Global Water Monitor

2022 SUMMARY REPORT

Global Water Monitor Consortium

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Summary

The year 2022 will be remembered as the third consecutive La Niña year. There were extraordinarily devastating floods in Pakistan, while multi-year droughts in eastern South America, the western USA and the Horn of Africa intensified further.

The Global Water Monitor provides free, rapid and global information on climate and water resources. This summary report contains information on rainfall, air temperature and humidity, soil water availability, river flows and storage in natural and artificial lakes in 2022. Trends in the water cycle and some of the most important hydrological events of 2022 are interpreted and discussed.

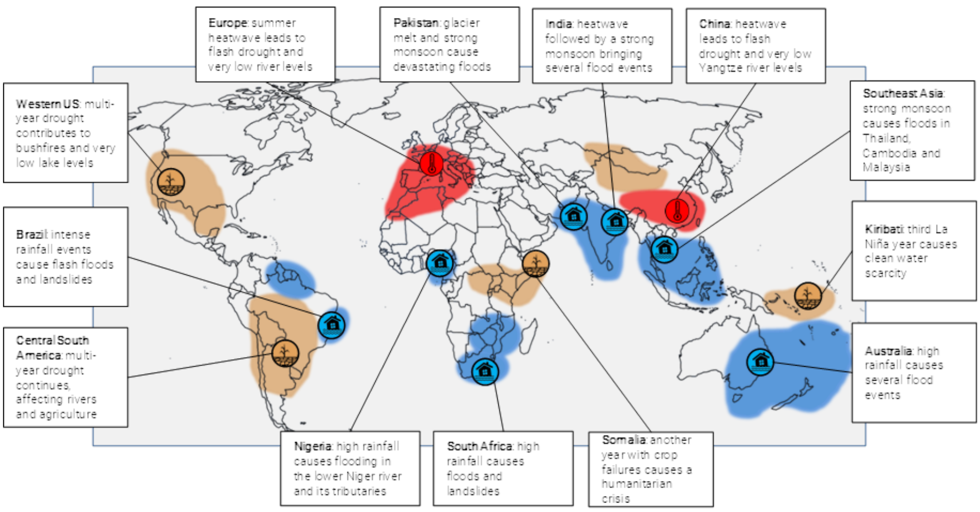
The global water cycle was dominated by warmer than average ocean waters in the western Pacific Ocean and cool waters in the east, combined with a negative Indian Ocean Dipole, with relatively warm sea water in the eastern and northern Indian Ocean and cool water in the west.

Global precipitation - averaged over the year and the land area - was very close to average values around 2000. However, the last two decades have seen increased air temperatures and declining air humidity, increasing heat stress and water requirements for people, crops and ecosystems alike.

A heatwave developed in south Asia early in the year, followed by a powerful monsoon with unusually high rainfall causing flooding and landslides in Pakistan, Afghanistan, India, Thailand, Cambodia, Australia and several other countries. Meanwhile, rainfall in the Americas, Africa and Central Asia was below average, intensifying drought conditions in the western USA, the centre of South America and the Horn of Africa. In western Europe and much of China, heatwaves and drought marked the summer of 2022, with rivers and lakes shrinking before returning to more average conditions later in the year.

At the end of 2022, dry conditions prevailed in the Great Plains of Canada and the USA, most of South America, western Russia, Mongolia and much of China, suggesting a risk of intensifying or newly developing drought.

Major water-related events in 2022



Contents

Preface

Our global water resources are under pressure. The growing world population needs more and more water for agriculture, industry and households, while global warming is changing both rainfall patterns and the water requirements of plants, people and ecosystems.

More than ever, we need information on the current state of the water cycle. Unfortunately, the global measurement network is in decline, and much of the remaining observations are not publicly available. Earth-observing satellites help fill gaps in our knowledge by measuring the atmosphere and the Earth's surface.

The Global Water Monitor Consortium brings together several public and private research and development organisations that share a goal of providing free, rapid and global information on climate and water resources.

Over the years, the partners have developed methods to combine and interpret water measurements made at thousands of ground stations and several tens of satellites orbiting the Earth. They use these to produce up-to-date information on different components of the water cycle.

Recently, they teamed up to provide comprehensive climate and water information via the Global Water Monitor (www.globalwater.online), an online data explorer that unlocks an extraordinary trove of climate and water data to anyone interested, free of charge. The development of the Monitor makes it possible to report on the state of our global water resources within a few days of the event. We produced this first annual report to use and demonstrate that capacity.

This year's report includes information on precipitation, air temperature and humidity, soil water availability, river flows and water volumes in natural and artificial lakes. It summarises the state and any trends in the global water cycle in 2022 and examines some of the most important hydrological events of the year.

7 January 2023

Albert van Dijk

Professor of Water Science and Management, Australian National University
Chair, Global Water Monitor Consortium

Measuring and Interpreting Change

How do satellites measure water?

Since the first Earth-observing satellite was launched sixty years ago, satellite remote sensing has become a crucial part of weather observation and forecasting systems worldwide. In more recent decades, the use of satellites to observe water at and below the Earth's surface has developed into practical solutions. Ideally, satellite measurements are calibrated to on-ground measurements where they exist to increase their accuracy. Once calibrated, they can provide information much faster, over much larger areas and with much greater detail than the on-ground measurement network alone.

All data discussed in this report were developed using methods that have been published in the scientific literature:

Precipitation, air temperature and air humidity are estimated by combining the latest satellite observations with all globally available weather station data and information from weather forecasting models[1]

Soil water is interpreted from measurements by passive and active satellite microwave (radar) instruments and made available by the EU Copernicus Climate Data Store[2]

River flow estimates are based on the automated measurement of river width in satellite imagery[3]

Lake and reservoir storage data are estimated by combining satellite measurements of surface water level and extent with topography[4].

The Global Water Monitor data explorer

The key objective of the Global Water Monitor is to make up-to-date, global and accurate climate and water information freely available and easily accessible. We developed a visual data explorer, the Global Water Monitor (www.globalwater.online). All data shown in this report are directly derived from that website and, therefore, can be reproduced or examined in more detail. Users can retrieve and visualise maps or time series for any location, administrative hydrological region or hand-drawn area. Some background on the calculations and interpretations available and as used in this report is provided below.

Understanding Anomalies

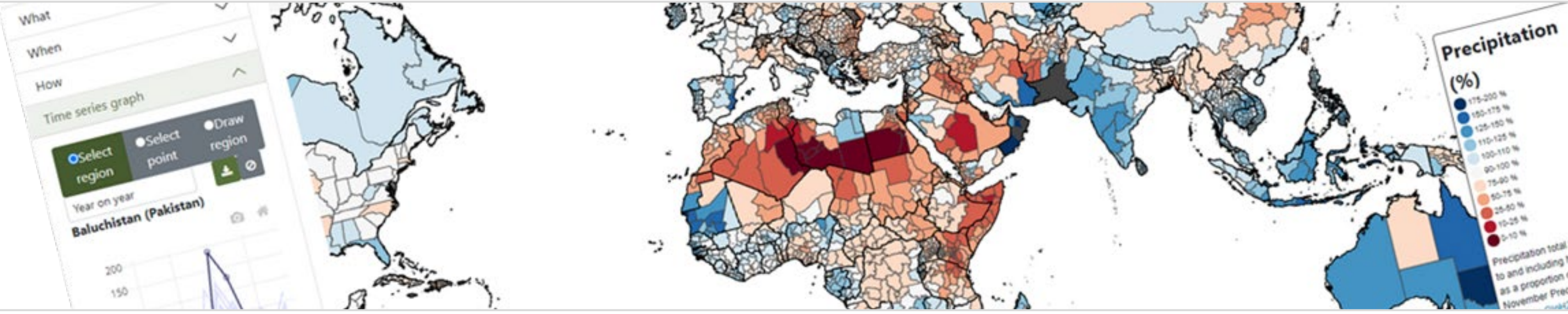
The 'normal' range of climate and water conditions varies worldwide, from arid deserts to tropical monsoon regions and frozen poles. Percentages and anomalies are insightful ways of comparing actual values to the distribution of values for the same area and time of year in the historical record. The metrics available in the Global Water Monitor and used in this report are:

Anomaly or absolute difference from mean provides information on the departure from long-term average conditions. For example, rainfall in a particular period (e.g., March to September) may be 100 mm more than the average for the same period in all previous years.

Percentage of the mean puts the same information in a relative context. For example, the same 100 mm difference would be 110% of (or 10% above) a longer-term average value of 1000 mm.

Standardised anomaly or sigma value is a useful means to compare the actual conditions to previous

[1] Beck et al., Bulletin of the American Meteorological Society, 2022 (link)
[2] Copernicus Climate Data Store (link, v202012 combined product)
[3] Hou et al., Remote Sensing of Environment, 2022 (link)
[4] Hou et al., Hydrology and Earth System Sciences, 2022 (link)



years in a way that accounts for the year-to-year variation experienced previously. It is calculated by dividing the actual anomaly by the standard deviation of values in previous years. Below is a general interpretation of the colour scale used in most maps in this report. Unusually high or low values often coincide with extreme values in the available record, but that is not always the case.

Sigma (σ)	Description*
> 2.0	*unusually high*
1.5 – 2.0	*high*
1.0 – 1.5	*high*
0.5 – 1.0	*above average*
0.25 – 0.50	*above average*
-0.25 – 0.25	*near-average*
-0.50 – -0.25	*below average*
-1.0 – -0.5	*below average*
-1.5 – -1.0	*low*
-2.0 – -1.5	*low*
< -2.0	*unusually low*

*Colour legend and interpretation of standard anomalies. *) colours are reversed for air temperature to be more intuitive*

Summarising by country or catchment

Summaries were calculated by **country** as defined by the International Organisation for Standardization (ISO 3166-1). They include fully independent countries and dependent administrative regions with varying degrees of autonomy. In the Global Water Monitor, summary data are also available for the next lower level of administrative regions within each country provided by ISO (e.g., states and provinces). We imply no political statement by using the current ISO list.

Many of the world's **river basins** cover more than one country. In those cases, country statistics do not provide a complete picture of water resource conditions across the river basin. Conversely, large countries may contain multiple river basins with different conditions. Therefore, summaries were also calculated by river basin. In the case of islands and coastal regions with multiple small catchments, river 'basins' can be a series of bordering catchments. In the Global Water Monitor, summary data are also available for individual smaller catchments within basins.

Limitations

Where there are no gaps in the data, averages across countries or catchments can be calculated without problems. Where there are some missing data, they can be estimated. However, where most data is missing, calculated averages can be misleading.

Summarising storage in lakes by country or basin is straightforward in principle, as they can be added up. However, not all water bodies are measured all the time, so gaps in the data need to be based on estimates from other times. Summarising river flows by country or catchment is challenging. For example, many countries contain multiple rivers. We selected the fifteen river observation locations with the largest long-term average flows within the country or catchment and calculated a weighted average value.

By its very nature, averaging over years and regions can hide locally severe conditions or extreme events that occur over short periods. This should be kept in mind when interpreting the information.

Satellite instruments can provide a near-immediate global overview of climate and water conditions, but they are not perfect. Where they are available, onsite observations are usually more accurate and necessary to calibrate remote sensing approaches like those used here. Protecting the remaining water measurement station network should therefore be a priority.

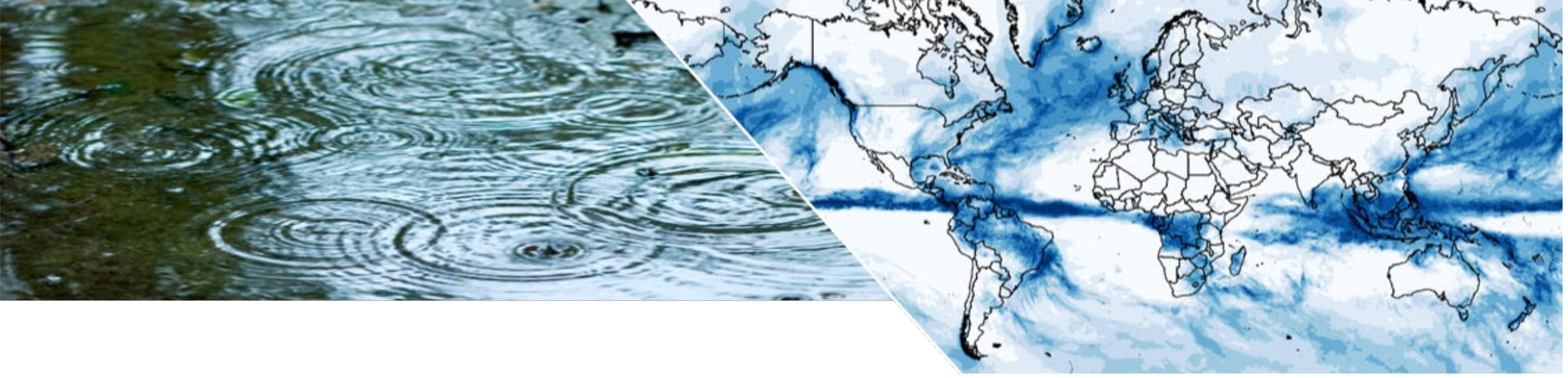
Record length, frequency and spatial detail vary between data sources. For example, climate data are available from 1979, water body data from 1984, soil water data from 1991, and river flow data from 2000 onwards.

Even satellite observations are unavailable in some regions and at some times. For example, soil water observations are only possible if the soil is not frozen or covered with dense forest, and river and lake observations require days without clouds. In the case of climate data, data gaps are filled by weather models, which have uncertainties of their own.

Efforts were made to confirm the interpretation of the data using background research, but the above limitations should be kept in mind when reading this report.

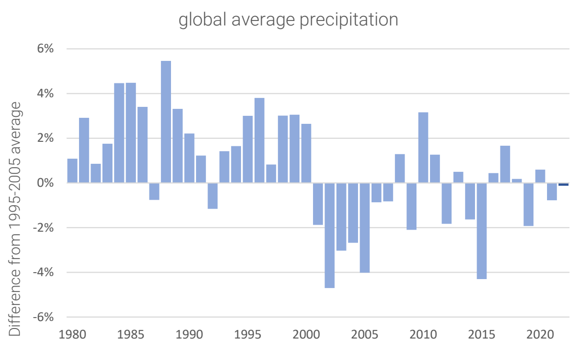
Anyone inclined to take action based on the information presented here should first consult the relevant local or national agencies.

Global Summary



Precipitation

Global precipitation was average. There does not appear to be a trend towards higher monthly rainfall extremes, but record low values occur increasingly often.

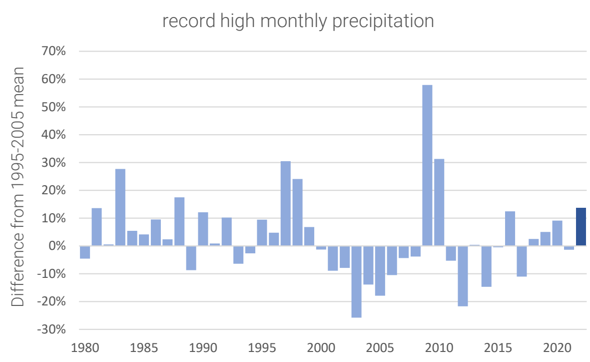


Annual precipitation over land relative to the average for 1995–2005.

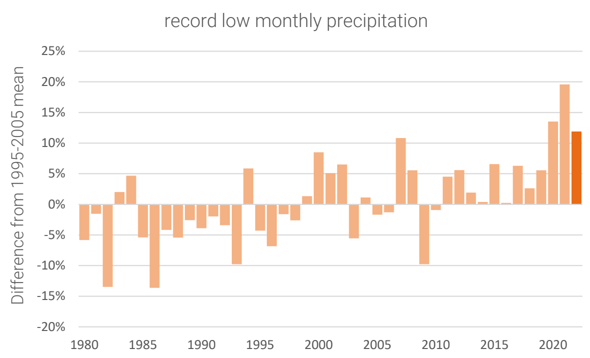
Average precipitation over the global land area was nearly identical (-0.5% lower) to the average for 1995–2005. There does not appear to be evidence for a trend in global average precipitation.

The number of times high monthly precipitation records were broken in one of the 4687 river catchments worldwide was the highest since 2010 and 14% higher than around 2000 (1995–2000). There does not appear to be a long-term trend towards more high monthly rainfall records. However, research has found that increasing trends in extreme precipitation over shorter periods (five days or less) have become more common than decreasing trends[5]. This would be expected to increase the risk of local flash floods.

The number of times low monthly precipitation records were broken was the third highest since 1979 and 12% higher than the average around 2000. The highest number of low rainfall records broken annually were in the last three years, and there appears to be a long-term trend towards more months with record low rainfall.



The number of times high monthly precipitation records were broken compared to the average for 1995–2005.



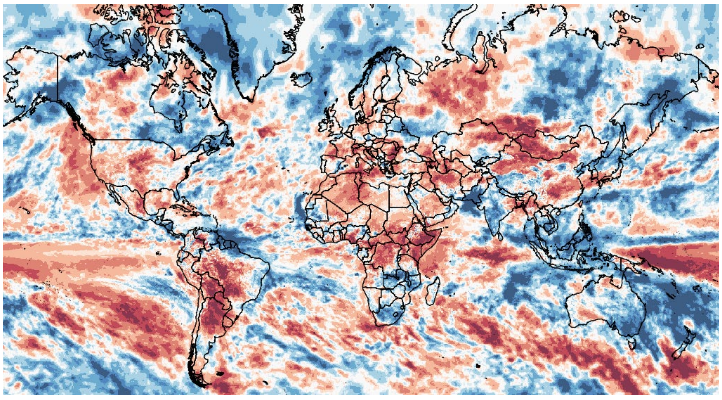
The number of times low monthly precipitation records were broken compared to the average for 1995–2005.

[5] *Seneviratne et al. (2021) Weather and Climate Extreme Events in a Changing Climate. In: Climate Change 2021: The Physical Science Basis, pp. 1513–1766, doi:10.1017/9781009157896.013*

Global patterns

Global patterns were dominated by surface temperature in the Pacific and Indian Oceans. A so-called La Niña pattern persisted in the Pacific Ocean for the third year in a row[6]. As is typical, rainfall was above average in southeast Asia and Oceania and below average in the Americas. The northern and eastern Indian Ocean were also relatively warm and contributed to heatwaves and a wet monsoon in neighbouring countries, including Pakistan and India.

Standardised anomaly in annual precipitation (see p.8 for legend)

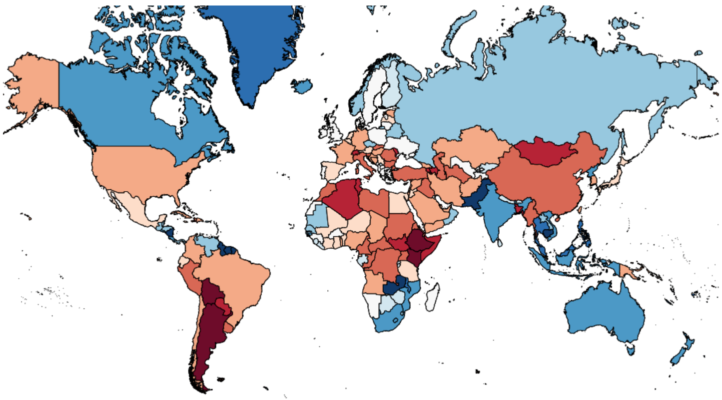


Precipitation by country

Annual rainfall was below average in northern and eastern Africa and parts of the Middle East and Central Asia. Unusually dry conditions ($\sigma<-2$) occurred in five countries: Bolivia and Argentina in South America, Ethiopia and Kenya in eastern Africa, and Tuvalu in the South Pacific Ocean.

Unusually wet conditions occurred in 17 countries located in south Asia (Pakistan), southeast Asia (Cambodia, Malaysia and Brunei Darussalam), the Caribbean and northern South America (Nicaragua, the Guyanas and Trinidad & Tobago), the northern Atlantic (Iceland and Greenland), Zambia in southern Africa and some islands in the southeast Pacific Ocean (e.g., New Caledonia, Palau, Tonga and Vanuatu).

By country

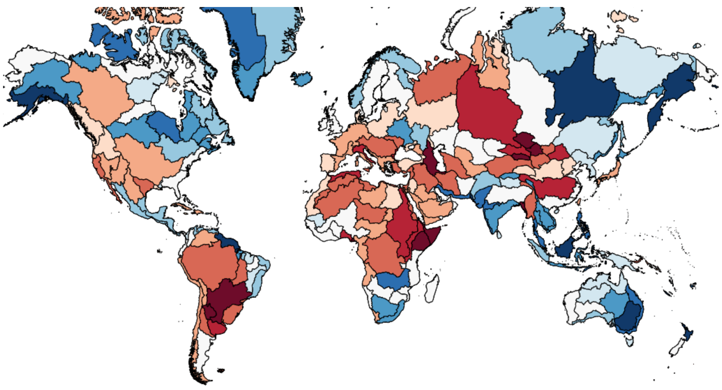


Precipitation by river basin

River basins experiencing very dry conditions included the Paraguay-Paraná and nearby basins in South America. Other regions experiencing unusually low rainfall included the Horn of Africa and several inland basins west of the Caspian Sea and in western China.

The most unusually high annual rainfall was observed along the Arabian Sea coast of Pakistan and the coast of the Guyanas. Rainfall was also very high in nearby areas, including the Persian Gulf Coast and the East Caribbean. Elsewhere, rainfall was unusually high in eastern Siberia and several regions around the Pacific Ocean, including eastern Australia and the Murray-Darling basin, the Alaska coast, Kalimantan (Borneo) and several South Pacific islands, including New Zealand North Island, Micronesia and New Caledonia.

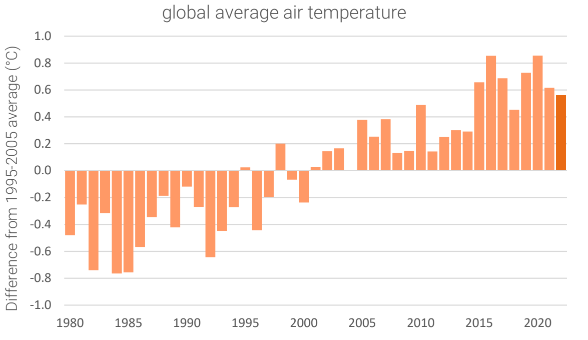
By river basin



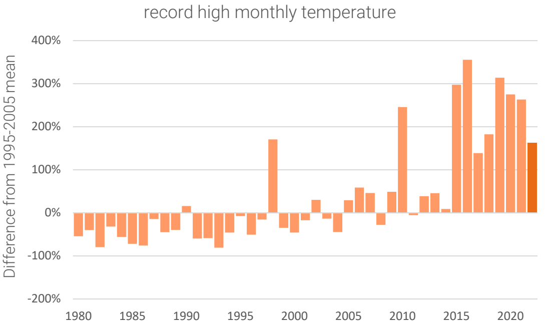
[6] https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ONI_v5.php

Air temperature

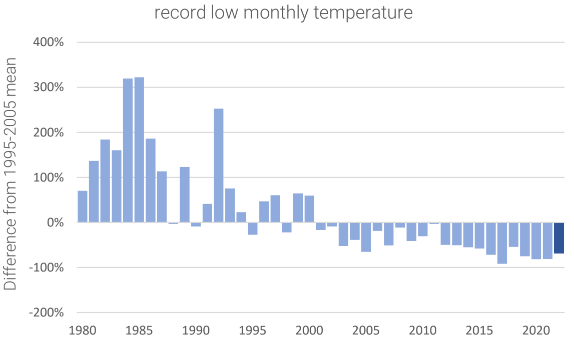
Global average temperature over land was slightly lower than the previous year but still clearly in line with global warming. Unusually high average annual temperatures were recorded in Europe and Central Asia.



Annual average temperature over the global land area compared to the average for 1995–2005.



The number of times high monthly temperature records were broken compared to the average for 1995–2005.



The number of times low monthly temperature records were broken compared to the average for 1995–2005.

Air temperature across the global land area was 0.56°C above the 1995–2005 average – the lowest since 2018 but still the seventh warmest year since 1979, in line with global warming trends.

The number of times high monthly average temperature records were broken in the 4687 river catchments worldwide was lower than the preceding four years, but nonetheless above the 1995–2005 average for the 11th year in a row, by 168% or 2.7 times. There is a clear long-term trend towards more record-high monthly average temperatures globally.

The number of times record-low monthly average temperatures was below the 1995–2005 average for the 22nd year in a row. There is a clear long-term trend towards fewer record-low monthly average temperatures globally.

Global Patterns

Annual average temperature was unusually high in Europe, parts of the Pacific, the Middle East, Central Asia and China.

By country

No less than 27 countries experienced unusually high average annual temperatures in 2022. They include 12 countries and territories in western Europe, including France, Spain and Italy; three in North Africa, including Morocco; two countries in Central Asia; eight countries in Oceania, including Papua New Guinea and New Zealand; and two island states in the western Atlantic.

The strongest absolute temperature deviation was measured in Monaco, France, where the average annual temperature was 1.8°C above the longer-term (1979–2021) average.

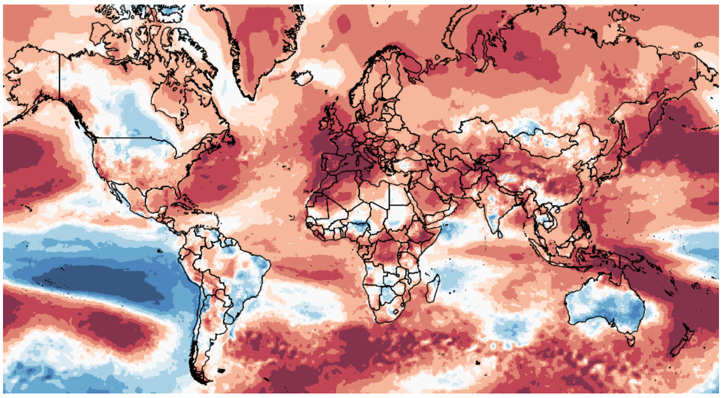
French Polynesia was the only country to experience unusually low temperatures in 2022, with average temperature 0.50°C below the longer-term average.

By river basin

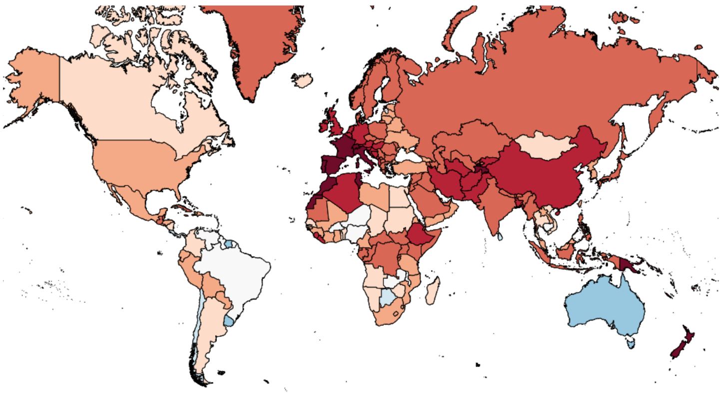
Average annual temperatures in 2022 were unusually high in many catchments and islands in the western Mediterranean, in inland Central Asia and many islands in the South Pacific Ocean.

Temperatures were not unusually low anywhere. Somewhat below-average temperatures were recorded in most of Australia, along the coast of South America and in inland Canada.

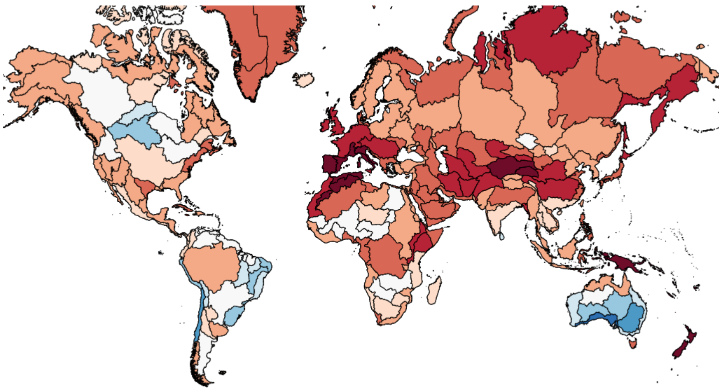
Standardised anomaly in annual average air temperature (see p.8 for legend - note the colour scale is reversed for temperature, with red showing higher values)



By country

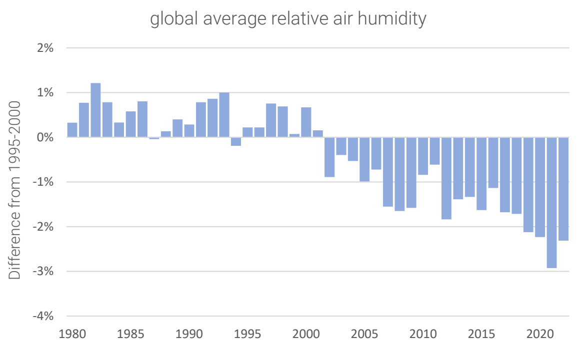


By river basin



Air humidity

Air humidity over land was the second lowest on record after the previous year, continuing a trend towards drier average and extreme conditions. Dry conditions prevailed nearly everywhere except for regions experiencing high rainfall.

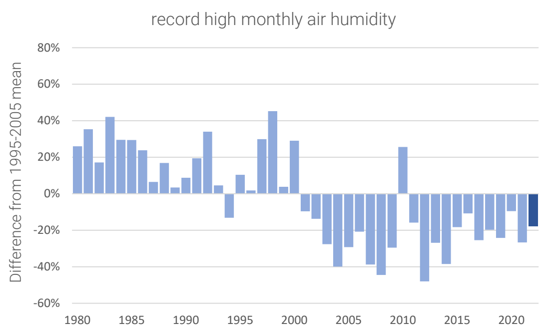


Annual average air humidity over the global land area compared to the average for 1995–2005.

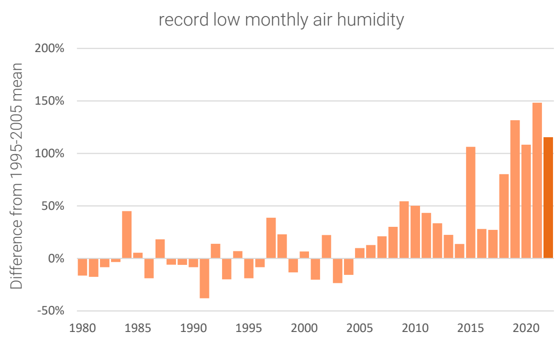
Relative air humidity over the global land surface was slightly higher than the previous year but 2.3% below the 1995-2005 average and the second driest on record. There has been a steady trend towards drier air, attributed to a more rapid rise in air temperature over land than over sea[7].

The number of times high monthly average air humidity records were broken in the 4687 river catchments worldwide was below the 1995–2005 average for the twelfth year in a row, by 18%. There is some evidence for a decline in record-high humidity events.

In contrast, the number of times low monthly average air humidity records were broken was 2.2 times (+115%) greater than the 1995–2000 average and the third highest since 1979. There appears to be a strong trend towards more frequent months with record-low air humidity. Very low humidity exacerbates the impacts of drought on ecosystems and people and increases the risk and severity of bushfires.



The number of times high monthly air humidity records were broken compared to the average for 1995–2005.



The number of times low monthly air humidity records were broken compared to the average for 1995–2005.

[7] *Seneviratne et al. (2021) Weather and Climate Extreme Events in a Changing Climate. In: Climate Change 2021: The Physical Science Basis, pp. 1513–1766, doi:10.1017/9781009157896.013*

Global patterns

Annual air humidity was below average across most of the land area. The main exceptions were associated with above-average precipitation, in south and southeast Asia, southern Africa, northeastern South America, southeast Australia and parts of Russia.

By country

A total of 36 countries experienced unusually low air humidity in 2022. They include 13 countries across Europe, four countries in central-west South America, three countries in northwest Africa, three countries in central Africa, two countries in Central Asia and a further eleven island states in the Pacific, Indian and Atlantic Oceans and the Caribbean.

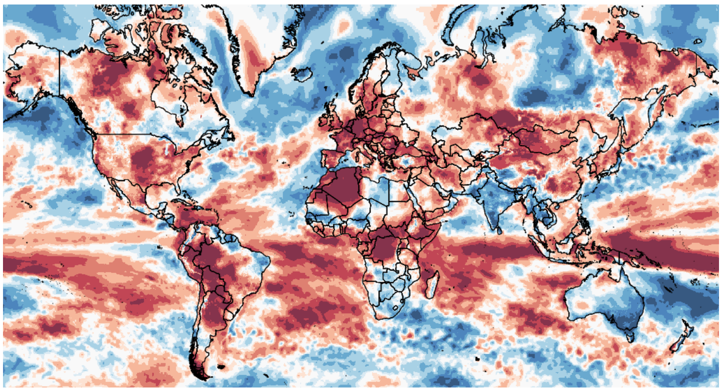
Unusually high humidity occurred in only four countries that experienced high rainfall: Cambodia, Thailand, Sri Lanka and New Caledonia.

By river basin

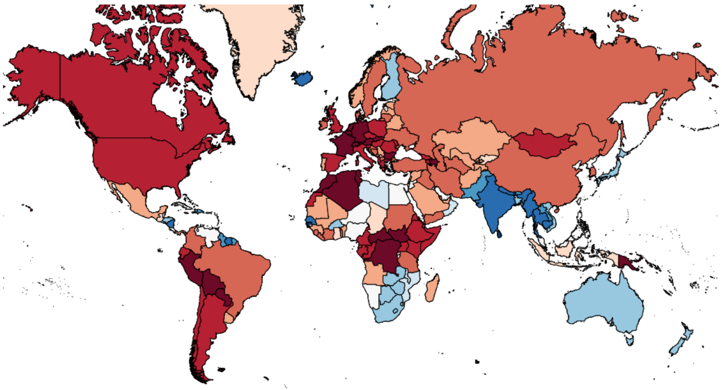
Relative air humidity was unusually dry in many river basins worldwide, including in the large basins of the Amazon, Mississippi-Missouri, Congo, Paraguya-Paraná, Ob and Danube river Basins. Air humidity was also unusually low across much of Europe and parts of Africa, Central Asia, several southwest Pacific islands and parts of the north coast of Canada and Siberia. The most unusually dry humidity was observed over the Bismarck and Solomon Islands near Papua New Guinea.

Unusually high humidity was observed along the coast of Pakistan, in the Mekong Basin, Eastern Australia, Sri Lanka and New Caledonia in the south Pacific.

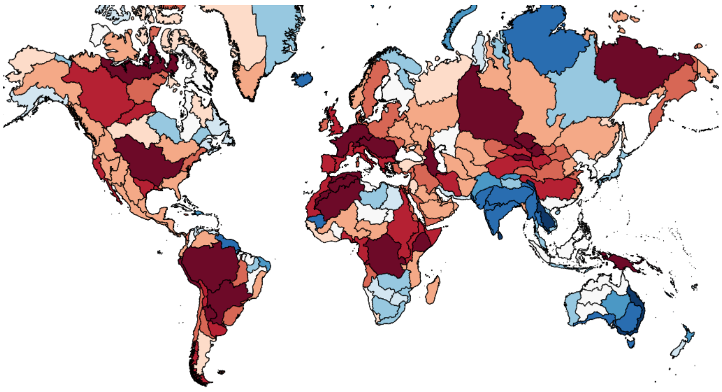
Standardised anomaly in annual average air humidity *(see p.8 for legend)*

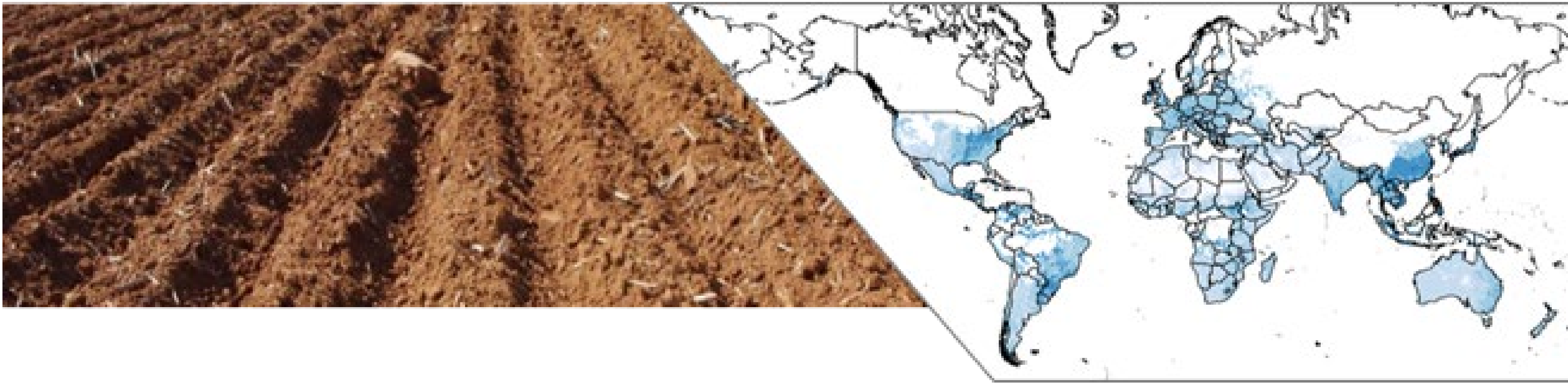


By country



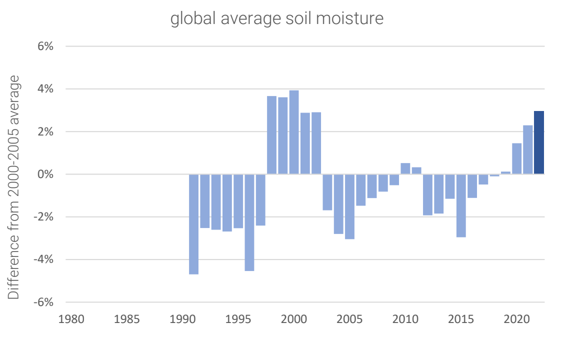
By river basin





Soil water

Despite warmer and drier conditions, high annual soil water conditions were observed in many regions.

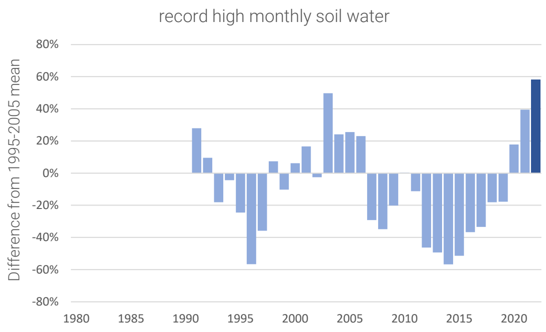


Annual soil water content over the global land area compared to the average for 1998–2021.

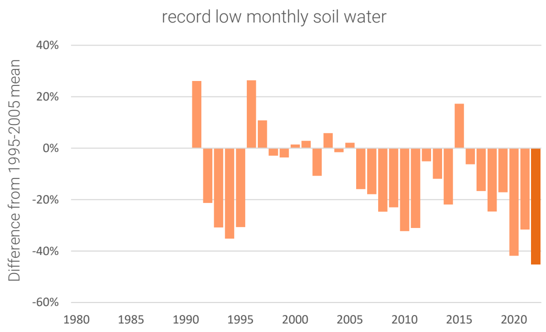
Soil water content over the land area was 3% above the 1998–2005 average. There appears to be a slow oscillating pattern in soil moisture that partly coincides with El Niño/La Niña phases, including a steep increase during the last three La Niña years. There is no clear evidence of an increasing trend.

The number of times high monthly average soil water records were broken in the 4687 river catchments globally was 58% above the 1998–2005 average and the highest since observations started in 1991. There does not appear to be evidence of a long-term trend, but there has been a steep increase since 2013.

Conversely, low monthly soil water records were broken the least often since measurements started in 1991 and were 48% below average. There appears to be a declining trend in record dry soil observations. Such a trend does not correspond with low rainfall and relative air humidity trends towards drier conditions although it does correspond with increasing trends in river flows and lake storage (next sections) and increasing vegetation in many regions[8]. The soil water record is based on several satellite instruments, and the possibility that inconsistencies between subsequent sensors are responsible for some shifts needs further analysis.



The number of times high monthly soil water records were broken compared to the average for 1995–2005.



The number of times low monthly soil water records were broken compared to the average for 1995–2005.

[8] *e.g., Liu et al. (2015) Nature Climate Change 5, 470–474*

Global patterns

Spatial patterns in soil water anomalies mostly reflected rainfall patterns, with relatively wet soils across most of southern and southeast Asia and Eastern Australia, southern Africa and Eastern Brazil.

Despite warmer air and drier rainfall and air humidity conditions, relatively high soil water conditions were also observed in the African Sahel region, eastern Europe and eastern China. There may be a connection with recent increases in vegetation cover in these regions.

Very dry soil conditions occurred in the Great Plains in the USA and Canada, Argentina, and parts of Siberia and Central Asia, the Middle East, Northern Africa and the Horn of Africa.

By country

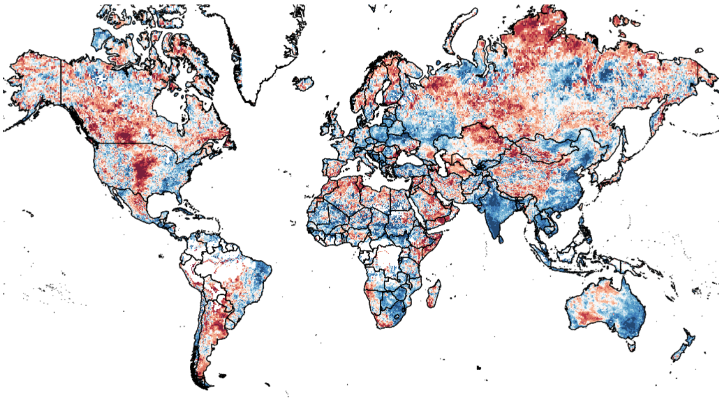
Despite dry and warm conditions in several countries, annual average soil water content was not unusually low in any country. The driest conditions occurred in Argentina, Peru, Tunisia and Somalia.

Unusually wet soil conditions occurred in 33 countries: ten countries across Africa, eight in south and southeast Asia (including India, Bangladesh, Thailand, Vietnam and Indonesia), six Caribbean countries, Turkey, and six smaller countries and territories elsewhere.

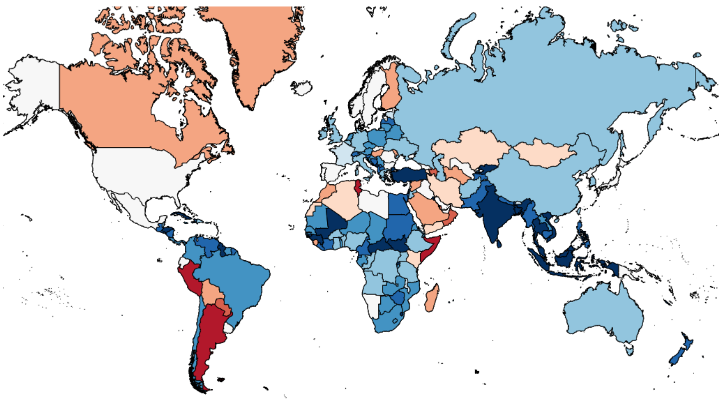
By river basin

Unusually dry average soil water conditions were only recorded in the East Siberian sea catchments. However, well-below-average conditions also occurred in several other basins in Siberia, the Mackenzie and others basins in Canada, the Paraguya-Paraná and La Plata basins in South America, and several basins in East and North Africa, the Middle East and Central Asia.

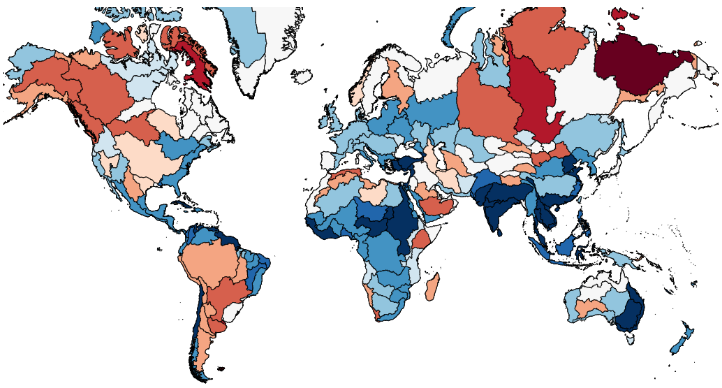
Standardised anomaly in annual average soil water content (see p.8 for legend)



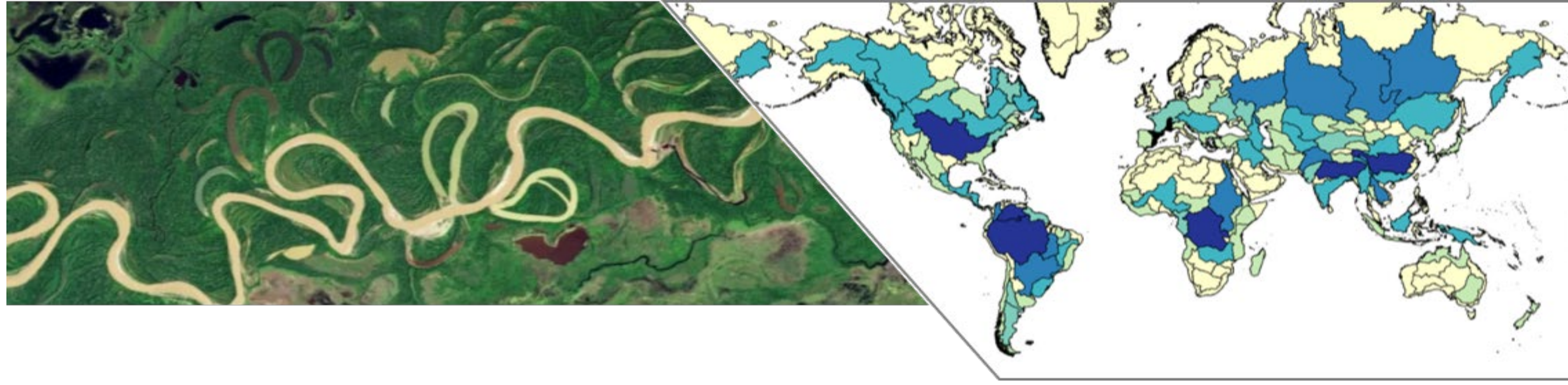
By country



By basin

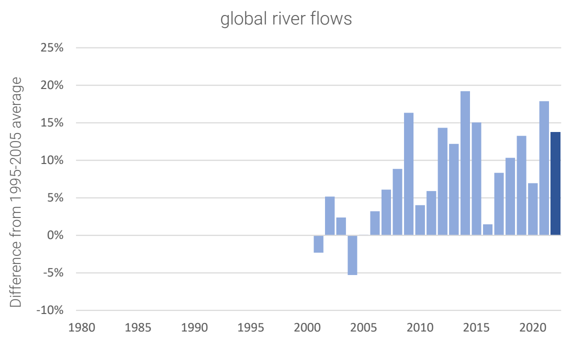


Unusually high soil water conditions (σ>2) were recorded in several basins in South and Southeast Asia, including the Ganges-Brahmaputra and Mekong, along the coasts of the East and South China Seas, Turkey, the Sahel region and Nile Basin, and eastern Australia including the Murray-Darling Basin. The most extreme departures (σ>3) occurred along the coast of the Guyanas in South America, and the coast of Vietnam, Sri Lanka and the Malaysian peninsula.



River flows

Global river flows were slightly lower than the previous year but part of an apparent increasing trend. Record low river flows appear to be getting less common globally.

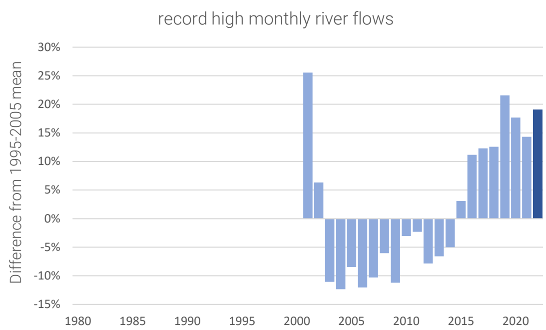


Global river flows compared to the average for 2001–2005.

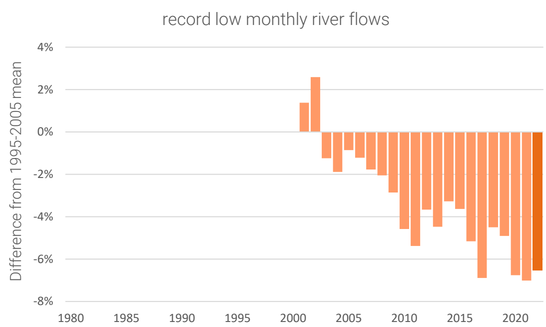
Global average river flows, estimated as the sum of river flows in all river basins, were 14% above the 2001–2005 average. There appears to be a trend towards increasing average river flows. Global total river flows are dominated by rivers in the world's wettest regions.

The number of times high monthly river flow records were broken at the 67,630 satellite river gauges was 20% above the 2001–2005 average. There appears to be a shift or trend towards more record river flows from around 2010.

Low monthly average river flow records were broken 7% less often than around 2000 (2001–2005). There appears to have been a clear trend towards fewer record-low river flows. There are several possible explanations[9], including increased regulation of river flows, the impact of global warming in cold regions, and the fact that low flow records cannot be broken where zero flows have previously occurred in that month. Further research is needed to test these explanations.



The number of times high monthly river flow records were broken compared to the average for 2001–2005.



The number of times low monthly river flow records were broken compared to the average for 2001–2005.

9 Gudmonsson et al. (2021) Science 371, 1159-1162

Global patterns

By country

Average flows in the main river(s) were average or above average in most countries. Annual average river flows were unusually high or at least the highest recorded since 2000 in South Africa, Mozambique and Zimbabwe in southern Africa, Chad and Mali in the Sahel, Azerbaijan and Tajikistan in Central Asia, and Canada.

Annual average river flows were the lowest recorded since 2000 in Egypt and Cote d'Ivoire in Africa and France, Italy and Czechia in Europe.

By basin

Both high and low average 2022 river flows were common in river basins worldwide.

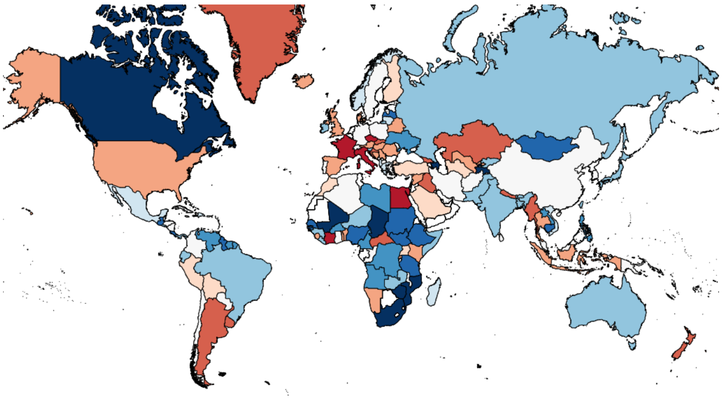
Unusually high annual flows were observed along the south coast and in the Orange and Zambezi river basins in southern Africa, along the Bengal coast in India, and in the Parnaiba river basin in Brazil.

High average flows were also observed in the Mackenzie River basin in Canada, in the Tocantins and nearby rivers in eastern Brazil, the Senegal, Nile and Lake Chad basins in Africa, the Mekong river and nearby rivers in southeast Asia, the Murray-Darling basin in Australia and isolated basins elsewhere.

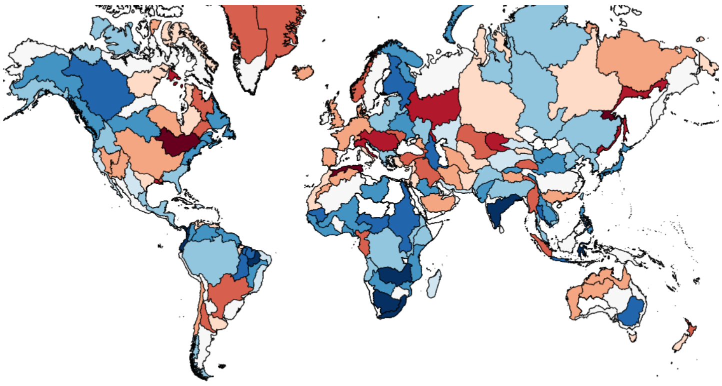
Unusually low flows were observed along the southwest Mediterranean coast, the St. Lawrence River basin in North America and the Okhotsk coast in eastern Siberia.

Standardised anomaly in annual average river flows in the major river(s) (see p.8 for legend; estimates are not available in some smaller and arid regions.)

By country



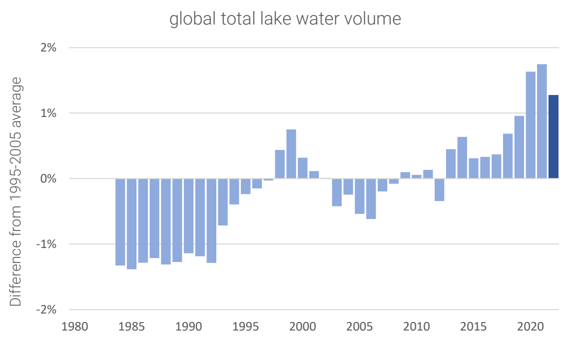
By river basin



Low average flows were also observed in the Danube and Po river basins in Europe, the Volga River basin and eastern coast of Siberia in Russia, and in the Lake Balkash basin in Central Asia.

Lakes

Global water volumes in lakes are gradually increasing. Both high and low storage records were broken more often than in the past.



Combined water storage in lakes compared to the average (1994–2021).

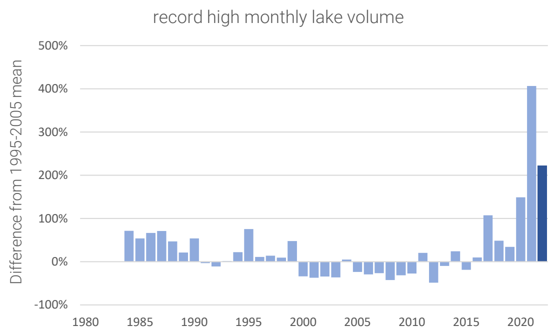
About two-thirds (64%) of all water in natural and artificial lakes worldwide are found in only six countries: Canada, the USA, China, Russia, Brazil and India (in descending order).

Water storage in lakes increased slightly from the previous year by 0.5%. Storage was 1.2% above average values around 2000 (1995–2005). The increasing trend in lake storage can be mainly attributed to new and expanded reservoir lakes, especially in China, India and the Nile Basin.

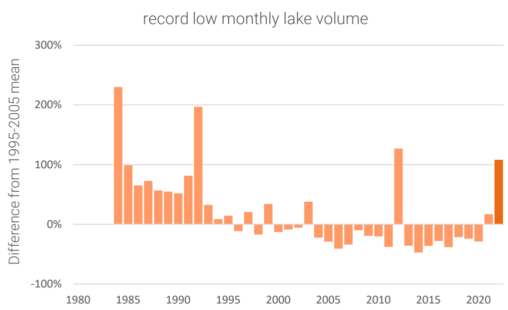
The number of times annual average lake storage records were exceeded in the 29,146 observed lakes was about three times greater than the average around 2000 (+223%). There has been a trend towards more frequent high-storage records.

The number of times low lake storage values were broken was about twice the average around 2000 (+108%) and the largest since 2012. There is evidence of a decreasing trend towards fewer low-storage records until the last two years.

The recent increase in record-high volumes and the initial decrease in record-low volumes before 2000 can be attributed to a combination of human and natural factors. Small and very large lakes are all counted equally. Dams continue to be built and expanded worldwide to secure water, and their filling explains some of the trends. In addition, most natural lakes are found in the Arctic region, where greater and earlier snowmelt can contribute to increased lake volumes.



The number of times high monthly lake storage records were broken compared to the average for 1995–2005.



The number of times low monthly lake storage records were broken compared to the average for 1995–2005.

Global patterns

By country

Storage in natural and artificial lakes was unusually high in Ethiopia, Kenya and Uganda in eastern Africa, mainly due to rainfall in previous years. Lake storage was also high in India and China due to the steady increase in artificial reservoir lakes, as well as in North Korea, and in Egypt, Libya, Yemen and Lebanon in the Middle East.

Lake water storage was unusually low in Niger and several smaller European countries.

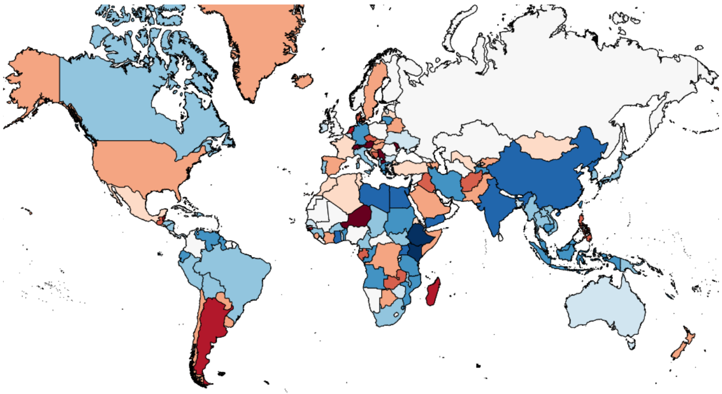
A way to highlight the impact of 2022 climate conditions is to consider changes in stored volume. Lake volume decreased from the previous year in 99 countries, increased in 59, and could not reliably be measured or was zero in the remaining 97 (typically small or arid) countries and territories.

In descending order, the greatest absolute decreases in surface water storage occurred in Canada, USA, Russia, Iraq and Zambia. The greatest increases occurred in Brazil and Thailand.

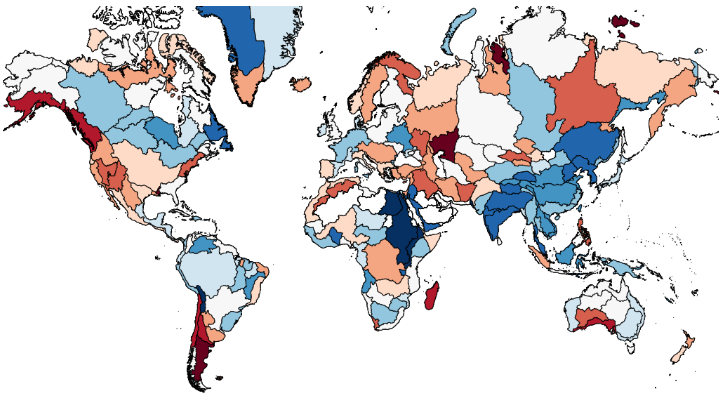
In relative terms, the most notable[10] relative decreases from the previous year were in Iraq (−32%), Morocco (-14%), Portugal (-13%) and Spain (-11%). The greatest increases were in Malawi (21%), Thailand (15%), Bolivia (14%) and Myanmar (12%).

Standardised anomaly in annual average lake water storage (see p.8 for legend; estimates are not available in some smaller regions).

By country



By river basin



By river basin

Unusually high water storage was observed in Africa in the Nile Basin, the Rift Valley and the Egypt Interior basin, where overflows from Lake Nasser continued to expand the Toshka Lakes. Unusually high lake volumes were also observed in the Lake Titicaca basin.

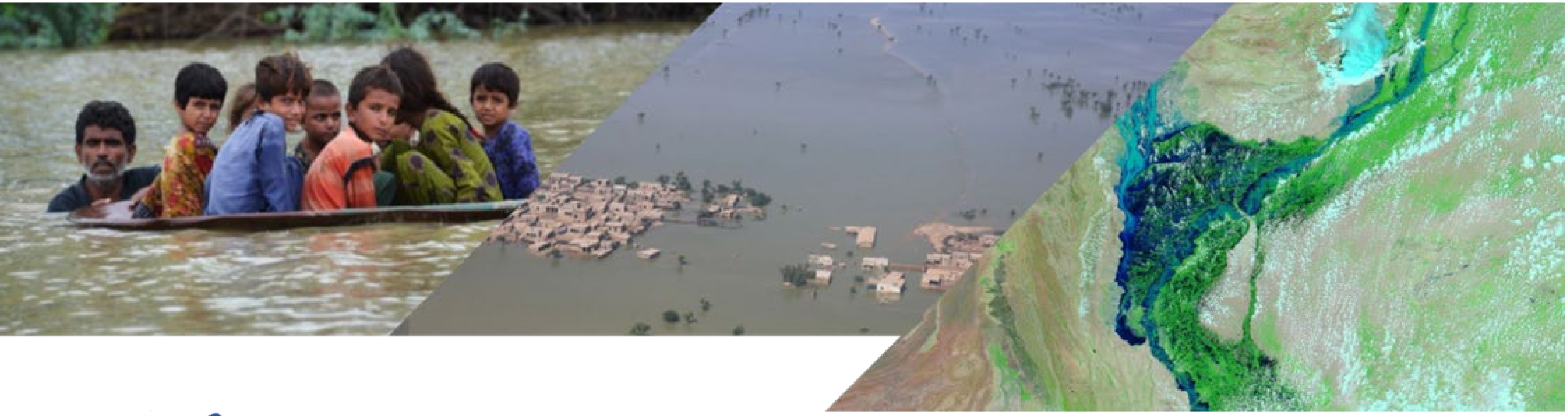
In terms of changes from the previous year, the largest absolute increase was observed in the Paraguay-Paraná basin (+17,000 GL). In relative terms, increases were greatest along the eastern Gulf of Thailand coast (+30%), the Sao Francisco basin in Brazil (+23%), Lake Titicaca basin (+14%), Salween river basin (+11) and along the South China coast (+11%).

Lake storage was unusually low in the Ural river basin in Central Asia, parts of northern Siberia, and the coast of southern Argentina. Storage was also very low along the Pacific coast of Alaska and Canada, in southern South America and in Madagascar.

In absolute terms, the greatest decline from the previous year was observed in the Tigris-Euphrates, Yenisey and Zambezi basins (all more than -10,000 GL). In relative terms, declines were greatest along the northwest African coast (-14%), the Salinas Grandes basin in South America (-13%) and the Atlantic river catchments of Portugal and Spain (-12%)[11].

[10] Only countries or river basins with a combined lake capacity exceeding 10,000 GL were considered, as satellite-estimate storage may be less acurrate for smaller storages.

Regions in Focus



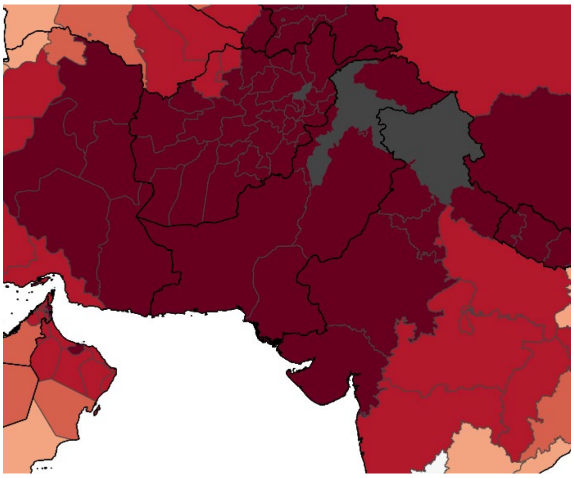
Pakistan

Severe heatwave followed by massive floods affecting millions

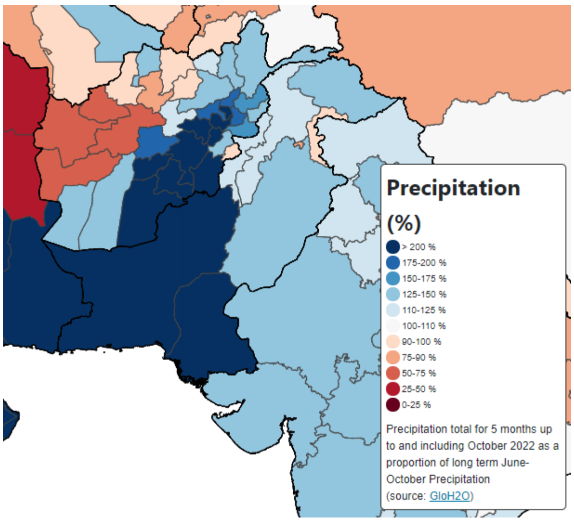
Between 14 June and October 2022, heavy rains caused a combination of riverine, urban and flash flooding with widespread fatalities, livestock losses, and damage to public and private infrastructure.

The Indus River floods followed a severe heatwave in Pakistan and India in March and April. The heatwave increased snow and ice melt in the Upper Indus Basin and was followed by unusually heavy monsoon rains. Both the heatwave and floods were attributed to high sea surface temperatures in the northern Indian Ocean.

The floods killed at least 1,739 people, making it the deadliest natural disaster in 2022. An estimated 1.1 million livestock and 3.8 million hectares of crops were lost. Around 33 million people were affected, and 7.9 million people were displaced[11]. Damages were estimated to exceed USD 14.9 billion, with total economic losses of USD 15.2 billion. The floods may drive up to 15 million people into poverty.[12]



Standardised anomalies for March-April average air temperature



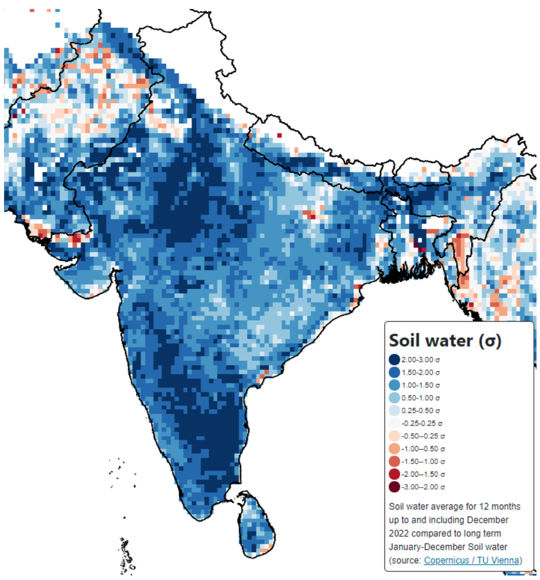
Relative anomalies in June-October total rainfall

[11] UN ReliefWeb, 4 October 2022 (link)

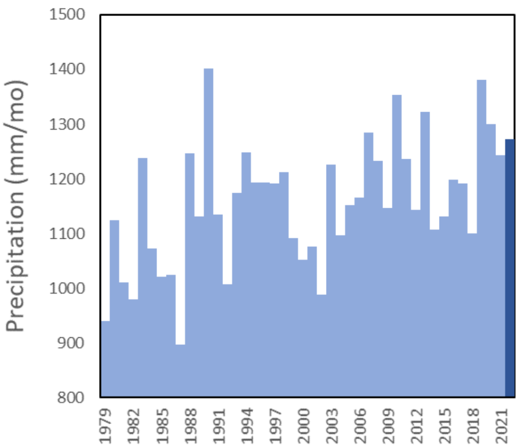
[12] WorldBank, 28 October 2022 (link)

India

Severe heatwave followed by a strong monsoon



Average annual soil water anomaly



After a severe heatwave in March-April, the June to September monsoon season had well above average rainfall for the fourth year in a row. The strong monsoon caused flooding, water logging and landslides affecting millions of people.

Soils were unusually wet in the northern, southern and far eastern states. The worst affected regions were in the northern and eastern states.

Between 9-10 September, widespread flooding across the States of Assam, Gujarat, Karnataka, Maharashtra, Madhya Pradesh, Uttarakhand and Uttar Pradesh killed at least 13 people. Almost 1,400 were affected, and more than 1,200 were evacuated.

On 23-24 September, heavy rainfall and thunderstorms were reported across northern India, resulting in at least 36 fatalities.

On 5 October, flash floods were reported in West Bengal in northeastern India.

Overall, around 2000 people died in flooding across India between June and October. Some 1300 sustained injuries, and more than 1.3 million people were evacuated[13].

At the national scale, there is a long-term increasing trend in annual rainfall, despite large year-to-year variation.

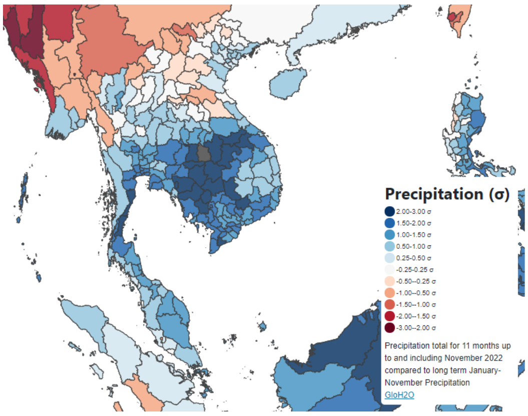
[13] ReliefWeb (link)

Southeast Asia

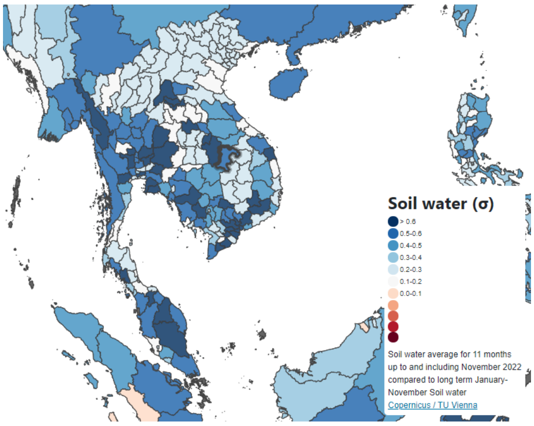
A very wet monsoon

Southeast Asia was affected by a strong monsoon, compounded by several cyclones and severe tropical storms. The most affected were southern Thailand, Cambodia and Malaysia.

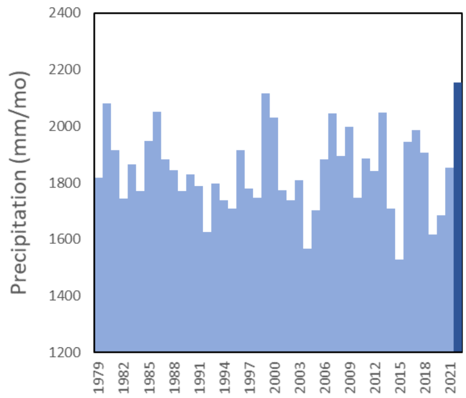
Annual rainfall for Cambodia was the highest since at least 1979, resulting in prolonged wet soil conditions from May until October. Heavy rainfall from September to October affected nearly 8,000 people[14].



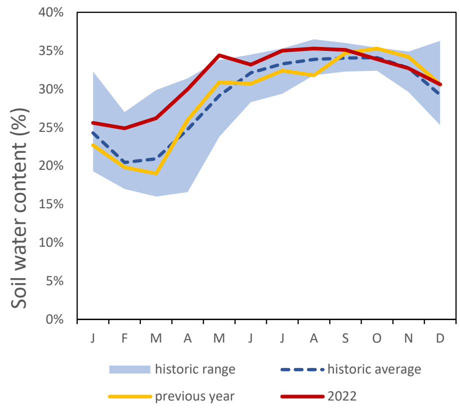
Annual rainfall anomalies



Annual soil water anomalies



Annual rainfall over Cambodia (1979–2022)



Average monthly soil water over Cambodia compared to previous years.

[14] ReliefWeb, 22 December 2022 (link)

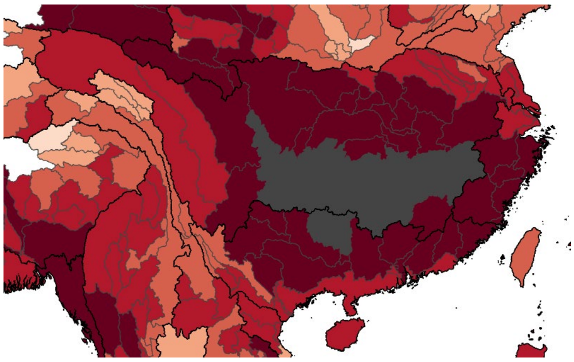
Eastern China

Flooding followed by a heatwave and flash drought

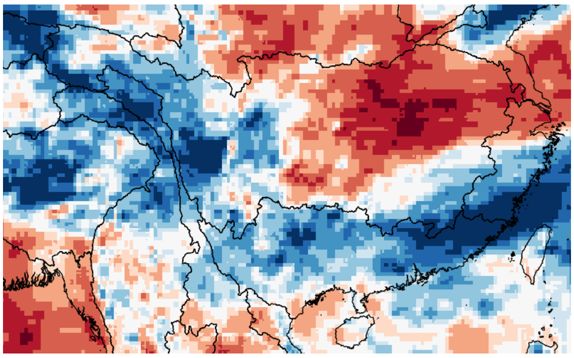
In May and June, high rainfall caused several flood events along the southern coast of China. The damage was estimated at more than USD 12 billion, making it worldwide the third most costly natural disaster in 2022.[13]

Most rain fell outside the Yangtze river Basin. A summer heatwave combined with low rainfall caused dry conditions in the basin from July to November, and unseasonally low river flows in the Yangtze River.

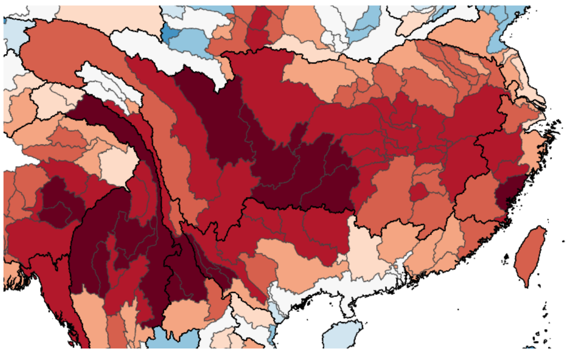
The drought affected more than 5 million and caused more than USD 8 billion in damage, making it the fourth most costly natural disaster in 2022 worldwide.[15]



Standardised anomaly of July-November air temperature



Standardised anomaly of May-June precipitation



Standardised anomaly of July-November precipitation

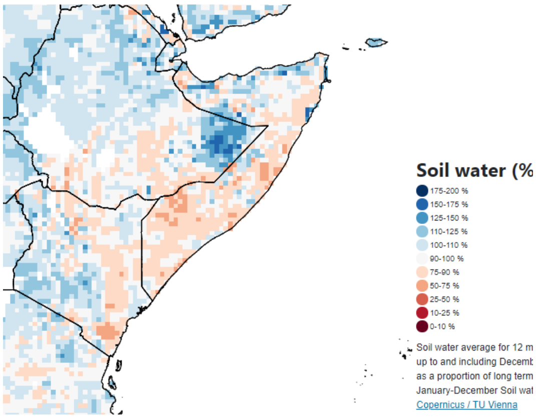
[15] source: Christian Aid, Counting The Cost 2022 (*link*)

Somalia

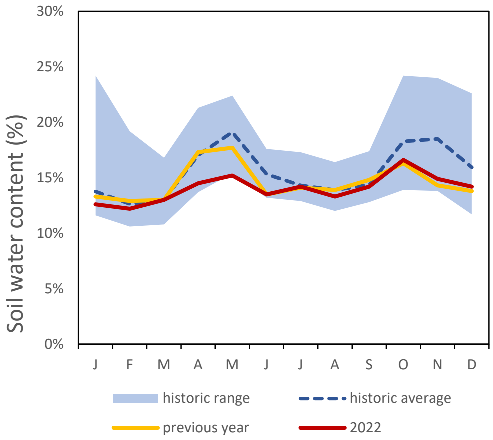
For a second year, both rainy seasons failed

For a second year, Somalia experienced very dry conditions during both cropping seasons. The drought surpassed the 2010/11 and 2016/17 droughts in terms of duration and severity. Four consecutive rainy seasons failed for the first time in at least 40 years[16].

Nearly half of the country's population was affected by the drought. More than 1.1 million people left their homes in search of food, water and livelihoods. About 300,000 people faced catastrophic food insecurity. About 1.8 million children under five years faced acute malnutrition, and more than half a million were likely severely malnourished.[17]



Annual average soil water as a percentage of average conditions.



[16] ReliefWeb, 24 October 2022 (link)

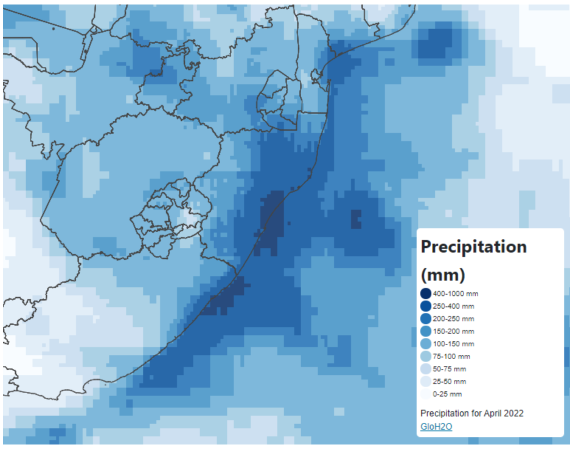
South Africa

Intense rainfall caused flash floods and landslides

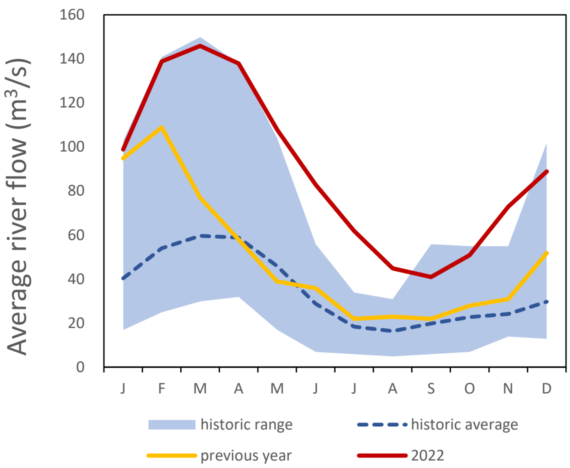
In early April, heavy rain fell along the eastern coast of South Africa, including the populous city of Durban. The ensuing floods and landslides killed an estimated 461 people, displaced over 40,000 people and destroyed over 12,000 houses.

Further flood events occurred in December in the Johannesburg region.

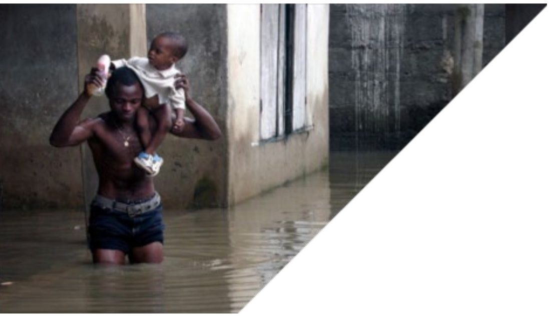
Orange river flows remained high for a second year, with flooding along its course in the beginning of the year and again towards the end of 2022.



Rainfall in April 2022



Average monthly river flows in the Orange River basin compared to previous years.



Nigeria

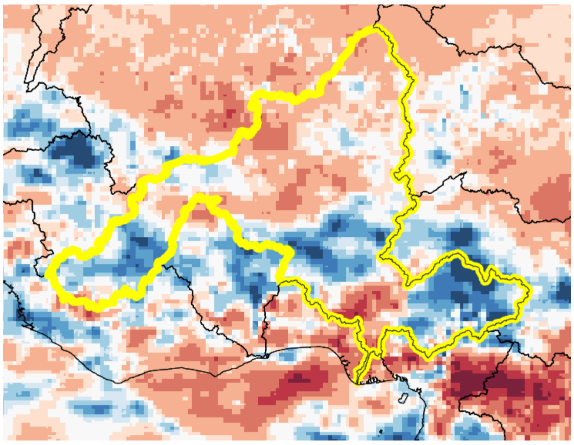
A very wet rainy season brought widespread flooding

Nigeria's rainy season was among the deadliest in more than a decade, with floods starting in July and continuing until November.

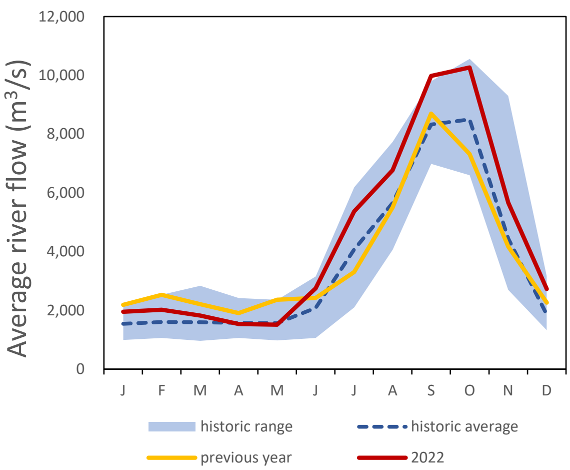
Heavy rains in the lower Niger and the catchment of the Benue River tributary in eastern Nigeria led to extensive flooding downstream.

The floods affected more than 4.4 million people across Nigeria, with over 2.4 million people displaced. The hardest hit was Bayelsa State in the Niger River delta. More than 660 people were killed, 174,000 houses were destroyed, and more than 676,000 hectares of farmland were damaged by the floods.

The events are expected to increase already alarming levels of hunger and malnutrition.[17]



Standardised rainfall anomalies for July-November over the Niger River Basin



Monthly river flows in the lower Niger River in Nigeria compared to previous year.

[17] ReliefWeb, 14 December 2022 (link)

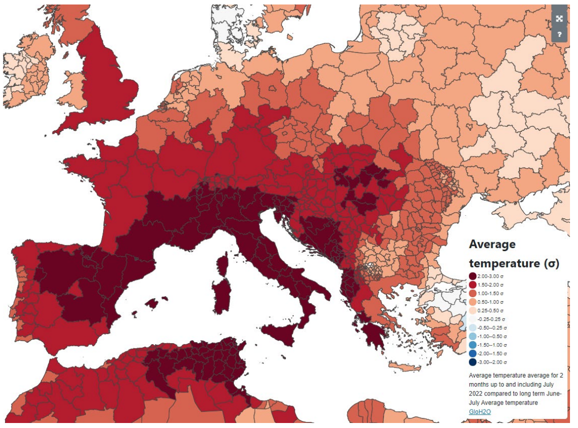
Europe

A summer heatwave caused a flash drought

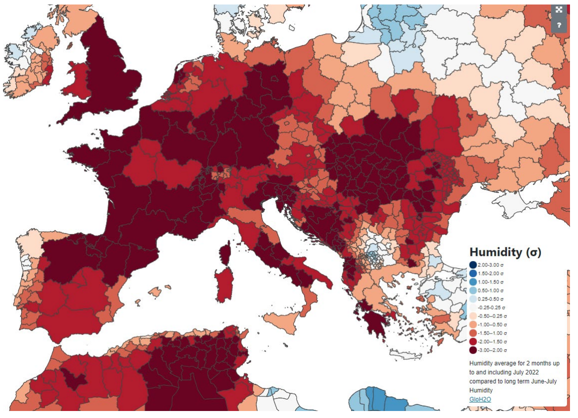
Two heatwaves hit Europe in mid-June and mid-July, affecting hundreds of millions of people. Based on mortality data, it has been estimated that 17,000 people died as a consequence of the heatwave.

The heatwave and dry conditions caused damage to agriculture, affected power generation and led to rare low water levels in several European rivers, including the Danube, Rhine, and Po Rivers.

The heatwave and drought were estimated to have caused more than USD 20 billion of damages, making it the second most costly natural disaster in 2022.[18]



June-July temperature anomalies



June-July air humidity anomalies

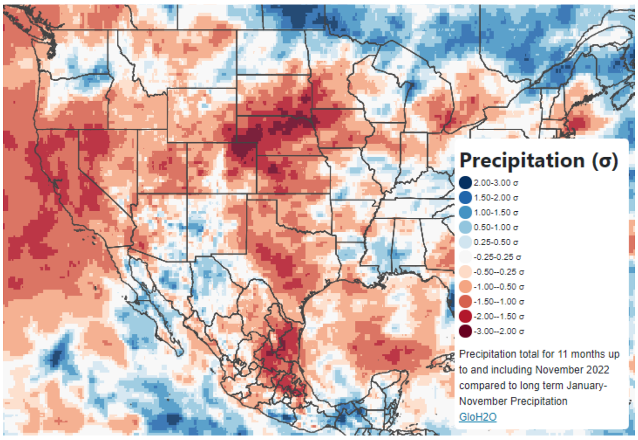
[18] Christian Aid, Counting The Cost 2022 (*link*)

United States of America

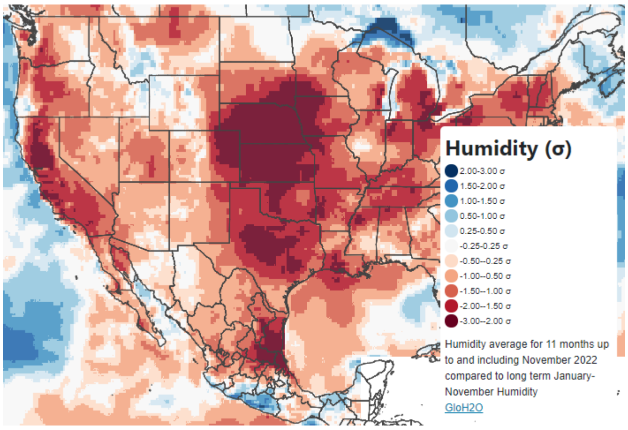
A multi-year drought in the western USA deepened further

Dry conditions continued for another year across most states in the central and western USA. The associated high temperatures and very low air humidity contributed to bushfires and low river inflows.

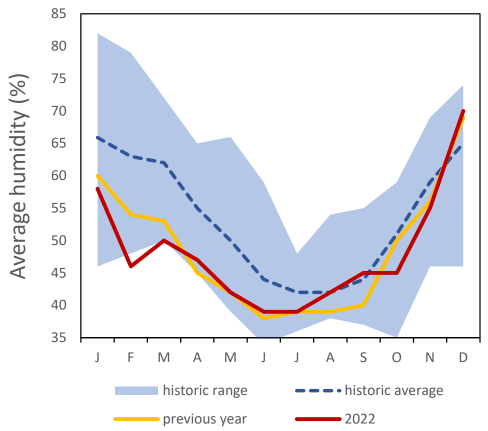
These conditions form part of a clear long-term trend towards earlier and more warm and dry conditions in the western US, corresponding with a longer and more severe fire season and declining inflows into the major lakes and reservoirs.



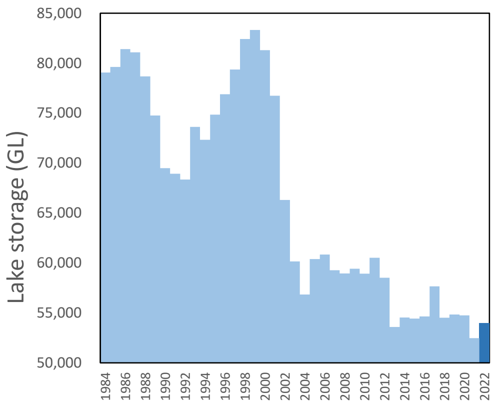
Annual precipitation anomalies



Annual air humidity anomalies



Monthly average air humidity in California compared to previous years.



Annual average lake storage in the US Colorado River basin

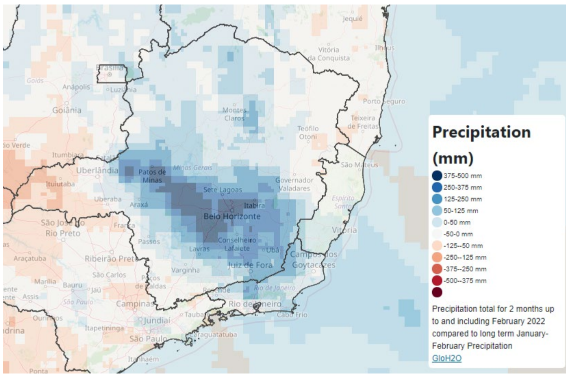
Brazil

Heavy rainfall caused floods and landslides

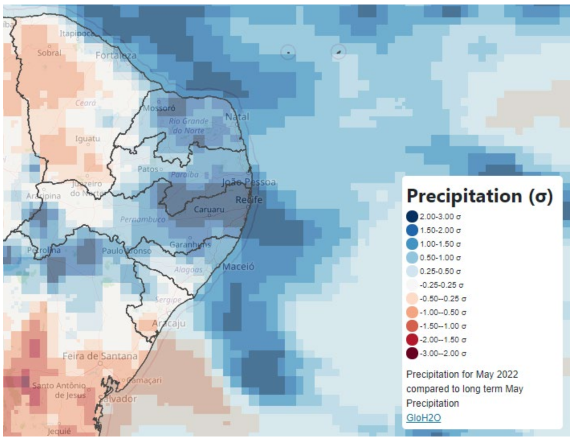
In late January and February, heavy rains caused flooding and mudslides in Brazil's Rio de Janeiro and Minas Gerais regions, taking at least 286 lives.

In late May, more floods and landslides in northeastern Brazil killed at least 127 people and left thousands homeless.

Further floods and landslides occurred in November and December in southeastern Brazil, with more than 78,000 people affected and 13,800 displaced.[19]



January-February rainfall anomalies over Rio de Janeiro and Minas Gerais



May 2022 rainfall anomalies over northeast Brazil

[19] ReliefWeb, 22 December 2022 (link)

Paraguay-Paraná River Basin

A multi-year drought has not relented

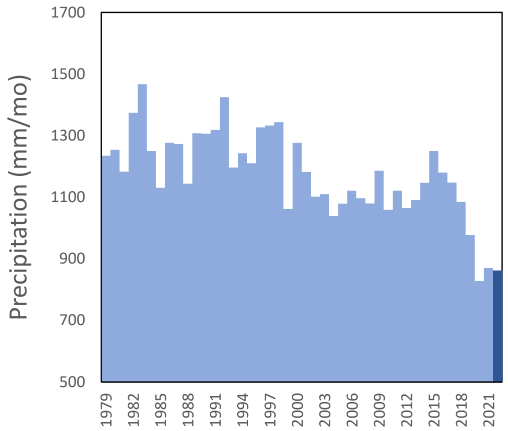
Extremely low rainfall continued a steep decline in annual rainfall since 2015 and a fourth year of drought.

Communities were especially badly affected in the western Paraguay, where almost half of the population is indigenous[20].

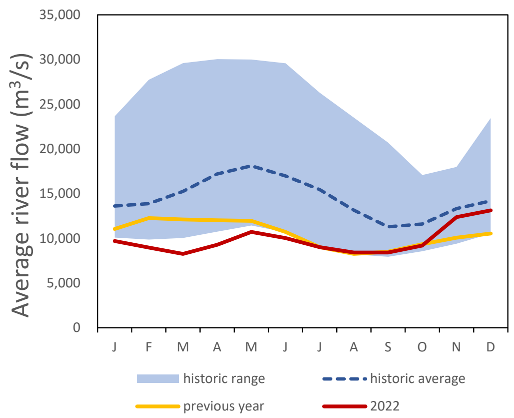
The drought-affected areas experienced further record-high temperatures in late November and early December, compounding drought impacts.

River flows were very low for the third year in a row.

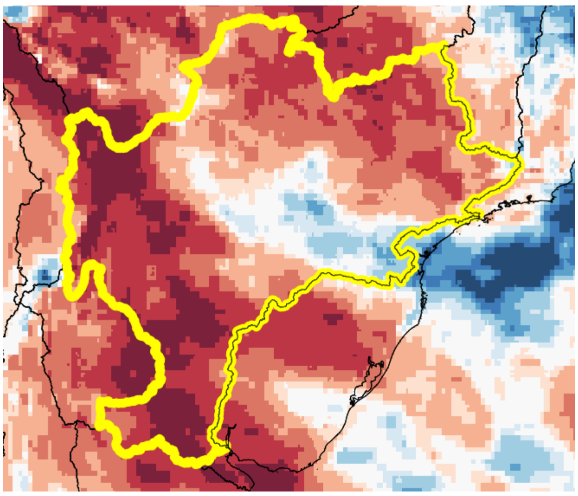
However, total water storage across the basin recovered somewhat in 2022.



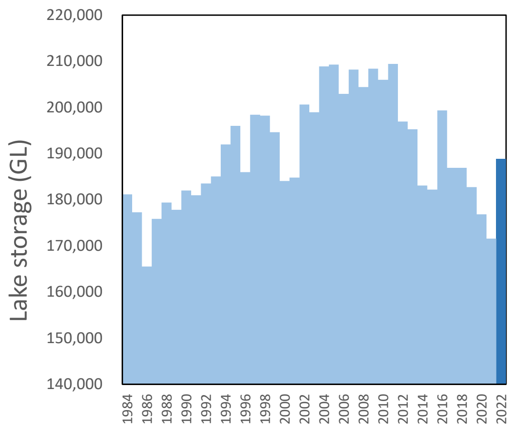
Annual rainfall for 1979–2022 over the Paraguay basin



Monthly average river flow in the Paraguay-Parana basin compared to previous years



Standardised annual rainfall anomalies over the Paraguay-Parana basin



Annual lake and reservoir storage in the basin

[20] ReliefWeb, 23 September 2022 (link)

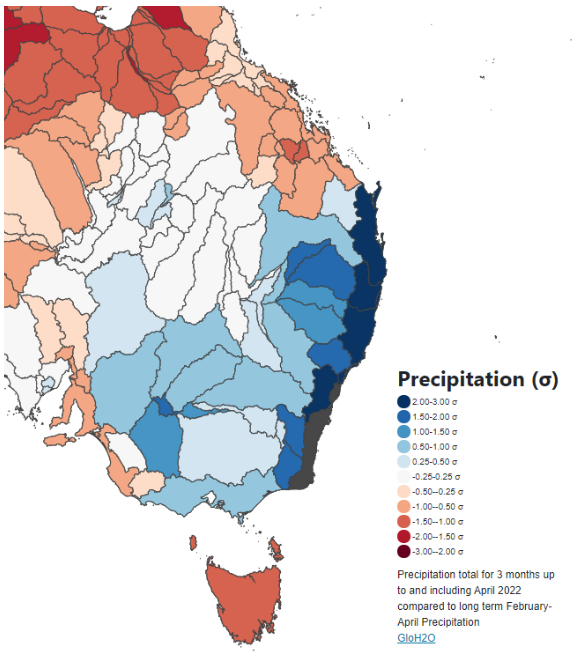
Australia

A wet year with widespread flooding

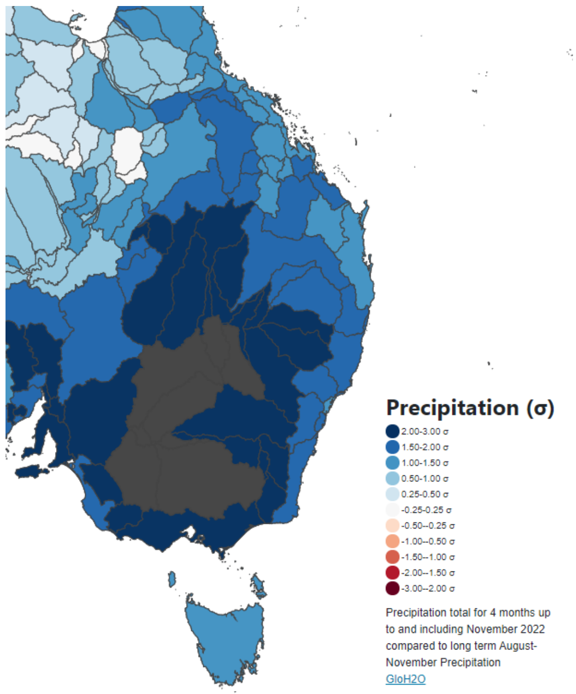
Another La Niña year caused the second 'once-in-a-century' flood within 11 years in parts of Australia. In the first half of the year, coastal catchments were particularly affected.

Heavy rains returned after August 2022, causing widespread and sometimes repeated flooding in inland New South Wales, Victoria and Tasmania. For example, residents of Camden near Sydney were ordered to evacuate on four occasions during the year.

The floods killed 22 people and displaced more than 60,000. The damage was estimated at USD 7.5 billion, making it the fifth most costly natural disaster globally in 2022.[21]



Precipitation anomalies for February-April 2022



Precipitation anomalies for August-November

[21] source: Christian Aid, Counting The Cost 2022 (*link*)

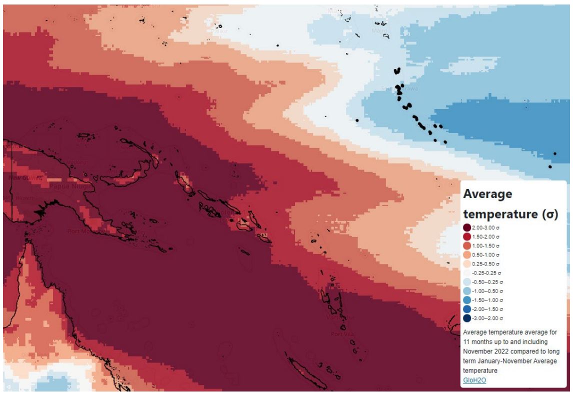
Kiribati

A third dry year led to water scarcity

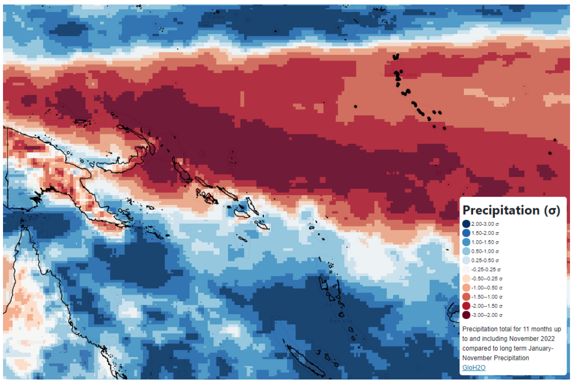
Persisting La Niña ocean circulation patterns in the western Pacific led to below-average rainfall for the third year in a row for Kiribati and parts of Tuvalu, Tokelau, Nauru and the northern islands of Papua New Guinea.

The government of the 120,000 nation of Kiribati declared a drought emergency in June in response to increasing water contamination, brackish water and other water accessibility issues[22].

In Tuvalu, 9,200 people or 86% of the population, faced drought conditions.



Annual air temperature anomaly



Annual rainfall anomaly

[22] ReliefWeb, May 2022 (link)

Outlook for 2023

A look at hydrological conditions at the end of 2022 can help assess the risk of droughts developing in 2023. This is true to a lesser extent for floods, as the change from drought to flood conditions can happen more rapidly following intense rainfall.

Precipitation during the second half of 2022 was unusually low over the Great Plains of Canada and the USA, most of South America, western Russia, Mongolia and much of China.

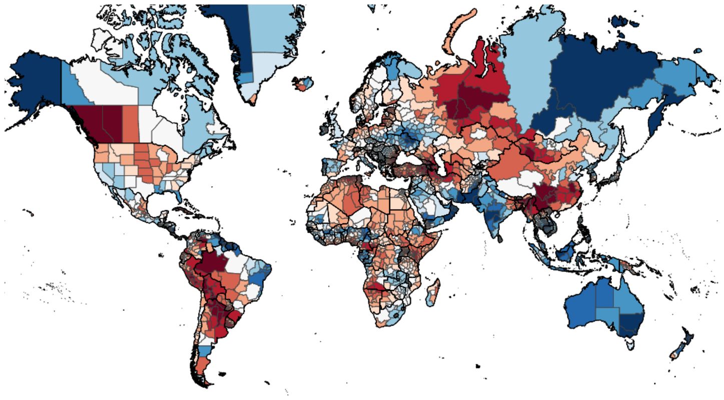
Soil wetness was also below average in these same regions, with the exception of eastern China.

Lake storage was unusually low or at least much below average in the Ural river Basin, parts of Mongolia, along the Pacific coast of Alaska and Canada, the US Atlantic coast, and the cone of South America.

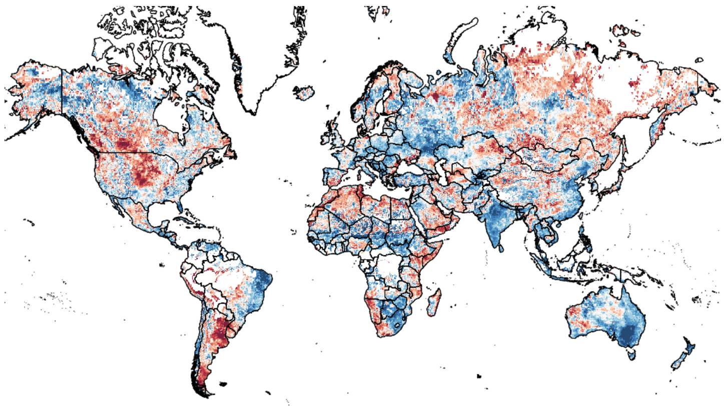
In these regions, therefore, there appears to be a risk of developing or intensifying drought and water scarcity in 2023.

Regions that are unlikely to develop drought conditions for at least several months include Pakistan, India, southeast Asia and Indonesia, southern Africa, eastern Australia, eastern Brazil and the Guyanas. In those regions, the greater risk may be flooding, landslides and other challenges related to excessive wetness, should high rainfall return.

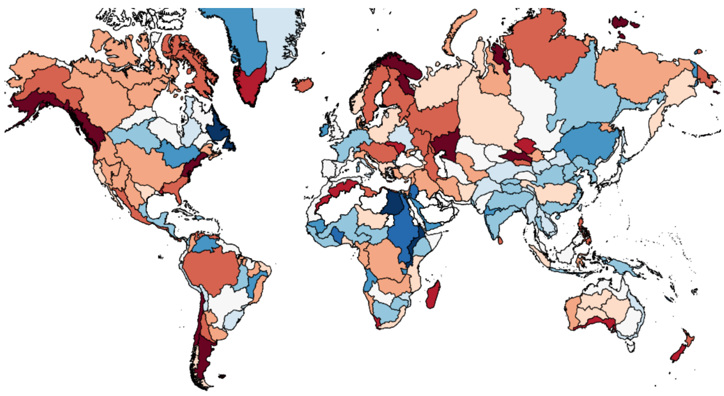
As of December 2022, La Niña conditions appear to be waning and a transition to El Niño conditions appears more likely. This may see increased precipitation in the Americas and reduced precipitation in southeast Asia and Australia, and a reversal of rainfall conditions for South Pacific island nations.



*Standardised anomaly in July–December rainfall averaged by administative region**



*Standardised anomaly in October–December soil water**



Standardised anomaly in October–December total lake water storage by river basin

* see p.8 for legend

About Us

The Global Water Monitor Consortium is a partnership of several individuals and organisations who share a mission to make global water information more current and available for public interest and debate. Together, they have developed the Global Water Monitor (www.globalwater.online), a web-based data explorer where users can find detailed current and past climate and water information.

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