEA LEVEL

Regional sea-level trends are based on gridded C3S altimetry data averaged from 50 km offshore to the coast by the Laboratory of Space Geophysical and Oceanographic Studies (LEGOS).

EXTREME EVENTS

Meteorological characteristics and statistics are based on reports from WMO Members in Regional Association V (South-West Pacific). Associated socioeconomic impacts are based on reports from WMO Members, EM-DAT data (see below) and UN organization reports.

EM-DAT DATA

EM-DAT data were used for historical climate impact calculations: www.emdat.be. EM-DAT is a global database on natural and technological disasters, containing essential core data on the occurrence and effects of more than 21 000 disasters in the world, from 1900 to the present. EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the School of Public Health of the Université catholique de Louvain located in Brussels, Belgium.

The indicators used for mortality, number of people affected and economic damage were total deaths, no. affected and total damages ('000 US$) respectively.

CLIMATE SERVICES

WMO Analysis of NDCs

Checklist for Climate Services Implementation (Members' climate services capacity, based on responses to this Checklist, can be viewed here)

WMO Hydrology Survey, 2020

2020 State of Climate Services: Risk Information and Early Warning Systems (WMO-No. 1252)

2021 State of Climate Services: Water (WMO-No. 1278)

WMO Climate services dashboard

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Endnotes

1 "Maritime Continent" is a term commonly used by meteorologists, climatologists and oceanographers to describe the region between the Indian and Pacific Oceans, including the archipelagos of Indonesia, the islands of Borneo and New Guinea, the Philippine Islands, the Malay Peninsula and the surrounding seas.

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