State of the Climate in the South-West Pacific

2024

WEATHER CLIMATE WATER

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Cover: State Highway 80 leading towards Mount Cook in the Southern Alps of New Zealand. This image was modified by generative AI in Adobe Photoshop.
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Contents

We need your feedback

This year, the WMO team has launched a process to gather feedback on the *State of the Climate* reports and areas for improvement. Once you have finished reading the publication, we ask that you kindly give us your feedback by responding to this short survey. Your input is highly appreciated.

Key messages

The year 2024 was the warmest year on record in the South-West Pacific region, at approximately 0.48 °C above the 1991–2020 average.

Extreme heat affected large parts of the region in 2024, with record-breaking temperatures in Australia and the Philippines, posing serious risks to public health, livelihoods and ecosystems.

Sea-level rise across the region exceeds the global average, posing a particular threat to the Pacific islands, where more than half the population live within 500 m of the coast. Adapting to rising sea levels presents complex challenges beyond physical solutions. On Fiji's Serua Island, deep ancestral ties to the land highlight how relocation involves significant cultural and spiritual considerations.

In Indonesia, glacier ice loss continued rapidly in 2024, with the total ice area in the western part of New Guinea declining by 30%–50% since 2022.

The late 2024 tropical cyclone season in the Philippines was unprecedented, with 12 storms in the September–November period – more than double the average. Strengthened early warning systems and anticipatory action in the Philippines enabled communities to prepare and respond to the storms, helping to protect lives, and ensure dignified, timely support as climate-related shocks become more frequent and intense.

Widespread extreme rainfall and flooding caused deadly and destructive impacts across the region, with major events in Australia, New Zealand, Fiji, Malaysia, Indonesia and the Philippines disrupting communities, infrastructure and economies.

In 2024, ocean warming in the South-West Pacific reached unprecedented levels, with record-breaking sea-surface temperatures, near-record ocean heat content, and nearly 40 million km^2 affected by marine heatwaves – the largest area since 1993.

The year 2024 was the warmest on record in the South-West Pacific. Ocean warming reached unprecedented levels, with record-breaking sea-surface temperatures. Nearly 40 million km^2 of ocean were affected by marine heatwaves – this is more than 10% of the global ocean surface area, or almost the size of the Asian continent. Ocean heat and acidification combined to inflict long-lasting damage on marine ecosystems and economies. Sea-level rise is an existential threat to entire island nations. It is increasingly evident that we are fast running out of time to turn the tide.

(Prof. Celeste Saulo)
Secretary-General

Global climate context

The global annual mean near-surface temperature in 2024 was 1.55 °C [1.42 °C to 1.68 °C] above the 1850–1900 pre-industrial average and 1.19 °C [1.15 °C to 1.24 °C] above the 1961–1990 baseline. The global mean temperature in 2024 was the highest on record for the period 1850–2024 according to all six datasets that WMO uses to monitor global mean temperature,[1] beating the previous record of 1.45 °C [1.32 °C to 1.57 °C] set in 2023. Each of the years from 2015 to 2024 was one of the 10 warmest years on record.

Atmospheric concentrations of the three major greenhouse gases reached new record observed highs in 2023, the latest year for which consolidated global figures are available, with levels of carbon dioxide (CO_2) at 420.0 ± 0.1 parts per million (ppm), methane (CH_4) at 1 934 ± 2 parts per billion (ppb) and nitrous oxide (N_2O) at 336.9 ± 0.1 ppb – respectively 151%, 265% and 125% of pre-industrial (before 1750) levels (Figure 1). Real-time data from specific locations, including Mauna Loa[2] (Hawaii, United States of America) and Kennaook/Cape Grim[3] (Tasmania, Australia) indicate that levels of CO_2, CH_4 and N_2O continued to increase in 2024.

The rate of ocean warming over the past two decades (2005–2024) was more than twice that observed over the period 1960–2005, and the ocean heat content in 2024 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 4.7 mm per year between 2015 and 2024, reaching a new record observed high in 2024. The ocean is a sink for CO_2. Over the past decade, it absorbed about one quarter of the annual emissions of anthropogenic CO_2 into the atmosphere.[4] CO_2 reacts with seawater and alters its carbonate chemistry, resulting in a decrease in pH, a process known as “ocean acidification”.

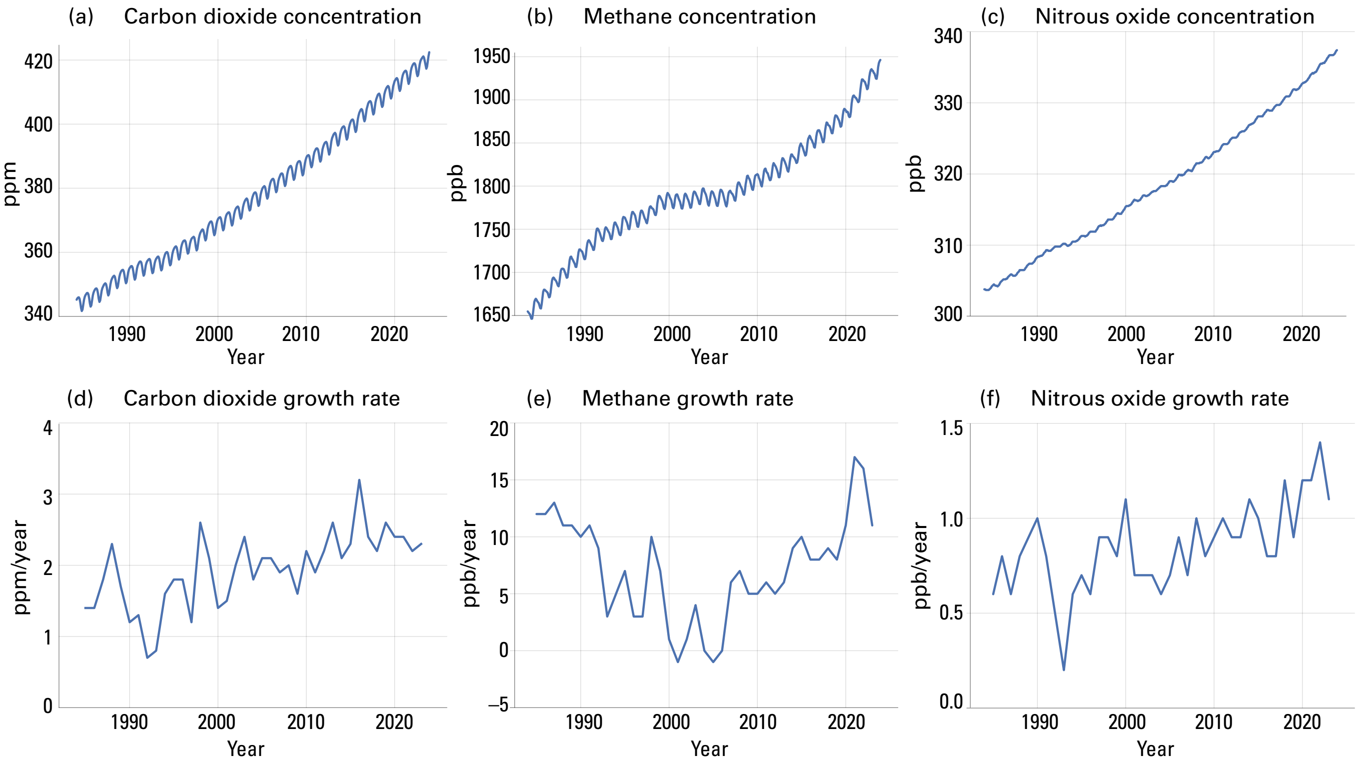


Figure 1: Top row: Monthly globally averaged mole fraction (measure of atmospheric concentration), from 1984 to 2023, of (a) CO_2 in parts per million, (b) CH_4 in parts per billion and (c) N_2O in parts per billion. Bottom row: Growth rates representing increases in successive annual means of mole fractions 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 climate indicators in the South-West Pacific. Some of the indicators are described in terms of anomalies, or departures from a reference period. Where possible, the most recent WMO climatological standard normal, 1991–2020, is used as a reference period for consistent reporting. Exceptions to the use of this reference period are explicitly noted.

TEMPERATURE

Variations in surface temperature have a large impact on natural systems and human beings.

The annual mean surface temperature averaged over both land and ocean areas in 2024 in the South-West Pacific region ranked as the warmest on record (Figure 2, top). The mean value for 2024 was 0.48 °C above the 1991–2020 average [0.44 °C–0.55 °C, depending on the dataset used]. Relative to a 1961–1990 baseline,[5] the mean value for 2024 was 0.81 °C [0.73 °C –0.85 °C, depending on the data set used] above the average. The year 2024 was warmer than 2023, due in part to continued influence from the 2023/2024 El Niño event. The years when an El Niño event decays are typically warmer in the South-West Pacific region than the years an El Niño event forms.

Temperatures in 2024 were higher than the 1991–2020 average over most of the region (Figure 2, bottom). From Malaysia and the Philippines, across to Vanuatu and down to southern Australia, temperatures were generally 0.5 °C to 1.0 °C above the 1991–2020 average. For many countries within this area, including Brunei Darussalam, the Philippines and Singapore, 2024 was the warmest year on record based on their national datasets. Below-average temperatures were recorded over only a few oceanic regions, including to the south of French Polynesia and to the south-west of New Zealand.

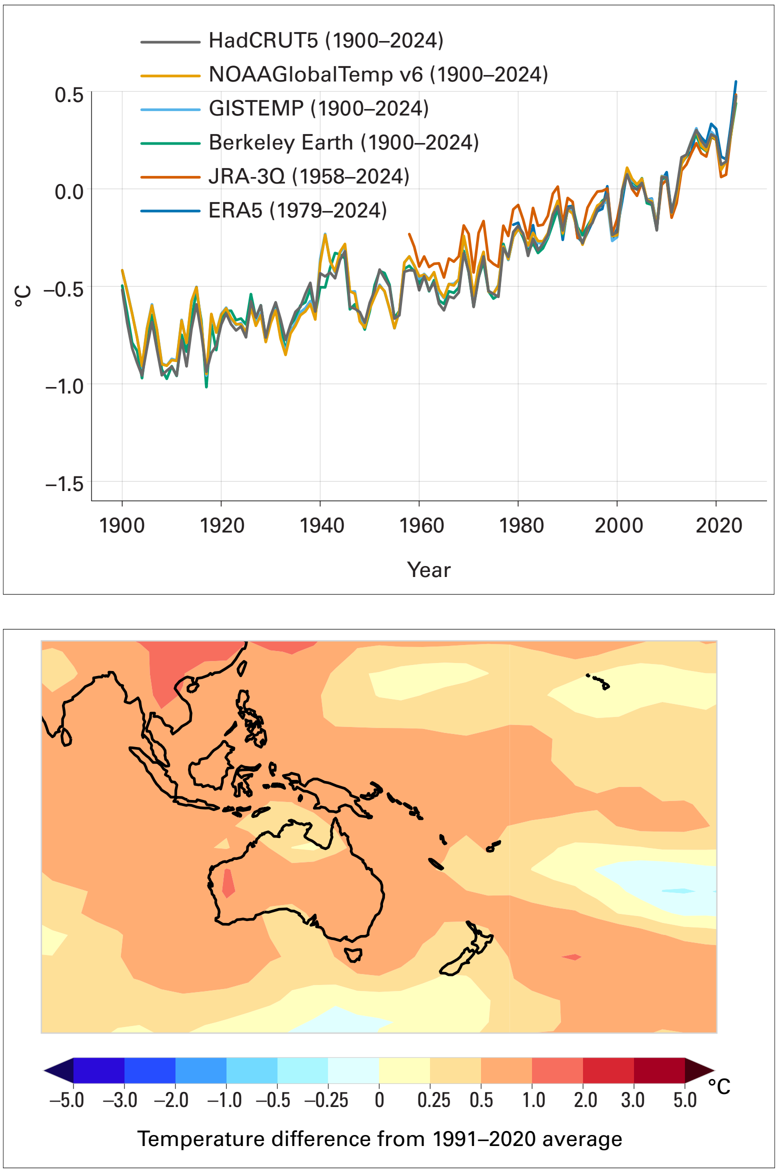


Figure 2. Annual regional mean land and ocean temperature for WMO Region V, South-West Pacific (°C, difference from the 1991–2020 average) from 1900 to 2024 (top) and annual near-surface temperature anomalies (°C, difference from the 1991–2020 average) for 2024 (bottom)

Source: Third-party map. The map (bottom) was taken from https://doi.org/10.5281/zenodo.3783894 in January 2025 and may not fully align with United Nations and WMO map guidance. HadCRUT5, Berkeley Earth, NOAAGlobalTemp and GISTEMP are based on in situ observations. ERA-5 and JRA-3Q are regional reanalysis datasets. For details on the datasets and the plotting, see Temperature data.

PRECIPITATION

Precipitation provides water for drinking, domestic uses, agriculture, industry and hydropower. Precipitation variations also drive droughts and floods.

In 2024 (Figure 3), the most significant precipitation deficits (those areas with precipitation amounts within the driest 20% of years between 1991 and 2020) were observed along the southern coast of Australia, in northern New Zealand, and in many Pacific islands, including the west coast of New Caledonia's Grande Terre, the Cook Islands, the Marshall Islands and Hawaii.

The most significant above-average precipitation amounts (those areas within the wettest 20% of years between 1991 and 2020) were recorded in parts of Malaysia, Indonesia, the northern Philippines, northern Australia, eastern Papua New Guinea, the Solomon Islands and southern New Zealand.

CRYOSPHERE

Snow is rare or unknown at low elevations over most of the region; however, snow and ice occur in some mountain areas. 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 a significant area of seasonal snow cover in the highland areas of New Zealand and southern Australia.

In New Zealand, 2024 winter maximum depths at high-elevation monitoring sites varied between 0.3 and 2.8 m and were between 41% and 179% of the climatological values.[6] The Murchison Mountains (Southland, 1 140 m elevation) had the lowest fraction of average snow depth, at 31% of its climatological average. Mt Larkins (Otago, 1 900 m elevation) had the highest fraction of average snow depth, at 140% of its climatological average. In mid-August, most sites from Mueller Hut (Canterbury, 1 818 m elevation) southward had below-average snow depths, with some (such as Mt Larkins) at record-low levels for the time of year and others (such as Mueller Hut) approaching such levels. However, consistent snowfall through September and October brought snow depths up to above average at these sites. Rapid melt then occurred during late October and November, and melt-out dates (when no snow remained) were either early or around usual. Melt out at Mueller Hut occurred on 4 December 2024, the second earliest date on record for this site.

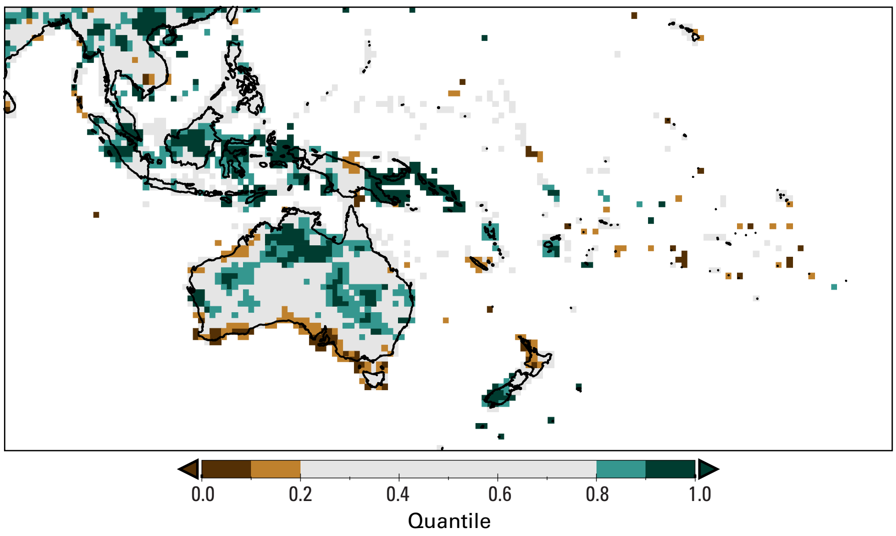


Figure 3. Precipitation anomalies for 2024 expressed as a quantile (difference from the 1991–2020 long-term average). Brown shading indicates regions where the annual rainfall amount was equal to or less than the driest 20% of years, while green shading indicates regions where the rainfall was equal to or greater than the wettest 20% of years between 1991 and 2020. National assessments may differ slightly due to small local features not captured by the global dataset.

Source: Third-party map. This map was taken from the Global Precipitation Climatology Centre (GPCC), Deutscher Wetterdienst (DWD), Germany, in February 2025 and may not fully align with United Nations and WMO map guidance.

In Australia, mountain snowpacks were generally below average for the second successive year. The longest-running snow depth measurement site, Spencers Creek (near Perisher Valley in New South Wales, 1 830 m elevation) reached its peak depth of 1.23 m on 30 July. The peak depth was about 35% below average and slightly below that of 2023, and snow depths were only above 1 m for about a month in late July and August. As in 2023, the start of the season was near its average date, but melting was abnormally early, with no snow cover remaining by early October. There were also few significant low-elevation snowfalls in mainland Australia.

In Indonesia, satellite estimates show a total ice area in the western part of the island of New Guinea in August 2024 of 0.11–0.16 km^2, a decrease of 30%–50% from the previous assessment of 0.23 km^2 in April 2022. This is consistent with the average ice coverage loss rate of ~0.07 km^2 per year during 2016–2022 (Figure 4). If this rate persists, total ice loss is expected in 2026 or very soon thereafter. In June 2010, a flexible accumulation stake was placed in an ice core borehole (4° 03′ S; 137° 11′ E). Around the end of 2023 and beginning of 2024, the ice thickness was about ~4 m. The ice has been thinning at a rate of 2–2.5 m/year since 2016.[7]

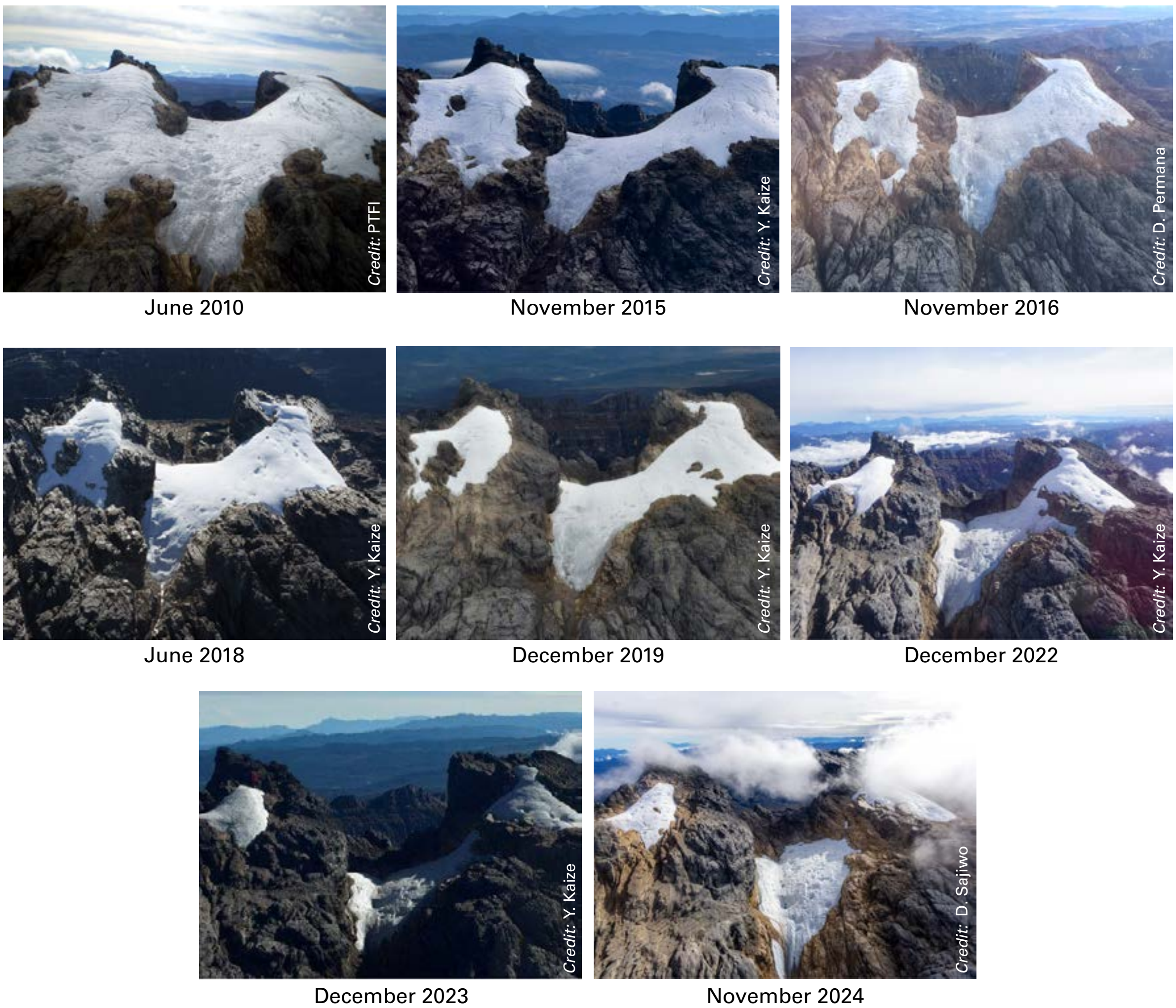


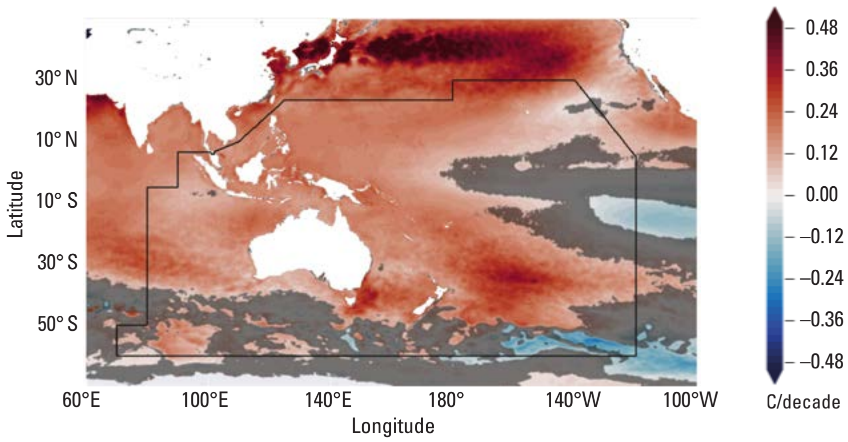
Figure 4. Oblique aerial photographs of the East Northwall Firn glaciers (Puncak Jaya, Indonesia), taken in June 2010, November 2015, November 2016, June 2018, December 2019, December 2022, December 2023 and November 2024

OCEANS

SEA-SURFACE TEMPERATURE

Variations in sea-surface temperature (SST) alter the transfer of energy, momentum and gases between the ocean and the atmosphere.

Most of the oceanic area of the WMO South-West Pacific region experienced surface ocean warming (Figure 5, top). SSTs in the central–eastern tropical Pacific Ocean show a nearly unchanged or slight cooling trend, likely associated with the increased incidence of La Niña events in the latter part of the period, moderating the long-term warming trend for the region. The area-averaged time series for the South-West Pacific region indicates average SST warming at a rate equivalent to the global mean rate (von Schuckmann et al., 2024). The annual average SST in the year 2024 breaks the record across the time series starting in the early 1980s (Figure 5, bottom).



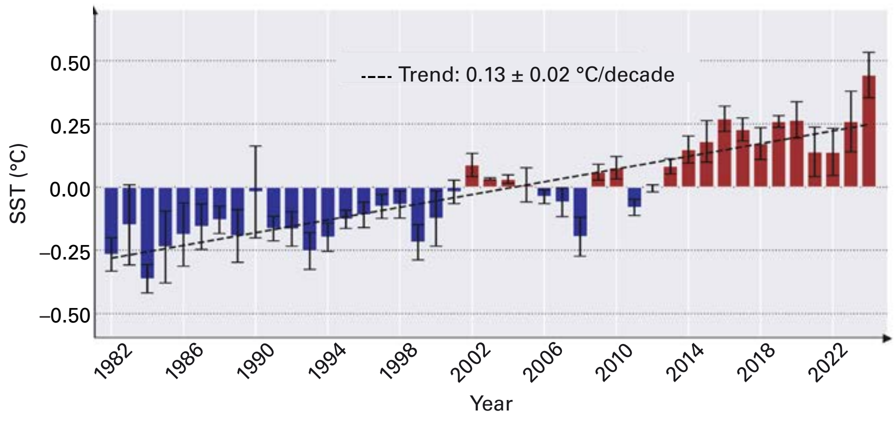


Figure 5. Top: Map of regional SST trends over the period 1982–2024 using the Copernicus Marine Service Operational Sea Surface Temperature and Ice Analysis (OSTIA) product. Grey areas indicate where less agreement could be obtained from an ensemble of three international SST products (Copernicus Marine OSTIA, Copernicus Marine ESA CCI, NOAA OISST). WMO Region V, South-West Pacific, is outlined in black. Bottom: SST anomalies averaged over WMO Region V, South-West Pacific, relative to the 1982–2024 reference period. The dashed line indicates the linear trend over the period. The Copernicus Marine OSTIA product was used to generate this graph, and the ensemble of this product with the other products (ESA CCI up to 2022; NOAA OISST up to 2024) was used to provide the annual mean ensemble spread (two standard deviations, black lines).

Source: Third-party map. The map (top) was taken from Copernicus Climate Change Service and Mercator Ocean International in April 2025 and may not fully align with United Nations and WMO map guidance.

OCEAN HEAT CONTENT

Ocean warming contributes to sea-level rise and alters ocean currents. It also indirectly alters storm tracks, increases ocean stratification and can lead to changes in marine ecosystems.

The Pacific and Indian Ocean fractions of the WMO South-West Pacific region show overall ocean warming (Figure 6, top). Areas of strongest ocean warming over the past five decades include the Tasman Sea, the Solomon Sea and most of the areas around the Pacific small island States (Figure 6, top). The 2024 area-averaged ocean heat content for the WMO South-West Pacific region matched those in 2021 and 2023 as joint second highest, behind 2022. The time series is dominated by large variations at inter-annual to decadal time scales (Figure 6, bottom).[8]

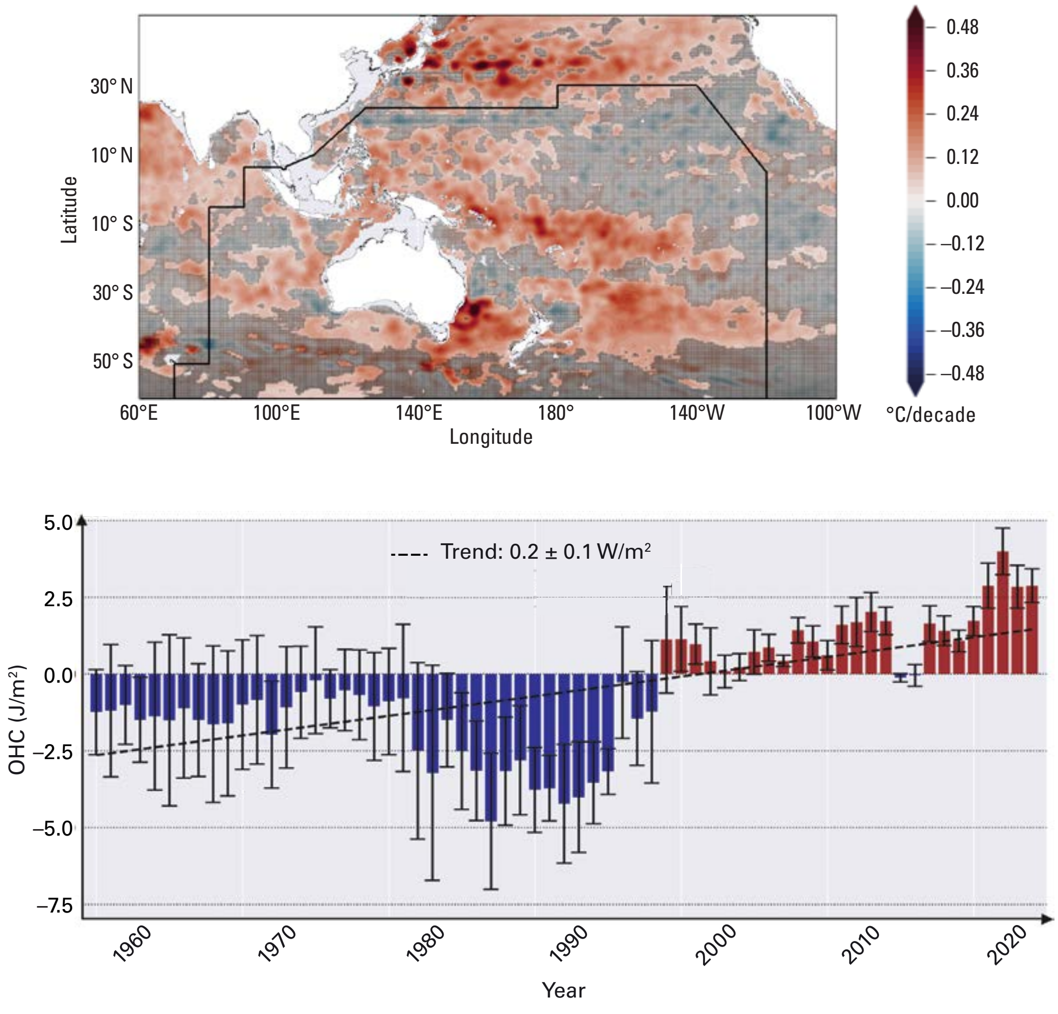


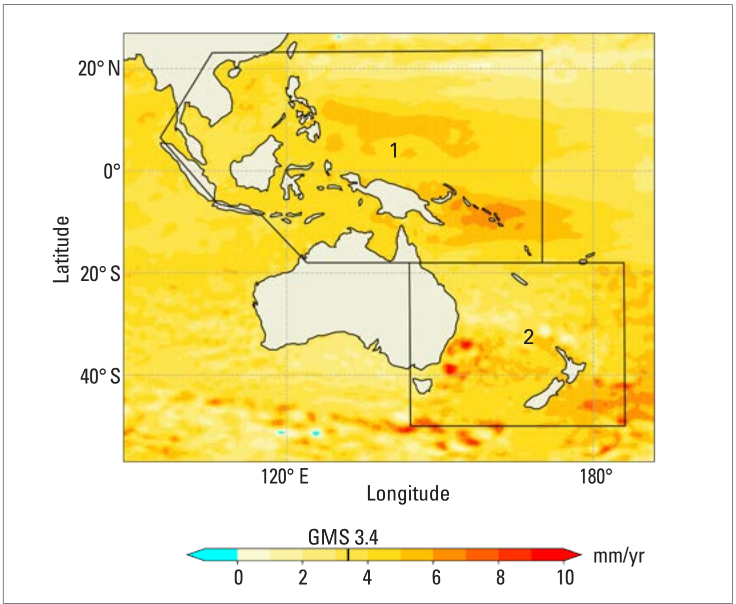
Figure 6. Top: Ocean heat content (OHC) trend (units: watts per square metre, W/m^2) over the period 1971–2024, integrated from the surface down to 700 m depth. Grey areas indicate where less agreement could be obtained from an ensemble of four different international ocean subsurface temperature products (Copernicus Marine; NOAA; EN4; IAP). Bottom: Area-mean ocean heat content averaged over the WMO South-West Pacific region relative to the 1960–2024 reference period. The dashed line indicates the linear trend over the period. The Copernicus Marine product has been used, and the ensemble of the four products is used to provide the annual mean ensemble spread (2 standard deviations, black lines).

Source: Third-party map. The map (top) was taken from Copernicus Climate Change Service and Mercator Ocean International in April 2025 and may not fully align with United Nations and WMO map guidance.

SEA LEVEL

Sea level rises in response to ocean warming (via thermal expansion) and the melting of glaciers, ice caps and ice sheets, thereby affecting the lives and livelihoods of coastal communities and low-lying island nations.

In 2024, the sea level continued to rise, as shown by high-precision satellite altimetry measurements (Figure 7, top). However, the rate of rise is not the same everywhere.



In the South-West Pacific region, the sea-level rise of the last three decades exceeds the global mean of 3.5 mm ± 0.3 mm/year. Sea-level time series from January 1993 to November 2024 have been averaged over two areas within the region (Figure 7, bottom left and bottom right), respectively. The mean rate of sea-level rise in both areas (3.95 mm ± 0.22 mm/year in area 1 and 3.93 mm ± 0.08 mm/year in area 2) is significantly higher than the global mean. The sea-level time series in area 1 (Figure 7, bottom left) displays strong inter-annual variability, mostly driven by the El Niño–Southern Oscillation (ENSO), with drops in sea level associated with El Niño in 1997/1998, 2015/2016, and to a lesser extent in 2023/2024.

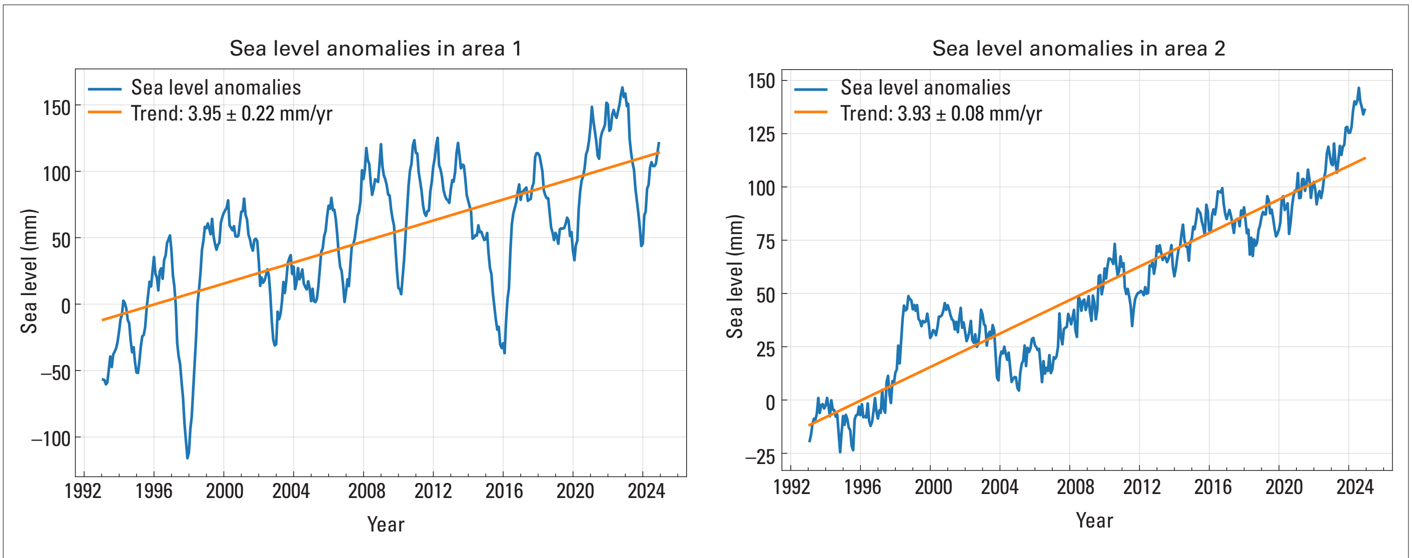


Figure 7. Altimetry-based sea-level time series (mm) from January 1993 to November 2024 for the western tropical Pacific Ocean (area 1) and the south-western Pacific Ocean (area 2). The map (top) shows the annual mean sea-level trend (mm/year) and location of areas summarized in the plots at the bottom left and bottom right. The plots show mean sea-level anomalies (blue) and estimated trend (orange line) for areas 1 and 2, respectively.

Source: Third-party map. The map (top) was taken from Copernicus Climate Change Service and Laboratory of Space Geophysical and Oceanographic Studies (LEGOS), France, in January 2025 and may not fully align with United Nations and WMO map guidance.

OCEAN ACIDIFICATION

Ocean acidification refers to the shift in the carbonate chemistry towards a less basic state (decrease in pH) and is a consequence of the increasing uptake of CO_2 by the oceans. Ocean acidification, together with ocean warming and deoxygenation, is affecting marine ecosystems, habitats and biodiversity.

The entire ocean area of the South-West Pacific region is experiencing ocean acidification, with the most intense decreases in regional surface pH observed in the Pacific around 10°N, the Great Australian Bight, the Tasman and Coral Seas, and in the area south of 50°S. On average for the region, the pH decreased by 0.017 ± 0.001 per decade over the period 1985–2023.[9]

Extreme events

Month	*Area*	*Event*
January–February	Philippines	Extreme rainfall in late January and early February in eastern Mindanao, associated with an active phase of the north-east monsoon, caused significant flooding and contributed to a landslide on 6 February in which at least 93 deaths were reported.
January–March	Australia	For the second successive year, there was widespread major flooding in northern Australia during the tropical wet season. The first significant single flood episode, resulting from a tropical low, affected the Northern Territory during mid-January, focused on the Victoria River catchment in the north-west. Victoria River Downs received 315.4 mm of rain in four days from 15 to 18 January. There were further heavy rain episodes through late March, with record flood heights on the McArthur River at Borroloola after Cyclone *Megan* crossed the Gulf of Carpentaria coast on 19 March. Victoria River Downs's ultimate annual total of 1 513.4 mm, most of which fell between January and March, exceeded its previous record by more than 300 mm. There was also major flooding in the Nullarbor region in southern Western Australia, badly disrupting road and rail transport between Western Australia and the eastern states, with 325.4 mm of rain falling in four days at Eyre during 9–12 March.
February	Australia	A significant heatwave affected Western Australia in February. On 18 February, Carnarvon reached 49.9 °C and Geraldton reached 49.3 °C, in both cases more than 2 °C above the previous highest temperature observed in more than 100 years of data. Emu Creek reached 48 °C on four consecutive days from 17 to 20 February, the first time this had occurred at an Australian location. This contributed to 2023/2024 being the hottest summer on record for many parts of Western Australia.
February–May	Philippines, Malaysia	Extreme heat affected the Philippines at various times during the year, most significantly in April at the same time as a major heatwave in mainland South-East Asia. On 27 April, 38.8 °C was observed at Ninoy Aquino International Airport, the highest temperature on record for a site in metropolitan Manila. Records were also set at a number of other Philippines locations. Numerous heatwaves were also reported in Malaysia between February and May, with temperatures of 37 °C to 40 °C over three or more consecutive days in each event.
March	Indonesia	The Indonesian island of Sumatra experienced significant flash flooding in March, with daily rainfalls as high as 505 mm, recorded on 8 March at Limau Manih Andalas University, in the city of Padang.

Month	*Area*	*Event*
July, October	Philippines	The Philippines was impacted by the strongest typhoon of the season in the north-west Pacific, *Krathon* (*Julian*), which reached a minimum central pressure of 920 hPa on 1 October in waters between the Philippines and Taiwan, province of China. Basco received 727.8 mm of rain in 24 hours. Flooding in July associated with Typhoons *Gaemi* (*Carina*) and *Prapiroon* (*Butchoy*), combined with monsoon rains, also had significant impacts through the country.
August	Australia	A notable early-season heatwave brought an Australian record high temperature for August of 41.6 °C on 26 August at Yampi Sound (Western Australia), while there were also August records for the Northern Territory (40.0 °C at Bradshaw – Angallari Valley) and Queensland (39.7 °C at Birdsville and Boulia).
October	New Zealand	In New Zealand, there was significant flooding in early October in the southern and eastern South Island, particularly in and around the city of Dunedin, with numerous properties inundated and many road closures. Dunedin (Musselburgh) received 131 mm of rain on 3 October, its wettest October day on record.
October–November	Philippines	The Philippines experienced a notable sequence of tropical cyclones in October and November. In a period of less than a month between 24 October and 17 November, five tropical cyclones made landfall in the Philippines, all crossing the island of Luzon (and in some cases also other islands), while a sixth passed close enough to the coast to have significant impacts. (See the Philippines case study for further details.)
November, December	Malaysia, Singapore	Significant flooding occurred in north-eastern peninsular Malaysia in late November and early December, associated with an active phase of the north-east monsoon. Besut, in Terengganu state, received 712.2 mm on 27 November. Six deaths were reported, and 137 000 people were displaced. It was also the wettest November on record for Singapore based on island-wide average rainfall.
December	Fiji	Significant flooding occurred in late December, particularly in western and northern Viti Levu, as a result of an active low-pressure trough followed by the passage of a tropical depression on 29–31 December. A number of stations, including Nadi Airport, received two to three times their normal December monthly rainfall.

TROPICAL CYCLONES

The South-West Pacific region encompasses the Australian and South Pacific tropical cyclone areas (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 areas. The tropical cyclone season in the southern hemisphere basins typically runs from November to April, while in the western North Pacific tropical cyclone activity peaks between June and November, although cyclones can occur at any time of year.

In the southern hemisphere, the 2023/2024 tropical cyclone season was below average in terms of the total number of named tropical cyclones that formed in both the South Pacific and Australian basins. This was also the fifth year in a row with a below-average number of named storms over the Australian basin and the third in a row for the South Pacific. Over the South Pacific, there were five named storms, including two which were considered severe tropical cyclones (category 3 or above): Tropical Cyclones *Lola* (October 2023) and *Mal* (November2023). The Australian area had eight named storms over the season, including six which were considered severe tropical cyclones; of these, Tropical Cyclones *Jasper* (December 2023) and *Olga* (April 2024) both reached category 5.

The pattern of tropical cyclone activity in the southern hemisphere was typical of El Niño conditions, which usually result in decreased activity closer to Australia, with fewer named storms overall. However, the increased activity farther east in the South Pacific typical of El Niño was absent in 2023/2024. El Niño also often decreases tropical cyclone numbers in the eastern Indian Ocean off the Australian coast, as occurred in the 2023/2024 season, when compared to La Niña conditions (although there is a high level of variability from year to year).

The year 2024 is most notable for being the first calendar year since 2009 in which no severe tropical cyclones were recorded in the South Pacific, and the least active calendar year on record, with only two named tropical cyclones (the most significant of these was Tropical Cyclone *Nat*, which reached category 2 status). In comparison, the Australian region recorded five severe tropical cyclones for 2024.

In the northern hemisphere, the western North Pacific had a near-average year, with a total of 26 tropical cyclones in 2024. A below-average start to the season was offset by an active later part of the season. A period in late October and early November was especially active in the vicinity of the Philippines, with six tropical cyclones affecting the country in less than three weeks (see the Philippines case study).

MARINE HEATWAVES

Marine heatwaves (MHWs) are prolonged periods of extreme heat that affect the ocean and have a range of consequences for marine life and dependent communities.

Most of the ocean area of the South-West Pacific region was affected by MHWs of strong, severe or extreme intensity during the year 2024 (Figure 8 (a)), particularly the equatorial region of the Maritime Continent and the western Pacific. During the months of January, April, May and June 2024, nearly 40 000 000 km^2 of the region's ocean was impacted by MHWs (Figure 8 (b)). The year 2024 marked a record high in MHW coverage since 1993, surpassing the second-highest values, which were recorded in 2023 and 2016 (Figure 8 (c)).

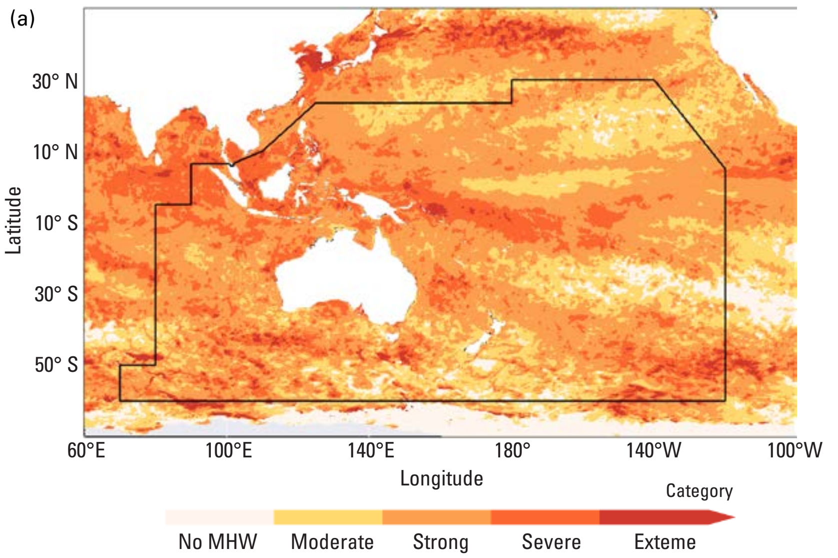
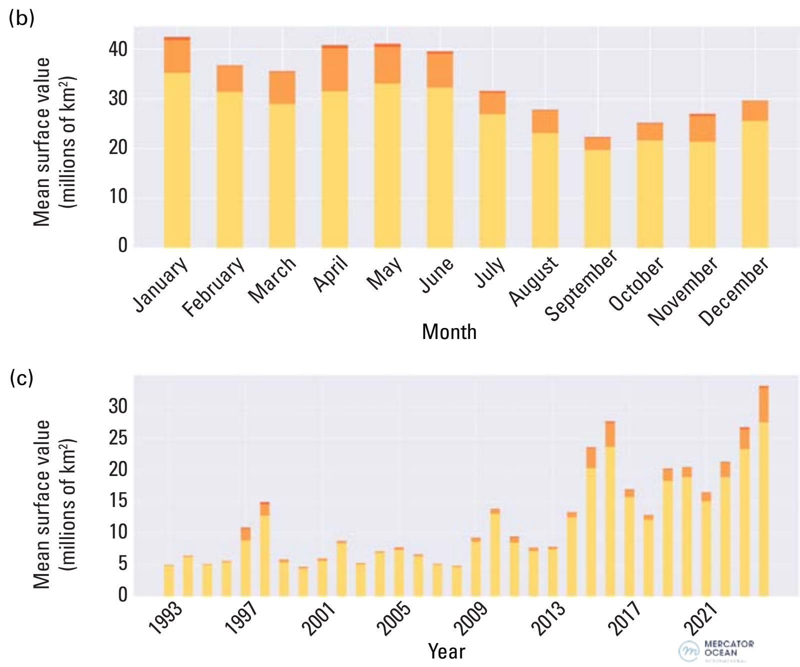


Figure 8. (a): Map of annual mean marine heatwaves (MHWs) by category in 2024 for WMO Region V, South-West Pacific (the area within the black lines) created using the Copernicus Marine product. The light shaded area ("No MHW" category) in the Southern Ocean indicates product limitations and/or limitations from seasonal sea-ice coverage. Below: Monthly mean surface area affected by MHWs during 2024 (b), and its annual mean over the entire record (c). The colours correspond to the categories in the map.

Source: Third-party map. The map (a) was taken from Copernicus Climate Change Service and Mercator Ocean International in April 2025 and may not fully align with United Nations and WMO map guidance.



Major climate drivers

There are many modes of natural variability in the climate system, often referred to as climate patterns or climate modes, which affect weather and climate at timescales ranging from days to months, or even decades.[10]

The tropical Pacific Ocean experienced El Niño conditions at the start of 2024, which gradually weakened, with a return to ENSO-neutral conditions by the middle of the year. The 2023/2024 El Niño event contributed to above-average rainfall along the equatorial tropical Pacific area as well as to below-average rainfall over parts of the off-equatorial South Pacific in the first part of 2024. The event also contributed to the warmer temperatures in 2024, as El Niño events typically have a lingering effect on temperatures in parts of the region, even after the event is over. Towards the end of 2024, there were signs that La Niña conditions were developing.

The Indian Ocean Dipole (IOD) was neutral for most of 2024, although there were signs of a short-lived negative IOD towards the end of the year. There was a marked period of negative Southern Annular Mode (SAM) in late July and August, and the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center monthly index for SAM for August was –2.15, the largest negative monthly value since July 2007. In the remainder of 2024, there were few sustained periods of positive or negative SAM.

Generally, a Madden-Julian Oscillation (MJO) signal was present throughout the year, except during the second quarter of 2024. The MJO was particularly active throughout the Maritime Continent and the western North Pacific beginning in mid-September. This coincided with the series of tropical cyclones that developed over the western North Pacific and their passage over the Philippines. Such a parade of tropical cyclones (10 tropical cyclones in the September–November period, excluding tropical depressions) caused increased tropical cyclone-associated rainfall, particularly over the northern Philippines. A number of tropical cyclones formed in the Australian region during periods when the MJO was active in the Maritime Continent and western North Pacific, including Tropical Cyclone *Kirrily* in January and Tropical Cyclones *Megan* and *Neville* in March.

Climate-related impacts and risks

An overview of the state of climate services in the South-West Pacific region can be accessed here.

Case Study – Fiji: Displacement and relocation induced by climate change

In the South-West Pacific, the impacts of climate change are threatening the lives and livelihoods of Pacific communities. The rise in sea level in much of the region is higher than the global average. Rising sea levels pose a serious risk of submerging significant portions of the Pacific islands, and with warming oceans, severe coral bleaching and declines in coral abundance have been observed.[11] Moreover, increasing ocean acidification and freshwater stress present mounting challenges, with projections indicating a significant decline in freshwater availability.[12] These climate-related impacts have severely affected food security, public health and livelihoods, undermining the resilience of island communities and leaving their future uncertain.

In past decades, extreme weather events in the Pacific have caused significant damage, impacting millions of people and resulting in thousands of fatalities and billions of US dollars (US$) of economic losses.[13] Estimates indicate that climate change impacts could result in substantial economic losses ranging from 2.2% to 3.5% of total annual gross domestic product (GDP) by the year 2050.[14] More than half of the population in Pacific islands resides within 500 m of the coastline,[15] increasing its exposure to storm surges and similar climate-related hazards.[16] It is estimated that each year, at least 50 000 Pacific Islanders face the risk of displacement due to the adverse effects of climate change.[17]

In this context, Pacific Islanders are facing difficult decisions about staying in high-risk areas or relocating to secure their futures. Nowhere is this more evident than in the small village of Serua Island, located about a five-minute boat ride from Fiji's main island Viti Levu. The island is home to around 150 people, a small community of farmers and fisherfolk with proud roots; this is the traditional residence of the paramount chief of Fiji's Serua Province.[18] Since the year 2000, locals have noticed sea levels rising around their island at an alarming pace,[19] with higher king tides and greater seawater intrusion.

Over the past two decades, coastal erosion and flooding have severely damaged the village, with the seawall being destroyed, homes being submerged and seawater killing food crops and washing away fertile soil. On two separate occasions, the island experienced such extreme flooding that it was possible to traverse the entire island by boat without encountering land.[20] As a response, resilient villagers have put up planks between homes, functioning as makeshift walkways when the sea inundates their gardens, and they now dock their boats outside their houses during high tides, prepared for the sea to breach their embankments.[21]

However, villagers are running out of adaptation options, with building of seawalls (Figure 9), mangrove plantations and improvement of drainage systems no longer being viable options to save the village from inundation. The Government of Fiji has offered support for the Islanders to relocate, but many are choosing to stay. Relocation is a complex task, fraught with legal, financial, economic and logistical considerations. It also has deep social implications, especially for Indigenous communities like those in the Pacific. The core reason for the villagers to stay on their island, and not relocate, stems from the concept of "*vanua*", which translates literally as "land", embodying the profound connection between the Indigenous communities and

Figure 9. The old seawall that was destroyed (left), with the new one built on top of it (right)

Source: Food and Agricultural Organization of the United Nations (FAO)/United Nations Framework Convention on Climate Change Regional Collaboration Centre for Asia and the Pacific (UNFCCC RCC Asia Pacific)

their ancestral lands. Vanua encompasses the interconnectedness between their lived realities and the natural environment, with a focus on their ways of life, shared values, spirituality, kinship bonds and strong stewardship responsibilities.[22] The Serua Islanders are concerned that relocating to the mainland would disrupt this sacred bond, and with their forebears and ancestors from the chiefly family buried there, moving across would be akin to watching them drown.[23]

Fearing the loss of identity, many of the village elders have refused to relocate and they are using all means available to them to survive. They are building new seawalls and restoring mangrove forests to protect the island from storm surges; moreover, they have moved their food plantations to the mainland, which they can reach by foot during low tide. However, the Islanders recognize that the inundation of their lands is seemingly inevitable, and younger generations have started relocating, not only due to climate change impacts, but also because it is easier for children to access schools and for parents to go to work.[24]

The United Nations Secretary-General António Guterres visited the Pacific islands in August 2024, witnessing first-hand how the impacts of climate change have devastated this region, “forcing families to relocate”.[25] From Tonga, he issued a “global SOS”, urging “the biggest emitters” to lead on climate change mitigation action, aligning their new climate pledges to the 1.5 °C pathway. He appealed to the world to step up commitments to finance and support vulnerable countries, emphasizing that “[w]e need a surge in funds to deal with surging seas.”[26]

Case Study – The Philippines: Unprecedented parade of tropical cyclones in the Philippines during the late boreal autumn

The late tropical cyclone season in the Philippines in September, October and November (SON) 2024 was marked by unprecedented activity. Normally, this period sees around 5 to 6 tropical cyclones, but 12 storms were recorded in SON 2024. The Philippines' tropical cyclone classification system, maintained by the Department of Science and Technology-Philippine Atmospheric, Geophysical and Astronomical Services Administration (DOST-PAGASA), provides the basis for the storm designations discussed here.[27]

Several factors contributed to the heightened tropical cyclone activity in SON 2024. Firstly, the western North Pacific subtropical high (WNPSH) was unusually strong and positioned farther north than usual, steering tropical cyclones towards the Philippines.[28] Additionally, persistently high ocean heat content in the Philippine Sea from mid-April 2024 created ideal conditions for tropical cyclone development. Warmer and deeper-than-average 20 °C isotherms[29] indicated significant upper-ocean heat storage, which fuelled tropical cyclone genesis and intensification. Reduced upwelling of colder waters due to stronger ocean stratification further enabled storms to maintain or increase their intensity. This combination of atmospheric and oceanic conditions created an environment conducive to the unprecedented frequency and intensity of tropical cyclones in the Philippines during SON 2024.

The collective impact of the tropical cyclones was devastating. Early estimates placed damages to infrastructure, homes and agriculture at US$ 430 million.[30] Tropical Cyclones *Trami* and *Kong-rey* displaced more than 600 000 people, and affected approximately 9 million individuals. In the Philippines, 159 deaths were reported,[31] with more reported in Viet Nam and Hainan Island (China). More than 200 000 houses were damaged. Typhoon *Xinying* led to the evacuation of more than 160 000 people from Luzon (the Philippines), while Typhoon *Toraji* and Super Typhoon *Usagi* were accompanied by 3-m storm surges and torrential rains.[32] Across the entire sequence, over 13 million people were impacted in 17 of the Philippines' 18 regions, with more than 1.4 million displaced.[33] The series of tropical cyclones caused flooding and landslides, resulting in damaged roads and bridges, and disrupted power, water supply and communication lines.

Tropical Cyclones *Toraji* (local name: *Nika*, 9–11 November), *Usagi* (*Ofel*, 12–16 November) and *Man-yi* (*Pepito*, 14–18 November), which all moved westward towards the Philippine Sea, devastated the country over 10 consecutive days. In terms of reported casualties, there were 14 dead, 15 injured and 2 still missing. A total of 78 960 houses were also reported damaged, as well as an estimated 12 892 466.31 Philippine pesos loss in agricultural production (approximately US$ 220 000). Infrastructure damage was valued at 2 960 608 343.33 pesos (approximately US$ 5.2 million).[34]

Building resilience to such extreme weather events is therefore a priority for the country. The Philippines submitted its National Adaptation Plan (NAP)[35] in May 2024, where it identifies wind patterns and tropical cyclones as among the key climatic impact drivers. It further indicates that while the frequency of tropical cyclones is expected to decrease, their intensity will significantly increase. The occurrence of super typhoons is projected to rise, as well as the average maximum wind speed of typhoons and super typhoons. These changes will result in severe damage to infrastructure, agriculture and coastal areas, affecting millions of Filipinos. Data models used in the NAP show that the northeastern part of the Philippines is the most vulnerable to tropical cyclones, as evidenced by the recent occurrences of Typhoons *Toraji*, *Usagi* and *Man-yi*. Five strategies were identified in the NAP aimed towards building resilience against extreme weather events: (1) Political commitment and institutional aspects; (2) Risk identification and early warning; (3) Knowledge management and education; (4) Risk management applications; and (5) Preparedness and response.

As part of the country's efforts to enhance adaptive capacities and resilience to the impacts of climate change and natural hazards (including tropical cyclones), the Government of the Philippines has successfully accessed the Green Climate Fund (GCF) for the first time, namely for the project Multi-hazard Impact-based Forecasting and Early Warning System for the Philippines.[36] This project builds on the country's existing early warning system and links it with forecast-based action and climate-resilient development and planning.

An example of strengthened preparedness and response was the activation of "anticipatory action"[37] for a number of coastal communities. By the second week of November 2024, the Bicol Region of the Philippines had been struck by five consecutive tropical cyclones. Each storm chipped away at inhabitants' livelihoods and sense of security in already vulnerable coastal areas focusing on recovery. Then came the warning of a sixth tropical cyclone. On 13 November, PAGASA issued Tropical Cyclone Wind Signal No. 1 for several provinces, including Catanduanes and Northern Samar, and parts of Camarines Sur, Albay, Sorsogon, Samar and Eastern Samar. At first, the forecasts did not meet the pre-agreed thresholds required to trigger anticipatory action. However, by the end of the day, the storm, later named Typhoon *Man-yi*, began rapidly intensifying. The thresholds were met, and the Food and Agricultural Organization of the United Nations (FAO) decided to act. With just three days before landfall, the FAO Anticipatory Action teams mobilized quickly. They began distributing unconditional cash transfers to 2 813 households in the island province of Catanduanes and delivered community cash grants to seven fishing communities. Simultaneously, fisherfolk were supported to evacuate 283 boats to safer grounds based on past simulation exercises for anticipatory action. These are vessels that are often critical for food and income for coastal families in this region. All interventions were completed just eight hours before Typhoon *Man-yi* struck the island as a category 4 super typhoon.

Thanks to the timely interventions, fisherfolk in Catanduanes were able to resume fishing just one week after the typhoon. FAO had also planned to reach communities in Northern Samar, but transfer delays meant cash arrived one day after landfall. Even so, this still served as a rapid response, underscoring a further need to explore the relation between these two provinces - a topic FAO is now exploring in a forthcoming study with Johns Hopkins University.

Maricel Laurente, a boat owner from Cabcab, San Andres, recalled:

> When I heard the news about Super Typhoon *Pepito* hitting Catanduanes, I was really nervous just thinking about losing our home. Even before Super Typhoon *Pepito* made landfall, FAO conducted an orientation for fishers on how to secure the boats in case of calamity. Our fisherfolk organization also had an emergency meeting on where and when we should start moving the boats

Figure 10. Fisherfolk in Catanduanes evacuating their boat
Source: FAO/Ruth Georget

> to safety. Because of this, there was little to no damage to the boats, and we were able to head out to sea as soon as it was safe. FAO also provided cash assistance to our organization, which we utilized in evacuating the boats and buying materials to help repair the boats. It was critical that the help was provided early because it enabled us to prepare ahead of time.

Ronald Echiverria, a fisherman from Marambong, Pandan, echoed that sense of security:

> Three days before the landfall, my fellow fishers and I have discussed about safekeeping our boats. The simulation exercises previously conducted with FAO taught us the correct step-by-step methods on securing your boats during the typhoon as well as the proper use of the materials they have provided for it. Because of this, we were able to move our boats to safety and even had enough time to secure our homes. FAO also provided the association with cash assistance. Our fisherfolk association used this to buy nylon, epoxy, plywood and fish baits. All this helped a lot because you can imagine how after a typhoon, fishers do not have the money to buy these materials necessary to head out to sea right away.

These stories illustrate that anticipatory action is not just about speed, it is about dignity and the power of communities to protect themselves when given the tools and support in time. As climate-related shocks grow in frequency and intensity, this approach will be a key approach moving forward for frontline communities.

Datasets and methods

A description of the data and methods used for this report can be accessed here.

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Endnotes

1 Data are from the following datasets: Berkeley Earth, ERA5, GISTEMP v4, HadCRUT.5.0.2.0, JRA-3Q and NOAAGlobalTemp v6.

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