State of the Climate in South-West Pacific

2020

WEATHER CLIMATE WATER

WORLD
METEOROLOGICAL
ORGANIZATION

WMO-No. 1276

WMO-No. 1276

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ISBN 978-92-63-11276-7

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Foreword

This report on the State of the Climate in South-West Pacific 2020 is the first of its kind for this region and a milestone multi-agency effort to deliver informed climate analysis and climate change trends. It includes a comprehensive integrated risk assessment and climate action guidance for building resilience to extreme weather events and climate change, thus promoting sustainable development.

The report covers states and territories across the vast South-West Pacific Ocean, the adjacent oceanic areas north of the equator and the eastern parts of the Indian Ocean. The ocean provides critical ecosystem services and is of particular importance for this region's species and habitats. The report highlights the real and potential risks associated with the changes occurring in ocean circulation, temperature, acidification and deoxygenation, as well as rising sea level. The Small Island Developing States are increasingly vulnerable to these changes, as their incomes are highly linked to fisheries, aquaculture and tourism.

Over land areas, the significant and growing impacts of extreme hydrometeorological phenomena and tropical cyclones, plus new multi-dimensional threats, pose increasing challenges to communities in the region to cope with the risks.

The COVID-19 pandemic has disrupted socio-economic development in the region, affecting key drivers of growth and revealing gaps in countries' capacities for addressing systemic and cascading risk.

Addressing the rising climate risks and associated impacts requires local, regional and transnational capacity building, development of climate services and integrated disaster risk reduction approaches. These constitute foundational elements for achieving the 2030 Agenda for Sustainable Development and recovering from the COVID-19 pandemic.

The World Meteorological Organization (WMO) is committed to enhance its collaboration with key stakeholders in the region, including Member States and United Nations Agencies, to continue providing annual updates through this series of reports.

I congratulate the lead author, co-authors and the contributing experts for delivering this first edition of the State of the Climate in the South-West Pacific. I thank our sister United Nations agencies for their collaboration and contribution, and extend special thanks to the Economic and Social Commission for Asia and the Pacific (ESCAP), which helped in coordinating the contributions to the socio-economic and policy-related sections of the report.

Prof. Petteri Taalas
Secretary General
World Meteorological Organization

Key messages

In the South-West Pacific region, 2020 was the second or third warmest year on record, depending on the data set. Near-surface temperatures over the land and ocean averaged across the region were about 0.37–0.44 °C above the 1981–2010 average.

A wide-range of precipitation anomalies occurred in the region. In tropical regions, it was a relatively wet year. Conversely, it was a dry year in many equatorial regions close to the international date line and in regions farther east. It was a very dry year in many parts of New Zealand. Rainfall over most parts of Australia was relatively close to average.

Tropical glaciers are highly sensitive indicators and recorders of climate change. Most tropical glaciers are currently in retreat, primarily due to recent anthropogenic atmospheric warming.

Storms and floods have historically been the most devastating extreme weather events in the region. The Philippines and Small Island Developing States have suffered greatly from regular typhoons/tropical cyclones.

In the South Pacific tropical cyclone region, in April, the category 5 Tropical Cyclone *Harold* led to extensive human and economic damage in the Solomon Islands, Vanuatu, Fiji and Tonga. In December, Fiji was affected by a second major event, Tropical Cyclone *Yasa*. Impacts from *Yasa* were also experienced in nearby Vanuatu and Tonga.

In the western Pacific tropical cyclone region, the Philippines was particularly devastated by consecutive tropical cyclones during the months of October and November. Typhoon *Goni* (*Rolly*) had one of the most intense landfalls of any tropical cyclone on record when it reached the Philippines on 30 October.

Climate and extreme weather events had major and diverse impacts on population movements and on the vulnerability of people already on the move in the region throughout 2020. Many displacement situations triggered by hydrometeorological events have become prolonged or protracted for people unable to return to their former homes or without options for integrating locally or settling elsewhere.

The multidimensional risks for the people and economies of the region increased. The coronavirus disease (COVID-19) pandemic has disrupted socioeconomic development in the region, affecting key drivers of growth including the private sector, trade, tourism and remittances, and has revealed gaps in countries' capacities for addressing systemic and cascading risks.

Ocean warming, deoxygenation and acidification are additional factors changing the oceans' circulation pattern and chemistry. Fish and zooplankton are migrating to higher latitudes and changing behaviours. Consequently, traditional fisheries are altering. This has critical implications for the Pacific islands where coastal fishing is a principal activity that provides for nutrition, welfare, culture and employment.

In 2020, a significant marine heatwave occurred over the Great Barrier Reef area of Australia. In February, sea-surface temperatures over this area were 1.2 °C above the 1961–1990 average, making it the warmest month in terms of Great Barrier Reef sea-surface temperatures on record. High temperatures affected the entire reef and widespread coral bleaching was reported, the third mass bleaching event in the past five years.

Under the scenario in which global mean temperature increases 2 °C above pre-industrial levels by 2050, up to 90% of the coral reefs in the Coral Triangle and the Great Barrier Reef could face severe degradation. The altering coral reef habitats can affect the several coastal communities vulnerable to ocean acidification impacts on reefs and their fisheries, aquaculture and tourism.

Countries in the Pacific are making substantial progress in achieving Sustainable Development Goal 13 on climate action. However, the region needs to accelerate progress towards achieving target 13.1 (strengthen resilience and adaptive capacity) and reverse current trends with a view to achieving other targets related to resilience to disasters (target 1.5 and target 11.5).

Building resilience to extreme climate events is foundational for achieving the 2030 Agenda for Sustainable Development. This requires a better understanding of specific risks affecting particular regions and countries, and increased capacity to address them.

PART I – PHYSICAL ASPECTS

1.1 STATE OF THE CLIMATE INDICATORS

The state of the climate indicators highligh important and interrelated components of the climate system on a global scale. They include concentrations of primary greenhouse gases, global mean temperature, ocean heat content (OHC), sea level, ocean acidification and various cryosphere indicators.

In 2019, concentrations of the three major greenhouse gases – carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) – reached record high levels with global mean concentrations of 410.5 ± 0.2 parts per million for CO_2, 1 877 ± 2 parts per billion for CH_4 and 332.0 ± 0.1 parts per billion for N_2O (data from World Data Centre for Greenhouse Gases). Despite an approximately 7% drop in CO_2 emissions in 2020,[1] data from individual stations indicate that CO_2 concentrations once again reached a record high in 2020.

Excess energy trapped by greenhouse gases continued to accumulate and warm the oceans. OHC reached a new record high in 2020. Water in the warming ocean expands, raising global sea level, which is further added to by the melting of ice on land. In 2020, global mean sea level continued to rise with the long-term rate of rise now amounting to 3.3 ± 0.3 mm/yr. Local variations in sea level are linked to local variations in ocean heat.

Global mean temperature for 2020 was 1.2 ± 0.1 °C above the 1850–1900 average. The period 1850–1900 is often used as an approximation of pre-industrial conditions. Despite La Niña conditions that developed late in the year, 2020 was one of the three warmest years on record, and the past six years (2015–2020) have been the six warmest years on record globally.

1.1.1 MAJOR CLIMATE DRIVERS

The South-West Pacific[2] region's climate is strongly influenced from year to year by major modes of climate variability. El Niño and the Southern Oscillation (ENSO) is the most prominent of these, but the Indian Ocean Dipole (IOD) is also important, especially in Australia and the Maritime Continent. Moreover, the Madden-Julian Oscillation (MJO) has a substantial influence on sub-seasonal climate variability in tropical areas.[3]

The year 2020 started with generally above average sea-surface temperatures (SSTs) in the equatorial Pacific. In the central and eastern Pacific, SSTs were not high enough for 2019–2020 to be classified as an El Niño event, but farther west, SSTs near the international date line were at levels typically associated with El Niño, contributing to some El Niño-like climate anomalies. Those anomalies had eased by April.

In the second half of the year, a moderate La Niña (cool-phase) event developed. SST reached La Niña thresholds by September and remained there for the rest of the year, reaching peak strength at about 1 °C below average in October and November. La Niña is typically associated with wetter than normal conditions across most of Australia, the Maritime Continent, and across the central Pacific from the Philippines Sea to the international date line. The Southern Oscillation Index was also generally at levels consistent with La Niña from August onwards, peaking at +16.9 in December.

The IOD was in a strongly positive phase in the later months of 2019. It returned to neutral conditions in the opening days of 2020, with no sustained departure from neutral conditions for the remainder of the year. IOD indices were briefly negative in August but not for long enough to constitute a negative phase. The IOD is a coupled ocean and atmosphere

1 Friedlingstein, P. et al., 2020: Global Carbon Budget 2020. *Earth System Science Data*, 12(4): 3269–3340, https://doi.org/10.5194/essd-12-3269-2020.

2 The South-West Pacific (WMO Regional Association V) is a vast region composed by: American Samoa, Australia, Brunei Darussalam, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Hawaii (US), Indonesia, Kiribati, Malaysia, Marshall Islands, Nauru, New Caledonia, New Zealand, Niue, Palau, Papua New Guinea, Philippines, Singapore, Solomon Islands, Timor-Leste, Tonga, Tuvalu and Vanuatu

3 More information on these modes of variability is available at http://www.bom.gov.au/climate/about/.

phenomenon developing in the equatorial Indian Ocean and affects the climate of the countries surrounding the Indian Ocean Basin, being a significant contributor to rainfall variability in this region.[4] The impact of the IOD on climate is typically most prominent in the second half of the year; it normally has little influence between January and May.

The MJO is a mode of tropical variability which moves from west to east on typical timescales of 30 to 60 days. There were three periods when it was particularly active in the Maritime Continent region, moving east into the western Pacific. In the first half of January this coincided with heavy rains in Indonesia and northern Australia, and in early April with the formation of Tropical Cyclone *Harold*. A third active phase in early October had limited impacts within the region but contributed to a period of high tropical cyclone activity in Viet Nam, just outside the regional boundary. Heavy rain in northern Australia and the passage of Tropical Cyclone *Yasa* in mid-December occurred despite relatively weak MJO signals at the time.

1.1.2 REGIONAL TEMPERATURES

In 2020, near-surface land and ocean temperatures averaged across the region were about 0.37–0.44 °C above the 1981–2010 average,[5] according to five independent analyses. This makes 2020 either the second or the third warmest year on record, depending on the data set. When averaged over land areas only, 2020 was either the third or the fourth warmest year on record (0.52 –0.68 °C above the 1981–2010 average), according to six independent analyses. It should be noted that the rate of warming and variability are typically higher for land areas only than for land and ocean areas combined (Figure 1), and that the land value is strongly influenced by temperatures in Australia, which makes up about 70% of the total land area in the region. The rate of warming is higher in the latter half of the record than in the first half, for both land only and land and ocean areas.

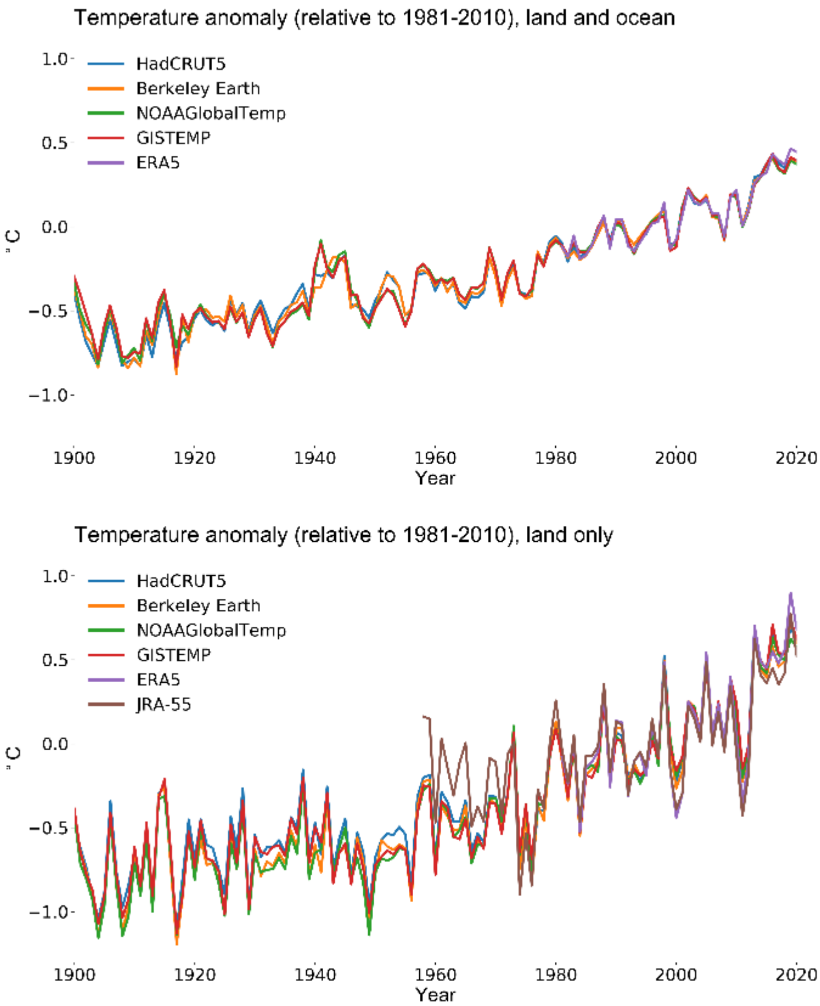


Figure 1. Area average temperature anomalies 1900–2020 (°C) difference from the 1981–2010 average, for land and ocean areas (left) and land areas only (right) in WMO Regional Association V. The data sets used are as labelled. Note that the four conventional data sets start in 1900, while the ERA5 reanalysis starts in 1979 and the JRA-55 reanalysis starts in 1955.

Average temperatures for 2020 were above the 1981–2010 average across most of the region (Figure 2), with below average temperatures in parts of South Australia and Victoria, the Great Australian Bight, neighbouring ocean areas and the tropical Pacific east of the date line. Despite below average temperatures in the south, Australia had its fourth warmest year on record,[6] while New Zealand had its

4 http://www.bom.gov.au/climate/enso/history/ln-2010-12/IOD-what.shtml

5 A 1981–2010 reference period is used owing to insufficient pre-1900 data on the region to define a 1850–1900 baseline as used for global assessments.

6 http://www.bom.gov.au/climate/current/annual/aus/. Note that the Australian national data set starts in 1910, and the New Zealand data set starts in 1909.

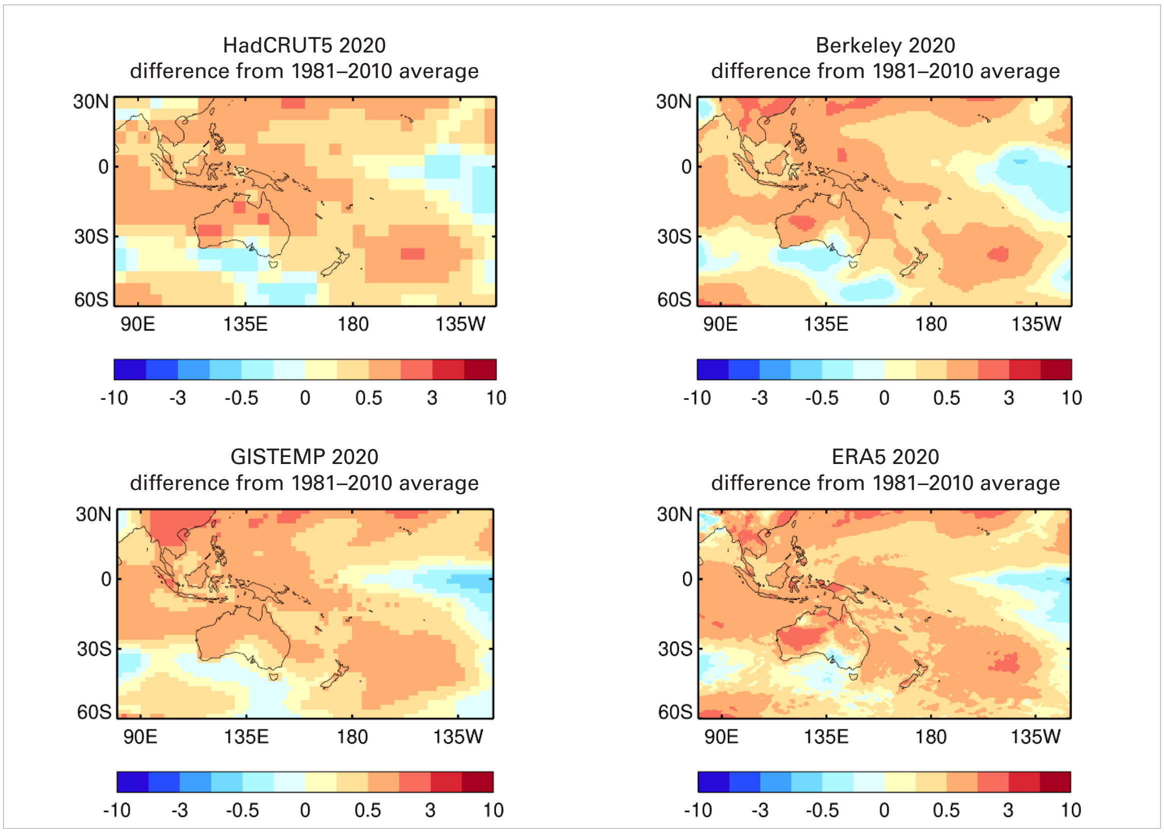


Figure 2. Annual average temperature anomalies for 2020 (°C) difference from the 1981–2010 average, from four data sets: HadCRUT5, Berkeley Earth, GISTEMP and ERA5.

seventh warmest year.[7] The pattern of temperature anomalies is consistent with La Niña conditions later in the year. Annual average temperatures were particularly high across the western edge of the Pacific and in parts of the Indian Ocean, with annual SSTs reaching record highs in places. The Philippines had its third warmest year on record. Some specific locations in the Pacific that experienced their warmest year on record in 2020 include the southern region (south of 18°S) of French Polynesia; Nuku'alofa in Tonga (which also had its highest temperature on record, 34.0 °C, on 29 February); Hilo (Hawaii); and Kahului (Maui, Hawaii).

1.1.3 SEA-SURFACE TEMPERATURES

SST is an important physical indicator of Earth's climate system. Changes in SST play a critical role in the coupling between the ocean and the atmosphere, as they can trigger the transfer of energy, momentum and gases between the two Earth system components.[8] At the regional scale, year-to-year up to decadal changes in SST, superimposed upon the overall warming trend, are linked to atmosphere-ocean climate modes (e.g. ENSO), and also reveal the structure of underlying ocean dynamics, such as ocean fronts, eddies, coastal upwelling and exchanges between the coastal shelf and open ocean.

The ocean area of the region shows overall surface ocean warming over the 1982–2020 period, particularly in the Tasman Sea, in the areas between 20°S and 40°S in the Indian and Pacific Ocean, and in the west of the Timor Sea at rates of more than 0.04 °C per year (Figure 3). 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

7 National Institute of Water and Atmospheric Research (NIWA), 2021: Annual climate summary 2020, https://niwa.co.nz/climate/summaries/annual-climate-summary-2020.

8 Intergovernmental Panel on Climate Change (IPCC), 2019: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (H.-O. Pörtner et al., eds.), https://www.ipcc.ch/srocc/.

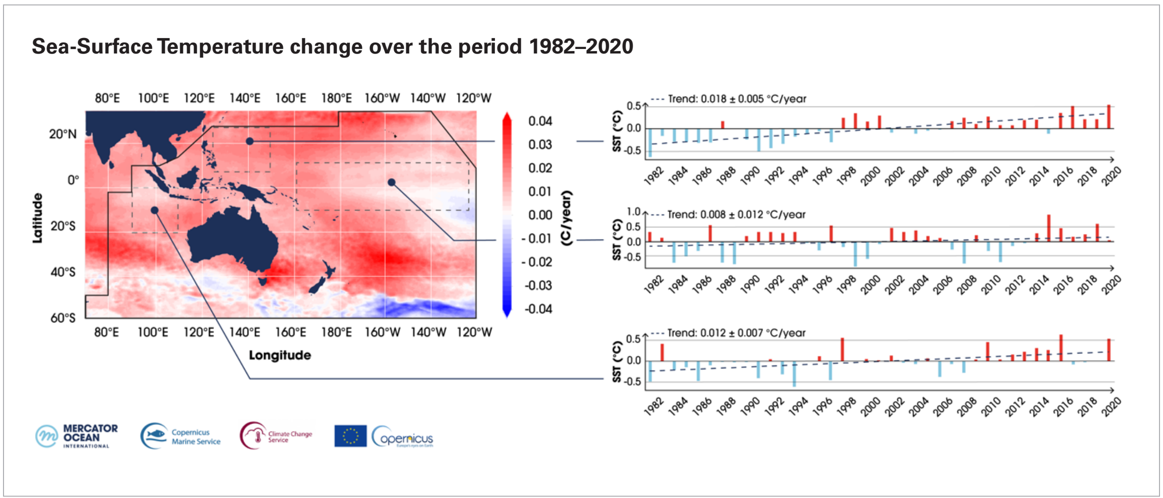


Figure 3. Left: Trends of SST (°C per year) over the period 1982–2020 derived from the remote sensing product (*SST_GLO_SST_L4_REP_OBSERVATIONS_010_024*) downloaded from Copernicus Marine Service. Right: Area-averaged time series of SST anomalies (°C) relative to the 1982–2020 reference period for the areas indicated in grey dashed lines (see left).

of 0.015 ± 0.001 °C per year.[9,10] In 2020, the area-averaged SST anomalies reached record values (nearly +0.5 °C) in the north-western area of the region, including the Philippine Sea (Figure 3). In that area, surface ocean warming has occurred at rates slightly higher than the global average.

Changes in SST in the tropical western Pacific and the tropical eastern Indian Ocean are affected by climate variability at interannual timescales, and in these areas surface ocean warming occurs at rates below the global average (Figure 3). In the tropical Pacific, ENSO is a major driver of lower- and higher-than-average SST values from one year to another.[11,12] In 2020, SSTs in the central tropical Pacific were near average (Figure 3), reflecting the transition from warm neutral conditions early in the year to La Niña later on.

1.1.4 OCEAN HEAT CONTENT

Owing to emissions of heat-trapping greenhouse gases resulting from human activities, the global ocean has warmed from absorbing more than 90% of the excess heat in the climate system. It is almost certain that the ocean will continue to absorb heat throughout the twenty-first century.[13,14] Ocean warming is continuing unabated. Since 1993, the rate of ocean warming has likely more than doubled, and it will continue to warm throughout the twenty-first century. Ocean warming contributes about 40% of observed global mean sea-level rise through thermal expansion of

9 Copernicus Marine Service, 2021: Taking the temperature of the ocean, 7 June, https://marine.copernicus.eu/news/temperature-ocean.

10 Copernicus Marine Environment Monitoring Service, 2021: Global ocean anomaly time series of sea surface temperature, https://marine.copernicus.eu/access-data/ocean-monitoring-indicators/global-ocean-anomaly-time-series-sea-surface-temperature.

11 McPhaden, M.J., 2015: Playing hide and seek with El Niño. *Nature Climate Change*, 5: 791–795, https://doi.org/10.1038/nclimate2775.

12 Johnson, Z.F. et al., 2020: Pacific decadal oscillation remotely forced by the equatorial Pacific and the Atlantic Oceans. *Climate Dynamics*, 55: 789–811, https://doi.org/10.1007/s00382-020-05295-2.

13 IPCC, 2019: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.

14 von Schuckmann, K. et al., 2020: Heat stored in the Earth system: Where does the energy go? *Earth System Science Data*, 12(3): 2013–2041, https://doi.org/10.5194/essd-12-2013-2020.

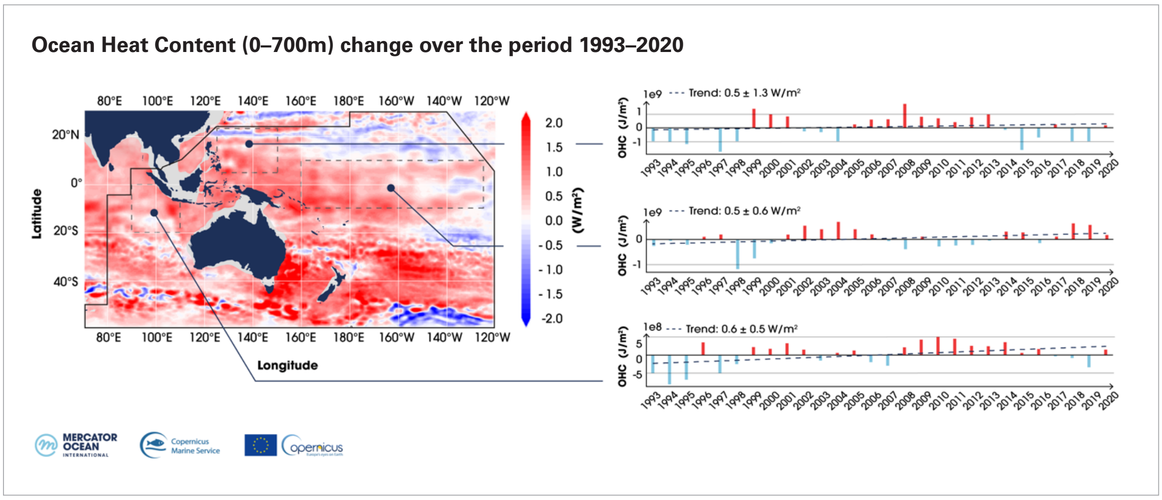


Figure 4. Left: Trends of OHC (W/m²) over the period 1993–2020, integrated from the surface down to 700 m depth and derived from the in situ-based product (*MULTIOBS_GLO_PHY_TSUV_3D_MYNRT_015_012*) downloaded from Copernicus Marine Service. Ocean warming rates at bathymetry shallower than 300 m have been masked in grey owing to product limitations. Right: Area-averaged time series of upper 700 m OHC anomalies (joule per square metre (J/m²)) for the three areas indicated in grey dashed lines (see left). For each area, the linear trend over the full period is indicated by grey lines.

seawater.[15,16] Ocean warming is altering ocean currents and indirectly altering storm tracks,[17] increasing ocean stratification.[18] Together with ocean acidification and deoxygenation, ocean warming can lead to dramatic changes in ecosystem assemblages, biodiversity impacts, population extinction, coral bleaching, infectious diseases and changes in behaviour (including reproduction), as well as the redistribution of habitats.[19,20,21,22]

Most of the areas in the region show upper (0–700 m) ocean warming since 1993, which is particularly strong in the Tasman Sea and in the area between 20°S and 40°S in the Pacific Ocean, with ocean heat content increasing at rates exceeding 2 watts per square metre (W/m²) – more than three times faster than the global rate of 0.6 W/m² (Figure 4).[23] 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 (e.g. ENSO) during which large amounts of heat are re-distributed from the surface down to deeper layers, and from the tropics to the subtropics.[24]

1.1.5 PRECIPITATION

Precipitation in large parts of the region is strongly influenced by ENSO, especially over the equatorial Pacific Ocean. In 2020, ENSO transitioned from a warm neutral state early in the year to La Niña conditions

15 IPCC, 2019: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*.

16 World Climate Research Programme (WCRP) Global Sea Level Budget Group, 2018: Global sea-level budget 1993–present. *Earth System Science Data*, 10(3): 1551–1590, https://doi.org/10.5194/essd-10-1551-2018.

17 IPCC, 2018: *Global Warming of 1.5°C: an IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* (V. Masson-Delmotte et al., eds.), https://www.ipcc.ch/sr15/.

18 Li, G. et al., 2020. Increasing ocean stratification over the past half-century. *Nature Climate Change*, 10: 1116–1123, https://doi.org/10.1038/s41558-020-00918-2.

19 IPCC, 2019: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*.

20 García Molinos, J. et al., 2016: Climate velocity and the future global redistribution of marine biodiversity. *Nature Climate Change*, 6: 83–88, https://doi.org/10.1038/nclimate2769.

21 Gattuso, J.-P. et al., 2015: Contrasting futures for ocean and society from different anthropogenic CO_2 emissions scenarios. *Science*, 349(6243): aac4722, https://doi.org/10.1126/science.aac4722.

22 Ramírez, F. et al., 2017: Climate impacts on global hot spots of marine biodiversity. *Science Advances*, 3(2): e1601198, https://doi.org/10.1126/sciadv.1601198.

23 von Schuckmann et al., 2020: Heat stored in the Earth system: Where does the energy go?

24 Cheng, L. et al., 2019: Evolution of ocean heat content related to ENSO. *Journal of Climate*, 32(12): 3529–3556, https://doi.org/10.1175/JCLI-D-18-0607.1.

through the later part of the year, and there was consequently a shift in rainfall drivers during this period.

In tropical regions, it was a relatively wet year over many parts of Indonesia, extending south-east into parts of Papua New Guinea, the Solomon Islands, Vanuatu, Fiji, Tonga and Samoa (Figure 5, top). Rainfall in some parts of this region was in the highest decile. In northern Vanuatu, Pekoa had its wettest year on record, and Sola its third-wettest, while Pago Pago in American Samoa also had its wettest year on record. There were also areas in the highest decile in Indonesia, particularly on the islands of Borneo, Sulawesi and Java (Figure 5, bottom). In contrast, the Philippines was near normal and Singapore was slightly drier than normal, while in the tropical South Pacific, New Caledonia's area-averaged annual rainfall was 5% below normal, although 2020 was still the wettest year since 2012 (Figure 5, top).

Conversely, it was a dry year in many equatorial regions close to the international date line, particularly from April onwards. Kapingamarangi, near the equator in the southern Federated States of Micronesia, had its driest year in 18 years of data, with rainfall 45% below normal for the year and 71% below normal for July to December. Tarawa, in western Kiribati, had its third-driest year on record. Farther east, in the Marquesas Islands of French Polynesia, annual rainfall was 46% below average. Farther north, the seasonal pattern was reversed, with Saipan having its second-driest January to July before rainfall returned to more normal levels later in the year (Figure 5).

Outside the tropics, it was a very dry year in many parts of New Zealand, particularly in the North Island (except for Taranaki and the Wellington region) and the northern South Island, with many areas having annual rainfall 20% to 40% below average. It was the driest year in more than 100 years of records at Ruakura (near Hamilton), and records were also set at several sites around Auckland.

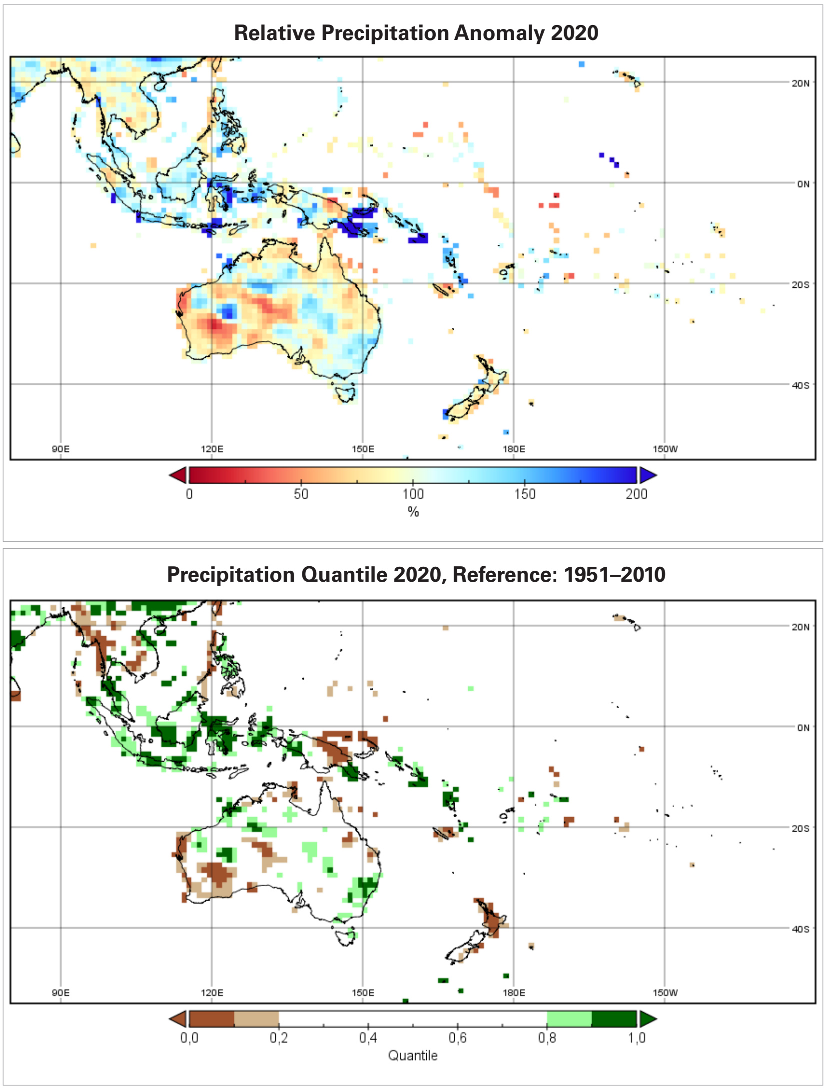


Figure 5. Precipitation **in 2020** in the region, expressed as a percentage of the 1981–2010 average (top) and as a quantile of the 1951–2010 period (bottom). *Source:* Global Precipitation Climatology Centre (GPCC), Deutscher Wetterdienst, Germany

During the 2019/2020 summer the dry conditions extended over the ocean, with Norfolk Island having its driest summer on record, although its rainfall was near average for the remainder of the year (Figure 5). Following the extremely dry 2019, rainfall over most parts of Australia was relatively close to average. It was wetter than average in many parts of New South Wales, easing a severe three-year drought in the region. It was also rather wet in many parts of north-western Australia, where heavy rains fell in December in an early start to the 2020/2021 wet season. Conversely, parts of south-east Queensland, particularly north of Brisbane, remained relatively dry, and it was also dry in the western parts of Western Australia outside the tropics (Figure 5, top).

1.1.6 SEA LEVEL

Since the early 1990s, sea level has routinely been measured globally and regionally by high-precision altimeter satellites.[25] These missions indicate that the global mean sea level has risen at an average rate of 3.3 ± 0.3 mm/yr during this period and even accelerated, in response to ocean warming and land-ice melt.

The altimetry-based regional sea-level trends from January 1993 to June 2020 in the Indian and Pacific oceans are shown in Figure 6.

The map shows that in the North Indian Ocean and in the western part of the tropical Pacific Ocean, the rates of sea-level change are substantially higher than the global mean rise. These regional variations are mostly due to non-uniform ocean thermal expansion (generally consistent with the SST changes shown in Figure 3), together with salinity changes in some regions.[26,27,28]

Also shown are the time series of coastal sea level in three oceanic regions relevant to the domain covered by this report including: south-east Indian Ocean , South-East Asia (western part of the tropical Pacific) and southern Australia.

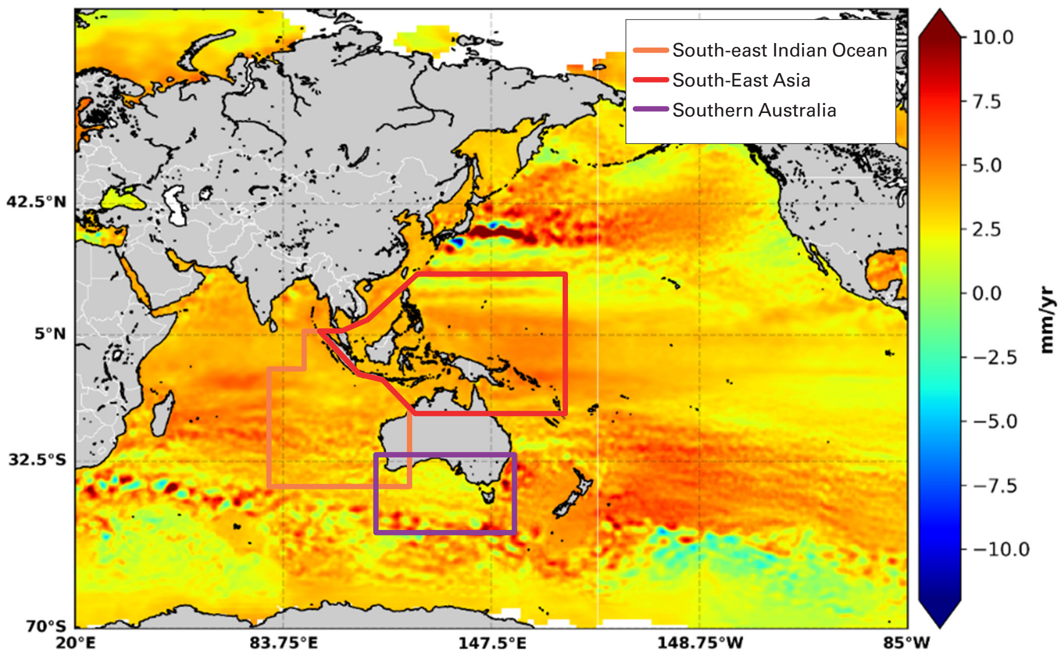


Figure 6. Sea-level trends from 1993 to 2020. The coloured frames indicate the regions where the coastal sea-level time series (see the figures to follow) are computed. *Source:* Copernicus Climate Change Service (C3S) gridded sea-level product (resolution 0.25°)

25 Topex/Poseidon and its successors Jason-1, Jason-2 , Jason-3 and Sentinel-6 MF, which launched in 1992, 2002, 2008, 2016 and 2020, respectively, as well as ERS-1 and ERS-2, Envisat, SARAL/Altika, and Sentinel-3A and Sentinel-3B.

26 Church, J.A. et al., 2013: Sea level change. In: *Climate Change 2013: the Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (T.F. Stocker et al., eds.). Cambridge and New York, Cambridge University Press, https://www.ipcc.ch/report/ar5/wg1/.

27 Cazenave, A. et al., 2018: Contemporary sea level changes from satellite altimetry: What have we learned? What are the new challenges? *Advances in Space Research*, 62(7): 1639–1653, https://doi.org/10.1016/j.asr.2018.07.017.

28 Hamlington, B.D. et al., 2020: Understanding of contemporary regional sea-level change and the implications for the future. *Reviews of Geophysics*, 58(3): e2019RG000672, https://doi.org/10.1029/2019RG000672.

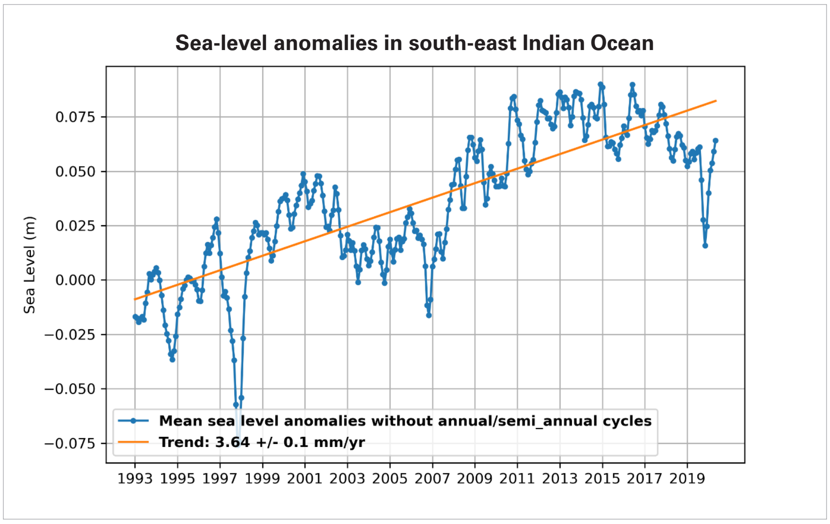


Figure 7. Altimetry-based coastal sea-level time series (m) from January 1993 to June 2020 for the south-east Indian Ocean. Seasonal cycle was removed; glacial isostatic adjustment correction was applied. The orange line represents the linear trend. *Source:* C3S

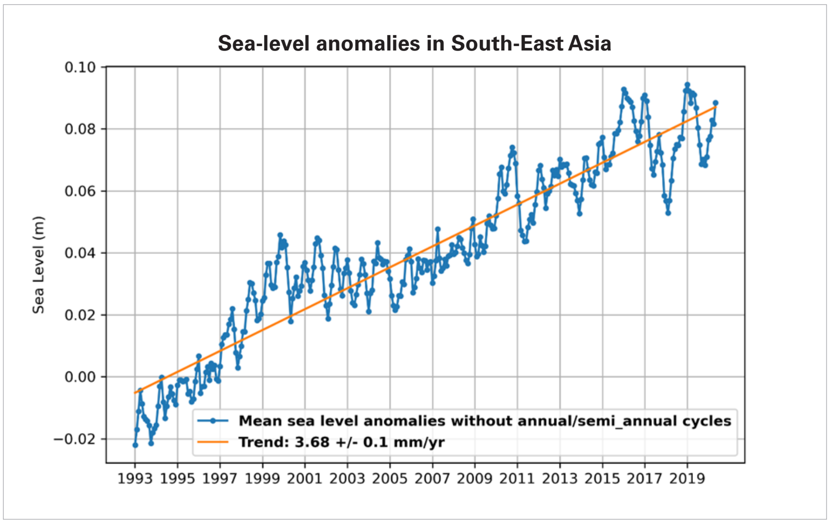


Figure 8. Altimetry-based coastal sea-level time series (m) from January 1993 to June 2020 for the South–East Asia (western part of the tropical pacific). Seasonal cycle was removed; glacial isostatic adjustment correction was applied. The orange line represents the linear trend. *Source:* C3S

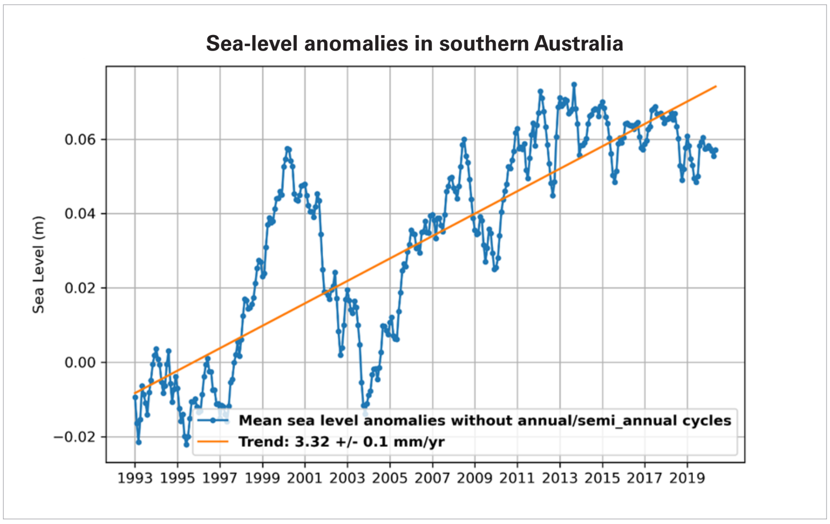


Figure 9. Altimetry-based coastal sea-level time series (m) from January 1993 to June 2020 for southern Australia. Seasonal cycle was removed; glacial isostatic adjustment correction was applied. The orange line represents the linear trend. *Source:* C3S

The coastal sea-level time series show strong interannual variability, mostly driven by ENSO and the IOD, as well as some decadal variability. The curves show temporary coastal sea level drops up to 10 cm amplitude in the South-East Asia region during the 1997–1998 and 2015–2016 El Niño events, while the south-east Indian Ocean shows similar short-term drops during the strong positive IOD events of 1997 and 2019. The coastal sea-level rise rates are in general slightly higher than the global mean rate, approaching 4 mm/yr in several areas, except in southern Australia, where the rate is similar to the global mean.

1.1.7 CRYOSPHERE

Snow is rare or unknown at low elevations over most of the region, but 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 Indonesian part of the island of Papua. There is significant seasonal snow cover in the highland regions of New Zealand and southern Australia.

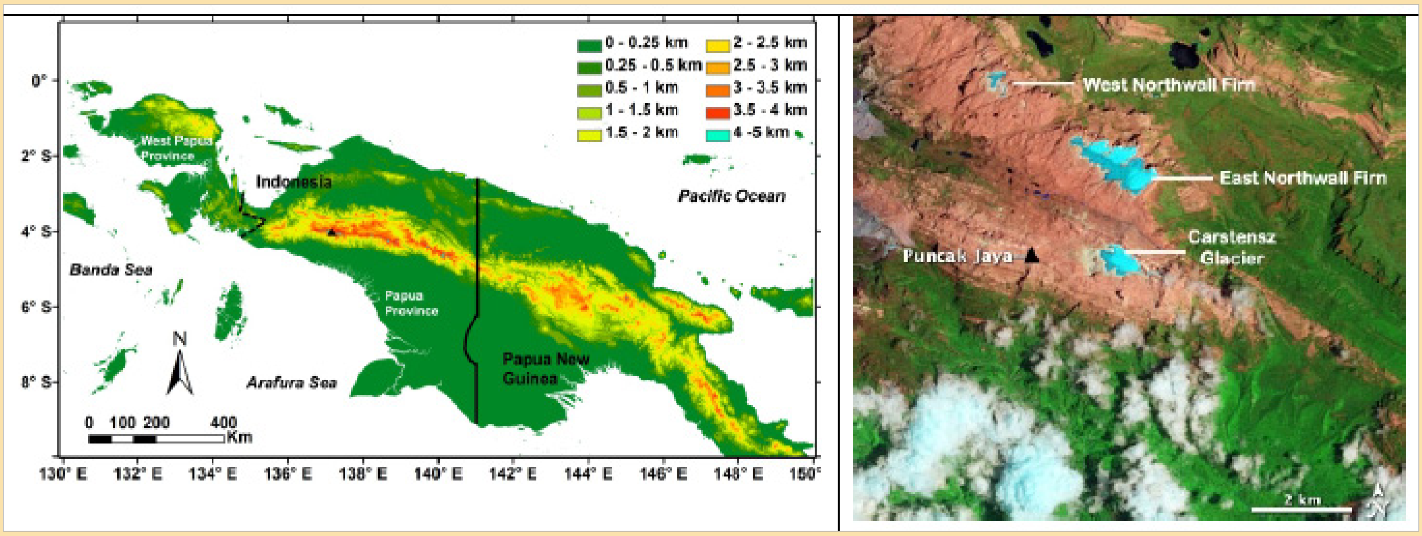
In New Zealand, in January 2020, a layer of ash and dust from Australian bushfires was deposited throughout much of the Southern Alps. This layer persisted until March when National Institute of Water and Atmospheric Research (NIWA) carried out the annual End of Summer Snowline Survey. In New Zealand, seasonal snow during 2020 experienced a marked midwinter hiatus, with very little snowfall at most monitored high-elevation sites from late July through much of August. Towards the end of August, snow depths were approximately half of usual for the time of year at several NIWA snow and ice monitoring sites, including Mount Philistine (Arthur's Pass National Park, 1 655 metres above sea level (m a.s.l.)) and Castle Mount (Fiordland National Park, 2 000 m a.s.l.). The depth of accumulated snow at Mueller Hut (Aoraki/Mount Cook National Park, 1 818 m a.s.l.) was the lowest in 10 years of record, with less than 45% of average depth. Notably, it was the warmest winter on record for New Zealand (mean temperature 9.6 °C, anomaly +1.1 °C). Several ski areas were affected by the lack of snow, including Temple Basin (Arthur's Pass), which announced that it would not be open for the whole season. New snowfall in late winter and early spring brought the snow depth up to average depths at most sites by the time of maximum depth in late September/early October. There was also a major cold outbreak in late September, with snow falling to sea level in the southern South Island.

In Australia, snow cover was close to average in the Snowy Mountains of New South Wales, due largely to heavy falls in late July and early August, but the mountains of Victoria had a snowpack which was well below average. There was a major low-elevation snow event in Tasmania and southern Victoria in early August, with snow settling to sea level in downtown Launceston, the most significant fall there since 1921. The temperature fell to –14.2 °C at Liawenee on 7 August, a state record for Tasmania.

BOX 1. TROPICAL GLACIERS IN INDONESIA

The glaciers near Puncak Jaya, in Papua, Indonesia, the highest peak between the Himalayas and the Andes, are the last remaining tropical glaciers in the Western Pacific Warm Pool (Figure 10).[29] The glaciers are located at 4 884 m a.s.l. (16 020 ft), 4°S and 137°E. Tropical glaciers are highly sensitive indicators and recorders of climate change.[30] Most tropical glaciers are currently in retreat primarily due to recent anthropogenic atmospheric warming, although strong El Niño events play an intermittent role in many regions by increasing air temperature and decreasing precipitation.[31,32,33] The glaciers near Puncak Jaya are remnants of glaciers that have existed for around 5 000 years,[34,35] and they have been retreating since around 1850 CE.[36] The closest available instrumental records to the glaciers are located 50–450 m below the glaciers' elevation. They cover the period 1997–2016 and indicate a near-zero probability that average daily temperature has fallen below the freezing point since 1997, which leads to unstoppable glacier demise.[37] In addition, the melting is also accelerated by more precipitation falling as rain rather than as snow. The melting of the glacier at both surface and base (basal melting) was confirmed by the 0 °C temperature at the bottom of ice cores derived in 2010.

Figure 10. Left: Topography of Papua Island (Indonesia and Papua New Guinea). The black dot indicates the approximate location of the glaciers. *Source:* Permana et al., 2019 Right: The location of the glaciers near Puncak Jaya, in Papua, on 9 October 2009. *Credit*: Landsat 5 satellite imagery (http://eoimages.gsfc.nasa.gov/images/imagerecords/79000/79084/grasberg_tm5_2009301_lrg.jpg)



29 Permana, D.S. et al., 2019: Disappearance of the last tropical glaciers in the Western Pacific Warm Pool (Papua, Indonesia) appears imminent. *Proceedings of the National Academy of Sciences of the United States of America*, 116(52): 26382–26388, https://doi.org/10.1073/pnas.1822037116.

30 Thompson, L.G. et al., 2011: Tropical glaciers, recorders and indicators of climate change, are disappearing globally. *Annals of Glaciology*, 52(59): 23–34.

31 Wagnon, P. et al., 2001: Anomalous heat and mass budget of Glaciar Zongo, Bolivia, during the 1997/98 El Niño year. *Journal of Glaciology*, 47(156): 21–28.

32 Francou, B. et al., 2004: New evidence for an ENSO impact on low-latitude glaciers: Antizana 15, Andes of Ecuador, 0°28'S. *Journal of Geophysical Research: Atmospheres,* 109(D18): D18106, https://doi.org/10.1029/2003JD004484.

33 Thompson, L.G. et al., 2017: Impacts of recent warming and the 2015/16 El Niño on tropical Peruvian ice fields. *Journal of Geophysical Research: Atmospheres*, 122(23): 12688–12701.

34 Hope, G.S. and J.A. Peterson, 1975: Glaciation and vegetation in the high New Guinea mountains. *Bulletin of the Royal Society of New Zealand*, 13: 155–162.

35 Löffler, E., 1982: Pleistocene and present-day glaciations. In: *Biogeography and Ecology of New Guinea*, Monographiae Biologicae, vol. 42. The Hague, W. Junk.

36 Permana, D.S., 2015: Reconstruction of tropical Pacific climate variability from Papua ice cores, Indonesia. PhD thesis, The Ohio State University, Columbus, United States of America.

37 Permana et al., 2019: Disappearance of the last tropical glaciers in the Western Pacific Warm Pool (Papua, Indonesia) appears imminent.

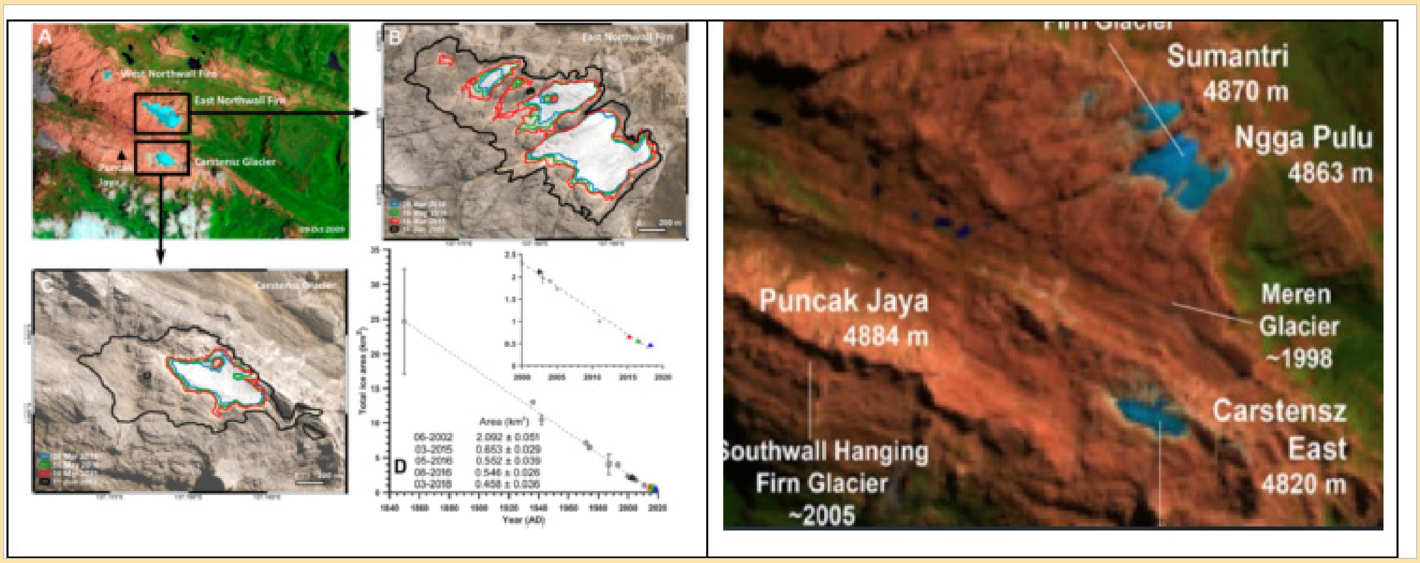


Figure 11. Left: Changes in the total ice area of Papua glaciers from 2002 to 2018. *Source:* Permana et al., 2019 Right: The total ice area of the glaciers near Puncak Jaya, in Papua, on 19 May 2020. *Credit*: Landsat 8 image, Christopher Shuman (National Aeronautics and Space Administration (NASA), Goddard Space Flight Center)

Loss of ice coverage

Total glacier area has decreased from ~19 km^2 in around 1850,[38,39] to ~2 km^2 in 2002; to ~1.8 km^2 in 2005;[40] to ~0.6 km^2 in 2015; to ~0.46 km^2 in March 2018;[41] and to ~0.34 km^2 in May 2020 (Figure 11).

Reduction in ice thickness

In June 2010, two ice cores, measuring 32.13 m (D1) and 31.25 m (D1B) in depth, were drilled to bedrock and extracted from the west dome (Sumantri Peak). A third core (D2), measuring 26.19 m, was extracted from the east dome (Soekarno Peak/Ngga Pulu).[42,43] At the same time, a flexible accumulation "stake" composed of fifteen 2-m-long pipes linearly connected by rope was placed in the D1 borehole. Changes in ice thickness since June 2010 were determined by measuring the accumulation stake during subsequent visits to the drill site, which revealed progressive exposure of pipe sections due to surface ice loss.[44] From 2010 to 2015, the ice had thinned ~5 m at a rate of ~1.05 m/yr. From 2015 to 2016, there was additional ice thinning of ~5 m, which was likely due to the effects of the very strong 2015–2016 El Niño.[45] Owing to the COVID-19 pandemic and the security issues in the region, during 2020–2021 the measurement was conducted by identifying the exposed stakes through aerial photographs of the glaciers taken during a flyover. At the beginning of 2021, the ice thickness had lost a further 12.5 m since November 2016, which is associated with a thinning rate of ~2.5 m/yr (Figure 12). If this rate persists, total ice loss will be expected at around the year 2024. It may be that the regional warming has passed such a threshold that the next very strong El Niño could lead to the demise of

38 Peterson, J.A. and L.F. Peterson, 1994: Ice retreat from the neoglacial maxima in the Puncak Jayakesuma area, Republic of Indonesia. *Zeitschrift für Gletscherkunde und Glazialgeologie*, 30: 1–9.

39 van Ufford, Q. and P. Sedgwick, 1998: Recession of the equatorial Puncak Jaya glaciers (~1825 to 1995), Irian Jaya (Western New Guinea), Indonesia. *Zeitschrift für Gletscherkunde und Glazialgeologie*, 34: 131–140.

40 Kincaid, J.L., 2007: An assessment of regional climate trends and changes to the Mt. Jaya glaciers of Irian Jaya. Master's thesis, Texas A&M University, United States of America.

41 Permana et al., 2019: Disappearance of the last tropical glaciers in the Western Pacific Warm Pool (Papua, Indonesia) appears imminent.

42 Thompson et al., 2011: Tropical glaciers, recorders and indicators of climate change, are disappearing globally.

43 Permana, 2015: Reconstruction of tropical Pacific climate variability from Papua ice cores, Indonesia.

44 Permana et al., 2019: Disappearance of the last tropical glaciers in the Western Pacific Warm Pool (Papua, Indonesia) appears imminent.

45 Ibid.

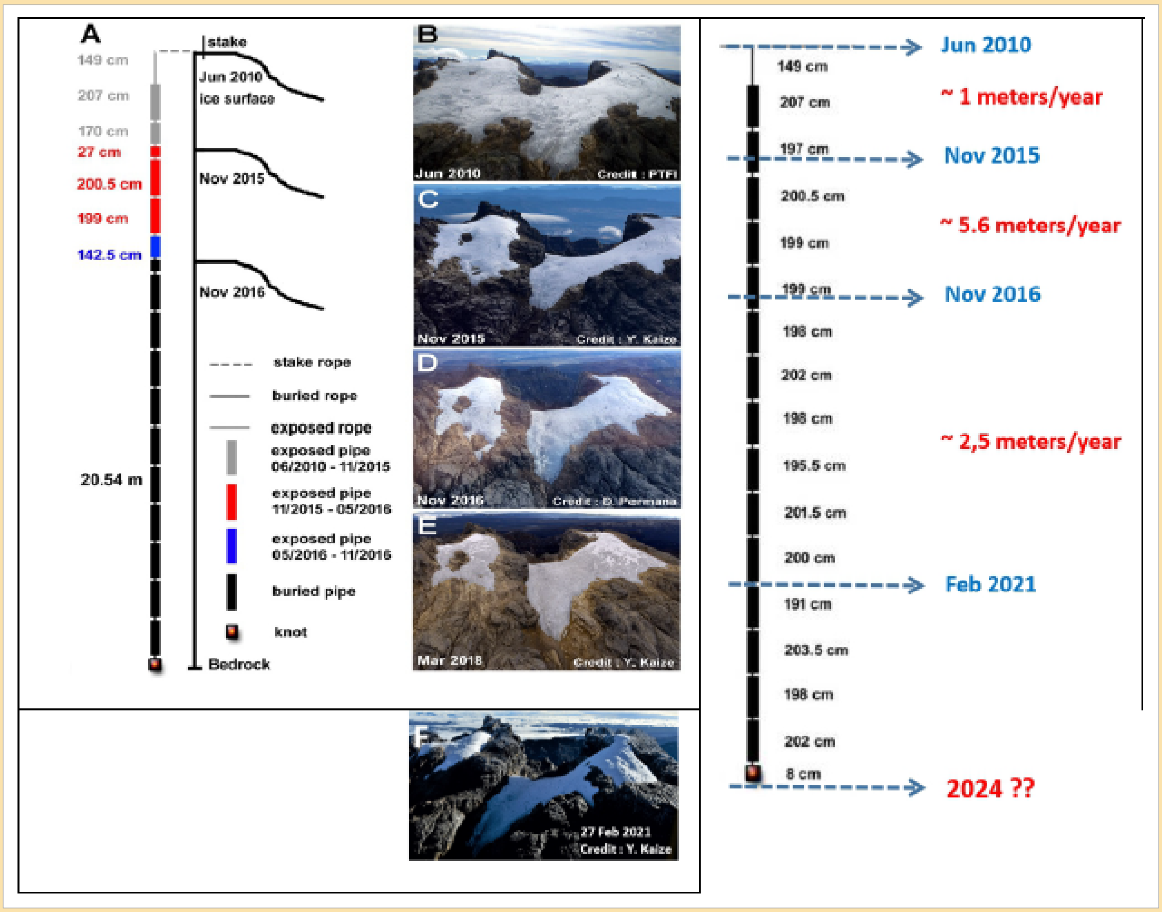


Figure 12. Left: Ice thinning and retreat of Papua glaciers; (A) schematic of connected pipes illustrating ice thickness changes in the glaciers from June 2010 to November 2015 (grey); to May 2016 (red); and to November 2016 (blue). Oblique aerial photographs of the glaciers, taken in (B) June 2010, (C) November 2015, (D) November 2016 and (E) March 2018, show the bifurcation of the ice mass. *Source:* Permana et al., 2019
Left bottom: (F) Photograph of the glaciers taken in February 2021
Right: Thinning rates at different times

the only remaining tropical glaciers between the Himalayas and the Andes.[46]

Total ice loss was also assessed by implementing a glacier mass balance model and future regional climate model projections for the region under different climate scenarios. The glacier mass balance model was evaluated and calibrated to reproduce the surface thinning based on the available stake measurements by using optimal combinations of lapse rates derived from the closest instrumental records of temperature and precipitation. The simulation of volumetric changes was driven by climate model projections over the South-East Asia region (Coordinated Regional Climate Downscaling Experiment–South-East Asia (CORDEX-SEA) project[47]). The model predicts that under almost all the scenarios, glacier shrinkage will continue unabated, leading to total ice loss by 2026.[48]

46 Ibid.

47 http://www.ukm.edu.my/seaclid-cordex

48 Permana et al., 2019: Disappearance of the last tropical glaciers in the Western Pacific Warm Pool (Papua, Indonesia) appears imminent.

1.2 EXTREME EVENTS

1.2.1 TROPICAL CYCLONES

The South-West Pacific region encompasses the Australian region, the South Pacific and parts of the western Pacific and eastern North Pacific tropical cyclone regions. It is an active region for tropical cyclones with most countries in it affected. The South Pacific and Australian tropical cyclone season of 2019–2020 coincided with an ENSO-neutral state with persistently warm equatorial SSTs in the Pacific. ENSO-neutral years typically see a westward shift in tropical cyclone genesis in the South Pacific towards Australia, when compared with either El Niño or La Niña.[49]

The 2019–2020 tropical cyclone season was less active than average in the Australian region, with eight cyclones, of which three reached severe status (category 3).[50] Generally, there is a high level of variability from year to year. In contrast, the South Pacific region was slightly more active than average, with eight tropical cyclones recorded, including the category 5 Tropical Cyclone *Harold* in April 2020, which was the first category 5 cyclone recorded in the region since 2018.

Tropical Cyclone *Harold* formed close to Papua New Guinea, and then tracked in a south-easterly direction, affecting the Solomon Islands, Vanuatu, Fiji and Tonga. There were 27 people killed in the Solomon Islands from being swept overboard off a ferry, and three further fatalities were recorded in Vanuatu.[51] *Harold* first made landfall on 6 April as a category 5 cyclone over Espiritu Santo, in northern Vanuatu. It was the first to do so since Tropical Cyclone *Pam* in 2015. Harold led to significant damage to infrastructure and the local boat

Figure 13. Path of destruction, Tropical Cyclone Yasa, in Nabouwalu, Bua, Fiji Credit: Fiji Department of Information

49 Australian Bureau of Meteorology: Tropical cyclone climatology maps, http://www.bom.gov.au/climate/maps/averages/tropical-cyclones/.

50 The cyclone categories refer to the Australian system: http://www.bom.gov.au/cyclone/tropical-cyclone-knowledge-centre/understanding/tc-info/.

51 Australian Department of Foreign Affairs and Trade: Tropical Cyclone Harold, https://www.dfat.gov.au/crisis-hub/Pages/tropical-cyclone-harold.

fleet, and also contributed towards the wettest April on record for northern Vanuatu.[52] *Harold* then passed south of Viti Levu, the main island of Fiji, leading to extensive damage to infrastructure from high winds, along with coastal and river inundation.

Just months after the devastation of *Harold*, Fiji experienced a second major event, Tropical Cyclone *Yasa*, one of the most powerful tropical cyclones worldwide in 2020. Yasa intensified to a category 5 system on 14 December before making landfall three days later over Viti Levu and Vanua Levu, main islands of Fiji (Figure 13). Exceptionally, *Yasa* was the earliest category 5 cyclone on record to have formed during the South Pacific season,[53] as well as the strongest cyclone in the South Pacific since Tropical Cyclone *Winston* in 2016. Fiji bore the brunt of *Yasa* with four reported deaths.[54] Impacts from *Yasa* were also experienced in nearby Vanuatu and Tonga.

As with the Australian region, the western North Pacific tropical cyclone region was less active in 2020 than usual. Despite this, the Philippines was particularly devastated by consecutive tropical cyclones during the months of October and November. Typhoon *Goni* (*Rolly*)[55] had one of the most intense landfalls of any tropical cyclone on record when it reached the Philippines on 30 October. The estimated 10-minute sustained winds were minimum 220 km/h at the time of landfall over Catanduanes island. Additionally, 90% of the island's infrastructure was damaged by the storm and 25 deaths were reported in the Philippines.[56] Typhoon *Vamco* (*Ulysses*) struck the Philippines merely weeks later. Both cyclones were recorded as two of the costliest tropical cyclones on record for the country. They contributed to the country's fourth-wettest October–November on record, after a dry July–September period. In 2020, no significant tropical cyclone impacts were reported in the Micronesian region or in United States-affiliated islands in the North Pacific.

In the eastern North Pacific part of the region, there was one significant tropical cyclone, Hurricane *Douglas*. *Douglas* passed within 48 km of the Hawaiian island of Oahu as a category 1 hurricane, the closest approach of a hurricane to Oahu on record, but it led to few significant impacts on the island.

Further information on the impacts of tropical cyclones in the region will be given in Part II of this report.

1.2.2 EXTREME RAINFALL, FLOODS AND STORMS

In Indonesia, extreme rainfall affected Jakarta on 1 January. Halim Airport received 377 mm, the wettest day for the Jakarta area since 1996. There was significant flooding through large parts of the city, with 16 reported deaths and over 13 000 displaced.[57]

During what was an active monsoon period, there was also very heavy rain in parts of northern Australia. A total of 562 mm fell on 11 January, at Dum in Mirrie, west of Darwin, a record daily rainfall for the Northern Territory. Heavy rain and widespread flooding affected the east coast of Australia in the second week of February. Daily totals were as high as 418 mm at Wattamolla, near Wollongong, while Sydney had 378 mm over the four days from 7 to 10 February. It was the wettest four-day period on record averaged over the Hawkesbury-Nepean River catchment. The flooding, although significant, was ameliorated by very dry antecedent conditions

52 https://www.pacificmet.net/sites/default/files/documents/ocof/OCOF_Summary_152_0.pdf

53 http://www.bom.gov.au/climate/tropical-note/archive/20201222.archive.shtml

54 Australian Department of Foreign Affairs and Trade: Tropical Cyclone Yasa, https://www.dfat.gov.au/crisis-hub/tropical-cyclone-yasa.

55 All first listed names are given by WMO Regional Specialized Meteorological Centres. Names in parentheses are the locally used names.

56 Philippines National Disaster Risk Reduction and Management Council, 2020: https://ndrrmc.gov.ph/attachments/article/4135/SitRep_no_11_re_STY_Rolly_as_of_10NOV2020.pdf.

57 Contribution by Indonesia

following the severe drought of 2019. The rain also led to the containment of all remaining wildfires burning in eastern Australia.

Severe thunderstorms affected south-eastern Australia on 19 and 20 January. The most severe impacts were in Canberra, where hail, 4–6 cm in diameter, contributed to extensive damage to houses and vehicles, with insured losses exceeding $A 1 billion.[58] There was also significant damage in some eastern suburbs of Melbourne. On 31 October, hail up to 14 cm in diameter – among the largest recorded in Queensland – fell across the southern edge of Brisbane, leading to widespread damage. In New Caledonia, a rare hailstorm occurred on the night of 30/31 May, with hailstones as large as 6 cm in diameter observed west of Nouméa.

June and July were wet in much of equatorial South-East Asia, with Singapore having its wettest June in the last decade. The wet June also ended a run of 28 consecutive months of above-average temperatures[59]. On 12–13 July, 38 lives were lost in the flooding in southern Sulawesi (Indonesia). There was also substantial flooding in Brunei Darussalam, and in southern Peninsular Malaysia, where rainfall was more than 60% above average in both June and July.[60]

Flooding affected the far south of New Zealand in early February. A total of 509 mm fell on 3 February in Milford Sound, while the inland town of Lauder had its wettest day on record on 4 February, with 84 mm. There were numerous evacuations in inland Southland, and the road to Milford Sound was severely damaged. Later in the year, on 9 November, Napier, in the eastern North Island, had 242 mm, its second-wettest day on record, causing local flooding and numerous landslides.[61]

1.2.3 HEATWAVES, WILDFIRES AND DROUGHTS

The most notable wildfires in the region occurred in eastern Australia in 2019 and early 2020. The unprecedented 2019–2020 wildfire season in eastern Australia led to severe smoke pollution affecting many parts of south-eastern Australia in early 2020, with fire debris and ash contaminating rivers and streams in some areas to the extent that rare aquatic species were transported to zoos for protection. While the most extreme temperature anomalies of the period at national level had occurred in December 2019, there were also a number of extreme heat events in early January 2020, with Penrith, western Sydney, reaching 48.9 °C – the highest temperature on record for any major Australian metropolitan area – and Canberra reaching 44.0 °C – more than one degree above the city's previous record.[62] Heavy rains in early February helped to bring the wildfires under control and to ease drought conditions that had prevailed since 2017. The 2020–2021 wildfire season was relatively inactive in southern Australia, but a long-lived fire in late spring burned large parts of Fraser Island, off the southern Queensland coast.

Other notable drought and heatwave conditions in the region were recorded in New Zealand, French Polynesia, New Caledonia, and the Federated States of Micronesia.

Between late December 2019 and late February 2020, a number of stations throughout New Zealand reported their longest dry spell,[63] including Blenheim, Auckland, Cheviot and Takaka. Dry conditions continued through much of the year in many places, with large parts of the North Island having annual rainfall 20% to 40% below average. Gisborne reached 38.2 °C in late January, the highest temperature recorded at that location. Nationwide,

58 Insurance Council of Australia

59 Meteorological Service Singapore, 2021: 2020 *Annual Climate Assessment: Singapore*, http://www.weather.gov.sg/wp-content/uploads/2021/03/Annual-Climate-Assessment-Report-2020-updated-3.pdf.

60 Contributions by Indonesia, Malaysia

61 NIWA monthly, seasonal and annual climate summaries (https://niwa.co.nz/climate/summaries)

62 Trewin, B. et al., 2021: *Australia's 2019/20 Summer of Extremes and its Climate Drivers*. 101st American Meteorological Society Annual Meeting, 10–15 January 2021 (virtual).

63 In New Zealand, a dry spell is defined as a period of consecutive days with each day recording less than 1 mm of rain.

New Zealand reported its warmest winter on record.[64] Dry, windy conditions contributed to a severe wildfire on 4 October, which destroyed more than 50 houses at Lake Ohau, in the central South Island.

In New Caledonia, Tontouta Airport, near Nouméa, reached 37.9 °C on 3 February, its second-highest temperature since records began in 1951.

In French Polynesia, extreme drought occurred in Faa'a between January and September and in Rapa from January to June, while exceptional drought occurred in Rikitea from June to September.[65]

In the southern Federated States of Micronesia, some parts near the equator were badly affected by drought in the second half of the year.

Fewer fire hotspots occurred in the Maritime Continent during the 2020 dry season. Traditionally the dry season lasts from June to October for much of the Maritime Continent (encompassing Brunei Darussalam, Indonesia, Malaysia, the Philippines and Singapore). However, owing to wetter-than-usual conditions associated with the La Niña event, the number of hotspots and associated smoke haze was subdued compared with previous years. In eastern Java, the dry season onset, which usually sets in by the end of May, was delayed until early to mid-June.[66] Regionally, increased rain during June and July also led to a delayed dry season onset, which did not occur until the beginning of August 2020. While extensive smoke plumes were not detected, brief periods of drier weather did occur, leading to localized smoke plumes such as in Kalimantan in September 2020. Overall, the number of hotspots detected in 2020 was only 20% of that detected in 2019.[67]

1.2.4 MARINE HEATWAVES

The most significant marine heatwave of 2020 occurred over the Great Barrier Reef region of Australia. In February, SSTs over the region were 1.2 °C above the 1961–1990 average, making it the hottest month on record. High temperatures affected the entire reef and widespread coral bleaching was reported, the third mass bleaching event in the past five years.

In 2020, marine heatwaves were relatively rare in equatorial and near-equatorial Pacific waters, compared with previous years, as the developing La Niña cooled ocean temperatures, although SSTs were above average across parts of the tropical and subtropical North Pacific through the later part of the year. The largest SST anomalies occurred south of the equatorial region.

64 Contribution by New Zealand

65 Contribution by French Polynesia

66 Contribution by Indonesia

67 ASEAN Specialised Meteorological Centre (ASMC), Bulletin of March 2021, asmc.asean.org.

PART II – RISKS AND IMPACTS

2.1 IMPACT OF EXTREME WEATHER EVENTS IN 2020

Storms and floods have been the most devastating extreme weather events in the region. The Philippines and Small Island Developing States (SIDS) have suffered greatly from high risk of typhoons/tropical cyclones. Moreover, floods have been frequently reported in South-East Asia, and droughts have affected many parts of the region.

In 2020, storms and floods continued to affect the people and their livelihoods. Although the region witnessed less than 500 fatalities, about one third of the yearly average from 2000 to 2019, more than 11 million people were affected, mainly by typhoons/tropical cyclones (Figure 14). Among others, Cyclone *Harold* in April, Typhoon *Vongfong* (*Ambo*) in May, Typhoon *Goni* (*Rolly*) and Typhoon *Molave* (*Quinta*) in October, and Typhoon *Vamco* (*Ulysses*) in November resulted in a large number of casualties.[68]

2.1.1 AFFECTED POPULATIONS AND DAMAGE

Between 2000 and 2019, the countries in the region recorded, on average, about 1 500 fatalities and close to 8 million people affected by extreme weather events per year.

The Philippines and Indonesia reported large numbers of affected people from extreme weather events. When population size is taken into consideration, the high impact experienced in Vanuatu and Fiji is evident, as more than one fifth of their populations were affected in 2020. In terms of damage,

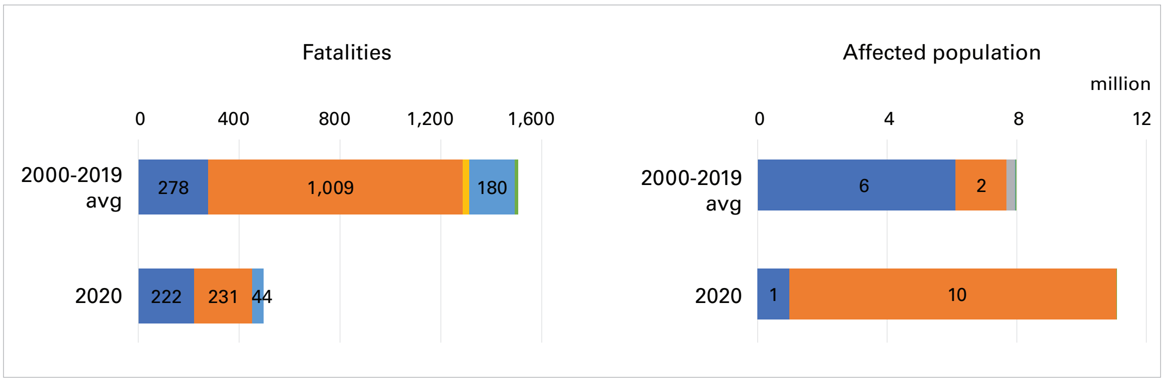


Figure 14. Fatalities and affected populations in the South-West Pacific. Note: The 2019–2020 Australian wildfires were classified as a 2019 event and were excluded from the 2020 analysis. *Source:* Centre for Research on the Epidemiology of Disasters (CRED), International Disaster Database (EM-DAT)

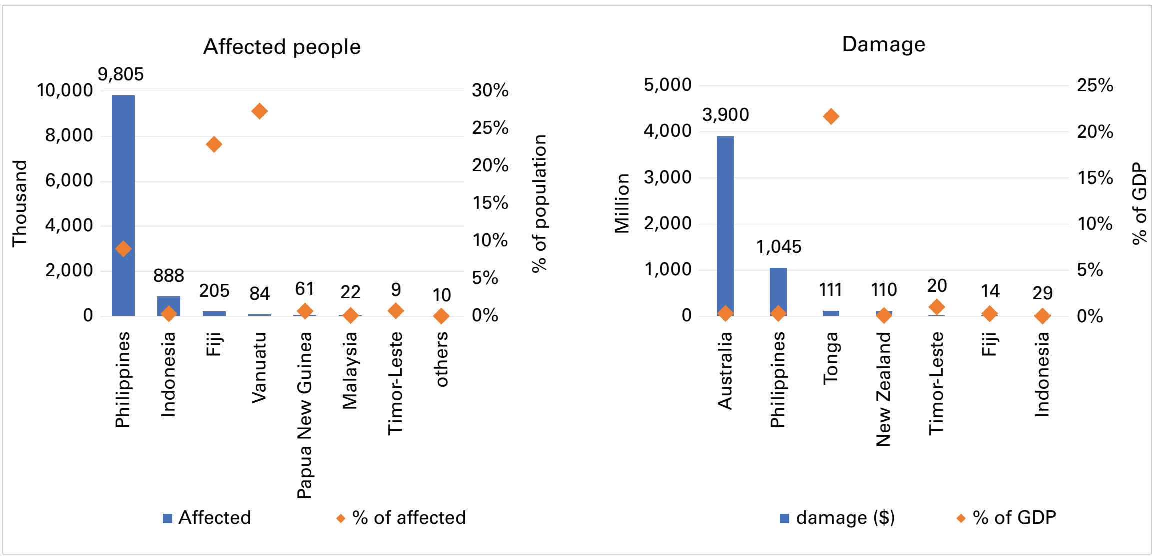


Figure 15. Affected people and damage by climate-related hazards in the South-West Pacific. *Sources*: CRED EM-DAT (data on people affected and damage by climate-related hazards); Economic and Social Commission for Asia and the Pacific (ESCAP) Sustainable Development Goals Gateway Data (https://dataexplorer.unescap.org) (data on population and GDP)

68 CRED EM-DAT, www.emdat.be

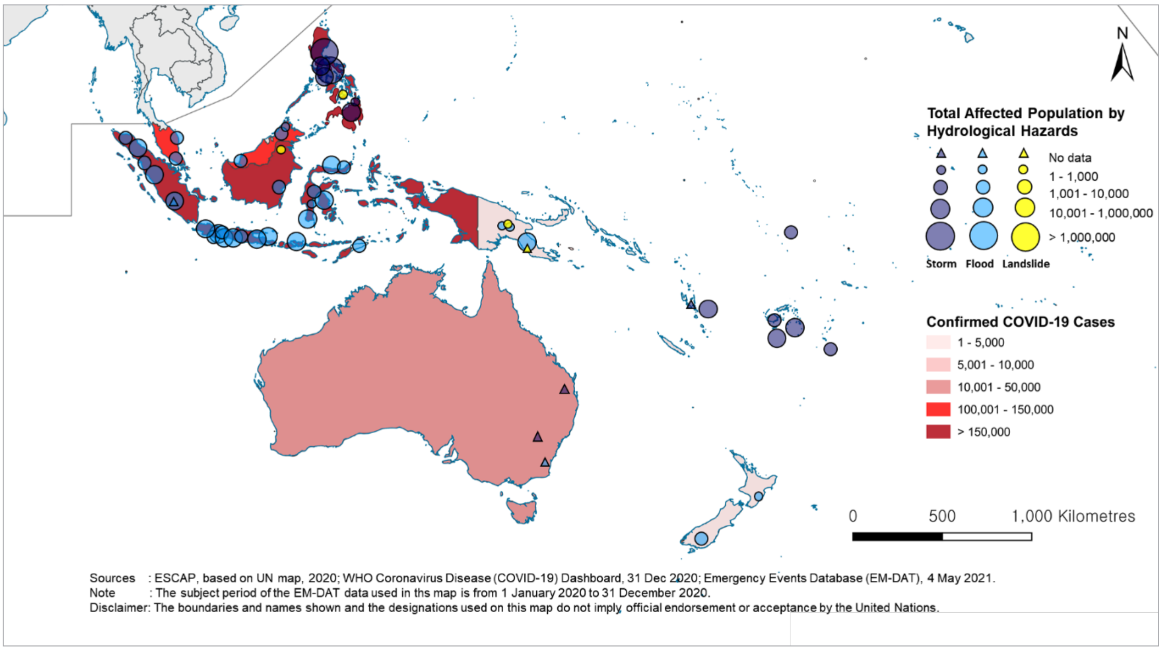


Figure 16. Climate-related hazards converging with COVID-19 in 2020. *Sources*: ESCAP, the World Health Organization (WHO), EM-DAT

Australia reported damage of almost US$ 4 billion, followed by the Philippines. Tonga recorded damage of about 22% of gross domestic product (GDP) (Figure 15).

Amid the COVID-19 pandemic, countries faced the dual challenge of tackling the pandemic and climate-related hazards (Figure 16). In particular, Indonesia and the Philippines faced extreme weather events amid high incidence of COVID-19.

2.1.2 DISPLACEMENT

Climate and weather events had major and diverse impacts on population movements and on the vulnerability of people on the move in the region throughout 2020. Much of the disaster displacement recorded globally in 2020 took place in the region. The Philippines was the most affected country, recording 4.4 million new displacements.[69] Vanuatu was particularly hard hit relative to its population size; in particular, Cyclone *Harold* triggered approximately 80 000 new displacements, nearly a quarter of the population. In the Philippines, Indonesia and Vanuatu, volcanic activity also forced people to flee their homes. Refugees, internally displaced people and migrants in the region are often among those most vulnerable to climate-related and weather-related hazards.[70] The overwhelming majority of weather-related displacements in the region take place within national borders, though cross-border movements also occur.

Many displacement situations triggered by hydrometeorological events have become prolonged or protracted for people unable to return to their former homes or without options for integrating locally or settling elsewhere. Typhoons *Goni* (*Rolly*) and *Vamco* (*Ulysses*) triggered more than 3 million displacements in the Philippines and in Viet Nam in November 2020. Torrential rains and violent winds from *Goni* (*Rolly*) caused storms and mudslides in the northern Philippines before moving on to Viet Nam, leaving behind extensive damage and destruction. Less than two weeks later, Typhoon *Vamco* (*Ulysses*) triggered another 1.9 million displacements, most of them in the Philippines. *Vamco*

69 Internal Displacement Monitoring Centre (IDMC), 2021: *Global Report on Internal Displacement 2021*, https://www.internal-displacement.org/global-report/grid2021/.

70 Office of the United Nations High Commissioner for Refugees (UNHCR). Climate change and disaster displacement, https://www.unhcr.org/climate-change-and-disasters.html.

(*Ulysses*) also destroyed temporary shelters and housing built in response to *Goni* (*Rolly*).[71]

In addition, mobility restrictions and economic downturns due to COVID-19 have slowed the delivery of humanitarian assistance to vulnerable people on the move in these regions, as well as efforts to support recovery for affected persons, including durable solutions for those displaced.[72] The vulnerabilities of displaced populations, which often live in densely populated settlements in Asia, were further amplified.[73]

In April, Tropical Cyclone *Harold* made landfall in Fiji, the Solomon Islands, Tonga and Vanuatu. It was one of the strongest storms ever recorded in the South Pacific, triggering an estimated 99 500 displacements.[74] Because of COVID-19 lockdowns and quarantines, response and recovery operations were hampered, leading to delays in providing equipment and assistance. The situation in the Pacific has made clear that climate change adaptation and disaster risk reduction remain essential and urgent imperatives for countries vulnerable to sudden-onset disasters.[75]

Likewise, in the Philippines, the pandemic complicated evacuation and response efforts ahead of Typhoon *Vongfong* (*Ambo*) in mid-May. More than 180 000 people were pre-emptively evacuated, though operations were hampered by the need for social distancing as residents could not be transported in large numbers and evacuation centres could only be used at half capacity.[76] The storm also damaged the only COVID-19 testing facility in Bicol Region.

2.1.3 IMPACT ON THE ECONOMY

In 2020, extreme weather events led to large disruptions across various sectors. In particular, tropical cyclones damaged roads, led to power cuts, destroyed health-care and education centres, and seriously damaged large areas of agricultural fields and food crops, thus having implications on food security, employment and the livelihood of farmers. Among others, Fiji, the Solomon Islands, Tonga, Vanuatu, the Philippines and Indonesia experienced tropical cyclones and floods.

Tropical Cyclone Harold: In Vanuatu, in April, Cyclone *Harold* affected approximately 129 000 people (42% of the population).[77] In Sanma Province, 80% to 90% of the population lost their houses, 60% of schools were damaged and 60% of croplands were severely damaged.[78] The loss and damage was estimated to be VT 68 billion (US$ 617 million), about 61% of GDP in 2020.[79] Fiji reported 180 000 people affected.[80] The cyclone also

71 IDMC, 2021: *Global Report on Internal Displacement 2021*.

72 Gaynor, T., 2020: Climate change is the defining crisis of our time and it particularly impacts the displaced. UNHCR, 30 November, https://www.unhcr.org/news/latest/2020/11/5fbf73384/climate-change-defining-crisis-time-particularly-impacts-displaced.html.

73 UNHCR and Potsdam Institute for Climate Impact Research, 2020: COVID-19, displacement and climate change, June, https://www.unhcr.org/protection/environment/5ef1ea167/covid-19-displacement-climate-change.html.

74 IDMC, 2021: *Global Report on Internal Displacement 2021*.

75 Ober, K. and S. Bakumenko, 2020: A new vulnerability: COVID-19 and Tropical Cyclone Harold create the perfect storm in the Pacific. *Refugees International*, 3 June, https://www.refugeesinternational.org/reports/2020/6/1/a-new-vulnerability-covid-19-and-tropical-cyclone-harold-create-the-perfect-storm-in-the-pacific.

76 United Nations Office for the Coordination of Humanitarian Affairs (OCHA), 2020: Philippines Typhoon Vongfong (Ambo) Snapshot, 20 May, https://reliefweb.int/sites/reliefweb.int/files/resources/200520_Typhoon%20Vongfong%20Ambo%20Snapshot.pdf.

77 Department of Strategic Policy, Planning and Aid Coordination, Vanuatu, 2020: *Post-Disaster Needs Assessment: TC Harold & COVID-19 – Volume A: Summary Report*, https://dsppac.gov.vu/index.php?option=com_content&view=article&id=135&Itemid=363.

78 Pacific Humanitarian Team, 2020: Tropical Cyclone Harold – Situation Report #6, 13 April, https://reliefweb.int/sites/reliefweb.int/files/resources/PHT%20Sitrep%206_TC%20Harold_13042020.pdf.

79 Department of Strategic Policy, Planning and Aid Coordination, Vanuatu, 2020: *Post-Disaster Needs Assessment*.

80 International Federation of Red Cross and Red Crescent Societies (IFRC), 2021: *Final Report. Fiji: Tropical Cyclone Harold*, 26 January, https://reliefweb.int/sites/reliefweb.int/files/resources/MDRFJ004do_0.pdf.

caused major power cuts and roads to be blocked.[81] Tonga reported major damage to houses, water supply and food crops. The Solomon Islands also reported damage to 25 schools in three provinces. The damages included those in classrooms, specialized classrooms, water-sanitation-hygiene infrastructures, staff houses, learning and teaching resources.[82]

Typhoon Vongfong (Ambo): In May, Typhoon *Vongfong* (*Ambo*) hit the Philippines, which affected 382 700 people and led to US$ 30.8 million of damage in the agriculture sector. Exposure and vulnerability to the storm also destroyed approximately 3 000 houses and partially damaged 23 health facilities and 13 900 houses.[83]

North Sulawesi Floods: In Indonesia, in July and August, floods affected 4 308 people in 11 villages and collapsed four bridges.[84]

Typhoons Goni (Rolly) and Vamco (Ulysses): In November, Typhoons *Goni* (*Rolly*) and *Vamco* (*Ulysses*) struck the Philippines. Typhoon *Goni* (*Rolly*) affected 3.36 million people and damaged 398 266 houses.[85] This was followed by Typhoon *Vamco* (*Ulysses*) that affected 5.2 million people and damaged 209 170 houses.[86] The two typhoons severely damaged the agriculture sector, as well as critical infrastructure such as roads, bridges, communication networks, ports, and health and education facilities.[87,88]

Tropical Cyclone Yasa: Tropical Cyclone *Yasa*, in December 2020, also had a high impact on Fiji. More than 139 000 people were affected by *Yasa*, 91% of whom were in the Northern Division. The Northern Division and the Eastern Division accounted for most damage, estimated to be US$ 250 million, about 4.5% of the country's GDP.[89] Approximately 8 300 houses and 90 schools were fully or partially damaged.[90]

2.1.4 FOOD SECURITY

Many of these extreme weather events had significant impact on the agriculture sector and food security. For example, in Vanuatu, Cyclone *Harold* affected the production areas of important foods (e.g. yam, taro, sweet potato and banana) and cash crops (e.g. kava, coconut and cocoa). The areas contain 67% of cattle farmers, 54% of chicken farmers and 50% of pig farmers. Between 22% and 66% of these crops were damaged, and 2% of cattle, 6% of pigs and 9% of chickens in the affected provinces were lost. The loss and damage in the agriculture sector was estimated to be VT 19.6 billion or US$ 177 million.[91]

In the Philippines, Super Typhoon *Goni* (*Rolly*) and Typhoon *Vamco* (*Ulysses*), in October and November 2020, respectively, damaged 225 893 hectares of agricultural land and resulted in US$ 186 million worth of agri-fishery products being damaged or lost.[92] Four of its

81 OCHA, ReliefWeb, 2020: Tropical Cyclone Harold – Apr 2020, https://reliefweb.int/disaster/tc-2020-000049-vut#overview.

82 OCHA, ReliefWeb, 2020: Pacific Humanitarian Team – Tropical Cyclone Harold Situation Report #12 (final), 7 May 2020, https://reliefweb.int/report/vanuatu/pacific-humanitarian-team-tropical-cyclone-harold-situation-report-12-final-7-may

83 OCHA, 2020: Philippines Typhoon Vongfong (Ambo) Snapshot, 20 May.

84 IFRC, 2020: *Emergency Plan of Action (EPoA) Indonesia: North Sulawesi Floods*, 10 August, https://reliefweb.int/sites/reliefweb.int/files/resources/MDRID018do.pdf.

85 IFRC, 2021: *Operation Update Report. Philippines: Floods and Typhoons 2020 (Typhoon Goni),* 5 March, https://reliefweb.int/sites/reliefweb.int/files/resources/MDRPH041eu3.pdf.

86 IFRC, 2021: *Operation Update Report. Philippines: Floods and Typhoons 2020 (Typhoon Vamco)*, 2 June, https://reliefweb.int/report/philippines/philippines-floods-and-typhoons-2020-typhoon-vamco-operation-update-report-n-4.

87 Ibid.

88 IFRC, 2021: *Operation Update Report. Philippines: Floods and Typhoons 2020 (Typhoon Goni).*

89 Government of the Republic of Fiji, 2021: Tropical Cyclone Yasa response and resilience plan.

90 Asian Development Bank (ADB), 2021: *Fiji: Tropical Cyclone Yasa Emergency Response Project*, https://www.adb.org/projects/54471-001/main#project-documents.

91 Department of Strategic Policy, Planning and Aid Coordination, Vanuatu, 2020: *Post-Disaster Needs Assessment*.

92 Food and Agriculture Organization of the United Nations (FAO), 2020: The Philippines: Super Typhoon Goni and Typhoon Vamco – Urgent call for assistance, http://www.fao.org/emergencies/resources/documents/resources-detail/en/c/1365196/.

provinces – Quezon, Catanduanes, Camarines Sur and Albay – were hit the hardest.[93] Rice, corn and other high-value crops, agricultural equipment, boats, fishing gear, and other livelihood assets and resources were destroyed. Livestock, poultry and fisheries were also affected. It was estimated that 256 000 people needed food and agricultural assistance, including 70 000 farmers and fishers.[94,95]

Tropical Cyclone *Yasa*, in December, affected an area of predominantly subsistence agriculture in Fiji, with more than 5 000 hectares, or 83% of total cropland, damaged.[96] In January 2021, the significant impact of *Yasa* on the volume and price of products in local markets was evident: the number of market vendors was down by 64% in Labasa and by 42% in Savusavu; moreover, prices increased and quantities decreased, compared with pre-cyclone data.[97]

In the region, 2.7 million people are estimated to have been undernourished in 2020. Moreover, 12% of the population was affected by moderate or severe food insecurity, including 2.6% facing severe levels of food insecurity. In 2020, there was a small improvement in food security in the region, at both levels of severity, in line with a trend that had begun in 2017 and that seemingly was not altered by the pandemic.[98]

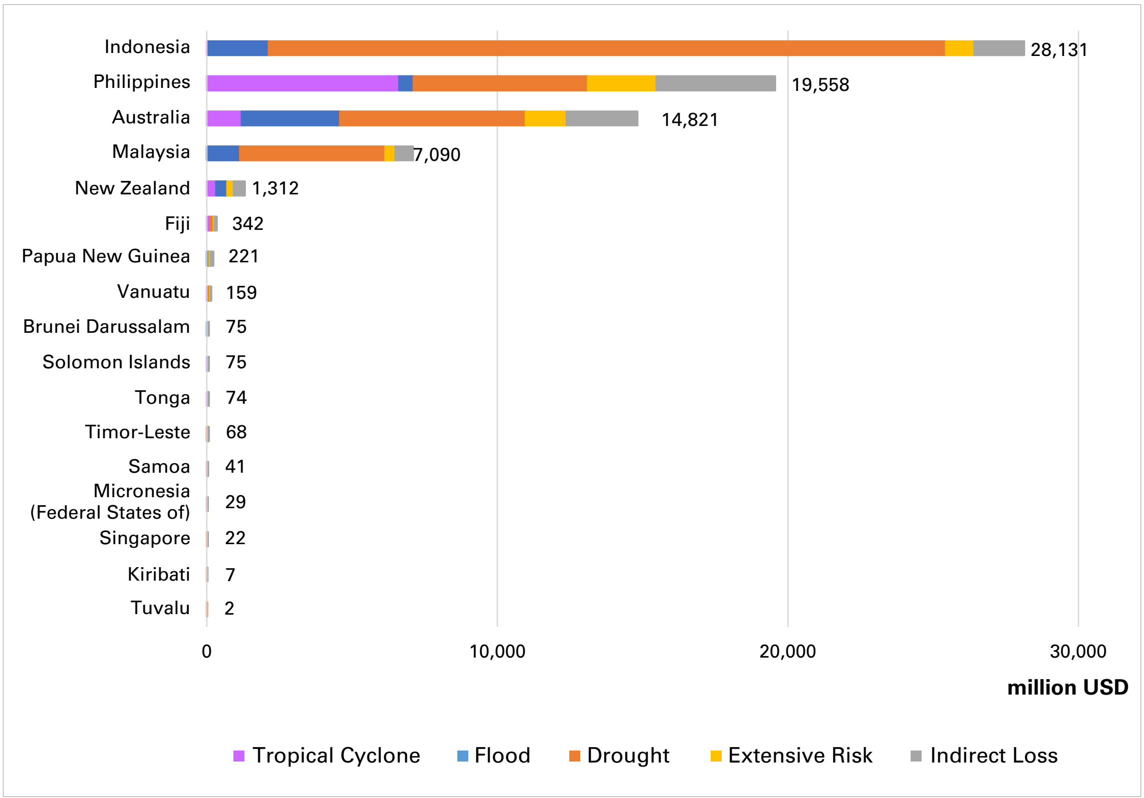


Figure 17. Total AAL from climate-related hazards in the South-West Pacific. Data sourced from ESCAP, 2021: The Risk and Resilience Portal. Note: Data unavailable for the Cook Islands, Nauru, Niue and the French, American and British territories in the Pacific.

93 OCHA, ReliefWeb, 2020: Philippines: Super Typhoon Goni (Rolly) Humanitarian Needs and Priorities (Nov 2020- April 2021), https://reliefweb.int/report/philippines/philippines-super-typhoon-goni-rolly-humanitarian-needs-and-priorities-nov-2020

94 OCHA, 2020: *Philippines. Super Typhoon Goni (Rolly) and Typhoon Vamco (Ulysses): Humanitarian Needs and Priorities*, https://philippines.un.org/en/106540-super-typhoon-goni-rolly-and-typhoon-vamco-ulysses-humanitarian-needs-and-priorities-nov.

95 FAO, 2020: The Philippines: Super Typhoon Goni and Typhoon Vamco – Urgent call for assistance.

96 Government of the Republic of Fiji, 2021: Tropical Cyclone Yasa response and resilience plan.

97 Ministry of Agriculture, Fiji, 2020: Detailed damage assessment report on Tropical Cyclone Yasa.

98 FAO, International Fund for Agricultural Development (IFAD), United Nations Children's Fund (UNICEF), World Food Programme (WFP) and WHO, 2021: *The State of Food Security and Nutrition in the World 2021. Transforming Food Systems for Food Security, Improved Nutrition and Affordable Healthy Diets for All.* Rome, FAO, https://doi.org/10.4060/cb4474en.

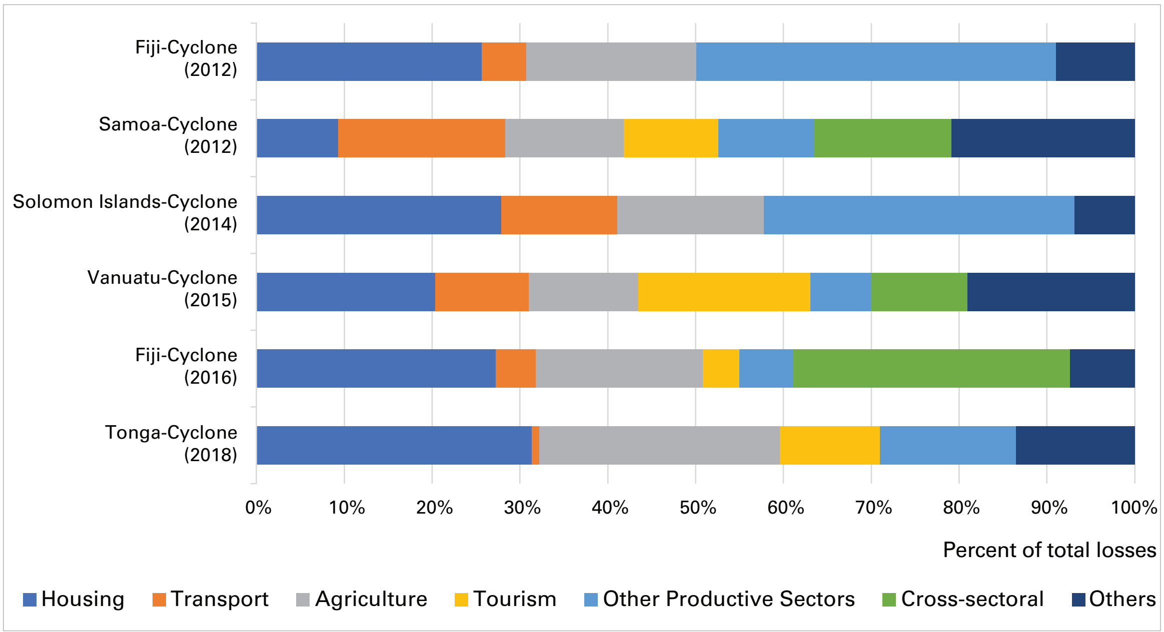


Figure 18. Examples of damage and losses by sector from major disasters. *Source:* Post-Disaster Needs Assessment reports collected from the Global Facility for Disaster Reduction and Recovery

2.2 POLICY ASPECTS

2.2.1 COST OF EXTREME WEATHER EVENTS AND SUSTAINABLE DEVELOPMENT

Extreme weather events continue to threaten the sustainable development of countries in the South-West Pacific. The average annual loss (AAL) from extreme weather events across the South-West Pacific is estimated to be as high as US$ 28.1 billion in Indonesia, US$ 19.6 billion in the Philippines, US$ 14.8 billion in Australia and US$ 7.1 billion in Malaysia (Figure 17). When the size of the economy is considered, the expected impact on SIDS can clearly be identified, with estimated AAL as high as 17.9% of GDP for Vanuatu, 14.6% of GDP for Tonga and 7.7% of GDP for the Federated States of Micronesia.

Extreme weather events have affected various economic sectors, from housing, transport and agriculture to other productive sectors (Figure 18). Although the magnitude of impacts differed based on the exposure and vulnerability of the affected region, there were large impacts on housing, transport, agriculture, tourism and other productive sectors. This can negatively affect transportation costs, employment, food security and trade, and thus raises the need to build resilience in those sectors with risk-informed investment for reducing the disaster risk.

Climate change can amplify existing risks and create new risks for natural and human systems.[99] For example, with climate change an increase in the intensity of typhoons is likely in regions of the western North Pacific near the Philippines, and it is likely that the global proportion of intense tropical cyclones has increased over the last 40 years.[100] It is estimated that storms with 5-year return periods are likely to produce losses of about 1% of national economic activity in the affected year, while storms with 20-year return periods are likely to

99 Cramer, W. et al., 2014: Detection and attribution of observed impacts. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (C.B. Field et al., eds.). Cambridge, Cambridge University Press, https://www.ipcc.ch/report/ar5/wg2/.

100 IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

induce losses of 2% of total national economic activity in the affected year.[101] Thus, building resilience to extreme weather events is critical to achieving the 2030 Agenda for Sustainable Development in the South-West Pacific. In this regard, the report of the Global Commission on Adaptation highlights that spending on climate adaptation is a high-return investment.[102]

Ocean warming, deoxygenation and acidification are additional factors changing the oceans' circulation pattern and chemistry.[103] Fish and zooplankton are migrating to higher latitudes and changing behaviours.[104] Consequently, traditional fisheries are altering. This would have critical implications for the Pacific islands where coastal fishing is a principal activity that provides for nutrition, welfare, culture and employment.[105] However, between 1990 and 2018, total fisheries production has decreased in some countries, by as much as 75% in Vanuatu, 23% in Tonga and 15% in New Caledonia.[106]

2.2.2 CLIMATE CHANGE AND EXTREME WEATHER IMPACTS ON ECOSYSTEMS

Extreme weather events produce negative environmental effects, and climate change can pose additional risks. SIDS in the South-West Pacific are especially threatened by climate change, with many islands sitting only metres above the sea level and subject to frequent and intense extreme weather events.[107] Increased evapotranspiration due to warmer temperatures can extend wildfire seasons, making extreme wildfires more frequent, and damaging and expanding their location of occurrence. In 2019 and 2020, in Australia, more than 10 million hectares were burned, 33 people were killed, more than 3 000 homes were destroyed and millions of animals died.[108]

Rising sea levels exacerbate ocean acidification, coastal erosion, coral reef bleaching and water temperature increase.[109] These can have profound impacts on the condition of coastal and oceanic habitats, as well as on the productivity of fisheries and aquaculture.[110] For instance, under the scenario in which global mean temperature increases 2 °C by 2050, up to 90% of the coral reefs in the Coral

101 ADB, 2019: *The Impact of Typhoons on Economic Activity in the Philippines: Evidence from Nightlight Intensity*. ADB Economics Working Paper Series, No. 589, https://www.adb.org/sites/default/files/publication/515536/ewp-589-impact-typhoons-philippines.pdf.

102 Global Commission on Adaptation, 2019: *Adapt Now: A Global Call for Leadership on Climate Resilience*, https://gca.org/wp-content/uploads/2019/09/GlobalCommission_Report_FINAL.pdf.

103 International Union for Conservation of Nature and Natural Resources (IUCN), 2017: Issues brief: the ocean and climate change, https://www.iucn.org/sites/dev/files/the_ocean_and_climate_change_issues_brief-v2.pdf.

104 Hoegh-Guldberg, O. et al., 2014: The ocean. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (V.R. Barros et al., eds.). Cambridge and New York, Cambridge University Press, https://www.ipcc.ch/report/ar5/wg2/.

105 Gillett, R., 2011: *Fisheries of the Pacific Islands: Regional and National Information*. Bangkok, FAO Regional Office for Asia and the Pacific, http://www.fao.org/3/i2092e/i2092e00.pdf.

106 The World Bank and FAO. Total fisheries production (metric tons), https://data.worldbank.org/indicator/ER.FSH.PROD.MT.

107 Global Center on Adaptation, 2020: *State and Trends in Adaptation Report 2020*, https://gca.org/reports/state-and-trends-in-adaptation-report-2020/.

108 World Bank Group, 2020: *Policy Note: Managing Wildfires in a Changing Climate*. Washington, DC, International Bank for Reconstruction and Development and World Bank, https://www.profor.info/sites/profor.info/files/PROFOR_Managing-Wildfires_2020_final.pdf.

109 Picourt, L. et al., 2017: *Measuring Progress on Ocean and Climate Initiatives: an Action-Oriented Report*. Ocean and Climate Initiatives Alliance, https://ocean-climate-alliance.org/wp-content/uploads/2017/11/OCIA-REPORT-OF-PROGRESS-FINAL-30_10_17.pdf.

110 Johnson, J. et al., 2016: *Pacific Islands Ocean Acidification Vulnerability Assessment*. Apia, Samoa, Secretariat of the Pacific Regional Environment Programme, https://www.sprep.org/attachments/Publications/CC/ocean-acidification.pdf.

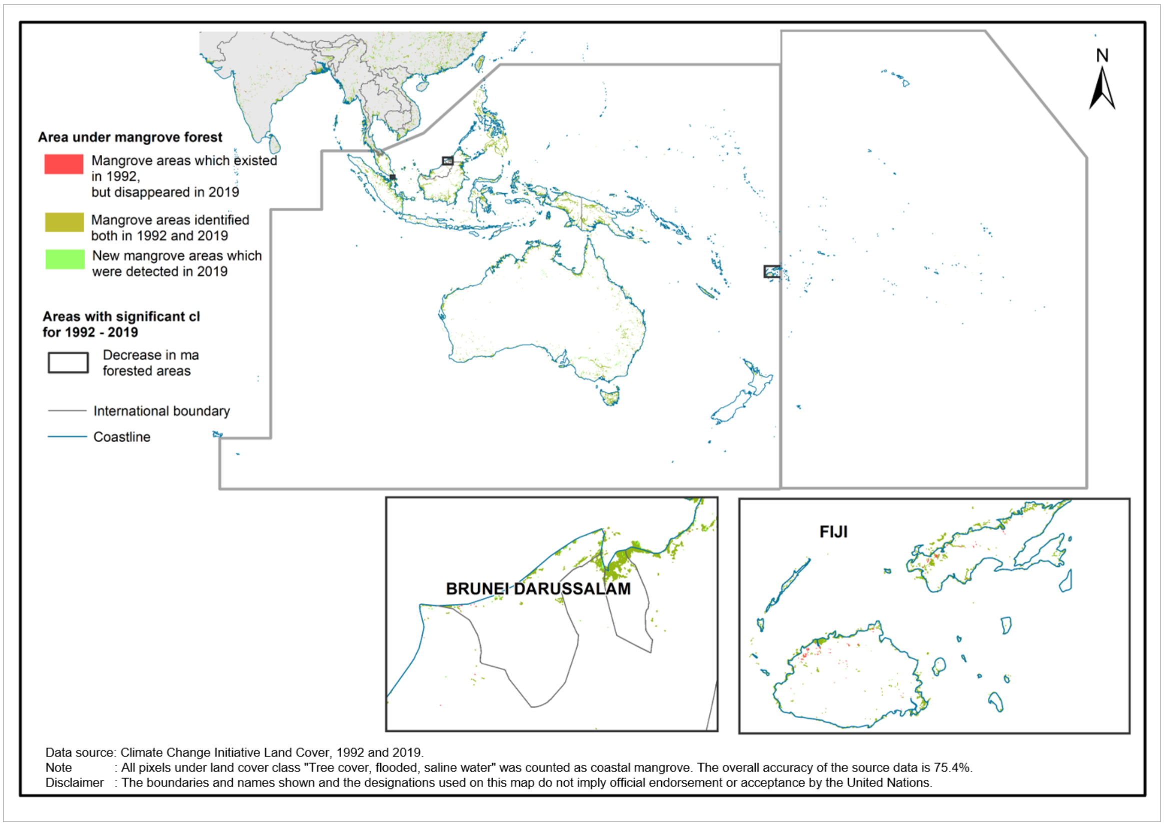


Figure 19. Changes in mangrove cover in the South-West Pacific. Data sourced from European Space Agency, Climate Change Initiative Land Cover, 1992–2019 (http://www.esa-landcover-cci.org/?q=node/164).

Triangle[111] and the Great Barrier Reef could face severe degradation.[112] It is expected to experience bleaching twice each decade by 2035 and annually by 2050, as a consequence of rising water temperatures.[113] Moreover, the altering coral reef habitats can affect the coastal communities in the Solomon Islands, Kiribati, Papua New Guinea, the Federated States of Micronesia, Tonga and Tuvalu, which are vulnerable to ocean acidification impacts on reefs and their fisheries, aquaculture and tourism.[114]

Mangroves provide coastal protection, but climate change can negatively affect mangroves through rise in sea level, rise in atmospheric CO_2, rise in air and water temperatures and change in the frequency and intensity of extreme weather events.[115] In the South-West Pacific, in 2019, mangroves were identified in Indonesia (47%), Australia (29%), Papua New Guinea (7%), Malaysia (7%) and the Philippines (6%). A significant decrease of mangroves had occurred between 1992 and 2019, in Brunei Darussalam, Australia, Fiji, New Zealand and the Federated States of Micronesia (Figure 19).

111 The Coral Triangle comprises Indonesia, Malaysia, Papua New Guinea, the Philippines, the Solomon Islands and Timor-Leste. See: World Wide Fund for Nature and ADB, 2012: *Ecological Footprint and Investment in Natural Capital in Asia and the Pacific*. Manila and Geneva, https://www.adb.org/publications/ecological-footprint-and-investment-natural-capital-asia-and-pacific.

112 Heron, S.F. et al., 2018: *Impacts of Climate Change on World Heritage Coral Reefs: Update to the First Global Scientific Assessment*. Paris, UNESCO World Heritage Centre, https://apo.org.au/sites/default/files/resource-files/2018-09/apo-nid193206.pdf.

113 Heron, S.F. et al., 2017: *Impacts of Climate Change on World Heritage Coral Reefs: A First Global Scientific Assessment*. Paris, UNESCO World Heritage Centre, https://whc.unesco.org/document/158688.

114 Johnson et al., 2016: *Pacific Islands Ocean Acidification Vulnerability Assessment*.

115 World Bank Group, 2016: *Mangroves as Protection from Storm Surges in a Changing Climate*, https://documents1.worldbank.org/curated/en/703121468000269119/pdf/WPS7596.pdf.

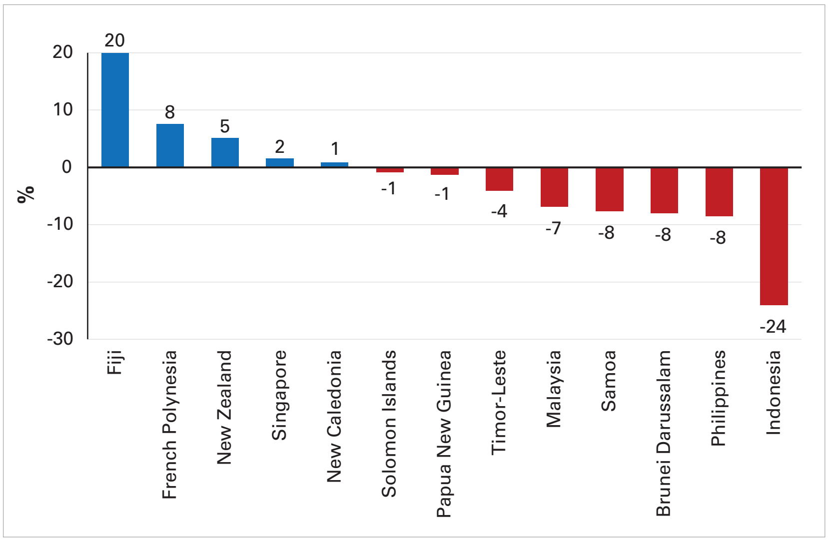


Figure 20. Percentage of change in forest cover 1990–2018. Data sourced from the World Bank and FAO (https://data.worldbank.org/indicator/AG.LND.FRST.ZS).

Forest ecosystems, one of the major sources of natural and economic resources and of ecosystem services, can face the impact of climate change.[116] Between 1990 and 2018, forest cover increased significantly in Fiji, French Polynesia and New Zealand, but decreased by 24% in Indonesia and 8% each in the Philippines, Brunei Darussalam and Samoa[117] (see Figure 20).

2.2.3 CLIMATE-RELATED HEALTH RISKS

Climate change can affect the occurrence of weather-related diseases. In the Philippines, during the first five weeks of 2020, 25 502 cases of dengue including 38 deaths were reported.[118] French Polynesia recorded 2 690 dengue cases on 23 February, and the Cook Islands reported 381 dengue cases between February and October.[119] Dengue cases were also reported in Australia and in New Caledonia, among others.[120]

In the South-West Pacific, malaria and dengue cases have increased in the past two to three decades. In particular, dengue cases have increased rapidly in recent years (Figure 21).

2.2.4 ADAPTATION TO EXTREME EVENTS: EARLY WARNING SYSTEMS (EWS)

The implementation of Early Warning Systems (EWS) is a key adaptation measure to reduce climate related risks and impacts. According to the 2020 State of Climate Services report[75], 41% of countries in the

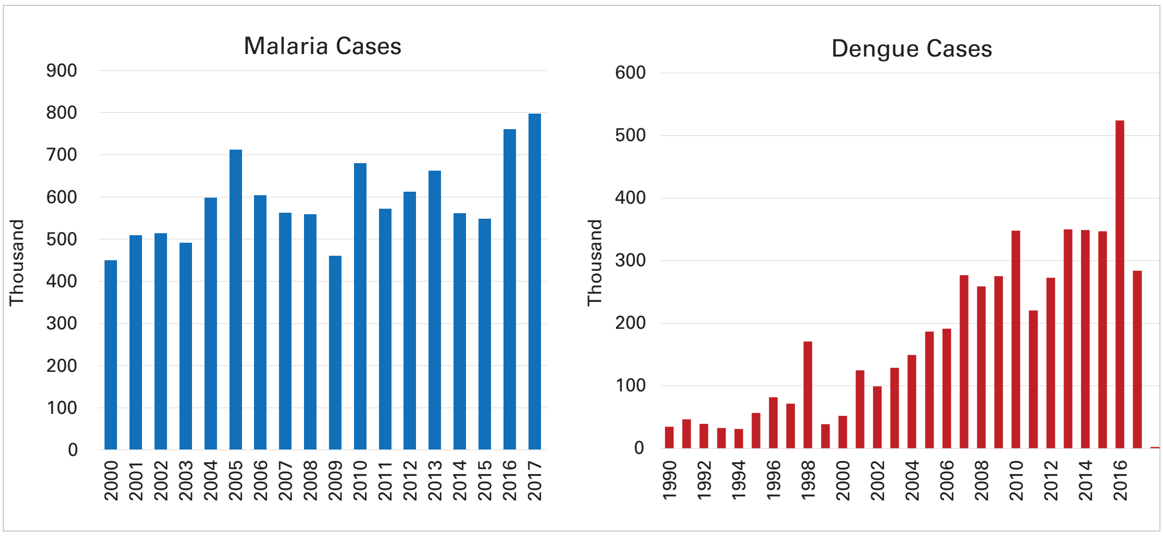


Figure 21. Confirmed malaria and dengue cases in the South-West Pacific. Data sourced from WHO The Global Health Observatory (https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/cases).

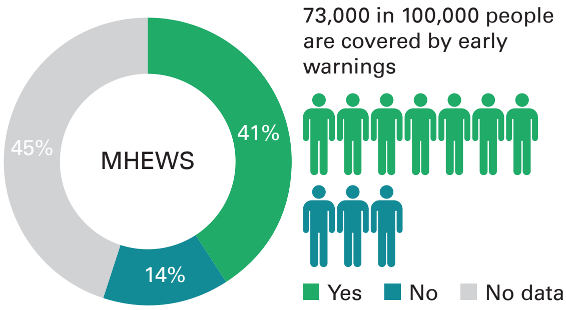
116 World Wide Fund for Nature and ADB, 2012: *Ecological Footprint and Investment in Natural Capital in Asia and the Pacific*.

117 World Bank: https://data.worldbank.org/indicator/AG.LND.FRST.ZS

118 IFRC, 2020: *Operation Update Report. Philippines: Re-emergence of Vaccine Preventable Diseases (Polio)*, 29 December, https://reliefweb.int/sites/reliefweb.int/files/resources/MDRPH032_12m.pdf.

119 Pacific Community (SPC), 2020: Epidemic and emerging disease alerts in the Pacific as of 03 November 2020, https://reliefweb.int/map/world/epidemic-and-emerging-disease-alerts-pacific-03-november-2020.

120 WHO, 2020: WHO Western Pacific Region: dengue situation update number 592, 9 April, https://iris.wpro.who.int/bitstream/handle/10665.1/14461/Dengue-20200409.pdf.



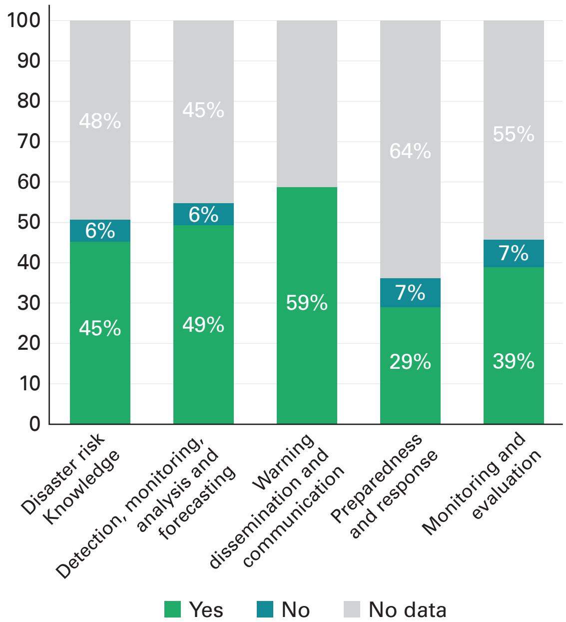


Figure 22. (left) WMO Members that reported having a MHEWS in place, as a percentage of the total number in the region (22). *Source:* WMO, *2020 State of Climate Services* (WMO-No. 1252)

Figure 23. (right) EWS capacities in South-West Pacific, by value chain component, calculated as a percentage of functions satisfied in each component area, across 22 WMO Members in the region. *Source:* WMO, *2020 State of Climate*

South-West Pacific have a multi-hazard early warning system in place, representing approximately 73 000 in 100 000 people covered by early warnings (Figure 22). The report highlights the region as having strong warning dissemination and communication (Figure 23) but notes that only 18% of countries are using Common Alerting Protocol[76] for warning dissemination.

It is important to note that data was reported from 13 countries, representing only 59% of the region. The overview is particularly not representative of SIDS' capacities, as only 39% of Pacific SIDS provided data, compared to 60% of Pacific least developed countries (LDCs). It is therefore imperative that more data, particularly from Pacific SIDS, be provided to have a more complete picture of EWS gaps and capacity within the region.

2.2.5 BUILD BACK BETTER FOR SUSTAINABLE DEVELOPMENT

Climate change and associated natural and biological hazards can exacerbate multidimensional risks for the people and economies of the region. Furthermore, the COVID-19 pandemic has highly disrupted socioeconomic development in the region, affecting key drivers of growth including the private sector, trade, tourism and remittances.[121] The pandemic has revealed gaps in countries' capacities to address systemic and cascading risks.

Countries in the Pacific are making substantial progress in achieving Sustainable Development Goal 13 (Climate Action). However, the region needs to accelerate progress towards achieving target 13.1 (strengthen resilience and adaptive capacity) and reverse the current trends with a view to achieving other targets related to resilience to disasters (target 1.5 and target 11.5).[122]

Therefore, building resilience to extreme climate events is foundational for achieving the 2030 Agenda for Sustainable Development. This requires a better understanding of specific risks affecting particular regions and countries, and increased capacity to address them. It will also require capitalizing on frontier technologies and investing in protecting the people and the economy with targeted and forward-looking fiscal spending.[123]

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121 ESCAP, 2021: Subregional cooperation to build back better from crises in Asia and the Pacific (ESCAP/77/3), https://www.unescap.org/sites/default/d8files/event-documents/ESCAP_77_3_E.pdf.

122 ESCAP, 2021: *Asia and the Pacific: SDG Progress Report 2021*. Bangkok, United Nations, https://www.unescap.org/sites/default/d8files/knowledge-products/ESCAP_Asia_and_the_Pacific_SDG_Progress_Report_2021.pdf.

123 ESCAP, 2021: *Asia-Pacific Disaster Report 2021: Resilience in a Riskier World* https://www.unescap.org/knowledge-products-series/asia-pacific-disaster-report

Climate services for addressing priorities identified in South West Pacific countries' Nationally Determined Contributions to the Paris Agreement

Climate-sensitive sectors such as agriculture, water resources, coastal zone management, ecosystem and biodiversity and health, as well as disaster risk reduction are top priorities in the Nationally Determined Contributions (NDCs) submitted by South West Pacific Parties to the United Nations Framework Convention on Climate Change as part of implementation of the Paris Agreement. Decision- and policy-makers concerned with promoting improved climate-related outcomes in these sectors require specialized, sector-specific information.

WMO classifies climate services capacities into four categories: basic, essential, full and advanced. According to the most recent data, 27% of Pacific countries are providing services at least at the essential level (Figure 24).

Guidance on implementation of climate services, and specifically for the priority sectors identified in South-West Pacific countries' NDCs is provided by the Global Framework for Climate Services.[124] In their NDCs, Pacific countries highlight the need to strengthen data collection and management, forecasting, capacity development and observing networks. These needs are addressed through GFCS guidance on strengthening the constituent components of climate information systems.[125] GFCS implementation at national level can be initiated or strengthened through the establishment of National Frameworks for Climate Services.[126]

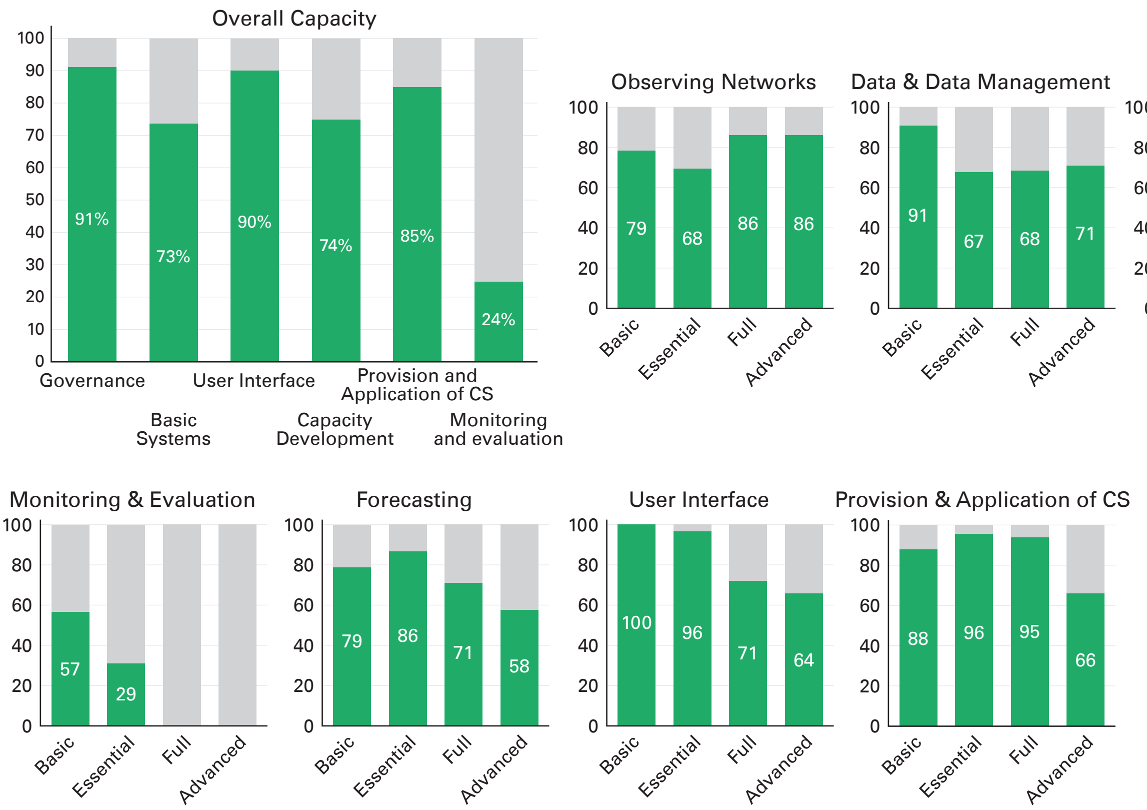

Figure 24. WMO Member capacities across the climate services value chain in South West Pacific divided by component, calculated as a percentage of functions satisfied in each component area for each functional capacity level, based on data from 7 WMO Members.

124 https://gfcs.wmo.int/priority-areas

125 https://gfcs.wmo.int/components-of-gfcs

126 https://gfcs.wmo.int/national-frameworks-for-climate-services

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DATASET DETAILS

TEMPERATURE DATA

Regional mean temperature is reported as the mean of the six data sets listed below. Regional mean temperature anomalies are expressed relative to the 1981–2010 average.

HADCRUT.5.0.1.0

Morice, C.P. et al., 2021. An updated assessment of near-surface temperature change from 1850: The HadCRUT5 data set. *Journal of Geophysical Research: Atmospheres*, 126(3): e2019JD032361, https://doi.org/10.1029/2019JD032361. HadCRUT.5.0.1.0 data were obtained from http://www.metoffice.gov.uk/hadobs/hadcrut5 on 14 February 2021 and are © British Crown Copyright, Met Office 2021, provided under an Open Government Licence, http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/.

NOAAGLOBALTEMP V5

Zhang, H.-M. et al., 2019: *NOAA Global Surface Temperature Dataset (NOAAGlobalTemp), version 5.0.* NOAA National Centers for Environmental Information. DOI:10.7289/V5FN144H, https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ncdc:C00934.

Huang, B. et al., 2020: Uncertainty estimates for sea surface temperature and land surface air temperature in NOAAGlobalTemp version 5. *Journal of Climate*, 33(4): 1351–1379, https://journals.ametsoc.org/view/journals/clim/33/4/jcli-d-19-0395.1.xml.

GISTEMP V4

GISTEMP Team, 2019: *GISS Surface Temperature Analysis (GISTEMP), version 4*. National Aeronautics and Space Administration (NASA) Goddard Institute for Space Studies, https://data.giss.nasa.gov/gistemp/.

Lenssen, N.J.L. et al., 2019: Improvements in the GISTEMP uncertainty model. *Journal of Geophysical Research: Atmospheres*, 124(12): 6307–6326, https://doi.org/10.1029/2018JD029522.

BERKELEY EARTH

Rohde, R.A. and Z. Hausfather, 2020: The Berkeley Earth land/ocean temperature record. *Earth System Science Data*, 12: 3469–3479, https://doi.org/10.5194/essd-12-3469-2020.

ERA5

Hersbach, H. et al., 2020: The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, 146(730): 1999–2049, https://doi.org/10.1002/qj.3803.

JRA-55

Kobayashi, S. et al., 2015: The JRA-55 reanalysis: general specifications and basic characteristics. *Journal of the Meteorological Society of Japan*, 93(1): 5–48, https://www.jstage.jst.go.jp/article/jmsj/93/1/93_2015-001/_article.

PRECIPITATION DATA

Regional time series analyses of the area-mean annual precipitation totals are from the Global Precipitation Climatology Centre (GPCC). Regional precipitation anomalies are expressed relative to the 1981–2010 average.

Schneider, U. et al., 2020: *GPCC Monitoring Product: Near Real-Time Monthly Land-Surface Precipitation from Rain-Gauges Based on SYNOP and CLIMAT Data*. DOI: 10.5676/DWD_GPCC/MP_M_V2020_100, https://opendata.dwd.de/climate_environment/GPCC/html/gpcc_monitoring_v2020_doi_download.html.

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