State of the Climate in Asia

2023

WEATHER CLIMATE WATER

WORLD
METEOROLOGICAL
ORGANIZATION

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Cover illustration: Yangtze river, Yunnan Province, China. Source: Adobe Stock

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We need your feedback

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

Key messages

In 2023, the mean temperature over Asia was 0.91 °C above the 1991–2020 reference period, the second highest on record.

Many parts of the region experienced extreme heat events in 2023. Japan experienced its hottest summer on record.

Glaciers in High-Mountain Asia have lost significant mass over the past 40 years, at an accelerating rate. In 2023, record-breaking high temperatures and drier conditions in the Eastern Himalayas and the Tien Shan (mountain range) exacerbated mass loss.

The ocean around Asia has shown an overall warming trend since time series began in 1982. In 2023, sea-surface temperature anomalies in the north-west Pacific Ocean were the highest on record.

South-west China suffered from a drought, with below-normal precipitation levels nearly every month of 2023. Essential winter precipitation was also below normal in the Hindu Kush region, and the rains associated with the Indian summer monsoon were insufficient.

In 2023, over 80% of reported hydrometeorological hazards in Asia were flood and storm events. Yemen suffered heavy rainfall and resulting widespread floods, with over 30 reported casualties and over 165 000 individuals affected in over 70 districts.

Overall, the 79 reported hydrometeorological hazard events in 2023 led to over 2 000 fatalities and impacted more than 9 million people.

Approximately 80% of WMO Members in the region provide climate services to support disaster risk reduction activities. However, there is a gap in climate projections and tailored products (provided by less than 50% of Members in WMO Regional Association II (Asia)) that are needed to inform risk management and adaptation to and mitigation of climate change and its impacts.

Foreword

We are at a critical juncture, where the impact of climate change intersects with societal inequalities. It is imperative that our actions and strategies mirror the urgency of these times. Reducing greenhouse gas emissions and adapting to the evolving climate is not merely an option, but a fundamental necessity.

WMO is committed to providing science and services that help bridge disparities and address developmental gaps. As Secretary-General, I am dedicated to prioritizing regional initiatives and ensuring that innovative solutions reach every Member, particularly those facing greater developmental challenges. The present report on the state of the climate in Asia is, in this context, a tool to inform decision-making at the regional level.

A comprehensive analysis of the climate landscape forms the cornerstone of informed decision-making and response strategies. This report, the fourth of its kind, sheds light on the occurrence of extreme weather events and monitors key climate indicators in Asia. It contextualizes these findings within broader climate trends. The report's conclusions are sobering. Many countries in the region experienced their hottest year on record in 2023, along with a barrage of extreme conditions, from droughts and heatwaves to floods and storms. Climate change exacerbated the frequency and severity of such events, profoundly impacting societies, economies and, most importantly, human lives.

WMO remains steadfast in its commitment to monitoring the climate system and providing authoritative information to leaders and the public alike. Through robust collaboration across the United Nations family and with partners, we are empowered to deliver impactful services grounded in reliable information. The Global Framework for Climate Services, and the Early Warnings for All initiative, stand as testaments to the effectiveness of such collaborative efforts. Our pledge extends to reaching every corner of the globe, ensuring that no Member or individual is left behind.

The spirit of collaboration and partnership has been instrumental in the creation of reports such as this one. I extend my sincere gratitude to our Members, sister United Nations agencies, and all the experts from both the Asian region and around the world for their invaluable contributions to the scientific coordination and authorship of this report.

(Prof. Celeste Saulo)
Secretary-General

Preface

Asia and the Pacific remained the most disaster-impacted region in 2023. Floods and storms continued to cause most disaster-related deaths and economic costs, as they affect the largest number of people. At the same time, the impact of an increasing number of heatwaves was also more severe.

Yet again, in 2023, vulnerable countries were disproportionately impacted. For example, Tropical Cyclone *Mocha*, the strongest cyclone in the Bay of Bengal in the last decade, hit Bangladesh and Myanmar. Early warning and better preparedness saved thousands of lives. In this regard, it is important to recognize the key contribution that regional cooperation made through the WMO/ESCAP Panel on Tropical Cyclones (PTC) in warning and forecasting with high accuracy and lead time. This underscores the importance of regional approaches for early warning of transboundary hazards.

A critical gap in the early warning information chain lies in knowledge and understanding of disaster risk. Addressing this gap is fundamental for effective multi-hazard early warning systems and therefore is a key determinant of the implementation of the Global Executive Action Plan on Early Warnings for All in Asia and the Pacific.

The Economic and Social Commission for Asia and the Pacific, ESCAP, has responded to this need by configuring the Risk and Resilience Portal to deepen the knowledge of risk, especially in hotspots where risk is intensifying under various warming scenarios. The 2023 edition of the ESCAP *Asia-Pacific Disaster Report* flagged that there is a narrow window for Asia and the Pacific to increase its resilience and protect its hard-won development gains from the socioeconomic impacts of climate change.

In this context, the *State of the Climate in Asia 2023* is an effort to bridge gaps between climate science and disaster risk through evidence-based policy proposals. ESCAP and WMO, working in partnership, will continue to invest in raising climate ambition and accelerating the implementation of sound policy, including bringing early warnings to all in the region so that no one is left behind as our climate change crisis continues to evolve.

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

Global climate context

The global annual mean near-surface temperature in 2023 was 1.45 ± 0.12°C above the 1850–1900 pre-industrial average. The year 2023 was the warmest year on record according to six globally averaged datasets.[1] The nine years 2015 to 2023 were the nine warmest years on record in all datasets.[2]

Atmospheric concentrations of the three major greenhouse gases reached new record-observed highs in 2022, the latest year for which consolidated global figures are available, with levels of carbon dioxide (CO_2) at 417.9 ± 0.2 parts per million (ppm), methane (CH_4) at 1923 ± 2 parts per billion (ppb) and nitrous oxide (N_2O) at 335.8 ± 0.1 ppb, respectively 150%, 264% and 124% of pre-industrial (before 1750) levels (Figure 1). Real-time data from specific locations, including Mauna Loa[3] (Hawaii, United States of America) and Kennaook/Cape Grim[4] (Tasmania, Australia) indicate that levels of CO_2, CH_4 and N_2O continued to increase in 2023.

Over the past two decades, the ocean warming rate has increased; the ocean heat content in 2023 was the highest on record. Ocean warming and accelerated loss of ice mass from the ice sheets contributed to the rise of the global mean sea level by 4.77 mm per year between 2014 and 2023, reaching a new record high in 2023. Between 1960 and 2021, the ocean absorbed about 25% of annual anthropogenic CO_2 emitted into the atmosphere,[5] and CO_2 reacts with seawater and lowers its pH. The limited number of long-term observations in the open ocean have shown a decline in pH, with a reduction of the average global surface ocean pH of 0.017–0.027 pH units per decade since the late 1980s.[6] This process, known as ocean acidification, affects many organisms and ecosystem services[7] and threatens food security by endangering fisheries and aquaculture.

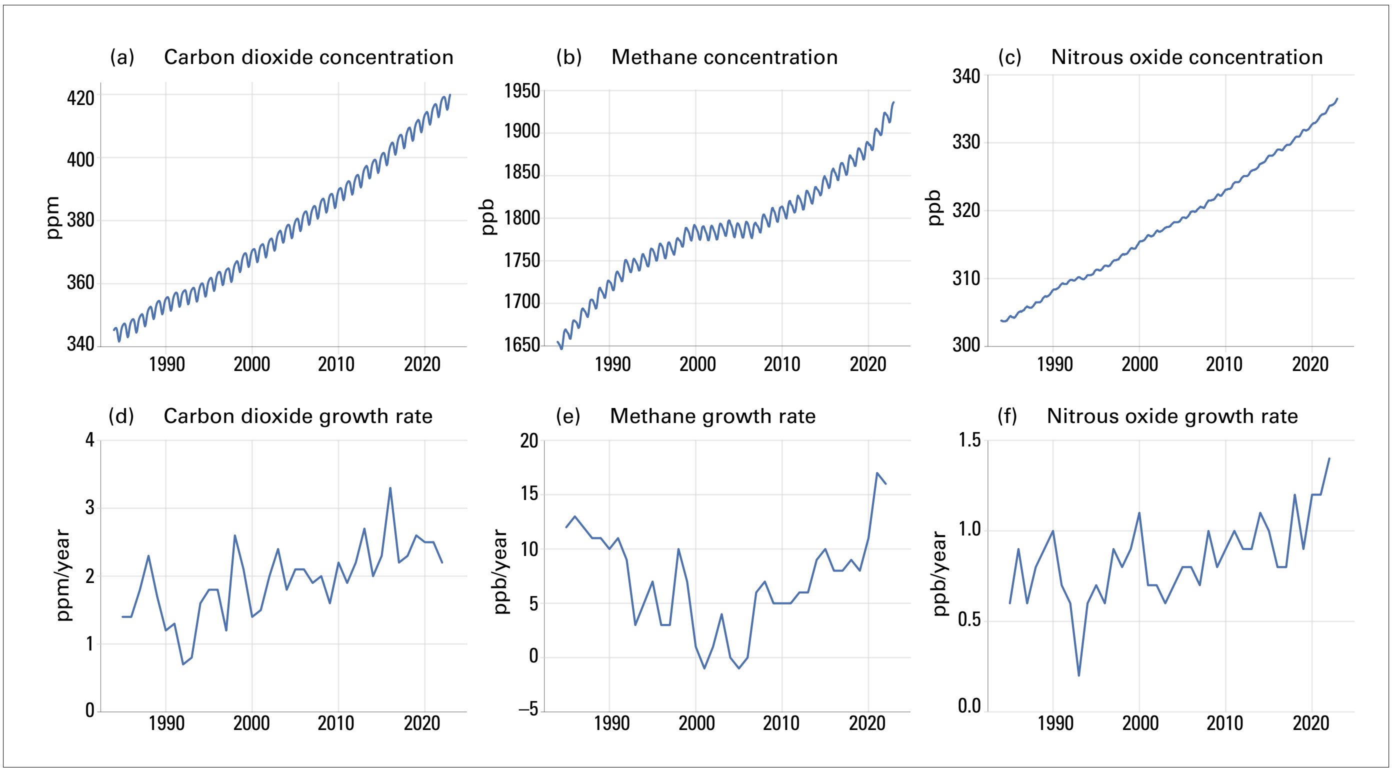

Figure 1. Top row: Monthly globally averaged mole fraction (measure of atmospheric concentration), from 1984 to 2022, of (a) CO_2 in parts per million, (b) CH_4 in parts per billion and (c) N_2O in parts per billion. Bottom row: the growth rates representing increases in successive annual means of mole fractions for (d) CO_2 in parts per million per year, (e) CH_4 in parts per billion per year and (f) N_2O in parts per billion per year.

Regional climate

The following sections analyse key indicators of the state of the climate in Asia during 2023. One such indicator that is particularly important, temperature, is described in terms of anomalies, or departures from a reference period. For global mean temperature, the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC)[8] uses the reference period 1850–1900 for calculating anomalies in relation to pre-industrial levels. However, this pre-industrial reference period cannot be used in all regions as a baseline for calculating regional anomalies due to insufficient data for calculating region-specific averages prior to 1900. Instead, the 1991–2020 climatological standard normal is used for computing anomalies in temperature and other indicators. Regional temperature anomalies can also be expressed relative to the WMO reference period for climate change assessment 1961–1990. In the present report, exceptions to the use of these baseline periods for the calculation of anomalies, where they occur, are explicitly noted.

TEMPERATURE

Variations in surface temperature and precipitation have a large impact on natural systems and on human beings. The mean temperature over Asia[9] in 2023 was the second highest on record (Figure 2), 0.91 °C [0.84 °C–0.96 °C] above the 1991–2020 average and 1.87 °C [1.81 °C–1.92 °C] above the 1961–1990 average. Particularly above average temperatures were recorded from western Siberia to central Asia and from eastern China to Japan. Japan and Kazakhstan each had record warm years.

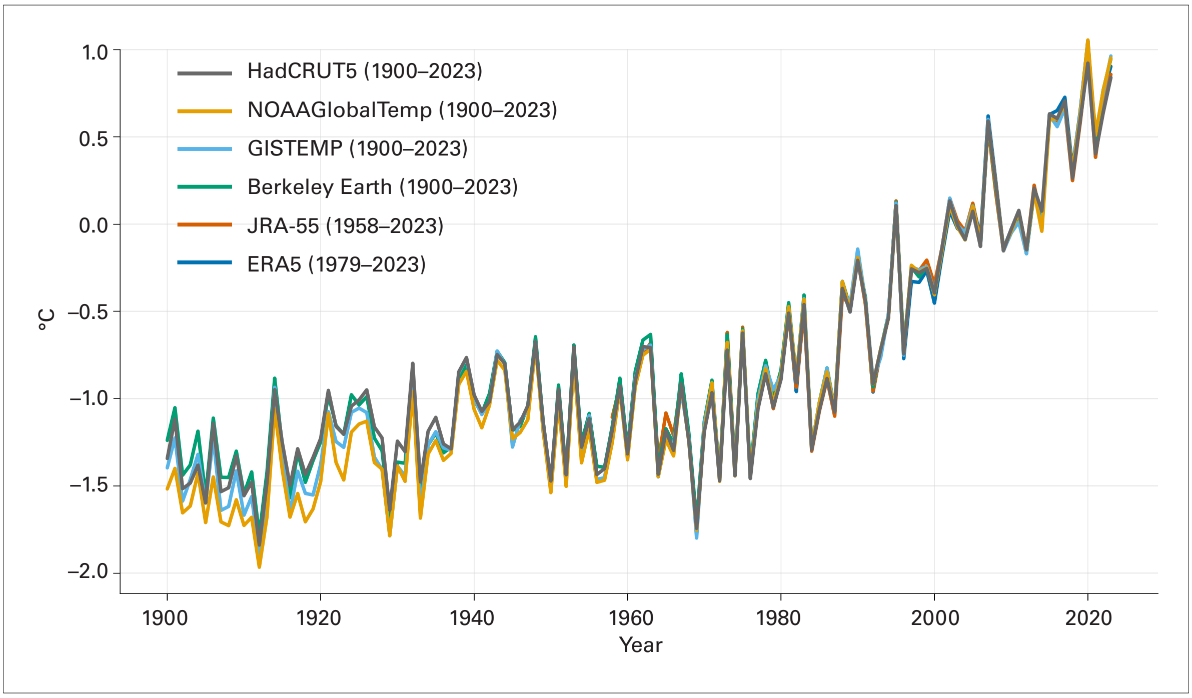

Figure 2. Annual mean temperature anomalies (°C), 1900 –2023, averaged over Asia, relative to the 1991–2020 average, for the six global temperature datasets indicated in the legend.

Source: HadCRUT5, Berkeley Earth, NOAAGlobalTemp and GISTEMP are based on in situ observations. ERA-5 and JRA-55 are reanalysis datasets. For details on the datasets and the plotting, see Temperature data.

Average temperatures were below normal in parts of the inland Indian Peninsula (Figure 3).

Over the long term, a clear warming trend has emerged in Asia in the latter half of the twentieth century (Figures 2 and 4). In the two recent sub-periods (1961–1990 and 1991–2023), Asia, the continent with the largest land mass extending to the Arctic, has warmed faster than the global land and ocean average. This indirectly reflects the fact that the temperature increase over land is larger than the temperature increase over the ocean, as stated in the IPCC AR6 report. The warming trend in Asia in 1991–2023 was almost double the warming trend during the 1961–1990 period, and much larger than the trends of the previous 30-year periods (Figure 4).

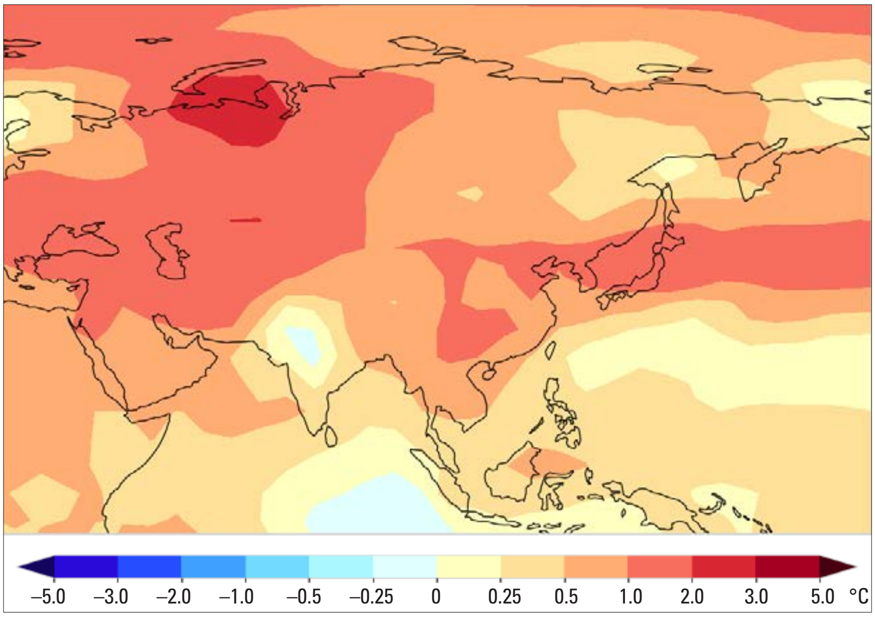

Figure 3. Mean near-surface temperature anomalies (°C, difference from the 1991–2020 average) for 2023. Data are the median of six datasets as indicated in the legend. See Datasets and methods for details.

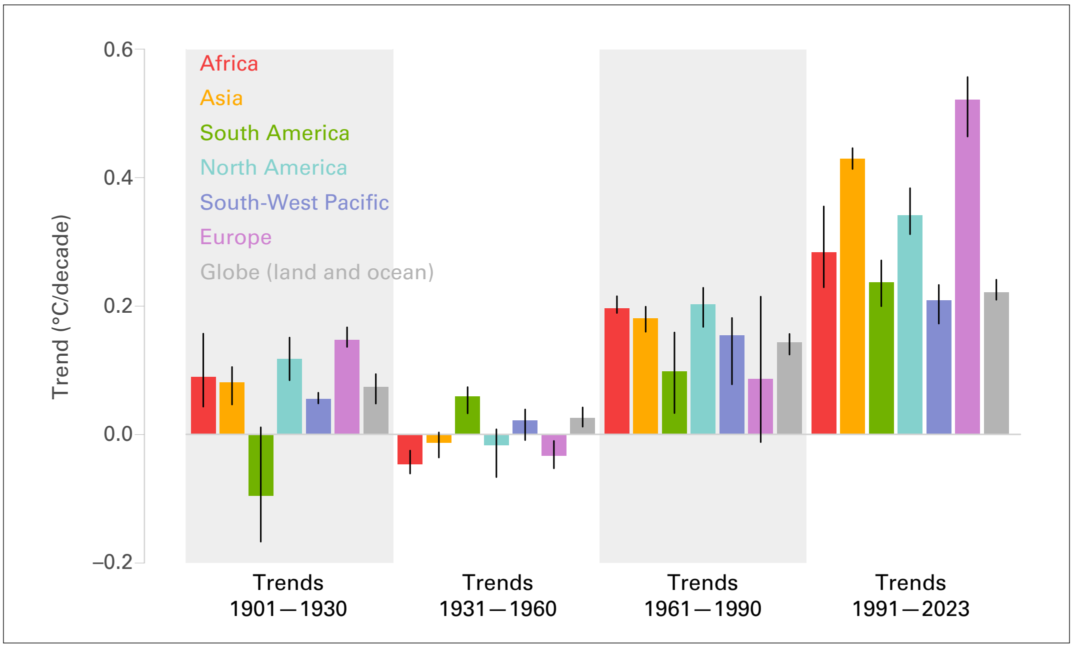

Figure 4. Trends in mean surface air temperature for the six WMO regions and the global mean (°C) over four sub-periods using the six datasets. The coloured bars indicate the trend in the mean of the datasets. The black vertical lines indicate the range between the largest and the smallest trends in the individual datasets.

PRECIPITATION

Precipitation is a key climate parameter, essential for society in terms of providing water for drinking and domestic purposes, agriculture, industry and hydropower. Variations in precipitation also drive major climate events such as droughts and floods. In 2023, substantial precipitation deficits in the region were observed in the Turan Lowland (Turkmenistan, Uzbekistan, Kazakhstan); the Hindu Kush (Afghanistan, Pakistan); the Himalayas; around the Ganges and lower course of the Brahmaputra Rivers (India and Bangladesh); the Arakan Mountains (Myanmar); and the lower course of the Mekong River (Figure 5 and 6). Other regions which had below-normal precipitation were the region between the Tian Shan and Gobi Altai (China and Mongolia); the Western Siberian Plain; the Stanovoy Range; the Arctic Coast between the Taymyr Peninsula and the New Siberian Islands (Russian Federation); as well as Japan and the south-western part of China.

The largest absolute precipitation excesses were observed around the lower course of the Indus River (Pakistan), the Tenasserim Range (Myanmar), in Kamchatka and the Kolyma Range (Russian Federation). Unusually high precipitation totals (Figure 6) were also noted in Manchuria and the Northern China Plain (China); between the Yamal and Taymyr Peninsulas (Russian Federation); the Kazakh Steppe (Kazakhstan); and the Arabian Peninsula (Saudi Arabia).

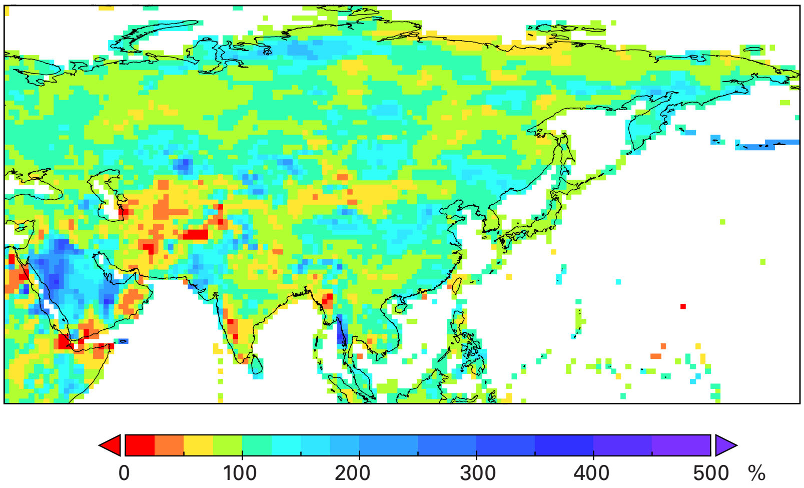

Figure 5. Precipitation anomalies for 2023, expressed as a percentage of the 1991–2020 average

Source: Global Precipitation Climatology Centre (GPCC), Deutscher Wetterdienst, Germany

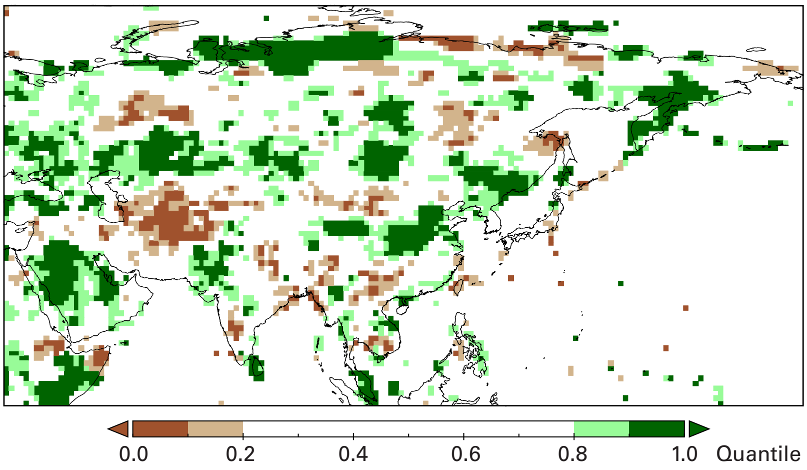

Figure 6. Total precipitation in 2023, expressed as a quantile of the 1991–2020 reference period, for areas that would have been in the driest 20% (brown) and wettest 20% (green) of years during the reference period, with darker shades of brown and green indicating the driest and wettest 10%, respectively

Source: GPCC, Deutscher Wetterdienst, Germany

CRYOSPHERE

ARCTIC SEA ICE

Sea-ice extent is a key indicator of climate variability and climate change in the polar regions. Sea ice strongly modulates surface ocean waves and the air-sea exchanges of heat, momentum, moisture, and so forth, thereby influencing the regional climate and the global climate. According to the consensus statement of the 11th and 12th sessions of the Arctic Climate Forum,[10,11] the maximum Arctic ice extent in winter 2023 was reached on 6 March 2023. The value of 14.6 million km^2 was the 5th lowest in the 45-year satellite record. Negative ice anomalies were most notable in the Western and Eastern Nordic regions. A smaller anomaly was noted in the Chukchi and Bering Region. The minimum Arctic ice extent in summer 2023 (approximately 4.4 million km^2) occurred on 17 September and was the eighth lowest annual minimum daily extent on record since 1979 (it should be noted that numbers and rankings may vary marginally across different datasets due to slightly different calculation methods and thresholds). Significant negative anomalies were most prominent in the areas of the Eurasian and Canadian Arctic, though some residual sea ice remained in both the Northern Sea Route and the northern route of the Northwest Passage shipping lanes until the time of freeze-up.[12]

GLACIERS

Glacier ice mass is sensitive to changes in regional temperature, precipitation, and surface radiation. The melting of glaciers affects sea level, regional water cycles and the occurrences of local hazards such as glacier lake outburst floods (GLOF). The High-Mountain Asia (HMA) region is the high-elevation area centred on the Tibetan Plateau; it contains the largest volume of ice outside of the polar regions, with glaciers covering an area of approximately 100 000 km^2. Over the last several decades, most of these glaciers have been retreating, with the altitudes of the equilibrium lines (the lower topographic limit of the glaciers) gradually rising.[13,14] In the past 40 years, four glaciers in the HMA region with more than 30 years of ongoing mass-balance measurements (Figure 7) have recorded significant mass losses, with an increase in the rate of mass loss since the mid-1990s. At the same time, these four glaciers show an overall weaker cumulative mass loss than the average for the global reference glaciers (indicated by a grey line in Figure 7) during the period 1980–2023. According to the Technical

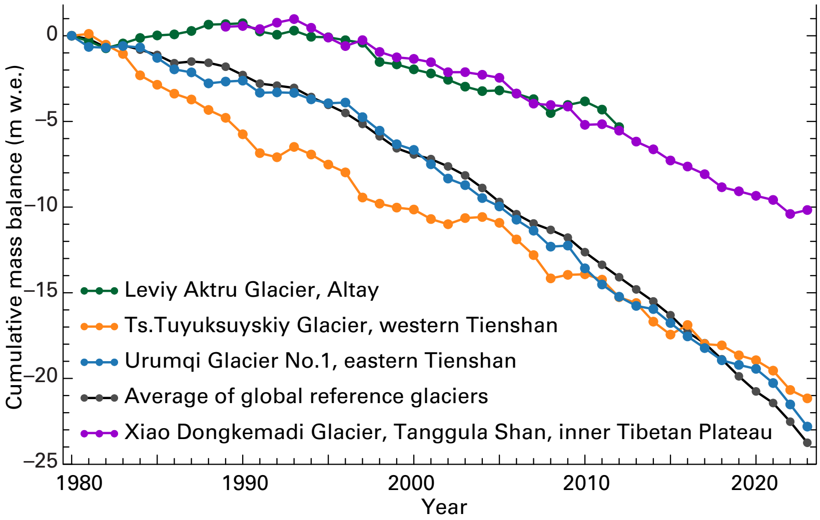

Figure 7. Cumulative mass balance (in metres water equivalent (m w.e.)) of four reference glaciers in the High Mountain Asia region and the average mass balance of the global reference glaciers

Source: Data regarding the global reference glaciers (grey), Leviy Aktru Glacier (green), Ts. Tuyuksuyskiy Glacier (orange) and Urumqi Glacier No. 1 (blue) are from the World Glacier Monitoring Service (WGMS) (see also WGMS. *Global Glacier Change Bulletin No. 5 (2020–2021)*; Zemp, M.; Gärtner-Roer, I.; Nussbaumer, S. U. et al., Eds.; ISC(WDS)/IUGG(IACS)/UNEP/UNESCO/WMO, WGMS: Zurich, Switzerland, 2023). Data regarding the Xiao Dongkemadi Glacier (purple) are from the Chinese Academy of Sciences (CAS).

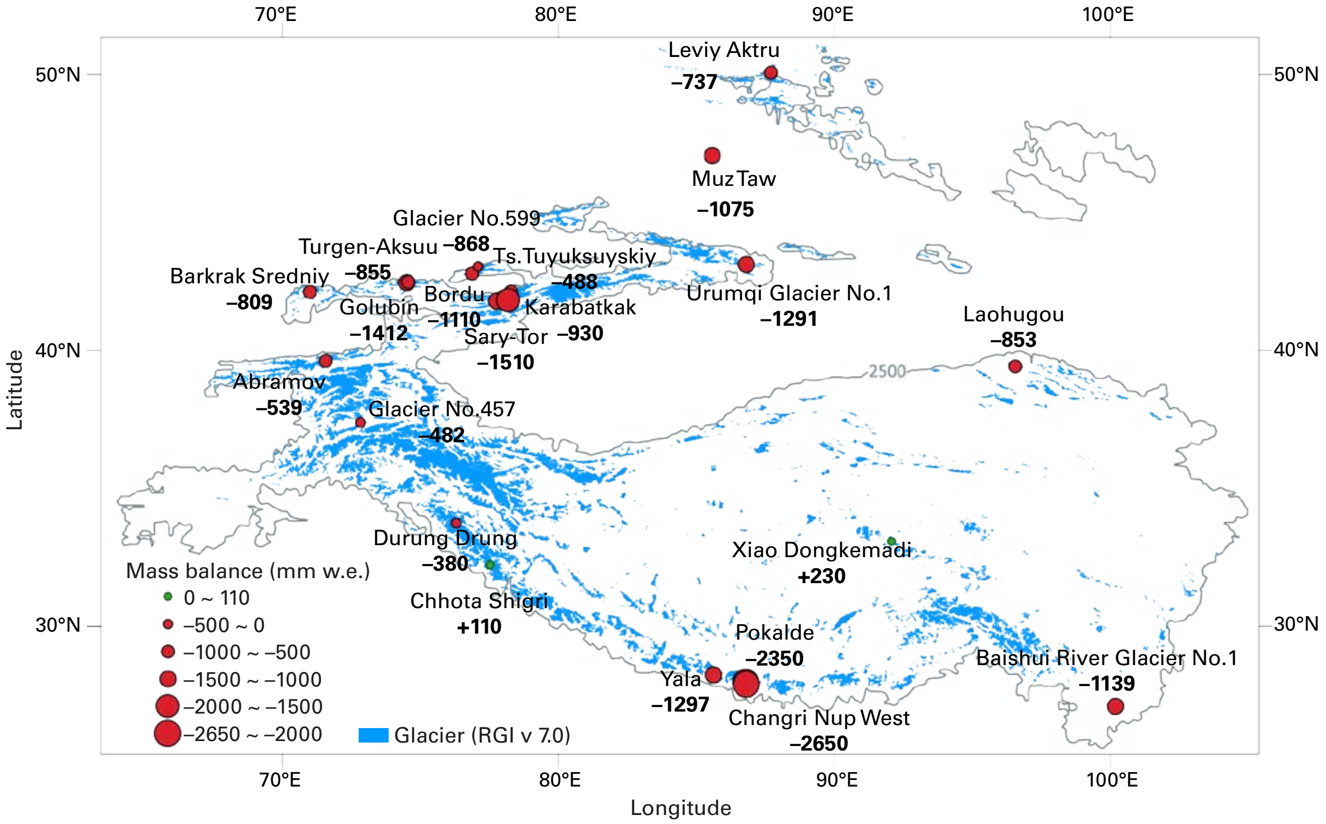

Figure 8. Preliminary estimations of the 2022–2023 mass balance of glaciers in the High Mountain Asia region. The area indicated by grey contours is 2500 metres above sea level.

Source: WMO Third Pole Regional Climate Centre Network (TPRCC-Network) and WGMS; the original observations upon which this figure is based are from China, India, Kazakhstan, Kyrgyzstan, Nepal, the Russian Federation, Tajikistan and Uzbekistan.

Summary of the Working Group I contribution to IPCC AR6, glaciers over South Asia have thinned, retreated, and lost mass since the 1970s (high confidence), although partial Karakoram glaciers have either slightly gained mass or are in an approximately balanced state (medium confidence).

For the glaciological year 2022/2023, 20 out of 22 glaciers observed in the HMA region show continued negative mass changes. Record-breaking high temperature and dry conditions in the East Himalaya and most of the Tien Shan exacerbated mass loss for most glaciers. During the period 2022–2023, Urumqi Glacier No. 1, in Eastern Tien Shan, recorded its second most negative mass balance (1.29 m w.e.) since measurements began in 1959 (Figure 8).

PERMAFROST

Permafrost is soil that continuously remains below 0 °C for two or more years and is a distinctive feature of high-latitude and high-altitude environments. It is characterised by two key variables, observed to monitor permafrost long-term changes that were defined as products of the Essential Climate Variables (ECVs) of the Global Climate Observing System (GCOS): mean annual permafrost temperature and thickness of the uppermost layer of seasonally thawing soil—defined as active layer thickness (ALT). Monitoring carried out by the Russian Federal Service for Hydrometeorology and Environmental Monitoring (RosHydroMet) indicates that almost throughout the entire territory of the permafrost zone of the Russian Federation in 2023, positive trends in the ALT thickness remained, close in value to the trends seen in the 1976–2022 period, which indicates the persistence of a stable trend of increasing the ALT.[15] The most rapid thawing of permafrost is in the European north, the Polar Urals, and the western regions of Western Siberia. Relatively moderate and weak rates of permafrost thawing are observed in the coastal regions of Central and North-East Siberia (Figure 9).

The trend of increasing ALT in the Russian Federation permafrost zone is due, first of all, to the continuing increase in air temperatures in the high latitudes of the Arctic. In terms of air temperature, 2023 was the sixth warmest year in the Arctic since 1900. IPCC AR6 estimates that thawing terrestrial permafrost will lead to carbon release (high confidence), though there is low confidence in the timing and magnitude. Furthermore, the report points out that permafrost thawing, as well as glacier melt and snow decline, are already impacting populations as well as irrigation, hydropower, water supply, cultural and other domains depending on ice, snow and permafrost.

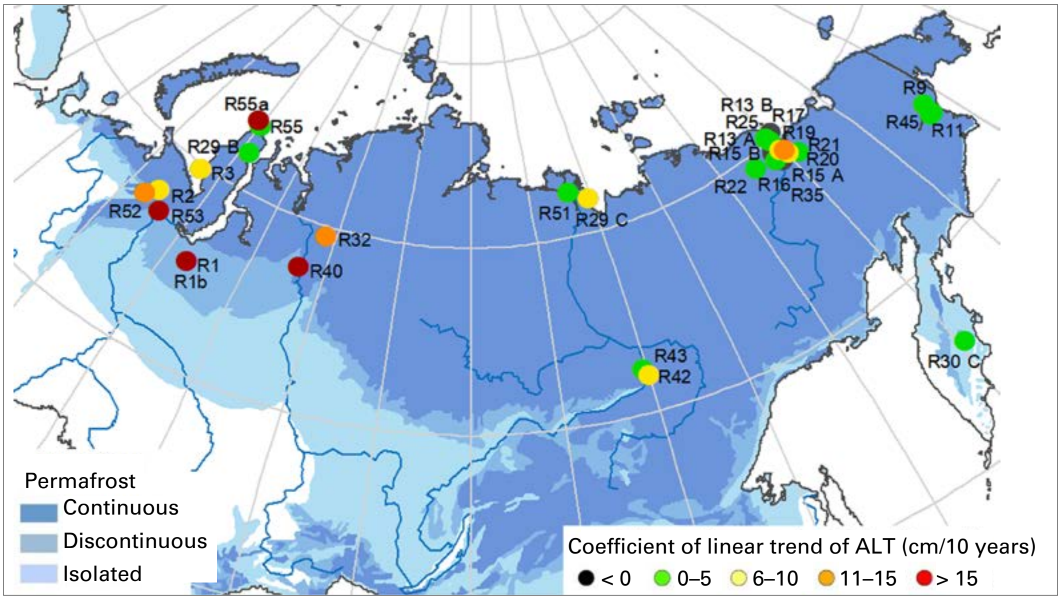

Figure 9. Long-term trend of the thickness of the uppermost layer of seasonally thawing soil (ALT in cm per 10 years) for the period 1976 –2023. Permafrost is classified by coverage in continuous (90% of the landscape), discontinuous (50 –90%), and sporadic (10 –50%) zones and isolated patches (10%), depending on the area continuity.

Source: Measurements from observation sites (site codes are indicated next to circles on the map), Russian Federal Service for Hydrometeorology (Roshydromet) within the Circumpolar Active Layer Monitoring Program. See Anisimov, O. A.; Lavrov, S. A.; Zhirkov, A. F. et al. Permafrost Data Assimilation and Reanalysis: Computational Setup and Model Validation for Northern European Russia and Eastern Siberia. *Russian Meteorology and Hydrology* **2020**, *45*, 269–275. https://doi.org/10.3103/S106837392004007X. See also Anisimov, O. A. Potential Feedback of Thawing Permafrost to the Global Climate System through Methane Emission. *Environmental Research Letters* **2007**, *2*, 91–98. http://dx.doi.org/10.1088/1748-9326/2/4/045016.

SNOW COVER

Snow cover plays an important role in the feedback mechanisms in the climate system (such as albedo,[16] run-off, soil moisture and vegetation). Hence, it is a crucial variable for monitoring climate change. In the past 27 years, the northern hemisphere's spring (March to May) snow cover extent (SCE)[17] over Asia exhibited a decreasing trend of 250000 km^2 per decade, with negative anomalies with respect to the 1998–2020 long-term average dominating since the mid-2000s. In the spring of 2023, the SCE in Asia was about 14.57 million km^2, slightly less than the 1998–2020 average. Spatially, lower-than-average snow extent appeared especially in the northern part of Central Asia and North-Eastern East Asia. On the contrary, positive SCE anomalies dominated from northern East Asia to central North Asia (Figure 10). In the HMA region, SCE was above normal in its western, mid-eastern region, and along the southern edge. However, the south-east area of HMA was dominated by negative anomalies.

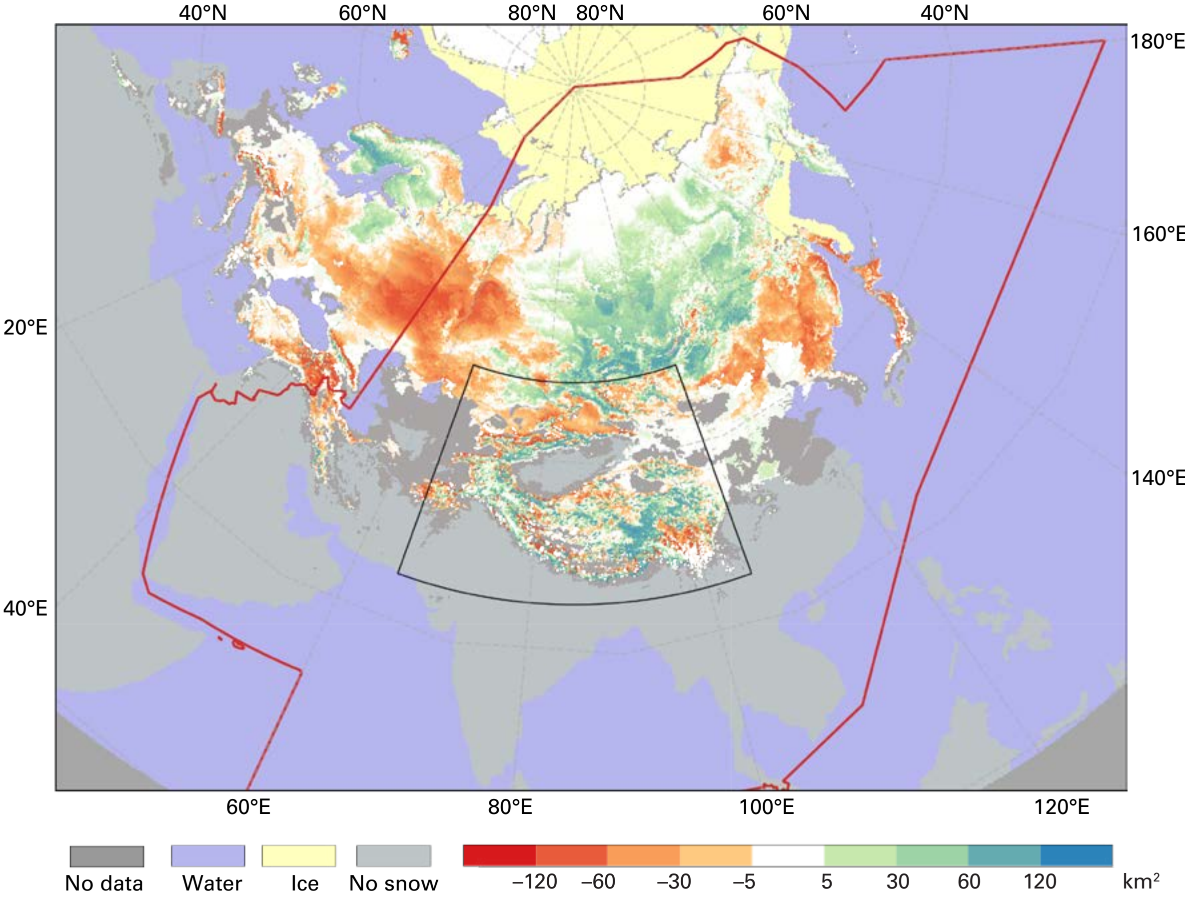

Figure 10. Anomalies of mean snow cover extent in the spring of 2023 (from March to May), relative to the 1998–2020 average. To derive the monthly snow cover extent anomalies for each grid, the number of monthly snow cover days was divided by the total number of days in that month and then multiplied by the area of the grid. The red line delimits the geographical area of WMO Regional Association II (Asia). The black line delimits the High Mountain Asia region.

*Source:*Interactive Multisensor Snow and Ice Mapping System and data in 25 km spatial resolution from the National Snow and Ice Data Center

SEA-SURFACE TEMPERATURE

Sea-surface temperature (SST) plays a critical role in the coupling between the ocean and atmosphere, as variations in SST alter the transfer of energy, momentum and gases between these two components of the Earth system.[18]

The ocean area of WMO Regional Association (RA) II (Asia) shows an overall surface ocean warming trend since 1982, at rates of more than 0.5 °C per decade in the areas of the Kuroshio current system, the Arabian Sea, the Southern Barents Sea, the Southern Kara Sea, and the South-Eastern Laptev Sea; the warming trend here is more than three times faster than the global surface ocean warming rate of 0.16 °C ± 0.01 °C per decade. In 2023, the area-averaged SST anomalies were the warmest on record in the north-west Pacific Ocean (area 2 in Figure 11) (>0.6 °C), whereas the values in the Indian Ocean (area 3 in Figure 11) were below the record values reached in 2020. The Barents Sea is identified as a climate change hotspot[19] and illustrates the recent Arctic amplification.[20] Surface ocean warming in this area also has a major impact on observed sea-ice loss, and there is a feedback mechanism in which loss of sea-ice (that reflects sunshine) in turn enhances ocean warming because darker sea surfaces can absorb more solar energy.[21]

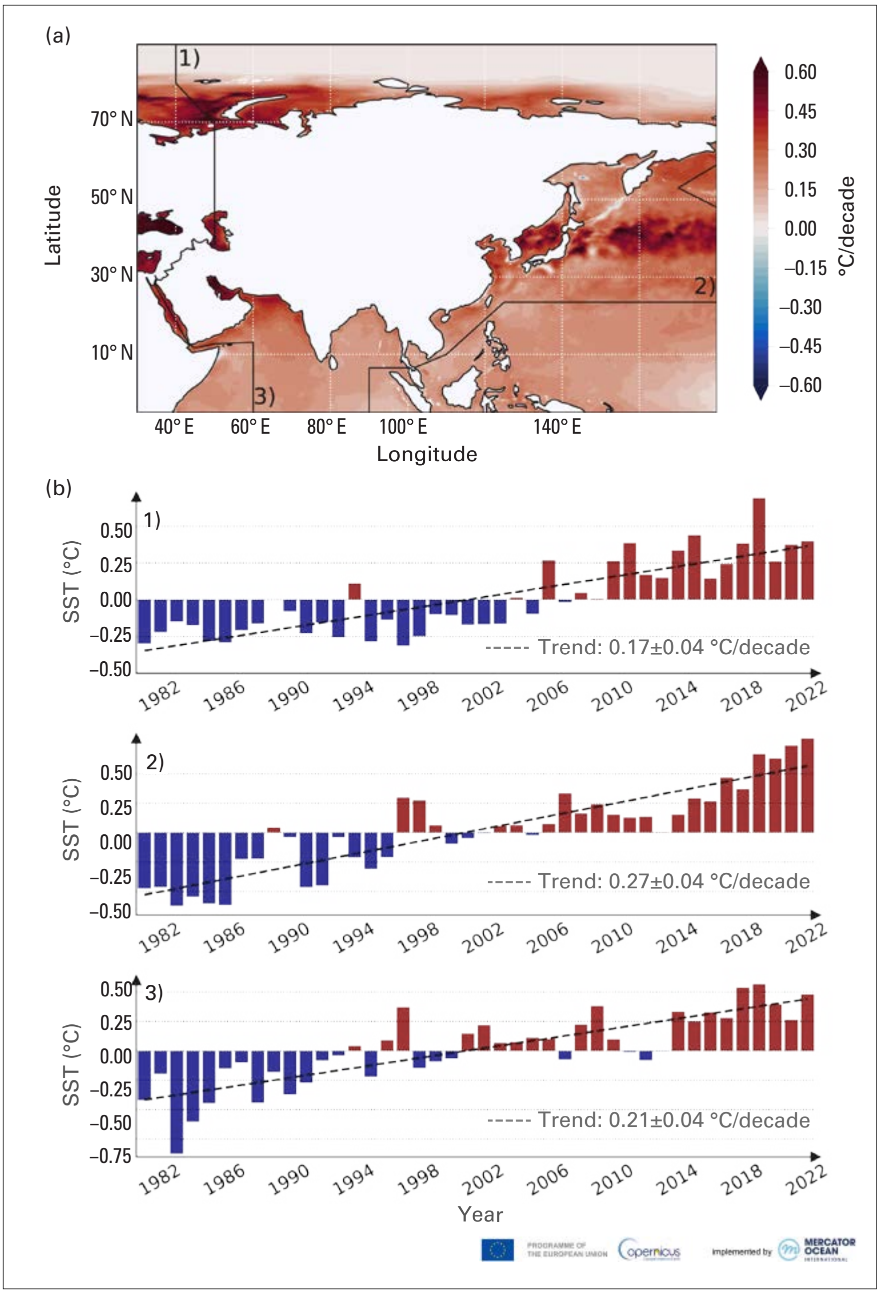

Figure 11. (a) Sea-surface temperature trend (in °C per decade) over the period 1982–2023. (b) Area-averaged time series of sea-surface temperature anomalies relative to the 1982–2022 reference period (in °C) within the three areas of WMO Regional Association II bordered by the black lines in panel (a): 1) the Arctic area north of 60°N; 2) the north-west Pacific Ocean area; and 3) the Indian Ocean area. The linear trend over the full period is indicated as a dashed line.

Source: Derived from the remote sensing product Global Ocean OSTIA Sea Surface Temperature and Sea Ice Reprocessed for 1982–2022, and Global Ocean OSTIA Sea Surface Temperature and Sea Ice Analysis for 2023, downloaded from the Copernicus Marine Service

OCEAN HEAT CONTENT

Due to emissions of heat-trapping greenhouse gases resulting from human activities, the global ocean has warmed. It has taken up more than 90% of the excess heat in the climate system,[22] making climate change irreversible on centennial to millennial timescales. Ocean warming contributes to about 40% of the observed global mean sea-level rise[23] and alters ocean currents. It also indirectly alters storm tracks,[24] increases ocean stratification[25] and can lead to changes in marine ecosystems.

Most of the regions in WMO RA II have been experiencing upper-ocean (0 m–700 m) warming since 1993 (the start date of the satellite altimetry records). Warming is particularly strong – at rates exceeding 2 W/m² (more than three times faster than the global mean upper-ocean warming rate) – in the North-Western Arabian Sea, the Philippine Sea and the seas east of Japan (Figure 12(a)). The northern flank of the Kuroshio current shows particularly strong warming rates of more than 4 W/m². This area is also known to undergo strong year-to-year and decadal scale variations. On average, in 2023, the upper ocean layer in this area recorded its third warmest year on record (Figure 12(b), 2). Both Asian parts of the north-west Pacific Ocean and the Indian Ocean are warming at a mean rate comparable to the global rate, which is estimated at 0.64 W/m² (Figure 12(b), 2 and 3). The northernmost Arctic area (Figure 12(b), 1) has experienced low warming rates, but it should be noted that the calculation of the rate may be affected by the limited observation of the ocean heat content in the region.

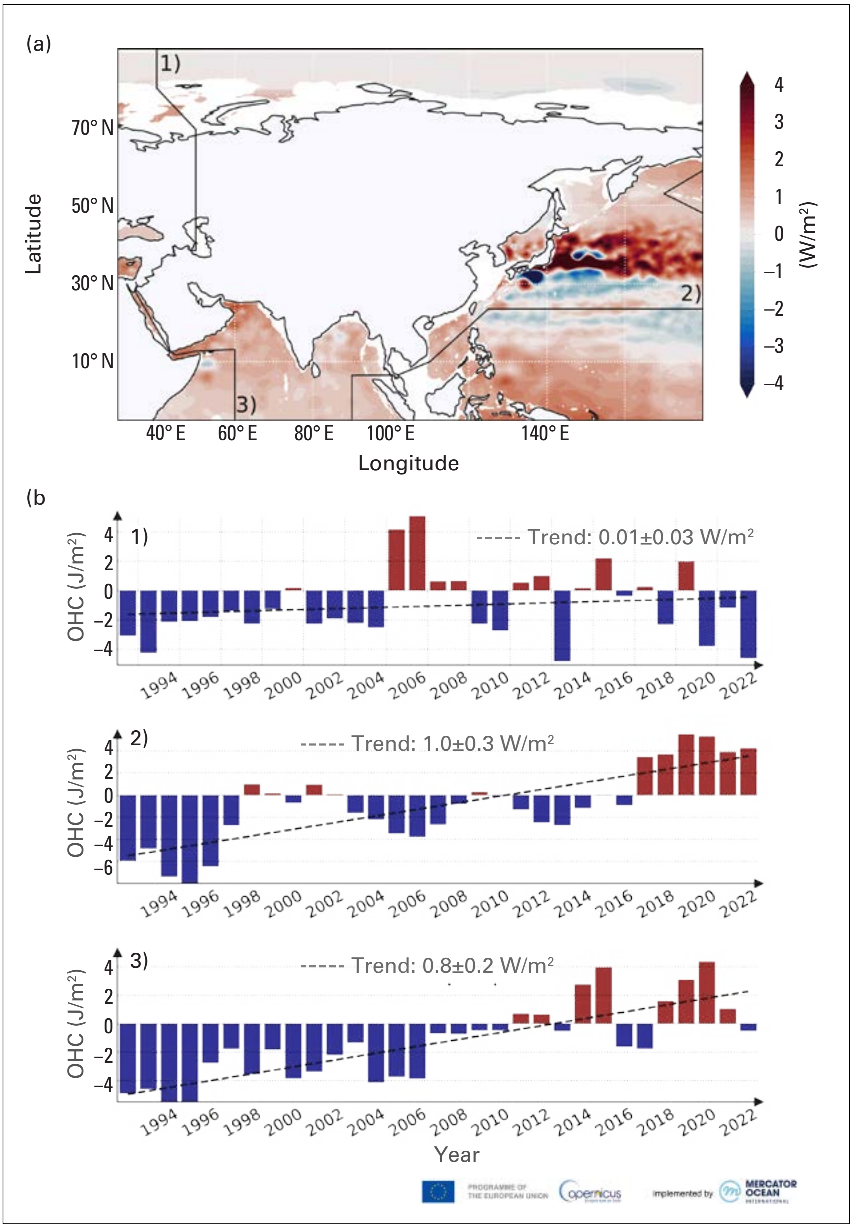

Figure 12. (a) Ocean heat content trend (watts per square metre, W/m²) over the period 1993–2023, integrated from the surface down to a depth of 700 m. Ocean warming rates in areas shallower than 300 m have been masked in white due to product limitations. (b) Area-averaged time series of ocean heat content anomalies relative to the 2005–2022 reference period (joules per square metre, J/m²) within three areas of WMO Regional Association II, as bordered by the black lines in panel (a): 1) the Arctic area north of 60°N; 2) the north-west Pacific Ocean area; and 3) the Indian Ocean area. The linear trend over the full period is indicated as a dashed line.

Source: Derived from the in situ-based product Multi Observation Global Ocean 3D Temperature Salinity Height Geostrophic Current and MLD, downloaded from Copernicus Marine Service

SEA LEVEL

In 2023, the global average sea level continued to rise at a sustained rate (3.43 ± 0.3 mm/year over the period from January 1993 to May 2023) in response to ocean warming (via thermal expansion) and the melting of glaciers, ice caps and ice sheets. However, the rate of rise is not the same everywhere. The observed non-uniform regional trends in sea level are essentially due to non-uniform ocean thermal expansion in conjunction with salinity changes in some regions.[26,27] Table 1 summarises the coastal sea-level trends over the period from January 1993 to May 2023 in six subregions (highlighted by the numbered boxes shown in Figure 13). The regional sea-level time series (not shown) displays strong interannual variability, mostly driven by the El Niño–Southern Oscillation (ENSO), especially in the Eastern Indian Ocean and tropical Pacific Ocean. The rates of sea-level rise in all six subregions are higher than the global mean rate over 1993–2023.

Table 1. Rate of area-averaged sea-level change over the period from January 1993 to May 2023 according to satellite measurements. Subregions are defined in Figure 13.

Subregion number	*Area*	*Trend in rate of sea-level rise (in mm per year)*
1	North-west Indian Ocean	4.07 ± 0.12
2	North-east Indian Ocean	4.44 ± 0.15
3	South-east Indian Ocean	4.19 ± 0.10
4	Sea off the eastern coast of Australia	4.11 ± 0.08
5	Western tropical Pacific region	4.53 ± 0.26
6	North-west Pacific region	3.92 ± 0.08
	Global mean	3.40 ± 0.33

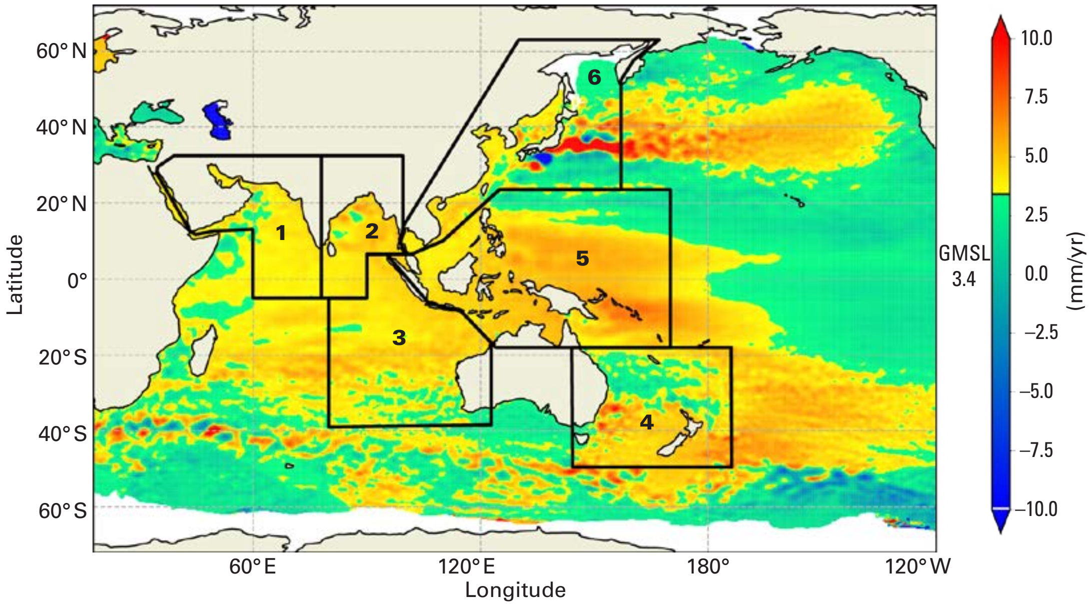

Figure 13. Spatial patterns in sea-level trends observed by altimeter satellites over the period from January 1993 to May 2023. The transition from green to yellow corresponds to the 3.4 mm/year global mean averaged trend. The numbered boxes represent subregions where the rates of area-averaged sea-level change are provided in Table 1.

Source: Copernicus Climate Change Service (C3S)

MAJOR CLIMATE DRIVERS

There are many modes of natural variability in the climate system, often referred to as climate patterns or climate modes, which affect weather and climate at timescales ranging from days to months, or even decades. The most relevant patterns for Asia include the El Niño–Southern Oscillation (ENSO), the Indian Ocean Dipole (IOD) and the Asian Monsoon. Their variations are described below.

EL NIÑO–SOUTHERN OSCILLATION

After three consecutive years of La Niña, which ended in early 2023, the tropical Pacific has experienced El Niño conditions since summer 2023. However, the atmosphere was slower to respond, and it was not until early September that El Niño conditions were well established in both the atmosphere and ocean.

This El Niño event can be linked to an anomalously warm and wet December in the Republic of Korea and eastern China, and hot and dry conditions in South Asia in summer 2023 associated with the weaker-than-normal Asian summer monsoon. For example, in August, India experienced a record-high monthly mean temperature, as well as an unprecedented rainfall deficit for the month.[28] Extreme hot conditions persisted over South-East Asia from early summer to autumn 2023 (see Extreme events for additional details).

INDIAN OCEAN DIPOLE

The IOD is an inherent and major mode of climate variability over the Indian Ocean. A positive IOD phase is characterised by below-normal SSTs and reduced convection in the south-eastern part of the tropical Indian Ocean, along with above-normal SSTs and enhanced convection in the western region. A positive IOD developed during August 2023 and peaked in October. As the year closed, the IOD remained positive.

ASIAN MONSOON

The Asian summer monsoon is one of the world’s prominent monsoon systems. It is also a key driver of the seasonal changes in atmospheric circulation and precipitation (dry and wet seasons) over several countries in South and East Asia. Precipitation associated with the Asian summer monsoon is a key source of fresh water in those regions.

In 2023, the mean rainfall over South-East Asia was normal. However, it showed large spatial-temporal variability. For example, the western and southern regions of Mongolia experienced warm and dry conditions in June and August, whereas the central region of Mongolia showed wet conditions in July. Similarly, precipitation was above normal in South Korea. Monthly precipitation was below normal in June over China, whereas it was above normal in August and September. Precipitation anomalies characteristic of El Niño typically occur in maritime South-East Asia and a drier-than-normal rainfall anomaly was observed in maritime South-East Asia in 2023.

The onset of the Indian summer monsoon was delayed in 2023. The Indian summer monsoon seasonal rainfall (ISMR), averaged over India as a whole, was 94% of its climatological normal for the 1971–2020 period (Figure 14). Both El Niño and IOD can influence the rainfall amount associated with the Asian summer monsoon. Under El Niño conditions, the rainfall amount tends to be smaller, but it also tends to increase under positive IOD conditions.[29]

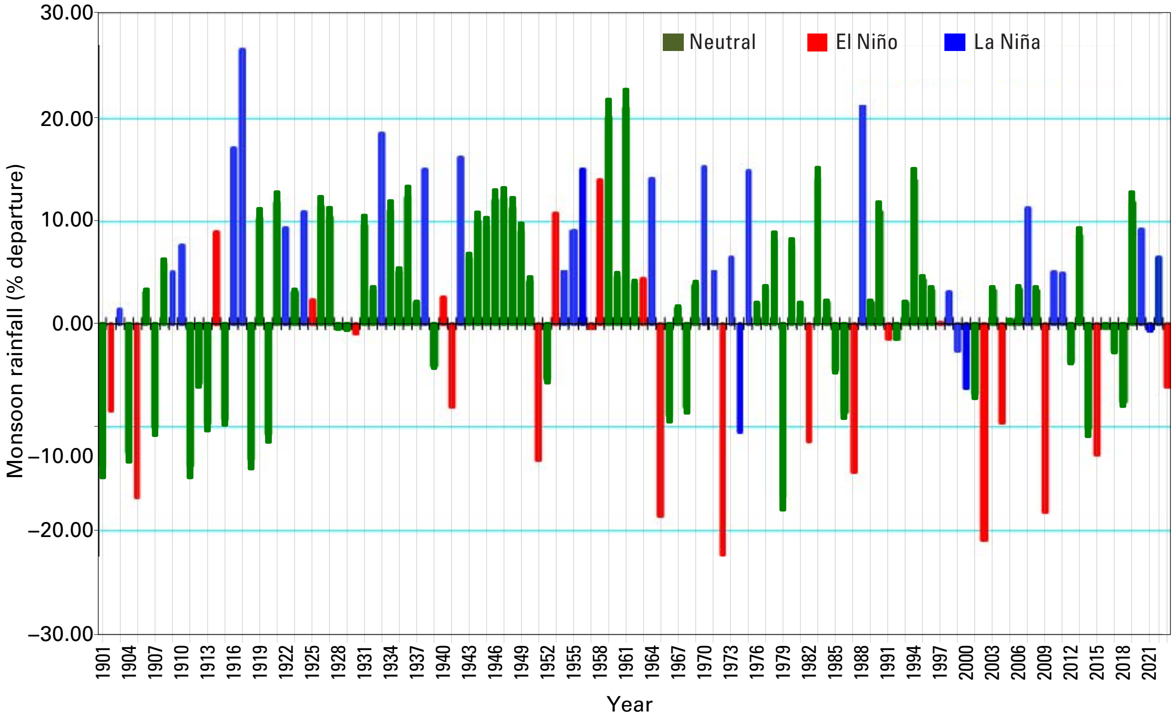

Figure 14. Time series of area-weighted rainfall anomalies over India (representative of South Asia) in the summer monsoon season (June to September) for the period 1901–2023. The red, blue and green colours indicate years with El Niño (red), La Niña (blue) and neutral (green) events, respectively. Anomalies are defined as a departure from the 1971–2020 average.

Source: WMO Regional Climate Centre (RCC), Pune, India

Extreme events

TROPICAL CYCLONES

WESTERN NORTH PACIFIC OCEAN AND SOUTH CHINA SEA

In 2023, a total of 17 named tropical cyclones (TCs) with maximum sustained wind speeds of ≥ 17.2 m/s formed over the western North Pacific Ocean and the South China Sea,[30] which is significantly below the 1991–2020 average (about 25).[31] The number of named TCs in 2023 was the third lowest number observed since 1951, following 14 in 2010 and 6 in 1998. This could be primarily attributed to suppressed TC activities since September in association with the evolution of El Niño.

One of the strongest TCs of the year, *Mawar* reached its peak intensity with maximum sustained winds of 115 knots and a central pressure of 900 hPa near the Mariana Islands on 25 May and then it passed north-eastward off the south of Japan. The typhoon itself and the activated Baiu front (rain band) in association with the intrusion of water vapour around the typhoon brought heavy rainfall mainly to the Pacific Ocean side of western and eastern Japan. This heavy rainfall caused inundation damage of 44 rivers and 308 landslides, and 23 rainfall stations recorded the highest 24-hour rainfall on record. Typhoon *Khanun* formed over the sea east of the Philippines on 26 July and passed around Okinawa (southern part of Japanese archipelago) and the west of Kyushu and crossed the Korean peninsula on 10 August. It brought over 1000 mm of total rainfall and maximum gust wind speed of over 50 m/s at Naha, Okinawa.

Typhoon *Doksuri* formed east of the Philippine Islands on 20 July and made landfall in Jinjiang, Fujian Province, China on 28 July. It was the second most intense tropical cyclone landing in Fujian since 1949. It brought heavy rainfall to the Zhejiang and Fujian provinces. The cumulative rainfall amount reached 841 mm at the Jiaoxi station of Putian of Fujian Province. After the landfall, it moved northward and brought record-breaking extreme heavy rainfall in large areas of the country including North China and the Huanghuai region. It caused significant flooding in both the Philippines and China, notably affecting the Beijing-Tianjin-Hebei region, where remnants of this typhoon led to the greatest basin-wide flood in the Haihe River since 1963. A 24-hour total rainfall amount reached 744.8 mm at Wangjiayuan Reservoir in Changping, Beijing, breaking a measurement record for 140 years.

NORTH INDIAN OCEAN

During 2023, six tropical cyclones (with maximum sustained wind speeds of ≥ 34 knots) formed over the region. The tropical cyclone activity over the North Indian Ocean was slightly above the average of 5.4 cyclones. Four out of the six above cyclones formed over the Bay of Bengal (*Mocha*, *Hamoon*, *Midhili*, *Michaung*), and two formed over the Arabian Sea (*Biparjoy*, *Tej*). Among them, Extremely Severe Cyclonic Storm *Mocha*, which formed during the pre-monsoon season, made landfall along the Rakhine Coast in Myanmar on 14 May, with maximum sustained winds of above 50 m/s and a reported loss of 156 lives in the region. The cyclone resulted in widespread flash floods, power outages, and significant damage to various structures, including buildings, cell phone towers, and trees in Myanmar.[32] *Michaung* made landfall in South Andhra Pradesh (the south-eastern part of India) on 5 December; 22 casualties were reported associated with this cyclone across the south-eastern part of India.

HEAVY PRECIPITATION AND FLOODING

Several extreme precipitation events took place in 2023. In May, heavy rainfall led to the establishment of new daily precipitation records at certain stations in Myanmar. In June and July, several flood and storm events resulted in at least 599 reported deaths across India, Pakistan and Nepal due to flooding, landslides and lightning. July and August witnessed landslides in India due to intense monsoon rains. In August of 2023, widespread floods and landslides struck multiple states in India, including Himachal Pradesh, and Uttarakhand, claiming 25 lives and causing extensive damage to infrastructure and agriculture.[33] Triggered by heavy rainfall, the disaster compounded the effects of an earlier monsoon surge in June. The Indian government declared a state of emergency in the worst-affected areas, initiating rescue and relief operations. The Indian Red Cross Society (IRCS) sought support from the International Federation of Red Cross and Red Crescent Societies (IFRC), highlighting the need for continued aid and intervention to address the long-term impact on communities.[34]

Heavy summer monsoon rainfall and floods caused at least 40 fatalities in the Republic of Korea.

In early September, the remnants of Typhoon *Haikui* led to unprecedented intense rainfall. The Hong Kong Observatory Headquarters recorded an hourly rainfall total of 158.1 mm on 7 September, the highest since records began in 1884, and 605.8 mm in a span of 12 hours. In October, heavy rainfall affected central provinces in Viet Nam. Several stations observed record-breaking daily rainfall amounts, for example at Hoanh Son station (337 mm) on 8 October and at Da Nang station (409 mm) on 13 October 2023.

In 2023, the daily precipitation amount in Madinah, in Saudi Arabia reached its highest recorded level on 2 January and heavy rainfall led to flooding in south Jeddah on 15 November. On 17 November, heavy rainfall hit various regions around Dubai, including Expo City which received 65.8 mm and Dubai International Airport which received 41.6 mm. These intense rains triggered flash floods in Dubai and surrounding areas.

In August and early September 2023, high precipitation totals—connected to extratropical cyclones—were observed in the far eastern part of the Russian Federation: catastrophic flooding occurred in Primorsky Krai. It is one of the largest disasters of the recent decade in terms of duration, extent and economic losses. About 40 000 hectares of rural land were damaged in the region. Pastures, roads, bridges, crops and residential buildings were flooded. Emergency regimes were introduced in 14 districts of the Primorsky territory. More than 2000 residents of flooded areas were evacuated, and six people died.

In 2023, Yemen suffered heavy rainfall and resulting widespread flooding. This sequence of intense short-duration rainstorm events damaged irrigation equipment and caused hazardous rockfall in Yarim District, Ibb Governorate, resulting in over 30 deaths.[35] The aftermath of these events resulted in severe flooding affecting over 165 000 individuals in over 70 districts, causing loss of life, damage to shelters, crops, and infrastructure, with internally displaced populations being particularly vulnerable and affected.[36] In late October, Cyclone *Tej* brought heavy rainfall to Yemen and Oman.

The flood that hit Astara County in the northern Islamic Republic of Iran from 17 to 19 September significantly affected 300 households. This flood resulted from intense and prolonged rainfall in Astara on 18 September. Within a span of 12 hours, 220 mm of rain was recorded. Notably, 135 mm fell between 3.30 a.m. and 6.30 a.m. on 18 September. The extent of damage was described as profound.

DROUGHTS

Since the beginning of the year, a drought has developed in south-west China, affecting the provinces of Yunnan, south-west Sichuan, and south-west Guizhou. Below-normal precipitation levels have been registered for nearly every month in 2023. The drought intensity in Yunnan province is the most significant since 1961. Water resources in the western part of HMA relies on precipitation during winter months and occasional rain in the Indian summer monsoon season. However, essential winter precipitation was below normal, and the rains associated with the monsoon were insufficient, despite significant and locally destructive flash floods in some areas during the summer (see also Snow cover section).

Below-normal rainfall during the Indian summer monsoon season led to a precipitation deficit in many parts of the Indian subcontinent. The Indian summer monsoon seasonal rainfall, averaged over India from June to September, was about 6% below the 1971–2000 average (see also Asian monsoon section). For the second consecutive year, certain regions in south-west India, the Ganges catchment, and the lower course of the Brahmaputra received less-than-normal precipitation. Additionally, some areas, including the Western Siberian Plain and southern Japan, experienced below-normal precipitation for the second year in a row. Afghanistan experienced another poor crop season due to a substantial reduction in snowmelt and rainfall, despite significant and locally destructive flash floods in some areas during the summer. Between May and October 2023, 15.3 million Afghans were estimated to face severe acute food insecurity.[37]

Below-normal rainfall in most parts of the Islamic Republic of Iran for the third consecutive year in 2023 has led to widespread drought in the country. The eastern half experienced severe rainfall shortages within the year. Decreased rain and severe drought in the region, along with above-normal temperatures, have led to the drying up of the main inland lakebed (the Hamoon Lake). Autumn 2023 was much warmer than normal in the Islamic Republic of Iran, with severe shortages of rainfall throughout the country.

HEATWAVES AND WILDFIRES

Many parts of the region experienced extreme heat in 2023. Prolonged heatwaves affected South and South-East Asia in early summer. In India, severe heatwaves in April and June resulted in about 110 fatalities due to heatstroke.[38]

A major and prolonged heatwave affected much of South-East Asia in April and May, extending as far west as Bangladesh and eastern India, and north to southern China. The most exceptional temperatures occurred in Thailand, Lao People's Democratic Republic, and Viet Nam. In Thailand, 44.6 °C at Tak on 15 April was the equal highest temperature on record in the country's main observation network,[39] while 41.0 °C at Bangkok Metropolis on 7 May was the highest on record in metropolitan Bangkok. Luang Prabang (Lao People's Democratic Republic) reached 43.5 °C on 6 and 7 May. In Viet Nam on 7 May, the highest temperature in the country's main observation network was recorded as 44.2 °C at Tuong Duong.[40] Ang Mo Kio (37.0 °C on 13 May) equalled Singapore's national record.

China experienced 14 high temperature events this summer. From 21 June to 9 July, north China experienced a significant heatwave, with about 70% of national meteorological stations exceeding 40 °C and 16 stations breaking their temperature records. The highest temperature at the Beijing Observatory was 41.1 °C, the second highest temperature since records began in 1951. The average number of high temperature days (daily maximum temperature exceeding 35 °C) over China (2425 stations) was 11.9 days, 3.9 days more than normal, resulting in the second hottest summer mean temperature (+0.8 °C) on record.[41]

A wildfire in the north-eastern part of Kazakhstan was associated with 14 fatalities in June 2023. July was also an exceptionally hot month for much of Kazakhstan.

In Saudi Arabia, the cities of Jeddah and Wejh each experienced one heatwave, while Gurait experienced three heatwave (12 days in total), with maximum temperatures reaching 45.2 °C on 26 July in Jeddah, and 46.5 °C on 13 August in Gurayat. The latter was the 7th highest recorded temperature at this station.

Japan, particularly in its northern part, experienced persistently hot conditions resulting in the country having its hottest summer on record dating back to 1898, with national mean temperatures for the season recorded at 1.76 °C above the 1991–2020 average. September 2023 was also the hottest September on record in Japan. Warm and dry conditions were observed in Mongolia during the summer, particularly in June and August over the western and southern parts, accompanied by record-high daily maximum temperatures (41.0 °C).[42]

MARINE HEATWAVES

Analogous to heatwaves on land, marine heatwaves (MHWs) are prolonged periods of extreme heat that affect the ocean. They have become more frequent in the twentieth and twenty-first centuries and can have a range of consequences for marine life and dependent communities. Satellite retrievals of sea-surface temperatures (SSTs) are used to monitor MHWs. MHWs are categorized as moderate when the SST is above the 90th percentile of the climatological distribution for five days or longer; the subsequent categories—strong, severe and extreme—are defined with respect to the difference between the SST and the climatological distribution average. An MHW is strong if that difference is more than two times the difference between the 90th percentile and the climatological distribution average, severe if it is more than three times that difference, and extreme if it is more than four times that difference.[43]

In 2023, the most prominent and persistent severe-to-extreme marine heatwaves occurred in a large area of the Arctic Ocean, in the Eastern Arabian Sea and the Northern Pacific, and lasted three to five months (Figure 15).

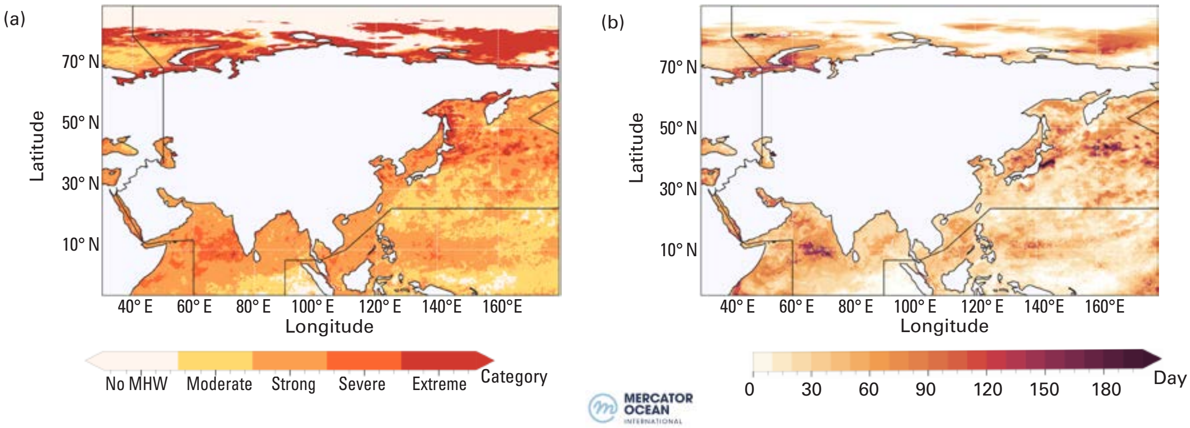

Figure 15. (a) Maximum categories of MHWs and (b) maximum duration of MHWs in 2023. Colours in (a) indicate the highest category of MHW for the year 2023 at each grid point and colours in (b) indicate the duration of MHW at the highest level for each grid point.

Source: Mercator Ocean International, France. Derived from the remote sensing product Global Ocean OSTIA Sea Surface Temperature and Sea Ice Reprocessed for 1982–2022 and Global Ocean OSTIA Sea Surface Temperature and Sea Ice Analysis for 2023, downloaded from the Copernicus Marine Service.

OTHER EXTREME EVENTS

Severe dust storms affected various parts of Asia. In mid-September, a dust storm swept across portions of the Islamic Republic of Iran, Afghanistan and Pakistan, posing significant health hazards. Strong winds in south-eastern Iran from 18 to 25 September caused a severe dust storm, resulting in casualties, injuries and hospitalizations. The dust emanated from the Hamun wetlands and, coupled with the Levar wind, affected the region, causing adverse health effects, school closures, transportation hazards and crop damage. These events underscore the far-reaching consequences of the persistent dust storms across diverse regions in Asia during 2023. In Western Asia, the United Arab Emirates (UAE) also encountered significant dust events on 10 January and 27 March, attributed to fresh south-easterly winds causing reduced visibility down to 1 000 metres.

On 22 March, a low-pressure system swept across Mongolia and China, triggering a significant dust storm fuelled by strong winds lifting sand and dust from the Gobi Desert. This event severely affected eastern China, with Beijing experiencing hazardous air quality, well above 500 μg/m^3 for coarse (PM_{10}) particles and above 200 μg/m^3 for fine ($PM_{2.5}$) particles,[44] affecting over 560 million people. Subsequently, on 11 April, winds carried a massive dust cloud over China and the Korean Peninsula, obscuring land and water from view. Beijing and the southern Republic of Korea, particularly Jeju Island, faced very low air quality.

Turkmenistan, Uzbekistan and parts of Kazakhstan reported high $PM_{2.5}$ values. Southern Wadi-Aldawasser and Jizan in Saudi Arabia recorded the highest (11 days) and second-highest (9 days) occurrences of dust storms. Several hazardous pollutants, like thick smog, also affected the daily lives of people living in parts of north-west South Asia, including India and Pakistan, in October 2023.[45]

Between December 2022 and January 2023, Afghanistan experienced an extreme cold wave. A record-breaking –33 °C was recorded in Ghor Province, in the central region of Afghanistan, resulting in 124 reported deaths from hypothermia and a substantial loss of livestock with estimates ranging from 70000 to 200000 animals.[46] Extreme cold occurred in parts of North-East Asia in the second half of January. In the far north-east of China temperatures fell below –50 °C, with Mohe reaching –50.8 °C on 22 January, the lowest there since 1969. Automatic weather stations in the area reported temperatures as low as –53 °C, while Tongulah (Russian Federation) reached –62.7 °C on 18 January, the country's lowest temperature since 2002. China experienced a nationwide cold wave from 14 to 17 December 2023. The daily minimum temperature of nine national stations, including Yunzhou (–33.2 °C) in Shanxi province and Qingshuihe (–31.3 °C) in Inner Mongolia, broke their historical records. The cold air processes have brought heavy snow and snowstorms, breaking the historical record for daily snow depth with 74 cm in Wendeng station in Shandong province. Heavy snow fell during this period in Japan and the Republic of Korea.

A significant Glacial Lake Outburst Flood (GLOF) originating in South Lhonak in India on 4 October, led to the catastrophic collapse of the Teesta III hydroelectric dam at Chungthang in North Sikkim, causing widespread devastation downstream.[47] According to the National Emergency Response Centre of India (NDMI), there were over 100 deaths and over 70 missing individuals. Around 4 500 were evacuated, and around 90 000 people were affected.[48] Additionally, about 2000 houses were damaged.[49] This type of disaster is increasingly observed because of climate change-induced glacier retreat[50] and highlights the compounding and cascading risks faced by vulnerable mountain communities. Glacial lakes formed by retreating glaciers, exemplified by the reduced expanse of South Lhonak Lake, pose threats that are transboundary, spanning across regions in Bhutan, India, Nepal and Pakistan. The International Centre for Integrated

Mountain Development (ICIMOD) reports a rapid disappearance of glaciers, which is at a 65% faster rate in the 2010s compared to the previous decade.[51] These events underscore the urgent need for global climate action to mitigate the increasing risks faced by mountainous regions.

Lightning is a significant hazard that claims numerous lives each year. In India, in recent years, lightning accompanied by thunderstorms has been a leading cause of fatalities. In 2023, thunderstorms and lightning claimed around 1200 lives in various parts of the country.

Tornadoes are among the extreme events that claim numerous lives each year. On 21 April, strong winds and a very large tornado struck Nay Pyi Taw, the capital city of Myanmar. The tornado led to eight fatalities, nearly 130 injured individuals, and the destruction of more than 230 houses across the affected region.

Climate-related impacts and risks

MORTALITY AND AFFECTED POPULATION

In 2023, a total of 79 disasters associated with hydrometeorological hazard events were reported in Asia according to the Emergency Events Database (EM-DAT);[52] of these, over 80% were related to flood and storm events. These reported hazard events resulted in over 2000 fatalities, of which over 60% were associated with flooding and over 15% with storms. Overall, more than nine million people were directly affected by these disaster events. Storms affected the largest number of people and caused the most economic damage during 2023 (Figure 16). Specifically, floods were the leading cause of death in reported events in 2023 by a substantial margin. In India, Yemen and Pakistan, floods were the natural hazard event which caused the greatest number of fatalities, highlighting the continuing high level of vulnerability of Asia to natural hazard events, especially floods.

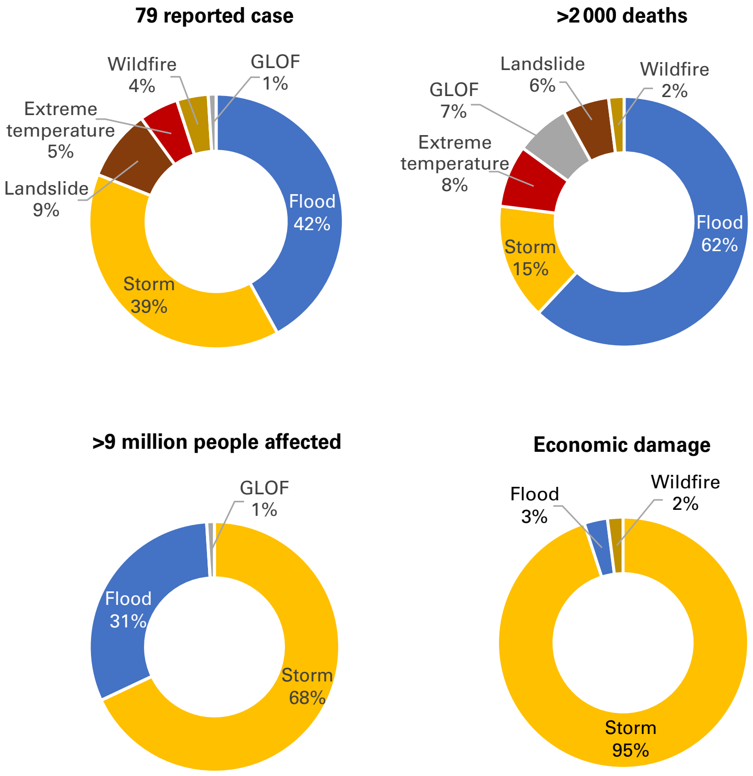

Figure 16. Overview of reported disasters in 2023 associated with hydrometeorological hazards in the Asia region

Source: United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) and The International Disaster Database (EM-DAT). ESCAP calculations are based on data from EM-DAT, accessed on 8 January 2024.

Note. The economic damages of some disaster occurrences are not presented in the figure due to data unavailability. In the figure, only cases reported in EM-DAT are considered. All mass movement events have been re-classified as "landslide".

STATUS OF EARLY WARNING SYSTEMS IN ASIA

According to the Global Status of Multi-Hazard Early Warning Systems 2023, only half of the world's countries are covered by an early warning system. Furthermore, even in the places with early warning systems, uneven progress can be observed across the four pillars of a multi-hazard early warning system: disaster risk knowledge, observations and forecasting, dissemination and communication, and preparedness to respond.[53]

In the Asia region, 21 countries (60%) reported the status of their early warning system on the Sendai Framework Monitoring (Figure 17). The average and the median of the composite score for global Target G of the Sendai Framework, measuring the overall progress on availability of and access to a multi-hazard early warning system, was 0.45 out of 1. It must also be noted that out of 21 countries, only 5 reported on all four indicators (G2 to G5, G1 is a composite indicator) of Target G, where each indicator is used to understand the comprehensiveness of the four pillars of the early warning system. The pillar which is the strongest in the region is warning and dissemination, where out of the total 18 countries which reported on this indicator, the average score was 0.86. The pillar which needs most strengthening in the region is risk knowledge, where only six countries reported on this indicator and the average score was 0.56, significantly lower than for the other pillars. The Asia region reported an average score of 0.89 for preparedness to respond, and 0.73 for observation and forecasting. Based on the reporting, there is much room for improvement, especially on pillar 1 of the early warning system. It should also be noted that monitoring and progress reporting will also be greatly improved with more countries reporting on all four indicators of Target G.

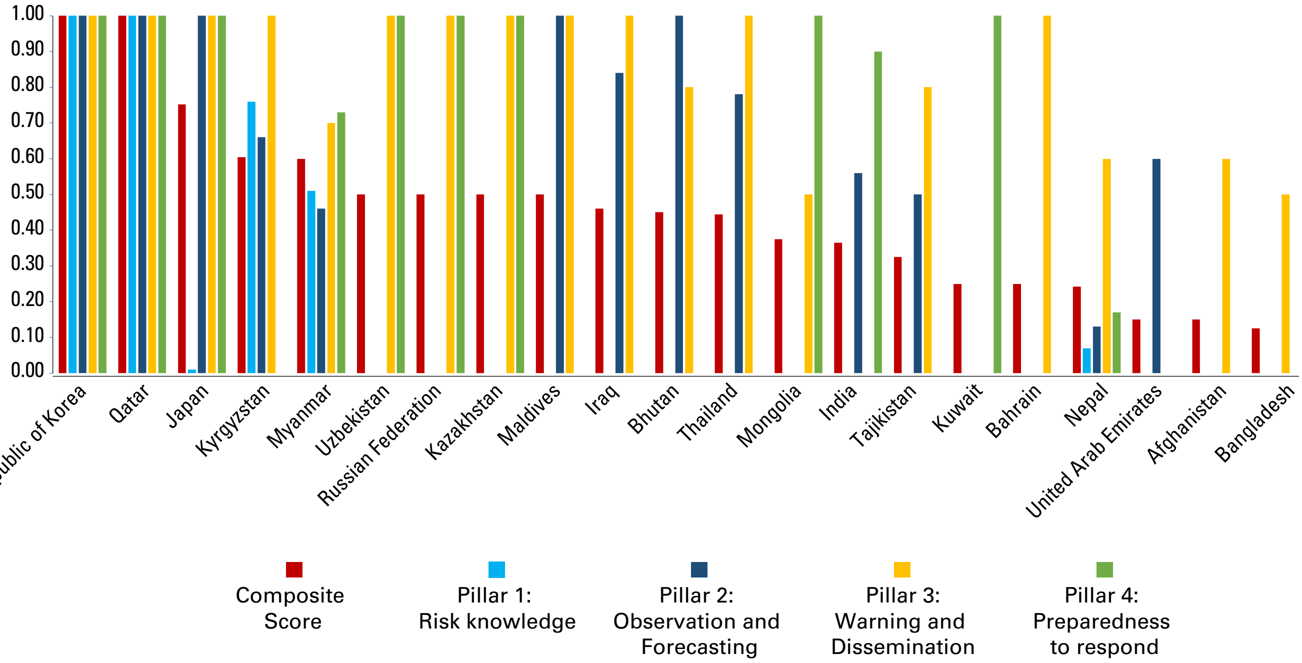

Figure 17. Sendai Target G scores of countries in the Asia region, as reported by countries in 2023 through the Sendai Monitor

Source: United Nations Office for Disaster Risk Reduction (UNDRR)

EARLY WARNING AND ANTICIPATORY ACTION IN ASIA

Given the high benefits relative to costs and the high visibility of the Early Warnings for All (EW4All) Initiative announced by the United Nations Secretary-General António Guterres in March 2022, early warning and anticipatory action have been gaining momentum in the Asia region. Five of the 30 countries receiving initial targeted support under this Initiative are located in the Asia region (Bangladesh, Cambodia, Lao People's Democratic Republic, Maldives and Tajikistan). One demonstrative application during 2023 was with Cyclone *Mocha*, which made landfall in Myanmar on 14 May 2023 as a category 4 tropical cyclone with wind speeds up to 250 km/h. This was the strongest cyclone in the Bay of Bengal in the last 10 years and caused significant damage to people's homes, infrastructure, power and water services (Figure 18). In addition, the cyclone wreaked havoc on millions of the most vulnerable people in the country, particularly in the Rakhine State of Myanmar, where the United Nations World Food Programme (WFP) estimated around 800 000 people needed priority attention to avoid deteriorating food security and livelihoods. Extensive crop damage, including rice seed stocks for the planting season starting in June, added to significant pressure on the medium-to-longer-term food security of households who are already grappling with disrupted livelihood activities.[54] WFP and the National Meteorological and Hydrological Service (NMHS), namely the Department of Meteorology and Hydrology (DMH), monitored the latest trajectory and potential impact of the cyclone and accordingly activated anticipatory action. Early warning messages followed, with a two-day lead time for the people likely to be affected, and anticipatory action disbursements in Teknaf, Cox's Bazar (Bangladesh) one day ahead of the cyclone.[55] The early warning message and the anticipatory cash empowered the communities to anticipate and mitigate the impacts of the cyclone and to build back faster after the hazard event.

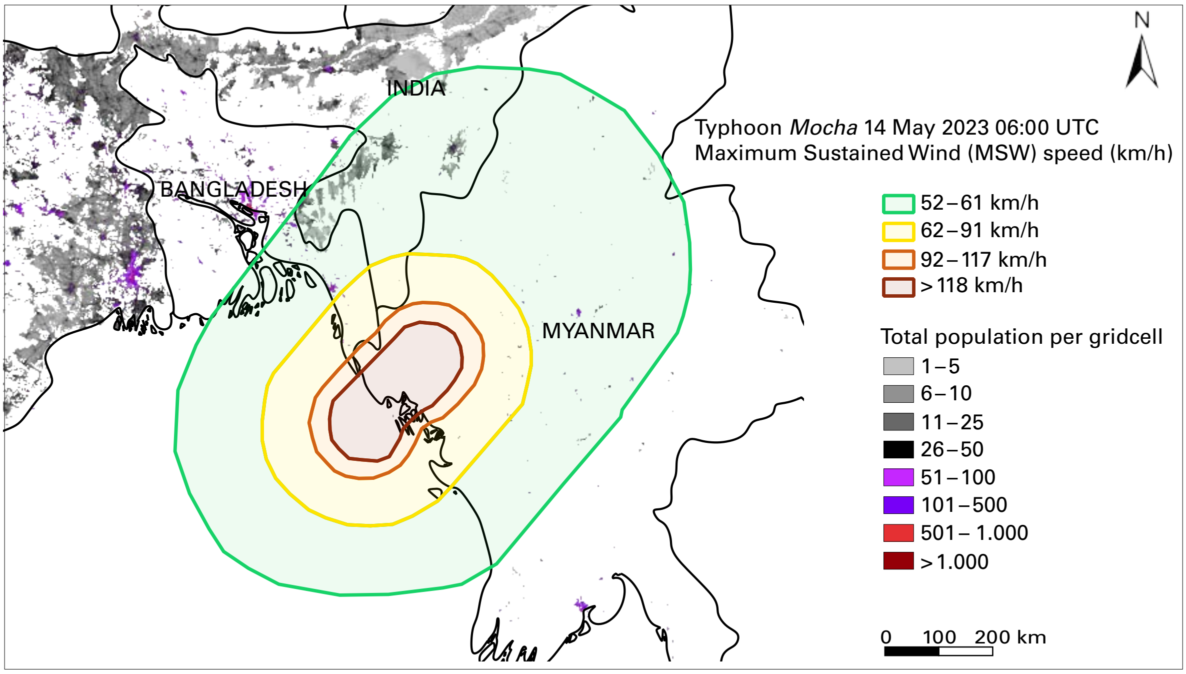

Figure 18. Impact-based forecasting of the population exposed to Typhoon *Mocha*. Maximum Sustained Wind speed of Typhoon *Mocha*, 14 May 2023 and Worldpop 2020 Population Estimates.

Source: UNESCAP and India Meteorological Department (IMD)

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

CHALLENGES AND OPPORTUNITIES

Over fifty years of data in Asia confirms the need for greater disaster risk reduction intervention in the region. From 1970–2021, there were 3612 disasters attributed to weather, climate and water extremes, with 984263 deaths and USD 1.4 trillion in economic losses (based on the analysis of disaster data from EM-DAT). Between 1970 and 2021, the region accounted for 47% of all reported deaths worldwide, with tropical cyclones being the leading cause of reported deaths. Tropical Cyclone *Nargis* in 2008 led to 138 366 deaths. Bangladesh had the highest death toll in Asia with 520758 deaths due to 281 events.[56] Furthermore, in 2023, torrential rains and floods hit East Asia during the summer, causing severe damage.[57] According to the WMO climate services checklist data, approximately 82% of Member countries in the region provide data services to support disaster risk reduction in the short and long term (Figure 19).

Disaster risk reduction in the Asia region is facing an alarming gap in climate projections and tailored products that are needed to inform long-term interventions such as adaptation to and mitigation of climate change and its impacts. Currently, less than 50% of Members are providing tailored products, indicating a significant inadequacy in view of the region's high vulnerability to climate-related disasters. National Meteorological and Hydrological Services (NMHSs) play a pivotal role in providing these services, and their level of engagement with the disaster risk reduction community has been assessed using a scale of 1 to 6, where 1 represents "initial engagement," and 6 represents "full engagement," based on the available data from the WMO climate services checklist. The average score across the region is 3.2 out of 6, implying that most of the engagement is in the initial stages, which primarily focuses on identifying needs (rated between 1 and 3) rather than providing tailored products and services (rated between 4 and 6) to address the sector's requirements.[58] Therefore, there is an urgent need to advance these efforts and provide more tailored support products to address long-term strategies as well as medium- and short-term activities and interventions to effectively mitigate disaster risks, considering the fact that by 2030, annual losses in Asia are expected to be over USD 160 billion, which is close to 0.6% of the region's GDP, up from 0.1% in the 1970s.[59]

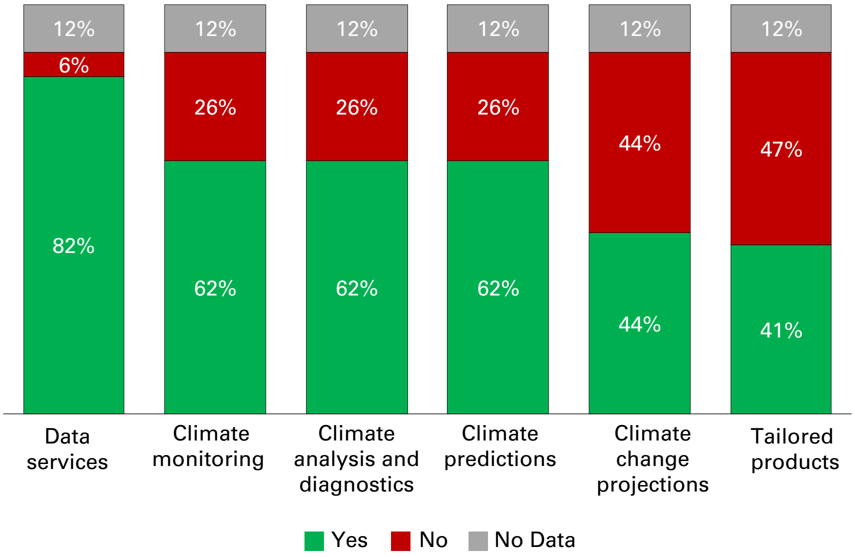

Figure 19. Percentage of Meteorological Services providing climate services for disaster risk reduction

In addition, analysis of the international sources of financing for disaster-related activities in Asia from 2012 to 2020 reveals a consistent growth, according to data from the Organization for Economic Development's Creditor Report System, and disaster-related Official Development Assistance (ODA) has remained relatively stable, with an average of around USD 1.4 billion per year over the past decade.[60] This indicates the need for further investment in disaster-related activities, considering the region's vulnerability to the impact of climate change.

WMO and the United Nations Office for Disaster Risk Reduction (UNDRR) are co-leading the Early Warnings for All (EW4All) initiative to ensure that everyone on Earth is protected by early warnings by 2027. The EW4All Executive Action Plan[53] was launched by United Nations Secretary-General António Guterres at the COP27 climate change conference in Sharm-El-Sheikh, Egypt in November 2022. To ensure the mainstreaming of this initiative in Asia, ministers, heads of NMHSs from 24 countries, and key regional partners issued a high-level declaration at the RA II Regional Conference (RA II RECO 2023), held in Abu Dhabi in March 2023, which includes strong recommendations to advance the four key multi-hazard early warning systems (MHEWS) pillars: risk knowledge and management; observations and forecasting; dissemination and communication; and preparedness and response.

Datasets and methods

TEMPERATURE DATA

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

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

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

The following six datasets were used:

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

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

JRA-55: Kobayashi, S.; Ota, Y.; Harada, Y. et al. The JRA-55 Reanalysis: General Specifications and Basic Characteristics. *Journal of the Meteorological Society of Japan*. Ser. II **2015**, *93*, 5–48. https://doi.org/10.2151/jmsj.2015-001. The data are available here.

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

HadCRUT.5.0.2.0: Morice, C. P.; Kennedy, J. J.; Rayner, N. A. et al. An Updated Assessment of Near-Surface Temperature Change From 1850: The HadCRUT5 Data Set. *Journal of Geophysical Research: Atmospheres* **2021**, *126*, e2019JD032361. https://doi.org/10.1029/2019JD032361. HadCRUT.5.0.2.0 data were obtained from http://www.metoffice.gov.uk/hadobs/hadcrut5 on 17 January 2024 and are © British Crown Copyright, Met Office 2024, provided under an Open Government Licence, http://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/.

NOAA Interim: Vose, R. S.; Huang, B.; Yin, X. et al. Implementing Full Spatial Coverage in NOAA's Global Temperature Analysis. *Geophysical Research Letters* **2021**, *48*, e2020GL090873. https://doi.org/10.1029/2020GL090873.

PRECIPITATION DATA

The following Global Precipitation Climatology Centre (GPCC) datasets were used in the analysis:

- First Guess Monthly, https://doi.org/10.5676/DWD_GPCC/FG_M_100
- Monitoring Product (Version 2022), https://doi.org/10.5676/DWD_GPCC/MP_M_V2022_100
- Full Data Monthly (Version 2022), https://doi.org/10.5676/DWD_GPCC/FD_M_V2022_100
- Precipitation Climatology (Version 2022), https://doi.org/10.5676/DWD_GPCC/CLIM_M_V2022_100

SEA-ICE DATA

In the present report, the estimation of sea-ice extent is based on an analysis of blended Arctic ice charts from the Arctic and Antarctic Research Institute (Russian Federation), the Canadian Ice Service (Canada) and the U.S. National Ice Center (United States of America), using passive microwave estimates (SMMR, SSM/I and SSMIS) from the National Snow and Ice Data Center.

GLACIERS DATA

Data are from the World Glacier Monitoring Service (WGMS) and the Chinese Academy of Sciences (CAS).

PERMAFROST DATA

Data are from measurements from the Russian Federal Service for Hydrometeorology (Roshydromet) within the Circumpolar Active Layer Monitoring Program.

SNOW COVER DATA

The Interactive Multisensor Snow and Ice Mapping System and data from the National Snow and Ice Data Center are used. To derive the monthly snow cover extent (SCE) anomalies for each grid, the number of monthly snow cover days is divided by the total number of days in that month and then multiplied by the area of the grid. Spatially, the mean SCE in spring for each grid is the average of the SCE in March, April and May for the grid in question. The area-averaged SCE over Asia is obtained by averaging the SCE of all the grids within the area bounded by the red line in Figure 10.

SEA-SURFACE TEMPERATURE DATA

Data are from the remote sensing product Global Ocean OSTIA Sea-Surface Temperature and Sea Ice Reprocessed for 1982–2021 and Global Ocean OSTIA Sea-Surface Temperature and Sea Ice Analysis for 2022, downloaded from the Copernicus Marine Service.

OCEAN HEAT CONTENT DATA

Data are from the in situ-based product Multi Observation Global Ocean 3D Temperature Salinity Height Geostrophic Current and MLD, downloaded from Copernicus Marine Service.

SEA LEVEL DATA

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

EXTREME EVENTS DATA

Meteorological characteristics and statistics are based on reports from WMO Members in Regional Association II (Asia), Regional Climate Centres and Regional Specialized Meteorological Centres in the region. Associated socioeconomic impacts are based on reports from WMO Members, EM-DAT data (see below) and reports from United Nations organizations.

EM-DAT DATA

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

The indicators used for mortality, number of people affected and economic damage were total deaths, number affected and total damages (in thousands of US dollars), respectively.

CLIMATE SERVICES

WMO Analysis of NDCs;

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

WMO Hydrology Survey, 2020;

World Meteorological Organization (WMO). *2020 State of Climate Services: Risk Information and Early Warning Systems* (WMO-No. 1252). Geneva, 2020.

World Meteorological Organization (WMO). *2021 State of Climate Services: Water* (WMO-No. 1278). Geneva, 2020

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Endnotes

[1] Data are from the following datasets: HadCRUT5, NOAAGlobalTemp, GISTEMP, Berkeley Earth, JRA-55 and ERA5. For details regarding these datasets see "Datasets and methods" in *State of the Global Climate 2023* (WMO-No. 1347).

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of the United Nations

UNDRR
UN Office for Disaster Risk Reduction

WFP
World Food
Programme

ESCAP
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